2. SITES 535, 539, AND 540[1]

Shipboard Scientific Party[2]

SITE 535

Date occupied: 0810 hr., 29 December 1980

Date departed: 2330 hr., 8 January 1981

Time on hole: 10 days, 15.3 hr.

Position: 23°42.48′N; 84°30.97′W

Water depth (sea level; corrected m, echo-sounding): 3450

Water depth (rig floor; corrected m, echo-sounding): 3466

Bottom felt (m, drill pipe): 3455.5

Penetration (m): 714

Number of cores: 79

Total length of cored section (m): 714

Total core recovered (m): 505.07

Core recovery (%): 71

Oldest sediment cored:
Depth sub-bottom (m): 714
Nature: Limestone
Age: Early Cretaceous (Berriasian)
Measured velocity (km/s): 4.71

Basement: Not penetrated

Principal results: See Summary section.

SITE 539 (HOLE 539)

Date occupied: 0352 hr., 18 January 1981

Date departed: 1640 hr., 18 January 1981

Time on hole: 12.7 hr.

Position: 23°47.34′N; 84°25.19′W

Water depth (sea level; corrected m, echo-sounding): 3089

Water depth (rig floor; corrected m, echo-sounding): 3099

Bottom felt (m, drill pipe): 3106

Penetration (m): 7

Number of cores: 2

Total length of cored section (m): 7

Total core recovered (m): 4.40

Core recovery (%): 63

Oldest sediment cored:
Depth sub-bottom (m): 7
Nature: Nannofossil ooze
Age: late Pleistocene–late Pliocene
Measured velocity (km/s): 1.55

Basement: Not penetrated

Principal results: See Summary section.

SITE 539 (HOLE 539A)

Date occupied: 1640 hr., 18 January 1981

Date departed: 0223 hr., 19 January 1981

Time on hole: 9.7 hr.

Position: 23°47.20′N; 84°25.19′W

Water depth (sea level; corrected m, echo-sounding): 3076

Water depth (rig floor; corrected m, echo-sounding): 3086

Bottom felt (m, drill pipe): 3099.5

Penetration (m): 7.5

Number of cores: 1

Total length of cored section (m): 7.5

Total core recovered (m): 7.23

Core recovery (%): 96

Oldest sediment cored:
Depth sub-bottom (m): 7.5
Nature: Nannofossil ooze and chalk
Age: late Oligocene
Measured velocity (km/s): 1.59

Basement: Not penetrated

Principal results: See Summary section.

SITE 540

Date occupied: 0330 hr., 19 January 1981

Date departed: 0748 hr., 25 January 1981

Time on hole: 6 days, 4.3 hr.

Position: 23°49.73′N; 84°22.25′W

Water depth (sea level; corrected m, echo-sounding): 2926

Water depth (rig floor; corrected m, echo-sounding): 2936

Bottom felt (m, drill pipe): 2940.5

Penetration (m): 745.4

Number of cores: 79

Total length of cored section (m): 745.5

Total core recovered (m): 335.75

[1] Buffler, R. T., Schlager, W., et al., *Init. Repts. DSDP*, 77: Washington (U.S. Govt. Printing Office).

[2] Richard T. Buffler (Co-chief Scientist), Institute for Geophysics (formerly Marine Science Institute), The University of Texas at Austin, Austin, Texas; Wolfgang Schlager (Co-Chief Scientist), School of Marine and Atmospheric Science, University of Miami, Miami, Florida (present address: University of Miami, 4600 Rickenbacker Causeway, Miami, Florida 33149); Jay L. Bowdler, Union Oil Company of California, Houston, Texas; Pierre H. Cotillon, Département de Géologie, Université Claude Bernard, 69622 Villeurbanne Cedex, France; Robert B. Halley, Branch of Oil and Gas Resources, U.S. Geological Survey, Denver, Colorado; Hajimu Kinoshita, Department of Geophysics, Chiba University, Chiba 260, Japan; Leslie B. Magoon III, U.S. Geological Survey, Menlo Park, California (present address: U.S. Geological Survey, 3475 Deer Creek Road, Palo Alto, California 94304); Charles L. McNulty, Department of Geology, University of Texas at Arlington, Arlington, Texas; James W. Patton, Marathon Oil Company, Littleton, Colorado; Kenneth A. Pisciotto, Scripps Institution of Oceanography, University of California at San Diego, La Jolla, California (present address: Sohio Petroleum, 50 Fremont Street, San Francisco, California 94105); Isabella Premoli Silva, Istituto di Paleontologia, Università di Milano, Milano, Italy; Otmara Avello Suarez, Oceanological Institute, Havana, Cuba; Margaret M. Testarmata, Institute for Geophysics (formerly Marine Science Institute), The University of Texas at Austin, Austin, Texas; Richard V. Tyson, School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, United Kingdom; David K. Watkins, Department of Geology, Florida State University, Tallahassee, Florida.

Core recovery (%): 45

Oldest sediment cored:
Depth sub-bottom (m): 745.5
Nature: Gray laminated skeletal limestone
Age: middle Albian
Measured velocity (km/s): 3.2

Basement: Not penetrated

Principal results: See Summary section.

SUMMARY

Sites 535, 539, and 540 were drilled in the eastern part of the study area (Fig. 1). They all had the same major objective, i.e., to examine an inferred mid-Cretaceous unconformity (MCU) and to penetrate as deep as possible into the thick pre-mid-Cretaceous sedimentary basin below. The sites have been designated the "basin sites." The pre-mid-Cretaceous rocks either crop out or subcrop beneath a thin Cenozoic cover along the eastern flank of a broad north-south erosional channel (Fig. 1). Sites 535 and 540 were positioned along this erosional slope, and together, they quite successfully sampled an almost continuous section of Lower Cretaceous limestones, plus the thin overlying Cenozoic cover. Seismic Line SF-15 shows the overall setting of the two sites (Fig. 2). Holes 539 and 539A represent unsuccessful attempts to spud.

Because of their similar locations and objectives, discussion of the three sites are combined into this one overall site chapter. The major results of Sites 535 and 540 are shown on summary diagrams (Figs. 3 and 4, respectively) and are discussed further below.

Sites 535 and 540 together penetrated over 1400 m of Cenozoic and Cretaceous section, with Hole 540 representing the upper part. The major lithologic sequences in Hole 540 from top to bottom are as follows:

1. The top consists of 272 m of carbonate ooze, chalk, and marly limestone with ash layers; the lower part is deformed by creep and slumping; age ranges from Pleistocene to late Paleocene.

2. In the middle are gravity-flow deposits (56 m)—mainly layered chalk and pebbly chalks and limestone; pebbles consist of shallow-water and deep-water limestone clasts; this interval includes a 3-4-m graded sandstone-conglomerate toward the top consisting of altered volcanic and limestone material; age ranges from late Paleocene to middle Cenomanian.

3. The lower section contains 417 m of limestone with rhythmic alternations of bioturbated, light-colored layers and laminated, dark, organic matter-rich layers; thin layers of carbonate silt and sand occur throughout; black chert is conspicuous in upper half; there are intercalations of several meters of homogeneous, micritic limestones and calcarenites with shallow-water detritus at the base; age ranges from lower Cenomanian to middle Albian.

The major lithologic sequences in Hole 535 are as follows:

1. The top contains 154 m of mainly upper Pleistocene clay and mud.

2. In the middle 233 m, banded, laminated, and variably bioturbated limestone occurs with layers of coarse skeletal debris, particularly toward the top; age is controversial—a late Albian(?)-Cenomanian(?) age is based on ammonites.

3. The lower section consists of 327 m of rhythmic alternations of (1) light-colored, massive, and variably bioturbated limestones; (2) darker laminated limestones, and (3) very dark carbonaceous, marly limestones with fine laminations; hardgrounds and cephalopod limestones are common toward the bottom; age ranges from Albian(?) to late Berriasian.

These two holes together provide the first view of Early Cretaceous deep-water sedimentation in the eastern Gulf of Mexico-western Straits of Florida region. The results establish that this part of the basin was at least at bathyal depths by the Early Cretaceous. The rhythmic sedimentation indicates alternating oxic and anoxic conditions, similar to other ocean basins at this time. The principal sediment component is fine-grained carbonate of pelagic origin. Thick intervals of massive, fine-grained, homogeneous limestone with high sedimentation rates, however, indicate significant neritic input from adjacent shallow-water platforms to the east, particularly during the late Albian and middle Hauterivian-late Berriasian. Occasionally, significant quantities of silt-sized and sand-sized skeletal debris reached this part of the basin, such as in the middle Albian.

Interbeds of dark, carbonaceous marl and marly limestone found in both the Aptian-Berriasian section of Hole 535 and in the lower Cenomanian-upper Albian section of Hole 540 are, in part, rich but immature petroleum source beds. Tar-filled fractures with a halo of oil stains in the Hauterivian-Valanginian part of the section suggest the possible presence of more mature hydrocarbons deeper in the section or downdip of the drill site.

The 56-m gravity-flow deposit in Hole 540 apparently spans a stratigraphic gap of over 30 Ma; an upper pebbly chalk contains upper Paleocene faunas and floras, the 3-4-m graded sandstone-conglomerate contains possible Upper Cretaceous fossils, and the remaining pebbly chalks contain middle Cenomanian fossils. Thus, the individual members of the composite unit, although genetically similar, probably were deposited during several different widespread episodes of erosion and deposition. Based on sedimentary structures and textures, these beds are interpreted to have been transported by mud flows, debris flows, and turbidity currents. Seismic data suggest that a source for the eroded shallow-water debris was the Florida Escarpment to the east. Similar deposits were encountered at nearby DSDP Site 97 (Worzel, Bryant, et al., 1973).

Major changes in lithology and physical properties correlate well with major seismic reflectors. The inferred mid-Cretaceous unconformity (MCU) (Fig. 2) was penetrated in Hole 540, where it correlates approximately with the top of the Cenomanian-Albian limestones. However, calculated reflections from the top of the 56-m Paleocene-Cenomanian gravity-flow deposit and an Eocene cherty limestone layer just above almost merge with the Cenomanian reflector and cannot be easily distinguished from it with any certainty. The MCU at Site

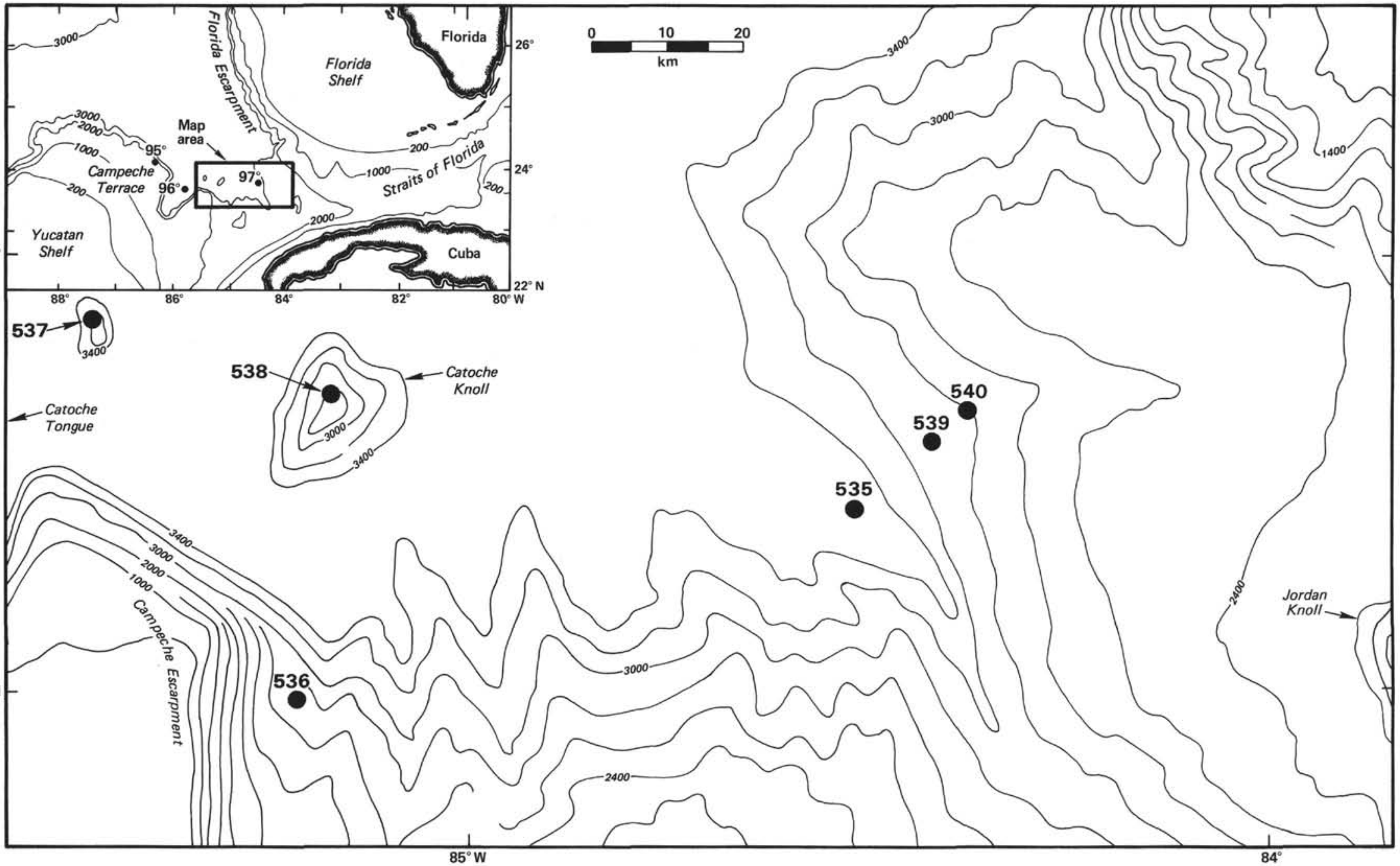


Figure 1. Location map of DSDP Site 97, 535, 539, and 540 in the southeastern Gulf of Mexico, western Straits of Florida. Locations of seismic Lines SF-15 and SF-22 are also shown.

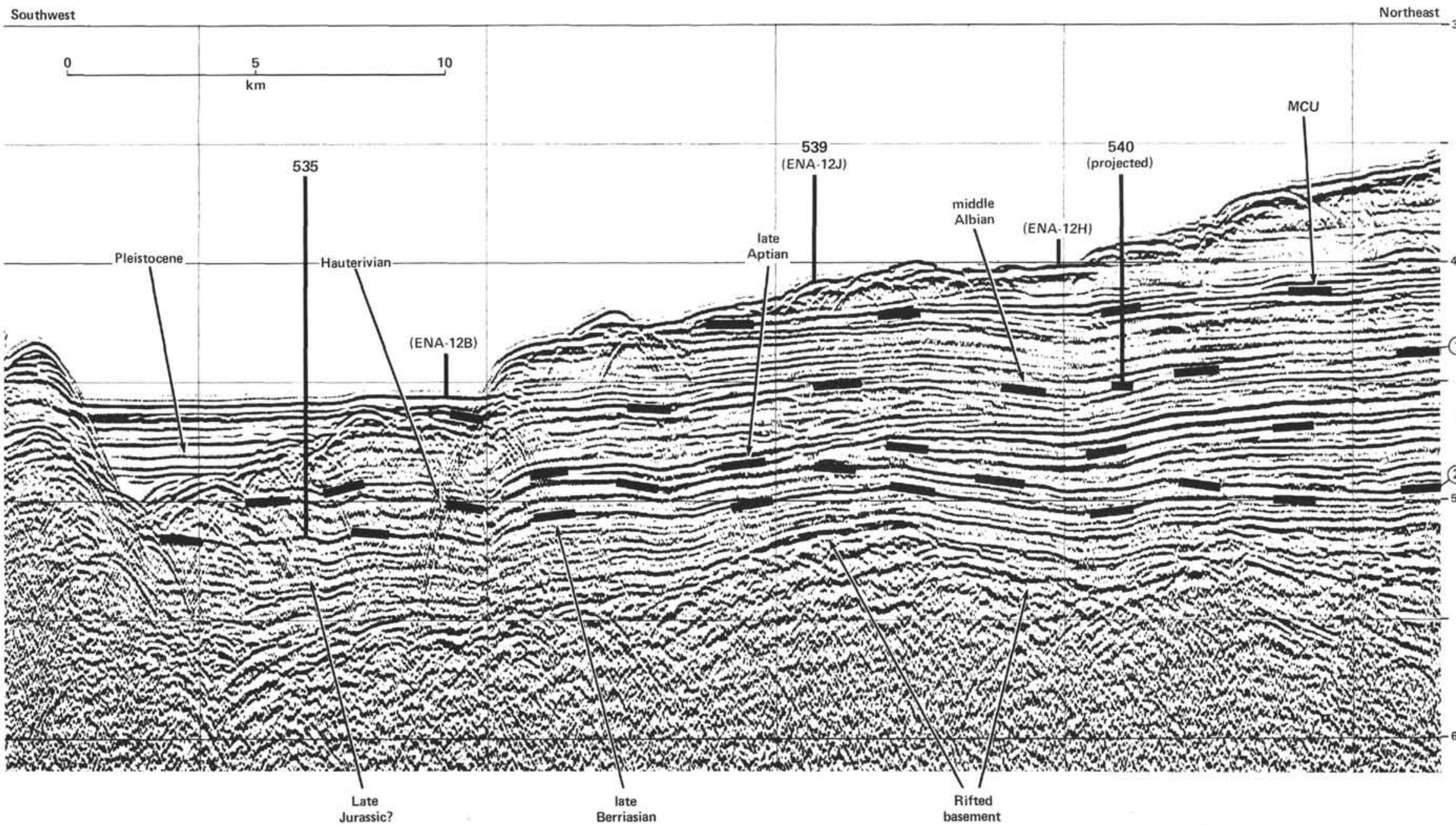


Figure 2. Annotated seismic Line SF-15 through Leg 77 Sites 535, 539, and 540. Ages of units are indicated. Also shown are precruise localities of these sites (designated ENA-12B, ENA-12J, and ENA-12H, respectively). Location of this seismic line is shown on Figure 1. Circled numbers are unconformities. (See text.)

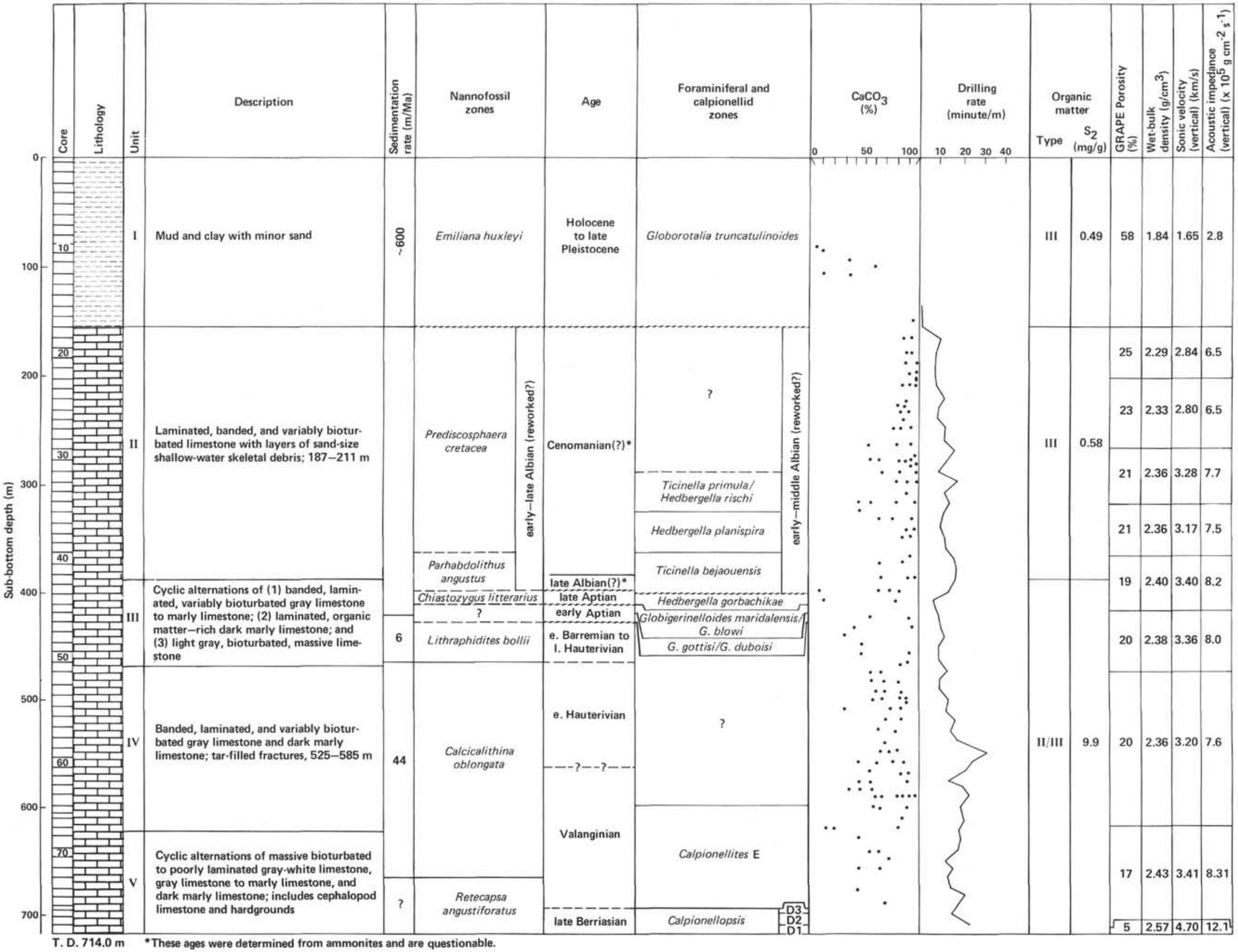


Figure 3. Stratigraphic summary of Hole 535. See Introduction and Explanatory Notes chapter for lithologic symbols.

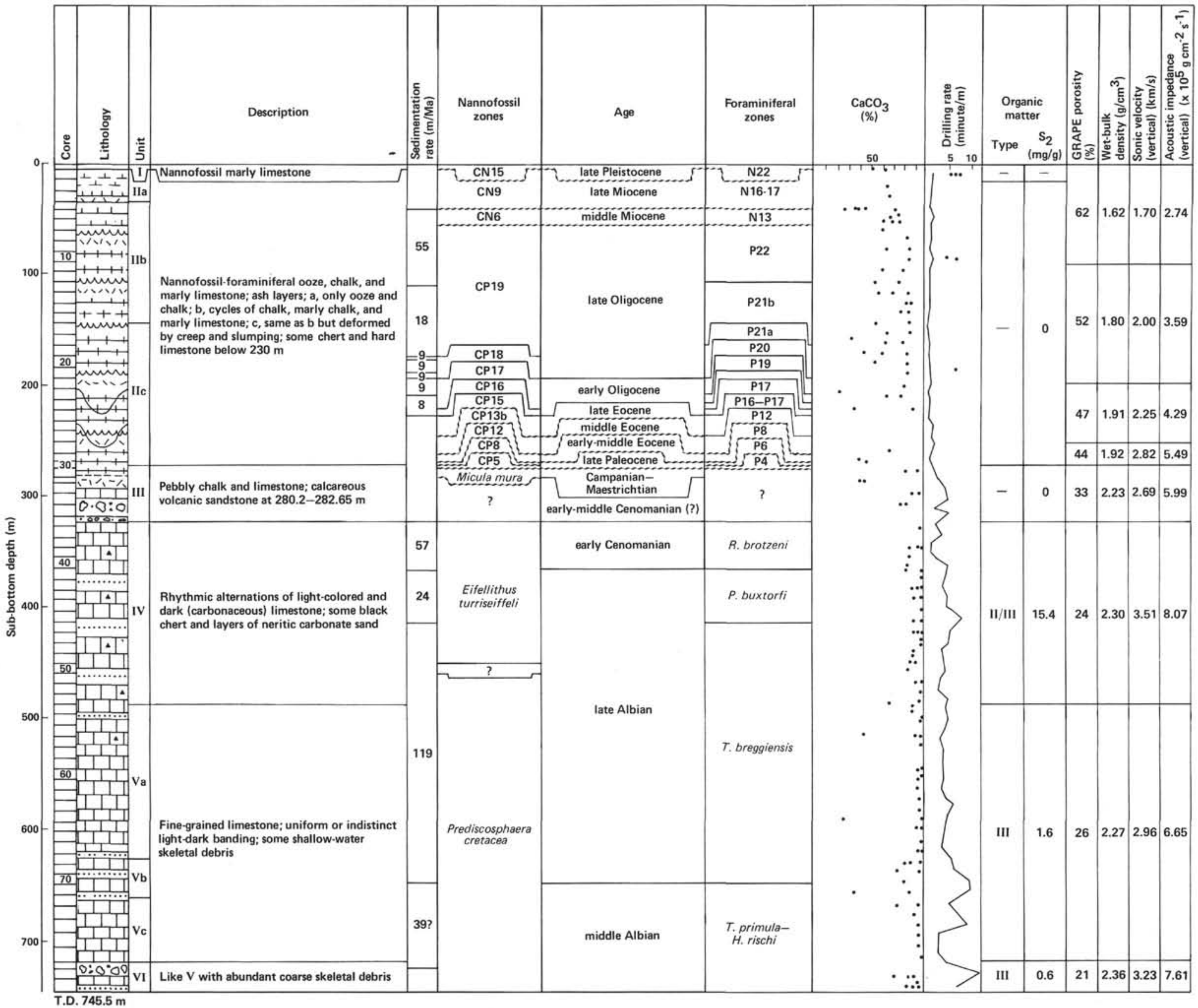


Figure 4. Stratigraphic summary of Hole 540. See Introduction and Explanatory Notes chapter for lithologic symbols.

540, therefore, is best described as a "bundle" of unconformities or reflectors ranging in age from Cenomanian to Eocene.

Below the MCU, two prominent unconformities (1 and 2) as well as several other prominent reflectors, clearly correlate with major changes in lithology (Fig. 2). Unconformity 1, middle Albian in age and probably just penetrated at the base of Hole 540, corresponds to the top of a unit of slumps and debris flows that are characterized by coarse neritic debris and a hummocky seismic character (Fig. 2). Unconformity 2, Hauterivian in age, marks the base of an abbreviated section of slowly deposited pelagic limestone and hardgrounds, which thickens considerably to the east (Fig. 2). In addition, the prominent reflector near the base of Hole 535 correlates with a package of hard, condensed limestones with numerous hardgrounds. Below the bottom of Hole 535, the seismic data show a sequence at least 0.4 s thick with a seismic character similar to that of the Lower Cretaceous section penetrated at 535 and 540. This similarity suggests the presence of additional deep-water carbonates, possibly of Late Jurassic age (Fig. 2).

BACKGROUND AND OBJECTIVES

A preliminary seismic stratigraphic analysis in the deep southeastern Gulf of Mexico showed that the eastern part of the study area is underlain by a thick sedimentary section, which can be subdivided into two major sequences separated by a prominent unconformity. This unconformity is a key Gulf-wide seismic horizon characterized by truncation, onlap or simply a strong reflector. The unconformity has been tentatively dated as mid-Cretaceous based on correlation with nearby DSDP Site 97 (Worzel, Bryant, et al., 1973) and with wells in the northeastern Gulf shelf. The unconformity is designated as "MCU" for mid-Cretaceous unconformity.

One of the main objectives of Leg 77 was to drill the MCU and sample the thick pre-mid-Cretaceous section below it. This older section either crops out or subcrops beneath a thin Cenozoic cover along the flanks of a broad north-south erosional channel and is within easy reach of the *Glomar Challenger.* It is up to 3 km thick and overlies an irregular block-faulted basement. It was postulated to represent a Jurassic through Lower Cretaceous sequence of nonmarine to shallow-marine sediments overlain by deep-marine sediments related to basin subsidence. The sequence had never been drilled before, although it originally was the objective of Site 97. Drilling the MCU and the rocks below, therefore, would provide important control points for interpreting the early history of this part of the Gulf basin. These results could then be tied to seismic data and extrapolated to surrounding regions. Sites with these objectives were designated ENA-12 sites by the JOIDES Passive Margin Panel.

A secondary drilling objective of Leg 77 was to investigate the post-MCU sedimentary and paleoceanographic history of the western Straits of Florida region. This could be accomplished by drilling a post-MCU section in a nearby area, where it is relatively thick (ENA-13 sites). This objective could be partially satisfied by drilling an abbreviated post-MCU section while drilling the ENA-12 sites.

The strategy of the ENA-12 sites, therefore, was to drill a sequence of offset sites along the flank of the erosional valley, in order to penetrate the maximum amount of section with single-bit holes. At this location, basement was over 2 km deep and was not an objective. Basement was to be drilled at additional sites designated ENA-14. This strategy proved quite successful; at Sites 535 and 540, designated as the "basin sites," more than 1400 m of upper Miocene through Berriasian (lowermost Cretaceous) deep-water limestones were recovered. The holes penetrated the MCU and an almost complete Lower Cretaceous sequence.

Before and during Leg 77, several primary and secondary ENA-12 sites were identified (ENA-12A through ENA-12J), based on a preliminary seismic stratigraphic analysis of the area. This analysis subdivided the pre-MCU section into three major sequences separated by two unconformities designated 1 and 2 (Fig. 2). ENA-12B located along seismic Line SF-15 was the first site to be drilled (Fig. 2). The final location chosen, which was to become Site 535, was moved about 3.3 km southwest of the original site to allow for a thicker section of soft sediment in which to spud. The site was located in the channel axis and was designed to drill the sequence between Unconformities 1 and 2 and also as much of the sequence below Unconformity 2 as possible. It was anticipated that the sequence between Unconformities 1 and 2 probably would represent the deep-water equivalents of the Lower Cretaceous carbonate platforms that rimmed the Gulf basin. It was hoped that the sequence below Unconformity 2 would be Jurassic in age and represent the transition from shallow-water to deep-water sediments.

The second basin site to be drilled was Site 539, located farther updip from Site 535 along seismic Line SF-15 and originally designated ENA-12J (Fig. 2). The objective of this site was to drill the MCU and the sequence between the MCU and Unconformity 1. A location farther updip was then chosen with the same objectives as Site 539 but with a thicker Cenozoic cover in which to spud. This site was designated ENA-12H and later became Site 540. Again, the main objective was to determine the nature and age of the MCU and the sequence directly below it. It was anticipated that this sequence also would be the deep-water equivalent of the adjacent shallow-water Lower Cretaceous carbonate margins. A secondary objective of the site was the Cenozoic cover, which had only been spot-cored at nearby Site 97 (Worzel, Bryant, et al., 1973).

OPERATIONS

Site 535

After the alignment and testing of the No. 3 generator, *Glomar Challenger* sailed from Ft. Lauderdale, Florida, at 1506 hr. on 27 December, for Site ENA-12B in the western approaches of the Straits of Florida. Riding against the Gulf stream all the way, average speed varied from 8.2 to 8.6 knots. At 1300 hr., 28 December, after leaving the busiest part of the Straits, we started collecting continuous records of magnetics, bathymetry (12-kHz profiles, 3.5-kHz profiles), and seismic profiles using air guns (120 and 10 cu. in.).

We approached Site ENA-12B (future Site 535) on a course of 234° at 7 knots, following seismic Line SF-15 for 26 km (Figs. 1 and 2). The air gun record was poor because of a malfunctioning preamplifier in the streamer. However, a characteristic topography of erosional scarps and terraces together with good Loran C coverage allowed us to accurately follow Line SF-15. At 0810 hr., 29 December, the beacon was dropped where the soft sediment cover over the Cretaceous subcrops first exceeded 100 m (3.3 km southwest of the originally designated position of ENA-12B) (Fig. 2).

The bottom-hole assembly was made up with a F94CK bit and run in, starting at 0946 hr. At 1817 hr., 29 December, Site 535 was spudded in 3455.5 m water depth. The mudline core was on deck at 1859 hr. After continuously coring 154 m of Quaternary muds (Cores 1 through 17), we recovered Lower Cretaceous chalks at 1540 hr., 30 December, in the bottom of Core 17. By evening, 2 January, we had recovered 42 cores of Lower Cretaceous limestones with the 9.5-m barrel, but the time required to cut a core had increased to more than 2 hr. The knobby pipe and 9.0-m core barrel were run in and used for Cores 43 to 53. When drilling rates improved, the 9.5-m barrel was inserted again and used for Cores 53 through 57. For the last part of the hole (Cores 58 through 79), the 9.0-m barrel had to be used again.

By 8 January morning, wear of the bit became serious; drilling time for one core had increased to more than 3 hr., recovery dropped to less than 20%, and core diameter was down to 42 mm. Core 79, calculated to be at a marked seismic reflector (Fig. 2), was thus designated the last core. It came on deck at 1234 hr., 8 January, and indeed indicated a considerable change in lithology and depositional environment. It was decided to drill one more core to clarify the situation. While this core was being cut, we lost circulation pressure and approximately 30,000 lb. of pull on the drill string, indicating loss of the bottom-hole assembly. It was decided that logging under these conditions represented too high a risk because the tool might get caught at the end of the broken pipe. The only safe option was to pull out of the hole, and the hole was plugged with 100 sacks of cement because of hydrocarbon shows. At 2215 hr., 8 January, the pipe was on deck. It had sheared off at the second joint above the bottom-hole assembly. The end of the pipe was slightly bent and rugged. It was easy to visualize that either the logging tool would not pass or wire would get entangled there.

At 2330 hr., 8 January, *Glomar Challenger* was underway again for Site ENA-14C (Site 536). She had occupied Site 535 for 10 days, 15.3 hr., and drilled with a single bit for 127 hr., 39 min. Core recovery averaged over 71%. Contrary to most expectations, currents had posed no problems at the site, although they intermittently reached velocities of 2.5 knots. All objectives except for logging had been accomplished. A summary of the coring at Site 535 is included as Table 1.

Table 1. Coring summary, Site 535.

Core	Date	Time	Depth from drill floor (m)	Depth below seafloor (m)	Length cored (m)	Length recovered (m)	Percent recovery
Hole 535							
	(Dec. 80)						
1	29	1859	3455.5–3458.0	0.0–2.5	2.5	2.45	98
2	29	2004	3458.0–3467.5	2.5–12.0	9.5	4.45	47
3	29	2115	3467.5–3477.0	12.0–21.5	9.5	6.67	70
4	29	2220	3477.0–3486.5	21.5–31.0	9.5	3.99	42
5	29	2330	3486.5–3496.0	31.0–40.5	9.5	7.24	76
6	30	0046	3496.0–3505.5	40.5–50.0	9.5	8.57	90
7	30	0200	3505.5–3515.0	50.0–59.5	9.5	9.37	99
8	30	0313	3515.0–3524.5	59.5–69.0	9.5	9.23	97
9	30	0422	3524.5–3534.0	69.0–78.5	9.5	7.34	77
10	30	0535	3534.0–3543.5	78.5–88.0	9.5	6.46	68
11	30	0653	3543.5–3553.0	88.0–97.5	9.5	9.83	100+
12	30	0806	3553.0–3562.5	97.5–107.0	9.5	6.63	70
13	30	1000	3562.5–3572.0	107.0–116.5	9.5	9.53	100+
14	30	1124	3572.0–3581.5	116.5–126.0	9.5	4.47	47
15	30	1241	3581.5–3591.0	126.0–135.5	9.5	6.70	71
16	30	1408	3591.0–3600.5	135.5–145.0	9.5	1.35	14
17	30	1540	3600.5–3610.0	145.0–154.5	9.5	3.00	32
18	30	1712	3610.0–3619.5	154.5–164.0	9.5	5.69	60
19	30	1958	3619.5–3629.0	164.0–173.5	9.5	9.97	100+
20	30	2235	3629.0–3638.5	173.5–183.0	9.5	9.92	100+
21	31	0118	3638.5–3648.0	183.0–192.5	9.5	6.61	70
22	31	0340	3648.0–3657.5	192.5–202.0	9.5	9.83	100+
23	31	0600	3657.5–3667.0	202.0–211.5	9.5	8.40	88
24	31	0854	3667.0–3676.5	211.5–221.0	9.5	5.50	58
25	31	1150	3676.5–3686.0	221.0–230.5	9.5	4.21	44
26	31	1436	3686.0–3695.5	230.5–240.0	9.5	0.85	9
27	31	1716	3695.5–3705.0	240.0–249.5	9.5	4.32	45
28	31	2021	3705.0–3714.5	249.5–259.0	9.5	9.99	100+
29	31	2322	3714.5–3724.0	259.0–268.5	9.5	0.00	0
	(Jan. 81)						
30	1	0312	3724.0–3733.5	268.5–278.0	9.5	8.76	92
31	1	0631	3733.5–3743.0	278.0–287.5	9.5	9.66	100+
32	1	0906	3743.0–3752.5	287.5–297.0	9.5	4.95	52
33	1	1256	3752.5–3762.0	297.0–306.5	9.5	9.75	100+
34	1	1550	3762.0–3771.5	306.5–316.0	9.5	3.20	34
35	1	1905	3771.5–3781.0	316.0–325.5	9.5	9.49	100
36	1	2201	3781.0–3790.5	325.5–335.0	9.5	8.07	85
37	2	0051	3790.5–3800.0	335.0–344.5	9.5	9.34	98
38	2	0348	3800.0–3809.5	344.5–354.0	9.5	9.28	98
39	2	0647	3809.5–3819.0	354.0–363.5	9.5	8.43	89
40	2	1022	3819.0–3828.5	363.5–373.0	9.5	2.13	22
41	2	1415	3828.5–3838.0	373.0–382.5	9.5	9.50	100
42	2	1758	3838.0–3847.5	382.5–392.0	9.5	7.54	79
43	2	2119	3847.5–3856.5	392.0–401.0	9.0	3.52	39
44	2	2323	3856.5–3865.5	401.0–410.0	9.0	2.47	27
45	3	0153	3865.5–3874.5	410.0–419.0	9.0	0.31	3
46	3	0437	3874.5–3883.5	419.0–428.0	9.0	3.05	34
47	3	0723	3883.5–3892.5	428.0–437.0	9.0	2.17	24
48	3	1026	3892.5–3901.5	437.0–446.0	9.0	6.83	76
49	3	1309	3901.5–3910.5	446.0–455.0	9.0	5.85	65
50	3	1544	3910.5–3919.5	455.0–464.0	9.0	5.27	59
51	3	1839	3919.5–3928.5	464.0–473.0	9.0	6.86	76
52	3	2315	3928.5–3933.0	473.0–477.5	4.5	5.75	100+
53	4	0207	3933.0–3942.5	477.5–487.0	9.5	7.89	83
54	4	0504	3942.5–3952.0	487.0–496.5	9.5	8.32	88
55	4	0824	3952.0–3961.5	496.5–506.0	9.5	8.62	91
56	4	1136	3961.5–3971.0	506.0–515.5	9.5	8.46	89
57	4	1521	3971.0–3980.5	515.5–525.0	9.5	9.64	100+
58	4	1914	3980.5–3989.5	525.0–534.0	9.0	8.05	89
59	4	2332	3989.5–3998.5	534.0–543.0	9.0	6.39	71
60	5	0531	3998.5–4007.5	543.0–552.0	9.0	8.76	97
61	5	1020	4007.5–4016.5	552.0–561.0	9.0	7.93	88
62	5	1439	4016.5–4025.5	561.0–570.0	9.0	8.12	90
63	5	1748	4025.5–5034.5	570.0–579.0	9.0	6.80	76
64	5	2209	4034.5–4043.5	579.0–588.0	9.0	9.66	100+
65	6	0236	4043.5–4052.5	588.0–597.0	9.0	8.30	92
66	6	0652	4052.5–4061.5	597.0–606.0	9.0	7.83	87
67	6	1229	4061.5–4066.0	606.0–610.5	4.5	6.40	100+
68	6	1623	4066.0–4075.0	610.5–619.5	9.0	7.26	81
69	6	2016	4075.0–4084.0	619.5–628.5	9.0	8.80	98
70	7	0035	4084.0–4093.0	628.5–637.5	9.0	8.00	89
71	7	0442	4093.0–4102.0	537.5–646.5	9.0	6.53	73
72	7	0750	4102.0–4111.0	646.5–655.5	9.0	5.92	66
73	7	1118	4111.0–4120.0	655.5–664.5	9.0	4.48	50
74	7	1436	4120.0–4129.0	664.5–673.5	9.0	3.44	38
75	7	1749	4129.0–4138.0	673.5–682.5	9.0	4.68	52
76	7	2213	4138.0–4147.0	682.5–691.5	9.0	3.69	41
77	8	0405	4147.0–4151.5	691.5–696.0	4.5	3.00	67
78	8	0737	4151.5–4160.5	696.0–705.0	9.0	1.37	15
79	8	1234	4160.5–4169.5	705.0–714.0	9.0	1.98	22
					714.0	505.07	71

Site 539

Early on the morning of 18 January 1981, we approached Site 539 (ENA-12J) from the west collecting magnetics, 12-kHz records for bathymetry, 3.5-kHz records for shallow sub-bottom penetration, and air gun profiles for deep sub-bottom penetration. Two air guns at 5 and 40 cu. in. were used.

The beacon was dropped on the first pass over the area at 0352 hr. in an area of very irregular bottom topography. A shallow valley with flat sediment fill near the beacon was chosen as the drill site after examination of the precision depth recorder records. We encountered considerable difficulty in relocating this area, which finally turned out to be only 200 m off the beacon. The problem was caused by the time lag with which the computer indicates the ship's position. At 0910 hr. the ship was in the desired position, and an attempt was made to spud. The bottom-hole assembly was made up with a F94CK bit and run in, and we finally spudded Hole 539 at 1536 hr. The mudline was cored at 3106 m and a 1-m core was recovered. The second core was drilled to 6 m before an extremely firm substratum was encountered. The sediments were too stiff to wash and core without rotation. No headway could be made, and the hole was abandoned at 1640 hr. when the bit cleared the mudline. The ship was repositioned about 850 ft. to the south. Hole 539A spudded in at 2014 hr. at 3099.5 m water depth and penetrated 7.5 m of sediment before again hitting hard substratum. The core was pulled and stiff Oligocene ooze was found in the bottom of the core barrel. Again, these sediments were too firm to wash and core without rotation. It was decided to abandon this site and move to Site 540 (ENA-12H). The pipe was pulled and we were underway by 0223 hr., 19 January. A summary of the coring at Holes 539 and 539A is included as Table 2.

Site 540

Glomar Challenger approached Site 540 (ENA-12H) on 19 January 1981 early in the morning. Originally ENA-12H was to be drilled in a valley with flat-lying, probably Quaternary, sediment over Tertiary erosional topography (Fig. 2). Site 539, which was located in the same meandering valley as ENA-12H, had clearly shown that the sediment fill was too thin to spud and the underlying sediment was too hard to penetrate without rotation. Site ENA-12H (540) was thus shifted from Line SF-15 to Line SF-22 and relocated 30 m above the valley floor where younger and softer Tertiary sediments could be expected (Fig. 5). Underway from Site 539, the ship surveyed the area with 3.5-kHz and 12-kHz profilers, and dropped the 13.5-kHz beacon on the bench at 0330 hr., 19 January. Using the beacon for precise positioning, the area was surveyed for the best location to spud, and the ship was finally positioned about 400 m north of the beacon on a flat spot.

Table 2. Coring summary, Site 539.

Core	Date (Jan. 1981)	Time	Depth from drill floor (m)	Depth below seafloor (m)	Length cored (m)	Length recovered (m)	Percent recovery
Hole 539							
1	18	1614	3106.0–3107.0	0.0–1.0	1.0	0.83	83
2	18	1723	3107.0–3113.0	1.0–7.0	6.0	3.57	60
					7.0	4.40	63
Hole 539A							
1	18	2051	3099.5–3107.0	0.0–7.5	7.5	7.23	96
					7.5	7.23	96

The bottom-hole assembly, made up with a F94CK bit and three bumper subs, was run in. Hole 540 was spudded at 1051 hr.; the mudline core was on deck at 1127 hr. The anticipated problems with spudding were soon to follow. Below 4 m of soft sediment, we immediately encountered very stiff ooze and later chalk layers that had to be penetrated with extreme caution. At 1920 hr., the first bumper sub was buried and we could start rotating. Continuous coring was interrupted twice to take heat flow measurements at 52 and 71 m. Drilling in underlying chalk and limestone proceeded quickly and on 24 January, 1303 hr., the hole was terminated at 745.5 m, following instructions from the JOIDES Pollution Prevention and Safety Panel. After 1 hr. of circulating, the go-devil was lowered to release the bit and start logging. When the bit could not be dropped, the overshot was brought back on deck after shearing the pin. A second attempt was equally unsuccessful. In the third attempt, a core barrel was lowered to pick up the go-devil; it too was stuck. With no possibility of releasing the bit, we had to abandon plans for logging and trip out. The pin on the overshot was sheared again and the tool brought back on deck. Trip out began at 2010 hr. The mudline was cleared at 2204 hr. and on 25 January, 0305 hr., the bit was on deck. After clearing the derrick floor and magnafluxing the bottom-hole assembly, *Glomar Challenger* headed for San Juan, Puerto Rico at 0748 hr., 25 January 1981.

Site 540 had been occupied for 124 hr., with 745 m (79 cores) drilled; that is slightly more than 1½ hr. per core, including the trips. Strong currents of up to 2.5 knots were felt intermittently at the site. The combination of currents with heavy seas and winds at 30–40 mph forced us to briefly interrupt drilling twice on 23 January, but the ship never went off station by more than 100 m. A summary of the coring at Site 540 is included as Table 3.

SEDIMENTOLOGY

Site 535

The sedimentary succession at Site 535 was divided into five units as summarized on Table 4 and in Figure 3.

The boundary between Units I and II was taken at the top of the core catcher in Core 17 with the first appearance of gray limestones. Below this boundary (which is lithologically, seismically, and stratigraphically distinct) the problem of subdivision becomes greater because of the much more subtle variations in sediment type. The most conspicuous and interesting feature of the succession between the base of Unit I and the bottom of the hole is the cyclic alternation of sediments. Five different types of cycles were observed (see Figs. 6 and 7):

Type A includes light and dark color alternations within laminated sediments; periodicity of the dark layers varies from 5 to 35 cm (typical color ranges given in Fig. 6).

Type B consists of light and dark color alternations, where the dark layers are laminated or sparsely biotur-

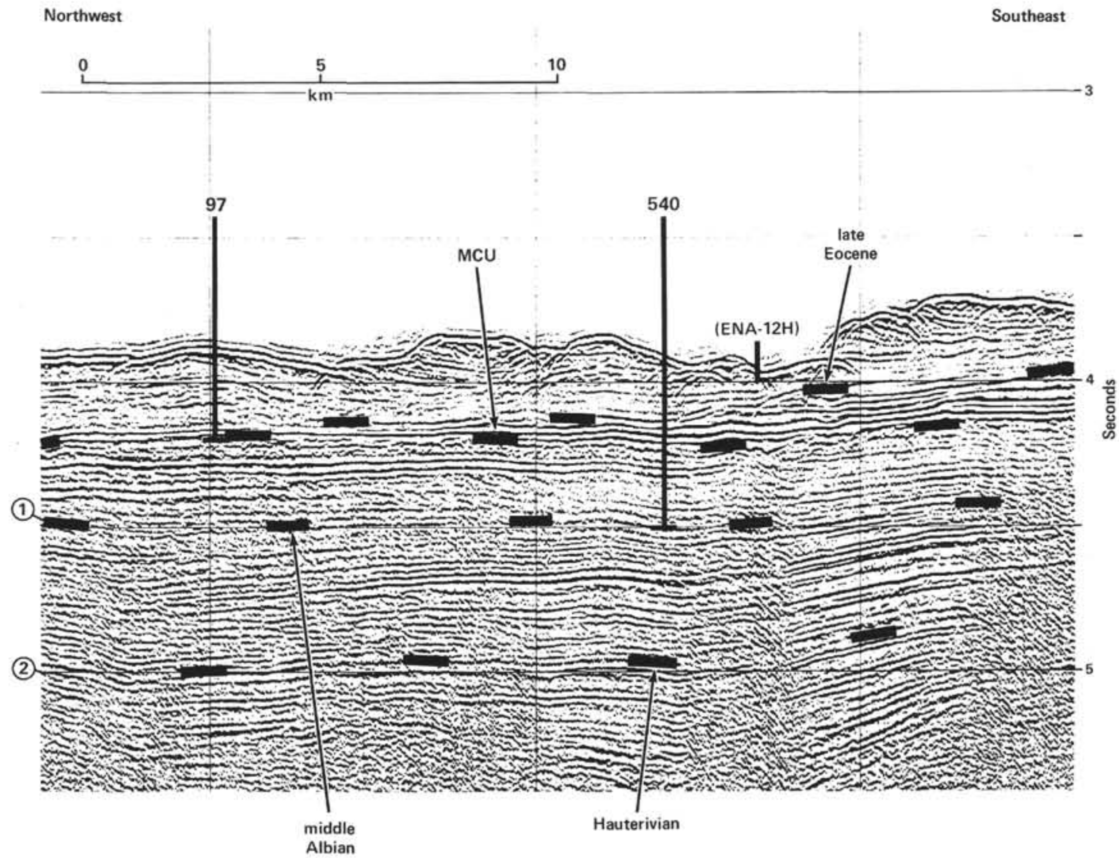


Figure 5. Annotated seismic Line SF-22 through DSDP Sites 97 and 540. See text for explanation of seismic markers and stratigraphy. Circled numbers are unconformities.

bated and where bioturbation increases and reaches a maximum in the light-colored layers. These cycles are both symmetrical and asymmetrical, the latter showing sharp upward changes from light to dark.

Type C includes light and dark color alternations of strong contrast where the lightest layers are conspicuous light gray to very light gray, massive, ammonite-bearing limestones and the darkest layers olive black marly limestones (and rarely olive black shales). These cycles are also both symmetrical and asymmetrical, and analogous, although more extreme, to Type B.

Type D cycle indicates relatively dark (olive gray) bioturbated layers alternating with thin (less than 5 cm) light-colored bands at about 35–60 cm intervals. The base of the light-colored layers is usually sharp, but may in part be bioturbated.

Type E includes generally light-colored bioturbated beds with periodic, comparatively thin, dark, slightly bioturbated or laminated bands with apparent periodicities of 10–50 cm.

Intervals showing Type C cycles were the most lithologically distinct because of the presence of the massive very light gray to light gray limestones and sharp, finely laminated olive black marly limestones. The appearance of these lithologies and the presence of these type of cycles were therefore used as the main criterion for distinguishing Units II to V. Both Units III and V are characterized by Type C cycles. The boundary between Units II and III was taken at the top of the first massive, light-colored limestone band, and the boundary between Units III and IV was taken as the base of the last massive white limestone in this part of the succession. The boundary between Units IV and V was taken at the top of the first, pure, massive, light-colored limestone, where both these and alternating olive black and olive gray marly limestones become abundant. This transition from Units IV to V is also marked by the decrease of "cross lamination," the reappearance of ammonite-rich limestones with hardgrounds, common stylolites, and the occurrence of a few swelling, kaolinite-montmorillonite-smectite ("bentonite") clay layers in Sections 535-68-5, 535-69-4, and 535-70-1. The boundary is also indicated by a change in the apparent periodicity of the cycles (see Fig. 7).

Although the lithologic basis for the division of Units II–V is relatively subtle, a fair degree of correlation exists between these and the divisions defined by seismic stratigraphy and physical properties (Fig. 3). The significance of the cyclic sedimentation will be discussed at the end of this section. The increasing proportions of bioturbated sediment at the base of Unit V may indicate yet another facies change at or near the bottom of the hole.

Montmorillonite and illite are the common background clays throughout the limestone section at this site. Kaolinite is conspicuously present in Cores 20 to 33 where redeposited skeletal debris is common. Kaolinite

Table 3. Coring summary, Site 540.

Core	Date (Jan. 1981)	Time	Depth from drill floor (m)	Depth below seafloor (m)	Length cored (m)	Length recovered (m)	Percent recovery
Hole 540							
1	19	1127	2940.5–2945.0	0.0–4.5	4.5	4.22	94
2	19	1234	2945.0–2954.5	4.5–14.0	9.5	9.68	100+
3	19	1338	2954.5–2964.0	14.0–23.5	9.5	6.30	66
4	19	1438	2964.0–2973.5	23.5–33.0	9.5	6.54	69
5	19	1539	2973.5–2983.0	33.0–42.5	9.5	3.69	39
6	19	1638	2983.0–2992.5	42.5–52.0	9.5	1.72	18
7	19	1920	2992.5–3002.0	42.0–61.5	9.5	6.87	72
8	19	2029	3002.0–3011.5	61.5–71.0	9.5	9.87	100+
9	19	2329	3011.5–3021.0	71.0–80.5	9.5	7.98	84
10	20	0037	3021.0–3030.5	80.5–90.0	9.5	6.49	68
11	20	0141	3030.5–3040.0	90.0–99.5	9.5	8.17	86
12	20	0240	3040.0–3049.5	99.5–109.0	9.5	7.19	76
13	20	0334	3049.5–3059.0	109.0–118.5	9.5	8.82	93
14	20	0430	3059.0–3068.5	118.5–128.0	9.5	9.31	98
15	20	0531	3068.5–3078.0	128.0–137.5	9.5	6.30	66
16	20	0633	3078.0–3087.5	137.5–147.0	9.5	8.57	90
17	20	0728	3087.5–3097.0	147.0–156.5	9.5	9.10	96
18	20	0822	3097.0–3106.5	156.5–166.0	9.5	6.42	68
19	20	0922	3106.5–3116.0	166.0–175.5	9.5	7.56	80
20	20	1021	3116.0–3125.5	175.5–185.0	9.5	4.77	50
21	20	1120	3125.5–3135.0	185.0–194.5	9.5	3.11	33
22	20	1222	3135.0–3144.5	194.5–204.0	9.5	0.87	9
23	20	1326	3144.5–3154.0	204.0–213.5	9.5	5.97	63
24	20	1423	3154.0–3163.5	213.5–223.0	9.5	7.75	82
25	20	1524	3163.5–3173.0	223.0–232.5	9.5	4.37	46
26	20	1633	3173.0–3182.5	232.5–242.0	9.5	4.80	51
27	20	1733	3182.5–3192.0	242.0–251.5	9.5	1.42	15
28	20	1845	3192.0–3201.5	251.5–261.0	9.5	3.08	32
29	20	1945	3201.5–3211.0	261.0–270.5	9.5	3.48	37
30	20	2053	3211.0–3220.5	270.5–280.0	9.5	2.53	27
31	20	2215	3220.5–3230.0	280.0–289.5	9.5	2.93	31
32	21	0003	3230.0–3239.5	289.5–299.0	9.5	2.61	27
33	21	0212	3239.5–3249.0	299.0–308.5	9.5	1.74	18
34	21	0336	3249.0–3258.5	308.5–318.0	9.5	0.83	9
35	21	0519	3258.5–3268.0	318.0–327.5	9.5	1.40	15
36	21	0641	3268.0–3277.5	327.5–337.0	9.5	1.05	11
37	21	0807	3277.5–3287.0	337.0–346.5	9.5	2.54	27
38	21	0916	3287.0–3296.5	346.5–356.0	9.5	0.47	5
39	21	1112	3296.5–3306.0	356.0–365.5	9.5	1.75	18
40	21	1256	3306.0–3315.5	365.5–375.0	9.5	1.41	15
41	21	1434	3315.5–3325.0	375.0–384.5	9.5	1.78	19
42	21	1620	3325.0–3334.5	384.5–394.0	9.5	3.20	34
43	21	1800	3334.5–3344.0	394.0–403.5	9.5	2.36	25
44	21	2019	3344.0–3353.5	403.5–413.0	9.5	2.70	28
45	21	2211	3353.5–3363.0	413.0–422.5	9.5	3.25	34
46	22	0001	3363.0–3372.5	422.5–432.0	9.5	2.06	22
47	22	0119	3372.5–3382.0	432.0–441.5	9.5	2.98	31
48	22	0305	3382.0–3391.5	441.5–451.0	9.5	2.01	21
49	22	0435	3391.5–3401.0	451.0–460.5	9.5	1.03	11
50	22	0604	3401.0–3410.5	460.5–470.0	9.5	2.30	24
51	22	0723	3410.5–3420.0	470.0–479.5	9.5	0.53	6
52	22	1002	3420.0–3429.5	479.5–489.0	9.5	2.90	31
53	22	1149	3429.5–3439.0	489.0–498.5	9.5	1.04	11
54	22	1341	3439.0–3448.5	498.5–508.0	9.5	6.44	68
55	22	1515	3448.5–3458.0	508.0–517.5	9.5	4.77	50
56	22	1647	3458.0–3467.5	517.5–527.0	9.5	3.98	42
57	22	1819	3467.5–3477.0	527.0–536.5	9.5	3.43	36
58	22	1951	3477.0–3486.5	536.5–546.0	9.5	2.98	31
59	22	2121	3486.5–3496.0	546.0–555.5	9.5	5.32	56
60	22	2303	3496.0–3505.5	555.5–565.0	9.5	3.15	33
61	23	0044	3505.5–3515.0	545.0–574.4	9.5	1.10	12
62	23	0234	3515.0–3524.5	574.4–584.0	9.5	3.55	37
63	23	0414	3524.5–3534.0	584.0–593.5	9.5	2.58	27
64	23	0558	3534.0–3543.5	593.5–603.0	9.5	1.21	13
65	23	0737	3543.5–3553.0	603.0–612.5	9.5	1.48	16
66	23	0909	3553.0–3562.5	612.5–622.0	9.5	3.48	37
67	23	1102	3562.5–3572.0	622.0–631.5	9.5	4.75	50
68	23	1310	3572.0–3581.5	631.5–641.0	9.5	3.17	33
69	23	1540	3581.5–3591.0	641.0–650.5	9.5	6.02	64
70	23	1813	3591.0–3600.5	650.5–660.0	9.5	8.78	92
71	23	1958	3600.5–3610.0	660.0–669.5	9.5	5.43	57
72	23	2230	3610.0–3619.5	669.5–679.0	9.5	7.76	82
73	24	0145	3619.5–3629.0	679.0–688.5	9.5	5.90	62
74	24	0312	3629.0–3638.5	688.5–698.0	9.5	3.86	41
75	24	0435	3638.5–3648.0	698.0–707.5	9.5	1.50	2
76	24	0605	3648.0–3657.5	707.5–717.0	9.5	2.66	28
77	24	0753	3657.5–3667.0	717.0–726.5	9.5	4.36	46
78	24	1055	3667.0–3676.5	726.5–736.0	9.5	7.59	80
79	24	1303	3676.5–3686.0	736.0–745.5	9.5	8.68	91
					745.5	335.75	45

also occurs in Cores 66 and 69 to 71. In both cases, the kaolinite may indicate redeposition. The deeper occurrence may support the above suggestion that the base of the section approaches a facies change.

Unit I (0.0–154.3 m) Core 535-1 to 535-17-7, 30 cm Holocene to upper Pleistocene

Olive gray to grayish olive clays and muds with subordinate yellowish brown to light brownish gray foraminiferal muds, olive gray to light olive gray muddy foraminifer ooze and light olive gray nannofossil clay make up Unit I.

The description of this sequence is based primarily on the texture and composition of the sediments, because strong drilling disturbance in Cores 6 through 17 resulted in the widespread destruction of the original sedimentary fabric and did not permit the recognition of primary and secondary sedimentary structures. The unit consists of a homogeneous sequence of slightly calcareous to calcareous olive gray clays and muds with minor amounts of sandy mud, foraminiferal mud, and muddy foraminifer ooze. The uppermost 60 cm is a yellowish brown to light brownish gray foraminiferal mud containing less than 30% foraminifers and less than 13% pteropods, but this rapidly gives way to a monotonous sequence of olive gray muds and clays. In Cores 1 and 3, sandy muds with up to 30–50% quartz grains are present, but in the remainder of the unit the dominant lithologies contain less than 5% quartz, although rare deformed sandy laminae and burrow fills do occur. Trace amounts of glauconite are common. Where present, the main biogenic components of these sediments are foraminifers (e.g., as recorded above and in patches of muddy foraminiferal ooze in Cores 12 and 14); siliceous microfossils rarely exceed 1%, and calcareous nannofossils constitute generally less than 3% except in rare, pale-colored, streaky burrow fills in which 20–30% were recorded. Shell debris was noted only once (in Core 12); pteropods were not observed below Core 1, and only a few percent of other biogenic constituents (e.g., tunicate and holothurian spicules and calcispheres in Cores 12 to 14) were encountered in the smear slides. The main calcareous component of the muds and clays is silt-size grains of unspecified carbonate; four carbonate bomb determinations gave results ranging from 10 to 60%. Wood fragments (including small twigs) are common in parts of this sequence and the Rock-Eval pyrolysis results indicate that the organic content of the sediments is predominantly and almost exclusively land derived. Six samples from Unit I yielded an average organic carbon value of 1.2%.

Although drilling disturbance disrupted most of the primary sedimentary structures, it seems likely that many of the deformed coarser laminae may have been small intercalated turbidites; one such sandy mud layer in the core catcher of Core 16 exhibits grading and a sharp basal contact. The calculated sedimentation rate for Unit I is 616 m/Ma. Such a high sedimentation rate suggests that Unit I may have been deposited from low-energy turbidity currents or from nepheloid layers. Most of the sediment was probably derived from the Mississippi Delta system. Seismic lines indicate that Site 535 is situated at the distal edge of the Mississippi Fan. Some angular

Table 4. Summary of lithologic units, Hole 535.

Age	Unit	Main lithology	Thickness (m)	Base: Sub-bottom depth (m)	Base: Core-Section	Recovery (approximate %)
Holocene-late Pleistocene	I	Mud and clay	154.3	154.3	17-7	70
Cenomanian(?)-early Albian(?)	II	Limestone	233.2	387.5	42-4	75
early Albian-late Hauterivian	III	Limestone and marly limestone	79.05	466.55	51-2	40
late Hauterivian-early Valanginian	IV	Limestone and marly limestone	146.65	613.2	68-2	90
early Valanginain-late Berriasian	V	Limestone and marly limestone	100.8	714.0	(T.D.) 79-1	57

Note: T.D. = terminal depth.

components of the coarse fraction may have been derived from a nearer source, such as Cuba.

Unit II (154.3-387.5 m) Core 535-17,CC to 535-42-4, 47 cm Cenomanian(?) to upper Albian(?)

This unit consists of banded, laminated, variably bioturbated and, in part, cross laminated alternations of yellowish gray, light olive gray, greenish gray to dark greenish gray limestones. Texturally, these limestones are predominantly mudstones but with laminae and beds of coarse silt to very fine sand-grade wackestones, packstones and grainstones and subordinate skeletal (oyster-rudist) grainstone beds.

Unit II can be divided into two parts on the basis of the more pronounced cyclicity in the lower division. The first interval spans 147.2 to 259.0 m and includes 535-17,CC to 535-28,CC. From 535-17,CC to 535-20-4, the sediments consist of light olive gray to greenish gray limestones that are predominantly laminated and only rarely bioturbated. Texturally the limestones are peloidal mudstones, but they contain common coarse silt to very fine sand-grade laminae and beds (less than 1 mm-3 cm thick) of shallow-water skeletal material. Some of these coarser layers are cross laminated. Slight color banding with a periodicity of less than 5-15 cm is apparent in the mudstones (these are the Type A cycles discussed previously). From 535-20-5, bioturbation becomes more common and predominates from 535-21-3 to 535-24-2, generally destroying any fine microlaminations but leaving centimeter scale color banding relatively intact. Below 535-21-2, silt-grade to sand-grade shallow-water skeletal material becomes more abundant, and from 535-22-5 to 535-24-4 irregular bioturbated skeletal limestone beds (generally about 3-5 cm but up to 30 cm thick; e.g., Fig. 8) and shelly burrow fills are common. These shelly beds are mostly fine-to-medium sand-sized grainstones but contain scattered very coarse to granule-size fragments. Thin sections of this material generally contain 5-35% peloids, 20-35% oyster debris, approximately 10% rudist fragments, 5-10% echinoderm debris, 10-30% foraminifers, and rare ooids. The thicker beds also contain 10-50% sand-size lithoclasts of foraminiferal wackestone. Observed in the bioturbated interval from 535-22-24, was the only occurrence of Type D cycles at this site. These cycles exhibit an apparent periodicity of 35-60 cm. Coarser shelly laminae are scattered throughout these cycles. Based on the fauna, the skeletal limestone beds probably represented redeposited sediments from shallower water; however, this inference could not be supported by diagnostic sedimentary structures because the beds have been homogenized by burrowing.

From 535-25-1 to the base of this first interval (535-28,CC), the sediments are predominantly laminated. Some sections contain minor bioturbation (less than 20%). Weak color banding with a periodicity of less than 5-20 cm is the most striking feature of this interval (5-20 cm, Type A cycles). Below 535-25-1, the abundance of skeletal material decreases sharply, occurring only in thin (less than 1 cm) grainstone laminae. These grainstones are dominated by peloids, unspecified mollusc debris, and benthic foraminifers. The mudstones are similar to those in the upper laminated part of the interval; they both are peloidal and contain scattered calcitized radiolarians. Thin layers of diagenetic celestite-strontianite were observed in 535-27-3 and 535-28-6. The average carbonate content of the lighter-colored limestone layers in this interval is 95.4% (eight samples) and that of the darker limestone layers, 88% (eight samples). Five samples from this interval have an average organic carbon value of 0.43%.

The second interval occurs between 268.5 and 387.5 m and spans 535-30-1 to 535-42-4. (No material was recovered in Core 29.) The principal distinction between the lower and upper interval of Unit II is the stronger cyclicity exhibited in the lower part of the sequence. The color contrasts between the end member lithologies (i.e., darker marly limestones and lighter limestones) become stronger, and the alternations between bioturbated and laminated intervals increase in frequency, with bioturbated limestones slightly predominant overall (approximately 60%). Several different types of cycles are present including A, B, and E (see Figs. 6 and 7) but the general periodicity is much the same as in the upper interval (10-20 cm).

The sediments of the lower interval of Unit II consist of dark greenish gray to greenish gray laminated or variably bioturbated limestones alternating with lighter-colored, yellowish gray, light gray, or light olive gray bioturbated or laminated limestones. The light-colored limestones contain an average carbonate content of 92.2% (13 samples), and the darker layers average 72.4% (eight samples). The former are much the same as their equivalents in the upper interval, but the latter are significantly more carbonate poor. Only one darker layer (in 535-35-5) was sufficiently low in carbonate to be classified as a marly limestone. Texturally, the limestones in the lower interval are (peloidal) mudstones, but down to 535-30-6 and in 535-37-42 there are sporadic coarse silt-size to very fine sand-size wackestone to

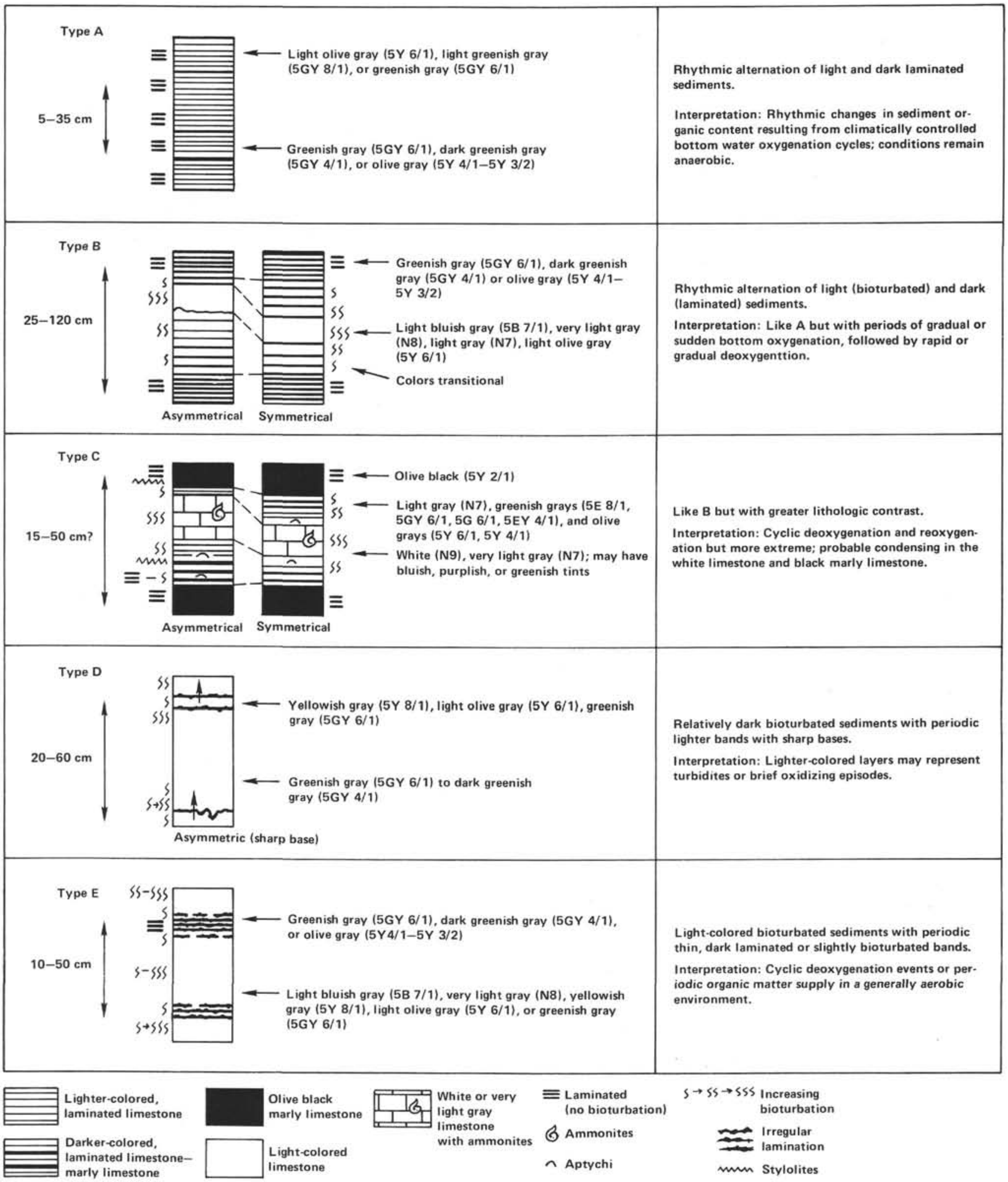


Figure 6. Idealized cycle types from Units II–V, Site 535.

packstone laminae and lenticules, some of which are cross laminated (Cores 30 and 39). The distribution of coarser skeletal debris as burrow fills shows a somewhat different pattern and these were recorded in Cores 31, 36, 37, and 38. The normal mudstones consist of dark and light micrite laminae, and variably peloidal, and contain small amounts of calcitized radiolarians, planktonic foraminifers, mollusc "filaments," dolomite rhombs, and pyrite. Macroscopic pyrite was noted in Cores 31, 33, and 36, but framboidal pyrite is probably ubiquitous. The intercalated wackestone and packstones contain 10 to 35% (coarse silt-size to very fine sand-size) peloids

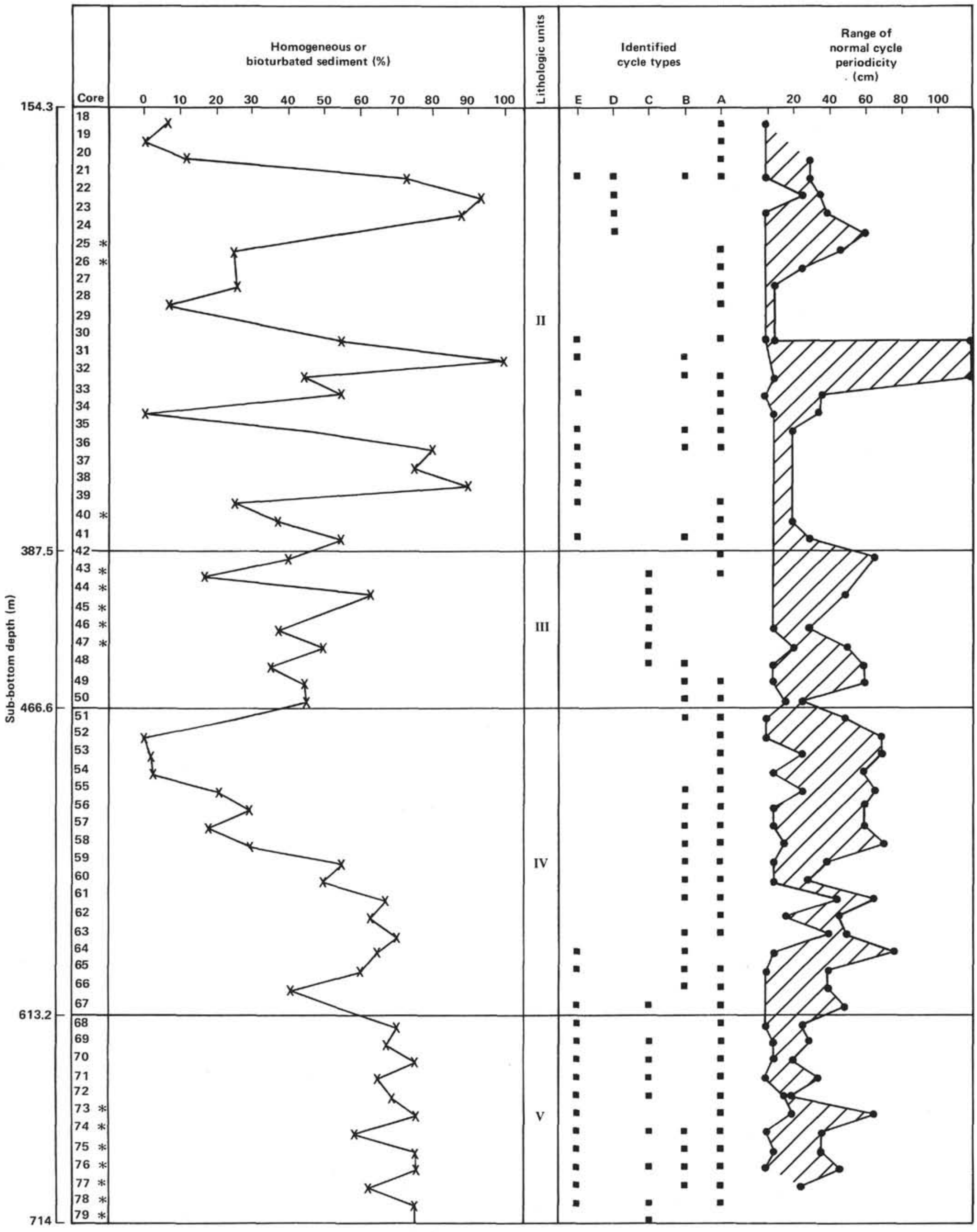


Figure 7. Bioturbation trends, distribution of cycle types and normal range of observed cycle periodicity at Site 535. Bioturbation trend calculated from core photographs. Asterisk after core number indicates poor recovery.

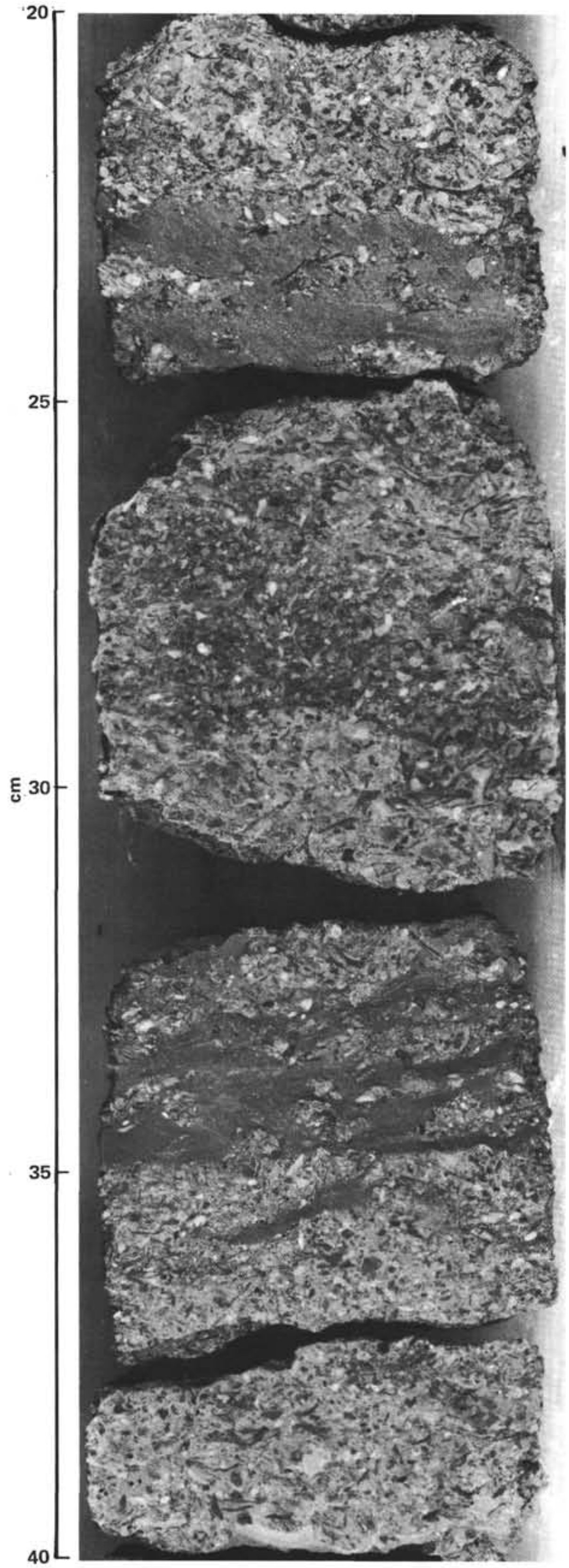


Figure 8. Limestone from Site 535 showing abundant skeletal debris mixed with mudstone by burrowing; Sample 535-23-1, 20–40 cm.

and lesser amounts (approximately 10%) of recrystallized planktonic and/or miliolid foraminifers, mollusc filaments, and calcitized radiolarians. The most coarse-grained packstones contained up to 10% shell and echinoderm debris. The coarse shallow-water skeletal material is apparently absent below Core 42 in this unit.

In Sections 535-34-2, 535-34-3, 535-35-1, 535-35-2, 535-36-1, and 535-36-2, intervals of curved and planar laminae ("en echelon laminae") were observed. The best example of this sedimentary structure is shown in Figure 9. These also occur in Unit IV but are less well developed. This structure has a very strong resemblance to the wavy bedding produced in low-amplitude ripple drift sets. Thickening and thinning of the component laminae seems much more common than truncations of one set against another. However, truncations do occur and although we could not always determine whether this was due to ripple migration across an erosional or depositional surface or to small shear planes, we have little doubt that features such as those shown in Figure 9 reflect traction current deposition. (See Patton et al., this volume, for a discussion of the pelletal nature of these limestones.) Other examples of wavy laminations in these cores may be due to small-scale slump features or diagenesis. Very similar bedding types have been reported from the Quaternary sediments of the continental slope of the Gulf of California where they mark "micro-unconformities" in the sequence (e.g., DSDP Leg 64; Curray, Moore, et al., 1982). Bioturbation is predominantly expressed as unidentifiable mottling. However, *Planolites* burrows are common, and one excellent example of *Zoophycos* was recorded in 535-32-1, 87 cm.

Other features worthy of note in this interval include patches of celestite-strontianite crystals associated with burrows in Sections 535-30-5, 535-37-1, and 535-38-7. These occur as a thin layer in Section 535-39-6, a fracture lining in Section 535-39-5, and as disseminated crystals in Sections 535-38-4 and 535-39-1. Irregular, possibly stylolitic ("horse-tail") laminae were observed in Section 535-31-3; single, subvertical stylolites occur in Sections 535-36-1 and 535-37-2, and subhorizontal stylolites occur in Sections 535-38-3 and 535-38-4. Three samples gave an average organic carbon value for the lower interval of Unit II as 2.35%. Rare ammonites were recorded in Sections 535-31-1, 535-31-2, and 535-36-4.

Unit III (387.5–466.44 m)
Core 535-42-4, 47 cm to 535-51-2, 105 cm
Albian(?) to upper Hauterivian

Cyclic alternations of banded, laminated, and variably bioturbated light olive gray, olive gray, light greenish gray to greenish gray limestones to marly limestones; laminated, organic matter–rich olive black marly limestones; and very light gray to light gray ammonite-bearing, bioturbated, massive limestones. Texturally the sediments are predominantly mudstones.

The upper and lower boundaries of Unit III are taken at the top and base, respectively, of the first and last massive, light gray, pure limestones observed in this part of the section. The sharp lithologic contrasts that char-

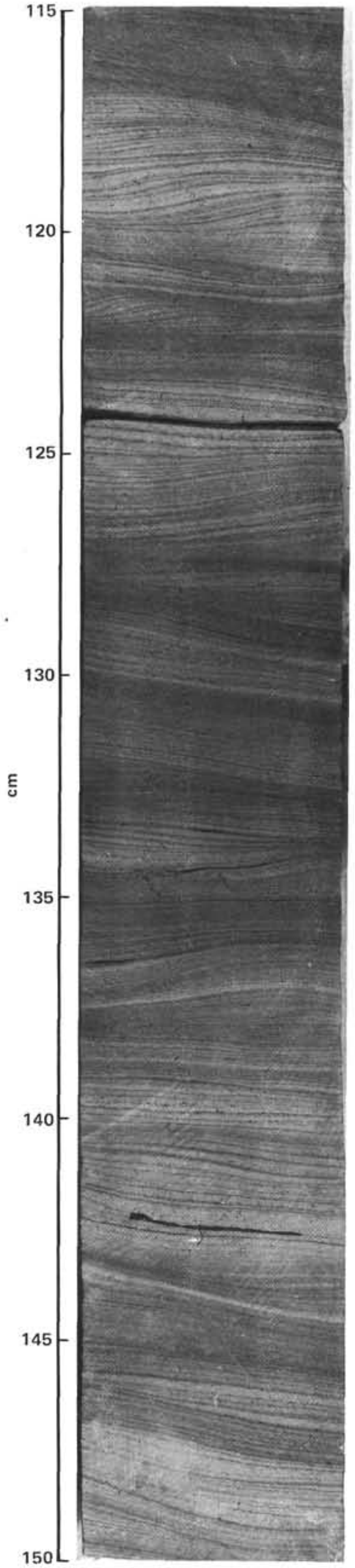


Figure 9. Cross laminations and wavy laminations in pelletal lime mudstone at Site 535. Note variability in thickness and direction of sets. Also note apparent truncation surfaces (e.g., about 144 cm). Sample 535-34-2, 115-150 cm. See text for further discussion.

acterize this unit clearly delineate this interval from the more monotonous limestones that occur above and below it. The typical feature of this sequence is the presence of high-amplitude, Type C cycles (see Figs. 6 and 10), which consist of three distinct lithologies described below:

1. *Olive black marly limestones.* These rocks generally occur as sharply defined 5-10 cm thick beds. They are microlaminated and often speckled due to the presence of white to light gray, compacted sand-size pellets, which are most abundant in the top and/or basal few millimeters of the beds. Four samples gave an average carbonate content of 51.2%. In smear slides and nannofossil preparations, 10-30% nannofossils and 2-30% dolomite rhombs were recovered, but the most consistently abundant carbonate component is crystalline calcite (10-50%). The average organic carbon value for these sediments is 4.7% (four samples) with predominantly type II kerogen.

2. *Light olive gray to olive gray, light greenish gray to greenish gray limestones.* This lithologic component of the Type C cycles varies from laminated (particularly adjacent to Lithology 1 above) to slightly bioturbated and irregularly laminated (in transition to Lithology 3 below). It is essentially equivalent to the laminated limestones in Unit II and occurs in beds ranging from 5 up to approximately 80 cm in thickness. Thin sections indicate a composition of micrite and "flakes" of organic matter, small amounts of calcitized radiolarians and foraminifers, and up to 5% dolomite rhombs, which appear to be concentrated in the darker laminae (identification verified for several samples with X-ray diffraction). Stylolites are common in this lithology. Scattered aptychi are also a conspicuous feature of this sediment, but ammonite body fossils appear to be very rare. Where bioturbation can be identified, it is primarily of the *Planolites* type. Average organic carbon is 1% (three samples).

3. *Light gray to very light gray limestone.* This limestone normally occurs as massive beds ranging from 5-20 cm in thickness that have normally been broken up to varying degrees during drilling. Apart from their very light color, their most conspicuous (but not consistent) feature is the presence of ammonite phragmocones, which are most abundant in the beds in Cores 43 to 47. The ammonites are generally preserved as casts and molds, usually infilled with micrite and with relatively common geopetal fabrics (see Fig. 11). Phylloceratid and baculitid forms were identified; two belemnites were also observed, one in Section 535-48-2 and one in Section 535-49-1. Five carbonate determinations gave an average value of 93.8% for these limestones. In thin section they are mudstones containing small scattered amounts of pyrite, planktonic foraminifers, mollusc "filaments," and calcitized radiolarians; smear slides indicate up to 40% (or possibly more) calcareous nannofossils, often including abundant nannoconids. These limestones tend to have a very uniform appearance, and mottling is generally very weak; good *Chondrites* burrows are often present, but identifiable *Planolites* burrows are usually rather sparse. Both the *Chondrites* burrows and the ammonites tend to be more common at the top of the lime-

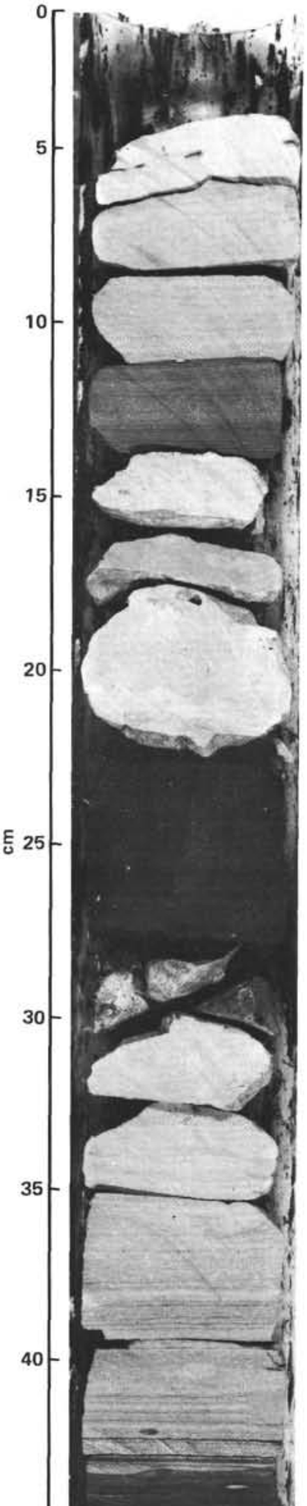


Figure 10. Core photo showing example of Type C sedimentary cycle. See text for explanation. Sample 535-46-2, 0-50 cm.

stone beds. Some of the beds show sharp upper contacts with the olive black marly limestones somewhat reminiscent of hardgrounds.

The poor recovery in Unit III, presumably caused by the pronounced differences in the competence of the three lithologies, prevents any precise analysis of this cyclic sedimentation. Both the periodicities and relative proportions of the different sediments may have been significantly modified. The best cycles were recovered in Sections 535-43-3 and 535-43,CC, and Cores 44, 46, and 47. From Core 48 to the base of the unit (where recovery is much better than in Cores 43 through 47), the black marly limestones and white limestones exhibit a reduction in intensity and frequency at the expense of Lithology 2 above. In this lower part of the unit, the true black marly limestone bands tend to be replaced by interbedded Lithologies 1 and 2. The poor recovery prohibits any conclusions on the periodicity of these cycles, particularly since the cycles here are not simple 1-2-1-2 alternations as in Unit II. The cycles do appear, however, to be symmetrical (in terms of the order, if not of the relative thickness, of each of the components) with a possible tendency for sharp asymmetric changes between Lithologies 3 and 1. The predominant "background" sediment is laminated olive gray limestone. The abundance of black shale type sediments and ammonite-rich limestones in this unit is suggestive of overall slower sedimentation rates, and this is supported by the calculated sedimentation rate of 5–6 m/Ma.

Unit IV (466.55–613.2 m)
Core 535-51-2, 105 cm to 535-68-2, 120 cm
upper Hauterivian to lower Valanginian

This unit consists of banded laminated and variously bioturbated alternations of very light gray, light gray, light olive gray, greenish gray limestones (mudstones) and olive gray, dark greenish gray, and olive black marly limestones (mudstones).

The upper interval of Unit IV, between 466.55 and 503.7 m (535-51-2 to 535-55-5), consists of a predominantly laminated sequence of banded olive gray to light olive gray limestones and marly limestones. The only class of cycle present is Type A (color alternations within completely laminated sediments), but the lighter-colored laminated zones are both horizontally laminated and cross laminated (the "en echelon" structure described for Unit II). Two light-colored bands average 85% carbonate and two darker bands, 70.5%; a single olive black marly limestone in 535-52-4 contains 68% carbonate. Texturally these limestones are mudstones that consist of a micrite matrix containing less than 5% calcitized, sparite-filled radiolarians; very fine-grained shell debris; and rare foraminifers. The micrite often occurs in irregular lenticular laminae and appears to be pelletal, as is suggested by the macroscopically speckled appearance of these rocks.

The "en echelon" cross lamination noted above is most abundant in Core 52, but remains relatively common to the base of the interval. Scarce bioturbation is present between Sections 535-53-5 and 535-55-2. Other interesting features include two thin intercalated pyritic

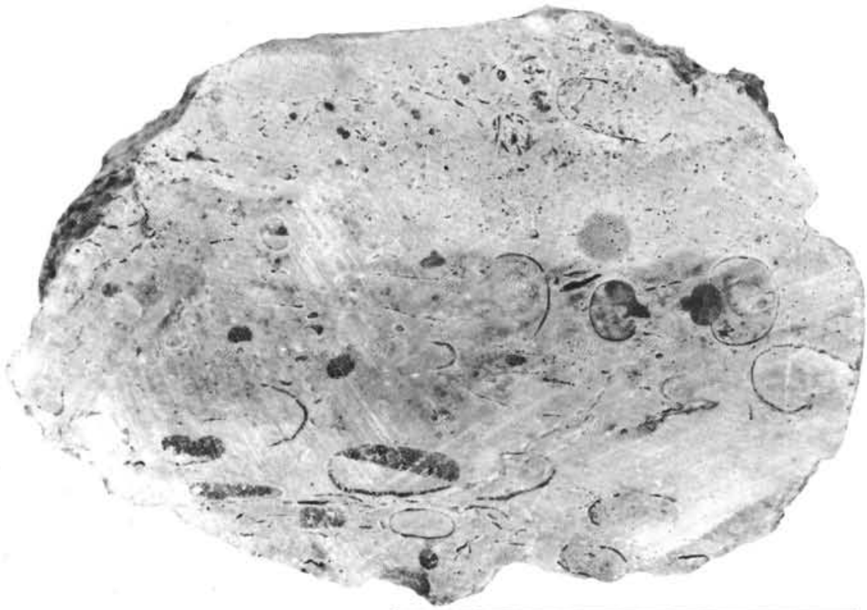


Figure 11. Limestone from 535-44-2, 67–71 cm, showing common ammonite fragments and molds. Several molds display classic geopetal fabrics with sparry calcite overlying an earlier micrite partial filling of the cavity.

mudstones in Core 52, two pyritic chert nodules, a small chert-filled pyritized ammonite in Section 535-53-3, and a vertical stylolite in Section 535-55-3 between 43 and 71 cm. There were ammonites in lighter-colored beds in Cores 53 to 55, but aptychi were generally more numerous and tended to be most common in the darker laminated beds.

The lower interval of Unit IV (503.7–613.2 m; Sections 535-55-5 to 535-68-2) is distinguished from the upper part by its stronger cyclicity and the appearance of very light gray to olive gray limestones and olive black marly limestones that generally increase in abundance towards Unit V. Type A and B cycles are present, and from Core 64 downward, Type E cycles also appear (see Fig. 7). Eight samples from the light-colored limestone bands gave an average carbonate value of 89.1%, whereas 11 samples from the darker layers averaged 71.7% (five limestones and six marly limestones). Six olive black bands were analyzed, yielding an average carbonate content of 48.8%; four were marly limestones, one band (in Section 535-68-2; 22%) an olive black shale (22%) and another (Section 535-64-6; 33%) transitional between the two. Only one other olive black shale was recorded at this site, from Section 535-48-5 in Unit III.

Texturally, all the limestones sampled for thin sections in this interval are mudstones consisting of 94–99% pelletal micrite or micrite with scattered amounts of calcitized radiolarians, planktonic foraminifers, and thin-shelled mollusc fragments. One of the dark limestones from Section 535-57-2 contains up to 35% dolomite rhombs, and dolomite and coccospheres are common to abundant in nannofossil preparations of the olive gray to dark olive gray marly limestones. The sediments of the lower interval are also macroscopically speckled and pelletal. Ammonites are relatively common in the lighter-colored bands in Cores 60 through 62; they are present throughout the interval but are rare in the other cores. Stylolites occur in Sections 535-59-2, 535-59-4, and 535-61-4.

Cross laminated structures (Fig. 9) are fairly common in Cores 56 to 58, are temporarily lost, and then occur less frequently and more sporadically between Core 535-63 and Section 535-68-2. Bioturbation is present to varying degrees through the lower interval of Unit IV; *Planolites* is the main identifiable trace fossil. One of the most interesting aspects of this unit was the presence of hydrocarbon-stained and asphalt-filled fractures in Sections 535-58-3 to 535-58-5, 535-59-1 to 535-59-4, 535-64-4 to 535-64-6, and 535-63-2. The significance of this material is discussed in the geochemistry section. The apparent periodicity of the cycles appears to decrease toward Unit V (see Fig. 7).

Unit V (613.2–714.0 m, terminal depth) Core 535-68-2, 120 cm to 535-79-1 lower Valanginian–upper Berriasian

Cyclic alternations of massive, bioturbated to poorly laminated light olive gray, light gray, very light gray, and white limestones with light olive gray, greenish gray, and dark greenish gray limestones to marly limestones and olive black marly limestones characterize this unit. The lighter-colored limestones often show pale yellowish brown or dark yellowish brown coloration, possibly indicating varying degrees of dolomitization. Most of the limestones are mudstones. A few of the light-colored limestones are skeletal wackestones (probably hardgrounds) that sometimes exhibit dusky blue, pale blue, and dusky green tints. Several thin bentonitic clays are present in the upper part.

The general lithologies of this unit are very similar to those described for Unit III, except that bioturbated rather than laminated limestones form the bulk of the interval. This predominance of lighter-colored bioturbated sediment, which becomes more pronounced toward the base of the hole, tends to make Type C cycles merge into Types B and E, although the olive black marly limestone beds and, to a lesser extent, the lightest-colored limestones are still well defined. Increasingly poor recovery and breakage of the cores toward the base of the unit make an exact reconstruction of the cycles progressively more difficult. The principal sediment types are described below:

1. *Olive black marly limestones.* Three carbonate determinations from these bands gave an average value of 49.3%. They are laminated and sometimes contain sand-size, light-colored pellets that can give the rock a macroscopically speckled appearance. They are often pyritic and nannofossil preparations contain common dolomite rhombs. Beds generally are 5 cm or less in thickness.

2. *Olive gray to greenish gray limestones and marly limestones.* Seven carbonate determinations from this lithology yielded an average composition of 64.5% carbonate, three limestone samples and four marly limestones (44–65%). In thin section, they are mudstones containing 15–35% dolomite rhombs in a micritic matrix showing faint, relict, laminated, or burrowed fabrics. Pyrite and possibly also marcasite are common. Scattered aptychi and relatively common stylolites are present. This lithology is laminated and bioturbated to varying degrees. Between Cores 70 and 79 microfolds occur, suggesting soft sediment deformation.

3a. *White, light gray, very light gray, or light olive gray limestones (mudstones).* These sediments are predominantly bioturbated, and sometimes laminated; with Lithology 2, they form the major part of Unit V. They are probably somewhat less pure than their equivalents in Unit III and often have a slightly brownish or greenish coloration, frequently corresponding to areas exhibiting more pronounced relict fabrics (e.g., small laminated or irregularly laminated patches amongst the bioturbation). Such relict laminated areas often exhibit only *Chondrites* burrows. The brownish coloration may also result from variable degrees of dolomitization. In thin section, they consist of approximately 45% micrite (sometimes with abundant nannoconids), the remainder including calcitized radiolarians, fine shell debris, foraminifers, pyrite, and, from Cores 70 to 79, calpionellids. Ammonites, aptychi, and stylolites are present.

3b. *White to light gray or very light gray, bluish, or greenish limestones (wackestones).* Although similar to Lithology 3a, these limestones are distinguished by their slight blue or greenish coloration and the greater abundance of ammonites and other skeletal material. They are wackestones with 15–30% skeletal particles, including 1–18% mollusc debris (cephalopods, pelecypods, and less than 3% gastropod fragments), 5–10% calpionellids, 2–3% calcitized radiolarians, 3–10% calcispheres, and trace amounts of up to 2% foraminifers. The fossil material is generally recrystallized to blocky calcite, and the micrite that fills voids in the bioclasts is lighter colored than the "pseudo-pelletal" micrite matrix. Some grains show indications of algal boring. Geopetal fabrics are common in the larger fossils. These limestone bands, several of which are interpreted as hardgrounds, were recorded from Sections 535-68-2, 535-71-2, 535-72-1, 535-78-1, and 535-79-1. In rare cases there are sharp contacts between these bands and Lithology 2, where a relief can be observed on the upper surface of the limestone (Sections 535-68-2 and 535-79-1). The best and most abundant examples of this type of sediment were recovered in Core 79. The color observed here may be due to the periodic establishment of reducing conditions indicated by the intercalated olive black marly limestones. The skeletal wackestones in Section 535-79-1 are composed of 5–15% mollusc debris, 0–15% coated grains, 7–15% calpionellids, less than 7% calcispheres, less than 7% calcitized radiolarians, up to 5% foraminifers, and up to 3% echinoderm fragments. Several glauconitic and phosphatic pellets occur in one thin section. The coated grains consist of recrystallized mollusc debris or fish debris coated by concentric layers of coarser and finer calcite crystals. In some core pieces of these limestones, large dendritic areas of pyrite (and chalcopyrite?) are present, and pyrite may replace or coat the fossils. Geopetal fabrics, erosional surfaces, and stylolites, which are sometimes lined by less than 2 mm of pale green glauconitic(?) clay, are also common.

4. *Medium light gray (N6) kaolinite-smectite-montmorillonite swelling "bentonitic" clays.* These sediments occur as thin layers (2–8 cm thick) in Sections 535-68-5, 535-69-4, and 535-70-1 and as a component of two dark-colored marly limestone bands in Section 535-69-5. The layer in Section 535-68-5 has a carbonate content of 15%.

Comments on Cyclic Sedimentation in Units II to V, Site 535

The various types of cycles observed in Units II to V were designated A to E (Fig. 6), where the sequence A through E is believed to represent an overall improvement in bottom oxygenation. This is generally indicated by the increasing proportions of bioturbated versus laminated sediments from Types A to C cycles. It does not indicate the relative magnitudes of time for which oxygenated or deoxygenated conditions prevailed during the deposition of the cycle, because some of the white bioturbated limestones in Type C cycles are clearly condensed and may record longer periods of time than the darker sediment. It is also clear that lamination is at least in part due to lower flow-regime traction currents (i.e., in at least some of the cross laminated intervals). The frequency and periodicity of the dark bands observed in these cycles is suggestive of a cyclic climatic control of bottom-water oxygenation, as is the presence of very similar cycles in coeval sediments in the central Atlantic and Alpine Tethys. The estimated durations of the cycles observed between Cores 535-48 and 535-76 range between 125,000 and 6,000 yr.

Many features of the Type C cycles observed at Site 535 are typical for clay, "black shale," and coccolithic limestone cycles described from the Tithonian to Upper Cretaceous from southern and northwest Europe, the western interior of the U.S., and other DSDP sites. The main points of similarity include:

1. the cyclic alternation of dark (carbonate-poor) and light-colored (carbonate-rich) lithologies in a symmetrical manner or with a tendency for sharp asymmetric changes between the top of the light layers and base of the dark (excepting Type D cycles—see Fig. 6),

2. the decrease in bioturbation from light to dark, with a concomitant increase in the preservation of microlaminations, and the tendency for any bioturbation in the darker layers to have a very low vertical penetration of the sediment,

3. the apparent scarcity of ammonites in the dark layers and their comparatively common or abundant occurrence in the light-colored, bioturbated limestone bands,

4. the higher organic carbon values of the black layers and their tendency to contain type II or type II–III kerogens,

5. the speckled appearance of many of the black layers caused by the presence of sand-size pellets, and the occurrence of common coccospheres in these layers; the pelletal fabric and appearance of the darker layers in thin section typical of Jurassic to Cretaceous rocks composed of clay and coccolithic pellet-rich alternations,

6. the presence of early diagenetic dolomite rhombs associated with the darker, more organic matter–rich layers,

7. the inverse relationship between the distribution of coarse detritus and the black laminated beds,

8. the inverse relationship between cross lamination and black laminated beds.

Regional Comparisons

The Cretacous sequence cored at Site 535 shows many similarities with the upper Tithonian to Barremian Blake-Bahama Formation of the central Atlantic. The latter unit exhibits an analogous cyclic repetition of laminated marly nannofossil chalks and better cemented bioturbated chalks (Jansa et al., 1979), but does not contain any equivalents of the cephalopod-rich hardground limestones observed in Units III and V at Site 535. Both sequences exhibit common stylolites, good preservation of nannofossils in the darkest lithologies, and common aptychi. The analogy between the two units may suggest that calcareous nannoplankton were the major source of carbonate in Units III to V.

Although the cyclic variations in sedimentary environments were periodically much more extreme at Site 535 than in the central Atlantic, the two basins were clearly similar until the Barremian–early Aptian. At that time the Atlantic Basin went through transition from the nannofossil chalks of the Blake-Bahama Formation to the carbonaceous claystones of the Hatteras Formation. No corresponding facies change was observed at Sites 535 and 540. This contrast may have resulted from:

1. the massive influx of platform-derived carbonate material at Site 535 not apparent in the Hatteras Formation (Tucholke and Mountain, 1979),

2. a significant difference in the water depths at Site 535 and in the central Atlantic basin, with the former remaining above the oxygen-deficient portion of the Atlantic bottom water,

3. the absence of deep bottom-water connections between the two regions.

The cored section at Site 535 is also similar to the coeval sequences in the west and central parts of Cuba (Pinar del Rio and Las Villas provinces; Pardo, 1975). These sequences consist of brown, gray, or dark gray, sometimes organic matter–rich, pelagic nannofossil limestones with shaley intercalations. They appear to be very analogous to the sequences at Site 535 but differ in that they contain significant amounts of black chert. Redeposited skeletal limestones with *Orbitolina* occur in the upper Aptian to Turonian pelagic limestones of the Las Villas Belt and may be equated with the partly coeval facies of Unit II. It is possible that Site 535 and the Cuban sections have a much greater affinity with each other than they do with the central Atlantic basin.

Site 539

Site 539 consisted of two short holes with a total thickness of only 14.5 m drilled. The first hole (539) drilled two cores to a total depth of 7 m. The first core recovered 0.83 m of brown to gray nannofossil mud, and the second core recovered 3.57 m, mainly nannofossil mud with the bottom 0.5 m consisting of nannofossil ooze and foraminiferal-nannofossil ooze. The sediments ranged in age from Holocene to late Pliocene.

The second hole (539A) drilled only one core to a total depth of 7.5 m and recovered 7.23 m. The upper 1.5 m was brown gray nannofossil mud followed by about 1 m of gray marl. The lower 5 m of the core consists of white nannofossil ooze. The age of the sediments ranges from Holocene or late Pleistocene to Miocene and late Oligocene.

Site 540

The sedimentary sequence cored at Site 540 is divided into six lithologic units summarized in Table 5 and Figure 4. The units are described in detail below.

Unit I (0–4.5 m)
Core 1
Holocene to upper Pleistocene

The predominant sediment type of this unit consists of light olive gray or medium gray to olive gray nannofossil marly limestone with some light yellowish brown patches and streaks. This unit also includes an interval of pale green semilithified nannofossil ooze in 540-1-2, 70–80 cm. A similar ooze, mixed with marly limestone, occurs in Section 540-1-3 between 50 and 124 cm and represents a layer completely disrupted by drilling. Clay is the major detrital constituent, making up 28–40% of the unit. Volcanic glass is also present (2–10%). The biogenic components include abundant nannofossils (40–45%) and foraminifers (5–10%). There are trace amounts of diatoms, radiolarians, and sponge spicules. Two carbonate bomb analyses indicate 51–63% $CaCO_3$.

Unit II (4.5–272.37 m)
Core 540-2 to 540-30-2, 37 cm
middle Miocene to upper Paleocene

The top of this unit is defined by the first appearance of light-colored ooze. This unit consists mainly of nan-

Table 5. Summary of lithologic units, Hole 540.

Age	Unit	Main lithology	Thickness (m)	Base: Sub-bottom depth (m)	Base: Core or Core-Section
Holocene-late Pleistocene	I	Marly limestone	4.5	4.5	1
middle Miocene-late Paleocene	II	Ooze, chalk, marly limestone	267.87	272.37	31-2
middle Paleocene-early Cenomanian	III	Pebbly marlstone and volcanic sands	55.78	328.15	36-1
early Cenomanian-late Albian	IV	Limestone	170.35	498.50	53
late Albian-middle Albian	V	Limestone	218.50	717.0	76
middle-early Albian	VI	Skeletal limestone	28.50	745.5	79

nofossil ooze, chalk, and limestone; white to greenish gray marly chalk; marly limestone; and greenish black marly limestone. Volcanic ash layers occur throughout Unit II.

All transitions between ooze and limestone can be observed in this sequence. This unit can be further subdivided into three subunits.

Subunit IIa (4.5–33 m, Cores 2 through 4) is composed of relatively pure light greenish gray nannofossil oozes and chalks with some patches of grayish orange glauconitic clay. Lithification is variable. Some pale brown mottles, bands, and deformed light gray layers are present in Cores 2 and 4. Dark gray pyritic spots and laminations are also present. Volcanic ash forms light gray layers or scattered bands and patches. Smear slides show that the relatively high percentage of carbonate (approximately 70%) is mostly microfossil material including nannofossils (66–93%) with rare foraminifers (maximum 2%). Clay averages 2–5%. In the last core of this subunit, chalk appears irregularly distributed in ooze.

No primary structures were observed in the first core because of drilling disturbance, but laminations and burrows were identified in the lower cores.

The top of *Subunit IIb* (33–142 m; Cores 540-5 to 540-16-3) is defined by the dominance of chalk and by the occurrence of interbedded nannofossil-foraminiferal marly limestones and sandy marly limestones. The latter sediments are greenish gray to light olive brown and occur as a minor lithology in 2–4 cm thick bands. The bases of these bands is usually sharp, and the tops are gradational and burrowed. Sandy marls in Cores 12 and 16 are greenish gray to greenish black.

The chalk that composes most of this subunit is white to light greenish gray (5G 8/1) or greenish gray with common dark gray (N5) pyritic spots and faint laminations. This sediment is made almost exclusively of nannofossils through Core 9; below this foraminifers become common. Volcanic ash occurs in Core 6 and Cores 9 to 14 as patches or burrow fills. In Cores 10 and 11, ash layers have sharp bases and burrowed, gradational tops. Bioturbation is common throughout the chalk and occurs as abundant irregular yellowish gray to light olive gray mottles. *Chondrites* and *Planolites* are the most common recognizable trace fossils. Dark greenish gray and greenish gray chert nodules occur in Cores 7, 10, and 12.

Foraminifers are always relatively abundant (10–28%) in the marls of this subunit but the nannofossil content decreases uniformly with increasing lithification down the core. Carbonate content varies from 32–65% for the marls and 70–88% for the chalks.

The top of *Subunit IIc* (142.0–272.4 m; 540-16-3 to 540-30-2, 37 cm) is defined by the first appearance of slump structures in the cores. The composition of the sediments is generally the same as Subunit IIb. They are composed of alternations of foraminiferal-nannofossil chalk and nannofossil marly limestone. The chalk is very light greenish gray to light greenish gray and bluish white. Less common are greenish gray bands and burrowed light greenish gray layers (e.g., Cores 18 and 24). Faint greenish gray laminations are sparsely distributed; well-preserved laminations are rare (e.g., Cores 23, 27, and 30). In thin section, these laminations consist of concentrations of calcitized radiolaria. Marly limestones are dark greenish gray layers usually less than 5 cm thick, but sometimes up to 10 cm thick (e.g., Cores 25, 29, and 30).

Minor constituents in this subunit include foraminiferal limestone, sandy marly limestones, volcanic ash, and chert. The limestone, at the top of Core 20 and in Cores 28 and 29, is mottled very light gray to medium light gray (N6). Sandy marly limestones are greenish gray to dark greenish gray and mixed with volcanic ash (Cores 18, 19, and 29). Ash is common and occurs in 1–3 cm thick layers sometimes mixed with chalk. In 540-25-1, 97–110 cm, greenish gray chalk mixed with a foraminiferal ash layer rich in biotite and feldspars may be autochthonous sediment reworked by an ash turbidite. Angular quartz (3–20%) is commonly associated with the ash layers. Grayish green to greenish gray or dark greenish gray chert occurs as nodules in Cores 20, 24, 26, 28, and 29 and as an olive gray band in Core 23.

Burrows are common in this subunit and are best seen in greenish layers. Identified burrows include *Planolites* and excellent examples of *Zoophycus*. Slumping and sliding, which characterize Subunit IIc, take the form of inclined and wavy layering, flow structures, folds, microfaults, and deformed burrows (Fig. 12). Very small scattered asphalt spots occur in Cores 26, 27, and 29. Finely divided pyrite is common in spots and mottled patches scattered throughout this subunit. Smear slides show that the trend for decreasing nannofossil content downsection observed in Subunit IIb continues in this subunit (10–20%). Foraminifers are always present (more than 10–20%), sometimes forming sand layers where they are mixed with quartz (e.g., Cores 23–24).

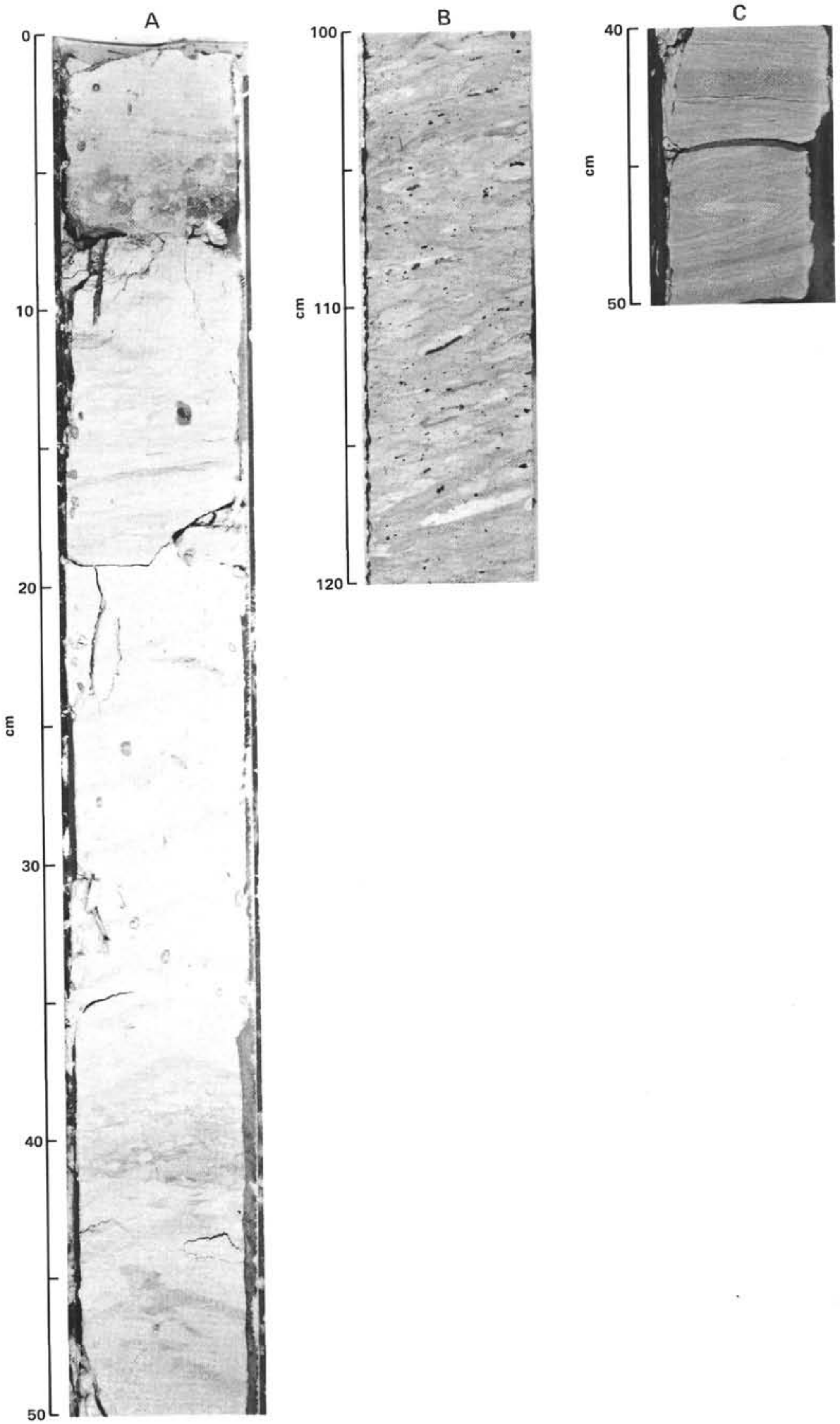


Figure 12. Soft sediment deformation, Hole 540. A. Sample 540-16-6, 0–50 cm; deformed *Zoophycus*-type burrows caused by sliding. B. Sample 540-29-1, 100–120 cm; deformed mottled texture. C. Sample 540-26-3, 40–50 cm; slump fold in chalk.

Unit III (272.37–328.15 m)
Core 540-30-2, 37 cm to 540-36-1, 67 cm
upper Paleocene to middle Cenomanian(?)

This unit is characterized by matrix-supported "pebbly chalk and limestones" and subordinate cross-laminated and parallel laminated sandstone. Sharp upper and lower contacts separate it from the pelagic facies of Units II and IV.

Pebbly chalk in Core 30 consists of claystone clasts up to 3 mm in diameter (olive black to dark greenish gray) scattered in a mottled greenish gray to light greenish gray foraminiferal chalk matrix. It overlies predominantly light-colored very light gray, light greenish gray, volcanic carbonate sandstone in Core 31. This sandstone is cross-bedded, laminated with several truncated cross-bed sets, and internally deformed. It consists of calcite-cemented foraminifers (25–60%), altered volcanic glass (0–20%), peloids (0–25%), lithoclasts (0–20%), mollusc fragments (0–15%), and echinoderm grains and calcispheres (*Pithonella* sp.). Some clay zeolite matrix is also present. Downward, the light sandstone passes into a strikingly dark (pyrite-rich) calcareous, conglomeratic volcanic sandstone (Fig. 13) in the upper 2 m of Core 31. The volcanic sandstone is dark gray and contains white and yellowish white lithoclasts of shallow-water limestone. The basal 30 cm is a conglomerate consisting of shallow-water limestone, black chert, and very coarse calcareous sand. The largest clasts are pebble-size (at the base), as large as 2 cm and generally decrease in size upward. This fining-upward trend gives the bed the appearance of being graded. The bed is poorly sorted as a whole. The composition near the top of the bed is altered volcanic glass (60%), unspecified carbonate (25%), and pyrite (15%). The overlying light-colored, volcanic, calcareous sandstone may have been deposited at the same time as the underlying dark calcareous volcanic sandstone; as such, the depositional unit is crudely graded and at least 3 m thick.

The remainder of the unit is a sequence of pebbly chalks and limestones (Fig. 14) interbedded with irregularly laminated and burrowed marls and limestones. Because of poor recovery in Cores 31 to 36 the proportions of interbeds are unknown. Pebbly limestones consist of lithologically diverse clasts, up to 4 cm in length, scattered in greenish gray to light olive gray fine-grained limestone matrix. Detrital components include: (1) white and yellowish gray shallow-water, skeletal carbonate debris ranging in size from fine-sand to cobbles of rudists and lithoclasts; (2) lithoclasts of pelagic chalk and limestone; (3) soft clay and claystone lithoclasts; (4) black chert; and (5) altered volcanic ash. Matrix material is gray chalk containing *Planolites* burrows and clayey streaks of greenish gray and medium light gray marly limestone. The other common interbed lithology is massive and occasionally laminated light olive gray to yellowish gray limestone containing radiolarian and other skeletal molds.

Unit III is conspicuous for three reasons. First, the large diversity of detrital elements makes it lithologically distinct from underlying and overlying units. Both debris flow and turbidity-current processes probably played roles in the deposition of this unit. Second, despite the previously mentioned differences, the unit does retain some intermediate characteristics of Units II and IV, in particular the volcanic ashes of Unit II and the black cherts and moldic pelagic limestones of Unit IV. Third, it must also be noted that the unit spans a large interval of time, about 40 Ma, but probably includes significant stratigraphic gaps. A similar unit was drilled at nearby DSDP Site 97 on Leg 10 (Worzel, Bryant, et al., 1973).

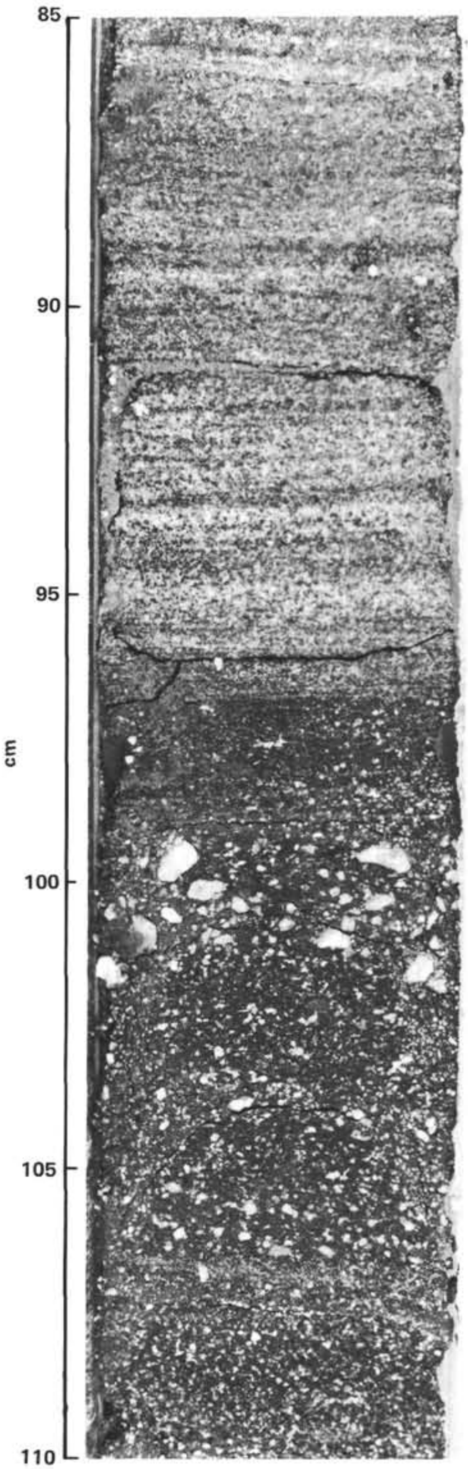


Figure 13. Light limestone lithoclasts in pyritic volcanic sandstone (turbidite), Sample 540-31-2, 85–110 cm.

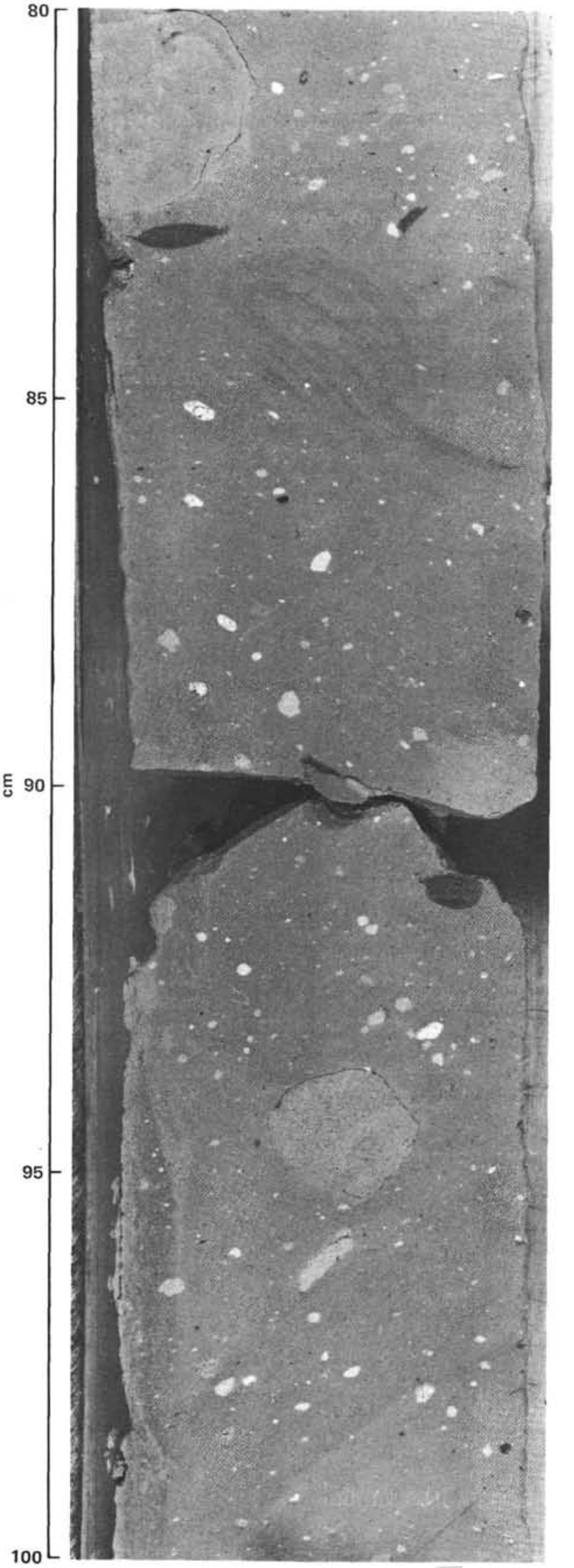


Figure 14. Typical pebbly limestone of Unit III showing poorly sorted lithoclasts in fine-grained limestone. Sample 540-32-1, 80–100 cm.

Unit IV (328.15–498.5 m)
Core 540-36-1, 65 cm to Core 540-53
lower Cenomanian–upper Albian

A sharp contact exists at 540-36-1, 65 cm between the pebbly chalks of Unit III and the pelagic or hemipelagic fine-grained limestones of the top of Unit IV.

This unit shows a rhythmic alternation (on a 30–60-cm scale) of light-colored limestone (about 93% $CaCO_3$) and dark somewhat clayey limestone (about 80% $CaCO_3$).

Smear slides show foraminifers to be sparse in the upper part of the unit but more abundant below Core 46. Dolomite rhombs are present in the marly limestones in Cores 36 through 44 and reach 20% in Core 37.

The light-colored beds are also massive; homogeneous; light olive gray to yellowish gray or greenish gray; fine-grained micritic limestone with common aligned circular voids (molds of radiolarians). Molds of pelecypods and ammonites can also be observed locally. Strong bioturbation (including *Planolites*) has destroyed much of the primary sedimentary structures particularly below Core 45. However, some banding and laminations are present. One type of lamination is formed by accumulations of calcitized planktonic forms (foraminifers, radiolarians and "filaments"). Another type of lamination reflects the intercalations of calcareous silt or sand. Laminations tend to be more widely spaced where the limestones are very compact.

The marly limestone is olive gray to olive black or dark gray. The highest percentage of clay recorded in this limestone is 35% in Core 52. Marly limestones alternate with the pure limestones described above and represent 30–40% of each cycle. In Units II and III this proportion is less. Marly limestones have a more well-developed banding and laminations and less, though more conspicuous, bioturbation than the pure limestones. *Planolites* and *Chondrites* type burrows are present.

The boundaries between the two lithologies are often gradational, the sharpest contacts tending to be at the top of dark marly limestones. Brecciation during drilling prevents any systematic observations about these contacts.

Skeletal lime sand and silt are very common in all parts of the cycles in Unit IV. They are often present in olive gray laminae, lenses, or more rarely in graded layers (Sections 540-44-1 through 540-46-2).

Less common lithologies include drilling fragments of the following limestone types: (1) coarse-grained limestones in Core 50, up to 3 mm thick, with peloids, radiolarians, and echinoid and mollusc fragments; (2) skeletal-pelletal limestones in Section 540-37-2; (3) a piece of skeletal limestone in Core 45 with intraclasts of radiolarian and foraminiferal mudstone, and molluscs, foraminifers, echinoids, and green algae debris with micritic envelopes; (4) white hydrozoan limestone, 540-52-1, 77–90 cm.

Black chert is very common in Unit IV. It usually appears as broken pieces of nodules but also occurs in the limestone matrix.

Unit IV is also characterized by deformation features including variable inclined layering in Core 47 at the bottom of Sections 1 and 2, slump folds in Core 40 and in 540-52-1, 0-80 cm, small faults (Core 53), and truncations of laminae (Cores 41 and 42). There is also evidence of deformation during compaction, such as pressure solution structures in Core 53, which may have been induced by bioturbation and differential lithification.

Unit V (498.5–717 m)
Cores 54–76
upper Albian to middle Albian

The top of this unit is marked by a sharp distinction between the well-developed cyclic alternations of Core 53 and the more homogeneous sequence of Core 54, however, this sharp contrast may be an artifact of poor recovery in Core 53. The principal characteristics of the unit are its great uniformity and the mottled and bioturbated aspect of the sediments.

Unit V consists of alternations of light-colored and dark limestones (average cycle 75 cm) corresponding to variations in the percentage of clay, pyrite, and organic matter. Colors recorded are light gray, very light gray, greenish gray, and light olive gray for the lighter layers; medium light gray or even dark greenish gray for the darkest ones.

Sedimentary structures in the limestone include faint laminations and layering and (in Section 540-55-1) cross-bedded intervals. The limestones are often intensely burrowed (mainly *Planolites* and *Chondrites*, sometimes *Zoophycus*). The bioturbation is most evident in the darker intervals where burrows are filled with lighter-colored material.

Pelecypod molds have been observed in the lighter-colored limestones (Cores 61 and 63). Thin sections show three very uniform microfacies: (1) pelletal-foraminiferal wackestones; (2) mudstone with radiolarians and foraminifers; and (3) unfossiliferous mudstone.

Three subunits have been distinguished. Subunit Va (498.5–623.2 m; 540-54 to 540-67-1, 120 cm) consists of fine-grained limestones with generally over 90% $CaCO_3$ and rare skeletal layers (Cores 59 and 67). Subunit Vb (623.2–663.0 m; 540-67-1, 120 cm to 540-71-2) is characterized by a distinctly mottled texture and by common intercalation of carbonate sand containing shallow-water debris and occasional pebble-size clasts (e.g., Section 540-69-2). The mottling is caused by local concentrations of divided pyrite within burrow structures (Fig. 15). Subunit Vb has slightly less carbonate than Subunit Va (66–96%). Subunit Vc (663.0–717.0 m; Section 540-71-3 to Core 76) consists of uniform, bioturbated limestone with scattered shell fragments and one whole echinoid test.

Unit VI (717–745.5 m)
Cores 77–79
middle Albian

This unit consists of fine-grained limestone with intercalated very coarse to very fine sand-size skeletal carbonate material. The dominant limestone is similar to that of Subunit Vc. In the interval from 540-77-3, 90 cm to 540-79-1, 75 cm, it is distinctly banded. There is a regular alternation of 5–10-cm thick light and dark sediment (greenish gray to dark greenish gray or greenish black). Below 540-78-2, 120 cm, bands become more

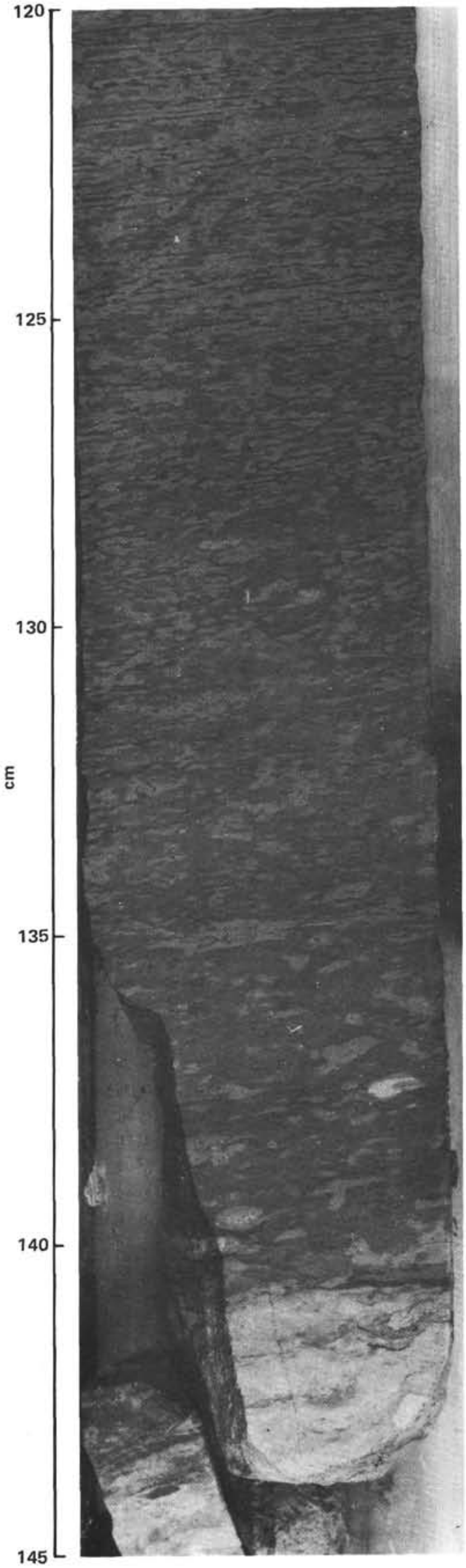


Figure 15. Mottled limestone. Flattened patches giving a pseudolaminated fabric. Sample 540-70-6, 120–145 cm.

diffuse and the wavelength of the cycles more irregular (up to 45 cm in Section 540-78-5) with a dark sediment prevailing.

Skeletal carbonate debris occurs in two forms: (1) small lenses (0.1–1 cm thick) of very fine to fine sand-size material in micritic limestone, and (2) layers tens of centimeters thick. Some of the fine material is cross-bedded. The thicker layers are light gray to medium light gray and medium gray and yellowish. They contain abundant debris and are strongly bioturbated. Grains are well sorted to poorly sorted and medium grained to coarse grained. Occasional limestone intraclasts in Sections 540-77-2 and 540-77-3 range up to 10 mm across. The thick layers are skeletal grainstones with mollusc fragments (mainly rudists), foraminifers, echinoderms, peloids, and some coated grains. Other thick layers are foraminiferal-peloidal packstones with similar compositions but also contain planktonic foraminifers and echinoid spines and green algae.

Summary of Site 540

The sequence at Site 540 is dominated by carbonate ooze and chalk in the Tertiary and fine-grained limestone with radiolarians, foraminifers and deep-water burrowers, such as *Planolites* and *Zoophycus*, in the Cretaceous. This indicates deposition in deep water and in pelagic to hemipelagic environments, consistently above the carbonate compensation depth.

From middle Albian to lower Cenomanian, the sequence at Site 540 suggests pelagic deposition in a mostly aerobic basin. However, high rates of calcareous sedimentation (up to 119 m/Ma during the late Albian) are difficult to explain by purely pelagic sedimentation. These rates suggest additional input of fine carbonate material from platforms, as well as the redeposition of coarser skeletal debris.

The Turonian through upper Paleocene is characterized by long gaps in the sedimentary sequence. Turonian to Santonian and lower Paleocene rocks are thin or absent as a result of erosion and/or nondeposition. Indications of sediment instability first appear in the upper Albian section (e.g., Cores 52–53 and 41–44), and slump structures are most common in the upper Paleocene to lower upper Oligocene interval. The overlying sediments appear to be undisturbed.

Intercalations of volcanic ash first appear in the Campanian-Maestrichtian with a thick, redeposited unit in Core 31. Thinner volcanic ash beds occur throughout the Tertiary to Quaternary sequence and may be related to volcanic activity on Cuba. The lower Miocene and a great part of the Pliocene section is also absent as a result of erosion or nondeposition.

BIOSTRATIGRAPHY

Site 535

Summary

The combination of the biostratigraphic events of nannofossils, planktonic foraminifers, and calpionellids recorded from Site 535 allows the following comments.

Unit I (535-1 to 535-17,CC partim) is upper Pleistocene. The *Emiliania huxleyi* nannofossil Zone and the *Globorotalia truncatulinoides* planktonic foraminiferal Zone persist throughout. Also, reworked lower Pleistocene and Miocene planktonic foraminifers and nannofossils, as well as Upper Cretaceous nannofossils, persist throughout most of this interval.

Residues from Unit II (Core 535-17 through Section 535-43-2) yield very poorly preserved nannofloras and very poor planktonic and benthic foraminiferal faunas. These suggest an early to middle Albian age. It should be noted that the more common benthic foraminifers of the richer faunules represent a mixed assemblage of shallow-water and mid-bathyal species.

Samples 535-31-1, 84–88 cm and 535-33-1, 35–37 cm yield juvenile specimens of *Acompsoceras*, which is characteristic of the lower to middle Cenomanian (Young, this volume). The presence of this ammonite and the persistent evidence of mixing of benthic foraminifers mentioned above combine to suggest that the foraminifers are extensively reworked from both shallower realms and older rocks.

This interpretation is supported by the occurrence of two possibly caved specimens of *Scaphites* in Core 45 (Young, this volume), which appears in the Vraconian (uppermost Albian).

The upper part of Unit III is characterized by poor recovery and rubbly material. The following sequence of nannofossil and planktonic foraminiferal zones have been found in this interval.

A specimen of *Scaphites* was found in Core 45. As noted above, this genus is unknown in rocks older than Vraconian, and its presence requires some explanation of the discrepancy in age implied by it and by the microfossils. Two interpretations are possible. First, the interval of Cores 43 through 46 may be reworked, as apparently was true of the interval above. Second, the *Scaphites*-bearing piece of rubble may have fallen from the lower part of the overlying unit to the bottom of the hole and was recovered with the rubble of Core 45. Indications that the latter interpretation is correct lie in the probability of wall caving, implied by the poor and rubbly recovery of the interval by a drilling break at the top of the interval and also by the lack of reworked or displaced material in the samples from the interval.

The occurrence of *Hedbergella sigali* with *Lithraphidites bollii* in Core 47 suggests that only the lowermost Barremian may be present in this core.

It appears, then, that the upper part of Unit III is characterized by a condensed sequence that includes unconformities. As a result, the following stratigraphic intervals are absent or poorly represented.

1. Most of the Albian is missing and is represented only by the *Scaphites*-bearing rubble.
2. Only four of eight Aptian foraminiferal zones were recovered, including two of the upper Aptian and two of the lower Aptian but none of the middle Aptian.
3. Most and perhaps all of the Barremian is missing. Despite the poor recovery, it is evident that this short, 35-m section represents an interval of almost 20 Ma.

In contrast, the lower part of Units III through V (the interval beginning with Core 47 and continuing to total depth) appears to represent a continuous sequence spanning the upper Hauterivian through most of the upper Berriasian.

Planktonic foraminifers are of little biostratigraphic value below the Barremian. Hauterivian and Valanginian nannofossils, however, are well documented from Cores 48 through 75. Further evidence of age is provided by the calpionellids, which are present from Core 65 to total depth. The interval from Cores 65 to 76 (partim) was assigned an early Valanginian age on the basis of species of the *Calpionellites* Zone. Cores from 76 (partim) to total depth were assigned a late Berriasian age because of forms of the *Calpionellopsis* Zone. Correlations based on the calpionellids agree with nannofossil and palynomorph data from this interval.

Foraminifers and Calpionellids

Cores 1 through 17, core catcher excluded, yield Pleistocene faunules. The uppermost 60 cm of Core 1 consist of two coarser layers, probably a graded foraminiferal-pteropod sand, which is attributable to the Holocene. The remainder of Core 1 is largely composed of turbiditic clay. The core catcher of Core 1 contains planktonic foraminiferal fauna of late Pleistocene age mixed with a fauna of different preservation, possibly early Pleistocene in age. The occurrence of fragments of *Alcyonaria* and small calcareous benthic foraminifers such as *Astrononion* and *Discorbis* suggests that some material from the shelf and/or outer shelf environment was redeposited at Site 535 during the Holocene.

The interval containing Cores 2 through 17 is composed primarily of turbiditic material that ranges from a turbiditic clay (535-5,CC) yielding very small foraminifers and wood debris to a turbiditic sand, very rich in large planktonic foraminifers, and in general, associated with rare to common fragments of larger foraminifers and other biogenic debris of shallow-water origin (535-12,CC; 535-13,CC; and 535-14,CC). In the latter samples, planktonic foraminifers are broken and abraded as a consequence of mechanical transport. Reworked faunas of early Pleistocene and late Miocene age may also occur.

The intermediate lithotype, turbiditic silty clay yields large amounts of commonly subrounded and subangular quartz grains. Mica flakes, including biotite, and a few fragments of mafic green rocks are minor components. In this lithotype, planktonic foraminifers are rare and small; shallow-water debris and wood fragments are common.

The aspect of planktonic foraminiferal faunas from Cores 1 to 17 (partim) is tropical except in 535-5-4, 114–116 cm and possibly 535-3-4, 15–18 cm. The former sample yields a planktonic fauna rich in cold-water species such as *Neogloboquadrina pachyderma* and is devoid of warm water globorotaliids.

In the interval from 535-17,CC through 535-43-2, foraminiferal faunas were recovered from relatively few layers, and, with few exceptions, they are poorly diversified and very badly preserved. Planktonic faunas, particularly those recorded from laminated limestones, are rare and composed of uniformly small forms; the larger forms are missing. The benthic forms associated with those faunas are also small and belong to miliolids, *Patellina* and *Trocholina*, suggesting that displacement from shelf and outer shelf areas was an important process.

The combined study of several thin sections from the hardest lithotypes and of washed residues from the more clayey layers allows recognition of a few taxa. Rare and poorly preserved *Favusella washitensis* occur in 535-17,CC. Core 18 contains rare and poorly preserved Cretaceous planktonic foraminifers, of which an occasional specimen is similar to one or another of the Vraconian fauna (e.g., ?*Planomalina buxtorfi*). Core catcher samples from Cores 19 to 28 contain very rare planktonic foraminifers; *F. washitensis* and unidentified hedbergellids are the only recurrent forms. This interval contains several layers of coarse redeposited shallow-water material, sometimes very rich in larger agglutinated foraminifers (535-22,CC; 535-23-1, 11–32 cm; 535-23-4, 21–23 cm; 535-23,CC; 535-25-3, 82–84 cm). The species recognized are *Orbitolina texana, Paracoskinolina sunnilandensis*, and a phylogenetically advanced specimen of *Cuneolina*, which may indicate an early, possibly middle, Albian age. Miliolids, fragments of rudist, thick-shelled pelecypods, and echinoids are associated in large amount with the orbitolinids. Thinner coarse layers contain mainly fine fragments of megafossils (presumably the same as in the coarsest layers), miliolids, and a form related to the genus *Nezzazata*.

The more clayey laminated limestone of 535-28,CC yields a medium-rich foraminiferal fauna composed of some planktonic but mainly benthic forms. The benthic assemblage is composed largely of allochthonous forms typical of shallow-water environment.

With the occurrence of more clayey layers in the interval from Section 535-31-6 to Core 42, the number of levels yielding relatively rich, slightly better-preserved, planktonic foraminifers increases. The best assemblage, in terms of richness as well as diversity, was recovered from 535-32-3, 110–112 cm (gray marly limestone). *F. washitensis, Hedbergella rischi, H. planispira, H.* cf. *infracretacea, Ticinella primula*, and *T. "praeberggiensis,"* the ancestral form of *T. breggiensis*, have been identified among others. They are characteristic of the *Ticinella primula/H. rischi* Zone of middle Albian age. The associated benthic assemblage is composed of *Spirillina minima, S. tenuissima, Ammodiscus cretaceous, Bathysiphon* sp., and *Praebulimina*, indicating a mid-bathyal environment.

The same planktonic assemblage, varying in abundance, occurs downhole through Core 35. Coarser layers containing shallow-water material are rare in this interval; very minute fragments are recorded only in 535-32-3, 78–82 cm.

The interval from Cores 36 to 39 yields *H. planispira* associated with *F. washitensis*. Planktonic faunas are mainly composed of small species except for *F. washitensis* and are indicative of an early Albian age. The benthic assemblages indicative of the mid-bathyal zone become more prominent in the shallow-water faunas.

Calcispherulids are common in some layers of this interval as well as some organic matter and fish debris (535-35-3, 29–32 cm; 535-37-1, 22–23 cm).

The several laminated layers from this interval contain small reworked shallow-water benthic foraminifers, such as *Trocholina, Patellina, Conorotalites* associated with common ostracodes and fragments of megafossils (535-36-1, 80–82 cm).

The interval from Cores 40 to Section 535-43-2 yields scattered *Ticinella bejaouaensis and some Hedbergella*, also belonging to the lower Albian. Some layers (535-41-5, 121–122 cm; 535-41-6, 2–3 cm; 535-42,CC) yield much fish debris, common fecal pellets, protochonchs of ammonites, and large crinoid fragments. Carbonaceous matter is present in variable amounts. Planktonic foraminifers are generally small, the larger specimens reach only 200 μm. The richer, mid-bathyal, benthic assemblages consist mainly of single species of the genera *Spirillina, Conicospirillina, Bathysiphon, Reophax,* and *Dentalina.* They are frequently pyritized; pyrite infills the tests of planktonic foraminifers.

Radiolarians are abundant to very abundant in 535-27,CC; Cores 18 through 20; and 535-28,CC. Elsewhere they are rare. Their preservation, whatever the abundance, is very poor. They are always heavily recrystallized and frequently are calcified. In the dark clayey layers, radiolarians are totally pyritized with frequent destruction of the tests.

Aptian forms appear in Section 535-43-3 in association with a pronounced lithic change. Section 535-43-3 and Core 44 contain *H. gorbachikae, H. trochoidea, H. similis, Globigerinelloides barri, G. ferreolensis,* and *Planomalina cheniourensis.* This fauna is correlative with the *H. gorbachikae* Zone of the upper Aptian. Core 45 contains *Caucasella* sp., *G. maridalensis, G. blowi, G.* cf. *duboisi, H.* cf. *infracretacea*, and *H. occulta*, which indicate the *G. maridalensis/G. blowi* Zone. Based on the occurrence of both zonal markers and the absence of *G. blowi* and *G. maridalensis,* Core 46 is attributed to the *G. gottisi/G. duboisi* Zone. Both mentioned zones are early Aptian in age.

Except for rare *H. sigali* in 535-47-2, 38–41 cm, rare to few *Caucasella* spp. are the only planktonic foraminifers found in Cores 47 through 64. The rare to sparse benthic faunules are dominated by simple forms, such as species of *Ammodiscus, Spirillina*, and *Conicospirillina.* The frequency and diversity are thus very low. All of the taxa are long ranging and without correlative utility, leaving that responsibility of age determination to the nannofossils.

Radiolarians are few to common but are much more abundant and persistent than the foraminifers. Their diversity is low, however, for radiolarian assemblages, but they provide some basis for inferences about depositional environment.

Both foraminifers and radiolarians are pyritized in most of the dark and organic-rich rocks. The relationship is most pronounced in the black shales, which contain little other than small residues of radiolarians and a few foraminifers. The dark, often laminated, marly limestones typically contain pyritized foraminifers and radiolarians and calcitic, recrystallized benthic foraminifers. The lighter limestones contain a mixture of pyritized and calcitic recrystallized benthic and planktonic foraminifers.

The interval from Cores 65 to 79 (bottom of hole) is distinguished by the well-known calpionellid assemblage of earliest Cretaceous age. Calpionellids are first encountered in 535-65-2, 25–27 cm. They are most common in light-colored, micritic limestones, which are more frequent in this interval than in the overlying ones. The interbedded, dominant gray layers, mainly laminated, contain only poorly preserved radiolarians, frequently associated with minute dolomite crystals.

The calpionellids occurring from Core 65 through Section 535-76-1 belong to the calpionellid Zone E (= *Calpionellites* Zone) of early Valanginian age. Section 535-76-2 contains a rich calpionellid assemblage attributable to Subzone D3 of *Calpionellopsis* Zone. The Valanginian/Berriasian boundary falls within this interval. The Subzone D2 of *Calpionellopsis* Zone is recorded in Core 77 through Section 535-79-1 based on the occurrence of the diagnostic species *C. simplex.* The Subzone D1 of the *Calpionellopsis* Zone is the oldest identified in Section 535-79-2. Thus, the upper Berriasian appears to be fully represented at Site 535 and the hole possibly bottomed in the very top of the lower Berriasian.

The softer, dark marly layers intercalated within limestones yield relatively rich mid-bathyal benthic assemblages similar to those recorded higher in the hole. Rare planktonic globigerinids, mainly heavily pyritized, occur all the way through this interval.

Displaced shallow-water debris and benthic foraminifers are either associated with the autochthonous benthic assemblages or found in thin lenses in the laminated limestones.

Nannofossils

Cores 1 through 17 contained calcareous nannofossils of the *Emiliania huxleyi* Zone (CN15) of late Pleistocene to Holocene age. The top of Core 1 (0–60 cm) is composed of foraminiferal mud with well-preserved, abundant, calcareous nannofossils. Little reworking of pre-Pleistocene nannofossils is evident in this biogenic deposit. From 535-1-1, 60 cm to the base of Core 17, the sediment consists of brown mud with common to few calcareous nannofossils. This brown mud contains two distinct assemblages. The younger is a homogeneous Neogene flora consisting in part of *Emiliania huxleyi, Gephyrocapsa oceanica, G. caribbeanica, Helicopontosphaera* spp., *Discoaster* spp., *Sphenolithus abies*, and *Reticulofenestra pseudoumbilica.* The older assemblage recovered from this mud is Upper Cretaceous in age and may compose up to 75% of the nannofossil assemblage. This flora is characterized by *Eiffellithus turriseiffeli, Micula staurophora, Prediscosphaera cretacea, E. eximius*, and *Gartnerago obliquum.*

The interval from 535-17,CC (partim) through Core 79 (terminal depth) is Early Cretaceous in age. Samples of the hard limestone from 535-17,CC and Core 18 contain only dissolution-resistant forms such as *Lithastrinus floralis, Parhabdolithus angustus, Watznaueria* spp., and *Rucinolithus irregularis*. These species suggest an Aptian through Albian age for Cores 17 and 18. Clay-rich beds within the laminated limestones of Cores 19 and 20 contain a moderately rich, moderately well-preserved flora that includes *Prediscosphaera cretacea, L. floralis,* and *Parhabdolithus angustus.* The absence of *E. turriseiffeli* suggests the *Prediscosphaera cretacea* Zone of early Albian to (early) late Albian age.

The hard limestones recovered in Cores 21 through 31 yield only poorly preserved, sparse assemblages of calcareous nannofossils. Assemblages contained only the most dissolution-resistant nannofossils, such as *L. floralis* and *Nannoconus truitti.* Those species that were recovered were typically heavily overgrown.

An increase in the clay content of some of the laminations within the limestone in Core 32 and subsequent cores resulted in better recovery of calcareous nannofossils from these intervals. Within these clay-rich laminae, nannofossils varied from common to abundant with moderate to good preservation. Core 32 through 535-39-3, 27–39 cm contain assemblages with *L. floralis, Parhabdolithus angustus, Chiastozygus litterarius, Corallithion achylosum*, and *N. truitti.* In addition, broken fragments of shields and stems of *Prediscosphaera cretacea* s.l. are present, indicating that the *P. cretacea* Zone extends into Core 39.

The interval from Cores 40 through 43 contains assemblages similar to the overlying strata, except that *P. cretacea* is absent. This cored interval has been assigned to the *Parhabdolithus angustus* Zone of late Aptian to early Albian age. The relative abundance of nannoconids in many samples within this interval is probably the result of selective dissolution of the nannofossil assemblage.

Samples 535-44-1, 79–80 cm and 535-44-2, 50–51 cm contain a moderately well-preserved nannofossil assemblage within clay-rich, pyritic, black marly limestones that are intercalated in hard limestones. These black marly limestone horizons yield assemblages that contain *Chiastozygus litterarius* but not *L. floralis* nor *P. angustus.* This core is placed in the *C. litterarius* Zone of latest Barremian to early Aptian age. Cores 45 and 46 yield only nondiagnostic nannofossil assemblages.

The black marly limestones of Cores 47 through 50 contain good assemblages of nannofossils, which included *Lithraphidites bollii.* This interval is placed within the *L. bollii* Zone of early Barremian to late Hauterivian age. *Cruciellipsis cuvillieri* is also present in Cores 48 through 50. The occurrence of *L. bollii* and *C. cuvillieri* together indicates a "middle" Hauterivian age for Cores 48 through 50.

Samples from the black marly limestones in Cores 51 through 72 contain moderate to good nannofossil assemblages. The species present include *Calcicalathina oblongata, Cruciellipsis cuvillieri, N. colomi, Micrantholithus obtusus,* and *Bipodorhabdus colligata.* This interval has been placed within the *Calcicalathina oblongata* Zone of early Valanginian to early Hauterivian age. It should be noted, however, that the upper boundary of this zone, marked by the first occurrence of *L. bollii,* may be a function of the dissolution of *L. bollii* rather than its evolutionary appearance. Cores 63 through 68 contain sporadic occurrences of *Diadorhombus rectus* and *Tubodiscus verenae.* These two species have been used by Roth (1978) to delineate a zone in the late to "middle" Valanginian. Wind and Čepek (1979) note, however, that both of these species may range into the Hauterivian.

Cores 73 through 79 contain black marly limestones with well-preserved assemblages of the *Retecapsa angustiforatus* Zone (late Berriasian to early Valanginian). The species present include *R. angustiforatus, Cruciellipsis cuvillieri, Cretarhabdus conicus, Lithraphidites carniolensis*, and *N. colomi.*

Site 539

Foraminifers

Hole 539

Sediment was recovered from the mudline, Cores 1 and 2. Below the latter, harder material was encountered and penetration ended because of inadequate seat for the bottom-hole assembly.

Material of the mudline contained abundant pteropods, foraminifers, and some sponge spicules. The foraminifers are both Recent and late Pleistocene in age, but mainly the latter. The foraminifers from 539-1,CC are also of Pleistocene age, but the fauna is dominated by globigerinid forms, and many of the typical carinae and globigerinoid species are absent, indicating a paleoenvironment of colder water and a glacial stage. Both the physical aspect and the foraminiferal fauna from Core 2 appear older than Pleistocene. The fauna includes late Pliocene to early Pleistocene forms, such as *Globorotalia miocenica* and *G. pertenuis* in abundance and few *G. truncatulinoides.* However, somewhat older forms, such as *Globigerina nepenthes, G. venezuelana,* and *Globoquadrina altispira* were not seen. An attribution to the latest Pliocene is suggested.

Hole 539A

The drilling in Hole 539A recovered one sediment core before drilling was abandoned. The interval from 0 to 135 cm in Section 539A-1-1 contains a rich, planktonic foraminiferal assemblage of Holocene age. Upper Pleistocene planktonic foraminiferal faunas with cold-water affinities occur in the interval from 539A-1-1, 136 cm through 539A-1-2, 78 cm. The keeled *Globorotalia* of *G. tumida* group and *G. cultrata–G. menardii* group are lacking. *G. truncatulinoides* is represented only by senestral individuals. *Neogloboquadrina dutertrei* and *G. crassula* occur in some amount. The interval from 539A-1-2, 79 cm through 539A-1-3, 92 cm contains upper Miocene planktonic foraminiferal assemblages. They can be attributed to Zone N18 through the upper part of Zone N17. Faunas are from moderately to strongly dissolved. The color change at Section 539A-1-1, 125 cm corresponds to the appearance of large amount of pyrite nodules. Pyrite infills foraminiferal tests and burrows.

The remainder (539A-1-3, 93 cm to 539A-1,CC) contains a rich assemblage of late Oligocene age, attributed to the upper part of *G. opima* Zone (= P21b).

Calcareous Nannofossils

Hole 539

The drilling in Hole 539 recovered two sediment cores before the hole was abandoned. The interval from Core 1 through 539-2-2, 130 cm contains nannofossil assemblages that include *Emiliania huxleyi, Gephyrocapsa oceanica, G. caribbeanica,* and *Ceratolithus cristatus.* This assemblage indicates the *E. huxleyi* Zone (CN15) of late Pleistocene to Holocene age. The interval from 539-2-2, 132 cm to 539-2,CC contains assemblages that include *Discoaster pentaradiatus, D. brouweri,* and *C. rugosus* but lack *D. surculus.* This interval is assigned to *D. pentaradiatus* Subzone (CN12c) of late Pliocene age. Both cores recovered sediment that contains abundant, well-preserved nannofossil assemblages.

Hole 539A

The drilling in Hole 539A recovered one sediment core before drilling was terminated. The interval from 539A-1-1, 0 cm through 539A-1-2, 90 cm contains assemblages typical of the *Emiliania huxleyi* Zone (CN15) of late Pleistocene to Holocene age. The interval from 539A-1-2, 90 cm through 539A-1-3, 85 cm contains *Discoaster asymmetricus* and *D. quinqueramu.* This assemblage indicates the *D. quinqueramus* Zone (CN9) of late Miocene age. The interval from 539A-1-3, 92 cm to 539A-1,CC is of the *Sphenolithus ciperoensis* Zone (CP19) of late Oligocene age. Species present in this interval include *S. ciperoensis, S. distentus, S. predistentus, Cyclicargolithus abisectus, C. floridanus,* and *Dictyococcites bisectus.*

Site 540

Summary

The micropaleontologic nature of the lithologic units is described below.

Unit I (Core 1) is a nannofossil marl of late Pleistocene (N22; CN15) age. Nannofossil assemblages include sparse reworked Pliocene, Miocene, and Upper Cretaceous species. No reworked foraminifers were observed.

Unit II (Cores 2 to 30) consists of upper Paleocene through upper Miocene nannofossil-foraminiferal ooze, chalk, and marly limestone with some volcanic ash layers. The Tertiary sedimentary record is interrupted by at least seven hiatuses, some of which are marked by obvious unconformities.

Cores 2 through 5 are upper Miocene (N17–N16; CN9). Middle Miocene microfossils occur as reworked elements of the assemblages from this interval. Core 6 through 540-7-1, 30 cm (in Unit IIb) are middle Miocene (N13; CN6). The interval from 540-7-1, 34 cm through Core 21 includes a thick sequence of upper Oligocene (P22–P21; CP19–CP18) sediments. The sediments in Core 22 through 540-23-2, 27 cm contain planktonic foraminifers of early Oligocene (P20–P19) age. The nannofossils, however, indicate a slightly younger age for this part of the section. This discrepancy is probably the result of the difficulty in distinguishing early forms of *Sphenolithus distentus* from its immediate ancestor *S. predistentus.* Thus, the foraminiferal age determination is probably more valid for this interval than that derived from the calcareous nannofossils. Foraminiferal and nannofossil data are in agreement in assigning the interval from 540-25-1, 0–85 cm to the early Oligocene (P17; CP16).

The interval from 540-25-1, 110 cm through 540-27-1 is assigned to the late Eocene (P17–P16; CP15). The interval from 540-27,CC through Core 28 contains middle Eocene (P12; CP13b) microfossil assemblages. Both microfossil groups agree on the assignment of Core 29 to the early Eocene, although dissolution makes zonal determination of the entire core difficult. Nannofossils indicate that Section 540-29-1 is in Zone CP12, and planktonic foraminifers indicate that 540-29,CC is in Zone P8. Because the foraminiferal Zone P8 is equivalent to part of the nannofossil Zone CP12, the age of Core 29 appears to be consistent.

The interval from 540-30-1 through 540-30-2, 40 cm is assigned to the late Paleocene (CP8; P6). The interval from 540-30-2, 41 cm through 540-30,CC is in foraminiferal Zone P4 and the nannofossils are of Zone CP5 and CP6 (partim). This indicates a small hiatus in the Paleocene.

Unit III is a complex redeposited unit consisting of pebbly chalks, a fining-upward interval of volcanic and calcareous sandstone and conglomerate, and another thick pebbly chalk with folds and large clasts. The upper pebbly unit in Core 30 contains upper Paleocene assemblages, the sandstone and conglomerate sequence in Core 31 contains Campanian–Maestrichtian planktonic foraminifer species, and the upper part of the lower pebbly chalks contain middle Cenomanian assemblages. Thus, the unit ranges in age from late Paleocene to middle Cenomanian and represents several different periods or pulses of debris flow and turbidity current deposition.

Unit IV (Cores 36 through 53) consists of rhythmic alternations of light-colored and dark limestone with some black chert and layers of neritic carbonate sand. The age of this unit is early Cenomanian through late Albian. The nannofossils within this unit are of the *Eiffellithus turriseiffeli* Zone (Cores 36 through 49) of late Albian through early Cenomanian age and of the *Prediscosphaera cretacea* Zone (Cores 51 through 53) of early Albian through early late Albian age. The age of Core 50 is indeterminant based on nannofossil evidence. The planktonic foraminifers yield a more detailed biostratigraphic division during this period of time than do the nannofossils. Planktonic foraminifers indicate a threefold division of Unit IV. Cores 37 through 40 are assigned to the *Rotalipora brotzeni* Zone of early Cenomanian age. Cores 41 through 45 are in the *Planomalina buxtorfi* Zone of latest Albian (= Vraconian) age. The remainder of Unit IV (Cores 46 through 53) is assigned to the *Ticinella breggiensis* Zone of late Albian age. The occurrence of the ammonites *Turrilitoides* and *Scaphites*

(Young, this volume) in Core 44 indicate a latest Albian (Vraconian) age, which is in agreement with microfossil data.

Unit V (Cores 54 through 77) consists of fine-grained limestones that contain fine calcareous silt/sand in the middle portion (Core 67 through Section 540-17-1). This unit is entirely within the *Prediscosphaera cretacea* nannofossil Zone of early Albian through early late Albian age. The higher resolution of the planktonic foraminifers indicates that Cores 54 through 70 are within the *Ticinella breggiensis* Zone of late Albian age, whereas Cores 71 through 76 are within the middle Albian *T. primula–Hedbergella rischi* Zone.

Unit VI (Cores 77 through 79) consists of fine-grained limestone with abundant coarse skeletal debris. The age of the unit remains uncertain. It may still belong to the *T. primula* Zone (*P. cretacea* nannofossil Zone). Shelf-derived foraminifers such as *Favusella washitensis* are common in the marly layers. Echinoid spines, crinoid fragments, and ostracodes are abundant. These fossils indicate the influx of shallow-water material to Site 540 during the middle to late Albian.

Foraminifers

Pleistocene foraminifers occur only in Core 1. A fairly typical fauna of the *Globorotalia truncatulinoides* Zone (N22) was recovered.

The Miocene extends from Core 2 to 540-7-1, 34 cm. Core 2 is correlative with N17 of the upper Miocene, indicating a hiatus of at least 5 Ma. Dissolution distorts the faunal content and reduces the frequency and preservation.

The long Oligocene succession (540-7-1, 35 cm through 540-25,CC) is upper Oligocene down to 540-23-2, 27 cm. Lower Oligocene species occur from there down to 540-24,CC, and concurrent nannofossils down to 540-25-1, 85 cm, immediately above an ash layer at 540-25-1, 85–110 cm. The presence of the ash and the brevity of the lower Oligocene suggest a hiatus above or below the ash bed.

The interval from 540-25-1, 110 cm to 540-27-1 was assigned to the uppermost Eocene *Turborotalia cunialensis* Zone on the basis of the assemblage in 540-25,CC. Foraminifers from the rest of the interval are poorly preserved, and assignment is based on nannofossil data. Poorly preserved foraminifers also prevail in residues down to 540-30,CC, but the fauna of 540-28,CC was correlated with the *Morozovella lehneri* Zone of the middle Eocene and that of 540-29,CC with the *M. aragonensis* Zone of the early Eocene. Late Paleocene species of the *Planorotalites pseudomenardii* Zone (P4) occur in 540-30-2, 32–35 cm and 540-30,CC.

The interval from Cores 31 through 36 is an extremely complex succession of turbiditic sediments, including hardgrounds; interpretation is complicated by poor core recovery. Faunas from some laminae of Core 31 are dominated by planktonic species of the Campanian-Maestrichtian, indicating the Late Cretaceous in spite of populations of widely mixed, Albian to Maestrichtian species in most residues. Cores 32 through 36 contain rotaliporas and other species of the *Rotalipora brotzeni* Zone.

Beginning with Core 37, light gray, mottled and/or laminated limestones with minor, thin intervals of dark marly limestone occur and continue to 540-76,CC. Although, with rare exceptions, the limestones could not be disaggregated, those of the softer, dark beds could be. These beds yielded well-preserved, although somewhat narrow, faunas, particularly within the *Planomalina buxtorfi* Zone of the uppermost Albian (Cores 41 through 45) and the upper part of the *Ticinella breggiensis* Zone. With increasing depth, the softer, dark beds became fewer and the foraminiferal fauna more restricted. Consequently, continuation of the upper Albian *T. breggiensis* Zone was based on the intermittent but continuing presence of *T. raynaudi* and absence of indicators of older horizons.

Below Core 70, *T. raynaudi* is absent and planktonic foraminiferal fauna contain only *T. primula, Hedbergella rischi,* and *H. planispira*. This assemblage has been assigned to *T. primula–H. rischi* Zone of middle Albian. *T. primula* and *H. rischi* have not been found in Cores 78 and 79; the age of the lowermost interval recovered at Site 540 remains thus open. Cores 78 and 79 may still belong to the *T. primula* Zone.

Cores 77 through 79 differ markedly in lithologic and paleontologic qualities from the overlying sequence. Skeletal particles of wide range in size occur in layers and as constituents of largely fine-grained limestone. Planktonic foraminifers from minor argillaceous layers change predominantly to shelf species, including well-preserved, large specimens of *Favusella washitensis*. Benthic forms become common, as they were at Site 535. Echinoderm material such as echinoid spines, microcrinoid fragments, and various ostracodes are also abundant. The autochthonous benthic assemblages of the fine-grained limestones are characteristic of mid-bathyal zone; *Praebulimina, Ellipsoidella, Gaudryina,* and *Osangularia* are the best-represented genera.

Calcareous Nannofossils

Core 1 contains assemblages that include *Emiliania huxleyi, Gephyrocapsa oceanica, G. caribbeanica*, and *Ceratolithus cristatus*, indicating the *E. huxleyi* Zone (CN15) of late Pleistocene through Holocene age. In addition, reworked nannofossils of Miocene and Pliocene age, as well as some Cretaceous species, occur as minor elements of these assemblages.

The sediments in Cores 2 through 7 (partim) are of Miocene age. Cores 2 through 5 contain *Discoaster berggrenii, D. quinqueramus*, and *Triquetrorhabdulus rugosus*, indicating the *D. quinqueramus* Zone (CN9) of late Miocene age. Numerous middle Miocene species, such as *D. neohamatus, D. bollii*, and *Catinaster coalithus*, occur as reworked elements of these assemblages. The abundance of these reworked species increases (stratigraphically) downwards. The youngest components in the assemblages in the interval from Core 6 through 540-7-1, 30 cm are of the *C. coalitus* Zone (CN6) of the middle Miocene. Species present include *C. coalitus, D.*

bollii, and *T. rugosus*. *D. kugleri* occurs as a reworked component in some samples in this interval.

The sediments in Cores 7 (partim) through 25 (partim) are of Oligocene age. The interval from 540-7-1, 34 cm through Core 19 contains *Sphenolithus ciperoensis*, *S. predistentus*, and *Dictyococcites bisectus*, indicating the *S. ciperoensis* Zone (CP19) of late Oligocene age.

Cores 20 and 21 contain *S. distentus* and *S. predistentus* but lack *S. ciperoensis*, indicating the *S. distentus* Zone (CP18) of late Oligocene age. Cores 22 through 24 contain *S. predistentus* with neither *Reticulofenestra umbilica* nor *R. hillae*. This association indicates the *S. predistentus* Zone (CP17) of early Oligocene age. *S. predistentus*, *R. umbilica*, and *R. hillae* are found in 540-25-1, 0–85 cm, indicating the *Helicopontosphaera reticulata* Zone (CP16) of early Oligocene age. A prominent ash layer (from 540-25-1, 87–110 cm) of indeterminant age separates the overlying Oligocene sequence from the underlying strata.

The interval from 540-25-1, 110 cm through 540-27-1 contains *D. barbadiensis*, *D. saipanensis*, and sporadically occurring *Isthmolithus recurvus*, indicating the *D. barbadiensis* Zone (CP15) of late Eocene age. The occurrence of *I. recurvus* in some samples (e.g., 540-26-1, 86–88 cm) denotes the *I. recurvus* Subzone (CP15b) of latest Eocene age. However, because *I. recurvus* occurs only sporadically through part of this interval, classification at the subzonal level is not warranted for the entire interval.

The interval from 540-27,CC through Core 28 contains *Nannotetrina quadrata* and *Chiasmolithus gigas*, indicating the *C. gigas* Subzone (CP13b) of middle Eocene age. Section 540-29-1 contains *D. lodoensis* and *D. sublodoensis* but lacks *N. quadrata*. This interval is assigned to the *D. sublodoensis* Zone (CP12) of the late early Eocene through early middle Eocene. The interval from 540-29-2 through 540-29,CC contains a dissolution assemblage whose zonal affinities are, as yet, uncertain. The presence of *D. lodensis* and *D. barbadiensis*, does, however, indicate an Eocene age for this interval.

Core 30 contains Paleocene sediments. The interval from 540-30-1, 0 cm through 540-30-2, 40 cm contains *D. multiradiatus*, *D. mohleri*, and sparse *Heliolithus kleinpellii*, indicating the *D. multiradiatus* Zone (CP8) of late Paleocene age. A sharp lithologic boundary occurs at 540-30-2, 40 cm. The interval from 540-30-2, 45 cm through 540-30,CC contains *H. kleinpellii*, *Fasciculithus tympaniformis*, and *C. danicus* but lacks any species of the genus *Discoaster*. This interval is assigned to the *H. kleinpellii* Zone (CP5) of early late Paleocene age.

The interval from Core 31 through 540-36-1, 60 cm is composed of sediments that, based on lithologic criteria, are obviously redeposited. Nannofossil assemblages within this interval yield differing ages. The vast majority of samples within this interval contain assemblages typical of the *Eiffellithus turriseiffeli* Zone of late Albian through early Cenomanian age. One sample (540-31-1, 12–13 cm), however, yields an assemblage that includes *Micula mura* and *Lithraphidites quadratus*, indicating the *M. mura* Zone of middle to late Maestrichtian age. This Maestrichtian sample is from sediments intercalated between two cross-bedded intervals that appear to be an integral part of the redeposition lithologic unit. This implies that the redeposition of at least part of this lithologic unit was at least as young as the middle to late Maestrichtian. The consistent *E. turriseiffeli* assemblage (late Albian through early Cenomanian) recovered from the majority of the redeposited unit (both matrix and some clasts) probably indicates the age of the sediment that was mobilized and redeposited.

Below this redeposited interval is a thick Albian through Cenomanian carbonate sequence with some black chert and marly interbeds. The interval from 540-36-1, 60 cm through Core 49 contains *E. turriseiffeli*, *Prediscosphaera cretacea*, and *Parhabdolithus angustus*, indicating the *E. turriseiffeli* Zone of late Albian through early Cenomanian age. The preservation of the assemblages, however, was rather poor to moderate. Thus the next younger zonal marker, *L. acutus*, may not have been preserved well enough to be recognizable. The Turonian zonal marker species *Gartnerago obliquum* and *M. staurophora* would have, in our opinion, been preserved and recognizable had they been present. Therefore, the age of the interval from 540-36-1, 60 cm through Core 49 is given as late Albian through Cenomanian.

Samples from Core 50 were devoid of age-diagnostic nannofossils. The interval from Cores 51 through 79 contains *Prediscosphaera cretacea*, *Parhabdolithus angustus*, and *Lithastrinus floralis*. This interval is assigned to the *Prediscosphaera cretacea* Zone of early Albian through (early) late Albian age. Preservation of nannofossils is sporadic throughout this interval. The majority of the hard limestones yield only very sparse assemblages of poorly preserved nannofossils. The clay-rich ("marly") layers do, however, yield sufficiently well-preserved nannofossil assemblages for age-diagnostic purposes. Even the clay-rich layers, however, contain a high percentage of amorphous calcite, which greatly dilutes the nannofossils.

Summary of the Transect

Sites 535, 539, and 540, located along a transect west of the Florida Escarpment, represent a discontinuous stratigraphic succession ranging in age from Holocene through late Berriasian.

Holocene and late Pleistocene ages are recorded by two different facies: (1) a nannofossil-foraminiferal ooze of the upper slope at Sites 539 and 540 and (2) a turbiditic clay in a canyon at the base of an escarpment at Site 535.

Only two short intervals containing Neogene microfossil assemblages were recovered: (1) parts of the upper Miocene nannofossil Zone CN9 and the planktonic foraminiferal Zones N17 and N16 at Sites 539 and 540, and (2) part of the middle Miocene nannofossil Zone CN6 and planktonic foraminiferal Zone N13 at Site 540.

Paleogene assemblages are better represented in the recovered sequence at Site 540. In particular, the stratigraphic record consists of a complete sequence of Oligocene except for its very oldest layers; some late (P17–P16), middle (P12, CP13b), and early (P8, CP12) Eocene; and foraminiferal Zone P4 and nannofossil Zone CP8 of the late Paleocene.

The biostratigraphic record for late Paleocene through late Cenomanian is practically missing. Rare specimens indicate the presence of some Campanian–Maestrichtian.

According to the occurrences of ammonites in Holes 535 and 540 (Young, this volume), a substantial overlap of the Cenomanian through middle Albian interval of these holes exists. However, the Cenomanian sediments recovered are different. At Site 535 the interval from 535-17,CC through 535-43-2 (240 m in length) is dominantly laminated limestone with conspicuous shallow-water components. Correlative sediments at Site 540 (Cores 32 through 40; 85 m in length) consist of an upper unit of pebbly mudstone with volcanic sandstone and a lower unit of limestone, laminated limestone, and rare chert.

The interval from Core 540-41 to terminal depth (360 m in length) at Site 540 is a continuous sequence of late Albian through middle Albian age. Apparently this interval of Site 540 is recorded at Site 535 by only the scaphitid-bearing rubble of Core 45.

Age of Lithologic Unit II, Hole 535

The age of Lithologic Unit II (154–387 m; Cores 535-17 to 535-42) in Hole 535 is somewhat controversial. Preliminary shipboard analysis of microfossils suggested that the interval was mainly middle to early Albian in age (Fig. 3). Postcruise investigation of ammonites, however, indicated a possible late Albian(?)–Cenomanian(?) age (see Young, this volume). A good juvenile specimen of *Acompsoceras* in Core 535-31 was dated as middle Cenomanian, but a *Scaphites* in Core 535-45 was dated as latest late Albian. The specimen in Core 45 was found in rubble along with a good Aptian section based on microfossils. It was considered as a sample displaced or caved from somewhere further up the hole.

Based only on these two ammonite occurrences, this entire 233 m interval was assigned a late Albian(?)–middle Cenomanian(?) age, ignoring the Albian microfauna and microflora data reported earlier in the shipboard reports. These older microfossils, which are a mixture of shallow-water and mid-bathyal forms, were considered to be reworked material.

Some of the scientific party question the Cenomanian age for this interval and still believe that the interval is from the middle-early Albian. This conclusion is based on the following evidence.

1. There are some good early-middle Albian foraminiferal faunas and nannofloras preserved in this section that occur in a logical age sequence (see this site chapter and Premoli Silva and McNulty; Lang and Watkins; Watkins and Bowdler, all this volume).

2. Postcruise palynologic investigations of Hole 535 support the Albian age for this interval (see Riley and Fenton, this volume).

3. The lithology and thickness of this sequence (233 m of laminated and bioturbated limestone) is completely different from the middle Cenomanian section at Hole 540 (53 m of pebbly chalks). It is more like the lithology of Unit III below, suggesting a continuation of similar sedimentation.

4. An early-middle Albian age for this interval would follow directly the Aptian age for Unit III below, making a logical and continuous age sequence. A Cenomanian age would mean a large hiatus or unconformity exists at the boundary between Units II and III.

5. No Cenomanian microfossils were found in the unit to support the ammonite age, although it is possible that Cenomanian pelagic faunas could have been overwhelmed by reworked material and not detected.

6. It is difficult to imagine a nearby source for mid-bathyal Albian microfossils. Intense erosion or scouring at mid-bathyal depths by bottom currents to expose older deep-water Albian sections during the middle Cenomanian would be required.

7. The seismic data (i.e., Line SF-15, Fig. 2) argue strongly for the Albian age. These data suggest that Hole 535 drilled through the lower part of a unit just below seismic Unconformity 1. The top of this unit (Unconformity 1) was just reached at Hole 540 and dated as middle Albian (Fig. 2). Thus, the seismic data indicate that the unit must be as old or older than middle Albian. The only way the interval could be Cenomanian, is to make it a large, cohesive slump-block, that was displaced from a younger stratigraphic position near the MCU to a lower position down along an old paleoerosional channel (Fig. 2). There is no evidence for this on the seismic data, although such a block could easily be below the resolution of the seismic data and masked by diffractions (Fig. 2).

8. The lithology in the upper part of the seismic unit just below Unconformity 1 is similar in both Holes 535 and 540. Coarse skeletal debris is found in the bottom of 540 as well as in the upper parts of 535, suggesting a similar origin for the hummocky, discontinuous seismic facies observed in this unit (Fig. 2).

In summary, both the microfossil data and the seismic stratigraphy argue for an Albian age and against a Cenomanian age. However, the ammonites, although juvenile specimens, are age diagnostic. This controversy cannot be solved at this time without further work.

SEDIMENTATION RATES

Site 535

The sediment recovered in Cores 1 through 17 (partim) consists mostly of Holocene through upper Pleistocene mud and clay. Estimated sedimentation rates of over 600 m/Ma for this unit represent rapid deposition in the distal parts of the Mississippi Fan. The sediment recovered in Cores 17 (partim) through 43 (partim) is dominated by redeposited material and lack of fossil control; thus, rate calculations are not possible. Cores 43 (partim) through 46 are characterized by numerous hiatuses, suggesting significant periods of erosion and/or nondeposition. No rates were calculated for this section either. Cores 47 through 79 (terminal depth) represent apparent continuous sedimentation from the base of the Barremian through the upper Berriasian. Biostratigraphic zones and calculated rates for this interval are shown below:

Hole 535 cores	Zone	Sediment accumulation rate (m/Ma)
47–50	*Lithraphidites bollii*	6
51–72	*Calcicalathina oblongata*	44
73–79	*Retecapsa angustiforata*	?

Thus, there is a significant increase in sedimentation rate in the middle Hauterivian corresponding to the boundary between lithologic Units III and IV.

Site 540

Seventy-nine sediment cores were recovered at Site 540. Very little sediment represents the upper Neogene, lower Paleogene, and Upper Cretaceous. The data from the Oligocene and Albian-Cenomanian intervals do, however, yield significant results because of the length of the sequences and absence of hiatuses. The data used to determine the sedimentation rates are predominantly derived from the study of core catcher samples.

The Oligocene section (Cores 7 through 25) is apparently represented by nearly continuous sedimentation. The biostratigraphic data used to define the sedimentation rates shown on this figure are shown below.

Hole 540 cores	Biozone	Sedimentation rate (m/Ma)
7–12	lower *Globigerina ciperoensis* Zone, P22	55
13–18	upper *Globorotalia opima* Zone, P21a	18
19	middle *G. opima* Zone, upper P21a; base defined by bottom of the *Sphenolithus ciperoensis* Zone (CP19)	9
20	lower to middle *G. opima* Zone, lower P21a	9
21	lower *G. opima* Zone and upper *Globigerina ampliaperta* Zone, upper P20; base defined by bottom of *S. distensus* Zone (CP18)	9
22	lower *G. ampliaperta* Zone, lower P20	9
23–24	*Cassigerinella chipolensis* Zone, P19	8

The sedimentation rates were slow (9 m/Ma) during the early through earliest late Oligocene (36–28 Ma). Subsequently, in the late Oligocene, the sedimentation rate increased rapidly to 18 m/Ma and then 55 m/Ma. Vail and others (1977) show evidence for a worldwide fall of sea level at approximately 29 Ma.

The sediment recovered in Cores 35 through 77 apparently represents continuous sedimentation from the early Cenomanian through the middle Albian. The biostratigraphic data used to define the sedimentation rates are given below.

Hole 540 cores	Biozone	Sedimentation rate (m/Ma)
35–40	*Rotalipora brotzeni* Zone	57
41–45	*Planulina buxtorfi* Zone	24
46–70	*Ticinella breggiensis* Zone	119
71–77	*T. primula* Zone	39

Sedimentation during the late Albian was rapid (119 m/Ma). This was followed by a decrease in rate of sedimentation during the Vraconian and early Cenomanian.

GEOCHEMISTRY

Site 535

Organic Geochemistry

Ninety-eight rock samples were taken from recovered material at Site 535 from Cores 12 (100 m) through 79 (706 m) for analysis by the Rock-Eval. From the Rock-Eval data, CHN and carbonate bomb (49 samples) were selected. These data were used to determine the hydrogen and oxygen indexes and lithology (limestone versus marl versus shale).

On the basis of lithology, the rocks penetrated at Site 535 are separated into five units. Organic geochemical analyses indicate that Units I and II are geochemically distinct and that Units III through V together constitute a third group (Fig. 16, Table 6). Unit I is an unconsolidated gray mud with visible plant fragments. Unit II is a thinly laminated carbonate rock of poor hydrocarbon source potential. The last group, Units III–V, is a cyclic carbonate rock of good hydrocarbon source potential.

Unit I was first penetrated at the mudline to a depth of 154.3 m (535-17-7, 30 cm); it is a poor, immature hydrocarbon source-rock. The lithology of this unit is a gray mud with several carbonate sand intervals. Coring the soft soupy sediment contorted and obscured most bedding planes. Calcium carbonate content of the mud is up to 10%, but the sand can be as high as 59% limestone. Very little to no pyrite is present, but woody debris and plant fragments are common. The origin of the sediment in Unit I is thought to be mainly the Mississippi River, 800 km to the northwest. There are no oil or gas indications in this unit.

Six sediment samples from 100 to 154.3 m were analyzed on the Rock-Eval for richness, type, and thermal maturity of the organic material (Fig. 16; Tables 6 and 7). The hydrocarbon source potential is poor (average 0.49 mg HC/g rock), and any hydrocarbons that would be generated, as indicated by the S_2/S_3 ratio, would be gas (type III kerogen). The maturity parameter, the temperature at maximum evolution of hydrocarbons during pyrolysis (S_2 peak temperature), is generally higher than either of the deeper units, probably as a result of the reworked, more mature(?) plant debris. From the production index ($S_1/[S_1 + S_2]$), there is no indication of generated or migrated hydrocarbons.

The type of organic material can be approximated using the S_2/S_3 ratio from the Rock-Eval analysis, but a

Table 6. Organic geochemical summary for Units I, II, and III–V for Hole 535.

Unit	Age	Thickness (m)	Core recovery (%)	Sedimentation rate (m/Ma)	Number Rock-Eval samples	S_1 (mg HC / g rock)	S_2 (mg HC / g rock)	S_3 (mg CO_2 / g rock)	S_2/S_3	Max. S_2 peak temp (°C)	$S_1/(S_1 + S_2)$	Number carbon samples	Carbon: Organic (wt.%)	Carbon: Carbonate (wt.%)	Average hydrogen index	Average oxgyen index
I	Holocene to Pleistocene	154.3	69	~600	6	0.09	0.49	2.2	0.22	424	0.15	6	1.17[a]		42	>100
II	Albian	233.2	74		29	0.05	1.86	1.13	1.7	417	0.08	11	1.3	75[b]	204	>100
					27[c]		0.58	0.97	0.6		0.07	9[c]	0.6	77	152	>100
					2[d]		19.1	1.21	15.8		0.01	2	4.7	66	440	31
III–V	lower Albian to Berriasian	326.5	69	6–44	63	0.15	10.2	1.5	6.8	424	0.04	32	4.0	59	393	48
					62[e]	0.11										
					35	0.09	3.3	0.9	3.7		0.06	4	0.3	92	193	>100
					28	0.22	18.9	1.9	10.2		0.01	28	4.5	55	422	41

[a] Hewlett Packard CHN analyzer.
[b] Carbonate bomb.
[c] Average after deleting two very rich samples (535-35-5, 15–18 cm; 535-41-5, 118–120 cm).
[d] Average of all samples >5.0 mg/g rock for S_2.
[e] Average after deleting oil-stained rock (535-58-4, 11–13 cm; Si = 3.06).

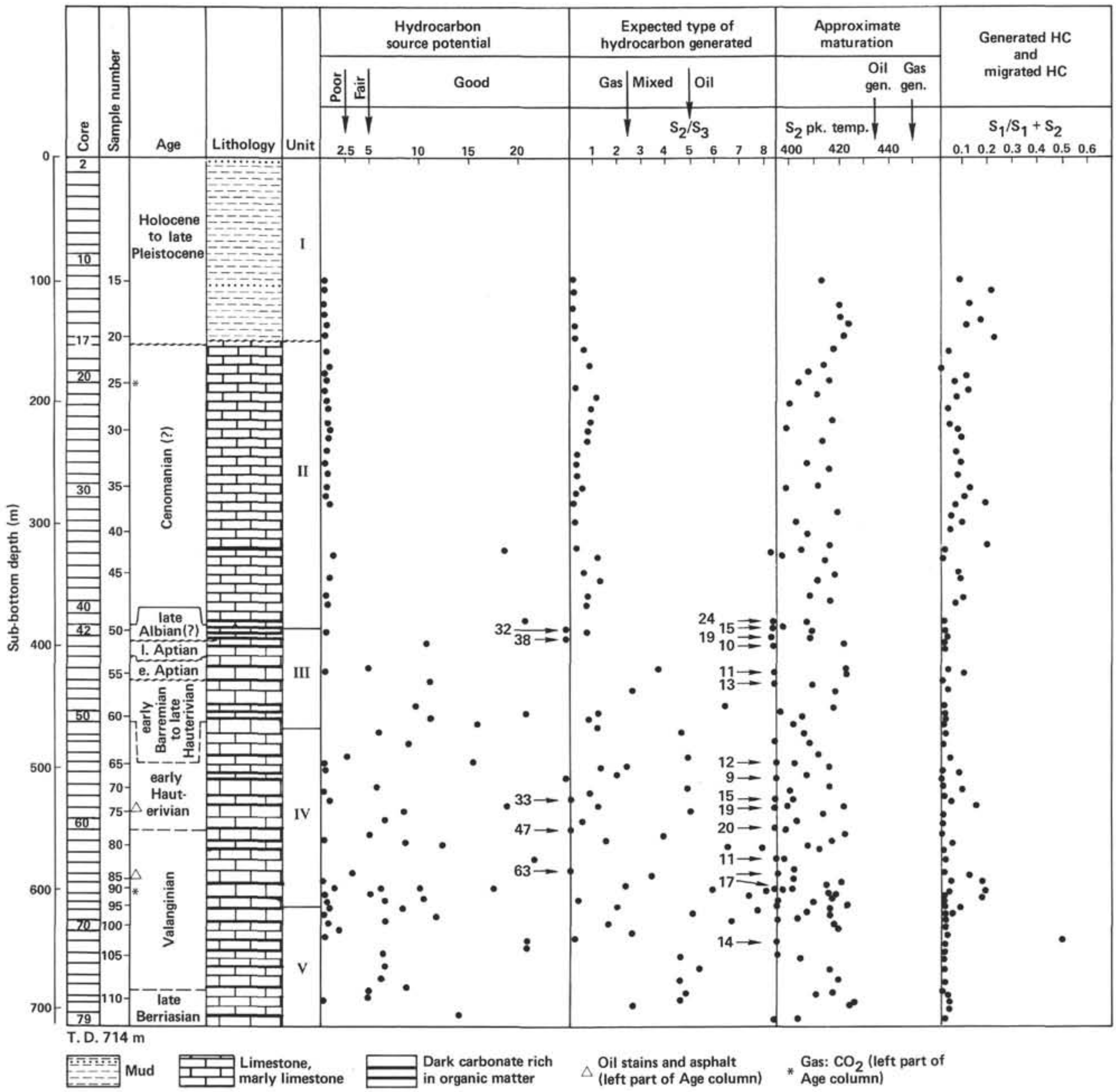


Figure 16. Organic geochemistry summary, Hole 535 (water depth, 3455.5 m). See text for description and see Table 7 for correlation of sample numbers with DSDP designations. T.D. = terminal depth. (After Clementz et al., 1976.)

Table 7. Organic geochemistry data for Hole 535.

Sample no.	Core-Sample (interval in cm)	Sub-bottom depth (m)	S_1 (mg HC / g rock)	S_2 (mg HC / g rock)	S_2/S_3	S_2 pk. temp. (°C)	$\frac{S_1}{S_1 + S_2}$	Organic carbon (wt.%)	CO_3 carbon (wt.%)	Hydrogen index (mg HC / g OC)	Oxygen index (mg CO_2 / g OC)
Unit I											
15	12-2, 100–102	100.00	0.05	0.48	0.23	414	0.09	1.35		36	>100
16	13-2, 140–142	109.90	0.09	0.35	0.19	415	0.21	1.27		27	>100
17	14-3, 50–52	120.00	0.06	0.44	0.19	420	0.12	1.06		41	>100
18	15-3, 100–102	130.00	0.08	0.40	0.16	421	0.17	1.07		38	>100
19	16-1, 78–80	136.28	0.10	0.71	0.33	424	0.11	1.17		61	>100
20	17-2, 43–46	146.93	0.15	0.53	0.22	424	0.22	1.10		48	>100
Unit II											
21	18-2, 67–70	156.67	0.04	0.73	0.72	408	0.04				
22	19-4, 136–138	169.36	0	0.73	0.85	413	0	0.40	85	181	>100
23	20-1, 139–143	174.89	0.04	0.37	0.46	406	0.10				
24	20-5, 83–85	180.33	0.03	0.32	0.46	416	0.08				
25	21-1, 79–81	183.79	0.05	0.47	0.39	403	0.09				
26	21-4, 30–32	187.80	0.05	0.35	0.27	403	0.12				
27	22-4, 100–101	198.00	0.05	0.70	1.14	410	0.07	0.46	91	151	>100
28	23-5, 0–02	208.00	0.04	0.84	0.94	395	0.04	0.53	85	158	>100
29	24-4, 88–90	216.88	0.06	1.06	0.86	417	0.05				
30	25-1, 96–98	221.96	0.06	0.73	0.70	395	0.07				
	26-1, 22–24	230.72	0.05	0.62	0.67	417	0.08	0.30	85	242	>100
32	27-2, 103–106	242.53	0.03	0.49	0.32	411	0.07				
33	28-1, 34–39	249.84	0.02	0.28	0.22	407	0.08	0.46	77	61	>100
34	28-6, 10–12	257.10	0.05	0.59	0.38	415	0.08				
35	30-1, 146–148	269.96	0.05	0.35	0.47	412	0.12				
36	30-4, 71–73	273.71	0.04	0.46	0.32	388	0.09				
37	31-3, 16–19	280.66	0.05	0.23	0.27	410	0.19				
38	31-7, 10–12	287.10	0.06	1.00	0.61	404	0.06	0.89	52	112	>100
39	32-3, 8–10	290.58	0.04	0.81	0.76	417	0.05	0.70	68	115	>100
40	33-1, 72–74	297.72	0.02	0.23	0.19	401	0.09				
41	34-2, 47–51	308.47	0.04	0.35	0.57	406	0.04				
42	35-4, 36–40	320.86	0.03	0.12	0.32	416	0.18				
43	35-5, 15–18	322.15	0.41	17.8	8.09	395	0.02	5.38	57	370	40
44	36-1, 52–54	326.02	0	1.41	1.09	414	0	0.64	68	220	>100
45	37-3, 49–51	338.99	0.03	0.49	0.53	417	0.06				
46	38-1, 61–62	345.11	0.06	0.79	1.20	410	0.06	0.60	85	167	>100
47	39-5, 57–60	360.57	0.06	0.50	0.75	406	0.10				
	40-1, 103–106	364.53	0.03	0.50	0.78	415	0.06				
	41-5, 121–123	380.18	0	20.4	23.5	405	0	4.00	75	510	21.7
Units III–V											
50	42-5, 21–22	388.71	0	31.9	15.3	391	0	7.35	65	434	28.3
51	43-1, 10–12	392.10	0.01	0.96	0.74	407	0.01				
52	43-3, 17–19	395.17	0	37.6	19.2	407	0	5.22	82	720	37.5
53	44-1, 81–82	401.81	0.11	10.7	9.1	420	0.01	1.60	80	669	73.8
54	46-2, 24–25	420.74	0.17	4.75	3.5	421	0.03				
55	46-2, 41–42	420.91	0.05	0.63	11.3	421	0.07	0.28	93	223	>100.0
56	47-1, 96–97	428.96	0.12	11.2	13.0	408	0.01	3.60	40	311	23.9
57	48-1, 51–52	437.51	0.11	3.98	2.5	417	0.03				
58	49-3, 91–92	449.91	0.12	9.12	6.1	416	0.01	2.50	50	365	59.6
59	50-2, 75–76	457.25	0.30	21.3	1.1	394	0.01	6.4	29	333	31.6
60	50-3, 27–34	458.27	0.19	11.1	0.7	403	0.02	6.3	37	176	26.5
61	51-2, 23–25	465.73	0.12	16.2	1.0	400	0.01	5.1	43	318	32.5
62	52-1, 63–65	473.63	0.06	5.60	4.2	404	0.01	1.32	56	424	100.0
63	53-3, 19–21	480.59	0	8.51	8.5	406	0	2.20	56	387	45.5
64	54-2, 96–97	489.46	0.10	2.46	4.7	410	0.04				
65	54-6, 51–52	495.01	0	15.1	11.8	401	0	2.70	62	559	47.4
66	55-1, 82–83	497.32	0.04	0.88	2.2	415	0.05				
67	55-4, 61–62	501.61	0	24.3	1.3	383	0	4.60	58	528	39.6
68	56-3, 136–132	510.31	0.08	1.07	1.7	405	0.07				
69	56-5, 78–80	512.78	0	24.0	9.1	393	0	4.48	44	536	58.7
70	57-3, 2–3	518.52	0	5.19	4.6	415	0	1.80	70	288	62.8
71	57-4, 84–85	520.84	0.07	0.79	0.8	398	0.08				
72	58-2, 106–108	527.56	0.50	32.7	14.9	398	0.01	8.20	61	399	26.8
73	58-4, 4–6	529.54	0.04	1.00	1.0	395	0.04				
74[a]	58-4, 11–13	529.61	3.06	18.6	18.9	420	0.14	3.10	83	600	31.8
75	59-2, 87–88	536.37	0.05	7.91	4.8	411	0.01				
76	60-3, 67–68	546.67	0.04	5.88	4.4	401	0.01				
77	61-1, 49–50	552.49	0	46.8	20.0	398	0	10.1	44	463	23.2
78	61-5, 66–67	558.66	0.04	4.51	3.6	420	0.01				
79	62-1, 106–107	562.06	0.04	0.89	1.3	415	0.04				
80	62-2, 66–67	563.16	0	8.19	6.3	406	0				
81	62-5, 133–134	568.33	0	11.7	7.7	410	0				
82	63-4, 103–104	575.53	0	21.2	10.8	395	0	5.00	44	424	39.4
83	64-4, 56–57	584.06	0.66	63.3	19.3	400	0.01	13.20	44	480	24.8
84	64-5, 12–13	585.12	0.37	2.84	3.1	399	0.11				
85	65-2, 38–40	589.88	0.06	0.33	0.4	419	0.16	0.20	91	164	>100.0
86	65-2, 120–122	590.70	0.06	1.38	2.1	414	0.04	0.50	88	276	>100.0
87	65-2, 132–134	590.82	0.08	5.29	5.6	395	0.02	1.10	82	481	86.0
88	65-2, 145–146	590.95	0.07	9.83	7.9	414	0.01	2.20	63	447	56.8
89	65-4, 20–21	592.70	0.03	0.13	0.4	410	0.17	0.12	94	109	>100.0
90	66-2, 35–36	598.85	0.16	17.2	16.9	398	0.01	3.12	61	551	32.7
91	66-4, 15–16	601.65	0.08	4.81	7.1	415	0.02				
92	66-5, 5–7	603.05	0.04	0.22	0.5	415	0.16				
93	67-2, 134–135	608.84	0.09	9.99	13.6	408	0.01	2.9	58	344	25.2
94	67-3, 75–77	609.75	0.14	5.89	8.7	422	0.02				
95	67-4, 75–77	611.25	0.06	0.77	1.8	414	0.07				
96	68-5, 113	617.63	0.12	7.70	7.3	405	0.02				
97	69-1, 63–64	620.63	0.06	1.28	4.7	415	0.04				

Table 7. (Continued).

Sample no.	Core-Sample (interval in cm)	Sub-bottom depth (m)	S_1 (mg HC / g rock)	S_2 (mg HC / g rock)	S_2/S_3	S_2 pk. temp. (°C)	$\frac{S_1}{S_1 + S_2}$	Organic carbon (wt.%)	CO_3 carbon (wt.%)	Hydrogen index (mg HC / g OC)	Oxygen index (mg CO_2 / g OC)
Units III-V (Cont.)											
98	69-6, 87–89	627.87	0.14	10.3	9.8	401	0.01	3.4	44	303	30.9
99	70-3, 141–142	632.91	0.08	6.82	6.4	416	0.01				
100	70-5, 58–59	635.08	0.06	1.55	1.4	417	0.03				
101	71-1, 109–110	638.59	0.04	1.96	2.4	396	0.02				
102	71-3, 97–98	641.97	0.29	20.1	14.5	410	0.01	6.6	45	305	21.1
103	71-4, 33–35	642.33	0.04	0.05	0.1		0.48				
104	72-4, 84–85	651.84	0.36	20.8	13.1	399	0.02	5.5	58	378	28.9
105	73-1, 92–93	656.42	0.15	5.47	4.3	402	0.03				
106	73-3, 43–44	658.93	0.09	5.71	5.1	413	0.02				
107	74-2, 117–121	667.17	0.14	5.65	4.3	417	0.02				
108	75-3, 116–117	677.66	0.15	7.65	5.8	415	0.02	3	43	254	43.7
109	76-2, 97–100	684.97	0.19	4.34	4.5	409	0.04				
110	77-1, 20–21	691.70	0.14	4.00	4.3	424	0.03				
111	78-1, 36–37	696.36	0.07	1.63	2.4	421	0.04				
112	79-1, 55–56	705.55	0.18	13.3	10.8	401	0.01	4	31	333	30.8

[a] Oil-stained sample.

more accurate approach short of the elemental analysis that includes oxygen is to determine the hydrogen and oxygen indexes from the S_2 and S_3 Rock-Eval data and the organic carbon data from the CHN analyses. The indexes for Unit I are too oxygen rich to be plotted on Figure 17. On this basis, the organic material in Unit I is predominantly terrestrial debris.

The top of Unit II was penetrated at 154.3 m (535-17,CC) and the bottom at 387.5 m (535-42-4, 47 cm) for a total thickness of 233.2 m. This unit has poor potential as a hydrocarbon source. Except for two rich (17.8 and 20.4 mg HC/g rock) dark gray limestone intervals (535-35-5, 15–18 cm; 535-41-5, 121–123 cm, respectively), this unit is a thinly laminated limestone that varies from light gray to gray. Several intervals of shallow-water skeletal limestone are included in the generally deep-water limestone. Bioturbation of the thinly laminated limestone is common, and pyrite is observed throughout this section. A fetid odor was noted when many of these cores were cut.

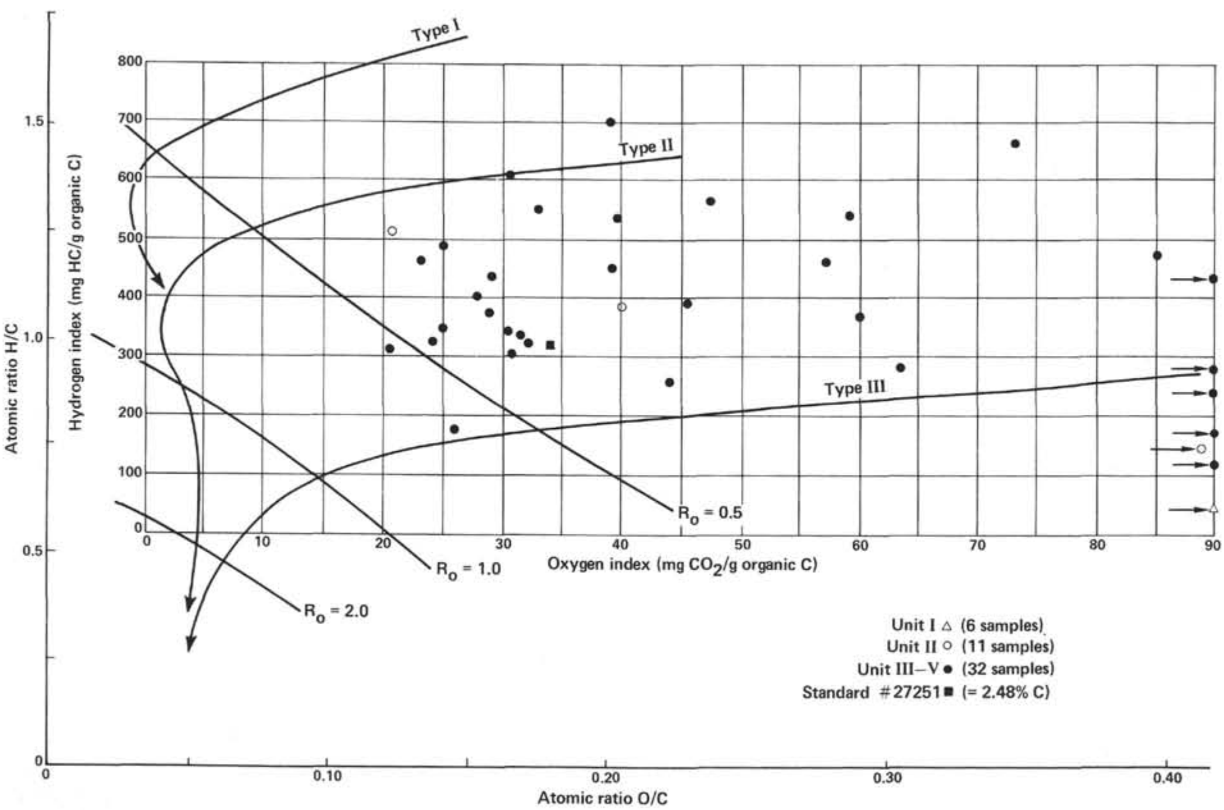


Figure 17. Modified van Krevelen diagram for Hole 535. The large open circle in the right-hand column represents the average for 9 of 11 samples from Unit II; the large triangle represents the average for 6 samples from Unit I. See Introduction and Explanatory Notes (this volume) for description, use, and interpretation of this diagram.

Twenty-nine limestone samples from Unit II were analyzed on the Rock-Eval for richness, type, and thermal maturity of organic matter. The hydrocarbon source potential is poor (0.58 mg HC/g rock) except for the two samples mentioned above, which demonstrate good hydrocarbon source potential. One of these samples immediately overlies the composite group (Units III–V), an organic matter–rich interval; so this sample is probably related to the depositional environment of this lower unit, not Unit II. From the S_2/S_3 ratio (0.60), one would expect gas to be generated from Unit II if it were mature; however, the S_2 peak temperature (417°C) is below the required 435°C temperature. A gas sample recovered from this unit (Section 535-20-6) and analyzed on the Carle gas chromatograph was found to be only carbon dioxide (CO_2). Figure 16 and Tables 6 and 7 show the data for Unit II.

Eleven samples were selected from Unit II for organic carbon and carbonate carbon analyses; two of the rich samples mentioned above are included. The nine lean samples have average values for organic carbon of 0.6 wt.% and for carbonate carbon of 77%, and hydrogen and oxygen indexes of 152 and more than 100, respectively. Except for the two rich intervals, all nine samples contain type III kerogen. Based on organic carbon content, Unit II is a fair, immature limestone source rock (more than 0.3 wt.% organic carbon).

The third geochemical group (Lithologic Units III–V), extending from 387.5 m (535-42-4, 47 cm) to 714 m (535-79-2, 110 cm; terminal depth), is 326.5 m thick and contains numerous intervals of potential oil source-rocks. Lithologically, the unit is predominantly a thinly laminated limestone that grades over short intervals from a very light gray limestone to very dark gray marl. In the limestone intervals, bioturbation is common, and high concentrations of pyrite are ubiquitous. A fetid odor was noted when most of these cores were cut.

Sixty-three rock samples were analyzed on the Rock-Eval for richness, type, and thermal maturity of the organic matter (Figs. 16–18; Tables 6, 7). Twenty-five rock samples show a poor (0.0–2.5 mg HC/g rock) to fair (2.5–5.0 mg HC/g rock) hydrocarbon source potential; the remainder are rich enough to be considered potentially good source rocks (i.e., they contain more than 5 mg HC/g rock). Carbonate rocks of all shades of gray were selected for analyses, which averaged 10.2 mg HC/g rock. The richness values are very high in comparison to Units I and II.

The richness (S_2) of the rock samples can be compared to their color (Fig. 19). Black and white photographs used in conjunction with a gray scale give a good estimate of color. The terminology used for these observations are as follows: (1) very light gray; (2) light gray; (3) gray; (4) dark gray; and (5) very dark gray. Light gray through very dark gray rocks are not bioturbated but are very thinly laminated. Very light gray to light gray limestones are frequently bioturbated. Where the core is not broken (i.e., section missing), the variations in color can occur over a thickness of 1 cm to 2 m. The frequency and intensity of the changes in color are dramatic and cyclic, probably the result of continual shift from an oxic to an anoxic depositional environment.

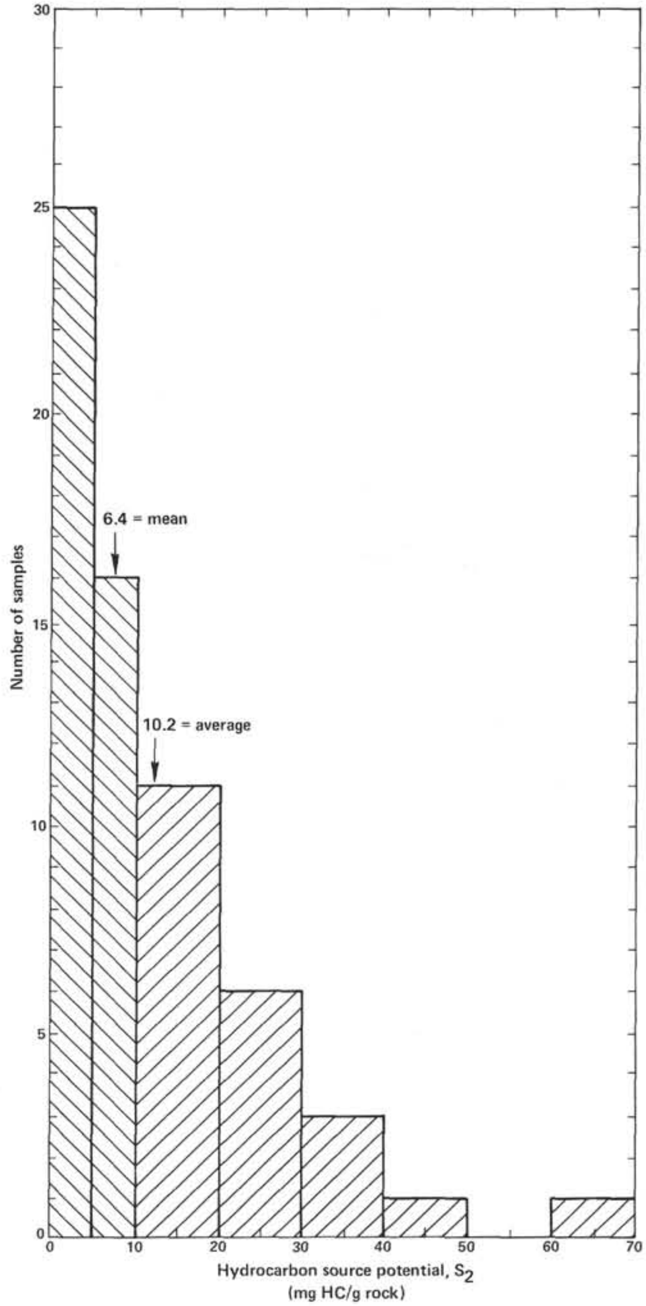


Figure 18. Histogram of hydrocarbon source potential as measured by the Rock-Eval S_2 peak, Units III–IV, Hole 535. Number of analyses = 63; average mg HC/g rock = 10.2; mean mg HC/g rock = 6.4.

In general, light gray limestones are poor source-rocks, and very dark gray ("dark") marl and limestone are good source-rocks (Fig. 19). The gray to dark gray rocks range from poor to good source-rocks (S_2). In Units III–V, light gray limestones are poor candidates as source-rocks, but it is not necessarily true from Rock-Eval data that the darker the limestone the richer the rock.

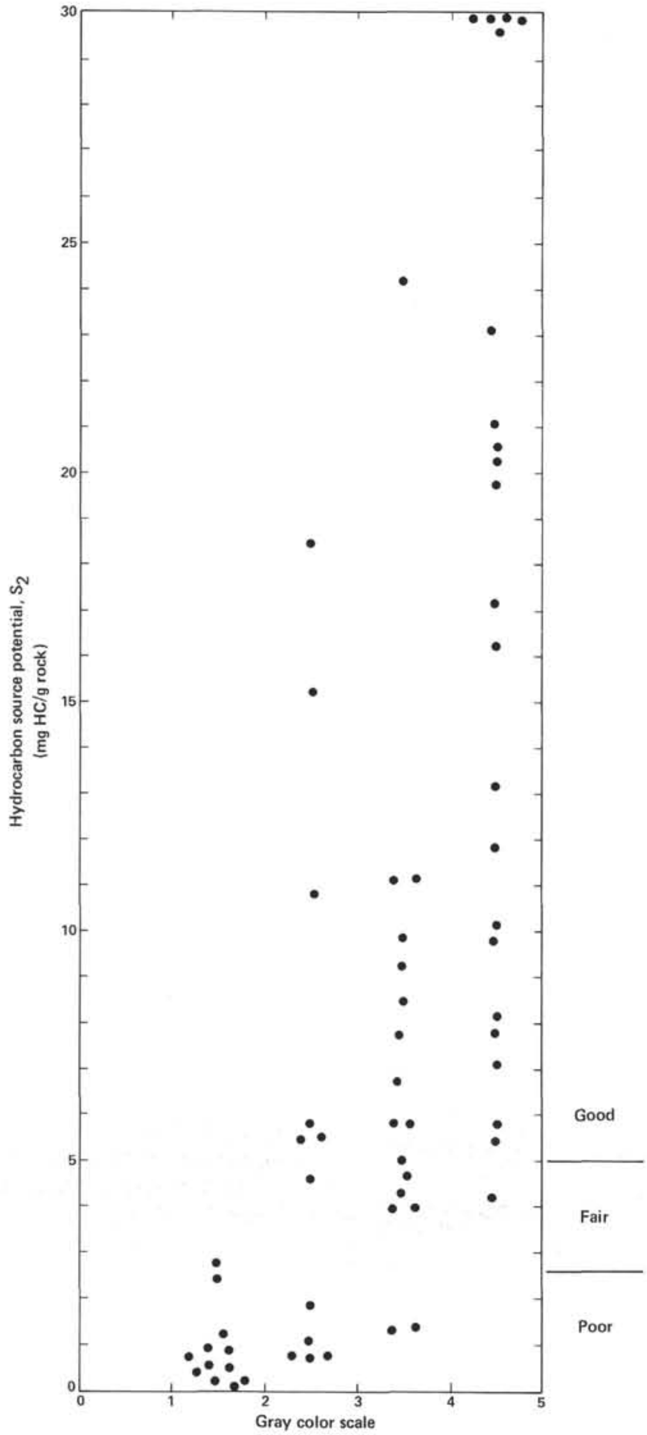


Figure 19. Hydrocarbon source potential versus color of sediments, Units III-V, Hole 535. See text for discussion.

The type of organic material can be approximated if no organic carbon values are available to calculate the hydrogen and oxygen indexes using the S_2 to S_3 ratio (Fig. 16; Clementz et al., 1979). To distinguish rich gas-prone source-rock (kerogen type III) from rich oil-prone source-rock (kerogen types II and II/III), the S_2 values can be compared to the S_2/S_3 ratio (Fig. 20). Four rock samples have values greater than 5 mg HC/g rock and

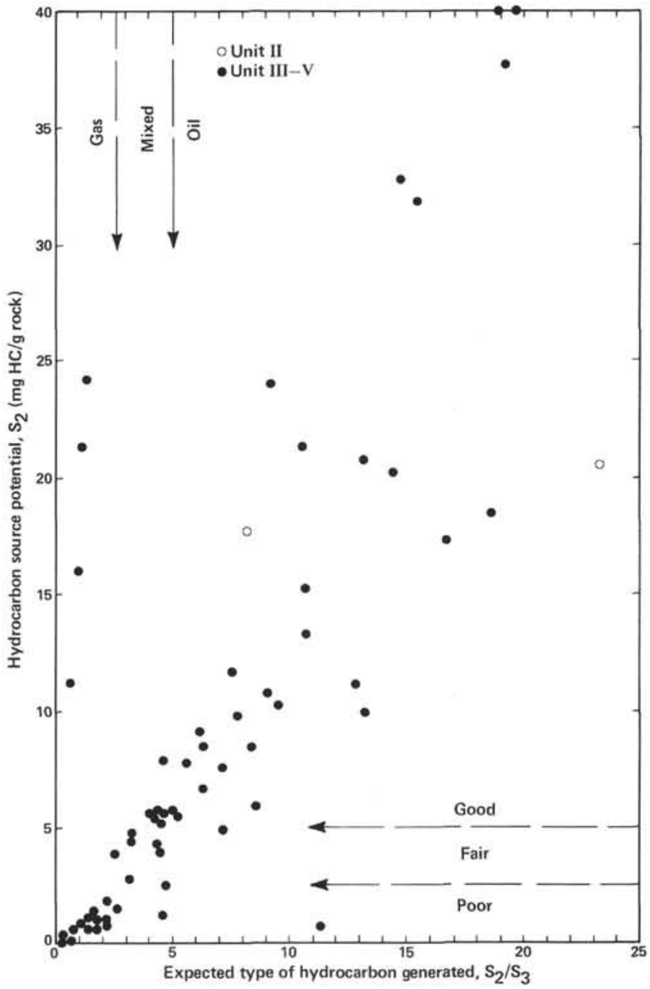


Figure 20. Source potential and expected hydrocarbon types as expressed in a plot of S_2 versus S_2/S_3 for Units II and III-V, Hole 535.

are gas prone. Three of the four samples are from Cores 50 and 51 and the fourth from Core 55; all are dark to very dark gray rocks. In contrast, one sample is a poor source-rock but very oil prone. The remainder of the samples except for the very rich ones, fall roughly on a 45° line that passes through the origin, suggesting that when the rock becomes richer (higher S_2 value), it also becomes more oil prone.

Thirty-two samples were selected for organic carbon and carbonate carbon analyses; four lean samples were included. The 28 rich samples have an average organic carbon content of 4.5 wt.% and an average carbonate carbon content of 55% (marly limestone), whereas, the lean samples (4) contain only 0.3 wt.% organic carbon and 92% carbonate carbon (limestone). The hydrogen and oxygen indexes for the rich rocks are 422 and 41, respectively, and for the lean rocks are 193 and more than 100, respectively. The rich rocks tend toward type II, but should still be considered type II/III, whereas the lean rocks are type III.

Carbonate and organic carbon data for both Unit II and Units III-V are plotted on Figure 21; the data are from Table 7. Except for the two very rich samples, or-

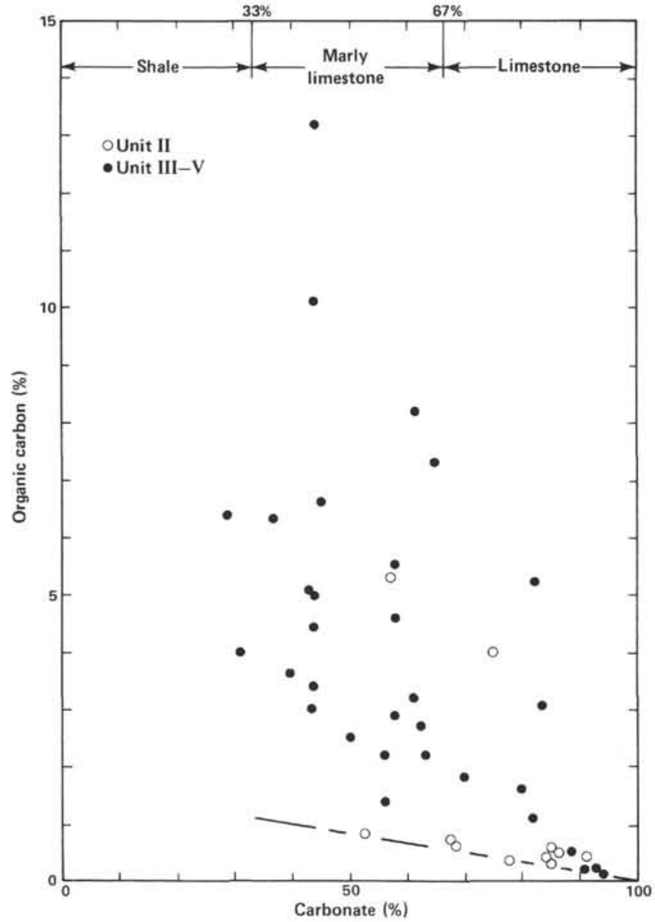


Figure 21. Carbonate versus organic carbon content of selected samples from Units II and III–V, Hole 535.

ganic carbon data for Unit II are below 1%, and also, all (except one) are limestones. The organic carbon data also fall on a fairly straight line, in contrast to the data for Units III–V, which do not fall on a line but are scattered in the marly limestone and limestone fields. Because these rocks, where they are rich in organic matter, are various shades of dark gray and are all carbonates, we propose that they be designated "dark carbonates" in contrast to "black shales," which are predominantly the mid-Cretaceous mudstone but do include some Neocomian marly limestone and limestones of the North Atlantic (Arthur and Natland, 1979).

Asphalt and oil stains were encountered from a depth of 530 to 538 m (Cores 58 and 59) and at 585 m (Core 64). The upper interval is fractured or brecciated, and in some the calcite-lined fractures are filled with breccia and asphalt (Fig. 22A). In addition, oil (darker areas) is most commonly present in the limestone associated with the asphalt-filled fractures (Fig. 22B). At least one limestone-asphalt contact appears to be a solution contact suggesting the fracture system has been flushed by water (Fig. 22C). The asphalt does not fluoresce under a fluoroscope as does the oil stain. Both the asphalt and the oil stain show fluorescence when cut with 1,1,2,2-tetrachloroethane. A fetid smell was noted when the core was cut.

The asphalt may have originated by fractionation of oil and subsequently migrated into the calcite-lined fractures or may be an example of a very asphaltic (immature) oil. It is difficult to believe that biodegradation could have played any part in its formation. The oil stains have barely penetrated the rock, implying that a more liquid precursor was never there. Additional shore-based studies in this volume address the origin of the asphalt and the oil stain.

A gas sample was recovered from Section 535-68-1 (610.5–612 m), analyzed on the Carle gas chromatograph, and found to contain only carbon dioxide.

Carbonate Bomb

Analyses for $CaCO_3$ content were run on 135 samples to determine chemical composition of the limestones and marly limestone and to evaluate the type of organic material. The carbonate bomb results are tabulated in Tables 8 and 9. The data show that most of the samples are high in $CaCO_3$ and can be classified as limestones or marly limestones. Even the dark sediments that are very rich in organic matter contain considerable $CaCO_3$.

CHN Analyzer

Organic carbon determinations were carried out on 41 acidified and dried samples. The results of these analyses were used with the carbonate bomb data to calculate the organic carbon content of the original sediment sample. The percent organic carbon of the sediment was then used with the Rock-Eval data to calculate the hydrogen and oxygen indexes. The results of the CHN analyzer and the percent organic carbon are shown on Table 9.

Interstitial Water

Interstitial water samples were taken every fifth or sixth core down through Core 28, and one additional water sample was taken from Core 50. Cores 2, 7, 12, and 17 were taken in soft Quaternary muds, and ample water for analysis was obtained. Cores 22 and 28 were taken in limestones and very little water was obtained. It was decided at this point to stop sampling because of the poor recovery of water in the limestones. One additional sample (Core 50) was attempted from a thick, relatively soft, dark marly limestone layer. Very little water was squeezed from this sample and only partial results were obtained. The results of the chemical analyses of these samples are tabulated in Table 10 and plotted graphically on Figure 23.

Site 540

Organic Geochemistry

Fifty-eight rock samples were taken at Site 540 spanning the interval from Cores 10 (85.62 m) through 79 (736.76 m) for Rock-Eval analysis. The Rock-Eval data were used to select 20 samples for CHN and carbonate bomb analyses. These data were used to determine the

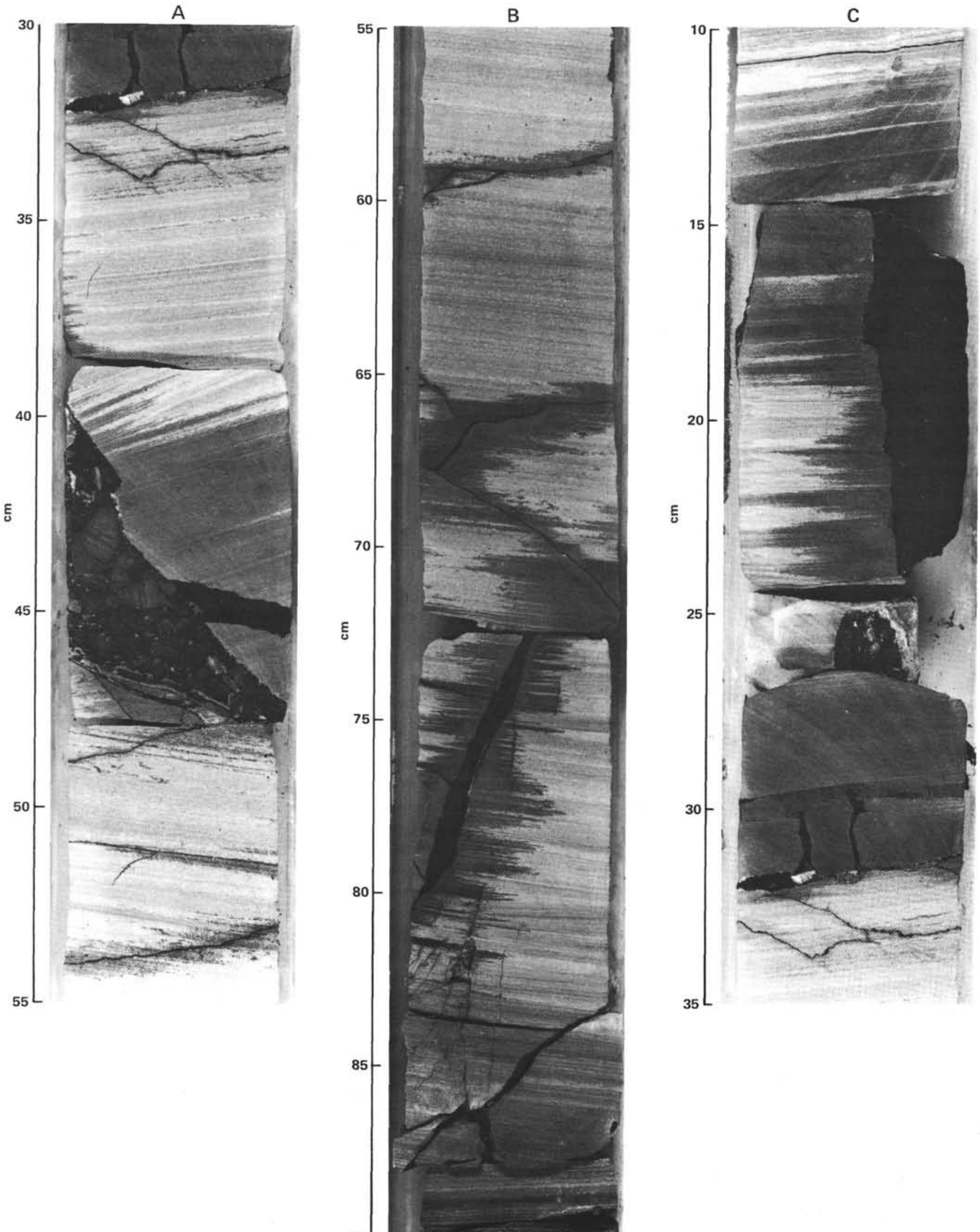


Figure 22. Occurrence of asphalt and oil stains in Core 535-58. Note that cm scales differ slightly in A, B, and C. A. Brecciated limestone with black asphalt in fractures. B. Oil-stained (darker areas) limestone associated with asphalt-filled fractures. C. Oil-stained limestone with corroded asphalt/limestone contacts suggesting water flushing prior to asphalt emplacement.

Table 8. Carbonate contents of sediments recovered at Hole 535 (carbonate bomb method).

Core-Section (interval in cm)	$CaCO_3$ (%)	Core-Section (interval in cm)	$CaCO_3$ (%)
10-1, 106–107	7	47-1, 85–86	94
10-2, 106–107	8	48-5, 66–67	31
11-7, 63–64	34	50-2, 12–13	91
12-4, 75–76	59	50-4, 30–31	48
13-3, 48–49	10	51-1, 37–40	90
13-6, 145–146	36	51-3, 24–26	85
17,CC (21–22)	92	52-4, 6–7	68
19-1, 33–34	92	53-1, 18–19	70
20-3, 124–126	94	53-6, 54–55	82
20-4, 142–144	89	54-1, 23–25	71
21-1, 118–121	89	54-3, 43–44	85
21-5, 44–46	99+	55-5, 84–85	68
22-1, 36–39	93	55-5, 111–112	74
22-4, 71–73	99	55-5, 120–121	86
22-7, 79–80	99	55-5, 140–141	90
23-1, 86–87	98	55-6, 30–31	90
23-4, 122–123	91	56-1, 25–26	73
25-2, 80–81	89	56-1, 78–79	86
26-1, 23–24	86	57-3, 0–2	79
26-4, 5–6	83	57-3, 58–60	85
27-1, 115–116	85	59-4, 57–58	70
28-1, 45–46	82	60-2, 10–12	65
28-5, 28–29	90	61-1, 39–40	62
30-1, 90–92	80	61-2, 12–13	88
30-4, 62–63	58	61-2, 64–65	80
30-4, 77–78	92	62-4, 0–1	55
31-1, 83–84	89	62-4, 51–53	85
31-5, 62–63	86	62-5, 42–43	91
31-5, 82–83	92	63-1, 65–66	92
31-5, 90–91	98	63-4, 112–114	57
31-6, 140–141	66	64-6, 49–50	33
31-6, 22–24	96	65-3, 4–6	61
32-1, 67–68	86	66-4, 81–82	60
32-3, 87–88	99+	66-4, 107–108	90
33-3, 1–2	99+	67-4, 83–84	64
33-5, 48–49	78	67-4, 88–89	89
33,CC	89	68-2, 117–118	22
34-2, 63–65	90	68-4, 37–38	83
35-1, 41	80	68-5, 72–74	15
35-5, 105	49	69-3, 44–46	49
36-2, 63–65	77	71-2, 56–57	55
36-5, 125–127	96	71-4, 84–85	66
37-3, 61–62	90	72-4, 51–52	74
37-5, 97–98	97	73-1, 93–94	44
38-4, 66–67	92	73-3, 23–24	64
40-1, 48–49	92	74-1, 112–113	57
41-5, 141–142	65	74-4, 10–11	65
42-4, 63–64	96	76-2, 142–143	44
42-4, 149–150	98	78-1, 35–36	70
43-3, 20–21	74		
43-5, 107–108	62		
46-2, 78–80	54		

Note: For additional carbonate bomb results from Hole 535, see Table 9.

Table 9. Total organic carbon contents of acidified samples from Hole 535.

Core-Section (interval in cm)	Acidified sample (%C)	$CaCO_3$ (%)	Organic carbon (%)
12-2, 100–102	1.35		1.35
13-2, 140–142	1.28		1.28
14-3, 50–52	1.06		1.06
15-3, 100–102	1.07		1.07
16-1, 78–80	1.18		1.17
17-2, 43–46	1.10		1.10
19-4, 136–138	2.65	85	0.40
22-4, 100–101	5.07	91	0.46
23-5, 0–2	3.52	85	0.53
24-4, 88–90	2.71	—	—
26-1, 22–24	2	85	0.3
28-1, 34–39	2	77	0.46
31-7, 10–12	1.86	52	0.89
32-3, 8–10	2.18	68	0.70
35-5, 15–18	12.5	57	5.38
36-1, 52–54	2	61	0.78
38-1, 61–62	4	85	0.60
41-5, 118–120	16	75	4.0
42-5, 21–22	21	65	7.35
43-3, 17–19	29	82	5.22
44-1, 81–82	8	80	1.6
46-2, 41–42	4	93	0.28
47-1, 96–97	6	40	3.6
49-3, 91–92	5	50	2.50
52-1, 63–65	3	56	1.32
53-3, 19–21	5	56	2.2
54-6, 51–52	7	62	2.7
55-4, 61–62	11	58	4.6
56-5, 78–80	8	33	5.36
57-3, 2–3	6	70	1.8
58-2, 106–108	21	61	8.2
58-4, 11–13	18	83	3.1
61-1, 49–50	18	44	10.1
63-4, 103–104	9	44	5.6
64-4, 56–57	23.5	44	13.2
65-2, 38–40	2	91	0.2
65-2, 120–122	4	88	0.5
65-2, 132–134	6	82	1.1
65-2, 145–146	6	63	2.2
65-4, 20–21	2	94	0.12
66-2, 35–36	8	61	3.12

Note: Carbonate bomb data and organic carbon contents of original material are given for reference. Final organic carbon contents determined with CHN analyzer.

hydrogen and oxygen indexes and lithology (limestone versus marly limestone versus shale).

On the basis of lithology, the rocks penetrated in Hole 540 are separated into six units. The first unit (Core 1) was not sampled for organic geochemistry. Results from the Rock-Eval analyses of Units II and III contain no detectable organic material, which is not surprising because these rocks are bioturbated and very light gray or are gravity-flow deposits. These units will not be discussed further, but the results of the analyses are shown in Table 11–12 and Figure 24. In contrast, Unit IV includes most of the limestones that are rich in organic matter at this site. Unit V contains one rich sample, but Unit VI contains no limestone rich in organic matter. The results of analyses of these units are also shown in Tables 11–12 and are discussed below.

Unit IV, extending from 328.15 m (540-36-1, 65 cm) to 498.5 m (through Core 53), is 170.35 m thick and contains numerous intervals of potential oil source-rocks. Lithologically, the unit is a thinly laminated limestone with thin beds or nodules of black chert. The limestone grades from a light gray to a very dark olive gray and contains very little pyrite. Towards the bottom of the unit (from Sections 540-48-2 to 540-53-1) the laminated bedding is mildly to severely bioturbated. The age of this unit is early Cenomanian to late Albian.

Table 10. Summary of shipboard interstitial water chemistry, Hole 535.

Core-Section (interval in cm)	Sub-bottom depth (m)	pH	Alkalinity (meq/l)	Salinity (‰)	Calcium (mmol/liter)	Magnesium (mmol/liter)	Chlorinity (‰)
Surface seawater		8.20	2.506	36.4	10.57	54.93	19.79
2-2, 144–150	0		12.022	37.5	18.59	62.41	19.96
7-6, 140–150	50	6.94	7.215	36.7	18.53	57.25	19.52
12-3, 140–150	100	7.06	11.376	37.3	19.04	56.56	19.76
17-2, 140–150	150	7.0	5.633	36.4	14.61	53.50	19.55
22-6, 140–150	200			37.3	18.14	46.31	20.58
28-6, 0–5	250			44.3	22.98		24.31
50-3, 27–34	450			49.4	29.37	51.20	27.39

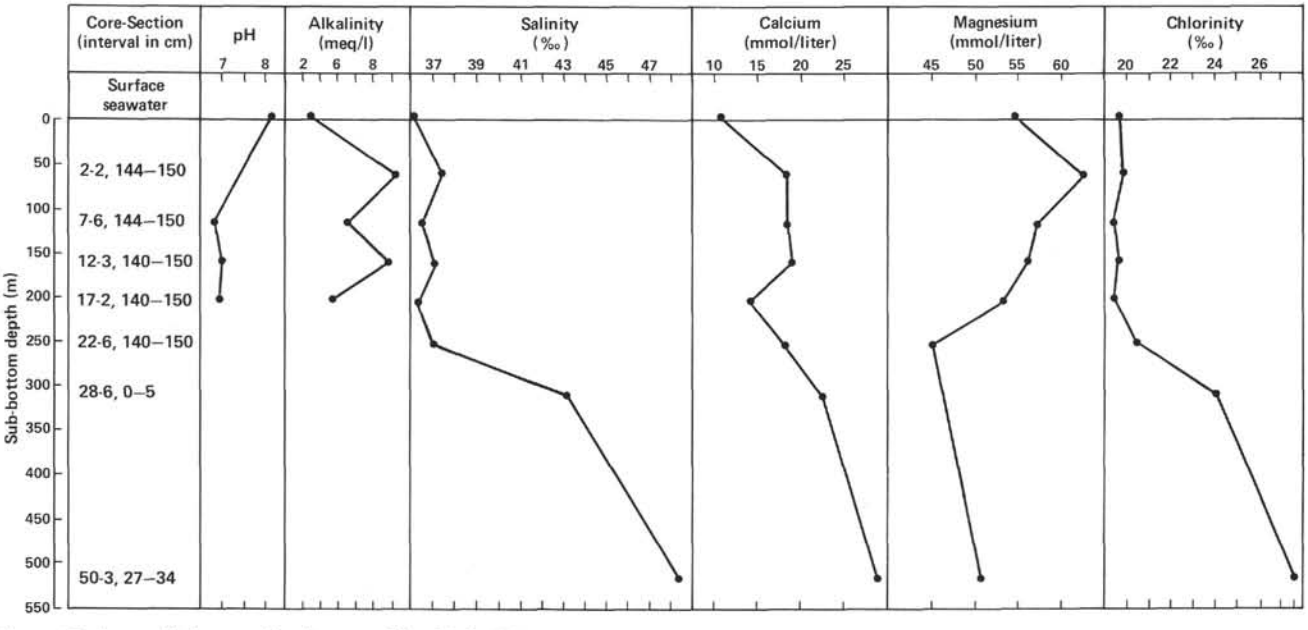


Figure 23. Interstitial water chemistry profiles, Hole 535.

Table 11. Organic geochemical summary for Units I–VI, Site 540.

Unit	Age	Thickness (m)	Core recovery (%)	Sedimentation rate (m/Ma)	Number Rock-Eval samples	S_1 (mg HC/g rock)	S_2 (mg HC/g rock)	S_3 (mg CO_2/g rock)	S_2/S_3	Max. S_2 peak temp (°C)	$S_1/(S_1+S_2)$	Number carbon samples	Carbon: Organic (wt.%)	Carbon: Carbonate (wt.%)	Average hydrogen index	Average oxgyen index
I	Holocene to late Pleistocene	4.5	100		0											
II	late Miocene to middle Paleocene	275.5	63	55–8	10	0	0	0	0		0	0				
III	Cenomanian	49.6	20		3	0	0	0	0		0	0				
IV	early Cenomanian to late Albian	161.6	21	119–24	17	0.07	15.4	1.7	8.9	421	0.02	9	4.0	80	459	55
					13[a]		21.3	1.8	12.0			7	5.0	82	489	42
					4[b]		1.6	0.8	1.9			2	0.5	73	354	>100
V	Albian	225.8	41	119–39	25	0.6	1.6	0.7	2.2	421	0.04	9	0.9	84	194[c]	65
					1[a]		7.7	0.8	10.2			1	1.8	85	428	42
					24[b]		1.3	0.7	1.9			8	0.8	84	161	68
VI	Albian	28.5	72		3	0.04	0.6	0.9	0.7	411	0.08	2	0.4	75	149	>100

[a] >5 mg HC/g rock.
[b] <5 mg HC/g rock.
[c] Data for Sample 540-73-1, 105–106 cm were deleted because there were no S_{1-3} values.

Seventeen samples were analyzed on the Rock-Eval for richness, type, and thermal maturity of the organic matter (Fig. 24). Four rock samples show a poor (0–2.5 mg HC/g rock) hydrogen source potential; three of these samples are at the bottom of the unit and are bioturbated. The remainder of the samples (13) are rich enough to be considered potentially good (i.e., more than 5 mg HC/g rock) source-rocks; they average 21.3 mg HC/g rock. The data for this unit are shown in Tables 11 and 12 and on Figure 24.

The type of organic material, if no organic carbon values are available to calculate the hydrogen and oxygen indexes, can be determined using the S_2/S_3 ratio (Fig. 24), and also by plotting the hydrogen source potential (S_2) versus the S_2/S_3 ratio (Fig. 25). As shown on Figure 25, the richer the sample, the more oil "prone" the organic matter.

Nine samples were run for organic carbon content; seven rich samples and two lean samples were analyzed to determine the hydrogen and oxygen indexes. Three

Table 12. Organic geochemistry data for Units II–VI, Hole 540.

Sample no.	Core-Section (interval in cm)	Sub-bottom depth (m)	S_1 (mg HC / g rock)	S_2 (mg HC / g rock)	S_2/S_3	S_2 pk. temp. (°C)	$S_1/(S_1+S_2)$	Organic carbon (wt.%)	CO_3 carbon (wt.%)	Hydrogen index (mg HC / g OC)	Oxygen index (mg CO_2 / g OC)
Unit II											
125	10-4, 62	85.62	0	0	0	0					
126	11-5, 13–14	96.13	0	0	0	0					
127	12-5, 17–19	105.17	0	0	0	0					
128	14-5, 148–150	125.48	0	0	0	0					
129	16-6, 70–72	145.70	0	0	0	0					
130	17-3, 148–150	151.48	0	0	0	0					
131	20-1, 103–105	176.53	0	0	0	0					
132	24-2, 45–47	215.45	0	0	0	0					
133	29-1, 56–57	261.56	0	0	0	0					
134	30-1, 80–81	271.30	0	0	0	0					
Unit III											
135	31-2, 27–29	281.77	0	0	0	0					
136	32-2, 34–35	291.34	0	0	0	0					
137	33-1, 119–121	300.19	0	0	0	0					
Unit IV											
138	36-1, 71–72	328.21	0.06	12.6	10.1	405	0	1.7	93	741	74
139	37-1, 72–73	337.72	0.09	13.7	6.7	400	0.01	7.9	75	176	26
140	37-2, 57–58	339.07	0.06	19.4	12.3	400	0	4.6	87	422	34
141	41-1, 120–121	376.20	0.13	1.5	1.9	412	0.08				
142	42-1, 60–61	385.10	0.09	14.6	9.5	395	0.01				
143	42-2, 33–34	386.33	0.05	21.8	10.8	390	0				
144	43-1, 57–61	394.67	0	20.8	15.9	395	0	5.6	84	371	23
145	44-2, 44–48	405.44	0	19.5	10.1	395	0	3.1	87	629	62
146	45-1, 18–19	413.19	0.21	14.4	7.9	395	0.01				
147	46-2, 10–12	424.10	0	24.2	11.4	391	0	6.5	83	372	33
148	47-1, 77–78	432.77	0	13.0	9.8	411	0				
149	47-2, 53–54	434.03	0	41.3	17.6	407	0	4.8	68	712	41
150	48-1, 144–146	442.94	0	34.1	16.6	407	0				
151	50-2, 60–61	462.60	0.30	5.9	5.2	421	0.05				
152	51-1, 5–7	470.05	0.11	2.3	3.0	418	0.05	0.5	65	460	>100
153	52-2, 37–38	481.37	0.05	0.6	0.5	400	0.07				
154	53-1, 38–39	489.38	0.07	2.0	2.0	400	0.03	0.8	82	250	>100
Unit V											
155	54-2, 74–75	500.74	0.05	0.8	1.2	413	0.06				
156	55-2, 144–145	510.44	0.04	1.2	1.3	408	0.03				
157	56-1, 130–131	518.80	0.08	1.1	1.8	411	0.07				
158	57-2, 104–108	529.54	0.07	1.2	1.8	412	0.06	1.0	83	120	68
159	58-2, 84–87	538.84	0.05	2.0	3.4	417	0.02	1.3	95	154	45
160	59-1, 32–33	546.32	0.08	2.3	2.5	421	0.03				
161	60-2, 111–112	558.11	0.11	1.8	3.0	406	0.05				
162	61-1, 36–37	565.36	0.07	0.8	1.2	408	0.08	0.6	90	133	>100
163	62-2, 41–42	576.41	0.07	0.7	1.1	405	0.09				
164	63-1, 86–88	584.86	0.11	7.7	10.2	415	0.01	1.8	85	428	42
165	64-1, 77–78	594.77	0.13	4.5	4.4	410	0.13				
166	65-1, 147–148	604.47	0.06	0.9	2.2	405	0.06	0.7	94	129	60
167	66-3, 47–48	615.97	0.07	1.9	2.7	410	0.04				
168	67-3, 69–70	625.69	0.06	2.0	3.9	405	0.03	0.9	80	222	58
169	68-3, 0–2	634.50	0.05	0.8	0.7	405	0.06				
170	69-1, 23–24	641.23	0.11	4.5	7.6	412	0.02	1.7	86	265	35
171	70-4, 62–66	655.62	0.02	0.2	0.2			0.2	51	100	>100
172	70-6, 88–91	658.88	0.01	0.2	0.2						
173	71-1, 99–100	660.99	0.01	0.2	0.2						
174	72-2, 105–106	672.05	0.02	0.3	0.6	410	0.06				
175	73-1, 105–106	680.05	0	0	0		0	0.2	80	0	0
176	73-4, 103–104	684.53	0.07	0.7	0.9	408	0.09				
177	74-2, 87–88	690.87	0.06	1.2	2.0	403	0.05				
178	75-1, 96–97	698.96	0.07	1.1	1.5	405	0.06				
179	76-2, 70–72	709.70	0.07	0.7	1.4	406	0.1				
Unit VI											
180	77-3, 131–132	721.31	0.05	0.32	0.4	400	0.14	0.3	71	107	>100
181	78-3, 11–12	729.61	0.04	0.73	0.7	400	0.05				
182	79-1, 76–77	736.76	0.03	0.76	0.9	411	0.04	0.4	79	190	>100

samples are type II kerogen and six samples are type II/III kerogen (Fig. 26). There appears to be good correlation between the two methods of determining kerogen type. All samples are thermally immature; the highest temperature at maximum pyrolysis yield of S_2 peak is 421°C, well below the 435°C needed for maturity. With the exception of one sample, all samples lie to the right of the 0.5% R_o (vitrinite reflectance) line on the van Krevelen diagram (Fig. 26).

Carbonate and organic carbon data (9 samples) are plotted on Figure 27 to determine the lithology of the rocks rich in organic matter. All samples in Unit IV with more than 1 wt.% organic carbon content are limestones and are classified as bituminous limestones.

The top of Unit V was penetrated at 498.5 m (top of Core 54) and the bottom at 717 m (through Core 76) for a total thickness of 218.5 m; the unit has poor potential as a hydrocarbon source. This unit is a bioturbated limestone (*Chondrites*, mottled, and wavy diffuse laminae) that is light gray to light olive gray. Very little to no pyrite was observed in this unit. The age of this unit is late to middle Albian.

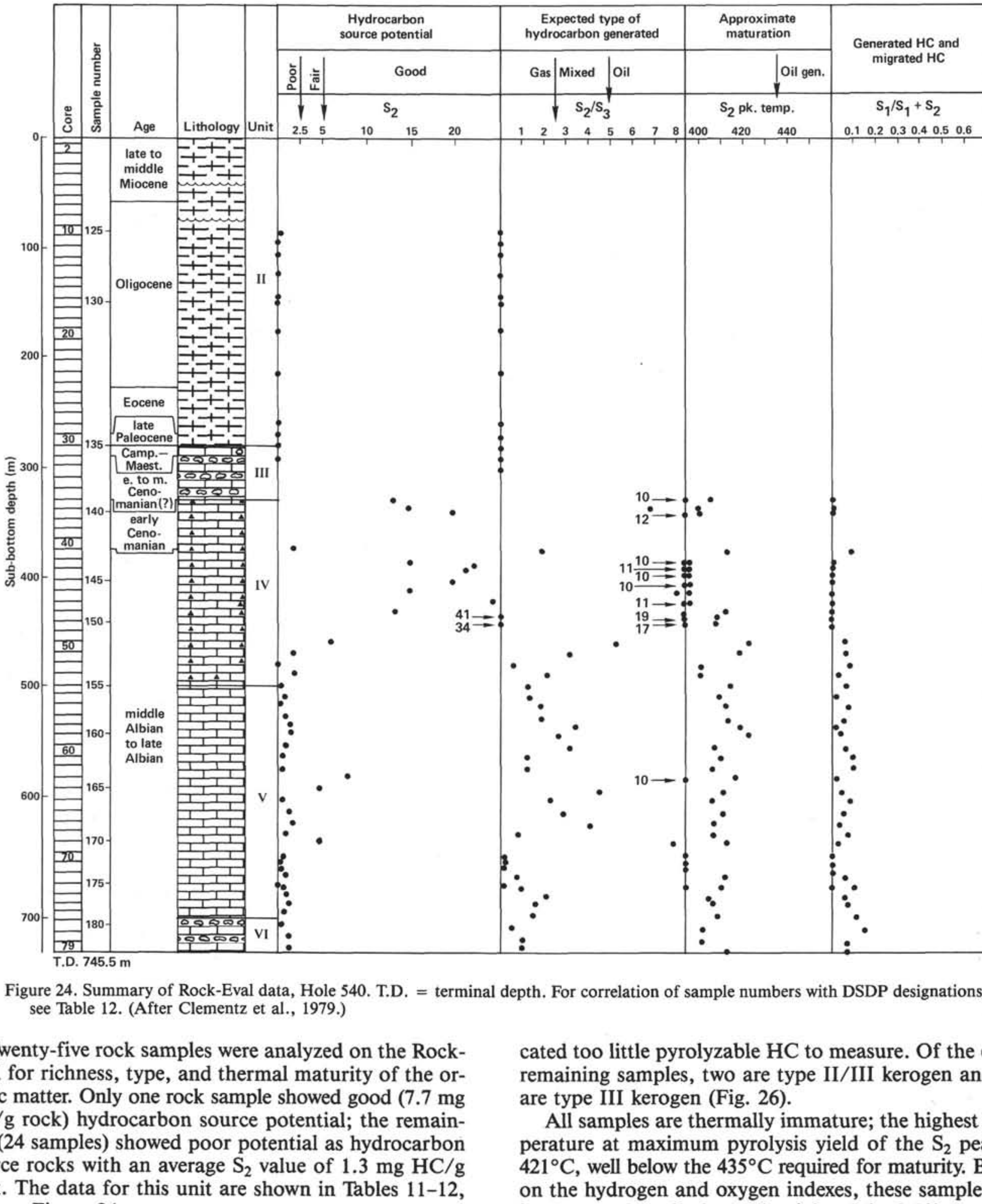


Figure 24. Summary of Rock-Eval data, Hole 540. T.D. = terminal depth. For correlation of sample numbers with DSDP designations, see Table 12. (After Clementz et al., 1979.)

Twenty-five rock samples were analyzed on the Rock-Eval for richness, type, and thermal maturity of the organic matter. Only one rock sample showed good (7.7 mg HC/g rock) hydrocarbon source potential; the remainder (24 samples) showed poor potential as hydrocarbon source rocks with an average S_2 value of 1.3 mg HC/g rock. The data for this unit are shown in Tables 11–12, and on Figure 24.

The type of kerogen using the Rock-Eval data is shown on Figure 25. The one rich sample is a potentially good oil source-rock. Two samples are potentially fair source-rocks for oil, a mixture of gas and oil, or condensate. The remainder of the samples are potentially poor source-rocks for a mixture of hydrocarbons or gas.

Nine samples were analyzed for organic carbon content to determine the hydrogen and oxygen indexes. One sample could not be used because the Rock-Eval indicated too little pyrolyzable HC to measure. Of the eight remaining samples, two are type II/III kerogen and six are type III kerogen (Fig. 26).

All samples are thermally immature; the highest temperature at maximum pyrolysis yield of the S_2 peak is 421°C, well below the 435°C required for maturity. Based on the hydrogen and oxygen indexes, these samples are immature; they all plot to the right of the 0.5% R_o value on a van Krevelen diagram (Fig. 26).

Carbonate and organic carbon data for the nine samples are compared on Figure 27 to determine the lithology. Except for one lean sample, all are limestone, and those that equal or exceed 0.3% are bituminous limestone.

Unit VI, which extends from 717 m (Core 77) to 745.5 m (terminal depth, Core 79), is at least 28.5 m thick and contains potentially poor source-rock. Litho-

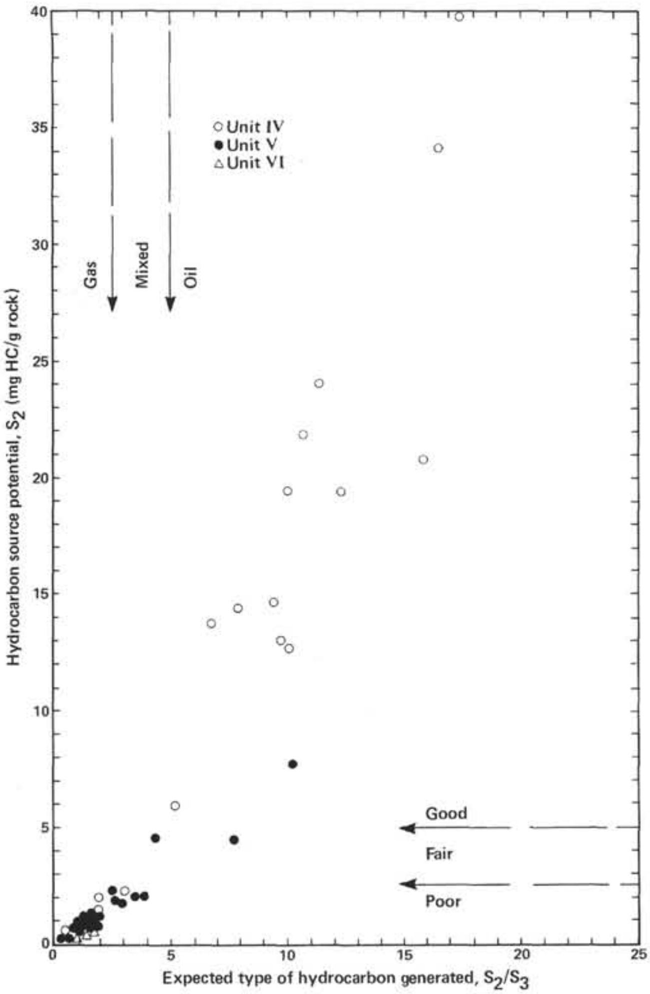


Figure 25. Hydrocarbon source potential and expected type plotted as Rock-Eval parameters S_2 versus S_2/S_3, Hole 540. See text for details.

logically, the unit is a bioturbated limestone with carbonate sand and coarse-grained skeletal limestone of middle Albian age.

Three samples were analyzed on the Rock-Eval for richness, type, and thermal maturity. The average S_2 value is 0.6 mg HC/g rock, indicating potentially poor source-rock. The type of organic matter as shown on Figure 25 is a potentially poor gas source-rock and on a van Krevelen diagram (Fig. 26) as type III kerogen with very low hydrogen content and high oxygen content, a gas source-rock. These rocks are thermally immature, based on S_2 peak temperature and on the van Krevelen diagram (Fig. 26).

Based on organic and carbonate carbon data, these rocks are limestones with 0.3 or more wt.% organic carbon (Fig. 27), threshold values for carbonate source-rocks.

Carbonate Bomb

One hundred fifty-three carbonate bomb samples were analyzed for percent $CaCO_3$ to determine lithology. The results are tabulated in Tables 13 and 14. These data show that most of the samples analyzed are limestones. Most of the marly limestones occur in Unit II.

CHN Analyzer

Organic carbon determinations were carried out on 20 acidified and dried samples. The results of these analyses were used with the carbonate bomb data to calculate the organic carbon content of the original sediment sample. The percent organic carbon of the sediment was then used with the Rock-Eval data to calculate the hydrogen and oxygen indexes. The results of the CHN analyzer and the percent organic carbon are shown in Table 14.

Interstitial Water

Five interstitial water samples from Tertiary oozes were taken and analyzed at Site 540. The results are tabulated and shown graphically in Table 15 and Figure 28. The data show a distinct increase in salinity, chlorinity, and calcium content and a decrease in magnesium content with depth.

Summary and Significance of Organic Geochemistry Results

Significant findings at Sites 535 and 540 that relate to organic geochemistry of petroleum source rocks follow.

1. Except for Site 370 in the North Atlantic (Arthur and Natland, 1979), Site 535 records the oldest (Berriasian) sedimentary rock showing indications of anoxic or very low oxygen conditions.
2. In contrast to the organic matter–rich "black shale" (interbedded dark and lighter-colored claystone, marlstone, and limestone) of the Hatteras Formation (Hauterivian-Cenomanian) in the North Atlantic (Arthur and Natland, 1979), the rock record at Site 535 suggests slightly older (Berriasian-early Albian) organic matter–rich "dark carbonate" (gray to very dark gray marly limestone and limestone).
3. In the eastern North Atlantic, two types of organic matter (II and II/III) are found (Tissot et al., 1979). This contrasts with the type III kerogen that was found at Sites 391 and 101 in the western North Atlantic (Tissot et al., 1979). Types II and II/III are found at Sites 535 and 540.
4. Oil-stained limestones were found adjacent to asphalt-filled fractures in the immature source-rock unit at Site 535 (lower Albian to Berriasian, Unit III–V). Oil-stained carbonate was also encountered at DSDP, Site 2, Leg 1 (Challenger Knoll; Davis and Bray, 1969). The Challenger Knoll oil was extracted from the core and exhaustively analyzed. The oil-stained limestones and possibly the asphalt at Site 535 could be similarly treated to provide additional geochemical data for oil from deep-ocean basins. Site 535 oil should be compared with the Site 2 oil as well as oil being produced in and around the Gulf of Mexico in the U.S. and Mexico.
5. Unit IV, Hole 540, contains laminated limestone with excellent oil source-rock potential and can rightly be classified as bituminous limestone containing good types II and II/III kerogens. Units III to V, Hole 535, contain both marly limestone with excellent rich imma-

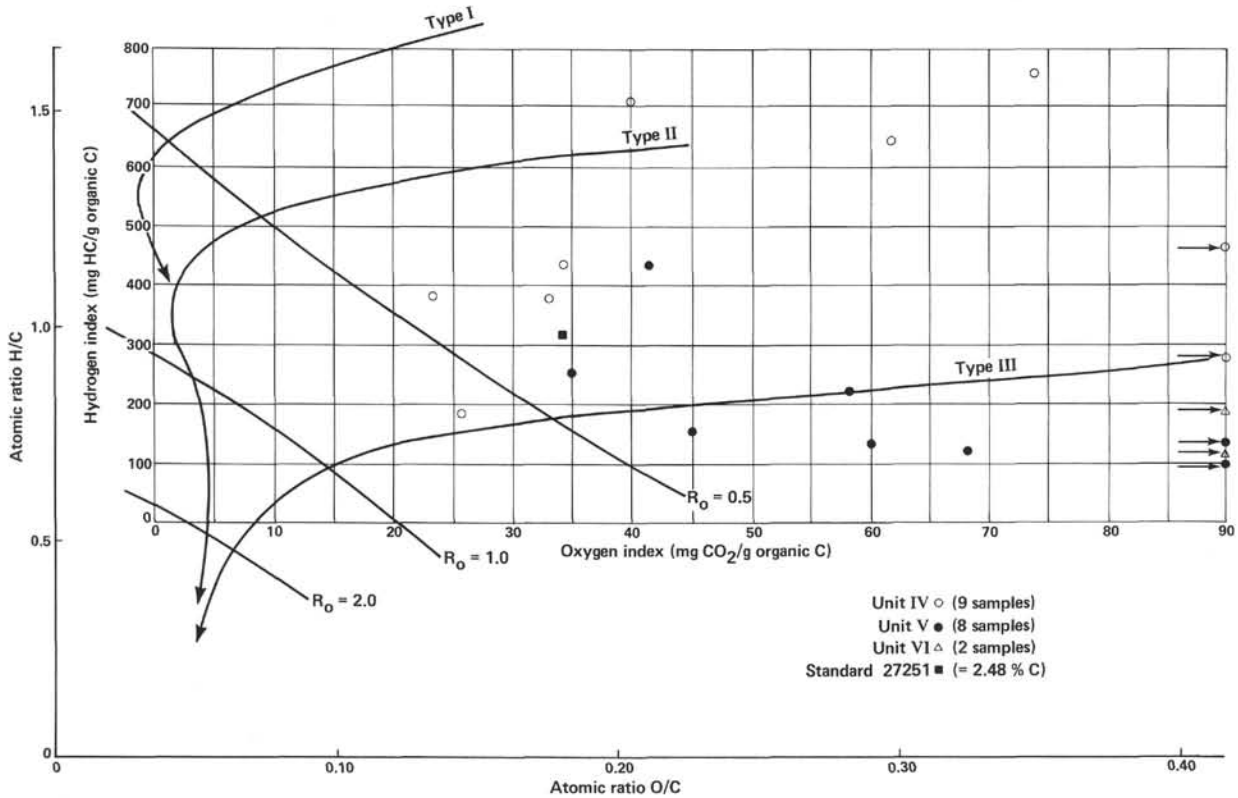


Figure 26. Modified van Krevelen diagram for Hole 540. See Introduction and Explanatory Notes (this volume) for description, use, and interpretation of this diagram.

ture oil source-rocks that were designated "dark carbonates" containing good type II/III kerogen.

6. The reef-debris reservoir facies of Late Jurassic through mid-Cretaceous age contains much of the oil of the Reforma-Campeche shelf and the Golden Lane of Mexico (Meyerhoff, 1980). Offshore in the Gulf of Mexico, a dark gray and black shale (carbonate?) interfingers with this reservoir (Meyerhoff, 1980). The dark carbonates penetrated at Sites 535 and 540 may be a carbonate facies of this shale, and, if the dark carbonate has sufficient lateral continuity and is mature under the proper geologic circumstances, it may be an important source rock for these oil fields and other fields that border the Gulf of Mexico.

7. The source rocks penetrated in Holes 535 and 540 can be contrasted with the rocks of the same age penetrated in the North Atlantic. The Albian-Aptian section in the western Straits of Florida is dominantly limestone, whereas in the North Atlantic black shales were penetrated. The Berriasian–Barremian section penetrated in Hole 535 is organic matter-rich marly limestone and limestone, but in the North Altantic this section is a very lean marly limestone.

PALEOMAGNETISM

Paleomagnetic sampling was concentrated in the upper portion of the thick Lower Cretaceous sequence recovered at Site 535 (Cores 18 to 56, 154.5–515.5 m). Onboard paleontologists dated this section as ranging from Albian to Hauterivian/Valanginian with a probable hiatus in the Barremian. It was, therefore, expected that these deep-water limestones recorded the early part of the long Cretaceous normal magnetic period and several of the younger reversals in the underlying magnetic anomaly sequence (Fig. 29).

Four hundred nine oriented samples were minicored at 0.5–0.8 m spacing in the interval 154.5–515.5 m, where recovery averaged 69%. Very low intensities prevented on-board measurements, so the samples were measured after the cruise with a cryogenic magnetometer at the University of Texas, Galveston Geophysics Laboratory. As of September 1981, samples from Cores 39 through 56 (354.0–515.5 m) have been analyzed. NRM intensities range 4.4×10^{-9} to 2.9×10^{-7} emu/cc and average 6.1×10^{-8} emu/cc. All samples were demagnetized in three to six steps between 25 and 300 Oe. Many samples displayed a soft component of magnetization, which was usually erased by demagnetization to 25 Oe. Orthogonal vector diagrams indicate that the remaining magnetization is a stable component (see Testarmata, this volume). Only 9 of the 179 samples displayed unsatisfactory vector diagrams, and these samples were excluded from further analysis.

The stable inclinations derived from the vector diagrams are plotted stratigraphically in Figure 30. The resulting reversal stratigraphy is quite surprising: only one reversely magnetized sample occurs among 169 normally magnetized samples. This pattern does not agree with the reversal sequence derived from the marine magnetic anomaly pattern and from other magnetostratigraphic studies for correlative periods. Two possible explanations for the discrepancy are (1) that the core was remagne-

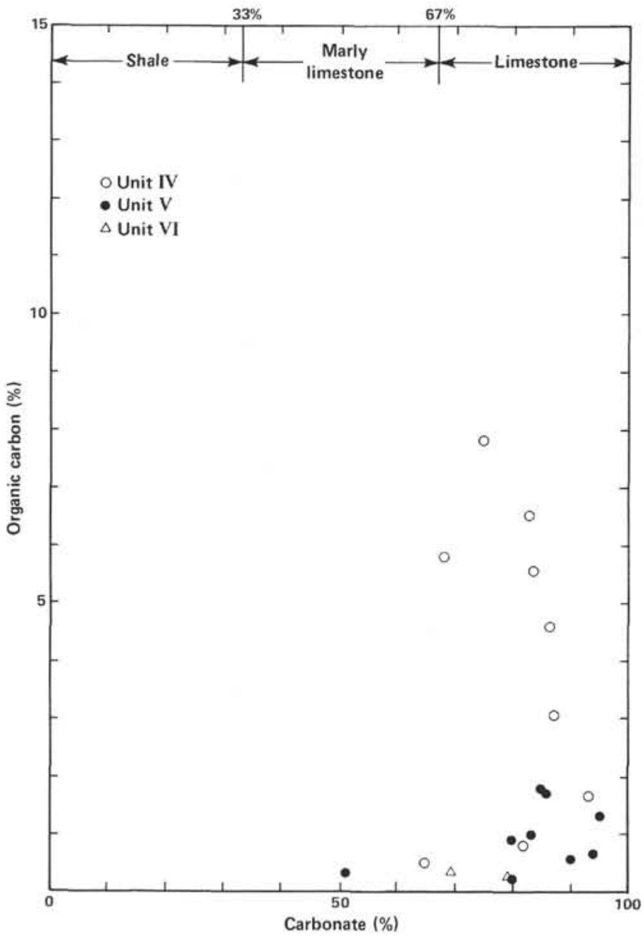


Figure 27. Organic carbon versus carbonate content, Units IV–VI, Hole 540.

tized, or (2) that the entire sampled interval is within the long Cretaceous normal zone and that the shipboard paleontologic dating is erroneous. Both of these alternatives will be investigated.

Postdepositional remagnetization can not be discerned from measured inclinations (averaging 37.8°) because the magnetic inclination of this site (41.3°) has changed by only 0.2° since 120 Ma. The presence of one reversely magnetized sample is not conclusive evidence against remagnetization, because the possibility exists that the sample was misoriented during the sampling procedure. Adjacent pieces of core need to be sampled to test the existence of the reversed zone.

PHYSICAL PROPERTIES

Site 535

Figure 31 summarizes the physical properties data at Site 535. Considering general trends first, all parameters change markedly at about 146 m, the unconformity between soft Quaternary mudstone and hard Cretaceous limestone. Below this level, density and thermal conductivity increase slightly, and porosity decreases with only minor perturbations in these smooth trends. Sonic ve-

Table 13. Carbonate content of sediments from Hole 540 (carbonate bomb method.).

Core-Section (interval in cm)	$CaCO_3$ (%)	Core-Section (interval in cm)	$CaCO_3$ (%)
1-1, 6–7	63	41-1, 117–118	88
1-1, 116–117	51	42-1, 55–56	97
3-3, 60–61	68	42-2, 93–94	89
4-3, 50–51	69	44-2, 41–42	90
5-1, 60–61	73	44-2, 85–86	99
5-2, 107–108	41	45-2, 35–36	95
5-2, 120–121	29	45-2, 101–102	99+
5-3, 20–21	42	45-2, 145–146	90
5-3, 51–52	37	46-1, 73–74	95
6-1, 73–74	69	46-2, 51–52	96
6-1, 105–106	77	47-1, 76–77	89
6-2, 8–9	62	47-2, 92–93	88
6,CC (5–6)	78	48-1, 138–139	91
6,CC (9–10)	72	48-2, 17–18	87
7-1, 4–5	61	49-1, 81–82	83
8-3, 70–71	84	50-1, 42–43	98
9-2, 82–83	65	50-2, 31–32	91
9-4, 82–83	87	51-1, 14–15	95
10-2, 76–77	86	52-1, 29–30	94
11-1, 113–114	80	52-2, 37–38	68
11-4, 109–110	61	53-1, 31–32	88
12-3, 29	55	54-2, 75–76	96
12-4, 28–29	77	54-4, 74–75	99+
13-2, 38–39	71	55-2, 71–72	94
13-2, 83–84	84	55-2, 147–148	92
13-4, 103–104	59	56-2, 55–56	99+
14-4, 44–45	87	58-1, 41–43	96
14-5, 21–22	86	58-2, 79–80	95
15-2, 77–78	87	59-1, 16–17	97
15-3, 57–58	79	59-2, 50–51	93
16-3, 83–84	85	60-1, 36–37	92
16-6, 70–71	56	61-1, 23–24	94
17-3, 148–149	65	61-1, 25–26	99
17-5, 110–111	87	62-2, 86–87	94
18-1, 71–72	80	63-1, 142–144	97
18-2, 67–68	62	63-2, 62–63	27
19-1, 70–71	84	64-1, 26–27	99+
19-5, 78–79	61	64-1, 70–71	93
20-1, 103–104	56	65-1, 64–65	99+
20-2, 76–77	85	66-1, 97–99	99+
21-1, 66–67	84	66-2, 100–102	95
22-1, 46–47	81	67-1, 145–146	83
23-1, 46–47	79	67-2, 18–20	97
23-3, 26–27	63	67-3, 123–124	82
24-3, 54–55	89	68-1, 70–71	96
24-3, 82–83	36	68-1, 86–87	75
28-2, 99–101	69	69-1, 9–10	66
29-1, 123	41	69-5, 21–22	81
29-2, 2–3	45	70-4, 46–48	38
30-1, 70–71	92	70-7, 18–20	88
30-2, 83–85	82	71-1, 98–99	74
31-1, 33–34	41	71-3, 48–49	94
31-1, 138–139	44	72-4, 48–49	89
32-1, 58–59	94	73-3, 21–22	66
32-2, 58–59	88	73-3, 117–118	94
33-1, 50–51	82	74-1, 12–13	95
33-1, 91–92	79	75-1, 58–60	96
35-1, 34–35	98	76-2, 83–84	99
37-1, 48–49	94	78-1, 77–78	83
37-1, 65–66	86	78-1, 80–81	71
37-1, 100–101	97	78-5, 65–66	90
38-1, 27–28	86	78-5, 71–72	85
39-1, 10–11	83	79-1, 66–67	93
39-1, 21–23	82	79-1, 75–76	83
39-1, 37–39	99	79-3, 73–74	93
40-1, 55–57	99	79-6, 48–49	90
41-1, 66–67	99	79-6, 113–114	93
41-1, 34–35	94		

Note: For additional carbonate bomb results from Hole 540, see Table 14.

Table 14. Total organic carbon contents of acidified samples from Hole 540.

Core-Section (interval in cm)	Acidified sample (%C)	$CaCO_3$ (%)	Organic carbon (%)
36-1, 71–72	24	93	1.7
37-1, 72–73	31	75	7.8
37-2, 57–58	35	87	4.6
43-1, 57–61	35	84	5.6
44-2, 44–48	24	87	3.1
46-2, 10–12	38	83	6.5
47-2, 53–54	18	68	5.8
52-2, 37–38	1.4	65	0.9
53-1, 38–39	4.18	82	0.75
57-2, 104–108	19	95	0.95
58-2, 84–87	25	95	1.25
61-1, 36–37	6	90	0.63
63-1, 86–88	12	85	1.8
65-1, 147–148	12	94	0.72
67-3, 69–70	4.3	80	0.86
69-1, 23–24	12	86	1.7
70-4, 62–66	0.4	51	0.20
73-1, 105–106	0.9	80	0.18
77-3, 131–132	1.03	71	0.30
79-1, 76–77	1.9	79	0.40

Note: Carbonate bomb data and organic carbon contents of original material are given for reference. Final organic carbon contents determined with CHN analyzer.

locity on the other hand generally increases with depth but shows considerable variation. Acoustic impedance, which represents the product of the velocity and density, reflects these velocity variations. Shear strength was measured for most of the unconsolidated sediment cores. These cores were highly disturbed by drilling, and their value was somewhat questionable.

We distinguished 10 groupings of physical properties based principally on vertical sonic velocity (Fig. 32, Table 16). These groupings generally correspond to zones of variable velocity separated by intervals of more constant velocity. Throughout the Cretaceous section, velocity values are distinctly anisotropic, with horizontal velocities usually 10% greater than vertical values. This difference probably reflects the laminated nature of the limestones.

Because temperature logging or heat flow probe were done at this site, an attempt was made to measure the thermal conductivity of sediment cores. More than about 40 measurements on soft sediments and consolidated sediments were made. Conductivity of the soft sediments with high porosity (i.e., high water content) is low (around 2–3 mcal deg^{-1} s^{-1} cm^{-1}), whereas consolidated sediments show rather high conductivity values (around 4–5 mcal deg^{-1} s^{-1} cm^{-1}). These values are quite reasonable when a comparison is made with some official values of a dry limestone (with porosity 2%; Clark, 1964). Some samples showed very low apparent conductivity values, even below 2%. This may have been caused by a poor contact between the flat probe and diamond-saw-trimmed sample surface or it may quite reasonably be explained by low conductivity of water (1.43 mcal deg^{-1} s^{-1} cm^{-1} at 20°C), which was used to moisten the sample surface and probably occasionally formed a thin layer between the thermal probe and the sample surface. All of these values are in good agreement with the estimate that the conductivity values fall between those of a single crystal of $CaCO_3$ (~9–10 mcal deg^{-1} s^{-1} cm^{-1})

Table 15. Summary of shipboard interstitial water chemistry, Site 540.

Core-Section (interval in cm)	Sub-bottom depth (m)	pH	Alkalinity (meq/l)	Salinity (‰)	Calcium (mmol/liter)	Magnesium (mmol/liter)	Chlorinity (‰)
Surface seawater		8.30	2.48	37.3	10.99	56.26	19.91
1-2, 114–120	2.64	7.58	3.32	36.2	10.93	52.13	19.11
7-3, 144–150	56.44	7.19	4.99	36.8	14.66	50.41	19.78
12-4, 144–150	105.44	7.16	4.22	37.4	15.08	50.77	20.11
19-3, 144–150	170.44	7.35	3.340	38.1	18.09	47.59	20.74
24-4, 140–150	219.40	7.47	3.340	39.7	20.95	46.73	21.04

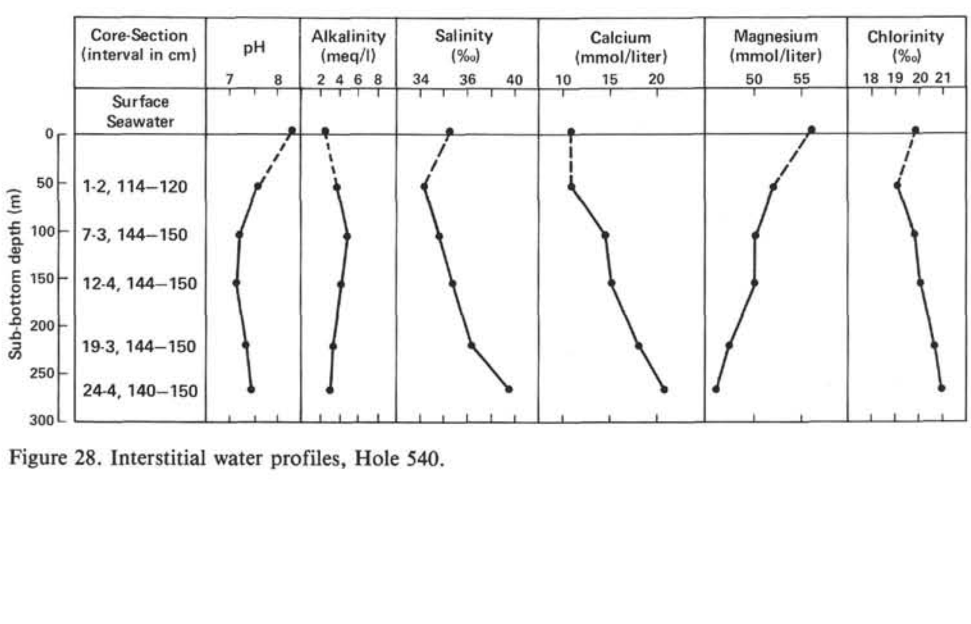


Figure 28. Interstitial water profiles, Hole 540.

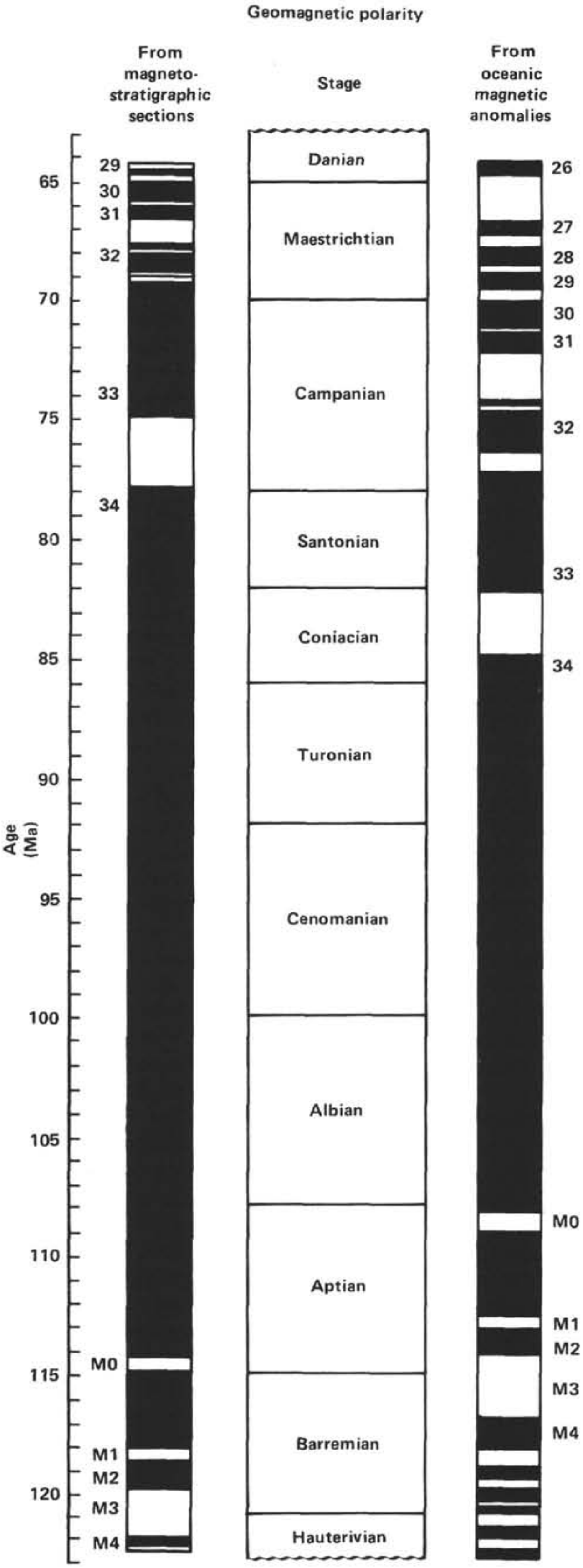


Figure 29. Two versions of the Cretaceous magnetic time scale. Black indicates normal polarity; white, reverse polarity. Modified from Lowrie and others (1980).

and the water (1.43 mcal deg^{-1} s^{-1} cm^{-1}). The thermal resistivity (reciprocal of the conductivity; $R = K^{-1}$) should also be a function of porosity (saturated with water) as suggested by several authors (e.g., Bullard and Day, 1961). Resistivity versus porosity plots for Site 535 show no clear relationship because of the gap in the data set as shown in Figure 33. Even so, these data fall on or near an empirical curve for limestone plus seawater.

Density variations in Lithologic Units II–V generally correlate with lithologic variations. In particular, the rhythms or cycles that characterize these units are mimicked by density cycles recorded by the GRAPE logs. An example for Section 535-42-4, is given in Figure 34. White, bioturbated limestones of the cycles are most dense; dark marly limestones are least dense; and gray laminated limestones fall between the extremes. These density variations are most pronounced where the cycles are best developed. GRAPE logging provides an initial, continuous, qualitative density log of these rhythms that are so characteristic of the lower 550 m of Site 535.

In addition to these trends, a number of interrelationships are noteworthy. The sonic velocity, the difference between parallel and perpendicular components of the sonic velocity (V) and the gravimetric density (ρ) data are statistically correlated to the gravimetric porosity (ϕ) data (Fig. 35). The population of individual data was divided into subpopulations for every 5% of the porosity value. The average and the standard deviation values were calculated for the subpopulations and plotted in relation to the porosity values (Fig. 35). Perpendicular and parallel components of the velocity data are treated independently except for soft (unconsolidated) sediments, which reflect the parallel component solely. Tendency of the V versus ϕ is similar to the data given by Anderson (1974) and Boyce (1976). The relation between ρ and ϕ may have important implications. The estimated best-fit line through the plots for ρ versus ϕ in Figure 35 is numerically approximated as

$$\rho_b = 2.75 - (1.725 \times \phi) \text{ (observed)},$$

whereas the formula normally used on shipboard is

$$\rho_b = 2.70 - (1.675 \times \phi) \text{ (Boyce, 1976)},$$

where ρ_b represent the wet-bulk density of a sample. The density values from these two formulas differ only by 2% from each other. This indicates that the ρ versus ϕ relation (Boyce, 1976) is a good approximation.

The second graph given in the middle part of Figure 35 shows a relation between the anisotropy of the sonic velocities and the porosity. Anisotropy is tentatively defined by

$$A_v = 100 \times \left(\frac{V_{\parallel} - V_{\perp}}{V_{\parallel} + V_{\perp}}\right) (\%).$$

Soft (unconsolidated) sediments are not included in the statistics. It is shown that the anisotropy factors show a peak at around 20% porosity. It is, however, assumed

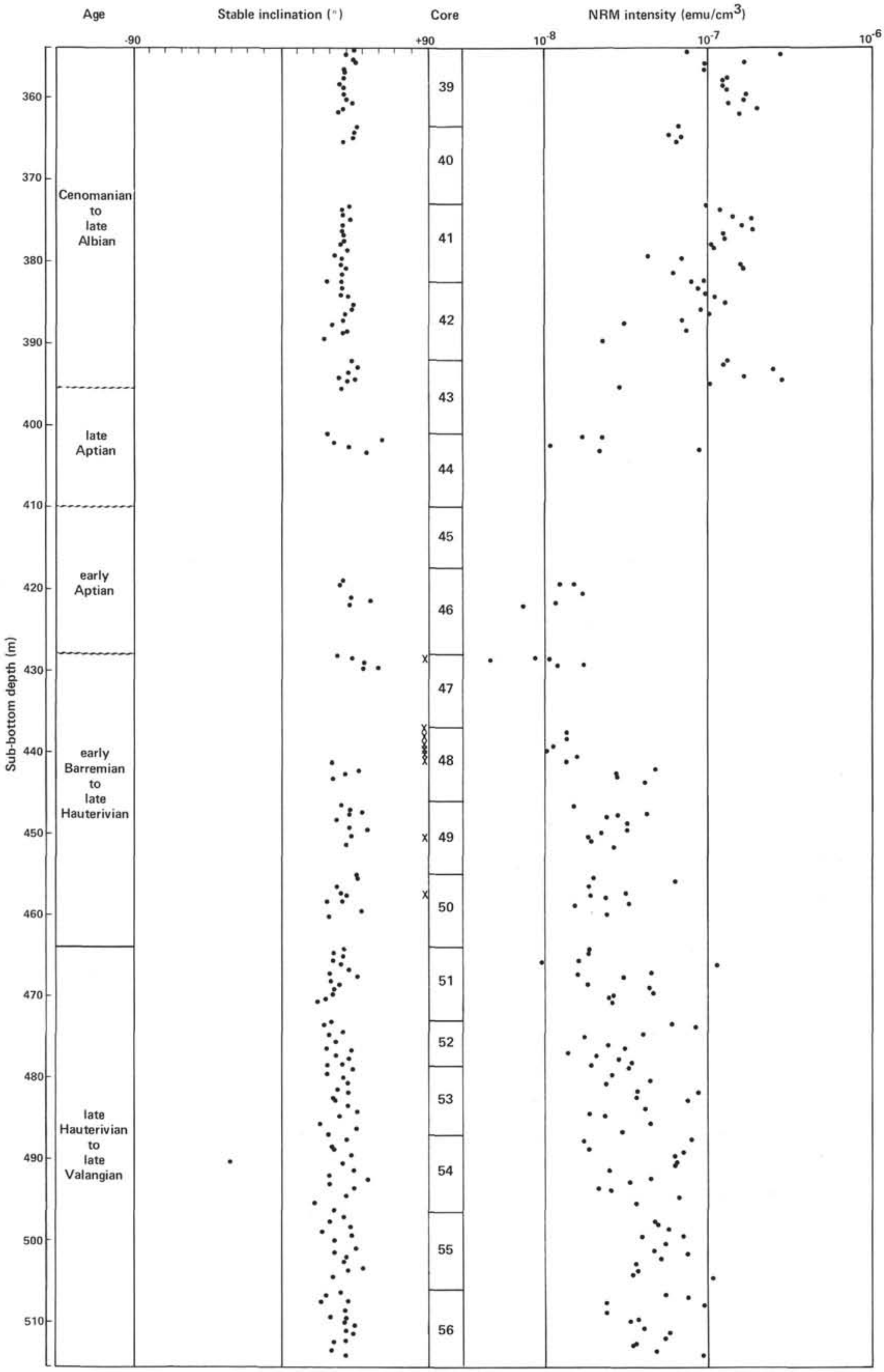


Figure 30. Stable inclinations and natural remanent magnetization (NRM) intensities of Lower Cretaceous samples from Hole 535. Note only one reverse sample is present in this portion of the core. X's indicates samples for which no stable inclination was obtained.

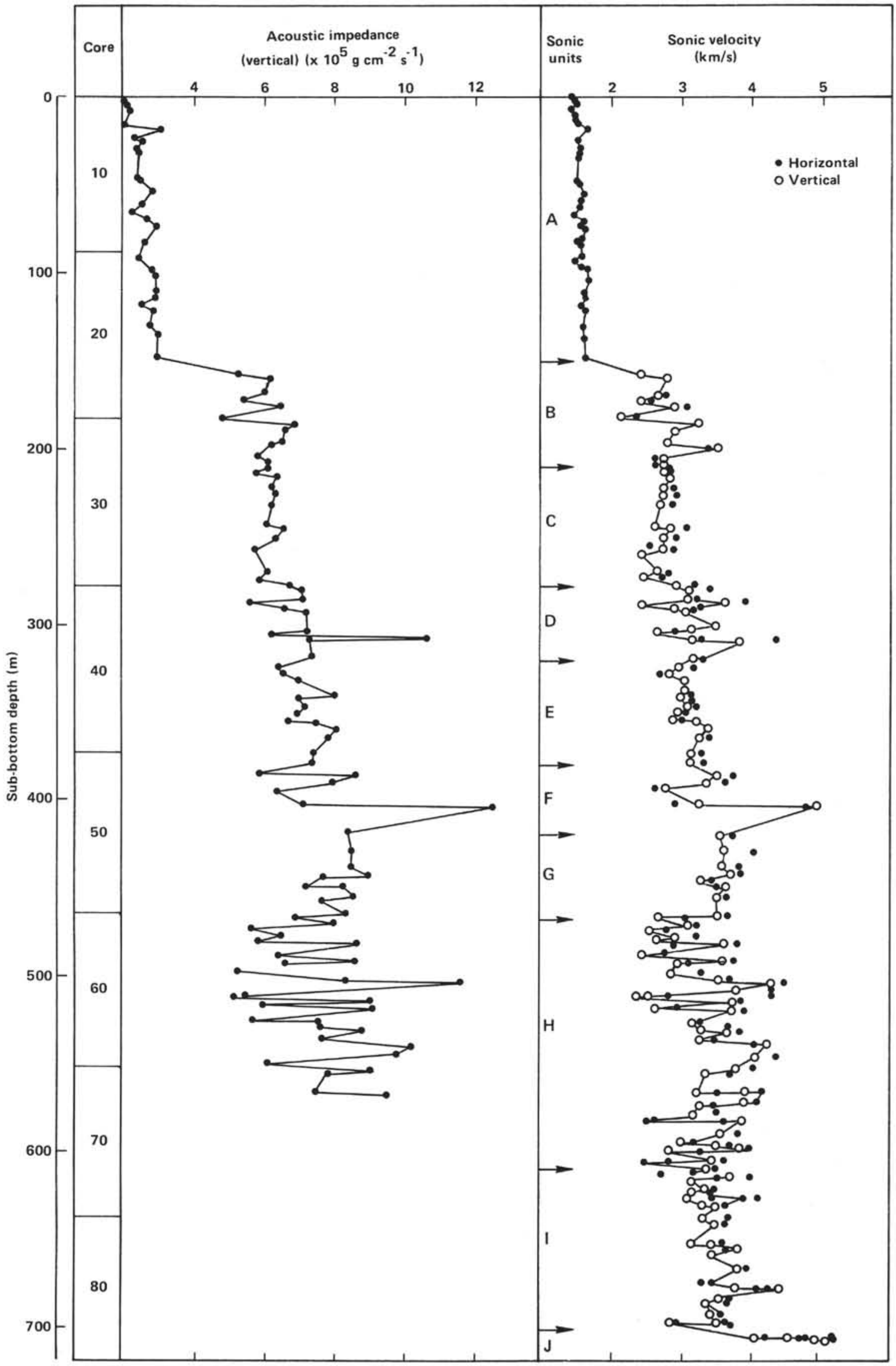


Figure 31. Summary of physical properties, Hole 535. See Appendix II at end of volume for raw data.

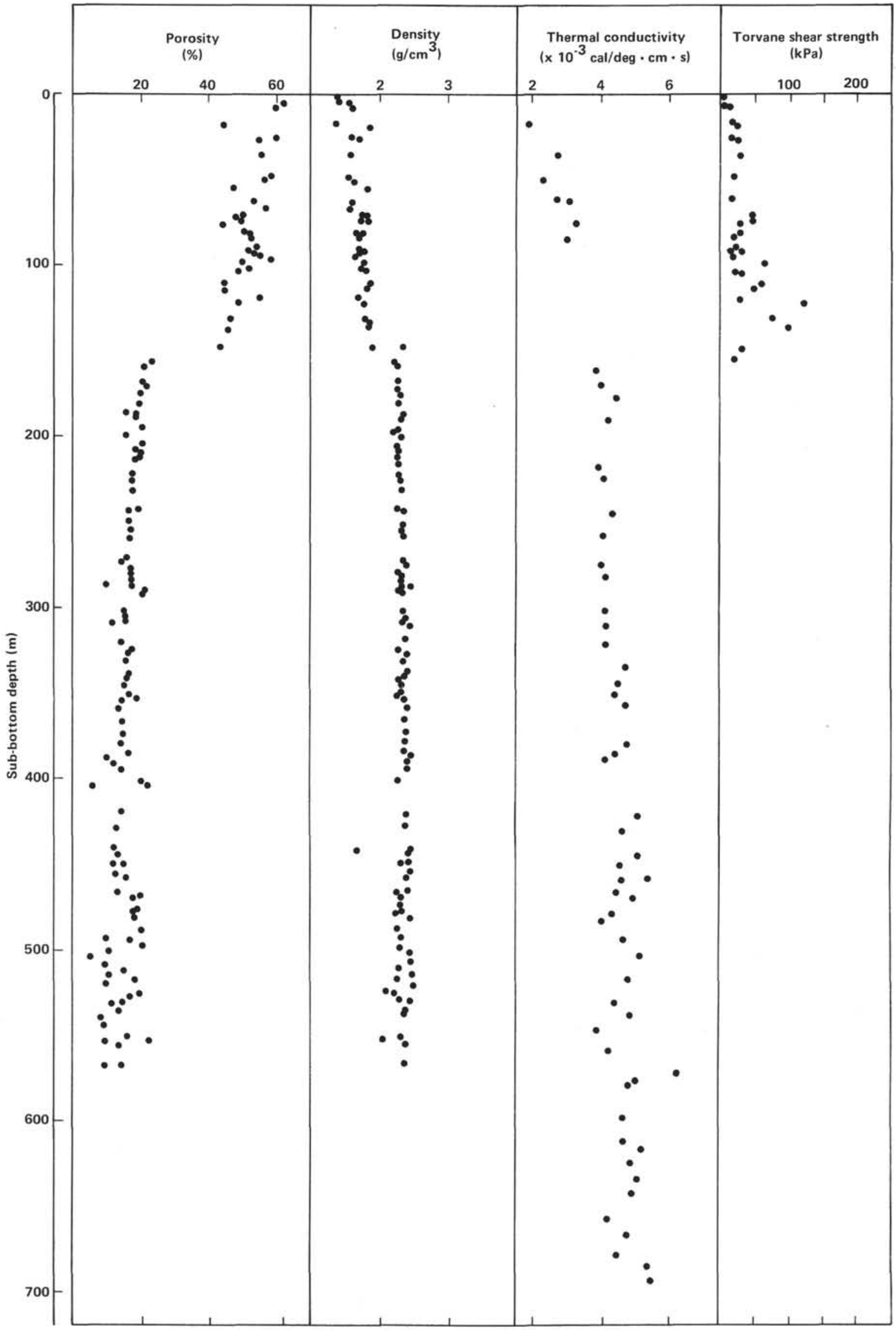


Figure 31. (Continued).

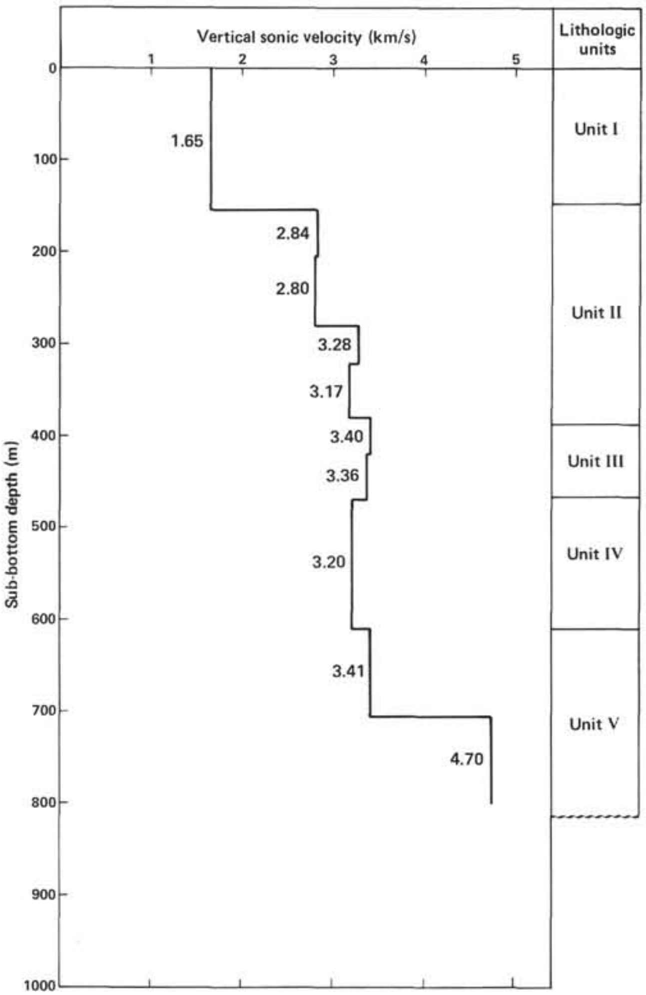


Figure 32. Sonic velocity groupings, Hole 535.

a priori that the unconsolidated sediments are elastically isotropic. The lowermost graph of Figure 35 shows a bimodal distribution of the frequency of porosity values. Zero frequency around 30–45% porosity corresponds to the lithologic boundary between Units I and II.

Another item of geophysical interest is suggested by the thermal conductivity data. Although downhole temperature measurements were not attempted, the vertical profile of the underground temperature might be estimated based upon estimated average heat flow (HF) value of (or nearby) this area (Martin and Case, 1975). Even though HF data for the location of Hole 535 is not available, we may assume that HF of the area is close to the average 0.825 HFU value for the area. The estimate of the temperature is given by solving the heat conduction formula in a reverse sense:

$$HF = K \times \text{grad } T \rightarrow T = \int \frac{HF}{K} dx \text{ (}x\text{: depth, positive downward),}$$

where K = thermal conductivity, assuming that heat is carried upward only by conduction. Using the average heat flow value and K varying as in Table 16, T, the thermal gradient can be calculated. Figure 36 illustrates the results of this calculation. The thermal conductivity values of the lowermost part between 710 and 1000 m are assumed to be an extrapolation of the upper part as shown by dotted lines in the figure.

Finally, acoustic impedance values can be used to compute reflectivity values or reflection coefficients for a number of horizons. These data suggest that strong seismic reflectors should occur at 0, 155, 380, and 700 m below the seafloor, and intermediate strength reflectors at 280 and 470 m.

Site 539

Only five measurements were made at Site 539. The results are listed in Table 17. No discussion is given for this site.

Site 540

Figure 37 summarizes the physical properties data and trends at Site 540. In addition to these data, two subsurface sediment temperature measurements were made at depths of 52 and 71 m using the DSDP heat flow probe.

All parameters show generally smooth trends to about 250 m. Velocity, density, and conductivity increase with depth in this interval; porosity decreases. Between 250 and 480 m, all parameters show extreme variability. This interval shows the greatest lithologic variation of the section. Below 480 m, all physical properties parameters are nearly constant, reflecting a fairly uniform lithologic interval.

As at Site 535, sonic velocity results permit several groupings or subdivisions of the section at Site 540 (Fig.

Table 16. Groupings of physical properties, Site 535.

Groupings	Sub-bottom depth (m)	Density (g/cm^3)	Porosity (%)	Sonic velocity Vertical (km/s)	Sonic velocity Horizontal (km/s)	Acoustic impedance (vertical) (10^5 g cm^{-2} s^{-1})	Thermal conductivity (10^{-3} cal/cm s deg)	Lithology
A	0–154	1.84	58	—	1.65	2.8	2.87	Soft sediment
B	155–204	2.29	25	2.84	2.88	6.5	4.19	
C	205–279	2.33	23	2.80	3.00	6.5	4.11	
D	280–319	2.36	21	3.28	3.35	7.7	4.19	
E	320–379	2.36	21	3.17	3.25	7.5	4.66	
F	380–419	2.40	19	3.40	3.45	8.2	4.55	Limestone
G	420–469	2.38	20	3.36	3.52	8.0	4.73	
H	470–609	2.36	20	3.20	3.50	7.6	4.80	
I	610–710	2.43	17	3.41	3.69	8.3	4.91	
J	710–?	2.57	5	4.70	4.72	12.1	—	

Note: Values represent averages.

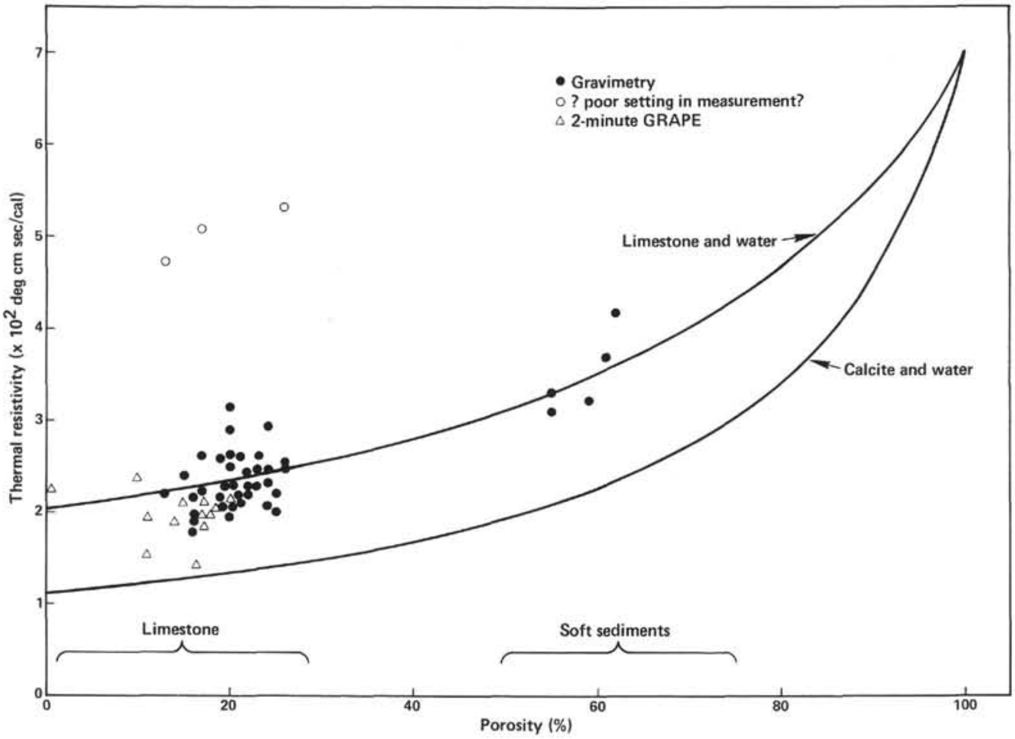


Figure 33. Thermal resistivity versus porosity, Hole 535. See text for discussion.

38 and Table 18). Of these, Interval F is notable for its apparent average high velocity. This interval corresponds with Lithologic Unit IV with abundant slump features.

Figure 39 contains cross-plots of porosity versus velocity, conductivity, density, and anisotropy, as well as a porosity histogram. Velocity, conductivity, and density all increase with decreasing porosity. Anisotropy appears to be evenly distributed throughout the section.

Heat flow measurements were run twice at sub-bottom depths 52 and 71 m. The probe was set at a 1-minute sampling rate and then lowered by the sand line into the hole. Lowering was stopped at 12 m above the bottom of the hole about 10 minutes before stabbing into the bottom sediment. The probe was kept there for about 25 minutes and then it was lifted off bottom. The mudline temperature was measured on each run by stopping the probe at the mudline for about 10 minutes while on the way out of the hole. The changes of the temperature with time are shown in Figure 40. Three temperature measurements, i.e., mudline (0 m) and 52 and 71 m sub-bottom depths are plotted in Figure 41. The conductivity data for this depth range are also plotted in the figure. The heat flow probe operation for further depth was not achieved, for after 70–80 m, the sediments were too firm to allow us to send the probe down without fear of its destruction. Results of the measurements are as follows:

Mudline temperature:	1st run	= 5.53°C
	2nd run	= 5.52°C
Bottom-hole temperature:	52 m	= 7.35°C
	71 m	= 8.09°C
Average of K (9–74 m depth)		= 2.74×10^{-3} cal/cm s deg
Temperature gradient (0–71 m depth)		= 36.06°C/km
Calculated heat flow (Q)		= ~0.99 HFU

The temperature gradient measured in this hole was probably lower than that before drilling. The magnitude of decrease in the bottom-hole temperature caused by flushing water circulation has not been estimated yet. The heat flow value of this hole, however, compared very closely to the local heat flow values (Martin and Case, 1975).

Summary

All the data for sonic velocity, density, thermal conductivity, and anisotropy are summarized for Sites 535 and 540 and plotted against the porosity in Figure 42. Also shown is the frequency distribution of porosity. Comparison of the present data to those of an elaborate study by Boyce (1976) reveals the remarkable features of the sediment samples of this area. First, a tight clustering of the density versus porosity plots along a single estimated line indicates a considerable homogeneity of the sediment. Secondly, the average anisotropy of the sonic velocity values is low (2–3%) compared to that of the sediments obtained in Leg 33 (2.5–7.5%) (Boyce, 1976). Thirdly, the porosity of the specimens obtained at Sites 535 and 540 is distributed in a bimodal manner. This distribution directly reflects the distinct unconformity between Quaternary mudstone and Cretaceous limestone at Site 535.

SEISMIC STRATIGRAPHY

Introduction

An extensive grid of multifold seismic data has been collected in the deep southeastern Gulf of Mexico by the University of Texas during the past few years (Fig. 43).

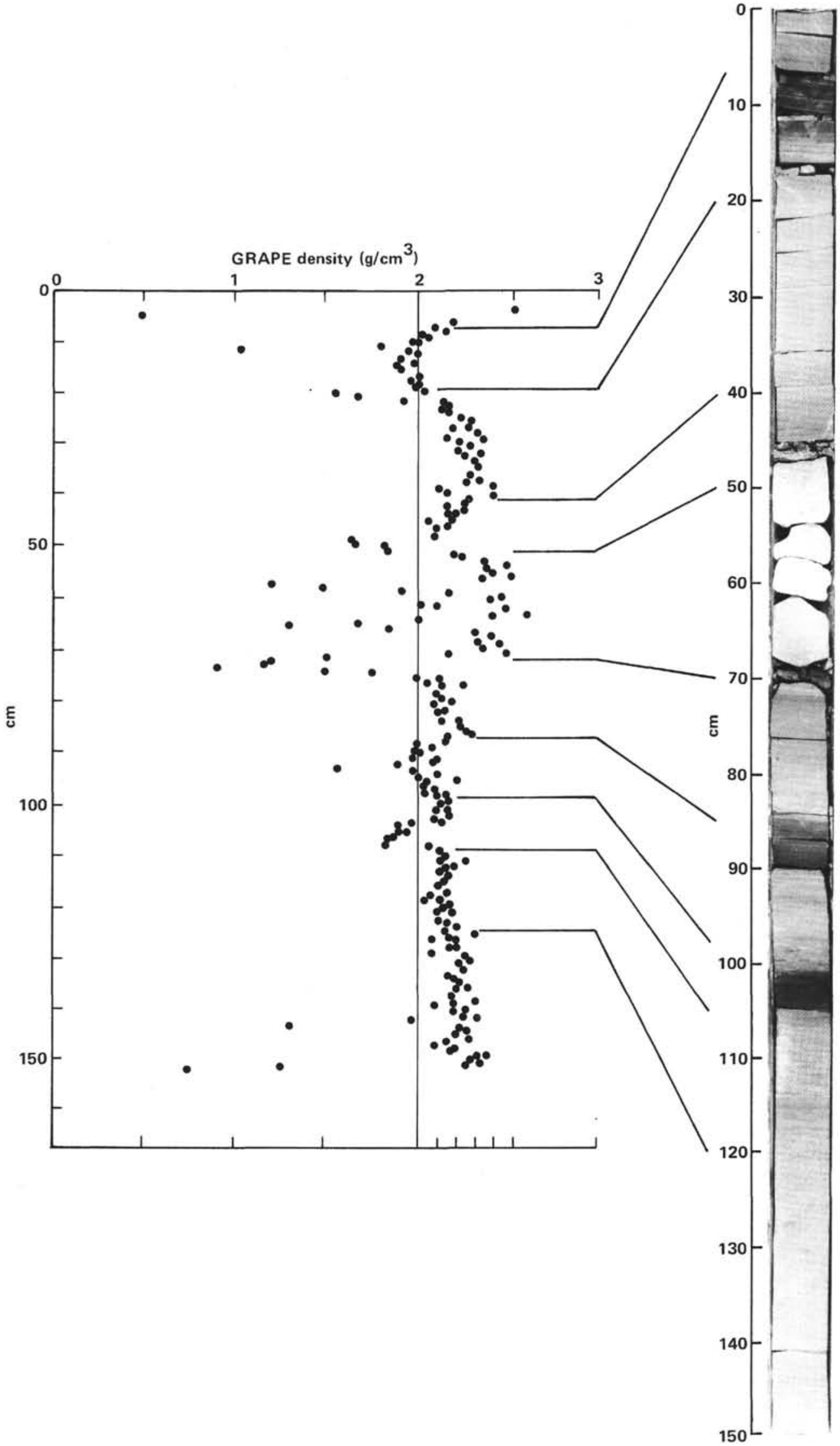


Figure 34. Comparison of raw GRAPE density with lithology of Section 535-42-4. White limestones are most dense; dark marly limestone, least dense; and gray, laminated limestones are intermediate in density.

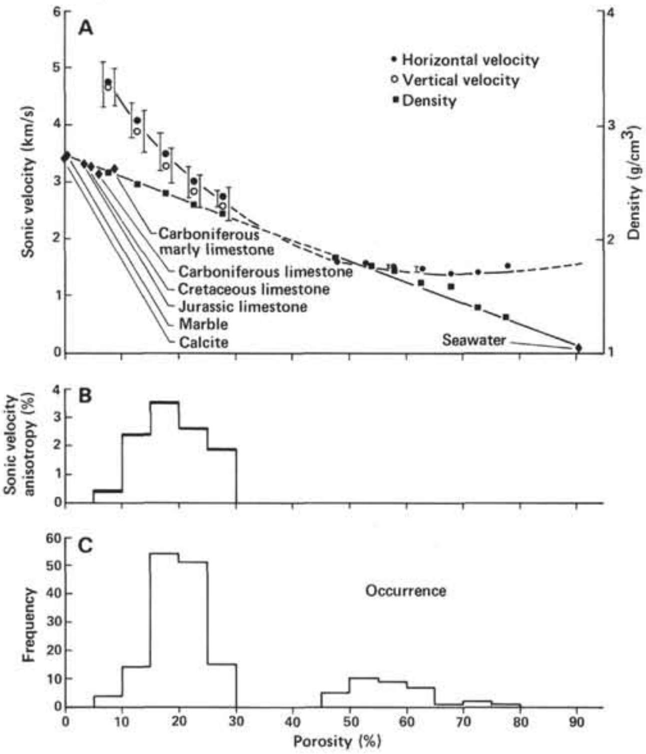


Figure 35. Porosity versus velocity and density (A), and velocity anisotropy (B) cross-plots for Hole 535. Porosity histogram (C) for Hole 535. See text for discussion.

These data were used to develop a preliminary seismic stratigraphic framework and to choose the drilling sites for Leg 77 (Fig. 43). The lines designated GT-2 and GT-3 (Gulf Tectonics) were collected in 1977 and 1978 as part of a regional study sponsored by industry. The lines designated SF (Straits of Florida) were collected late in 1980 as part of an IPOD site survey specifically for Leg 77.

The basin sites, Sites 535 and 540, were located along the eastern flank of a broad north-south erosional channel, where a thick pre-middle Cretaceous Mesozoic section either outcrops or subcrops beneath a thin Cenozoic cover (Figs. 1, 2, 43). The general setting of the sites and the background and objectives for drilling them were discussed in the Background and Objectives section.

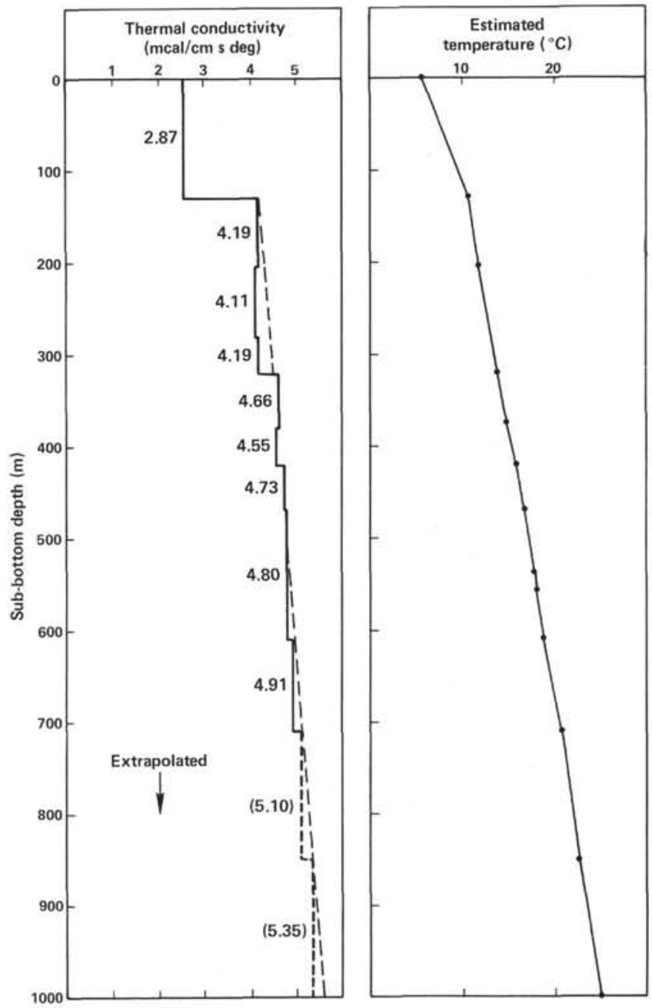


Figure 36. Subsurface temperature values and geochemical gradient calculated from thermal conductivity data and assumed heat flow, Hole 535.

Regional Setting

The new seismic data revealed for the first time details of the deep crustal structure and stratigraphy of the deep-water southeastern Gulf and allowed for the development of a preliminary model for the early history of

Table 17. Summary of physical properties for Site 539.

Core-Section (interval in cm)	Sonic velocity (km/s) Horizontal	Sonic velocity (km/s) Vertical	2-minute GRAPE Wet-bulk density (g/cm³) (horizontal)	2-minute GRAPE φ (%)	Gravimetrics Wet-bulk density (g/cm³)	Gravimetrics φ (%)	Gravimetrics Water content (%)	Torvane shear (kPa)	Thermal conductivity (×10⁻³ cal / deg·cm·s)	Lithology
Hole 539										
2-2, 100–102	1.544		1.63	64	1.50	71	48			Mud and ooze
2-3, 145–147	1.556		1.70	60	1.62	64	40		2.18	Mud and ooze
Hole 539A										
1-1, 100–102	1.524		1.50	72	1.42	77	54	4.79		Nannofossil ooze
1-3, 100–102	1.624		1.70	60	1.70	58	34	26.8		
1-5, 100–102	1.631		1.79	54	1.74	56	32	52.7	3.06	

Note: ϕ = porosity.

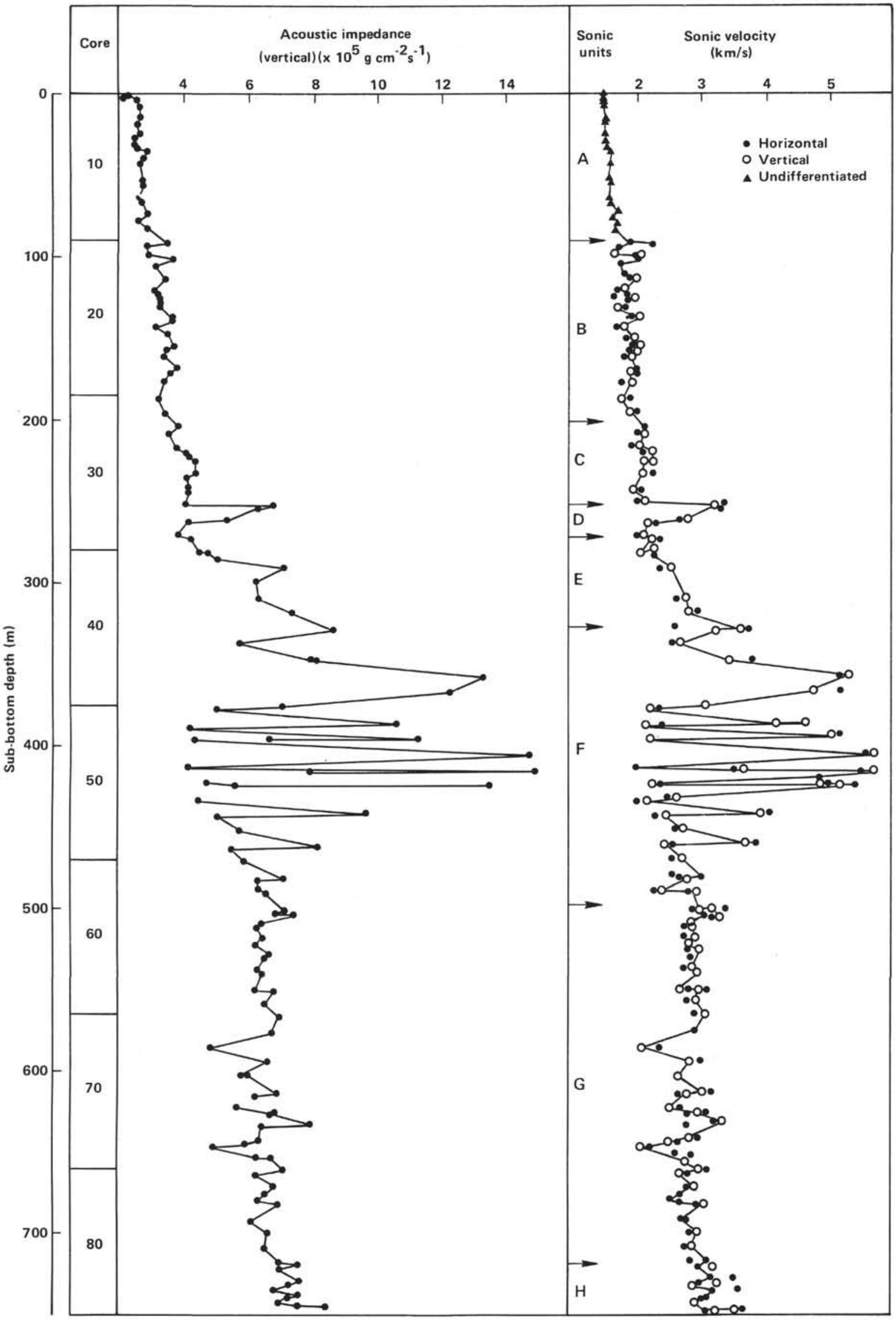


Figure 37. Physical properties plots, Hole 540. See text for discussion of trends and Appendix II at end of volume for raw data.

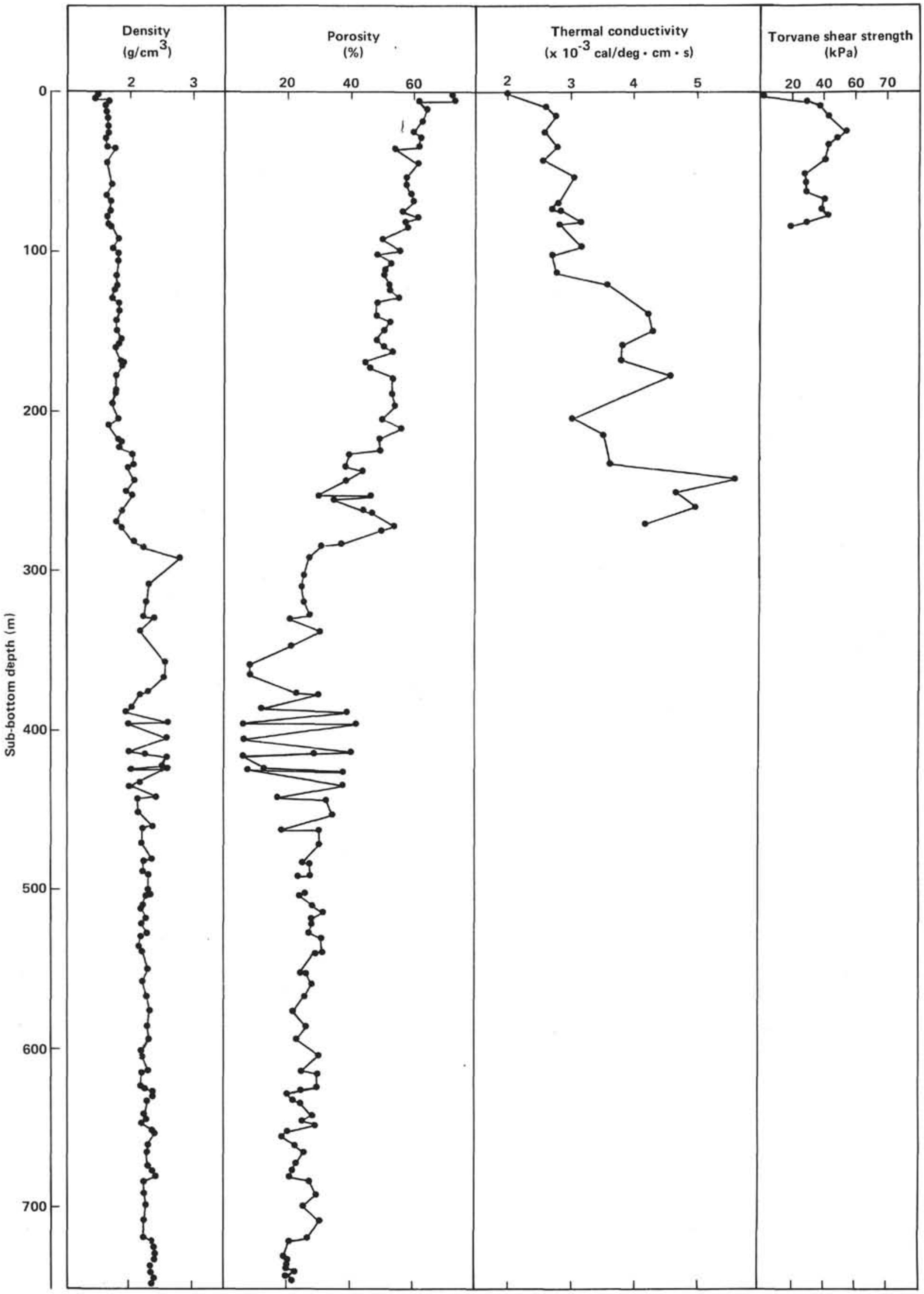


Figure 37. (Continued).

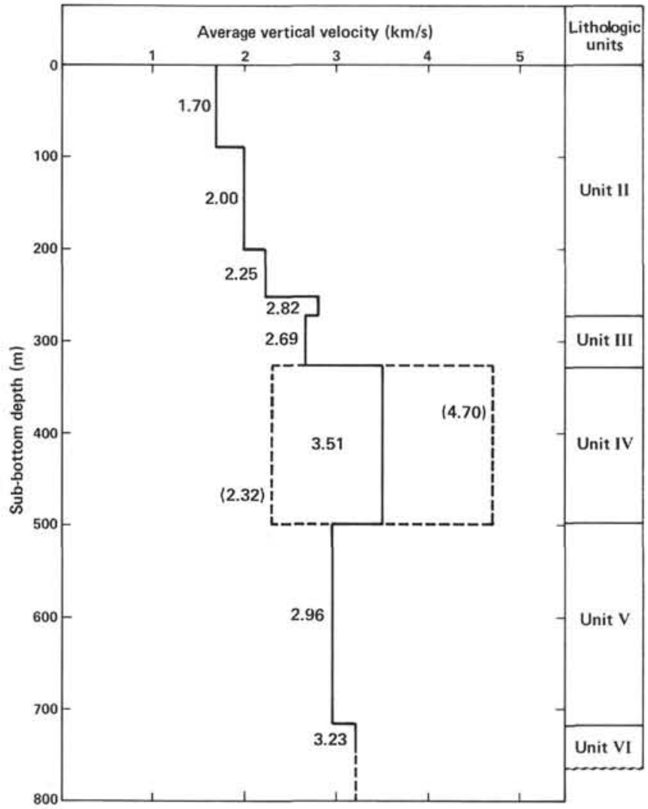


Figure 38. Average interval velocities (vertical measurements) estimated for core data, Hole 540.

the area. Of primary interest is the presence of a thick section of pre-middle Cretaceous sedimentary rocks filling in and overlying an irregular block-faulted acoustic basement. The basement is inferred to represent a rifted and attenuated continental crust formed during the early rifting and later seafloor spreading phase of early Gulf history. The overlying sequence is inferred to represent synrift and postrift sediments, probably a transition upward from nonmarine to shallow-marine sediments deposited as the basin subsided. This sequence is truncated by a major unconformity that was tentatively dated as middle Cretaceous based on seismic correlation with DSDP Site 97 (Worzel, Bryant, et al., 1973) and a tentative seismic tie to wells in the northeastern Gulf. This unconformity is recognized Gulf-wide on the seismic data by truncation or onlap, or as a strong prominent reflector. It is a key marker for interpreting the geologic history of the region. It is designated as "MCU" on all the seismic sections (e.g., Figs. 2, 5).

Preliminary Seismic Stratigraphic Framework

Introduction

The entire eastern part of the study area (east of the main erosional channel, Fig. 1) is underlain by a thick (up to 2-3 km) pre-MCU sedimentary section, which overlies and fills in an irregular block-faulted basement. These rocks either outcrop or subcrop beneath a thin Cenozoic cover along the eastern flank of the erosional channel (Figs. 1, 2). The pre-MCU section was subdivided on a preliminary basis into three main seismic sequences (upper, middle, and lower) separated by major unconformities designated as Unconformities 1 and 2 (Figs. 2, 5). The prominent MCU separates the upper sequence from the overlying Cenozoic section. The unconformities are recognized by both truncation of reflections below and onlap of reflections above.

Upper Sequence

The upper sequence between the MCU and Unconformity 1 can be observed on Lines SF-15 and SF-22 (Figs. 2, 5) as well as regional Line SF-4 just to the north (Fig. 44) (see Fig. 43 for location). Near the channel area, it is characterized by uniform, continuous reflections, whereas further east it becomes more discontinuous in character as it approaches the Florida Escarpment (Figs. 2, 44). At the base of the escarpment, the sequence becomes much more chaotic and is overlain by a thick wedge of sediments coming from the scarp (Fig. 44).

The MCU, which truncates the upper sequence, can be projected and followed continuously from the basin up onto the bank margin along the Florida Escarpment (Fig. 44). The surface is interpreted to go under the wedge. Here it probably represents a fossil bank margin at approximately middle Cretaceous time. Relief on the margin from bank to deep basin (and thus an approximation of paleowater depth) probably was somewhere between 1000 and 1500 m.

Table 18. Physical properties groupings, Site 540.

Groupings	Sub-bottom depth (m)	Number of samples	Wet-bulk density (g/cm^3)	Porosity (%)	Sonic velocity[a] Vertical (km/s)	Sonic velocity[a] Horizontal (km/s)	Acoustic impedance[a] (vertical) ($\times 10^5$ g cm^{-2} s^{-1})	Thermal conductivity ($\times 10^{-3}$ cal deg^{-1} cm^{-1} s^{-1})	Lithologic units
A	0-90	19	1.62	62	1.70		2.77	2.72	I and II
B	90-200	22	1.80	52	2.00	2.00	3.59	3.64	II
C	200-252	10	1.91	47	2.25	2.25	4.29	4.08	II
D	252-272	5	1.92	44	2.82	2.82	5.49		II
E	272-328	8	2.23	33	2.69	2.60	5.99		III
F	328-498	30	2.30	24	3.51	3.56	8.07		IV
					(S.D. 1.19	1.27	3.61)[b]		
G	498-717	42	2.27	26	2.96	2.96	6.65		V
H[c]	717-746	11	2.36	21	3.23	3.36	7.61		VI

[a] Corrections applied based on Boyce (1976).
[b] Abnormally large standard deviations are remarkable. S.D. = Standard deviation.
[c] Lithology uncertain.

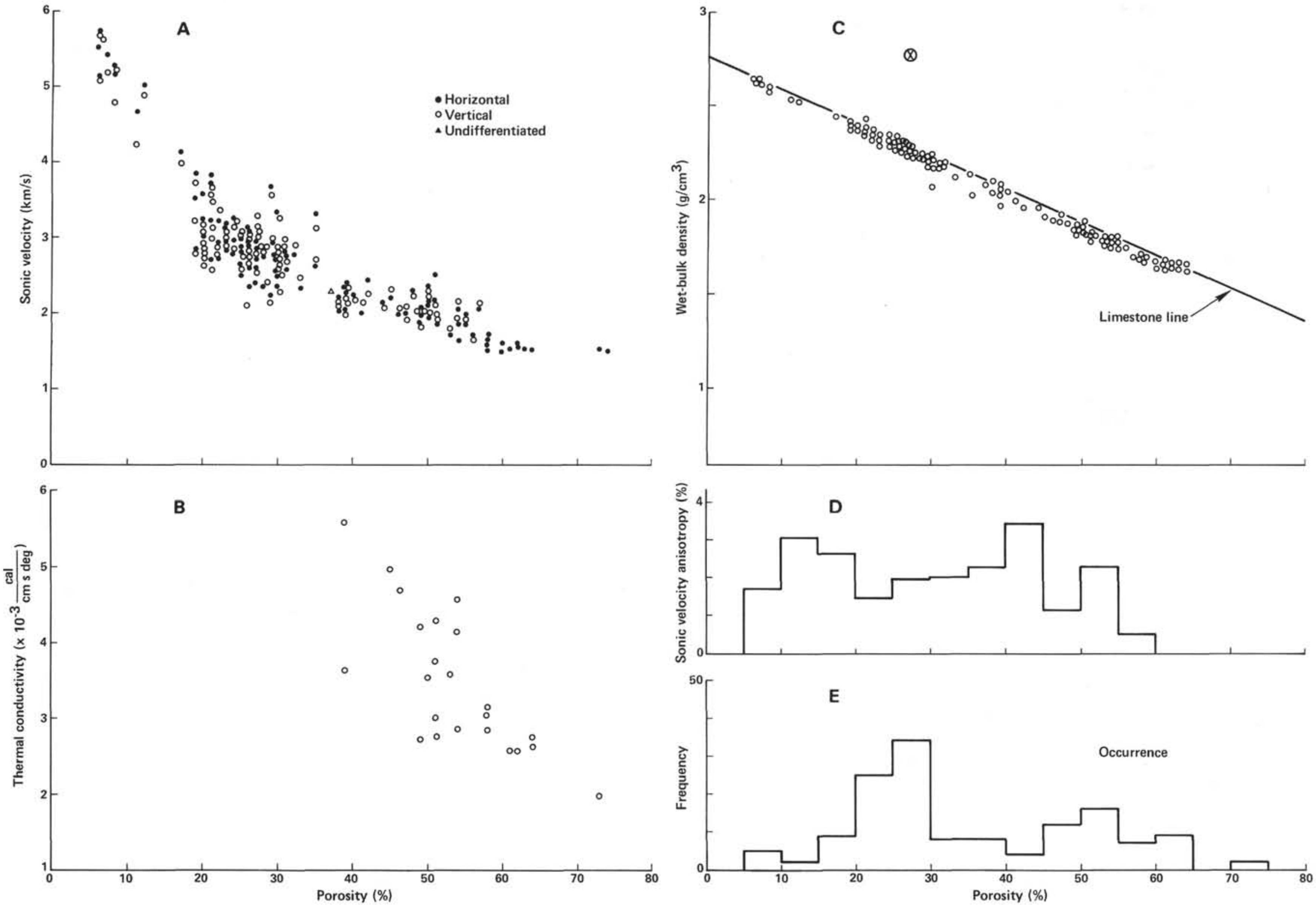


Figure 39. Cross-plots of porosity versus velocity (A), conductivity (B), density (C), and velocity anisotropy (D) and a porosity histogram (E) for Hole 540. See text for discussion.

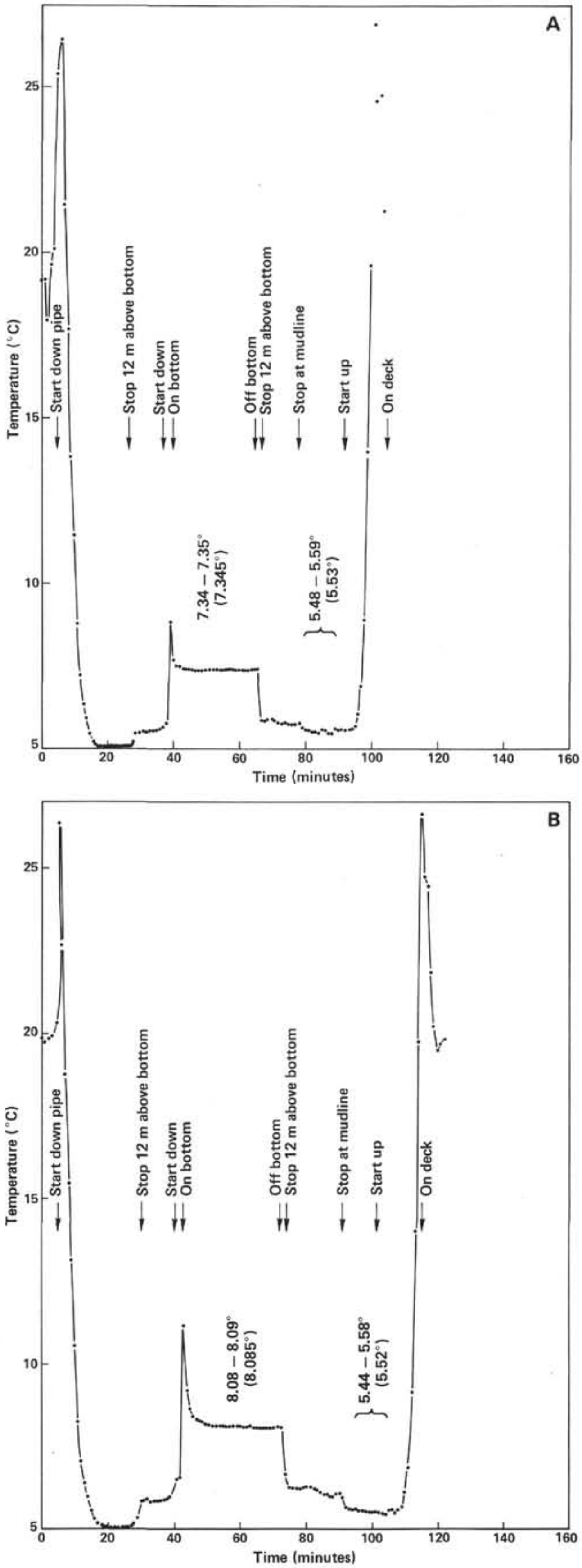


Figure 40. Heat flow probe measurements, Hole 540. A. Sub-bottom depth = 52 m. B. Sub-bottom depth = 71 m.

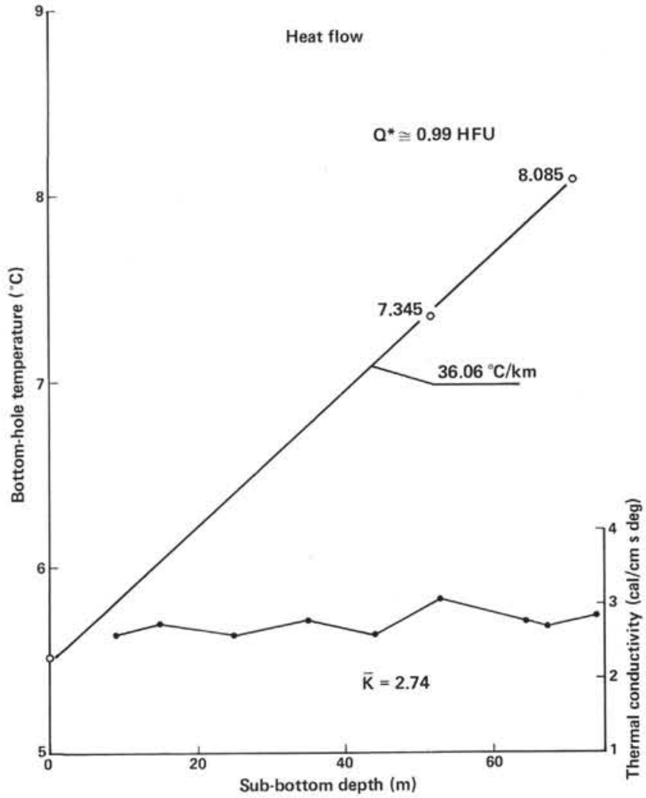


Figure 41. Subsurface temperature measurements and thermal conductivities, Hole 540. Q* value reduced 1.7% for *in situ* value. See text.

Middle Sequence

The middle sequence between Unconformities 1 and 2 actually consists of two main subunits. The upper subunit has a wedge shape in east-west profiles thinning updip to the east; it is thickest beneath the channel area (Figs. 2, 44). Internally, the unit has a seismic facies characterized by discontinuous, hummocky, overlapping reflectors (Figs. 2, 44). This facies extends for some distance in a general north-south direction beneath the channel area throughout the study area. This subunit onlaps, thins, and wedges out to the east onto the prograding reflections of the underlying subunit discussed below (Figs. 2, 44).

The lower subunit also has a wedge shape but in the direction opposite to the overlying subunit. The thinnest part is beneath the channel area, and it thickens to the east toward the Florida Escarpment (Figs. 2, 44). Internally, it consists of gently westward prograding, internally thinning, continuous, relative high-amplitude reflections that onlap or downlap onto Unconformity 2 (see Figs. 2, 44).

Lower Sequence

The sequence below Unconformity 2 consists of a series of relatively uniform and continuous reflections (Figs. 2, 44). The lower part is somewhat more discontinuous and onlaps and fills in an irregular acoustic basement interpreted to be the top of a rifted and block-faulted crust.

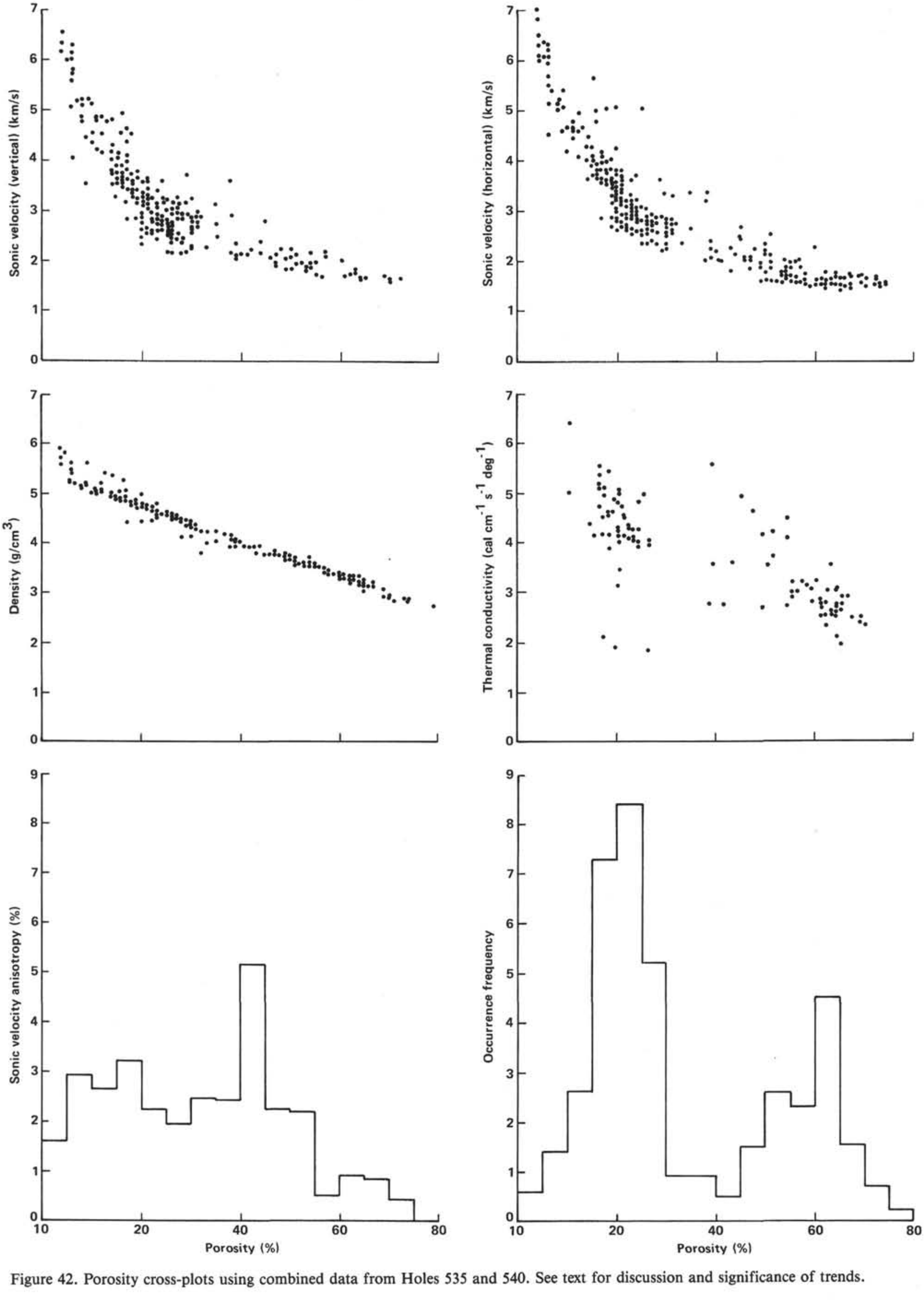


Figure 42. Porosity cross-plots using combined data from Holes 535 and 540. See text for discussion and significance of trends.

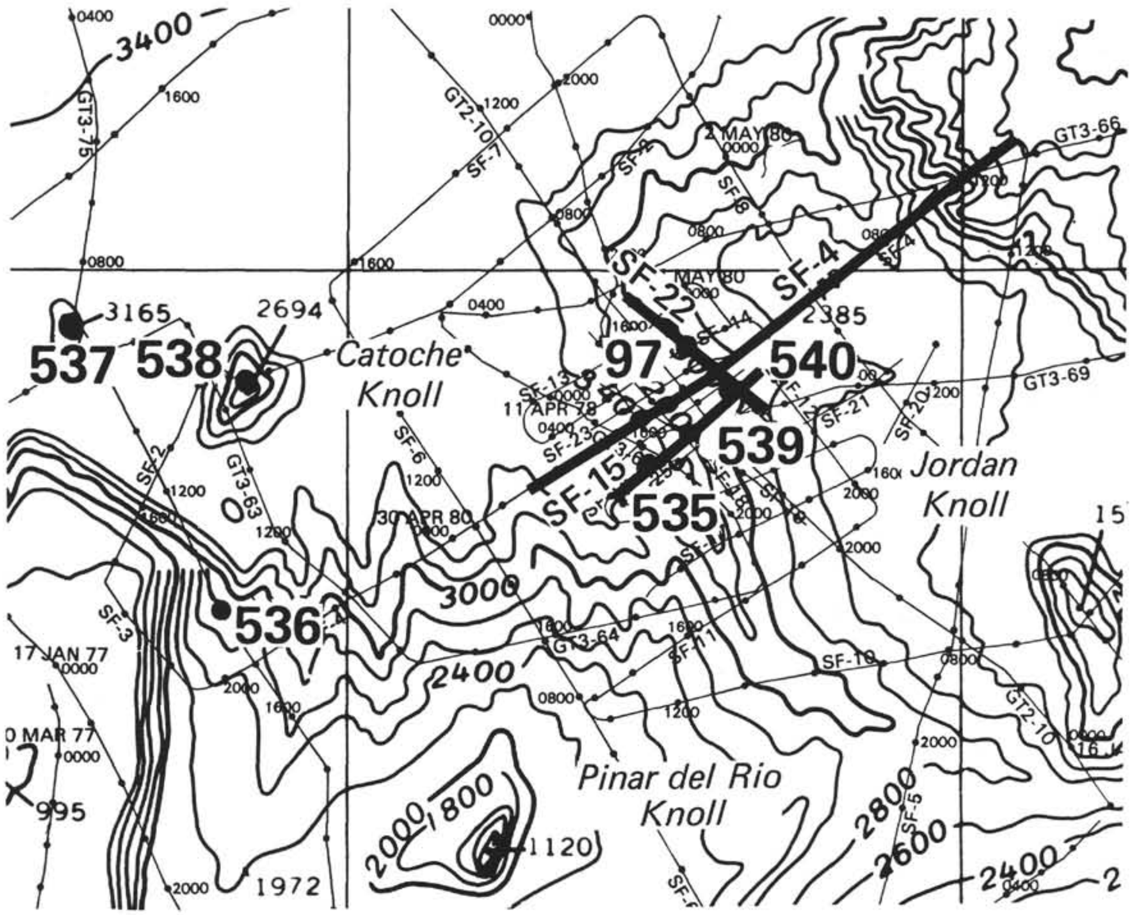


Figure 43. Map of southeastern Gulf of Mexico showing location of University of Texas Institute for Geophysics multifold seismic lines used to develop seismic stratigraphic framework and to select Leg 77 drilling Sites 535 to 540. Heavy lines indicate location of Line SF-15 (Figs. 2, 45), SF-22 (Figs. 5, 46), and SF-4 (Fig. 44).

Pre-MCU Drilling Objectives

Sites 535 and 540 were designed to drill as much as possible of this thick pre-MCU section in the eastern part of the study area. The section is at or near the sea bottom along the channel and is easily accessible to the drill. Site 540 was designed to drill through an abbreviated post-middle Cretaceous section and date the MCU, and to then drill the sequence between the MCU and Unconformity 1. Site 535 was designed to pick up approximately where 540 left off (stratigraphically) and drill the rest of the sequence between Unconformities 1 and 2 and then penetrate below Unconformity 2 as far as possible. The two holes combined would provide an almost continuous section from the MCU down into the lowermost sequence below Unconformity 2. The objectives of these sites were to date the seismic units and their bounding unconformities and determine the nature of the rocks corresponding to the various seismic facies.

Cenozoic Sequence

Overlying the MCU is a Cenozoic sequence (drilled earlier in Hole 97; Worzel, Bryant, et al., 1973) that thins by erosion along the channel (Figs. 2, 44). The lower part of the section is characterized by continuous, high-amplitude reflections eroded by a major unconformity with significant local relief. The upper part is characterized by more irregular, discontinuous, lower amplitude reflections. Based on the results of Hole 97, this sequence is composed of Tertiary ooze and chalk.

Correlation of Drilling Results with Seismic Data

Introduction

Sites 535 and 540 were quite successful in meeting the drilling objectives. Together they penetrated and sampled an abbreviated Tertiary section, the MCU, and the entire Lower Cretaceous. Unfortunately, Jurassic rocks were not reached. There is an excellent correlation between the lithologic units and unconformities drilled and the major reflections and unconformities observed on the seismic data. Each site is discussed separately below.

Site 535

The section drilled at Site 535 was divided into five major lithologic units (I–V) (Fig. 3; see also Sedimentology section). Velocities measured perpendicular to the core were taken throughout the section. These measurements were grouped into 10 subgroups, and average values were determined for each subgroup (Fig. 3; see also Physical Properties section). These average values were

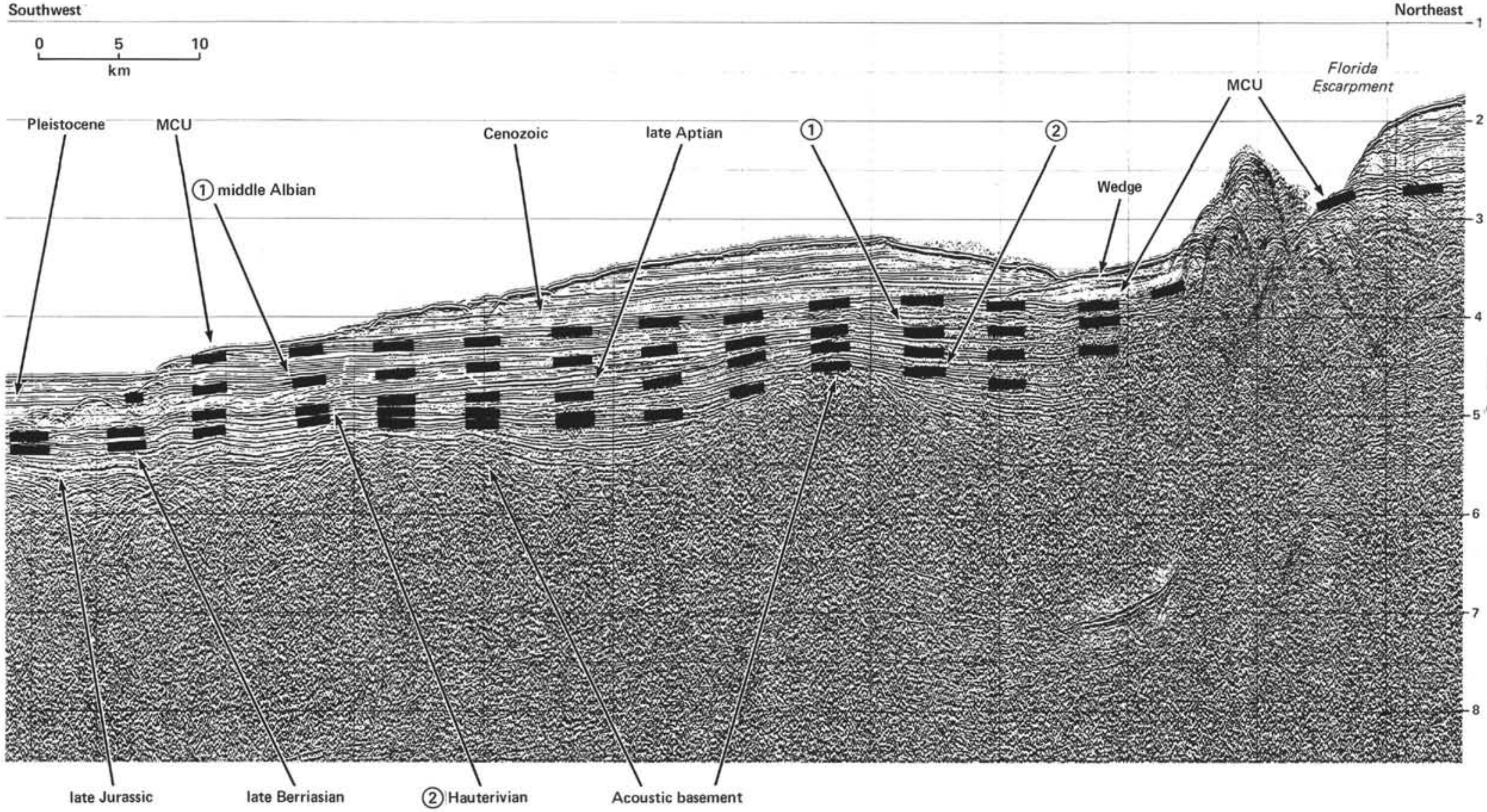


Figure 44. Portion of regional seismic Line SF-4 across basin area east of erosional channel showing thick pre-middle Cretaceous (pre-MCU) Mesozoic section with prominent seismic sequences and unconformities (circled numbers). See Figure 43 for location.

used to convert lithologic unit boundaries to two-way traveltime. This allowed for a direct comparison of the drilling results with seismic Line SF-15, along which Site 535 was drilled (Fig. 45).

This conversion indicates a good correlation between the lithologic units and the major seismic units, unconformities, and seismic facies. Lithologic Unit I (154 m of Quaternary mud) corresponds to the horizontally layered sequence on the seismic data that onlaps and fills the erosional channel (Figs. 2, 44–45). This sequence apparently represents the very distal fine-grained part of the Pleistocene Mississippi Fan system that filled the entire eastern deep Gulf.

Lithologic Unit II appears to correspond to part of the upper subunit of the "middle sequence" lying between Unconformities 1 and 2 (Figs. 2, 45). It is laterally equivalent to the hummocky seismic facies of this subunit, although at the drill site, the facies is characterized by somewhat more uniform and continuous reflections (Fig. 45). The regional relationships of this unit are discussed further below.

The upper and lower boundaries of Lithologic Unit III correlate with two, closely spaced, high-amplitude reflections, which are prominent unconformities along Line SF-15 (Figs. 2, 45). The upper unconformity occurs within the "middle sequence", whereas the lower unconformity corresponds to Unconformity 2. The unit appears to be the thin and abbreviated part of a wedge of sediments that progrades and onlaps Unconformity 2 from the east. Sedimentation evidently was much reduced at the drill site, possibly because of its distal location or currents sweeping through the channel area. This is supported by the low sedimentation rate (6 m/Ma, Fig. 3).

Lithologic Units IV and V correspond to the upper part of the "lower sequence" lying below Unconformity 2. It is characterized by relatively low-amplitude reflections. The lower boundary correlates with a prominent, high-amplitude reflection and regional unconformity, suggesting a major change in sedimentation. Such a boundary may have been reached in the bottom of Hole 535; the last core had a much higher velocity than any previous measurements (4.70 km/s for five samples) (Fig. 3). Unfortunately, we parted way with the bottom-hole assembly and were not able to either confirm this lithologic change or determine the nature and age of the rocks below.

This hole allows us now to date fairly accurately the major seismic units and unconformities. The prominent unconformity between Units I and II is an erosional channel that cut down through the Lower Cretaceous rocks and is now filled with Pleistocene mud, representing a large hiatus. The two unconformities correlated with the upper and lower boundaries of Unit III are tentatively dated as late Aptian and Hauterivian, respectively, again supporting a period of abbreviated sedimentation at the drill site (Fig. 2). The unconformity at the base of the hole is tentatively dated as late Berriasian, possibly marking the top of a sequence that includes Upper Jurassic rocks (Fig. 2). The uniform, continuous reflections of this older sequence just below the

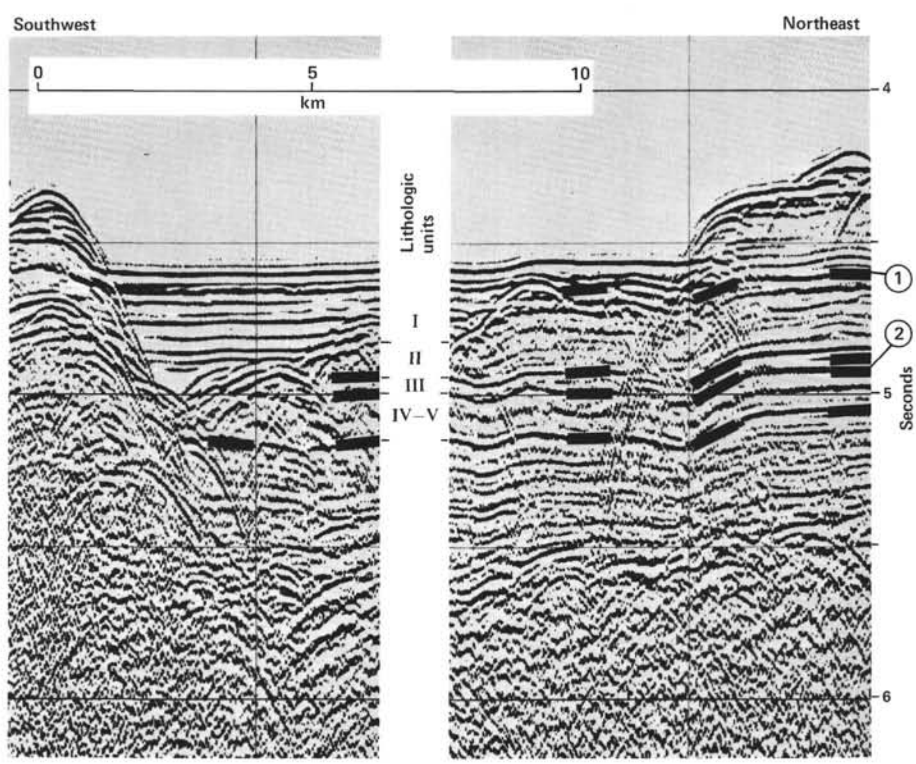


Figure 45. Portion of Line SF-15 (Fig. 2) showing correlation between Lithologic Units I–V at Site 535 and major seismic sequences and unconformities (MCU, circled numbers, and dashed boundaries). See Figure 43 for location.

unconformity suggests a continuation of deep marine sedimentation at the drill site area, similar to the Lower Cretaceous rocks above.

Site 540

A detailed sonic velocity structure for the hole was determined from laboratory measurements. The velocity data were divided into eight groups based on similarities in velocities and correspondence with lithologic units (Fig. 4, see also Physical Properties section). The sedimentary section drilled was divided into six major lithologic units (I–VI, Fig. 4, see also Sedimentology section). The first four velocity units correspond to Lithologic Unit II, and the remaining four units correspond to Lithologic Units III–VI, respectively. These data allow for conversion of drilling data to two-way time, which provides a direct comparison with seismic Line SF-22, along which Hole 540 was drilled (Fig. 46).

There appears to be some correlation between lithologic units and the seismic data. Unit III occurs at the base of a sequence of high-amplitude reflections, and its base correlates approximately with the MCU. Here the MCU is defined as a prominent unconformity separating high-amplitude reflections above from low-amplitude reflections below. The unconformity does not show as a prominent reflector, but it can be recognized by the change in seismic character as well as truncation below and onlap above.

The age of Unit III (the gravity-flow deposits) ranges from the middle Cenomanian to late Paleocene, so the interval here spans a considerable length of time. It probably represents a bundle of unconformities below the resolution of the seismic system. These unconformities can be expected to diverge laterally and may be individually recognized where the section is thicker. The term MCU is still considered appropriate, however, because the lowermost unconformity (base of Unit III) is middle Cretaceous in age, based on the early Cenomanian age for Unit IV below.

The base of Unit IV appears to correlate with the base of a sequence of high-amplitude, continuous reflections (Fig. 46). This probably corresponds to the change from the rhythmically bedded Unit IV above to the more uniform limestone of Unit V below (characterized by a more discontinuous, lower-amplitude seismic facies) (Fig. 46). The age of this boundary is late Albian.

The bottom of the hole correlates approximately with the top of a zone of higher-amplitude reflections and Unconformity 1 (Fig. 46). This unconformity may correspond to the lithologic change from Units IV to V, which is characterized by a significant increase in coarse skeletal debris. This boundary does not correlate exactly with the seismic unconformity but this could be due to inexact velocities. Unconformity 1 can be dated as middle Albian (Figs. 2, 5).

There are two unconformities seen on the seismic data in the Tertiary section that don't correlate with major lithologic boundaries, but they do correlate with unconformities or hiatuses identified by the paleontology. One unconformity occurs just below the sea bottom at the

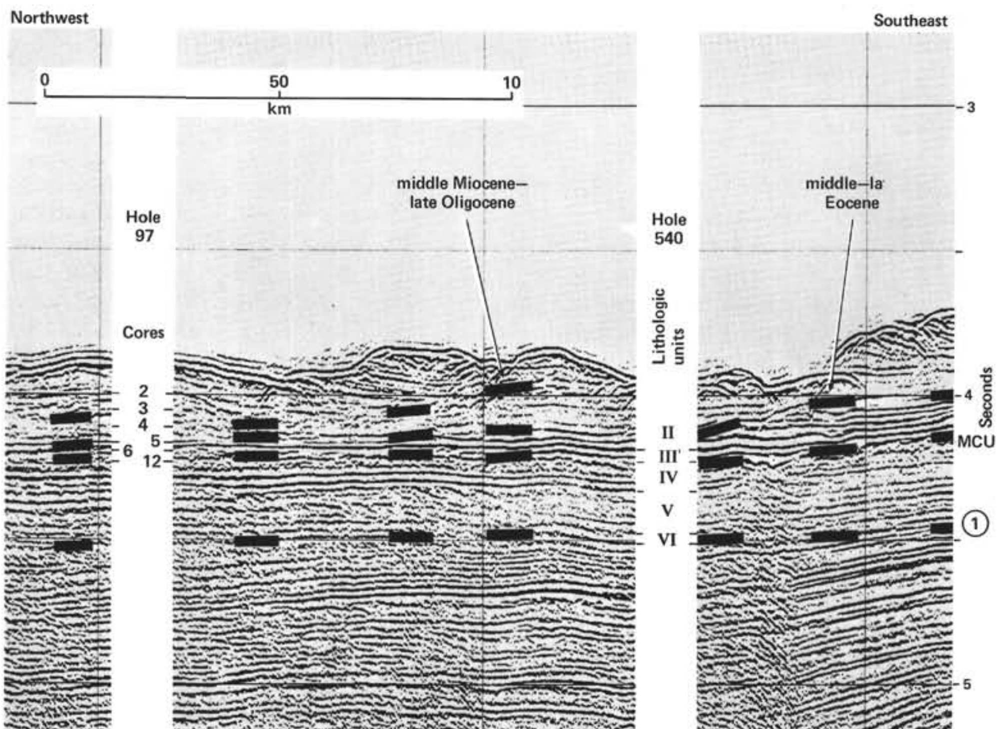


Figure 46. Portion of seismic Line SF-22 (Fig. 5) showing correlation of lithologic units at Site 540 (II–VI) and cores at Hole 97 (2—late Miocene; 3—middle Miocene; 4—early Oligocene; 5—late Eocene; 6–12—Cenomanian) with major seismic sequences and unconformities (MCU, circled number, and dashed boundaries). See Figure 43 for location.

well site (Fig. 46). It dips to the northwest, truncating beds below, and is onlapped by a thickening section above. It probably correlates with a prominent hiatus between middle Miocene and upper Oligocene (Fig. 4).

Another northwest-dipping unconformity crosses the well site, also truncating beds below and being onlapped by beds above. This is a very prominent unconformity and has been mapped regionally. It has been studied in considerable detail and found to correlate with a middle to upper Eocene hiatus. A description of this unconformity in the drill site area and a discussion of its possible origins is presented in Angstadt and others, 1983.

Above the Eocene unconformity the seismic data is characterized by a relatively low-amplitude seismic facies, which probably corresponds to the uniformly deposited oozes and chalks of Unit II. Between the Eocene unconformity and the MCU is a series of high-amplitude reflections, which probably corresponds to the alternations of hard limestone beds and chert within the overall chalk sequence toward the bottom of Unit II.

Regional Implications

Correlation of the drilling results with the seismic data has led to several conclusions regarding the regional setting and geologic history in the vicinity of the drill sites. These conclusions are discussed below.

1. The drilling results have allowed us to date several major unconformities that have been identified on the regional seismic lines:

a) early Miocene
b) middle-late Eocene (Angstadt et al., 1983)
c) Late Cretaceous, which in this area includes the MCU
d) middle Albian—Unconformity 1
e) late Aptian, between Unconformities 1 and 2
f) Hauterivian—Unconformity 2
g) late Berriasian

All of the Cretaceous unconformities correlate with major changes in lithology and sedimentation.

2. The seismic data support an Albian age for Lithologic Unit II drilled in Site 535, as suggested by the microfossils, not a Cenomanian age as indicated by the ammonites. Unit II correlates with the upper seismic subunit in the "middle sequence" between Unconformities 1 and 2 (Fig. 2). This is supported by the middle Albian age established for Unconformity 1 at Site 540. For Unit II to be Cenomanian in age, it would have to be composed of a large slump block displaced down the paleoslope of the submarine canyon from a position at the MCU. If present, such a block might be below the resolution of the seismic data or masked by diffractions from the irregular channel surface (Figs. 2, 45). See the Biostratigraphy section for further discussion of this problem.

3. The region of the hummocky seismic facies seen on the seismic data in the "middle sequence" is still a problem. Because of its internal geometry and its northeast-southwest distribution, this facies originally was thought to represent rapid deposition as lobes in a deep-sea fan system, although the facies could represent extensive slump deposits internally remobilized along a paleoslope. The seismic facies at Site 535 is more uniform and continuous and represents the lateral equivalent of the main hummocky facies to the east (assuming Unit II is Albian in age and not a displaced block as discussed in Point 2 above) (Fig. 2). The presence of coarse skeletal debris in both Units II (Site 535) and VI (Site 540) supports the seismic evidence that the two units belong to the same seismic unit, which includes the hummocky facies (upper subunit of middle sequence) (Fig. 2).

Unit II (Site 535) consists mainly of fine-grained hemipelagic carbonate material interspersed with coarse skeletal debris. These sediments probably were deposited at fairly high rates of sedimentation by currents, as suggested by (1) the general lack of pelagic fossils, (2) the relatively high sedimentation rate (if an Albian age is assumed), (3) the presence of the coarse debris, indicating gravity-flow deposits, and (4) common occurrence of cross laminations. This fits well with the general model inferred for the hummocky facies, but it doesn't explain the hummocky facies itself. A true fan model seems less likely now, as there is no evidence for turbidite beds in Unit II (Site 535) as well as Unit VI (Site 540) (i.e., graded sequences with sharp lower boundaries). Neither site drilled directly into the hummocky facies; it may represent mainly lobes of coarse debris deposited by gravity-flow mechanisms along a broad north-south channel system. The units drilled may be the lateral, more finer-grained equivalent. The source for the coarse debris could be an extensive area of submarine canyons cut into the Florida Escarpment northeast of the drill site area.

Alternatively, the hummocky facies could represent an extensive area of internally deformed beds that slumped down a paleoslope shortly after deposition. These beds could have become unstable along the flank of an old erosional channel system developed at the site of the present channel.

4. The results of Site 540 can be tied to nearby Site 97 (Worzel, Bryant, et al., 1973) using seismic Line SF-22 (Fig. 46). Data at the two sites agree quite well. Cenomanian pebbly limestones similar to those of Unit III (540) were recovered in Cores 6 through 12 at the bottom of Hole 97. The two horizons correlate along the seismic line and correspond to the MCU. The Eocene unconformity at Site 540 progressively truncates the sequence of high-amplitude reflectors and intersects Hole 97 at about Core 97-5 of late Eocene age. The tracing of the early Miocene unconformity to Hole 97 seems to support a much thinner Oligocene section at 97. It appears to intersect the hole between Cores 97-3 (middle Miocene) and 97-4 (early Oligocene), which agrees with the age of the unconformity at Hole 540.

5. The thin gravity-flow deposits corresponding to the MCU at both Sites 97 (Worzel, Bryant, et al., 1973) and 540 apparently are the distal portions of thick talus wedges that formed along the base of the Florida Escarpment. East-west regional Line SF-4 shows how the MCU horizon expands into one of these wedges (Fig. 44). The source of the carbonate debris evidently was the Florida Escarpment to the east. Erosion of the scarp is suggested by submarine canyons. Preliminary dating

of the gravity-flow deposits at Site 540 (Unit III) suggest at least three separate periods or pulses of debris flow and turbidity current sedimentation (middle Cenomanian, Late Cretaceous, and late Paleocene). Thickening of the upper and middle Lower Cretaceous sequences toward the Florida Escarpment, as well as a lateral facies change in this direction (continuous to discontinuous), indicates that the Florida Escarpment area also was the source of sediments throughout much of the Lower Cretaceous.

CONCLUSIONS

The conclusions concerning this site are given in the Summary section earlier in this chapter.

REFERENCES

Anderson, R. S., 1974. Statistical correlation of physical properties and sound velocity in sediments. *In* Hampton, L. (Ed.), *Physics of Sound in Marine Sediments:* New York (Plenum Press), pp. 481–518.

Angstadt, D. M., Austin, J. A., and Buffler, R. T., 1983. Deep-sea erosional unconformity in the southeastern Gulf of Mexico. *Geology*, 11:215–218.

Arthur, M. A., and Natland, J. H., 1979. Carbonaceous sediments in the North and South Atlantic: the role of salinity in stable stratification of Early Cretaceous basins. *In* Talwani, M., Hay, W. W., and Ryan, W. B. F. (Eds.), *Deep Drilling Results in the Atlantic Ocean: Continental Margins and Paleoenvironment:* Washington (Am. Geophys. Union), Maurice Ewing Series, 3:375–401.

Boyce, R. E., 1976. Definitions and laboratory techniques of compressional sound velocity parameters and wet-water content, wet-bulk density, and porosity parameters by gravimetric and gamma-ray attenuation techniques. *In* Schlanger, S. O., Jackson, E. D., et al., *Init. Repts. DSDP*, 33: Washington (U.S. Govt. Printing Office), 931–957.

Bullard, E. C., and Day, A. A., 1961. The flow of heat through the floor of the Atlantic Ocean. *Geophys. J.*, 4:282–292.

Clark, S. P., 1964. *Handbook of Physical Constants* (Rev. ed.): Boulder, Colorado (Geol. Soc. Am.), p. 471.

Clementz, D. M., Demaison, G. J., and Daly, A. R., 1979. Well site geochemistry by programmed pyrolysis. *Offshore Technol. Conf. Proc.*, No. OTC 3410, 465–469.

Curray, J. R., Moore, D. G., et al., 1982. *Init. Repts. DSDP*, 64: Washington (U.S. Govt. Printing Office).

Davis, J. B., and Bray, E. E., 1969. Analyses of oil and cap rock from Challenger (Sigsbee) Knoll. *In* Ewing, M., Worzel, J. L., et al., *Init. Repts. DSDP*, 1: Washington (U.S. Govt. Printing Office), 415–500.

Jansa, L. F., Enos, P., Tucholke, B. E., Gradstein, F. M., and Sheridan, R. E., 1979. Mesozoic-Cenozoic sedimentary formations of the North American Basin; western North Atlantic. *In* Talwani, M., Hay, W. W., and Ryan, W. B. F. (Eds.), *Deep Drilling Results in the Atlantic Ocean: Continental Margins and Paleoenvironment:* Washington (Am. Geophys. Union), Maurice Ewing Series, 3: 1–57.

Lowrie, W., Channell, J. E. T., and Alvarez, W., 1980. A review of magnetic stratigraphy investigations in Cretaceous pelagic carbonate rocks. *J. Geophys. Res.*, 85:3597–3605.

Martin, R. G., and Case, J. E., 1975. Geophysical studies in the Gulf of Mexico. *In* Nairn, A. E. M., and Stehli, F. G. (Eds.), *Ocean Basins and Margins* (Vol. 3): New York (Plenum), pp. 65–106.

Meyerhoff, A. A., 1980. Geology of the Reforma-Campeche shelf. *Oil and Gas Journal*, April 21, 1980:121–124.

Pardo, G., 1975. Geology of Cuba. *In* Nairn, A. E. M., and Stehli, F. G. (Eds.), *Ocean Margins and Basins: The Gulf of Mexico and Caribbean* (Vol. 3): New York (Plenum), 553–615.

Roth, P. R., 1978. Cretaceous nannoplankton biostratigraphy and oceanography of the northwestern Atlantic ocean. *In* Benson, W. E., Sheridan, R. E., et al., *Init. Repts. DSDP*, 44: Washington (U.S. Govt. Printing Office), 731–759.

Tissot, B., Deroo, G., and Herlim, J. P., 1979. Organic matter in Cretaceous sediments of the North Atlantic: contribution to sedimentology and paleography. *In* Talwani, M., Hay, W. W., and Ryan, W. B. F. (Eds.), *Deep Drilling Results in the Atlantic Ocean: Continental Margins and Paleoenvironment:* Washington (Am. Geophys. Union), Maurice Ewing Series, 3:362–374.

Tucholke, B. E., and Mountain, G. S., 1979. Seismic stratigraphy, lithostratigraphy and paleosedimentation patterns in the North American Basin. *In* Talwani, M., Hay, W. W., and Ryan, W. B. F. (Eds.), *Deep Drilling Results in the Atlantic Ocean: Continental Margins and Paleoenvironment:* Washington (Am. Geophys. Union), Maurice Ewing Series, 3:58–85.

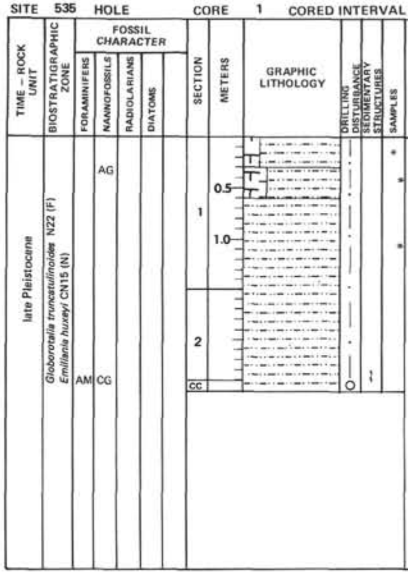
Vail, P. R., Mitchum, R. M., Jr., Todd, R. G., Widmier, J. M., Thompson, S., III, Sangree, J. B., Bubb, J. N., and Hatlelid, W. G., 1977. Seismic stratigraphy and global changes in sea level. *In* Payton, C. E. (Ed.), *Seismic Stratigraphy—Applications to Hydrocarbon Explorations:* Tulsa, Oklahoma (Am. Assoc. Pet. Geol.), AAPG Mem. 26:49–212.

Wind, F. H., and Čepek, P., 1979. Lower Cretaceous calcareous nannoplankton from DSDP Hole 397A (Northwest African margin). *In* von Rad, U., Ryan, W. B. F., et al., *Init. Repts. DSDP*, 47, Pt. 1: Washington (U.S. Govt. Printing Office), 221–256.

Worzel, J. L., Bryant, W., et al., 1973. *Init. Repts. DSDP*, 10: Washington (U.S. Govt. Printing Office).

Date of Initial Receipt: October 13, 1983
Date of Acceptance: November 3, 1983

SITE 535 HOLE CORE 1 CORED INTERVAL 0.0–2.5 m



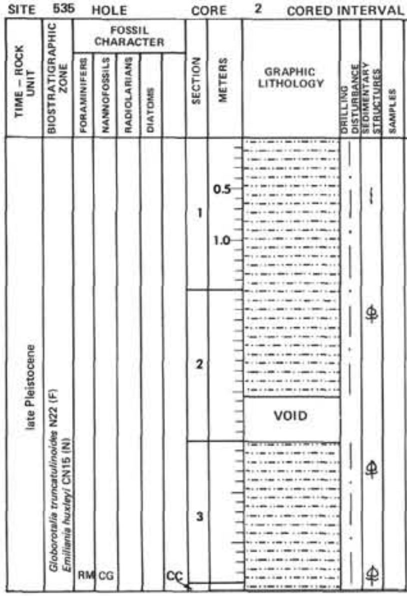
LITHOLOGIC DESCRIPTION

FORAMINIFERAL MUD, moderate yellowish brown (10YR 5/4) to light brownish gray (5YR 6/1), with sharp upper and and basal contacts with clay. Lower two-thirds of core is homogeneous olive gray MUD (5Y 3/2) with rare sand laminae and burrows filled with very light gray (N8) sandy mud.

SMEAR SLIDE SUMMARY (%):

	1, 15 M	1, 45 M	1, 106 D
Texture:			
Sand	24	21	–
Silt	24	20	12
Clay	52	59	88
Composition:			
Quartz	1	1	12
Feldspar	–	–	2
Clay	52	59	85
Pyrite	–	–	Tr
Carbonate unspec.	7	5	–
Foraminifers	26	30	–
Calc. nannofossils	5	3	Tr
Diatoms	1	1	Tr
Radiolarians	–	–	Tr
Sponge spicules	Tr	Tr	–
Fish remains	–	–	1
Plant debris	–	–	2
Pteropods	8	13	–

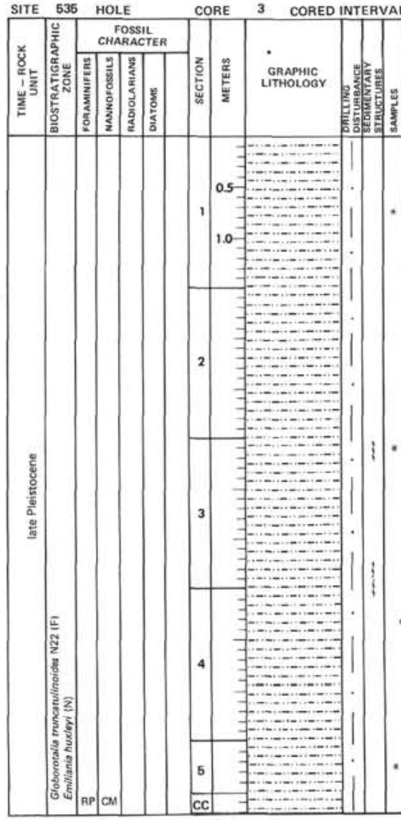
SITE 535 HOLE CORE 2 CORED INTERVAL 2.5–12.0 m



LITHOLOGIC DESCRIPTION

MUD, olive gray (5Y 4/1), homogeneous, with scattered burrows and small (~2 mm) wood fragments. Moderate drilling deformation.

SITE 535 HOLE CORE 3 CORED INTERVAL 12.0–21.5 m



LITHOLOGIC DESCRIPTION

Alternating olive gray and pale reddish brown

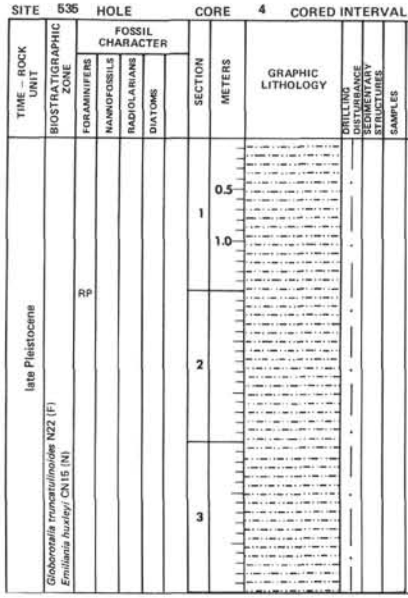
MUD and SANDY MUD, olive gray (5Y 4/1) alternating with pale reddish brown (10R 5/4) only in Section 4, 30–40 cm, homogeneous with rare burrows filled with sand. Moderate drilling deformation.

SMEAR SLIDE SUMMARY (%):

	1, 75 D	3, 10 D	4, 32 D	5, 25 D
Texture:				
Sand	2	20	–	60
Silt	15	20	5	30
Clay	83	60	95	10
Composition:				
Quartz	5	30	2	50
Feldspar	–	–	–	30
Heavy minerals	–	Tr	–	–
Clay	79	56	94	10
Glauconite	Tr	1	–	Tr
Pyrite	–	–	–	Tr
Carbonate unspec.	10	10	3	–
Foraminifers	Tr	–	–	–
Calc. nannofossils	1	–	Tr	–
Plant debris	3	3	1	–
Rock fragments	–	–	–	10

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

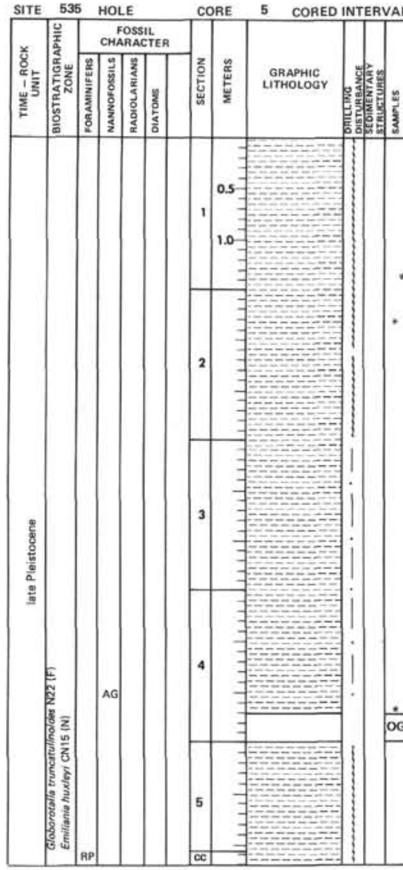
SITE 535 HOLE CORE 4 CORED INTERVAL 21.5–31.0 m



LITHOLOGIC DESCRIPTION

MUD, olive gray (5Y 4/1), homogeneous, disturbed by drilling. Several thin silty laminations.

SITE 535 HOLE CORE 5 CORED INTERVAL 31.0–40.5 m



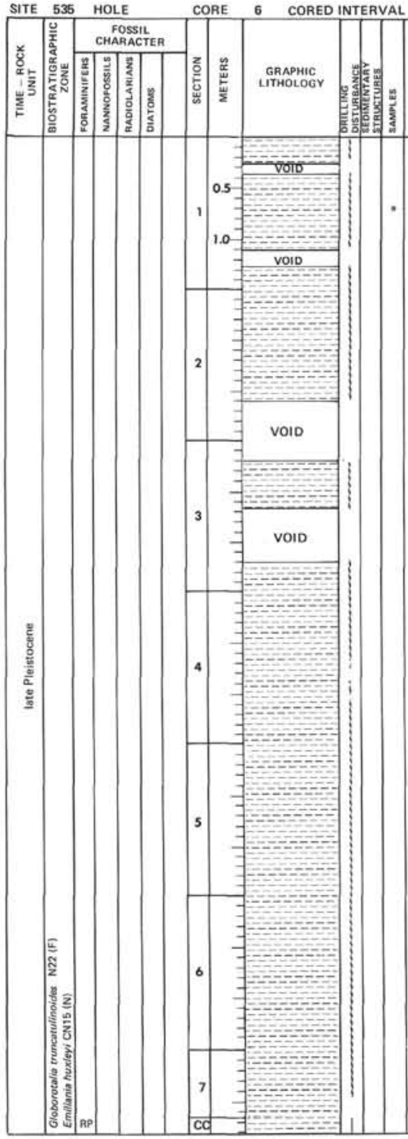
LITHOLOGIC DESCRIPTION

CLAY, light olive gray (5Y 5/2) to olive gray (5Y 3/2), homogeneous with scattered mud patches 1–2 cm across; foraminifer layers <1 cm thick in Section 4, 37 and 115 cm, and in Section 5, 11 and 50–60 cm. Drilling deformation moderate to extreme.

SMEAR SLIDE SUMMARY (%):

	1, 138	2, 31	4, 115
	D	M	M
Texture:			
Silt	5	20	10
Clay	95	80	90
Composition:			
Quartz	3	8	8
Feldspar	–	2	2
Clay	96	80	60
Glauconite	–	Tr	–
Pyrite	1	–	–
Carbonate unspec.	–	2	–
Foraminifers	–	–	30
Calc. nannofossils	–	–	Tr

SITE 535 HOLE CORE 6 CORED INTERVAL 40.5–50.0 m



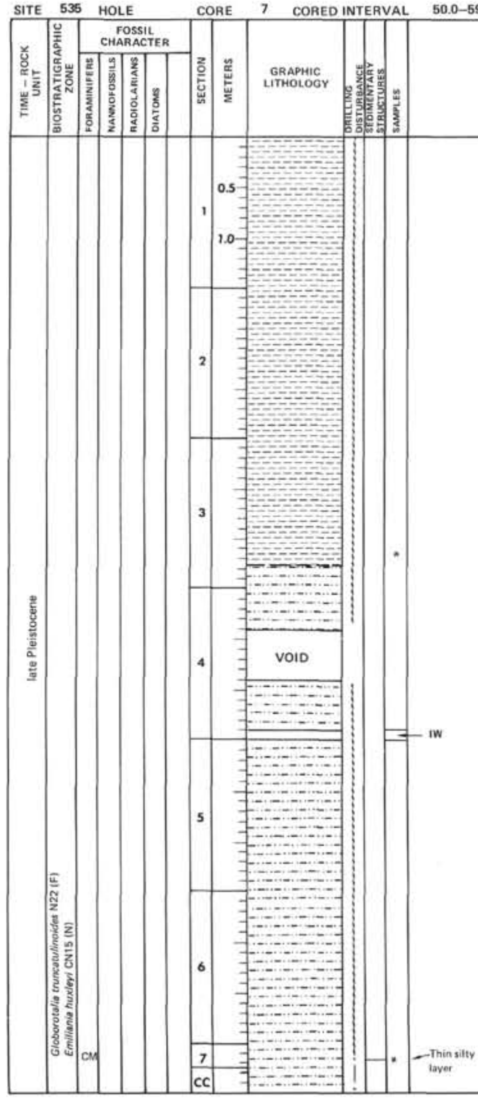
LITHOLOGIC DESCRIPTION

CLAY, olive gray (5Y 3/2) to grayish olive (10Y 4/2) and light olive gray (5Y 5/2), homogeneous except for several small foraminifer-rich patches in Section 4, 20 and 22 cm.

SMEAR SLIDE SUMMARY (%):

	1, 70
	D
Texture:	
Silt	10
Clay	90
Composition:	
Quartz	2
Clay	90
Carbonate unspec.	7
Calc. nannofossils	Tr
Plant debris	1

SITE 535 HOLE CORE 7 CORED INTERVAL 50.0–59.5 m



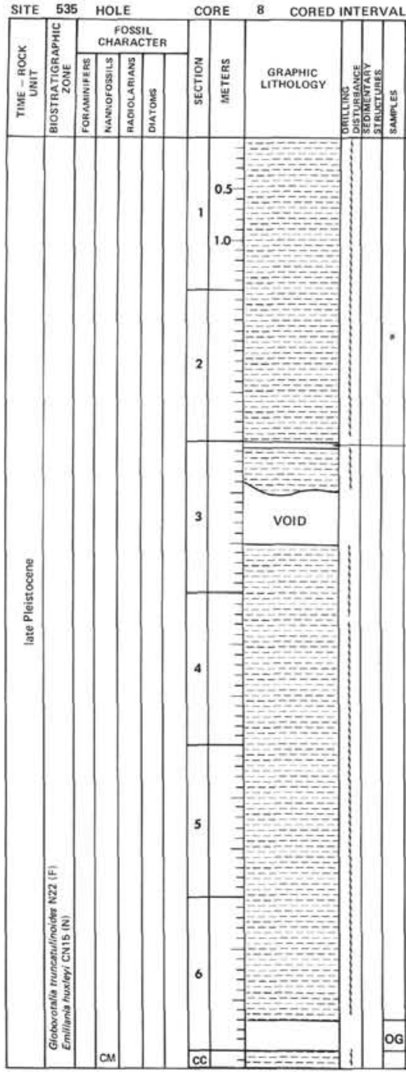
LITHOLOGIC DESCRIPTION

CLAY, changing to MUD near base of Section 3, olive gray (5Y 3/2) to light olive gray (5Y 5/2), homogeneous and very deformed by drilling. Mud in Section 4, 90 cm downcore is a drilling mixture of clay and silt. Muddy interval in Section 2, 125–135 cm.

SMEAR SLIDE SUMMARY (%):

	3, 118	7, 21
	D	M
Texture:		
Silt	20	10
Clay	80	90
Composition:		
Quartz	10	2
Feldspar	1	1
Clay	80	90
Glauconite	Tr	–
Carbonate unspec.	7	–
Foraminifers	Tr	–
Calc. nannofossils	1	–
Radiolarians	Tr	–
Plant debris	1	–

SITE 535 HOLE CORE 8 CORED INTERVAL 59.5–69.0 m



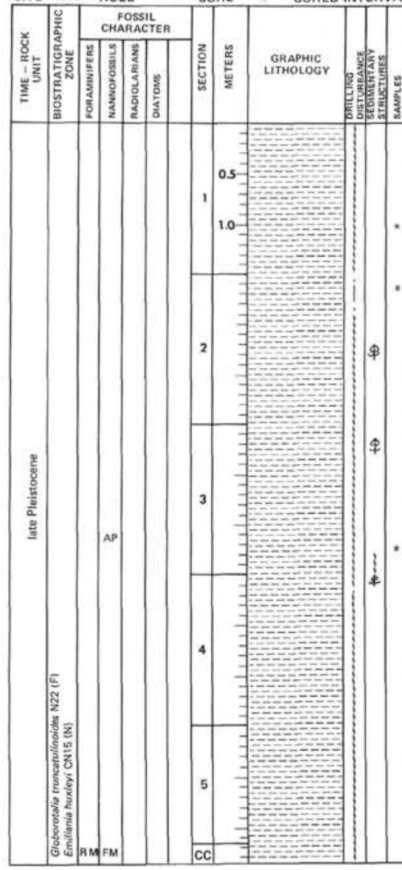
LITHOLOGIC DESCRIPTION

CLAY, olive gray (5Y 4/1), homogeneous and slightly calcareous. Intense drilling deformation.

SMEAR SLIDE SUMMARY (%):

	2, 48
	D
Texture:	
Silt	8
Clay	92
Composition:	
Quartz	5
Feldspar	1
Clay	90
Carbonate unspec.	2
Calc. nannofossils	1

SITE 535 HOLE CORE 9 CORED INTERVAL 69.0–78.5 m



light olive gray

olive gray

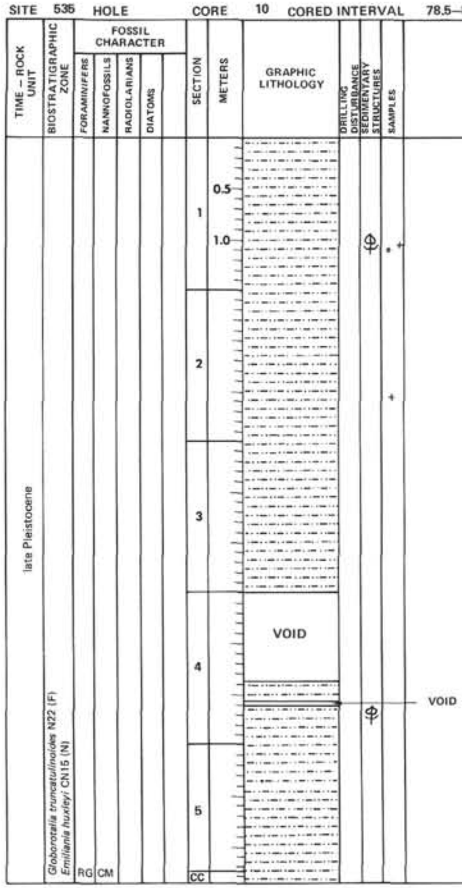
LITHOLOGIC DESCRIPTION

CLAY, olive gray (5Y 4/1), homogeneous except for several thin layers of sandy mud in Section 2, 5–35 cm, and scattered plant and wood fragments. Large burrow(?) in Section 3, 125 cm, is lined with nannofossils and filled with clay. Intense drilling deformation.

SMEAR SLIDE SUMMARY (%):

	1, 100	2, 15	3, 123
	D	M	M
Texture:			
Sand	–	10	–
Silt	10	30	40
Clay	90	60	60
Composition:			
Quartz	1	28	–
Feldspar	Tr	1	–
Clay	90	59	60
Glauconite	–	Tr	–
Carbonate unspec.	7	10	10
Foraminifers	–	1	–
Calc. nannofossils	2	1	30
Plant debris	–	Tr	–

SITE 535 HOLE CORE 10 CORED INTERVAL 78.5–88.0 m



LITHOLOGIC DESCRIPTION

MUD, olive gray (5Y 4/1), silt fraction shows blotchy concentration throughout core – mixed by intense drilling deformation. Scattered plant fragments. Silty at Section 1, 121 cm, and at Section 2, 100–120 cm.

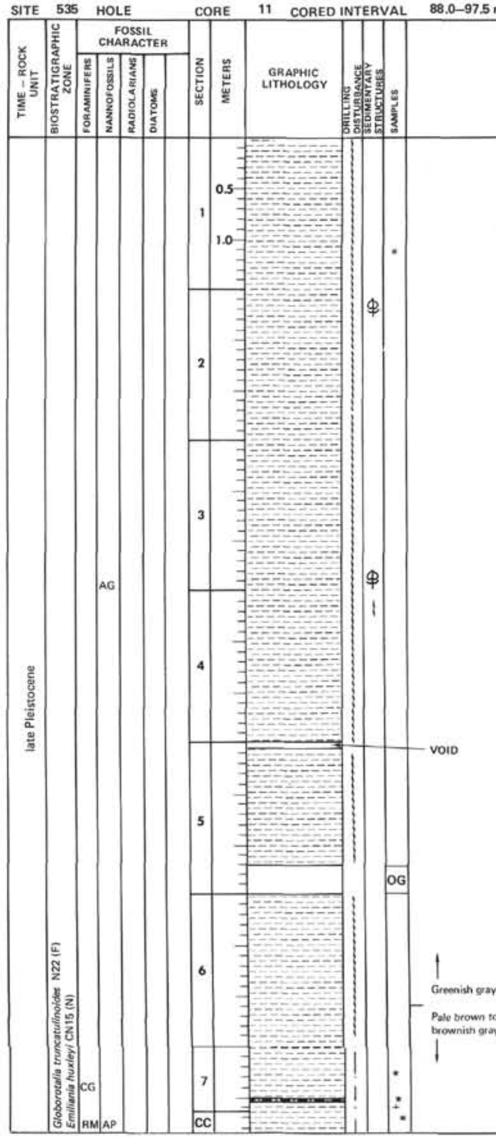
SMEAR SLIDE SUMMARY (%):

	1, 100
	D
Texture:	
Silt	15
Clay	85
Composition:	
Quartz	5
Feldspar	Tr
Clay	90
Carbonate unspec.	10

ORGANIC CARBON AND CARBONATE (%):

	1, 106	2, 106
Organic carbon	–	–
Carbonate	7	8

SITE 535 HOLE CORE 11 CORED INTERVAL 88.0–97.5 m



LITHOLOGIC DESCRIPTION

CLAY, olive gray (5Y 4/1), homogeneous and highly deformed in Sections 1–5. Contains scattered plant fragments. In Section 6, 110 cm clay changes to pale brown (5YR 5/2) and brownish gray (5YR 4/1). Core-Catcher contains patches of nannofossil-rich clay. Burrow lined with *nannofossils and filled with clay occurs* in Section 4, 20 cm.

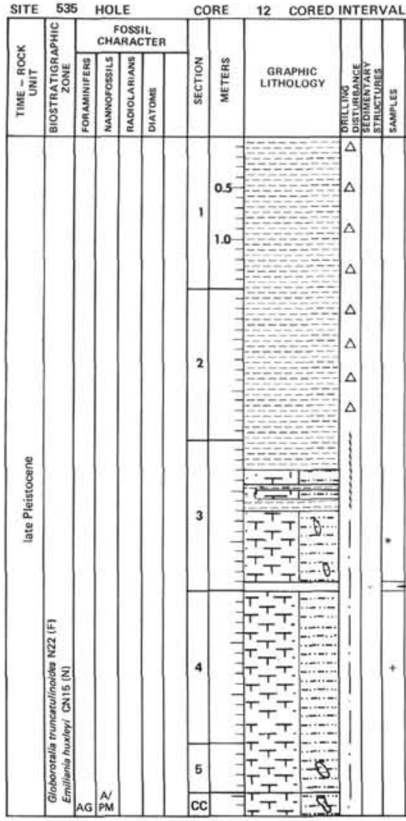
SMEAR SLIDE SUMMARY (%):

	1, 110	7, 26	7, 50
	D	D	M
Texture:			
Sand	–	–	5
Silt	10	10	30
Clay	90	90	65
Composition:			
Quartz	1	2	10
Feldspar	–	1	2
Heavy minerals	–	–	Tr
Clay	90	90	75
Carbonate unspec.	8	6	10
Foraminifers	–	–	Tr
Calc. nannofossils	1	1	1

ORGANIC CARBON AND CARBONATE (%):

	7, 63
Organic carbon	–
Carbonate	34

SITE 535 HOLE CORE 12 CORED INTERVAL 97.5–107.0 m



LITHOLOGIC DESCRIPTION

CLAY, olive gray (5Y 4/1), homogeneous, brecciated and intensely deformed by drilling, from Section 1 through top of Section 3. Section 3, 30–65 cm is a deformed mixture of clay and MUDDY FORAMINIFERAL OOZE. MUDDY FORAMINIFERAL OOZE, olive gray (5Y 4/1) with scattered lighter patches (light olive gray [5Y 5/2]) occurs from Section 3, 65 cm to base of core. Ooze is massive and contains several long (2–5 cm) clay fragments. Moderate drilling deformation in lower half of core.

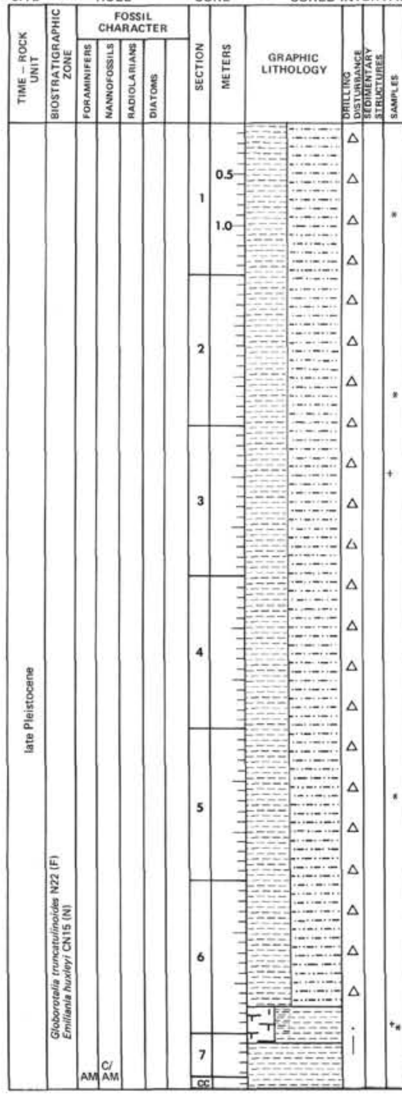
SMEAR SLIDE SUMMARY (%):

	3, 100
	D
Texture:	
Sand	40
Silt	40
Clay	20
Composition:	
Quartz	5
Feldspar	1
Clay	20
Glauconite	Tr
Carbonate unspec.	3
Foraminifers	60
Calc. nannofossils	2
Sponge spicules	1
Shell debris	5
Calcispheres and tunicate spicules	3

ORGANIC CARBON AND CARBONATE (%):

	4, 75
Organic carbon	–
Carbonate	59

SITE 535 HOLE CORE 13 CORED INTERVAL 107.0–116.5 m



LITHOLOGIC DESCRIPTION

Drilling breccia of olive gray (5Y 4/1) to grayish olive (10Y 4/2) CLAY and MUD with scattered plant fragments to Section 6, 125 cm. CALCAREOUS (NANNOFOSSIL) CLAY occurs between Section 6, 125 cm and Section 7, 4 cm. Olive gray (5Y 4/1) CLAY, moderately deformed with scattered plant fragments and foraminifer-rich patches from Section 7, 4–53 cm, and Core-Catcher. No sedimentary structures apparent.

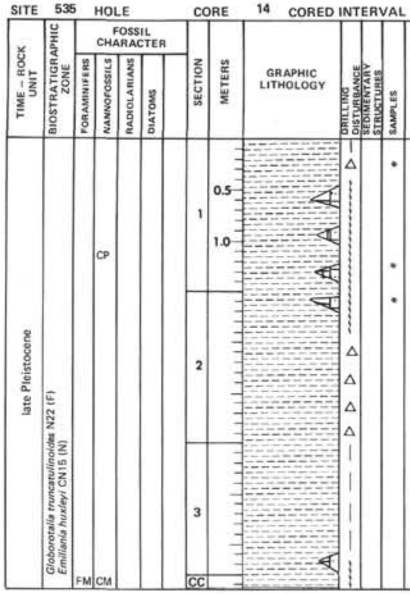
SMEAR SLIDE SUMMARY (%):

	1, 90	2, 120	5, 65	6, 146
	D	D	M	M
Texture:				
Silt	20	10	30	9
Clay	80	90	70	91
Composition:				
Quartz	5	5	Tr	1
Feldspar	2	1	–	–
Clay	80	90	60	72
Carbonate unspec.	12	4	15	5
Foraminifers	–	–	–	1
Calc. nannofossils	1	Tr	25	20
Calcispheres and tunicate spicules	–	–	–	2

ORGANIC CARBON AND CARBONATE (%):

	3, 48	6, 145
Organic carbon	–	–
Carbonate	10	36

SITE 535 HOLE CORE 14 CORED INTERVAL 116.5–126.0 m



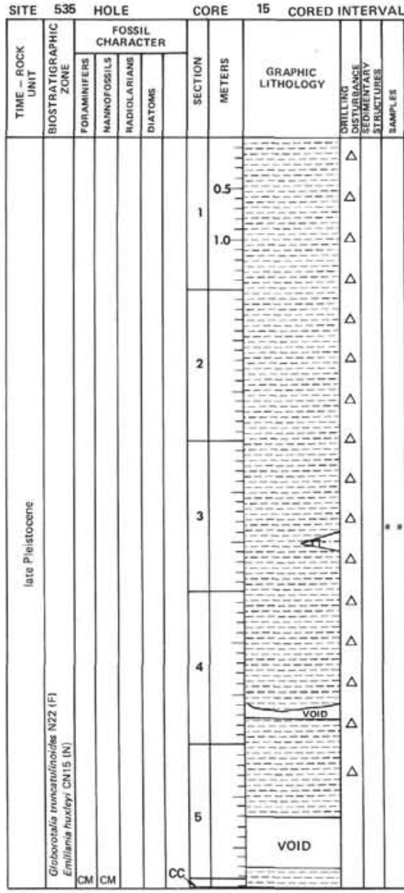
LITHOLOGIC DESCRIPTION

CLAY, olive gray (5Y 4/1), homogeneous with scattered patches of MUDDY FORAMINIFERAL OOZE and occasional plant fragments. Foraminiferal mud is light olive gray (5Y 5/2–5Y 6/1). Intense drilling deformation for most of core.

SMEAR SLIDE SUMMARY (%):

	1, 25 D	1, 125 M	2, 10 M
Texture:			
Sand	5	10	5
Silt	5	80	75
Clay	90	10	20
Composition:			
Quartz	–	10	5
Clay	90	10	20
Carbonate unspec.	5	20	10
Foraminifers	–	50	60
Calc. nannofossils	5	–	1
Radiolarians	–	3	2
Sponge spicules	1	–	1
Plant debris	Tr	1	1
Tunicate and holothurian spicules	–	1	–

SITE 535 HOLE CORE 15 CORED INTERVAL 126.0–135.5 m



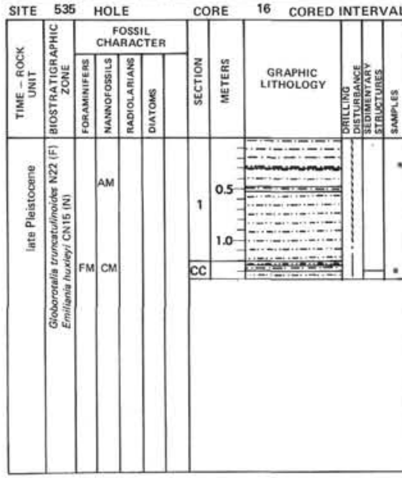
LITHOLOGIC DESCRIPTION

CLAY, grayish olive (10Y 4/2), with several small, scattered patches of muddy foraminiferal ooze. Core is drilling breccia down to Section 4, 28 cm, then very deformed to base.

SMEAR SLIDE SUMMARY (%):

	3, 83 D	3, 93 M
Texture:		
Sand	–	40
Silt	10	20
Clay	90	40
Composition:		
Clay	90	40
Carbonate unspec.	–	20
Foraminifers	–	40

SITE 535 HOLE CORE 16 CORED INTERVAL 135.5–145.0 m



LITHOLOGIC DESCRIPTION

MUD and SANDY MUD, olive gray to light olive gray (5Y 4/1–5Y 5/2 and 5Y 6/1), alternating as shown. Mud is homogeneous; sandy mud layer in Core-Catcher has sharp basal contact and is graded. Most of core is very deformed by drilling. Thin sandy layers at 100–105 cm.

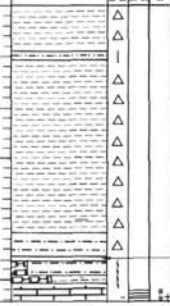
SMEAR SLIDE SUMMARY (%):

	1, 24 M	CC, 10 D
Texture:		
Sand	60	–
Silt	20	10
Clay	10	90
Composition:		
Quartz	50	–
Feldspar	2	–
Clay	10	90
Carbonate unspec.	10	9
Calc. nannofossils	–	1
Rock fragments	8	–
Silt	20	–

SITE 535 HOLE CORE 17 CORED INTERVAL 145.0–154.5 m

TIME – ROCK UNIT: late Pleistocene / upper Albian
BIOSTRATIGRAPHIC ZONE: *Emiliania huxleyi* CN15 (N) / *Planomalina buxtorfi* LC19
FOSSIL CHARACTER: FORAMINIFERS: FP; NANNOFOSSILS: RP/M, AG
SECTION: 1, 2, CC
METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

Top 2.5 meters of core consists of a drilling breccia of olive gray (5Y 4/1) CLAY and MUD; a coherent layer of mud occurs in Section 1, 50 cm. Section 2, 75–98 cm is SANDY MUD, light olive gray (5Y 5/2). A drilling mixture of clay, sandy foraminiferal mud, calcareous silty mud, and calcareous claystone occurs between Section 2, 102–120 cm. The Core-Catcher is mainly light gray (N7) LIMESTONE with faint laminations and a sub-horizontal calcite veinlet.

SMEAR SLIDE SUMMARY (%):

	CC, 15	CC, 21
	M	M
Composition:		
Clay	5	3
Carbonate unspec.	95	95
Calc. nannofossils	–	1
Dolomite	2	1

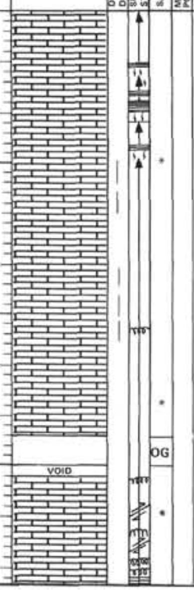
ORGANIC CARBON AND CARBONATE (%):

	CC, 21
Organic carbon	–
Carbonate	92

SITE 535 HOLE CORE 18 CORED INTERVAL 154.5–164.0 m

TIME – ROCK UNIT: Albian
BIOSTRATIGRAPHIC ZONE: *Planomalina buxtorfi* L19
FOSSIL CHARACTER: NANNOFOSSILS: RP; FORAMINIFERS: FP
SECTION: 1, 2, 3, 4
METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

LIMESTONE, light olive gray (5Y 6/1) to greenish gray (5GY 6/1), banded and laminated as marked. Laminations and thin beds 0.1 mm–2 cm thick are either alternations of coarse (silt-size) and fine (clay) carbonate particles and/or color variations. Coarser laminations and layers have apparent load structures and some appear to be rippled on a very fine scale. Boundaries between layers is variable; both sharp and gradational. Coarser layers always lighter in color. Several small offsets noted in Section 4. No Core-Catcher.

Thin Section:
4, 50: Limestone (peloidal, wackestone) – consists primarily of micrite and thin laminations composed of layers or lenses of peloids with lesser amounts of shell debris, calcified radiolaria, arenaceous foraminifers and pyrite. One layer is normally graded. Long axis of shell debris is subparallel to bedding. Dolomite occurs as scattered rhombic crystals (~5%).

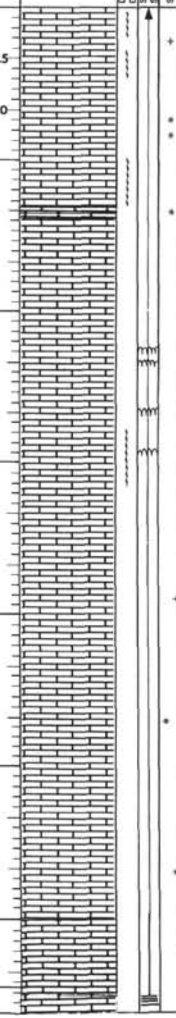
SMEAR SLIDE SUMMARY (%):

	1, 150
	D
Composition:	
Clay	15
Carbonate unspec.	80
Foraminifers	Tr
Calc. nannofossils	Tr
Sponge spicules	Tr
Dolomite	5

SITE 535 HOLE CORE 19 CORED INTERVAL 164.0–173.5 m

TIME – ROCK UNIT: Albian
FOSSIL CHARACTER: NANNOFOSSILS: FM; FORAMINIFERS: FP, RP, RP, RP
SECTION: 1, 2, 3, 4, 5, 6, 7, CC
METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

LIMESTONE, greenish gray (5GY 6/1) to light gray (N7) and light olive gray (5Y 6/1), laminated throughout. Laminations are irregular and caused by alternations of light, coarser-grained carbonate and darker fine-grained carbonate. Light and dark alternations also occur on a scale of 5–20 cm throughout the core; these are superimposed on the laminations. Coarser layers appear rippled and/or loaded on darker, fine-grained layers. Bedding is inclined ~1–3° to core axis. A thin (3 cm thick) layer of laminated, scarse pyritic carbonate sand occurs at 50 cm in Section 2; two more are in the Core-Catcher.

Thin Sections:
5, 104: Micritic limestone (mudstone) – fine-grained, laminated with coarser material in some laminations consisting of calcite-replaced radiolaria, peloids, pelagic foraminifers and recrystallized debris (calcite). Dolomite rhombs make up about 7% of sample.
6, 102: Micritic limestone (mudstone) – fine-grained and laminated. Laminations consist of darker micrite (more clay-rich?) and coarser material including calcite-replaced radiolaria, foraminifers, and pyrite.

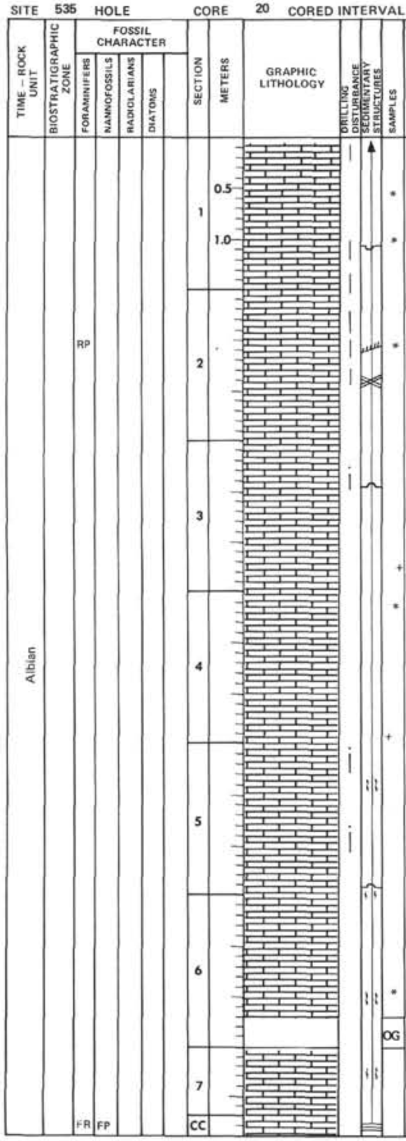
SMEAR SLIDE SUMMARY (%):

	1, 110	1, 125	2, 51
	D	D	M
Composition:			
Clay	10	15	–
Pyrite	–	–	50
Carbonate unspec.	85	75	50
Dolomite	5	10	–

ORGANIC CARBON AND CARBONATE (%):

	1, 33	4, 136
Organic Carbon	–	0.40
Carbonate	92	85

SITE 535 HOLE CORE 20 CORED INTERVAL 173.5–183.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE, banded greenish gray (5GY 6/1) to dark greenish gray (5GY 4/1) on a scale of 1 mm–20 cm, laminated throughout. Several scales of rhythmicity superimposed: 1) laminations – consist of micritic limestone, usually dark, alternating with lighter micritic limestone or irregular, lighter colored laminations of carbonate silt or very fine-grained sand, and 2) 1–20 cm banding – consists of light-dark alternations of laminated micritic limestone and of intervals of micritic limestone alternating with lighter intervals rich in carbonate silt/fine sand laminations. Burrows are sparse. Several small slumped laminations in Sections 3 and 5. Load structures in silty layers in Section 1, ~110 cm; clay-filled veins in Section 2, 68–87 cm. Microcross laminations in carbonate silt in Section 2, 59 cm.

Thin Section:

2, 58: Laminated micritic limestone (mudstone) – fine-grained micrite with coarser-grained laminations. Coarser layers composed of peloids (50%), skeletal fragments (replaced radiolarians? and thin bivalve shell fragments – 10%), and cement (40%). Grain size of coarser material is ~50 µm. Pyrite fringes some laminations.

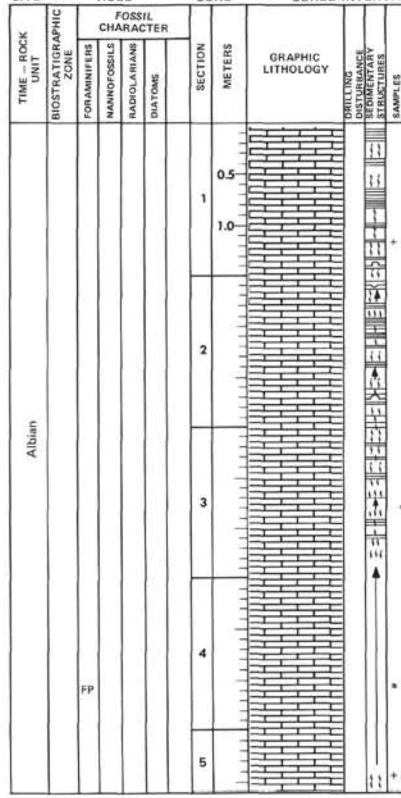
SMEAR SLIDE SUMMARY (%):

	1, 55	1, 100	4, 156	6, 96
	D	D	M	M
Composition:				
Clay	20	10	10	10
Carbonate unspec.	80	90	90	90

ORGANIC CARBON AND CARBONATE (%):

	3, 124	4, 142
	(light)	(dark)
Organic carbon	–	–
Carbonate	94	89

SITE 535 HOLE CORE 21 CORED INTERVAL 183.0–192.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE, banded greenish gray (5GY 6/1–5G 6/1) to dark greenish gray (5G 4/1) changing to a somewhat uniform and lighter greenish gray (5GY 6/1) to yellowish gray (5Y 8/1) in Section 4, 90 cm, and persisting to base of core. Alternating laminated and burrowed intervals in Sections 1–3 give way to burrowed limestone at base of Section 3 through Section 5. In laminated zones burrows are mostly subparallel to bedding which is approximately horizontal. Discrete, light colored carbonate silt laminations and thin (1 mm–3 mm) lenses common in Sections 1–3; silt grains are mixed and disseminated in massive, burrowed limestone from base of Section 3 through Section 5. Several silt layers with load structures; occasional small slumps in laminated intervals as marked. Larger burrows are filled with carbonate silt. Shell fragment in Section 2, 65 cm.

Thin Section:

4, 106: Limestone (skeletal wackestone with a burrow-fill of skeletal packstone) – wackestone contains 20% peloids of very fine sand-size and about 5% skeletal fragments (thin-shelled rudists?) and foraminifers (*Orbitolina*) in a fine-grained matrix with some discernible silt-size peloids, skeletal fragments, and calcite spheres (replaced radiolaria?). Packstone filling the burrow contains about 20% oyster and rudist shell fragments, 20% peloids, 5% blocky calcite cement, and minor echinoderm fragments and miliolid foraminifers in a micritic matrix.

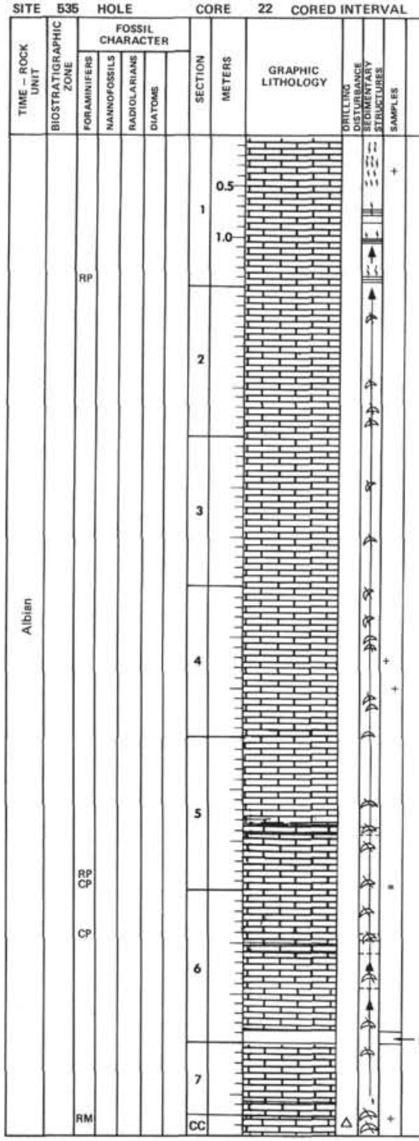
SMEAR SLIDE SUMMARY (%):

	3, 80	5, 47
	D	D
Composition:		
Clay	30	20
Carbonate unspec.	70	80
Calc. nannofossils	–	Tr

ORGANIC CARBON AND CARBONATE (%):

	1, 118	5, 44
Organic carbon	–	–
Carbonate	89	99

SITE 535 HOLE CORE 22 CORED INTERVAL 192.5–202.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE, mottled greenish gray (5GY 6/1–5Y 6/1), with alternating laminated and burrowed intervals in Section 1 as marked. Limestone is very finely crystalline with a mixed coarser carbonate silt component and abundant 1–2 cm x 2–3 cm burrows filled with fine-to-coarse carbonate sand and shell fragments. Coarser carbonate and shell debris becomes more abundant in burrows and as scattered particles in the limestone downcore. In Sections 5–7, intervals of skeletal debris up to 35 cm thick become common. These intervals are entensively burrowed and mixed with the enclosing fine-grained limestone; basal and upper contacts are gradational and commonly burrowed. Skeletal limestone consists of mixed fine-grained limestone and 1–5 mm fragments of carbonate sand (peloids?) and oyster-like shell fragments. Shell fragments aligned subparallel to bedding (generally perpendicular to core axis). Interbedded with skeletal layers and normal fine-grained limestone are thin (2–5 cm) light greenish gray (5GY 8/1) gray (5Y 8/1) layers commonly with sharp basal contacts and burrowed, gradational tops. Basal contacts are commonly irregular where material fills burrows. These layers are composed of fine silt-size carbonate.

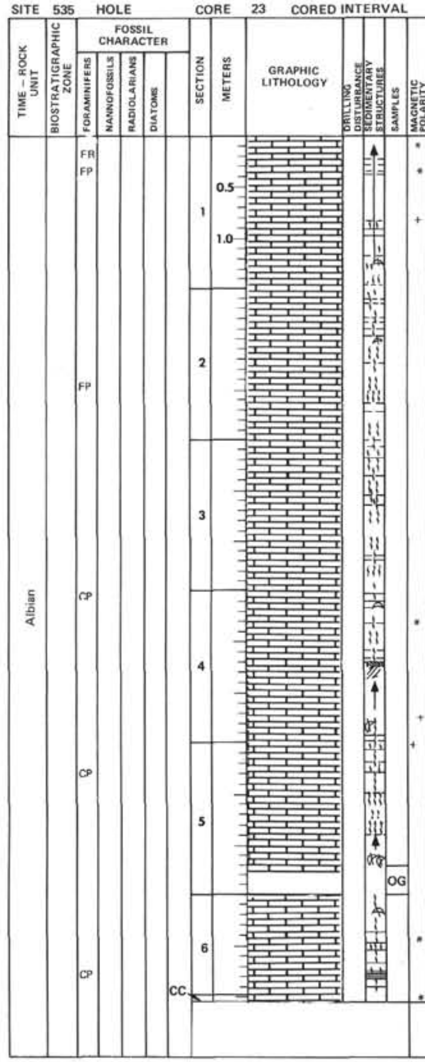
Thin Section:

5, 144: Micritic limestone (mudstone) – finely crystalline limestone composed of 85% micrite, 10–12% cement, and 3–5% grains. Grains include rudists (40%), oyster/mollusc fragments (20%), benthic foraminifers (20%), peloids (5%), carbonate rock fragments (5%) and trace amounts of echinoderm fragments.

ORGANIC CARBON AND CARBONATE (%):

	1, 36	4, 71	4, 100	CC
Organic carbon	–	–	0.46	–
Carbonate	93	99	91	99

SITE 535 HOLE CORE 23 CORED INTERVAL 202.0–211.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE (interbedded mudstone and skeletal grainstone). Bioclastic layers are generally greenish gray (5GY 6/1 and massive with abundant medium dark gray (N4) and yellowish gray (5Y 8/1) shell fragments. Dark gray shell fragments are 1 mm–10 mm across and are mostly oyster/mollusc fragments aligned subparallel to bedding. Lighter fragments are mainly rudists and foraminifers with some size range. Finer grained carbonate is mixed with the coarser grained shell debris. Interbedded fine-grained limestone is greenish gray (5GY 6/1), with scattered shell fragments and abundant burrows, many filled with coarse shell debris. Contacts between fine-grained limestone and bioclastic layers are gradational and extensively burrowed. Only one bioclastic interval has a sharp base (Section 1, 90–94 cm; pyritized base). Most bioclastic intervals are not discrete layers but burrowed mixtures of shell debris and fine-grained carbonate. Several thin carbonate silt layers occur. Both (Sections 4 and 6) are laminated; the layer in Section 4 appears rippled and faulted.

Thin Sections:

1, 11: Limestone (grainstone) – fragments in this limestone consist of dark carbonate rock fragments (50%), mollusc fragments (20%), rudists (10%), foraminifers (10%), peloids (10%), and minor echinoderm and coral fragments. Matrix is calcite cement (80%) and micrite (10%). Average grain size is about 500 μm. Dark color of lithoclasts may be due to pyrite.

1, 30: Limestone (grainstone) – fragments, ~500 μm in size, include limestone clasts (40%), molluscs (20%), foraminifers (20%), rudists (10%), pelloids (5%) with minor coral, bryozoa and calcareous green algae. Some interpenetration at grain contacts. Matrix is 50% cement, 50% micrite.

4, 21: Limestone (skeletal wackestone with a layer of skeletal packstone and burrow fills of skeletal grainstone) – Packstone contains coarse sand-size fragments of oysters, rudists, and miliolids (30%) and peloids (20%). Some rudist fragments have sediment-filled chambers. Grainstone contains medium sand-size voids (10%), peloids and rounded lithoclasts (25%), skeletal grains (35%) and blocky calcite cement (30%).

6, 41: Limestone mudstone with lenses, layers, and burrow fills of packstone–grainstone) – general composition is matrix (micrite and detritus <30 μm 70%), skeletal grains (molluscs, calcite spheres, textularid and miliolid foraminifers – 20%), peloids (10%) and calcite cement (traces).

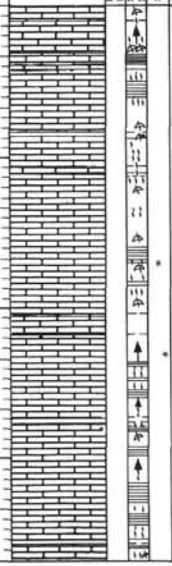
CC: Limestone (grainstone) – consists principally of shallow water carbonate grains (60%) cemented by calcite (40%). Grains include peloids (25%), foraminifers (25%), rudists (10%), molluscs (20%), limestone lithoclasts (10%), and echinoderms (5%). Some pallial canals of rudist fragments are filled with chalcedony. One 3 mm mudstone/packstone layer occurs in this sample.

ORGANIC CARBON AND CARBONATE (%):

	1, 86	4, 122	5, 1
Organic carbon	–	–	0.53
Carbonate	98	91	85

SITE 535 HOLE CORE 24 CORED INTERVAL 211.5–221.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
Albian		CP				1, 2, 3, 4	0.5, 1.0



LITHOLOGIC DESCRIPTION

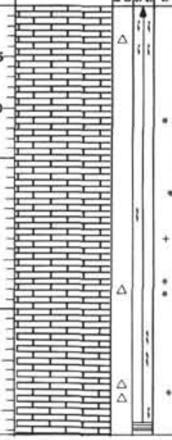
LIMESTONE (interbedded mudstone and skeletal grainstone). Fine-grained limestone is variable. The most common type is massive, greenish gray (5GY 6/1) and burrowed. It contains scattered bioclastic debris and large burrows filled with fine-to-coarse sand-size carbonate bioclastic debris. A less abundant type is banded and laminated greenish gray (5GY 6/1) limestone with minor bioturbation and little or no coarse bioclastic material. Yellowish gray (5Y 8/1) to greenish gray (5GY 6/1) limestone is a third variant; it is laminated and/or bioturbated with sharp base and sharp or gradational top. Bioclastic limestone is similar to that in previous core. Occurs as indistinct intervals with mixed and gradational contacts rather than sharp contacts. Burrows common throughout. Shell material is primarily fragments of molluscs and rudists ranging 1–10 mm in size.

SMEAR SLIDE SUMMARY (%):

	2, 103	3, 42
	M	D
Composition:		
Clay	5	15
Pyrite	–	1
Carbonate unspec.	95	84
Calc. nannofossils	Tr	–

SITE 535 HOLE CORE 25 CORED INTERVAL 221.0–230.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
Albian		CP, FP, FP				1, 2, 3	0.5, 1.0



LITHOLOGIC DESCRIPTION

LIMESTONE, greenish gray (5GY 6/1) with thin bands of light olive gray (5Y 6/1); banded and laminated throughout with only minor bioturbation and scattered thin (1–2 mm), light gray (N7) sandy laminations. Light olive gray limestone bands are 2–15 cm thick. Contacts between bands, layers, and laminations are sharp. The thin sandy laminations are mixtures of light and dark grains, primarily skeletal grains, peloids, and pyrite.

Thin Sections:

2, 32: Limestone (grainstone) – grains in this sample include foraminifers (30%) peloids (or limestone lithoclasts?, 30%) and mollusc fragments (30%). Matrix is 85% cement, 15% micrite.

3, 83: Limestone (grainstone) – sample consists of 60% grains, 30% cement and 10% micrite. Grain types include peloids (35%), molluscs (75%), foraminifers (30%), limestone lithoclasts (10%), and traces of ooids, calcareous green algae and echinoderms. Sand is well sorted with an average grain size of about 250 μm.

SMEAR SLIDE SUMMARY (%):

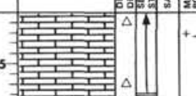
	1, 112	2, 121	2, 133
	D	D	D
COMPOSITION:			
Quartz	Tr	Tr	Tr
Clay	10	25	15
Pyrite	Tr	–	–
Carbonate unspec.	89	75	85
Plant debris	1	Tr	Tr

ORGANIC CARBON AND CARBONATE (%):

	2, 80
Organic carbon	–
Carbonate	89

SITE 535 HOLE CORE 26 CORED INTERVAL 230.5–240.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
Albian		RP				1	0.5



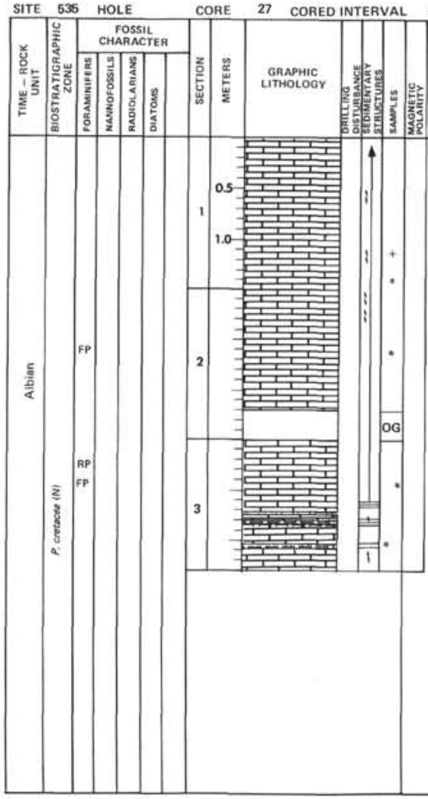
LITHOLOGIC DESCRIPTION

LIMESTONE, medium gray (N5) with light olive gray (5Y 6/1) to yellowish gray (5Y 8/1) bands, laminated and banded throughout with some sand-size debris in discontinuous laminations at 38 cm. Formations and banding a consequence of both color and slight compositional changes.

ORGANIC CARBON AND CARBONATE (%):

	1, 22	1, 23
Organic carbon	0.30	–
Carbonate	85	86

SITE 535 HOLE CORE 27 CORED INTERVAL 240.0–249.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE, medium gray (N5) banded with light gray (5Y 6/1) with sharp contacts between color changes. Laminated and banded throughout with scattered, sparse burrows. Section 3 contains 3 layers of dark greenish gray, coarsely crystalline (0.5–1 mm) celestite and strontianite. Crystals deform and displace laminations of enclosing limestones. Thin, occasional sandy laminations about 1 mm thick occur in all sections.

Thin Sections:

2, 64: Limestone (mudstone) – rock is primarily micrite (95%) with about 5% grains. Grains form one major and several minor laminations and fill burrows. Grain types include 40% molluscs, 40% foraminifers and 10% peloids. Cement occurs as small spheres (replaced radiolaria) throughout the matrix.

3, 47: Laminated limestone (mudstone with grainstone laminations) – laminations are of two types: 1) composed or peloids (200–400 μm), foraminifers (miliolids, textularids), mollusc fragments, plus secondary dolomite cement, and 2) composed of pelagic foraminifers and replaced radiolaria. Type 1 tend to be lensoid and discontinuous; type 2 laminations are more continuous, about 30–100 μm thick and have a maximum frequency of 4/mm. Pyrite is concentrated in the laminations.

3, 106: Celestite/strontianite vein or layer – thin section shows isolated clasts and inclusions of fine-grained limestone within and surrounded by crystals of celestite and strontianite up to 1 cm long.

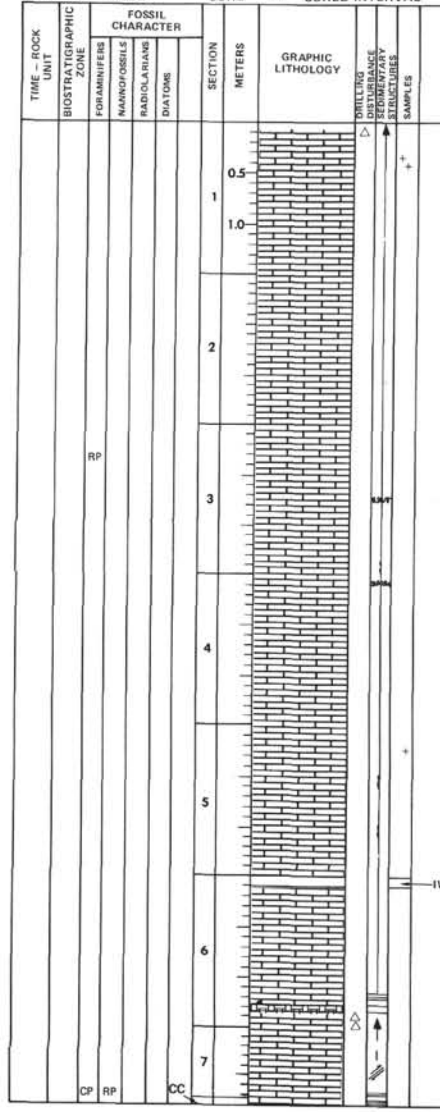
SMEAR SLIDE SUMMARY (%):

	1, 140
	D
Composition:	
Quartz	1
Clay	10
Carbonate unspec.	89

ORGANIC CARBON AND CARBONATE (%):

	1, 115
Organic carbon	–
Carbonate	85

SITE 535 HOLE CORE 28 CORED INTERVAL 249.5–259.0 m



LITHOLOGIC DESCRIPTION

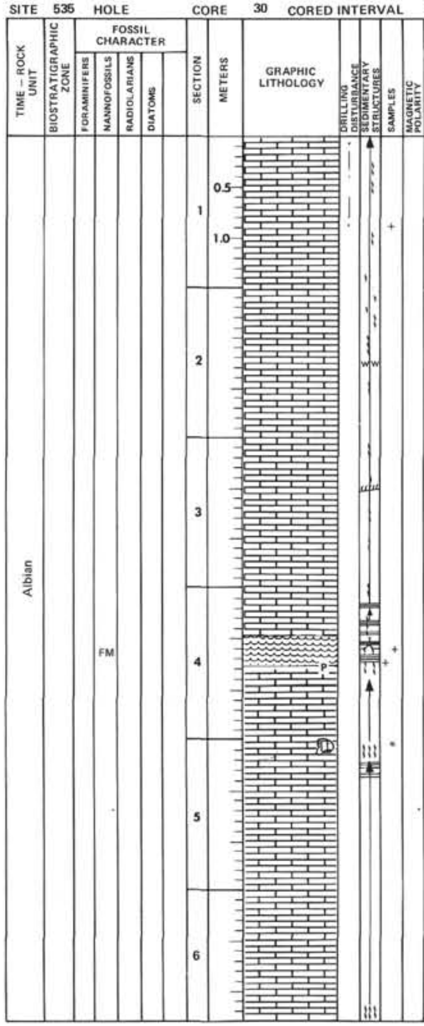
LIMESTONE, banded medium gray (N5) and light olive gray (5Y 6/1), banded and laminated throughout with scattered burrows and some contorted laminations. Thin (0.5–1 mm) laminae of fine carbonate sand are sparsely scattered throughout; many are discontinuous. Thin layer of displaced celestite/strontianite crystals near base of Section 6. Small fault in Section 7, 50 cm.

ORGANIC CARBON AND CARBONATE (%):

	1, 34	1, 45	5, 28
Organic carbon	0.46	–	–
Carbonate	77	82	90

NOTE: Core 29, 259.0–268.5 m: no recovery.

SITE 535 HOLE CORE 30 CORED INTERVAL 268.5–278.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE, banded greenish gray (5GY 6/1) to dark greenish gray (5GY 4/1). Color changes are gradational. Core is indistinctly laminated in upper 3 sections, then alternately is distinctly laminated and burrowed below. Many laminations are light colored, discontinuous layers of very fine-grained carbonate sand or silt, some with subtle load features and apparent rippled surfaces. These alternate with darker, finer grained limestone laminations. Many burrows are 2–5 mm long and subparallel to bedding. One sandy layer in Section 3, 49 cm, is microcross-laminated. A sharp color change occurs in Section 4, 75 cm, where dark greenish gray marly limestone overlies lighter greenish gray limestone. Limestone changes from distinctly laminated at top of Section 4 to indistinctly laminated just below, then darker and more burrowed towards color change in this Section at 75 cm. Contact actually occurs between two discrete pieces and may be a drilling artifact?; white limestone pieces on base of dark layer suggests it is a true contact. Burrow filled with coarsely crystalline celestite/strontianite occurs at top Section 5. Base Sections 4, 5, and 6 are burrowed throughout.

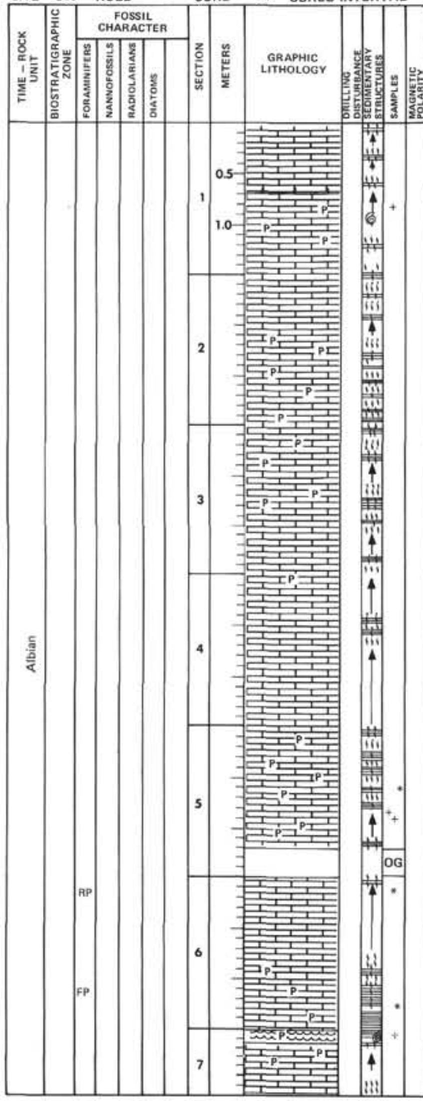
Thin Section:

6, 3: Burrow-fill of celestite/strontianite – thin section shows large void-filling crystals of celestite and strontianite and minor fine-grained carbonate.

ORGANIC CARBON AND CARBONATE (%):

	1, 90	4, 62	4, 77
Organic carbon	–	–	–
Carbonate	80	58	92

SITE 535 HOLE CORE 31 CORED INTERVAL 278.0–287.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, predominantly greenish gray (5G 6/1–5GY 6/1) to dark greenish gray (5G 4/1) but with several light greenish gray (5GY 8/1) to yellowish gray (5Y 8/1) and mottled light bluish gray (5B 7/1), medium light gray (N6) and yellowish gray intervals. Most abundant greenish gray limestone (Sections 1–5) is alternately burrowed and indistinctly laminated as marked. Pyrite is common; in Section 2, pyrite fills and replaces small ammonite shells. First large, well-preserved ammonite occurs in Section 1, 88 cm. Scattered large burrows are filled with carbonate sand. Fine to very fine carbonate sand/silt is disseminated throughout this limestone. A sandy interval occurs in Section 3, 74–83 cm. This limestone changes to light greenish gray to yellowish gray limestone in Section 5, 77 cm. This lighter limestone is burrowed (chondrites at 77–81 cm), and has a diffuse planar fabric. Light bluish gray limestone (Section 6, ~10–90 cm, and Section 7, 19–67 cm) is massive with an indistinct, burrowed texture. No sharp boundaries on light yellowish gray (apparent) burrows. Greenish gray limestone grades to dark greenish gray marly limestone from Section 6, 90 cm–Section 7, 19 cm, where a moderately sharp transition back to lighter greenish gray then medium bluish gray limestone occurs. Ammonite in Section 7, 7 cm.

Thin Section:

6, 128: Laminated limestone (mudstone) – rock consists primarily of micrite. Laminations composed of coarser and finer micrite without any coarse debris.

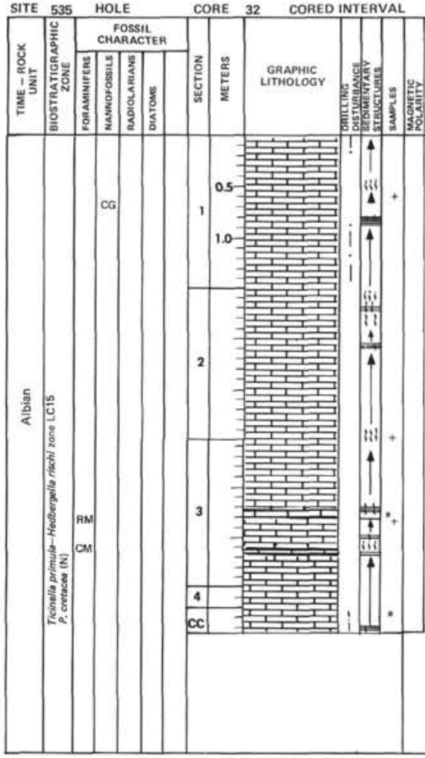
SMEAR SLIDE SUMMARY (%):

	6, 76
	D
Composition:	
Clay	5
Carbonate unspec.	95

ORGANIC CARBON AND CARBONATE (%):

	1, 83	5, 62	5, 82	5, 90	7, 10
Organic carbon	–	–	–	–	0.89
Carbonate	89	86	92	98	52

SITE 535 HOLE CORE 32 CORED INTERVAL 287.5–297.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE, light bluish gray (5G 7/1), yellowish gray (5Y 8/1), greenish gray (5GY 6/1) to dark greenish gray (5G 4/1), alternately burrowed, massive, and indistinctly laminated as marked. Core consists of several sequences of burrowed yellowish gray and mottled bluish gray limestone passing downwards into burrowed and indistinctly laminated greenish gray limestone to laminated and sparsely burrowed dark greenish gray limestone. The approximate sequence boundaries are in Section 1, 87 cm, Section 2, 61 cm, and Section 3, 20 cm. The base of the first sequence, Section 1, 87 cm, is sharp, the underlying sequence basal contacts are gradational. Large burrows filled with light limestone are common in the basal dark limestone of all sequences. One, Section 1, 87 cm, is back-filled and horizontal (zoophycus). Mottled bluish gray limestone in sequences is identical to that in Core 31. Light colored laminations in limestone in Section 3, 100–110 cm, consist of small (1 mm) aligned lenses or nodules surrounded by anastamosing clay seams. Two thin layers of fine-grained carbonate sand or silt occur in Section 3. The thicker layer at 75–79 cm contains a large back-filled burrow. Contacts with the surrounding limestone are generally sharp.

Thin Section:

3, 78: Limestone (wackestone) – laminated, with laminations defined by concentrations of silt- and sand-size carbonate grains, some of which are peloids and planktonic foraminifera. Matrix also appears peloidal.

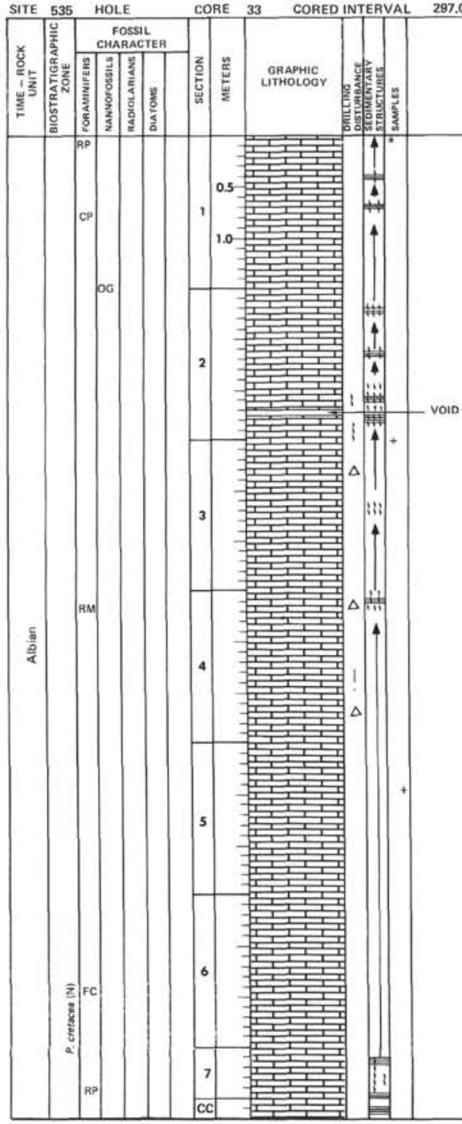
SMEAR SLIDE SUMMARY (%):

	CC, 5
	D
Composition:	
Clay	10
Carbonate unspec.	90

ORGANIC CARBON AND CARBONATE (%):

	1, 67	3, 8	3, 87
Organic carbon	–	0.70	–
Carbonate	86	68	99

SITE 535 HOLE CORE 33 CORED INTERVAL 297.0–306.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE, banded greenish gray (5GY 6/1), dark greenish gray (5GY 4/1), and grayish olive green (5GY 3/2) to light gray and medium gray (N7–N6). Section 1 and top of Section 2 and Sections 5–7 plus base of Section 4 are indistinctly- to well-laminated and darker colored. Section 2 below 65 cm and the upper half of Section 3 are massive, burrowed gray limestone. Indistinct laminations and thicker color banding are superimposed in dark limestones. These pass gradationally to burrowed greenish then gray limestones in top Section 2. In turn, the gray limestone alternates with darker limestone and decreases in abundance in the lower half of Section 4. Some light gray, irregular and discontinuous limestone bands occur in darker limestone in lower half of Section 5 and in Section 6. Pyrite is scattered throughout the core particularly in Section 6. Thinnest laminations yield frequency of 41 mm.

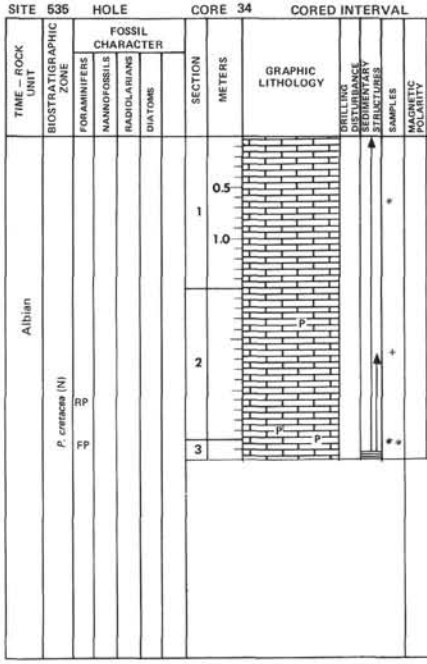
Thin Section:

1, 1: Laminated limestone (mudstone) – laminations are defined by parallel bands of micrite which differ slightly in color and are separated by horizons of pyritic patches (40–120 μm thick) containing some recrystallized carbonate debris, filaments and planktonic foraminifera. Pyritic horizons are always irregular. Thickness of micrite bands range from 200 μm–2 mm.

ORGANIC CARBON AND CARBONATE (%):

	3, 1	5, 48
Organic carbon	–	–
Carbonate	99	78

SITE 535 HOLE CORE 34 CORED INTERVAL 306.5–316.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE, greenish gray (5GY 6/1) to light olive gray (5Y 6/1), laminated and faintly color-banded throughout. Laminations are inclined slightly throughout core. Cross laminations are common below Section 2, 75 cm. Packages of laminations dip more steeply than laminations above Section 2, 75 cm. Adjacent layers pinch and swell in these packages and are not truncated.

Thin Section:

2, 118: Laminated limestone (mudstone) – rock consists of clayey micrite with some calcite replaced radiolaria, filaments, planktonic, foraminifers and minor dolomite. Pyrite concentrations define laminations. Thinnest laminations are ~0,20 mm.

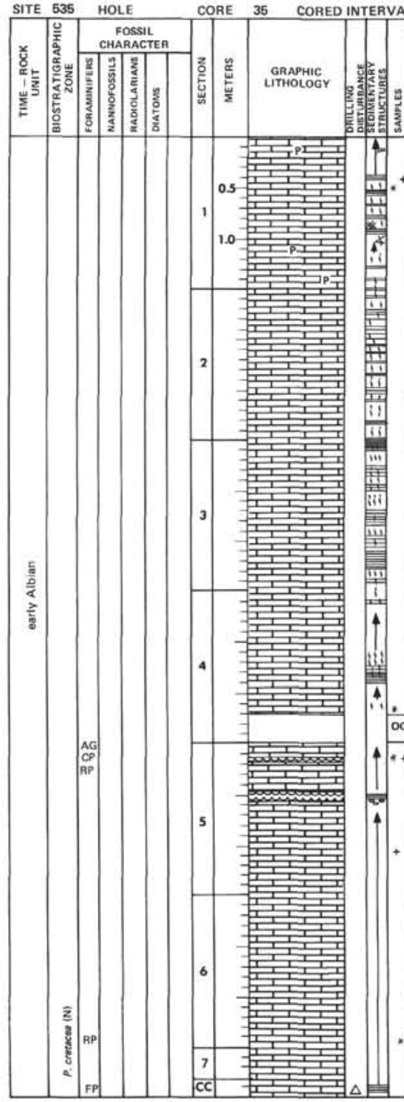
SMEAR SLIDE SUMMARY (%):

	1, 63 M	3, 1 M	3, 3 M
Texture:			
Silt	40	50	–
Clay	60	50	–
Composition:			
Quartz	Tr	Tr	–
Clay	60	5	–
Pyrite	15	7	9
Carbonate unspec.	25	87	90
Calc. nannofossils	Tr	–	–
Dolomite	Tr	1	–
Organic matter	–	–	Tr

ORGANIC CARBON AND CARBONATE (%):

	2, 63
Organic carbon	–
Carbonate	90

SITE 535 HOLE CORE 35 CORED INTERVAL 316.0–325.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE, banded greenish gray (5GY 6/1) and light olive gray (5Y 6/1) with several intervals of light and medium gray to very light gray (N6, N7, and N8). Core is alternately laminated and burrowed as marked; several intervals of cross laminated, inclined, and discordant laminations occur in Sections 1 and 2. Thickest, continuous intervals of massive light gray limestone is in Section 4, 18–70 and 95–120 cm. Two very dark greenish gray intervals of marly limestone occur in Section 5, 12–18 and 42–54 cm. In Section 5, 54–65 cm, flattened limestone fragments or lenses of various colors occur in the greenish gray host limestone; some may be burrow fills.

Thin Section:

5, 18: Marly limestone (mudstone) – laminated limestone with abundant clay. Background laminations are olive gray micrite layers (~0.20 mm thick) separated by dark, pyritic laminae ~40–50 µm thick; both are lenticular in places. Common calcite "filaments" aligned parallel to stratification. These may be true filaments or calcite-cement filling voids that have been flattened during compaction.

6, 142: Laminated limestone (mudstone) – laminations consist of oriented blebs (compacted peloids?) of darker material (light in transmitted light), organic debris, carbonate rhombs, and a few scattered planktonic foraminifera. Blebs are about 0.5–1 mm long.

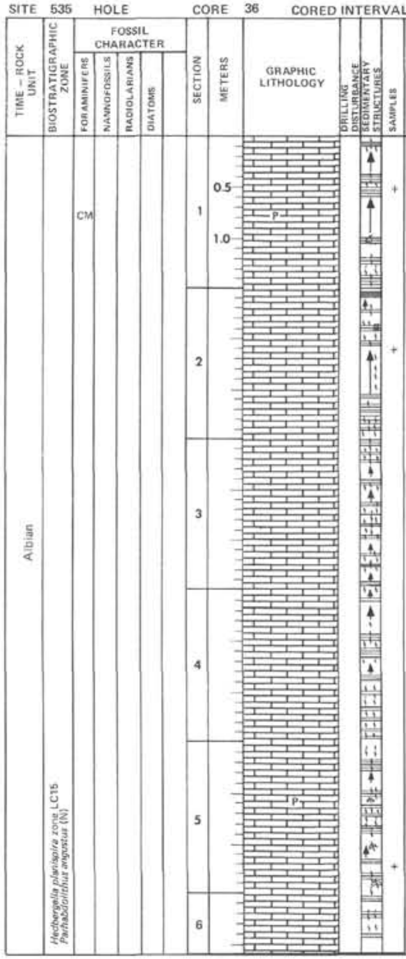
SMEAR SLIDE SUMMARY (%):

	1, 51 M	4, 117 M
Composition:		
Carbonate unspec.	80	99
Calc. nannofossils	10	–
Dolomite	5	1

ORGANIC CARBON AND CARBONATE (%):

	1, 41	5, 18	5, 106
Organic carbon	–	5.38	–
Carbonate	80	57	49

SITE 535 HOLE CORE 36 CORED INTERVAL 325.5–335.0 m



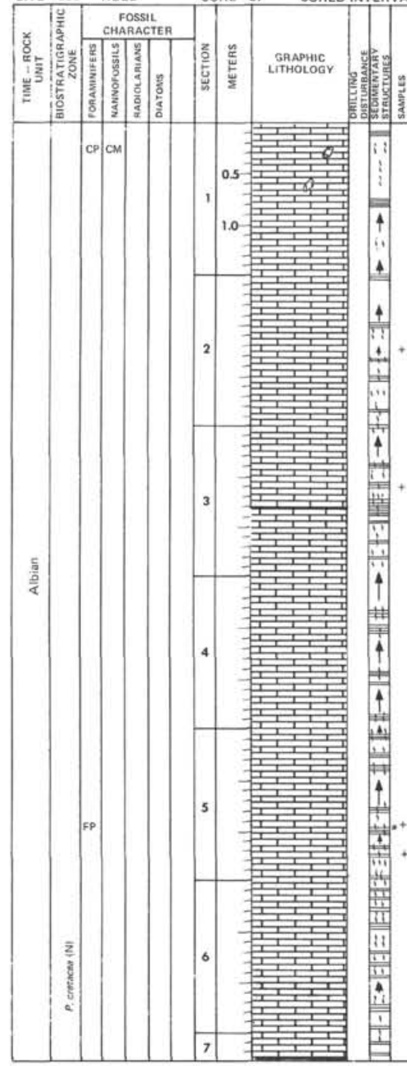
LITHOLOGIC DESCRIPTION

LIMESTONE, banded light gray (N7), olive gray (5Y 4/1), light olive gray (5Y 5/2), light bluish gray (5G 7/1), medium gray (N6) and greenish gray (5GY 6/1). First 2 sections are banded and distinctly laminated except for several small massive intervals. Last 4 sections are lighter in color and indistinctly laminated. Laminations dip about 20° in Section 1, 80–100 cm, but shallow and bend at ~104 cm to 5–10° ; truncation of layers indeterminate. Massive intervals have common small pyrite spots and cavities (1 mm), also have faint planar fabric. Laminated intervals have abundant small (< 1 mm) elongate spots parallel to bedding. Carbonate silt and sand fill several burrows in Section 4. Sparse crushed shell fragments in Section 5 may be ammonites.

ORGANIC CARBON AND CARBONATE (%):

	1, 52	2, 63	5, 125
Organic carbon	0.64	–	–
Carbonate	88	77	99

SITE 535 HOLE CORE 37 CORED INTERVAL 335.0–344.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE, light bluish gray (5G 7/1) to greenish gray (5G 6/1) with several dark greenish gray (5GY 4/1); color banding is subtle and gradational. Limestone is alternately indistinctly laminated and massive as marked. Patches of celestite/strontianite occur in Section 1. Some intervals of the limestone in each section contain fine carbonate sand and silt mixed by burrowing and filling burrows. Discrete, laminated layers of fine carbonate sand silt are scattered throughout the core; thicker layers occur in Sections 3–5. These consist of coarser carbonate debris (mostly peloids foraminifers and shell debris, pyrite, and micrite (see thin section notes). A thin vertical stylolite occurs in Section 2, 84–87 cm.

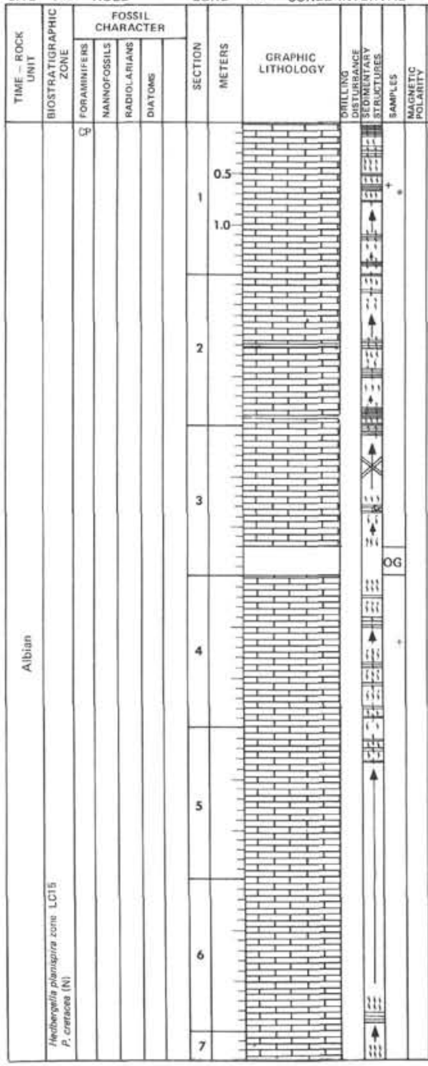
Thin Section:

5, 97: Limestone (peloidal wackestone with pellodal/bioclastic packstone layers) – wackestone consists of 10–60% peloids, 2–10% recrystallized bioclastic grains (filaments and replaced radiolaria?), 20–55% micrite (+ clay). Packstone laminations contain ~35% peloids, 15% micrite, 10–15% recrystallized foraminifers, 5–10% undifferentiated shell debris, and 10% cement. Peloids are somewhat indistinct, occurring as lighter gray, rounded blotchy particles of very fine sand to coarse silt size.

ORGANIC CARBON AND CARBONATE (%):

	3, 61	5, 97
Organic carbon	–	–
Carbonate	90	97

SITE 535 HOLE CORE 38 CORED INTERVAL 344.5–354.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE, light olive gray (5YR 6/1), greenish gray (5GY 6/1) to dark greenish gray (5GY 4/1), banded and alternately burrowed, and indistinctly laminated as marked. Thicker burrowed intervals prevail in lower part of core. Carbonate silt and very fine sand form same laminations; this material also fills burrows and is sporadically mixed with finer grained limestone throughout the core. Several thin, laminated sand/silt layers in Section 2. Burrows mainly planolites type with several possible zoophycus or teichichnus(?), large vertical burrow (zoophycus or teichichnus?) in Section 4, 16 cm, has an irregular hole of dark greenish gray celestite/strontianite.

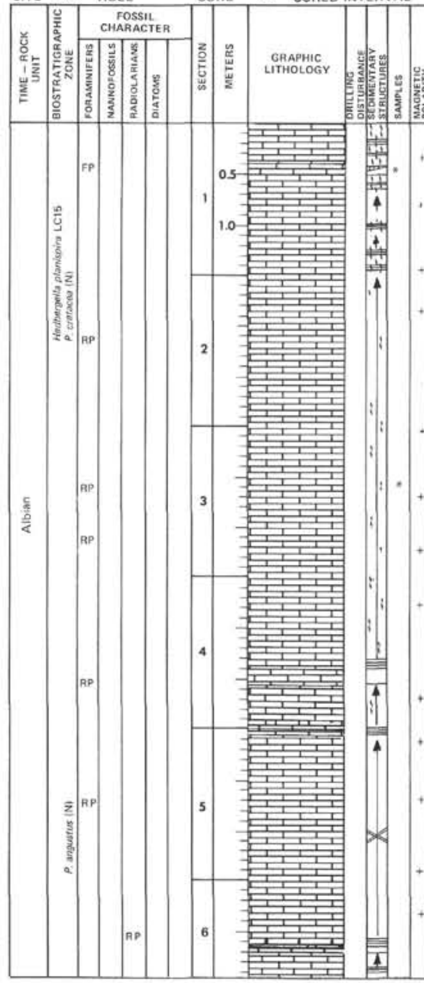
SMEAR SLIDE SUMMARY (%):

	1, 70
	M
Composition:	
Carbonate unspec.	100

ORGANIC CARBON AND CARBONATE (%):

	4, 66	1, 61
Organic carbon	–	0.60
Carbonate	92	85

SITE 535 HOLE CORE 39 CORED INTERVAL 354.0–363.5 m



LITHOLOGIC DESCRIPTION

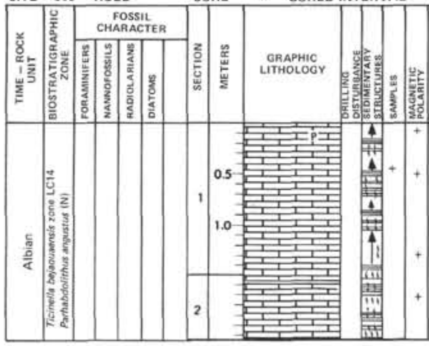
LIMESTONE, banded greenish gray (5GY 6/1, 5G 6/1) and dark greenish gray (5G 4/1) to light gray (N7) and medium light gray (N6). Section 1 contains alternating indistinctly laminated and massive intervals. Below this the limestone is laminated with only scattered burrows. Thin layers of carbonate silt and fine sand occur sporadically. The layer between Section 1, 40–50 cm, has a microcross-laminated top. Others are massive or finely laminated as marked. Pyrite occurs near the base of the layer at about Section 2, 102 cm. Fine carbonate sand and silt comprise many of the fine light laminations throughout the core. Frequency of laminations is on the order of 12–13 per cm. Fracture in Section 5, 100–105 cm, is 2 cm wide and lined with dark green celestite/strontianite and filled almost completely with 1–2 cm calcite crystals. A 3 mm thick layer of celestite/strontiante(?) occurs in Section 6, 81 cm.

Thin Section:

1, 46: Limestone (wackestone) — homogeneous wackestone with ~25% carbonate silt and fine sand in a micritic matrix. Matrix appears pelletal, but is indistinct. Grains include planktonic foraminifers, "filament" molluscs and unspecified debris, largest grains about 175 cm.

3, 60: Laminated limestone (mudstone with wackestone layers) — alternating layers of micrite and fine-grained carbonate sand and silt. Layers are as thin as 40 μm and are composed of peloids and shallow water carbonate debris including some miliolid foraminifers. Matrix contains fine, silt-size rhombs of carbonate (dolomite?), scattered planktonic foraminifers, and echinoderm debris.

SITE 535 HOLE CORE 40 CORED INTERVAL 363.5–373.0 m



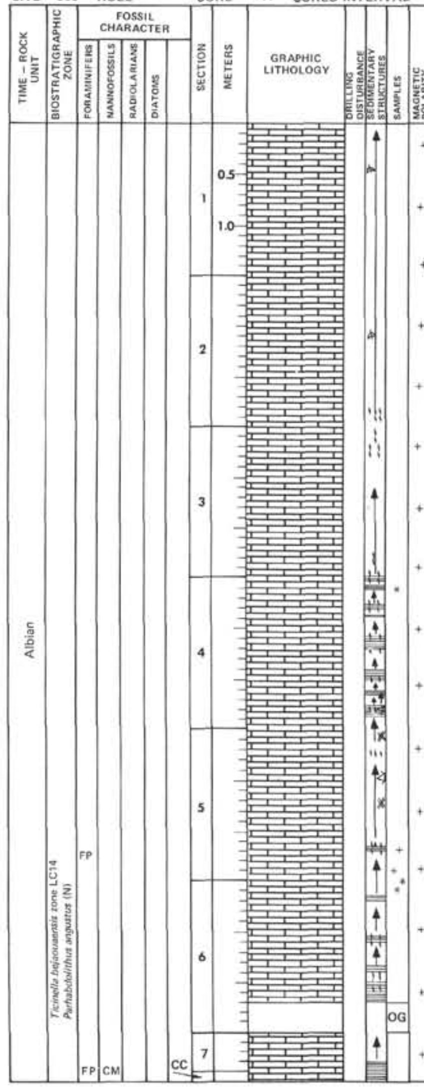
LITHOLOGIC DESCRIPTION

LIMESTONE, greenish gray (5GY 6/1) to dark greenish gray (5GY 4/1) with light olive gray (5Y 6/1) laminations. Alternately laminated, indistinctly laminated, and burrowed intervals as marked. Many of the light colored laminae are irregular and discontinuous silty layers. Thicker layer of carbonate silt occurs at top of Section 2. Occasional sand- and silt-filled burrows occur in laminated intervals.

ORGANIC CARBON AND CARBONATE (%):

	1, 48
Organic carbon	–
Carbonate	92

SITE 535 HOLE CORE 41 CORED INTERVAL 373.0–382.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE, medium gray to light gray (N5–N7), generally divisable into three alternating types: 1) light gray limestone that is indistinctly laminated to massive and contains scattered and flattened carbonate pellets(?); 2) medium gray limestone that is well-laminated containing yellowish gray, discontinuous silty layers? and 3) light gray limestone that is massive and mottled by oxidized zones surrounding pyrite-lined burrows. Most contacts between these limestone types are gradational. Overall, the core is massive and burrowed in Sections 1–3, then alternately laminated and indistinctly laminated below, the frequency and thickness of alternations decreasing downcore. Laminations dip steeply (up to 34° to core axis) in Section 4, 112–130 cm, and Section 6, 30–40 cm. Small calcite veins in Section 5.

Thin Section:

6, 2: Laminated limestone (mudstone) – laminations given by alternations of light (400–450 μm) and dark (120–200 μm) micritic layers with pyrite concentrations. Patches of light and fine micrite also occur in darker laminae.

SMEAR SLIDE SUMMARY (%):

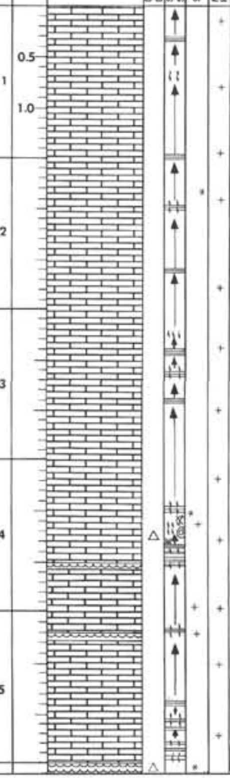
	4, 10	6, 10
	M	D
Texture:		
Silt	40	50
Clay	60	50
Composition:		
Clay	60	20
Pyrite	7	–
Carbonate unspec.	–	80
Calc. nannofossils	32	–
Fish remains	–	Tr
Siderite(?)	1	–
Dolomite	–	Tr

ORGANIC CARBON AND CARBONATE (%):

	5, 118	5, 141
Organic carbon	4.0	–
Carbonate	75	65

SITE 535 HOLE CORE 42 CORED INTERVAL 382.5–392.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION
Albian	*Ticinella bejaouaensis* zone LC14 / *Parhabdolithus angustus* (N)	FP				4
		FP				4
		CM	CG			5
					CC	CC



LITHOLOGIC DESCRIPTION

LIMESTONE, banded medium gray (N5) and olive gray (5Y 4/1) to light gray (N7), alternately laminated, indistinctly laminated, and burrowed intervals all with gradational contacts. Burrowed and massive limestones occur in Sections 2–3, 112–150 and 0–33 cm, and in Section 4, 46–58 cm; the second interval in Section 4 is very light gray and contains some ammonite fragments. The shallow interval is slightly darker gray and indistinctly mottled (oxidation around burrows?). Some of the well laminated intervals have abundant yellowish gray particles scattered along bedding planes. Core is very dark in last section.

Thin Sections:

2, 38: Limestone (mudstone) – micritic limestone containing ~44% micrite, 35% calcareous nannofossils (nannoconids), 10% bivalve fragments, 5% foraminifera, 5% clay, and 1% echinoderms.

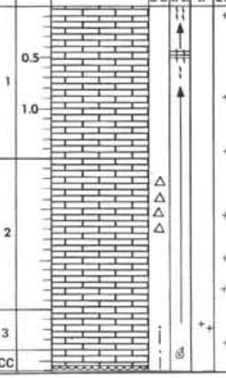
4, 51: Limestone (mudstone) – calcite-filled fracture in mudstone containing scattered radiolaria, foraminifers, pyrite framboids, *calpionellids*(?) and *nannoconids*.

ORGANIC CARBON AND CARBONATE (%):

	4, 63	4, 149	5, 21
Organic carbon	–	–	7.35
Carbonate	96	98	65

SITE 535 HOLE CORE 43 CORED INTERVAL 392.0–401.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION
Aptian—early Aptian	*Hedbergella gorbachikae—H. trocoidea* zone LC14–13 / *Chiastozygus litterarius* (N) / *Parhabdolithus angustus* (N)		AG			2
		RP				3
		AM				CC



LITHOLOGIC DESCRIPTION

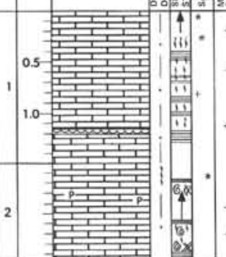
LIMESTONE, medium gray (N5) to light gray (N7), massive and indistinctly laminated in top of Section 1, well laminated below. Changes to dark gray (N3), laminated MARLY LIMESTONE in Section 3, 14–21 cm, then a small piece of very light gray (N8) to white (N9) limestone from 25–28 cm. White limestone contains several distinct burrows filled with darker limestone (chondrites?). Piece of indistinctly laminated medium gray limestone is below white limestone in Section 3. Core-Catcher contains several pieces of white limestone with scattered foraminifers and ammonite shells(?) above a piece of olive black marly limestone ("black shale"). Contacts between light and dark lithologies in Section 3 and Core-Catcher unknown because of fracturing during drilling.

ORGANIC CARBON AND CARBONATE (%):

	3, 17	3, 20
Organic carbon	5.22	–
Carbonate	82	74

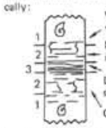
SITE 535 HOLE CORE 44 CORED INTERVAL 401.0–410.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION
Aptian	*Hedbergella gorbachikae* zone LC13 / *Chiastozygus litterarius* (N)	CM				1
			AG			1
		CM	CM			2



LITHOLOGIC DESCRIPTION

LIMESTONE, white (N9), bluish white (5B 9/1) and light greenish gray (5GY 8/1) to greenish gray (5GY 6/1), and MARLY LIMESTONE, olive black (5Y 2/1). Core broken into fragments by drilling with only a few lithologic contacts intact. A general gradational sequence from light to dark limestone occurs several times in the core. Specifically:



Darkest intervals occur in Section 1, at 35, 84, and 118 cm, and in Section 2, at 40, 50, and 75 cm. Some variability in successive sequences. Darkest layer is in Section 1, at 118 cm, a marly limestone. Some ammonites have geopetal infills of limestone with calcite span above (e.g. Section 2, 69–72 cm).

Thin Section:

1, 2: Limestone (mudstone) – contains calcareous nannoplankton (*nannoconids*) (50%), micrite (35%), foraminifera (10%), and clay (5%). Some bioturbation noted.

2, 16: Limestone (mudstone) – nannofossil, micritic limestone containing calcareous nannofossils (*nannoconids*) (60%), micrite (31%), clay (5%), foraminifera (2%), and filaments (2%). Filaments parallel to stratification. *Nannoconids* with exceptional preservation.

SMEAR SLIDE SUMMARY (%):

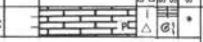
	1, 22
	M
Texture:	
Clay	100
Composition:	
Clay	50
Carbonate unspec.	20
Dolomite(?)	30

ORGANIC CARBON AND CARBONATE (%):

	1, 81
Organic carbon	1.6
Carbonate	80

SITE 535 HOLE CORE 45 CORED INTERVAL 410.0–419.0 m

TIME–ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION
Aptian	*Globigerinelloides maridalensis*–*G. blowi* zone LC10–9	CM				CC



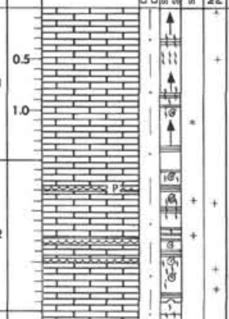
LITHOLOGIC DESCRIPTION

LIMESTONE, olive gray (5Y 6/1) to very light gray (N8) and light gray (N7). Top 5 cm is a coherent piece of light olive gray limestone with indistinct laminations and chondrites. Remainder of core is drilling breccia of light gray limestone with abundant ammonite debris (one baculitid specimen), some chondrites and patchy pyrite. Ammonites mostly as molds and casts with common geopetal fabric.

Thin Section:
CC: Limestone (mudstone) – mostly scattered planktonic foraminifera and planktonic mollusc shell fragments in a micritic matrix.

SITE 535 HOLE CORE 46 CORED INTERVAL 419.0–428.0 m

TIME–ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION
Aptian–late Barremian	*Globigerinelloides gottisi*–*G. duboisi* zone LC8; *Micrantholithus hoschulzi* (N)?	RP, RP	RP, FP			1, 2, CC



LITHOLOGIC DESCRIPTION

LIMESTONE, light gray (N7) to light olive gray (5Y 5/2) and MARLY LIMESTONE, olive black (5Y 2/1). Core broken into fragments by drilling with only several contacts intact. Section 1 is predominantly burrowed to indistinctly laminated light olive gray limestone in the upper part and laminated darker olive gray limestone with common bedding parallel stylolites; alternations in this part are between lighter limestone and dark organic-rich, marly limestone-calcareous claystone laminations. Several pieces of massive, very light gray limestone with ammonites occurs in Section 1, between 88–109 cm. Section 2 consists of several white ammonite limestone to light olive gray limestone to olive black marly limestone sequences as shown schematically for Core 44. Marly limestone layers are marked on graphic lithology column. Stylolitic surfaces occur at 47, 65, 66, and 129 cm. Scattered planolites and chondrites throughout. Some ammonites have geopetal fabric. One dark micritic limestone has a light limestone lens.

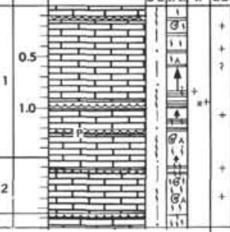
Thin Section:
1, 110: Laminated limestone (mudstone) – principally a micritic laminated limestone with organic- and clay-rich laminations and scattered skeletal fragments (calcite-replaced radiolaria?). Several dark laminations are wavy with incipient pressure solution features.

ORGANIC CARBON AND CARBONATE (%):

	2, 41	2, 78
Organic carbon	0.28	–
Carbonate	93	54

SITE 535 HOLE CORE 47 CORED INTERVAL 428.0–437.0 m

TIME–ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION
late Hauterivian–early Barremian	*Lithraphidites bollii* (N)	FP	CG			1, 2, CC



LITHOLOGIC DESCRIPTION

Alternating 1) very light gray to light gray (N8–N7) ammonite-bearing, massive LIMESTONE; 2) laminated to indistinctly laminated light gray (N7) to light olive gray (5Y 5/2) LIMESTONE; and 3) olive black (5Y 2/1), laminated MARLY LIMESTONE in sequences as shown for Core 44. Marly limestone intervals marked. Light massive limestone contains irregular, medium gray pyritic patches. Ammonites in this limestone are filled with lime mud and spar; some are pyritized, others sit with long axes parallel to core axis. Aptychi occur with some ammonites and singly in darker laminated limestone. Core is broken into discrete pieces by drilling; most contacts between lithologies destroyed.

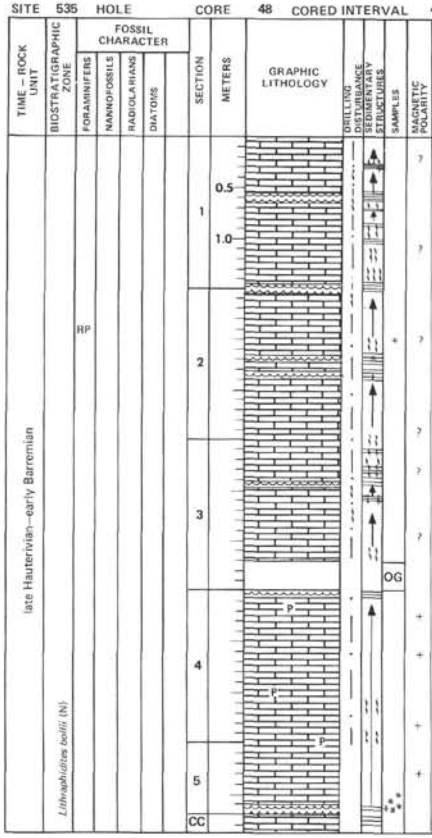
SMEAR SLIDE SUMMARY (%):

	1, 98 M
Texture:	
Clay	100
Composition:	
Clay	60
Carbonate unspec.	38
Calc. nannofossils	2

ORGANIC CARBON AND CARBONATE (%):

	1, 85	1, 96
Organic carbon	–	3.6
Carbonate	94	40

SITE 535 HOLE CORE 48 CORED INTERVAL 437.0–446.0 m



LITHOLOGIC DESCRIPTION

Alternations of light gray (N7) LIMESTONE, light gray to light olive gray (5Y 5/2) LIMESTONE, and olive gray (5Y 4/1) to olive black (5Y 2/1) MARLY LIMESTONE, and CALCAREOUS CLAYSTONE in sequences similar to that illustrated for Core 44. Core is principally laminated to indistinctly laminated light olive gray limestone with only several intervals of massive white to light gray limestone (few ammonites); marly limestone intervals occur more frequently (as marked). Although core is fractured by drilling, transitions from dark to lighter limestone are generally sharp. Transitions from lamination to indistinctly laminated and massive intervals are gradational. Chondrites burrows and pyrite occur sporadically. Stylolites common where thin clay-rich laminations alternate with limestone.

Thin Section:

5, 50: Limestone (mudstone) – principally micrite (98%) with scattered recrystallized skeletal fragments (~0.1–0.3 mm) and small (0.01 mm) pyrite grains. No laminations or indistinct peloidal texture. One fragment may be a *calpionelid*. *Nannoconids* common.

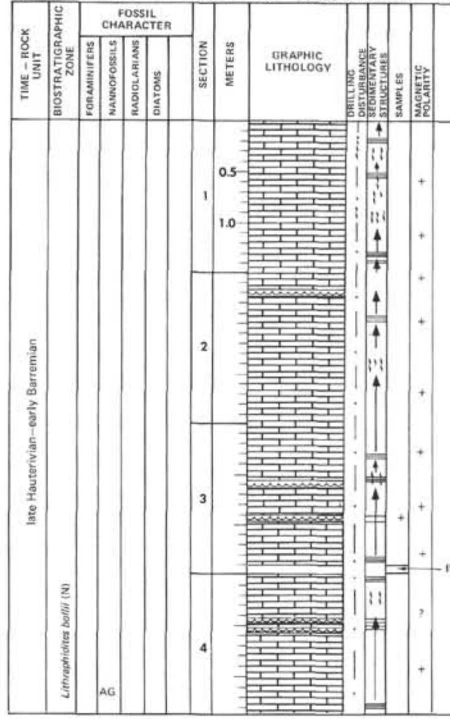
SMEAR SLIDE SUMMARY (%):

	2, 52	5, 56	5, 64	5, 66
	D	D	M	D
Composition:				
Clay	–	5	55	40
Pyrite	1	1	2	Tr
Carbonate unspec.	60	95	10	50
Calc. nannofossils	40	Tr	31	10
Dolomite	–	Tr	2	Tr

ORGANIC CARBON AND CARBONATE (%):

	5, 66
Organic carbon	–
Carbonate	31

SITE 535 HOLE CORE 49 CORED INTERVAL 446.0–455.0 m



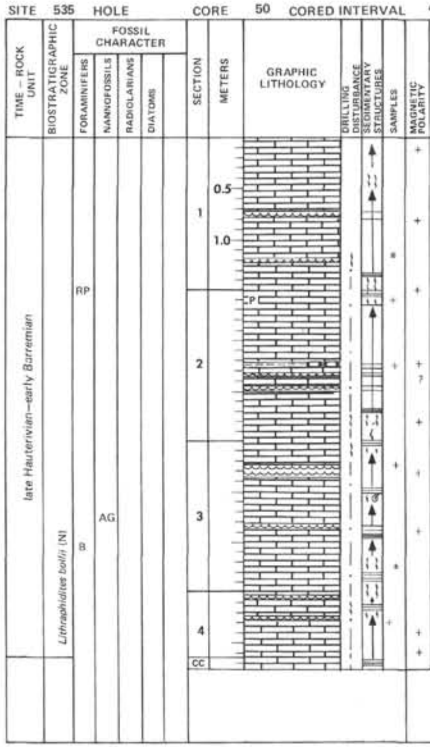
LITHOLOGIC DESCRIPTION

Alternating white to light gray (N8) massive LIMESTONE, laminated to indistinctly laminated, light olive gray (5Y 5/2) LIMESTONE, and olive gray (5Y 4/1) to olive black (5Y 2/1) laminated MARLY LIMESTONE in sequences similar to those illustrated for Core 44. Differs in that white massive limestone is minor (only a few ammonite fragments). Very similar to Core 48. Marly limestone intervals are marked but these have dark limestones above and below and may be somewhat wider than shown. Core is broken into fragments by drilling but many contacts are intact and are gradational.

ORGANIC CARBON AND CARBONATE (%):

	3, 91
Organic carbon	2.50
Carbonate	50

SITE 535 HOLE CORE 50 CORED INTERVAL 455.0–464.0 m



LITHOLOGIC DESCRIPTION

Alternating massive white (N9) to very light gray (N8) LIMESTONE, light gray (N7) to light olive gray (5Y 6/1) to greenish gray (5GY 6/1) burrowed, indistinctly laminated, and laminated LIMESTONE, and laminated olive gray (5Y 4/2) to brownish black MARLY LIMESTONE and CALCAREOUS CLAYSTONE in sequences very similar to those in Cores 48–49. White limestone is a minor component and contains a few ammonites. The dark marly limestone occurs (as marked) with gradational to sharp contacts with surrounding greenish gray limestone. Greenish limestone predominates in core. Core is broken into drilling fragments but many contacts are preserved. Dark marly limestone contains up to 20% dolomite rhombs.

Thin Section:

3, 123: Laminated limestone (mudstone) – laminae formed by wispy, clayey (organic matter?) layers, some of which are stylolitic, bounding micritic laminae. Microfossils and skeletal silt-size carbonate scattered throughout matrix. Dolomite (~5%) occurs as scattered rhombs throughout the thin section and concentrated along dark laminae. Average 12 laminae/mm.

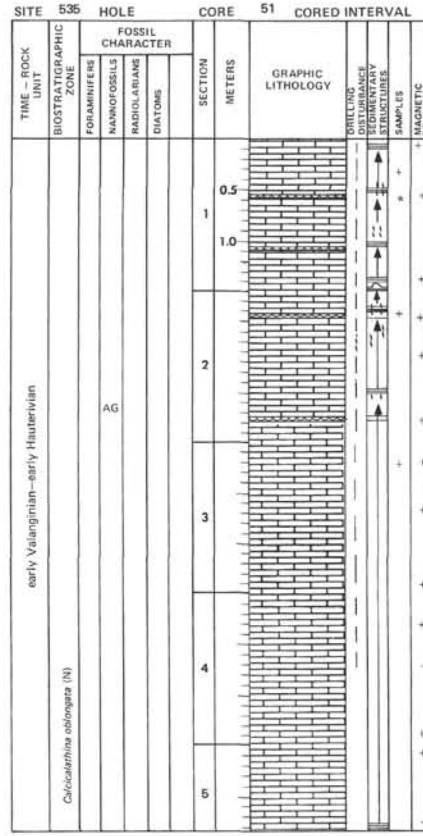
SMEAR SLIDE SUMMARY (%):

	1, 119
	M
Composition:	
Clay	30
Carbonate unspec.	35
Calc. nannofossils	10
Plant debris and organic matter	5
Dolomite	20

ORGANIC CARBON AND CARBONATE (%):

	2, 13	2, 75	3, 27	4, 30
Organic carbon	–	6.4	–	–
Carbonate	91	29	37	48

SITE 535 HOLE CORE 51 CORED INTERVAL 464.0–473.0 m



LITHOLOGIC DESCRIPTION

Alternating white (N9) to very light gray (N8) massive LIMESTONE with medium gray (N6) mottles, laminated to indistinctly laminated light olive gray (5Y 6/1) to olive gray (5Y 4/1) LIMESTONE, and brownish black (5YR 2/1) to olive black laminated MARLY LIMESTONE CALCAREOUS CLAYSTONE, as in Cores 49 and 50. These alternating lithologies give way to a fairly uniform sequence of olive gray to light olive gray, well-laminated limestone which begins near the base of Section 2 and continues through the rest of the lower part of the core. Calcite-replaced radiolaria near top of Section 1.

Thin Section:

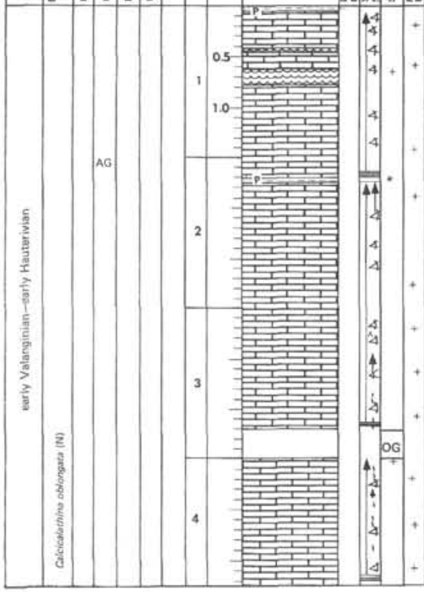
1, 60: Limestone (mudstone) — structureless limestone composed mostly of micrite (98%) with scattered, calcite-filled radiolaria (~ 0.2 mm), foraminifers and *nannoconids*.

ORGANIC CARBON AND CARBONATE (%):

	1, 37	2, 23	3, 24
Organic carbon	–	5.1	–
Carbonate	90	43	85

SITE 535 HOLE CORE 52 CORED INTERVAL 473.0–477.5 m

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



LIMESTONE, olive gray (5Y 4/1) to light olive gray (5Y 6/1), laminated throughout with two thin layers of medium dark gray pyritic CLAYSTONE. Sparse burrowing. In many places laminated zones are inclined relative to laminations above and below. Laminations in these packages appear to be truncated in some cases, compressed in others. Average lamination thickness is ~0.1–0.3 mm; average frequency is ~10–12 laminations per cm. Ammonite aptychus at Section 3, 32 cm.

SMEAR SLIDE SUMMARY (%):

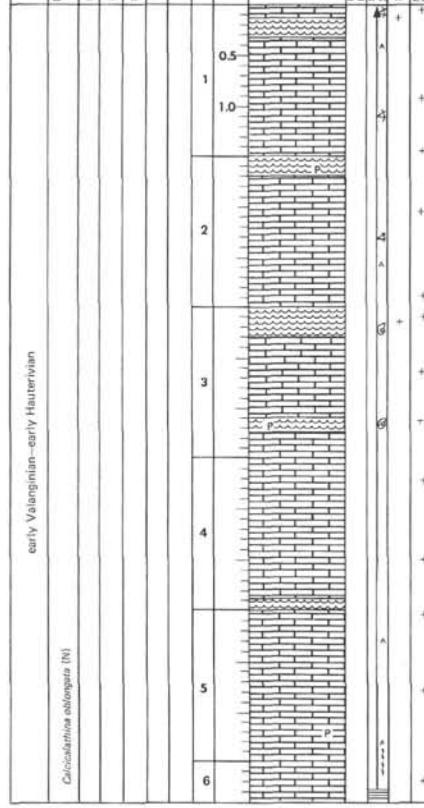
	2, 22
	M
Composition:	
Clay	80
Pyrite	20

ORGANIC CARBON AND CAR[illegible]TE (%):

	1, 63	4, 6
Organic carbon	1.32	–
Carbonate	56	68

SITE 535 HOLE CORE 53 CORED INTERVAL 477.5–487.0 m

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

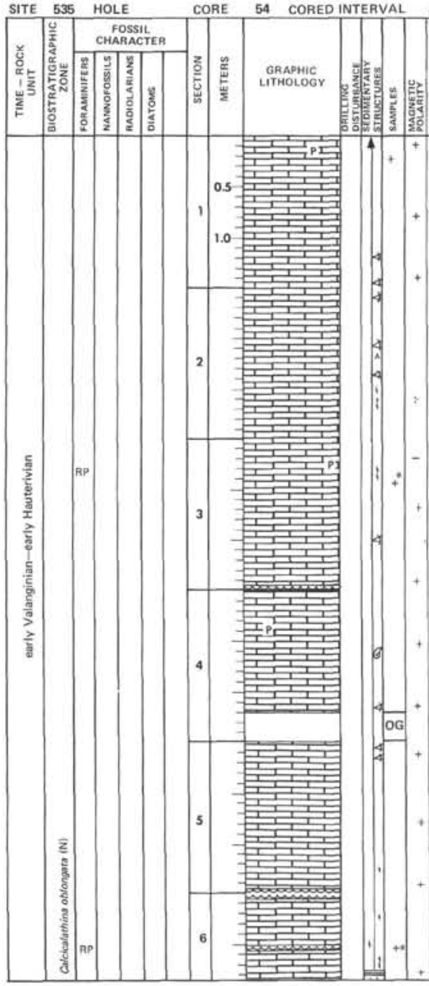


LIMESTONE, olive gray (5Y 4/1) to light olive gray (5Y 6/1) laminated throughout with scattered ammonites and ammonite aptychi and pyrite. Angular discordancy in laminated sequence (as marked) are similar to those in previous core. Minor burrowing near base of core. Ammonite at Section 3, 29 cm, has chambers partly filled with chert. Small pyrite/chert nodules at Section 3, 121 cm.

ORGANIC CARBON AND CARBONATE (%):

	1, 18	3, 19
Organic carbon	–	2.2
Carbonate	70	56

SITE 535 HOLE CORE 54 CORED INTERVAL 487.0–496.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE, light olive gray (5Y 6/1) to olive gray (5Y 4/1), banded and laminated throughout. Packages of laminated limestone inclined relative to surrounding laminations as noted. Ammonite aptychus is Section 2, 70 cm. Flattened ammonite mold in Section 4, 88 cm. Compaction of laminations around a pyritized fragment occurs in Section 4, 44 cm. Scattered burrows cut laminations.

Thin Section:

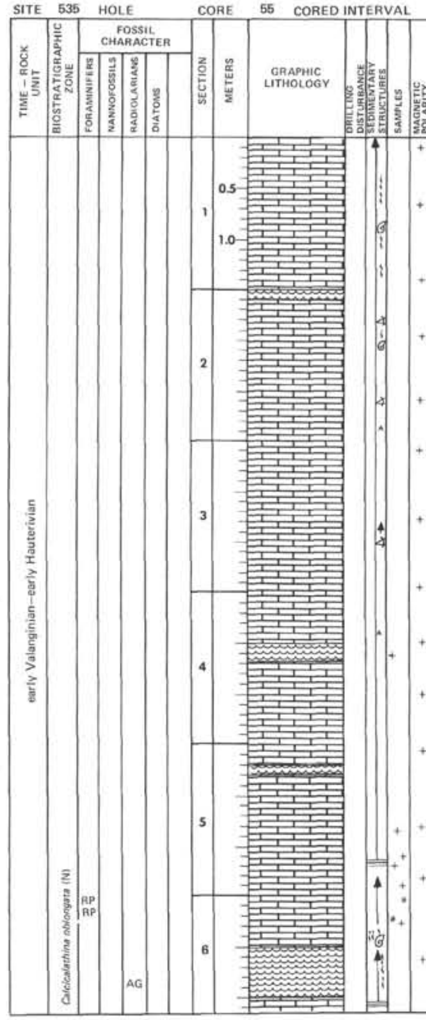
3, 38: Laminated limestone [mudstone] – micritic (99%) limestone in which laminations consist of clayey and less clayey irregular and discontinuous lenses and layers composed of micrite. Trace amount of fine (0.1–0.05 mm) microfossil/skeletal debris. Rare dolomite rhombs are present.

6, 51: Laminated limestone (mudstone) – sample composed principally of micrite (98%) with minor skeletal carbonate (1%) and pyrite (1%). Micrite appears micropelletal. Indistinct light and dark alternations give rise to laminations.

ORGANIC CARBON AND CARBONATE (%):

	1, 23	3, 43	6, 51
Organic carbon	–	–	2.7
Carbonate	71	85	62

SITE 535 HOLE CORE 55 CORED INTERVAL 496.5–506.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE, banded light olive gray (5Y 6/1) to olive gray (5Y 3/2) and greenish gray, laminated throughout except for a thin interval of light greenish gray (5GY 8/1) to very light gray (N8) burrowed ammonite-bearing limestone between Section 5, 125 cm, and Section 6, 50 cm. Laminated limestone shows distinct 10–50 cm light-dark color banding. Several packages of inclined laminations occur as marked. Ammonite and ammonite aptychi occur sporadically. The contacts with the burrowed light limestone in Sections 5 and 6 are gradational; both color and burrowing are transitional at these boundaries. A vertical stylolite occurs between 43 and 71 cm in Section 3.

Thin Section:

6, 9: Limestone (mudstone) – micritic limestone with sparse scattered microfossils. Micrite has slightly clotted appearance; only one sparry, courser zone. Microfossils are mostly small (~0.2 mm) calcite-filled radiolaria with several small planktonic foraminifers and sparse skeletal debris. *Nannoconids* present.

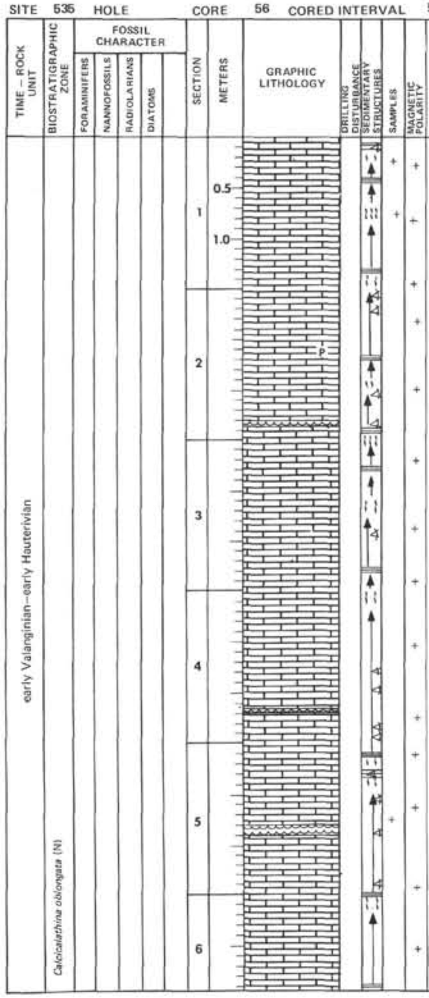
6, 27: Limestone (mudstone) – micritic limestone as in Section 6, 9 cm. Crude concentrations of microfossils in parts of sample give faint laminations. Clay variations also impart layering to the sample. *Nannoconids* common.

ORGANIC CARBON AND CARBONATE (%):

	4, 61	5, 84	5, 111	5, 120	5, 140
Organic carbon	4.6	–	–	–	–
Carbonate	58	68	74	86	90

	6, 30
Organic carbon	–
Carbonate	90

SITE 535 HOLE CORE 56 CORED INTERVAL 506.0–515.5 m



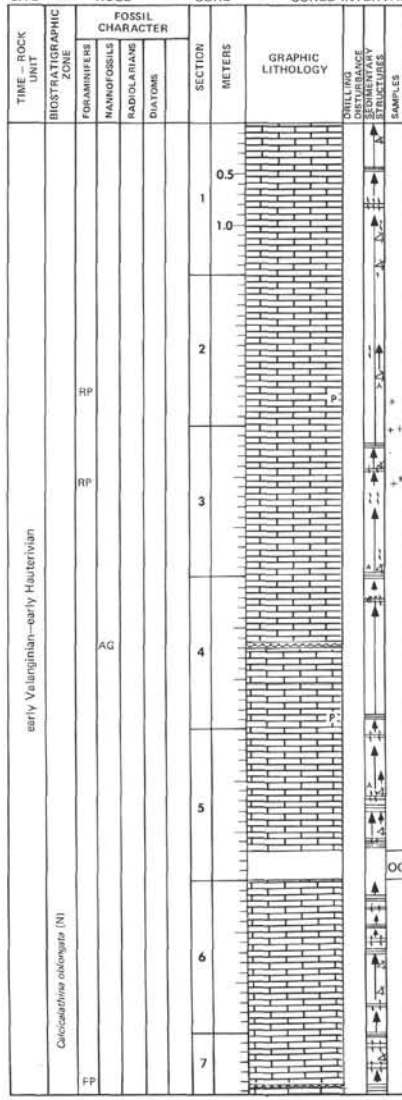
LITHOLOGIC DESCRIPTION

LIMESTONE, banded olive gray (5Y 4/1) to light olive gray (5Y 6/1) and laminated alternating with burrowed light olive gray to very light gray (N8) limestone. Common packages of inclined laminations in laminated limestones as marked. Boundaries between laminated and burrowed intervals are gradational. Some limestones are dark and perhaps marly (e.g. Section 5, 72–80 cm).

ORGANIC CARBON AND CARBONATE (%):

	1, 25	1, 78	5, 78
Organic carbon	–	–	4.48
Carbonate	73	86	43

SITE 535 HOLE CORE 57 CORED INTERVAL 515.5–525.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE, banded olive gray (5Y 4/1) and light olive gray (5Y 6/1) to very light gray (N8) with several dark olive gray intervals. Alternately laminated, indistinctly laminated, and burrowed as marked. Inclined layers (cross laminations?) in the laminated sequences are common. In some places laminations are deformed (pinched and swollen – e.g. at Section 4, 20 cm). Several dark intervals of MARLY LIMESTONE as marked. Scattered ammonite aptychi. Celcite-replaced radiolaria common near middle of core; *calcispheres* abundant near base of core.

Thin Sections:

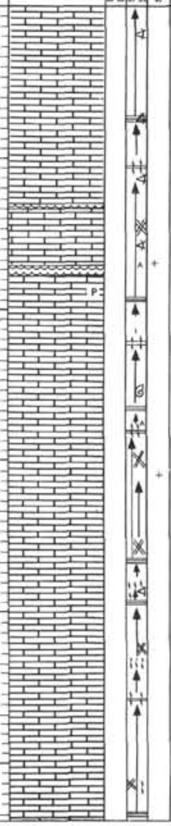
2, 121: Dolomitic limestone (mudstone) – sample contains ellipsoid-shaped gray patches filled with dolomite rhombs and host clayey micrite with pervasive dolomite rhombs. Dolomite (~35%), calcite (65%). Some pyritized and calcitized radiolaria and scattered skeletal fragments in sample.

3, 57: Limestone (mudstone) – micritic (95%) limestone with scattered microfossils, principally spar-filled radiolaria, minor shell debris and planktonic foraminifers. *Nannoconids* common.

ORGANIC CARBON AND CARBONATE (%):

	3, 1	3, 2	3, 58
Organic carbon	–	1.8	–
Carbonate	79	70	85

SITE 535 HOLE CORE 58 CORED INTERVAL 525.0–534.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES
early Valanginian–early Hauterivian	*Calcicalathina oblongata* (N)		AG			1, 2, 3, 4, 5, 6	0.5, 1.0	

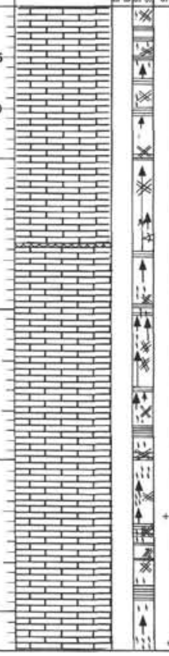
LITHOLOGIC DESCRIPTION

LIMESTONE, light gray (N7) and light olive gray (5Y 6/1) with darker olive gray to olive black intervals, one a MARLY LIMESTONE. Alternately burrowed (planolites type) laminated and indistinctly laminated as marked. Inclined and truncated laminae in some of the laminated limestones. Scattered ammonites and ammonite aptychi. Base of Section 3 and to two-thirds of Section 4 are cut by large fractures partially lined with calcite and filled with tar. Piece in Section 4, 19–29 cm, contains part of a vertical fracture about 2 cm wide filled with black tar. Fracture between Section 4, 40–45 cm, contains brecciated limestone fragments cemented together by tar. Other tar-filled fractures have oil stained areas adjacent to them.

ORGANIC CARBON AND CARBONATE (%):

	2, 106	4, 4
Organic carbon	8.2	3.1
Carbonate	61	83

SITE 535 HOLE CORE 59 CORED INTERVAL 534.0–543.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES
early Valanginian–early Hauterivian	*Calcicalathina oblongata* (N)	RP, RP	AG			1, 2, 3, 4, 5	0.5, 1.0	

LITHOLOGIC DESCRIPTION

LIMESTONE, alternating between very light gray (N8) to light gray (N7) massive, burrowed limestone, light olive gray (5Y 6/1), greenish gray (5GY 6/1) and olive gray (5Y 4/1) laminated to indistinctly laminated limestone with abundant pyrite, and dark olive black MARLY LIMESTONE. Core is cut by abundant calcite-lined, tar-filled fractures. A number of pieces are brecciated with offsets of 1 mm to 1.5 cm (e.g. Section 4, 85–107 cm). Many tar-filled fractures have oil stained areas surrounding them. Several fractures are filled only with calcite. Several stylolitic seams also occur in this core, most not parallel to bedding. Coccospheres and dolomite rhombs noted in samples from Section 3, 77 cm.

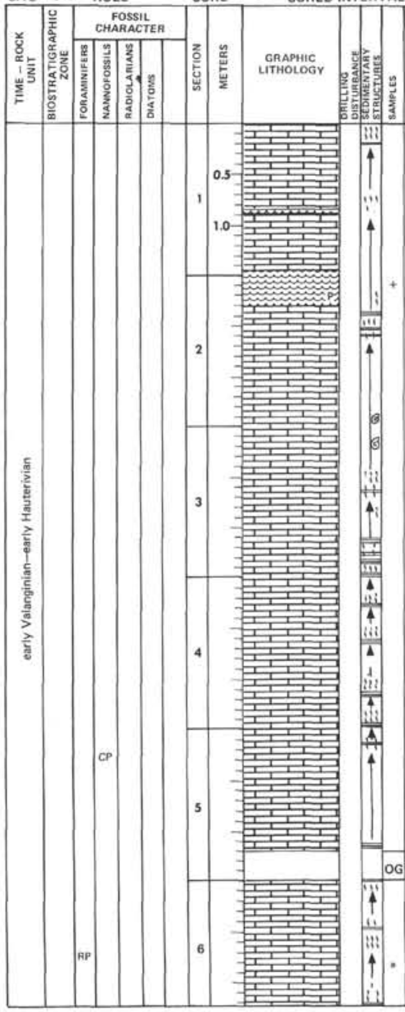
Thin Section:

5, 35: Limestone (mudstone) – massive micritic (98%) limestone with scattered calcite-filled radiolaria, some partly pyritized, and minor skeletal debris. No structure or laminations. *Nannoconids* common.

ORGANIC CARBON AND CARBONATE (%):

	4, 57
Organic carbon	–
Carbonate	70

SITE 535 HOLE CORE 60 CORED INTERVAL 543.0–552.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating between very light gray (N8) to light gray (N7) massive, burrowed limestone, light olive gray (5Y 6/1), olive gray (5Y 4/1), and greenish gray (5GY 6/1) laminated to indistinctly laminated limestone, and olive gray to olive black marly limestone. Most transitions are gradational. Ammonites are abundant in base of Section 2 in light massive limestone; pyrite replaces shells in many cases. Spar fills some ammonites. No good geopetal structures. Scattered fine bioclastic fragments noted in Section 4, possibly ammonites. Planolites is common burrow type.

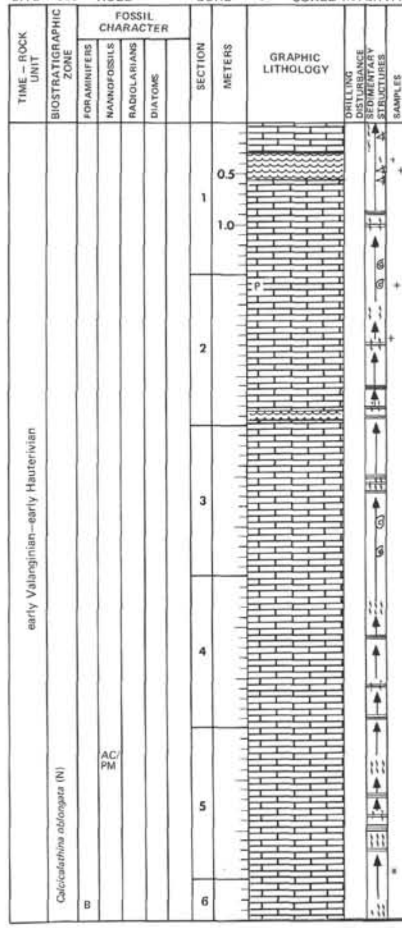
Thin Section:

6, 82: Limestone (mudstone) – micritic limestone was sparse skeletal debris. Approximate composition is micrite (97%), calcareous radiolaria (2%), mollusc fragments and spicules (1%), pyrite and organic matter (traces). *Nannoconids* common.

ORGANIC CARBON AND CARBONATE (%):

	2, 10
Organic carbon	–
Carbonate	65

SITE 535 HOLE CORE 61 CORED INTERVAL 552.0–561.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating between very light gray (N8) burrowed massive limestone, light olive gray (5Y 6/1) laminated to indistinctly laminated limestone, and olive gray (5Y 4/1) to olive black (5Y 2/1) laminated marly limestone. Spar-filled ammonites common in light gray limestone. This type also has medium gray, pyrite-rich mottles. Slightly inclined layers occur in some of the laminated limestones. Stylolitic seam at Section 4, 90 cm. Changes between different limestone types are gradational. Dolomite rhombs noted in sample from Section 5, 69 cm. Calcite-replaced radiolaria in Section 6.

Thin Section:

5, 147: Massive limestone (mudstone) – principally micrite (98%) with scattered calcite-filled radiolaria and filaments. Filaments all aligned in similar direction.

ORGANIC CARBON AND CARBONATE (%):

	1, 39	1, 49	2, 12	2, 64
Organic carbon	–	10.1	–	–
Carbonate	62	44	88	80

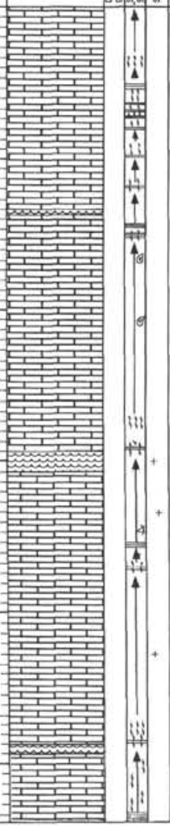
SITE 535 HOLE CORE 62 CORED INTERVAL 561.0–570.0 m

TIME-ROCK UNIT: early Valanginian–early Hauterivian

BIOSTRATIGRAPHIC ZONE: *Calcicalathina oblongata* (N)

FOSSIL CHARACTER: Foraminifers: RP; Nannofossils: CP/M

SECTIONS: 1–6; METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating very light gray (N8) to light olive gray (5Y 6/1) burrowed and massive limestone, laminated to indistinctly laminated light olive gray to olive gray (5Y 4/1) limestone and darker olive gray, olive black (5Y 2/1) to brownish black (5YR 2/1) laminated marly limestone. Contacts between different limestone types are gradational. Ammonites occur in the massive light limestones in Section 2. Burrows are well displayed in Section 3 where light and dark fillings enhance them.

ORGANIC CARBON AND CARBONATE (%):

	4, 1	4,51	5, 42
Organic carbon	–	–	–
Carbonate	55	85	91

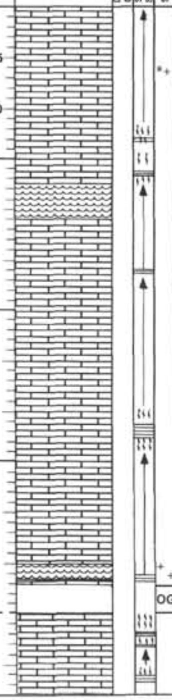
SITE 535 HOLE CORE 63 CORED INTERVAL 570.0–579.0 m

TIME-ROCK UNIT: early Valanginia–early Hauterivian

BIOSTRATIGRAPHIC ZONE: *Calcicalathina oblongata* (N)

FOSSIL CHARACTER: Foraminifers: RP, RP, B; Nannofossils: AG

SECTIONS: 1–5; METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating very light gray (N8) to light olive gray (5Y 6/1), burrowed and massive limestone, laminated to indistinctly laminated and burrowed light olive gray to olive gray (5Y 4/1) limestone, and laminated olive black (5Y 2/1) marly limestone. Two dark marly limestone intervals are marked. Boundaries between limestone types are gradational. Calcite-replaced radiolaria common near middle of core.

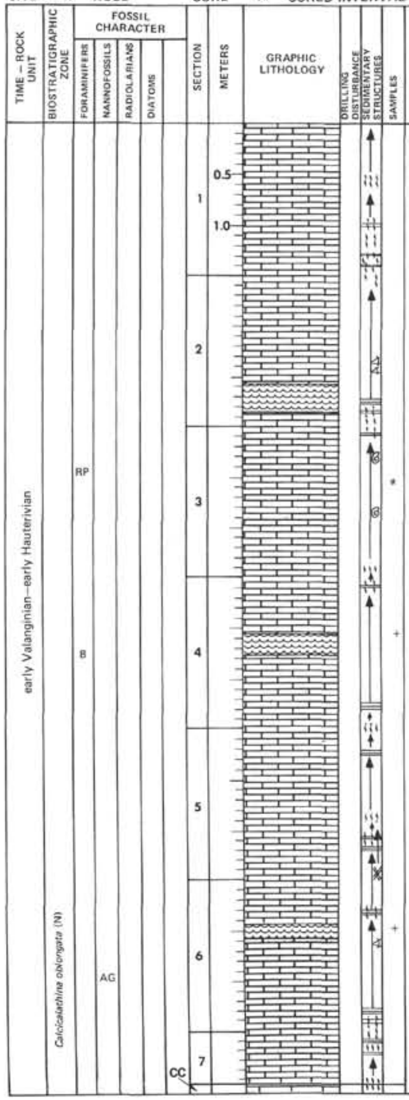
Thin Section:

1, 63: Limestone (mudstone) – micritic (99%) limestone with only scattered microfossils mostly spar-filled radiolaria and filaments. Possible *calpionellids* but slide too thick. No obvious concentrations of fossils or clay to suggest layering. *Nannoconids* common.

ORGANIC CARBON AND CARBONATE (%):

	1, 65	4, 103	4, 112
Organic carbon	–	5.6	–
Carbonate	92	44	57

SITE 535 HOLE CORE 64 CORED INTERVAL 579.0–588.0 m



LITHOLOGIC DESCRIPTION

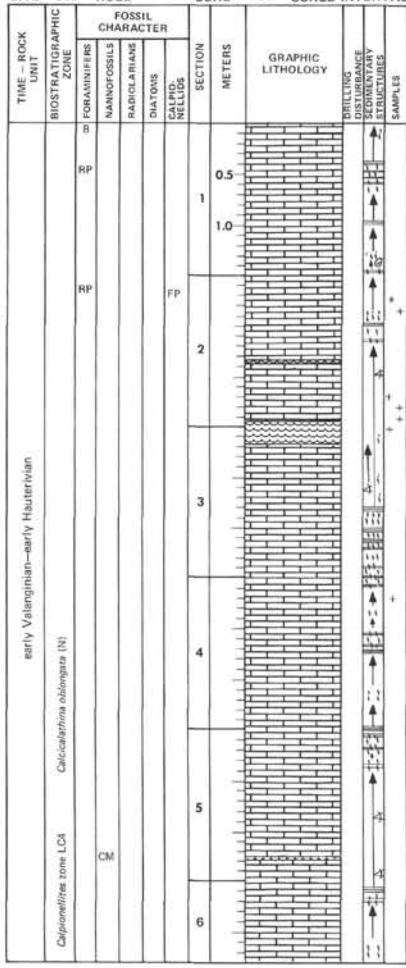
LIMESTONE and MARLY LIMESTONE, alternating burrowed and massive very light gray (N8) to light olive gray (5Y 6/1) limestone with some ammonites, laminated to indistinctly laminated and burrowed light olive gray to olive gray (5Y 4/1) limestone, and olive gray to olive black (5Y 2/1) marly limestone. All contacts between limestone types are gradational, although color changes, particularly to marly limestones, are commonly abrupt. Packages of inclined laminations occur in laminated sequences in Sections 2 and 6. Calcite-lined, tar-filled fractures occur in Sections 4 and 5. Oil stains noted at base of Section 4 and top of Section 6.

Thin Section:
3, 55: Limestone (mudstone) – massive micritic (95%) limestone with scattered microfossils, mostly spar-filled and pyrite-coated radiolaria with some shell debris. *Nannoconids* present.

ORGANIC CARBON AND CARBONATE (%):

	4, 56	6, 49
Organic carbon	13.2	–
Carbonate	44	33

SITE 535 HOLE CORE 65 CORED INTERVAL 588.0–597.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating massive and burrowed light greenish gray (5GY 8/1) to very light gray (N8) limestone with sparse ammonite, burrowed and indistinctly laminated to laminated light olive gray (5Y 6/1) to olive gray (5Y 4/1) limestone, and laminated olive gray (5Y 4/1–5Y 3/2) to olive black (5Y 2/1) marly limestone. Contacts between limestone types gradational with some abrupt color changes. Scattered intervals of inclined laminations in laminated limestones. Some truncation noted. Aligned, light-colored planar spots ~0.2–1 mm long comprise some laminae. Planolites is a common burrow type throughout core. Light gray, burrowed limestone has common darker gray, diffuse mottles (pyrite in burrows?).

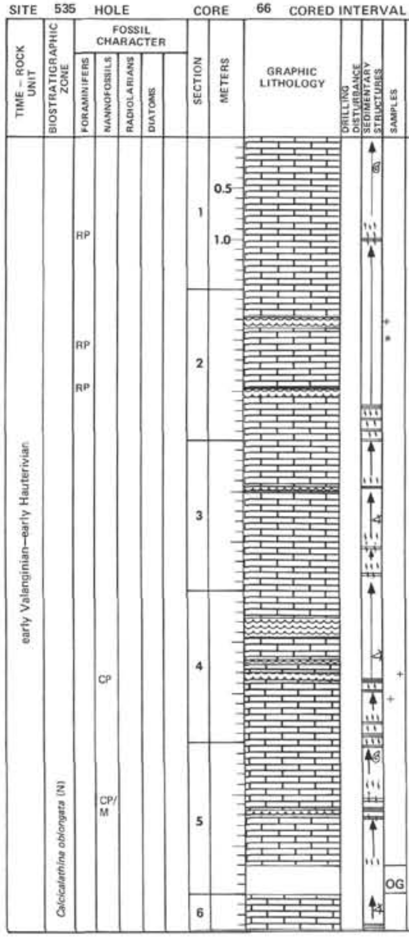
Thin Section:
2, 25: Limestone (mudstone) – micritic (90%) limestone with scattered calcite-filled radiolaria (10%) and minor replaced spines foraminifers and mollusc debris. *Nannoconids* common.

ORGANIC CARBON AND CARBONATE (%)

	2, 38	2, 120	2, 132	2, 145
Organic carbon	0.2	0.5	1.1	2.2
Carbonate	91	88	82	63

	3, 4	4, 20
Organic carbon	–	0.12
Carbonate	61	94

SITE 535 HOLE CORE 66 CORED INTERVAL 597.0–606.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating white (N9) to very light gray (N8) massive and burrowed ammonite-bearing limestone, light olive gray (5Y 6/1) to olive gray (5Y 4/1) laminated to burrowed and indistinctly laminated limestone, and laminated olive gray to olive black marly limestone. Progression of sequences similar to that illustrated for Core 44. All contacts gradational with some abrupt color changes, particularly to marly limestones. Sequences thickness are variable (~40 cm to a meter, including the three limestone types). Inclined layering in some of the laminated intervals. Some dark intervals have abundant light spots and laminae (e.g. Section 2, 55 cm).

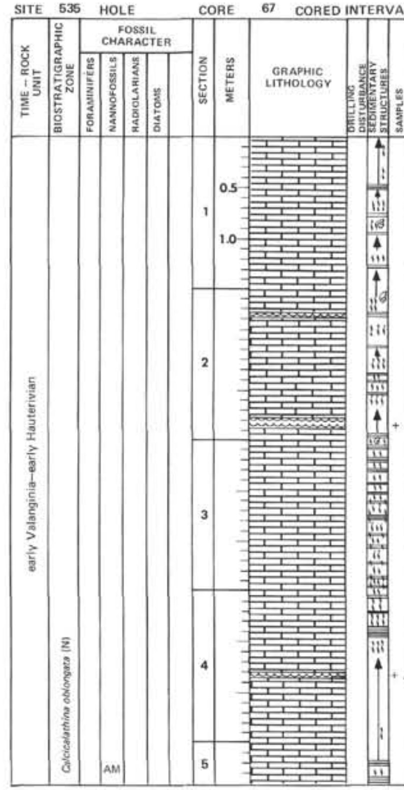
Thin Section:

2, 49: Limestone (mudstone) – micrite (95%) with some coarser grained calcite microfossil debris, mainly radiolaria but with several benthic foraminifers and shell fragments. No concentrations of skeletal debris in thin section.

ORGANIC CARBON AND CARBONATE (%):

	2, 35	4, 81	4, 107
Organic carbon	3.12	–	–
Carbonate	61	60	90

SITE 535 HOLE CORE 67 CORED INTERVAL 606.0–610.0 m



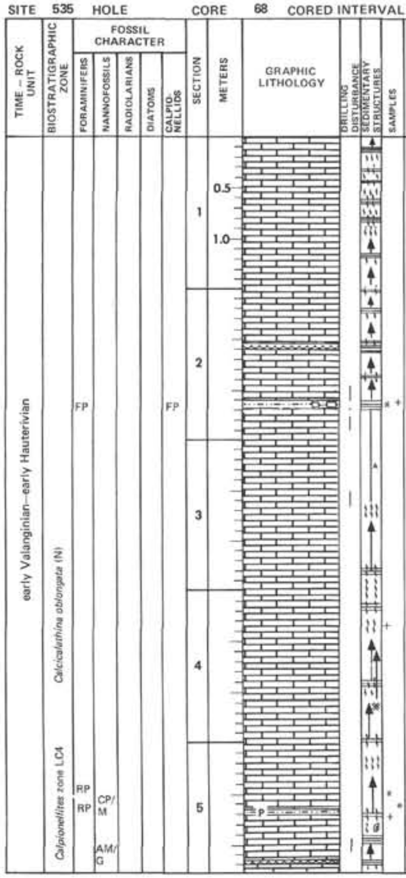
LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating very light gray (N8) massive and burrowed to indistinctly laminated limestone, laminated to indistinctly laminated light gray (N7) to light olive gray (5Y 6/1) limestone, and laminated olive gray (5Y 4/1) to olive black (5Y 2/1) marly limestone. All contacts gradational. Darker marly intervals less abundant and thinner than in Cores 65 and 66. Light limestone is mottled with medium gray pyrite-rich blotches and scattered calcite- and pyrite-filled radiolaria. Scattered ammonites occur in this limestone. Section 1, 0–50 cm, contains light–dark alternations each about 1–2 cm thick. Rare dolomite rhombs and pollen grains, and common pyrite, and abundant coccoliths at Section 5, 37 cm.

ORGANIC CARBON AND CARBONATE (%):

	2, 134	4, 83	4, 88
Organic carbon	2.9	–	–
Carbonate	58	64	89

SITE 535 HOLE CORE 68 CORED INTERVAL 610.5–619.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE, MARLY LIMESTONE, and CALCAREOUS MUDSTONE alternating very light gray (N8) massive and burrowed to indistinctly laminated ammonite-bearing limestone with pyrite-rich medium gray mottling, laminated to indistinctly laminated and burrowed light olive gray (5Y 6/1) to olive gray (5Y 4/1) limestone, and laminated olive gray to olive black (5Y 2/1) marly limestone and calcareous mudstone. Differs from Core 67 in that laminated limestones are more variable in color and white limestones have a greenish tint. Most contacts gradational as in overlying cores; sharp contact at Section 2, 118 cm, between dark marly limestone and underlying white limestone is between two pieces and may be artifact of drilling. Top of white limestone at this contact is burrowed with several (stylolitic?) fractures. Fragments of white limestone fill holes on surface of this piece. Scattered chondrites type burrows throughout core. Calcite-filled fracture in Section 4. Thin medium light gray (N6) pyrite-rich MUDSTONE occurs at ~75 cm in Section 5. Common dolomite rhombs and coccolith at Section 5, 73 cm.

Thin Section:

2, 119: Limestone (mudstone) – mainly micrite (95%) with very little scattered shell debris plus foraminifers and radiolarians. Several 1–2 mm long, oblong patches of finely divided pyrite are distinctly different than enclosing micrite – possible cross sections of burrows. *Nannoconids* common.

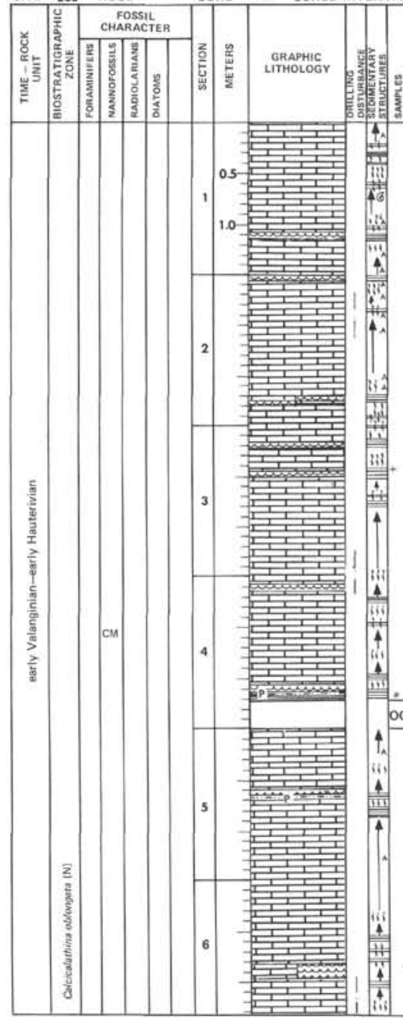
5, 50: Dolomitic limestone (mudstone) – wavy laminated dolomitic micrite. Dolomite crystals (~5–10 μm) along an edge of light band of calcite cutting across section containing quartz silt and needle-shaped (50–60 μm long) opaque grains, probably marcasite.

5, 63: Dolomitic limestone (mudstone) – mottled darker and lighter micritic patches speckled pervasively with small rhombic to sub-rhombic dolomite crystals and a few scattered, calcite-filled radiolaria.

ORGANIC CARBON AND CARBONATE (%):

	2, 117	4, 37	5, 97
Organic carbon	–	–	–
Carbonate	22	83	15

SITE 535 HOLE CORE 69 CORED INTERVAL 619.5–628.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating light gray (N8) to white (N9) massive and burrowed limestone with sparse medium gray pyritie-rich mottles, laminated to indistinctly laminated and burrowed greenish gray (5GY 6/1) to light greenish gray (5GY 8/1) limestone, and olive gray (5Y 4/1) to olive black (5Y 2/1) laminated marly limestone. Contacts gradational but color changes abrupt as in overlying cores. Abundant ammonite aphychi in Sections 1 and 2 in white limestone. Common and well displayed chondrites type burrows in Sections 4 and 5. Two thin layers of pyrite-rich MUDSTONE in Sections 4 and 5. Laminated limestones commonly have dark laminae that are stylolitic (e.g. Section 3, 50 and 75 cm); many are irregular and wispy and enclose small lenses of lighter limestone.

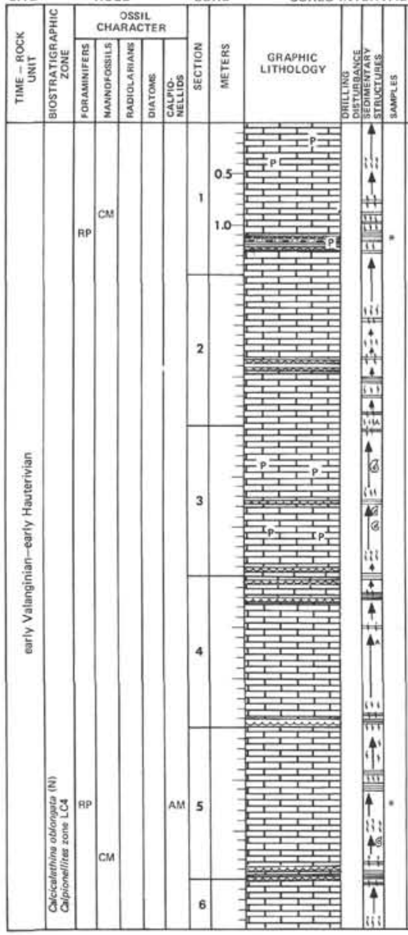
SMEAR SLIDE SUMMARY (%):

	4, 115
Composition:	
Quartz	1
Clay	95
Pyrite	2
Calc. nannofossils	1

ORGANIC CARBON AND CARBONATE (%):

	3, 44	6, 87
Organic carbon	–	3,4
Carbonate	49	44

SITE 535 HOLE CORE 70 CORED INTERVAL 628.5–637.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating white (N9) to very light gray (N8) massive and extensively burrowed limestone, streaky olive gray (5Y 4/1) to light olive gray (5Y 6/1) laminated to indistinctly laminated and burrowed limestone, and laminated olive gray to olive black (5Y 2/1) marly limestone. Contacts gradational but color changes sometimes sharp as in overlying cores. White limestone and some of the laminated and indistinctly laminated light olive gray limestone have 1–3 cm long pyrite streaks and abundant pyrite mottling. Three thin (1–2 cm) layers of pyrite-rich MUDSTONE occur, one in Section 1 as marked and two in Section 5 (not shown). Ammonites common as white limestone in Section 3. Chondrites is common burrow type. Dolomite rhombs, coccoliths, pyrite and quartz silt noted at Section 1, 93 cm.

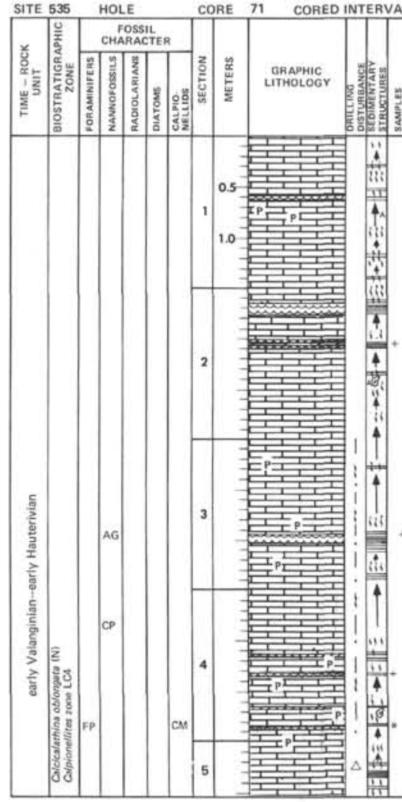
Thin Section:

5, 76: Limestone (mudstone) – structureless limestone composed mostly of micrite (98%) with scattered calcite-filled radiolaria, a few possible *calpionellids* and silt-size quartz grains. *Nannoconids* present.

SMEAR SLIDE SUMMARY (%):

	1, 114
	D
Composition:	
Quartz	Tr
Clay	80
Pyrite	20
Carbonate unspec.	Tr

SITE 535 HOLE CORE 71 CORED INTERVAL 637.5–646.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating white (N9), yellowish gray (5Y 8/1) to very light gray (N8) and light greenish gray (5GY 8/1) massive and burrowed limestone, light olive gray (5Y 6/1) to olive gray (5Y 4/1), laminated to indistinctly laminated and burrowed limestones and olive gray to olive black (5Y 2/1) marly limestone. Contacts are often artificially sharp drilling breaks. Upper contact of white limestone at Section 2, 90 cm, is irregular, burrowed, contains ammonites and shell debris and several stylolitic subhorizontal fractures or seams, and is tinted dusky blue (5PB 3/2), pale blue green (5BG 7/2) and dusky green (5G 3/2). Olive gray (5Y 4/1) clay (glauconite?) lines the more prominent stylolitic surfaces in this limestone near its upper contact. Common stylolites in laminated limestones. Chondrites is common burrow type. Common coccoliths in marly limestone at Section 3, 93 cm. Dolomite rhombs at Section 5, 43 cm.

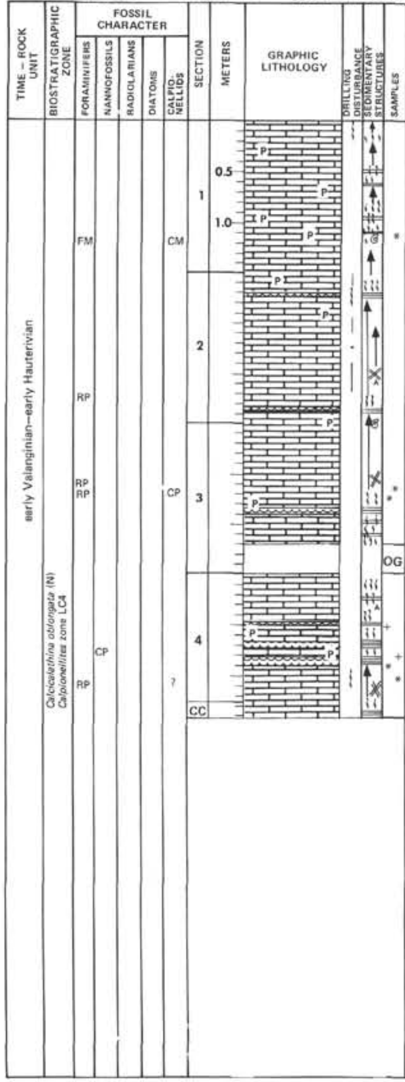
Thin Section:

4, 139: Limestone (mudstone) – massive limestone composed mainly of micrite (98%) with scattered microfossils – round, calcite-filled radiolaria, *calcispheres* and some skeletal debris. *Calpionellids* are common. Several large pyrite crystals also in this section. *Nannoconids* present.

ORGANIC CARBON AND CARBONATE (%):

	2, 56	3, 97	4, 84
Organic carbon	–	6.6	–
Carbonate	55	45	66

SITE 535 HOLE CORE 72 CORED INTERVAL 646.5–655.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating very light gray (N8) to white (N9) and mottled pale yellowish brown (10YR 6/2) massive, burrowed limestone, light olive gray (5Y 6/1) burrowed and indistinctly laminated to laminated limestone, and olive gray (5Y 4/1) to olive black (5Y 2/1) and dark greenish gray (5GY 4/1) marly limestone. White limestone is predominant type in this core; contains more brownish mottling than that in overlying cores. Contacts are gradational where preserved, sharp where broken by drilling. White limestone is medium bluish gray (5B 5/1) at Section 1, 112 cm, just below a small piece of marly limestone with stylolitic laminae. This light limestone has common small ammonite fragments and whole specimens, subhorizontal stylolitic seams or fractures, mollusc fragments, and pyrite (pieces between 112–118 cm, Section 1). Laminated and indistinctly laminated light olive gray limestones in Sections 3 and 4 have subtle greenish and reddish brown tints. Calcite-filled fractures occur in Sections 2–4. Dolomite and pyrite common at Section 4, 83 cm.

Thin Sections:

1, 115: Bioclastic limestone (skeletal wackestone) – complex skeletal wackestone with skeletal debris (~15%) including ammonite, mollusc, and gastropod(?) fragments (up to 1 cm across), benthic foraminifera and some *calpionellids*. All shell material has been recrystallized to blocky and coarse-grained calcite. Geopetal structure and void-fill spar common in larger fossils. Skeletal fragments set in matrix of micrite (80–85%). Fine-grained pyrite replaces some shell fragments as well as micrite in a blotchy pattern. Several bifurcating, pyrite-coated stylolites and numerous calcite-filled veins in this sample. *Nannoconids* common.

3, 63: Limestone (mudstone) – micritic limestone with small (~0.1–0.5 mm) irregular patches of slightly coarser-grained micrite and scattered calcite-filled radiolaria and skeletal fragments. No laminations or concentrations of microfossil debris noted. *Nannoconids* present.

3, 74: Limestone (mudstone) – same as Sample at Section 3, 63 cm but some radiolaria are filled with micrite and several *calpionellids* are present. *Nannoconids* common.

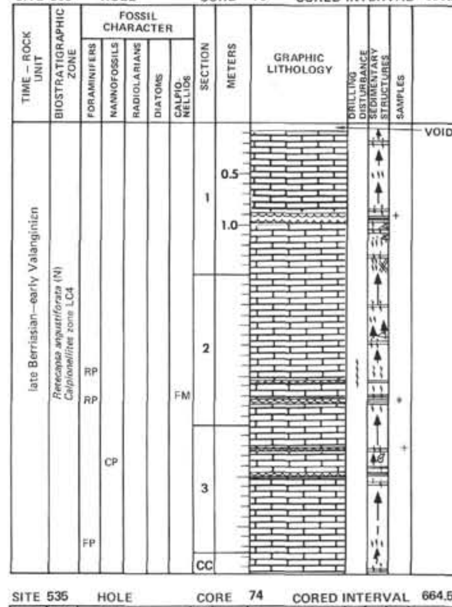
4, 95: Limestone (mudstone) – micritic (98%) limestone with scattered microfossils (2%) mainly calcite-filled radiolaria, small filaments(?) and a few small foraminifera. Indistinct laminations or layering in this sample come from darker and lighter zones of micrite and from crude concentrations of microfossils. *Nannoconids* present.

4, 105: Limestone (mudstone) – same as Section 4, 95 cm. *Nannoconids* rare or poorly preserved.

ORGANIC CARBON AND CARBONATE (%):

	4, 51	4, 84
Organic carbon	–	5.5
Carbonate	74	58

SITE 535 HOLE CORE 73 CORED INTERVAL 655.5–664.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating very light gray (N8), to light greenish gray (5GY 8/1) massive and burrowed limestone, laminated to burrowed and indistinctly laminated light gray to light greenish gray (5GY 8/1) limestone, and laminated and pyrite-rich olive black (5Y 2/1) marly limestone. Light colored limestone more greenish than overlying cores. Massive light gray limestones have scattered ammonites and some pyrite mottling. Laminated limestone have thin stylolitic marly laminae in places (e.g. Section 3, 23–40 cm). Marly limestones have abundant pyrite and thin stylolitic laminae. Drilling has destroyed some contacts between limestone types. Where preserved they are gradational; color changes are sharp. Dolomite, pryite, and quartz silt noted at Section 3, 46 cm.

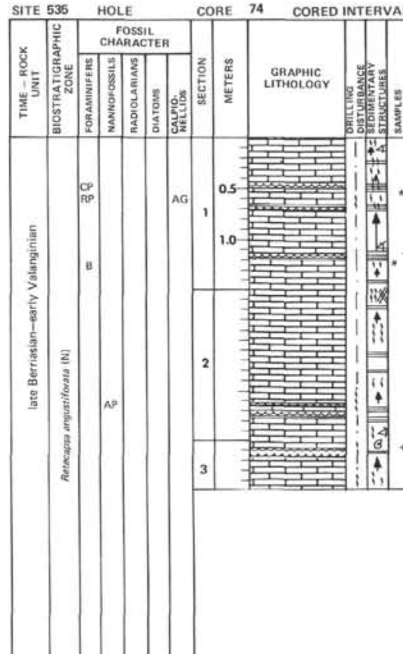
Thin Section:

2, 125: Dolomitic marly limestone (mudstone) – micritic (85%) limestone with scattered small (~0.2 mm) spar-filled radiolaria and some skeletal debris (2%). Screen of incipient dolomitization (~13%[+]) covers most of the slide. Dolomite appears to occur as small (~0.5 mm) rhombs, but are difficult to resolve through the micrite. *Nannoconids* present.

ORGANIC CARBON CARBONATE (%):

	1, 93	3, 23
Organic carbon	–	–
Carbonate	44	64

SITE 535 HOLE CORE 74 CORED INTERVAL 664.5–673.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating very light gray (N8) to light olive gray (5Y 6/1) massive burrowed limestone, banded, laminated to burrowed and indistinctly laminated light olive gray (5Y 6/1) to olive gray (5Y 4/1) limestone, and olive black (5Y 2/1) marly limestone. Ammonites in light limestone at top Section 3. Distinction between very light gray massive limestone and light olive gray laminated and burrowed limestone is less distinct than in overlying cores. Some inclined layers occur in laminated limestone. Calcite-filled fractures in top Section 2. Contacts between light colored limestones are generally gradational. Sharp color changes between darker marly limestones and these lighter limestones; some are drilling artifacts, others are real.

Thin Section:

1, 57: Limestone (mudstone) – sample consists of micrite (54%), calcareous nannofossils (*nannoconids*) (30%), clay (5%), pyrite (1%), calcitized radiolaria (10%), *calpionellids* (Tr), and sponge spicules (Tr).

1, 121: Dolomitic limestone (mudstone) – mostly micrite (65%) with a pervasive overprint of dolomite rhombs (~35%). Only a few microfossils occur, mostly pyrite-rimmed and spar-filled radiolaria. Blotchy lenticular zones of fine- and coarser-grained dolomite give rock a mottled appearance and a hint of faint layering. Finer-grained dolomite in lenses may be fill of small burrows that have been flattened.

ORGANIC CARBON AND CARBONATE (%):

	1, 112	3, 10
Organic carbon	–	–
Carbonate	57	65

SITE 535 HOLE CORE 75 CORED INTERVAL 673.5–682.5 m

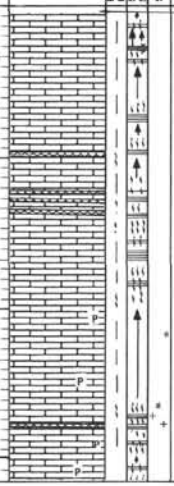
TIME – ROCK UNIT: late Berriasian–early Valanginian

BIOSTRATIGRAPHIC ZONE: *Retecapsa angustiforata* (N); *Calpionellopsis* zone D3, LC3

FOSSIL CHARACTER (FORAMINIFERS / NANNOFOSSILS / RADIOLARIANS / DIATOMS): CM; FP; B; B CM AG; CM

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

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating very light gray (N8) to light olive gray (5Y 6/1) burrowed to faintly laminated limestone, light olive gray (5Y 6/1) to olive gray (5Y 4/1) laminated to indistinctly laminated and burrowed limestone, and laminated olive black (5Y 2/1) marly limestone. Light limestone types are somewhat similar as in overlying core. Common olive gray stylolitic and anastomosing clayey seams in these limestones. No ammonites recorded. Pyrite mottling is common. Laminations near top Section 1 are variably inclined. Coccoliths, dolomite rhombs, and pyrite occur at Section 1, 142 cm; coccoliths and pyrite at Section 3, 104 cm. Thin Section at Section 3, 27 cm suggests part of this core may be a calcareous dolostone.

Thin Section:

3, 27: Calcareous dolomite – sample consists of abundant small (5–15 μm) dolomite rhombs set in a micritic calcite matrix (~ 70% dolomite/30% calcite). *Calpionellids* are rare.

3, 98: Limestone (mudstone) – mostly micrite (96%), with sparse calcitized radiolaria (2%), *calpionellids* (1%), dolomite rhombs (1%), filaments (Tr), and some fish remains (Tr).

ORGANIC CARBON AND CARBONATE (%):

	3, 116
Organic carbon	3.0
Carbonate	43

SITE 535 HOLE CORE 76 CORED INTERVAL 682.5–691.5 m

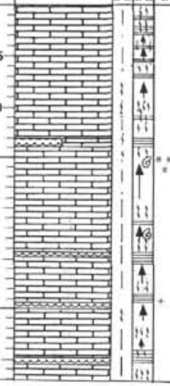
TIME – ROCK UNIT: late Berriasian–early Valanginian

BIOSTRATIGRAPHIC ZONE: *Retecapsa angustiforata* (N); *Calpionellopsis* zone D2, LC3

FOSSIL CHARACTER (FORAMINIFERS / NANNOFOSSILS / RADIOLARIANS / DIATOMS / CALPIONELLIDS): FP FM FP; AG; CP; FG FM AG

SECTION: 1, 2, 3 — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating very light gray (N8) to white (N9) massive burrowed limestone, very light gray to light olive gray (5Y 6/1) laminated, indistinctly laminated and burrowed limestone, and laminated olive black (5Y 2/1) marly limestone. Distinction between light limestone types is better than in two overlying core. Pieces of white limestone at 120 cm, Section 1, and at 4–12 and 75–82 cm, Section 2 mottled with grayish pyrite patches. The pieces in Section 2 have subhorizontal stylolitic surfaces, ammonites, and shell debris similar to the white limestone at Section 2, 90 cm, Core 71. Drilling has destroyed most contacts, but where preserved they are gradational. Sharp color changes between light limestone and darker marly limestone. Coccoliths common in Section 2, 96 cm.

Thin Section:

2, 3: Bioclastic limestone (skeletal wackestone) – this rock is a mixture of skeletal fragments (30%) and two generations of micrite. Skeletal debris includes mostly fragments of ammonites – molluscs (15%), gastropods (3%), and bryozoans/green algae(?) (Tr), as well as *calpionellids* (5%), *calcisoheres* (3%), and spar-filled radiolarians (2%). Geopetal structure is common for large shell fragments; several specimens show consistent up direction. Most shell walls of the large fragments replaced by blocky calcite; blocky calcite also fills space in shell chambers above geopetal fill. Some micritized gastropod shells noted. One oyster(?) shell fragment has original fibrous calcite structure. Largest shell fragment in this section is 5 mm long. Light micrite is geopetal fill in large mollusc/gastropod shells; it also fills most *calpionellids*. Light micrite occurs as irregular patches in (later?) darker micrite and as larger areas; one area looks like a micrite intraclast that has been bored, the coring(?) filled with darker micrite. Dark micrite is mostly matrix material, never occurring as geopetal fill. *Nannoconids* present.

2, 6: Bioclastic limestone (skeletal wackestone) – very similar to Section 2, 3 cm. Estimate of composition is 78% micrite, 10% *calpionellids*, 3% radiolaria, 2% ammonite fragments, 2% gastropods, 2% molluscs, 2% foraminifers, and 1% pyrite. Two generations of micrite. Darker micrite may contain finely divided pyrite. It appears to have a pseudopelletal structure; lighter micrite is nonpelletal. *Nannoconids* present.

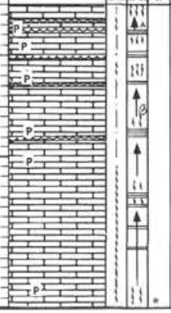
2, 12: *Calpionellid* limestone (wackestone) – sample is composed of micrite (~ 80%) with common *calpionellids* (10%) and *calcispheres* (10%) plus minor calcite-filled radiolaria (2%) and some skeletal debris (< 1%). Micrite is of two types (light and dark). Light micrite fills most of skeletal debris. One large mollusc fragment has light micrite geopetal fill that contains *calpionellids*. This shell has sinuous discontinuous rod-shaped patches of spar in geopetal fill; similar rod-shaped spar bodies occur in nearby sediment – either borings or shell fragments. *Nannoconids* common.

ORGANIC CARBON AND CARBONATE (%):

	2, 142
Organic carbon	–
Carbonate	44

SITE 535 HOLE CORE 77 CORED INTERVAL 691.5–696.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	CALPIONELLIDS	SECTION	METERS
early Valanginian–late Berriasian	*Retecapsa angustiforata* (N) *Calpionellopsis* zone D2, LC3	CP, CP	CM			CG	1, 2	0.5, 1.0



LITHOLOGIC DESCRIPTION

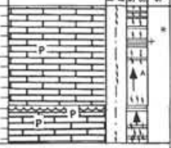
LIMESTONE and MARLY LIMESTONE, alternating very light gray (N8) to yellowish gray (5Y 8/1), burrowed to faintly banded or laminated limestone with sparse greenish gray to olive gray laminae, light olive gray (5Y 6/1) to greenish gray (5GY 6/1) limestone with streaky and irregular olive gray laminations, and laminated olive gray (5Y 3/2) to olive black (5Y 2/1) limestone with dark yellowish brown (10YR 4/2) tint. Occasional ammonites noted in light limestone. Some clayey seams in both light limestone and darker marly limestone are stylolites. Dolomite rhombs, pyrite and coccoliths noted at Section 2, 74 cm.

Thin Section:

2, 143: Limestone (mudstone) – micritic limestone with ~10% calcite-filled radiolaria, 1–2% *calpionellids* and one ostracod noted. *Nannoconids* present.

SITE 535 HOLE CORE 78 CORED INTERVAL 696.0–705.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	CALPIONELLIDS	SECTION	METERS
late Berriasian–early Valanginian	*Retecapsa angustiforata* (N) *Calpionellopsis* zone D2, LC3	RP, RP	CP			CM	1	0.5, 1.0



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating white (N9) to very light gray (N8) burrowed to massive limestone with scattered olive gray. Stylolitic layers and laminations, light olive gray (5Y 6/1) to olive gray (5Y 4/1) laminated to burrowed limestone, and laminated pyrite-rich olive gray to olive black (5Y 2/1) marly limestone. Olive gray limestone between 26–38 cm has streaky, lensoid layers of white limestone in it; wispy clay seams surround the lenses. Marly limestone at 100 cm has a lens of pyrite ~3 mm thick in it plus two thin (1–2 mm) layers of pyrite-rich mudstone. Core has been broken into pieces by drilling.

Thin Section:

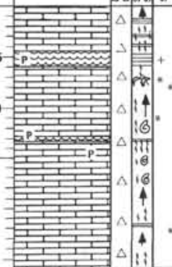
1, 23: *Calpionellid* limestone (mudstone) – sample consists of ~7% *calpionellids*, rare replaced radiolarian, and mollusc debris in homogeneous micrite. Sample is indistinctly laminated. *Nannoconids* present.

ORGANIC CARBON AND CARBONATE (%):

	1, 35
Organic carbon	–
Carbonate	70

SITE 535 HOLE CORE 79 CORED INTERVAL 705.0–714.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	CALPIONELLIDS	SECTION	METERS
late Berriasian–early Valanginian	*Retecapsa angustiforata* (N) *Calpionellopsis* zone D1, LC3	FP, CP, CP	AM, AP			AG	1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE, alternating burrowed very light gray (N8) to light gray (N7) limestone (skeletal packstone to wackestone) containing abundant whole and fragmented mollusc shells, ammonites, and subhorizontal stylolitic fractures, very light gray to white homogeneous to faintly laminated, burrowed limestone with minor pyrite and some olive gray (5Y 4/1) and light olive gray (5Y 6/1) layers and seams, and olive black (5Y 2/1) laminated and pyrite-rich marly limestone. Core is broken into pieces that may have been rotated and displaced in the liner; spacers have been placed in liners. White limestone fragments with abundant skeletal debris occur between 65–121 cm, Section 1, and 0–10, 34–36, and 65–75 cm in Section 2. Round (cross-section) calcite-coated grains ~1 cm in diameter occur in pieces at 70, 79, 96, and 108 cm, Section 1. Piece at 88 cm has abundant pyrite (and chalcopyrite?) on upper irregular surface (~0.5–1 cm thick) which forms dendritic patterns downward into white limestone. Pyrite also surrounds and coats shell debris at top of this piece and lines a partial stylolite. Piece at 70 cm has pyrite-filled spaces between skeletal fragments. Common stylolites separate pieces with skeletal fragments from more massive white limestone (eg. at 36 and 101 cm in Section 2). Some of these stylolites are lined with pale green clay (glauconite?). Pieces at base Section 1 have irregular patches of clearer light to medium gray limestone in host light greenish gray limestone. Some skeletal debris is replaced by pyrite. Vertical stylolite at 108 cm, Section 2.

Thin Sections:

1, 77: Bioclastic limestone (skeletal wackestone) – sample is chaotic mixture of skeletal grains (~40%) in light and dark micrite (~60%). No clear relation between light and dark micrite types. Skeletal fragments are molluscs (~10%), coated grains (10%), *calpionellids* (7%), *calcispheres* (7%), filled radiolaria (7%), and foraminifera (Tr) and several glauconitic-phosphatic pellets. Coated grains mostly have recrystallized mollusc fragment cores; few have fish debris. Some coatings are assymetric. Some concentric laminae have recrystallized to spar.

1, 83: Bioclastic limestone (skeletal wackestone) – similar to Section 1, 77 cm. Composition is micrite (64%), coated grains (~15%), *calpionellids* (10%), mollusc fragments (5%), foraminifers (5%), echinoderms (Tr), and pyrite (1%). Coated grains up to 2 mm long with concentric laminations formed by calcite crystal-size variation. Some laminae as thin as 5 μm and may be organic rich. Most cores are mollusc fragments, one gastropod fragment core and one planktonic foraminifer. Several erosional surfaces noted. Two micrite generations, one pelloidal and dark, the other homogeneous and light gray.

1, 111: Bioclastic limestone (skeletal wackestone) – similar to Section 1, 83 cm, with micrite (50%), mollusc fragments (15%), *calpionellids* (15%), calcite spar (15%), echinoderm fragments (3%), and benthic foraminifers (2%). Molluscs preserved as coated grains and micrite rims. Cements coarsen towards interior of grains and pores. Micrite occurs on upper surfaces of mollusc fragments in cement-rich areas. Prominant erosional horizon cuts across sample; fractures and molds below this horizon partially filled with micrite.

2, 79: Limestone (mudstone) – mostly micrite (91%) with some *calpionellids* (5%), globosphaerite (2%), pyrite (1%), filaments (1%), and clay (Tr).

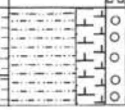
ORGANIC CARBON AND CARBONATE (%):

	1, 55
Organic carbon	4.0
Carbonate	31

SITE 539 HOLE CORE 1 CORED INTERVAL 0.0–1.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Pleistocene–Holocene	*Emiliania huxleyi*		AG			1	0.5
						CC	

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

NANNOFOSSIL MUD, pale yellowish brown (10YR 6/2) to light olive gray (5Y 6/1), soupy.

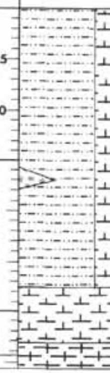
SMEAR SLIDE SUMMARY (%):

	1, 2 M	1, 62 D
Texture:		
Sand	5	5
Silt	35	39
Clay	60	56
Composition:		
Quartz	5	1
Mica	1	2
Clay	61	56
Carbonate unspec.	5	5
Foraminifers	5	5
Calc. nannofossils	20	30
Diatoms	1	–
Radiolarians	1	–
Sponge spicules	1	1

SITE 539 HOLE CORE 2 CORED INTERVAL 1.0–7.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Pleistocene–Holocene	*Emiliania huxleyi* zone (N)		AG			1, 2	0.5, 1.0
late Pliocene early Pleistocene	*Discoaster dentaradiatus*		AG			3, CC	

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

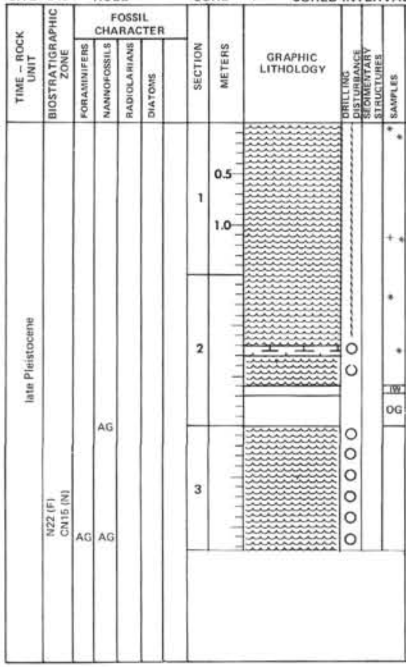
NANNOFOSSIL MUD, NANNOFOSSIL OOZE, and FORAMINIFERAL NANNOFOSSIL OOZE. Mud is light olive gray (5Y 6/1) to olive gray (5Y 4/1) with scattered grayish green (10G 4/2) glauconitic laminations in lower part of Section 1. Nannofossil ooze is light gray (N7) to very light gray (N8) with light olive gray (5Y 6/1) and greenish gray (5GY 6/1) streaks. Nannofossil-foraminiferal ooze is light gray (N7) to greenish gray (5GY 6/1) with some darker streaks. Core very deformed by drilling.

SMEAR SLIDE SUMMARY (%):

	1, 40 D	1, 137 M	2, 18 M	2, 144 M
Texture:				
Sand	1	30	40	5
Silt	26	35	30	75
Clay	73	44	30	20
Composition:				
Clay	73	44	30	20
Volcanic glass	–	–	20	–
Glauconite	–	30	–	–
Pyrite	–	–	10	–
Carbonate unspec.	5	5	5	5
Foraminifers	1	5	20	5
Calc. nannofossils	20	20	20	67
Diatoms	–	–	–	2
Sponge spicules	1	1	–	1
Plant debris	–	–	–	–
Dolomite	–	–	–	–

	3, 36 D
Texture:	
Sand	–
Silt	–
Clay	–
Composition:	
Clay	5
Volcanic glass	5
Glauconite	–
Pyrite	–
Carbonate unspec.	5
Foraminifers	10
Calc. nannofossils	75
Diatoms	–
Sponge spicules	–
Plant debris	Tr
Dolomite	Tr

SITE 540 HOLE CORE 1 CORED INTERVAL 0.0–4.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARL, light olive gray (5Y 6/1), medium gray (N6) to olive gray (5Y 4/1) with some light yellowish brown (10YR 6/4) patches and streaks. Interval of pale green (10G 6/2) semi-lithified NANNOFOSSIL OOZE occurs at 70–80 cm, Section 2. Ooze is also mixed with marl from 50–124 cm in Section 3. Intense drilling deformation.

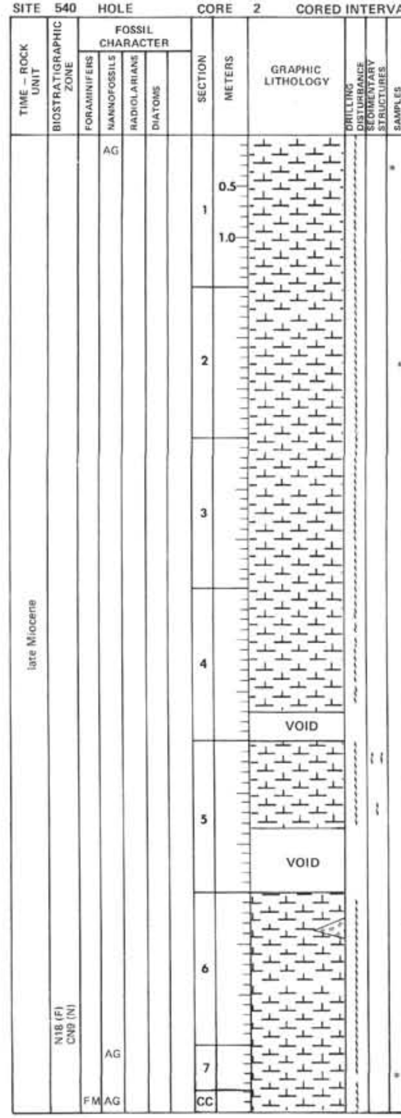
SMEAR SLIDE SUMMARY (%):

	1, 16 D	1, 116 D	2, 21 D	2, 75 M
Texture:				
Sand	5	10	5	–
Silt	55	60	67	60
Clay	40	30	28	40
Composition:				
Quartz	–	–	–	Tr
Mica	Tr	–	Tr	–
Clay	40	30	28	40
Volcanic glass	2	–	10	Tr
Glauconite	–	–	–	Tr
Carbonate unspec.	5	5	5	10
Foraminifers	5	10	5	–
Calc. nannofossils	45	40	50	45
Diatoms	1	5	2	–
Radiolarians	1	Tr	Tr	–
Sponge spicules	Tr	Tr	Tr	–
Plant debris	1	–	–	–
Pteropods	Tr	–	–	–
Tunicate spicules	Tr	Tr	–	–
Dolomite	–	–	–	1

ORGANIC CARBON AND CARBONATE (%):

	1, 6	1, 116
Organic carbon	–	–
Carbonate	63	51

SITE 540 HOLE CORE 2 CORED INTERVAL 4.5–14.0 m



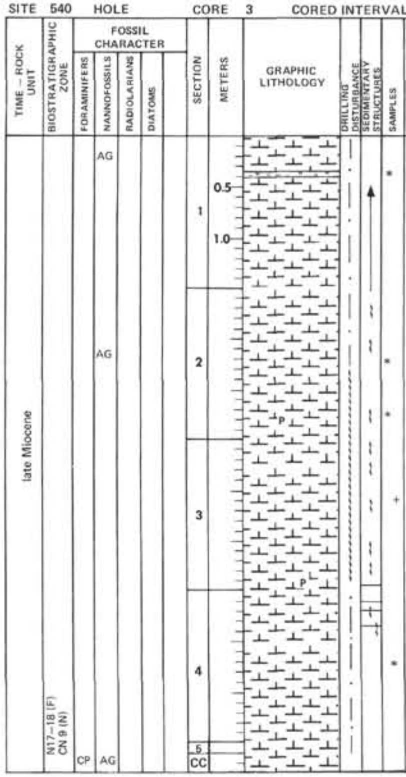
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, light greenish gray (5G 8/1) to pale green (10G 6/2) with scattered patches, streaks, and deformed light gray (N7) layers, some ash-rich. Pteropods common between 110–115 cm in Section 4. Sections 6–7 have some grayish orange (10YR 7/4) streaks of clay and patches of dark blue green (5BG 3/2) glauconitic(?) clay. Intense drilling deformation throughout.

SMEAR SLIDE SUMMARY (%):

	1, 31 D	1, 126 D	2, 77 D	6, 33 M	7, 31 D
Composition:					
Quartz	1	1	Tr	–	–
Mica	–	–	Tr	–	–
Heavy minerals	Tr	Tr	–	–	–
Clay	2	5	5	–	12
Volcanic glass	Tr	–	Tr	89	–
Glauconite	–	–	Tr	–	–
Pyrite	–	–	–	–	5
Foraminifers	–	Tr	Tr	Tr	–
Calc. nannofossils	83	92	90	10	81
Diatoms	–	–	Tr	–	–
Dolomite	Tr	Tr	–	–	Tr
Tunicate spicules	–	–	–	Tr	–

SITE 540 HOLE CORE 3 CORED INTERVAL 14.0–23.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, light greenish gray (5G 8/1) with very pale green (10G 8/2), light gray (N7) and very pale orange (10YR 8/2) streaks and patches scattered throughout. Common dark gray (N6) pyrite spots throughout. Thin medium light gray (N6) VOLCANIC ASH layer in Section 1. Ooze lithification is variable throughout; some pieces have firmness of chalk. Moderate to intense drilling deformation.

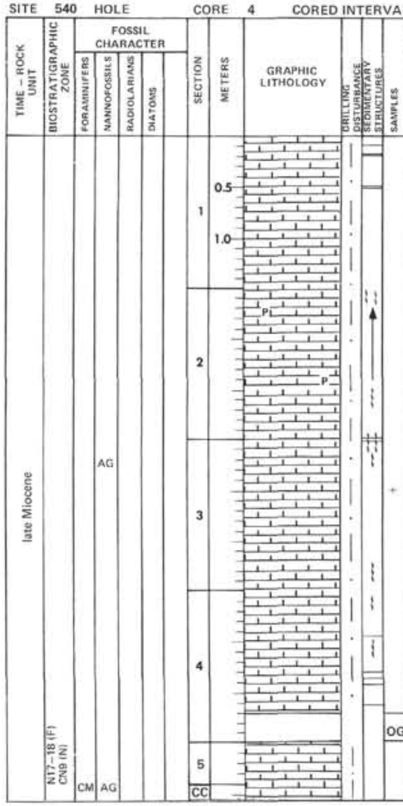
SMEAR SLIDE SUMMARY (%):

	1, 38	2, 72	2, 127	4, 74
	M	D	D	D
Composition:				
Clay	–	10	10	7
Volcanic glass	98	Tr	–	Tr
Pyrite	–	Tr	20	–
Carbonate unspec.	Tr	5	2	5
Foraminifers	–	1	2	Tr
Calc. nannofossils	2	89	66	88
Diatoms	–	Tr	–	–
Radiolarians	–	Tr	–	Tr
Sponge spicules	–	Tr	–	–
Plant debris	–	–	–	Tr
Dolomite	–	Tr	–	Tr

ORGANIC CARBON AND CARBONATE (%):

	3, 60
Organic carbon	–
Carbonate	68

SITE 540 HOLE CORE 4 CORED INTERVAL 23.5–33.0 m



LITHOLOGIC DESCRIPTION

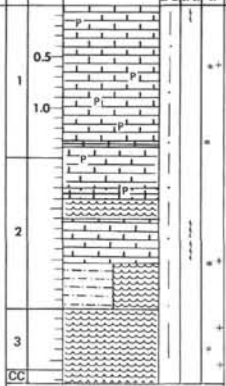
NANNOFOSSIL CHALK, light greenish gray (5G 8/1) with scattered light gray (N7) to dark gray (N3) pyritic laminations and burrow fills, pale green (10G 6/2) patches and pale brown (10YR 6/3) mottling and bands. Pale brown band at 17–21 cm, Section 2. Core is variously lithified chalk and ooze. Generally homogeneous. Moderate drilling deformation.

ORGANIC CARBON AND CARBONATE (%):

	3, 50
Organic carbon	–
Carbonate	69

SITE 540 HOLE CORE 5 CORED INTERVAL 33.0–42.5 m

TIME – ROCK UNIT: late Miocene
BIOSTRATIGRAPHIC ZONE: N16 (F) CN9 (N)
FOSSIL CHARACTER (FORAMINIFERS / NANNOFOSSILS / RADIOLARIANS / DIATOMS): AM; RP



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK with interbedded FORAMINIFERAL-NANNOFOSSIL CHALK, NANNOFOSSIL and FORAMINIFERAL MARLS and SANDY MARLS. Chalks are light greenish gray (5G 8/1) to greenish gray (5G 6/1) and pale brown (10YR 7/3) with scattered burrows and dark gray (N3) pyrite spots. Marls are light olive brown (5Y 5/6) to pale green (10G 6/2) and dark greenish gray (5G 4/1) and burrowed. Sand in some thin marls is mostly fine sand-size subangular quartz; most sandy marls are light olive brown. Moderate drilling deformation.

SMEAR SLIDE SUMMARY (%):

	1, 60	1, 137	2, 109	3, 40
	D	D	M	D
Composition:				
Quartz	1	1	46	3
Heavy minerals	Tr	–	1	Tr
Clay	5	15	20	30
Volcanic glass	–	–	–	Tr
Pyrite	–	Tr	–	Tr
Carbonate unspec.	54	49	20	44
Foraminifers	10	25	10	–
Calc. nannofossils	30	10	3	20
Diatoms	–	Tr	–	–
Radiolarians	Tr	–	–	–
Sponge spicules	1	Tr	Tr	3
Dolomite	–	–	–	1

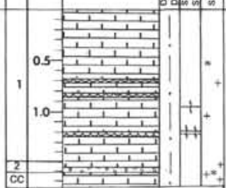
ORGANIC CARBON AND CARBONATE (%):

	1, 60	2, 107	2, 120	3, 20
Organic carbon	–	–	–	–
Carbonate	70	41	29	42

	3, 51
Organic carbon	–
Carbonate	37

SITE 540 HOLE CORE 6 CORED INTERVAL 42.5–52.0 m

TIME – ROCK UNIT: middle Miocene
BIOSTRATIGRAPHIC ZONE: N13 (F) CN6 (N)
FOSSIL CHARACTER (FORAMINIFERS / NANNOFOSSILS / RADIOLARIANS / DIATOMS): AG AG; AG AG



LITHOLOGIC DESCRIPTION

Interbedded NANNOFOSSIL CHALK and FORAMINIFERAL NANNOFOSSIL MARL. Chalk is light greenish gray (5G 8/1), indistinctly layered in part and burrowed. Marl is light olive brown (5Y 5/6) and burrowed. Thin layer of medium dark gray (N4) VOLCANIC ASH in Section 2. Moderate drilling deformation. Variably lithified.

SMEAR SLIDE SUMMARY (%):

	1, 59	2, 12
	D	M
Composition:		
Quartz	–	3
Heavy minerals	–	Tr
Clay	5	–
Volcanic glass	Tr	95
Pyrite	–	2
Carbonate unspec.	30	–
Calc. nannofossils	62	–
Radiolarians	Tr	–
Sponge spicules	3	

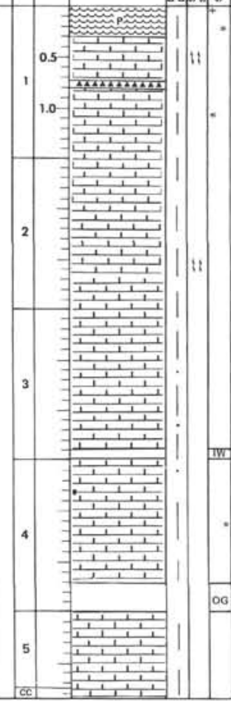
ORGANIC CARBON AND CARBONATE (%):

	1, 73	1, 105	2, 8	CC, 5
Organic carbon	–	–	–	–
Carbonate	69	77	62	78

	CC, 9
Organic carbon	–
Carbonate	72

SITE 540 HOLE CORE 7 CORED INTERVAL 52.0–61.5 m

TIME – ROCK UNIT: middle Miocene; late Oligocene
BIOSTRATIGRAPHIC ZONE: N16 (F) CN6 (N); P22 (F) CP19 (N)
FOSSIL CHARACTER (FORAMINIFERS / NANNOFOSSILS / RADIOLARIANS / DIATOMS): FP AM, AG; AG AM



LITHOLOGIC DESCRIPTION

NANNFOOSSIL CHALK, pale green (10G 6/2) to white (N9) and very light gray (N8) with scattered black (N1) pyrite spots. Pale green chalk occurs mostly as thin layers that are burrowed. Chalk is variably lithified; some ooze alternations. Slight to moderate drilling deformation. Pale green CHERT layer in Section 1. Top 30 cm of core is pale green NANNOFOSSIL MARL. Sharp color change to very light gray chalk below at 32 cm.

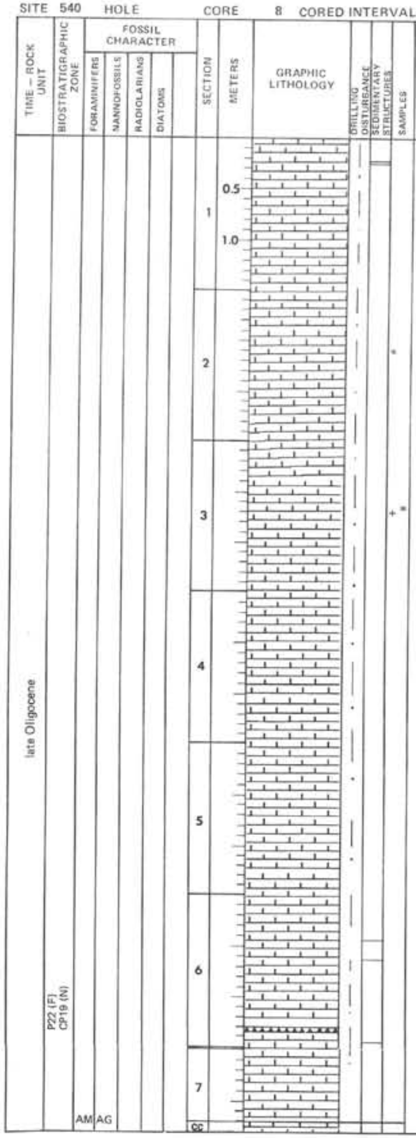
SMEAR SLIDE SUMMARY (%):

	1, 21	1, 104	4, 65
	D	D	D
Composition:			
Clay	15	1	3
Volcanic glass	Tr	Tr	Tr
Carbonate unspec.	5	20	5
Foraminifers	10	1	10
Calc. nannofossils	70	75	82
Radiolarians	Tr	Tr	Tr
Sponge spicules	1	3	–

ORGANIC CARBON AND CARBONATE (%):

	1, 4
Organic carbon	–
Carbonate	61

SITE 540 HOLE CORE 8 CORED INTERVAL 61.5–71.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, white (N9) to light greenish gray (5G 8/1) with widely spaced pale green (10G 6/2) patches and light gray (N7) pyrite spots throughout. Grayish layer at 20–23 cm, Section 1 probably contains ash. Greenish gray (5G 6/1) CHERT at 131–134 cm, Section 6. Chalk is variably lithified; ooze firmness in places.

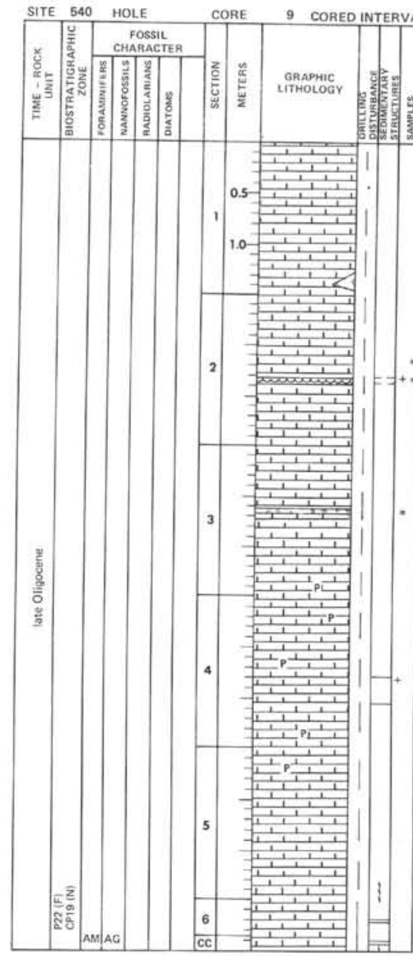
SMEAR SLIDE SUMMARY (%):

	2, 60 D	3, 69 D
Composition:		
Clay	Tr	Tr
Volcanic glass	–	Tr
Carbonate unspec.	15	25
Foraminifers	7	10
Calc. nannofossils	74	63
Diatoms	Tr	–
Radiolarians	Tr	Tr
Sponge spicules	Tr	2

ORGANIC CARBON AND CARBONATE (%):

	3, 70
Organic carbon	–
Carbonate	84

SITE 540 HOLE CORE 9 CORED INTERVAL 71.0–80.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, light greenish gray (5GY 8/1–5G 8/1) with scattered indistinct greenish gray (5GY 6/1–6G 6/1) MARLY bands ~2–4 cm wide and some very light gray (N8) mottling throughout. Thin layer of medium gray (N4) VOLCANIC ASH in Section 3 and patch in Section 1. Chalk is variably lithified. Slight drilling deformation.

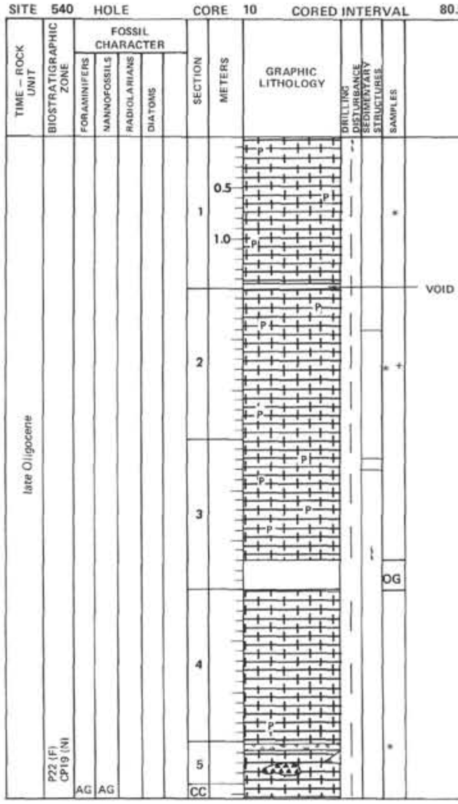
SMEAR SLIDE SUMMARY (%):

	2, 66 D	2, 83 M	3, 68 M
Texture:			
Sand	7	10	–
Silt	88	75	100
Clay	5	15	–
Composition:			
Quartz	–	Tr	–
Heavy minerals	–	Tr	–
Clay	5	10	2
Volcanic glass	–	–	60
Glauconite	–	Tr	–
Pyrite	–	–	20
Carbonate unspec.	10	10	–
Foraminifers	7	10	–
Calc. nannofossils	76	68	20
Radiolarians	–	Tr	–
Sponge spicules	2	2	–

ORGANIC CARBON AND CARBONATE (%):

	2, 82	4, 82
Organic carbon	–	–
Carbonate	65	87

SITE 540 HOLE CORE 10 CORED INTERVAL 80.5–90.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, light greenish gray (5GY 8/1–5G 8/1), homogeneous with medium dark gray (N4) pyrite patches and thin, indistinct greenish gray (5G 6/1) scattered throghout. Olive gray (5Y 4/1) VOLCANIC ASH layer in Section 5 has sharp base and burrowed(?) gradational top. Dark greenish gray (5G 4/1) CHERT nodule at 21–22 cm, Section 5. Possible burrows in chert. Chalk is variably lithified; soft ooze in places.

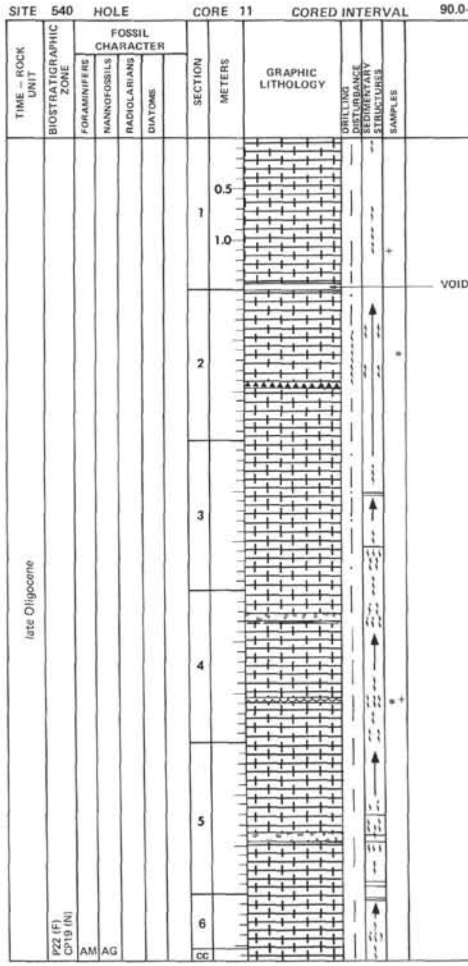
SMEAR SLIDE SUMMARY (%):

	1, 75	2, 78	5, 5
	D	D	M
Composition:			
Quartz	–	–	2
Feldspar	–	–	Tr
Mica	–	–	Tr
Clay	10	10	7
Volcanic glass	–	–	86
Foraminifers	20	25	Tr
Calc. nannofossils	68	63	5
Radiolarians	–	Tr	–
Sponge spicules	2	2	–

ORGANIC CARBON AND CARBONATE (%):

	2, 76
Organic carbon	–
Carbonate	86

SITE 540 HOLE CORE 11 CORED INTERVAL 90.0–99.5 m



LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, light greenish gray (5GY 8/1–5G 8/1) with scattered medium to light gray (N7–N5) pyrite patches. Generally homogeneous and burrowed throughout with common zoophycos burrows that are yellowish gray (5Y 8/1) to light olive gray (5Y 6/1). Several thin, burrowed intervals of greenish gray (5G 6/1) chalk and MARL; darkest at 108 cm, Section 4. Scattered medium light gray (N6) to dark greenish gray (5GY 4/1) layers of VOLCANIC ASH have sharp bases and burrowed, gradational tops. Thin greenish gray (5G 6/1) CHERT band in Section 2. Chalk is variably lithified.

SMEAR SLIDE SUMMARY (%):

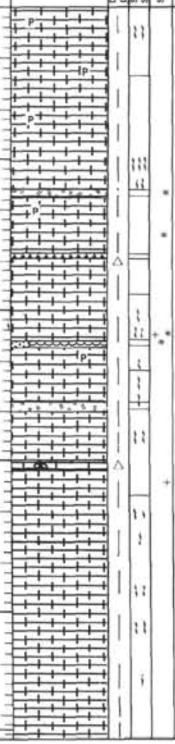
	2, 65	4, 109
	D	M
Texture:		
Sand	7	8
Silt	88	57
Clay	5	35
Composition:		
Quartz	–	1
Feldspar	Tr	–
Clay	5	35
Glauconite	–	Tr
Carbonate unspec.	10	–
Foraminifers	7	7
Calc. nannofossils	78	52
Sponge spicules	–	1

ORGANIC CARBON AND CARBONATE (%):

	1, 113	4, 109
Organic carbon	–	–
Carbonate	80	61

SITE 540 HOLE CORE 12 CORED INTERVAL 99.5–109.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Oligocene	P21b (F) CP19 (N)	AM	AG			1, 2, 3, 4, 5, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, bluish white (5B 9/1) to light greenish gray (5G 8/1) with scattered medium gray (N5) pyrite patches and faint light greenish gray laminations. Burrowed throughout with common zoophycos. Thin olive gray (5Y 4/1) to medium gray (N5) VOLCANIC ASH layers occur sporadically and a thin greenish gray (5G 6/1) CHERT band is in Section 2. Chert also forms a nodule in SILICEOUS LIMESTONE at the top of Section 4. SANDY NANNOFOSSIL MARL at 32 cm, Section 3 contains common sand-size quartz grains. Chalk in this core is variably lithified with some soft portions.

SMEAR SLIDE SUMMARY (%):

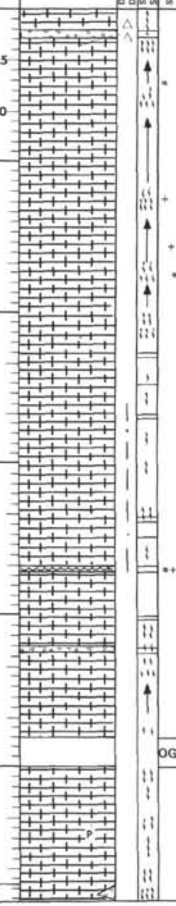
	2, 32 M	2, 77 D	3, 27 M	3, 32 M
Texture:				
Sand	90	10	15	50
Silt	10	85	75	50
Clay	Tr	5	10	–
Composition:				
Quartz	–	Tr	–	20
Feldspar	2	–	–	1
Clay	Tr	5	10	–
Volcanic glass	95	–	–	–
Glauconite	–	–	–	1
Pyrite	3	–	–	–
Carbonate unspec.	–	20	14	40
Foraminifers	Tr	10	15	28
Calc. nannofossils	Tr	65	60	10
Sponge spicules	–	Tr	1	–
Echinoid spines	–	–	–	Tr

ORGANIC CARBON AND CARBONATE (%):

	3, 29	4, 28
Organic carbon	–	–
Carbonate	55	77

SITE 540 HOLE CORE 13 CORED INTERVAL 109.0–118.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Oligocene	P21b (F) CP19 (N)	AM	AG			1, 2, 3, 4, 5, 6, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

FORAMINIFERAL NANNOFOSSIL CHALK, light greenish gray (5G 8/1–5GY 8/1), homogeneous with grayish pyrite streaks and indistinct burrowing throughout. Planolites, zoophycos common with some chondrites-type burrows. Several thin medium light gray to light gray (N5–N7) VOLCANIC ASH layers and patches throughout. Chalk contains scattered and intensely bioturbated greenish gray (5GY 6/1) bands that have up to 10% finer quartz sand.

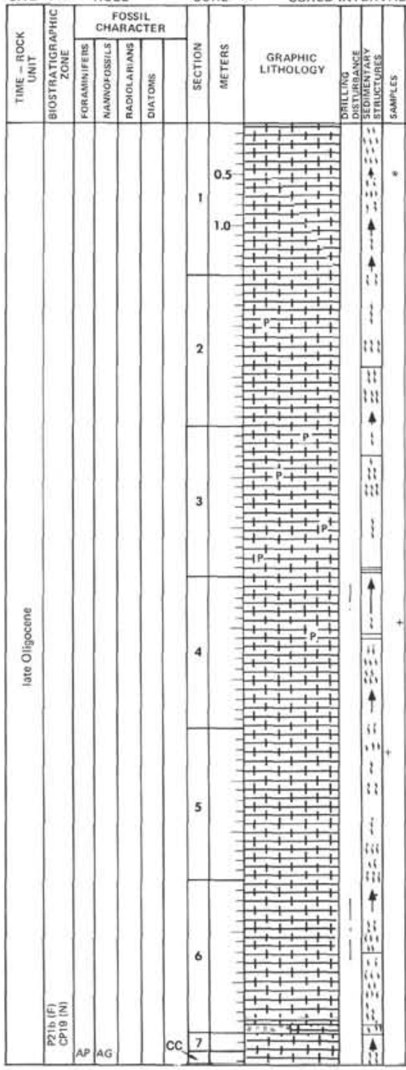
SMEAR SLIDE SUMMARY (%):

	1, 75 D	2, 111 M	4, 103 M
Texture:			
Sand	–	–	20
Silt	–	–	75
Clay	–	–	5
Composition:			
Quartz	–	10	5
Clay	5	25	5
Glauconite	–	1	–
Carbonate unspec.	–	–	10
Foraminifers	20	20	15
Calc. nannofossils	75	44	70

ORGANIC CARBON AND CARBONATE (%):

	2, 38	2, 83	4, 103
Organic carbon	–	–	–
Carbonate	71	84	59

SITE 540 HOLE CORE 14 CORED INTERVAL 118.5–128.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, light greenish gray (5G 8/1) to white (N9) with scattered indistinct greenish gray (5GY 6/1) bands and laminae. Chalk is burrowed throughout; burrows displayed best where thin, darker bands provide color contrast. Pyrite patches and blebs common. Zoophycos occur sporodically. Some indistinct laminations and color banding at 140–145 cm, Section 3. Thin layer of medium light gray (N6) VOLCANIC ASH mixed with chalk by burrowing at base Section 6. Top of this layer appears to be truncated with later burrows cutting it.

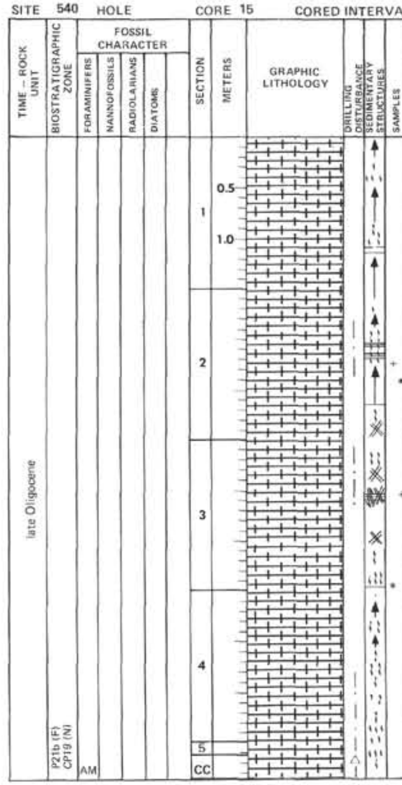
SMEAR SLIDE SUMMARY (%):

	1, 50
Composition:	
Clay	5
Calc. nannofossils	80
Foraminifers	15

ORGANIC CARBON AND CARBONATE (%):

	4, 44	5, 21
Organic carbon	—	—
Carbonate	87	86

SITE 540 HOLE CORE 15 CORED INTERVAL 128.0–137.5 m



LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, light greenish gray (5GY 8/1–5G 8/1) with thin, burrowed greenish gray (5GY 6/1) bands and light gray (N7) pyritic discolorations. Greenish gray band at 52–60 cm, Section 3 is faulted and tilted; one surface has slickensides. Other slickensided surfaces and fractures as noted. Burrows common throughout chalk (planolites and some chondrites). Section 4 has several faintly stylolitic pyrite layers.

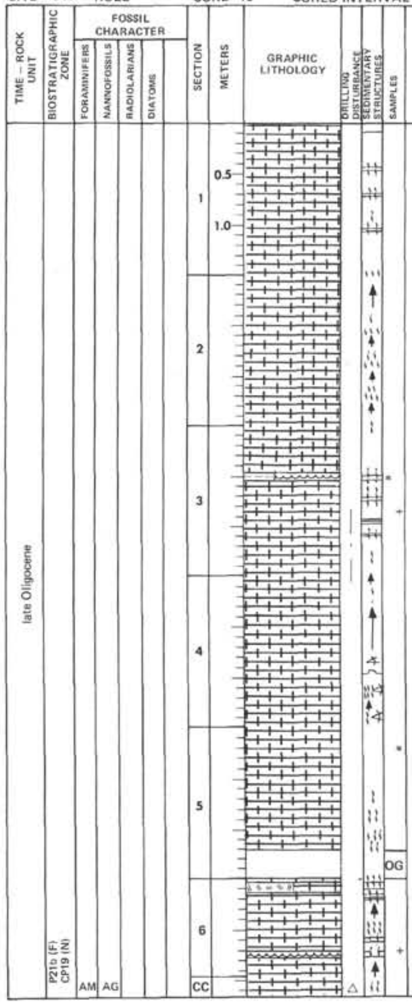
SMEAR SLIDE SUMMARY (%):

	2, 90	3, 145
	D	M
Texture:		
Sand	15	5
Silt	80	90
Clay	5	5
Composition:		
Clay	5	5
Volcanic glass	Tr	—
Carbonate unspec.	40	10
Foraminifers	15	5
Calc. nannofossils	40	80

ORGANIC CARBON AND CARBONATE (%):

	2, 77	3, 57
Organic carbon	—	—
Carbonate	87	79

SITE 540 HOLE CORE 16 CORED INTERVAL 137.5–147.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, light greenish gray (5GY 8/1) with scattered thin, burrowed greenish gray (5G 6/1) zones. Layer in Section 3 at 50 cm is greenish gray to greenish black (5G 2/1) SANDY MARL with common sand-size quartz grains. Fine sand-size quartz also occurs in lighter chalks (eg. Smear Slide at Section 5, 20 cm). Mixed light gray (N6), burrowed VOLCANIC ASH and CHALK layer occur at top Section 6. Chalk in general contains some faint laminations. Inclined laminations in Section 4 dip in different directions in single piece; dip ~45° (slumps).

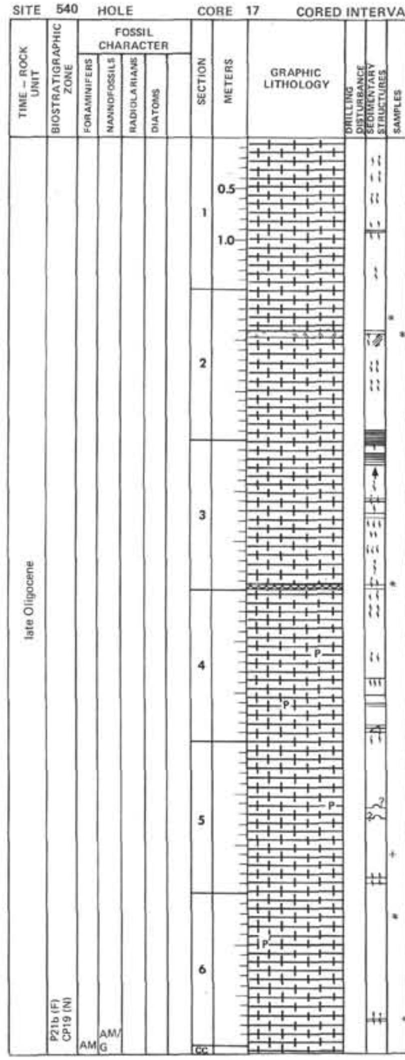
SMEAR SLIDE SUMMARY (%):

	3, 52 M	5, 20 D
Texture:		
Sand	40	15
Silt	60	85
Composition:		
Quartz	20	Tr
Glauconite	2	–
Pyrite	5	–
Carbonate unspec.	20	45
Foraminifers	10	15
Calc. nannofossils	47	40

ORGANIC CARBON AND CARBONATE (%):

	3, 83	6, 70
Organic carbon	–	–
Carbonate	85	56

SITE 540 HOLE CORE 17 CORED INTERVAL 147.0–156.5 m



LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, light greenish gray (5GY 8/1–5G 8/1) homogeneous with some burrow mottling and scattered greenish gray (5G 6/1) burrowed zones 3–5 cm thick. NANNOFOSSIL MARL at base of Section 3 is burrowed. Thin layer of medium gray (N6) VOLCANIC ASH in Section 2. Chalk is faintly laminated in places and burrowed throughout. Inclined indistinct laminations occur at base Section 4 and faint slump folds in Section 5; axis of one fold is pyritized. Large pyritic patch (purplish gray) also occurs at 40–45 cm in Section 6. Microfaulted marly layer occurs below ash in Section 2. Zoophycos common and well developed at 110 cm Section 3.

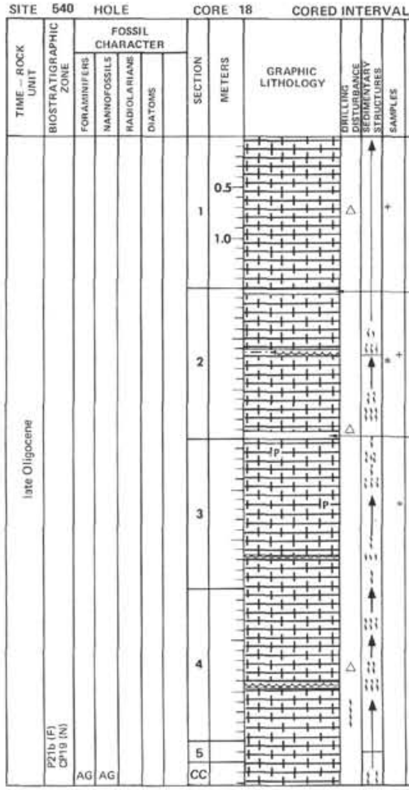
SMEAR SLIDE SUMMARY (%):

	2, 30 D	2, 42 M	6, 25 D	6, 127 M
Composition:				
Clay	–	10	5	15
Volcanic glass	–	80	–	–
Pyrite	–	5	–	1
Carbonate unspec.	20	–	20	5
Foraminifers	10	–	20	20
Calc. nannofossils	70	5	55	59

ORGANIC CARBON AND CARBONATE (%):

	3, 148	5, 110
Organic carbon	–	–
Carbonate	65	87

SITE 540 HOLE CORE 18 CORED INTERVAL 156.5–166.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, light greenish gray (5GY 8/1–5G 8/1) with greenish gray (5Y 6/1–5GY 6/1) bands and bioturbated layers 2–5 cm thick. Some of the darker green layers are NANNOFOSSIL MARLS and the thin layer at 70 cm, Section 2 is a SANDY MARL. Lighter chalk is mixed with these darker layers by burrowing. Zoophycos is common; abundant at top Section 4. Pyrite spots scattered throughout.

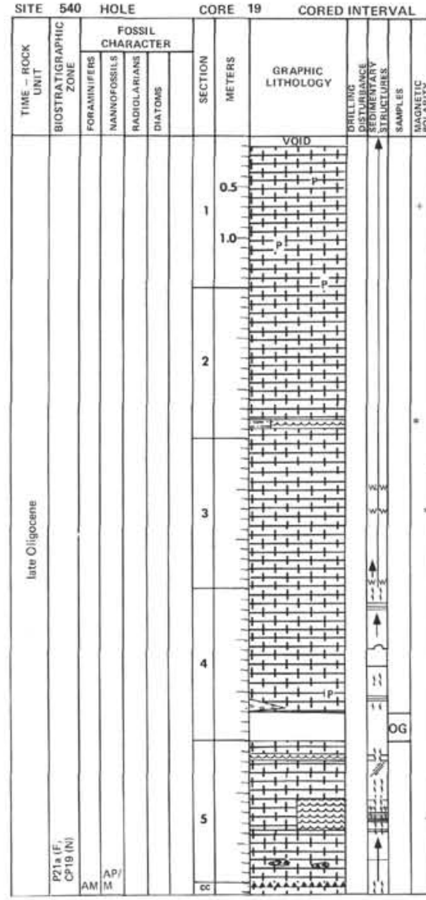
SMEAR SLIDE SUMMARY (%):

	2, 70	3, 63
	M	D
Texture:		
Sand	70	20
Silt	30	75
Clay	–	5
Composition:		
Quartz	40	–
Clay	–	5
Carbonate unspec.	10	10
Foraminifers	30	20
Calc. nannofossils	20	65

ORGANIC CARBON AND CARBONATE (%):

	1, 71	2, 67
Organic carbon	–	–
Carbonate	80	62

SITE 540 HOLE CORE 19 CORED INTERVAL 166.0–175.5 m



LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, light greenish gray (5GY 8/1–5G 8/1) with widely spaced pale greenish gray (5GY 6/1) layers that are intensely bioturbated. Similar greenish gray (5GY 6/1) burrowed layers are NANNOFOSSIL MARLS as marked. One layer at 133 cm, Section 2 contains detrital sand-size quartz grains. Small patch of VOLCANIC ASH at base of Section 4. Greenish gray CHERT nodules at base of core. Wavy layering and slump folds common in Sections 3 and 4 and small microfaulted layer of pale green chalk occurs at top Section 5.

SMEAR SLIDE SUMMARY (%):

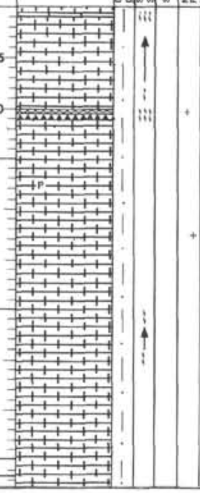
	2, 133	3, 73
	M	D
Texture:		
Sand	20	30
Silt	75	65
Clay	5	5
Composition:		
Quartz	20	–
Mica	1	–
Heavy minerals	Tr	–
Clay	5	5
Pyrite	1	–
Carbonate unspec.	20	5
Foraminifers	10	30
Calc. nannofossils	43	60

ORGANIC CARBON AND CARBONATE (%):

	1, 70	5, 78
Organic carbon	–	–
Carbonate	84	61

SITE 540 HOLE CORE 20 CORED INTERVAL 175.5–185.0 m

TIME – ROCK UNIT: late Oligocene
BIOSTRATIGRAPHIC ZONE: P21a (F), CP18 (N)
FOSSIL CHARACTER: Foraminifers AM
SECTION: 1, 2, 3, 4, CC
METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

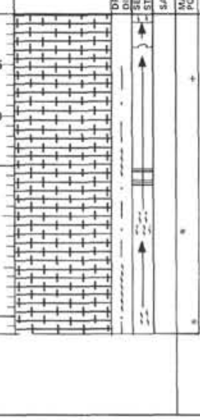
FORAMINIFERAL-NANNOFOSSIL CHALK, light greenish gray (5G 8/1) with some pale green (10G 6/2) burrowed intervals ~2–5 cm thick. Some of the darker of these bands are MARLS. Planolites-type burrows common. Zoophycos also present. Core is broken somewhat by drilling. Light greenish gray FORAMINIFERAL LIMESTONE occurs at top Section 1 and a grayish green (10G 4/2) CHERT nodule is also in Section 1.

ORGANIC CARBON AND CARBONATE (%):

	1, 103	2, 76
Organic carbon	–	–
Carbonate	56	85

SITE 540 HOLE CORE 21 CORED INTERVAL 185.0–194.5 m

TIME – ROCK UNIT: late Oligocene
BIOSTRATIGRAPHIC ZONE: CP18 (N)
SECTION: 1, 2, CC
METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, very light gray (N8) to light greenish gray (5GY 8/1) with sparse 2–3 cm burrowed bands and layers of greenish gray (5GY 6/1– chalk; most conspicuous darker, burrowed zone is at 64–69 cm, Section 2. Color of chalk varies somewhat in Section 2 to light olive gray (5Y 6/1) and light brownish gray (5YR 6/1) with common burrows. Core is broken into drilling fragments.

SMEAR SLIDE SUMMARY (%):

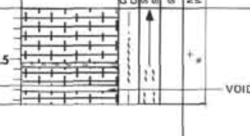
	2, 66	CC, 8
	M	D
Composition:		
Quartz	3	Tr
Heavy minerals	1	5
Volcanic glass	70	–
Carbonate unspec.	5	5
Foraminifers	10	1
Calc. nannofossils	11	84
Radiolarians	Tr	–
Sponge spicules	–	5

ORGANIC CARBON AND CARBONATE (%):

	1, 66
Organic carbon	–
Carbonate	84

SITE 540 HOLE CORE 22 CORED INTERVAL 194.5–204.0 m

TIME – ROCK UNIT: late Oligocene
BIOSTRATIGRAPHIC ZONE: P20 (F), CP17 (N)
FOSSIL CHARACTER: Foraminifers AM, Nannofossils AM
SECTION: 1, CC
METERS: 0.5



LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, very light gray (N8) to light greenish gray (5GY 8/1) with a thin, burrowed VOLCANIC ASH Layer at 55 cm. Burrows common throughout. Core brecciated by drilling.

SMEAR SLIDE SUMMARY (%):

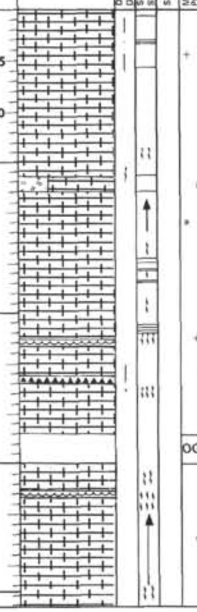
	1, 55
	M
Texture:	
Sand	95
Silt	5
Composition:	
Quartz	5
Volcanic glass	80
Carbonate unspec.	3
Foraminifers	10
Calc. nannofossils	2

ORGANIC CARBON AND CARBONATE (%):

	1, 46
Organic carbon	–
Carbonate	81

SITE 540 HOLE CORE 23 CORED INTERVAL 204.0–213.5 m

TIME – ROCK UNIT: early Oligocene
BIOSTRATIGRAPHIC ZONE: P19 (F), CP17 (N)
FOSSIL CHARACTER: Foraminifers AP, AM; Nannofossils AM/P
SECTION: 1, 2, 3, 4, CC
METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, light greenish gray (5GY 8/1) to very light gray (N8) with several thin burrowed bands of greenish gray (5G 6/1) MARL as marked. Chalk and marl are faintly laminated or layered in places and burrowed throughout. Light gray (N7) chalk and VOLCANIC ASH mixed by burrowing occurs in top Section 2. Thin olive gray (5Y 4/1) chert band in Section 3. Core is broken and brecciated in places by drilling.

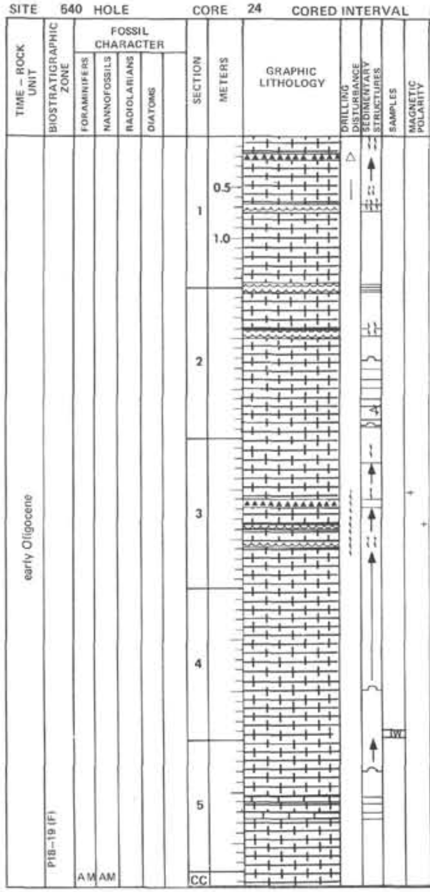
SMEAR SLIDE SUMMARY (%):

	2, 25	2, 60	3, 59	4, 72
	M	D	M	D
Composition:				
Quartz	3	–	Tr	Tr
Clay	5	5	5	5
Volcanic glass	30	–	–	Tr
Carbonate unspec.	–	15	5	15
Foraminifers	50	25	50	30
Calc. nannofossils	12	50	42	40
Sponge spicules	–	–	3	–

ORGANIC CARBON AND CARBONATE (%):

	1, 46	3, 26
Organic carbon	–	–
Carbonate	79	63

SITE 540 HOLE CORE 24 CORED INTERVAL 213.5–223.0 m



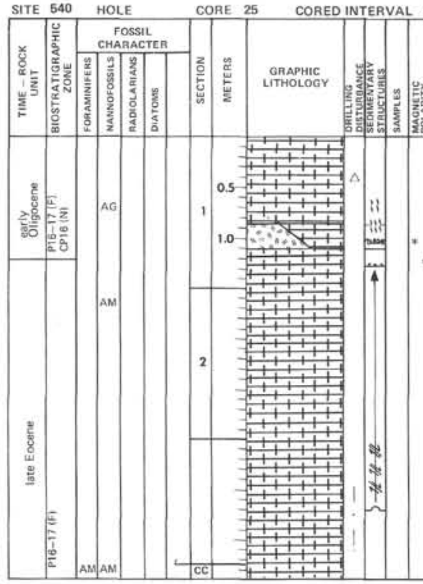
LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, very light gray (N8) to bluish white (5B 9/1) with darker light greenish gray (5G 8/1) widely spaced burrowed zones. Several layers of burrowed greenish gray (5GY 6/1–5G 6/1) MARL and medium gray (N5) and dark greenish gray (5GY 4/1) CHERT (nodular?) scattered throughout. Slump folds common in Sections 2–5 in chalk.

ORGANIC CARBON AND CARBONATE (%):

	3, 54	3, 82
Organic carbon	–	–
Carbonate	89	36

SITE 540 HOLE CORE 25 CORED INTERVAL 223.0–232.5 m



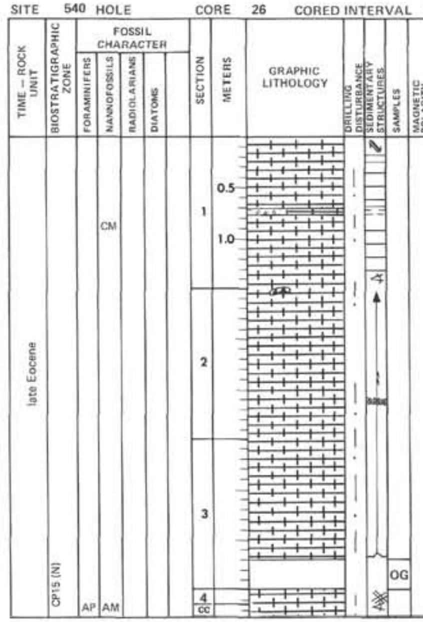
LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, light greenish gray (5G 8/1) with common burrows. Burrows best seen where pale green (10G 6/2) chalk is mixed with lighter chalk. Chaotic greenish gray (5G 6/1) mixed chalk and VOLCANIC ASH zone occurs at ~100 cm, Section 1. Below is a thin graded and burrowed pale green interval ~5 cm thick. Abundant slump folds in chalk of Section 3 and top Section 2; microfaults are in top Section 3.

SMEAR SLIDE SUMMARY (%):

	1, 100 M	1, 122 D
Composition:		
Quartz	15	Tr
Feldspar	2	Tr
Mica	–	Tr
Heavy minerals	–	Tr
Clay	–	1
Volcanic glass	80	1
Carbonate unspec.	Tr	48
Foraminifers	2	50
Calc. nannofossils	1	10

SITE 540 HOLE CORE 26 CORED INTERVAL 232.5–242.0 m



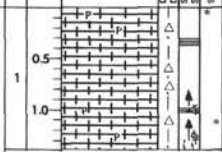
LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, light greenish gray (5GY 8/1), faintly layered throughout with common shearing, microfaults, and slump folds. Thin layer of mixed VOLCANIC ASH and chalk occurs at 73 cm, Section 1. Greenish gray (5G 6/1) nodule at top Section 2. Small lenses or chips of greenish gray MARL occur at base Section 1 and in Section 4. Small asphalt spots (~1 mm) are at 50 and 70 cm in Section 2.

SITE 540 HOLE CORE 27 CORED INTERVAL 242.0–251.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
late Eocene	CP15 (N)		AG		
middle Eocene	P12/CP13b (F)	AP	AM		

SECTION: 1; METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK, very light gray (N8) with bands and faint light greenish gray (5GY 8/1) laminations. Common pyrite and several asphaltic spots noted. Core broken by drilling.

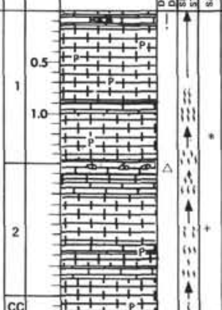
SMEAR SLIDE SUMMARY (%):

	1, 4	1, 114
	M	D
Composition:		
Quartz	Tr	–
Mica	1	–
Clay	5	5
Pyrite	Tr	–
Carbonate unspec.	35	10
Foraminifers	20	10
Calc. nannofossils	39	75

SITE 540 HOLE CORE 28 CORED INTERVAL 251.5–261.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
middle Eocene	P12/CP13b	AP	AG		

SECTION: 1, 2, CC; METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

Interbedded light greenish gray (5GY 8/1) FORAMINIFERAL-NANNOFOSSIL CHALK and mottled very light gray (N8) to medium light gray (N6) LIMESTONE. Chalk is massive and burrowed with scattered pyrite spots and thin marly bands. Mottling of limestone apparently result of burrowing and pyrite. Small greenish gray CHERT nodules occur in limestone.

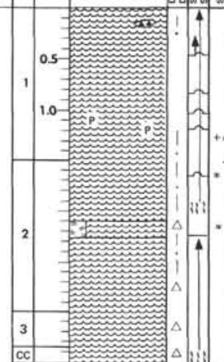
SMEAR SLIDE SUMMARY (%):

	1, 126
	D
Composition:	
Clay	5
Carbonate unspec.	10
Foraminifers	10
Calc. nannofossils	75

SITE 540 HOLE CORE 29 CORED INTERVAL 261.0–270.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
middle–late Eocene	CP12		CG		
early Eocene	P8	AP	RM		

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



LITHOLOGIC DESCRIPTION

Interbedded FORAMINIFERAL-NANNOFOSSIL MARL CHALK and LIMESTONE and mixed VOLCANIC ASH and CHALK. Two types of marly chalk and limestone occur: 1) extensively burrow mottled bluish white (5B 9/1) to medium gray (N5) with minor CHERT, and 2) extensively burrow mottled light greenish gray (5G 8/1) to greenish gray (5G 6/1) with a distinct, slightly dipping sheared fabric and common dark pyrite or asphaltic patches. First kind occurs between 0–35 cm in Section 1, 25–42 and 75–150 cm, Section 2, Section 3, and Core-Catcher. Type 2 comprises remainder. Burrows mainly of planolites variety although zoophycos also occurs. Lithification is variable; major chalk/marl and limestone intervals shown. Mixed interval of ash and marl occurs in Section 2. Slump folds common as marked.

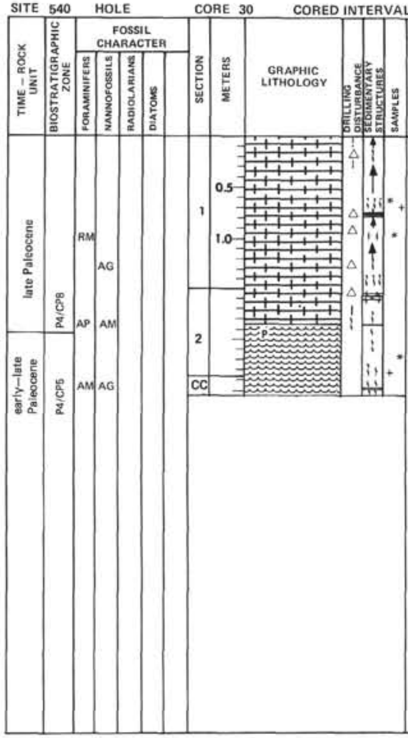
SMEAR SLIDE SUMMARY (%):

	1, 125	2, 14	2, 68
	D	D	M
Composition:			
Quartz	5	–	1
Mica	1	5	–
Clay	20	–	–
Volcanic glass	–	–	10
Pyrite	1	1	5
Carbonate unspec.	28	50	20
Foraminifers	15	10	30
Calc. nannofossils	30	35	28
Radiolarians	–	–	5
Sponge spicules	–	–	1

ORGANIC CARBON AND CARBONATE (%):

	1, 123	2, 2
Organic carbon	–	–
Carbonate	41	45

SITE 540 HOLE CORE 30 CORED INTERVAL 270.5–280.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFERAL-NANNOFOSSIL CHALK and PEBBLY CHALK. Chalk is white (N9) to very light gray (N8) with some light gray (N7) burrow mottling and irregularly laminated greenish gray (5GY 6/1) bands. Scattered tiny pyrite spots. Sharp contact (partly drilling artifact) between chalk and marl at 37 cm in Section 2. Pebbly chalk is mottled greenish gray (5G 6/1) to light greenish gray (5GY 8/1) with common angular to rounded olive black (5Y 2/1) to dark greenish gray (5GY 4/1) clayey chips (0.2–3.0 mm) and several pyrite patches. Large lighter colored burrows throughout this lithology. No distinct fabric. Greenish gray chalk occurs at 11 cm in Core-Catcher. It has some dark greenish gray layering and is cut by large subhorizontal burrows filled with lighter chalk. All lithologies hard, approaching limestones.

Thin Section:

1, 96: Limestone (radiolarian mudstone) – consists of scattered radiolarian molds in a micrite matrix. Several laminations formed by alignment or concentration of these molds. Rare foraminifera and flat, platy shell fragments also present.

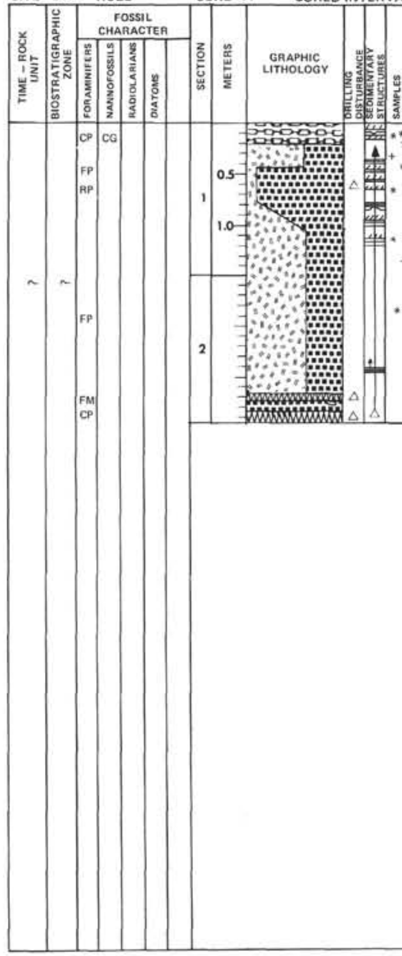
SMEAR SLIDE SUMMARY (%):

	1, 62	2, 64
	D	D
Composition:		
Quartz	–	Tr
Clay	–	5
Volcanic glass	–	Tr
Glauconite	–	Tr
Pyrite	Tr	–
Carbonate unspec.	70	60
Foraminifers	15	20
Calc. nannofossils	15	15

ORGANIC CARBON AND CARBONATE (%):

	1, 70	2, 83
Organic carbon	–	–
Carbonate	92	82

SITE 540 HOLE CORE 31 CORED INTERVAL 280.0–289.5 m



LITHOLOGIC DESCRIPTION

CHALK and CALCAREOUS-VOLCANIC SANDSTONE. Chalk, in top 20 cm of Section 1, is banded and irregularly laminated light gray (N7) and medium light gray (N6) to greenish gray (5GY 6/1–5G 6/1). Contains one good graded layer (~2 cm thick) with loadcasts and some microcross-laminations; several thin layers are fine-grained chalk. Bulk of core is a poorly sorted, generally fining upward sequence of calcareous volcanic sandstone. Large, yellowish gray (5Y 8/1) fragments of bioclastic limestone containing rudist, coral, and shell fragments occur near the base of the core with an interbedded carbonate sand composed of skeletal fragments and a piece of chert. Sandstone above is medium dark gray (N4) and very poorly sorted, massive with white bioclastic limestone fragments and altered lapilli up to 1 cm across. A thin finer-grained, laminated interval occurs at 80–95 cm in Section 2. Dark sandstone fines upward to cross-laminated dark greenish gray (5G 4/1) and greenish gray (5G 6/1) calcareous volcanic sandstone and very light gray (N8) to light greenish gray (5GY 8/1) volcanic carbonate sandstone (medium- to fine-grained). Volcanic grains appear to be sand-size glass fragments (with pyrite) altered to clay. Lighter colored carbonate sand occurs mainly between 45–90 cm in Section 1; lightest portions contain common pithonella.

Thin Sections:

1, 10: Limestone (skeletal grainstone) and medium-grained well-sorted carbonate sand containing less than 20% fine-grained micrite cement, about 60% grains and 10% secondary porosity. Grain types include foraminifers (25%), peloids (25%), lithoclasts (20%), mollusc fragments (15%), and echinoderm fragments and spores.

1, 41: Limestone (foraminiferal grainstone) – microspar cemented grainstone composed of planktonic and benthic foraminifers (~50–60%), altered volcanic grains (~10–20%), and cement (~30%). Clay and minor mollusc fragments are also present. Foraminifers commonly occur as single chambers – circular cross sections. Volcanic fragments contain pyrite; appear to be glass altered to clay.

2, 34: Calcareous-volcanic sandstone – consists of 30% clay grains (altered volcanic glass), 30% shallow-water skeletal carbonate debris and pelagic grains, lithoclasts, 10% pyrite line calcite grains (cement?) and some unidentified grains (15%), and scattered zeolites.

SMEAR SLIDE SUMMARY (%):

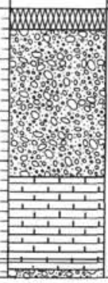
	1, 12	1, 21	1, 66	1, 115
	M	M	M	D
Texture:				
Sand	–	40	40	60
Silt	100	50	55	30
Clay	–	10	5	10
Composition:				
Feldspar	–	Tr	–	–
Clay	–	–	5	–
Volcanic glass	–	60	–	60
Pyrite	–	10	–	15
Carbonate unspec.	100	30	70	25
Foraminifers	–	Tr	10	–
Pithonella	Tr	Tr	15	–

ORGANIC CARBON AND CARBONATE (%):

	1, 33	1, 138
Organic carbon	–	–
Carbonate	41	44

SITE 540 HOLE CORE 32 CORED INTERVAL 289.5–299.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	SECTION	METERS
late Cenomanian	~	RP	CM	1	0.5, 1.0
		AM			
		CP		2	
		CM		CC	



LITHOLOGIC DESCRIPTION

BIOCLASTIC LIMESTONE, PEBBLY MARLSTONE, and CHALK. Limestone is yellowish gray (5Y 8/1), porous and contains large angular fragments of skeletal debris (rudists, coral and other mollusc fragments), similar to base of Core 31. Pebbly marlstone is greenish gray (5GY 6/1) with scattered subangular fragments of white (N9), yellowish gray (5Y 8/1) and medium light gray (N6) limestone, chalk, and claystone/altered volcanic clasts. Fragments range from 0.5 mm to 4 cm across. Many elongate clasts dip ~30° to core axis; contact at 15 cm in Section 2 also dips ~30°. Marly chalk is greenish gray (5GY 6/1) with abundant medium light gray (N6) burrows.

SMEAR SLIDE SUMMARY (%):

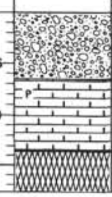
	1, 50	2, 46
	D	D
Texture:		
Sand	10	Tr
Silt	80	95
Clay	10	5
Composition:		
Quartz	Tr	–
Feldspar	Tr	–
Clay	10	5
Pyrite	–	Tr
Carbonate unspec.	85	89
Foraminifers	–	1
Calc. nannofossils	5	5

ORGANIC CARBON AND CARBONATE (%):

	1, 58	2, 58
Organic carbon	–	–
Carbonate	94	88

SITE 540 HOLE CORE 33 CORED INTERVAL 299.0–308.5 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	SECTION	METERS
late Cenomanian	~	CM	1	0.5, 1.0
		RM		
		CM		
		RP	2	
		RP		



LITHOLOGIC DESCRIPTION

PEBBLY LIMESTONE, MARLY CHALK, and BIOCLASTIC LIMESTONE. Pebbly marlstone is greenish gray (5GY 6/1) with 1.5–4.5 cm. Subangular fragments of white (N9) and yellowish gray (5Y 8/1) to light greenish gray (5GY 8/1) limestone and chalk and some darker clasts (claystones?). Marly chalk is pale greenish gray (5GY 6/1) with dark greenish gray (5G 4/1) and medium light gray (N6) burrow mottling and irregular layers. Most burrows appear to be flattened planolites type. Below 114 cm, Section 1 carbonate sand (foraminifers and shell debris) fills burrows. Bioclastic limestone at base of core is light olive gray (5Y 6/1) to greenish gray (5GY 6/1) and contains mostly medium to very coarse sand-size skeletal fragments (including rudists and foraminifers) and several soft dark greenish gray (5GY 4/1) clayey or marl fragments.

Thin Sections:

1, 52: Limestone (mudstone) – sample is principally micrite and fine-grained cement with rare foraminifers and dolomite.

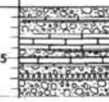
2, 1: Bioclastic limestone (skeletal grainstone) – poorly sorted grainstone with about 50% fine-grained (90–150 μm) carbonate debris, 10% foraminifers, 10% peloids, 10% mollusc fragments, 5% echinoderms, 10% lithoclasts, and rare green algae. Almost no cement. Some pelagic material in matrix and in lithoclasts.

ORGANIC CARBON AND CARBONATE (%):

	1, 50	1, 91
Organic carbon	–	–
Carbonate	82	79

SITE 540 HOLE CORE 34 CORED INTERVAL 308.5–318.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	SECTION	METERS
~	~	FM	1	0.5



LITHOLOGIC DESCRIPTION

PEBBLY LIMESTONE, LIMESTONE, and BIOCLASTIC LIMESTONE. Pebbly limestone is greenish gray (5GY 6/1) with sparse white (N9) to yellowish gray (5Y 8/1) porous fine-grained limestone fragments, rudists, and darker light greenish gray (5G 8/1) limestone and greenish gray (5G 4/1) marly limestone clasts. Grain size ranges from 0.5 mm to 3 cm. Limestone is massive light olive gray (5Y 6/1) with skeletal molds and yellowish gray (5Y 8/1) with small open pores; some pores aligned. Bioclastic limestone is very light gray (N8) to yellowish gray with common rudist fragments, large foraminifers and peloids. Several pieces are moderately well sorted and have cemented and porous, uncemented parts. Core is broken into drilling fragments.

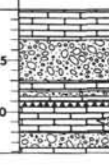
Thin Sections:

1, 33: Limestone (foraminiferal wackestone) – sample consists mostly of micrite with a few percent scattered foraminifers, calcite replaced radiolaria, *calcispheres*, "filament", and unidentified grains.

1, 63: Limestone (skeletal-miliolid grainstone) – grains in this rock include miliolid foraminifers (30%), micritic peloids (30%), limestone lithoclasts (10%), mollusc fragments (10%), echinoderms (5%), and rare red and green algae. Some rhombic calcite cement in about a third of the thin section. Some lithoclasts are radiolaria mudstones. Partial silica (chalcedony) replacement of mollusc and echinoderm grains. Excellent primary porosity; no secondary porosity.

SITE 540 HOLE CORE 35 CORED INTERVAL 318.0–327.5 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	SECTION	METERS
~	~	1	0.5, 1.0



LITHOLOGIC DESCRIPTION

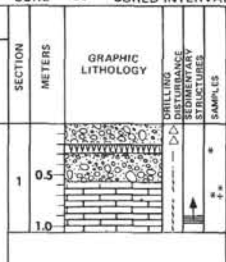
LIMESTONE, PEBBLY LIMESTONE, and CHERT. Limestone is light olive gray (5Y 6/1) and massive with scattered open pores (~0.5 mm) and irregular layering in places. Pebbly limestone is light olive gray (5Y 6/1) with common, angular, yellowish gray (5Y 8/1) fragments (0.5–5 mm) of limestone, skeletal debris (algae, molluscs and foraminifers) and dark greenish gray (5GY 4/1) marly limestone/claystone. Chert is black and chonchoidally fractured. Contact relationships uncertain; core brecciated by drilling.

ORGANIC CARBON AND CARBONATE (%):

	1, 34
Organic carbon	–
Carbonate	98

SITE 540 HOLE CORE 36 CORED INTERVAL 327.5–337.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
early Cenomanian	?	FM FP			



LITHOLOGIC DESCRIPTION

PEBBLY LIMESTONE, BIOCLASTIC LIMESTONE, and LIMESTONE. Pebbly limestone is light olive gray (5Y 6/1) to greenish gray (5GY 6/1) with medium sand- to granule-size, angular to rounded fragments of yellowish gray (5Y 8/1) to light greenish gray (5GY 8/1) bioclastic limestone and fine-grained chalk. Bioclastic limestone is yellowish gray and consists of fine- to medium-sand-size skeletal debris; porous. Limestone is very light gray (N8) and pale greenish gray (5GY 6/1) to greenish gray (5GY 6/1) and olive black (5Y 2/1), indistinctly mottled or layered with common small skeletal fragment molds. Some thin yellowish gray carbonate sand laminae. Core is broken into drilling biscuits.

Thin Sections:

1, 23: Limestone (pelloidal grainstone) – fine-grained and contains about 50% peloids with a peculiar spotted pattern, some reminiscent of "girvarella". Other grains include echinoderm fragments (20%) and foraminifers (10%). Mollusc fragment molds (20%) are common. One red algae fragment and some planktonic debris also present. Primary porosity ~10%.

1, 67: Marly limestone (wackestone) – contains scattered (50–150 µm) grains in a dark micritic matrix. Grains include foraminifers and light-colored pellets; most grains are unidentifiable. A subhorizontal burrow ~3 mm in diameter and filled with calcite that is slightly coarser grained than enclosing micrite cuts through this sample.

SMEAR SLIDE SUMMARY (%):

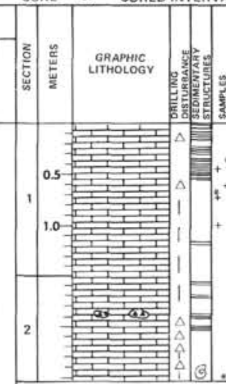
	1, 70 D
Composition:	
Mica	Tr
Carbonate unspec.	56
Foraminifers	3
Calc. nannofossils	2
Dolomite	4

ORGANIC CARBON AND CARBONATE (%):

	1, 71
Organic carbon	1.7
Carbonate	93

SITE 540 HOLE CORE 37 CORED INTERVAL 337.0–346.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
early Cenomanian	*Eiffelithus turriseiffeli* – *Lithraphidites acutus*	FM FP	AG		



LITHOLOGIC DESCRIPTION

LIMESTONE, light olive gray (5Y 6/1) to yellowish gray (5Y 7/2) with darker olive gray zones. Lighter limestone is massive with common small circular pores (~0.2–0.5 mm) concentrated along thin horizons. Several intervals are faintly layered. Pelecypod and ammonite molds at base of core. Darker zones (e.g. at 55–75 cm, Section 1 and 55–60 cm, Section 2) are laminated or indistinctly laminated. Between 30–50 cm in Section 1 are alternations ~0.5–1.5 cm thick of medium gray (N5) layers and light olive gray laminated layers. Latter are composed of small lenses of fine-grained carbonate material oriented parallel to bedding. Pieces at 64–74 cm, Section 1 have brownish phosphatic(?) nodules and small iron-oxide inclusions. Black (N1) CHERT bands occur in light limestone in Section 2.

Thin Section:

2, 100: Bioclastic limestone (packstone-grainstone) – consists of small echinoderm fragments, pellets, and foraminifers in a fine-grained cement and micritic matrix. About 75% of the grains have been leached giving rock a secondary moldic porosity (~25%).

SMEAR SLIDE SUMMARY (%):

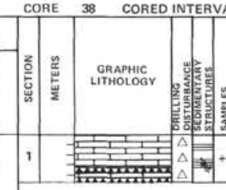
	1, 39 M	1, 41 M	1, 67 D
Composition:			
Clay	35	30	40
Pyrite	Tr	–	–
Carbonate unspec.	45	45	40
Foraminifers	5	2	5
Calc. nannofossils	–	–	10
Diatoms	Tr	–	–
Dolomite	15	18	–
Iron-oxides	–	–	5

ORGANIC CARBON AND CARBONATE (%):

	1, 48	1, 65	1, 72	1, 100
Organic carbon	–	–	7.8	–
Carbonate	94	86	75	97
	2, 57			
Organic carbon	4.6			
Carbonate	87			

SITE 540 HOLE CORE 38 CORED INTERVAL 346.5–356.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
early Cenomanian	*Eiffelithus turriseiffeli* – *Lithraphidites acutus*		CP		



LITHOLOGIC DESCRIPTION

LIMESTONE and CHERT. Limestone is light olive gray (5Y 6/1) to greenish gray (5GY 6/1) and yellowish gray (5Y 8/1). Mostly very fine- to fine-sand grainstone with moldic porosity (mainly pelecypod fragments). Where irregularly laminated, laminae are light colored and contain slightly coarser grained (~medium-grained sand-size) carbonate. Limestone is slightly darker and laminated at 25–35 cm. Laminations ~1–2 mm thick. Chert is black (N1) to dark gray (N3) and laminated in part. Core is broken into fragments by drilling.

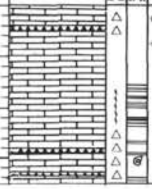
ORGANIC CARBON AND CARBONATE (%):

	1, 27
Organic carbon	–
Carbonate	86

SITE 540 HOLE CORE 39 CORED INTERVAL 356.0–365.5 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
early Cenomanian	*Eiffellithus turriseiffeli* / *Lithraphidites acutus*	CP	AM			1, 2	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

LIMESTONE and CHERT. Limestone is light olive gray (5Y 6/1) and homogeneous or irregularly laminated as marked. Laminations composed of silt to fine-sand-size carbonate and typically light gray (N7) or yellowish gray (5Y 8/1). Scattered microfossil molds common; ammonite molds rare. Limestone is olive black (5Y 2/1) to olive gray (5Y 4/1) and well laminated between 10–25 cm, Section 1. Chert is black (N1) and massive. Contacts between lithologies not preserved. Core is brecciated in part by drilling.

Thin Sections:

1, 26: Chert – thin dark clay laminations in microcrystalline-cryptocrystalline quartz. Quartz-filled and replaced radiolaria and foraminifers common.

1, 142: Chert – as above but with transition to micritic limestone at one edge.

SMEAR SLIDE SUMMARY (%):

	1, 12	1, 115
	M	D
Composition:		
Quartz	Tr	–
Mica	–	Tr
Clay	60	30
Carbonate unspec.	30	60
Foraminifers	Tr	Tr
Calc. nannofossils	5	–
Plant debris	5	Tr
Dolomite	–	10

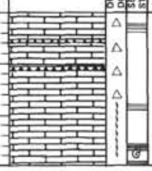
ORGANIC CARBON AND CARBONATE (%):

	1, 10	1, 21	1, 37
Organic carbon	–	–	–
Carbonate	83	82	99

SITE 540 HOLE CORE 40 CORED INTERVAL 365.5–375.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
early Cenomanian	*Eiffellithus turriseiffeli*		CP			1	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

LIMESTONE and CHERT. Limestone is light olive gray (5GY 6/1), generally burrowed but with some laminated intervals as marked. Common spherical microfossil molds. Some laminations are yellowish gray (5Y 8/1) and slightly coarser grained than most. Rare ammonite molds. Limestone is olive gray (5Y 4/1) to olive black (5Y 2/1) and well-laminated between 129–139 cm. Several pieces show sharp change from limestone to marly limestone. Chert is black (N1) and massive; one piece has a light olive gray rind of siliceous limestone. Core fragmented by drilling.

SMEAR SLIDE SUMMARY (%):

	1, 127
	M
Composition:	
Clay	39
Carbonate unspec.	50
Foraminifers	Tr
Plant debris	1
Dolomite	10

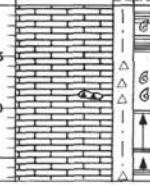
ORGANIC CARBON AND CARBONATE (%):

	1, 55
Organic carbon	–
Carbonate	99

SITE 540 HOLE CORE 41 CORED INTERVAL 375.0–384.5 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Albian	*Planulina buxtorfi* / *Eiffellithus turriseiffeli*	AM, CM	AP			1, 2	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

LIMESTONE, light olive gray (5Y 6/1) to olive gray (5Y 4/1), homogeneous to faintly laminated and well-laminated. Laminations composed of yellowish gray (5Y 8/1) silt-size carbonate. Molds of ammonites and pelecypods common. Thin CHERT laminations in limestone at 90–91 cm, Section 1.

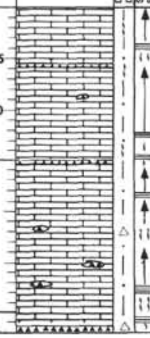
ORGANIC CARBON AND CARBONATE (%):

	1, 34	1, 66
Organic carbon	–	–
Carbonate	94	99

SITE 540 HOLE CORE 42 CORED INTERVAL 384.5–394.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Albian	*Planulina buxtorfi* / *Eiffellithus turriseiffeli*	CG, AM				1, 2, 3	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

LIMESTONE and CHERT. Limestone is light olive gray (5Y 6/1–5Y 5/2) to olive black (5Y 2/1) with light–dark gradational color changes and homogeneous or burrowed – banded or laminated variations as marked. Common radiolaria and some mollusc molds. Some laminations consist of elongate light-colored particles. Olive gray (5Y 4/1) chert mini-nodules as marked. Chert laminations at 97 cm in Section 2 in marly limestone. Grayish black (N2) chert fragments scattered throughout. Core brecciated in part by drilling.

ORGANIC CARBON AND CARBONATE (%):

	1, 56	2, 93
Organic carbon	–	–
Carbonate	97	89

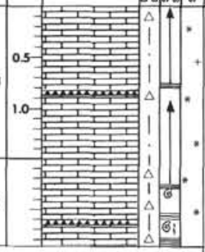
SITE 540 HOLE CORE 43 CORED INTERVAL 394.0–403.5 m

TIME – ROCK UNIT: late Albian

BIOSTRATIGRAPHIC ZONE: *Planulina buxtorfi* / *Eiffellithus turriseiffeli*

FOSSIL CHARACTER: Foraminifers CP, RM, RP, FP; Nannofossils AG

SECTION: 1, 2



LITHOLOGIC DESCRIPTION

LIMESTONE and CHERT. Limestone is light olive gray (5Y 6/1) to olive gray (5Y 4/1), the darker intervals generally laminated, the lighter zones indistinctly laminated with some ammonite molds or massive, hard, and siliceous(?). Fine laminations in darker intervals sometimes composed of silt-size carbonate. Chert is black (N1) and occurs as fragments and small nodules in limestone. Core is fragmented by drilling.

Thin Sections:

1, 90: Limestone (radiolarian mudstone) – predominantly mudstone with thin concentrations of calcite-filled radiolaria ~0.3–2.0 mm thick. Matrix contains 50–60% microspar patches ~0.01–0.03 mm across. Trace amounts of thin recrystallized pelecypod debris.

1, 137: Limestone (radiolarian mudstone) – sample contains ~5% radiolaria as molds or filled and replaced by calcite in a laminated micrite. Scattered fine-grained skeletal debris also present.

2, 54: Limestone (interlayered radiolarian mudstone and wackestone) – wackestone contains ~20% *calcispheres*(?) or radiolarians and minor pelecypod fragments in a 25% micrite/50% microsparite matrix. Microfossils are filled with and recrystallized to calcite. Mudstone interlayers consists of micrite with small 0.01–0.03 mm microsparite patches (~50%) and rare microfossils which are generally smaller than in wackestone layers.

SMEAR SLIDE SUMMARY (%):

	1, 22	2, 22
	D	D
Composition:		
Clay	53	43
Carbonate unspec.	30	43
Foraminifers	–	1
Diatoms	–	2
Plant debris	Tr	1
Dolomite	7	–

ORGANIC CARBON AND CARBONATE (%):

	1, 57
Organic carbon	5.6
Carbonate	84

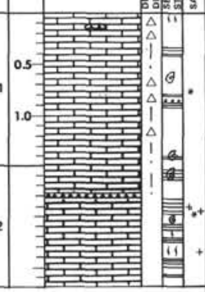
SITE 540 HOLE CORE 44 CORED INTERVAL 403.5–413.0 m

TIME – ROCK UNIT: late Albian

BIOSTRATIGRAPHIC ZONE: *Planulina buxtorfi* / *Eiffellithus turriseiffeli*

FOSSIL CHARACTER: Foraminifers CM, CM; Nannofossils AG

SECTION: 1, 2



LITHOLOGIC DESCRIPTION

LIMESTONE and CHERT. Limestone is light olive gray (5Y 6/1) to olive gray (5Y 4/1) and olive black (5Y 2/1), homogeneous to well laminated with common ammonite molds. Darker, well laminated intervals have rare yellowish gray (5Y 8/1) laminae. A 0.5 x 1.0 cm clast of laminated limestone occurs in the homogeneous interval at 27 cm, Section 1. Layer (3 cm thick) of graded carbonate at 87–90 cm, Section 1. Chert is black (N1) and conchoidally fractured. Core is fragmented by drilling.

Thin Section:

1, 77: Limestone (mudstone) – micritic limestone with abundant small planktonic and benthic foraminifers, calcite-filled, replaced radiolaria, and rare pelecypod fragments. Micrite comprises ~70% of sample.

SMEAR SLIDE SUMMARY (%):

	2, 42
	M
Composition:	
Clay	50
Carbonate unspec.	43
Calc. nannofossils	5
Diatoms	Tr
Plant debris	2

ORGANIC CARBON AND CARBONATE (%):

	2, 41	2, 44	2, 85
Organic carbon	–	3.1	–
Carbonate	90	87	99

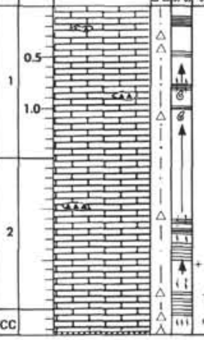
SITE 540 HOLE CORE 45 CORED INTERVAL 413.0–422.5 m

TIME – ROCK UNIT: late Albian

BIOSTRATIGRAPHIC ZONE: *Planulina buxtorfi* / *Eiffellithus turriseiffeli*

FOSSIL CHARACTER: Foraminifers CM, CM

SECTION: 1, 2, CC



LITHOLOGIC DESCRIPTION

LIMESTONE, CHERT, and BIOCLASTIC LIMESTONE. Limestone is very light gray (N8) and light olive gray (5Y 6/1) to dark gray (N3) and olive gray (5Y 4/1). Lighter zones are homogeneous to laminated, very hard (siliceous?) with common radiolaria and ammonite molds. Darker intervals are very well laminated with some clayey bands and rare burrows. Burrows commonly filled with yellowish gray silt- and fine sand-size carbonate. Black (N1) and medium gray (N6) chert nodules occur sporadically in limestone. Single fragment of olive gray (5Y 6/1) bioclastic limestone containing large foraminifers and skeletal fragment molds occurs at base of core.

Thin Section:

CC: Bioclastic limestone (wackestone) – moderately well-sorted wackestone, fine- to medium-grained composed mostly of limestone intraclasts (30%) in mixed micrite/microspar matrix (~35%/13%). Intraclasts are mostly dark, micritic radiolaria and foraminiferal mudstone fragments. Other grain types include mollusc fragments (20%), foraminifers (1%), echinoderms (1%), and green algae (Tr). Chalcedony fills some voids in skeletal fragments. Many grains have micritic envelopes. Other grain boundaries are indistinct and appear to merge with surrounding matrix. Some porosity; mostly indistinct moldic, probably secondary.

ORGANIC CARBON AND CARBONATE (%):

	2, 35	2, 101	2, 145
Organic carbon	–	–	–
Carbonate	95	99	90

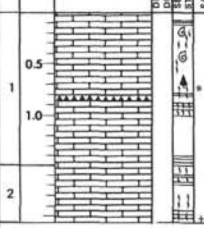
SITE 540 HOLE CORE 46 CORED INTERVAL 422.5–432.0 m

TIME – ROCK UNIT: late Albian

BIOSTRATIGRAPHIC ZONE: *Ticinella breggiensis* / *Eiffellithus turriseiffeli*

FOSSIL CHARACTER: Foraminifers AP

SECTION: 1, 2



LITHOLOGIC DESCRIPTION

LIMESTONE and CHERT. Limestone is light olive gray (5Y 6/1) and greenish gray (5GY 6/1) to olive gray (5Y 4/1) and olive black (5Y 2/1), massive and burrowed to indistinctly layered and well-laminated. Radiolaria and ammonite molds common in lighter limestone. Laminations at 94–95 cm, Section 1 in darker limestone are composed of small (~1 mm long) light-colored lenses aligned parallel to bedding. Thin yellowish gray (5Y 8/1) lamination at 15 cm in Section 2 is a very fine-grained, graded carbonate sand with some load structures. Chert is black (N1), structureless and conchoidally fractured with sharp irregular contact with limestone (nodule?).

SMEAR SLIDE SUMMARY (%):

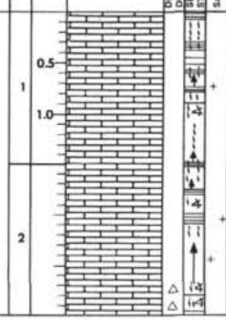
	1, 74
	D
Composition:	
Clay	40
Carbonate unspec.	58
Foraminifers	5
Calc. nannofossils	2

ORGANIC CARBON AND CARBONATE (%):

	1, 73	2, 10	2, 51
Organic carbon	–	6.5	–
Carbonate	95	83	96

SITE 540 HOLE CORE 47 CORED INTERVAL 432.0–441.5 m

Time-rock unit: late Albian
Biostratigraphic zone: *Ticinella breggiensis*, *Eiffellithus turriseiffeli*
Fossil character: CM, CG, CP, CP



LITHOLOGIC DESCRIPTION

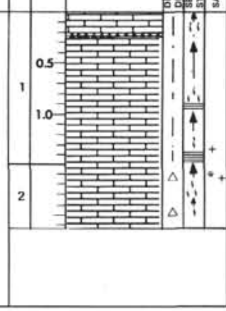
LIMESTONE, light olive gray (5Y 6/1) to olive gray (5Y 4/1). Lighter zones mostly massive and homogeneous but with some clear burrowed and indistinctly laminated intervals. Rare small pelecypod and radiolaria molds. Faint, inclined layering occurs in base Section 1 and much of Section 2. Darker intervals are laminated to indistinctly laminated. Some very thin yellowish gray (5Y 8/1) laminations and one lense (at ~80 cm, Section 1) are slightly coarser-grained than enclosing limestone. Gradational changes from darker limestone to lighter limestone in Section 1, sharp in Section 2.

ORGANIC CARBON AND CARBONATE (%):

	1, 76	2, 53	2, 92
Organic carbon	–	5.8	–
Carbonate	89	68	88

SITE 540 HOLE CORE 48 CORED INTERVAL 441.5–451.0 m

Time-rock unit: late Albian
Biostratigraphic zone: *Ticinella breggiensis*, *Eiffellithus turriseiffeli*
Fossil character: CM, FR, CG



LITHOLOGIC DESCRIPTION

LIMESTONE and CHERT. Limestone is light gray (N7) and slightly greenish gray (5GY 6/1) changing to olive gray (5Y 4/1) and light olive gray (5Y 6/1) at ~80 cm in Section 1. Burrowed throughout but with several irregularly laminated or layered intervals. Planolites-type burrows present. Planar fabric best developed below 80 cm, Section 1. Chert is black (N1) and lenticular. Lower part of core brecciated by drilling.

Thin Section:

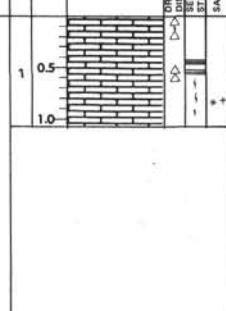
2, 10: Limestone (radiolarian-foraminiferal wackestone) – consists of foraminifera (~15%) and radiolaria molds (<1%; many calcite-filled) in a micritc matrix (85%). Rare platy grains (mollusc fragments?) also are present.

ORGANIC CARBON AND CARBONATE (%):

	1, 138	2, 17
Organic carbon	–	–
Carbonate	91	87

SITE 540 HOLE CORE 49 CORED INTERVAL 451.0–460.5 m

Time-rock unit: late Albian
Biostratigraphic zone: *Ticinella breggiensis*, *Eiffellithus turriseiffeli*
Fossil character: CM, CM



LITHOLOGIC DESCRIPTION

LIMESTONE, light olive gray (5Y 6/1) to olive gray (5Y 4/1) with a lighter interval of light gray (N7) to greenish gray (5GY 6/1) between 20–75 cm. Darker zones generally have good planar fabric but perfect laminations are rare. Burrows as marked. Lighter zone has faint irregular laminations as shown. Parts of core brecciated by drilling.

SMEAR SLIDE SUMMARY (%):

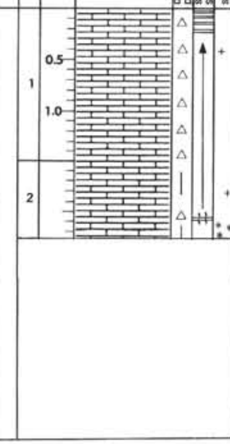
	1, 81
	D
Composition:	
Clay	40
Carbonate unspec.	48
Foraminifers	10
Calc. nannofossils	2

ORGANIC CARBON AND CARBONATE (%):

	1, 81
Organic carbon	–
Carbonate	83

SITE 540 HOLE CORE 50 CORED INTERVAL 460.5–470.0 m

Time-rock unit: late Albian
Biostratigraphic zone: *Ticinella breggiensis*
Fossil character: RP, FP, CP



LITHOLOGIC DESCRIPTION

LIMESTONE, light olive gray (5Y 6/1) to greenish gray (5GY 6/1), indistinctly and irregularly laminated or layered with common discontinuous layers or lenses of yellowish gray (5Y 8/1) slightly coasered grained carbonate (foraminifers and unidentified carbonate debris). Thickest layers up to 3 mm; usually <1 mm. Several pieces (e.g. 110–125 cm, Section 1, 60–65 and 75–78 cm, Section 2) are massive with common small pelecypod molds. Core is fragmented by drilling.

Thin Sections:

2, 62: Limestone (mollusc-wackestone) – consists of mollusc fragments and molds in microspar. Slight silicification of some of the skeletal fragments.

2, 67: Limestone (mudstone) – consists of ~98% micrite and ~2% calcite-filled radiolaria molds and <1% foraminifers.

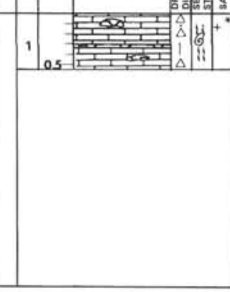
2, 75: Limestone (grainstone) – consists of peloids (75%), foraminifers (10%), *calcispheres*(?) (5%), and rare echinoderm and mollusc fragments with some blocky calcite cement. Porosity (~5%) is mostly primary.

ORGANIC CARBON AND CARBONATE (%):

	1, 42	2, 31
Organic carbon	–	–
Carbonate	98	91

SITE 540 HOLE CORE 51 CORED INTERVAL 470.0–479.5 m

Time-rock unit: late Albian
Biostratigraphic zone: *Ticinella breggiensis*, *Prediscosphaera cretacea*
Fossil character: RP, CP, AG, CP



LITHOLOGIC DESCRIPTION

LIMESTONE and CHERT. Limestone is greenish gray (5GY 6/1) to light greenish gray (5GY 8/1) generally bioturbated and homogeneous with a faint, irregular planar fabric. Contains thin yellowish gray (5Y 8/1) laminae of carbonate silt or fine sand and minor moldic porosity. Ammonite mold at 30 cm. Chert is black (N1) and occurs as separate pieces and small nodules and bands in limestone. Core almost completely brecciated by drilling.

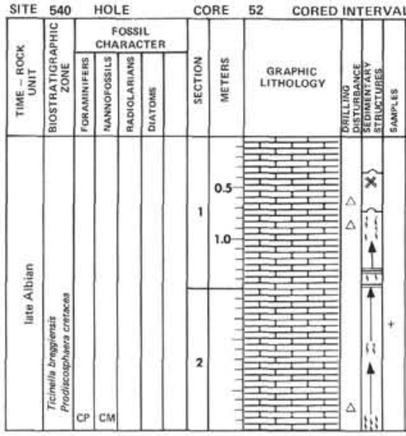
Thin Section:

1, 5: Limestone (mudstone) – consists of ~97% micrite and ~3% foraminifers with rare radiolaria.

ORGANIC CARBON AND CARBONATE (%):

	1, 14
Organic carbon	–
Carbonate	95

SITE 540 HOLE CORE 52 CORED INTERVAL 479.5–489.0 m



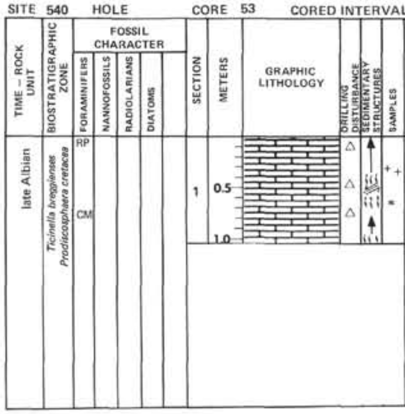
LITHOLOGIC DESCRIPTION

LIMESTONE, white (N9) and very light gray (N8) to greenish gray (5GY 6/1) and dark greenish gray (5GY 4/1). Top part of Section 1 (0–80 cm) is deformed with common slump folds and some pervasive fracturing. Below this, limestone is laminated and burrowed as marked. Laminations are indistinct and those parts have more of a planar fabric. Planolites and chondrites-type burrows common. Limestone pieces between 75–90 cm, Section 1, are white and contrast sharply with enclosing limestones. Small yellowish gray (5Y 8/1) clast in this interval is composed principally of a hydrozoan. Other color changes in core are gradational.

ORGANIC CARBON AND CARBONATE (%):

	2, 37
Organic carbon	0.49
Carbonate	68

SITE 540 HOLE CORE 53 CORED INTERVAL 489.0–498.5 m



LITHOLOGIC DESCRIPTION

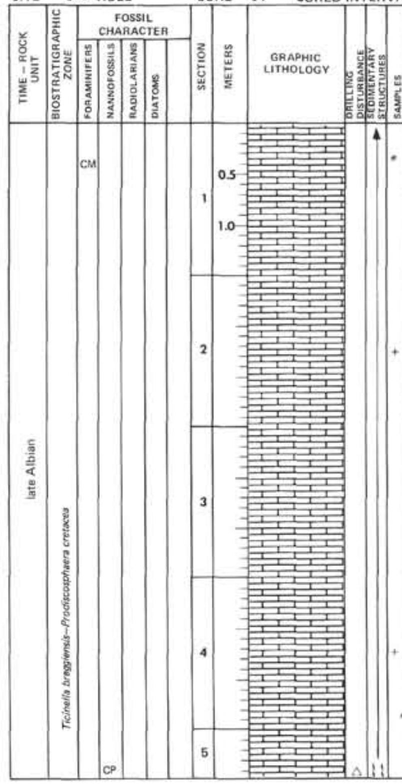
LIMESTONE, variable colors (partly result of burrowing) include light gray (10YR 7/1–N7) to medium dark gray (N4) and black (N1). Extensively burrowed; planolites(?) and zoophycos common. Fabric of rock reflects compaction of light and dark material around flattened, burrow fills. Some stylolitic seams noted at 43, 49, and 60 cm. Small fault offsets layering at 40–43 cm.

Thin Section:
1, 64: Limestone (mudstone) – consists of ~82% micrite, 15% foraminifers, and 3% radiolaria. Moldic and primary porosity ≅10%.

ORGANIC CARBON AND CARBONATE (%):

	1, 31	1, 38
Organic carbon	–	0.75
Carbonate	88	82

SITE 540 HOLE CORE 54 CORED INTERVAL 498.5–508.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE, mottled light gray (N7) and light olive gray (5Y 6/1) to greenish gray (5GY 6/1). Homogeneous and burrowed throughout with common planolites and chondrites. Faint layering occurs sporadically throughout.

Thin Section:
1, 36: Limestone (pellet-foraminiferal wackestone) – principally micrite (~75%), but contains common pellets, platy grains, and foraminifers.

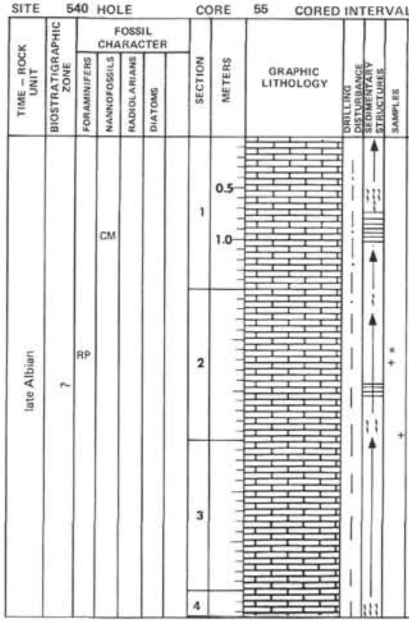
SMEAR SLIDE SUMMARY (%):

	4, 137
	D
Composition:	
Carbonate unspec.	100

ORGANIC CARBON AND CARBONATE (%):

	2, 75	4, 74
Organic carbon	–	–
Carbonate	96	99

SITE 540 HOLE CORE 55 CORED INTERVAL 508.0–517.5 m



LITHOLOGIC DESCRIPTION

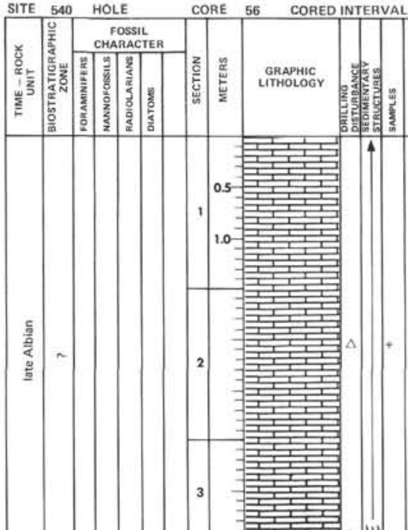
LIMESTONE, light olive gray (5Y 6/1) to light gray (10YR 7/1), color changes gradational, Several indistinctly laminated or layered intervals as marked, but most of core is homogeneous and burrowed. Truncation (or pseudotruncation) of layers is common in Section 1 between 80–120 cm.

Thin Section:
2, 62: Limestone (mudstone) – consists almost wholly of micrite with rare radiolaria.

ORGANIC CARBON AND CARBONATE (%):

	2, 71	2, 147
Organic carbon	–	–
Carbonate	94	92

SITE 540 HOLE CORE 56 CORED INTERVAL 517.5–527.0 m



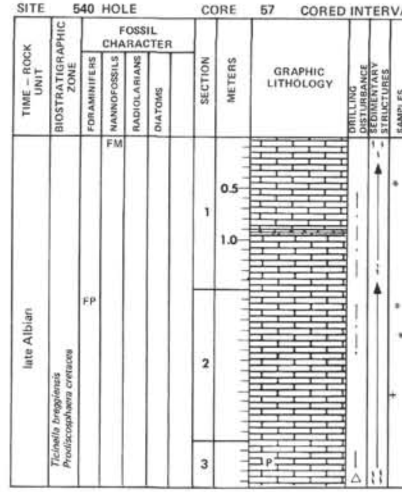
LITHOLOGIC DESCRIPTION

LIMESTONE, light gray (N7) to medium light gray (N6), homogeneous and burrowed throughout. Some chondrites.

ORGANIC CARBON AND CARBONATE (%):

	2, 55
Organic carbon	–
Carbonate	99

SITE 540 HOLE CORE 57 CORED INTERVAL 527.0–536.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE, light gray (N7) to medium light gray (N6), homogeneous and burrowed throughout, Some faint layering scattered throughout, Color changes subtle and gradational. Piece of black (N1) CHERT occurs in Section 1. Core is fragmented by drilling.

Thin Section:
2, 17: Limestone (mudstone) – micritic limestone with rare foraminifers and radiolaria.

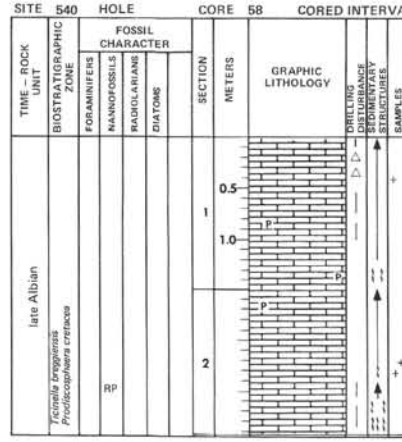
SMEAR SLIDE SUMMARY (%):

	1, 41	2, 48
	D	D
Carbonate unspec.	100	100

ORGANIC CARBON AND CARBONATE (%):

	2, 104
Organic carbon	0.95
Carbonate	83

SITE 540 HOLE CORE 58 CORED INTERVAL 536.5–546.0 m



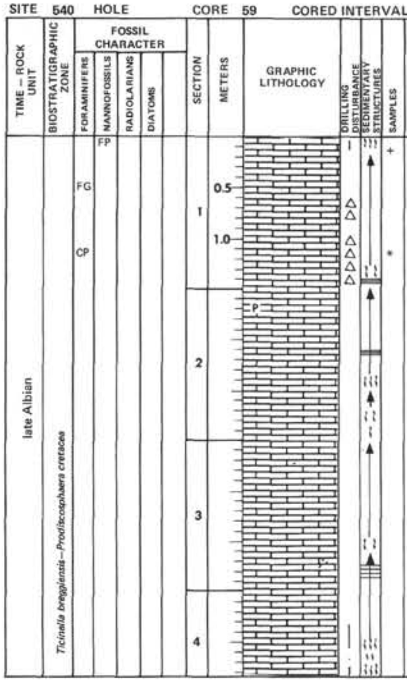
LITHOLOGIC DESCRIPTION

LIMESTONE, light gray (N7) to medium light gray (N6) and medium gray (N5), homogeneous and burrowed throughout. Chondrites between 95–120 cm. Color changes gradational; darkest between top and 100 cm, Section 2. Some finely-divided pyrite patches as marked.

ORGANIC CARBON AND CARBONATE (%):

	1, 41	2, 79	2, 84
Organic carbon	–	–	1.25
Carbonate	96	95	95

SITE 540 HOLE CORE 59 CORED INTERVAL 546.0–555.5 m



LITHOLOGIC DESCRIPTION

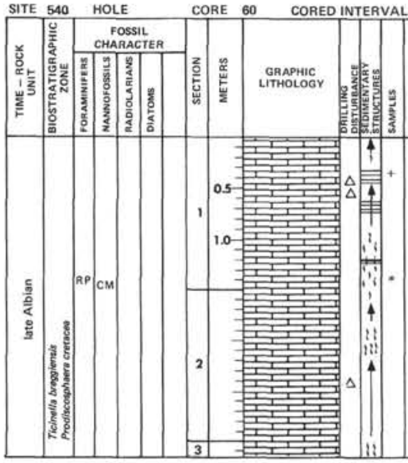
LIMESTONE, variable colors – mostly light olive gray (5Y 6/1) and light gray (N7) to medium dark gray (N4), olive gray (5Y 4/1), and greenish gray (5GY 6/1). Darker colors prevail in Section 1; Sections 2–4 more homogeneous. Most of core is moderately to extensively burrowed with some faint layering as marked. Burrows mostly sub-horizontal or flattened giving rock a gently dipping fabric (e.g. 110–150 cm, Section 3). Several pieces of white (N9) limestone occur in Section 1. Very large burrows between 35–60 cm, Section 2.

Thin Section:
1, 119: Limestone (foraminifer-pellet wackestone) – contains foraminifers, pellets and mollusc fragments in micrite (~ 97%). Some secondary moldic porosity.

ORGANIC CARBON AND CARBONATE (%):

	1, 16
Organic carbon	–
Carbonate	94

SITE 540 HOLE CORE 60 CORED INTERVAL 555.5–565.0 m



LITHOLOGIC DESCRIPTION

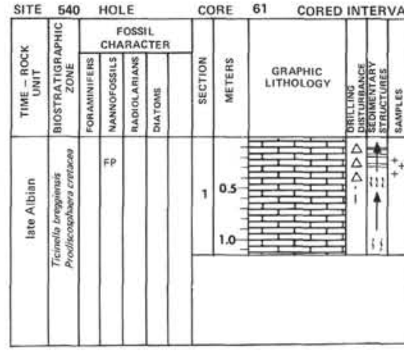
LIMESTONE, light gray (N7) and medium dark gray (N4–N5) changing to grayish brown (2.5Y 5/2) near top Section 2. Limestone in Section 1 has a gently dipping planar fabric but is not clearly layered or laminated; some of this due to bedding parallel and/or compacted burrows. Some moldic porosity (< 1%) at 135–150 cm in this section. Limestone in Sections 2 and 3 is more homogeneous and burrowed throughout. Large burrow between 40–83 cm in Section 2. Some light colored, slightly coarser-grained carbonate lenses or burrow fills at base Section 2 and in Section 3.

Thin Section:
1, 140: Limestone (radiolarian mudstone) – consists of micrite (97%) with a few radiolaria (3%) and rare foraminifers.

ORGANIC CARBON AND CARBONATE (%):

	1, 36
Organic carbon	–
Carbonate	92

SITE 540 HOLE CORE 61 CORED INTERVAL 565.0–574.5 m



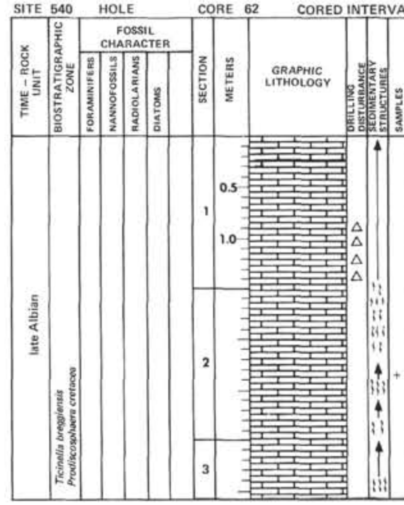
LITHOLOGIC DESCRIPTION

LIMESTONE, light olive gray (5Y 6/1) to yellowish gray (5Y 8/1), burrowed throughout. Pieces of lighter colored limestone at top of core have common microfossil and pelecypod shell molds. Some faint irregular, layering between 10–30 cm. Lower half of core has common medium gray (N5) burrow mottling. Brecciated by drilling at 0–40 cm. Strong H_2S odor when core is broken or cut.

ORGANIC CARBON AND CARBONATE (%):

	1, 23	1, 25	1, 36
Organic carbon	–	–	0.63
Carbonate	94	99	90

SITE 540 HOLE CORE 62 CORED INTERVAL 574.5–584.0 m



LITHOLOGIC DESCRIPTION

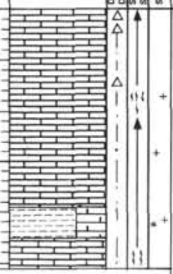
LIMESTONE, light olive gray (5Y 6/1) and yellowish gray (5Y 8/1) to greenish gray (5GY 6/1) with some medium gray (N6) burrow mottling. Core is generally homogeneous and burrowed throughout. Some planolites-type burrows have chondrites burrowing. Strong H_2S odor when broken or cut.

ORGANIC CARBON AND CARBONATE (%):

	2, 86
Organic carbon	–
Carbonate	94

SITE 540 HOLE CORE 63 CORED INTERVAL 584.0–593.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Albian	*Ticinella breggiensis* *Prodiscosphaera cretacea*	CM	CG			1, 2	0.5, 1.0



LITHOLOGIC DESCRIPTION

LIMESTONE and CALCAREOUS CLAYSTONE. Limestone is yellowish gray (5Y 8/1) to light gray (N7), greenish gray (5GY 6/1) and dark greenish gray (5GY 4/1). Lighter colored zones generally homogeneous, burrowed, and have moldic porosity (microfossil and small shell molds). Darker limestones have a planar fabric and are strongly bioturbated (planolites common, some chondrites). Color changes gradational. Calcareous claystone in Section 2 is dark greenish gray to greenish black (5G 2/1), homogeneous and burrowed (planolites) with lighter limestone filling burrows. Strong H_2S odor when core is cut or broken.

SMEAR SLIDE SUMMARY (%):

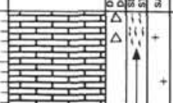
	2, 69
	M
Texture:	
Sand	Tr
Silt	30
Clay	70
Composition:	
Quartz	Tr
Clay	70
Pyrite	2
Carbonate unspec.	25
Calc. nannofossils	1
Iron-oxides	2

ORGANIC CARBON AND CARBONATE (%):

	1, 88	1, 142	2, 62
Organic carbon	1.8	–	–
Carbonate	85	97	27

SITE 540 HOLE CORE 64 CORED INTERVAL 593.5–603.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Albian	*Ticinella breggiensis* *Prodiscosphaera cretacea*		FP			1	0.5, 1.0



LITHOLOGIC DESCRIPTION

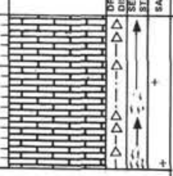
LIMESTONE, light olive gray (5Y 6/1) to greenish gray (5GY 6/1), extensively burrowed. Many planolites-type burrows in darker intervals are filled with lighter colored limestone. Burrows appear flattened and sheared giving core a fabric that dips ~20° to core axis. One white (N9) limestone fragment at 82 cm is hard with stylolitic seams and apparent tension cracks; probably an included clast rather than burrow filling. Core has strong H_2S odor when broken or cut.

ORGANIC CARBON AND CARBONATE (%):

	1, 26	1, 70
Organic carbon	–	–
Carbonate	99	93

SITE 540 HOLE CORE 65 CORED INTERVAL 603.0–612.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Albian	*Ticinella breggiensis* *Prodiscosphaera cretacea*					1	0.5, 1.0



LITHOLOGIC DESCRIPTION

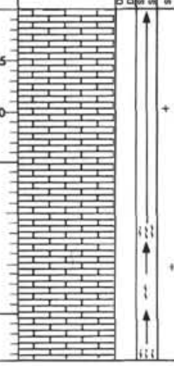
LIMESTONE, very light gray (N8) mottled with light gray (N7). Pieces at 58, 67, 93, and 145–150 cm are darker and contain wispy, anastomosing clayey seams around lighter limestone lenses. Burrows common throughout.

ORGANIC CARBON AND CARBONATE (%):

	1, 64	1, 147
Organic Carbon	–	0.72
Carbonate	99	94

SITE 540 HOLE CORE 66 CORED INTERVAL 612.5–622.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Albian	*Ticinella breggiensis* *Prodiscosphaera cretacea*					1, 2, 3	0.5, 1.0



LITHOLOGIC DESCRIPTION

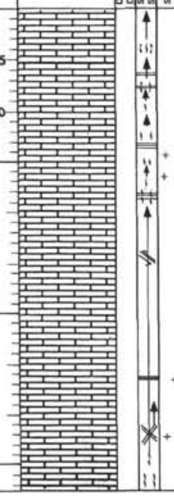
LIMESTONE, light gray (N7) to greenish gray (5GY 6/1), bioturbated throughout with planar fabric in places. Much of burrowing is bedding parallel. Some chondrites. Scattered pelecypod fragments in Section 2. Changes from lighter to darker zones are gradational. Strong H_2S odor when cut or broken.

ORGANIC CARBON AND CARBONATE (%):

	1, 97	2, 100
Organic carbon	–	–
Carbonate	99	95

SITE 540 HOLE CORE 67 CORED INTERVAL 622.0–631.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Albian	*Ticinella breggiensis* *Prodiscosphaera cretacea*		CM			1, 2, 3, 4	0.5, 1.0



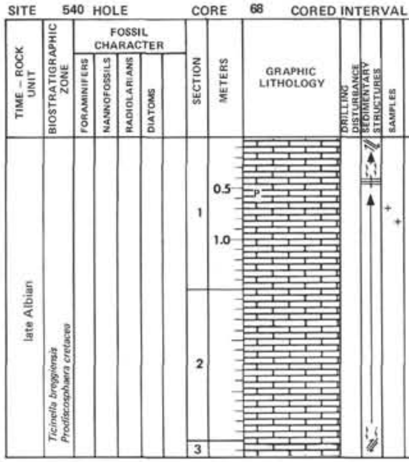
LITHOLOGIC DESCRIPTION

LIMESTONE, very light gray (N8) to medium gray (N5), alternating extensively burrowed and less burrowed intervals down to ~45 cm, Section 2. Some wispy laminations or layering, resembling solution seams, as marked. Some skeletal debris(?) fills burrows at ~125–130 cm in Section 1. Microfossil molds also common in this part of core. Below 45 cm in Section 2 limestone is more homogeneous with sparse medium gray (N5) indistinct burrow mottling. Some chondrites and zoophycos burrows noted. Limestone at 119–150 cm, Section 3 contains mixed carbonate sand and silt. Thin burrowed carbonate sandy layer at ~119 cm. Stylolites occur at base of this section.

ORGANIC CARBON AND CARBONATE (%):

	1, 145	2, 18	3, 69	3, 123
Organic carbon	–	–	0.86	–
Carbonate	83	97	80	82

SITE 540 HOLE CORE 68 CORED INTERVAL 631.5–641.0 m



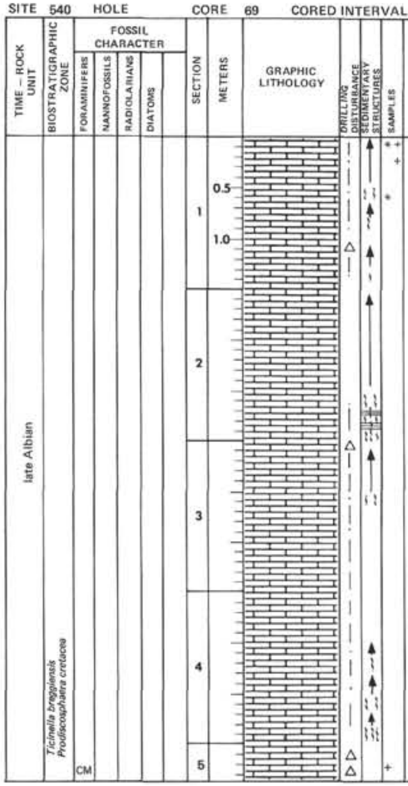
LITHOLOGIC DESCRIPTION

LIMESTONE, *very light gray (N8) to medium gray (N5)*, homogeneous and burrowed throughout. Some pieces have an inclined, planar sheared fabric. Mottles occur as darker patches in lighter-colored limestone. Slickensides at top and base, Section 1 and top Section 3. Large burrow at 130–140 cm, Section 1. Color variations gradational.

ORGANIC CARBON AND CARBONATE (%):

	1, 70	1, 86
Organic carbon	–	–
Carbonate	96	75

SITE 540 HOLE CORE 69 CORED INTERVAL 641.0–650.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE, very light gray (N8) to medium gray (N5), darker color forming blotchy patches in dominantly lighter limestone. Burrowed throughout. Somewhat variable between 115 cm, Section 2 and 70 cm, Section 2. Indistinctly layered with radiolaria molds and several limestone fragments at top of this interval (limestone fragments at 130 cm, Section 2 and 0–5 cm, Section 3). Carbonate sand fills burrows at 32–39 cm and at 55–58 cm, Section 3. Limestone clasts again at 68–70 cm in this section in a sandy (carbonate sand) limestone. A less burrowed, color banded interval occurs below this zone (70–150 cm, Section 3). Mottled limestone similar to that in Section 1 occurs below this.

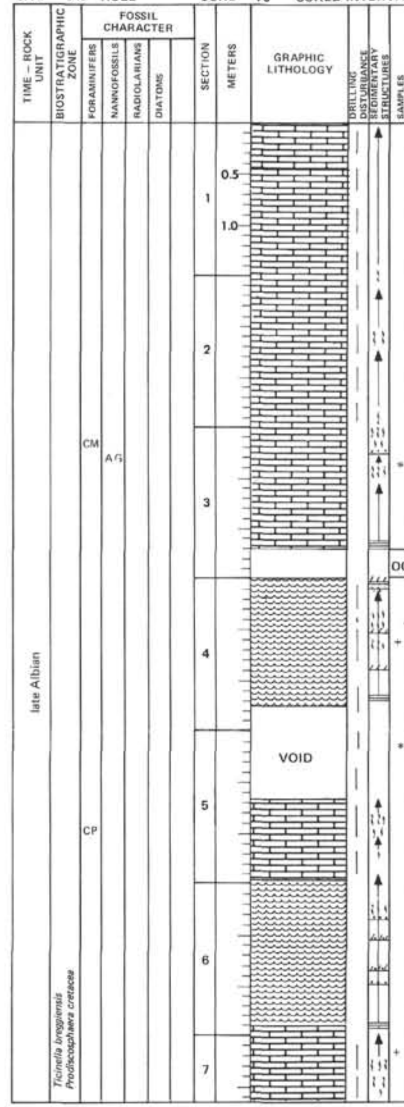
SMEAR SLIDE SUMMARY (%):

	1, 5	1, 60
	D	D
Composition:		
Clay	75	64
Pyrite	2	1
Carbonate unspec.	20	30
Dolomite	3	5

ORGANIC CARBON AND CARBONATE (%):

	1, 9	1, 23	5, 21
Organic carbon	–	1.7	–
Carbonate	66	86	81

SITE 540 HOLE CORE 70 CORED INTERVAL 650.5–660.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE and MARLY LIMESTONE. Limestone is medium light gray (N6) to light gray (N7), homogeneous, and burrow mottled, and faintly banded in first two sections. Becomes sandy (carbonate sand) at top Section 3 with common thin sandy layers some graded and micro-cross-laminated. Burrows are also filled with fine carbonate sand. Sand is light yellowish gray (5Y 8/1). Marly limestone in Sections 4 and 6 is dark gray (N3) to grayish black (N2), laminated (sandy laminae), with occasional lighter bands. Sandy laminae sometimes graded and cross-laminated. Sparse burrows.

Thin Section:

5, 72: Limestone (grainstone) – contains peloids (50%), foraminifers (20%), echinoderm fragments (20%), mollusc fragments (20%) and rare quartz. Large calcite crystals (overgrowths of echinoderms?) scattered throughout. Primary porosity ≤25%.

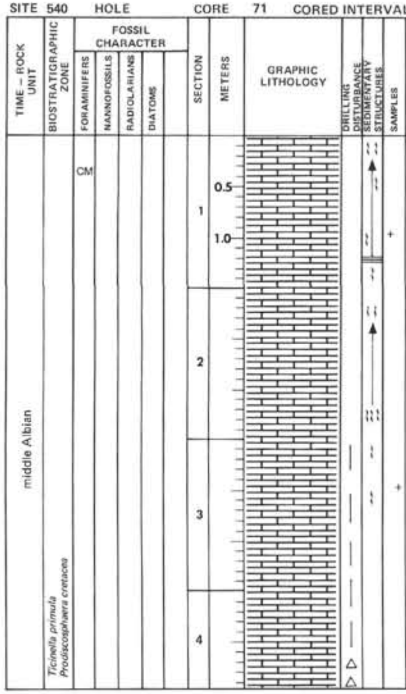
SMEAR SLIDE SUMMARY (%):

	3, 23
	D
Composition:	
Quartz	Tr
Clay	44
Volcanic glass	Tr
Glauconite	Tr
Carbonate unspec.	44
Foraminifers	6
Calc. nannofossils	1
Phosphate	Tr
Dolomite	5

ORGANIC CARBON AND CARBONATE (%):

	4, 46	4, 62	7, 18
Organic carbon	–	0.20	–
Carbonate	38	51	88

SITE 540 HOLE CORE 71 CORED INTERVAL 660.0–669.5 m



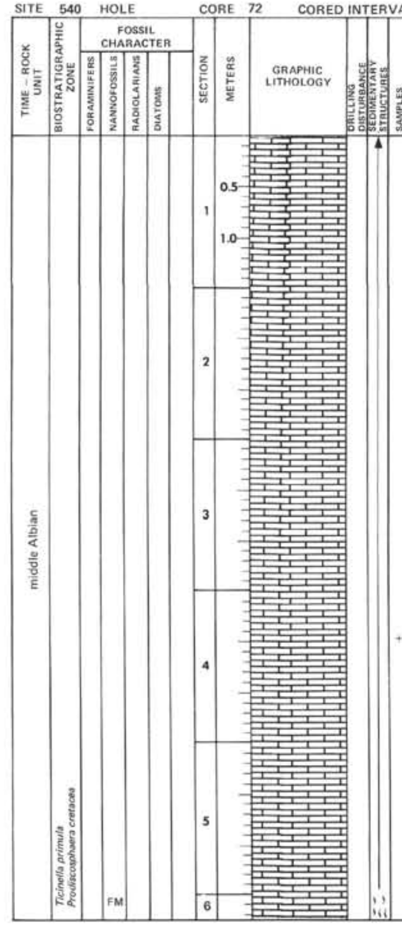
LITHOLOGIC DESCRIPTION

LIMESTONE, medium light gray (N6) to dark gray (N3), laminated in Section 1 and burrowed to homogeneous below Section 1. Laminations are greenish gray (5Y 6/1). Scattered burrows in Section 1; some filled with yellowish gray (5GY 8/1) sandy limestone. Dark laminated limestone grades to lighter more homogeneous limestone at base of Section 1. More intensely burrowed zone occurs in Section 2 as marked.

ORGANIC CARBON AND CARBONATE (%):

	1, 98	3, 48
Organic carbon	–	–
Carbonate	74	94

SITE 540 HOLE CORE 72 CORED INTERVAL 669.5–679.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE, medium light gray (N5) to greenish gray (5G 6/1) homogeneous and burrowed throughout. Sharp change to light olive gray (5Y 6/1) limestone at 15 cm in Section 6. Contact is irregular and lighter underlying limestone has burrows filled with the darker overlying material. Strong H_2S odor when core is broken or cut.

ORGANIC CARBON AND CARBONATE (%):

	4, 48
Organic carbon	–
Carbonate	89

SITE 540 HOLE CORE 73 CORED INTERVAL 679.0–688.5 m

TIME – ROCK UNIT: middle Albian

BIOSTRATIGRAPHIC ZONE: *Ticinella primula*, *Prediscosphaera cretacea*

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

SECTION: 1, 2, 3, 4 — METERS: 0.5, 1.0 — GRAPHIC LITHOLOGY — DRILLING DISTURBANCE — SEDIMENTARY STRUCTURES — SAMPLES: OG

LITHOLOGIC DESCRIPTION

LIMESTONE, light gray (N7) and medium light gray (N6) to medium gray (N5), medium dark gray (N4), and medium bluish gray (5B 5/1) giving the core an overall irregular banded appearance. Top 40 cm, Section 1 has yellowish gray (5Y 8/1) and medium gray (N5) mottling associated with burrowing. Some planar fabric or layering in Sections 1 and 2, but overall core is burrowed and homogeneous. Bedded intervals in Section 2 show some slight distortions due to slumping or differential compaction. Strong H_2S odor when core is cut or broken. Sharp color change from dark (above) to light (below) at ~70 cm, Section 3.

ORGANIC CARBON AND CARBONATE (%):

	1, 105	3, 21	3, 117
Organic carbon	0.18	–	–
Carbonate	80	66	94

SITE 540 HOLE CORE 74 CORED INTERVAL 688.5–698.0 m

TIME – ROCK UNIT: middle Albian

BIOSTRATIGRAPHIC ZONE: *Ticinella primula*, *Prediscosphaera cretacea*

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

SECTION: 1, 2, 3 — METERS: 0.5, 1.0 — GRAPHIC LITHOLOGY — DRILLING DISTURBANCE — SEDIMENTARY STRUCTURES — SAMPLES

LITHOLOGIC DESCRIPTION

LIMESTONE, light olive gray (5Y 6/1), homogeneous and indistinctly burrowed throughout. Scattered white shell fragments 1–10 mm across are common. One large echinoid ~3 cm across at 71 cm in Section 1. Shell is slightly broken and deformed. Delicate surface ornamentation preserved. Large burrow at 141 cm in Section 2.

ORGANIC CARBON AND CARBONATE (%):

	1, 12
Organic carbon	–
Carbonate	95

SITE 540 HOLE CORE 75 CORED INTERVAL 698.0–707.5 m

TIME – ROCK UNIT: middle Albian

BIOSTRATIGRAPHIC ZONE: *Ticinella primula*, *Prediscosphaera cretacea*

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

SECTION: 1 — METERS: 0.5, 1.0 — GRAPHIC LITHOLOGY — DRILLING DISTURBANCE — SEDIMENTARY STRUCTURES — SAMPLES

LITHOLOGIC DESCRIPTION

LIMESTONE, light gray (N7) and medium light gray (N6) to light olive gray (5Y 6/1), burrowed throughout with only crude planar fabric shown by slightly darker streaks.

ORGANIC CARBON AND CARBONATE (%):

	1, 58
Organic carbon	–
Carbonate	96

SITE 540 HOLE CORE 76 CORED INTERVAL 707.5–717.0 m

TIME – ROCK UNIT: middle Albian

BIOSTRATIGRAPHIC ZONE: *Ticinella primula*, *Prediscosphaera cretacea*

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

SECTION: 1, 2 — METERS: 0.5, 1.0 — GRAPHIC LITHOLOGY — DRILLING DISTURBANCE — SEDIMENTARY STRUCTURES — SAMPLES

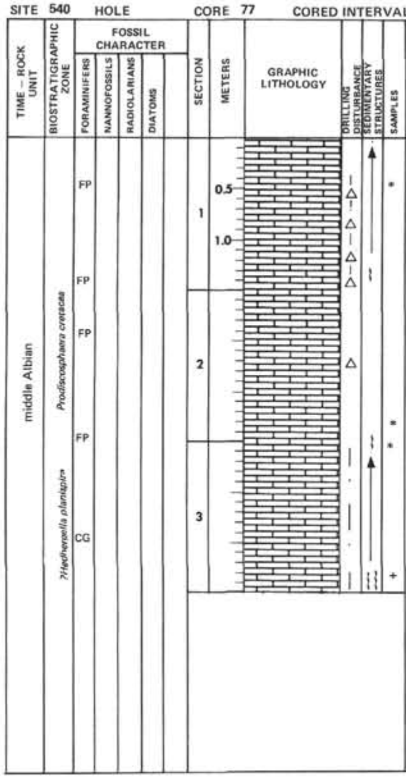
LITHOLOGIC DESCRIPTION

LIMESTONE and CHERT. Limestone is light olive gray (5Y 6/1), homogeneous and burrowed throughout. Large burrows at 15–30 cm in Section 2. Lighter olive gray band at ~60 cm in same section. Two fragments of olive black (5Y 2/1) chert at base of core. These are fragments of nodules; both have limestone rinds. One piece is faintly laminated with an unsilicified, limestone-filled burrow in the center of it.

ORGANIC CARBON AND CARBONATE (%):

	2, 83
Organic carbon	–
Carbonate	99

SITE 540 HOLE CORE 77 CORED INTERVAL 717.0–726.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE (mudstone and skeletal grainstone). Limestone is greenish gray (5GY 6/1) and consists of fine-grained carbonate with varying proportions of skeletal carbonate sand. Between top Section 1 and ~110 cm, Section 2 and between ~ 70 cm, Secton 3 and base of core this limestone contains abundant small lenses and burrow fills of mostly very fine- to fine-grained skeletal material. Subordinate medium- to very coarse-grained material is also present. Between about 110 cm, Section 2 and 70 cm, Section 3 rock is dominantly greenish gray, poorly sorted, coarse-grained to granule grade limestone (grainstone). Fine-grained limestone (mudstone) interbeds are present between ~0–70 cm, Section 3. Grains include oyster and rudist fragments and a few greenish gray limestone intraclasts that are rounded, subangular and up to 7 mm across. No good sedimentary structures. Coarser limestone occurs principally as irregular layers and burrow fills. All transitions from mudstone to graintstone are gradational and mixed by burrowing. Diffuse dark and light banding in last 45 cm of core.

Thin Sections:

1, 47: Limestone (mudstone) – fine-grained micritic limestone with scattered foraminifers and echinoid fragments.

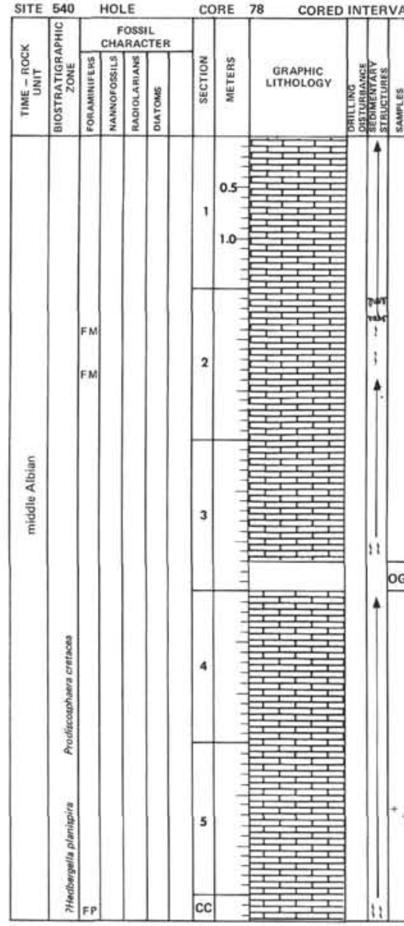
2, 130: Limestone (skeletal grainstone) – consists of mollusc fragments (~50%; abundant rudist fragments), foraminifers (20%), peloids (10%), echinoderm fragments (5%), coated grains (5%), and rare dolomite rhombs. Minor cement. Some grains interpenetrate. Primary porosity ~30%.

3, 6: Limestone (skeletal grainstone) – consists of mollusc fragments (50%; abundant rudist fragments), peloids (40%), limestone lithoclasts (10%), and rare foraminifers and echinoderm fragments. Some grain interpenetration. No cement. Primary porosity ~30%.

ORGANIC CARBON AND CARBONATE (%):

	3, 131
Organic carbon	0.30
Carbonate	77

SITE 540 HOLE CORE 78 CORED INTERVAL 726.5–736.0 m



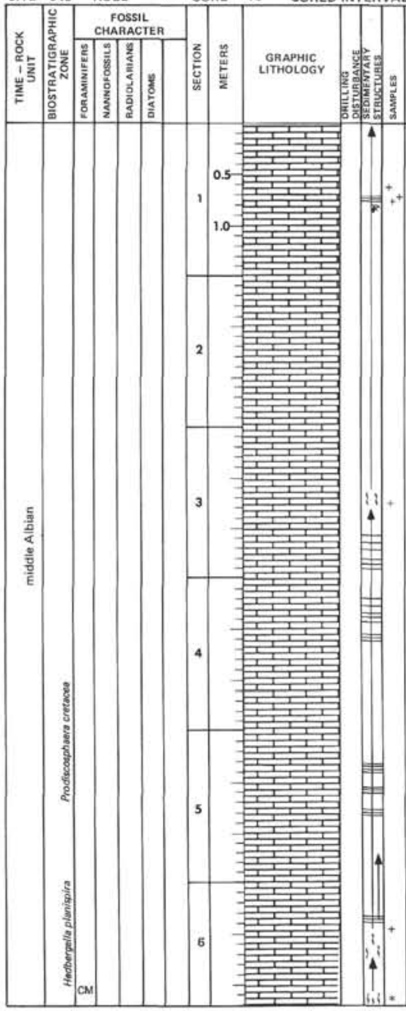
LITHOLOGIC DESCRIPTION

LIMESTONE, banded light gray (N7) to medium gray (N5) and medium dark gray (N4), burrowed throughout. Many burrows filled with fine- to coarse-grained carbonate sand. Thin lenses and layers of this sand are also common throughout. In first two sections dark bands are about 1–3 cm thick, lighter ones ~3–5 cm thick. Below this darker zones are thicker, more diffuse and irregularly distributed. Vertical stylolites in Section 1 at 35–50 cm.

ORGANIC CARBON AND CARBONATE (%):

	5, 65	5, 71
Organic carbon	–	–
Carbonate	90	85

SITE 540 HOLE CORE 79 CORED INTERVAL 736.0–745.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE (mudstone and packstone). Colors vary from *light gray (N7) and yellowish gray (5Y 8/1) to medium gray* (N5) and medium dark gray, lighter colors generally corresponding to coarser grained limestone. Mudstone with abundant thin layers, lenses and burrow fills of packstone is the dominant lithology in Section 1 and from base of Section 3 to top Section 6. In the upper part layers and lenses of sand are less common. Sand-size carbonate is mostly well-sorted, medium-grained skeletal debris. Skeletal packstone predominates from top of Section 2 to middle of Section 3 and from about middle of Section 6 to base of core. The upper interval is well-sorted, medium-grained and thoroughly homogenized by burrowing. The lower sand is medium- to coarse-grained, fills large burrows and forms irregular layers. Latter contains some recognizable echinoid debris. Boundaries between lithologies are gradational, partly a result of burrowing. Color variations are also gradational.

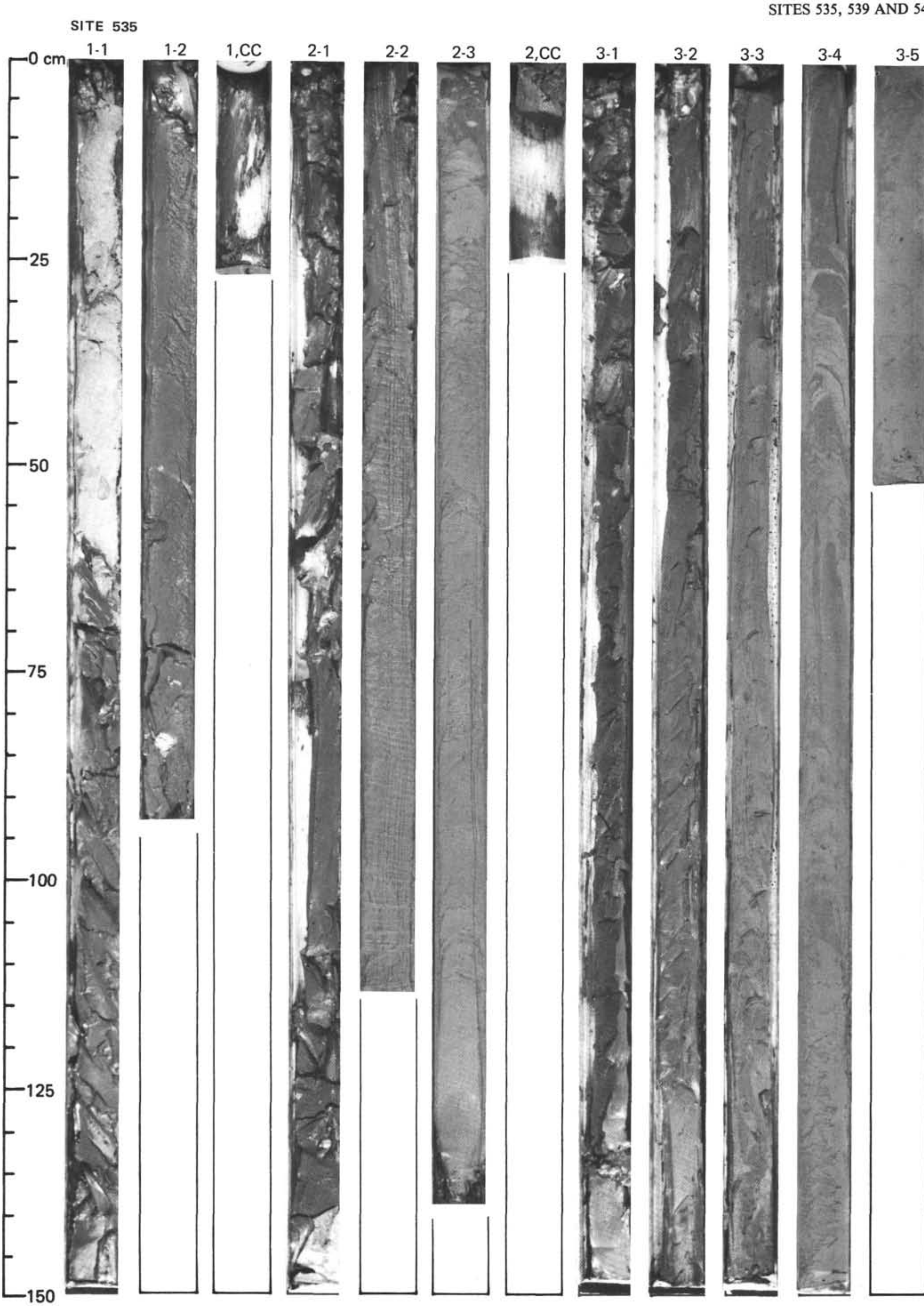
Thin Section:

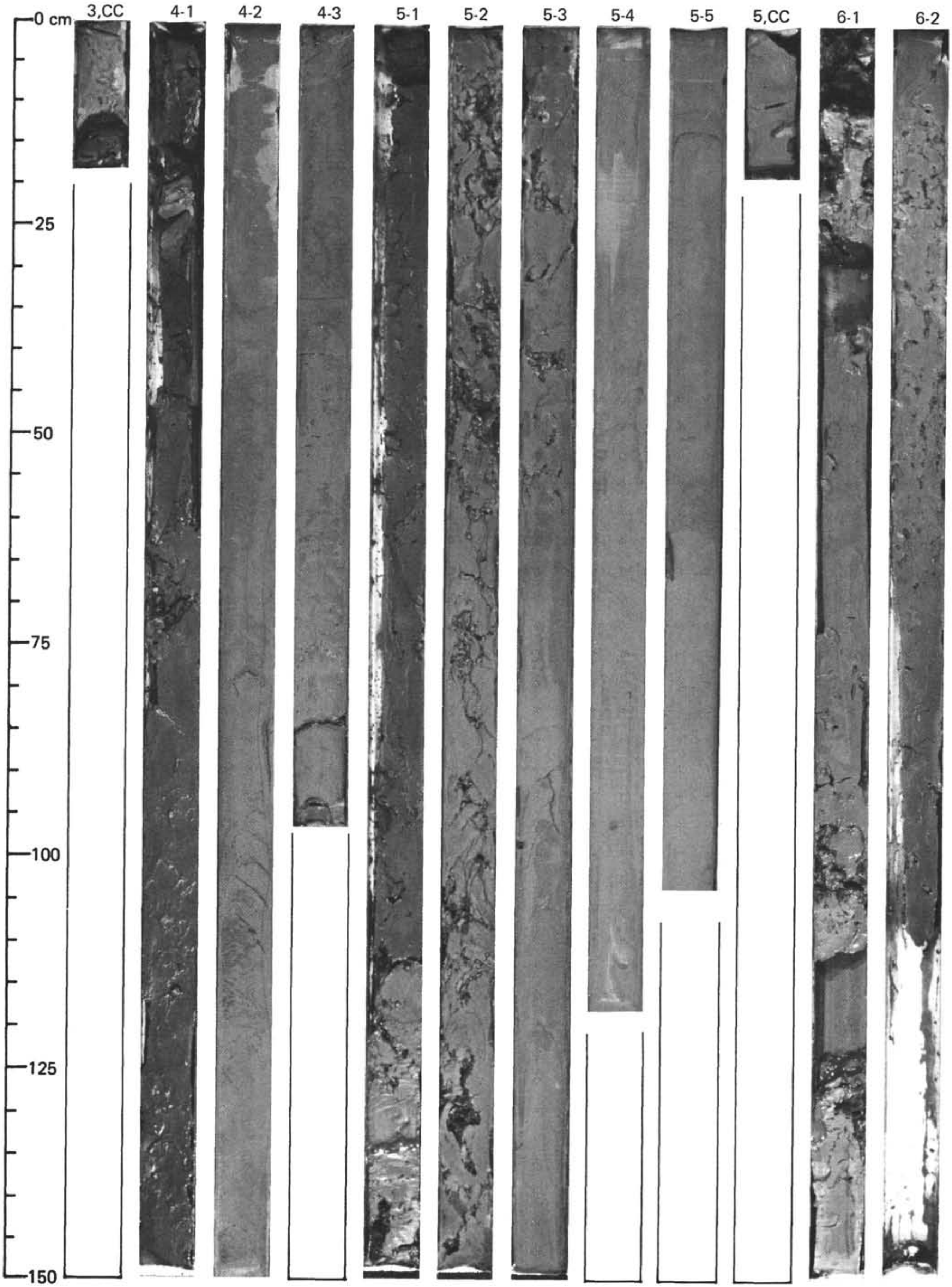
6, 113: Limestone (foraminifer-peloidal packstone) – consists of peloids (40%), planktonic and benthic foraminifers (some miliolids) (30%), echinoid fragments (10%; including spines); and fragments of rudists (5%), other molluscs (5%) and rare green algae. Sample is mostly packstone with small areas of grainstone fringed by 5–10 μm irregular calcite crystals. Large poikilotropic calcite crystals (200–300 μm) occur in pores. Primary porosity ≃10%.

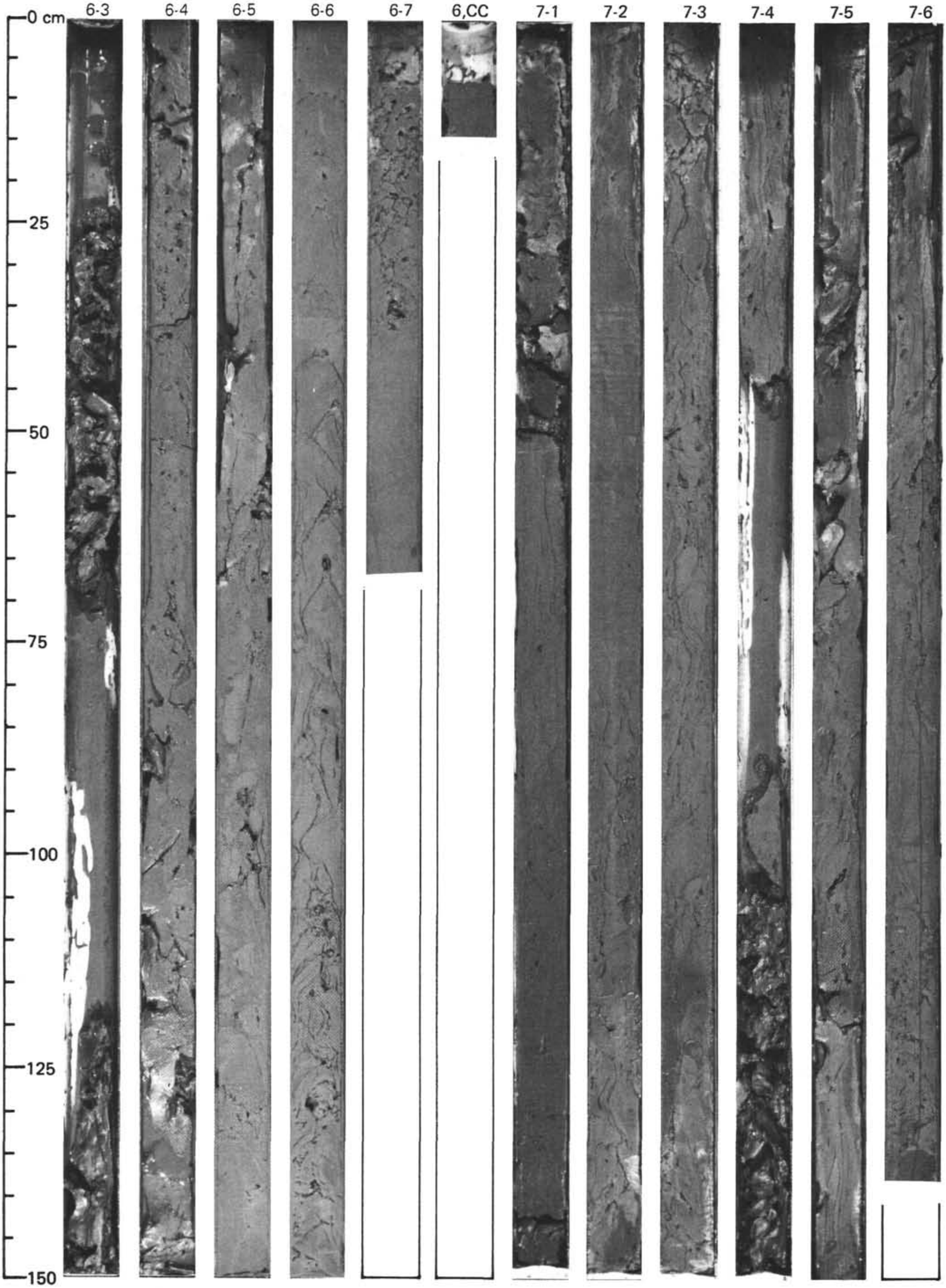
ORGANIC CARBON AND CARBONATE (%):

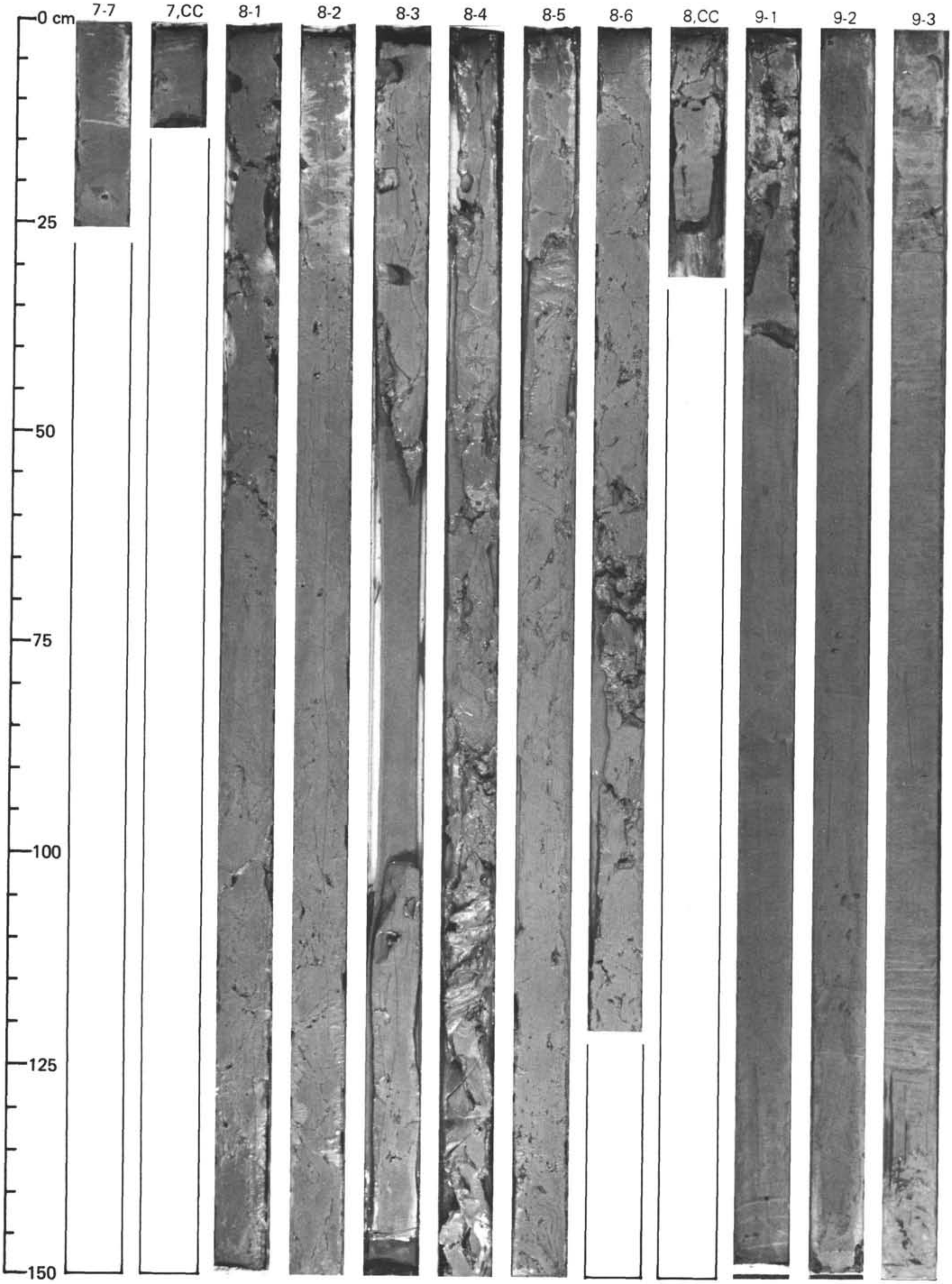
	1, 66	1, 75	1, 76	3, 73
Organic carbon	–	–	0.40	–
Carbonate	93	83	79	93

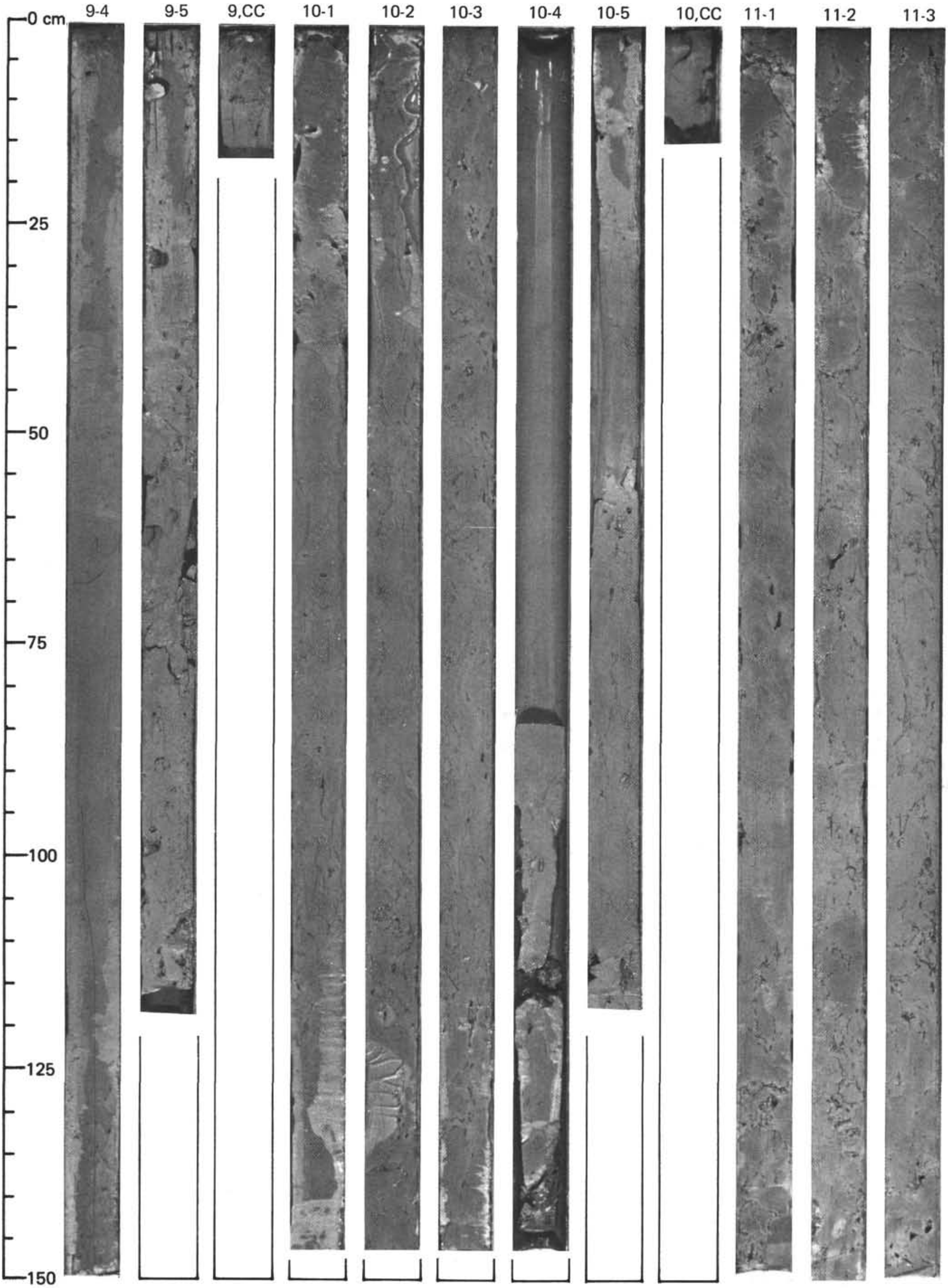
	6, 48	6, 113
Organic carbon	–	–
Carbonate	90	93

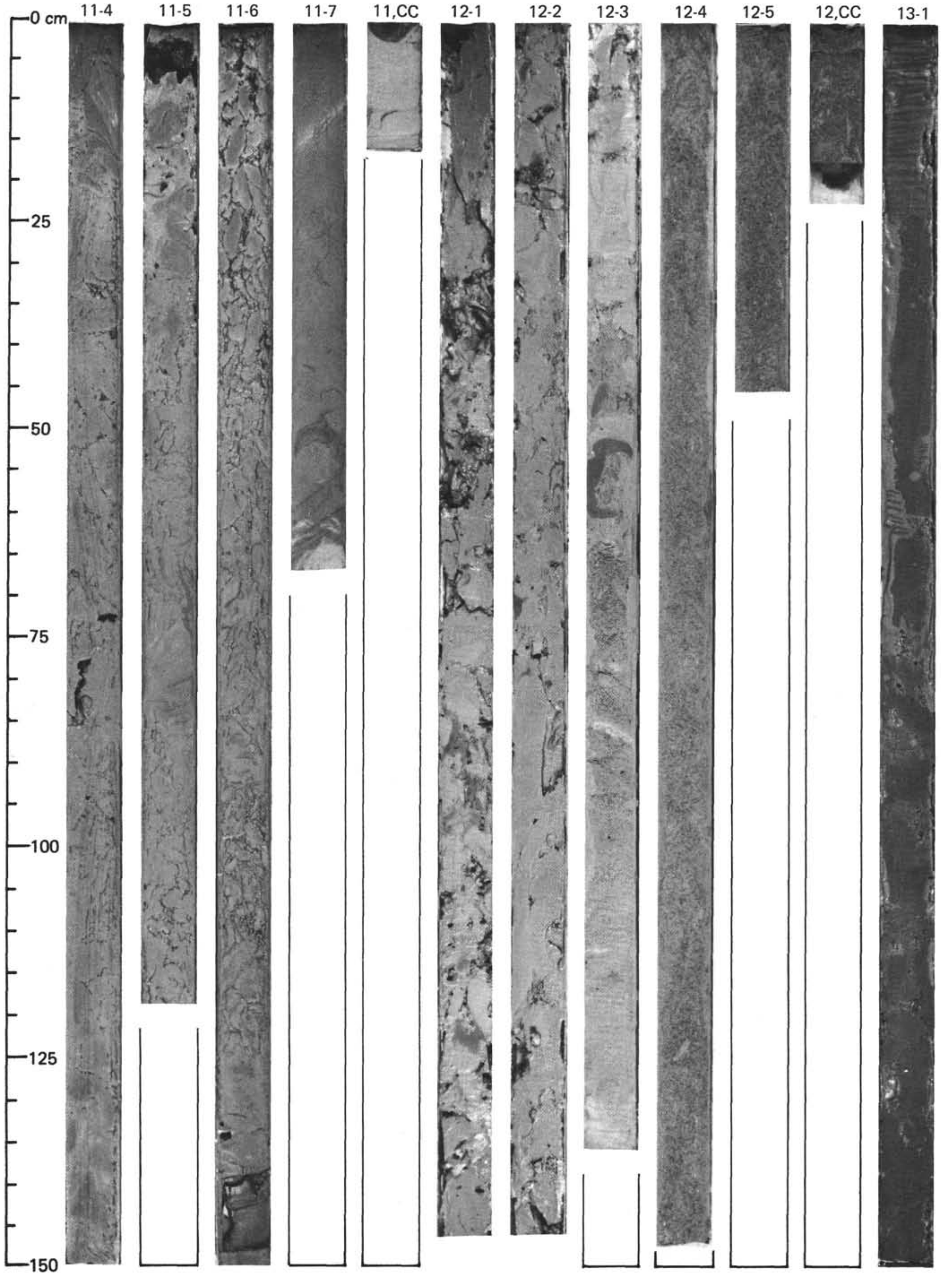

SITE 535
0 cm
25
50
75
100
125
150
1-1
1-2
1,CC
2-1
2-2
2-3
2,CC
3-1
3-2
3-3
3-4
3-5


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

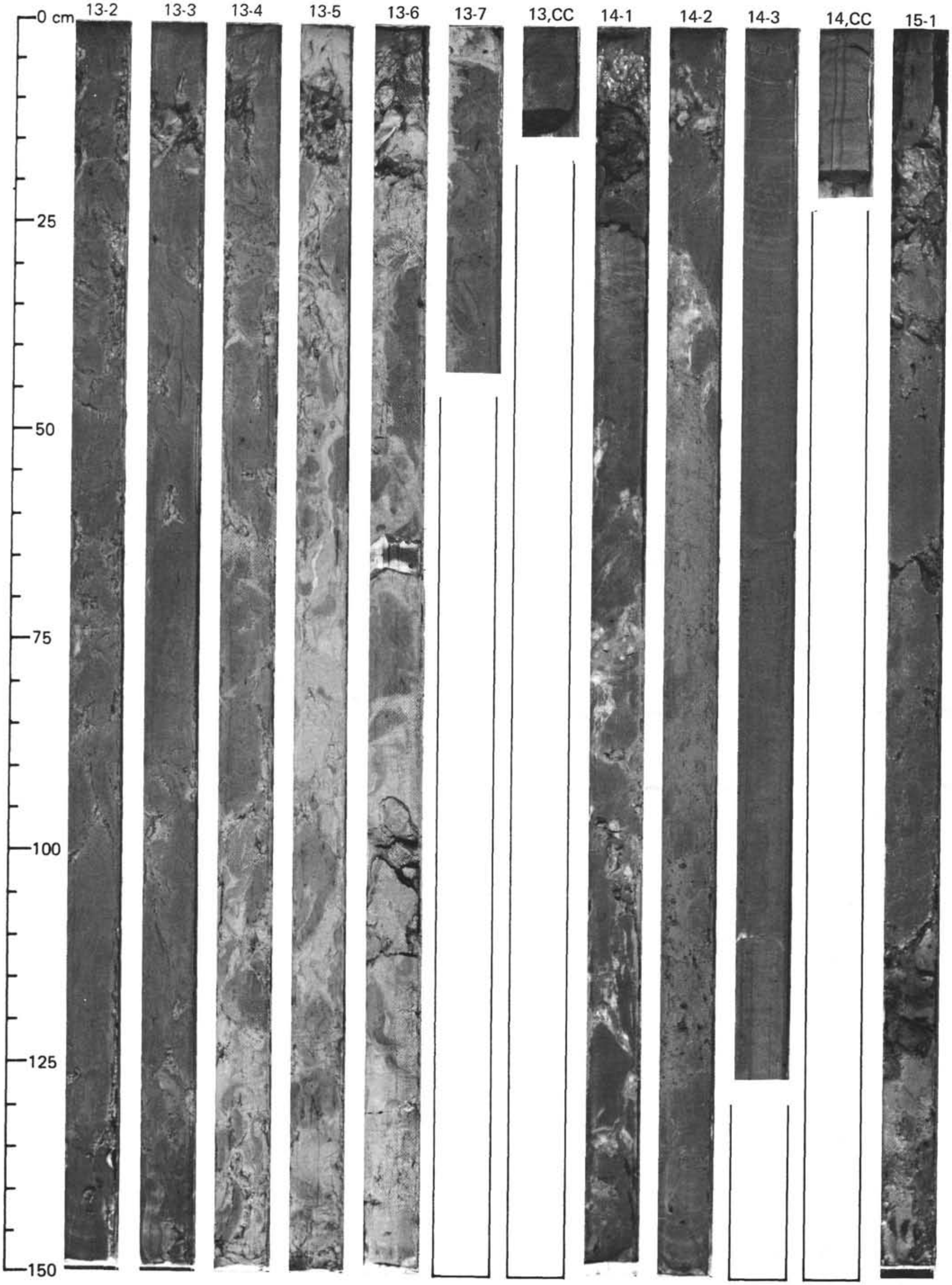

0 cm
25
50
75
100
125
150
6-3
6-4
6-5
6-6
6-7
6,CC
7-1
7-2
7-3
7-4
7-5
7-6

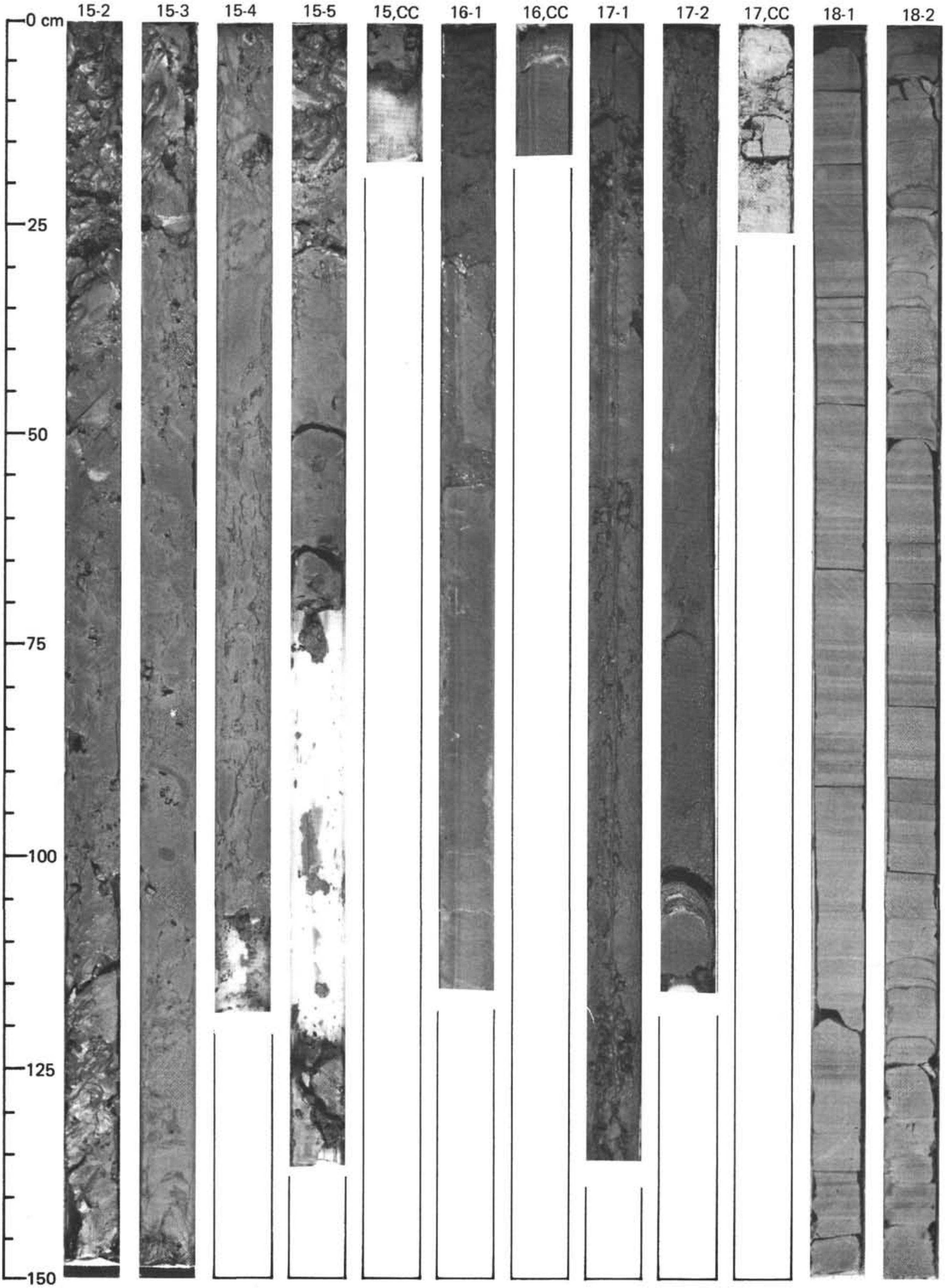

0 cm
25
50
75
100
125
150
7-7
7,CC
8-1
8-2
8-3
8-4
8-5
8-6
8,CC
9-1
9-2
9-3

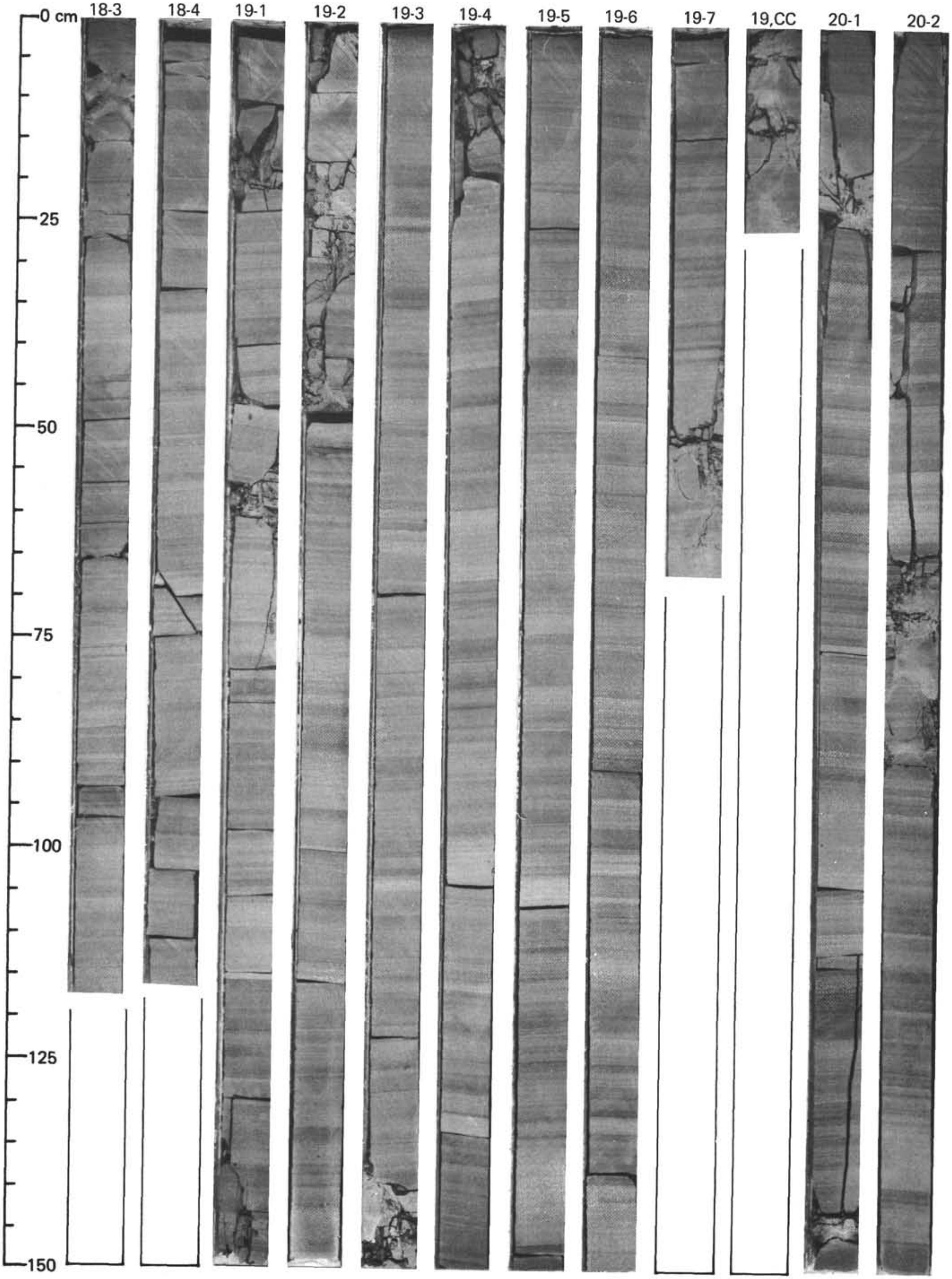

0 cm
25
50
75
100
125
150
9-4
9-5
9,CC
10-1
10-2
10-3
10-4
10-5
10,CC
11-1
11-2
11-3

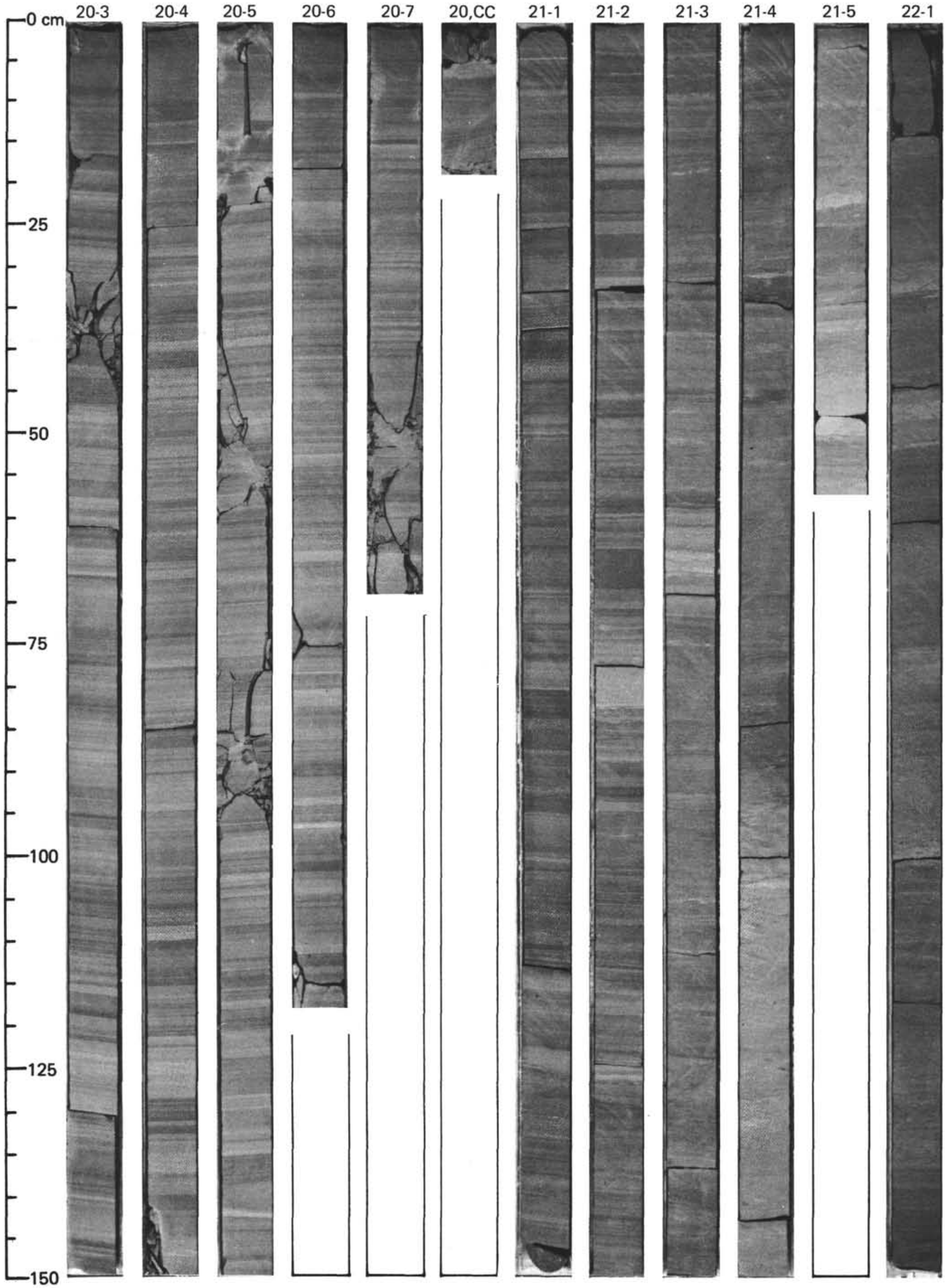


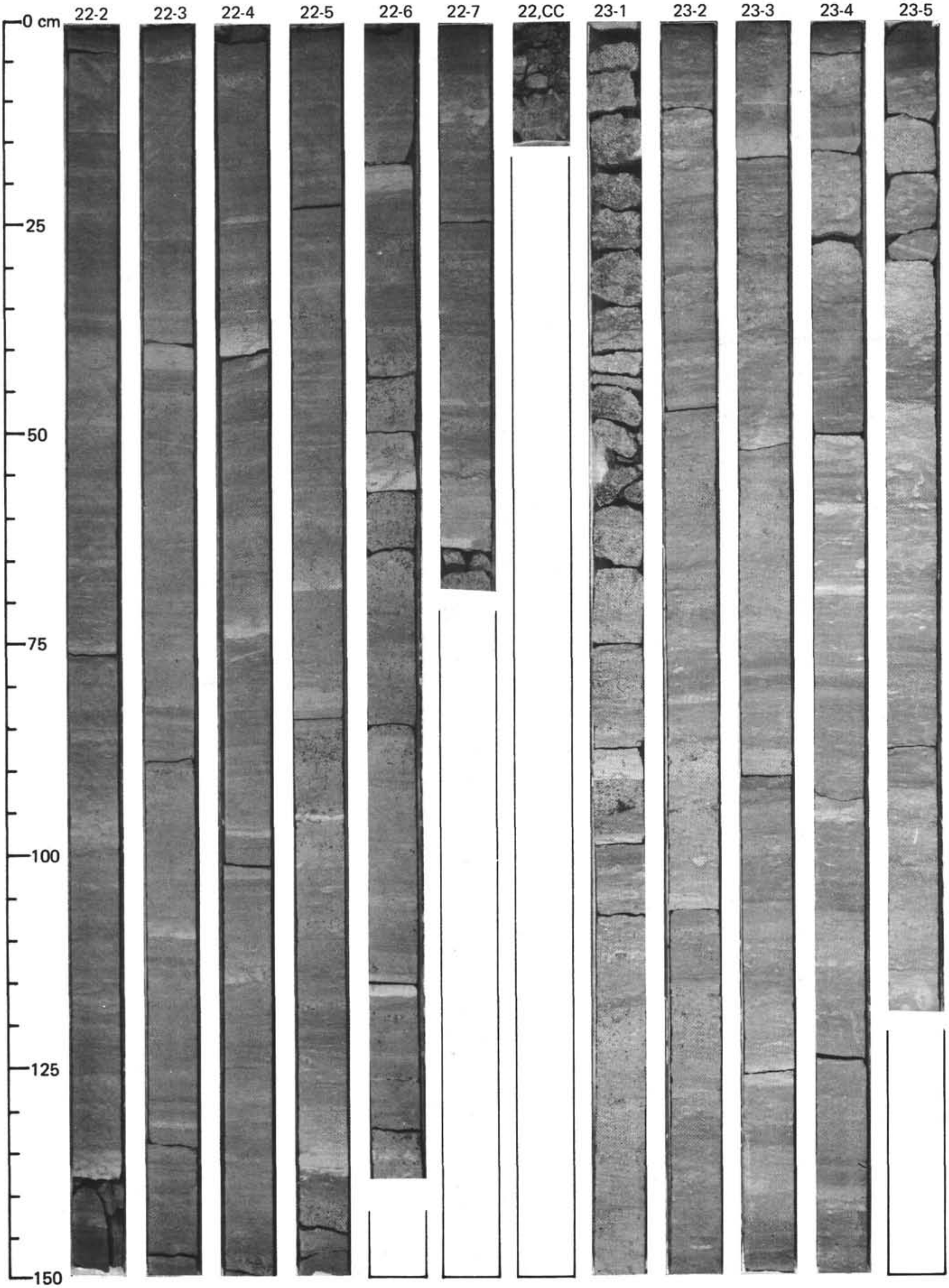
0 cm
25
50
75
100
125
150
11-4
11-5
11-6
11-7
11,CC
12-1
12-2
12-3
12-4
12-5
12,CC
13-1

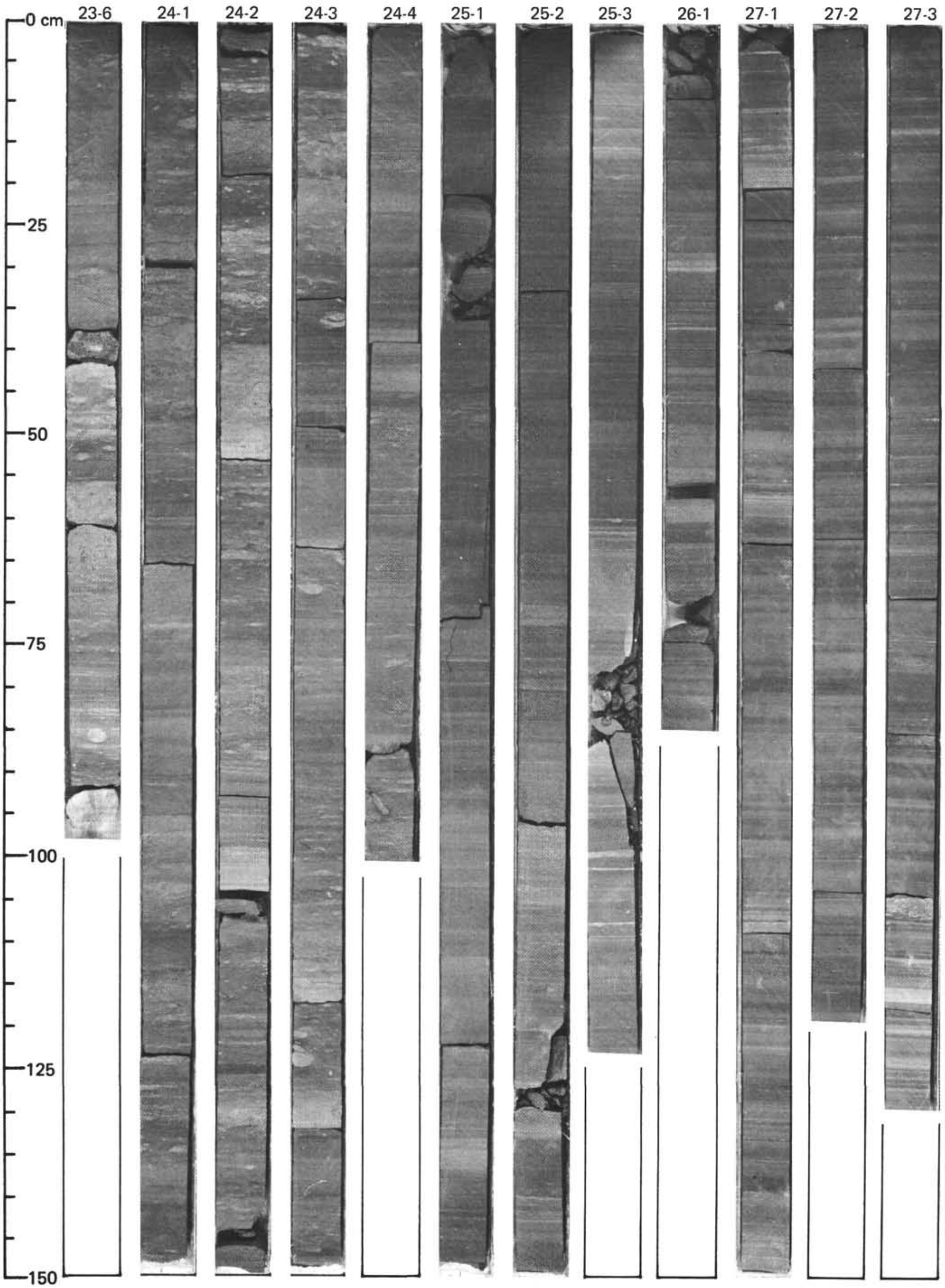

0 cm
25
50
75
100
125
150
13-2
13-3
13-4
13-5
13-6
13-7
13,CC
14-1
14-2
14-3
14,CC
15-1

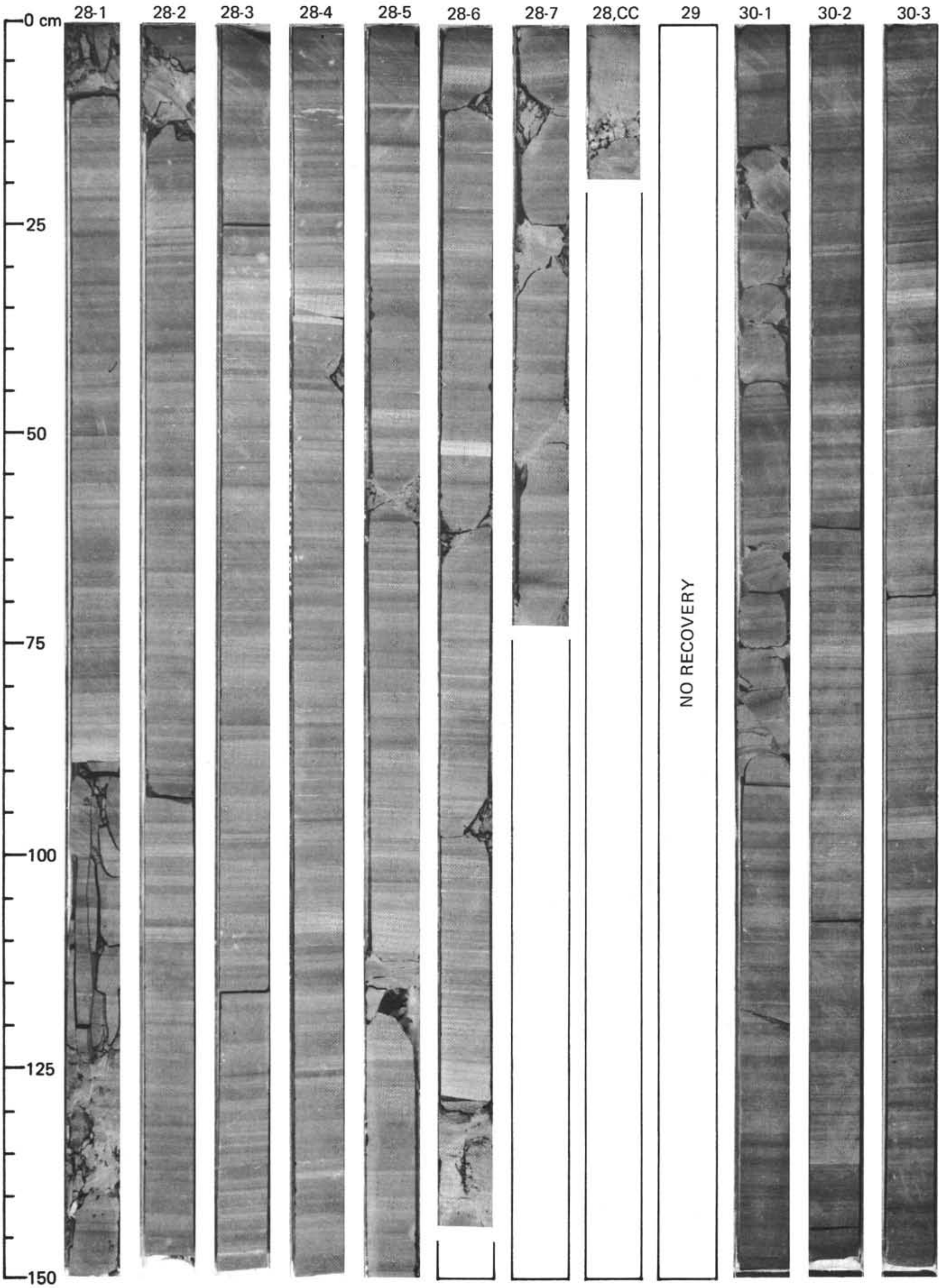

0 cm
25
50
75
100
125
150
15-2
15-3
15-4
15-5
15,CC
16-1
16,CC
17-1
17-2
17,CC
18-1
18-2

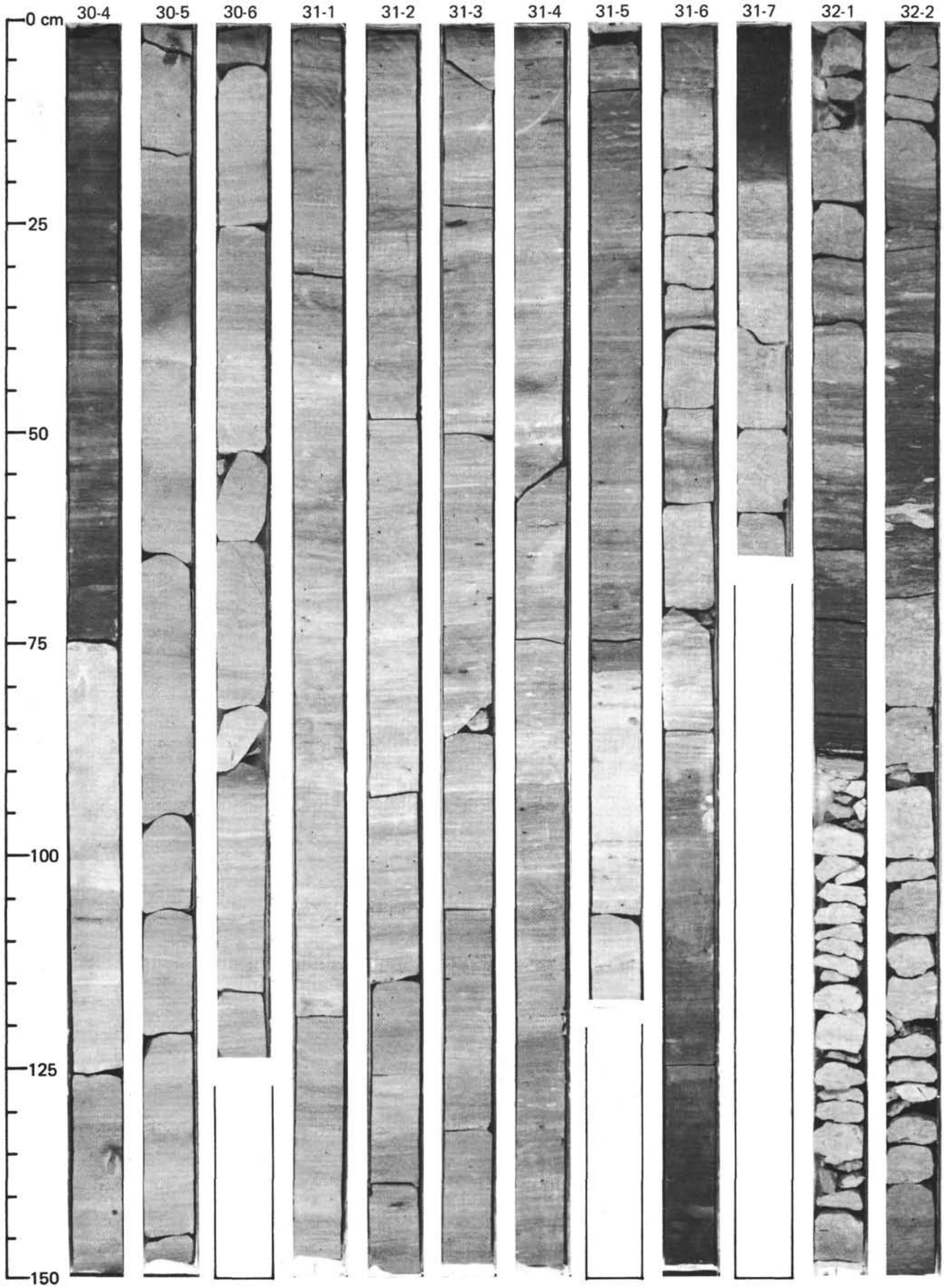

0 cm
25
50
75
100
125
150
18-3
18-4
19-1
19-2
19-3
19-4
19-5
19-6
19-7
19,CC
20-1
20-2

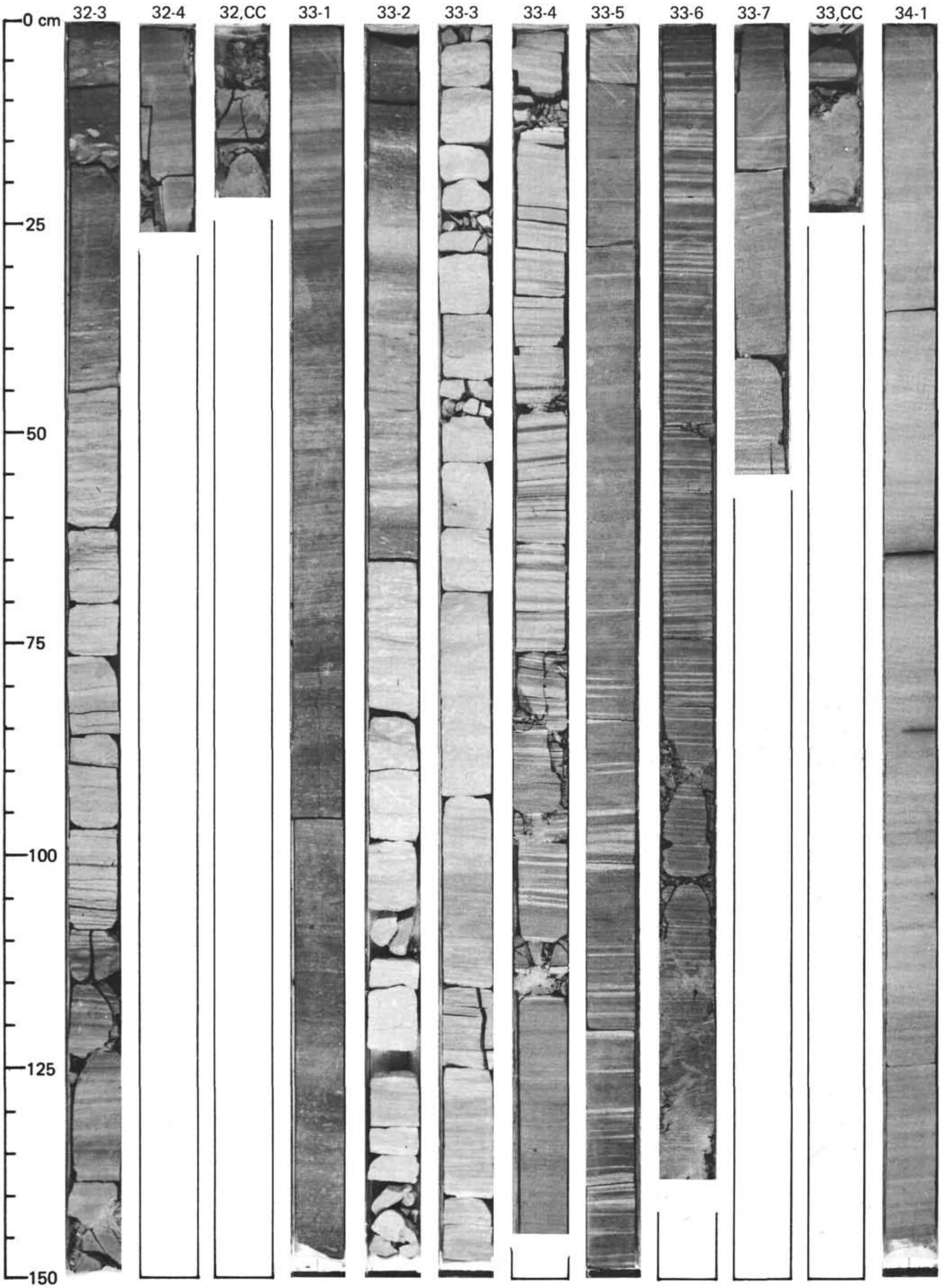

0 cm
25
50
75
100
125
150
20-3
20-4
20-5
20-6
20-7
20,CC
21-1
21-2
21-3
21-4
21-5
22-1

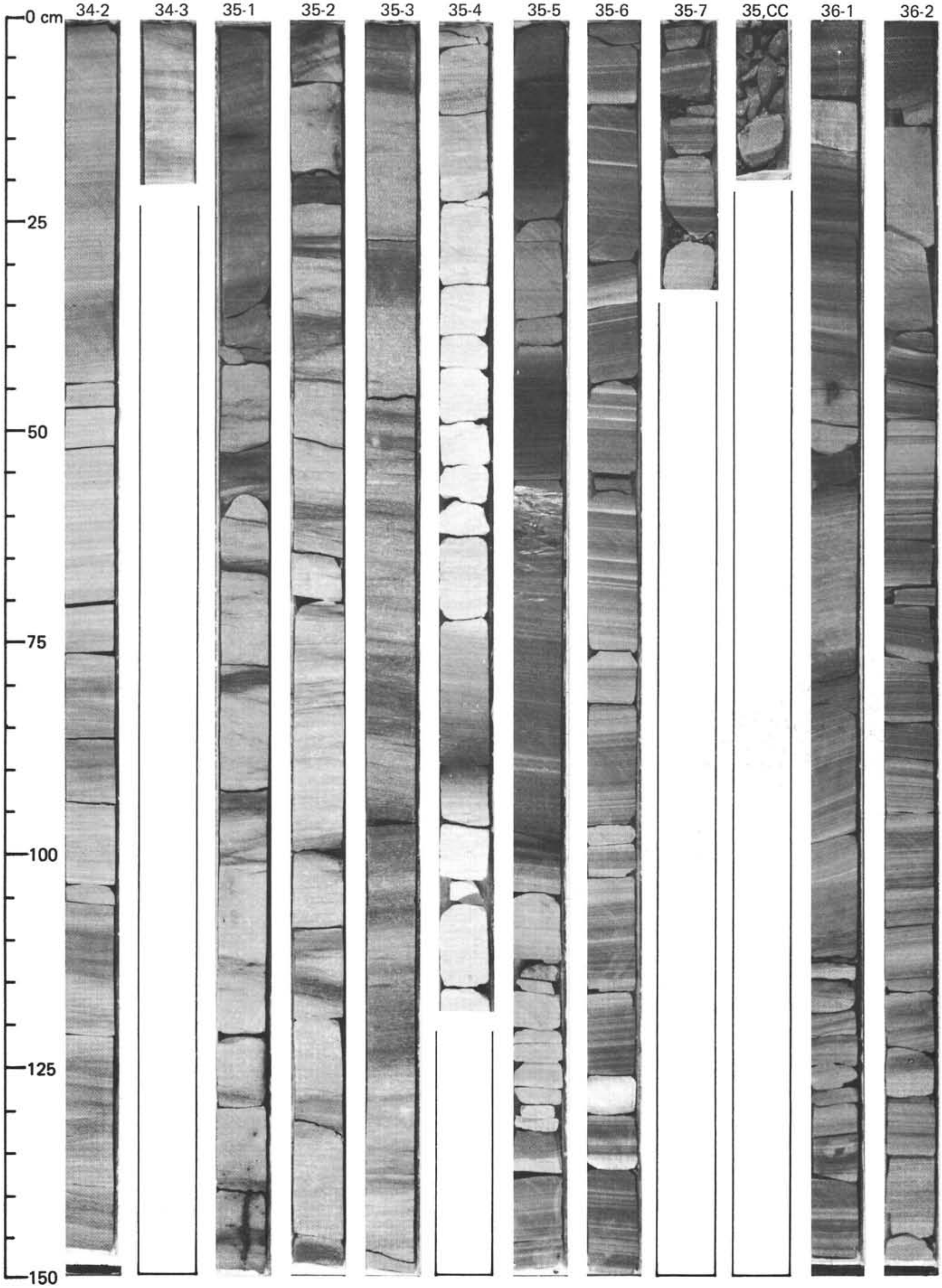

22-2
22-3
22-4
22-5
22-6
22-7
22,CC
23-1
23-2
23-3
23-4
23-5
0 cm
25
50
75
100
125
150

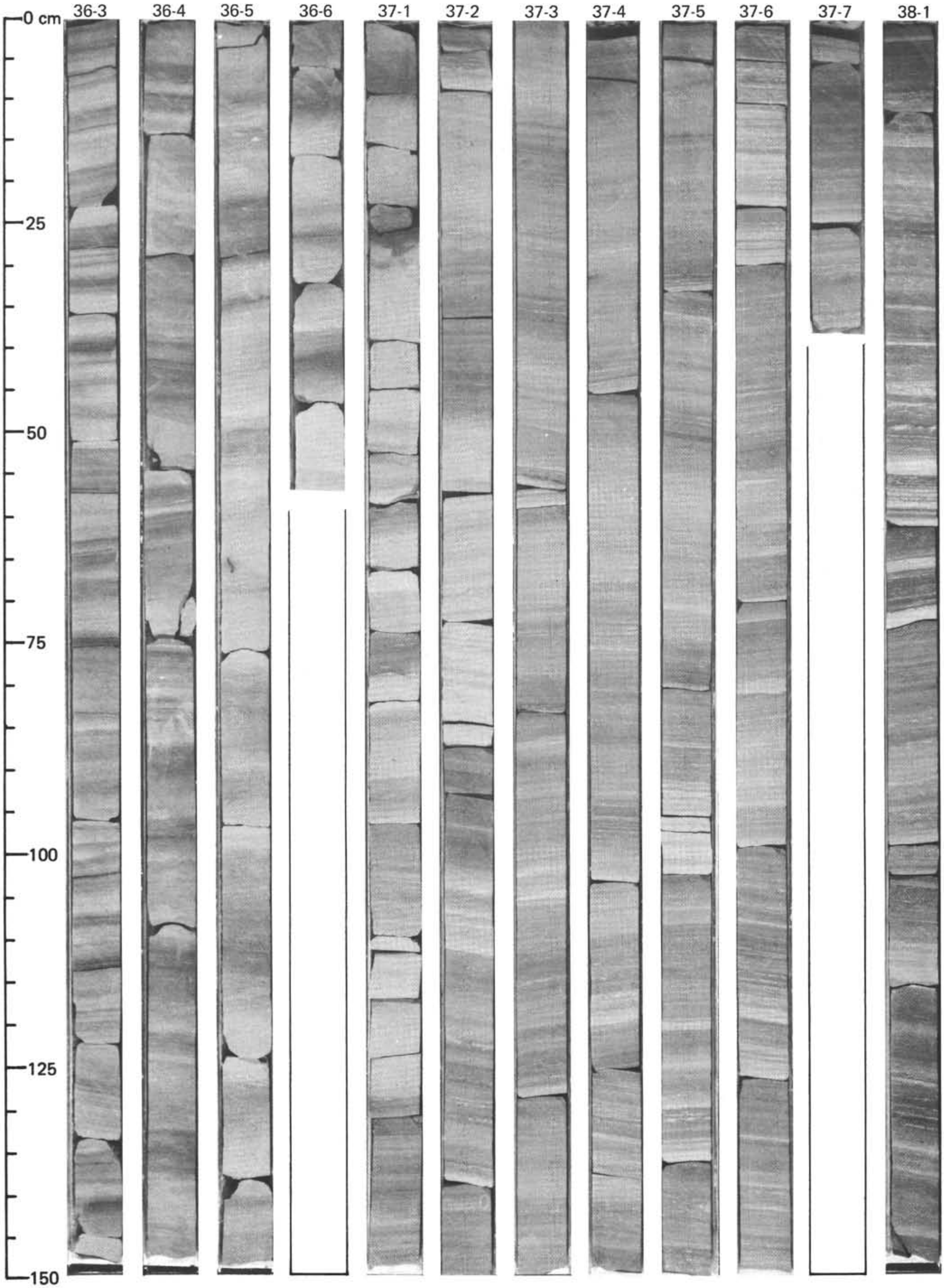

0 cm
25
50
75
100
125
150
23-6
24-1
24-2
24-3
24-4
25-1
25-2
25-3
26-1
27-1
27-2
27-3

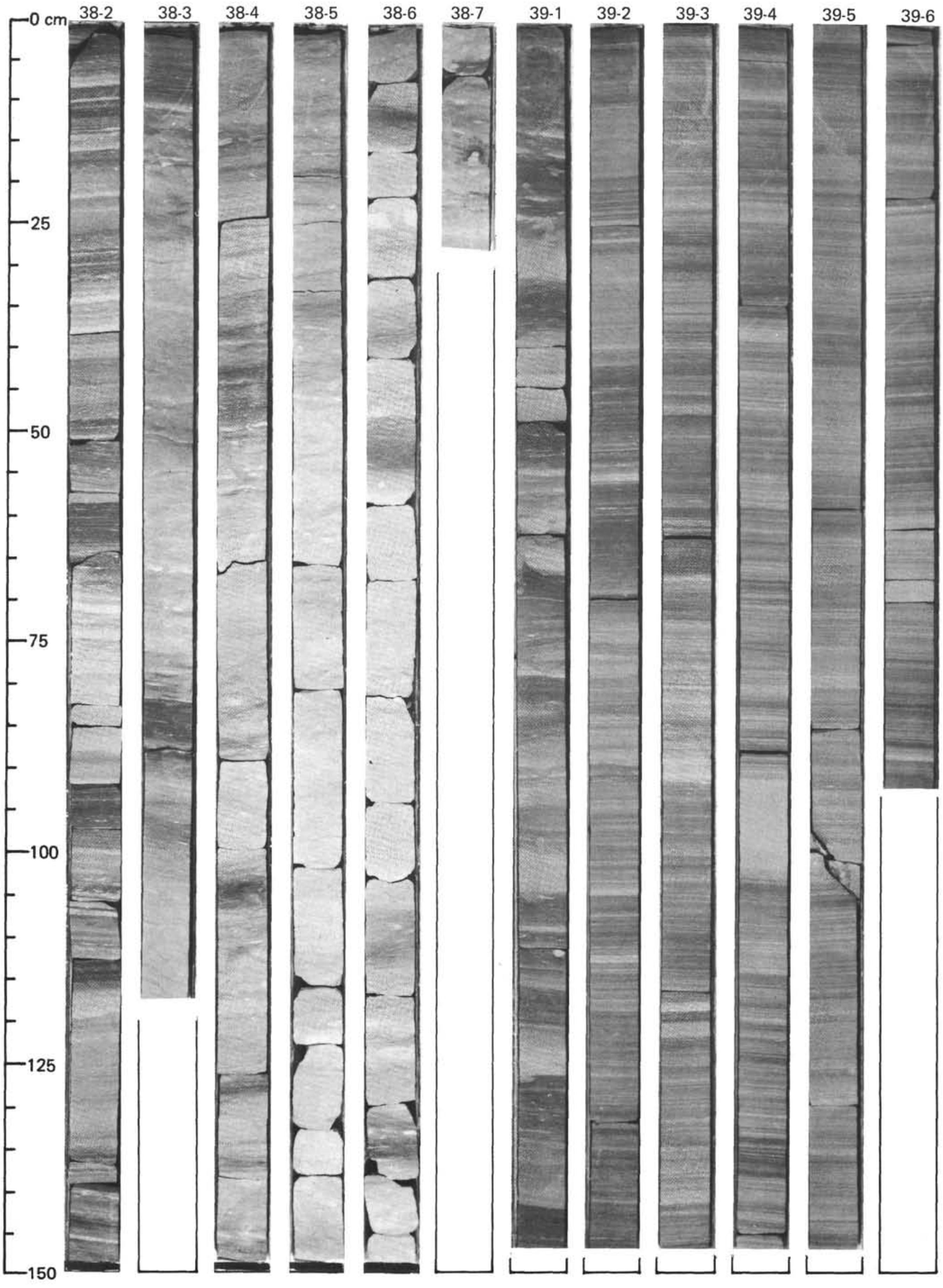

0 cm
25
50
75
100
125
150
28-1
28-2
28-3
28-4
28-5
28-6
28-7
28,CC
29
30-1
30-2
30-3
NO RECOVERY

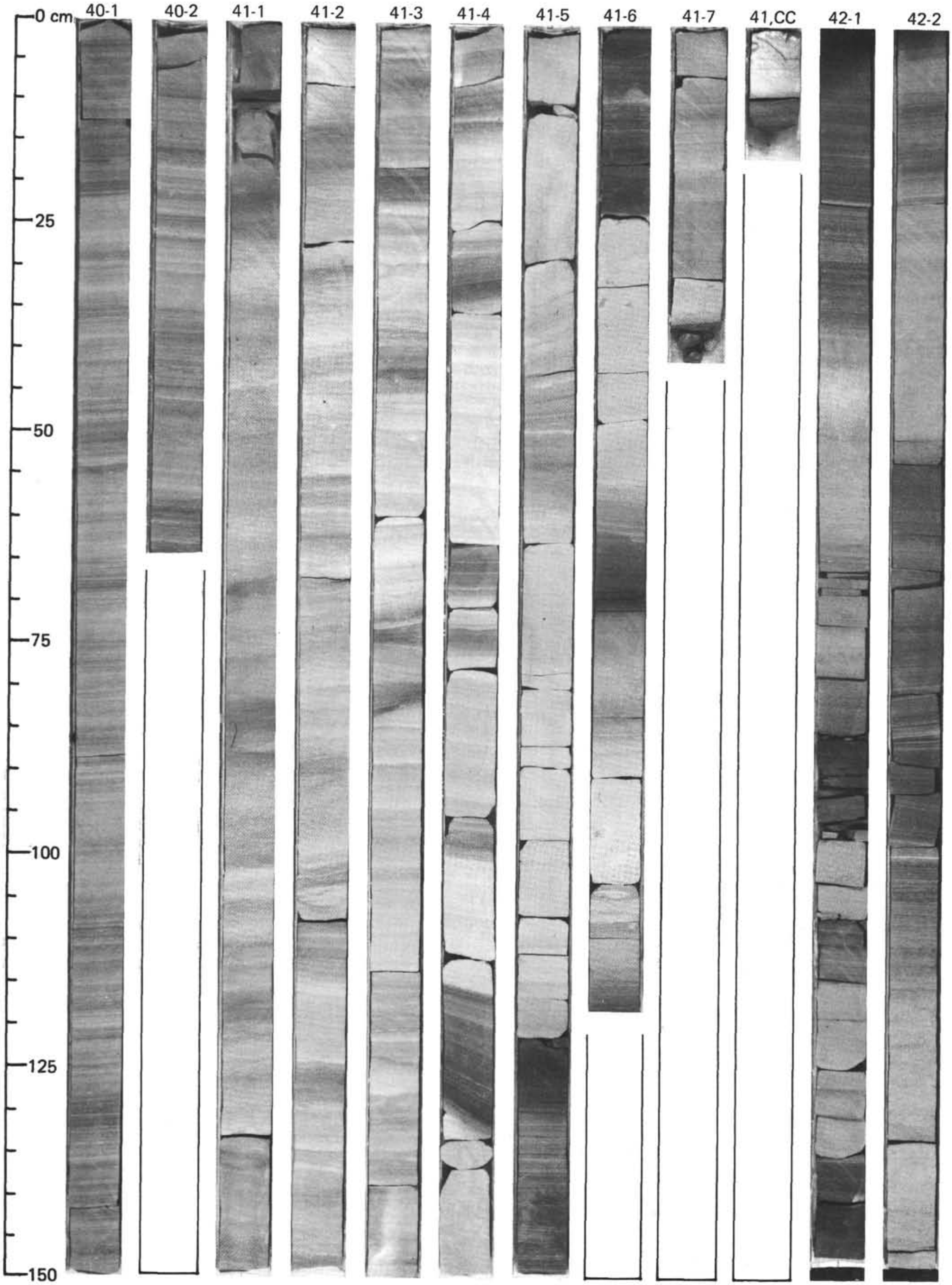

0 cm
25
50
75
100
125
150
30-4
30-5
30-6
31-1
31-2
31-3
31-4
31-5
31-6
31-7
32-1
32-2

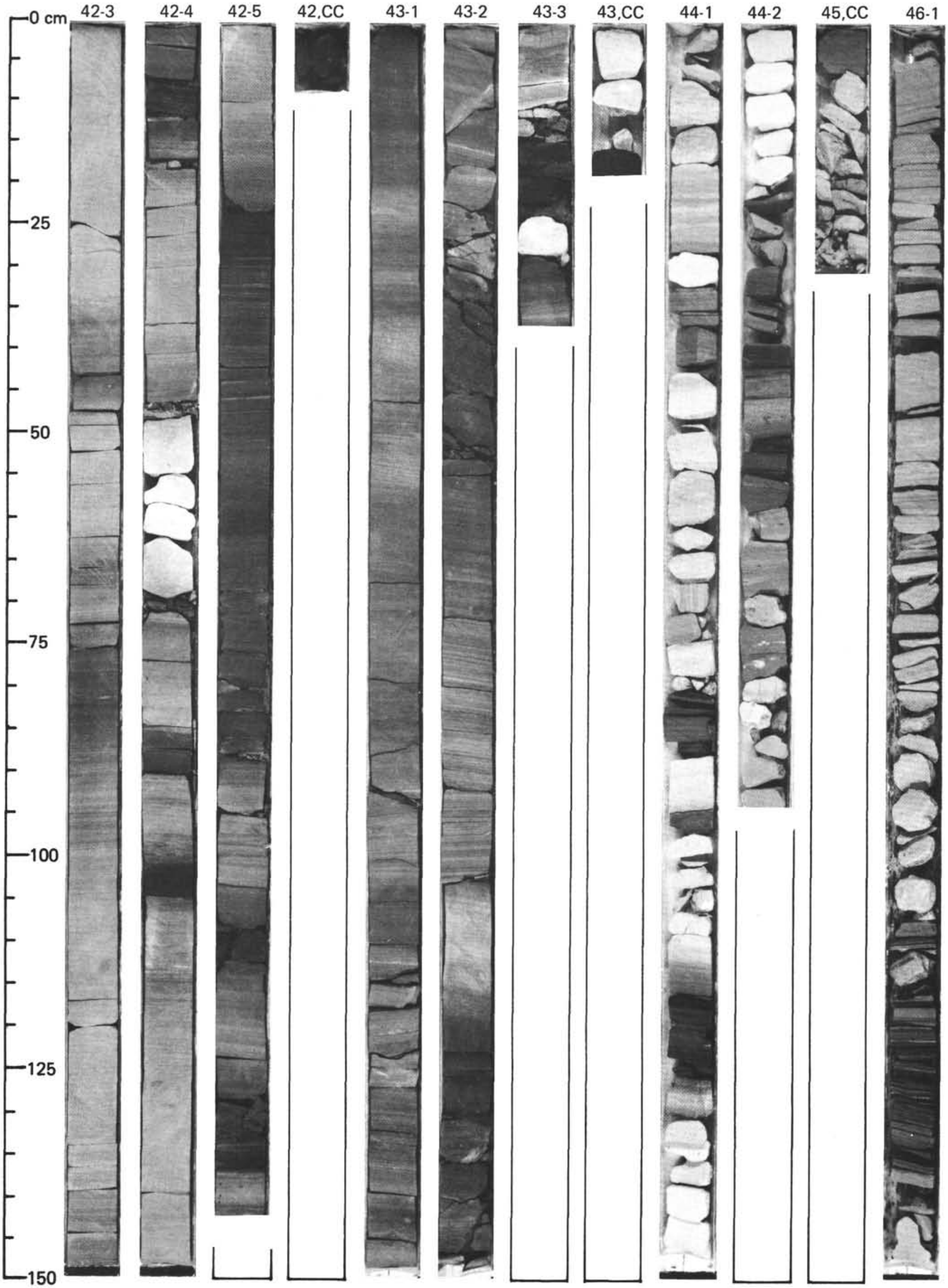

0 cm
25
50
75
100
125
150
32-3
32-4
32,CC
33-1
33-2
33-3
33-4
33-5
33-6
33-7
33,CC
34-1

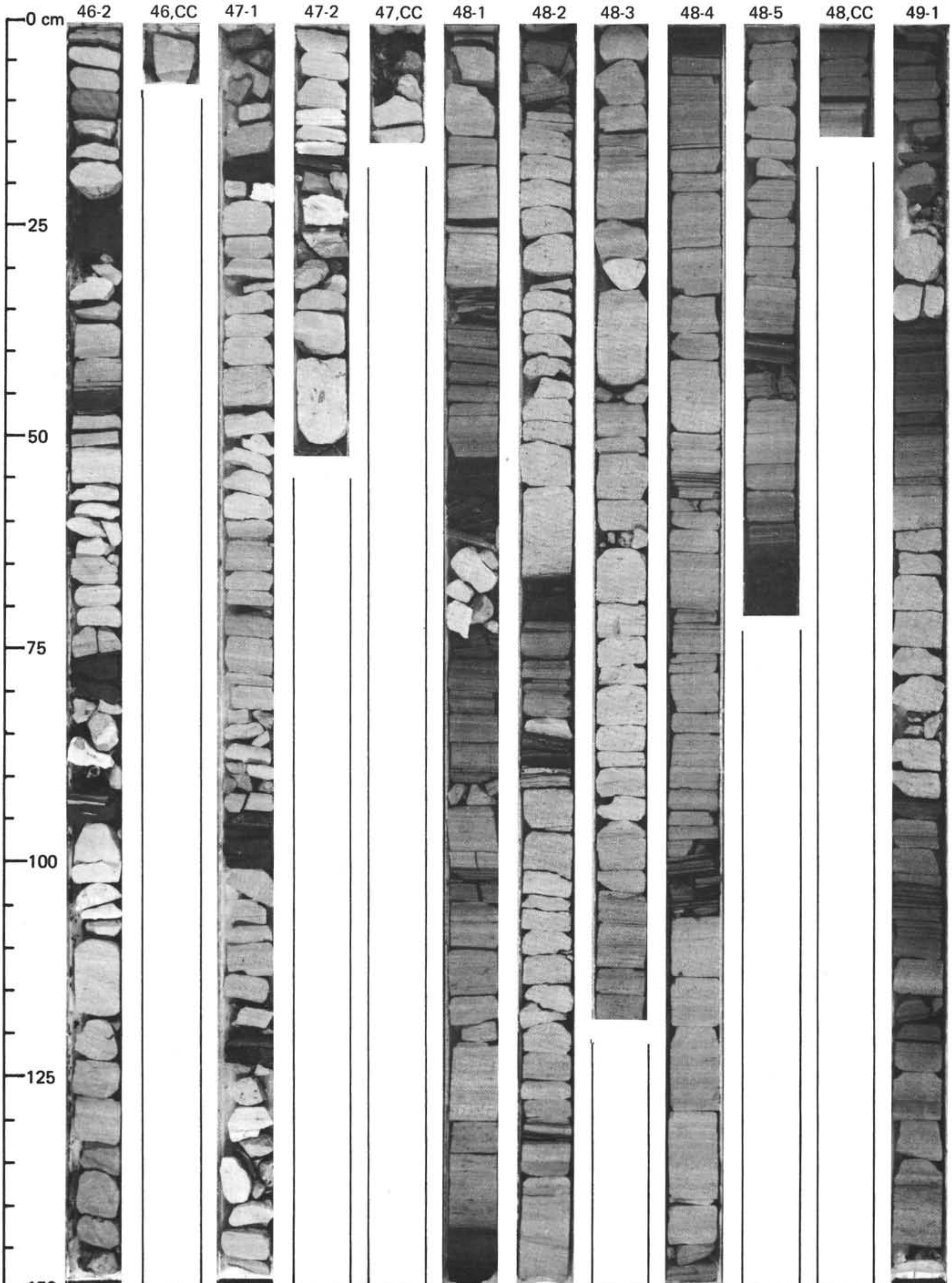

0 cm
25
50
75
100
125
150
34-2
34-3
35-1
35-2
35-3
35-4
35-5
35-6
35-7
35,CC
36-1
36-2

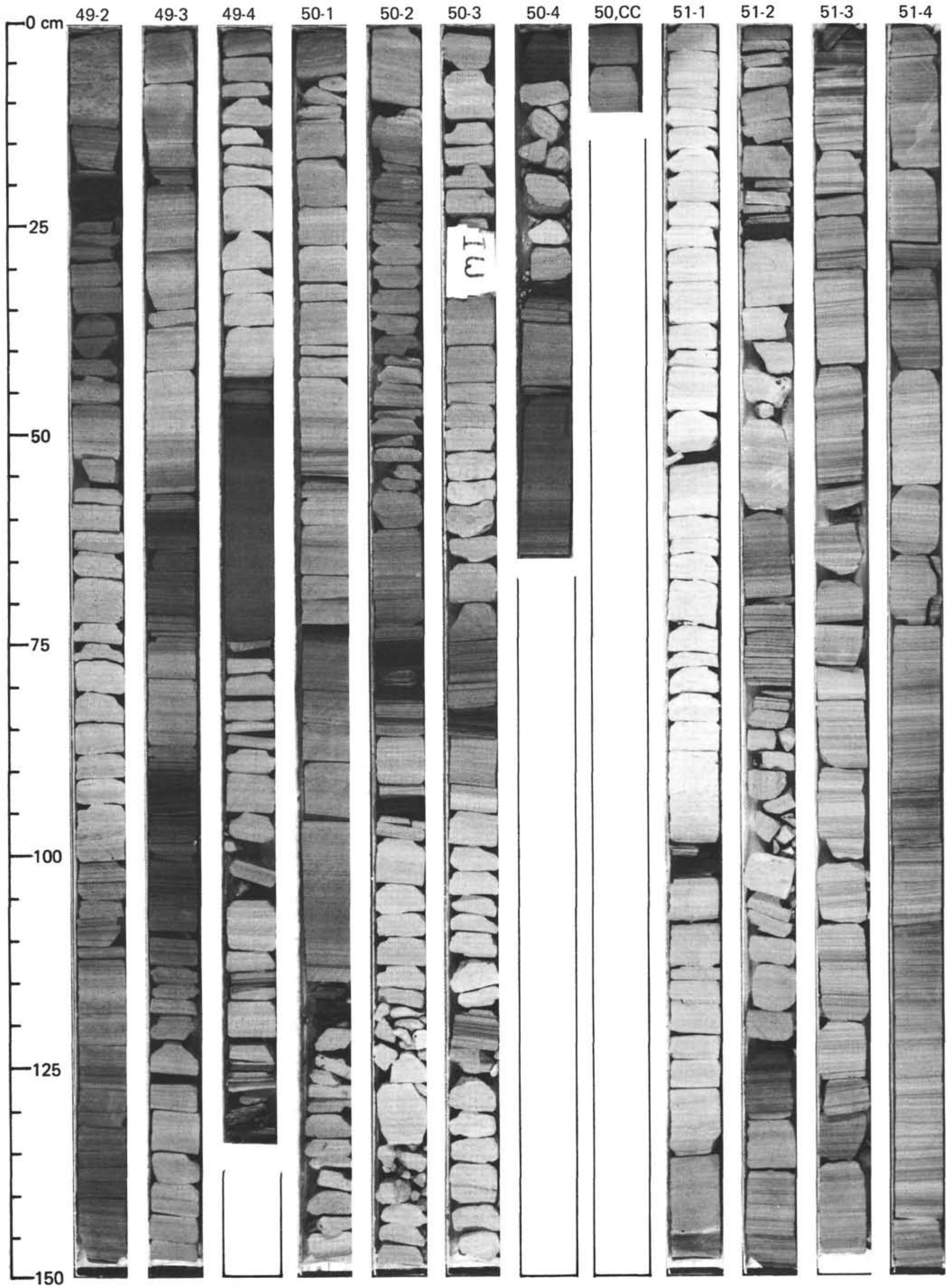

0 cm
25
50
75
100
125
150
36-3
36-4
36-5
36-6
37-1
37-2
37-3
37-4
37-5
37-6
37-7
38-1

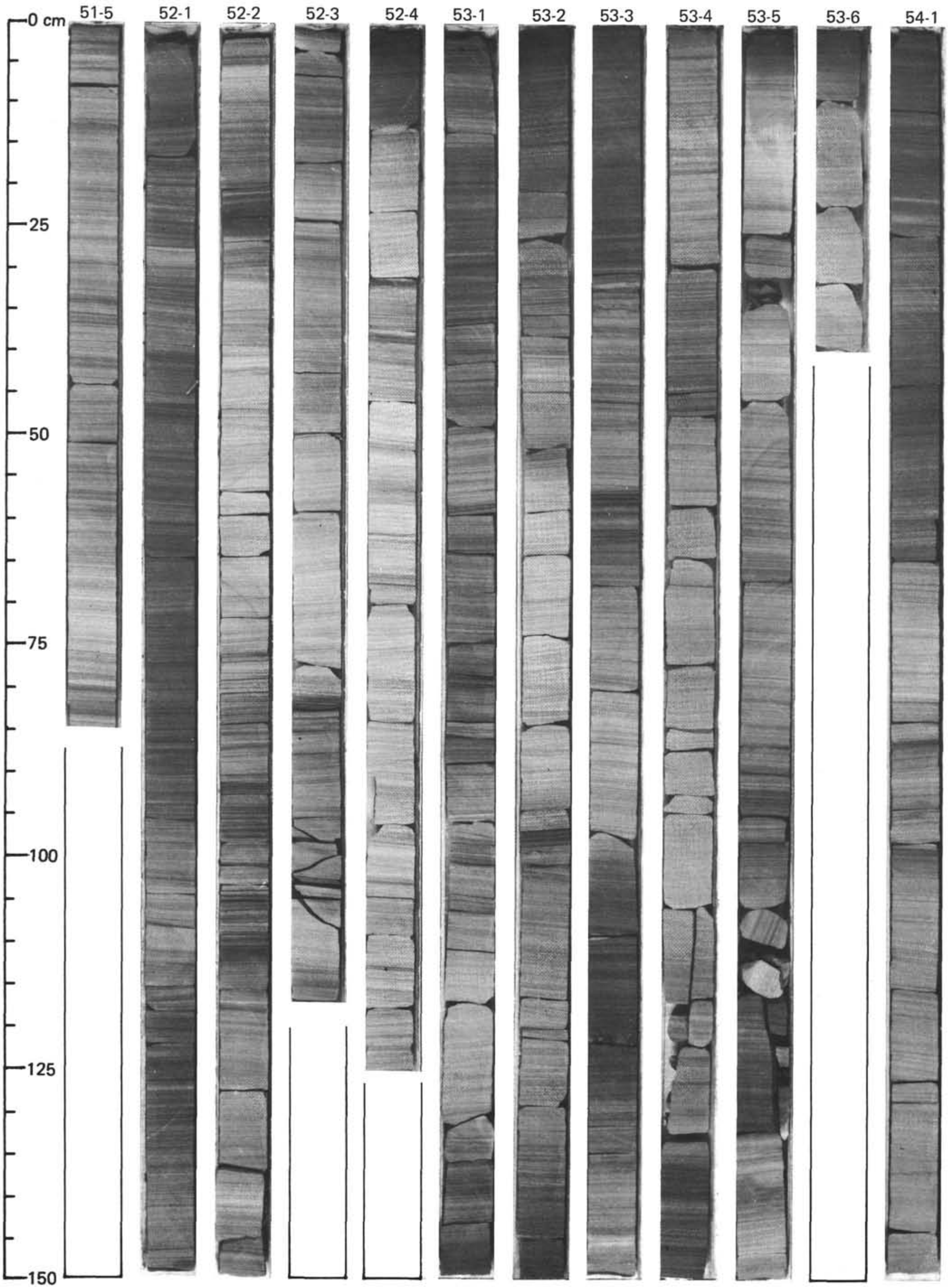

0 cm
25
50
75
100
125
150
38-2
38-3
38-4
38-5
38-6
38-7
39-1
39-2
39-3
39-4
39-5
39-6

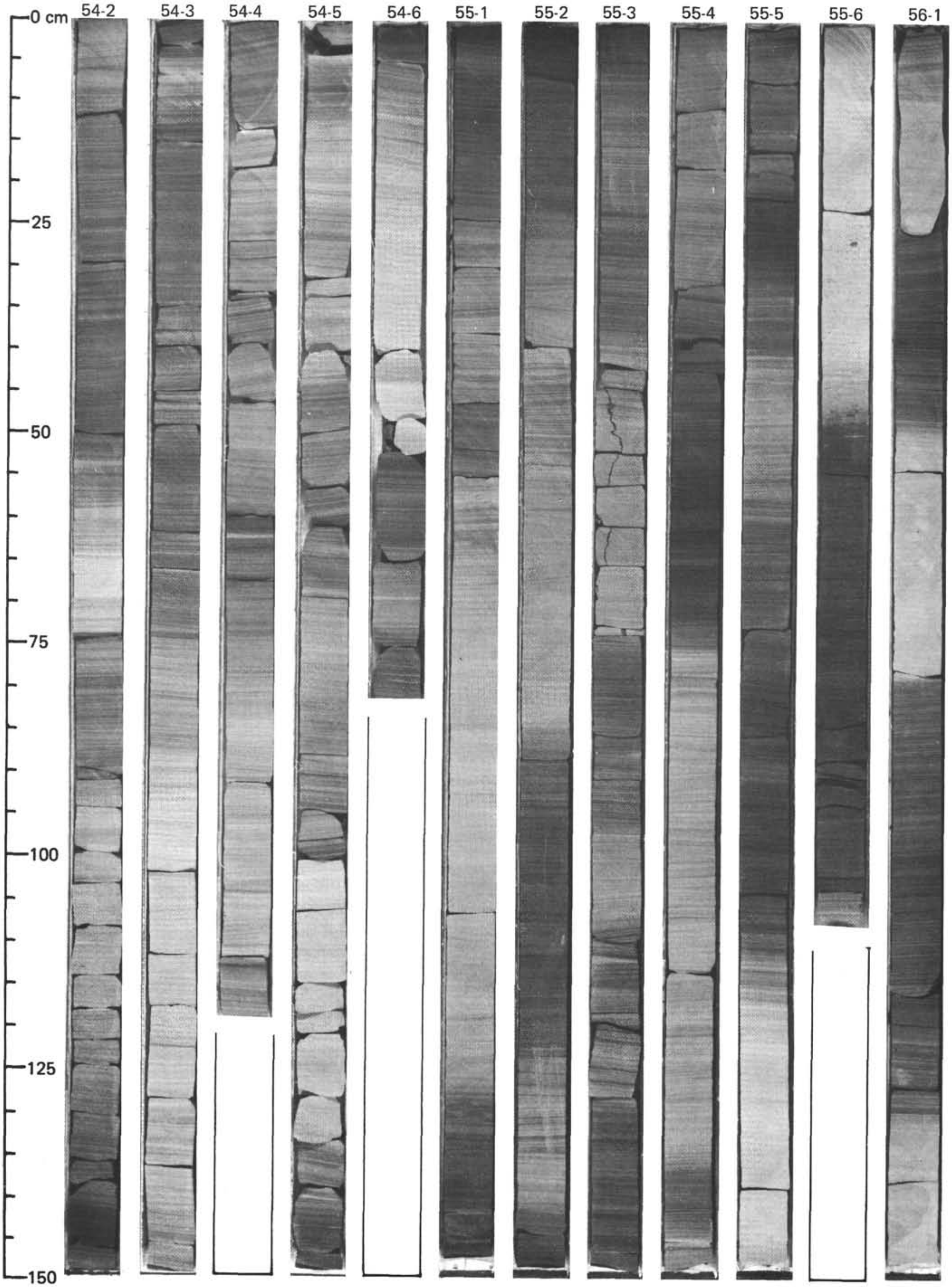

0 cm
25
50
75
100
125
150
40-1
40-2
41-1
41-2
41-3
41-4
41-5
41-6
41-7
41,CC
42-1
42-2

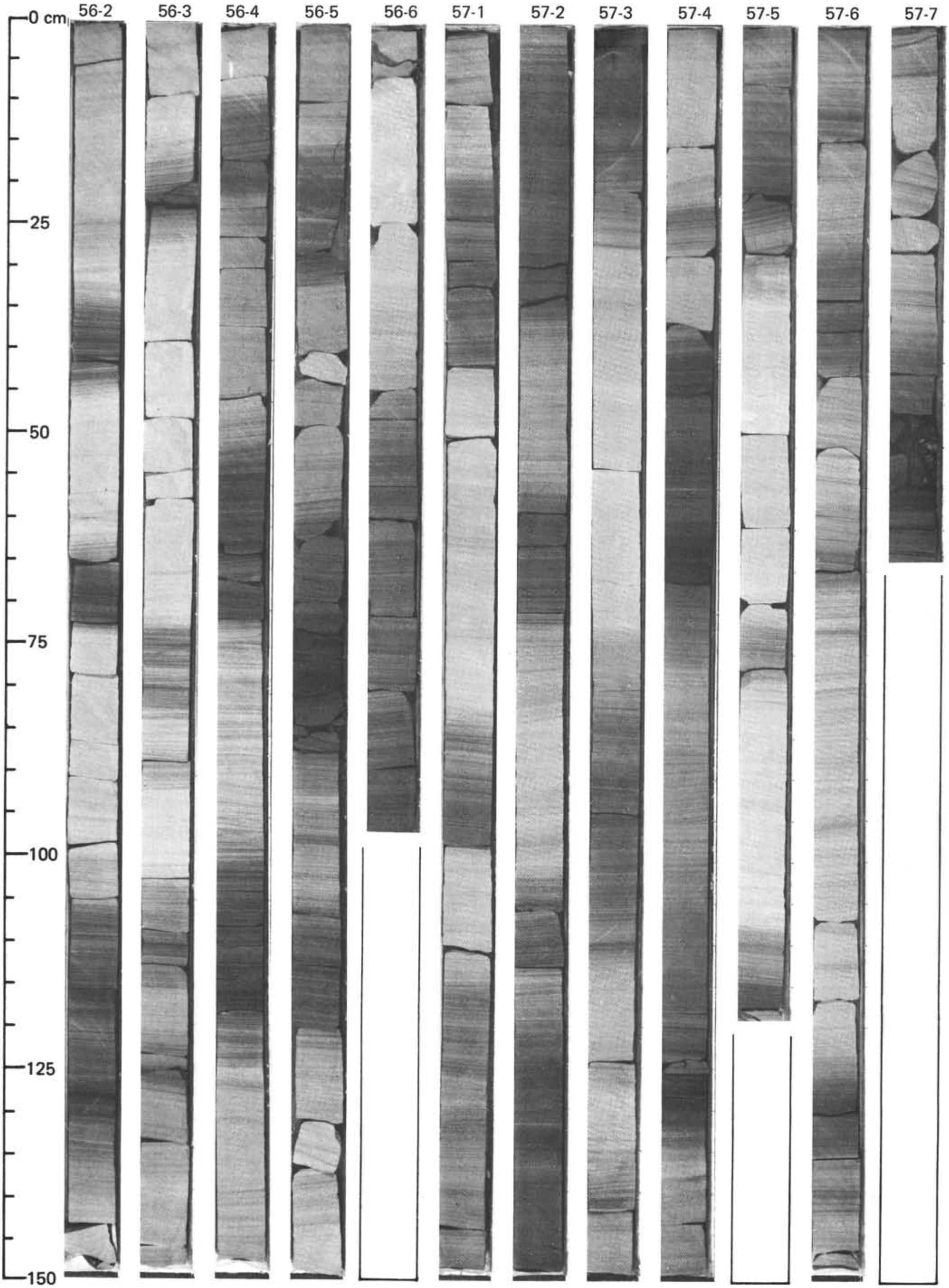

0 cm
25
50
75
100
125
150
42-3
42-4
42-5
42,CC
43-1
43-2
43-3
43,CC
44-1
44-2
45,CC
46-1

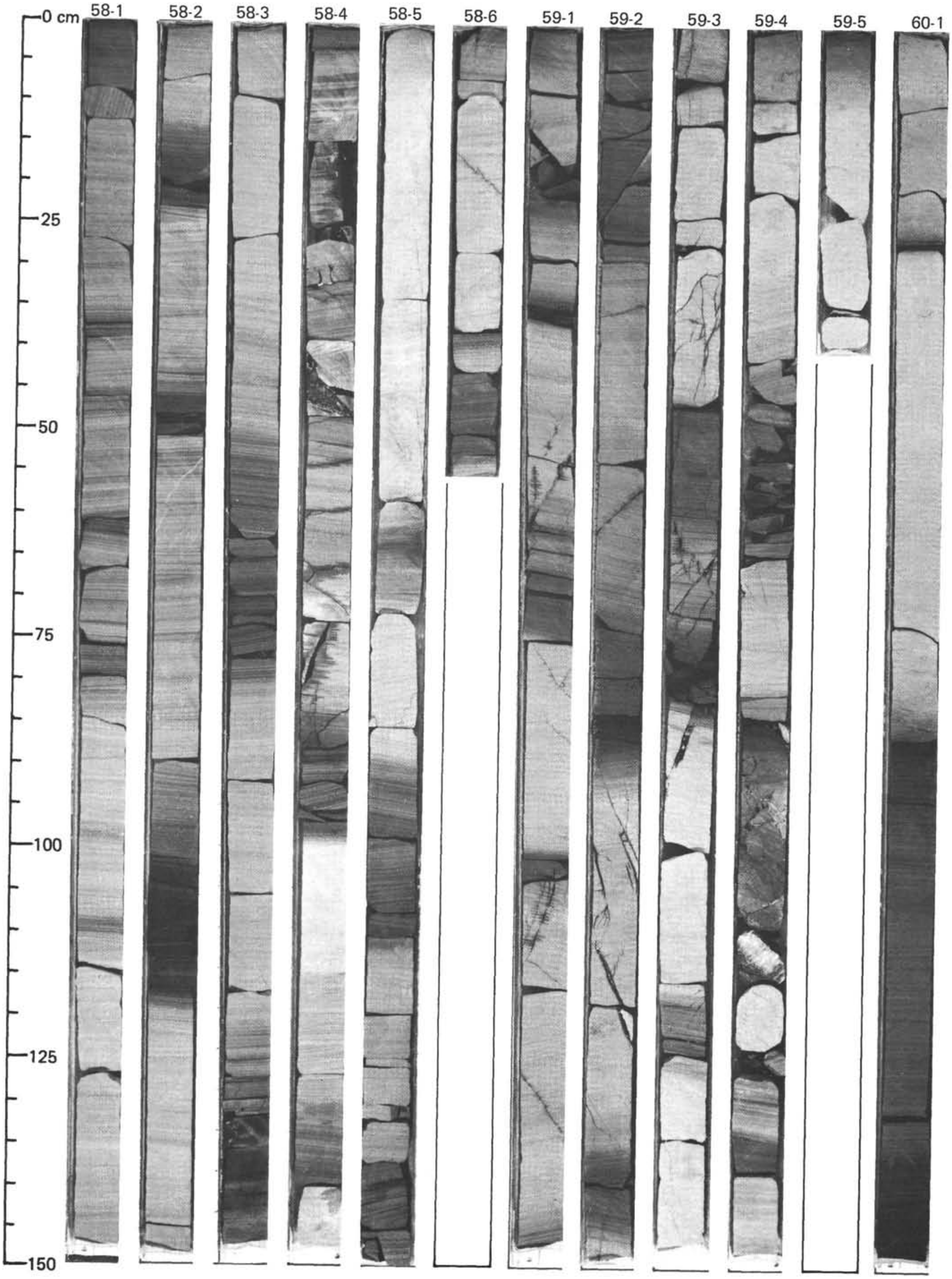

0 cm
25
50
75
100
125
150
46-2
46,CC
47-1
47-2
47,CC
48-1
48-2
48-3
48-4
48-5
48,CC
49-1

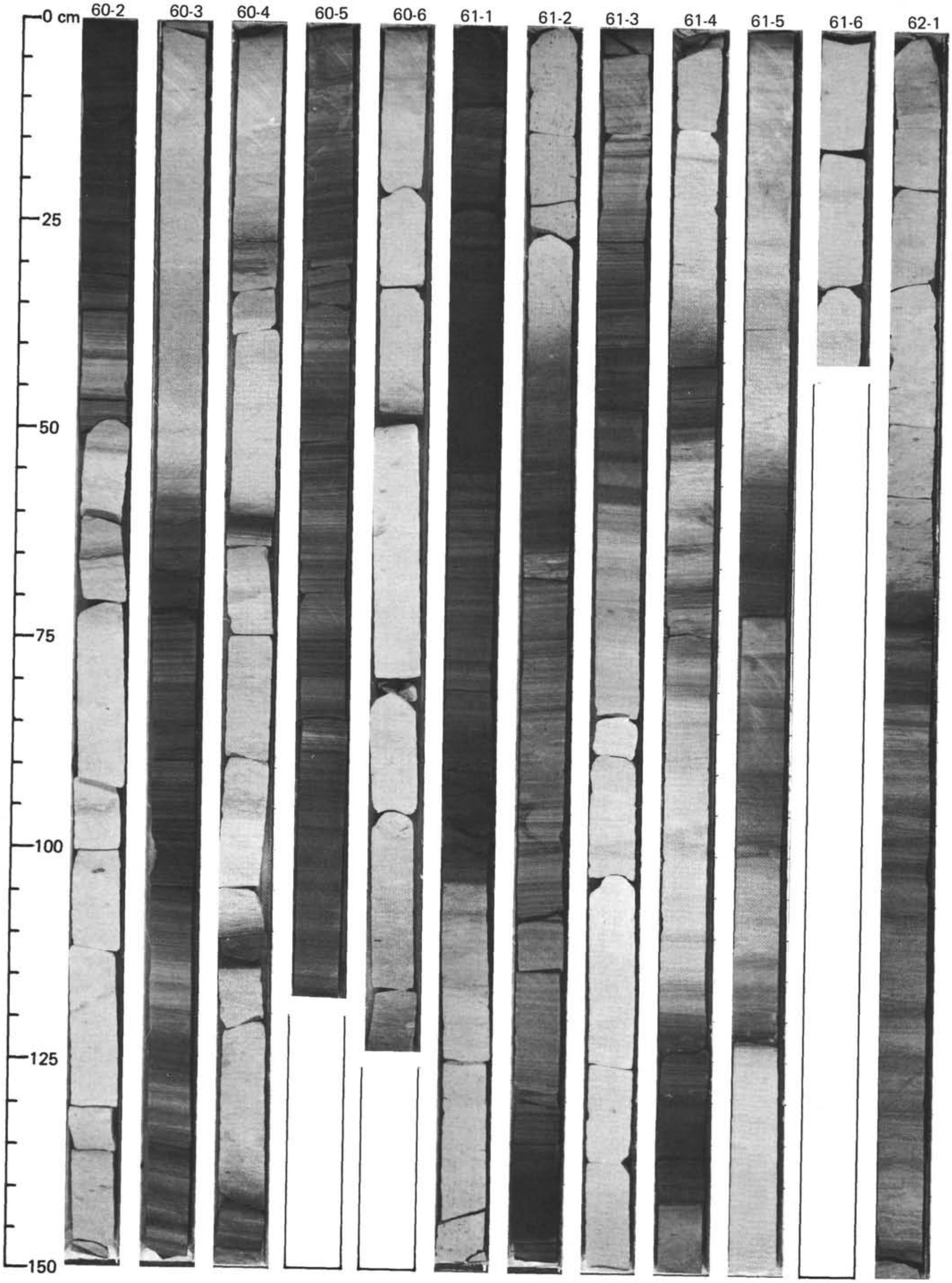

0 cm
25
50
75
100
125
150
49-2
49-3
49-4
50-1
50-2
50-3
50-4
50,CC
51-1
51-2
51-3
51-4

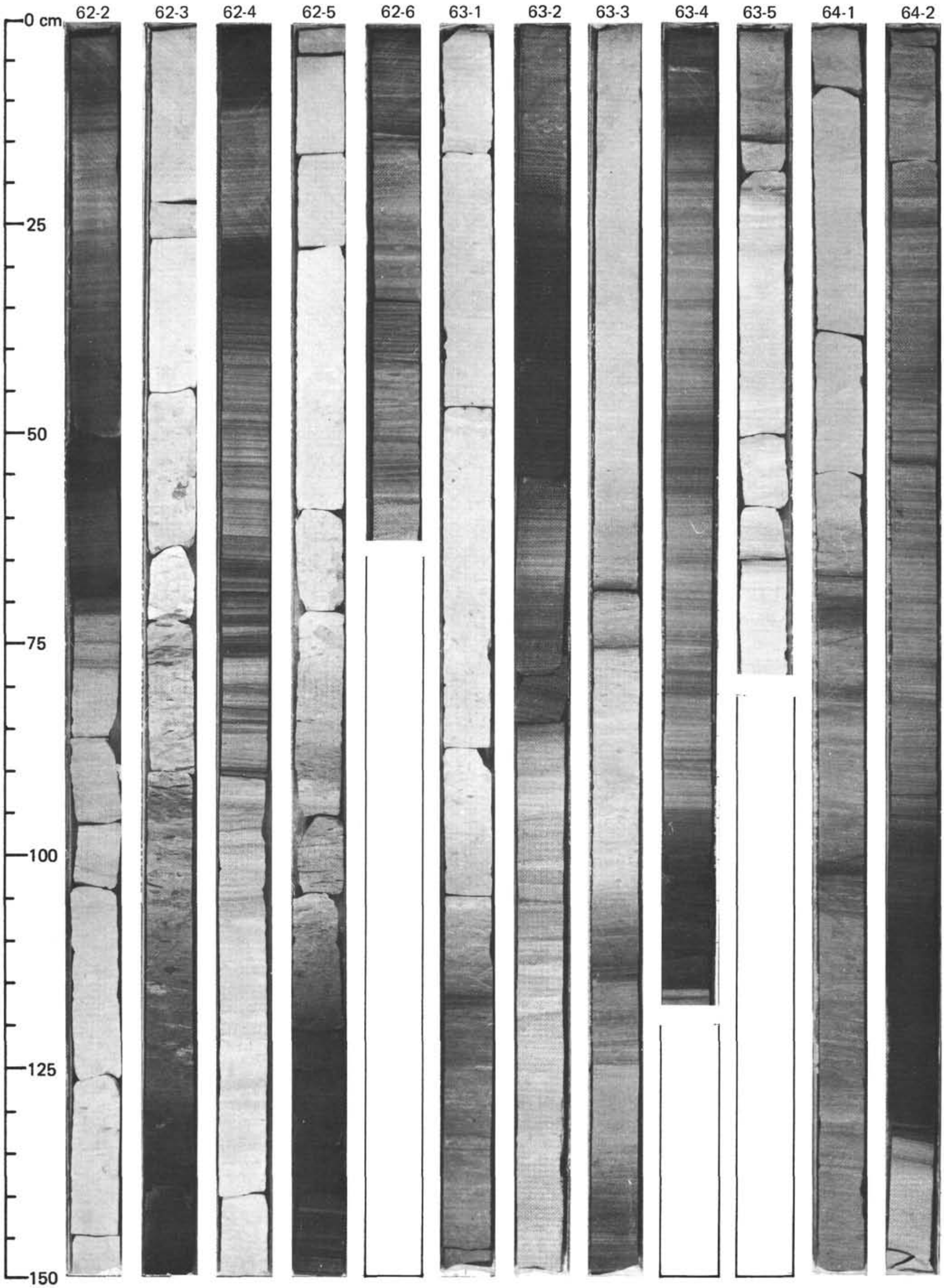

0 cm
25
50
75
100
125
150
51-5
52-1
52-2
52-3
52-4
53-1
53-2
53-3
53-4
53-5
53-6
54-1

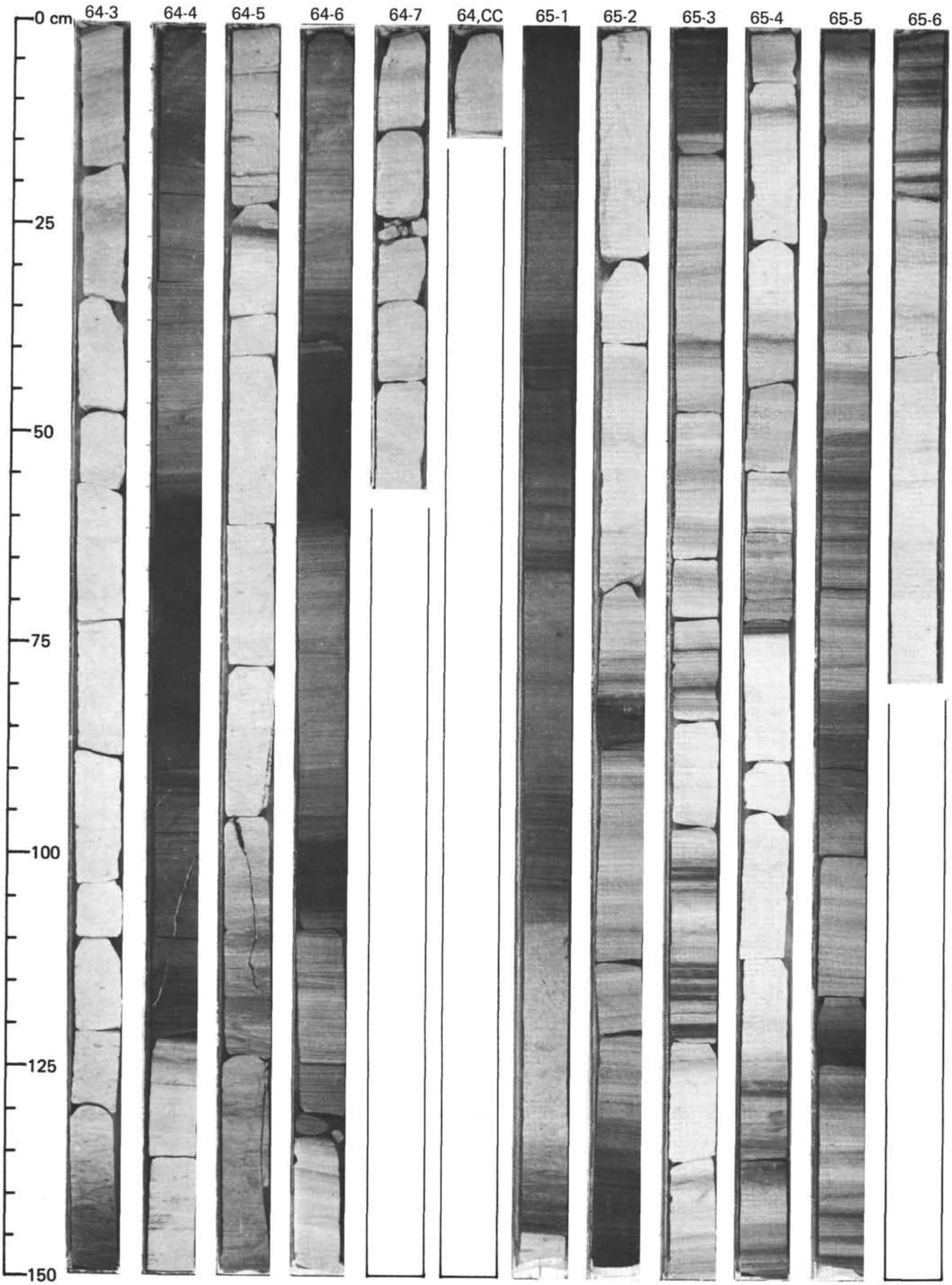

0 cm
25
50
75
100
125
150
54-2
54-3
54-4
54-5
54-6
55-1
55-2
55-3
55-4
55-5
55-6
56-1

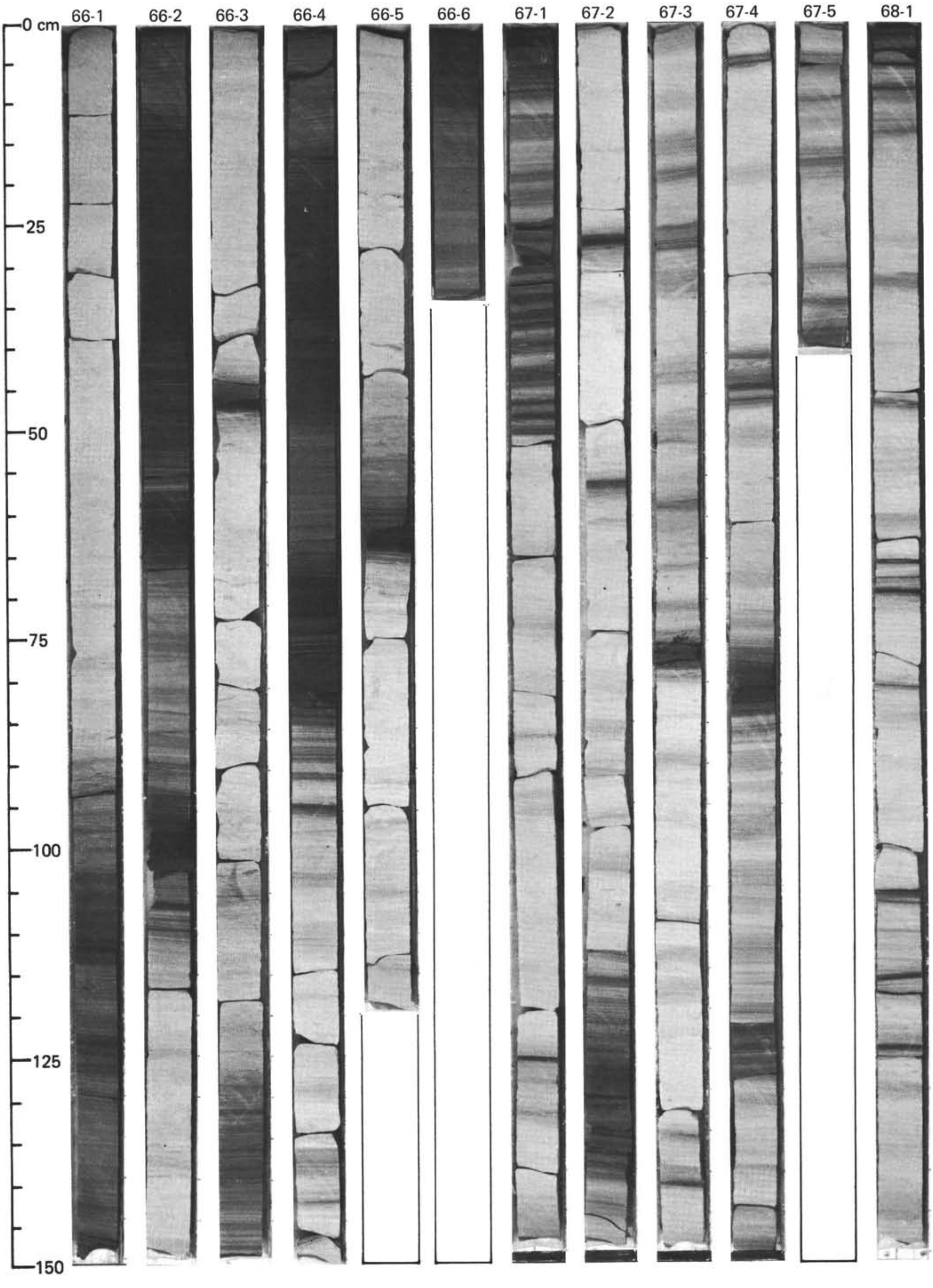

0 cm
25
50
75
100
125
150
56-2
56-3
56-4
56-5
56-6
57-1
57-2
57-3
57-4
57-5
57-6
57-7

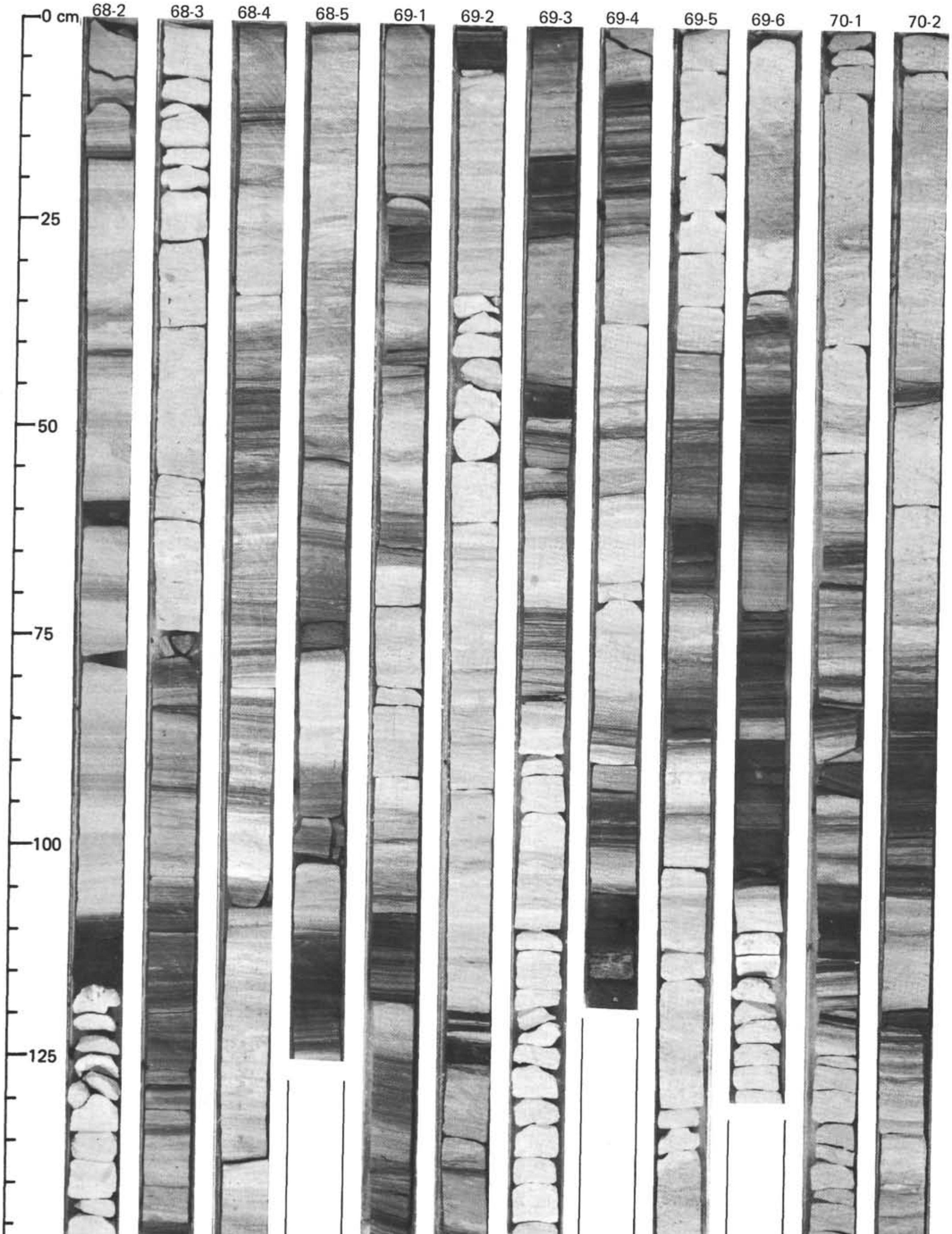

0 cm
25
50
75
100
125
150
58-1
58-2
58-3
58-4
58-5
58-6
59-1
59-2
59-3
59-4
59-5
60-1

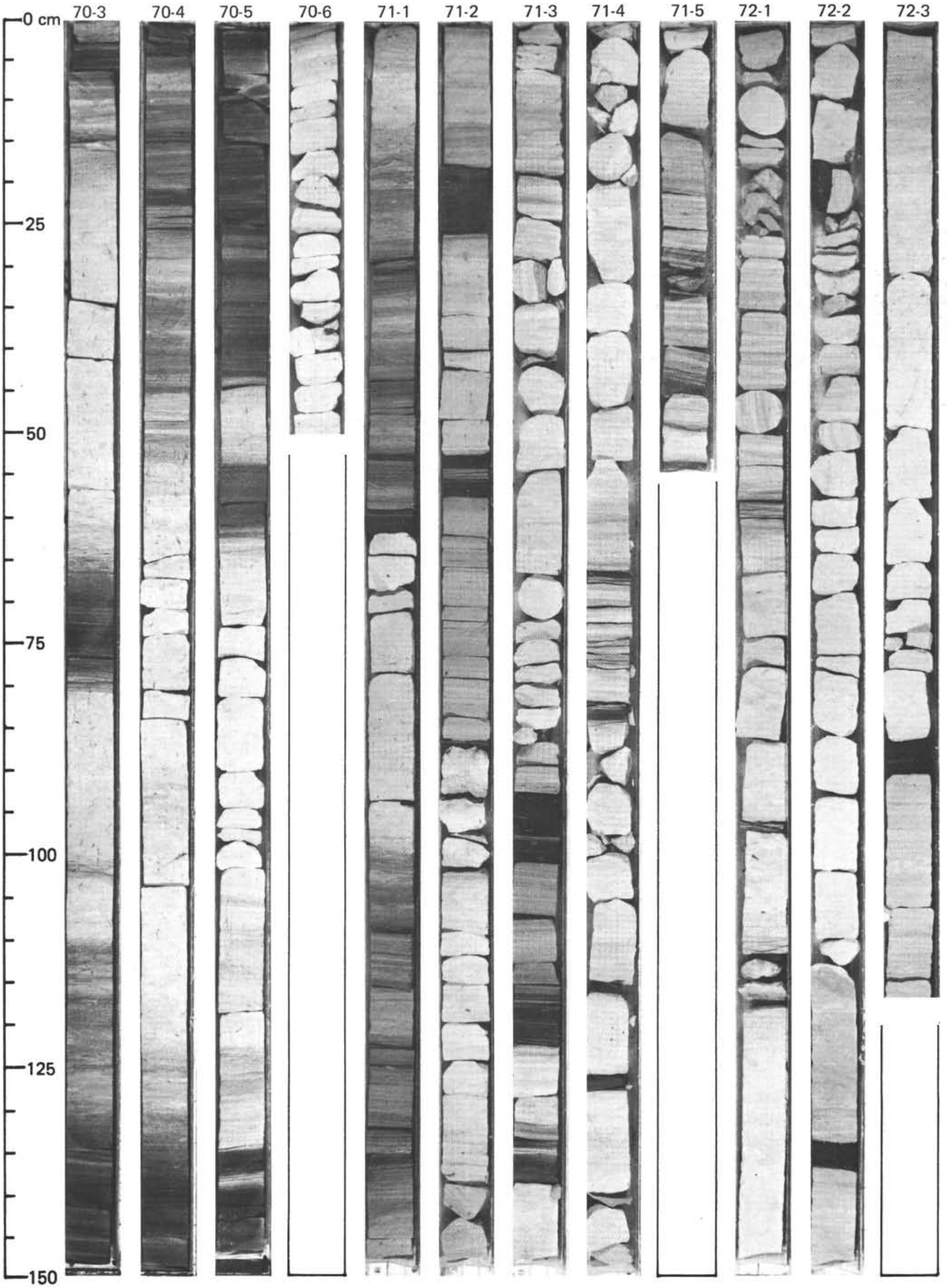

0 cm
25
50
75
100
125
150
60-2
60-3
60-4
60-5
60-6
61-1
61-2
61-3
61-4
61-5
61-6
62-1

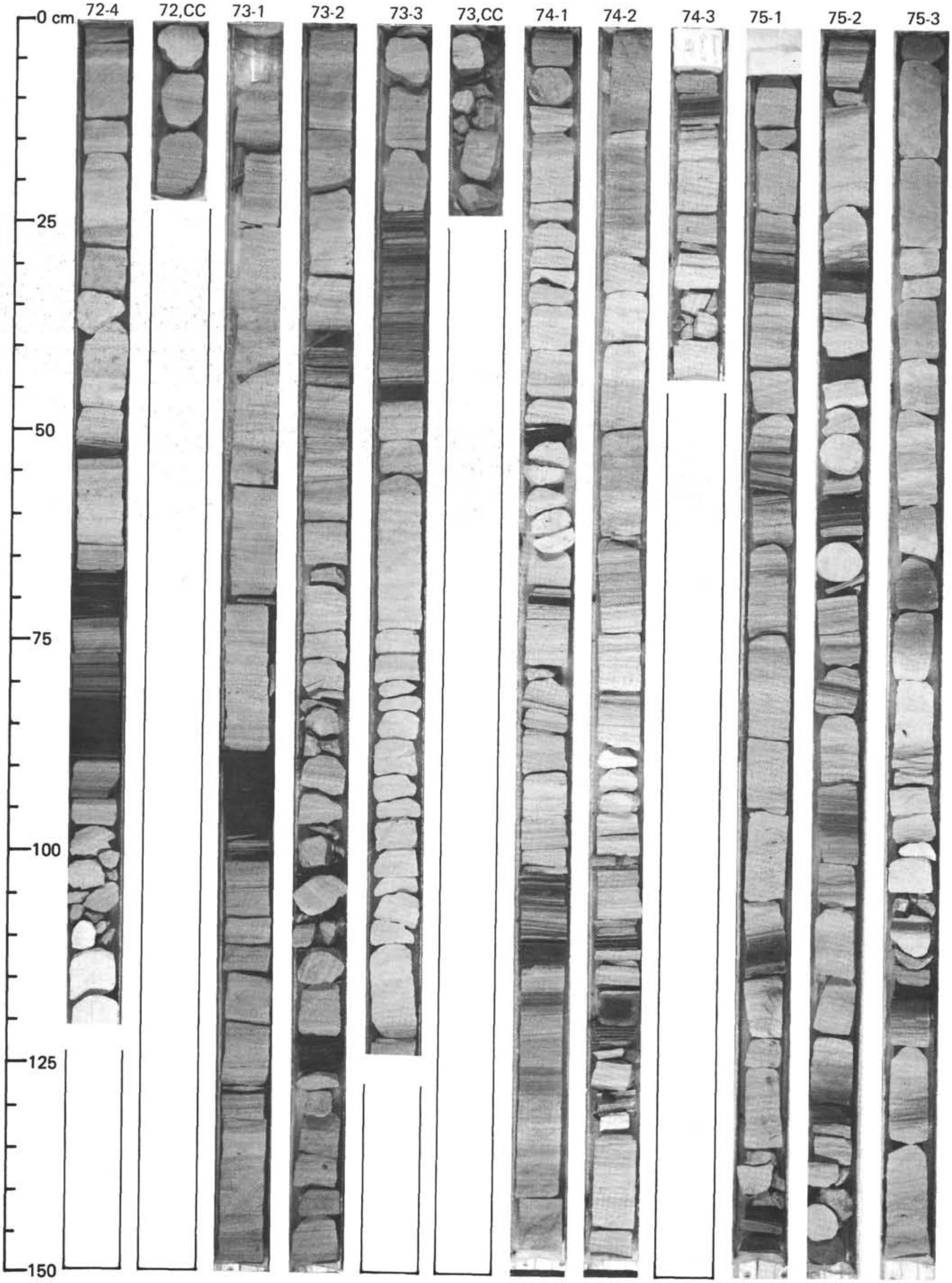

0 cm
25
50
75
100
125
150
62-2
62-3
62-4
62-5
62-6
63-1
63-2
63-3
63-4
63-5
64-1
64-2

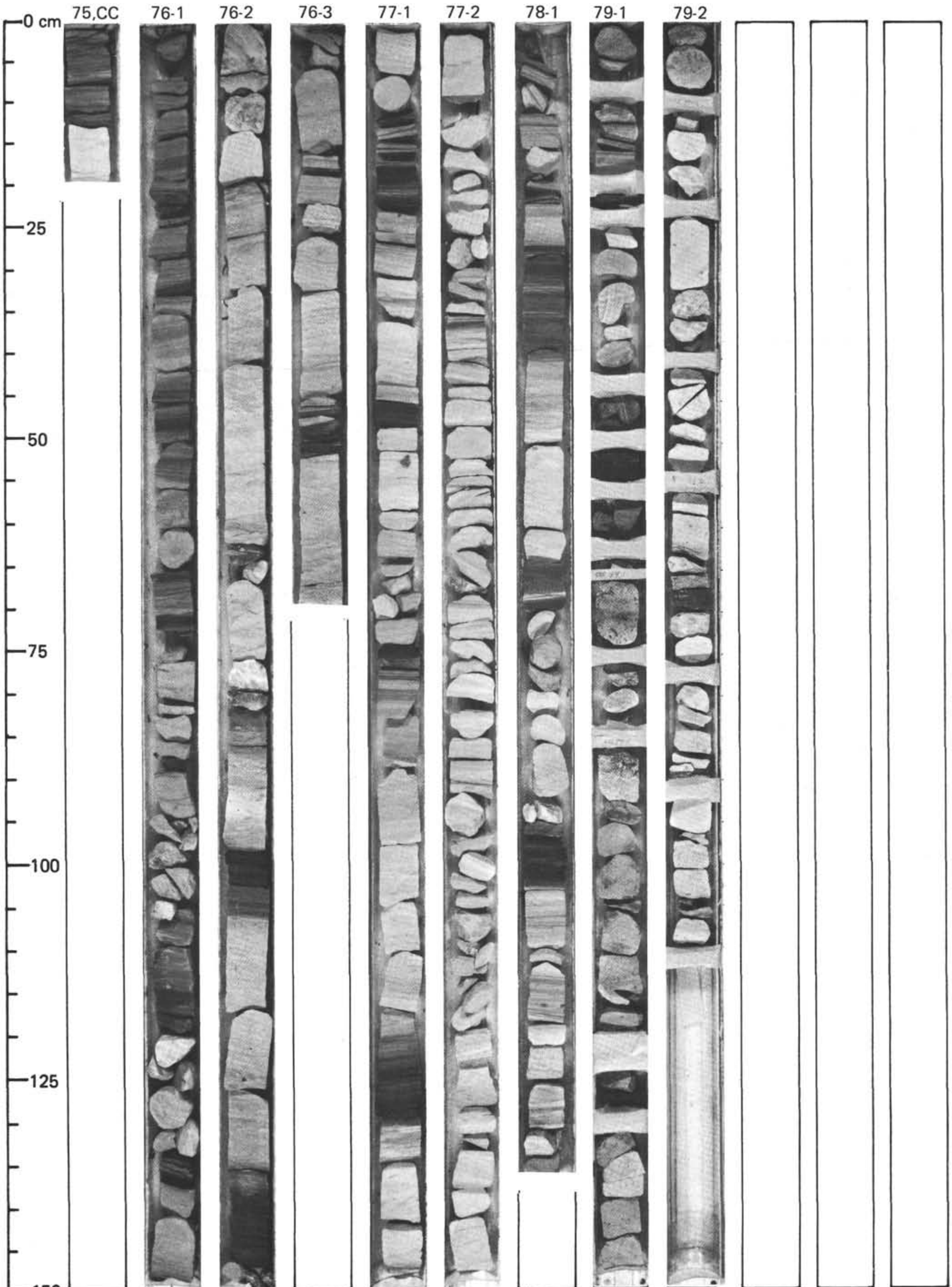

0 cm
25
50
75
100
125
150
64-3
64-4
64-5
64-6
64-7
64,CC
65-1
65-2
65-3
65-4
65-5
65-6

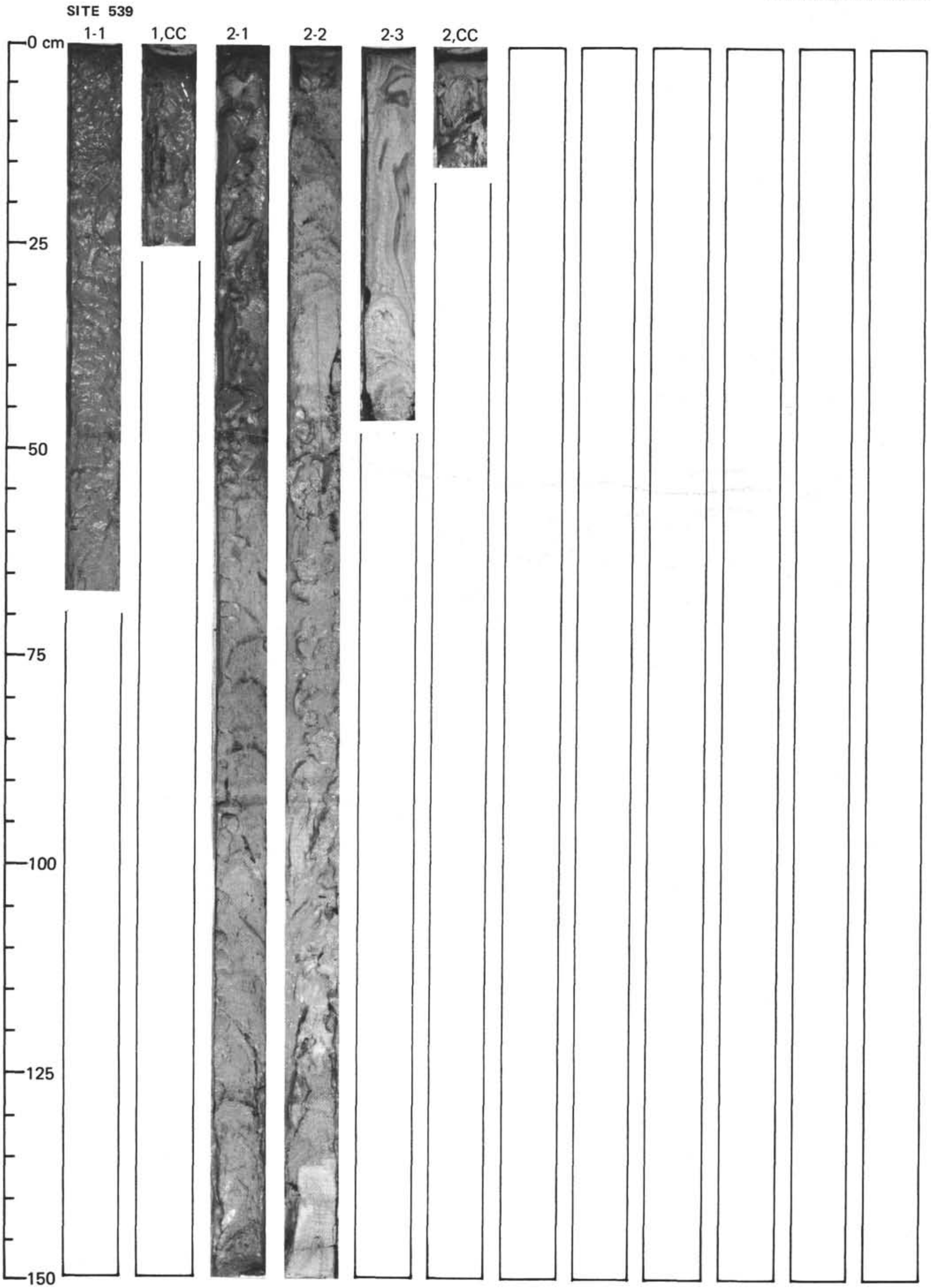

0 cm
25
50
75
100
125
150
66-1
66-2
66-3
66-4
66-5
66-6
67-1
67-2
67-3
67-4
67-5
68-1

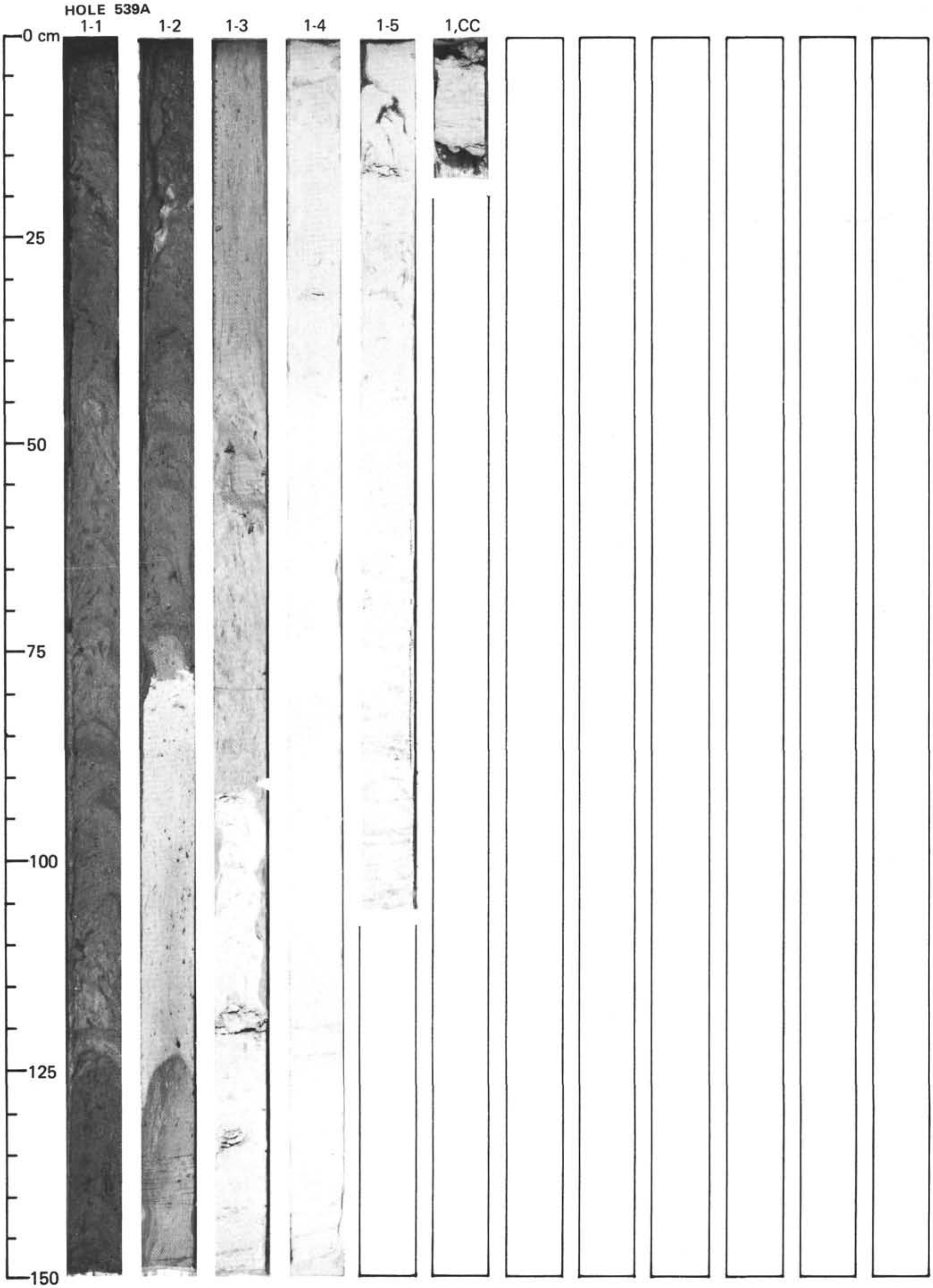

0 cm
25
50
75
100
125
150
68-2
68-3
68-4
68-5
69-1
69-2
69-3
69-4
69-5
69-6
70-1
70-2

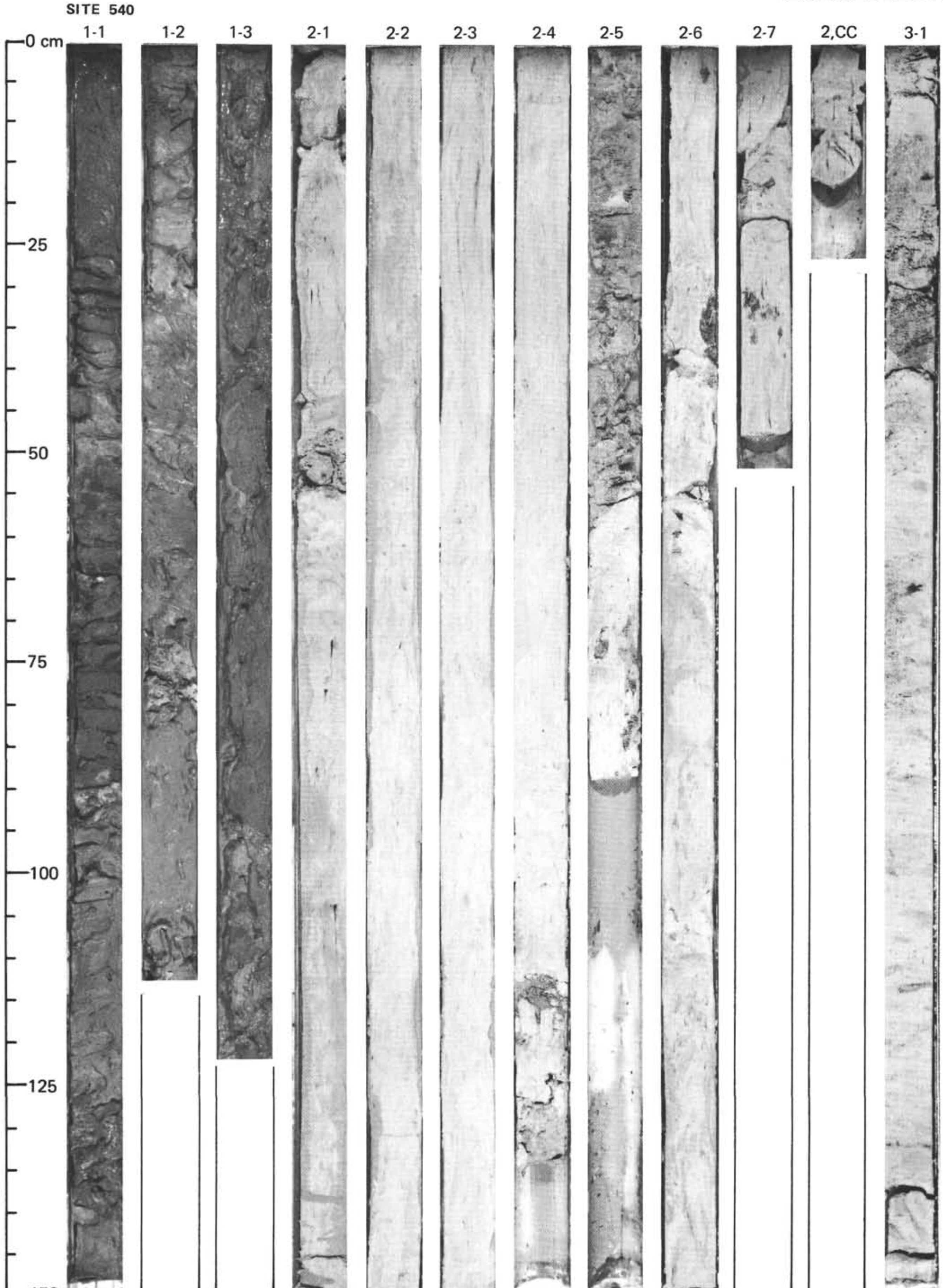

0 cm
25
50
75
100
125
150
70-3
70-4
70-5
70-6
71-1
71-2
71-3
71-4
71-5
72-1
72-2
72-3

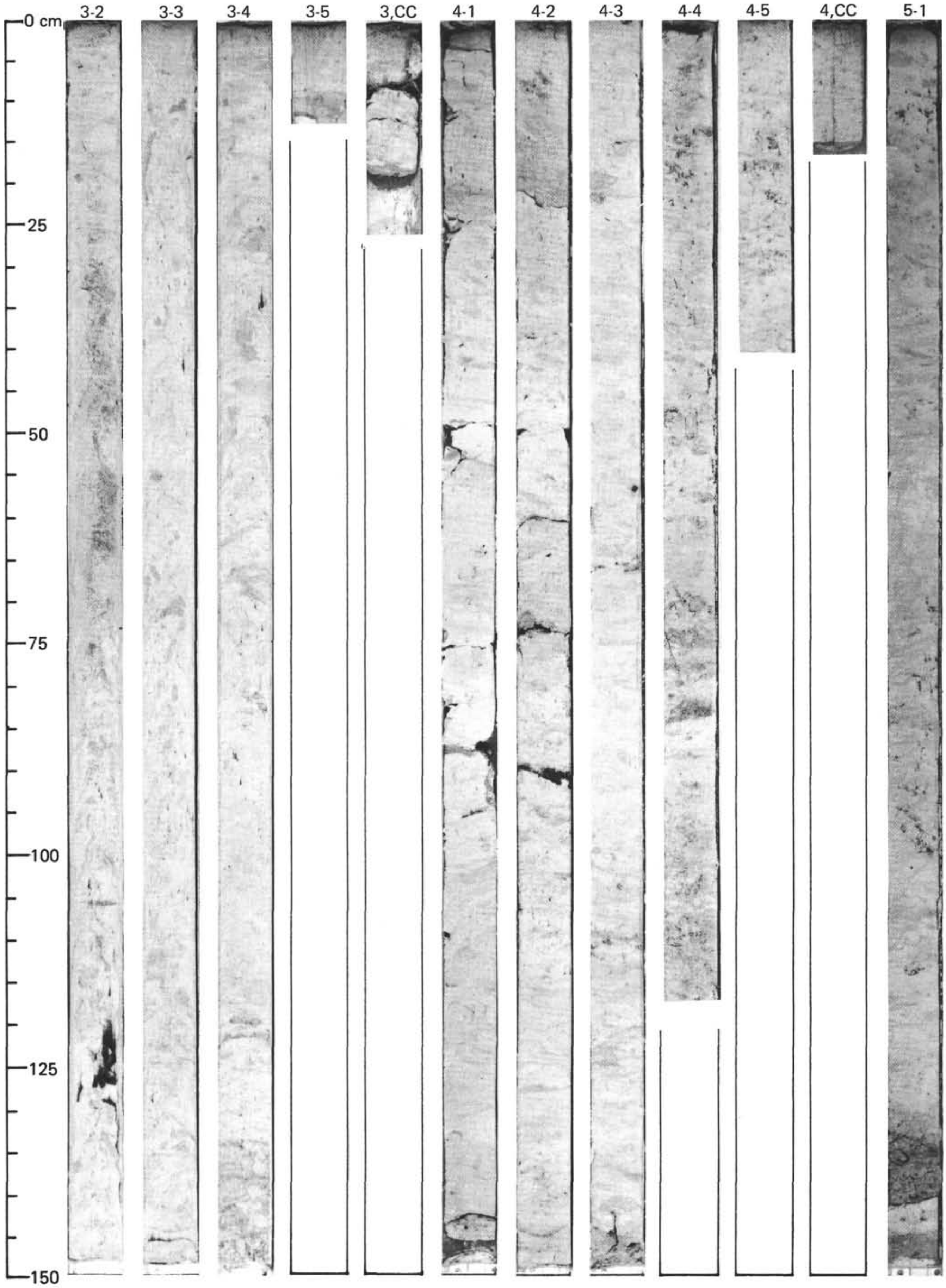

0 cm
25
50
75
100
125
150
72-4
72,CC
73-1
73-2
73-3
73,CC
74-1
74-2
74-3
75-1
75-2
75-3

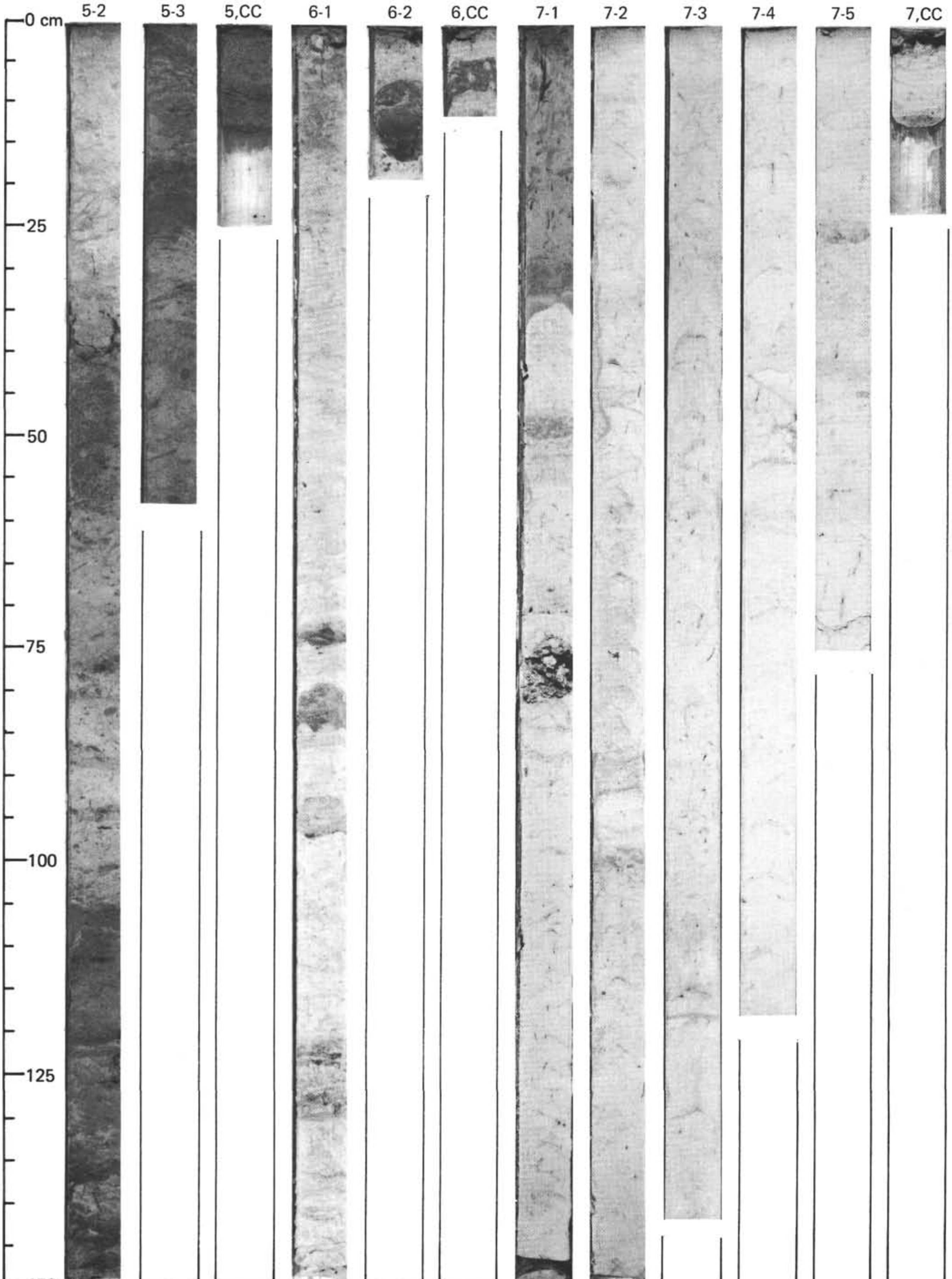

0 cm
25
50
75
100
125
150
75,CC
76-1
76-2
76-3
77-1
77-2
78-1
79-1
79-2


SITE 539
0 cm
25
50
75
100
125
150
1-1
1,CC
2-1
2-2
2-3
2,CC

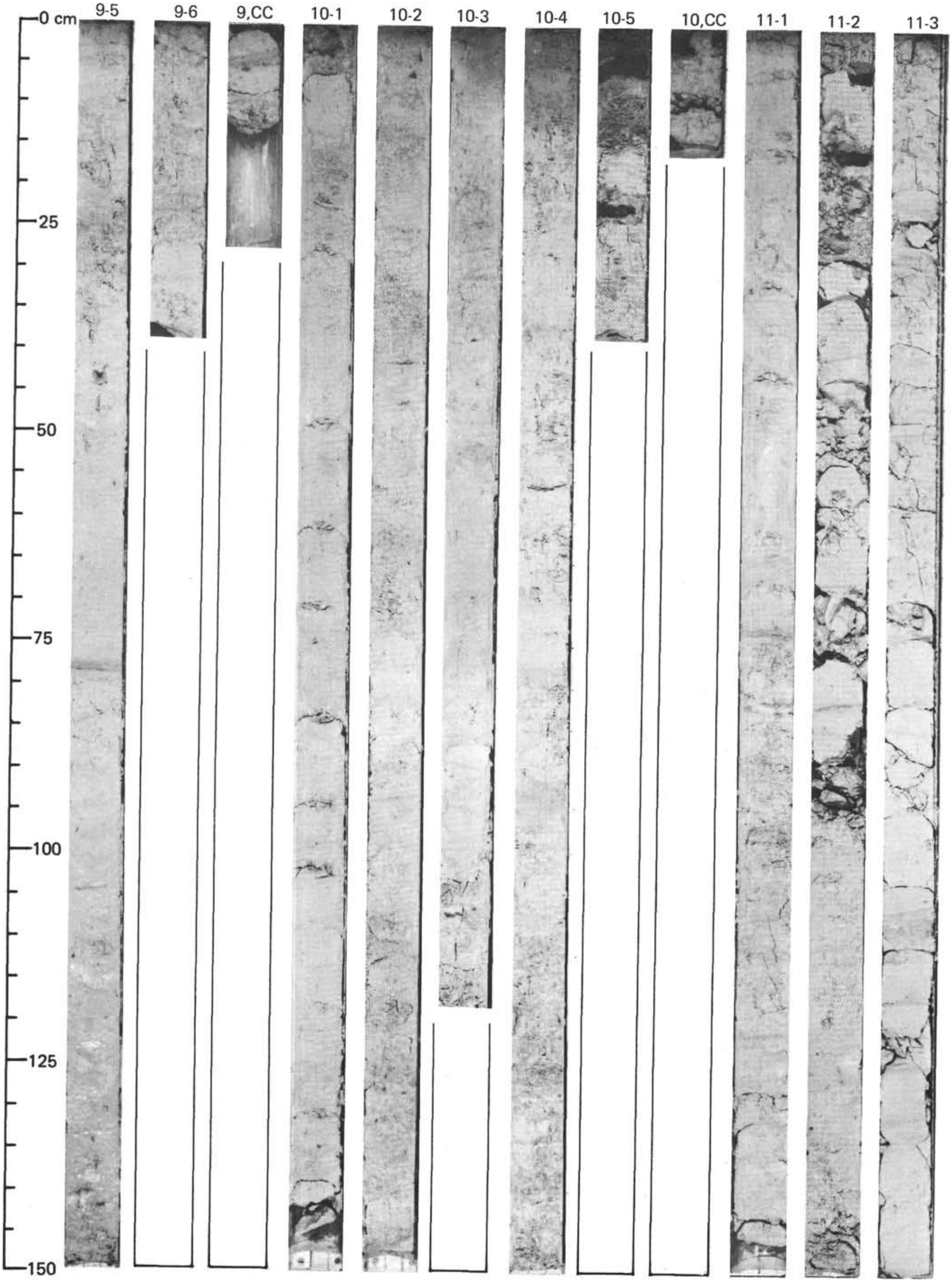

HOLE 539A
1-1
1-2
1-3
1-4
1-5
1,CC
0 cm
25
50
75
100
125
150

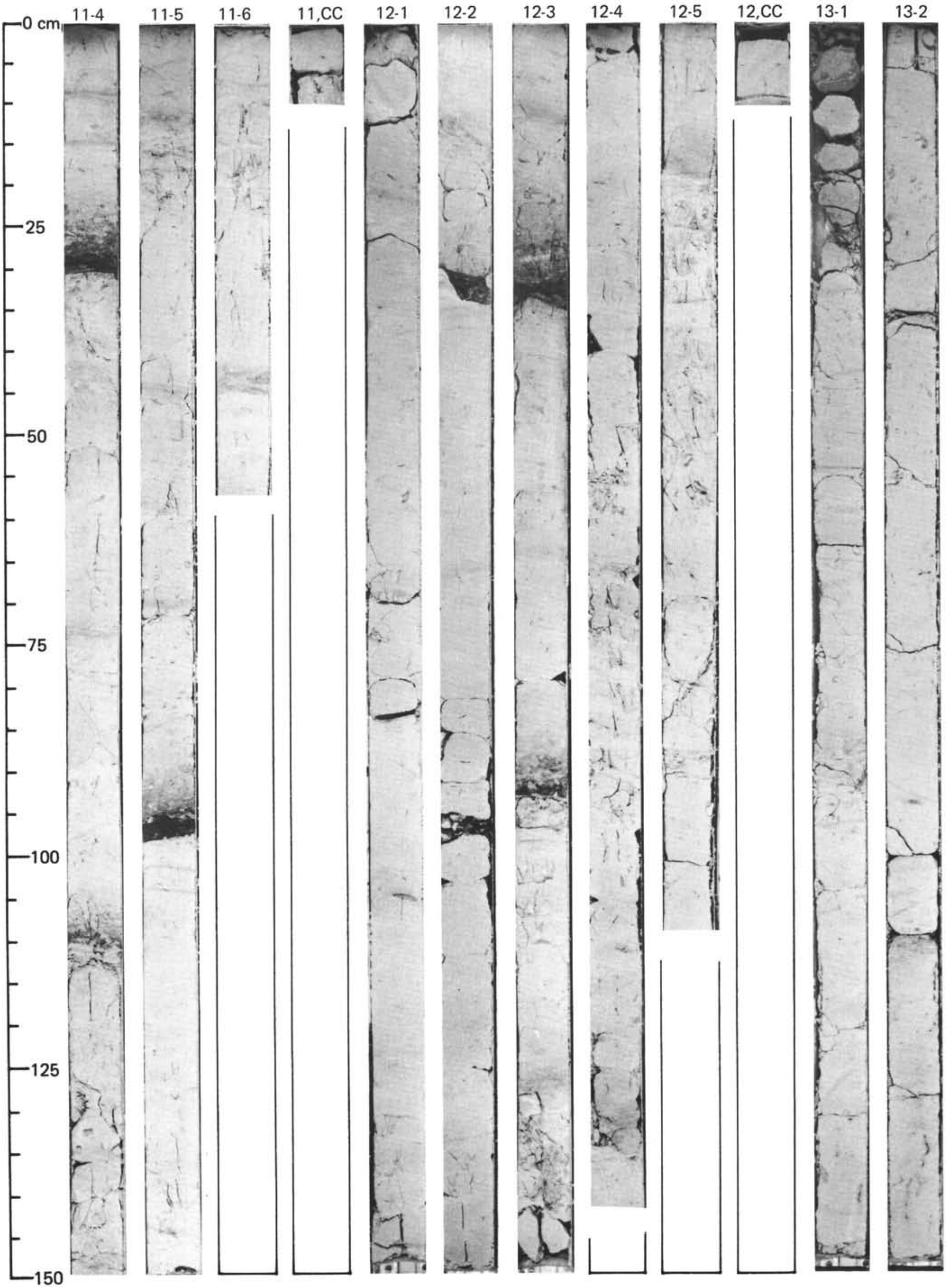

SITE 540
1-1
1-2
1-3
2-1
2-2
2-3
2-4
2-5
2-6
2-7
2,CC
3-1
0 cm
25
50
75
100
125
150

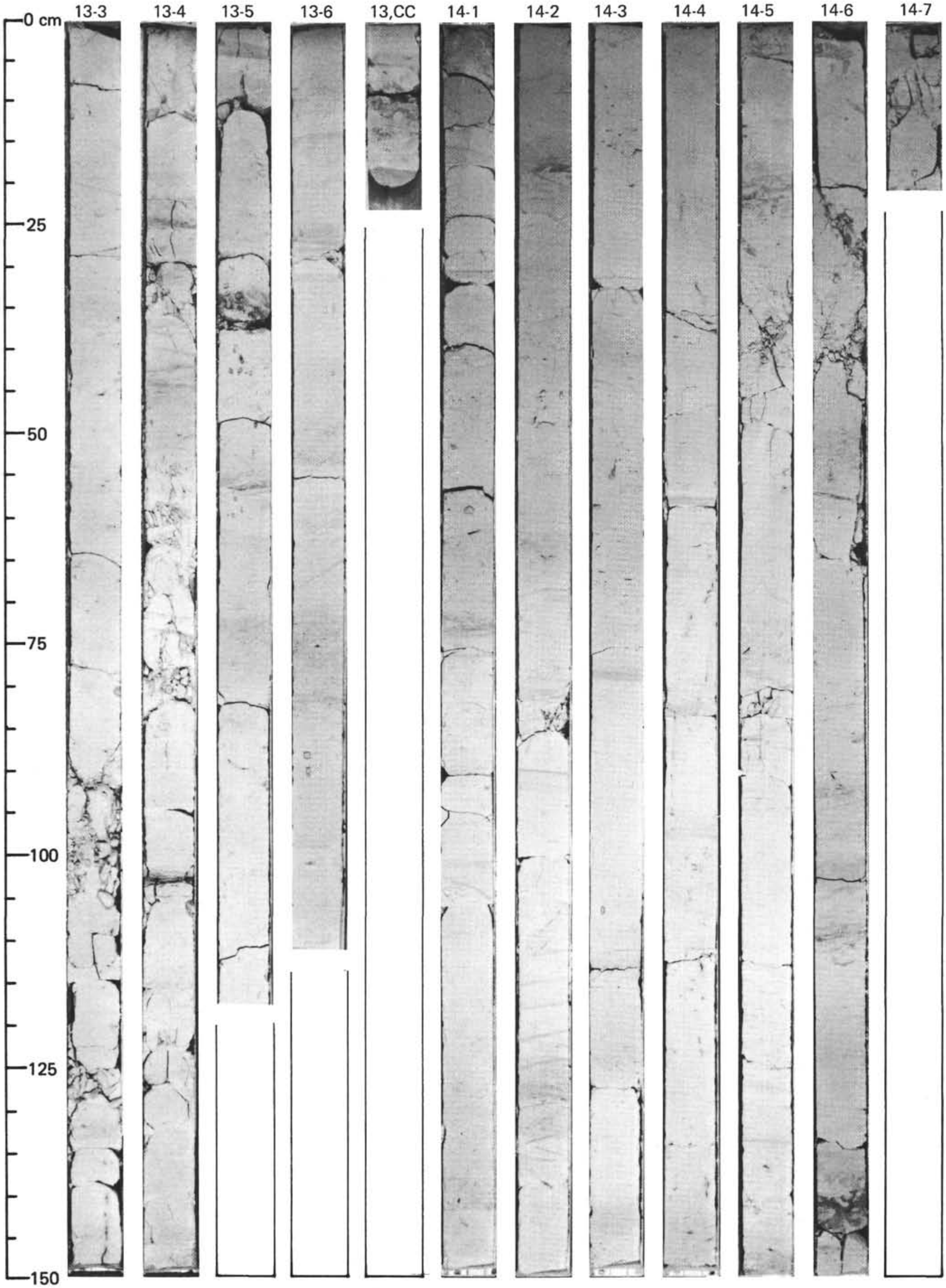

3-2
3-3
3-4
3-5
3,CC
4-1
4-2
4-3
4-4
4-5
4,CC
5-1
0 cm
25
50
75
100
125
150

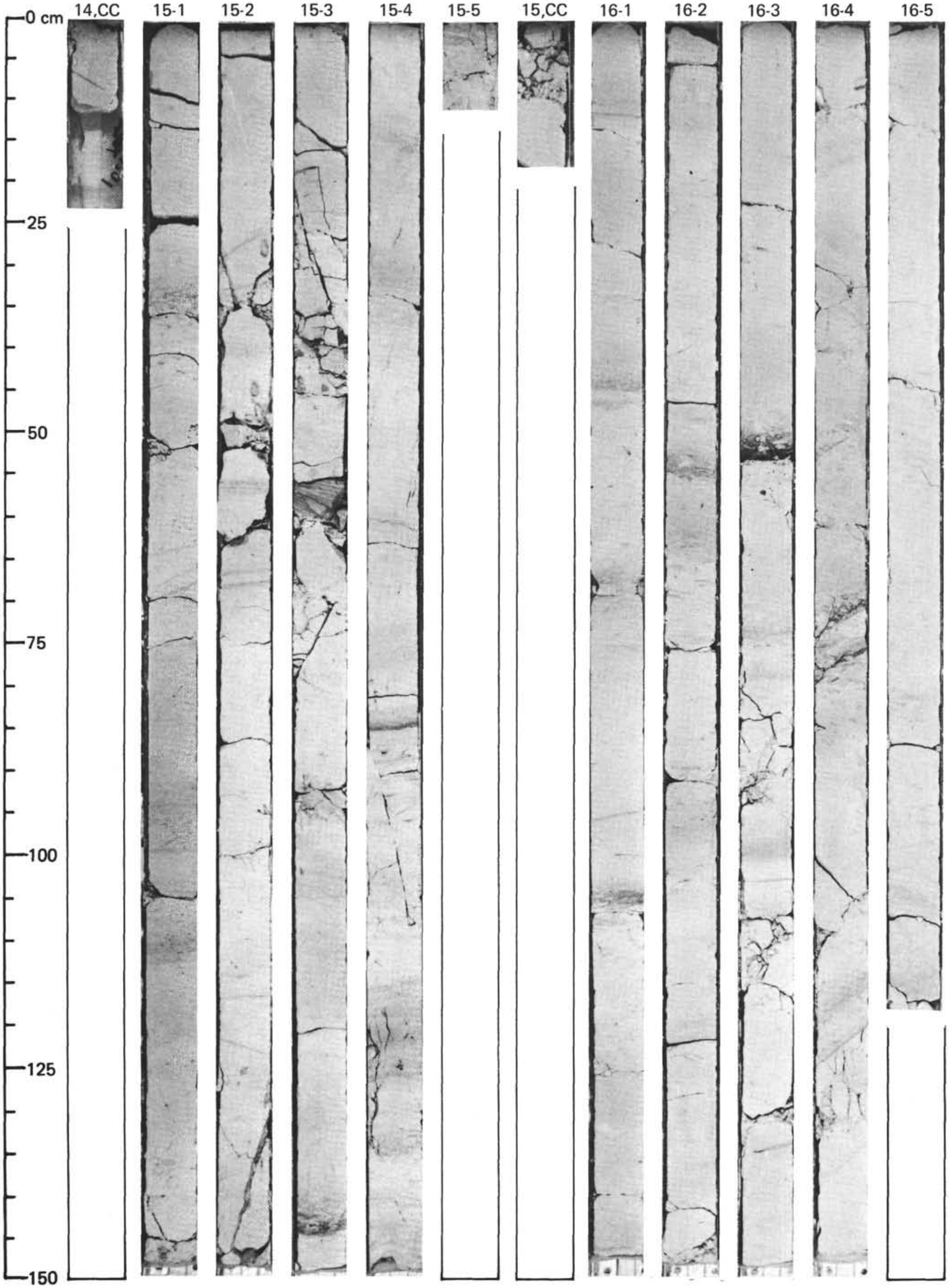

0 cm
25
50
75
100
125
150
5-2
5-3
5,CC
6-1
6-2
6,CC
7-1
7-2
7-3
7-4
7-5
7,CC

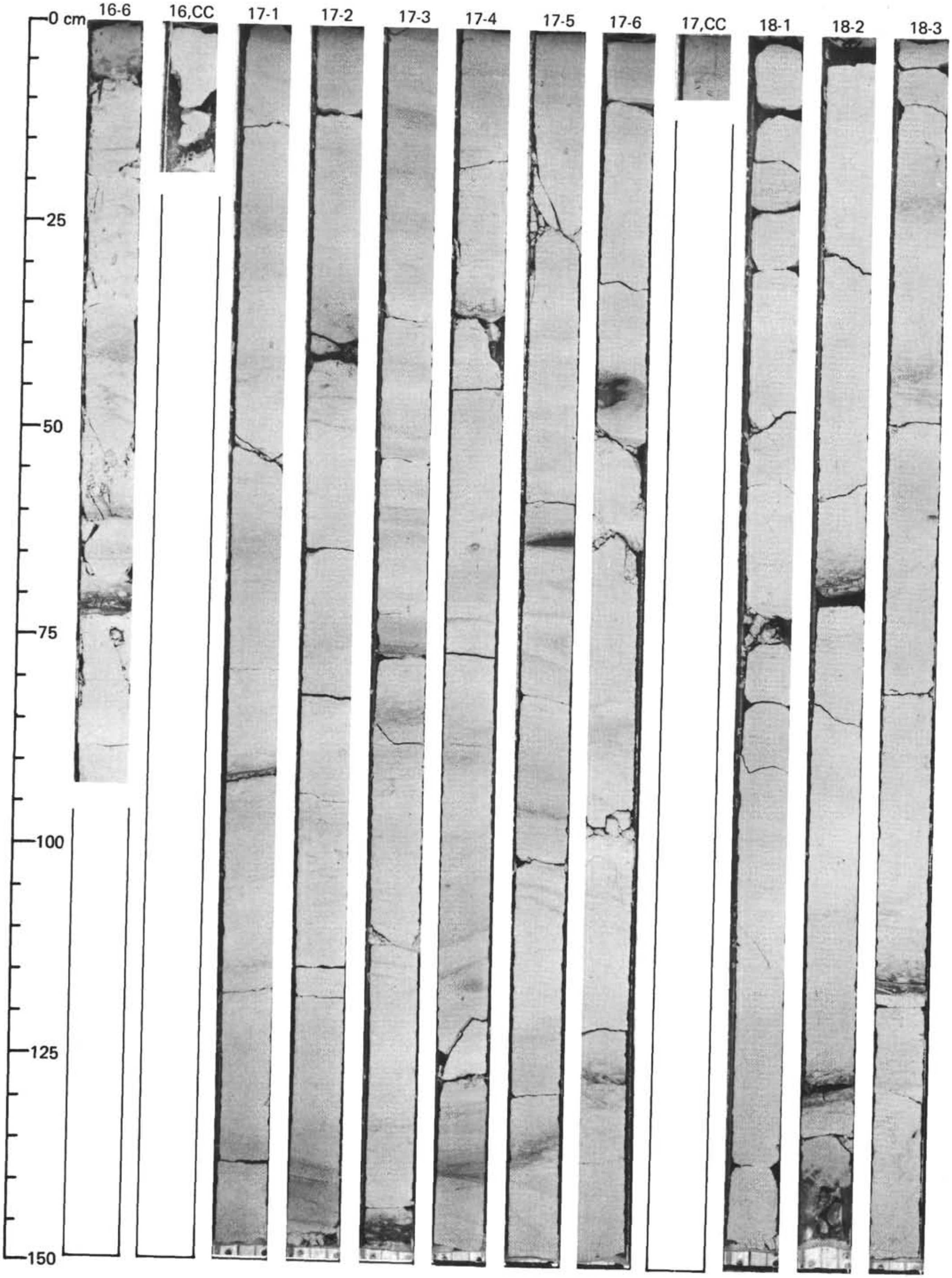

0 cm
25
50
75
100
125
150
8-1
8-2
8-3
8-4
8-5
8-6
8-7
8,CC
9-1
9-2
9-3
9-4

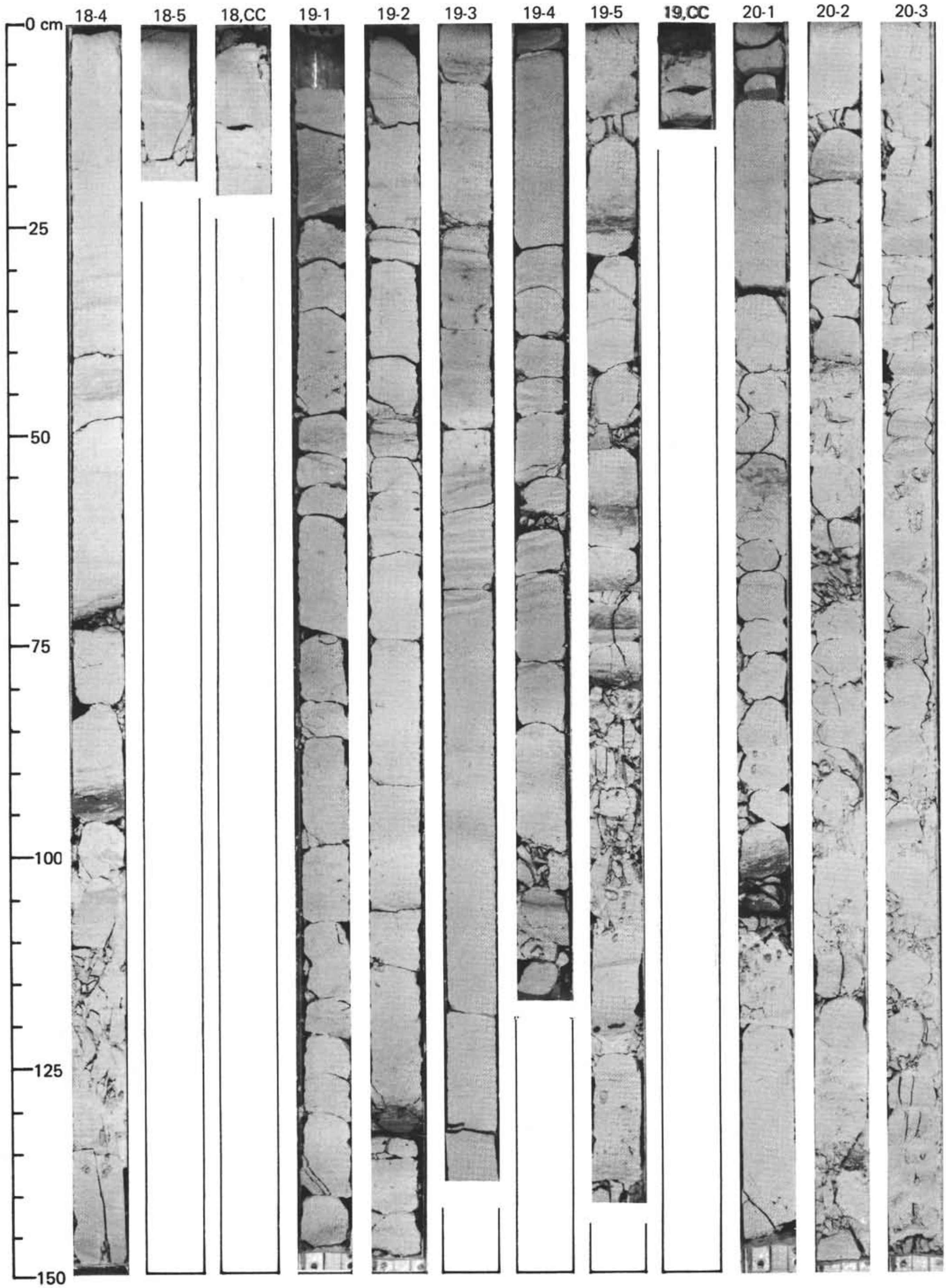

0 cm
25
50
75
100
125
150
9-5
9-6
9,CC
10-1
10-2
10-3
10-4
10-5
10,CC
11-1
11-2
11-3


0 cm
25
50
75
100
125
150
11-4
11-5
11-6
11,CC
12-1
12-2
12-3
12-4
12-5
12,CC
13-1
13-2

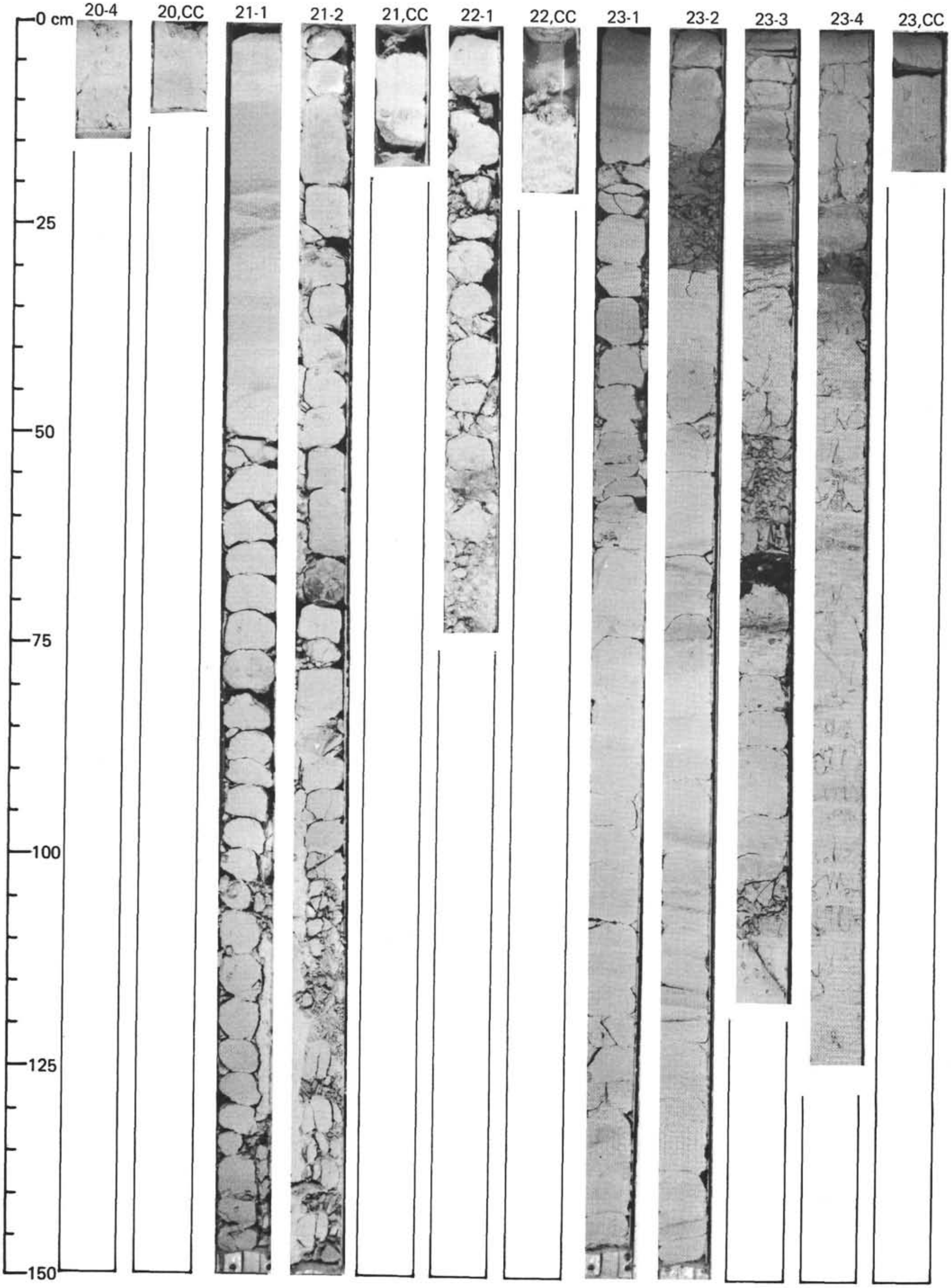

0 cm
25
50
75
100
125
150
13-3
13-4
13-5
13-6
13,CC
14-1
14-2
14-3
14-4
14-5
14-6
14-7

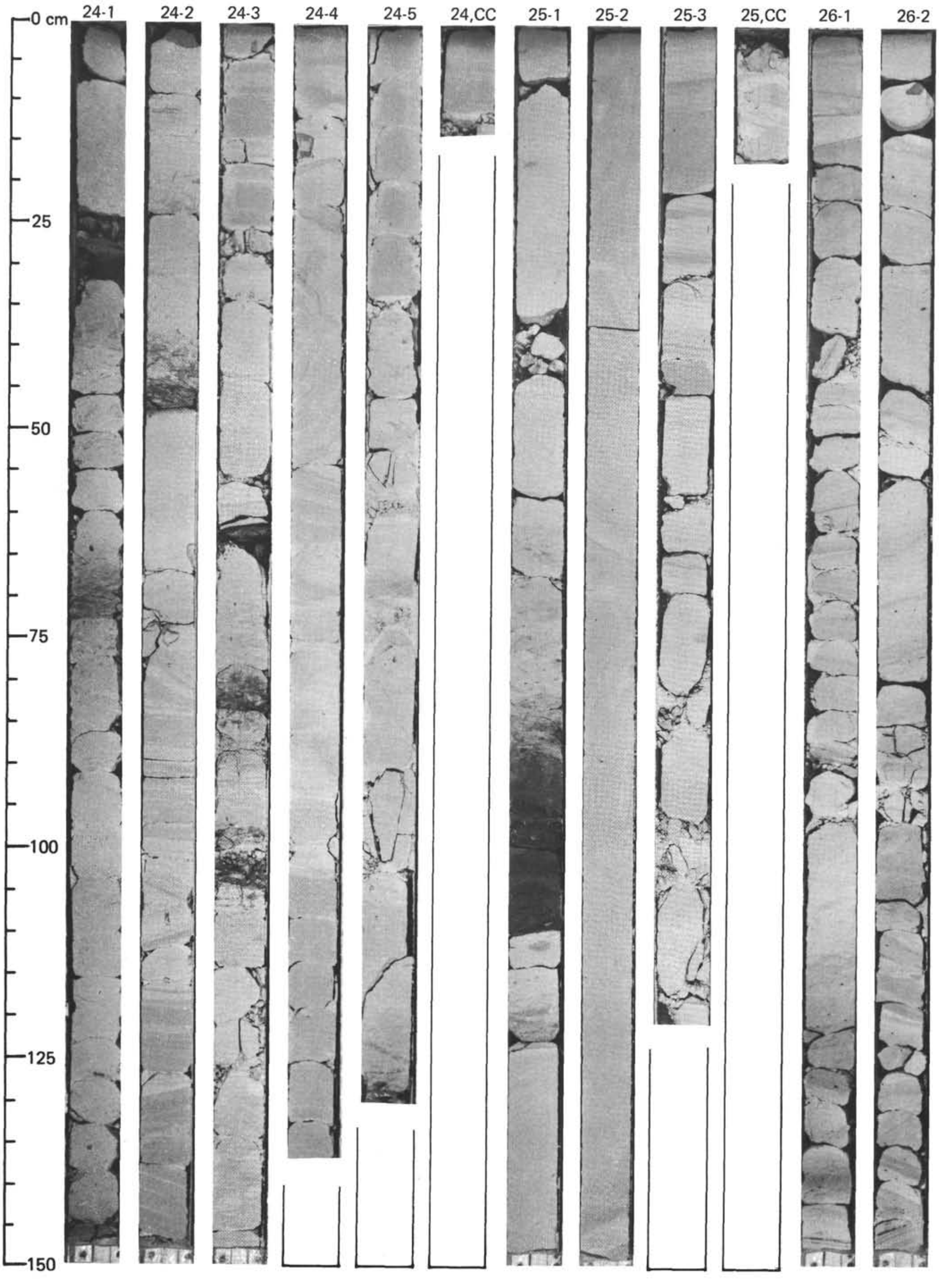

0 cm
25
50
75
100
125
150
14,CC
15-1
15-2
15-3
15-4
15-5
15,CC
16-1
16-2
16-3
16-4
16-5

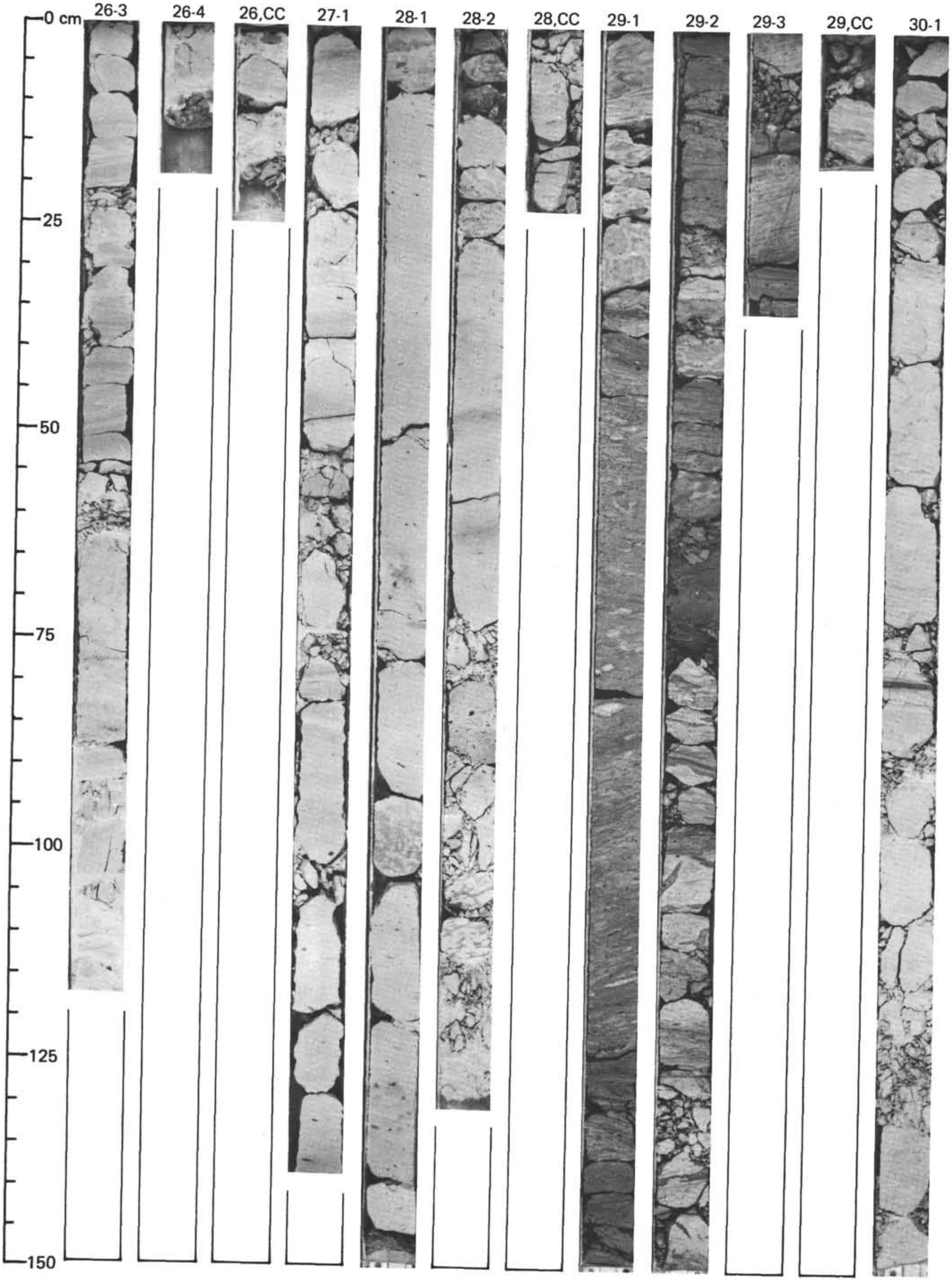

0 cm
25
50
75
100
125
150
16-6
16,CC
17-1
17-2
17-3
17-4
17-5
17-6
17,CC
18-1
18-2
18-3

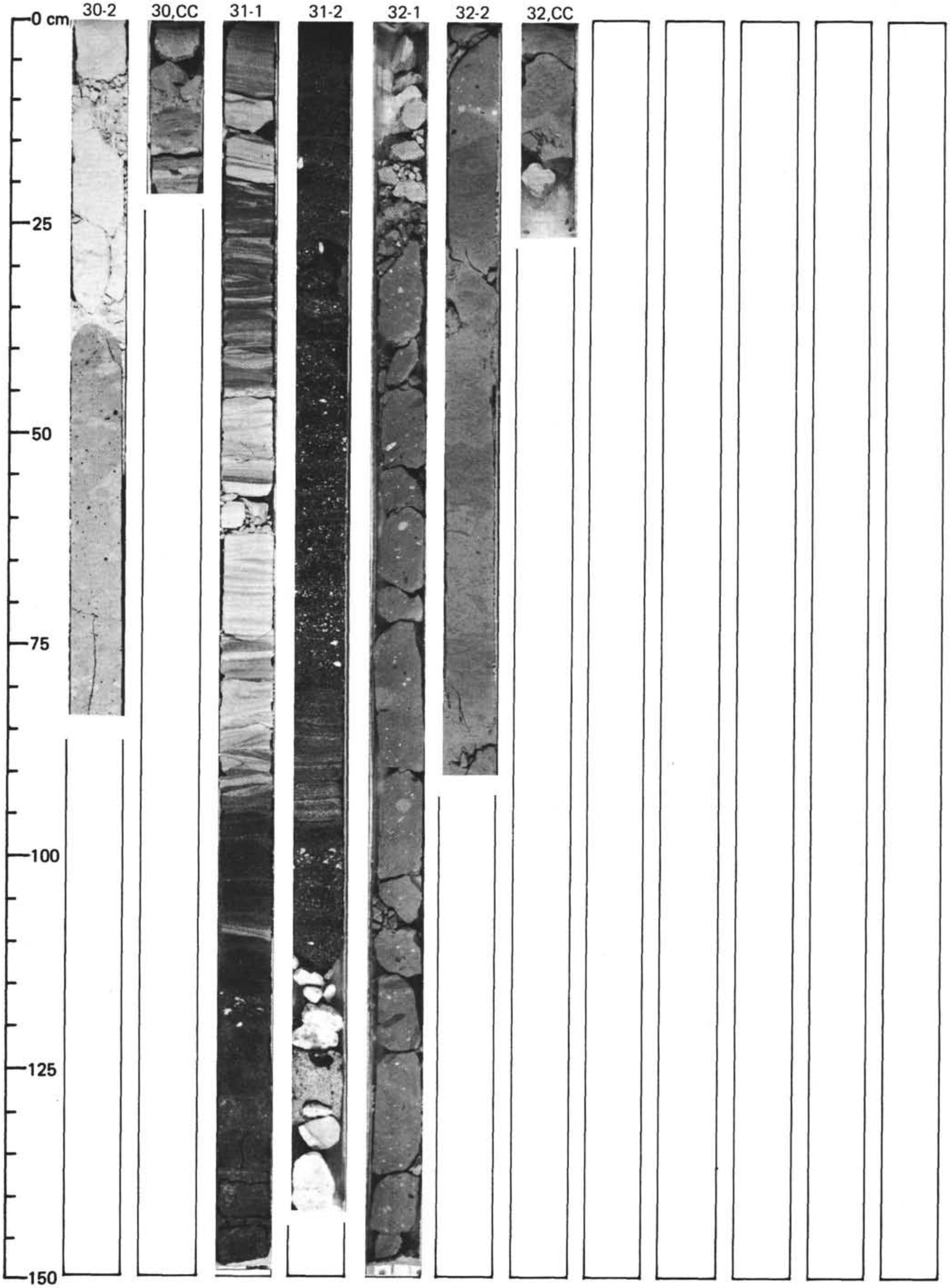


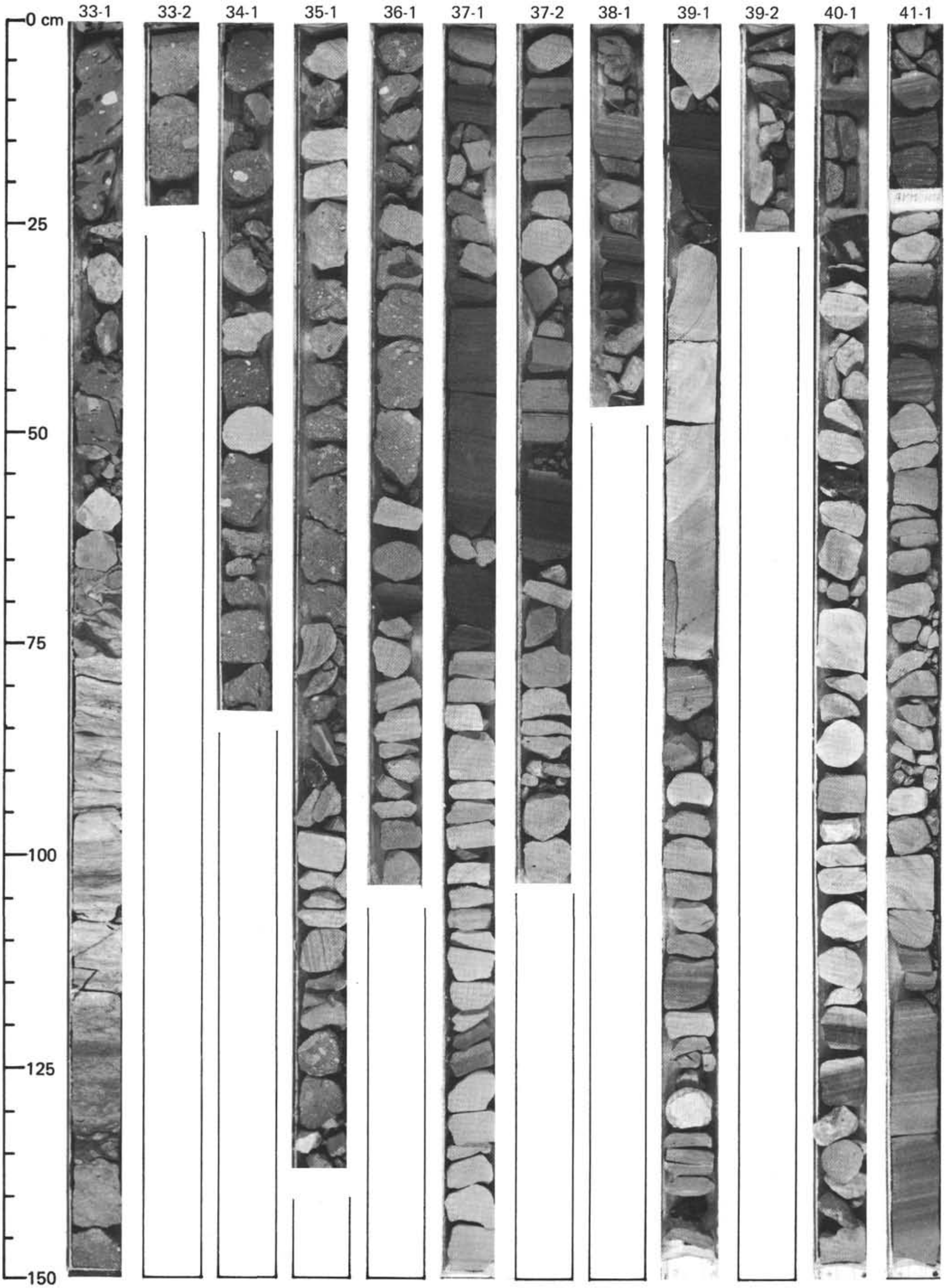
0 cm
25
50
75
100
125
150
18-4
18-5
18,CC
19-1
19-2
19-3
19-4
19-5
19,CC
20-1
20-2
20-3

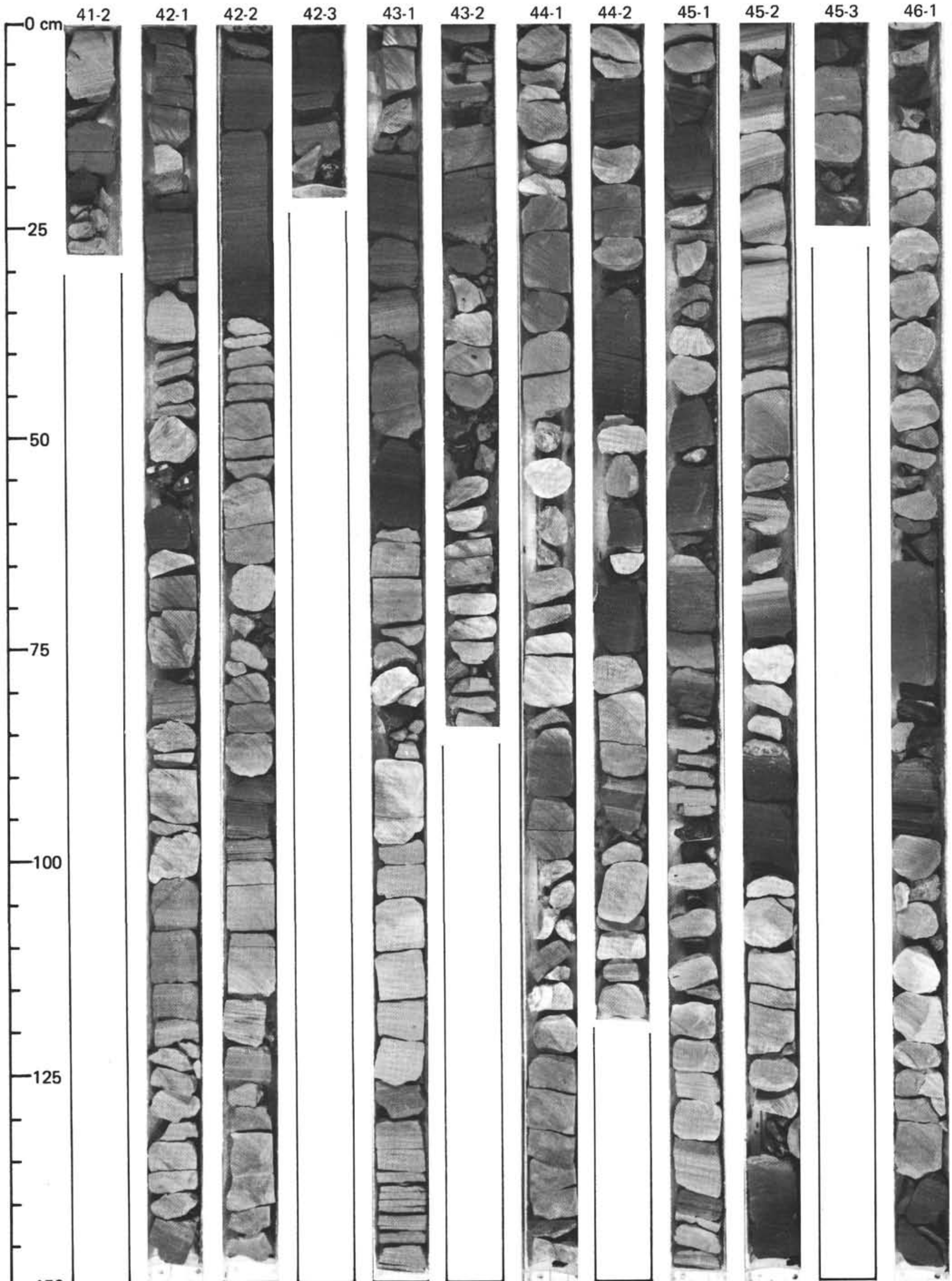

0 cm
25
50
75
100
125
150
20-4
20,CC
21-1
21-2
21,CC
22-1
22,CC
23-1
23-2
23-3
23-4
23,CC

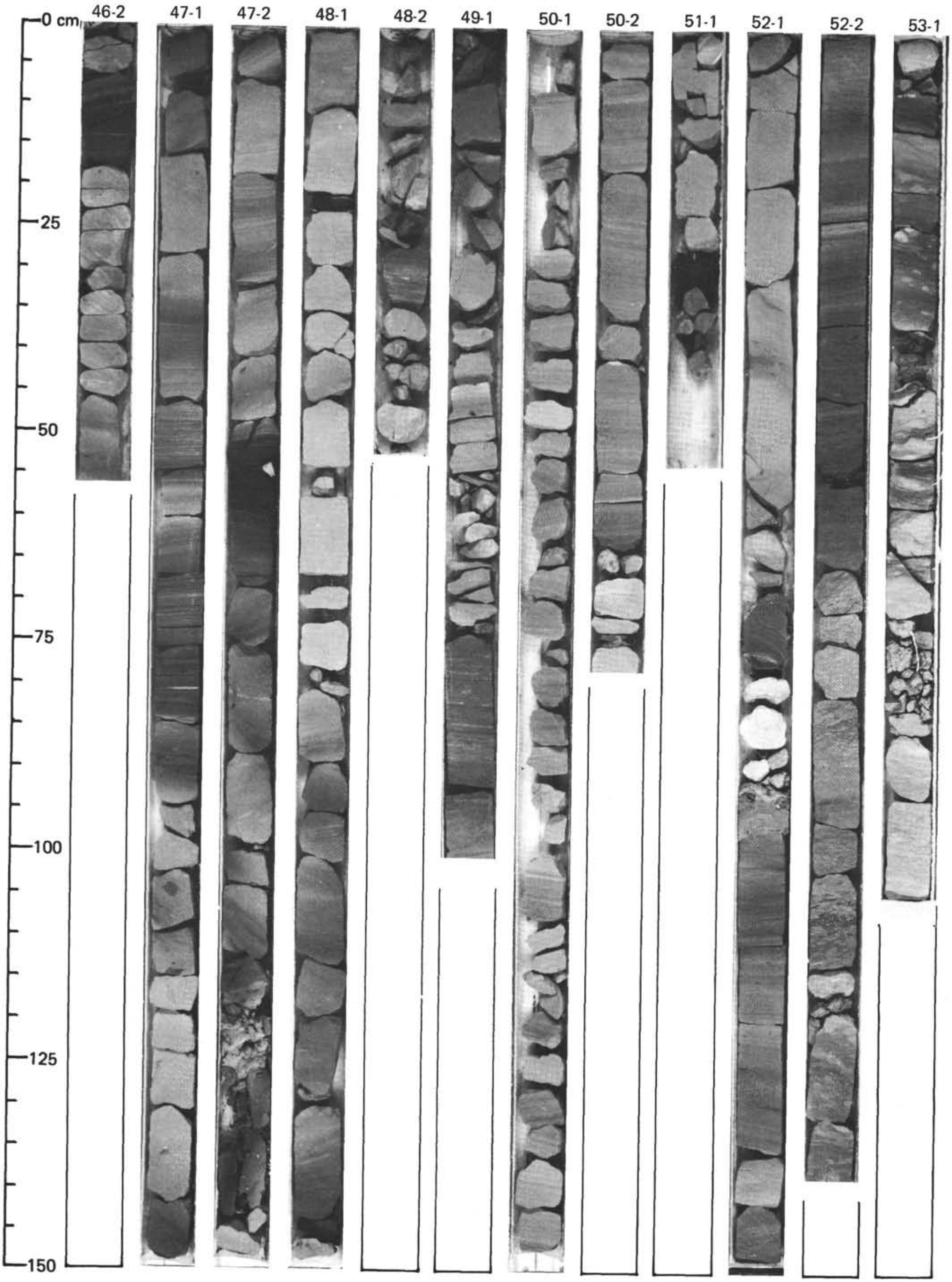

0 cm
25
50
75
100
125
150
24-1
24-2
24-3
24-4
24-5
24,CC
25-1
25-2
25-3
25,CC
26-1
26-2

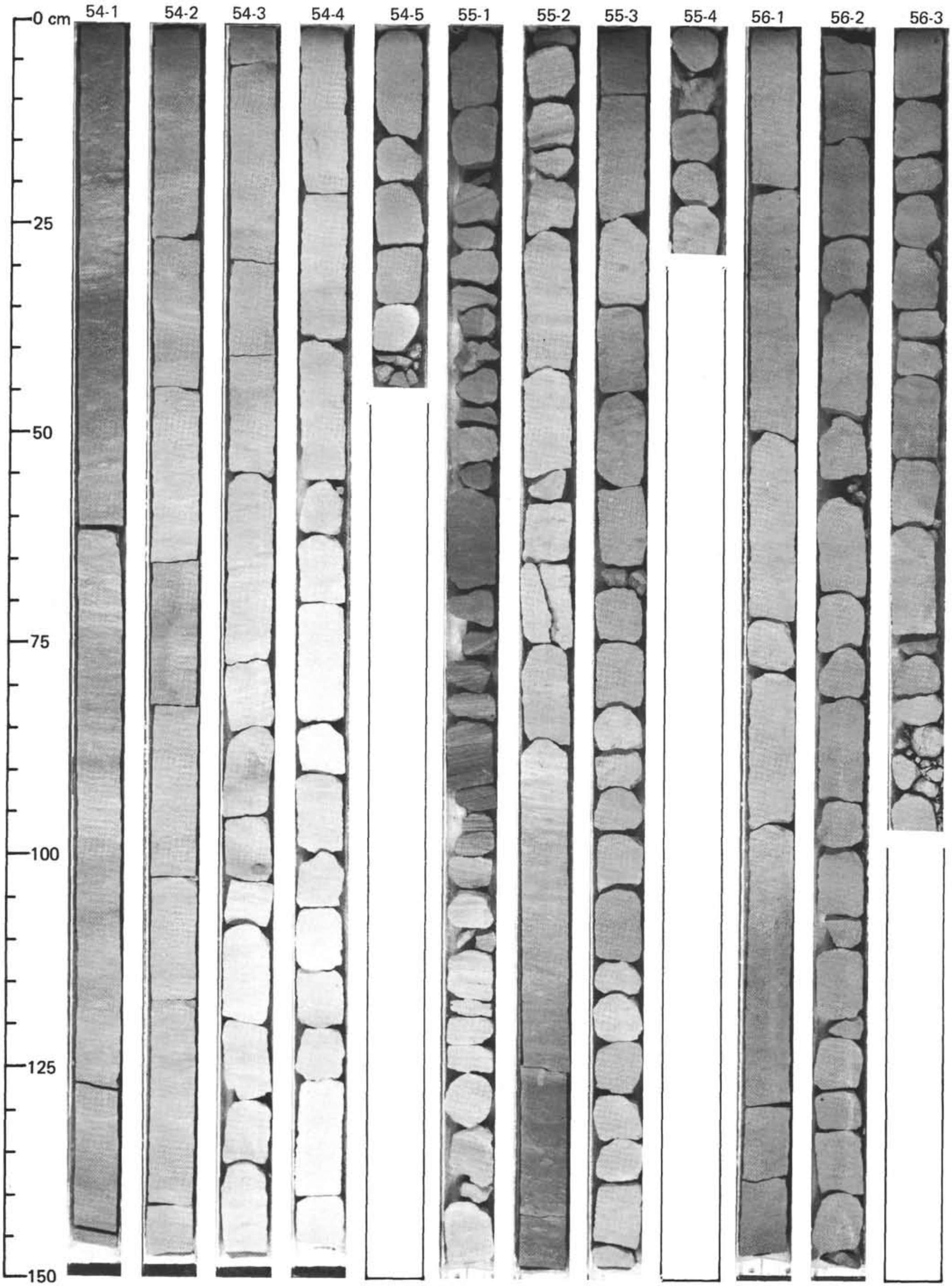

0 cm
25
50
75
100
125
150
26-3
26-4
26,CC
27-1
28-1
28-2
28,CC
29-1
29-2
29-3
29,CC
30-1

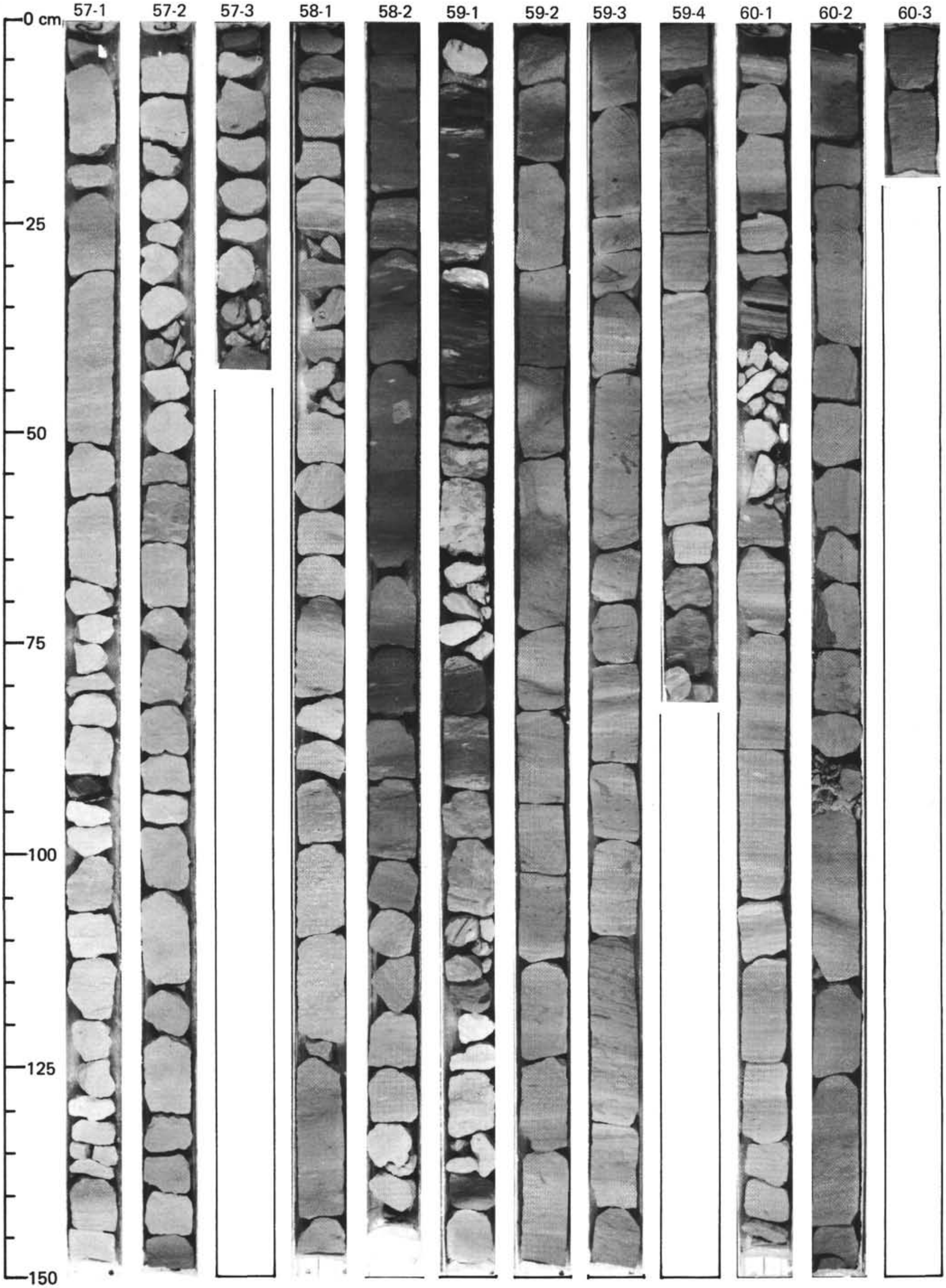

0 cm
25
50
75
100
125
150
30-2
30,CC
31-1
31-2
32-1
32-2
32,CC

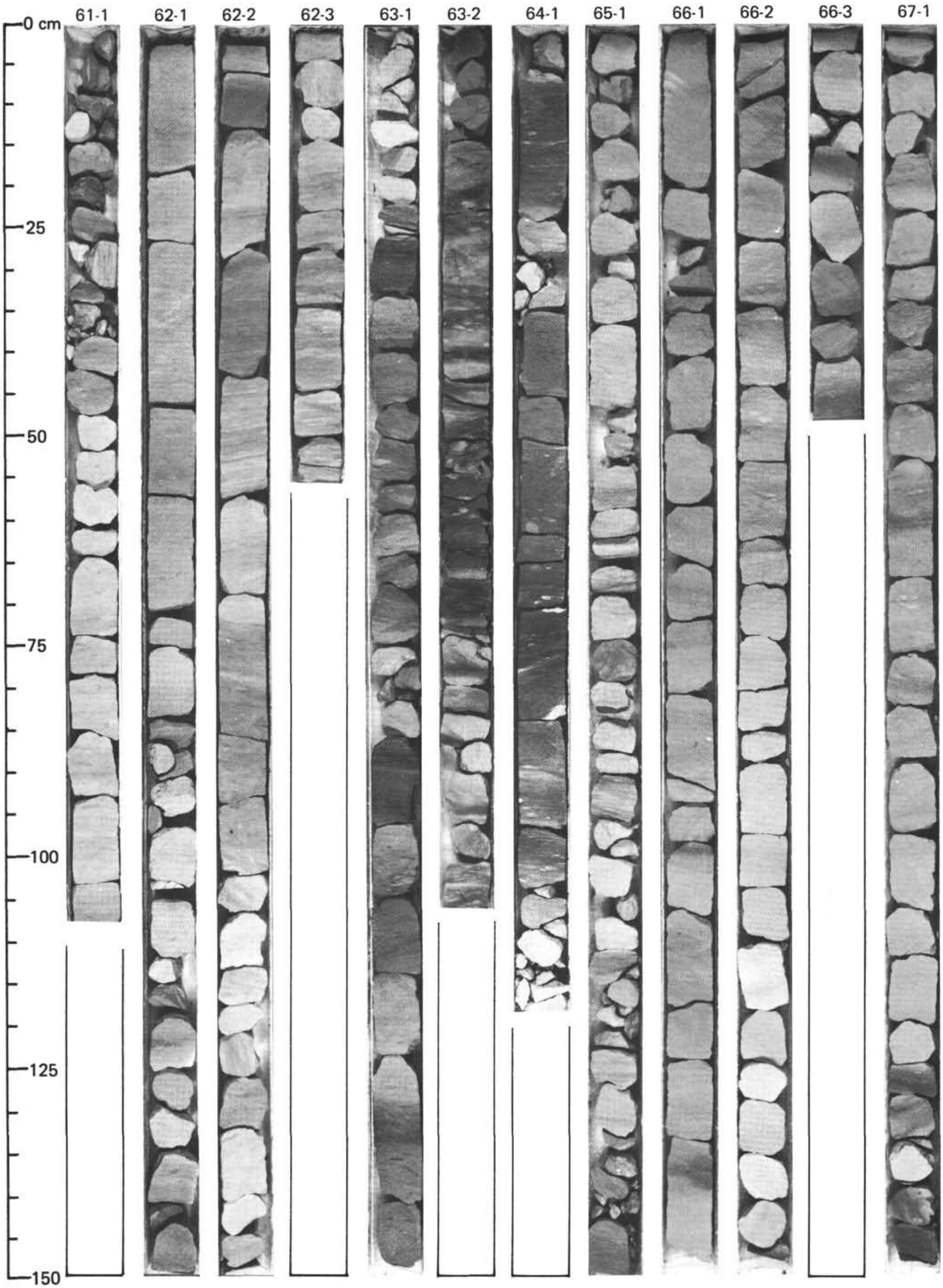

0 cm
25
50
75
100
125
150
33-1
33-2
34-1
35-1
36-1
37-1
37-2
38-1
39-1
39-2
40-1
41-1

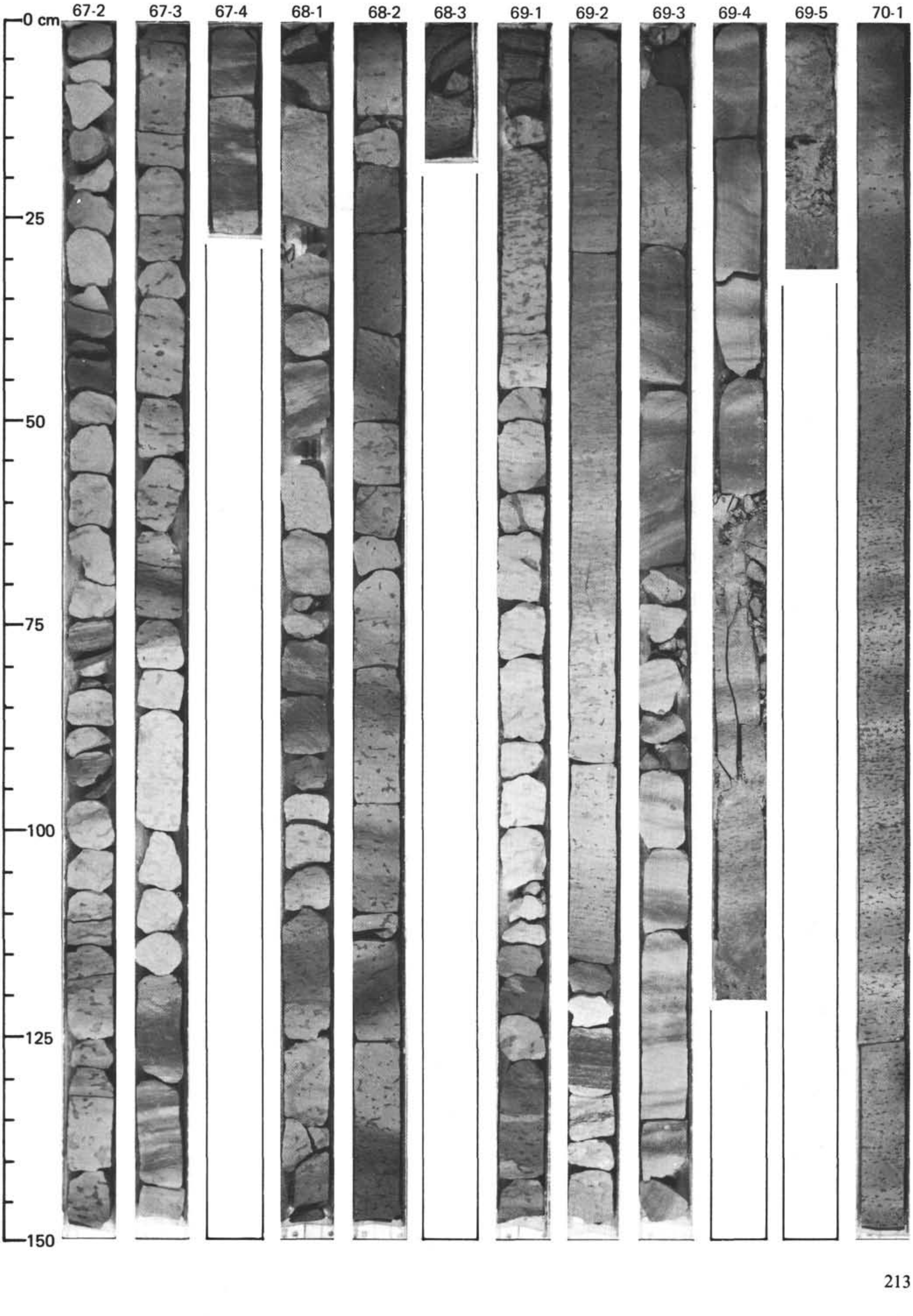

0 cm
25
50
75
100
125
150
41-2
42-1
42-2
42-3
43-1
43-2
44-1
44-2
45-1
45-2
45-3
46-1


0 cm
25
50
75
100
125
150
46-2
47-1
47-2
48-1
48-2
49-1
50-1
50-2
51-1
52-1
52-2
53-1

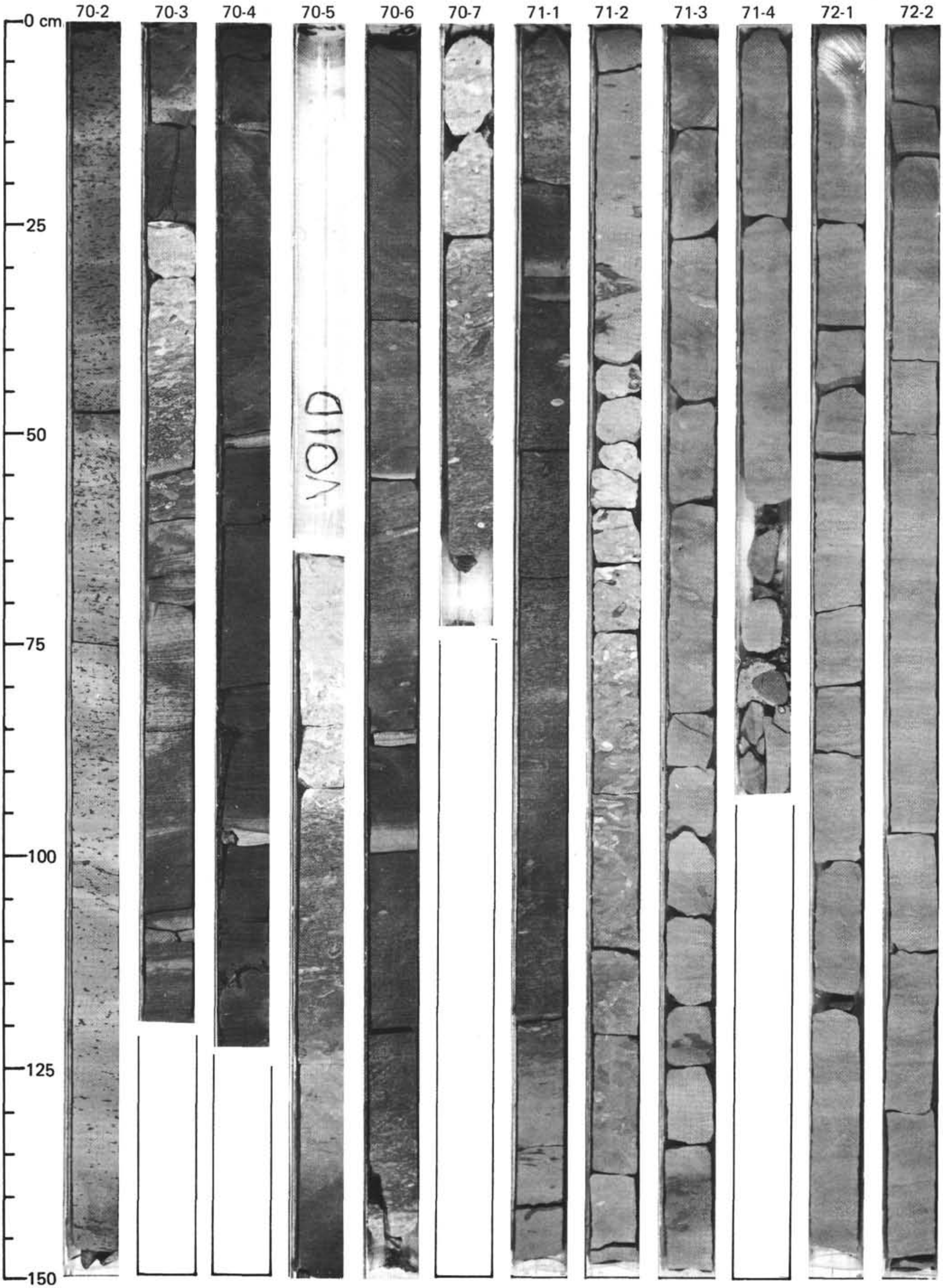

0 cm
25
50
75
100
125
150
54-1
54-2
54-3
54-4
54-5
55-1
55-2
55-3
55-4
56-1
56-2
56-3


0 cm
25
50
75
100
125
150
57-1
57-2
57-3
58-1
58-2
59-1
59-2
59-3
59-4
60-1
60-2
60-3

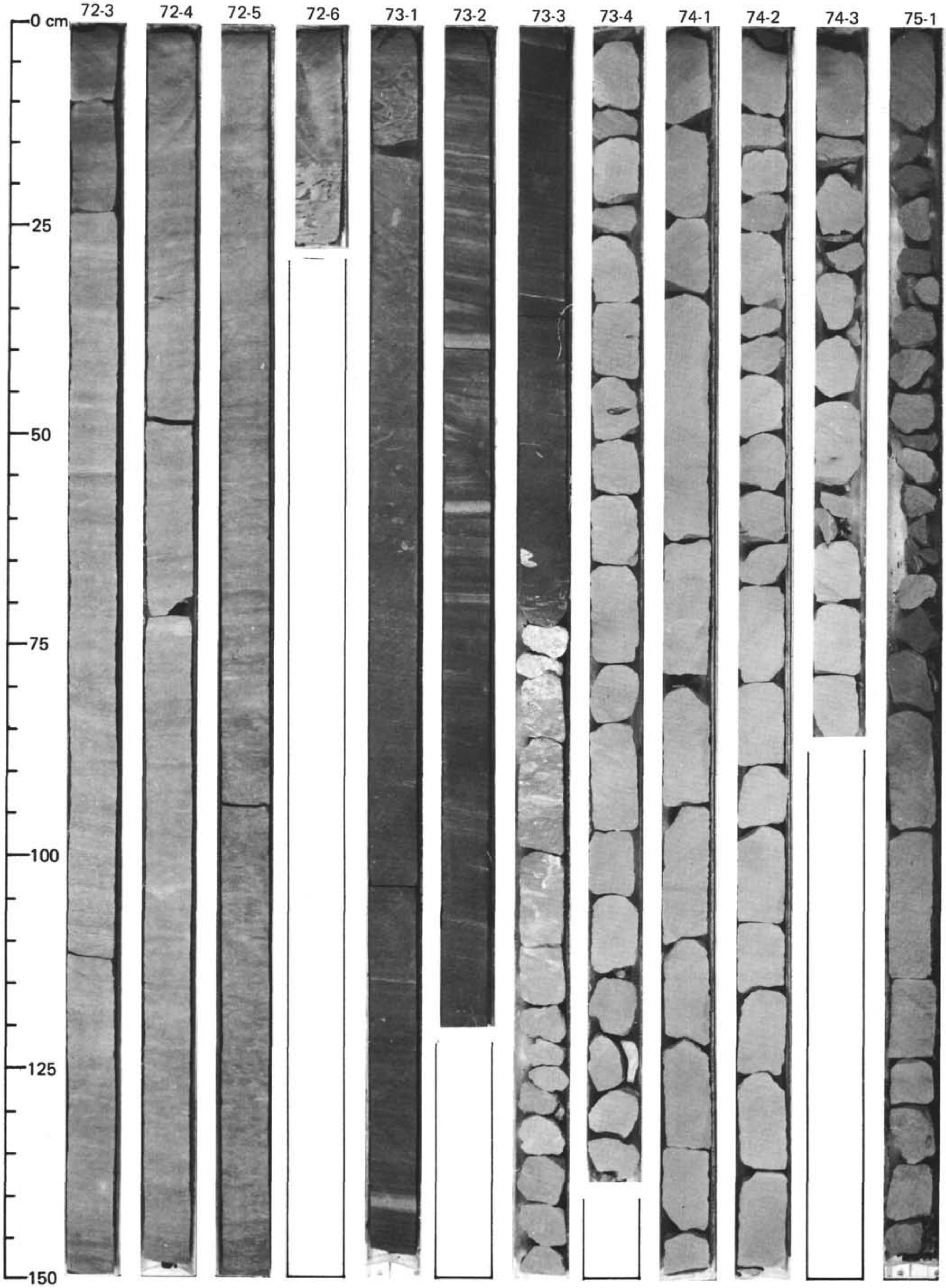

61-1
62-1
62-2
62-3
63-1
63-2
64-1
65-1
66-1
66-2
66-3
67-1
0 cm
25
50
75
100
125
150

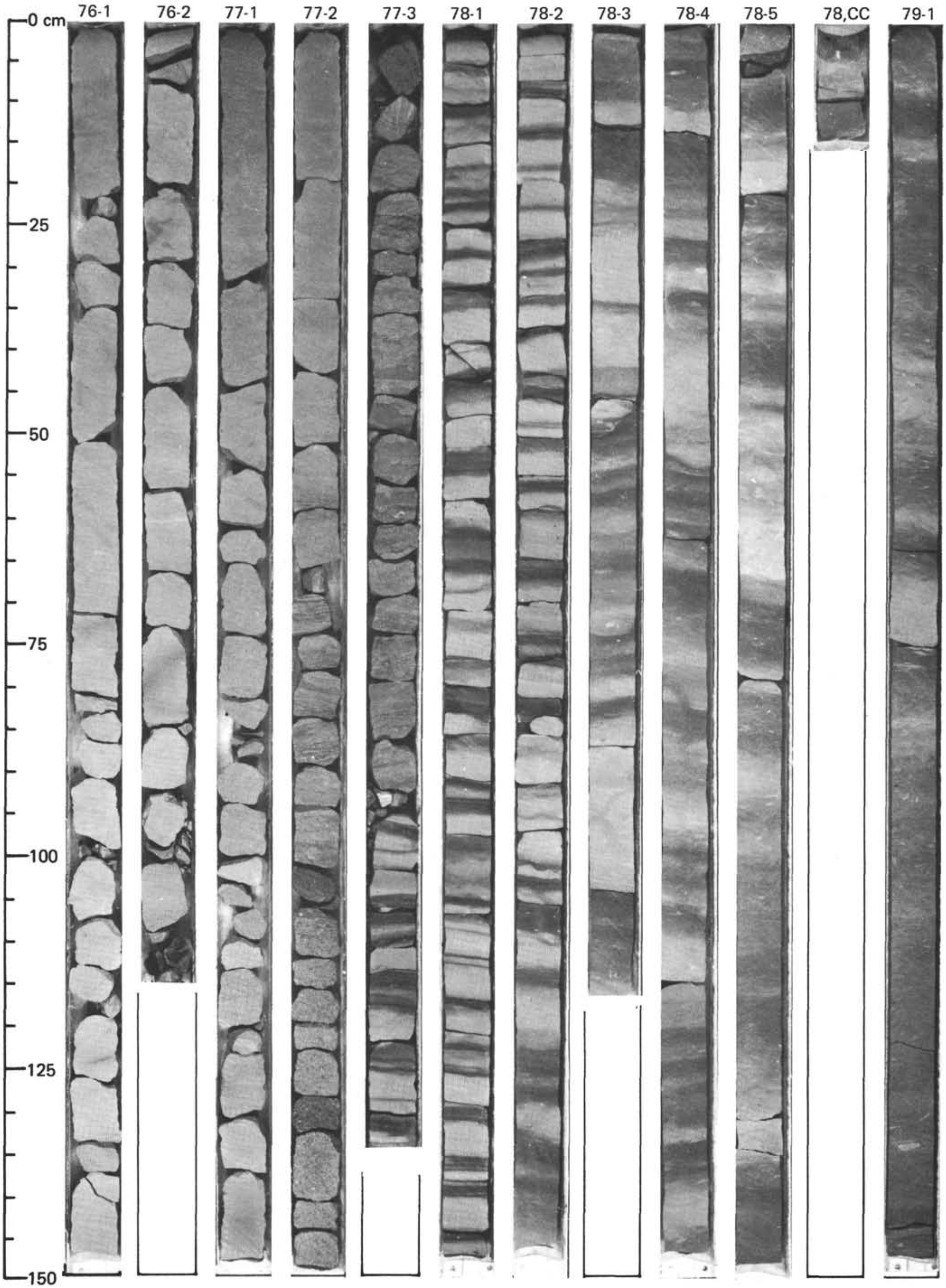


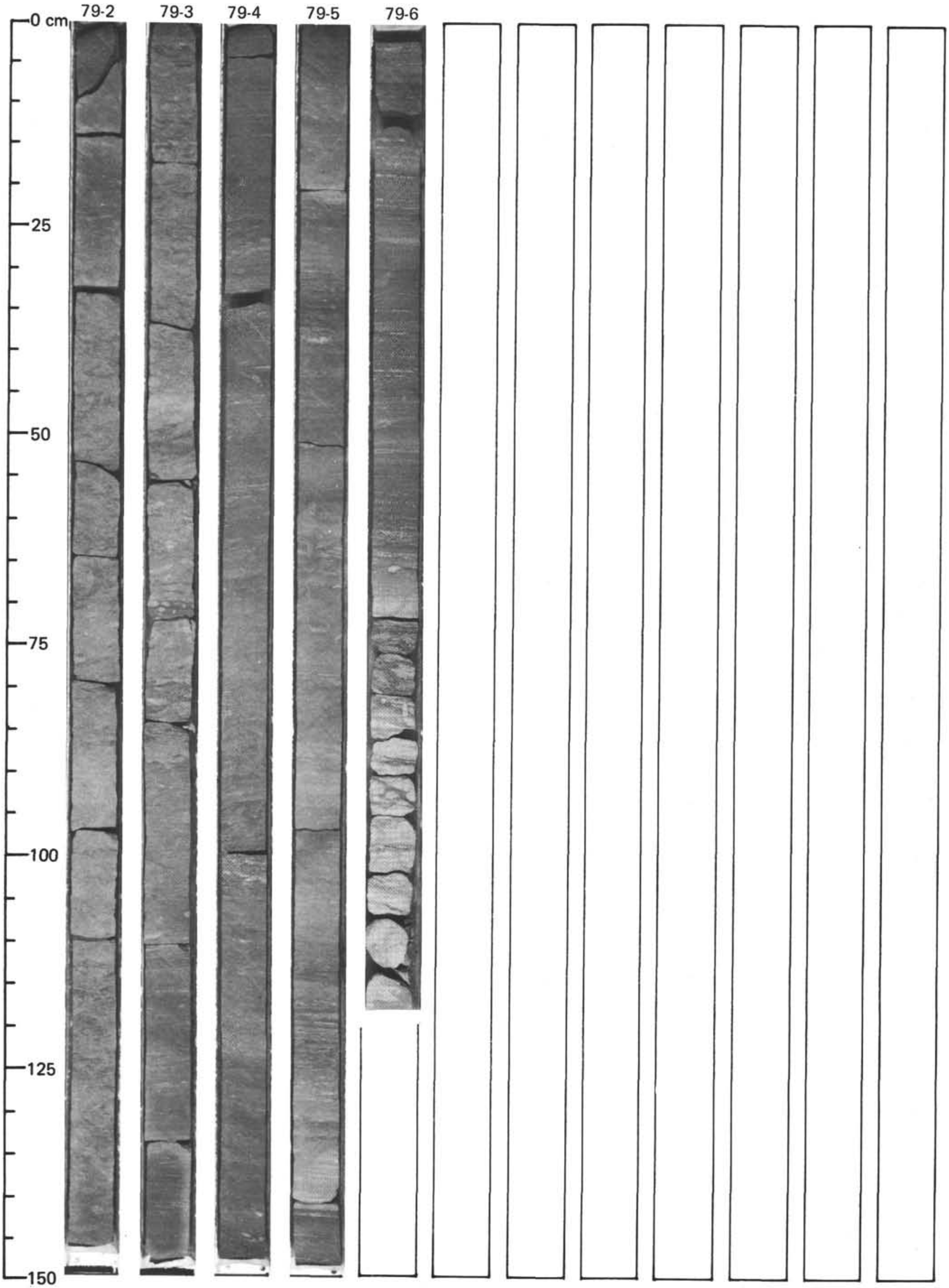
0 cm
25
50
75
100
125
150
67-2
67-3
67-4
68-1
68-2
68-3
69-1
69-2
69-3
69-4
69-5
70-1



0 cm
25
50
75
100
125
150
70-2
70-3
70-4
70-5
70-6
70-7
71-1
71-2
71-3
71-4
72-1
72-2
VOID


72-3
72-4
72-5
72-6
73-1
73-2
73-3
73-4
74-1
74-2
74-3
75-1
0 cm
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
76-1
76-2
77-1
77-2
77-3
78-1
78-2
78-3
78-4
78-5
78,CC
79-1


0 cm
25
50
75
100
125
150
79-2
79-3
79-4
79-5
79-6