3. WALVIS RIDGE—SITES 362 AND 363

The Shipboard Scientific Party[1]

SITE DATA—362 AND 362A

Position: 19°45.45′S, 10°31.95′E (Abutment Plateau portion of the Frio Ridge segment of Walvis Ridge)

Water Depth: 1325 corrected meters, echo sounding, 1336 meters, drill pipe measurement

Number of Holes: 2

Number of Cores: 44 (362) and 12 (362A)

Total Length of Cored Section: 418 (362) and 109.5 (362A) meters

Total Core Recovered: 367.25 (362) and 76.95 (362A) meters

Percentage Core Recovery: 87.8% (362) and 70.36% (362A)

Oldest Sediment Cored:
Depth sub-bottom: 1081 meters
Nature: limestone
Age: lower Eocene
Measured velocity: 4.04 km/sec

Basement:
Depth sub-bottom: not reached
Nature: not known; inferred basaltic

Principal Results: Site 362 is located on the Abutment Plateau of the Frio Ridge segment of the Walvis Ridge where it adjoins the continental margin of southwest Africa. To avoid hydrocarbon entrapment, the site was targeted near the axis of a north-south linear trough at 1330 hours, 26 June, seismic reflection profile *Jean Charcot* Walda Cruise, profile 11, near an intersection with 0900 hours, May 13, reflection profile *Vema* 29-06, profile record 928, and 2100 hours, 12 May, reflection profile *Atlantis II*, Cruise 67, Leg 6, latitude 19°45′S, longitude 10°32′E, water depth 1325 meters. This location permitted the sampling of a thick stratigraphic section with acoustic marker horizons that can be traced northward into the Angola Basin, southward into the Cape Basin, eastward beneath the African slope and shelf, and westward toward northern Valdivia Bank. Two holes were drilled. Hole 362 was terminated at 806 meters sub-bottom when the newly designed internal bit seal deformed and prevented the inner core barrel from seating. Hole 362A was abandoned at 1081 meters sub-bottom because of bit failure.

The section penetrated is stratigraphically continuous in its entirety and extends from the Holocene to the lower Eocene. It consists of biogenic oozes, both siliceous and calcareous, chalk, marly chalk, and limestone. Planktonic foraminifers are predominantly of the cool-temperate type with intermixing of subtropical species at various levels.

Four lithologic units are recognized. Unit 1 is a Pleistocene to upper Miocene diatomaceous marly nannofossil ooze and chalk bearing radiolarians and silicoflagellates, 36-188 meters sub-bottom. A strong erosional and regressive cycle occurs in the upper Miocene. Unit 2 is an upper Miocene to uppermost Oligocene foraminifer-bearing nannofossil chalk, 188-820 meters sub-bottom, well-bedded with cyclic intercalations of marly material and containing a strong dissolution cycle in the middle Miocene *Globorotalia fohsi fohsi* and *G. fohsi lobata* zones. Unit 3 is an Oligocene-age *Braarudosphaera* chalk, 820-924 meters sub-bottom, with intercalations of marly nannofossil chalk showing evidence of dissolution and winnowing between pure white beds totally dominated by the *Braarudosphaera*. Unit 4 is an upper to lower Eocene marly nannofossil chalk and limestone, 924-1081 meters sub-bottom, with an appreciable diagenetic recalcification and cementation which eventually caused the destruction of the bearings in the core bit.

A strong, regionally widespread reflector at 0.94 seconds correlates with the top of the *Braarudosphaera* chalk unit. This acoustic horizon can be traced all the way to Site 360 in the southern Cape Basin. Lithologic Unit 1 is confined to progradational foreset beds along the African slope and is absent from the shelf in the Abutment Plateau area. Sound velocities are generally less than 1.7 km/sec for the upper 500 meters of the section penetrated and reach values of 3.75 to 4.03 km/sec in the calcite-cemented chalks and limestones of lithologic Unit 4. Forty-four cores were taken in Hole 362 and 12 in Hole 362A.

SITE DATA—363

Position: 19°38.75′S, 09°02.80′E (isolated basement high on north-facing escarpment of Frio Ridge portion of Walvis Ridge)

Water Depth: 2248 corrected meters, echo sounding, 2247 meters, drill pipe measurement

Number of Holes: 1

Number of Cores: 40

Total Length of Cored Section: 380.0 meters

Total Core Recovered: 226.9 meters

Percentage Core Recovery: 59.7%

Oldest Sediment Cored:
Depth sub-bottom: 715 meters
Nature: limestone interlayered with calcarenite
Age: lower Aptian
Measured velocity: 3.11 km/sec

Basement:
Depth sub-bottom: 750 meters inferred from seismic reflection profile
Nature: basaltic based on dredge hauls within a few tens of kilometers of the drill site at a similar depth (2800 m) below sea level

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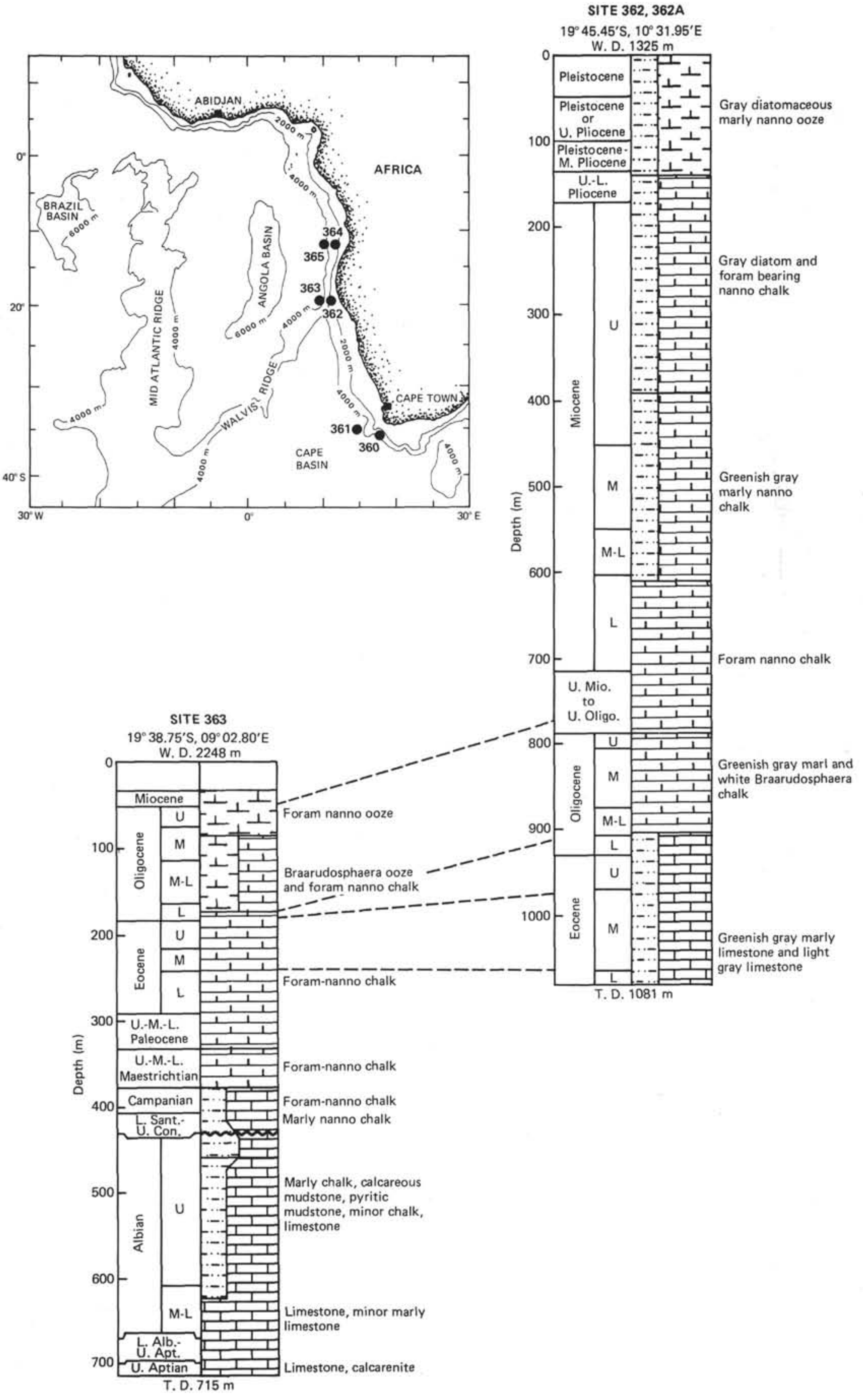
[1] Hans M. Bolli, Swiss Federal Institute of Technology, Zurich, Switzerland (Co-chief scientist); William B. F. Ryan, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York (Co-chief scientist); James B. Foresman, Phillips Petroleum Corp., Bartlesville, Oklahoma; William E. Hottman, Texas A&M University, College Station, Texas; Hideo Kagami, Ocean Research Institute, Tokyo, Japan; Jose F. Longoria, National Autonomous University of Mexico, Mexico D.F., Mexico; Brian K. McKnight, University of Wisconsin, Oshkosh, Wisconsin; Marthe Melguen, Centre Océanologique de Bretagne, Brest, France; James Natland, Scripps Institution of Oceanography, La Jolla, California; Franca Proto-Decima, Padova University, Padova, Italy; William G. Siesser, University of Cape Town, Rondebosch, South Africa.


ABIDJAN
AFRICA
BRAZIL BASIN
6000 m
2000 m
4000 m
ANGOLA BASIN
MID ATLANTIC RIDGE
WALVIS RIDGE
CAPE TOWN
CAPE BASIN
364
365
363
362
361
360
0°
20°
40° S
30° W
30° E
SITE 362, 362A
19° 45.45'S, 10° 31.95'E
W. D. 1325 m
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000
Pleistocene
Pleistocene or U. Pliocene
Pleistocene-M. Pliocene
U.-L. Pliocene
Miocene
U
M
M-L
L
U. Mio. to U. Oligo.
Oligocene
U
M
M-L
L
Eocene
U
M
L
T. D. 1081 m
Gray diatomaceous marly nanno ooze
Gray diatom and foram bearing nanno chalk
Greenish gray marly nanno chalk
Foram nanno chalk
Greenish gray marl and white Braarudosphaera chalk
Greenish gray marly limestone and light gray limestone
SITE 363
19° 38.75'S, 09° 02.80'E
W. D. 2248 m
Depth (m)
0
100
200
300
400
500
600
700
Miocene
Oligocene
U
M
M-L
L
Eocene
U
M
L
U.-M.-L. Paleocene
U.-M.-L. Maestrichtian
Campanian
L. Sant.-U. Con.
Albian
U
M-L
L. Alb.-U. Apt.
U. Aptian
T. D. 715 m
Foram nanno ooze
Braarudosphaera ooze and foram nanno chalk
Foram-nanno chalk
Foram-nanno chalk
Foram-nanno chalk
Marly nanno chalk
Marly chalk, calcareous mudstone, pyritic mudstone, minor chalk, limestone
Limestone, minor marly limestone
Limestone, calcarenite

Principal Results: Site 363 is located close to the crest of an isolated basement high along the north-facing escarpment of the Frio Ridge segment of the Walvis Ridge at 1530 hours, 23 June, seismic reflection profile *Jean Charcot*, Walda Cruise, profile 9, latitude 19°39′S, longitude 09°03′E, water depth 2248 meters. The selected location permitted sampling in a single hole of a stratigraphic overlap with Site 362 on the Abutment Plateau and of a continuation of the latter section into the Lower Cretaceous. The hole was terminated at 715 meters sub-bottom just tens of meters from the basement with a shearing off of all three cones of the core bit. The section recovered extends from the upper Miocene to the lower Aptian, with one prominent erosional gap between the Recent and the upper Miocene. Another gap occurs between the Coniacian and the uppermost Albian, but may partly reflect ecologic conditions which prevented North Atlantic Cenomanian-Santonian marker fossils from reaching the South Atlantic. The section consists predominantly of biogenic oozes, chalks, marls, and limestones. The oldest sediments at the base of the hole have shallow-water to supratidal components including calcareous algae and are coincident with the basement isochrone inferred from its seaward position from the continental edge on strike with magnetic anomaly M-O. We can conclude that the Frio Ridge is a fracture zone escarpment which was created at the axis of an Aptian-age mid-oceanic ridge and has gradually subsided to its present depth, never experiencing a significant subsequent uplift as was suggested to have occurred at about 80 million years (Connary, 1972). The Upper Cretaceous and Tertiary planktonic faunas here on the northern side of the Walvis Ridge consist of warmer and more tropical assemblages than that at Site 362 on the southern Cape Basin side.

Three lithologic units are recognized. Unit 1 is an upper Miocene to lower Maestrichtian nannofossil ooze and chalk containing white *Braarudosphaera* ooze layers in the Oligocene, 31-373 meters sub-bottom. Unit 2 is a Campanian to lower Aptian nannofossil marl, 373-696 meters sub-bottom. There is considerable evidence of condensation of the section by winnowing along thin, numerous erosional contacts. The Albian has dark layers characterized by disseminated pyrite, suggesting at least localized reducing conditions. The input of terrigenous clays in the marls of this unit is strongly cyclic and perhaps climatically controlled. Recrystallization including dolomitization is extensive in the Aptian. Pore fluids show the influence of underlying volcanic basement (Sotelo and Gieskes, this volume). Unit 3 consists of lower Aptian limestone, 696-715 meters sub-bottom, interlayered with calcarenites containing fragments of lamillibranchs and calcareous algae, suggesting a high-energy, near-shore environment.

Sound velocities reach 3.0 to 3.5 km/sec in the Lower Cretaceous marls and limestones. Forty cores were taken.

BACKGROUND AND OBJECTIVES

Background

The northeast-southwest-trending easternmost segment of the Walvis Ridge forms a high-standing topographic barrier in the eastern South Atlantic which intersects the western continental margin of southern Africa. This barrier acts as an obstruction to oceanic water masses passing northward from the Cape Basin to the Angola Basin. Marked differences exist in the sedimentary and morphological development of the southwest African continental margin on the two sides of this important structural feature.

Where the Walvis Ridge parallels the "transform direction" for the earliest phase of opening of the South Atlantic, its steep north-facing escarpment resembles a fracture zone wall termed a "marginal fracture ridge" by Francheteau and LePichon (1972). The crest of this linear high has beec called the Frio Ridge by Barnaby (1974) (see Figure 1). The pre-drift reconstruction of Bullard et al. (1965) would indicate that the entire Frio Ridge along with its structural abutment with the African margin (called the Abutment Plateau by Barnaby) occurs in a geographical province created since the initial continental breakup.

Within the northern part of the Cape Basin to the south of Frio Ridge it has recently been possible to recognize magnetic anomaly lineations of the Mesozoic "Cape Sequence" of Larson and Ladd (1973). The projection of these anomaly stripes northward onto the Frio Ridge fracture zone lineament (Figure 2) raises the possibility that the crustal rocks beneath the ridge segment and its abutment zone were emplaced during the earliest opening phase of the ocean prior to the end of evaporite deposition in the Angola and Guinea basins to the north.

According to basement contours of Barnaby (1974) reproduced in Figure 3, the Frio Ridge consists of two en echelon, steep-sided basement highs separated by a gap at approximately 10°E longitude where the sill depth is 3.8 seconds (two-way reflection time). A second and slightly deeper gap with a 4.2 seconds thalweg winds a route between the easternmost segment of the Frio Ridge basement high and a north-south structural unit parallel to the continental margin underlying the modern shelf break. Both passageways are inferred to have been important conduits for oceanic water-mass transport during the Mesozoic.

Seismic reflection profiles permit the correlation of deeply buried sedimentary horizons of the Cape Basin northward into shallower levels of the Abutment Plateau and even into a small southwest-northeast oriented trough perched high on the crest of the Frio Ridge (Goslin et al., 1974). These profiles illustrate quite clearly that the deepest and hence oldest strata visible above the acoustic basement were deposited after the relative relief of the basement was created. A sampling of these strata should provide evidence as to the age of this easternmost segment of the Walvis Ridge.

Scientific Objectives

Several objectives were considered achievable if deep penetration could be effected at a combination of two drill sites—one on the Abutment Plateau (Site 362) to sample the younger part of the sediment section and to identify key seismic reflectors and a second (Site 363) to attempt a sampling of older Mesozoic rocks and the acoustic basement. The basement site was designed in order to determine the nature of igneous crust believed to be part of a marginal fracture ridge.

New information was sought in order to learn:

1) the age of the initial open-marine sedimentation on the crest of a topographic barrier between the Cape and Angola basins which was thought to have (a) isolated the two basins at the time of Aptian salt deposition, and (b) stood 3 to 4 km higher than the basin floor during the Upper Cretaceous and Tertiary;

2) sedimentary history of the continental margin at the juncture of the Walvis Ridge and the African continent;

3) the role played by the Walvis Ridge as a barrier to faunal migration and as an influence on the northward movement of cold-water masses;

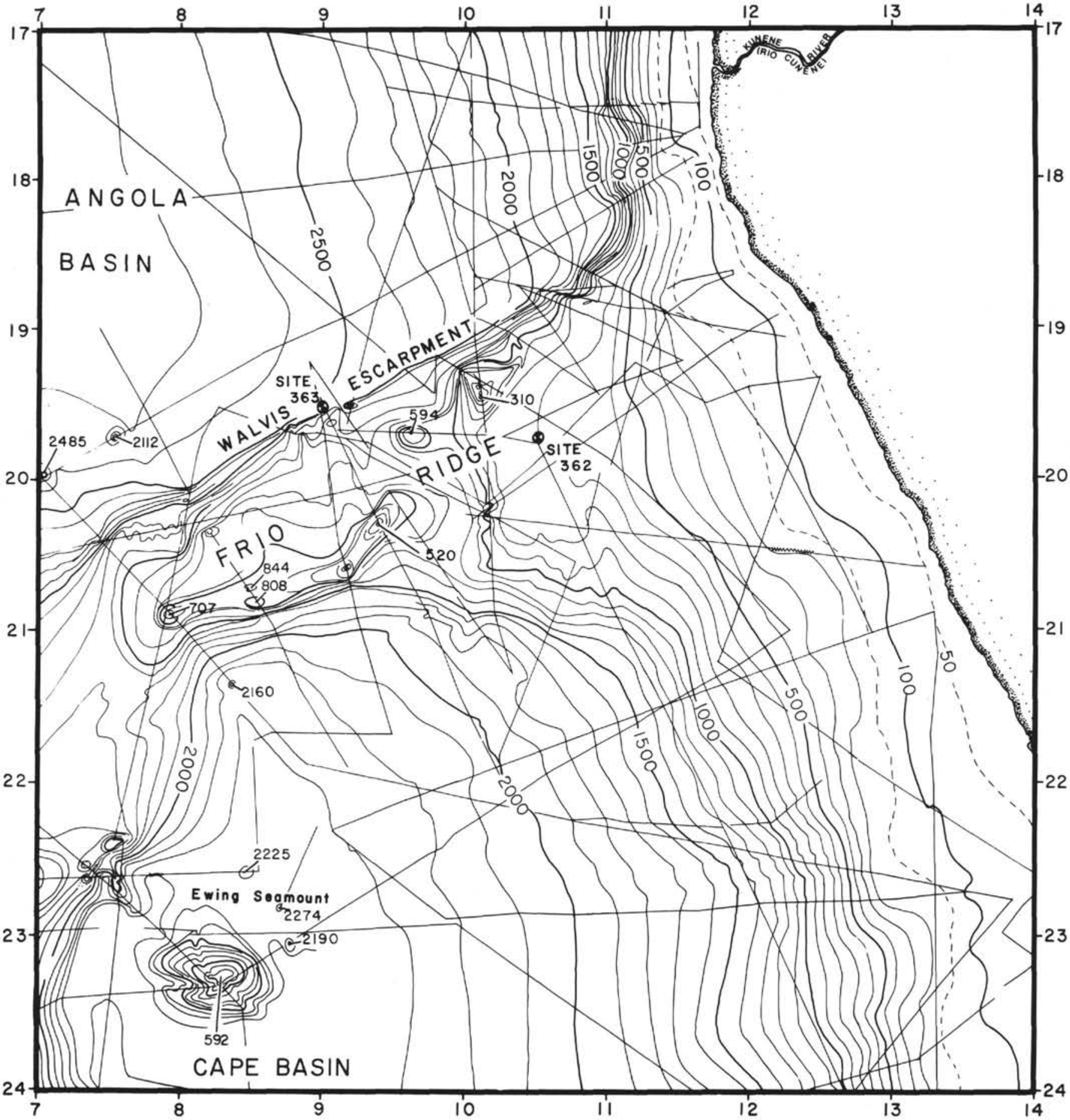


Figure 1. *Chart of eastern Walvis Ridge showing location of Sites 362/362A and 363, based in part on Barnaby (1974).*

4) the role played by the Walvis Ridge in isolating the Angola Basin to allow evaporite deposition there;

5) the petrology of basement rocks emplaced on the steep fracture zone ridge;

6) the stratigraphic position and lithologic makeup of important seismic horizons including Reflectors *Davy* and *Atlantis II*;

7) the origin of thick upper Cenozoic biogenic sediment sequences in relation to climatically controlled events, and

8) interhemispheric conditions of high-latitude Austral-New Zealand faunal groups with low-latitude tropical to semi-tropical groups.

Strategy

Because of the overriding concern for potential hydrocarbon entrapment in thick continental margin sections, we deemed it necessary to locate carefully the deepest stratigraphic hole (Site 362) in a synclinal setting

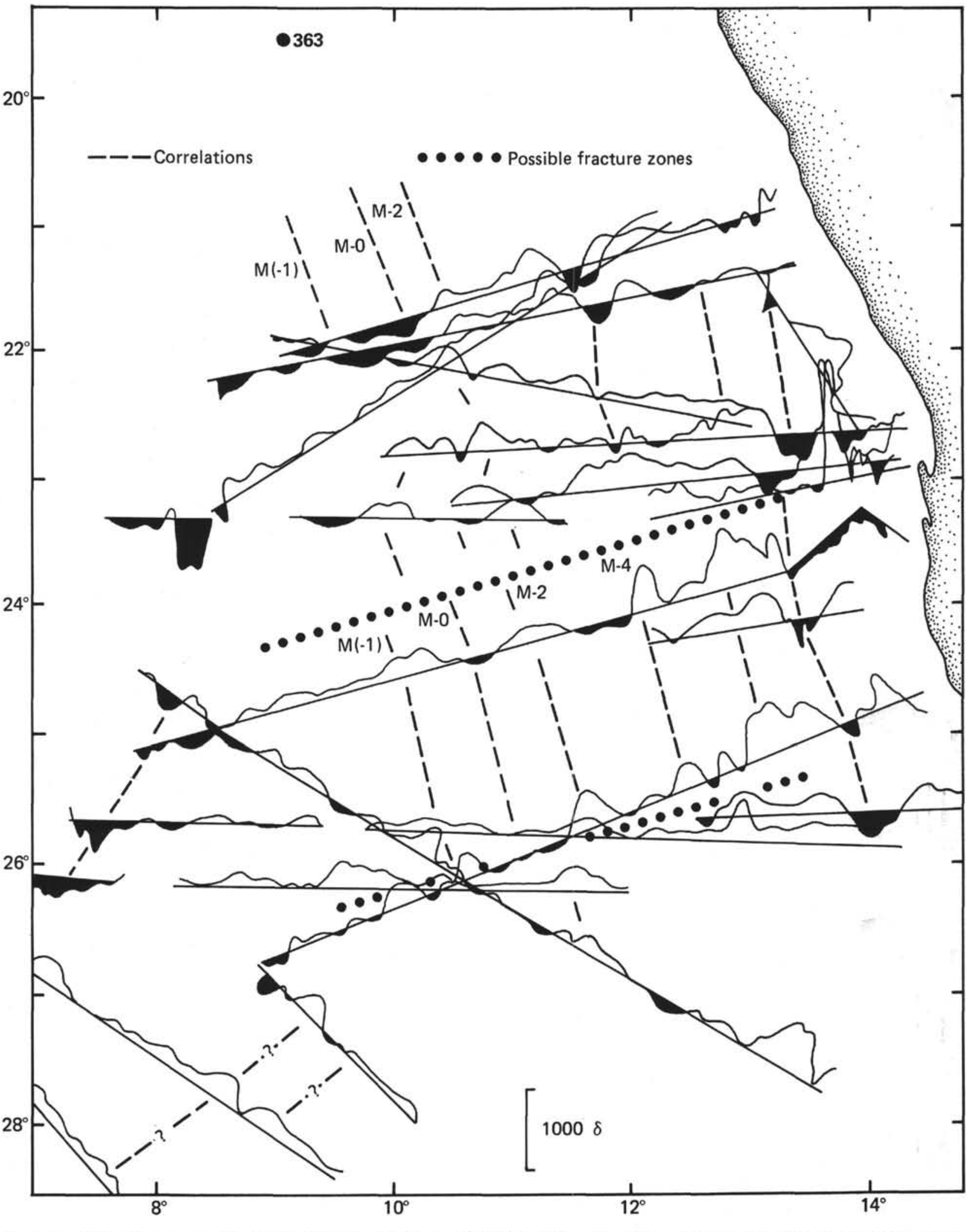


Figure 2. *Magnetic anomalies in the Cape Basin south of Walvis Ridge, based on Barnaby (1974). Projection of Site 363 is to anomaly M-O.*

such as exists on the Abutment Plateau. An appropriate site was chosen at 1330 hours, 26 June, 1971, on Walda Profile 11 (Figure 4) of the *Jean Charcot* (Goslin, et al., 1974). The exact location was positioned near an intersection with a

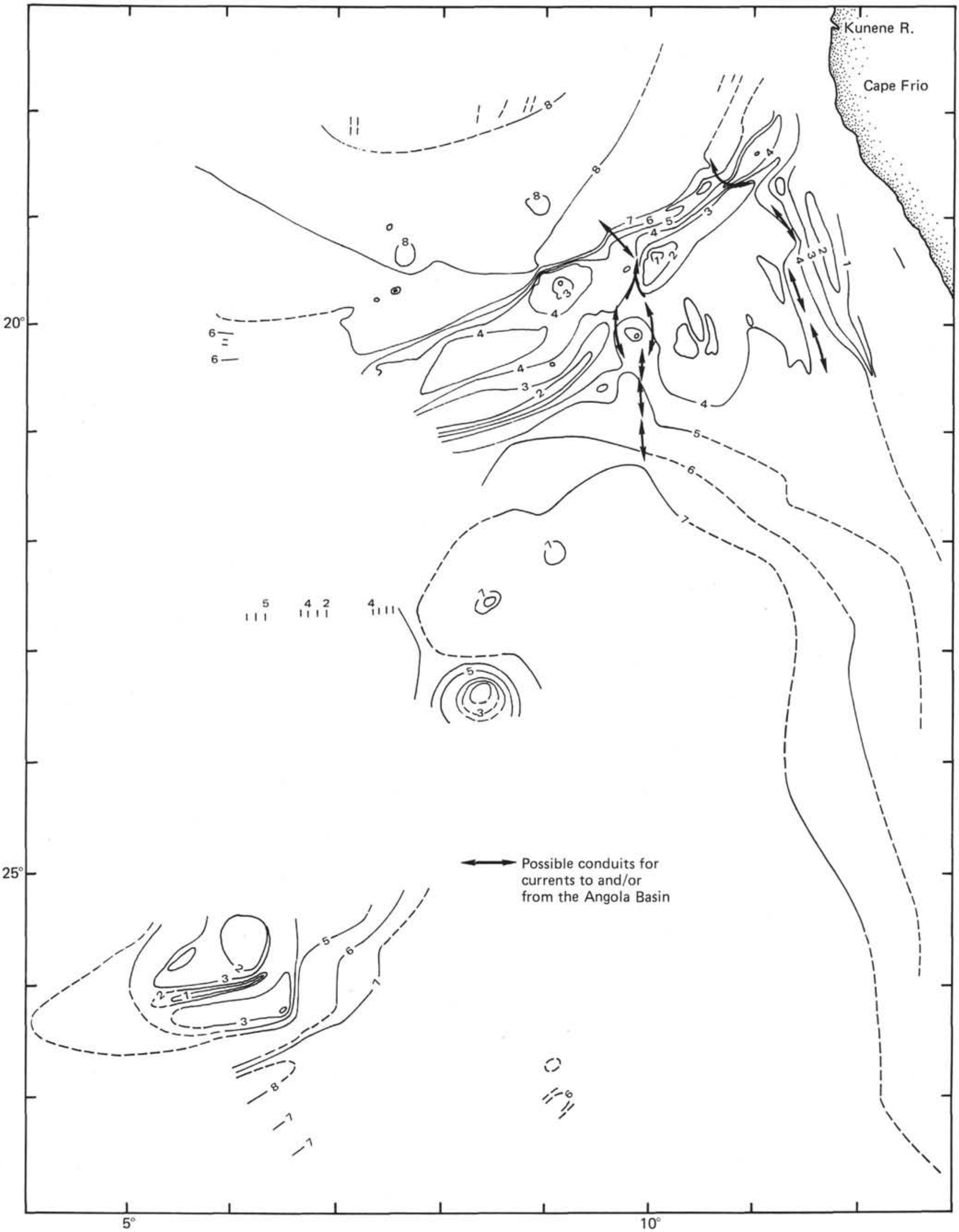


Figure 3. *Basement contours on Walvis Ridge, based on Barnaby (1974).*

Figure 4. *Succession of Miocene white chalk and darker marly chalk, intensively burrowed, Hole 362A, Sample 4-3, 29-53 cm.*

Vema profile that provides correlation eastward to shallower regions of the modern slope and shelf, northwards into the Angola Basin, and southwards into the Cape Basin.

Unfortunately, at this selected site, the basement lay too deep to be sampled (>2 km below the seabed). Therefore a second hole (Site 363) was targeted further west at 1530 hours, 23 June 1971, on Walda Profile 9 (Figure 5) to where the deeper horizons of the first drill site could once again be identified at an equivalent depth (3 km) below sea level, yet under a much thinner overburden. The second site had also to be positioned sufficiently far northward on Walda profile 9 to be isolated from updip hydrocarbon migration from the aforementioned Frio Ridge crestal trough.

OPERATIONS

Approach to Site 362/362A

Site 362/362A was approached from a heading of 335° on the afternoon of 17 January 1975. The site is located on the Abutment Plateau of the Frio Ridge segment of the Walvis Ridge where the ridge adjoins the continental margin of southwest Africa. To avoid hydrocarbon entrapment, the site was targeted near the axis of a north-south linear trough at 1330 hours, 26 June, seismic reflection profile 11 of the *Jean Charcot* Walda Cruise, near an intersection with 0900 hours, 13 May, reflection profile *Vema* 29-06, profile record 928, and 2100 hours, 12 May, reflection profile *Atlantis II*, Cruise 67, Leg 6. Beacon drop was at 1830 hours on 17 January. The mean satellite-fix location of the site was 19°45.45'S, 10°31.95'E. The water depth was 1336 meters (drill string length). The first core was recovered at 0330 hours on 18 January (Table 1). The site consisted of two holes. Hole 362 was occupied until 1030 hours on 20 January. Penetration was 805.5 meters. Forty-four cores were taken. Recovery was nearly 100 per cent through Core 21, and between 60 per cent and 100 per cent from Cores 22 to 41. Only core catchers were recovered in Cores 42 to 44 because failure of the experimental bit seal prevented latching of the core barrel. With this, the string was pulled, a new core bit (without bit seal) was attached, and the string was lowered again to the sea floor. Core 1 of Hole 362A was retrieved at 1115 hours on 21 January. The hole was occupied until 1500 hours, 23 January. Twelve cores were taken between 696 and 1081 meters sub-bottom. Recovery ranged between about 50 per cent and 100 per cent through Core 10, but dropped to less than 10 per cent in Cores 11 and 12. By this time, the penetration rate had dropped to less than 4 meters per hour. We saw little likelihood of reaching our Cretaceous objective, and so decided to pull the drill string. The string was entirely on deck by 2000 hours on 23 January. We streamed the gear and headed on a westerly course (274°) for Site 363.

During occupation of Hole 362, the rate of penetration was high until Cores 34 and 35, when a drop from 36 m/hour to 26 m/hour occurred. This is at about the top of Acoustic Unit IV, marked by a sharp change in the physical properties. From Cores 37 to 44, the rate generally dropped from about 20 m/hour to a minimum of 12 m/hour (Core 43).

The penetration rate at Hole 362A from about the depth where Hole 362 was abandoned was low, about 12 m/hour, and gradually became lower, to a minimum of 4 m/hour in Core 12. These low rates apparently were the result of an

Figure 5. *Well-preserved "Zoophycos" type burrows in Miocene chalk, Hole 362, Sample 35-3, 80-95 cm.*

increasing component of terrigenous clay in the Oligocene and Eocene section of the hole. Medium insert four-cone Smith F94CK and F94C core bits were used at the two holes, respectively. Drilling became increasingly "gummy" in Hole 362A, so that the core bit could not cut into the hole.

No mature hydrocarbons were detected in either Holes 362 or 362A. However, H_2S and CO_2 were high in Cores 10 to 25. The core lab had to be opened and ventilated with large fans at the passageways. Nevertheless, the scientific party feels that the noxious fumes did not affect their judgment, and that their interpretations on Site 362/362A are valid despite all.

Approach to Site 363

Site 363 was approached from a heading of 270° in the early morning of 24 January 1975. The site is located close to the crest of an isolated basement high along the north-facing escarpment of the Frio Ridge segment of the Walvis Ridge at 1530 hours, 23 June, seismic reflection profile 9 of the *Jean Charcot* Walda Cruise. The selected location permitted sampling in a single hole of a stratigraphic overlap with Site 362 on the Abutment Plateau, and of a continuation of the latter section into the Lower Cretaceous. Beacon drop was at 0430 hours on 24 January. The mean satellite fix location of the site was 19°38.75'S, 09°02.80'E. The water depth was 2247 meters (drill string length). Penetration was 715 meters with the hole terminating in lower Aptian limestone interlayered with calcarenite. Basement, estimated at 750 meters sub-bottom, was not reached. The first core was recovered at 1445 hours on January 24 (Table 2). A total of 40 cores was taken, the final one being retrieved at 1630 hours on 27 January. Recovery was high initially, but dropped to a low of 14 per cent as early as Core 7. However, recovery improved to 100 per cent in Cores 10-12 and 14, and then began oscillating — 23 per cent in Core 17, 84 per cent in Core 18, 48 per cent in Core 20, 100 per cent in Core 21, 12 per cent in Core 22, and so on. With increasing induration, recovery improved, reaching 100 per cent in three straight cores, 28-30. Recovery dropped abruptly in the final two cores, signaling destruction of the core bit, although this was masked by a sudden increase in the rate of penetration. Following recovery of Core 40, we thought the barrel was plugged and lowered the center bit. This jammed forcing retrieval of the entire drill string. The core bit had lost all three cones and all core guides when we brought it on deck.

Penetration rates were high, between 40 m/hour and 80 m/hour through Core 21, except for Core 13, 26 m/hour. With Core 22, however, the penetration rate dropped to 24 m/hour, and remained below 20 m/hour except for Cores 28 (26 m/hour) and 39 (20.2 m/hour) The slowest drilling rates were for Cores 23 and 24, less than 10 m/hour. Interestingly, none of these changes in rate or recovery correspond to major reflectors or changes in lithology.

A three-cone medium-insert Smith F94C core bit was used at Site 363. Although there were only three cones, the bearing size was larger than on the four-cone bits, and we thought this might improve bit life. Unfortunately we were wrong.The bit was destroyed after only 28 hours of rotation, a low for Leg 40.

No mature hydrocarbons were encountered at Site 363.

We departed the site at 0030 hours on 28 January 1975. Because our incoming profiler record was difficult to use to pick the basement depth (we were close to the edge of the steep north-facing escarpment of Frio Ridge), we first proceeded on a southwesterly course (224°) before circling back over the beacon on a course of 060°. This gave a high-quality reflection record from which we picked the basement depth at about 720 meters, just a few meters beyond our total penetration at the site. Shortly after passing over the northern scarp of Frio Ridge, we changed heading to 018° and proceeded to Site 364.

LITHOLOGY

Site 362/362A Lithologic Descriptions

Site 362/362A, water depth 1325 meters, is located at 19°45.45'S, 10°31.95'E on the northern flank of the

TABLE 1
Coring Summary, Site 362/362A

Core	Date (January)	Time	Depth From Drill Floor (m)	Depth Below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Recovered (%)
Hole 362							
1	18	0330	1372-1381.5	36-45	9.5	9.5	100
2	18	0420	1381.5-1391	45.5-55.0	9.5	8.65	91
3	18	0505	1391-1400.5	55.0-64.5	9.5	9.5	100
4	18	0555	1400.5-1410	64.5-74.0	9.5	9.5	100
5	18	0640	1410-1419.5	74.0-83.5	9.5	9.5	100
6	18	0730	1418.5-1429	83.5-93.0	9.5	9.5	100
7	18	0820	1429-1438.5	93-102.5	9.5	9.5	100
8	18	0905	1438.5-1448	102.5-112	9.5	9.5	100
9	18	0950	1448-1457.5	112-121.5	9.5	9.5	100
10	18	1040	1457.5-1467	121.5-131	9.5	9.5	100
11	18	1140	1467-1496.5	131-140.5	9.5	9.5	100
12	18	1230	1476.5-1486	140.5-150	9.5	9.5	100
13	18	1325	1486-1495.5	150-159.5	9.5	9.5	100
14	18	1410	1495.5-1505	159.5-169	9.5	9.5	100
15	18	1505	1514.5-1524	178.5-188	9.5	9.2	97
16	18	1615	1533.5-1543	197.5-207	9.5	9.5	100
17	18	1710	1552.5-1562	216.5-226	9.5	9.5	100
18	18	1805	1571.5-1501	235.5-245	9.5	9.5	100
19	18	1900	1540.5-1600	254.5-264	9.5	9.5	100
20	18	2015	1609.5-1619	273.5-283	9.5	9.5	100
21	18	2115	1628.5-1638	292.5-302	9.5	9.5	100
22	18	2205	1647.5-1657	311.5-321	9.5	5.3	56
23	18	2300	1666.5-1676	330.5-340	9.5	8.65	91
24	18	2355	1685.5-1695	349.5-359	9.5	9.5	100
25	19	0105	1704.5-1714	368.5-378	9.5	9.5	100
26	19	0210	1723.5-1733	387.5-397	9.5	9.5	100
27	19	0320	1742.5-1752	406.5-416	9.5	8.8	93
28	19	0430	1761.5-1741	425.5-435	9.5	9.5	100
29	19	0610	1780.5-1790	444.5-454	9.5	6.4	67
30	19	0810	1799.5-1809	463.5-473	9.5	5.5	58
31	19	0930	1818.5-1828	482.5-492	9.5	6.85	72
32	19	1100	1837.5-1847	501.5-511	9.5	9.5	100
33	19	1220	1856.5-1866	520.5-530	9.5	9.5	100
34	19	1410	1885-1894.5	549-558.5	9.5	9.5	100
35	19	1610	1913.5-1923	577.5-587	9.5	9.5	100
36	19	1740	1932.5-1942	596.5-606	9.5	5.4	57
37	19	1900	1951.5-1961	615.5-625	9.5	9.5	100
38	19	2050	1980-1989.5	644-653.5	9.5	9.4	99
39	20	2330	2008.5-2018	672.5-682	9.5	8.1	85
40	20	0115	2037-2046.5	701-710.5	9.5	9.5	100
41	20	0350	2065.5-2075	729.5-739.0	9.5	9.5	100
42	20	0615	2094.0-2103.5	758.0-767.5	9.5	cc only	∿1
43	20	0900	2122.5-2132	786.5-796	9.5	cc only	∿1
44	20	1030	2132-2141.5	796-805.5	9.5	cc only	∿1
Hole 362A							
1	21	1115	2032-2037	696-701	5.0	4.8	96
2	21	1920	2132-2141.5	796-805.5	9.5	9.05	95
3	21	2200	2170-2170.5	834-843.5	9.5	9.5	100
4	22	0120	2208-2217.5	872-881.5	9.5	9.5	100
5	22	0535	2246-2255.5	910-919.5	9.5	9.5	100
6	22	0830	2265-2274.5	929-938.5	9.5	9.5	100
7	22	1150	2284-2293.5	948-957.5	9.5	6.85	72
8	22	1525	2303-2312.5	967-976.5	9.5	5.9	62
9	22	2025	2331.5-2341	995.5-1005	9.5	5.75	61
10	23	0200	2360-2369.5	1024-1033.5	9.5	4.35	46
11	23	1055	2398-2407.5	1062-1071.5	9.5	1.0	11
12	23	1500	2407.5-2414	1071.5-1081	9.5	1.1	12

easternmost part of Walvis Ridge, in a trough showing a thick sedimentary cover and well-defined reflectors which can be followed both in the Cape and Angola basins . Two holes were drilled: 362 reached 806 meters sub-bottom, and 362A was abandoned at 1081 meters sub-bottom. The section penetrated is stratigraphically continuous and extends from Holocene to lower Eocene. It consists predominantly of pelagic biogenic oozes, both siliceous and calcareous, and of their consolidated, cemented equivalents (chalk, limestone). It was possible to define four lithologic units, one of them containing an almost pure "*Braarudosphaera* chalk" (Figure 6, Table 3).

TABLE 2
Coring Summary, Hole 363

Core No.	Date (January)	Time	Depth From Drill Floor (m)	Depth Below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Recovery (%)
1	24	1445	2278–2287.5	31.0–40.5	9.5	9.5	100
2	24	1555	2297–2306.5	50–59.5	9.5	6.65	70
3	24	1705	2316–2325.5	69–78.5	9.5	5.55	58
4	24	1800	2335.0–2344.5	88–97.5	9.5	3.70	39
5	24	1920	2354–2363.5	107–116.5	9.5	6.35	67
6	24	2035	2373–2382.5	126–135.5	9.5	5.4	57
7	24	2150	2392–2401.5	145–154.5	9.5	1.35	14
8	24	2300	2411–2420.5	164–173.5	9.5	2.4	25
9	25	0020	2430–2439.5	183–192.5	9.5	4.9	51
10	25	0130	2449–2458.5	202–211.5	9.5	9.5	100
11	25	0250	2468–2477.5	221–230.5	9.5	9.5	100
12	25	0400	2487–2496.5	240–249.5	9.5	9.5	100
13	25	0525	2506–2515.5	259–268.5	9.5	6.9	73
14	25	0740	2525–2534.5	278–287.5	9.5	9.5	100
15	25	0910	2544–2553.5	297–306.5	9.5	4.7	49
16	25	1020	2553.5–2563	306.5–316	9.5	2.3	24
17	25	1140	2563–2572.5	316–325.5	9.5	2.2	23
18	25	1250	2572.5–2582	325.5–335	9.5	7.2	76
19	25	1555	2582–2591.5	335–344.5	9.5	7.95	84
20	25	1515	2591.5–2601	344.5–354	9.5	4.7	48
21	25	1700	2610.5–2620	363.5–373	9.5	9.5	100
22	25	1825	2620.0–2629.5	373–382.5	9.5	1.0	12
23	25	2050	2629.5–2639	382.5–392.0	9.5	2.4	25
24	25	2325	2648.5–2658	401.5–411	9.5	2.75	29
25	26	0200	2667.5–2677	420.5–430	9.5	2.2	23
26	26	0415	2686.5–2696	439.5–449	9.5	6.0	63
27	26	0645	2705.5–2715	458.5–468	9.5	2.4	25
28	26	0845	2724.5–2734	477.5–487	9.5	9.5	100
29	26	1055	2743.5–2753	496.5–506	9.5	9.5	100
30	26	1325	2762.5–2772	515.5–525	9.5	9.5	100
31	26	1540	2781.5–2791	534.5–544	9.5	8.7	92
32	26	1745	2800.5–2810	553.5–563	9.5	6.6	70
33	26	2010	2819.5–2829	572.5–582	9.5	8.05	85
34	26	2220	2838.5–2848	591.5–601	9.5	4.7	50
35	27	0145	2857.5–2867	610.5–620	9.5	4.2	44
36	27	0430	2876.5–2886	629.5–639	9.5	4.65	49
37	27	0705	2895.5–2905	648.5–658	9.5	8.75	92
38	27	1040	2914.5–2924	667.5–677	9.5	2.9	31
39	27	1320	2933.5–2943	686.5–696	9.5	3.2	34
40	27	1630	2952.5–2962	705.5–715	9.5	0.5	5

The following is a unit-by-unit description of the cored sedimentary sequence.

Unit 1

Unit 1a: Cores 1-10, 36-131 meters (Pleistocene-Pliocene)

The youngest sedimentary sequence at this site is predominantly an olive to dark olive fine sandy, silty calcareous clay. No sedimentary structures can be recognized. The cores are strongly disturbed both by the drilling/coring process and by very abundant gas (H_2S) cracks, resulting in a blending of sediments of various colors and perhaps of different age. Throughout this unit, the sediment contains less than about 5 per cent sand-, 15 to 20 per cent silt-, and 80 per cent clay-sized particles. The major components are calcareous nannofossils (15-60%), clay minerals (10-60%), and diatoms (5-40%). They are associated with minor components such as: planktonic foraminifers (1-5%), radiolarians (1-4%), silicoflagellates (≤1%), siliceous spicules (1%), unspecified carbonate (1-5%), quartz (1-2%), pyrite (1-2%), and traces of micas and heavy minerals (tourmaline, epidote, apatite). Subunit 1a is a diatomaceous marly nannofossil ooze, with radiolarians, silicoflagellates, and siliceous sponge spicules. In the coarse fraction, planktonic foraminifers are dominant (30-70%), followed by radiolarians (5-70%), calcareous benthic foraminifers (3-5%), echinoids (5-10%), diatoms (3-5%), sponge spicules (1%), and quartz (1-2%). Radiolarians are particularly abundant (70%) in Core 5. The preservation of radiolarians and diatoms is good (except in Core 6), whereas the preservation of planktonic foraminifers is good to moderate (≤20% fragmented tests), and the preservation of benthic foraminifers is moderate to poor (the fragmentation affecting more particularly the arenaceous species). Cores 5 and 6 are bioturbated, indicating abundant mud-feeding organisms on the ocean bottom and thus the occurrence of conditions favorable to life. The mean $CaCO_3$ content of this subunit and its standard deviation is 45 ±16 per cent (49 determinations, see barrel sheets) with a low of 15 per cent and a high of 88 per cent.

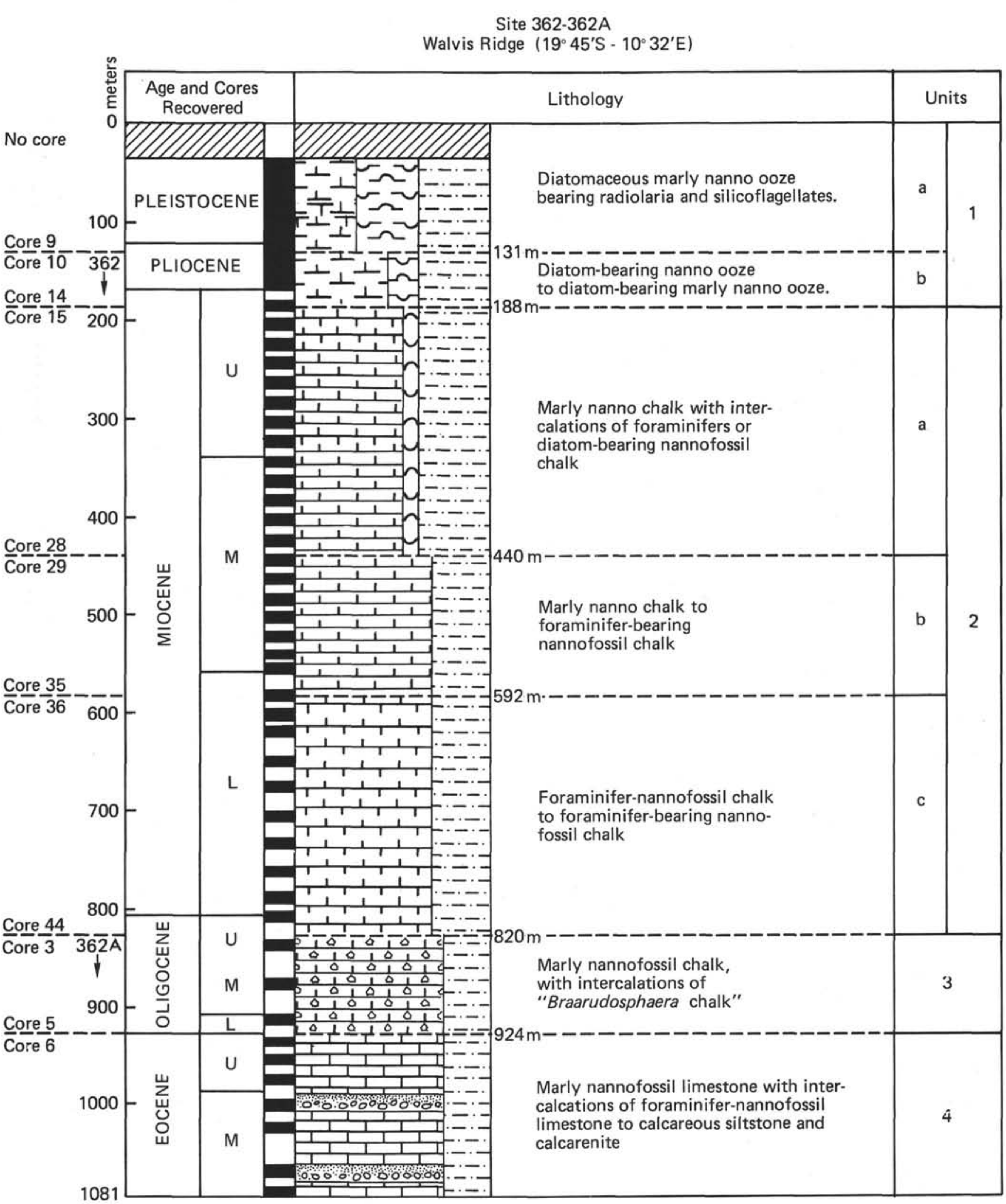


Figure 6. *Lithologic column, Site 362/362A.*

Unit 1b: Cores 11-15, 131-188 meters (Pliocene-upper Miocene)

This subunit differs from 1a in having fewer diatoms (2-10%, except in Core 11, where they constitute 20% of the sediment), radiolarians, and siliceous spicules (2-6%). Sediments are highly disturbed diatom-bearing marly nannofossil oozes and diatom-bearing nannofossil oozes.

Braarudosphaera bigelowi pentaliths, well-preserved coccospheres, and dolomitic rhombs occur in some levels.

TABLE 3
Lithological Units Site 362/362A

Unit No.	Lithology	Core	Depth in Section[a] (m)	Thickness (m)	Age	Major Changes
1a	Diatomaceous marly nannofossil ooze bearing radiolaria and silicoflagellates	1-10	36-131	95	Pleistocene-Pliocene	
1b	Diatom-bearing nannofossil ooze to diatom-bearing marly nannofossil ooze	11-15	131-188	57	Pliocene-upper Miocene	Net decrease in the relative abundance of siliceous microfossils
2a	Light or strong marly nannofossil ooze to marly nannofossil chalk, with intercalations of foraminifers or diatom-bearing nannofossil chalk	16-28	188-440	252	Upper middle Miocene	Passage from ooze to chalk
2b	Marly nannofossil chalk to foraminifer-bearing nannofossil chalk	29-35	440-592	152	Upper middle Miocene - lower Miocene	Disappearance of siliceous microfossils
2c	Foraminifer-nannofossil chalk to foraminifer-bearing nannofossil chalk	36-44 & 362A 1-2	592-820	228	Lower Miocene - upper Oligocene	
3	Marly nannofossil chalk with intercalations of "*Braarudosphaera* chalk"	362A 3-5	820-924	104	Oligocene	Appearance of "*Braarudosphaera* chalk"
4	Marly limestone with intercalcations of limestone to massive limestone, and coarse calcarenite	362A 6-12	924-1081	157	Upper to middle Eocene	Disappearance of "*Braarudosphaera* chalk" and passage from chalk to limestone

[a] Depths taken at midpoints between cores if boundaries are not actually within cores.

In the coarse fraction, siliceous microfossils are also less abundant (radiolarians, 1-10%; diatoms, 5%) and less well-preserved (obvious dissolution) than in Subunit 1a.

There is no significant change in the planktonic foraminifer preservation, which is good to fair (≤20% of fragmented tests). Ostracodes (≤3%), fish otoliths (1-2%), and rare mollusk fragments also occur.

The mean $CaCO_3$ content of the total sediment is 46 ±9 per cent and ranges from 33 to 59 per cent (see barrel sheets).

Unit 2

Unit 2, late Miocene-late Oligocene, differs from Unit 1 in having few, if any, siliceous microfossils and by exhibiting abundant bioturbation, evidence for cyclic sedimentation (pulses of terrigenous material alternating with more purely biogenous sediments) and for erosion. On the basis of the relative abundance of terrigenous material and of foraminifers in the sediment, three subunits are distinguished.

Unit 2a: Cores 16-28, 188-440 meters (Late-middle Miocene)

Subunit 2a differs from Unit 1 in being more indurated, grading from ooze into chalk, Diatoms (1-10%), radiolarians, and siliceous spicules (0.5-2%) are still present but in small amounts.

This subunit presents the following lithological types: variably marly nannofossil ooze or chalk with intercalations of foraminifer- or diatom-bearing nannofossil chalk.

Among the nannofossils, well-preserved coccospheres are still present.

The major changes appearing in the composition of the coarse fraction are the following:

1) scarcity of siliceous microfossils (diatoms 1%, radiolarians 1-2%);

2) relatively poor preservation of calcareous benthic foraminifers and very poor preservation of arenaceous benthic foraminifers. Both types are associated with well to moderately preserved planktonic foraminifers — an association which is very surprising since it is well known that benthic foraminifers are more resistant to dissolution or mechanical fragmentation than are planktonic foraminifers;

3) abundance of pyrite (~10%) in aggregates of various shapes, as isolated crystals or as fillings in foraminifer chambers;

4) abundance (5-40%) of brownish red mud aggregates, which appear to be internal molds of foraminifers (especially of arenaceous foraminifers) and, less frequently, fillings of burrows.

Careful observation reveals that a black pyrite mud constitutes the central part of many of these aggregates, and that the red color of the external part results from the oxidation of the pyritic mud. This oxidation may have taken place in situ, but it is more likely artificial, due to the interaction of H_2O_2 (used for the preparation of the coarse fraction samples) with the sediment in the laboratory. The abundance of broken or damaged tests of foraminifers filled by the same brownish red mud favors this hypothesis. It is very important to note that the interaction of H_2O_2/pyritic mud occurring in the foraminifers during sample preparation seems to be, in the case of foraminifers originally filled by mud (especially pyritic mud), the major factor controlling fragmentation and preservation. The more affected foraminifers are the arenaceous species (frequently 70-100% of fragmented tests) and the calcareous benthic species (30-40% fragmented tests). In the absence of a muddy filling, calcareous foraminifers are not affected by H_2O_2.

This subunit has more $CaCO_3$ than Unit 1, averaging 63 ±12 per cent (49 determinations, see barrel sheets) with a low of 34 per cent and a high of 85 per cent.

Unit 2b: Cores 29-35, 440-592 meters (middle Miocene-early Miocene)

The top of this sedimentary sequence (Cores 29-31) consists predominantly of a greenish gray to light olive-gray marly chalk with minor fluctuations (10%) in terrigenous content, moderately to strongly burrowed. The sediment contains less than 1 per cent sand, 20-40 per cent fine silt-sized particles, and 60-80 per cent of clay-sized particles. The major components are calcareous nannofossils (35-60%) and clay minerals (30-60%). Of minor importance are foraminifers (0.5-5%), pyrite (trace-2%), quartz (trace-2%), and heavy minerals (trace).

The base of this subunit (Cores 32-35) is essentially of the same texture and composition as the top, but differs in the appearance of cyclic sedimentation, reflected by the occurrence of white nannofossil chalk layers interbedded with greenish gray to light brownish gray marly chalk. The nannofossil chalk contains 50 per cent clay-sized particles (mostly of carbonate). More than 70 per cent of the sediment consists of calcareous nannofossils (among which are well-preserved coccospheres) associated with minor amounts (≤20%) of clay minerals, of unspecified carbonate (2-5%), and of foraminifers (1-5%). The white chalk seems to be more intensively burrowed than the overlying marly chalk (Figure 4), and presents very well-preserved zoophycos (Figure 5).

In this subunit, the coarse fraction is characterized by abundant (40-95%) and well- to moderately-preserved (≤20% fragmented tests) planktonic foraminifers. They are generally associated with benthic foraminifers (10-25% of calcareous species; 3-7% of arenaceous species), echinoids (1-3%), ostracodes (≤1%), fish remains (≤2%), pyrite (1-5%), and mud aggregates (3-70%). Throughout Subunit 2a, large fluctuations occur, which are related to:

1) the abundance (3-70%) of mud aggregates (brownish red or light gray in color), among which numerous (10% in Core 31) internal molds or fillings of foraminifers are present. Mud aggregates are particularly abundant in Cores 29 to 33 and in Core 35.

2) the abundance of pyrite (appearing as filling in foraminifers, echinoids, or as free aggregates of various shapes). Pyrite is relatively abundant (5%) in Cores 29 and 30.

3) the degree of fragmentation of the calcareous benthic foraminifers (10-80% of fragmented or broken tests). The preservation is particularly poor (50-80% of broken tests) in Cores 29 and 33 and in Core 35.

4) the degree of fragmentation of the arenaceous benthic foraminifers (40-95% of strongly fragmented tests). Fragmentation is particularly high in Cores 29 to 33 and Core 35.

Obviously there is a high correlation between the presence of mud aggregates, pyrite in the sediments, and the poor preservation of benthic foraminifers. The degree of fragmentation of planktonic foraminifers is also affected in the same way but to a lesser degree: fragmentation fluctuates from 10-20 per cent in samples very poor in mud aggregates to 20-30 per cent in mud aggregate-rich samples.

In summary, the large fluctuations in the degree of preservation of the foraminifers throughout Subunit 2b result from use of H_2O_2 in sample preparation. The original degree of preservation of the calcareous foraminifers treated by H_2O_2 can only be estimated from samples very poor or devoid of mud or pyritized mud aggregates. Better still, avoid the use of H_2O_2.

The $CaCO_3$ content of this subunit and its standard deviation is 58 ±9 per cent (23 determinations, see barrel sheets) ranging from 46 to 75 per cent.

Unit 2c: Cores 36-44, and Cores 1-3 (362A), 592-820 meters (early Miocene-late Oligocene)

This subunit has more foraminifers than Subunit 2b. The sedimentary sequence consists predominantly of dark brownish gray to greenish gray marly chalk, with interbeds of lighter greenish gray-brown tinted chalk. The sediment is moderately to strongly burrowed. Very well preserved zoophycos are present. The sediment texture is the same as in the previous subunit (silt, 20-50%; clay, 30-80%). The sediment composition is also very similar to the composition of Subunit 2a, with the exception of the clay-mineral content (10-40%) and the proportion of foraminifer-nannofossil chalk to foraminifer-bearing nannofossil chalk.

In the coarse fraction, planktonic foraminifers are dominant (70-90%), associated with calcareous (3-5%) and arenaceous (1-5%) benthic foraminifers, fish debris (3%), echinoids (1%), and various amounts of mud aggregates (trace-25%). The preservation of calcareous foraminifers is moderate (30-40% of fragmented planktonic foraminifer tests) throughout this subunit.

The $CaCO_3$ content and its standard deviation is 53 ±8 per cent (29 determinations, see barrel sheets) ranging from 37 to 67 per cent. There are no $CaCO_3$ data for Cores 42-44 of Hole 362.

Unit 3

Hole 362A: Cores 3-5, 820-924 meters (Oligocene)

Unit 3 differs from the two preceding units by the occurrence of white layers of "*Braarudosphaera* chalk." This "chalk" locally has the appearance of a very soft white ooze (chantilly cream!). It is interbedded with dark brownish gray to dark olive-gray or brownish gray marly nannofossil chalk. This sequence is intensively burrowed (Figure 7) and has cross laminations associated with coarse calcareous concretions in the chalk (Figure 8) or silty layers with erosional contacts (Figure 9). The sediment has 40 to 70 per cent silt-sized and 25-50 per cent clay-sized particles but is locally coarser. As previously, the major components are calcareous

Figure 7. *Heavily burrowed limestone and marly limestone, Hole 362A, Sample 5-3, 126-142.*

nannofossils (coccoliths and *Braarudosphaera* pentaliths) and clay minerals (15-30%). The secondary components are foraminifers (2-10%), dolomite rhombs (2-35%), unspecified carbonate (2-7%), quartz (2-10%), and pyrite (1%). The "*Braarudosphaera* chalk" contains very few coccoliths (≤10%) and is up to 98 per cent whole or broken *Braarudosphaera bigelowi* pentaliths.

The coarse fraction consists of planktonic foraminifers (95%), with calcareous benthic foraminifers (2%), fish debris (1%), echinoids (1%), and arenaceous foraminifers (1%).

Planktonic and benthic foraminifers are both moderately preserved (20-25% fragmented).

The $CaCO_3$ content varies from 33 per cent in the marly chalk to 86 per cent in the "*Braarudosphaera* chalk," av-

Figure 8. *Laminations and calcareous white concretions in Oligocene* Braarudosphaera *chalk, Hole 362A, Sample 4-4, 87-110 cm.*

Figure 9. *Example of erosion contact (marl/silt layer), Hole 362A, Sample 4-5, 67-80 cm.*

eraging 66 ±24 per cent (9 determinations, see barrel sheets).

Unit 4

Hole 362A: Cores 6-12, 924-1081 meters (upper to middle Eocene)

Unit 4 differs from Unit 3 in the lack of "*Braarudosphaera* chalk," in the presence of massive limestone, of laminated limestone, and of coarse calcarenite and slumping features.

Cores 6 to 9 consist of greenish-gray to grayish-brown light-gray marly nannofossil limestone. The sediment is intensively burrowed. At the base of this unit (Cores 10-12), turbidite deposits (calcareous siltstones and sandstones, or calcarenites) occur. The turbidite sequence presents a coarse calcarenite (Figure 10) at the base, grading into a cross or parallel laminated limestone (Figures 11 and 12), and a very fine, massive limestone (Figure 13). The oldest sediments of this unit (Core 12) are strongly affected by diagenesis, which has resulted in a progressive silicification or recalcification of the sediment.

Figure 10. *Eocene coarse calcarenite grading to laminated calcareous siltstone, Hole 362A, Sample 9-2, 0-25 cm.*

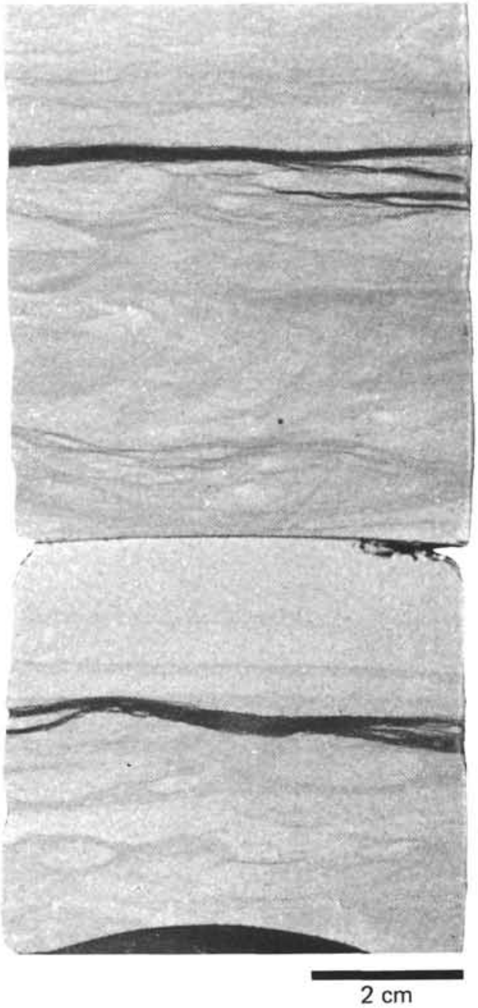


Figure 11. *Laminated Eocene calcareous siltstone, Hole 362A, Sample 9-1, 125-138 cm.*

The scarcity of coccoliths (5%), the abundance of unspecified carbonate (60%), and the strong recrystallization of the foraminifers in Core 12 reflect the intensity of the diagenesis. The major sediment components are: calcareous nannofossils (5-50%), clay minerals (20-30%), and unspecified carbonate (25-60%). These are associated with small amounts of foraminifers (2-5%, with the exception of Core 8 which contains 25% of foraminifers), quartz (1-2%), and traces of tourmaline, chlorite, zoisite, and diopside.

The coarse fraction contains planktonic foraminifers (80-98%), calcareous benthic foraminifers (1-3%), arenaceous foraminifers (3-20%), echinoids (2%), ostracodes (2%), and fish debris (trace-5%). The preservation of the planktonic foraminifers ranges from moderate (25% fragments) in upper Eocene (Core 6) to good in lower-upper Eocene and middle Eocene sediments (Cores 7-9, 11, and 12). The core catcher of Core 10 consists only of crystallized calcareous aggregates; and the foraminifers of Core 12 are entirely recrystallized.

The $CaCO_3$ content of this unit is high, averaging 74 ψ± 13 per cent, ranging from 71 to 95 per cent (14 determinations, see barrel sheets).

Figure 12. *Laminated Eocene limestone, Hole 362A, Sample 10-3, 63-75 cm.*

Site 363 Lithologic Descriptions

Site 363 was spudded into sediments which drape the north side of a peak on the Frio Ridge portion of the Walvis Ridge (Barnaby, 1974). The sediments dip gently to the north, eventually lapping over the nearby steep northern scarp of Frio Ridge which is free of an acoustically definable sediment cover. Dredge stations on this scarp by R/V *Jean Charcot* close to Site 363 recovered highly altered basalts (Hekinian, 1972) and Albian shallow-water fossils judged to be in situ (Pastouret and Goslin, 1975). Erosional material described by Hekinian indicates that some portion of Walvis Ridge must once have been at sea level. The location of Site 363 was picked to take advantage of these preliminary discoveries and decipher the shallow water history of the ridge as well as the nature of volcanic basement. However, the thick sequence of indurated Cretaceous limestones encountered at the site was not anticipated, and unfortunately succeeded in destroying the bit just short of basement after an unusually short rotating life of 28.6 hours. The sediment section recovered, nevertheless, meets many of the objectives anticipated but not reached at Site 362, such as a section cored continuously across the Cretaceous-Tertiary boundary, and penetration of Lower Cretaceous sediments bearing on

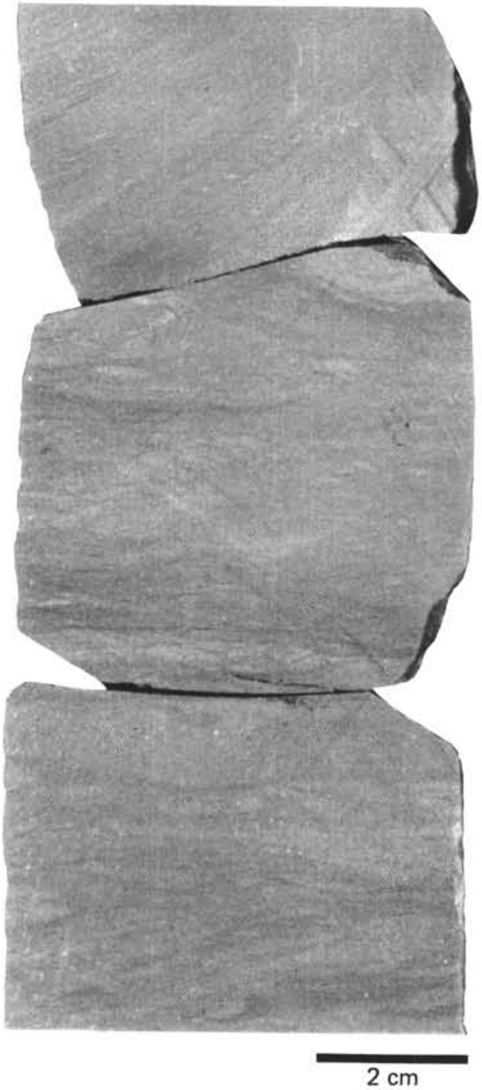


Figure 13. *Massive Eocene limestone, Hole 362A, Sample 9-1, 111-125 cm.*

the relationship of the Walvis Ridge to the adjoining Cape and Angola basins. Site 363 also dates the Walvis Ridge, contains information on the subsidence of the ridge, and reveals complex changes in current action and the condition of water masses which periodically swept across it.

Site 363 was drilled to a depth of 715 meters sub-bottom in 2247 meters of water, yielding sediments ranging in age from middle Miocene to upper Aptian. Coring began at 31 meters and cores of 9.5 meters length were spaced at 19-meter intervals throughout the site, except between 297 and 354 meters, and 363.5 meters and 392 meters, which were cored continuously. A total of 40 cores was taken with a recovery of 59.7 per cent, representing 33.2 per cent of the total sediment column. We divided the sedimentary sequence into three stratigraphic units and several subunits on the basis of composition, color, sedimentary structures, and location of hiatuses in the record. Compositional percentages are based on visual estimate of the frequency of major components in smear slides and of calcium carbonate content listed on the barrel sheets at the end of this chapter. A summary of the lithologic units and their age is given in Figure 14. Smear-slide, $CaCO_3$, and X-ray diffraction data (Siesser and Bremner, this volume) are synthesized on Figure 15. This will be discussed separately later.

Unit 1: (Cores 1-21, 31-373 m) Foraminifer and Nannofossil Oozes and Chalks

Unit 1 consists of 342 meters of uppermost Cretaceous to middle Miocene pale yellow, light yellow-brown, light gray, and light greenish gray oozes (Cores 1-3) and chalks (Cores 4-21). White *Braarudosphaera* ooze layers occur in middle and lower Oligocene Cores 4-8 (Figure 16) which are designated Subunit 1B (Core 4, Section 2, 65 cm, to Core 8, Section 2, 120 cm). A marked decrease in the preservation of nannofossils occurs in Core 18, Section 2 through Core 21, beginning at the Cretaceous-Tertiary boundary (Core 18, Section 2, 50 cm). These cores are designated Subunit 1D. $CaCO_3$ in Unit 1 ranges from 34 to 98 per cent, averaging 60-80 per cent in most cores (Figure 15). It is 90 per cent or more in *Braarudosphaera* ooze layers.

Colors throughout Unit 1 vary from pale orange to pale gray at relatively sharp contacts not always blurred by burrowing, which is locally moderate to intense. The contacts may possibly be bedding planes, but there are no definite beds or laminations until the base of the Eocene (Core 14). There is a small but consistent terrigenous component, primarily a few per cent detrital quartz and clay. Terrigenous material is slightly more abundant in the lowest cores of the unit where minor silty burrows and marly chalk laminations occur more frequently. Core 14 marks the latest period of evidence for current activity recorded in the cores, with silty laminations, minor slump features, erosional contacts, and winnowed zones scattered from there to the base of the unit. However, current activity may have shortened the middle and upper Eocene sections, and there is an abrupt contact from orange ooze to gray ooze in Core 1, Section 4, at 80 cm corresponding to a break between middle and lower Miocene. Both the Miocene and upper-middle Eocene sections at Site 363 are thinner than their counterparts at Site 362, but the thickness of the Oligocene is about the same. Sedimentologic evidence for currents in Cores 1-14 may have been obliterated by intense burrowing (and possibly by coring deformation) but may be represented by some of the sharp alternations in color, from gray to orange, as in Core 1. The color differences are manifested mainly by small amounts of hydrous iron oxides in the orange chalks, absent in the gray. This may reflect sediment sorting of heavy minerals by currents, with subsequent alteration and oxidation of ferromagnesian silicates and iron oxides in the orange layers.

The proportion of foraminifers to nannofossils observed in smear slides fluctuates greatly within each core, but foraminifers are rarely more abundant than about 30 per cent. Both planktonic and benthic foraminifers are well represented. Very soft, even soupy, pure white *Braarudosphaera* oozes occur in intervals of 2 to 60 cm in length, alternating with the usual orange and gray foraminifer-nannofossil chalks (Figure 16). In all likelihood *Braarudosphaera* oozes predominate in this interval as most of them probably washed out during coring (recovery is very low in Cores 7 and 8). This *Braarudosphaera* interval corresponds to a major acous-

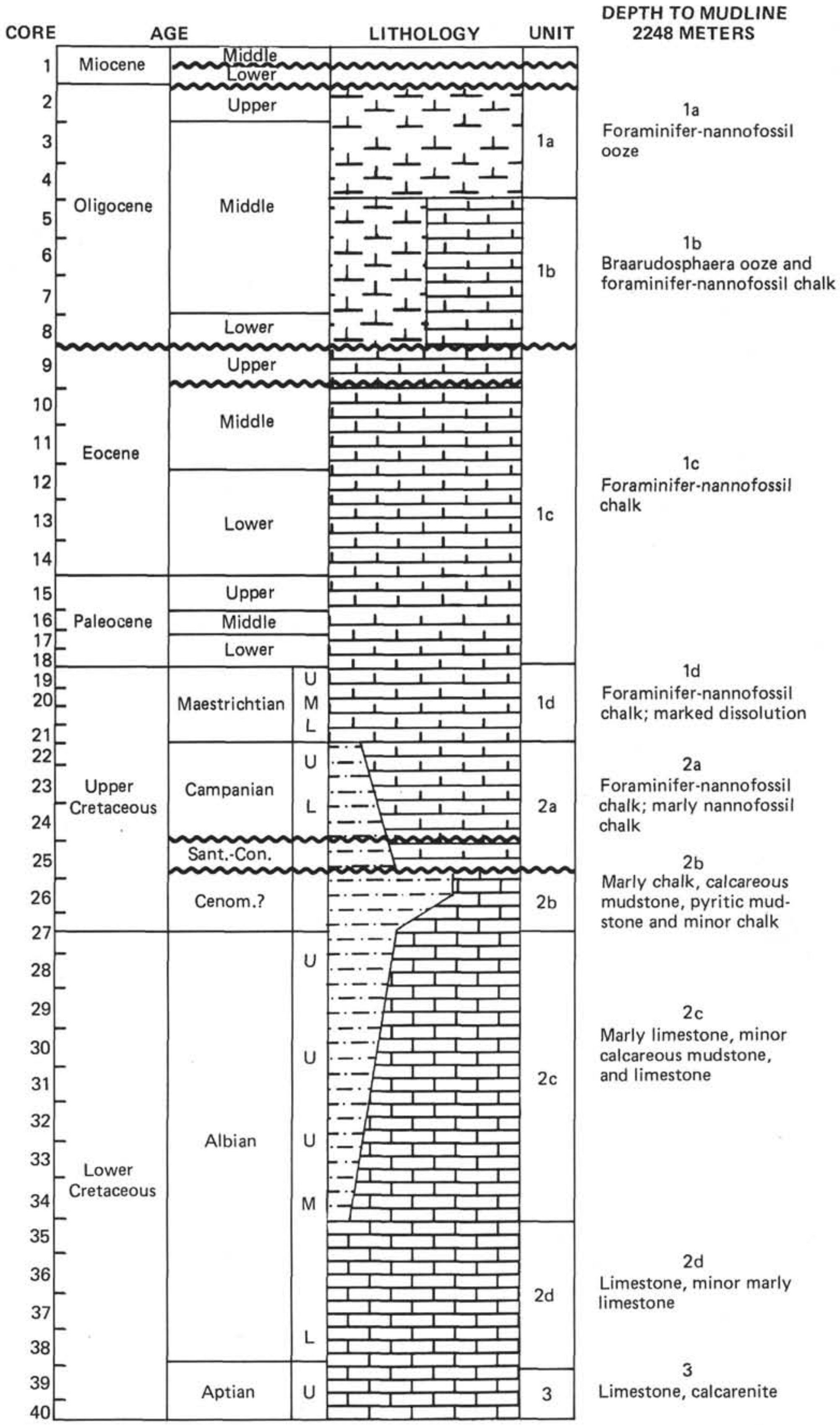


Figure 14. *Lithologic column Site 363.*

tic reflector and correlates with Oligocene *Braarudosphaera* oozes at Site 362, where it is designated Lithologic Unit 3 and is a major reflector, and at Site 360, where it is also a major reflector. These unusual oozes are predominantly or entirely

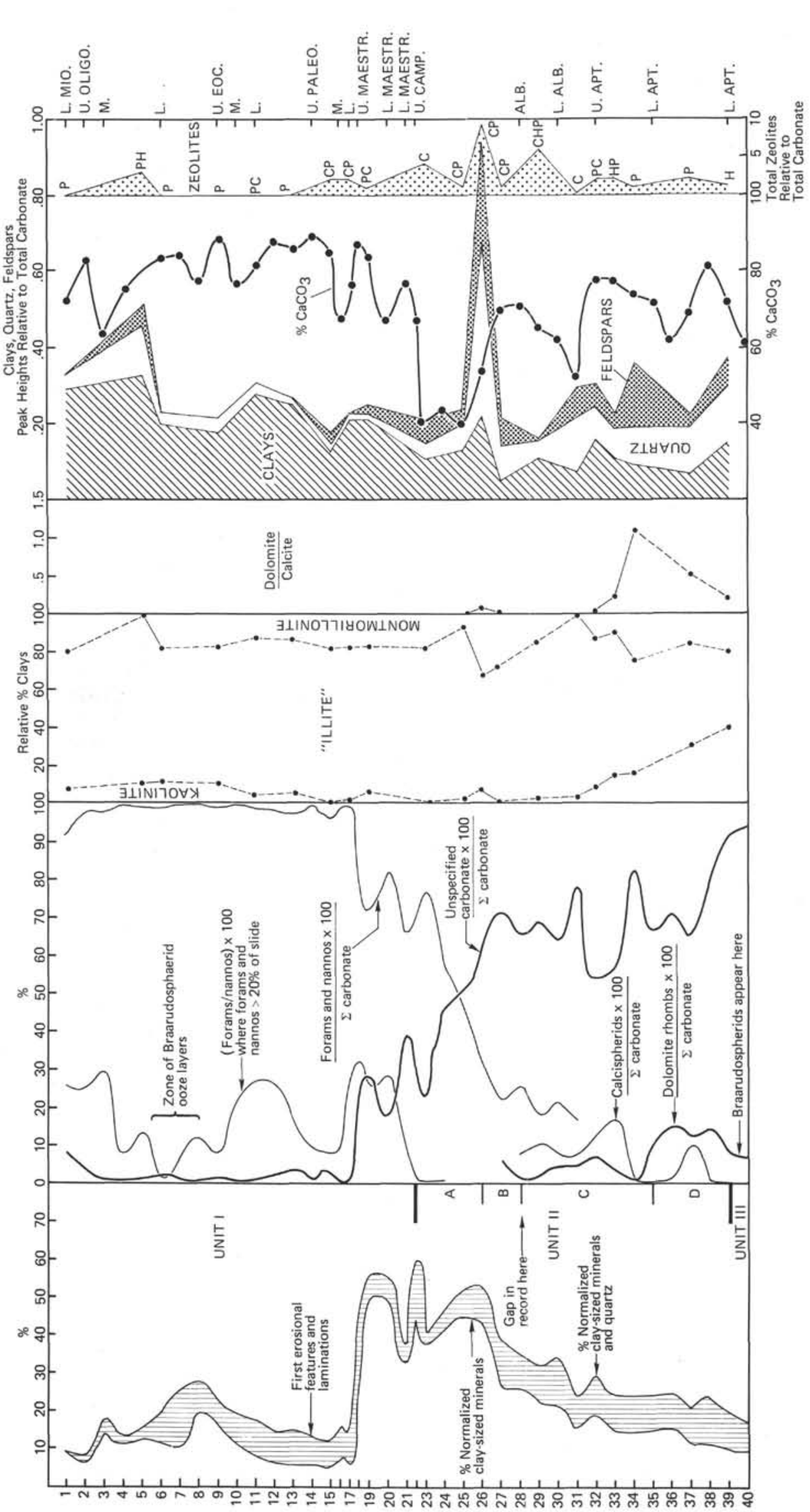


Figure 15. *Summary of smear slide, X-ray diffraction, and CaCO$_3$ data Site 363. See text for explanation.*

composed of *Braarudosphaera*. Such predominance makes it unlikely that dissolution removed all the other species, especially since *Braarudosphaera* itself is invariably well preserved. Unusual blooms are therefore suggested, requir-

Figure 16. Braarudosphaera *ooze, Site 363, Sample 7-1, 101-125 cm.*

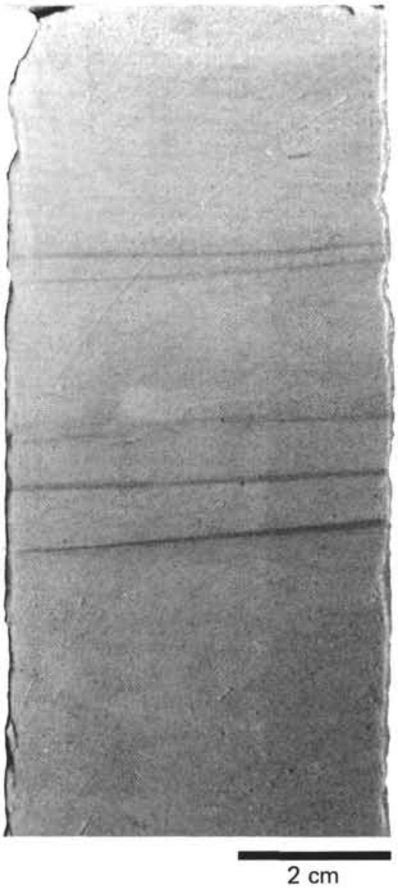


Figure 17. *Fine silty laminations in limestone, Site 363, Sample 19-4, 109-133 cm.*

ing unusual oceanographic conditions. *Braarudosphaera* is found in greatest abundance in near-shore waters with salinities reduced by fresh-water drainage from the land. It forms only a small percentage of the population of nannofloras in the more saline open ocean. The inferred blooms apparently were restricted to the Cape Basin as *Braarudosphaera* oozes were not found at Site 364 in the Angola Basin. They may have been related to high fresh-water influx from the Orange River during the Oligocene, coupled with upwelling of nutrient-rich intermediate or deep low-salinity water masses. The Walvis Ridge, which acts to deflect the Benguela Current toward the west away from the African coast, may have prevented the blooms from extending into the Angola Basin.

Cores 14 through 21 all show evidence for current activity. The features include fine laminations richer in terrigenous material than the surrounding chalks, sometimes inclined 10° to 15° from horizontal or showing slight grading or cross-bedding (Figure 17). The laminations usually occur in closely spaced clusters, occasionally accompanied by inclined erosional contacts and slump structures. Several winnowed zones occur entirely within chalky zones, however, and are thus unrelated to terrigenous input. These generally have a higher proportion of foraminifers to nannofossils than unwinnowed zones. The current activity, though, did not obliterate burrowing.

Core 18, Section 2 through Core 21 differs little from Core 14 through Core 18, Section 2, in color variations, degree of bioturbation, or frequency and style of current-related features. Nevertheless, a significant increase in the clay-sized fraction was observed in smear slides of these cores (Figure 15). Most of this is carbonate rather than true clays since the calcium carbonate (listed on the barrel sheets) data for samples from these cores indicates 65-87 per cent $CaCO_3$ (Figure 15), levels similar to most other cores in Unit 1. The increase in the clay-sized fraction is matched by an increase in unspecified carbonate observed in smear slides. This is the fraction of identifiable carbonate that can neither be assigned to nannofossils and foraminifers nor to any other fossil or mineral category. It appears as large clay-to fine silt-sized grains with irregular shapes. Most of this material is probably broken-up nannofossils, since many of the recognizable nannofossils are partially fragmented. Partial recrystallization may also have occurred in these cores with the resulting cementing calcite appearing as unspecified carbonate (micarb) grains. The clay-sized fraction is therefore primarily unspecified carbonate that is too fine to resolve as carbonate. Coincident with the jump in unspecified carbonate in Core 18 is also a sharp increase in the proportion of foraminifers to nannofossils, consistent with the breakdown of nannofossils into unspecified carbonate grains, and in the proportion of foraminifers showing signs of dissolution (Melguen, this volume).

The sudden breakdown of nannofossils and the poorer foraminifer preservation at Core 18 correspond with the Cretaceous-Tertiary boundary and the period of slowest sedimentation rate at Site 363 (see Sedimentation and Accumulation Rates section, this chapter). This time period apparently saw a worldwide rise in the carbonate compensation depth (Worsley, 1974), the effect of which we are apparently seeing here. A similar reduction in nannofossil preservation was observed at the Cretaceous-Tertiary boundary at Site 364, and at Site 361, which was much deeper, pelagic clays were deposited at this time. These also are the probable results of a higher CCD.

Since the Cretaceous-Tertiary boundary at Site 363 coincides with a break in fossil preservation and sedimentation rate, it is convenient to designate Cores 18 to 21 as Subunit 1d. It is important to note that there was no change in the supply of terrigenous material at this time ($CaCO_3$ averages 78 ±8% in Cores 1-16, and 83 ±4% in Cores 17-19; see barrel sheets and Figure 15, nor any significant change in the appearance or frequency of sedimentary structures in the sediments. The low sedimentation rate is *not* the result of an erosional hiatus, which in any event cannot explain the poor nannofossil and foraminifer preservation. At Site 363, it appears that a sharp rise in the carbonate compensation depth alone was responsible for the reduction in sedimentation rate. Nevertheless, Site 363 was apparently elevated enough to receive a significant thickness of Paleocene carbonate sediments, usually absent in deeper sites on the ocean floor because of the worldwide rise in the CCD.

Unit 2: (Cores 22-39, 373-696 m) Marly Chalks, Marly Limestones, Calcareous Mudstones, and Limestones

Unit 2 consists of 323 meters of cyclically bedded chalks, marly chalks, and calcareous mudstones. Through Core 35, these sediments are gray brown, dark gray-brown, or greenish gray in color, considerably darker than chalks and oozes of Unit 1. This is because the terrigenous component of these cores is considerably greater than in Unit 1 and possibly because near-bottom conditions were generally more reducing, or diagenetic effects more pronounced. Silty laminations are more common, even abundant, and more closely spaced than in Cores 14 to 21 of Unit 1 (Figure 18). Other sedimentary structures such as slumps and erosional contacts are also more abundant (Figure 19). The abundances and proportions of quartz, alkali, feldspar, and plagioclase are greater in Unit 2 than Unit 1 (see Figure 15). Several black pyritic layers are found in Core 26 (Figure 19) nearly coinciding with the peak of terrigenous influx to Site 363, during which silts and calcareous mudstones predominated. Below Core 27, the terrigenous component is lower, dropping to levels comparable to Unit 1 in Cores 35 to 39. However, the cyclic alternation of dark sediments (with a higher terrigenous component) and light-colored limey layers persists (Figure 20). This cyclic appearance is related either to fluctuating terrigenous input or to a consistent sorting mechanism perhaps established with the migration of small dunes in a fairly constant and strong current regime.

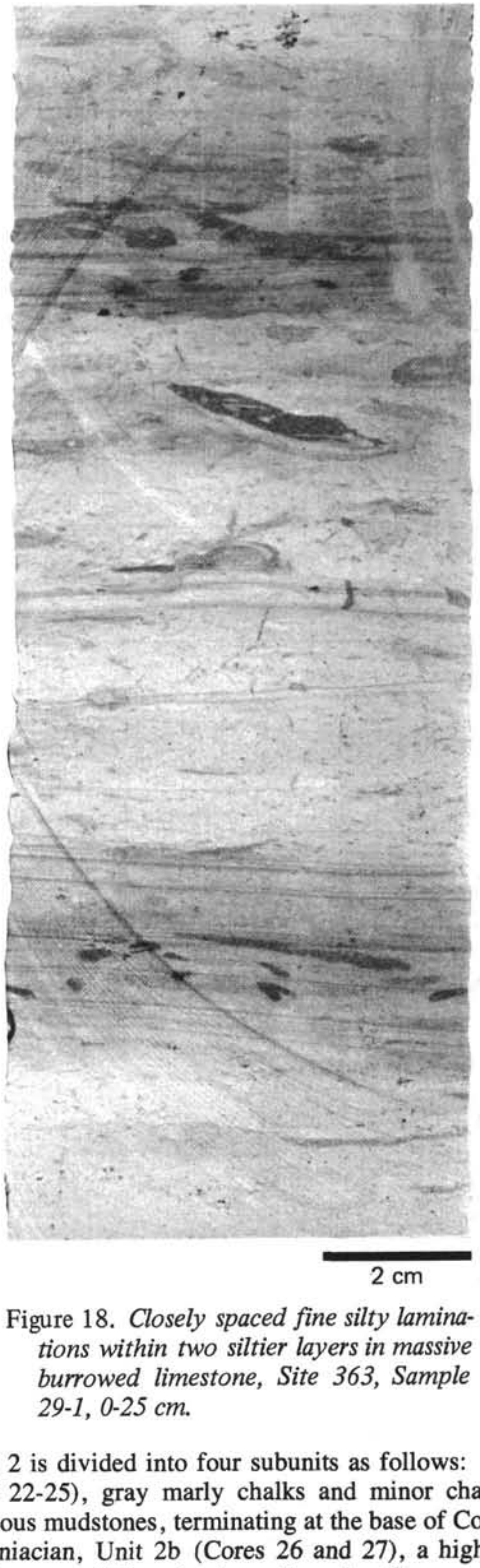


Figure 18. *Closely spaced fine silty laminations within two siltier layers in massive burrowed limestone, Site 363, Sample 29-1, 0-25 cm.*

Unit 2 is divided into four subunits as follows: Unit 2a (Cores 22-25), gray marly chalks and minor chalks and calcareous mudstones, terminating at the base of Core 25 in the Coniacian, Unit 2b (Cores 26 and 27), a highly telescoped upper Albian (perhaps Turonian-Cenomanian) of marly chalks and calcareous mudstones with black pyritic mudstones, a high terrigeous component, and much evidence for current activity; Unit 2c (Cores 28-35), marly limestones, lesser limestones, and calcareous mudstones with limestones more abundant toward the base until Unit 2d (Cores 36-39) limestones predominate over marly limestones. The latter contact (Units 2c to 2d) is gradational and

Figure 19. *Finely laminated, internally cross-bedded silty layer with concentration of pyrite toward base. This is above a micro-faulted and slump-deformed zone. Site 363, Core 26-1, 121-150 cm.*

Figure 20. *Sequence of burrowed limey layer and finely laminated silt-rich layer, Site 363, Sample 28-6, 50-70 cm.*

is arbitrarily placed between Cores 35 and 36 below which limestones are truly predominant.

Units 2a and 2c are similar although induration has proceeded sufficiently in the latter to term the rocks limestone rather than chalk. Both units show regular alternations of color—light grays to dark grays or gray browns—and have interlayers of pale gray-green. The only difference between the lighter gray and the pale gray-green marly chalks appears to be a slightly higher but still small percentage of a green chloritic mica observed in smear slides of the latter. There appears to be no difference in the range of compositions (e.g., terrigenous/calcareous, sand:silt:clay) exhibited by the lighter gray marly chalks compared with the greenish marly chalks, nor any relationship of these colors to the onset or termination of zones of silty laminations. Calcareous mudstones, however, are usually a much darker brownish gray than the marly chalks and are rarely green in color. The differences probably indicate small original differences in the proportions of ferromagnesian silicates and detrital magnetite in the layers, the result of sorting. Oxidation and breakdown of these minerals during diagenesis resulted in different colors, depending on the abundance of the minerals (more iron oxides—a redder or browner color) and the extent of the breakdown. The pulses of heightened terrigenous input throughout Unit 2 do not in general correspond to the color fluctuations. The oldest greenish marls are in Core 34; below this, colors are gray or gray-brown corresponding strictly to the amount of terrigenous material in the sediment. Here diagenesis has extensively recrystallized all chalks to limestones, apparently reconstituting most iron originally present in detrital iron oxides and ferromagnesian silicates into the ubiquitous green mica observed in smear slides of these sediments.

Laminations, silty zones, erosional contacts, and dipping, graded- or cross-bedded features are common throughout Unit 2 but are most extreme in Core 26, Unit 2b, upper Albian in age (Figure 21). Here in addition are found spectacular deformed sediment layers, flow structures, microfaults and soft-sediment slump features (Figure 19). These alternate with zones of homogeneous sediments, deposited in a more tranquil regime, locally intensely bioturbated. In these same sediments where bottom life occasionally thrived in between bursts of terrigenous material, are five 2 to 4 cm thick, black pyritic mudstones. Pyrite amounts to perhaps 15 per cent of these layers, but organic carbon is low (Foresman, this volume). These layers are therefore not sapropels. The pyrite is probably mechanically concentrated since the layers occur in cores with abundant evidence for sorting of sands and silts. The pyrite may have formed as a result of breakdown of organic material during diagenesis of sediments, and originally it may have been highly dispersed. The intense sediment sorting processes evident in the proximal cores may have produced "placer" pyrite layers. But the possibility cannot be excluded that the pyrite source was originally an organic-carbon rich euxinic deposit or sapropel of local or regional extent, eroded and reworked by currents.

The terrigenous material in Unit 2 is predominantly quartz and clays with minor garnet, tourmaline, and zircon indicating continental provenance. There is no obvious volcanic material in the form of lithic grains, ash layers, breccias, or detrital minerals diagnostic of volcanic sources, such as sanidine, olivine, or pyroxenes. Thus, no portion of the Walvis Ridge was supplying major amounts of mafic or salic volcanic materials to Site 363 at any time recorded by the recovered sediments. There is no indication of volcanic activity in the Upper Cretaceous during which the Walvis Ridge has been hypothesized to have uplifted and had volcanic activity (Connary, 1972; Francheteau and Le Pichon, 1973).

Since most silty laminations and cross-bedded lenses carry some sand-sized quartz, fairly strong currents must have prevailed near the summit of Walvis Ridge during upper Albian and Upper Cretaceous times. Either bottom currents or turbidity currents moved continent-derived sediments from the continental margin along the narrow crest of Walvis Ridge to Site 363, a distance at that time of possibly 150 km. No massive turbidites were recovered at Site 363 although turbidity currents were almost certainly responsible for transporting terrigenous material to the vicinity of the site. The cyclicity of terrigenous and calcareous laminations and layers suggests sediment reworking in the form of large

Figure 21. *Layer graded from sand to fine silt at erosional contact with deformed finely laminated marly limestone, Site 363, Sample 26-1, 90-110 cm.*

ripples or small dunes in which sediments were sorted into coarse and fine, light and heavy, components.

In general, during deposition of Unit 2, calcareous microfossils provided the carbonate component of the sediments. These were chiefly planktonic and benthic foraminifers, and nannofossils, all deposited in bathyal depths (see Biostratigraphy and Paleontology, this chapter) but well above the depth where dissolution could have been important. Preservation of many of these fossils is poor, however, because of extensive recrystallization. The Aptian-Albian foraminiferal assemblage is both endemic and dwarfed, reflecting both the isolation and restricted circulation of the South Atlantic at that time. Large calcite grains which chiefly filled the chambers of foraminifera are abundant, and dolomite rhombs form several per cent of the smear slides in the lowest cores. Calcispherulids are a relatively abundant minor component. Large ammonites were found in several places as well as a few *Inoceramus* shells (see T. Matsumoto, this volume).

Cementation in the lowest cores of Unit 2 is essentially complete in the carbonates. Stylolites, solution pits, and coronas around dolomite crystals can be seen. Laminations and burrows, however, are well preserved (Figure 22). Pyrite flecks and micronodules are fairly common. Sandy layers with abundant continent-derived quartz are found as deep as Core 38, though erosional contacts are much less common than in Cores 22 to 32.

In summary, Unit 2 is characterized by a major pulse of terrigenous sediments peaking the late Albian probably deposited in the midst of a fairly steady supply of calcareous microfossils. These sediments were pushed around by currents, mixed, sorted, deposited, eroded, and deposited again. In Core 26, current sorting produced several unusual black layers rich in the heavy component pyrite, whose source is a matter of speculation. The peak of terrigenous influx nearly corresponded with the peak of current activity and resulted in the most telescoped portion of the hole, from the top of the Albian through the Santonian. But the added terrigenous input was more than compensated by the erosional power of currents, resulting in overall lower sedimentation rates than either before or since. The sediments were moved off the Walvis Ridge to either or both basins on either side.

Unit 3: (Core 39, Lower Part of Section 4, and Core 40, 696-715 m) Limestones, Including Calcarenites

Approximately 1 meter of limestone was recovered in the last two cores. This material contained the only evidence at Site 363 for the shallow-water history of the Walvis Ridge. The limestone is several separate, subrounded pieces with smaller diameters than that of the core line. This is the type of material usually recovered just prior to bit failure. The limestone pieces in Core 40 are out of sequence. All are light brownish gray massive foraminifer limestones with a few small lenses of carbonate sandstone (calcarenite). Thin sections were made of six of these pieces. In the sections, the calcarenites consist of well-rounded massive limestone grains in a micritic cement (Figure 23). The sand grains appear to have been rounded in a high-energy (near-shore) environment. Opal fills cavities and chambers of unknown organisms (Figure 24). The planktonic assemblage is judged

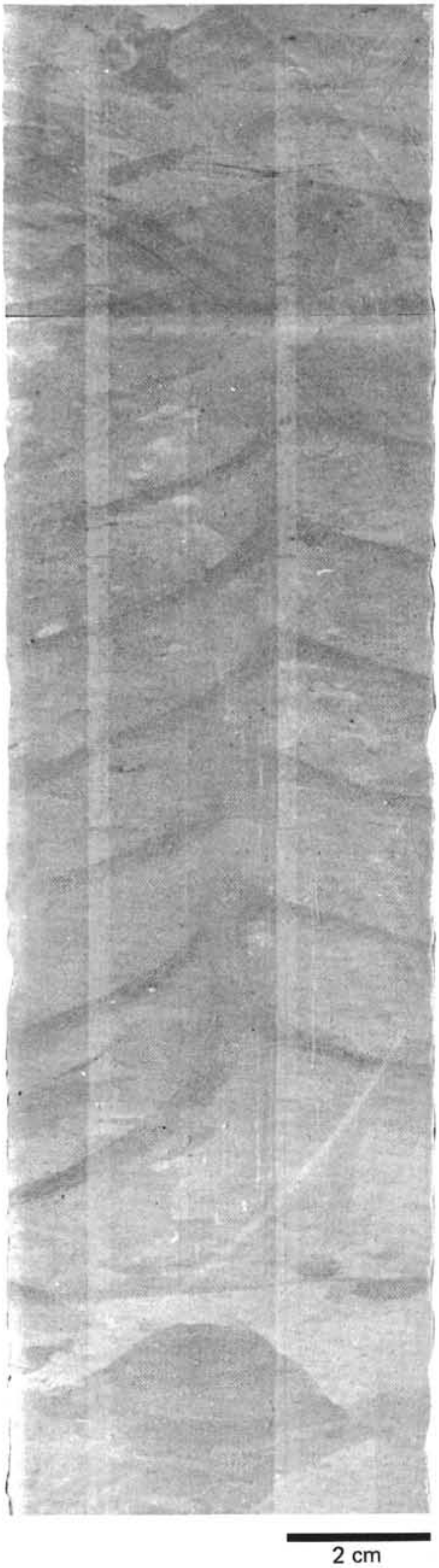


Figure 22. *Longitudinal section through large Zoophycus burrow, Site 363, Core 21-4, 104-117 cm.*

Figure 23. *Rounded grains of recrystallized limestone from calcareous algae (?), in micrite cement. Photomicrograph in plane polarized light. Site 363, Core 40.*

Figure 24. *Opal in cavities of possible calcareous algae particles all in recrystallized limestone matrix.*

to be lower neritic in character (see Biostratigraphy Summary, this chapter). In the massive limestones, fragments of calcareous algae occur (Figure 25), such as are typically formed in shallow-water sediments. In addition, slightly birefringent phosphatic material also occurs in the thin sections (Figure 26). Such phosphatic material is virtually unknown in sediments deposited below about 500 meters because P_2O_5 supersaturation in seawater is prevented below this by increasing partial pressure of CO_2 (Kazakov, 1937; Roberson, 1966). According to Gulbrandsen (1969), formation of phosphate minerals in seawater requires "a special steady supply of phosphate, originally derived from organic matter, and a decreased capacity of seawater for phosphate. These conditions probably prevail in shallow parts of seas...where large amounts of organic matter accumulate in oxygenated waters of higher than normal salinity." Phosphate-rich marine sediments often are found in shallow waters in regions of upwelling (Blatt et al., 1972).

The limestone is judged to be upper Aptian in age, a minimum though probably very close estimate of the age of Walvis Ridge basement at this site.

After retrieving Core 40, the drill advanced several meters through a very soft formation. The center bit was lowered to clear an obstruction in the throat of the bit which appeared to be blocking circulation. The center bit jammed, necessitating retrieval of the entire drill string. When the bit was finally brought to the surface, all the cones were gone, and the center bit had punched out any possible material from the soft formation that may have been in the bit. One can only speculate what this material might have been, but very rapid drilling rates were achieved with a bit having virtually no ability to cut. Perhaps the material was a poorly consolidated sand.

Basement is estimated at 720 meters sub-bottom from the departing *Glomar Challenger* profile although basement relief of perhaps 50 meters is evident in the vicinity of the site. Bit failure so close to basement thwarted the primary objective of the site. It is therefore not possible to say whether this part of the ridge was ever subaerial, although we know it was shallow, and we do not know the nature of volcanic basement.

SUMMARY OF OBSERVATIONAL DATA ON SITE 363 SEDIMENTS

The curves plotted on Figure 15 summarize smear-slide observations and $CaCO_3$ data, both on the barrel sheets at the end of this chapter, as well as X-ray diffraction data of Siesser and Bremner (this volume). There are several difficulties in using these data to establish down-hole trends. A word on these is in order.

Figure 25. *Recrystallized and fragmental thalli (?) of calcareous algae. Photomicrograph in crossed nichols. Site 363, Core 40.*

Smear-Slide Data

Visual estimates (not point counts) were made of components in smear slides. The size range of particles (foraminifers versus coccolith pentaliths, for example) is so great that areal proportions are difficult to estimate and are even more difficult to relate to the true volume per cent. A similar problem occurs with flat micaceous flakes (chlorite?) which can easily be overestimated on an areal basis.

In addition, clay-sized carbonate particles were typically listed as clays, and the true clay-mineral component could not be seen because the index of refraction of many of the finer clays matched that of the mounting medium almost exactly. The clay minerals could only be seen when clumped on carbonate particles (in which case the carbonate particles were darkened), or when observed on portions of smear slides not covered with Caedex.

Another problem is sediment heterogeneity—especially in intervals of cyclic alternation of terrigenous and biogenous materials. The selection of intervals chosen for smear slides might not be representative of the proportions of each sediment type in any given lithologic unit.

Because of these difficulties, the visual estimates of each sediment type were averaged for the smear slides of each core, then a grand average was computed based on the proportions of each sediment type present in a core. These data are plotted on Figure 15, with smooth curves through the data points. Hopefully, the visual observations lumped together in this way are more representative than individual smear slides and can give a crude estimate of major variations in lithology through time.

X-ray Diffraction Data

The principal means of determining abundances of minerals in sediments using X-ray diffraction data has always been to relate particular peak heights to peak heights of minerals present in different, but known, proportions in a set of standards. This can work well when only two or three minerals are involved, but is difficult in such heterogeneous materials as the sediments of Leg 40. Siesser and Bremner (this volume) used a variant of this approach to determine relative abundances of the three clay minerals, kaolinite, K-mica ("illite"), and montmorillonite. They did not include chlorite in this analysis, nor differentiate mixed-layer clays from the others. These data are plotted versus depth on Figure 15.

Siesser and Bremner (this volume) rightly made no attempt to determine the proportions of quartz or clays to calcite, nor dolomite to calcite based on the diffraction data. The data for these minerals plotted on Figure 15 are simply the ratios of peak heights (or the sum of peak heights for the clay minerals and feldspars) to the peak height for calcite. In the lower part of Site 363, where dolomite becomes prominent, quartz, feldspars, and total clay peak heights were calibrated to the sum of peak heights for calcite and dolomite. This assumes that equivalent amounts of calcite and dolomite produce comparable peak heights.

As with the smear-slide data, only gross mineralogical changes ought to be inferred from X-ray diffraction peak height data such as this. Apart from having the peak height data plotted normalized to total carbonate peak height, Figure 15 is essentially equivalent to the tables of Siesser and Bremner (this volume).

Since only 19 samples were submitted to X-ray diffraction analysis for Site 363, some lithologies doubtless are severely over- or under-represented. Only one calcareous mudstone (from Core 26) for example, was analyzed, although these are abundant from Cores 22 to 27. For this reason, X-ray diffraction data points are connected by straight lines on Figure 15, rather than smooth curves, to distinguish them from smear-slide and $CaCO_3$ data, which are based on several determinations per core.

$CaCO_3$ Data

Most $CaCO_3$ data were determined by measuring organic and total carbon at the DSDP sediment laboratory with a LECO 70-second Analyzer. Organic carbon is subtracted from total carbon, and $CaCO_3$ calculated from the difference stoichiometrically. No attempt is made to take into account the weight difference due to dolomite, since Mg/Ca was not determined.

About 20 per cent of the $CaCO_3$ data was determined onboard ship by the "Karbonat Bombe" method (measures CO_2 pressure build-up in a sealed vessel as powdered sediment in the vessel is mixed with hydrochloric acid). It is less precise than the LECO method, and also does not distinguish calcite from dolomite.

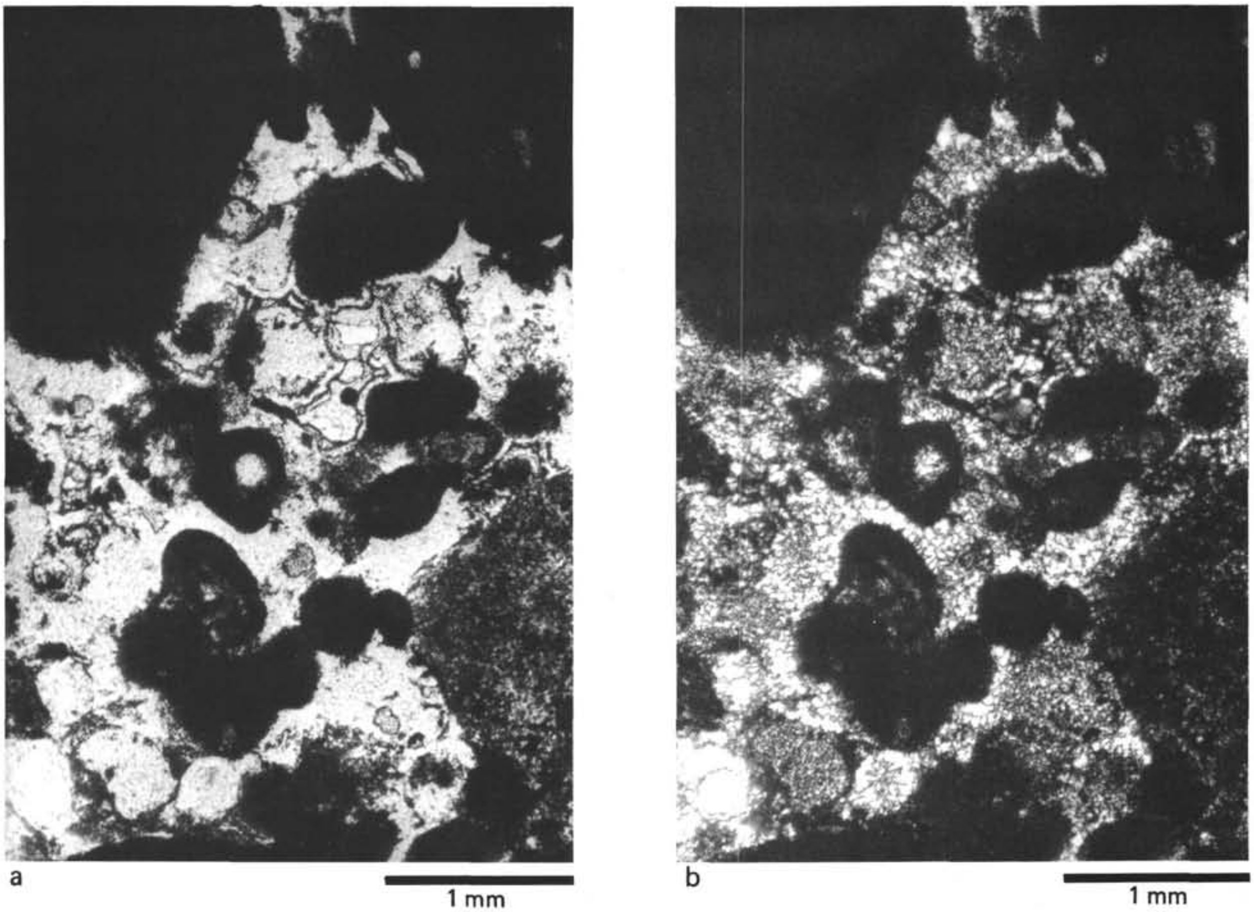


Figure 26. *Round particles of possible calcareous algae cemented by phosphorite. Site 363, Core 40. (A) In plane polarized light. (B) With crossed nichols.*

Overall Quality of the Data

Of the data on Figure 15, the $CaCO_3$ data is most representative of the variations in terrigenous and biogenous input. *Relative* differences in the proportions of quartz, feldspars, and clays, and of calcite to dolomite, are indicated by the X-ray diffraction data. The smear-slide observations on carbonate particles reveal gross changes in the state of preservation of foraminifers and nannofossils which are probably valid. The proportions of clays plus quartz in smear slides tend to be underestimated compared with the non-$CaCO_3$ component of the sediments (determined by difference from the $CaCO_3$ data), but mimic it in a general way. There is an important exception to this in the Paleocene and Upper Cretaceous sediments, where fine carbonate particles were estimated as clays in smear slides. For this reason, clays estimated from smear slides are plotted as "clay-sized" particles on Figure 15.

In short, Figure 15 is not a quantitative indicator of mineral or particle abundance. Its advantage, though, is that downhole trends can be readily appreciated at a glance.

INTERPRETATION OF FIGURE 15

The data presented on Figure 15 reflect variations in the terrigenous input, probable provenance, calcium carbonate dissolution, and diagenesis.

Terrigenous Input and Provenance

Continent-derived quartz, feldspars, and clays are present in every core. Quartz and feldspar are notably more abundant in the Cretaceous than in the Tertiary section. Feldspars include both plagioclase and alkali feldspar. Clays include more kaolinite in the Aptian, and more montmorillonite in the late Albian-Santonian than at other times. Total carbonate is about as high in the Lower Cretaceous as in the Tertiary, but drops noticeably in Unit 2a, the late Albian-Santonian interval of abundant mudstones.

The quartz and alkali feldspars (plus heavy minerals such as tourmaline and zircon) point to a largely granitic provenance in the Aptian. The decline in kaolinite and the shift toward more montmorillonite might reflect a trend to a more basaltic provenance by the Late Cretaceous. This might be more of a jump than a shift. The history of Site 363 can be summed up in four stages:

1) subsidence from shallow-neritic to bathyal depths, accompanied by

2) gradual progradation of continent-derived shelf deposits out over Walvis Ridge, peaking in the late Albian;

3) gradual reduction of sources for terrigenous material through the Late Cretaceous into the Neogene, causing a decline of terrigenous input, and finally;

4) removal of perhaps 700 meters of Neogene to Recent section (estimated from its thickness at Site 362), perhaps in several events, by erosion related to the Benguela Current.

But the second of these stages might also involve a more radical change in current patterns in the South Atlantic. Even with a heightened terrigenous input, Unit 2a has been shortened considerably by erosion. The timing of this coincides roughly with the onset of the second period of anoxic sedimentation in the Angola Basin (see Chapter 4, this volume), and could presumably reflect extensive horizontal and vertical water movements north of Walvis Ridge, perhaps alternating periods of stagnation and flushing of deep waters (see Chapter 4, this volume).

Calcium Carbonate Dissolution

On the basis of foraminifer fragmentation data, Melguen (this volume) proposes "dissolution cycles" (elevations of the carbonate compensation depth) at the end of the Cretaceous and in the Eocene at Sites 360, 361, 362, and 363.

The event at the end of the Cretaceous is seen in Site 363 smear slides mainly as a disintegration of nannofossils to so-called "unspecified carbonate." A large portion of this is estimated as "clay-sized" material (Figure 15). One result of this is that the proportion of foraminifers to recognizable nannofossils appears to increase, even though foraminifers have been subjected to dissolution as well. Similar increases in the proportion of foraminifers to nannofossils occur in the Eocene and upper Oligocene-lower Miocene, and may reflect the latter two of Melguen's dissolution cycles.

Diagenesis

Apart from evidence for calcium carbonate dissolution just described, Figure 15 illustrates little about calcium carbonate diagenesis. The principal effects in the lower cores are induration and cementation, especially the infilling of foraminifer tests with calcite crystals. Other diagenetic effects chiefly involve transformations of silicate minerals and the formation of dolomite.

The heightened proportion of kaolinite in the lower Aptian might reflect diagenetic breakdown of alkali feldspars with depth. The latter are abundant enough for this to be a plausible effect. It may be tied to dolomitization, which is marked in these same cores. Matsumoto et al. (this volume) have shown that the mineral dolomite here is a typically high-iron variety, approaching calcian ankerite in composition. Similar high-iron dolomite occurs associated with sapropels at Site 364, and Matsumoto et al. believe the high iron reflects euxinic conditions (low Eh) during formation of the dolomite. However, there is no evidence for reducing conditions in the dolomitic limestones at Site 363. It is possible, then, that dolomitization at Site 363 was diagenetic, and occurred after the carbonates were buried, removing them from the oxidizing conditions of near-surface sediments. The dolomitizing fluids may have migrated into the sediments from the underlying (presumed basaltic) volcanic basement. Pore fluids in the lower cores have heightened Mg^{+2} and Ca^{+2}, and Mg^{+2}/Ca^{+2}, an effect which at other DSDP sites appears to be the result of cation exchange with volcanic basement (Sotelo and Gieskes, this volume). The age of the dolomitized sediments, though, is the same as those of Site 364 which were, apparently, formed in a hypersaline environment (Matsumoto et al., this volume). Thus, a similar origin for dolomites of Site 363 is equally plausible.

Matsumoto et al. (this volume) noted that opal was fairly abundant in these lower cores, based on their own X-ray diffraction data. They presumed that this was the result of higher biogenic productivity of siliceous organisms in the Early Cretaceous. However, Kastner et al. (1977, in press) have found that diagenetic conversion of clays to opal is accelerated in the presence of $CaCO_3$, which is abundant in these cores. The infilling of foraminifer tests with opal (Figure 24) supports this alternate interpretation.

This evidence for the mobilization of silica is somewhat at odds with the presence of phillipsite in the Cretaceous cores. That phillipsite occurs at all is surprising, since Stonecipher (1976) found that phillipsite occurs in no DSDP cores through Leg 35 older than Eocene nor more deeply buried than 600 meters. The diagenetic conversion of montmorillonites (smectites) to mixed-layer clays (smectite-illites) through time eventually promotes conversion of phillipsite to clinoptilolite by releasing silica. Apparently, opal formed as a result of silica release, but not all phillipsite was converted to clinoptilolite. Both clinoptilolite and phillipsite still occur in the Cretaceous samples from Site 363 examined by X-ray diffraction.

Phillipsite also usually requires a basaltic precursor (Stonecipher, 1976) and is typically associated with smectites (derived mainly from basalts) in younger sediments. The provenance of terrigenous material in the Aptian cores of Site 363 is primarily granitic, although the presence of montmorillonite suggests partially mafic sources as well.

However, it is possible that the phillipsite has an origin similar to that at Sites 361 and 364, where it occurs in sapropels with little or no associated montmorillonite (Seisser and Bremner, this volume). Natland (this volume) ascribed its presence in these sites to heightened salinity, following the stability diagrams of Hess (1966) and its occurrence in siliceous tuffs in saline lakes (Hay, 1966). The stability diagrams showed that silica activity decreases in waters with high Na/K. This results in expansion of the stability volume of phillipsite at the expense of montmorillonite. This explanation could also serve at Site 363, and suggests that the seawater masses that enveloped and periodically swept over Walvis Ridge were unusually saline. They would have been, in all likelihood, the saline anoxic waters trapped behind Walvis Ridge in the Angola Basin that followed evaporite deposition there, and in which high-Na dolomites (Matsumoto et al., this volume) and carbonaceous shales were deposited.

GEOCHEMICAL MEASUREMENTS

Site 362/362A

While drilling on Sites 362 and offset 362A, a continuous gassy section was penetrated in beds of diatomaceous nannofossil ooze of Pleistocene and middle Miocene age which lay between the sediment-water interface and a depth of 464 meters. Immediately after the first cores were recovered, trains of small gas bubbles which rapidly came out of solution could be seen through the liner. Gas pockets quickly began to form as the cores began to expand and part simultaneously (Figure 27). Sometimes within minutes after sectioning and capping a core, the resulting confined pressure caused the

Figure 27. *Gas cracks in Sample 362-8-2, 29-50 cm.*

taped polypropylene end caps to be forced from the liner, thus extruding several centimeters of slurry onto the lab deck. In most instances, however, gas pressure was only enough to cause a bulge in the flexible end caps.

On an air-free basis the gas consists primarily of methane (CH_4) with a lesser amount of carbon dioxide (CO_2), and of hydrogen sulfide (H_2S) and free nitrogen (N_2). As shown graphically in Figure 28, these components follow parallel trends of concentration, reaching a maximum in the stratigraphic interval between Cores 9 and 26, cut at depths of 121.5 and 387.5 meters, respectively. Clearly, based on composition and nature of the sediments, this gas was generated in situ from bacterial activity taking place in the unconsolidated sediments.

Site 363

Neither the presence of gas, nor other evidence of hydrocarbons were detected in the cores recovered at Site 363. A few bubbles were noticed in the fluid recovered with Cores 3 and 4. This was followed by slight bulging of the end caps when nearing ambient temperature. Upon analysis, however, the gas was found to consist only of air.

PHYSICAL PROPERTIES

Sites 362 and 362A

At Site 362 and offset Site 362A, 1081 meters of Quaternary-Tertiary diatomaceous marly nannofossil ooze, Pliocene-Miocene marly nannofossil chalk, and Eocene limestones were found. This site provided an opportunity to compare the physical properties of siliceous sediments with carbonate sediments. No major unconformities were discovered at this site, so all changes in the physical properties can be directly related to increasing overburden pressures and cementation.

Unfortunately, Cores 8 through 22 contained significant amounts of H_2S, CH_4, and CO_2 gas (see Figure 28 and Foresman, this volume). The disturbance caused by the expansion of these gases was manifested by the highly variable physical properties measured in this zone. The abundance of gas encountered was such that it caused the explosion and removal of the end caps of some core containers. From these same core liners sediment was exuded, indicating that gas expansion had caused an increase in core volume. Once the gaseous zone was passed through, the degree of core disturbance was greatly reduced.

Bulk Density

Compared with the bulk density-depth relationship at previous sites, the bulk density values obtained from the upper sediments at this site are somewhat random and do not conform as well to a linear decrease with depth. This variability can be attributed to gas expansion and core disturbance in the upper 500 meters of recovered sediment. The gravimetric measurements of bulk density, as plotted on Figure 29, are less random throughout the entire sediment column.

The values of bulk density, measured both gravimetrically and by GRAPE, were much lower for the diatomaceous marly nannofossil ooze than for other oozes measured thus far on this leg. The porosity values for this type of sediment were greater, suggesting that the diatomaceous ooze was more loosely packed than other types of ooze. Although the upper section at this site was disturbed, the bulk density

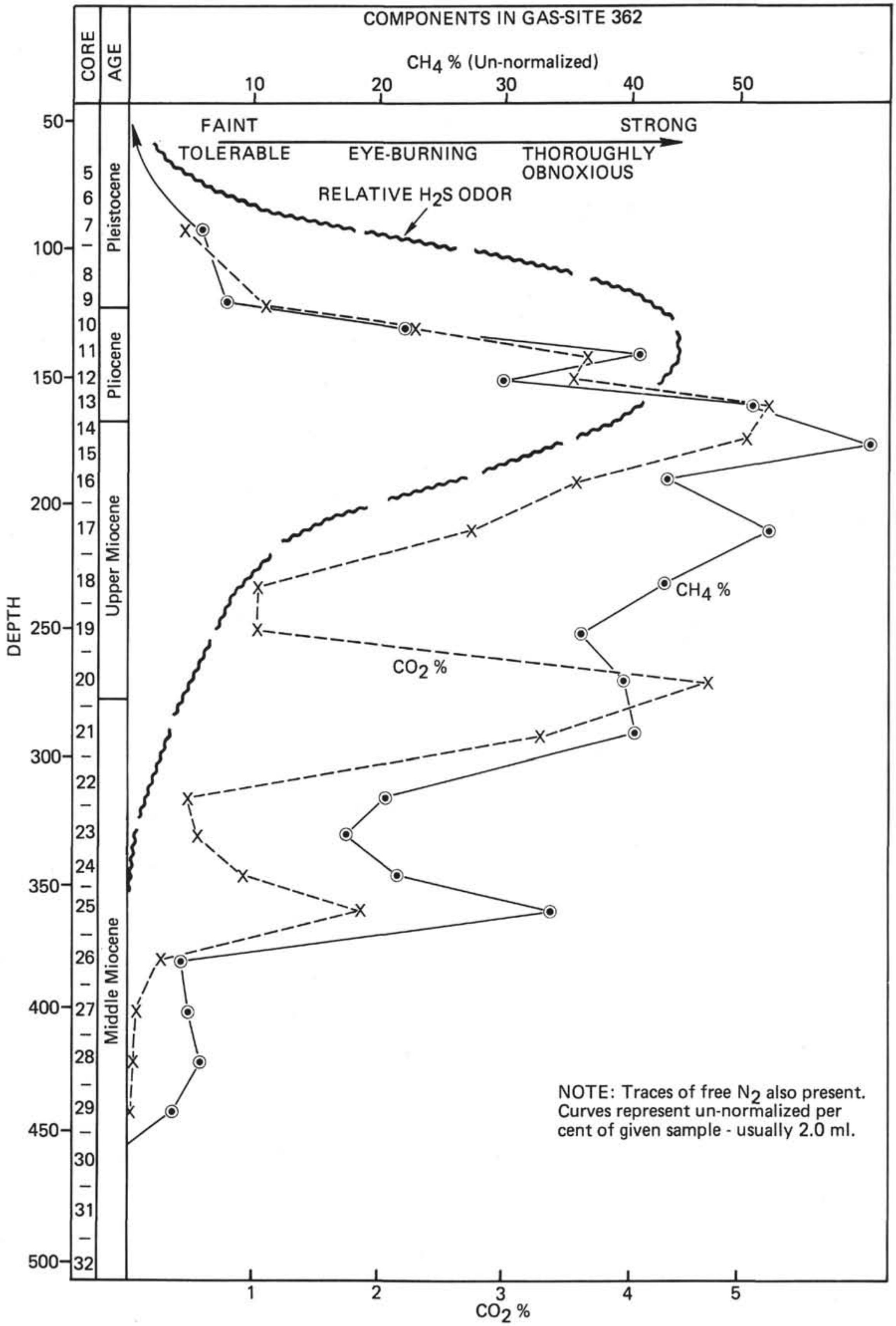


Figure 28. *CO_2 and CH_4 versus depth, Site 362/362A. H_2S "stink" factor also shown.*

increased generally with depth. This increase correlates with the changes from an ooze to a chalk and then to a limestone.

The plot of porosity values on Figure 29 illustrates a typical curve of porosity reduction with depth. Initial poros-

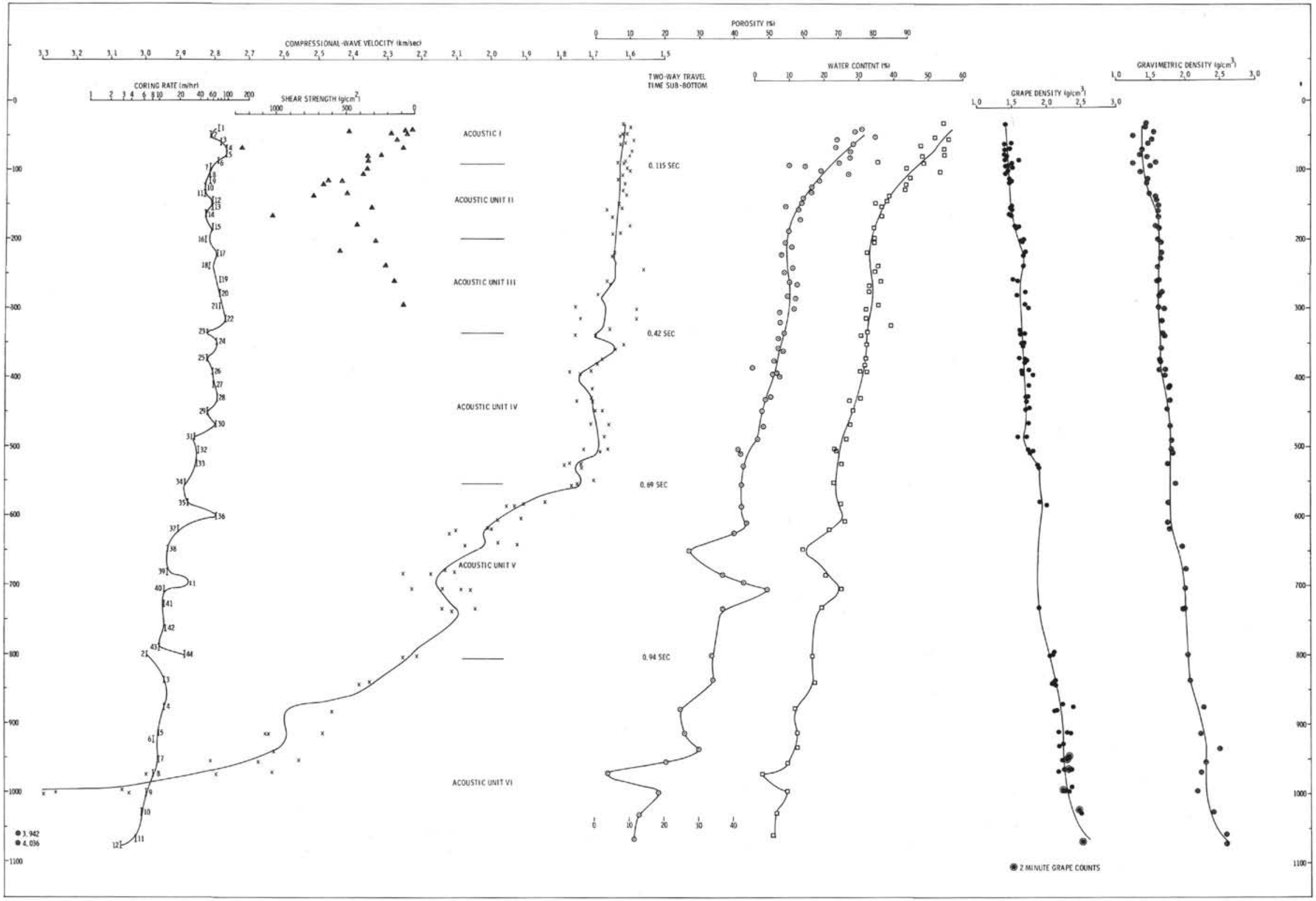


Figure 29. *Downhole variations in physical properties at Site 362/362A and the inferred level of key seismic reflecting interfaces separating the various acoustic units.*

ity in the diatomaceous nannofossil ooze was between 70 and 80 per cent. In the more calcareous ooze, the values of porosity ranged from 60 to 70 per cent, while the porosity of the chalk varied between 35 and 60 per cent. In many of the lower chalks in which cementation and recrystallization have occurred, the porosity was reduced to 5-30 per cent. In the deepest cores of Hole 362A, recrystallization processes have proceeded to a point such that the chalk has become a limestone. A number of these limestones had large pores, some of which were filled with uncemented clay material. Although some of these pores were several millimeters in diameter, there was little communication between them.

Sonic Velocity

Initial sonic velocity measurements from the upper 100 meters of Site 362 averaged 1.62 km/sec. The presence of gas caused core disturbance and attenuated sound energy in the section between 100 and 330 meters. This disturbance is clearly evident in Figure 29, where sonic velocity is plotted versus depth, which shows much scatter. Thus, the measured velocities do not reflect the in situ conditions. At a depth of 510 meters, the slope on the velocity plot rapidly increases and continues linearly to a value of 4.0 at 1075 meters. This sharp break in slope can be attributed to a change in the nature of the chalk, possibly heralding the beginning of cementation. The velocity values which were greater than 3.0 come from sections in which recrystallization of the chalk into a limestone has occurred. Shallow recrystallization processes as observed at this site lend evidence to the hypothesis that the rocks below the depth sampled may be either completely cemented or recrystallized. If this trend continues with depth, then a persistent velocity increase with depth can be expected.

We defined seven major acoustic units (see Correlation of Reflection Profile with Drilling Results, this chapter) from the seismic profile made while approaching this site (see Figures 33 and 34). The mean measured compressional-wave velocities of these acoustic units are presented in Table 4. The acoustic units are not completely comparable to lithologic units, but they do show positive correlation with certain of the physical properties. The base of Acoustic Unit I corresponds to a sediment found to have a markedly decreased number of diatoms. This change in lithology accompanied concomitant changes in the measured values of porosity, bulk density, and water content. Another correlation, between acoustic units and physical properties, occurs at the base of Acoustic Unit IV. Here, a marked increase in sonic velocity and in bulk density values was found. The top of Acoustic Unit VI may correspond to a sharp increase in bulk density.

TABLE 4
Mean Compressional-Wave Velocities, Site 362/362A

Unit	Time to Base of Unit (sec)	Mean Measured Velocity
Acoustic Unit I	0.115	1.63
Acoustic Unit II	0.24	1.62
Acoustic Unit III	0.42	1.65
Acoustic Unit IV	0.69	1.72
Acoustic Unit V	0.94	2.07
Acoustic Unit VI	1.31	2.84
Acoustic Unit VII	1.60	not penetrated

[a]Two-way reflection

Shear Strength

Selected sections of Cores 1 through 22 were used to measure the natural and remolded shear strengths. The sediment lithology of these cores ranged from a diatomaceous marly nannofossil ooze, with other minor siliceous components, to marly nannofossil chalk. Shear strength increased linearly to a value of 1122 g/cm^2 at 168 meters depth subbottom (Figure 29). This maximum was encountered in the H_2S gas zone. The largest amount of gas was measured just below this depth (Figure 28). As Figure 29 illustrates, below 168 meters the plotted values of shear strength decrease to a value of 75 g/cm^2 at 300 meters. This was almost as low as the initial values measured at much shallower depths at previous sites. The low initial values of shear strength may be due to a high water content. Figure 29 displays the general decrease of water content which occurred with increasing depth. The initial values of 90-120 per cent decreased 5-20 per cent in the limestones below 850 meters. The decrease in shear strength values between 170 and 300 meters was not accompanied by a corresponding increase in water content. This decrease may, then, be due to gas expansion core disturbance.

Summary

In the comparison of siliceous sediments to calcareous oozes, measured values of water content and porosity were greater in the former, while the bulk density and shear strength values were greater in the latter. Despite these differences, the measured velocities of the oozes were nearly equal. All of the measured physical properties reflect the changes from an ooze to a chalk to a limestone. These changes are most clearly evident from the plots of velocity and bulk density.

Site 363

Site 363 was located on a topographic high of the northern flank of the Walvis Ridge system. This topographic feature is the surface expression of a basement high which formed in Aptian time. The formation of this ridge system coincided with the opening of the South Atlantic. The basement high has probably maintained the same basement-elevation difference since its creation. As it was a peak subject to currents flowing across the ridge system, the depositional history of this site is represented by a condensed section of biogenic material with several major hiatuses. The hiatuses indicate that erosional-depositional processes have been active since the origin of the ridge system. Associated with some of the hiatuses are slump features and dipping beds, indicating that the recovered sediments may have been deposited on a locally steep slope. The physical properties of the recovered material reflect these major discordances and yield information about the actual amount of sediment deposited.

GRAPE

The bulk density plotted on Figure 30 increases in a linear fashion from 1.7 g/cm^3 at 50 meters to 2.4 at 615 meters. The porosity, also plotted on Figure 30 decreases in a corresponding manner. The high values of 1.7 g/cm^3 would not be found

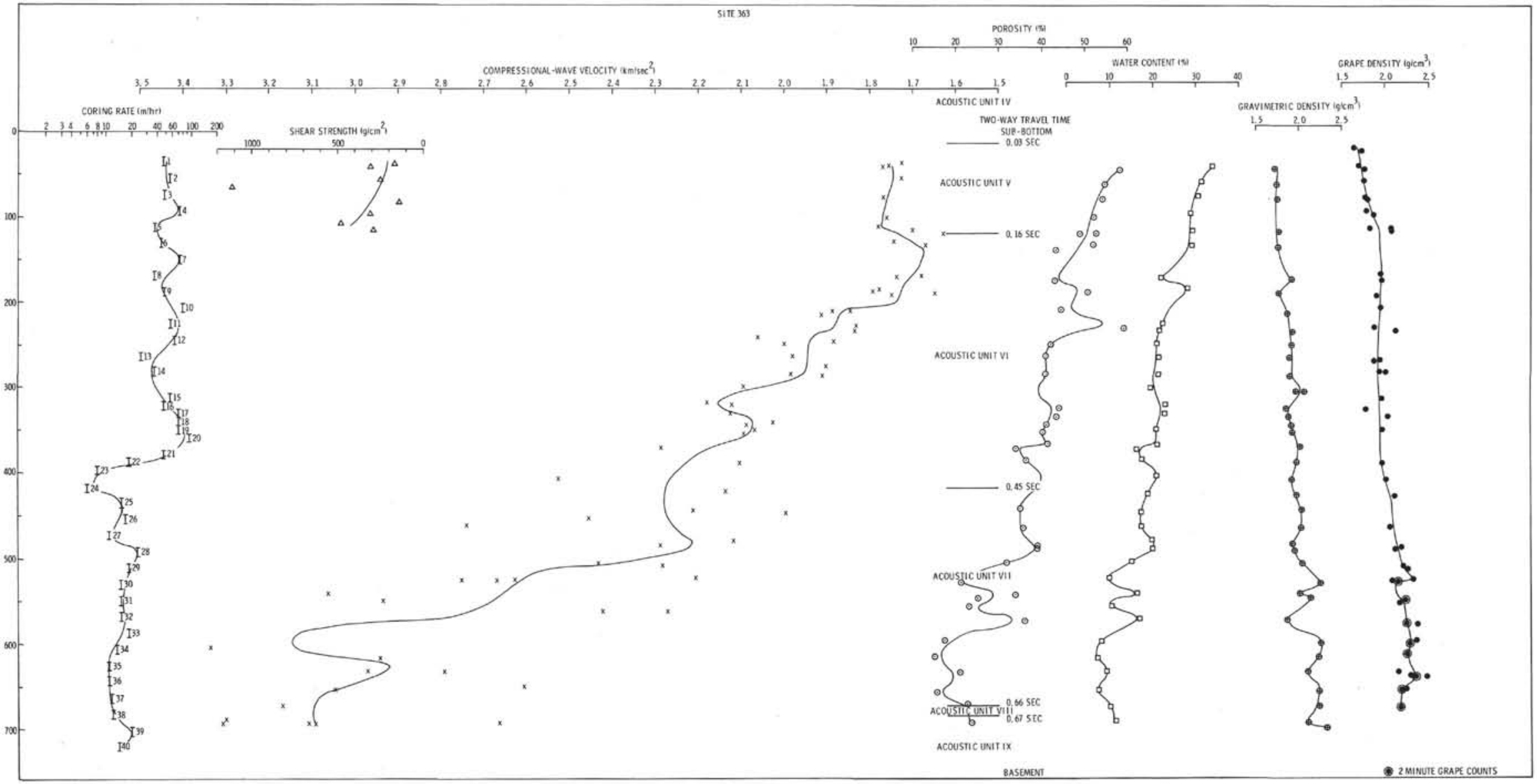


Figure 30. *Downhole variations in physical properties at Site 363 and the inferred level of key seismic reflecting interfaces separating the various acoustic units.*

in near-surface sediments of this lithology unless a previous overburden has been removed. As the rates of sediment deposition during Oligocene and Miocene periods at Sites 362 and 363 are about the same (see below), sediments of comparable age should have seen about the same overburden. At Site 362, bulk-density values only reach 1.7 g/cm³ in the lower Miocene at 630 meters sub-bottom. The first sediments recovered from Site 363 at 50 meters were lower Miocene. As sedimentation rates at the two sites did not vary, an overburden of between 450 and 800 meters might have been removed from the present site in order for similar bulk densities to be found. With the periodic removal of the most recently deposited, less indurated sediments, the entire section was never present at one time. Consolidation tests (Hottman et al., this volume) suggest that the maximum amount of sediment that was ever deposited on top of the Miocene at this site was 100 meters or less. This implies that erosion has to be the dominant process since Miocene along this portion of the Walvis Ridge.

Figure 30 displays a reduction in porosity values from 56 per cent at 40 meters to a low of 15 per cent at 615 meters. For comparably aged rock, the measured values of porosity are greater at Site 363 than that at other sites. This is because the section has never been complete at Site 363 and cementation and recrystallization have not proceeded to the same extent as at other sites.

Sonic Velocity

Initial sonic velocity measurements of material recovered at 40 meters depth are greater than 1.7 km/sec (Figure 30). These same sediments have high values for bulk density. The velocity ranges between 1.7 at a depth of 40 meters to 1.8 at 210 meters. At 210 meters, plotted values display a marked break in slope and increase rapidly to values greater than 3.0 km/sec at depths below 650 meters.

Through the use of key markers in the stratigraphic section, correlation of reflectors from Sites 362 and 363 were made (see below). The seismic reflectors themselves are not completely transferable from Site 362 to Site 363 but their nature and age are sufficiently similar to compare them. From the comparison of the seismic reflectors, the same acoustic units were described for each site. Site 363 was spudded in at the base of Acoustic Unit IV and penetrated into Acoustic Unit VIII which rests on basement. The acoustic units and their mean measured velocities are listed in Table 5. In general, the velocities of Site 363 acoustic units are lower than in comparable units at Site 362. This is because Site 363 had less overburden and cementation at shallow depths. The two reflectors that are most easily traced to other areas of the South Atlantic are at the base of Acoustic Unit V, a *Braarudosphaera* chalk, and the base of Acoustic Unit VI, a Cretaceous unconformity. The significance of these reflectors is discussed in a later section.

TABLE 5
Mean Compressional-Wave Velocities, Site 363

Unit[a]	Time to Base of Unit[b] (sec)	Mean Measured Velocity
Acoustic Unit IV	0.03	1.74?[c]
Acoustic Unit V	0.16	1.73
Acoustic Unit VI	0.45	1.97
Acoustic Unit VII	0.66	2.66
Acoustic Unit VIII	0.67	3.11
Basement IX		Not penetrated

[a] Continuation of acoustic units from Site 362/362A
[b] Two-way reflection time
[c] Based on a single sample

Shear Strength

Shear strength measurements were made on the upper 100 meters of sediment recovered at Site 363 (Figure 30). Below 112 meters, the sediment was a chalk which cracked with penetration of the miniature vane. The initial values of 166.7 g/cm² are unexpectedly low for Miocene sediments that may have had several hundred meters of overburden at a previous time. As shown in Figure 30, shear strength rapidly increases to 1133 g/cm² at 58 meters. Just as rapidly, the shear strength decreases to a low value of 292 g/cm² at 112 meters. This rapid change is similar to that illustrated on the shear strength profile presented in Figure 30 for Site 362. At Site 362, the maximum occurred at 168 meters, whereas at the present site it occurred at 58 meters.

The values of water content decrease linearly from 52 to 7 per cent (Figure 30). The initial values of approximately 52 per cent are significantly smaller than the water content values of the upper sediment at Site 362. These smaller values result from dewatering by previous overburden pressures.

Summary

Because of the topographic setting of Site 363, characterized by a complex series of erosional and depositional cycles, the true sediment column has been thinned. A comparison of physical properties measured at Sites 362 an- 363 suggests that several hundred meters of Tertiary sediments may have been removed by a Pleistocene (?) erosional event. Since a complete sediment column has never been present, the physical properties measured here reflect primarily the net amount of sediment deposited between erosional events. The initial values of sonic velocity and bulk density are greater than expected at shallow depths, thereby reflecting the previous overburden. The bulk density and sonic velocity from the older and deeper sediments are not as great as similar-aged sediments from Site 362 since they were never subjected to the same amount of overburden.

BIOSTRATIGRAPHY AND PALEONTOLOGY

General Remarks, Site 362/362A

At Site 362 805.5 meters of Pleistocene to upper Oligocene sediments were penetrated, and the offset Hole 362A recovered lower Miocene to lower Eocene sediments between 636 and 1081 meters. Pleistocene to upper Pliocene sediments were penetrated in the first 100 meters, the middle to lower Pliocene measures about 60 meters, and the Miocene extends over some 610 meters. The Oligocene has a thickness of about 170 meters and the upper Eocene to lower Eocene measures about 140 meters.

At Site 362, coring was continuous from Cores 1 to 14 (36-169 m). An alternating coring/drilling ratio of l:1 was maintained from Cores 15 to 33 (178.5-530.5 m). The interval 549-805.5 meters (Cores 34-44) was cored mostly at a coring/drilling ratio of 1:2.

With the closely spaced coring of Sites 362 and its extension 362A, a nearly complete Pleistocene to late lower Eocene section was recovered, and most of the planktonic foraminiferal and calcareous nannoplankton zones were recognized. The very thick Miocene section is remarkable, particularly the upper part which alone measures about 280 meters.

Biostratigraphy

For the subdivision of the section by means of planktonic foraminiferal and calcareous nannoplankton zones and correlation of the zonal schemes applied, reference is made to Tables 6 and 7. As at Site 360, both the Austral-New Zealand and the tropical planktonic foraminiferal zonal schemes are applied. In addition to planktonic foraminifers and calcareous nannoplankton, radiolarians and diatoms are also of stratigraphic significance where they occur in the upper part of the section. The radiolarian distribution pattern at Site 362 is similar to that of the Northern Pacific and is used for this site.

Pleistocene-Pliocene

Site 362, Cores 1 to 14 (36-169 m). Only Core 1 is definitely Pleistocene on the basis of both planktonic foraminifers and calcareous nannoplankton. Whereas Cores 2 to 5 (upper part) still fall into the Pleistocene nannofossil *Emiliania ovata* Zone, Core 5 (lower part) to Core 10 (upper part) could only be dated as Pleistocene or Pliocene because of the paucity of index forms. The absence of warm-water foraminiferal markers allows Cores 2 to 7 only to be given a Pleistocene or upper Pliocene date. The radiolarian species *Axoprunum angelinum* in Pleistocene Sample 2-4, 99 cm gives a minimum age of 400,000 years. From Core 7 (lower part) downwards the subdivision of the section on the basis of planktonic foraminifers becomes more accurate, both on the tropical and the Austral-New Zealand zonal schemes. The same also applies for the calcareous nannoplankton zones from Core 10. The base of the Pliocene lies between Cores 14 and 15 on the basis of both planktonic foraminifers (first occurrence of *Globorotalia margaritae)* and calcareous nannoplankton.

On the basis of nannofossils part of the lower Pliocene seems to be absent. On the basis of radiolarians the Miocene/Pliocene boundary is within Core 14, very close to the boundary picked using calcareous nannoplankton and planktonic foraminifers.

The diatoms of Core 1 (36-45.5 m) are assigned to the Pleistocene *Pseudoeunotia doliolus* Zone. Those of Cores 2 to 4 (45.5-74 m) are characteristic of the Pliocene-Pleistocene boundary interval. Cores 5 to 7 (74-102.5 m) are placed in the Pliocene *Rhizosolenia praebergonii* Zone and Cores 8 to 10 (102.5-128 m) in the *Nitzschia jouseae* Zone. The interval of Cores 10 and 11 (128-134 m) is in the *Thalassiosira convexa* Zone, and Cores 11 to 22 (134-321 m) contain no stratigraphically significant markers. The upper Miocene-lower Pliocene boundary is placed within this interval since Cores 23 to 27 (330.5-416 m) are correlatable with the Miocene *Coscinodiscus yabei* Zone.

Miocene

Site 362, Cores 15 to 42 (178.5-767.5 m). Most planktonic foraminiferal (tropical and boreal) and nannoplankton zones could be distinguished in the Miocene, which was of considerable extent (610 m). The thickness of the zones is quite variable. On the basis of planktonic foraminifers, the upper Miocene *Globorotalia dutertrei* and *Globorotalia acostaensis* zones are particularly outstanding (about 280 m); their thickness is almost as much as the remaining middle and lower Miocene combined. Within the tropical zonal scheme, several of the middle and lower Miocene zones either could not clearly be identified or are much reduced in thickness. The reason for this is apparently the marginal position of Site 362 in relation to the distribution of tropical planktonic foraminifers during the Neogene. Using calcareous nannoplankton, the sequence of Miocene zones is continuous and more recognizable.

Oligocene

Hole 362A, Cores 2 to 6, Section 4 (796-ca.938 m). The Oligocene contains a typical warm-water planktonic foraminiferal fauna with index species present allowing a subdivision into the *Globigerina ciperoensis ciperoensis, Globorotalia opima opima, Globigerina ampliapertura,* and *Cassigerinella chipolensis/Pseudohastigerina micra* zones. *Globorotalia kugleri* is absent (but it is present in the lower Miocene). It may have been missed in the uncored interval of 95 meters between Core 1 (696-701 m) and Core 2 (796-805.5 m). The calcareous nannoplankton distribution through the Oligocene and its zonal sequence do not show a sedimentary gap.

Eocene

Hole 362A, Cores 6, CC to 11 (ca.938-1081 m). Because of the poor preservation of planktonic foraminifers, the subdivision of the Eocene section using this fossil group proved rather unsatisfactory. The *Globorotalia cerroazulensis* s.l. Zone, the uppermost in the Eocene, was only recognized in the core catcher of Core 6. The deeper upper Eocene *Globigerinatheka semiinvoluta* Zone is better developed. The middle and lower Eocene part of the section could only tentatively be zoned; individual zones could not be clearly distinguished.

There is good agreement between planktonic foraminifers and calcareous nannoplankton on the location of the Eocene-Oligocene boundary within Core 6. As at Site 363 it is very slightly higher based on nannoplankton. The upper-middle Eocene *Chiasmolithus oamaruensis* Zone was not recognized, but it may fall within the uncored interval between Cores 8 and 9. The normal sequence there of the nannoplankton assemblages shows that the middle to lower Eocene part of the section is continuous.

Paleontology

Planktonic foraminifers, benthic foraminifers in lesser numbers, and calcareous nannoplankton are present throughout the section, allowing them to be studied and their distribution followed from the Pleistocene to the lower Eocene. Radiolarians are frequent in the Pleistocene to

TABLE 6
Correlation of Pleistocene to Upper Oligocene Calcareous Nannoplankton and Planktonic Foraminiferal Zones in Site 362

AGE		CALCAREOUS NANNOPLANKTON ZONES		DEPTH BELOW SEA FLOOR IN METERS	CORE	AUSTRAL-NEW ZEALAND PLANKTONIC FORAMINIFERAL ZONES (Jenkins 1966, 1967, 1975)	TROPICAL PLANKTONIC FORAMINIFERAL ZONES (Bolli 1957, 1966, 1973)	AGE	
PLEISTOCENE		Emiliania huxleyi/ Gephyrocapsa oceanica		36 - 45,5	1	Globorotalia truncatulinoides	Globorotalia truncatulinoides	PLEISTOCENE	
		Emiliania ovata		45,5- 55	2	Globorotalia inflata	Globorotalia truncatulinoides or Globorotalia truncatulinoides cf. tosaensis	PLEISTOCENE or UPPER PLIOCENE	
				55 - 64,5	3				
				64,5- 74	4				
PLEISTOCENE or PLIOCENE		?		74 - 83,4	5				
				83,5- 93	6				
				93 -102,5	7				
				102,5-112	8		Globorotalia miocenica	M	PLIOCENE
				112 -121,5	9				
PLIOCENE	U	Discoaster brouweri		121,5-131	10	Globorotalia puncticulata			
	L	Reticulofenestra pseudoumbilica		131 -140,5	11		Globorotalia margaritae	L	
				140,5-150	12				
				150 -159,5	13				
		Amaurolithus tricorniculatus	Ceratolithus acutus	159,5-169	14				
MIOCENE	U		Triquetrorhabdulus rugosus	178,5-188	15		Globorotalia dutertrei	U	MIOCENE
				197,5-207	16				
				216,5-226	17				
				235,5-245	18	Globorotalia conomiozea			
		Discoaster quinqueramus	Amaurolithus primus	245,5-264	19				
				273,5-283	20		Globorotalia acostaensis		
				292,5-302	21				
				311,5-321	22	Globorotalia miotumida			
				330,5-340	23				
			Discoaster berggrenii	349,5-359	24				
				368,5-378	25				
				387,5-397	26				
		Discoaster calcaris		406,5-416	27				
				425,5-435	28				
				444,5-454	29				
	M	Discoaster hamatus		463,5-473	30		Globorotalia menardii	M	
				482,5-492	31				
		Cotinaster coalitus Discoaster kugleri		501,5-511	32	Globorotalia mayeri mayeri	Globorotalia mayeri / Globorotalia fohsi robusta		
				520,5-530	33		Globorotalia fohsi lobata		
		Discoaster exilis		549 -558,5	34		Globorotalia fohsi fohsi Globorotalia fohsi peripheroronda		
		Sphenolithus heteromorphus		577,5-587	35	Orbulina suturalis			
	L			596,5-606	36	Praeorbulina glomerosa curva	Praeorbulina glomerosa curva	L	
		Helicosphaera ampliaperta		615,5-625	37	Globigerinoides trilobus trilobus	Globigerinatella insueta		
		Sphenolithus belemnos		644 -653,5	38		Globigerinita stainforthi Globigerinita dissimilis		
		Discoaster druggii		672,5-682	39		Globigerinoides primordius/ Globorotalia kugleri		
				701 -710,5	40	Globigerina woodi			
OLIGOCENE	U	Triquetrorhabdulus carinatus		729,5-739	41				
				758 -767,5	42	Globigerina euapertura			
				786,5-796	43		Globigerina ciperoensis ciperoensis	U	OLIGOCENE
		Sphenolithus ciperoensis		796 -805,5	44				

upper Pliocene, and continue in much reduced numbers well into the middle Miocene down to Core 26. Rich diatom associations are also present with an identical distribution to the radiolarians, i.e., from Cores 1 to 26. The following

TABLE 7
Correlation of Oligocene and Eocene Calcareous Nannoplankton and Planktonic Foraminiferal Zones in Site 362A

AGE		CALCAREOUS NANNOPLANKTON ZONES	DEPTH BELOW SEA FLOOR IN METERS	CORE	TROPICAL PLANKTONIC FORAMINIFERAL ZONES (Bolli 1957, 1966, 1973)	AGE	
			696 - 701	1	Globigerinoides primordius	L	MIOCENE
OLIGOCENE	M	Sphenolithus distentus	796 - 805,5	2	Globigerina ciperoensis cip.	U	OLIGOCENE
			834 - 843,5	3	Globorotalia opima opima	M	
		Sphenolithus predistentus	872 - 881,5	4	Globigerina ampliapertura		
	L	Helicosphaera reticulata	910 - 919,5	5	Cassigerinella chipolensis/ Pseudohastigerina micra	L	
		Ericsonia subdisticha	929 - 938,5	6	Globorotalia cerroazulensis s.l.	U	EOCENE
EOCENE	U	Sphenolithus pseudoradians/ Isthmolithus recurvus	948 - 957,5	7	Globigerinatheka semiinvoluta		
			967 -976,5	8			
	M	Reticulofenestra umbilica	995,5-1005	9	Truncorotaloides rohri to Orbulinoides beckmanni	M	
		Nannotetrina fulgens	1024 -1033,5	10	Globorotalia lehneri to Globigerinatheka subconglobata subconglobata		
			1062 -1071,5	11			
		Discoaster sublodoensis	1071,5-1081	12	Globorotalia palmerae (equivalent)	L	

faunal/floral groups present at Site 362/362A were studied for special contributions included in this volume and the supplement volume:

Neogene planktonic foraminifers (Jenkins)
Paleogene planktonic foraminifers (Toumarkine)
Neogene benthic foraminifers (Cameron)
Paleogene benthic foraminifers (Proto Decima and Bolli)
Calcareous nannoplankton (Proto Decima, Medizza, and Todesco)
Tertiary radiolarians (Pisias and Moore)
Tertiary diatoms (Schrader)

Planktonic Foraminifers

Neogene: Planktonic foraminifers are frequent throughout, though dissolution has affected them to some degree, particularly in the Oligocene and Eocene (see Toumarkine, her fig. 6, this volume). Preservation in general is good in the Neogene, but often poor in the Paleogene where specimens are frequently broken or rolled. The Neogene faunas (Cores 1-42, 36-767.5 m), in contrast to those of Cape Basin Site 360, are characterized by an increased presence of temperate- to warm-water species such as *Globorotalia fohsi peripheroacuta, G. fohsi lobata, G. menardii, G. dutertrei, G. truncatulinoides truncatulinoides,* and *Globigerinoides ruber*. On the other hand, temperate- to colder-water species such as *Globigerina pachyderma, G. bulloides, G. miozea conoidea, G. miozea miozea* (which dominate the Cape Basin Site 360 faunas) continue to be present here, though in lesser numbers. The Site 362 Neogene planktonic foraminiferal fauna thus consists of both cooler- and temperate- to warmer-water species. This is explained by the position of the site on Walvis Ridge, between the Cape Basin and Angola Basin. That fluctuations in water temperature must have existed here through at least part of the Neogene is shown by the only restricted occurrence of e.g., *Globorotalia fohsi peripheroacuta* in Sample 34, CC or *G. fohsi lobata* in Sample 33, CC. The occurrence and distribution of planktonic foraminifers throughout the Neogene also seems to indicate progressive cooling. This is indicated by the absence in the lower and middle Pliocene of such typical tropical species as *Globorotalia multicamerata, G. miocenica,* and *G. exilis*.

Paleogene: The Paleogene planktonic foraminifers are also not fully tropical in their species composition. This is shown by the occurrence in the upper Eocene of only minute *Globigerinatheka semiinvoluta,* as are also present in the Alpine-northern Mediterranean region, and by frequent *Globigerinatheka subconglobata luterbacheri* and *G. index index*. In the lower Eocene the abundant and large sized *Globorotalia aragonensis caucasica* and the absence of *G. palmerae* point to more temperate conditions. The presence here of *Cribrohantkenina* and *Globigerinatheka semiinvoluta* indicate that water temperatures were warmer than those at Cape Basin Site 360.

Benthic Foraminifers

As at Site 360, benthic foraminifers are infrequent compared with the planktonic forms. However, their occurrence throughout the Neogene and Paleogene justified closer study of the occurrence of taxa, both to show their distribution in the cores and to compare this distribution with the planktonic foraminiferal zones. Dissolution is negligible or moderate through most of the section. Thus, the distribution charts present a fairly complete picture of the species present and their stratigraphic significance.

Calcareous Nannoplankton

Calcareous nannofossils are abundant throughout the section, but discoasters are rare in some samples, particularly in the Pleistocene-Pliocene part of the section, making a zonal subdivision difficult. Sample 9, CC contains abundant reworked lower Eocene coccoliths of the *Discoaster binodosus* Zone. This is the same zone where oval-shaped nannofossils (Proto Decima et al; this volume, Plate 2, Figures 9-12) were found at Site 361.

A sharp change in the nannoflora takes place in the middle and lower Oligocene *Sphenolithus distentus, Sphenolithus predistentus,* and *Helicosphaera reticulata* zones (362A, Cores 3, CC-5). The usual associations are here replaced by very rich *Braarudosphaera* layers. Though Recent *Braarudosphaera* are abundant in coastal waters and only rare in the open ocean, they are here associated with rich open-sea planktonic foraminifers, and the benthic foraminifers present are also not of the shallow-water type. It is difficult therefore to use the *Braarudosphaera* blooms as depth indicators in this site.

Cool to temperate waters are suggested for the Pleistocene by the frequent *Coccolithus pelagicus,* and for the Pliocene and upper to middle Miocene by the scarcity of discoasters. For the middle to lower Miocene and the Oligocene the common sphenoliths indicate more temperate conditions. Compared with Cape Basin Site 360, a strong reduction of chiasmoliths occurs in the Oligocene and Eocene of Site 362A, an indication of warmer water conditions. Nannoplankton thus show a trend of progressive cooling from the Paleogene through the Neogene, as also indicated by the planktonic foraminifer distribution.

Radiolarians

Pleistocene to upper Miocene radiolarians occur at Site 362 from Cores 1 to 26 (36-397 m). Specimens are infrequent in Cores 8-26 but common in Cores 1 to 7 where *Cycladophora davisiana* is abundant.

Opal Phytoplankton Remains

Cores 1 to 26 yield a rich and diverse diatom flora. Of interest are the displaced fresh-water assemblages in Samples 7-5, 79-80 cm and 17-6, 79-80 cm with abundant *Melosira granulata* and *Stephanodiscus astreae,* associated with phytoliths. Fecal pellets in Sample 5-5, 79-80 cm contain well-preserved marine diatoms. No diatoms are present below Sample 27-1, 79-80 cm.

General Remarks, Site 363

The section at Site 363 is complementary to Site 362/362A, where drilling penetrated 1081 meters of Pleistocene to middle Eocene sediments. Site 363 repeats the lower 230 meters of Site 362/362A (middle Miocene to lower middle Eocene), continues through the lower Eocene and Paleocene (100 m), the Upper (110 m) and Lower Cretaceous (275 m), bottoming in upper Aptian calcarenite at 715 meters.

From 31 m through most of the hole, a 9.5 meter core was taken every 19 meters. The Cretaceous-Tertiary boundary interval (Cores 15-23, 297-392 m) was cored continuously, with the exception of 354-363 meters.

Only Core 1 and the upper part of Core 2, both rich in well-preserved planktonic foraminifers and calcareous nannoplankton, are Miocene in age. Core 2 through the upper part of Core 9 contains a complete sequence of upper, middle, and lower Oligocene planktonic foraminifer zones. The lower part of Core 9 through Core 14 contains most of the Eocene planktonic foraminifer zones. The upper part of the upper Paleocene probably falls into the uncored interval between Cores 14 and 15. Cores 15 to 18 (upper part) contain most of the recognized middle and lower Paleocene planktonic foraminifer zones. The oldest known Paleocene (*Globigerina eugubina* Zone, *Markalius inversus* Zone) was not recognized in Core 18 which contains the Cretaceous/Tertiary boundary. Preservation of planktonic foraminifers and calcareous nannoplankton is mostly good, with only moderate dissolution effects.

Core 18 (lower part) to Core 21 contains a rich and well-preserved upper, middle, and lower Maestrichtian planktonic foraminifer fauna of Tethyan character. Because of strong dissolution Cores 22 to 25 are barren of planktonic foraminifers, but calcareous nannofossils in this interval are upper Campanian-Coniacian in age. The Cenomanian and Turonian thus appear to be missing.

The next deeper core, Core 26, is already middle-upper Albian. Core 39, the deepest core containing planktonic foraminifers, is upper Aptian. The Albian-Aptian planktonic foraminifers are of a cooler water, boreal type, indicating that no opening of the South Atlantic to the Tethys to the North existed at that time.

Calcareous nannofossils occur throughout the Cretaceous cores; their preservation is good in Maestrichtian Cores 18 and 19, becoming gradually less well preserved downhole in Cores 20 to 25. Below this, calcareous nannofossils are scarce and generally poorly preserved. Core 40, the deepest core containing calcareous nannoplankton, is dated as upper Aptian/lower Albian. In general there is good agreement between planktonic foraminifer and calcareous nannoplankton dates throughout ohe Tertiary and Upper Cretaceous.

Radiolarians are absent in the Neogene-Paleogene, and mostly rare and poorly preserved in the Cretaceous, allowing only very tentative age determinations.

Calcisphaerulids occur from the lower Paleocene (Core 18) to the Campanian (Core 22) and again in the Albian-Aptian (Cores 26-39), where they often constitute most or all of the 44-63 μm fraction. Several of the taxa distinguished are of stratigraphic significance in that Paleocene, Maestrichtian, Campanian-Maestrichtian, Albian, and Aptian-Albian species can be distinguished.

Several ammonites were recovered in the Albian-Aptian. They are sufficiently well preserved to allow the distinction of four different species (phylloceratids and desmoceratids). Their mode of preservation was the subject of a special investigation by Wiedmann and Neugebauer (supplemental volume) which indicates deposition on the outer shelf/upper continental slope in sediments of slightly reducing conditions.

No phytoplankton opal skeletons were seen in samples investigated from Cores 1 to 39.

Biostratigraphy

Miocene

From top to bottom Core 1 (31-40.5 m) contains the middle Miocene *Globorotalia menardii* and *Globorotalia fohsi lobata* zones, and the lower Miocene *Globigerinoides primordius* Zone; the upper two zones are contaminated with Pleistocene. On the basis of calcareous nannoplankton, the upper Miocene *Discoaster hamatus*, the middle Miocene *Discoaster exilis* and the lower Miocene *Discoaster druggii* Zone are distinguished. A distinct color change from gray to reddish takes place btween the middle and lower Miocene within Section 4 of Core 1. Core 2, Section 2, is still in the planktonic foraminifer *Globigerinoides primordius* Zone, but is upper Oligocene based on calcareous nannoplankton.

Site 363 contains the most extensive and complete Paleogene section recovered on Leg 40, having planktonic foraminifers similar to those of the Caribbean and the more temperate-water Mediterranean area. As a result a large number of Paleogene planktonic foraminifer and calcareous nannoplankton zones can be distinguished. Reference is made to Table 8 for their occurrence and correlation.

Oligocene

The lower part of Core 2 to the upper part of Core 9 contain a complete sequence of the tropical planktonic foraminifer zones. Ranges of some of the index species seem to deviate somewhat from those generally recognized, e.g., *Cassigerinella chipolensis* was found only in the *Globorotalia opima opima* Zone and *Globigerinoides primordius* occurs before *Globorotalia kugleri* in the *Globigerina ciperoensis ciperoensis* Zone. Except for *Cassigerinella chipolensis* it is not certain whether such unusual occurrences are the result of environmental conditions or possibly contamination during drilling or preparation of samples.

Almost all Oligocene calcareous nannoplankton zones were recognized. Many intervals in the middle and lower Oligocene contain floods of *Braarudosphaera*.

Eocene-Oligocene Boundary

Core 9 bridges the Eocene-Oligocene boundary. Based on planktonic foraminifers, the boundary is defined by the extinction of *Hantkenina, Cribrohantkenina,* and the *Globorotalia cerroazulensis* group, which occur last in Section 3, 98-100 cm. Six samples taken from Section 3 were examined to determine the boundary. Using calcareous nannoplankton, the Eocene-Oligocene boundary is based on the last occurrence of *Discoaster saipanensis* in Section 3, 9-10 cm and thus lies about 90 cm above that determined by planktonic foraminifers.

Except for some gradational color changes and locally intense burrowing, the lithology of Core 9 is homogeneous. It thus can be assumed that sedimentation at Site 363 was continuous and unchanged across the Eocene-Oligocene boundary.

Eocene (Cores 9 to 14)

The upper Eocene as represented in Cores 9 and 10 is condensed in thickness. Compared with other regions, some anomalies occur in the distribution of *Globorotalia cerroazulensis cunialensis,* which here appears earlier, within the *Globigerinatheka semiinvoluta* Zone. The zonal marker *G. semiinvoluta* itself is represented by specimens smaller than normal size, similar to those of the Alpine-Mediterranean region.

The middle Eocene, Cores 10 and 11, also appears condensed. The genus *Globigerinatheka* is particularly well developed here, including the evolutionary lineage *G. subconglobata curryi-G. subconglobata euganea-Orbulinoides beckmanni*. Of interest also is the evolution of *Globorotalia cerroazulensis* during the middle Eocene, which apparently took place slightly earlier than in the Caribbean and Mediterranean areas. The lower Eocene, Cores 11 to 14, has an uninterrupted zonal sequence from the *Globorotalia edgari* to the *Globorotalia palmerae* Zone, though the zonal marker *G. palmerae* was not seen in the section. Very well preserved *Globorotalia aragonensis caucasica* characterize that zonal interval.

The calcareous nannoplankton, though not too well preserved, also offer a nearly complete zonal subdivision of the Eocene.

Paleocene (Cores 15 to 18)

With the exception of the upper Paleocene *Globorotalia velascoensis* and the basal Paleocene *Globigerina eugubina,* all zones are present. The upper part of the upper Paleocene may have occurred in the uncored gap between Cores 14 and 15. The basal zone, however, seems to be absent from the section.

Calcareous nannoplankton preservation is better in the Paleocene, than in the Eocene. Like the basal planktonic foraminifer zone, the lowest Paleocene nannoplankton *Markalius inversus* Zone is also absent.

The Cretaceous-Tertiary boundary falls within the slightly disturbed Section 2 of Core 18. A lower Paleocene *Globorotalia pseudobulloides* Zone fauna is present at 34-38 cm and an upper Maestrichtian *Globotruncana mayaroensis* Zone fauna at 42-44 cm. The location of the Cretaceous-Tertiary boundary as based on calcareous nannoplankton is the same. It is placed at Sample 18-2, 40 cm where *Cruciplacolithus tenuis* is still present, indicating that the *Markalius inversus* Zone is absent.

There is no apparent lithologic change visible within the several closely spaced Lower Tertiary and Upper Cretaceous samples taken in order to place the Cretaceous-Tertiary boundary precisely. The sediment is an indurated marl. The boundary, however, is marked by a slight color change in that the Paleocene interval 34-38 cm is dark reddish brown, the Upper Cretaceous interval 42-44 cm light reddish brown. The upper part of Section 2, from 0 to 30 cm, as well as the interval from 80 cm to about 150 cm of Section 1, is strongly disturbed (soupy).

Cretaceous

The dating and zonal subdivision of the Site 363 Cretaceous is based largely on planktonic foraminifers and calcareous nannoplankton (Table 9). Several ammonites were found in the Albian and Aptian. Their assigned ages do not compare too well with those of the microfossils. Some calcisphaerulid species in the Maestrichtian-Campanian and

TABLE 8
Correlation of Miocene to Paleocene Calcareous Nannoplankton and Planktonic Foraminiferal Zones in Site 363

AGE		CALCAREOUS NANNOPLANKTON ZONES	DEPTH BELOW SEA FLOOR IN METERS	CORE	PLANKTONIC FORAMINIFERAL ZONES		AGE
MIOCENE	U	Discoaster hamatus	31 - 40,5	1	Globorotalia menardii	M	MIOCENE
	M	Discoaster exilis			Globorotalia fohsi lobata		
	L	Discoaster druggii					
OLIGOCENE	U	Sphenolithus ciperoensis	50 - 59,5	2	Globigerinoides primordius	L	
					Globorotalia kugleri	U	OLIGOCENE
			69 - 78,5	3	Globigerina ciperoensis ciperoensis		
		Sphenolithus distentus			Globorotalia opima opima	M	
	M		88 - 97,5	4			
			107 -116,5	5			
		Sphenolithus predistentus			Globigerina ampliapertura		
			126 -135,5	6			
	L	Helicosphaera reticulata	145 -154,5	7			
			164 -173,5	8			
		Ericsonia subdisticha			Cassigerinella chipolensis / Pseudohastigerina micra	L	
EOCENE	U	Sphenolithus pseudoradians	183 -192,5	9	Globorotalia cerroazulensis s.l.	U	EOCENE
		Isthmolithus recurvus			Globigerinatheka semiinvoluta		
	M	Chiasmolithus oamaruensis	202 -211,5	10	Truncorotaloides rohri	M	
		Reticulofenestra umbilica			Orbulinoides beckmanni		
		Nannotetrina fulgens	221 -230,5	11	Globorotalia lehneri - Hantkenina aragonensis		
		Discoaster sublodoensis	240 -249,5	12	Globorotalia palmerae	L	
	L	Discoaster lodoensis	259 -268,5	13	Globorotalia aragonensis		
		Tribrachiatus orthostylus			Globorotalia formosa formosa		
		Discoaster binodosus	278 -287,5	14	Globorotalia subbotinae		
		Tribrachiatus contortus			Globorotalia edgari		
PALEOCENE	U	Discoaster multiradiatus	297 -306,6	15	Globorotalia pseudomenardii	U	PALEOCENE
		Discoaster nobilis					
	M	Fasciculithus tympaniformis	306,5-316	16	Globorotalia pusilla pusilla	M	
			316 -325,5	17	Globorotalia angulata		
					Globorotalia uncinata		
					Globorotalia trinidadensis	L	
	L	Cruciplacolithus tenuis	325,5-335	18	Globorotalia pseudobulloides		

Albian-Aptian seem to be of stratigraphic significance; their distribution can be compared with that of other fossil groups.

Cores 18 to 21 are Maestrichtian on the basis of both planktonic foraminifers and calcareous nannoplankton. Samples 18-2, 136-138 cm to 19-2, 58-60 cm are in the upper Maestrichtian *Globotruncana mayaroensis* Zone. Sample 19-4, 58-60 cm to Core 20 are in the middle Maestrichtian *Globotruncana gansseri* Zone, and Core 21 is in the lower Maestrichtian *Globotruncana havanensis* Zone. Based on calcareous nannoplankton, the Maestrichtian is subdivided from top to bottom into the *Micula mura, Lithraphidites quadratus, Arkhangelskiella cymbiformis,* and *Tetralithus trifidus* zones.

The Maestrichtian (Cores 18-21) and the Albian and upper Aptian (Cores 26-40) assemblages are rich and well developed. The Campanian to Cenomanian, if present at all, therefore has to occur in the interval below Core 21 and above Core 26. Probably because of strong dissolution, planktonic foraminifers are absent in Cores 22 to 25. The more resistant benthic foraminifers, however, remain common to abundant in this interval, as do the calcareous nannofossils. Based on the nannofossils, Core 22 falls into the Maestrichtian/Campanian *Tetralithus trifidus* Zone, Cores 23 and 24 into the Campanian *Eiffellithus eximius* Zone, and Core 25 into the *Marthasterites furcatus* Zone of Coniacian/Santonian age. Both the Turonian and Cenomanian, which should occur in the 9.5 meter interval between Cores 25 and 26, are either very condensed or, more likely, totally absent.

Planktonic foraminifers re-appear in Core 26 and continue to Core 39. Specimen frequency is variable; small

TABLE 9
Correlation of Cretaceous Calcareous Nannoplankton and Planktonic Foraminiferal Zones, and Other Fossil Groups in Site 363

CALCAREOUS NANNOPLANKTON			DEPTH BELOW SEA FLOOR IN METERS	CORE	PLANKTONIC FORAMINIFERA			BENTHONIC FORAMINIFERA		RADIOLARIA	AMMONITES
AGE		ZONES			ZONES	AGE					
			325,5-335	18							
MAASTRICHTIAN		Micula mura	335 -344,5	19	Globotruncana mayaroensis	U	MAASTRICHTIAN	U	MAASTRICHTIAN		
		Lithraphidites quadratus Arkhangelskiella cymbiformis	344,5-354	20	Globotruncana gansseri	M					
		Tetralithus trifidus	363,5-373	21	Globotruncana havanensis	L		L			
CAMPANIAN			373 -382,5	22				U	CAMPANIAN	U. CRETACEOUS	
		Eiffellithus eximius	382,5-392	23				L		CAMPANIAN. prob. UPPER	
			401,5-411	24							
L.SANT.-U.CON.		Marthasterites furcatus	420,5-430	25				SANTONIAN - CONIACIAN		CAMPANIAN - SANTONIAN	
U	ALBIAN	Eiffellithus turriseiffeli	439,5-449	26	Rotalipora ticinensis - Biticinella breggiensis	U M	ALBIAN	ALBIAN		MESOZOIC	
			458,5-468	27							
			477,5-487	28							
			496,5-506	29							
			515,5-525	30	Ticinella primula					APT. - BARREMIAN	
			534,5-544	31		L		APTIAN		CRETACEOUS or MESOZOIC s.l.	UPPER ALBIAN
			553,5-563	32	Ticinella bejaouensis - Globigerinelloides algeriana	BASAL ALBIAN - UPPER APTIAN					MIDDLE ALBIAN
			572,5-582	33							
M		Prediscosphaera cretacea	591,5-601	34						APTIAN - BARREMIAN or HAUTERIVIAN - VALANGINIAN	
			610,5-620	35							
			629,5-639	36							
L			648,5-658	37							UPPER APTIAN
			667,5-677	38							
		Parhabdolithus angustus	686,5-696	39							
U	APTIAN		705,5-715	40							

forms retained in the 63 μm mesh predominate, often occurring in floods. Dissolution has affected the faunas to varying degrees.

Based on the planktonic foraminifer associations which are predominantly of the cool-water hedbergellid type, the Lower Cretaceous can be subdivided into the following three biostratigraphic units: Cores 26 to 29, middle-upper Albian *Biticinella breggiensis-Rotalipora ticinensis* zones, Core 30 to Sample 31-1, 124-126 cm, lower to middle Albian *Ticinella primula* Zone, and Samples 31, CC to 39-2, 92-94 cm, upper Aptian to basal Albian *Globigerinelloides algeriana-Ticinella bejaouensis* zones.

Calcareous nannofossils become poor and of inferior preservation below Core 25. Core 26 to Sample 34-3, 41-42 cm are assigned to the upper Albian *Eiffellithus turriseiffeli* Zone, Sample 34, CC to Core 38 to the lower-middle Albian *Prediscosphaera cretacea* Zone, and Cores 39-40 to the upper Aptian, lower Albian *Parhabdolithus angustus* Zone.

The best radiolarians occur in the Upper Cretaceous Cores 23 to 25 and are dated as Campanian-Santonian. The radiolarians in Cores 26 through 30, Section 6, are only a few undiagnostic forms. Based on *Spongosaturnalis horridus,* Sample 30-6, 27-29 cm is Aptian/Barremian. Cores 31 to 33 contain faunas of only general Cretaceous or Mesozoic character. Cores 34 to 39 are dated as Aptian/Barremian or Hauterivian/Valanginian, based on the above faunas and the presence of *Amphipyndax stocki,* a species that occurs first in the Barremian or Hauterivian/Valanginian.

Several ammonites were recovered in the Albian/Aptian. *Puzosia mayoriana* from Core 31 is given an upper Albian age. *Phylloceras velledae* from Core 32 and *Beudanticeras* cf. *newtoni* from Core 33 are assigned to the middle Albian, and *Phylloceras* cf. *morelianum* from Core 37 to the upper Aptian.

As can be seen from the zonal correlation on Table 9, the age assignments within the Albian/Aptian of Cores 26-40 may differ quite considerably based on the various fossil groups. There is good agreement on the Albian/Aptian boundary based on planktonic and benthic foraminifers, and radiolarians. From planktonic foraminifers it lies within Core 31, from benthic foraminifers between Cores 30 and 31, and from radiolarians the highest recognized Aptian is in Core 30. From ammonites the boundary is somewhat deeper, within Cores 34 to 36. It is not higher than within Core 39 based on calcareous nannoplankton. Ages on benthic foraminifers and radiolarians must be regarded as rather tentative.

Paleontology

From the Miocene to the upper Aptian penetrated at Site 363, the Oligocene to Maestrichtian and the Albian-upper Aptian have particularly rich and well-developed faunas and floras. Only fragments of the middle and lower Miocene and a very incomplete Campanian to Cenomanian were recovered. In the Oligocene to Maestrichtian, planktonic foraminifers and calcareous nannoplankton of tropical/subtropical warm-water types are generally abundant and well preserved. Benthic foraminifers are also present throughout this interval, but are less frequent than the planktonic foraminifers.

The Albian-Aptian is characterized by generally quite rich planktonic foraminifer faunas of mainly cooler-water and small-sized hedbergellid forms, accompanied by a less frequent benthic fauna. Calcareous nannofossils are present throughout the Lower Cretaceous, where their preservation is only moderate. Radiolarians are present in most samples examined from Cores 22 to 39, but are infrequent with poor preservation. Several ammonites were recovered from Cores 31, 32, and 37. Calcisphaerulidae occur sparsely in the lower Paleocene to Campanian Cores 18-22, but are very frequent, mostly as floods, from Cores 26 to 39.

The following faunal/floral groups of Site 363 are treated in special contributions in this and the supplement volumes:

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)
Miocene to upper Aptian calcareous nannoplankton (Proto Decima, Medizza and Todesco)
Cretaceous radiolarians (Foreman)
Calcisphaerulidae (Bolli)
Ammonites (Wiedmann and Neugebauer)

Planktonic foraminifers

Neogene: The Miocene planktonic foraminifers in Core 1 and the upper part of Core 2 are well preserved and with species such as *Globorotalia fohsi lobata* of tropical aspect.

Paleogene: The heavily cored Oligocene to Paleocene of some 285 meters thickness contains rich and mostly well-preserved planktonic foraminifer faunas throughout. These are predominantly of tropical to temperate origin. The faunas can thus readily be compared with those of the Caribbean and Alpine-Mediterranean regions.

The Oligocene is characterized by the presence of such zonal markers as *Globorotalia opima opima* and *Globigerina ciperoensis ciperoensis*. It has already been noted in the biostratigraphic part of this chapter that the distribution of some of the Oligocene index forms is slightly anomalous compared with that generally found.

As also pointed out in the biostratigraphic part, Core 9 offers a unique opportunity to study the planktonic foraminifer distribution across the Eocene/Oligocene boundary in an apparently undisturbed and continuous sedimentary sequence. The index forms *Cribrohantkenina*, *Hantkenina*, and the *Globorotalia cerroazulensis* subspecies became extinct at virtually the same level (in Core 9, Section 2, between investigated intervals of 98-100 cm and 82-84 cm).

The Eocene planktonic foraminifers show some affinities to the Alpine-Mediterranean faunas, indicating a tendency towards more temperate waters. This is shown by the presence in the lower Eocene of rich and well-preserved *Globorotalia aragonensis caucasica* which are not known from tropical areas such as the Caribbean. Also of significance is the absence of *Globorotalia palmerae* which is known only from a rather narrow latitudinal strip extending from the Caribbean via North Africa-Syria to India.

The genus *Globigerinatheka* with its species and subspecies is well developed in the middle and upper Eocene. The evolutionary trends previously established in the Caribbean, Alpine region, and Pacific can be followed here also. *Globorotalia cerroazulensis* is another index form whose gradual evolution through the middle and upper Eocene from non-keeled subspecies to a distinctly keeled end form (*G. cerroazulensis cunialensis*) is well developed here. The fact that the lower upper Eocene marker *Globigerinatheka semiinvoluta* occurs only in small specimens is a further indication of a more temperate climate during the Eocene in the Site 363 area. This is further supported by the presence of *Globigerinatheka index* and *G. subconglobata luterbacheri*, forms known from the Alpine, but not from the Caribbean middle-upper Eocene.

The basal Eocene small-sized *Globorotalia edgari*, first described in the Caribbean (Leg 15), is also present on Walvis Ridge, an indication that this index form has wide geographic distribution.

The Paleocene planktonic foraminifers follow the known warm-water association and distribution of species including the index forms *Globorotalia pseudobulloides*, *G. trinidadensis*, *G. uncinata*, *G. angulata*, *G. pusilla pusilla*, *G. pseudomenardii*, and *G. velascoensis*. The uppermost and lowermost Paleocene zones, *Globorotalia velascoensis* and *Globigerina eugubina*, were not recognized.

Cretaceous: The Cretaceous planktonic foraminifers of Site 363 can be divided into two distinct groups, a Maestrichtian Tethyan type fauna (Cores 18-21) and a boreal Albian-Aptian fauna (Cores 26-39). Cores 22 to 25 and 40 are devoid of planktonic foraminifers.

The rich and well-preserved Maestrichtian planktonic foraminifers in Cores 18 to 21 allow a subdivision of the Maestrichtian into three zones, and contain among numerous other diagnostic species, *Globotruncana contusa*, *G. stuarti*, and the zonal markers *G. havanensis*, *G. gansseri*, and *G. mayaroensis*. A rapid diminution of the planktonic foraminifer specimens as a result of dissolution takes place towards the base of the Maestrichtian. In Core 21 the fauna is less rich than in Core 20, and in Core 22 it is completely absent, although other calcareous fossils such as benthic foraminifers and calcareous nannoplankton are still preserved there.

The Albian-Aptian fauna is characterized by a proliferation of *Hedbergella* types and a general absence of keeled forms. Further, a diminution in the size of specimens and a tendency in some species towards a reduced number of chambers are further indications for a boreal-type fauna as known from the Southern Indian Ocean. No obvious signs of a warm water Tethyan-type fauna were noted.

These rather monotonous Albian-Aptian faunas with scarce or absent index forms may be good paleoenvironment indicators but make a zonal subdivision difficult. Because the Tethyan Maestrichtian species have received much attention in the literature, they are neither described nor illustrated in this volume; only their occurrence and distributions are plotted on the range chart. Instead, attention is focused on the Albian-Aptian species with short notes on their less well-described characteristics. Most species are also illustrated.

Benthic Foraminifers

Paleogene: Like the planktonic foraminifers, well-preserved benthic assemblages occur from Core 2 (*Globigerina ciperoensis ciperoensis* Zone) through Core 17 (*Globorotalia trinidadensis* Zone). Because of low dissolution effects in this section, it is assumed that the assemblages are fully representative. Their distribution is plotted against the planktonic foraminiferal zonal scheme to emphasize the stratigraphic significance of individual species (Proto Decima and Bolli, this volume, table 4).

Upper Cretaceous: Benthic foraminifers occur throughout the Upper Cretaceous Cores 19-25. They appear to be rather infrequent in the Maestrichtian Cores 18 to 21 where planktonic foraminifers strongly predominate, but become common in the Campanian to Coniacian Cores 22 to 25 where planktonic foraminifers are totally absent because of selective dissolution. Rotaloid species are the most frequent of the benthic forms, with some genera of agglutinated, buliminid and nodosariid forms also present. The fauna does not change significantly from the bottom to the top of the Upper Cretaceous section. Large Gaudryinas and Dorothias and some other forms are indicative of an upper slope or shelf edge environment. If this is the case, the absence of planktonic foraminifers in Cores 22 to 25 due to dissolution would have to be explained by a quite shallow CCD.

Lower Cretaceous: Benthic foraminifers in the Albian Cores 26 to 31 are fairly frequent, but become less abundant in Cores 32 to 37 and are very scarce with only small-sized specimens in Cores 38 to 40. The fauna is of Austral nature, with species identical to those from the Great Australian Basin, the Indian Ocean, India, and South Africa. The Walvis Ridge Lower Cretaceous was thus part of the Austral bioprovince with no connection to the North Atlantic. As in the Upper Cretaceous, rotaloid species are strongly predominant.

Calcareous Nannoplankton

Nannofossil assemblages ranging in age from middle Miocene to Lower Cretaceous were encountered at Site 363.

Core 1 contains a non-continuous sequence of three upper to lower Miocene nannofossil zones (*Discoaster hamatus*, *Discoaster exilis*, and *Discoaster druggii* zones). Abundant well to moderately preserved coccoliths of Oligocene age are present from Cores 2 to 8. The presence of the diagnostic *Sphenolithus* species and other markers allows recognition of almost all Oligocene biozones. Unusual intervals predominantly composed of *Braarudosphaera* are common in the middle and lower Oligocene. They could be the result of periodic blooms and indicate near-shore influence.

The Eocene/Oligocene boundary, based on the last occurrence of *Discoaster saipanensis* is placed in the upper part of Core 9 which appears characterized by continuous sedimentation. In the fairly complete Eocene and Paleocene sections, the nannoplankton preservation is rather poor in the Eocene, but is better in the Paleocene.

The Cretaceous/Tertiary boundary is placed at Sample 18-2, 40 cm. The lowermost Paleocene contains abundant *Thoracosphaera* and common *Braarudosphaera* which are typical of Danian sediments. *Cruciplacolithus tenuis* is present to the Cretaceous/Tertiary boundary; thus the oldest known Tertiary nannofossil associations are, as in all known deep oceanic sequences, not represented at this site.

Sample 18-2, 41 cm to Core 25 represent a continuous sequence of Upper Cretaceous nannofossil zones from upper Maestrichtian to Santonian/Coniacian. Preservation is good in the upper Maestrichtian *Micula mura* Zone, Cores 18 and 19, and moderate to good in Cores 20-25, with some scattered samples having poorly preserved specimens. Core 25 is referred to the Santonian/Coniacian *Marthasterites furcatus* Zone.

Nannofloras become sparse and are generally poorly preserved below Core 25. *Braarudosphaera* and *Nannoconus* of the *truittii* group characterize this deeper interval. An upper Albian age is inferred for Cores 26 to 34, based on the presence of *Eiffellithus turriseiffeli* and the absence of younger markers. The Cenomanian index form *Lithraphidites alatus* was not observed, and the rare specimens of *Micula staurophora* in Sample 26-2, 94-95 cm, suggesting a Turonian age, are most likely the result of contamination from above. *Lithraphidites alatus*, however, could also be absent for ecological reasons. The possibility of a younger age of the upper part of this interval cannot therefore be entirely excluded. Still, an Albian age is more likely, with a gap in the sedimentary sequence confined to the Cenomanian and Turonian.

Cores 35 to 38, below the first occurrence of *Eiffellithus turriseiffeli* and above that of *Prediscosphaera cretacea*, are referred to the lower middle Albian *Prediscosphaera cretacea* Zone.

Core 39 contains no *Prediscosphaera cretacea*. Based on some questionable specimens of *Parhabdolithus angustus* it is tentatively placed into the nominal zone which is upper Aptian/lower Albian.

Core 40 only contains *Watznaueria* and *Parhabdolithus embergeri* and could therefore not be dated using nannofossils.

The presence of *Scyphosphaera*, *Sphenolithus* and *Rhabdosphaera*, and the scarcity of *Chiasmolithus* indicate rather warm-water conditions for the Paleocene of Site 363 on Walvis Ridge in contrast to the Cape Basin Sites 360 and 361. The occurrence of *Braarudosphaera* and the abundance of *Thoracosphaera* in the lowermost Paleocene may indicate neritic or upper bathyal conditions. Based on the presence of *Micula mura*, warm-water conditions are also suggested for the Upper Maestrichtian.

Radiolarians

No Cenozoic radiolarians were found at Site 363, but they are present in most cores throughout the Cretaceous. With few exceptions they are rare to very rare and mostly poorly preserved. Only in some cores where calcium carbonate dissolution was particularly strong and where planktonic foraminifers consequently have disappeared are radiolarians common.

Calcisphaerulidae

Calcisphaerulidae occur in small numbers from the lower Paleocene upper part of Core 18 to the Campanian Core 22. In Cores 23 to 25 they are absent, probably as a result of strong calcium carbonate dissolution. But Calcisphaerulidae are very frequent, often occurring as floods in the finer fractions of the upper Albian Core 26 to the upper Aptian Core 39 samples. Several species can be distinguished, most having apparent stratigraphic significance. The *Pithonella* cf. *bollii* and *P. tintanophax,* originally reported from the lower Paleocene of the Antarctic Site 323 of Leg 35 (Rögl, 1976), are restricted to the lower Paleocene part of Core 18. In the Maestrichtian (lower part of Core 18 to 21) *P. cooki* occurs, originally described from the Upper Cretaceous of the Indian Ocean Site 260, Leg 27. *P. krasheninnikovi,* also first described from the Upper Cretaceous of Site 260, is present in the middle-lower Maestrichtian to Campanian Cores 20 to 22. Cores 26 to 39 contain very frequent spherical forms here tentatively included in *P.* cf. *sphaerica.* A small, elliptical form placed in *P.* cf. *ovalis* was observed in smaller numbers in Cores 26 to 34. *Bonetocardiella* cf. *conoidea,* a characteristically shaped form, occurs in the upper Albian Cores 27 to 32, and is particularly well represented in Cores 27 and 28. It is curious that only in the Cretaceous of Site 363 are Calcisphaerulids so frequent. At Sites 361 and 364 only rare and poorly preserved specimens were seen.

Ammonites

The following four ammonite species occur in the Albian-Aptian of Site 363: *Puzosia mayoriana* (Sample 31-3, 19-22 and 37-39 cm, upper Albian); *Phylloceras velledae* (Sample 32-3, 29-32 cm, middle Albian); *Beudanticeras* cf. *newtoni* (Sample 33-4, 149-151 cm, middle Albian); *Phylloceras* cf. *morelianum* (Sample 37-2, 129-131 cm, upper Aptian).

This association is interpreted to show a more open basin relationship than the Albian ammonites of the Angola Basin Site 364. The fauna is related to faunas of Angola, South Africa, Madagascar, and Europe. From this it is concluded that the connection of the South Atlantic with the North Atlantic was already open in the middle Albian, earlier than generally assumed.

The ammonites are preserved in a uniform and unusual way. The shells were fractured and collapsed, then mineralized by glauconite, framboidal pyrite, and elongated calcite. Shell material itself is not preserved.

CORRELATION OF REFLECTION PROFILE WITH DRILLING RESULTS

Site 362

Nine acoustic units are recognized at Site 362 and are shown on Figure 33 and Figure 34. Drilling penetrated the first six of these units.

The base of Acoustic Unit I (reflector purple) correlates to the base of Lithologic Unit 1a in Core 6 at 89 meters (Figure 34).

The base of Acoustic Unit II (reflector black) correlates to Core 16 at 190 meters.

The base of Acoustic Unit III (reflector green) correlates to Core 23 at 335 meters.

The base of Acoustic Unit IV (reflector yellow) correlates to a major change in the physical properties noticed at Core 34 at 555 meters.

The base of Acoustic Unit V (reflector blue) correlates to the top of the *Braarudosphaera* chalk between Cores 2 and 3 of Hole 362A at 810 meters.

The base of Acoustic Unit VI (reflector red) was not penetrated at Site 362A. Its inferred depth is 1300 meters sub-bottom.

Interval sound velocities are given in Table 10, based on Figure 33.

Site 363

Nine acoustic units are recognized on the Frio Ridge segment of the Walvis Ridge. The last five of these occur at Site 363 (Figure 35).

The base of Acoustic Unit IV (reflector yellow) correlates to the major unconformity at 24 meters sub-bottom observed in Core 1.

The base of Acoustic Unit V (reflector light blue) correlates with the upper level of the *Braarudosphaera* chalk at 135 meters.

The base of Acoustic Unit VI (reflector red) correlates with a major unconformity between the Upper and Lower Cretaceous at 435 meters sub-bottom.

The base of Acoustic Unit VII (reflector yellow) correlates with the indurated calcarenite facies encountered in Cores 39 and 40 at 695 meters.

The base of Acoustic Unit VIII (reflector brown) occurs at the top of the acoustic basement inferred to be at ≈720 meters sub-bottom. Acoustic Unit IX is the acoustic basement.

Calculated interval velocities are given in Table 11 (based on Figure 35).

SEDIMENTATION ACCUMULATION RATES, SITES 362 AND 363

The general method of derivation of sedimentation rates and bulk sediment accumulation rates (corrected for post-burial compaction of older strata using smoothed downhole variations in gravimetric bulk and porosity density) was given in Chapter 2 of this volume. Again, these were calibrated to nannofossil datums corresponding to zonal boundaries interpolated at 1-m.y. intervals. Accumulation rates are expressed for both the total bulk sediment and the carbonate fraction. These are presented on Figures 31 and 32 along with age-depth curves, the nannofossil zonations, average $CaCO_3$, and the average percent sand, silt, and clay in each core. Where zones either are missing or were not identified perhaps for ecological reasons (i.e., *Lithraphidites*

TABLE 10
Interval Velocities – Site 362/362A

Acoustic Unit	Time to Base (sec)	Depth to Base (m)	Velocity (km/sec)
I	0.115	89	1.55
II	0.24	190	1.61
III	0.42	335	1.62
IV	0.69	555	1.63
V	0.94	810	2.04
VI	1.31	1300[a]	2.65

[a] Base of this unit was not reached by drilling of Hole 362A. It was penetrated at Site 363 and corresponds there to an unconformity between the Lower and Upper Cretaceous.

TABLE 11
Interval Velocities – Site 363

Acoustic Unit	Time to Base (sec)	Depth to Base (m)	Velocity (km/sec)
IV	0.03	34	1.60
V	0.16	135	1.62
VI	0.45	435	2.07
VII	0.66	695	2.48
VIII	0.67	720	5.0

alatus Zone), sedimentation rates are assumed to be uniform between whatever zonal boundaries could be identified. This results in an almost certainly unrealistic set of stepped accumulation rate curves in the Cretaceous of Site 363 (Figure 32). The artificiality of these Cretaceous portions of the curves expresses both the general lack of precision of Cretaceous marine calcareous-microfossil biostratigraphy, as well as the weak links of Cretaceous zonal boundaries to any absolute geochronologic framework.

The curves for Site 362/362A shows six general maxima in the Tertiary and those for Site 363 three, corresponding to the older three at Site 362/362A. The maxima occur respectively at 6, 15, 23, 33-35, 42, and 44-49 million years. The first three of these occurred as well at Site 360 but are of considerably less magnitude (the 6-m.y. maxima of the carbonate accumulation rate curve at Site 360 is 58 g/cm²/m.y. × 10^2 whereas at Site 362 is 122 g/cm²/m.y. × 10^2). The 33-35-m.y. maximum is the period of major

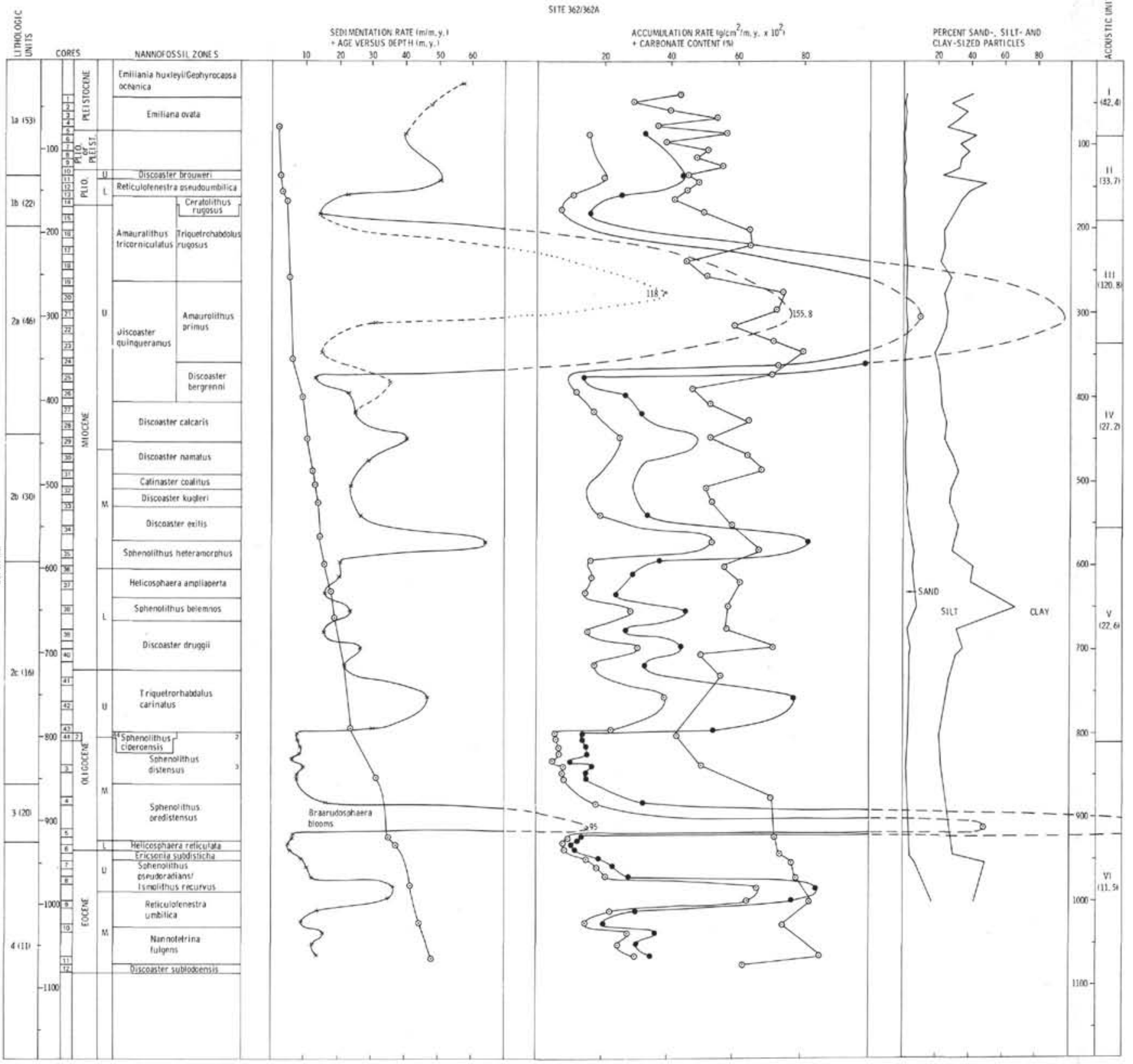


Figure 31. *Biostratigraphic zonations, sedimentation rates, accumulation rates, carbonate contents, and the proportion of sand to silt and clay versus depth at Site 362/362A. Mean sedimentation rates for lithologic units and acoustic units in parentheses to left and right of figure, respectively.*

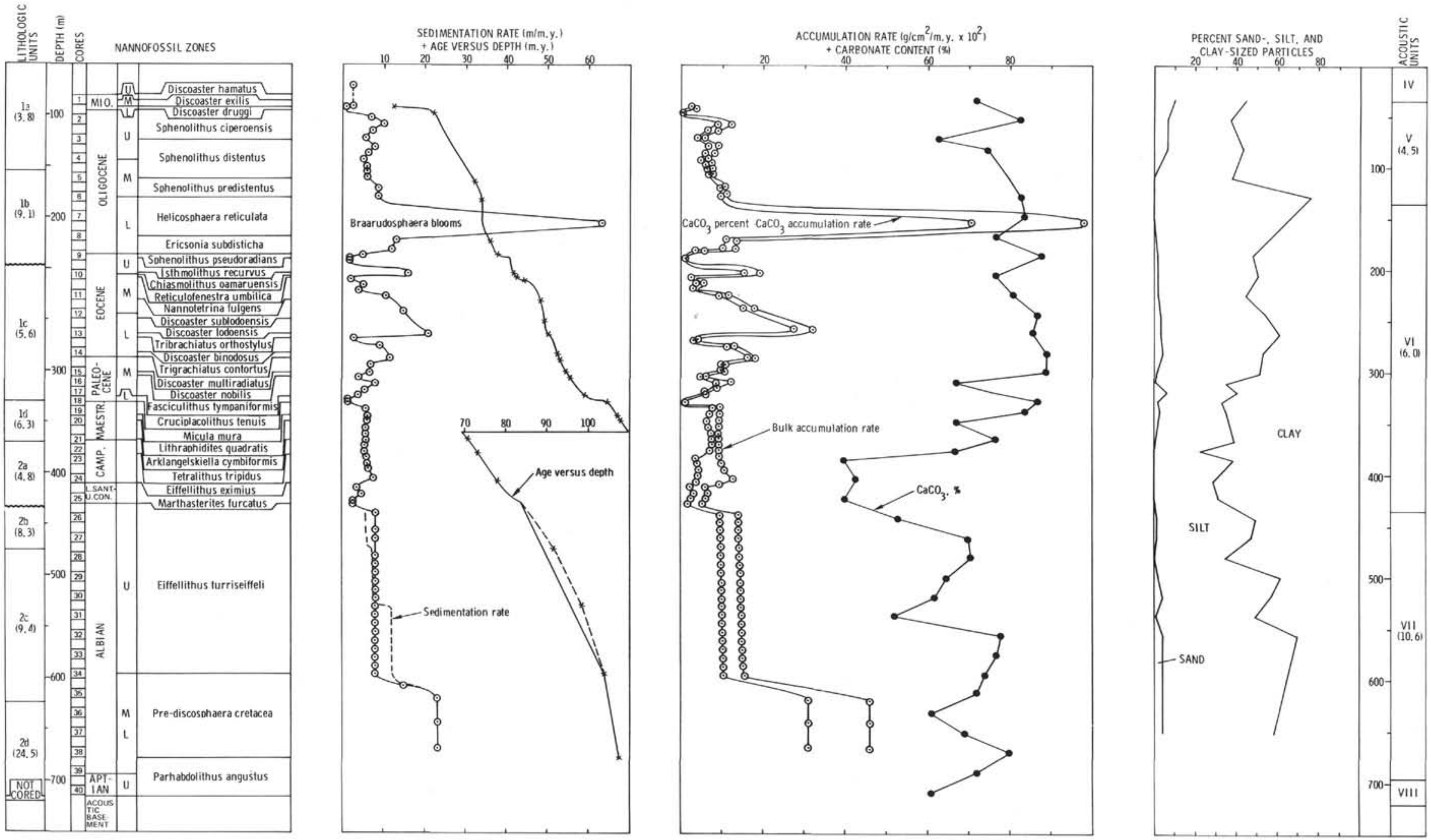


Figure 32. *Biostratigraphic zonation, sedimentation rates, carbonate contents, and the proportions of sand to silt and clay versus depth at Site 363. Mean sedimentation rates for lithologic units and acoustic units in parentheses to left and right of figure, respectively.*

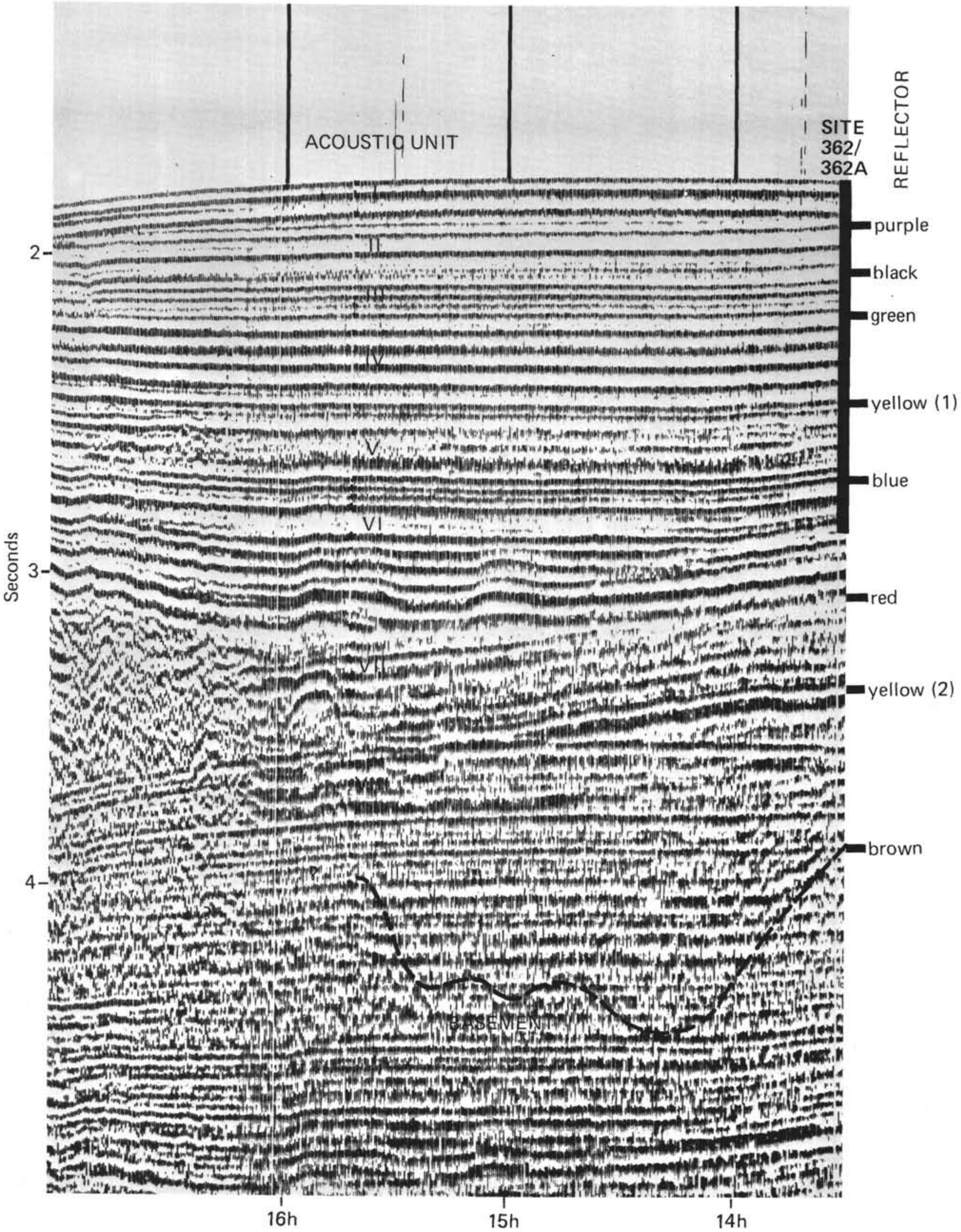


Figure 33. *Acoustic units on* Walda *profile 11 (Goslin et al., 1974), near Site 362/362A.*

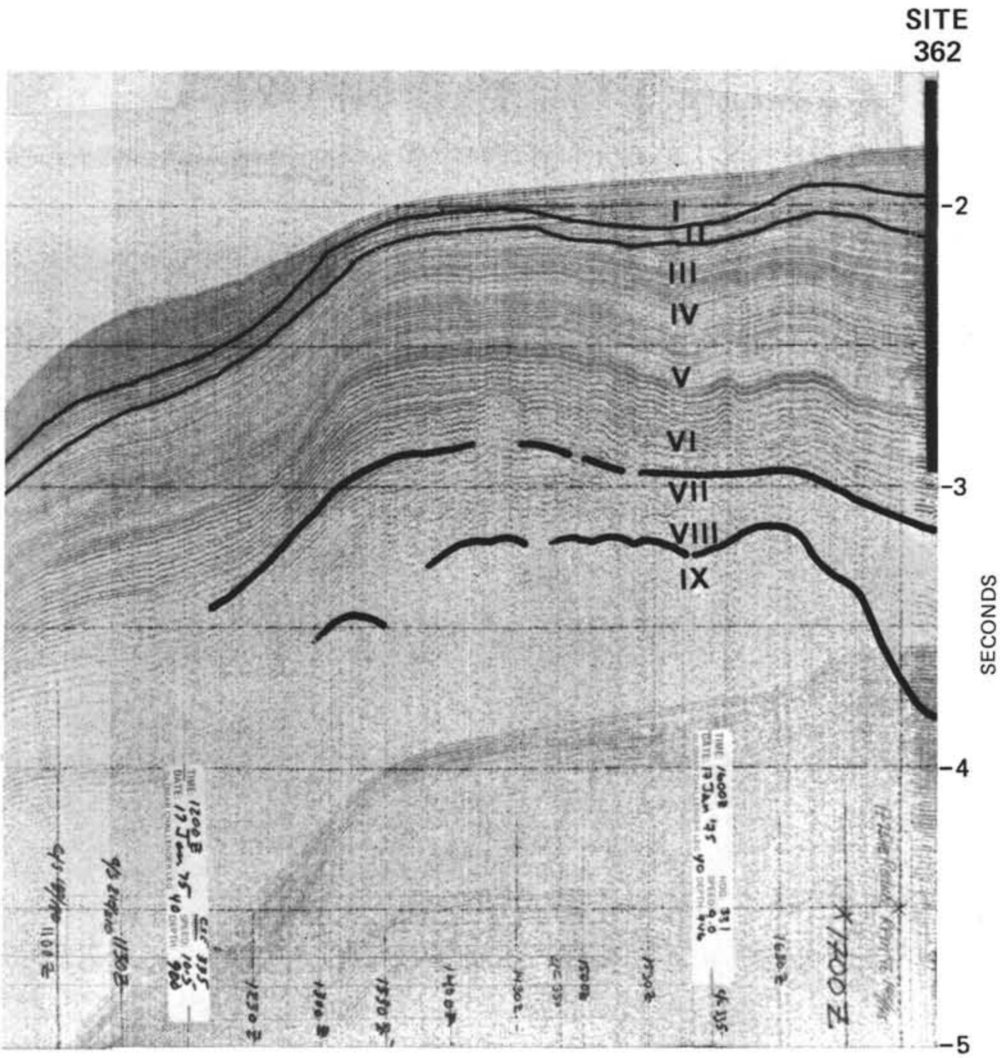


Figure 34. *Acoustic units on* Challenger *approach to profile Site 362/362A.*

Braarudosphaera blooms at Sites 362 and 363 that did not occur at Site 360. On the other hand, a maximum at 36 m.y. at Site 360 did not occur at Sites 362 and 363. Neglecting the *Braarudosphaera* blooms, and lumping the maxima at 42 and 46-49 m.y. into a broad general Eocene maximum, then we can see that the remaining maxima correspond to four of the five maxima documented by van Andel et al. (1975) in the equatorial Pacific, the only exception being a Pacific maximum at 28-30 m.y.

For the portion of their histories that overlap, Site 363 had lower sedimentation and accumulation rates than Site 362/362A, although rates were nearly comparable in the early-middle Eocene and the late Oligocene. Apart from its very earliest history, the Eocene rates are about as rapid as Site 363 ever experienced. This sedimentation was also well over 80 per cent calcareous, higher than in the Cretaceous. Total carbonate accumulation at Site 360 was comparable to that of Site 362 throughout the Tertiary, except for the three maxima in the Miocene, when it was lower.

As at Site 360, an alternative sedimentation rate curve has been plotted based on a connection of the age/depth curves from the base of the *Discoaster quinqueramus* nannofossil zone directly to the base of the *Triquetrorhabdulus rugosus* Zone (see Chapter 2, this volume, for explanation). A late Miocene sedimentation rate maximum still exists, reduced in magnitude, but still higher than any other Tertiary maxima except the *Braarudosphaera* blooms.

SUMMARY AND CONCLUSIONS

Site 362/362A is located in 1325 meters of water on the Abutment Plateau of the Frio Ridge segment of Walvis Ridge where it joins the continental margin of southwest Africa. It lies near the axis of a north-south linear trough at 1330 hours, 26 June, on *Jean Charcot* Cruise Walda, seismic reflection profile 11, and near the intersection of reflection profile *Vema* 29-06, profile record 928, 0900 hours, 13 May, with reflection profile *Atlantis II* Cruise 67, Leg 6, 2100 hours, 12 May; the latitude is 19°45′S, and the longitude 10°32′E. Acoustic marker horizons can be traced northwards into the Angola Basin, southwards into the Cape Basin, eastwards beneath the African continental slope and shelf, and westwards towards the northern Valdivia Bank.

Hole 362 was drilled through 806 meters of sediment ranging in age from late Oligocene to Pleistocene; Hole 362A extended this drilling to 1081 meters, bottoming in lower Eocene sediments.

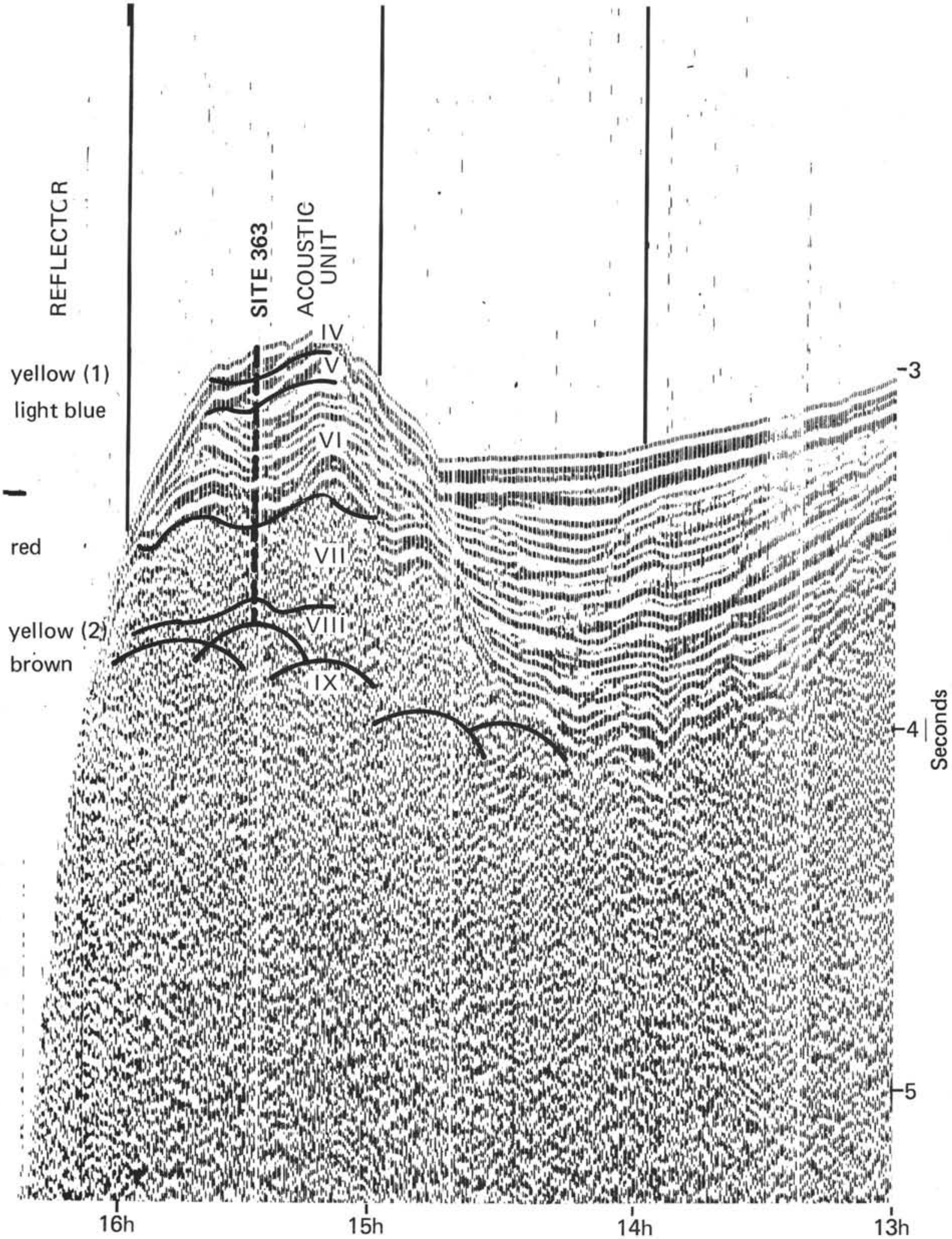


Figure 35. *Acoustic units on* Walda *9 profile (Goslin et al., 1974), near Site 363.*

Site 363 is located in 2248 meters of water close to the crest of an isolated basement high along the north-facing escarpment of the Frio Ridge segment of Walvis Ridge. It lies at 1530 hours, 23 June, *Jean Charcot*, Cruise Walda, seismic reflection profile 9, latitude 19°39'S, longitude 09°03'E. The location, about 160 km due west of Site 362/362A, was positioned to allow drilling to extend the section recovered at Site 362/362A, with only a small stratigraphic overlap. Site 363 was drilled to 715 meters sub-bottom, where it was ended because of bit failure shortly above basement. A section ranging in age from Early Cretaceous (Aptian) to middle Miocene was obtained, with several hiatuses.

We here summarize the history of this area of Walvis Ridge from the Cretaceous to the present, commenting particularly on its role in separating waters of the Cape and Angola basins. The ridge formed during the Early Cretaceous and has had its present high relief and elevation above oceanic crust throughout its history. Site 363 itself, though, has been under moderate to deep water (at least lower neritic conditions) since the late Aptian (Core 40), gradually subsiding to its present bathyal level. Some high-energy, nearshore, and much shallower environment, probably an island, produced the calcarenites and algal structures in the oldest sediments recovered at the site. Connary (1972) suggested that Walvis Ridge was uplifted about 80 m.y. ago, but this is not confirmed by the faunal assemblages at the site.

We have no evidence bearing on the composition of basement at Site 363, although badly altered basalts with alkalic affinities were recovered in a nearby dredge haul (Hekinian, 1972). Other evidence on the composition of Walvis Ridge is skimpy, but it and its counterpart in the western South Atlantic, the Rio Grande Rise-São Paulo Ridge complex, appear to be submerged oceanic volcanic islands and seamounts with a typically alkalic character. Trachytic tuffs belonging to a moderately alkalic lineage and with a K-Ar age of 40 m.y. were cored at DSDP Site 359 in the Walvis Seamount Province (Fodor, Keil, et al., 1977). These were apparently emplaced subaerially and chemically resemble trachytes from Tristan da Cunha (Baker et al., 1964), which is near the crest of the Mid-Atlantic Ridge. Tristan da Cunha has been proposed to be the locus of current Walvis Ridge-Rio Grande Rise "hotspot" or mantle-plume activity (Wilson, 1963; Morgan, 1972). Altered hyaloclastite fragments were recovered in a middle Eocene slump breccia containing shallow-water fossils at DSDP Site 357 on the Rio Grande Rise. The glass fragments have fresh clinopyroxene microphenocrysts resembling those of typical oceanic island alkalic basalts (Fodor and Thiede, 1977). Sanidine grains were also found in the breccia, suggesting the presence of a trachyte component. The breccia was inferred to have eroded from a nearby island of probable Campanian-Santonian age. Thiede (in press) inferred from sediment and stratigraphic data that the island was large, perhaps 2 to 3 km above sea level. From a dredge station slightly further west than Site 357, Fodor, Husler, and Kumar (1977) have described alkalic basalts, trachybasalts, and trachyandesites. Finally, still further to the west, an altered alkalic basalt pebble eroded from the São Paulo Ridge was recovered in a Cretaceous marly chalk at DSDP Site 356 (Fodor, Husler, and Keil, 1977). Thus, both the Walvis Ridge and Rio Grande Rise-São Paulo Ridge complexes appear to have originated near the crest of the Mid-Atlantic Ridge as sea-floor spreading progressed, continually isolating the Angola and Brazil Basins from the more vigorously circulating waters of the Cape and Argentine basins, even to the present day (see Chapter 4, this volume).

Since the age of formation of Walvis Ridge at Site 363 is essentially the same as that of adjacent oceanic crust in the Cape Basin, and since it has an abrupt steep northern scarp suggesting fracture zone topography, a fracture-zone ridge-crest origin is also indicated. Geophysical evidence shows that the "oceanic" layer is unusually thickened on the Frio Ridge portion of Walvis Ridge (Connary, 1972; Barnaby, 1974, Goslin and Sibouet, 1976), indicating excess volcanism must have occurred at this point on the Mid-Atlantic Ridge, as originally suggested by Wilson (1963, 1965). This would have created a very shallow sill across the entire ocean basin, including the Mid-Atlantic Ridge, separating the Brazil-Angola basins from the Argentine-Cape basins. The ridge is the principal reason for facies contrasts between the Cape and Angola basins documented on Leg 40 that have prevailed since the basins were formed.

Pautot et al. (1973) found the Angola Basin salt layer did not extend southward to Walvis Ridge, and instead proposed that a line of seamounts at 11°S was the barrier behind which they accumulated. Leyden et al. (1976), though, proposed that the salt originally north of the Frio Ridge segment of Walvis Ridge was faulted and carried to the west by sea-floor spreading (see Figure 36). The São Paulo Ridge, not surprisingly, has a steep *south*-facing scarp, interpreted as a "prominent expression of an east-west trending fracture zone" by Gamboa et al. (1977), and is the southern barrier of the Brazil Basin salt layer. The São Paulo Ridge south-facing scarp would match the north-facing scarp on Frio Ridge, and presumably mark the former juncture of the two ridges along a transform fault. Ocean floor between Frio Ridge and the southern limit of the Angola salt is therefore younger than either the salt or the ridge. As the São Paulo and Frio ridges slid past each other, the widening trough between the Brazil and Angola basin salt layers could probably only have received water from the larger basins to the south via this narrow and almost certainly shallow fracture zone passages. An apparent ridge-crest jump in conjunction with formation of the Valdivia Bank portion of Walvis Ridge (Barnaby, 1974) shifted the locus of island volcanism south of the Frio and São Paulo ridges. In this new spreading arrangement, these two portions of the ridge system could not continue to grow, and eventually they slid past each other, rather abruptly deepening the basin north of Site 363 when the edge of the Brazil Basin salt deposit finally slipped by. In the Albian reconstruction of Leyden et al. (1976), Site 356 is actually northeast of Site 363 (Figure 36).

The effect of this on sedimentation at Site 363 is uncertain, but we may speculate that the site became more prone to slumping and erosion with the removal of the São Paulo Ridge and the salt behind it. Some sources of terrigenous sediments (from the Brazil side) may also have been cut off.

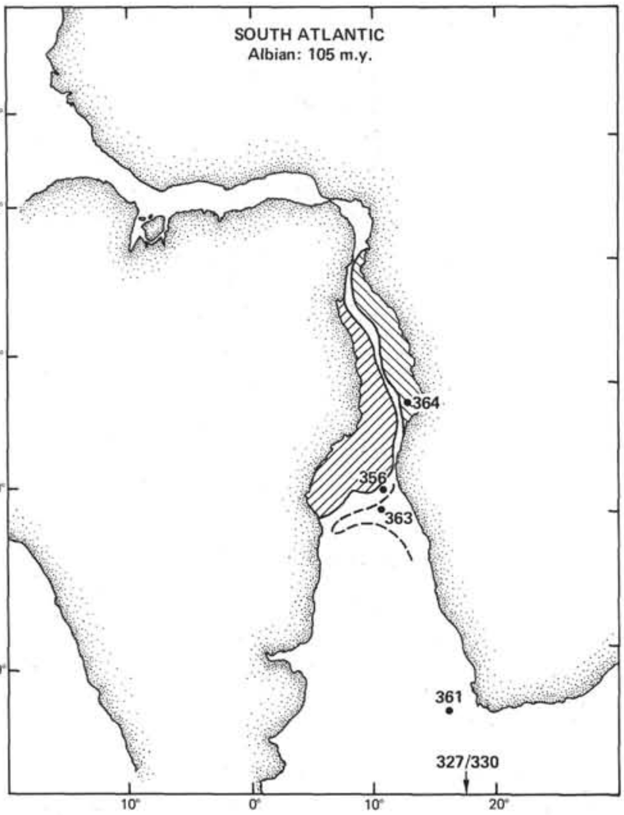


Figure 36. *Location of DSDP sites in the South Atlantic which reached Lower Cretaceous sediments plotted on the South Atlantic reconstruction of Leyden et al. (1976) for Albian times (105 m.y. ago). The edges of the Angola and Brazil diapir fields (indicating the edges of the salt deposits) are shown just after separation by rifting. Note position of Site 356 to north end east of Site 363, and edge of Brazil salt plateau between there and the Angola salt plateau. Sites 327 and 330 are off diagram to south on Falkland Plateau.*

Surprisingly little evidence for volcanism was found at Site 363. There was an apparent increase in the flux of montmorillonite to the site in late Albian-Santonian times, indicating a probable increase in volcanic provenance; however, every clay- or silt-rich layer from which a smear slide was made has a significant quartz component, implying mixing of mature crustal components with any ash or clays weathered from volcanic materials that were supplied to the area. Stormberg-age basalts in Africa dated at 150 to 190 m.y. and extrusive and intrusive components of the Damaraland igneous complexes (±130 m.y.; Marsh, 1973) could have been the source of the montmorillonitic component of the sediments. On the other hand, the 2-3 km high Coniacian-Santonian island of Thiede (in press) may have been partly a consequence of the proposed ridge-crest reorientation at 80 m.y. (Connary, 1972). Perhaps the flat-toped Valdivia Bank was the Walvis-Ridge portion of this island complex, and was leveled by stream and wave erosion, supplying some of the montmorillonite to Site 363. If this was the timing of major volcanism further to the southwest on Walvis Ridge, though, it does not correspond with the recorded peak of nonbiogenous sedimentation at Site 363, which was 15 to 20 m.y. earlier. And, again, no volcanic material is present that is not mixed with a major component of continent-derived quartz, feldspars, and clays.

On the basis of zeolitic muds recovered at Site 356 on the Rio Grande Rise, McCoy and Zimmerman (1977) suggest that the Eocene was a period of major volcanism in the South Atlantic, concentrated along the Rio Grande Rise-Walvis Ridge trends. This would have included the period of eruption of the trachytic tuff at Site 359 in the Walvis Seamount Province (Fodor and Thiede, 1977), over 1500 km from Site 363. Little or no ash from volcanic eruptions that far away reached Site 363, which was experiencing mainly biogenous sedimentation at that time. Part of the middle-upper Eocene section at Site 363 has been removed by erosion, however, that could have contained thin ash layers derived from this volcanism.

With or without volcanic components, the main terrigenous contribution to Sites 363 and 362/362A has been from Africa, principally considerable clay, silt-sized quartz, feldspars, and heavy minerals. This apparently peaked in the Late Cretaceous when African highlands were presumably higher than in the Tertiary, and the shelf-slope system was not as mature. Prior to the Late Cretaceous, Site 363 was apparently isolated enough to receive mostly carbonate sedimentation. Gradual subsidence of the site relative to the prograding continental margin and increased current activity heightened the input of terrigenous material in the Late Cretaceous. Possibly the pair of northeast-trending ridges that form the basement of Frio Ridge (Barnaby, 1974) funneled terrigenous sediments to Site 363.

Paleocene and older cores at Site 363 show considerable evidence for current action-winnowing, erosional contacts, soft-sediment deformation, and the like. The Upper Cretaceous section is shortened by small erosional breaks, as evidenced by the large time interval represented mainly by rapidly supplied terrigenous material in Unit 2a, Turonian to Campanian in age. There is another possible time gap wherein all or part of the Cenomanian is missing. But this may merely reflect ecological conditions which did not allow the North Atlantic Cenomanian marker nannofossil *Lithraphidites alatus* to have lived in the South Atlantic.

Even though terrigenous influx peaked in the Late Cretaceous, current activity was also sharply higher than at any other time until the Pleistocene, resulting in lower overall sediment accumulation rates from the latest Albian to the Campanian. The onset of this coincides with the beginning of the second period of predominantly euxinic conditions in the Angola Basin, within the Albian *Eiffellithus turriseiffelli* Zone (Chapter 4, this volume). Throughout this time, waters in the Angola Basin can only have been replenished from the south. It is tempting to speculate that this was accomplished by transfer of surface waters northward, and spillage of denser, more saline, periodically oxygen-depleted Angola Basin deeper waters southward over Walvis Ridge in a manner similar to Atlantic-Mediterranean exchange today. The spillage would have been responsible for the redeposition and winnowing effects so predominant in the Upper Cretaceous cores of Site 363. With the breakup of euxinic conditions in the Angola Basin in Santonian-Coniacian times, the vigor of currents and the incidence of erosion at Site 363 diminished, for all intents and purposes, ceasing by Campanian-Maestrichtian times.

Two aspects of the sedimentary petrology and mineralogy of Site 363 sediments suggest that, indeed, Angola Basin waters spilled over Walvis Ridge in the Cretaceous. The first is that reworked pyrite possibly from sapropels is present in upper Albian "placer"-type deposits in Core 26. There are five thin beds of this material in Core 26 which has nearly the highest terrigenous component of the site. The sapropels from which the pyrite may have been derived could have been deposited beneath the top of a stagnant water mass. Contemporaneous sapropels at Site 364 were deposited in water less than 500 meters deeper (based on the present difference in the depths of sediments at the two sites, and calculations by Melguen, this volume). This interpretation, though, is not the only explanation for these unusual beds (see Lithologic Summary, this chapter).

The presence of dolomite and the persistence of phillipsite in the lowest cores of Site 363 are more likely indicators of unusually saline bottom water conditions in the Aptian and Albian. The dolomite occurs in cores which correlate with the most dolomitic limestones of Site 364, immediately following salt deposition in the Angola Basin. For at least the first half of this time period, both the Cape and Angola basins were euxinic. Dolomitic limestones of Albian age were also deposited at Site 356 on the São Paulo Ridge, which, as shown on Figure 36, was probably between Sites 363 and 364. Supko and Perch-Nielsen (1977) compared the Site 356 dolomites with Red Sea dolomites, which were deposited immediately above massive halite and other evaporites. The sequence of dolomites following evaporites thus seems to have occurred in the early opening stages of both the Red Sea and South Atlantic, and in both cases, carbonaceous sediments are intimately associated with dolomites in the late- and immediately post-evaporite stages of deposition. This is consistent with many recent geological and geochemical studies linking evaporites and dolomites (e.g., Deffeyes et al., 1965; Supko et al., 1974; see Bathurst, 1975, for summary and additional references). The geographic proximity of Sites 356, 363, and 364 in the Aptian and Albian (Figure 36) offers at least one compelling reason why Sites 363 and 356 dolomites may have formed in the still-saline waters trapped behind the Frio-São Paulo Ridge complex.

An alternative model for diagenetic formation of dolomite at Site 363 invokes a change in composition of pore fluids near volcanic basement. It is discussed in the lithology section of this chapter.

The phillipsite in the lower cores of Site 363 also indicates a more saline environment than normal marine conditions. The arguments of Natland (this volume) for similar occurrences at Sites 361 and 364 apply here. Briefly, phillipsite is most abundant in recent marine sediments but invariably is transformed to clinoptilolite as diagenesis proceeds (Kastner and Stonecipher, 1976). It is not found in typical marine or continental margin sediments cored by DSDP older than Eocene or buried more deeply than about 600 meters (Stonecipher, 1976). Its persistence here can be explained by its formation in more saline waters than are typical of the oceans, based on arguments of Hess (1966) and analogies to saline lake occurrences (Hay, 1964). Its association with dolomite at Site 363 lends credence to the argument that the dolomite, too, was formed under unusually saline conditions closely following deposition, and is not related to pore fluid modifications resulting from proximity to volcanic basement. At present, however, there is no clear way to decide between these alternatives.

The uppermost Cretaceous sediments at Site 363 indicate the gradual installation of a more tranquil sedimentation regime and a waning of terrigenous input. Conditions were tranquil through most of the South Atlantic. Pelagic clays were deposited at Site 361, and well burrowed, weakly laminated limestones and marly limestones were deposited at Site 364.

Post-middle Miocene sediments have been removed from Site 363 by erosion or slumping, as indicated by overcompaction of surface cores. Profiler records near the site show truncated beds, scouring, and moat features around individual peaks. This is evidence for very recent current activity. The Pleistocene erosional event which is inferred to have removed sediments from Site 361 (see Chapter 2, this volume), is also inferred to have done the same thing at Site 363.

Apart from a partial overlap at Site 363 in the Paleogene, the history of the Walvis Ridge area in the Tertiary which we shall now take up focuses on Site 362/362A. This site is in a structural depression south of the Frio Ridge and east of Valdivia Bank. It has been the recipient of sediments deposited directly through the water column and either slumped or provided by turbidity currents from these ridges and the African continental margin (Abutment Plateau region of Barnaby, 1974) to the north and east. In spite of its proximity to terrigenous sources, however, Site 362/362A has seen mainly biogenous sedimentation. Beds or laminae rich in terrigenous material are rare. This is the result of (1) development of mature shelf-slope system, (2) reduction of elevation of African sourcelands, (3) harshening of arid climatic conditions in western Africa, and (4) development of a prevailing current system which diverts terrigenous material away from the site. These effects have become even more pronounced in the Neogene, resulting in much more homogeneous sedimentation.

From the Eocene to the middle Miocene, sedimentation was cyclic, with carbonate-rich sequences (foraminifer-nannofossil chalk or nannofossil chalk) alternating with marly chalks. The middle-upper Eocene is characterized by turbidite sedimentation, represented by a succession of coarse calcarenites and calcareous siltstones grading into laminated and then into massive limestones. Dissolution phenomena are more pronounced in adjacent beds, indicating that calcareous components were carried from higher elevations (the nearby ridges) and were protected from dissolution effects by rapid burial. Lithification in these sediments is pronounced.

Decreases in the extent of foraminifer preservation are evident in the Eocene, in the Miocene and, to a lesser extent, in the Oligocene. These reflect at least local elevations of the calcium carbonate compensation depth (Melguen, this volume) and correlate with similar effects at Site 360 in the Cape Basin, and at Site 363. These events probably reflect the installation of a cold-water current system in the South Atlantic, essentially the entry of Antarctic intermediate and bottom waters into the Cape and Argentine basins.

The late Miocene, Pliocene, and Pleistocene have seen several changes in the character of sedimentation at Site 362/362A. The change from cyclic to homogeneous sedimentation has already been mentioned. Other changes include the increasing development of siliceous microfossils, particularly abundant and well-preserved in the Pleistocene. Their abundance reflects the presence of an area of high fertility, in which upwelling phenomena and cold surface currents (the Benguela) provide high plankton production and silica supply. The heightened productivity resulted in a greater supply of organic carbon to the sediments, increasing their H_2S content (as we discovered to our discomfort in the core lab of *Glomar Challenger*). This in turn had a deleterious effect on bottom life. There is no bioturbation in these sediments.

An unusual aspect of sedimentation at both Sites 362/362A and 363 is the occurrence of numerous Oligocene beds of almost pure *Braarudosphaera* ooze. These beds are responsible for a prominent reflector which can be traced all the way to Site 360 off Cape Town, where they were also cored. They also occur at DSDP Sites 14, 17, 19, 20, 22, 331, 358, and 359, all in the South Atlantic, suggesting that *Braarudosphaera* blooms were regional in extent. Today, though, *Braarudosphaera bigelowii* is only abundant in coastal waters whose salinity has been reduced by supply of low-density fresh water from streams or rivers. Bukry (this volume) speculates that *B. bigelowii* represents an encystment stage of an organism that can be unusually extended by lack of supply of a critical nutrient abundant in normal-salinity sea water. In any case, periodic South-Atlantic-wide reductions in surface-water salinity appear required to explain the aberrant regional blooms (see Noël and Melguen, this volume; Proto-Decima et al., this volume; and Bukry, this volume, for further discussion).

The section at Site 362-362A is characterized by a comparable faunal/floral association to that at Site 360. The boreal/tropical species ratio and the number of specimens present in each fossil group shift toward more warm-water forms. Thus, both boreal and tropical zonal schemes apply to the Neogene of Hole 362. On the other hand, only the tropical zonal schemes could be used for the Paleogene of Hole 362A. The increase in cold-water forms at the site thus implies a progressive cooling throughout the Tertiary, becoming more and more pronounced during the Neogene.

Because of its location in the tropics (19°45′S), Site 362/362A should be dominated by warm-water forms. This is not the case because cold-water masses from the Cape Basin still reach the crest and northern slopes of Walvis Ridge. The change to more tropical forms, though, takes place within a short distance to the north. Site 363, at a latitude of 19°39′S, is only slightly further north than Site 362/362A, but is characterized primarily by warm-water planktonic foraminifers in the Neogene. The Neogene section, though, is only 50 meters thick and does not include the Plio-Pleistocene. Thus we did not recover a complete section which would document the role of Walvis Ridge as a barrier to cold-water currents from the Cape Basin to the present day.

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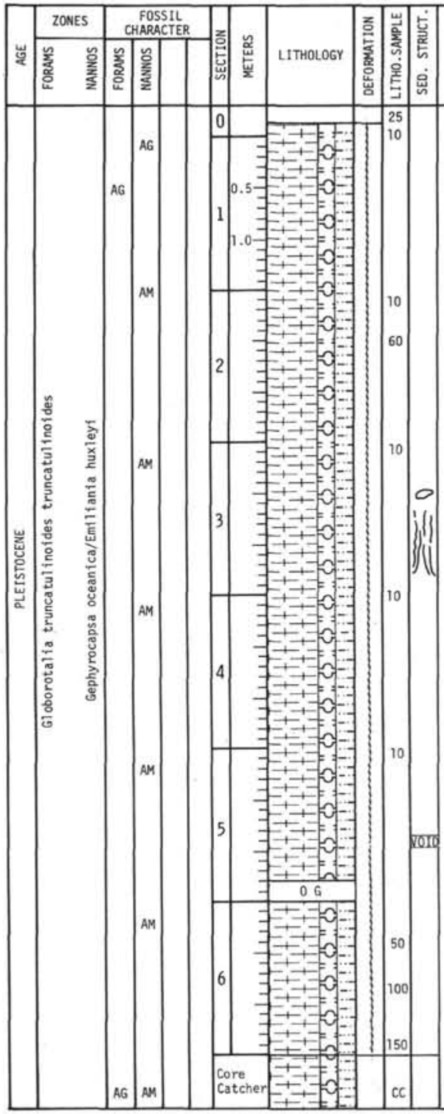
Site 362 Hole Core 1 Cored Interval: 36.0-45.5 m



LITHOLOGIC DESCRIPTION

5Y 4/4
5Y 4/3

MUDDY FORAMINIFERA-RADIOLARIAN-BEARING DIATOMACEOUS CALCAREOUS NANNOFOSSIL OOZE with patches of foraminifera nannofossil ooze.

5Y 4/4
5Y 4/3
5Y 4/3

Homogeneous, fine, soft sediment. Color dominantly olive (5Y 4/4), with intercalation or interpenetration (core very deformed by flowing) of darker (5Y 4/3) gray olive patches. Core's deformation is particularly strong in Sections 3, 4, 5 and 6. No particular structures.

SEDIMENT TEXTURE (SS)
≤5% Sand, 15-20% Silt, 75% Clay

5Y 4/4

SEDIMENT COMPOSITION (SS)
Major components
50-60% Calcareous nannos
10-20% Clay minerals
5-90% Diatoms
3- 5% Forams. planct.

5Y 4/4

Minor components
2- 4% Rads
<1% Silicoflagellates
1-¯5% Authigenic carbonate
1- 2% Quartz
T% Micarb
1- 2% Pyrite
T Tourmaline, Epidote, Apatite

Darker patch
5Y 4/2
5Y 4/3
Sediment flowing

Remark: H_2S odor.

Carbonate Bomb: 5-33 to 40 cm = 52.2% $CaCO_3$

5Y 4/3

Carbon-Carbonate (DSDP)
4-20 (9.4, 2.9, 55)
6-20 (8.1, 3.0, 42)

Carbon-Carbonate (OG)
5-130 (9.6, 6.0, 30)
5-150 (7.7, 3.4, 36)

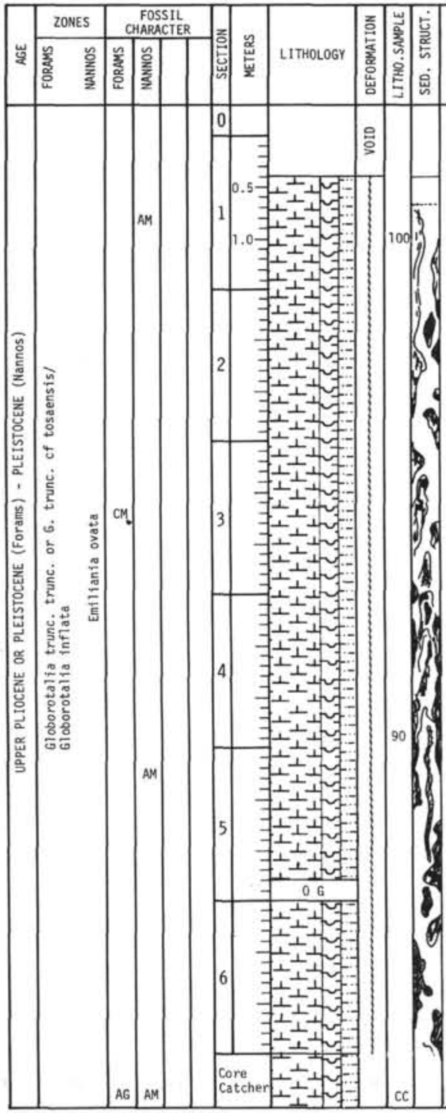
5Y 4/4
5Y 4/3

Grain Size (DSDP)
4-88 (1.6, 42.5, 55.9)
5-88 (1.3, 35.5, 63.1)

5Y 4/4
5Y 4/3
5Y 4/3

Munsell chart used.

Site 362 Hole Core 2 Cored Interval: 45.5-55.0 m



LITHOLOGIC DESCRIPTION

DIATOMACEOUS NANNO OOZE TO MARLY NANNO OOZE BEARING DIATOMS

5Y 4/3

Fine sediment, dominantly olive to olive gray, with interpenetration (core very strongly deformed) of darker gray olive (5Y 4/3) patches.

SEDIMENT TEXTURE
2-5% Sand, 15-17% Silt, 79-83% Clay

SEDIMENT COMPOSITION (SS)
Major components
40-50% Calcareous nannofossils
15-40% Clay minerals
10-20% Diatoms
1% Forams planct.

5Y 4/4

Minor components
2.0% Rads
0.5% Silicoflagellates
3-5.0% Authigenic carbonate
1-2.0% Quartz
0.5% Micas
1.0% Pyrite
T Tourmaline, Epidote, Garnet

5Y 4/3

Remark: H_2S odor

5Y 4/2

Carbonate Bomb: 1-57 to 58 cm = 40.3% $CaCO_3$

5Y 4/3
5Y 4/3

Carbon-Carbonate (DSDP)
4-20 (8.1, 6.5, 15)
6-20 (8.6, 6.2, 20)

5Y 5/2
5Y 5/3

Carbon-Carbonate (OG)
5-130 (4.9, 0.1, 40)
5-150 (3.8, 0.1, 31)

5Y 4/2

Grain Size (DSDP)
4-88 (0.8, 29.3, 69.9)
6-28 (0.2, 26.5, 73.3)

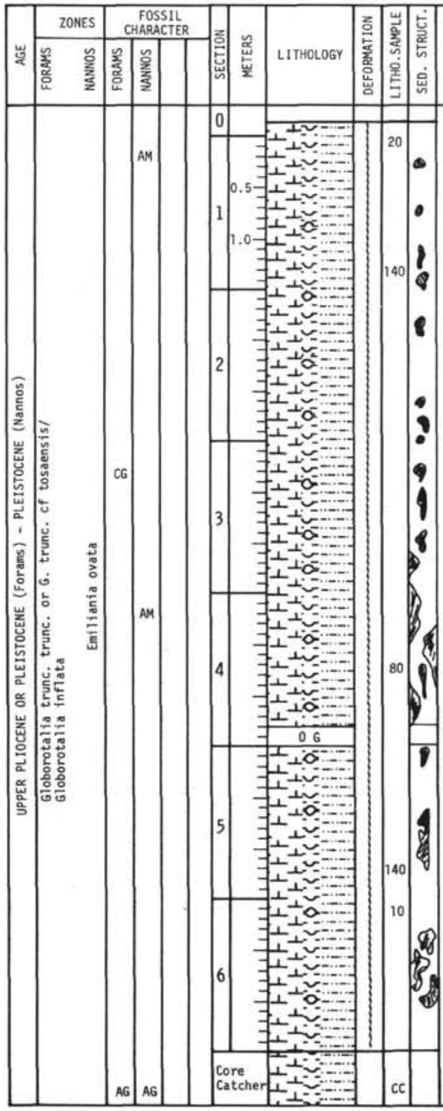
Dominantly
5Y 4/3 (olive)
with patches
5Y 4/2
(olive gray)

5Y 3/2 dark olive gray

5Y 4/2 olive gray to 5Y 4/3-4/4 olive

Explanatory notes in Chapter 1

Site 362 Hole Core 3 Cored Interval: 55.0-64.5 m



LITHOLOGIC DESCRIPTION

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

Olive (5Y 4/3) to Olive gray (5Y 4/2) dominant

MARLY DIATOMACEOUS NANNO OOZE TO DIATOM BEARING MARLY NANNOFOSSIL OOZE

Fine sediment, strongly deformed by drilling, showing an interpentration of dark gray patches in olive (5Y 4/3) to olive gray (5Y 4/2) sediment.

SEDIMENT TEXTURE
2% Light sand, 15-30% Silt, 70-80% Clay

SEDIMENT COMPOSITION (SS)
Major components
30.0-40.0% Calcareous nannofossils
30.0-35.0% Clay minerals
15.0-20.0% Diatoms
0.5- 2.0% Forams. planct.

Minor components
2-4% Rads
T Silicoflagellates
3-5% Authigenic carbonate
1% Quartz
T% Micarb
1-2% Pyrite
T Tourmaline

Remarks: 1) H_2S odor
2) Sediment rich in organic matter

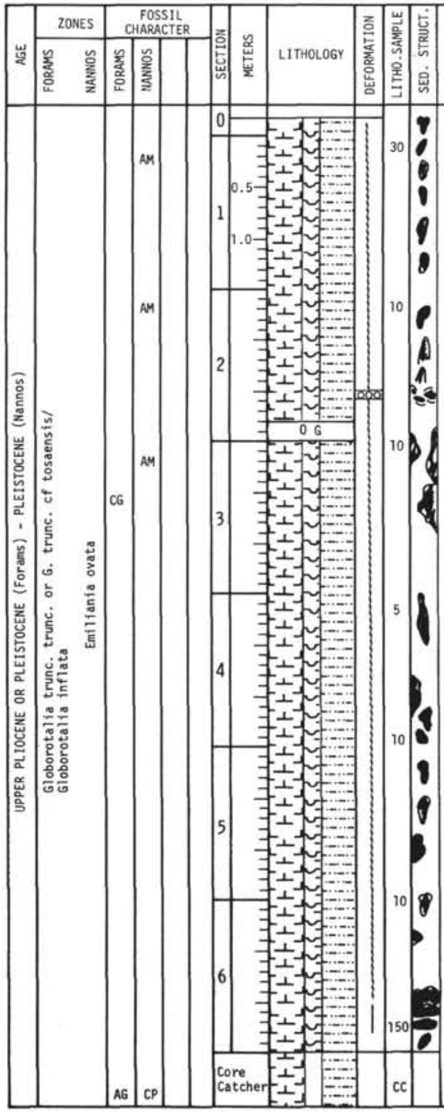
Carbonate Bomb: 1-23 to 30 cm = 52.7% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (7.9, 3.1, 40)
6-20 (8.2, 2.6, 47)

Carbon-Carbonate (OG)
4-130 (8.1, 4.1, 33)
4-150 (7.9, 4.9, 25)

Grain Size (DSDP)
4-88 (0.6, 25.9, 73.5)
6-88 (1.8, 47.4, 50.7)

Site 362 Hole Core 4 Cored Interval: 64.5-74.0 m



LITHOLOGIC DESCRIPTION

5Y 3/2 (dark olive gray)
5Y 3/2
5Y 3/2
5Y 4/4
5Y 3/2
5Y 3/2
5Y 3/2

DIATOMACEOUS CALCAREOUS NANNOFOSSIL MUD, TO DIATOMACEOUS CALCAREOUS NANNO OOZE, TO CALCAREOUS NANNO BEARING DIATOMACEOUS MUD

Fine, dominantly olive (5Y 4/3) to olive gray (5Y 4/2) sediment, strongly deformed by drilling, and bearing, thus darker gray (5Y 3/2) patches interpenetrating the olive to olive gray sediment.

TEXTURE
1% Sand, 25-30% Silt, 70-75% Clay

COMPOSITION (SS)
Major components
15-30% Calcareous nannofossils
15-60% Clay minerals
1% Forams
3-40% Diatoms

Minor components
1% Rads
2-10% Silic. spicules
T% Silicoflagellates
3-10% Authigenic carbonate
1- 3% Quartz
1- 2% Pyrite

Remarks: 1) Sediment rich in organic matter
2) H_2S odor

Carbonate Bomb: 1-23 to 30 cm = 40.3% $CaCO_3$

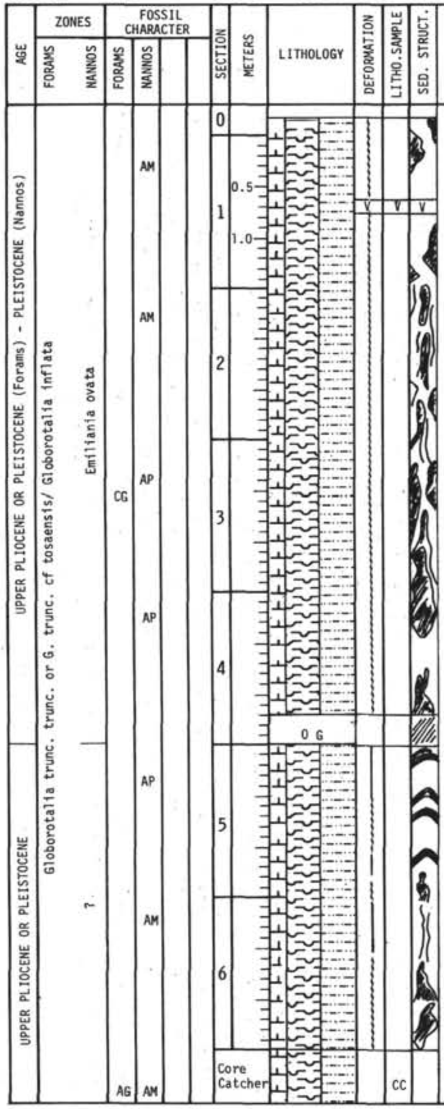
Carbon-Carbonate (DSDP)
4-20 (8.2, 5.9, 19)
6-20 (7.5, 2.7, 40)

Carbon-Carbonate (OG)
2-130 (10.0, 0.1, 83)
2-150 (10.6, 0.1, 88)

Grain Size (DSDP)
4-88 (0.6, 27.6, 71.9)
6-88 (1.0, 36.7, 62.3)

Explanatory notes in Chapter 1

Site 362 Hole Core 5 Cored Interval: 74.0-83.5 m



LITHOLOGIC DESCRIPTION

5Y 4/2
Olive
gray

5Y 4/2

5Y 4/2
5Y 4/3
Olive

5Y 4/2
Olive
gray

5Y 3/2

OG sample

5Y 3/2
Dark olive
gray
5Y 3/2

5Y 3/2
Dark
olive
gray

Olive gray (5Y 4/2), Olive (5Y 4/3) dominant

DIATOMACEOUS MUD, BEARING CALCAREOUS NANNOFOSSILS

Fine, olive gray to olive, strongly deformed sediment, interpenetrated by dark gray patches (flowing structures).

TEXTURE
Homogeneous light sandy-silty clay:
2-5% Sand, 25% Silt, 70% Clay

COMPOSITION (SS)
Major components
15% Calcareous nannofossils
40% Clay minerals
T Forams. planct.
30-40% Diatoms

Minor components
1-2% Rads
3% Silic. spicules
T Silicoflagellates
3% Pyrite
<1% Dolomite rhombs
≤1% Mica

Remarks: 1) H_2S odor
2) Abundant organic matter

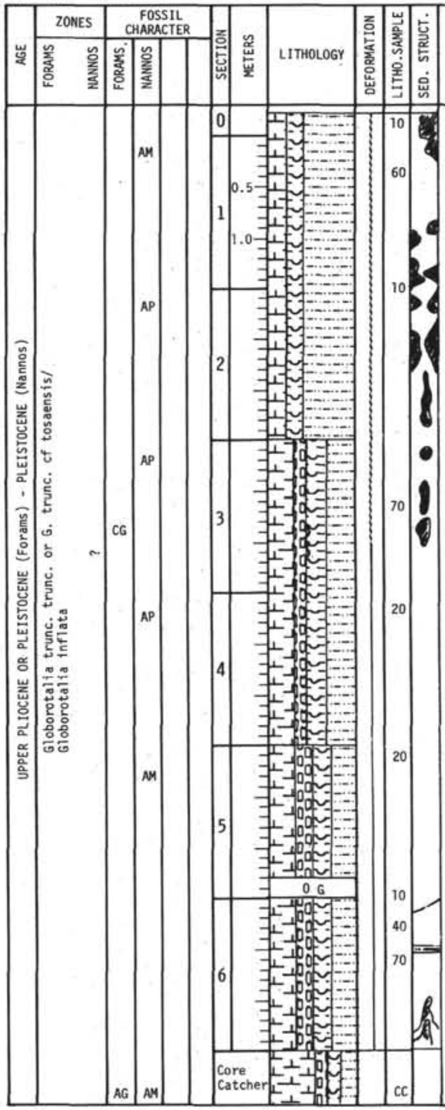
Carbonate Bomb: 1-23 to 30 cm = 37.8% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (7.3, 2.6, 39)
6-20 (8.1, 1.6, 54)

Carbon-Carbonate (OG)
4-130 (8.4, 5.4, 25)
4-150 (9.2, 6.3, 25)

Grain Size (DSDP)
4-88 (0.6, 25.7, 73.7)
6-88 (0.4, 24.0, 75.6)

Site 362 Hole Core 6 Cored Interval: 83.5-93.0 m



LITHOLOGIC DESCRIPTION

5Y 4/2

5Y 4/4
Olive

5Y 4/3
Olive

5Y 4/3

5Y 4/4

5Y 4/2
Olive gray

5Y 4/2

5Y 4/4
Olive
5Y 4/4

+Firm below
this

Olive

5Y 4/4

DIATOMACEOUS MUD, BEARING CALCAREOUS NANNOFOSSILS AND ABUNDANT DOLOMITIC RHOMBS - TO DIATOM RADIOLARIAN BEARING CALCAREOUS NANNO OOZE, RICH IN DOLOMITIC RHOMBS

Fine olive (5Y 4/4) sediment bearing interpenetration of olive gray (5Y 4/2), and darker olive gray (5Y 3/2) patches or streaks, due to drilling deformation.

TEXTURE
Homogeneous, slight sandy (1% Sand), Silty (20% Silt), Clay (80%)

COMPOSITION (SS)
Major components
10-60% Calcaerous nannofossils
20-50% Clay minerals
T Forams
5-30% Diatoms

Minor components
5-10% Rads and Silic. spicules
3- 5% Authigenic carbonate
1- 3% Pyrite
5-15% Dolomite rhombs

Remark: Abundance of dolomitic rhombs in several levels

Carbonate Bomb: 1-23 to 30 cm = 33.7% $CaCO_3$

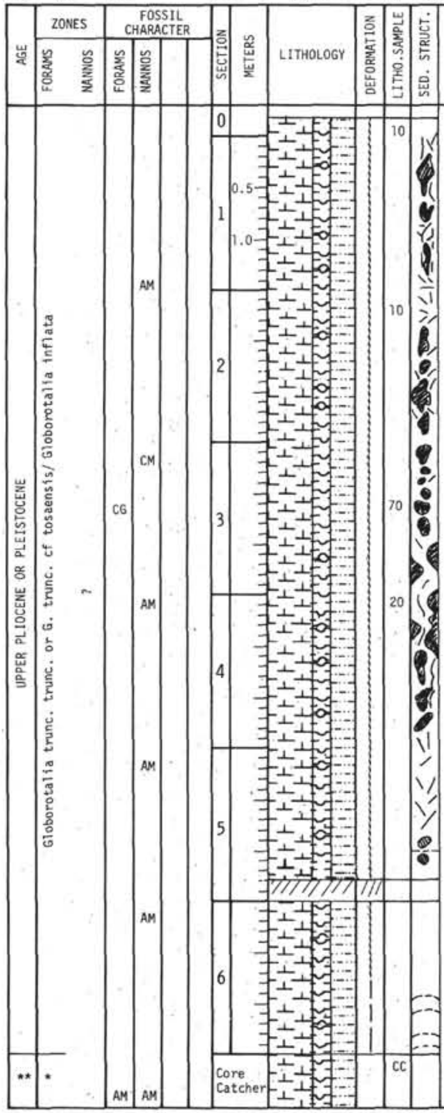
Carbon-Carbonate (DSDP)
4-20 (9.1, 1.6, 63)
6-20 (8.3, 2.4, 50)

Carbon-Carbonate (OG)
5-130 (7.9, 0.1, 65)
5-150 (8.8, 0.1, 73)

Grain Size (DSDP)
4-88 (0.4, 24.0, 75.6)
6-88 (0.3, 61.8, 38.0)

Explanatory notes in Chapter 1

Site 362 Hole Core 7 Cored Interval: 93.0-102.5 m



LITHOLOGIC DESCRIPTION

5Y 4/3
5Y 3/2
5Y 4/2
5Y 3/2
Gas cracks
5Y 3/2
5Y 3/2
5Y 4/2
Streaked area
5Y 3/2
Gas cracks 5Y 4/3
5Y 4/2
OG sample
Mottles and gas escapes
5Y 4/4
5Y 4/3
5Y 4/2

Olive (5Y 4/3) and olive gray (5Y 4/2) dominant

DIATOM BEARING CLACAREOUS NANNO OOZE

Fine, olive to olive gray sediment, interpenetrated with darker gray patches (drilling deformation) and hatched by H_2S - abundant gas cracks.

TEXTURE
Light sandy, silty clay:
2% Sand, 15-20% Silt, 80% Clay

COMPOSITION (SS)
Major components
50-70% Calcareous nannofossils
20% Clay minerals
T- 2% Forams
4- 5% Diatoms

Minor components
2- 6% Rads and Silic. spicules
5-10% Authigenic carbonate
1- 2% Pyrite
T Epidote and Tourmaline

Remarks: 1) Presence of Braarudosphaera bigelowi fragments and dolomitic rhombs
2) Strong H_2S odor

Carbonate Bomb: 1-23 to 30 cm = 33.7% $CaCO_3$

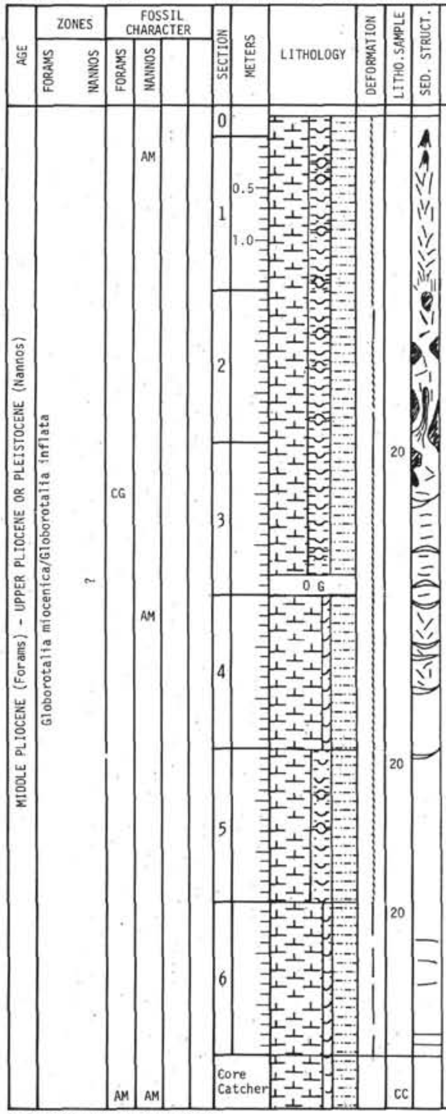
Carbon-Carbonate (DSDP)
4-20 (8.4, 3.0, 45)
6-20 (7.5, 2.6, 41)

Carbon-Carbonate (OG)
5-130 (7.1, 2.2, 41)
5-150 (7.1, 2.8, 36)

Grain Size (DSDP)
4-88 (0.3, 31.2, 68.5)
6-88 (0.3, 26.7, 72.9)

** MIDDLE PLIOCENE (Forams) - UPPER PLIOCENE OR PLEISTOCENE (Nannos)
* Globorotalia miocenica/Globorotalia inflata

Site 362 Hole Core 8 Cored Interval: 102.5-112.0 m



LITHOLOGIC DESCRIPTION

5Y 4/3
5Y 4/2
Abundant gas cracks and bubbles
5Y 4/3
5Y 3/2
5Y 4/3
5Y 3/2
Large gas cracks
Gas cracks
No gas cracks
Horizontal zones of color variations
5Y 4/3
5Y 4/2
5Y 3/2

DIATOM-RADIOLARIAN BEARING CALCAREOUS NANNO OOZE TO DIATOMACEOUS MARLY NANNO OOZE

Fine, olive gray (5Y 4/2) to olive (5Y 4/3) sediment, ± uniformaly mixed by drilling disturbance - H_2S - abundant gas cracks. Presence of horizontal bands of varying color at the basis of the core.

TEXTURE
Slight sandy, silty, clay:
1-2% Sand, 10-20% Silt, 75-80% Clay

COMPOSITION (SS)
Major components
50-60% Calcareous nannofossils
20% Clay minerals
2- 3% Forams
5-25% Diatoms

Minor components
6% Rads and Silic. spicules
3% Authigenic carbonate
1-2% Pyrite
2% Epidote, Garnet and Tourmaline

Remarks: 1) H_2S odor
2) Presence of ± dissolved diatoms

Carbonate Bomb: 1-23 to 30 cm = 41.8% $CaCO_3$

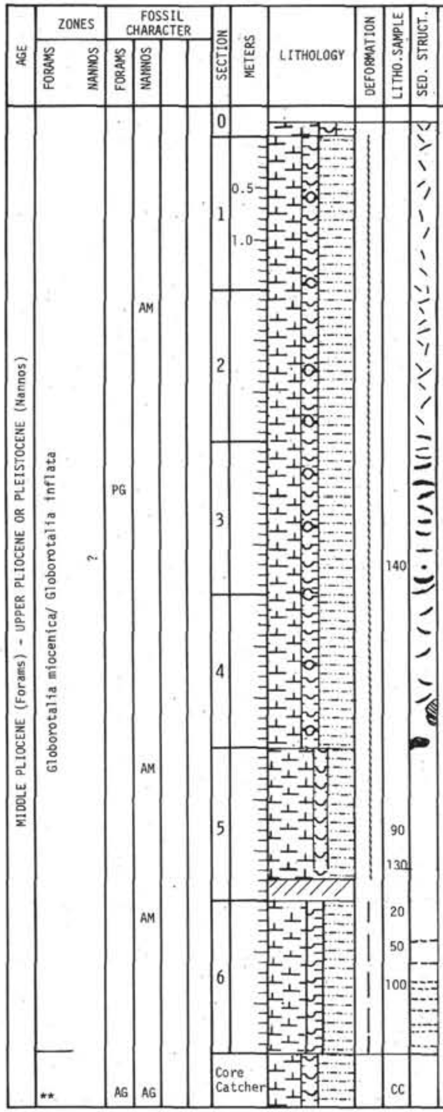
Carbon-Carbonate (DSDP)
4-20 (6.5, 2.8, 31)
6-20 (7.5, 2.7, 41)

Carbon-Carbonate (OG)
3-130 (9.0, 0.1, 74)
3-150 (8.4, 0.1, 69)

Grain Size (DSDP)
4-88 (0.5, 38.5, 61.0)
6-88 (0.8, 41.2, 58.0)

Explanatory notes in Chapter 1

Site 362 Hole Core 9 Cored Interval: 112.0-121.5 m



LITHOLOGIC DESCRIPTION

Very disturbed core = drilling deformation and gas cracks

very abundant gas cracks

Olive (5Y 4/3) to Olive gray (5Y 4/2) dominant

Less gas cracks, but important drilling deformation

OG sample

5Y 4/2

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

DIATOM BEARING NANNO OOZE TO MARLY DIATOM BEARING NANNO OOZE

Fine homogeneous, olive (5Y 4/3, 5Y 4/4) to olive gray (5Y 4/2), sediment, with dark olive gray (5Y 3/2) patches. Presence of parallel bands of various color (5Y 3/2, 5Y 4/2, 5Y 4/3) at the basis of the core. Numerous large gas cracks - gas and drilling+high deformation.

TEXTURE
Slight sandy, silty, clay:
1-2% Sand, 15-20% Silt, 80% Clay

COMPOSITION
Major components
65.0% Calcareous nannofossils
15.0-30.0% Clay minerals
0.5- 1.0% Forams
5.0-10.0% Diatoms

Minor components
2% Rads and Silic. spicules
3% Authigenic carbonate
3% Pyrite
≤1% Quartz

Remarks: 1) Presence of Braarudosphaera and well preserved Coccospheres
2) Increasing dissolution of siliceous microfossils
3) H_2S odor

Carbonate Bomb: 2-23 to 30 cm = 45.9% $CaCO_3$

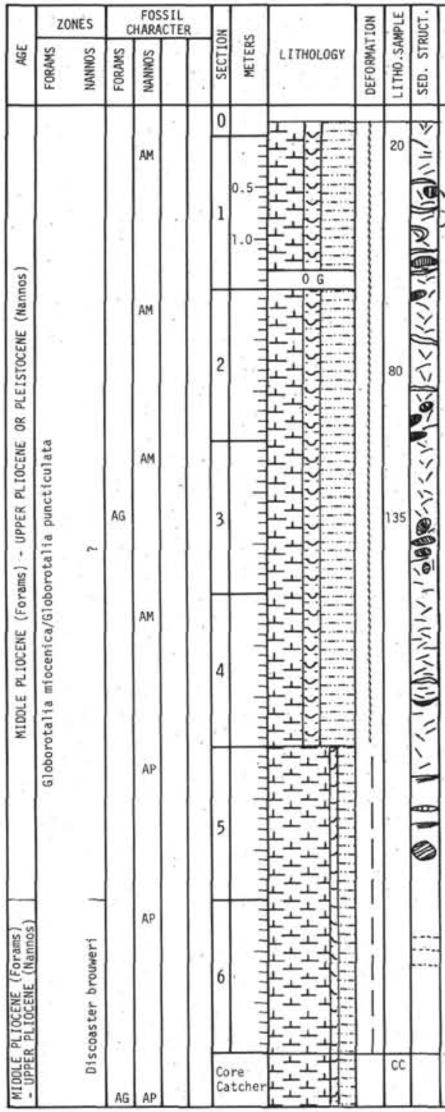
Carbon-Carbonate (DSDP)
6-20 (9.3, 3.0, 53)

Carbon-Carbonate (OG)
5-130 (8.4, 3.1, 44)
5-150 (8.7, 3.0, 48)

Grain Size (DSDP)
6-88 (0.2, 34.4, 65.3)

** Globorotalia miocenica/Globorotalia puncticulata

Site 362 Hole Core 10 Cored Interval: 121.5-131.0 m



LITHOLOGIC DESCRIPTION

5Y 4/2

Gas cracks

5Y 4/2

5Y 4/2

Olive gray (5Y 4/2) and olive (5Y 5/3-5Y 5/2) dominant

5Y 3/2

5Y 3/2 dark olive gray
5Y 5/3 olive

Abundant gas cracks

Gas cracks

Thin layer white crystals

5Y 5/2 olive gray

FORAMINIFERAL CALCAREOUS NANNO OOZE TO DIATOM BEARING CALCAREOUS NANNO OOZE

Fine, olive gray to olive, homogeneous sediment, interpenetrated by darker gray patches and strongly hatched by gas cracks.

TEXTURE
Slight dandy, silty, clay:
≤3% Sand, 15-20% Silt, ≈80% Clay

COMPOSITION
Major components
60-70% Calcareous nannos
15% Clay minerals
5-10% Forams
T-10% Diatoms

Minor components
T-4% Rads and Silic. spicules
5% Authigenic carbonate
3% Pyrite
2% Quartz

Remarks: 1) H_2S odor
2) Coccospheres present

Carbonate Bomb: 1-28 to 29 cm = 43.5% $CaCO_3$

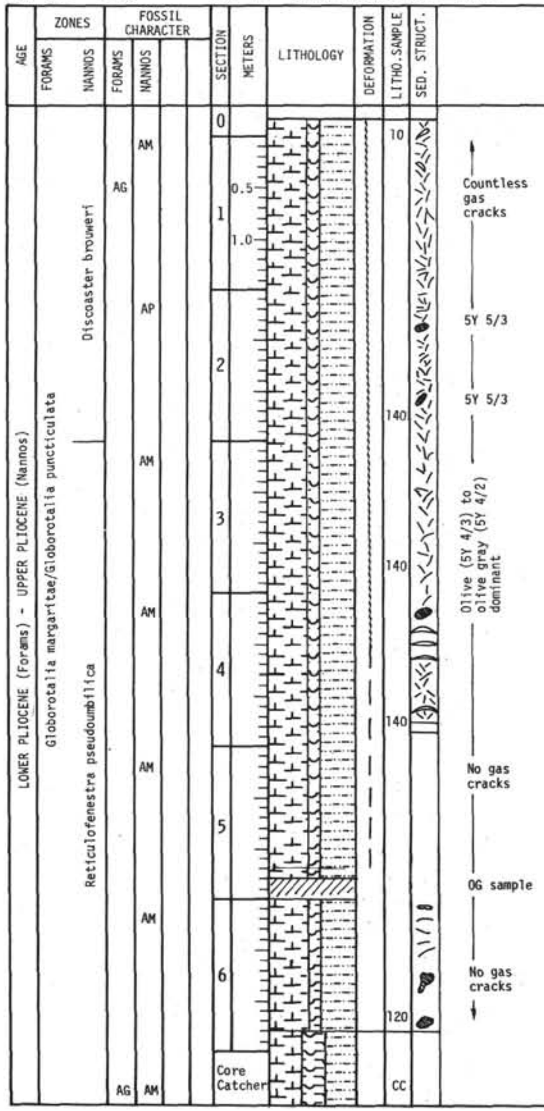
Carbon-Carbonate (DSDP)
4-20 (8.2, 1.8, 53)
6-20 (6.8, 2.2, 39)

Carbon-Carbonate (OG)
1-130 (8.6, 0.1, 71)
1-150 (8.8, 0.1, 73)

Grain Size (DSDP)
4-88 (0.4, 27.5, 72.0)
6-88 (0.8, 37.7, 61.4)

Explanatory notes in Chapter 1

Site 362 Hole Core 11 Cored Interval: 131.0-140.5 m



LITHOLOGIC DESCRIPTION

<u>MARLY DIATOMACEOUS NANNO OOZE TO MARLY NANNO OOZE</u>

Fine, olive (5Y 4/3) to olive gray (5Y 4/2), to dark olive gray (5Y 3/2) sediment, almost very strongly hatched by gas cracks - water content great.

<u>TEXTURE</u>
Slight sandy, silty, clay:
1-2% Sand, 15-20% Silt, ≈80% Clay

<u>COMPOSITION (SS)</u>
<u>Major components</u>
50-60% Calcareous nannofossils
25-30% Clay minerals
1- 2% Forams
5-20% Diatoms

<u>Minor components</u>
1% Rads and Sponge spicules
3% Authigenic carbonate
2-3% Pyrite
T Tourmaline, Epidote and Chlorite

Remarks: 1) H_2S odor
2) Discoasters abundant
3) Recristallization of microfossils

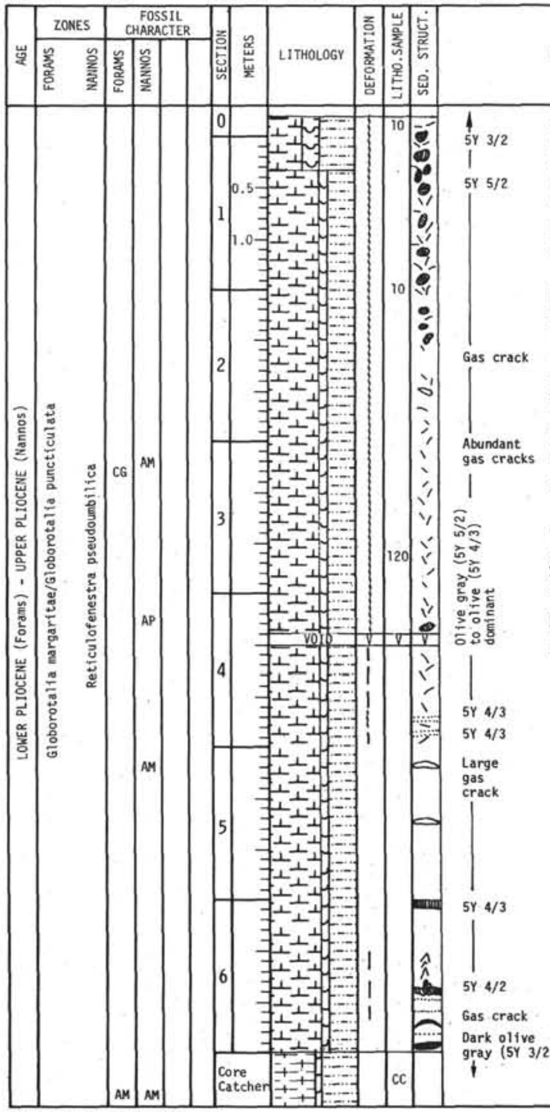
Carbonate Bomb: 1-28 to 29 cm = 43.5% $CaCO_3$

<u>Carbon-Carbonate (DSDP)</u>
4-20 (8.9, 3.4, 46)
6-20 (7.9, 3.0, 41)

<u>Carbon-Carbonate (OG)</u>
5-130 (7.9, 1.8, 51)
5-150 (7.9, 2.8, 42)

<u>Grain Size (DSDP)</u>
4-88 (0.5, 23.6, 76.0)

Site 362 Hole Core 12 Cored Interval: 140.5-150.0 m



LITHOLOGIC DESCRIPTION

<u>MARLY FORAMINIFERA DIATOM BEARING NANNO OOZE TO CALCAREOUS NANNO OOZE</u>

Fine, homogeneous, olive gray (5Y 5/2) - olive (5Y 4/3) sediment, strongly deformed and homogenized by drilling and gas cracks.

<u>TEXTURE</u>
Light sandy, silty, clay:
1-2% Sand, 15-20% Silt, ≈80% Clay

<u>COMPOSITION (SS)</u>
<u>Major components</u>
40-60% Calcareous nannofossils
15-35% Clay minerals
3- 7% Forams
2% Diatoms

<u>Minor components</u>
T-1% Rads and Silic. spicules
5% Authigenic carbonate
2-3% Pyrite
1-3% Quartz
T-2% Epidote, Chlorite and Tourmaline

Remarks: 1) Abundant H_2S odor
2) Coccospheres present

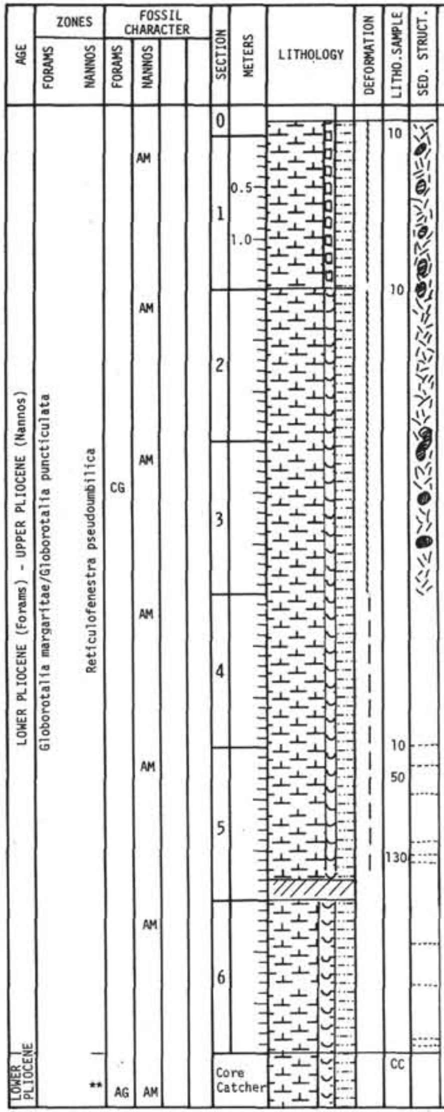
Carbonate Bomb: 1-23 to 30 cm = 33.3% $CaCO_3$

<u>Carbon-Carbonate (DSDP)</u>
4-20 (7.9, 2.2, 47)
5-22 (8.5, 1.4, 59)

<u>Grain Size (DSDP)</u>
4-88 (0.7, 36.6, 62.7)
6-88 (2.2, 57.2, 40.6)

Explanatory notes in Chapter 1

Site 362 Hole Core 13 Cored Interval: 150.0-159.5 m



LITHOLOGIC DESCRIPTION

Intensive drilling deformation and abundant gas cracks

Olive gray (5Y 5/2) dominant.

MARLY NANNO OOZE TO DIATOMACEOUS NANNO OOZE TO DOLOMITIC RHOMBS RICH MARLY NANNO OOZE

Fine, olive gray (5Y 5/2) to olive (5Y 4/3) sediment, interpenetrated by darker gray (5Y 3/2) patches or nondeformed layers.

TEXTURE
Slight sandy, silty, clay:
3% Sand, 35% Silt, 60% Clay

COMPOSITION
Major components
40-60% Calcareous nannos
15-30% Clay minerals
T-20% Dolomite rhombs
2-25% Biatoms
T- 3% Forams
T- 7% Authigenic carbonate

Minor components
T-1% Rads
2-3% Pyrite
<1% Quartz
T Epidote, Zircon and Tourmaline

Remarks: 1) H_2S odor
2) Levels with well preserved diatoms (cf. CC)

Carbonate Bomb: 1-23 to 30 cm = 60.8% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (7.2, 2.1, 42)
6-20 (8.3, 1.8, 55)

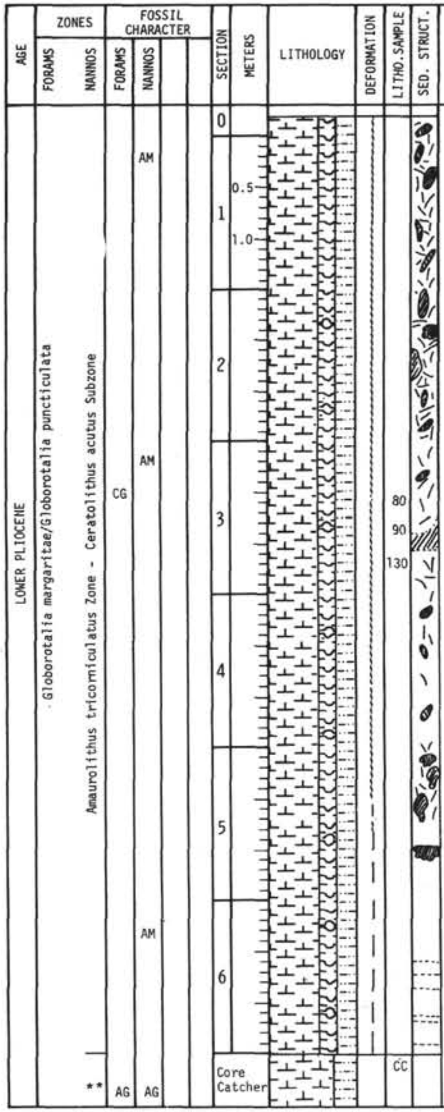
Carbon-Carbonate (OG)
4-130 (7.5, 4.2, 27)
4-150 (7.2, 2.3, 41)

Grain Size (DSDP)
4-88 (0.3, 33.1, 66.6)
6-88 (0.8, 44.8, 54.3)

5Y 3/2
5Y 4/3
5Y 3/2
5Y 3/2
OG sample
5Y 3/2
5Y 3/2

** Amaurolithus tricorniculatus Zone
Ceratolithus acutus Subzone

Site 362 Hole Core 14 Cored Interval: 159.5-169.0 m



LITHOLOGIC DESCRIPTION

T
Gase and drill deformed throughout, melange of olive (5Y 5/3) and olive gray (5Y 5/2)

5Y 4/3

CALCAREOUS NANNO OOZE TO DIATOM BEARING CALCAREOUS NANNO OOZE TO DAITOM BEARING MARLY NANNO OOZE

Fine variegated disturbed mixed olive gray (5Y 4/2 or 5Y 5/2) to homogeneous olive (5Y 4/3) sediment, strongly deformed in the upper part of the core by drilling and gas escape.

TEXTURE
2% Sand, 10-15% Silt, 80% Clay

COMPOSITION
Major components
60-80% Calcareous nannofossils
15-20% Clav
2- 3% Forams
10-15% to <1% Diatoms

Minor components
T-3% Rads and Silic. spicules
5% Authigenic carbonate
2-3% Pyrite
1-3% Quartz
T Tourmaline and Epidote

Remarks: 1) H_2S odor
2) Coccospheres present

Carbon-Carbonate (DSDP)
4-20 (7.9, 3.2, 39)
6-20 (8.2, 3.1, 42)

Grain Size (DSDP)
4-88 (0.5, 30.7, 68.8)
6-88 (0.5, 37.5, 62.0)

More homogeneous olive (5Y 4/3) Drill and gas melange a bit lighter

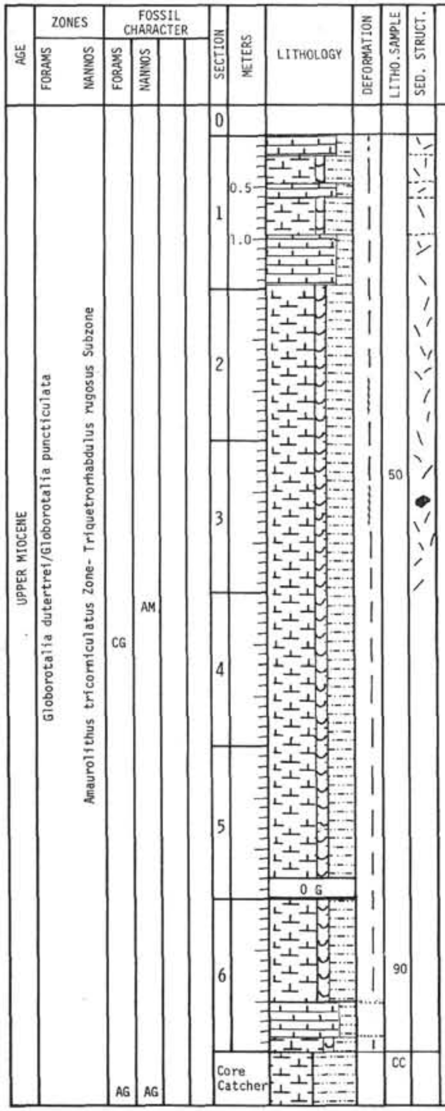
5Y 4/3
olive

5Y 4/2
olive gray
5Y 4/3
olive

5Y 3/2 dark
olive gray
5Y 4/3
5Y 5/2
5Y 4/2 olive gray
5Y 4/2 olive gray

**Triquetrorhabdulus rugosus (Subzone)
Explanatory notes in Chapter 1

Site 362 Hole Core 15 Cored Interval: 178.5-188.0 m



LITHOLOGIC DESCRIPTION

5Y 6/2 light olive gray chalk Ooze

Chalk 5Y 4/2 olive gray Ooze

5Y 5/2 olive gray chalk

Uniform 5Y 5/2 olive gray

Nearly uniform 5Y 5/2 olive gray

Gradation from 5Y 4/2 olive gray to 5Y 5/2 olive gray ooze

Uniform olive gray (5Y 4/2) ooze

5Y 4/3 olive

5Y 5/2, olive gray, with olive (5Y 4/3) blotches

Chalk

MARLY CALCAREOUS NANNO OOZE TO MARL, TO DIATOM BEARING CALCAREOUS NANNO OOZE

Fine, nearly uniform olive gray (5Y 5/2) to olive (5Y 4/3) ooze, with small zones of chalk.

TEXTURE
Silty clay, with small traces of sand:
T% Sand, 5-10% Silt, 30% Clay

COMPOSITION
Major components
45-60% Calcareous nannos
20-50% Clay minerals
1- 2% Forams
3-10% Diatoms

Minor components
T Rads and Silic. spicules
3-5% Authigenic carbonate
1-2% Pyrite
1% Quartz
T Epidote and Chlorite

Remarks: 1) Less H_2S smell in the core
2) First appearance of chalk
3) Coccospheres present

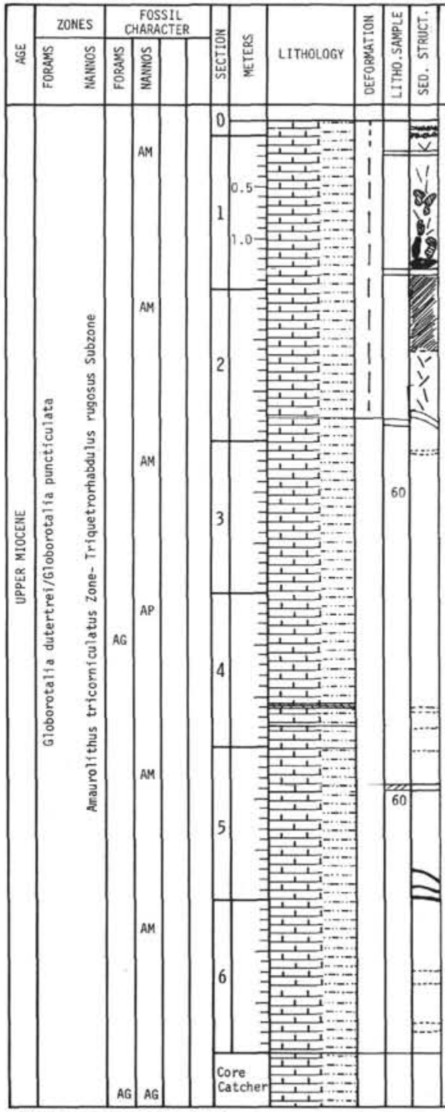
Carbonate Bomb: 1-23 to 30 cm = 59.5% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (7.4, 2.5, 41)
5-20 (7.7, 1.7, 50)

Carbon-Carbonate (OG)
5-130 (7.8, 2.0, 48)
5-150 (8.1, 2.0, 50)

Grain Size (DSDP)
4-88 (0.2, 24.1, 75.7)
5-88 (0.4, 34.7, 64.9)

Site 362 Hole Core 16 Cored Interval: 197.5-207.0 m



LITHOLOGIC DESCRIPTION

5Y 3/2
5Y 4/2

Gradationally darker = 5Y 5/2→5Y 3/2 (dark olive gray)

5Y 5/2 olive gray with gas cracks

Small chalk zone

Nearly uniform olive gray (5Y 5/2)

Gradation from 5Y 5/2 olive gray to 5Y 4/2 (darker)

Small chalk

Zones (5Y 5/2- olive gray)

5Y 5/2
5Y 4/2
5Y 5/2

5Y 4/2 olive gray

Almost uniform colors olive gray 5Y 4/2-5Y 5/2

5Y 4/2

CALCAREOUS NANNO OOZE

Fine, light olive gray (5Y 6/2) to dark olive gray (5Y 3/2), ooze to mud, in the upperpart of the core. Nearly uniform olive gray (5Y 5/2-5Y 4/2) ooze, marly ooze in the lower part.

TEXTURE
Very slight sandy, silty, clay:
T-1% Sand, 15% Silt, 85% Clay

COMPOSITION
Major components
60-70% Calcareous nannos
15-25% Clay minerals
1% Forams
T Diatoms

Minor components
0% Rads and Silic. spicules
2% Authigenic carbonate
2-5% Pyrite
T-2% Quartz
T Chlorite and Tourmaline

Remarks: 1) Less H_2S odor
2) Coccospheres present

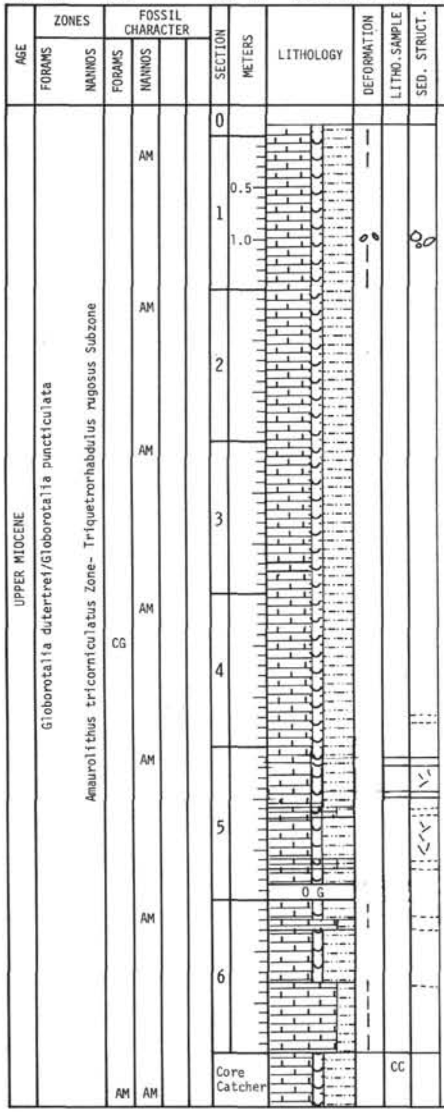
Carbonate Bomb: 1-29 to 30 cm = 65.1% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (9.0, 1.1, 66)
6-20 (8.7, 1.4, 61)

Grain Size (DSDP)
4-88 (0.5, 22.1, 77.5)
6-88 (0.9, 25.3, 73.8)

Explanatory notes in Chapter 1

Site 362 Hole Core 17 Cored Interval: 216.5-226.0 m



LITHOLOGIC DESCRIPTION

Nearly uniform olive gray (5Y 5/2) chalk (100 cm splitting breccia)

Gradation of olive gray (5Y 5/2) ooze in olive (5Y 4/3 to 5Y 5/2) chalk at the basis.

5Y 5/2 ooze and chalk

5Y 4/2

Void
Gas cracks
Void

5Y 4/3

5Y 5/2

5Y 4/3

OG sample

Chalk

Olive gray (5Y 4/2-5Y 5/2) chalk

FORAMINIFERA BEARING CALCAREOUS NANNO OOZE TO DIATOM BEARING MARLY NANNO OOZE

Intercalations of olive gray (5Y 5/2) ooze or chalk in olive (5Y 4/3) to olive gray (5Y 4/2-5/2) chalk. Deformation rare, except minor splitting breccia or gas cracks.

TEXTURE
Light sandy, silty clay:
2-3% Sand, 10% Silt, 85% Clay

COMPOSITION
Major components
70% Calcareous nannofossils
15-20% Clay minerals
2- 5% Forams
2- 4% Diatoms

Minor components
1% Rads and Silic. spicules
2% Authigenic carbonate
3% Dolomite rhombs
1% Pyrite
T Quartz

Remark: Sharp decrease of siliceous microfossils

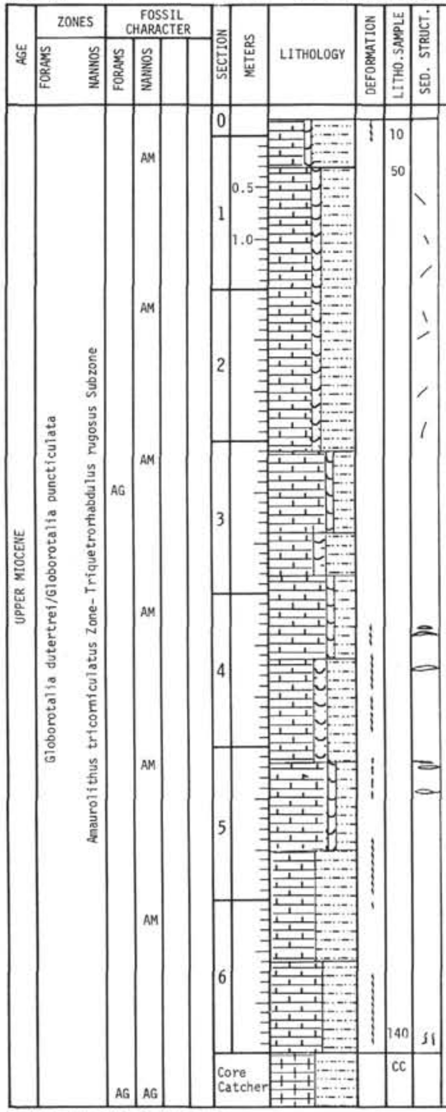
Carbonate Bomb: 1-23 to 30 cm = 66.5% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (8.7, 0.8, 65)
6-20 (8.4, 0.7, 64)

Carbon-Carbonate (OG)
5-130 (8.3, 1.0, 61)
5-150 (8.0, 0.6, 62)

Grain Size (DSDP)
4-88 (0.9, 25.3, 73.8)
6-88 (1.2, 21.1, 77.7)

Site 362 Hole Core 18 Cored Interval: 235.5-245.0 m



LITHOLOGIC DESCRIPTION

5Y 4/2
olive gray

5Y 4/2

Olive gray (5Y 5/2) chalk

Greenish gray (5Y 6/1) chalk

Ooze

Chalk

Gas cracks

Gas cracks
Olive gray (5Y 5/2) ooze with 5Y 6/1 greenish gray

Chalk

Ooze

Chalk/ooze zone badly disturbed by gas and drill burrows

DIATOM BEARING CALCAREOUS NANNOFOSSIL OOZE OR CHALK TO CALCAREOUS NANNO CHALK OR OOZE TO FORAMINIFERA BEARING STRONG MARLY NANNO OOZE OR CHALK

Fine, homogeneous (except variations in color), olive gray (5Y 5/2) to greenish gray (5Y 6/1) chalk to ooze. Deformed in a few places by gas cracks and drilling.

TEXTURE
Slight sandy, silty, clay:
1-3% Sand, 10-15% Silt, 80-85% Clay

COMPOSITION
Major components
30-60% Calcareous nannos
15-50% Clay
2-10% Forams
T-10% Diatoms

Minor components
T-2% Rads and Silic. spicules
2-8% Authigenic carbonate
2-3% Pyrite
T Quartz

Remarks: 1) Coccospheres present
2) Slight H_2S
3) First appearance of burrows
4) Rich locally in aragonite needles (cf. CC)

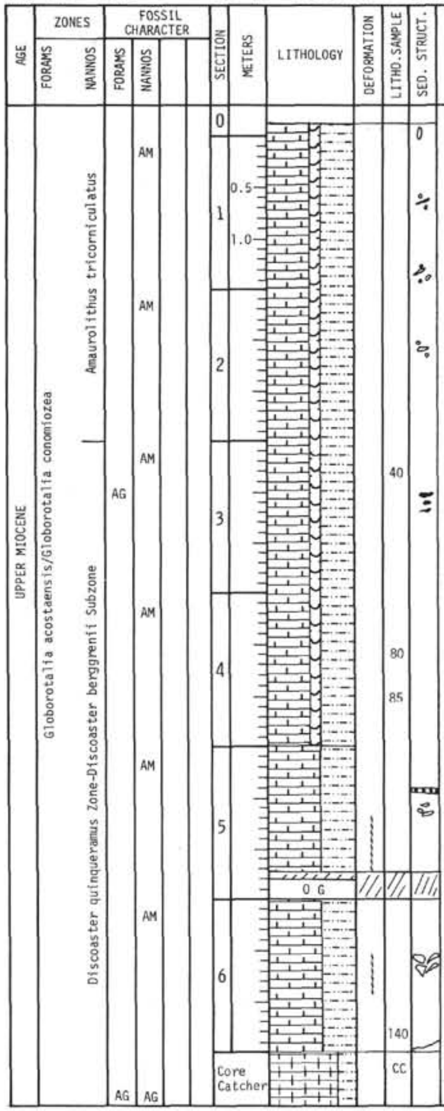
Carbonate Bomb: 1-23 to 30 cm = 33.8% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (7.1, 1.0, 51)
6-20 (7.0, 1.1, 49)

Grain Size (DSDP)
4-88 (1.2, 21.1, 73.8)
6-88 (1.3, 21.7, 77.7)

Explanatory notes in Chapter 1

Site 362 Hole Core 19 Cored Interval: 254.5-264.0 m



LITHOLOGIC DESCRIPTION

Burrow
5Y 6/1 greenish bray
5Y 5/2 in burrow
5Y 4/2 olive gray
5Y 5/2 olive gray
Burrows 5GY 6/1
5Y 5/2
5Y 4/2
5GY 6/1 greenish gray
5Y 4/2 olive
5Y 5/2 olive gray
5Y 5/2
5Y 4/2
5Y 5/2
5Y 4/2
5Y 5/2
5GY 6/1
Zoophycos
5Y 5/2
5GY 6/1
OG sample
5Y 4/2
Fractured
5Y 4/2
5Y 3/2 erosional contact

CALCAREOUS NANNO CHALK TO MARLY NANNO CHALK TO FORAMINIFERA BEARING CALCAREOUS NANNO CHALK

Fine, olive gray (5Y 5/2) to greenish gray (5GY 6/1), chalk to marly chalk, moderately burrowed.

TEXTURE
Slight sandy, silty, clay:
2% Sand, 15-25% Silt, 85% Clay

COMPOSITION
Major components
70-80% Calcareous nannofossils
10-20% Clay minerals
T- 5% Forams
1- 5% Diatoms

Minor components
2-4% Authigenic carbonate
T-2% Dolomite rhombs
1-2% Pyrite
T Aragonite needles

Remarks: 1) Presence of Coccospheres
2) Core moderately burrowed

Carbonate Bomb: 1-23 to 30 cm = 60.2% $CaCO_3$

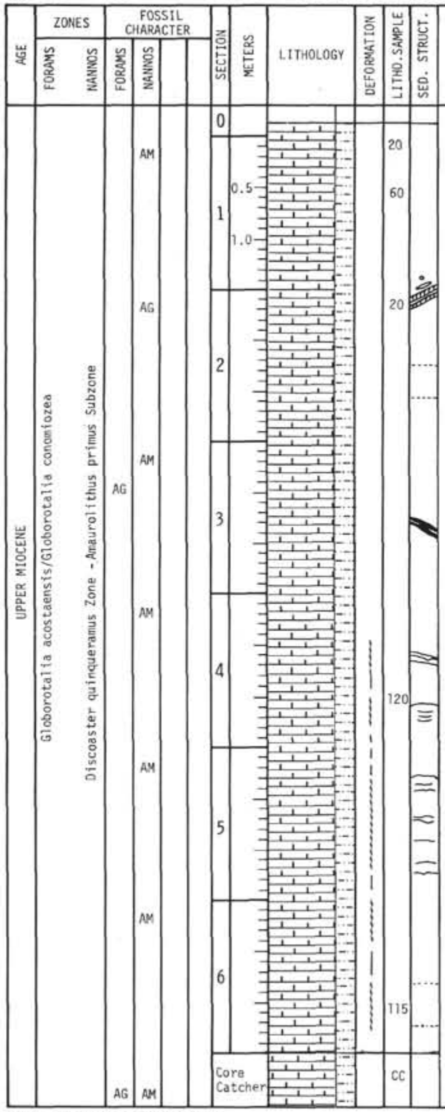
Carbon-Carbonate (DSDP)
4-20 (7.8, 0.9, 57)
6-20 (6.9, 1.8, 42)

Carbon-Carbonate (OG)
5-130 (7.7, 0.8, 57)
5-150 (8.2, 1.5, 56)

Grain Size (DSDP)
4-88 (0.7, 21.0, 78.3)
6-88 (2.3, 33.3, 64.4)

Sharp contact green olive gray mudstone/white gray chalk

Site 362 Hole Core 20 Cored Interval: 273.5-283.0 m



LITHOLOGIC DESCRIPTION

Olive gray (5Y 5/2) grading to greenish gray (5GY 6/1)
Burrows
Zoophycos
5Y 5/2 olive gray
Very uniform greenish gray (5GY 6/1)
Cracked zone
Gas escapes
Ooze
Gas escapes
Olive gray (5Y 5/2 to 5Y 4/2)
burrows and cracks

CALCAREOUS NANNO CHALK (WITH LOCAL OOZE)

Uniform greenish gray (5GY 6/1) chalk, to ooze, moderately burrowed (Zoophycos), and bearing few gas cracks in the lower part of the core.

TEXTURE
Light sandy silty clay:
≤1% Sand, 5-7% Silt, 90% Clay

COMPOSITION (SS)
Major components
70-80% Calcareous nannofossils
15-20% Clay minerals

Minor components
T-3% Forams
2-5% Authienic carbonate
≤1% Diatoms
~1% Pyrite
T Quartz
T-2% Micarb
T-2% Tourmaline

Remarks: 1) Burrows appear always darker than the surrounding sediment
2) Coccospheres present

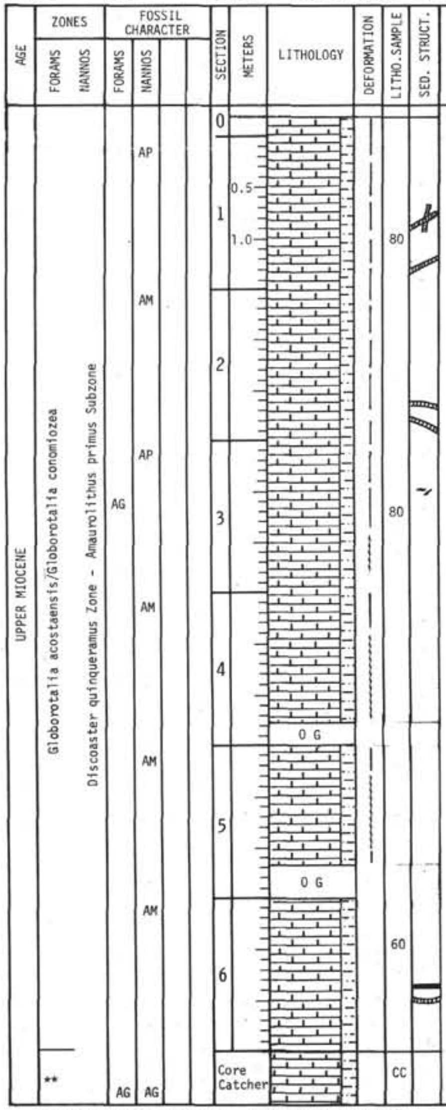
Carbonate Bomb: 1-29 to 30 cm = 63.2% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (10.7, 0.8, 82)
6-20 (9.7, 0.5, 76)

Grain Size (DSDP)
4-88 (1.1, 24.7, 74.2)
6-88 (1.7, 20.7, 77.7)

Explanatory notes in Chapter 1

Site 362 Hole Core 21 Cored Interval: 292.5-302.0 m



LITHOLOGIC DESCRIPTION

greenish gray (5GY 6/1)

Zoophycos

Burrows

Badly fractured

OG sample

OG sample

Zoophycos

CALCAREOUS NANNO CHALK TO MARLY NANNO CHALK BEARING FORAMINIFERA

Uniform greenish gray chalk, moderately to strongly fractured (splitting effect), moderately burrowed.

TEXTURE
Light sandy, silty, clay:
T-3% Sand, 15-20% Silt, ≈80% Clay

COMPOSITION (SS)
Major components
50-70% Calcareous nannofossils
20-30% Clay minerals
1- 5% Forams

Minor components
3- 5% Authigenic carbonate
1- 3% Pyrite
1- 3% Diatoms
<1% Rads
~T Quartz, Tourmaline, Augite and Sphene

Remarks: 1) Locally strong recrystallization
2) Coccospheres present

Carbonate Bomb: 1-43 to 50 cm = 76.8% $CaCO_3$

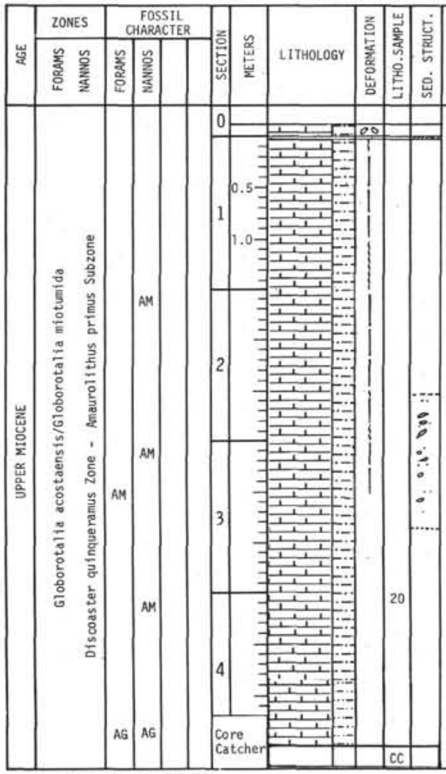
Carbon-Carbonate (DSDP)
4-20 (9.3, 0.6, 73)
6-20 (9.3, 0.8, 70)

Carbon-Carbonate (OG)
5-130 (9.0, 0.5, 71)
5-150 (8.9, 0.5, 70)

Grain Size (DSDP)
4-99 (1.2, 27.9, 70.9)
6-88 (1.0, 22.5, 76.5)

** Globorotalia acostaensis/Globorotalia miotumida

Site 362 Hole Core 22 Cored Interval: 311.5-321.0 m



LITHOLOGIC DESCRIPTION

Drilling breccia and void
Greenish gray (5GY 6/1)

Olive (5Y 4/3)

Burrows
Mostly very tiny and few larger

Gray

End

CALCAREOUS NANNO CHALK TO FORAMINIFERA BEARING CALCAREOUS NANNO CHALK

Fine, greenish gray, to olive, to gray chalk, to marly chalk, moderately to strongly burrowed and locally strongly fractured.

TEXTURE
Light sandy, silty, clay:
1-3% Sand, 10-20% Silt, 80-90% Clay

COMPOSITION (SS)
Major components
70-75% Calcareous nannofossils
10-20% Clay minerals

Minor components
1-5% Forams
3-5% Authigenic carbonate
3-5% Pyrite
≤1% Rads and Silic. spicules

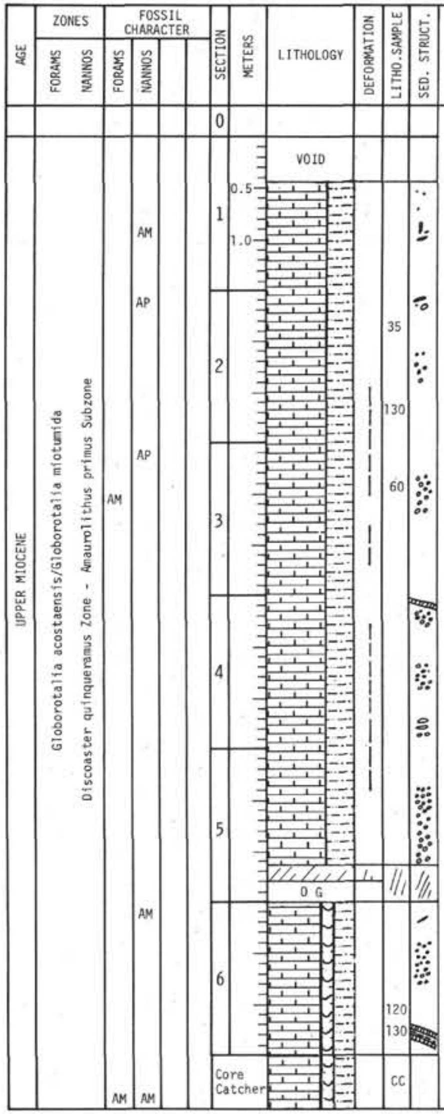
Remarks: 1) The size of the calcareous nannofossils is obviously increasing, with depth, passing from clay size to silt size
2) Coccospheres present

Carbonate Bomb: 2-29 to 30 cm = 58.8% $CaCO_3$

Grain Size (DSDP)
4-88 (2.3, 23.3, 74.3)

Explanatory notes in Chapter 1

Site 362 Hole Core 23 Cored Interval: 330.5-340.0 m



LITHOLOGIC DESCRIPTION

Olive gray (5Y 4/2)
Olive gray (5Y 5/2) to greenish gray (5GY 6/1)
Burrows
Intensively cracked
Fractured
Fractured
Light olive gray (5Y 6/2)
Burrows
Fractured
Burrows
Greenish gray (5GY 6/1)
Fractured
Pale olive gray
Very abundant tiny burrows
OG sample
Contact: light gray/ greenish gray

<u>CALCAREOUS NANNO CHALK PASSING TO DIATOM BEARING MARLY NANNO CHALK, AND TO DIATOMACEOUS CALCAREOUS NANNO CHALK AT THE BASE OF THE CORE</u>

Olive gray, to greenish gray to pale olive gray chalk, locally intensively burrowed (Chondrites and Zoophycos), and fractured.

<u>TEXTURE</u>
Light sandy silty clay to sandy silty clay:
T-7% Sand, 25% Silt, $\leq$70% Clay

<u>COMPOSITION (SS)</u>
<u>Major component</u>
60-75% Calcareous nannofossils
10-20% Clay minerals
0-15% Diatoms

<u>Minor components</u>
0-5% Forams
0-5% Rads
<1% Silicoflagellates
$\bar{<}$3% Authigenic carbonate
$\bar{<}$1% Pyrite
$\bar{T}$ Quartz, Mica, Tourmaline, Augite and Chlorite

Remark: Core catcher very rich in diatoms and siliceous spicules.

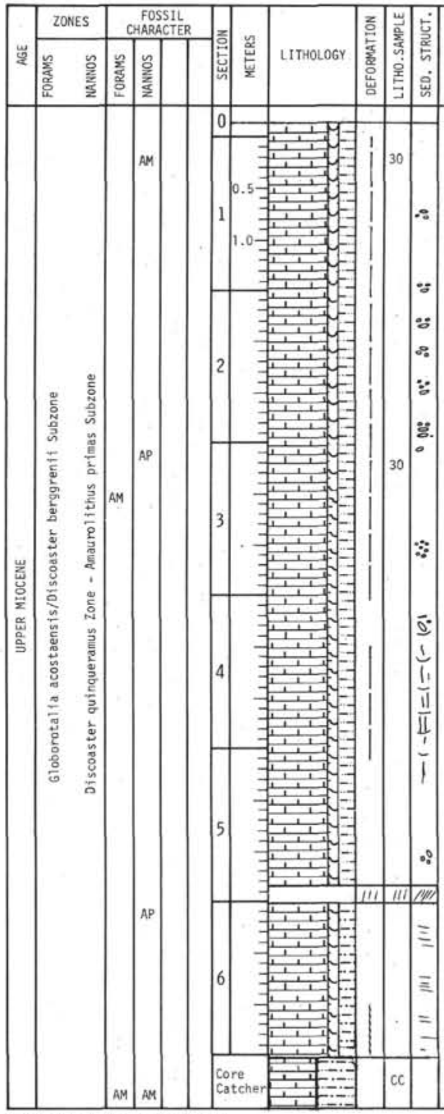
Carbonate Bomb: 1-85 to 86 cm = 72.6% $CaCO_3$

<u>Carbon-Carbonate (DSDP)</u>
4-20 (9.2, 0.8, 70)
6-20 (8.8, 0.7, 67)

<u>Carbon-Carbonate (OG)</u>
5-130 (9.2, 0.0, 76)
5-150 (8.7, 0.4, 69)

<u>Grain Size (DSDP)</u>
4-88 (1.1, 20.9, 78.0)
6-88 (0.7, 21.4, 77.8)

Site 362 Hole Core 24 Cored Interval: 349.5-359.0 m



LITHOLOGIC DESCRIPTION

Lengthwise fractures
Very uniform light greenish gray chalk (5G 8/1)
Numerous Zoophycos
Burrows
Burrows, gas cracks and fracturation
OG sample
Gas cracks

<u>CALCAREOUS NANNO CHALK TO FORAMINIFERA BEARING MARLY NANNO CHALK</u>

Very uniform, fine, light greenish gray chalk (5G 8/1), with burrows, filled with lighter or darker sediment. Locally fractured by gas cracks.

<u>TEXTURE</u>
Silty clay:
0-1% Sand, 10-15% Silt, ≈85% Clay

<u>COMPOSITION (SS)</u>
<u>Major components</u>
55-65% Calcareous nannofossils
20-50% Clay minerals

<u>Minor components</u>
T-5% Diatoms
T Rads
3% Forams
<1% Pyrite
$\bar{~}$3% Authigenic carbonate
T Tourmaline

Remarks: 1) Very homogeneous, but varying sediment compaction along the core
2) Coccospheres present

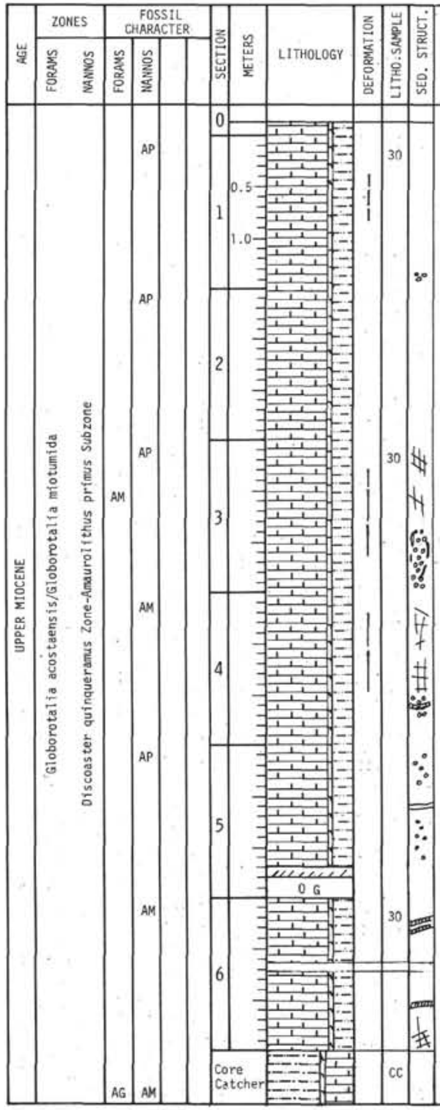
Carbonate Bomb: 1-29 to 30 cm = 83.9% $CaCO_3$

<u>Carbon-Carbonate (DSDP)</u>
4-20 (9.9, 0.5, 78)
6-20 (10.0, 0.6, 79)

<u>Grain Size (DSDP)</u>
4-88 (0.7, 18.0, 81.3)
6-88 (0.8, 18.5, 80.7)

Explanatory notes in Chapter 1

Site 362 Hole Core 25 Cored Interval: 368.5-378.0 m



LITHOLOGIC DESCRIPTION

Light greenish gray (5G 8/1) to light olive gray (5Y 6/2)

Light olive gray chalk (5Y 6/2)
Fractures

Burrows

Fractures

Burrows

Faint burrows
Light greenish gray (5G 8/1) to light olive gray (5G 6/2)

OG sample

Zoophycos

Fractures

<u>CALCAREOUS NANNO CHALK TO DIATOM BEARING MARLY NANNO CHALK</u>

Very uniform light greenish gray to light olive gray chalk, moderately to intensively fractured. Numerous burrows, faint to large (Zoophycos).

<u>TEXTURE</u>
Light sandy, silty, clay:
≤2% Sand, 10-15% Silt, ≈80% Clay

<u>COMPOSITION</u>
<u>Major components</u>
30-60% Calcareous nannofossils
20-60% Clay minerals
4- 6% Diatoms

<u>Minor components</u>
T-2% Forams
<1% Rads
≤T Silicoflagellates
5% Authigenic carbonate
T Pyrite
T Quartz
T Chlorite and Tourmaline

Remark: Coccospheres present

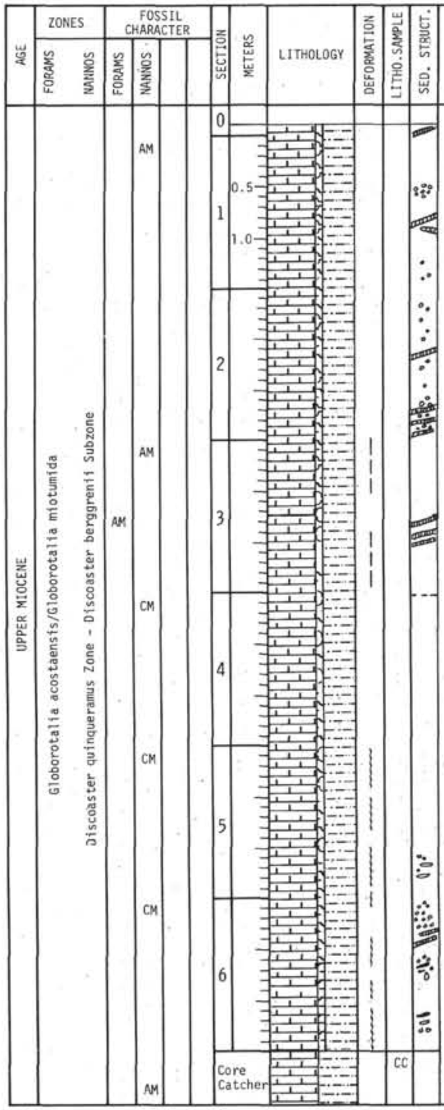
Carbonate Bomb: 1-29 to 30 cm = 77.8% $CaCO_3$

<u>Carbon-Carbonate (DSDP)</u>
4-20 (8.9, 0.5, 70)
6-20 (8.7, 0.7, 67)

<u>Carbon-Carbonate (OG)</u>
5-130 (8.7, 0.5, 69)
5-150 (8.5, 0.6, 66)

<u>Grain Size (DSDP)</u>
4-88 (0.9, 23.6, 81.7)
6-88 (0.4, 18.0, 77.4)

Site 362 Hole Core 26 Cored Interval: 387.5-397.0 m



LITHOLOGIC DESCRIPTION

Greenish gray (5GY 5/1)

Tiny burrows

Zoophycos

Faint burrows

Broken up

Zoophycos

Broken up

Dark greenish gray (5GY 4/1)

Greenish gray marly chalk (5GY 5/1)
Drill breccia and burrows

Drill breccia moderately to heavily burrowed

<u>MARLY NANNO CHALK TO FORAMINIFERA BEARING MARLY CHALK</u>

Greenish gray to dark greenish gray marly chalk, locally fractured through drilling, moderately to heavily burrowed.

<u>TEXTURE</u>
Very slighty sandy, silty, clay:
T-1% Sand, 15-20% Silt, ≈80% Clay

<u>COMPOSITION (SS)</u>
<u>Major components</u>
35-60% Calcareous nannofossils
25-40% Clay minerals
T- 5% Forams

<u>Minor components</u>
2-3% Diatoms
1-3% Rads
2-3% Pyrite
3-5% Authigenic carbonate
2% Dolomite rhombs
3% Tourmaline, Augite and Rutile

Remark: Coccospheres present

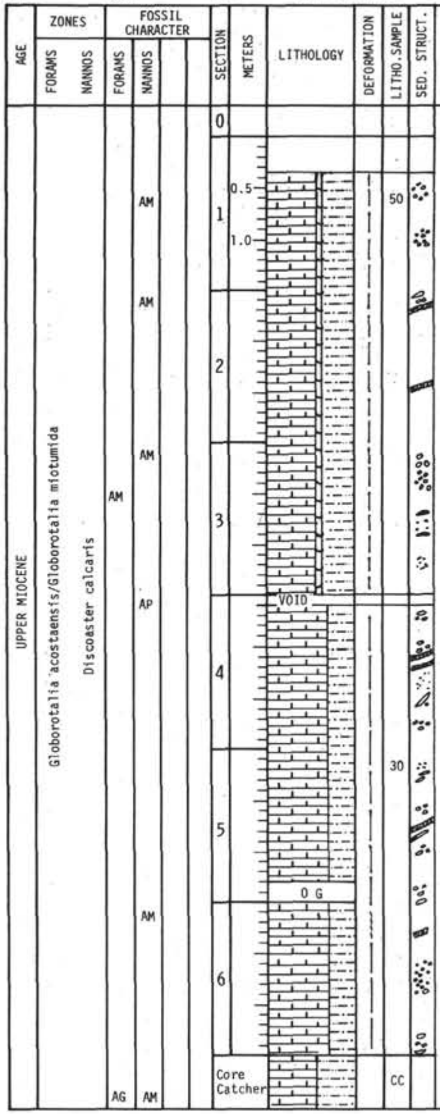
Carbonate Bomb: 1-29 to 30 cm = 59.7% $CaCO_3$

<u>Carbon-Carbonate (DSD')</u>
4-20 (6.2, 0.8, 46)
6-20 (5.4, 1.1, 35)

<u>Grain Size (DSDP)</u>
4-88 (1.0, 21.6, 77.4)
6-88 (1.1, 21.9, 77.1)

Explanatory notes in Chapter 1

Site 36' Hole Core 27 Cored Interval: 406.5-416.0 m



LITHOLOGIC DESCRIPTION

Void

Greenish gray (5GY 6/1)

Tiny light colored burrows

Core fractured

Zoophycos

Blotchy burrowed

Tiny burrows

Void

5GY 5/1

Tiny burrows

Dark blotchy burrows

Heavily broken by drilling

Faint tiny burrows

Patchy burrows

MARLY NANNO CHALK

Uniform, greenish gray (5GY 6/1) chalk moderately burrowed, locally heavily fractured by drilling. Burrows are rather faint, round, patchy, with few Zoophycos.

TEXTURE
Very fine silty clay:
T% Sand, 15% Silt, 80% Clay

COMPOSITION (SS)
Major components
50-60% Calcareous nannofossils
30-40% Clay minerals

Minor components
T-2% Forams
0-2% Diatoms
0-2% Rads
4-7% Carbonate unspecified
1-2% Pyrite
0-2% Quartz
T-3% Tourmaline

Remark: Coccospheres present

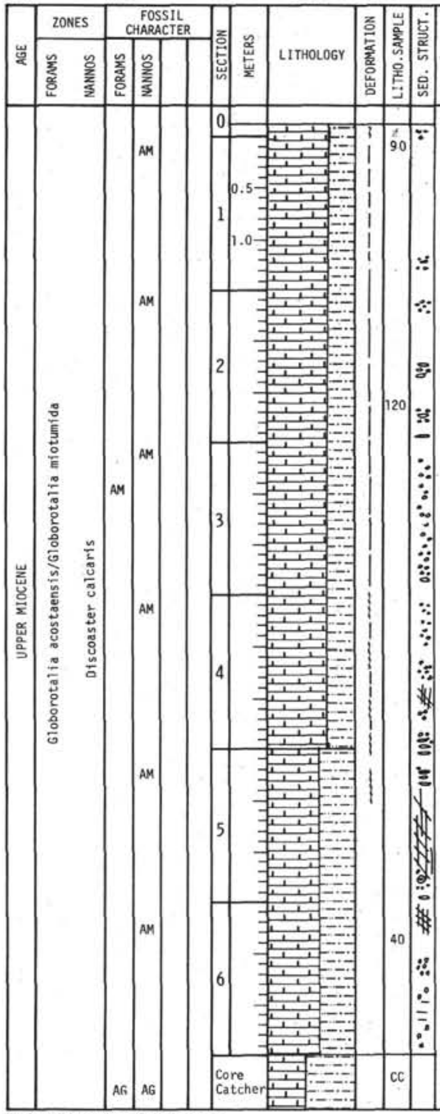
Carbonate Bomb: 1-104 to 105 cm = 61.6% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (5.6, 0.5, 42)
6-20 (6.5, 0.6, 50)

Carbon-Carbonate (OG)
5-130 (7.0, 1.5, 55)
5-150 (6.4, 0.5, 50)

Grain Size (DSDP)
4-91 (0.9, 19.2, 79.9)
6-88 (1.4, 24.3, 74.3)

Site 362 Hole Core 28 Cored Interval: 425.5-435.0 m



LITHOLOGIC DESCRIPTION

Blotchy burrows

Greenish gray (5GY 5/1) to greenish gray (5GY 6/1)

Broken by drilling

Abundant mottles

Fractured

Fractured

CALCAREOUS NANNO CHALK TO HEAVILY MARLY NANNO CHALK

Nearly uniform greenish gray (5GY 6/1) chalk, moderately burrowed, locally heavily fractured by drilling and splitting. Apparently very homogeneous.

TEXTURE
Silty clay:
T% Sand, 20% Silt, 80% Clay

COMPOSITION (SS)
Major components
35-60% Calcareous nannofossils
20-60% Clay minerals
T- 2% Diatoms

Minor components
T-2% Forams
5% Carbonate unspecified
T Dolomite rhombs
≤1% Pyrite
T Quartz
T-2% Heavy minerals

Remark: Coccospheres present

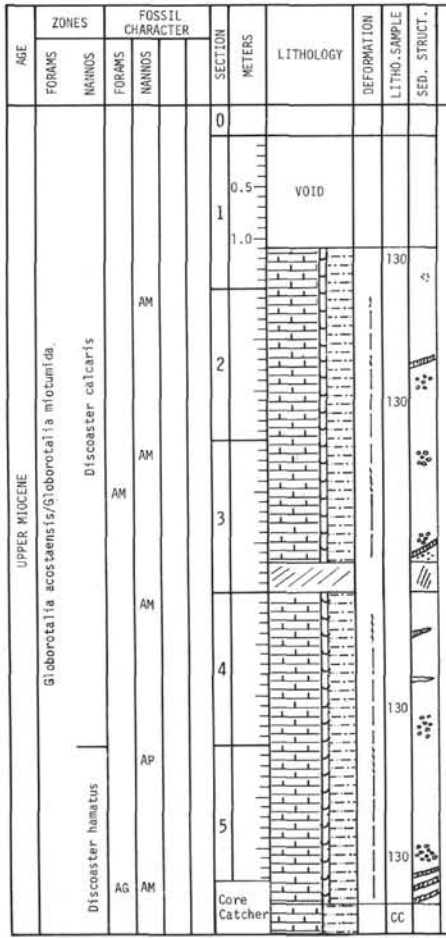
Carbonate Bomb: 1-19 to 20 cm = 59.7% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (9.1, 0.6, 71)
6-20 (7.6, 0.6, 58)

Grain Size (DSDP)
4-88 (1.5, 23.9, 74.6)
6-88 (1.9, 23.8, 74.3)

Explanatory notes in Chapter 1

Site 362 Hole Core 29 Cored Interval: 444.5-454.0 m



LITHOLOGIC DESCRIPTION

MARLY NANNO CHALK

Void

Greenish gray (5GY 6/1)

Pyrite

Fractured

Zoophycos and tiny burrows

OG sample

Zoophycos

Very homogeneous greenish gray chalk, moderately burrowed, with tiny burrowed concentrated into zones.

TEXTURE
Silty clay:
T% Sand, 20% Silt, 80% Clay

COMPOSITION (SS)
Major components
50-60% Calcareous nannofossils
30-40% Clay minerals

Minor components
1-8% Forams
2-3% Pyrite
T-3% Quartz
T-4% Tourmaline

Remark: Coccospheres present

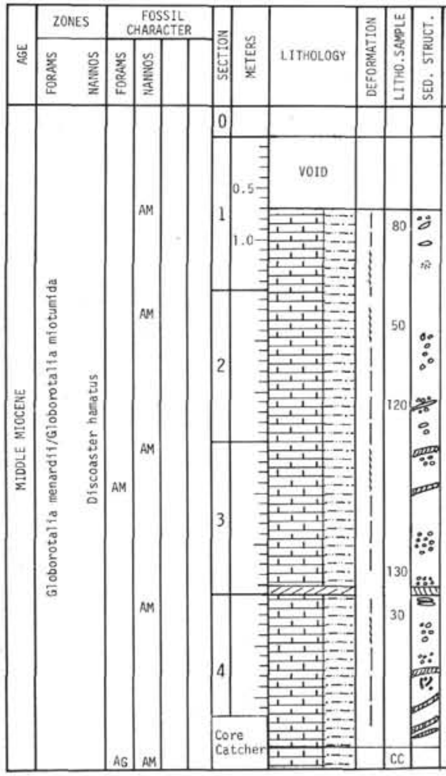
Carbonate Bomb: 2-19 to 20 cm = 58.1% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (6.4, 0.6, 48)

Carbon-Carbonate (OG)
3-130 (6.3, 0.5, 49)
3-150 (6.8, 0.4, 53)

Grain Size (DSDP)
4-88 (0.7, 23.5, 75.8)

Site 362 Hole Core 30 Cored Interval: 463.5-473.0 m



LITHOLOGIC DESCRIPTION

NANNO CHALK TO LIGHT MARLY NANNO CHALK

Void

Greenish gray (5GY 6/1)

Pyrite

Burrows

Burrows

Zoophycos

Moriads of tiny burrows. Blotchy composite burrows. OG sample

MACROSCOPIC CORE DESCRIPTION
Very uniform, apparently homogeneous greenish gray chalk, throughout burrowed, with a few pyritic inclusions. Locally heavily fractured by drilling.

TEXTURE
Silty clay:
T% Sand, 30% Silt, 70% Clay

COMPOSITION (SS)
Major components
65% Calcareous nannofossil
30% Clay minerals

Minor components
T Forams
2-3% Dolomite rhombs
0-2% Quartz
0-2% Tourmaline

Remarks: 1) Coccospheres present
2) Dolomitic rhombs dissolved on the edges

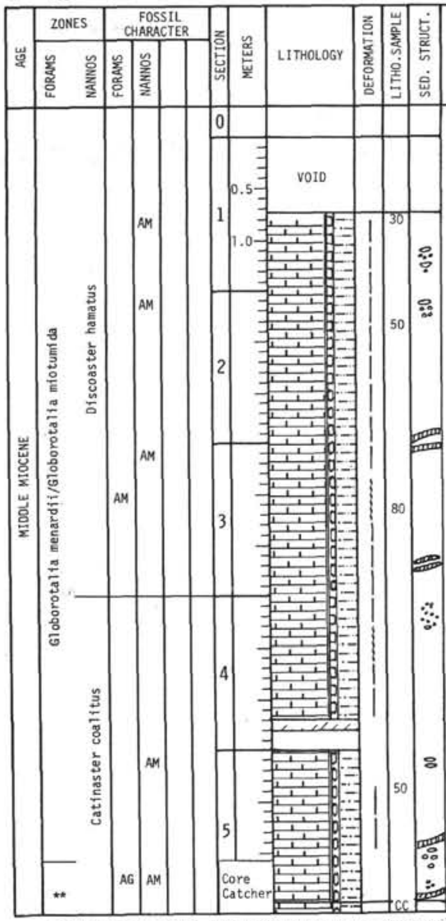
Carbonate Bomb: 1-77 to 78 cm = 51.3% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (9.2, 0.3, 74)

Grain Size (DSDP)
4-88 (0.7, 28.2, 71.1)

Explanatory notes in Chapter 1

Site 362 Hole Core 31 Cored Interval: 482.5-492.0 m



**Globorotalia fohsi robusta to Globorotalia mayeri/Globorotalia mayeri mayeri

LITHOLOGIC DESCRIPTION

Void

Greenish gray (5GY 6/1)

Zoophycos

Tiny burrows

OG sample

Patchy burrows

CALCAREOUS NANNO CHALK TO FORAMINIFERA BEARING NANNO CHALK

Homogeneous, fine, greenish gray chalk, moderately burrowed, very similar to previous Cores 29 and 30.

TEXTURE
Silty clay:
T% Sand, 40% Silt (mostly Coccoliths), 60% Clay

COMPOSITION
Major components
70% Calcareous nannofossils
20% Clay minerals

Minor components
0-5% Forams
3-5% Carbonate unspecified
≤1% Pyrite
≤2% Tourmaline
3-5% Dolomite rhombs

Remarks: 1) Dolomitic rhombs common (cf. CC) often dissolved on the edges
2) Coccospheres abundant

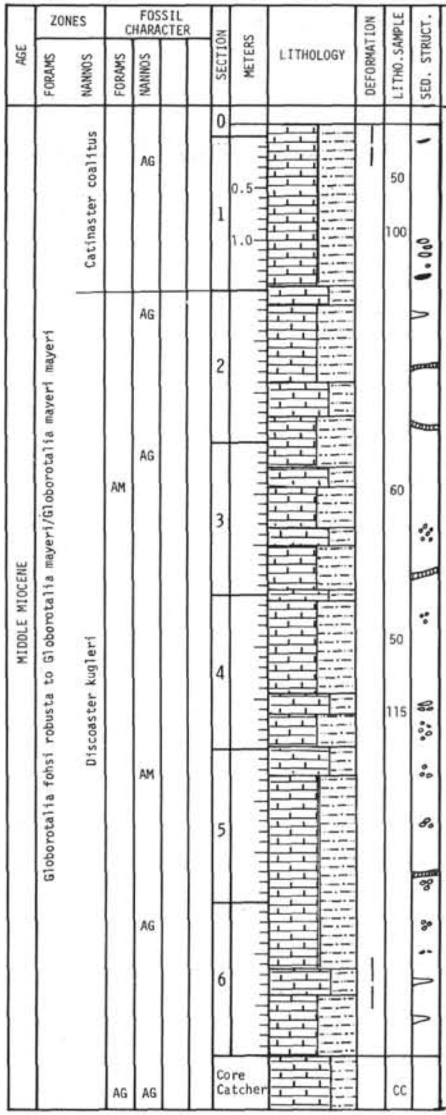
Carbonate Bomb: 1-80 to 81 cm = 66.8% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (8.9, 0,4, 70)

Carbon-Carbonate (OG)
4-130 (8.8, 0.3, 71)
4-150 (8.1, 0.3, 65)

Grain Size (DSDP)
4-75 (0.7, 31.0, 68.3)

Site 362 Hole Core 32 Cored Interval: 501.5-511 m



LITHOLOGIC DESCRIPTION

Greenish gray (5GY 6/1)

Burrows

5Y 6/1
Light olive gray (5Y 6/1) to light greenish gray (5GY 6/1) with light brownish gray (5YR 6/1)

5GY 6/1
5Y 6/1
5GY 6/1
Marly chalk
5YR 6/1
Marly chalk
Chalk

Marly chalk

Marly chalk

Marly chalk
5YR 6/1

Marly chalk

Marly chalk

Chalk N7

Marly chalk

MARLY NANNO CHALK WITH MINOR INTERCALATIONS OF CHALK

Greenish gray to light brownish gray marly chalk (highly dominant) with intercalation of white chalk (N7), bearing light darker gray burrows.

TEXTURE
Light silty clay to very fine clayey silt:
≈50% Fine Silt (Coccoliths), ≈50% Clay

COMPOSITION (SS)
Major components
60-70% Calcareous nannofossils
25% Clay minerals

Minor components
T-2% Forams
1-2% Pyrite
1% Carbonate unspecified
1% Heavy minerals

Remark: Coccospheres abundant

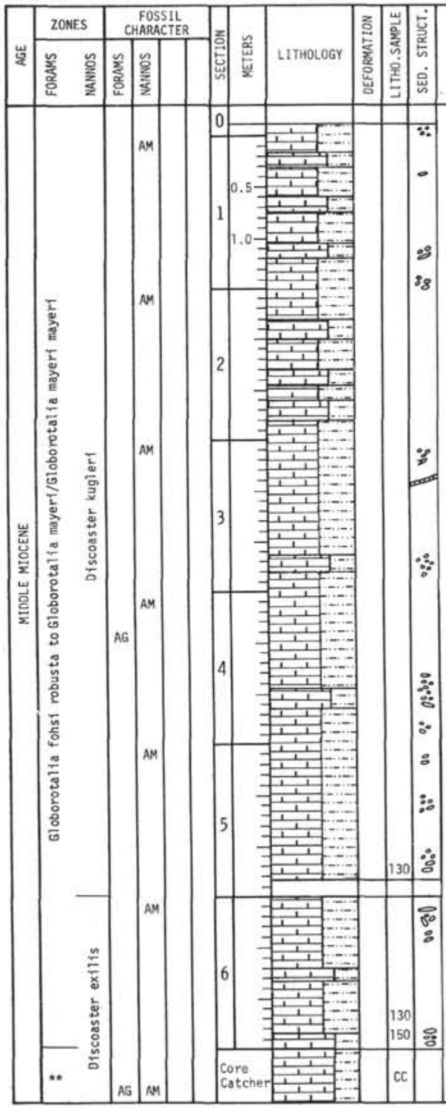
Carbonate Bomb: 1-29 to 30 cm = 56.4% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (7.2, 0.2, 47)
6-20 (6.0, 0.2, 48)

Grain Size (DSDP)
6-88 (2.0, 25.7, 72.4)

Explanatory notes in Chapter 1

Site 362 Hole Core 33 Cored Interval: 520.5-530.5 m



LITHOLOGIC DESCRIPTION

Marly chalk 5YR 6/1
Chalk 5GY 6/1
Marly chalk
Chalk
Marly chalk
Chalk
Marly chalk
Chalk
Marly chalk
Marly chalk
Chalk
Marly chalk
Chalk
Marly chalk
Marl 5GY 5/1 to 5GY 6/1
OG sample
Marly chalk
Marl
Marly chalk

MARLY NANNO CHALK TO VERY LIGHT MARLY NANNO CHALK

Cyclic sedimentation:
Fine, light greenish gray (5YR 6/1) marly chalk to greenish gray (5GY 5/1) marl, with intercalation of 12 chalky zones (=15 cm long each), light greenish gray (5GY 6/1). Moderately burrowed.

TEXTURE
Very fine silty clay or clayey silt:
≤1% Sand, 50% Silt, 50% Clay

COMPOSITION (SS)
Major components
60-65% Calcareous nannofossils
25-30% Clay minerals

Minor components
1% Forams
1-5% Authigenic carbonate
T% Mica
3% Quartz
2% Heavy minerals
1-3% Pyrite

Remarks: 1) Nannoflora represented by resistant species (Dissolution's effect)
2) Coccospheres present

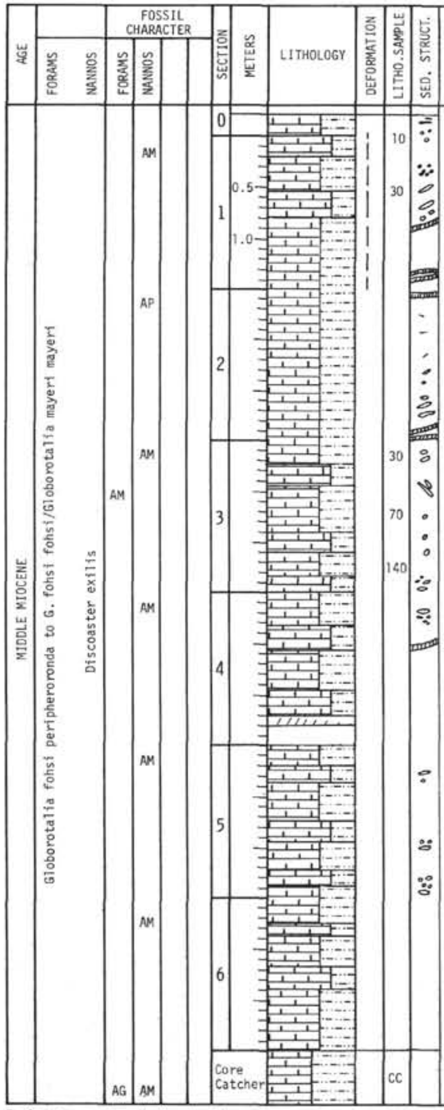
Carbonate Bomb: 1-23 to 30 cm = 56.4% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (6.0, 0.2, 48)
6-20 (6.5, 0.4, 5)

Grain Size (DSDP)
4-88 (1.4, 27.2, 71.4)
6-88 (0.7, 23.2, 76.0)

** Globorotalia fohsi lobata/Globorotalia mayeri mayeri

Site 362 Hole Core 34 Cored Interval: 549.0-558.5 m



LITHOLOGIC DESCRIPTION

Marly chalk
Chalk (N7)
Marly chalk
Chalk
Marly chalk N6
Light gray
Medium light gray (N7)
Light greenish gray (5GY 6/1)
Marl
Marly chalk
Marl
Marly chalk
Marl
Marly chalk
Marl, light gray (N6)
Marly chalk greenish gray (5GY 6/1)
Marl N6
Marly chalk (5GY 6/1)
OG sample
Olive gray (5Y 5/2)
Chalk 5GY 6/1
Olive gray (5Y 5/2)
Chalk 5GY 6/1
Marl 5Y 5/2
Chalk olive gray (5GY 6/1)
Marl 5Y 4/1
Marl
Chalky marl
Marl
Chalky marl
Marl 5Y 5/2-5YR 5/2

MARLY NANNO CHALK AND NANNO CHALK

Cyclic sedimentation:
Intercalations of numerous chalky zones in marly chalk to marl (5YR 6/1, 5Y 6/1, light brownish gray and light olive gray, to 5Y 5/2, olive gray), gradational contact. Moderately to intensively burrowed.

TEXTURE
Silty clay:
1% Sand, 25% Silt, 75% Clay

COMPOSITION (SS)
Major components
50-65% Calcareous nannofossils
20-40% Clay minerals

Minor components
1-2% Forams
3% Authigenic carbonate
1% Quartz
0-1% Tourmaline

Remark: Coccospheres present

Carbonate Bomb: 1-23 to 30 cm = 65% $CaCO_3$

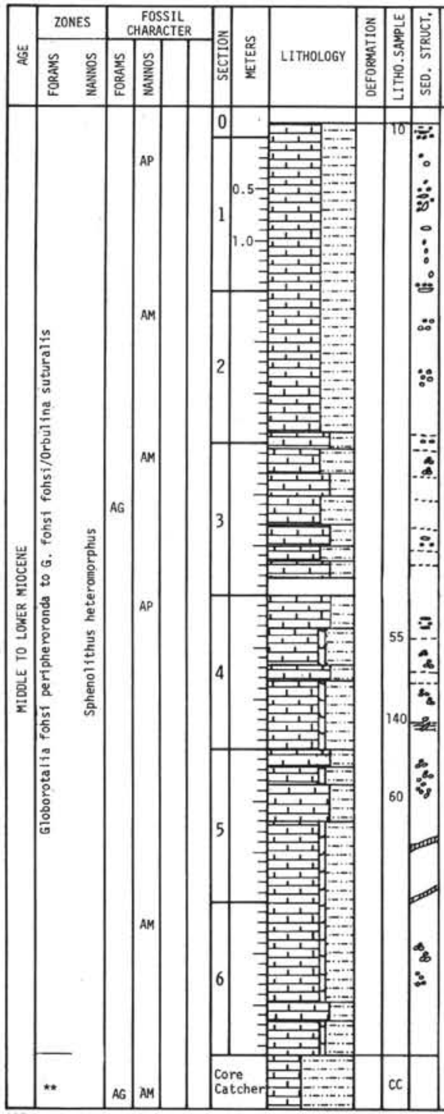
Carbon-Carbonate (DSDP)
4-20 (5.8, 0.3, 46)
6-20 (8.0, 0.1, 66)

Carbon-Carbonate (OG)
4-130 (7.2, 0.3, 58)
4-150 (6.6, 0.3, 53)

Grain Size (DSDP)
4-88 (1.1, 24.5, 74.4)
6-88 (4.1, 33.8, 62.2)

Explanatory notes in Chapter 1

Site 362 Hole Core 35 Cored Interval: 577.5-587.0 m



LITHOLOGIC DESCRIPTION

Greenish gray (5GY 6/1) to brown tinted greenish gray marl

Chalky marl

Marl 5GY 6/1

Marly chalk (5GY 6/1)
Greenish gray (5GY 5/1)
5GY 6/1
5GY 5/1
5GY 6/1
OG sample
Chalky marl
5GY 6/1

Marl 5GY 5/1

Chalky marl (5GY 6/1)

Olive gray (5Y 4/1) with small dark greenish gray zone (5GY 4/1)
Chalky marl to chalk
Marl
Chalky marl
5GY 6/1 to chalk
Greenish gray (5GY 5/1) marl

Foraminifera abundant
Burrows

Tinted brown marl (5GY 6/1-5/1)
Green gray chalky marl
Tinted brown marl (5GY 5/1)

MARLY NANNO CHALK AND FORAMINIFERA BEARING NANNO CHALK

Cyclic sedimentation:
Intercalation of lighter chalk or chalky marl zones (5GY 5/1) in marls, greenish gray (5GY 5/1) more or less tinted with brown, slightly burrowed foraminifera

TEXTURE
Silty clay:
≤2% Sand, 15% Silt, 85% Clay

COMPOSITION (SS)
Major components
30-60% Calcareous nannofossils
30-60% Clay minerals

Minor components
2-5% Forams
2-3% Carbonate unspecified
0-2% Quartz
2-4% Heavy minerals

Remark: Note presence of silty zones rich in foraminifera

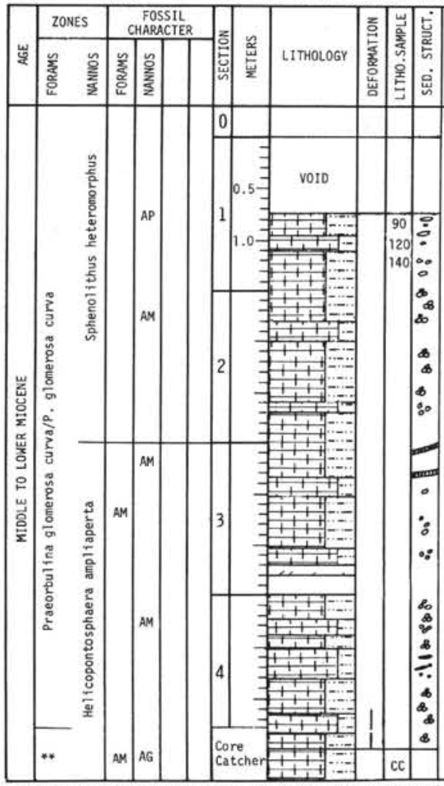
Carbonate Bomb: 1-23 to 30 cm = 68.2% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (8.3, 0.1, 68)
6-20 (6.6, 0.1, 54)

Grain Size (DSDP)
4-88 (7.5, 24.5, 68.1)
6-88 (3.3, 21.5, 75.1)

**Praeorbulina glomerosa curva/P. glomerosa curva

Site 362 Hole Core 36 Cored Interval: 596.5-606.0 m



LITHOLOGIC DESCRIPTION

Void

Marl
Chalky marl

Marl

Chalky marl

Marl

Chalky marl

Marl

Chalky marl

Marl
Chalky marl

OG sample

Marl
Chalky marl
Marl
Chalky marl

Marl
Chalk
Marl

FORAMINIFERA BEARING MARLY NANNO CHALK TO FORAMINIFERA BEARING NANNO CHALK

Cyclic sedimentation:
Fine marl, olive gray (5Y 5/1) to brownish gray (5YR 5/1), with intercalation of light olive gray (5Y 6/1) chalky marl; moderately burrowed, presence of abundant foraminifera, especially in the darker zones.

TEXTURE
Very light sandy, silty clay:
1-2% Sand, 30-40% Silt (nannoflora), 60-70% Clay

COMPOSITION (SS)
Major components
50-60% Calcareous nannofossils
20-30% Clay minerals

Minor components
Forams
Carbonate unspecified
T Pyrite
T- 2% Mica

Remark: The darker marly zones seem to be richer in foraminifera than the whiter zones

Carbonate Bomb: 1-83 to 85 cm = 56.8% $CaCO_3$

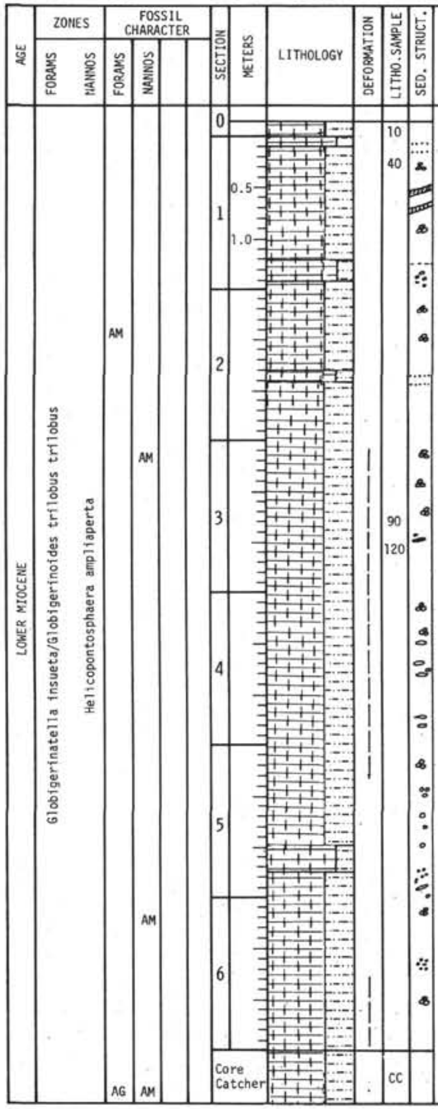
Carbon-Carbonate (DSDP)
4-20 (5.8, 0.1, 47)

Carbon-Carbonate (OG)
3-130 (6.9, 0.1, 56)
3-150 (7.3, 0.1, 59)

Grain Size (DSDP)
4-88 (9.3, 31.4, 59.3)

**Globigerinatella insueta/Globigerinoides trilobus trilobus
Explanatory notes in Chapter 1

Site 362 Hole Core 37 Cored Interval: 615.5-625.0 m



LITHOLOGIC DESCRIPTION

Marl
Chalky marl

Marl
5Y 5/2 to
5GY 6/1

Chalky marl

Marl
5Y 5/2 with
2.5Y 5/4
at 75-80 cm

Marl 5Y 5/2
(0-80 cm) to
2.5Y 5/2 (90-
150 cm)

Marl 2.5Y 4/2
dark grayish
brown, with
hematite
staining

Marl 2.5Y 4/2
dark grayish
brown

Chalky marl
2.5Y 5/2

Marl, dark
brownish
gray grading
to olive gray

FORAMINIFERAL MARLY NANNO CHALK TO FORAMINIFERAL BEARING MARLY NANNO CHALK TO FORAMINIFERAL NANNO CHALK

Less obvious cyclic sedimentation than above; essentially fine marl, olive gray (5Y 5/2) to dark brownish gray (2.5Y 5/2) in the lower part of the core. A few intercallations of chalky marl zones grayish brown (2.5Y 5/2). Moderately burrowed.

TEXTURE
Light sandy silty clay:
1-2% Sand, 30% Silt, 70% Clay

COMPOSITION (SS)
Major components
50-60% Calcareous nannofossils
30-40% Clay minerals

Minor components
5-15% Forams
3% Carbonate unspecified
<1% Pyrite
T-¯2% Quartz
2- 4% Tourmaline

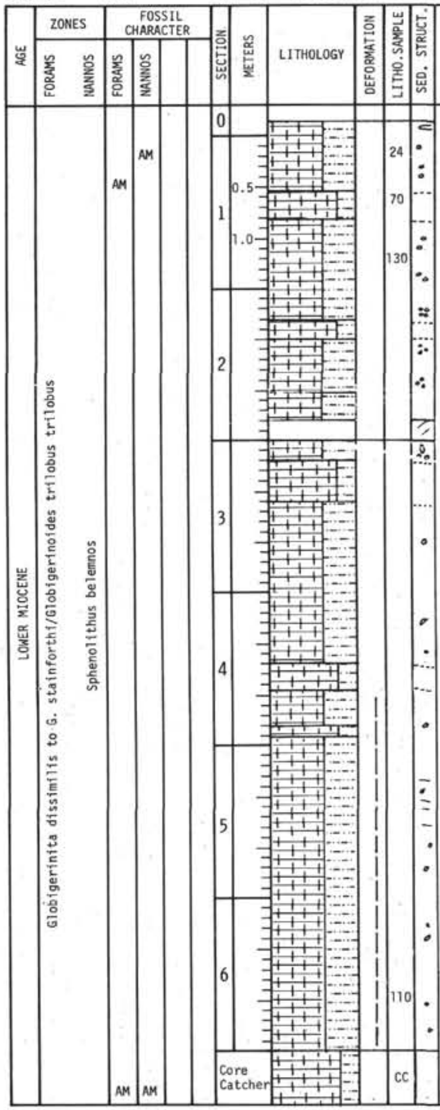
Remarks: 1) Net increase of terrigenous input
2) Decrease of burrow's intensity

Carbonate Bomb: 1-29 to 30 cm = 67.1% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (7.0, 0.1, 57)
6-20 (7.2, 0.1, 60)

Grain Size (DSDP)
4-88 (9.0, 25.5, 65.5)
6-88 (12.7, 32.3, 55.0)

Site 362 Hole Core 38 Cored Interval: 644.0-653.5 m



LITHOLOGIC DESCRIPTION

Marl
dark brownish
gray 2.5Y 5/2

Marly chalk
5GY 6/1

Marl
2.5Y 5/2

Marly chalk

Marl

OG sample
Marl

Marly chalk
5GY 6/1

Marl
2.5Y 5/2
with Fe
stains

Marly chalk

Fe stains

Marl,
dark brownish
gray 2.5Y 5/2

FORAMINIFERAL MARLY NANNO CHALK TO FORAMINIFERAL NANNO CHALK

Dark brownish gray (2.5Y 5/2) marl, with a few intercalations of greenish gray (5GY 6/1) brown tinted marly chalk, moderately burrowed, tendency to break along the Fe stains.

TEXTURE
Silty clay to sandy silty clay:
T-10% Sand, 20-50% Silt, 40-80% Clay

COMPOSITION (SS)
Major components
50-60% Calcareous nannofossils
10-25% Clay minerals
15-60% Forams

Minor components
1-10% Carbonate unspecified
2% Tourmaline
2% Pyrite

Remarks: 1) Abundant planktonic foraminifera
2) Great similarity to core 37
3) Presence of Coccospheres

Carbonate Bomb: 1-29 to 30 cm = 57% $CaCO_3$

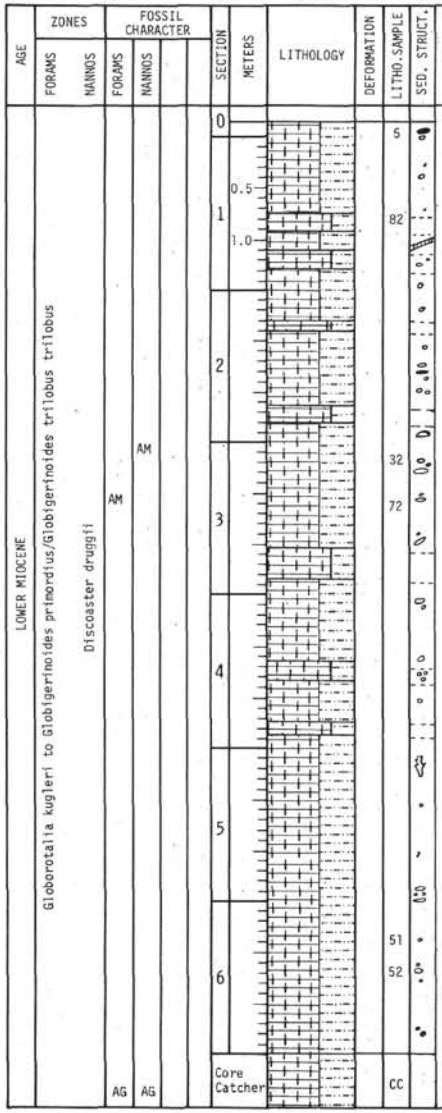
Carbon-Carbonate (DSDP)
4-20 (6.6, 0.1, 54)
6-20 (7.0, 0.2, 57)

Carbon-Carbonate (OG)
2-130 (7.7, 0.1, 63)
2-150 (6.6, 0.1, 54)

Grain Size (DSDP)
4-88 (12.2, 35.7, 52.1)
6-88 (2.4, 81.4, 16.2)

Explanatory notes in Chapter 1

Site 362 Hole Core 39 Cored Interval: 672.5-687.0 m



LITHOLOGIC DESCRIPTION

Greenish gray (5GY 5/1) marly chalk
Greenish gray
Lighter greenish gray (5GY 6/1)
5GY 6/1
5GY 6/1
5GY 6/1
5GY 5/1
5GY 6/1
5GY 5/1
5GY 6/1
5GY 5/1
5GY 6/1
5GY 5/1
5GY 6/1
Spiral burrow
5GY 5/1
5GY 6/1
5GY 5/1

FORAMINIFERAL MARLY NANNO CHALK TO FORAMINIFERAL NANNO CHALK

Greenish gray (5GY 5/1) marly chalk dominant with interbedded lighter greenish gray (5GY 6/1) marly chalk, mottled and burrowed throughout. Locally fractured.

TEXTURE
Light sandy, silty clay:
1-10% Sand, 20-50% Silt, 40-80% Clay

COMPOSITION (SS)
Major components
50-60% Calcareous nannofossils
10-20% Clay minerals
15-30% Forams

Minor components
5-10% Carbonate unspecified
1- 2% Pyrite
2% Quartz
2% Heavy minerals

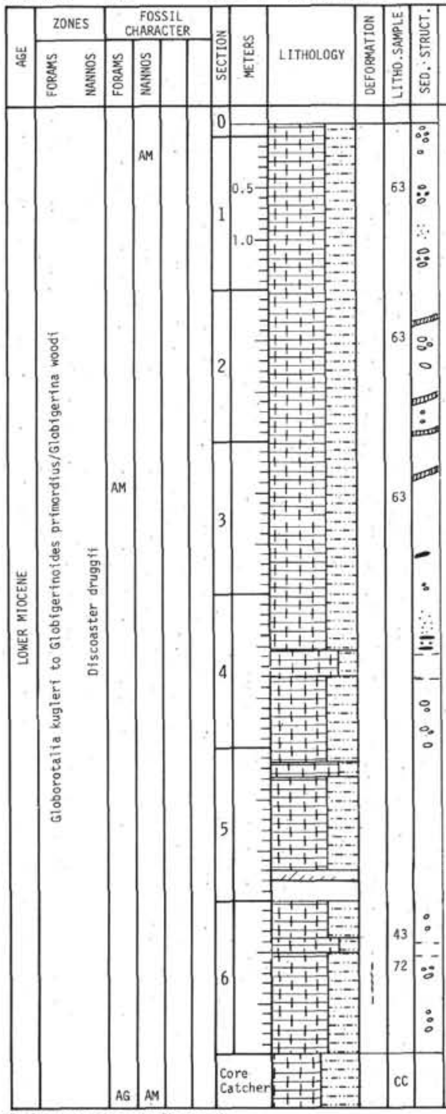
Remarks: 1) Abundance of foraminifera, apparently well preserved
2) Coccospheres present

Carbonate Bomb: 2-42 to 43 cm = 50.8% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (7.0, 0.2, 57)
6-20 (7.1, 0.1, 59)

Grain Size (DSDP)
4-88 (1.0, 27.4, 71.6)
6-88 (1.0, 31.2, 67.8)

Site 362 Hole Core 40 Cored Interval: 701.0-710.5 m



LITHOLOGIC DESCRIPTION

Marly chalk
Greenish gray (5GY 6/1)
Chalky zone
Lighter chalky zone
OG sample
Chalky zone

FORAMINIFERA BEARING MARLY NANNO CHALK TO FORAMINIFERA BEARING NANNO CHALK

Very uniform greenish gray (5GY 6/1) marly chalk, with only 3 short interbedded chalky zones. Abundant burrows = both darker and lighter than the surrounding sediment.

TEXTURE
Light sandy, silty, clay:
T-3% Sand, 5-20% Silt, 80-90% Clay

COMPOSITION (SS)
Major components
50-60% Calcareous nannofossils
30-40% Clay minerals

Minor components
3-5% Forams,
3% Carbonate unspecified
T-2% Pyrite
T-2% Quartz
T Heavy minerals

Remarks: 1) Discoasters very abundant
2) Coccospheres present
3) This core corresponds to core 1 of Site 362A

Carbonate Bomb: 1-23 to 30 cm = 37.4% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (6.3, 0.1, 51)
6-20 (5.7, 0.1, 47)

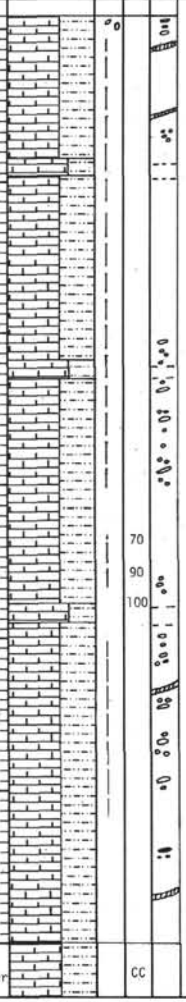
Carbon-Carbonate (OG)
5-130 (6.8, 0.2, 55)
5-150 (6.4, 0.2, 52)

Grain Size (DSDP)
4-88 (3.1, 31.3, 65.6)
6-88 (1.1, 26.3, 72.5)

Explanatory notes in Chapter 1

Site 362 Hole Core 41 Cored Interval: 729.5-739.0 m

AGE	ZONES		FOSSIL CHARACTER				SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	SED. STRUCT.
	FORAMS	NANNOS	FORAMS	NANNOS								
LOWER MIOCENE (Forams) - UPPER OLIGOCENE (Nannos)	Globorotalia kugleri to Globigerinoides primordius/Globigerina euapertura to Globigerina woodi	Triquetrorhabdulus carinatus					0					
				AM			1	0.5 1.0				
				AP			2					
			AP	AM			3					
				AM			4				70 90 100	
				AP			5					
				AM			6					
			AG	AG			Core Catcher				CC	



LITHOLOGIC DESCRIPTION

Chalky zone

5GY 6/1

Greenish gray (5G 6/1) marly chalk

5GY 6/1

MARLY NANNO CHALK TO FORAMINIFERA BEARING MARLY NANNO CHALK

Uniform greenish gray (5G 6/1) marly chalk, with only three very short more chalky zones 5GY 6/1. Heavily burrowed.

TEXTURE
Silty clay: T% Sand, 10-40% Silt (Coccoliths and Discoasters), 60% Clay

COMPOSITION (SS)
Major components
55-60% Calcareous nannofossils
30-40% Clay minerals

Minor components
2-5% Forams
2% Pyrite
T Quartz
T Tourmaline

Remarks: 1) Less chalky than the precedent cores
2) Coccospheres present

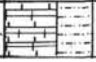
Carbonate Bomb: 1-29 to 30 cm = 56.6% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (6.7, 0.1, 55)
6-20 (6.5, 0.1, 53)

Grain Size (DSDP)
4-90 (3.2, 30.0, 66.7)
6-84 (1.5, 18.3, 80.3)

Site 362 Hole Core 42 Cored Interval: 758.0-767.5 m

AGE	ZONES		FOSSIL CHARACTER				SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	SED. STRUCT.
	FORAMS	NANNOS	FORAMS	NANNOS								
UPPER OLIGOCENE TO LOWER MIOCENE	G. kugleri to G. primordius/ G. euapertura	Triquetrorhabdulus carinatus	AG	AP			Core Catcher				CC	



LITHOLOGIC DESCRIPTION

FORAMINIFERA BERAING LIGHT MARLY NANNO CHALK

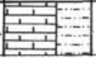
TEXTURE
Light sandy, silty, clay:
2-3% Sand, 60% Silt, 40% Clay

COMPOSITION (SS)
Major components
60% Calcareous nannofossils
≤30% Clay minerals

Minor components
5% Forams
3% Carbonate unspecified
1% Pyrite

Site 362 Hole Core 43 Cored Interval: 786.5-796.0 m

AGE	ZONES		FOSSIL CHARACTER				SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE
	FORAMS	NANNOS	FORAMS	NANNOS							
UPPER OLIGOCENE/LOWER MIOCENE	Globigerina ciperoensis cip./ G. euapertura	Triquetrorhabdulus carinatus	AG	AM			Core Catcher				CC



LITHOLOGIC DESCRIPTION

FORAMINIFERA BEARING MARLY NANNOFOSSIL CHALK

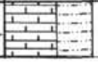
TEXTURE
Light sandy, silty, clay:
2-3% Sand, ≤60% Silt, ≤40% Clay

COMPOSITION (SS)
Major components
50% Calcareous nannofossils
30-40% Clay minerals
10% Forams

Minor components
3.0% Carbonate unspecified
0.5-1.0% Pyrite

Site 362 Hole Core 44 Cored Interval: 796.0-805.5 m

AGE	ZONES		FOSSIL CHARACTER				SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE
	FORAMS	NANNOS	FORAMS	NANNOS							
UPPER OLIGOCENE	Globigerina ciperoensis cip./G. euapertura	Sphenolithus ciperoensis		AM			Core Catcher				CC



LITHOLOGIC DESCRIPTION

MARLY NANNO CHALK

TEXTURE
Clayey silt:
<1% Sand, 60% Silt (Coccoliths and Discoasters), 40% Clay

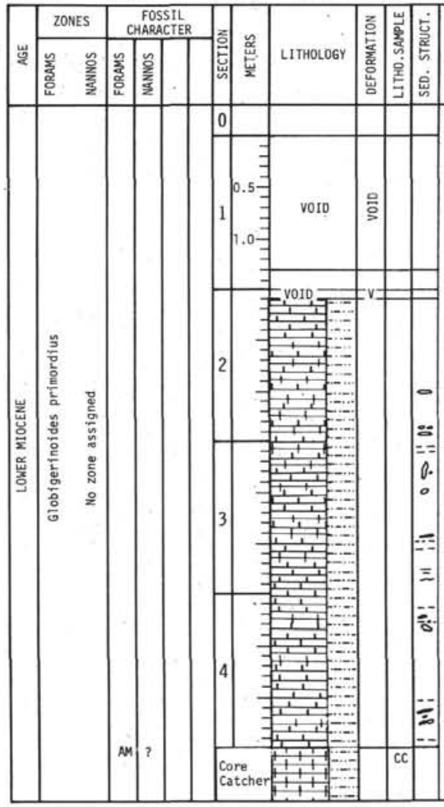
COMPOSITION (SS)
Major components
<50% Calcareous nannofossils
≤50% Clay minerals

Minor components
<1% Forams
~2% Quartz

Remark: Nannoflora obviously dissolved (abundance of large resistant forms)

Explanatory notes in Chapter 1

Site 362 Hole A Core 1 Cored Interval: 696.0-701.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFERA BEARING MARLY NANNO CHALK

Olive gray (5Y 4/2 to 2.5Y 5/2) marl, obviously burrowed, with very few short, lighter, more chalky zones.

TEXTURE
Very fine clayey silt:
2-3% Sand, >70% Silt (Coccoliths and Discoasters), <30% Clay

COMPOSITION (SS)
Major components
50% Calcareous nannofossils
25-30% Clay minerals
5-10% Forams

Minor components
2-3% Carbonate unspecified
T Mica

Remark: The core was pulled during working operations down to last 362 site depth, but sampled well above the depth it was pulled. The core was not sampled in core lab for this reason.

Carbon-Carbonate (DSDP)
1-80 (8.0, 0.1, 66)

Chalky zone

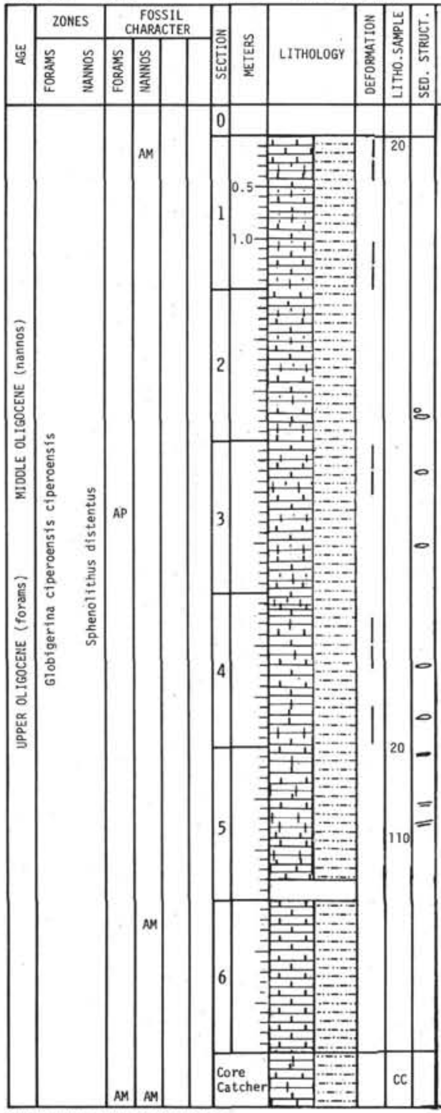
Chalky zone

Chalky zone

Greenish gray (5GY 6/1)

Light gray (N7)

Site 362 Hole A Core 2 Cored Interval: 796.0-805.5 m



LITHOLOGIC DESCRIPTION

MARLY NANNO CHALK TO FORAMINIFERA BEARING MARLY NANNO CHALK

Very uniform, dark greenish gray, to dark olive gray, to dark grayish brown. Marl, faintly mottled and streaked throughout by burrows.

TEXTURE
Silty clay:
0.5-1.0% Sand, 40% Silty, 60% Clay

COMPOSITION
Major components
40-50% Calcareous nannofossils
40-50% Clay minerals

Minor components
5% Forams,
3-5% Carbonate unspecified
T Pyrite
1-4% Quartz
2% Tourmaline

Remark: Dissolution obvious on nannoflora

Carbonate Bomb: 1-23 to 30 cm = 45.35% $CaCO_3$

Carbon-Carbonate (DSDP)
4-20 (4.8, 0.1, 39)
6-25 (4.6, 0.1, 38)

Grain Size (DSDP)
4-117 (0.3, 17.4, 82.3)
6-89 (2.3, 20.2, 77.5)

Dark greenish gray (5GY 4/1) marl

Tending to dark olive gray (5Y 4/1)

Dark greenish gray (5GY 4/1) with dark grayish brown (10YR 4/2)

OG sample

Grayish brown (10YR 4/2) with dark grayish green (5GY 4/1)

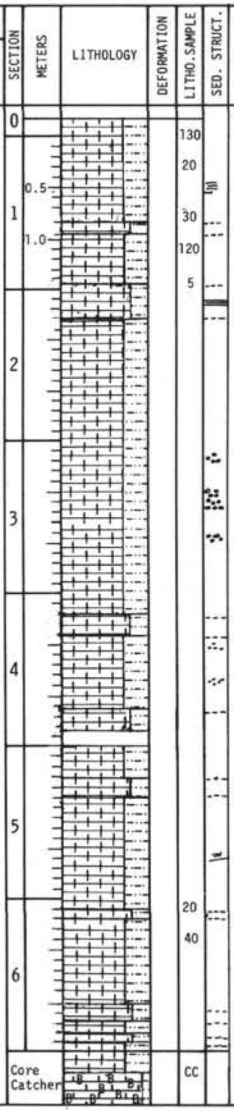
Explanatory notes in Chapter 1

Site 362 Hole A Core 3 Cored Interval: 834.0-843.5 m

AGE: MIDDLE OLIGOCENE

ZONES
FORAMS: Globorotalia opima opima
NANNOS: Sphenolithus distentus

FOSSIL CHARACTER
FORAMS: AP, AM
NANNOS: AM, AM, AP, AM, AM



LITHOLOGIC DESCRIPTION

5Y 4/1
Chalky zone
5Y 4/2 dark gray chalk
Laminations
5Y 4/2 dark gray green
10YR 4/2 dark brownish gray
5Y 4/2
Brownish
Greenish
Burrows
Fe oxide
Greenish
Slightly chalky 5Y 6/1
More chalky
OG sample
More chalky
Greener
Lighter color
Lighter color
Lighter color

<u>FORAMINIFERA BEARING BRAARUDOSPHAERA CHALK TO MARLY NANNO CHALK</u>

Dominant dark brownish gray (10YR 4/2) to dark olive gray (5Y 4/2) marl, with a few interbedded more chalky zones (5Y 6/1). Marls well burrowed. Chalk burrowed at top only.

<u>TEXTURE</u>
Very fine clayey silt:
3-5% Sand, 70% Silt (Coccoliths and Discoasters), 25% Clay

<u>COMPOSITION</u>
<u>Major components</u>
50-70% Calcareous nannofossils
15-30% Clay minerals
10% Forams

<u>Minor components</u>
1% Pyrite
5% Carbonate unspecified
2-5% Quartz
<2% Mica
≤2% Tourmaline

Remarks: 1) The core catcher sediment contain 25-30% Braarosphaera pentaliths (entire core broken)
2) Presence of Erosion contacts

<u>Carbon-Carbonate (DSDP)</u>
4-20 (5.2, 0.1, 43)
6-20 (6.7, 0.1, 55)

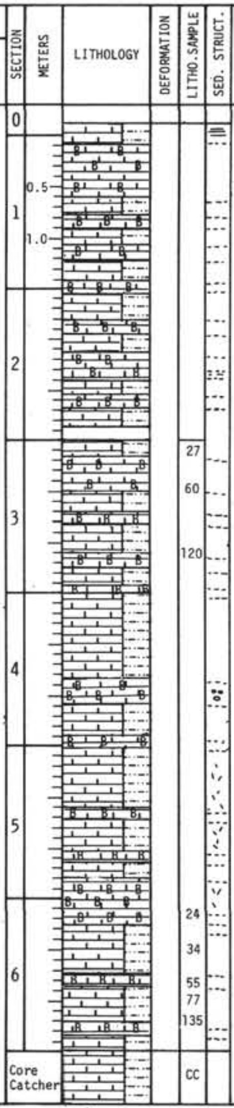
<u>Grain Size (DSDP)</u>
4-85 (0.6, 21.3, 78.1)

Site 362 Hole A Core 4 Cored Interval: 872.0-881.5 m

AGE: MIDDLE OLIGOCENE

ZONES
FORAMS: Globigerina ampliapertura
NANNOS: Sphenolithus predistentus

FOSSIL CHARACTER
FORAMS: AP, CM
NANNOS: AM, AM, AM, AM, AP, AM, AM



LITHOLOGIC DESCRIPTION

Marl 5GY 5/1
Limestone burrowed 5GY 6/1
Marl
Limestone
Marl brownish chalk
Marl limestone
Marl
Limestone
Marl
Limestone
Burrows
Limestone
Marl
Limestone
OG sample
Marl
Limestone
5GY 7/1
5GY 5/1
Limestone
5GY 7/1
5GY 6/1
5GY 6/1
Marl 5GY 5/1
5B 7/1
5B 5/1
Marl
Chalk
Marl 5GY 5/1
Chalk
5GY 5/1
5GY 6/1
5GY 5/1
Limestone
5B 5/1
5GY 4/1
5GY 4/1
Marl
5YR 7/1
5YR 4/1
Chalk
5YR 4/1

<u>BRAARUDOSPHAERA BEARING MARLY NANNO CHALK TO BRAARUDOSPHAERA CHALK TO FORAMINIFERA BEARING LIGHT MARLY NANNO CHALK</u>

Cyclic sedimentation = greenish gray (5GY 4/1 to 5GY 5/1) marl, to brownish gray (5YR 5/1 to 5YR 4/1), with intercalation of 20 limestone zones (light bluish gray [5B 7/1] or bluish white [5B 8/1]). Intensively burrowed. Presence of erosion contacts.

<u>TEXTURE</u>
Clayey silt:
1-2% Sand, 50% Silt (pentaliths), 50% Clay

<u>COMPOSITION (SS)</u>
<u>Major components</u>
15-60% Coccoliths
2-35% Braarudosphaera
5-10% Forams
3-20% Clay minerals

<u>Minor components</u>
5-7% Carbonate unspecified
1% Pyrite
<1% Mica
≤1% Quartz
T-2% Tourmaline

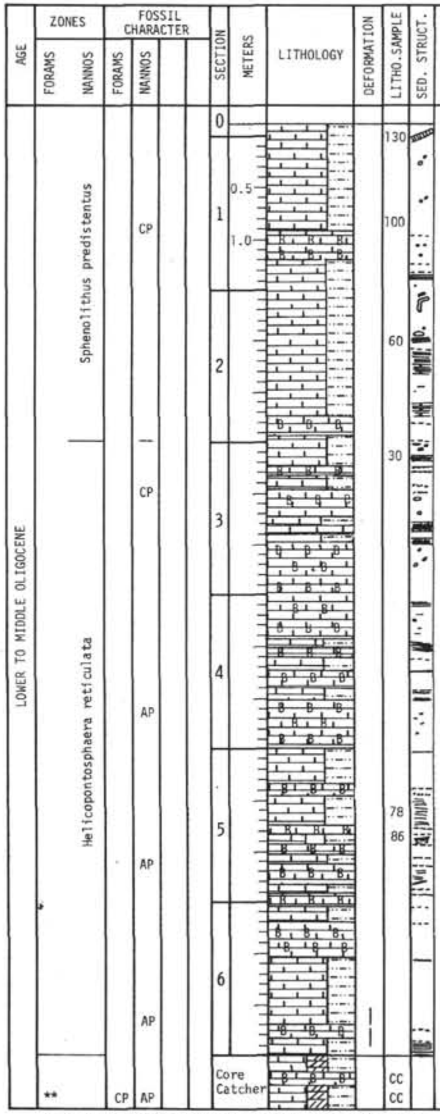
Remark: Some of the Braarudosphaera chalk zones contain 95% of Braarudosphaera bigelowi, among which 30% are complete pentaliths

Carbonate Bomb: 1-0 to 1 cm = 38.2% $CaCO_3$

<u>Carbon-Carbonate (DSDP)</u>
4-80 (10.4, 0.1, 86)
6-78 (10.3, 0.0, 86)

Explanatory notes in Chapter 1

Site 362 Hole A Core 5 Cored Interval: 910.0-919.5 m



LITHOLOGIC DESCRIPTION

5YR 5/1
Brownish
gray

Light gray
(N9)
Dark gray
(N4)
Light bluish
gray (5B 5/1)

Medium dark
gray (N4)
to medium
gray (N5-N6)

Greenish gray
(5G 7/1)
5B 7/1 Marl
Marl
Marl
5B 7/1
5B 5/1
Marl
Marl
Chalk 5Y 7/2
5G 8/1
5G 8/1

Erosional
contact
Marl With fine
laminations

Marl

Stylolites

Marl

5G 8/1 Sandy
layer
Marl
5G 8/1
Marl
5G 8/1
Marl 5G 7/1
Marl 5G 5/1 Dark Zoophycos

Marl 5GY 5/1

Bluish white
5B 9/1 Erosional
5B 8/1 contact

Greenish gray (5G 5/1)
to light greenish gray (5G 7/1)
5B 5/1
5GY 5/1 to 5B 7/1 light
bluish gray

BRAARUDOSPHAERA BEARING MARLY CHALK, HIGHLY DOLOMITIZED TO BRAARUDOSPHAERA CHALK

Cyclic sedimentation:
Appearance of brownish gray (5YR 5/1), gray (N4, N5) or greenish gray (5B 6/1) marls with light gray (5Y 7/2, 5G 8/1) to bluish white limestone. Marly layers highly burrowed and presenting locally fine laminations.

TEXTURE
Very fine clayey silt:
2% Sand, ≈60% (Coccoliths and pentaliths), 40% Clay

COMPOSITION (SS)
Major components
20-50% Calcareous nannofossils
30% Clay minerals
2-35% Dolomite rhombs
2-80% Braarudosphaera

Minor components
2- 5% Forams
2-10% Quartz
T Pyrite

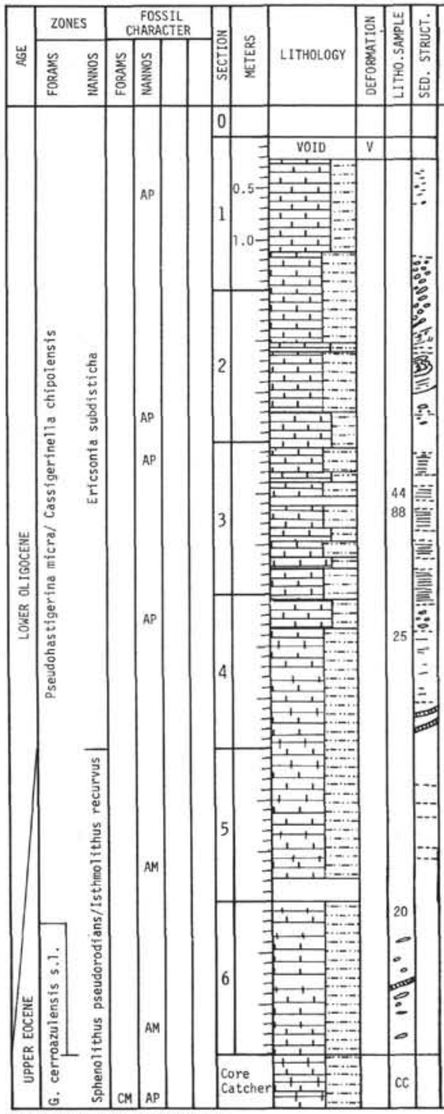
Remarks: 1) The Braarudosphaera chalk is almost entirely composed of Braarudosphaera pentaliths (≥80%), without any other or few Coccoliths. Traces of recalcification.
2) The dolomitic rhombs are well crystallized and all of the same size
3) More chalk (50-70% of the core) than in the previous cores.

Carbonate Bomb: 1-82 to 84 cm = 33.2% $CaCO_3$

Carbon-Carbonate (DSDP)
4-137 (10.7, 0.1, 88)
6-115 (11.0, 0.1, 91)

** Pseudohastigerina micra/Cassigerinella chipolensis

Site 362 Hole A Core 6 Cored Interval: 929.0-938.5 m



LITHOLOGIC DESCRIPTION

Burrows
5B 7/1
5B 6/1
5B 7/1

10YR 5/1
Burrows
inclined 20°

Slump
contact and
fault
N6-N7
slumping

Burrows
N6-N7

10YR 5/1
N6-N5
10YR 5/1
N6-N5
10YR 5/1
N6-N5
10YR 5/1
N6-N5
10YR 5/1

N7-N6
medium gray

5G 6/1
Greenish gray

5G 5/1 light
greenish gray
with Zoophycos

5G 6/1 light
greenish gray
5G 5/1

5G 6/1
5G 5/1
5G 6/1

OG sample
5G 5/1 greenish
gray

5G 6/1 light
greenish gray

MARLY NANNO CHALK DOMINANT WITH CALCAREOUS NANNO CHALK AND FORAMINIFERA BEARING MARLY NANNO CHALK

Dominantly marly, less hard than previous cores - gray brown (10YR 5/1), to greenish gray (5G 6/1), to light greenish gray (5G 5/1) marls, heavily burrowed, with intercalations of a very few lighter (light gray [N7] or medium light gray [N6]) more chalky zones. Presence of slumping structures along core (cf. Section 2), and laminated marly zones.

TEXTURE
Very fine silty clay or clayey silt:
1-2% Sand, ≈50% Silt (Coccoliths),≈50% Clay

COMPOSITION
Major components
40-50% Calcareous nannofossils
25-30% Clay minerals
≤25% Carbonate unspecified

Minor components
5% Forams
1-2% Quartz
1-2% Mica
T-2% Tourmaline and Zeolite

Remark: Transitional zone between Braarudosphaera chalk and the dominantly more marly and less hard sediments of Eocene time. The sediments are more homogeneous.

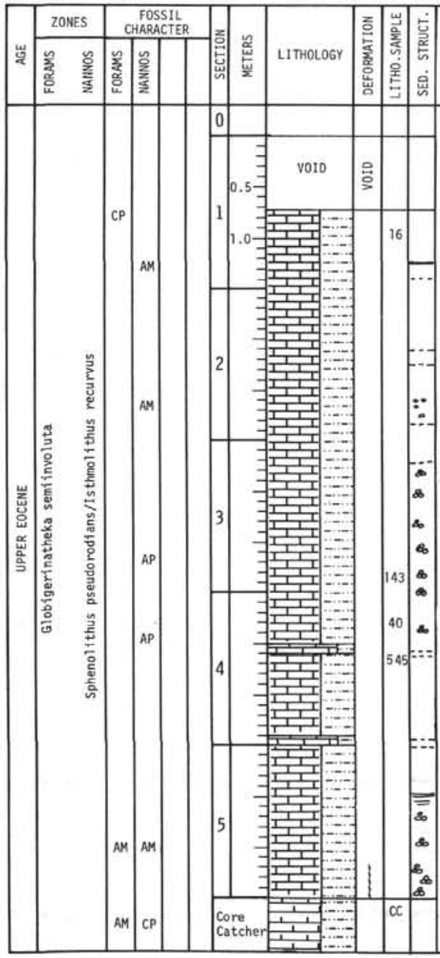
Carbonate Bomb: 1-58 to 59 cm = 67.1% $CaCO_3$

Carbon-Carbonate (DSDP)
4-29 (8.7, 0.1, 71)
6-145 (9.5, 0.1, 78)

Grain Size (DSDP)
4-30 (2.8, 29.2, 68.0)

Explanatory notes in Chapter 1

Site 362 Hole A Core 7 Cored Interval: 948.0-957.5 m



LITHOLOGIC DESCRIPTION

10YR 5/2

Sharp contact
5G 6/1

10YR 5/2 with
gray spots and
red halves
5G 6/1

Prominent
burrows

10YR 5/2 and
5G 6/1

5G 6/1

5G 7/1

N6 gray
streaks

5G 6/1

Zoophycos

5G 6/1 locally
tinted red

MARLY NANNO CHALK/LIMESTONE TO CALCAREOUS NANNO CHALK/LIMESTONE

Greenish gray (5G 6/1) and grayish brown (10YR 5/2), locally red tinted endurated marl, heavily burrowed and heavily abundant foraminifera. Presence of 2 minor lenses of marly limestone.

TEXTURE
Very fine silty clay on clayey silt:
<1% Sand, 60% Silt, 40% Clay

COMPOSITION
Major components
30-50% Calcareous nannofossils
30% Clay minerals
40% Carbonate unspecified

Minor components
<1% Dolomite rhombs
1-2% Quartz
2% Forams

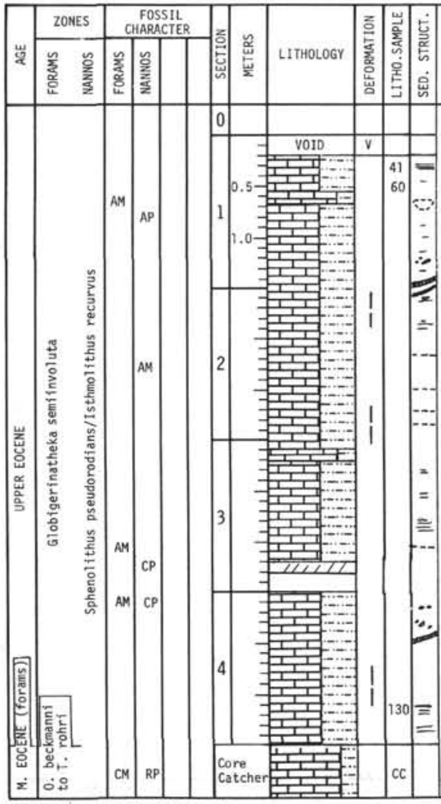
Remarks: 1) The abundant unspecified carbonate are pieces of dissolved and recalcified calcareous nannofossils (placoliths, sphenoliths). The degree of diagenesis and thus the difficulty of identifying the nannofossil remains increases regularly from Core 5 to the basis of the Core.
2) The sediments are increasingly rich in marlstones, with small interbedded limestone zones.

Carbonate Bomb: 1-140 to 141 cm = 67.6% $CaCO_3$

Carbon-Carbonate (DSDP)
4-54 (10.1, 0.1, 83)

Grain Size (DSDP)
4-42 (5.2, 48.0, 46.8)

Site 362 Hole A Core 8 Cored Interval: 967.0-976.5 m



LITHOLOGIC DESCRIPTION

5G 5/1

5G 7/1
light bluish
gray
5G 6/1

Zoophycos

5G 5/1

5G 6/1

5G 5/1
5G 6/1

5G 7/1

5G 6/1

OG sample

Zoophycos

5G 7/1 light
greenish gray
marly limestone

Gray streaks

MARLY LIMESTONE TO LIMESTONE

Mostly greenish gray (5G 6/1-5G 7/1) marly limestone, well burrowed and mottled. A few darker greenish gray (5G 5/1) zones.

TEXTURE
Very fine silty clay/clayey silt:
<5% Sand, 70-80% Silt very fine (pentaliths and sphenoliths fragments),
15-20% Clay

COMPOSITION
Major components
20-30% Calcareous nannofossils
10-20% Clay minerals
30-40% Carbonate unspecified
10-25% Forams

Minor components
2-5% Quartz
1% Heavy minerals

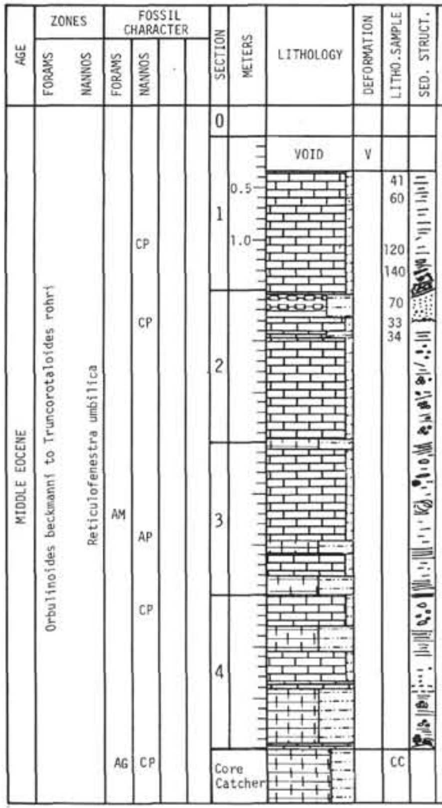
Remark: The limestone is a nanno chalk modified by diagenesis (dissolution, recalcification...) = only placolith, sphenolith and pentalith fragments can be recognized.

Carbonate Bomb: 1-76 to 77 cm = 82.4% $CaCO_3$

Carbon-Carbonate (DSDP)
4-40 (8.7, 0.1, 72)

Explanatory notes in Chapter 1

Site 362 Hole A Core 9 Cored Interval: 995.5-1005.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFIERAL CALCAREOUS NANNO CHALK/ LIMESTONE TO CALCAREOUS SILTSTONE TO MARLY LIMESTONE

Light bluish gray (5B 7/1) with very fine parallel laminations streaked with white, cross beds
Burrows (0.5 cm, thick dark greenish gray laminae plus sandy layer at basis)

5B 5/1 to N7
Contact with 33 cm calcarenite above

5G 7/1, burrowed nanno foram limestone

5G 6/1

Greenish gray (5G 6/1)

5G 7/1

Greenish gray (5G 6/1)
5G 6/1
5G 6/1
5GY 4/1

Small calcarenite layer 5G 8/1

5G 6/1
5G 4/1

5B 9/1 bluish white streaked with 5B 7/1, light bluish gray limestone

Light bluish gray (5B 7/1) limestone, grading to light greenish gray (5G 8/1) bluish white (5B 9/1) calcareous sandstone locally, and to a light greenish gray nanno foram, burrowed massive limestone (Sections 1, 2, 3) and finally to a greenish gray (5G 6/1) marly limestone (Section 4).

TEXTURE
Light sandy, clayey silt:
3-5% Sand, 50-60% Silt, 30-40% Clay

COMPOSITION (SS)
Major components
50-60% Carbonate unspecified
20-70% Calcareous nannofossils
20% Clay minerals
20% Forams

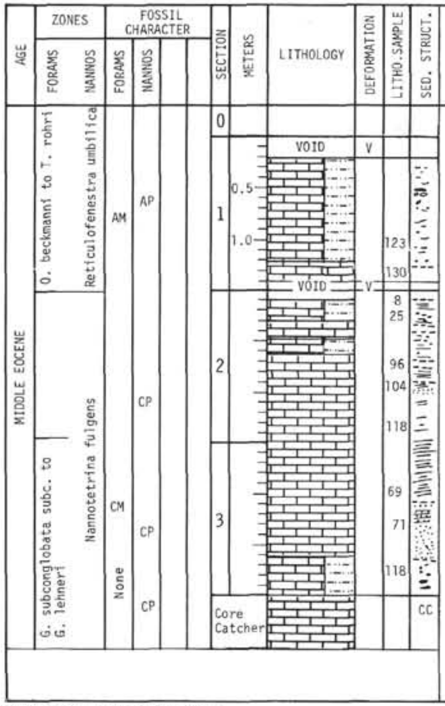
Minor components
<1% Pyrite
1-2% Quartz
0-5% Heavy minerals (Tourmaline, Chlorite, Diopside)

Carbonate Bomb: 1-133 to 134 cm = 94.6% $CaCO_3$

Carbon-Carbonate (DSDP)
4-130 (8.2, 0.1, 68)

Grain Size (DSDP)
4-120 (15.5, 41.6, 42.8)

Site 362 Hole A Core 10 Cored Interval: 1024.0-1033.5 m



Explanatory notes in Chapter 1

LITHOLOGIC DESCRIPTION

FORAMINIFERAL CALCAREOUS NANNO CHALK OR LIMESTONE

Greenish gray 5G 5/1, mottled and burrowed

5G 8/1
5G 5/1
5G 8/1
5G 5/1
5G 8/1

Turbidite with very fine laminations at the base 5G 8/1

Fairly massive coarse calcarenite and finer laminated at the top

5G 5/1 marl

Greenish gray (5G 5/1) indurated burrowed marl with interlayers of 5G 8/1 to 5B 8/1 greenish and bluish white laminated limestones and calcarenites. Presence of a large (1.5 m) turbidite sequence, with coarse calcarenite at the base and then fine laminated calcarenite or limestone.

TEXTURE
Light sandy, clayey, silt:
3-5% Sand, 6-80% Silt (fine carbonate), 20-30% Clay

COMPOSITION (SS)
Major components
60-75% Carbonate unspecified
15-20% Forams
5% Calcareous nannofossils

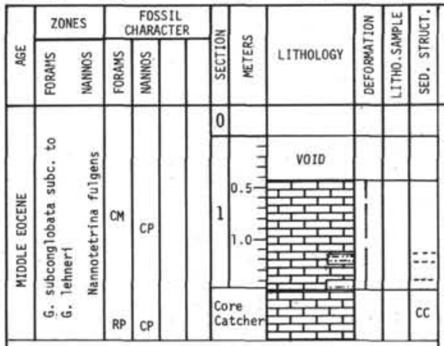
Minor components
1-2% Quartz
T Mica
T-2% Zoisite, Tourmaline, Epidote

Remark: Strong diagenesis gives a great amount of unsepcified carbonates (which in fact are fragments of broken pentaliths, sphenoliths, placoliths, etc.

Carbonate Bomb: 1-67 to 68 cm = 62.50% $CaCO_3$

Carbon-Carbonate (DSDP)
2-127 (9.9, 0.1, 82)

Site 362 Hole A Core 11 Cored Interval: 1062.0-1071.5 m



LITHOLOGIC DESCRIPTION

FORAMINIFERAL CALCAREOUS NANNO CHALK/ LIMESTONE OR MARLY LIMESTONE

Bluish white (5B 9/1, to light greenish gray (5G 8/1) limestones cobbles streaked with darker or lighter burrows. Light brownish gray at the base.

TEXTURE
Sandy, clayey silt:
10% Sand, 80% Silt, 10% Clay

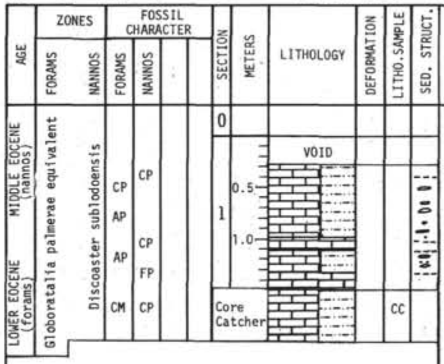
COMPOSITION (SS)
Major components
60% Carbonate unspecified
15% Forams
5% Calcareous nannofossils

Minor components
<20% Clay minerals
T Quartz

Remark: Very strong diagenesis

Carbonate Bomb: CC = 84.5% $CaCO_3$

Site 362 Hole A Core 12 Cored Interval: 1071.5-1081.0 m



LITHOLOGIC DESCRIPTION

Greenish cobbles
5YR 5/2 marl
5B 5/1
5YR 5/2
5B 5/1

MARLY LIMESTONE TO FORAM NANNO LIMESTONE

Reddish gray indurated marl, interlayered with bluish white (5B 9/1) limestone, well mottled with burrows.

TEXTURE
Light sandy, clayey silt:
5% Sand, 80% Silt, 15% Clay

COMPOSITION (SS)
Major components
30-75% Carbonate unspecified
10-15% Forams
10% Calcareous nannofossils

Minor components
10-40% Clay minerals

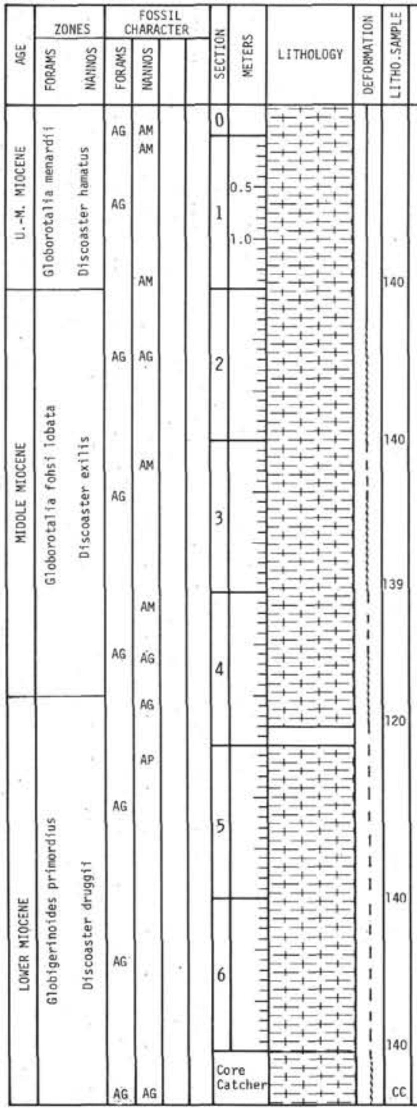
Remark: The unspecified carbonate are fragments of placoliths, sphenoliths....., strongly affected by diagenesis. Effects of diagenesis are also reflected in the silicification of the sediment (e.g., interpenetrated white layer), and thus in a diminution of the $CaCO_3$ content.

Carbonate Bomb: CC = 41.38% $CaCO_3$

Carbon-Carbonate (DSDP)
1-80 (9.8, 0.1, 82)

Explanatory notes in Chapter 1

Site 363 Hole Core 1 Cored Interval: 31.0-40.5 m



LITHOLOGIC DESCRIPTION

5G 8/1-
5B 9/1
5B 7/1
5Y 8/1
5Y 8/1
2.5Y 7/4
5Y 8/1
2.5Y 7/4
5Y 8/1
2.5Y 7/4
↓
0 G
2.5Y 7/4
5Y 8/1
2.5Y 7/4
5Y 8/1
2.5Y 7/4
5Y 8/1
2.5Y 7/4
2.5Y 6/4

FORAM-NANNO OOZE
Sections 1 and 2 light greenish gray (5G 8/1) and light bluish gray (5B 7/1). Beginning in Section 3, patches of light yellowish brown (2.5Y 6/4) and pale yellow (2.5Y 7/4) alternating with the greenish grays and becoming predominant in Sections 4-6. Occasional small pyritic spots, Sections 1-3. Core mostly heavily disturbed by drilling. No burrows evident.

MINERALOGY (Average from SS)
1% Quartz
8% Clay
10% Carbonate unspecified
T Fe-oxide
17% Forams
63% Nannos
0- 1% Fish remains
T Zircon

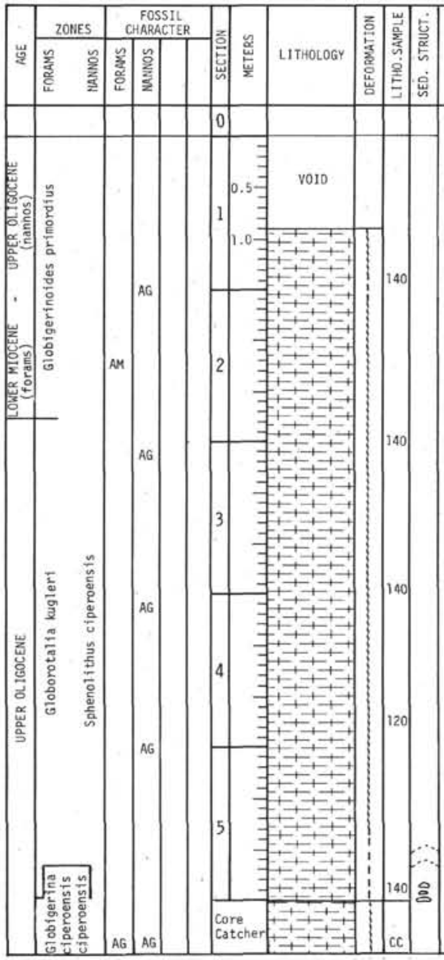
TEXTURE (Average from SS)
19.3% Sand, 54.3% Silt, 26.4% Clay

Carbon-Carbonate (DSDP)
4-20 (9.6, 0.1, 80)
6-20 (8.6, 0.0, 71)

Carbon-Carbonate (OG)
4-130 (7.8, 0.1, 64)
4-150 (8.1, 0.1, 67)

Grain Size (DSDP)
4-88 (8.1, 35.9, 56.0)
6-88 (12.8, 28.2, 59.1)

Site 363 Hole Core 2 Cored Interval: 50.0-59.5 m



LITHOLOGIC DESCRIPTION

2.5Y 7/2
2.5Y 7/2

FORAM-NANNO OOZE
Very fine gray (2.5Y 7/2) to brownish gray (2.5Y 7/4). Moderately to strongly deformed by drilling.

MINERALOGY (Average from SS)
2% Quartz
6% Clay
2% Carbonate unspecified
T Fe-oxide
18% Forams
71% Nannos
0- 1% Fish remains
T Zircon

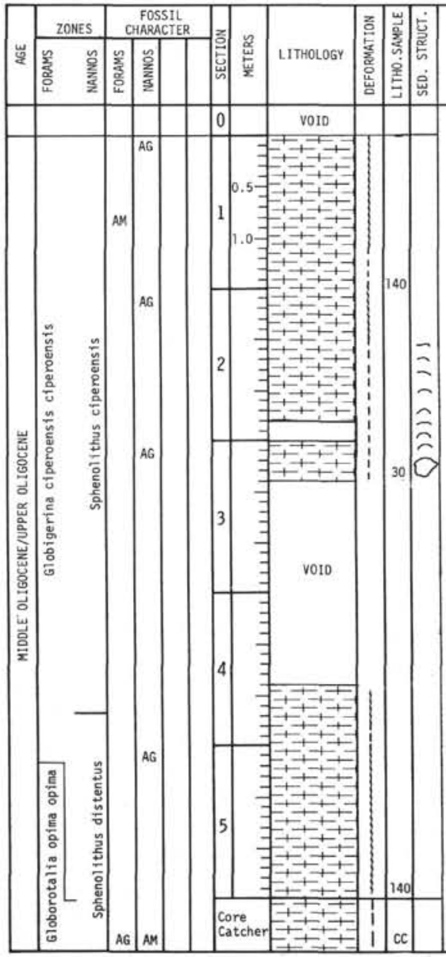
TEXTURE (Average from SS)
19% Sand, 54% Silt, 27% Clay

Carbon-Carbonate (DSDP)
4-20 (8.2, 0.0, 68)

Grain Size (DSDP)
4-88 (7.3, 30.3, 62.4)

Explanatory notes in Chapter 1

Site 363 Hole Core 3 Cored Interval: 69.0-78.5 m



LITHOLOGIC DESCRIPTION

FORAM-NANNO OOZE
Very fine light yellow brown (10YR 6/4). Light gray (2.5Y 7/2) and brownish gray (2.5Y 7/4) through most of core, with brown patch (7.5YR 5/4) in Section 3. Moderately to strongly deformed by drilling.

MINERALOGY (Average from SS)
4% Quartz
14% Clay
0% Carbonate unspecified
T Fe-oxide
18% Forams
61% Nannos
T Fish remains
T Zircon

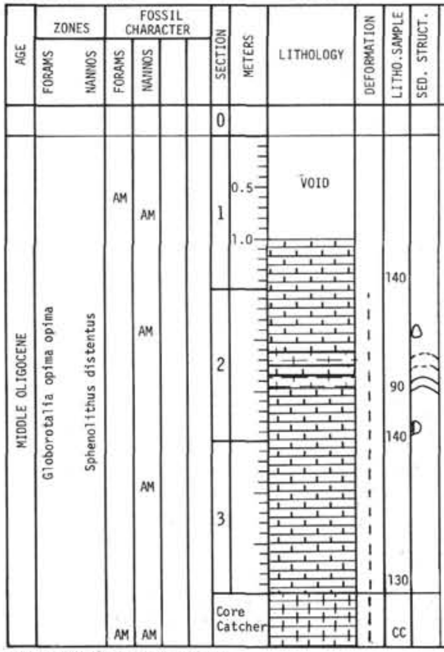
TEXTURE (Average from SS)
20% Sand, 41% Silt, 39% Clay

0 G

Carbon-Carbonate (OG)
2-130 (7.4, 0.1, 61)
2-150 (7.7, 0.1, 64)

7.5YR 5/4

Site 363 Hole Core 4 Cored Interval: 88.0-97.5 m



LITHOLOGIC DESCRIPTION

NANNO CHALK INTERLAYERED WITH "BRAARUDOSPHAERA" OOZE
Very fine brownish gray (2.5Y 7/4) light gray (2.5Y 7/2) and yellow brown (10YR 6/4) chalk. Thin layers of light bluish gray (5B 7/1) "Braarudosphaera" ooze. Slight deformation.

MINERALOGY (Average from SS)

2.5Y 7/4

Chalks
1.5% Quartz
11.0% Clay
T Opaques

10YR 6/4

6.0% Forams
73.0% Nannos
T Chlorite

5B 7/1

5B 7/1

"Braarudosphaera" Ooze
2% Quartz
10% Clay
5% Carbonate unspecified
10% Forams
67% Nannos
T Chlorite
T Opaques

10YR 6/4

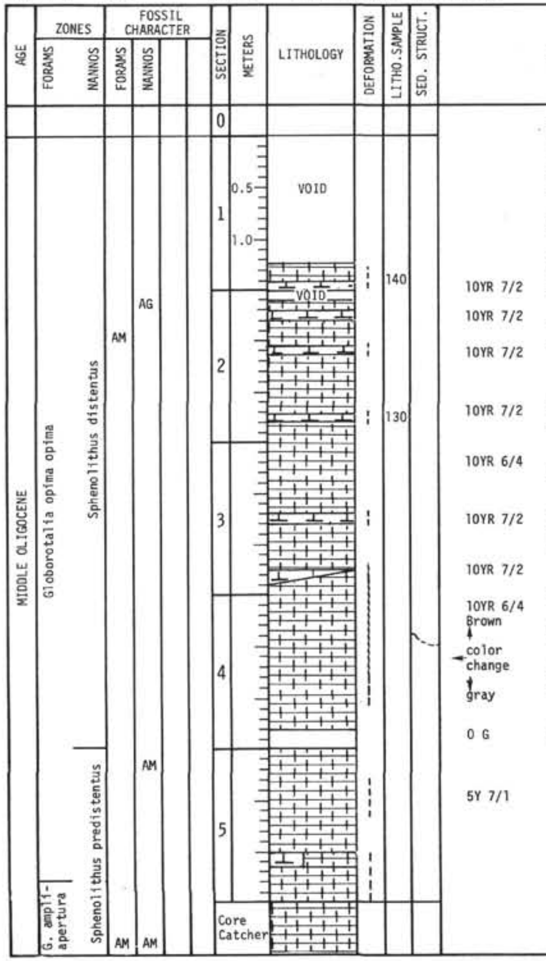
TEXTURE (Average from SS)
Chalks: 6% Sand, 58% Silt, 36% Clay
Ooze: 9% Sand, 62% Silt, 29% Clay

Carbon-Carbonate (DSDP)
3-20 (8.4, 0.0, 70)

Grain Size (DSDP)
3-98 (7.3, 36.6, 56.1)

Explanatory notes in Chapter 1

Site 363 Hole Core 5 Cored Interval: 107.0-116.5 m



LITHOLOGIC DESCRIPTION

FORAM-NANNO CHALK INTERLAYERED WITH "BRAARUDOSPHAERA" OOZE

Yellow brown (10YR 6/4) chalk interlayered with light gray (10YR 7/1) "Braarudosphaera" ooze followed by light gray (5Y 7/1) chalk occasionally moderately disturbed. Color contacts sharp.

MINERALOGY (Average from SS)

Chalks
2% Quartz
13% Clay
1% Carbonate unspecified
10% Forams
72% Nannos
T Chlorite
T Opaques

OOZE
T Quartz
10% Clay
T Heavyies
1% Forams
90% Nannos
T Fish remains

TEXTURE (Average from SS)
Chalk: 19% Sand, 54% Silt, 27% Clay
Braarudosphaera ooze: T Sand, 75% Silt, 25% Clay

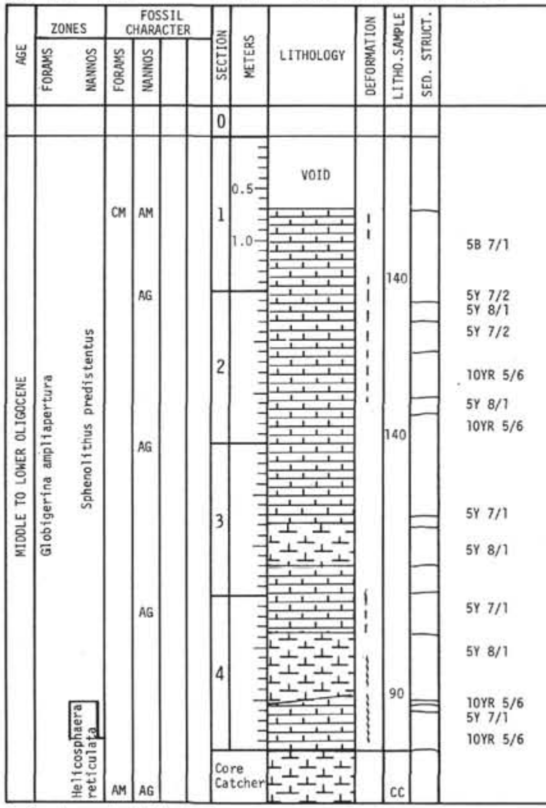
Remarks: SS 1-140 P. joidesa

Carbon-Carbonate (DSDP)
4-20 (9.4, 0.1, 78)

Carbon-Carbonate (OG)
4-130 (9.8, 0.1, 81)
4-150 (9.7, 0.1, 81)

Grain Size (DSDP)
4-88 (0.4, 38.1, 61.5)

Site 363 Hole Core 6 Cored Interval: 126.0-135.5 m



LITHOLOGIC DESCRIPTION

NANNO CHALK WITH INTERLAYERS OF "BRAARUDOSPHAERA" OOZE

Yellow brown (10YR 5/6), light gray (5B 7/1 and 5B 7/2), white (5Y 8/1) chalks, interlayered with white (5Y 8/1) oozes. Undeformed to moderately deformed except Section 4, intensely deformed color changes in chalks abrupt.

MINERALOGY (Average from SS)

Chalk
7% Quartz
12% Clay
1% Carbonate unspecified
1% Forams
75% Nannos
T Opaques
T Fe-oxides (in brown chalks)

Oozes
10% Quartz
10% Clay
2% Carbonate unspecified
1% Forams
77% Nannos
T Fish remains

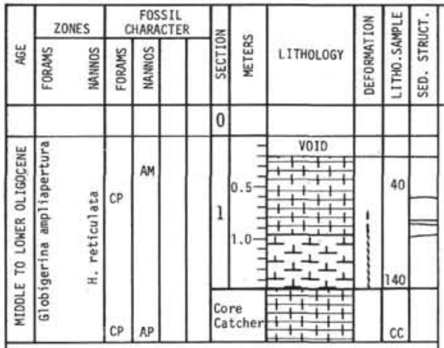
TEXTURE (Average from SS)
Chalk: 3% Sand, 67% Silt, 30% Clay
Oozes: 0% Sand, 75% Silt, 25% Clay

Carbon-Carbonate (DSDP)
4-20 (9.6, 0.0, 80)

Grain Size (DSDP)
4-88 (0.2, 76.2, 23.6)

Explanatory notes in Chapter 1

Site 363 Hole Core 7 Cored Interval: 145.0-154.5 m



LITHOLOGIC DESCRIPTION

FORAM-NANNO CHALK AND "BRAARUDOSPHAERA" OOZE
Light gray green (5G 6/1) and brownish white (5B 7/1) chalk with white (5Y 8/1) ooze.

5G 6/1

5B 7/1
5Y 8/1
5G 6/1

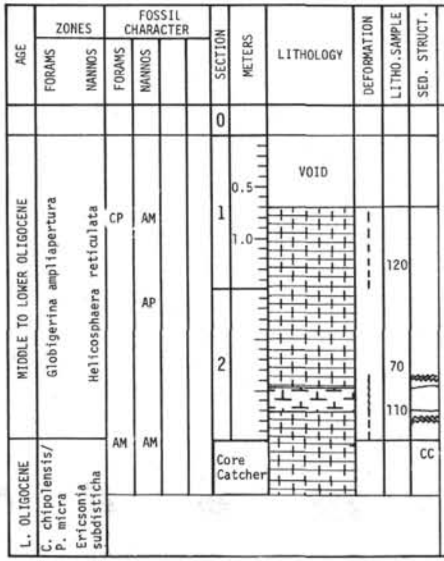
5Y 8/1

MINERALOGY
SS 1-40
Chalk
5% Quartz
15% Clay
T Heavies
10% Forams
65% Nannos
2% Opaques
T Fish remains

SS 1-140
Ooze
15% Quartz
10% Clay
75% Nannos

TEXTURE
Chalk: 10% Sand, 40% Silt, 50% Clay
Ooze: 0% Sand, 80% Silt, 20% Clay

Site 363 Hole Core 8 Cored Interval: 164.0-173.5 m



LITHOLOGIC DESCRIPTION

FORAM-NANNO CHALK "BRAARUDOSPHAERA" OOZE
Greenish gray (5G 6/1) chalk moderately burrowed "Braarudosphaera" white (5Y 8/1) ooze. Very disturbed.

MINERALOGY (Average from SS)
Chalks
8% Quartz
20% Clay
8% Forams
65% Nannos
T Opaques
Rare Garnet

5G 6/1

SS 2-110
Ooze
15% Quartz
5% Clay
80% Nannos

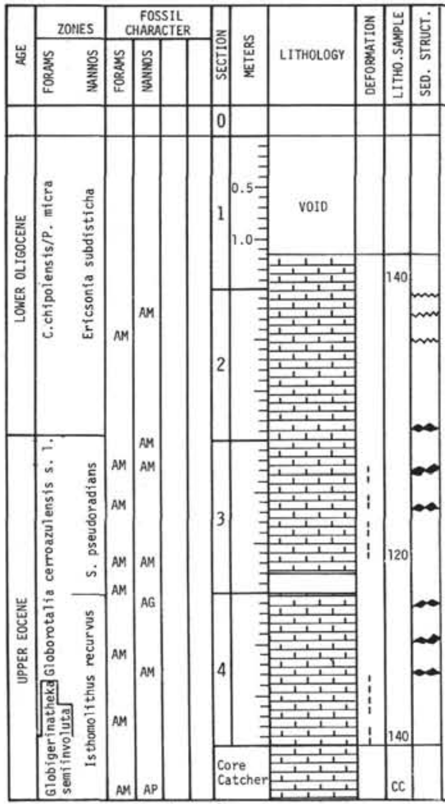
5Y 8/1

5G 6/1

TEXTURE
Chalks (Average from SS): 10% Sand, 42% Silt, 48% Clay
Ooze (SS 2-110): 0% Sand, 80% Silt, 20% Clay

Carbon-Carbonate (OG)
1-130 (8.2, 0.1, 68)
1-150 (10.3, 0.1, 85)

Site 363 Hole Core 9 Cored Interval: 183.0-192.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK
Light brownish gray (5Y 7/3), light gray (5Y 7/1) and pale brown (10YR 7/4) chalks. Gradational color changes locally intense burrowing including Zoophycos, small burrows.

MINERALOGY (Average from SS)
5% Quartz
16% Clay
1% Carbonate unspecified
6% Forams
71% Nannos
T Opaques
T Fe-oxide (in brownish chalks)

5Y 7/3

5Y 7/1

TEXTURE (Average from SS)
15% Sand, 53% Silt, 32% Clay

Carbon-Carbonate (DSDP)
4-20 (9.2, 0.0, 77)

10YR 7/4 }
5Y 7/1 } alternating shades

Carbon-Carbonate (OG)
3-130 (10.8, 0.1, 90)
3-150 (9.7, 0.0, 81)

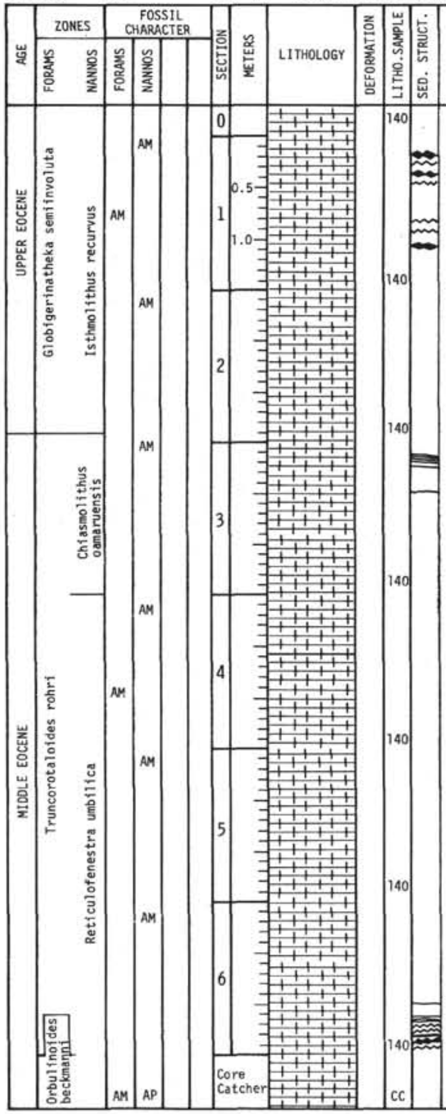
0 G

Grain Size (DSDP)
4-88 (2.4, 46.2, 51.4)

10YR 7/4 }
5Y 7/1 } alternating shades

Explanatory notes in Chapter 1

Site 363 Hole Core 10 Cored Interval: 202.0-211.5 m



Zoophycos

N6

N6

LITHOLOGIC DESCRIPTION

FORAM-NANNO CHALK
Pale brown (10YR 7/4) and light gray (5Y 7/1) chalks, steadily alternating gradational color changes ~20 to 30 cm each. Two zones of very light gray (N6) chalk minor laminations in two places (<10 cm). Locally intense burrowing.

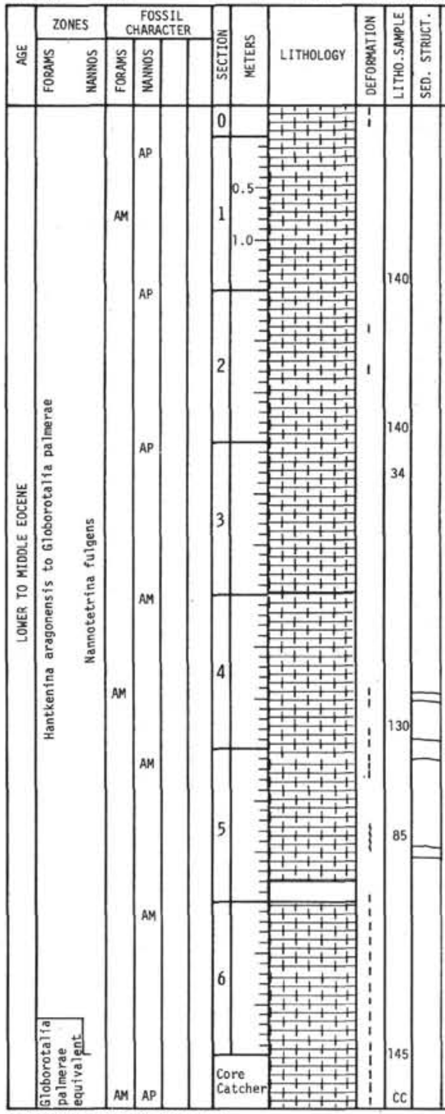
MINERALOGY (Average from SS)
8% Quartz
11% Clay
15% Forams
64% Nannos
T Opaques
?% Chlorite
T Fe-oxide (in brownish zones)
T Zeolite
Rare Garnet
Rare Tourmaline

TEXTURE
6% Sand, 42% Silt, 52% Clay

Carbon-Carbonate (DSDP)
4-20 (9.0, 0.0, 75)
6-20 (9.5, 0.1, 78)

Grain Size (DSDP)
4-88 (3.6, 47.3, 49.1)
6-88 (1.3, 49.9, 48.8)

Site 363 Hole Core 11 Cored Interval: 221.0-230.5 m



10YR 7.5/3 alternating with 10YR 7/1

5Y 8/1

5Y 8/1

5Y 8/1

0 G

LITHOLOGIC DESCRIPTION

FORAM-NANNO CHALK
Light gray (10YR 7/1) yellowish gray (10YR 7.5/3) and minor white (5Y 8/1) chalks. Homogeneous gradational color changes, minor laminations, locally intense burrowing.

MINERALOGY (Average from SS)
10% Quartz
8% Clay
2% Carbonate unspecified
T Chlorite
19% Forams
69% Nannos
T Zeolites
T Fe-oxide
Rare Tourmaline
Rare Rutile

TEXTURE (Average from SS)
19% Sand, 51% Silt, 30% Clay

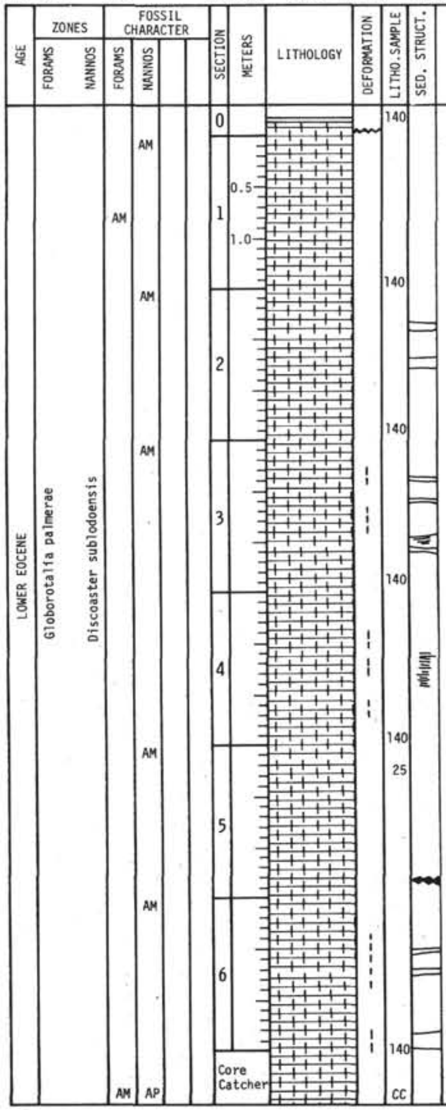
Carbon-Carbonate (DSDP)
4-20 (0.1, 0.1, 83)
6-20 (9.4, 0.1, 78)

Carbon-Carbonate (OG)
5-130 (9.3, 0.0, 77)
5-150 (9.7, 0.0, 81)

Grain Size (DSDP)
4-88 (2.3, 46.2, 51.5)
6-88 (2.5, 39.6, 57.9)

Explanatory notes in Chapter 1

Site 363 Hole Core 12 Cored Interval: 240.0-249.5 m



LITHOLOGIC DESCRIPTION

FORAM-NANNO CHALK

Yellowish gray (10YR 7.5/3), light gray (10YR 7/1) chalks with white (5Y 8/1) and pale gray (10YR 8/2) intercalations. Most of core shows gradational color changes, smeared by burrowing. Fine laminations in Sections 3 and 4.

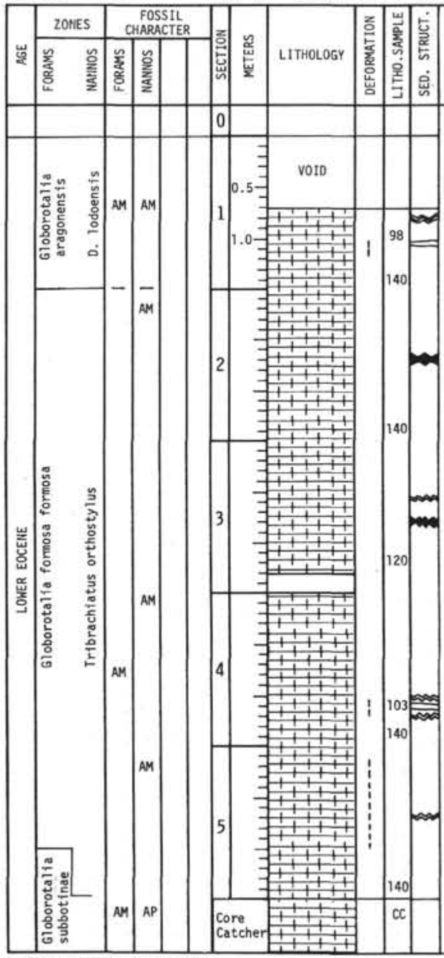
MINERALOGY (Average from SS)
9% Quartz
6% Clay
2% Carbonate unspecified
T Opaques
T Fe-oxide
17% Forams
64% Nannos
T Zeolite
Rare Garnet
Rare Tourmaline

TEXTURE (Average from SS)
17% Sand, 58% Silt, 25% Clay

Carbon-Carbonate (DSDP)
4-20 (10.6, 0.1, 88)
6-20 (9.7, 0.0, 80)

Grain Size (DSDP)
12-4 (4.9, 50.3, 44.8)
12-6 (2.6, 51.4, 46.0)

Site 363 Hole Core 13 Cored Interval: 259.0-268.5 m



LITHOLOGIC DESCRIPTION

FORAM-NANNO CHALK

Pale brown (10YR 7/4) minor yellowish gray (10YR 7.5/3) chalks with interlayers of yellowish gray (10YR 8/2) chalk. Locally intensively burrowed. Color changes gradational, smeared by burrowing.

MINERALOGY (Average from SS)
9% Quartz
6% Clay
3% Carbonate unspecified
T Opaques
12% Forams
73% Nannos
1% Zeolites
T Fe-oxide
T Chlorite
Rare Garnet

TEXTURE (Average from SS)
11% Sand, 60% Silt, 29% Clay

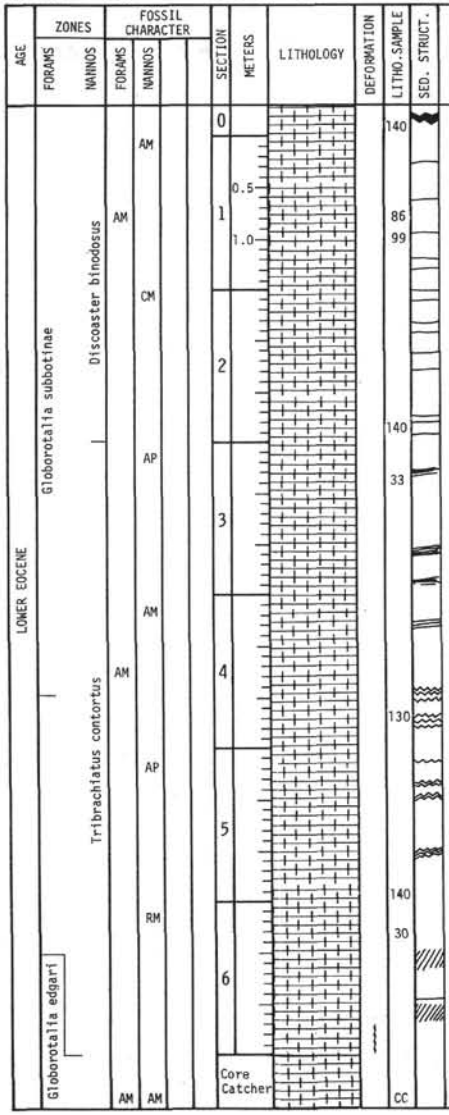
Carbon-Carbonate (DSDP)
4-20 (10.6, 0.0, 88)

Carbon-Carbonate (OG)
3-130 (9.8, 0.0, 81)
3-150 (10.0, 0.0, 83)

Grain Size (DSDP)
4-88 (3.9, 61.2, 34.9)

Explanatory notes in Chapter 1

Site 363 Hole Core 14 Cored Interval: 278.0-287.5 m



LITHOLOGIC DESCRIPTION

10YR 7.5/2
10YR 7/3
10YR 8/1
10YR 7/3
10YR 8/1
10YR 8/2
10YR 7/3
10YR 8/1
10YR 7/3
10YR 8/1
10YR 7/3
10YR 7/3
10YR 7/3
10YR 8/3
10YR 8/3
10YR 8/2
10YR 8/3
10YR 8/3
10YR 8/2

FORAM-NANNO CHALK

Pale brown (10YR 8/3), yellowish white (10YR 8/2 or 10YR 7.5/2) to pale brown (10YR 7/3) chalks, often sharply interlayered. Generally intense burrowing. Locally dense concentration of laminations and cross beds.

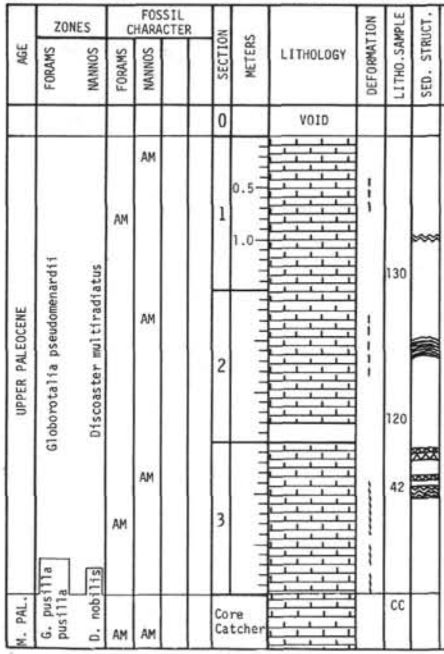
MINERALOGY (Average from SS)
7.0% Quartz
6.0% Clay
0% Carbonate unspecified
T Opaques
8.0% Forams
77.0% Nannos
1.5% Zeolite
T Fe-oxide

TEXTURE (Average from SS)
12% Sand, 61% Silt, 27% Clay

Carbon-Carbonate (DSDP)
4-20 (10.6, 0.0, 88)
6-20 (10.6, 0.0, 88)

Grain Size (DSDP)
4-88 (2.1, 52.4, 44.5)
6-88 (7.3, 44.5, 48.2)

Site 363 Hole Core 15 Cored Interval: 297.5-306.0 m



LITHOLOGIC DESCRIPTION

Chert nodule
10YR 7/1
10YR 7/1
Laminations
O G
10YR 7/1
10YR 7/1
10YR 7/1
Drilling breccia

NANNOFOSSIL CHALK

Light gray (10YR 7/1) chalk with darker light olive gray (5Y 6/1) strongly burrowed zones in Section 3.

MINERALOGY (Average from SS)
6% Quartz
5% Clay
3% Unspecified carbonate
T Chlorite
6% Forams
75% Nannos
3% Zeolite
T Fe-oxide
(Abundant micarb in SS 1-130)

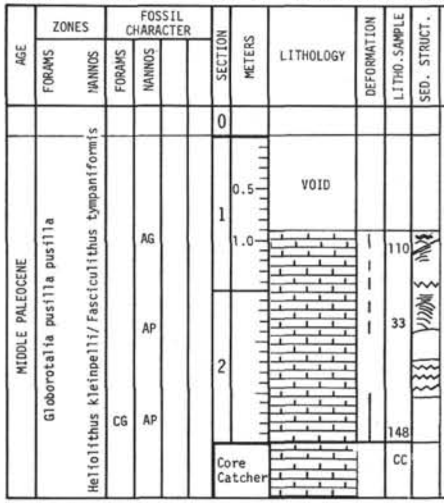
TEXTURE (Average from SS)
10% Sand, 53% Silt, 37% Clay

Carbon-Carbonate (DSDP)
3-20 (10.1, 0.1, 84)

Carbon-Carbonate (OG)
2-130 (10.3, 0.1, 85)
3-150 (10.1, 0.1, 83)

Grain Size (DSDP)
3-88 (1.9, 49.7, 48.4)

Site 363 Hole Core 16 Cored Interval: 306.5-316.0 m



LITHOLOGIC DESCRIPTION

Erosional contact
10YR 7/1
5Y 6/2
10YR 8/1
10YR 7/2
10YR 8/1

NANNOFOSSIL CHALK

Light gray (10YR 7/1), olive green (5Y 6/2), very light gray (10YR 8/1), and light brownish gray (10YR 7/2) chalks. Laminations, erosional contacts. Abundant burrows.

MINERALOGY (Average from SS)
8% Quartz
8% Clay
0% Carbonate unspecified
T Opaques
T Chlorite
6% Forams
73% Nannos
5% Zeolite
T Fe-oxide

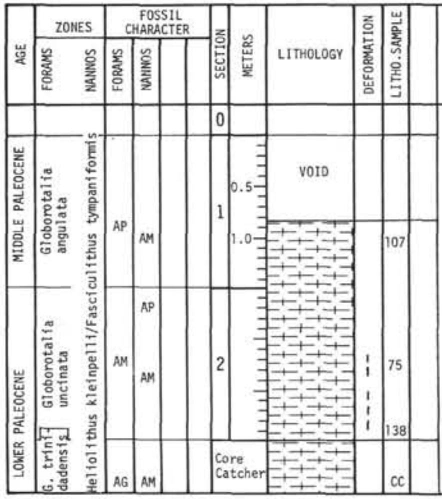
TEXTURE (Average from SS)
7% Sand, 46% Silt, 47% Clay

Carbon-Carbonate (DSDP)
2-20 (6.7, 0.1, 55)

Grain Size (DSDP)
2-88 (1.4, 33.6, 65.0)

Explanatory notes in Chapter 1

Site 363 Hole Core 17 Cored Interval: 316.0-325.5 m



LITHOLOGIC DESCRIPTION

5Y 6/2
10YR 8/1
10YR 7/1
10YR 8/1
10YR 7/1
10YR 8/1
10YR 7/1
10YR 8/1

FORAM-NANNO CHALK
Light green gray (5Y 6/2) at the top, then alternating light gray (10YR 8/1) and light brownish gray (10YR 7/1) locally moderately burrowed.

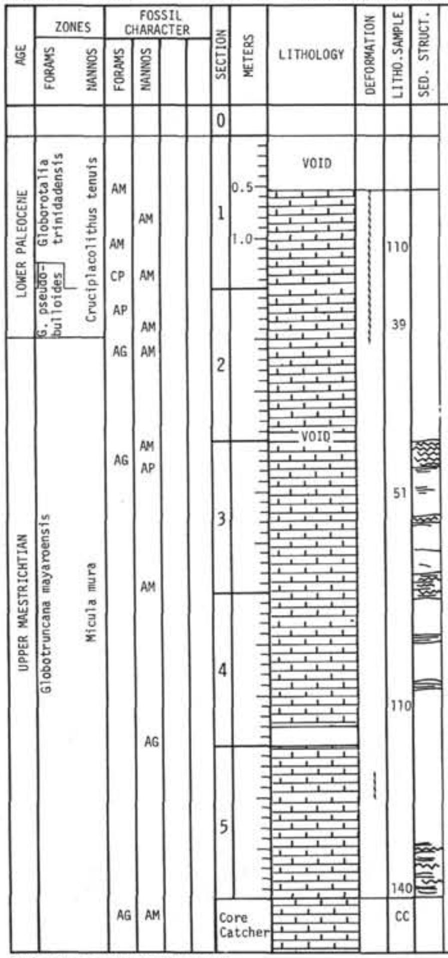
MINERALOGY (Average from SS)
8% Quartz
6% Clay
0% Carbonate unspecified
T Fe-oxide
18% Forams
63% nannos
1% Zeolite

TEXTURE (Average from SS)
18% Sand, 32% Silt, 50% Clay

Carbon-Carbonate (DSDP)
2-20 (9.4, 0.1, 78)

Grain Size (DSDP)
2-88 (6.7, 33.7, 59.6)

Site 363 Hole Core 18 Cored Interval: 325.5-335.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK
Very fine brownish gray (10YR 8/2 to 10YR 8/4) chalk, homogeneous, minor laminations, slightly to intensely burrowed. Winnowed chalks in Section 5.

10YR 8/2
10YR 3/4

MINERALOGY (Average from SS)
7% Quartz
37% Clay
16% Carbonate unspecified
T Opaques
T Chlorite
12% Forams
34% Nannos
T Zeolite
T Fe-oxide

TEXTURE (Average from SS)
18% Sand, 42% Silt, 46% Clay

Carbon-Carbonate (OG)
4-130 (10.4, 0.0, 86)
4-150 (10.7, 0.0, 88)

Grain Size (DSDP)
4-88 (2.5, 31.4, 66.2)

10YR 8/4
10YR 8/2
10YR 8/4
10YR 8/2
10YR 8/4

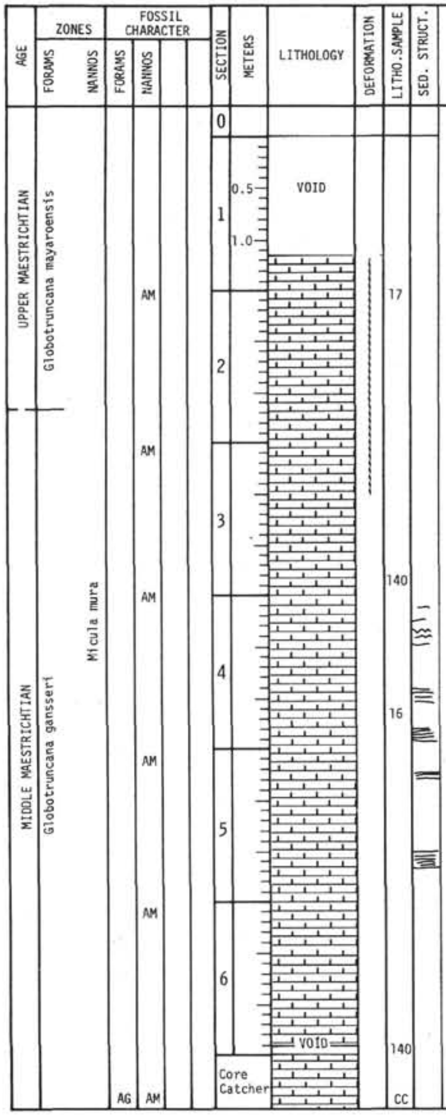
Laminations

O G

Laminations and burrows

Explanatory notes in Chapter 1

Site 363 Hole Core 19 Cored Interval: 335.0-344.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK
Very fine, homogeneous, pale brown (10YR 8/3 to 10YR 8/2) chalk, locally mottled, burrowed, and laminated.

MINERALOGY (Average from SS)
6% Quartz
55% Clay
14% Carbonate unspecified
T Fe-oxide
7% Forams
27% Nannos
1% Zeolite
T Opaques

Drilling breccia

TEXTURE (Average from SS)
8% Sand, 39% Silt, 53% Clay

Carbon-Carbonate (DSDP)
4-20 (9.9, 0.0, 82)
6-20 (9.9, 0.0, 82)

Grain Size (DSDP)
4-88 (2.5, 31.4, 66.2)
6-88 (3.9, 32.6, 63.5)

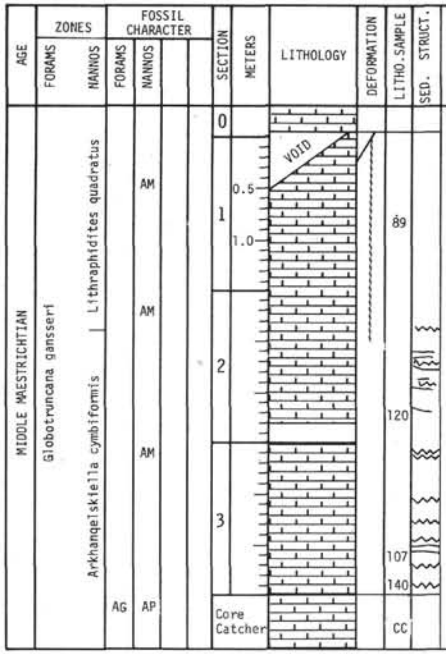
10YR 8/3

10YR 8/3

10YR 8/3

10YR 8/3
to
10YR 8/2

Site 363 Hole Core 20 Cored Interval: 344.5-354.0 m



LITHOLOGIC DESCRIPTION

Microfaults

NANNOFOSSIL CHALK
Marly in burrows. Very fine, homogeneous, pale brown (10YR 8/3) chalk, moderately burrowed, with occasional laminations, generally darker and richer in terrigenous material.

10YR 8/3

MINERALOGY (Average from SS)
5% Quartz
42% Clay
9% Carbonate unspecified
T Opaques
T Chlorite
10% Forams
34% Nannos
T Zeolite
T Fe-oxide

10YR 8/3

TEXTURE (Average from SS)
12% Sand, 39% Silt, 49% Clay

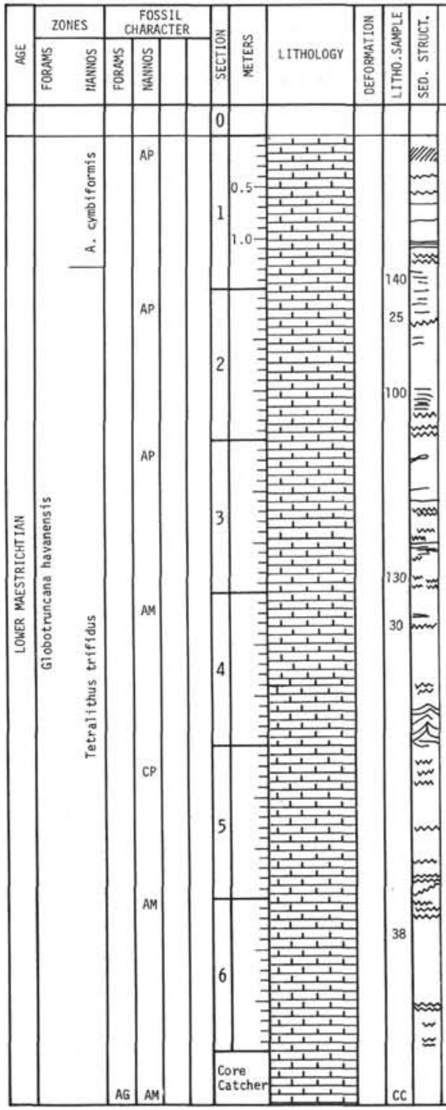
0 G

Carbon-Carbonate (OG)
2-130 (8.9, 0.1, 74)
2-150 (4.9, 0.1, 41)

10YR 8/3

Explanatory notes in Chapter 1

Site 363 Hole Core 21 Cored Interval: 363.5-373.0 m



LITHOLOGIC DESCRIPTION

10YR 7/3
10YR 8/2
10YR 7/3
10YR 8/2
to
10YR 8/3
Zoophycos
10YR 7/3
Flow structure
10YR 6/4
10YR 7/3
Large
Zoophycos
10YR 7/3
to
10YR 6/3
10YR 6/3

NANNOFOSSIL CHALK
Marly in burrows and laminations. Homogeneous, fine, very pale brown (10YR 8/2 or 10YR 8/3) chalk, sometimes slightly darker brown (10YR 7/3) or light yellowish brown (10YR 6/4). Locally strongly burrowed but bearing many fine laminations. Zoophycos burrows well developed. Some flow structures.

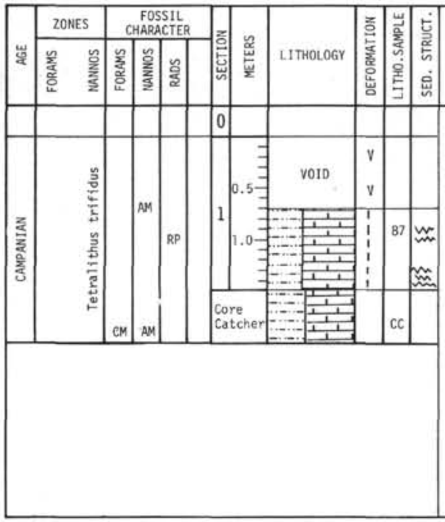
MINERALOGY (Average from SS)
6.0% Quartz
33.0% Clay
20.0% Carbonate unspecified
T Opaques
T Chlorite
Rare Epidote
3.0% Forams
36.0% Nannos
1.5% Zeolite
T Fe-oxide
Rare Tourmaline

TEXTURE (Average from SS)
6% Sand, 53% Silt, 41% Clay

Carbon-Carbonate (DSDP)
4-7 (9.1, 0.0, 75)
5-36 (8.9, 0.0, 74)

Grain Size (DSDP)
3-68 (1.1, 36.7, 62.3)
4-16 (0.5, 40.2, 59.3)
6-88 (2.4, 38.3, 59.3)

Site 363 Hole Core 22 Cored Interval: 373.0-392.5 m



LITHOLOGIC DESCRIPTION

10YR 6/2

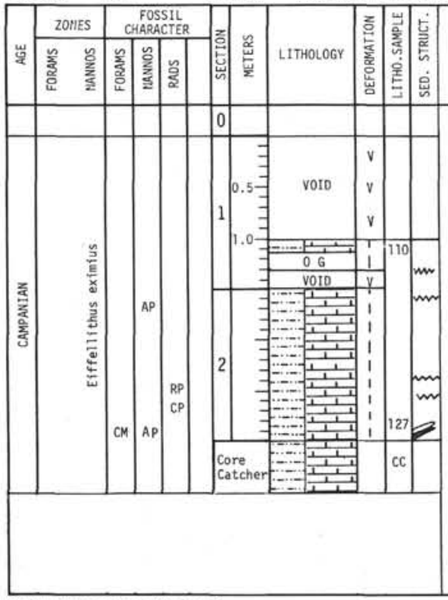
MARLY NANNOFOSSIL CHALK
Light brownish gray (10YR 6/2) marly chalk. Zoophycos abundant. Minor pale chalk layers.

MINERALOGY (Average of SS)
12% Quartz
34% Clay
10% Carbonate unspecified
T Fe-oxide
T Chlorite
0% Forams
45% Nannos
T Zeolite
T Opaques

TEXTURE (Average from SS)
3% Sand, 37% Silt, 60% Clay

Grain Size (DSDP)
1-137 (0.4, 22.5, 77.0)

Site 363 Hole Core 23 Cored Interval: 382.5-392.0 m



LITHOLOGIC DESCRIPTION

Greener
at very
top
10YR 5/2
10YR 5/1
Flow structure

MARLY NANNOFOSSIL CHALK
Gray (10YR 5/1) to grayish brown (10YR 5/2) marly chalk, locally burrowed and laminated. Zoophycos present. Occasional flow structure in bedding.

MINERALOGY (Average from SS)
6% Quartz
44% Clay
11% Carbonate unspecified
T Opaques
T Chlorite
0% Forams
36% Nannos
3% Zeolite
T Fe-oxide

TEXTURE (Average from SS)
2% Sand, 49% Silt, 49% Clay

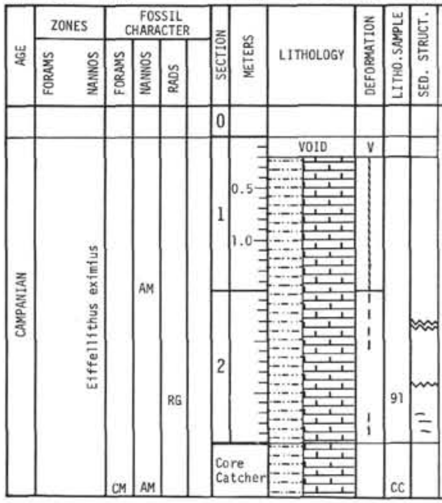
Carbon-Carbonate (DSDP)
2-20 (4.5, 0.1, 37)

Carbon-Carbonate (OG)
1-115 (4.3, 0.1, 36)
1-135 (5.4, 0.1, 45)

Grain Size (DSDP)
2-88 (0.8, 37.6, 61.7)

Explanatory notes in Chapter 1

Site 363 Hole Core 24 Cored Interval: 401.5-411.0 m



LITHOLOGIC DESCRIPTION

Drill breccia

10YR 5/1

10YR 5/1

5GY 8/1 in spots

10YR 5/1

MARLY NANNOFOSSIL CHALK

Gray (10YR 5/1) marly chalk, locally light brownish gray (5GY 8/1). Section 1 is soupy drilling breccia. Section 2 slightly burrowed and laminated.

MINERALOGY (Average from SS)

5% Quartz
42% Clay
20% Carbonate unspecified
T Opaques
0% Forams
28% Nannos
3% Zeolite

TEXTURE (Average from SS)

2% Sand, 46% Silt, 52% Clay

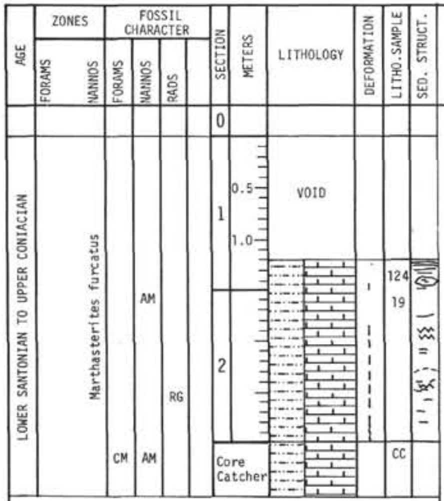
Carbon-Carbonate (DSDP)

2-28 (5.8, 0.1, 48)

Grain Size (DSDP)

2-88 (0.5, 28.5, 71.0)

Site 363 Hole Core 25 Cored Interval: 420.5-430.0 m



LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL CHALK

Dark olive (5Y 4/2), dark brownish gray (2.5Y 5/2) light greenish gray (5GY 8/1) and gray (10YR 5/1) marly chalks. Darker shades slightly richer in terrigenous material. Green shades do not correspond to sediment structures. Core is fairly well laminated and burrowed.

5Y 4/2
2.5Y 5/2 Laminations
10YR 5/1

10YR 5/1

Locally 5GY 8/1

Larger greenish zone 5GY 2/1

10YR 5/1

MINERALOGY (Average from SS)

8.0% Quartz
45.0% Clay
23.0% Carbonate unspecified
T Opaques
T Chlorite
3.0% Forams
18.0% Nannos
1.5% Zeolite
T Fe-oxide

TEXTURE (Average from SS)

4% Sand, 47% Silt, 49% Clay

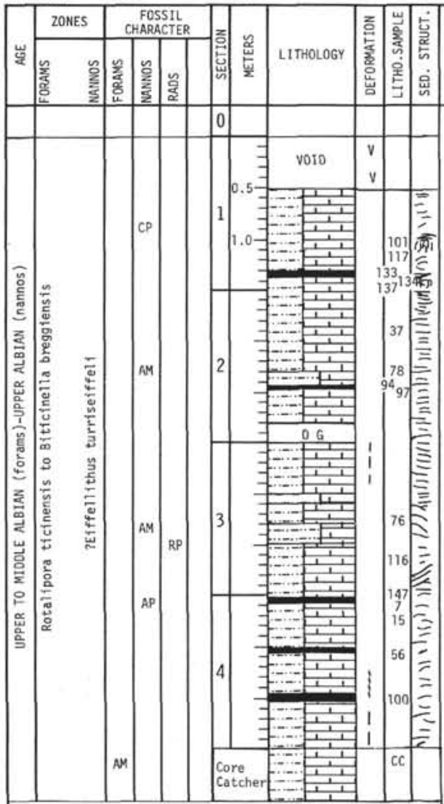
Carbon-Carbonate (DSDP)

2-20 (4.5, 0.1, 37)

Grain Size (DSDP)

2-94 (0.2, 32.0, 67.8)

Site 363 Hole Core 26 Cored Interval: 439.5-449.0 m



LITHOLOGIC DESCRIPTION

Silty

Silty

5GY 6/1 alternating with 10YR 5/2

MARLY NANNOFOSSIL CHALK, CALCAREOUS MUDSTONE, CARBONACEOUS MUDSTONE (Black)

Pale gray (2.5Y 8/2), pale greenish gray (5GY 6/1), gray (5Y 5/1, 5Y 5/2), marly chalk. Grayish brown (10YR 5/2) and gray (5Y 5/2) calcareous mudstone. Black (5Y 2.5/2) carbonaceous mudstone. Alternating smooth and turbulently deposited sediments. Abundant laminations, silty layers, soft-sediment deformation. Burrowing prominent in relatively homogeneous layers deposited under quiescent conditions. Very frequent color changes. Carbonaceous layers probably sapropelic. Contain abundant pyrite. Small pyritic patches locally.

5GY 6/1 alternating with
10YR 5/2
5GY 6/1
10YR 5/2
2.5Y 8/2

5Y 5/2

2.5Y 8/2

5Y 5/1

5Y 5/1

5Y 5/1

MINERALOGY (Average from SS)

Marly chalk

9% Quartz
38% Clay
32% Unspecified carbonate
1% Forams
17% Nannos
5% Zeolite

Calcareous and carbonaceous mudstones

11% Quartz
52% Clay
15% Unspecified carbonate
5% Carbonaceous
T Fe-oxide
T Chlorite
2% Forams
5% Nannos
5% Zeolite
5% Pyrite
T Magnetite

TEXTURE (Average from SS)

Marly chalks: 5% Sand, 41% Silt, 54% Clay
Mudstones: 5% Sand, 44% Silt, 51% Clay

Carbon-Carbonate (DSDP)

4-20 (8.0, 0.1, 66)

Carbon-Carbonate (OG)

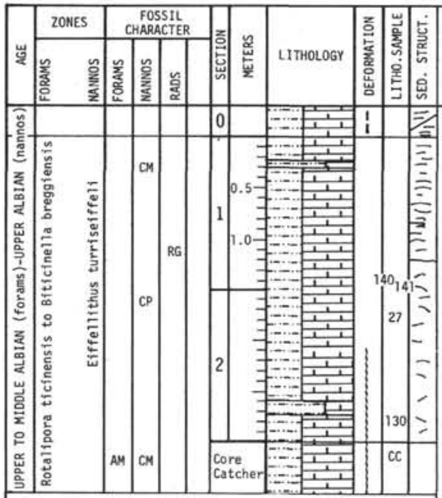
2-130 (3.4, 0.1, 28)
2-150 (6.5, 0.1, 53)

Grain Size (DSDP)

4-88 (1.7, 48.3, 50.0)

Explanatory notes in Chapter 1

Site 363 Hole Core 27 Cored Interval: 458.5-468.0 m



LITHOLOGIC DESCRIPTION

10YR 6/1
10YR 5/3
5G 6/1
Silty
10YR 5/2
Pyrite
Alternating
10YR 5/2
and
5G 6/1
10YR 6/2
10YR 6/1

MARLY NANNOFOSSIL CHALK, CALCAREOUS MUDSTONE

Gray (10YR 6/1), greenish gray (5G 6/1) marly chalks. Grayish brown (10YR 5/2) and olive gray (5Y 5/2) mudstones. Alternating smooth and turbulently deposited sediments. Abundant laminations, silty layers, soft sediment deformation. Very frequent color changes. Darker zones have more laminations. Dark on light and light on dark burrows in more quietly deposited materials.

MINERALOGY (Average from SS)
Marly chalks
10% Quartz
28% Clay
36% Carbonate unspecified
T Chlorite
T Fe-oxide
2% Forams
9% Nannos
2% Zeolites
T Opaques
T Pyrite
Rare Garnet
Rare Zircon

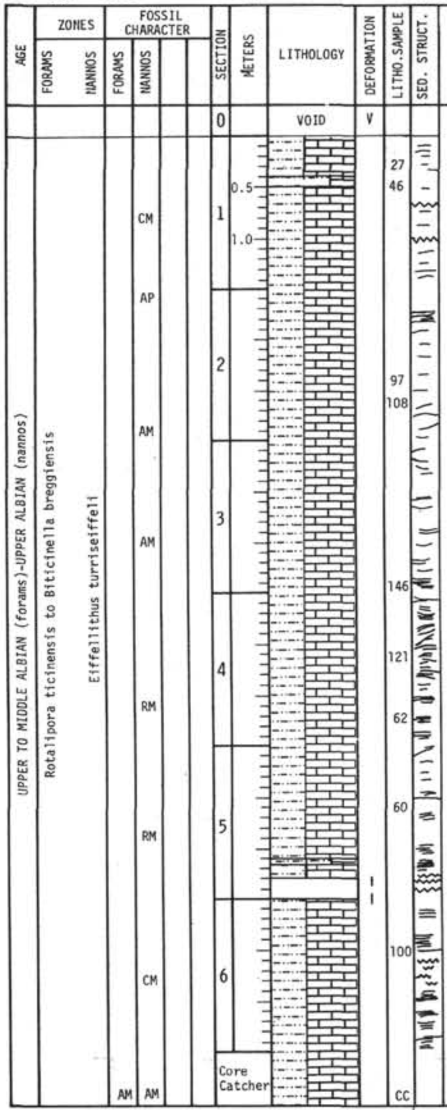
Calcareousmudstones contain up to 50% Clay 5% Zeolites, and T% Magnetite and Fe-Oxide.

TEXTURE (Average from SS)
Marly chalks: 18% Sand, 48% Silt, 34% Clay
Mudstones: 5% Sand, 40% Silt, 55% Clay

Carbon-Carbonate (DSDP)
1-2 (8.4, 0.1, 69)

Grain Size (DSDP)
1-88 (1.4, 46.1, 52.5)

Site 363 Hole Core 28 Cored Interval: 477.5-487.0 m



LITHOLOGIC DESCRIPTION

5G 6/1
10YR 5/3
5G 6/1
Alternating
with
10YR 5/2
10YR 6/2
5Y 7/1 to
5Y 8/1
5Y 5/2
10YR 6/1
10YR 6/1
10YR 6/1
5Y 7/1
10YR 5/1
0 G
10YR 7/1
5Y 7/1

MARLY LIMESTONE, CALCAREOUS MUDSTONE

Alternation of light greenish gray (5G 6/1) and brownish gray (10YR 5/2) marly limestones with very light gray (5Y 7/1 to 5Y 8/1) marly limestones and darker olive gray (5Y 5/2) calcareous mudstones. Abundantly laminated and burrowed. Greenish zones do not correspond to sediment structures, but laminated areas tend to be darker browns. Some soft sediment deformation and erosional contacts.

MINERALOGY (Average from SS)
Marly limestones
10% Quartz
26% Clays
40% Carbonate unspecified
3% Zeolite
T Fe-oxide
T Pyrite
1% Forams
15% Nannos
T Dolomite
T Opaques
T Chlorite
Rare Tourmaline
Rare Garnet

TEXTURE (Average from SS)
16% Sand, 49% Silt, 35% Clay

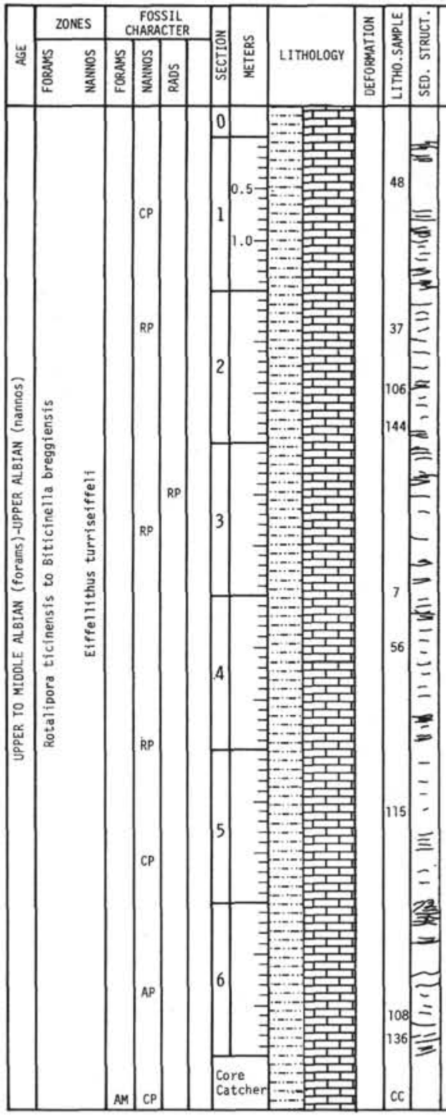
Carbon-Carbonate (DSDP)
4-115 (9.8, 0.1, 81)
6-61 (8.1, 0.2, 66)

Carbon-Carbonate (OG)
5-130 (9.2, 0.1, 76)
5-150 (9.0, 0.1, 74)

Grain Size (DSDP)
4-101 (0.7, 38.0. 61.3)
6-55 (0.2, 31.2, 68.5)

Explanatory notes in Chapter 1

Site 363 Hole Core 29 Cored Interval: 496.5-506.0 m



LITHOLOGIC DESCRIPTION

10YR 6/2
5Y 7/1
5Y 7/1
5Y 5/2
5Y 6/2
Laminations
5Y 7/1
with
5Y 6/2
Laminations
5Y 7/1
10YR 6/2
5YR 6/1
5B 5/1
5YR 6/1
5Y 7/1
10YR 6/2

MARLY LIMESTONE

Light gray (5Y 7/1 and 5YR 6/1), marly limestones with darker gray (5Y 6/2) and light brownish gray (10YR 6/2) zones as well as olive gray (5Y 5/2) or brownish gray (5B 5/1) muddy laminated zones. The core is cyclically bedded with erosional and winnowing features, burrowing and bioturbation. Burrows generally darker. Laminae are often silty. Some load-cast structures.

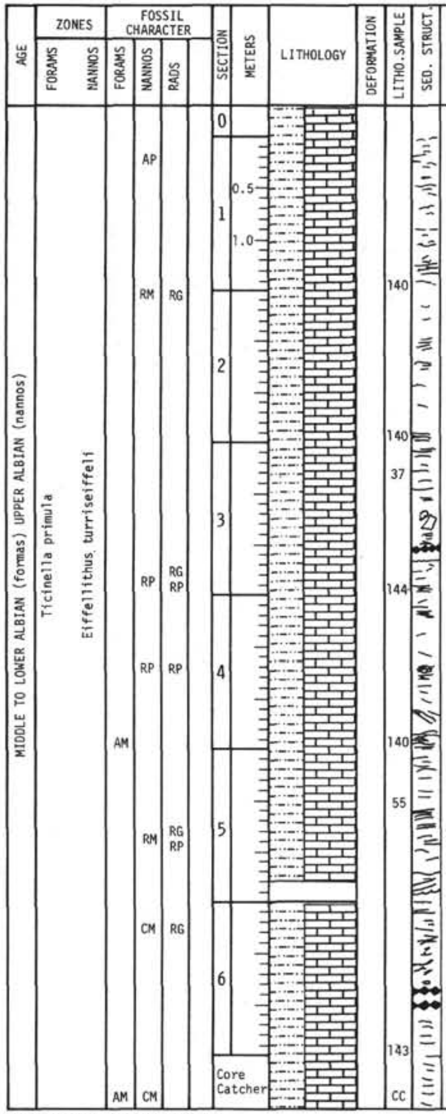
MINERALOGY (Average from SS)
9% Quartz
23% Clay
46% Carbonate unspecified
5% Calcisphers.
T Pyrite
T Opaques
2% Forams
10% Nannos
1% Dolomite
4% Zeolite
T Fe-oxide
T Chlorite
Rare Zircon

TEXTURE (Average from SS)
23% Sand, 59% Silt, 18% Clay

Carbon-Carbonate (DSDP)
3-64 (10.1, 0.1, 84)
4-135 (7.0, 0.1, 57)
6-78 (8.8, 0.1, 73)

Grain Size (DSDP)
4-129 (3.0, 58.2, 38.8)
6-64 (2.3, 60.1, 37.6)

Site 363 Hole Core 30 Cored Interval: 515.5-525.0 m



LITHOLOGIC DESCRIPTION

5Y 7/1
mottled
Silt layer
5Y 7/1
Silty
5Y 7/1
Rotated
5Y 6/2
fragments
Erosion
contact
5Y 7/1
Mottles
10YR 6/2
Fractures
5Y 7/1
10YR 6/2
burrow,
mottles
Eros. cont.
0 G
5Y 7/1
10YR 7/1
Mottles
10YR 7/1
10YR 5/1

MARLY LIMESTONE

Light gray (5Y 7/1), light brownish gray (10YR 6/2), gray (10YR 5/1) and light gray (10YR 6/2) marly limestones. The core is cyclically bedded with lighter-colored homogeneous limestones alternating with darker, laminated limestones. It is locally intensively burrowed, has a number of erosional contacts and winnowed zones. Some soft sediment, deformation. Some laminations are silty. Compaction fractures.

MINERALOGY (Average from SS)
10% Quartz
25% Clays
38% Carbonate unspecified
5% Calcisphers.
T Pyrite
T Chlorite
1% Forams
12% Nannos
3% Dolomite
3% Zeolite
T Opaques
T Fe-oxide
Rare Zircon

TEXTURE (Average from SS)
10% Sand, 50% Silt, 40% Clay

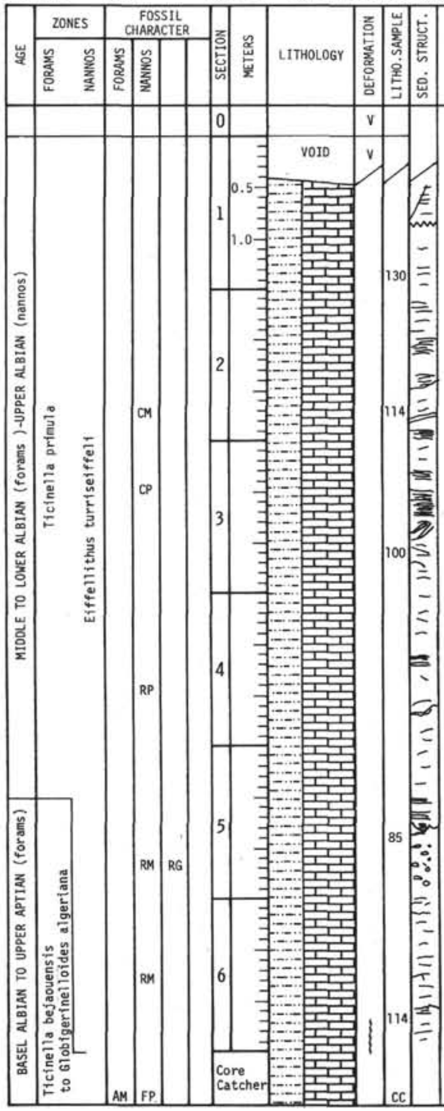
Carbon-Carbonate (DSDP)
3-134 (7.5, 0.1, 73)
4-66 (8.1, 0.1, 67)
6-21 (6.1, 0.1, 48)

Carbon-Carbonate (OG)
5-130 (8.6, 0.1, 70)
5-150 (9.8, 0.1, 81)

Grain Size (DSDP)
4-82 (4.6, 52.5, 42.8)

Explanatory notes in Chapter 1

Site 363 Hole Core 31 Cored Interval: 534.5-544.0 m



LITHOLOGIC DESCRIPTION

Fault

10YR 6/1
to 10YR 5/1

Laminations
and mottles
20 Ammonite }
36 Ammonite } Removed

Contact

2 Contacts

10YR 5/1

10YR 6/1

10YR 5/1

10YR 6/1
Contact

10YR 7/1

Mottles

10YR 7/1
to 10YR 6/1

70 Ammonite removed

Rotated pieces

MARLY LIMESTONE

Light gray (10YR 7/1) and gray (10YR 6/1 to 10YR 5/1) marly limestones. The core is cyclically bedded with lighter-colored homogeneous limestones alternating with darker, laminated marly limestones. It is locally intensively burrowed, has a number of erosional contacts and winnowed zones. Some soft sediment deformation, silty laminations, and compaction fractures.

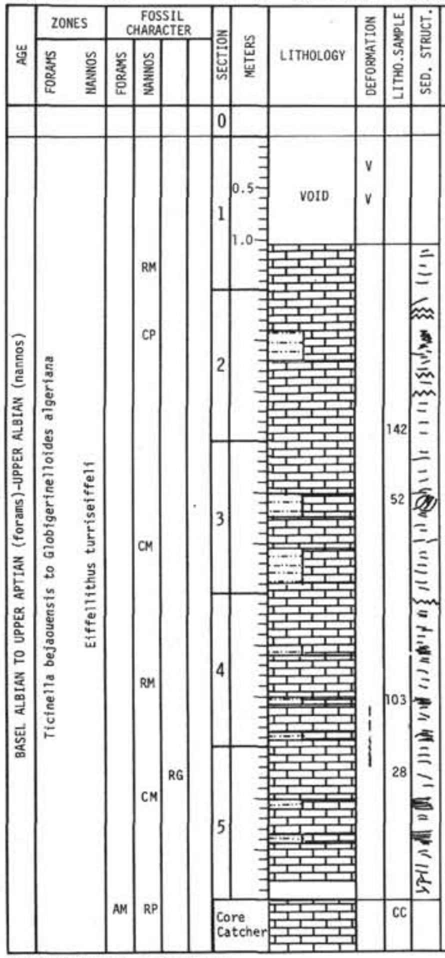
MINERALOGY (Average from SS)
9% Quartz
19% Clay
55% Carbonate unspecified
8% Calcisphers
T Chlorite
0% Forams
9% Nannos
2% Dolomite
2% Zeolite
T Chlorite
T Opaques
Rare Zircon
Rare Garnet

TEXTURE (Average from SS)
16% Sand, 54% Silt, 30% Clay

Carbon-Carbonate (DSDP)
2-127 (8.0, 0.1, 66)
6-67 (7.1, 0.2, 57)

Grain Size (DSDP)
6-69 (1.3, 48.2, 50.5)

Site 363 Hole Core 32 Cored Interval: 553.5-563.0 m



LITHOLOGIC DESCRIPTION

20
5Y 7/1

10YR 5/1
Heavily
mottled

5Y 7/1

Silty
10YR 8/1

10YR 5/1
Flow

10YR 8/1

10YR 5/1
Winnowing
5Y 7/1
Erosion

10YR 8/1
10YR 5/1

10YR 8/1

10YR 5/1

10YR 8/1
10YR 5/1

10YR 8/1

10YR 5/1
10YR 8/1

10YR 5/1

10YR 8/1
Faults
0 G

MARLY LIMESTONE AND LIMESTONE

White (10YR 8/1) and gray (5Y 7/1) limestone with gray (10YR 5/1) or gray (10YR 6/1) marly limestone interlayers. Cyclically bedded with alternating impulses of terrigenous material, various laminated and having erosional contacts, and massively bedded, bioturbated limestones.

MINERALOGY (Average from limestone SS)
6.0% Quartz
12.0% Clay
48.0% Carbonate unspecified
18.0% Calcisphers.
T Pyrite
T Opaques
0% Forams
16.0% Nannos
9.0% Dolomite
1.5% Zeolite
T Chlorite

(Average of marly limestone SS)
10% Quartz
25% Clay
30% Carbonate unspecified
10% Calcisphers.
T Chlorite
2% Forams
15% Nannos
5% Dolomite
T Opaques

TEXTURE (Average of marly limestone SS)
22% Sand, 44% Silt, 34% Clay

(Average of limestone SS)
32% Sand, 45% Silt, 23% Clay

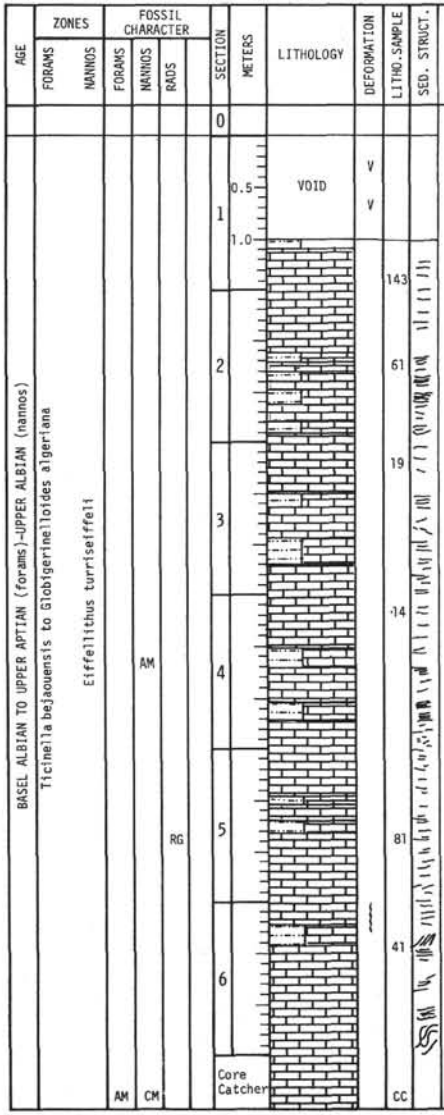
Carbon-Carbonate (DSDP)
4-72 (9.7, 0.1, 80)

Carbon-Carbonate (OG)
5-130 (9.7, 0.1, 80)
5-150 (9.7, 0.1, 80)

Grain Size (DSDP)
4-72 (4.2, 66.3, 29.4)

Explanatory notes in Chapter 1

Site 363 Hole Core 33 Cored Interval: 572.5-582.0 m



LITHOLOGIC DESCRIPTION

MARLY LIMESTONE AND LIMESTONE

Light gray (10YR 7/1) limestones alternating with gray (10YR 6/1) and darker gray (10YR 5/1) marly limestones. Cyclically bedded and well laminated, especially in darker zones. Erosional contacts, winnowed zones, pyritic patches, silty zones. Locally burrowed.

MINERALOGY (Average from SS)

11% Quartz
16% Clay
51% Carbonate unspecified
12% Calcisphers.
2% Pyrite
T Fe-oxide
1% Forams
12% Nannos
3% Dolomite
2% Zeolite
T Chlorite
T Opaques
Rare Garnet

Limestone is just barely below 30% Clay plus Quartz and marly is just barely above, so they have been averaged together.

TEXTURE (Average from SS)

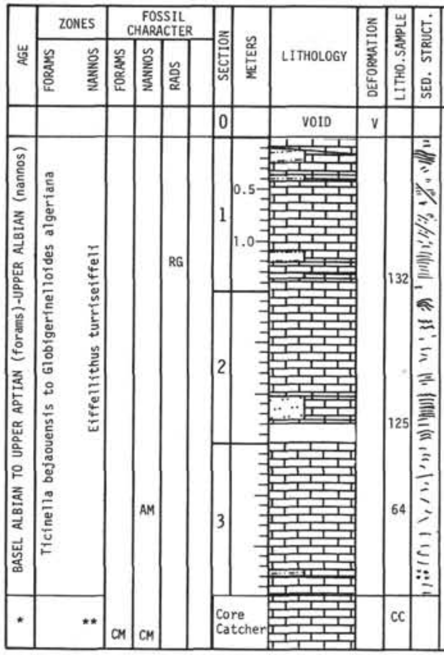
40% Sand, 40% Silt, 20% Clay

Carbon-Carbonate (DSDP)

4-87 (9.9, 0.1, 76)
6-103 (9.6, 0.1, 79)

10YR 6/1
10YR 5/1
10YR 5/1
10YR 5/1
10YR 6/1
10YR 5/1
Small fault
10YR 5/1
10YR 6/1
10YR 5/1
10YR 7/1
Mottled
10YR 5/1
10YR 5/1
10YR 6/1
10YR 5/1
10YR 6/1
Flow structure

Site 363 Hole Core 34 Cored Interval: 591.5-601.0 m



LITHOLOGIC DESCRIPTION

10YR 5/1
10YR 5/1
Fault
10YR 7/1
Fault, to 6/1
10YR 5/1
10YR 5/1
10YR 7/1 to 6/1
10YR 5/1
0 G
10YR 6/2
Mottles

LIMESTONE AND MARLY LIMESTONE WITH MINOR SILTY MARLY LIMESTONE

Light gray (10YR 7/1) limestone with minor gray (10YR 6/1 and 10YR 5/1) marly limestone, some layers rather silty. Limestone occassionally white (10YR 8/1). Cyclically bedded with pulses of darker terrigenous material diluted by carbonate. Laminated virtually throughout. Cementation has blurred and dimmed burrows. Some soft sediment deformation and minor faulting.

MINERALOGY (Average from SS)

12% Quartz
20% Clay
55% Carbonate unspecified
T Zeolite
T Opaques
0% Forams
13% Nannos
T Pyrite
T Fe-oxide
T Chlorite
Rare Zircon
Rare Garnet

TEXTURE (Average from SS)

14% Sand, 55% Silt, 31% Clay

Carbon-Carbonate (DSDP)

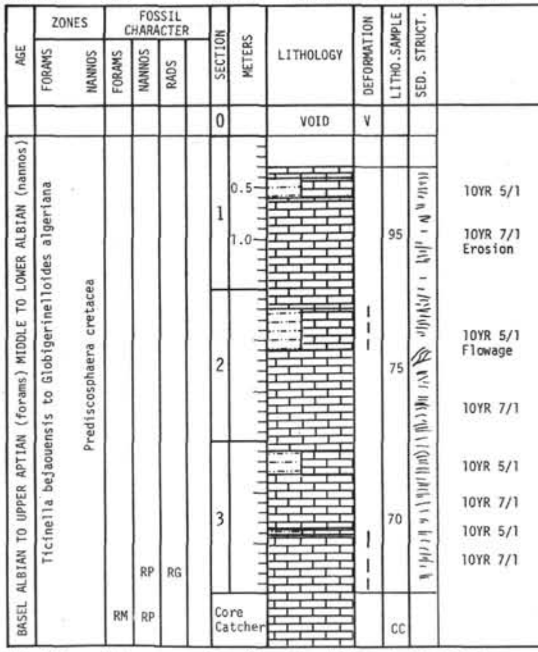
2-14 (9.6, 0.1, 79)

Carbon-Carbonate (OG)

2-130 (4.1, 0.1, 33)
2-150 (5.0, 0.1, 41)

*BASEL ALBIAN TO UPPER APTIAN (forams) **Prediscosphaera cretacea
MIDDLE TO LOWER ALBIAN (nannos)
Explanatory notes in Chapter 1

Site 363 Hole Core 35 Cored Interval: 610.5-620.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE AND MARLY LIMESTONE

Light gray (10YR 7/1) limestone intercalated with gray (10YR 5/1) marly limestone. Cyclically bedded with pulses of darker terrigenous material diluted by carbonate. Laminated virtually throughout. Cementation has blurred and dimmed burrows. Some soft sediment deformation and minor faulting.

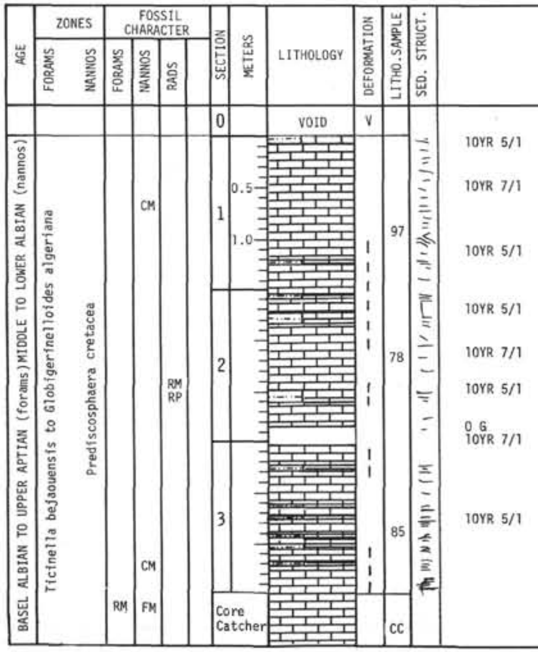
MINERALOGY (Average from SS)
11% Quartz
17% Clay
50% Carbonate unspecified
T Pyrite
T Opaques
0% Forams
14% Nannos
8% Dolomite
T Zeolite
Rare Tourmaline

Pyrite 10% in 35 CC.

TEXTURE (Average from SS)
21% Sand, 56% Silt, 23% Clay

Carbon-Carbonate (DSDP)
1-52 (9.2, 0.2, 74)

Site 363 Hole Core 36 Cored Interval: 629.5-639.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE, MINOR MARLY LIMESTONE

Gray (10YR 7/1) limestone and minor darker gray (10YR 5/1) marly limestone. Well laminated throughout. Soft sediment slumping, cross bedding, silty layers locally. Some silty layers pyritic. Minor pyritic patches. Well indurated. Marly layers thin but still there are pulses of terrigenous material that locally darken the limestones slightly. Not much burrowing.

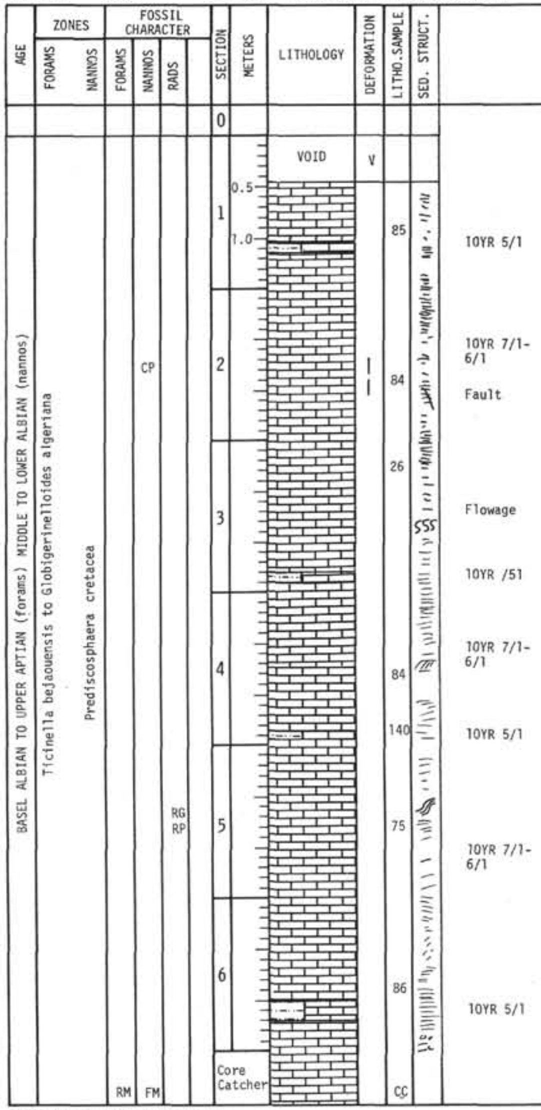
MINERALOGY (Average from SS)
9% Quartz
16% Clay
11% Dolomite
50% Carbonate unspecified
T Forams
5% Nannos
1% Calcisphers.
T Fe-oxide
Rare Garnet
Rare Zircon

TEXTURE (Average from SS)
12% Sand, 53% Silt, 35% Clay

Carbon-Carbonate (DSDP)
1-84 (7.9, 0.1, 65)

Carbon-Carbonate (OG)
2-138 (9.7, 0.1, 80)
2-150 (4.2, 0.1, 34)

Site 363 Hole Core 37 Cored Interval: 648.5-658.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE WITH MINOR MARLY LIMESTONE

Light gray (10YR 7/1) or gray (10YR 6/1) limestone with minor layers of gray (10YR 5/1) marly limestone. Well laminated throughout. Very regular cyclic pulses of terrigenous material responsible for color variations. This core intensively burrowed in several sections. Some silty layers, including pyritic silts. Soft-sediment slumping and compaction faulting. Very well indurated.

MINERALOGY (Average from SS)
9% Quartz
12% Clay
49% Carbonate unspecified
8% Calcisphers.
T Chlorite
3% Forams
6% Nannos
10% Dolomite
T Zeolite
T Fe-oxide
Rare Zircon
Rare Amphibole?
Rare Garnet

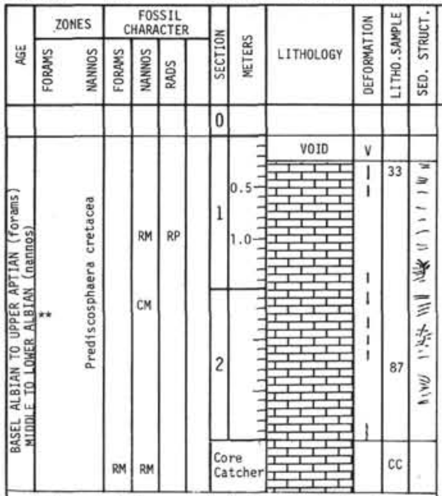
TEXTURE (Average from SS)
18% Sand, 58% Silt, 24% Clay

Carbon-Carbonate (DSDP)
4-59 (7.8, 0.1, 64)
6-79 (7.1, 0.3, 57)

Grain Size (DSDP)
4-61 (6.3, 58.6, 35.1)
6-81 (1.5, 51.0, 47.5)

Explanatory notes in Chapter 1

Site 363 Hole Core 38 Cored Interval: 667.5-677.0 m



**Ticinella bejaouensis to Globigerinelloides algeriana

LITHOLOGIC DESCRIPTION

Contorted bedding
10YR 7/1
minor
10YR 5/1 in laminated zones
Faulted laminae

LIMESTONE
Light gray (10YR 7/1) limestone with very minor gray (10YR 5/1) slightly marly zones. Well laminated throughout. Irregular sandy patches still predominantly carbonate. Pyritic patches. Very well indurated. Compaction faulting. Many dips shown in sediment structures probably induced by drilling.

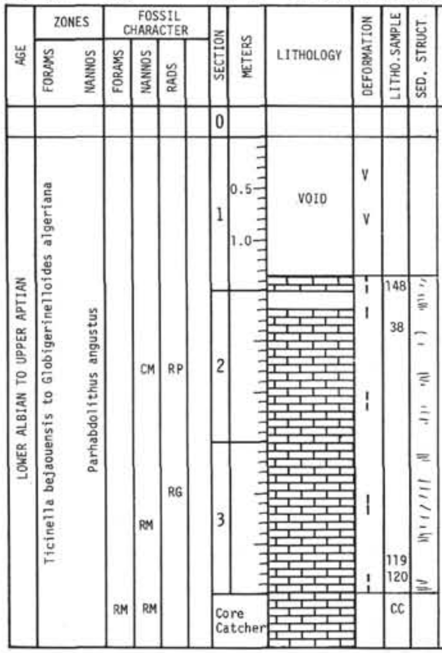
MINERALOGY (Average from SS)
12% Quartz
12% Clay
55% Carbonate unspecified
1% Forams
2% Nannos
10% Dolomite
Rare Amphibole
Rare Garnet
Rare Zircon
Rare Chlorite

Smear slide CC has 20% Pyrite.

TEXTURE (Average from SS)
27% Sand, 53% Silt, 20% Clay

Carbon-Carbonate (DSDP)
1-92 (9.4, 0.1, 78)

Site 363 Hole Core 39 Cored Interval: 686.5-696.0 m



LITHOLOGIC DESCRIPTION

LIMESTONE
Yellowish gray (10YR 7/1) limestone. Well laminated throughout. Minor cross beds. Pyritic silty layers. Very well indurated. Lower part of Section 3 has calcarenite lenses (beginning of Unit III).

O G

MINERALOGY (Average from SS)
10% Quartz
10% Clay
60% Carbonate unspecified
T Chlorite
0% Forams
0% Nannos
5% Dolomite
T Zeolite
Rare Zircon
Rare Tourmaline

SS 1-148 and 3-120 are in pyritic layers.

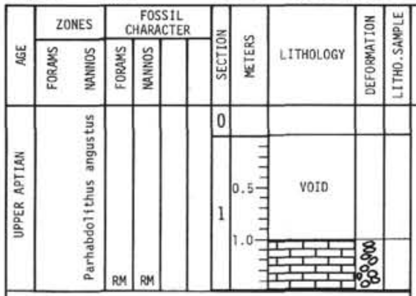
TEXTURE (Average from SS)
18% Sand, 41% Silt, 41% Clay

Carbon-Carbonate (DSDP)
2-94 (9.7, 0.1, 80)

Sandy layer

Carbon-Carbonate (OG)
2-0 (8.8, 0.1, 73)
2-20 (6.9, 0.2, 56)

Site 363 Hole Core 40 Cored Interval: 705.5-715.0 m



LITHOLOGIC DESCRIPTION

SS 115
6 Thin sections
SS 145

LIMESTONE WITH CALCARENITE LAYERS
Yellowish gray (10YR 7/1) limestone. No core catcher. Core consists of 9 numbered pieces of limestone, out of sequence, each considerably less than the core liner diameter. Several pieces contain calcarenite patches of layers. Thin sections reveal abundant foraminifera with chambers filled with chalcedony. Pieces give off phosphatic odor when cut with saw and have collophane in thin section. Calcarenites consist partly of forams, partly of spherical limestone sand grains rounded in high energy environment (wave base?). Traces of calcareous algae are present.

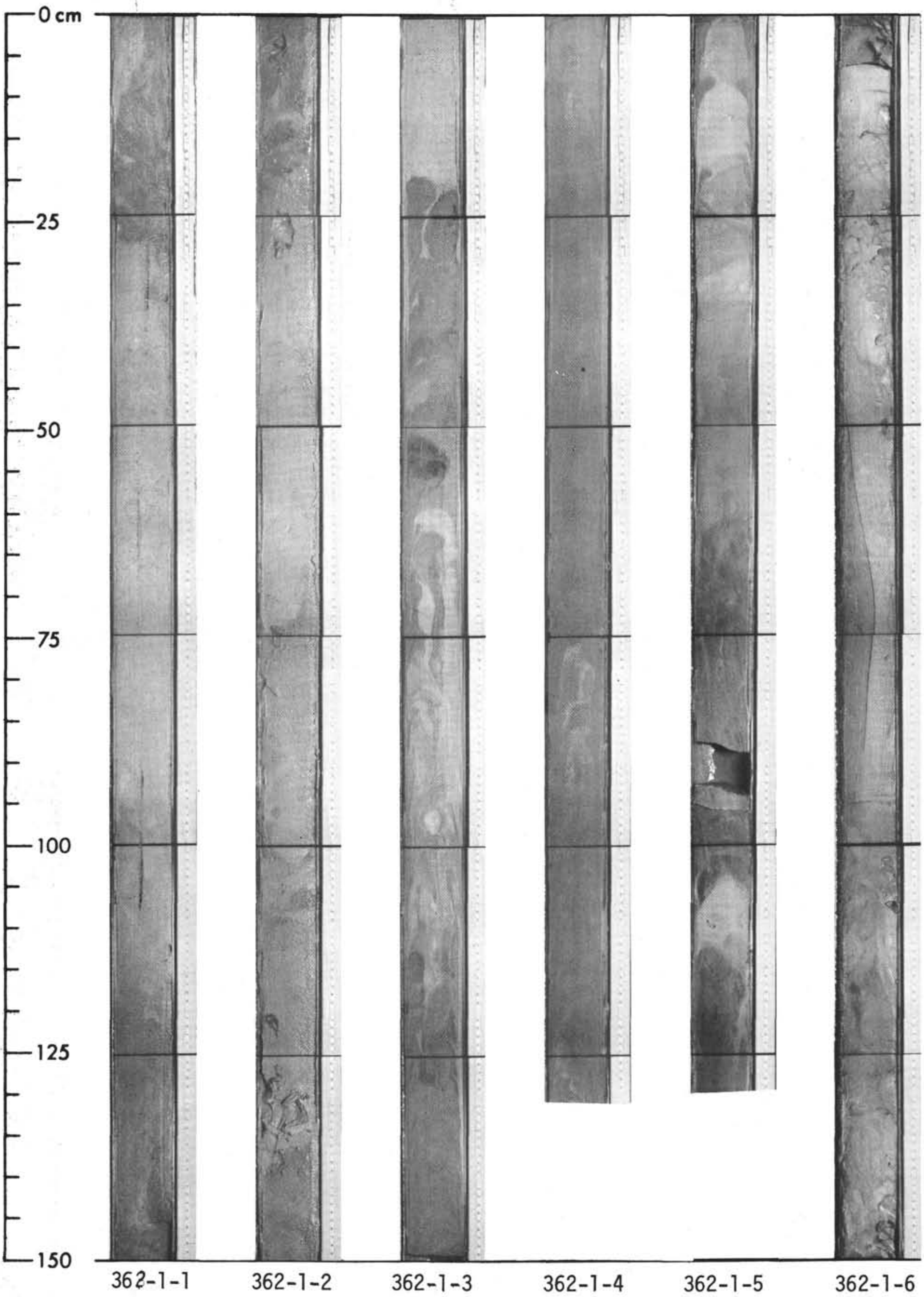
MINERALOGY
SS 1-115
8% Quartz
10% Clay
70% Carbonate unspecified
0% Forams
0% Nannos
1% Pyrite
Rare Garnet

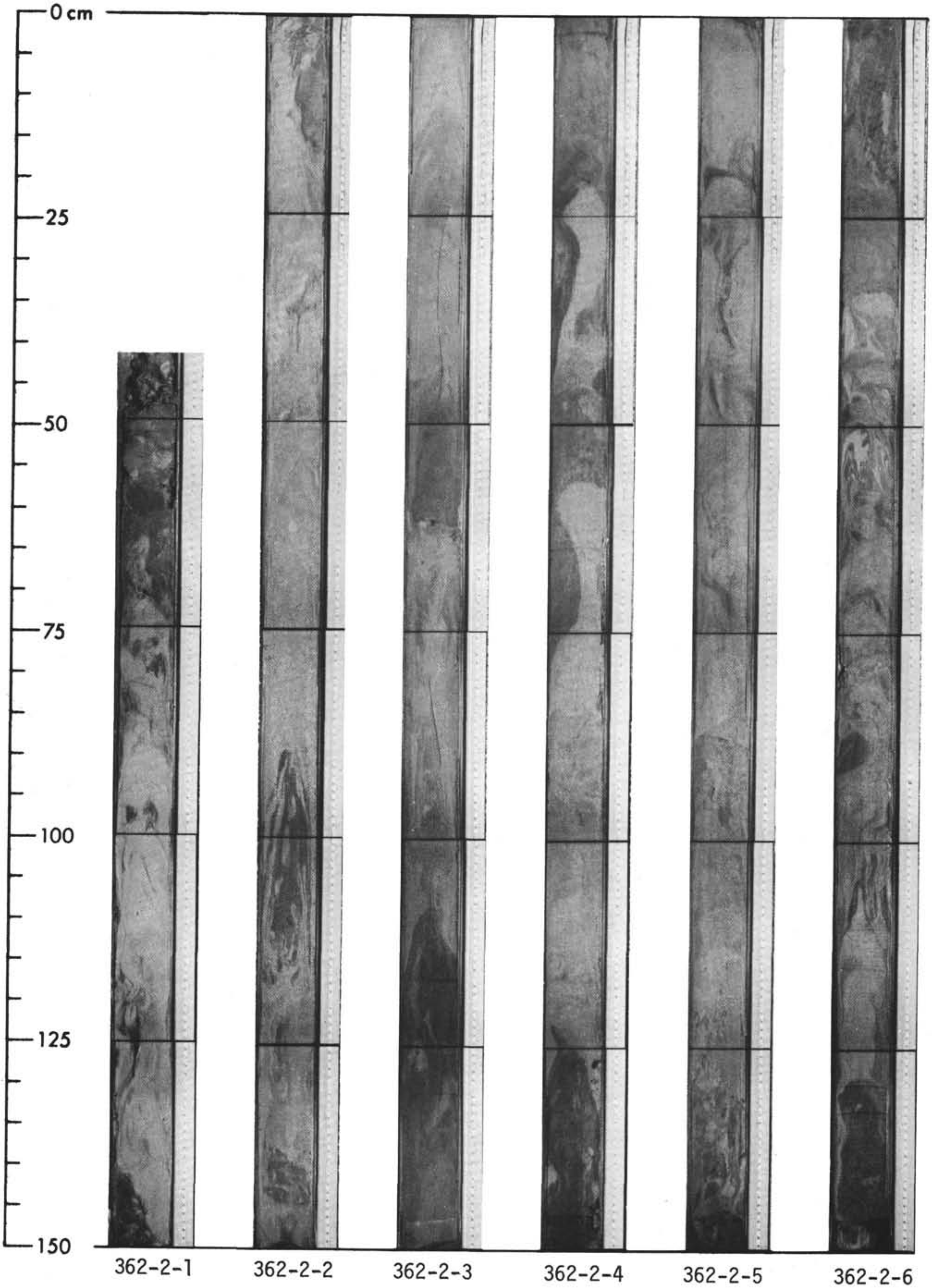
Abundant forams observed in thin section disintegrate upon making smear slides.

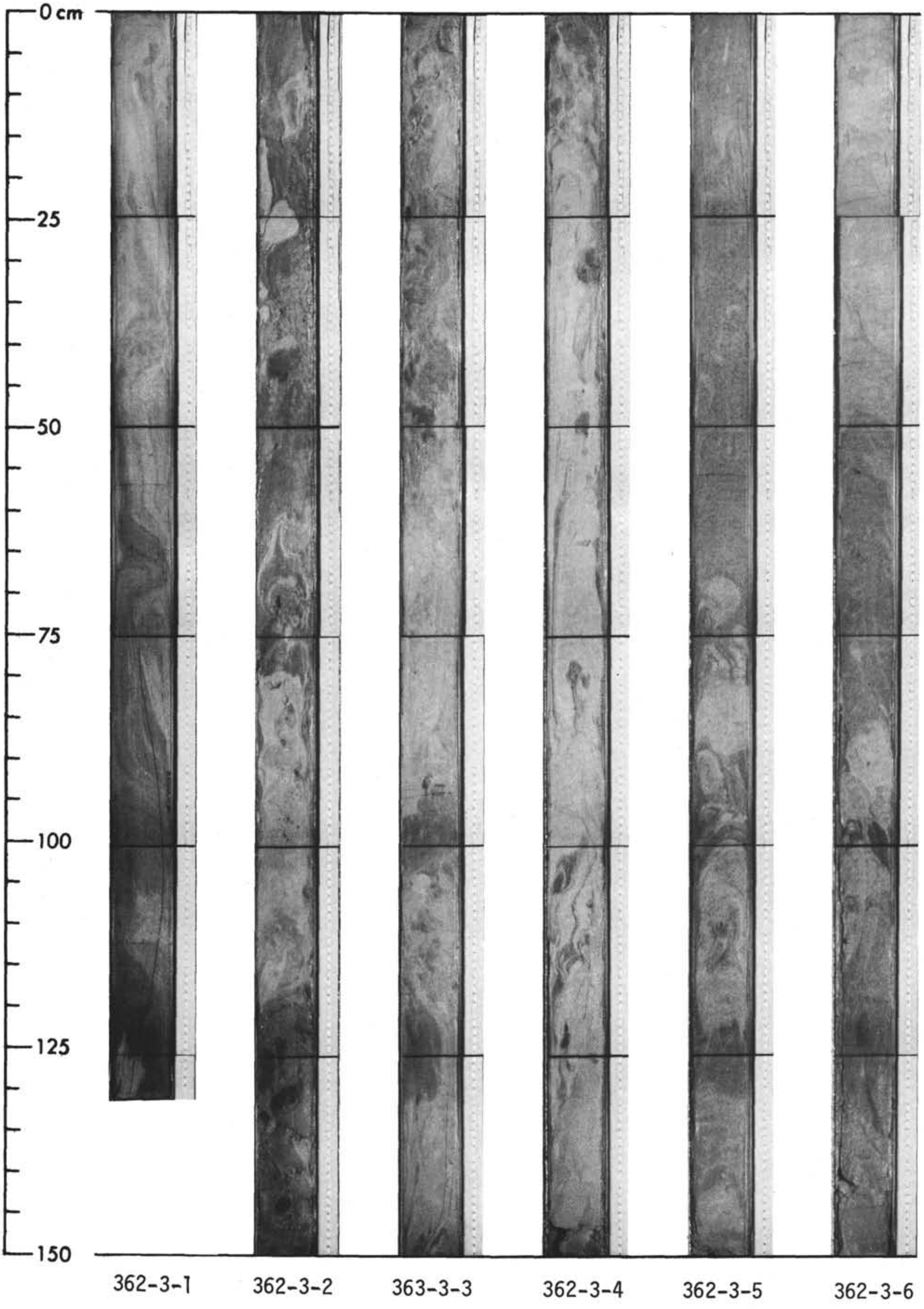
TEXTURE
25% Sand, 60% Silt, 15% Clay

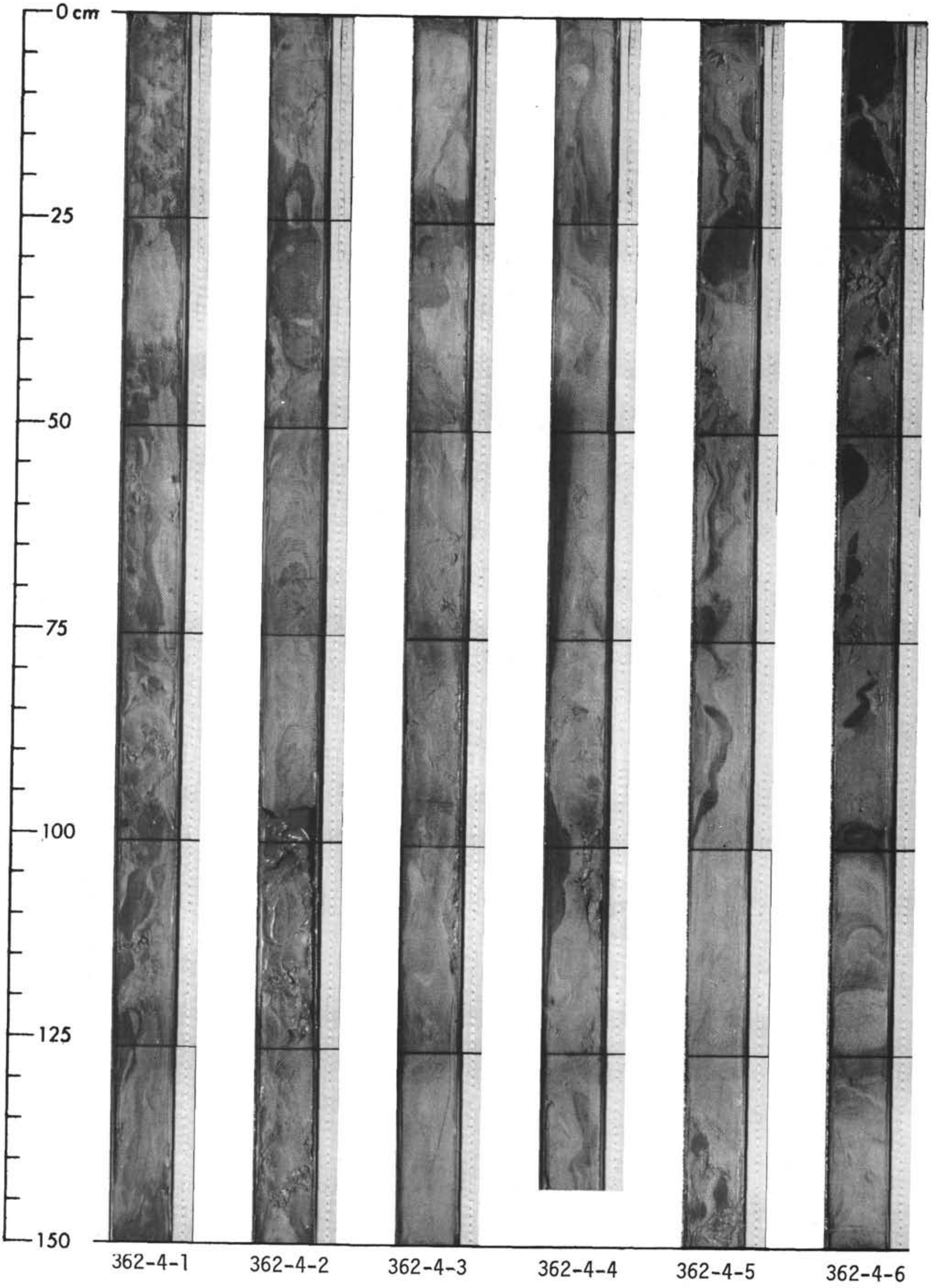
Thin section descriptions will be included in the Initial Report for Leg 40.

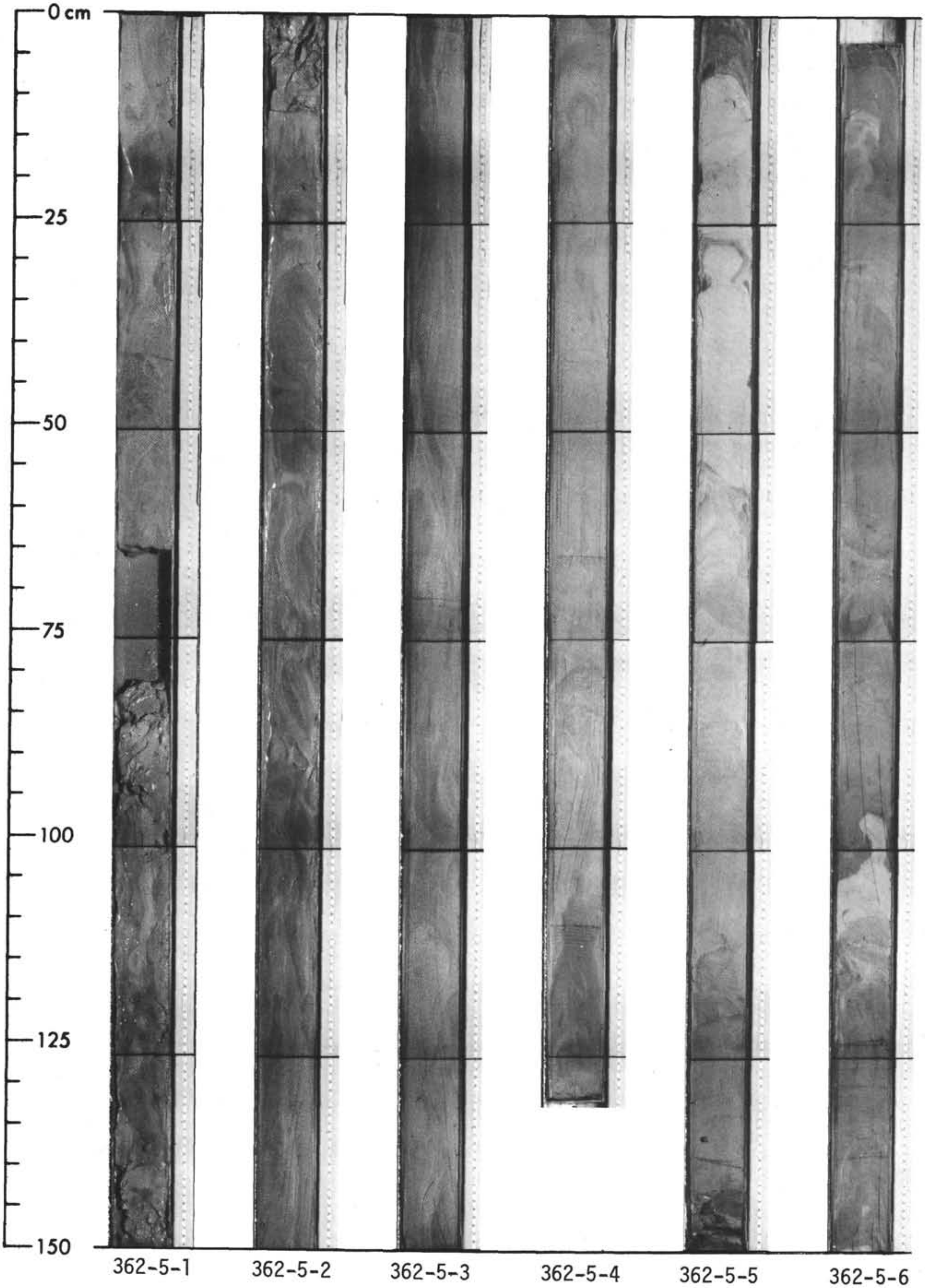
Explanatory notes in Chapter 1

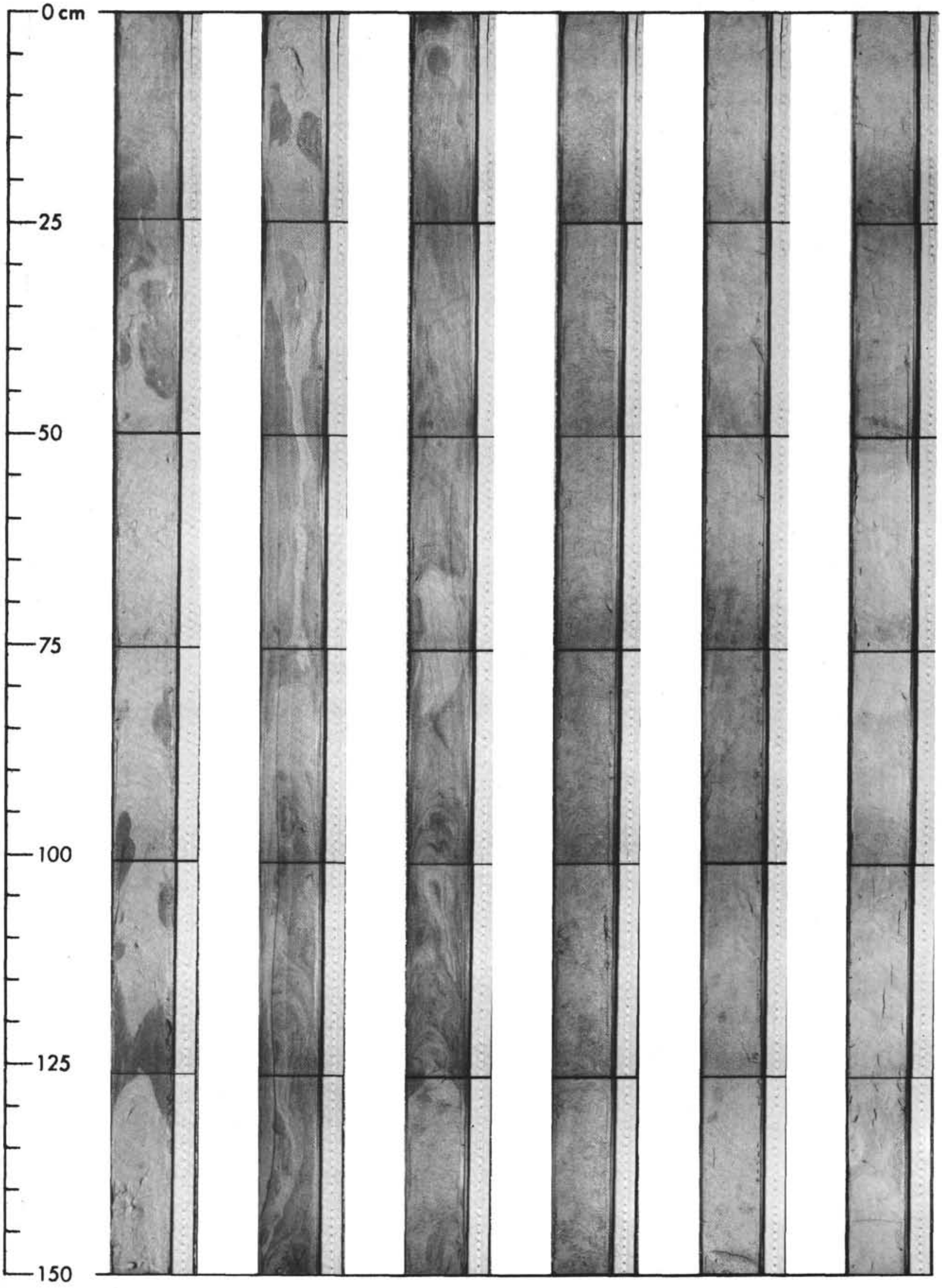

0 cm
25
50
75
100
125
150
362-1-1
362-1-2
362-1-3
362-1-4
362-1-5
362-1-6

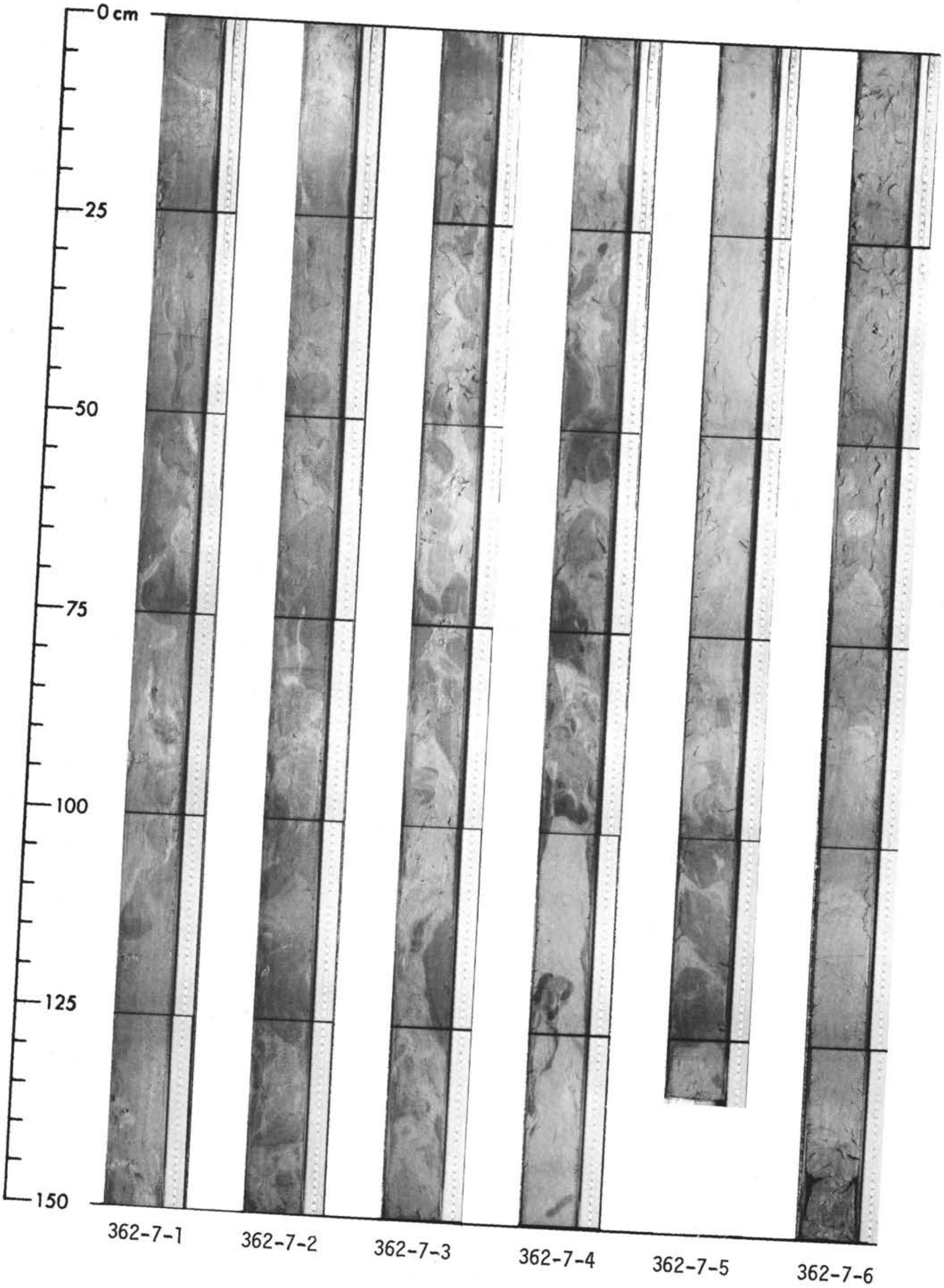

0 cm
25
50
75
100
125
150
362-2-1
362-2-2
362-2-3
362-2-4
362-2-5
362-2-6

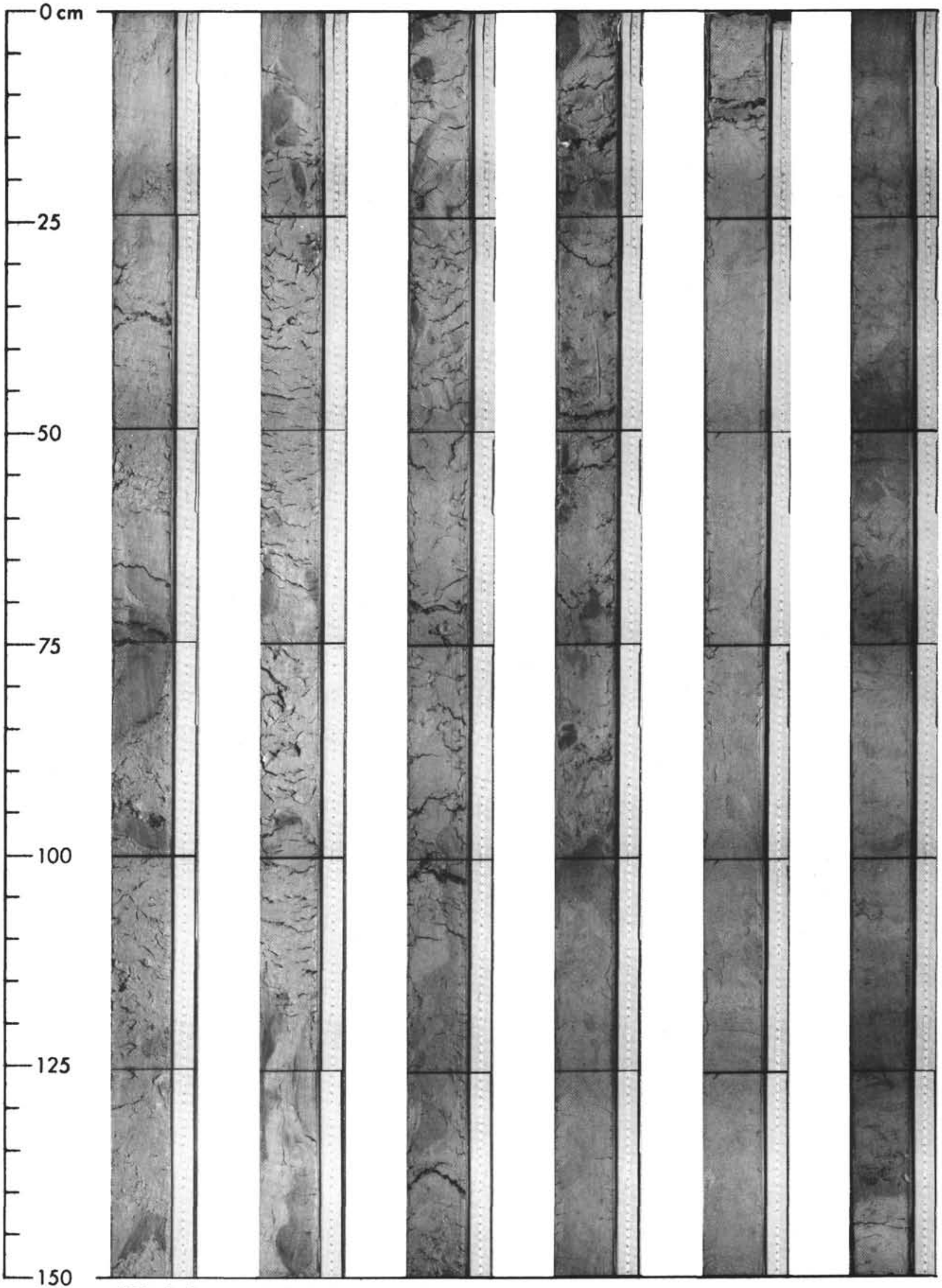

0 cm
25
50
75
100
125
150
362-3-1
362-3-2
363-3-3
362-3-4
362-3-5
362-3-6

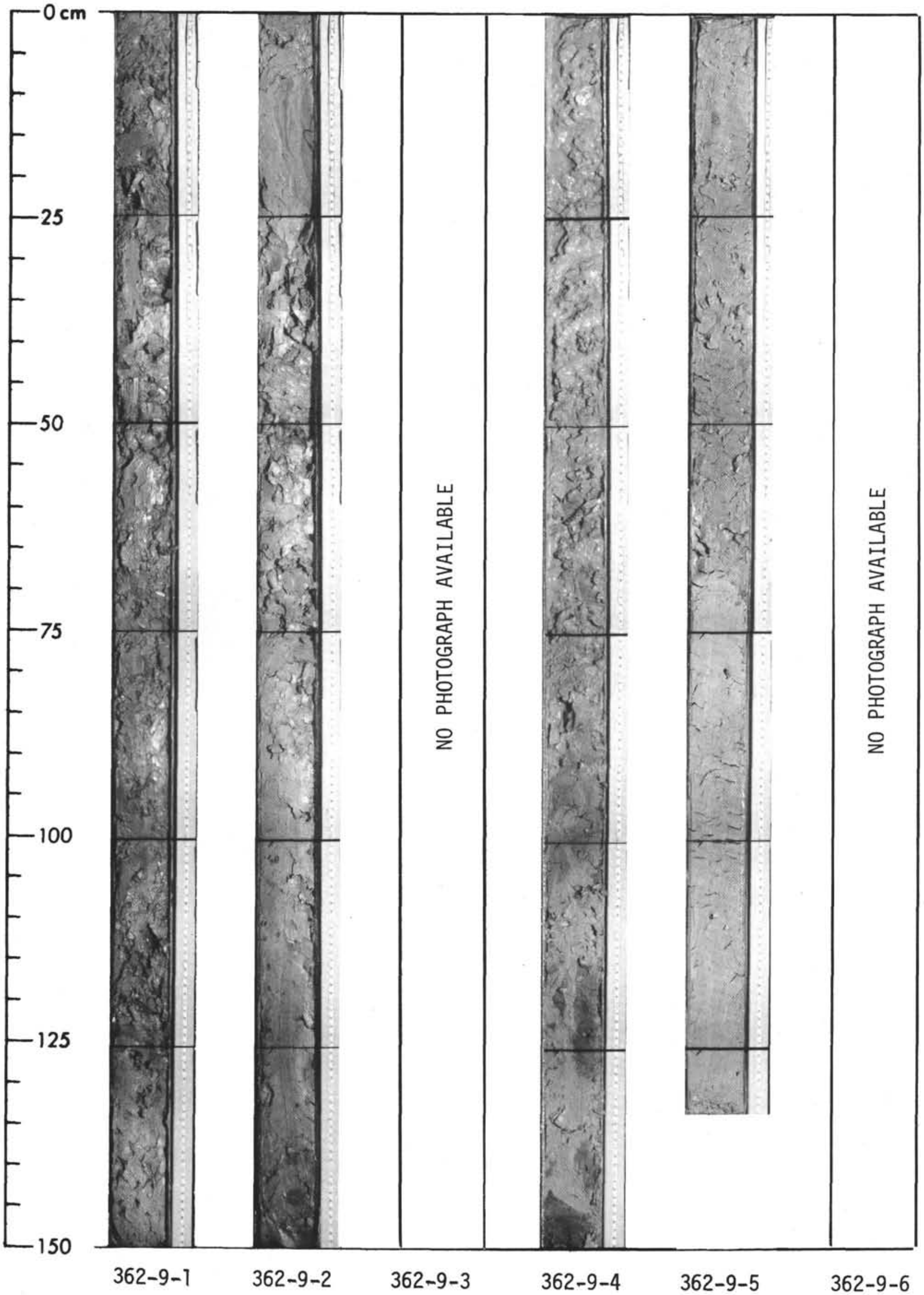

0 cm
25
50
75
100
125
150
362-4-1
362-4-2
362-4-3
362-4-4
362-4-5
362-4-6

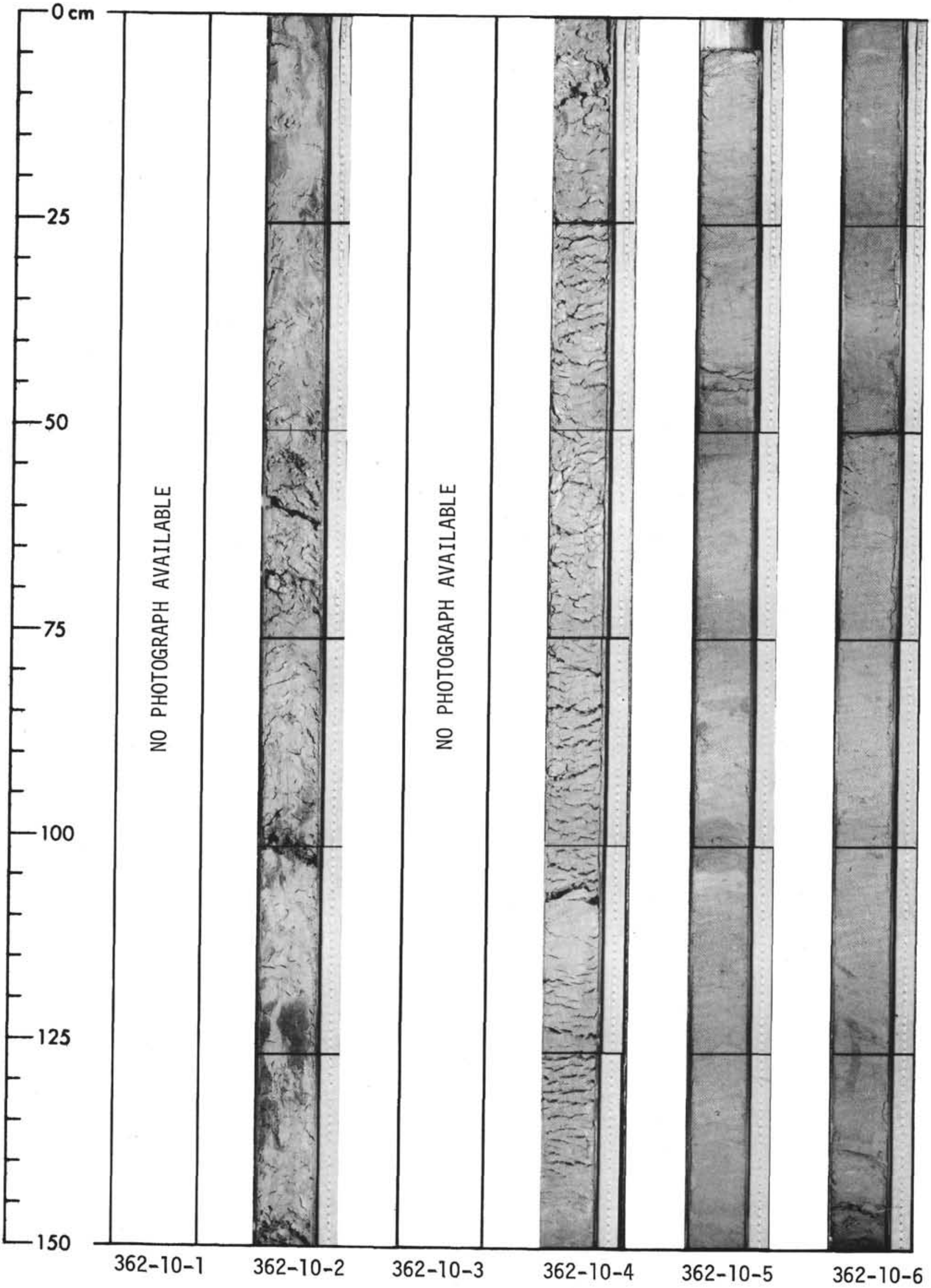

0 cm
25
50
75
100
125
150
362-5-1
362-5-2
362-5-3
362-5-4
362-5-5
362-5-6

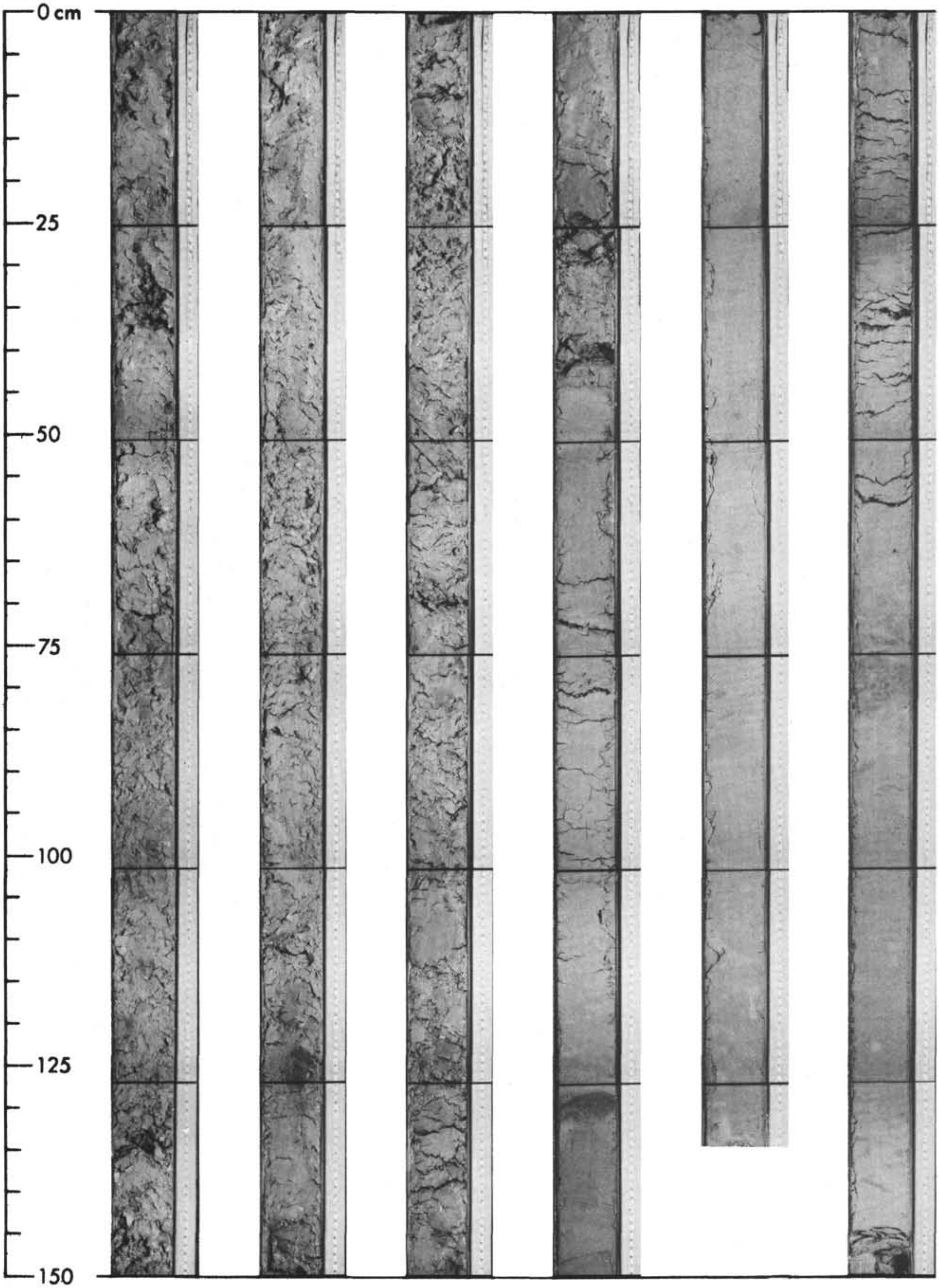

0 cm
25
50
75
100
125
150
362-6-1
362-6-2
363-6-3
362-6-4
362-6-5
362-6-6


0 cm
25
50
75
100
125
150
362-7-1
362-7-2
362-7-3
362-7-4
362-7-5
362-7-6


0 cm
25
50
75
100
125
150
362-8-1
362-8-2
362-8-3
362-8-4
362-8-5
362-8-6


0 cm
25
50
75
100
125
150
NO PHOTOGRAPH AVAILABLE
NO PHOTOGRAPH AVAILABLE
362-9-1
362-9-2
362-9-3
362-9-4
362-9-5
362-9-6


0 cm
25
50
75
100
125
150
NO PHOTOGRAPH AVAILABLE
NO PHOTOGRAPH AVAILABLE
362-10-1
362-10-2
362-10-3
362-10-4
362-10-5
362-10-6



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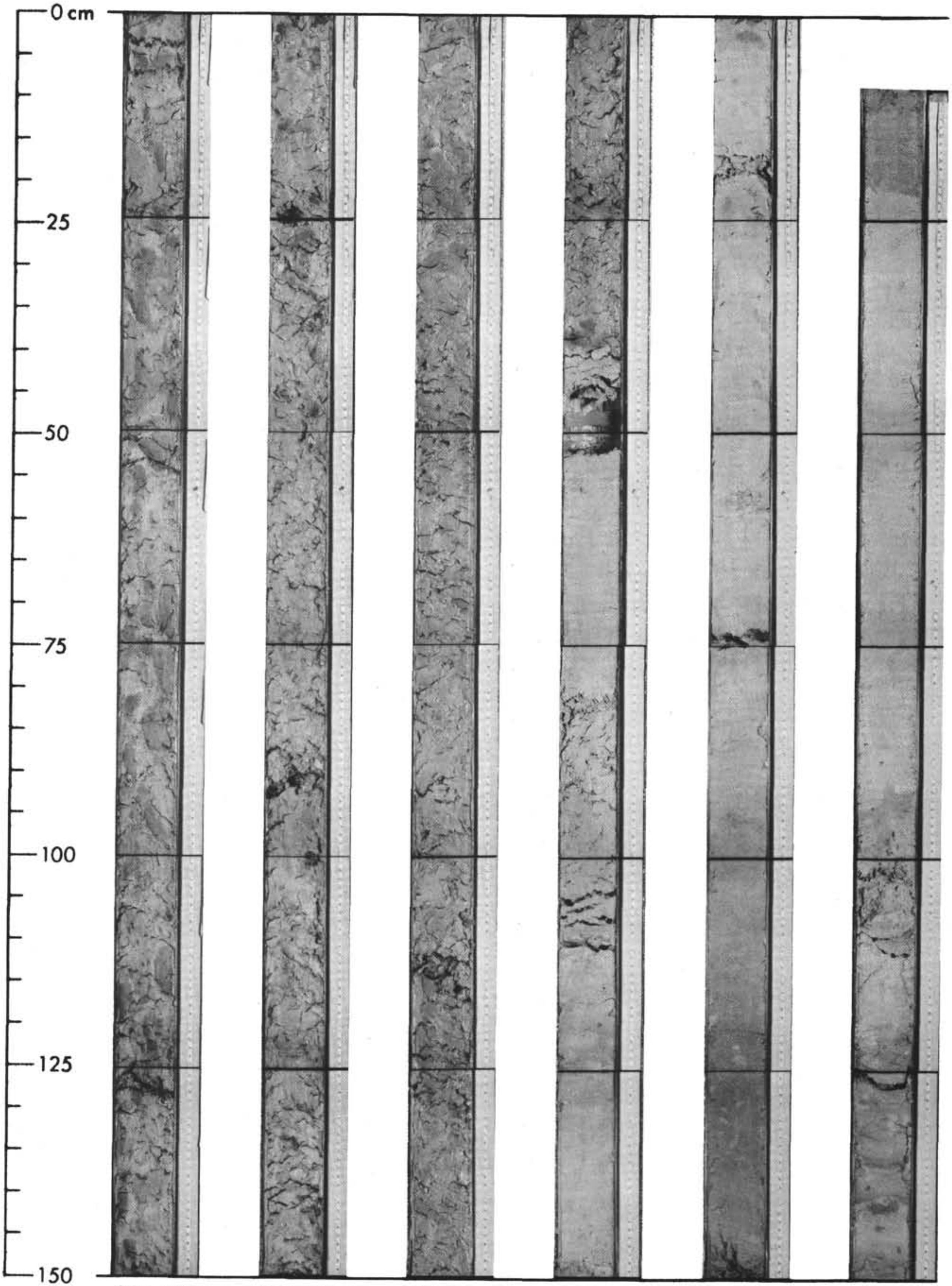
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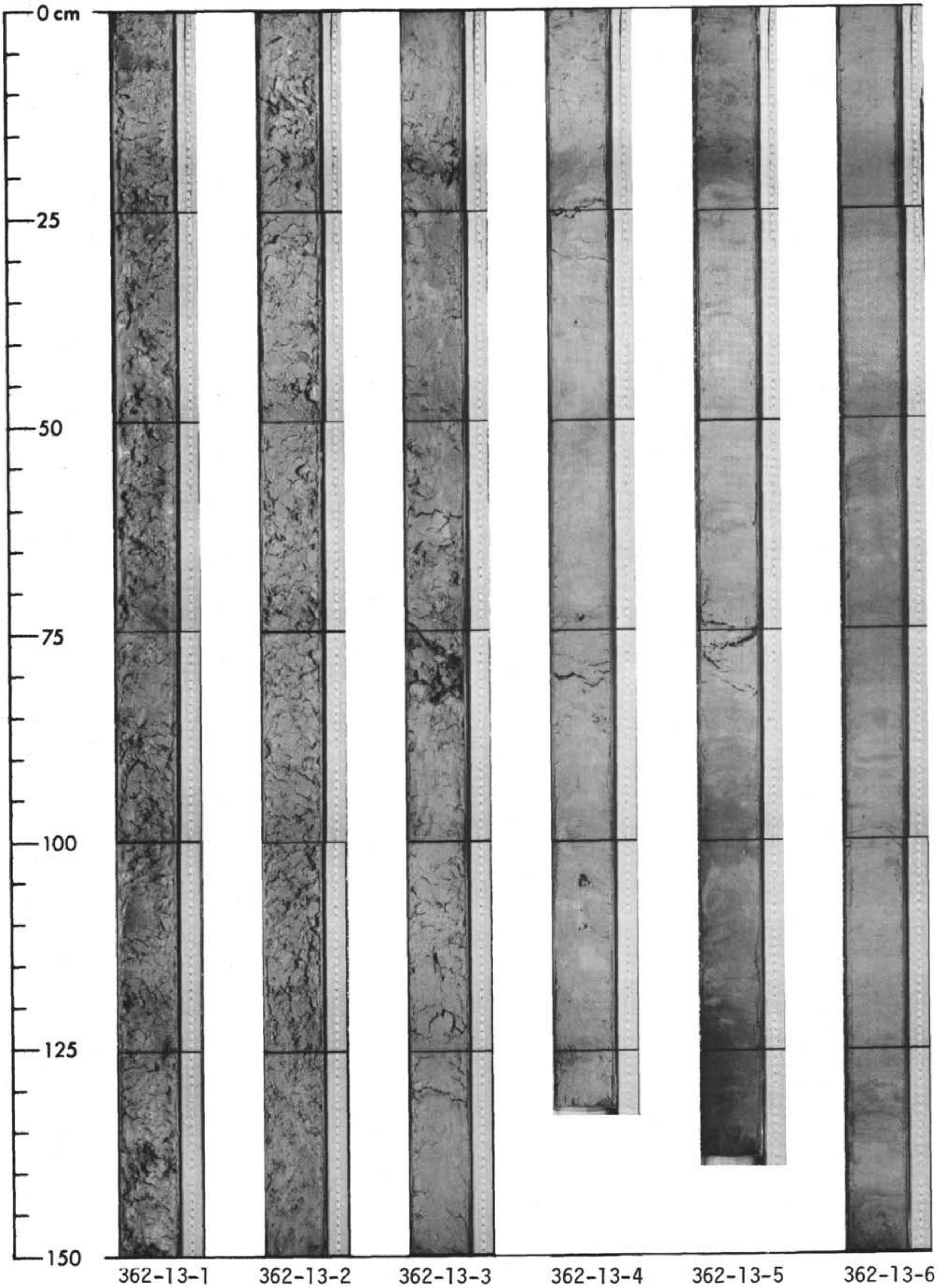
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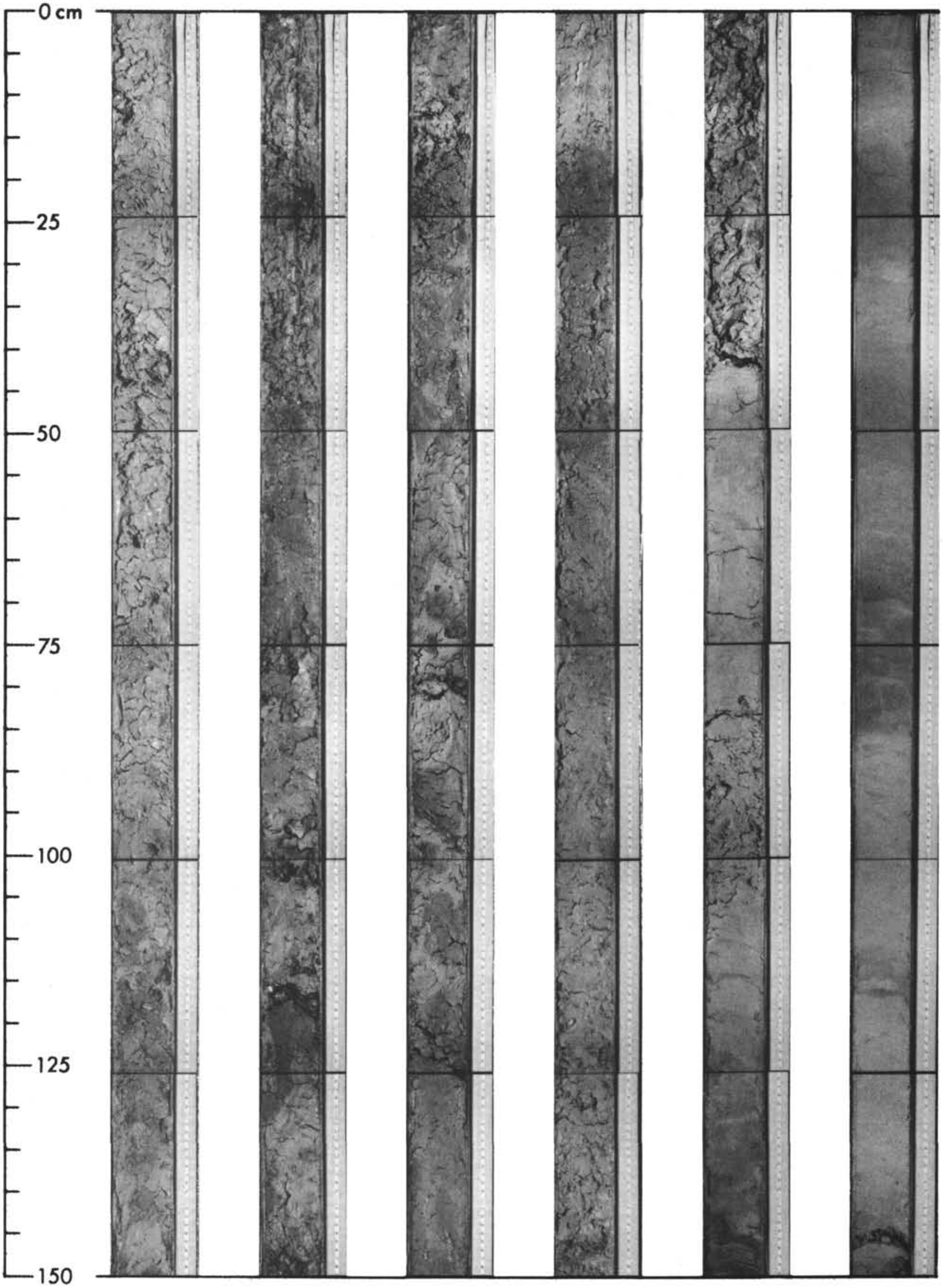
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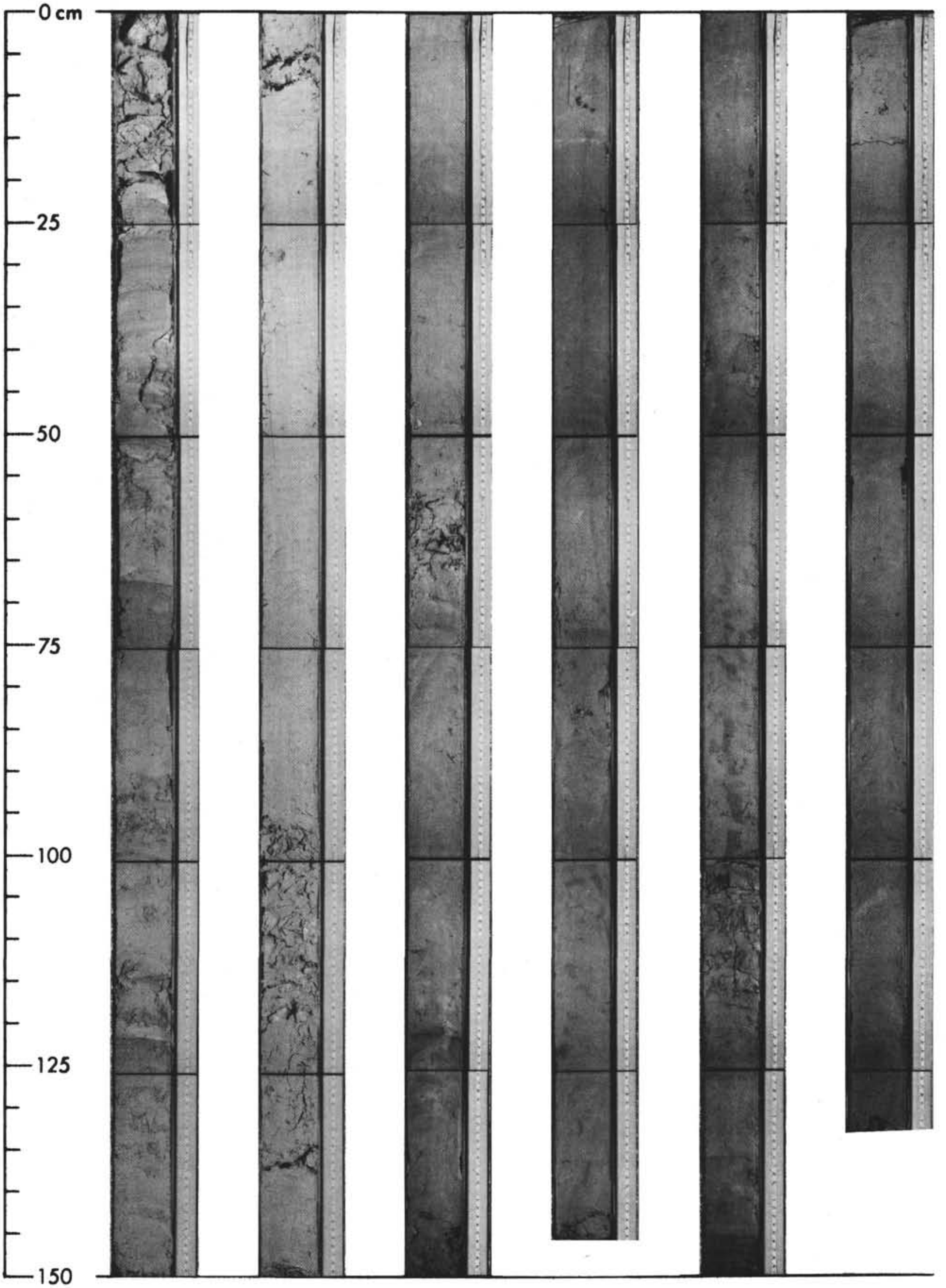
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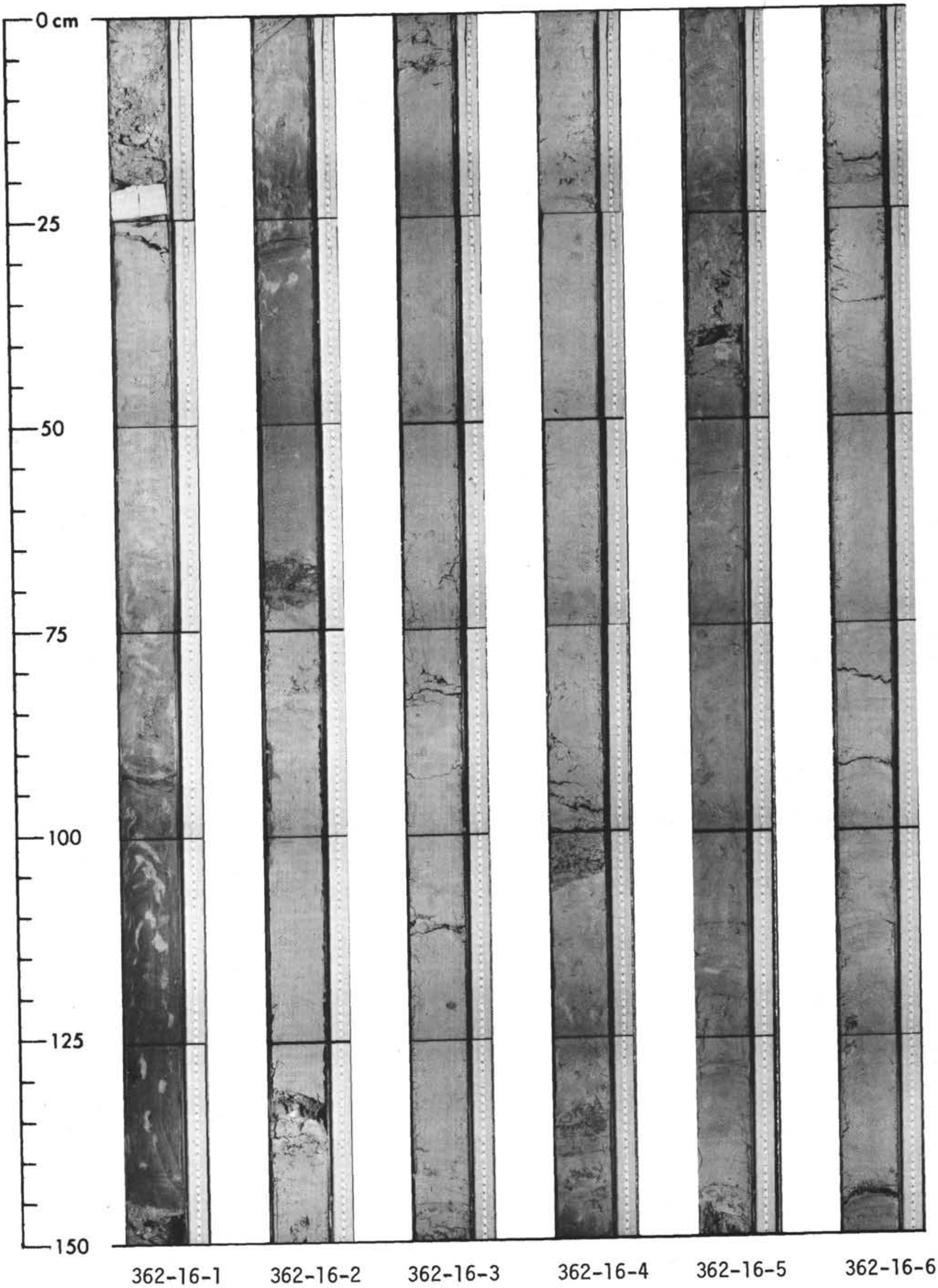
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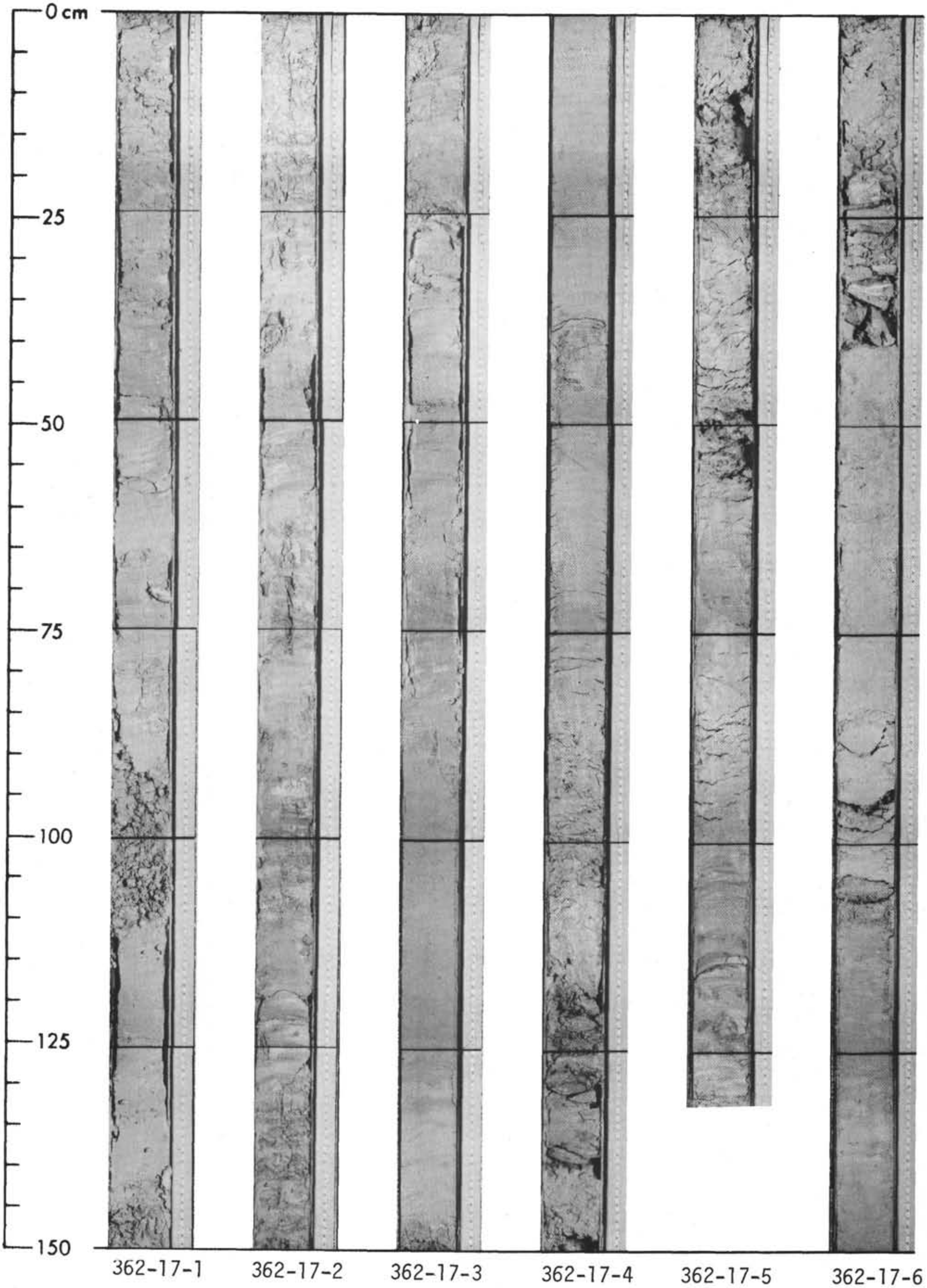
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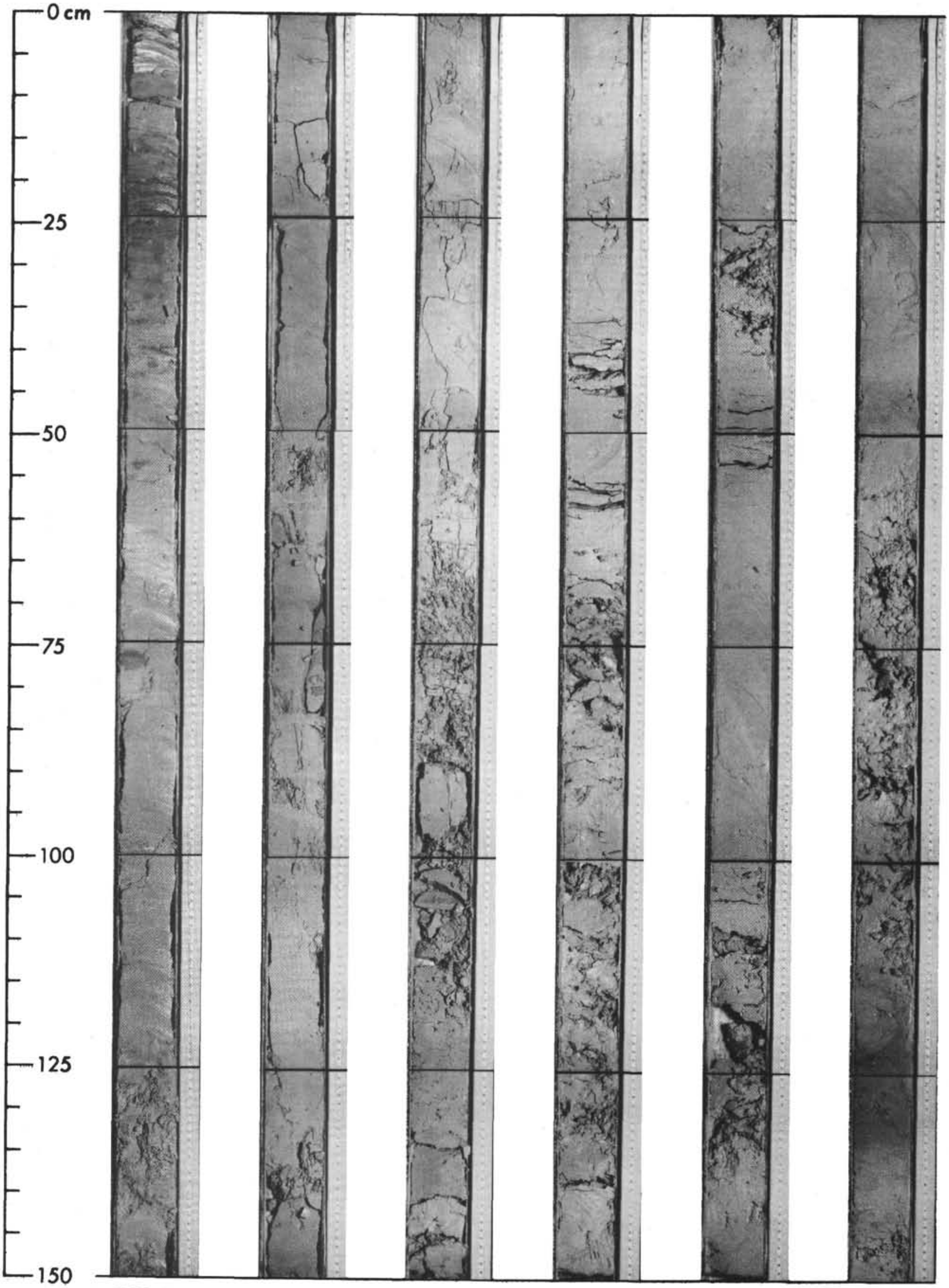
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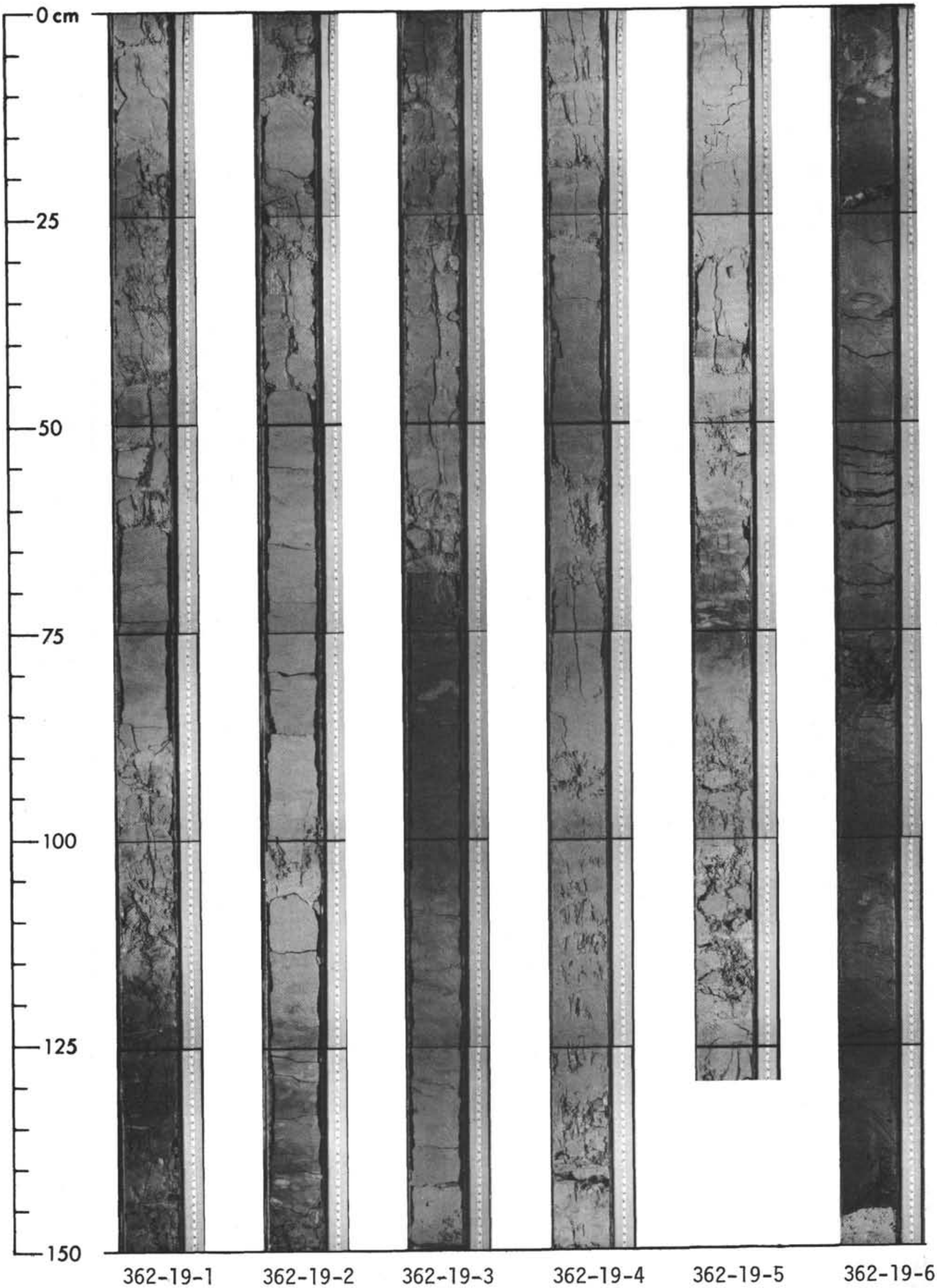
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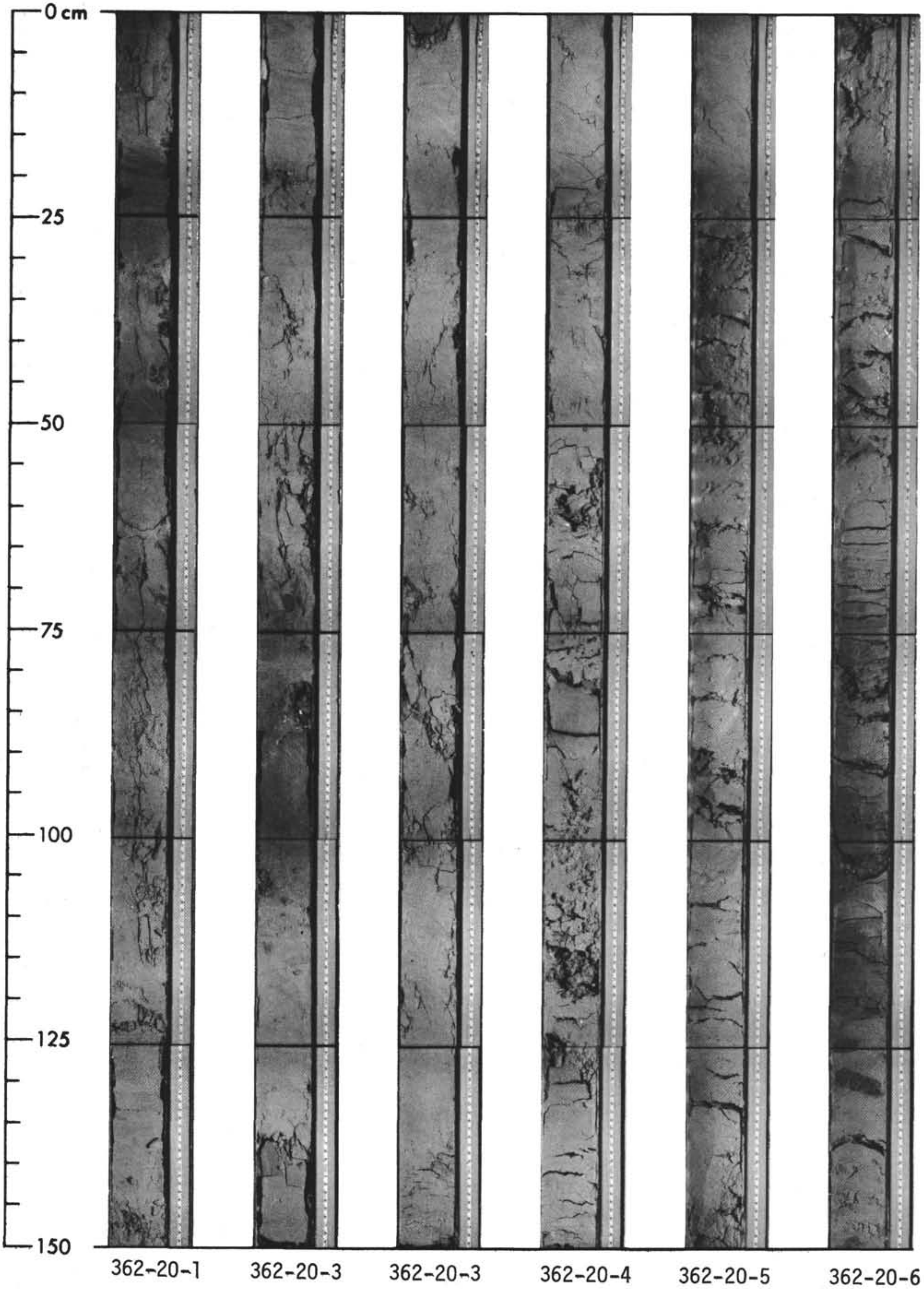
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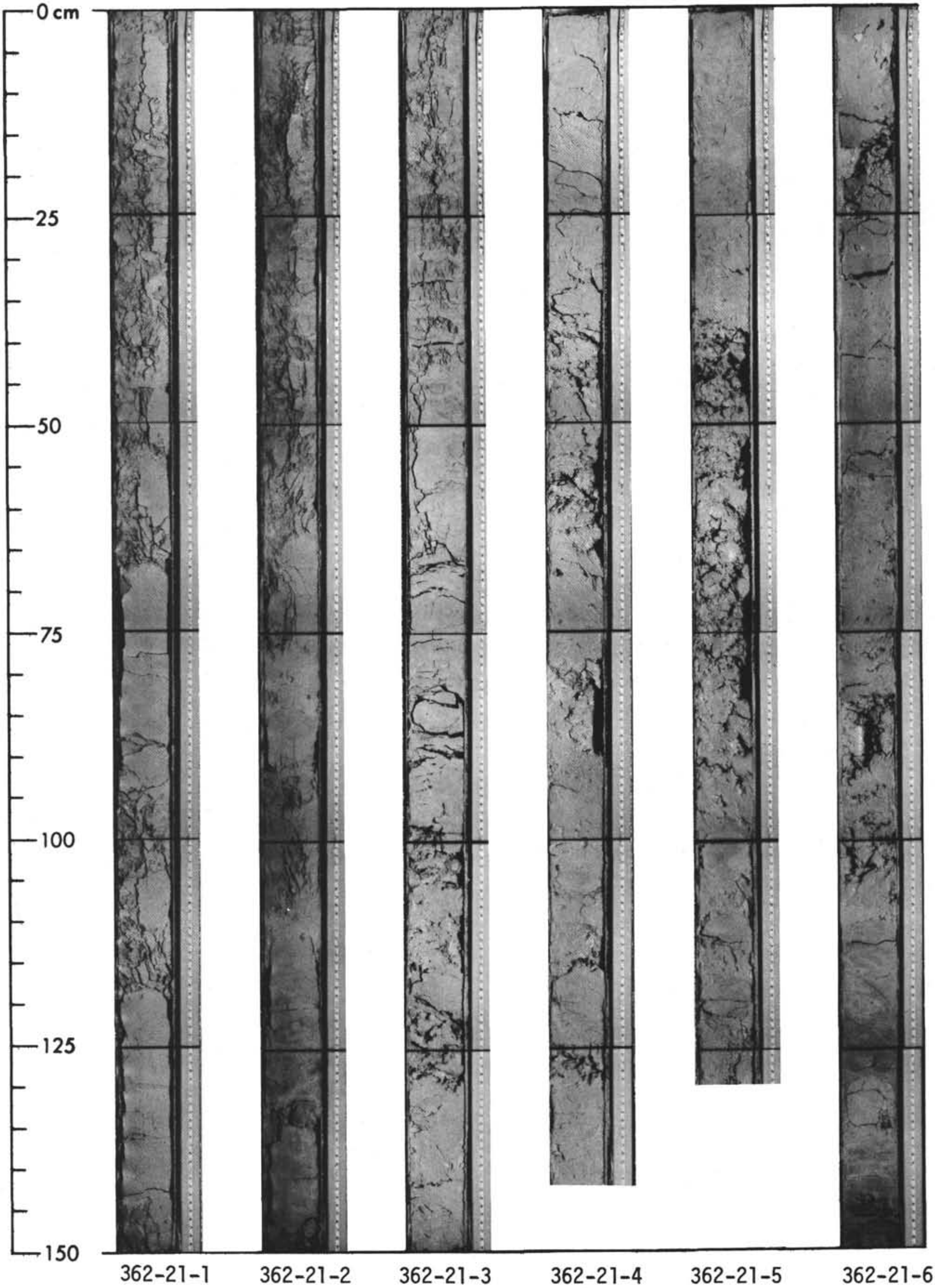
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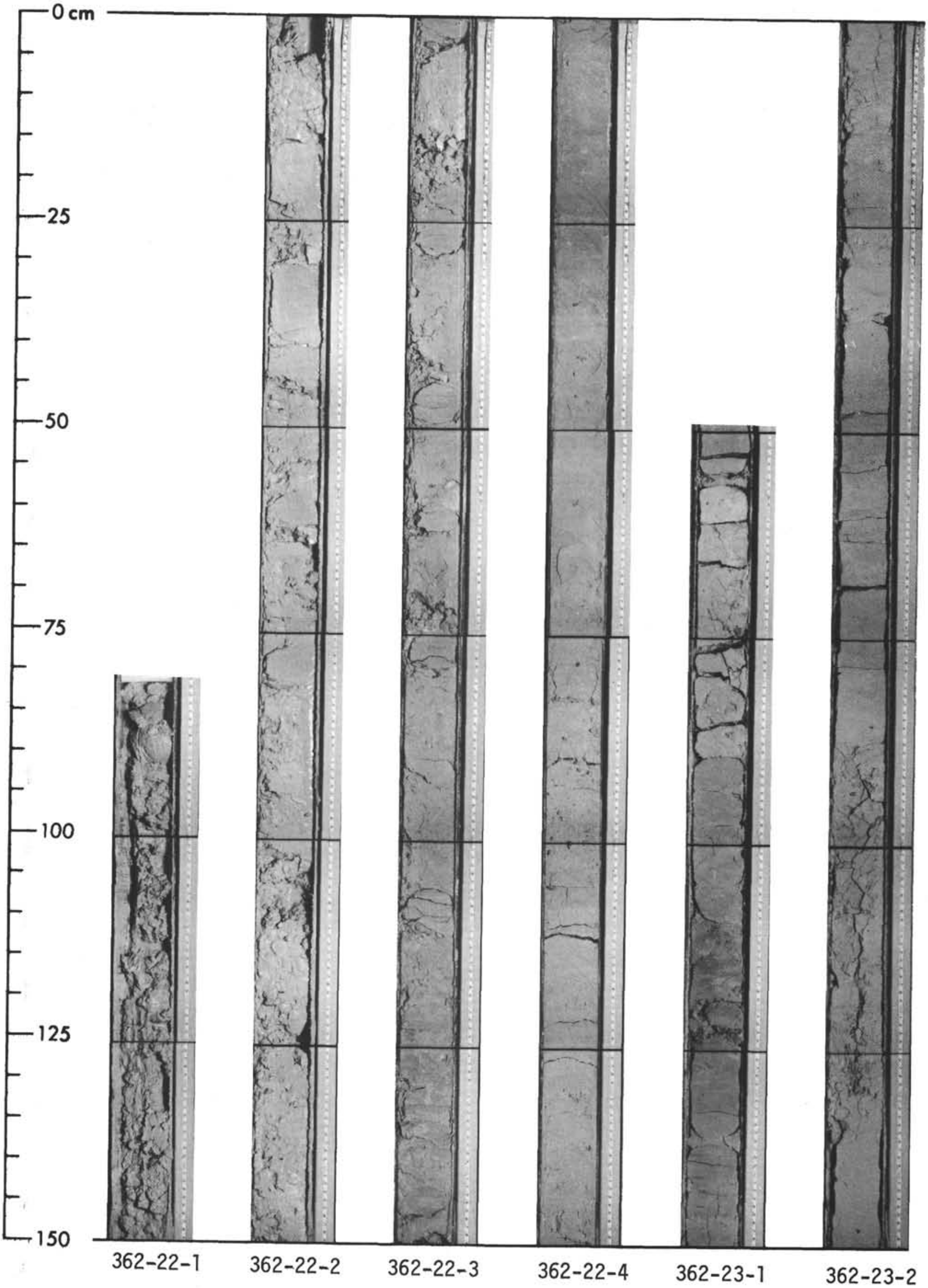

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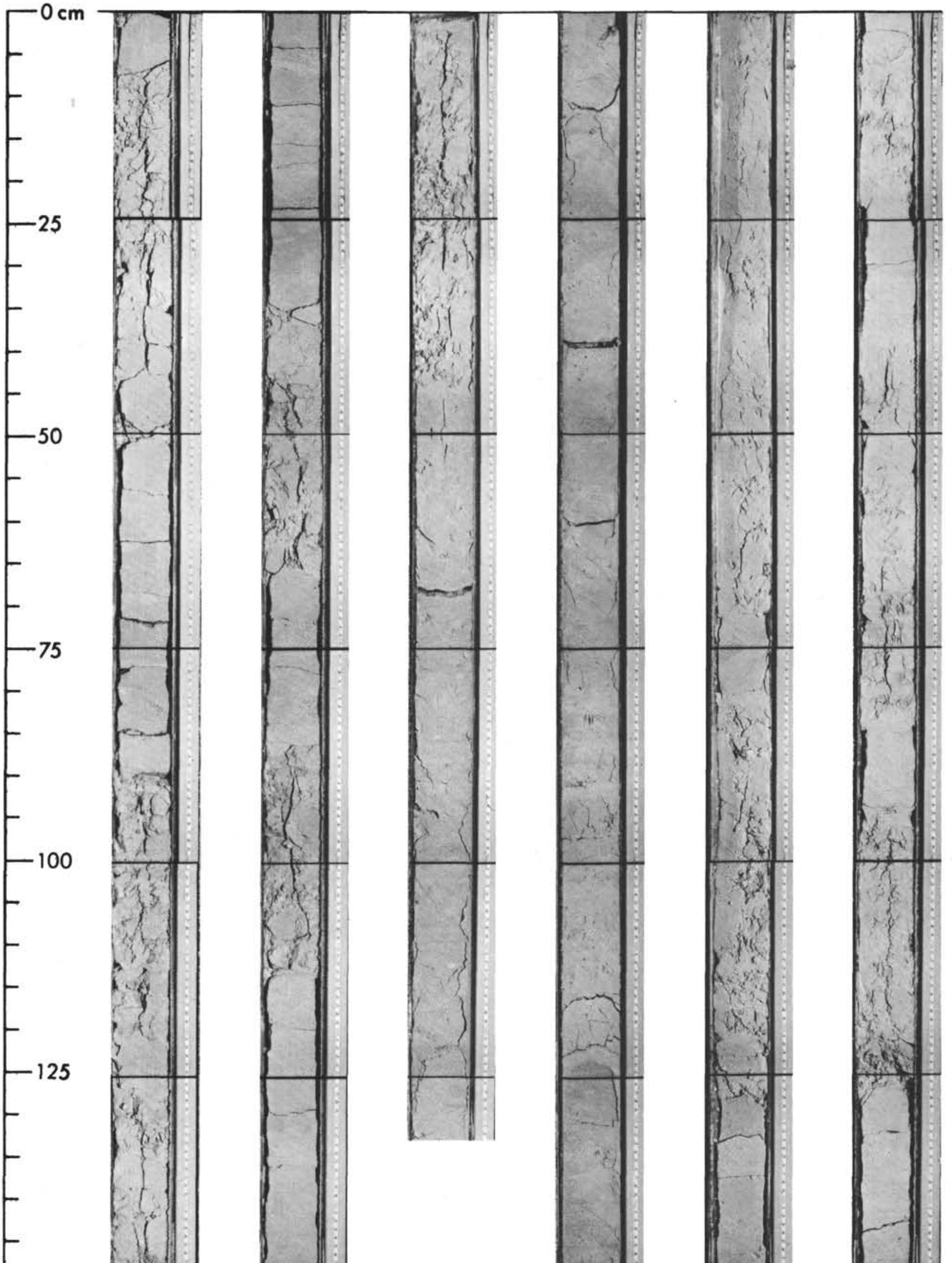
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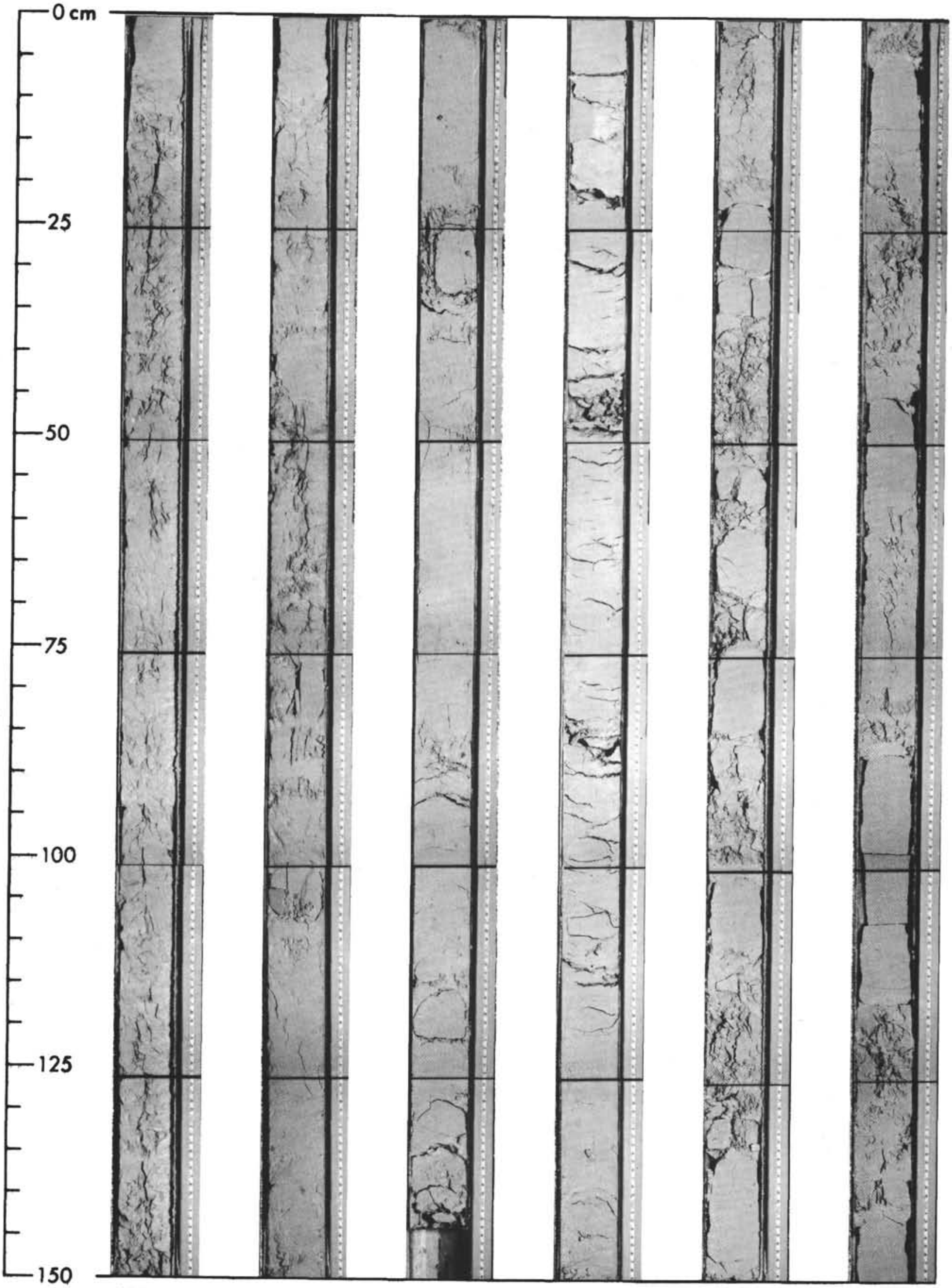
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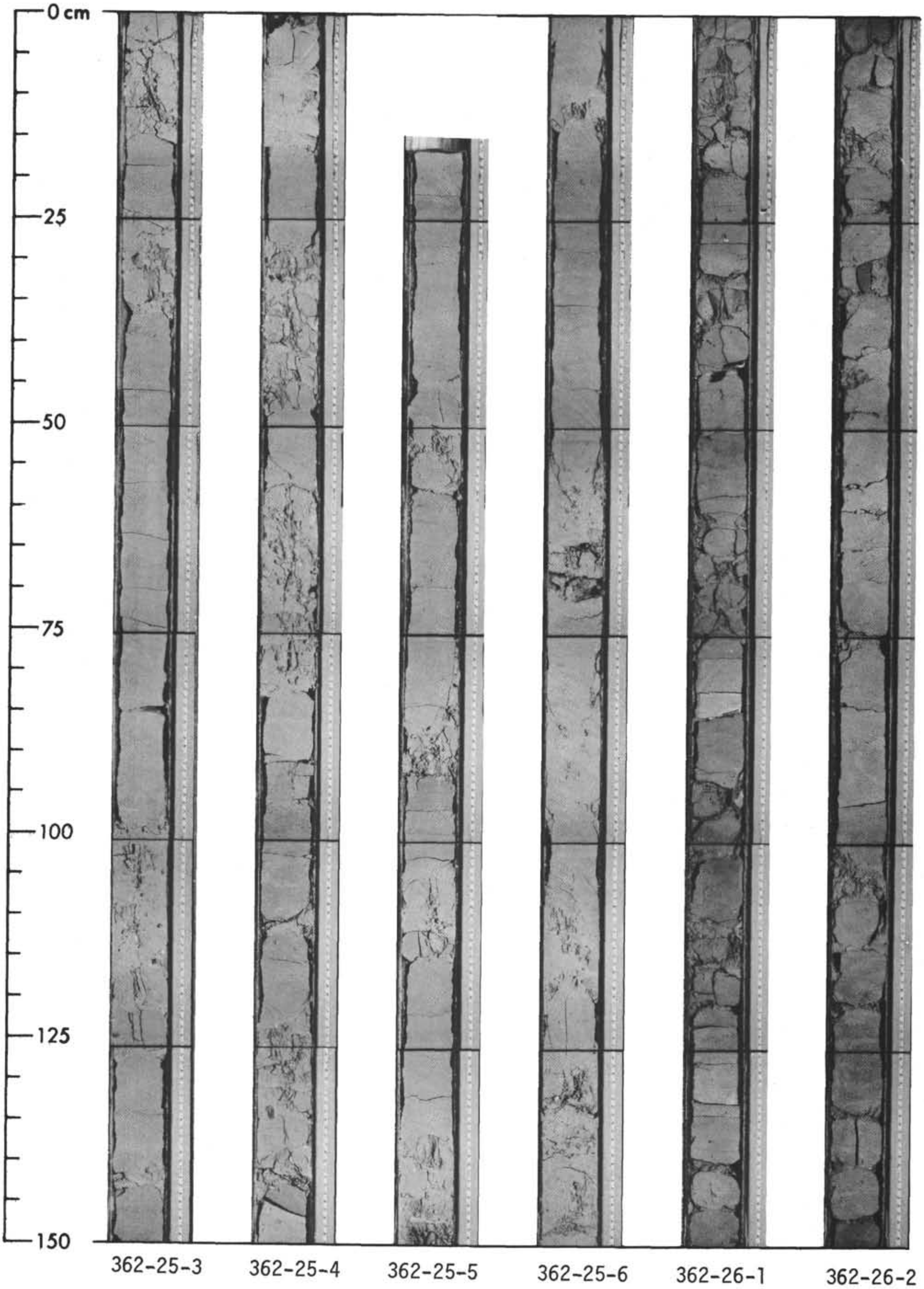
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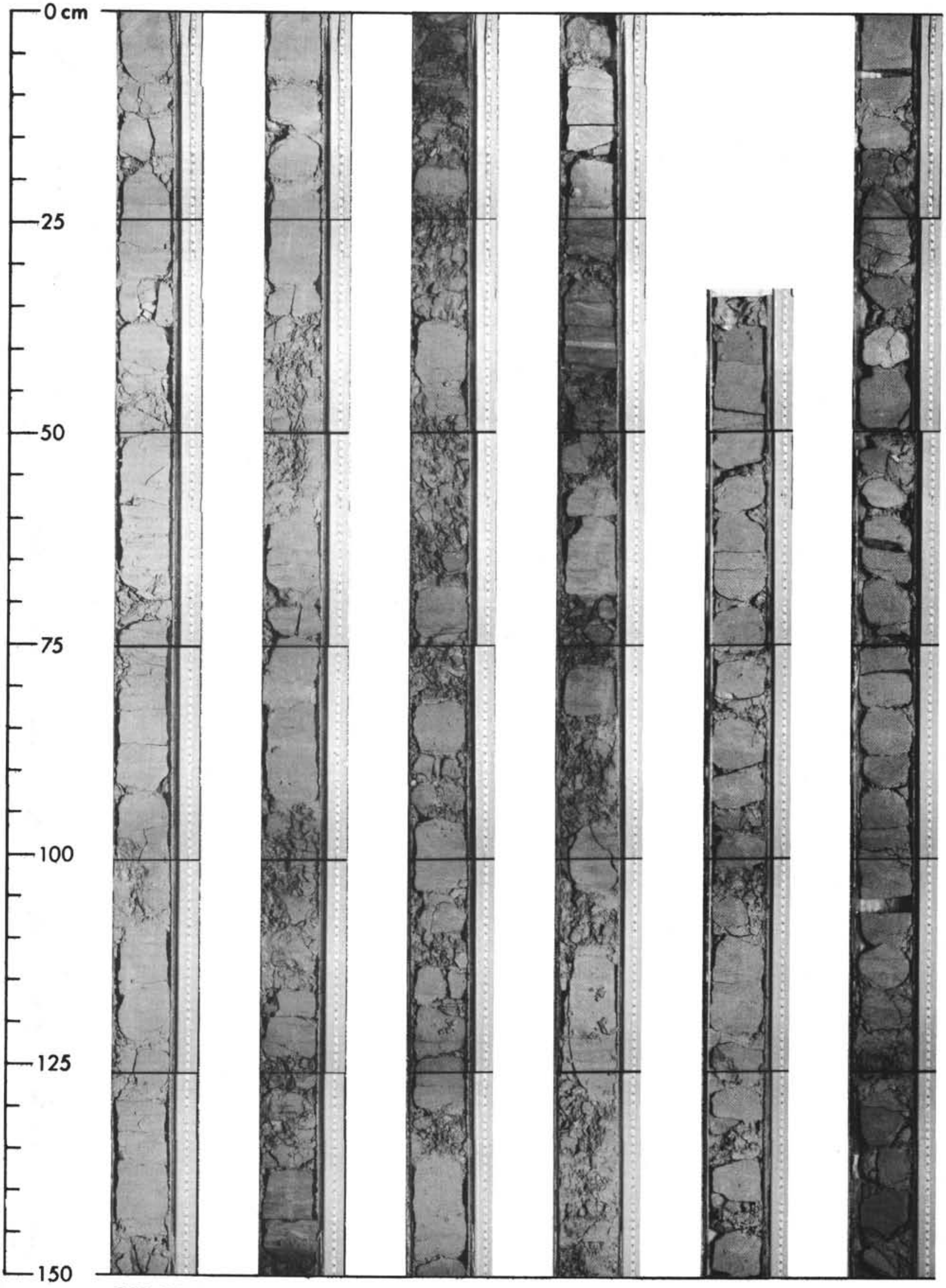
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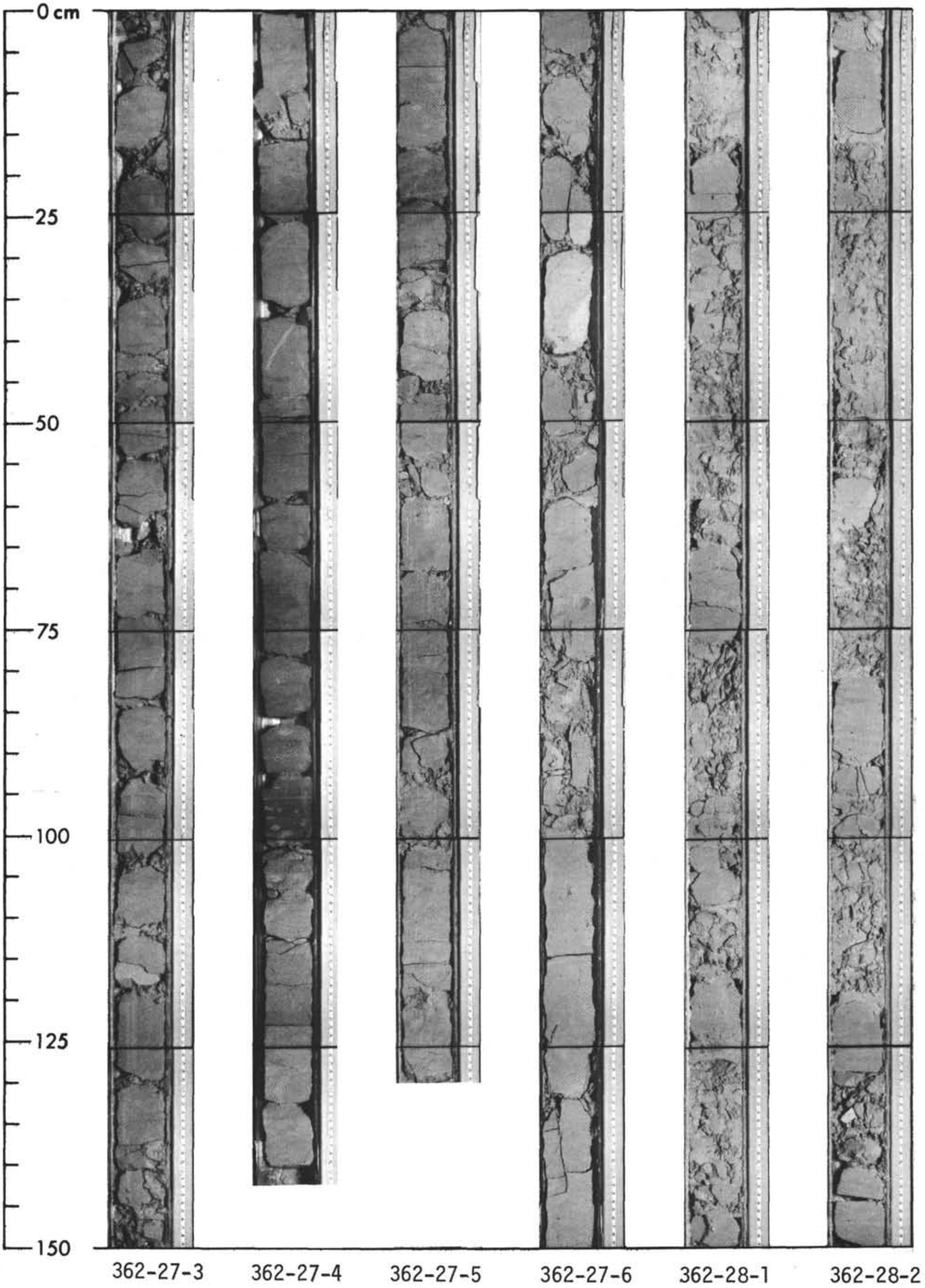
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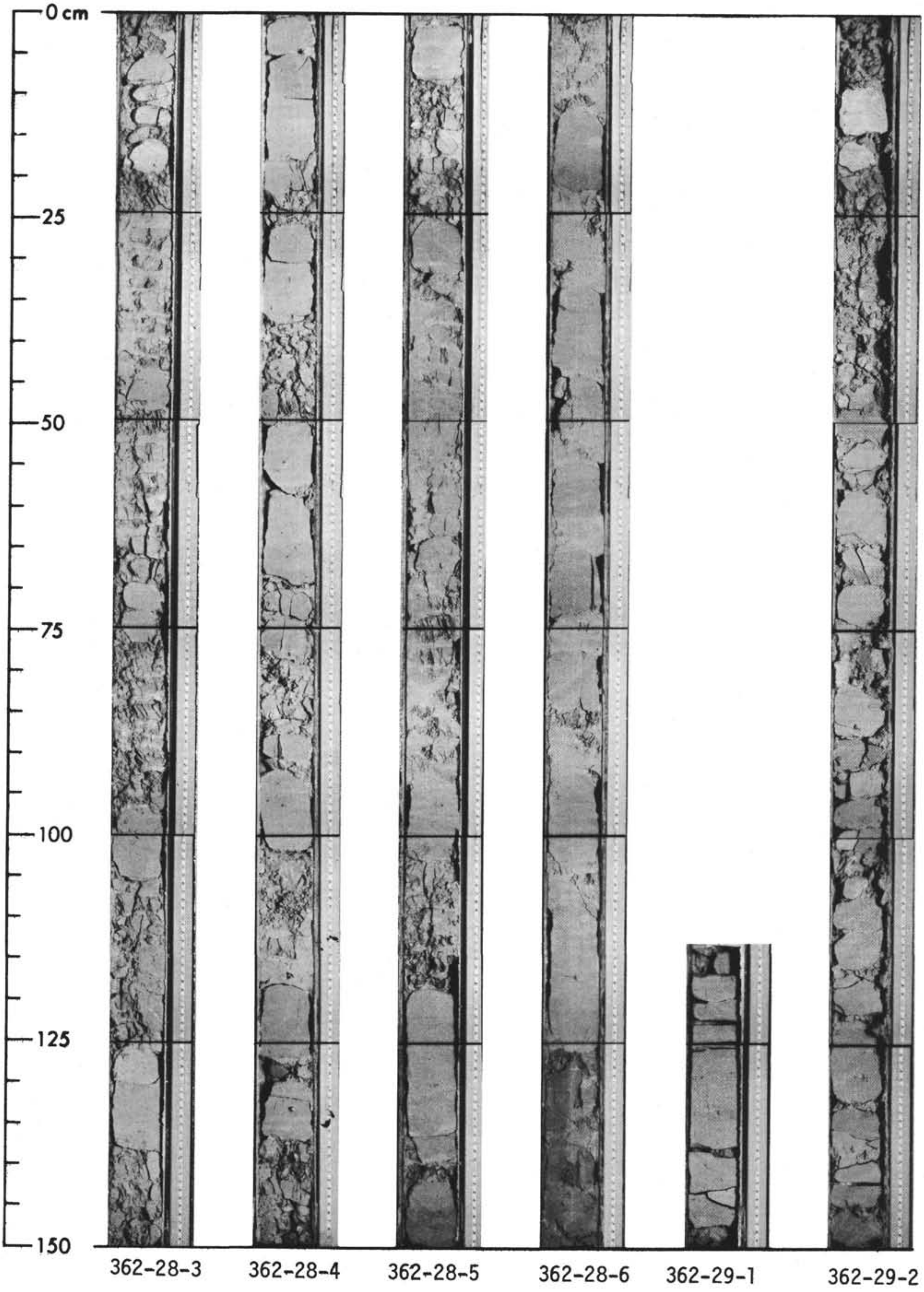
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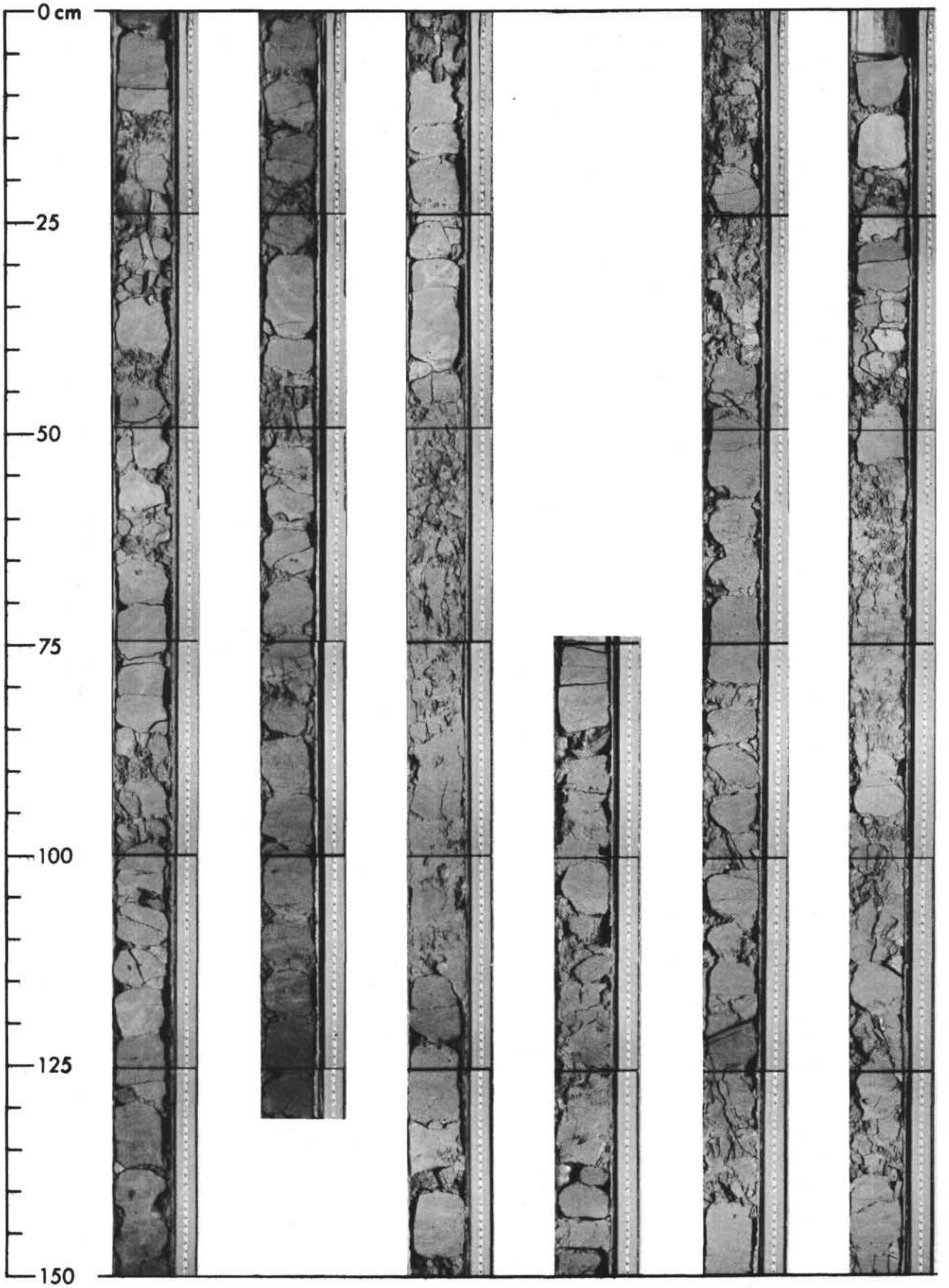
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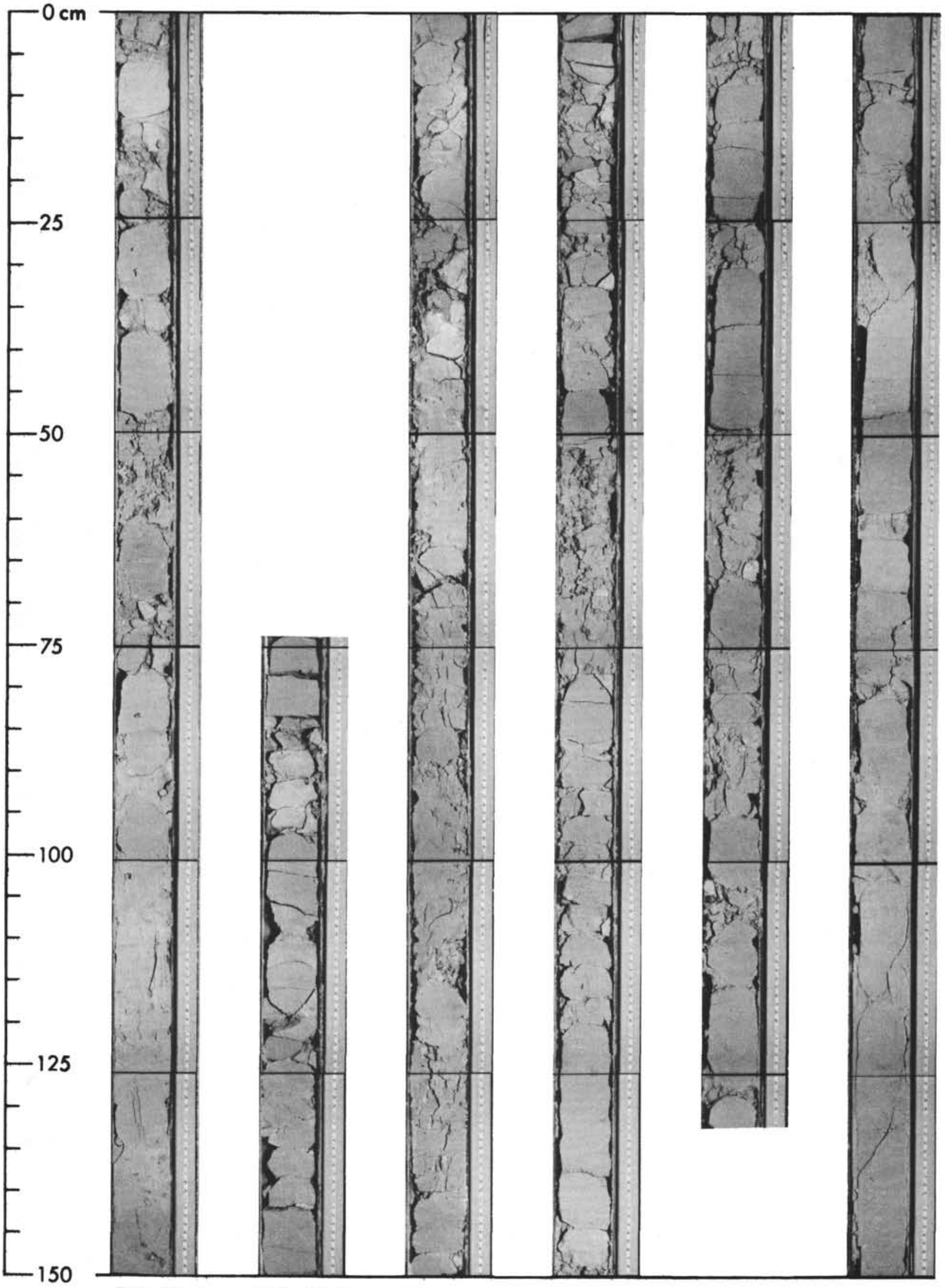
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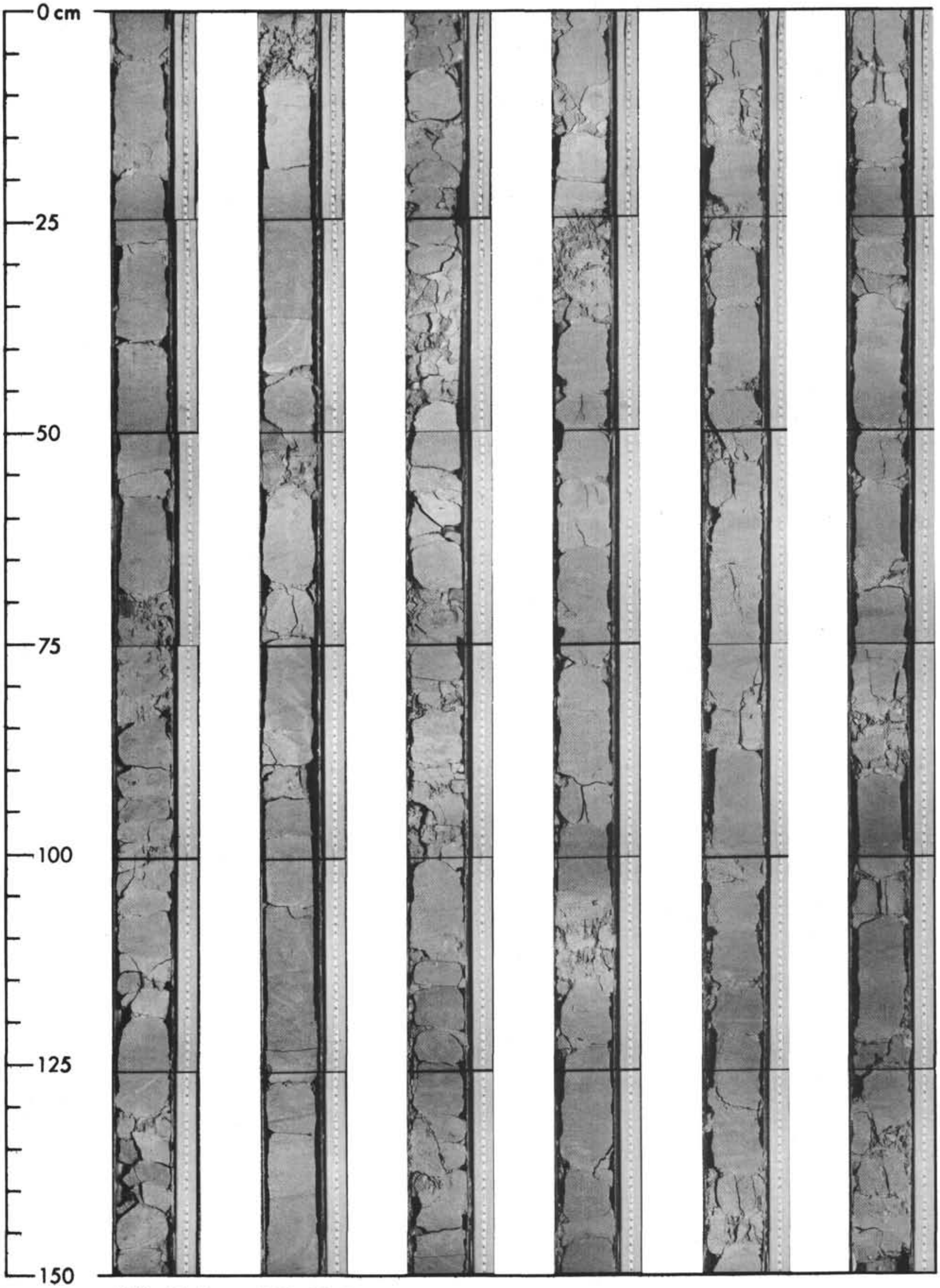
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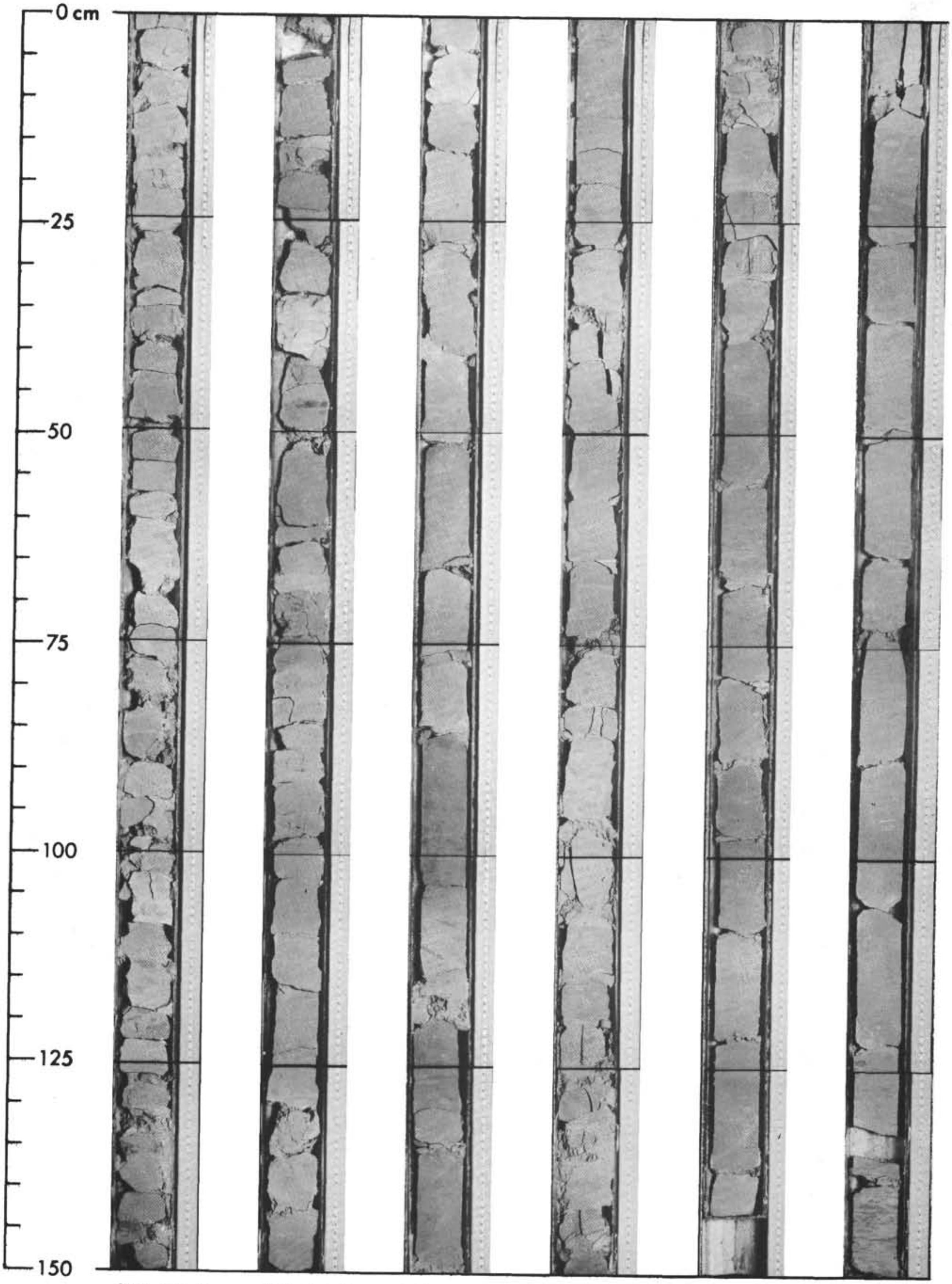
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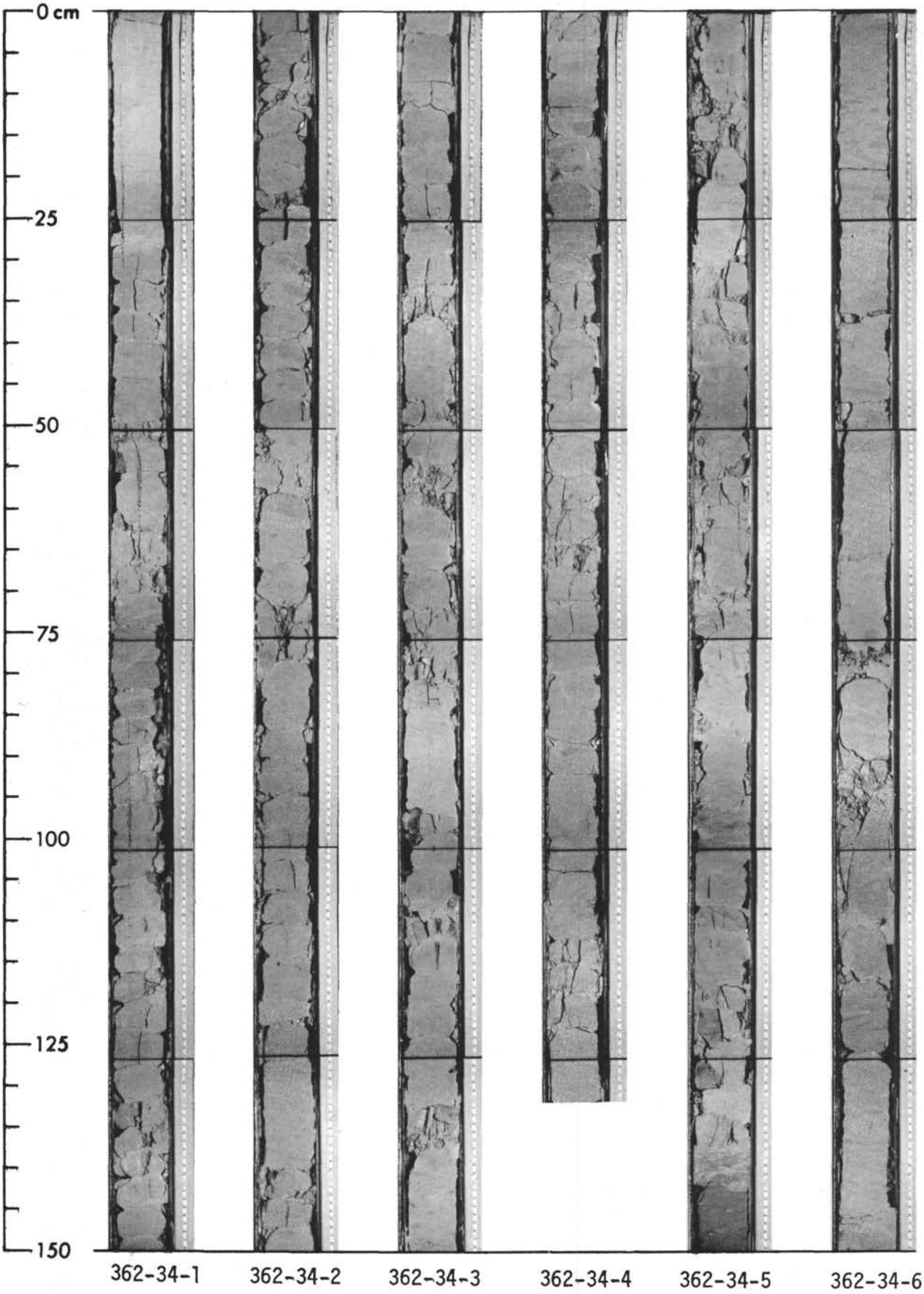
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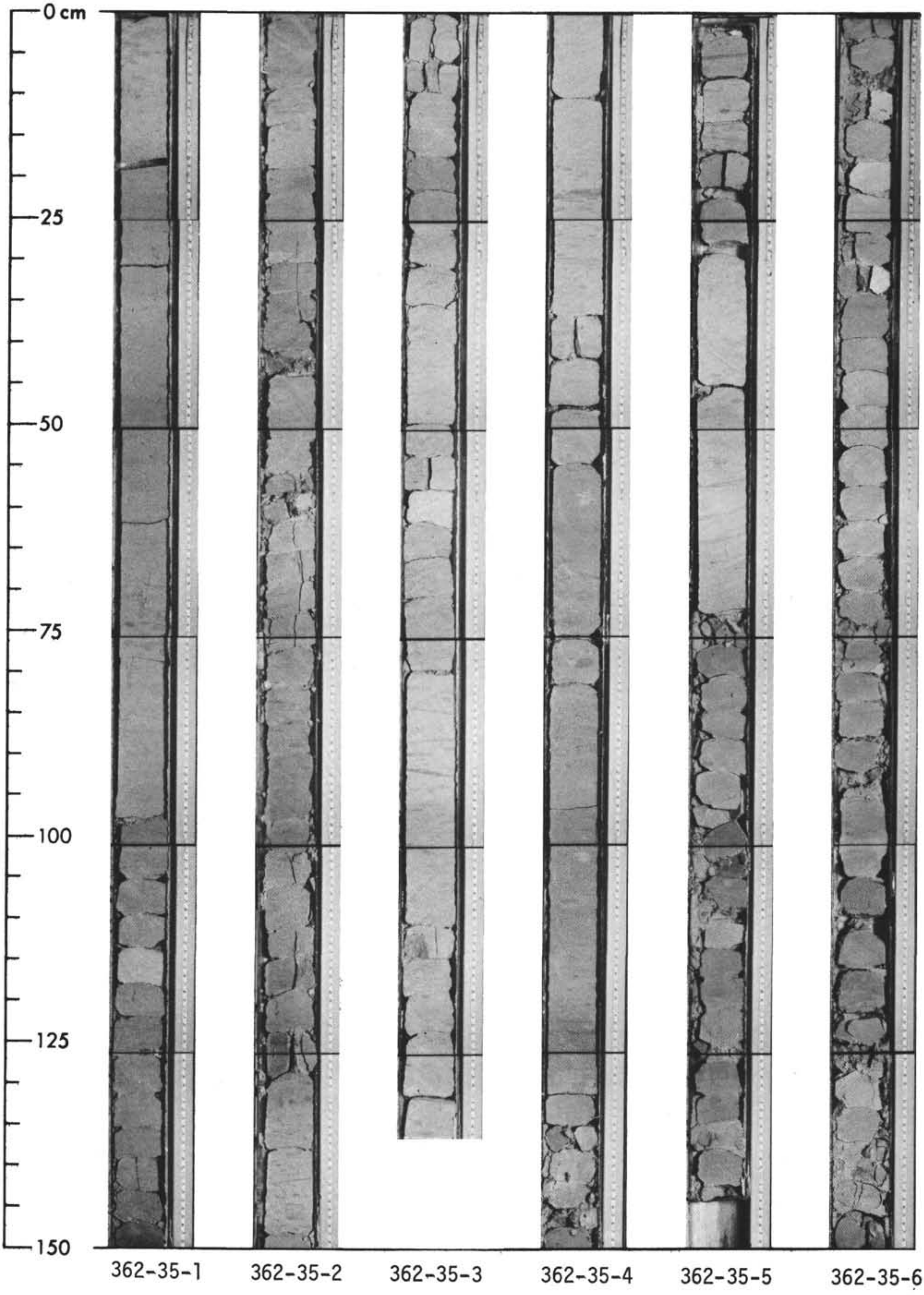
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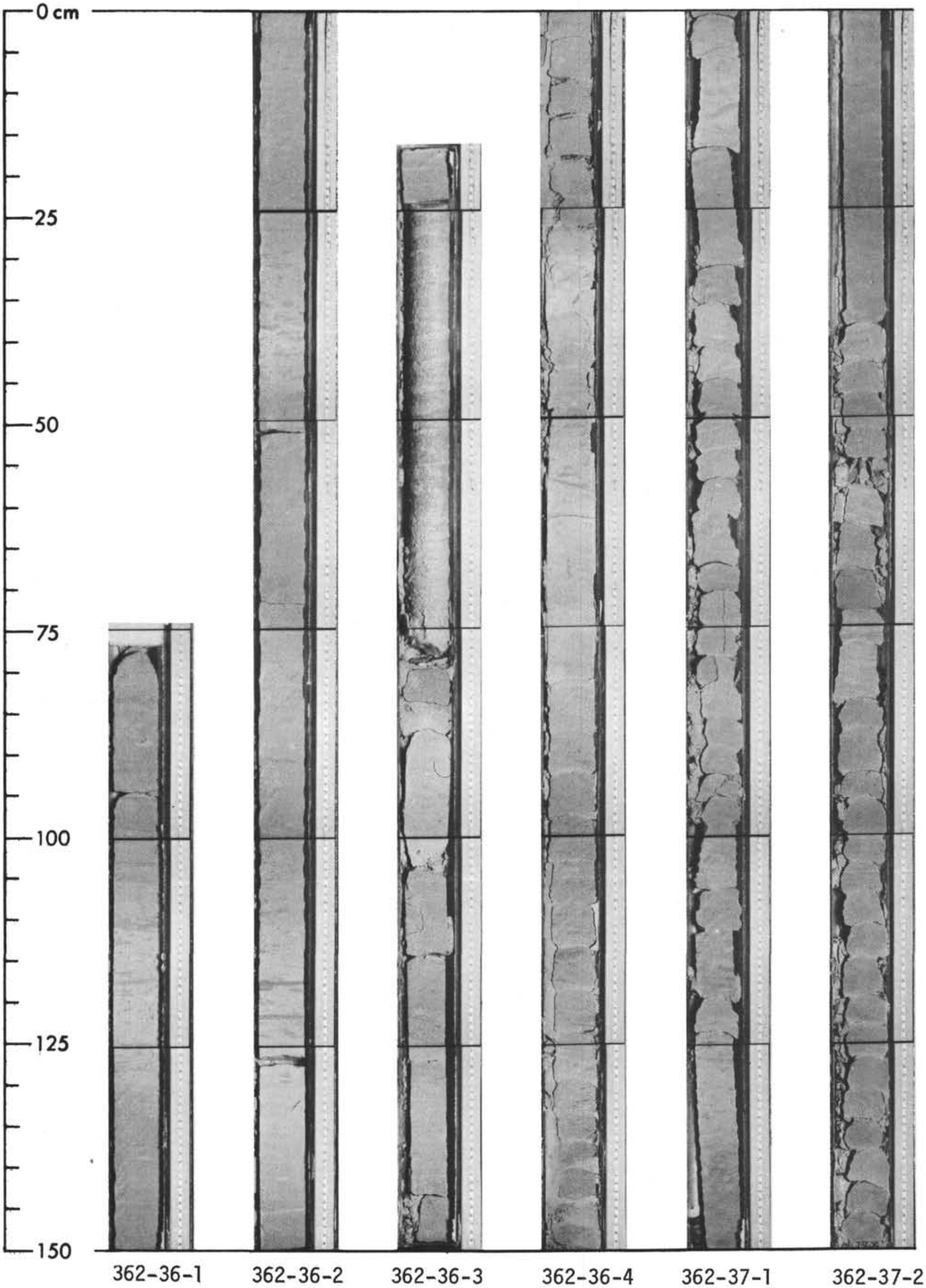
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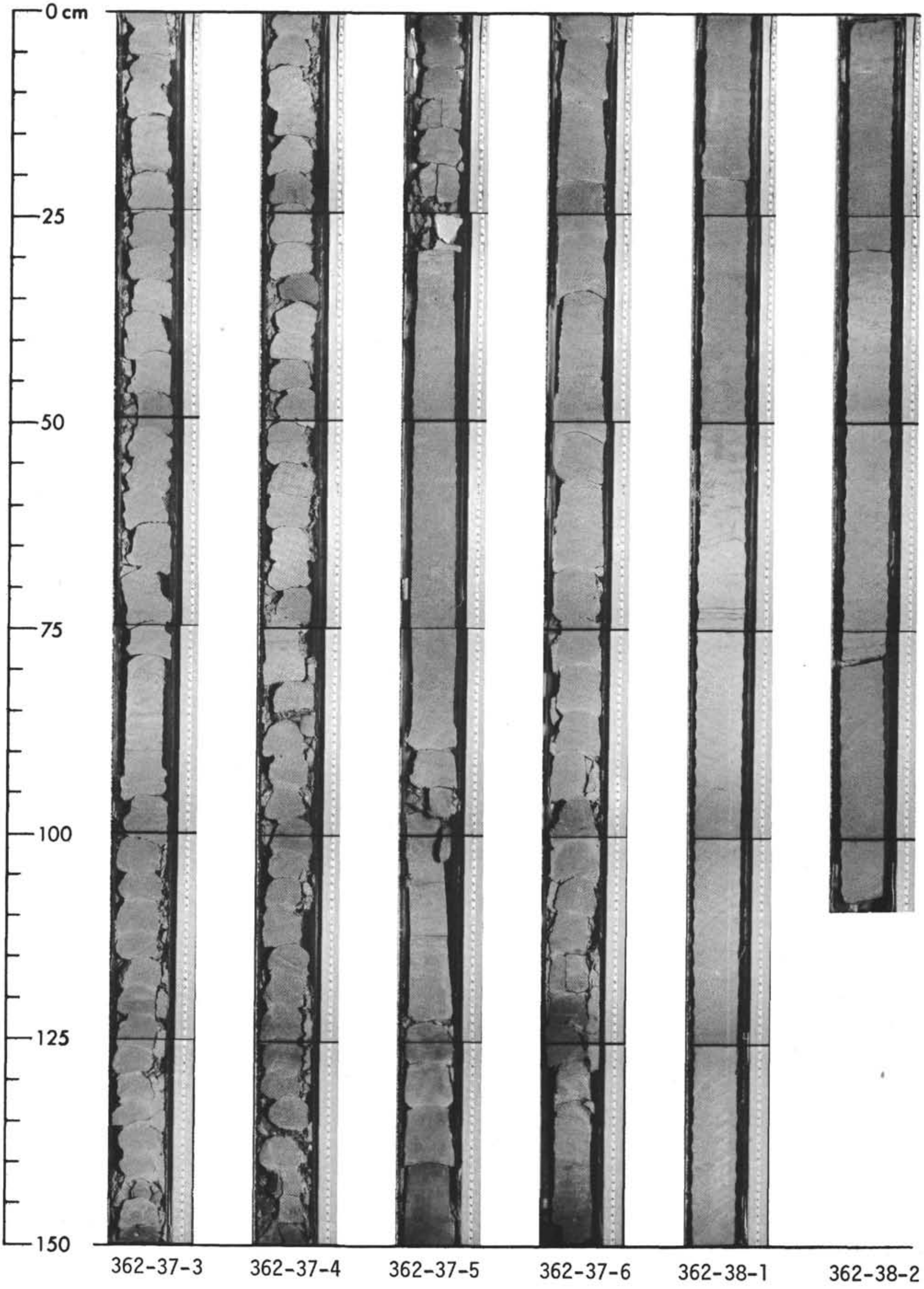
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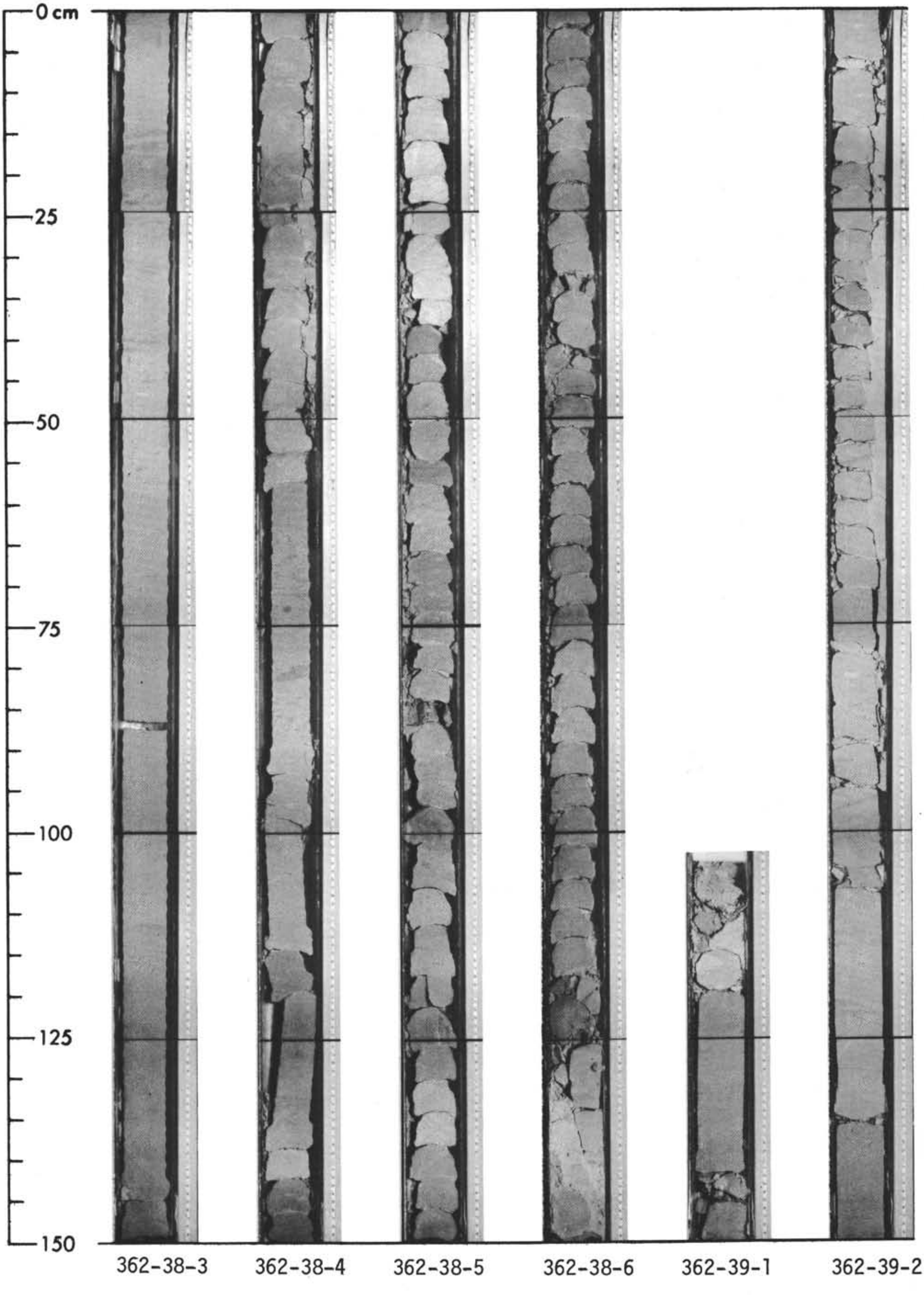
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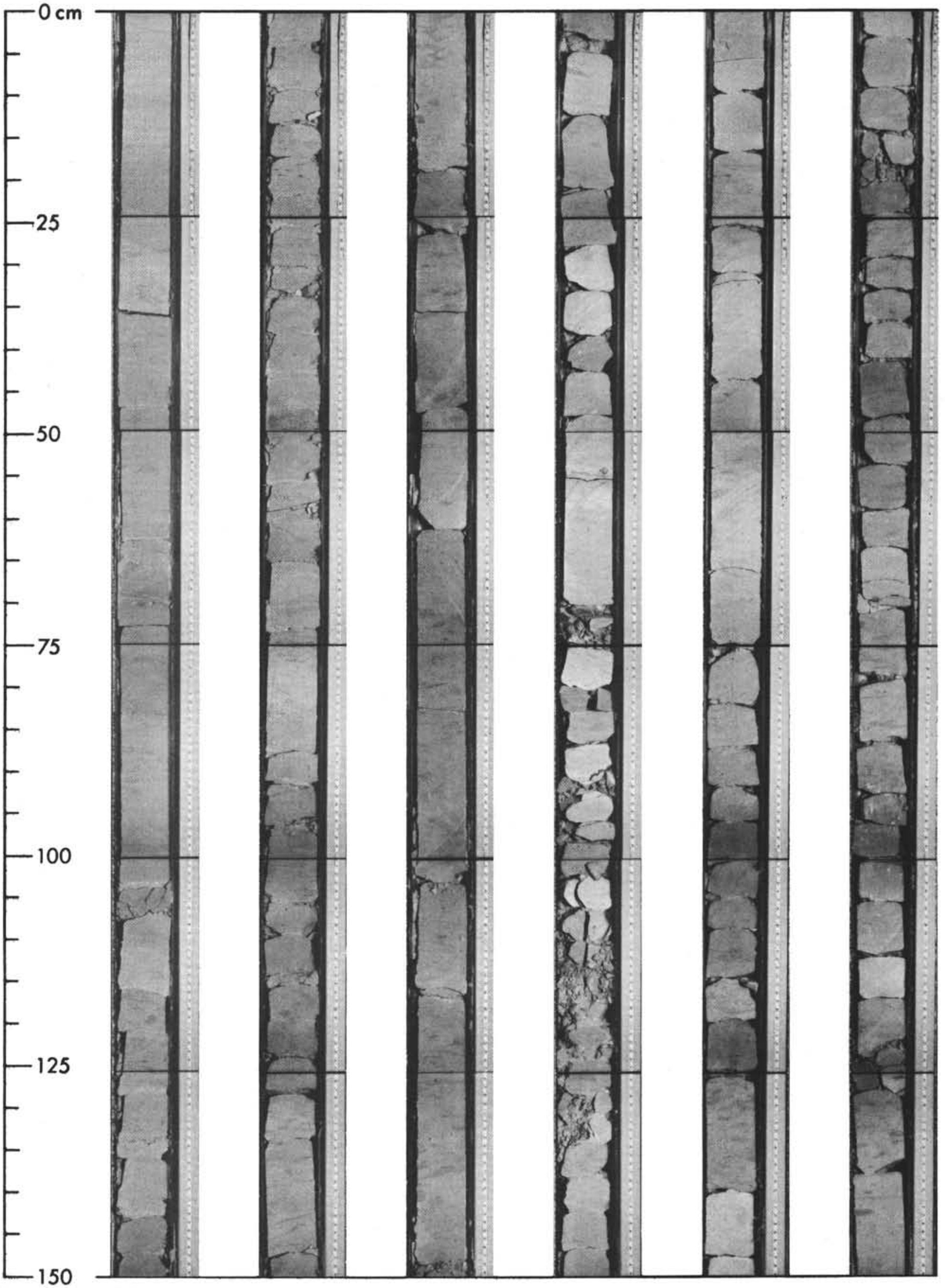
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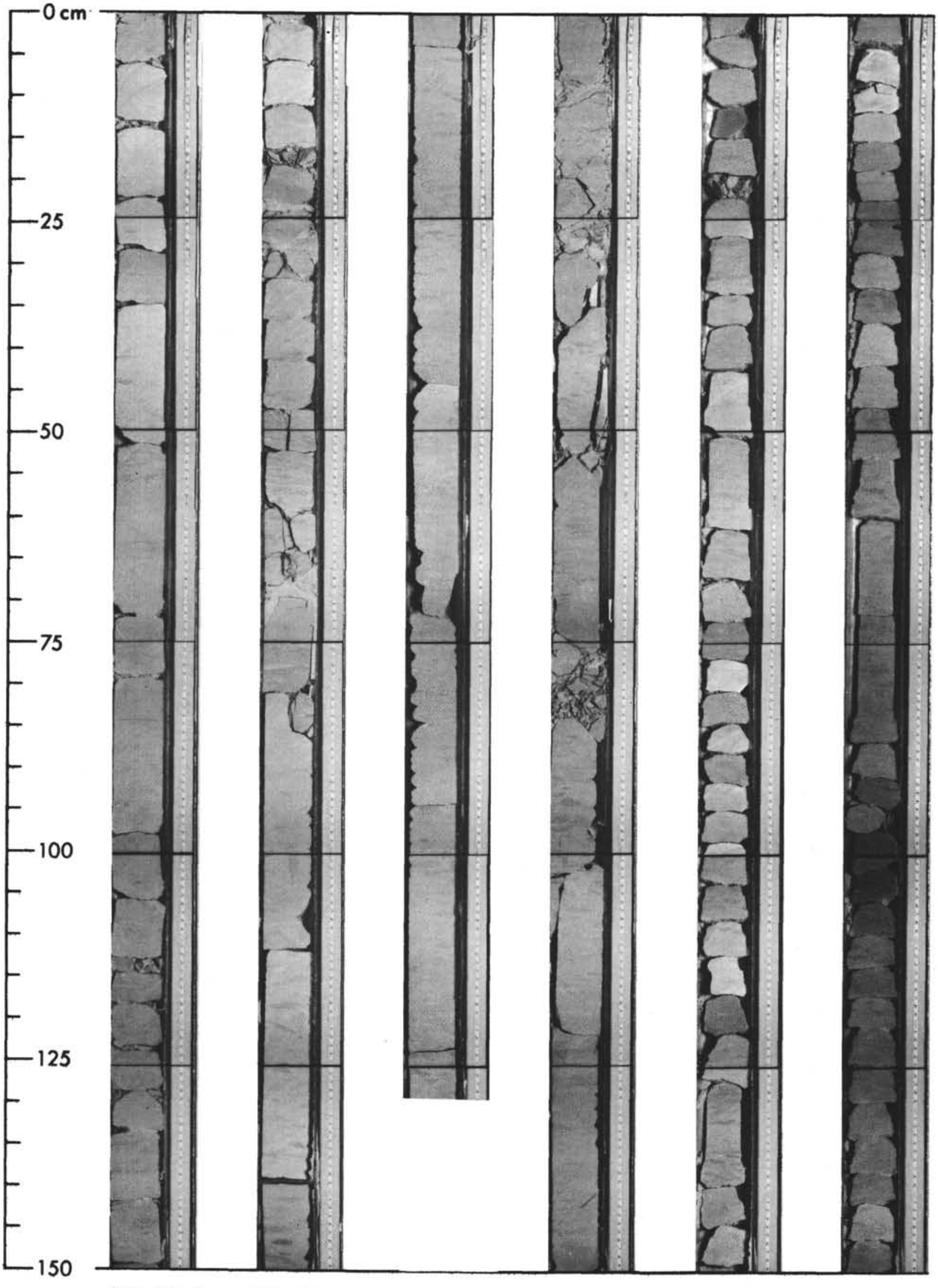

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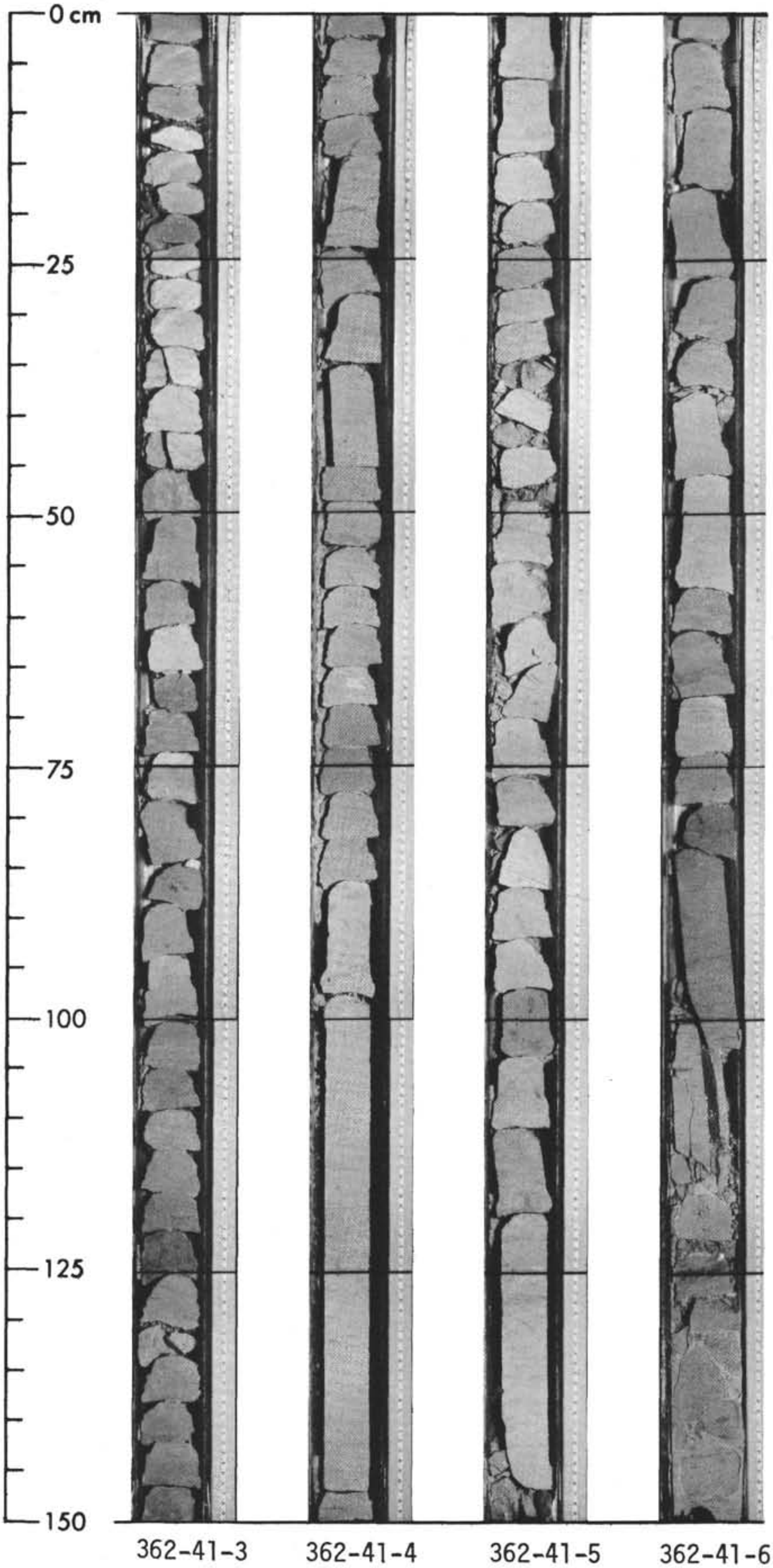
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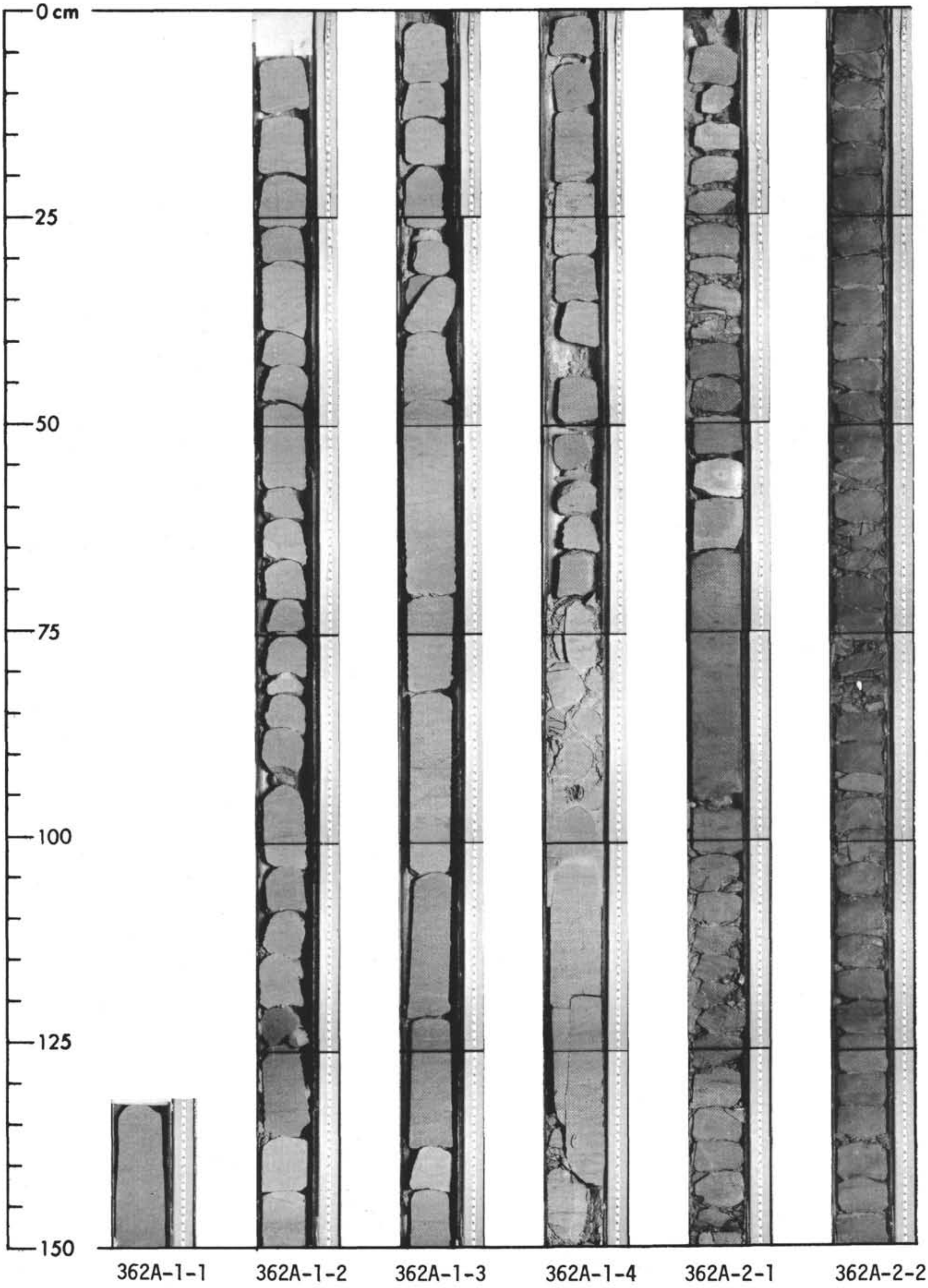
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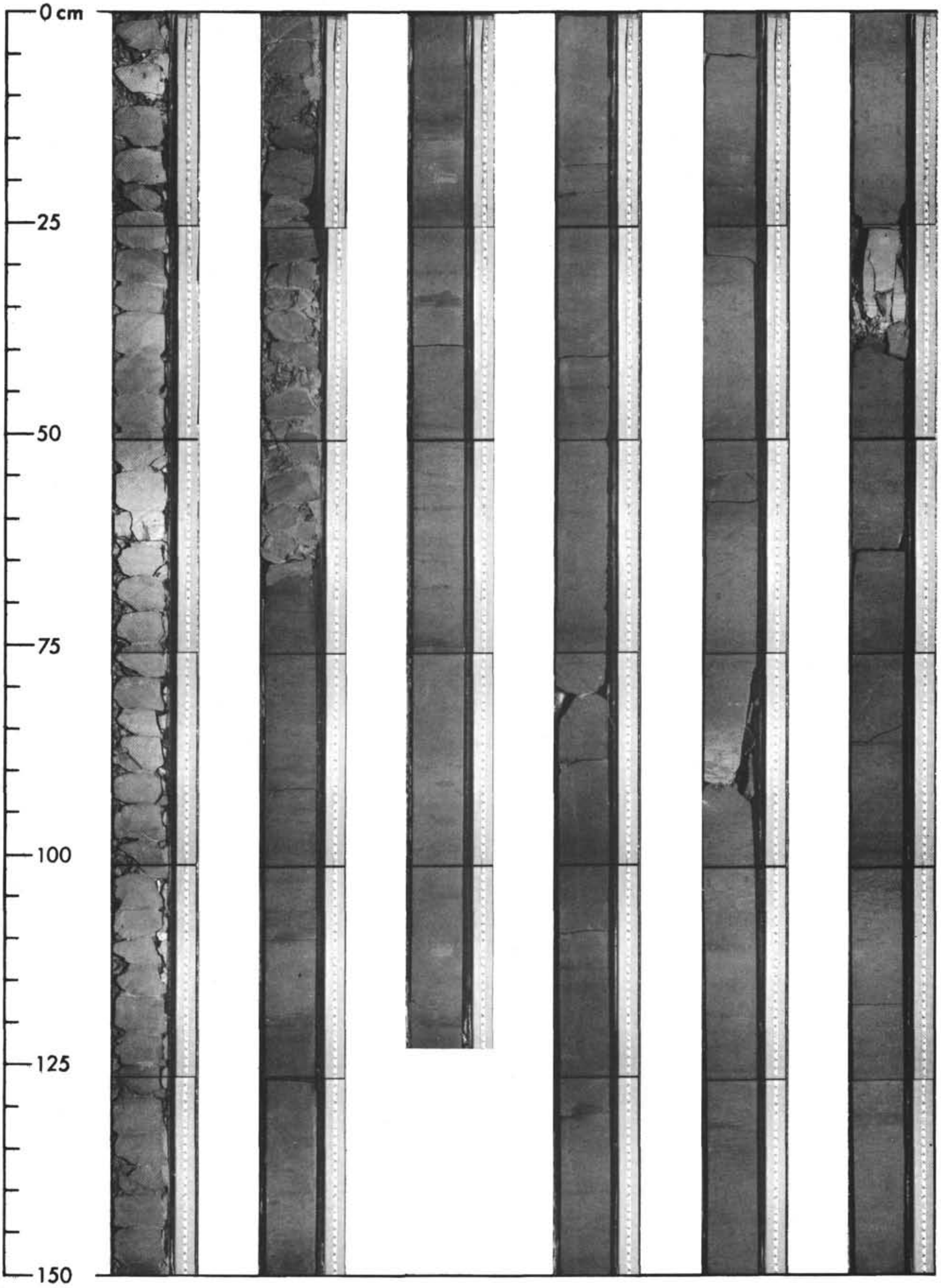
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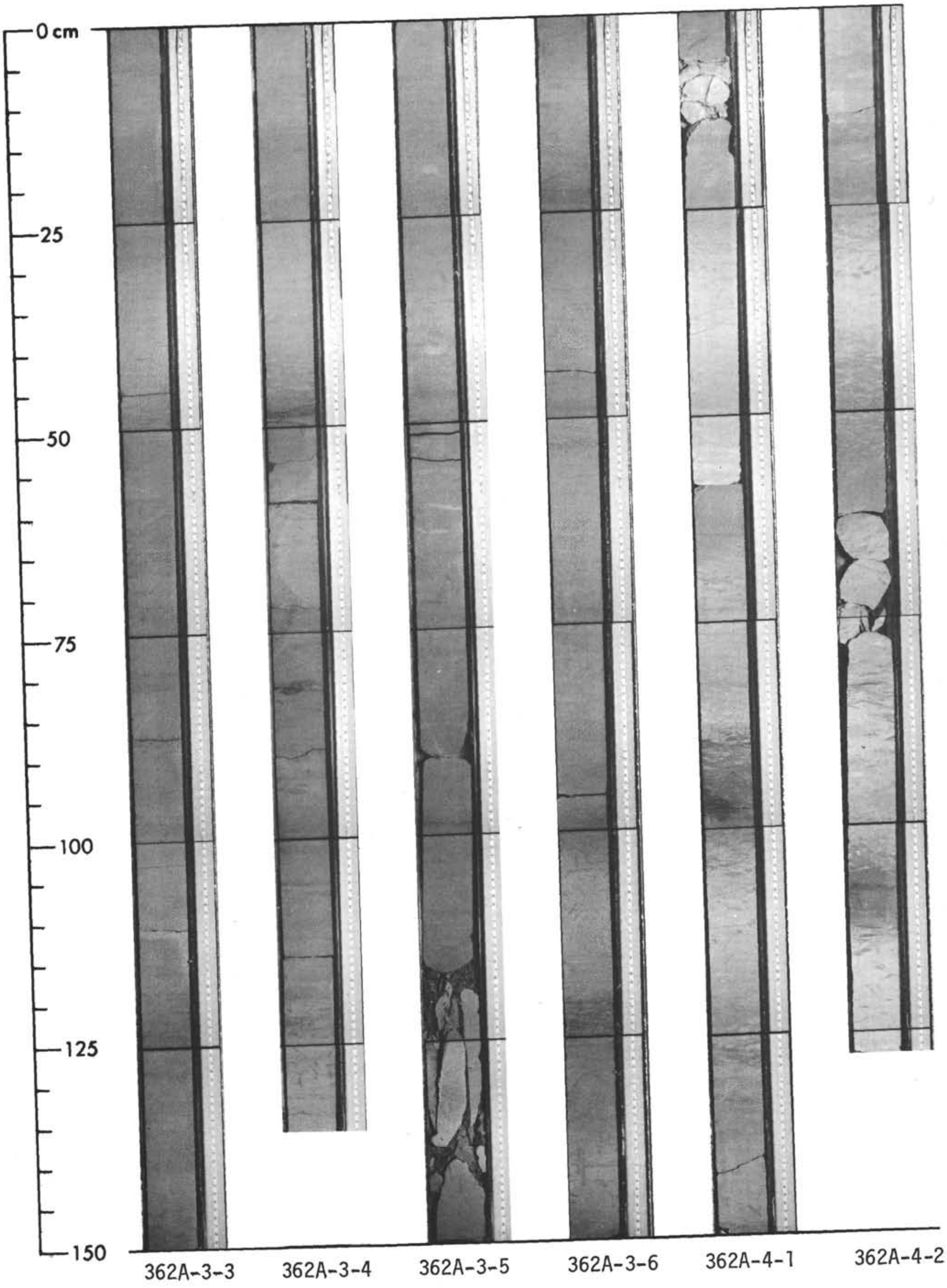
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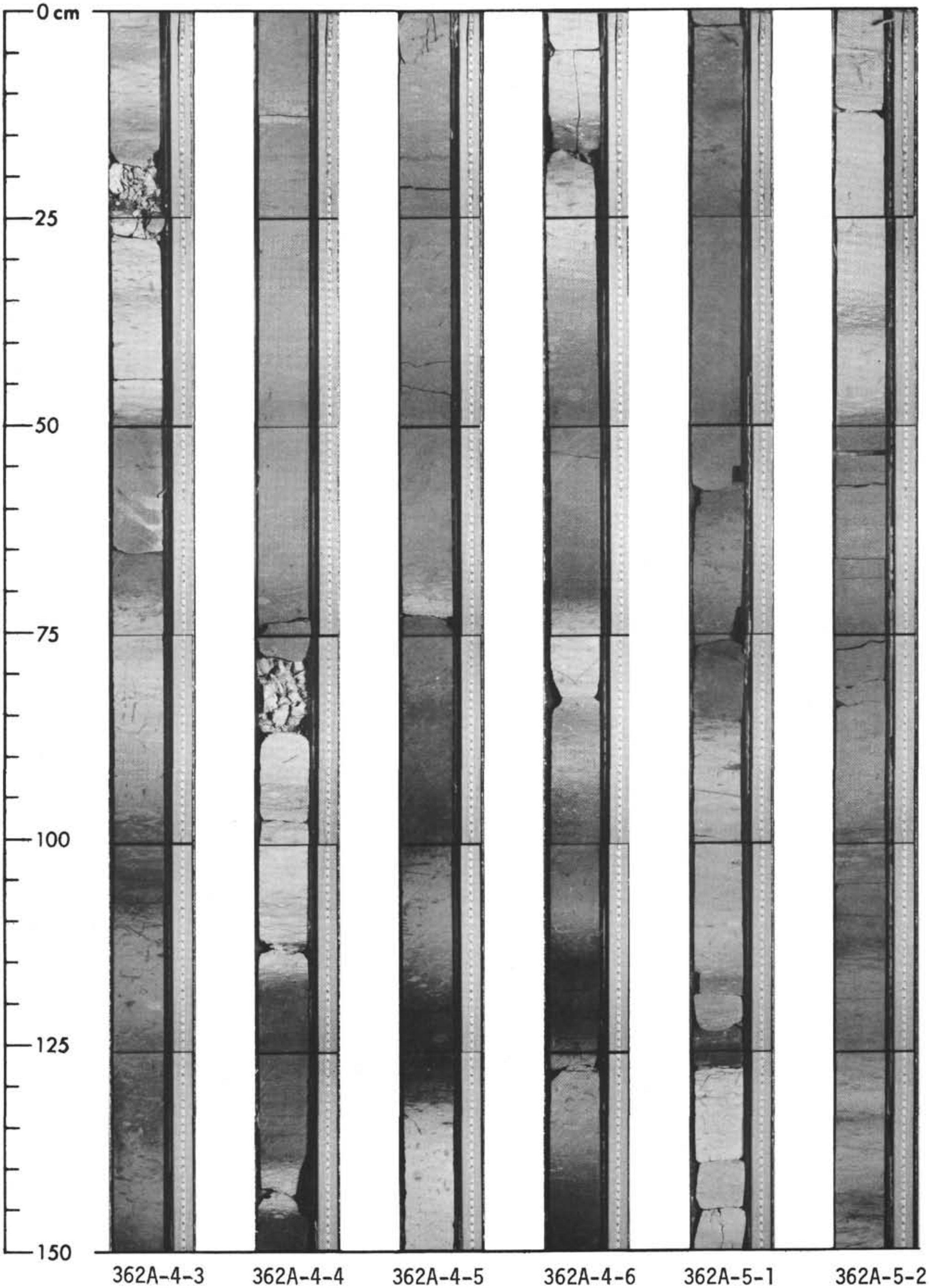
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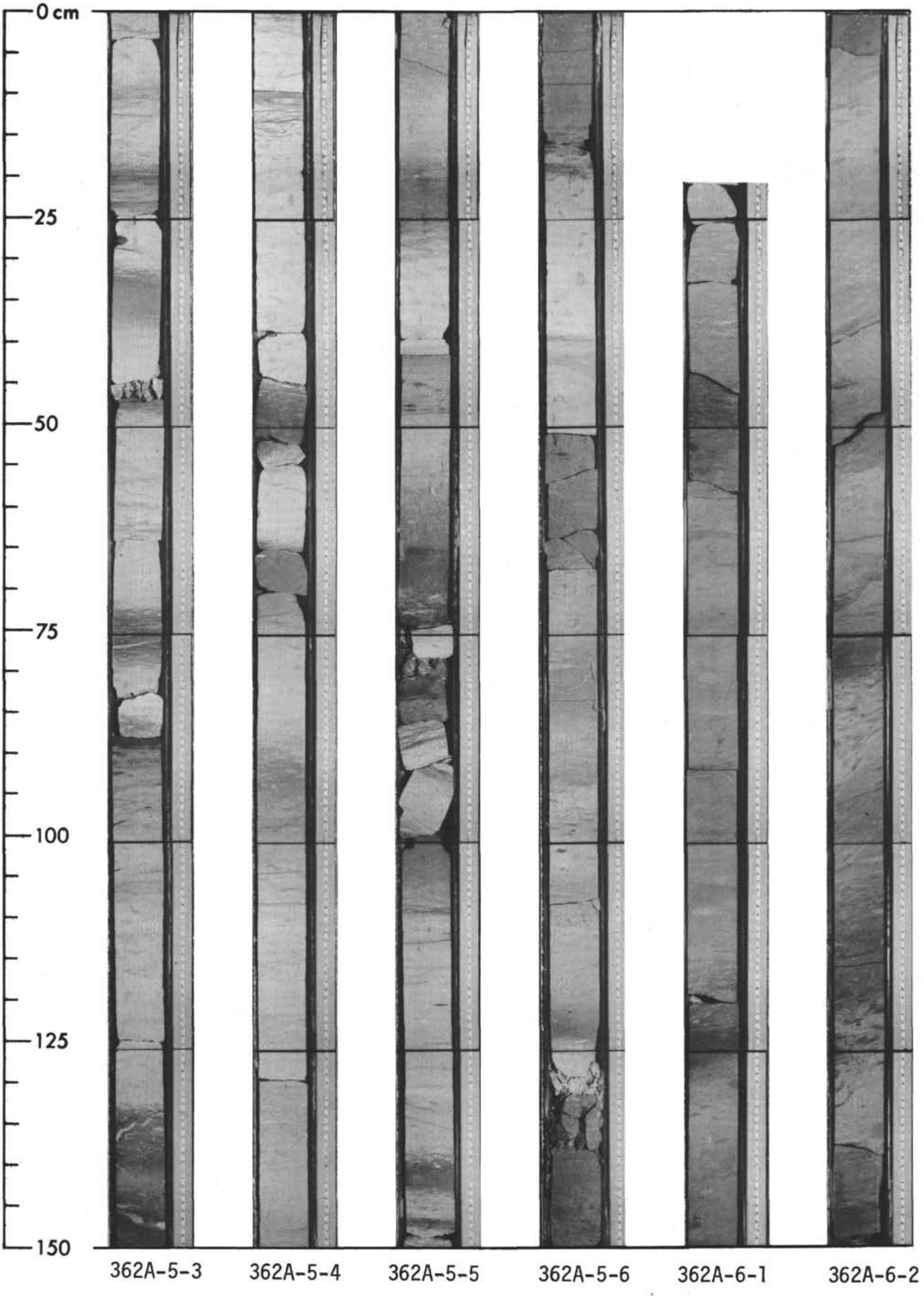
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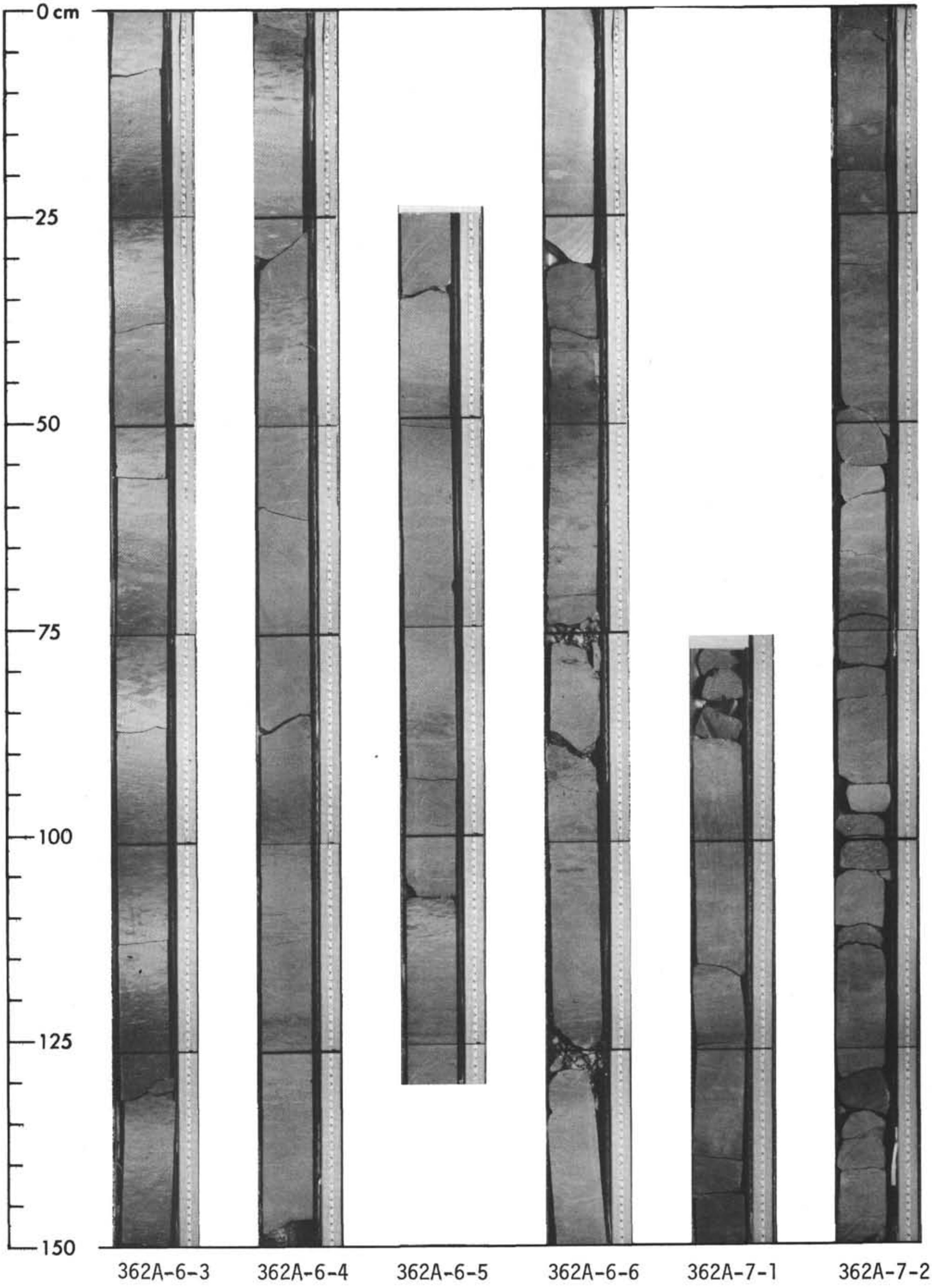
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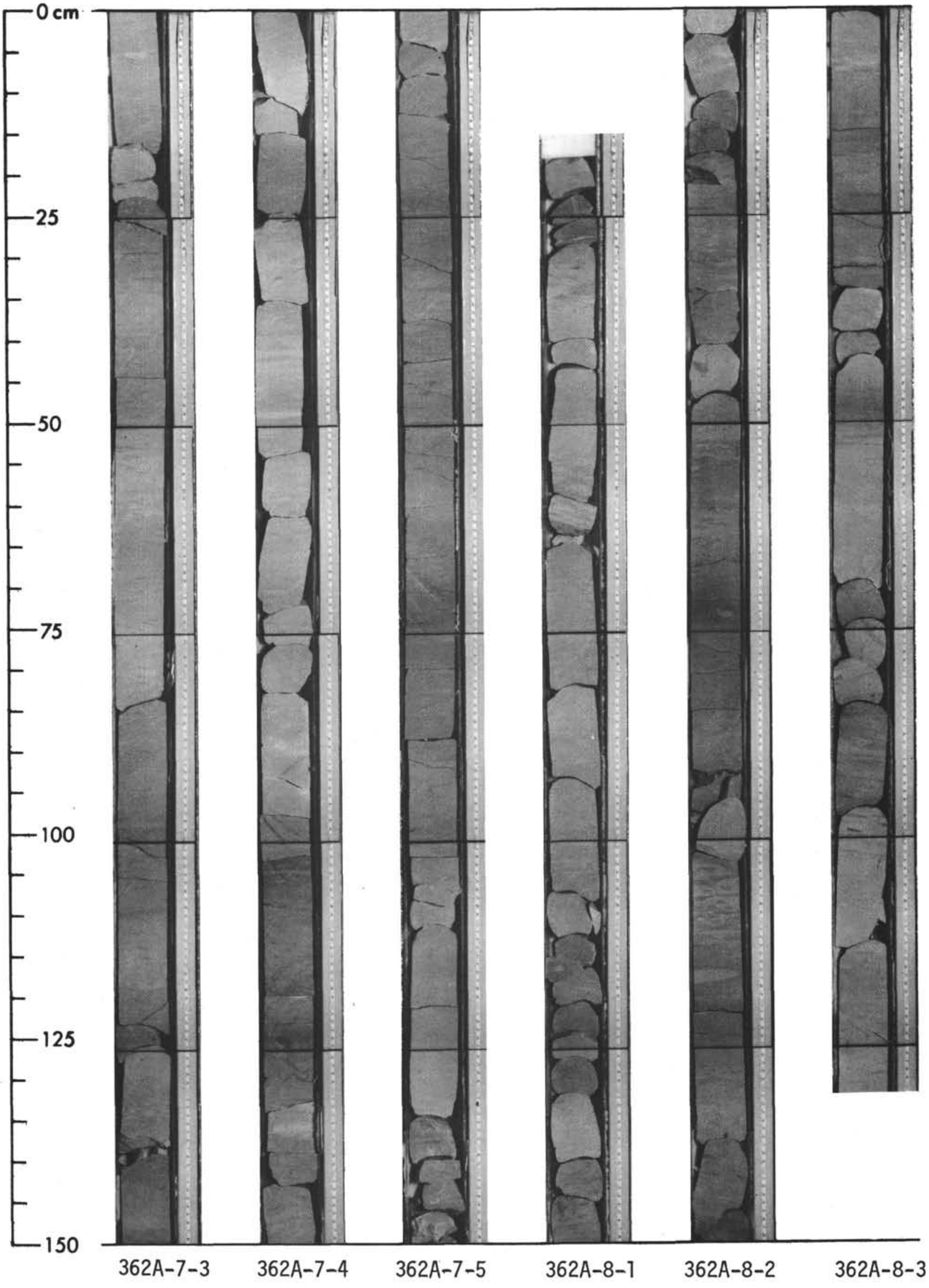
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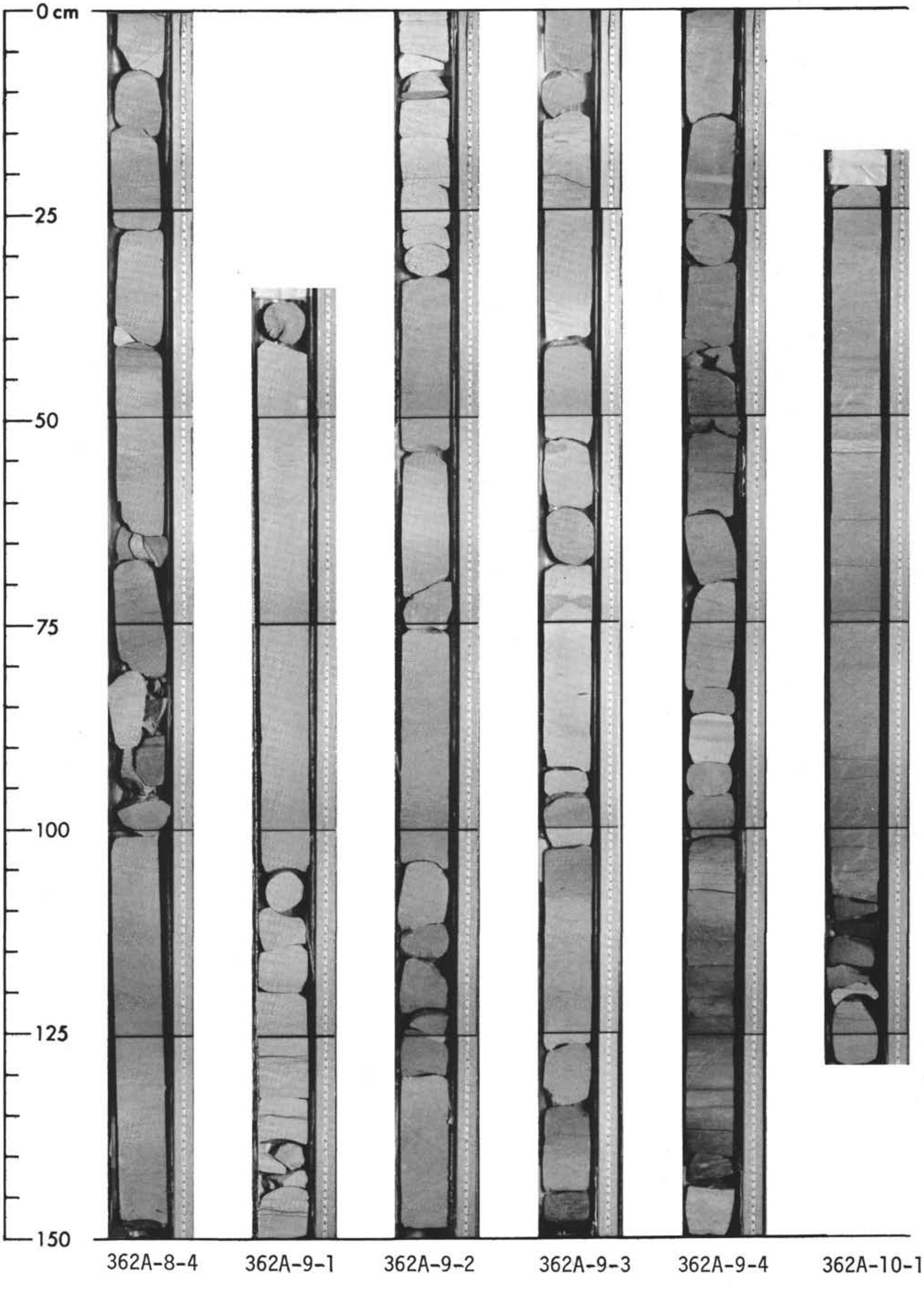
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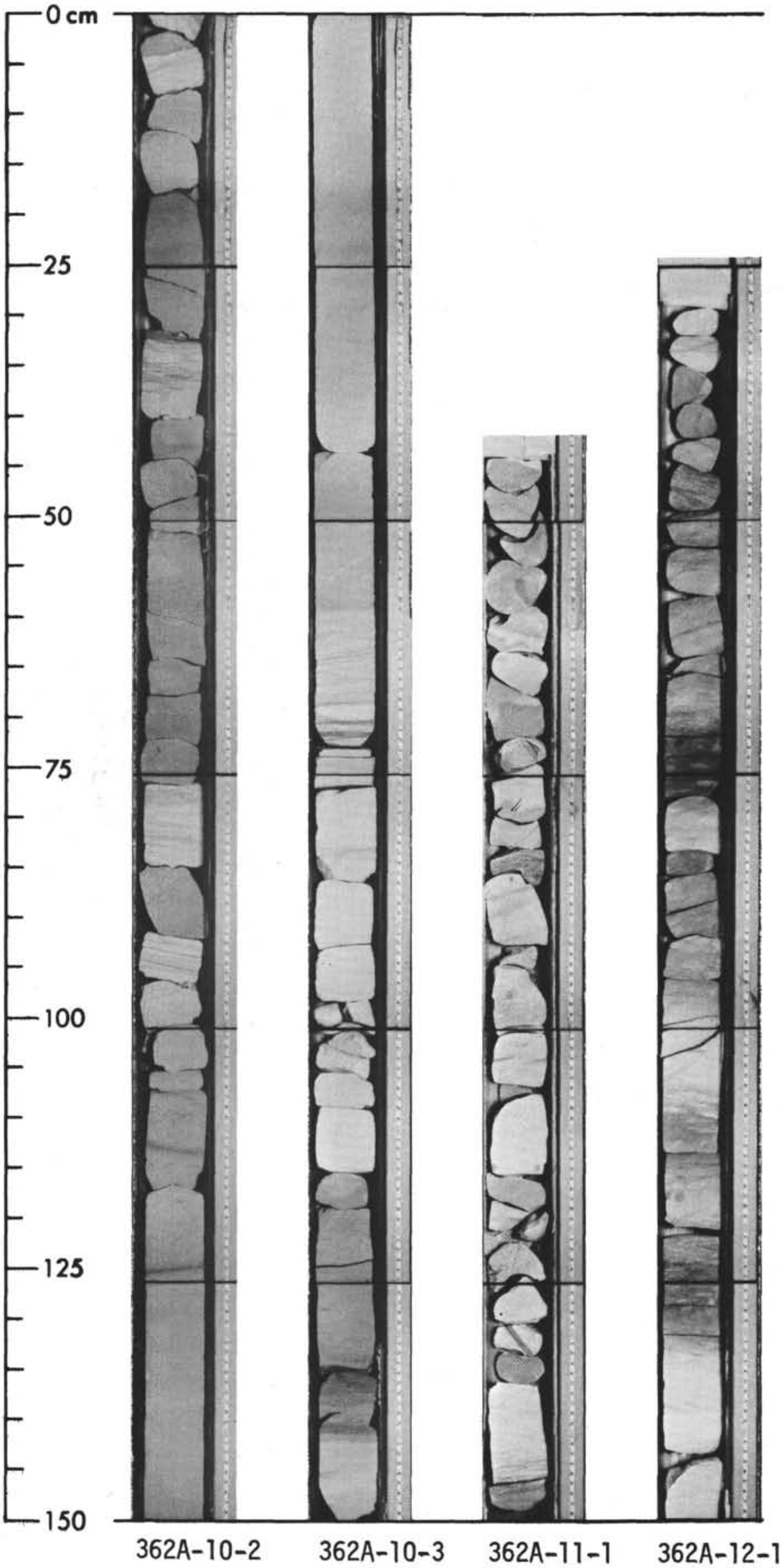
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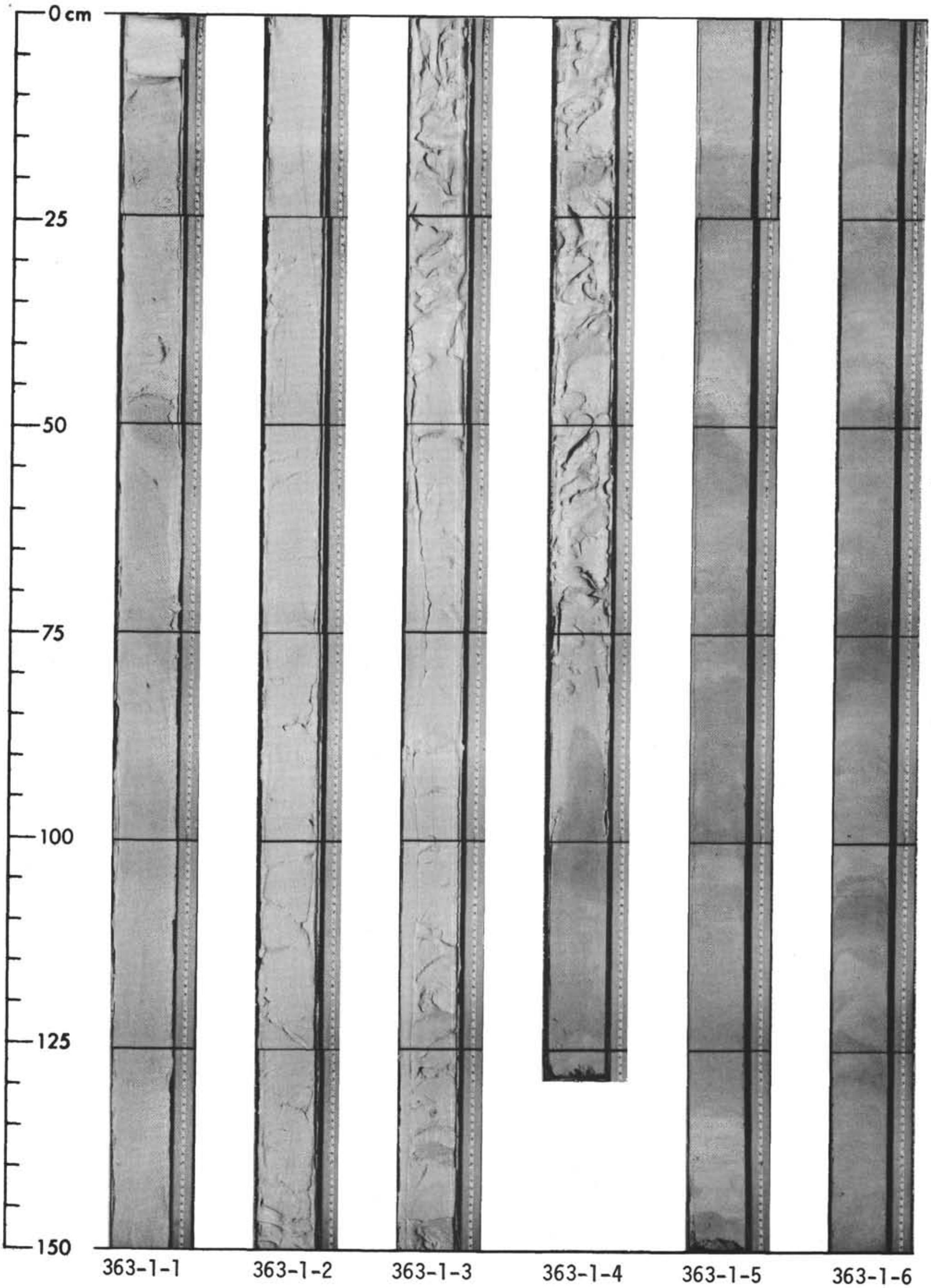
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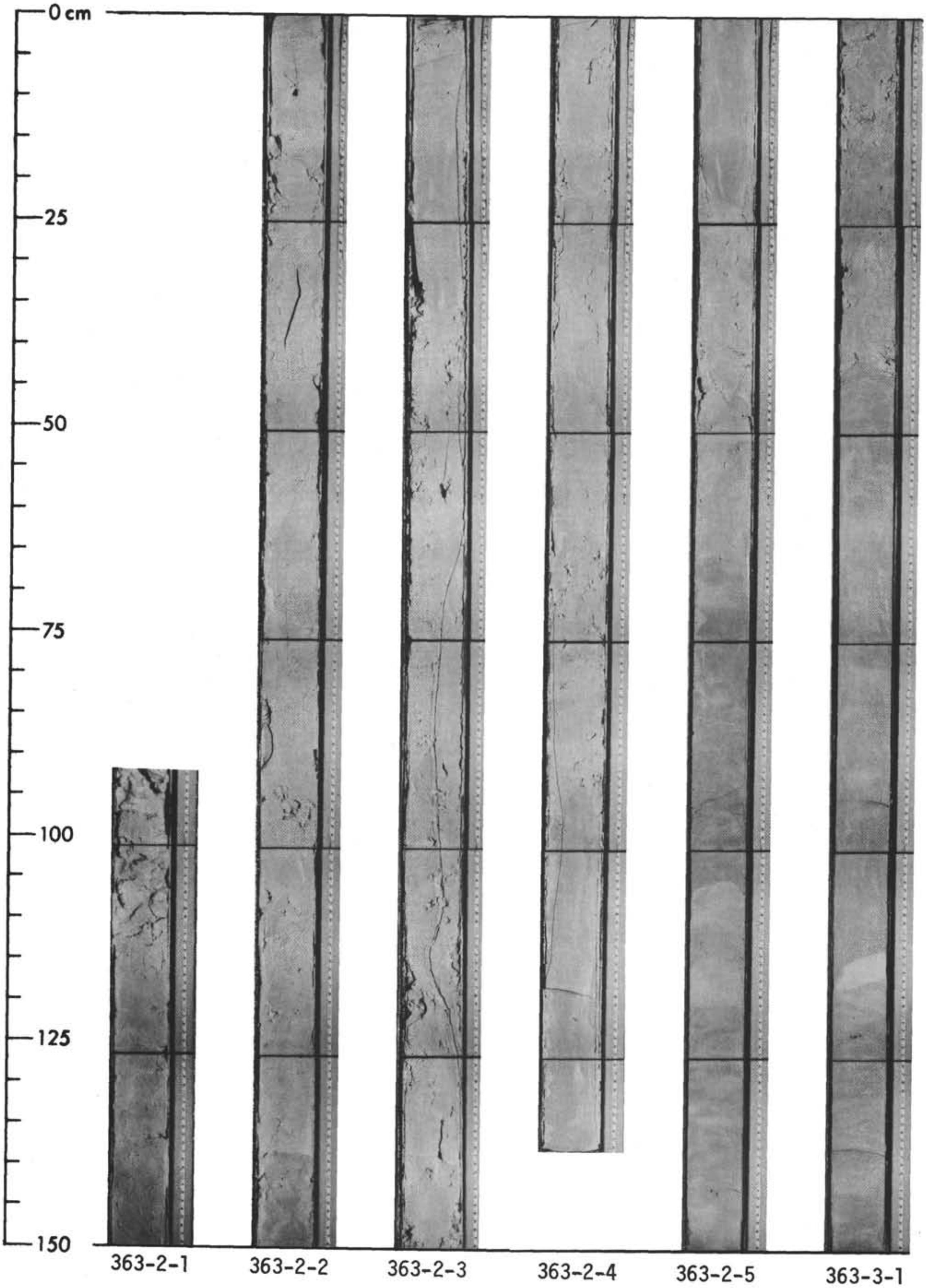
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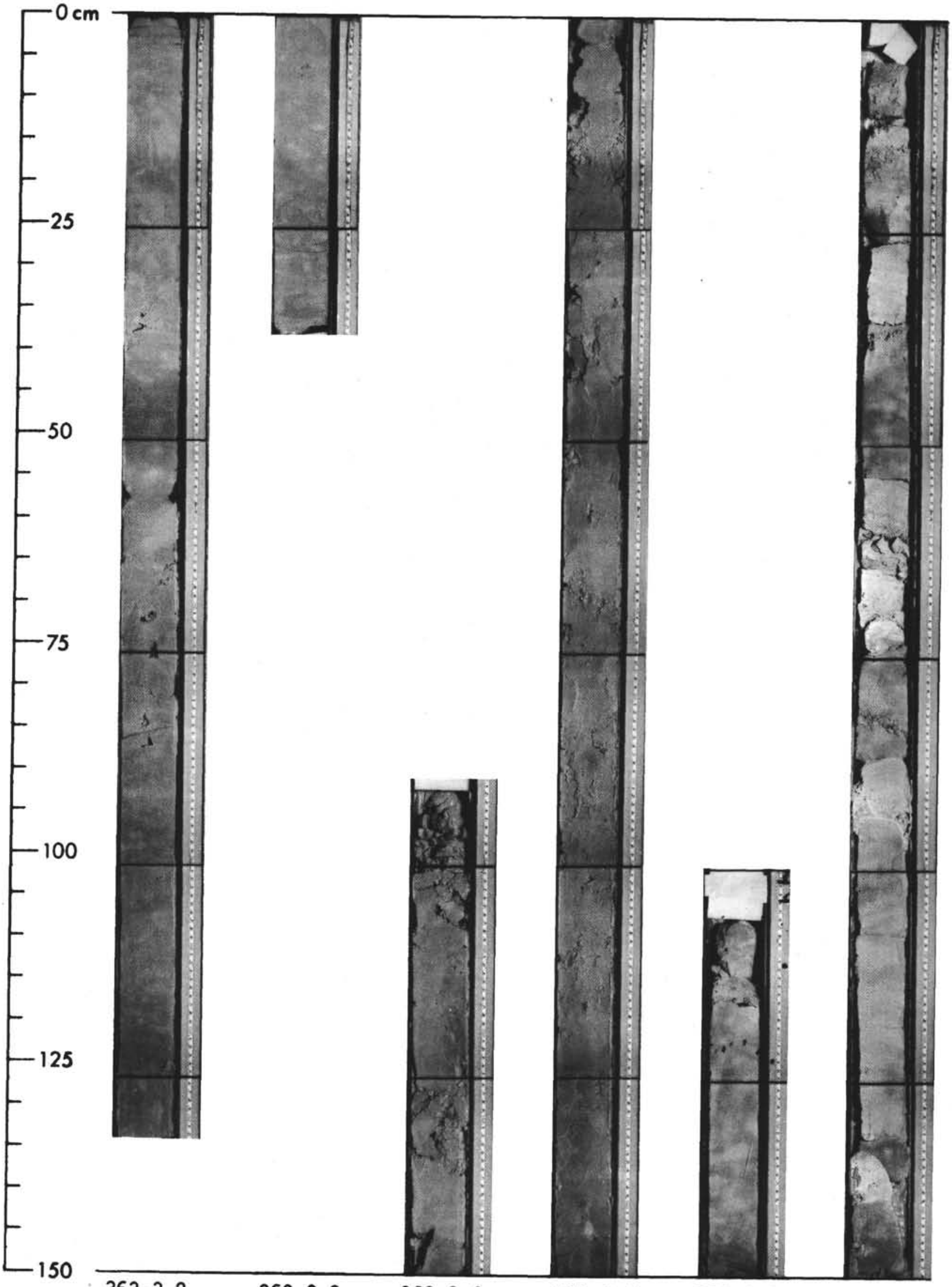
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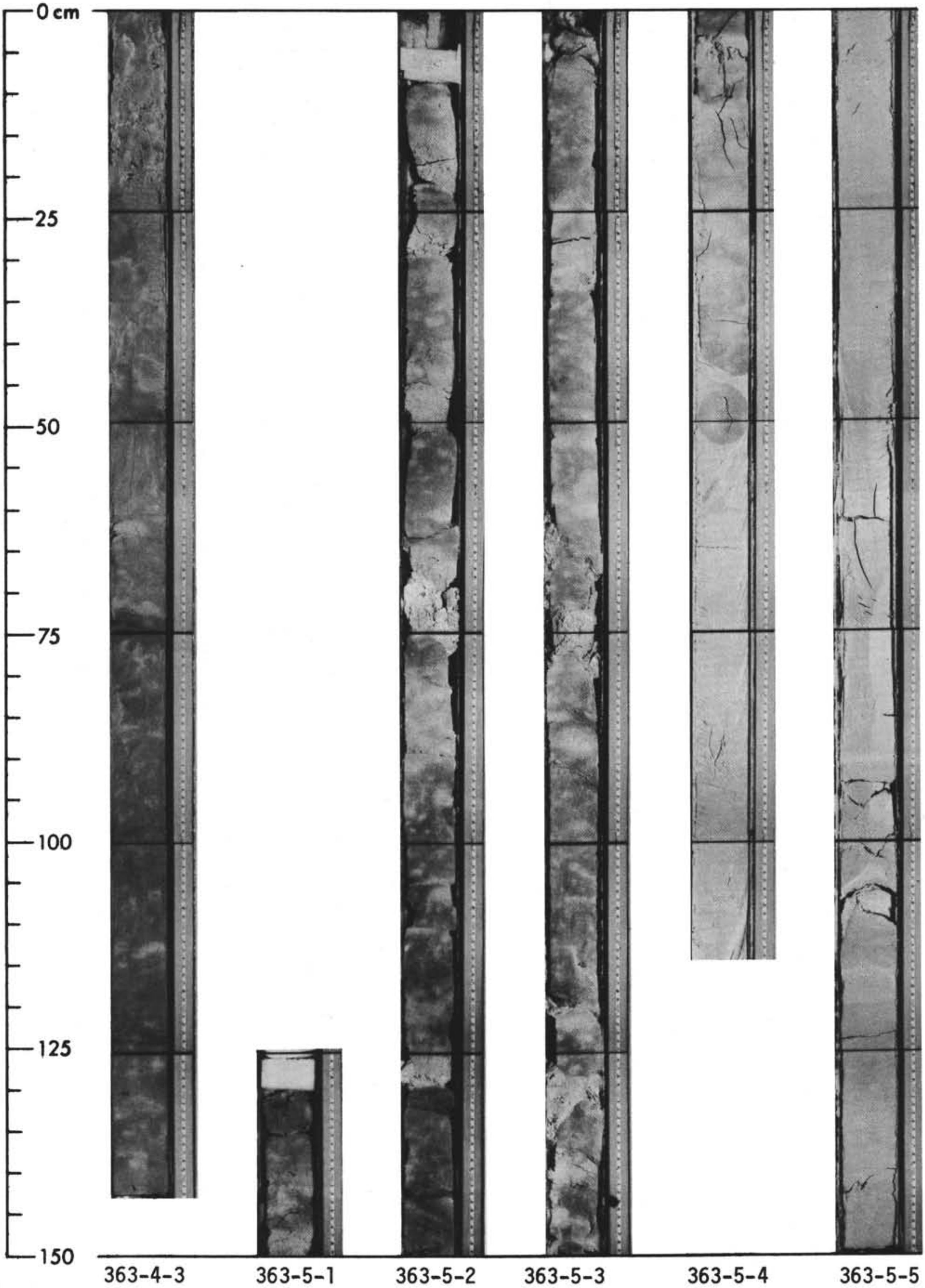
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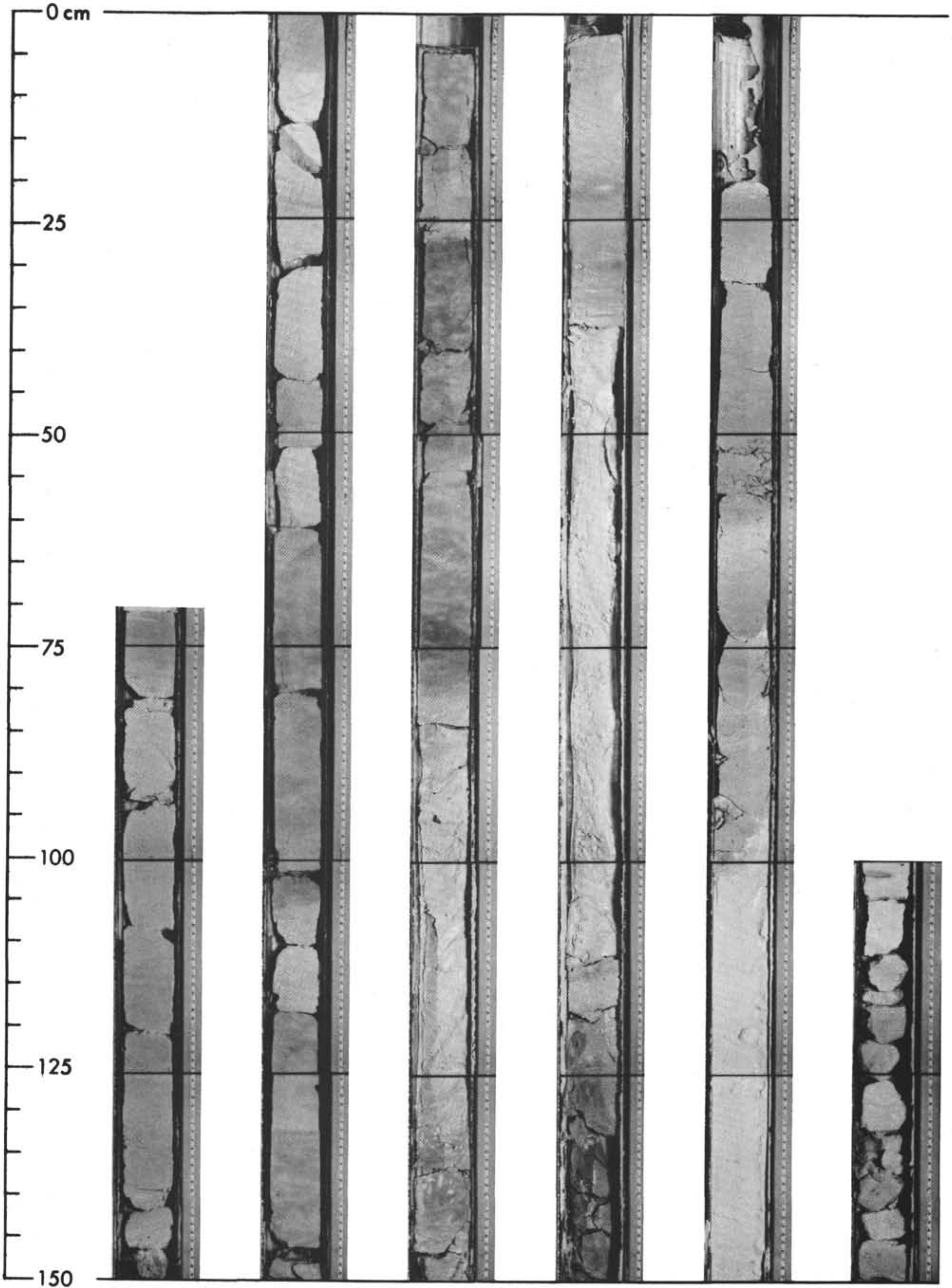
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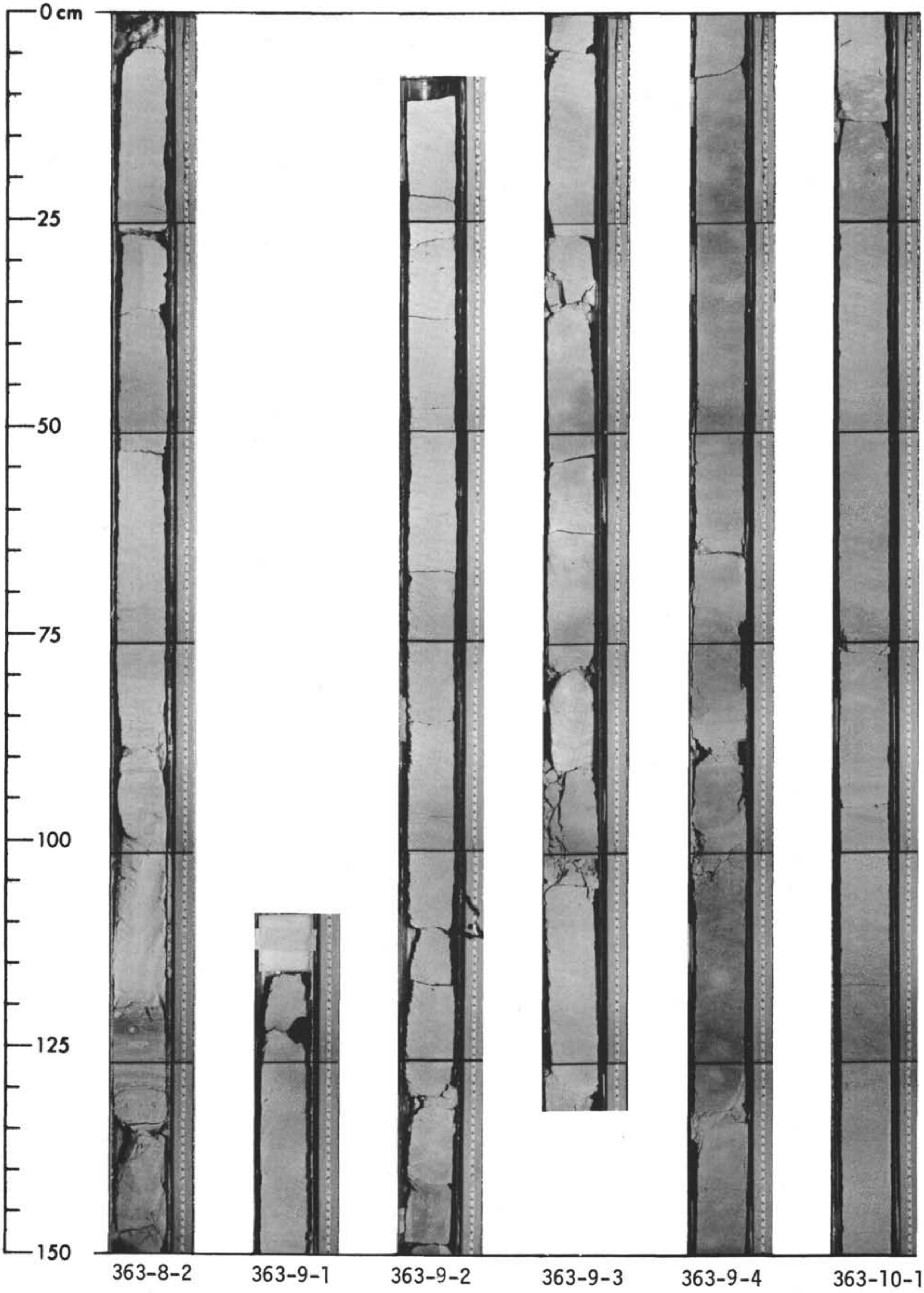
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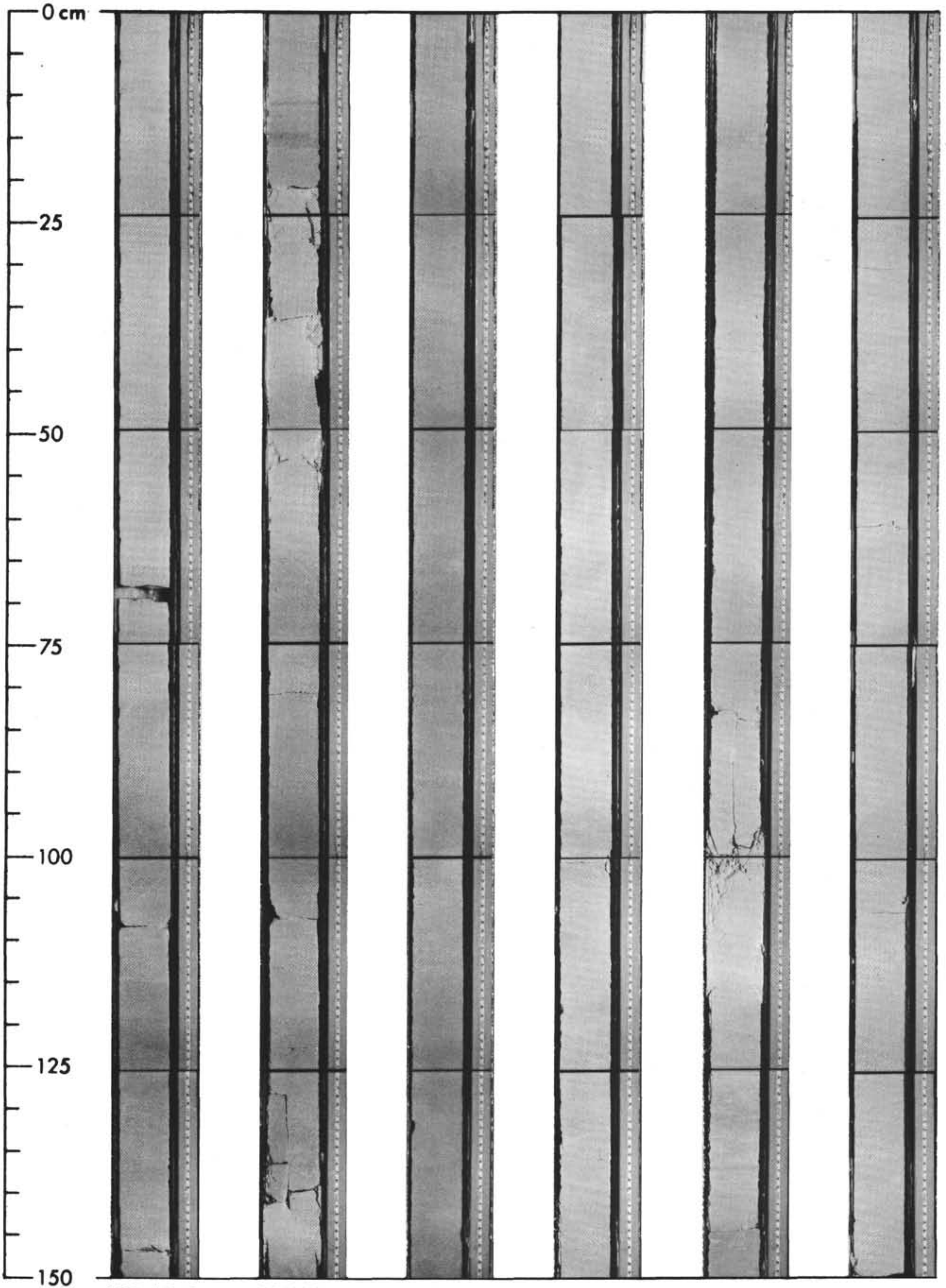
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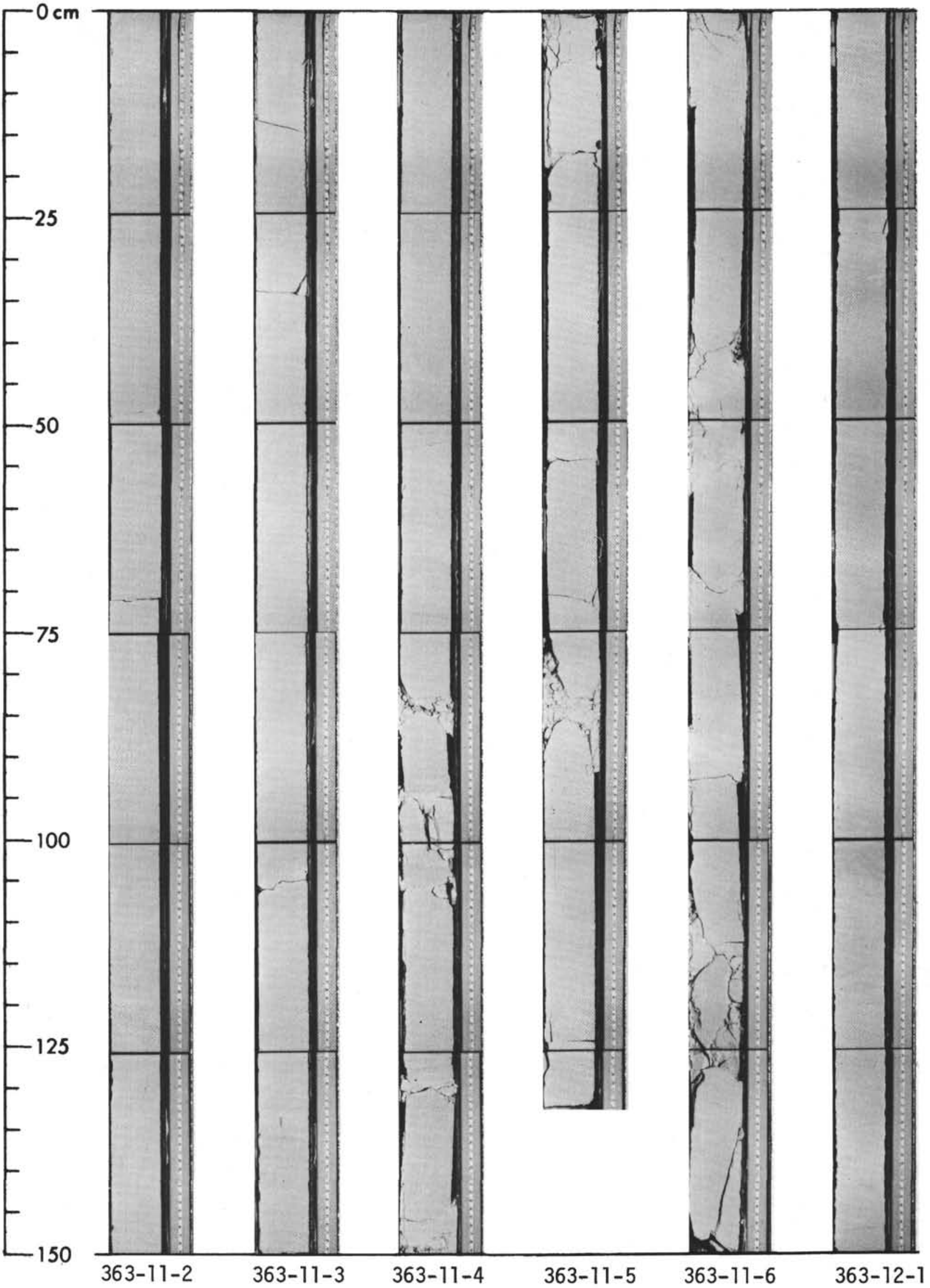
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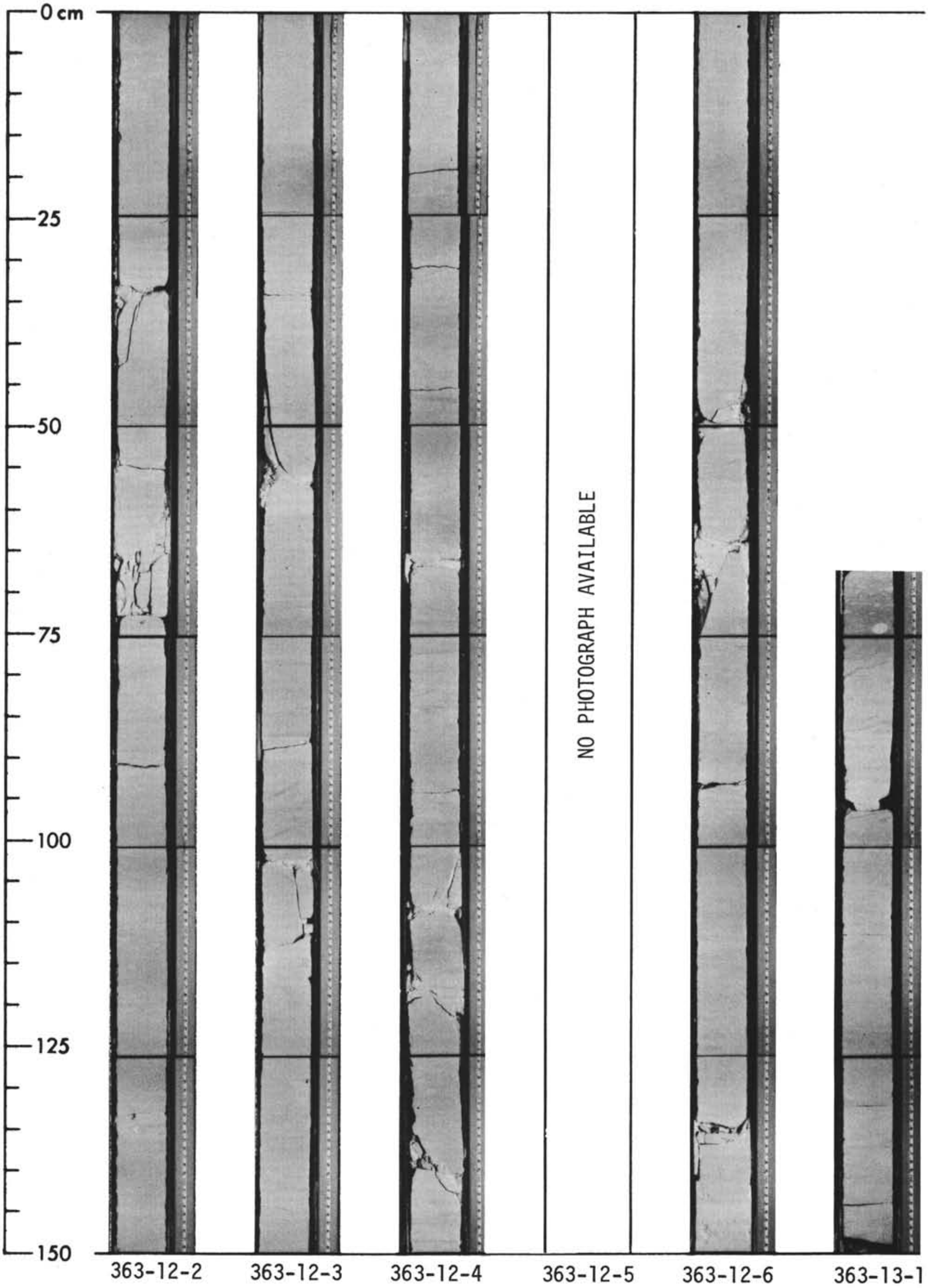
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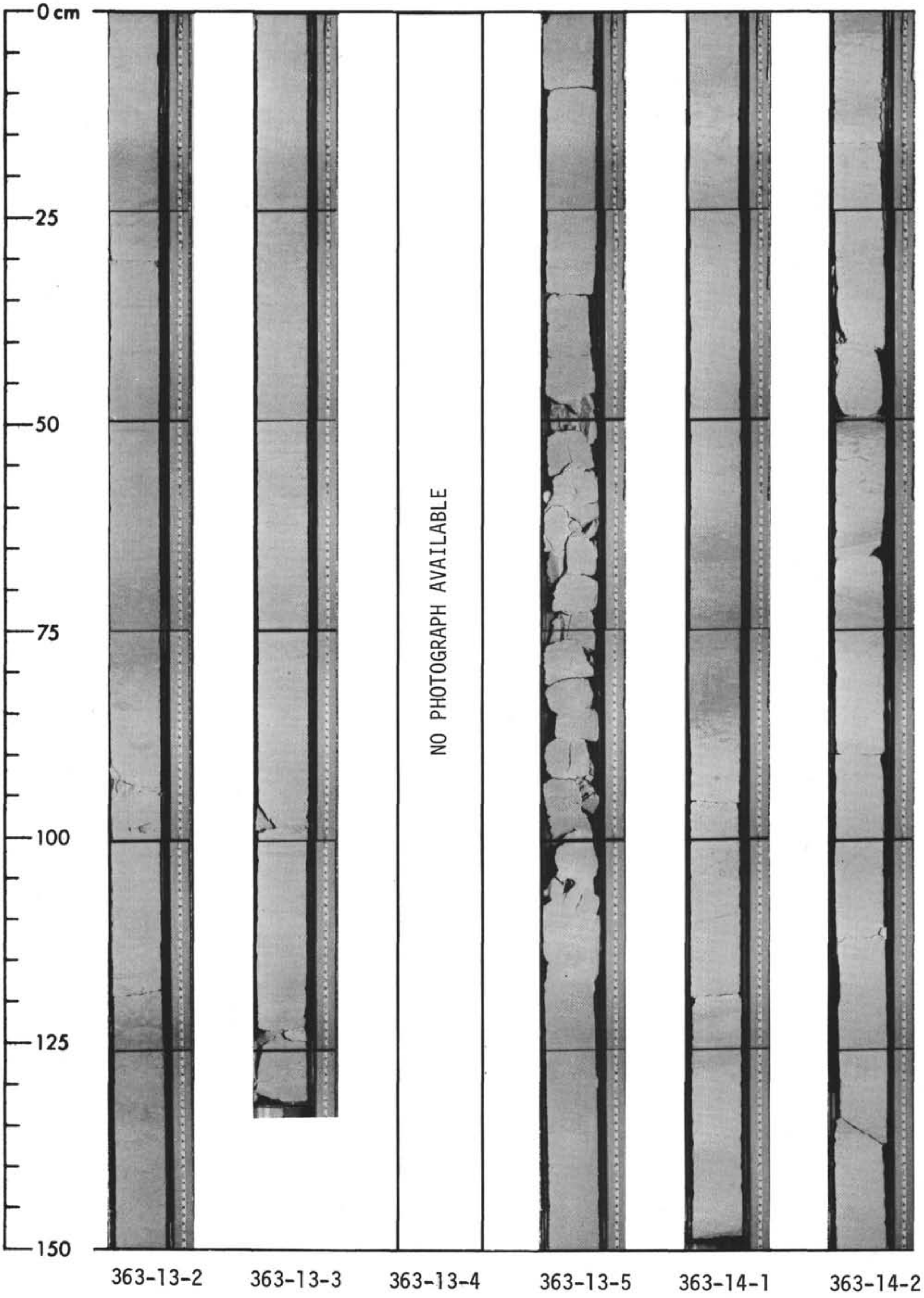
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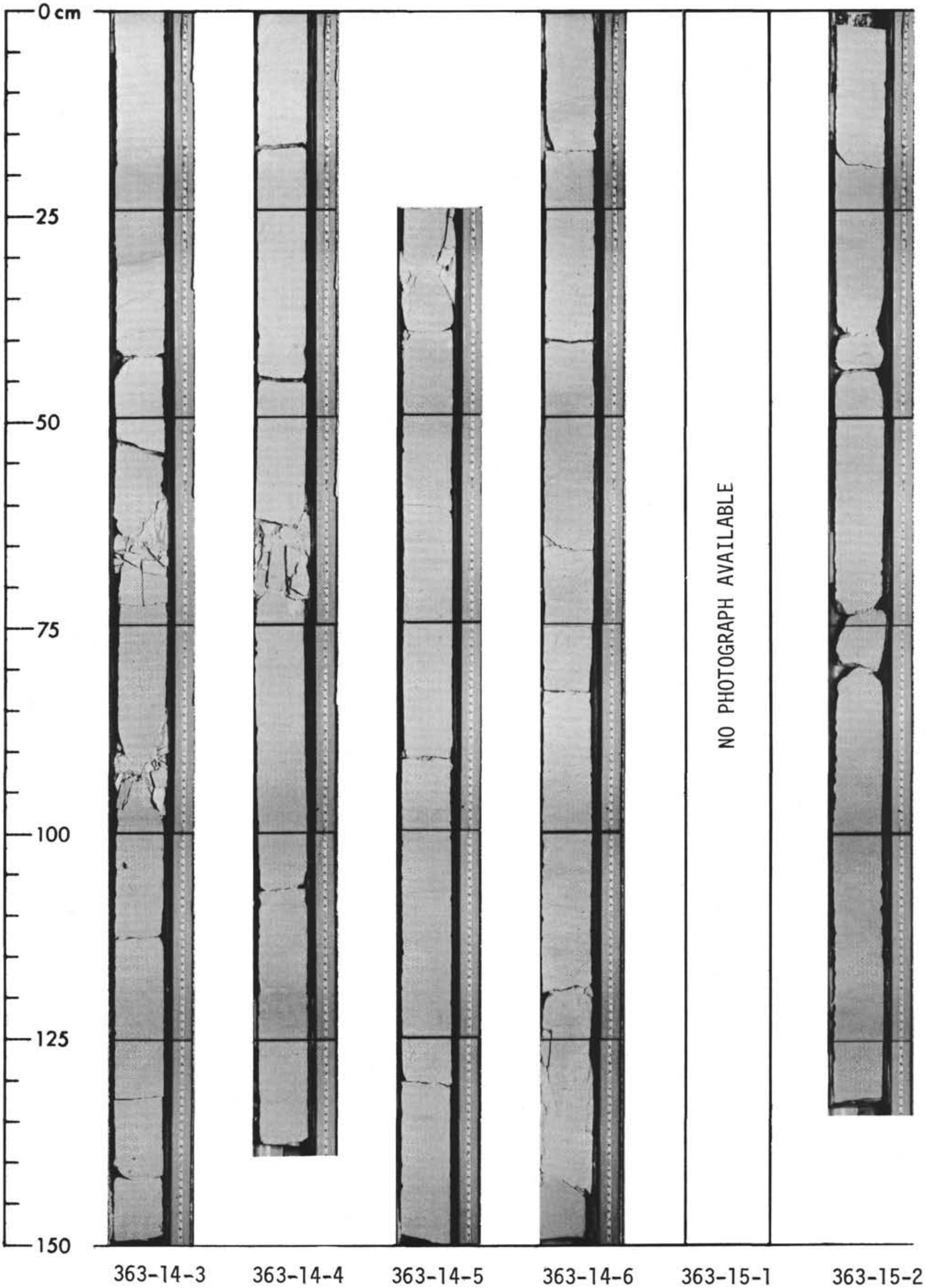
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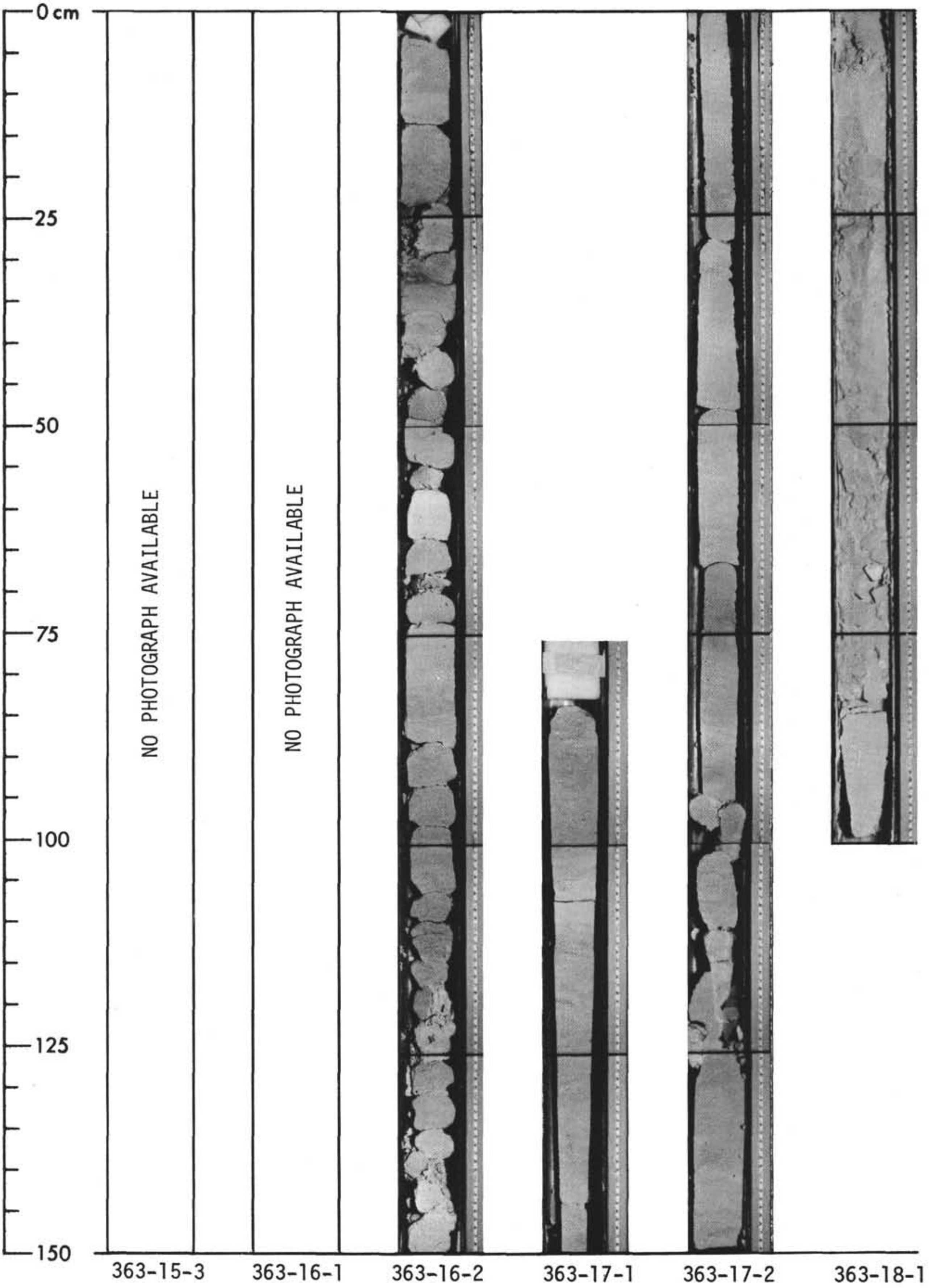
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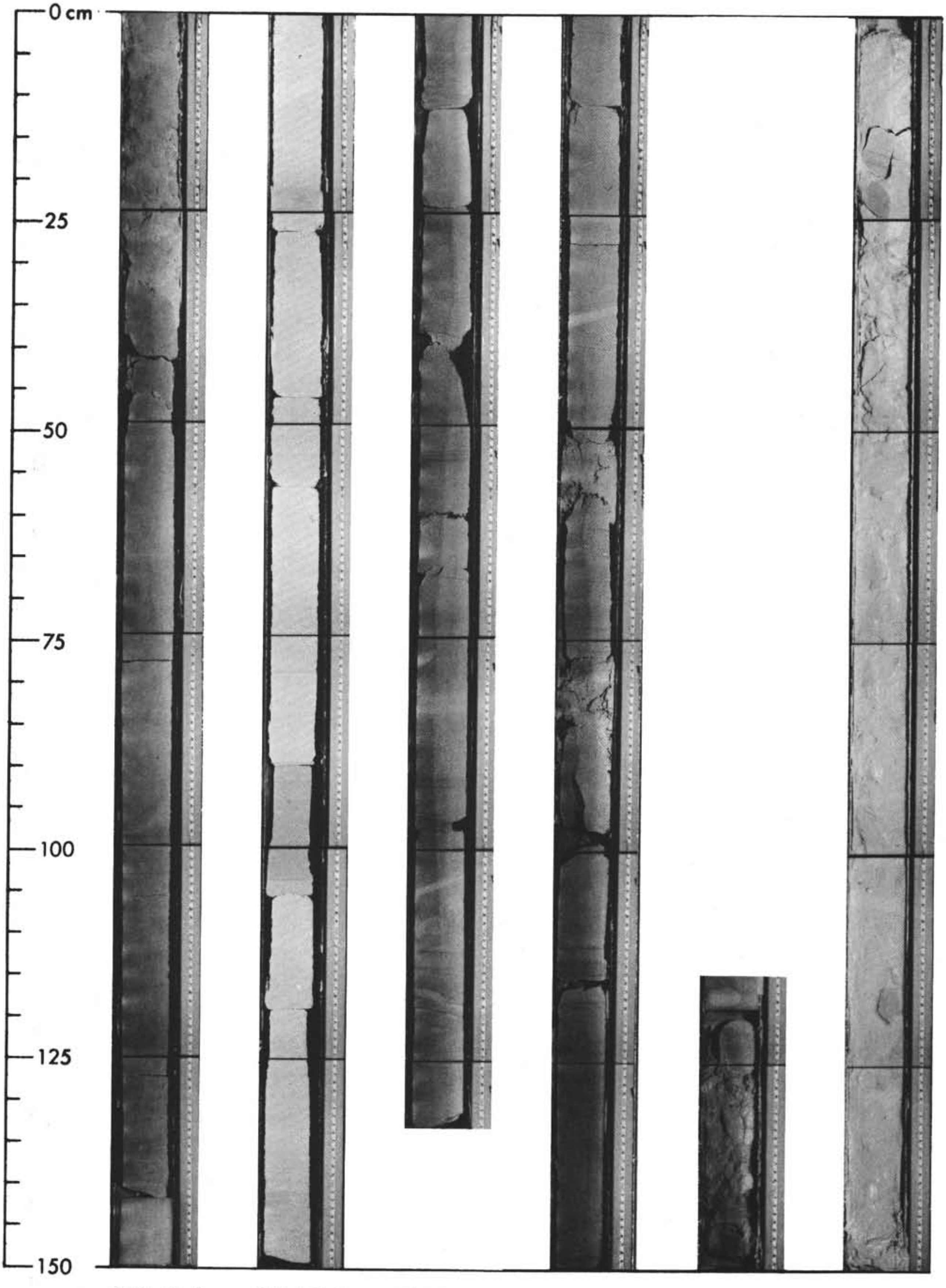
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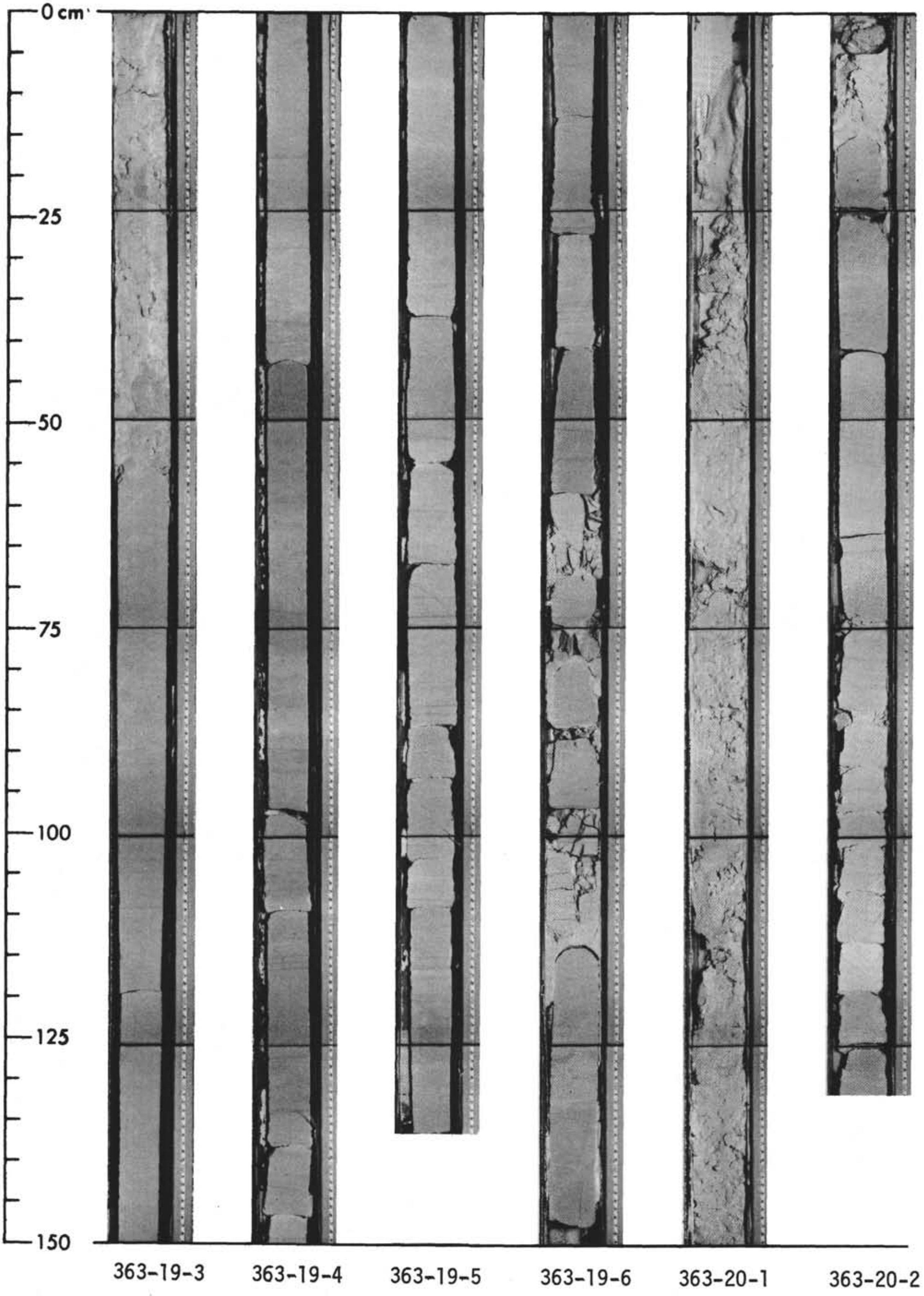
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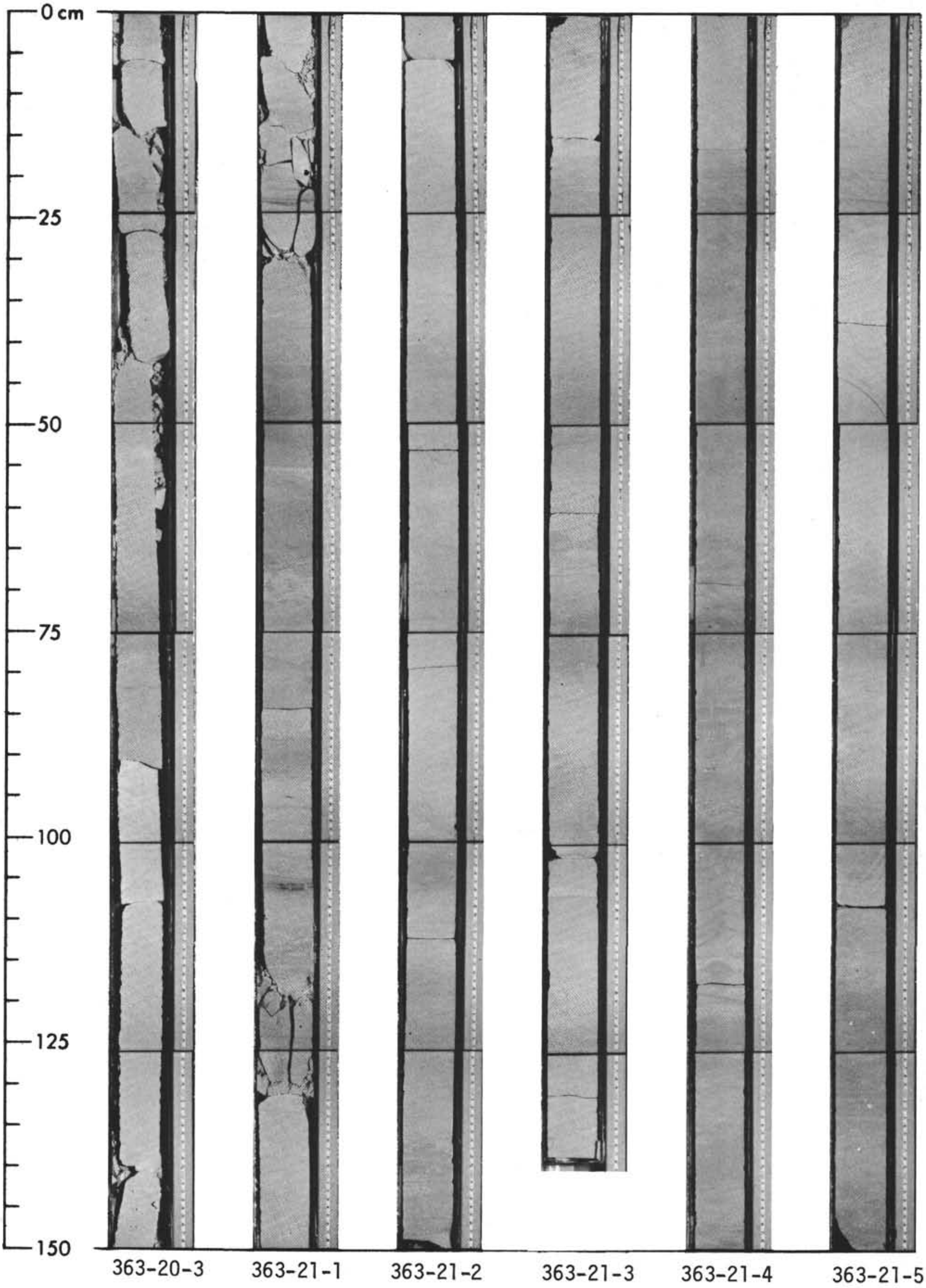
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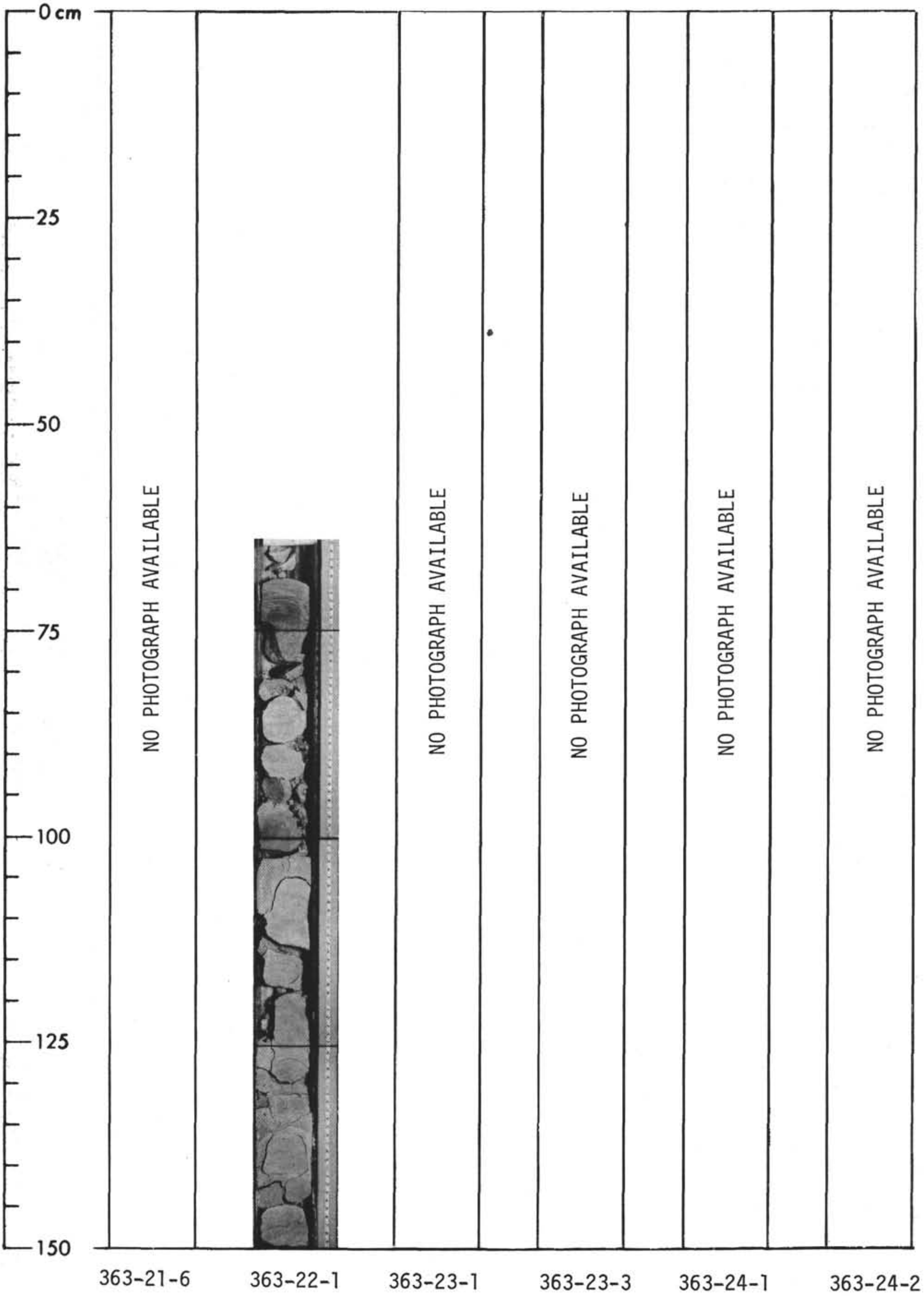
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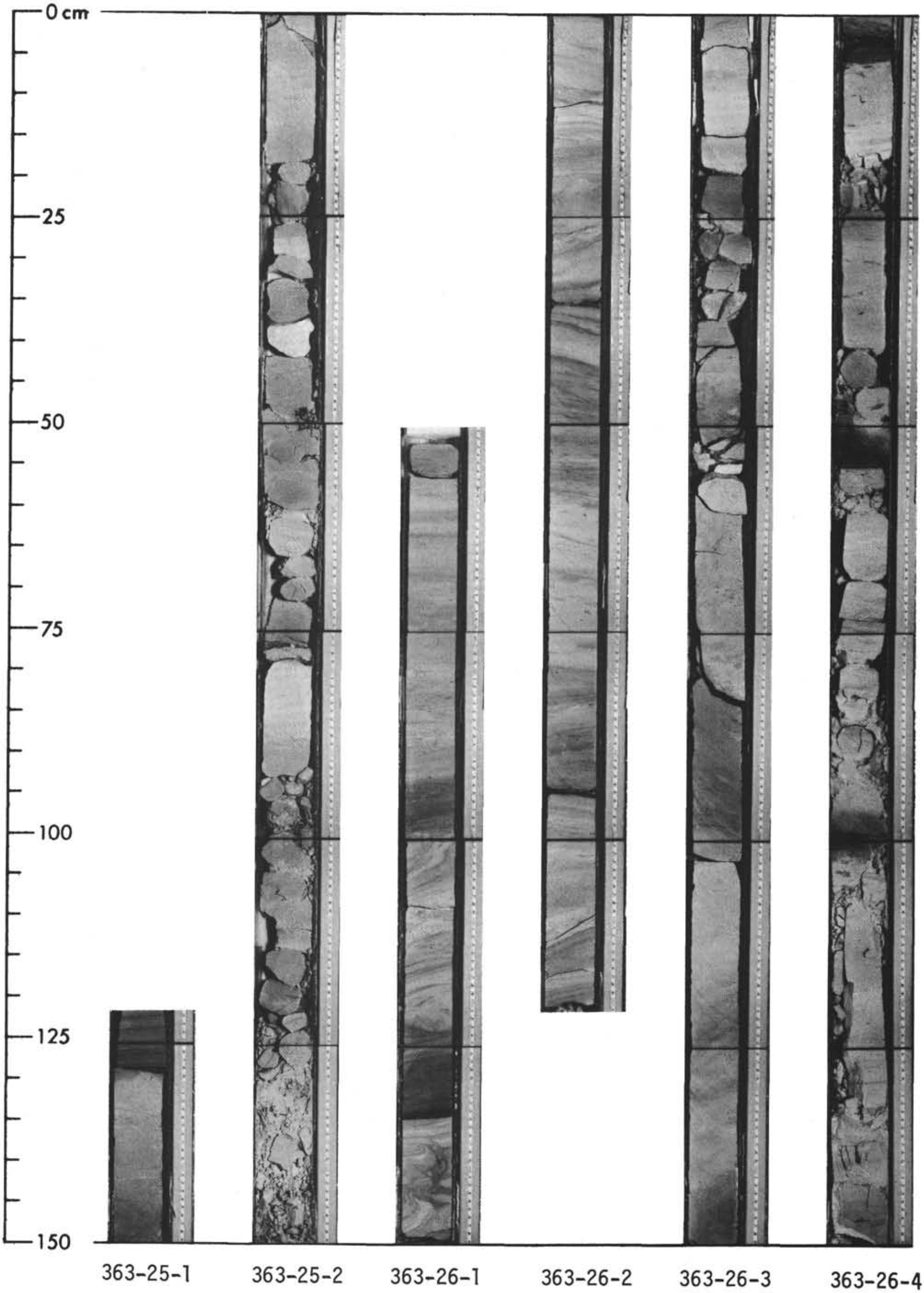
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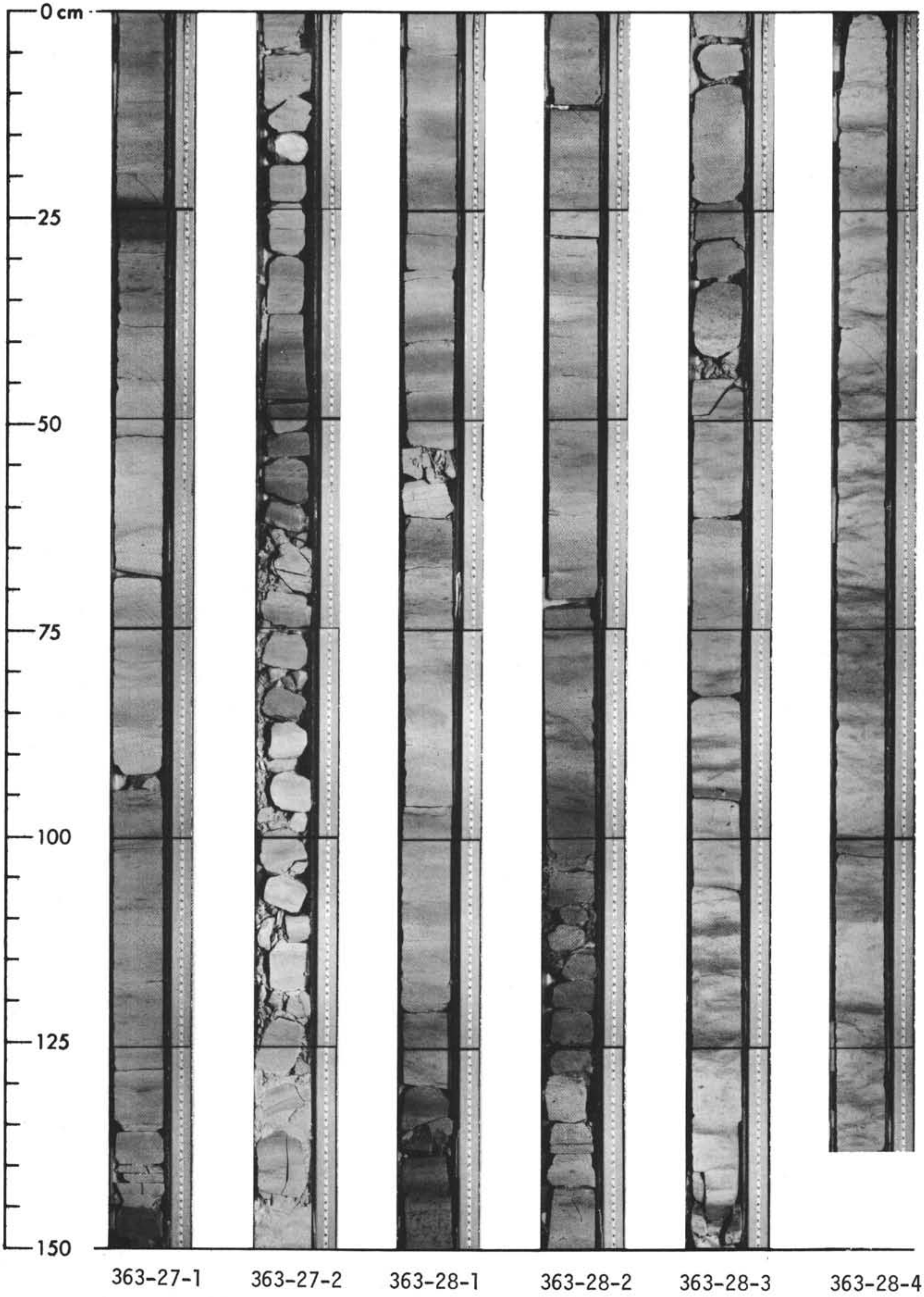
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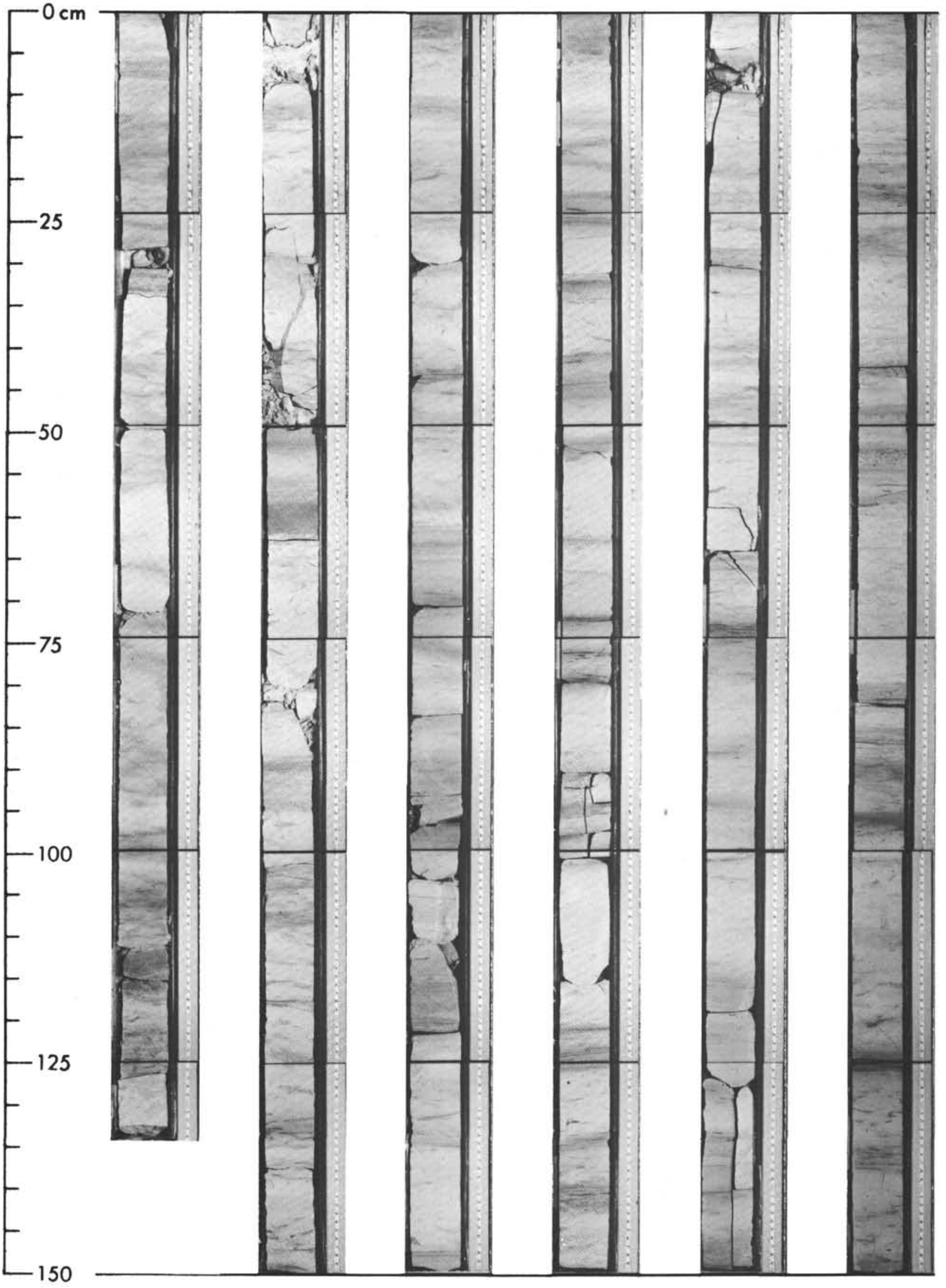

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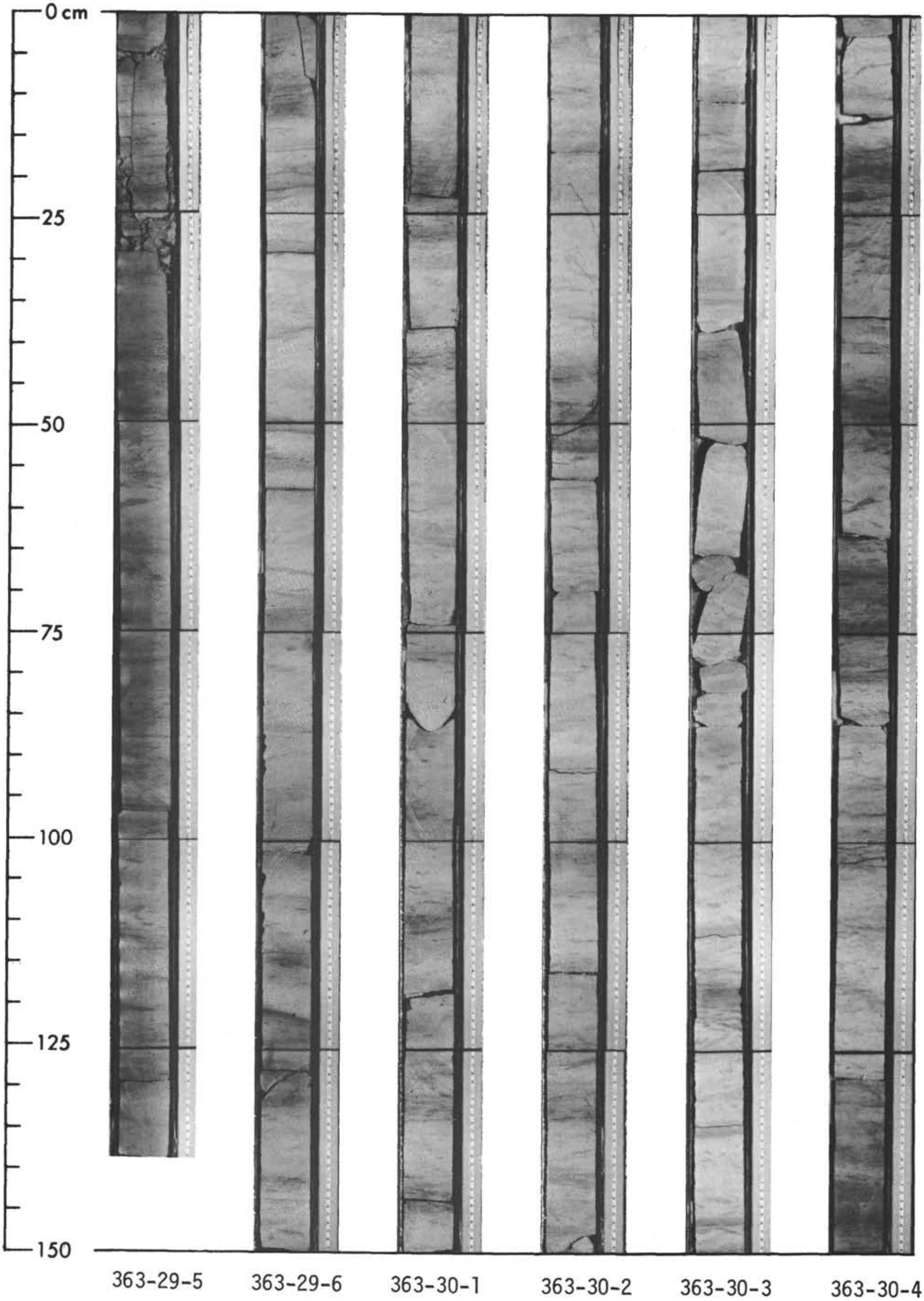
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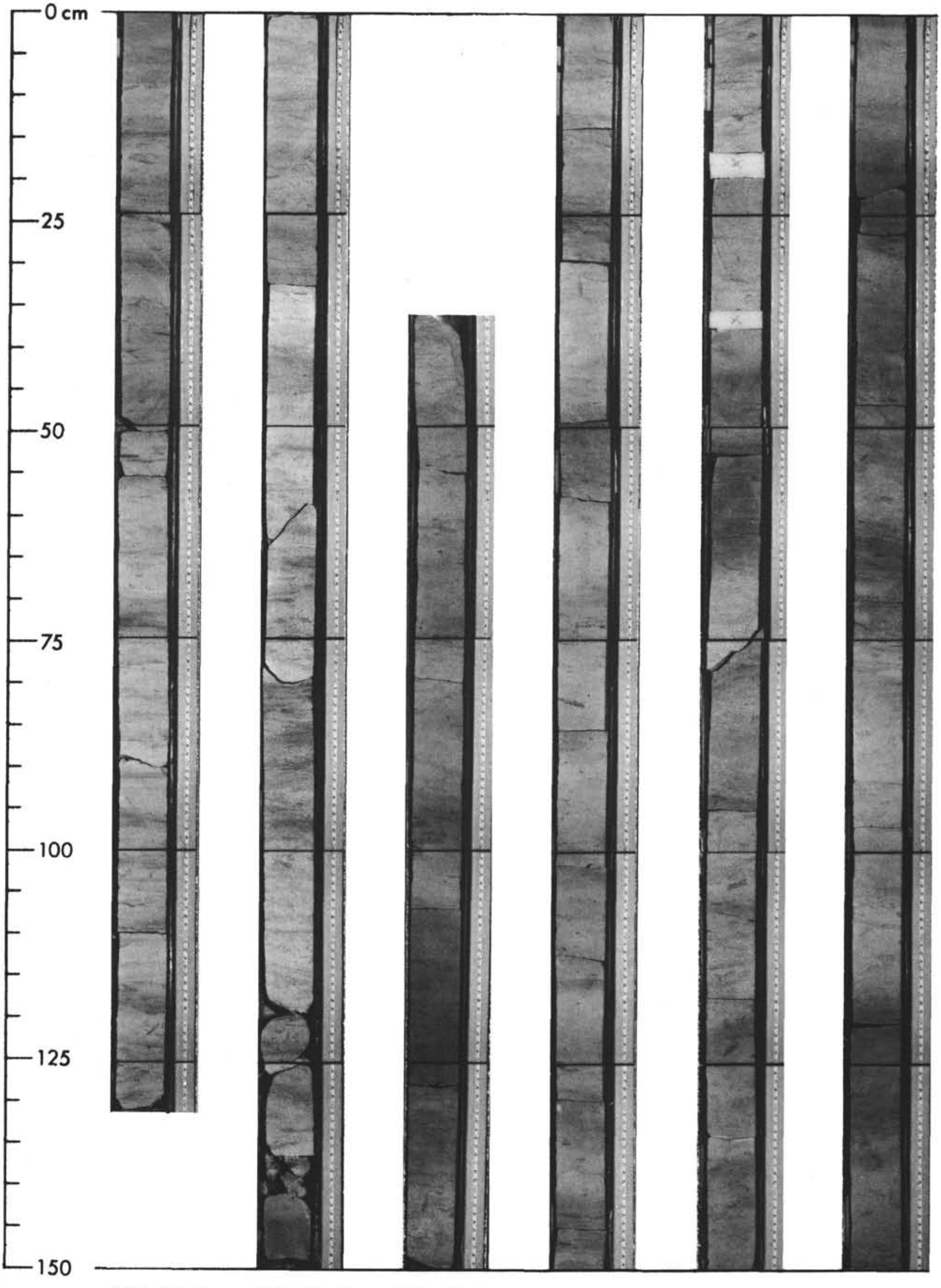
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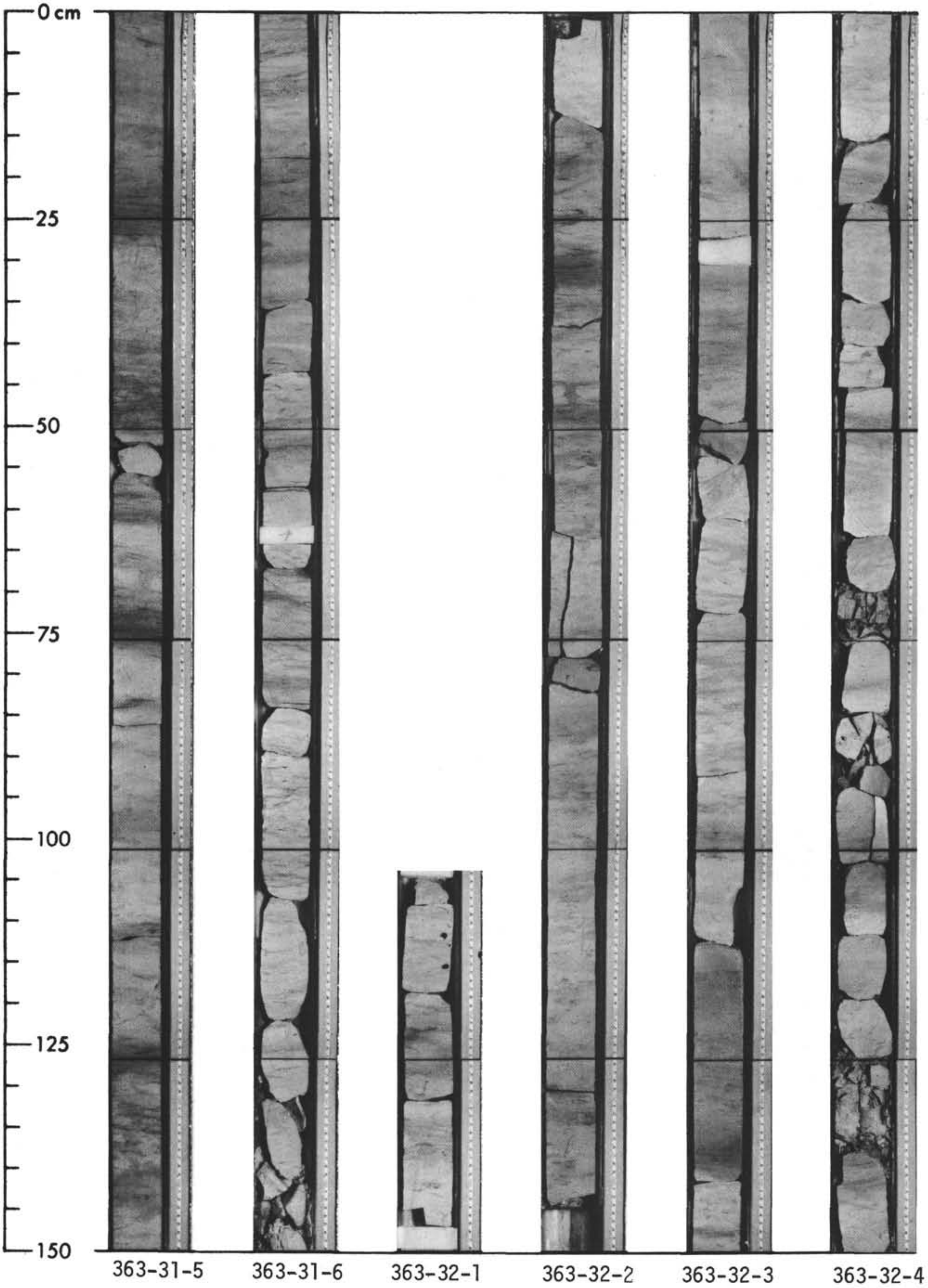
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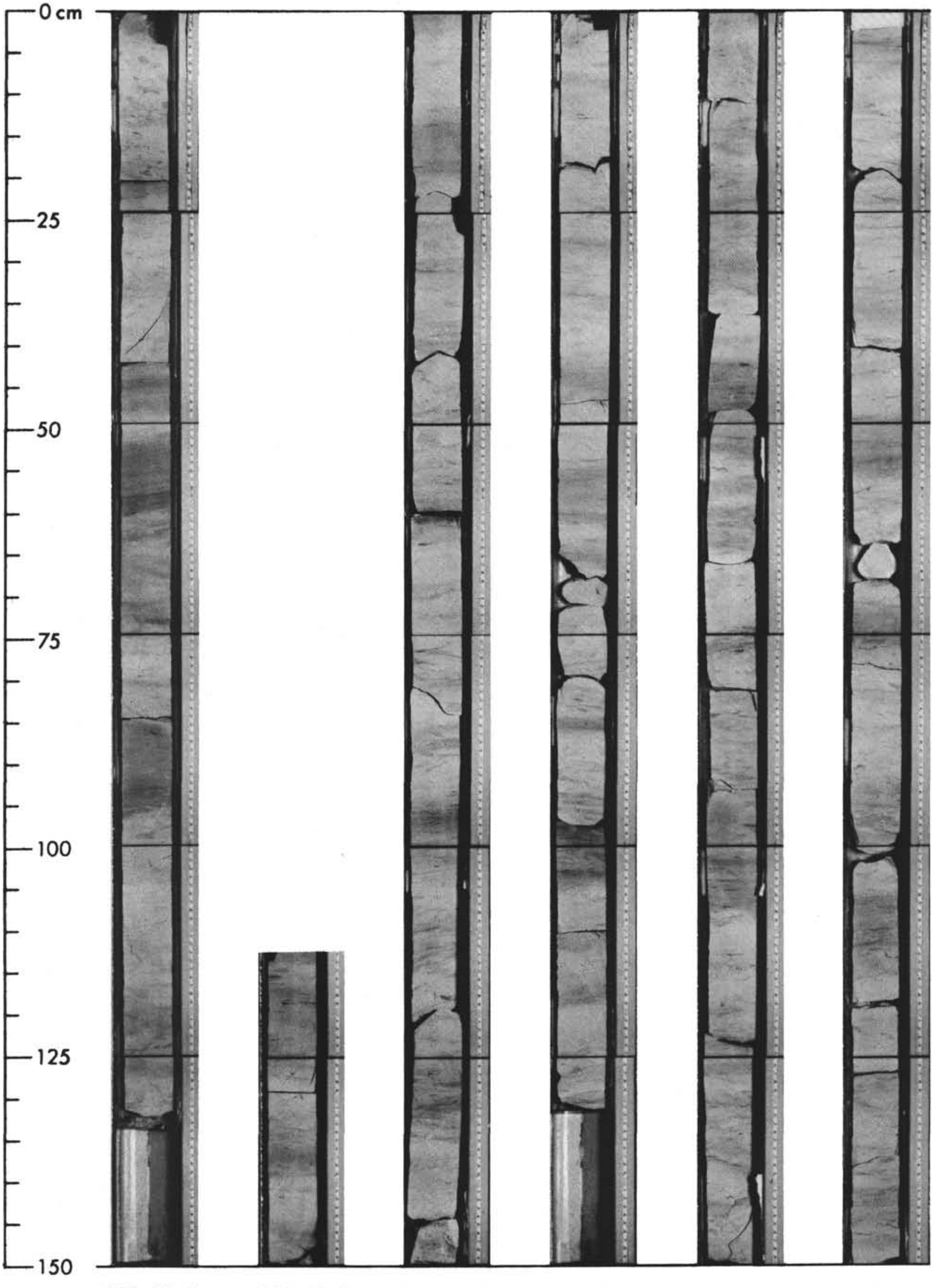
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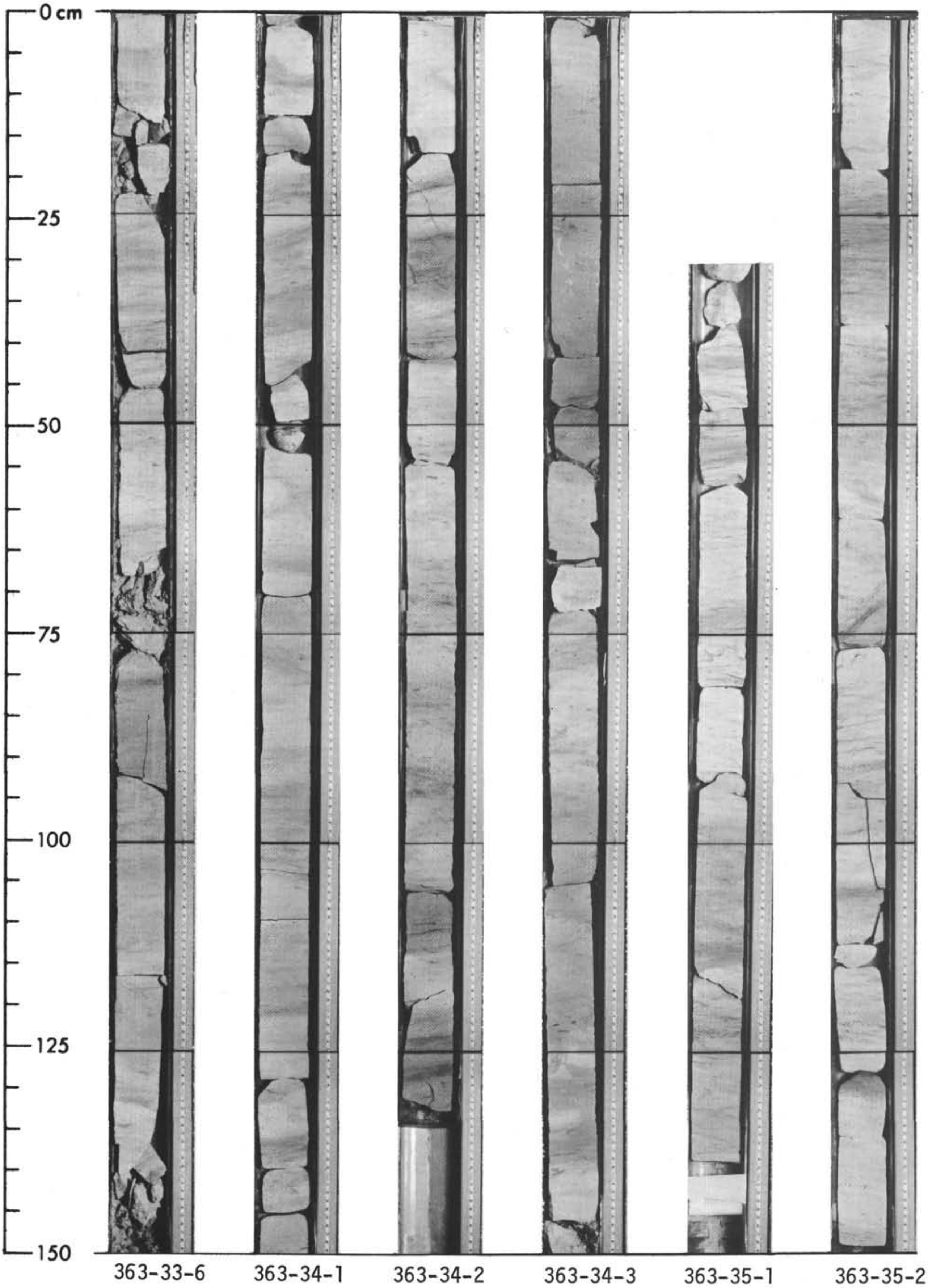
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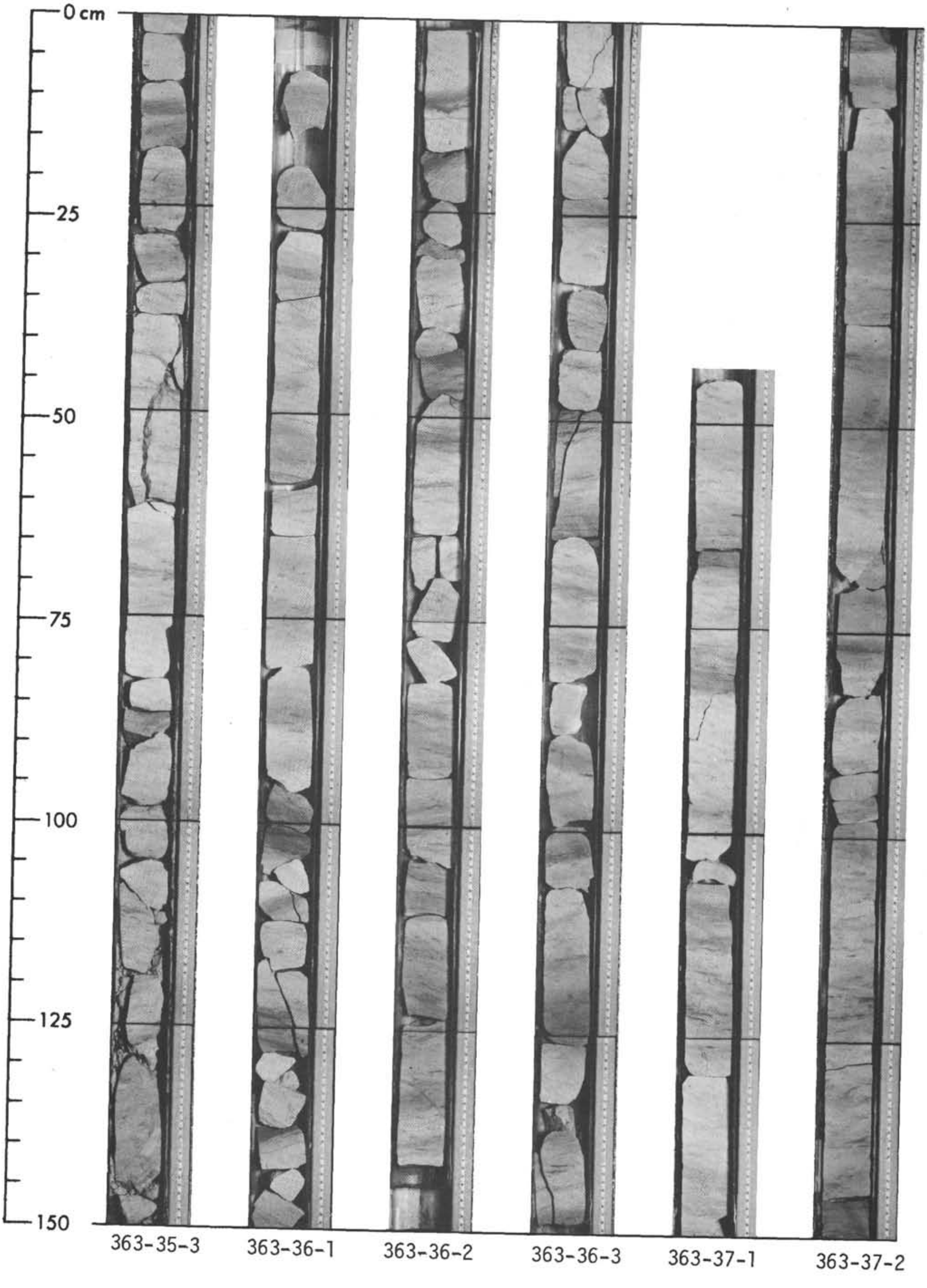
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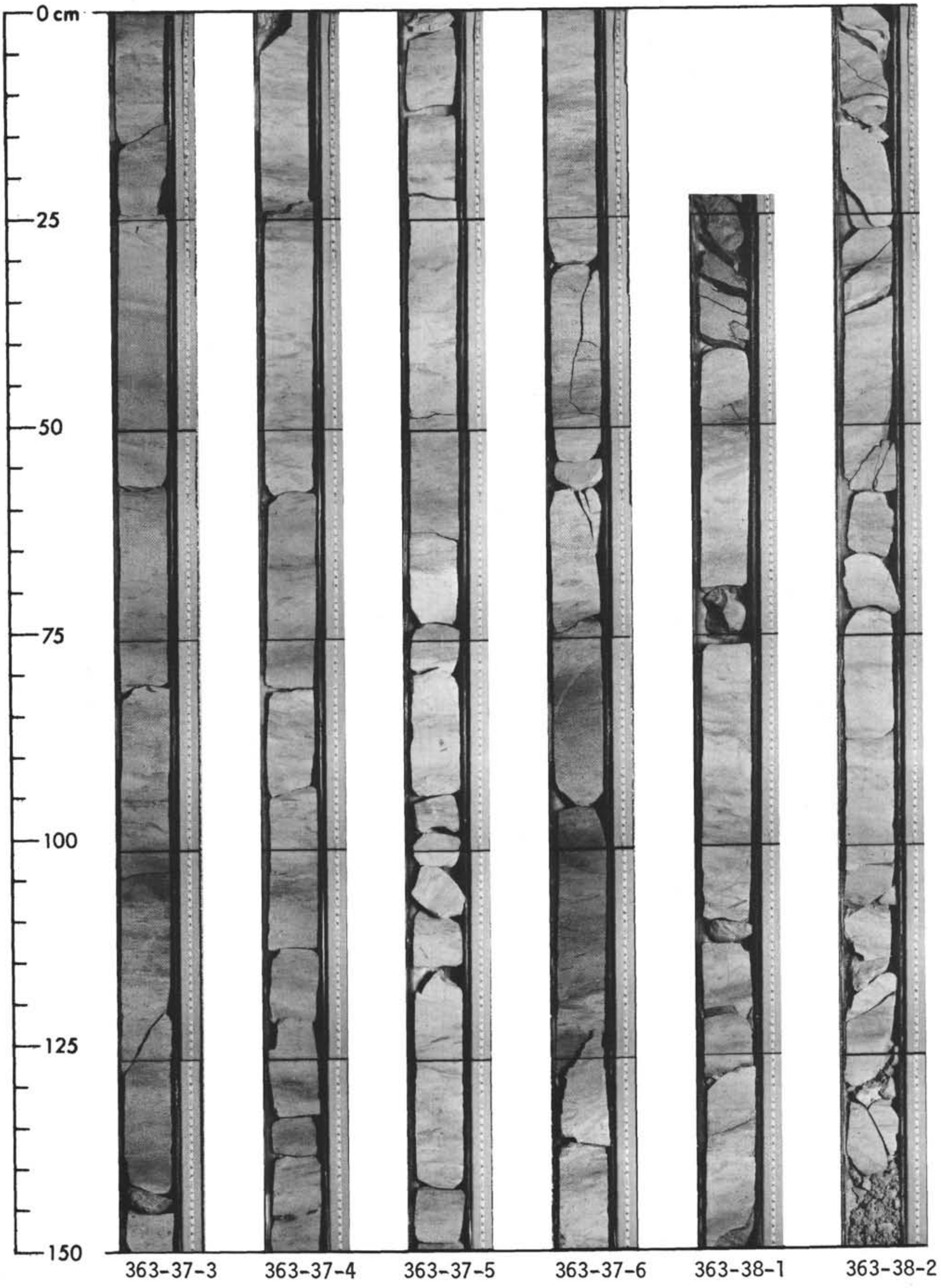
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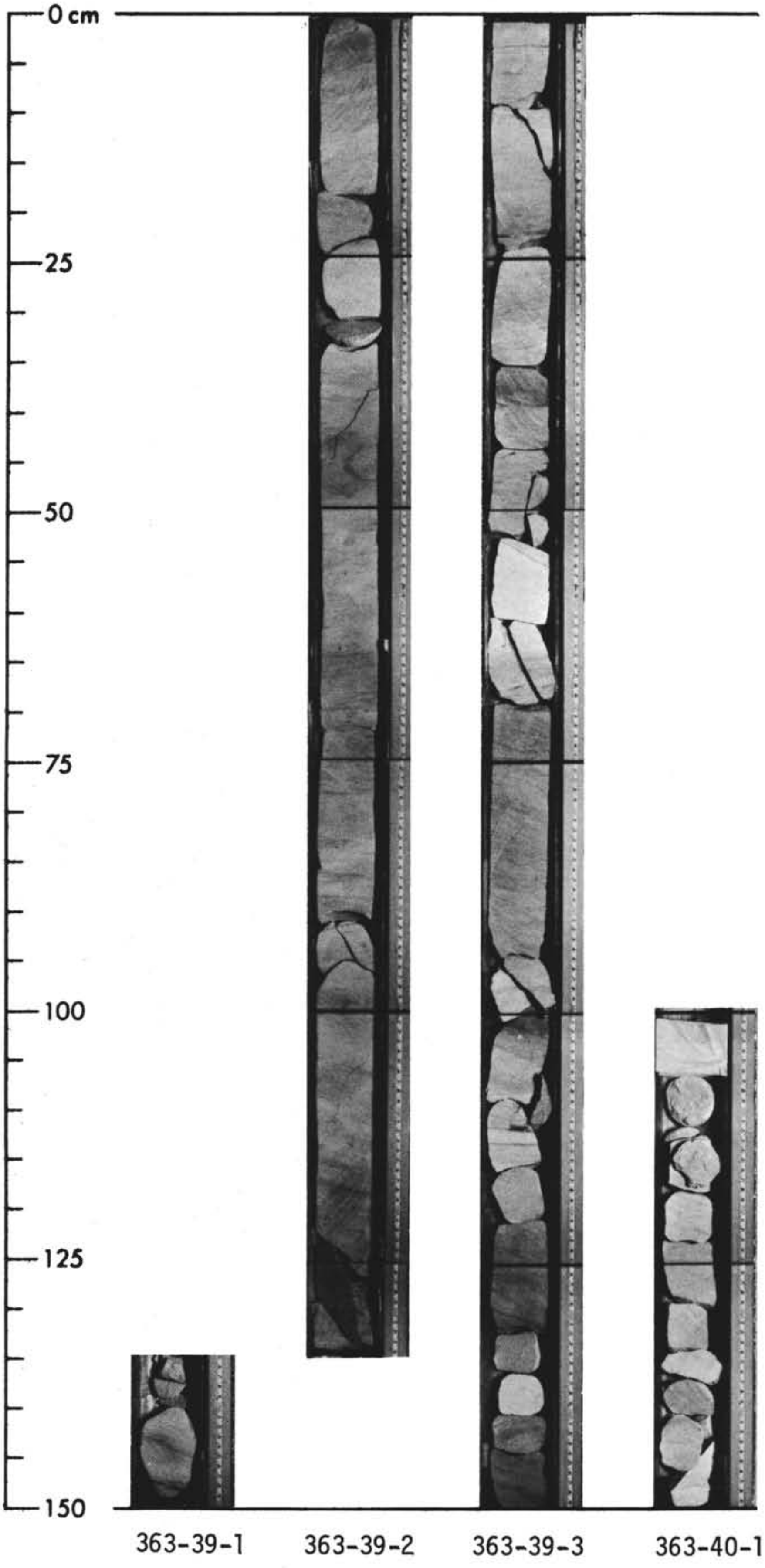
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