4. ANGOLA CONTINENTAL MARGIN—SITES 364 AND 365

The Shipboard Scientific Party[1]

SITE DATA—364

Position: 11°34.32′S, 11°58.30′E (seaward edge of salt plateau on continental slope, southwest of Luanda, Angola)

Water Depth: 2448 corrected meters, echo sounding, 2439 meters, drill pipe measurement

Number of Holes: 1

Number of Cores: 46

Total Length of Cored Section: 427.5 meters

Total Core Recovered: 295.61 meters

Percentage Core Recovery: 69.1%

Oldest Sediment Cored:
Depth sub-bottom: 1086 meters
Nature: euxinic shale and dolomitic limestone
Age: upper Aptian
Measured velocity: 3.90 km/sec

Basement:
Depth sub-bottom: > 3 km (not reached)
Nature: presumed basaltic, underlying evaporite sequence

Principal Results: A sequence from the Pleistocene down into the upper Aptian was penetrated containing a major erosional disconformity corresponding to most of the Oligocene and the upper Eocene. The drilling terminated with a worn-out bit in dolomitic limestones with very high interstitial salinities just above the Aptian evaporite and salt formations. The Paleogene and Upper Cretaceous series is for the most part pelagic in nature, and contains tropical to sub-tropical faunas deposited in generally tranquil deep-water environments. The Lower Cretaceous faunas include ammonites and *Inoceramus* and characteristically indicate non-tropical environments and an initial immigration of marine life into the Angola Basin from the south following the termination of the Aptian salinity crisis. There is no evidence of shallow littoral or intertidal sedimentation, even for the deposits directly overlying the evaporites.

Sapropels and sapropelic limestones occur in the upper Coniacian to Cenomanian interval and in the lower Albian and upper Aptian. Albian marly chalks and limestones contain pressure-solution stylolites, steeply dipping bedding contacts, overturned folds, and interformational breccias probably linked to salt diapirism.

Sedimentation rates range from approximately 40 m/m.y. for the Lower Cretaceous to 18 m/m.y. for the Upper Cretaceous with a significant reduction during the Cenomanian and Turonian. Gaps of 8 million years last across the Cretaceous/Tertiary boundary and of 16 million years between the upper Oligocene and the middle Eocene. The Neogene sequence is markedly terrigenous and siliceous. It corresponds to a major phase of deltaic out-building and fore-slope progradation recognizable in seismic reflection profiles and reflects climatic changes after the late Eocene. Compressional wave velocities reach 5 km/sec in basal dolomitic limestone.

SITE DATA—365

Position: 11°39.10′S, 11°53.72′E (eastern side of a partly buried submarine canyon incised into the Cenozoic and Mesozoic cover above the salt and evaporite layer just to the southwest of Site 364 on the continental slope of Angola

Water Depth: 3018 corrected meters, echo-sounding, 3040 meters, drill pipe measurement.

Water Depth (rig floor): 3028 corrected meters, echo sounding

Bottom Felt at: 3050 meters, drill pipe

Penetration: 687 meters

Number of Holes: 1

Number of Cores: 7

Total Length of Cored Section: 63 meters

Total Core Recovered: 34.65 meters

Percentage Core Recovery: 55.0%

Oldest Sediment Cored:
Depth sub-bottom: 687 meters
Nature: radiolarian-bearing clay and mudstone
Age: Oligocene-Miocene
Measured velocity: 2.14 km/sec

Basement:
Depth sub-bottom: > 3 km, not reached

Principal Results: Site 365 was drilled rapidly with very intermittent coring in an unsuccessful desperate attempt to reach the Aptian evaporite and salt formation before time ran out at the end of the leg. Interstitial salinities in the last sediment core at 687 meters sub-bottom exceeded those at the base of Site 364, indicating that the salt was not far below.

The canyon fill consists primarily of Neogene-age terrigenous muds and mudstones containing primitive arenaceous benthic foraminifers, fish teeth, and palynomorphs, along with allochthonous blocks of Coniacian-Santonian nannofossil ooze and Cenomanian to upper Albian sapropelic mudstone reworked from the canyon wall. The Mesozoic strata indicated their displaced nature by extremely steep bedding inclinations ranging up to 70° from the horizontal and by mixed assemblages spanning a broad stratigraphic interval. The depositional

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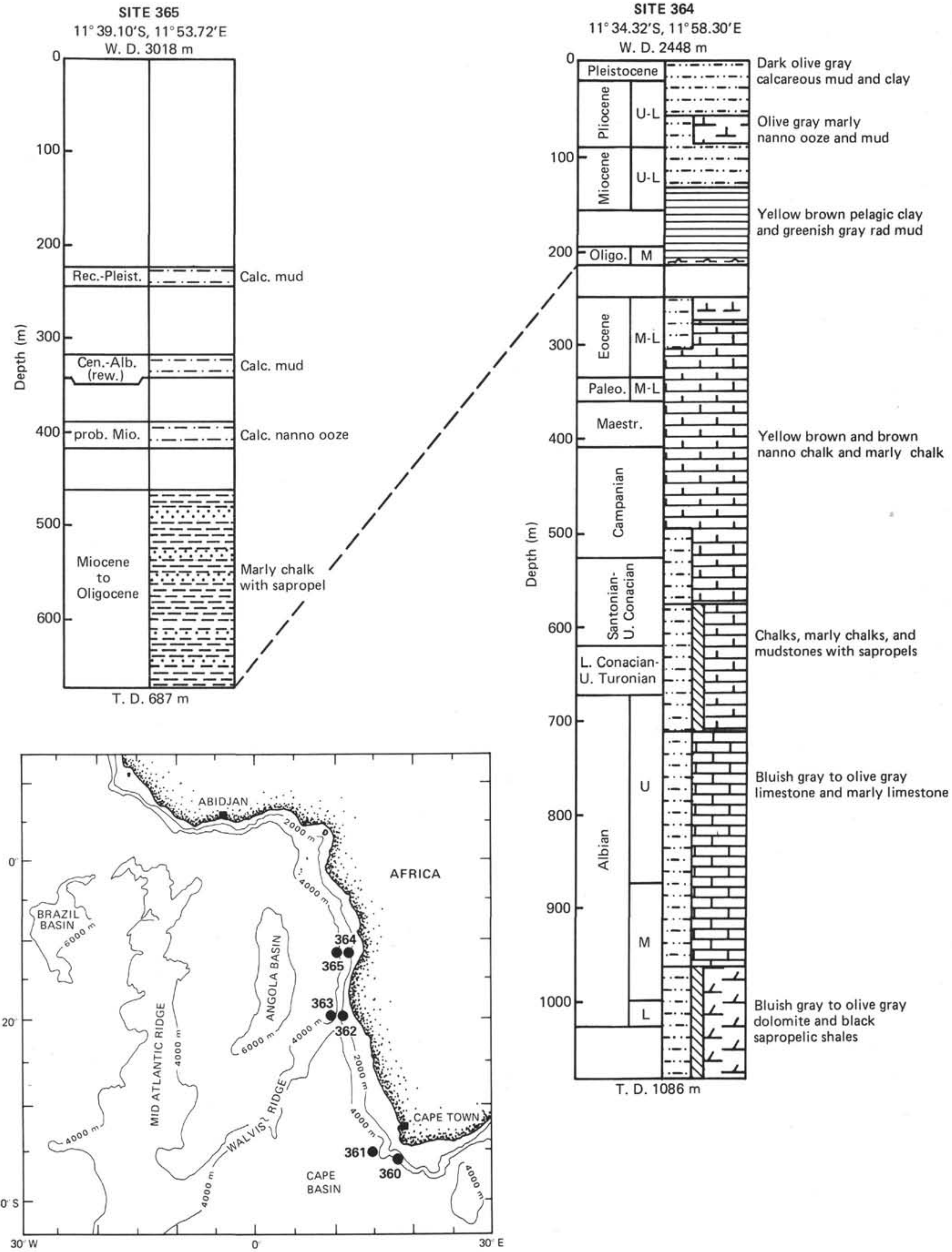
SITE 365
11° 39.10'S, 11° 53.72'E
W. D. 3018 m
Depth (m)
0
100
200
300
400
500
600
Rec.-Pleist.
Calc. mud
Cen.-Alb. (rew.)
Calc. mud
prob. Mio.
Calc. nanno ooze
Miocene to Oligocene
Marly chalk with sapropel
T. D. 687 m
SITE 364
11° 34.32'S, 11° 58.30'E
W. D. 2448 m
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000
Pleistocene
Pliocene
U-L
Miocene
U-L
Oligo.
M
Eocene
M-L
Paleo.
M-L
Maestr.
Campanian
Santonian-U. Conacian
L. Conacian-U. Turonian
Albian
U
M
L
Dark olive gray calcareous mud and clay
Olive gray marly nanno ooze and mud
Yellow brown pelagic clay and greenish gray rad mud
Yellow brown and brown nanno chalk and marly chalk
Chalks, marly chalks, and mudstones with sapropels
Bluish gray to olive gray limestone and marly limestone
Bluish gray to olive gray dolomite and black sapropelic shales
T. D. 1086 m
ABIDJAN
2000 m
4000 m
AFRICA
BRAZIL BASIN
6000 m
364
365
ANGOLA BASIN
363
362
MID ATLANTIC RIDGE
4000 m
6000 m
4000 m
2000 m
WALVIS RIDGE
4000 m
4000 m
CAPE TOWN
361
360
CAPE BASIN
4000 m
4000 m
0°
20°
40° S
30° W
0°
30° E

environment was continuously deep, well oxygenated, and, during the interval of the Miocene and Oligocene recorded in the cores, below the calcium compensation depth.

BACKGROUND AND OBJECTIVES

The Angola Basin is the deepest depression of the eastern South Atlantic (Figure 1). To the south, it is isolated almost entirely from the Cape Basin by the high-standing Walvis Ridge, and to the west, it is barred from the Brazil and Argentine basins by the broad crestal zone of the Mid-Atlantic Ridge.

Because of this high degree of isolation, its oceanic bottom water mass is significantly warmer and hence less corrosive to carbonate skeletal sedimentary components than that of all the other Atlantic Ocean basins. In fact, there are only four real routes for deep-water masses to enter into the Angola Basin.

The Antarctic Bottom-Water (AABW) arrives from the north by the deepest of these passages. Its course takes it from the Scotia Sea via the Argentine Basin through the Vema Channel to the Brazil Basin, then by means of a narrow route through the Romanche Fracture Zone to the Guinea Basin, and at last across a 4.8-km-deep sill southward along the western margin of Africa where it circulates as a weak, clockwise gyre within the central Angola Basin depression.

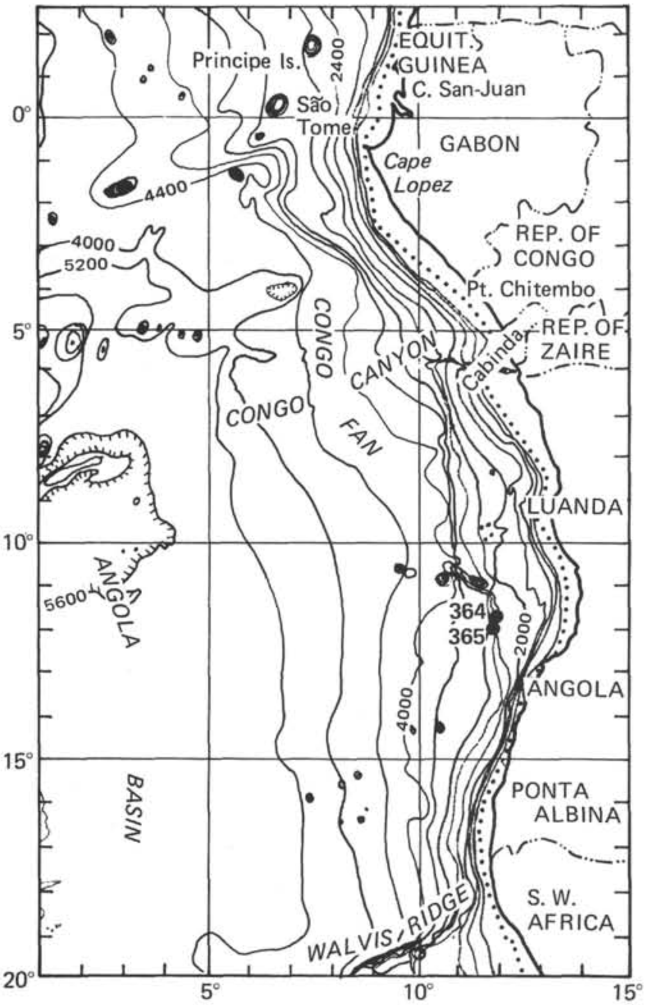

Figure 1. *Bathymetric map of the continental margin of southern Africa off Angola (Emery et al., 1975).*

Deep and intermediate water masses can only flow into the Angola Basin from the Cape Basin through three portals in Walvis Ridge. The lowest standing sill to the south is approximately 3.8 km at a position east of Tristan da Cunha and lies across a late Paleocene basement isochrone. The next shallowest sill, at approximately 3.7 km, is over a Santonian to Campanian age isochrone at 30°S, 1°E. The shallowest sill is at 3.2 km through a heavily scoured passage between Frio Ridge and Valdivia Bank above a late Aptian to Albian isochrone.

The isolated setting of the Angola Basin was inherited from its very birth. Indeed, its first 20 million years were so restricted as to permit the formation of a huge layer of evaporites exceeding in places 3 km in thickness. This evaporite body is found today along the eastern rim of the ocean basin landward of a mid-Aptian isochrone identified at Sites 361 and 363 of Leg 40 as nearly coincident with magnetic lineation M-O of Larson and Ladd (1974).

The equatorial position of the Angola Basin and the deflection away from the Angola Basin of the cold, northerly directed Benguela current in the Cape Basin at the eastern intersection of the Walvis Ridge and the South West African continental margin, should result in highly calcareous pelagic deposition on topographic highs in the Angola Basin. These should be stratigraphically correlatable to worldwide sequences through well-studied lineages of tropical and semi-tropical faunas. The interplay of deep geostropic currents headed southward along the continental rise, and surface- to intermediate-depth currents passing northward, both intersecting important volumes of clastic sediments arriving from the mouth of the Congo River, should also result in a highly cyclic and perhaps climatically controlled terrigenous sedimentation in topographic lows. The influence of deep-water masses on the degree of preservation of biogenic skeletal components should also have changed through time as the basin became progressively less isolated with the subsidence of and intermittent creation of gaps across the Walvis Ridge barrier, and as the Antarctic Bottom Water became volumetrically more important with the development of a polar icecap in the Cenozoic.

Scientific Objectives

A drill site location was selected along the eastern margin of the Angola Basin (Figure 1). Cored sequences of sediment to depths of 1000-1400 meters below the sea floor were expected to provide insight to the following investigations:

1) age of the upper limit of the marginal evaporite deposition;

2) depositional facies of the evaporites and associated salt deposits leading to an understanding of the processes by which they accumulated;

3) basin depth during and immediately after evaporite deposition;

4) quantitative information on subsidence rates of the continental margin during its earliest evolution;

5) age and nature of crust over which the seaward edge of the evaporite body is draped;

6) age of the commencement of haleokinetic deformation resulting from flowage of the salt layer;

7) nature of the "transgressive" marine facies directly overlying the evaporite strata;

8) control on degree of carbonate preservation provided by inflowing bottom waters since the Lower Cretaceous (Aptian stage);

9) age and cause of a mid-Cenozoic major stratigraphic discontinuity seen in the vast majority of seismic reflection profiles across the West African continental margin;

10) correlation of high-latitude Austral-New Zealand faunal assemblages with their tropical to sub-tropical counterparts;

11) sediment contribution to the deep basin through time by the Congo River deltaic complex;

12) identification of age and nature of prominent seismic horizons including the *Davy* and *Atlantis II* reflectors of Emery et al. (1975).

Strategy

Because deep penetration was required to achieve the selected scientific objective of reaching into the marginal salt deposit, the first drill site (364) was targeted southward of the major fracture zone which intersects the coast between Luanda and Lobita, where the overburden above the roof of the evaporites is the thinnest of the entire West Africa margin and yet is still conformable.

A second requirement was to position the drilling location into the salt body in a synclinal setting with the seaward limb of the syncline cropping out on the marginal escarpment so as to minimize totally the possibility of hydrocarbon entrapment either within the evaporites or within the overlying horizons.

The Site 364 setting at 0340 hours, 12 July 1971, on Walda Profile 21 of the *Jean Charcot* met both of these requirements (Figure 2). Identified on the profile are five prominent reflecting interfaces:

1) the Mid-Cenozoic discontinuity (Reflector *Davy*);

2) an intermediate conformable horizon much more deeply buried in the basin than on the salt plateau (Reflector *Atlantis II*);

3) the roof of the evaporite body;

4) the base of the salt layer;

5) a non-coherent and topographically irregular acoustic basement thought to be Layer "2" of the oceanic crust.

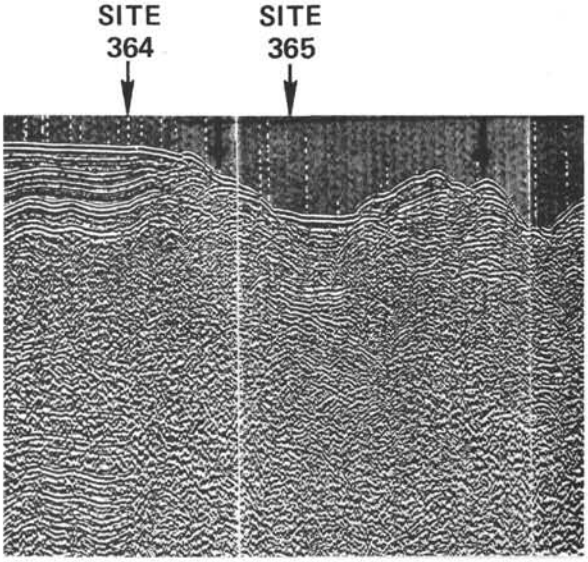

Figure 2. *Walda Profile 21 of the* Jean Charcot *showing locations of both Sites 364 and 365.*

When it became evident that drilling at Site 364 would not penetrate into the evaporite and salt layer due to destruction of the drill bit, an alternate location was picked (Site 365) to short-cut much of the stratigraphic sequence already successfully cored. This hole is within a canyon that had been excavated into the salt body and subsequently partly filled. Its position at 0145, 12 July 1971 on the same Walda Profile 21 offered the opportunity to enter the salt layer at a sub-crop below the level of the relatively thick Albian and Aptian limestones which had been responsible for the severe degradation of the core bit journal bearings at Site 364. At Site 365, though, it was necessary only to pass through considerably younger and hence less indurated canyon fill to reach the salt.

OPERATIONS

Approach to Site 364

We approached Site 364 from the southwest during the early morning of 30 January 1975 on a heading of 022° to try and intersect the Walda 21 profile at the desired target. At 0423 we slowed the *Glomar Challenger* to 5 knots and at 0442 jettisoned the acoustic positioning beacon and retrieved the towed seismic and magnetic gear. Satellite fixes while on station showed that we had slightly overshot the original target on the *Charcot* profile to the north, but the underway reflection profile indicated us to be in a synclinal setting optimum from the hydrocarbon safety point of view. Information on the Site 364 cores is given in Table 1.

Drilling at Site 364

The hole was spudded in at 1550, using a 4-cone journal bearing core bit with medium-length tungsten carbide inserts selected for efficiency in limestones, dolomites, and evaporites. We experienced some delays associated with the need to drop a second beacon, with difficulties in getting electrical power to the Bowen power sub, and with a malfunctioning valve in the hydraulic system for the sandline winch. Anomalously high torquing occurred in the cutting of Cores 1 through 6, accompanied by appreciable backflow of drilling fluid when the pipe joints were opened to retrieve the core barrel. This torquing and backflowing ended abruptly during the cutting of Core 7 at the level of a major erosional gap and mostly likely correlated with the very sticky nature of the Neogene terrigenous mud and pelagic clay which tore into chunks rather than washed into a slurry. Penetration rates slowed appreciably upon entering the Eocene section.

We experienced a second formation change at approximately 363 meters sub-bottom near the end of the cutting of Core 11, correlative with another significant decrease in the penetration rate. This break may coincide with a hiatus across the Cretaceous/Tertiary boundary.

TABLE 1
Coring Summary, Site 364

Core	Date	Time	Depth From Drill Floor (m)	Depth Below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Recovered (%)
1	30 Jan.	1730	2456.6-2466	7.5-17	9.5	9.5	100
2	30 Jan.	1830	2485-2494.5	36-45.5	9.5	4.35	96
3	30 Jan.	2130	2513.5-2523	64.5-74	9.5	8.9	94
4	31 Jan.	0020	2551.5-2561.0	102.5-112.0	9.5	9.5	100
5	31 Jan.	0235	2599-2608.5	150-159.5	9.5	4.9	552
6	31 Jan.	0415	2646.5-2656.0	197.5-207	9.5	5.1	54
7	31 Jan.	0640	2694.0-2703.5	245.0-254.5	9.5	1.7	18
8	31 Jan.	0905	2732-2741.5	283.0-292.5	9.5	9.4	99
9	31 Jan.	1125	2770-2779.5	321-330.5	9.5	5.95	63
10	31 Jan.	1350	2798.5-2808.0	349.5-359	9.5	8.75	92
11	31 Jan.	1540	2808.0-2817.5	359-368.5	9.5	9.5	100
12	31 Jan.	1800	2817.5-2827.0	368.5-378	9.5	9.4	99
13	31 Jan.	2000	2846.0-2855.0	397-4065	9.5	2.75	29
14	31 Jan.	2250	2874.5-2884.0	425.5-435	9.5	8.2	86
15	1 Feb.	0135	29125.-2922	463.5-479	9.5	7.3	77
16	1 Feb.	0430	2950.5-2960	501.5-511	9.5	8.4	88
17	1 Feb.	0910	2978-2988.5	530-539.5	9.5	9.5	100
18	1 Feb.	0910	2998-3007.5	549-558.5	9.5	4.0	42
19	1 Feb.	1140	3017-3026.5	568-577.5	9.5	6.15	65
20	1 Feb.	1340	3026.5-3036	577.5-587	9.5	6.75	71
21	1 Feb.	1650	3045.5-3050	596.5-601	4.5	9.3	98
22	1 Feb.	2035	3064.5-3074	615.5-625	9.5	4.85	51
23	2 Feb.	0015	3093-3102.5	644-653.5	9.5	5.6	59
24	2 Feb.	0525	3121.5-3131	672.5-682	9.5	3.15	33
25	2 Feb.	0950	3150-3159.5	701-710.5	9.5	9.5	100
26	2 Feb.	1540	3159.5-3169	710.5-720	9.5	9.5	100
27	2 Feb.	2050	3169-3178.5	720-729.5	9.5	6.05	64
28	3 Feb.	0105	3197.5-3207	748.5-758	9.5	5.7	60
29	3 Feb.	0415	3216.5-3226	767.5-777	9.5	5.6	59
30	3 Feb.	0755	3235.5-3245	786.5-796	9.5	4.6	48
31	3 Feb.	1145	3254.5-3264	805.5-815	9.5	6.05	64
32	3 Feb.	1530	3273.5-3283	824.5-834	9.5	6.25	66
33	3 Feb.	1930	3292.5-3302	843.5-853	9.5	7.1	75
34	3 Feb.	2345	3321-3330.5	872-881.5	9.5	5.35	56
35	4 Feb.	0500	3340-3349.5	891-900.5	9.5	5.1	54
36	4 Feb.	0950	3359-3368.5	910-919.5	9.5	3.65	38
37	4 Feb.	1445	3378-3387.5	929-938.5	9.5	7.7	81
38	4 Feb.	1950	3397-3406.5	849-957.5	9.5	9.4	99
39	4 Feb.	2335	3416-3425.5	967-976.5	9.5	8.1	85
40	5 Feb.	0315	3435-3414.5	986-995.5	9.5	6.45	68
41	5 Feb.	0750	3454-3463.5	1005-1014.5	9.5	4.8	51
42	5 Feb.	1335	3473-3482.5	1024-1033.5	9.5	8.5	89
43	5 Feb.	1630	3482.5-3492	1033.5-1043	9.5	4.0	4.2
44	5 Feb.	2005	3492-3501.5	1043-1052.5	9.5	4.8	51
45	6 Feb.	0015	3511-3520.5	1062-1071.5	9.5	4.0	42
46	6 Feb.			1081-1086	5.0	0.5	10

Very slight bit bounce occurred while penetrating between Cores 21 and 22, suggestive of some indurated stringers or perhaps pyrite concretions. We encountered a particularly hard stringer at 649 meters sub-bottom while cutting Core 23.

Penetration rates increased near the end of cutting Core 24 and remained steady down through Core 25.

Indurated levels also occurred at 736 meters, 758 meters, and 794 meters sub-bottom. From Core 28 downward the overall degree of induration appears to have increased judging from the bit weight indicator.

The first sign of bit wear occurred while cutting Core 43, diagnosed by excessive torque. The torque increased erratically and caused great difficulty in cutting Core 46, which could only be penetrated 5 meters. At this point, further progress was deemed hopeless, and we abandoned the hole.

Upon pulling the drill string during the morning of 6 February, after a week on site and more than 89 hours of rotation time, we found all four cones of the core-bit to have been sheared off; its throat was practically closed from grinding of the drill stem in the basal dolomitic limestones.

Approach to Site 365

Since we did not reach the objective of sampling the salt and evaporite formation at Site 364 by penetrating the Mesozoic and Cenozoic cover, we decided to spend the remaining two drilling days of the leg in a final effort to sample the salt, this time using a nearby canyon which had eroded out many of the indurated formations which had led to bit failure at Site 364. We did not stream seismic gear and the *Challenger* proceeded southwest at half speed using the dynamic positioning equipment to establish bearing from the position of Site 364. The new drill site (365) was reached by dead reckoning at midday on 6 February. It was some 10 km southwest of Site 364.

Drilling at Site 365

The coring summary for Site 365 is given in Table 2. Spudding in took place at 2345 and the first core was cut at 225 meters sub-bottom, revealing that we were penetrating the Neogene canyon fill as had been predicted. We worked the drill string down rapidly with both pumps. Other cores were cut at approximately 100 and 80 meter intervals to keep a check on lithology and the possible presence of gas.

A small firm zone was detected at approximately 515 meters sub-bottom while within Core 5. Cores 6 and 7, however, continued to be cut rapidly. Unfortunately, time ran out before the canyon fill could be completely penetrated, and we decided to pull the string at 1100 on 8 February to make the scheduled arrival in Abidjan, Ivory Coast. We noticed a definite firming up of the formation at about 660 meters sub-bottom. It is difficult to estimate just how thick the canyon fill was, but it seems likely that another 300 meters might have been required to reach the salt and evaporites, entailing perhaps another day on site.

Interestingly enough, we encountered little torquing of the type experienced for the Neogene section of Site 364 at Site 365, perhaps as a consequence of a slightly coarse grain size at the latter site and a significantly higher rate of sediment accumulation.

LITHOLOGY

Site 364 Lithologic Descriptions

We expected Site 364 to provide insight into the age and depositional facies of the evaporite formation, leading to an understanding of the processes by which it accumulated. Unfortunately, we did not anticipate the thick sequence of indurated Cretaceous limestones encountered at the site. The bit was destroyed apparently only a few tens of meters from the objective, reaching lower Albian-Aptian dolomites with interstitial water of high salinity. However, the sedimentary section recovered contains remarkably detailed information on euxinic changes of the sea water in the Angola Basin during the Cretaceous.

We drilled Site 364 to a depth of 1086 meters sub-bottom in 2449 meters of water yielding sediments ranging from Pleistocene to lower Albian-upper Aptian. Coring began at 7.5 meters sub-bottom and cores of 9.5 meters barrel length were taken throughout the site. Coring was not continuous except at the boundary between Tertiary and Cretaceous. We took a total of 46 cores with a recovery of 69.1 per cent, representing 27.2 per cent of the total sediment column.

We subdivide the sediments into seven lithologic units on the basis of composition, color, texture, and sedimentary structures. They are summarized in Table 3 and Figure 3.

Unit 1: Calcareous Mud

Unit 1 is composed of dark olive-gray calcareous mud and soft clay. It was taken as a "punch" core. When split, it smelled of H_2S. The mud contains 60 per cent clay, 20 per cent nannofossils, 10 per cent plant debris, 5 per cent foraminifers, 4 per cent pyrite, and 1 per cent quartz. The black clay in Core 2 shows essentially the same composition. Abundance of clay flakes associated with plant debris indicates recent transportation of terrigenous materials to the site through many submarine canyons dissecting the continental margin; such canyons were observed on *Glomar Challenger* seismic profiles taken while approaching the site. The composition and H_2S odor, together with a lack of burrowing, suggest fairly stagnant bottom conditions.

The boundary between Unit 1 and Unit 2 is taken as the first appearance of distinct calcareous nannofossil ooze in Core 3.

Unit 2: Marly Nannofossil Ooze and Mud

The unit is represented by the first recovered calcareous nannofossil ooze of lower Pliocene age and by olive-gray zeolite-bearing mud of probable middle Miocene age. Composition of the ooze is 55 per cent nannofossils, 29 per cent clay, and 10 per cent foraminifers. Composition of the mud averages 60-90 per cent clay, 0-25 per cent nannofossils, 1-5 per cent quartz, 0-5 per cent zeolite, and 0-1 per cent foraminifers. Color, odor, and presence of pyrite are similar to Unit 1, indicating reducing conditions began to prevail about this time. Abundance of nannofossils may have contributed to high surface-water productivity.

The boundary between Unit 2 and Unit 3 is placed at the first pelagic clay recovered in Core 5 of middle Miocene age.

Unit 3: Pelagic Clay and Radiolarian Ooze

Core 5 starts with dark yellowish brown to olive marly nannofossil ooze at the top becoming to yellowish brown to gray pelagic clay toward the bottom. The composition of Core 5 averages 35-70 per cent clay, 5-50 per cent nannofossils, 5-10 per cent dolomite rhombs, 1-3 per cent quartz, and 0-5 per cent zeolite.

TABLE 2
Coring Summary, Site 365

Core	Date	Time	Depth From Drill Floor (m)	Depth Below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Recovered (%)
1	7 Feb.	0700	3275-3284.5	225-234.5	9.5	9.5	100.0
2	7 Feb.	1330	3370-3379.5	320-329.5	9.5	3.45	36.3
3	7 Feb.	2020	3446-3455.5	396-405.5	9.5	4.5	47.4
4	7 Feb.	2345	3512.5-3522	462.5-472	9.5	3.15	33.2
5	8 Feb.	0230	3560-3569.5	510-519.5	9.5	4.65	48.9
6	8 Feb.	0730	3664.5-3674	614.5-624	9.5	5.75	60.5
7	8 Feb.	1520	3731-3737	681-687	6.0	3.65	38.4

TABLE 3
Lithologic Summary of Site 364

Unit	Dominant Lithology	Depth in Section (m)	Thickness (m)	Age
1	Calcareous mud	Cores 1-2 7.5-55	55	Pleistocene to Upper Pliocene
2	Marly nanno ooze and mud	Cores 3-4 55-131	76	Lower Pliocene to middle Miocene
3	Pelagic clay and rad mud	Cores 5-7 131-250	119	Middle Miocene to middle Oligocene
4	Nanno chalk	Cores 7-19 250-577	327	Middle Eocene to Santonian
5	Marly chalk with sapropel	Cores 20-25 577-710	133	Santonian to Cenomanian (?)
6	Limestone	Cores 26-38 710-962	252	Albian (?)
7	Marly dolomitic limestone with sapropel	Cores 39-46 962-1086	+124	Lower Albian to upper Aptian (?)

Core 6 differs from Core 5 and Core 7 in color variation, sedimentary structure, and composition. It consists of greenish gray to light greenish gray zeolite-bearing mud with intercalations of sand having up to 70 per cent quartz. The bottom of the core, about 70 cm thick, consists of greenish gray radiolarian mud. The composition of the core averages 75-85 per cent clay, 15-20 per cent radiolarians, 5-10 per cent diatoms, 1-5 per cent sponge spicules, 0-5 per cent zeolite, and 1-2 per cent quartz.

Core 7, excluding the core catcher, consists of brown to olive-gray pelagic clay similar to the lower half of the Core 5.

Compared with Unit 4, discussed below, Unit 3 shows a distinct increase in the level of calcium carbonate dissolution. This we attribute to Antarctic Bottom Water influx during the time of deposition of the middle and lower part of the unit. The base of the unit appears to be disconformably overlying Unit 4, with a possible missing interval of 16 million years.

Unit 4: Nannofossil Chalk

This unit is characterized by the dominance of carbonate. From Core 7,CC to Core 19, the sediment is composed of up to 95 per cent nannofossils. The unit is divided into two subunits; upper nannofossil chalk and lower nannofossil chalk, depending on the proportions of intercalations of terrigenous mudstones.

Subunit 4a (Cores 7-15) consists of yellow brown, light gray, brown and reddish yellow nannofossil chalk. The composition of the subunit averages 77 to 95 per cent nannofossils, 5 to 15 per cent clay, and 0 to 2 per cent quartz except for Core 12 which shows rather dark brown color and contains abundant terrigenous matter.

Subunit 4b (Cores 16-19) consists of brown, light brown, and pale brown nannofossil chalk. It differs from Subunit 4a in having abundant intercalations of calcareous mudstone. Core 16 has abundant terrigenous material and a thin carbonaceous layer.

Unit 5: Marly Chalk with Sapropel

This unit is characterized by the presence of finely laminated black sapropelic shales. It is divided into two subunits according to abundant appearance of the sapropelic shale.

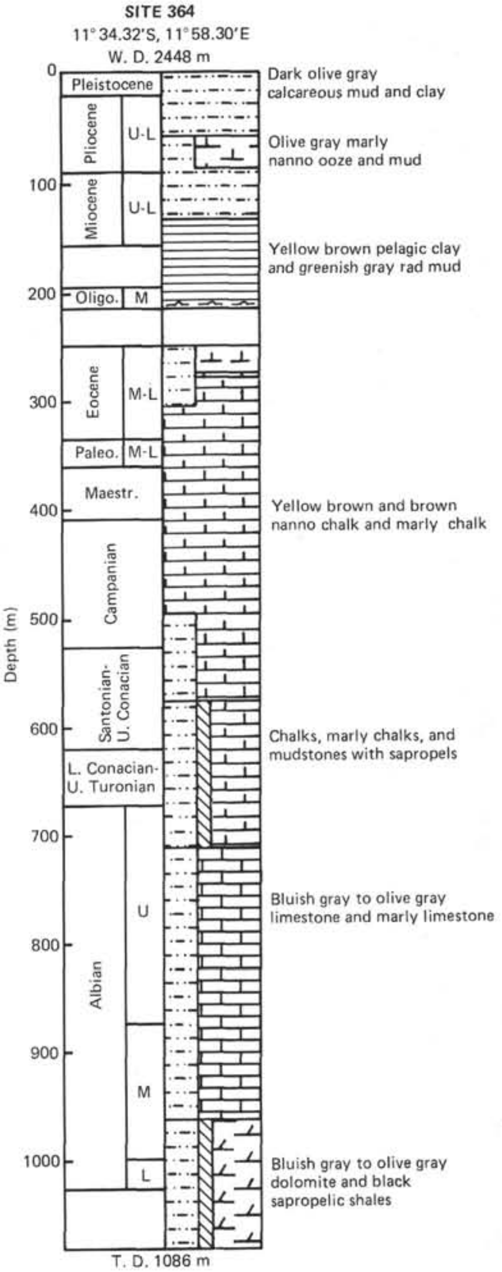

Figure 3. *Lithologic column for Site 364.*

Subunit 5a (Cores 20-22) consists of greenish gray to brown nannofossil chalk and marly nannofossil chalk interbedded with thin sapropels. In Core 22, marly nannofossil chalk is interlayered with dark greenish gray mudstone and very dark greenish brown claystone without sapropels.

Subunit 5b (Cores 23-25) consists of greenish gray and dark greenish gray marly chalk and calcareous mudstone interlayered with abundant black sapropelic shale. It contains barite, pyrite, and marcasite (Figure 4).

The unit indicates that euxinic conditions often prevailed in this part of the Atlantic Ocean during Coniacian/Santonian times.

Unit 6: Limestone

The unit is characterized by the abundance of calcium carbonate as limestone. It is divided into three subunits on the basis of composition, color, and induration.

Figure 4. *Barite in lithologic Subunit 5b, Site 364, Sample 23-2, 75-85 cm.*

Subunit 6a (Cores 26-28) consists of indurated marly nannofossil chalk with alternations of greenish gray and reddish brown material. Smear slides of Core 27 have 68 per cent unspecified carbonate, 15 per cent nannofossils, 15 per cent clay, 2 per cent foraminifers, and trace amounts of quartz.

Subunit 6b (Cores 29-31) consists of light bluish gray massive limestone, with stylolitic seams and "marble" structure (Figure 5). Core 29 has stylolitic 86 per cent unspecified carbonate, 10 per cent clay, a trace of nannofossils, and a trace of quartz. In massive limestones, there are segregation laminae of clay, which look like willow leaves.

Subunit 6c (Cores 32-38) consists of light bluish gray limestone and marly limestone. Cores 37 and 38 are olive-gray in color. Core 35 smear slides average 40 per cent clay, 33 per cent unspecified carbonate, 15 per cent nannofossils, 2 per cent pyrite, and 1 per cent quartz. Slump folds and microfaults are abundant (Figures 6 and 7).

Unit 7: Marly Dolomitic Limestone With Sapropel

The deepest unit is characterized by the occurrence of black sapropelic shale. It is divided into two subunits based on the proportion of sapropel.

Subunit 7a (Cores 39-41) consists of light gray to olive-gray marly limestone interbedded with thin black sapropelic shales. The composition of marly limestone in Core 41 is 48 per cent unspecified carbonate, 20 per cent dolomite rhombs, 20 per cent clay, and 2 per cent pyrite. Core 40 shows the steepest inclination of bedding planes, to about 60° from the horizontal, which might be caused by local slumping relating to salt deformation (Figure 8).

Figure 5. *Limestone showing "marble" structure in Unit 6, Site 364, Sample 29-4, 25-47 cm.*

Figure 6. *Folding in Unit 6 limestone, Site 364, Sample 36-2, 125-147 cm.*

Subunit 7b (Cores 42-46) consists of light bluish gray dolomitic limestone and black shale. In Core 46, we recovered only 1 meter of dark olive-gray dolomite. The composition of the dolomite in Core 44 is 93 per cent dolomite, 5 per cent unspecified carbonate, and a trace of quartz. Figure 9 shows a nodular-type dolomite from this unit.

Sedimentary History

Unit 7 is characterized by a predominant sapropelic shale of lower Albian to upper Aptian age. Bottom water conditions were stagnant enough at this time to preclude the oxidation of carbonaceous matter and the formation of current-related sedimentary structures. Instead, finely laminated shales and carbonates predominate. The lowermost limestones have been extensively dolomitized, apparently in high Fe and Na solutions (Matsumoto et al., this volume). This probably reflects the formation of dolomite in the highly saline bottom water conditions that may have persisted into the euxinic stages of sedimentation in the Angola Basin. Dolomitization, however, may also have been diagenetic (Natland, this volume). From our drilling, it is clear that salt deposition ceased no later than upper Aptian in the site, but that euxinic conditions persisted into lower Albian, and recurred at the beginning of the Upper Cretaceous as seen in Unit 5. These facts lead to consideration that there was clearly a barrier ridge between the Cape and Angola basins during Cretaceous times. The older part of the barrier may correspond to formation of the Frio Ridge and the younger to the Valdivia Bank portion of the Walvis Ridge.

Units 6 and 4 indicate that the Cretaceous South Atlantic periodically achieved a state of interchange of shallow and deep waters through the Walvis Ridge barrier to the Angola Basin, allowing normal pelagic calcareous sediments to accumulate. The sediment accumulation rate of Unit 6 was a drastically fast, 55 m/m.y.; planktonic carbonate productivity was great enough to produce massive limestone. The sediment accumulation rate for Unit 4 is 12 m/m.y. (see below). Unit 3 indicates that a sharp drop in the sedimentation rate occurred in Eocene times. This may amount to an erosional hiatus. Such a hiatus appears on the profiler records and may be interpreted as a major mid-Tertiary disconformity, or it may be interpreted simply as the result of slow deposition caused by dissolution of planktonic carbonate. Major dissolution cycles detected at Sites 360 and 362 took place in the upper Miocene, the middle to lower Oligocene, and the upper Eocene. The latter cycle correlates well with Unit 3 at Site 364. Possibly Antarctic Bottom Water influx increased from this time, causing increased dissolution.

Units 1 and 2 are evidence for marked influx of terrigenous materials from the African continent to Site 364, probably by way of the Congo and other rivers. They also indicate fairly stagnant bottom conditions in the Angola Basin during their deposition persisting to the present day.

Site 365 Lithologic Descriptions

We drilled Site 365 to a sub-sea-floor depth of 687 meters, recovering sediments that range in age from Pleistocene to pre-upper Albian.

Figure 7. *Folding in Unit 6 limestone, Site 364, Sample 29-2, 26-38 cm. Core diameter is 5.6 cm.*

The primary drilling objective at this site was to reach an expected Aptian evaporite layer in the small amount of time remaining for Leg 40. Thus, only seven widely spaced cores were taken. The following sub-sea-floor intervals were cored: 225-243.5 meters, 320-329.5 meters, 396-405.5 meters, 462.5-372 meters, 510-519.5 meters, 614.5-624 meters, and 681-687 meters. A total of 33.2 meters of sediment was recovered.

The sediments are subdivided into five lithologic units on the basis of composition and texture (Table 4). Compositional percentages are based on visual estimates of smear-slide components. Coarse fractions (63-180 μm and > 180 μm) of each core catcher sample were also examined.

Unit 1: Mud

Unit 1 is composed entirely of olive-gray, olive-black, or dark gray-green soft mud. The unit has a maximum estimated thickness of 223.7 meters. The mud averages 70 per cent clay, 4 per cent quartz, 6 per cent plant fragments, 6 per cent pyrite, 3 per cent foraminifers, 3 per cent nannofossils, 2 per cent radiolarians, and 2 per cent mica, plus minor (< 2 per cent) and trace amounts of a variety of components (see Core Summary Forms).

TABLE 4
Lithologic Summary of Site 365

Unit	Dominant Lithology	Depth in Section (m)	Thickness (m)	Age
1	Mud	225-233.7 (Core 1)	≤233.7	Pleistocene
2	Mud	233.7-234 (core 1)	0.3	Miocene
3	Nannofossil ooze	234-277 (Core 1)	43	Miocene
4	Mudstone (sapropel)	277-434 (Cores 2-3)	157	Turonian-Cenomanian/upper Albian (allochthanous)
5	Mudstone	434-687 (Cores 4-7	253	Miocene

Unit 1 is represented solely by the sediment in Core 1, but these sediments are almost certainly not from the actual sub-sea-floor interval cored. Washing was started some time after seafloor penetration, and continued until the sediment was felt to "stiffen up." Washing was then stopped and coring began (at −225 m). Thus the sediments of Unit 1 may have entered the core barrel at any level, but probably before washing started. In all likelihood, they represent sediment from near the top of the stratigraphic column.

The boundary between Unit 1 and Unit 2 is taken as the first recovered stiff terrigenous mud, which is in Core 1, Section 6.

Unit 2: Mud

Unit 2 consists of a minimum thickness of 30 cm of moderate brown, stiff mud. The mud has no apparent bedding or burrowing; it is slightly mottled. Composition of the mud is 75 per cent clay, 15 per cent quartz, 5 per cent zeolites, 3 per cent pyrite, and 2 per cent iron oxides.

The boundary between Unit 2 and Unit 3 is at the mud-nannofossil ooze contact in Core 1, Section 6.

Unit 3: Nannofossil Ooze

Unit 3 consists of an estimated thickness of 43 meters of light to moderate brown nannofossil ooze. There is no apparent bedding. The ooze is composed of 87 per cent nannofossils, 10 per cent clay, 2 per cent quartz, and 2 per cent plant fragments, plus minor and trace components. Examination of the coarse fraction of a red zone in core catcher sediment shows 65 per cent foraminifers, 35 per cent mica, and traces of fish teeth, glauconite, and pyrite; a gray zone in the same sediment showed 30 per cent foraminifers, 65 per cent pyrite, 4 per cent barite, and traces of quartz, mica, and fish teeth.

Figure 8. *Reverse faults and steeply dipping beds in marly limestone of Unit 7, Site 364, Sample 40-4, 61-82 cm.*

Figure 9. *Nodular structure in dolomitic limestone, Site 364, Sample 43-1, 79-94 cm.*

The boundary between Unit 3 and Unit 4 is arbitrarily placed halfway between the bottom of Core 1 and the top of Core 2.

Unit 4: Mudstone (Sapropel)

Unit 4 consists of an estimated thickness of 157 meters of predominantly black mudstone, with minor amounts of black claystone and bluish gray marly nannofossil chalk. The mudstones and claystones are thinly laminated, with bedding inclinations ranging from horizontal to 70°. Moderate burrowing is present.

The laminated mudstones and claystones average 69 per cent clay, 16 per cent pyrite and carbonaceous material, 8 per cent quartz, 6 per cent mica, and 3 per cent dolomite, plus minor and trace amounts of other components. Recognizable plant debris in the mudstones allows the term "sapropel" to be applied to them. The marly nannofossil chalk is composed of 55 per cent nannofossils, 30 per cent clay, 6 per cent quartz, and 5 per cent pyrite, plus minor and trace components. Examination of the coarse-fractions of the core catchers of Cores 2 and 3 gave the following averages: 70 per cent foraminifers, 22 per cent rock fragments, 6 per cent pyrite, 2 per cent quartz, and trace components.

The boundary between Unit 4 and Unit 5 is placed halfway between the bottom of Core 3 and the top of Core 4.

Unit 5: Mudstone

Unit 5 consists of an estimated 253 meters of predominantly bluish and greenish gray mudstones with minor, thin sandy layers, and one 10-cm bed of sandstone. Bedding of the mudstones is massive. Burrowing is moderate in both mudstones and sandy layers. Zoophycos is common.

The mudstones average 68 per cent clay, 18 per cent mica, 8 per cent quartz, and 2 per cent pyrite, plus minor and trace components. Trace amounts of iron oxides locally cause reddish colors in this predominantly gray unit. The coarse fraction averages 41 per cent quartz, 16 per cent unspecified carbonate, 15 per cent fish remains, 13 per cent rock fragments, 10 per cent mica, and 2 per cent pyrite. Angular mud clasts were found in Core 5. Numerous sand-sized white "specks" in the mudstones are agglutinated benthic foraminifers.

Sandstones average 47 per cent quartz, 19 per cent clay, 15 per cent dolomite, 8 per cent mica, 6 per cent zeolite, 3 per cent pyrite, and 2 per cent feldspar, plus minor and trace components. The dolomite occurs as cement. At least one sandy bed is graded, suggesting that these may be turbiditic sands.

Sedimentary History

The facies inferred to be immediately above salt at Site 364 is euxinic sapropelic shale alternating with dolomitic limestone. At Site 365, we attempted to bypass much of the overburden over the salt layer by coring into a deep cleft cut through virtually the entire sequence into the salt and filled with younger sediments. The origin of the canyon is uncertain. Erosion, faulting, or collapse into a gap created by dissolution of the halite beneath are all possibilities. Reflectors are directly traceable to the wall of the canyon from Site 364, a scant 10 km away. Unfortunately, coring did not penetrate the salt although drilling terminated over 300 meters below the inferred top of the salt horizon at Site 364. At this point, interstitial water salinities of 122 per mille were obtained (Sotelo and Gieskes, this volume), indicating that salt was very close at hand. We infer that the wall of the canyon where salt was expected was never penetrated, and that all that was cored is canyon fill.

The oldest in situ sediments cored are Miocene with some reworked Cretaceous. The Cretaceous sapropels of Unit 4 are clearly allochthonous, with high angled dips, and may represent a block caved from the canyon walls during Miocene time. The Miocene sediments were deposited primarily below the CCD and are laterally extensive to sediments in the deep Angola Basin west of the salt escarpment.

GEOCHEMICAL MEASUREMENTS

Neither the presence of gas nor evidence of liquid hydrocarbons was detected in the cores recovered at either Sites 364 or 365 (see Foresman, this volume).

PHYSICAL PROPERTIES

Site 364

The sediments at this site range in age from Pleistocene to upper Aptian. The lithology of this section is calcareous biogenic remains in various stages of alteration and lithification, with minor siliceous, authigenic, and terrigenous components. In Cores 29-40, much of the bedding shows steep dips and folding. This may be intraformational folding due to slumpage or salt flowage. Because of the varying dips, the sonic velocity and GRAPE measurements were not always made parallel to the bedding.

GRAPE

The bulk density plotted in Figure 10 increases from 1.5 g/cm^3 at 40 meters to maximum values of 2.5 g/cm^3 at 1000 meters. The presence of sapropels causes deviations from normal patterns. The sapropels of Lithologic Units 5a, 5b, 7a, and 7b cause a major deviation in the plots of physical properties. These highly carbonaceous shales have low bulk density compared to other shales buried at comparable depths. One interesting feature in the GRAPE records is a very sharp bulk density peak, 2.79 g/cm^3, at 50 cm in Core 38, Section 4. A comparison with the visual core descriptions shows this to be a thin layer of pyrite.

The porosity plotted in Figure 10 decreases with depth. The initial values of 75 per cent at 10-meters depth are reduced to a minimum of 9 per cent at 1045 meters. The low porosity values at depth are in cemented and dolomitic limestones. Both sapropel units have larger values of porosity than the adjoining chalks and limestones.

One interesting feature of both the bulk density and porosity plots is the interval between 100 and 250 meters where the values of each remain constant. In this interval, a pronounced lack of calcium carbonate is evident. The dominant lithology is a zeolite-bearing mud, rich in siliceous microfossils. The water content profile also displays uniformity over this same interval. These data add emphasis to the hypothesis that the lithology is the controlling factor for the major physical properties in this interval. There also appears to be a break in the plots of physical properties below this unit, suggesting a possible hiatus.

Sonic Velocity

Sonic velocity measurements ranged from 1.64 km/sec to 5.3 km/sec at Site 364 as shown in Figure 10. The acoustic units as shown in Table 5 correspond to major lithologic changes, but are not directly comparable to the lithologic units. Acoustic Unit I encompasses the first three lithologic units which range from calcareous mud, to marly nannofossil ooze, to a barren zeolite mud. Acoustic Unit II corresponds to the chalks of Lithologic Units 4a and 4b. At the base of these chalks, an euxinic facies represented by sapropels and hard chalks presents a good reflector which is Acoustic Unit III. Acoustic Unit IV signals the first appearance of limestones with some velocities greater than 3.0 km/sec. Interbedded with the limestones are low-velocity calcareous mudstones. Acoustic Unit V corresponds to high-velocity dolomites (greater than 4.0 km/sec) and low-velocity sapropels (velocities less than 2.8 km/sec). This

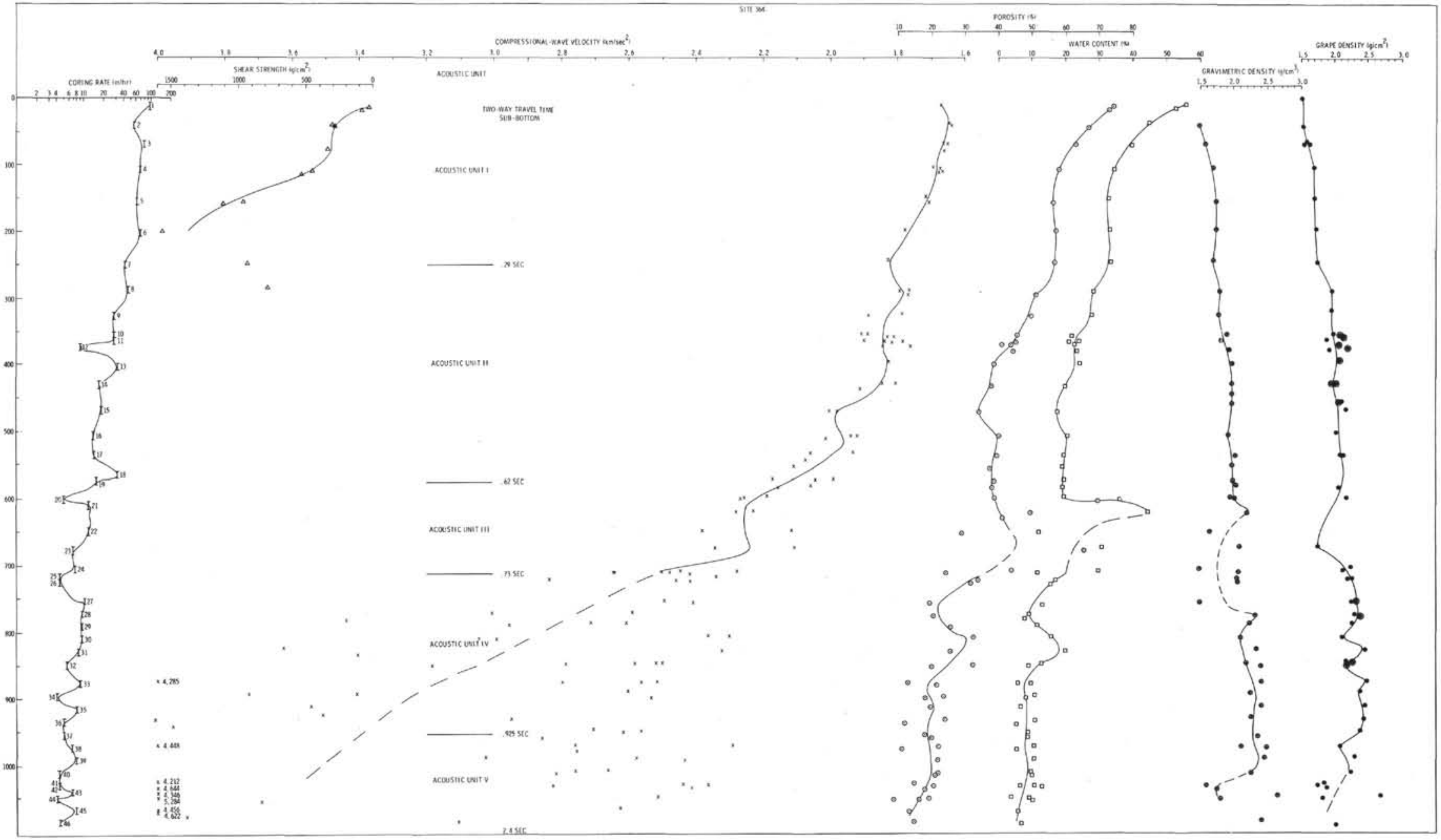

Figure 10. *Bulk density, porosity, water content, sonic velocity, and shear strength versus depth at Site 364.*

TABLE 5
Velocity Travel Time Data for Site 364 Acoustic Units

Acoustic Unit	Time to Base of Unit[a] (sec)	Mean Measured Velocity (km/sec)
I	0.29	1.68
II	0.62	1.91
III	0.73	2.27
IV	0.925	2.91
V	2.4	3.30

[a] Two-way reflection time

unit comprises the dolomites and sapropels on top of the salt and extends to the base of the salt at 2.4 seconds subbottom.

Shear Strength

The measured shear strength values plotted on Figure 10 increase from 33 g/cm² at a depth of 11 meters to a maximum of 1570 g/cm² at 198 meters. Below 200 meters, the shear strength decreases to 800 g/cm² as a chalk is entered at 275 meters. The high values of shear strength are in the middle of the non-carbonate mud where the values of water content, porosity, and bulk density remain constant. Water content in Figure 10 decreases from 126 per cent at a depth of 11 meters to a minimum of 4 per cent in the dolomites at 1045 meters. Abnormally high values of water content are associated with the sapropels between 580 meters and 710 meters.

Summary

Site 364 offered an opportunity to examine the changes of physical properties with depth in a mainly biogenic section. The only deviations from typical curves are in the non-calcareous muds of Lithologic Unit 3 and in the sapropels of Lithologic Units 5a, 5b, 7a, and 7b. The major reflectors shown in Figure 10 correspond with the major lithologic breaks. In the lower two acoustic units, extremely high velocities, between 3.0 and 5.3 km/sec, were measured for the recovered limestones and dolomites.

Site 365

Since Site 365 was a last-ditch effort to recover samples of the Angola Basin, salt cores were widely spaced both in depth and age. We recovered five different lithologies in seven cores. The lithologies varied from a Pleistocene mud to a Miocene nannofossil ooze with a large "slump" block of Cretaceous mudstones with interbedded sapropels resting on older Tertiary mudstones.

Although core control at this site is rather poor, certain generalizations can be made about the physical properties. As can be seen in Table 6, the bulk density, sonic velocity, and shear strength increase with depth. The slump unit of Cretaceous sediment does show values larger than expected for near-surface sediments. The exact nature of the slump cannot be determined from the limited amount of data available from this site.

BIOSTRATIGRAPHY AND PALEONTOLOGY

General Remarks, Site 364

At Site 364 in the Angola Basin, we penetrated 1086 meters of Pleistocene to upper Aptian sediments. Coring was not continuous except for Cores 10-12 across the Cretaceous Tertiary boundary. Ten cores were taken in the Pleistocene to Paleocene (359 m). About 300 meters of Upper Cretaceous Maestrichtian to upper Turonian are represented by 13 fairly regularly spaced cores (11-23). The Lower Cretaceous (upper Albian to upper Aptian), some 420 meters thick, is represented by 23 cores, one core taken every 19 meters (50% coring).

Core 1 (7.5-17 m) is rich in tropical Pleistocene planktonic foraminifers and calcareous nannoplankton. Core 2 (36-45.5 m) is virtually devoid of calcareous microfossils; only in the core catcher are some planktonic foraminifers and coccoliths (which, in addition, also occur in Section 2) of upper Pliocene age present. Core 3 (64.5-74 m) is Pliocene on the basis of both planktonic foraminifers and calcareous nannoplankton. Core 4 (102.5-112 m) is upper Miocene. Cores 5 to 7, Section 1 (150-159.5, 197.5-207, and 245-254.5 m) are strongly affected by calcium carbonate dissolution and can only tentatively be dated as middle-lower Miocene. Dissolution is less marked in Cores 7, CC to 10 (254.5, 283-292.5, 321-330.5, and 341.5-359 m) in which a number of middle Eocene to lower Paleocene planktonic foraminiferal and calcareous nannoplankton zones are present.

Cores 11 and 12 (359-378 m) are void of planktonic foraminifers, but benthic forms are present. They are dated as Maestrichtian on the basis of abundant calcareous nannoplankton. The Cretaceous/Tertiary boundary thus falls between Cores 10 and 11. Both the lower Tertiary and the uppermost Cretaceous are strongly affected by calcium carbonate dissolution. This is in contrast to the Walvis Ridge Site 363 where dissolution in the same stratigraphic interval is negligible. Cores 13-23 (397-653 m) are lower Maestrichtian-upper Turonian on the basis of planktonic microfossils. Core 24 (672.5-682 m) is already upper Albian; thus part of the Turonian and the whole of the Cenomanian appear to be missing as at Site 363 (but see discussion on calcareous nannoplankton below). Because of very poor faunas, Cores 24 and 25 are not datable using planktonic foraminifers. But below this, they are more frequent and are of a cooler water, boreal type, as at Site 363. Cores 24-34 (672.5-881.1 m) are placed in the Albian, and Cores 35-41 (891-1014.5 m) in the upper Aptian. Cores 42-46 (1024-1086 m) are devoid of planktonic foraminifers. On the basis of calcareous nannoplankton, Cores 24-33 are in the upper part of the Albian, Cores 34-41 in the upper part of the lower to middle Albian, and Core 41 (lower part) to Core 42 in the lower Albian.

Except for Core 6, CC and Section 7-1, which contain a rich Oligocene fauna, Cenozoic radiolarians are absent. Most of the Cretaceous is also barren in radiolarians, except for Cores 23 to 27.

Six different phylloceratid and desmoceratid ammonite species were recovered within the interval of the upper-middle Albian Cores 29-37. In spite of a somewhat different

TABLE 6
Physical Properties Data, Site 365

Sample (Interval in cm)	Depth (m)	Bulk Density (g/cm^3)	GRAPE (g/cm^3)	Velocity (km/sec)	Water Content[a] (%)	Porosity (%)	Shear Strength (g/cm^2)
1-6, 32	233.5	1.342	1.40	1.637	57.07	76.63	81.3
1-6, 40	233.5		1.41	1.632			
1-6, 90	234	1.636	1.78	1.701	37.02	60.58	1127
1-6, 143	234.5	1.853	2.10	1.632	24.13	43.88	1150
2-3, 22	221.5	1.908	1.98	1.798	24.17	46.13	
2-3, 69	322		1.92	1.779			
3-2, 16	397.5	1.806		1.830	26.69	48.22	
3-2, 56	398			1.839			
3-3, 10	399	1.569	1.67	1.848	29.42	46.16	
3-3, 144	400.5		1.52	1.896			
4-1, 88	462.5	2.081	1.96	1.971	22.86	47.59	
4-2, 113	465	1.897	1.92	2.002	24.24	46.01	
5-2, 62	512	1.956	1.95	2.04	22.18	43.39	
5-2, 109	512.5		2.00	2.022			
5-3, 10	513		1.99	1.998			
5-3, 46	513.5	1.929	2.01	2.025	22.38	43.18	
6-2, 64	616.5	1.904	2.03	2.084	21.25	40.48	
6-2, 139	617.5		2.1	2.021			
6-4, 80	620		2.01	2.094			
7-1, 142	682.5	1.879		2.03	10.69	20.10	
7-2, 66	683	1.920	2.04	2.14	34.43	66.09	

[a] % of total weight

depositional environment compared with the Walvis Ridge Site 363, the Angola Basin Site 364 ammonites are of the same preservation which indicates deposition on the outer shelf/upper continental slope in sediments of slightly reducing conditions.

Abundant spores and pollen, and rare dinoflagellates were studied from Cores 21 to 45 for their distribution and stratigraphic implication (Morgan, this volume).

Biostratigraphy, Site 364

The general planktonic foraminiferal and calcareous nannoplankton zonation of the section, and correlation of the zonal scheme applied is given in Tables 7 and 8.

Tertiary

Wide spacing between cores and strong calcium carbonate dissolution over much of the section prevents the recognition of continuous planktonic foraminiferal and calcareous nannoplankton zonal sequences through the 359 meters of Cenozoic sediments. But where present, the planktonic foraminiferal and calcareous nannoplankton associations allow good zonal assignments (see Table 8). The planktonic foraminiferal fauna is largely of tropical aspect. But the absence of *Globorotalia tumida*, which is one of the best warm-water indicators in the Pliocene-Pleistocene, is surprising. On the basis of planktonic foraminifers the Pleistocene *Globorotalia truncatulinoides truncatulinoides* Zone and the two Pliocene zones *Globorotalia miocenica* and *Globorotalia margaritae* were recognized in Core 1, and Cores 2 and 3, respectively. Core 4 is upper Miocene *Neogloboquadrina dutertrei* Zone. Because of dissolution virtually no planktonic foraminifers occur in Cores 5, 6, and the upper part of Core 7. Only the core-catcher sample of Core 5 could be dated as the middle Miocene *Globorotalia fohsi peripheroronda* Zone. The calcareous nannoplankton in Cores 1-7 confirm the planktonic foraminiferal ages. The core-catcher sample of Core 7 is already middle Eocene on the basis of both calcareous nannoplankton (*Nannotetrina fulgens* Zone) and very poor planktonic foraminiferal evidence. The lower part of the Miocene, the Oligocene, and the upper Eocene are thus either absent or very strongly condensed in Core 6 and above the core catcher of Core 7.

The lower Eocene *Globorotalia palmerae* to *Globorotalia aragonensis* and the *Globorotalia formosa formosa* zones could be distinguished in Core 8, and the *Globorotalia subbotinae* and the *Globorotalia edgari* zones in Core 9. The core catcher of Core 9 is already upper Paleocene *Globorotalia velascoensis* Zone. The middle Paleocene *Globorotalia angulata* Zone and the lower Paleocene *Globorotalia trinidadensis* Zone occur in Core 10. On the basis of calcareous nannoplankton the lower Eocene *Discoaster sublodoensis*, *Discoaster lodoensis*, and *Tribrachiatus orthostylus* zones are condensed into Core 8. Core 9 is assigned to the lower Eocene *Tribrachiatus contortus* Zone. Core 10 contains the *Heliolithus kleinpellii* and the *Fasciculithus tympaniformis* zones in its upper and middle sections, and at its base the lower Paleocene *Cruciplacolithus tenuis* Zone.

The Cretaceous/Tertiary Boundary

This boundary falls between Cores 10 and 11 of Site 364. Core 10 (with full recovery) is strongly affected by calcium carbonate dissolution which has only rudimentary planktonic foraminiferal and calcareous nannoplankton associations remaining. Core 10, CC is in the lower Paleocene *Globorotalia trinidadensis* Zone on the basis of planktonic foraminifers and in the *Cruciplacolithus tenuis* Zone of calcareous nannoplankton. The lowermost Paleocene is thus absent in Core 10. Core 11 (also with full recovery) has no planktonic foraminifers, but benthic forms are present as are calcareous nannoplankton. This is unlike Site 363 where rich and well preserved lower Paleocene calcareous mic-

TABLE 7

Correlation of Cretaceous Calcareous Nannoplankton and Planktonic Foraminiferal Zones, and Ages of Other Fossil Groups in Site 364

CALCAREOUS NANNOPLANKTON			DEPTH BELOW SEA FLOOR IN METERS	CORE	PLANKTONIC FORAMINIFERA			BENTHONIC FORAMINIFERA		RADIOLARIA	AMMONITES	PALYNOMORPHS
AGE		ZONES			ZONES	AGE						
	MAASTRICHTIAN	Arkhangelskiella cymbiformis	359 - 368,5	11				? L	MAASTR.			
			368,5- 378	12								
		Tetralithus trifidus	397 - 406,5	13	Globotruncana havanensis	L	MAASTRICHTIAN					
	CAMPANIAN		425,5- 435	14					CAMPANIAN			
		Eiffellithus eximius	463,5- 473	15			CAMPANIAN to SANTONIAN					
			501,5- 511	16								
	SANTONIAN to UPPER CONIACIAN	Marthasterites furcatus	530 - 539,5	17					SANTONIAN			
			549 - 558	18								
			568 - 577,5	19								
			577,5- 587	20								
			596,5- 601	21	Globotruncana primitiva	U	CONIACIAN	U	CONIACIAN			
			615,5- 625	22								
	L.CON.-U.TUR.	Micula staurophora	644 - 653,5	23	Globotruncana sigali		L. CONIACIAN - U. TURONIAN		L. CONIACIAN - U. TURONIAN			CONIACIAN to U. TURONIAN
U	ALBIAN	Eiffellithus turriseiffeli	672,5- 682	24					?L.CENOMANIAN - UPPER ALBIAN			
			701 - 710,5	25						CENOMANIAN - UPPER ALBIAN		
			710,5- 720	26	Rotalipora ticinensis - Biticinella breggiensis	U M	ALBIAN	U	ALBIAN	UPPER ALBIAN		
			720 - 729,5	27						ALBIAN-APTIAN		VRACONIAN or CENOMANIAN
			748,5- 758	28								
			767,5- 777	29							UPPER ALBIAN	UPPER ALBIAN
			786,5- 796	30								
			805,5- 815	31				M	ALBIAN			
			824,5- 834	32	Ticinella primula - Ticinella bejaouensis	M L	ALBIAN					
			843,5- 853	33								
M	ALBIAN	Prediscosphaera cretacea	872 - 881,5	34								
			891 - 900,5	35	Hedbergella trochoidea - Hedbergella gorbachikae	U	APTIAN					
			910 - 919,5	36								
			929 - 938,5	37							U.-M. ALBIAN	
			948 - 957,5	38	Globigerinelloides algeriana			U	APTIAN			MIDDLE ALBIAN
			967 - 976,5	39								
			986 - 995,5	40								
L	ALBIAN	Parhabdolithus angustus	1005 -1014,5	41								
			1024 -1033,5	42								LOWER ALBIAN
			1033,5-1043	43								
			1043 -1052,5	44								
			1062 -1071,5	45								
			1081 -1086,5	46								

rofossils, including planktonic foraminifers, occur above the boundary in Core 18, and an equally rich and well preserved Upper Cretaceous assemblage below it. At Site 364, the absence of upper-middle Maestrichtian *Micula mura* and *Lithraphites quadratus* in the uppermost part of Core 11 suggests a middle-lower Maestrichtian *Arkhangelskiella cymbiformis* Zone for Sections 11-1 to 13-1. The youngest Cretaceous planktonic foraminifers occur in Cores 13, CC and 14 and are of lower Maestrichtian *Globotruncana havanensis* Zone age. The upper Maestrichtian and probably part of the middle Maestrichtian are thus absent.

Cretaceous

Dating and zoning of the Cretaceous is based primarily on planktonic foraminifers and calcareous nannoplankton. Additional biostratigraphic information is supplied by ammonites, benthic foraminifers, and palynomorphs (see Table 8).

As pointed out above, the Maestrichtian of Cores 11-14 is incomplete in that its upper part is absent. Cores 15-20 are poor in planktonic foraminifers as a result of strong calcium carbonate dissolution. The residual fauna preserved is of Campanian to Santonian age. Planktonic foraminifers are again abundant in Cores 21 and 22 which are assigned to the upper Coniacian *Globotruncana primitiva* Zone. The more dissolved Core 23 planktonic foraminifers indicate a lower Coniacian-upper Turonian *Globotruncana sigali* Zone age. The calcareous nannoplankton zones follow a similar stratigraphic breakdown: *Eiffellithus eximius* Zone, Campanian (Cores 15-16); *Marthasterites furcatus* Zone, Santonian-upper Coniacian (Cores 17-23, upper part); *Micula*

TABLE 8
Correlation of Pleistocene to Paleocene Calcareous Nannoplankton and Planktonic Foraminiferal Zones in Site 364

AGE		CALCAREOUS NANNOPLANKTON ZONES	DEPTH BELOW SEA FLOOR IN METERS	CORE	PLANKTONIC FORAMINIFERAL ZONES	AGE	
PLEISTOCENE		Emiliania huxleyi/ Gephyrocapsa oceanica Emiliania ovata	7,5- 17	1	Globorotalia truncatulinoides truncatulinoides	PLEISTOCENE	
PLIOCENE	U	Discoaster brouweri	36 - 45,5	2	Globorotalia miocenica	M	PLIOCENE
	L	Reticulofenestra pseudoumbilica Ceratolithus rugosus Ceratolithus acutus	64,5- 74	3	Globorotalia margaritae	L	
MIOCENE	U	Discoaster berggrenii Discoaster calcaris Discoaster hamatus	102,5-112	4	Neogloboquadrina dutertrei	U	MIOCENE
	L	Helicosphaera ampliaperta	150 -159,5	5	Globorotalia fohsi peripheroronda	M	
			197,5-207	6			
			245 -254,5	7			
EOCENE	M	Nannotetrina fulgens				M	EOCENE
	L	Discoaster sublodoensis Discoaster lodoensis Tribrachiatus orthostylus	283 -292,5	8	G. palmerae - G. aragonensis Globorotalia formosa formosa	L	
		Tribrachiatus contortus	321 -330,5	9	Globorotalia subbotinae Globorotalia edgari		
					Globorotalia velascoensis	U	PALEOCENE
PALEOCENE	M	Heliolithus kleinpellii Fasciculithus tympaniformis	349,5-359	10	Globorotalia angulata	M	
	L	Cruciplacolithus tenuis			Globorotalia trinidadensis	L	

staurophora Zone, lower Coniacian-upper Turonian (Core 23, lower part).

Cores 24 and 25 are again so poor in planktonic foraminifers that no age determination is possible for this interval. On calcareous nannoplankton they are already in the upper Albian *Eiffellithus turriseiffeli* Zone which continues to Core 33. Cores 34 to the upper part of Core 41 are in the middle to lower Albian *Prediscosphaera cretacea* Zone. The lower part of Core 41 and Core 42 belong to the lower Albian part of the *Parhabdolithus angustus* Zone. Cores 43-46 are barren of calcareous nannoplankton.

Planktonic foraminifers re-appear in great numbers in Core 26. As at Site 363, the cold water *Hedbergella* associations are dominant. The Lower Cretaceous of Cores 26 to 41 is subdivided as follows:

Core 26-upper Core 31: *Rotalipora ticinensis* to *Globigerinelloides breggiensis* zones, upper to middle Albian;

Lower Core 31-Core 34: *Ticinella primula* to *Ticinella bejaouensis* zones, middle to lower Albian;

Cores 35-37: *Hedbergella trochoidea* to *Hedbergella gorbachikae* zones, upper Aptian;

Cores 38-41: *Globigerinelloides algeriana* Zone, upper Aptian

Cores 42-46: devoid of planktonic foraminifers.

The radiolarian-poor faunas that occur in Cores 25-27 indicate Cenomanian-upper Albian for Core 25, upper Albian for Core 26 and Albian-Aptian for Core 27.

The two ammonite species *Puzosia quenstetti* and *Cainoceras* n.sp.ex. aff. *liberum* from Cores 29 and 32 are upper Albian, the four species *Cainoceras* aff. *angustidorsatum*, *Mortoniceratidae* gen. et sp. indet., *Neokentroceras* ? sp., and *Hamites tenuis* are regarded as upper-middle Albian.

Specimens of *Inoceramus* sp. cf. *Inoceramus anglicus* occur in Core 39. The species has been described from the Albian of various regions.

On palynomorphs Cores 23-25 are regarded as Coniacian to upper Turonian, Core 27 Cenomanian or Vraconian, Cores 29-32 upper Albian, Cores 38-40 middle Albian, and Cores 42-46 lower Albian. Several zonal schemes have been considered for the Site 364 palynomorphs. Most useful seem those established in Senegal and Ivory Coast, to the north of Site 346. Others from coastal Brazil are thought applicable mainly for the Lower Cretaceous when South America and Africa were still close.

As at Site 363, Aptian-Albian age assignments at Site 364 differ from one fossil group to another (Table 8). Using planktonic foraminifers, the Albian-Aptian boundary lies between Cores 34 and 35. However, the oldest ammonites in Core 37 are still dated as upper to middle Albian. Using benthic foraminifers, the boundary lies between Cores 36 and 37, but using calcareous nannoplankton it is within Core 41. On the basis of palynomorphs, the Albian-Aptian boundary was not reached at Site 364.

Paleontology, Site 364

Because of wide spacing of cores, the 359 meters of Tertiary sediments at Site 364 were recovered in only a fragmentary way. Furthermore, the calcareous microfossils which constitute the overwhelming part of the faunas and floras were strongly affected or even completely destroyed in some cores by calcium carbonate dissolution. The presence and distribution of planktonic and benthic foraminifers, as well as calcareous nannoplankton, are therefore determined by these factors.

The effects of strong dissolution and diagenesis are also evident in much of the approximately 720 meters of Cretaceous sediments, especially in the Maestrichtian to Santonian and again in the upper part of the upper Albian, where they mainly affected the planktonic foraminifers. Benthic foraminifers and calcareous nannoplankton are much less affected and occur throughout the interval. Ammonites were recovered from Cores 29, 32, and 37. In contrast to Site 363 where Calcisphaerulidae occur from the lower Paleocene to upper Aptian, they are absent from the age-equivalent strata at Site 364. On the other hand, palynomorphs, in particular pollen and spores, but also dinoflagellates occur throughout the Cretaceous of Site 364.

The following faunal/floral groups of Site 364 are treated in special contributions to this volume (* in supplement volume):

Neogene-Paleogene planktonic foraminifers (Toumarkine)
Cretaceous planktonic foraminifers (Caron)
Paleogene benthic foraminifers (Proto Decima and Bolli)
Upper Cretaceous benthic foraminifers (Beckmann)
Lower Cretaceous benthic foraminifers (Scheibnerová)
Pleistocene to upper Aptian calcareous nannoplankton (Proto Decima, Medizza, and Todesco)
Cenozoic radiolarians (Pisias and Moore)
Cretaceous radiolarians (Foreman)
Ammonites (Wiedmann and Neugebauer)*
Inocerami (Matsumoto)*
Senonian to Albian palynomorphs (Morgan)

Planktonic Foraminifers

Neogene: Of the seven cores that recovered sediments within the 250 meters of Neogene sediments drilled, only Cores 1, 2, CC, 3, and 4 contain reasonably rich planktonic foraminiferal faunas. In the others the faunas were largely or completely destroyed by calcium carbonate dissolution. The Pleistocene planktonic foraminifers of Core 1 (7.5-17 m) are of a typical tropical-sub-tropical character. The typical tropical form, *Globorotalia tumida tumida*, is absent which suggests some cooling occurred during that period of the Pleistocene. The Pliocene fauna is characterized by the index fossils *Globorotalia miocenica*, *G. multicamerata*, *G. margaritae*, and *Globigerinoides obliquus extremus*, forms generally present in the tropical-sub-tropical Pliocene of the Atlantic and Caribbean areas.

Paleogene: Most samples examined from Cores 7, CC to 10, representing about 100 meters of Paleogene sediments, contain either no planktonic foraminifers, or forms that are strongly affected and reduced by calcium carbonate dissolution. It is mainly the thick-shelled species that resisted dissolution best, such as *Globigerina senni* which, in Core 7, CC, for example, is the only species that remains. Despite this strong dissolution, zonal markers when present are usually sufficiently well preserved to allow the distinction of several lower Eocene and Paleocene zones.

Cretaceous: Two distinct groups of planktonic foraminifers can be distinguished, a Maestrichtian to upper Turonian Tethyan fauna (Cores 13-23) and a boreal Albian-Aptian fauna (Cores 26-41). The Maestrichtian Cores 11-12 contain no planktonic foraminifers, those of the upper Albian Cores 24 and 25 are strongly impoverished and not diagnostic. The lowermost Cores 42-46 are devoid of planktonic foraminifers. The Maestrichtian faunas of Cores 13, CC and 14 are also impoverished through dissolution, but several species including the zonal marker *Globotruncana havanensis* occur. The planktonic foraminifers of the Campanian-Santonian interval (Cores 15-20) are even more rare than in the lower Maestrichtian. Here only a few resistant forms including some specimens of *Globotruncana fornicata* are preserved.

From the upper Coniacian to the Turonian, dissolution was less pronounced. This resulted in the presence of rich faunas dominated by *Hedbergella*, particularly in the Coniacian (Cores 21-22). The interval is characterized by several *Globotruncana* species including the zonal markers *Globotruncana primitiva* and *G. sigali*.

As at Site 363, the Lower Cretaceous-upper Aptian planktonic foraminifers (Cores 35-41) are dominated by rich *Hedbergella* faunas, an indication of a cooler water environment. In contrast to Site 363 species diversification is normal. Dissolution effects are quite strong in Cores 35-41 but, despite this fact, rich faunas remain because tests are preserved as carbonate casts in the dolomitic and sapropelic shales. The majority of the species belongs to *Hedbergella* including a number of index forms such as *H. trochoidea* and *H. gorbachikae*. Tethyan forms including the zonal marker *Globigerinelloides algeriana* are absent, but *G. blowi*, *G. barri*, and *G. maridalensis* do occur. Fossil preservation is much better in the Albian interval (Cores 26-34), resulting in a fauna of high genus and species diversity. The *Ticinella* group is outstanding, with such species as *T. bejaouensis* and *T. primula* in the lower to middle Albian (Cores 31-34) and of *T. praeticinensis* in the middle to upper Albian. *Whiteinella* with *W. bornholmensis* and *W. baltica* are also frequent in this interval. These forms were originally described from the upper Turonian to Coniacian of the Baltic. Their occurrence in the Albian of Site 364 indicates a much longer range. It is possible that the distribution of this genus was strongly controlled by environment. Fossil preservation is again so poor in the upper Albian Cores 24 and 25, perhaps due to calcium carbonate dissolution or diagenesis, that only a few undiagnostic planktonic foraminifers remain.

Benthic Foraminifers

Paleogene: The strong dissolution evident in the Paleogene Cores 7-10 also had its effect on the benthic foraminifers. Not only are the number of specimens preserved not representative of the association originally present, but the taxa remaining appear reduced as well. In contrast, a reasonable middle Eocene fauna occurs in Core 7, CC. The samples examined from Cores 8 and 9 consist of only few specimens representing a few species, but planktonic foraminifers in Cores 8 and 9 are more abundant. It is therefore possible that in this interval the faunal character was originally predominantly a planktonic one. In Core 10, on the other hand, quite a rich benthic fauna is present compared with impoverished planktonic foraminifers. *Bandyella beckmanni* is described as a new species from Sample 10-1, 58-60 cm (Proto Decima and Bolli, this volume).

Upper Cretaceous: Benthic foraminifers are present throughout the Upper Cretaceous Cores 11-23. Their frequency is variable and appears to be determined at least in part by calcium carbonate dissolution, which eliminated all the planktonic foraminifers in Cores 11 and 12, for example. Benthic foraminifers are comparatively rare in Core 18 where the planktonic forms are also nearly absent. The faunal composition through Cores 23 to 11 does not show a distinct trend or change. The appearance of *Bathysiphon* in the upper part of the section may be of ecological significance. Some faunal elements such as *Bathysiphon, Gyroidina, Osangularia,* and *Nutallinella* point to a deeper water middle- to possibly lower-slope environment. The scarcity of primitive agglutinated forms of Lituolids, however, suggests a depth of not more than about 2000 meters. Without reliable data on paleoclimatology and bottom conditions, such depth estimates remain rather speculative.

The Upper Cretaceous benthic foraminifers of both Sites 363 and 364 show influences of tropical to subtropical, temperate and austral character. In particular, evidence for a warmer climate prevails in the Senonian and Maestrichtian of Site 364. This is also confirmed by the planktonic foraminifers.

Lower Cretaceous: Benthic foraminifers occur in the upper Albian to upper Aptian Cores 24-41 where they are fairly regularly distributed. Cores 42 to 46 contain only very poor benthic foraminifers or are barren. The fauna consists mainly of calcareous forms and is of the non-tropical austral type. Consequently, the Angola Basin at that time must have formed part of the Austral biogeoprovince. Ecological reasons may be responsible for some differences in the faunal composition of Sites 363 and 364. Though many species occur at both Sites 363 and 364, there are several taxa that are restricted to one or the other. For instance, *Lingulogavelinella frankei africana* only occurs at Site 364. A distinct faunal change takes place between Site 364 Cores 26 and 25 where such species as *Orithostella indica, Osangularia utaturensis*, and *Spirobolivina australis* disappear. A comparable change within the Albian has also been observed in the Great Australian Basin and in other areas of the Austral biogeoprovince.

Calcareous Nannoplankton

Coccolith assemblages ranging in age from Holocene to Lower Cretaceous occur in this discontinuously cored section.

Good to moderately preserved Holocene-Pleistocene assemblages with abundant *Helicosphaera carteri* and *Gephyrocapsa oceanica* are present in Core 1. Core 1 (uppermost Section 1) contains many reworked Upper Cretaceous and Paleogene forms. In the core catcher of Core 1 a peculiar association composed almost exclusively of *H. carteri* was found. This species is characteristic of tropical or subtropical areas.

Samples from Core 2 (36-46.5 m) are barren except for Section 2, 9-10 cm and the core catcher that contains a poorly preserved upper Pliocene assemblage of the *Discoaster brouweri* Zone. Nannofloras are rare to common and contain reworked Upper Cretaceous and Cenozoic specimens.

Moderately well preserved lower Pliocene assemblages occur throughout Core 3 (64.5-74 m). The great abundance of discoasters, such as *D. brouweri* and *D. pentaradiatus* suggests warm-water conditions. Core 4 (102.5-112 m) contains upper Miocene coccolith assemblages. Preservation is moderate to good. Discoasters are abundant and sphenoliths are common.

Coccoliths are very rare in Core 5 (150-159.5 m) except for Sample 364-5-4, 9-10 cm (153 m) that contains an upper lower Miocene assemblage. The concurrence of abundant *Sphenolithus heteromorphus,* common *Cyclococcolithina mcintyreii,* and rare *Helicosphaera ampliaperta* suggests the assignment of this sample to the upper part of the *Helicosphaera ampliaperta* Zone.

Samples of Cores 6 (197.5-207 m) and 7 (245-254.5 m) are barren of calcareous nannofossils except for Sample 7, CC that contains a moderately preserved middle Eocene assemblage of the *Nannotetrina fulgens* Zone.

The lower Eocene *Discoaster sublodoensis, Discoaster lodoensis,* and *Tribrachiatus orthostylus* zones are condensed in Core 8 (283-295.5 m). Coccoliths are abundant, but are only moderately to poorly preserved.

Lowermost Eocene and Paleocene assemblages are present in Cores 9 to 10. The great abundance of discoasters and the poor preservation of placoliths suggest dissolution effects in this interval. Core 9 is assigned to the lower Eocene *Tribrachiatus contortus* Zone, Core 10 contains the middle Paleocene *Heliolithus kleinpellii, Fasciculithus tympaniformis* zones, and the lower Paleocene *Cruciplacolithus tenuis* Zone.

Cores 11 to 12 (359-378 m) contain abundant but poorly preserved coccolith assemblages which suggest an Upper Cretaceous Maestrichtian age. Because of the absence of diagnostic species a closer biostratigraphic assignment is difficult. However, the absence of *Micula mura* and *Lithraphidites quadratus* might suggest an *Arkhangelskiella cymbiformis* Zone age.

Cores 13 to 14 (397-435 m) are assigned to the upper Campanian to lower Maestrichtian *Tetralithus trifidus* Zone except for Sample 364-13-1, 40-41 cm, that is referred to the lower Maestrichtian *Arkhangelskiella cymbiformis* Zone based on the absence of *Tetralithus trifidus*.

Cores 15 to 16 (463.5-511 m) yield assemblages including *Broinsonia parca* and *Eiffellithus eximius* typical of the Campanian *Eiffellithus eximius* Zone.

Cores 17 through 23, Section 1-3 (530-648 m) recovered assemblages of the *Marthasterites furcatus* Zone which is considered to be of Coniacian/Santonian age. Based on the absence of *M. furcatus,* Section 4, 7-8 cm of Core 23 is assigned to the lower Coniacian-upper Turonian *Micula staurophora* Zone.

In the interval represented by Cores 24 to 33 (672.5-853 m), assemblages occur typical of the upper Albian *Eiffellithus turriseiffeli* Zone. If the Cenomanian marker *Lithraphidites alatus* is absent for ecological reasons, Cenomanian could be present in the upper part of this interval.

Nannofossils are poor to moderately preserved; overgrowth and fragmentation have affected some assemblages.

Cores 34 to 41 (Section 2, 139-141 cm) (872-1007 m) contain coccoliths of the lower to middle Albian *Prediscosphaera cretacea* Zone. The lower part of Core 41 (Sections 3-6 and core catcher) and Core 42 (1007-1033.5 m) yield only poorly preserved assemblages of the Aptian to Albian *Parhabdolithus angustus* Zone. The presence of *Hayesites albiensis* suggests a still lower Albian age.

Core 43 (1033.5-1043 m) is barren of calcareous nannofossils.

Radiolarians

The core catcher of Core 6, which contains no foraminifers or calcareous nannoplankton, has a radiolarian fauna that includes *Artophormis gracilis* and *Lithocyclia crux*. It is assigned to the middle Oligocene *Theocyrtis tuberosa* Zone.

Cretaceous radiolarians that occur in Cores 23 to 27 and in 35 are mostly poor in number and preservation. Consequently, index forms are very scarce. *Dictyomitra rotundata* in Cores 25 and 26 is considered Cenomanian to upper Albian. *Acaemiotyle umbilicata* which occurs in the same cores but indicates lower Albian to upper Aptian we regard as reworked.

Ammonites

The following six ammonite taxa occur in the Albian of Site 364:

Puzosia quenstedti Samples 29-2, 26-29 cm, upper Albian, see Figure 11.

Cainoceras n.sp. ex aff. *liberum* Sample 32-3, 60-64 cm, upper Albian)

Cainoceras aff. *angustidorsatum* (Section 37-1, top, upper-middle Albian)

Mortoniceratidae gen. et sp. indet. (bottom of Section 37-2) upper to middle Albian)

Neokentroceras ? sp. (bottom of Section 37-2, upper to middle Albian)

Hamites tenuis (bottom of Section 37-2, upper to middle Albian)

Of the four levels within which these ammonites were recovered, two indicate upper Albian, and two upper to middle Albian ages. These levels include several trachyostraceous and one heteromorphic species, placing them in an inner shelf to epicontinental environment, rather than a bathyal one. This interpretation finds support in sedimentological observations and by the presence of *Placunopsis* (Plate 2, Figure 4 of Wiedmann and Neugebauer, supplementary volume). Based on ammonites, the lower Albian is regarded as the oldest marine sediment exposed in Angola. Ammonites of this age however, were not found in the deeper cores of Site 364. Their absence there may have resulted from ecological factors or they may be so rare that none were seen in the core material available.

Inocerami

Flattened molds of two specimens of *Inoceramus* sp. cf. *Inoceramus anglicus* occur in Sample 39-5, 86-89 cm (Figure 12) and are described and illustrated by Matsumoto (this volume).

Palynomorphs

Of the 19 Cretaceous samples processed between Cores 21 and 45, all yielded frequent spores and pollen and rare dinoflagellates. Most of them come from sapropels but some also are in marly shales. Ephedroid and gymnospermous (*Classopollis*) pollen dominate in Cores 27-44, while most of the flora in Cores 23-25 consists of poorly ornamented tricolpate pollen with secondary abundance of *Ephedripites, Cretaceiporites,* and *Hexaporollenites*. Little attention has so far been paid to dinoflagellates in West Africa and eastern South America. Their occurrence at Site 364 together with pollen and spores offers a good opportunity to compare ages and ranges. Several dinoflagellate species which were previously recorded and dated elsewhere occur. They include *Hystrichosphaeridium arundum* from the Albian of Europe and "*Dioxya*" *villosa* from the middle and upper Albian of Australia.

General Remarks, Site 365

Site 365, located on the marginal escarpment of the Angola Basin some 20 miles southwest of Site 364, was chosen to obtain a complementary section to Site 364; it was expected to bypass the upper part of the section at that site and reach the elusive halite layer. However, these objectives were not met and the hole terminated in upper Tertiary sediments. In all, 687 meters of Recent to upper Tertiary sediments were penetrated and seven cores taken from 225 meters down at widely spaced intervals.

Sections 1-5 of Core 1 (225-234.5 m) contain abundant Recent to Pleistocene planktonic foraminifers. Only the lower part of Section 6 and the core catcher carry older (Upper Cretaceous) microfossils. These include benthic foraminifers and calcareous nannoplankton, with *Marthasterites furcatus* dating the sediments as Santonian to Coniacian in age. It is evident that the Recent to Pleistocene part of the core must come from the very top of the section. The Cretaceous fossils of the lower part of Core 1 either are part of a slump mass of that age or are reworked in the Tertiary. This is proven by the presence of upper Tertiary microfossils in Cores 4-7.

Core 2 (320-329.5 m) and Core 3 (396-405.5 m) are closely comparable with the lower part of Core 1 in that Cretaceous benthic foraminifers and calcareous nannoplankton of varying ages are abundant. Rare planktonic foraminifers are also present, but only in the core catcher of Core 3 are there numerous *Hedbergella* and *Praeglobotruncana* species. A single specimen of *Rotalipora apenninica* found with this fauna indicates the presence of Cenomanian in the Angola Basin (it was not recovered at Site 364).

The basal part of Core 1, and Cores 2 and 3 consist largely of dark brown to black partly sapropelic clay and mudstones. Cores 4-7 (462.5-472 m, 510-519.5 m, 614-624 m, and 681-687 m) consist of greenish gray mudstones with scattered fine sandy layers. These cores are quite different lithologically from those above and are also characterized by frequent small white specks which are primitive arenaceous foraminifers, mainly tubular *Bathysiphon* specimens. This interval contains no Cretaceous calcareous foraminifers or calcareous nannoplankton. Of special interest here are the fairly abundant but pyritized radiolarians in Sample 7-1,

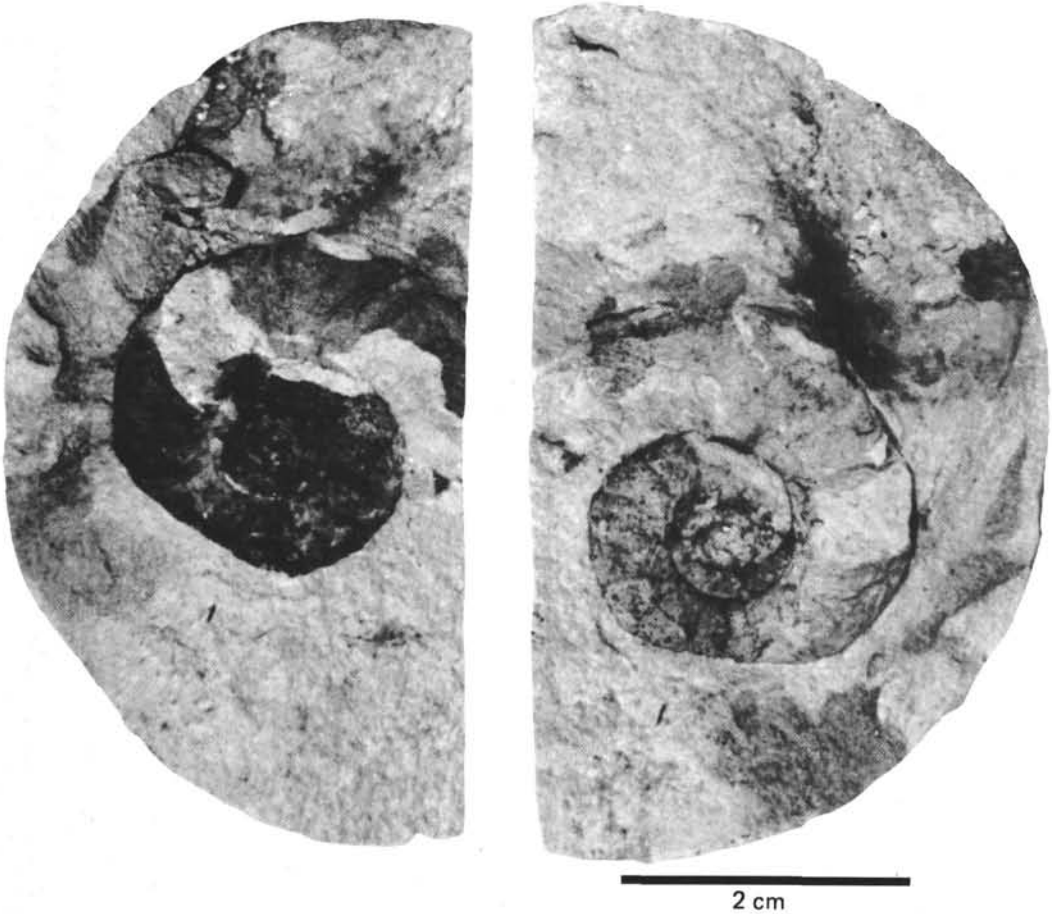

Figure 11. *The ammonite Puzosia cuenstedti, Site 364, Sample 29-2, 26-29 cm, upper Albian.*

32-35 cm which are assigned to the middle Oligocene *Theocyrtis tuberosa* Zone, the same age as found for the radiolarians in the core catcher of Core 6, Site 364. Pollen, spores, and dinoflagellates which occur in Cores 4 to 7 give a still younger age, in the upper Tertiary, possibly upper Miocene. Ichthyoliths in Cores 4-7 suggest a lower Miocene to upper Oligocene age and diatoms in Core 7 an age not older than Tertiary.

The radiolarians, diatoms, palynomorphs, and ichthyoliths in Cores 4 to 7 are thus critical in defining the age of the sediments in the lower part of the section (462.5-487 m) as upper Tertiary. This proves that the Cretaceous microfossils encountered in Cores 1-3 are either reworked in the upper Tertiary, or are part of masses of Cretaceous sediments slumped from the nearby escarpment into upper Tertiary sediments.

Biostratigraphy, Site 365

The general planktonic foraminiferal and calcareous nannoplankton zonation and correlation scheme for Site 365 is given in Table 9. Extremely widely spaced coring, downhole slumping, reworking or slumping within the section, and intervals devoid of diagnostic foraminifers and calcareous nannoplankton, render Site 365 difficult for an accurate biostratigraphic investigation. Despite this, three distinct faunal units can be distinguished:

1) Core 1, Sections 1-5 with a rich Recent to Pleistocene planktonic microfauna.

2) Core 1, Section 6, to Core 3, CC with foraminifers and calcareous nannoplankton of different Cretaceous ages.

3) Cores 4 to 7 with upper Tertiary arenaceous foraminifers, radiolarians, diatoms, palynomorphs, and ichthyoliths.

Faunal unit 2 contains foraminifers and calcareous nannoplankton of different Cretaceous ages. In Core 1, Section 6, and its core catcher, benthic foraminifers indicate a Santonian?- Campanian age, and nannoplankton a Coniacian to Santonian age. Core 2, Section 3, is Albian to Cenomanian on the basis of benthic foraminifers, and probably upper Albian on nannoplankton.

Core 2, CC is again Campanian on the basis of benthic foraminifers, and probably post-Santonian on nannoplankton. Finally, Core 3, CC is Albian to Coniacian on the basis of benthic foraminifers, Cenomanian on planktonic foraminifers, and upper Albian on nannoplankton. Individual samples from Core 1, Section 6, to Core 3 contain quite homogeneous faunas and floras, an indication that we are probably dealing with sediment masses of different Cretaceous ages that slumped into younger Tertiary sediments.

The arenaceous foraminifers in Cores 4-7 are of little stratigraphic significance, except for *Cyclammina* sp. which points to a Tertiary age. The species association is that of a deep water fauna. Of significance is the total absence of any calcareous remains such as foraminifers or nannoplankton, and the presence of quite abundant fish debris including denticles. The absence of calcium carbonate and the amount of fish remains point to a condensation of the sediment

Figure 12. *Inoceramus sp. cf. Inoceramus angelicus, Site 364, Sample 39-5, 86-89 cm.*

TABLE 9
Correlation of Age Determinations in Site 365

DEPTH BELOW SEA FLOOR IN METERS	CORE	AGE BASED ON					
		FORAMINIFERA	NANNOPLANKTON	PALYNOMORPHS	RADIOLARIA	DIATOMS	ICHTHYOLITHS
225 -234,5	1	Recent to Pleistocene ?Campanian-Santonian	Recent to Pleistocene Santonian - Coniac.			Recent to Pleistocene	
320 -329,5	2	Cenomanian-Albian Campanian	probably Upper Albian probably post Santonian				
396 -405,5	3	Cenomanian-U.Albian	Upper Albian	Upper Cretaceous			
462,5-472	4	arenaceous facies fauna to Tertiary aspect		Upper Tertiary (probably Upper Miocene)			Miocene to Oligocene
510 -519,5	5						
614,5-624	6						
681 -687	7				Middle Oligocene	Tertiary	

through CaCO₃ dissolution. No sediments directly comparable with those of Cores 4 to 7 were cored at nearby Site 364. The most similar sediments at Site 364, and on the basis of radiolarians, most age-equivalent, are those of Core 6 which are also non-calcareous, and contain abundant radiolarians and some fish debris.

Paleontology, Site 365

Because of their erratic and restricted occurrence and the particular conditions of the section as pointed out above, foraminifers and calcareous nannoplankton were not treated in the same detailed way as in the other Leg 40 sites, and no distribution charts are presented. Occurrences and ages of the more important planktonic and benthic foraminifers are therefore listed here. The following faunal and floral groups of Site 365 are treated in special contributions in this volume (* = in supplement volume):

Tertiary radiolarians (Pisias and Moore)
Opal phytoplankton (Schrader)*
Late Tertiary palynomorphs (Partridge)
Ichthyoliths (Doyle, Dunsworth, and Riedel)*

Planktonic Foraminifera

The rich Recent to Pleistocene planktonic foraminiferal fauna of Core 1, Sections 1-5, consists of abundant *Globorotalia menardii menardii, G. menardii cultrata, Globigerinoides trilobus* s.l., *G. ruber* (with many red colored specimens), and *Orbulina universa*. Also present are *Globorotalia truncatulinoides truncatulinoides, G. tumida tumida, G. dutertrei, Pulleniatina obliquiloculata*, and others. The only other planktonic fauna of significance is that of Cenomanian age in the core catcher of Core 3. In addition to a single specimen of *Rotalipora apenninica,* it consists of *Hedbergella delrioensis, H. portsdownensis, H. costellata, Clavihedbergella simplicissima, Praeglobotruncana delrioensis, P. stephani, P. stephani gibba*, and *Rotalipora praebalernaensis*.

Benthic foraminifers

Rare benthic foraminifers occur with the abundant planktonic forms in Core 1, Sections 1-5. The following are the more important Cretaceous benthic species from Core 1, Section 6 to Core 3, core catcher (kindly determined by J. P. Beckmann):

Sample 1-6, 82-84 cm: *Bathysiphon* sp., *Recurvoides* sp., *Glomospira* sp., *Trochammina* sp. The preservation of these specimens is similar to that found in the arenaceous forms of Cores 4-7, which are upper Tertiary.

Sample 1-6, 127-129 cm: *Bathysiphon* sp., *Spiroplectammina dentata* (Alth), *Gyroidina* cf. *rumoiensis* Takayanagy, *Gyroidina* sp., *Conorbina* cf. *marginata* Brotzen, *Osangularia* sp., Age: Santonian to ?Campanian, fauna possibly heterogeneous.

Sample 1, CC (gray sediment): *Clavulina gabonica* Le Calvez, de Klasz, and Brun, *Gyroidina* cf. *grahami* (Martin), *Conorbina* cf. *marginata* Brotzen, *Gavelinella* sp. (*? costata* Brotzen), ?*Osangularia* sp. Age: About Santonian to Campanian.

Sample 1, CC (red sediment): *Clavulina gabonica, Tritaxia* cf. *insignis* (Plummer), *Dorothia* cf. *oxycona* (Reuss), *Spiroplectammina dentata, Aragonia ouezzanensis* (Rey), *Vaginulinopsis* sp., *Conorbina* cf. *marginata, Globorotalites conicus* (Carsey), *Gavelinella* sp. aff. *daini* (Schijfsma), *Gyroidina* cf. *grahami, Gyroidina* cf. *rumoiensis*. Age: About Santonian to Campanian.

Sample 2-3, 41-43 cm: *Clavulina* cf. *gabonica, Gyroidina* sp. (high globular), *Gyroidina* sp., *Dorothia oxycona, Gavelinella* sp., *Textularia* sp. Age: Albian to Cenomanian (fauna similar to that of the Cenomanian Gautier Formation of Trinidad, West Indies).

Sample 2-3, 60-62 cm: ?*Plectina* sp., *Textularia* sp., *Gyroidina mauretanica*. Age: Albian to Cenomanian.

Sample 2, CC: *Dorothia trochoides* (Marsson), *Clavulina* cf. *gabonica, Spiroplectammina dentata, Lenticulina* sp., *Conorbina* cf. *marginata,* ?*Nuttallinella* sp., *Reussella szajnochae* (Grzbovsky). Age: approximately Campanian.

Sample 3, CC: ?*Gavelinella* sp., *Gyroidina mauretanica* Charbonnier, *Clavulina gabonica* Le Calvez, de Klasz, and Brun, ?*Tritaxia* sp., ?*Trochammina* sp., ?Gaudryina sp., ?*Ellipsoglandulina* sp., *Textularia* or *Spiroplectammina* sp., *Lenticulina* spp. Age: Albian to Coniacian.

The foraminiferal fauna of Cores 4-7 consists of primitive arenaceous forms with Rhizammininae, and with tubular forms of *Bathysiphon* type dominant. *Glomospira* sp., *Trochammina* sp., and very rare *Cyclammina* sp. also occur. The *Glomospira* specimens are as usual composed of very fine material, have a shiny surface, and are well preserved. The walls of the other genera are made of fine quartz grains, giving the tests a whitish, sugary appearance. Specimens are very delicate and break up easily during preparation, in particular after drying of the sediment. This is especially true for the *Trochammina* and *Cyclammina* specimens. The tubes of the Rhizammininae often show up as small white specks on the surface of the dark greenish gray sediment.

Calcareous Nannoplankton

Sections 1-5 of Core 1 (225-234.5 m) contain Quaternary coccoliths. This interval entered the core barrel near the mud line and was carried down to the coring depth. Only parts of Section 6 and the core catcher represent the sediments in situ. There they are characterized by moderately to poorly preserved nannofloras with *Marthasterites furcatus* suggesting a Santonian to Coniacian age.

Core 2 contains assemblages of probably upper Albian in Section 3, while the core catcher seems to be younger, probably post-Santonian, based on the presence of *Micula staurophora* and the absence of the solution-resistant *Lithastrinus floralis*.

Sections 1-3 of Core 3 are barren of calcareous nannofossils, but two core-catcher samples examined from this core contain nannofossils. The two are of different lithologies. The light colored one contains abundant, moderately preserved nannofloras of upper Albian age. The dark one has abundant coccolith fragments which suggest strong dissolution effects.

Core 4 does not contain coccoliths except for some very rare *Watznaueria*. But small fragments are abundant in the catcher of this core. Cores 5 to 7 are totally barren of calcareous nannofossils.

Radiolarians

Of great importance for the dating of the lower part of the section (Cores 4-7) is a pyritized radiolarian fauna in Sample 7-1, 32-35 cm. The fauna includes *Artophormis gracilis, Lithocyclia angustum, L. crux*, and *Dorcadospyris* spp. from which it is assigned to the middle Oligocene *Theocyrtis tuberosa* Zone. Though the zonal marker is absent, the zone is determined by the presence of *Lithocyclia angustum* and *L. crux*.

Opal Phytoplankton

A well-preserved Recent to Pleistocene tropical diatom assemblage with *Pseudoeunotia doliolus* and *Thalassiosira oestrupida* occurs in Core 1-1, 79-80 cm. The samples investigated from Cores 2 to 6 contain no opal phytoplankton. Samples 7-1, 24-25 cm and 7-2, 37-38 cm contain poorly preserved *Stephanopyxis* aff. *turris*, *Coscinodiscus* aff. *divisus*, and *Coscinodiscus* aff. *marginatus*. Their age is tentatively assumed to be not older than Tertiary.

Palynomorphs

Samples from Cores 3-7 were investigated for dinoflagellates, acritarchs, spores, and pollen. Core 3 contains an Upper Cretaceous flora whose age agrees with that of the foraminifers and calcareous nannoplankton. The assemblage of Cores 4 to 7 is interpreted as having a general upper Tertiary age, probably upper Miocene. The lower age limit of this Neogene flora is determined by the common occurrence in all samples of the family Compositae. The most abundant species is *Tubulifloridites* sp., a form similar to the Recent genera *Mutisia* L. and *Echinops* L. Other Compositae present but not as abundant are *Tubulifloridites antipodica* and *Fenestrites spinosus. Acaciapollenites myriosporites, Polyadopollenites* sp., *Echiperiporites estelae, Chenopodipollis* sp., *Marginipollis concinnus*, and *Monoporites* sp. are other pollen that favor a young Tertiary age.

Ichthyoliths

Fish debris is quite abundant in Cores 4-7, where 26 subtypes of ichthyoliths have been distinguished (Doyle et al., supplement volume). From previous reports, most of these are known to occur in the Oligocene/Miocene, with several of the subtypes present in Cores 4 to 7 known only from this interval. The ichthyoliths thus confirm the Oligocene to Miocene age of these cores as determined by radiolarians and palynomorphs.

SEDIMENTATION AND ACCUMULATION RATES, SITES 364 AND 365

Procedures for deriving sedimentation and accumulation rates curves are described in Chapter 2 (this volume). Figure 13 presents plots of age versus depth; $CaCO_3$ versus depth; the per cent of sand, silt, and clay versus depth; and derived sedimentation and accumulation rate curves versus depth for Site 364. No such curves are presented for Site 365 which was too sparsely cored for the exercise to be meaningful. Again, uniform sedimentation rates are assumed between zonal boundaries and are interpolated at 1-m.y. intervals. Again this results in artificially "stepped" accumulation rate curves for the Cretaceous, where zonal boundaries are far apart chronologically.

The mean sedimentation rate at Site 364 has been 9.49 m/m.y., lower only than Site 363 of all the Leg 40 sites. Notwithstanding a long Eocene to Miocene hiatus in the section, sedimentation rates have been nearly this low or lower since the late Albian. Only in the deposition of Unit 6 (18.8 m/m.y.) and Unit 7 (42.3 m/m.y.) have sedimentation rates been higher.

Because of the long Tertiary hiatus, possibly caused by single erosional events, and represented in profiler records by an angular unconformity, there is no way of knowing whether carbonate accumulation rate maxima occurred in the Miocene as they did at Sites 360, 362, and 363. There was a jump in carbonate accumulation in the early Eocene, however, which may represent part of the same broad Eocene maximum that occurred at Sites 360, 361, 362, and 363. Two generalized Cretaceous maxima occur, one just above the evaporites in the Unit 7 dolomites, the other straddling a sequence of black shales alternating with dolomitic limestones (Unit 5) and brown shales with limestones (Unit 4). A probable disconformity occurs in Unit 5 where the Cenomanian and Turonian are missing. Part of this interval could be present, however, if the Cenomanian marker fossil *Lithraphidites alatus* were absent for ecological reasons.

CORRELATION OF REFLECTION PROFILE WITH DRILLING RESULTS

Site 364

Six acoustic units are recognized on the *Charcot* reflection profile on which Site 364 has been projected (see Figure 14 and Table 10).

The base of Acoustic Unit I (Reflector *Davy* of Emery et al., 1975) occurs in Core 7 and marks a transition in the Eocene from low-carbonate muds of Lithologic Unit 3 to high-carbonate oozes and chalks of Lithologic Unit 4 (see Figure 15). At Site 361 in the Cape Basin, Reflector *Davy* is Paleocene in age and corresponds with a laterally extensive marly chalk horizon.

The base of Acoustic Unit II (Reflector *AII* of Emery et al., 1975) occurs between Cores 19 and 20 and marks the top of a sapropel sequence corresponding to Lithologic Unit 5, which is Campanian-Santonian in age. At Site 361, Reflector *AII* is Aptian in age, and also corresponds with the top of a sapropelic unit. The two major reflecting horizons

TABLE 10
Interval Velocities for Acoustic Units of Site 364

Acoustic Unit	Time to Base[a] (sec)	Depth to Base (m)	Velocity (km/sec)
I	0.29	250	1.72
II	0.62	580	2.00
III	0.73	710	2.36
IV	0.925	1025	3.23
V	≈ 2.4	>4100	4.0

[a] Times measured on *Glomar Challenger* seismic profile at the drill site.

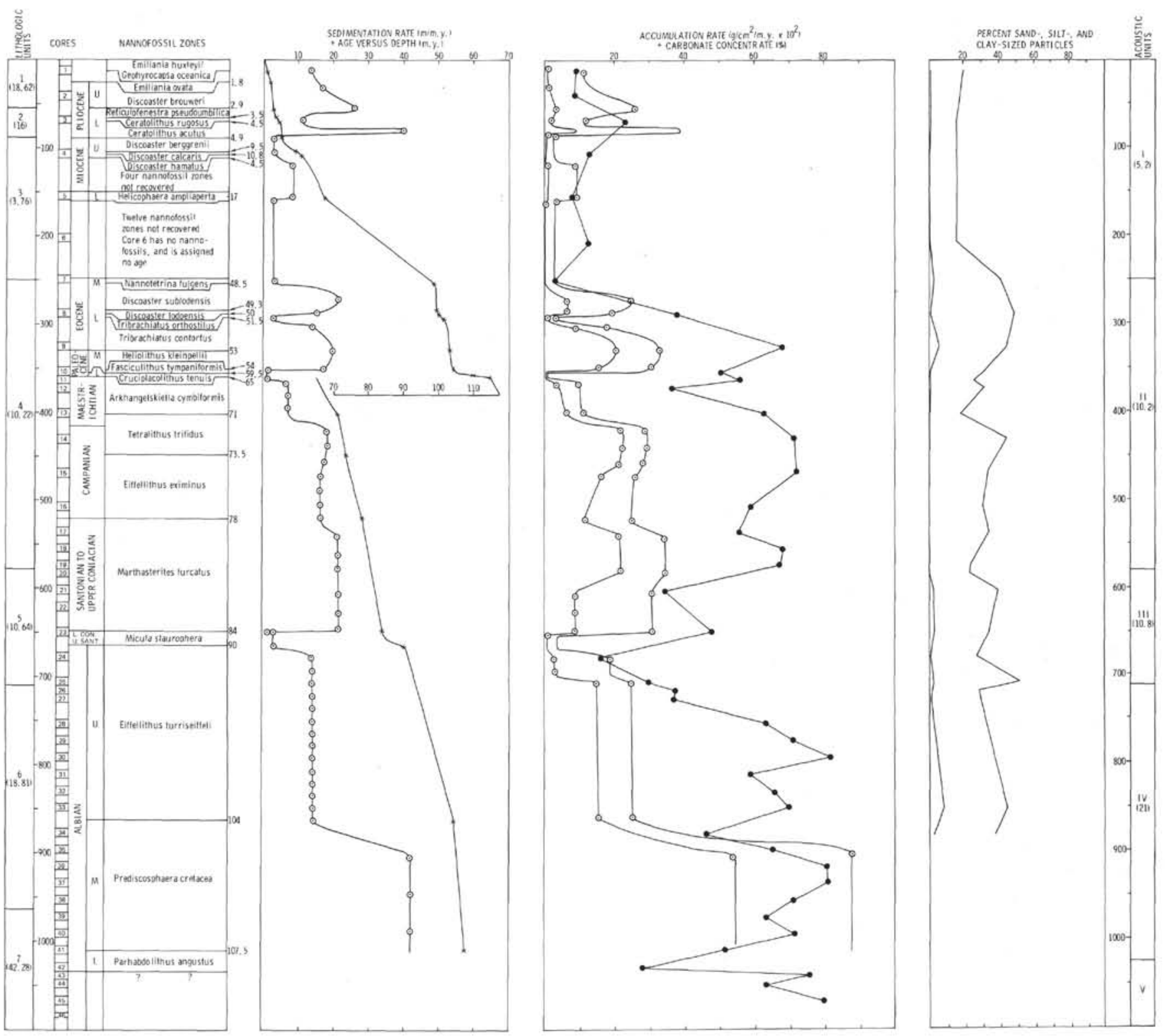

Figure 13. *Biostratigraphic zonation, sedimentation rates, accumulation rates, and the proportion of sand to silt and clay at Site 364.*

of Emery et al. (1975) thus have different ages in the Cape and Angola basins, although the cause of the reflectors is much the same in both basins.

The base of Acoustic Unit III occurs between Cores 25 and 26 and marks the base of the above-mentioned sapropel sequence.

The base of Acoustic Unit IV corresponds to the top of a dolomitic unit in Core 42 at which level a major drilling break was recorded. Apparently, the top of the salt layer is only tens of meters below this dolomitic facies in which the drilling was halted at 1085 meters.

The base of Acoustic Unit V corresponds to the base of the massive salt layer and the top of the acoustic basement.

Acoustic Unit VI is the acoustic basement which occurs at this site coincident with magnetic anomaly M-4 of Aptian age.

Site 365

No correlations are made to seismic reflectors at Site 365 because the cores were so widely spaced.

SUMMARY AND CONCLUSIONS

Site 364 is located in the Angola Basin atop a plateau some 10 km to the east of an abrupt escarpment that marks the presumed outer limit of a massive layer of salt and evaporites along the continental margin of southwest Af-

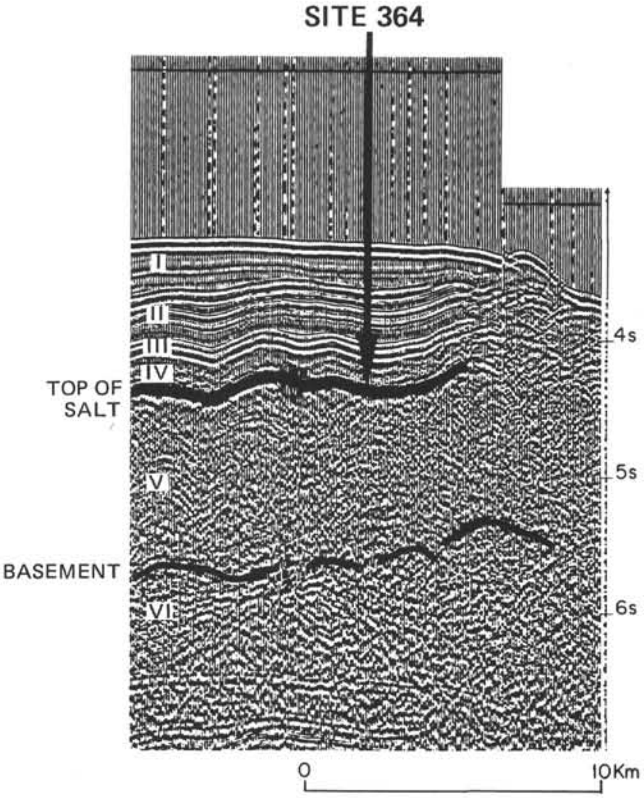

Figure 14. *Correlation of acoustic units and reflecting horizons of the* Jean Charcot *profile Walda 21 of Figure 2, to the recovered lithologic column.*

rica. The site is 3 km north of *Jean Charcot* profile Walda 21, Record 288, 12 July at 0245 hours, latitude 11°34′S, longitude 11°58′E. It was drilled in 2448 meters of water to a depth of 1086 meters sub-bottom where it had to be abandoned because of bit failure only an estimated few tens of meters above the evaporites. Pore water salinities at this point were over 70 parts per mille. The sediments penetrated a range in age from late Aptian to Pleistocene.

Site 365 was drilled in 3018 meters of water, along the base of the eastern wall of a partly filled submarine canyon some 10 km southwest of Site 364. The site was selected in an attempt to bypass the hard limestones which dulled our bit at Site 364, and reach the evaporite body underlying the surficial kilometer of sediments on the marginal plateau. Site 365 is on *Jean Charcot* profile Walda 21, Record 287, 12 July at 0145 hours, latitude 11°39′S, longitude 11°54′E. It was drilled to a depth of 687 meters sub-bottom where it had to be abandoned to meet the scheduled arrival time in Abidjan, Ivory Coast. Only seven cores were taken at widely spaced intervals. The evaporite body was not reached, although interstitial water salinities were over 120 parts per mille.

We recognize seven lithologic units at Site 364 which record the history of opening of the South Atlantic north of Walvis Ridge, the history of circulation of seawater, the development of microfossil assemblages in the Angola Basin, and the evolution of the Angola Basin marginal plateau since the late Aptian, shortly after cessation of evaporite deposition. The seven cores of Site 365 represent five lithologic units. These bear mainly on the development of a Tertiary erosional episode which cut canyons into the evaporite deposit and which is evidenced by a marked change in style and acoustic signature of sediments observed in profiler records across the flatter parts of the marginal plateau. This episode is seen at Site 364 as a break in sedimentation or an erosional gap in which up to 16 million years accumulation of sediments are missing.

The lower four units at Site 364 range in age from late Aptian(?) to Eocene. The bulk of the sediments at Site 364 (over 700 m) are Cretaceous in age, beginning at about the middle of Unit 4. Within this interval, two of the lithologic units (5 and 7) contain carbonates or marly carbonates interbedded with black, putrid, finely laminated sapropels with up to 15 per cent organic carbon and abundant pyrite. The lowest unit, Unit 7, presumably directly overlies the evaporite sequence, and is late Aptian-early Albian in age. The other sapropelic unit, Unit 5, is Coniacian-Santonian to late Albian in age. Unit 7, but not Unit 5, is characterized by dolomitic limestone and finely laminated, almost varved black shales and marly limestones. Unit 5 black shales are interbedded with burrowed limestones. Unit 6, which lacks sapropels, is mainly late Aptian-early Albian to mid-Albian massive limestone with stylolitic seams and "marble" structure. Units 6 and 7 accumulated at rapid rates of 18.8 and 42.3 m/m.y., respectively.

This Cretaceous sequence is of greatest importance for the history of circulation and continental margin development in the Angola Basin. At the time of our early summary of Leg 40 results (Bolli, Ryan, et al., 1975), we argued that the Angola Basin sapropels reflected a transition from very restricted evaporite conditions of sedimentation to one slightly less restricted, but by no means open, namely euxinic conditions of bottom stagnation and oxygen starvation. But since Site 364 was shallow in the Cretaceous, it is also possible that the carbonaceous sediments were the result of an oxygen minimum (Arthur, 1976; Thiede and van Andel, 1977). In this situation, high productivity would have exhausted the oxygen content of fairly shallow water masses; sediments deposited within these water masses would therefore have been carbonaceous. Oxygenated conditions would have prevailed above and below the oxygen depleted zone, allowing oxidation and eventual solution of most organic carbon before it was deposited in the sediments.

Our work since Leg 40 reaffirms our original contention that the Angola Basin was euxinic. The arguments for this rather than a prolonged oxygen minimum are geological, paleontological, and mineralogical.

1) The results of Site 363 establish that Walvis Ridge has been high standing since the Early Cretaceous. In Chapter 3, we presented arguments that the São Paulo and Frio ridges were once joined but were sundered and separated along an east-west-trending transform fault which left major scarps on opposing sides of the two ridges. When the two ridges were joined, the median trough of the Mid-Atlantic Ridge north of Walvis Ridge was to the north and east of Site 363. Between the site and the trough was the wide, shallow salt plateau now on the Brazilian side of the South Atlantic. Until a passage for water opened along the transform fault, the only way water could get from the Cape Basin into the Angola Basin was over both Walvis Ridge

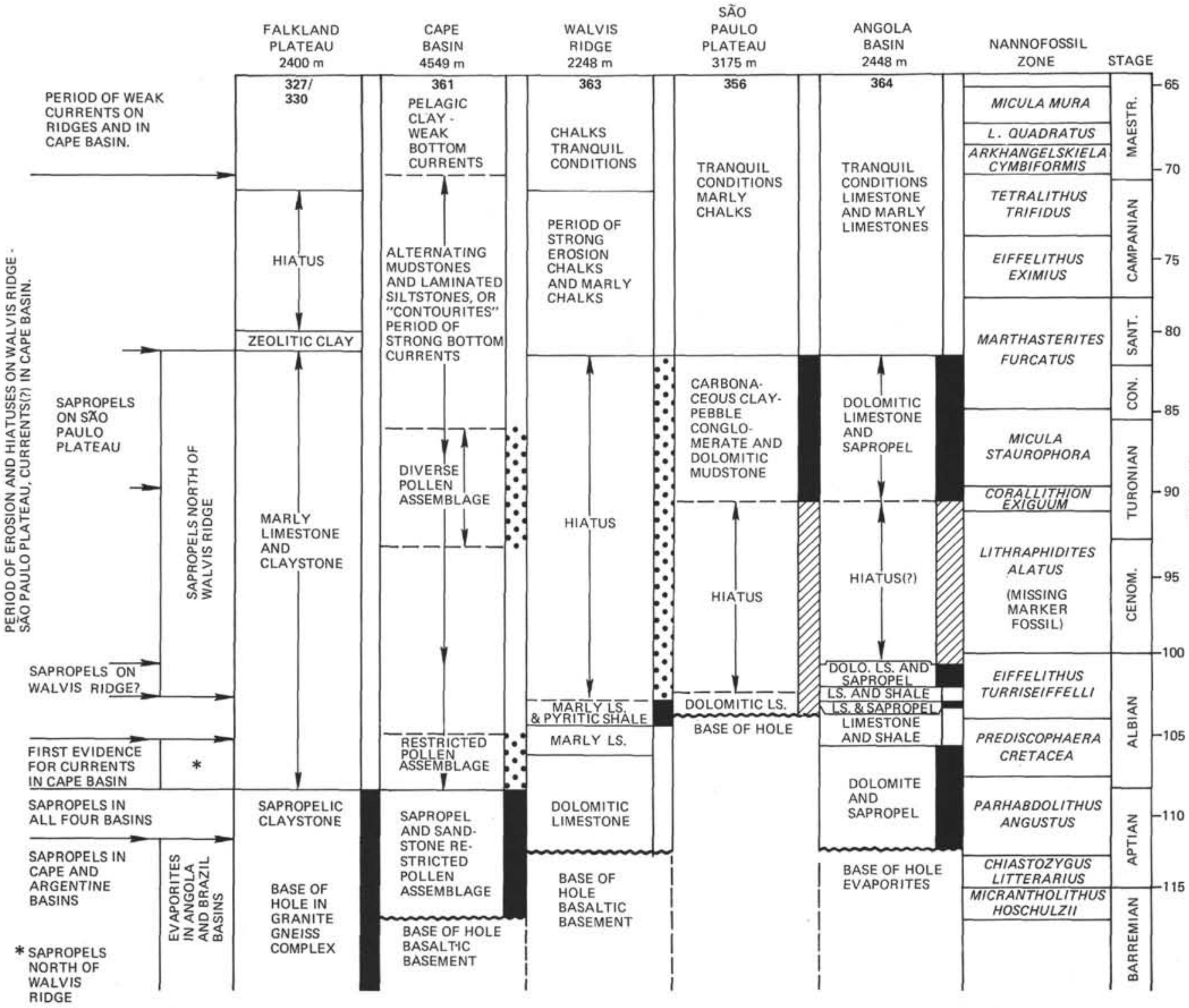

Figure 15. *Correlation of anoxic events at various DSDP sites in the South Atlantic using nannofossil biostratigraphy. Sites 327 and 330 were cored on the Falkland Plateau during Leg 36. Site 356 was cored on the São Paulo Plateau during Leg 39. All other sites were cored on Leg 40. Anoxic intervals indicated by columns in black, hiatuses (during which anoxic intervals were possible) are indicated by cross-hatches, and intervals of possible spillage of anoxic waters over Walvis Ridge into the Cape Basin (resulting in transport of pollen to Site 361) are indicated by dots.*

and the salt plateau. A more isolated segment of an active spreading center, yet one still receiving a supply of ocean water, can hardly be imagined.

2) The oldest sediments at Site 361 are Aptian sapropels deposited in the deepest parts of the Cape Basin at a time when evaporites were accumulating in the Angola Basin. Euxinic conditions developed in the Angola Basin *before* they broke up in the Cape Basin (see Figure 15), and persisted later, well into the Albian. This implies a gradual transition from evaporitic to oxygenated conditions in the Angola Basin, a logical consequence of gradual widening of the South Atlantic consistent with its degree of isolation from the world ocean.

3) Evidence for this isolation is largely paleontological, namely that only Austral-boreal planktonic and benthic foraminifers were deposited in Site 364 sediments until the Late Cretaceous (Caron, this volume; Scheibnerová, this volume). This confirms the results of Premoli-Silva and Boersma (1977) on Cretaceous sediments from Site 356 in the Brazil Basin. No warm-water assemblages worked their way into either the Angola or Brazil basins until the bulge of West Africa was fully separated from the north coast of Brazil, probably in Turonian times.

4) Oxygen minima are usually observed in areas of high productivity, yet Aptian-Albian planktonic foraminifers at Site 364 are dwarf forms, implying restricted conditions for growth in surface waters at that time.

5) Bottom-water conditions during both periods of sapropel deposition were inimical to much bottom life, since burrows and bioturbation are absent in the shales. But whereas burrows are absent even in interbedded dolomites in the first interval of sapropel sedimentation at Site 364, in the second interval they are abundant in the interbedded limestones. The first interval of sapropelic sedimentation was therefore more intensely anoxic, more relentlessly poisonous to bottom life than the second. In the first interval, shaly layers alternate with thin carbonate laminae in a varve-like fashion. The second interval appears to have

been more cyclic, with anoxic conditions alternating with better ventilated conditions. In neither period of anoxic conditions is there evidence for vigorous current activity. The first period of sapropel sedimentation we therefore consider to be one of gradual ventilation of the Angola Basin, the equivalent of the deposition of dolomites and carbonaceous shales above evaporites in the Red Sea at DSDP Sites 225, 227, and 228 (Stoffers and Ross, 1974; Supko et al., 1974). The second period of anoxic sedimentation at Site 364 is more problematic because of its cyclicity. Alternating conditions of density stratification are required. Pliocene and Quaternary sediments in the eastern Mediterranean have a somewhat similar alternation of sapropels and carbonate oozes (Ryan, Hsü, et al., 1973), but apparently the periods of most pronounced stagnation are at least partly related to episodes of heightened supply of light, fresh melt waters from glaciers. We have no comparable source of fresh waters for the Cretaceous South Atlantic. But a Red Sea circulation model could still apply, though perhaps not in the most obvious way. Today, the Red Sea is oxygenated by the very vigor of its thermohaline circulation. Rates of evaporation are so high at its northern end that the dense, saline waters so created sink and literally flush the basin once every 20 years (Siedler, 1969). If we imagine that climatic conditions could fluctuate so that evaporation rates could slow, then either (a) residence times could be increased, allowing oxygen depletion to occur, or (b) surface waters would not be as dense, and would settle to shallower density levels, above stagnant anoxic bottom waters. A Red Sea-type circulation model is thus completely sufficient to explain the sedimentary facies of Site 364.

6) With access of water only from the south, warmer temperature prevailing over the Angola Basin than the Cape Basin (Morgan, this volume), and the presence of a barrier across the Mid-Atlantic Ridge including Walvis Ridge and the São Paulo Plateau, there seems little chance that a cold deep-water mass could have reached the Angola Basin to promote the circulation needed to cause nutrient-rich waters to well up. This would have limited productivity, and thus the potential for an oxygen minimum. Instead a circulation system analogous to paired linked basins separated by high sills (such as the Balearic and Ionian basins in the Mediterranean, or the Mediterranean-Black Sea basins) seems more likely (Natland, this volume; McCoy and Zimmerman, 1977).

7) Sapropelic sediments at Site 364 contain evidence for mineral precipitation or diagenesis in waters of high salinities. These are (a) the authigenic mineral assemblage in the sapropelic shales of kaolinite, illite, and phillipsite (Siesser and Bremner, this volume) requiring elevated Na_{+}/K_{+} (Natland, this volume); and (b) high Na- and Fe-dolomite rhombs in associated dolomitic limestones analogous to Red Sea dolomite (Matsumoto et al., this volume). These dolomite rhombs replace calcite, much of which might have had a chemical rather than biogenic origin since the limestones are poor in calcareous microfossils. The original calcite may have formed in a manner similar to Friedman's (1972) Red Sea deep-water evaporite facies, wherein gypsum reaching the sea floor is degraded by bacteria to calcite and hydrogen sulfide (Natland, this volume).

With these arguments for euxinic conditions in the Cretaceous Angola Basin now stated, we can summarize the interrelationships among the various DSDP sites in the South Atlantic which have reached Aptian and Albian sediments. Some of this has already been presented in the Summary and Conclusions sections of Chapters 2 and 3 of this volume, and other pertinent information and discussion is in Deep Sea Drilling Project Initial Reports Volumes 36 and 39. The pertinent data are presented on Figure 15. We would like to emphasize the following points.

1) Anoxic conditions ceased at Sites 327/330 on the Falkland Plateau and Site 361 in the Cape Basin in the same fossil zone. This implies that anoxic conditions at the two locations were linked (occurred in the same basin). The difference in depths between the two locations suggests that the anoxic water mass was at least 2200 meters deep. Today, Site 361 is anomalously shallow, perhaps because of Paleogene uplift (see Chapter 2, this volume). A more reasonable estimate of the depth of the anoxic water mass is therefore closer to 3000 meters.

2) Dolomitic limestones occur in the late Aptian and Albian of Sites 363, 356, and 364. This is the south-to-north geographic order for these sites in Albian times (Figure 36 of Chapter 3, this volume), and implies that unusually saline water prevailed at all three sites. This is supported by independent mineralogical arguments for Sites 363 (Chapter 3, this volume) and 364 (Matsumoto et al., this volume). Localized (i.e., lagoonal) dolomitization environments for Sites 356 and 363 are thus unlikely, and a more regional highly saline environment (water trapped behind the Walvis-São Paulo Ridge) is consequently favored.

3) Anoxic conditions at Site 364 were effectively continuous from the Aptian to the Coniacian-Santonian. A brief interval in the Albian has no sapropels, but this may merely mean that the site was briefly above the top of an anoxic water mass. The later interval of sapropelic sedimentation was, of course, cyclic, implying episodic stagnation and oxygenation.

4) A marked period of currents over Walvis-São Paulo Ridge and in the Cape Basin followed breakup of anoxic conditions at Sites 327/330 and 361. Much of this current activity could have been generated by spillage of dense, highly saline, periodically anoxic waters over Walvis-São Paulo Ridge from the Angola Basin (Natland, this volume). This may be tied to cyclic flushing of anoxic waters between intervals of sapropel deposition at Site 364. A facies change to a more basaltic provenance occurred at Site 361, apparently the result of currents sweeping fine clays and silts from the vicinity of the Orange River delta, the nearest source of sediments with a major Karroo basalt sourceland (Natland, this volume). In addition, a diverse (more tropical) pollen assemblage was also supplied to Site 361 in the Turonian (MacLachlan and Pieterse, this volume), and this, too, had to come from the north.

5) Both this diverse pollen assemblage and, respectively, possible and certain intervals of carbonaceous sedimentation at Sites 363 and 356 (Walvis-São Paulo Ridge) occurred during the interval of cyclic sapropel sedimentation at Site 364. The Cenomanian-Turonian portion of the section at all three sites may be unrecognizable because the marker nannofossil could be missing for ecological reasons (Proto-Decima et al., this volume). The hiatus at Site 363, though, seems too long to explain in this way. Additional erosion is required. All in all, though, the data allow us to

speculate that anoxic waters in the Angola Basin swept across Walvis-São Paulo Ridge, allowing carbonaceous sediments to be deposited on it, and periodically eroding it or dumping coarse clastic sediments on it (Site 356). Perhaps organic matter was carried all the way to Site 361. The termination of anoxic conditions at Sites 356 and 364 in the same nannofossil zone supports this, and is further evidence against an oxygen minimum explanation for the carbonaceous sediments. By this time in the Late Cretaceous, the two sites were on opposite sides of a South Atlantic ocean basin wider by about 500 km than in the Albian. The conditions that would have promoted an oxygen minimum are hardly likely to have operated for such a length of time and to have ceased simultaneously on both sides of the South Atlantic.

6) With cessation of anoxic conditions north of Walvis-São Paulo Ridge, currents at Sites 361 and 363 persisted through most of the remainder of the Cretaceous. Then tranquil conditions set in at all sites until the Tertiary climatic deterioration and development of Antarctic Bottom Waters began. Were it not for this, the normal condition of the South Atlantic would be one of weak bottom currents and little erosion. This in itself is an argument that the current systems which were so strong in the much more restricted Cretaceous South Atlantic were generated within that basin, that the principal dynamic features of that circulation were thermohaline, driven by a high rate of evaporation over the Angola and Brazil basins. There is no other plausible mechanism for producing vigorous currents in the Cretaceous. The intervals of carbonaceous sedimentation at the various sites are linked to the sedimentary history of the other sites by the vicissitudes of this thermohaline circulation. Only a euxinic model successfully links all the aspects of Cretaceous sedimentation at all the sites represented on Figure 15.

Although the deep evaporite objective was not reached at either Sites 364 or 365, the high pore water salinities are evidence that we must indeed have been very close to salt at both sites. These salinities were not exceptionally high in the upper sapropel-dolomitic limestone sequence nor in the upper part of the deeper one (Sotelo and Gieskes, this volume), hence, it is doubtful that high interstitial water salinities were responsible for the diagenetic formation of the dolomite or the clay-zeolite minerals in the carbonaceous shales. At Site 365, the high interstitial water salinities appear to have resulted from lateral migration of saline pore fluids from the incised walls of the canyon cut through to the salt, into the Tertiary clays filling the canyon.

Thiede and van Andel (1977) propose that migration of the Angola Basin salts occurred between the times of deposition of the two sapropelic units, between about 80 and 90 million years ago during the time of deposition of Unit 6. This salt migration would have been seaward, uplifting carbonates and sapropels atop the evaporites, countering the effects of cooling and subsidence of the oceanic lithosphere, and keeping Site 364 within their proposed oxygen minimum zone of water. Paleontological evidence, however, summarized earlier in this chapter, indicates that Site 364 was at fairly shallow outer shelf or shelf break depths at the time of the first sapropel deposition, i.e., no more than 500 meters deep. Given that Site 364 and the underlying salt are on oceanic crust, which was extruded probably at about 2500 meters water depth, and that this crust may have subsided to 3000 meters by the end of evaporite deposition, then most of the 3 km of salt presently beneath Site 364 must have been there at that time. Some isostatic compensation would have carried the top of the salt a few hundred meters below sea level during the time of deposition of the first carbonaceous sediments.

There is no evidence for disturbance of sediments by the postulated salt migration between 80 and 90 million years ago. Our drilling results confirm interpretations of reflection profile records that sedimentation over the evaporites was essentially flat and conformable from the Aptian until the Paleogene.

We have no evidence bearing on the question whether evaporites beneath Site 364 were deposited either intratidally or in fairly deep water. Correlation of sediment physical properties with reflection records indicates that drilling at Site 364 terminated extremely close to if not actually below the pronounced reflector we presumed to be the top of the evaporites. This hole may have ended in a local depression in the salt not resolvable from the surface. The sediments we recovered in the deepest cores at Site 364 suggest outer-shelf or shelf-break depths, neither shallow enough nor deep enough to argue for or against desiccation of the Angola Basin as a cause of evaporite deposition.

Because of the isolation of the Angola Basin during most of the Cretaceous, and because Site 364 has been on a continental margin salt plateau since that time, it is difficult to derive a meaningful history of the carbonate compensation depth pertinent to the entire Angola Basin. The Tertiary unconformity at Site 364 allows no comparison with possible dissolution cycles found at Sites 360 and 362 in the Miocene.

Understanding the behavior of the CCD in the Cretaceous is complicated by difficulties in evaluating the state of preservation of calcareous microfossils. Limestones associated with carbonaceous shales are extensively dolomitized and, as just discussed, may represent chemical precipitates rather than deposits of calcareous microfossil tests. Both primary and diagenetic features of the limestones might therefore be misinterpreted as representing poor calcareous microfossil preservation, hence, implying extensive calcium carbonate dissolution. During deposition of Units 6 and 4, respectively, after the Aptian-Albian and Coniacian-Santonian sapropel sequences, preservation of calcareous microfossils was better and sediment accumulation rates high. Unit 6 is primarily massive limestone deposited at a rate of 18.8 m/m.y. Unit 7 sediment accumulation rates were higher than this partly because of greater terrigenous input, preservation of all organic carbon, and perhaps the formation of extensive chemical precipitates of calcium carbonate. Both $CaCO_3$ and non-$CaCO_3$ accumulation rates were higher for Unit 7 than Unit 6 (Figures 16 and 17).

Elevation of the CCD at Sites 364 and 365 seems most firmly established for the end of the Cretaceous, where part of the Maestrichtian is missing. $CaCO_3$ accumulation rates were low (Figure 16), and calcareous microfossils are poorly preserved. A less certain hiatus or erosional break may have occurred in the Cenomanian. However, the critical Cenomanian marker fossil *Lithraphidites alatus* may be missing for ecological reasons, and a Cenomanian

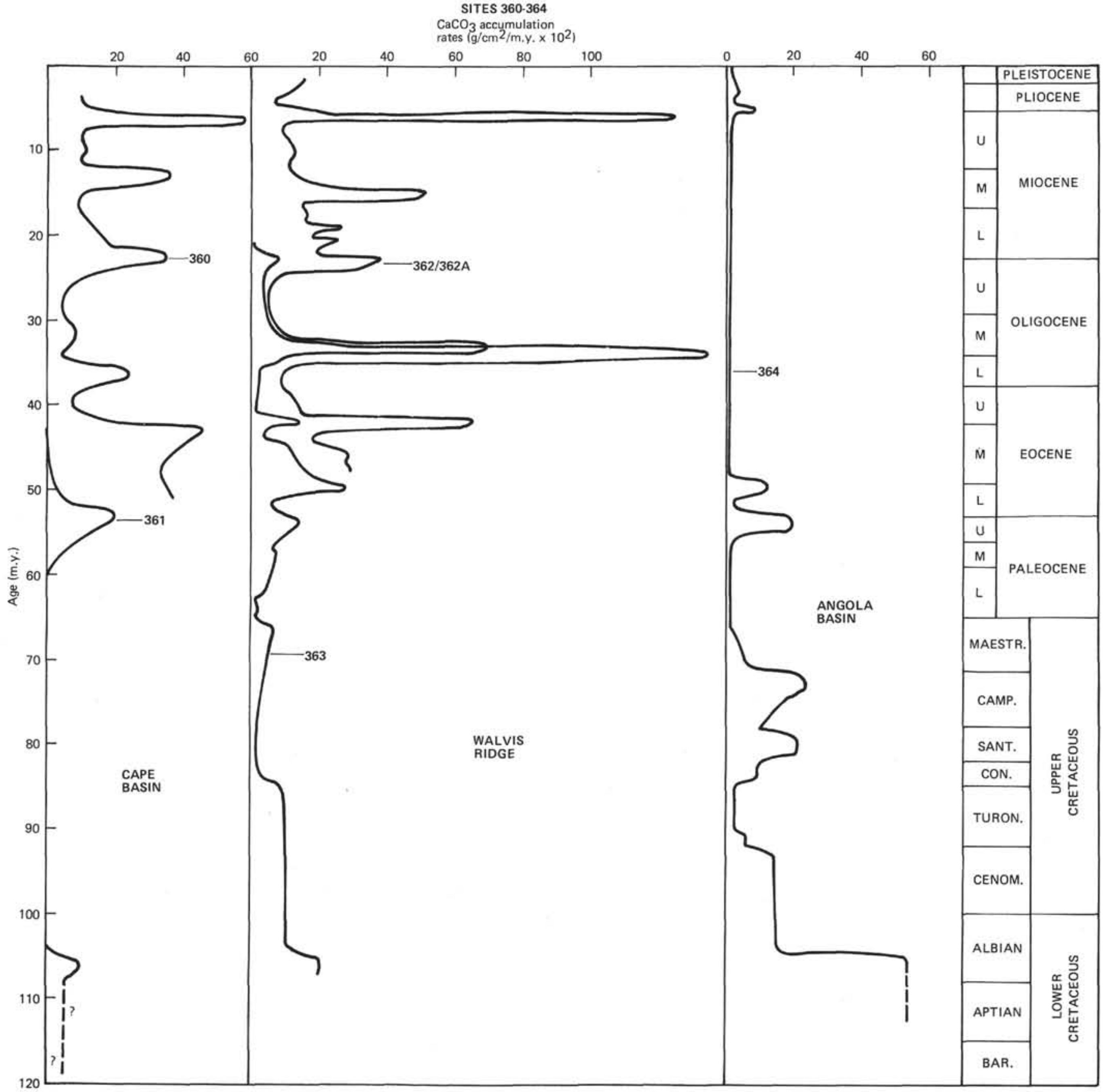

Figure 16. *$CaCO_3$ accumulation rates versus age, Sites 360-364.*

planktonic foraminifer assemblage is present in allochthonous material at Site 365 (Caron, this volume). Palynomorphs of Cenomanian age also occur at Site 364. These tend to suggest little or no break in sedimentation at this time, but are difficult to translate directly into the accumulation rate curves for Site 364 (Figures 16 and 17) because of uncertainties of correlation among fossil groups and between holes.

Evidence for an elevated CCD at the end of the Cretaceous was also present at Site 363 on Walvis Ridge, in the form of enhanced dissolution of calcareous microfossils (Chapter 3, this volume), and at Site 361 in the Cape Basin, which was much deeper than either Sites 363 or 364, where pelagic clays were deposited at this time. These patterns of sedimentation may be related to an apparent worldwide rise in the CCD (Worsley, 1974), and, because all three sites were affected, imply that the South Atlantic had achieved sufficient interchange of waters with the world ocean to be influenced by worldwide, rather than merely local, oceanographic conditions.

Whether the CCD rose in the middle Eocene at Site 364 is obscured somewhat by a number of factors. The Eocene-Miocene gap in sedimentation coincides in time with a change in the pattern of sedimentation on the Angola marginal plateau. Portions of the plateau were eroded, including the submarine canyon where Site 365 was placed. Erosional debris from Africa was more quickly added to the margin as prograded deltas and fan deposits. Dingle (1973) attributes

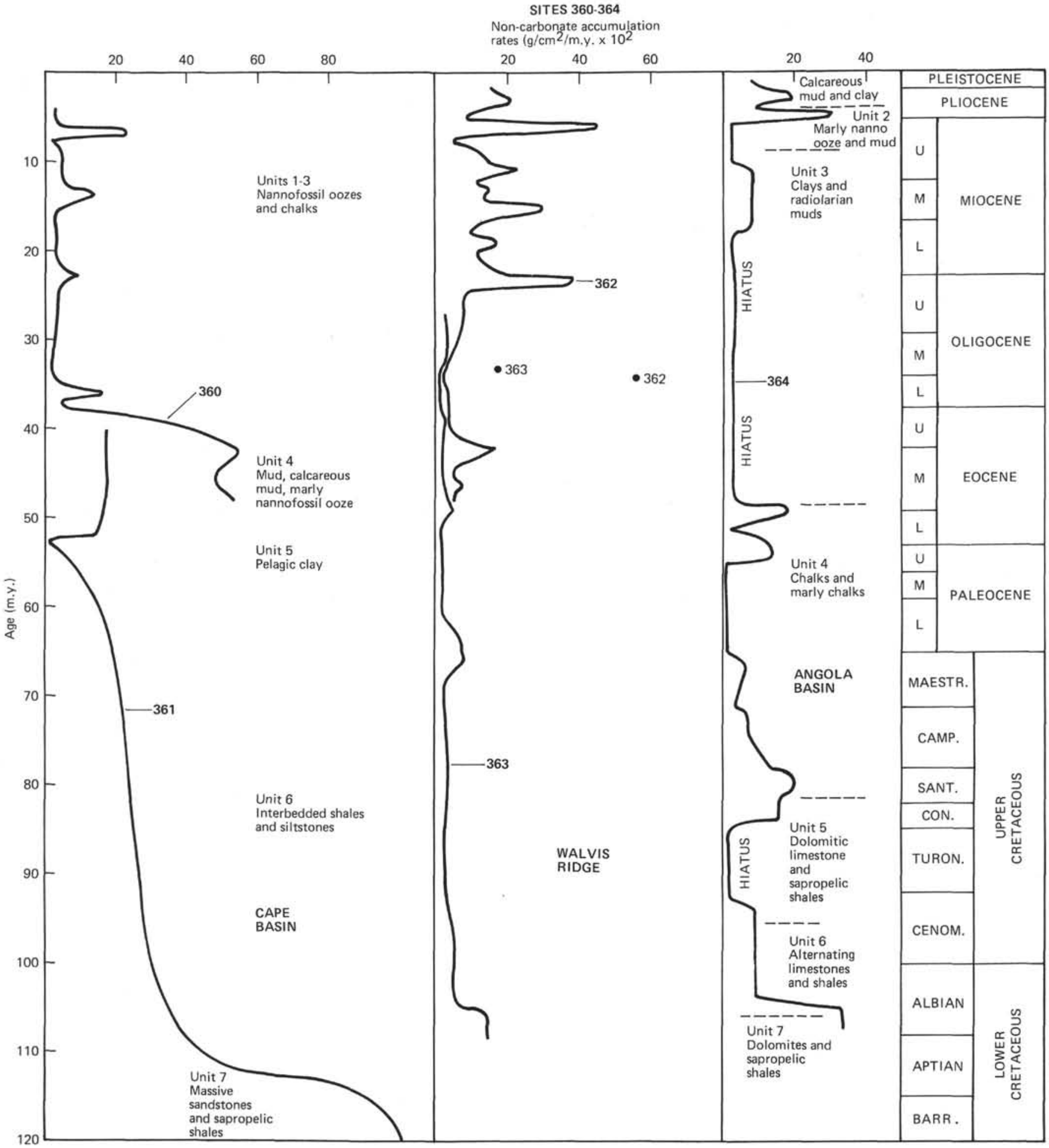

Figure 17. *Non-$CaCO_3$ accumulation rates are primarily terrigenous accumulation rates, and were derived from bulk accumulation rate and $CaCO_3$ accumulation rate curves presented in Chapters 2-4 of this volume.*

similar heightened sediment supply and incision of canyons into the continental margin west of Cape Town to a major late Eocene regression. This regression does not coincide with any known period of epeirogenic uplift of portions of continental Africa (Siesser, this volume). It may be related to development of the Antarctic ice cap.

On the other hand, Miocene elevation of the rift plateaus of East Africa (King, 1971) was instrumental in establishing the Congo River drainage. This was part of the "Post-African" erosional event of King (1967), which created the largest erosion surface in Africa. Terrigenous material from the Congo River may be included in the topmost cores of Site 364. The Eocene-Miocene gap at Site 364 could have resulted from a Miocene erosional event related to this uplift.

A factor which also may have reduced the influx of terrigenous material to Site 364 in the Paleogene and early Neogene could have been the formation of salt diapirs and arches, which could have blocked or diverted the increased supply of terrigenous material from Africa. Nettleton (1934) estimated that salt diapirism requires 600 meters of overburden, a thickness which was reached at Site 364 in the Eocene, and earlier toward land.

The combination of incision of canyons within 10 km of Site 364, epeirogenic movements, and salt diapirism may have triggered creep of near-surface sediments downslope toward the canyons or the shelf break, thus removing all or part of the sediments represented by the 16 million year hiatus. This type of "mass wasting" may be promoted at depths where carbonate dissolution is pronounced (Berger and Johnson, 1976), which was the case at Site 364 at this time. Berger and Johnson discovered that it can also occur in thin flat sheets, such as on the Ontong-Java Plateau, where 50 meters of surface sediments are missing along a 200 km transect of nearly flat-lying carbonates. This would explain the apparent disconformable relationship of sediments above the discontinuity to those below. The physical basis for this type of movement is uncertain, and we have no data bearing on it for Site 364. But this mechanism at least does not force us to hypothesize bottom currents as a mechanism for erosion when we have no other sedimentological evidence for them. And it provides us an explanation for why terrigenous supply to the site was seemingly unusually low at a time of heightened erosion on land, progradation of deltas, cutting of canyons, and building of submarine fans. On the other hand, cutting of canyons may have served to isolate Site 364 from much of its previous terrigenous sediment supply, more simply explaining the very low sediment accumulation rate.

The Eocene regression, though, may have intensified bottom currents by the Oligocene (Siesser, this volume). The final separation of Antarctica from Australia and the formation of the Circum-Antarctic current date from about this time (Kennett et al., 1975). Siesser (this volume) suggests that enough cold water was flowing into the South Atlantic by the Oligocene to initiate the Benguela current, which wells up south of Walvis Ridge, and was apparently responsible for the harshening of arid climatic conditions in southwest Africa (Namibia) and Angola at this time.

The combination of influx of cold corrosive waters into the South Atlantic, and high productivity associated with upwelling may have promoted a local rise in the CCD at Site 362 in the Eocene and again in the Miocene (Melguen, this volume). The latter of these episodes may be related to development of the ice shelves around Antarctica, and hence the initiation of the Antarctic Bottom Current (McCoy and Zimmerman, 1977). But today, little of this cold water reaches the Angola Basin, which consequently has the deepest CCD in the South Atlantic (Connary and Ewing, 1974). It is difficult then, to attribute nondeposition of carbonate at Sites 364 and 365 in the Eocene-Miocene either to a pronounced influx of cold waters, or to heightened productivity associated with upwelling of cold waters, especially when the present current system (i.e., the Benguela) seems to have been established in the Oligocene. Perhaps the answer to this riddle lies toward the other extreme, that productivity was low. With a decreased input of terrigenous material as well (clay deposition at both Sites 364 and 365), the residence time of undissolved calcareous microfossil tests on the sea floor before burial would have been high, allowing extensive dissolution at Site 364, and total dissolution at Site 365, which was about 800 meters deeper. The alternative is that much more cold water entered the Angola Basin in the Eocene to Miocene time period than now. This would require major gaps in the barriers around the Angola Basin, such as Walvis Ridge, first to have opened, then to have served as a passage for cold water, and finally either to have closed, or to have stopped serving as a passage for cold water. We have no evidence for this one way or the other, but one of the deeper gaps in Walvis Ridge near Tristan de Cunha Island is now at a depth of 3800 meters on a basement isochrone which is Paleocene in age, and therefore could have served as a passage for cold water in the Eocene or Miocene.

Comparison of Carbonate and non-Carbonate Accumulation Rates at Sites 360-364

It is useful to consider the various factors controlling continental margin evolution along the western coast of southern Africa in terms of $CaCO_3$ and non-$CaCO_3$ rates of accumulation (expressed in $g/cm^2/yr \times 10^2$). Where Figure 15 summarized evidence for oceanographic conditions at the Leg 40 drill sites, Figures 16 and 17 summarize the biogenous and terrigenous contributions to the sediments along the continental margin since the Cretaceous. Apart from a minor spurt of siliceous sedimentation at Site 362 in the Miocene, productivity has been chiefly calcareous at all sites. The non-carbonate component is almost overwhelmingly terrigenous.

In what follows, it is important to bear in mind the different settings of the various Leg 40 sites with respect to the edge of the continent. Site 361 and Site 364 are both above oceanic crust. Yet because of the thick sequences of evaporites at Site 364, the sediments we cored there have more of the characteristics of continental shelf or platform deposits than would otherwise be expected. Site 361 sediments, though, are massive to distal turbidites, and include deep marine pelagic clays. They are thus more typical of deep marine sediments shed primarily from a continental source. In terms of evaluating productivity or CCD fluctuations, though, all Leg 40 sites may be too close to the edge of the continent to interpret effects in the adjacent basins. Coastal upwelling may have been important, increasing productivity, and thus locally altering the carbonate preservation versus depth relationship. Site 363 may prove to be most instructive in this respect, since it is more distal than either Sites 360 or 362.

The accumulation rate curves (Figures 16 and 17) are highly generalized for the Cretaceous because of poor biostratigraphic control and correlation with absolute ages. Nevertheless, Sites 361, 363, and 364 had initially high non-carbonate accumulation rates in the Aptian and Albian. Site 360, closer to the African coast than any of these sites, had a high terrigenous sediment accumulation rate in the Eocene, which declined rather abruptly. In general, all these declines reflect a diminishing of sourceland relief with time. Increases in non-carbonate sediment accumulation rate at Site 362 since the Oligocene reflect (1) progradation of deltas, such as that of the nearby Orange River, and (2) higher productivity, evidenced by the pulse of siliceous sedimentation in the Miocene, a consequence of the entry of cold Antarctic waters into the South Atlantic. Miocene and post-Miocene uplift in central Africa may also have contributed to this trend, as well as the increase in non-carbonate accumulation rate at Site 364 since the Miocene.

Spikes in the non-carbonate accumulation rates at Sites 360, 362, and 363 in the Tertiary are coincident with spikes in the carbonate accumulation rate. Van Andel et al. (1975) noted a similar effect in equatorial sediments of the Pacific, but there it was not nearly so pronounced. It is perhaps surprising that increases in carbonate accumulation rate are not reflected in more purely calcareous sediments. It is possible that much of the silt and especially mud that reached the sea floor at the Leg 40 sites was carried there by descending biogenous particles such as fecal pellets that directly reflect the rate of carbonate supply. Alternatively, shelf and slope mixing processes might counterbalance heightened carbonate supply by accelerating bulk sediment transport rates, and therefore the mixing rates of terrigenous and carbonate sediments. A somewhat more ad hoc explanation could be that wind patterns and especially rainfall and consequent run-off were accelerated during periods of high productivity and possible coastal upwelling.

In the case of the Oligocene *Braarudosphaera* blooms, however, we apparently are seeing the effects of coring and sampling bias in the heightened terrigenous sediment accumulation rate. The *Braarudosphaera* oozes are much purer carbonate oozes than adjacent beds of more typical foraminifer-nannofossil ooze or chalk. Yet recovery of the *Braarudosphaera* oozes was much lower than their likely abundance at the sites. In addition, both *Braarudosphaera* ooze and foraminifer-nannofossil chalk samples were analyzed for $CaCO_3$. The latter are certainly over-represented in terms of proportion of recovered lithologies because of the necessity to obtain data on contrasting lithologies. Proper weighting of the $CaCO_3$ content through this interval to the proper proportion of *Braarudosphaera* oozes would almost certainly eliminate the spikes in the non-carbonate accumulation rates at Sites 362 and 363 in the Oligocene. This is shown on Figure 17 by indicating the peaks as asterisks, but leaving the non-$CaCO_3$ accumulation rate curve essentially flat through the Oligocene.

Sharp peaks in $CaCO_3$ accumulation rate occur at 6-7 m.y., 13-15 m.y., 22-24 m.y., and 41-43 m.y. at Sites 360 and 362/362A. *Braarudosphaera* blooms occurred 33-35 m.y. ago at Sites 362 and 363 only. A broad Eocene maximum from 44-50 m.y. also occurred at all three sites. The shape of the 362/362A curve is mimicked by the Site 363 curve from 22-50 m.y. ago, but the peaks are not as great. The first three maxima at Sites 360 and 362/362A correspond with maxima found in the equatorial Pacific by Van Andel et al. (1975). One maximum at 36 m.y. occurs at Site 360 but is not present at the other sites nor in the equatorial Pacific. A maximum at 30 m.y. is present in the equatorial Pacific but is not in the South Atlantic. Only a portion of the Eocene maximum occurs at Site 364 and perhaps at Site 361, although that site was in much deeper water than any of the other Leg 40 sites, and was close to the depth of the CCD.

Melguen (this volume) and Noël and Melguen (this volume) have proposed that the CCD was shallow in the middle Miocene and middle Eocene based partly on the poor state of preservation of planktonic foraminifers and nannofossils, respectively, at Sites 360, 362/362A, and 363. They also noted poor microfossil preservation associated with an apparent jump in the CCD at the Cretaceous-Tertiary boundary, considered by Worsley (1974) to be worldwide in extent. On the $CaCO_3$ accumulation rate curves, there are spikes corresponding to the middle Miocene and middle Eocene, but none at the Cretaceous-Tertiary boundary. Rather than a "South Atlantic" jump in the CCD in the Eocene and Miocene, it is possible that the poor preservation of calcareous microfossils resulted from a local elevation of the CCD, near the continent of Africa, perhaps the consequence of high productivity due to upwelling. Increased organic matter in the sediments would produce carbolic acid, and dissolve carbonate microfossil tests (Adelseck, 1977). The high $CaCO_3$ accumulation rate at Site 362 in the late Miocene, for example, resulted in rapid burial of organic carbon, present at levels of 2 to 4 per cent in the cores. It is therefore no surprise that calcareous microfossils in these sediments are poorly preserved. Anaerobic processes have since produced considerable H_2S, which was evident at obnoxious levels when the cores were split.

Two factors argue that the Tertiary $CaCO_3$ accumulation rate spikes reflect productivity rather than a general rise in the CCD. First, the Tertiary "dissolution cycles" have been documented at continental margin sites with a history of Pleistocene upwelling (the Benguela current) which almost certainly occurred in some form during the Tertiary. The "dissolution cycles" cannot be separated from peaks in the $CaCO_3$ accumulation rates, which probably resulted from such upwelling. The contrast with the Cretaceous-Tertiary boundary, where no peak occurs but preservation is still poor, is instructive in this regard. A more positive case for a shallower CCD at any time during the Tertiary would have existed had there been no peaks in $CaCO_3$ accumulation rate during the intervals of poor preservation.

This argument cannot be made, though, without qualification. The most direct evidence for past episodes of upwelling in the geologic record would be pulses in primary productivity. In the Leg 40 sediments, opaline silica, which is not nearly so readily dissolved in the water column as $CaCO_3$, is not sufficiently prevalent to serve as an indicator of productivity. We are left with $CaCO_3$ accumulation rate data only, and are thus open to charges of possible circular reasoning. However, the peaks in $CaCO_3$ accumulation rate coincide with periods of poor calcareous microfossil preservation. The $CaCO_3$ accumulation rate would have been even higher if preservation had been normal. Therefore, the peaks can have been a consequence of high productivity resulting from upwelling.

The second factor favoring the upwelling-productivity argument is that the middle and late Miocene spikes at Sites 360 and 362/362A are not strictly coincident in time. The 36-m.y. pulse at Site 360 also must have a local explanation. These suggest a shifting, sometimes very local, zone of high productivity (perhaps of upwelling) along the continental margin, and are evidence that these pulses are not the result of an ocean-wide rise in the CCD. One could also argue that the reduced peaks at Site 363 compared with Site 362 are a consequence of Site 363 being separated from the brunt of upwelling by Walvis Ridge.

There remains the problem of the coincidence of the South Atlantic peaks in $CaCO_3$ accumulation rates with those of the equatorial Pacific. Upwelling of cold water along the southwestern African coast could have been coincident in time with pulses of cold water through the central Pacific basins. Where the result in the Pacific was to shoal the CCD, the effect in the South Atlantic may have been to promote productivity along continental margin zones of upwelling. A generalized South Atlantic rise in the CCD cannot be inferred from the fact that spikes in the $CaCO_3$ accumulation rates coincide in time with those in the Pacific. In fairness, though, South Atlantic-wide shoalings of the CCD in the Eocene and Miocene cannot be precluded on the available data. This possibility merely cannot be sorted out from theoretically similar effects resulting from heightened productivity. At least one argument favors a kind of peculiar blend of the two possibilities. If the CCD rises through most of the world ocean, and the supply of dissolved carbonate to the sea remains constant, then shallow sites (those still above the CCD) should receive an absolute glut of carbonate sediments, assuming mass balance. The possible link between a shallow Cretaceous CCD and the development of extensive force-reef facies at the same time was pointed out by Ryan and Cita (1977). Here we leave open the possibility that something similar occurred in the Tertiary. Assuming that productivity remains constant, however, preservation should get better at shallow depths in order to maintain a mass balance, and this has not occurred at the Leg 40 sites. Either productivity also had to increase, or there must have been peculiar local effects in the preservation versus depth relationships along the continental margin in the Cape Basin whose causes cannot as yet be evaluated.

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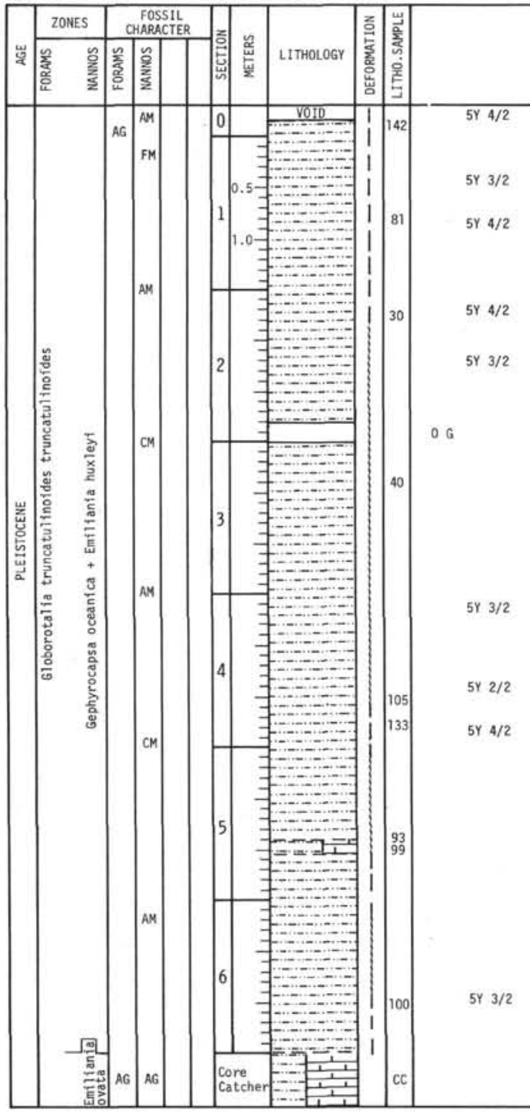
Site 364 Hole Core 1 Cored Interval: 7.5-17.0 m



LITHOLOGIC DESCRIPTION

DARK OLIVE GRAY CALCAREOUS MUD BEARING PLANT DEBRIS

MEGASCOPIC CORE DESCRIPTION
Soft, plastic dark olive gray (5Y 3/2) mud with zones of olive gray (5Y 4/2) and black (5Y 2/2). Faint H_2S odor throughout.

TEXTURE

	1-18	5-99
Sand	0%	3%
Silt	10%	15%
Clay	90%	82%

COMPOSITION (SS)
1-81
60% Clay
20% Nannos
10% Plant debris
5% Forams
4% Pyrite
1% Quartz

5-99
45% Clay
30% Nannos
10% Forams
5% Plant debris
5% Pyrite
3% Quartz

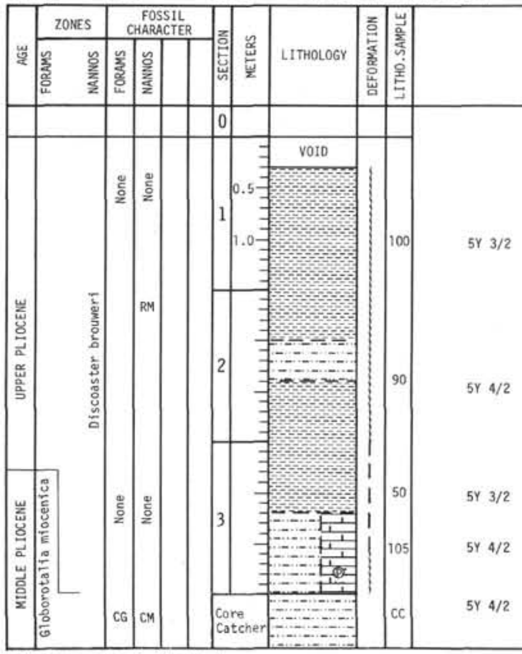
Carbonate Bomb: 1-27 to 28 cm = 11.1% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (3.3, 2.5, 7)
6-20 (3.7, 3.4, 2)

Carbon-Carbonate (OG)
2-130 (3.0, 1.5, 12)
2-150 (3.1, 1.5, 13)

Grain Size (DSDP)
4-96 (1.1, 22.1, 76.8)
6-88 (0.7, 15.3, 84.0)

Site 364 Hole Core 2 Cored Interval: 36.0-45.5 m



LITHOLOGIC DESCRIPTION

BLACK CLAY; MARLY NANNOFOSSIL OOZE; CALCAREOUS MUD.

MEGASCOPIC CORE DESCRIPTION
Moderate to intensely deformed, dark olive gray (5Y 3/2) mud and olive gray (5Y 4/2) mud. Faint H_2S odor. Has abundant plant debris.

TEXTURE

	3-50	CC
Sand	0%	0%
Silt	5%	20%
Clay	95%	80%

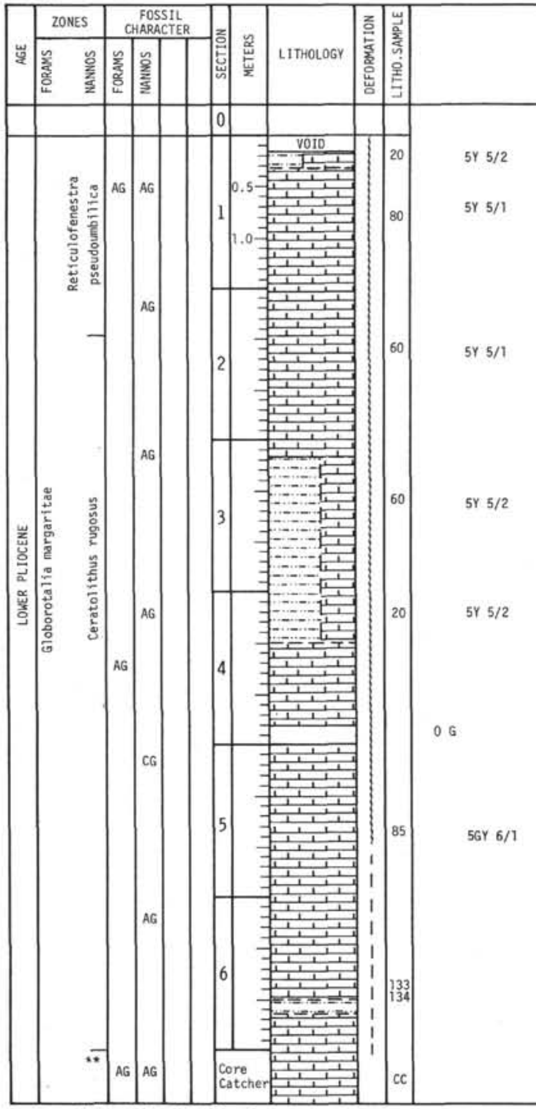
COMPOSITION (SS)
1-100
75% Clay
10% Plant debris
5% Zeolite
5% Carbonate unspecified
2% Quartz
2% Pyrite

3-105
54% Clay
35% Nannos
5% Plant debris
3% Forams
2% Pyrite
1% Quartz

Carbonate Bomb: 1-31 to 32 cm = 8.7% $CaCO_3$

Explanatory notes in Chapter 1

Site 364 Hole Core 3 Cored Interval: 64.5-73.0 m



LITHOLOGIC DESCRIPTION

CALCAREOUS NANNOFOSSIL OOZE AND MARLY NANNOFOSSIL OOZE

MEGASCOPIC CORE DESCRIPTION
Firm mud: most is olive gray (5Y 5/2) and gray (5Y 5/1) mud with some lighter greenish gray (5GY 6/1). Many black streaks and faint greenish streaks stretched vertically by drilling. Black patches appear to be finely disseminated pyrite.

TEXTURE

	2-60	3-60
Sand	0%	0%
Silt	20%	7%
Clay	80%	93%

COMPOSITION (SS)
2-60
55% Nannos
29% Clay
10% Forams

4-20
68% Clay
30% Nannos

Carbonate Bomb: 1-36 to 37 cm = 33.3% $CaCO_3$

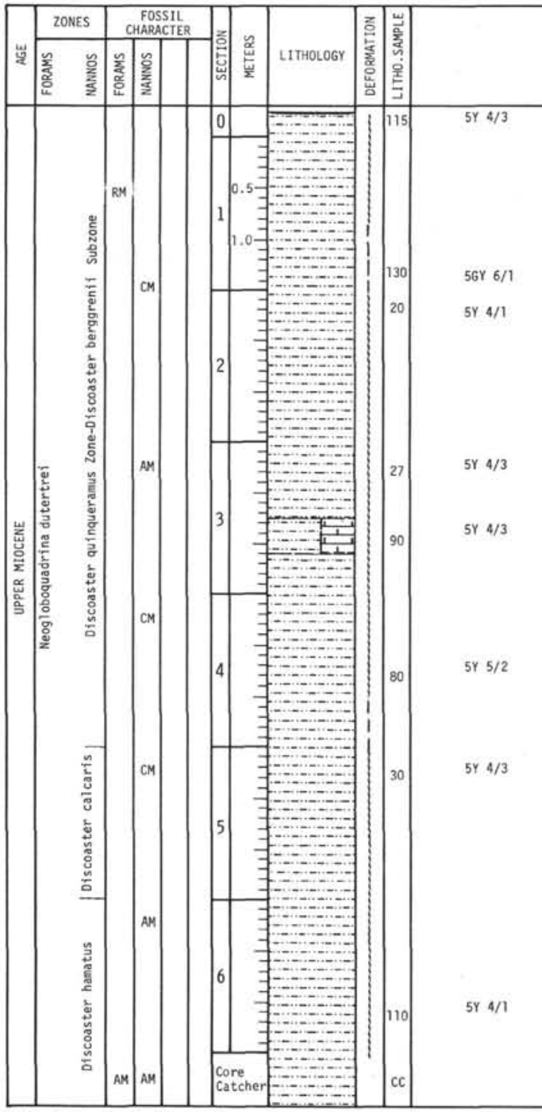
Carbon-Carbonate (DSDP)
4-20 (2.5, 0.4, 17)
6-23 (4.8, 0.2, 38)

Carbon-Carbonate (OG)
4-130 (4.0, 0.4, 30)
4-150 (0.2, 0.1, 0)

Grain Size (DSDP)
4-88 (1.4, 15.3, 83.3)
6-88 (0.4, 14.4, 85.2)

** Amaurolithus tricorniculatus Zone
Ceratolithus acutus Subzone

Site 364 Hole Core 4 Cored Interval: 102.5-112.0 m



LITHOLOGIC DESCRIPTION

ZEOLITE BEARING OLIVE GRAY MUD WITH MINOR CALCAREOUS MUD

MEGASCOPIC CORE DESCRIPTION
Firm mud: highly disturbed with vertical color changes from dark greenish gray (5GY 6/1) and dark gray (5Y 4/1) to olive gray (5Y 5/2) and olive (5Y 4/3). Mottles observed through lower half.

TEXTURE
0- 2% Sand
5-30% Silt
70-95% Clay

COMPOSITION (SS)
60-90% Clay
T-35% Nannos
1- 5% Quartz
T- 5% Zeolite
0- 1% Forams

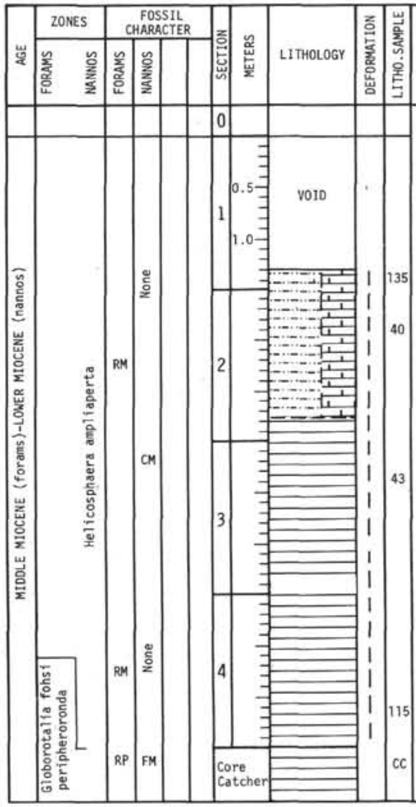
Carbonate Bomb: 1-29 to 30 cm = 7.9% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (2.8, 0.2, 22)
6-20 (1.3, 0.2, 9)

Grain Size (DSDP)
4-88 (0.1, 19.5, 80.4)
6-88 (0.4, 11.9, 87.7)

Explanatory notes in Chapter 1

Site 364 Hole Core 5 Cored Interval: 150.0-159.5 m



LITHOLOGIC DESCRIPTION

PELAGIC CLAY AND MARLY NANNOFOSSIL OOZE

MEGASCOPIC CORE DESCRIPTION
Stiff mud. Mostly yellowish brown (10YR 5/4) with minor gray (5Y 5/1), olive (5Y 5/3) and dark yellowish brown (10YR 4/4). Slightly mottled.

TEXTURE
0% Sand
5-15% Silt
85-95% Clay

COMPOSITION (SS)
35-70% Clay
5-50% Nannos
5-10% Dolomite rhombs
1- 3% Quartz
T- 5% Zeolite

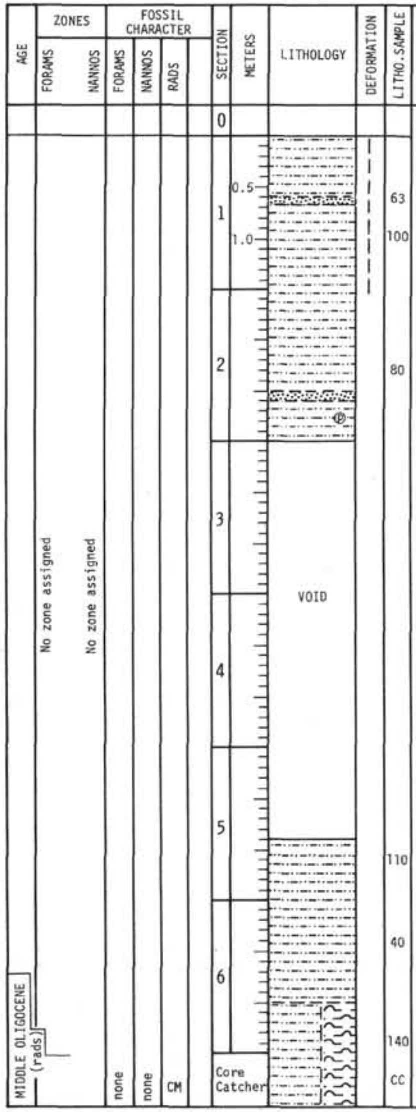
Carbonate Bomb: 2-29 to 30 cm = 30.1% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (0.4, 0.1, 2)

Carbon-Carbonate (OG)
3-130 (0.2, 0.1, 0)
3-150 (0.3, 0.1, 1)

Grain Size (DSDP)
4-88 (0.0, 13.9, 86.0)

Site 364 Hole Core 6 Cored Interval: 197.5-207.0 m



LITHOLOGIC DESCRIPTION

ZEOLITE BEARING GREENISH GRAY MUD AND RADIOLARIAN MUD

MEGASCOPIC CORE DESCRIPTION
Stiff mud: greenish gray (5GY 5/1) with light greenish gray (5GY 6/1). Subtle color changes too slight to give different names. Slightly mottled throughout. Note sandy layers with 70% Quartz.

TEXTURE

	6-40	CC
Sand	0%	2%
Silt	20%	45%
Clay	80%	48%

COMPOSITION (SS)
75-85% Clay
15-20% Rads
5-10% Diatoms
1- 5% Sponge spicules
T- 5% Zeolite
1- 3% Quartz

Carbonate Bomb: 1-29 to 30 cm = 8.7% $CaCO_3$

Carbon-Carbonate (DSDP)
6-20 (0.2, 0.1, 1)

Grain Size (DSDP)
1-88 (0.4, 16.4, 83.2)
6-88 (0.3, 19.5, 80.1)

Explanatory notes in Chapter 1

Site 364 Hole Core 7 Cored Interval: 245.0-254.5 m

AGE	ZONES FORAMS	ZONES NANNOS	FOSSIL CHARACTER FORAMS	FOSSIL CHARACTER NANNOS			SECTION	METERS	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
							0				
			None	None			1	0.5 1.0	| | |	30 140	10YR 5/3 5Y 5/2
*		**	RP	AM			Core Catcher			CC	5Y 5/1

* MIDDLE EOCENE
** Nannotetrina fulgens

ZEOLITE BEARING MUD VERGING ON MARLY NANNOFOSSIL OOZE

MEGASCOPIC CORE DESCRIPTION
Stiff mud. Brown (10YR 5/3) olive gray (5Y 5/2) with minor olive gray (5Y 5/1). Moderately mottled.

TEXTURE
0% Sand
5-25% Silt
70-95% Clay

COMPOSITION (SS)
60-85% Clay
5-40% Nannos
1- 5% Quartz
1- 5% Zeolite

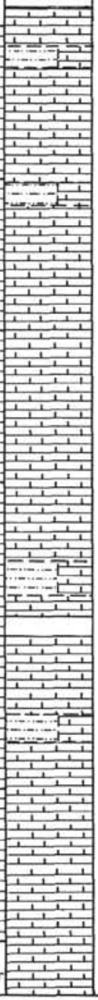
Carbonate Bomb: 1-29 to 30 cm = 5.56% $CaCO_3$

Remarks
Brown clay foramtion?

Carbon-Carbonate (DSDP)
1-20 (0.2, 0.1, 1)

Grain Size (DSDP)
1-88 (2.4, 38.7, 58.8)

Site 364 Hole Core 8 Cored Interval: 283.0-292.5 m



AGE	ZONES FORAMS	ZONES NANNOS	FOSSIL CHARACTER FORAMS	FOSSIL CHARACTER NANNOS			SECTION	METERS	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LOWER EOCENE	Globorotalia palmerae to Globorotalia aragonensis	Discoaster sublodoensis	None				0			109	10YR 2/2
				AM AM			1	0.5 1.0		30 123	10YR 6/3
							2			20 95	10YR 6/3
		Discoaster lodoensis		AM			3			100	10YR 5/4
			RP	AM			4			110	10YR 5/4 O G
		Tribrachiatus orthostylus		AM			5			90	10YR 5/4
			CM	CM			6			69	10YR 5/4
	**		AG	AM			Core Catcher			CC	

CALCAREOUS NANNOFOSSIL CHALK WITH MARLY NANNOFOSSIL CHALK

MEGASCOPIC CORE DESCRIPTION
Very stiff ooze to soft chalk. Yellowish brown (10YR 5/4), pale brown (10YR 6/3) with minor light gray (10YR 2/2). Colors greatly mixed by burrows. Shearing through drilling has stretched burrows making them flattened.

TEXTURE
0% Sand
1-15% Silt
85-99% Clay

COMPOSITION (SS)
30-95% Nannos
20-65% Clay
2- 5% Carbonate unspecified
1- 3% Quartz
0- 2% Forams

Carbonate Bomb: 1-29 to 30 cm = 37.3% $CaCO_3$

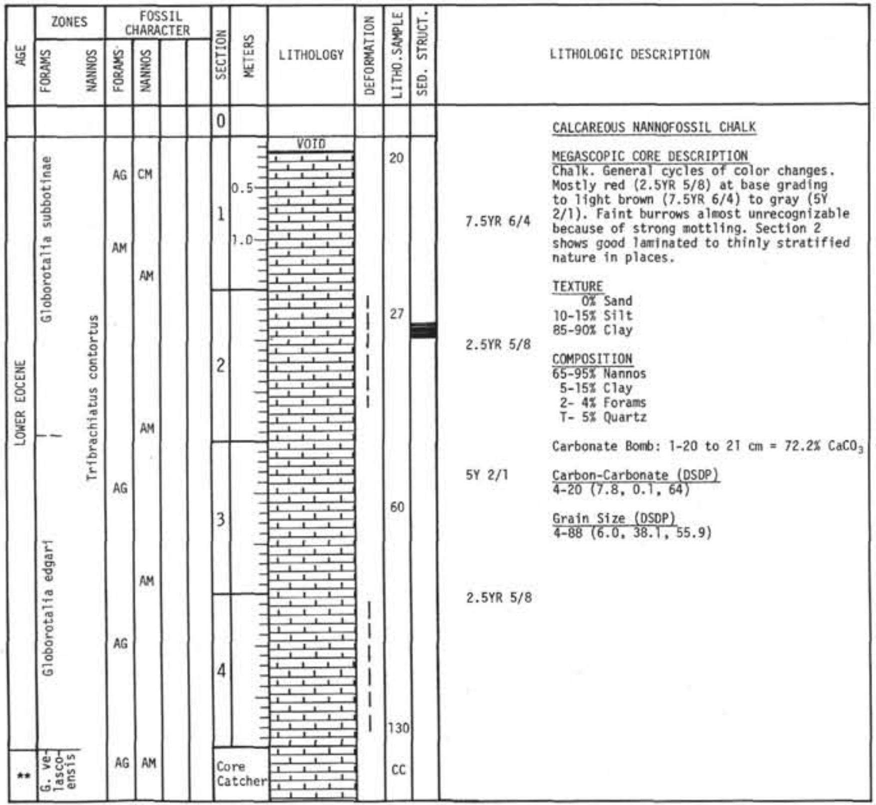
Carbon-Carbonate (DSDP)
4-20 (4.4, 0.0, 36)
6-20 (1.9, 0.0, 16)

Carbon-Carbonate (OG)
4-130 (6.7, 0.1, 55)
4-150 (5.5, 0.1, 45)

Grain Size (DSDP)
4-88 (0.1, 59.0, 40.9)
6-88 (0.2, 38.4, 61.5)

**Globorotalia formosa formosa
Explanatory notes in Chapter 1

Site 364 Hole Core 9 Cored Interval: 321.0-330.5 m



CALCAREOUS NANNOFOSSIL CHALK

MEGASCOPIC CORE DESCRIPTION
Chalk. General cycles of color changes. Mostly red (2.5YR 5/8) at base grading to light brown (7.5YR 6/4) to gray (5Y 2/1). Faint burrows almost unrecognizable because of strong mottling. Section 2 shows good laminated to thinly stratified nature in places.

TEXTURE
0% Sand
10-15% Silt
85-90% Clay

COMPOSITION
65-95% Nannos
5-15% Clay
2- 4% Forams
T- 5% Quartz

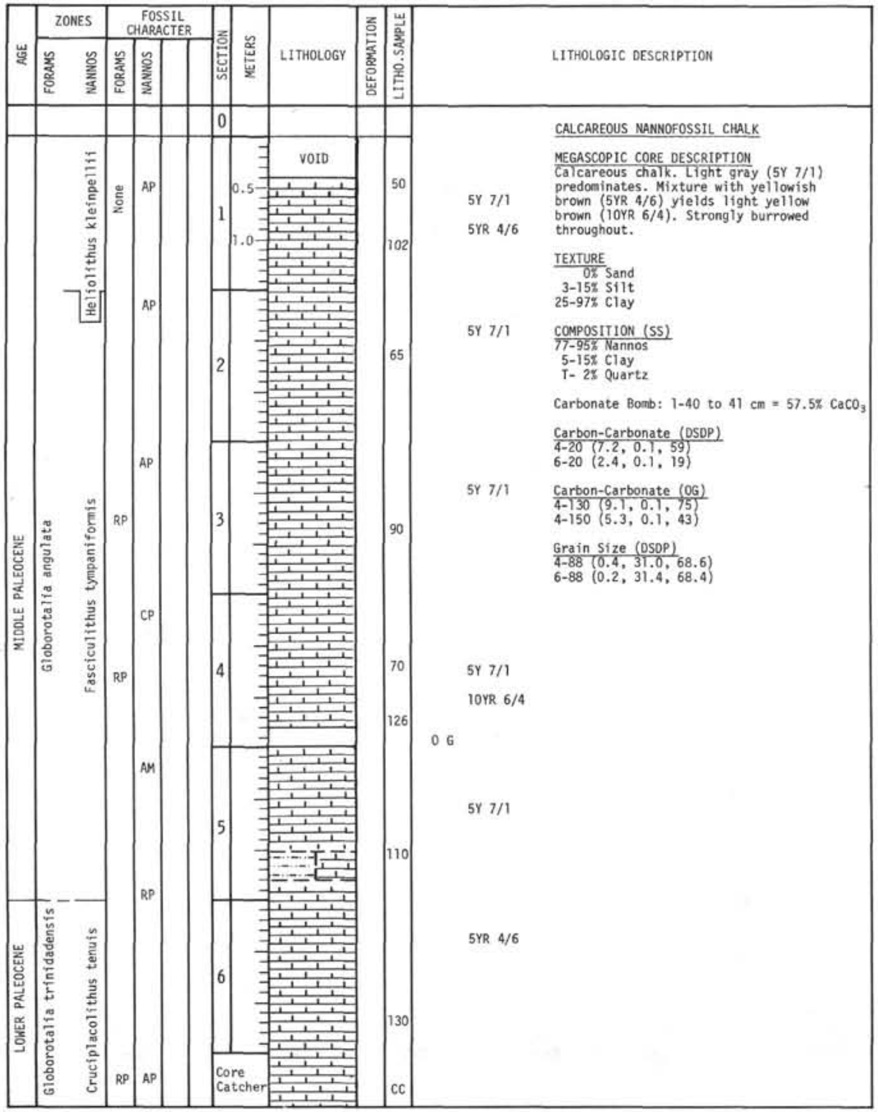
Carbonate Bomb: 1-20 to 21 cm = 72.2% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (7.8, 0.1, 64)

Grain Size (DSDP)
4-88 (6.0, 38.1, 55.9)

**UPPER PALEOCENE (forams) LOWER EOCENE (nannos)

Site 364 Hole Core 10 Cored Interval: 349.5-359.0 m



CALCAREOUS NANNOFOSSIL CHALK

MEGASCOPIC CORE DESCRIPTION
Calcareous chalk. Light gray (5Y 7/1) predominates. Mixture with yellowish brown (5YR 4/6) yields light yellow brown (10YR 6/4). Strongly burrowed throughout.

TEXTURE
0% Sand
3-15% Silt
25-97% Clay

COMPOSITION (SS)
77-95% Nannos
5-15% Clay
T- 2% Quartz

Carbonate Bomb: 1-40 to 41 cm = 57.5% $CaCO_3$

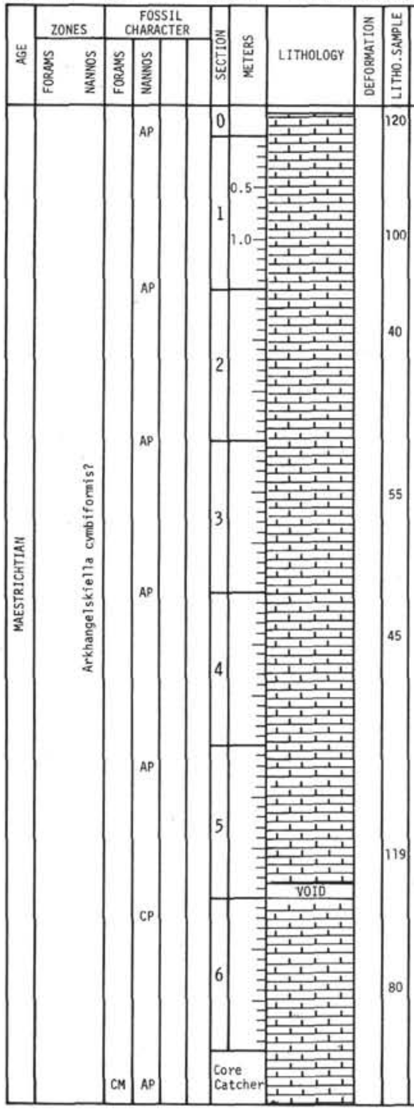
Carbon-Carbonate (DSDP)
4-20 (7.2, 0.1, 59)
6-20 (2.4, 0.1, 19)

Carbon-Carbonate (OG)
4-130 (9.1, 0.1, 75)
4-150 (5.3, 0.1, 43)

Grain Size (DSDP)
4-88 (0.4, 31.0, 68.6)
6-88 (0.2, 31.4, 68.4)

Explanatory notes in Chapter 1

Site 364 Hole Core 11 Cored Interval: 359.0-368.5 m



LITHOLOGIC DESCRIPTION

5Y 7/1

5Y 7/1

10YR 5/4

10YR 5/4

5Y 7/1

10YR 5/4

5Y 7/1

CALCAREOUS NANNOFOSSIL CHALK

MEGASCOPIC CORE DESCRIPTION
Chalk and marly chalk. Alternate yellow brown (10YR 5/4) and light gray (5Y 7/1). Strong burrowing throughout. Drilling disturbed core by rotating slabs 1"-1 1/2" apart.

TEXTURE
0% Sand
5-10% Silt
90-95% Clay

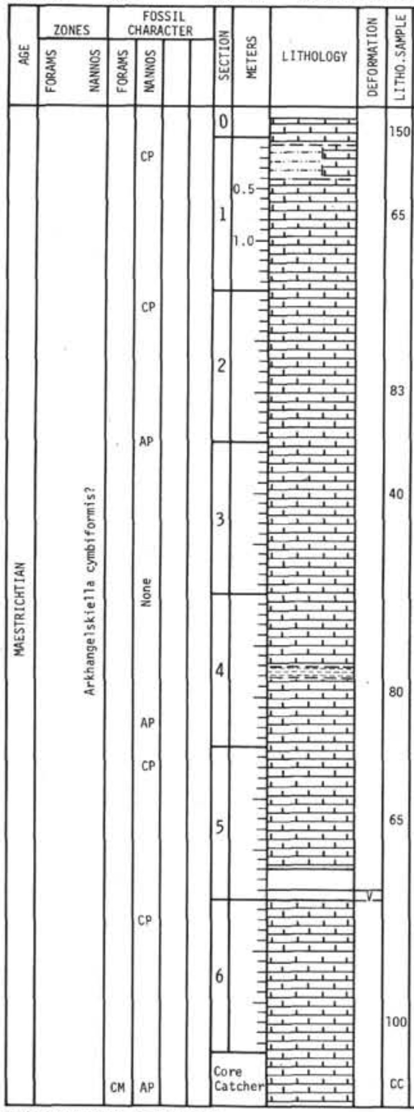
COMPOSITION (SS)
50-70% Carbonate unspecified
15-35% Nannos
10-20% Clay
1- 3% Quartz

Carbonate Bomb: 1-29 to 30 cm = 69.0% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (6.5, 0.0, 54)
6-20 (5.5, 0.0, 45)

Grain Size (DSDP)
4-88 (0.2, 31.4, 68.4)
6-88 (0.1, 19.6, 80.3)

Site 364 Hole Core 12 Cored Interval: 368.5-378.0 m



LITHOLOGIC DESCRIPTION

7.5YR 5/4

7.5YR 5/4

7.5YR 5/4

7.5YR 5/4

10YR 4/4

5Y 7/2

0 G

CALCAREOUS NANNOFOSSIL CHALK

MEGASCOPIC CORE DESCRIPTION
Chalk - marly chalk. Mostly brown (7.5YR 5/4) with minor light gray (5Y 7/2) mud dark yellowish brown (10YR 4/4). Brown part burrowed at top, gray part heavily burrowed. Drilling has broken core on 3 1/4"-1 1/2" slabs.

TEXTURE
0% Sand
3- 5% Silt
95-97% Clay

COMPOSITION (SS)
40-65% Carbonate unspecified
20-45% Nannos
10-30% Clay
T- 2% Quartz

Carbonate Bomb: 1-29 to 30 cm = 33.3% $CaCO_3$

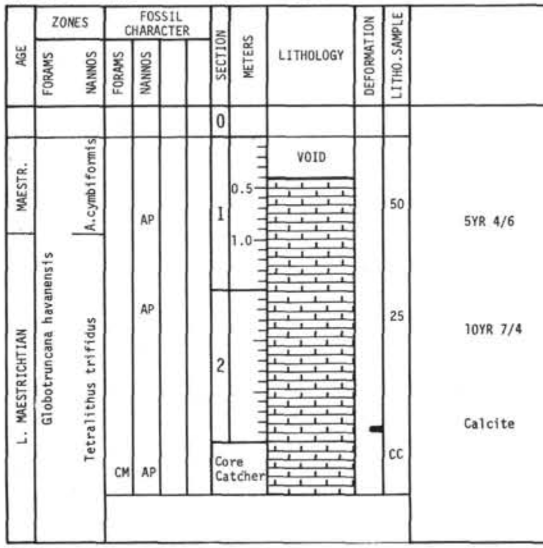
Carbon-Carbonate (DSDP)
4-20 (0.1, 0.0, 1)
6-20 (4.0, 0.0, 33)

Carbon-Carbonate (OG)
5-120 (4.6, 0.1, 38)
5-140 (5.8, 0.1, 48)

Grain Size (DSDP)
4-88 (1.0, 32.4, 66.6)
6-88 (0.3, 29.4, 70.3)

Explanatory notes in Chapter 1

Site 364 Hole Core 13 Cored Interval: 397.0-406.5 m



LITHOLOGIC DESCRIPTION

CALCAREOUS NANNOFOSSIL CHALK

MEGASCOPIC CORE DESCRIPTION
Chalk. Very pale brown (10YR 7/4) and yellowish red (5YR 4/6) with minor light gray (5Y 7/2). Moderate to heavy burrowing throughout. Orientation of some parts is dubious due to drilling. First appearance of Inoceramus(?) fragment (calcite).

TEXTURE
0% Sand
3-15% Silt
85-97% Clay

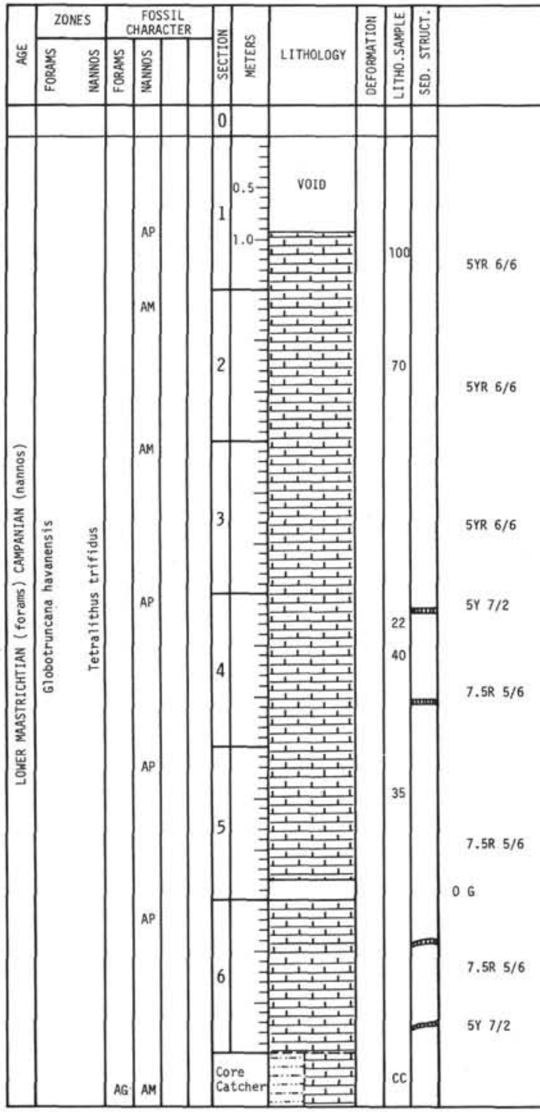
COMPOSITION (SS)
40-70% Carbonate unspecified
20-50% Nannos
5-15% Clay
T- 1% Quartz

Carbonate Bomb: 1-36 to 37 cm = 60.6% $CaCO_3$

Carbon-Carbonate (DSDP)
2-20 (7.8, 0.0, 65)

Grain Size (DSDP)
2-108 (0.1, 18.2, 81.7)

Site 364 Hole Core 14 Cored Interval: 425.5-435.0 m



LITHOLOGIC DESCRIPTION

CALCAREOUS NANNOFOSSIL CHALK WITH MINOR MARLY NANNOFOSSIL CHALK

MEGASCOPIC CORE DESCRIPTION
Chalk. Reddish yellow (5YR 6/6) to brown (7.5R 5/6) with minor mottles and light gray (5Y 7/2). Heavily burrowed throughout. White prismatic carbonate (calcite) layers.

TEXTURE
0% Sand
3% Silt
97% Clay

COMPOSITION (SS)
45-70% Carbonate unspecified
15-40% Nannos
10-40% Clay
T- 1% Quartz

Carbonate Bomb: 1-98 to 100 cm = 75.0% $CaCO_3$

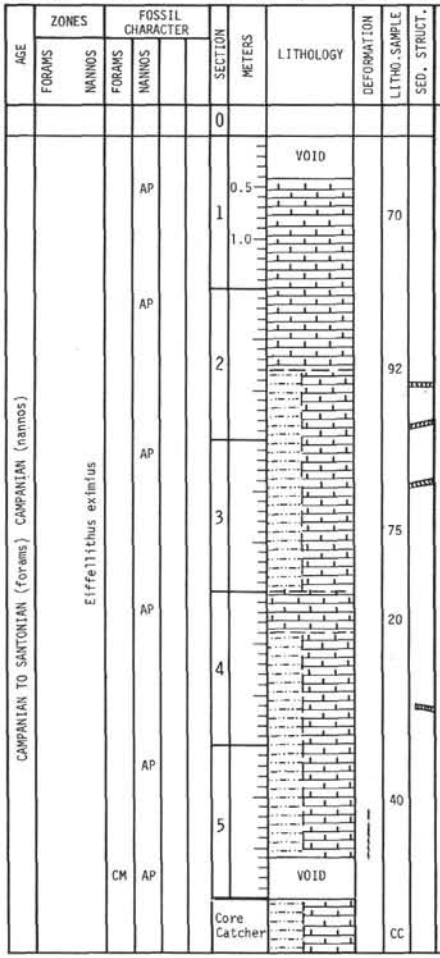
Carbon-Carbonate (DSDP)
4-17 (8.6, 0.0, 71)
6-20 (8.5, 0.0, 7)

Carbon-Carbonate (OG)
5-130 (9.0, 0.0, 71)
5-150 (8.6, 0.0, 70)

Grain Size (DSDP)
4-88 (0.1, 64.5, 35.4)
6-88 (0.1, 23.6, 76.2)

Explanatory notes in Chapter 1

Site 364 Hole Core 15 Cored Interval: 463.5-473.0 m



LITHOLOGIC DESCRIPTION

CALCAREOUS NANNOFOSSIL CHALK AND MARLY NANNOFOSSIL CHALK

MEGASCOPIC CORE DESCRIPTION
Marly chalk. Reddish yellow (5YR 6/6) and light brown (7.5YR 6/4) with 10-15% of light gray (5Y 7/2), to yellowish red (5YR 5/6). Heavily burrowed throughout.

7.5YR 6/6

TEXTURE
0% Sand
3-10% Silt
90-97% Clay

COMPOSITION (SS)
35-50% Carbonate unspecified
20-50% Clay
15-30% Nannos
T- 2% Quartz

5Y 7/2

Carbonate Bomb: 1-65 to 66 cm = 72.3% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (8.7, 0.0, 72)

5YR 5/6

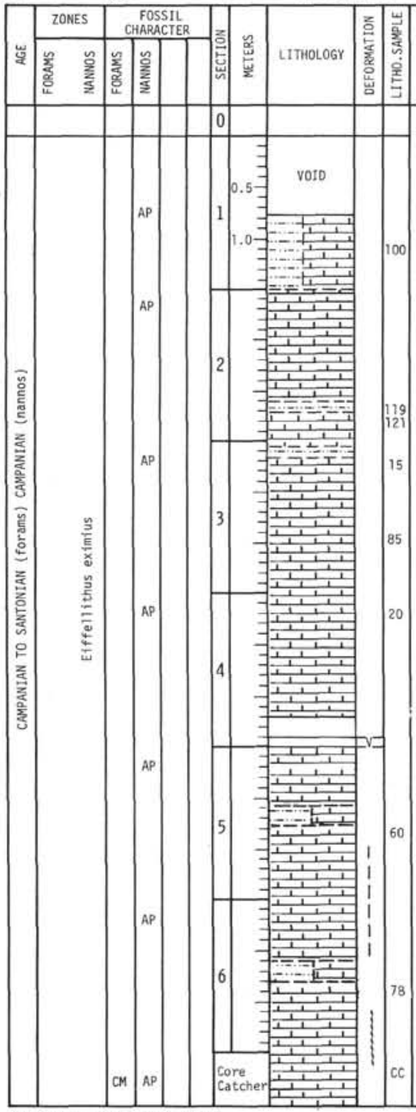
Grain Size (DSDP)
4-88 (0.2, 33.5, 66.4)

5Y 7/2

7.5YR 6/4

5YR 5/6

Site 364 Hole Core 16 Cored Interval: 501.5-511.0 m



LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL CHALK TO CALCAREOUS NANNOFOSSIL CHALK WITH INTERCALATION OF LAYERS COMPOSED OF CLAYEY SILTSTONE AND CALCAREOUS MUDSTONE

MEGASCOPIC CORE DESCRIPTION
Marly chalk to chalk. Light brown (7.5YR 6/4) with 10-20% brown (7.5YR 5/4) and 15-30% light gray (5Y 7/2). First appearance of distinct layer of mudstone. Heavily burrowed throughout.

7.5YR 7/2

7.5YR 6/4

TEXTURE

	major	minor
Sand	0%	1- 2%
Silt	3- 5%	20-80%
Clay	45-97%	10-80%

COMPOSITION (SS)
Major only
40-70% Carbonate unspecified
20-50% Clay
10-20% Nannos
T- 2% Quartz

7.5YR 6/4

Carbonate Bomb: 1-91 to 92 cm = 59.4% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (7.1, 0.0, 72)
6-20 (8.1, 0.1, 58)

7.5YR 5/4

Carbon-Carbonate (OG)
4-120 (8.5, 0.0, 70)
4-140 (4.4, 0.1, 36)

Grain Size (DSDP)
4-88 (0.1, 30.0, 69.9)
6-88 (0.2, 30.5, 69.3)

7.5YR 6/4

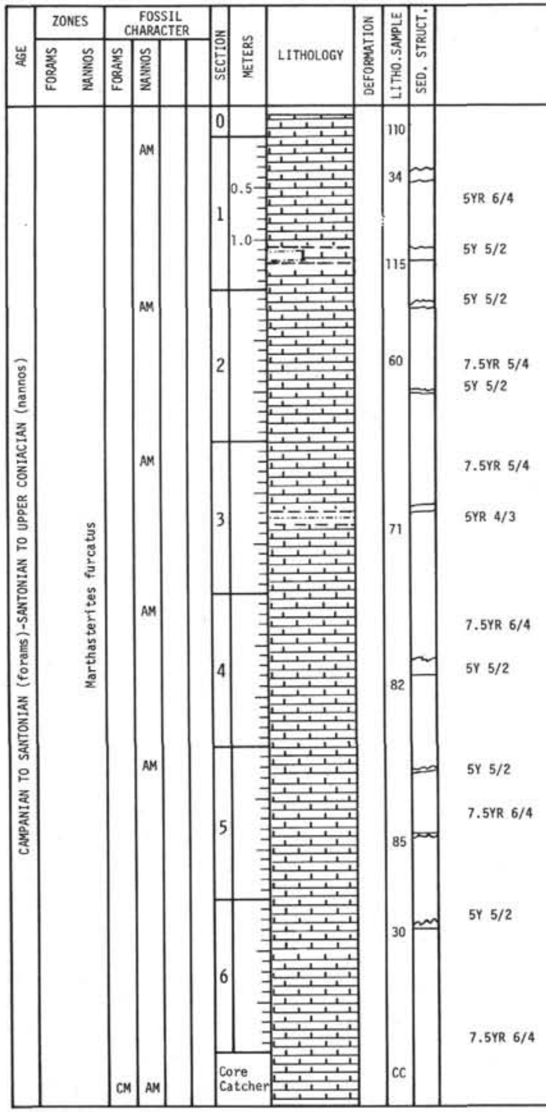
0 G

5Y 7/2

7.5YR 6/4

Explanatory notes in Chapter 1

Site 364 Hole Core 17 Cored Interval: 530.0-539.5 m



LITHOLOGIC DESCRIPTION

CALCAREOUS NANNOFOSSIL CHALK; MINOR CALCAREOUS MUDSTONE

MEGASCOPIC CORE DESCRIPTION
Marly chalk. Mixture of brown (7.5YR 5/4), light brown (7.5YR 6/4) and reddish brown (5YR 4/3). Intensely burrowed throughout.

TEXTURE
0% Sand
3-10% Silt
90-97% Clay

COMPOSITION (SS)
1-115
40% Carbonate unspecified
20% Nannos
20% Clay
15% Quartz

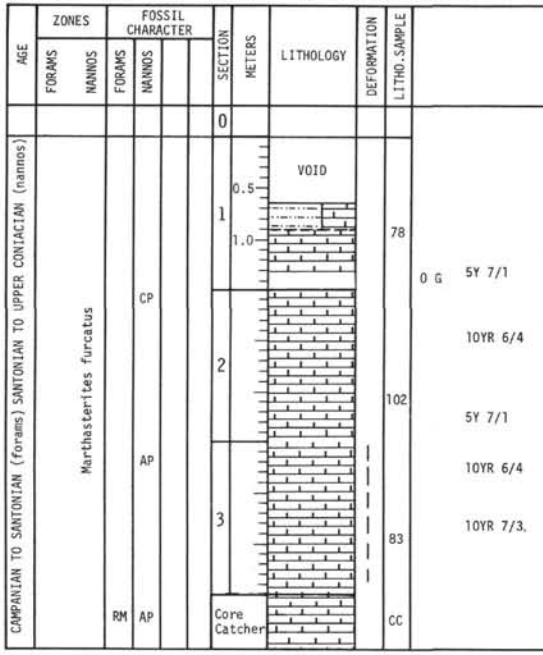
3-71
60% Clay
17% Quartz
5% Nannos
15% Carbonate unspecified

Carbonate Bomb: 1-22 to 23 cm = 73.4% $CaCO_3$

Carbon-Carbonate (DSDP)
4-19 (8.3, 0.0, 69)
6-20 (8.5, 0.0, 71)

Grain Size (DSDP)
4-88 (0.1, 33.4, 66.5)
6-88 (0.0, 34.4, 65.6)

Site 364 Hole Core 18 Cored Interval: 549.0-558.5 m



LITHOLOGIC DESCRIPTION

CALCAREOUS NANNOFOSSIL CHALK WITH MINOR MARLY NANNOFOSSIL CHALK

MEGASCOPIC CORE DESCRIPTION
Marly chalk. Mostly pale brown (10YR 6/4) with light gray (5Y 7/1) and light gray (10YR 7/2). Intensively burrowed.

TEXTURE
0% Sand
3% Silt
97% Clay

COMPOSITION (SS)
1-78
60% Clay
30% Carbonate unspecified
10% Nannos
T Quartz

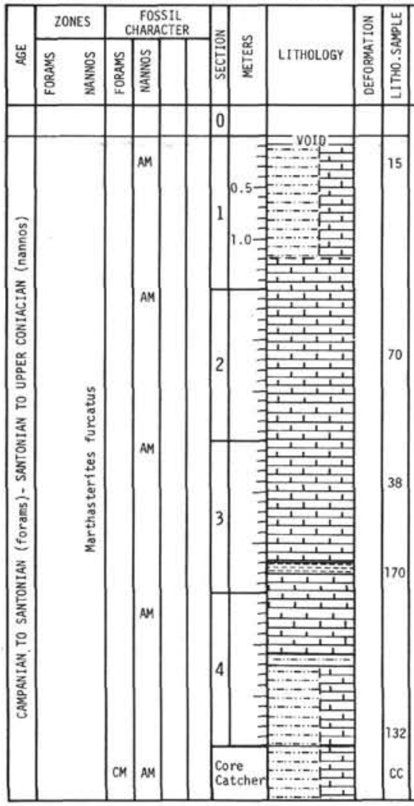
3-83
75% Carbonate unspecified
15% Nannos
10% Clay
T Quartz

Carbonate Bomb: 2-132 to 133 cm = 76.8% $CaCO_3$

Carbon-Carbonate (OG)
1-130 (7.7, 0.1, 64)
1-150 (8.0, 0.1, 66)

Explanatory notes in Chapter 1

Site 364 Hole Core 19 Cored Interval: 568.0-577.5 m



LITHOLOGIC DESCRIPTION

CALCAREOUS NANNOFOSSIL CHALK; MARLY NANNOFOSSIL CHALK; MINOR CARBONATE-FREE PELAGIC CLAYSTONE

MEGASCOPIC CORE DESCRIPTION
Marly chalk. Most of core is pale brown (10YR 6/4 and 10YR 6/3) and brown (7.5YR 5/4) with light gray (5Y 6/1 and 5Y 7/1) and dark reddish brown (5YR 3/3) beds. Intensely burrowed.

TEXTURE
0% Sand
3% Silt
97% Clay

COMPOSITION (SS)
2-70
45% Carbonate unspecified
30% Nannos
25% Clay
T Quartz

3-130
90% Clay
3% Quartz
2% Zeolite
T Carbonate unspecified

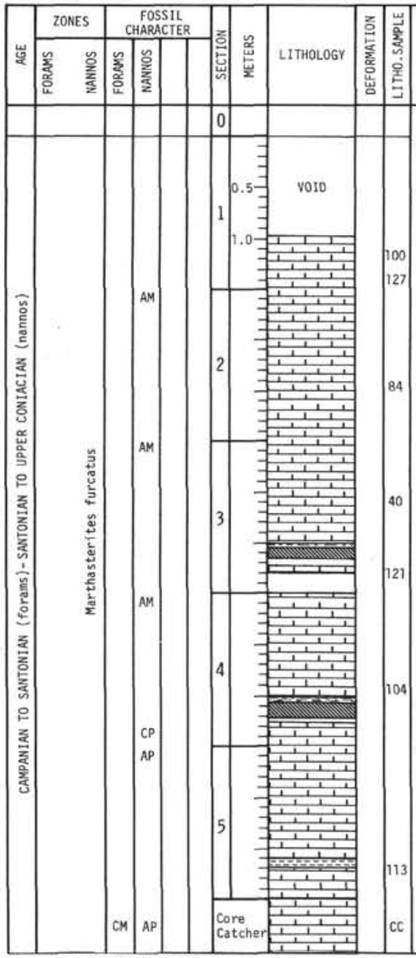
Carbonate Bomb: 1-29 to 30 cm = 63.6% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (8.6, 0.0, 71)

Grain Size (DSDP)
4-88 (0.0, 23.5, 76.5)

10YR 6/4
5Y 6/1
10YR 6/3
5Y 6/1
5Y 7/1
7.5YR 5/4
5YR 3/3
5YR 3/3
10YR 6/3

Site 364 Hole Core 20 Cored Interval: 577.5-587.0 m



LITHOLOGIC DESCRIPTION

CALCAREOUS NANNOFOSSIL CHALK WITH MINOR SAPPROPEL BEDS AND CARBONATE-FREE BROWN CLAY

MEGASCOPIC CORE DESCRIPTION
Marly chalk. Greenish gray (5G 6/1) with minor dark greenish gray (5GY 4/1) at the top turning to light brownish gray (2.5Y 6/2) at base with dark brown (7.5YR 3/2).

TEXTURE
0% Sand
3% Silt
97% Clay

COMPOSITION (SS)
2-84
80% Clay
10% Mica
3% Quartz
3% Zeolite

3-40
40% Carbonate unspecified
20% Nannos
35% Clay
3% Quartz

Carbonate Bomb: 1-100 to 101 cm = 70.8% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (9.5, 0.1, 78)

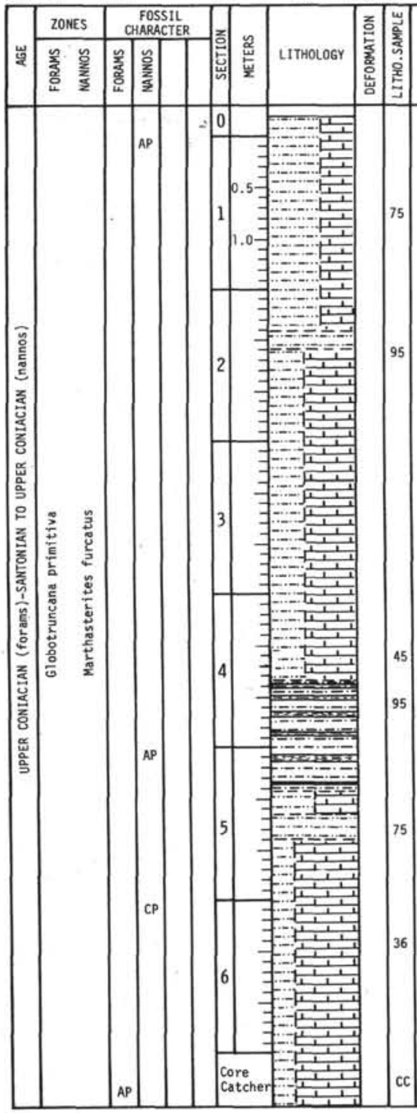
Carbon-Carbonate (OG)
3-130 (22.9, 21.3, 13)
3-150 (8.3, 0.2, 68)

Grain Size (DSDP)
4-88 (0.0, 23.5, 76.5)

5GY 4/1
5G 6/1
0 G
2.5Y 6/3
7.5YR 3/2

Explanatory notes in Chapter 1

Site 364 Hole Core 21 Cored Interval: 596.5-601.0 m



LITHOLOGIC DESCRIPTION

10YR 4/3
2.5Y 3/2
10YR 5/2
5G 6/1
5GY 4/1
Pyrite
5G 6/1
Authigenic barite
10YR 5/2

MARLY NANNOFOSSIL CHALK AND MUDSTONE WITH SAPROPEL BEDS

MEGASCOPIC CORE DESCRIPTION

Marly chalk and mudstone; brown (10YR 4/3) with minor very dark grayish brown (2.5Y 3/2) beds at the top turning to grayish brown (10YR 5/2) at the middle and the base with dark greenish gray (5GY 4/1) and greenish gray (5G 6/1). Light layers heavily burrowed, darker layers lightly or not burrowed.

TEXTURE

	2-75	4-95
Sand	0%	0%
Silt	15%	22%
Clay	85%	78%

COMPOSITION (SS)

1-75
50% Clay
42% Carbonate unspecified
7% Nannos
1% Quartz

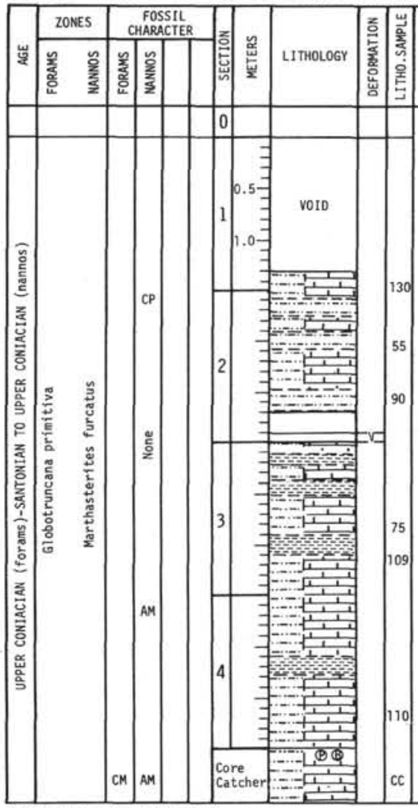
5-75
85% Clay
5% Zeolite
8% Carbonate unspecified

Carbonate Bomb: 1-29 to 30 cm = 46.9% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (6.7, 0.1, 55)
6-7 (0.2, 0.1, 1)

Grain Size (DSDP)
4-78 (2.0, 34.3, 63.6)
6-88 (2.5, 39.6, 57.9)

Site 364 Hole Core 22 Cored Interval: 615.5-625.0 m



LITHOLOGIC DESCRIPTION

0 G

5G 6/1
5GY 4/1
10YR 5/2
10YR 5/2
2.5Y 3/2
10YR 5/2
2.5Y 3/2
5G 6/1
5G 6/1

MARLY NANNOFOSSIL CHALK; MUDSTONE, DARK CLAYSTONE

MEGASCOPIC CORE DESCRIPTION

Marly chalk and mudstone, greenish gray (5G 6/1) and grayish brown (10YR 5/2) with dark greenish gray (5GY 4/1) and very dark grayish brown (2.5Y 3/2). Mostly chalks are burrowed throughout. Mudstone only in lighter part.

TEXTURE

	2-55	3-109
Sand	0%	0%
Silt	20%	5%
Clay	80%	95%

COMPOSITION (SS)

3-75
50% Carbonate unspecified
30% Clay
20% Nannos
T Quartz

3-109
95% Clay
2% Quartz
2% Zeolite

Carbonate Bomb: 3-16 to 17 cm = 3.0% $CaCO_3$

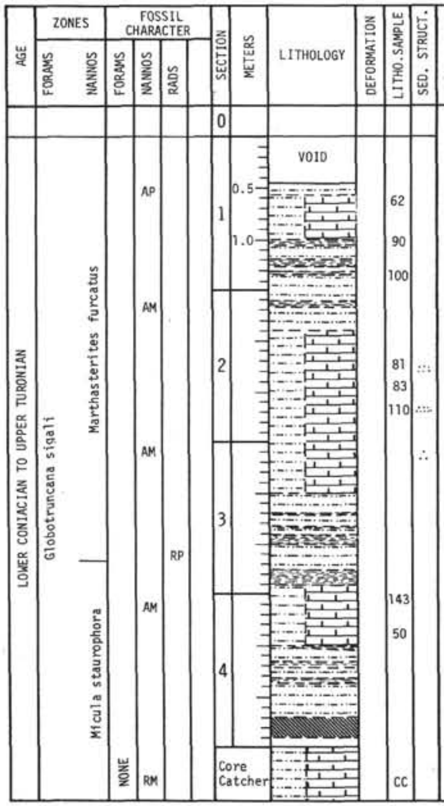
Carbon-Carbonate (DSDP)
4-20 (7.4, 0.0, 61)

Carbon-Carbonate (OG)
2-120 (5.3, 0.1, 43)
2-140 (6.9, 0.1, 57)

Grain Size (DSDP)
4-88 (0.0, 31.0, 69.0

Explanatory notes in Chapter 1

Site 364 Hole Core 23 Cored Interval: 644.0-653.5 m



LITHOLOGIC DESCRIPTION

5G 6/1
N1
Barite
Barite
5G 6/1
Pyrite
5G 6/1
N1
5G 6/1

MARLY NANNOFOSSIL CHALK AND BLACK MUDSTONE WITH SAPROPELS

MEGASCOPIC CORE DESCRIPTION
Marly chalk, greenish gray (5G 6/1) slight laminated - burrows make most laminae discontinuous. Laminated mudstone, greenish gray (5G 6/1), slightly burrowed. Black (N1) shale laminated to thinly laminated. Rich in pyrite.

TEXTURE
2-83
0% Sand
5% Silt
95% Clay

COMPOSITION (SS)
3-143
50% Carbonate unspecified
30% Clay
20% Nannos
T Quartz

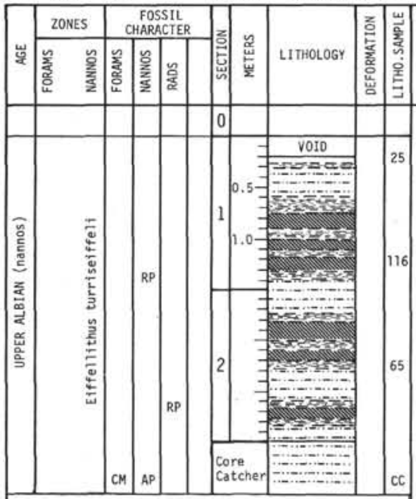
4-30
50% Carbonate unspecified
25% Nannos
25% Clay
T Quartz

Carbonate Bomb: 1-58 to 59 cm = 55.3% $CaCO_3$

Carbon-Carbonate (DSDP)
4-30 (5.4, 0.5, 41)

Grain Size (DSDP)
4-88 (2.9, 31.5, 65.7)

Site 364 Hole Core 24 Cored Interval: 672.5-682.0 m



LITHOLOGIC DESCRIPTION

N1
5GY 4/1
N1
5GY 4/1
N1
5GY 4/1

CALCAREOUS MUDSTONE AND BLACK SAPROPELIC SHALE

MEGASCOPIC CORE DESCRIPTION
Dark calcareous mudstone, dark greenish gray (5GY 4/1). Light burrowing. Laminated. Fine pyrite specks with black (N1) shale. Laminated pyrite-bearing.

TEXTURE
2-65
0% Sand
1% Silt
99% Clay

COMPOSITION (SS)
2-65
50% Carbonate unspecified
35% Clay
15% Nannos
T Quartz

CC
89% Clay
5% Quartz
5% Carbonaceous matter
T Zeolite

Carbonate Bomb: 1-27 to 28 cm = 5.3% $CaCO_3$

Carbon-Carbonate (DSDP)
2-12 (0.9, 0.9, 0)

Carbon-Carbonate (OG)
1-0 (8.7, 1.6, 59)
1-20 (0.1, 0.1, 0)

Grain Size (DSDP)
2-88 (0.6, 26.5, 72.9)

Explanatory notes in Chapter 1

Site 364 Hole Core 25 Cored Interval: 701.0-710.5 m

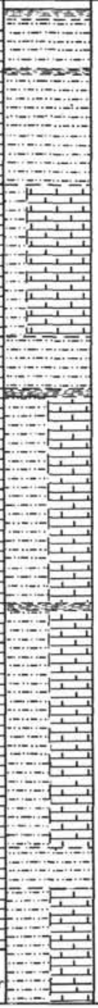
AGE | ZONES: FORAMS, NANNOS | FOSSIL CHARACTER: FORAMS, NANNOS, RADS | SECTION | METERS | LITHOLOGY | DEFORMATION | LITHO.SAMPLE | LITHOLOGIC DESCRIPTION

UPPER ALBIAN (nannos)

Eiffellithus turriseiffeli

Fossil character: CP; RP (rads); CP; RP; RP; CP; NONE (forams) CP (core catcher)

Sections: 0, 1 (0.5, 1.0), 2, 3, 4, 5, 6, Core Catcher



Litho. samples: 140, 45, 100, 27, 120, 132, 139, 30, CC

5G 6/1

N1

5GY 4/1

5G 6/1

5GY 4/1

5G 6/1 Pyrite cluster

5G 2/1

5G 4/1

5G 6/1 Marcasite

MARLY NANNOFOSSIL CHALK, CALCAREOUS MUDSTONE AND BLACK SAPROPELIC SHALE

MEGASCOPIC CORE DESCRIPTION

Greenish gray (5G 6/1) to dark greenish gray (5G 4/1). Marly chalk intensely burrowed. Dark greenish gray (5GY 4/1) mudstone shows laminations in several areas, heavily burrowed.

TEXTURE

	0-140	4-132
Sand	0%	0%
Silt	5%	3%
Clay	95%	97%

COMPOSITION (SS)

4-132
50% Clay
46% Carbonate unspecified
3% Nannos
T Quartz

1-45
90% Clay
8% Plant debris
1% Carbonate unspecified
T Quartz

Carbonate Bomb: 1-122 to 123 cm = 15.9% $CaCO_3$

Carbon-Carbonate (DSDP)
4-91, (4.4, 0.2, 35)
6-104 (4.9, 0.0, 40)

Grain Size (DSDP)
6-102 (2.5, 49.5, 48.0

Site 364 Hole Core 26 Cored Interval: 710.5-720.0 m

AGE | FORAMS | NANNOS | FOSSIL CHARACTER: FORAMS, NANNOS | SECTION | METERS | LITHOLOGY | DEFORMATION | LITHO.SAMPLE | LITHOLOGIC DESCRIPTION

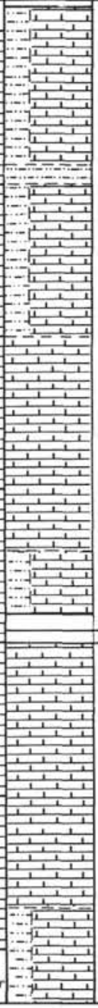
UPPER TO MIDDLE ALBIAN (forams)-UPPER ALBIAN (nannos)

Rotalipora ticinensis to *Biticinella breggiensis*

Eiffellithus turriseiffeli

Fossil character: AP; RP; CP; AP; CP; AP; AP; AP; AP; AP CM; CM AP RP (core catcher)

Sections: 0, 1 (0.5, 1.0), 2, 3, 4, 5, 6, Core Catcher



Deformation: V

Litho. samples: 95, 127, 64, 145, 25, 101, 6, CC

5YR 3/3

5YR 3/3

5YR 3/3

5YR 3/3

5YR 4/3

5G 6/1

5G 6/1

10YR 4/2

0 G
VOID

5G 6/1

5G 6/1

5YR 4/3

NANNOFOSSIL CHALK; FORAMINIFERA-BEARING NANNOFOSSIL CHALK AND MARLY NANNOFOSSIL CHALK

MEGASCOPIC CORE DESCRIPTION

Greenish gray (5G 6/1) to reddish brown (5YR 4/3) chalk. Most shows burrowing. Dark reddish brown (5YR 3/3) calcareous mudstone or marly chalk moderate burrowing but hard to see because of uniform color over most of core.

TEXTURE

	1-95	3-64
Sand	0%	0%
Silt	3%	12%
Clay	97%	88%

COMPOSITION (SS)

2-127
58% Carbonate unspecified
20% Clay
15% Nannos
7% Calcispherides

3-64
57% Carbonate unspecified
25% Clay
10% Nannos
8% Forams

Carbonate Bomb: 1-143 to 144 cm = 26.5% $CaCO_3$
2-135 to 136 cm = 33.3% $CaCO_3$

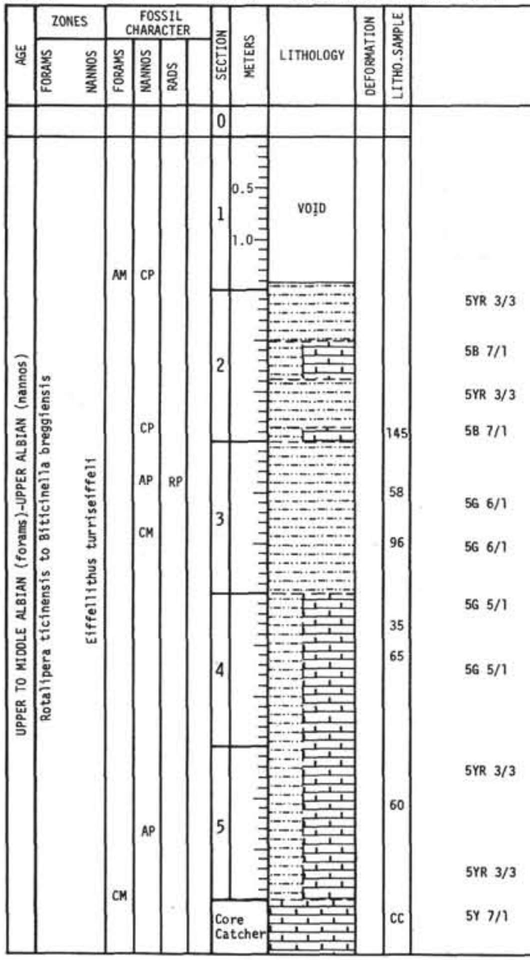
Carbon-Carbonate (DSDP)
4-73 (3.8, 0.1, 32)
6-55 (5.4, 0.1, 45)

Carbon-Carbonate (OG)
4-120 (5.4, 0.1, 44)
4-140 (5.6, 0.1, 46)

Grain Size (DSDP)
4-78 (3.0, 24.8, 72.2)
6-54 (1.0, 28.2, 70.8)

Explanatory notes in Chapter 1

Site 364 Hole Core 27 Cored Interval: 720.0-729.5 m



LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL CHALK; CALCAREOUS MUDSTONE

MEGASCOPIC CORE DESCRIPTION
Marly chalk, greenish gray (5G 5/1), light bluish gray (5B 7/1) to dark reddish brown (5YR 3/3). Mudstone ranges in color from dark reddish brown (5YR 3/3) to greenish gray (5G 6/1). Some lamination preserved but most disturbed by burrows.

TEXTURE

	2-145	3-96
Sand	3%	0%
Silt	8%	4%
Clay	89%	96%

COMPOSITION (SS)
3-96
60% Clay
35% Carbonate unspecified
3% Quartz
T Nannos

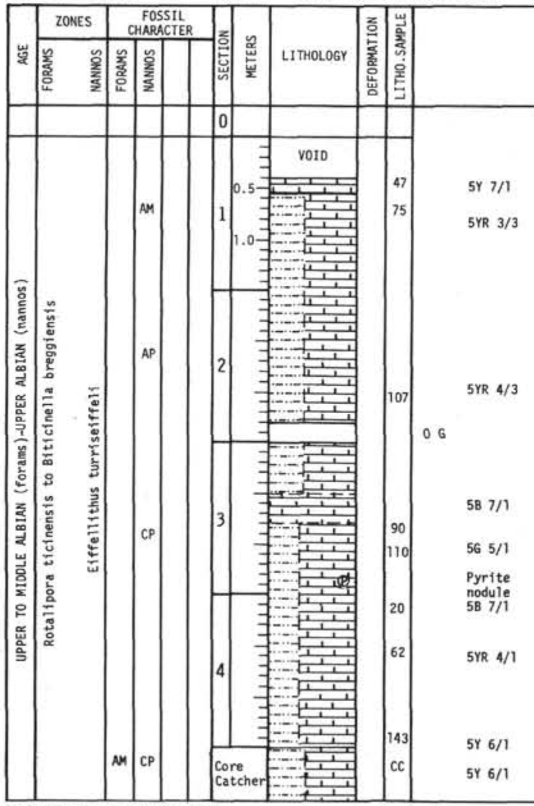
4-35
68% Carbonate unspecified
15% Nannos
15% Clay
2% Forams
T Quartz

Carbonate Bomb: 2-143 to 144 cm = 49.6% $CaCO_3$

Carbon-Carbonate (DSDP)
4-73 (2.3, 0.1, 19)

Grain Size (DSDP)
4-65 (1.0, 28.2, 70.8)

Site 364 Hole Core 28 Cored Interval: 748.5-758.0 m



LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL CHALK; CALCAREOUS NANNOFOSSIL CHALK

MEGASCOPIC CORE DESCRIPTION
Marly chalk. Dark reddish brown (5YR 3/3) grading to reddish brown (5YR 4/3) chalk. Dark greenish gray (5G 5/1), light bluish gray (5B 7/1 to 5YR 4/1). Heavily burrowed throughout. Chalk in the upper Section 4 shows styolitic seams and irregular lenses of greenish gray.

TEXTURE

	2-107	4-62
Sand	0%	0%
Silt	5%	5%
Clay	95%	95%

COMPOSITION (SS)
2-107
46% Carbonate unspecified
40% Clay
10% Nannos
2% Quartz

4-62
73% Carbonate unspecified
15% Clay
10% Nannos
T Quartz

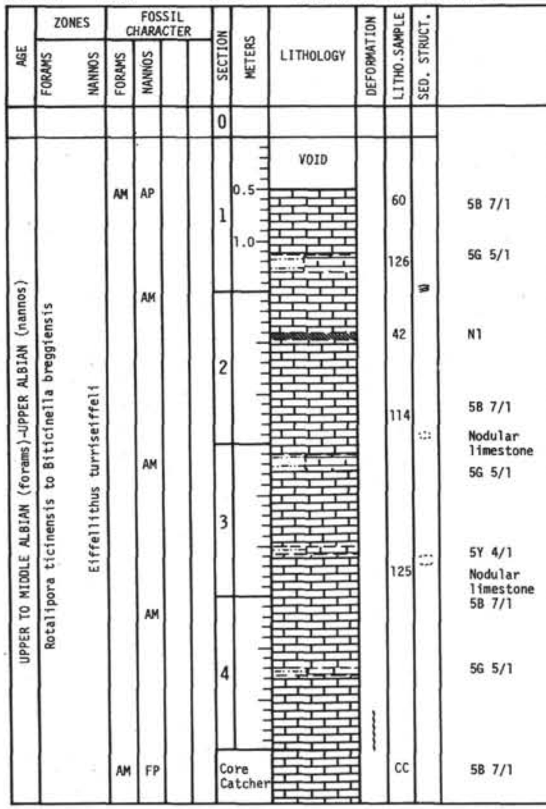
Carbonate Bomb: 1-60 to 61 cm = 54.5% $CaCO_3$

Carbon-Carbonate (DSDP)
4-18 (10.2, 0.0, 85)

Carbon-Carbonate (OG)
2-130 (8.8, 0.1, 71)
2-150 (5.3, 0.1, 44)

Explanatory notes in Chapter 1

Site 364 Hole Core 29 Cored Interval: 767.5-777.0 m



LITHOLOGIC DESCRIPTION

<u>LIMESTONE WITH MARLY CHALK WITH A SAPROPELIC LAYER</u>

<u>MEGASCOPIC CORE DESCRIPTION</u>
Light bluish gray chlak (5B 7/1) with darker greenish irregular lenses and laminae. Styolic seams with black (N1) seam fillings. Moderately burrowed. Some laminae curved at base and appear truncated, some steeply dipping to 45° and offset by faults.

<u>TEXTURE</u>

	1-126	3-125
Sand	0%	0%
Silt	20%	7%
Clay	80%	93%

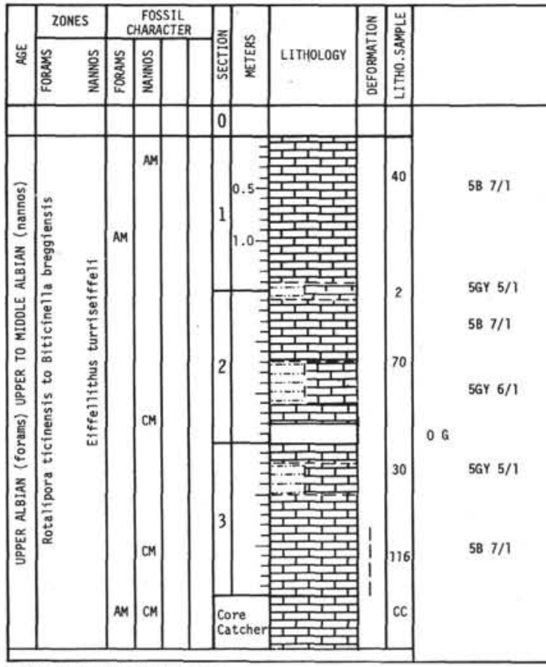
<u>COMPOSITION (SS)</u>
<u>1-126</u>
95% Carbonate unspecified
5% Clay

<u>2-114</u>
86% Carbonate unspecified
10% Clay
T Nannos
T Quartz

Carbonate Bomb: 1-82 to 83 cm = 75.5% $CaCO_3$

<u>Carbon-Carbonate (DSDP)</u>
4-15 (8.1, 0.1, 67)

Site 364 Hole Core 30 Cored Interval: 786.5-796.0 m



LITHOLOGIC DESCRIPTION

<u>LITHOLOGICAL TYPE</u>

<u>LIMESTONE WITH MARLY LIMESTONE AND FORAMINIFERAL CHALK</u>

<u>MEGASCOPIC CORE DESCRIPTION</u>
Limestone, light bluish gray (5B 7/1) with laminations, streaks and burrow fills of greenish gray. Dark greenish gray (5GY 5/1) and greenish gray (5GY 6/1) characterize minor lithology.

<u>TEXTURE</u>

	2-2	3-30
Sand	0%	0%
Silt	40%	40%
Clay	60%	60%

<u>COMPOSITION (SS)</u>
<u>2-2</u>
43% Carbonate unspecified
30% Forams
25% Clay
2% Nannos

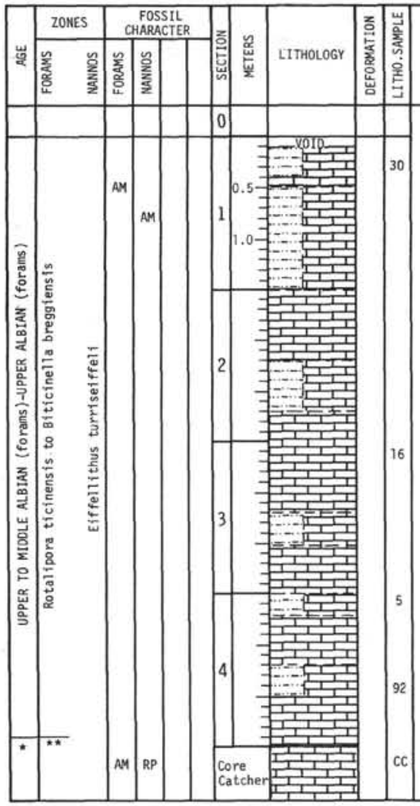
<u>3-30</u>
50% Clay
25+15% Carbonate unspecified
3% Nannos
2% Forams
2% Quartz

Carbonate Bomb: 1-32 to 33 cm = 69.4% $CaCO_3$

<u>Carbon-Carbonate (OG)</u>
2-130 (10.7, 0.1, 89)
2-150 (10.7, 0.1, 88)

Explanatory notes in Chapter 1

Site 364 Hole Core 31 Cored Interval: 805.5-815.0 m



LITHOLOGIC DESCRIPTION

5GY 5/1
5GY 5/1
5B 7/1
5G 6/1
5B 7/1
5G 6/1
5GY 5/1
5B 7/1
5GY 5/1
5B 7/1

LIMESTONE AND MARLY LIMESTONE

MEGASCOPIC CORE DESCRIPTION
Limestone, light bluish gray (5B 7/1). Burrows common throughout. Styotic seams develop in some part. The irregular clay stringer and styolic seams give the rock a "marbled" appearance. Marly limestone. Dark greenish gray (5GY 5/1), greenish gray (5G 6/1) with many laminations and sandy texture.

TEXTURE

	1-30	4-5
Sand	2%	0%
Silt	20%	20%
Clay	78%	80%

COMPOSITION (SS)
1-30
55% Carbonate unspecified
40% Clay
4% Forams
1% Nannos

4-5
50% Clay
45% Carbonate unspecified
2% Nannos
1% Forams

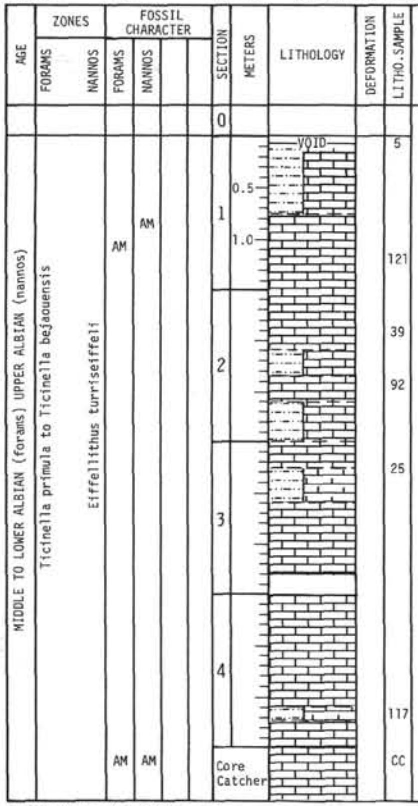
Carbonate Bomb: 1-72 to 73 cm = 35.1% $CaCO_3$

Carbon-Carbonate (DSDP)
4-52 (10.0, 0.1, 83)

* MIDDLE TO LOWER ALBIAN (forams)
UPPER ALBIAN (nannos)

* *Ticinella primula to Ticinella bejaouensis

Site 364 Hole Core 32 Cored Interval: 824.5-834.0 m



LITHOLOGIC DESCRIPTION

5GY 4/1
5B 9/1
5B 9/1
5GY 4/1
0 G 5B 9/1
5GY 4/1
5B 9/1

LIMESTONE AND MARLY NANNOFOSSIL LIMESTONE

MEGASCOPIC CORE DESCRIPTION
Light bluish gray (5B 9/1) limestone looks like "marble" with irregular dark wispy bands are numerous. Burrowing throughout. Dark greenish gray (5GY 4/1) marly limestones show poorly defined laminations and some burrowing.

TEXTURE

	1-5	1-121
Sand	0%	2%
Silt	20%	10%
Clay	80%	88%

COMPOSITION (SS)
1-5
47% Carbonate unspecified
30% Clay
20% Nannos
2% Forams

3-25
60% Clay
25% Nannos
10% Carbonate unspecified
2% Quartz

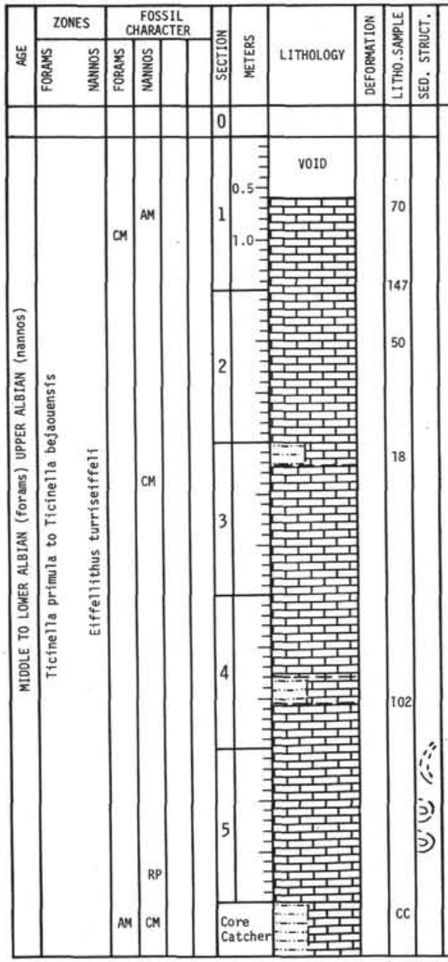
Carbonate Bomb: 1-51 to 52 cm = 35.8% $CaCO_3$

Carbon-Carbonate (DSDP)
4-92 (10.6, 0.1, 87)

Carbon-Carbonate (OG)
3-130 (8.7, 0.1, 88)
3-150 (6.6, 0.2, 54)

Explanatory notes in Chapter 1

Site 364 Hole Core 33 Cored Interval: 843.5-852.0 m



LITHOLOGIC DESCRIPTION

5Y 4/1
5Y 4/1
5YR 6/1
5B 7/1
5B 7/1
5G 5/1
Folds

LIMESTONE

MEGASCOPIC CORE DESCRIPTION

Colors alternate from olive gray (5Y 4/1), light bluish gray (5B 7/1) to light brownish gray (5YR 6/1). Zones of well developed lamination cut by a few burrows alternate with nonlaminated zones.. Some laminae are wavy and irregular.

TEXTURE

	1-147	4-102
Sand	0%	0%
Silt	3%	10%
Clay	97%	90%

COMPOSITION (SS)

1-147
78% Carbonate unspecified
20% Clay
2% Nannos

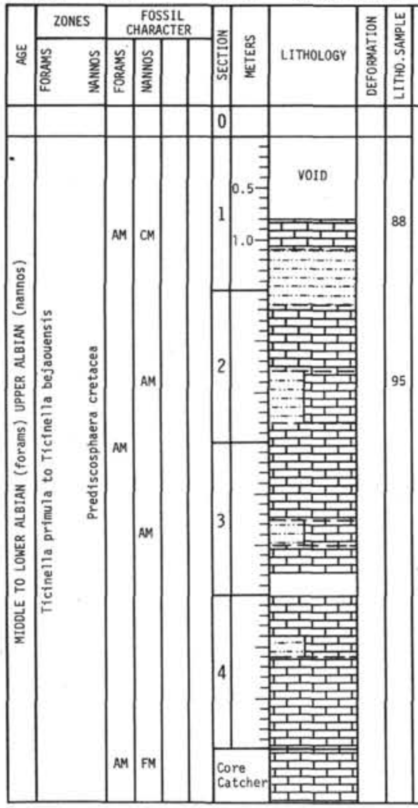
3-18
49% Carbonate unspecified
35% Clay
15% Nannos

Carbonate Bomb: 1-105 to 106 cm = 86.3% $CaCO_3$

Carbon-Carbonate (DSDP)
3-75 (7.2, 0.7, 54)

Grain Size (DSDP)
4-58 (8.4, 35.7, 55.9)

Site 364 Hole Core 34 Cored Interval: 872.0-881.5 m



LITHOLOGIC DESCRIPTION

5B 7/1
5GY 4/1
5GY 6/1
5B 7/1
5Y 5/1
0 G 5B 7/1
5Y 5/1
5GY 5/1

LIMESTONE AND MARLY LIMESTONE

MEGASCOPIC CORE DESCRIPTION
Limestone. Light bluish gray (5B 7/1) with minor grayish green (5GY 5/1). Styolitic seams, burrows, irregular laminae and nodular structure are common. Marly limestone. Dark green gray (5GY 4/1), greenish gray (5GY 6/1) to olive gray (5Y 5/1).

TEXTURE

	2-95	4-25
Sand	0%	0%
Silt	3%	2%
Clay	97%	98%

COMPOSITION (SS)
2-95
53% Carbonate unspecified
40% Clay
2% Forams
2% Quartz
1% Nannos

4-25
75% Carbonate unspecified
25% Clay

Carbonate Bomb: 1-138 to 139 cm = 24.6% $CaCO_3$

Carbon-Carbonate (DSDP)
4-53 (7.5, 0.3, 60)

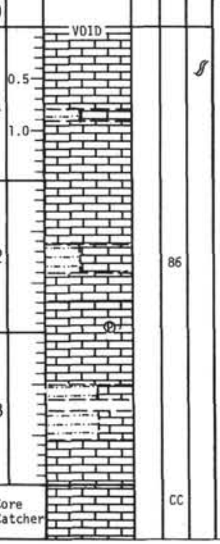
Carbon-Carbonate (OG)
3-130 (6.7, 0.6, 51)
3-150 (6.4, 0.1, 52)

Grain Size (DSDP)
4-50 (2.5, 34.7, 62.8)

Explanatory notes in Chapter 1

Site 364 Hole Core 35 Cored Interval: 891.0-900.5 m

AGE	ZONES FORAMS	ZONES NANNOS	FOSSIL CHARACTER FORAMS	FOSSIL CHARACTER NANNOS	SECTION	LITHO. SAMPLE
					0	
UPPER APTIAN (forams)-MIDDLE ALBIAN (nannos)	Hedbergella trochoidea to H. gorbachikae	Prediscosphaera cretacea		AM	1	
			AM	AM AM	2	86
				AM	3	
			RM	AM	Core Catcher	CC



Contorted bedding
5B 7/1
5G 4/1
5B 7/1
5G 5/1
5GY 4/1
5Y 4/1

LITHOLOGIC DESCRIPTION

LIMESTONE AND MARLY LIMESTONE

MEGASCOPIC CORE DESCRIPTION
Limestone. Light bluish gray (5B 7/1) with zone of greenish gray (5G 5/1). Some wavy lamination, contorted bedding appear deformed locally. Burrowing present only in light layers especially near top.

TEXTURE
2-86
3% Sand
25% Silt
72% Clay

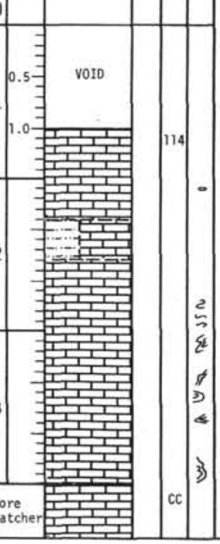
COMPOSITION (SS)
2-86
40% Clay
33% Carbonate unspecified
15% Forams
7% Dolomite rhombs
2% Nannos
1% Quartz
2% Pyrite

Carbonate Bomb: 1-17 to 18 cm = 74.2% $CaCO_3$

Carbon-Carbonate (DSDP)
3-67 (8.2, 1.4, 57)

Site 364 Hole Core 36 Cored Interval: 910.0-919.5 m

AGE	ZONES FORAMS	ZONES NANNOS	FOSSIL CHARACTER FORAMS	FOSSIL CHARACTER NANNOS	SECTION	LITHO. SAMPLE
					0	
UPPER APTIAN (forams)-MIDDLE ALBIAN (nannos)	Hedbergella trochoidea to H. gorbachikae	Prediscosphaera cretacea			1	114
					2	
					3	
			CM	CM	Core Catcher	CC



5Y 6/1
Nodular
5B 7/1
5GY 6/1
Folding
Contorted
bed
5GY 6/1

LITHOLOGIC DESCRIPTION

LIMESTONE AND MARLY LIMESTONE

MEGASCOPIC CORE DESCRIPTION
Limestone. Gray (5Y 6/1) to light bluish gray (5B 7/1) with minor greenish gray (5GY 6/1) stringers and laminae. The lower half core is strongly folded and appear to be "slump" structure.

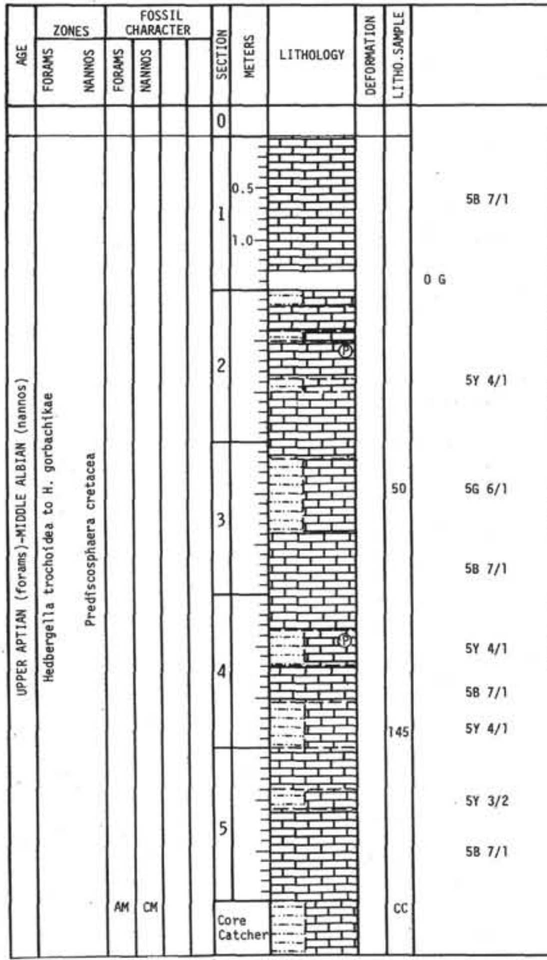
TEXTURE
1-114
0% Sand
20% Silt
80% Clay

COMPOSITION SS)
1-114
77% Carbonate unspecified
20% Clay
3% Dolomite rhombs

Carbonate Bomb: 2-40 to 41 cm = 81.0% $CaCO_3$

Explanatory notes in Chapter 1

Site 364 Hole Core 37 Cored Interval: 929.0-938.5 m



LITHOLOGIC DESCRIPTION

LIMESTONE AND MARLY LIMESTONE

MEGASCOPIC CORE DESCRIPTION
Limestone. Light bluish gray (5B 7/1) with several darker laminated zones with greenish gray (5G 6/1) laminae. Many olive gray (5Y 4/1) patches that appear to be disturbed burrow fillings. Marly limestone: greenish gray (5G 6/1) and olive gray (5Y 4/1) with strongly laminated layer in some area.

TEXTURE

	3-50	4-145
Sand	0%	3%
Silt	15%	25%
Clay	85%	72%

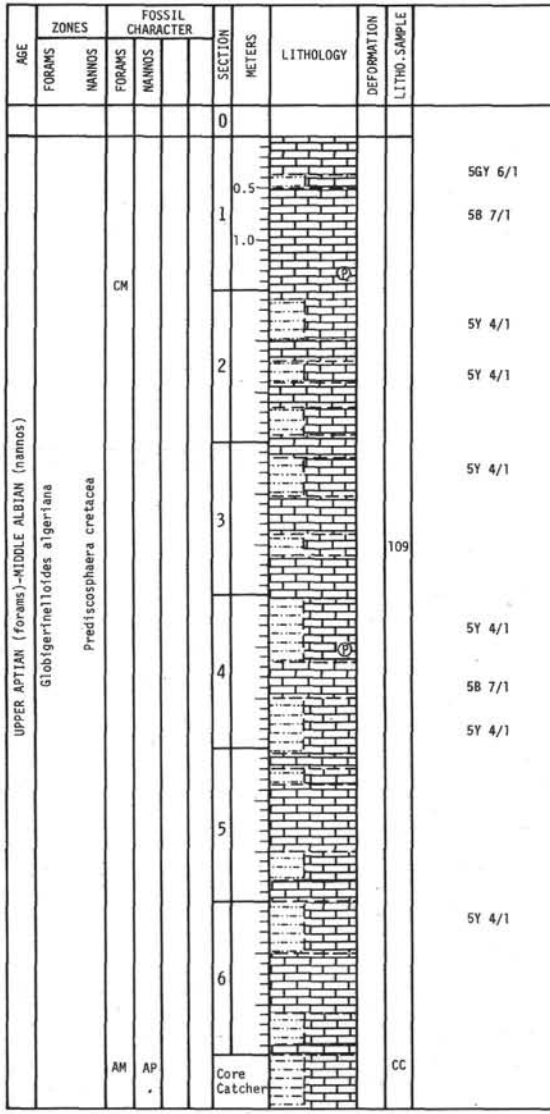
COMPOSITION (SS)
3-50
49% Carbonate unspecified
35% Clay
8% Dolomite rhombs
3% Nannos

4-145
44% Carbonate unspecified
15% Clay
13% Nannos
3% Pyrite
3% Forams
2% Dolomite rhombs

Carbonate Bomb: 1-6 to 7 cm = 81.8% $CaCO_3$

Carbon-Carbonate (OG)
1-130 (10.3, 0.1, 85)
1-150 (9.4, 0.1, 77)

Site 364 Hole Core 38 Cored Interval: 948.0-957.5 m



LITHOLOGIC DESCRIPTION

MARLY LIMESTONE AND LIMESTONE

MEGASCOPIC CORE DESCRIPTION
Marly limestone olive gray (5Y 4/1) laminated heavily. Burrowing limited. Limestone, light bluish gray (5B 7/1) massive limestone, heavily burrowed. Bluish black halos around some structure may be organic remains.

TEXTURE
3-109
5% Sand
30% Silt
65% Clay

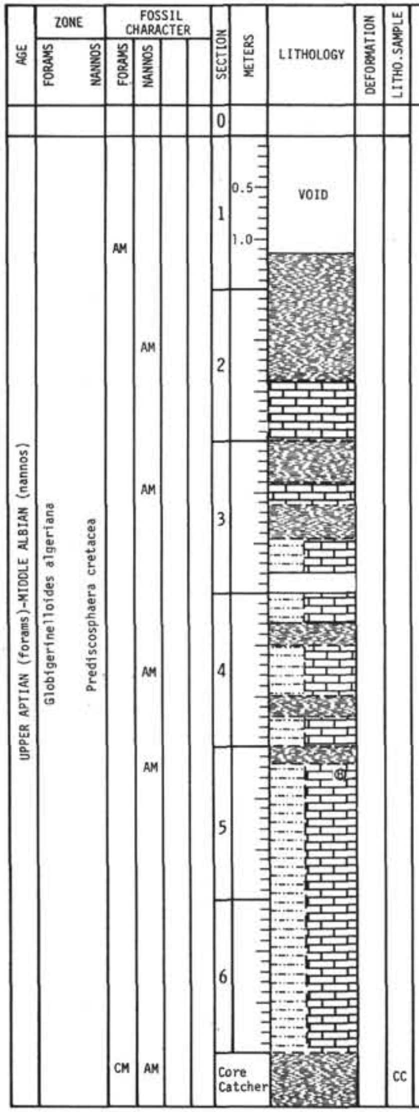
COMPOSITION (SS)
3-109
38% Carbonate unspecified
25% Organic matter
15% Nannos
15% Clay
10% Dolomite rhombs
5% Forams
2% Pyrite
T Quartz

Carbonate Bomb: 1-21 to 22 cm = 86.6% $CaCO_3$

Carbon-Carbonate (DSDP)
4-143 (7.8, 1.2, 55)
6-116 (10.0, 1.3, 73)

Explanatory notes in Chapter 1

Site 364 Hole Core 39 Cored Interval: 967.0-976.5 m



LITHOLOGIC DESCRIPTION

MARLY LIMESTONE AND BLACK SHALE WITH MINOR SAPROPELIC SHALE

MEGASCOPIC CORE DESCRIPTION
Marly limestone, most light gray (5Y 7/1) and light olive gray (5Y 6/1) to olive gray (5Y 4/1). Black shale, petrolified odor. Olive gray (5Y 4/1) to olive black (5Y 2/1). Laminated.

5Y 4/1

TEXTURE

	2-118	CC
Sand	5%	0%
Silt	25%	25%
Clay	70%	75%

COMPOSITION (SS)
2-118
52% Carbonate unspecified
20% Organic matter
15% Clay
10% Dolomite rhombs
3% Nannos

5Y 7/1

5Y 3/1

CC
62% Clay
10% Organic matter
3% Dolomite rhombs
3% Quartz
2% Pyrite

O G

5Y 4/1

Carbonate Bomb: 1-140 to 141 cm = 16.1% $CaCO_3$

5Y 3/1

Carbon-Carbonate (DSDP)
6-85 (11.2, 1.4, 82)

Carbon-Carbonate (OG)
3-127 (10.3, 1.5, 73)
3-150 (10.1, 2.4, 64)

5Y 6/1

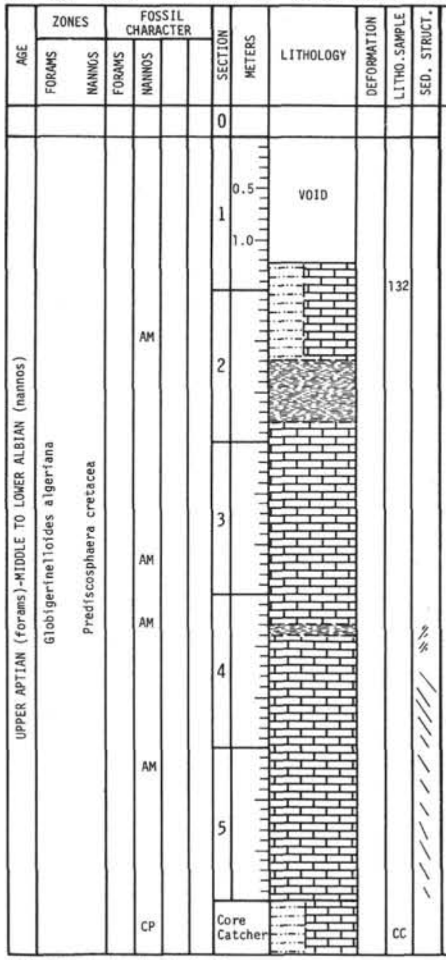
Barite vein

Shell (Inoceramus)

5Y 6/1

Shell

Site 364 Hole Core 40 Cored Interval: 986.0-995.5 m



LITHOLOGIC DESCRIPTION

LAMINATED LIMESTONE AND MARLY LIMESTONE WITH BLACK SAPROPELIC SHALE

MEGASCOPIC CORE DESCRIPTION
Olive gray (5Y 5/2), thinly laminated. Most lamination are straight and parallel. Small faults and folds are observed in the upper part of the core, while lower half dips steeply up to 60°. Petroliferous odor.

5Y 4/1

TEXTURE
1-132
0% Sand
15% Silt
85% Clay

COMPOSITION (SS)
1-132
49% Carbonate unspecified
35% Clay
8% Dolomite rhombs
3% Nannos
T Quartz

5Y 3/1

5Y 5/2

Carbonate Bomb: 2-132 to 133 cm = 85.8% $CaCO_3$

Carbon-Carbonate (DSDP)
4-44 (11.8, 4.9, 58)

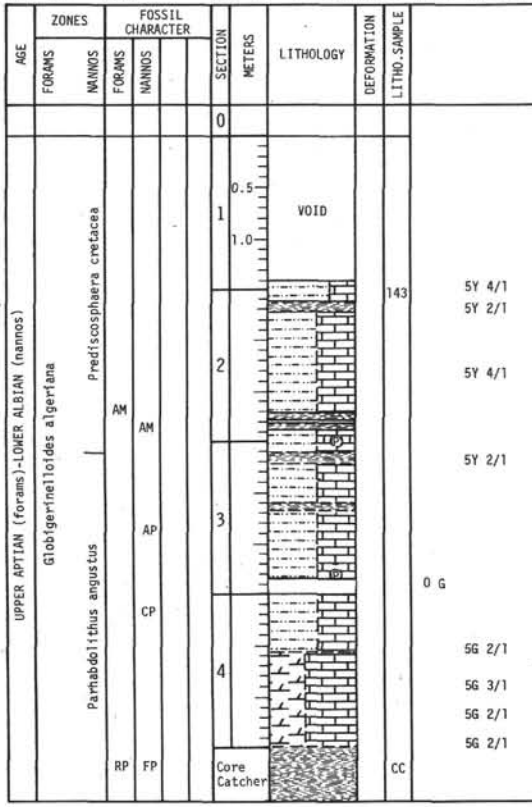
N1
Reverse faults

Inclination
60° maximum

5Y 5/2

Explanatory notes in Chapter 1

Site 364 Hole Core 41 Cored Interval: 1005.0-1014.5 m



LITHOLOGIC DESCRIPTION

MARLY LIMESTONE, BLACK SAPROPELIC SHALE AND DOLOMITIC LIMESTONE

MEGASCOPIC CORE DESCRIPTION
Thinly laminated marly limestone with petroliferous odor and appearance of sandy texture. Mostly olive gray (5Y 4/1). In the lower half of the core, some layers of massive limestone with burrowing with greenish black (5G 2/1).

TEXTURE
1-143
5% Sand
40% Silt
55% Clay

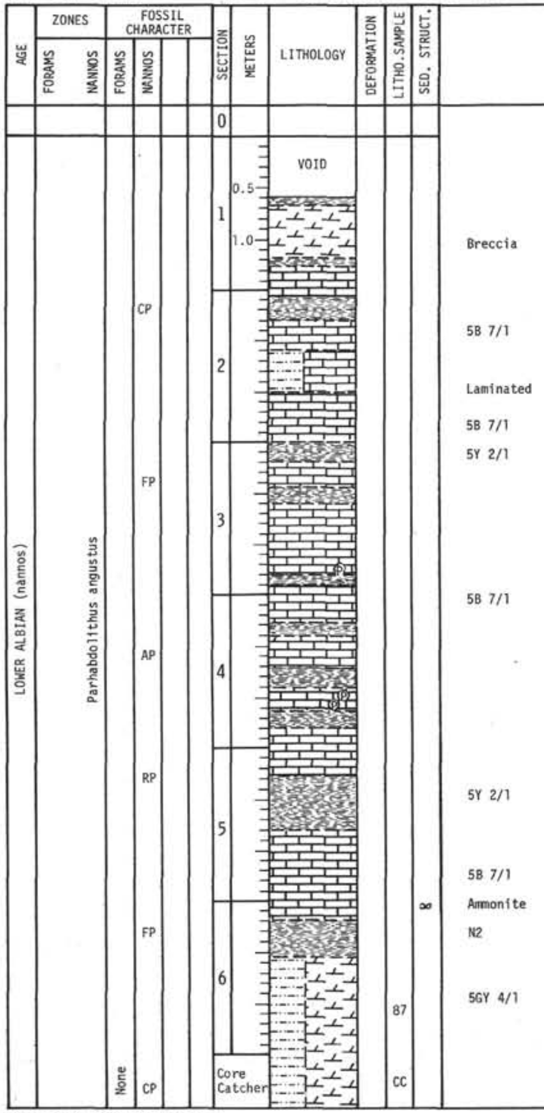
COMPOSITION (SS)
1-143
48% Carbonate unspecified
20% Dolomite rhombs
20% Clay
2% Pyrite

Carbonate Bomb: 2-140 to 141 cm = 35.4% $CaCO_3$

Carbon-Carbonate (DSDP)
4-32 (8.0, 3.8, 35)

Carbon-Carbonate (OG)
3-130 (11.2, 0.7, 87)
3-150 (12.2, 6.0, 51)

Site 364 Hole Core 42 Cored Interval: 1024.0-1033.5 m



LITHOLOGIC DESCRIPTION

MARLY DOLOMITIC LIMESTONE ALTERNATING WITH BLACK SHALE

MEGASCOPIC CORE DESCRIPTION
Light bluish gray (5B 7/1) limestone. Some have numerous fractures, heavy burrowing, pyritic burrow fillings. Some fragments appear to be rounded clasts rather than burrow fillings. Laminated calcareous mudstone olive black (5Y 2/1) to gray black (N2).

TEXTURE
6-87 to 89
30% Sand
20% Silt
50% Clay

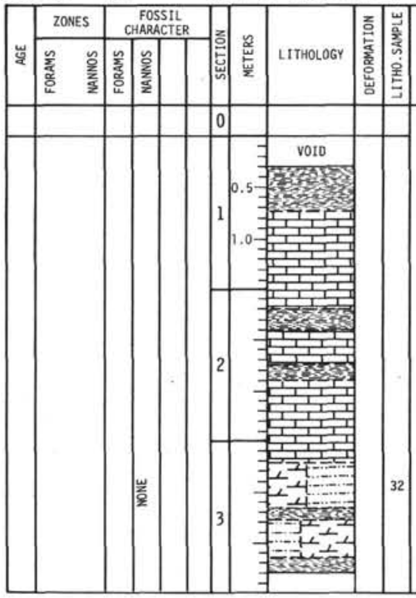
COMPOSITION (Thin section)
6-87 to 89
40% Clay
20% Forams
15% Organic matter
11% Carbonate unspecified
10% Dolomite rhombs
2% Quartz
2% Pyrite

Carbonate Bomb: 2-17 to 18 cm = 16.5% $CaCO_3$

Carbon-Carbonate (DSDP)
4-75 (12.7, 7.3, 45)
6-32 (25.5, 22.5, 25)

Explanatory notes in Chapter 1

Site 364 Hole Core 43 Cored Interval: 1033.5-1043.0 m



LITHOLOGIC DESCRIPTION

5Y 2/1
5G 6/1
5B 7/1
5B 7/1
5Y 4/1
0 G

LIMESTONE AND BLACK SHALE
(Part of limestone is dolomitic)

MEGASCOPIC CORE DESCRIPTION
Limestone, greenish gray (5G 6/1) to light bluish gray (5B 7/1). Very heavily burrowed, somewhat brecciated, dolomitic. Lower part has numerous fractures and faults. Black shale, olive black (5Y 2/1). Some evidence of minor burrowing at top.

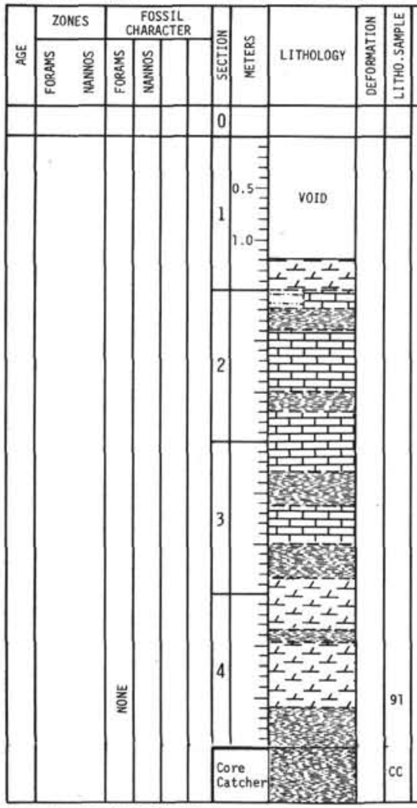
TEXTURE
3-32
3% Sand
32% Silt
65% Clay

COMPOSITION (SS)
60% Clay
28% Dolomite rhombs
10% Carbonate unspecified
1% Pyrite

Carbonate Bomb: 2-109 to 110 cm = 90.5% $CaCO_3$

Carbon-Carbonate (OG)
1-130 (14.7, 7.4, 61)
1-150 (9.5, 0.3, 77)

Site 364 Hole Core 44 Cored Interval: 1043.0-1052.5 m



LITHOLOGIC DESCRIPTION

5GY 4/1
N1
5Y 4/1
N1
5GY 5/1

ALTERNATING DOLOMITIC LIMESTONE AND BLACK SHALE

MEGASCOPIC CORE DESCRIPTION
Black (N1) shale interbedded with olive gray (5Y 4/1), dark greenish gray (5GY 4/1) and olive gray (5Y 4/1) limestone. Limestone moderate to heavily burrowed. Shale thinly laminated, fine-grained, uniformly black shale is calcareous.

TEXTURE
4-91
0% Sand
85% Silt
15% Clay

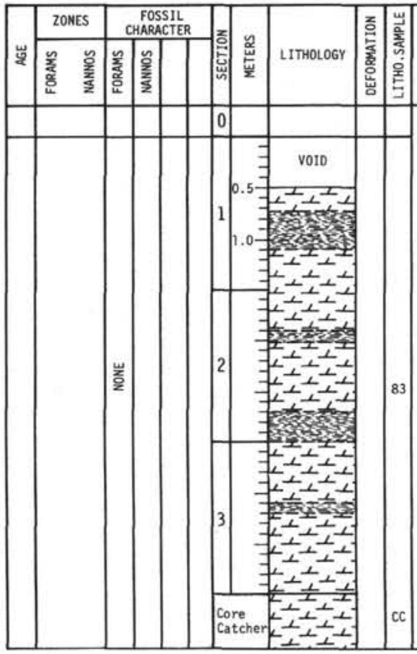
COMPOSITION (SS)
4-91
93% Dolomite
5% Carbonate unspecified
T Quartz

Carbonate Bomb: 2-17 to 18 cm = 53.5% $CaCO_3$

Carbon-Carbonate (DSDP)
4-10 (11.4, 1.2, 84)

Explanatory notes in Chapter 1

Site 364 Hole Core 45 Cored Interval: 1062.0-1071.5 m



LITHOLOGIC DESCRIPTION

5Y 4/1
N1
5Y 4/1
N1
5Y 2/1
N1

DOLOMITIC LIMESTONE AND BLACK SHALE

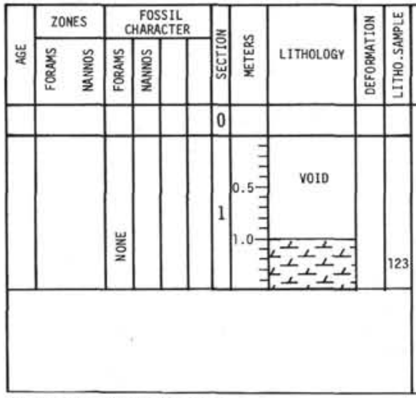
MEGASCOPIC CORE DESCRIPTION
Olive gray (5Y 4/1) to olive black (5Y 2/1) dolomite, heavily burrowed. Faulting and contorted laminae are observed at the lower half of the core.

TEXTURE
2-83
0% Sand
80% Silt
20% Clay

COMPOSITION (SS)
58% Dolomite
30% Clay
5% Carbonate unspecified
2% Pyrite

Carbonate Bomb: 1-140 to 141 cm = 80.3% $CaCO_3$

Site 364 Hole Core 46 Cored Interval: 1081.0-1086.0 m



LITHOLOGIC DESCRIPTION

5Y 4/1
5Y 3/1

DOLOMITE

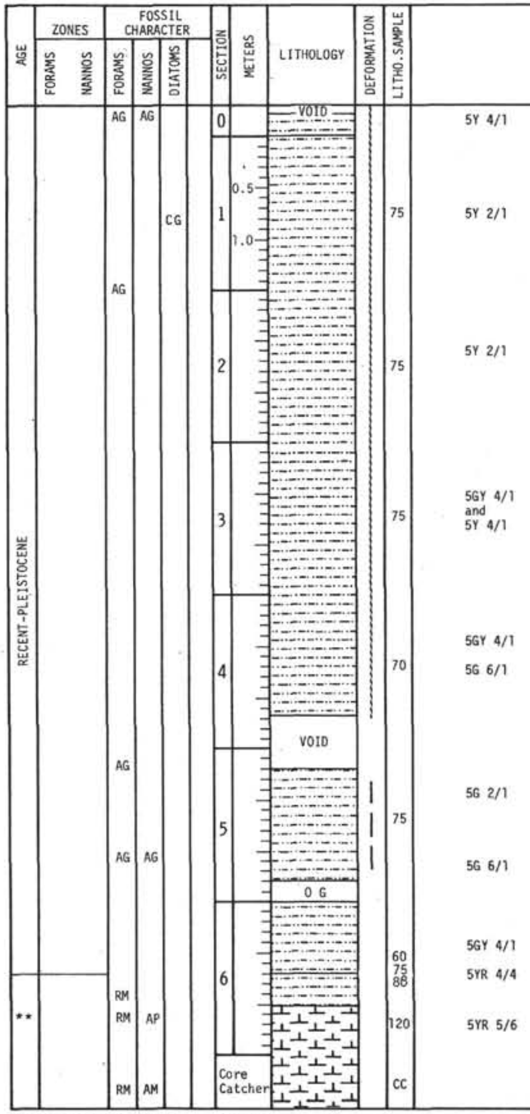
MEGASCOPIC CORE DESCRIPTION
Olive gray (5Y 4/1) to dark oli-e gray (5Y 3/1). Dolomite, heavily burrowed.

TEXTURE
1-123
2% Sand
85% Silt
13% Clay

COMPOSITION (SS)
75% Dolomite
10% Clay
3% Carbonate unspecified
2% Pyrite
T Quartz

Explanatory notes in Chapter 1

Site 365 Hole Core 1 Cored Interval: 225.0-234.5 m



LITHOLOGIC DESCRIPTION

7.1 meters of olive gray (5Y 4/1), olive black (5Y 2/1), and dark gray green (5GY 4/1) mud containing carbonaceous material and pyrite. Underlying the mud is 30 cm of moderate brown (5YR 4/4) terrigenous mud and 50 cm of moderate brown (5YR 4/4) and light brown (5YR 5/6) calcareous nannofossil ooze.

MUD
SS 1-75, 2-75, 3-75, 4-70, 5-75, 6-60
70-95% Clay
3-10% Pyrite
2-10% Plant debris
1- 5% Quartz
2- 3% Mica
1- 5% Forams
T- 5% Nannos
0- 2% Diatoms
0- 4% Rads
0- 2% Sponge spicules

Sand: 1%, Silt: 15%, Clay: 84%

MUD (Section 6, 70-100 cm)
SS 6-28, 6-75
75% Clay
3% Pyrite
5% Zeolites
2% Iron oxide
15% Quartz

Sand: 0%, Silt: 3-5%, Clay: 95-97%

NANNOFOSSIL OOZE
SS 6-120
81-92% Nannos
5-15% Clay
2% Plant debris
1- 2% Quartz

Sand: 0%, Silt: 20%, Clay: 80%

Coarse Fractions: 1 cc red and gray
Red: Forams 65%, Mica 35%, plus traces of Fish teeth, Glauconite, and Pyrite.
Gray: Pyrite 65%, Forams 30%, Barite 4%, plus Fish teeth, Quartz, and Mica.

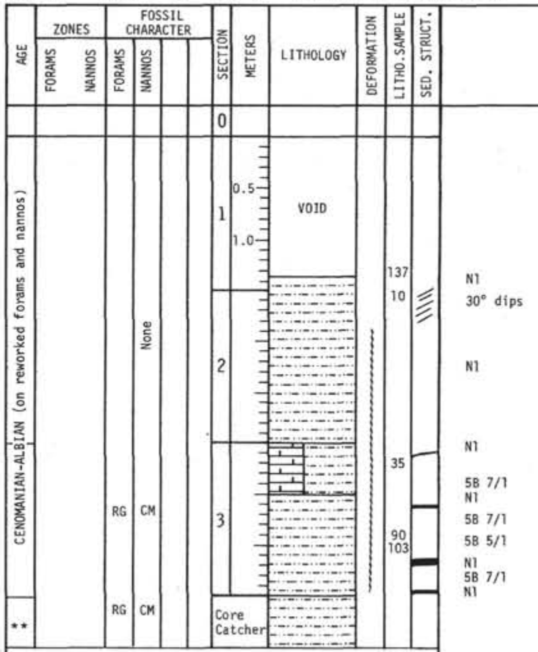
Carbon-Carbonate (DSDP)
4-20 (2.8, 1.0, 15)
6-122 (7.9, 0.0, 66)

Carbon-Carbonate (OG)
5-130 (2.7, 2.1, 5)
5-150 (3.0, 2.5, 4)

Grain Size (DSDP)
4-66 (3.3, 15.0, 81.7)
6-115 (0.0, 32.7, 67.3)

** CENOMANIAN-ALBIAN (on reworked forams and nannos)

Site 365 Hole Core 2 Cored Interval: 320.0-329.5 m



LITHOLOGIC DESCRIPTION

Black (N1) pyritic and organic-rich laminated mudstone overlying light bluish gray (5B 7/1) marly nannofossil chalk and medium bluish gray (5B 5/1) mudstone. Thin interbeds of black laminated mudstone present in Section 3. Laminae dipping 30° in top 10 cm of Section 2.

LAMINATED MUDSTONE (Sections 1 and 2)
SS 1-137, 2-10
60-70% Clay
5-10% Pyrite
10-15% Organics
10-20% Quartz
T Fish remains
T Unspecified carbonate
1% Heavy minerals

Sand: 1%, Silt: 15%, Clay 84%

MARLY NANNOFOSSIL CHALK (Section 3)
SS 3-35
30% Clay
50-60% Nannos
5% Pyrite
1% Dolomite rhombs
5- 7% Quartz
1% Zeolites
2% Unspecified carbonate

Sand: 1%, Silt: 15%, Clay 84%

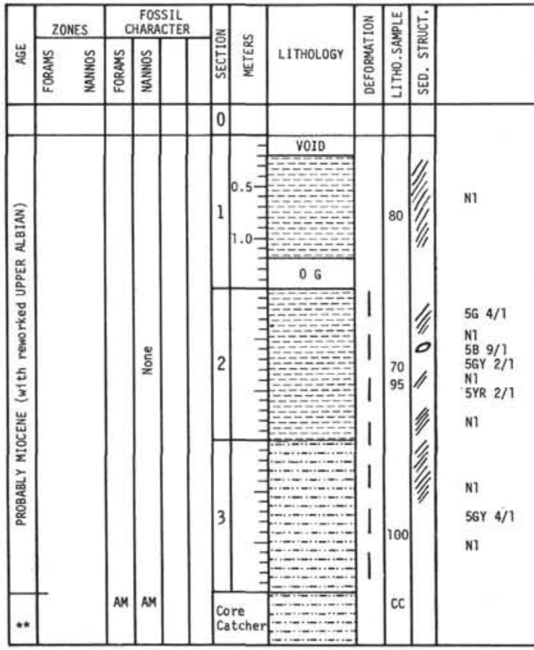
MUDSTONE (Section 3)
SS 3-90, 3-103
80-85% Clay
5-10% Pyrite
2- 5% Quartz
1-10% Mica
T- 2% Zeolites
T- 1% Heavies
T- 1% Dolomite rhombs
T Unspecified carbonate
T Rads
T- 1% Nannos

Coarse Fractions: 2 cc white
Forams 55%, Lith. fragments 35%, Pyrite 7%, Quartz 3%, Mica 1%, Fish debris T%, and Aragonite T%.

Carbon-Carbonate (DSDP)
2-44 (15.7, 15.6, 1)

** CAMPANIAN (on reworked forams and nannos)
Explanatory notes in Chapter 1

Site 365 Hole Core 3 Cored Interval: 396.0-405.5 m



LITHOLOGIC DESCRIPTION

Laminated claystone and mudstone with 1 thin bluish white (5B 9/1) limestone bed. Black (N1) is predominant color. Dark greenish gray (5GY 4/1), greenish black (5GY 2/1), and brownish black (5YR 2/1) layers are present. Soft mud occurs near base of Section 2. Moderate burrowing.

LAMINATED CLAYSTONE AND MUDSTONE
SS 1-80, 2-70, 2-95, 3-100, CC
50-60% Clay
10% Quartz
5-15% Mica
3-10% Pyrite
10-15% Organics
2% Dolomite rhombs
T Nannos

CLAYSTONE	MUDSTONE
0% Sand	4% Sand
5% Silt	30% Silt
95% Clay	66% Clay

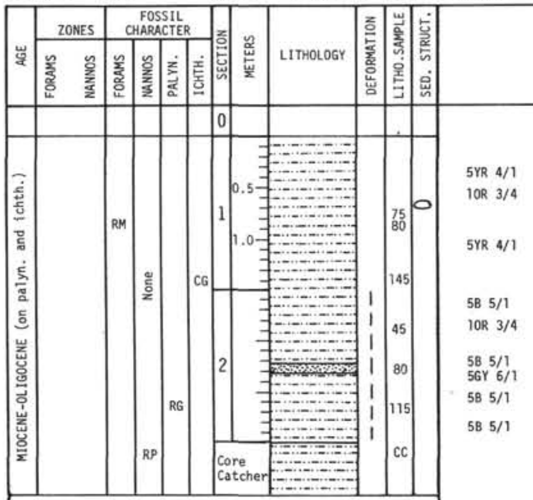
Coarse Fractions: 3 cc
Forams 84%, Lith. fragments 9%, Pyrite 5%, Quartz 1%, Feldspar T%.

Carbon-Carbonate (DSDP)
1-84 (18.5, 17.4, 9)

Carbon-Carbonate (OG)
1-120 (6.7, 6.6, 1)
1-150 (2.4, 2.4, 0)

** CENOMANIAN-UPPER ALBIAN (on reworked forams and nannos)

Site 365 Hole Core 4 Cored Interval: 462.5-472.0 m



LITHOLOGIC DESCRIPTION

Brownish gray (5YR 4/1) and medium bluish gray (5B 5/1) mudstone with minor amounts of dark reddish brown (10YR 3/4) mudstone. Red and brown colors identical to grays except for percent of iron oxide. Section 2 has 10 cm of greenish gray (5GY 6/1) dolomite cemented sandstone.

MUDSTONE
SS 1-75, 1-80, 1-145, 2-45, 2-115
70-75% Clay
15-20% Mica
2-10% Quartz
2% Pyrite
T Chlorite
T Heavy minerals

Sand: 2%, Silt: 25%, Clay: 73%

SANDSTONE (75-85 cm in Section 2)
Coarse-grained green sandstone that is cemented with carbonate in lower 4 cm.

35-40% Quartz
5% Feldspar
3% Chlorite
3% Mica
1% Epidote
1% Opaques
T Zircon
45% Dolomite
3% Carbonate

Dolomite occurs as silt-size rhombs. Larger carbonate fragments present.

Sand: 40%, Silt: 40%, Clay: 20%

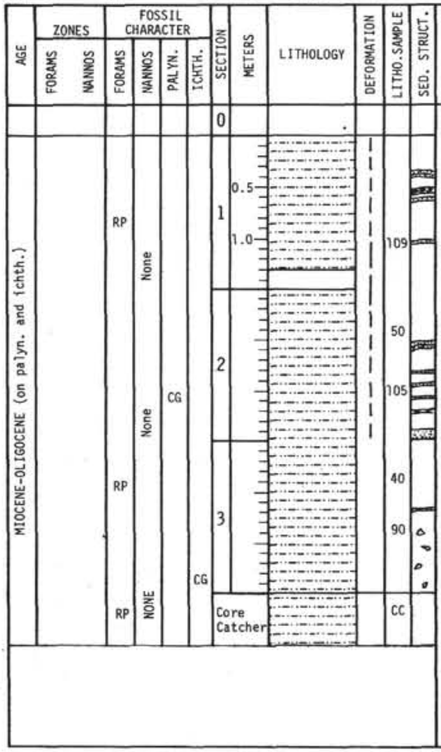
Coarse Fractions: 4 cc
Quartz 40%, Unspecified carbonate 25%, Fish teeth 18%, Mica 7%, Pyrite 6%, and Epidote 4%.

Carbon-Carbonate (DSDP)
1-34 (0.1, 0.1, 0)

Grain Size (DSDP)
1-42 (0.2, 18.1, 81.6)

Explanatory notes in Chapter 1

Site 365 Hole Core 5 Cored Interval: 510.0-519.5 m



LITHOLOGIC DESCRIPTION

5G 6/1

0 G

5B 5/1

5B 5/1

10R 4/2
5B 5/1

Greenish gray (5G 6/1) mudstone with scattered fine sandy layers that probably represent turbidites. One bed is graded. Burrowing is moderate but most sandy layers are burrowed. Good Zoophycos occur in Sections 1 and 2. Angular mud clasts occur in Section 3 between 75 and 150 cm.

<u>MUDSTONE</u>
SS 1-109, 3-90, 2-105, CC
82% Clay
7% Quartz
10% Mica
1% Pyrite
T Heavy minerals

Sand: 1%, Silt: 10%, Clay: 89%

<u>SANDSTONE</u> (Thin beds in unit)
SS 2-50, 3-40
65-70% Quartz
5% Feldspar
3- 5% Mica
15-20% Clay
2- 3% Heavies
3- 5% Pyrite

Sand: 70%, Silt: 20%, Clay: 10%

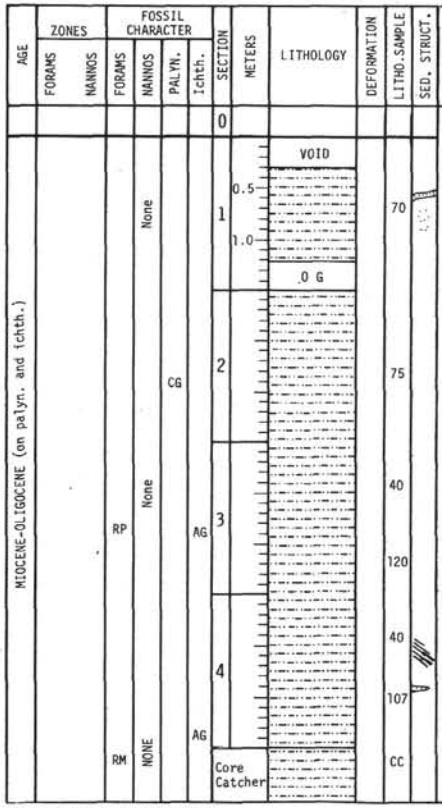
<u>Coarse Fractions</u>:
Quartz 65%, Unspecified carbonate 25%, Fish teeth 1%, Chlorite 5%, Mica 2%.

<u>Carbon-Carbonate (DSDP)</u>
2-5 (0.1, 0.1, 0)

<u>Carbon-Carbonate (OG)</u>
1-130 (0.2, 0.2, 0)
1-150 (0.2, 0.1, 1)

<u>Grain Size (DSDP)</u>
2-36 (1.2, 16.8, 82.0)

Site 365 Hole Core 6 Cored Interval: 614.5-624.0 m



LITHOLOGIC DESCRIPTION

5G 6/1

5G 4/1

10R 3/4

Mudstone: greenish gray (5G 6/1), medium bluish gray (5B 5/1), with minor reddish brown. Moderately burrowed. Agglutinated benthonic foraminifera appear as white "specks" in the dark mudstone.

<u>MUDSTONE</u>
SS 1-70, 2-75, 3-40, 3-120, 4-40, 4-107
65-70% Clay
20-25% Mica
3- 5% Quartz
1- 3% Pyrite
1% Heavies
T- 5% Zeolites
T- 5% Chlorite

Sand: 1%, Silt: 25%, Clay: 74%

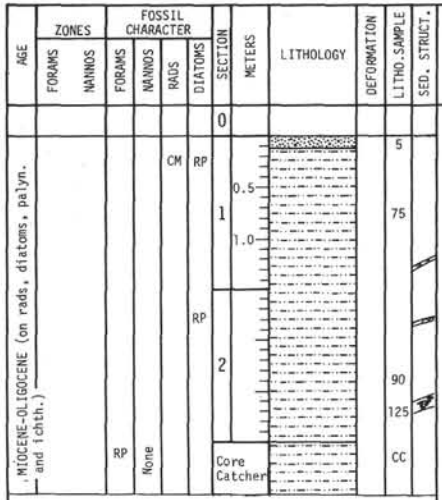
<u>Coarse Fractions</u>: 6 cc
Quartz 30%, Fish debris 33%, Mica 25%, Unspecified carbonate 10%, and Pyrite 2%.

<u>Carbon-Carbonate (DSDP)</u>
4-15 (0.4, 0.4, 0)

<u>Grain Size (DSDP)</u>
4-16 (2.5, 58.7, 38.9)

Explanatory notes in Chapter 1

Site 365 Hole Core 7 Cored Interval: 681.0-687.0 m



LITHOLOGIC DESCRIPTION

5G 4/1
5B 2/1
Zoophycos
5B 5/1
10R 4/2
5B 5/1

Medium bluish gray (5B 5/1) mudstone with abundant white benthonic foraminifera. Slightly burrowed. At top is 12 cm of greenish gray (5B 6/1) sand with numerous black grains. This same sand fills between the core and the liner in both sections and probably represents a sandy unit between Cores 6 and 7 that was washed instead of cored.

<u>MUDSTONE</u>
SS 1-75, 2-90, 2-125, CC
80% Clay
5-15% Mica
3% Quartz
2% Pyrite
T- 2% Chlorite
1- 2% Zeolites
0- 3% Organics

Sand: 1%, Silt: 10-15%, Clay: 84-89%

SAND
SS 1-5
49% Quartz
10% Mica
20% Clay
6% Pyrite
15% Zeolites

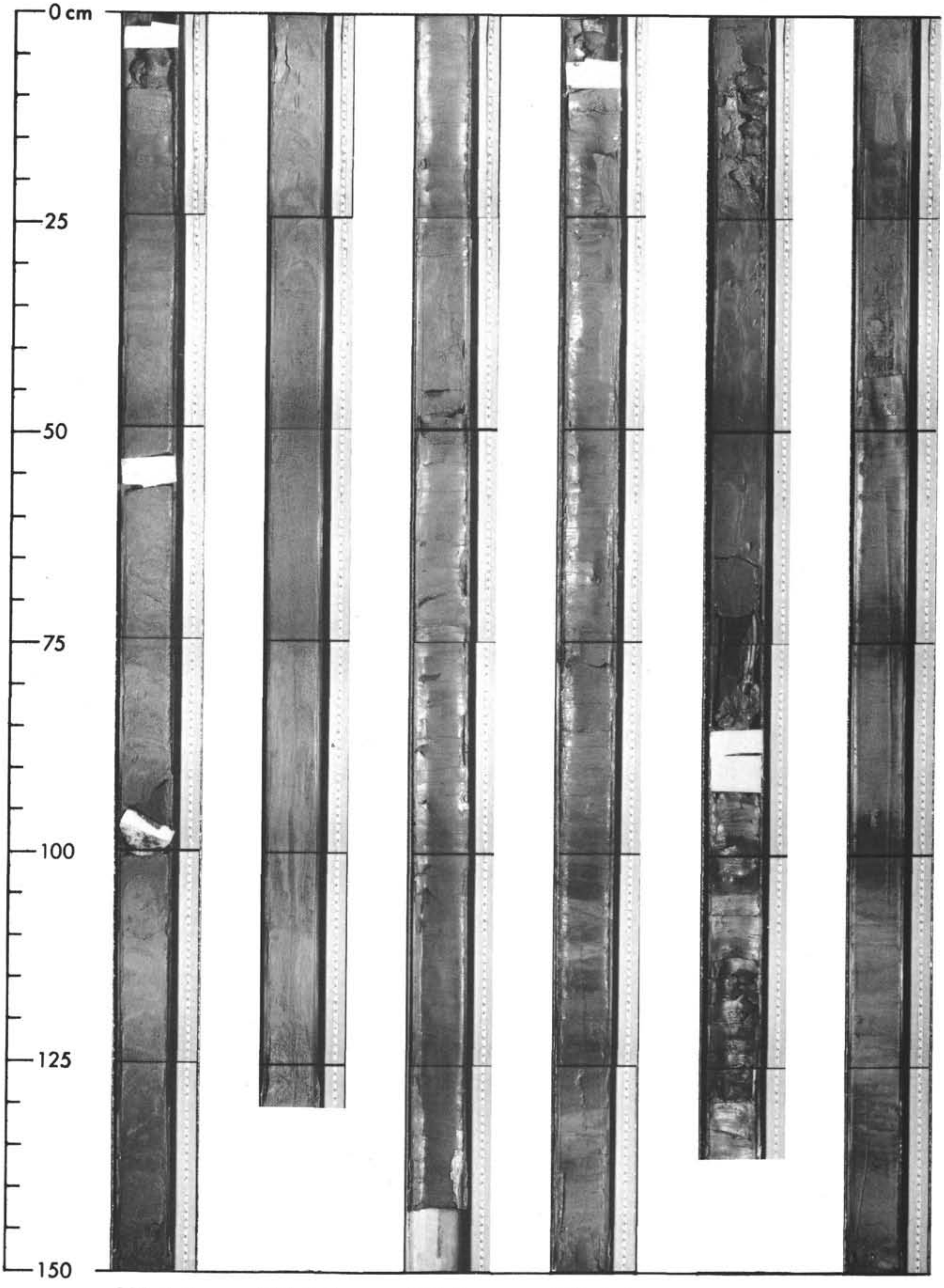
The numerous euhedral silt-sized zeolites in this sand suggests it is a washed residue from the drilling operation.

Coarse Fractions: 7 cc
Quartz and Fedlspar 30%, Lith. fragments 50%, Fish teeth 9%, Mica 5%, Unspecified carbonate 2%, Pyrite 1%, Forams 2%, Pyritized rads T%. Some quartz well-rounded.

Carbon-Carbonate (DSDP)
1-63 (0.1, 0.1, 0)

Grain Size (DSDP)
1-38 (0.4, 40.5, 59.1)

Explanatory notes in Chapter 1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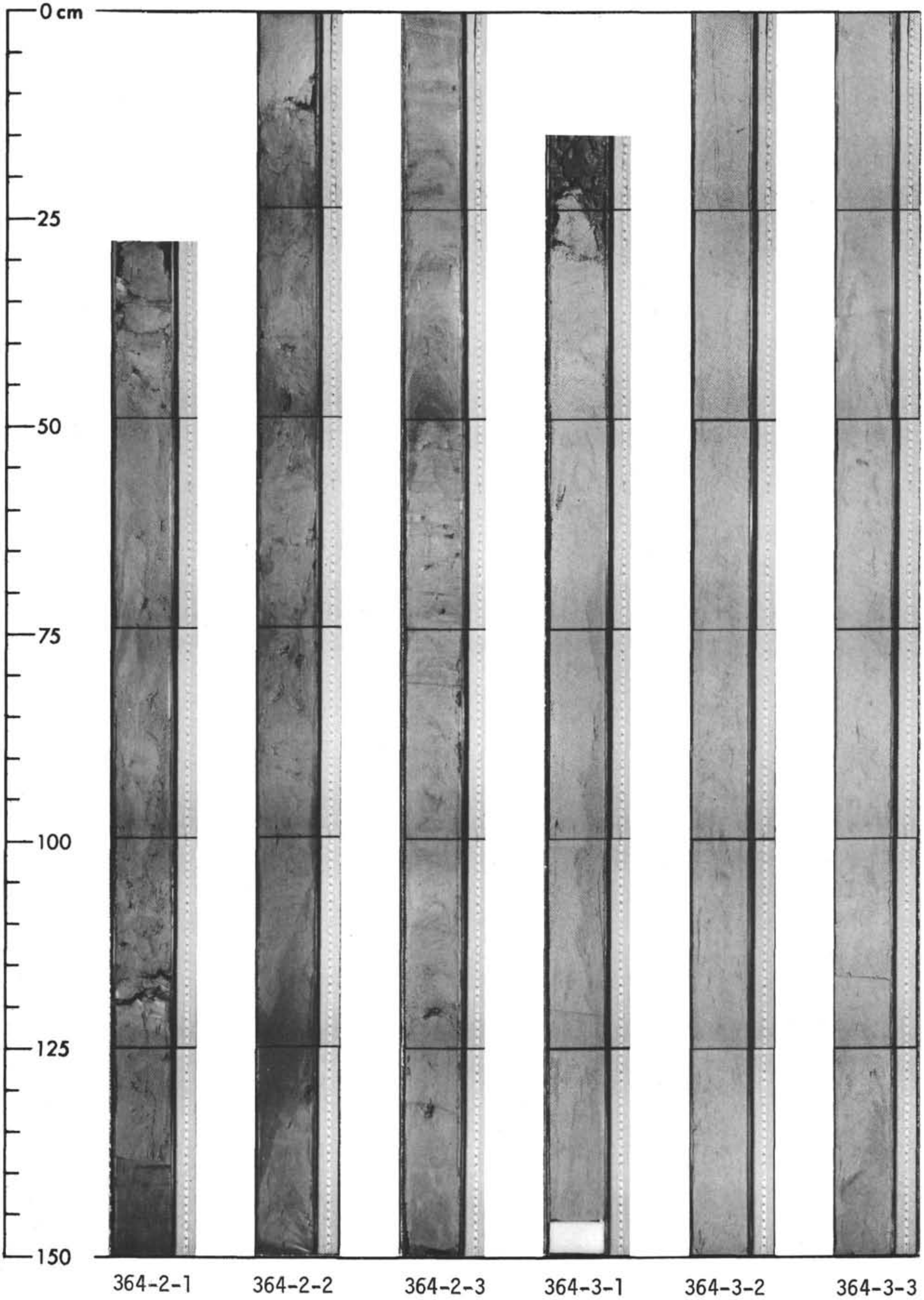
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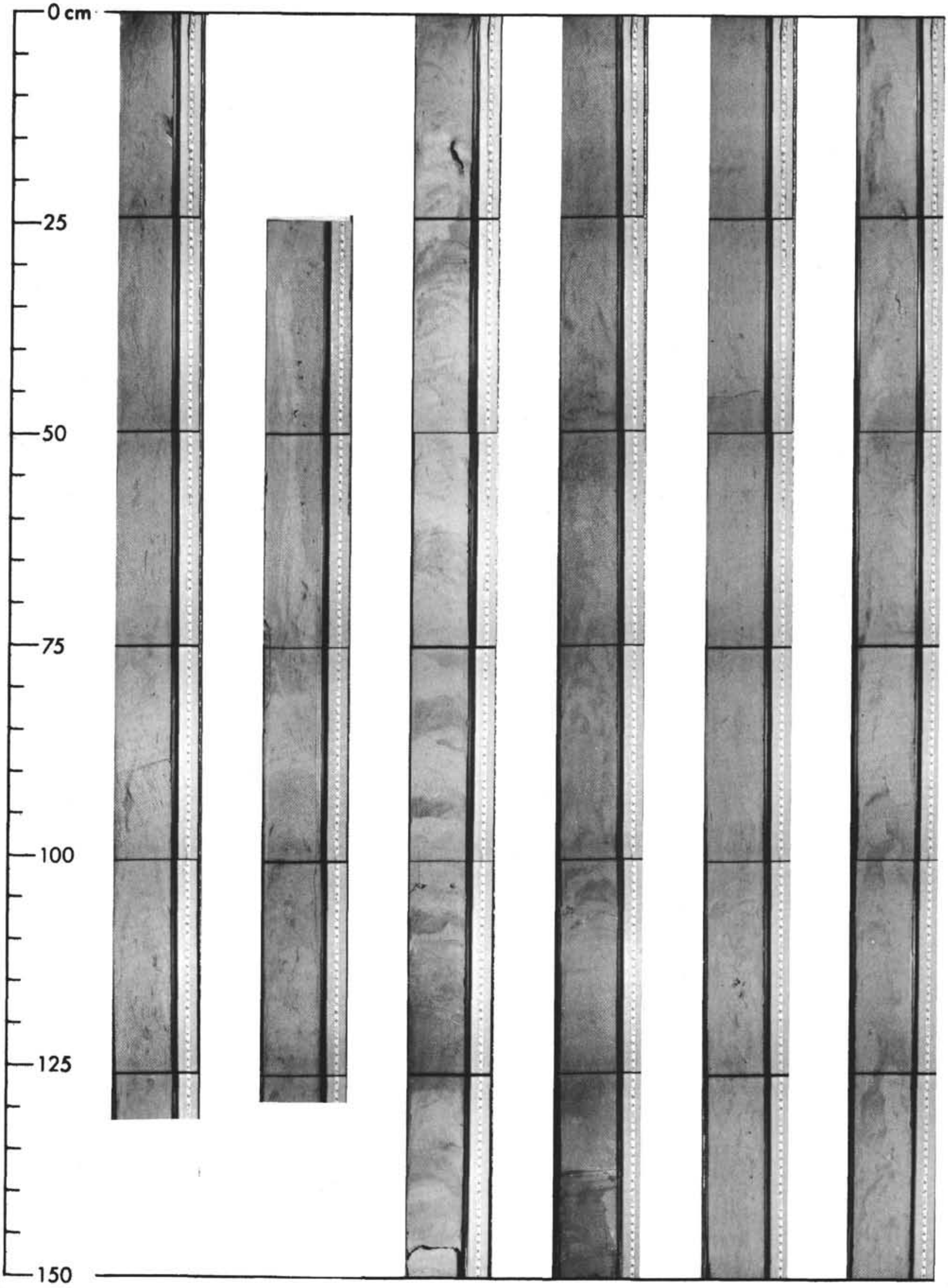

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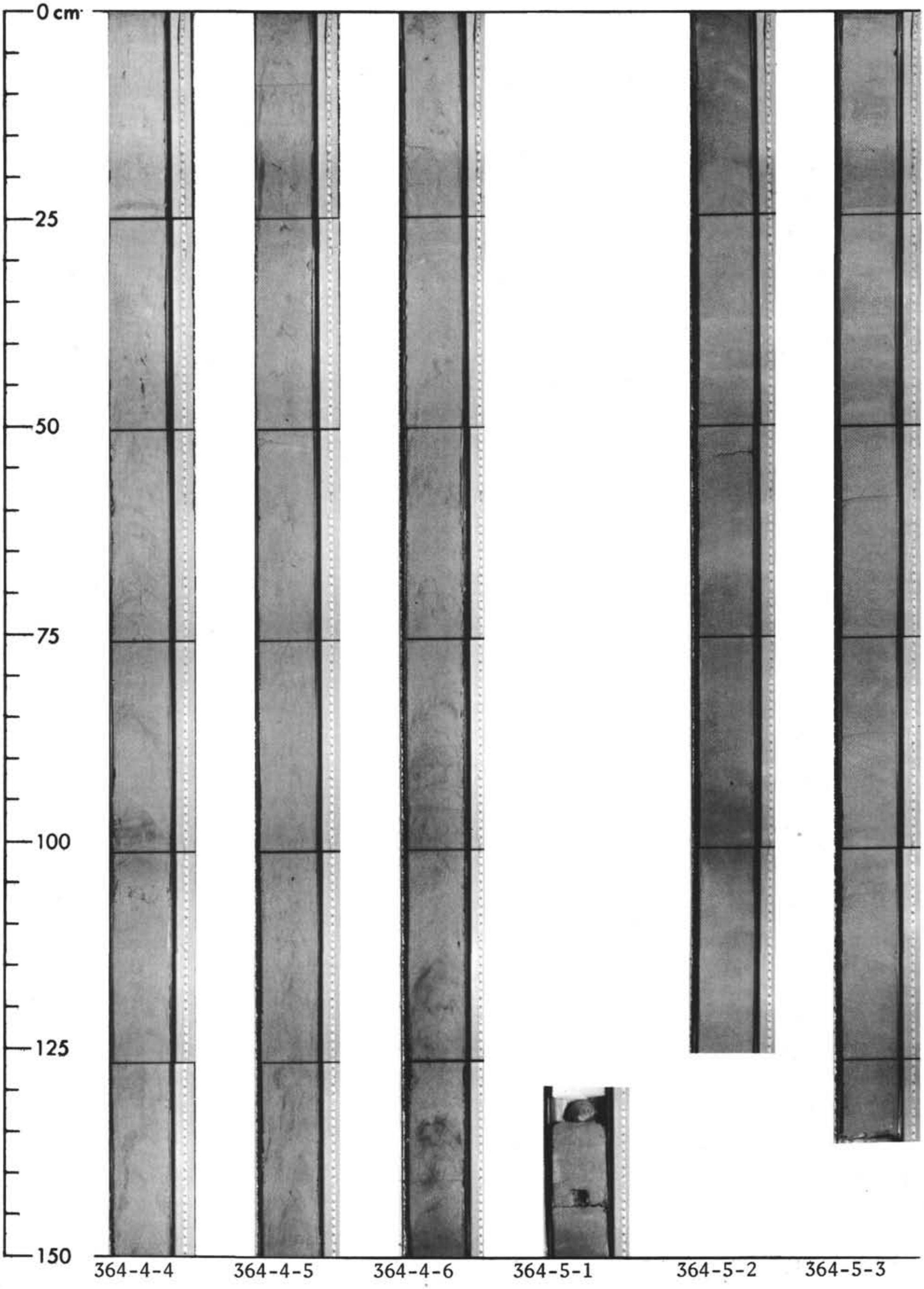
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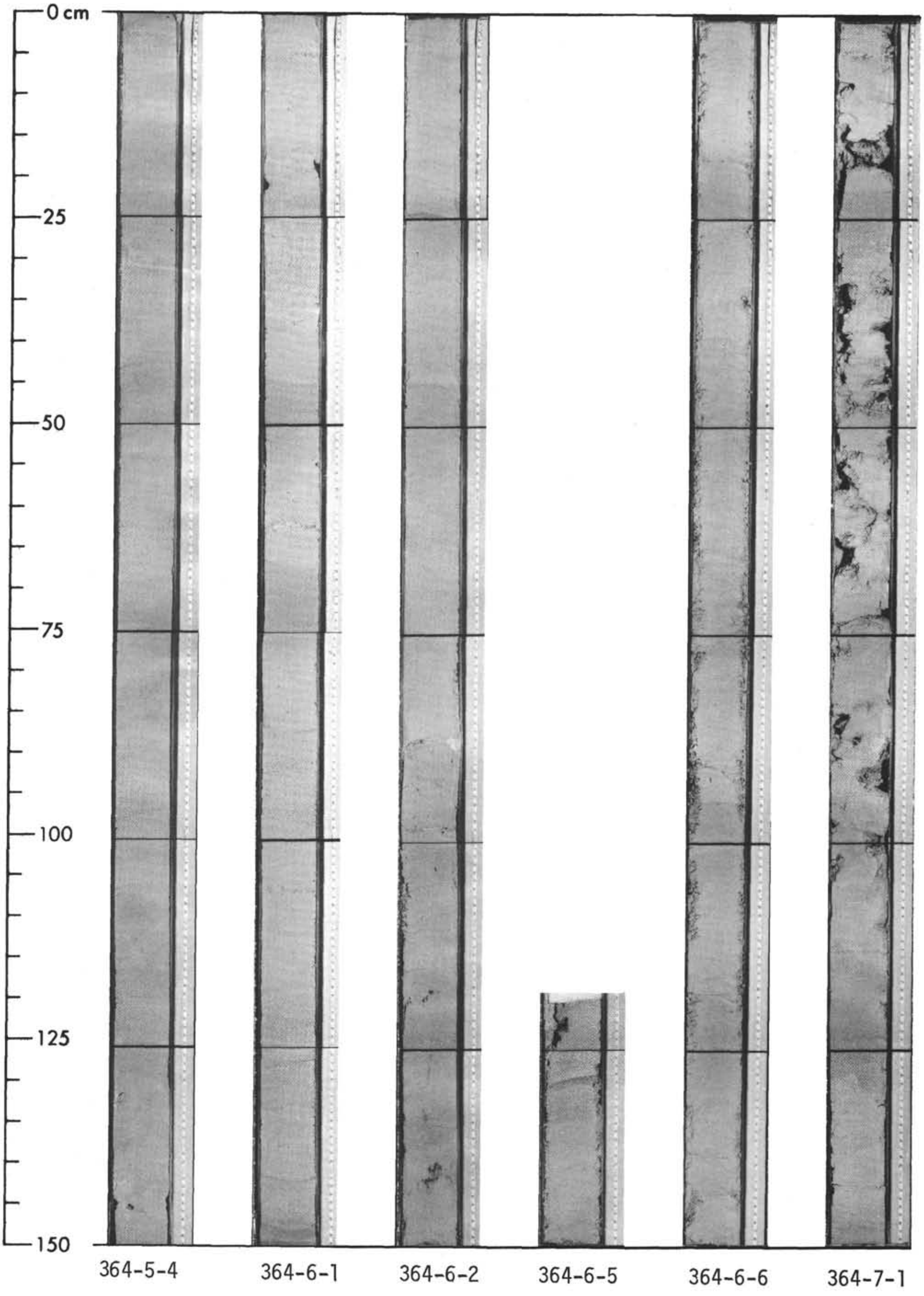
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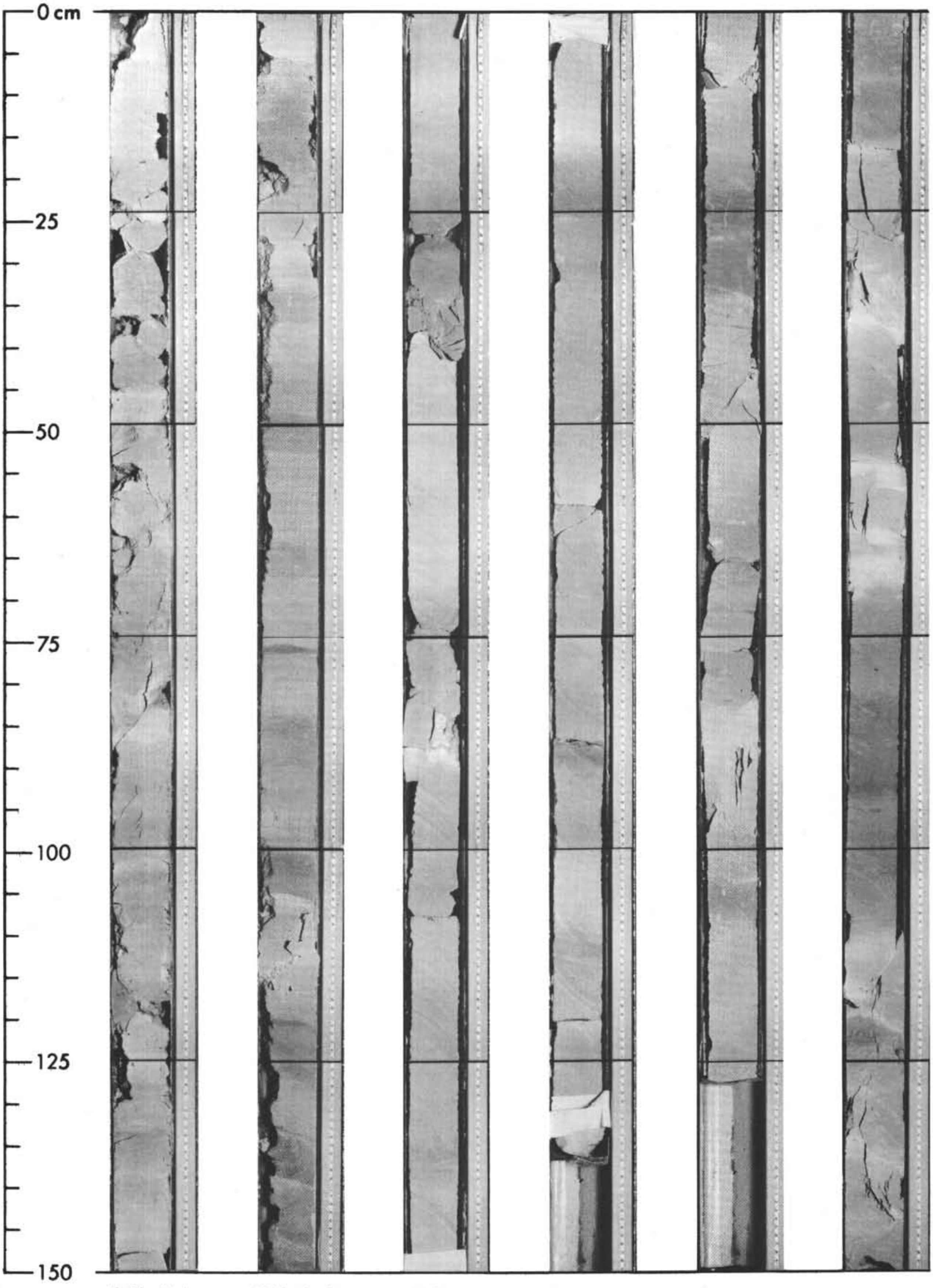
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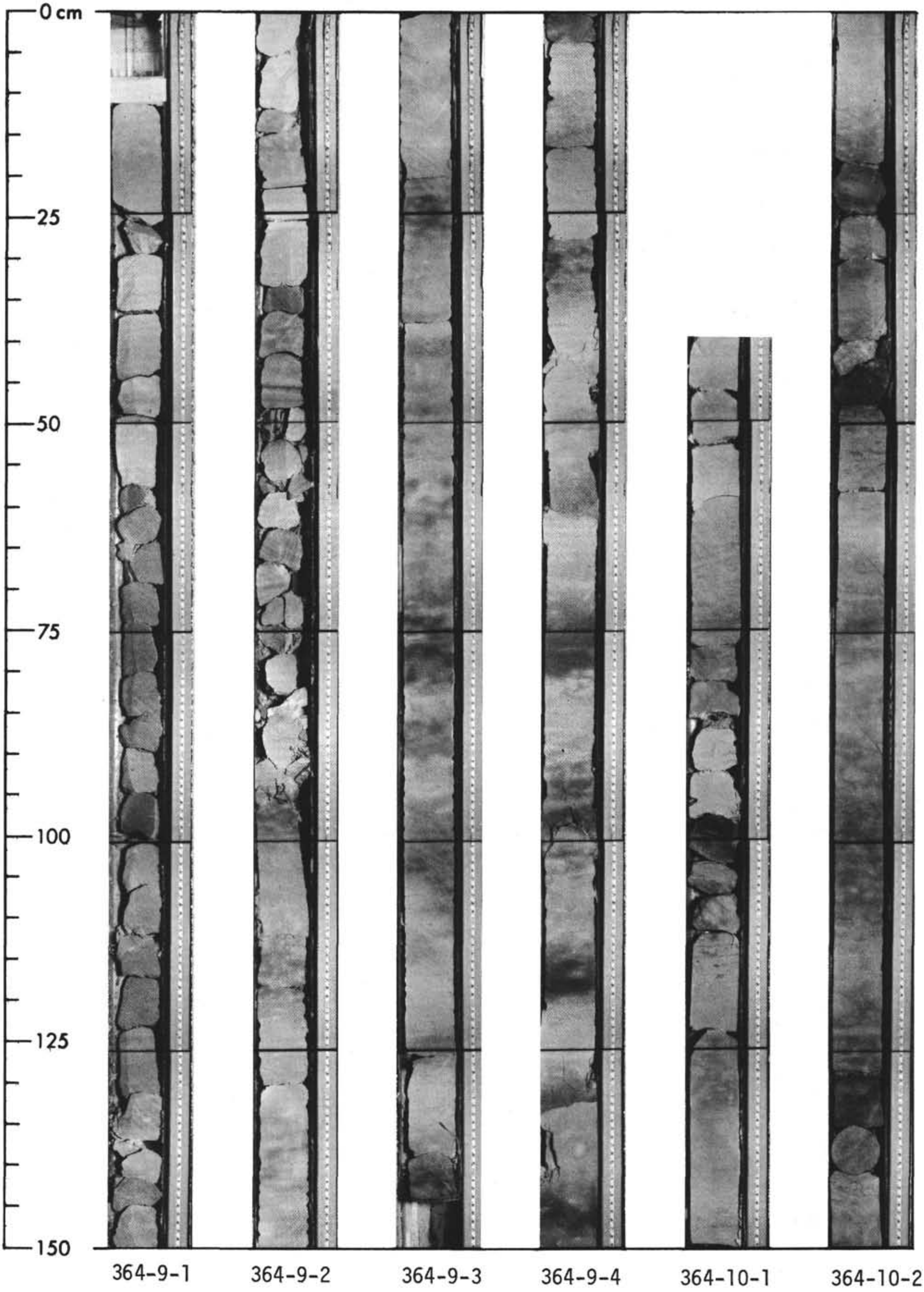
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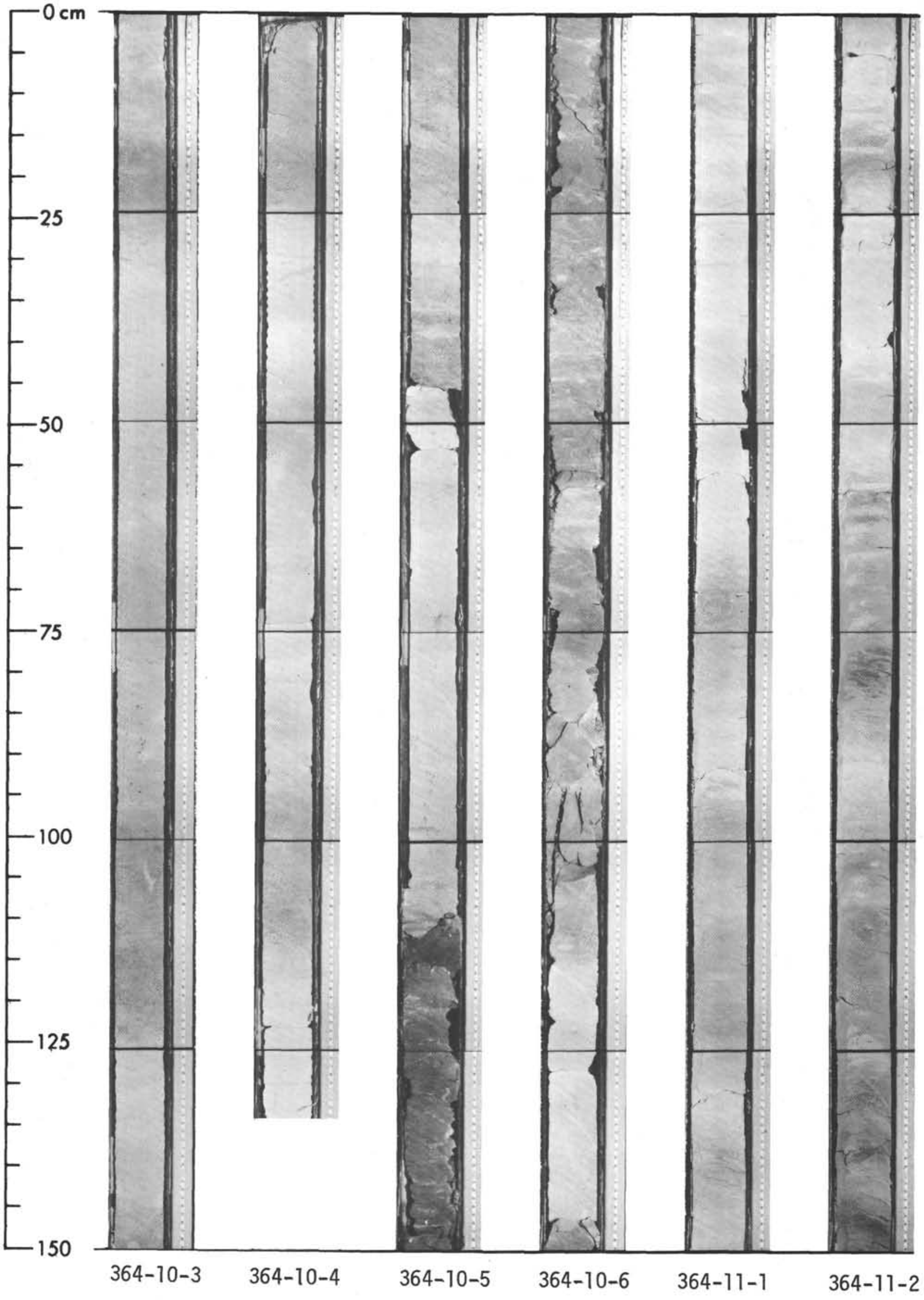
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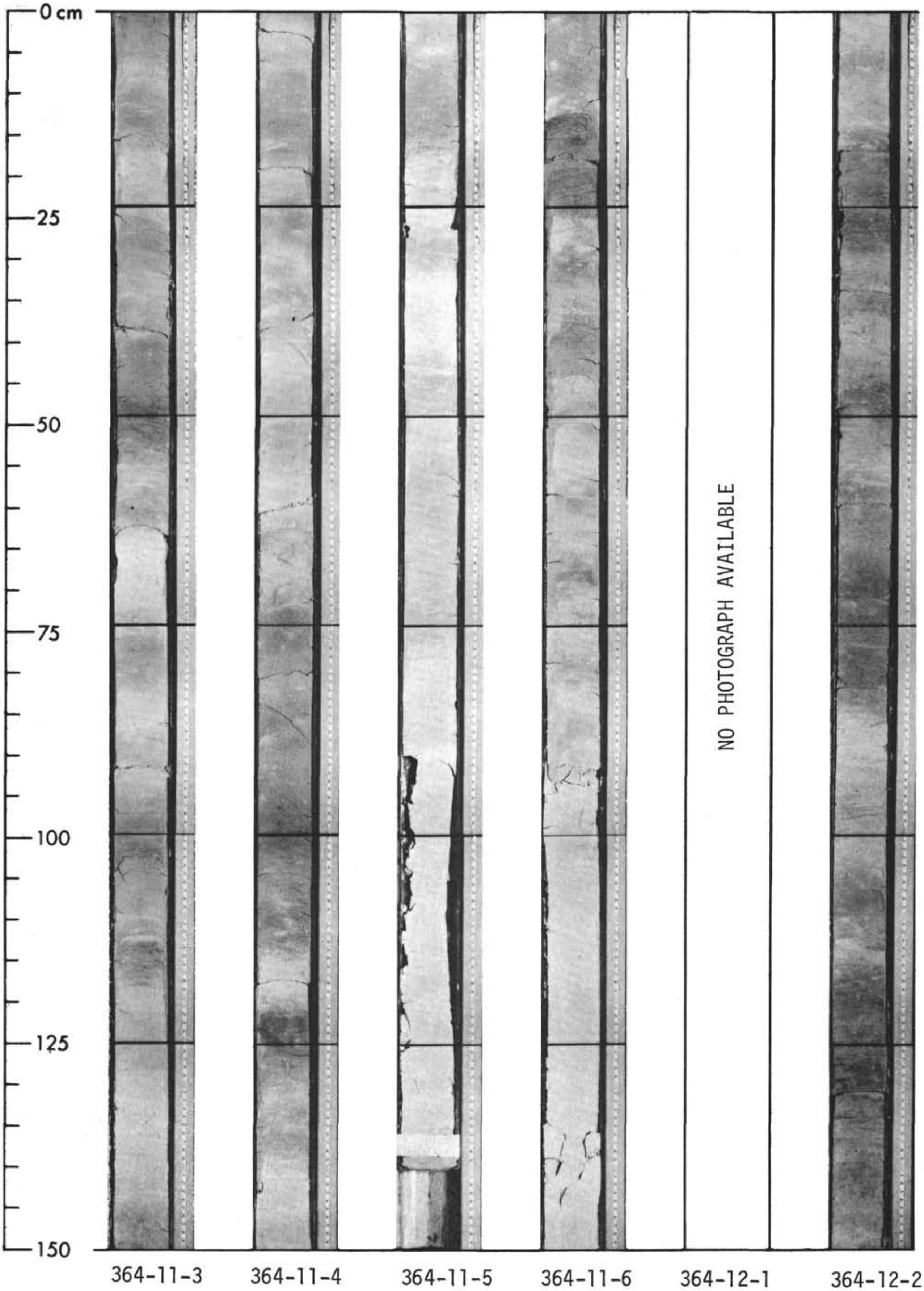
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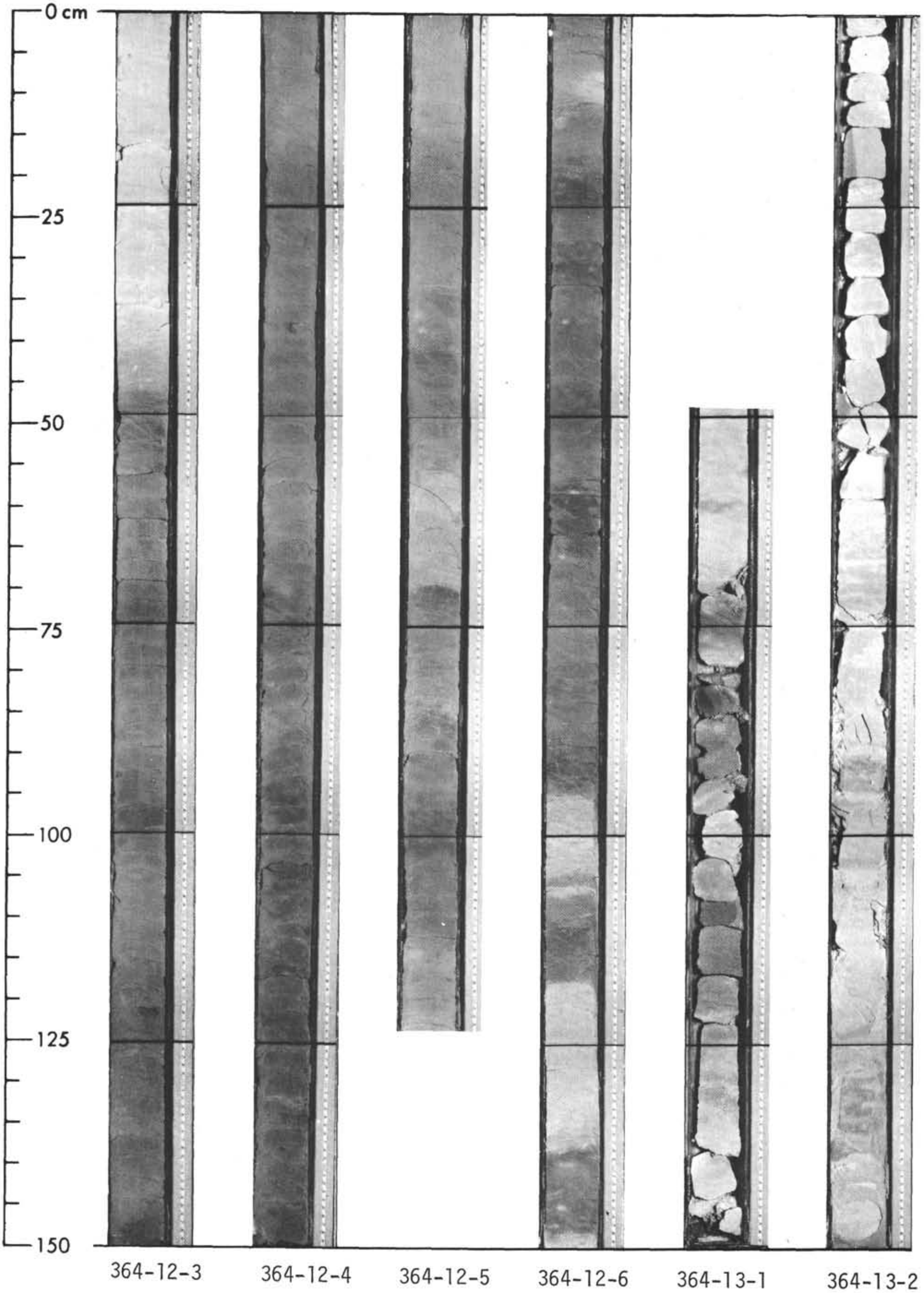
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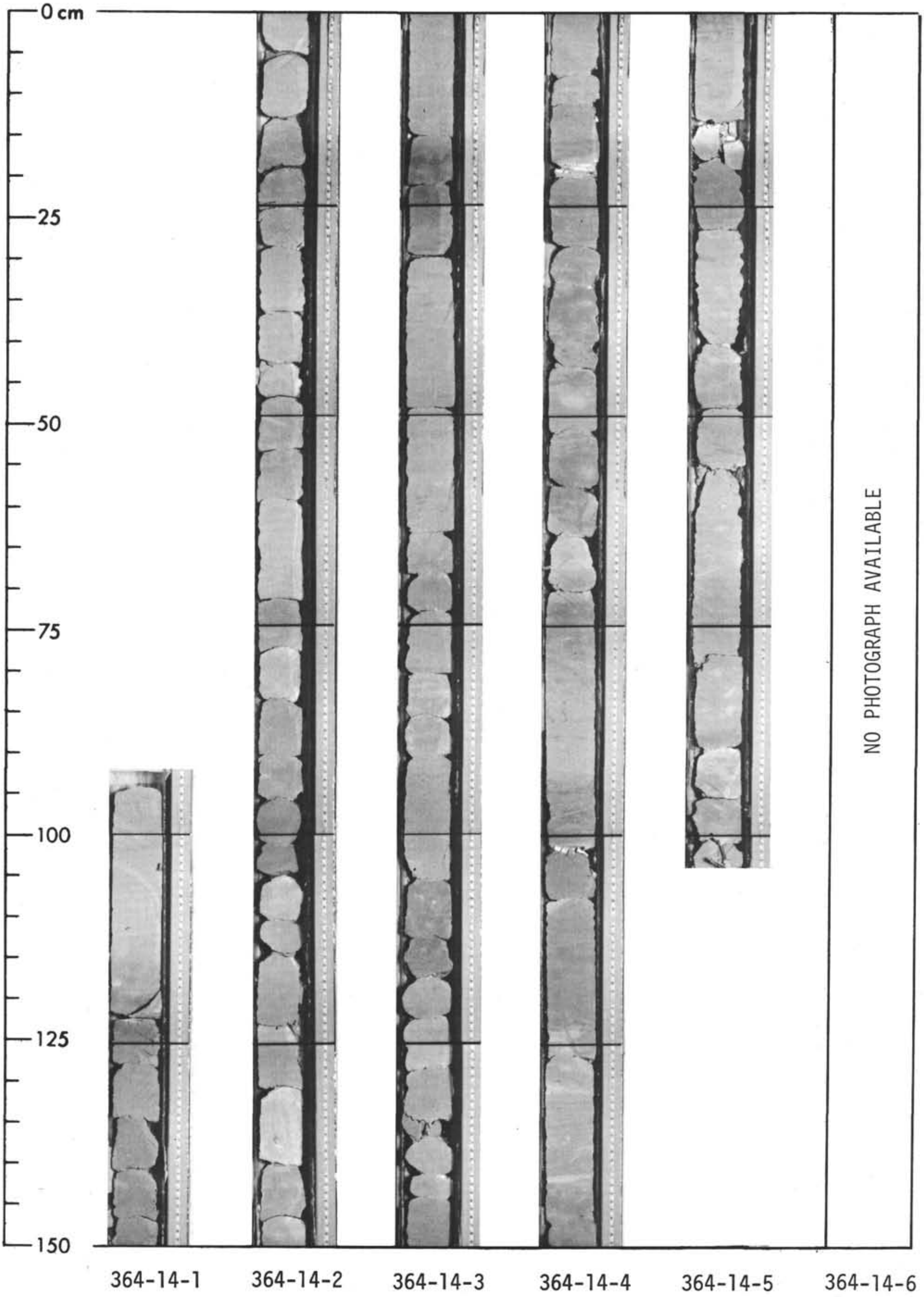
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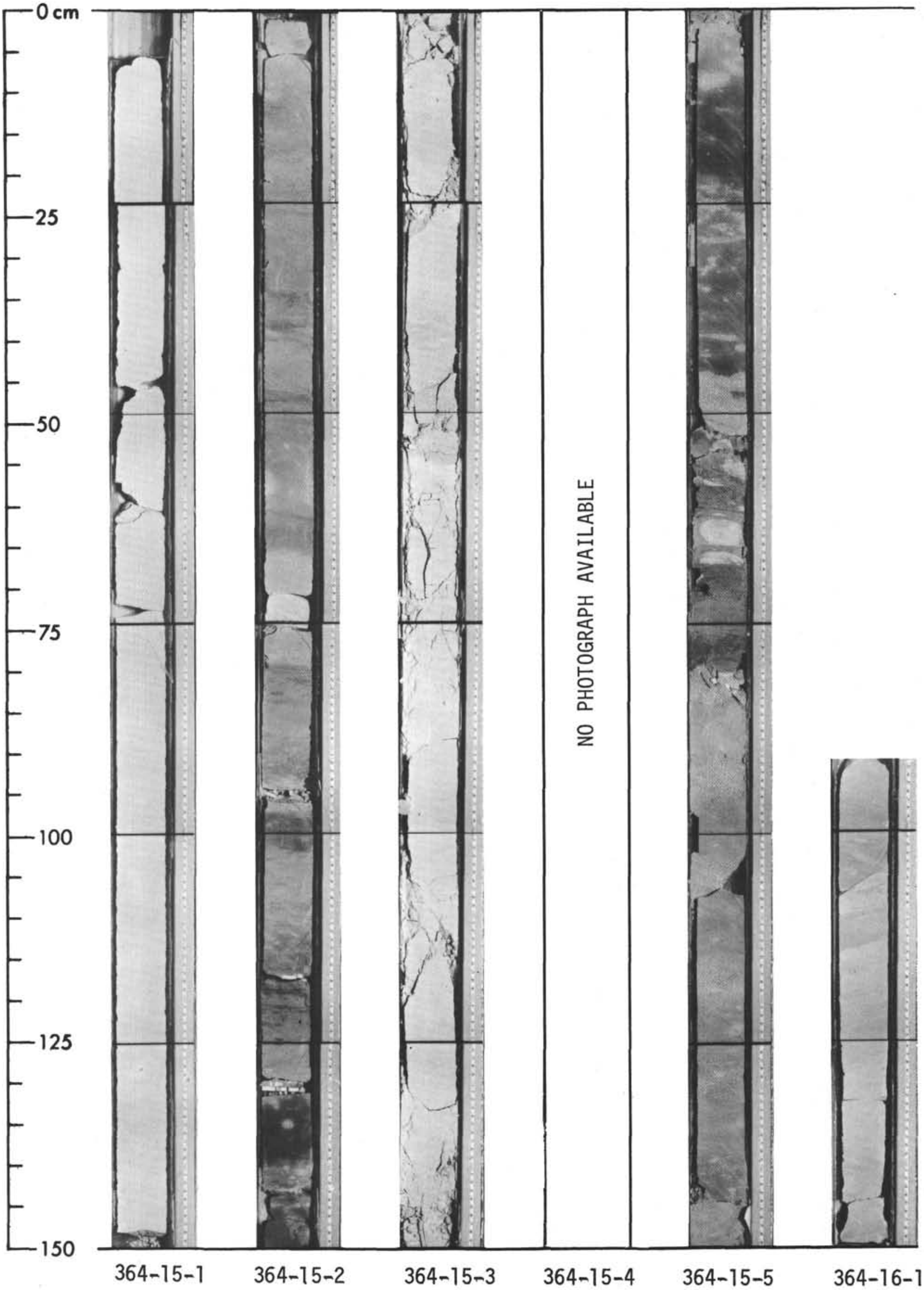
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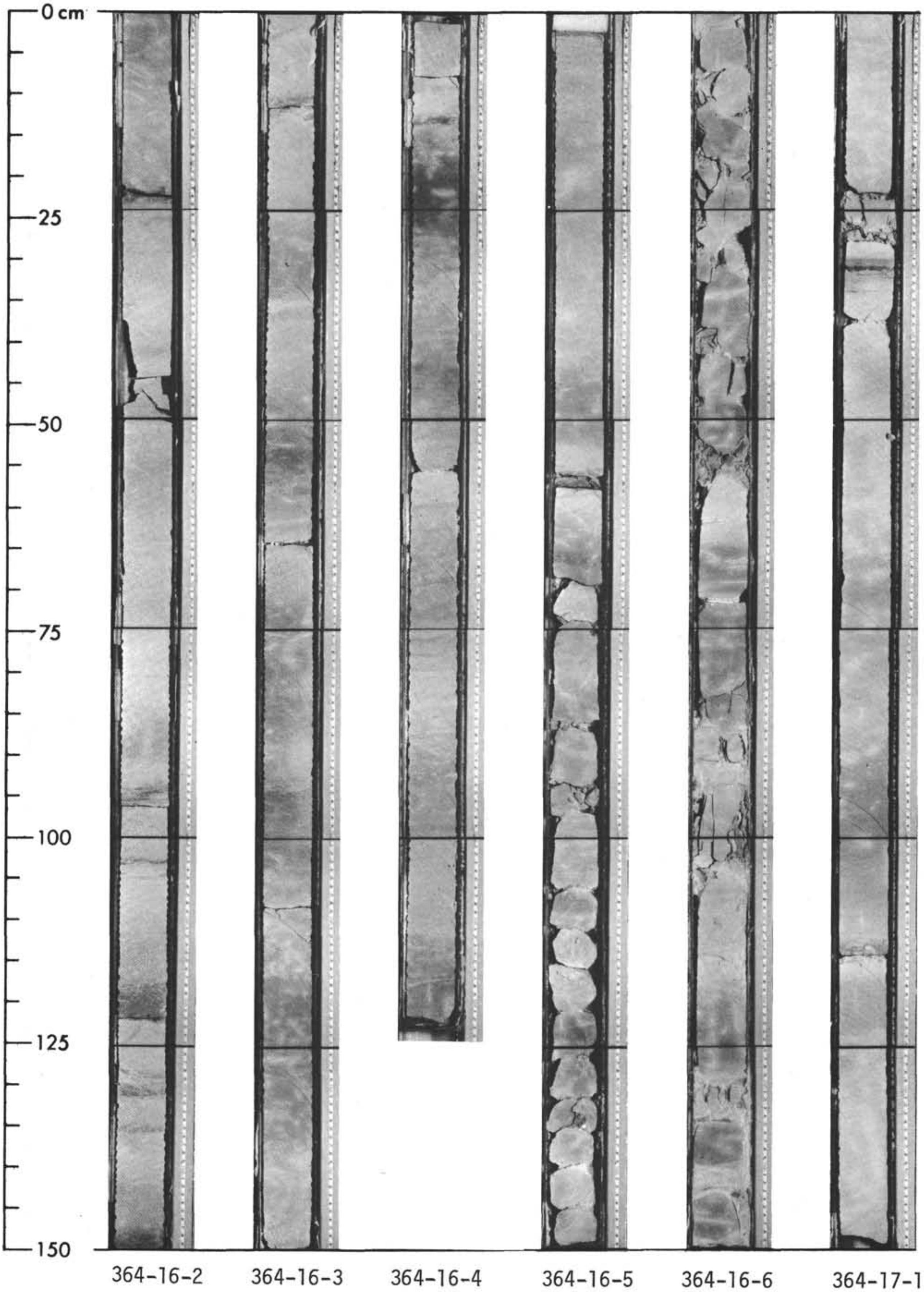
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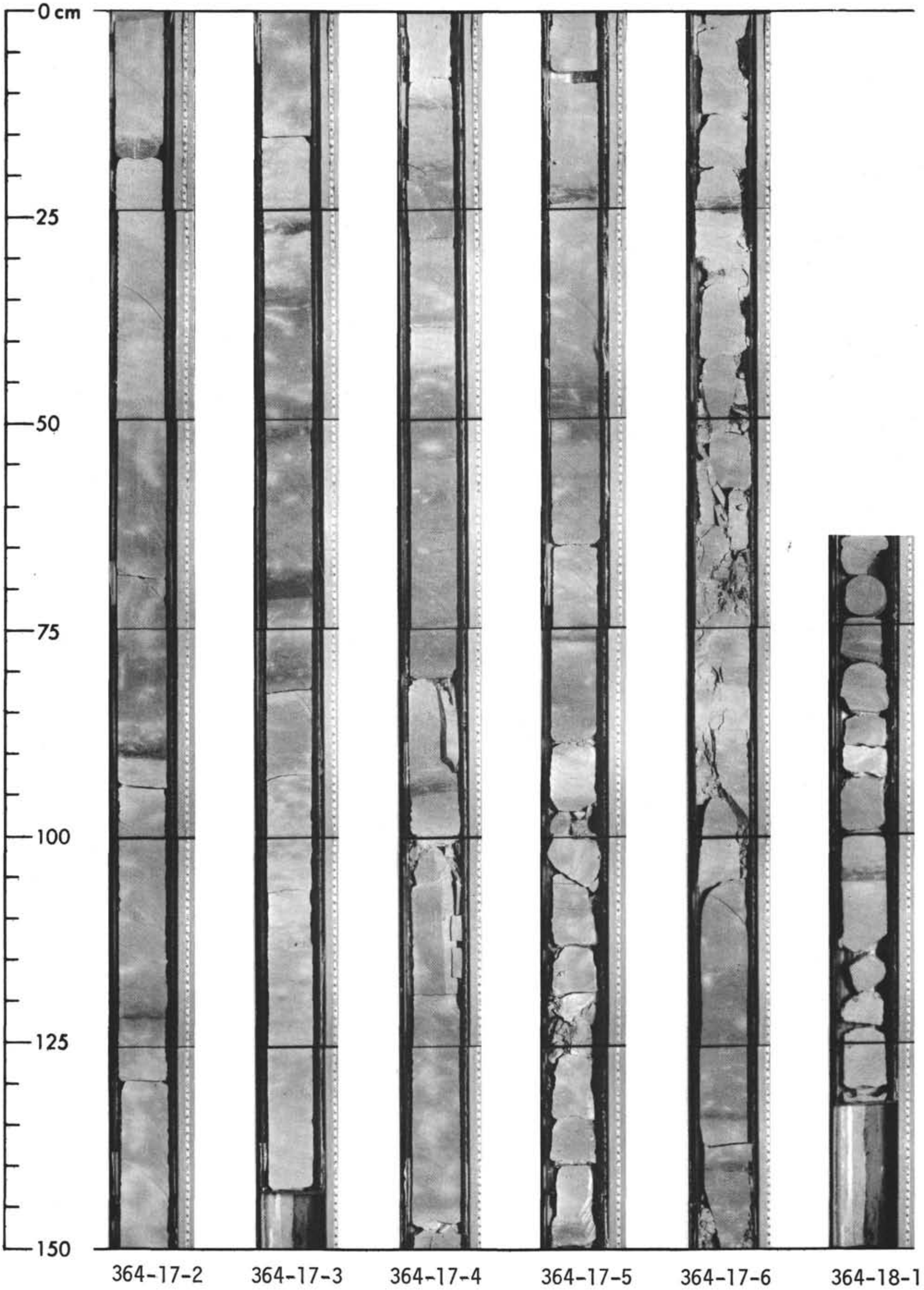
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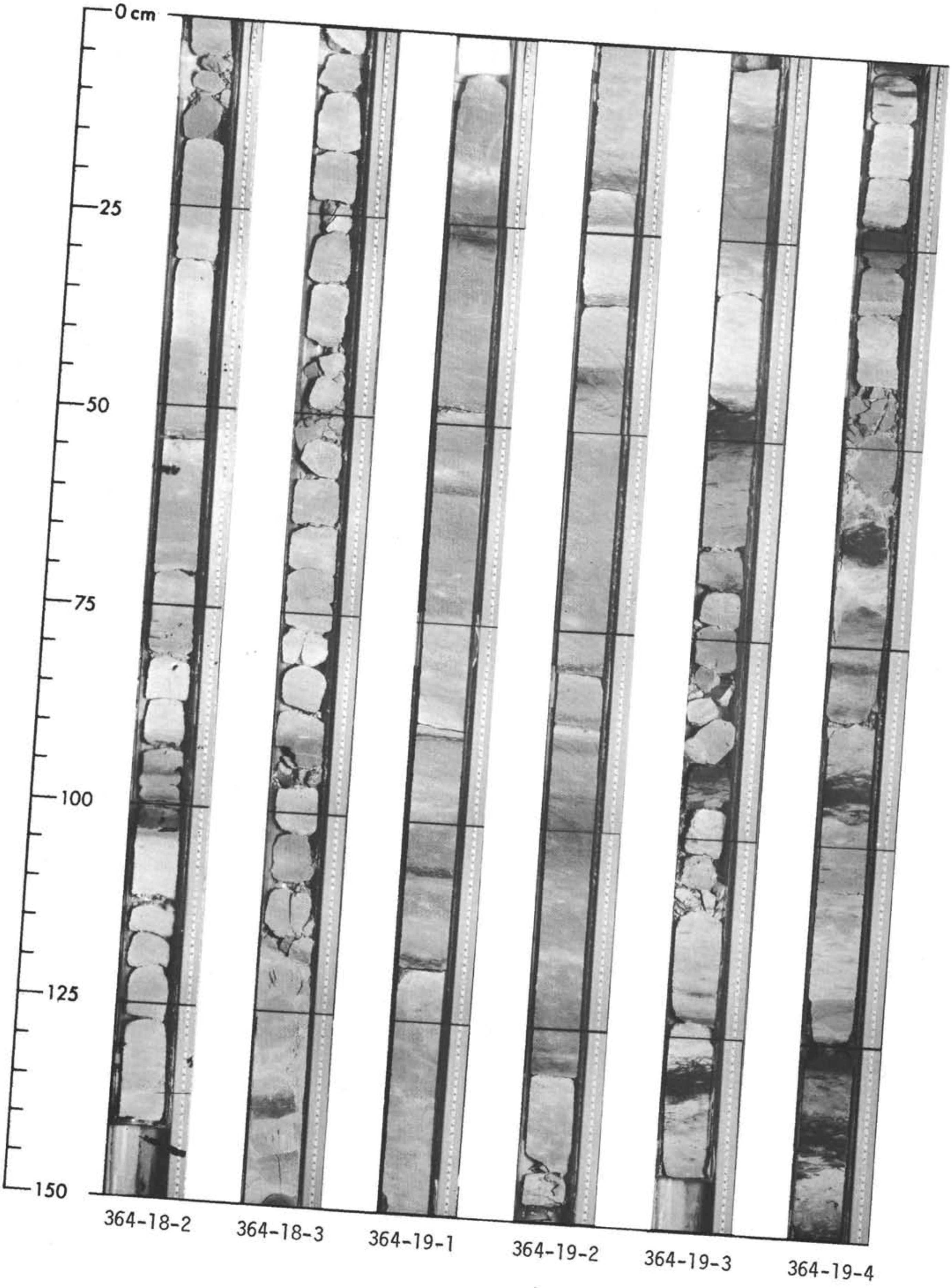
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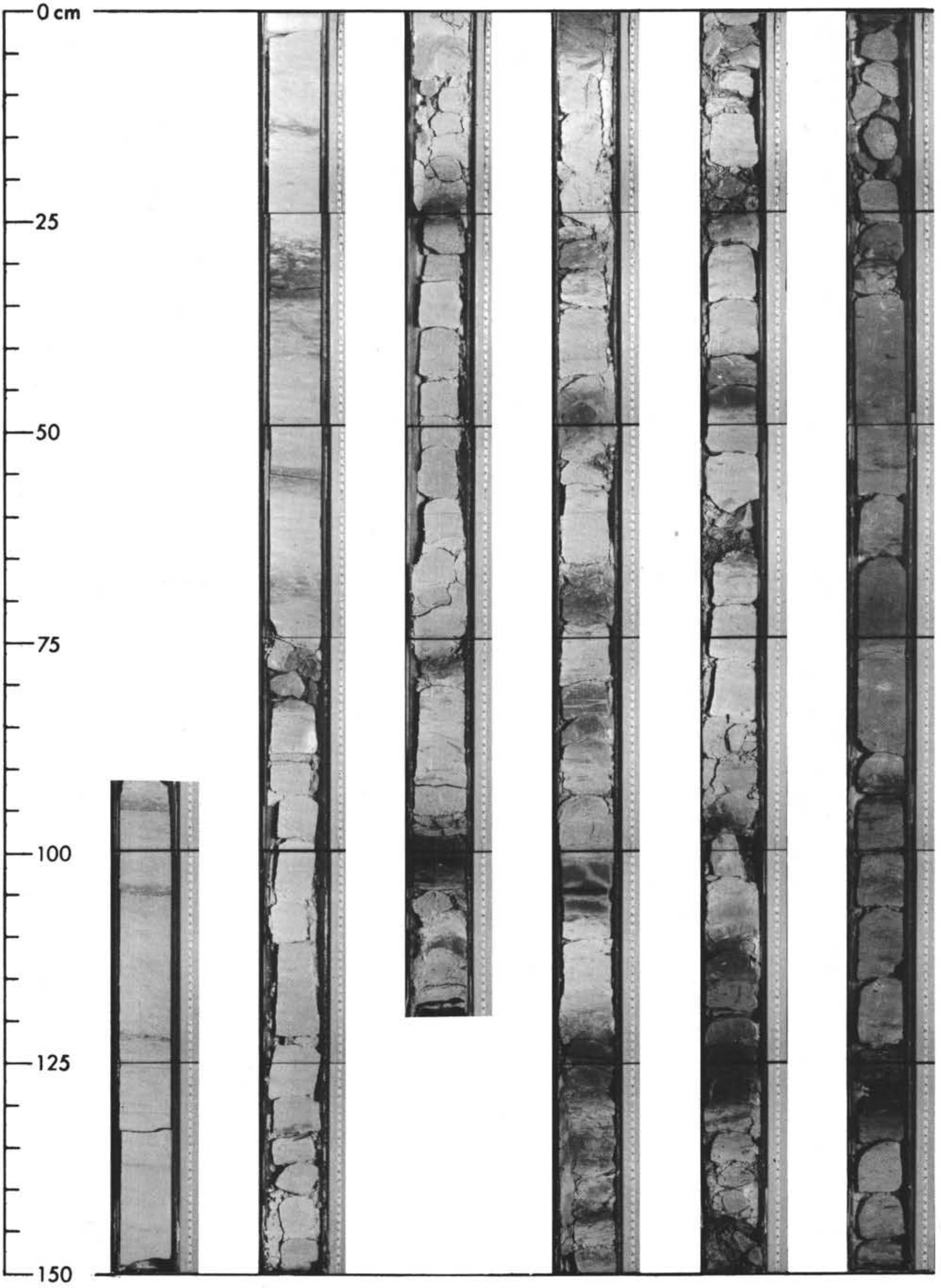
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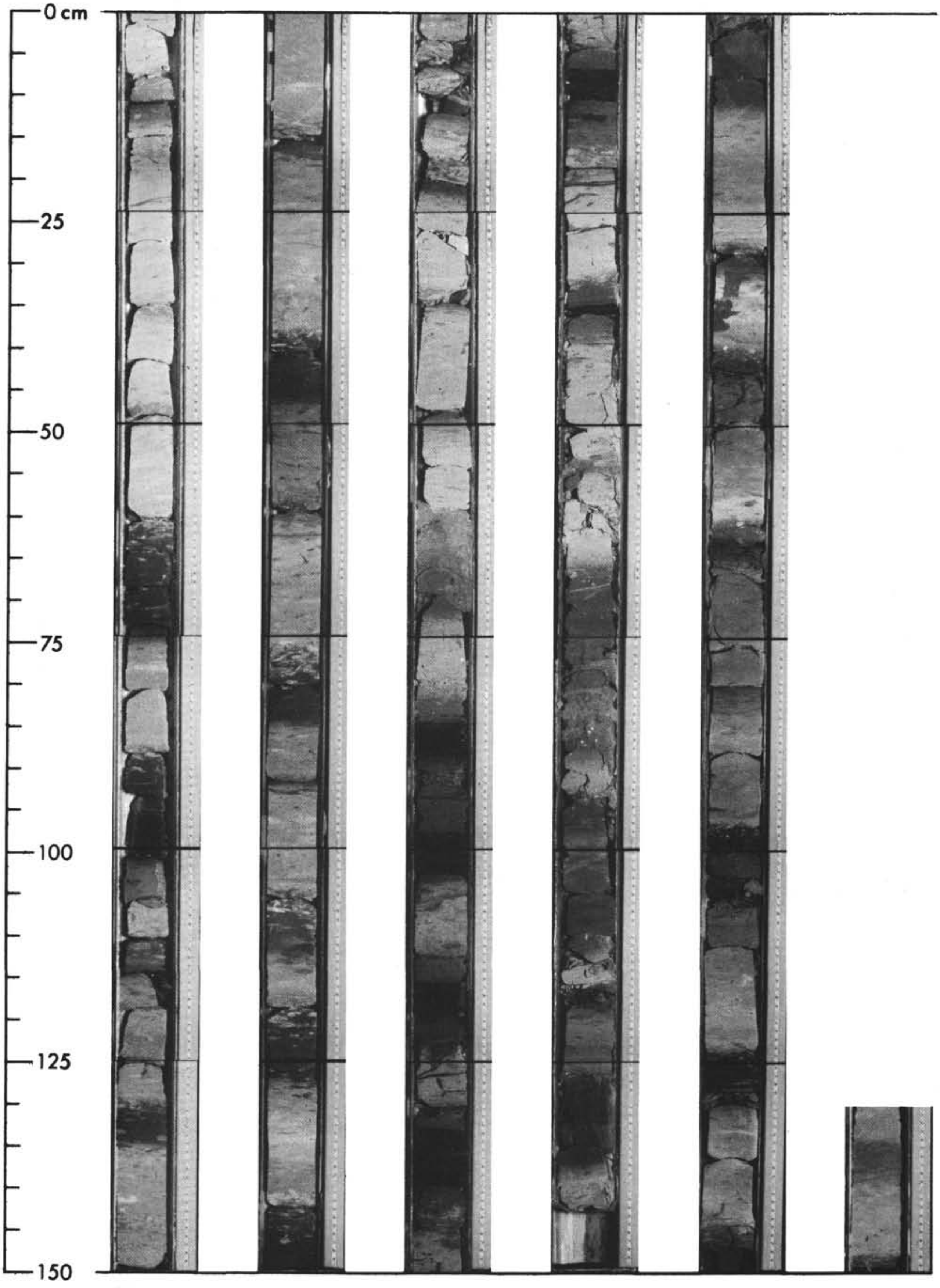
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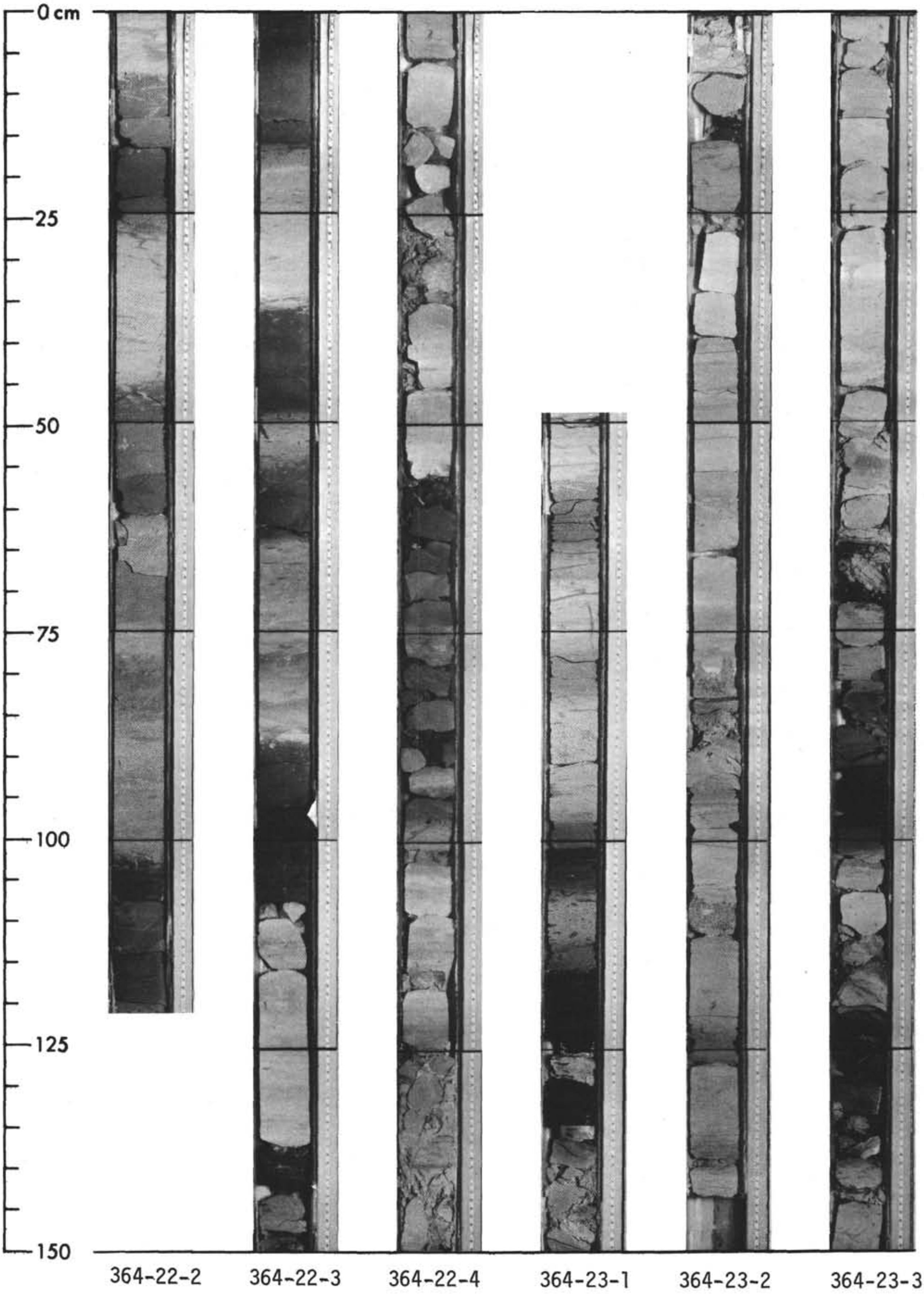
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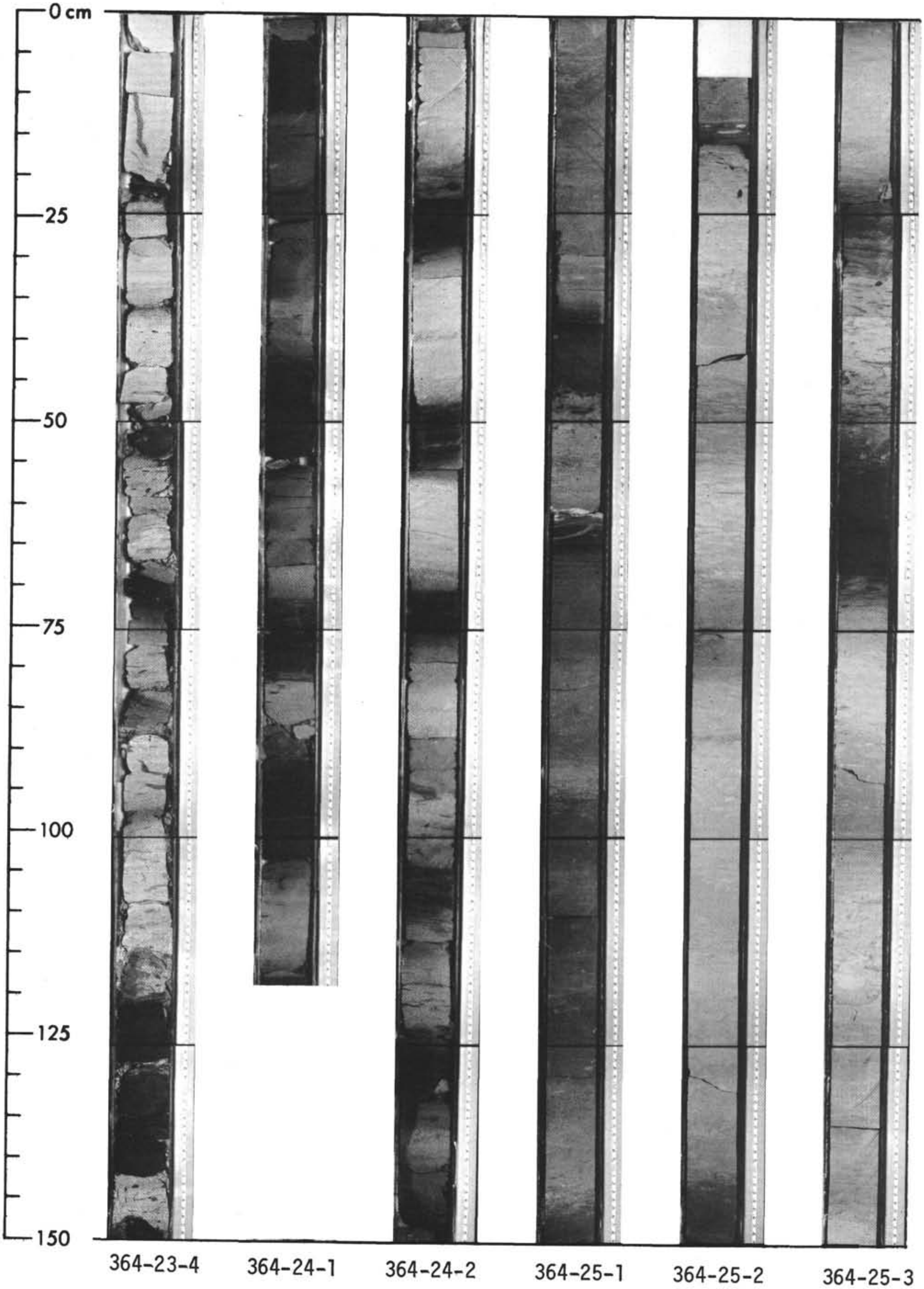
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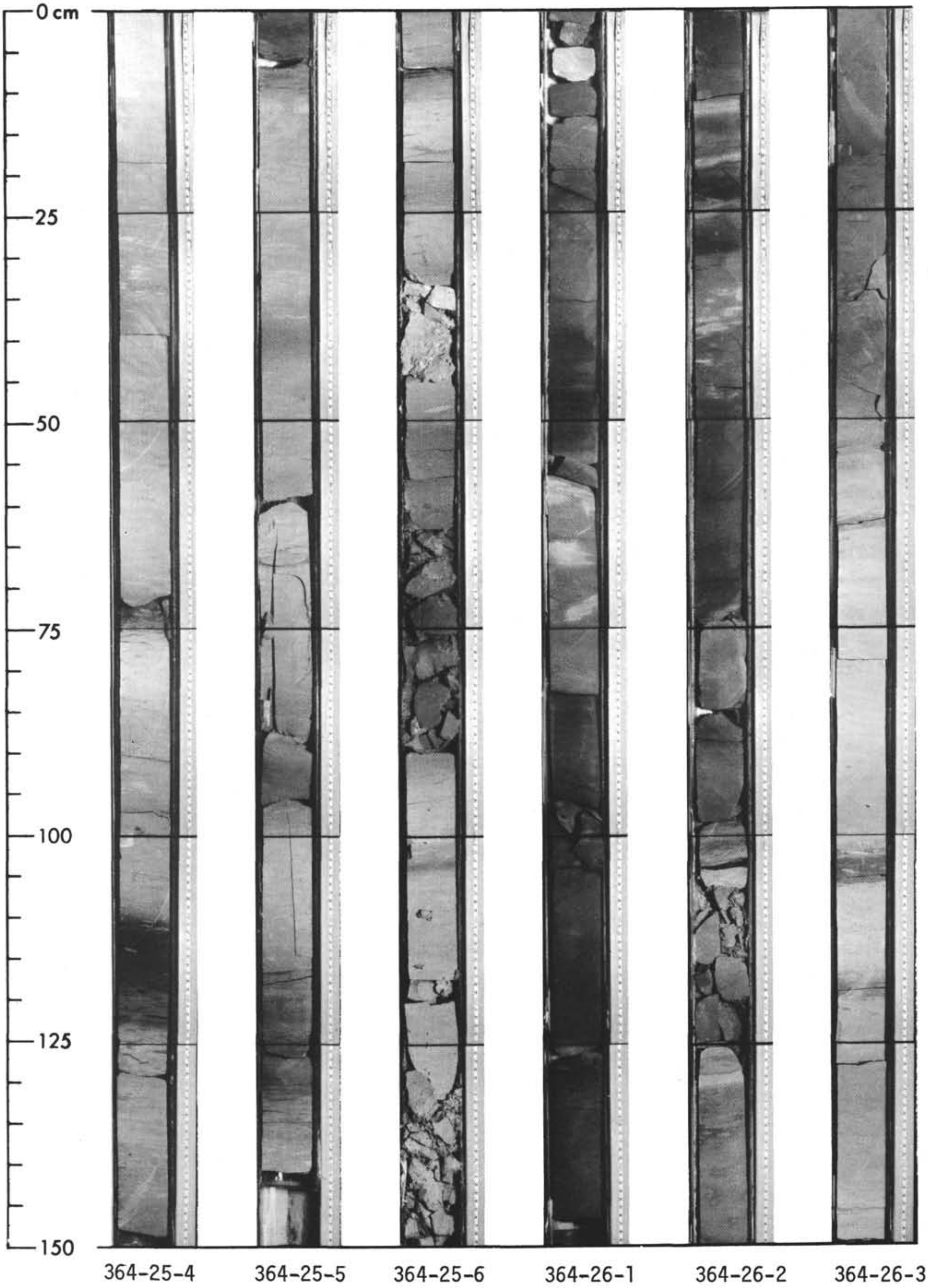
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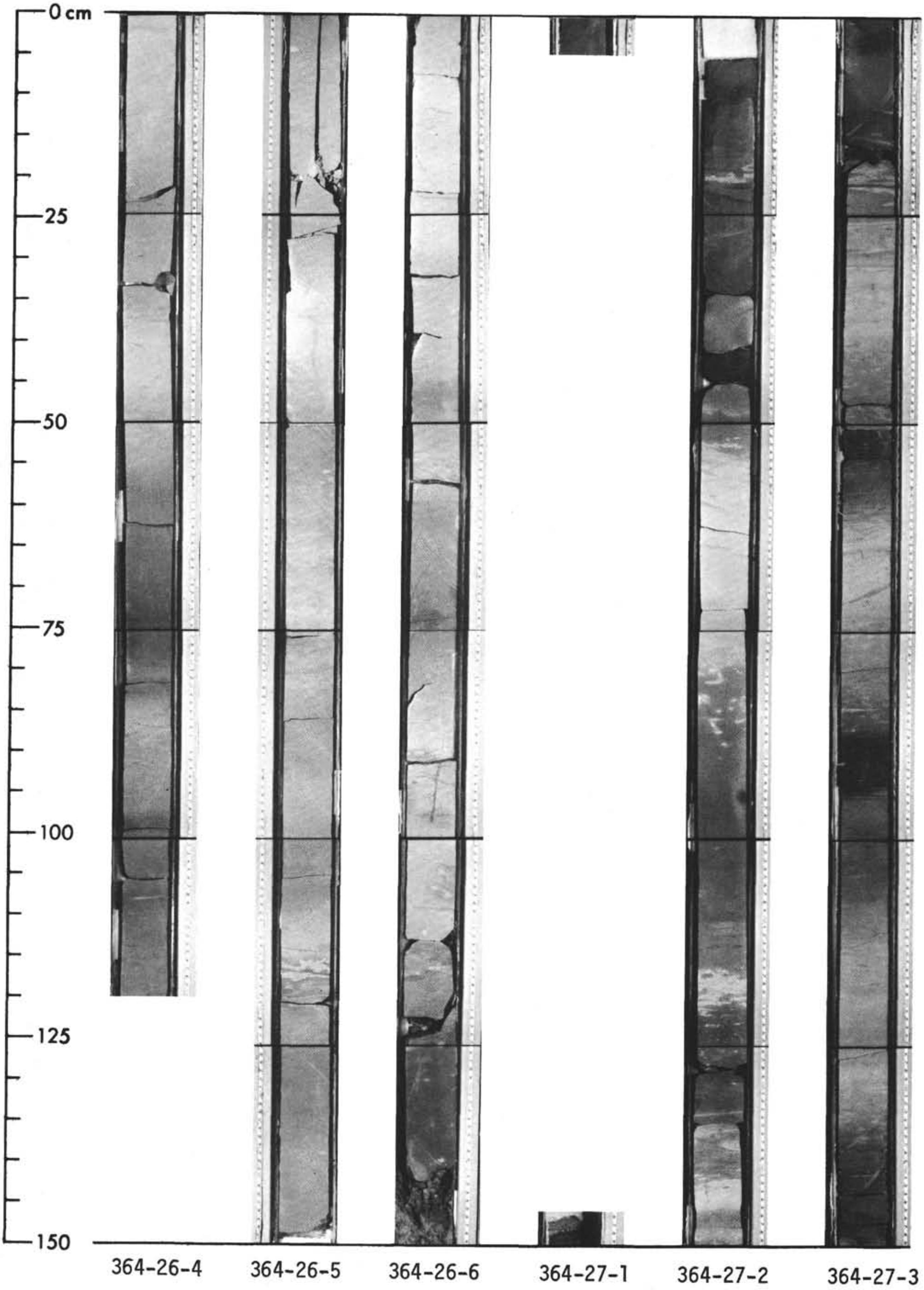
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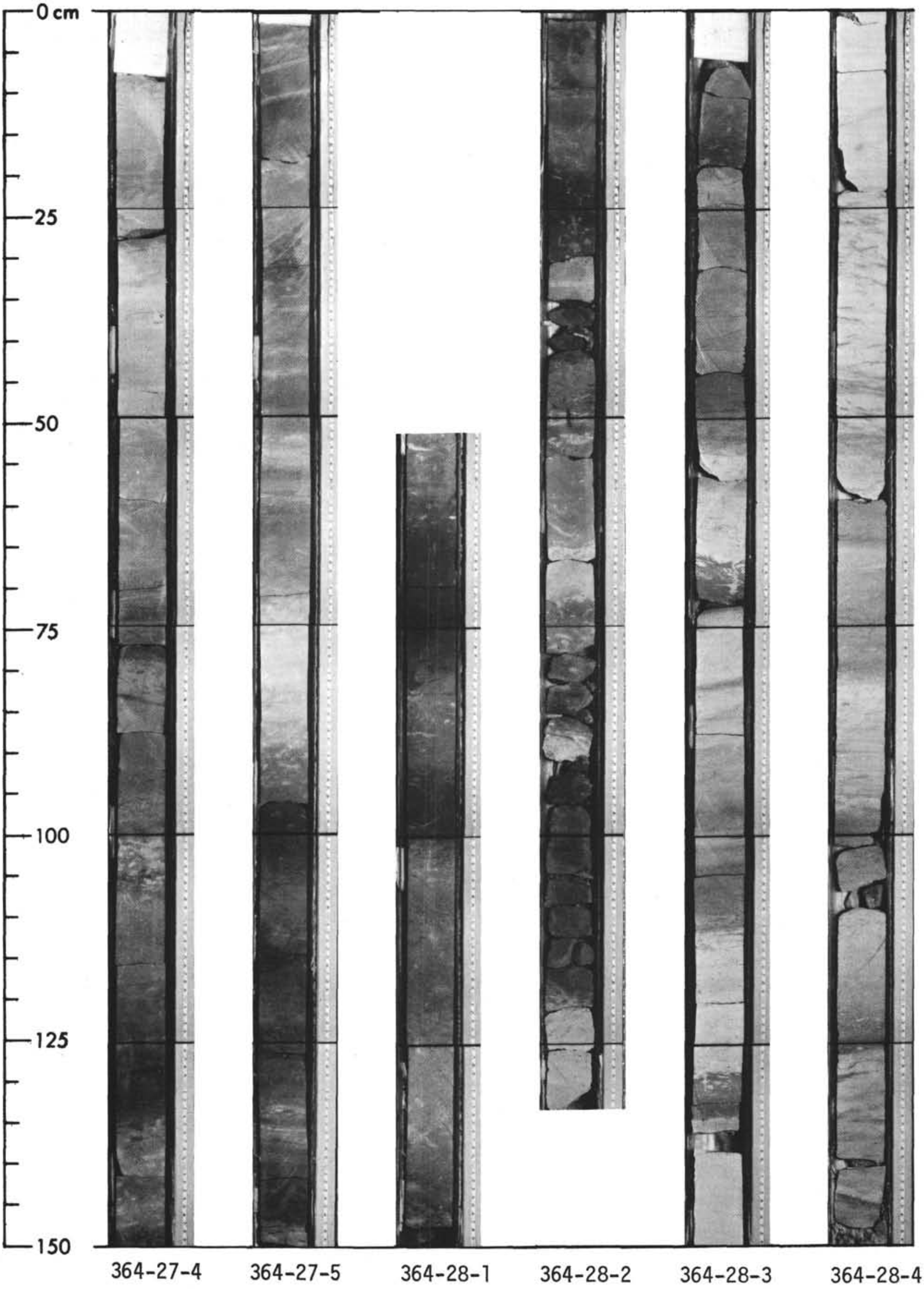
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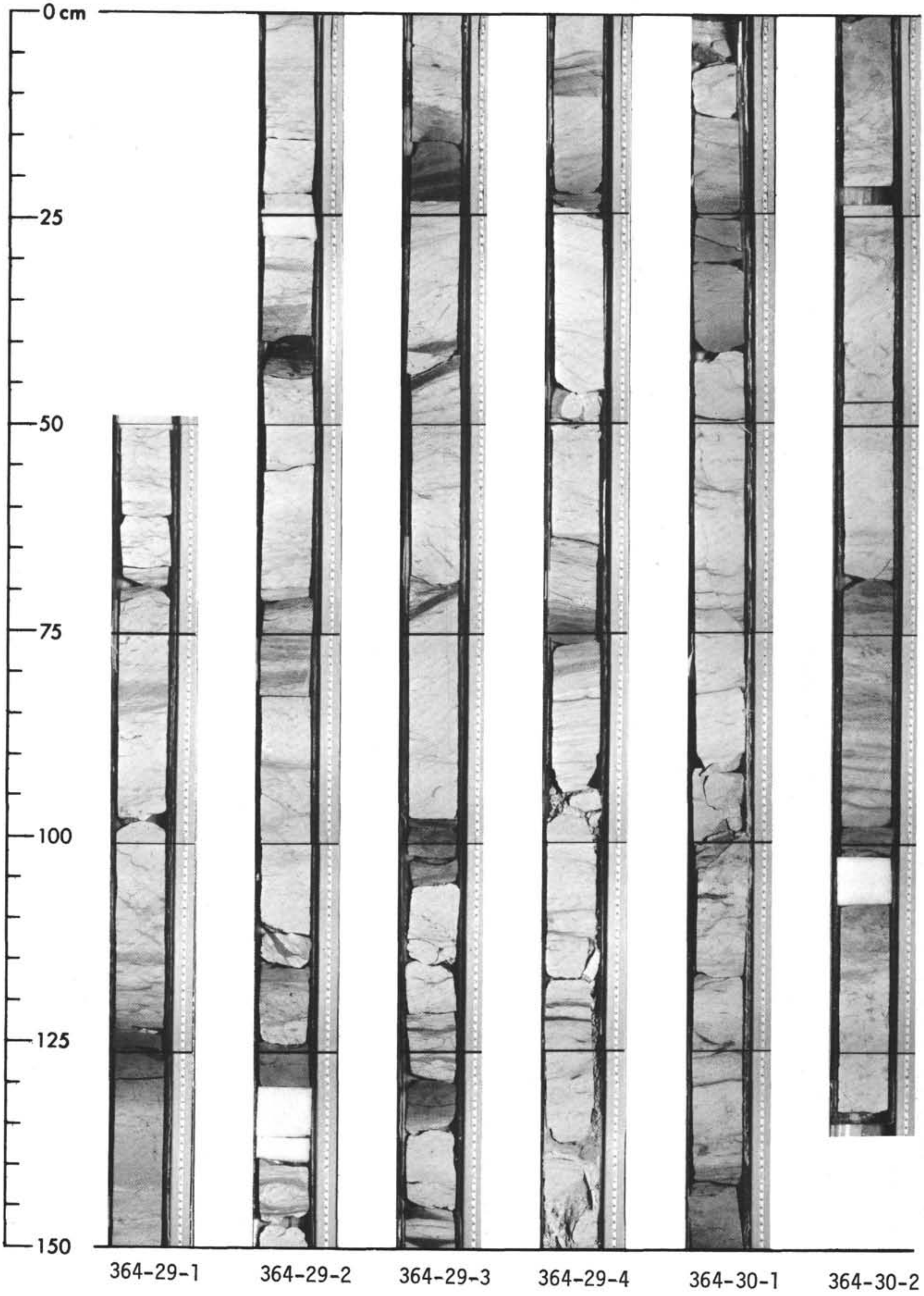
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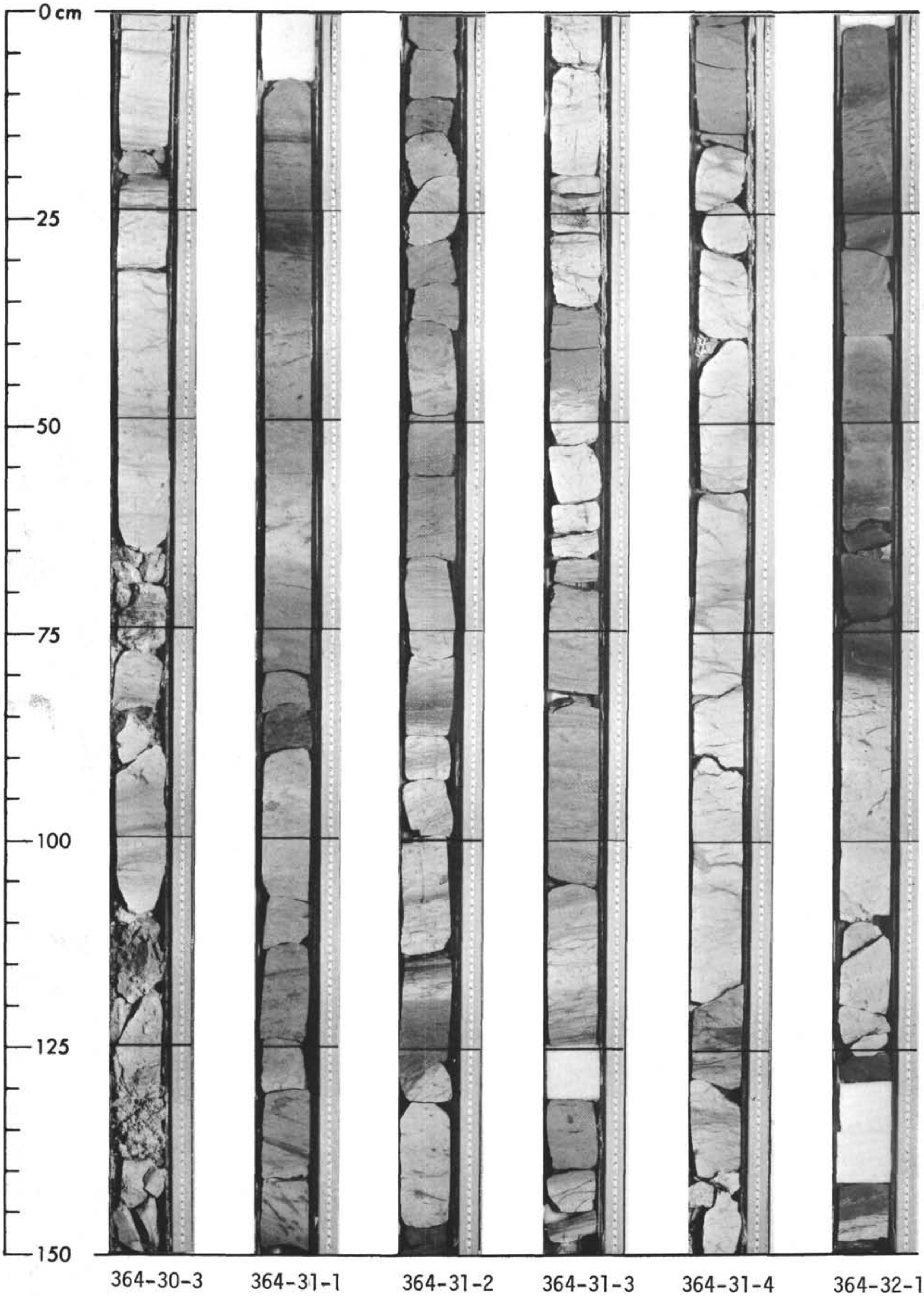
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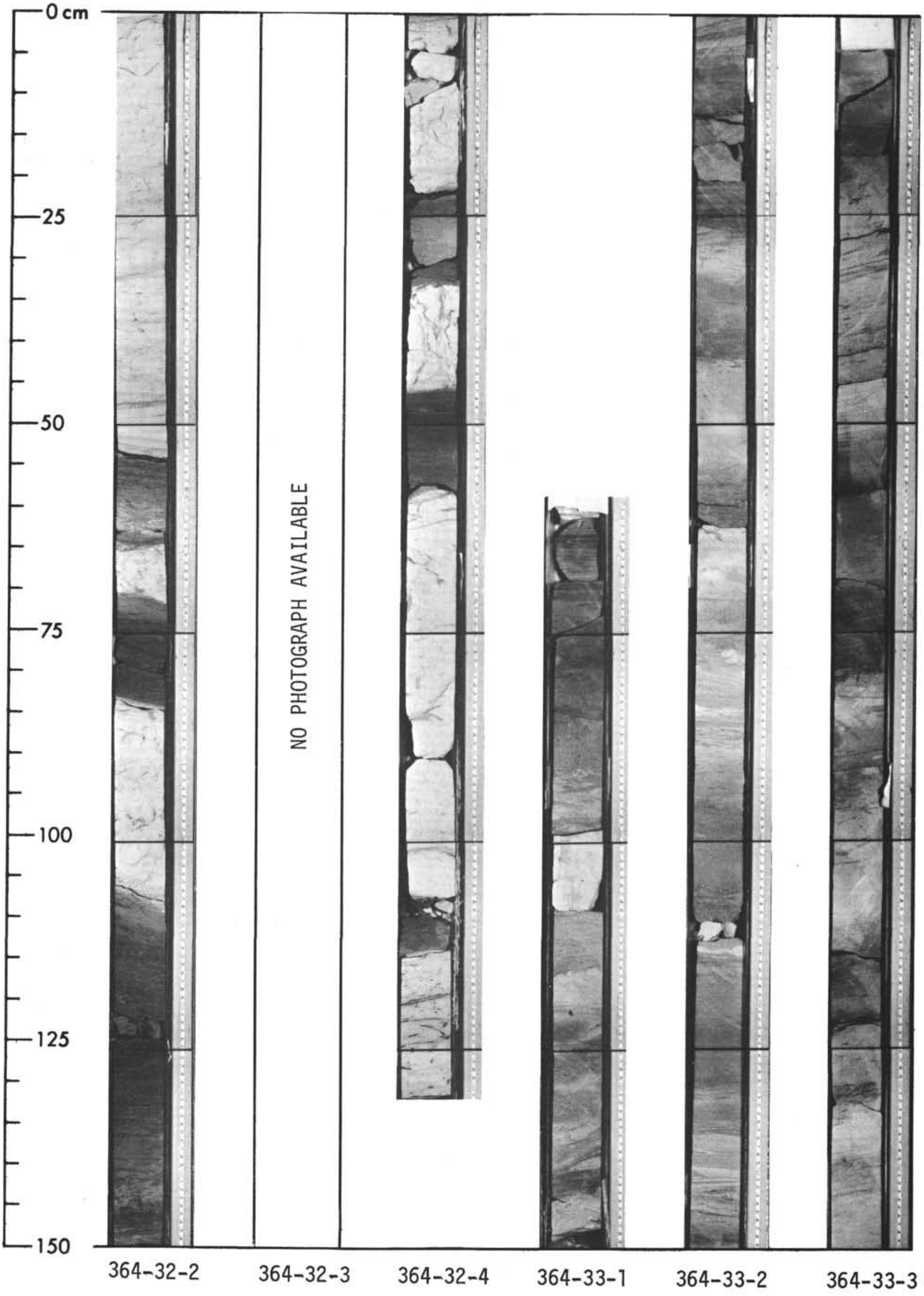
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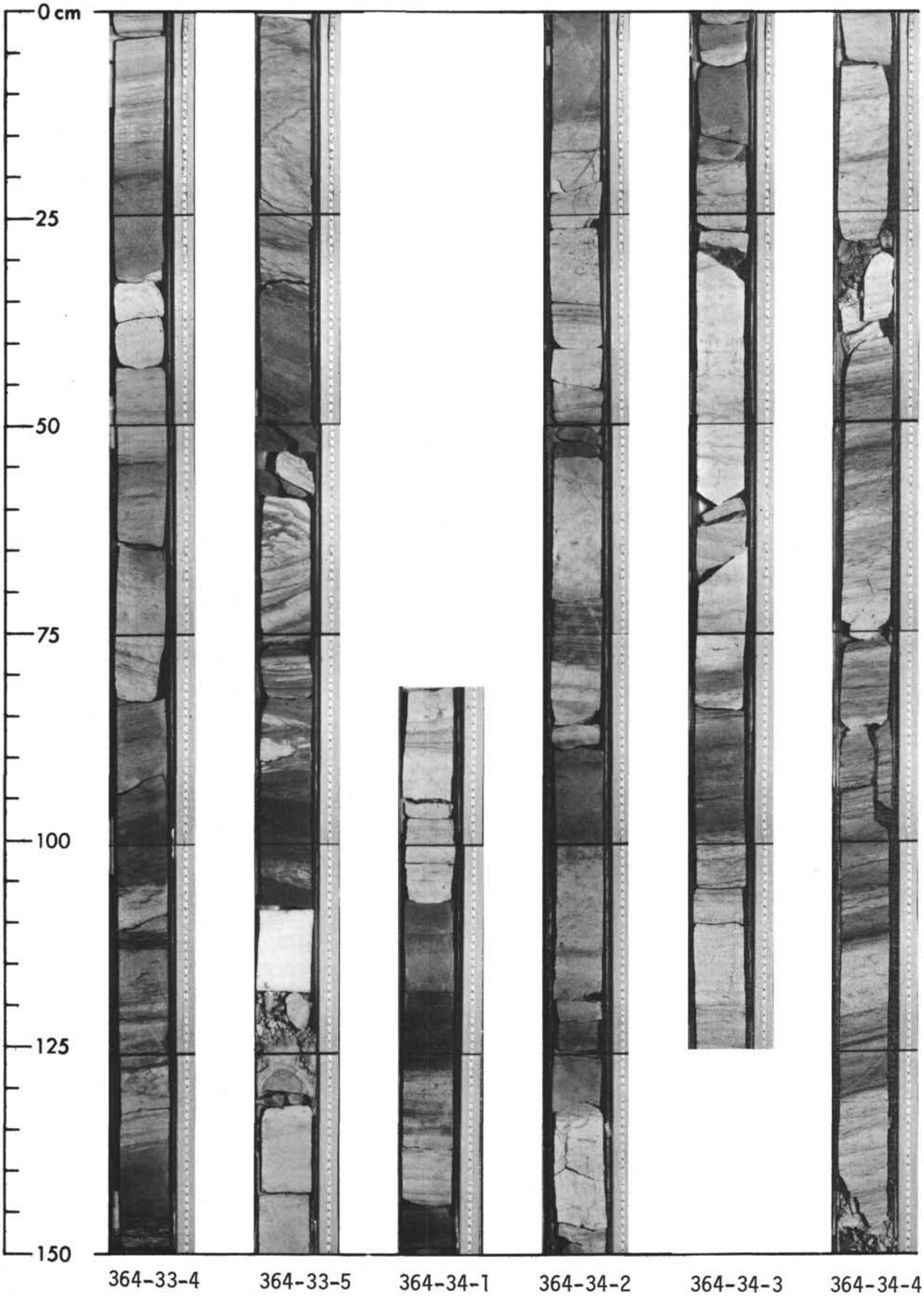
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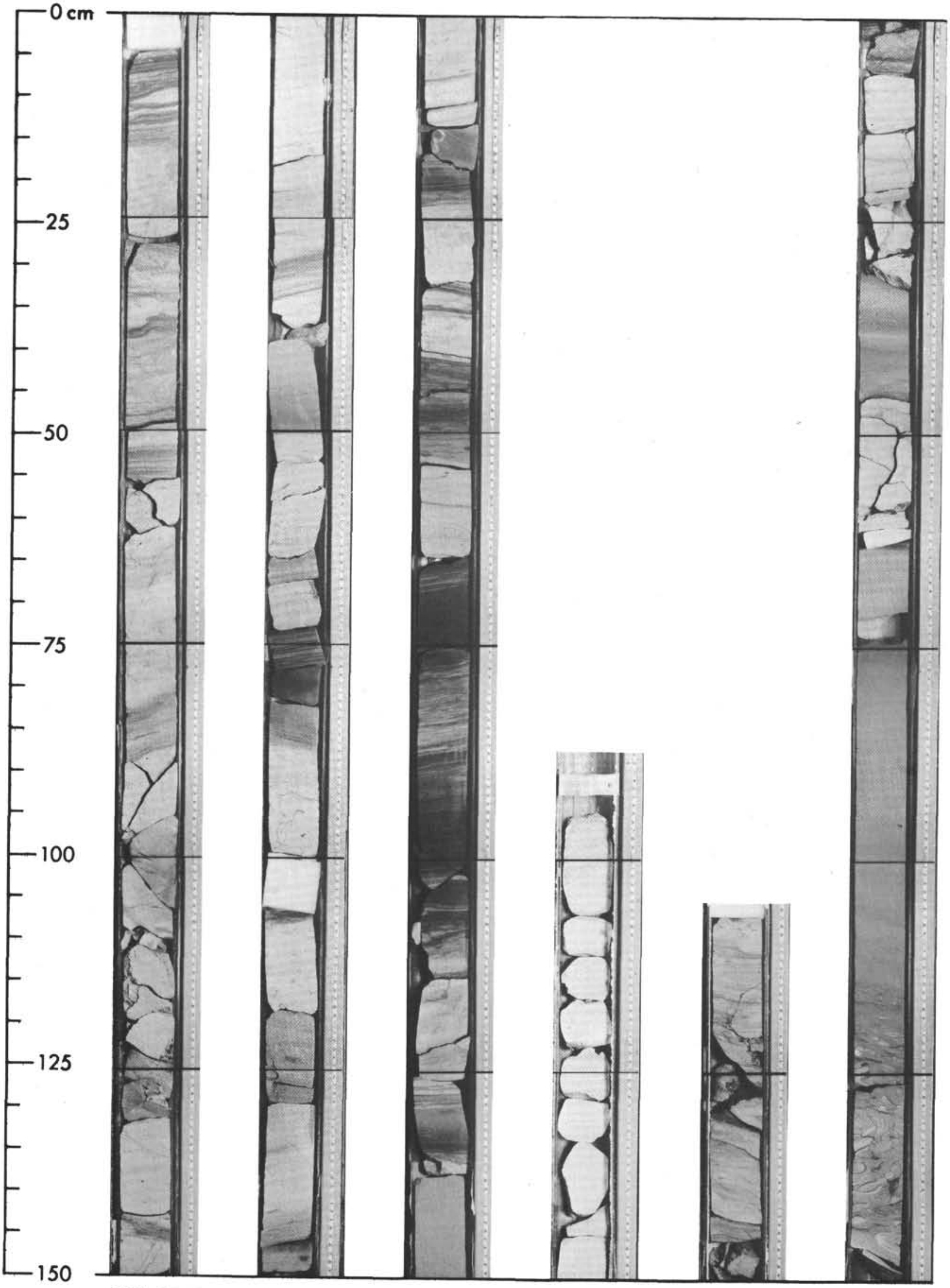

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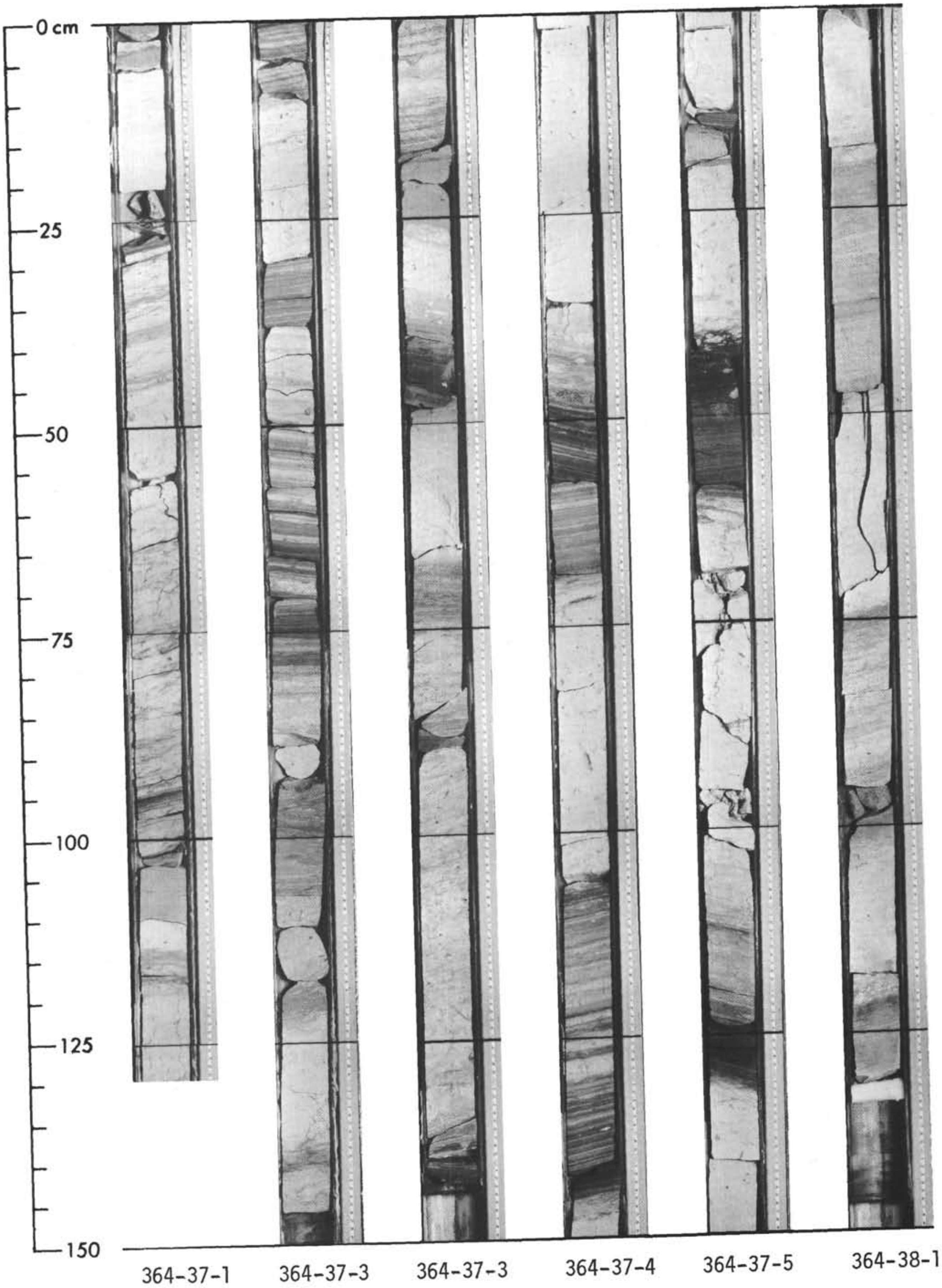
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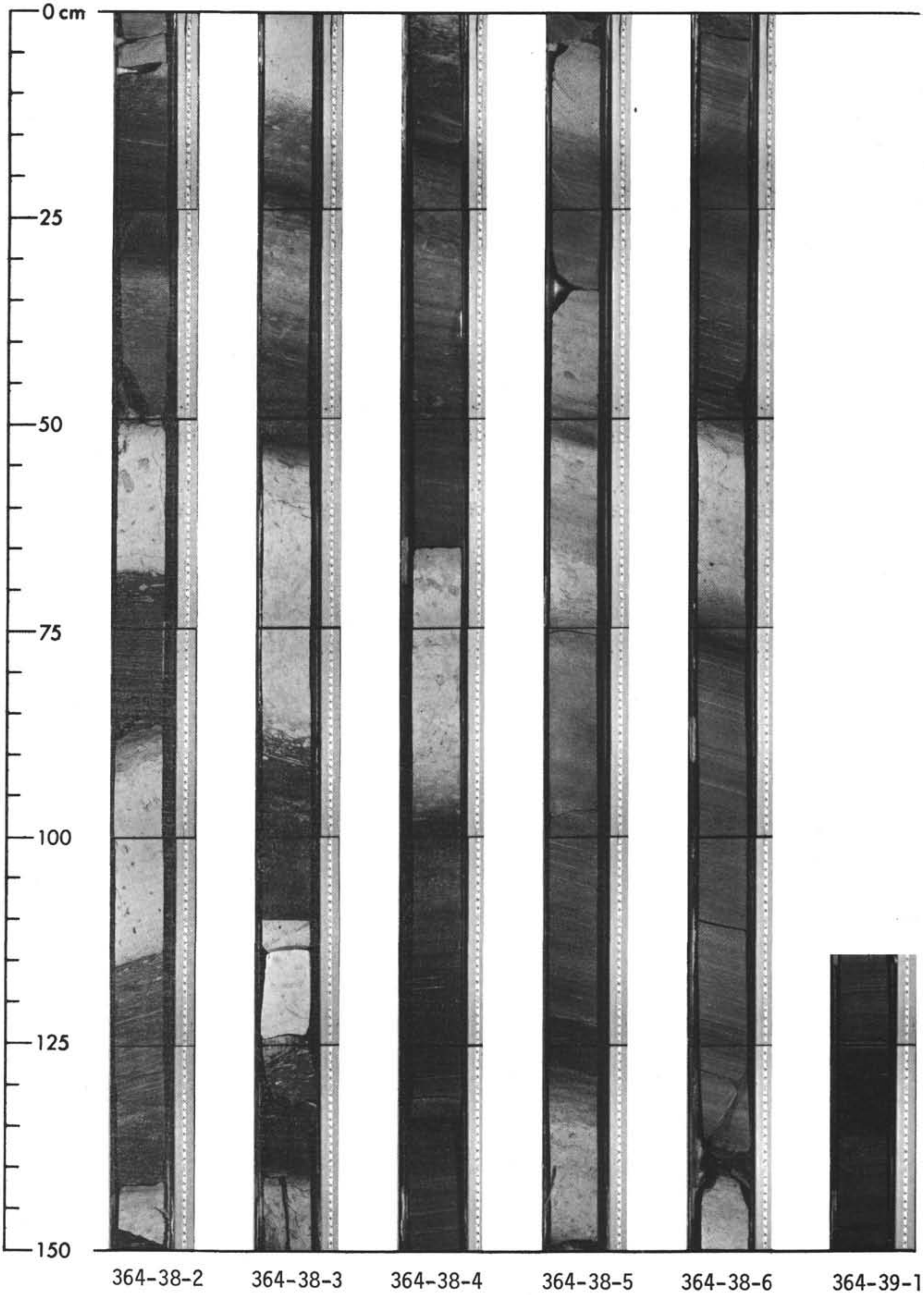
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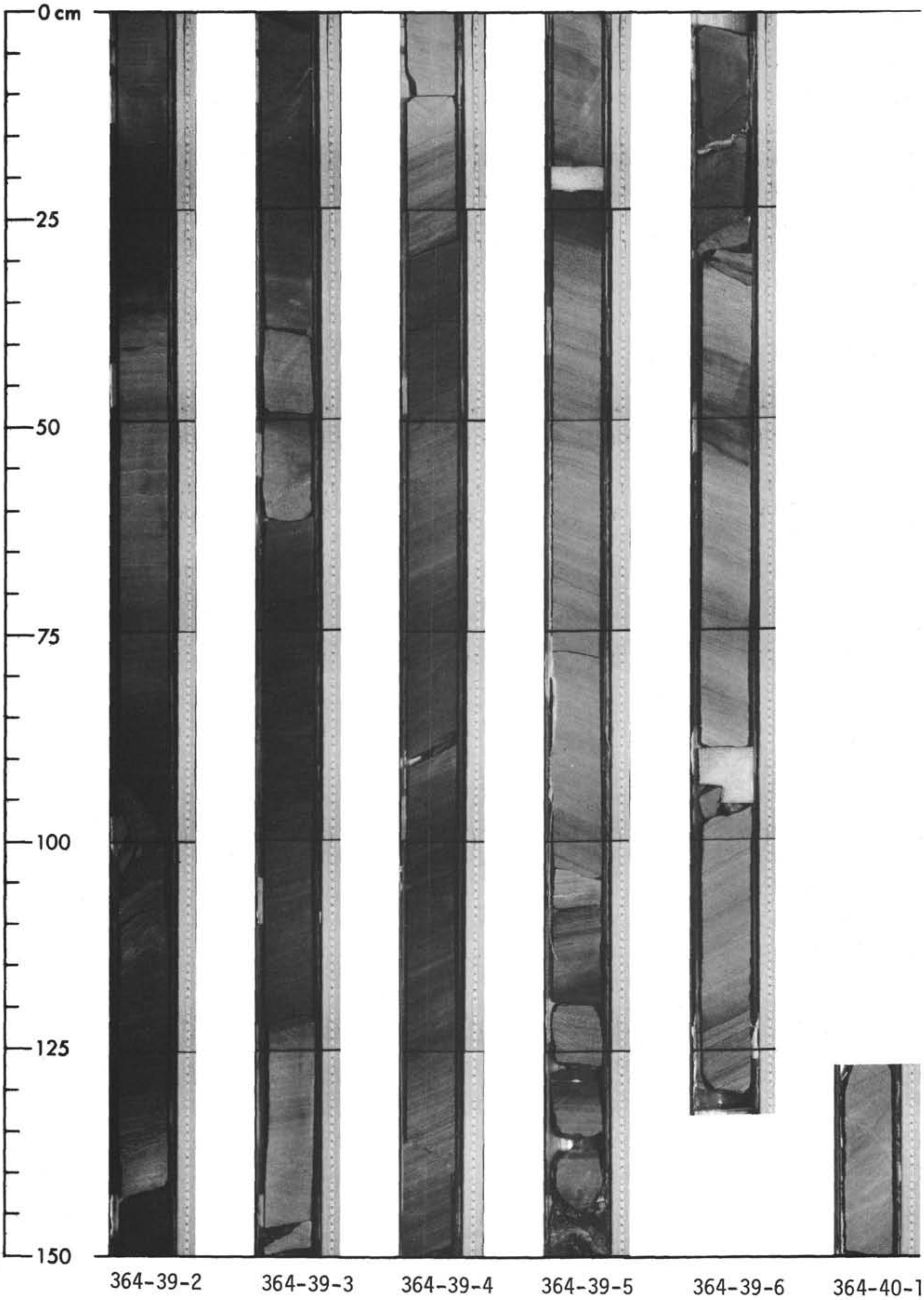
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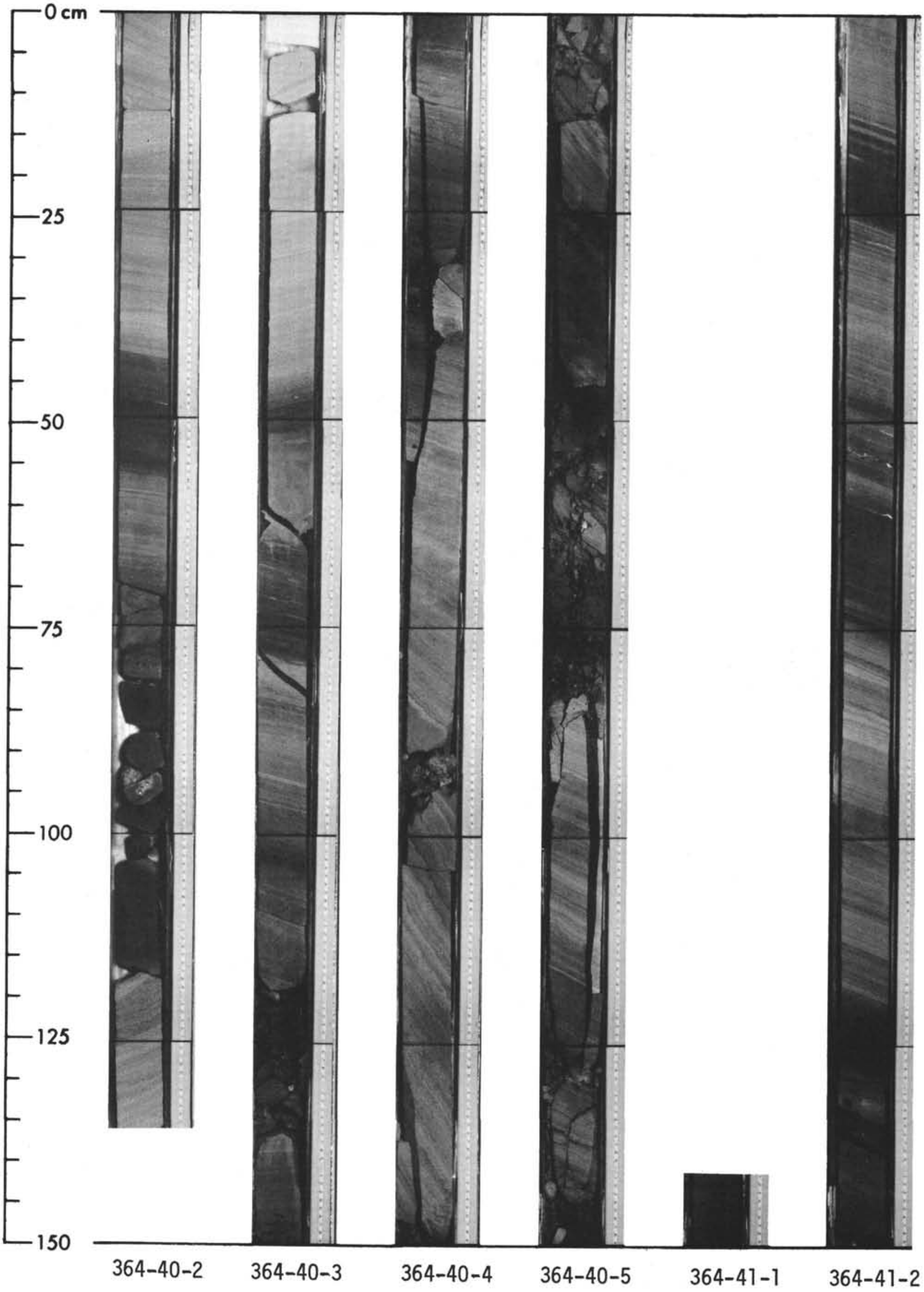
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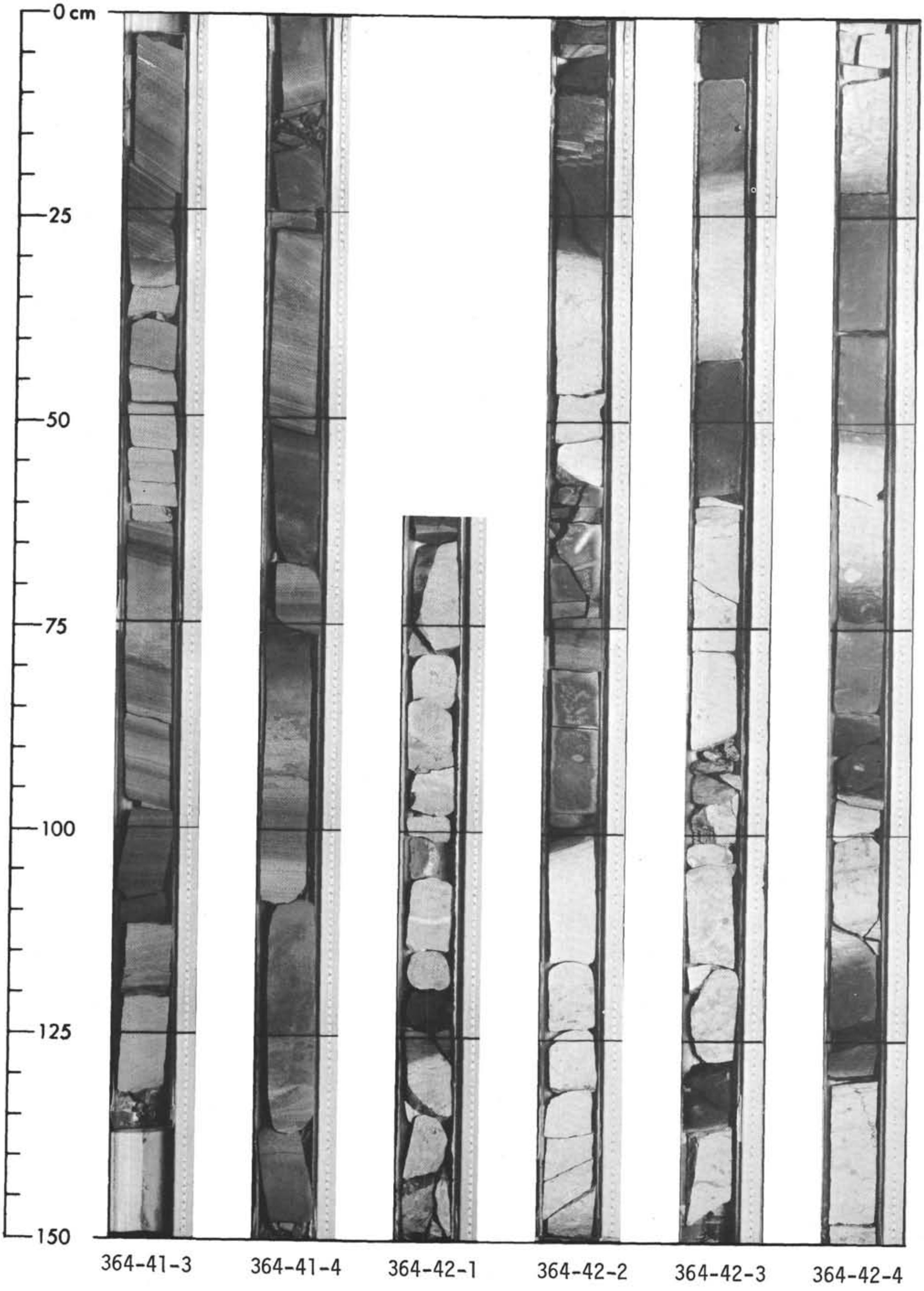
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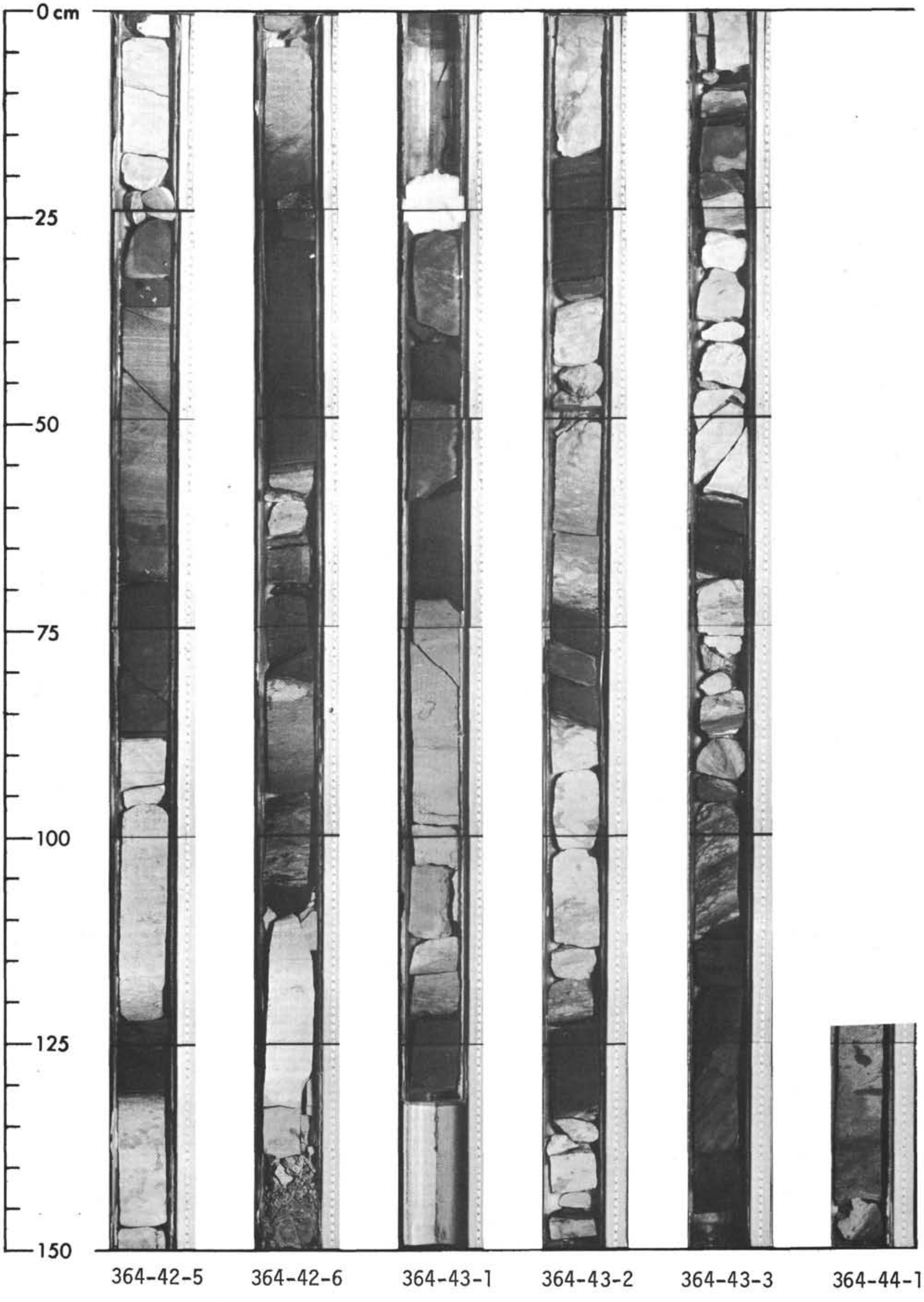
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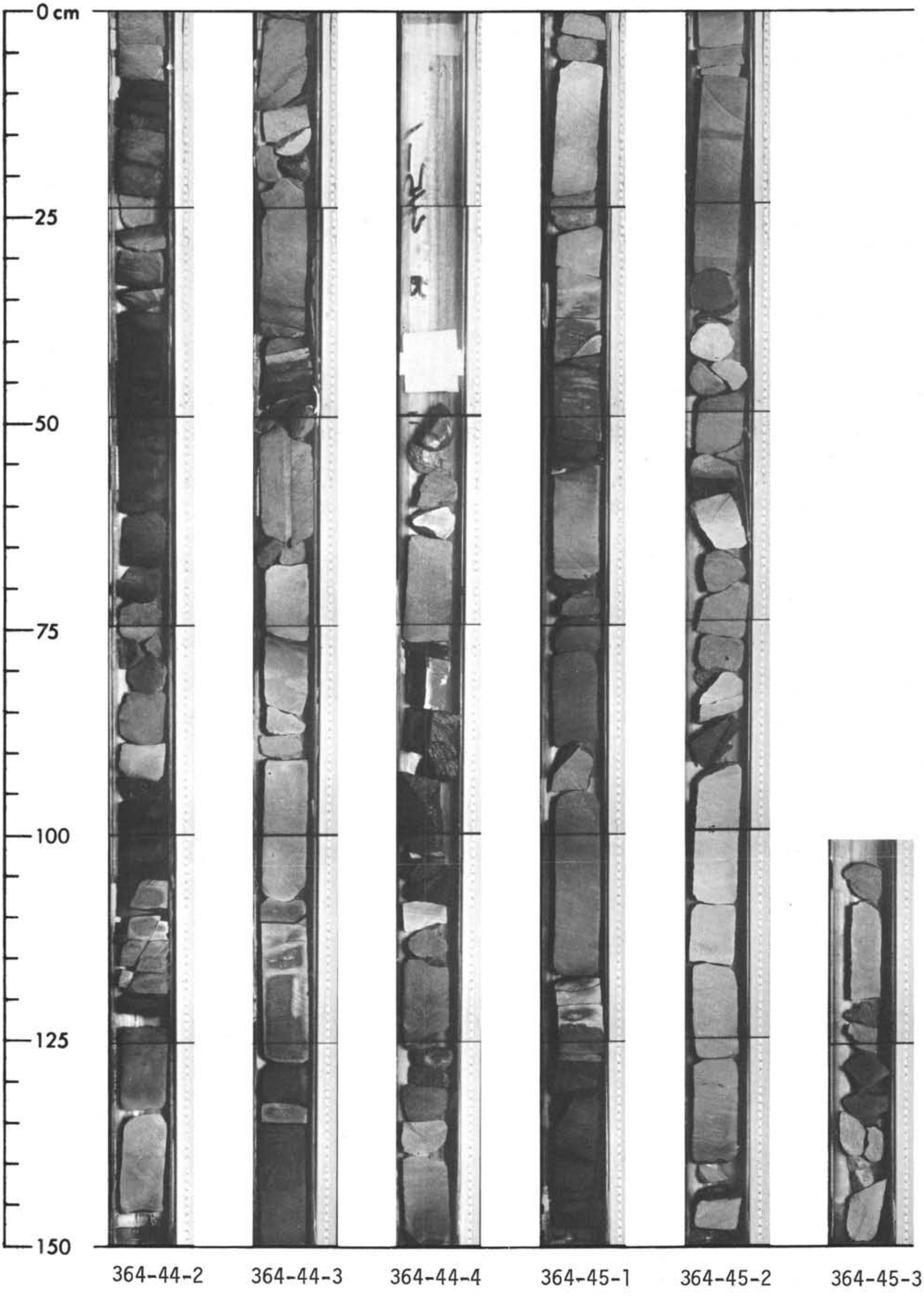
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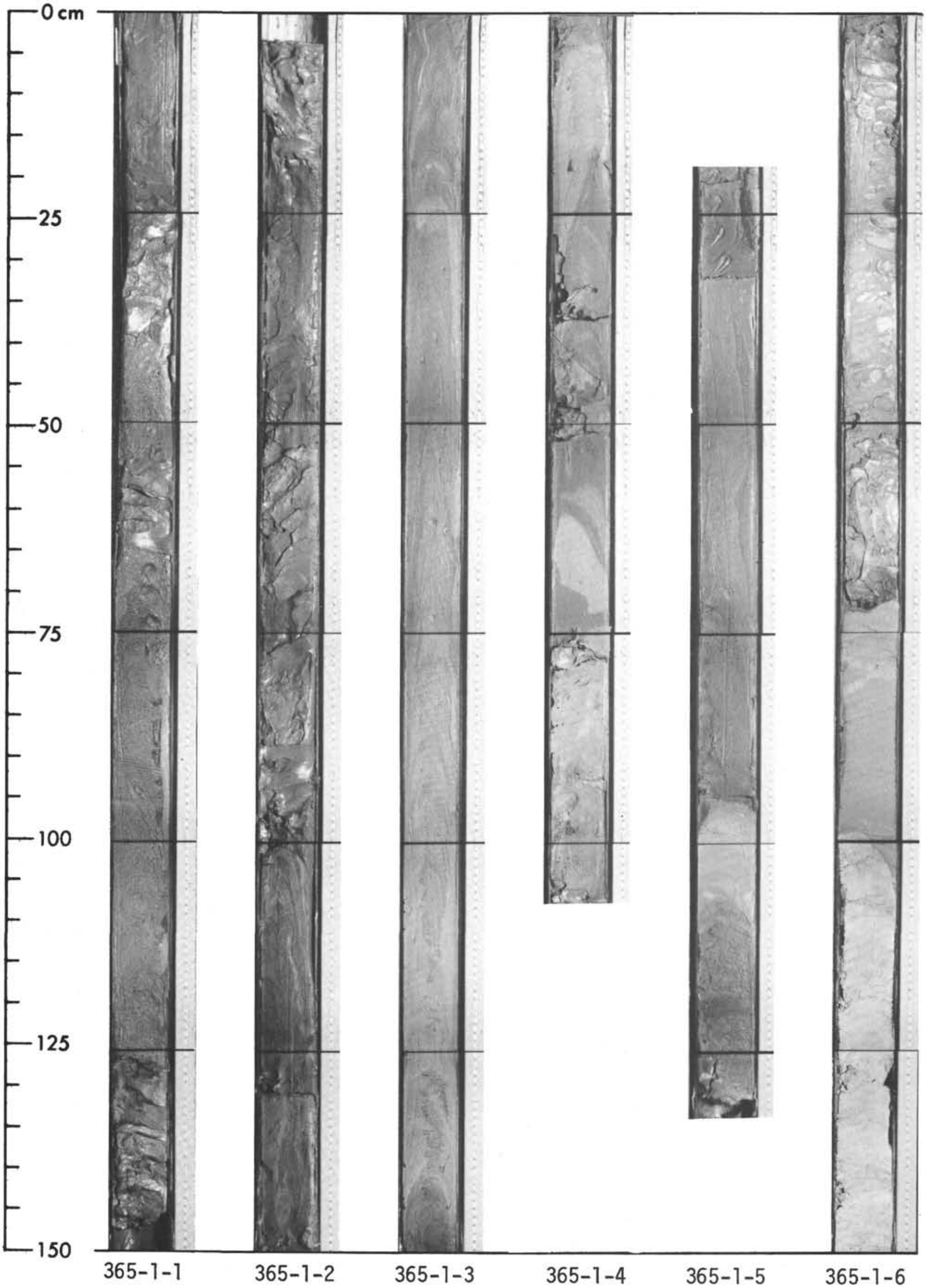
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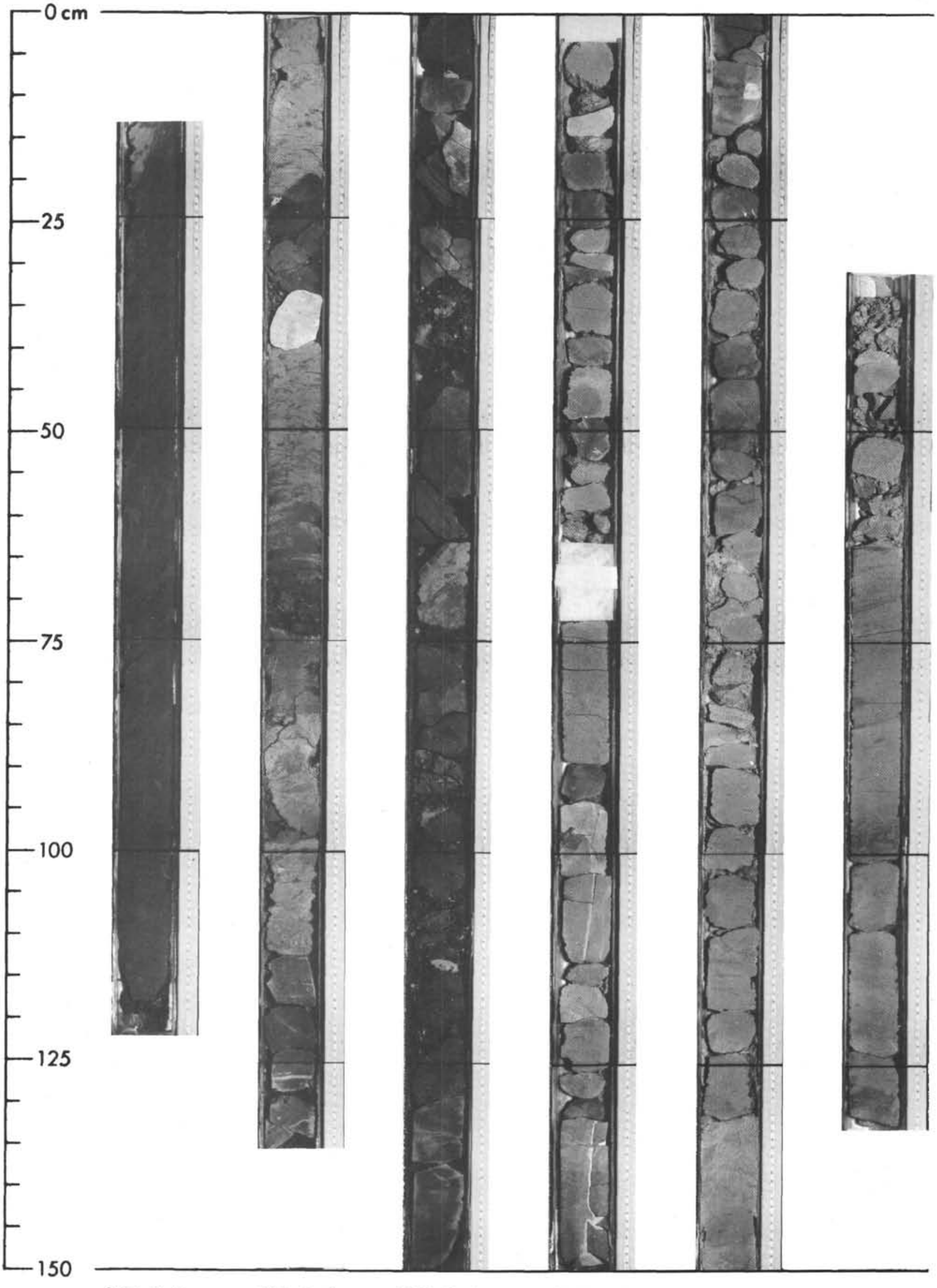

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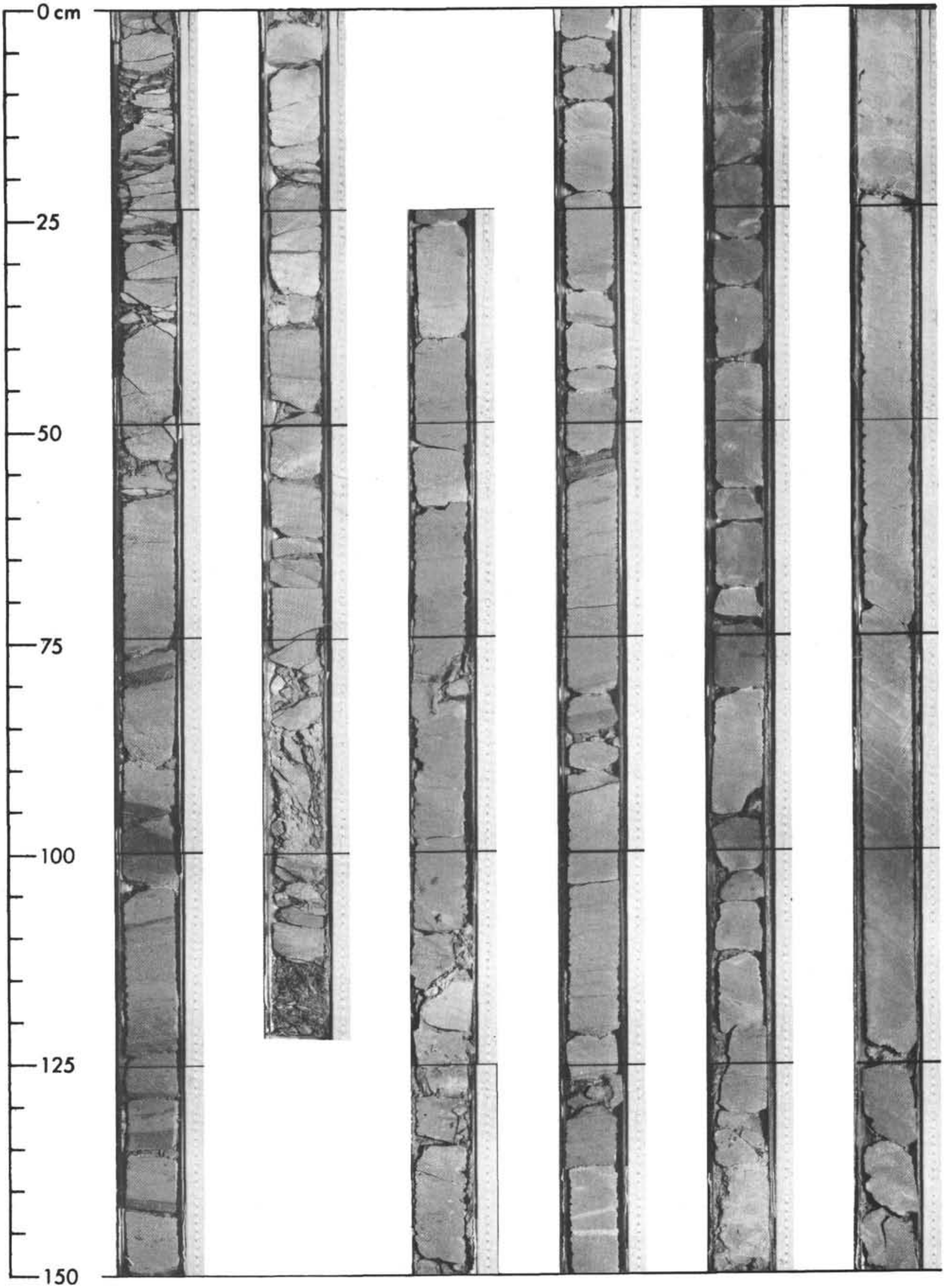

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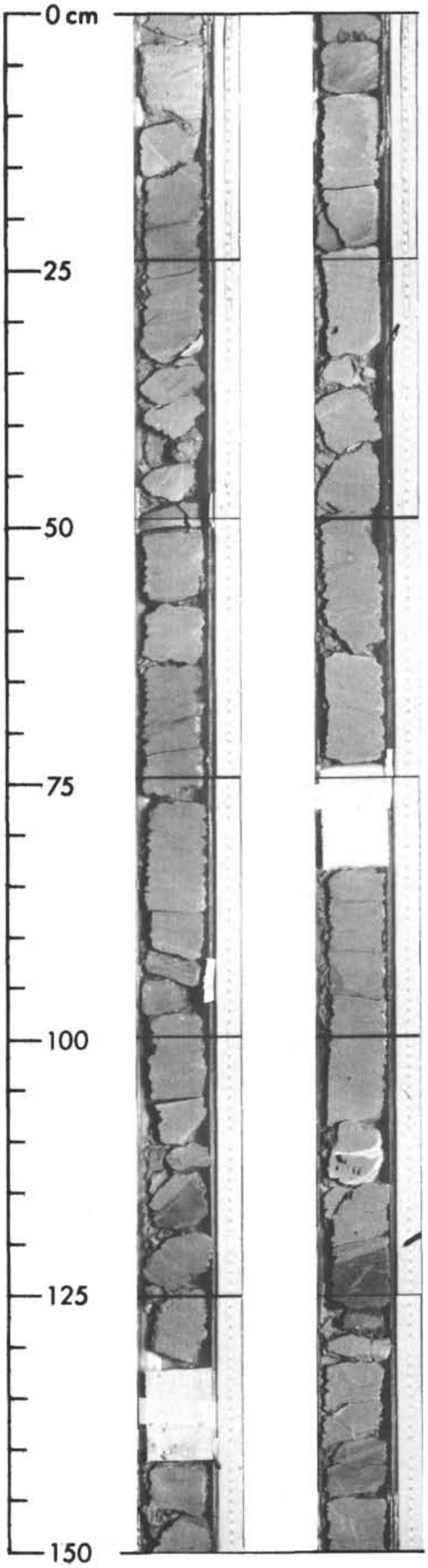
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