2. SITE 511[1]

Shipboard Scientific Party[2]

Date occupied: 15 January 1980; 0611 hr. (beacon dropped)

Date departed: 21 January 1980; 0342 hr. (underway; beacon close aboard 0532)

Number of holes: 1

Time on hole: 141 hr.

Position: 51°00.28′S, 46°58.30′W

Water depth (sea level; corrected m, echo-sounding): 2589

Water depth (rig floor; corrected m, echo-sounding): 2599

Bottom felt (m, drill pipe): 2602

Penetration (m): 632

Number of cores: 70

Total length of cored section (m): 632

Total core recovered (m): 385.62

Core recovery (%): 61

Oldest sediment cored:
Depth sub-bottom (m): 632
Nature: Black mudstone and nannofossil mudstone (black shales), rich in organic matter
Age: Late Jurassic
Measured velocity (km/s): ~2.3

Principal results: Drilling at Site 511 gave definitive results on the nature and age of the seismically determined wedge of sediments on the Falkland Plateau. The section drilled and continuously cored in the basin province of the plateau, about 10 km south of Site 330 on Maurice Ewing Bank, consists largely of diatomaceous, nannofossil, calcareous, and zeolitic oozes of Paleocene–Eocene to early Oligocene age between seafloor and a major erosional unconformity at 195 meters depth. This unit is underlain by 14 meters of early Maestrichtian calcareous and zeolitic calcareous oozes followed by 203 meters of zeolitic clays and claystones of Turonian to Campanian age, below which are 86 meters of early Albian to Turonian claystones and nannofossil claystones and chalks. The chalks rest on mudstones and nannofossil mudstones of Jurassic to early Albian age, rich in organic matter and called the black shales, of which 134 meters were cored for a TD of 632 meters below seafloor. A depositional hiatus of some 20 m.y. separates the Jurassic from the Cretaceous sediments.

At Site 511, the first successful heat flow measurement was obtained on the plateau, through use of the Downhole Temperature Probe. The heat flow is 1.5 HFU.

BACKGROUND AND OBJECTIVES

The Falkland Plateau extending eastward off southernmost South America is bounded on the north by the Falkland Escarpment and on the south by the Falkland Trough and North Scotia Ridge (Fig. 1). The western part of the plateau is a segment of oceanic crust (or attenuated continental crust) over which have been deposited 4–6 km of sediment in a basin bounded by the Falkland Islands Platform on the west, a narrow ridge associated with the Falkland Escarpment on the north, Maurice Ewing Bank on the east, and the North Scotia Ridge on the south. Maurice Ewing Bank, a subsided continental block that received thick carbonate as well as siliceous biogenic sediment throughout most of its history, forms the eastern part of the plateau.

In the basin thick, widespread sheets of sediment dip southward from the Falkland Escarpment ridge and are terminated updip by erosional truncation (Ludwig, this volume). They lap out against the Falkland Islands Platform and Maurice Ewing Bank. The lower boundary of the depositional sequence has been disrupted through movement of the North Scotia Ridge toward the plateau, resulting in deformation and uplift of near-surface sediment layers onto the north side of the ridge and subduction of lower layers beneath the ridge.

The wedge of sediments on the plateau appears to represent basin-slope and basin-floor seismic facies units. In the parallel sheet-drape facies generally described by Sangree and Widmier (1977), "Parallel reflections... drape over contemporaneous topography with only gradual changes in thickness or reflection character and suggest uniform deposition independent of the bottom relief. This pattern is strongly indicative of deep-marine hemipelagic clays and oozes" (p. 176).

Site 511 is located in the basin province of the Falkland Plateau, on the back slope of a cuesta-type ridge and about 10 km south of DSDP Site 330 on Maurice Ewing Bank, where Leg 36 scientists drilled 567 meters of Mesozoic and Cenozoic sediment above continental basement (Shipboard Scientific Party et al., 1977). During Middle to Late Jurassic to late Early Cretaceous (Aptian) time, shallow marine sedimentation, sometimes under euxinic conditions, prevailed on the bank. Predominantly pelagic deposition was established over the bank during Albian time as the bank subsided, with subsequent accumulation of clays containing planktonic fossils.

Multichannel seismic reflection records collected during *Conrad* cruise 21-06 (Fig. 2) show reflections dipping steeply to the south from the vicinity of Site 330.

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[1] Ludwig, W. J., Krasheninnikov, V. A., et al., *Init. Repts. DSDP*, 71: Washington (U.S. Govt. Printing Office).

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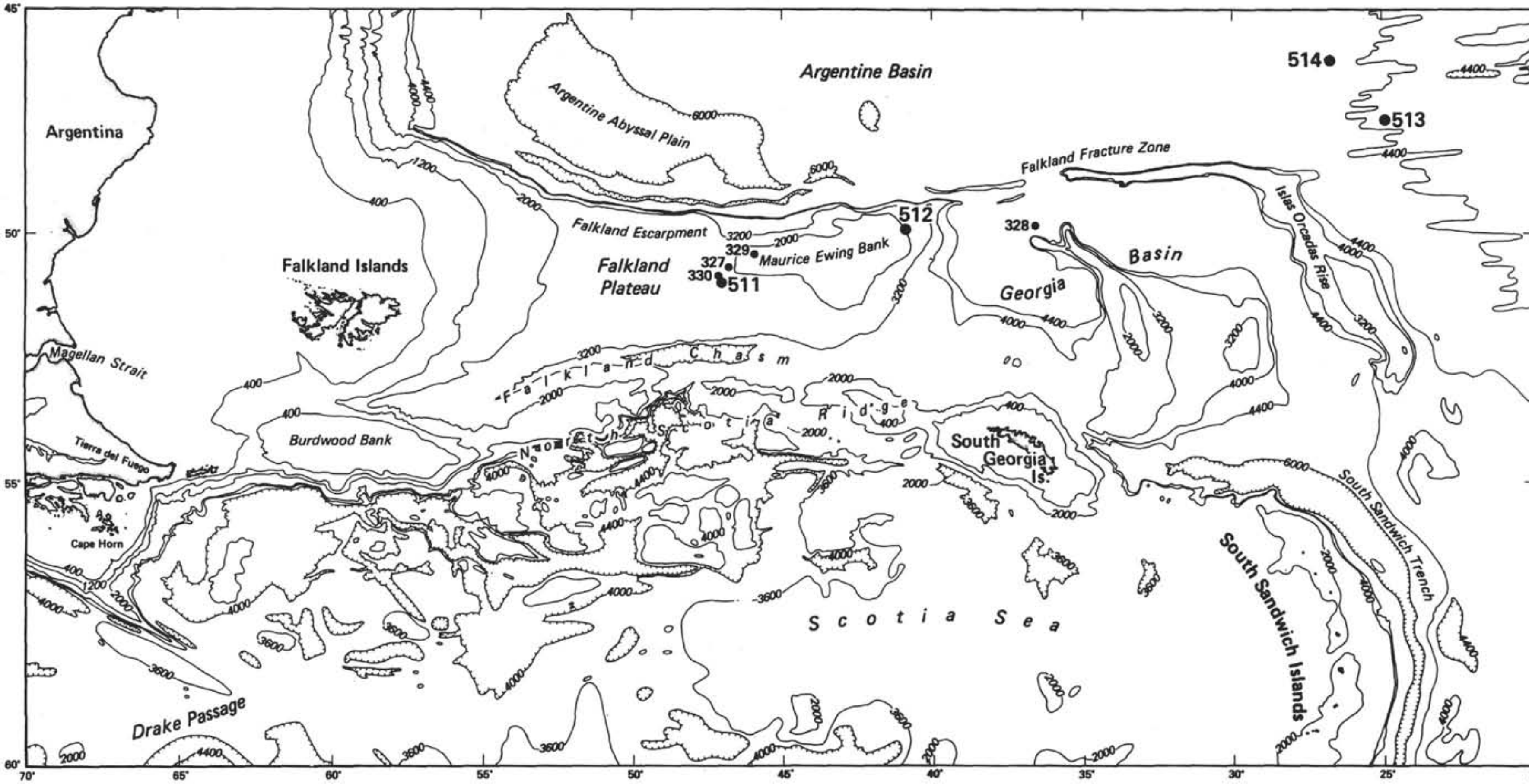


Figure 1. Locations of Site 511 and other Leg 71 drill sites.

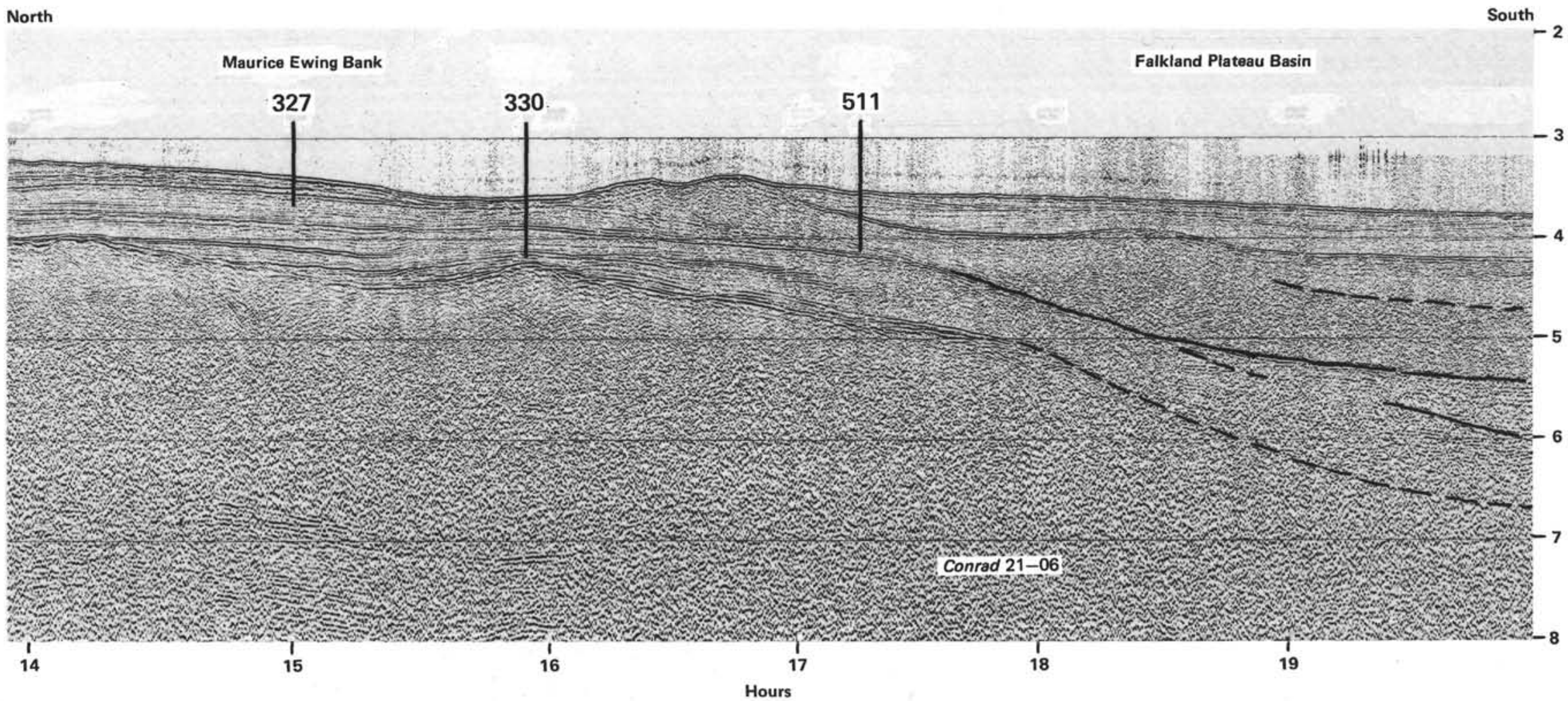


Figure 2. *Robert D. Conrad* 21–06 multichannel seismic reflection profile near Sites 511, 330, and 327. See Figure 3 for location.

Under the ridge structure, reflections are weak owing to the effect of scattering of seismic energy. Nevertheless, several prominent reflections may be traced from Site 330 to Site 511. The unconformity that apparently marks a major erosional hiatus on the plateau is present at Site 511. Thus Site 511 has been situated to delineate and define the depositional environment and the erosion and subsidence history of the Falkland Plateau. Cores from the site are expected to help clarify the biostratigraphic, biogeographic, and sedimentological history related to major changes in circulation patterns through the Mesozoic and Cenozoic. The paleoceanographic alterations occurred in response to the breakup of Gondwanaland and the initial opening and enlargement of the South Atlantic, the development of bottom water passageways through the North Scotia Ridge, the opening of the Drake Passage, and the climatic evolution of Antarctica and the Southern Ocean.

SURVEY AND OPERATIONS

Glomar Challenger left Punta Arenas, Chile, at 1535 hr. on 10 January 1980. The route to the first drill site took the ship through the Strait of Magellan, then eastward to skirt the Falkland Islands to the south and on to Site 511 on the Falkland Plateau. The magnetometer and seismic reflection gear were streamed about midway between the mainland and the Falkland Islands. Progress was slowed first by head winds, then by low visibility in fog, and the average speed was held to 8.3 kn. As a result the ship arrived on site about 18 hr. later than anticipated.

Multichannel Seismic Line 142 (Fig. 2) obtained during *Conrad* cruise 21-06 was used as the basis for site location. *Challenger* arrived at the longitudinal location of the seismic line at 0430, 15 January, at a preselected point south of Site 511. After the ship changed course to the north and the speed was reduced to 5 kn., the site area on the back slope of a well-mapped, cuesta-type ridge was soon located. We profiled a short distance past the site to confirm its morphostructural setting, turned back, and dropped the beacon at 0611 hr., 15 January. Subsequent satellite fixes indicated that at 1700 hr. we were about one mile to the east of the approved site on the *Conrad* 21-06 seismic line; however, because the *Challenger* seismic line matched the *Conrad* line, the beacon position was occupied for the site (Fig. 3).

The first core was recovered from Site 511 at 1838 hr., 15 January (Table 1). Drilling and coring proceeded routinely to 0812, 20 January, when the hole was terminated at 632 meters below seafloor (the depth corresponding approximately to a 4.1 s reflector limit of penetration imposed by the JOIDES Safety Panel). Heat flow measurements were obtained at 52.5 meters and 119 meters below seafloor. Upon completion of the hole, a gamma-ray and neutron log was run through the pipe.

Our plan called for offsetting *Challenger* about 600 meters to the south and drilling an A hole to obtain a better percentage of core recovery in the 110-220-meter interval (below seafloor) than was obtained at the main site. The Paleocene section there is either missing or was missed in the coring, and as a consequence we were unable accurately to date a major erosional unconformity at 195 meters depth. However, after the drill string was pulled above the mud line, it was found that the hydraulic release on the drill bit had been activated and the bit had been dropped. Because of increasingly heavy seas and a 7-day limitation on site occupation time south of 50°S, it became necessary to leave Site 511 and move on to the next site on Maurice Ewing Bank.

LITHOLOGICAL SUMMARY

A sequence of pelagic and hemipelagic oozes and claystones was continuously cored at Site 511 to a sub-bottom depth of 632 meters. Below a thin veneer of Pliocene to Recent sediments, strata ranged in age from Late Jurassic to early Oligocene. The dominant lithologies cored were nannofossil-diatomaceous oozes, zeolitic claystones, and muddy nannofossil chalks.

Lithologic units were distinguished principally on the basis of color and composition. The six major units, their ages, thicknesses, colors, and major characteristics are summarized in Figure 4 and Table 2. In general, sediments cored below Core 27 (223.5 m) were sufficiently indurated to be termed claystones and chalks, whereas those above this depth were clays and oozes.

Unit 1

Unit 1 consists of a 3-meter veneer of gray to olive gray, siliceous, gravelly sands and thin foraminiferal oozes of Pliocene-Recent age. Pebbles are subangular to angular and of highly varied lithology including quartzite, basalt, and granite. Several Mn nodules (up to 5 cm in diameter) and manganiferous zones several centimeters thick were encountered in this unit. These youngest Cenozoic glaciomarine sediments unconformably overlie Unit 2.

Unit 2

Subunit 2A

Subunit 2A consists of massive, gray to dark gray, muddy diatomaceous oozes and muddy nannofossil-diatomaceous oozes of Paleogene age recovered in Cores 3 to 20 (3-186 m sub-bottom). This subunit consists of slightly to moderately bioturbated diatomaceous oozes with variable carbonate content.

The recovered cores are characterized by severe drilling disturbance resulting in the occurrence of frequent zones of coarse sand and gravel caved in from the Pliocene-Recent strata above; it is thought that many of the large Mn nodules from the lower part of this unit may have been similarly derived. The small Mn nodules (less than 1 cm diameter) which occur commonly in the uppermost part of the unit are thought to be *in situ*.

Disseminated, very fine, sand-sized detrital glauconite is common, particularly in the lower part of the unit.

Several more indurated zones (4-10 cm thick) were encountered in Core 12. No apparent difference in composition was noted between these harder layers and the surrounding oozes.

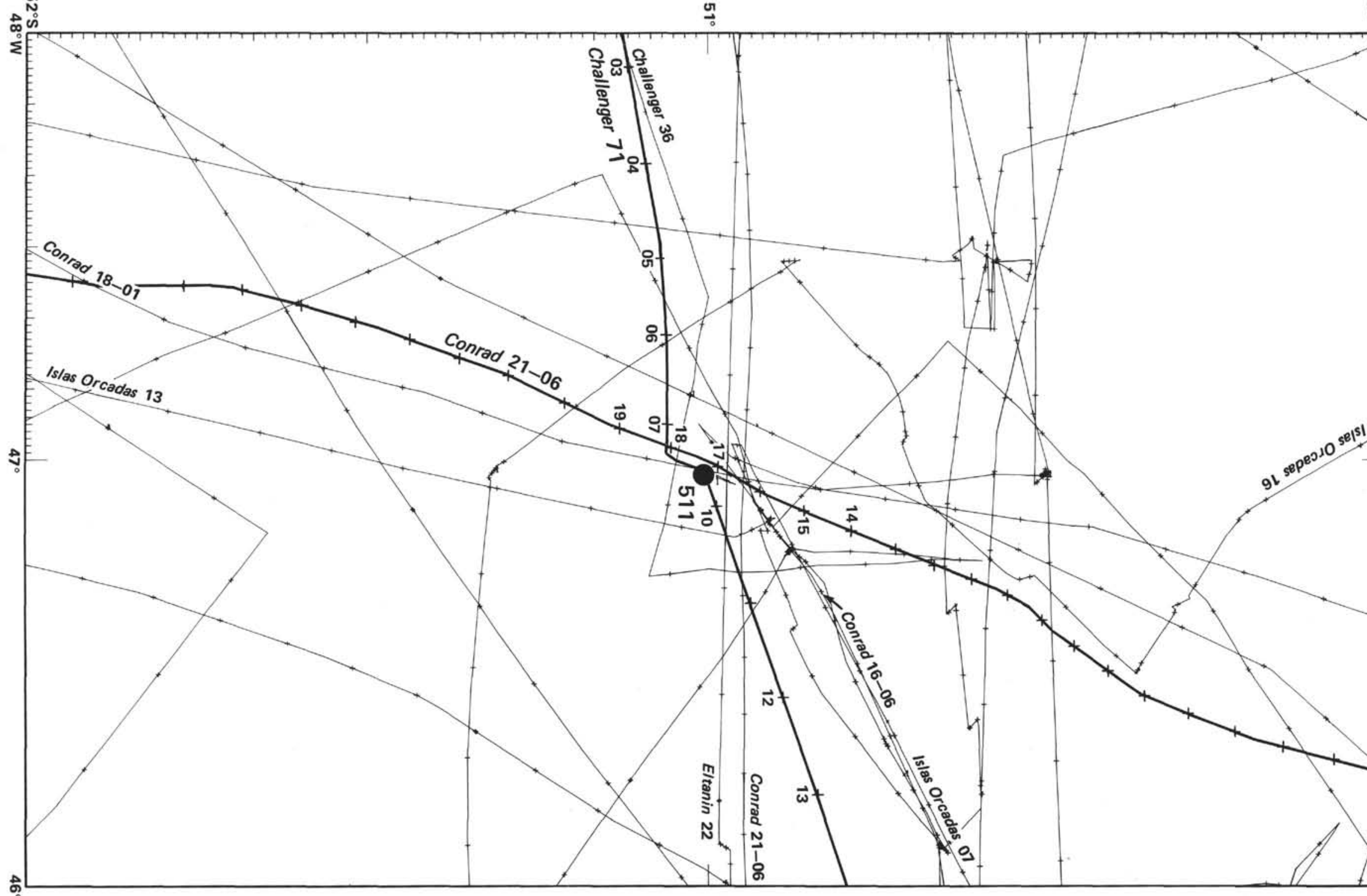
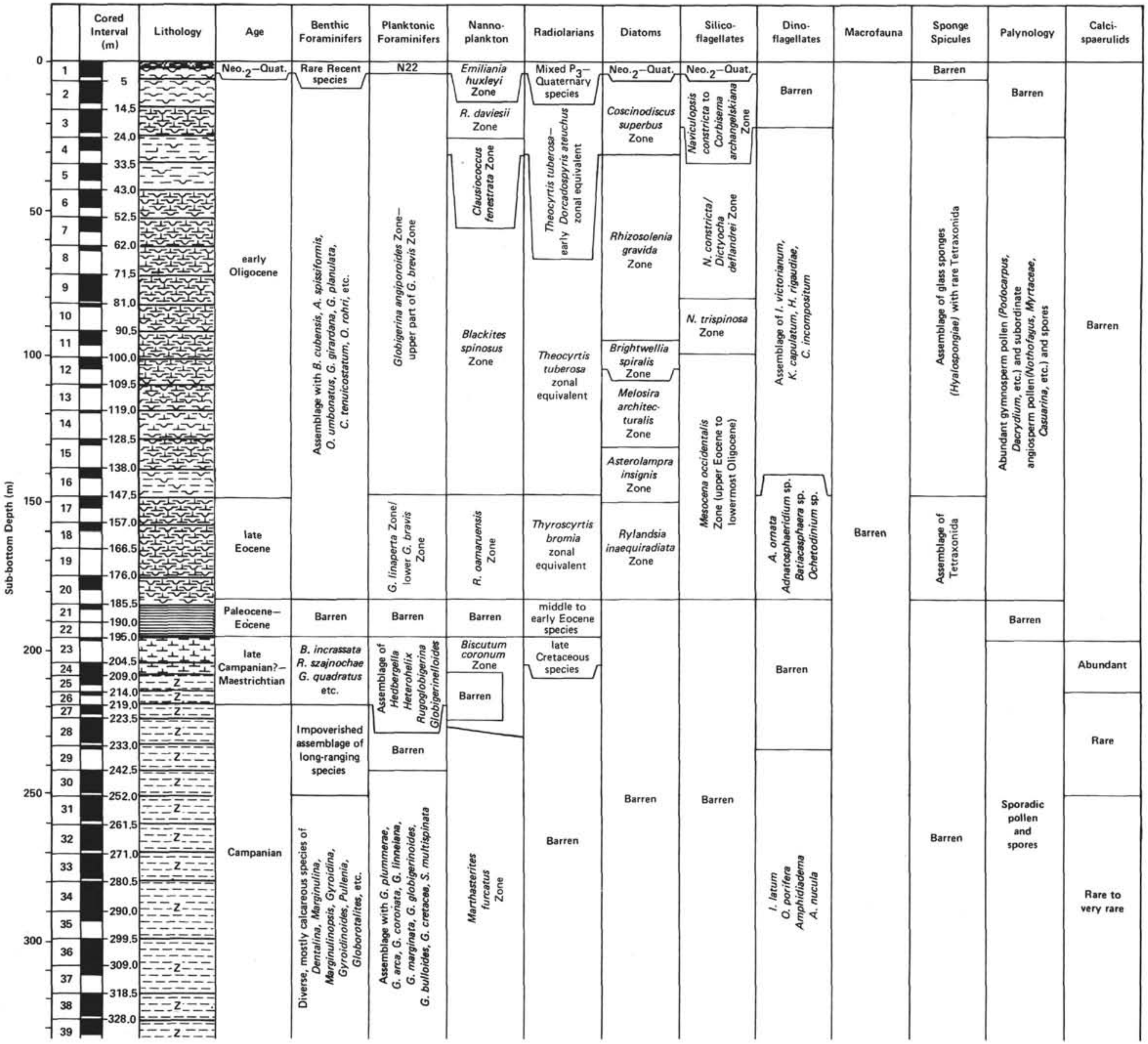


Figure 3. *Glomar Challenger* 71 and *Conrad* 21–06 tracks (bold lines) and other ship tracks in the vicinity of Site 511.


Sub-bottom Depth (m)
Cored Interval (m)
Lithology
Age
Benthic Foraminifers
Planktonic Foraminifers
Nannoplankton
Radiolarians
Diatoms
Silicoflagellates
Dinoflagellates
Macrofauna
Sponge Spicules
Palynology
Calcispaerulids
0
50
100
150
200
250
300
5
14.5
24.0
33.5
43.0
52.5
62.0
71.5
81.0
90.5
100.0
109.5
119.0
128.5
138.0
147.5
157.0
166.5
176.0
185.5
190.0
195.0
204.5
209.0
214.0
219.0
223.5
233.0
242.5
252.0
261.5
271.0
280.5
290.0
299.5
309.0
318.5
328.0
Neo.2–Quat.
early Oligocene
late Eocene
Paleocene–Eocene
late Campanian?–Maestrichtian
Campanian
Rare Recent species
Assemblage with B. cubensis, A. spissiformis, O. umbonatus, G. girardana, G. planulata, C. tenuicostatum, O. rohri, etc.
Barren
B. incrassata R. szajnochae G. quadratus etc.
Impoverished assemblage of long-ranging species
Diverse, mostly calcareous species of Dentalina, Marginulina, Marginulinopsis, Gyroidina, Gyroidinoides, Pullenia, Globorotalites, etc.
N22
Globigerina angiporoides Zone–upper part of G. brevis Zone
G. linaperta Zone/lower G. bravis Zone
Barren
Assemblage of Hedbergella Heterohelix Rugoglobigerina Globigerinelloides
Barren
Assemblage with G. plummerae, G. arca, G. coronata, G. linneiana, G. marginata, G. globigerinoides, G. bulloides, G. cretacea, S. multispinata
Emiliania huxleyi Zone
R. daviesii Zone
Clausicoccus fenestrata Zone
Blackites spinosus Zone
R. oamaruensis Zone
Barren
Biscutum coronum Zone
Barren
Marthasterites furcatus Zone
Mixed P3–Quaternary species
Theocyrtis tuberosa–early Dorcadospyris ateuchus zonal equivalent
Theocyrtis tuberosa zonal equivalent
Thyroscyrtis bromia zonal equivalent
middle to early Eocene species
late Cretaceous species
Barren
Neo.2–Quat.
Coscinodiscus superbus Zone
Rhizosolenia gravida Zone
Brightwellia spiralis Zone
Melosira architecturalis Zone
Asterolampra insignis Zone
Rylandsia inaequiradiata Zone
Barren
Neo.2–Quat.
Naviculopsis constricta to Corbisema archangelskiana Zone
N. constricta/Dictyocha deflandrei Zone
N. trispinosa Zone
Mesocena occidentalis Zone (upper Eocene to lowermost Oligocene)
Barren
Barren
Assemblage of I. victorianum, K. capulatum, H. rigaudiae, C. incompositum
A. ornata Adnatosphaeridium sp. Batiacasphaera sp. Ochetodinium sp.
Barren
I. latum O. porifera Amphidiadema A. nucula
Barren
Barren
Assemblage of glass sponges (Hyalospongiae) with rare Tetraxonida
Assemblage of Tetraxonida
Barren
Barren
Abundant gymnosperm pollen (Podocarpus, Dacrydium, etc.) and subordinate angiosperm pollen (Nothofagus, Myrtaceae, Casuarina, etc.) and spores
Barren
Sporadic pollen and spores
Barren
Abundant
Rare
Rare to very rare

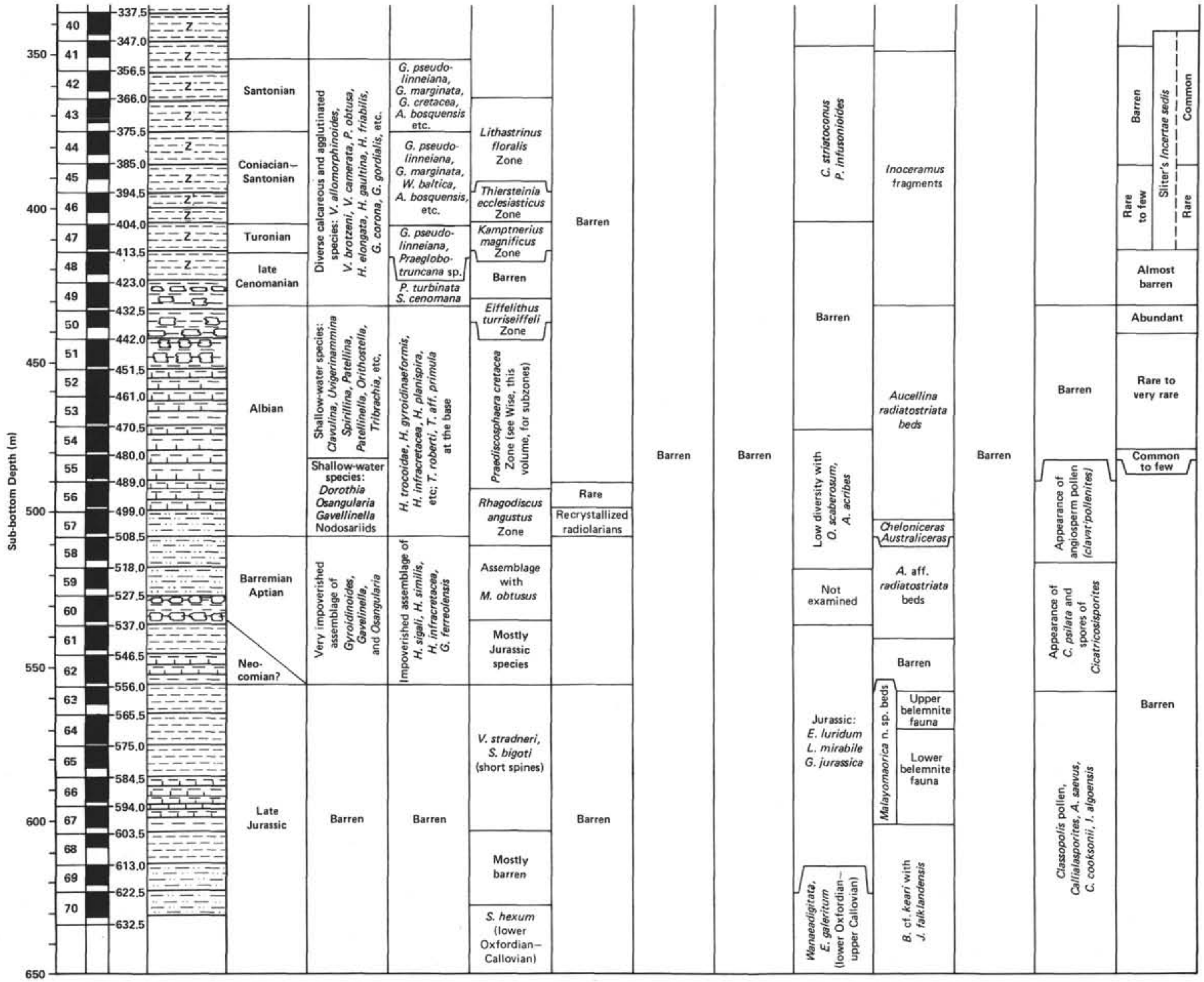


Figure 4. Columnar section of Hole 511 showing the lithology recovered and biostratigraphic correlations. Although the cored interval for Core 24 was 4.5 m, 9 m of sediment were recovered. (Refer to Ludwig et al., Introduction, this volume, for a key to the lithologic symbols.).

Table 1. Coring summary, Site 511.

Core No.	Date (Jan. 1980)	Time	Depth from Drill Floor (m)	Depth below Seafloor (m)	Length Cored (m)	Length Recovered (m)	Core Recovered (%)
Hole 511							
1	15	1838	2602.0–2607.0	0.0–5.0	5.0	4.89	97.8
2	15	2105	2607.0–2616.5	5.0–14.5	9.5	6.20	65.2
3	15	2213	2616.5–2626.0	14.5–24.0	9.5	6.50	68.4
4	15	2320	2626.0–2635.5	24.0–33.5	9.5	3.70	38.9
5	16	0030	2635.5–2645.0	33.5–43.0	9.5	5.98	62.9
6	16	0210	2645.0–2654.5	43.0–52.5	9.5	5.41	57.0
	Heat flow						
7	16	0501	2654.5–2664.0	52.5–62.0	9.5	3.54	37.2
8	16	0610	2664.0–2673.5	62.0–71.5	9.5	0.04	0.4
9	16	0730	2673.5–2683.0	71.5–80.0	9.5	9.67	101
10	16	0848	2683.0–2692.5	80.0–89.5	9.5	0.40	4.2
11	16	1000	2692.5–2702.0	89.5–99.0	9.5	4.94	52.0
12	16	1120	2702.0–2711.5	99.0–108.5	9.5	3.12	32.8
13	16	1243	2711.5–2721.0	109.5–119.0	9.5	0.32	3.3
	Heat flow						
14	16	1541	2721.0–2730.5	119.0–128.5	9.5	0.05	0.5
15	16	1705	2730.5–2740.0	128.5–138.0	9.5	1.16	12.2
16	16	1805	2740.0–2749.5	138.0–147.5	9.5	2.40	25.2
17	16	1913	2749.5–2759.0	147.5–157.0	9.5	3.52	37.0
18	16	2034	2759.0–2768.5	157.0–166.5	9.5	2.82	29.6
19	16	2137	2768.5–2778.0	166.5–176.0	9.5	0	0
20	16	2316	2778.0–2787.5	176.0–185.5	9.5	3.78	39.7
21	17	0030	2787.0–2792.0	185.5–190.0	4.5	0.72	16.0
22	17	0150	2792.0–2797.0	190.0–195.0	5.0	0	0
23	17	0332	2797.0–2806.5	195.0–204.5	9.5	0.69	7.2
24	17	0451	2806.5–2811.0	204.5–209.0	4.5	9.78	217.3
25	17	0555	2811.0–2816.0	209.0–214.0	5.0	1.65	33.0
26	17	0709	2816.0–2821.0	214.0–219.0	5.0	0.15	3.0
27	17	0921	2821.0–2825.5	219.0–223.5	4.5	2.42	53.7
28	17	1050	2825.5–2835.0	223.5–233.0	9.5	9.38	100
29	17	1210	2835.0–2844.5	233.0–242.5	9.5	0.45	4.7
30	17	1401	2844.5–2854.0	242.5–252.0	9.5	8.16	85.8
31	17	1517	2854.0–2863.5	252.0–261.5	9.5	9.24	97.2
32	17	1640	2863.5–2873.0	261.5–271.0	9.5	9.00	94.7
33	17	1810	2873.0–2882.5	271.0–280.5	9.5	9.20	96.8
34	17	1928	2882.5–2892.0	280.5–290.0	9.5	9.75	100
35	17	2100	2892.0–2901.5	290.0–299.5	9.5	2.43	41
36	17	2227	2901.5–2911.0	299.5–309.0	9.5	9.59	100
37	17	2347	2911.0–2920.5	309.0–318.5	9.5	2.43	26
38	18	0115	2920.5–2930.0	318.5–328.0	9.5	8.08	85
39	18	0250	2930.0–2939.5	328.0–337.5	9.5	5.21	55
40	18	0403	2939.5–2949.0	337.5–347.0	9.5	7.87	83
41	18	0640	2949.0–2958.5	347.0–356.5	9.5	4.59	48
42	18	0810	2958.5–2968.0	356.5–366.0	9.5	7.03	74
43	18	0932	2968.0–2977.5	366.0–375.5	9.5	6.51	69
44	18	1050	2977.5–2987.0	375.5–385.0	9.5	7.01	74
45	18	1224	2987.0–2996.5	385.0–394.5	9.5	4.20	44
46	18	1400	2996.0–3006.0	394.5–404.0	9.5	5.25	55
47	18	1510	3006.0–3015.5	404.0–413.5	9.5	8.98	94
48	18	1644	3015.5–3025.0	413.5–423.0	9.5	5.84	61
49	18	1820	3025.0–3034.5	423.0–432.5	9.5	8.05	84
50	18	1927	3034.5–3044.0	432.5–442.0	9.5	5.30	56
51	18	2045	3044.0–3053.5	442.0–451.5	9.5	8.95	94
52	18	2215	3053.5–3063.0	451.5–461.0	9.5	9.89	100
53	18	2345	3063.0–3072.5	461.0–470.5	9.5	9.20	97
54	19	0124	3072.5–3082.0	470.5–480.0	9.5	8.72	92
55	19	0258	3082.0–3091.5	480.0–489.5	9.5	8.04	85
56	19	0532	3091.5–3101.0	489.5–499.0	9.5	7.48	79
57	19	0756	3101.0–3110.5	499.0–508.5	9.5	8.05	89
58	19	0950	3110.5–3120.0	508.5–518.0	9.5	6.18	65
59	19	1150	3120.0–3129.5	518.0–527.5	9.5	6.03	63
60	19	1350	3129.5–3139.0	527.5–535.0	9.5	8.23	87
61	19	1614	3139.0–3148.5	537.0–546.5	9.5	7.44	78
62	19	1809	3148.5–3158.0	546.5–556.0	9.5	8.69	91
63	19	1952	3158.0–3167.5	556.0–565.5	9.5	4.89	51
64	19	2130	3167.5–3177.0	565.0–575.0	9.5	7.97	84
65	19	2317	3177.0–3186.5	575.0–584.5	9.5	6.60	69
66	20	0056	3186.5–3196.0	584.5–594.0	9.5	7.94	84
67	20	0240	3196.0–3205.5	594.0–603.5	9.5	7.21	76
68	20	0425	3205.5–3215.0	603.5–613.0	9.5	3.16	33
69	20	0602	3215.0–3224.5	613.0–622.5	9.5	6.65	70
70	20	0812	3224.5–3234.0	622.5–632.0	9.5	6.78	71
Total					632.0	385.5	61

Subunit 2B

Subunit 2B, consisting of 72 cm of greenish gray (5GY 6/1) clays obtained in Core 21, is characterized by minor amounts of glauconite, chert, and volcanic ash. In Core 22, no sample was recovered; in the absence of core, Subunit 2B is arbitrarily continued to the base of Core 22.

Unit 3

This unit consists of gray, calcareous, and zeolitic foraminiferal oozes in Cores 23 and 24 (195–209 m, sub-bottom). These sediments are early Maestrichtian to late Campanian in age and are characterized by minor to moderate bioturbation, the presence of occasional chert pebbles (up to 5 cm diameter), and disseminated minor glauconite.

Unit 4

Unit 4 (Cores 25–47, 209–412 m sub-bottom) consists of zeolitic clays and claystones commencing near the bottom of Core 24. These units are Maestrichtian–Campanian to Turonian in age. Though the contact with Unit 3 is transitional, marked by an alternation of zeolitic clays and calcareous oozes, it is placed at 209 meters (bottom of Core 24), below which the zeolitic clays and claystones predominate. In general the darker zones (5Y 4/1) are more zeolitic than the lighter sections (5Y 6/1), which tend to be somewhat more calcareous. Dark greenish black mottles, lenses, and thin laminae (1–2 mm) were common throughout the unit.

The generally gray zeolitic clays and claystones are characterized by moderate to very intense bioturbation which has, in many sections, completely obliterated any evidence of stratification. The tremendous concentration of burrows of different colors (gray, light gray, dark gray, greenish gray, and dark greenish gray) in some sections gives the core a "conglomeratic" appearance. Many types of burrows were identified, including solid, ring, *Zoophycos, Chondrites, Planolites*, and *Teichichnus.*

Pyrite is frequently encountered, usually in burrows. In Core 42, however, pyrite occurs as a vein-filling along vertically and obliquely oriented fractures. Irregularly shaped, slightly brownish concretions of barite, ranging in diameter from ~0.5–4 cm, occur frequently throughout the unit.

Below Core 41, Section 3, fragments of the pelecypod *Inoceramus*, up to 3 mm thick and 3–4 cm long, were locally abundant.

Unit 5

Cores 48–56 (413.5–492 m sub-bottom) are early Albian to Turonian sediments dominated by reddish brown zones that frequently have a "blotchy" appearance. The unit is marked by minor to intense bioturbation with burrows frequently filled with pyrite.

Layers of skeletal carbonate debris, principally pelecypods (*Aucellina* and *Inoceramus*), occur frequently (Fig. 5) as muddy microcoquinas. Single, thin, whole pelecypod valves occur as well throughout the unit and *Inoceramus* "needles" are frequently concentrated in thin olive gray claystone bands. Scattered solitary corals also occur in this unit.

Small barite nodules (approximately 0.5 cm), similar to those in Unit 4, occur in Cores 54 and 55.

In Core 51, Section 1, several very dark gray, highly calcareous sapropelic claystone layers (0.5 cm thick) are interstratified with reddish brown calcareous claystones and muddy calcareous chalks (muddy microcoquinas).

Unit 6

The lowest lithologic unit cored (Cores 57–70, 498–632 m sub-bottom) is Late Jurassic to early Albian in

Table 2. Characteristics of lithologic units.

Depth below Seafloor (m)	Core	Unit	Major Lithology	Color	Characteristics
		1	Siliceous gravelly sand and minor foram ooze	5Y 6/4 (pale olive) 5Y 5/1 (gray)	Subangular-angular pebbles (up to 4 cm), varied lithologies. Mn nodules (up to 5 cm), thin Mn-rich zones, interstratified foram ooze and gravelly sand
3	1, Sect. 2				
	1, Sect. 3	2A	Muddy diatomaceous oozes and muddy nannofossil-diatomaceous oozes	5Y 5/2 (olive gray) near top to 5Y 4/1-5Y 7/1 (dk. gray-lt. gray) in most of unit	Minor-moderate bioturbation, sparse Mn nodules, lenses of fine glauconitic sand, occasional pebbles of chert, granite, basalt, and sandstone
186	20				
	21	2B	Clay	5 GY 6/1 (greenish-gray)	Minor glauconite, chert, ash
195	22				
	23	3	Calcareous ooze and zeolitic calcareous ooze	5Y 6/1 (gray) 5Y 7/1 (lt. gray)	Minor-moderate bioturbation, chert pebbles (4-5 cm), minor glauconite
209	24				
	25	4	Zeolitic clays and claystones	*Major:* 5Y 4/1-5Y 6/1 (dk. gray) to (gray) 2.5Y 4/0-5/0 (dk. gray-gray) *Minor:* 5Y 5/2-5Y 6/2 (olive-gray to lt. olive-gray) 5GY 2/1-6/1 (dk. greenish gray to greenish gray) 2.5 YR 3/4-4/4 (dk. reddish brown to reddish brown)	Moderate-very intense bioturbation, pyrite common, minor glauconite in upper part. *Inoceramus* fragments common in lower part. Barite (?) nodules
412	47				
	48	5	Claystones, nannofossil claystones, and muddy nannofossil chalks	*Major:* 5YR 3/3-5/3 (dk. reddish brown to reddish brown) 5YR 5/4 (reddish brown) *Secondary:* 2.5Y 4/0-5/0 (dk. gray-gray) 5G 6/1 (greenish gray) *Minor:* 7-5YR 5/2 (brown) 5 RP 4/2 (grayish purple) 5GY 4/1-8/1 (lt.-dk. greenish gray) 5YR 7/1 (lt. gray)	Minor-intense bioturbation, pyrite common, thin pelecypod fragments locally very abundant. Solitary corals, small barite (?) nodules, thin, dark gray, sapropelic layers (Core 51-1)
498	56, Sect. 4				
	56, Sect. 5	6	Mudstones and nannofossil mudstones	*Major:* 5Y 2.5/1 (black) *Minor:* 2.5Y 5/1 (gray) 5Y 5/1 (gray) 2.5Y 8/0 (white) 5Y 4/2 (olive gray)	Black shales; petroliferous; often finely laminated and fissile, minor bioturbation, pyrite very common, thin zeolite claystones, minor chert, cone-in-cone calcite. Hard calcareous zones with local very high concentrations of pelecypod debris; belemnites common
632					

age and consists of black, massive, thinly laminated mudstones and nannofossil claystones which in places are very fissile. These mudstones (black shales) are highly petroliferous below Core 60 and display only minor bioturbation. The monotonous sequence of black mudstones is interrupted by (1) occasional layers of concentrated pelecypod debris (*Aucellina* and *Inoceramus*) forming muddy micrococquinas similar to those in the overlying unit; (2) soft gray (5Y 5/1) layers (0.5–3.0 cm thick) of zeolitic claystone; (3) hard, muddy calcarenite layers; and (4) occasional layers of coarsely crystalline cone-in-cone calcite.

Pyrite is a common constituent, occurring as masses up to several centimeters in diameter, in burrows, and finely disseminated along thin laminae in zones 1–2 cm thick. Belemnites (up to 1 cm diameter and several cm long) occur scattered throughout this unit (Fig. 6).

Minor slumping and microfaulting of laminae were noted in the unit (e.g., Core 56, Sections 4–5; Core 62, Section 4). Dips of strata are generally 0.5° throughout the unit except in Core 52, in which dips are consistently 10–15° despite dip test results of less than 1° from the vertical for the inclination of the hole.

PALEONTOLOGY

Biostratigraphy Summary

The 70 cores taken continuously at Site 511 ranged from Holocene to Late Jurassic in age. Nearly all cores contained microfossils and those in the lower portions of the hole contained fossil mollusks and solitary corals as well. A broad range of microfossil groups are represented in various intervals of the section. Those dealt with in these reports include benthic and planktonic foraminifers, calcareous nannofossils, diatoms, silicoflagellates, radiolarians, pollen, spores, dinoflagellates, sponge spicules, calcisphaerulids, onychites, and calcareous microorganisms of unknown affinity (Upper Cretaceous).

One of the most significant results of this site was the collection of a 154-meter diatomaceous-ooze sequence of early Oligocene age, with exceptionally well preserved and diverse diatoms, radiolarians, and silicoflagellates along with sufficient numbers of calcareous nannofossils and foraminifers to provide temporal control by correlation with lower-latitude zonations and the well-established New Zealand stages. Although siliceous se-

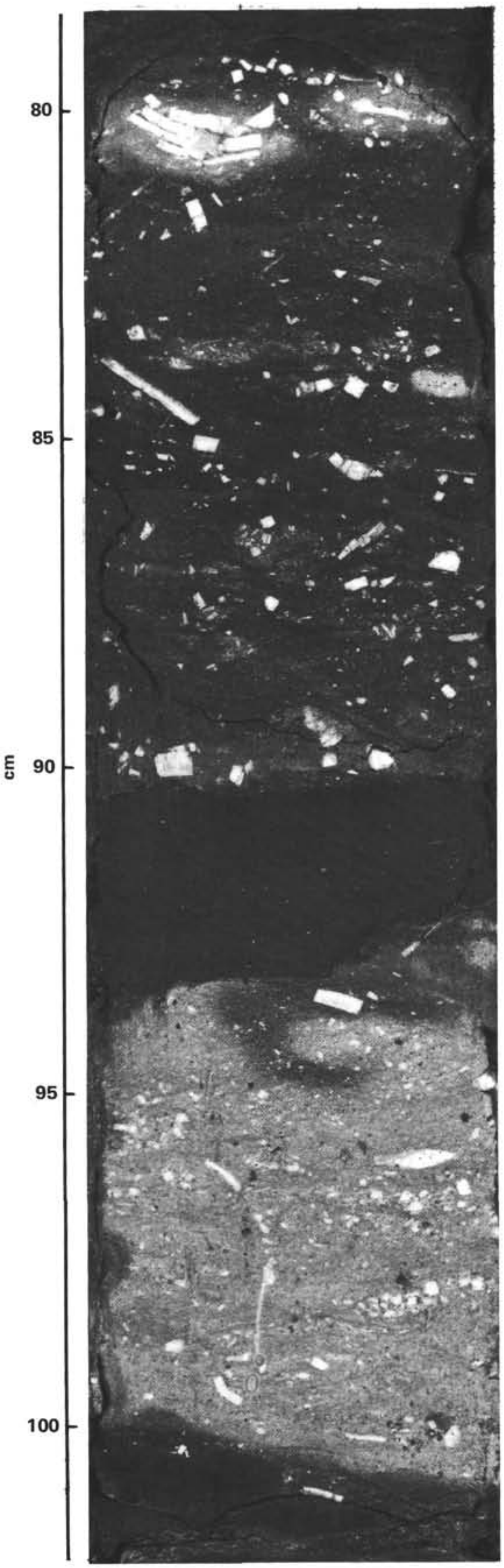


Figure 5. Layers of skeletal carbonate debris, principally pelecypods, occur frequently as microcoquinas in Lithologic Unit 5 (Sample 511-48-2, 77–102 cm).

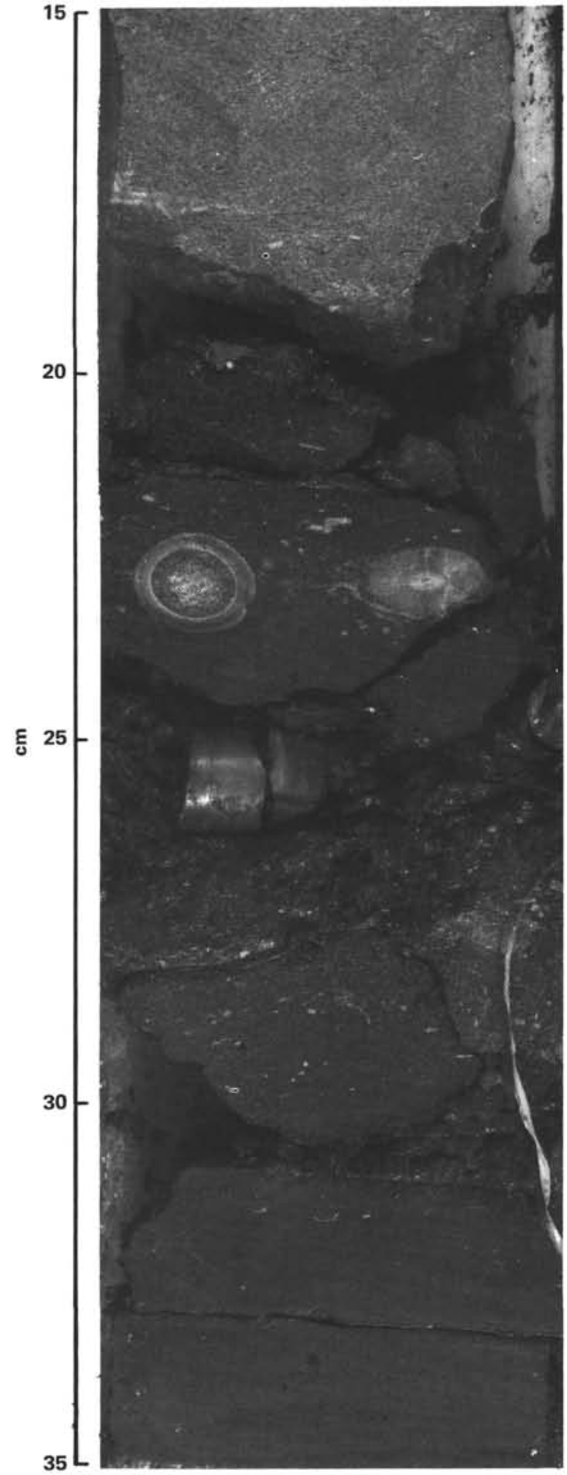


Figure 6. Belemnites in Unit 6 (Sample 511-60-2, 15–35 cm).

quences of this age have been sampled before by DSDP (for example, DSDP Site 274, Leg 28), the critical time control by calcareous planktonic faunas and floras has, until now, always been lacking. The section at Site 511, combined with the upper Oligocene to lower Miocene section recovered at Site 513, provides a complete Oligocene section rich in siliceous microfossils. This composite section is the most complete record available in the southern high latitudes for Oligocene diatom stratigraphy. Gombos and Ciesielski (this volume) have defined 12 diatom biostratigraphic zones for the interval from lower Miocene to upper Eocene based on a study of the composite section.

A second notable result of coring at Site 511 was the sampling of a long (174 m) Campanian-Coniacian section in the Cretaceous. Most of this unexpectedly thick section was not encountered at the nearby DSDP Site 327, Leg 36.

In addition to these results, a continuously cored section was taken through the upper portion of the Lower Cretaceous-Jurassic black shale sequence of the Falkland Plateau. This long, continuous section was characterized by high core recovery, and therefore makes possible further subdivision of the black shales by the calcareous microfossils, palynomorphs, and mollusks.

Cenozoic

The top 3 meters of the Cenozoic section contains a glacial marine sequence characteristic of this area (see Ciesielski, 1978). Approximately 10 cm of Pleistocene to Holocene calcareous ooze (repeated by a double hit of the core barrel) overlie sandy or gravelly diatomaceous sediments, dated from the Brunhes to the Gauss chrons. These are separated by an erosional disconformity from the long lower Oligocene sequence. Upper age limits for the Oligocene section are imposed by the presence of the coccoliths *Reticulofenestra umbilica* in Core 2 and *Ismolithus recurvus* in Core 4; their extinctions (according to Hardenbol and Berggren, 1978) fall well within the early Oligocene. This age is supported by co-occurring planktonic foraminifers which are dated within Zones P18-P20. The luxuriant and well-preserved assemblages of siliceous microfossils offer the opportunity for a finer siliceous zonation of this interval in addition to the description of many new taxa. Pollen and spores are also relatively diverse and numerous in the lower Oligocene sediments.

The Oligocene sequence spans two radiolarian zones, four silicoflagellate zones, and five diatom zones. Many of these siliceous microfossil zones or datums within these zones have been revised or defined as new in these reports (see Gombos and Ciesielski, this volume; Weaver, this volume; Shaw and Ciesielski, this volume). The lowermost Oligocene and the underlying upper Eocene section, however, fall within the same silicoflagellate zone; thus, the group cannot at present be used to distinguish the Oligocene/Eocene boundary. This boundary has been placed at the top of Core 17 because of the occurrence of a single specimen of the planktonic foraminifer, *Globigerapsis index* and the presence of rare specimens of the coccolith *Discoaster saipanensis*. Dinoflagellate assemblages also suggest placement of the boundary there. Interestingly, two distinct assemblages of glass sponge spicules were noted, one characteristic of the Oligocene sediments (Cores 2-16) and the other present in Cores 17-20.

Calcareous microfossils do provide good control for the upper Eocene diatomaceous oozes which were sampled in Cores 18 and 20. Unfortunately, a complete sampling of this section and of much of the lower Oligocene was precluded by drilling problems. Coccoliths, however, are exceptionally well preserved in Cores 18 and 20 and correlate well with the *Reticulofenestra oamaruensis* Zone of New Zealand. The planktonic foraminifers belong to Zones P15 and P16 and can also be tied in closely to the classic New Zealand sections. It is not certain if the uppermost Eocene zone for planktonic foraminifers was sampled in Hole 511, primarily because of drilling problems.

Dating of the Eocene section is supported by the radiolarians, which are assigned to the *Thyrsocyrtis bromia* zonal equivalent. When the Eocene and Oligocene radiolarian assemblages are considered together, an overall cooling trend is noted. The Eocene populations indicate relatively warm (temperate) conditions whereas a cooling is evident in those from the Oligocene Cores 16-13. Radiolarians from Cores 12-11 are characteristic of proximity to Polar Front upwelling conditions and those from Cores 9-2 suggest a cool subantarctic/antarctic water mass. This overall cooling trend may reflect the northward migration of major water mass boundaries across Site 511 during the Eocene-Oligocene. A transgression over the Falkland Plateau of the front separating temperature and subantarctic/antarctic water masses may account for the upwelling and temperature change noted in Cores 13-2.

A high productivity of siliceous planktonic organisms throughout the late Eocene-early Oligocene is indicated by the exceptionally high sediment accumulation rate of about 44 m/m.y. recorded for this interval (Fig. 7).

Core 21 sampled a yellowish pelagic clay (Lithologic Subunit 2B) with some poorly preserved radiolarians and a few specimens of the diatom *Trinacria simulacrum*. This core is thought to be late Paleocene to early Eocene in age. Unfortunately, Core 22 contained no sediment so little more can be said about this poorly dated interval. Low accumulation rates plotted in Figure 7 suggest a disconformity between these cores and the Cretaceous sediment of Core 23.

Mesozoic

Cores 23 and 24 recovered an early Maestrichtian-late Campanian calcareous ooze which contained well-preserved foraminifers and a high-latitude coccolith assemblage so far observed only from DSDP Hole 327A. DSDP cores of this age from comparable latitudes in the Pacific sector of the Southern Ocean contain no carbonate. Benthic foraminifers dominated by calcareous species which lived above the lysocline data Cores 25-27 as early Maestrichtian-Campanian. The next core down, however, is nearly barren of all microfossils, owing to dissolution; only a few benthic foraminifers and lower Campanian coccoliths are present. Below that begins the long (19-core) section of zeolitic clays and claystones which are dated primarily by planktonic foraminifers. Sedimentation rates in this interval were exceptionally high (Fig. 7). Core 29 to Sample 511-41-3, 55-57 cm are dated as Campanian by somewhat rare *Globotruncana*. Coccoliths further suggest an early Campanian age. The interval from Sample 511-41,CC to Sample 511-43,CC

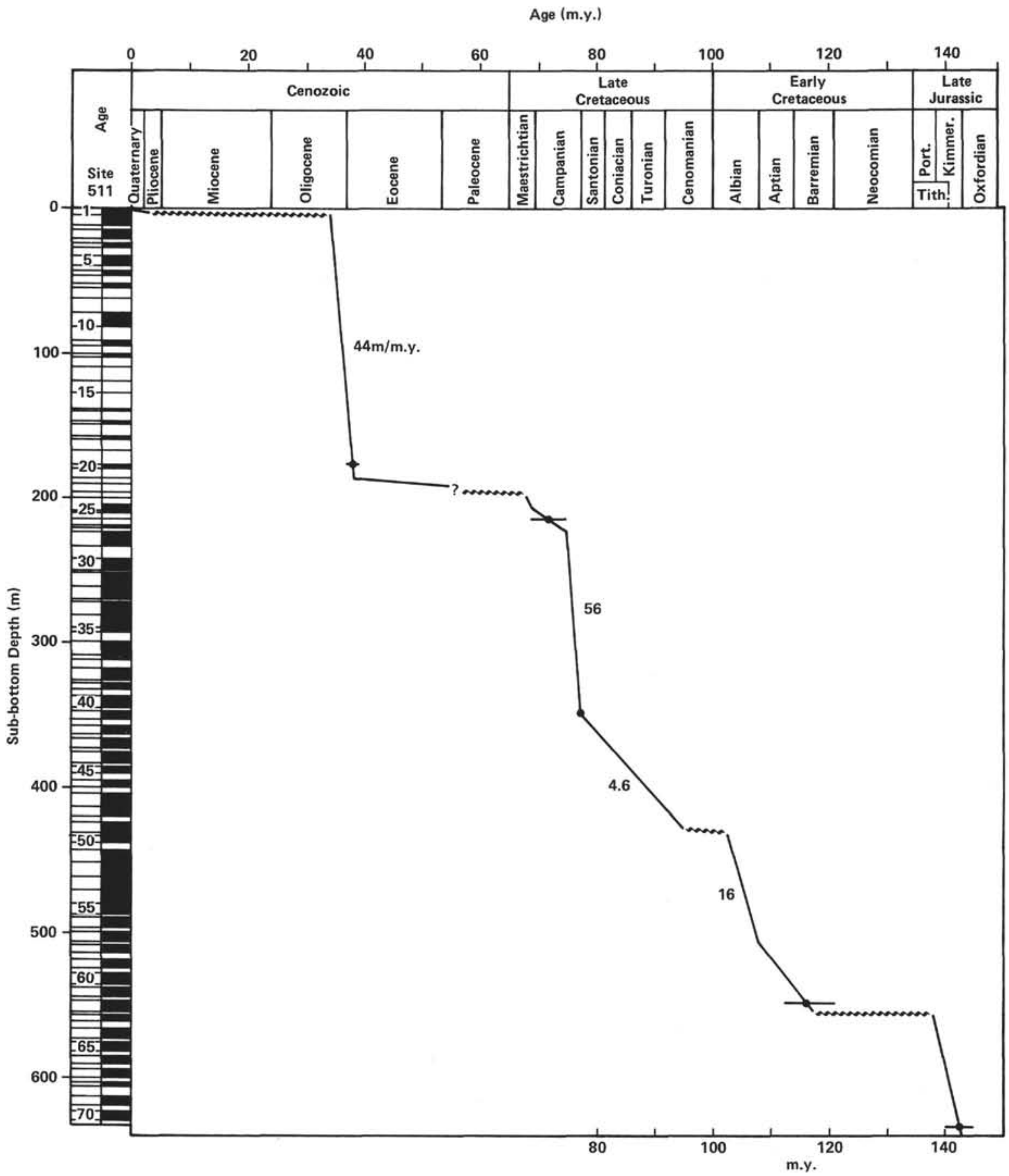


Figure 7. Sedimentation rates at Site 511.

is Santonian (probably late Santonian because of the absence of the coccolith *Lithastrinus floralis*), whereas Cores 44–46 are considered undifferentiated Coniacian-Santonian. Planktonic foraminifers date Core 47 down to the topmost sample of Core 48 as Turonian in age; the remainder of that core is Cenomanian.

In general, the occurrence of planktonic foraminifers in the Upper Cretaceous sediments is quite sporadic because of dissolution. Preservation varies from moderate to poor. Two rather distinct assemblages of benthic foraminiferal assemblages were noted in this interval. An upper assemblage (Cores 31–41) includes diverse calcareous forms (up to 150 species) which inhabit bathyal depths above the CCD, whereas the lower assemblage (Cores 41–49) is dominated by agglutinated species. Benthic foraminifers are generally rare and poorly preserved in the lower section, with pronounced alternations in the percentages of calcareous and arenaceous species. This suggests numerous fluctuations of the CCD above and below the site of deposition.

Calcisphaerulids are found throughout the Maestrichtian–upper Cenomanian interval, and calcareous microorganisms of unknown affinity, first described by Sliter (1977), are present in Cores 44–47.

Cores 50–56 contain abundant calcareous microfossils dated as middle to early Albian (*Prediscosphaera prediscosphaera* calcareous nannofossil Zone). The change in sedimentation rate from the Turonian to the middle Albian is striking (Fig. 7) and indicates a highly condensed section with hiatuses in and about the Coniacian–late Albian interval. This was interpreted by DSDP Leg 36 scientists as a time of rapid subsidence of the Falkland Plateau, from shelf-break depths down close to its present depth below sea level, as a result of seafloor spreading.

This interpretation seems to be substantiated by the invertebrate macrofossils which became common in the shallow-water deposits below the Campanian–Coniacian interval. Fragile bivalves are present in Core 49, Section 3, and become very abundant in the Albian section below, where the genus *Aucellina* is identified. Solitary corals appear in Sections 4, 5, and 6 of Core 49 and also in Core 50. Fragments of the bivalve *Inoceramus* are the only mollusk shells found with any regularity in the Santonian–Coniacian section. These first appear in Core 41 and are present down the hole to Core 70.

Cores 50–70 sampled continuously an Albian–Upper Jurassic section nearly identical to that which was cored on an interval basis in DSDP Holes 327A and 330. Rich benthic foraminiferal faunas indicative of shelf-break depths (100–400 m) are present down to Core 57, which is dated by foraminifers as Albian (the *Ticinella roberti* Zone). Coccoliths occur sporadically in Core 57 and are assigned to the *Parhabdolithus angustus* Zone, which Thierstein (1973) dates as late Aptian to early Albian. Coccoliths become notably less common in the black shales, which are first encountered downhole in Core 56 (Lithologic Unit 6).

Planktonic foraminifers occur sporadically in Cores 58–62 but date this portion of the black shales as Barremian to Aptian. Mollusks date Cores 57 and 58 as Aptian and Cores 59–62 as Barremian. From Core 58 down to the fourth section of Core 62, abundant fragments of the shallow-water coccolith *Micrantholithus obtusus* (mid-Aptian or older) occur at selected intervals, but few other age-diagnostic calcareous nannofossils are present. No coccoliths positively indicate the presence of Hauterivian or older Cretaceous strata. Palynomorphs do indicate an Early Cretaceous age for Cores 58–61. Although spores are not numerous, species present are also found in Lower Cretaceous rocks of Argentina and South Africa which have been dated with various degrees of certainty as later Valanginian to Barremian in age. For this report, we adopt an age of Aptian to Neocomian for Cores 58–62.

Palynomorphs, coccoliths, and mollusks all indicate a Late Jurassic age for Cores 63–70. The pollen and spore assemblages, which abound with *Classopolis* pollen, are conditionally attributed to the Tithonian. The mollusks, which include the bivalves *Malayomaorica* and *Jeletzkyella*, the perisphinctid ammonite *Virgatosphinctes*, and the belemnite *Hibolithes*, indicate an early late Tithonian to a probable early Kimmeridgian age for Cores 63-1 to 67-3. Cores 67-4 to 70-5 did not yield any diagnostic macrofossils. Cores 63–70 contain the coccolith *Watznaueria britanica* with a well-developed small central area and bar. The co-occurrence of *Stephanolithion bigoti* (short lateral spines) and *Vekshinella stradneri* in Cores 65–67 indicates an Oxfordian to early Tithonian age for that interval. The absence of *V. stradneri* and the presence of *S. bigoti* and *S. hexum* in Core 70 may suggest an early Oxfordian to Callovian age for that core. Dinoflagellates suggest an early Oxfordian to late Callovian age for Core 70.

In addition to the above, onychites (arm hooks associated with the belemnite animal) were encountered in foraminiferal washings from Cores 66–70. These had also been encountered in the Jurassic strata of DSDP Hole 330 (Cores 5–10).

Sedimentation Rates

The accumulation rates indicated in Figure 7 testify to the highly episodic nature of sedimentation on the Falkland Plateau. At any given locality, episodes of exceptionally high sedimentation separated by hiatuses or condensed intervals seem to be the norm for this area (compare with DSDP Leg 36 results). The Neogene and Mesozoic time scales used here were taken from Vail and Hardenbol (1979). The Plio/Pleistocene boundary in the Neogene was set at 1.8 Ma. The Paleogene time scale is from Hardenbol and Berggren (1978).

Foraminifers

Both planktonic and benthic foraminifers occur through the entire Site 511 section in almost all stratigraphic subdivisions of the Mesozoic and Cenozoic deposits, but their species diversity and abundance show significant fluctuations (Fig. 8). Foraminifers are missing or extremely rare at the base of the section (Jurassic–Aptian), in the dissolution facies at the Tertiary/Cretaceous boundary, and in some beds within the upper Cenomanian–Campanian interval. Benthic foraminifers are rather scarce compared to planktonic forms. Nevertheless, their distribution through the section permits interpretation of the Mesozoic–Cenozoic paleoenvironmental changes in the area under study.

Cenozoic

Quaternary foraminifers are found in Core 1 (Samples 511-1-top to 511-1-2, 85–87 cm). This assemblage consists of abundant *Globorotalia inflata, Globigerina pachyderma, G. bulloides*, common *Globorotalia truncatulinoides*, and rare *G. scitula. G. truncatulinoides* is represented by low-conical specimens which are considered a cool-water form (subspecies?) of this species (Herb, 1968). A low-diversity benthic foraminiferal assemblage is present, consisting of the deep-water species *Pyrgo murrhina, Hoeglundina elegans, Gyroidina soldanii, Laticarinina pauperata*, and *Cibicidoides wuellerstorfi*; all are characteristic of the lower bathyal zone north of the Antarctic Convergence (Herb, 1971). Foraminifers are absent in the remaining siliceous oozes of Cores 1 and 2 (except Sample 511-2,CC).

Lower Oligocene assemblages of planktonic foraminifers are found in the diatomaceous oozes and nanno-diatomaceous oozes of Core 2 (Sample 511-2,CC) to

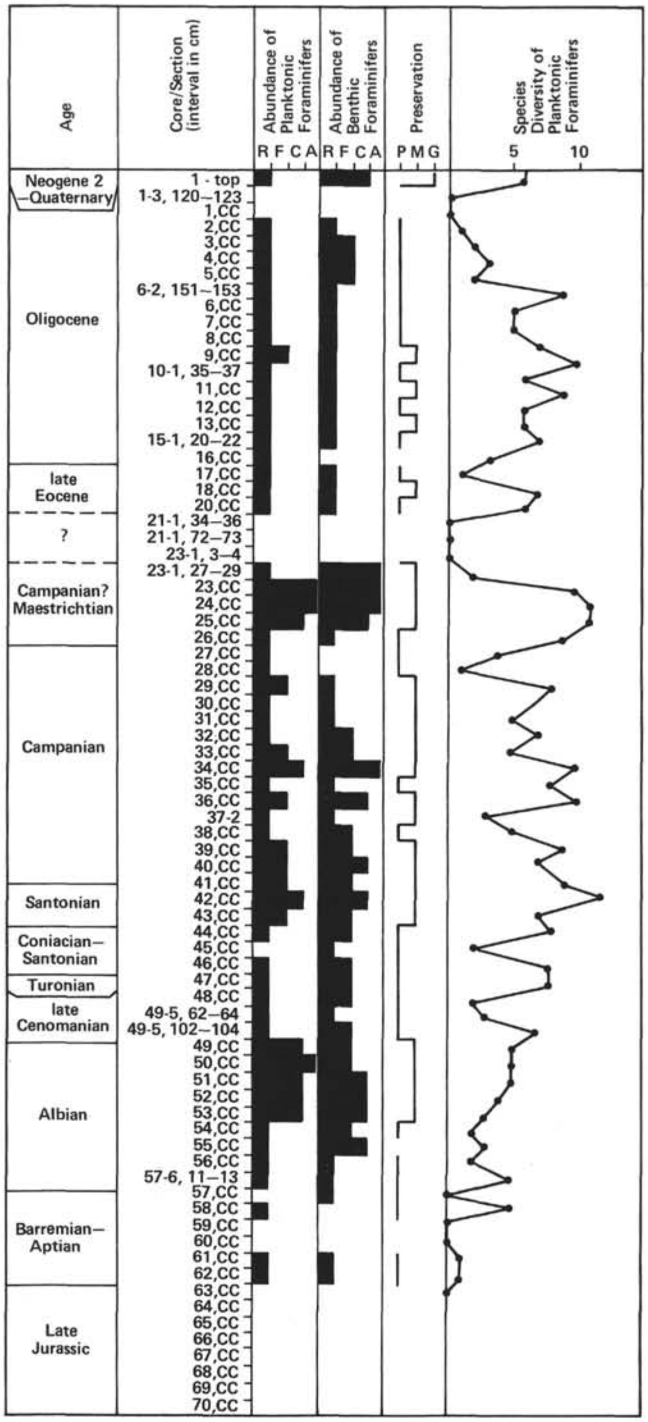


Figure 8. Abundance, preservation, and species diversity of foraminifers at Site 511. (Abundance: R, rare; F, few; C, common; A, abundant. Preservation: P, poor, M, medium; G, good.)

Core 15. They are sparse and preservation is poor except in several samples (Cores 9, 11, 15) from the lower part of the section. They are represented by *Globigerina angiporoides, G.* aff. *linaperta, G. prasaepis, G. officinalis, G. praebulloides, G. ouachitaensis, G. brevispira, Globorotaloides suteri, Globigerinita martini, Chiloguembelina cubensis, Globorotalia permicra, G. munda*, and *G. gemma.* According to Blow's (1969) zonal scale, this assemblage limits the age of the sediments and is restricted to the *Globigerina tapuriensis* Zone through the *G. ampliapertura* Zone. Impoverished assemblages of planktonic foraminifers reflect cold-water conditions at high latitudes in the Southern Hemisphere. They resemble the lower Oligocene foraminiferal fauna of the southern part of New Zealand (the *G. angiporoides* Zone and the upper part of the *G. brevis* Zone according to Jenkins's [1971] zonal scale).

Samples of Core 16 contain very poor assemblages of planktonic foraminifers: *Globigerina* aff. *linaperta, G. labiacrassata, G. angiporoides*, and *Globorotaloides suteri.* This interval is tentatively assigned to the lower Oligocene because of the absence of the typical upper Eocene species.

In the interval from Sample 511-17-1, 90–92 cm to Sample 511-18-2, 27–29 cm, sediments also include an impoverished assemblage of planktonic foraminifers: *Globorotaloides suteri, Globigerina linaperta, G. angiporoides, G.* aff. *galavisi, G. praebulloides, Globigerinita martini*, and *Globorotalia munda.* In Sample 511-17-1, 90–92 cm, however, one specimen of *Globigerapsis index* was found. If it is *in situ*, sediments should be attributed to the uppermost part of the upper Eocene.

Sample 511-18,CC and Core 20 are characterized by the low-diversity planktonic foraminiferal assemblage composed of *Globigerina angiporoides, G. linaperta, G. tripartita, Globigerinita pera, Globorotaloides suteri, Chiloguembelina cubensis*, and *Globigerapsis index.* The presence of the latter testifies to the late Eocene age of the sediments. The upper Eocene/lower Oligocene boundary is placed just above Sample 511-17-1, 90–92 cm, the last sample containing *G. index.* These deposits are correlated with the tropical *G. semiinvoluta, Globorotalia cocoensis*, and *G. cunialensis* zones and with the *Globigerina linaperta* and *G. brevis* zones (lower part) of New Zealand.

The upper Eocene–lower Oligocene portion of the section is characterized by a rather diverse assemblage of benthic foraminifers consisting of about 80 species. The quantity of specimens is low in these sediments owing to dissolution and dilution by radiolarians and diatoms; most species are very rare and irregular in occurrence. Preservation is poor.

The dominant benthic species occurring throughout the whole upper Eocene/lower Oligocene section are *Fissurina* sp., *Guttulina adhaerens, Pullenia bulloides, P. quinqueloba, Cibicidoides* sp., *Oridorsalis umbonatus, Nonion havanense, Anomalinoides spissiformis, Stilostomella curvatura, S. bradyi, S. antillea*, and *Bulimina* sp. Common are also *Karreriella* sp., *Pyrulina cylindroides, Gyroidina planulata, G. zealandica, Orthomorphina rohri*, and *O. glandigena.*

The presence of these foraminifers is consistent with the accumulation of Paleogene diatomaceous and nanno-diatomaceous oozes at lower bathyal water depths. Poor preservation of benthic and planktonic species shows that the foraminiferal lysocline probably occupied the same position.

In Cores 21 and 22 and Sample 511-23-1, 3–4 cm, foraminifers are absent (dissolution facies).

Mesozoic

Comparatively rich planktonic foraminiferal assemblages characterize calcareous sediments in the interval from Sample 511-23-1, 27–29 cm to Sample 511-26,CC: *Globigerinelloides multispinatus, G. impensus, Schackoina multispinata, Hedbergella holmdelensis, Rugoglobigerina pilula, R. rotundata, R. pustulosa, Heterohelix reussi, H. pulchra, H. globulosa*, and *H. glabrans*. All these species are well developed in the Campanian–Maestrichtian. The influence of Austral climates is evidenced by the absence of representatives of the *Globotruncana* and by many species of heterohelicids. As a result, neither zonal subdivision of these sediments nor an exact age determination within the Campanian–Maestrichtian interval are possible. Taking into account the age of the underlying deposits, which are Campanian, it is probable that the calcareous oozes of Cores 23–26 belong only to the Maestrichtian. Calcisphaerulids are common in many samples.

The upper Campanian(?)–Maestrichtian calcareous sediments contain a very monotonous, highly diverse assemblage of benthic foraminifers mainly dominated by *Gaudryina healyi, G. pyramidata, Spiroplectammina complanata, Ramulina aculeata, Marginulinopsis texaensis, Dentalina gracilis, D. legumen, Globulina subsphaerica, Lenticulina muensteri, Pullenia coryelli, P. americana, Valvulineria brotzeni, V. allomorphinoides, Gyroidinoides gudkoffi, G. nitidus, G. quadratus, Quadrimorphina camerata, Gavelinella beccariiformis, Globorotalites spineus*, and *Reussella szajnochae*. The abundance of these moderately well preserved benthic foraminifers dominated by calcareous species leads us to conclude that they inhabited depths similar to their modern counterparts, that is, depths above the foraminiferal lysocline.

Sediments of Core 27 and most of Core 28 (to Sample 511-28-5, 90–92 cm) represent a dissolution facies and contain a very low diversity assemblage of Upper Cretaceous benthic foraminifers, consisting of rare *Dentalina gracilis, Ramulina aculeata, Valvulineria brotzeni, Osangularia corderiana, Globorotalites michelinianus*, and *Bandyella* aff. *greatvalleyensis*.

Comparatively diverse and quite different assemblages of planktonic foraminifers were encountered in sediments of Campanian age (from Core 29 to Sample 511-41-3, 55–57 cm). They include *Globotruncana linneiana, G. cretacea, G. marginata, G. bulloides, G. globigerinoides, Globigerinelloides asperus, G. bollii, Archaeoglobigerina blowi, Heterohelix globulosa, H. reussi, H. pulchra, H. ramsayensis, Hedbergella crassa, H.* spp. Specimens of *Globotruncana arca* and *G. plummerae* are rare but very important for age determinations. In general, hedbergellids and heterohelicids, together with some representatives of the genus *Globigerinelloides*, strongly predominate and are accompanied by comparatively rare *Globotruncana*.

Sediments within the interval from Sample 511-41,CC to Sample 511-43,CC belong to the Santonian. Among planktonic foraminifers are numerous low- and high-spired specimens of *Archaeoglobigerina bosquensis*, accompanied by *Whiteinella baltica, Globotruncana pseudolinneiana, G. marginata, G. cretacea, Globigerinelloides asperus, Hedbergella crassa, H.* spp., *Heterohelix reussi, H. globulosa*, and *H. pulchra*.

To the undifferentiated Coniacian–Santonian are assigned sediments within the interval from Sample 511-44-1, 44–46 cm to Sample 511-46,CC. *Whiteinella baltica* and *Archaeoglobigerina bosquensis* occupy a subordinate position; the genus *Globotruncana* is represented only by *G. pseudolinneiana* and *G. marginata*. Very common are specimens of *Hedbergella* spp., *Heterohelix globulosa, H. reussi*, and *Globigerinelloides asperus*. *Schackoina cenomana* is present but very rare in almost every sample.

The planktonic foraminiferal assemblage from Sample 511-47-3, 44–46 cm to Sample 511-47-6, 44–46 cm includes rare specimens of small *Globotruncana pseudolinneiana* (the *G. lapparenti* type) together with *Schackoina cenomana, Hedbergella* aff. *agalarovae, Globigerinelloides asperus, Heterohelix globulosa*, and *Globotruncanella inornata*. If these sediments correspond to the level of the evolutionary appearance of *Globotruncana pseudolinneiana*, they belong to the upper Turonian.

In sediments within the interval from Sample 511-47,CC to Sample 5-48-1, 35–37 cm, double-keeled *Globotruncana* species are absent. The assemblage of planktonic foraminifers consists of rather numerous *Praeglobotruncana* aff. *oraviensis* (with a spinose test), together with *Hedbergella planispira, H. bornholmensis, H.* aff. *holtzi, Schackoina cenomana, Globigerinelloides asperus, Heterohelix globulosa, H. reussi*. The age of the sediments is Turonian, probably early Turonian.

Sediments within the interval from Sample 511-48-1, 70–72 cm to Sample 511-49-5, 102–104 cm are characterized by *Hedbergella praehelvetica, H. planispira, H. delrioensis, H. portsdownensis, H. infracretacea, Heterohelix* sp. (a very small form), *Globigerinelloides eaglefordensis*, and *Schackoina cenomana*. In Sample 511-49-5, 102–104 cm, very rare specimens of *Praeglobotruncana turbinata* were found. This last species indicates a late Cenomanian age for the sediments (although an early Turonian age is not excluded).

The distribution of planktonic foraminifers in the Upper Cretaceous sediments is very inconsistent. Many samples from Cores 30, 32–36, 40–44, and 47–49 contain few to common tests of moderate preservation; in other layers, poorly preserved tests or barren intervals (dissolution facies) were observed.

The Coniacian–Santonian assemblage of planktonic foraminifers at Site 511 closely resembles that of the high latitudes of the Northern Hemisphere (the lower Senonian microfauna of Bornholm Island, Denmark [Douglas and Rankin, 1969]).

Calcisphaerulids occur throughout the Maestrichtian–upper Cenomanian section, and calcareous microorganisms of unknown affinity (Sliter, 1977, plate 14) were found in Cores 41–47.

The upper (Cores 28–37) and lower (Cores 38–48) parts of the Campanian–upper Cenomanian section are characterized by two different ecological assemblages of benthic foraminifers. Cores 28–37 contain more than 150 species which usually inhabit bathyal water depth above the CCD. Many of these species occur in sediments very rarely and irregularly; others, such as *Dentalina legumen, Lenticulina muensteri, Gyroidinoides nitidus, Globorotalites michelinianus, G.* sp., *Gavelinella stephensoni, Valvulinelia brotzeni*, and *Pleurostomella obtusa*, are present constantly. Common are also *Dentalina gracilis, D. catenula, D. basiplanata, Astacolus jarvisi, P. subnodosa*, and *Bolivina watersi*. In Cores 31–37 the assemblage of benthic foraminifers is even more diverse. In addition to the species just mentioned, *Dorothia trochoides, Lingulina pygmaea, Globulina lacrima, Charltonina* sp., *Conorotalites* sp., *P. torta, Ellipsopleurostomella curta*, and *Bulimina reussi* are common.

The lower part of the section (Cores 38–48) is characterized by an assemblage which includes most species in the overlying sediments, but agglutinated species are dominant. *Glomospira corona, G. gordialis, G. irregularis, Ammodiscus* sp., *Silicosigmoilinella* sp., *Hyperammina elongata, H. gaultina, H. friabilis, Rzehakina epigona, Ammobaculites echinatus*, and *Spiroplectammina* sp. are also present sporadically. The species composition and diversity are quite variable in this interval, especially in the lower part. Assemblages where calcareous species dominate, testifying to conditions above the CCD, alternate with assemblages consisting mostly of arenaceous species, indicative of sedimentation below the CCD. The quantity of benthic foraminifers and their state of preservation also vary throughout the section. These foraminifers are usually rare or very rare and poorly preserved; only in some samples of Cores 30–34, 36, 41, 42, and 47 are they common to few, with moderate preservation.

Rather rich assemblages of planktonic foraminifers are characteristic of Albian sediments recovered in the interval from Sample 511-49-5, 120–122 cm to Sample 511-57-6, 11–13 cm. They include moderately preserved tests of *Hedbergella delrioensis, H. trocoidea, H. planispira, H. infracretacea, H. brittonensis, H. amabilis*, and *H. globigerinellinoides*. Sediments from Sample 511-55-6, 34–36 cm down to Sample 511-57-6, 11–13 cm contain the lower Albian species *Ticinella roberti, T.* aff. *primula, H. trocoidea, H. infracretacea, H. delrioensis, H. planispira*, and *Globigerinelloides gyroidinaeformis*; these belong to the *T. roberti* Zone. Foraminifers are abundant to common with some exceptions in Cores 49–54 and 56; preservation is generally moderate. In Sample 511-49-5, 120–122 cm, among the common Albian planktonic foraminifers, very rare specimens of *T. raynaudi* were identified; these indicate late Albian age for the sediments.

Calcisphaerulids are abundant to common in Cores 50–51 (down to Sample 511-51-2, 60–62 cm), rare in Samples 511-51-3, 60–62 cm to 511-51,CC, disappear completely in Cores 52–53, and again are present in some sample of Cores 54–55. They are not present in Cores 56–57.

Albian sediments (Cores 49–57) contain a moderately well preserved and diverse benthic foraminiferal fauna consisting mostly of shallow-water species ("shallow-water" is defined as 100–400 m, shelf-break fauna, after Sliter, 1977): *Dorothia trochoides, Glomospira corona, G. gordialis, Clavulina gabonica, Lenticulina* sp., *Uvigerinammina jankoi, Osangularia utaturiensis, Patellinella australis, Spirillina elongata, Gyroidinoides primitiva, Anomalinoides indica, Gavelinella intermedia*, and *Pleurostomella obtusa*. Less common are *D. gradata, Gaudryina dividens, L. turgidula, Hoeglundina cretacea, S. minima, Conorboides minutissima, Tribrachia australiana, Marginulina* sp., and *Praebulimina* sp. This assemblage is typical for the Albian deposits of the Southern Hemisphere (Austral fauna) (Scheibnerová, 1974; Sliter, 1977).

Cores 58–62 are characterized by a low-diversity assemblage of planktonic foraminifers composed of *Hedbergella infracretacea, H. globigerinellinoides, H.* aff. *delrioensis, H. similis, H. gorbachikae, H. sigali, H.* sp., and *Globigerinelloides ferreolensis*; the assemblage suggests a Barremian–Aptian age for the sediments. The Aptian/Albian boundary is drawn below the first occurrence of *Ticinella roberti* and *T.* aff. *primula* in Sample 511-57-6, 11–13 cm. Benthic foraminifers are practically absent in Cores 58–62 sediments except in Samples 511-61,CC and 511-62,CC, where tiny, thin-walled *Astacolus, Gyroidinoides, Gavelinella, Frondicularia*, and *Marginulina* are recognized.

Cores 63–70 (Upper Jurassic section) are barren of foraminifers.

Calcareous Nannofossils

Coccoliths were present in sparse to moderate numbers throughout most of the Cenozoic–Mesozoic section of Hole 511, becoming abundant only in the Maestrichtian–Campanian and mid-Cretaceous intervals. Preservation was generally poor to moderate because of dissolution, although exceptionally well preserved assemblages were noted in the upper Eocene, Campanian, and Albian. Diversity was generally low because of the high latitudine of the site, the problem of dissolution, and in the case of the Aptian–Jurassic, a highly restricted (euxinic) depositional environment.

A short (10-cm) interval (repeated by a double hit of the drill string) at the top of Section 511-1-1, belongs to the *Emiliania huxleyi* Zone; the rest of that core is barren of coccoliths. Cores 2 and 3 contain a limited flora characterized by the presence of *Reticulofenestra umbilica* and belong to the *R. daviesii* Zone whereas Sections 1–3 of 511-4 contain *Clausiococcus fenestratus* and are assigned to the zone of that name. These two zones are equivalent to the *R. placomorpha* Zone of New Zealand (Edwards, 1971). Rare discoasters are present as well as a few *Sphenolithus moriformis* and *Zygrhablithus bijugatus*. Other taxa commonly present are *Chiasmolithus altus, R. bisecta*, and *Coccolithus pelagicus*.

Sample 511-4,CC to Core 16 contains an assemblage similar to that just noted plus *Ismolithus recurvus* and can be assigned to the early Oligocene *Blackites spinosus* Zone of Edwards (originally called the *B. rectus* Zone; see Edwards, 1971). A few rhabdoliths are seen in this interval, as well as *Pontosphaera multipora* and *P. pulcheroides*.

Cores 17–20 contain common and exceptionally well preserved coccoliths of late Eocene age. These are assigned to the *Reticulofenestra oamaruensis* Zone of Edwards (1971) because of the presence of *R. oamaruensis* and *Discoaster saipanensis*. Other members of this assemblage include *Ismolithus recurvus, R. bisecta, Chiasmolithus oamaruensis, D. tani* (few), *C. altus*, and *Coccolithus pelagicus*. Core 21 is barren of coccoliths.

Core 23 contains an early Maestrichtian nannoflora dominated by the cool-water *Biscutum coronum* and can be assigned to Wind's (1979) proposed zone of the same name. Other species include *B. dissimilis, Arkhangelskiella specillata, Gartnerago costatum, Eiffellithus turriseiffeli, Prediscosphaera cretacea, Nephrolithus corystus* (mostly rims), *Kamptnerius magnificus, Ahmuellerella octoradiata*, and members of the *Lucianorhabdus/Phanolithus* plexus. Core 24 contains a somewhat different assemblage with common *Monomarginatus pectinatus, Misceomarginatus pleniporus, Marthasterites inconspicuus*, and *Biscutum coronum*. This assemblage is also assigned to the *B. coronum* Zone of Wind (1979), but the core may be early Maestrichtian or latest Campanian in age (see Wind and Wise, this volume).

The interval from Core 25 through Section 511-27-2 was barren of coccoliths. Section 511-28-1 through Core 42 contained *Marthasterites furcatus* but no *Lithastrinus floralis* and, considering the foraminifers present, is mostly dated as early Campanian in age. *L. floralis* is present downhole starting in Core 43, indicating an age of mid-Santonian or older. Other common species within this interval are *Watznaueria barnesae, Micula decussata, Biscutum constans, Eiffellithus eximius, E. turriseiffeli, Seribiscutum primitivum, Kamptnerius magnificus, Cretarhabdus conicus*, and *Prediscosphaera cretacea*. *E. trabeculatus* makes a brief appearance in Cores 39 and 40 (warm interval?). *Thiersteinia ecclesiastica* n. gen., n. sp., is present from Section 511-46-1 to Section 511-48-1 and is used to define a new zone.

Micula decussata and *Kamptnerius magnificus* are present down to the uppermost sample of Core 48 (middle Turonian or younger); the other core sections are barren. These species are absent in Core 49 (lower Turonian or older).

Section 511-50-2 to Section 511-56-1 contain an assemblage similar to Core 49 except that *Eiffellithus turriseiffeli* is absent; thus this interval is assigned to the *Prediscosphaera cretacea* Zone of Thierstein (1973). Core 51 contains common *Sollasites falklandensis* and overlies the subzone of the same name.

Prediscosphaera cretacea is absent below Core 56, Section 1, but *Lithastrinus floralis* is present down through Section 511-58-2; therefore this assemblage belongs to the *Parhabdolithus angustus* Zone which Thierstein (1973) dates as middle Aptian to early Albian in age. Cores 58 to 62, Section 1, do not contain *L. floralis* but in selected intervals are flooded with fragments of *Micrantholithus obtusus*. The rest of Core 62 is essentially barren of coccoliths except for the core catcher.

Sample 511-62,CC to Core 70 contains *Watznaueria britanica* (small central area and bar generally present), *Zygolithus erectus*, and other forms described from the Jurassic of DSDP Hole 330, Leg 36 (*Vekshinella stradneri, Ethmorhabdus gallicus*, and *Stephanolithion minutum* with short lateral spines). This assemblage is found in the Volgian of the Russian platform (Medd, in press). *S. hexum* and *S. bigoti* co-occur in Core 70, which would indicate a Callovian–early Oxfordian age for the base of the drilled sequence.

Radiolarians

Radiolarians are common and well preserved in Cores 1 through 20 at Site 511. Cores 21, 23, 56, and 57 also contain radiolarians but they are sparse and generally recrystallized. All other cores examined are barren of any siliceous microfossil remains. Only core-catcher samples were studied at Site 511.

In the absence of any well-established, high-latitude, Paleogene radiolarian zonation, the cored sequence between Cores 2 and 20 is equated to Riedel and Sanfilippo's (1978) standard low-latitude zonal scheme.

Age Determinations

Age determinations can be summarized as follows:

Core 23:	Late Cretaceous
Core 21:	middle to early Eocene
Cores 17–20:	late Eocene
Cores 5–16:	early Oligocene
Cores 2–4:	early Oligocene—possibly early late Oligocene
Core 1:	mixed Pleistocene and Oligocene

Core 23 is dated as Late Cretaceous because several radiolarian genera known to be restricted to this time period occur in it. No identifications to the specific level are possible because the specimens are very poorly preserved. Most radiolarians are represented as internal casts composed of glauconite or are entirely replaced by this mineral.

Core 21 is tentatively dated as middle to early Eocene, because the *Amphymenium splendiarmatum* and *Amphicraspedum prolixum* group co-occur in the presence of many specimens of *Buryella* species. Nearly all specimens are recrystallized to some degree and most cannot be identified to the specific level.

Cores 20–17 are late Eocene in age, equivalent to the *Thyrsocyrtis bromia* zonal equivalent at low latitudes. This age determination is based upon the occurrence of *Theocyrtis* sp., the ancestral form of *Theocyrtis tuberosa* known only to occur in the upper half of the *T. bromia* Zone at low latitudes. In addition, the co-occurrence of *Cryptoprora ornata, Theocyrtis diabloensis*, and *Lychnocanoma amphitrite* within these cores indicates a late Eocene age.

Cores 17 through 5 are early Oligocene, equivalent to the *Theocrytis turberosa* Zone at low latitudes. This determination is based upon the occurrence of *Calocycletta acanthocephala* throughout the sequence of cores. This radiolarian is known only from sediments of the early Oligocene age (*T. tuberosa* Zone) in mid- to low-latitude regions (DSDP, Legs 22 and 31). Johnson

(1974) found *C. acanthocephala* restricted to *T. tuberosa* Zone sediments in the Indian Ocean (DSDP Site 216, Leg 22) and Ling (1975) also encountered this species in the lower half of the *T. tuberosa* Zone at DSDP Site 292, Leg 31, in the Northwest Pacific–Japan Sea area.

Cores 4 to 2 contain *Calocycletta* cf. *parva*. This species is believed to be the ancestral form of *C. parva*, which appears in the late Oligocene in mid- to low-latitude areas. Dinkelman (1973) reports *C.* cf. *parva* restricted to the early Oligocene *Theocyrtis tuberosa* Zone, but Moore (1972) believes this species may range into the basal *Dorcadospyris ateuchus* Zone, or early late Oligocene. Therefore, Cores 4 through 2 are dated as probable early Oligocene, but possibly early late Oligocene in age.

Core 1 contains a homogenized mixture of Pleistocene and early Oligocene radiolarians, indicating that the integrity of this interval is disrupted.

Paleoclimatic Interpretation

The presence in Cores 20 through 16 of *Calocycletta* species of Orosphaerid and Collosphaerid radiolarians, and of *Cryptoprora ornata, Theocyrtis* sp. (ancestral *T. tuberosa*), *Lychnocanoma amphitrite, Lithocyclia crux*, and *Thyrsocyrtis bromia* (very rare) are indicative of relatively warm conditions, probably cool temperate waters, in the vicinity of Site 511 during the latest Eocene and early Oligocene interval.

However, by Core 12 the dominant species in the overall radiolarian assemblage have changed. Most warm-water elements such as the *Calocycletta* have disappeared, and the assemblage becomes dominated by cooler-water *Spongoplegma, Prunopyle*, and Eucyrtid species. This assemblage persists through Core 11 and is considered transitional, indicative of significant upwelling conditions during climatic deterioration within the earliest Oligocene. The convergence of cool temperate and subantarctic waters and the eventual transgression of subantarctic waters over Site 511 are proposed. However, the exact timing of this event cannot be ascertained from radiolarian data.

Between Cores 11 and 9 further climatic deterioration is evidenced by the radiolarian taxa encountered. The radiolarian assemblage in Cores 9 through 2 generally resembles the early Oligocene assemblage recorded by Chen (1975), from Leg 28, Site 274, at 69°S on the Ross Sea continental margin. *Cyclampterium*(?) *longiventer, Spongomelissa fenestrata, Lithomelissa challengerae, S. sphaerocephalis, S.* sp., and *Eucyrtidium* sp. are significant constitutents of this radiolarian assemblage. Chen (1975) encountered this assemblage in Cores 31 through 39 at Site 274, and owing to the proximity of Site 274 to the Antarctic continent, it must be considered antarctic in character. Radiolarians in Cores 9 through 2 at Site 511 appear to represent the northerly elements of a broad antarctic/subantarctic paleobiogeographic province encompassing 18° of latitude in the circum-Antarctic seas during the early Oligocene.

By Core 5 at Site 511, a slight moderation of climate is evidenced by the reappearance of *Calocycletta* and warm-water Eucyrtid species. A slight southerly shift of warmer subantarctic waters over Site 511 seems feasible to explain this faunal modification.

In summary, climate through the latest Eocene and early Oligocene at Site 511 fluctuates from cool temperate to broadly subantarctic/antarctic in character. The exact timing of this transition cannot be ascertained from radiolarian data; it is, however, an early Oligocene event.

Diatoms

Diatoms are well preserved and abundant in Core 1. A detailed examination of this core revealed the presence of three disconformities. The siliceous gravelly sand and foraminiferal ooze from 0–37 cm of Section 1 is assigned to the *Coscinodiscus lentiginosus* Zone of the Brunhes Magnetic Chronozone.

The lithology change at 37 cm marks a disconformable boundary separating the upper *Coscinodiscus lentiginosus* Zone from the *C. elliptipora/Actinocyclus ingens* Zone encountered at 511-1-1, 52–53 cm. Sample 511-1-1, 91–92 cm is assigned to the *C. kolbei/Rhizosolenia barboi* Zone of the uppermost Pliocene.

No zonal designation is given to Sample 511-1-1, 120–121 cm because of considerable downhole slumping of younger microfossils and reworking of lower Pliocene and upper Miocene microfossils. This sample is probably close to an apparent disconformity separating lower Matuyama Chronozone sediments (511-1-1, 91–92 cm) from upper Gauss Chronozone sediments (511-1-1, 142–143 cm). Sample 511-1-1, 142–143 cm contains a flora characteristic of the *Nitzschia weaveri* Zone. Samples 511-1-2, 31–31, 65–66, and 89–90 cm are assigned to the *N. interfrigidaria/Coscinodiscus vulnificus* Zone of the mid-Gauss and are apparently conformable to the *N. weaveri* Zone of basal Section 1.

The third disconformity in Core 1 probably coincides with the sharp lithology change at Section 2, 144 cm. This sharp boundary between the siliceous gravelly sand above and the diatom ooze below separates the middle Pliocene of Sample 511-1-2, 89–90 cm from the lower Oligocene of Sample 511-3-1, 4–5 cm.

Abundant and diverse diatom assemblages of early Oligocene to late Eocene age occur in sediments recovered in Core 1, Section 3 through Core 20, Section 3. Six diatom zones have been identified in this interval (see Gombos and Ciesielski, this volume). The interval from Sample 511-1-3, 132–134 cm through Sample 511-4-3, 10–12 cm contains part of the *Coscinodiscus superbus* group Zone; that from Sample 511-5-1, 10–12 cm through Sample 511-11-2, 30–32 cm contains the *Rhizosolenia gravida* Zone; Sample 511-11-3, 30–32 cm through Sample 511-12-1, 11–13 cm contains the *Brightwellia spiralis* Zone; Sample 511-12-2, 11–13 cm through Sample 511-15-1, 13–15 cm contains the *Melosira architecturalis* Zone; Sample 511-16-1, 22–24 cm through Sample 511-16-2, 22–24 cm contains the *Asterolampra insignis* Zone; and Sample 511-17-1, 83–85 cm through Sample 511-20-3, 23–25 cm contains the *Rylandsia inaequiradiata* Zone.

In Hole 511, the Eocene/Oligocene boundary occurs somewhere within or between Cores 16 and 17; that is, close to the top of the *R. inaequiradiata* Zone. This boundary cannot be closely defined on the basis of any definite diatom appearance or extinction datum. However, a significant change in the relative abundance of the genus *Pyxilla* was observed in the vicinity of the boundary. In Core 20 (below the boundary) the abundance of this genus is about 1500–2000 specimens per 2 traverses at ×400 magnification. Above Core 20 the abundance decrease by an order of magnitude. It is not certain if this dramatic abundance change reflects actual oceanographic conditions or if it is a preservational phenomenon.

Sporadic specimens of reworked Eocene diatoms were noted throughout the hole.

Silicoflagellates

Silicoflagellates are common and well preserved in most sediments examined from Cores 1–20; below Sample 511-20,CC, they are absent. Species diversity is low in Pliocene to Recent sediments and high in lower Oligocene to upper Eocene sediments.

Samples 511-1-4, 15–16 cm, through 511-3-3, 65–66 cm, are assigned to the revised *Naviculopis constricta–Corbisema archangelskiana* Interval Zone of the lower Oligocene (see Shaw and Ciesielski, this volume). The dominant silicoflagellate flora throughout this interval are *Naviculopsis trispinosa, N. biapiculata, Distephanus crux*, and *Dictyocha deflandrei.* Other species commonly present in this zone include *Corbisema apiculata, C. flexuosa, C. geometrica, Dictyocha aspera martinii, Distephanus crux loeblichii*, and others.

Core 3 below Sample 511-3-4, 65–66 cm, Cores 4 through 7, and Core 9 through Sample 511-9-4, 80–81 cm contain a newly defined *Naviculopsis constricta/Dictyocha deflandrei* concurrent Range Zone. The well-preserved and diverse assemblage in these lower Oligocene sediments includes *N. constricta, N. biapiculata, N. trispinosa, Corbisema geometrica, C. apiculata, Dictyocha aspera martinii, Mesocena occidentalis*, and others. Sediment recovery in Core 8 was poor and the core was not sampled for study.

Sample 511-9-5, 80–81 cm through Sample 511-11-4, 5–6 cm is placed in the newly defined *Naviculopsis trispinosa* Zone of the lower Oligocene and is characterized by the abundant occurrence of *N. trispinosa.* The first consistent occurrence of *Dictyocha deflandrei* marks the top of this zone; only few to rare *D. deflandrei* occur sporadically within the zone. Other species common in this interval include *Corbisema hastata globulata, C. triacantha, Mesocena apiculata, M. occidentalis, N. biapiculata*, and *N. constricta.*

Sample 511-11,CC through Sample 511-18,CC is placed in the newly defined *Mesocena occidentalis* Zone. The rich silicoflagellate assemblage of this upper Eocene to lowermost Oligocene interval includes common *Corbisema hastata globulata, C. triacantha, Distephanus boliviensis, D. crux crux, M. apiculata, M. occidentalis, Naviculopsis biapiculata*, and *N. constricta. N. trispinosa* is present (< 10%) but is significantly less abundant than in younger strata of this site.

Sponge Spicules

At Site 511 sponge spicules were recognized in Paleogene sediments (Cores 2–20); in Mesozoic deposits they are totally absent. In Cores 2–20 the assemblage is represented mostly by spicules of glass sponges (class Hyalospongiae) with a compact skeleton. In much smaller numbers are isolated macroscleres and microscleres. Rare are spicules of tetraradiate sponges (order Tetraxonida), the number of which increases considerably in the upper Eocene deposits.

When morphological types are compared, two assemblages of sponge spicules are distinguished. The first characterizes the lower Oligocene deposits (from Sample 511-2-1, 98–100 cm to Sample 511-16,CC) The second association is present in upper Eocene sediments (Cores 17–20). Rather numerous are representatives of the order Tetraxonida: dichotriaenes, anatriaenes, oxeas, strongyles, styles. Fossil microscleres such as sigmas occurred rarely, and only in the upper Eocene.

Pollen and Spores

Cenozoic

In Cores 1–3 (Quaternary to the uppermost layers of the lower Oligocene) spores and pollen are absent.

In Cores 4, 5, 6, 9, 11, 12 (lower Oligocene), pollen and spores are relatively diverse and numerous. Abundant are Gymnosperm pollens: *Podocarpus* sp., *Dacrydium* sp., *D. cupressinum, Phyllocladus* sp., *P. mawsonii, Microcachryidites antarcticus*, and *Pinus* sp. Angiosperms are represented by the pollens *Nothofagus* (*brassi* type and *fusca* type), *Casuarina* sp., Myrtaceae, Proteaceae, Combretaceae, *Tricolpites* sp., *T. reticulata, Rhoipites minusculus, R. baculatus, Psilatricolporites* sp. Among spores were identified *Cyathea* sp., *Gleichenia* sp., *Anogramma* sp., *Matonisporites* sp., *Cyatheacidites* sp., *Leiotriletes regularis, Cingutriletes australis, Cicatricosisporites* sp., Polypodiaceae.

In Cores 15–17 palynomorphs are few: *Podocarpus* sp., *Dacrydium* sp., *D. cupressium, Phyllocladus* sp., *Nothofagus* sp., *N.* sp. (*fusca* type), *N.* sp. (*brassi* type), *Tricolpites* sp., *Triatriopollenites* sp., *Psilatricolporites* sp., Polypodiaceae, *Cyathea* sp., *Leiotriletes* sp., *Gleichenia* sp., and *Cicatricosisporites* sp.

In Cores 18–20 only very rare grains of pollen and spores were found: *Podocarpus* sp., *Dacrydium* sp., *Phyllocladus* sp., *Nothofagus* sp., *Tricolpites* sp., *Cyathea* sp., *Leiotriletes* sp., and Polypodiaceae. Impoverished assemblages of pollen and spores testify only to the Eocene–Oligocene age of the sediments.

Mesozoic

In Upper Cretaceous deposits (Cores 29–49), spores and pollen grains are sporadic. They are missing in the greater part of Albian sediments (Cores 49–55). In underlying deposits of the Lower Cretaceous and Upper Jurassic, considerable amounts of satisfactorily preserved spores and pollen make it possible to subdivide sediments into three units with different palynological assemblages.

In Cores 56–58 Gymnosperm spores and pollen are present in relatively equal quantities. Sporadic grains of Angiosperm pollen of the genus *Clavatipollenites* were recognized. Among spores, *Gleicheniidites* spp. and *Cyathidites minor* are predominant. Very common are spores such as *Cicatricosisporites* spp., *Ceratosporites distalgranulatus, Coronatispora valdensis, Crybelosporites* spp., *Cyatheacidites tectifera, Muricingulisporis annulatus, Perotrilites linearis, Taurocusporites* sp., *Polypodiaceoisporites elegans. Classopollis* pollen predominates within the Gymnosperms. Pollen of *Cyclusphaera psilata* is also present.

This assemblage has some species common to a palynological association from the Baqueró continental formation (Santa Cruz Province, Argentina), the age of which is palynologically determined as Barremian–Aptian (Archangelsky and Gamerro, 1967). It is also similar to an assemblage, tentatively assigned an Aptian–Albian age, from deposits off the South African coast penetrated by Hole 361, Leg 40 (McLachlan and Pieterse, 1978) and to an Albian assemblage from Hole 327, Leg 36, on the Falkland Plateau (Hedlund and Beju, 1977). It is noteworthy that according to planktonic foraminifers, the age of the sediments at Site 511 is dated as upper Aptian (Core 58)–lower Albian, the *Ticinella roberti* Zone (Cores 57 and 56).

In Cores 59–62 the palynological assemblage is characterized by a predominance of Gymnosperm pollens; among them *Classopollis* is dominant. Pollens from *Cyclusphaera psilata* and *Inaperturopollenites limbatus* are constantly present. Angiosperm pollens are missing. Spores are not numerous, though represented by diverse genera and species such as *Antulsporites saevus, A. granulatus, Contignisporites cooksoni, Cicatricosisporites* spp., *Dictyotosporites complex, Distaltriangulisporites* sp., *Foveosporites subtriangularis, Ischiosporites volkheimeri, Interulobites algoensis, I. sinosus, I.* aff. *triangularis, Matonisporites crassiangulatus, Nevesisporites* sp., *Polypodiaceoisporites elegans, Staplinisporites caminus, Taurocusporites segmentatus.*

Though most spore species of this assemblage are peculiar to Upper Jurassic and Lower Cretaceous deposits of Argentina, South Africa, and Australia, presence of such typically Lower Cretaceous forms as *Cyclusphaera psilata, Cicatricosisporites* spp., *Inaperturopollenites limbatus, Polypodiaceoisporites elegans*, and *Taurocusporites segmentatus* enable us to date deposits as Early Cretaceous. The assemblage can be correlated with spores and pollen from the Agrio and Ortiz formations of Neuquén Territory in Argentina (Volkheimer and Sepulveda, 1976; Volkheimer et al., 1977), the age of which was determined by ammonites in the Agrio Formation as Hauterivian–Barremian. In addition, a similar assemblage was observed in deposits of the Sundays River Formation (Alboa Basin, South Africa). Its age was tentatively determined as late Valanginian–early Hauterivian on the basis of ostracodes, benthic foraminifers, and mollusks (Scott, 1976).

In Cores 63–70 the palynological assemblage abounds with *Classopolis* pollen. Spores are not numerous, being represented mainly by the same species and genera as in the previous assemblage. A peculiar feature is the absence of species typical of the Lower Cretaceous deposits only. From this standpoint the age of the assemblage is Late Jurassic. Most similar to this assemblage are those from the Vaca Muerta Formation (Argentina) of Tithonian age (Volkheimer and Quattrocchio, 1975) and the Kirkwood Formation (the Uitenhage Group, Algoa Basin, South Africa), supposedly of Late Jurassic–Early Cretaceous age (Scott, 1976). Similarity with the above formations is suggested by the absence of *Cyclusphaera psilata* and presence of some species of the genus *Interulobites.* As there are no data on Oxfordian and Kimmeridgian palynoassemblages from Argentina and South Africa, and no spores of *Interulobites* have been identified from the Oxfordian–Kimmeridgian of Australia (Filatoff, 1975), the assemblage at Site 511 in the interval from 556 to 632 meters is conditionally attributed to the Tithonian.

Mesozoic Dinoflagellates[3]

The interval between Sample 511-29-1, 0–3 cm and Sample 511-40-5, 34–36 cm is dated as Late Cretaceous (early Campanian to Santonian). Restricted to this interval are *Isabeladinium latum* and *Chatangiella granulifera, Odontochitina porifera, Amphidiadema denticulata,* and *A. nucula. Xenascus ceratioides* occurs at and below Sample 511-34-4, 124–126 cm; the last appearance datum (LAD) of *Conosphaeridium striatoconus* is in Sample 511-40-5, 34–36 cm. The underlying interval between Sample 511-41-3, 51–53 cm and Sample 511-47-1, 42–44 cm is Late Cretaceous (Coniacian to Turonian). *C. striatoconus* occurs throughout the interval, and the LAD of *Palaeohystrichophora infusorioides* is in Sample 511-42-4, 110–112 cm. *Actinotheca aphroditae* occurs only in Sample 511-42-4, 110–112 cm. No dinoflagellates were recovered from the interval between Sample 511-48-3, 42–44 cm and Sample 511-53,CC; the age is therefore indeterminate. The interval between Sample 511-54-3, 46–48 cm and Sample 511-58-2, 52–54 cm contains a low-diversity assemblage with *Ovoidinium scabrosum, Angustidinium acribes*, and *?Oligosphaeridium asterigerum.* The interval is interpreted as Early Cretaceous (Cenomanian to Albian) because of this association. Samples from Cores 59 and 60 were not examined. The interval between Sample 511-61-1, 69–71 cm and Sample 511-67-2, 80–82 cm contains *Endoscrinium luridum* (in Sample 511-61-1, 69–71 cm only), *Leptodinium mirabile* (LAD in Sample 511-64-5, 45–47 cm), and *Gonyaulacysta jurassica* (LAD in Sample 511-67-2, 80–82 cm). The interval is dated as Late Jurassic (early Kimmeridgian to late Oxfordian) by this assemblage. Samples from Cores 68 and 69 are nondiagnostic. The deepest sample examined is at 511-70-1, 50–52 cm; it contains *Wanaea digitata, Rigaudella* sp. cf. *R. aemulum, Endoscrinium galeritum;* and *Gonyaulacysta juras-*

[3] Additional report by D. K. Goodman and M. E. Millioud, Exxon Production Research Company, Houston, Texas.

sica, which indicate an early Late to late Middle Jurassic (early Oxfordian to late Callovian) age. Based on dinoflagellate data, the Jurassic/Cretaceous boundary is in the interval between Sample 511-58-2, 52-54 cm and Sample 511-61-1, 69-71 cm. No Cretaceous sediments older than Albian and no Jurassic sediments younger than early Kimmeridgian were identified.

Macrofauna

Cores 41-43 contain numerous but fragmentary remains of *Inoceramus* s.l., a few other indeterminate pelecypods, and locally, a number of generically indeterminate solitary corals (evidently redeposited, at least in part). The sediments were deposited in the bathyal to outermost neritic environment, judging by the general absence of such shelf-bound fossils as belemnites and thick-shelled pelecypods in the presence of depth-tolerant organisms such as *Inoceramus.*

In Cores 50-56 *Aucellina* species range from extremely numerous (coquinas) to rare—*A.* sp. cf. *radiatostriata, A.* sp. cf. *andina,* and *A.* sp. indet. The coquinas were deposited under the influence of strong bottom currents. The presence of other, apparently shelf-bound pelecypods suggests an inner neritic origin, although an alternate interpretation can be made in favor of an outer neritic to bathyal environment.

Rare aconeceratid, cheloniceratic, and ancyloceratic ammonites of Aptian affinities are found in Sections 57-3 to 58-1. These are all depth-tolerant or nectoplanktonic ammonites which suggest a bathyal to outermost neritic environment similar to that of Cores 41-49.

Section 58-4 to Core 62 did not yield any immediately diagnostic macrofossils, although belemnites and buchiid pelecypods were present. No shells comparable to *Aucellina* were present; this fact could suggest a pre-Aptian age. A significant fluctuation in water depth is seen in this interval. Sections 58-4 to 60-4 were definitely deposited in an inner neritic to littoral environment in close proximity to the basin shoreline. This is indicated by abundant thick-shelled shallow-water pelecypods (often forming coquinas), including numerous oysters. Belemnites, which come from inner- to median-shelf environments at depths of less than 150 meters, are common, whereas ammonites, which favor outer-shelf to upper bathyal environments, are nearly totally absent. The alteration of belemnite-bearing and oyster-rich units indicates a frequent alternation between a normally saline environment and a distinctly brackish (presumably delta-influenced) environment.

The interval from Section 60-5 to Core 63, on the other hand, was deposited in the same bathyal to outermost neritic environment as Section 41-3 to Core 49 and Sections 57-2 to 58-3. This is suggested by the general paucity or complete absence of most fossils (pelecypods, belemnites, and large ornate gastropods). The depositional environment is one of very low energy and reducing conditions.

The hiatus between Core 62 and Core 63 probably includes the upper Tithonian as well as the Berriasian to Hauterivian (or possibly even Barremian) rocks. This is strongly suggested by the occurrence of the exclusively Late (but not Latest) Jurassic *Malayomaorica* sp. and/or *Jeletzkyella* sp. in Core 63. A perisphinctid ammonite in Sample 511-63-3, 49-50 cm is identified as *Virgatosphinctes (Pseudoinvoluticeras)* sp. of early Tithonian affinities. The appearance of fairly common belemnites and a general increase of fossil content in Sections 64-1 to 65-2 suggest a shallowing trend which apparently brought the bottom of the basin into a mid- to outer neritic environment. This trend culminates in the appearance of numerous interbeds of a presumably inner neritic to littoral pelecypod coquina in sandy siltstone containing common to abundant pelecypods and some *Hibolites*-like belemnites (Sample 511-65-2, 90 cm). This abrupt lithological and faunal change marks the second episode downhole of inner neritic to littoral deposition at Site 511.

This second interval of shallow depositional environment is seen from Sections 65-2 to 65-3 in a distinctly cyclical alternation of fossil-rich sandy to pure siltstones with very thin interbeds of pelecypod coquina. The faunal composition of these units is exactly the same as in the Cretaceous (Sections 58-4 to 60-4), including numerous oysters in some coquinoid interbeds. The environment was much the same as in the Cretaceous.

The lowermost cores from Site 511 (Sections 67-4 to 70-5) consist of siltstone (black and petroliferous), rich in belemnite of the genus *Hibolites* but lacking thick-shelled shallow-water pelecypods. This suggests a low-to very low energy, mid-neritic (50-?150-meter) depositional environment.

PALEOMAGNETISM

Paleomagnetic measurements were made on Leg 71 sediments using samples taken by pushing plastic cylinders (2.5 cm in diameter and approximately 2.5 cm in length) into the sediment. These samples are oriented by a notch pointing in the uphole direction. Additional samples were taken in the harder sediments of Site 511 using a diamond-tipped drill, after an orientation arrow was inscribed on the sediment. Measurement of natural remanent magnetization (NRM) and postdemagnetization remanence were carried out using the shipboard Digico fluxgate spinner magnetometer, integrating the readings over up to 2^9 spins. Demagnetization was performed on board the *Glomar Challenger* by means of a Schonstedt alternating field demagnetizer. Samples were demagnetized along three mutually perpendicular axes at the peak field; then one further demagnetization was carried out at half the peak field with the third axis reversed with respect to the demagnetizer coils. This additional demagnetization reduces the effect of any anhysteretic remanent magnetization (ARM) which may build up in the sample.

At Site 511, 135 samples were taken for paleomagnetic study at intervals of approximately 3 meters in the more complete sections of the hole. Pilot demagnetization shows that the NRM is stable and probably represents a primary magnetization. Samples with stronger NRM intensities were demagnetized at 150 oersteds (Oe). Demagnetization produced changes in inclination of usually less than 10°. Gaps in sampling in the upper part of the hole prevent the identification of magnetic epochs within the Cenozoic. The NRM inclinations of Mesozoic sediments are shown in Figure 9. The majority of the samples are normally magnetized (i.e., have negative inclinations), representing the long Cretaceous Normal Interval. Three samples with low or reversed inclination occur in the lower part of the Cretaceous sediments. Only the zone between Samples 511-60-6, 44-46 cm and 511-60-6, 51-53 cm has been confirmed by resampling; however, it is possible that these sediments were deposited during the Serra Geral Mixed Interval (as defined by van Hinte, 1976). The NRM of these samples may comprise a reversed primary magnetization with a normal secondary overprint. Demagnetization of these samples was not carried out on board the *Glomar Challenger* because the NRM intensities were too low. Two reversed samples occur in Jurassic sediments (in Cores 63 and 68), but these have not been confirmed by resampling.

The upper boundary of the long Cretaceous Normal Interval is marked by the top of Core 27. The reversed sample in Core 35 has a very weak intensity and is not considered to represent a true geomagnetic reversal. The mean absolute inclination for the Mesozoic sediments is $53.5 \pm 21.9°$, which would indicate a paleolatitude of 34.0° for the Falkland Plateau.

Intensity variation in Hole 511 sediments reflects lithology (Fig. 10). The Cenozoic and Maestrichtian oozes (Subunits 2A and 2B, and Unit 3) were predominantly low in intensity, ranging from 0.2 to 0.9 μG. Intensity in the zeolitic clays is low (0.5–2.0 μG) to a depth of about 320 meters, below which values increase to between 20 and 140 μG. Sediments have a marked red color below 350 meters, reflecting a high iron oxide content; this red coloration is also marked in the nannofossil claystones and chalks of Unit 5, which have an intensity of 10–140 μG. Intensities within the black shales (Unit 6) are low (0.1–1.0 μG).

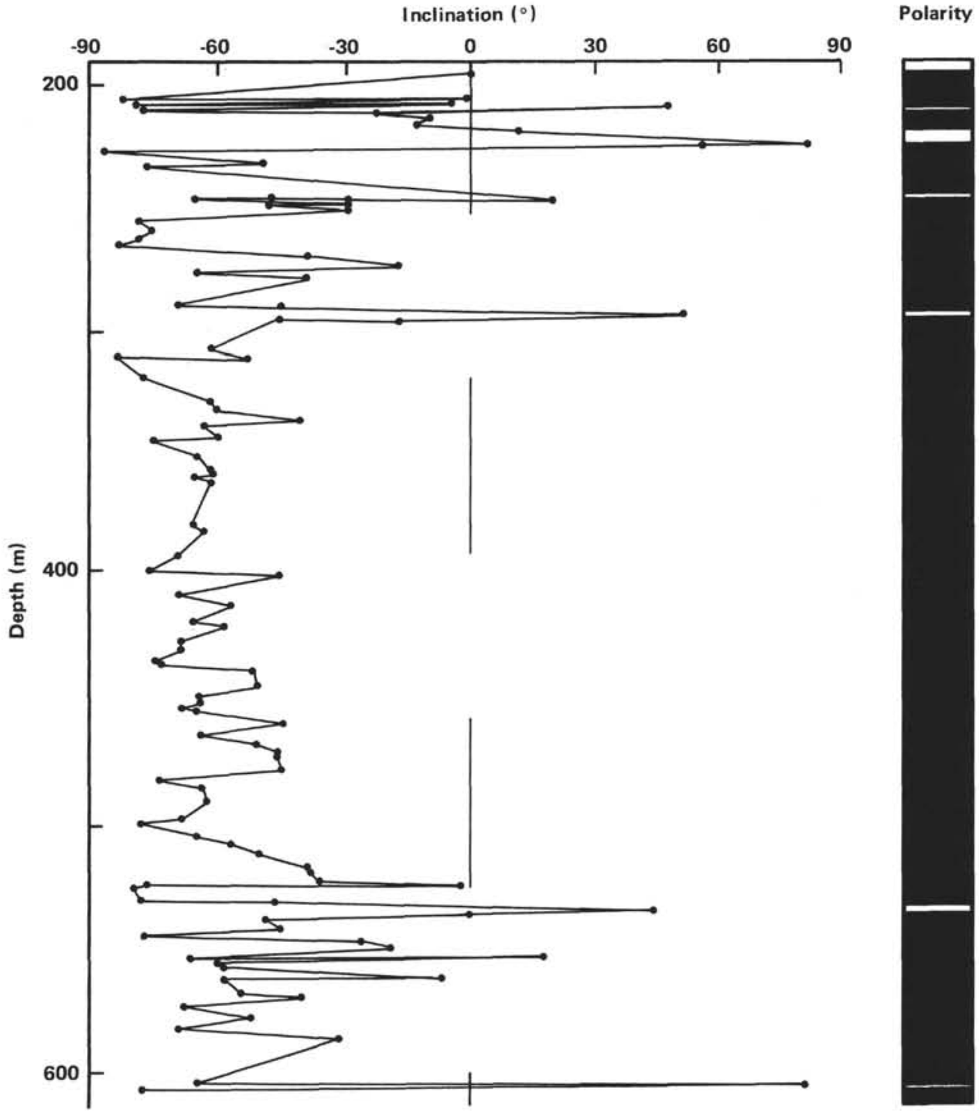


Figure 9. Variation in natural remanent magnetization (NRM) inclinations within the Mesozoic at Site 511.

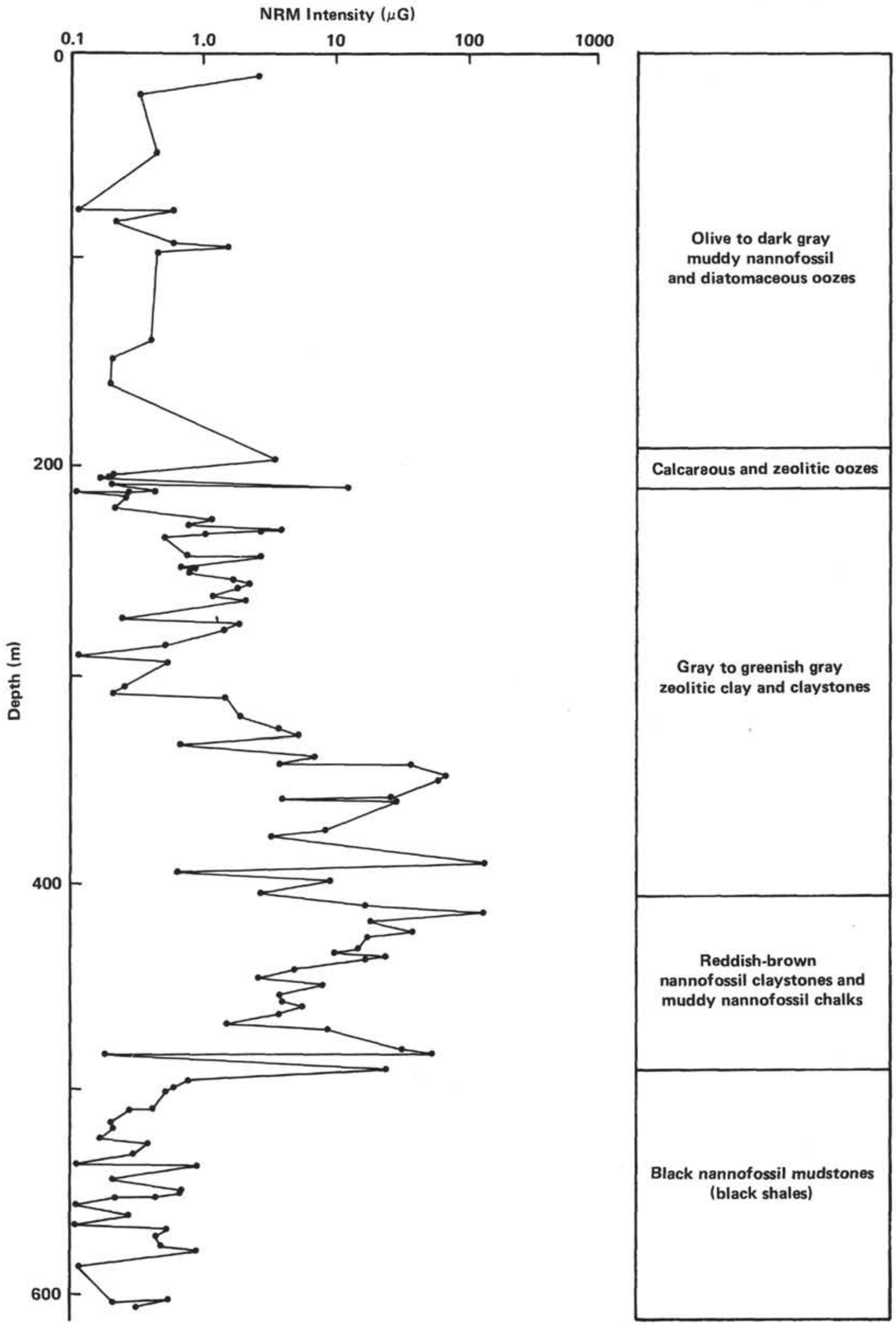


Figure 10. Correlation between natural remanent magnetization (NRM) intensity and lithology at Site 511.

ORGANIC GEOCHEMISTRY

Sediments encountered in Site 511 were analyzed onboard ship for organic carbon, gases in gas pockets, and fluorescence and were subjected to a pyrolysis/fluorescence procedure (Heacock et al., 1970) to provide an estimate of hydrocarbon occurrence. Gas samples were taken wherever possible, although the gases were not severely pressured in any of the cores taken. Results of these shipboard procedures and analyses are discussed hereafter, followed by General Observations that take into account both the shipboard and shore laboratory studies (see Schaefer et al.; von der Dick et al.; Copelin and Larter; Deroo et al.; all this volume). In some instances, the more sophisticated shore laboratory analyses changed significantly the impressions of the maturation and migration patterns derived from the shipboard analyses (Ludwig et al., 1980).

Organic Carbon

Samples for organic carbon analyses were selected mainly in fine-grained and dark material. The values obtained should therefore reflect zones of enrichment in organic carbon. Samples were dried, crushed, treated with HCl, washed, weighed, and analyzed on a Hewlett Packard 185B CHN analyzer. Prior to this, the HP 185B was calibrated by different standards, and integrator counts were plotted against weight in milligrams of organic carbon. Errors and deviations in organic carbon analyses may be due to resistant carbonates (e.g., dolomite) and especially to weighing on a rolling and pitching vessel. Both the organic carbon values and the carbonate contents (determined by the carbonate bomb technique) are listed in Table 3.

Pyrolysis/Fluorescence

Pyrolysis/fluorescence should give a background for both the presence of heavy free hydrocarbons in a sediment and the generative potential of the sediment for releasing bitumen at stages of higher maturity when related to organic carbon content. The procedure was improved by injecting N_2 into the pyrolysis tube, thus preventing hydrocarbons from burning. The values obtained by this method seem to be more reliable.

The fluorescence units of pyrolyzed sediments of different types and ages are plotted against carbon content in Figure 11.

Gas Analyses

We noticed no highly pressured gas or large gas pockets in any of the cores. Gas analyses were run on a Carle-GC equipped with a thermal conductivity cell and a much more sensitive Hewlett Packard 5710 AGC, equipped with a dual FID system.

Fluorescence

Random samples were taken to look for fluorescence, but even the black shales showed no indications.

Discussion of the Shipboard Results

Organic carbon values of Site 511 range from 0.1% to 4.1% and can be roughly divided into two units.

Table 3. Organic carbon, nitrogen, and carbonate content, Hole 511.

Core/Section (interval in cm)	N (%)	C_{org} (%)	C_{org} Corrected for CO_3^{--} (%)	CO_3^{--} (%)
2,CC, 7–9	0.08	0.165	0.12	30
2-4, 10–12	0.06	0.06	0.06	2
3-4, 40–41	0.1	0.7	0.7	
4-2, 118–120	0.1	0.9	0.9	
5-4, 90–92	0.1	0.62	0.62	
6-3, 90–92	0.95	0.44	0.43	2
11-3, 110–111	1.1	0.68	0.65	5
12-1, 80–82	0.12	0.95	0.94	1
15-1, 72–74	0.09	0.44	0.43	2
16-1, 90–92	0.09	0.59	0.58	2
17-2, 60–62	0.04	0.44	0.41	7
18-1, 70–72	0.07	0.37	0.33	11
20-2, 64–66	0.08	0.51	0.44	13
21-1, 15–17	0.05	0.13	0.13	0
24-3, 98–99	0.06	0.32	0.15	53
25-1, 103–104	0.04	0.03	0.03	1
28-1, 78–80	0.06	0.26	0.25	2
28-7, 0–1	0.08	0.62	0.61	1.5
31-3, 144–146	0.1	0.8	0.78	2
32-5, 146–148	0.1	0.85	0.82	3
33-2, 92–94	0.09	0.62	0.60	2.8
33-5, 106–109	0.07	0.6	0.59	2.0
34-2, 113–115	0.09	0.71	0.70	2.0
34-7, 51–54	0.08	0.67	0.54	20.0
36-2, 141–143	0.07	0.57	0.54	6
38-2, 41–42	0.09	0.69	0.67	2.9
39-3, 81–82	0.08	1.9	1.14	40
40-2, 10–11	0.09	0.63	0.63	
41-3, 36–37	0.06	0.18	0.18	0.5
43-1, 23–25	0.08	0.26	0.26	0.4
44-3, 51–53	0.08	0.34	0.25	25.5
45-2, 93–95	0.07	0.31	0.31	
46-3, 61–63	0.1	0.42	0.42	
50-3, 62–64	0.06	0.26	0.21	21.0
51-1, 141–143	0.07	0.1	0.1	0
53-5, 65–66	0.03	0.11	0.08	25.5
55-5, 140–142	0.06	0.27	0.26	3
55-6, 127–129	0.06	0.68	0.68	
56-2, 74–76	0.47	0.15	0.14	8
56-5, 56–58	0.5	0.51	0.51	
57-3, 100–102	0.1	1.7	1.7	
58-1, 72–74	0.07	0.63	0.63	
59-1, 86–88	0.2	4.1	2.8	35.0
61-2, 81–82	0.16	3.8	3.7	3
62-3, 54–56	0.14	2.55	2.55	
63-3, 16–17	0.19	3.3	3.3	
66-3, 92–94	0.2	4.2	4.1	2
68-2, 71–72	0.18	3.2	3.2	
69-3, 75–77	0.19	2.95	2.95	
70-4, 96–98	0.16	2.85	2.85	

Samples from the Tertiary and Cretaceous down to the Aptian contain only small quantities of organic carbon. This is in agreement with the general features of sediments exhibiting brighter and reddish colors and indications of bioturbation. Probably this type of organic matter belongs to a kerogen Type III originating from continental runoff of higher terrestrial plant debris and perhaps reworked coaly and/or oxidized sedimentary particles. If this is so, the low content of organic carbon is apparently a result of a low but relatively constant ratio of the flux of organic and mineral matter through the water column (von der Dick, 1979). Extreme low values at the Tertiary/Cretaceous boundary can be assigned to more variable conditions. Pyrolysis/fluorescence data (Fig. 11) are very low and seem to reflect primarily the crudity of the method. The sedimentary sequence completely changed when the Lower Cretaceous black shales were encountered. Organic carbon values average 3.5%.

Pyrolysis/fluorescence data exhibit an extreme increase compared to the claystones and muddy nanno-

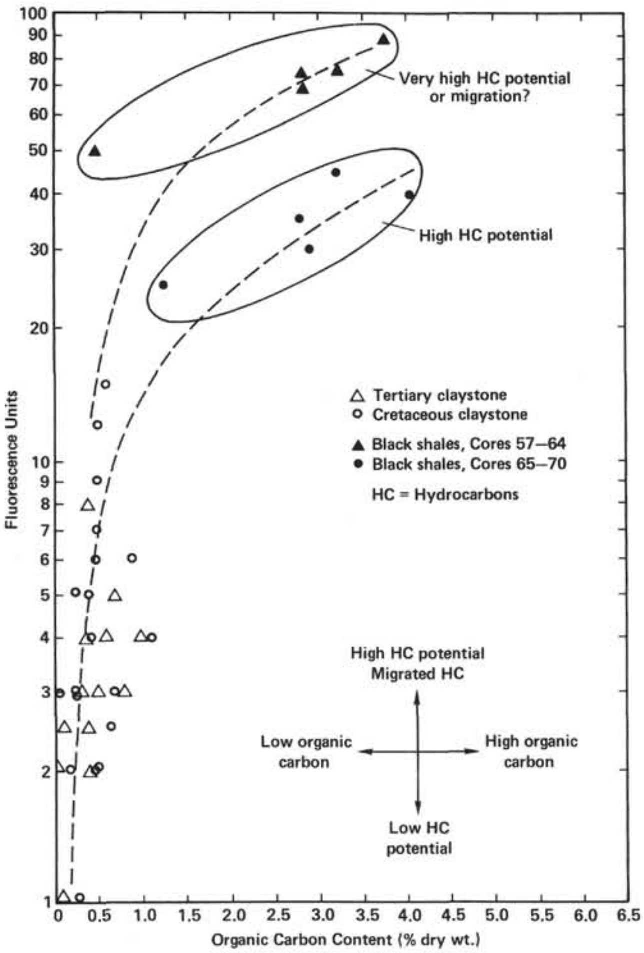


Figure 11. Fluorescence of pyrolyzed sediments of different types and ages plotted against carbon content (shipboard measurements).

fossil chalk in the upper part of the section (Fig. 11), thus reflecting the high potential of the black shales for generating oil. Although very crude, this quick method seems to be a useful indicator for any hydrocarbon-bearing sediments and accumulations, whether free or bound to the kerogen matrix.

When Core 60 was drilled at about 530 meters and retrieved, an intense odor of oil was present. This odor was most intense in Cores 60–63 and dropped to moderate intensity in the subsequent cores. Methane was detected first in Core 41, and ethane was initially encountered in Core 54, where it exhibited a C_1/C_2 ratio of 400. This ratio decreased to a minimum value of $C_1/C_2 = 93$ in Core 61 (Fig. 12) and fluctuated between 130 and 210 in the deeper parts of the section. The same trend could be traced in the C_2/C_5 and C_2/C_3 ratios (Fig. 12). In general, low C_1/C_2, C_2/C_3, and C_2/C_5 ratios together with strong odor and high fluorescence values indicate a high degree of maturity. However, an objective determination of the thermal evolution is necessary; this was done in shore laboratory studies described hereafter.

The upper part of the shales (Core 60–63) seems to be of special interest for hydrocarbon generation and migration. Indications for a high hydrocarbon potential and/or a migration of released low-molecular organics within this part include (1) the intense odor of oil; (2) the minimum values for C_1/C_2; C_2/C_3; C_2/C_5 (Fig. 12); inversion of iC_4/nC_4 (Table 4); and absolute maximum fluorescence values (Fig. 11).

Gaseous hydrocarbons encountered in the hole consist predominantly of methane up to 30%, followed by ethane up to 0.4% and higher hydrocarbons, each decreasing in concentration by about one order of magnitude per increasing carbon number. Ratios of C_1/C_2, C_1/C_2, and C_2/C_5 follow the *same pattern below Core 63*, but are *different above Core 60.*

These features of Cores 63-70, reflecting "in phase" behavior (Whelan, 1979), were also recognized in Site 397; the behavior is apparently a result of an *in situ* reaction. Migrating hydrocarbons, if leaving the source rock, are *not in phase* because of the now discernible separation process involved in migration and diffusion. The ratio of iC_5/nC_5 is always 1, except in Cores 60-63 (Table 4). Indeed, this inversion is a result either of a different organic facies or of migration toward barren sediments across a border. If a migration has taken place, light hydrocarbons generated below this border (in phase) are selectively separated when reaching the denser chalks. According to their molecular size and form, volatility, water solubility, and polarity (which are important for migration and diffusion processes to take place), these compounds are gradually allowed to pass the border.

General Observations from Shipboard and Shore Laboratory Studies

Amount and Type of Organic Matter

The black shales of Site 511 (Lithologic Unit 6) exhibit high organic-carbon contents, on average about 3.5% per dry weight. Both microscopy and geochemical analyses reveal that the high organic content is the result mainly of an accumulation of liptinitic (to a great part marine) organic matter. Because of the high content of organic carbon and high amounts of liptinitic ("bituminous") organic matter, the black shales have an excellent potential to generate hydrocarbons from the source rock at stages of a higher maturity. Based on Rock-Eval pyrolysis and microscopy, the type of organic matter present in the shales can be defined as a kerogen Type II.

The organic gross composition of the Aptian–Upper Jurassic shales is relatively homogeneous throughout the cored sections. Nevertheless, a detailed geochemical analysis shows a general decrease in the contribution of land-derived organic matter from the Jurassic toward the lower Albian. This trend is in agreement with the occurrence of marine chalks at the top of the shales.

The change from euxinic conditions toward a better-ventilated sedimentary system on the Maurice Ewing Bank is reflected by the rapid drop of organic carbon within a "transitional zone" (Deroo et al., this volume) to lower and very low values at the boundary of the Aptian/Albian. The drop of organic carbon accompanies a general shift from a bituminous organic facies to a non-marine and residual type of organic matter (von der Dick et al.; Deroo et al.; both this volume).

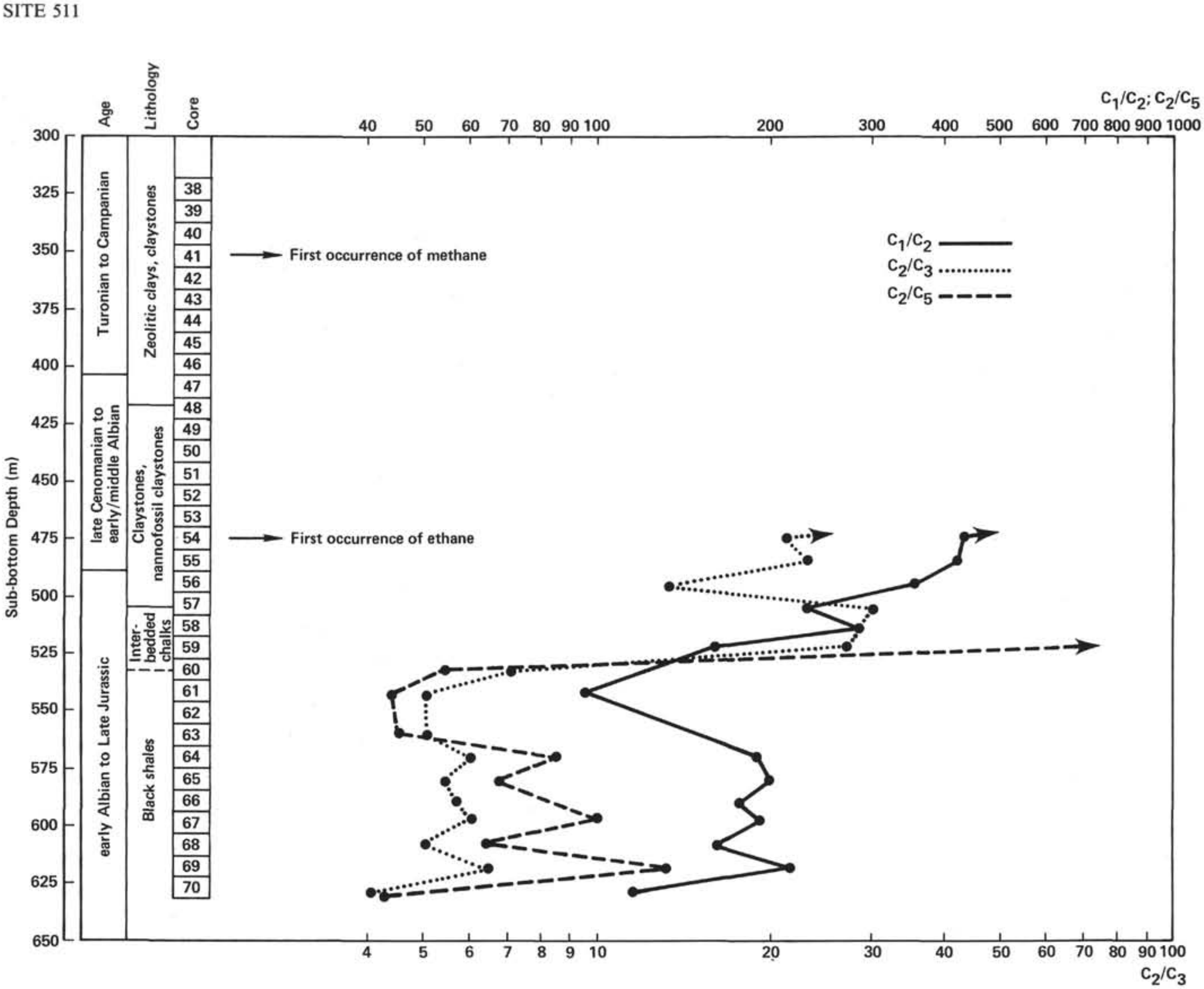


Figure 12. Gaseous hydrocarbon ratios within the Mesozoic sediments (shipboard measurements).

Table 4. Analysis of gas pockets, Hole 511, Cores 52–70.

	52	54	55	56	57	58	59	60	61	63	64	65	66	67	68	69	70
C_1/C_2	./.	430	422	353	236	286	160	120	95	152	188	200	176	193	158	209	114
C_2/nC_3	./.	21	23	13	30	29	27	7	5	5	6	5.4	5.7	6	5	6.5	4
C_2/nC_5	./.	$>^a8^3$	$>^a6^3$	$>10^3$	$>10^3$	$>10^3$	660	54	44	45	86	67	83	100	64	133	42
iC_4/nC_4	./.	./.	./.	./.	<1	<1	<1	<1	<1	>1	>1	>1	>1	>1	>1	2	>1
$neoC_5/nC_5$	>10	>10	>1	>10	./.	>10	1	0.5	0.6	1.1	1.4	1.4	1.2	1.1	1	1.3	1.3
	← Zone of Diffusion and Scattering →							← Zone of Accumulation? →			← Zone of Generation →						

[a] Limits of detection.

The remarkable change in the composition and quantity of organic matter at the Aptian/Albian boundary can be related to the improvement of the water circulation on the Falkland Plateau and in other southern parts of the early South Atlantic Ocean (Reyment, 1980). Apart from a few exceptions, a residual type of organic matter represents the organic fraction of the Albian–Recent sediments. The low organic content (about 0.2–0.3% for Units 1, 3, and 5 and Subunit 2B, and 0.4–0.5% for Subunit 2A and Unit 4) and the dominating inert type of organic carbon indicate environmental conditions opposite to those in the black shales. The slightly higher accumulation of organic carbon in Subunit 2A and Unit 4 may be related to the high sedimentation rates of these units, which hinder through rapid burial the almost complete oxidation of organic matter. Microscopic analyses made on shore and chemical analyses of the extracts suggest that *no* liquid compounds have migrated upward in the section.

The redistribution of light hydrocarbons has been minimal and is discernible only at major stratigraphic or lithologic boundaries (i.e., the Tertiary/Cretaceous unconformity, or the transition from the black shales to the Cretaceous chalks and claystones).

Thermal Evolution of the Black Shales

The vitrinite reflectance, as an indicator of the thermal history of organic matter, is 0.44% Rm downhole at a depth of 630 meters. Therefore, the shales are still in an immature stage of oil generation. The low amounts of extractable compounds (bitumen or extract) and of light hydrocarbons (Schaefer et al., this volume), as well as the patterns of the hydrocarbons all indicate low maturity. Thus, the distribution of hydrocarbons reflects mainly the type of organic matter rather than a diagenetic transformation.

The gradients of several parameters as indicators of an increasing thermal evolution with depth of burial are quite high, apparently in response to the relatively high thermal gradient of about 7°C/100 m (Langseth and Ludwig, this volume). On the Northwest African continental margin, which has a much lower thermal gradient of 4.2°C/100 m, a comparable vitrinite reflectance is reached at a depth of 1400 meters in sediments of an equivalent age (Cornford et al., 1979). Decreasing atomic N/C and O/C ratios of bitumen point to splitting off of functional groups and correspond to the slow increase of hydrocarbons (normalized to organic carbon) with depth of burial. We expect, therefore, that the zone of oil formation will be quickly reached in the black shales in regions of somewhat deeper burial and comparable thermal gradient (either updip on Maurice Ewing Bank or downdip in the "basinal" province of the Falkland Plateau).

An estimation of the vitrinite reflectance in the Tertiary claystones is 0.26% Rm. The only slightly higher degree of maturity at the top of the Cretaceous black shales does not allow for significant additional overburden at the Cretaceous/Tertiary disconformity of Site 511.

PHYSICAL PROPERTIES

Sound velocities, gravimetric densities, vane shear penetration, and thermal conductivity measurements were taken. In general, sound velocity and gravimetric density were measured on identical samples. Penetration and vane shear were taken as close to the sample as possible without disturbing it. From the basic measurements, acoustic impedance, water content, and porosity have been computed without corrections for salt content. For the wet-bulk density samples, determined by the cylinder technique, a raw, estimated shrinkage coefficient was determined. The procedures for determination of sound velocity and vane shear strength followed Boyce (1976). The results of the physical properties measurements are given in the core descriptions at the end of this chapter.

Wet-Bulk Density

The wet-bulk density data discussed here were determined by gravimetric methods, either by cylinder technique (in soft sediments) or chunk technique. For the uppermost few meters only the GRAPE densities must suffice, because no gravimetric determinations were possible in this section (Table 5).

Table 5. GRAPE densities, Cores 1 and 2.

Core/Section	Dist. from Top of Section (m)	GRAPE Density
1-1	0	2.2
	0.4	2.15
	0.5	2.25
	1.5	1.9
1-2	0	1.9
	1.4	1.9
1-3	0	1.8
	1.4	1.6
2-1	0	1.4

sity decreases again until it reaches a value of 1.4 g/cm^3 in Core 2 at the boundary of Oligocene sediments.

The gravimetric data show stable values of 1.5 g/cm^3 down to 100 meters; values then decrease to 1.2 g/cm^3 between 100 and 190 meters below seafloor. The reduction corresponds to an increase in diatom content, although drilling disturbance could also contribute.

In association with the Tertiary/Cretaceous boundary and a change in lithology from diatomaceous oozes to clays, the wet-bulk density changes from 1.2 to 1.6 g/cm^3. In the Cretaceous section down to the bottom of the hole, the bulk density of the clays and claystones increases continuously up to 1.9, even in the black shales below 500 meters. Some low porosity values, up to 2.6, are due to calcareous and sandy layers within the black shales.

Water Content and Porosity

The values for water content and porosity discussed here and plotted in the core descriptions are not corrected for salt water. Because of the homogeneous lithology (at least over large parts of the site), water content and porosity correlate quite well.

Porosity decreases from 80% at the top of the section to 75% at 100 meters and then increases again to 80% at the Tertiary/Cretaceous boundary. In this section the normal inverse relation with bulk density is obvious. In the uppermost Cretaceous, the porosity drops within 50 meters down to 55% and then increases rapidly again to 68%. There is some evidence that an increase in calcium carbonate may in part cause the drop in porosity. A slight deviation of the bulk-density curve from the consolidation trend can be recognized during the same interval.

From 250 meters to the bottom of the hole, the porosity of the fine-grained sediments follows a normal consolidation curve similar to bulk density. Some low porosities, especially in the black shales, are due to carbonates, carbonate sands, and sandy layers.

Sound Velocity

The sound velocities are very stable within the Tertiary sediments, with a mean value of 1.6 km/s for the upper 200 meters. Between 200 and 250 meters a strong increase to 2.5 km/s occurs; it is parallel to the observed drop in porosity in the same interval. The sound velocity is again stable between 250 and 300 meters (1.6–1.8 km/s) and increases to about 2.2 km/s between 300 and 350 meters. From 350 meters down to the bottom of the hole, the fine-grained sediments show a continuous increase in sound velocity from 1.7 to 1.9 km/s. High velocities, mainly in the upper part of the black shales, are caused by calcareous layers and the associated drop in porosity. Large differences between horizontal and vertical velocities are due to shell layers. Down to the Tertiary/Cretaceous boundary the acoustic impedance (velocity × density) is stable, whereas in the Cretaceous it increases continuously owing to the increase of bulk density; all peaks of the sound velocity curve are apparent in the acoustic impedance data.

Penetration and Shear Strength

Penetration was measured down to 400 meters and shear strength down to 300 meters. The penetration values are very high in the upper 130 meters of the section; this may in part be caused by drilling disturbance. Some lower values are due to higher $CaCO_3$ percentages.

From 150 to 210 meters penetration values are stable near 5 mm, whereas below that point penetrations near 2 mm were measured. The change occurs within the interval with significantly lower porosities. The vane shear values are widely scattered and give no more than a general trend since only a few measurements are valid; most of them did not show a clear shear point.

GEOPHYSICS

Correlation of Seismic Reflectors with Lithology

Site 511 is located on the back slope of a cuesta-type sedimentary ridge in the basin province of the Falkland Plateau. The general configuration of reflectors in this province is that of thick sheets of sediments dipping to the south and terminated updip by erosional truncation (Fig. 2) (Ludwig, this volume).

Correlation of geologic units cored with reflectors of the *Conrad* 21-06 seismic line is shown in Figure 13.

Drilling at Site 511 provided definitive information on the nature and age of the wedge of sediments filling the Falkland Plateau Basin. From analyses of vertical reflection and sonobuoy reflection and refraction data, Ludwig and Rabinowitz (1980) conclude that after the inception of seafloor spreading off the north flank of the Falkland Plateau, the plateau was a broad depression well below sea level, bordered on the west by the Falkland Islands Platform, on the north by a continental rim, on the east by the emerged microcontinental Maurice Ewing Bank, and on the south by the North Scotia Ridge. The basin floor thus formed was underlain either by oceanic crust or attenuated continental crust. The configuration of apparently conformable uniform foresets shown by seismic profiles and the configurations shown by Ludwig et al. (1978) strongly indicate deposition as a single, continuous event. Therefore, Ludwig and Rabinowitz (1980) postulate that the wedge of sediments may represent some post-breakup, prograded slope-type deposition of sediments eroded from the continental rim followed by basin-slope and basin-floor seismic facies units of deep-marine, pelagic, and hemipelagic sediments. The reflection geometry and lithology at drill sites indicate shallow-marine coastal downlap of sediments on a paleoshelf edge, followed by slope front fill, and by draping of pelagic sequences.

Heat Flow

At Site 511, a successful heat flow measurement was obtained for the first time on the Falkland Plateau using the DSDP Downhole Temperature Probe (DHTP), consisting of an Uyeda electronic package and von Herzen thermistors. More than 50 previous attempts by Lamont-Doherty scientists to obtain heat flow measurements through use of thermistor probes attached to a conventional piston corer had failed, owing to a seafloor cover of manganese and glacial material which destroyed the probes.

At Site 511 the DHTP was lowered twice, to sub-bottom depths of 52.5 and 113 meters. Readings of thermistor resistance sampled every minute are stored in the probe and are played back and displayed upon retrieval. Resistance readings are then converted to temperature data using the thermistor calibration data. The heave compensator was used during the drilling; this usually results in good stability of the bottom hole assembly in the unconsolidated sediments penetrated by the probe.

The temperature versus time data of the two lowerings were then plotted. The temperatures in the sediments at their depths sub-bottom define a gradient of $0.074°C\ m^{-1}$ (Langseth and Ludwig, this volume).

Thermal conductivities were measured on core samples at irregular intervals aboard ship and on shore. These measurements gave a mean value of $0.842\ W\ °C^{-1}m^{-1}$. The heat flow indicated by these observations is $62.3\ mW\ m^{-2}$ (1.49 HFU), a value compatible with the geological evolution of the plateau.

SUMMARY AND CONCLUSIONS

Site 511 is located about 10 km south of Site 330 (DSDP Leg 36) in the basin province of the Falkland Plateau. The site was drilled and continuously cored to a sub-bottom depth of 632 meters. Heat flow measurements were made in unconsolidated sediments at sub-bottom depths of 52.5 and 113 meters.

Lithostratigraphy

From top to bottom, the sediments cored consist of the following lithologic units:

Unit 1—3 meters of gray to olive gray siliceous oozes and thin foraminiferal oozes of Pliocene–Recent age, with manganese nodules and ice-rafted pebbles and grains.

Unit 2—192 meters of section divisible into two subunits. *Subunit 2A* comprises 182.5 meters of olive to dark gray muddy diatomaceous oozes and muddy nannofossil-diatomaceous oozes spanning the late Eocene–early Oligocene interval. *Subunit 2B* encompasses 9.5 meters, of which only the uppermost 72 cm were recov-

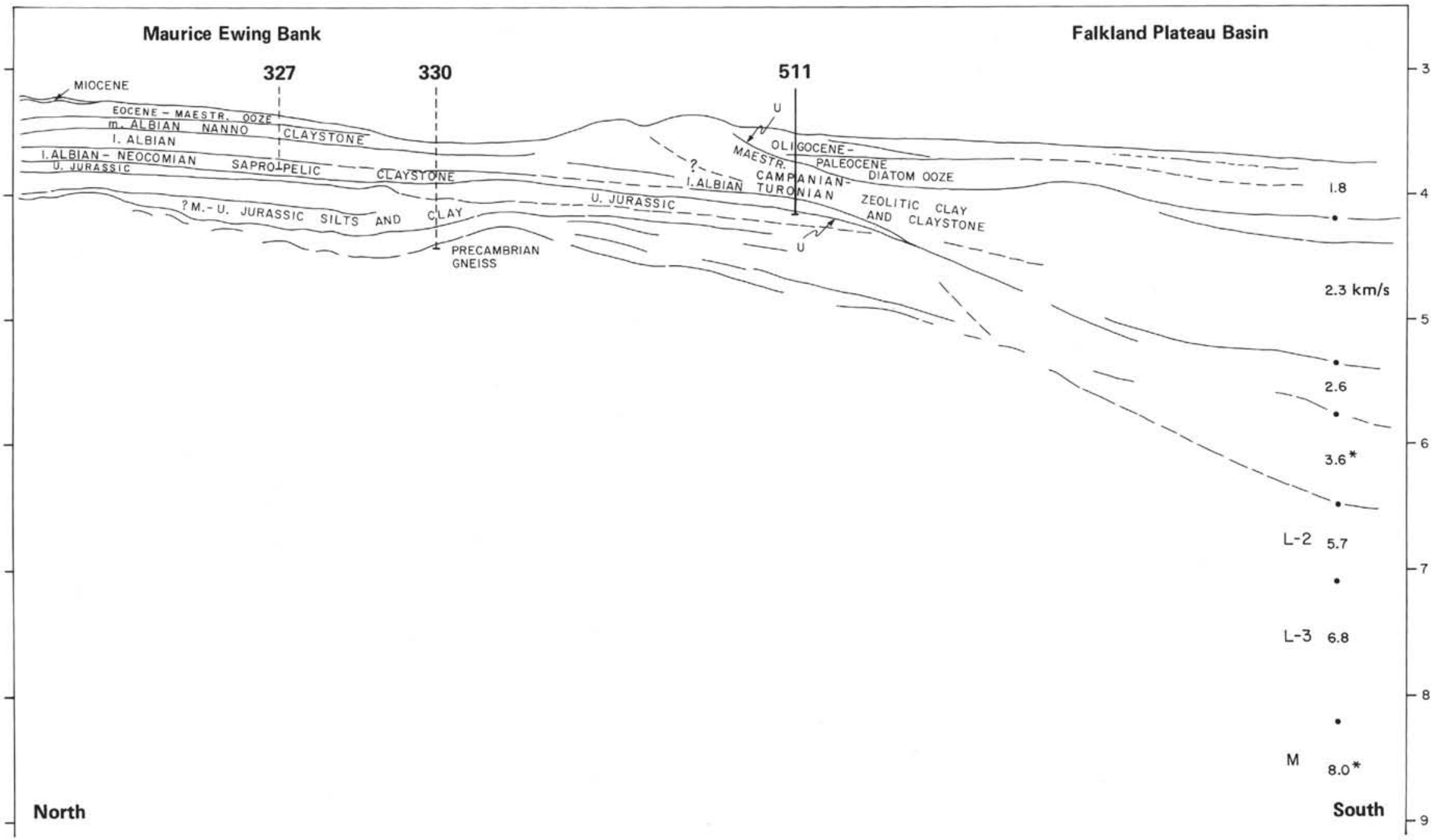


Figure 13. Interpretative line drawing of *Conrad* 21-06 seismic reflection profile (Fig. 2) and correlation with lithology cored at Sites 327, 330, and 511.

ered. It consists of greenish gray pelagic clay with minor glauconite, chert, and volcanic ash, of Paleocene or Eocene age.

Unit 3—14 meters of gray calcareous oozes and zeolitic foraminiferal oozes with occasional chert pebbles and disseminated minor glauconite, of late Campanian(?) to early Maestrichtian age.

Unit 4—203.5 meters of gray to greenish gray zeolitic clays and claystones with intercalations of nannofossil and foraminiferal claystones, ranging in age from Turonian to Campanian-early Maestrichtian.

Unit 5—80 meters of variegated, often reddish brown claystones, nannofossil claystones, and muddy nannofossil chalk, of early Albian to Turonian age.

Unit 6—140 meters of black, massive, thinly laminated mudstones and nannofossil mudstones of Later Jurassic to early Albian age, in places highly petroliferous and indicative of anoxic conditions. Pyrite is common. Belemnite rostra are common, benthic microfossils are essentially absent, and microcoquinas of *Inoceramus* and *Aucellina* occur frequently.

Principal Results

Hiatuses recognized within this succession occur at the Quaternary/Pliocene, Pliocene/early Oligocene, Paleocene or Eocene/Maestrichtian, Cenomanian/Albian, and Upper Jurassic/Lower Cretaceous boundaries. The unconformity that truncates the southward-dipping sheets of sediment on the plateau (Figs. 2 and 13) lies between Units 2 and 3 at Site 511 and probably corresponds to the Paleocene or Eocene/Maestrichtian hiatus, the maximum duration of which was not precisely determined. The unconformity is believed to represent a major erosional surface caused by bottom-current scouring.

Microfossils occur in nearly all of the cores. The most significant biostratigraphic results at Site 511 are the collection of the following assemblages:

1) 183 meters of lower Oligocene and upper Eocene diatomaceous ooze and muddy nannofossil-diatomaceous oozes with exceptionally well preserved and diverse diatoms, radiolarians, and silicoflagellates, together with sufficient numbers of calcareous nannofossils and foraminifers to provide temporal control by correlation with lower-latitude zonations and the well-established New Zealand stages;

2) 183 meters of lower Campanian-Turonian biogenic sediments, sometimes containing rich and diverse planktonic foraminifers and nannofossils not previously described from the high latitudes of the Southern Hemisphere;

3) Continuous cores through most of the Lower Cretaceous-Upper Jurassic black shale and claystone that enabled us to determine stratigraphic subdivisions and to refine paleogeographic reconstructions based on molluskan and microfossil data;

4) Benthic foraminifers and other floral and faunal groups that demonstrate subsidence of the Falkland Plateau with a distinct acceleration at or near the Lower/Upper Cretaceous boundary.

Accumulation rates of biogenic sediments testify to the highly episodic nature of sedimentation on the Falkland Plateau; periods of exceptionally rapid sedimentation separated by hiatuses or condensed intervals seem to be the norm for the area. High productivity of siliceous plankton during the late Eocene-early Oligocene is indicated by the very high sediment accumulation rate (about 44 m/m.y.) calculated for this interval. A rather high sedimentation rate marks the Campanian interval.

Sediments of Tertiary through Albian age contain only small quantities of organic carbon. In contrast, the underlying black shale of Late Jurassic-Aptian age contains 1.7-4.1% organic carbon (average 3.5%). Organic geochemical investigations and ratios of gaseous hydrocarbons suggest that (1) the black shale has not reached a high degree of maturity; (2) the hydrocarbons presently occurring in the black shale were formed *in situ*, that is, the shale is both the source and host rock; and (3) no significant amount of additional overburden is necessary to explain the degree of organic maturation of the black shales.

Drilling at Site 511 provided data that significantly build on drilling results from Leg 36 on Maurice Ewing Bank. They indicate that, with some exceptions, lithostratigraphic units were essentially continuous across the bank and the basin province of the plateau; interruption of units is due largely to erosion. Further, a major erosional event took place at or near the Paleocene or Eocene/Maestrichtian boundary, implying that a circum-Antarctic Australia current may have been in existance and admitted to the area *prior* to the opening of the Drake Passage in the Oligocene-middle Miocene. This, in turn, implies the existence of a passageway for currents between East and West Antarctica during the Late Cretaceous-early Tertiary, a fact which has already been determined from paleomagnetic data.

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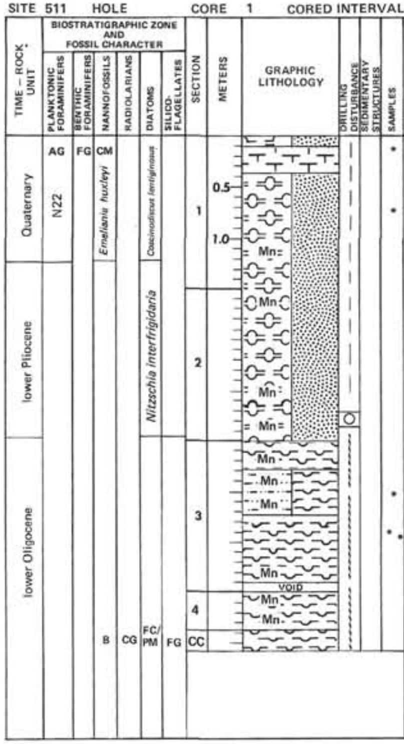
SITE 511 HOLE CORE 1 CORED INTERVAL 0.0–5.0 m



LITHOLOGIC DESCRIPTION

Section 1, 0–11 cm: SILICEOUS GRAVELLY MEDIUM–GRAINED SAND; pale olive (5Y 6/4); sub-angular to angular pebbles <2,5 cm, including Mn nodule, granite, and basalt pebbles up to 4 cm.

Section 1, 11–37 cm: FORAMINIFER OOZE; white (5Y 8/1) to gray (5Y 5/1), with 3–4 cm lenses of gravelly, medium-grained quartz sand *and minor ash and pebbles.*

Section 1, 37–150 cm and Section 2, 1–144 cm: GRAVELLY DIATOMACEOUS MEDIUM-GRAINED QUARTZ SAND. Mud content varies irregularly. Mn nodules and encrustations present.

Section 2, 144–150 cm and Section 3, 0–20 cm: DIATOM OOZE; pale olive (5Y 6/3) with lenses of olive gray (5Y 5/2).

Section 3, 20–74 cm: MANGANIFEROUS MUDDY DIATOM OOZE; dark grayish brown (2.5Y 4/2); highly disturbed lens of siliceous gravelly muddy sand (5Y 6/3) at 35–40 cm. Occasional clasts (<2 cm) of diatom ooze.

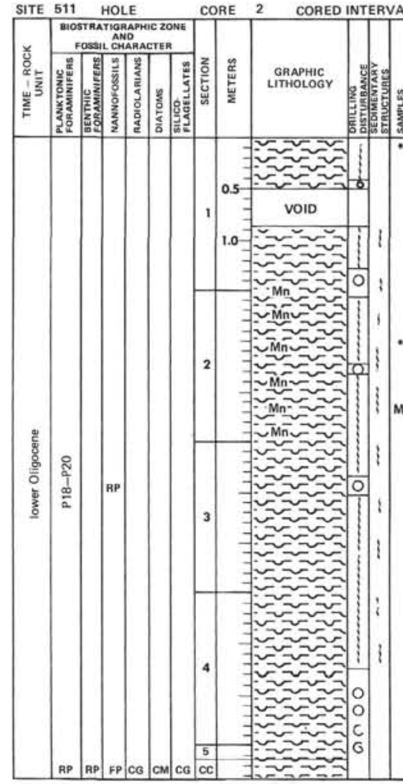
Section 3, 74–139 cm and Section 4, 0–39 cm: DIATOM OOZE; as above with lenses of muddy ooze (5Y 5/2) at 74–130 cm and siliceous gravelly muddy sand (5Y 6/3) at 89–94 cm.

SMEAR SLIDE SUMMARY

	1-14	1-71	3-54	3-95	3-100
	D	D	D	M	D
Quartz	2	37	4	3	7
Feldspar	TR	TR	1	–	1
Mica	TR	–	–	TR	–
Heavy minerals	TR	1	TR	–	TR
Clay minerals	12	30	36	20	15
Carbonate unspec.	10	–	–	–	–
Foraminifers	60	TR	–	TR	TR
Nannofossils	TR	–	TR	–	–
Diatoms	15	30	50	74	74
Radiolarians	1	2	1	2	2
Silicoflagellates	TR	–	–	TR	–
Sponge spicules	TR	TR	1	1	1
Micronodules	–	–	7	–	–

CARBONATE BOMB:
4, 31–33 (2)

SITE 511 HOLE CORE 2 CORED INTERVAL 5.0–14.5 m



LITHOLOGIC DESCRIPTION

DIATOM OOZE; pale olive (5Y 6/3) with occasional intervals of increased clay content (Section 1, 15–17 cm; Section 4, 21–22 cm, 70–73 cm). Clay intervals gray (5Y 5/1). Minor bioturbation below Section 1, 104 cm. Rare subangular pebbles (2 cm) in Sections 1 and 3.

SMEAR SLIDE SUMMARY

	1-10	2-51
	D	D
Quartz	3	3
Feldspar	–	TR
Heavy minerals	–	TR
Clay minerals	25	10
Diatoms	70	83
Radiolarians	1	2
Silicoflagellates	1	1
Sponge spicules	1	1
Volcanic glass	TR	–

CARBONATE BOMB:
3, 120–122 (6)

MAGNETIC DATA: 2-113
Inclination –60.4
Declination 96.6
Intensity (emu/cc) 0.354E–05

GRAIN SIZE:
1-30 (9, 22, 69)
4-41 (1, 33, 67)

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.

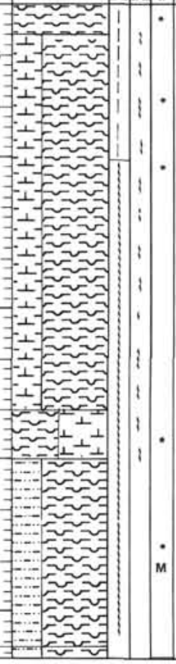
SITE 511 HOLE CORE 3 CORED INTERVAL 14.5–24.0 m

TIME – ROCK UNIT: lower Oligocene

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER: PLANKTONIC FORAMINIFERS P18–20, RP; BENTHIC FORAMINIFERS RM; NANNOFOSSILS *Reticulofenestra umbilica*, C/MG, FP; RADIOLARIANS CG; DIATOMS CM; SILICO-FLAGELLATES FG

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

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES: M

LITHOLOGIC DESCRIPTION

Section 1, 0–33 cm: DIATOM OOZE; dark gray (2.5Y 4/0); carbonate content increases downward. Small (<1 cm) pale yellow (2.5Y 8/4) sedimentary clasts at 29–31 cm.

Section 1, 33 cm–Section 3, 100 cm: NANNOFOSSIL DIATOMACEOUS OOZE: light gray (2.5Y 7/0), very slightly bioturbated; occasional irregular dark stringers, some with volcanic ash.

Section 3, 100–150 cm: DIATOMACEOUS NANNOFOSSIL OOZE; gray (2.5Y 6/0) and very dark gray (2.5Y 3/0); irregularly interbedded with nannofossil diatom ooze; very slightly bioturbated.

Section 4 and Section 5, 0–33 cm: MUDDY DIATOMACEOUS OOZE; dark gray (2.5YR 4/0) with very dark gray (2.5YN 3/0) coarser grained zones containing glauconite and high content of biogenic siliceous skeletons (radiolarians and diatoms). Nannofossil content variable. Very slightly bioturbated throughout.

Core-Catcher: MUDDY DIATOMACEOUS OOZE; gray (2.5Y 5/0).

SMEAR SLIDE SUMMARY

	1-16 D	1-94 D	2-18 D	3-131 D	4-87 D
Quartz	1	1	TR	TR	TR
Mica	TR	–	TR	1	–
Clay minerals	8	1	–	–	30
Foraminifers	–	–	TR	TR	–
Nannofossils	12	30	35	50	5
Diatoms	77	65	60	45	64
Radiolarians	TR	1	1	2	TR
Silicoflagellates	2	1	1	1	1
Sponge spicules	TR	1	1	1	TR

CARBONATE BOMB:
5, 7–8 (2)

MAGNETIC DATA:	4-102
Inclination	–30.7
Declination	31.7
Intensity (emu/cc)	0.260E–06

GRAIN SIZE:
2-55 (0, 31, 68)
4-55 (2, 30, 68)

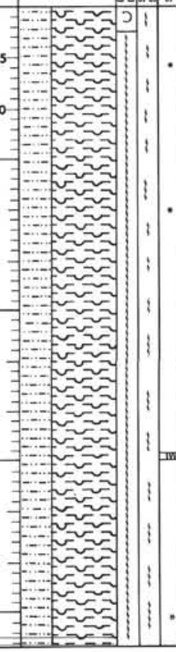
SITE 511 HOLE CORE 5 CORED INTERVAL 33.5–43.0 m

TIME – ROCK UNIT: lower Oligocene

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER: PLANKTONIC FORAMINIFERS P18–20, RP; BENTHIC FORAMINIFERS RP; NANNOFOSSILS CM; RADIOLARIANS *Blackites spinosus*, CG; DIATOMS *Theocyrtis tuberosa*, AM; SILICO-FLAGELLATES *Hemiaulus incisus*, CG

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

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES: IW

LITHOLOGIC DESCRIPTION

MUDDY DIATOMACEOUS OOZE; as in Core 4, dark gray (2.5Y 4/0); very slightly bioturbated throughout; diatom content increases downward.

SMEAR SLIDE SUMMARY

	1-60 D	2-50 D	5-10 D
Quartz	–	1	2
Mica	TR	–	–
Clay minerals	37	33	14
Foraminifers	TR	TR	TR
Nannofossils	5	3	5
Diatoms	56	60	70
Radiolarians	1	1	2
Silicoflagellates	1	1	1
Sponge spicules	TR	TR	1
Micronodules	–	1	1

CARBONATE BOMB:
5, 7–9 (6)

GRAIN SIZE:
2-32 (1, 24, 75)
4-32 (1, 32, 67)

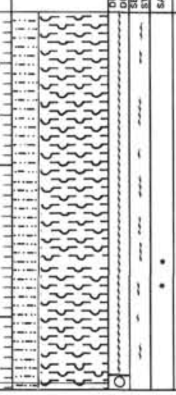
SITE 511 HOLE CORE 4 CORED INTERVAL 24.0–33.5 m

TIME – ROCK UNIT: lower Oligocene

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER: PLANKTONIC FORAMINIFERS P18–20, RP; BENTHIC FORAMINIFERS RP; NANNOFOSSILS CM; RADIOLARIANS CG; DIATOMS CM; SILICO-FLAGELLATES CG

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

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

Section 1–Section 3, 65 cm: MUDDY DIATOMACEOUS OOZE; gray (2.5Y 5/0) and dark gray (7.5YR 4/0) with lenses and stringers of light gray (2.5YN 7/0–2.5Y 7/0) ooze containing high nannofossil percentages. Very slight bioturbation throughout.

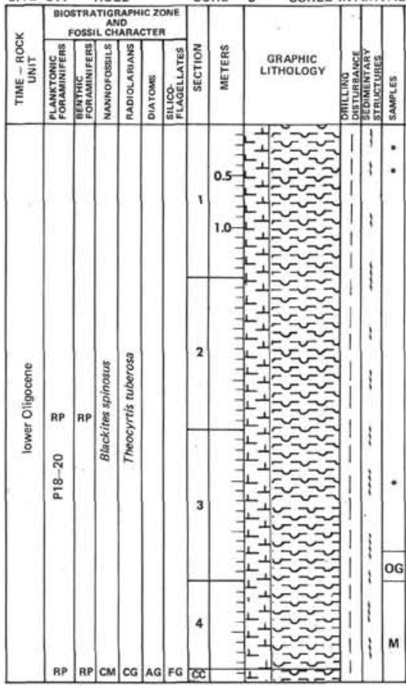
Core-Catcher: MUDDY DIATOMACEOUS OOZE; gray (2.5Y 5/0).

SMEAR SLIDE SUMMARY

	2-99 M	2-120 D
Quartz	1	1
Mica	–	TR
Heavy minerals	TR	–
Clay minerals	–	30
Foraminifers	–	TR
Nannofossils	53	10
Diatoms	40	58
Radiolarians	3	–
Silicoflagellates	1	–
Sponge spicules	1	TR
Volcanic glass	1	–

CARBONATE BOMB:
2, 61–62 (8.5)

SITE 511 HOLE CORE 6 CORED INTERVAL 43.0–52.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL DIATOMACEOUS OOZE; gray (2.5Y 5/0), with intervals 2–3 cm thick of darker ooze (2.5Y 4/0) where nannofossil content is lower, i.e. Section 1, 0–52 cm; Section 2, 0–10, 60–80, and 127–147 cm; and Section 3. Very slight bioturbation throughout. Clay content appreciable Section 1, 0–50 cm, decreasing downward.

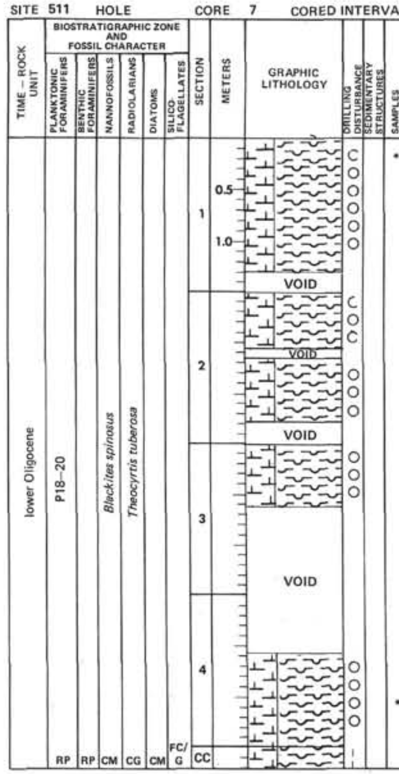
SMEAR SLIDE SUMMARY

	1-28	1-41	3-56
	M	D	D
Quartz	TR	1	1
Clay minerals	35	3	–
Foraminifers	TR	TR	1
Nannofossils	3	20	23
Diatoms	60	70	69
Radiolarians	1	4	3
Silicoflagellates	1	1	1
Sponge spicules	TR	TR	1
Volcanic glass	–	1	1

CARBONATE BOMB:
4, 58–60 (5.5)

MAGNETIC DATA:	4-69
Inclination	– 2.3
Declination	76.1
Intensity (emu/cc)	0.430E–06

SITE 511 HOLE CORE 7 CORED INTERVAL 52.5–62.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL DIATOMACEOUS OOZE, as in Core 6; with clasts (1–2 cm) of creamy (2.5Y 7/2) to light gray, stiffer nannofossil diatom ooze that contain less clay than the soupy matrix. Abundant Mn nodules and lithic clasts (quartzite, gravity, ash/zeolite); larger Mn nodules noted in graphic column. In Core-Catcher chert(?), Mn nodules and other lithic clasts.

SMEAR SLIDE SUMMARY

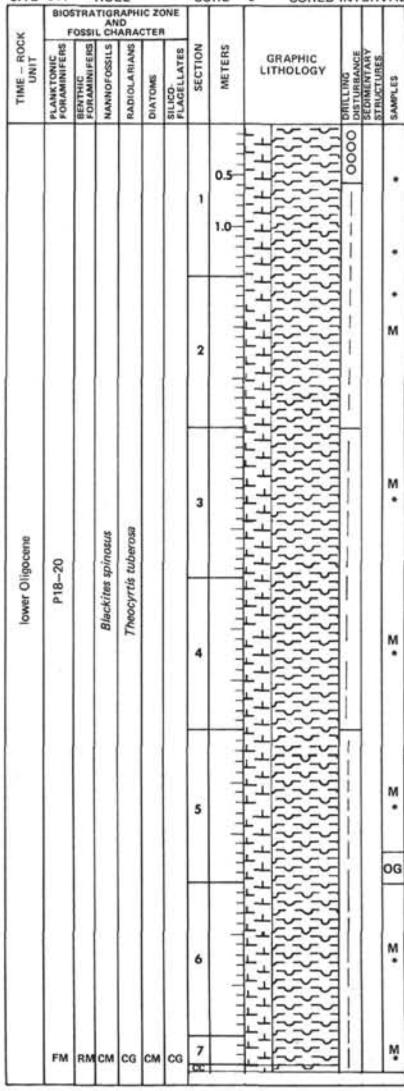
	1-20	4-103
	M	D
Quartz	TR	TR
Mica	TR	–
Clay minerals	25	13
Foraminifers	TR	–
Nannofossils	15	25
Diatoms	60	60
Radiolarians	TR	TR
Sponge spicules	TR	TR
Micronodules	TR	2

SITE 511 HOLE CORE 8 CORED INTERVAL 62.0–71.5 m

LITHOLOGIC DESCRIPTION

NANNOFOSSIL DIATOMACEOUS OOZE; Core-Catcher only; dark gray (2.5Y 4/0), containing Mn nodule (2.5 cm), subangular granite clast and light gray (5Y 7/2) clast of nannofossil-rich diatom ooze.

SITE 511 HOLE CORE 9 CORED INTERVAL 71.5–80.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL DIATOMACEOUS OOZE; dark gray (5Y 4/1), slightly mottled, homogeneous. Abundant Mn nodules up to 3 cm, and sub-angular to sub-rounded clasts, up to 4 cm, of varied lithologies, in upper 60 cm of Section 1. Also, in that interval, 1–2 cm lenses of light gray (2.5Y 7/2) slightly diatomaceous fine quartz sand.

SMEAR SLIDE SUMMARY

	1-58	1-125	2-75	3-75	4-75	5-75	6-75	7-50
	M	D	D	D	D	D	D	D
Quartz	50	TR	1	1	2	TR	2	TR
Mica	–	–	–	–	–	TR	–	–
Clay minerals	–	11	10	13	11	24	20	23
Zeolites	2	TR	TR	TR	2	TR	TR	TR
Foraminifers	35	TR	TR	TR	1	–	–	1
Nannofossils	–	25	25	20	25	20	20	25
Diatoms	10	60	60	65	55	50	55	50
Radiolarians	–	2	2	TR	–	–	–	–
Silicoflagellates	–	–	–	–	–	TR	–	–
Sponge spicules	–	–	–	–	–	1	–	TR
Micronodules	3	2	2	1	3	2	1	1
Volcanic glass	–	–	–	–	–	1	2	–

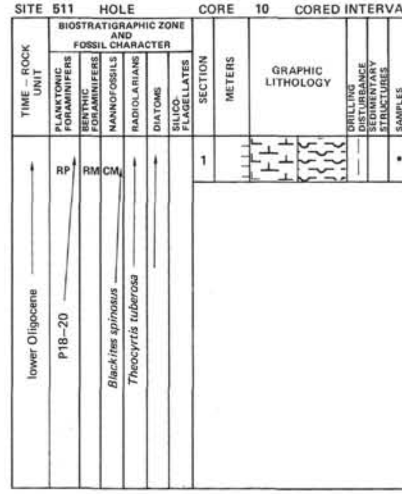
CARBONATE BOMB:
3, 111–112 (9)

MAGNETIC DATA:	2-60	3-60	4-60	5-60
Inclination	50.2	– 0.2	–14.4	–17.4
Declination	52.1	175.5	306.7	41.8
Intensity (emu/cc)	0.140E–06	0.640E–06	0.320E–06	0.160E–06

MAGNETIC DATA:	6-60	7-11
Inclination	–28.0	–40.7
Declination	330.2	348.9
Intensity (emu/cc)	0.150E–06	0.200E–06

GRAIN SIZE:
2-70 (2, 32, 66)
4-70 (2, 38, 60)
6-70 (6, 41, 53)

SITE 511 HOLE CORE 10 CORED INTERVAL 80.0–89.5 m



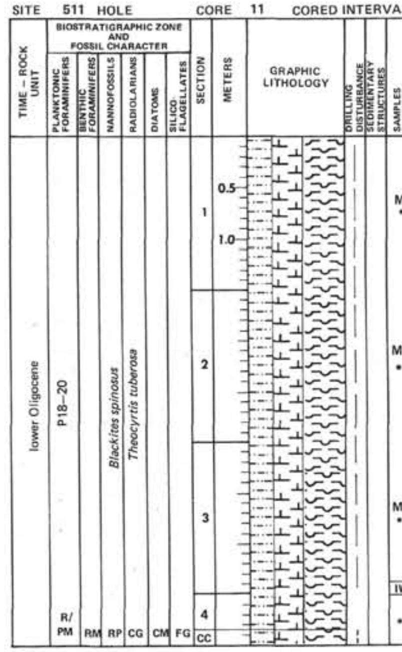
LITHOLOGIC DESCRIPTION

NANNOFOSSIL DIATOMACEOUS OOZE; as in previous cores; dark gray; slightly more calcareous. High clay content. Pebble (2x5x6 cm) of finely laminated fine sandstone at 38–40 cm.

SMEAR SLIDE SUMMARY

	1-24
	D
Quartz	1
Clay minerals	26
Zeolites	1
Foraminifers	2
Nannofossils	30
Diatoms	40
Sponge spicules	TR

SITE 511 HOLE CORE 11 CORED INTERVAL 89.5–99.0 m



LITHOLOGIC DESCRIPTION

MUDDY NANNOFOSSIL DIATOMACEOUS OOZE; dark gray (5Y 4/1); massive; slightly mottled; somewhat more calcareous; becoming stiffer down core. Prominent burrows in Section 2, 30–50 cm.

SMEAR SLIDE SUMMARY

	1-75	2-75	3-75	4-32
	D	D	D	D
Quartz	TR	TR	1	TR
Heavy minerals	–	–	–	2
Clay minerals	20	25	27	25
Zeolites	2	TR	–	TR
Foraminifers	2	1	1	–
Nannofossils	35	25	25	20
Diatoms	40	45	45	50
Radiolarians	–	2	–	–
Sponge spicules	–	1	–	–
Volcanic glass	TR	–	–	–
Micronodules	1	1	1	3

CARBONATE BOMB:
2, 123–125 (10)

MAGNETIC DATA:	1-61	2-61	3-61
Inclination	–54.0	–22.7	19.4
Declination	182.1	3.3	183.2
Intensity (emu/cc)	0.570E–06	0.167E–05	0.510E–06

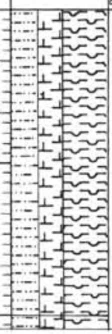
GRAIN SIZE:
1-71 (1, 36, 63)
3-71 (1, 38, 62)

SITE 511 HOLE CORE 12 CORED INTERVAL 99.0–108.5 m

Time-rock unit: lower Oligocene

Biostratigraphic zone and fossil character: Planktonic foraminifers: P18–20 (RP); Benthic foraminifers: RM; Nannofossils: *Blackites spinosus* (FM); Radiolarians: *Theocyrtis tuberosa* (CG); Diatoms: C/MG; Silicoflagellates: FG

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



LITHOLOGIC DESCRIPTION

MUDDY NANNOFOSSIL DIATOMACEOUS OOZE; as in previous core; dark gray (5Y 4/1); slightly mottled; more indurated than overlying cores. Very fine sandy, glauconite-rich, very dark gray (5Y 3/1) lens, 2 cm thick, in Section 2, 74 cm. Lowest 50 cm of Section 2, lighter gray (5Y 5/1), as in Core-Catcher.

SMEAR SLIDE SUMMARY

	1-75	2-74	2-82
	D	M	D
Quartz	1	5	TR
Mica	–	10	1
Pyrite	–	TR	–
Other heavy minerals	1	–	–
Clay minerals	25	–	18
Glauconite	–	60	2
Foraminifers	–	5	TR
Nannofossils	20	–	25
Diatoms	50	15	50
Radiolarians	–	5	–
Sponge spicules	1	–	2
Micronodules	2	2	–
Volcanic glass	–	TR	–

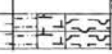
CARBONATE BOMB:
2, 111–113 (11.5)

SITE 511 HOLE CORE 13 CORED INTERVAL 109.5–113.0 m

Time-rock unit: lower Oligocene

Biostratigraphic zone and fossil character: Planktonic foraminifers: P18–20 (RM); Benthic foraminifers: RM; Nannofossils: *Blackites spinosus* (FM); Radiolarians: *Theocyrtis tuberosa* (CG); Diatoms: CM; Silicoflagellates: FG

Sections: 1, CC



LITHOLOGIC DESCRIPTION

NANNOFOSSIL DIATOMACEOUS OOZE; as in previous cores; gray (5Y 3/1); stiff.

SMEAR SLIDE SUMMARY

	1-10
	D
Quartz	2
Clay minerals	17
Glauconite	1
Nannofossils	25
Diatoms	50
Volcanic glass	1

SITE 511 HOLE CORE 14 CORED INTERVAL 119.0–128.5 m

Time-rock unit: lower Oligocene

Biostratigraphic zone and fossil character: Planktonic foraminifers: P18–20; Nannofossils: *Blackites spinosus*; Radiolarians: *Theocyrtis tuberosa*; Diatoms: CM; Silicoflagellates: FG

Section: CC

LITHOLOGIC DESCRIPTION

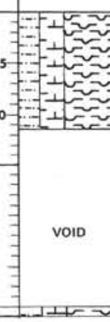
GRAVEL in Core-Catcher; assorted pebbles (2–7 cm), angular to subrounded; granite, fine sandstone, Mn nodules.

SITE 511 HOLE CORE 15 CORED INTERVAL 128.5–138.0 m

Time-rock unit: lower Oligocene

Biostratigraphic zone and fossil character: Planktonic foraminifers: P18–20 (RP); Benthic foraminifers: RP; Nannofossils: *Blackites spinosus* (CM); Radiolarians: *Theocyrtis tuberosa*; Diatoms: CM; Silicoflagellates: FG

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



LITHOLOGIC DESCRIPTION

NANNOFOSSIL DIATOMACEOUS OOZE; as in previous cores; gray (5Y 5/1 to 5Y 6/1); homogeneous; slightly mottled; less indurated. Large, fine-grained sandstone cobble in top 7 cm.

SMEAR SLIDE SUMMARY

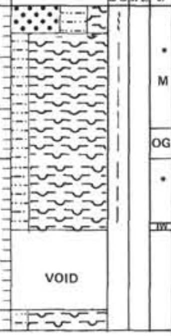
	1-56
	D
Quartz	1
Clay minerals	15
Foraminifers	1
Nannofossils	25
Diatoms	55
Sponge spicules	1
Micronodules	2

CARBONATE BOMB:
1, 72–74 (8)

GRAIN SIZE:
1-68 (1, 43, 56)

SITE 511 HOLE CORE 16 CORED INTERVAL 138.0–147.5 m

Time-rock unit	upper Eocene
Planktonic foraminifers	P15–16
Radiolarians	*Theocyrtis tuberosa*
Silicoflagellates	*Bachmannocena spinosa*
Fossil character (Radiolarians / Diatoms / Silicoflagellates)	CG / C/PM / FG
Sections	1, 2, CC
Meters	0.5, 1.0
Samples	•, M, OG, •, IW



LITHOLOGIC DESCRIPTION

MUDDY DIATOMACEOUS OOZE; olive gray (5Y 4/2); slightly mottled. Small concentrations (<0.5 cm) glauconite-rich ooze in Section 1, 21 cm and between 80 and 120 cm.

In Section 2, 21–42 cm, marked increase in glauconite content and in fine horizontal gray (5Y 5/1) laminae; top contact of this interval is sharp, inclined. Section 2, 42–64 cm is gray (5Y 5/1), very slightly mottled.

Top 17 cm of core are very dark gray (5Y 3/1), highly disturbed gravelly, sandy, muddy sediment containing lithic cavings and Mn nodules.

SMEAR SLIDE SUMMARY

	1-48	2-24
	D	M
Quartz	2	3
Feldspar	TR	–
Mica	–	TR
Clay minerals	15	15
Glauconite	2	12
Diatoms	75	64
Radiolarians	4	5
Silicoflagellates	TR	TR
Sponge spicules	1	1
Volcanic glass	1	–

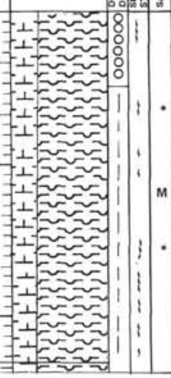
CARBONATE BOMB:
2, 28–29 (1)

MAGNETIC DATA: 1-76

Inclination	29.4
Declination	19.1
Intensity (emu/cc)	0.430E–06

SITE 511 HOLE CORE 17 CORED INTERVAL 147.5–157.0 m

Time-rock unit	lower Oligocene
Planktonic foraminifers	P18–20
Radiolarians	*Theocyrtis tuberosa*
Fossil character (Planktonic forams / Benthic forams / Nannofossils / Radiolarians / Diatoms / Silicoflagellates)	RP / RP / F/MG / CG / CA/M / FG
Sections	1, 2, 3, CC
Meters	0.5, 1.0
Samples	•, M, •



LITHOLOGIC DESCRIPTION

NANNOFOSSIL DIATOMACEOUS OOZE; as in previous cores; gray (5Y 5/1); slight mottling throughout, becoming moderately mottled in Section 3. Mn nodules in upper half of Section 1; rare lithic angular pebbles also in this interval. Lenses of white (5Y 8/1) ooze in Section 2, 24–30 and 77–90 cm. Local minor glauconite in Section 3 and Core-Catcher.

SMEAR SLIDE SUMMARY

	1-97	2-82
	D	*D*
Quartz	1	1
Feldspar	TR	TR
Mica	TR	TR
Clay minerals	2	2
Foraminifers	TR	–
Nannofossils	23	17
Diatoms	69	23
Radiolarians	4	4
Silicoflagellates	–	1
Sponge spicules	1	1
Volcanic glass	TR	1
Micronodules	–	TR

CARBONATE BOMB:
3, 32–34 (8)

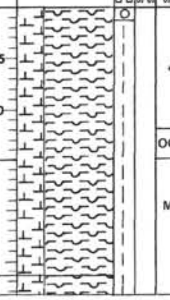
MAGNETIC DATA: 2-34

Inclination	–60.6
Declination	161.5
Intensity (emu/cc)	0.150E–06

GRAIN SIZE:
1-100 (1, 48, 52)

SITE 511 HOLE CORE 18 CORED INTERVAL 157.0–166.5 m

Time-rock unit	upper Eocene
Planktonic foraminifers	P15–16
Nannofossils	*Reticulofenestra oamaruensis*
Radiolarians	*Thyrsocyrtis bromia*
Fossil character (Planktonic forams / Benthic forams / Nannofossils / Radiolarians / Diatoms / Silicoflagellates)	RM / RM / CA/G / CG / CM / FG
Sections	1, 2, CC
Meters	0.5, 1.0
Samples	•, OG, M



LITHOLOGIC DESCRIPTION

NANNOFOSSIL DIATOMACEOUS OOZE; as in previous cores; gray (5Y 6/1); slightly mottled; very faint color banding Section 2, 6–14 cm. Lithic cavings and Mn nodule Section 1, 0–15 cm.

SMEAR SLIDE SUMMARY

	1-60
	M
Quartz	1
Feldspar	TR
Clay minerals	7
Foraminifers	TR
Nannofossils	23
Diatoms	59
Radiolarians	7
Sponge spicules	2
Volcanic glass	1
Micronodules	TR

CARBONATE BOMB:
2, 79–82 (16)

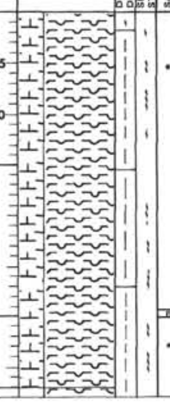
MAGNETIC DATA: 2-45

Inclination	–25.6
Declination	195.2
Intensity (emu/cc)	0.170E–06

Core 19, 166.5–176.0 m: No recovery.

SITE 511 HOLE CORE 20 CORED INTERVAL 176.0–185.5 m

Time-rock unit	upper Eocene
Planktonic foraminifers	P15–16
Nannofossils	*Reticulofenestra oamaruensis*
Radiolarians	*Thyrsocyrtis bromia*
Fossil character (Planktonic forams / Benthic forams / Nannofossils / Radiolarians / Diatoms / Silicoflagellates)	RP / RM / CG / CG / CM / CG
Sections	1, 2, 3, CC
Meters	0.5, 1.0
Samples	•, IW, •



LITHOLOGIC DESCRIPTION

NANNOFOSSIL DIATOMACEOUS OOZE; as in previous cores; gray (5Y 6/1); lightly mottled, more heavily in Section 2, 60–144 cm. Very light color banding in Section 1, 115–135 cm. Glauconite present in darker bands (olive gray [5Y 4/2]) through section.

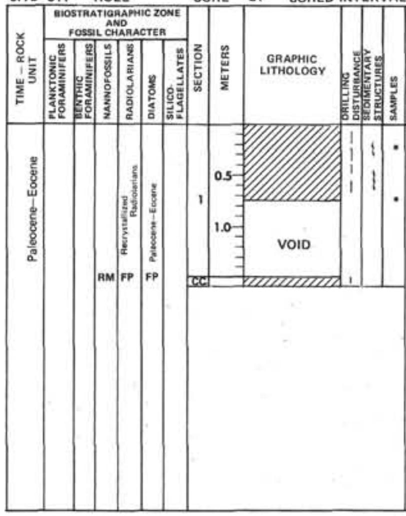
SMEAR SLIDE SUMMARY

	1-50	3-30
	D	D
Quartz	1	1
Feldspar	TR	TR
Clay minerals	3	8
Glauconite	2	2
Foraminifers	TR	TR
Nannofossils	24	25
Diatoms	65	57
Radiolarians	3	4
Silicoflagellates	1	1
Sponge spicules	1	1
Volcanic glass	TR	–

CARBONATE BOMB:
2, 110–112 (15)

GRAIN SIZE:
1-15 (1, 44, 55)
3-15 (1, 40, 59)

SITE 511 HOLE CORE 21 CORED INTERVAL 185.5–140.0 m



LITHOLOGIC DESCRIPTION

PELAGIC CLAY; greenish gray (5GY 6/1), moderately glauconitic in upper 69 cm; lightly mottled throughout; dark brown stringers at 10–20 cm. Lowest 4 cm (2.5Y 6/4) heavily mottled with ash stringer between 71 and 72 cm and 0.5 cm ash-rich clast between 70 and 71 cm.

SMEAR SLIDE SUMMARY

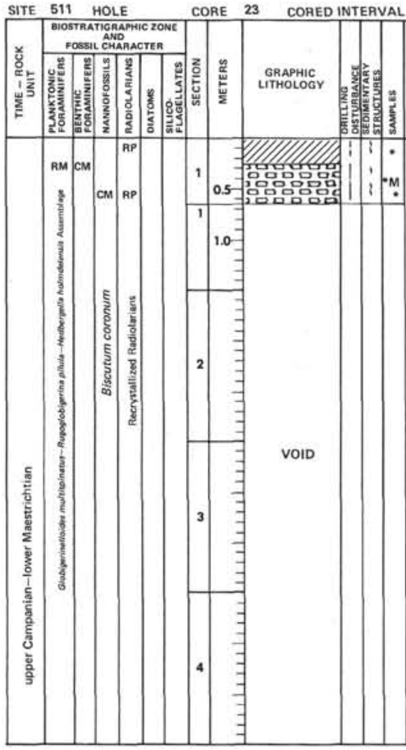
	1-21	1-71
	D	D
Quartz	3	1
Feldspar	–	TR
Clay minerals	87	94
Glauconite	7	–
Zeolites	2	3
Volcanic glass	1	2

CARBONATE BOMB:
1, 46–48 (.01)

GRAIN SIZE:
1-55 (20, 31, 49)

Note: Core 22, 190.0–195.0 m: No recovery.

SITE 511 HOLE CORE 23 CORED INTERVAL 195.5–204.5 m



LITHOLOGIC DESCRIPTION

0–23 cm: GLAUCONITIC PELAGIC CLAY; olive gray (5Y 4/2), lightly mottled; with pale yellow (2.5Y 7/4) sedimentary clasts, 0.5–1.0 cm, high in clay content. In sharp but disturbed contact with

23–53 cm: CALCAREOUS OOZE; gray (5Y 6/1), lightly mottled, containing 5–8% glauconite; some gray (5Y 5/1) lenses contain less glauconite. Interval in sharp contact with

53–61 cm: CALCAREOUS OOZE; light brownish gray (2.5Y 6/2) containing <1% glauconite.

SMEAR SLIDE SUMMARY

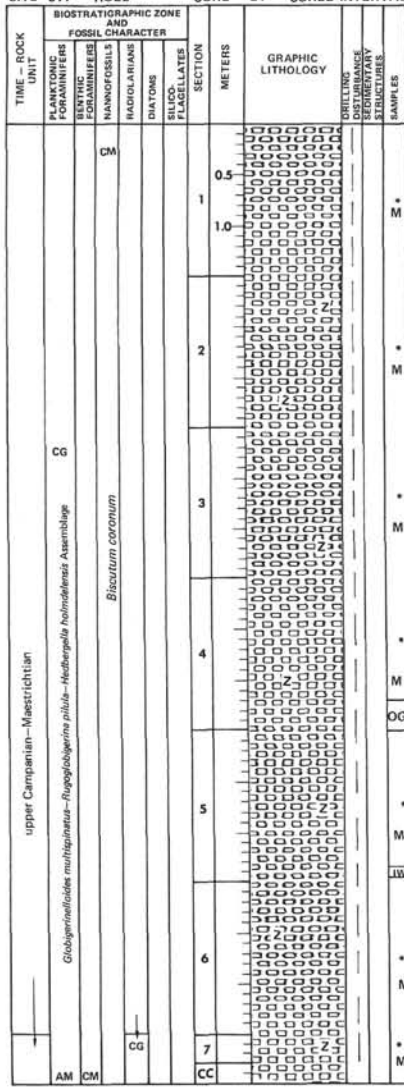
	1-12	1-36	1-56
	D	D	D
Quartz	9	TR	TR
Feldspar	–	TR	–
Clay minerals	77	6	20
Glauconite	11	4	TR
Zeolites	3	–	–
Carbonate unspec.	–	70	45
Foraminifers	–	20	35
Sponge spicules	–	TR	–
Volcanic glass	–	–	TR

CARBONATE BOMB:
1, 38–40 (28)

MAGNETIC DATA:	1-43
Inclination	3.3
Declination	71.1
Intensity (emu/cc)	0.365E–05

GRAIN SIZE:
1-4 (16, 24, 60)

SITE 511 HOLE CORE 24 CORED INTERVAL 204.5–209.0 m



LITHOLOGIC DESCRIPTION

ZEOLITIC CALCAREOUS FORAMINIFERAL OOZE; light gray (5Y 7/1); slightly (~ 1–1.5%) glauconitic between 0–42 cm; sub-angular chert pebble at 18–20 cm.

Note: Section 7 is 65 cm long.

SMEAR SLIDE SUMMARY

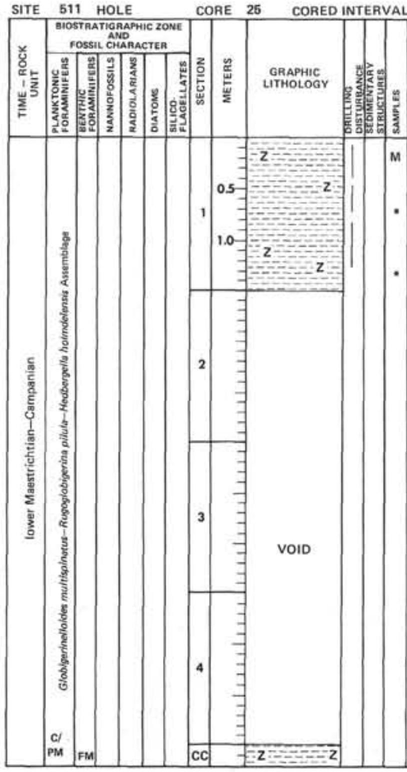
	1-75	2-75	3-75	4-60	5-70	6-75	7-63
	D	D	D	D	D	D	D
Quartz	TR	1	–	–	TR	TR	–
Clay minerals	15	19	20	20	15	20	20
Zeolites	–	10	15	10	15	15	15
Carbonate unspec.	30	25	30	25	20	20	20
Foraminifers	40	45	35	45	50	45	45
Nannofossils	–	–	–	–	TR	–	–

MAGNETIC DATA:	1-95	2-95	3-95	4-95
Inclination	2.1	– 2.9	50.9	–23.1
Declination	128.1	320.0	146.5	188.6
Intensity (emu/cc)	0.150E–06	0.210E–06	0.190E–06	0.200E–06

MAGNETIC DATA:	5-95	6-95	7-39
Inclination	–10.6	–14.7	11.1
Declination	37.0	233.4	33.2
Intensity (emu/cc)	0.140E–06	0.310E–06	0.510E–06

GRAIN SIZE:
2-11 (13, 21, 66)
4-11 (17, 23, 60)
6-11 (18, 23, 60)

SITE 511 HOLE CORE 25 CORED INTERVAL 209.0–214.0 m



LITHOLOGIC DESCRIPTION

ZEOLITIC CLAY: brown (7.5YR 5/2); intensely mottled with blue gray and cream colored clay; very intensely mottled between 58–90 cm; well indurated.

At 148–150 cm: small (<1 cm) black basalt(?) clasts.

At 90–150 cm: reddish brown(5YR 4/3), less mottled.

Core-Catcher: contains brown (10YR 5/3) intensely mottled zeolitic clay enclosing clasts of basalt(?) and a chert pebble.

SMEAR SLIDE SUMMARY

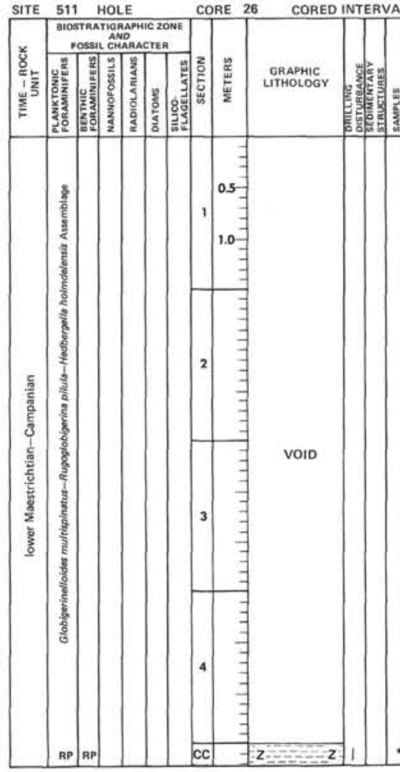
	1-73	1-138
	D	D
Quartz	1	TR
Clay minerals	38	63
Zeolites	30	35
Carbonate unspec.	30	–
Volcanic glass	1	–
Micronodules	–	2

CARBONATE BOMB:
1, 138–139 (0)

MAGNETIC DATA:	**1-120**
Inclination	83.1
Declination	285.2
Intensity (emu/cc)	0.110E–04

GRAIN SIZE:
1-8 (0, 20, 80)

SITE 511 HOLE CORE 26 CORED INTERVAL 214.0–219.0 m



LITHOLOGIC DESCRIPTION

Core-Catcher: ZEOLITIC CLAY; gray (2.5Y 6/0) and grayish brown (10YR 5/2).

SMEAR SLIDE SUMMARY

	CC
	D
Quartz	1
Clay minerals	53
Zeolites	30
Carbonate unspec.	15
Micronodules	1

SITE 511 HOLE CORE 27 CORED INTERVAL 219.0–223.5 m

TIME – ROCK UNIT: Campanian

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER (PLANKTONIC FORAMINIFERS / BENTHIC FORAMINIFERS / NANNOFOSSILS / RADIOLARIANS / DIATOMS / SILICO-FLAGELLATES): *Globigerinelloides multispinatus–Rugoglobigerina pilula–Hedbergella holmdelensis* Assemblage; RP

SECTION: 1, 2, 3, 4

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

ZEOLITIC CLAY

Section 1, 0–108 cm: olive gray (5Y 5/2); homogeneous, massive, unmottled.

Section 1, 117–150 cm: olive (5Y 5/3); more indurated, more fissile than above, and moderately mottled.

Section 2, 0–41 cm: very soupy mixture of COARSE SAND to granule sized, moderately well sorted lithic sand of varied lithologies – quartz, Mn nodules, granitoids, chert, volcanics, metamorphics. Most likely cavings. Abundant zeolites and clay occur as fines.

Section 2, 41–92 cm: highly disturbed mixture of sands as above and zeolitic clay.

SMEAR SLIDE SUMMARY

	1-60	1-131
	D	D
Quartz	1	1
Mica	–	1
Clay minerals	64	65
Zeolites	35	25
Carbonate unspec.	–	5
Volcanic glass	–	TR
Pyrite(?)	–	3

CARBONATE BOMB:
1, 42–43 (0)

MAGNETIC DATA:	1-61
Inclination	61.7
Declination	165.6
Intensity (emu/cc)	0.190E–06

GRAIN SIZE:
1-100 (0, 10, 90)
2-52 (22, 11, 67)

SITE 511 HOLE CORE 28 CORED INTERVAL 223.5–233.0 m

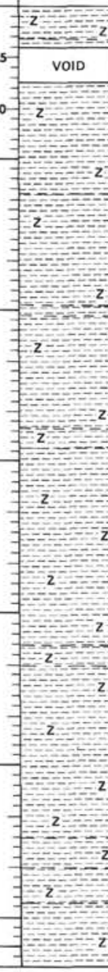
TIME – ROCK UNIT: Campanian

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER (PLANKTONIC FORAMINIFERS / BENTHIC FORAMINIFERS / NANNOFOSSILS / RADIOLARIANS / DIATOMS / SILICO-FLAGELLATES): *Globotruncana pseudolinneiana–Globotruncana* aff. *coronata–Archaeoglobigerina cosquensis–Whiteinella baltica–Globigerinelloides asperus* Assemblage; RP; FM

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



Samples: M, OG

LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE; mostly highly bioturbated; drilling disturbance occurs as "drilling biscuits" throughout entire core.

Section 1, 0–36 cm: dark gray (5Y 4/1).

Section 1, 36–40 and 75–150 cm: olive gray (5Y 5/2) to olive (5Y 5/3); finely laminated (2–5 mm), laminae inclined ~5°.

Section 2, 0–36 cm: olive gray; prominent 0.5 cm green laminae at 32 cm.

Section 2, 36–143 cm: dark gray (5Y 4/1); laminated.

Section 2, 143 cm–Section 3, 2 cm: olive gray.

Section 3, 2–117 cm: dark gray (5Y 4/1).

Section 3, 117–131 cm: olive gray (5Y 5/1).

Section 3, 131 cm–Section 5, 30 cm: gray (5Y 5/1), less mottled than overlying sections; prominent lens 5Y 7/2 in Section 4, 127–140 cm.

Section 5, 30–50 cm: gray (5Y 5/1); highly burrowed.

Section 5, 50 cm–Section 6, 70 cm: olive gray.

Section 6, 70–100 cm: gray (5Y 5/1); 100–133 cm olive gray (5Y 5/2); 133 cm–Section 7, 61 cm: dark olive gray (5Y 4/2) becoming very dark gray (5Y 3/1) downward.

Section 7, 61–64 cm and Core-Catcher: olive gray.

SMEAR SLIDE SUMMARY

	1-21	1-140	2-100	3-75	4-75	5-60	6-75	7-30
	D	D	D	D	D	D	D	D
Quartz	1	1	1	TR	2	1	1	1
Clay minerals	69	68	66	68	68	63	53	52
Zeolites	25	30	30	30	30	35	30	25
Carbonate unspec.	TR	–	–	TR	–	TR	1	2
Foraminifers	2	–	–	–	–	–	2	2
Nannofossils	–	–	–	–	–	–	10	15
Micronodules	3	–	2	2	TR	1	3	3
Volcanic glass	–	1	1	–	–	TR	–	–

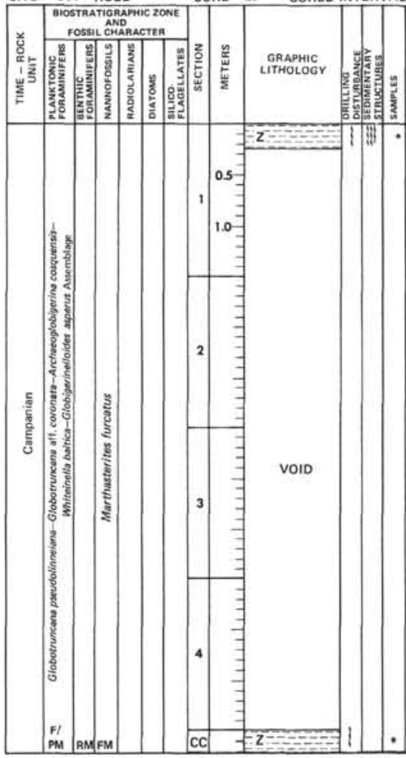
CARBONATE BOMB:
2, 112–113 (0)
4, 112–113 (0)

MAGNETIC DATA:	2-73	3-73	4-73	5-73
Inclination	–65.4	–81.6	–82.6	–46.0
Declination	58.9	120.3	182.3	334.5
Intensity (emu/cc)	0.144E–05	0.720E–06	0.441E–05	0.273E–05

MAGNETIC DATA:	6-73	7-38
Inclination	–77.4	–65.9
Declination	326.0	21.9
Intensity (emu/cc)	0.870E–06	0.530E–06

GRAIN SIZE:
1-140 (0, 9, 91)
3-5 (0, 9, 91)
5-5 (0, 11, 89)

SITE 511 HOLE CORE 29 CORED INTERVAL 233.0–242.5 m



LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE; dark gray (5Y 4/1); intensely burrowed.

Core-Catcher, 0–8 cm: light olive gray (5Y 6/2), chaotic mixture with <0.5 cm zones of gray, green and cream clay.

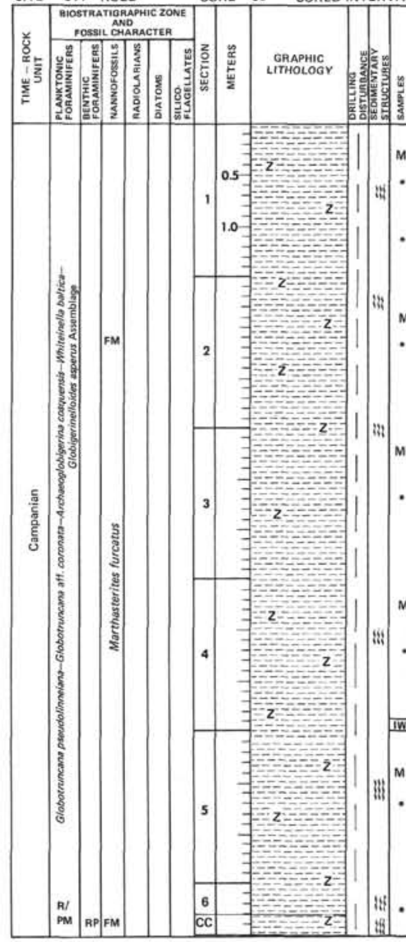
Core-Catcher, 8–20 cm: very dark gray (2.5Y 3/0) to dark gray (2.5Y 4/0); homogeneous, only slightly bioturbated.

SMEAR SLIDE SUMMARY

	1-12	CC
	D	D
Quartz	1	1
Mica	–	TR
Clay minerals	50	47
Zeolites	30	30
Carbonate unspec.	5	5
Foraminifers	1	2
Nannofossils	10	15
Volcanic glass	1	–
Micronodules	2	TR

CARBONATE BOMB:
CC (19)

SITE 511 HOLE CORE 30 CORED INTERVAL 242.5–252.0 m



LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE; mostly dark gray (5Y 4/1) with lighter colored zones as noted below, that generally contain lower percentages of zeolites. Claystone generally intensely burrowed with burrows, 1–2 cm in diameter, of light gray (5Y 7/1) to greenish black (5GY 2/1). "Drilling biscuits" ubiquitous.

Section 1, 112–114 cm: light yellowish brown (2.5Y 6/4).

Section 2, 10–26 and 51–56 cm: light gray (5Y 7/1); at 13 cm – 2 mm of 2.5Y 6/4.
Section 3, 36 cm: lens of light yellowish brown (2.5Y 6/4).
Section 3, 41–66 cm: light gray (5Y 7/1–5Y 6/1).
Section 4, 16–38, 56–60 cm, and 125–137 cm: gray (5Y 6/1); prominent burrows (2.5Y 6/4) at 62, 66, and 106 cm.

Section 5, 30–56 cm: gray (5Y 6/1); at 82–144 cm – light olive gray (5Y 6/2) to gray (5Y 7/1).

Section 6, 0–9 cm: olive gray (5Y 5/2); greenish black laminae (5GY 2/1), 1–2 mm, at 8 and 8.5 cm.

Core-Catcher: dark gray, intensely mottled.

SMEAR SLIDE SUMMARY

	1-60	1-113	2-75	3-75	4-75	5-75	6-30
	D	M	D	D	D	D	D
Quartz	1	–	2	1	1	1	TR
Mica	–	–	–	–	–	TR	–
Clay minerals	55	20	55	56	54	57	55
Zeolites	35	10	30	35	35	30	30
Carbonate unspec.	–	67	–	1	–	–	–
Foraminifers	–	–	5	1	5	2	5
Nannofossils	5	2	5	5	5	5	5
Volcanic glass	1	1	1	–	–	–	–
Micronodules	3	–	2	1	–	5	5

CARBONATE BOMB:
1, 14–15 (0)

MAGNETIC DATA:	1-31	2-31	3-31
Inclination	23.0	–48.9	–28.3
Declination	78.3	61.8	312.8
Intensity (emu/cc)	0.680E–06	0.270E–05	0.630E–06

MAGNETIC DATA:	4-31	5-31
Inclination	–45.9	–30.3
Declination	301.3	352.4
Intensity (emu/cc)	0.890E–06	0.730E–06

GRAIN SIZE:
2-8 (0, 15, 85)
4-8 (0, 17, 83)
6-8 (0, 8, 92)

SITE 511 HOLE CORE 31 CORED INTERVAL 252.0–261.5 m

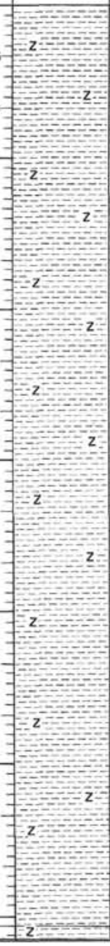
TIME-ROCK UNIT: Campanian

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER:
Planktonic foraminifers: *Globotruncana pseudolinneiana–Globotruncana* aff. *coronata–Archaeoglobigerina cosquensis–Whiteinella baltica–Globigerinelloides asperus* Assemblage (RP)
Benthic foraminifers: RM
Nannofossils: *Marthasterites furcatus* (FM)

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



SAMPLES: M, M, M, OG

LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE; dark gray (2.5Y 4/0) with color changes as noted below; intense burrowing throughout core; "drilling biscuits" ubiquitous.

Interbedded with the predominate dark gray claystone are zones, 2–5 cm thick, which may be one of three colors – 1) greenish black (5GY 2/1); 2) light gray (2.5Y 7/0); and 3) pale yellow (2.5Y 7/4). The greenish black zones may contain very small glauconite grains.

Sedimentary clasts, pale yellow and brown (10YR 5/3 and 10YR 2/2) noted in Section 6, 16–17 and 150 cm (see smear slide 6-17).

SMEAR SLIDE SUMMARY

	1-28	2-69	4-136	5-2	6-17	6-26
	D	D	D		M	D
Quartz	TR	TR	TR	–	–	TR
Heavy minerals	–	–	–	TR	–	–
Clay minerals	82	82	81	85	97	90
Glauconite	TR	–	–	–	–	–
Zeolites	15	15	15	10	2	10
Foraminifers	1	1	2	3	TR	TR
Nannofossils	1	1	1	2	TR	TR
Diatoms	–	–	–	TR	–	–
Volcanic glass	1	1	1	–	1	–

CARBONATE BOMB:
1, 136–139 (4)
4, 133–135 (39)

MAGNETIC DATA:	1-90	3-100	5-95
Inclination	–74.1	–78.5	–72.4
Declination	25.5	166.5	133.2
Intensity (emu/cc)	0.157E–05	0.262E–05	0.193E–05

GRAIN SIZE:
1-23 (1, 12, 88)
3-23 (0, 8, 92)
5-23 (0, 7, 92)

SITE 511 HOLE CORE 32 CORED INTERVAL 261.5–271.0 m

TIME-ROCK UNIT: Campanian

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER:
Planktonic foraminifers: *Globotruncana pseudolinneiana–Globotruncana* aff. *coronata–Archaeoglobigerina cosquensis–Whiteinella baltica–Globigerinelloides asperus* Assemblage (R/PM)
Benthic foraminifers: RM
Nannofossils: *Marthasterites furcatus* (FM)

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY

SAMPLES: M, M, M

LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE; as in Core 31.
Burrows in Section 1 may be *Planolites* and *Chondrites* types.
Unusual shaped burrow in Section 6, 45–50 cm; ? *Zoophycus*.
Pale yellow zones may contain less zeolite than dark gray zones.

SMEAR SLIDE SUMMARY

	1-60	2-48	2-145	3-66	4-87	5-46	6-83
	D	D	D	D	D	D	D
Quartz	–	–	–	1	TR	–	–
Heavy minerals	–	–	TR	–	–	–	–
Clay minerals	82	79	86	63	80	75	77
Zeolites	18	18	10	32	17	22	20
Foraminifers	TR	1	2	1	1	1	1
Nannofossils	TR	1	2	2	1	1	1
Volcanic glass	1	1	TR	1	1	1	1

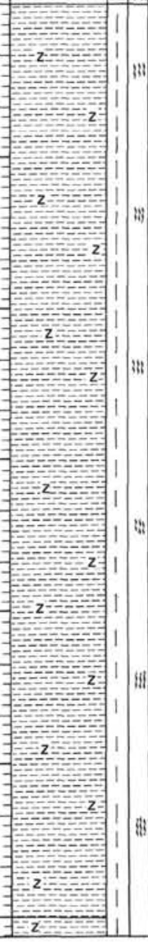
CARBONATE BOMB:
2, 140–144 (44)

MAGNETIC DATA:	1-59	3-61	5-89
Inclination	–80.3	–84.1	–45.4
Declination	266.7	348.0	243.2
Intensity (emu/cc)	0.970E–06	0.191E–05	0.460E–06

GRAIN SIZE:
1-32 (0, 14, 86)
3-32 (0, 9, 91)
5-32 (0, 17, 83)

SITE 511 HOLE CORE 33 CORED INTERVAL 271.0–280.5 m

TIME-ROCK UNIT	PLANKTONIC FORAMINIFERS	BENTHIC FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SILICO-FLAGELLATES	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
Campanian	*Globotruncana pseudolinneiana–Globotruncana* aff. *coronata–Archaeoglobigerina cosquensis–Whiteinella baltica–Globigerinelloides asperus* Assemblage		*Marthasterites furcatus*				1, 2, 3, 4, 5, 6, CC	0.5, 1.0				M, •, M, •, M •, •
	F/PM	RM	FM									



LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE; as in previous cores.
Barite(?) nodules in Section 4, 3–11 cm.

Teichichnus(?) burrow in Section 5, 20–30 cm.

SMEAR SLIDE SUMMARY

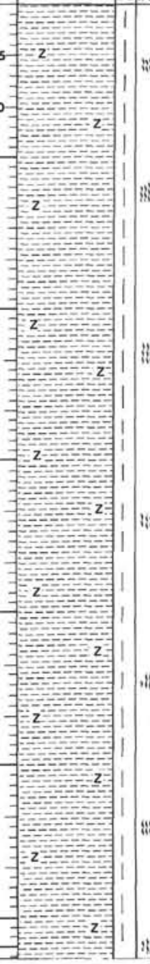
	1-82	4-103	5-94	6-96
	D	D	D	D
Clay minerals	73	76	77	76
Zeolites	20	8	22	7
Carbonate unspec.	–	5	–	6
Foraminifers	2	3	TR	1
Nannofossils	4	7	TR	9
Volcanic glass	1	1	1	1

MAGNETIC DATA:	1-33	3-40	5-89
Inclination	–18.6	–78.9	–40.4
Declination	343.5	305.0	126.2
Intensity (emu/cc)	0.200E–06	0.203E–05	0.136E–06

GRAIN SIZE:
3-32 (0, 19, 81)
5-32 (0, 6, 94)

SITE 511 HOLE CORE 34 CORED INTERVAL 280.5–290.0 m

TIME-ROCK UNIT	PLANKTONIC FORAMINIFERS	BENTHIC FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SILICO-FLAGELLATES	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
Campanian	*Globotruncana pseudolinneiana–Globotruncana* aff. *coronata–Archaeoglobigerina cosquensis–Whiteinella baltica–Globigerinelloides asperus* Assemblage		*Marthasterites furcatus*				1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0				•, •, •, OG, •
	CM	CM	CM									



LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE; as in previous cores.
Intense burrowing possibly *Chondrites* and *Planolites* types.

Barite(?) nodules, Section 3, 88–89 cm and Section 6, 118–122 cm, and Section 7, 15–16 cm.

SMEAR SLIDE SUMMARY

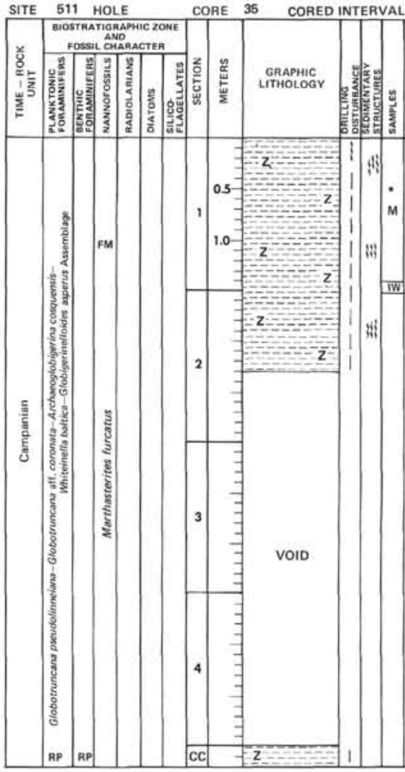
	1-85	2-83	4-90	6-84
	D	D	D	D
Quartz	1	–	1	TR
Heavy minerals	–	TR	–	–
Clay minerals	78	71	71	72
Zeolites	19	7	25	17
Carbonate unspec.	–	12	–	5
Foraminifers	TR	1	1	–
Nannofossils	1	8	1	5
Volcanic glass	1	1	1	1

CARBONATE BOMB:
1, 1–3 (3)

MAGNETIC DATA:	5-17
Inclination	–65.9
Declination	127.2
Intensity (emu/cc)	0.600E–06

GRAIN SIZE:
1-26 (0, 13, 87)
3-26 (0, 12, 88)
5-26 (0, 9, 91)
7-26 (0, 12, 88)

SITE 511 HOLE CORE 35 CORED INTERVAL 290.0–299.5 m



LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE; as in previous cores.
Section 2, 40–41 cm: pyrite nodule.

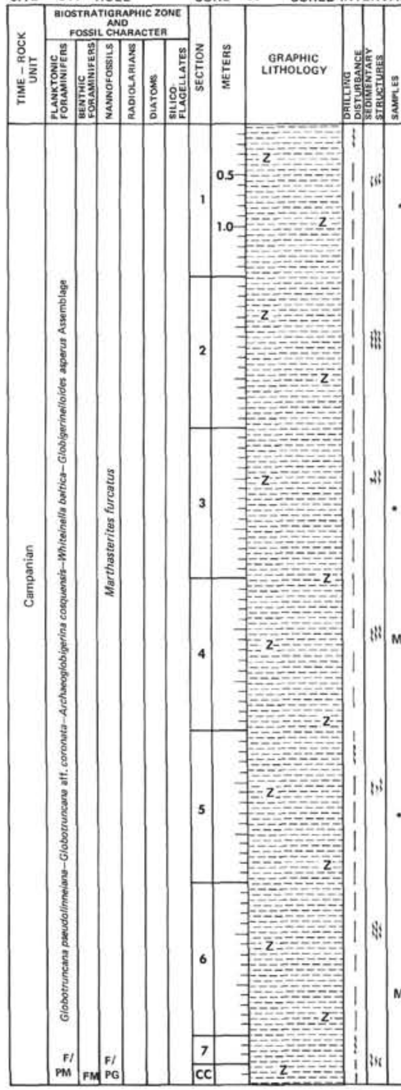
SMEAR SLIDE SUMMARY

	1-50
	D
Quartz	TR
Clay minerals	72
Zeolites	25
Foraminifers	1
Nannofossils	1
Volcanic glass	1

MAGNETIC DATA:	1-80
Inclination	56.8
Declination	246.1
Intensity (emu/cc)	0.800E–07

GRAIN SIZE:
1-28 (0, 14, 87)

SITE 511 HOLE CORE 36 CORED INTERVAL 299.5–309.0 m



LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE; as in previous cores.
Section 4, 0–18 and 145–146 cm: horizontal banding.
Section 5, 114–117 cm: ?barite nodule.
Note: Section 7 is 40 cm long.

SMEAR SLIDE SUMMARY

	1-89	3-87	5-82
	D	D	D
Quartz	TR	1	–
Clay minerals	77	69	66
Zeolites	19	27	12
Carbonate unspec.	–	–	12
Foraminifers	1	1	2
Nannofossils	2	1	7
Volcanic glass	1	1	1

CARBONATE BOMB:
2, 63–66 (30)

MAGNETIC DATA:	4-67	6-102
Inclination	–61.8	–49.8
Declination	124.9	294.7
Intensity (emu/cc)	0.320E–06	0.210E–06

GRAIN SIZE:
1-18 (0, 19, 81)
3-18 (0, 18, 82)
5-18 (0, 15, 85)
7-18 (0, 18, 82)

SITE 511 HOLE CORE 37 CORED INTERVAL 309.0–318.5 m

TIME – ROCK UNIT: Campanian

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER: PLANKTONIC FORAMINIFERS | BENTHIC FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS | SILICO-FLAGELLATES

Globotruncana pseudolinneiana–Globotruncana aff. *coronata–Archaeoglobigerina cosquensis–Whiteinella baltica–Globigerinelloides asperus* Assemblage

Marthasterites furcatus

R/PM RP F/PM

SECTION: 1, 2, 3, 4

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY

DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES

M
OG

LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE; as in previous cores.
Horizontal stratification evident despite intense burrowing.

SMEAR SLIDE SUMMARY

	1-60	2-51
	D	D
Quartz	TR	1
Barite	–	1
Clay minerals	70	79
Zeolites	20	10
Foraminifers	2	1
Nannofossils	5	5
Volcanic glass	–	1
Micronodules	3	2

CARBONATE BOMB:
1, 50–51 (5)

MAGNETIC DATA:	1-59
Inclination	–82.9
Declination	187.5
Intensity (emu/cc)	0.149E–05

GRAIN SIZE:
2-3 (0, 22, 78)

SITE 511 HOLE CORE 38 CORED INTERVAL 318.5–328.0 m

TIME – ROCK UNIT: Campanian

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER: PLANKTONIC FORAMINIFERS | BENTHIC FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS | SILICO-FLAGELLATES

Globotruncana pseudolinneiana–Globotruncana aff. *coronata–Archaeoglobigerina cosquensis–Whiteinella baltica–Globigerinelloides asperus* Assemblage

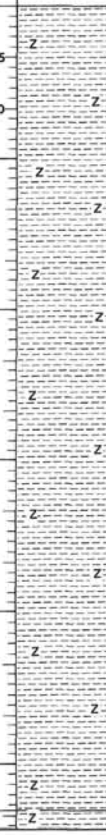
Marthasterites furcatus

RP FP

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES

M
M

LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE; as in previous cores; mostly dark gray (2.5Y 4/1) with gradations into zones of light gray (2.5Y 7/2) light olive gray (5Y 6/2) and greenish black (5GY 2/1). Abundant burrows; especially ?*Zoophycos*; mostly "solid burrows".

Section 1, 106–112 cm: non-zeolitic very hard, light gray siltstone.

Section 5, 12 cm: prominent "ring" burrows.

SMEAR SLIDE SUMMARY

	1-60	1-108	2-75	3-75	4-75	5-75	6-75
	D	M	D	D	D	D	D
Quartz	1	–	2	1	1	1	1
Feldspar	–	–	–	–	–	1	–
Unknown mineral	–	89	–	–	–	–	–
Clay minerals	69	5	66	80	80	77	71
Zeolites	15	5	20	10	10	20	15
Foraminifers	1	1	2	1	2	–	1
Nannofossils	10	–	5	5	5	–	10
Diatoms	–	–	–	–	–	–	TR
Volcanic glass	1	–	TR	–	–	–	1
Micronodules	3	TR	5	3	2	1	1

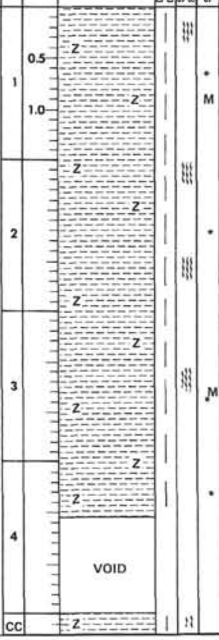
CARBONATE BOMB:
3, 64–65 (2)

MAGNETIC DATA:	2-83	4-88
Inclination	–77.7	–60.1
Declination	113.7	173.0
Intensity (emu/cc)	0.201E–05	0.412E–05

GRAIN SIZE:
2-42 (0, 7, 93)
4-42 (0, 14, 86)
6-42 (0, 13, 87)

SITE 511 HOLE CORE 39 CORED INTERVAL 328.0–337.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER	SECTION	METERS	GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION
Campanian	Planktonic foraminifers: *Globotruncana pseudolinneiana–Globotruncana* aff. *coronata–Archaeoglobigerina cosquensis–Whiteinella baltica–Globigerinelloides asperus* Assemblage (F/PM); Benthic foraminifers: RM; Nannofossils: *Marthasterites furcatus* (F/PM)	1, 2, 3, 4, CC	0.5, 1.0	Z; VOID	see below



ZEOLITIC CLAYSTONE; as in previous cores.

Section 1: fine horizontal laminations through most of section. Burrows up to 2 cm in diameter, often filled with finely disseminated pyrite which also occurs disseminated and as small crystals elsewhere in the core.

Section 4: burrows large (up to 3.5 cm diameter) multicolored.

SMEAR SLIDE SUMMARY

	1-70	2-75	3-95	4-35
	D	D	D	D
Quartz	–	1	–	–
Feldspar	1	–	–	–
Clay minerals	69	79	90	76
Zeolites	15	10	5	10
Foraminifers	1	1	1	1
Nannofossils	10	5	3	10
Volcanic glass	–	1	TR	–
Micronodules	2	3	1	3

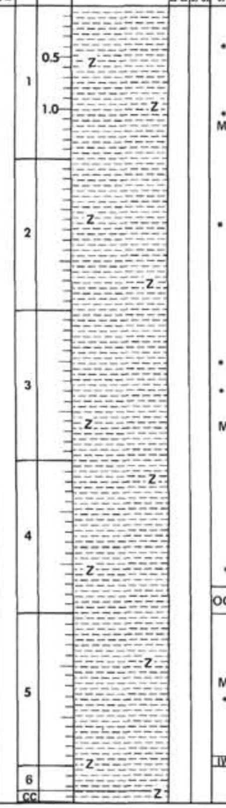
CARBONATE BOMB:
3, 84–85 (49)

MAGNETIC DATA:	1-94	3-96
Inclination	–59.5	–39.5
Declination	225.4	197.5
Intensity (emu/cc)	0.545E–06	0.590E–06

GRAIN SIZE:
2-31 (0, 11, 89)
4-31 (0, 13, 87)

SITE 511 HOLE CORE 40 CORED INTERVAL 337.5–347.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER	SECTION	METERS	GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION
Campanian	Planktonic foraminifers: *Globotruncana pseudolinneiana–Globotruncana* aff. *coronata–Archaeoglobigerina cosquensis–Whiteinella baltica–Globigerinelloides asperus* Assemblage (FM); Benthic foraminifers: FM; Nannofossils: *Marthasterites furcatus* (FM)	1, 2, 3, 4, 5, 6, CC	0.5, 1.0	Z	see below



ZEOLITIC CLAYSTONES; as in previous cores.
Burrows mainly "solid" and "*?Chondrites*" types; some "ring" burrows.

SMEAR SLIDE SUMMARY

	1-40	1-110	2-75	3-58	3-83	4-103	5-80
	D	D	D	M	D	D	D
Quartz	–	1	TR	TR	TR	TR	2
Feldspar	–	–	–	–	1	TR	1
Unidentified mineral	15	–	–	–	–	–	–
Barite	–	TR	–	–	–	–	–
Clay minerals	77	65	74	84	72	78	81
Zeolites	10	20	20	10	20	15	15
Carbonate unspec.	–	–	TR	–	–	–	–
Foraminifers	2	1	1	2	TR	TR	TR
Nannofossils	3	10	2	3	2	2	TR
Micronodules	3	2	3	1	5	5	1
Mica	–	1	–	–	–	–	–

CARBONATE BOMB:
3, 31–32 (28)

MAGNETIC DATA:	1-118	3-127	5-73
Inclination	–66.2	–62.0	–78.5
Declination	240.4	166.3	266.2
Intensity (emu/cc)	0.618E–05	0.358E–05	0.341E–04

GRAIN SIZE:
2-12 (0, 14, 87)
4-12 (0, 23, 77)
6-12 (0, 8, 92)

SITE 511 HOLE CORE 41 CORED INTERVAL 347.0–356.5 m

TIME – ROCK UNIT: Campanian Santonian

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER:
- Planktonic foraminifers: F/MG; F/RM — *Globotruncana pseudolinneiana–Globotruncana* aff. *coronata–Archaeoglobigerina cosquensis–Whiteinella baltica–Globigerinelloides asperus* Assemblage
- Benthic foraminifers: RM
- Nannofossils: *Marthasterites furcatus*

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

GRAPHIC LITHOLOGY

LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE AND CLAYSTONE

Zeolitic claystone as in previous cores in Section 1, 0 cm–Section 2, 16 cm and from Section 3, 106–145 cm.

Mainly dark gray, with light gray, gray, and pale olive zones. Numerous burrows of "solid", ?*Chondrites* and *Zoophycus* types. Prominent "ring" burrow Section 2, 6.5 cm.

Section 2, 16–104 cm: CLAYSTONE, reddish brown (2.5YR 4/4), moderately burrowed with small (<0.5 cm) green burrows; ?*Zoophycus* burrow at 26 cm. Sharp contact with Section 2, 104–146 cm – light gray (5Y 7/1) to white (5Y 8/1), slightly mottled. Claystone, in sharp contact with Section 2, 146 cm–Section 3, 70 cm, reddish brown (2.5YR 4/3) claystone as above but with 1 mm green laminae at Section 3, 5 cm, and *Inoceramus* fragments.

Section 3, 70–106 cm: transition from reddish brown claystones to dark gray zeolitic claystone (Section 3, 106–145 cm). Abundant and often large *Inoceramus* fragments below Section 3, 70 cm. Abundant pyrite Section 3, 143–144 cm.

SMEAR SLIDE SUMMARY

	1-75	2-65	2-130	3-50	3-120
	D	D	D	D	M
Quartz	1	TR	1	TR	5
Feldspar	–	TR	–	–	–
Mica	TR	–	–	–	–
Barite	–	–	–	–	TR
Clay minerals	77	88	87	79	58
Zeolites	15	5	5	5	10
Carbonate unspec.	–	–	–	–	20
Foraminifers	1	1	2	5	–
Nannofossils	5	5	5	10	5
Micronodules	1	TR	–	1	2
Volcanic glass	–	1	–	–	–

CARBONATE BOMB:
1, 123–125 (11.5)
2, 115–116 (69)
3, 36–38 (0.5)

MAGNETIC DATA:	1-26	2-55	3-50
Inclination	–71.2	–67.8	–63.1
Declination	328.1	228.9	137.2
Intensity (emu/cc)	0.674E–04	0.634E–04	0.559E–04

GRAIN SIZE:
3-44 (2, 15, 83)

SITE 511 HOLE CORE 42 CORED INTERVAL 356.5–366.0 m

TIME – ROCK UNIT: Santonian

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER:
- Planktonic foraminifers: CM — *Globotruncana pseudolinneiana–Globotruncana* aff. *coronata–Archaeoglobigerina cosquensis–Whiteinella baltica–Globigerinelloides asperus* Assemblage
- Benthic foraminifers: FM
- Nannofossils: FM — *Marthasterites furcatus*

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

GRAPHIC LITHOLOGY

LITHOLOGIC DESCRIPTION

Section 1, 0 cm–Section 2, 88 cm: CLAYSTONE; alternating intervals of reddish brown (2.5Y 4/4) and greenish gray (5G 6/1), claystone generally with gradational contacts, moderately burrowed. Abundant pyrite in burrows and along fractures. Large barite(?) crystal Section 1, 50–55 cm.

Section 2, 88 cm–Section 5, 90 cm: ZEOLITIC CLAYSTONE. Much as in previous cores but with added colors, intermixed with dark gray (5Y 4/1), i.e. greenish gray (5G 6/1), pale brown (10YR 6/3) laminae (Section 3), dark grayish brown (10YR 4/2), and light yellowish brown (10YR 6/4). *Inoceramus* fragment (2 cm) at Section 2, 143 cm. Hard, calcareous claystone layer in Section 3, 138–143 cm.

Core moderately burrowed, locally with prominent ?*Zoophycus*.

Inoceramus and *Chondrites* in Core-Catcher.

SMEAR SLIDE SUMMARY

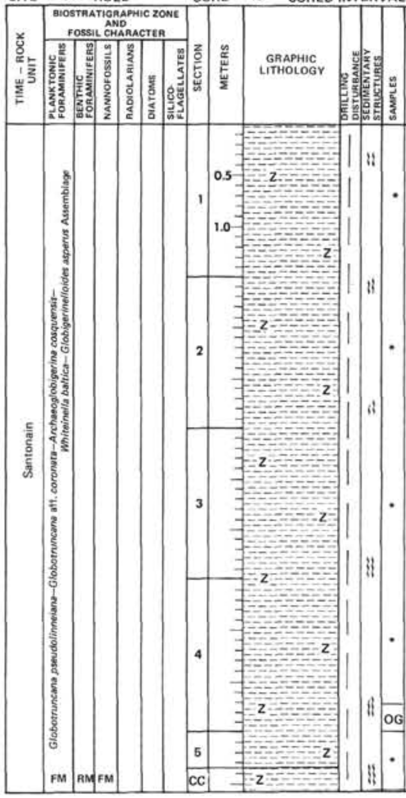
	1-85	2-105	3-75	4-75	5-45
	D	D	D	D	D
Quartz	3	1	1	TR	1
Feldspar	–	1	–	TR	–
Heavy minerals	–	–	–	–	TR
Clay minerals	82	75	73	79	81
Zeolites	10	15	15	15	7
Foraminifers	TR	2	–	TR	2
Nannofossils	5	5	10	5	7
Micronodules	1	1	1	1	2

CARBONATE BOMB:
4, 97–98 (6)

MAGNETIC DATA:	1-98	2-78	3-70
Inclination	–59.5	–67.5	–59.3
Declination	12.3	139.5	98.3
Intensity (emu/cc)	0.258E–04	0.314E–05	0.274E–04

GRAIN SIZE:
3-62 (0, 11, 89)

SITE 511 HOLE CORE 43 CORED INTERVAL 366.0–375.5 m



LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE
Mainly gray and dark gray with greenish black zones and pale yellow lenses as in upper cores. Moderate burrowing. Laminations present in Sections 1 and 4. Pyrite nodules and chert? nodules in Sections 2 and 4. *Inoceramus* fragments present.

Section 3, 141–150 cm: zeolitic claystone is calcareous and greenish black. *Chondrites*? type burrows present.

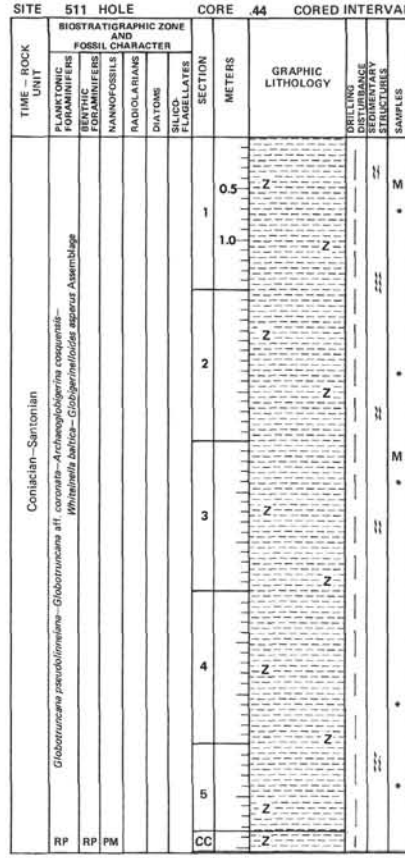
SMEAR SLIDE SUMMARY

	1-75	2-75	3-75	4-60	5-30
	D	D	D	D	D
Quartz	1	1	1	1	1
Clay minerals	69	78	81	74	72
Zeolites	18	15	15	20	22
Carbonate unspec.	5	–	–	–	–
Foraminifers	1	TR	TR	1	1
Nannofossils	5	5	2	3	3
Volcanic glass	1	1	1	1	1

CARBONATE BOMB:
1, 25–27 (0.4)

GRAIN SIZE:
1-11 (0, 19, 81)
3-11 (0, 15, 85)

SITE 511 HOLE CORE 44 CORED INTERVAL 375.5–385.0 m



LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE; as in Core 43, predominately gray with greenish black zones. Burrowing moderate.

Chert nodules common, 2–3 cm.

Inoceramus fragments moderately abundant.

SMEAR SLIDE SUMMARY

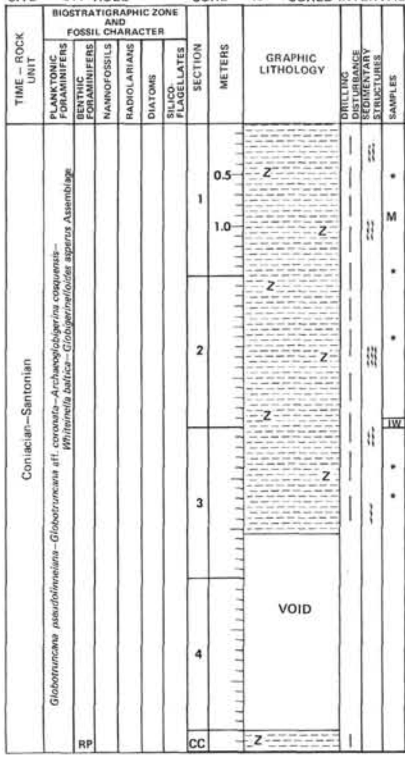
	1-75	2-84	3-49	4-101	5-48
	D	M	D	D	D
Quartz	1	–	1	1	1
Clay minerals	82	–	82	82	74
Zeolites	15	–	15	15	22
Carbonate unspec.	–	100	–	–	–
Foraminifers	TR	–	TR	TR	TR
Nannofossils	1	–	1	2	3
Volcanic glass	1	–	1	–	–

CARBONATE BOMB:
3, 52–53 (4)

MAGNETIC DATA:	1-39	3-15
Inclination	–66.1	–62.0
Declination	50.7	342.5
Intensity (emu/cc)	0.811E–06	0.248E–06

GRAIN SIZE:
2-16 (0, 22, 78)
4-16 (0, 15, 85)

SITE 511 HOLE CORE 45 CORED INTERVAL 385.0–394.5 m



LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE; as in Cores 43 and 44, dark gray (5Y 4/1) and dark greenish gray (5G 4/1) with pale yellow laminae and white laminae in Section 2, 96–127 cm. Well preserved *Chondrites* and ?*Zoophycos* in Section 2.

Burrowing moderate to light except Section 2, 131–141 cm which is heavily burrowed.

Section 3, 54–105 cm: dark reddish brown (2.5YR 3/4) lightly burrowed, with dark gray lenses and greenish black stringers, and chert(?).

Core-Catcher: dark reddish brown, negligible burrowing.

SMEAR SLIDE SUMMARY

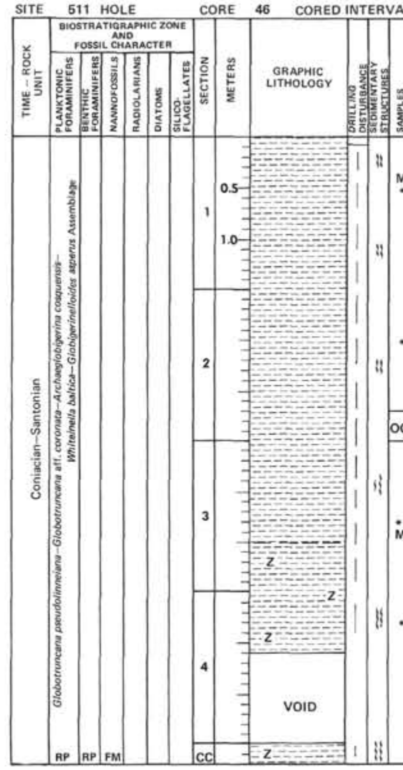
	1-53	1-146	2-69	3-41	3-76
	D	D	D	D	D
Quartz	1	1	1	3	3
Clay minerals	77	77	76	82	82
Glauconite	–	–	TR	–	–
Zeolites	20	20	20	15	15
Foraminifers	TR	TR	TR	TR	–
Nannofossils	2	1	2	TR	–
Volcanic glass	TR	1	1	TR	–

CARBONATE BOMB:
2, 91–93 (2)

MAGNETIC DATA:	3-89
Inclination	–67.6
Declination	310.9
Intensity (emu/cc)	0.132E–03

GRAIN SIZE:
1-30 (0, 17, 83)
3-30 (0, 19, 81)

SITE 511 HOLE CORE 46 CORED INTERVAL 394.5–404.0 m



LITHOLOGIC DESCRIPTION

CLAYSTONE AND ZEOLITIC CLAYSTONE; gray (2.5Y 5/0) to dark gray (2.5Y 4/0) with intervals 10–30 cm of greenish gray (5GY 6/1) and greenish black. Chert nodules 0.5–3 cm common. *Inoceramus* fragments present in Sections 1 and 3. Burrowing moderate to slight; ?*Zoophycos* present in Section 3.

SMEAR SLIDE SUMMARY

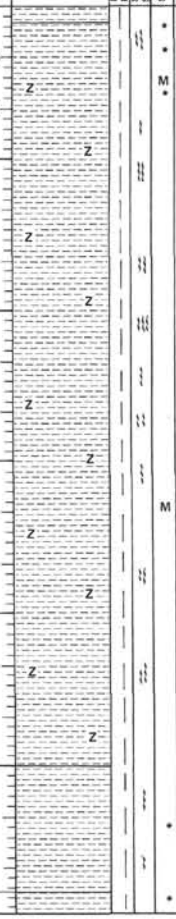
	1-54	2-51	3-81	4-30
	D	D	D	D
Quartz	1	1	TR	TR
Clay minerals	85	86	88	84
Zeolites	10	8	12	15
Foraminifers	1	1	TR	TR
Nannofossils	2	3	TR	TR
Volcanic glass	1	1	–	1

CARBONATE BOMB:
3, 61–63 (0)

MAGNETIC DATA:	1-34	3-84
Inclination	–76.2	–44.2
Declination	290.6	342.6
Intensity (emu/cc)	0.420E–06	0.893E–05

GRAIN SIZE:
1-30 (0, 18, 82)
3-30 (0, 30, 70)

SITE 511 HOLE CORE 47 CORED INTERVAL 404.0–413.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES	LITHOLOGIC DESCRIPTION
Turonian	*Globotruncana pseudolinneiana–Globotruncana* aff. *coronata–Archaeoglobigerina cosquensis–Whiteinella baltica–Globigerinelloides asperus* Assemblage; Planktonic foraminifers RP, Benthic foraminifers RM, Nannofossils F/RM	1, 2, 3, 4, 5, 6, CC	0.5, 1.0			see below

ZEOLITIC CLAYSTONE AND CLAYSTONE; as in preceding Core 46. Section 1, 0–20 cm: dark reddish brown (2.5YR 3/4).

Zeolitic claystones through Sections 1–5 predominately gray and dark gray with zones of greenish gray (5G 4/1) and intervals 1–5 cm where greenish black, white (2.5Y 8/0) and yellowish laminae appear.

Burrowing varies from light to heavy as shown; ?*Chondrites* burrows present.

Chert nodules rare to absent; rare chert clasts in Section 3, 9–15 and 81–83 cm.

Inoceramus present in Sections 4, 5, and 6.

Section 6: greenish gray (5GY 6/1) claystone mixed with grayish brown (2.5Y 5/2) at 122 cm. Lightly burrowed. Greenish black laminae at 25–26 cm. From 122–128 cm and Core-Catcher: claystone is dark reddish brown (5YR 3/3) with light blue (5B 7/6) mottling.

SMEAR SLIDE SUMMARY

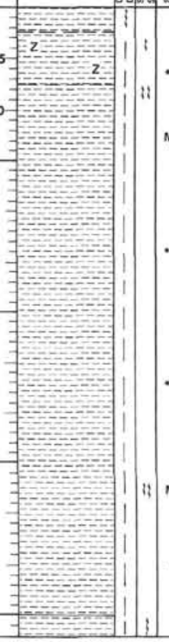
	1-14	1-49	3-90	6-61	CC
	D	D	D	D	D
Quartz	TR	1	1	1	TR
Clay minerals	92	82	80	84	80
Zeolites	8	15	17	–	9
Carbonate unspec.	–	–	–	5	4
Foraminifers	TR	1	1	2	1
Nannofossils	TR	1	1	8	6
Volcanic glass	TR	TR	TR	TR	TR

CARBONATE BOMB:
2, 84–86 (0)
6, 72–74 (5)

MAGNETIC DATA:	1-79	4-52
Inclination	–70.2	–56.0
Declination	11.1	276.9
Intensity (emu/cc)	0.221E–05	0.154E–04

GRAIN SIZE:
1-22 (0, 21, 79)
3-22 (0, 22, 78)
5-22 (0, 25, 75)

SITE 511 HOLE CORE 48 CORED INTERVAL 413.5–423.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES	LITHOLOGIC DESCRIPTION
Turonian / Cenomanian	Planktonic foraminifers RP, Benthic foraminifers RP	1, 2, 3, 4, CC	0.5, 1.0			see below

CLAYSTONE

Dark reddish brown (5YR 3/3) with sparse light blue (5B 7/6) and pale blue green (5BG 7/2) mottling. Rare red (10R 5/8) lenses, Section 2, 113–114 cm, and yellow (2.5Y 7/8) mottling in Section 4, 41–48, 68–76, and 87–102 cm. Pyrite present as thin lamina in Section 1, 104–105 cm, and as grains (< 1 cm) in Section 4 where it appears to be related to yellow mottling. Burrowing is light to moderate as shown. In Section 2, the intervals 89–90 and 93–100 cm are rich in *Inoceramus* debris. Section 4, 103–150 cm and Core-Catcher are gray (2.5Y 5/0) with dark gray mottling in the Core-Catcher.

SMEAR SLIDE SUMMARY

	1-63	2-96	3-72	4-109
	D	M	D	D
Quartz	1	–	1	1
Mica	TR	–	–	–
Clay minerals	78	20	98	88
Zeolites	15	–	–	11
Carbonate unspec.	–	–	1	–
Foraminifers	1	–	–	TR
Nannofossils	4	–	–	TR
Volcanic glass	1	–	TR	TR
Inoceramus fragments	–	80	–	–

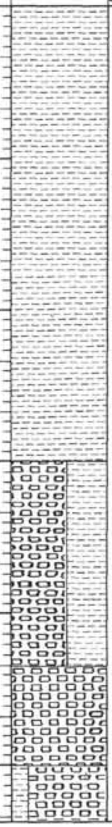
CARBONATE BOMB:
2, 97–99 (44)
4, 48–50 (0)

MAGNETIC DATA:	1-132	4-31
Inclination	–69.2	–57.2
Declination	299.2	273.4
Intensity (emu/cc)	0.141E–03	0.155E–04

SITE 511 HOLE CORE 49 CORED INTERVAL 423.0–432.5 m

TIME – ROCK UNIT	PLANKTONIC FORAMINIFERS	BENTHIC FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SILICO-FLAGELLATES	SECTION	METERS
Cenomanian	*Hedbergella kingi* Assemblage		no data; *Eiffellithus tourriseiffeli*				1, 2, 3, 4, 5, 6	0.5, 1.0
	RP	RP						
Albian	RP	RP						
	CM	RM	CM					

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE · SEDIMENTARY STRUCTURES · SAMPLES: M, M, OG, M

LITHOLOGIC DESCRIPTION

CLAYSTONE AND CALCAREOUS CLAYSTONE; predominately dark reddish brown (5YR 3/3) with intervals of reddish brown (5YR 4/3 – Section 1, 8–22 cm), and brown (7.5YR 5/2 – Section 1, 22–95 cm and Section 2, 0–95 cm), almost all of which has a light blue (5B 7/6) mottling. The CALCAREOUS OOZE in Section 5, 51–150 cm is highly variegated in color, in intervals from 1–17 cm thick. Colors range through tones of brown, gray, pinkish gray, pale red purple, gray blue green, and pale blue green. Burrowing is slight. *Aucellina* fragments occur in Section 3 and Section 4, 73–89 cm; *Inoceramus and unidentified shell material are present in Section 6,* and solitary horn corals are well preserved in Section 4, 99–122 cm and throughout Section 5.

SMEAR SLIDE SUMMARY

	1-82	2-26	4-40	5-59	5-78	5-118	6-20
	D	D	D	D	D	D	D
Quartz	TR	TR	–	–	–	–	–
Clay minerals	95	100	55	35	25	15	55
Zeolites	5	–	–	–	–	–	–
Carbonate unspec.	–	TR	40	40	45	63	25
Foraminifers	TR	–	TR	2	5	2	TR
Nannofossils	TR	–	5	3	10	20	20
Volcanic glass	TR	TR	–	–	–	–	–
Inoceramus fragments	–	–	TR	20	15	–	–

CARBONATE BOMB:
5, 38–40 (13)
5, 99–101 (88)

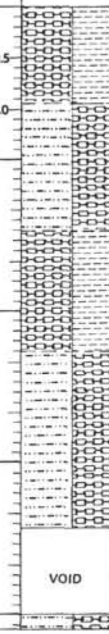
MAGNETIC DATA:	1-103	3-44	6-21
Inclination	–66.8	–65.6	–70.5
Declination	5.3	24.2	156.8
Intensity (emu/cc)	0.399E–04	0.177E–04	0.143E–04

GRAIN SIZE:
3-21 (0, 7, 92)
5-21 (1, 10, 89)

SITE 511 HOLE CORE 50 CORED INTERVAL 432.5–442.0 m

TIME – ROCK UNIT	PLANKTONIC FORAMINIFERS	BENTHIC FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SILICO-FLAGELLATES	SECTION	METERS
Albian	*Hedbergella planispira–Hedbergella delrioensis* Assemblage		*Eiffellithus tourriseiffeli*; *Prediscosphaera cretacea*				1, 2, 3, 4, CC	0.5, 1.0
	A/PM	FM	CM					

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE · SEDIMENTARY STRUCTURES · SAMPLES: M, M, IW

LITHOLOGIC DESCRIPTION

CALCAREOUS CLAYSTONE AND MUDDY CALCAREOUS CHALK
Section 1, 0–94 cm: reddish brown (2.5YR 4/4); top 6 cm dark reddish brown (2.5YR 3/4); light gray burrows (5Y 7/1) at 6–11 cm. Interval highly fossiliferous – small (< 1 cm) pelecypods and solitary corals. Some brownish red zones grading into yellow brown (10YR 5/4).

Section 1, 94 cm–Section 2, 70 cm: greenish gray (5G 6/1) muddy calcareous chalk; moderately burrowed; numerous pelecypods and corals. Section 2, 105–106 cm – white interval of carbonate granules and quartz grains. Yellowish brown (10YR 5/4) zones in Section 2, 0–70 cm.

Section 2, 70 cm–Section 3, 42 cm: reddish brown (2.5YR 4/4) calcareous claystone, highly fossiliferous; abundant carbonate Section 2, 110–150 cm.

Section 3, 42 cm–Section 4, 63 cm: brown (7.5YR 5/2) muddy calcareous chalk with very dark gray (5Y 3/1) laminae Section 3, 55–60 and 78–81 cm. Moderately burrowed; sparse pelecypods.

Core-Catcher: as in Section 4.

SMEAR SLIDE SUMMARY

	1-54	1-127	2-67	2-104	3-60	3-131	4-62
	D	D	D	D	D	D	D
Quartz	5	5	3	2	1	1	1
Feldspar	1	–	2	–	1	–	–
Clay minerals	51	24	54	58	38	28	36
Zeolites	3	–	1	2	–	1	1
Carbonate unspec.	10	35	10	15	10	35	2
Foraminifers	5	20	10	5	15	10	5
Nannofossils	25	15	20	20	35	25	55
Micronodules	–	1	–	–	–	–	–
Volcanic glass	–	–	–	–	–	TR	–

CARBONATE BOMB:
1, 107–109 (11)
3, 61–62 (24)

MAGNETIC DATA:	1-71	3-66
Inclination	–67.2	–50.7
Declination	305.5	125.9
Intensity (emu/cc)	0.881E–05	0.242E–04

GRAIN SIZE:
1-21 (3, 21, 76)
3-21 (7, 24, 69)

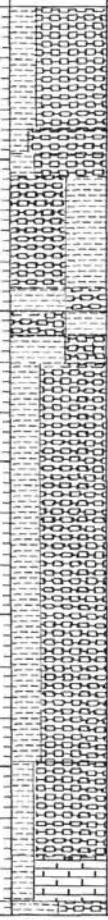
SITE 511 HOLE CORE 51 CORED INTERVAL 442.0–451.5 m

TIME – ROCK UNIT: lower–middle Albian

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER: PLANKTONIC FORAMINIFERS: *Hedbergella planispira–Hedbergella delrioensis* Assemblage; NANNOFOSSILS: *Prediscosphaera cretacea*; C/PM, RM, CM

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

METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

MUDDY CALCAREOUS CHALK AND CALCAREOUS CLAYSTONE

Section 1, 0–27 cm: muddy chalk (coquina); red (2.5YR 5/6–4/6) in top 9 cm, light greenish gray (5GY 5/1) below. Abundant pelecypods (~1 cm) and shell debris. Sharp angular lower contact.

Section 1, 27–118 cm: interbedded red to red brown (5YR 5/3) chalk as above and calcareous claystone.

Section 1, 118–143 cm: red brown calcareous claystone with 0.5 cm lenses and laminae of very dark gray sapropelic material.

Section 1, 143 cm–Section 2, 16 cm: red brown chalk (coquina).

Section 2, 16–129 cm: red (1.5YR 4/6) to red brown calcareous claystone with some light gray (5Y 7/1) zones; fewer pelecypods.

Section 2, 129–149 cm: light gray muddy chalk (coquina); abundant pelecypods.

Section 2, 149 cm–Section 3, 27 cm: red brown, highly calcareous claystone; abundant fossils.

Section 3, 27–49 cm: muddy chalk, light greenish gray (5GY 8/1) to light bluish gray (5B 7/1).

Section 3, 49 cm–Section 5, 143 cm: alternating red brown and light gray muddy chalk (coquina) and calcareous claystone.

Section 5, 143 cm–Section 6, 84 cm: alternating red/red brown and greenish gray muddy chalks (coquina).

Section 5, 84–130 cm: red brown muddy nannofossil chalk.

Section 5, 130–135 cm: red brown muddy chalk (coquina).

SMEAR SLIDE SUMMARY

	1-20	1-132	2-73	3-75	4-75	5-75	6-110
	D	M	D	D	D	D	D
Quartz	–	1	TR	–	TR	1	2
Clay minerals	25	36	39	25	29	38	24
Zeolites	TR	1	1	2	1	1	2
Carbonate unspec.	25	1	5	30	20	15	2
Foraminifers	10	1	5	5	10	5	10
Nannofossils	40	15	50	38	40	40	60
Organic carbon	–	45	–	–	–	–	–

CARBONATE BOMB:
1, 141–143 (24.5)

MAGNETIC DATA:	2-36	4-92	6-55
Inclination	–49.9	–60.9	–65.0
Declination	275.1	12.8	124.0
Intensity (emu/cc)	0.416E–05	0.244E–05	0.852E–05

GRAIN SIZE:
2-20 (1, 13, 87)
6-20 (15, 24, 61)

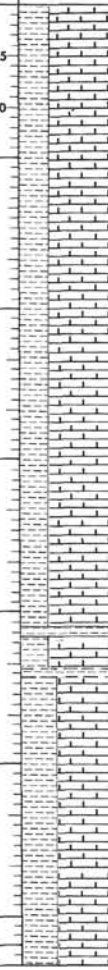
SITE 511 HOLE CORE 52 CORED INTERVAL 451.5–461.0 m

TIME – ROCK UNIT: lower–middle Albian

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER: PLANKTONIC FORAMINIFERS: *Hedbergella planispira–Hedbergella delrioensis* Assemblage; NANNOFOSSILS: *Prediscosphaera cretacea*; C/PM, FM, AM

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

METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

MUDDY NANNOFOSSIL CHALK; brown (7.5YR 5/4) to reddish brown (5YR 5/4) with greenish gry (5GY 6/1) zones, lenses and burrow fillings increasing downwards. Highly fossiliferous (*Inoceramus*) in Section 1, less so below to Section 5, 18 cm.

Section 5, 18–27 cm: grayish purple (5RP 4/2) homogeneous claystone.

Section 5, 58–65 cm: light gray (5YR 7/1) fossiliferous claystone.

Nannofossil chalks in Sections 5, 6, and 7 contain abundant pelecypod shell debris, much of it *Inoceramus*. These chalks are reddish brown with greenish gray zones as above. Greenish black laminae at Section 6, 57 cm.

Note: Section 7 is 67 cm long.

SMEAR SLIDE SUMMARY

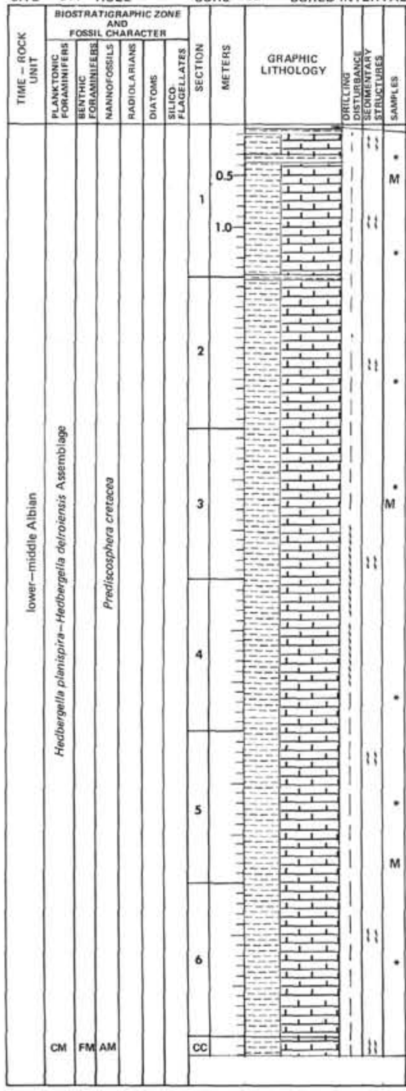
	1-75	2-75	3-55	4-76	5-24	5-64	6-24	7-12
	D	D	D	D	M	M	D	D
Quartz	1	1	1	TR	3	2	3	1
Feldspar	–	–	1	TR	2	1	–	–
Clay minerals	33	32	22	20	85	81	22	29
Zeolites	1	TR	1	TR	TR	3	–	–
Carbonate unspec.	5	2	10	20	–	–	2	10
Foraminifers	5	10	10	5	–	–	2	5
Nannofossils	55	55	55	55	–	–	70	55
Micronodules	–	–	–	–	10	10	1	–
Volcanic glass	–	–	–	–	–	3	–	–

CARBONATE BOMB:
2, 22–23 (28)

MAGNETIC DATA:	1-78	3-38	5-53
Inclination	–61.3	–54.3	–40.2
Declination	268.4	124.4	245.9
Intensity (emu/cc)	0.389E–05	0.399E–05	0.407E–05

GRAIN SIZE:
1-42 (12, 30, 58)
3-42 (3, 21, 76)
5-42 (3, 19, 79)

SITE 511 HOLE CORE 53 CORED INTERVAL 461.0–470.5 m



LITHOLOGIC DESCRIPTION

VOID

MUDDY NANNOFOSSIL CHALK
Intercalated and "blotchy" light gray to greenish gray (5GY 6/1) and reddish brown (5YR 5/4) with gray zones becoming more abundant down section.

Section 1, 4–8, 30–37, and 145–150 cm: are sparsely fossiliferous claystones. Abundant pelecypod (*Inoceramus*) fragments throughout Section 1, but present throughout the core.

Burrowing moderate, "solid" and "ring" varieties appearing and *Chondrites* and *Zoophycos* present in Sections 5 and 6.

SMEAR SLIDE SUMMARY

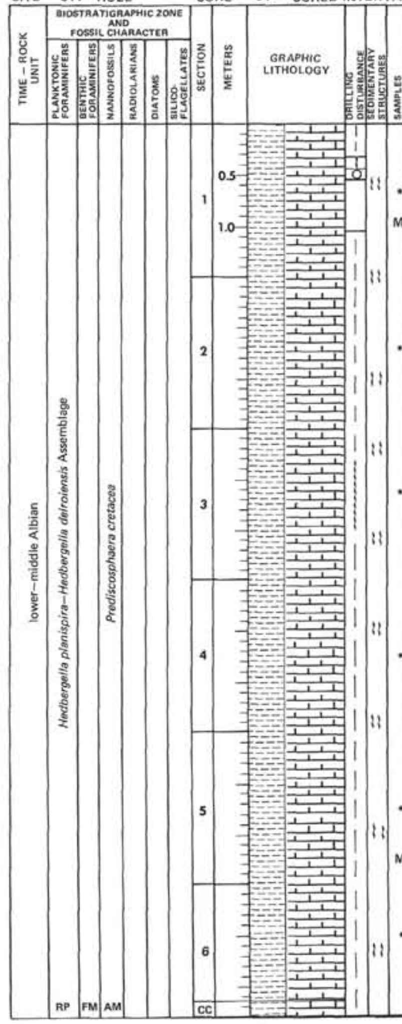
	1-35	1-130	2-105	3-68	4-120	5-72	6-78
	M	D	D	D	D	D	D
Quartz	1	1	1	1	1	1	1
Feldspar	TR	–	–	TR	–	–	–
Clay minerals	46	33	34	40	38	34	28
Carbonate unspec.	5	10	20	2	10	5	1
Foraminifers	3	1	TR	1	TR	TR	TR
Nannofossils	45	55	45	55	50	60	70
Volcanic glass	TR	–	–	–	–	–	–
Micronodules	–	–	–	1	1	–	–

CARBONATE BOMB:
5, 64–65 (25.5)

MAGNETIC DATA:	1-63	3-69	5-119
Inclination	–64.0	–51.2	–43.6
Declination	124.5	163.5	172.5
Intensity (emu/cc)	0.546E–05	0.367E–05	0.128E–05

GRAIN SIZE:
2-20 (3, 17, 80)
4-20 (3, 17, 80)
6-20 (1, 19, 80)

SITE 511 HOLE CORE 54 CORED INTERVAL 470.5–480.0 m



LITHOLOGIC DESCRIPTION

MUDDY NANNOFOSSIL CHALK; as in previous Core 53; predominately reddish brown, with thick, gray to greenish gray zones (i.e. Section 2, 50–130 cm) down section. Pelecypod debris moderate; locally abundant. Burrowing moderate throughout; burrows commonly light greenish gray (5GY 8/1) with darker green centers. "*Zoophycos*" at Section 2, 164 and 172 cm. Abundant sparry calcite associated with pelecypod laminae. Barite(?) nodules abundant in Section 5, 58–59 and 145–150 cm and Section 6, 0–4 and 97–101 cm.

SMEAR SLIDE SUMMARY

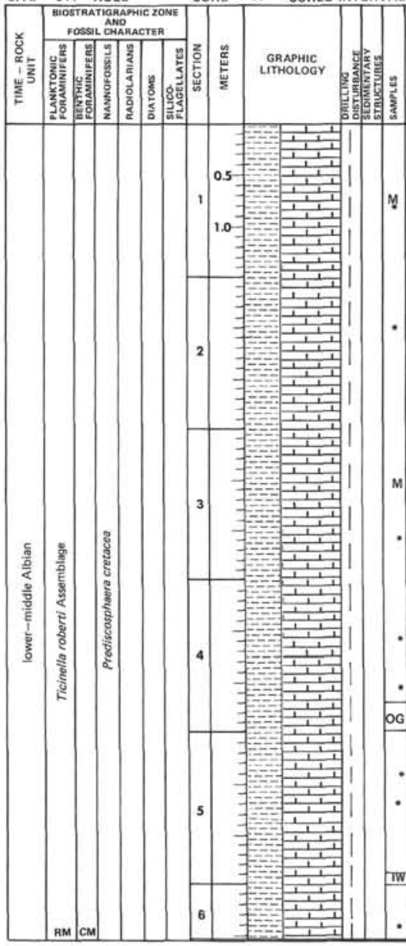
	1-72	2-75	3-68	4-75	5-75	6-55
	D	D	D	D	D	D
Quartz	–	–	1	1	1	–
Dolomite	TR	TR	–	–	TR	–
Clay minerals	31	28	23	28	37	32
Zeolites	TR	–	–	TR	1	–
Carbonate unspec.	2	5	10	15	5	2
Foraminifers	2	2	1	1	1	1
Nannofossils	65	65	65	55	55	65
Micronodules	TR	–	–	–	TR	–
Volcanic glass	–	–	TR	–	–	–

CARBONATE BOMB:
5, 62–63 (15)

MAGNETIC DATA:	1-98	5-115
Inclination	–46.2	–45.3
Declination	219.4	12.8
Intensity (emu/cc)	0.843E–05	0.288E–04

GRAIN SIZE:
2-20 (1, 19, 80)
4-20 (2, 17, 82)
6-20 (0, 11, 89)

SITE 511 HOLE CORE 55 CORED INTERVAL 480.0–489.5 m



LITHOLOGIC DESCRIPTION

MUDDY NANNOFOSSIL CHALK; as in previous Cores 53 and 54 except that below Section 1, 114 cm, the color is predominately greenish gray (5G 6/1) with lesser reddish brown (5YR 5/3), greenish black (5GY 2/1) and dark greenish gray (5GY 4/1) zones. The top 114 cm of Section 1 is reddish brown with rare gray spots. In Section 5, 73–74 cm is a grayish purple (5P 4/2) claystone layer.

Pelecypod fragments are sparse throughout. Burrowing moderate (dark greenish gray), with *Zoophycos* noted in Section 2.

Pyrite is common in Sections 2, 3, 4, and 5 (in burrows), and 6.

SMEAR SLIDE SUMMARY

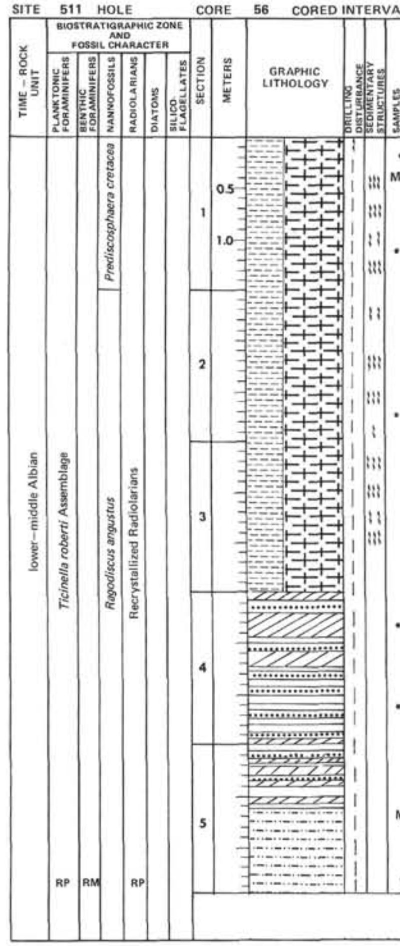
	1-85	2-52	3-110	4-60	4-102	5-45	5-74	6-40
	D	D	D	D	M	D	M	D
Quartz	TR	TR	1	1	1	TR	–	TR
Feldspar	TR	–	–	–	–	TR	–	–
Dolomite	TR	–	TR	–	–	–	–	–
Barite	TR	–	–	TR	TR	–	TR	–
Pyrite	–	–	–	–	40	–	–	–
Clay minerals	35	34	37	38	18	33	92	30
Mica	–	–	–	–	–	–	TR	TR
Zeolites	–	TR	–	–	1	1	1	–
Carbonat unspec.	–	–	1	1	–	–	–	–
Foraminifers	TR	–	–	TR	–	–	1	–
Nannofossils	65	65	60	60	40	65	3	70
Micronodules	–	1	1	TR	–	1	3	TR
Volcanic glass	–	–	–	TR	–	–	–	–

CARBONATE BOMB:
1, 49–51 (29)
6, 42–43 (7)

MAGNETIC DATA:	1-78	3-58
Inclination	–75.8	–63.8
Declination	201.9	321.9
Intensity (emu/cc)	0.604E–04	0.210E–06

GRAIN SIZE:
1-21 (0, 10, 90)
3-21 (1, 11, 88)
5-21 (1, 10, 90)

SITE 511 HOLE CORE 56 CORED INTERVAL 489.5–499.0 m



LITHOLOGIC DESCRIPTION

MUDDY NANNOFOSSIL CHALK AND "BLACK SHALE"

Sections 1–3: muddy chalk as in previous Cores 54 and 55; greenish gray (5GY 6/1) with zones of greenish black (5GY 2/1) except top 32 cm, Section 1 which are pinkish gray (7.5YR 6/2) with some red brown (5YR 5/2). Burrowing moderate to heavy as shown; *Zoophycos* and *Chondrites* present. Sparse shell fragments (?*Aucellina*) in Sections 2 and 3. Pyrite in burrows.

Section 4 and Section 5, 1–55 cm: alternating layers of muddy nannofossil chalk, greenish black zeolitic claystone, and black shale. Chalks moderately burrowed, with *Zoophycos* and *Chondrites* throughout. Zeolitic claystones moderately burrowed, filled with indurated carbonate or pyrite; finely laminated. Black shales, often fissile and very finely laminated, are moderately burrowed.

Section 5, 55–148 cm: "black shale" (5Y 2.5/1) finely laminated, with greenish gray laminae in intervals 66–70, 102–104, and 141–142 cm. *Aucellina*(?) fragments between 70–84 cm.

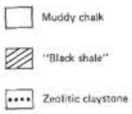
Slight to moderate burrowing in Sections 4 and 5.

SMEAR SLIDE SUMMARY

	1-28	1-113	2-122	4-36	4-114	5-130
	D	D	M	D	D	D
Quartz	TR	TR	1	2	TR	TR
Clay minerals	30	35	69	83	15	90
Zeolites	–	–	28	15	–	10
Carbonate unspec.	5	2	2	–	–	–
Foraminifers	–	–	–	–	TR	TR
Nannofossils	65	63	1	TR	85	TR
Volcanic glass	TR	TR	1	TR	TR	–

CARBONATE BOMB:
2, 76–78 (11.5)
5, 58–60 (0)

MAGNETIC DATA:	1-32	5-71
Inclination	–61.8	–68.8
Declination	233.2	285.7
Intensity (emu/cc)	0.232E–04	0.680E–06



GRAIN SIZE:
1-28 (10, 10, 89)
3-28 (0, 6, 94)
5-28 (0, 15, 85)

SITE 511 HOLE CORE 57 CORED INTERVAL 499.0–508.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES	LITHOLOGIC DESCRIPTION
lower–middle Albian	Planktonic foraminifers: *Ticinella roberti* Assemblage (RP); Benthic foraminifers: RP; Radiolarians: Recrystallized Radiolarians (RP)	1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0		Samples: M (Section 1), M (Section 3)	see below

"BLACK SHALE" (5Y 2.5/1). Most probably a black mudstone; very fine laminations common, along which fissile cleavage can occur. Gray (2.5Y 5/0) and greenish gray (5GY 6/1) – the latter often nannofossil-rich – zones in Section 1, 43–52, 58–67, 99–107, and 140–142 cm; in Section 2, 9–10, 19–20, 35–37, and 142–144 cm; in Section 3, 15–17 and 87–89 cm; in Section 4, 15–24, 37–43, 78–79, 99–101, 100–111, and 123–130 cm.

Burrowing sparse to moderate as shown, including *Zoophycos* and *Chondrites* occurring mostly in gray zones. Burrows commonly filled with calcilutite and/or pyrite. Pyrite laminae common in Section 5.

Microfaulting(?) in Section 2, 122–125 cm, Section 3, 80–88 cm, Section 4, 15–23 cm, and Section 6, 28–31 cm.

Aucellina(?) fragments sparse in Section 5.

In Section 6, 10–24 cm: white (2.5Y 8/2 and 2.5Y 8/0) layers rich in nannofossils and finely comminuted carbonate.

SMEAR SLIDE SUMMARY

	1-29 D	1-64 M	2-61 M	4-80 D	6-21 M
Quartz	1	1	–	1	–
Clay minerals	94	59	3	85	20
Zeolites	2	–	–	2	–
Carbonate unspec.	–	–	97	TR	TR
Nannofossils	–	40	–	TR	8
Undetermined mineral	3	–	–	12	–
Volcanic glass	–	TR	–	–	–

CARBONATE BOMB:
2, 14–16 (0)
5, 82–84 (0)

MAGNETIC DATA:	1-87	3-56
Inclination	–79.2	–62.1
Declination	222.6	250.5
Intensity (emu/cc)	0.600E–06	0.540E–06

GRAIN SIZE:
1-28 (0, 17, 83)

SITE 511 HOLE CORE 58 CORED INTERVAL 508.5–518.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES	LITHOLOGIC DESCRIPTION
Barremian–Aptian	Planktonic foraminifers: *Hedbergella sigali–Hedbergella infracretacea* Assemblage (RP); Nannofossils: FP	1, 2, 3, 4, CC	0.5, 1.0		Samples: M (Section 1), M (Section 2), OG (Section 3), M (Section 4)	see below

"BLACK SHALE", as in Core 57. Sparsely laminated throughout; laminae greenish black or very dark brown (10YR 2/2), i.e. Section 2, 139–144 cm. Grey and greenish gray zones in Section 1, 67–68 cm, Section 2, 92–101 cm, Section 3, 114–121 cm, and Section 4, 56–70 and 70–86 cm (greenish black) and 86–89 cm.

Burrowing sparse throughout core.

Pyrite common in stringers, lenses, and rare small (0.5 cm) nodules. Lenses, burrow fillings and laminae of white calcilutite to fine calcarenite common – i. e. Section 2, 30–32, 50–52, and 55–56 cm; Section 3, 52–53 cm; in Section 4, 120–121 and 146–147 cm; in Section 1, 22–26, 53–57, 100–103, 109–110, and 137–138 cm.

Aucellina(?) sparse through Sections 1, 2, and 4. Pale yellow (2.5Y 8/4) lens, Section 3, 60–62 cm, contains 40% carbonate.

Microfaulting(?) in Section 1, 45–47 cm and Section 3, 95–97 and 101–104 cm.

Coquina in Core-Catcher, 11–18 cm.

SMEAR SLIDE SUMMARY

	1-85 D	2-96 M	3-61 M	4-70 M
Quartz	1	TR	TR	TR
Clay minerals	87	15	91	85
Glauconite	–	–	–	TR
Zeolites	2	–	–	2
Carbonate unspec.	–	5	8	3
Foraminifers	–	5	TR	–
Nannofossils	3	75	1	–
Undetermined mineral	7	–	–	10
Volcanic glass	–	TR	TR	–

CARBONATE BOMB:
1, 71–73 (0)
4, 72–74 (0)

MAGNETIC DATA:	1-89	2-60	4-130
Inclination	–53.7	–48.7	–38.9
Declination	117.2	359.3	191.0
Intensity (emu/cc)	0.390E–06	0.300E–06	0.200E–06

GRAIN SIZE:
1-84 (0, 16, 84)

SITE 511 HOLE CORE 59 CORED INTERVAL 518.0–527.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER: PLANKTONIC FORAMINIFERS	BENTHIC FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SILICO-FLAGELLATES	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
Barremian–Aptian			Chiastozygus litterarius FP				1, 2, 3, 4, CC	0.5, 1.0	VOID			M, •, •, M

LITHOLOGIC DESCRIPTION

"BLACK SHALE", as in previous core. Soft greenish gray layer, Section 2, 123–125 cm. White laminae of shell debris common through core, i.e. Section 1, 78–87 cm; very common in Section 2; in Section 3, 98–100 and 103–110 cm they contain abundant nannofossils. Section 4, 39–51, 54–65, 89–93, and 98–100 cm again with abundant nannofossils. Layers with large *Inoceramus* fragments and other shells in Section 3, 112–150 cm and Section 4, 0–39, 107–111, and 124–135 cm; and in Core-Catcher 0–6 and 8–9 cm.

Belemnite fragments sparse in Sections 3 and 4 and Core-Catcher.

SMEAR SLIDE SUMMARY

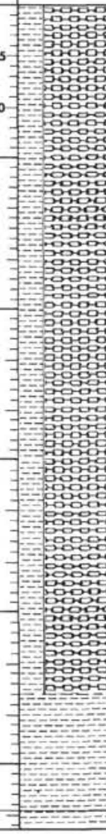
	1-70 D	4-55 M
Clay minerals	93	10
Carbonate unspec.	1	10
Nannofossils	3	80
Undetermined mineral	3	–

CARBONATE BOMB:
1, 86–88 (39)
3, 105–107 (69)

MAGNETIC DATA:	1-34	2-141	4-91
Inclination	–38.7	–37.6	– 0.6
Declination	177.9	222.2	189.6
Intensity (emu/cc)	0.230E–06	0.180E–06	0.190E–06

SITE 511 HOLE CORE 60 CORED INTERVAL 527.5–537.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER: PLANKTONIC FORAMINIFERS	BENTHIC FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SILICO-FLAGELLATES	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
Barremian–Aptian							1, 2, 3, 4, 5, 6, CC	0.5, 1.0				M, •, •, M, •, IW, •, OG, M



LITHOLOGIC DESCRIPTION

MUDDY CHALK AND CHALK

Predominately dark gray (5Y 4/1) muddy chalk, with lesser intervals (Section 1, 43–58 cm; Section 2, 4–17 and 100–145 cm; Section 3, 43–44, 78–80, and 110–125 cm; Section 4, 9–16 cm; Section 5, 0–9 and 42–80 cm) of light gray (5Y 6/1) chalk that contains a high percent of nannofossils and carbonate unspecified, and less clay minerals. The rock is highly indurated. Laminations are common.

Pale gray laminae in dark gray muddy chalk are enriched in carbonate.

Belemnite fragments common and *Inoceramus* fragments abundant in laminae in Sections 1, 2, and 4. Bioturbation is sparse to rare.

Aucellina(?) fragments sparse in Section 4.

Cherty layer, Section 5, 41–42 cm.

Section 5, 80 cm–Section 6, 58 cm and Core-Catcher: finely to very finely laminated highly petroliferous (oil shale) black (5Y 2.5/1) with brownish overtone claystone.

SMEAR SLIDE SUMMARY

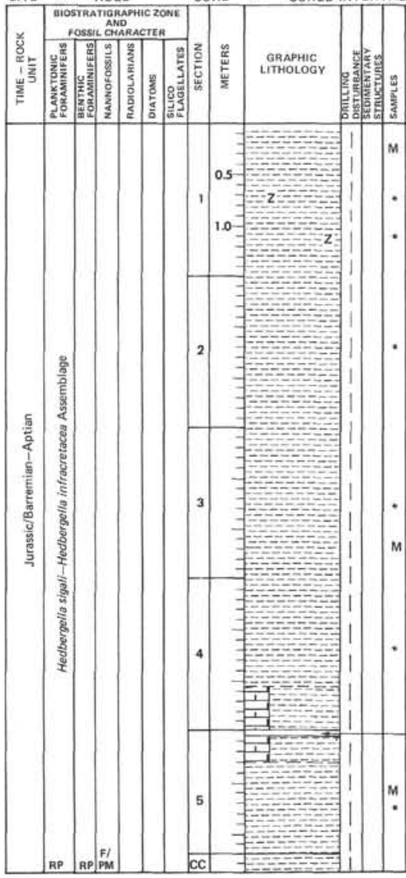
	1-87 D	2-122 D	4-65 D	5-90 D
Quartz	TR	–	–	–
Clay minerals	20	5	25	83
Zeolites	–	–	–	6
Carbonate unspec.	5	93	45	4
Nannofossils	67	2	30	–
Inoceramus fragments	8	–	–	–
Undetermined mineral	–	–	–	7

CARBONATE BOMB:
1, 32–34 (39)
2, 125–127 (94)

MAGNETIC DATA:	1-54	3-129	6-52
Inclination	–78.8	–47.0	0.0
Declination	219.7	162.6	168.1
Intensity (emu/cc)	0.410E–06	0.260E–06	0.130E–06

GRAIN SIZE:
3-95 (1, 26, 74)

SITE 511 HOLE CORE 61 CORED INTERVAL 537.0–546.5 m



LITHOLOGIC DESCRIPTION

BLACK SHALE (CLAYSTONE)
Black (5Y 2.5/1), finely laminated, highly indurated, petroliferous. Occassional layers, 1–5 cm, olive gray (5Y 4/2) containing finely comminuted pelecypod debris. Fine gray layers (5Y 5/1) 1.0– < 1.0 cm are present, containing appreciable zeolites in Section 1.

Through Sections 2, 3, and 4, color becomes lighter, to very dark gray (5Y 3/1) and light olive gray (5Y 4/2–5/2), or alternations of light and dark gray.

Section 4, 90 cm–Section 5, 30 cm: dark olive gray (5Y 3/2) NANNOFOSSIL CLAYSTONE. Interval Section 5, 30–120 cm is less carbonate-rich and very dark gray (5Y 3/1) in color, as in Sections 2 and 3.

Pyrite lamina, Section 4, 25 cm.

Cone-in-cone calcite and pyrite gray (5Y 6/1) to light gray (5Y 7/1) in Section 4, 14–17 cm.

SMEAR SLIDE SUMMARY

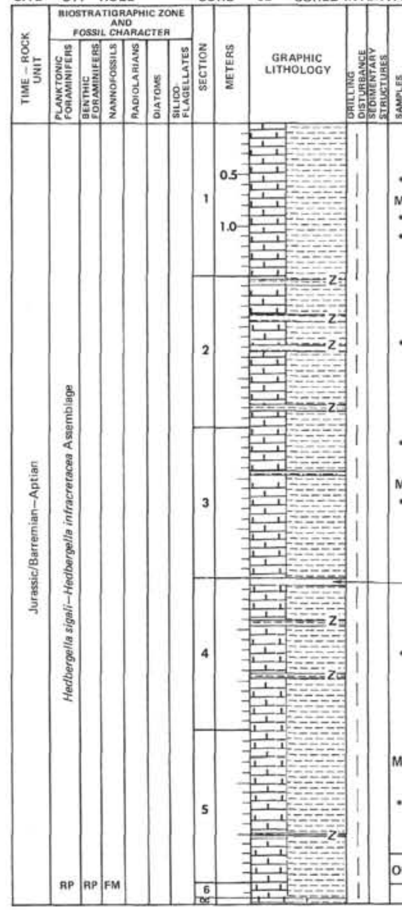
	1-74	1-116	2-75	3-80	4-75	5-75
	D	M	D	D	D	D
Quartz	1	–	TR	TR	1	1
Feldspar	3	1	1	15	10	3
Mica	5	–	–	–	–	–
Clay minerals	87	64	75	70	79	57
Zeolites	3	25	3	3	3	1
Carbonate unspec.	1	–	1	2	2	5
Nannofossils	TR	–	15	TR	–	30
Organic carbon	–	10	2	10	5	3

CARBONATE BOMB:
2, 46–48 (5)

MAGNETIC DATA:	1-27	3-126	5-54
Inclination	–49.1	–45.6	–83.3
Declination	118.3	297.6	259.3
Intensity (emu/cc)	0.108E–05	0.180E–06	0.200E–06

GRAIN SIZE:
1-24 (0, 17, 83)
3-24 (0, 27, 73)
5-24 (0, 22, 78)

SITE 511 HOLE CORE 62 CORED INTERVAL 546.5–556.0 m



LITHOLOGIC DESCRIPTION

MUDSTONE AND NANNOFOSSIL MUDSTONE
Petroliferous; very dark gray (5Y 3/1), hard, massive; locally faintly bedded. Change from more to fewer nannofossils is subtle. Stratification varies from horizontal to 5–10°.

Olive gray (5Y 5/2) layers, 1–10 cm thick (located as shown) are zeolitic claystone. They are commonly overlain by 0.5–1 cm dark grayish green (5GY 4/1) lamina.

In Section 3, 26–27 cm, is an olive gray (5Y 5/2) layer of calcarenite and from 41–43 cm, a fine to medium quartz sand in a dark gray mud matrix. Belemnites present in Section 5.

SMEAR SLIDE SUMMARY

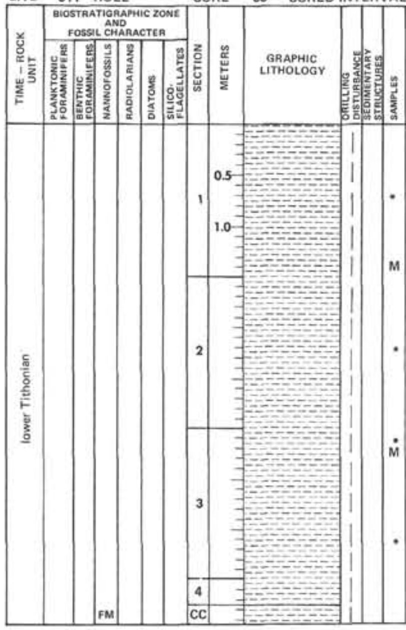
	1-65	1-97	1-117	2-75	3-20	3-80	4-80	5-70
	D	D	M	D	M	D	D	D
Quartz	1	1	–	2	1	1	1	2
Feldspar	2	15	2	10	15	15	20	10
Mica	–	5	–	1	5	–	–	–
Clay minerals	66	67	75	70	67	70	66	53
Zeolites	1	2	20	2	10	2	2	–
Carbonate unspec.	1	–	–	2	–	2	1	5
Nannofossils	25	–	–	–	–	–	–	20
Volcanic glass	1	–	–	–	–	TR	–	–
Organic carbon	–	10	3	15	3	–	10	10

CARBONATE BOMB:
1, 22–24 (4)

MAGNETIC DATA:	1-83	3-61	5-27
Inclination	–25.2	–18.3	19.1
Declination	13.9	24.0	6.2
Intensity (emu/cc)	0.710E–06	0.660E–06	0.450E–06

GRAIN SIZE:
2-30 (0, 24, 75)
4-30 (0, 20, 80)

SITE 511 HOLE CORE 63 CORED INTERVAL 556.0–565.5 m



LITHOLOGIC DESCRIPTION

CLAYSTONE (BLACK SHALE)
Black (5Y 2.5/1), petroliferous, hard; vague horizontal laminations; little visible carbonate; minore pelecypod concentration Section 1, 84 and 146–146.5 cm.

Thin (0.5 cm) gray (2.5Y 6/1) lenses and laminae Section 1, 108–110 cm.

Belemnites, Section 2, 102 cm.
Cone-in-cone, Section 3, 72–97 cm, high in calcite.

SMEAR SLIDE SUMMARY

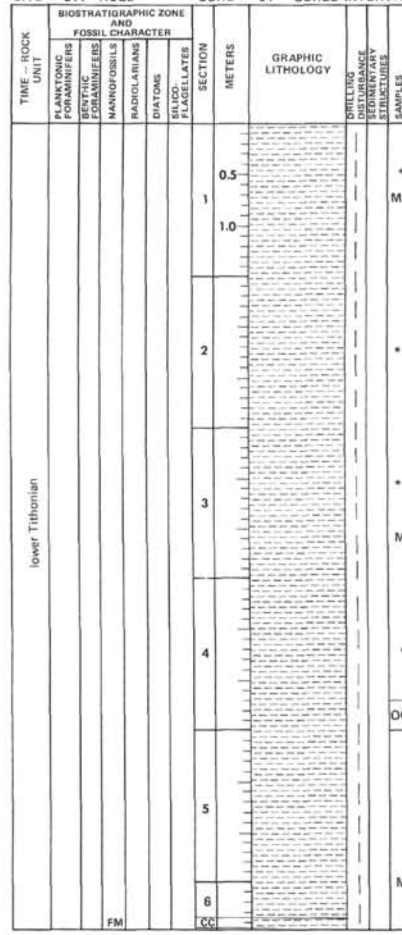
	1-75	2-75	3-15	3-115
	D	D	D	D
Quartz	1	1	–	1
Feldspar	10	5	5	10
Clay minerals	75	69	82	65
Zeolites	2	2	3	1
Carbonate unspec.	2	3	1	–
Nannofossils	–	10	5	15
Organics	10	10	5	7
Volcanic glass	–	–	–	1

CARBONATE BOMB:
1, 107–109 (4)
3, 81–83 (91)

MAGNETIC DATA:	1-142	3-13
Inclination	–60.0	– 3.0
Declination	258.7	306.2
Intensity (emu/cc)	0.130E–06	0.290E–06

GRAIN SIZE:
2-27 (0, 24, 76)

SITE 511 HOLE CORE 64 CORED INTERVAL 565.5–575.0 m



LITHOLOGIC DESCRIPTION

CLAYSTONE (BLACK SHALE); as in previous Core 63.
White laminae of fine, thin-shelled pelecypod debris at Section 1, 129, 133, and 141 cm; Section 2, 33 and 94 cm; Section 3, 41, 83, 87, and 100 cm; Section 4, 18, 45, 92, and 125 cm; and Section 5, 52, 94, 131, 133, 142, and 146 cm.

Belemnites present in all sections and Core-Catcher where the belemnite fragment is surrounded by 0.5 cm halo of fine pyrite.

Pyrite present as 3–4 mm masses, as 0.5 laminae, or disseminated in claystone matrix in Sections 1, 3, 5, 6, and Core-Catcher.

SMEAR SLIDE SUMMARY

	1-50	2-75	3-55	4-75	5-90
	D	D	D	D	D
Quartz	1	1	1	1	1
Feldspar	5	5	10	5	10
Clay minerals	70	66	58	65	57
Zeolites	2	1	5	2	1
Carbonate unspec.	2	2	1	2	1
Nannofossils	10	15	10	15	15
Organics	10	10	15	10	15

CARBONATE BOMB:
3, 128–130 (3.5)

MAGNETIC DATA:	1-79	3-122	6-5
Inclination	–54.9	–40.1	–71.6
Declination	13.3	178.7	95.9
Intensity (emu/cc)	0.120E–06	0.450E–06	0.440E–06

GRAIN SIZE:
2-33 (0, 21, 79)
4-33 (0, 25, 75)

SITE 511 HOLE CORE 65 CORED INTERVAL 575.0–584.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES
middle Oxfordian–lower Tithonian	*Hedbergella sigali–Hedbergella infracretacea* Assemblage (Planktonic foraminifers RP; Benthic foraminifers RP; Nannofossils FM)	1, 2, 3, 4, 5, CC	0.5, 1.0		M, IW, M

LITHOLOGIC DESCRIPTION

CLAYSTONE (BLACK SHALE); as in previous sections; petroliferous; with intervals of calcareous claystone which are black (5Y 2.5/1) and enriched in many laminae of pelecypod debris, i. e. Section 2, 110–124 cm; Section 2, 144 cm, and Section 3, 7, and 14–45 cm.

Minor zeolitic layers, 1.0 cm, gray (2.5Y 6/1) or light gray (2.5Y 7/0) occur in Sections 1 and 2.

Very fine- to fine-grained, hard, muddy, gray (2.5Y 6/0) calcarenite intervals occur in Section 1, 3–10, 22–28 cm, Section 2, 124–144 cm; Section 3, 7–14 cm; and Section 4, 29–32 cm.

Thin, white laminae of comminuted pelecypod debris occur mainly in the black, calcareous claystones but are also present in numerous laminae in Sections 4 and 5.

Disseminated pyrite is present in Section 1, 133 cm, Section 2, and Section 3, 103–109 cm.

Belemnites are common in Section 4.

SMEAR SLIDE SUMMARY

	1-62 M	1-75 D	2-75 D	2-130 M	3-25 D	3-75 D	4-120 D
Quartz	–	1	–	–	1	–	–
Feldspar	5	5	5	2	3	5	2
Mica	–	–	1	–	1	1	–
Clay minerals	85	72	76	27	74	71	77
Zeolites	10	5	5	1	1	1	1
Carbonate unspec.	–	2	1	70	10	2	5
Nannofossils	–	10	5	–	10	5	10
Organic matter	–	5	7	–	3	15	5

CARBONATE BOMB:
2, 125–127 (75.5)
3, 8–10 (67.5)

MAGNETIC DATA:	1-94	4-118
Inclination	–46.1	–74.1
Declination	136.0	322.6
Intensity (emu/cc)	0.470E–06	0.300E–07

GRAIN SIZE:
1-90 (0, 18, 82)
3-90 (1, 22, 77)

SITE 511 HOLE CORE 66 CORED INTERVAL 584.5–594.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES
middle Oxfordian–lower Tithonian	Nannofossils FM	1, 2, 3, 4, 5, 6	0.5, 1.0		M, OG

LITHOLOGIC DESCRIPTION

NANNOFOSSIL CLAYSTONE (BLACK SHALE)
Black, as in previous cores, bearing appreciable quantities of nannofossils.

Entire core finely laminated.

In Section 1, 38–40 and 48–54 cm, dark gray (2.5Y 4/0) to very dark gray (2.5Y 3/0), hard, slightly muddy calcarenites, the upper one fine-grained, the lower coarse-grained in bottom 3 cm and fine-grained in upper 3 cm.

Inoceramus in thin laminae present but generally sparse throughout core; locally abundant.

Belemnites present in every section; common in Section 4.

Pyrite laminae in Sections 3, and 4, 13–14, 24–25, and 41–42 cm.

Aucellina(?) sparse throughout.

SMEAR SLIDE SUMMARY

	1-50 M	1-105 D	2-75 D	3-26 M	3-80 D	4-60 D	5-95 D
Quartz	–	TR	1	1	1	1	TR
Pyrite	–	–	–	12	–	–	–
Clay minerals	10	80	79	63	74	79	80
Zeolites	–	1	TR	–	TR	TR	1
Carbonate unspec.	70	–	–	1	1	4	–
Nannofossils	–	18	20	23	24	15	19
Inoceramus debris	20	–	–	–	–	–	–
Volcanic glass	–	1	–	–	–	1	TR

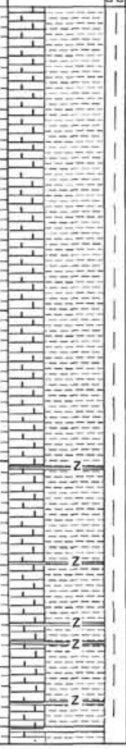
CARBONATE BOMB:
3, 92–94 (3)

MAGNETIC DATA:	1-101
Inclination	–32.2
Declination	119.6
Intensity (emu/cc)	0.110E–06

GRAIN SIZE:
3-95 (1, 22, 77)

SITE 511 HOLE CORE 67 CORED INTERVAL 594.0–603.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER: PLANKTONIC FORAMINIFERS	BENTHIC FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SILICO-FLAGELLATES	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
middle Oxfordian–lower Tithonian							1	0.5 1.0				*
							2					*
							3					*
							4					*
							5					*
							CC					



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CLAYSTONE (BLACK SHALE); as in Core 66; black, thinly laminated.

Inoceramus sparsely distributed in thin laminae.

Belemnites present throughout core, but not abundant.

Gray (2.5Y 5/0) zeolitic layers in Section 3, 107–109 cm; Section 4, 96–98 cm; and Section 5, 10–11, 29–30, 83–85 and 102 cm.

Pyrite laminae Section 5, 77–80 cm.

Core-Catcher, 0–7 cm: dark gray calcarenite with *Inoceramus* "needles".

SMEAR SLIDE SUMMARY

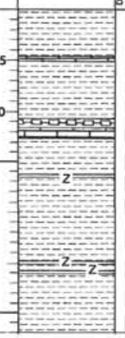
	1-50	2-20	3-60	4-75	5-45
	D	D	D	D	D
Quartz	1	1	1	1	1
Clay minerals	71	74	72	73	72
Zeolites	TR	–	–	TR	TR
Carbonate unspec.	–	2	–	TR	TR
Nannofossils	27	23	27	26	27
Volcanic glass	1	TR	TR	–	TR

CARBONATE BOMB:
3, 43–45 (8)

GRAIN SIZE:
1-51 (1, 22, 78)

SITE 511 HOLE CORE 68 CORED INTERVAL 603.5–613.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER: PLANKTONIC FORAMINIFERS	BENTHIC FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SILICO-FLAGELLATES	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
Oxfordian–lower Tithonian							1	0.5 1.0				* M
							2					* OG
							3					



LITHOLOGIC DESCRIPTION

CLAYSTONE (BLACK SHALE); as in previous cores, very finely laminated with strong fissile tendency.

Dark gray (2.5Y 4/0) calcarenite layers in Section 1, 49–50 and 118–124 cm.

Gray (2.5Y 6/0) calcareous chalk layer, Section 1, 106–118 cm.

Inoceramus and other shell debris sparsely distributed.

Aucellenia(?) sparse.

Belemnites present throughout but not abundant.

Gray zeolitic layers in Section 2, as shown.

SMEAR SLIDE SUMMARY

	1-29	2-85
	D	D
Quartz	2	2
Clay minerals	94	84
Zeolites	1	5
Carbonate unspec.	2	2
Nannofossils	1	7

CARBONATE BOMB:
1, 115–117 (80)
2, 70–72 (0)

MAGNETIC DATA:	1-112
Inclination	82.6
Declination	123.6
Intensity (emu/cc)	0.540E–06

GRAIN SIZE:
1-29 (0, 16, 84)

SITE 511 HOLE CORE 69 CORED INTERVAL 613.0–622.5 m

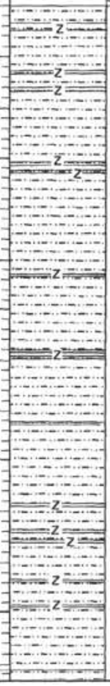
TIME – ROCK UNIT: Oxfordian–lower Tithonian

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER: PLANKTONIC FORAMINIFERS | BENTHIC FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS | SILICO-FLAGELLATES

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES

LITHOLOGIC DESCRIPTION

MUDSTONE (BLACK SHALE)
Black (5Y 2.5/1) and finely laminated as in previous cores but much softer.

Gray (2.5Y 5/0) zeolitic layers as shown.

Inoceramus and other white shell laminae very sparse in Sections 1 and 3 only.

Belemnites present throughout but sparse.

Section 5, 0–5 cm, greenish (5G 6/1) with abundant tiny greenish black (5GY 2/1) grains; ?glauconite?

Section 5, 6–7 cm, 0.5 cm pyrite nodule.

SMEAR SLIDE SUMMARY

	1-70	4-83	5-3
	D	M	M
Quartz	1	2	2
Mica	–	TR	–
Clay minerals	90	65	58
Glauconite	–	–	12
Zeolites	9	12	10
Carbonate unspec.	TR	1	TR
Undetermined mineral	20	20	18

CARBONATE BOMB:
3, 73–75 (0)
5, 2–4 (3)

GRAIN SIZE:
1-70 (0, 23, 77)

SITE 511 HOLE CORE 70 CORED INTERVAL 622.5–632.0 m

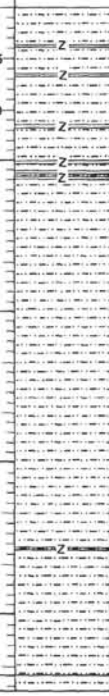
TIME – ROCK UNIT: Callovian–Oxfordian

BIOSTRATIGRAPHIC ZONE AND FOSSIL CHARACTER: PLANKTONIC FORAMINIFERS | BENTHIC FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS | SILICO-FLAGELLATES

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES

OG

LITHOLOGIC DESCRIPTION

MUDSTONE (BLACK SHALE); as in Core 69; black, laminated, with sparse shell debris laminae except in Sections 4 and 5, where they are moderately abundant and 0.5–1 cm thick. Belemnites continue to be present but not abundant. A lamina of carbonate sand (*Inoceramus* "needles") occurs in Section 5, 36 cm. *Aucellina*(?) also present in Section 5, 18–21 and 27–35 cm.

In Section 2, 136–138 cm: a relatively large, elongate black (shiny) inclusion is embedded; plant(?) stem.

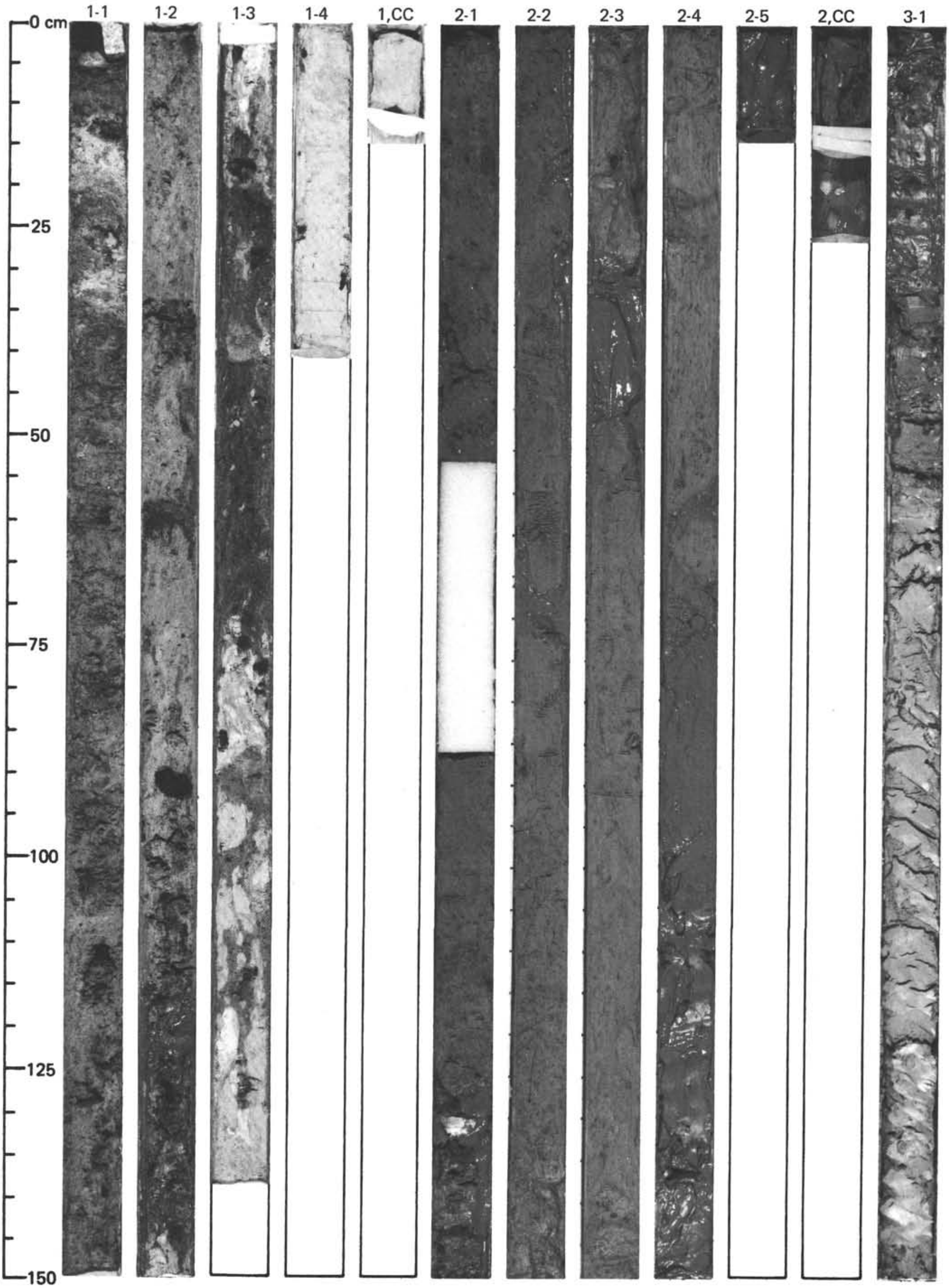
Gray zeolitic layers as shown.

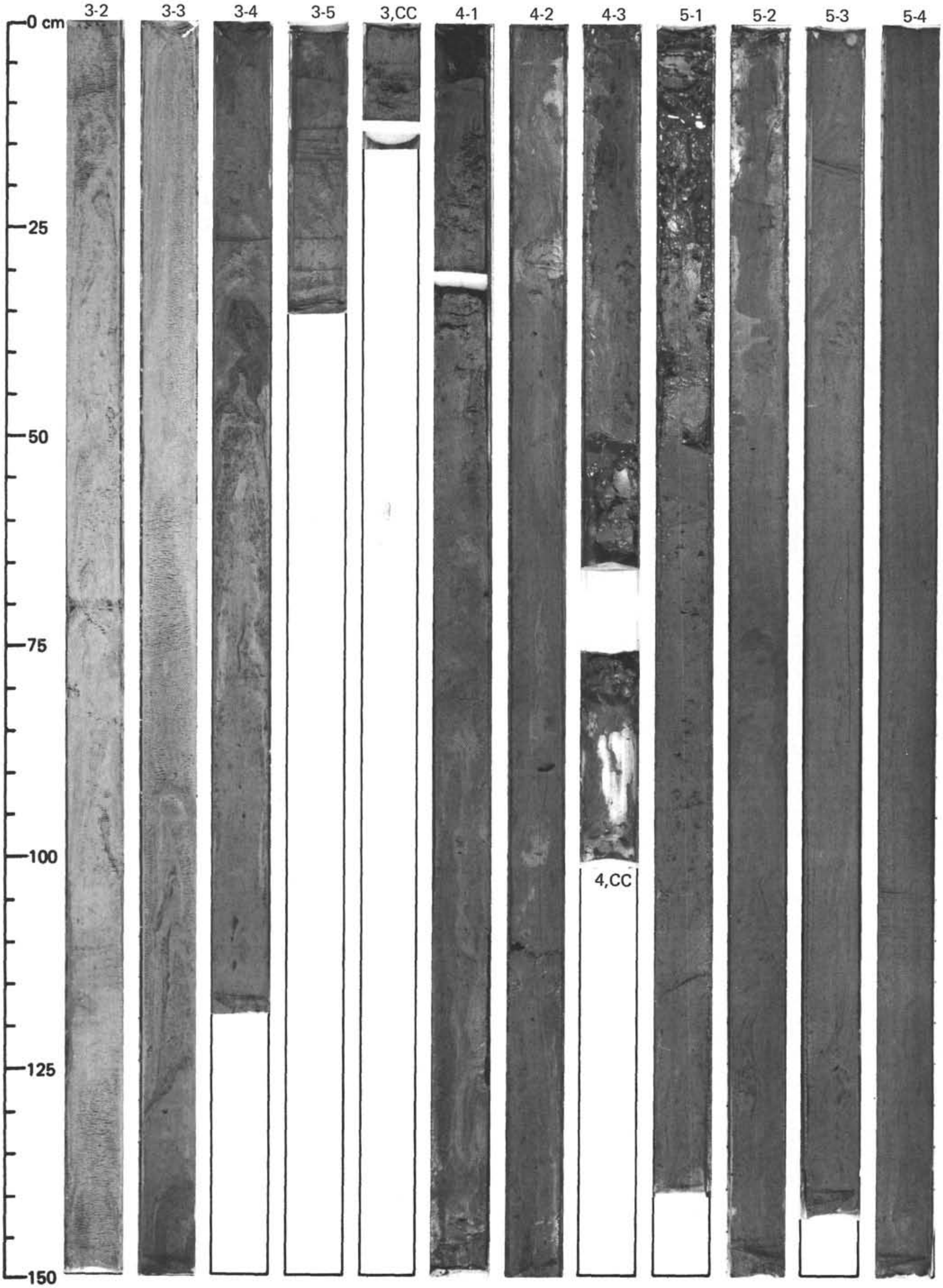
SMEAR SLIDE SUMMARY

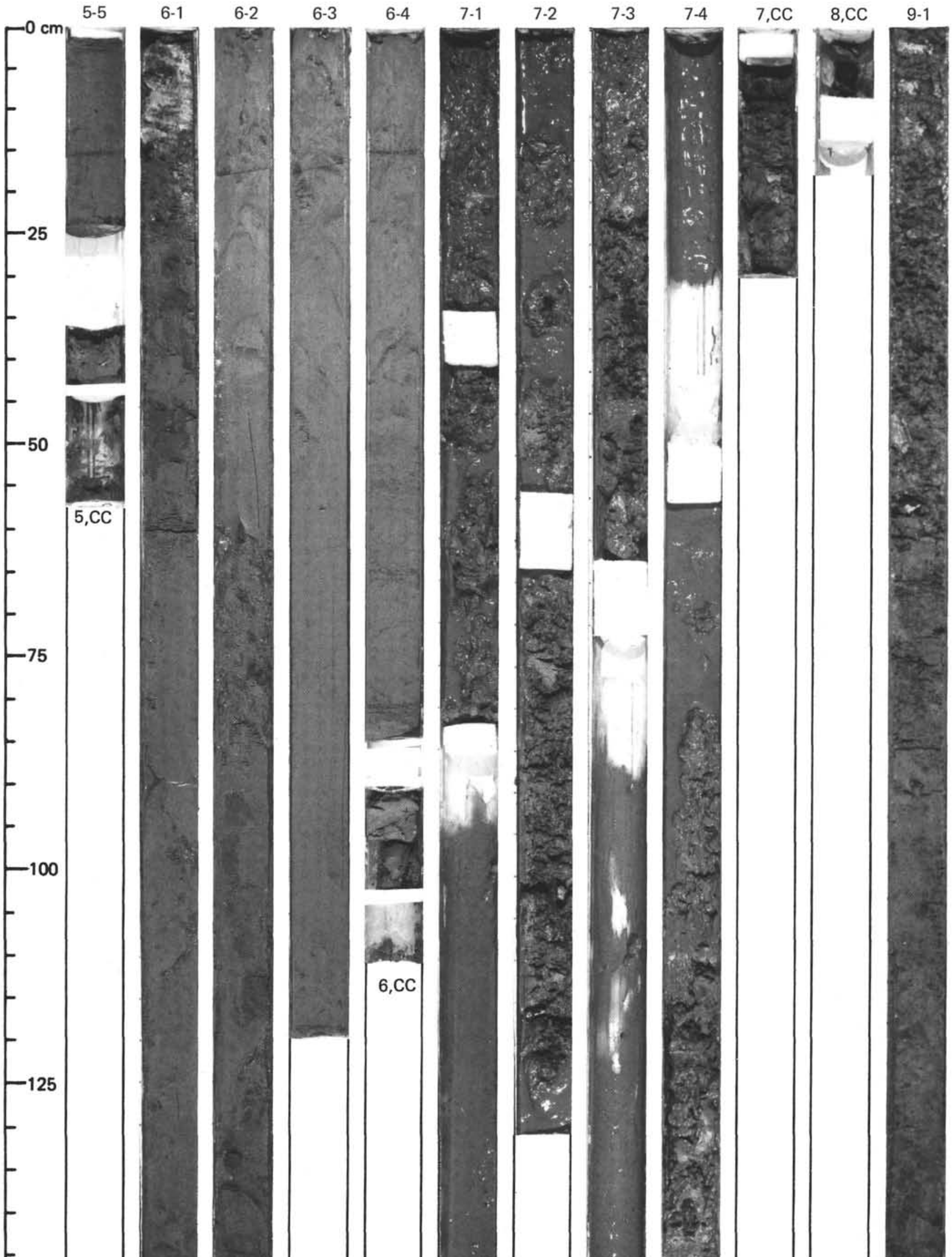
	1-60	2-55	5-25
	D	D	D
Quartz	2	1	1
Clay minerals	71	80	86
Zeolites	12	10	7
Carbonate unspec.	–	1	–
Undetermined mineral	15	8	6

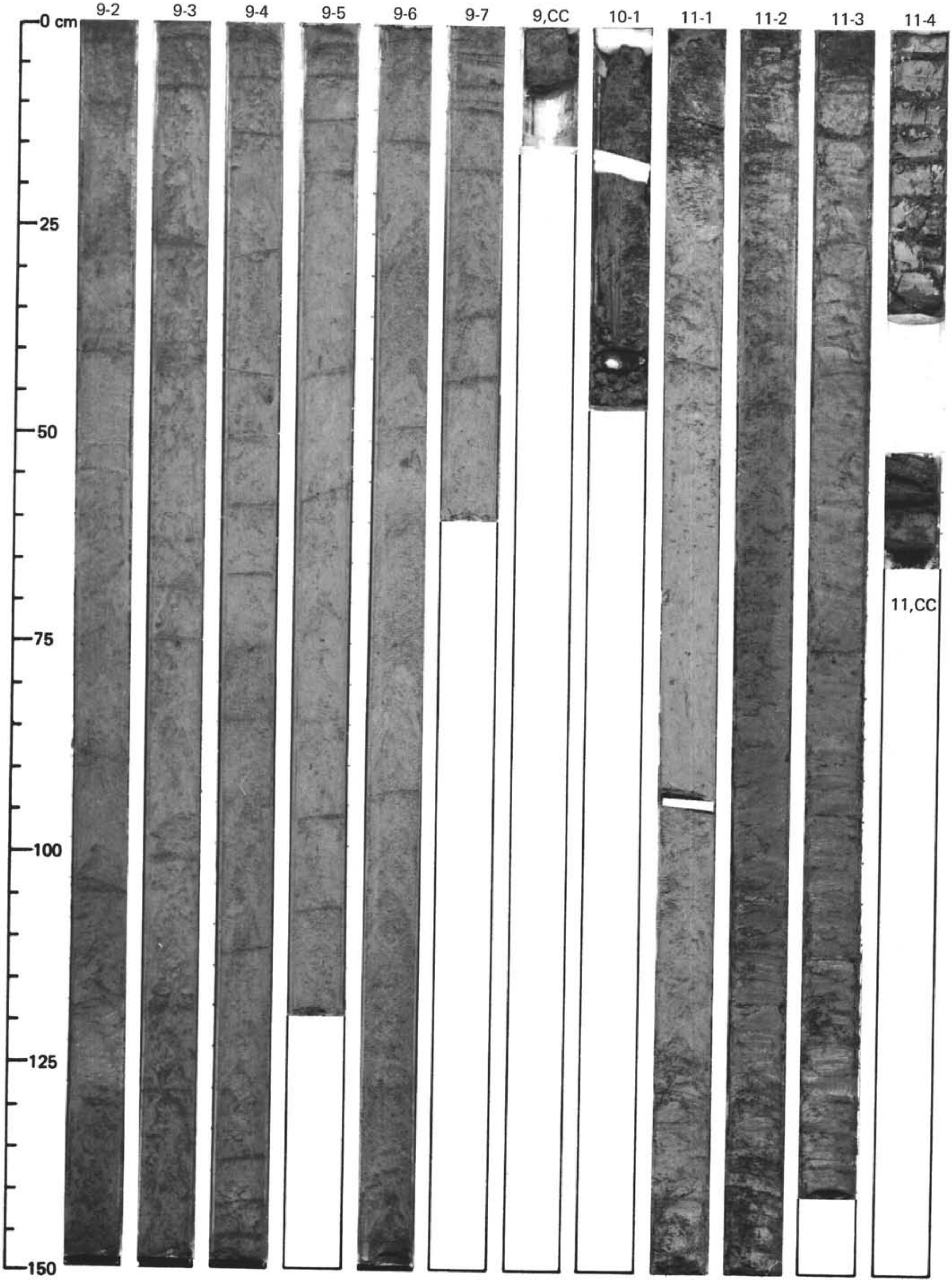
CARBONATE BOMB:
4, 94–96 (0.2)

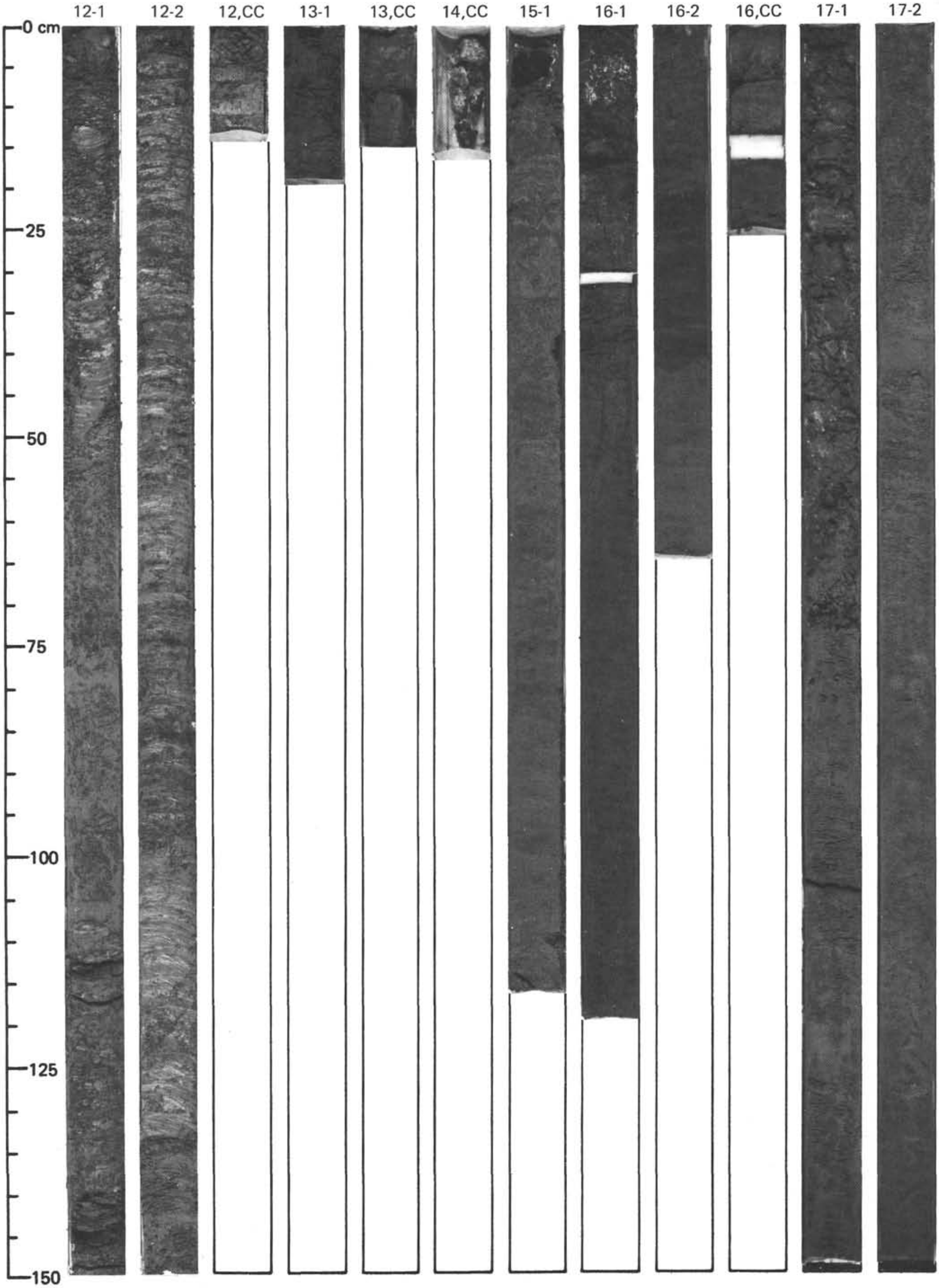
GRAIN SIZE:
2-65 (0, 10, 90)

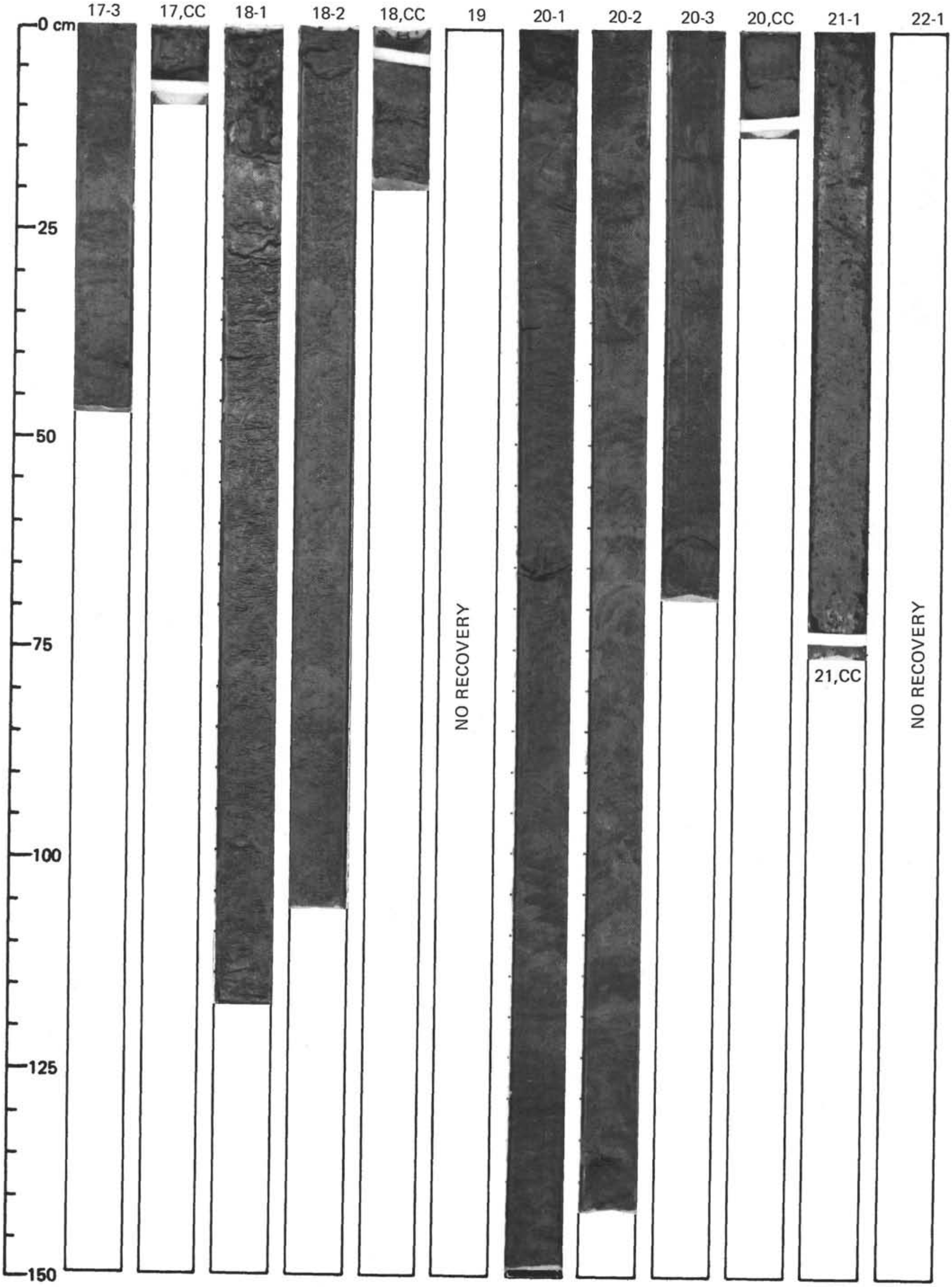

0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1-4
1,CC
2-1
2-2
2-3
2-4
2-5
2,CC
3-1

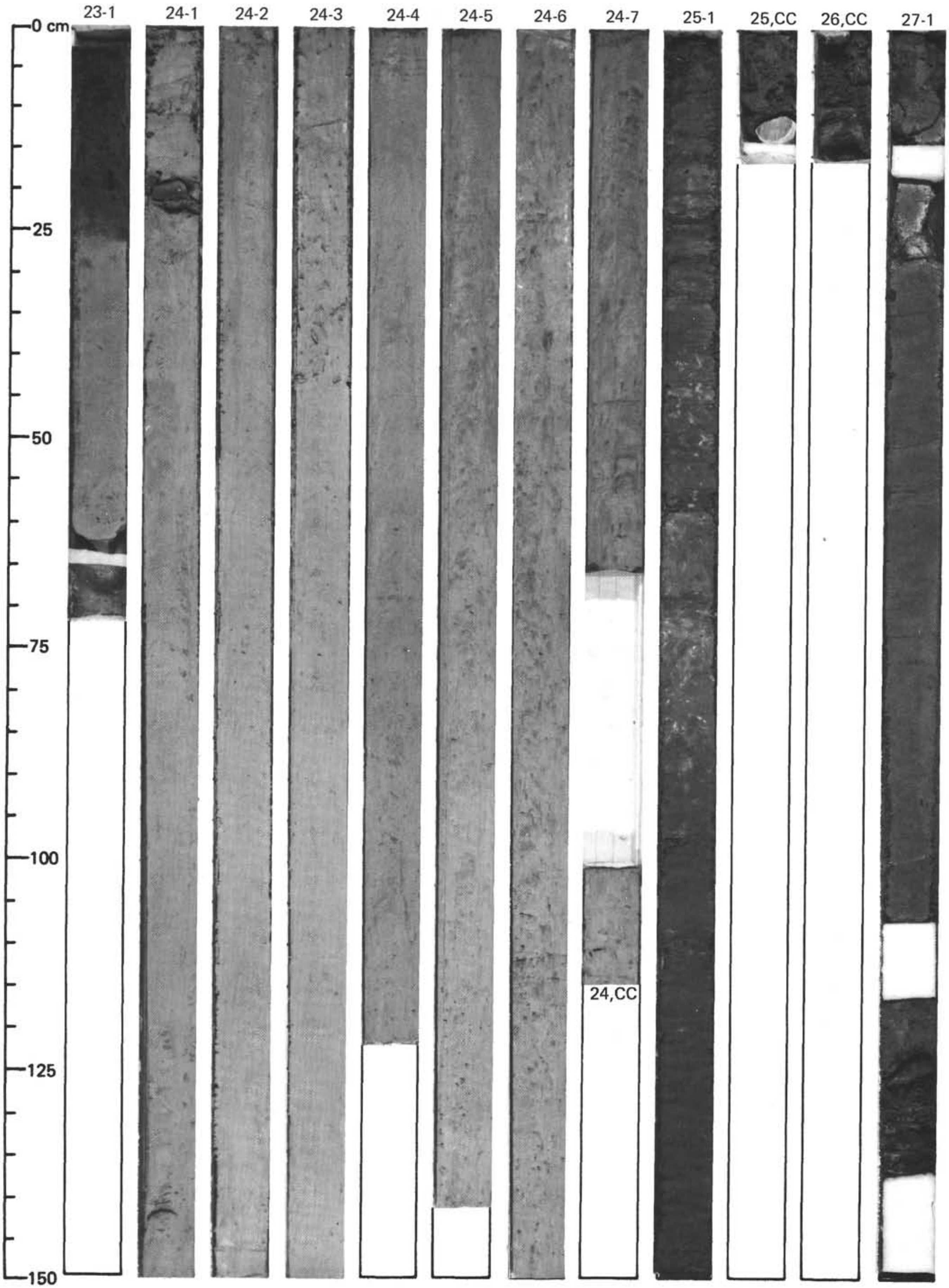

0 cm
25
50
75
100
125
150
3-2
3-3
3-4
3-5
3,CC
4-1
4-2
4-3
4,CC
5-1
5-2
5-3
5-4

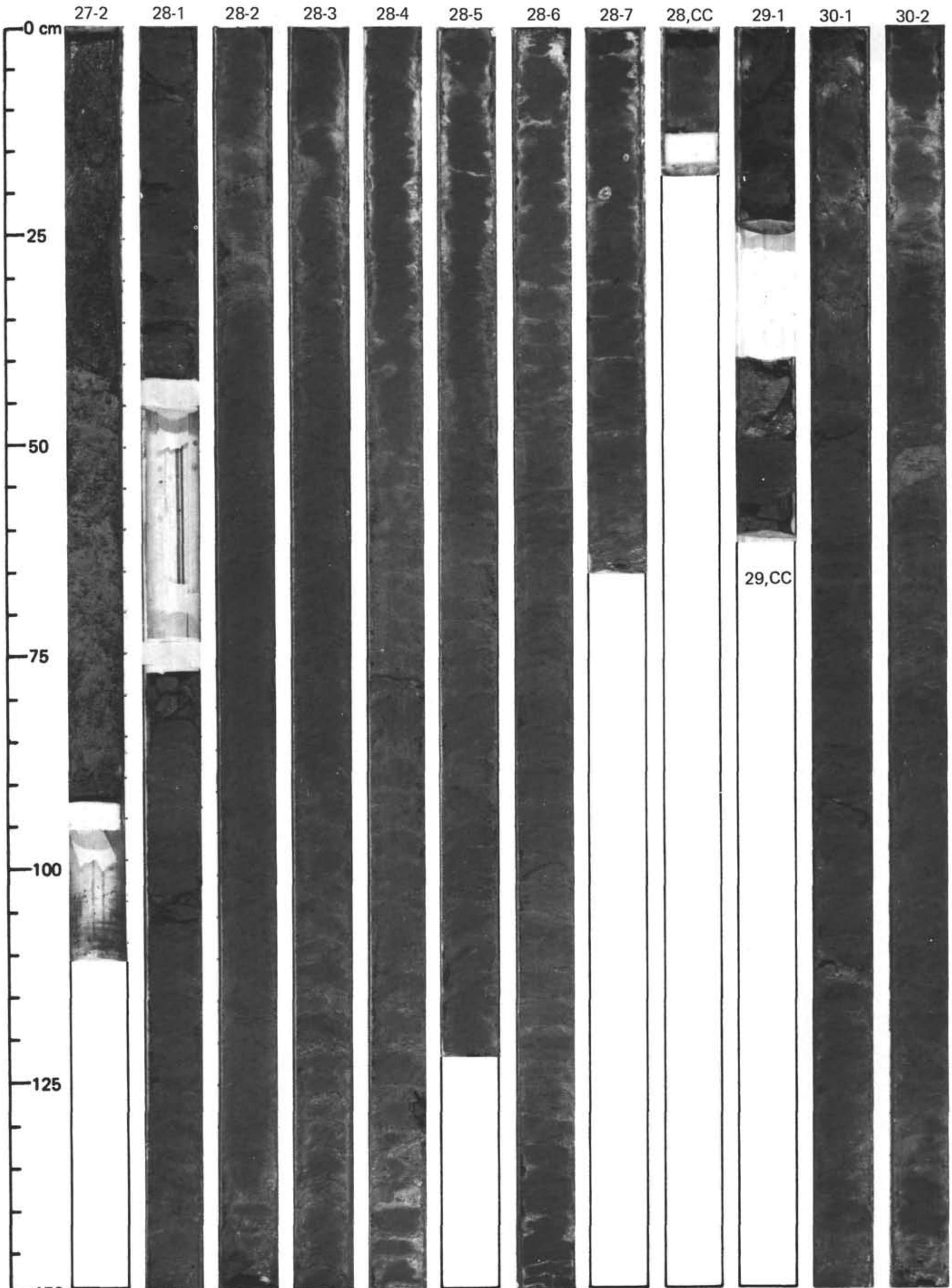

5-5
6-1
6-2
6-3
6-4
7-1
7-2
7-3
7-4
7,CC
8,CC
9-1
0 cm
25
50
75
100
125
150
5,CC
6,CC

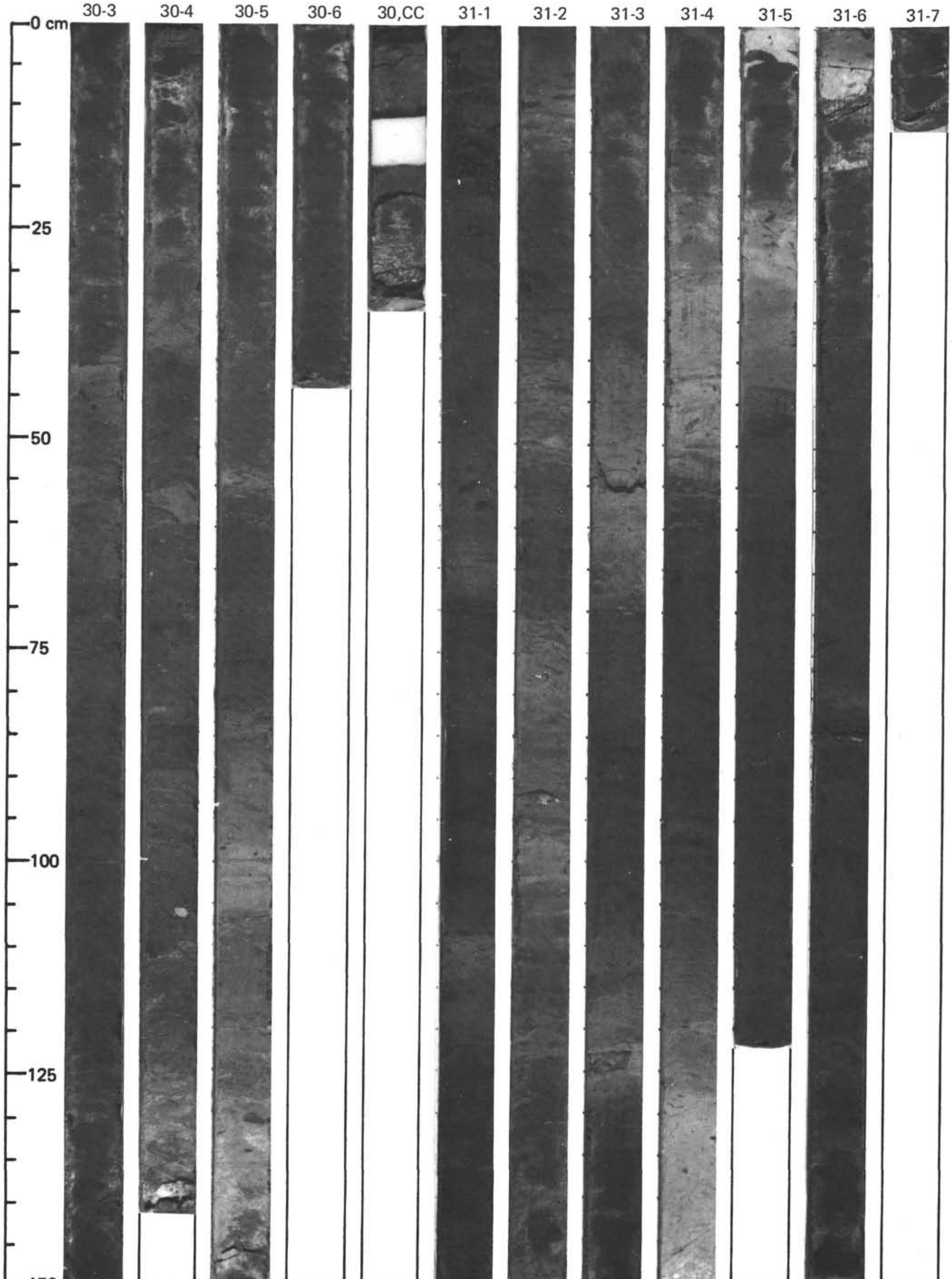

0 cm
25
50
75
100
125
150
9-2
9-3
9-4
9-5
9-6
9-7
9,CC
10-1
11-1
11-2
11-3
11-4
11,CC

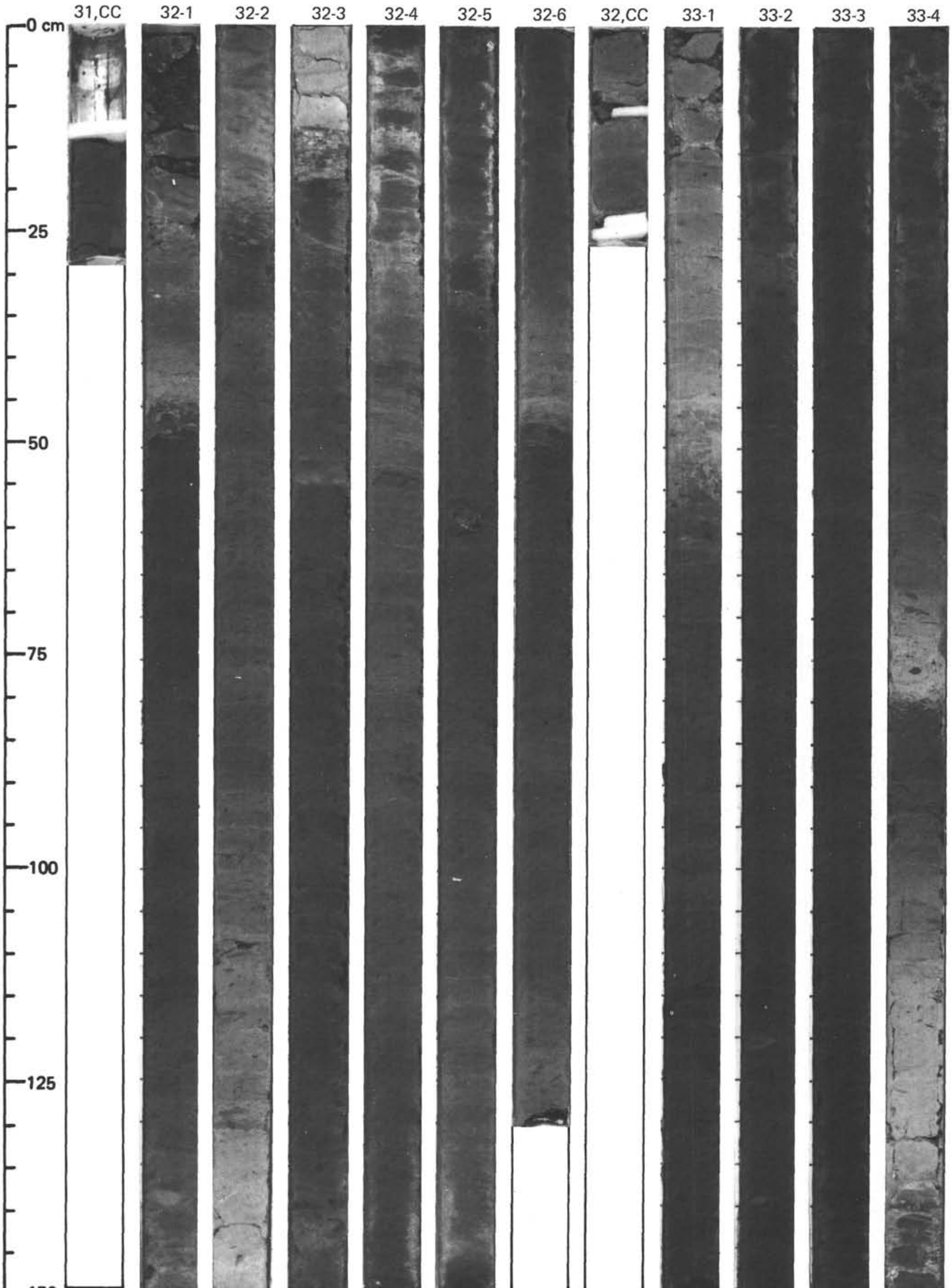

12-1
12-2
12,CC
13-1
13,CC
14,CC
15-1
16-1
16-2
16,CC
17-1
17-2
0 cm
25
50
75
100
125
150

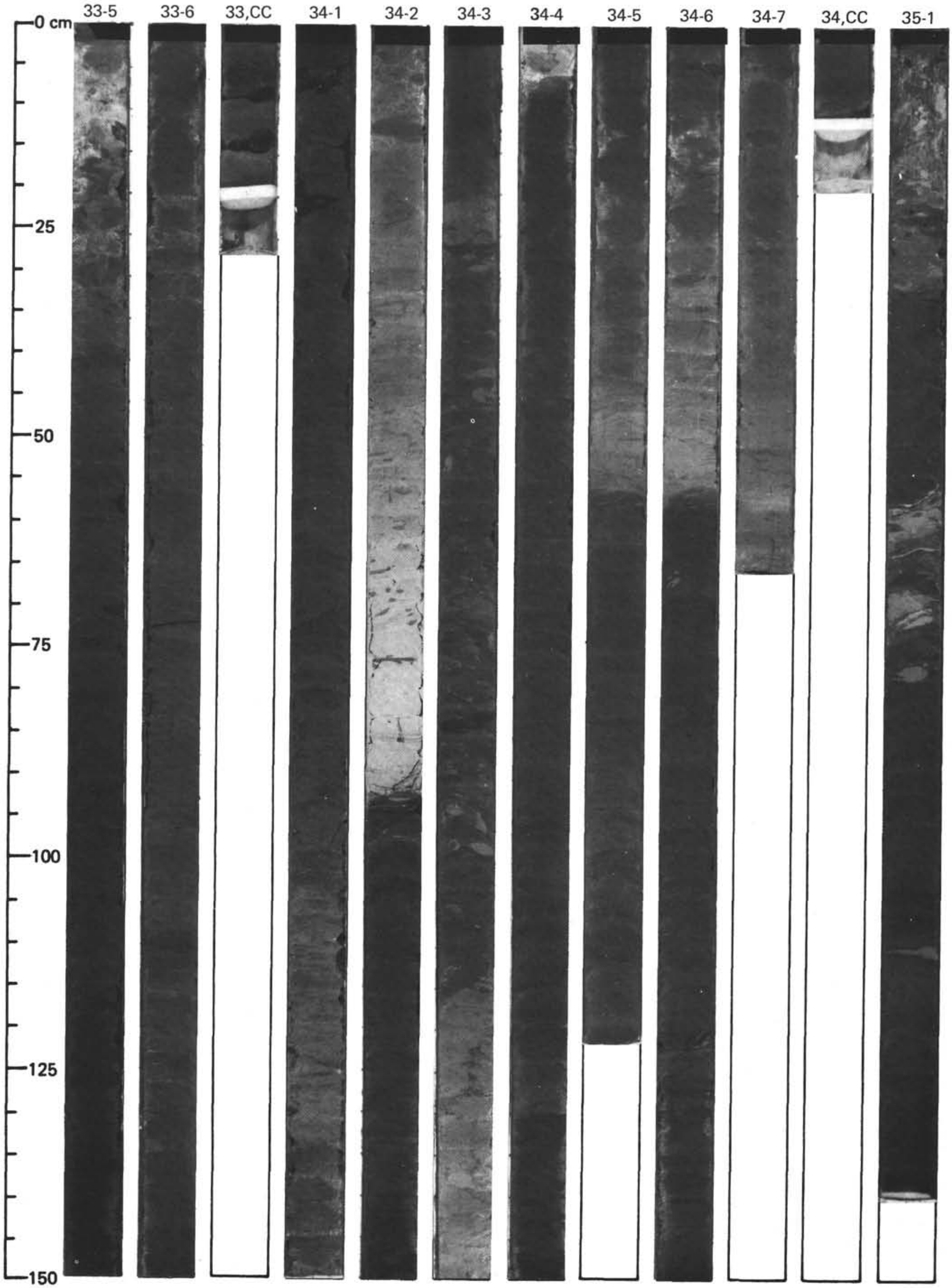

0 cm
25
50
75
100
125
150
17-3
17,CC
18-1
18-2
18,CC
19
20-1
20-2
20-3
20,CC
21-1
22-1
NO RECOVERY
21,CC
NO RECOVERY

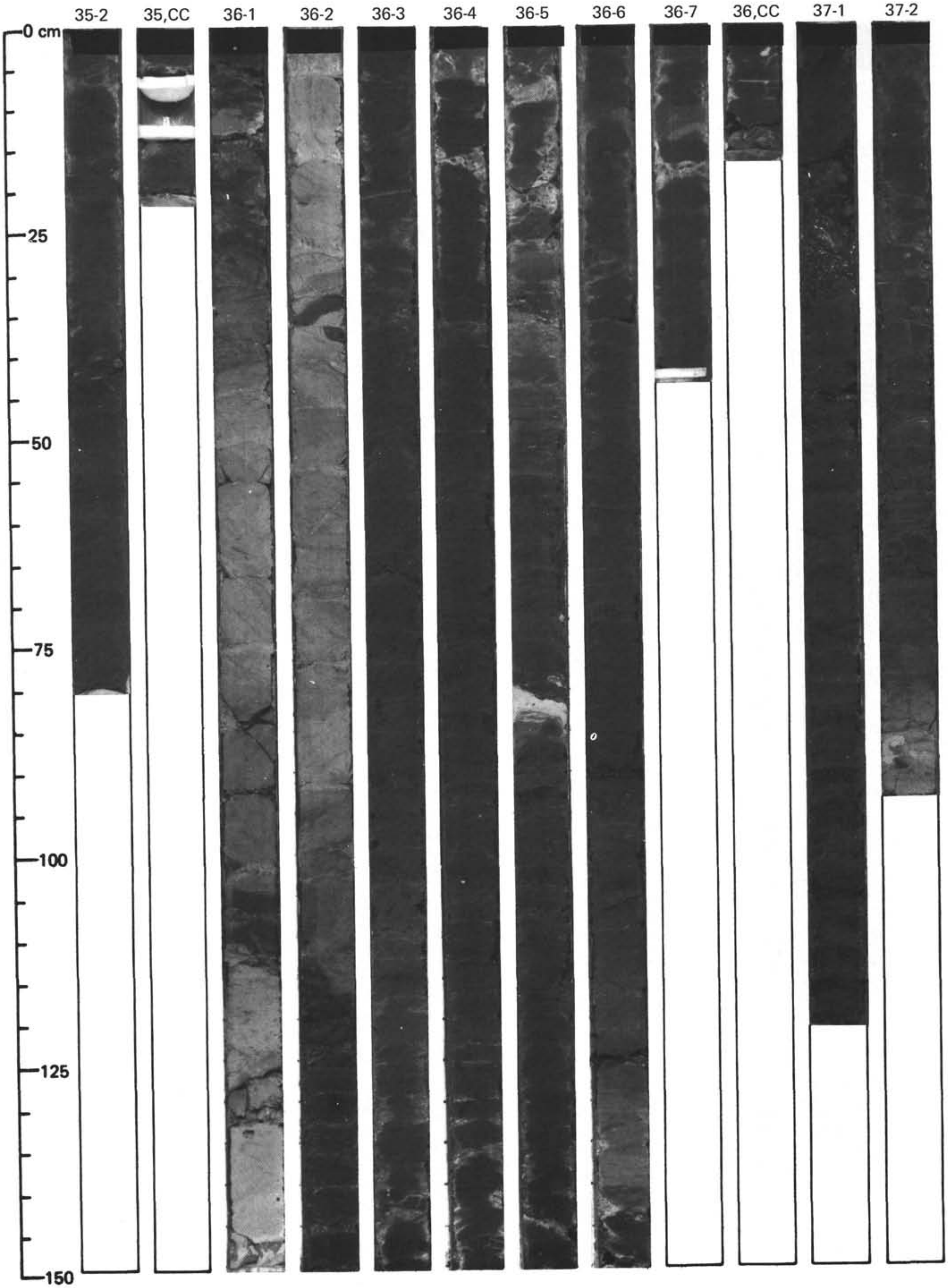

23-1
24-1
24-2
24-3
24-4
24-5
24-6
24-7
25-1
25,CC
26,CC
27-1
0 cm
25
50
75
100
125
150
24,CC

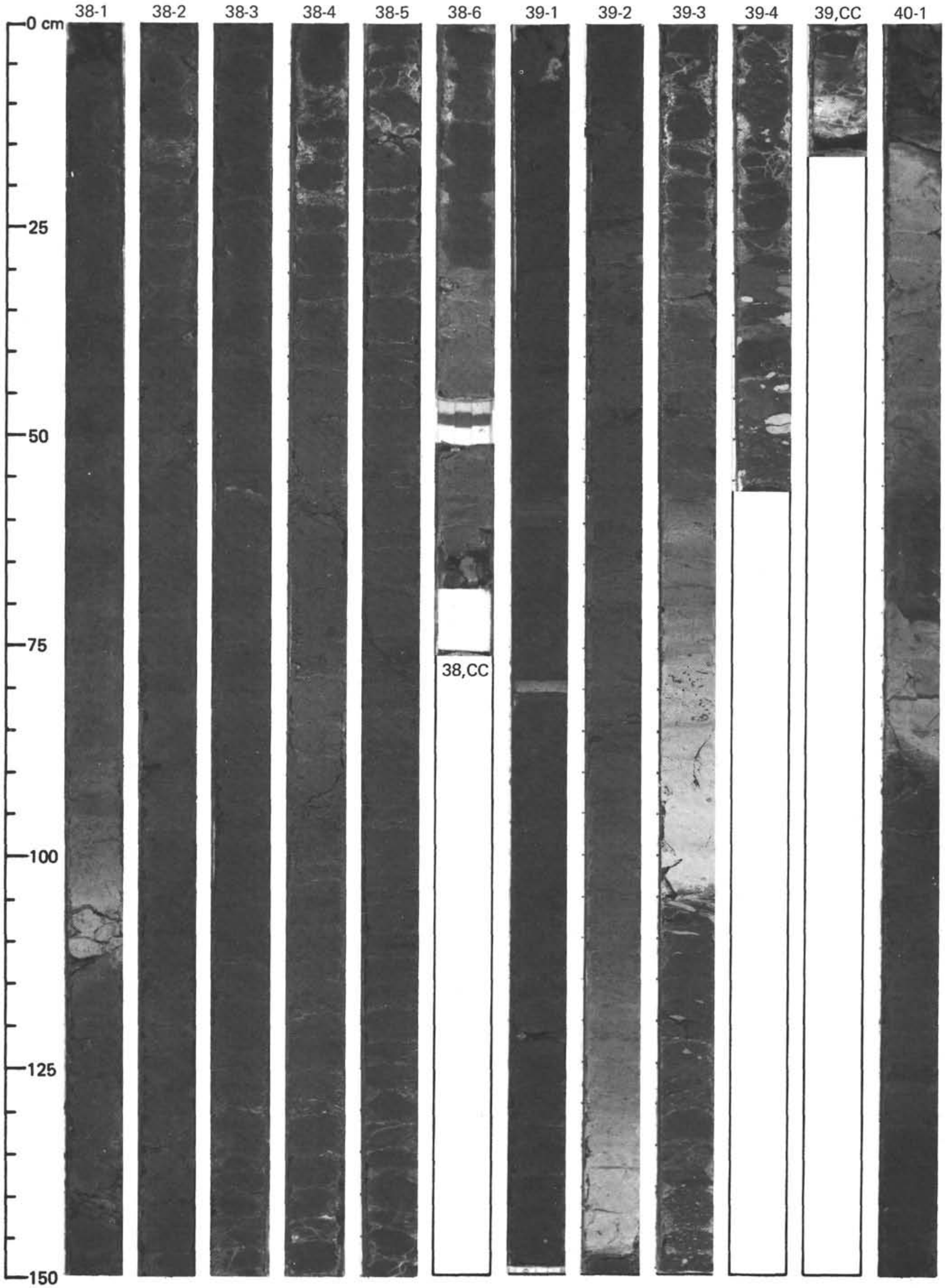

27-2
28-1
28-2
28-3
28-4
28-5
28-6
28-7
28,CC
29-1
30-1
30-2
29,CC
0 cm
25
50
75
100
125
150

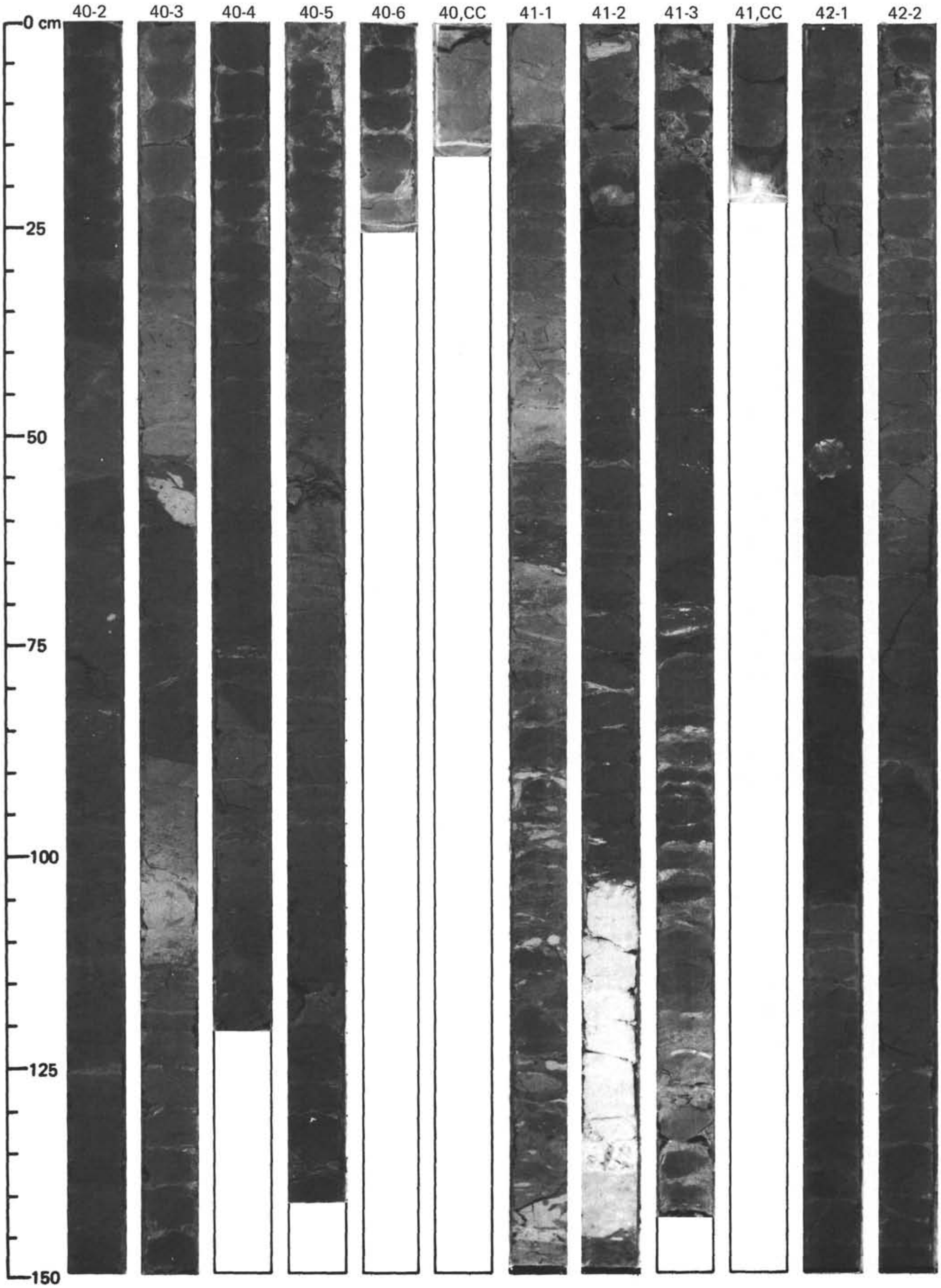

30-3
30-4
30-5
30-6
30,CC
31-1
31-2
31-3
31-4
31-5
31-6
31-7
0 cm
25
50
75
100
125
150

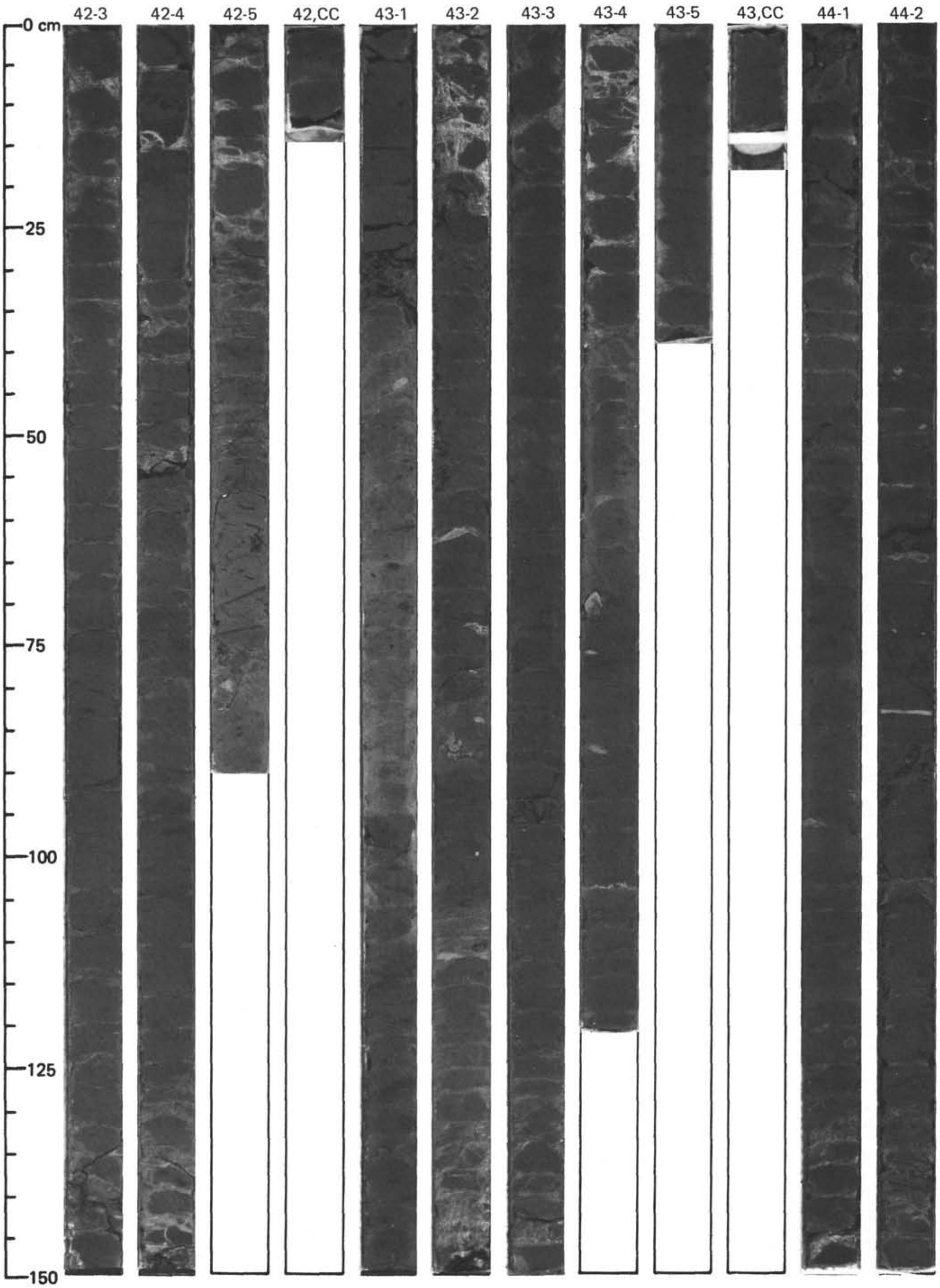

31,CC
32-1
32-2
32-3
32-4
32-5
32-6
32,CC
33-1
33-2
33-3
33-4
0 cm
25
50
75
100
125
150

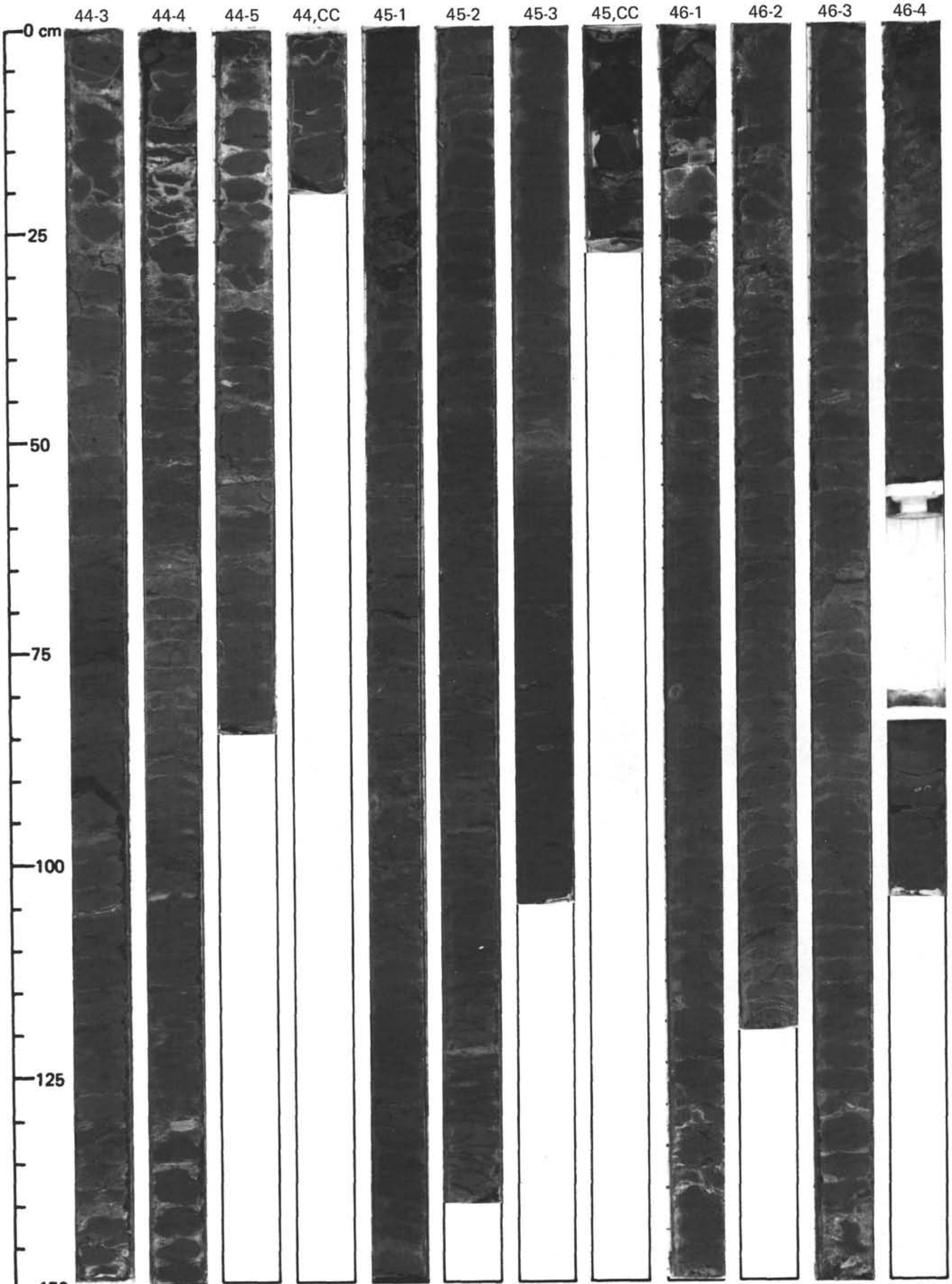

0 cm
25
50
75
100
125
150
33-5
33-6
33,CC
34-1
34-2
34-3
34-4
34-5
34-6
34-7
34,CC
35-1

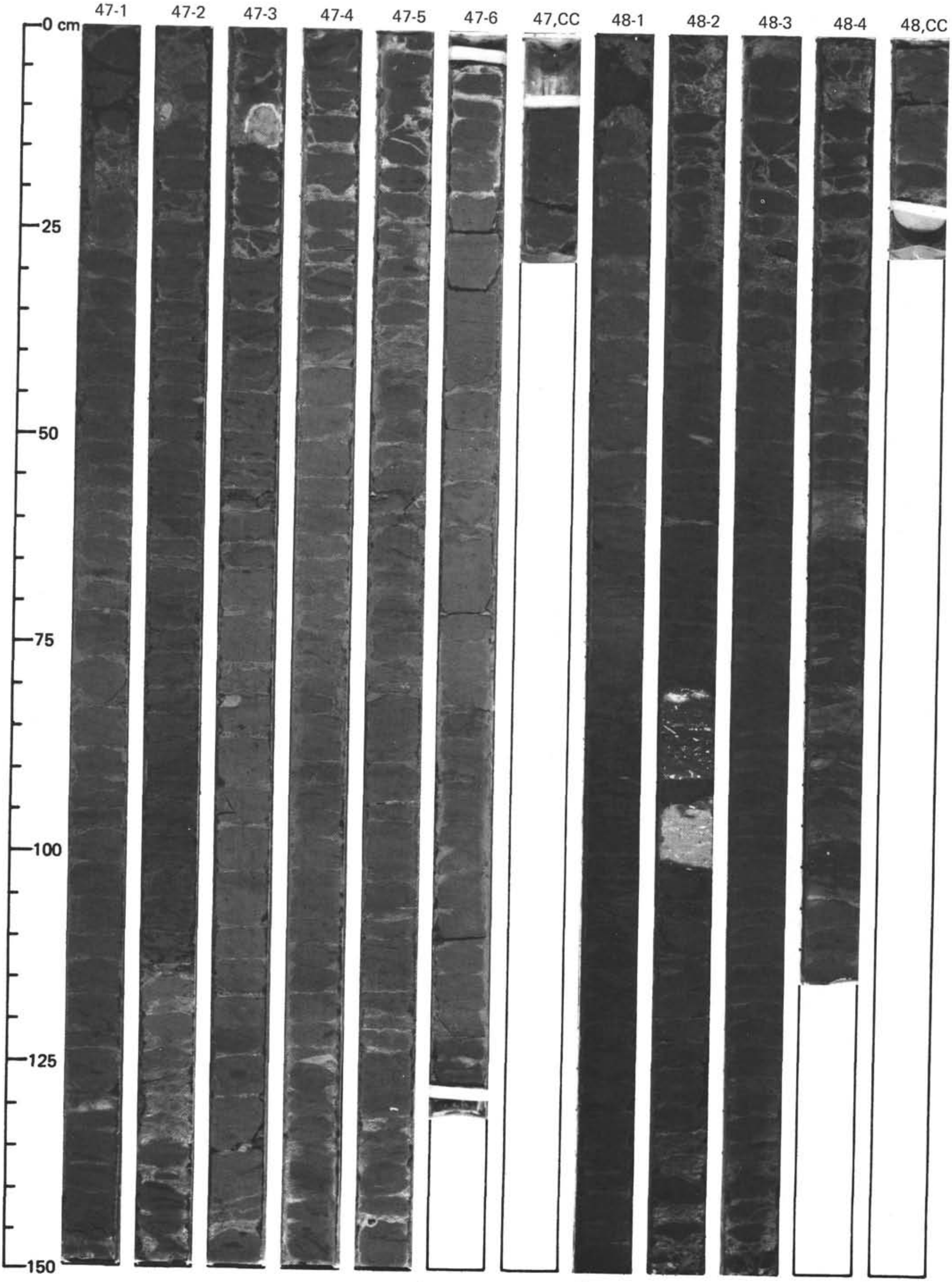

35-2
35,CC
36-1
36-2
36-3
36-4
36-5
36-6
36-7
36,CC
37-1
37-2
0 cm
25
50
75
100
125
150

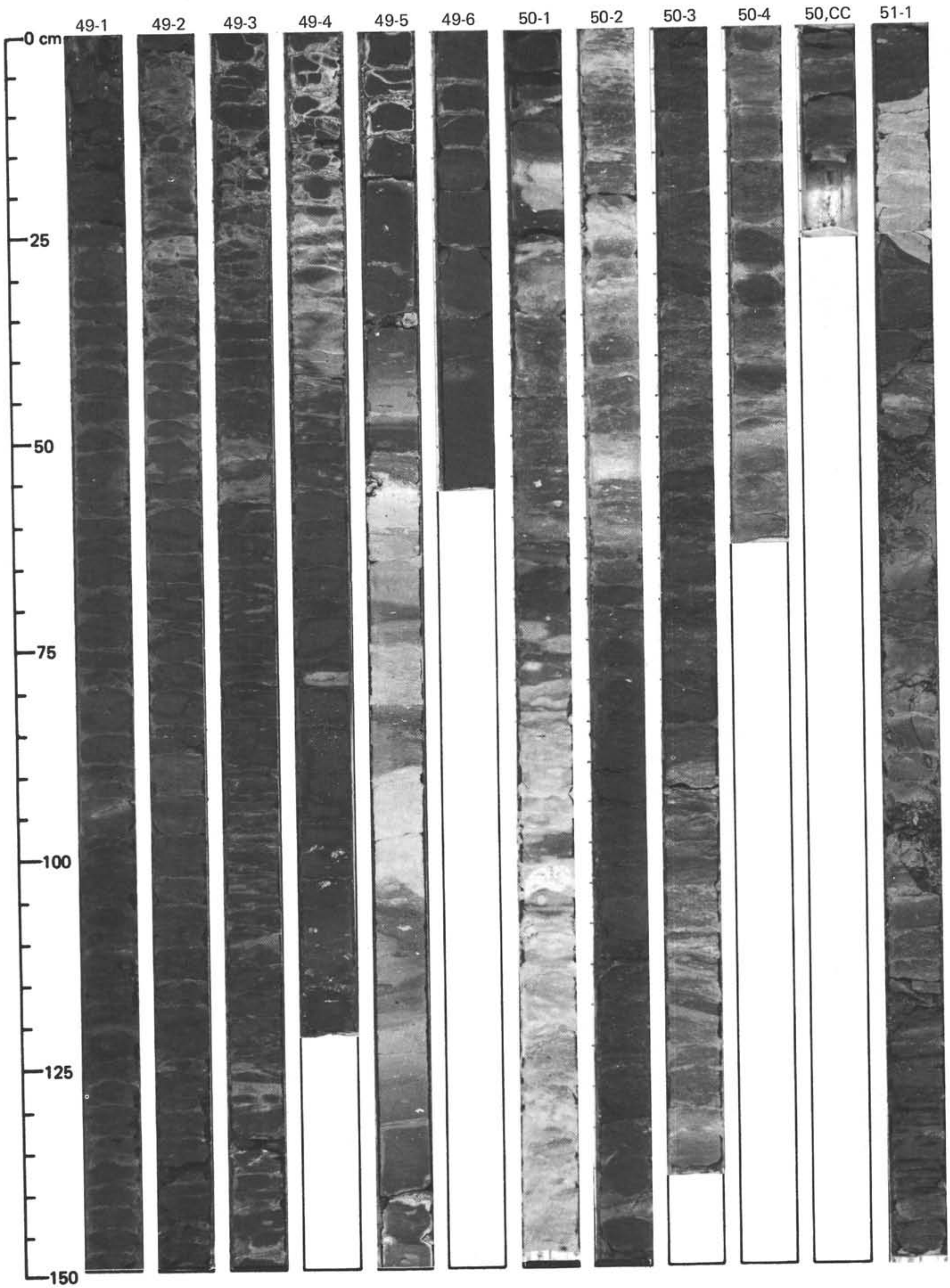

38-1
38-2
38-3
38-4
38-5
38-6
39-1
39-2
39-3
39-4
39,CC
40-1
0 cm
25
50
75
100
125
150
38,CC

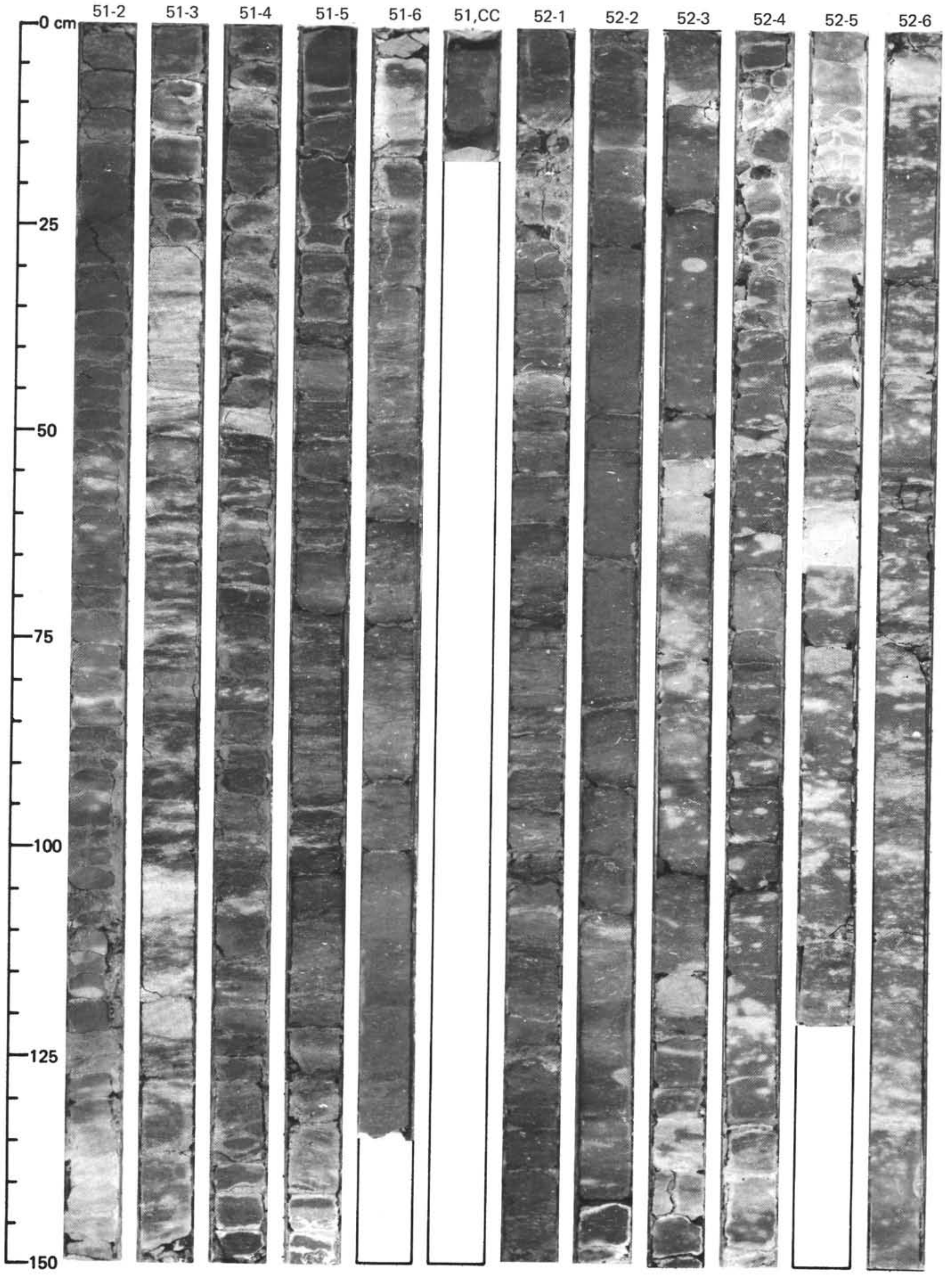

40-2
40-3
40-4
40-5
40-6
40,CC
41-1
41-2
41-3
41,CC
42-1
42-2
0 cm
25
50
75
100
125
150

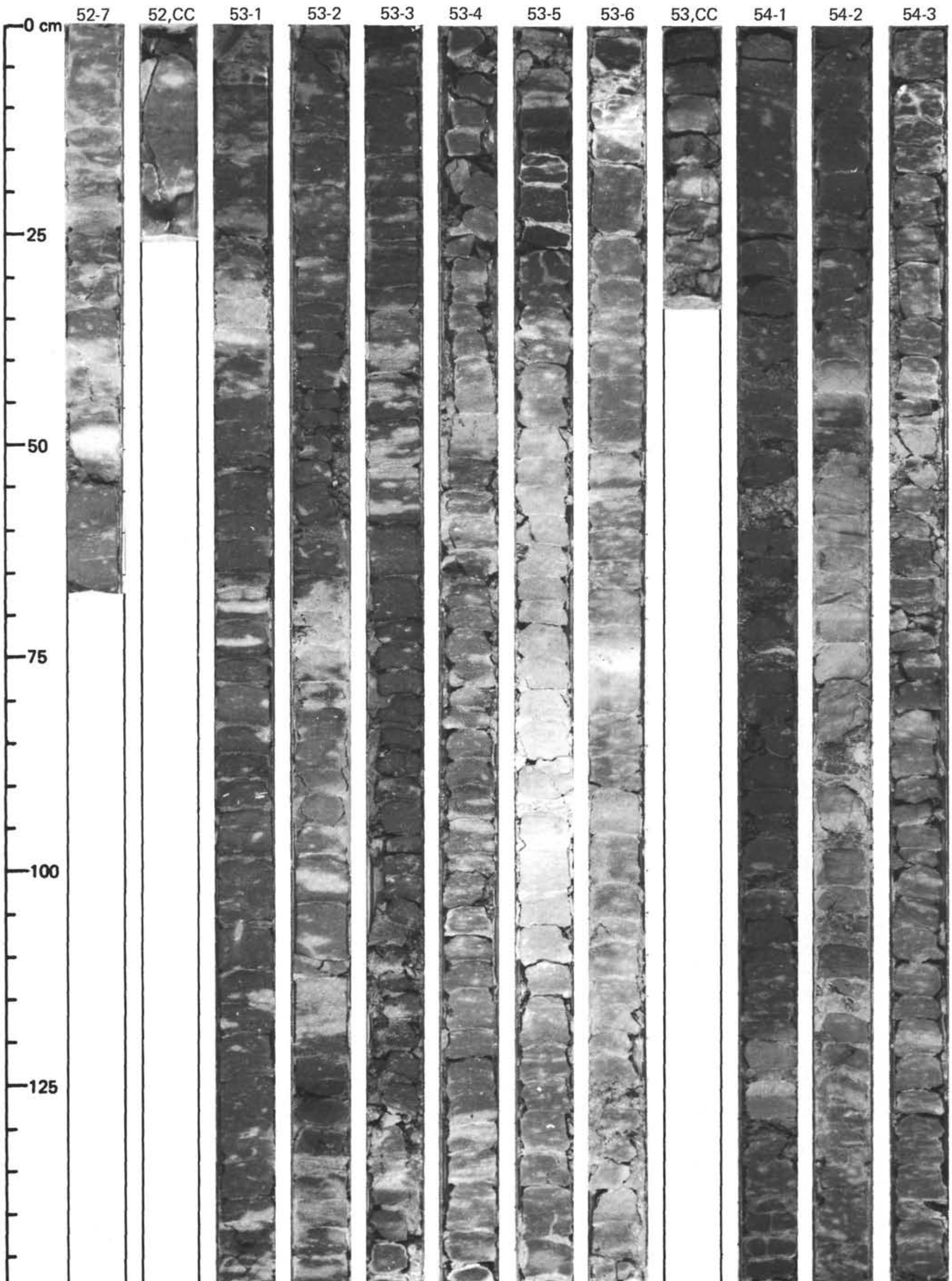

42-3
42-4
42-5
42,CC
43-1
43-2
43-3
43-4
43-5
43,CC
44-1
44-2
0 cm
25
50
75
100
125
150

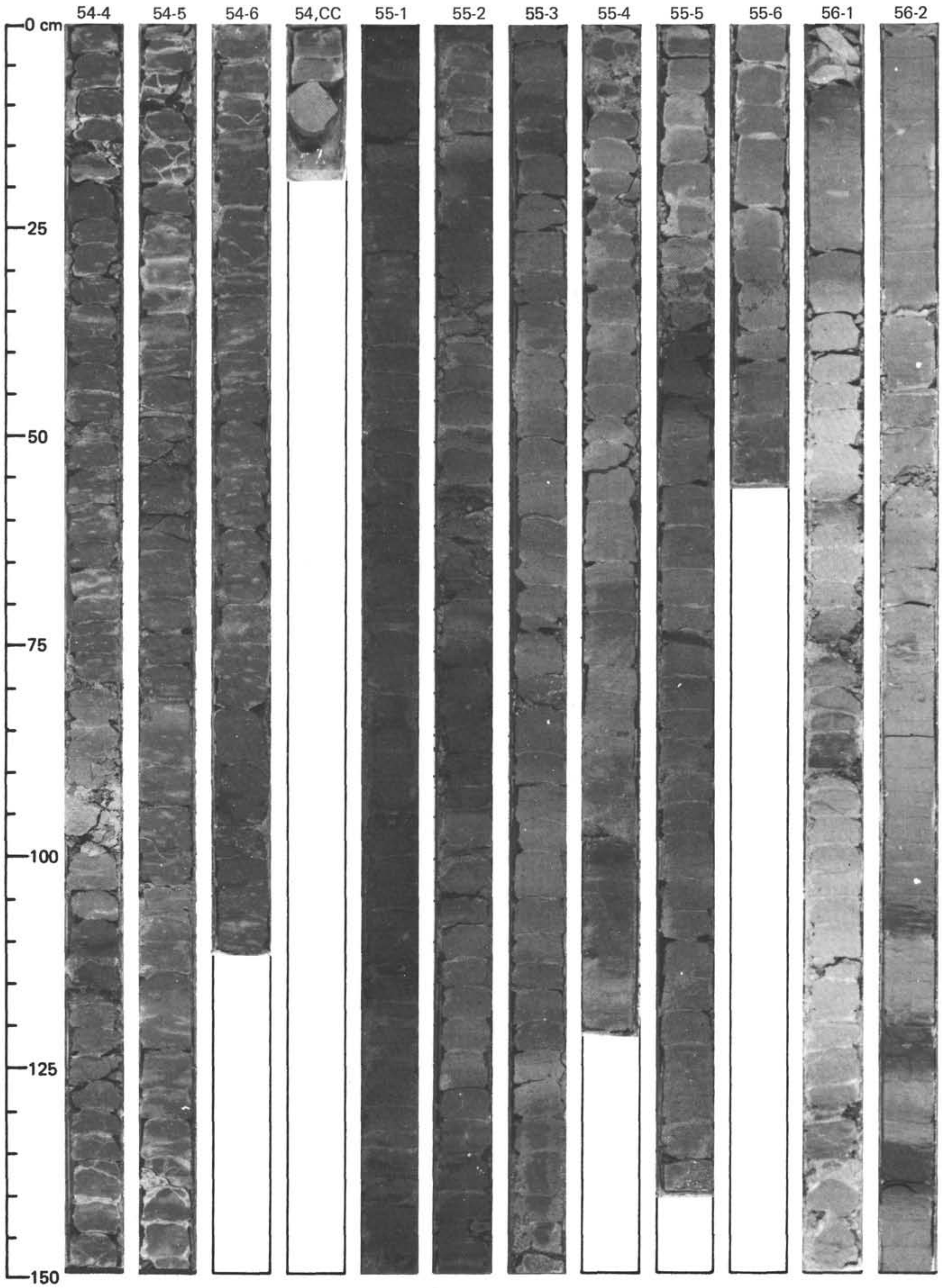

44-3
44-4
44-5
44,CC
45-1
45-2
45-3
45,CC
46-1
46-2
46-3
46-4
0 cm
25
50
75
100
125
150

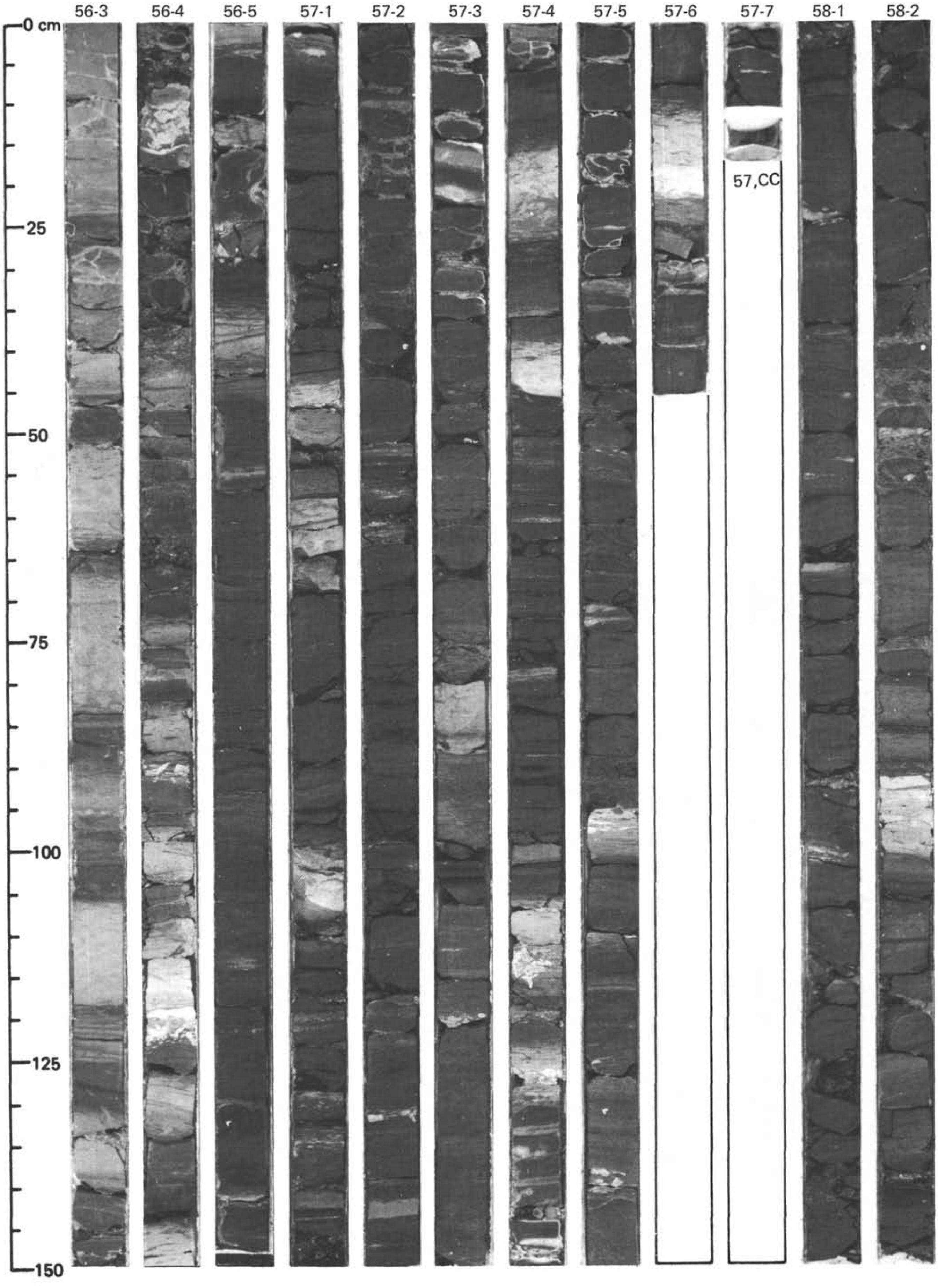

47-1
47-2
47-3
47-4
47-5
47-6
47,CC
48-1
48-2
48-3
48-4
48,CC
0 cm
25
50
75
100
125
150

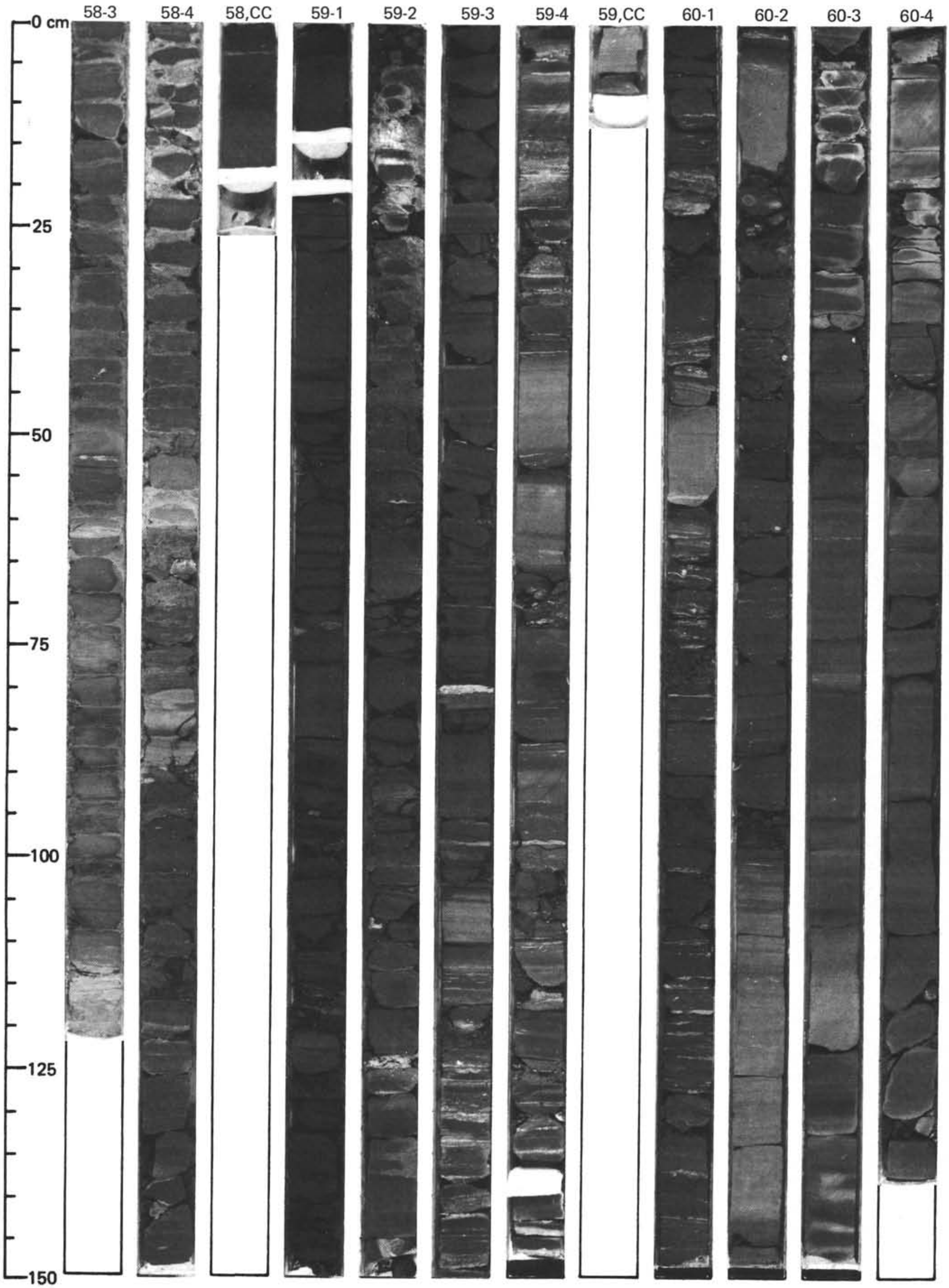

49-1
49-2
49-3
49-4
49-5
49-6
50-1
50-2
50-3
50-4
50,CC
51-1
0 cm
25
50
75
100
125
150

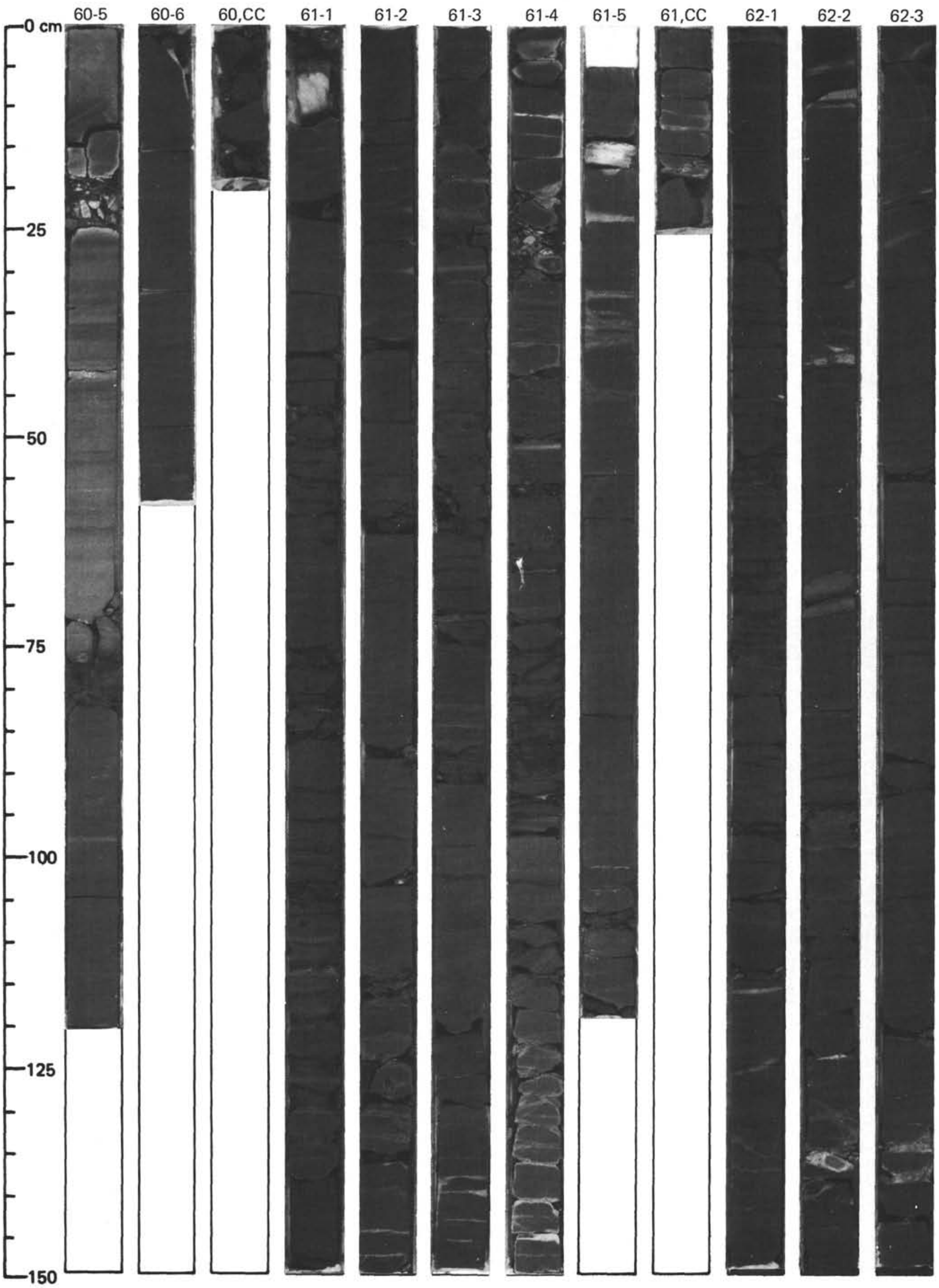

51-2
51-3
51-4
51-5
51-6
51,CC
52-1
52-2
52-3
52-4
52-5
52-6
0 cm
25
50
75
100
125
150

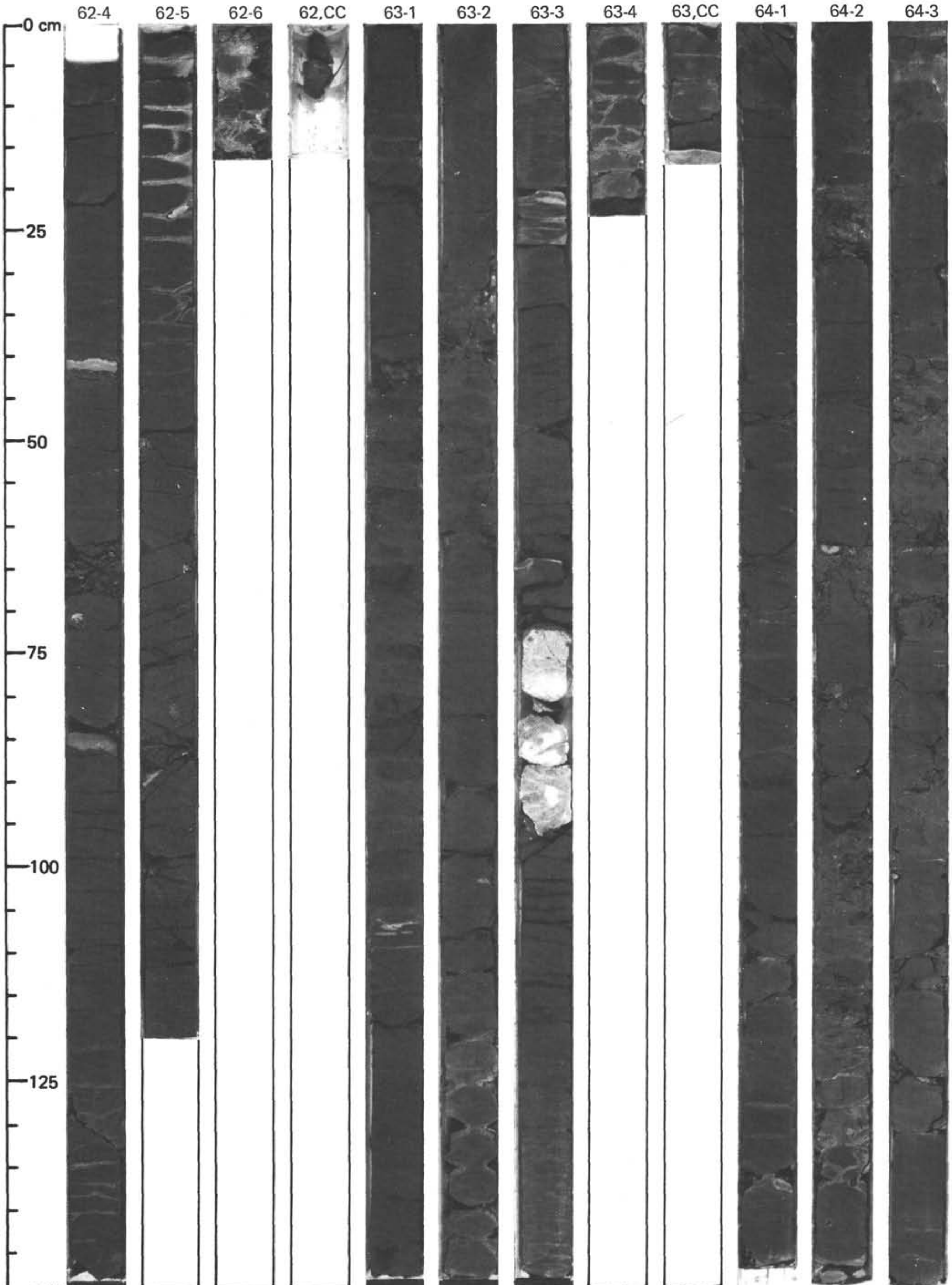

52-7
52,CC
53-1
53-2
53-3
53-4
53-5
53-6
53,CC
54-1
54-2
54-3
0 cm
25
50
75
100
125
150

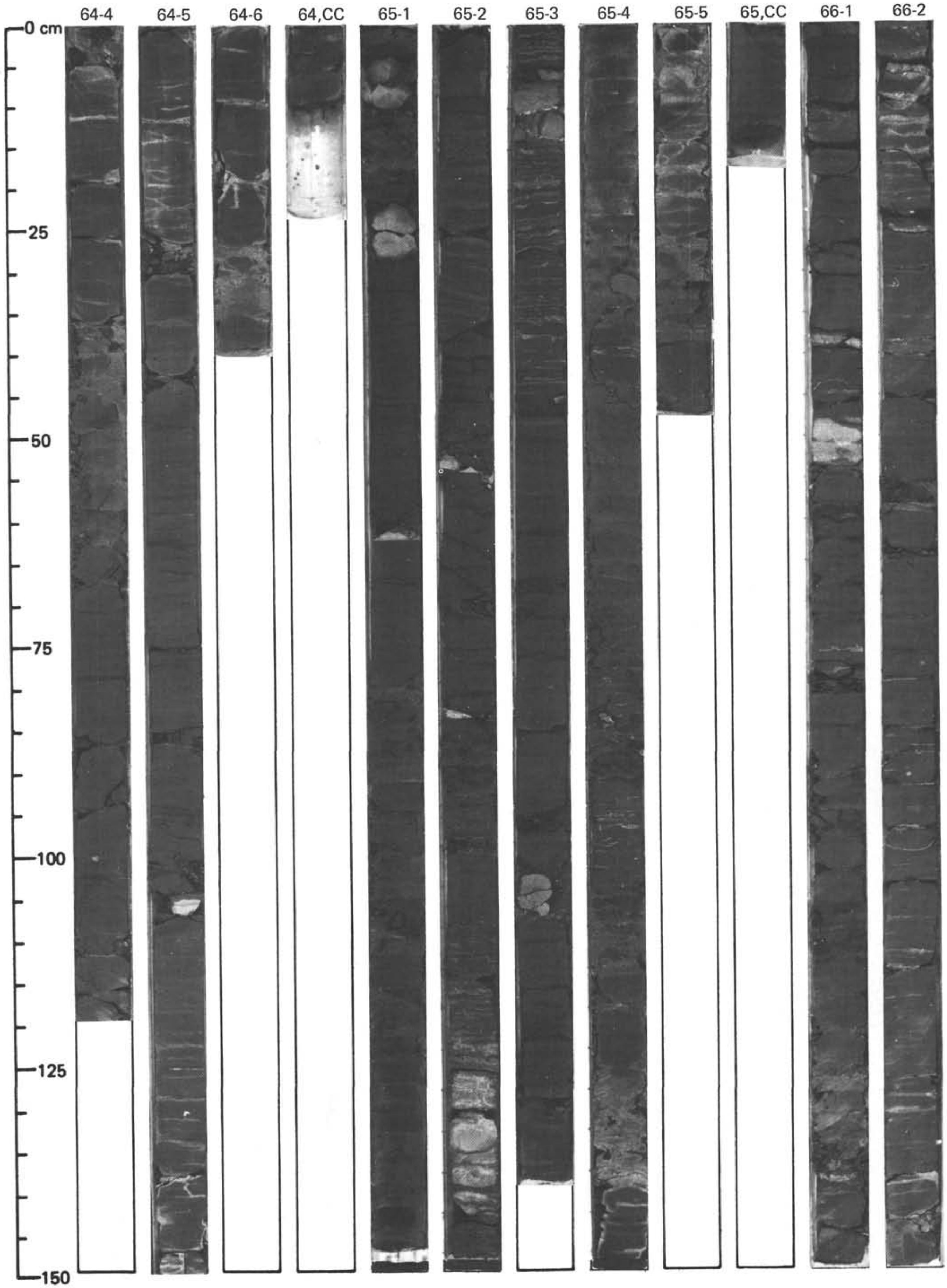

54-4
54-5
54-6
54,CC
55-1
55-2
55-3
55-4
55-5
55-6
56-1
56-2
0 cm
25
50
75
100
125
150

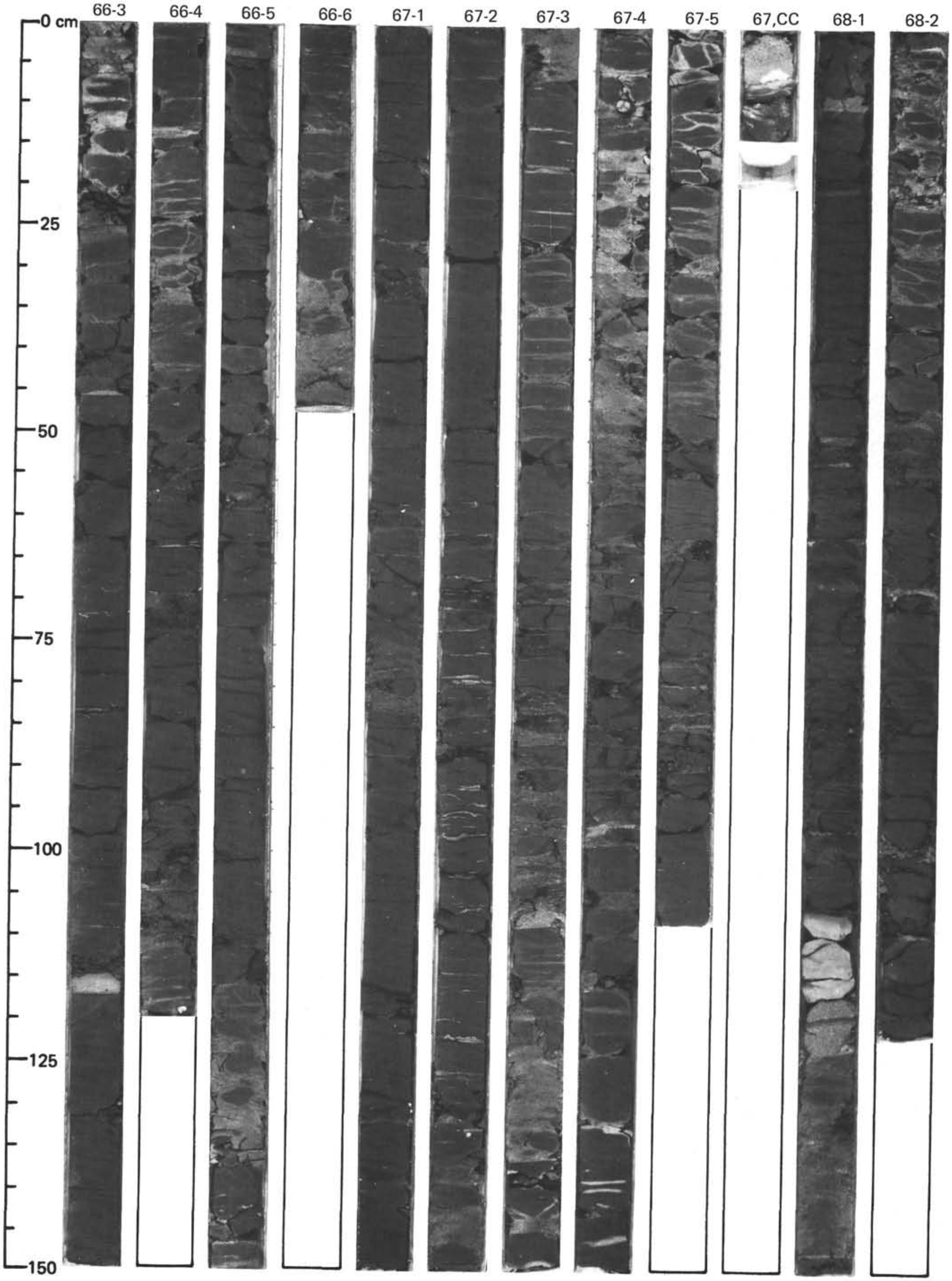

56-3
56-4
56-5
57-1
57-2
57-3
57-4
57-5
57-6
57-7
58-1
58-2
57,CC
0 cm
25
50
75
100
125
150

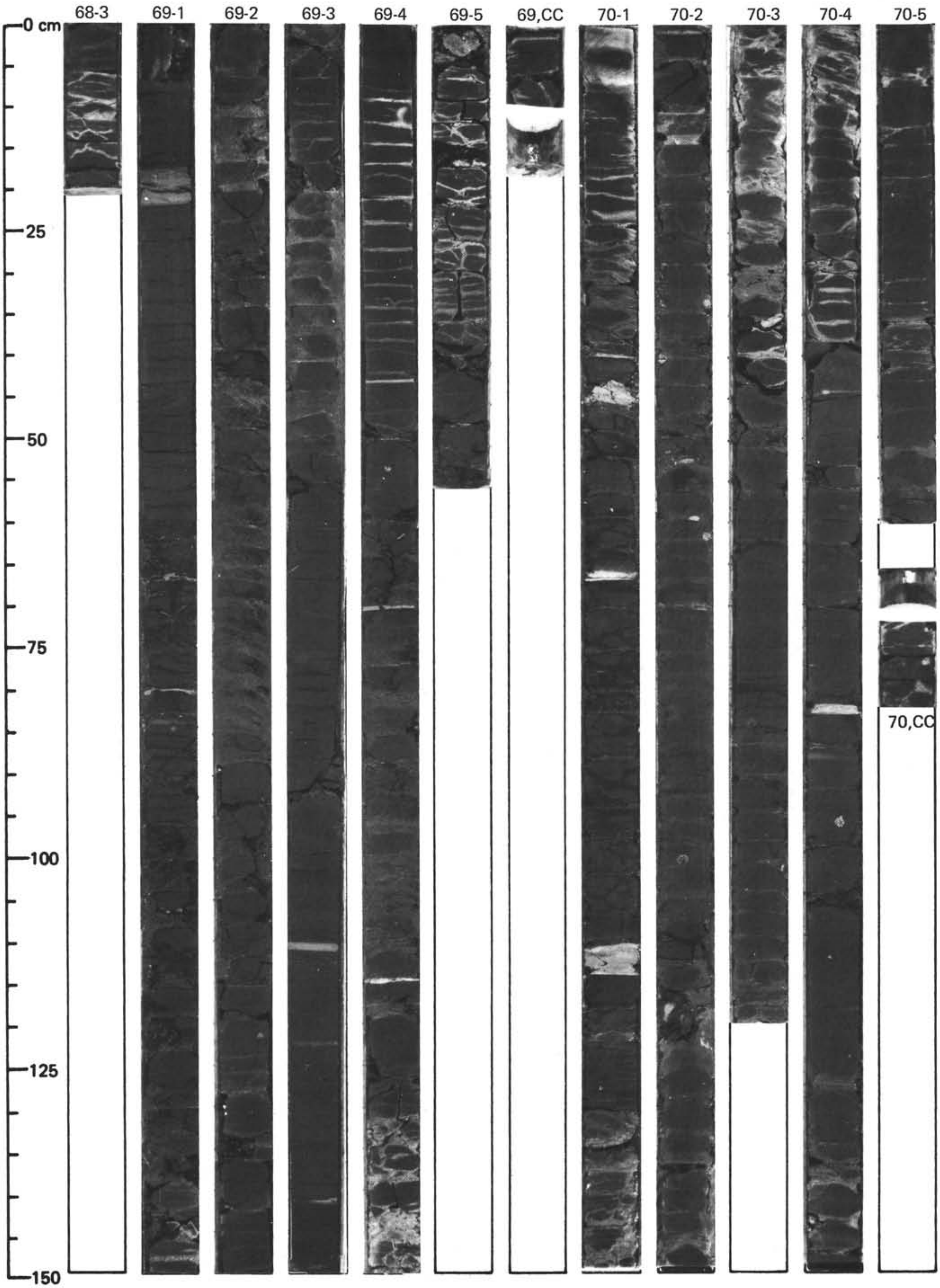

58-3
58-4
58,CC
59-1
59-2
59-3
59-4
59,CC
60-1
60-2
60-3
60-4
0 cm
25
50
75
100
125
150


60-5
60-6
60,CC
61-1
61-2
61-3
61-4
61-5
61,CC
62-1
62-2
62-3
0 cm
25
50
75
100
125
150


62-4
62-5
62-6
62,CC
63-1
63-2
63-3
63-4
63,CC
64-1
64-2
64-3
0 cm
25
50
75
100
125
150


64-4
64-5
64-6
64,CC
65-1
65-2
65-3
65-4
65-5
65,CC
66-1
66-2
0 cm
25
50
75
100
125
150


66-3
66-4
66-5
66-6
67-1
67-2
67-3
67-4
67-5
67,CC
68-1
68-2
0 cm
25
50
75
100
125
150


68-3
69-1
69-2
69-3
69-4
69-5
69,CC
70-1
70-2
70-3
70-4
70-5
70,CC
0 cm
25
50
75
100
125
150