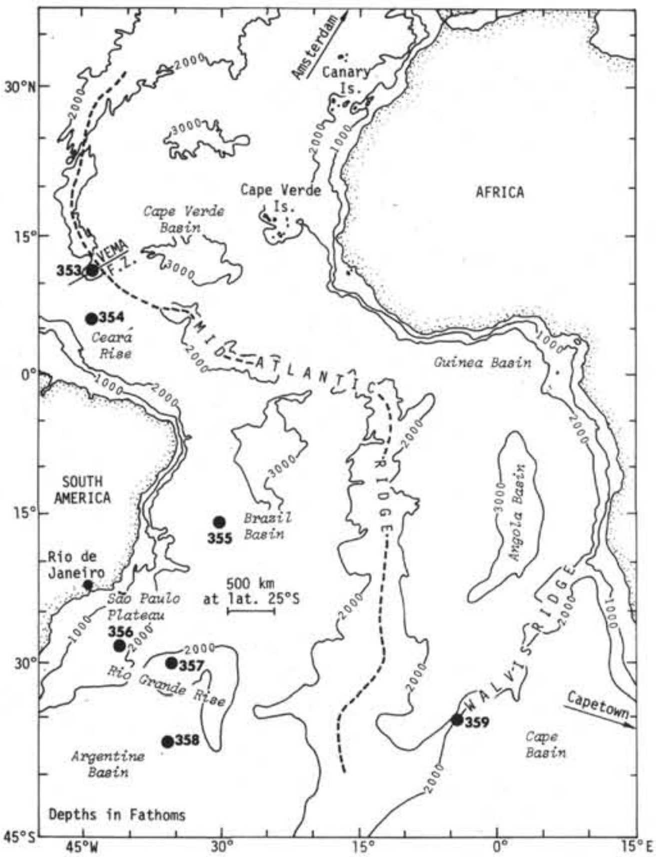
5. SITE 356: SÃO PAULO PLATEAU

The Shipboard Scientific Party[1]



SITE DATA

Date Occupied: 16 November 1974 (1317Z)

Date Departed: 21 November 1974 (1850Z)

Time on Site: 5 days, 5 hours, 33 minutes

Position: 28°17.22′S, 41°05.28′W

Accepted Water Depth: 3175 meters (echo sounding, corrected)

Penetration: 741 meters

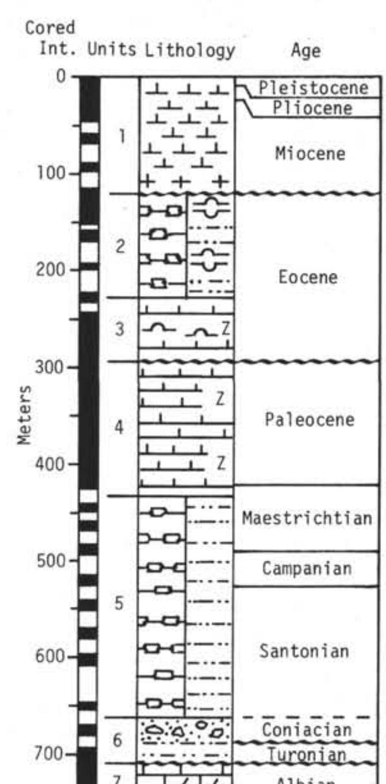
Number of Holes: 2

Number of Cores:
Hole 356: 44
Hole 356A: 2

Total Length of Cored Sections:
Hole 356: 418 meters
Hole 356A: 19 meters

Total Core Recovered:
Hole 356: 215.9 meters
Hole 356A: 17.6 meters

Principal Results: We cored sediments to a subbottom depth of 741 meters on the southern edge of the São Paulo Plateau. The oldest sediments recovered are Albian laminated dolomitic limestones, which were deposited at intermediate depth (~1000 m). These are overlain by Turonian-Coniacian conglomerates and mudstones, rich in organic matter, which were laid down in part at least, in a semirestricted basin of local or regional extent. Post-Coniacian sediments are mostly pelagic biogenic carbonates with varying admixtures of terrigenous material, and were deposited in an open marine basin. The carbonate section is continuous across the Cretaceous-Tertiary boundary; a thick Danian section was recovered. Siliceous components are present in significant quantities only in the Eocene. There is a hiatus at the Paleocene-Eocene boundary, an important hiatus from middle



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Eocene to lower Miocene, and a hiatus from lower Miocene to Pliocene.

BACKGROUND AND OBJECTIVES

Site 356 is on the southeastern edge of the São Paulo Plateau at a water depth of 3175 meters (Figure 1). The plateau is triangular in plan view, and extends up to 950 km offshore from the Brazilian shoreline.

Two-ship refraction profiles in 1960 and seismic-refraction surveys in 1967, carried out by Lamont-Doherty Geological Observatory, had indicated in this area a shallow seismic horizon which could contain evaporites (Leyden et al., 1971). As a result of further surveys carried out by L-DGO in 1972, 1973, and 1974, the full extent of the diapir zone off the margin of Brazil has been established (Leyden and Nunes, 1972; Leyden et al., in press). The diapir zone off Brazil extends 810 km offshore at 28°S and narrows to less than 30 km at 11°S. In the south, the seaward edge of the diapir zone lies in more than 2000 meters of water, whereas in the north, the zone occurs only on the shelf (Figure 2).

Most of the area of the São Paulo Plateau is underlain by diapirs. An east-west basement ridge marks the southern margin of the plateau (Figure 3). This ridge can be followed westward for some distance in the sub-bottom and may connect on land with the southern edges of the Precambrian Ponta Grossa Arch (see Kumar et al., this volume).

The eastern edge of the São Paulo Plateau roughly coincides with the eastern limit of the diapir zone; whether the scarp is controlled by basement structure is not known.

A similar zone of diapirs has been mapped between 1°N and 14°S from Gabon to Angola, off the West African margin (Leyden et al., 1972; Pautot et al., 1972). Leyden and Nunes (1972) have shown that when the boundaries of the diapir zones on both sides of the Atlantic are brought together, they fit each other perfectly and form one continuous zone of salt deposition in the South Atlantic.

The salt present on both sides of the Atlantic is supposed to be Aptian-Albian in age (Asmus and Ponte, 1973). If the rifting in the South Atlantic started sometime in the Neocomian, about 127 m.y. ago (Larson and Ladd, 1973), the South Atlantic must have still been a narrow restricted basin in Aptian-Albian time. Spreading started in the southern South Atlantic, and the region south of Walvis Ridge and Rio Grande Rise formed an open marine basin. The Walvis Ridge and the basement ridge of the São Paulo Plateau, together with the Rio Grande Rise, formed a barrier to open circulation. Circulation was also restricted between the North Atlantic and the South Atlantic until late in the Cretaceous (Reyment and Tait, 1972). Hence, conditions were well suited for salt deposition in the northern South Atlantic.

Site 356 is in the zone between the escarpment of São Paulo Plateau and the area of diapirs (Figure 2). This zone either contains a very thin salt layer (not thick enough to form large diapirs), gypsum, and anhydrite, or contains nonevaporitic sediments. Owing to considerations of safety and politics, it was not possible to drill within the zone of diapirs (most of the diapir zone lies within the 200-mile limit claimed by Brazil as

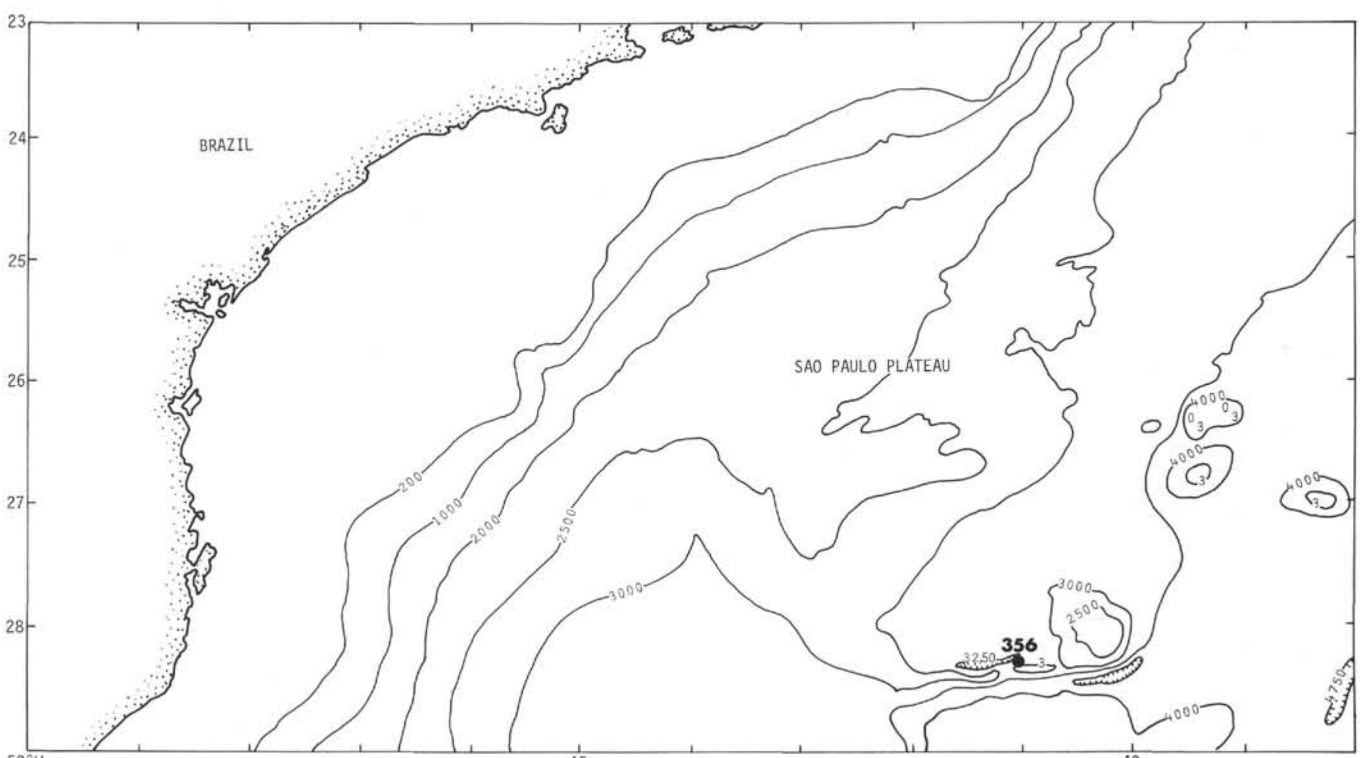

Figure 1. *Base map of São Paulo Plateau showing location of Site 356. Contours in meters, from Connary and Moody, 1975, bathymetry of the continental margin of Brazil (unpublished).*

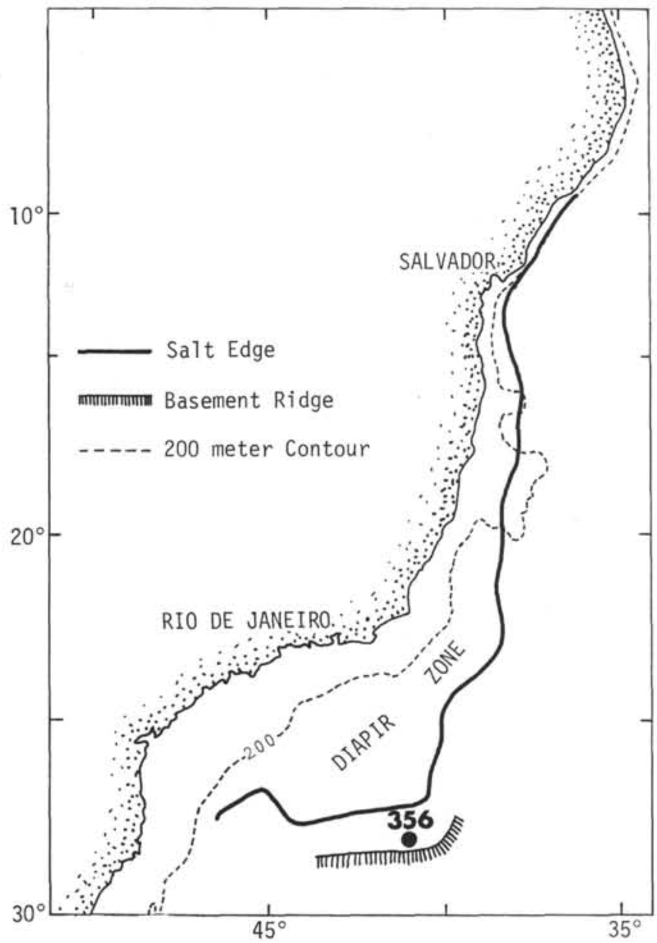

Figure 2. *Site 356 in relation to the shelf break, inferred edge of the salt diapir zone, and southern escarpment of the São Paulo Plateau. From Leyden et al (in press).*

territorial waters). The present site was chosen because it appeared to offer us the opportunity to sample (a) sediments younger than the salt, (b) sediment equivalent in age to salt, (c) sediments older than the salt, and (d) the basement of the São Paulo Plateau.

Drilling at Site 356 was expected to help answer the following questions:

1) What was the nature of the South Atlantic basin before the time salt was deposited—i.e., shallow or deep?

2) Did the salt form in deep or shallow water?

3) What is the nature of the basement rocks underlying the salt: is the basement ridge forming the southern edge of the São Paulo Plateau made up of oceanic tholeiites, or rocks related to fracture zones?

4) What is the relationship between the basement under the São Paulo Plateau and the basement under the Rio Grande Rise?

Site 356 was the first site drilled to address the question of the origin of salt in the South Atlantic. All pre-existing information on salt came from onshore outcrops and wells, some wells on the shelf, and seismic data. In addition to investigating the salt question, we attempted, by coring in the upper part of the stratigraphic sequence, to detail changes in the pattern of sediment accumulation on the plateau during the Tertiary. The sediments were expected to show transition from an isolated basin in the Cretaceous to a semi-isolated enclosed condition, and finally to open marine conditions. Periods of eustatic low sea level, such as the Miocene and Plio-Pleistocene, were expected to show increased supply of terrigenous components.

OPERATIONS

We approached Site 356 on a heading of 210°T. It was our intent to come onto a course of 180°, roughly at right angles to the basement ridge, some eight miles north (point A, Figure 4) of the proposed site location (see Figure 3, 2150 hr on LDGO record number 1514, cruise RC 16). At 1020Z, 16 November 1974, we believed we were about 4.5 miles north of point A (based on a computer input omission and resultant bad dead reckoning), and altered course to 180°T. A satellite fix received just before the turn showed *Glomar Challenger* east and slightly north of the turn point. We changed heading to 230° at 1045Z and to 180° at 1053Z and reduced speed to 6 knots at 1100Z. We passed the proposed site and found a more likely drilling location at 1200Z. At 1233Z we turned onto a reciprocal course. We dropped the beacon while underway at 1317Z, retrieved gear, and returned over the beacon.

The site is on the north slope of the basement ridge (i.e., south of the valley), with ~0.75 sec to basement (Figure 5) and roughly the same sequence of internal reflectors as the (slightly thicker) section north of the valley (Figure 4).

As at all Leg 39 sites, the bottom-hole assembly consisted of a Smith 10-1/8″ F94CK chisel-tooth tungsten carbide inset bit, core barrel, three 8-1/4″ drill collars, one Baash-Ross bumper sub, three 8-1/4″ drill collars, two Baash-Ross bumper subs, two 8-1/4″ drill collars, one 7-1/2″ drill collar, and one joint of 5-1/2″ heavy weight drill pipe. The bit chosen seems to offer the best compromise between penetration rates in soft sediments and ability to drill through hard formations such as chert or basalt.

Accepted water depth as measured by PDR was 3175 meters, corrected, or 3185 meters to the rig floor. The driller thought he felt bottom in the joint between 3193.5-3203 meters; a water core was pulled. The next attempt (3203-3212.5 m) yielded about a thumbnail full of Pleistocene foraminifer sand. Since bottom had obviously been reached somewhere in this joint, depth to the sediment/water interface was accepted as 3203 meters below the rig floor for measurement purposes, and coring began.

The first nine cores (see Table 1) cut very easily and quickly (5-15 min per core). The sequence between Cores 9 and 16 was silicified, and it took about twice as long to cut each core (Figure 6). (At about this degree of induration, it is no longer possible to pump the material completely away in the drilled intervals; but the problem did not arise in this case, since this section was of high biostratigraphic interest and therefore continuously cored.) The section from Cores 19 through 30 cut at a slightly faster rate; the downhole

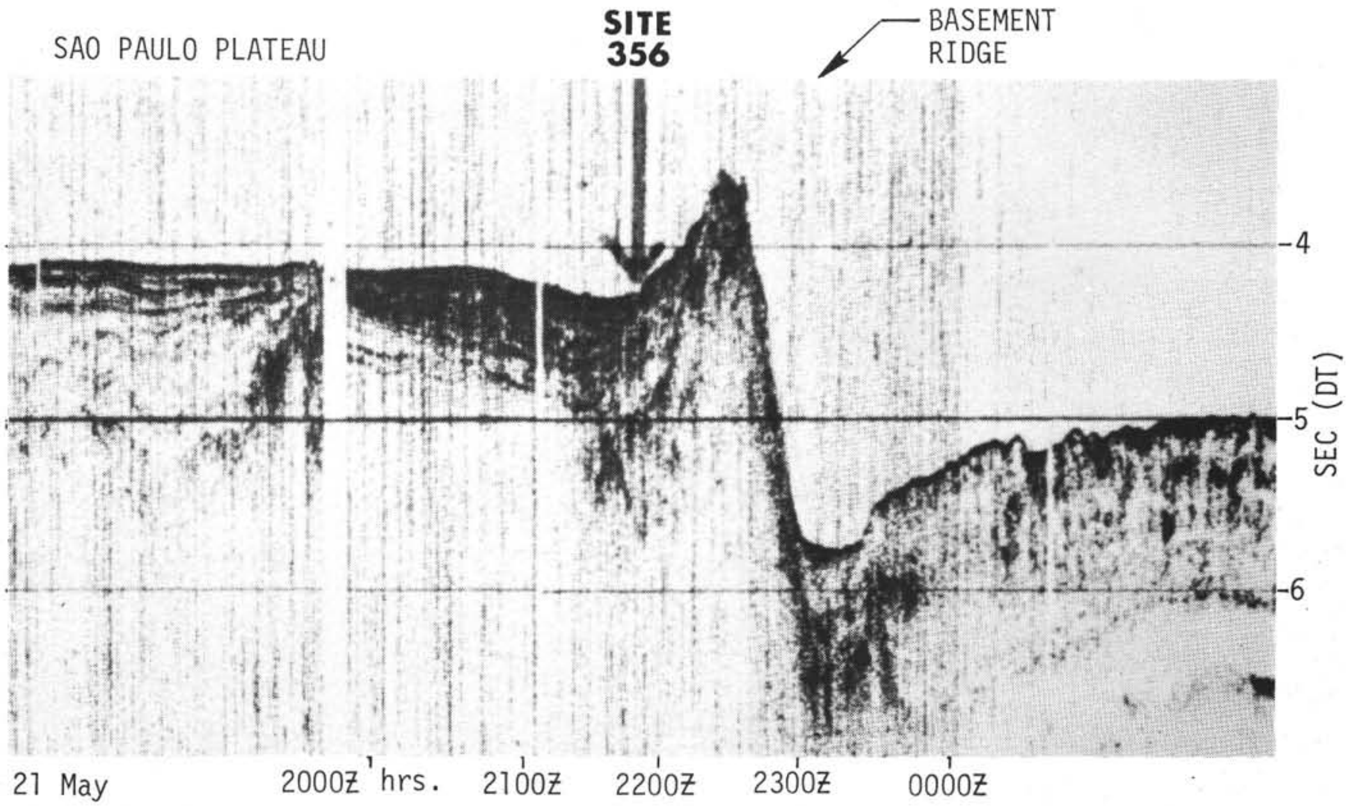

Figure 3. *Lamont-Doherty Geological Observatory seismic profile number 1514 (Cruise RC 16-10) shot on a heading of 153° across the location of Site 356 and the basement ridge marking the southern edge of the São Paulo Plateau.*

TABLE 1
Coring Summary, Site 356

Core	Depth Below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Recovery (m)
Hole 356				
1	0.0-9.5	9.5	Tr	0
2	9.5-19.0	9.5	9.5	100
3	38.0-47.5	9.5	9.5	100
4	57.0-66.5	9.5	9.4	99
5	85.5-95.0	9.5	9.5	100
6	114.0-123.5	9.5	8.8	93
7	133.0-142.5	9.5	9.5	100
8	161.5-171.0	9.5	2.6	27
9	190.0-199.5	9.5	2.5	26
10	218.5-228.0	9.5	5.2	55
11	237.5-247.0	9.5	4.7	50
12	247.0-256.5	9.5	3.2	34
13	256.5-266.0	9.5	1.8	19
14	266.0-275.5	9.5	1.6	17
15	275.5-285.0	9.5	4.5	47
16	285.0-294.5	9.5	2.1	22
17	294.5-304.0	9.5	9.5	100
18	304.0-313.5	9.5	8.6	91
19	313.5-323.0	9.5	8.3	87
20	323.0-332.5	9.5	4.6	48
21	332.5-342.0	9.5	5.2	55
22	342.0-351.5	9.5	8.3	87
23	351.5-361.0	9.5	8.4	88
24	361.0-370.7	9.5	9.5	100
25	370.5-380.0	9.5	6.3	66
26	380.0-389.5	9.5	9.5	100
27	389.5-399.0	9.5	9.3	98
28	399.0-408.5	9.5	8.8	93

TABLE 1 – *Continued*

Core	Depth Below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Recovery (m)
29	408.5-418.0	9.5	9.2	97
30	418.0-427.5	9.5	9.2	97
31	437.0-446.5	9.5	9.5	100
32	456.0-465.5	9.5	8.1	85
33	484.5-494.0	9.5	9.5	100
34	513.0-522.5	9.5	9.5	100
35	541.5-551.0	9.5	9.5	100
36	570.0-579.5	9.5	6.0	63
37	598.5-608.0	9.5	9.5	100
38	646.0-655.5	9.5	4.2	44
39	674.5-684.0	9.5	8.2	86
40	693.5-703.0	9.5	9.5	100
41	703.0-712.5	9.5	6.5	68
42	712.5-722.0	9.5	9.0	95
43	722.0-731.5	9.5	9.5	100
44	731.5-741.0	9.5	8.3	87
Total		418.0	315.9	76
Hole 356A				
1	19.0-28.5	9.5	9.5	100
2	28.5-38.0	9.5	8.1	85
Total		19.0	17.6	93

slowing within the Core 19 to 30 interval (Figure 6) was probably a consequence of greater compaction and a higher state of diagenesis of the chalks down the section. Between Cores 30 and 38, drilling and coring were slower, probably because of the high clay content

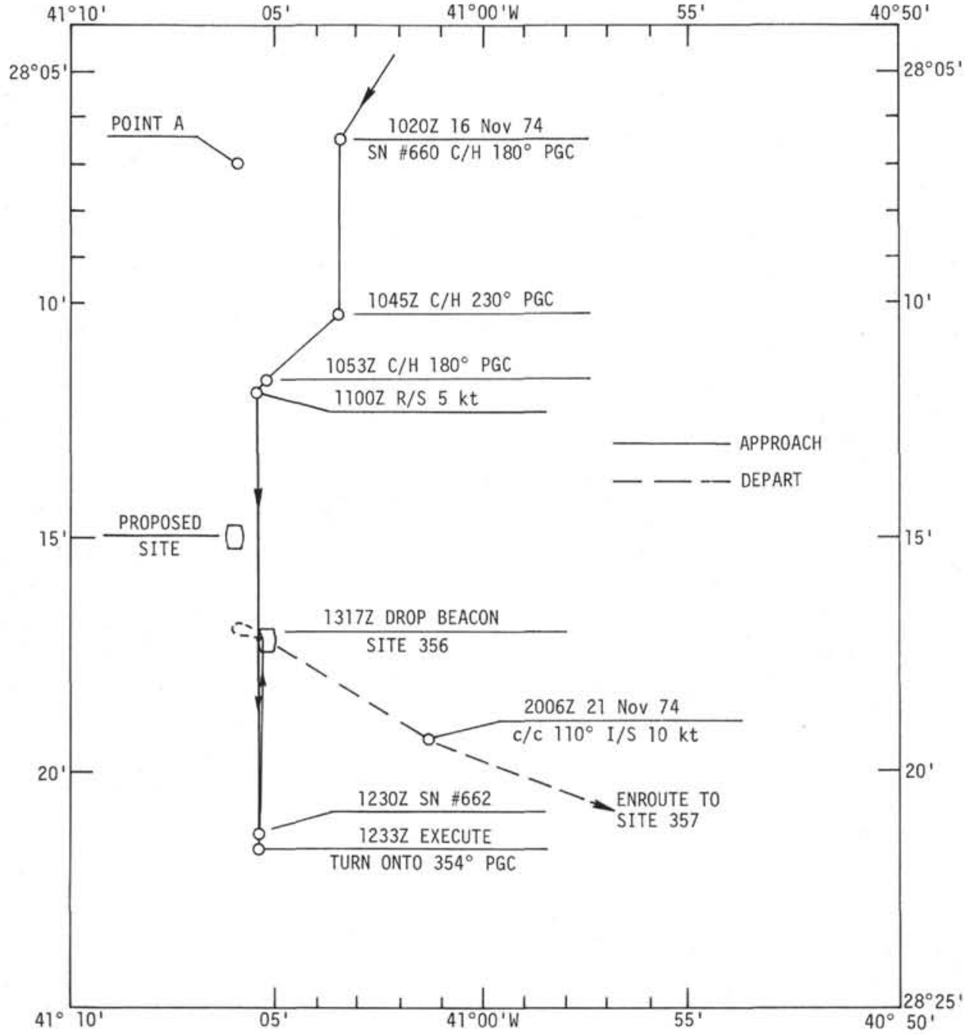

Figure 4. Glomar Challenger *track in the vicinity of Site 356, São Paulo Plateau.*

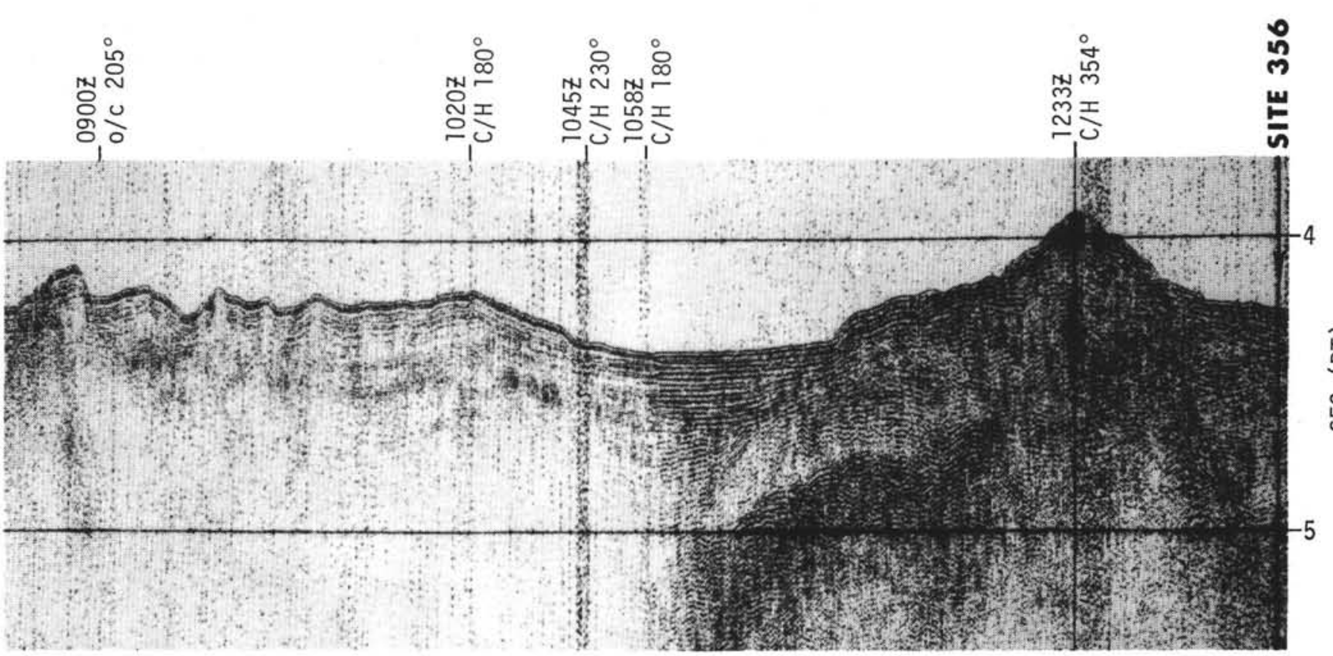

Figure 5. Glomar Challenger *seismic reflection profile shot on approach to Site 356.*

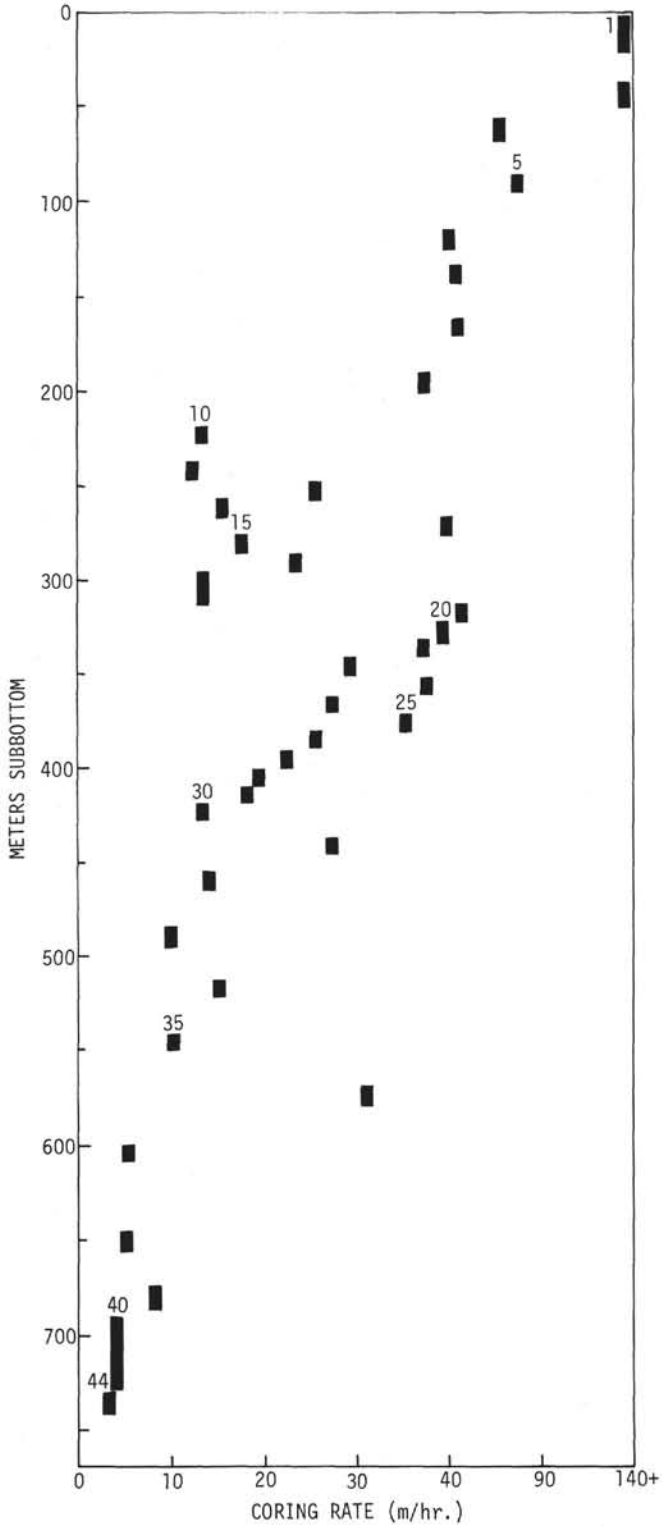

Figure 6. *Coring rates, Site 356. Every fifth core is designated by number.*

in this marly chalk sequence. The tungsten carbide inset center bit was dropped to drill the interval between 608 and 646 meters subbottom, at a rate of about one joint per hour.

The limestone section below Core 38 cored very slowly; it took up to three hours to cut a single core. This rate (3 m/hr) is of the same order as that required to core basalt, and presents a real problem in penetrating such a limestone section when time is a constraining factor.

Basement at 0.75 sec on the approach (Figure 4) and departure records correlates with the top of the limestone, but there is some faint indication of layering for an additional 0.25 sec, which, assuming a velocity of 2.4 km/sec, could be an additional 300 meters of sedimentary rock above the igneous basement of the ridge. At a rate of three hours per core, an additional four days would have been needed to core to basement. Accordingly, we decided to abandon the site after cutting Core 44.

The pipe was tripped to slightly above the mud line and a second hole was spudded at 0650 hr, 21 November 74, in order to sample the uncored interval between 19 and 38 meters subbottom, which should contain a hiatus or very slow rate of deposition. Core 1A was cut and retrieved, Core 2A was cut and tripped to the surface with the drill pipe. Examination of Core 1A showed it to correlate almost exactly with Core 3, indicating we were about 18 meters too low in section. There are two possible explanations for the depth discrepancy: We may have spudded Hole 356A at a point some 18 meters shallower, or the drill pipe count may have been in error by two joints. The second explanation is the more probable, since the ship had not been offset to spud Hole 356A, and color changes and an ash layer in Cores 3 and 1A correlate so closely. By the time the situation was discovered, the pipe had been tripped almost to the surface. The Chief Scientists awarded themselves the Royal Order of Albatross and hindsight wins again!

Glomar Challenger got underway at 1850Z, 21 November 74, on course 290°; streamed gear, and executed a Williamson turn to pass over the beacon on course 120° at 6 knots. We crossed the beacon at 1935Z, and at 2006 altered course to 110° and increased speed to 10 knots, enroute to Site 357.

LITHOLOGY

Site 356 was drilled at the southeastern edge of São Paulo Plateau on the Brazilian continental margin. The total penetration was 741 meters and the oldest sediments drilled were of late Albian age. Crystalline basement was not reached. The sequence consists of calcareous, calcareous hemipelagic, pelagic siliceous-calcareous, and terrigenous sediments. The sequence has been divided into the seven units described below. Table 2 and Figure 7 summarize the lithology and stratigraphy of the sedimentary section drilled at Site 356.

Unit 1

Unit 1 starts with Core 1 and ends in Core 5, Section 5. It is composed primarily of calcareous oozes. A 1.5 meter layer of siliceous nannofossil ooze occurs within the unit, and the bottom of the unit is marly in composition. Colors range from grayish orange to greenish gray to pinkish gray. Texturally the unit is composed of 55% clay-, 25% silt-, and 20% sand-sized

TABLE 2
Lithologic Summary, Site 356

Unit	Cores	Depth Below Sea Floor (m)	Thickness (m)	Age	Description
1	1 to 5(5)	0-93	93	Pleistocene-early Miocene	Calcareous oozes
2	5(5) to 10(4)	93-222	129	Middle Eocene-early Eocene	Calcareous-siliceous and siliceous-calcareous oozes
3	10(4) to 16	222-294.5	72.5	Early Eocene	Silicified calcareous chalks
4	17 to 30	294.5-432	137.5	Late Paleocene-Maestrichtian	Nanno and nanno-foram chalks
5	31 to 38	432-665	233	Maestrichtian-Santonian	Marly calcareous chalks
6	39 to 41(4)	665-708	43	Coniacian-Mid Turonian	Dark gray mudstones and clay-pebble conglomerates
7	41(4) to 44	708-?	3-?	Late Albian	Marly dolomitic and calcareous mudstones

material, and contains 40% nannofossils, 15% foraminifers, and 10% authigenic carbonate. The remaining 35% consists of clay minerals, pyrite, glauconite, quartz, feldspar, and zeolite. Volcanic glass is present as a discrete ash layer and disseminated in the surrounding sediment.

The 3-cm-thick lower Miocene rhyolitic vitric ash present in Section 4-5 is the only distinct volcanic ash bed observed at this site. Chemical analysis is given in Table 3. Volcanic components are predominantly glass shards (99%-100%); crystal components (mica) are rare (1%); lithic fragments are absent. Three types of shards are present: clear plates, elongated striated fragments, and shards with bubble-wall textures. The majority are colorless and unaltered; about 10% indicate devitrification. Many of the clear plates have a very fine scalloped surface, suggesting a small-scale bubble-wall texture. Elongated striated shard types contain pipestem vesicles filled with carbonates and clays.

The ash deposit is graded; sand to silt ratios, based upon point counts of smear slides (Figure 8), vary from 1.4 (base) to 1.0 (middle) to 0.8 (top). Glass shard morphological types reflect this size grading: clear plates form larger sand-sized fragments, striated forms occur in both sand and silt sizes, and bubble-wall shard fragments occur predominantly in the silt sizes. This graded texture, and its relationship to shard types, as well as the coarseness and angularity of shard particles, all indicate an air-fall deposit with a minimum of disturbance by oceanic currents or by benthic organisms.

In its upper part, Unit 1 also contains slumped zeolitic foraminifer-nannofossil ooze of late Eocene age. The slumped material also includes small pieces of manganese crust.

TABLE 3
Chemical Analysis of Volcanic Ash[a], Sample 4-5, 58 cm

SiO_2	72.8
TiO_2	0.18
Al_2O_3	11.9
FeO	1.1
MnO	0.02
MgO	0.06
CaO	0.70
Na_2O	3.2
K_2O	3.8
P_2O_5	0.03
	93.79[b]

[a]R. Fodor, analyst; analysis by electron microprobe.

[b]6% H_2O suggested.

Unit 2

Unit 2 begins in Core 5, Section 5, and extends down to Core 10, Section 4. It is greenish gray to light greenish gray, and is composed primarily of calcareous-siliceous and siliceous-calcareous oozes. Occasionally the sediment has been compacted enough to be designated as a chalk instead of an ooze. The average textural composition of the unit is 55% clay, 25% silt, and 15% sand. The average composition for the entire unit is as follows: 25% nannofossils, 10%-15% foraminifers, 10% radiolarians, and 10% diatoms. Authigenic components make up 20%, and the remaining 20% consists of quartz and clay minerals. A few dark gray layers, composed of predominantly siliceous biogenic material, are present.

The unit is quite mottled, and a few distinct burrows are evident. Bedding is seldom apparent. This unit is distinguished from Unit 1 on the basis of its color and the presence of siliceous biogenic components.

Unit 3

Unit 3 begins in Core 10, Section 4, and extends down to Core 16. It is composed primarily of silicified chalks, but occasionally contains siliceous-nannofossil oozes, zeolitic chalks, and nannofossil oozes as well. The chalks are well indurated; some of them could almost be termed limestones. One 3-meter layer of marly chalk is present. The unit is light greenish-gray, and sometimes medium bluish gray. It contains 45% clay-, 30% silt-, and 25% sand-sized material, and is

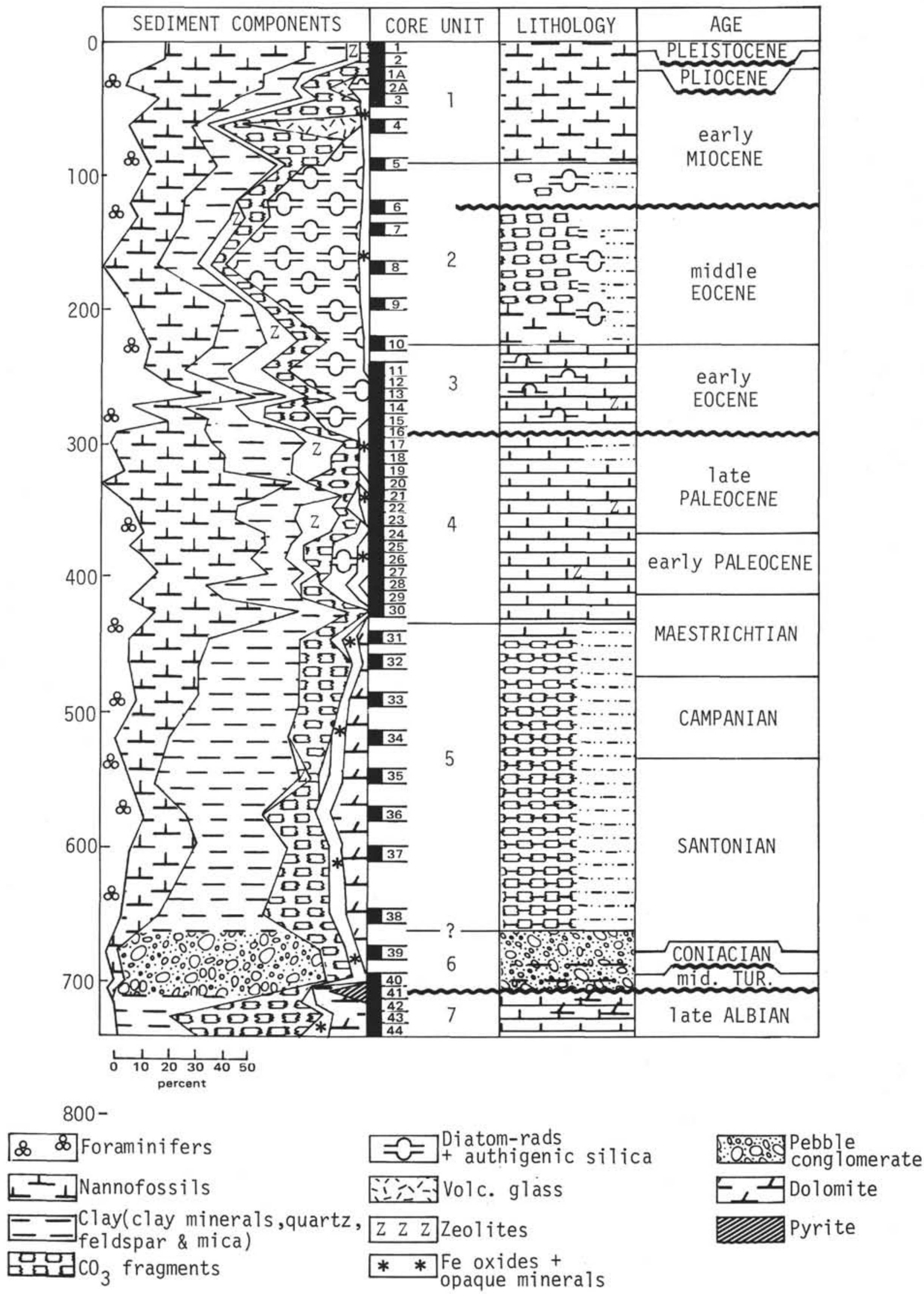

Figure 7. *Lithologic summary, Site 356.*

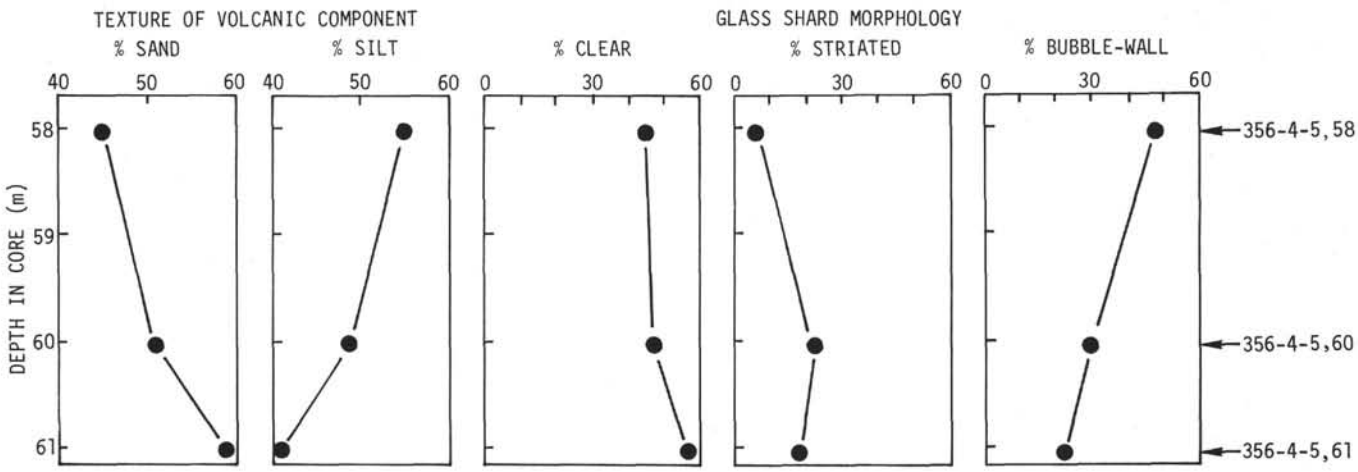

Figure 8. *Textural and compositional variations in a volcanic ash layer (Sample 356-4-5, 58-61 cm).*

composed of 10% nannofossils and 10%-15% foraminifers. Authigenic silica (cement for the sediment particles) makes up 15%-20% of the unit and authigenic carbonate 10%-15%. The remaining 30% comprises zeolites and clays, micronodules, and dolomite rhombs.

Unit 3 is basically a well-indurated cemented version of Unit 2. In fact, the main distinction between Units 3 and 2 is the induration of Unit 3, which contains alternating bands of chalks (from 10 cm to 1 m thick) and oozes (up to 1 m thick). Light bluish gray and light greenish gray beds alternate in the chalks. Occasional white streaks (1-2 mm thick) of dolomitic foraminiferal limestone are present within the chalks.

This unit is well bedded and moderately burrowed. Some burrows are moderate yellowish brown with a dark rim, others are dark gray. Burrows reach a maximum width of 1 cm in this unit.

Unit 4

This unit extends from Core 17 to Core 30. Unit 4 is distinguished from the overlying Unit 3 by a lack of siliceous material, and is composed of nannofossil and nannofossil-foraminifer chalks. Sometimes the composition grades to marly nannofossil chalk and zeolitic nannofossil chalk. The terrigenous component increases toward the base of the unit. Cores 28 and 29 contain several 10- to 40-cm-thick layers of ferruginous calcareous mudstone. Colors in this unit are very diverse, and range from greenish black, light bluish gray, pale yellowish brown to pinkish gray. Unit 4 is composed of 60% clay-, 25% silt-, and 15% sand-sized material, and contains 40% nannofossils and 10-15% foraminifers. Clay minerals form 10%-15% of the sediment and the authigenic carbonate 10%. The remaining 20% includes zeolite, opaque minerals, feldspars, and glauconite. The bedding in this unit is not readily apparent, except as color banding. Most burrows are parallel to the bedding, but some are at angles up to 90° with the bedding.

Slumped material occurs in the unit at several levels. Core 19 (upper Paleocene) contains a 20-cm thick bed of slump breccia (Sample 19-4, 130-150 cm). This breccia consists of greenish gray, angular to subrounded pebble-size chalk fragments. The age of the slumped material is early Maestrichtian to mid-Campanian.

Core 24 (Sections 3-6) and Core 25 (Section 1, 0-135 cm) (lower Paleocene) contain three beds of slump material, from 80 cm to 4 meters thick. This material is middle to early Maestrichtian in age and hence is slightly younger than the slumped breccia of Core 19. Slumped material of Cores 24 and 25 is marly siliceous chalk, dark yellowish brown to greenish gray. Soft-sediment deformation is apparent in one of the slump beds.

A 1.5-meter-thick bed of dolomitic calcareous chalk occurs in Core 28.

Unit 5

Unit 5 extends from Core 31 to Core 38. It is composed of marly calcareous chalks which are sometimes slightly dolomitic. The unit is distinguished from the overlying unit by its higher clay-mineral content. Texturally the sediment is 65% clay-, 20% silt-, and 10%-15% sand-sized material, and contains 20% nannofossils, 10% foraminifers, and as much as 25% clay minerals. Quartz makes up 10% of the sediment, feldspar 5%. The remaining 30% is mica, opaque minerals, and radiolarians. Color in this unit varies from light gray to dark greenish gray to pale red.

The unit is moderately indurated. Foraminifers have been recrystallized and appear as small soft white specks. The unit is well bedded; bedding is readily apparent because of bands of various shades of gray.

Inoceramus fragments are present from a depth of 50 meters in the unit to its bottom. Fragments are generally 2-5 mm wide and 2-5 cm long. A 2-cm-thick coarse layer of brown sand-sized grains composed of glauconite and iron oxides occurs in Section 35-1. Other dark bands of calcareous mud, usually about 1 cm thick, are also present within the unit.

A small, sub-rounded basalt pebble, about 3.5 cm long and 2 cm thick, was recovered from Section 38-3, along with pebble-sized fragments of dark mudstone. The basalt pebble is dark gray and contains phenocrysts of oxidized olivine, clinopyroxene, and plagioclase. Thin-section examination indicates that the basalt is highly altered. Groundmass consists of a mixture of plagioclase laths, altered Fe-Mg silicates, probably layer-lattice silicates such as chlorite or serpentine, and titaniferous magnetite (see Fodor et al., this volume).

Unit 6

This unit extends from Core 39 to Core 41, Section 4. It is composed of clay-pebble conglomerates and mudstones. The pebbles consist of calcareous mudstone, zeolitic siltstone, ferruginous mudstone, and basalt pebbles and cobbles. Fine-grained layers are silty claystone, calcareous mudstone, and dolomitic calcareous mudstone. Color in the unit varies from light gray to dark gray. Textural composition is 60% clay-, 25%-30% silt-, and 10%-15% clay-sized material. Only traces of foraminifers and nannofossils occur, but authigenic carbonate (recrystallized calcareous biogenic material) forms 10% of the sediment. Clay minerals make up 40%-45% of the sediment, quartz 20%, and feldspar 10%. The remaining 15% includes limonite, opaque minerals, mica, glauconite, pyrite, and heavy minerals.

This unit is well indurated and well bedded. Burrowing and graded bedding are common. The conglomerates occur as several discrete layers (30 cm to 2 m thick) in the top part of the unit, and grade upward into dark gray silty claystone. Each conglomerate-to-mudstone bed is separated from the next by a light gray calcareous mudstone bed. Because of intense alteration, the composition and nature of basalt pebbles in Core 39 cannot be determined. The lower part of the unit consists of alternate bands (30-50 cm thick), dark gray, medium gray, and greenish-gray, with sharp and gradational contacts. The dark gray bands of silty mudstone contain pyrite nodules and stringers ranging from 2 mm to 2 cm in size. The higher bands consist of calcareous mudstone or dolomitic calcareous mudstone. Organic carbon content is as high as 4.8% in Core 41 (Section 2).

Inoceramus fragments are infrequent. Thin calcite layers (approximately 1 cm thick) occur at the base of the unit.

Unit 6 is the most distinctive unit at Site 356. The conglomerates and dark claystones make it very easy to distinguish from units above and below.

Unit 7

Unit 7 begins in Core 41, Section 4, and continues at least to the bottom of the hole. The sediment is well indurated and light bluish-gray to medium dark gray, with occasional white and green bands. The unit is composed primarily of marly dolomitic limestones and has a textural composition of 45%-50% clay-, 35% silt-, and 15%-20% sand-sized components. It contains 50% authigenic carbonate (recrystallized calcareous biogenic material), 15% dolomite, 15% clay minerals, and 10% quartz. The remaining 10% includes feldspar, heavy minerals, opaque minerals, glauconite, and iron oxides.

The unit is very well bedded and shows graded beds, load casts, and burrows. Contacts between beds are fairly sharp. Beds are only 10-20 cm thick. The lighter beds are dolomitic limestone or marly dolomitic limestone, and the darker ones are calcareous mudstone. The white laminae, recrystallized carbonate, are sometimes only 2-5 cm apart, and range from 1 mm to 1 cm in thickness. A few coarse layers with graded bedding also occur. They contain glauconite, quartz, iron oxides, and recrystallized limestone grains. Unit 7 is distinguished from Unit 6 by its color, banding, and composition.

GEOCHEMISTRY

We measured *p*H, alkalinity, salinity, and Ca^{++}, and Mg^{++}, contents of twelve interstitial water samples onboard ship. Data are presented in Table 4 and Figure 9.

PHYSICAL PROPERTIES

The measured and computed physical properties at Site 356 correlate remarkably well with the lithology of the sequence. Three of six lithologic boundaries are represented by marked discontinuities superimposed on the compaction trend. A rather high degree of seismic anisotropy is also apparent. Only velocities measured in the vertical are recorded here. Corresponding horizontal values are discussed in a later chapter (Carlson and Christensen, this volume).

Measurements of acoustic velocity at Site 356 by the previously described delay line method proved an unqualified success. Standards were checked after every five or six sample measurements, often more frequently. For 51 standard measurements, the range of error was 0.04 to 0.95%, (average of 0.34%).

Physical properties data from Site 356 are summarized in Table 5 and Figure 10, according to the format described for Site 354. The uppermost unit consists of poorly consolidated oozes, characterized by low acoustic velocities which increase slowly with depth to a maximum of 1.63 to 1.64 km/sec. A shallow gradient also appears to occur in wet bulk density, though there is significant scatter in the density data. Water content shows a marked decrease within the ooze unit, beginning at about 125 meters. There is only a suggestion of increasing density in the same interval.

The silicified chalk unit (222 to 294.5 m) stands out dramatically. The acoustic velocities in this unit are widely scattered and high; they reach a maximum of more than 2.5 km/sec and the minimum is 1.75 km/sec. The average of 18 measurements for the unit is 2.07 km/sec. The highest velocities occur in the uppermost part of the chalk, as do markedly higher density values.

The lower limit of the silicified chalk is marked by a pronounced velocity inversion, which is also reflected in a slight increase in water content within the upper part of the underlying unit of nannofossil and nannofossil-foraminifer oozes. Within this unit, which extends to a depth of 432 meters, velocity, density, and water content show the strongest gradients in the section. The nannofossil-foraminifer ooze cannot be clearly distinguished from the underlying marly calcareous chalk. Though the velocities and densities in the chalk appear to be nearly constant, the previously

TABLE 4
Summary of Shipboard Geochemical Data, Site 356

Sample	Sample (Interval in cm)	Subdepth (m)	pH	Alkalinity (meq/l)	Salinity (°/oo)	Ca++ (mmoles/l)	Mg++ (mmoles/l)	Remarks
27	2-3, 144-150	14	7.38	2.54	34.9	11.22	53.10	
28	4-5, 144-150	64.5	7.28	2.96	34.9	15.59	48.77	
29	6-4, 144-150	120	7.27	3.36	34.6	20.50	44.64	
30	10-3, 144-150	223	7.39	1.93	34.4	26.91	41.41	
31	12-1, 142-150	248.5	7.24	2.36	34.4	31.23	36.42	
32	17-3, 142-150	299	7.36	2.30	34.1	39.72	28.74	
33	22-5, 144-150	349.5	7.29	0.60	34.6	37.58	31.17	
34	27-5, 144-150	397.0	7.12	1.54	34.4	43.09	26.58	
35	32-5, 132-150	464.5	7.80	0.26	35.2	47.21	21.48	
36	34-2, 144-150	516	7.75	–	34.9	55.41	16.25	
37	37-5, 140-150	606	–	–	36.0	65.34	11.19	Not enough H_2O for pH, Alk
38	38-2, 0-10	649	–	–	36.0	66.68	10.66	Not enough H_2O for pH, Alk

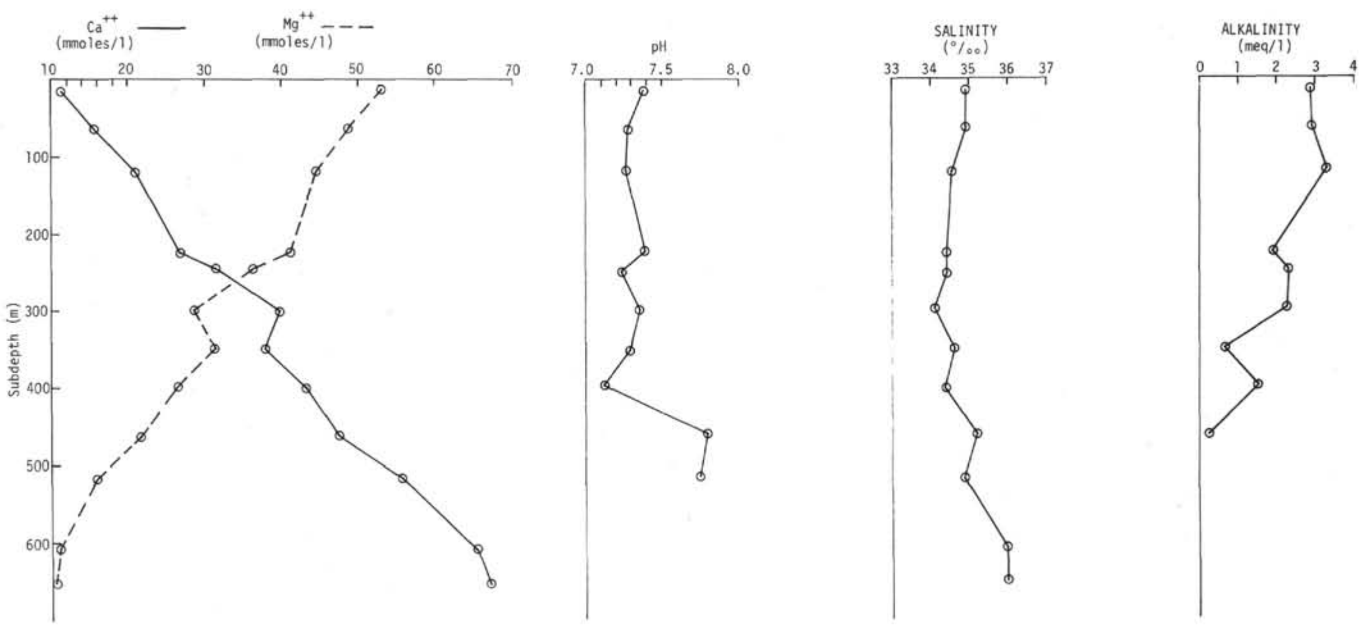

Figure 9. *Geochemical parameters (*pH*, salinity, alkalinity, Ca++, and Mg++ content) of interstitial waters versus depth, Site 356.*

discussed gradient extends to a depth of about 500 meters. The velocity and density maxima at this depth are followed by a modest inversion, extending to 600 meters, which is also evident in the water content data.

The lowermost mudstone units in the section are easily distinguished from the overlying chalks by their higher maximum velocities and densities and by much greater scatter in the data.

BIOSTRATIGRAPHIC SUMMARY

An extensive sequence of Cretaceous and Tertiary deposits was cored at this site. Calcareous fossils are abundant in most samples. Radiolarians and diatoms are abundant to common only in the lower Miocene and the middle Eocene, and occur in trace quantities in the lower Eocene and the Albian. The combined stratigraphic zonations, based on planktonic foraminifers, calcareous nannofossils, silicoflagellates, and radiolarians, are presented in Figure 11.

Most of the Neogene is missing at Site 356. The top cores contain Pleistocene mixed into Pliocene. A hiatus separates these sediments from a thick lower Miocene sequence. We were able to use both calcareous and siliceous fossils to zone the lower Miocene, which is complete at this site. A second hiatus occurs between the lowermost Miocene and the middle Eocene. Below the hiatus, poorly preserved calcareous faunas and floras of middle Eocene and early Eocene age are present. A third hiatus spans the lowermost Eocene and the upper Paleocene. Below this hiatus, however, we cored a thick and nearly complete sequence of Paleocene deposits, the highlight of which is a very thick and nearly complete Danian section (Cores 25-29, about 50 m thick). We recognized, together with large quantities of reworked upper Maestrichtian fossils, very abundant, well preserved, and diverse Danian calcareous faunas and floras. This is one of the best preserved and thickest Danian deposits retrieved so far from the deep sea. In addition, it contains the "oldest" Danian levels so far described.

We place the Cretaceous/Tertiary boundary at Sample 29-3, 33 cm. Below this level, no more Danian

TABLE 5
Physical Properties Data, Site 356

Sample (Interval in cm)	Depth (m)	Velocity (km/sec)	Density (g/cc) S	Density (g/cc) I	Density (g/cc) G	Wt %	Porosity (%) S	Porosity (%) I	Porosity (%) G	Acoustic Impedance S	Acoustic Impedance I	Acoustic Impedance G
3-1, 45	28.45	1.535	–	1.520	1.668	–	–	70.45	61.61	2.49	2.33	2.56
3-1, 45	38.48	–	1.623	–	–	40.88	64.30	–	–	–	–	–
3-2, 91	40.41	1.520	1.560	–	–	42.58	68.06	–	–	2.37	–	–
3-3, 130	42.30	1.539	1.591	–	–	42.07	66.21	–	–	2.45	–	–
3-4, 45	42.95	1.529	1.579	–	–	44.09	66.93	–	–	2.41	–	–
3-5, 102	45.02	1.543	1.564	–	–	43.79	67.82	–	–	2.41	–	–
3-6, 103	46.53	1.535	1.557	–	–	45.32	68.24	–	–	2.39	–	–
4-1, 80	57.80	1.543	–	–	–	–	–	–	–	–	–	–
4-2, 136	59.86	1.529	–	1.490	1.628	–	–	72.24	64.00	2.42	2.28	2.49
4-2, 155	60.06	–	1.581	–	–	44.82	66.81	–	–	–	–	–
4-3, 67	60.67	1.517	1.569	–	–	44.10	67.52	–	–	2.38	–	–
4-4, 100	62.50	1.517	1.583	–	–	44.84	66.69	–	–	2.40	–	–
4-5, 125	64.25	1.542	1.633	1.539	1.662	42.10	63.70	69.31	61.97	2.52	2.37	2.56
4-6, 83	65.33	1.523	1.533	–	–	44.43	69.67	–	–	2.33	–	–
5-1, 110	86.60	1.571	1.523	–	–	48.02	70.27	–	–	2.39	–	–
5-3, 88	89.38	1.568	–	1.463	1.628	45.59	–	73.85	64.00	–	2.29	2.55
5-4, 70	90.70	1.594	–	1.493	1.611	45.67	–	72.06	65.01	–	2.38	2.57
5-5, 62	92.12	1.598	1.606	–	–	42.41	65.31	–	–	2.57	–	–
5-6, 65	93.65	1.526	1.453	–	–	50.70	74.45	–	–	2.22	–	–
6-2, 65	116.15	1.553	1.542	–	–	44.58	69.13	–	–	2.39	–	–
6-3, 139	118.39	1.531	1.523	1.436	1.594	46.06	70.27	65.46	66.03	2.33	2.20	2.44
6-4, 90	119.40	1.532	1.572	1.462	1.563	46.07	67.34	73.91	67.88	2.41	2.24	2.39
6-5, 72	120.72	1.532	1.551	–	–	44.70	68.60	–	–	2.38	–	–
6-6, 125	122.75	1.549	1.617	–	–	41.37	64.66	–	–	2.50	–	–
7-1, 121	134.21	–	–	–	–	41.87	–	–	–	–	–	–
7-1, 135	134.35	1.545	–	–	–	–	–	–	–	–	–	–
7-2, 120	135.70	1.551	–	–	–	41.65	–	–	–	–	–	–
7-3, 82	136.82	1.558	1.570	1.523	1.678	40.58	67.46	70.27	61.01	2.45	2.37	2.61
7-4, 90	138.40	1.550	1.586	–	–	42.17	66.51	–	–	2.46	–	–
7-5, 61	139.61	1.550	1.608	–	–	40.22	65.19	–	–	2.49	–	–
7-6, 90	141.40	1.572	1.514	–	–	31.99	70.81	–	–	2.38	–	–
8-1, 145	162.95	1.628	1.681	1.644	–	33.72	60.84	63.04	–	2.74	2.58	–
8-2, 145	164.45	1.593	1.718	1.613	1.717	17.40	58.63	64.90	58.69	2.74	2.57	2.74
9-1, 148	191.48	1.639	–	1.550	1.631	–	–	68.66	63.82	–	2.54	2.67
9-2, 48	191.98	1.620	–	–	1.693	–	–	–	60.12	–	–	2.74
9-2, 38	191.88	1.614	–	–	–	–	–	–	–	–	–	–
10-2, 148	221.48	1.997	–	1.793	1.774	–	–	54.15	55.28	–	3.58	3.54
10-3, 2	221.52	2.136	–	1.819	1.845	–	–	52.60	51.04	–	3.89	3.94
10-4, 15	223.15	2.466	–	–	–	22.30	–	–	–	–	–	–
11-1, 44	237.94	2.240	–	1.815	1.826	20.66	–	52.84	52.18	–	4.07	4.09
11-1, 52	238.02	1.846	–	–	–	28.56	–	–	–	–	–	–
11-2, 73	239.73	2.536	–	2.106	1.848	28.66	–	35.46	50.87	–	5.34	4.69
11-3, 98	241.48	2.095	–	1.967	1.821	27.50	–	43.76	52.48	–	4.12	3.81
12-1, 3	247.03	1.811	–	2.067	1.777	27.50	–	37.79	55.10	–	3.74	3.22
12-2, 103	249.53	1.746	–	1.847	1.726	32.45	–	50.93	58.15	–	3.22	3.01
12-2, 3	249.03	1.909	–	–	–	–	–	–	–	–	–	–
13-1, 132	257.83	1.863	–	1.637	–	31.55	–	63.46	–	–	3.05	–
13-2, 38	258.38	1.846	–	1.650	1.737	31.84	–	62.69	57.49	–	3.05	3.21
14-1, 18	266.18	1.900	–	1.691	1.766	–	–	60.24	55.76	–	3.21	3.36
15-1, 75	276.25	2.346	–	–	1.812	–	–	–	53.01	–	–	4.25
15-2, 125	278.25	2.416	–	1.714	1.754	26.06	–	58.87	56.48	–	4.14	4.24
15-3, 96	279.46	2.272	–	1.695	1.756	–	–	60.00	56.36	–	3.85	3.99
16-1, 88	285.88	1.972	–	–	–	27.54	–	–	–	–	–	–
16-2, 127	287.77	1.912	–	1.758	1.823	27.98	–	56.24	52.36	–	3.36	3.49
17-1, 23	294.73	1.722	–	1.785	1.847	29.65	–	54.63	50.93	–	3.07	3.18
17-2, 130	297.30	1.765	–	1.782	1.824	31.48	–	54.81	52.30	–	3.15	3.22
17-4, 137	300.37	1.717	–	1.784	1.839	29.25	–	54.69	51.40	–	3.06	3.16
18-1, 143	305.43	1.698	–	1.785	1.896	30.37	–	54.63	48.00	–	3.03	3.22
18-2, 111	306.61	1.746	–	1.799	1.858	–	–	53.79	50.27	–	3.14	3.24
18-3, 55	307.55	–	–	1.789	1.866	–	–	54.39	49.79	–	–	–
18-4, 95	309.45	1.675	–	–	–	–	–	–	–	–	–	–
18-6, 52	312.02	1.712	–	1.801	1.818	31.49	–	53.67	52.66	–	3.08	3.11
19-1, 142	314.92	1.698	–	1.783	1.882	30.65	–	54.75	48.84	–	3.03	3.20
19-2, 142	316.42	1.701	–	1.795	1.865	28.70	–	54.03	49.85	–	3.05	3.17
19-3, 103	317.53	1.722	–	1.796	1.863	30.09	–	53.97	49.97	–	3.09	3.21
19-4, 41	318.41	1.737	–	–	–	–	–	–	–	–	–	–
19-5, 148	320.98	1.719	–	1.843	1.910	27.06	–	51.16	47.16	–	3.17	3.28
19-6, 96	321.96	1.715	–	–	–	–	–	–	–	–	–	–

TABLE 5 – *Continued*

Sample (Interval in cm)	Depth (m)	Velocity (km/sec)	Density (g/cc) S	I	G	Wt %	Porosity (%) S	I	G	Acoustic Impedance S	I	G
20-2, 96	325.46	1.700	–	1.809	1.840	27.96	–	53.19	51.34	–	3.08	3.13
21-1, 108	333.58	1.728	–	1.801	1.834	28.40	–	53.67	51.70	–	3.11	3.17
22-1, 127	343.27	1.705	–	1.809	1.883	28.16	–	53.19	48.78	–	3.08	3.21
22-2, 7	343.57	1.719	–	–	–	–	–	–	–	–	–	–
22-3, 51	345.51	1.706	–	–	1.879	27.62	–	–	49.01	–	–	3.21
23-1, 47	351.97	1.728	–	1.828	1.906	27.29	–	52.06	47.40	–	3.16	3.29
23-3, 118	354.98	1.774	–	–	–	25.49	–	–	–	–	–	–
23-2, 145	354.45	1.784	–	–	–	–	–	–	–	–	–	–
23-4, 144	357.44	1.740	–	1.876	1.930	24.27	–	49.19	45.97	–	3.26	3.36
24-1, 149	362.49	1.783	–	1.902	1.955	23.20	–	47.64	44.48	–	3.39	3.49
24-2, 148	363.98	1.817	–	–	–	–	–	–	–	–	–	–
24-3, 149	365.49	1.835	–	–	1.900	24.76	–	–	47.76	–	–	3.49
24-5, 149	368.49	1.883	–	1.871	1.961	22.83	–	49.49	44.12	–	3.52	3.69
25-1, 147	371.97	1.871	–	–	–	–	–	–	–	–	–	–
25-2, 103	373.03	1.703	–	1.871	2.099	21.82	–	49.49	35.88	–	3.19	3.57
25-3, 107	374.57	1.845	–	–	–	–	–	–	–	–	–	–
25-4, 108	376.08	1.839	–	–	1.717	23.74	–	–	58.69	–	–	3.16
26-1, 58	380.58	1.936	–	1.956	2.029	22.63	–	44.42	40.06	–	3.79	3.93
26-3, 12	383.12	1.804	–	1.893	1.919	24.27	–	48.18	44.63	–	3.41	3.46
26-6, 36	387.86	1.785	–	–	1.961	–	–	–	44.12	–	–	3.50
27-1, 4	389.54	1.858	–	1.905	2.003	22.55	–	47.46	41.61	–	3.54	3.72
27-5, 45	395.95	1.925	–	–	–	–	–	–	–	–	–	–
28-1, 133	400.33	1.813	–	2.080	2.008	22.92	–	37.01	41.31	–	3.77	3.64
28-3, 87	402.87	1.866	–	1.921	1.985	23.44	–	46.51	42.69	–	3.58	3.70
28-6, 107	407.57	1.995	–	–	–	–	–	–	–	–	–	–
29-2, 148	411.48	1.798	–	1.808	1.890	27.45	–	53.25	48.36	–	3.25	3.40
29-3, 148	412.98	1.944	–	2.051	2.111	18.16	–	38.75	35.16	–	3.99	4.10
29-4, 63	413.63	1.950	–	–	–	–	–	–	–	–	–	–
29-6, 107	417.07	1.939	–	–	–	–	–	–	–	–	–	–
30-6, 3	425.53	1.861	–	1.989	2.130	19.01	–	42.45	34.03	–	3.70	3.96
31-2, 24	438.74	1.910	–	–	–	–	–	–	–	–	–	–
31-6, 15	444.65	1.886	–	2.062	2.135	19.59	–	38.09	33.73	–	3.89	4.03
32-1, 117	457.17	1.968	–	2.125	2.168	16.01	–	34.33	31.76	–	4.18	4.27
32-3, 30	459.30	1.968	–	–	–	–	–	–	–	–	–	–
33-2, 132	487.32	2.036	–	2.163	2.237	15.18	–	32.06	27.64	–	4.40	4.55
34-1, 148	514.48	2.149	–	2.195	2.260	13.94	–	30.15	26.27	–	4.72	4.86
34-3, 148	517.48	2.099	–	2.153	–	14.32	–	32.66	–	–	4.52	–
34-6, 134	521.84	2.070	–	–	–	–	–	–	–	–	–	–
35-1, 140	542.90	2.104	–	2.172	2.210	14.09	–	31.52	29.25	–	4.57	4.65
35-3, 29	544.79	–	–	–	–	–	–	–	–	–	–	–
35-6, 73	549.73	2.035	–	2.094	2.158	16.26	–	36.18	32.36	–	4.26	4.39
36-1, 18	570.18	2.073	–	2.132	2.174	17.01	–	33.91	31.40	–	4.42	4.51
36-4, 40	574.90	2.077	–	–	–	–	–	–	–	–	–	–
37-2, 146	601.46	2.242	–	2.138	1.921	–	–	33.55	46.51	–	4.79	4.31
37-3, 149	602.99	2.345	–	–	–	–	–	–	–	–	–	–
37-5, 58	605.08	2.286	–	–	–	–	–	–	–	–	–	–
37-0, 0	608.00	2.340	–	2.194	2.044	–	–	30.21	39.16	–	5.13	4.78
38-1, 149	647.49	2.289	–	2.189	2.044	14.24	–	30.51	39.16	–	5.01	4.68
38-3, 8	649.08	2.340	–	–	–	–	–	–	–	–	–	–
39-2, 149	677.49	3.372	–	2.201	2.034	13.61	–	29.79	39.76	–	7.42	6.86
39-4, 142	680.42	2.288	–	2.184	2.021	13.83	–	30.81	40.54	–	5.00	4.62
39-6, 88	682.88	2.592	–	–	–	–	–	–	–	–	–	–
40-1, 65	694.15	2.463	–	2.224	2.015	13.83	–	28.42	40.90	–	5.48	4.96
40-3, 127	697.77	2.292	–	–	1.949	–	–	–	44.84	–	–	4.47
40-6, 84	701.84	–	2.263	2.050	–	–	12.06	38.81	–	5.19	4.70	–
40-6, 62	701.62	2.294	–	–	–	12.06	–	–	–	–	–	–
41-2, 48	704.98	2.221	–	20.96	1.932	17.62	–	36.06	45.85	–	4.66	4.29
41-4, 53	708.03	2.056	–	–	1.832	–	–	–	51.82	–	–	3.77
41-4, 119	708.69	2.845	–	2.406	2.198	9.40	–	17.55	29.97	–	6.85	6.25
41-5, 125	710.25	2.839	–	–	2.167	–	–	–	31.82	–	–	6.15
42-1, 105	713.55	2.861	–	2.343	2.209	8.08	–	21.31	29.31	–	6.70	6.32
42-3, 144	716.94	2.404	–	–	–	–	–	–	–	–	–	–
42-6, 147	721.47	3.952	–	2.896	2.239	–	–	–	27.52	–	8.44	8.85
43-1, 148	723.48	2.865	–	2.261	2.081	11.13	–	26.21	36.96	–	6.48	5.96
43-3, 2	725.02	2.799	–	–	2.087	–	–	–	36.60	–	–	5.84
43-5, 148	729.48	3.524	–	2.353	2.201	8.82	–	20.72	29.79	–	8.29	7.76
44-1, 146	732.96	–	–	–	2.189	–	–	–	30.51	–	–	–
44-3, 108	735.58	2.658	–	–	2.047	–	–	–	38.99	–	–	5.44

NOTE: S = syringe technique, I = immersion technique, G = GRAPE.

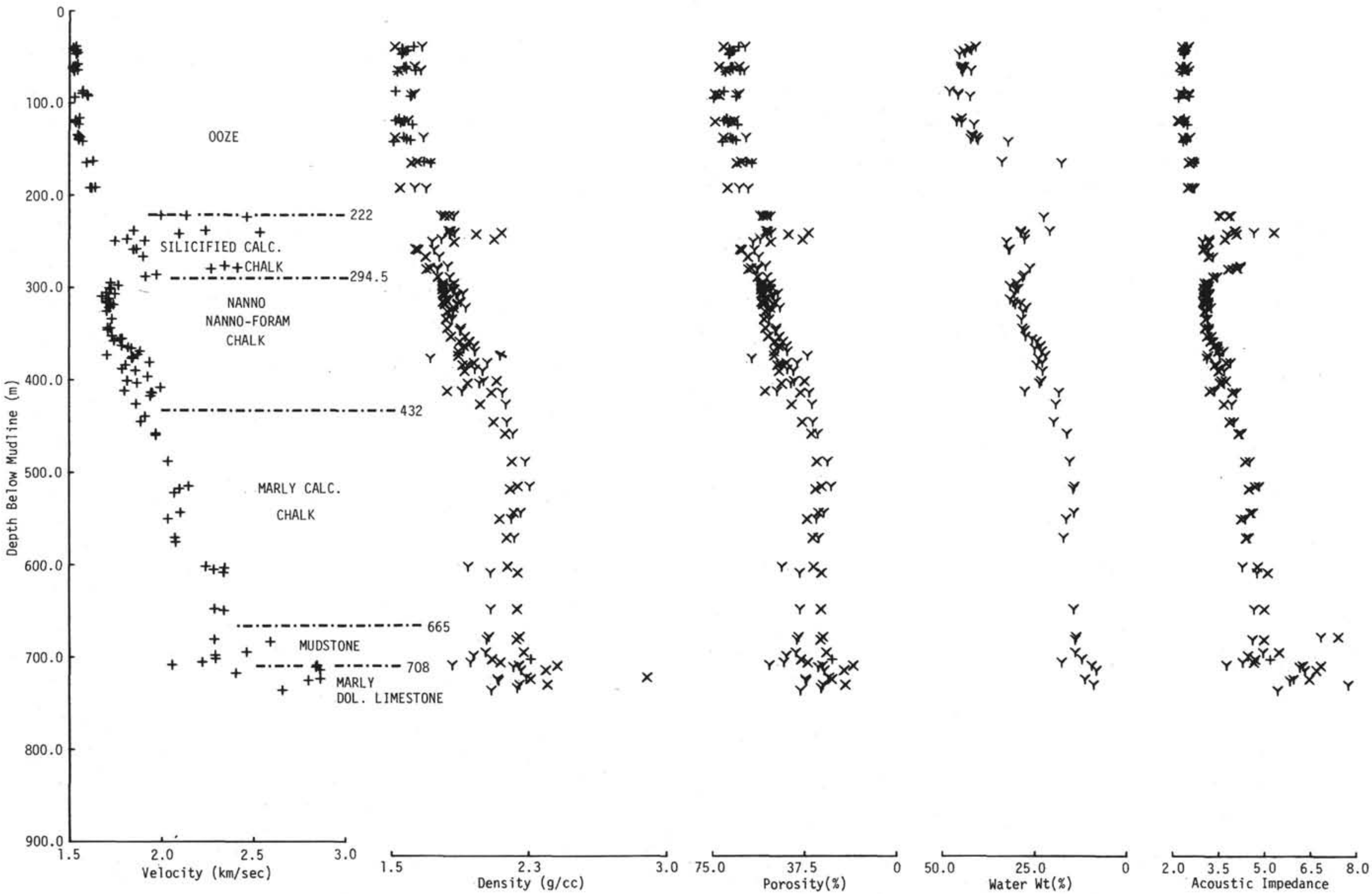

Figure 10. *Physical properties versus depth; +, x, and y, represent syringe, immersion, and GRAPE values, respectively.*

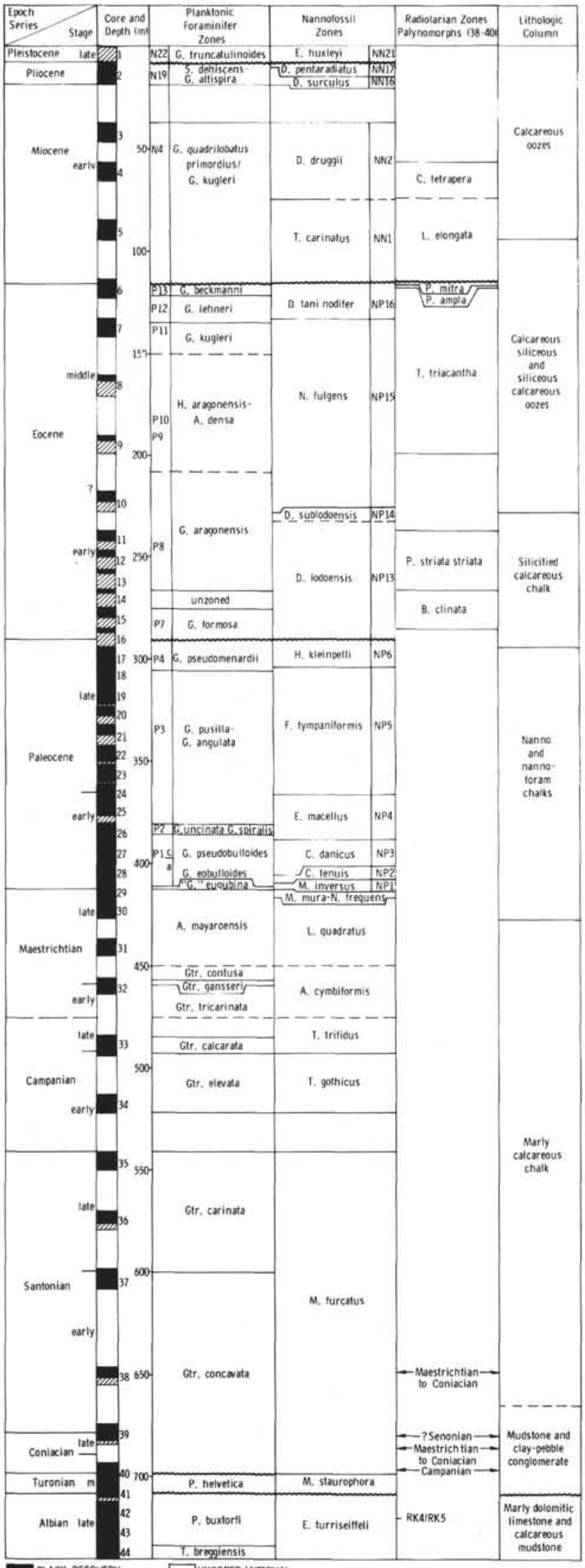

Figure 11. *Biostratigraphic summary, Site 356.*

fossils occur and the lithology changes markedly. Diverse upper Maestrichtian to Coniacian planktonic faunas and floras are present. Although we identified the complete sequence of zones, small sections of zones are apparently missing. Reworking is also common, particularly in the Campanian sediments. Dissolution has destroyed the foraminifer faunas of parts of the lower and upper Campanian section at this site.

The foraminifers in Core 41 indicate a middle Turonian age, whereas the calcareous nannofossils indicate a late Turonian age. The deposits between Core 39 and Section 41-4 represent part of an episode of sapropel formation at this site from the middle to late Turonian through the early Santonian. The sapropels are separated from the underlying indurated limestone by a sharp lithologic break. The entire Cenomanian and lower Turonian are apparently missing, since the limestone yielded a fauna and flora of late Albian age. This upper Albian limestone, which continues to the bottom of the hole, contains plentiful calcareous fossils (some of them presumably redeposited from a topographic high and/or by turbidites), as well as the only common radiolarians of Cretaceous age.

Paleoecology

Site 356 lies in the present climatic "temperate" zone and the latitudinal "subtropics." Sediment there, being thus situated, is apt to contain varying percentages of the so-called tropical and subtropical species. The presence and/or relative percentages of these climatic indicator species (or faunas) in the past can provide information regarding the paleoclimatology of this area, as well as the paleochemistry of water masses in this area and paleocirculation patterns.

Depth-restricted foraminifers, primarily the benthic species, and ostracodes and some species of coccoliths can further provide information on the depositional depths of this site and can signal the presence of reworked material.

Water Depth and Redeposition of Fossils

Throughout this sequence the benthic foraminifers indicate deposition of sediment at depths between about 1000 and 3000 meters. Depths closer to the deeper limit are indicated at the top of the sequence (Tertiary) and depths toward the shallower limit in the Cretaceous part of the sequence. The ostracodes, dating back to about 75 m.y.B.P., do not indicate any time wherein shallow faunas were present (Benson, this volume).

Calcareous nannofossils—the presence of *Z. bijugatus* and high diversity of nannofossil faunas—suggest a possible shallower origin, less than 1000 meters, for Eocene sediments. In the sediments of Late Cretaceous (late Campanian and Maestrichtian) age, the presence of *K. magnificus* indicates shallower conditions. The presence of littoral diatoms in the middle Eocene sediment supports the evidence of the calcareous nannofossils for relatively shallow accumulation conditions or transport from littoral areas into deeper depths (Fenner, this volume).

The in-situ benthic foraminifers corroborate a shallower water depth in the Cretaceous, but not in the early Tertiary. Since slumping and redeposition have mixed faunas from different depths, it may not be possible to resolve the inconsistencies between the foraminifers and the nannofossil and diatom data.

Paleotemperatures and Paleocirculation

Tertiary

Both tropical and subtropical components are present in most of the Tertiary faunas. However, evidence from the mid-Eocene foraminifers, coccoliths, and radiolarians indicates a significant change in water temperature and/or circulation.

The low discoaster/chiasmolithus ratio in both middle and lower Eocene faunas indicates cooler water (although see Perch-Nielsen, this volume). An incursion of cooler water species into the middle and lower Eocene radiolarian faunas confirms this indication.

A change below Sample 6, CC in the ratio of keeled globorotalids and acute-edged acaraninids to globigerinids and round-edged acaraninids indicates cooler waters in the mid-Eocene. All keeled globorotalids, except for an occasional *G. aragonensis*, disappear in the lower Eocene faunas at this site.

Studies of the biogeographic patterns of planktonic foraminifers in the subtropics depict similar faunal changes (Premoli-Silva and Haq, in preparation). Keeled globorotalids, except for *G. aragonensis*, disappeared in the early Eocene after the time of *G. formosa* at middle latitudes. This disappearance has been correlated with the first buildup of Antarctic land ice (Kennett, 1974, unpublished) and with the contemporaneous cooling of deep waters in the Southern Hemisphere (Shackleton and Kennett, 1974).

The middle Eocene was a time of generally carbonate-poor facies in the Atlantic (Premoli-Silva and Haq, in preparation), as well as of increased latitudinal differentiation of planktonic foraminifer and nannofossil assemblages.

The two main hiatuses in the Tertiary cover the time from late middle Eocene through Oligocene and late early Miocene through Pliocene. It may be no coincidence that these were also the coldest periods of the Tertiary, as indicated by high-latitude paleotemperature curves by Shackleton and Kennett (1974) and Boersma and Shackleton (this volume). A warming trend, i.e., warm relative to the Oligocene and later Miocene, characterized the early Miocene, and may be responsible for the presence of sediments of that age at this site.

There is one significant piece of evidence from the nannofossils which indicates restricted circulation or special conditions in this area in the earliest Danian. In Core 29-1, a *Thoracosphaera-Braarudosphaera* chalk occurs. Haq et al. (this volume) find that similar chalks are an oceanwide phenomenon in the lowermost Danian indicating oceanwide special conditions during that time, and because it indicates restricted environments in other parts of the world, it may have similar significance here. It is here taken as a local rather than oceanwide phenomenon.

Cretaceous

There is generally a stratigraphic hiatus at the Cretaceous/Tertiary boundary, reflecting the events which resulted in mass extinctions of faunas and floras at the end of the Maestrichtian. The completeness of the section at this site is contrary to the suggestion of Worsley (1974) that good Maestrichtian/Paleocene calcareous sections should be found only on the shelf, since the CCD in the open ocean had shallowed into the photic zone, precluding abundant deposition of carbonate at any great depth. Site 356, however, lay close to 1000 meters in the Late Cretaceous.

Foraminifers

Cores taken at this site on the São Paulo Plateau contain foraminifers ranging in age from Pleistocene to Early Cretaceous. At least one sample per section from all 44 cores was examined for foraminifers.

Plio/Pleistocene

Although only the core catcher from Core 1 contains slight amounts of sediment, a diverse tropical assemblage of planktonic foraminifers occurs; it includes *Globorotalia truncatulinoides*, *G. inflata*, *G. cultrata*, *G. tumida*, *G. flexuosa*, *Pulleniatina obliquiloculata*, and pink *Globigerinoides ruber*. This assemblage is well preserved, and many forms still have visible spines and spine bases. Benthic foraminifers are rare, but the genera *Lagena*, *Pyrgo*, *Laticarinina*, and hispid and hispido-costate *Uvigerina* can be recognized. Smooth and spiny ostracodes are also present.

The fauna is of Pleistocene age. The pink *G. ruber* indicate the late Pleistocene and *G. flexuosa*, which became extinct at 80,000 yr B.P., sets an upper age limit. The benthic foraminifers are bathyal.

Section 2-1 through Sample 2, CC contains Pleistocene fossils mixed in with the Pliocene species *Globorotalia miocenica*, *G. multicamerata*, *Globigerinoides obliquus*, and *Neogloboquadrina humerosa*. There is apparently extensive mixing throughout this core, but the age is considered to be Pliocene (N19), older than the extinction of *Sphaeroidinellopsis*, but younger than the extinction of *Globorotalia margaritae*.

Miocene

Cores 3-5 all contain sediments of early Miocene age.

The faunas in all three cores, very similar in their content, include *Globorotalia (Turborotalia) kugleri*, *Globoquadrina dehiscens*, *G. altispira*, *Catapsydrax* sp., and in Core 5, *Globigerinoides primordius*. There are few benthic forms in these samples; those present belong to the genera *Cassidulina*, *Stilostomella*, and *Laticarinina*. Occasional fish teeth and echinoid fragments are present, and radiolarians and diatoms are common in Cores 4 and 5.

These faunas all appear to belong in the lowermost Miocene (N4-N5). The lower portion of Core 5, however, has an "Oligocene character. " Recognition of passage from the Miocene into the uppermost

Oligocene is still difficult because definitive criteria are lacking.

Eocene

Eocene sediments were recovered in Cores 6-15. The sediments of middle Eocene age (Cores 6-10) vary from chalky, foraminifer-rich sediments to radiolarian and diatom-rich sediments which contain only a very small proportion of foraminifers. Those sediments composed predominantly of radiolarians characteristically contain more diverse assemblages of planktonic foraminifers and a greater percentage (relative to globigerinids) of keeled globorotalids. In the radiolarian-rich samples, however, benthic foraminifers are scarcer, if present at all.

Samples from Core 6 are rich in foraminifers, particularly *Truncorotaloides rohri*, *Globorotalia (Morozovella) lehneri*, *G. (M.) spinulosa*, *Acarinina densa*, *A. bullbroki*, *A. mckannai*, *Pseudohastigerina micra*, and *Hantkenina aragonensis*. Keeled globorotalids and acute-edged acaraninids are abundant; round-edged acaraninids and globigerinids are secondary in importance. *Chilogumbelina* and *Pseudohastigerina*, however, are also important components of the fauna. The preservation of this assemblage is good, and excellent in Section 6-2. Benthic foraminifers are very scarce.

Core 6 probably encompasses both the *Orbulinoides beckmanni* (P13) and *Globorotalia lehneri* (P12) zones.

Cores 7 through 10 contain less diverse faunas in which the globigerinids and round-edged acaraninids predominate. Faunas typically include *"Globigerinita" howei*, *Globigerina (Subbotina) trilocularis*, *Acarinina mckannai*, *A. wilcoxensis*, *Chilogumbelina wilcoxensis*, and primitive *Globigerinatheka*. The keeled *Globorotalia (Morozovella) aragonensis* first appears in Core 9.

The benthic species in all these cores are rare, but *Globocassidulina*, *Stilostomella* (= *Siphonodosaria*), and several lagenids occasionally occur, along with a few smooth ostracodes.

The faunas are often contaminated and sometimes lacking in zonal index fossils. However, this group of cores is called middle Eocene: Cores 6, P13-P12; Core 7, P11; Core 8, P10; Core 9, P9; and Core 10, P 8.

The planktonic foraminifers between Core 6, at the top, and Cores 7-10 also indicate a significant environmental change. Cooling is signaled by the decreased abundance of keeled globorotalids and acute-edged acaraninids below Core 6.

Lower Eocene faunas at this site are even more depleted than those of the middle Eocene. Cores 11 through 16, when a fauna is preserved and recognizable, contain poorly preserved specimens of *Acarinina wilcoxensis*, *A. mckannai*, *Globorotalia (J.) broedermanni*, *Globigerina (S). trilocularis*, and *Globorotalia (M.) aragonensis*. Benthic foraminifers are rare.

Since many of the age-diagnostic species are absent, Cores 11-14 are tentatively assigned to the lower Eocene, P8, and Cores 15 and 16 to P7, on the basis of right-coiled *G. (M.) aragonensis* (Premoli-Silva, in preparation).

Paleocene

A striking Paleocene sequence, including an excellently preserved and complete Danian section, occurs from Sample 16, CC through Sample 29-3, 33 cm. This section, further, includes some of the oldest Tertiary samples from the *"Globigerina" eugubina* Zone yet recorded.

Zones P4 through P2 can be recognized from Core 17 through Section 26-3. The age-diagnostic species *Globorotalia (Planorotalites) pseudomenardii*, *G. (P.) pusilla*, *G. (M.) angulata*, and *G. (M.) uncinata* are all present in this series of cores. Many of these faunas are poorly preserved and contain admixed Cretaceous fossils.

The Danian (P1) occurs in Sections 26-5 through 29-3. Only P1b appears to be absent. The *"Globigerina" eugubina* Zone, however, is well represented in several samples, and the oldest part of this zone so far recorded is found in Core 29 at the lithologic break marking the Cretaceous/Tertiary boundary. The *G. eugubina* fauna contains, besides *G. eugubina* and *G. fringa*, the probable precursor of *Globoconusa daubjergensis*. Within the Danian there are also admixed very well preserved planktonic foraminifers of latest Cretaceous age. Preservation of most of this Danian sequence is remarkably good.

Benthic foraminifers are common in the Paleocene samples. Most species are bathyal, although there is a large component of admixed Cretaceous benthic species from slightly shallower depths.

Cretaceous

An extensive and fairly well preserved sequence of Cretaceous deposits, including fossils of Maestrichtian through Coniacian, Turonian, and late Albian ages, was recovered in Cores 29 through 44. The biostratigraphic zonation of Premoli-Silva and Bolli (1973) was used to zone this sequence.

The presence in Cores 29 through 31 of *Abathomphalus mayaroensis*, along with *Globotruncana contusa*, *G. ventricosa*, *Rugoglobigerina rugosa*, and *Racemiguembelina fructicosa* places these cores in the upper Maestrichtian *A. mayaroensis* Zone. Preservation is poorer in the top two cores, but the faunas are more diverse and better preserved in Core 31. The biserial planktonic species also become more numerous and more diverse in Core 31.

Benthic species appear mixed, apparently because of downslope redeposition. Important forms include *Hyperamina* and the nodosarids.

The top section of Core 32 belongs to the *Globotruncana contusa* Zone, but lower sections contain assemblages dominated by *G. tricarinata*, *G. falsostuarti*, *G. gagnebini*, *G. havenensis*, *G. plummerae*, and abundant rugotruncanids. Some anomalous benthic forms from this core are discussed below. The Maestrichtian faunas appear tropical and open marine, and seem to have been deposited at bathyal depths. The lower sections of Core 32 are assigned to the *G. tricarinata* Zone, of early Maestrichtian age.

Cores 33 and 34 contain unusual benthic faunas which include many large agglutinated forms (see

Sliter, this volume). Among the planktonic species are *Globotruncana calcarata*, *G. elevata*, *G. leupoldi*, *Heterohelix pulchra*, and *Pseudotextularia elegans*. In Core 34, the first specimens of *Rugoglobigerina rugosa* appear. The preservation of these fossils is fair; many are broken or are recrystallizing.

The large agglutinated forms are considered redeposited; the supposed in-situ benthonic forms include a *Gavelinella-Gyroidinoides* fauna with *Pullenia*, *Osangularia*, *Aragonia*, and fewer nodosarids than in younger samples.

Cores 33 and 34 apparently span the Campanian *G. calcarata* and *G. elevata* zones.

Cores 35 through 39 and the top of 40 contain similar faunas, including *G. fornicata*, *G. carinata*, *G. coronata*, *G. linneianna*, and in the lower cores, *G. concavata*. Among the smaller fauna, *Clavihedbergella simplex*, *Heterohelix reussi*, *Rugoglobigerina pilula*, and *Shackoina* spp. are present.

The benthic faunas in this sequence of cores have an austral character, and there has been much redeposition of material, presumably down the slope. The *Gyroidinoides-Gavelinella* fauna predominates, along with *Tritaxia*, *Pleurostomella*, *Ramulina*, and *Hyperamina*. The faunas are thought to characterize the bathyal zone.

The faunas span the Santonian and the top of the Coniacian; both the *G. carinata* and the *G. concavata* zones are well represented.

An unusual sequence of lithologies occurs in Cores 39 through 41 (Section 4). The sediments were apparently deposited in conditions ranging from totally reducing to totally open marine.

Foraminifers occur at various, though not all, levels, and the faunas vary from planktonic ooze to a highly dissolved and depauperate benthic fauna to an *Ammodiscus* and a few fragments. The relationship between the types of faunas and the chemical and other properties of the sediments is being investigated. At one level in Core 40, however, an ooze intercalated into the reducing layers contains a recognizable Turonian fauna that includes the zonal marker *Globotruncana helvetica*.

Core 41 is replete with black layers rich in pyrite, and these layers yielded no foraminiferal residue. Section 41-4, however, contains light gray limestone, at the bottom, which is rich in planktonic foraminifers. Although the limestone is badly preserved and highly altered by diagenesis, it is possible to distinguish in it *Planomalina buxtorfi*, *Hedbergella amabilis*, *H. delrioensis*, and *Heterohelix globulosa*. No rotaliporids are present. This same assemblage persists from Core 41 through Section 44-4; all of these cores have been assigned to the upper Albian *P. buxtorfi* Zone. The lack of rotaliporids, rather than a depth of dissolution indicator, signals the austral character of this fauna. The cores also contain abundant evidence of turbidites, but the supposed in-situ benthic fauna still contains *Gavelinella*, deep pleurostomellids, and other bathyal taxa, suggesting a water depth close to 1000 meters.

The bottom of Core 44 yielded a foraminiferal fauna dominated by *Hedbergella* and small *Heterohelicidae*. *Ticinella* is rare and limited to a few "primitive" species. The presence of *T. breggiensis* allows us to recognize the *T. breggiensis* Zone at the bottom of this hole.

Calcareous Nannofossils

All 44 cores recovered at this site contain calcareous nannofossils. With a few exceptions, preservation of the nannofossils is moderate to good in the Cenozoic, deteriorates in the Upper Cretaceous samples, and becomes poor in the upper Albian limestones in which the hole bottomed.

The distribution of coccolith zones is summarized in Figure 11, and the distribution of species is shown in a chapter by Perch-Nielsen (this volume).

Pleistocene

The only sample from Core 1, Sample 1, CC, contains a subtropical assemblage of the *E. huxleyi* Zone and sparse reworked Pliocene forms.

Pliocene

Subtropical assemblages of the *Discoaster pentaradiatus* and *D. surculus* zones occur in Core 2. The presence of scarce to a few *Reticulofenestra pseudoumbilica* in all samples of Core 2 could indicate that this core belongs to the *R. pseudoumbilica* Zone. They are, however, here considered to be reworked. Slumps of lower Eocene (NP 13) zeolitic ooze occur in Sections 2-1 and 2-2.

Miocene

The lower Miocene assemblages found in Cores 3 through 6 (Section 1) all lack age-diagnostic sphenoliths, but include *Discoaster druggi*, *Triquetrorhabdulus milowi*, and, from Core 5 downward, extremely well-preserved *T. carinatus*, up to 60 μm long; a new *Triquetrorhabdulus* similar to *T. striatus*, *T. challengeri*, also occurs. These assemblages would indicate the *D. druggi* Zone (NN2), if it were not for the more than sporadic occurrence in most samples of *Reticulofenestra abisecta*. This species usually terminates below NN2. Discoasters, common in all Miocene samples, indicate a subtropical climate at this site in early Miocene time.

A hiatus in Core 6, Section 1, includes the very lowermost part of the lower Miocene, the whole Oligocene, and the upper Eocene part of the sequence.

Eocene

The mid-Eocene assemblages in Cores 6 through 10 and the lower Eocene assemblages in Cores 11 through 16 (Section 1) all contain few to common *Zygrhablithus bijugatus*. This species is usually found preserved only in samples from shelf areas or depths to about 1000 (?) meters, below which it dissolves (Edwards, personal communication). Another indication of shallow water conditions during the mid-Eocene is the high diversity of the assemblage and the presence of few to common Pontosphaeraceae. Relatively cool climatic conditions during the mid-Eocene are indicated by the estimated discoaster/chiasmolith ratio, which is very low here.

On the same line of evidence, a warmer climate is indicated during the early Eocene (but see discussion in Perch-Nielsen, this volume). In the lower Eocene samples, diversity of the coccolith assemblage drops, as does the state of preservation.

A hiatus cored in Section 16-2 includes at least NP11 to NP7 (lowermost Eocene and uppermost Paleocene).

Paleocene

From NP6 (*Heliolithus kleinpelli* Zone) downward through all remaining coccolith zones to the base of the Danian, an extraordinarily thick sequence of Paleocene (over 120 m) was cored continuously, with very high recovery, in Cores 16 through 29. The Cretaceous/Tertiary boundary occurs at Sample 356-29-3, 33 cm. The coccolith assemblages are rich and moderately well preserved from Core 17 downward, until the diversity diminishes because fewer species had evolved. *Thoracosphaera* spp. also becomes increasingly abundant toward the base of the Danian, and in Samples 29-1, 81 cm and 29-1, 90 cm, it forms a *Thoracosphaera-Braarudosphaera* chalk. The remainder of the Danian is characterized by the presence of common *Thoracosphaera* and reworked, very well preserved Maestrichtian coccoliths, including the upper Maestrichtian form *Micula mura*, which also occurs in the underlying Maestrichtian sequence. The presence of Tertiary planktonic foraminifers of the *G. eugubina* Zone shows this assemblage to belong to the Danian, despite the lack of *Biantholithus sparsus*, which elsewhere occurs at the very base of this stage. The common occurrence of *Thoracosphaera* in the Danian, and especially in its lowermost part, has been noted worldwide. The presence of few to common *Braarudosphaera* in the Danian samples of Core 29 indicates restricted conditions, as found in bays or other near-continent or shelf areas. The samples collected from this sequence will provide excellent material for further studies on the evolution of the earliest Tertiary coccoliths. Reworked Late Cretaceous, mainly Maestrichtian, coccoliths are rare to few in most Paleocene samples. Their abundance generally increases downward. In several cores (e.g., 19 and 24) whole layers (slumps) of Maestrichtian chalk occur.

Tertiary/Cretaceous Boundary

Although very long hiatuses or very compressed Paleocene sequences have been commonly reported from other DSDP sites, and were found at Site 354 on the Ceará Rise and Site 355 in the Brazil Basin, no biostratigraphically recognizable hiatus was found at this site. In the lowermost Tertiary as well as in the uppermost Cretaceous, coccoliths are common and moderately well preserved. The lowermost Tertiary coccolith zone (*M. inversus-B. sparsus*) and the uppermost Cretaceous coccolith zone (*M. mura-N. frequens*) are represented. Reworked Cretaceous coccoliths are, however, present in various amounts in all lower Danian samples.

Upper Cretaceous and Upper Albian

The upper Cretaceous assemblages are quite diverse but only poorly to moderately well preserved in Cores 29 through 38. In Cores 39 to 41 (Section 4), coccoliths are usually few and poorly preserved. *Kamptnerius magnificus*, a species indicative of relatively shallow water deposits, is rare in most samples from Cores 29 through 32; below Core 32, it occurs only sporadically. *Arkhangelskiella cymbiformis*, which was very rare in the open ocean Site 355 in the Brazil Basin, is more common in the Maestrichtian and upper Campanian at this site. It is usually even more common in shelf deposits of chalk, as in the North Sea area. *Marthasterites furcatus* shows a wide variation of forms, and is most common in Sample 37, CC. It is an easily recognizable marker fossil for the Santonian and Coniacian, and was reported also in the upper Cretaceous on the Falkland Plateau. A late Turonian age is indicated for the lowermost Upper Cretaceous sediments by the presence of *Micula staurophora* and scarce *Gartnerago obliquum* and the absence of *M. furcatus*. Below the lithologic change in Section 41-4, infrequent *Nannoconus* occur in most samples. Because of the very poor preservation of the coccoliths in this interval, age assignment is difficult. The only species classed as few or common in some samples are *W. barnesae* and *E. turriseiffeli*, two solution-resistant species. Other forms occur rarely and sporadically. The presence of *E. turriseiffeli* suggests a maximum age of late Albian. *Lithraphidites alatus*, the marker species of the Cenomanian, is absent at this site.

Radiolaria

The first three cores are barren of siliceous microfossils. Abundant to common radiolarians occur at this site only in the lower Miocene and lower and middle Eocene sediment (Cores 4-15). Radiolarians form a consistent but low-frequency constituent of the coarse fraction in the upper Paleocene sediment (Cores 16 to 23). Except in a few samples from near the bottom of the hole (Samples 42-6, 30-32 cm, and 44, CC) no radiolarians are present in the lower Paleocene and Cretaceous sediments.

Diversity is generally high in the lower Miocene and middle Eocene interval, and decreases downhole in the lower Eocene and upper Paleocene interval. Preservation shows the same trend downhole.

A well-preserved assemblage of the lower Miocene *C. tetrapora* Zone is present in Core 4 and in the bottom and core-catcher sample of Core 2 of Hole 356A. The *Lychnocanoma elongata* Zone is represented in Core 5, and extends down to Sample 6-1, 80 cm. Spines and mesh fragments of orosphaerids, as well as a few callosphaerids, are also present. The total aspect of the assemblages is of a tropical open ocean environment.

The lower Miocene sediment directly overlies middle Eocene sediment containing assemblages of the *Podocyrtis mitra* Zone, Samples 6-1, 113 cm and 6-2, 35 cm. The presence of scarce specimens of *Sethochytris triconiscus* points to the upper part of the zone. Although there is no problem assigning this zone by the standard equatorial radiolarian zonation, a number of species present may indicate a cool- or temperate-water admixed element in the assemblage. An assemblage indicative of the middle Eocene *P. ampla* Zone occurs in Sample 6-2, 35 cm; the rest of Core 6 and Cores 7 through 9 can be assigned to the *Thyrsocyrtis triacantha* Zone. Core 10 contains no age-diagnostic radiolarians.

The lower Eocene *P. striata striata* Zone occurs throughout Cores 10 to 13, and Cores 14 and 15 belong to the *Buryella clinata* Zone. Again, poor preservation of the assemblages makes it difficult to distinguish between *P. striata striata*, the earliest evolutionary appearance of which defines the base of the *P. striata striata Zone*, and *P. striata exquisita*.

Although the radiolarians in Sample 16-2, 113 cm still have an "Eocene look," the radiolarian assemblages from Sample 16-2, 143 cm to the bottom of Core 23 fit into the unzoned upper Paleocene interval, as described by Foreman (1973). *Dictyoceras caia* occurs only in Cores 16 and 17; *Bekoma divaricata*, *Buryella tetradica*, *B. pentadica*, *Stylosphaera goruna*, and *Orbula* sp. occur consistently but sparsely in all samples down to 23, CC. From the samples examined, it is clear that dissolution and remobilization of biogenic silica has occurred in all samples of early Eocene and late Paleocene age. Recrystallization of silica is evident from Core 24 to Sample 27, CC, where only the general shape of radiolarians, mainly spumellarians, can be recognized.

No radiolarians are present in the sediment below Sample 27, CC except in Sample 42-6, 30-32 cm. The radiolarians in this assemblage are recrystallized, but the following species can be recognized: *Lithocampe ananassa*, *Cyrtocapsa grutterinki*, *Crucella* sp. A., *Spongosaturnalis polymorphus*, *Dictyomitra formosa*, *Amphipyndax* sp. cf. *A. stocki*, and *Patulibracchium* cf. *P. ungulae*. The assemblage indicates a late Albian age (RK4/5).

Silicoflagellates

Bukry (this volume) reports on rich middle Eocene silicoflagellate assemblages from Sections 6-2 through 9-2. Sections 6-2 through 7-1 are assigned to the *D. hexacantha* Zone, Sections 7-3 through 9-1 to the newly defined *D. spinosa* Subzone of the *N. foliacea* Zone, and Section 9-2 to an unnamed subzone of the *N. foliacea* Zone. *D. spinosa* and *Naviculopsis foliacea* occur in all four cores, whereas *D. hexacantha* s. str. is restricted to the upper two. The sequence containing silicoflagellates belongs to the upper part of the *Nannotetrina fulgens* Zone (NP 15) and to the *Discoaster bifax* Subzone of Bukry (1973).

Diatoms

Fenner (this volume) reports on diatoms from Cores 5, lower Miocene, through Core 9, middle Eocene. The diatoms in the middle Miocene samples from Core 5 and the top of Section 6-1 are rare and poorly preserved, and permit no age assignment. Below the hiatus in Section 6-1 and through the upper part of Core 9, diatoms are common and well preserved. In the lower part of Core 9 and below, the zeolite content of the sediment increases and diatoms are lacking because of diagenetic dissolution.

Benthic diatoms such as *Auliscus* sp. and *Arachnoidiscus decorus*, and species of the genera *Rhabdonema*, *Raphoneis*, *Sceptroneis*, and *Cymatosira* (interpreted as littoral diatoms according to their present habitat), occur in all diatom-bearing middle Eocene cores, and indicate relatively shallow conditions or transport from littoral areas into deeper depths. These diatom assemblages also include warm-, temperate-, and cold-water species.

Palynomorphs

Ionnides and Colin (this volume) have studied palynomorphs from Cores 38 through 41. They assign a Senonian age, probably younger than late Coniacian, to Core 38, where a sparse and impoverished assemblage including *Dinopterygium cladoides*, *D. acuminatum*, and *Xenascus ceratoides* occurs. Core 39 contains the richest palynomorph assemblage which includes, among others, *Dinogymnium*, a genus not known to occur before late Coniacian. The palynologic information for Core 40 does not indicate an age more precise than Late Cretaceous; Core 41, virtually devoid of any palynomorphs, shows rare occurrences apparently derived from older sediments.

SEDIMENT ACCUMULATION RATES

Figure 12 summarizes the sediment accumulation history at Site 356. Five intervals containing hiatuses or showing extremely slow accumulation rates were cored; two others probably occur between cores.

The accumulation rate was more than 1 cm/1000 yr in the late Albian, when the marly dolomitic limestones and calcareous mudstones with calcareous laminae (Cores 44 to 41) were deposited. Nondeposition or erosion followed during the Cenomanian and early Turonian until, later in the late Turonian, black claystones and gray marlstones (Cores 41 through 40) were deposited. Similar sediments then formed an intraformational clay-pebble conglomerate (Cores 40 and 39) during the Coniacian. During the latest Coniacian and the Santonian, marly chalks (Cores 38 to 35) were deposited at a rate of about 2 to 3 cm/1000 yr. Between Cores 35 (upper Santonian) and 36 (Campanian), an interval with slow accumulation or a hiatus occurs, if, as in Figure 12, a long duration is accepted for the Campanian. Accumulation continued at a rate of about 1-2 cm/1000 yr in the late Campanian and the Maestrichtian, and slowed only at the end of the Maestrichtian (Cores 33 to 29).

The thick Paleocene sequence (Cores 29 to 16) of nannofossil and nannofossil-foraminifer chalks was deposited at a rate of about 2 cm/1000 yr. Accumulation then ceased for some 5 m.y. during the latest Paleocene and the earliest Eocene (~57 to 52 m.y.B.P.), or sediments deposited then were eroded in the earliest Eocene. The early Eocene silicified chalks (Cores 16 to 10) were deposited at the high rate of about 6 cm/1000 yr, and are overlain in Core 10 by a thin sequence of siliceous calcareous ooze, which accumulated at the very slow rate of about 0.5 cm/1000 yr, probably as a result of a high rate of dissolution of biogenic sediments. During the remainder of the middle Eocene (Cores 10-6), accumulation of siliceous

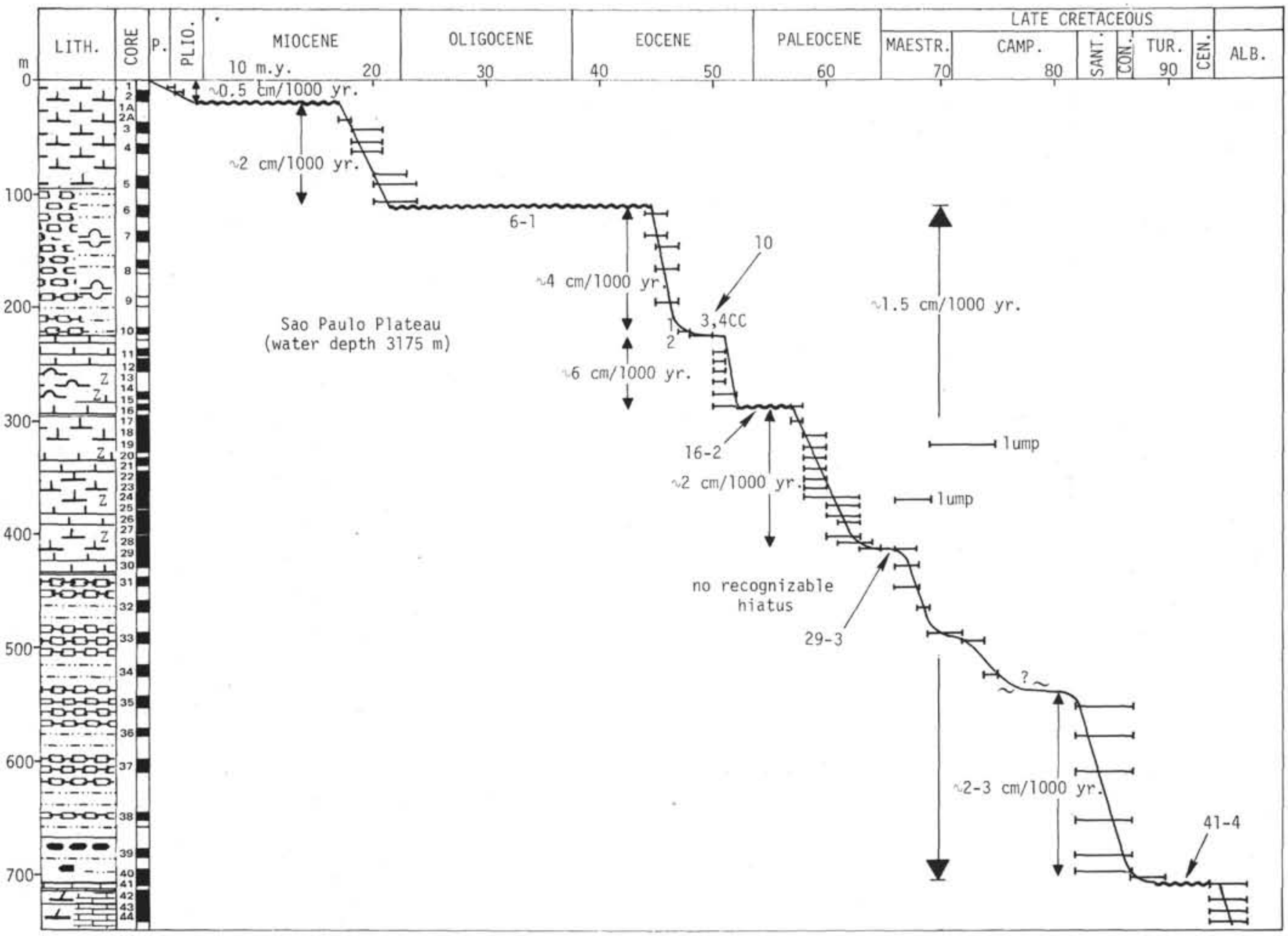

Figure 12. *Sedimentation history, Site 356.*

calcareous oozes continued at a rate of about 4 cm/1000 yr until it ceased about 44 m.y. ago. Section 6-1 includes a hiatus representing some 24 m.y. and ending about 20 m.y. ago in the early Miocene, when accumulation resumed.

Lower Miocene nannofossil-foraminifer oozes (Cores 5 to 3, 2A, 1A) were deposited at a rate of 2 cm/1000 yr; upper lower to upper Miocene sediments were not recovered. If upper lower to upper Miocene sediments are present between Cores 3 and 2, which were taken with a 19-meter uncored interval between, they would have had to accumulate at an average rate of 0.1 to 0.2 cm/1000 yr. This seems unlikely, and we therefore assume that most of the time for which no sediments were recovered is represented by a hiatus. The rate of sediment accumulation in the uppermost part of the sequence was low, in the order of 0.5 cm/1000 yr.

Surprisingly many hiatuses or intervals with very slow accumulation occur at this site. But during the periods when sediments *were* being deposited, accumulation was more rapid than "normal" calcareous ooze accumulation. This may be explained to some extent by the location of Site 356 on the northern flank of a high ridge crest, at the base of which lies a channel almost filled with sediments. The site thus was constantly an area potentially influenced by processes occurring in this valley. Eroding currents probably produced hiatuses or very slow sediment accumulation, while other currents resulted in higher than normal rates of deposition. In fact, the average accumulation rate from the Coniacian through the mid-Eocene is 1.5 cm/1000 yr.

A major hiatus was expected at the Cretaceous/Tertiary boundary. The presence at this site of a calcareous Danian succession over 50 meters thick, including the base of the Tertiary, is remarkable, as is the presence of topmost Maestrichtian. Apparently this site was never below the CCD.

Although the occurrence of abundant *Braarudosphaera* in some Danian samples could be interpreted as indicating shallow water, foraminifers provide evidence indicating water depths close to 1500 meters. A deep CCD at the Cretaceous/Tertiary boundary is indicated by evidence from other DSDP sites, and is discussed in a later chapter (Supko and Perch-Nielsen, this volume).

The slow accumulation in the Campanian and the Cenomanian hiatus correlate well with hiatuses found in the sediment sequences cored on the Falkland Plateau (Leg 36, Site 327).

CORRELATION OF REFLECTION PROFILE WITH DRILLING RESULTS

Both the Lamont reference profile (Figure 3) and the approach profile to Site 356 obtained by *Glomar Challenger* (Figure 5) are of poor quality, so correlation of profiles with the stratigraphic section drilled and cored is difficult at best. Figure 13 contains an interpretive line drawing of the approach profile (Figure 5), ages and lithologies of sedimentary units penetrated, core control, and average interval velocities of sediment as measured with the Hamilton frame onboard ship. Four major reflecting horizons were picked on the approach profile at 0.12, 0.28, 0.50, and 0.75 sec. These reflectors occur throughout the plateau, and can be correlated from track to track on L-DGO seismic profiles (see Kumar et al., this volume).

At an average velocity of 1.54 km/sec, the 0.12 sec reflector correlates very well with the boundary, at 93 meters, between the nannofossil and foraminifer oozes of Unit 1 and the siliceous calcareous oozes of Unit 2. The average measured Hamilton frame velocity of 1.62 km/sec (Table 5), for cores between the bottom of Unit 1 and the defined lithologic boundary between Units 2 and 3, calculates to 0.16 sec, exactly the measured difference between reflectors 2 and 3. By similar calculation (see velocities in Table 2), the reflector at 0.5 sec corresponds exactly to the boundary between the nannofossil and nannofossil-foraminifer chalks of Unit 4 and the marly calcareous chalks of Unit 5. The average core velocity (2.28 km/sec) between the top of Unit 5 and the top of the upper Albian limestone sequence (Unit 7) allows calculation of a depth of 716 meters for the 0.75 sec reflector. That is, the 0.75 sec reflector, originally interpreted as regional basement on the basis of Lamont-Doherty reference profiles for the area and the Site 356 approach profile, corresponds to the top of the Albian limestones. Close examination of the approach profile (Figure 5) indicates that true basement may indeed be below the 0.75 sec reflector (dotted line in the drawing of Figure 13).

SUMMARY AND CONCLUSIONS

Site 356, at the base of the northern flank of the basement ridge at the southeastern edge of the São Paulo Plateau, was drilled and cored to a sediment depth of 741 meters. Igneous basement was not reached; there is reason to believe that true basement lies some hundreds of meters below the total depth reached. The stratigraphic section consists mostly of biogenic sediment, predominantly nannofossil and foraminifer oozes and chalks, with an important siliceous contribution in the Eocene. Seven sedimentary units have been described. Sediment accumulation rates are generally high, on the order of 15 m/m.y.; several important hiatuses (see Figure 12) indicate periods of nondeposition or removal of sediment by erosional processes.

Age of Basement and Oldest Sediments

Because the oldest sediments and the crystalline basement could not be reached at this site, we have only an incomplete record with which to interpret the geologic history of this area. We may assume that sediments began to accumulate at this site soon after the opening of the South Atlantic. Estimates for the date of opening of the South Atlantic vary; an estimate of between 120 and 130 m.y. ago may be made on the basis of dating of lavas presumably associated with the rifting (Amaral et al., 1966) and on the basis of ages of recognized magnetic anomalies in the South Atlantic (Larson and Ladd, 1973). The oldest sediments cored at this site are approximately 100 m.y. old. Hence, the record for approximately the first 20 to 30 m.y. of the geologic history of this area was not sampled. But this estimate does not take into account the time needed to create the oceanic crust between this site and the ocean-continent boundary off the Brazilian continent; so the date for the opening of the South Atlantic is only an estimate of the oldest possible basement age at this site.

We can use the age of the salt to guess at the youngest possible age for the basement. The salt beds in the South Atlantic are Aptian-Albian in age (Asmus and Ponte, 1973; Brink, 1974). The ridge at the southern edge of the São Paulo Plateau, together with the Walvis Ridge, appears to have acted as a barrier to circulation during formation of the salt (Leyden and Nunes, 1972; Leyden et al., in press). The São Paulo ridge must have formed the barrier during deposition of the salt layer, which contains diapiric structures about 100 km to the northwest. Hence the crust at Site 356 must have been created prior to the late Aptian (approximately 110 m.y.), and the basement age must be somewhere between 110 and 127 m.y. This estimate is supported by the age of the crust underlying Site 364, which is near the seaward edge of the salt layer on the African side. The crust underlying Site 364 is of anomaly M-4 age (116 m.y., Larson and Pitman, 1972; Bolli, Ryan, et al., 1975). Site 356 is on the Brazilian margin in a situation somewhat analogous to that of Site 364 on the Angolan margin.

Our estimates assume that the crust under the São Paulo Plateau is oceanic. The fit of South America with Africa (Bullard et al., 1965) in this area, and the geophysical data from the São Paulo Plateau (Leyden et al., 1971) support this assumption. Leyden (in press), however, has suggested the existence of a "transitional oceanic" crust, underlying the plateau, presumably created by intrusion of mafic material into tensional fissures in continental crust, and not from a central spreading ridge.

Sediment thickness under the plateau ranges up to 4 km (Francisconi and Kowsmann, in press). Presumably the São Paulo ridge, which formed during or immediately after the opening of the South Atlantic, acted as a barrier, so sediments supplied from the Brazilian continent could not escape into the open ocean. The sedimentary sequence underlying the São Paulo Plateau appears to be the offshore equivalent of the sequence in the Santos Basin, which underlies the Brazilian shelf between 23° and 28° latitudes (Kumar et al., this volume; Asmus and Ponte, 1973; Asmus, 1975; Ponte and Asmus, in press).

Early Cretaceous History

At the time the oldest unit cored at this site (Unit 7) was emplaced, salt deposition had ceased. Since salt

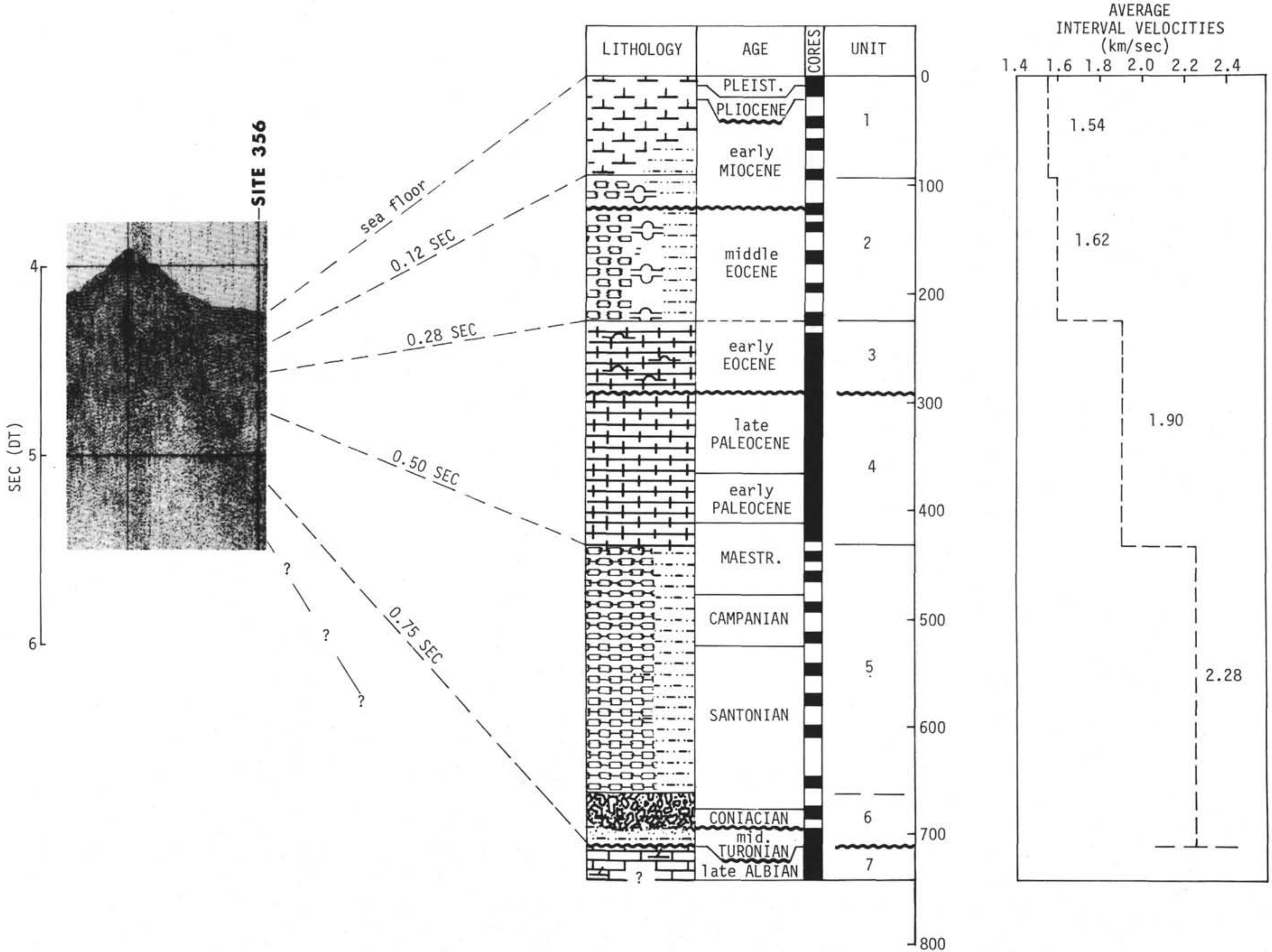

Figure 13. *Correlation of the Site 356 approach reflection profile with the lithostratigraphic section cored. Average interval velocities are based on Hamilton Frame measurements made aboard ship.*

deposition had ceased by the end of the Aptian (Asmus and Ponte, 1973; Brink, 1974), and Unit 7 is of late Albian age, the sampled part of Unit 7 represents conditions that existed approximately 6 to 8 m.y. after the end of salt deposition. Sediments equivalent in age and composition to Unit 7 were cored at Site 364 in the Angola Basin off the West African margin. At Site 364, upper Albian limestones overlie upper Aptian to lower Albian sapropelic shales and marly dolomitic limestones, which overlie the salt (Bolli, Ryan, et al., 1975).

The marly dolomitic limestones of Unit 7 were deposited in an open marine environment. Hence the dolomitic limestones of the kind represented in Unit 7 were deposited throughout the South Atlantic when open marine conditions were established at the end of salt deposition. The bulk of the sediment of Unit 7 is terrigenous-calcareous in composition. Therefore, the abundant white laminae of pure calcium carbonate must be the result of some process which removed the terrigenous clays and allowed calcium carbonate to concentrate in thin discrete layers. The thickness, abundance, and ungraded nature of these laminae suggest that bottom currents may have formed them by removing the terrigenous clays. Short-term rapid accumulation of pelagic calcareous material or calcareous turbidites may produce such laminae, but in the case of pelagic calcareous material one would expect the upper or lower contacts to be gradational, and in the case of calcareous turbidites one would expect graded bedding and gradational upper contacts.

The coarse sand-sized graded layers of Unit 7 probably represent turbidites which originated at the Brazilian margin. The presence of quartz in the coarse graded layers supports this suggestion. Thus, eroding, as well as depositing, currents were operating in the area at the time Unit 7 was deposited.

The benthic foraminifers imply a depth of approximately 1000 meters at the site when Unit 7 was deposited. So the basin was at least that deep 6 to 8 m.y. after salt deposition had ceased. Assuming that conditions remained more or less unchanged, one may conclude that the basin was several hundred meters deep when salt deposition ended in the South Atlantic. On the other hand, if the basin was only tens of meters deep at the end of salt deposition, a slow subsidence of only 0.2 mm/yr (1000 m in 5 m.y.) would be sufficient to create a depth of 1000 meters during the deposition of Unit 7. Aptian sediments at Site 361 and 364 (Walvis Ridge and Angola Basin, respectively) indicate, however, that the eastern basin was a few hundred meters deep at the end of salt deposition (Bolli, Ryan, et al., 1975). By analogy, the basin at Site 356 was most probably also a few hundred meters deep when salt deposition ended in late Aptian. The basin then subsided.

Deposition of salt took place entirely within the Aptian, probably within the late Aptian. Even if we assume that the entire period of salt deposition was only 3 m.y., a subsidence of 1 mm/yr could accommodate deposition of the 3 km of salts (Bolli, Ryan, et al., 1975; Leyden et al., 1971) that occur on both sides of the Atlantic. Although this rate of subsidence is not excessive, analogy with other salts suggests that deposition of salt occurs at such a high rate that crustal subsidence cannot keep pace with it (Faure, in press; Ryan, personal communication, 1975). Such indirect evidence thus favors an interpretation in which the basin is considered to have been 3 to 4 km deep before the salts began to accumulate, and almost filled to a depth of less than 1 km after the salt deposition had ceased (Bolli, Ryan, et al., 1975).

Coniacian-Turonian Mudstones

Cores 39, 40, and 41 contain repeating sequences of black carbonaceous mudstones (containing pyrite) and medium gray and greenish-gray layers of nannofossil marl. The black carbonaceous layers indicate reducing conditions, whereas the light gray layers were deposited under aerobic conditions (presence of benthic foraminifers and burrows). Two alternative hypotheses warrant consideration: that the black mudstone layers were periodically introduced from outside, or the redox state of the depositional site changed periodically.

If the pyritiferous mudstones were introduced periodically into an otherwise aerobic area of deposition, one would expect to see evidence of resedimentation. The conglomerate-to-dark clay sequence of Core 39 does indeed appear to have been transported through sediment-gravity flows. The sediments of Core 41, by contrast, show gradational contacts and hence do not suggest resedimentation of the sediments contained in black layers. Gradational contacts imply in situ deposition. The high organic content and pyrite in the black layers indicate reducing conditions, and the presence of benthic foraminifers in the gray layers and burrowing indicate bottom life and therefore oxidizing conditions. Conditions of cyclic change from oxidizing to reducing conditions could explain this. The overall low accumulation rate of Unit 6 favors formation in situ of a major part of the sediments in this unit, rather than their introduction from outside. The graded conglomerate-to-clay sequence may represent local resedimentation in an already anaerobic basin.

Black sapropelic sediments were noted in the Cretaceous and Paleocene at several Leg 14 sites (see Berger and von Rad, 1972); they included a well-developed rhythmic sequence of black pyrite-bearing carbonaceous shales and gray-green dolomitic lutites. The authors explained the presence of the dark layers as a consequence of redeposition processes, although the preponderance of carbonaceous sediments in the Cretaceous North Atlantic (and Caribbean, for discussion see Saunders et al., 1973, and their fig. 11) sediments makes periodic basin-wide stagnation an alternative possibility.

Although the dark layers of Core 39 show evidence of resedimentation (conglomeratic nature, grading on a large scale), those of Cores 40 and 41 have gradational contacts at top and bottom. Thus, while some of the dark layers may have been emplaced by resedimentation processes, at least some seem to have formed in situ during periods when reducing conditions prevailed. The prominent basement ridge nearby leads one to suspect periodic reduced (or cessation of) deep circulation by relative fluctuations of the ridge topography and/or eustatic sea level.

Post-Coniacian History

Oxidizing conditions existed in the basin during deposition of the Santonian to Maestrichtian marly chalks (Unit 5). The sediments are fairly well burrowed, indicating that bottom-dwelling organisms existed in the area. The significance of the presence of *Inoceramus* fragments in terms of environment of deposition is unknown (see Thiede and Dinkelman, this volume). The terrigenous components were being supplied from the margin, whereas the calcareous component is pelagic-biogenic in nature. Occasional gravity-controlled bottom flows deposited coarse graded layers. It is significant that conglomerates and coarse-grained sandstones were being deposited in the Santos basin during the time the marly chalks were deposited.

Unit 4 consists of relatively pure nannofossil and nannofossil-foraminifer chalks, only locally marly, of late Maestrichtian to late Paleocene age. The Cretaceous/Tertiary boundary at this site is represented by continuous deposition. Since benthic foraminifers indicate a water depth of 1000 meters at this time, it is necessary to look more critically at Worsley's (1974) hypothesis that the CCD in the open ocean had shallowed into the photic zone, thereby precluding abundant deposition of carbonates at any great depth. Indeed, a very thick (approximately 50 m) Danian section was recovered, perhaps the best and oldest Danian section yet recovered from the deep sea.

The supply of terrigenous sediment to the area was cut off during the period when the Maestrichtian-upper Paleocene chalks were deposited. A Paleocene hiatus occurs in the Santos basin, suggesting that supply of coarse terrigenous material was minimal during that time (Leyden et al., in press; Asmus, 1975). Apparently because no terrigenous material was supplied to the basin, the resulting sediments in the distal part of the basin are pelagic-calcareous in nature. Cretaceous slump material present in Paleocene Cores 19, 24, and 25 must have come from the nearby São Paulo ridge, because supply of terrigenous material from South America was only minimal. Moreover, the slumped material is different from the sediments being deposited in the basin at that time. The slump material is almost entirely pelagic, which further supports the argument that it came from the ridge.

The Eocene was a time of incursion of cooler waters and of important contributions of siliceous fossil tests to the sediment. In contrast to the foraminifers and ostracodes (Benson, this volume), which indicate deposition at bathyal depths, nannofossils indicate water depths possibly less than 1000 meters. Benthic diatoms (Fenner, this volume) also indicate shallow water, but the high Eocene sedimentation rate of 4 m/10 m.y. may reflect transport into the basin from shallow water areas. Evidence from all three major fossil groups (nannofossils, foraminifers, and radiolarians) indicates cool subtropical conditions, which are typical of middle latitudes at this time (Premoli-Silva, in preparation). The Eocene sediments are divided into two lithologic units. The siliceous component of the middle Eocene Unit 2 is composed of the tests of radiolarians and frustules of diatoms. In the lower Eocene Unit 3, the silica forms a cement for the (silicified) chalks. Because the transition from Unit 2 to Unit 3 is very sharp, it is probable that silica was remobilized as cement by chemical changes in the pore water, and not solely by overburden and burial. Preservation of siliceous biogenic components progressively deteriorates from Unit 2 down into Unit 3.

Major hiatuses cover the time span from late middle Eocene through Oligocene and late early Miocene through Pliocene. A correlation with high latitude paleotemperature curves (Shackleton and Kennett, 1975) indicates these to be the coldest periods of the late Paleogene and pre-Pleistocene Cenozoic.

The Neogene sediments of Unit 1 are almost entirely pelagic; hence terrigenous material has not reached this site since the early Miocene. Continued slumping from the nearby São Paulo ridge is indicated by the presence of manganese crust and zeolitic foraminifer-nannofossil ooze of Eocene age. Early Miocene vulcanism produced an ash layer in Core 4. The volcanic ash appears to be from a continental source (interpreted silica content 60%), but no continental vulcanism of Miocene age is known from the Brazilian continent at this time. The volcanic islands of the Columbia-Trinidade seamount chain (see base map for Site 355) to the north of Site 356 have, however, been active as recently as Pliocene time (Cordani, 1970).

Figure 14 summarizes the possible sources of sediments for various units identified at Site 356.

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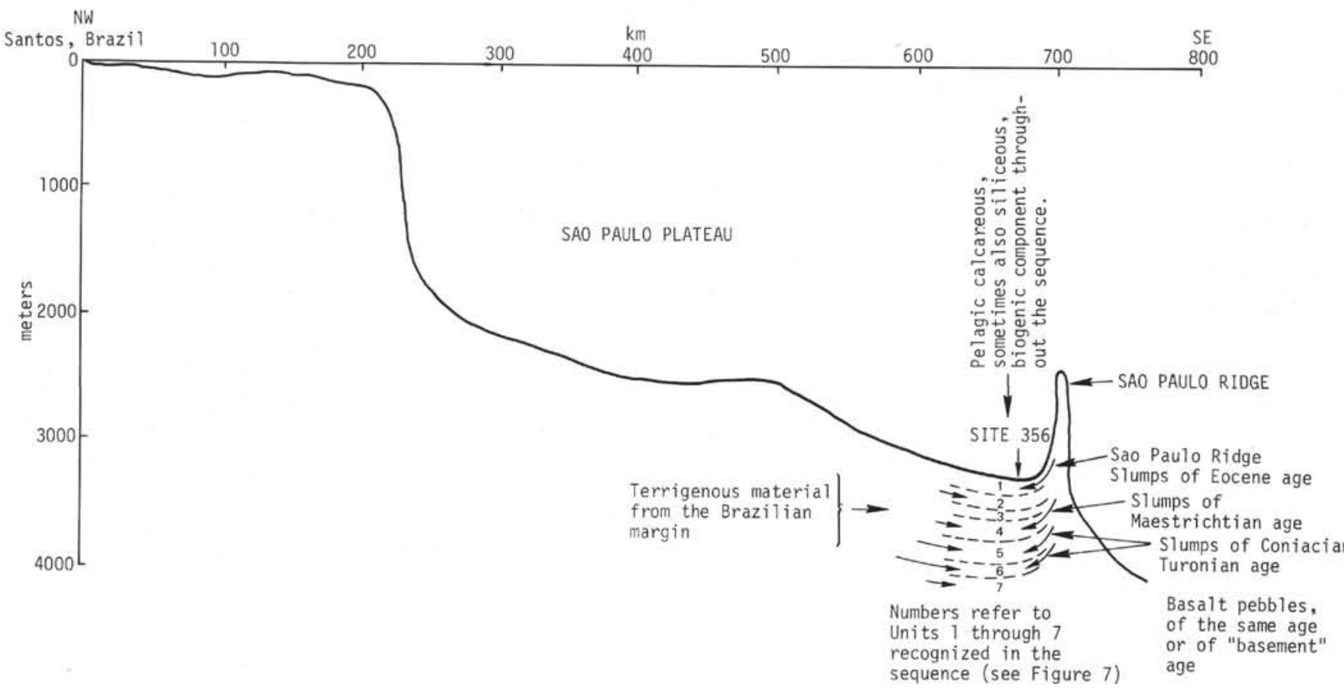

Figure 14. *Summary of sediment sources, Site 356.*

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APPENDIX A
Smear-slide Summary

	Sand	Silt	Clay	Quartz	Feldspar	Mica	Heavy Minerals	Clay	Volcanic Glass	Iron Oxides	Glauconite	Pyrite	Opaques	Micronodules	Dolomite	Zeolite	Authigenic Carbonate	Authigenic Silica	Foraminifers	Calcareous Nannofossils	Diatoms	Radiolaria	Sponge Spicules	Silicoflagellates	Fish Remains	Plant Debris	Shell	Remarks
Hole 356																												
2-1, 51	10	20	70	5				10									5		15	60			5					
2-1, 85	25	35	40	10												10			20	60								
2-1, 89	25	30	45	5				15									10		30	40								
3-1, 128	25	30	45	15		1		10		1						5	5		40	25								
3-3, 67	20	30	50	15				15									20		15	35								
3-5, 23	10	30	60	10						20						10	20		10	30								
3-6, 141	20	30	50	15				15								10	15		20	25								
4-2, 70	20	30	50	10						1			5			5	15		20	40	1	1	5					
4-5, 59	90		10	1	1				90								5			5								
5-1, 6	20	30	50	15					5	1					1		10		20	25	5	15	5					
5-1, 100	15	25	60	20				10	5	1			5			5	10		15	15		5	5					
5-6, 75	20	30	50	10				10	5	1							10		15	35		10	5					
6-1, 80	20	35	45	15				10	5	1			5				10		10	30	10	15	10					
6-2, 134	15	25	60	10				10									10		10	20	15	15	10					
6-4, 100	20	30	50	5				10								1	10		10	20	15	20	10					
7-1, 50	20	30	50	5	1			10								5	10		20	15	15	15	5					
7-4, 60	15	25	60	10	1			10		5						5	5		5	25	10	15	10					
8-2, 105	10	20	70	5				10					5			5	5			20	15	25	10					
9-2, 49	10	30	60	5				5					5			1	10		5	45	10	10	10					
9-2, 143	20	30	50	5				5					5		5	5	5		15	25	10	15	10					
10-3, 85	15	25	60	5				15					5			10	10		10	40			5					
10-4, 73	20	30	50	10				10								10	15	20	25	1	10							
10-4, 86	20	30	50	10				10								15	10		20	30	5							
11-1, 45	10	20	30	5				15					5			10	10	25		20		15						
11-2, 32	10	30	60					20		1				5		20	10	20	10	15	5							
11-2, 70	20	30	50					10							20	5	10	20	25	10								
12-1, 97	10	20	70					10								10	10	40	20	10								
12-2, 50	40	20	40					1								20	10		15	40	5							
13-2, 25	20	30	50	5		5		20						1		15	5	20	5	30								
13-2, 65	50	30	20												1	5	10	10	70	5								
14-1, 60	20	30	50	5				15								10	15	25	10	20								
15-1, 119	50	50		5													30	20	35		10							
15-3, 100	20	30	50	5				20		1		1				10	10	10	15	30								
16-2, 20	15	25	60	10				10				5			1	5	10	20	10	30								
16-2, 147	15	25	60	20	5	5		15					5		1	5	10		1	35								
17-1, 80	15	25	60	10	5	10		20					5			10				40								
17-3, 14	15	25	60	10	5			15					5			20	10		5	30								
18-2, 50	15	25	60	10				15					5			15	10		5	40								
19-2, 100	10	20	70	10	5	5		10							1	10	10		5	50								
19-4, 137	10	20	70	15				10		5			5		5	20	10		10	25								
20-2, 100	10	20	70		1	1		5			1					1	20	5	1	70	1	1			1			
21-2, 90	5	25	70	2	1	1		30		1	1						10		1	60	1	1	1					
22-3, 100	15	25	60	10				15	5				5			10	5		10	40								
23-2, 56	15	25	60	5		5		10					5			15	10		10	40								
23-2, 100	10	20	70	5		5		15					1			15	10		10	40	1							
23-3, 71	10	20	70	5	5			10		1			5			20	5		20	30	1	1						

APPENDIX A – *Continued*

	Sand	Silt	Clay	Quartz	Feldspar	Mica	Heavy Minerals	Clay	Volcanic Glass	Iron Oxides	Glauconite	Pyrite	Opaques	Micronodules	Dolomite	Zeolite	Authigenic Carbonate	Authigenic Silica	Foraminifers	Calcareous Nannofossils	Diatoms	Radiolaria	Sponge Spicules	Silicoflagellates	Fish Remains	Plant Debris	Shell	Remarks
24-2, 70	20	30	50	5				10								10	10		15	45	5							
24-4, 29	15	25	60	10		1		10		5						10	10		25	10	5	15						
24-4, 35	20	30	50	20	5			10							1	15	5		25	20	5	5						
24-4, 37	10	20	70	5				5		1						5	10		10	60		1	5					
24-4, 39	10	20	70	10				10								1	10		10	60								
25-2, 95	10	20	70	10				10					5			10	10		10	40		10						
25-3, 100	15	25	60	10						1			1				10		10	60		10						
26-2, 100	20	30	50	5				10		5			5			5	10		20	40		10						
26-5, 30	10	20	70	5	1			10								10	10		10	45		10						
27-3, 75	20	30	50	5				10		5			5			5	5		20	40		10						
27-6, 70	20	30	50	5				10								5	10		20	40		10						
28-3, 75	20	30	50	5	5	1		10		5						5	10		20	30		10						
28-4, 120	15	25	60	20	10	1		15		10			5		1	5			10	15		10						
28-6, 100	15	25	60	5				10						1	10		25		10	30		10						
29-1, 35	15	25	60	20	10			30		5			5				5		10	15		5						
29-3, 20	15	25	60	10	5	1		20									15		20	15		15						
29-3, 75	10	20	70	5		1		10					5		5		20		5	50								
29-5, 75	20	30	50	5				10									10		10	55		10						
30-3, 100	15	25	60	5		1		10									15		25	45								
30-6, 46	15	25	60	10				10					1						15	65								
31-2, 75	15	25	60	15	5			15					5		5		10		10	30		5						
32-3, 75	15	25	60	10	5			15					5		5		25		10	25								
32-5, 24	15	25	60	15	10	5		15								1	15		10	30								
33-2, 50	10	20	70	15	5	5		15		5					5		15		10	25			1					
33-4, 60	10	20	70	15	10	1		15							10		15		15	20								
34-1, 83	10	20	70	10		1		50		5					10		10		5	15								
34-3, 55																											100	Inoceramus
34-3, 75	10	20	70	5	5	1		20		5					10		25		5	25								
35-1, 24											100																	Glauconite nodule
35-1, 25										100																		Nodule
35-2, 81	10	20	70	5	5		5	75	5	5					5	5			5									
35-3, 60	10	20	70	10	5			20		5			5		15		5		15	20								
36-2, 75	10	20	70	10	5		1	15					5		15	1	20		15	15								
37-2, 100	15	25	60	10	5			20					5		10		15		10	25								
38-1, 100	10	20	70	5	5	1		25		5			5		5		30		5	15								
38-3, 130	10	20	70	10	5	5		20			1		5		10		20		10	15								
39-1, 140	5	15	80	30	20			30		5			5				10			10								
39-1, 143	10	50	40	30	20	10		30		1			5			10												
39-2, 69	20	30	50	15	5	5		30		1			5		5		20		5	10								
39-2, 105	10	30	60	15	5			25		1			1		20		20		5	5								
39-3, 80	10	20	70	10	1	1	1	80		1	1	2																
39-4, 111	20	30	50	20	1			70				1	2		1	1	10		1									
40-1, 100	15	25	60	15	10			40		1			5						10	10								
40-3, 59	10	30	60	10	1			80			5		2															
40-3, 61																	100											Limestone pebble
40-3-63				10	5			40					5		5		20		5	10								Pebble
40-3, 87	20	30	50	30	20					15							35											
40-4, 62	10	20	70	20	1		1	70					2															
40-5, 140	10	30	60	10				90		1																		Pebble

41-2, 32	10	20	70	10	5			20			1	10		20		20	5	10				
41-2, 40	20	30	50	35	20			35					10									
41-2, 43	10	20	70	25	10			30				35										
41-4, 60																100						Crust
41-5, 120	5	25	60	10				2				1		1		85	1					
42-1, 100	10	30	60	10	5			40		5	1		5	10		10	10	5				
42-1, 130	20	50	30	10				10		1				40		40						
42-2, 105	15	25	40	30	15	5	1	40		5	5		5									
42-4, 65	20	40	40	10										20		70	5					
43-1, 120	20	40	40	10	5			15		10	5			20		35						
43-2, 75	30	30	40	10	5	1		20		5	1			10		50	5	1				
43-6, 19	15	25	60	10	5					5	1		5	30		40	5					
43-6, 93	15	70	15	1								1				98						
43-6, 98	10	30	60	5	1					1	1	2				90	1					
43-6, 144	25	35	40	10	5			20						20		35	10	1				
44-2, 90	15	25	60	10	5	5	5	15		5	5		5	15		35	5	1				
44-4, 104	10	30	60	5	5			20		5			5	15		45	5					
Hole 356A																						
1-1, 13	10	30	60	2							20						2	70				
1-4, 85	10	30	60	10	5			10							10	25	15	25		5		
1-5, 16	3	27	70	2	1						1	1				20	5	70				
1-6, 145	10	20	70	10	5			10							15	15	10	35		1		
2-2, 100	10	30	60	10		1					1		1		5	25	10	50				
2-6, 93	20	30	50	2	1				1								5	70	1	10	2	
2-6, 100	20	30	50	10				5	10							10	10	35	10	10	5	

APPENDIX B
Carbonate and Quartz Determinations
Leg 39

Section	Sediment Depth (cm)	$CaCO_3$ (%)	Org (%)	Total Carb (%)	Qtz (%)
2-2	1110	82.01	0.05	9.90	
2-2	1151	72.79	0.69	9.42	12.73
2-2	1195	50.71	0.94	7.03	8.86
3-2	4068	49.55	0.07	6.02	
3-4	4355	41.85	1.01	6.03	11.25
3-6	4692	44.72	0.70	6.07	14.81
4-3	6078	31.93	1.37	5.20	10.32
4-3	6086	43.68	0.17	5.42	
4-5	6359	10.73	0.92	2.21	7.57
5-4	9033	43.48	1.12	6.34	16.63
5-5	9270	46.17	0.07	5.61	
6-1	11466	17.03	1.39	3.43	15.91
6-4	11860	28.55	0.15	3.58	
6-4	11910	19.61	1.03	3.38	5.57
6-6	12295	36.95	0.52	4.99	7.78
7-1	13350	54.70	0.54	7.11	8.53
7-4	13760	17.89	0.71	2.86	6.96
7-4	13770	21.19	0.23	2.77	
8-2	16380	26.58	0.54	3.73	4.73
8-2	16390	34.44	0.15	4.28	
9-2	19254	40.68	0.17	5.06	
9-2	19270	36.51	0.67	5.05	4.56
10-3	22186	24.07	0.85	3.74	4.91
10-3	22192	31.52	0.17	3.95	
10-4	22391	48.94	0.55	6.43	7.24
11-1	23777	26.32	0.18	3.34	
11-1	23783	17.90	0.58	2.73	4.44
12-1	24735	22.92	0.15	2.90	
12-2	24894	22.66	0.57	3.29	4.21
13-2	25856	15.79	0.55	2.45	3.79
14-1	26637	20.59	0.11	2.58	
15-1	27669	42.70	0.86	5.98	3.69
16-1	28596	23.90	0.15	3.02	
16-2	28702	20.91	0.49	3.00	5.09
17-3	29800	14.90	0.39	2.17	
17-4	29970	13.22	0.61	2.20	7.49
18-2	30660	17.57	0.69	2.80	8.27
19-4	31840	43.06	0.07	5.24	
19-4	31840	16.47	0.70	2.68	5.93
20-2	32455	26.19	0.68	3.82	6.81
22-1	34330	32.08	0.57	4.42	6.20
23-2	35350	30.17	0.18	3.80	
23-3	35408	31.13	0.62	4.36	5.98
24-2	36396	48.32	0.41	6.21	3.89
24-3	36445	47.62	0.21	5.93	
24-3	36500	19.73	0.10	2.47	
24-4	36584	66.86	0.09	8.11	
24-5	36820	43.12	0.11	5.29	
24-6	36940	44.19	0.58	5.88	5.27
25-2	37198	45.43	0.82	6.28	7.04
25-5	37730	49.05	0.57	6.46	5.64
26-2	38168	40.92	0.67	5.58	8.96
26-2	38258	48.70	0.17	6.02	
27-1	39085	40.24	0.69	5.55	6.71
28-1	40034	26.18	0.55	3.70	7.40
29-1	40930	40.30	0.85	5.81	8.64
29-2	41090	34.24	0.18	4.29	
29-3	41230	57.57	0.34	7.25	9.76
29-3	41299	69.13	0.08	8.38	
29-4	41344	46.76	0.07	5.68	
29-6	41660	68.04	0.08	8.25	
30-6	42597	49.26	0.53	6.44	10.69
31-5	44380	63.00	0.00	7.56	8.76
31-5	44396	66.51	0.07	8.05	
32-3	45931	40.12	0.07	4.89	11.37
33-2	48655	36.42	0.06	4.43	

APPENDIX B – *Continued*

Section	Sediment Depth (cm)	$CaCO_3$ (%)	Org (%)	Total Carb (%)	Qtz (%)
33-2	48680	40.19	0.02	4,85	10.15
34-2	51520	41.73	0.09	5.10	
34-2	51520	38.89	0.17	4.84	13.27
35-3	54480	37.22	0.10	4.57	15.13
35-3	54550	30.60	0.12	3.79	
36-1	57021	35.36	0.29	4.54	15.14
36-1	57130	44.29	0.13	5.45	
37-4	60380	40.77	0.19	5.08	14.95
37-4	60383	47.76	0.09	5.82	
38-3	64959	34.63	0.29	4.45	12.62
38-3	64986	46.41	0.09	5.66	
39-2	67600	63.18	0.22	7.80	8.75
39-4	68005	35.75	0.36	4.65	13.56
39-5	68071	0.36	1.82	1.86	
39-5	68125	5.29	5.311	5.95	13.08
40-1	69427	55.70	0.38	7.07	2.29
40-5	70007	45.22	0.10	5.53	
40-6	70154	10.13	3.03	5.45	16.64
40-6	70155	13.50	2.46	4.08	
41-2	70484	49.04	0.31	6.19	17.32
41-2	70524	3.81	4.84	5.23	
41-3	70710	14.98	4.84	6.64	16.47
41-4	70804	32.43	11.97	15.86	10.41
41-4	70806	38.68	10.45	15.14	8.90
41-5	71048	51.81	0.64	6.86	
42-3	71696	20.08	0.102	2.51	
43-4	72657	33.09	0.12	4.09	
43-5	72897	28.04	0.08	3.45	
43-5	72897	20.51	0.22	2.68	
44-4	73700	43.61	0.10	5.33	
1-4	2430	32.47	0.08	3.97	12.15
1-4	2436	27.78	0.81	4.14	12.15
1-4	2483	28.97	0.53	4.01	12.81
1-5	2525	36.63	0.59	4.99	15.29
1-5	2595	41.52	0.11	5.09	
1-6	2795	39.16	0.86	5.56	15.52
2-5	3462	45.36	0.14	5.59	
2-5	3567	34.28	0.88	4.99	16.74

Site 356 Hole Core 2 Cored Interval: 9.5-19.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
PLIOCENE	NN17		AM		0				
PLIOCENE	NN16		AM						
			AM		1	0.5			51
EOCENE	NP13		CM			1.0			85, 89
			CM						
		AG							
PLIOCENE	(N19) S. dehiscens/G. altispira; Discoaster surculus NN16		AM		2				
			AM		3				
			AM		4				
			AM		5				
			AM	–	6		VOID		
		AG	AM	–	Core Catcher				

LITHOLOGIC DESCRIPTION

FORAM-NANNO OOZE, grayish orange (10YR 7/4).

SS 51	SS 85
60% Calcareous Nannos	60% Calcareous Nannos
15% Forams	20% Forams
10% Clay	10% Zeolite
5% Sponge spicules	10% Quartz Sand
5% Authigenic carbonate (sand size)	

SS 89
50% Calcareous nannos
30% Forams
15% Clay
10% Carbonate authigenic

Zeolitic foram-nanno ooze (83-88 cm) (108-113 cm) very pale orange (10YR 8/2), a coarser layer at bottom which is richer in forams than the surrounding displaced lower Eocene sediment.

Bomb CO_3: Sec. 2, 12 cm = 82%

Zeolitic ooze as above (103-108 cm) displaced.

95-104 void

Site 356 Hole Core 3 Cored Interval: 38.0-47.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.
EARLY MIOCENE	(N4) G. quadrilobatus primordius/kugleri; Discoaster druggi NN2				0					
			AM		1	0.5, 1.0			128	
			AM		2					
			AM		3				67	
			AM		4					
			AM		5				23	
			AM		6				141	
		AM	CM	–	Core Catcher					

LITHOLOGIC DESCRIPTION

FORAM-NANNO ooze, yellowish gray (5Y 8/1), contains segments, lumps of pinkish gray (5YR 8/1) NANNO-FORAM ooze.
SS 128 (Pinkish gray ooze)
40% Forams
25% Calcareous nannos
15% Quartz
10% Clay

Pinkish gray ooze at 75 cm, Sec. 2.

Mn crust, contains bores made by animals

Limestone pebble (2 cm)

Mn crust

SS 67 (Gray FORAM-NANNO OOZE)
35% Calcareous nannos
15% Forams
20% Authigenic carbonate
15% Quartz
15% Clay

Pink ooze

Faintly bedded 22-40 cm, Sec. 4

Slight change in color to orange 82 cm, Sec. 4

Slightly orangish in color 108 cm, Sec. 4

Nodule of ferruginous calcareousooze.
SS 23
30% Nannos
10% Forams
20% Carbonate
20% Fe-oxide?
10% Zeolite
10% Quartz

Burrows(?), color becomes slightly darker deformed bedding below (127-136 cm, Sec. 5).
SS 141
25% Nannos
20% Forams
15% Carbonate
15% Clay
15% Quartz

At 137 cm (Sec. 6) with sharp contact color changes to light bluish gray (5B 7/1). Composition remains almost unchanged.

FORAM-NANNO OOZE

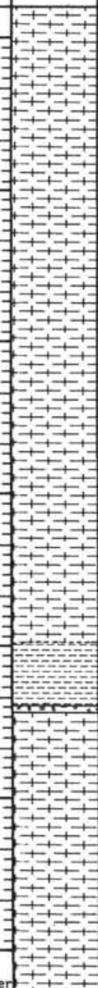
Explanatory Notes in Chapter 1

Site 356 Hole Core 4 Cored Interval: 57.0-66.5 m

AGE: EARLY MIOCENE

ZONE: (N4) G. quadrilobatus primordius/kugleri; Discoaster druggi NN2; C. tetrapera

SECTION	FORAMS	COCCO-LITHS	RADS	LITHO. SAMPLE
0				
1		AM	RP	
2		CM	RP	70
3		CM	CP	
4		CM	CM	
5		CM		59
6		CM	CM	
Core Catcher	AM	AM	CG	



LITHOLOGIC DESCRIPTION

FORAM-NANNO OOZE, light bluish gray (5B 7/2), contains black streaks on the surface throughout the core most probably because of very fine-grained pyrite.

SS 70
40% Nannos
20% Forams
15% Carbonate
10% Quartz (silt size)
5% Sponge spicules
5% Zeolite

Bomb CO_3: Sec. 3, 89 cm = 43%
Bomb CO_3: Sec. 3, 140 cm = 5%

SS 59
90% Volcanic glass
5% Authigenic carbonate
5% Nannos (calcareous)
TR% Quartz, Feldspar

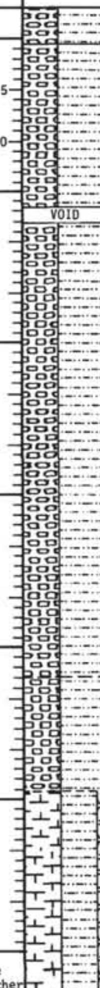
Volcanic ash (58-61, Sec. 5), sand (90), Clay (10) layer.

Site 356 Hole Core 5 Cored Interval: 85.5-95.0 m

AGE: EARLY MIOCENE

ZONE: (N4) G. quadrilobatus primordius/kugleri; Triquetrorhabdulus carinatus NN1; L. elongata

SECTION	FORAMS	COCCO-LITHS	RADS	LITHO. SAMPLE
0				
1		AM	FPM	6, 100
2		AM	FPM	
3		CM	FPM	
4		CM	FPM	
5		CM	CM	
6		CM	CM	75
Core Catcher	FM	CM	CM	



LITHOLOGIC DESCRIPTION

MARLY CALCAREOUS OOZE, light bluish gray (5B 7/1), silty clay, black streaks on cut surface.

SS 6 (Dark greenish gray band siliceous calcareous ooze)
20% Forams
25% Calcareous nannos
15% Quartz Silt
5% Volcanic glass
10% Authigenic carbonate
25% Siliceous

SS 100
15% Forams
15% Calcareous nannos
20% Silt Quartz
10% Clay
5% Rads
5% Sponge spicules
10% Authigenic carbonate

Sec. 3 is probably marly calcareous ooze.

Black mottles on cut surface, pyrite? (85-95 cm, Sec. 3).

Bomb CO_3: Sec. 3, 100 cm = 51%

Fells more sandy than Sections 1 and 2, similar to 3.

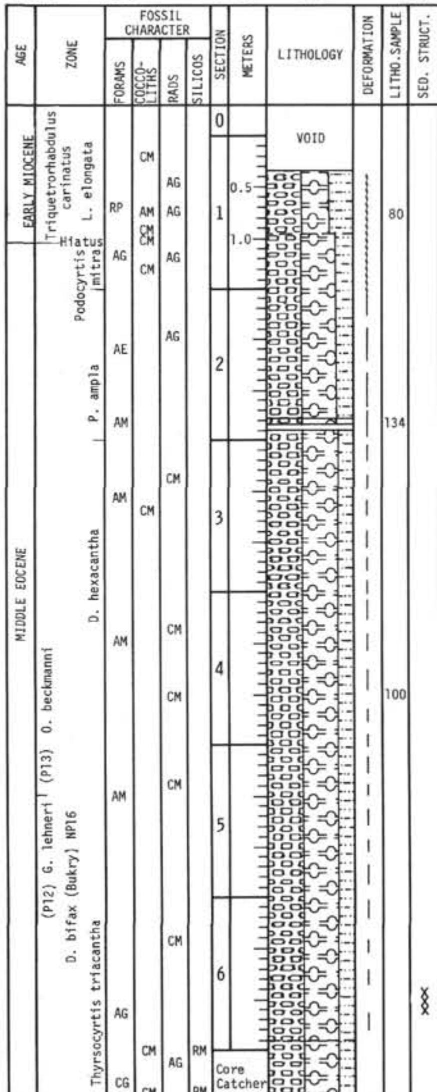
Marly calcareous ooze

Greenish gray (5GY 6/1), moderately mottled, 30-140 cm, Sec. 5.

SS 75
35% Calcareous nannos
15% Forams
10% Silt Quartz
10% Clay
5% Glass
10% Carbonate authigenic
15% Siliceous biogenic

Explanatory Notes in Chapter 1

Site 356 Hole Core 6 Cored Interval: 114.0-123.5 m



LITHOLOGIC DESCRIPTION

39-95 cm (Sec. 1) MARLY NANNO OOZE, greenish gray (5GY 6/1).

95 cm and below, greenish gray (5G 6/1), CALCAREOUS SILICEOUS OOZE, slightly mottled (pyrite?).

SS 80 (Marly nanno ooze)
30% Calcareous nannos
10% Forams
15% Quartz Silt
10% Clay
10% Authigenic carbonate
25% Siliceous biogenic

(133-134, 136 cm) medium light gray band (N6) fine pyrite?

SS 134 (Calcareous siliceous ooze)
20% Calcareous nannos
10% Forams
15% Diatoms
15% Rads
10% Sponge spicules
10% Authigenic carbonate
10% Quartz
10% Clay

SS 100 (Calcareous siliceous ooze)
20% Calcareous nannos
10% Forams
15% Diatoms
20% Rads
10% Sponge spicules
5% Quartz Silt
10% Clay
10% Authigenic carbonate

Greenisb gray (5G 6/1)

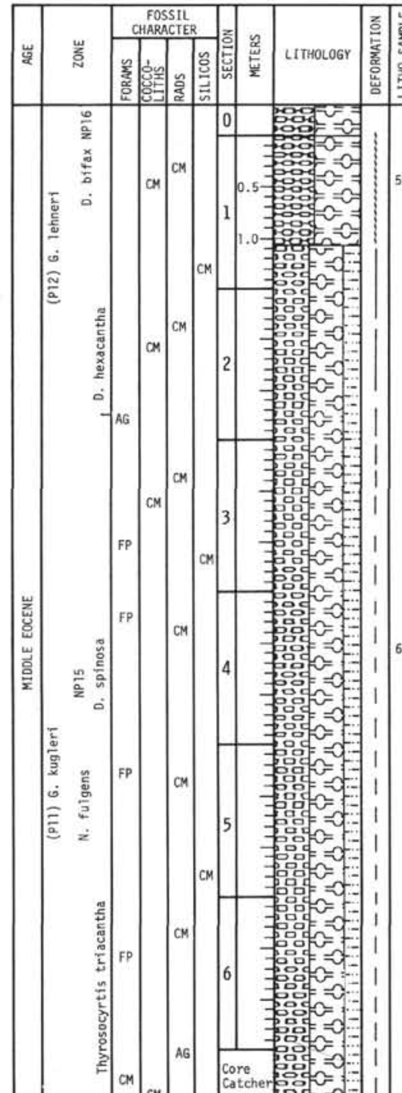
64-91 cm (Sec. 6) light greenish gray (5GY 8/1)

Burrows (91-135) greenish gray (5G 6/1)

135-150 cm light greenish gray (5GY 8/1)

Dark layer (N6)

Site 356 Hole Core 7 Cored Interval: 133.0-142.5 m



LITHOLOGIC DESCRIPTION

SILICEOUS-CALCAREOUS CHALK (0-107 cm), light greenish gray (5G 8/1), sandy.

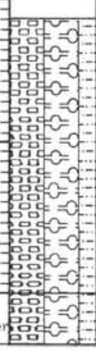
SS 50
20% Forams
15% Calcareous nannos
15% Diatoms
15% Rads
5% Sponge spicules
10% Authigenic carbonate
10% Clay
5% Sand and Silt

107 cm down, SILICEOUS-NANNO OOZE, greenish gray (5G 6/1), mottled with gray and brown color on cut surface, clayey, dark band at 111 cm.

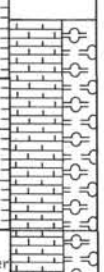
SS 60 (Siliceous-Nanno ooze)
25% Nannos
5% Forams
5% Authigenic carbonate (total CO_3=35%)
10% Diatoms
15% Rads
10% Sponge spicules (total SiO_2=35%)
10% Silt
10% Clay
5% Zeolite
5% Micronodules

Explanatory Notes in Chapter 1

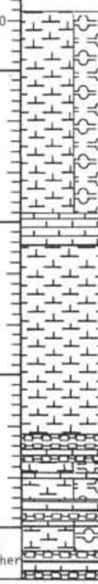
Site 356 Hole Core 8 Cored Interval: 161.5-171.0 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SILICOS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE EOCENE	(P9/P10) H. aragonensis; N. fulgens* NP15; Thyrsocyrtis triacantah; D. spinosa	CG, CM	CM, CM, CM	CM, CM, AM	FM, FM	0, 1, 2, Core Catcher	0.5, 1.0	VOID 	△	105	SILICEOUS-NANNO OOZE Greenish gray (5G 6/1), slightly mottled, clayey. Nanno-siliceous ooze 103-106 medium bluish gray band (5B 5/1) 106-109 light bluish gray SS 105 10% Sponge spicules 25% Rads 15% Diatoms 20% Calcareous nannos 5% Quartz 10% Clay 5% Opaques 5% Authigenic carbonate 5% Zeolite

Site 356 Hole Core 9 Cored Interval: 190.0-199.5 m

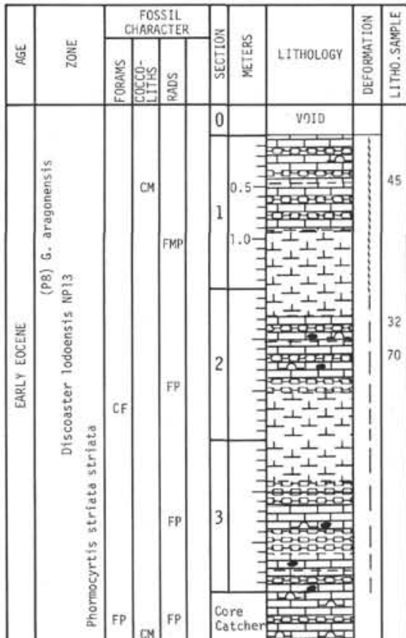
AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE EOCENE	(P9) A. densa; N. fulgens NP15; Thrysocyrtis triacanta; D. spinosa	CM, AE, AP	CM, CM	CM, CM, AM	0, 1, 2, Core Catcher	0.5, 1.0	VOID 	△	49, 143	SILICEOUS NANNO CHALK, greenish gray (5G 6/1), moderately indurated. SS 49 45% Calcareous nannos 5% Forams 10% Authigenic carbonate 30% Siliceous 10% Silt and Clay TR% Pyrite SS 143 (Siliceous calcareous ooze) 25% Calcareous nannos 15% Forams 10% Diatoms 15% Rads 10% Sponge spicules 10% Silt and Clay 5% Authigenic carbonate 5% Zeolite TR% Dolomite rhombs and Pyrite 143-145 cm horizon relatively rich in forams (15%) 145-150 cm Forams >15%, horizon appears more sandy than 143-145 cm interval

Site 356 Hole Core 10 Cored Interval: 218.5-228.0 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SILICOS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY EOCENE MIDDLE	(P8) G. aragonensis; Rhabdosphaera inflata NP15; Hiatus?; D. kuepperi	CP, CP, AG, CP	AM, AM, CM, CM, CM	FPM, FPM, FP, FP, CP/M	CM, FM	0, 1, 2, 3, 4, Core Catcher	0.5, 1.0	VOID 	△	85, 73, 86	SILICEOUS-NANNO OOZE (92 cm in Sec. 1 to 143 cm in Sec. 2), greenish gray (5G 6/1), some chalk fragments in the drilling breccia from above. 143 cm in Sec. 2 to 24 cm in Sec. 3, nanno chalk, greenish gray (5G 6/1) SS 85 (Nanno ooze) 40% Calcareous nannos 10% Forams 10% Authigenic carbonate 20% Silt, Clay 10% Zeolite 5% Opaques 5% Silica 24 cm in Sec. 3 to 60 cm in Sec. 4, greenish gray (5G 6/1) SS 73 (Silicified chalk/limestone) 25% Forams 15% Authigenic carbonate 20% Silica 10% Quartz 10% Clay 10% Zeolite 10% Diatoms 60 cm to 83 cm silicified chalk (limestone), light greenish gray (5G 8/1) SS 86 (Zeolitic nanno chalk) 30% Calcareous nannos 20% Forams 10% Authigenic carbonate 5% Quartz Silt 15% Clay 5% Diatoms 15% Zeolite 85-93 cm greenish gray ooze, siliceous nanno ooze 93-100 cm silicified chalk/limestone 100-127 cm siliceous nanno ooze 127-134 cm silicfied chalk/limestone (light greenish gray (5G 8/1) 134-150 cm medium bluish gray (5B 5/1), silicified chalk/limestone

Explanatory Notes in Chapter 1

Site 356 Hole Core 11 Cored Interval: 237.5-247.0 m



LITHOLOGIC DESCRIPTION

Silicified chalk/limestone, medium bluish gray (5B 5/1) at 0-49 cm.

Silicified chalk/limestone, light greenish gray (5G 8/1) at 49-94 cm.

Nanno ooze, greenish gray (5G 6/1), mottled, at 94 cm Sec. 1 to 25 cm Sec. 2.

Silicified chalk/limestone, greenish gray (5G 6/1) mottled, at 25-50 cm.

Bomb CO_3: Sec. 2, 69 cm = 44%

At 50-100 cm silicified chalk/limestone, light greenish gray (5G 8/1) occasional white streaks of white or very light gray layers composed of dolomitic foraminifera limestone (smear slide 70 is from such dolomitic limestone).

Nanno ooze, greenish gray (5G 6/1) at 100 cm in Sec. 2 to 40 cm in Sec. 2.

Silicified chalk limestone, light greenish gray (5G 8/1) with white streaks of dolomitic limestone as above at 40-130 cm.

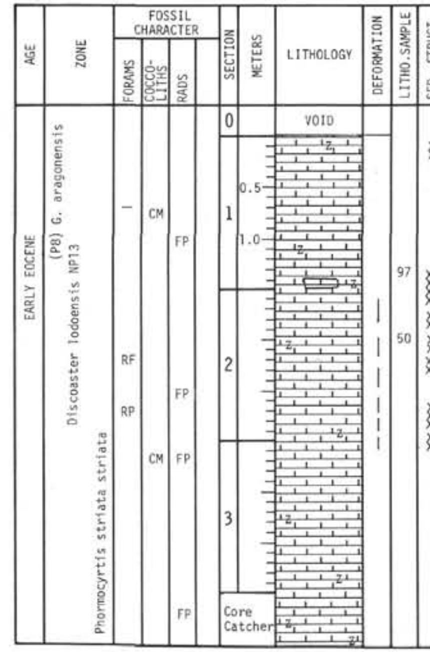
Silicified chalk/limestone greenish gray (5G 6/1) at 130-150 cm.

SS 1-45 (Silicified chalk/limestone)
20% Calcareous nannos
15% Rads
10% Authigenic carbonate
25% Silica
15% Clay
5% Quartz
10% Zeolite

SS 2-32 (Silicified chalk/limestone)
15% Calcareous nannos
10% Forams
10% Authigenic carbonate
20% Silica cement
20% Zeolite
20% Clay
5% Micronodules

SS 2-70 (Dolomitic foraminiferal limestone)
25% Forams
10% Calcareous nannos
20% Silica cement
10% Clay
10% Authigenic carbonate
20% Dolomite rhombs
5% Zeolite

Site 356 Hole Core 12 Cored Interval: 247.0-256.5 m



LITHOLOGIC DESCRIPTION

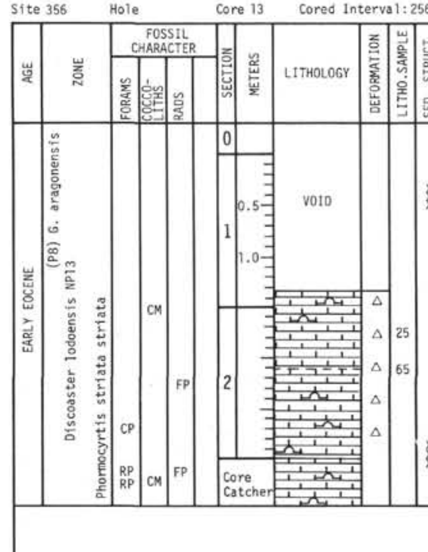
Zeolitic nanno chalk, greenish gray (5G 6/1), burrowed, moderate yellowish brown (10YR 5/4) color in the burrows, burrows are generally parallel to the bedding. Some burrows are large (~1 cm) in diameter. Dark rim (probably pyrite) present around burrows. Large burrows at 12 and 97 cm.

SS 97 (This slide is from brown material in burrow, siliceous limestone)
10% Nannos calcareous
20% Forams
10% Carbonate
40% Silica cement
10% Zeolite

SS 50 (Zeolitic nanno chalk)
40% Calcareous nannos
15% Forams
10% Authigenic carbonate
20% Zeolite
5% Diatoms
10% Clay

20 burrows (~1 cm or less) in the first section
65 burrows in the second section
smaller burrows (<<1 cm) are darker in color
large burrow at 63-64 cm in the second section

Site 356 Hole Core 13 Cored Interval: 256.5-266.0 m



LITHOLOGIC DESCRIPTION

SILICIFIED NANNO CHALK, medium bluish gray (5B 5/1), 130 cm (Sec. 1) to 60 cm (Sec. 2), burrowed 37-44 cm.

SS 25 (Silicified nanno chalk)
30% Calcareous nannos
5% Forams
5% Authigenic carbonate
10-15% Zeolite
20% Silica cement
20% Clay
5% Chlorite
5% Quartz Silt

Dark band at color boundary.

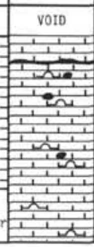
SS 65 (From white layer FORAM CHALK)
70% Forams
5% Calcareous nannos
10% Authigenic carbonate
10% Silica cement
5% Zeolite

SILICIFIED NANNO CHALK, greenish gray (5G 6/1) 60 cm (Sec. 2) to end of core. Contains foram-rich layers appearing as white bands (smear at 65). Color is lighter probably because of more forams than above. Burrowed at 135-140 cm.

Explanatory Notes in Chapter 1

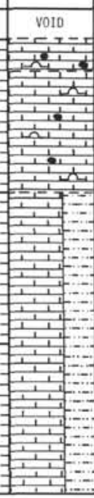
Site 356 Hole Core 14 Cored Interval: 266.0-275.5 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY EOCENE	unzoned; Discoaster lodoensis NP13; Buryella clinata	RP	CM	FP	0		VOID			Silicified nanno chalk, greenish gray (5G 6/1), black mottles, 15-16 burrows in the section.
					1	0.5, 1.0		△ △ △ △ △	60	dark band SS 60 20% Calcareous nannos 10% Forams 15% Authigenic carbonate 10% Zeolite 15% Clay 25% Silica Cement 5% Quartz
		RP	CM	FP CM	Core Catcher					



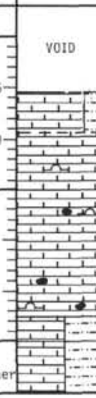
Site 356 Hole Core 15 Cored Interval: 275.5-285.0 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.	LITHOLOGIC DESCRIPTION
EARLY EOCENE	(P7) G. formosa; Discoaster lodoensis NP13; Buryella clinata		CM	RP	0		VOID				Silicified nanno chalk, medium bluish gray (5B 5/1) at 0-30 cm. Silicified nanno chalk, greenish gray (5G 6/1), mottled, burrowed at 30-150 cm. 1 cm wide burrow at 90 cm. SS 119 (Silicified foram chalk occurs in white band) 35% Forams 10% Diatoms 30% Authigenic carbonate 20% Silica 5% Quartz
					1	0.5, 1.0			119	x X X X X	
		FP			2					X X	Marly nanno chalk (Secs. 2 and 3). Medium bluish gray (5B 5/1), mottled, burrowed throughout. Burrowing at 35, 45-50, 60, 90, cm in Sec. 1; 10, 30 cm in Sec. 2; 45, 112 cm in Sec. 3.
		CM	FP	RM/P	3				100	X X	SS 100 (MARLY NANNO CHALK) 30% Calcareous nannos 15% Forams 10% Authigenic carbonate 10% Zeolite 10% Silica cement 20% Clay 5% Quartz



Site 356 Hole Core 16 Cored Interval: 285.0-294.5 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY EOCENE	(P7) G. formosa; Discoaster lodoensis NP13			RP	0		VOID			56 cm (Sec. 1) to 90 cm (Sec. 1) MARLY NANNO CHALK, medium bluish gray (5B 5/1), mottled, burrowed. SILICIFIED NANNO CHALK (90 cm Sec. 1 to 124 cm Sec. 2), greenish gray (5G 6/1), mottled, burrowed.
		CP			1	0.5, 1.0			20	SS 20 (Siliceous nanno chalk) 30% Calcareous nannos 10% Forams 10% Authigenic carbonate 20% Silica cement 10% Clay 5-10% Quartz 5% Zeolite
		FP	CM CM	RP	2					Marly nanno chalk (124 cm to end of core), greenish black (5G 2/1), feldspars show overgrowths.
	Hiatus									
LATE PALEOCENE	(P4) Heliolithus kleinpelli NP6	CP		RP					147	SS 147 35% Calcareous nannos 10% Authigenic carbonate 15% Clay 5% Mica (Chlorite, Biotite) 20% Silty Quartz 5% Feldspar 5% Zeolite 5% Opaques
		CM	FM	FP	Core Catcher					



Explanatory Notes in Chapter 1

Site 356 Hole Core 17 Cored Interval: 294.5-304.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.
LATE PALEOCENE	(P4) G. pseudomenardii; Heliolithus kleinpelli NP6				0					
		FP	AM	RP	1	0.5, 1.0			80	
		FP	AM		2				14	X X
			CM	RP	3					X X X
		—	AM		4					XXXX XXX
		FP	CM	RP	5					
			CM		6					
		FM	CM	RP	Core Catcher					

LITHOLOGIC DESCRIPTION

MARLY NANNO CHALK, greenish black (5G 2/1). Mottled with burrows, mostly <1 cm in size (intermediate size), somewhat fissile.

SS 80 (Marly nanno chalk)
40% Calcareous nannos
20% Clay
10% Quartz
10% Mica
10% Zeolite
5% Opaques
5% Feldspar (Feldspars have overgrowths)

SS 14 (Composition in burrows, marly zeolitic nanno chalk)
30% Calcareous nannos
5% Forams
10% Authigenic carbonate
20% Zeolite
10% Quartz
15% Clay
5% Mica
5% Opaques

Section 3 has burrows slightly larger than Sections 1 and 2 (intermediate and large).

Bomb CO_3: Sec. 3, 130 cm = 61%
Bomb CO_3: Sec. 3, 148 cm = 81%
Bomb CO_3: Sec. 5, 132 cm = 82%

Burrows will be identified by width size in this core and others to follow, 1-2 mm small, 2 mm-~1 cm intermediate, >1 cm large. Burrows are horizontal, parallel to bedding unless otherwise stated.

Site 356 Hole Core 18 Cored Interval: 304.0-313.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.
LATE PALEOCENE	(P4) G. pseudomenardii				0		VOID			
		AM	CM	RP	1	0.5, 1.0				X X
		AM	CM	RP	2				50	X X X X
				RP	3					X X X
	(P3) G. pusilla/angulata; Fasciculithus tympaniformis NP5	FP			4					
				RP	5					X X
		AM			6					
		CM	CM	FP	Core Catcher					

LITHOLOGIC DESCRIPTION

MARLY NANNO CHALK, greenish black (5G 2/1), burrowed mostly small to intermediate sized.

Large burrow at 145 cm.

SS 50
40% Calcareous nannos
10% Authigenic carbonate
10% Quartz
15% Clay
15% Zeolite
5% Forams
5% Opaques (Pyrite)
TR% Authigenic feldspar

Burrows at 31, 70, 116 in Sec. 2.

Bomb CO_3: Sec. 2, 146 cm = 19%

Burrows at 32, 75-80 cm in Sec. 3.

Sec. 4, sparse burrowed throughout.

Burrows at 130.

Explanatory Notes in Chapter 1

Site 356 Hole Core 19 Cored Interval: 313.5-323.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.	LITHOLOGIC DESCRIPTION
LATE PALEOCENE	(P3) G. pusilla/angulata; Fasciculithus tympaniformis NP5				0		VOID				NANNO CHALK, greenish black (5G 2/1), moderately burrowed, most burrows horizontal but some (<10%) perpendicular to bedding.
				RP	1	0.5, 1.0					
		CG			2				100		SS 100 (Nanno chalk) 50% Calcareous nannos 10% Authigenic carbonate 5% Forams 10% Zeolite 10% Clay 10% Quartz 5% Feldspar 5-TR% Mica Medium-size burrows, some burrows appear compressed by overburden. Section 3: most burrows are intermediate size some (~10%) are large, some appear compressed.
			CM	RP	3						
					4				137		Same kind of burrows as in Section 3. SS 137 (Marly calcareous chalk) 25% Calcareous nannos 10% Forams 10% Authigenic carbonate 20% Zeolite 15% Quartz 10% Clay 5% Limonite 5% Opaques (130-150 cm) Breccia consisting of greenish gray (5G 6/1) angular to subrounded pebble size limestone/chalk fragments. Slump because of late Campanian, early Maestrichtian age (smear 137 from this breccia). Section 4: intermediate to large burrows.
			CM	RP	5						
					6						50-80 cm large and intermediate burrows, medium bluish gray (5B 5/1).
		CM	CM	RP	Core Catcher						

Site 356 Hole Core 20 Cored Interval: 323.0-332.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.	LITHOLOGIC DESCRIPTION
LATE PALEOCENE	(P3) G. pusilla/angulata; Fasciculithus tympaniformis NP5				0		VOID				NANNO CHALK, greenish black (5G 2/1), burrows, burrows are dark gray/black in color (clay 70/ silt 20/ sand 5-10). Large burrow at 23, small burrows at 50-59.
				RP	1	0.5, 1.0					Large burrow at 10
			CM		2				100		Small burrows at 90 SS 100 (NANNO CHALK) 60-70% Calcareous nannos 10-20% Authigenic carbonate 1- 5% Clay 1% Feldspar (Authigenic?) 1% Mica 1% Glauconite 1% Zeolite 1% Siliceous material 1 each Diatoms, Rads, Fish remains Color changes to medium bluish gray (5B 5/1) at 130.
		—		—	3						Section 3 shows burrows at 10, 55 and 120-130 cm, mostly medium to small burrows.
		CM	CM	R/FP	Core Catcher						

Explanatory Notes in Chapter 1

Site 356 | Hole | Core 21 | Cored Interval: 332.5-342.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: COCCO-LITHS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.	LITHOLOGIC DESCRIPTION
LATE PALEOCENE	Fasciculithus tympaniformis NP5		CM		0						MARLY NANNO CHALK, dark greenish gray (5GY 4/1), (clay 70/Silt 25/Sand 5), burrowed.
					1	0.5	VOID				
						1.0					
					2				90		Section 2: intermediate burrows at 14, 32, 56, 90, large burrows at 70, small 140-150. SS 2-90 (Marly nanno chalk) 50-60% Calcareous nannos 5-10% Authigenic carbonate 20-30% Clay 1- 2% Quartz (twined) Feldspar, Mica, Glauconite, Fe-oxides, Forams, Diatoms, Rads, Sponge spicules 1 each.
					3						Section 3: small and intermediate burrows at 28-30, 70, 130 cm.
	(P3) G. pusilla/angulata				4						Section 4: small and intermediate burrows at 7, 28, 45, 70, 100, 130-140 cm, some burrows are inclined to the bedding plane.
		CM	CM	R/R P/M	Core Catcher						

Site 356 | Hole | Core 22 | Cored Interval: 342.0-351.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: COCCO-LITHS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.	LITHOLOGIC DESCRIPTION
LATE PALEOCENE	Fasciculithus tympaniformis NP5				0						MARLY NANNO CHALK, dark greenish gray (5GY 4/1) burrowed. Section 1: intermediate size burrows throughout.
					1	0.5	VOID				
						1.0					
					2						Section 2: small and intermediate size burrows. Large burrow at 145.
			CM		3				100		SS 100 (Marly nanno chalk) 40% Calcareous nannos 10% Forams 5% Authigenic carbonate 10% Quartz 15% Clay 5% Volcanic glass (with hexagonal, and opaque inclusions) 5-10% Zeolite (some resorbed) 5% Opaques Section 3: very small burrows at 85-86 cm, large burrow at 135, small and intermediate size burrows.
					4						Section 4: small and intermediate size burrows at 11, 35, 60, 120 and 136 cm.
					5						Section 5: large burrows at 25, 57, 85 cm, very small ones at 100.
	(P3) G. pusilla/angulata		CM		6						Section 6: large burrows at 20, 40, 50 cm, vertical burrows at 27-30, color becomes slightly lighter at 80 cm.
		CM	CM	RP	Core Catcher						

Explanatory Notes in Chapter 1

Site 356 Hole Core 23 Cored Interval: 351.5-361.0 m

AGE: LATE PALEOCENE

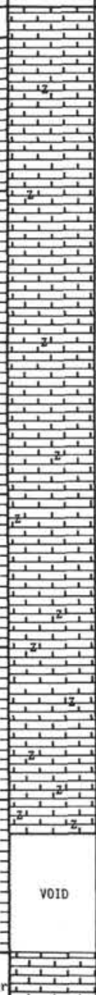
ZONE: Fasciculithus tympaniformis NP5; (P3) G. pusilla/angulata

FOSSIL CHARACTER: FORAMS: CM, CG, CM; COCCO-LITHS: CM, CM, CM, CM, CM, CM, CM

SECTION: 0, 1, 2, 3, 4, 5, 6, Core Catcher

METERS: 0.5, 1.0

LITHOLOGY:



DEFORMATION: NO DISTURBANCE

LITHO. SAMPLE: 56, 100, 71

LITHOLOGIC DESCRIPTION

Zeolitic nanno chalk, alternating bands of darker color (medium bluish gray, 5B 5/1) and lighter color (greenish gray, 5G 6/1), well burrowed in all the sections, excellent examples of Zoophycus, most burrows are dark gray, but some are light gray in color (smear slide 3-71 is from a light-colored burrow).

Section 1: 0-30 dark, 30-40 light, 40-50 dark, 50-70 light, 70-80 dark, 80-100 light, 100-115 dark, 115-145 light, 145-150 dark. Intermediate size Zoophycus at 74, 94, small burrows at 100, light gray burrows appear at 130.

SS 56 (Zeolitic nanno chalk)
40% Calcareous nannos
5-10% Forams
10% Authigenic carbonate
15% Zeolite
10% Clay
5% Quartz
5% Opaques
5-TR% Mica

Section 2: 0-18 dark, 18-42 light, 42-56 dark, 56-70 light, 70-90 dark, 90-115 light, 115-127 dark, 127-150 light. Small to intermediate size burrows at 30-40, 90-105, 127. Burrows appear just below the boundary from dark to light layer.

SS 100 (Zeolitic nanno chalk)
40% Calcareous nannos
5-10% Forams
10% Authigenic carbonate
15% Zeolite
10% Clay
5% Quartz
5-TR% Mica
5% Opaques

SS 71 (From light colored burrow, Zeolitic foram-nanno chalk)
30% Calcareous nannos
20% Forams
15-20% Zeolite
10% Clay
5% Quartz
5% Feldspar
5% Authigenic carbonate
5-TR% Opaques
10% Radiolarians
5% Diatoms TR
5% Limonite

Section 3: 0-10 dark, 10-30 light, 30-40 dark, 40-69 light, 69-77 dark, 77-100 light, 100-107 dark, 107-132 light, 132-150 dark. Small burrows throughout Section 3, especially between 10-30, 50, 70-71, some burrows intermediate size (10-30 cm).

Section 4: 0-20 light, 20-32 dark, 32-150 light, small burrows throughout.

Section 5: light color, 137-150 some dark bands, very small burrows at 95, intermediate size burrow at 124.

Section 6: light color, small burrows at 20 cm.

Site 356 Hole Core 24 Cored Interval: 361.0-370.5 m

AGE: LATE PALEOCENE; EARLY PALEOCENE

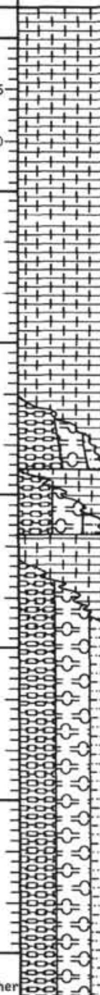
ZONE: (P3) G. pusilla/angulata; Fasciculithus tympaniformis NP5; Ellipsolithus macellus NP4

FOSSIL CHARACTER: FORAMS: AG, AE, AG, AG, AG, CG; COCCO-LITHS: CM, AM, AM, CM, CM, AM, CM

SECTION: 0, 1, 2, 3, 4, 5, 6, Core Catcher

METERS: 0.5, 1.0

LITHOLOGY:



LITHO. SAMPLE: 70, 29, 35, 37, 39

LITHOLOGIC DESCRIPTION

FORAM NANNO CHALK, greenish gray (5G 6/1), well burrowed, Zoophycus quite common.

Section 1: Zoophycus at 0-12, 50-60, 90, 134 cm, 148 cm burrow with the following shape present, similar burrow also present at Section 2, 85 cm.

SS 70 (Foram nanno chalk)
45% Calcareous nannos
15% Forams
10% Authigenic carbonate
10% Zeolite
5% Diatoms
10% Clay
5% Quartz

Section 2: Zoophycus at 10, 20, and 97 cm, vertical burrow at 56, Y-shaped burrow at 110.

Section 3: 57-125 cm, slump material of late Cretaceous age MARLY SILICEOUS CHALK, dark yellowish brown (10YR 4/2), mixed with greenish gray (5G 6/1) sediment. Here termed Slump III.

125 (Sec. 3) to 40 (Sec. 4): Slump II, dark yellowish brown as above, contains dark and light gray sediment at the base. Soft sediment deformation near base. 40-67 cm greenish gray foram-nanno chalk.

Slump I: 67 cm (Sec. 4) to end of core slumped dark yellowish brown marly siliceous chalk, mottled.

Smears all in slumped material:

SS 4-29 (Marly siliceous chalk, yellow brown)
10% Calcareous nannos
25% Forams
10% Authigenic carbonate
5% Diatoms
15% Rads
10% Zeolite
10% Clay
10% Quartz
5% Limonite

SS 4-35 (Marly calcareous chalk, dark gray, thin layer, just under yellow brown)
20% Calcareous nannos
25% Forams
5% Authigenic carbonate
10-15% Zeolite
5% Diatoms
10% Clay
20% Quartz
5-TR% Feldspar (overgrowth)
5% Rads

SS 4-37 (light gray, forming the core of deformed = sediment structure, nanno chalk)
60% Calcareous nannos
10% Forams
10% Authigenic carbonate
5% Clay
5-TR% Quartz
5% Zeolite
5% Sponge spicules
TR% Limonite, Rads

SS 4-39 (Nanno chalk, dark gray thin layer in contact with in-place sediment)
60% Calcareous nannos
10% Forams
10% Authigenic carbonate
5-10% Quartz
10% Clay
TR% Zeolite

Section 5: 0-20 cm - some gray color in the sediment.

Section 6: 100-150 cm, some gray in the sediment.

Explanatory Notes in Chapter 1

Site 356 Hole Core 25 Cored Interval: 370.5-380.0 m

AGE | ZONE | FOSSIL CHARACTER (FORAMS, COCCO-LITHS, RADS) | SECTION | METERS | LITHOLOGY | DEFORMATION | LITHO. SAMPLE | SED. STRUCT. | LITHOLOGIC DESCRIPTION

AGE: EARLY PALEOCENE

ZONE: (P3) G. pussila-G. angulata; Ellipsolithus macellus NP4

Fossil character: CM, CM, CM, AG, AG AM, AM, CG CM F/VP

Sections: 0, 1, 2, 3, 4, 5, Core Catcher; Meters: 0.5, 1.0

Lithology: VOID

Litho. sample: 95, 100

LITHOLOGIC DESCRIPTION

NANNO CHALK, pinkish gray (5YR 8/1), burrowed. Light greenish gray (5GY 8/1) interval 83-150 cm (Sec. 2), marly nanno chalk, slightly burrowed.

Slump 120-135 cm.

Base of Slump I at 135 cm, dark yellowish brown (10YR 4/2) MARLY SILICEOUS CHALK.

Bomb CO_3: Sec. 2, 80 cm = 49%

SS 95 (Marly nanno chalk, light greenish gray)
40% Calcareous nannos
10% Forams
10% Authigenic carbonate
10% Zeolite
10% Rads
10% Clay
5-10% Quartz
5% Opaques

SS 100 (Nanno chalk, pinkish gray)
60% Calcareous nannos
10% Forams
10% Authigenic carbonate
10% Rads
10% Quartz
TR% Opaques, Limonite

Small burrows (50-60 cm).

Small burrows.

Site 356 Hole Core 26 Cored Interval: 380.0-389.5 m

AGE | ZONE | FOSSIL CHARACTER (FORAMS, COCCO-LITHS, RADS) | SECTION | METERS | LITHOLOGY | DEFORMATION | LITHO. SAMPLE | SED. STRUCT. | LITHOLOGIC DESCRIPTION

AGE: EARLY PALEOCENE

ZONE: (P2) Ellipsolithus macellus NP4; (P1c) C. danicus NP3

Fossil character: CM, CM, AM, AG, AM, AG AM, AE, CM, AM CM F/VP

Sections: 0, 1, 2, 3, 4, 5, 6, Core Catcher; Meters: 0.5, 1.0

Litho. sample: 100, 30

LITHOLOGIC DESCRIPTION

Foram nanno chalk, pinkish gray (5YR 8/1), homogeneous.

Nanno chalk, greenish gray (5G 6/1) 105 (Sec. 4) to 45 (Sec. 5).

Some gray color 80-115 cm.

Small burrows.

Some gray between 120 and 150 cm (Sec. 2).

SS 100 (Foram nanno chalk)
40% Calcareous nannos
20% Forams
10% Authigenic carbonate
10% Clay
5% Quartz
TR- 5% Zeolite
TR- 5% Opaques
TR- 5% Limonite
10% Rads

Bomb CO_3: Sec. 2, 78 cm = 53%

Small burrows at 144.

Sec. 4: small burrows throughout.

Small burrows at 42.

Burrows, vertical burrow at 88 cm.

Color changes to greenish gray at 105 (Sec. 4) to 45 (Sec. 5).

SS 30 (Nanno chalk)
45% Calcareous nannos
10% Forams
10% Authigenic carbonate
10% Zeolite
10% Rads
10% Clay
5% Quartz
TR% Feldspar (Auth.)

Burrows at 48 cm.

Explanatory Notes in Chapter 1

Site 356 Hole Core 27 Cored Interval: 389.5-399.0 m

AGE: EARLY PALEOCENE
ZONE: (P1c) G. pseudobulloides; Chiasmolithus danicus NP3

FOSSIL CHARACTER: Forams AG (Sec. 1), AG (Sec. 2), AG (Sec. 3), AG (Sec. 5), AM (Core Catcher); Coccoliths AM (Sec. 1), AM (Sec. 2), AM (Sec. 3), AM (Sec. 4), AM (Sec. 5), AM (Sec. 6), CM (Core Catcher); Rads VR/VP (Core Catcher)

SECTIONS: 0, 1, 2, 3, 4, 5, 6, Core Catcher. METERS: 0.5, 1.0

LITHO. SAMPLE: 75 (Sec. 3), 70 (Sec. 6)

LITHOLOGIC DESCRIPTION

FORAM NANNO CHALK, pinkish gray (5YR 8/1), dark yellowish brown (10YR 4/2) near the bottom, mostly homogeneous, somewhat mottled.

SS 75 (Foram nanno chalk)
40% Calcareous nannos
20% Forams
5% Authigenic carbonate
10% Rads
5% Zeolite
10% Clay
5% Quartz
TR- 5% Opaques
TR- 5% Limonite

Dark yellowish brown (10YR 4/2), occasional bluish gray spots and irregular bands.

Light brown band at 54 cm.
Bluish gray band at 70 cm.

SS 70 (Smear slide from bluish gray band, foram nanno chalk)
40% Calcareous nannos
20% Forams
10% Authigenic carbonate
5% Zeolite
10% Rads
10% Clay
5% Quartz

Site 356 Hole Core 28 Cored Interval: 399.0-408.5 m

AGE: EARLY PALEOCENE
ZONE: (P1a) G. eobulloides; Chiasmolithus danicus NP3; Cruciplacolithus tenuis NP2

FOSSIL CHARACTER: Forams AG (Sec. 1), AG (Sec. 3), AE (Sec. 6), AG (Core Catcher); Coccoliths AM (Sec. 1), AM (Sec. 2), AM (Sec. 3), CM (Sec. 4), CM (Sec. 5), CM (Sec. 6), CM (Core Catcher); Rads vRvP (Core Catcher)

SECTIONS: 0 (VOID), 1, 2, 3, 4, 5, 6, Core Catcher. METERS: 0.5, 1.0

LITHO. SAMPLE: 75 (Sec. 3), 120 (Sec. 4), 100 (Sec. 6)

LITHOLOGIC DESCRIPTION

FORAM NANNO CHALK, occasional blue gray spots and bands, pinkish gray (5YR 8/1), pale yellowish brown (10YR 6/2) or dark yellowish brown (10YR 4/2). Dark yellowish brown color because of presence of limonite in FERRUGENOUS CALCAREOUS MUDSTONE. Sec. 6 (40-150 cm) is DOLOMITIC CALCAREOUS light bluish gray (5B 7/1).

Dark yellowish brown (10YR 4/2).

At 84 cm (Sec. 2) color changes to pale yellowish brown (10YR 6/2).

SS 75 (Foram nanno chalk)
30% Calcareous nannos
20% Forams
10% Authigenic carbonate
10% Rads
5% Limonite
10% Clay
5% Quartz
TR- 5% Feldspar (overgrowth)
TR% Mica
TR- 5% Zeolite

At 130 cm (Sec. 3) color changes to pinkish gray (5YR 8/1).

Burrowed.

Sec. 4: 62 cm color change to dark yellowish brown (10YR 4/2), 90 cm color change to pale yellowish brown, 104 cm color change to dark yellowish brown, 130 cm color change to pinkish gray.

SS 120 (Ferrugenous calcareous mudstone)
20% Quartz
10% Feldspar (overgrowths)
15% Clay
10% Limonite
15% Calcareous nannos
10% Forams
5-10% Rads
5% Opaques
TR% Mica, Dolomite rhombs
5% Zeolite

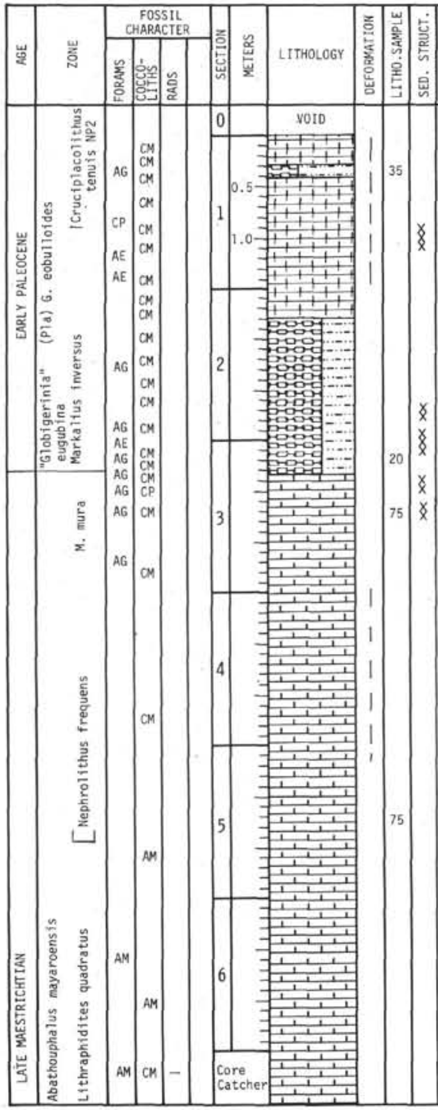
Sec. 5: 70 cm color change to dark yellowish brown, 90 cm color change to pale yellowish brown, 105 cm color change to dark yellowish brown, 147 cm color change to pinkish gray (5YR 8/1).

Sec. 6: 11 cm color change to dark yellowish brown, 46 cm color change to light bluish gray (5B 7/1).

SS 100 (Dolomitic calcareous chalk)
30% Calcareous nannos
10% Forams
25% Authigenic carbonate
10% Rads
10% Dolomite rhombs (imperfect)
10% Clay
5% Quartz
TR% Micronodules

Explanatory Notes in Chapter 1

Site 356 Hole Core 29 Cored Interval: 408.5-418.0 m



LITHOLOGIC DESCRIPTION

FORAM-NANNO CHALK, pale yellowish brown (10YR 6/2), pinkish gray (5YR 8/1), MARLY CALCAREOUS CHALK, medium bluish gray (5B 5/1).

Pale yellowish brown (10YR 6/2).

Sec. 1: 26 cm color change to dark yellowish brown (10YR 4/2), 39 cm color change to pale yellowish brown, 80 cm color change to pinkish gray (5YR 8/1), 95 cm color change to pale yellowish brown (10YR 6/2).

Zoophycus at 84-90 cm (Sec. 1).

At 30 cm (Sec. 2) color change to medium bluish gray (5B 5/1).

Intermediate size burrows at 110, 140 cm (Sec. 2).

Zoophycus at top of Sec. 3.

At 31 cm (Sec. 3) color change to light bluish gray (5B 7/1) Danian/Maestrichtian boundary?

NANNO CHALK, pinkish gray (5YR 8/1), light bluish gray, 31 cm (Sec. 3) to end of core, mottled, bluish bands and spotes.

Burrows 31-35 cm (Sec. 3), small to intermediate size also at 51 cm.

Color change to pinkish gray (5YR 8/1).

Smears:

SS 1-35 (Calcareous mud, dark yellowish brown)
- 30% Clay
- 20% Quartz
- 10% Feldspar (overgrowths)
- 5% Limonite
- 15% Calcareous nannos
- 5-10% Forams
- 5% Rads
- 5% Authigenic carbonate
- 5% Opaques

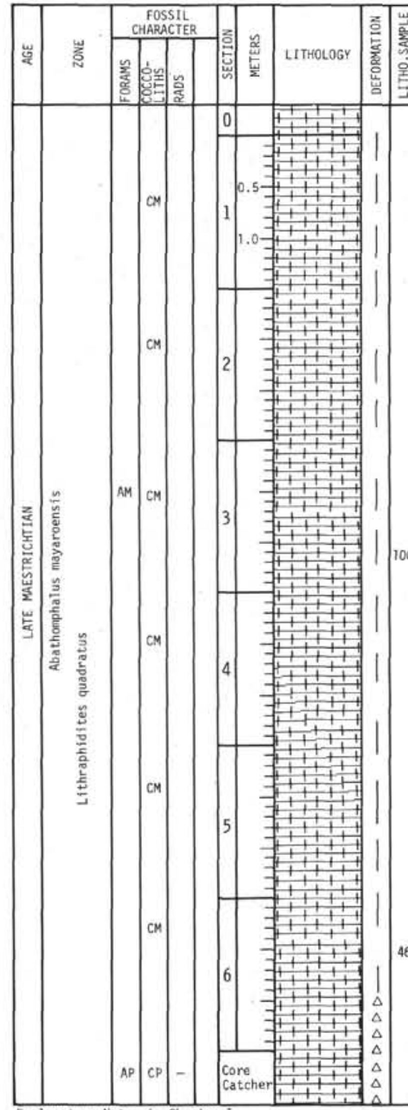
SS 3-20 (Marly Calcareous chalk, medium bluish gray)
- 15% Calcareous nannos
- 20% Forams
- 15% Authigenic carbonate
- 20% Clay
- 10% Quartz
- 5% Feldspar
- TR% Mica

SS 3-75 (Nanno chalk, light bluish gray)
- 50% Calcareous nannos
- 5% Forams
- 20% Authigenic carbonate
- 5% Dolomite rhombs
- 10% Clay
- 5% Quartz
- TR% Mica
- TR- 5% Opaques

SS 5-75 (Nanno chalk, pinkish gray)
- 55% Calcareus nannos
- 10% Forams
- 10% Authigenic carbonate
- 10% Rads
- 10% Clay
- 5% Quartz

Bomb CO_3: Sec. 6, 149 cm = 53%

Site 356 Hole Core 30 Cored Interval: 418.0-427.5 m



LITHOLOGIC DESCRIPTION

Foraminiferal nannofossil chalk, light bluish gray (5B 7/1), mottled or pinkish gray (5YR 8/1).

SS 100 (Foraminiferal-nannofossil chalk)
- 45% Calcareous nannos
- 25% Forams
- 15% Authigenic carbonate
- 10% Clay
- 5% Quartz
- TR% Mica

Color change to pinkish gray (5YR 8/1).

SS 46
- 65% Calcareous nannos
- 15% Forams
- 10% Clay
- 5-10% Quartz
- TR% Opaques

Drilling breccia contains pinkish gray and bluish gray chalk fragments.

Explanatory Notes in Chapter 1

Site 356 Hole Core 31 Cored Interval: 437.0-446.5 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.	LITHOLOGIC DESCRIPTION
LATE MAESTRICHTIAN	Lithraphidites quadratus				0						MARLY NANNO CHALK, light gray (N7), very slightly mottled, homogeneous, some burrows.
			CM		1	0.5, 1.0					
			CM		2				75		SS 75 (Marly nanno chalk) 30% Calcareous nannos 5-10% Forams 10% Authigenic carbonate 5% Rads 5% Dolomite rhombs 15% Clay 15% Quartz 5% Feldspar
			CM		3						
		FP	CM		4						Small burrows. Intermediate size burrows.
		AM, AM	CM		5						
	Abathomphalus mayaroensis	AM	CM		6						Small burrows.
		CP	CM	—	Core Catcher						

Site 356 Hole Core 32 Cored Interval: 456.0-465.5 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.	LITHOLOGIC DESCRIPTION
MIDDLE MAESTRICHTIAN	G. contusa				0						MARLY CALCAREOUS CHALK, light gray (N7), mottled, burrowed, bluish gray occasionally because of additional silt-size material.
		AM	CM		1	0.5, 1.0	VOID				
	Globotruncana gansseri	AM, AM	CM		2						
		AM	CM		3				75		SS 75 (Marly calcareous chalk, light gray) 25% Calcareous nannos 5-10% Forams 25% Authigenic carbonate 15% Clay 5-10% Quartz 5% Feldspar 5% Opaques 5% Dolomite rhombs
		AM, AM	FP		4						
EARLY MAESTRICHTIAN	Globotruncana tricarinata / Arkhangelskiella cymbiformis	AM	CM		5				24		SS 24 (Marly calcareous chalk, bluish gray) 30% Calcareous nannos 10% Forams 15% Authigenic carbonate 15% Clay 15% Quartz 10% Feldspar (overgrowths) TR- 5% Mica TR% Zeolite Intermediate size burrow. Small burrows.
		AM	CM		6						
		AM	CP	—	Core Catcher						

Explanatory Notes in Chapter 1

Site 356 Hole Core 33 Cored Interval: 484.5-494.0 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	LITHO. SAMPLE
LATE CAMPANIAN	Globotruncana calcarata / Tetralithus trifidus	AM			0	
		CM	CM		1	
		AP				
			CM		2	50
		AM	CM		3	
		AM				
			CM		4	60
		AM	CM		5	
			CM		6	
EARLY CAMPANIAN	Globotruncana elevata / Tetralithus gothicus	AM				
		CM	CP	–	Core Catcher	

METERS: 0.5, 1.0

LITHOLOGIC DESCRIPTION

MARLY CALCAREOUS CHALK, light gray (N7), light brownish gray (5YR 6/1), and pale red (5R 6/2), slightly burrowed, mottled throughout.

Light gray (N7).

Color change to light brownish gray (5YR 6/1).

Color change to pale red (5R 6/2).

SS 50 (Marly calcareous chalk, pale red [5R 6/2])
20% Calcareous nannos
15% Forams
15% Authigenic carbonate
10% Dolomite rhombs
15% Clay
15% Quartz
10% Feldspar
TR% Mica

Intermediate size burrow at 120 cm (Sec. 2).

Vertical burrow at 145 cm (Sec. 2), other small intermediate size burrows.

Color change to light brownish gray.

Bomb CO_3: Sec. 3, 59 cm = 33%

SS 60 (Marly calcareous chalk, light brownish gray [5YR 6/1])
20% Calcareous nannos
15% Forams
15% Authigenic carbonate
10% Dolomite rhombs
15% Clay
10% Feldspar
15% Quartz
TR% Mica

70-150 cm (Sec. 4) small and intermediate size burrows.

0-30 cm (Sec. 5) small and intermediate size burrows.

Small burrows (Sec. 6, 20-30 cm).

Site 356 Hole Core 34 Cored Interval: 513.0-522.5 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	LITHO. SAMPLE
	Tetralithus gothicus	AP	CM		0	
					1	83
		AP	FP		2	
			CM		3	55
						75
		AP				
			FP		4	
		AP	CP		5	
EARLY CAMPANIAN	Globotruncana elevata	AP	CP		6	
		CM	CP	–	Core Catcher	

METERS: 0.5, 1.0

LITHOLOGIC DESCRIPTION

MARLY CALCAREOUS CHALK, olive gray (5Y 4/1), burrowed and mottled throughout, indurated, forams have been recrystalized, contains Inoceramus fragments which are usually 2-5 mm thick and <1 to 5 cm long, contains occasional dark band of calcareous mud (Sec. 1, 82-84 cm).

SS 83 (Calcareous mud)
15% Calcareous nannos
5% Forams
10% Authigenic carbonate
5-10% Dolomie rhombs
50% Clay
5-10% Quartz
TR% Mica
5-10% Mn(?)

Inoceramus fragments at 55, 56, 74 cm in Sec. 1.

Inoceramus fragments at 65, 105, 125-126 cm in Sec. 2.

Inoceramus fragments at 38, 55 cm in Sec. 3.

Inoceramus fragment at 55 cm in Sec. 3, 100% Calcite.

SS 75 (Marly calcareous chalk)
25% Calcareous nannos
5% Forams
25% Authigenic carbonate
5-10% Dolomite rhombs
20% Clay
5% Quartz
5% Feldspar
TR% Mica

Inoceramus fragments at 32, 43, 55-65, Sec. 4.

Color slightly lighter (105-125 cm), contains dark gray to bluish gray small to intermediate size burrows.

Inoceramus fragments at 27, 52, 103 cm.

Intermediate size burrow at 128, 143 cm.

Inoceramus fragments at 128, 134 cm.

Small burrows 30-40, 6-80, 105-128 cm.

Explanatory Notes in Chapter 1

Site 356 Hole Core 35 Cored Interval: 541.5-551.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.	LITHOLOGIC DESCRIPTION
LATE SANTONIAN	Globotruncana concavata carinata; Marthasterites furcatus	AM, AP, AM, AM, AP, AM, AM, AM, AP	CM, CM, CM, CM, CM, CM, CP	vRvP	0, 1 (0.5, 1.0), 2, 3, 4, 5, 6, Core Catcher				25, 81, 60		see below

DOLOMITIC MARLY CALCAREOUS CHALK, olive gray (5Y 4/1), dark greenish gray (5GY 4/1), medium dark gray (N4), indurated, contains some re-crystallized forams which occur as rounded white specks on the cut surface, burrowed, mottled, some dark bands of mud, contains a coarse layer consisting of Glauconite, Fe-Mn nodule, and Inoceramus fragments.

Coarse layer:

Green rounded grains	Brown rounded nodule
Glauconite	Mn and Fe-oxide with Quartz(?) and Clay(?)

Dark gray band 81-83 cm.

SS 81 (Mudstone)
- 75% Clay
- TR- 5% Quartz
- TR- 5% Feldspar
- 5% Zeolite
- TR- 5% Heavy minerals
- TR- 5% Volcanic glass
- 5% Mn(?)
- TR% Dolomite rhombs
- 5% Forams

Small burrows (0-60 cm), intermediate size burrow at 85 cm.

SS 60 (Dolomitic marly calcareous chalk)
- 20% Calcareous nannos
- 15% Forams
- 5% Authigenic carbonate
- 15% Dolomite rhombs (some rounded, some euhedral, large [sand/silt] size)
- 10% Quartz
- 20% Clay
- 5% Feldspar
- 5% Opaques
- TR- 5% Limonite

Burrows at 39, 40, 42, 44, 51, and 55 cm, Zoophycus at 40, 42 cm, intermediate size burrow at 142 cm, small burrows at 0-120 cm.

120-150 cm intermediate size burrows.

Small to intermediate size burrows.

Slightly lighter color (40-42 cm).

Bluish gray at 140-142 cm.

Site 356 Hole Core 36 Cored Interval: 570.0-579.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE SANTONIAN	Globotruncana concavata carinata; Marthasterites furcatus	AP, AP, AP, AP	CM, CM, CM, CM, CM		0, 1 (0.5, 1.0), 2, 3, 4, Core Catcher		VOID		75	see below

DOLOMITIC MARLY CALCAREOUS CHALK, medium dark gray (N4), small to intermediate size burrows throughout, occasional Inoceramus fragments.

Bomb CO_3: Sec. 1, 21 cm = 34%

SS 75
- 15% Calcareous nannos
- 15% Forams
- 15% Dolomite rhombs
- 20% Authigenic carbonate
- 5% Opaques
- 15% Clay
- 10% Quartz
- 5% Feldspar
- TR% Zeolite, Heavy minerals

Inoceramus fragment at 19 cm.

Explanatory Notes in Chapter 1

Site 356 Hole Core 37 Cored Interval: 598.5-608.0 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE SANTONIAN	G. carinata	AM	CM		0, 1				MARLY CALCAREOUS CHALK, olive gray (5Y 4/1), small and intermediat size burrows throughout, burrows are slightly darker gray in color, occasional *Inoceramus* fragments. Inoceramus fragments at 56 and 148 cm.
EARLY SANTONIAN	Globotruncana concanata concavata / Marthasterites furcatus	AM	CM		2			100	SS 100: 25% Calcareous nannos; 10% Forams; 15% Authigenic carbonate; 10% Dolomite rhombs; 20% Clay; 5-10% Quartz; 5% Feldspar; 5% Opaques
		AM	CM		3				Large burrow at 62. Intermediate size burrows at 52 and 60.
		AM	CM		4				45-47 cm, lighter gray band.
		AM	CM		5				
		AM	CM		6				140-150 cm, large and intermediate size burrows. Small *Inoceramus* fragments.
		CP	CP	—	Core Catcher				

Site 356 Hole Core 38 Cored Interval: 646.0-655.5 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	PALYNO	SECTION	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY SANTONIAN	Globotruncana concavata concavata / Marthasterites furcatus		CM			0, 1	VOID		100	MARLY CALCAREOUS CHALK, medium gray (N5), small and intermediate size burrows throughout, *Inoceramus* fragments, occasional bluish gray bands. Inoceramus fragment at 78 cm. SS 100 (Marly calcareous chalk): 15% Calcareous nannos; 5% Forams; 30% Authigenic carbonate; 5% Dolomite rhombs; 25% Clay; 5% Quartz; 5% Feldspar; TR% Mica; 5-TR% Opaques; 5-TR% Limonite
			CM			2				Inoceramus fragments at 12, 72 cm. Intermediate size burrows at 50-60 cm.
		CM	CM			3			130	40-105 cm Inoceramus fragments, black shale fragments. 78 cm basalt pebble, Inoceramus. Bluish gray band at 130 cm. Bomb CO_3: Sec. 3, 108 cm = 40%
		CP	CP	—		Core Catcher				SS 130 (Marly calcareous chalk): 15% Calcareous nannos; 5-10% Forams; 20% Authigenic carbonate; 10% Dolomite rhombs; 20% Clay; 10% Quartz; 5% Feldspar; 5% Mica; TR% Glauconite; 5% Opaques

Explanatory Notes in Chapter 1

Site 356 Hole Core 39 Cored Interval: 674.5-684.0 m

AGE: LATE CONIACIAN/EARLY SANTONIAN

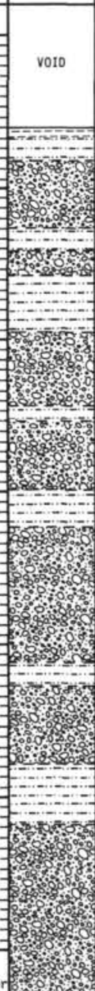
ZONE: *Globotruncana concavata concavata*; *Marthasterites furcatus*

FOSSIL CHARACTER (FORAMS / COCCOLITHS / RADS / PALYNO): Sec. 1: — CP; Sec. 2: CP; Sec. 3: — FP; Sec. 4: — FP, RP; Sec. 5: FP; Sec. 6: — CP; Core Catcher: — FP —

SECTION: 0, 1, 2, 3, 4, 5, 6, Core Catcher

METERS: 0.5, 1.0

LITHOLOGY: VOID



LITHO. SAMPLE: 140, 143, 69, 105, 80, 111

LITHOLOGIC DESCRIPTION

CLAY-PEBBLE CONGLOMERATE, consist of light gray (calcareous mudstone), medium gray (N5), and dark gray (N3) pebbles, each conglomerate horizon ends in dark gray clay. Medium gray sediments are present in between graded conglomerate to clay horizons.

Sec. 1: dark bands at 108, burrows at 118, graded bed at 140, medium gray (90-110), dark gray (118-139), medium gray (139-150).

Sec. 2: 0-3 void, 3-97 (clay pebble conglomerate), 47-55 dark gray, 55-90 medium gray, 90-100 dark gray, 100-111 medium gray, 111-150 medium gray with burrows.

Sec. 3: 0-74 medium gray, 74-91 dark gray, 91-150 medium gray, 22-72 soft sediment deformation, 64-72 minor disturbance, 92-101 dark gray pebbles, 110-150 homogeneous medium gray.

Sec. 4: 0-8 homogeneous medium gray, 8-32 dark gray, 32-150 coarse conglomerate consisting of light gray, dark gray, green, coarse (up to 4 cm) pebbles.

Sec. 5: burrow at 29.

Sec. 6: same as 4.

SS 140 (Calcareous mudstone)
30% Quartz
30% Clay
20% Feldspar (overgrowth)
10% Authigenic carbonate
TR- 5% Limonite
TR- 5% Opaques
10% Calcareous nannos

SS 143 (Zeolitic siltstone, from dark green pebble)
30% Quartz Silt
20% Feldspar Silt
10% Mica
30% Clay
5-10% Zeolite
TR- 5% Opaques
TR% Limonite

SS 69 (Calcareous mudstone, from a green band)
30% Clay
15% Quartz
5% Feldspar
5% Mica
20% Authigenic carbonate
5% Opaques
TR% Limonite
5% Forams
10% Calcareous nannos
TR% Limonite

SS 105 (Calcareous mudstone, medium gray)
15% Quartz
5% Feldspar (some overgrowth)
25% Clay
15-20% Dolomite rhombs
20% Authigenic carbonate
5% Calcareous nannos
5-10% Forams
TR% Opaques
TR% Limonite

SS 80 (Silty claystone, dark gray)
70-80% Clay
10% Quartz
1% Feldspar
1% Mica
1% Heavies
1% Glauconite
1- 2% Pyrite
1% Fe-oxide

SS 111 (Sandy silt claystone, green coarse layer)
60-70% Clay
20-30% Quartz
1- 2% Opaques
1% Feldspar
1- 2% Glauconite
1% Pyrite
1% Dolomite rhombs
1% Forams (recrystallized)

Site 356 Hole Core 40 Cored Interval: 693.5-703.0 m

AGE: CONIACIAN; MIDDLE TURONIAN

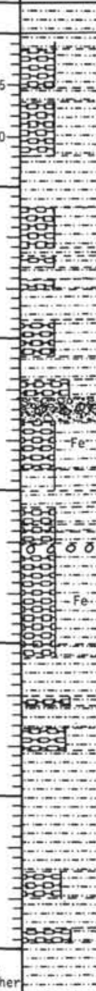
ZONE: *Marthasterites furcatus*; *G. concavata concavata*; *Praeglobotruncana helvetica*; *Micula staurophora*

FOSSIL CHARACTER (FORAMS / COCCOLITHS / RADS / PALYNO): Sec. 1: AP CM, CM; Sec. 2: CM; Sec. 3: — CM, CM; Sec. 4: =, CP; Sec. 5: AP CP; Sec. 6: RP CP; Core Catcher: RP FP —

SECTION: 0, 1, 2, 3, 4, 5, 6, Core Catcher

METERS: 0.5, 1.0

LITHOLOGY: Fe, Fe



LITHO. SAMPLE: 100, 59, 61, 63, 81, 62, 140

LITHOLOGIC DESCRIPTION

CALCAREOUS MUDSTONE, medium gray (N5) and SILTY CLAYSTONE, dark gray (N3), moderately burrowed throughout from one into other, occasional *Inoceramus* fragments, pebbles in coarse conglomeratic layers consist of limestone, silty mudstone, calcareous mudstone, ferrugenous mudstone, etc.

At 13 cm color change to medium gray, 51-61 cm dark gray, 120 cm color change to dark gray.

Sec. 2 alternating medium gray and dark gray layers.

Sec. 3 alternating medium and dark gray layers.

From dark green pebble
White pebble
Calcareous mudstone (light green pebble)
Color change to dark red (10R 2/2)
Dark red fragment
Color change to medium gray
From a greenish band
Alternating dark gray, light gray layers.
Occasionally dark red layers which are graded and glauconitic.
Dark and medium gray
Dark gray
Dark and medium gray

SS 1-100 (Medium gray sediment, calcareous mudstone)
40% Clay
15% Quartz
10% Feldspar
10% Calcareous nannos
5-10% Forams
10% Authigenic carbonate

SS 3-59 (Silty mudstone)
80-90% Clay
5-10% Quartz
1% Feldspar
1% Opaques
1- 5% Glauconite

SS 3-61 (Limestone pebble)
100% Authigenic carbonate

SS 3-63 (Calcareous mudstone
40% Clay
10% Quartz
5% Feldspar
10% Calcareous nannos
5% Forams
5% Opaques
5% Dolomite rhombs
20% Authigenic carbonate

SS 3-81 (Fe. calcareous mudstone)
30% Quartz
20% Feldspar
15% Limonite
35% Authigenic carbonate

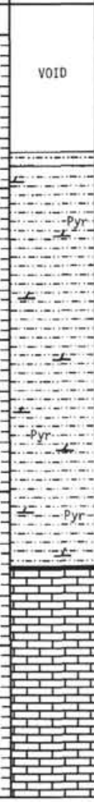
SS 4-62 (Mudstone)
60-70% Clay
10-20% Quartz
1- 2% Opaques
1% Feldspar
1% Heavy

SS 5-140 (Silty mudstone)
80-90% Clay
5-10% Quartz
1- 2% Fe-oxide

Explanatory Notes in Chapter 1

Site 356 Hole Core 41 Cored Interval: 703.0-712.5 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	PALYNO	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
MIDDLE TURONIAN	Praeglobotruncana helvetica; Micula staurophora	— , —, AP, CP, —, —	FP, CP, CP, FP, CP			0, 1, 2, 3, 4	0.5, 1.0	VOID		83, 60
Hiatus										
LATE ALBIAN	Planomalina buxtorfi; Eiffellithus turriseiffeli	CP, CP	FP, RP, RP	—		5				120, 135



LITHOLOGIC DESCRIPTION

Dolomitic calcareous mudstone, greenish gray (5G 6/1), mudstone, medium bluish gray (5B 5/1), and mudstone, dark gray (N3), the latter contain pyrite nodules 2-4 mm, some are 1-2 cm across, burrowed.

Medium bluish gray (5B 5/1), greenish gray (5G 6/1).
Color change to dark gray (N3).
Pyrite nodules.
Pyr = Pyrite

Greenish gray band.
Bluish gray band.
Dark gray.
Alternating greenish gray (Dolomitic calcareous mudstone), bluish gray (mudstone), and dark gray (pyritiferous mudstone).

Bomb CO_3: Sec. 2, 83 cm = 3%

Alternating dolomitic calcareous mudstone, and pyritiferous mudstone.

From thin white layers in dark gray mudstone calcite 100%.

*Contact is a "drilling artifact" and hiatus.

LIMESTONE, light bluish gray (5B 7/1), faint greenish, grayish bands, occasional white layers.

Bomb CO_3: Sec. 5, 135 cm = 42%

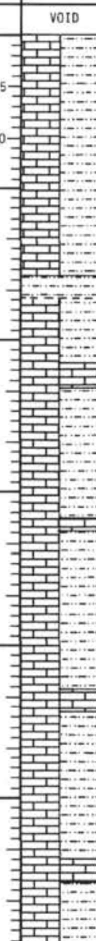
SS 2-32 (Dolomitic calcareous mudstone)
- 20% Clay
- 10% Quartz
- 5% Feldspar
- 20% Dolomite rhombs
- 20% Authigenic carbonate
- 5% Forams
- 10% Calcareous nannos
- TR% Glauconite
- 5-10% Opaques (pyrite)

SS 2-40 (Mudstone)
- 35% Clay
- 20% Feldspar
- 35% Quartz
- 10% Opaques

SS 120 (Limestone)
- 85% Recrystallized carbonate
- 5-10% Quartz
- 1- 2% Clay
- 1% Pyrite
- 1% Dolomite rhombs
- 1% Forams

Site 356 Hole Core 42 Cored Interval: 712.5-722.0 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	PALYNO	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
LATE ALBIAN	Planomalina buxtorfi; Eiffellithus turriseiffeli; RK4/PK5	FP, RP, RP, FP, FP, FP, AM	CP, RP			0, 1, 2, 3, 4, 5, 6	0.5, 1.0	VOID		100, 130, 105, 65



LITHOLOGIC DESCRIPTION

Calcareous mudstone, also contains green and brown layers, medium gray (N5), light brownish gray (5YR 6/1), darker layers are mudstone, light layers are limestone or dolomitic limestone. Fine layers of $CaCO_3$ 2 to 5 cm apart, each layer is 1-2 mm or more thick.

Unidentified sediment structure, also seen at Sec. 2, 8 and 51 cm.

Burrows! 1 cm

SS 100 (Calcareous mudstone)
- 40% Clay
- 10% Quartz
- 5% Feldspar
- 10% Dolomite rhombs
- 10% Authigenic carbonate
- 5% Opaques
- 5-10% Forams
- 5% Calcareous nannos
- 5% Limonite

SS 130 (From thin white layer, dolomitic limestone)
- 40% Dolomite
- 40% Authigenic carbonate
- 10% Clay
- 10% Quartz
- TR% Limonite

SS 105 (Mudstone, from dark layer)
- 40% Clay
- 30% Quartz
- 15% Feldspar
- 5% Mica
- TR- 5% Heavy
- TR- 5% Glauconite
- 5% Opaques
- TR- 5% Limonite
- Pyrite replacing Diatom

SS 65 (White band, dolomitic limestone)
- TR- 5% Forams
- 70% Authigenic carbonate
- 20% Dolomite rhombs
- 10% Quartz

Recrystallize foram layers ~1 cm thick.

Explanatory Notes in Chapter 1

Site 356 Hole Core 43 Cored Interval: 722.0-731.5 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.
LATE ALBIAN	Planomalina buxtorfi; Eiffellithus turriseiffeli	FP	FP		0–1	0.5, 1.0			120	
		FP	FP		2				75	
		FP	RP		3					
			RP		4					
		FP	RP		5					
			FP		6				19, 93, 98, 144	
		CP	RP	–	Core Catcher					

LITHOLOGIC DESCRIPTION

MARLY LIMESTONE, medium dark gray (N4), very hard, white bands 2 to 5 cm apart sometimes closer, bands are 1 to 2 mm thick, sometimes ~1 cm thick, some white layers appear graded, contain features reminding one of turbidity currents, some beds contain glauconite, Fe-oxide grains.

Graded bed consisting of gray limestone sand-size grains, glauconite and Fe-oxide brown grains.

SS 120 (Recrystallized limestone)
- 35% Authigenic carbonate
- 20% Dolomite rhombs
- 5% Glauconite
- 10% Fe-oxide
- 15% Clay
- 5% Feldspar
- 5-10% Quartz

SS 75 (Marly limestone)
- 50% Authigenic carbonate
- 5% Forams
- TR% Calcareous nannos
- 10% Dolomite rhombs
- TR% Glauconite
- 20% Clay
- 10% Quartz
- 5% Feldspar
- TR% Mica

Sediment structure displaying settling from turbulent suspension:

SS 19 (In a poorly graded coarse layer, dolomitic recrystallized limestone)
- 40% Authigenic carbonate
- 30% Dolomite rhombs
- 5% Limonite
- 5% Forams
- TR- 5% Opaques
- 10% Quartz
- 5% Feldspar
- TR% Glauconite

SS 93 (Gray pebble, limestone)
- 99% Recrystallized carbonate
- 1% Quartz
- TR% Pyrite

SS 98 (Green and brown grains, quartzitic limestone)
- 80-90% Carbonate
- 1- 5% Quartz
- 1- 2% Pyrite
- 1% Feldspar
- 1% Glauconite
- 1% Fe-oxide
- 1% Forams

?

SS 144 (Marly dolomitic limestone)
- 35% Authigenic carbonate
- 5-10% Forams
- 20% Dolomite rhombs
- 20% Clay
- 10% Quartz
- 5% Feldspar

Site 356 Hole Core 44 Cored Interval: 731.5-741.0 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.
LATE ALBIAN	Ticinella breggiensis – Planomalina buxtorfi; Eiffellithus turriseiffeli		RP		0–1	0.5, 1.0	VOID			
		CP	FP		2				90	
			RP		3					
		FP	FP		4				104	
		AP	FP		5					
		AP	FP		6					
		CP	RP	vRvP	Core Catcher					

LITHOLOGIC DESCRIPTION

MARLY DOLOMITIC LIMESTONE, medium gray (N5), banded light and dark layers, thin white layers very common 2 to 5 cm apart sometimes closer, 1-2 mm thick sometimes ~1 cm thick. Occasional coarse, graded layer, displaying current marks. Coarse layers contain glauconite, limestone, iron oxide, quartz.

Bomb CO_3: Sec. 2, 10 cm = 35%

Coarse graded layers at 22, 48, 63, 100, 108.

SS 90 (Marly dolomitic limestone)
- 35% Authigenic carbonate
- 15% dolomite rhombs
- TR% Calcareous nannos
- 5% Forams
- TR- 5% Opaques
- TR- 5% Limonite
- TR- 5% Glauconite
- 15% Clay
- 10% Quartz
- 5% Feldspar
- 5% Mica
- TR- 5% Heavy

Coarse graded layers at 8, 72, 85, 105 cm.

Coarse layers at 35, 104-105, 142 graded.

SS 104 (Marly dolomitic limestone, from coarse layer with red and green grains)
- 45% Authigenic carbonate
- 5% Forams
- 15% Dolomite rhombs
- 20% Clay
- 5% Quartz
- 5% Feldspar
- TR- 5% Limonite
- TR- 5% Opaques

Graded layers at 5, 54, 65-67 cm, 129-130 cm.

Graded beds at 5, 35, 60, 70 cm.

Explanatory Notes in Chapter 1

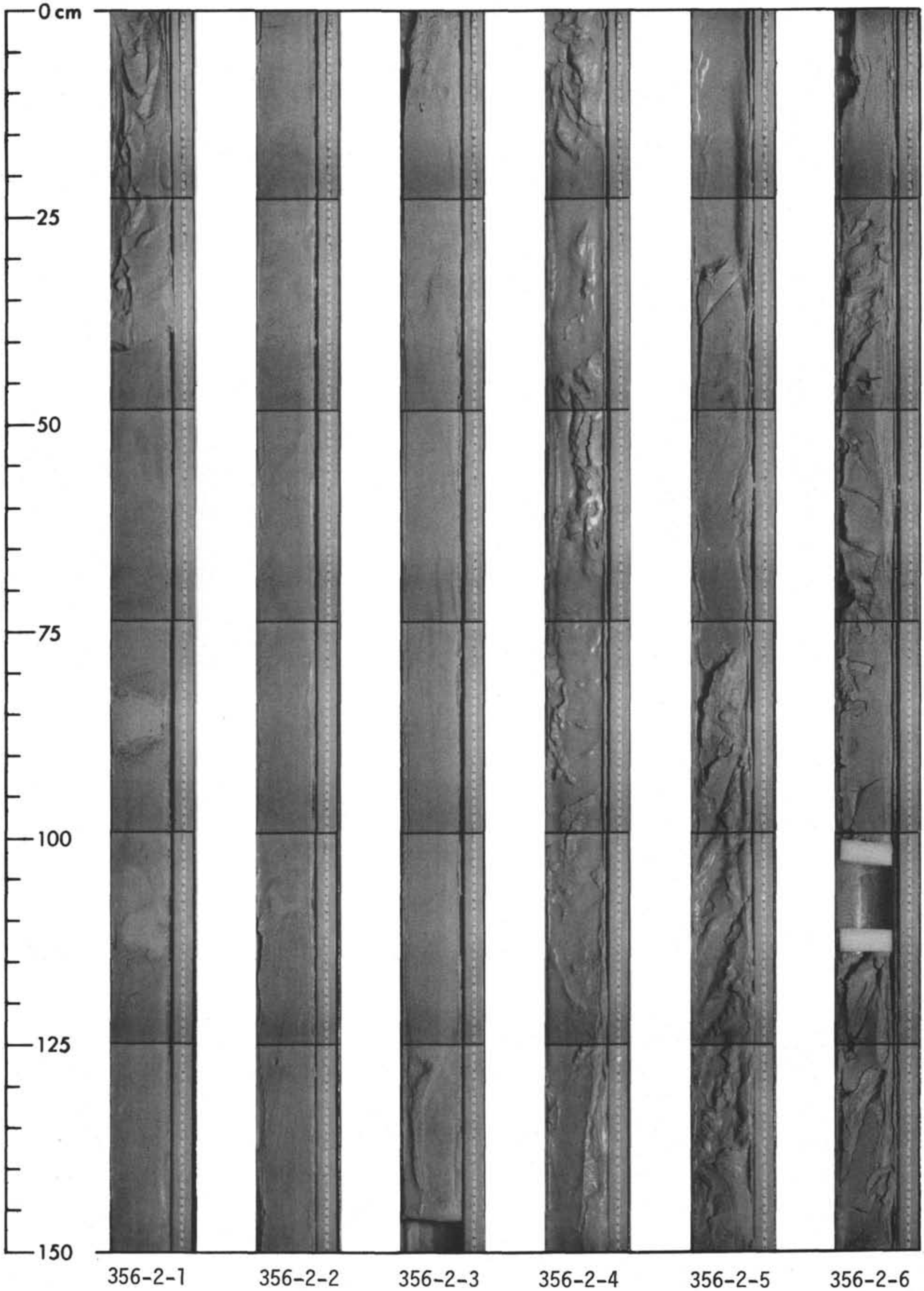
Site 356 Hole A Core 1 Cored Interval: 19.0-28.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY MIOCENE	(N4) G. primordius/kugleri	CM	Sphenolithus belemnos NN3		0					
					1	0.5, 1.0			13	CALCAREOUS OOZE, very pale orange (10YR 8/2). SS 13 (Dark orange glauconitic Lump Nanno ooze) 70% Calcareous nannos; 20% Glauconite; 1- 2% Forams; 12% Quartz
					2			△		
					3			△		Glauconite nanno ooze lump
					4				85	MARLY CALCAREOUS OOZE, color change (135 cm Sec. 4) to light bluish gray (5B 7/1), some mixing with pale sediment due to drilling disturbance, some greenish nanno ooze near top. SS 16 (Nanno ooze) 70% Calcareous nannos; 1- 5% Forams; 10-20% Authigenic carbonate; 1% Pyrite; 1% Glauconite; 1% Feldspar; 1- 2% Quartz
					5				16	SS 145 (Marly calcareous ooze) 35% Calcareous nannos; 10% Forams; 15% Authigenic carbonate; 15% Zeolite; 10% Clay; 5% Feldspar; 5-10% Quartz
					6				145	
			CM	—	Core Catcher					

Site 356 Hole A Core 2 Cored Interval: 28.5-38.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY MIOCENE	(N4) G. primordius/kugleri; NN2 - Sphenolithus belemnos NN3	CM			0					NANNO OOZE, greenish gray (5G 6/1) mottled, has black bleak streaks because of presence of pyrite.
					1	0.5, 1.0	VOID			Mixed with some yellow ooze from above.
					2				100	SS 100 (Nanno ooze) 50% Calcareous nannos; 10% Forams; 25% Authigenic carbonate; 5% Zeolite; 5-10% Quartz; TR% Mica; TR% Glauconite; TR% Opaques
					3					Yellow ooze from above.
					4					Bomb CO_3: Sec. 4, 108 cm = 29%. Bomb CO_3: Sec. 5, 30 cm = 42%. Color remains unchanged but the ooze feels less sticky (113).
	Discoaster druggi				5					SS 93 (Siliceous nanno ooze) 30% Calcareous nannos; 10-15% Forams; 5-10% Diatoms; 5-10% Rads; 5-10% Sponge; 10% Authigenic carbonate; 5-10% Clay; 5-10% Quartz; 10% Volcanic glass
				CM	6				93, 100	SS 100 (Siliceous calcareous ooze) 40% Calcareous nannos; 5-10% Forams; 10% Authigenic carbonate; 10% Diatoms; 10% Rads; 5% Sponge spicules; 5-10% Quartz; 5% Clay; 5% Volcanic glass
	C. tetrapera		CM	AM	Core Catcher					

Explanatory Notes in Chapter 1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75
100
125
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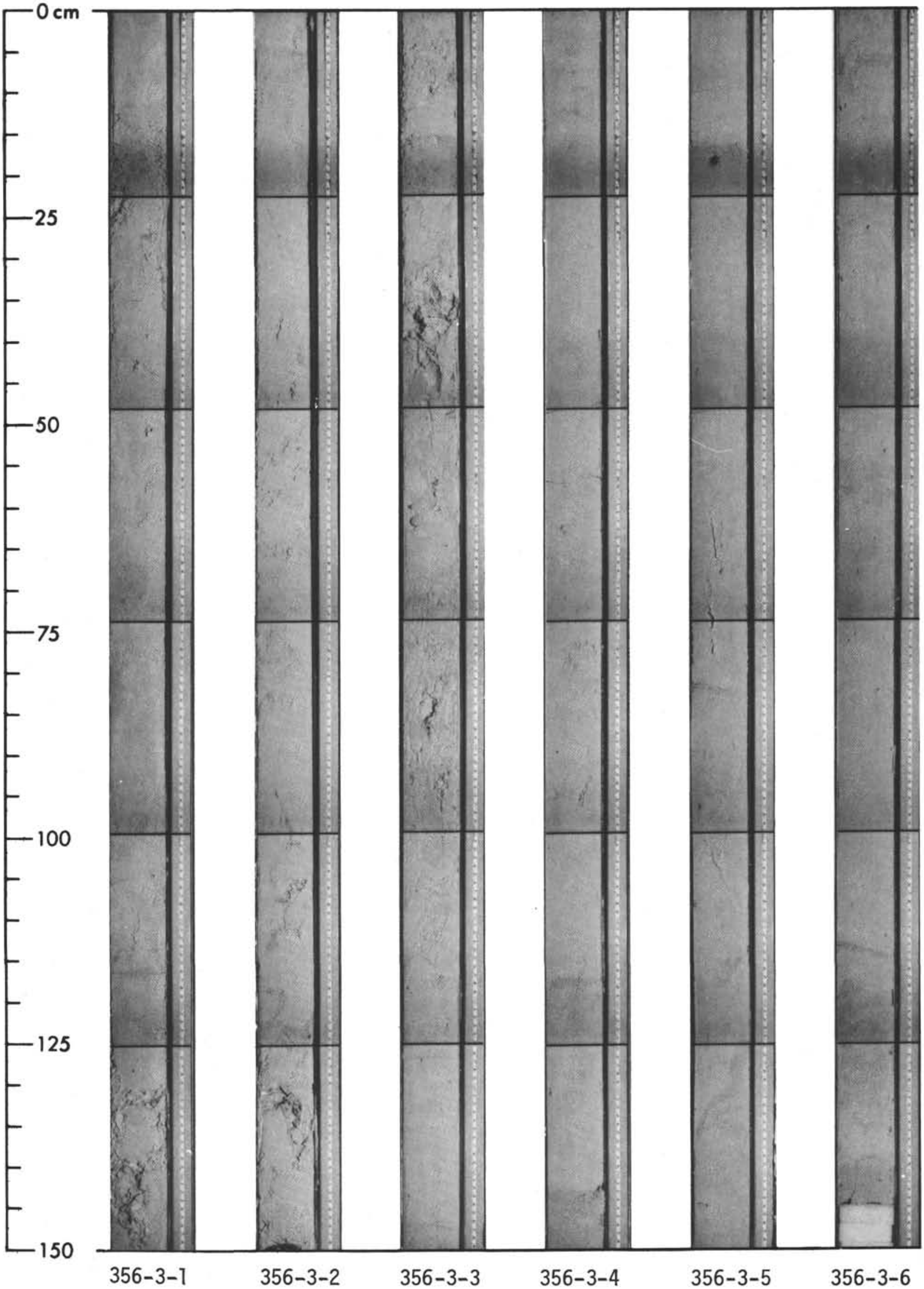
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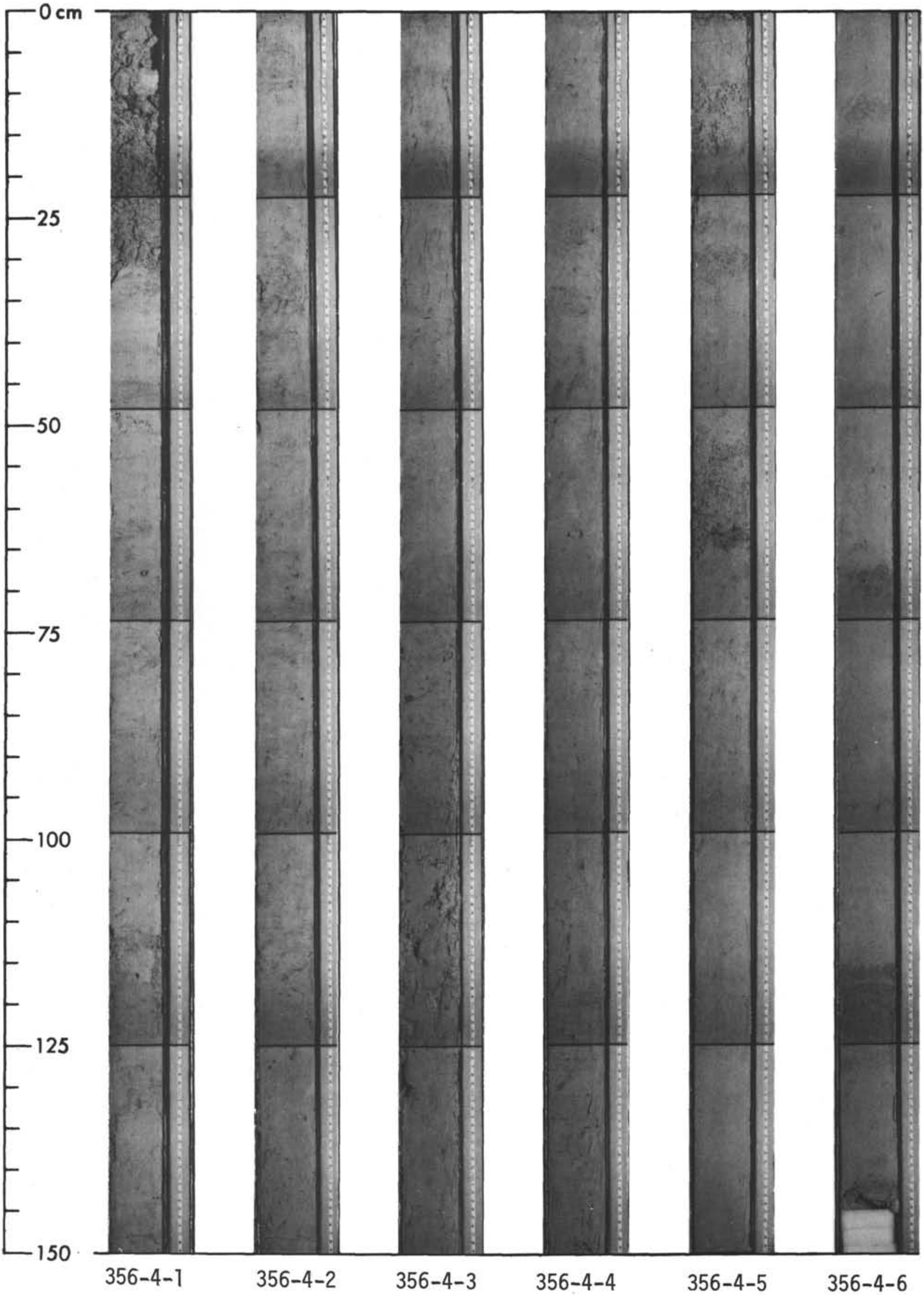
0 cm
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100
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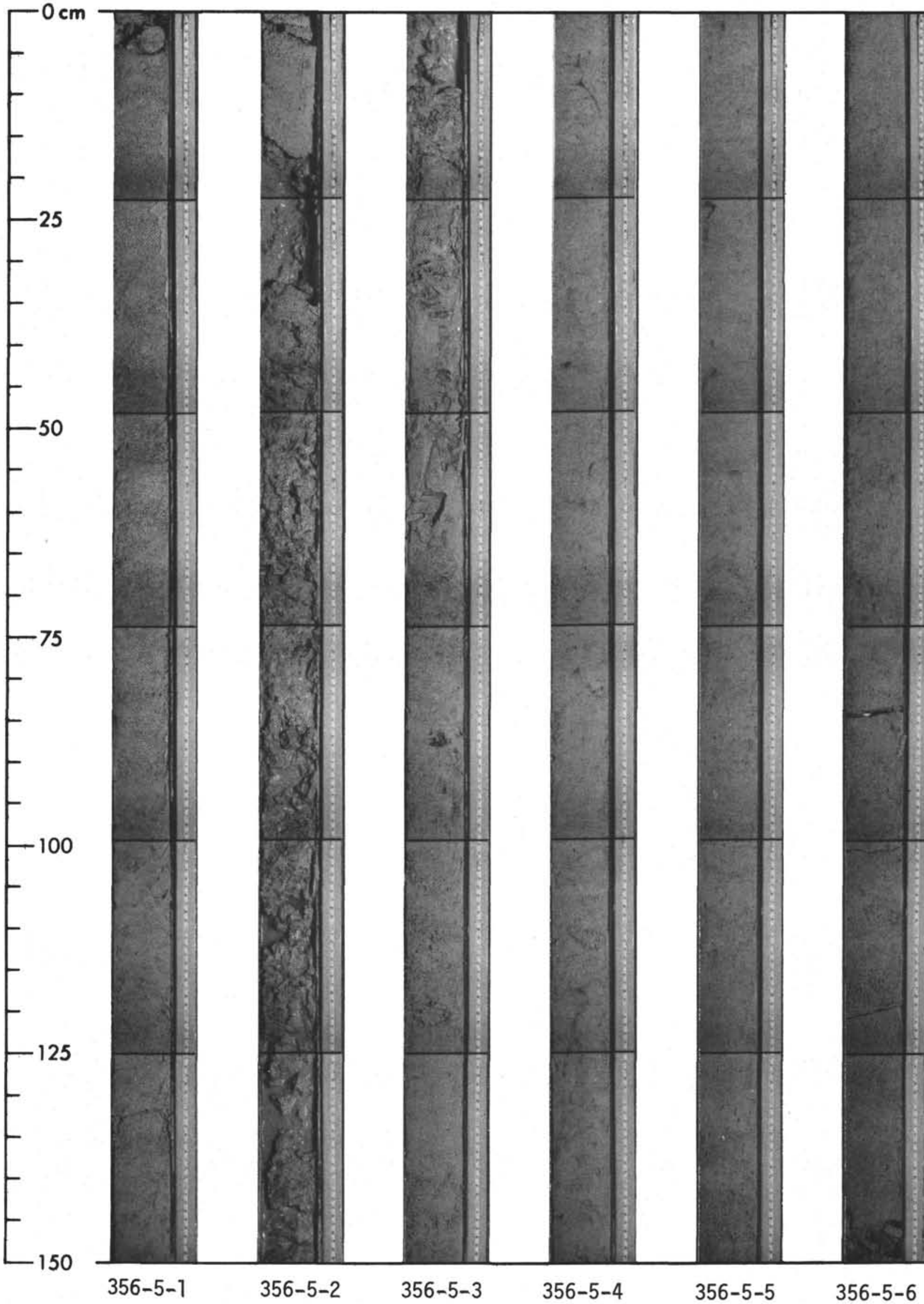
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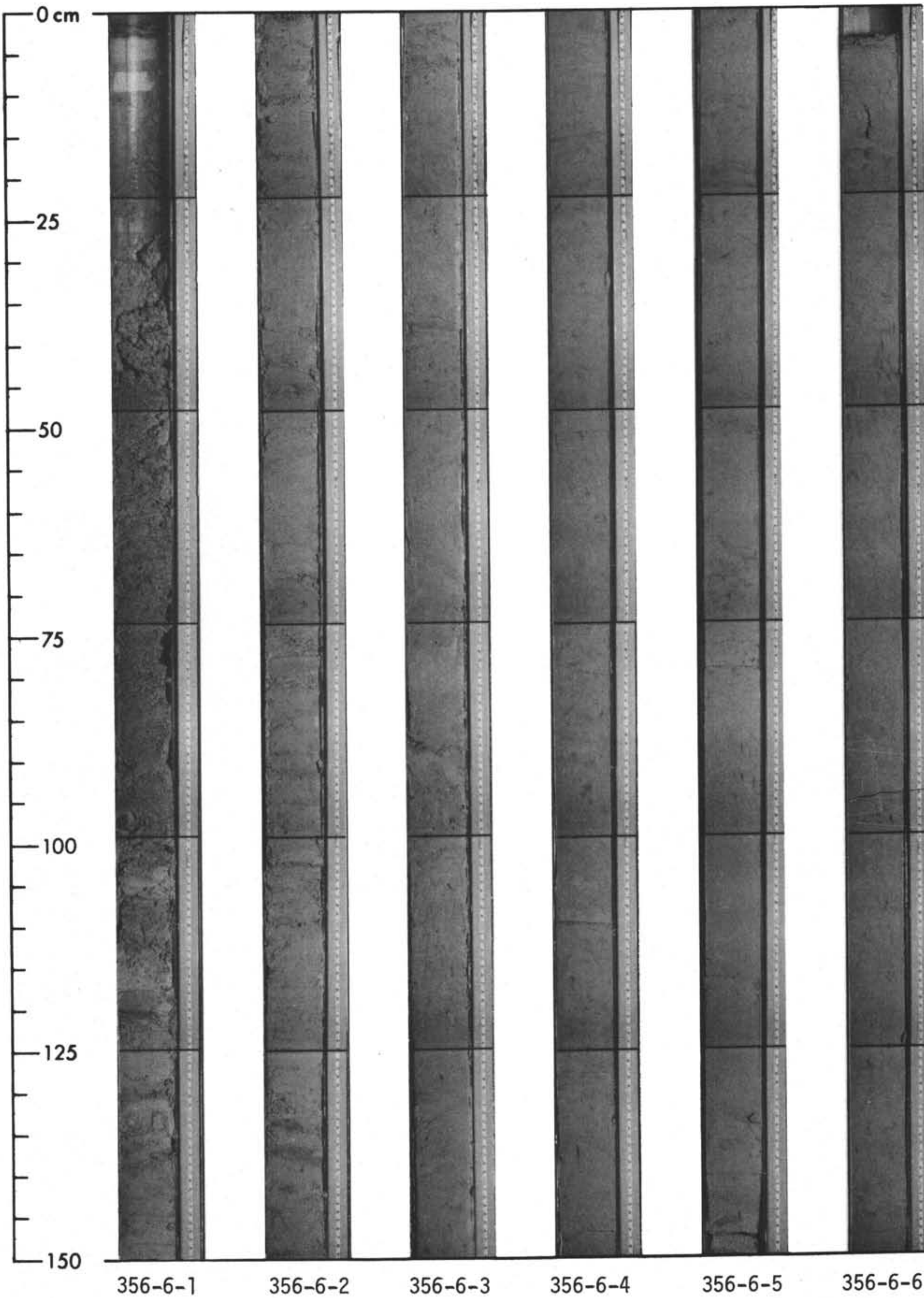
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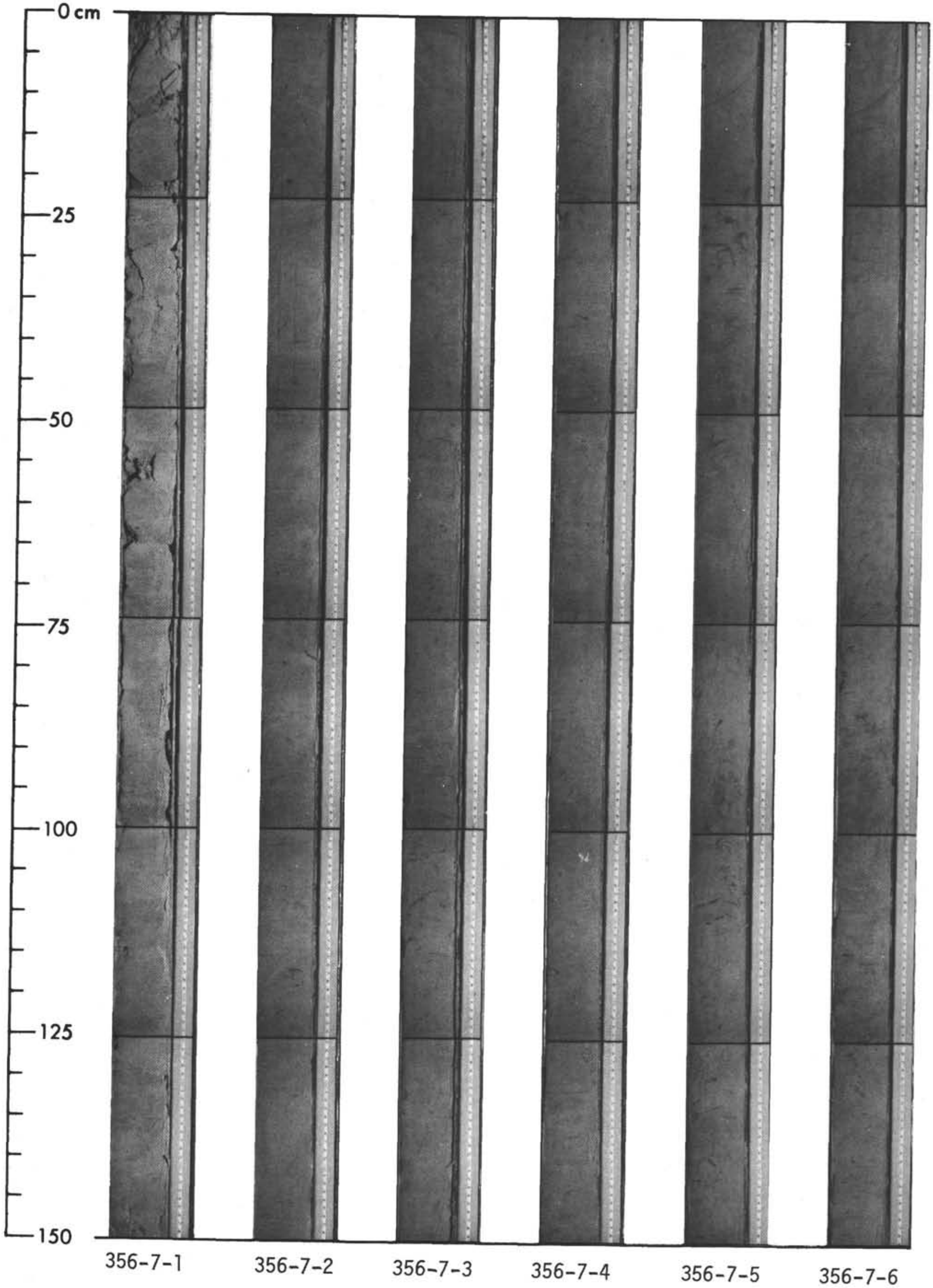
356-6-6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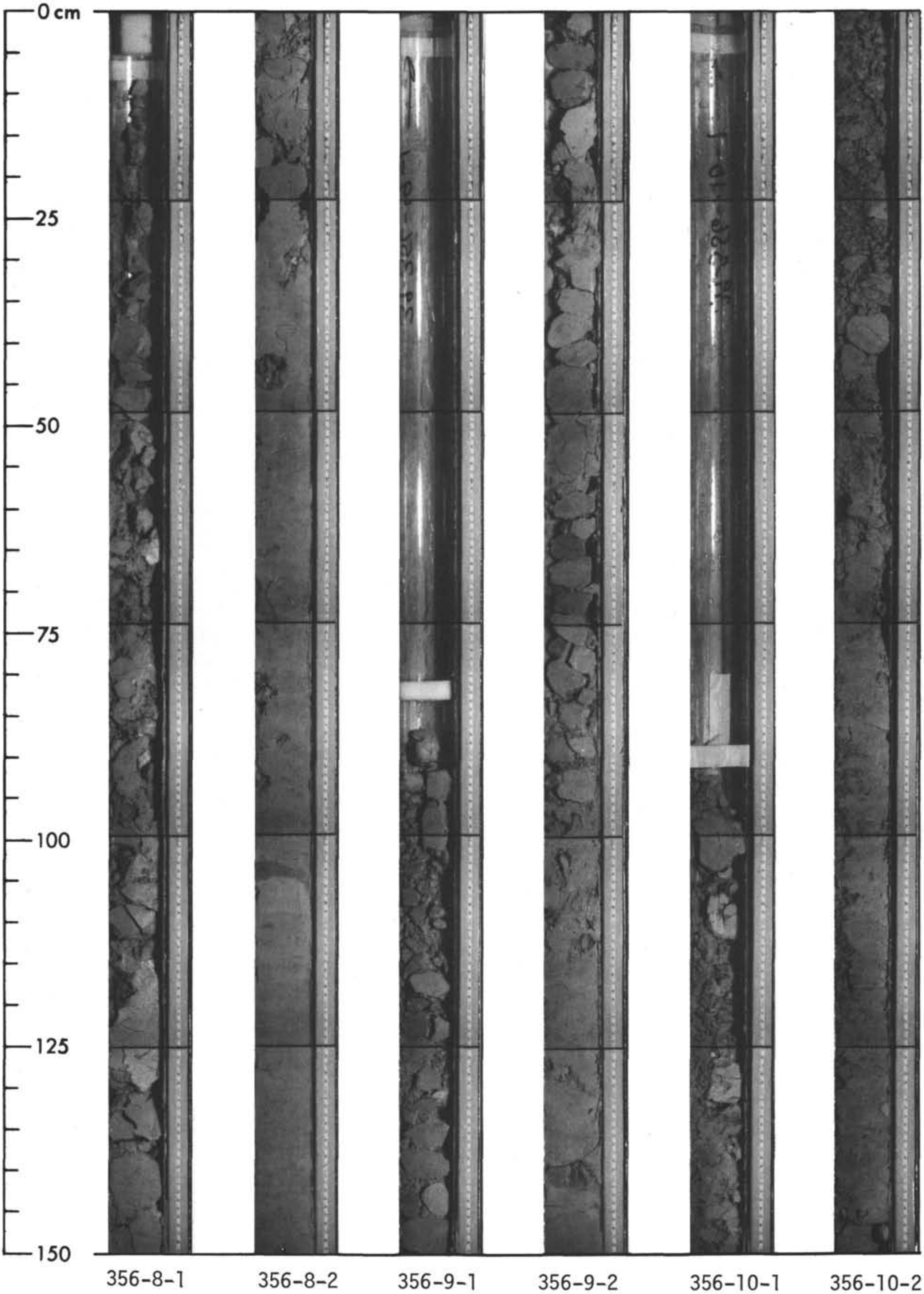
356-7-6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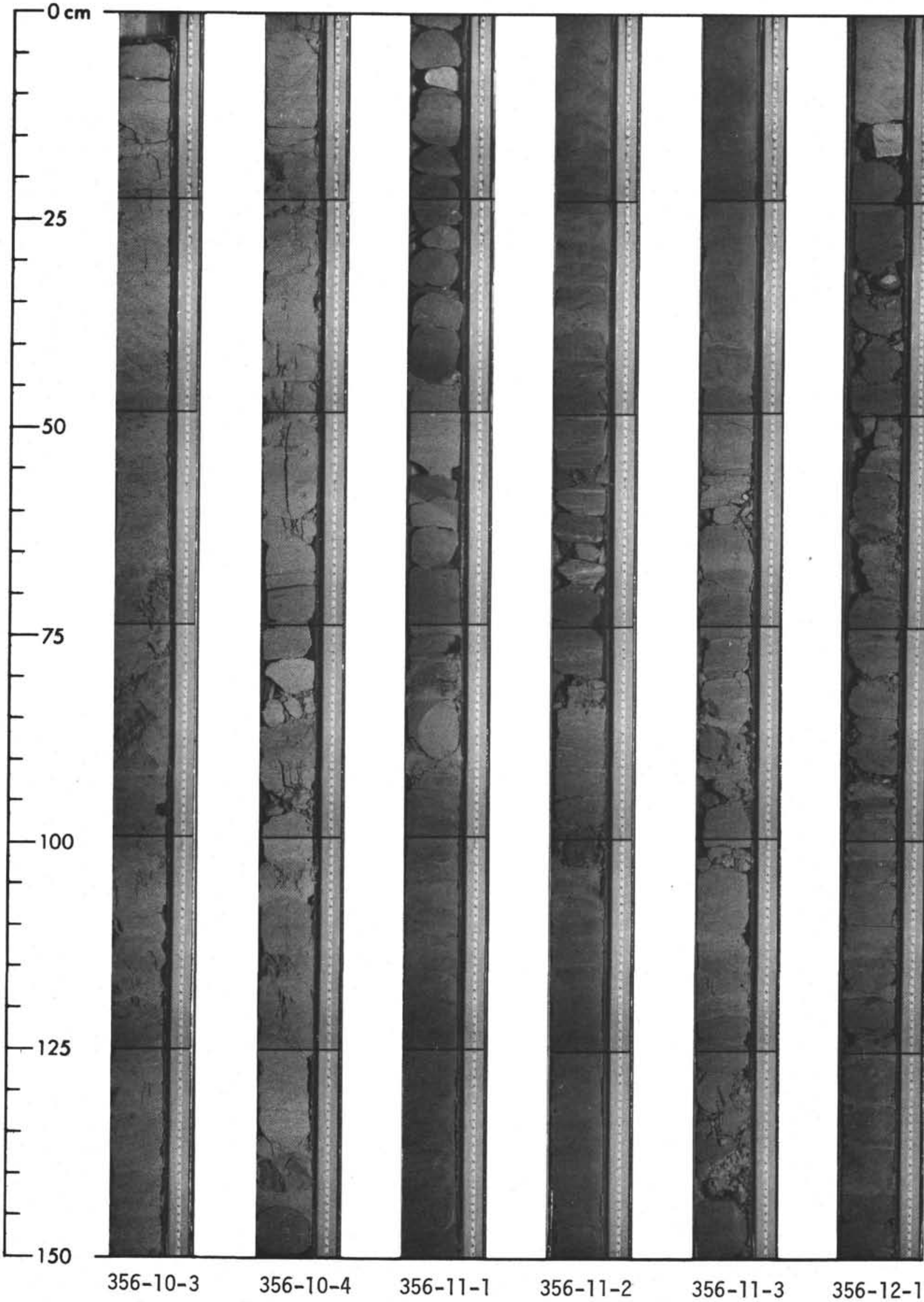
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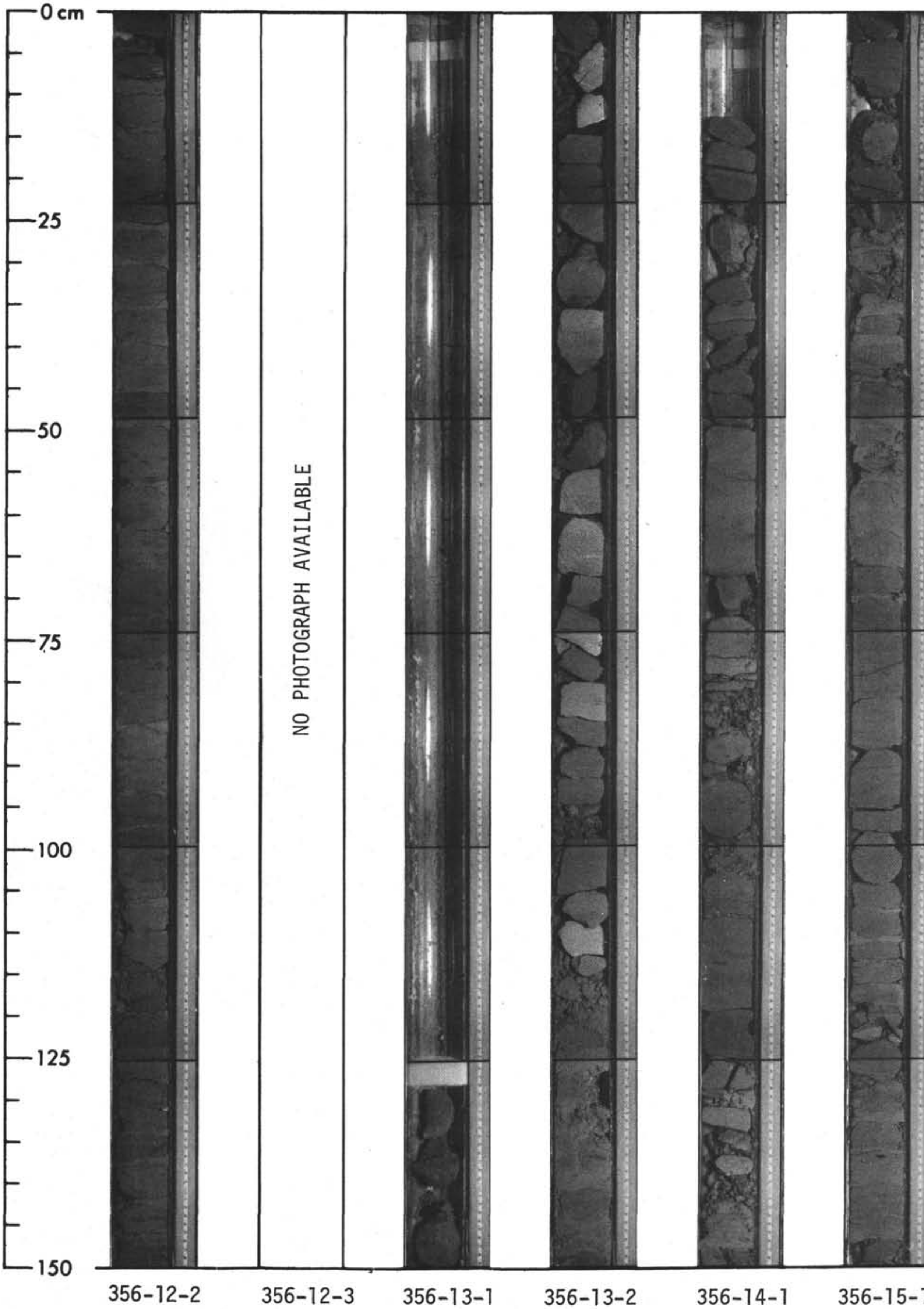
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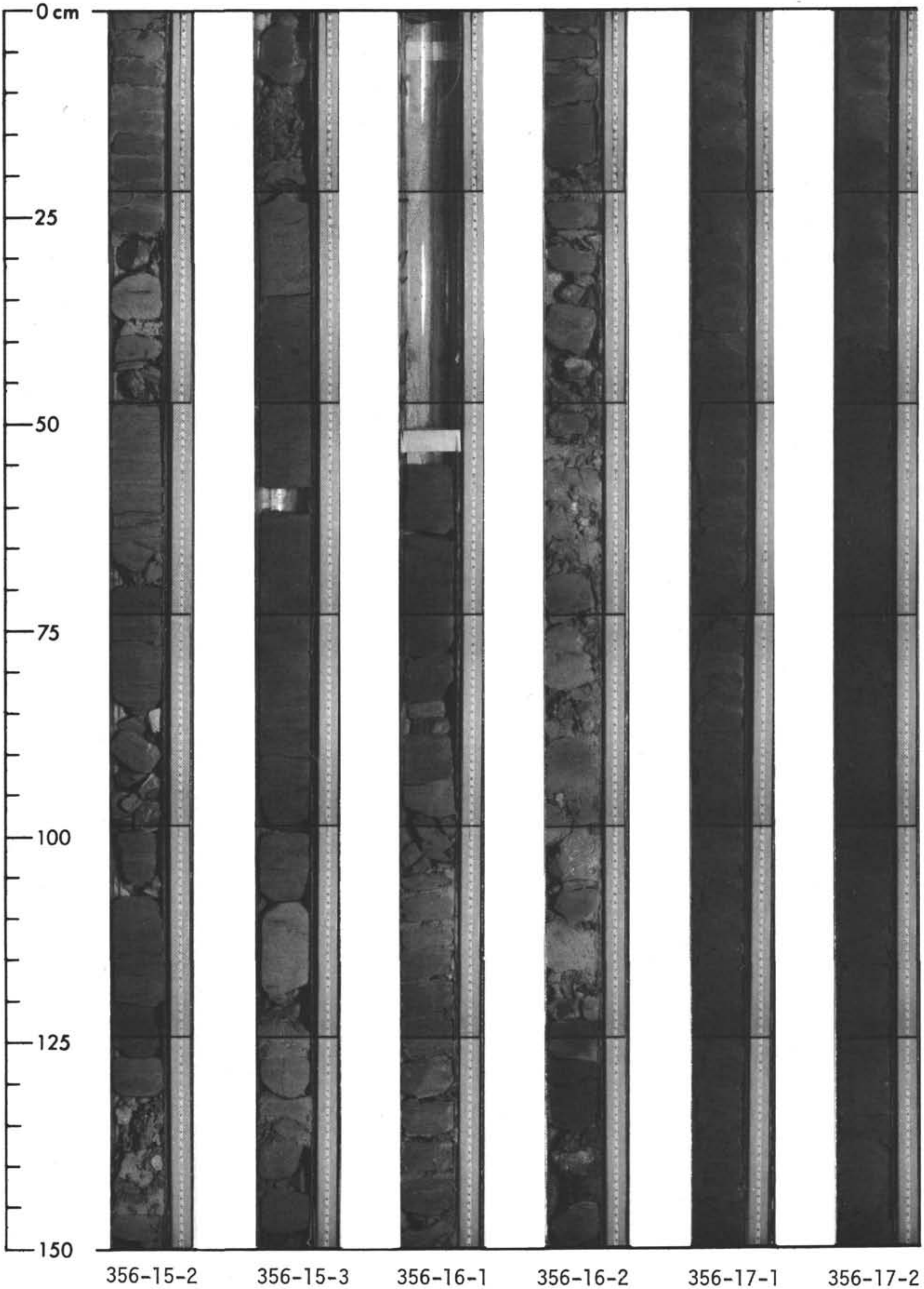
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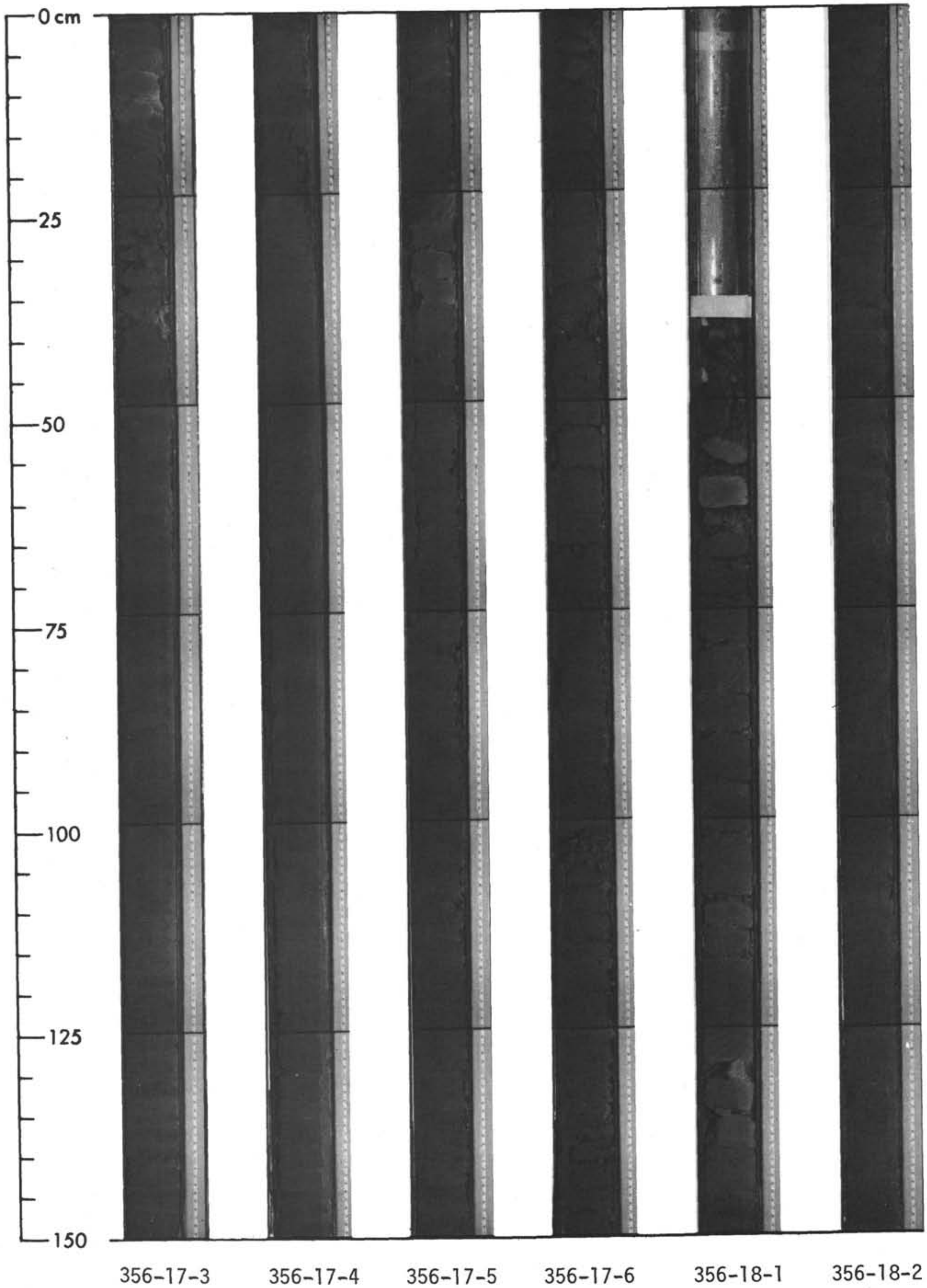
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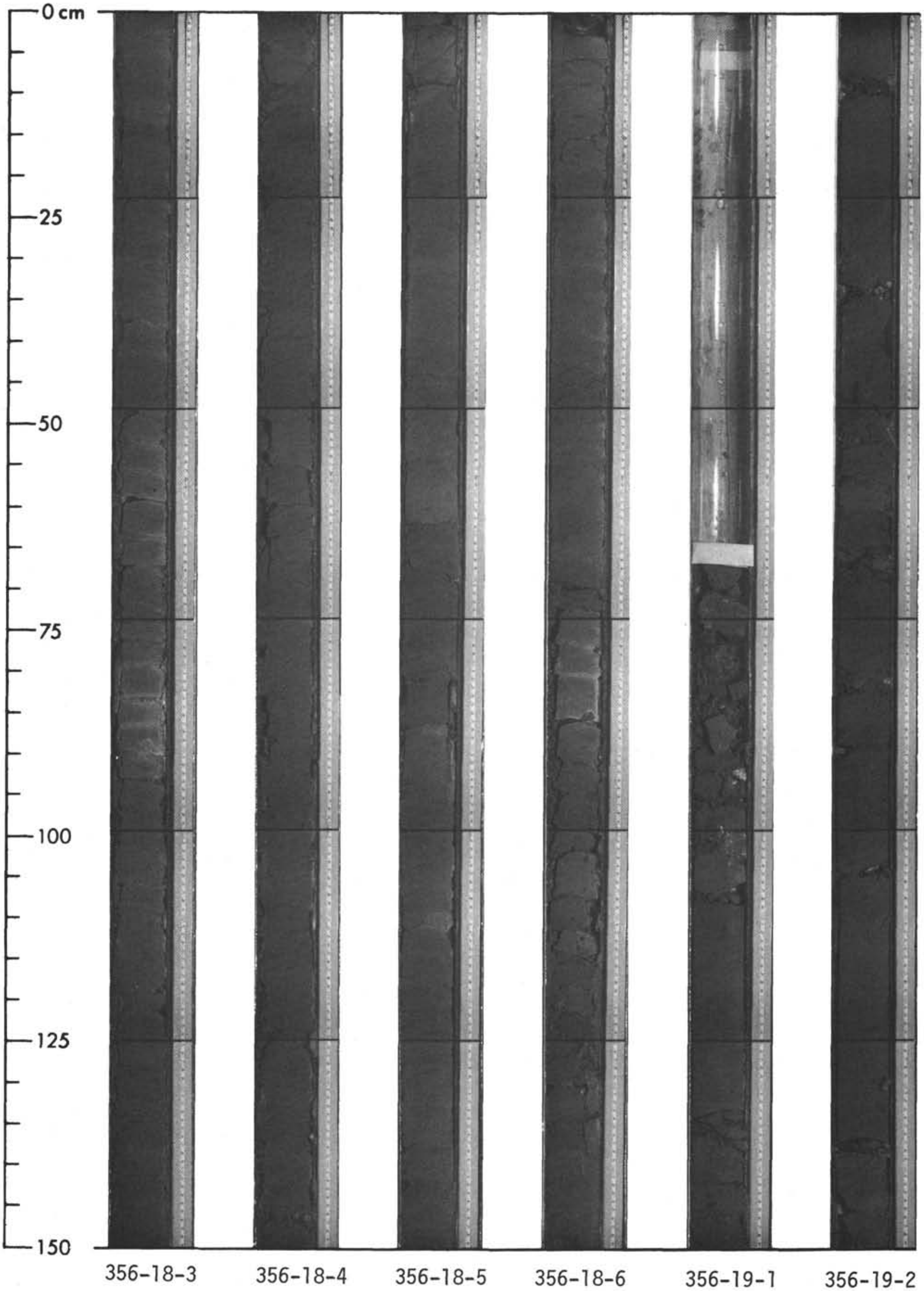
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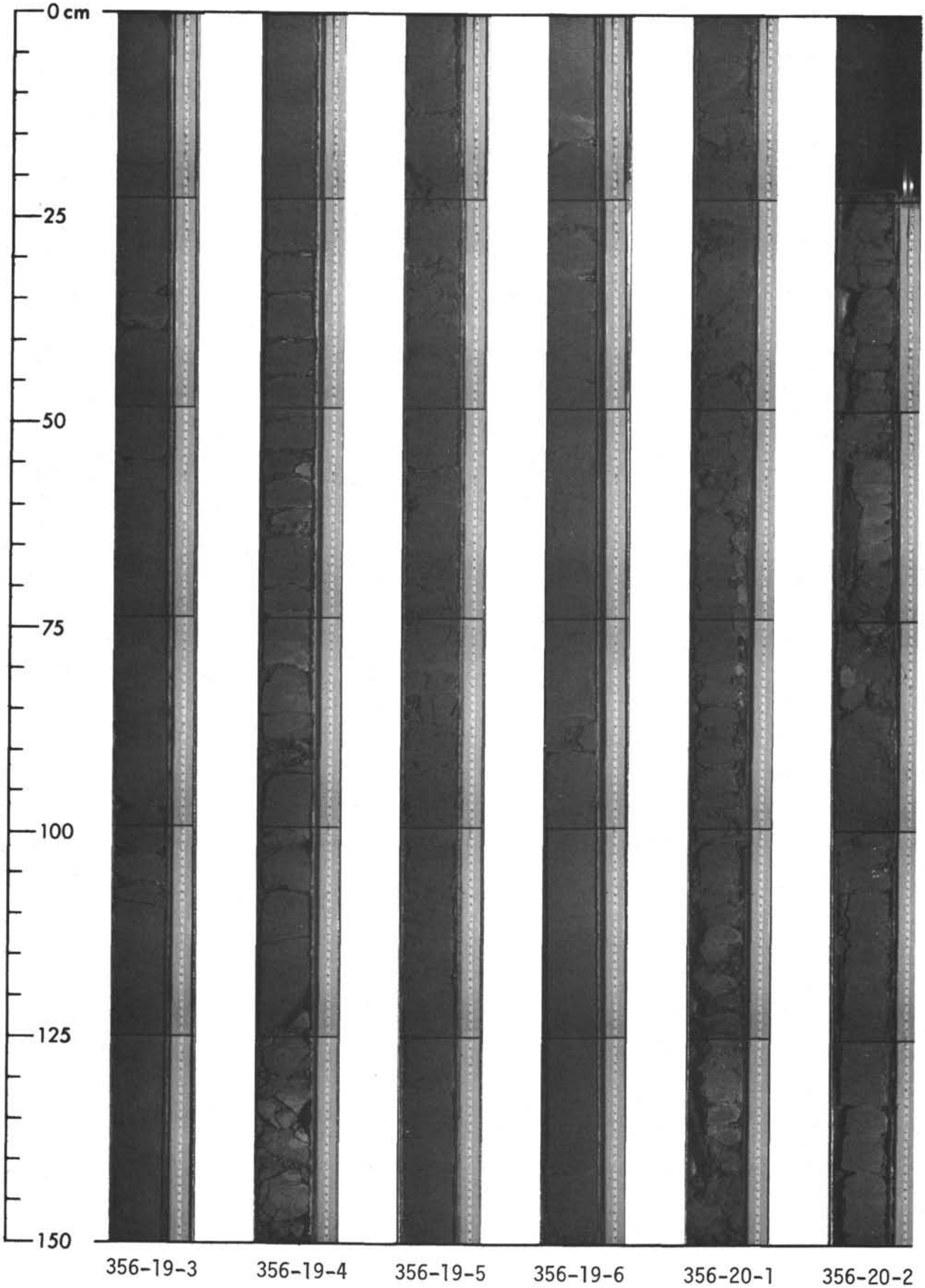
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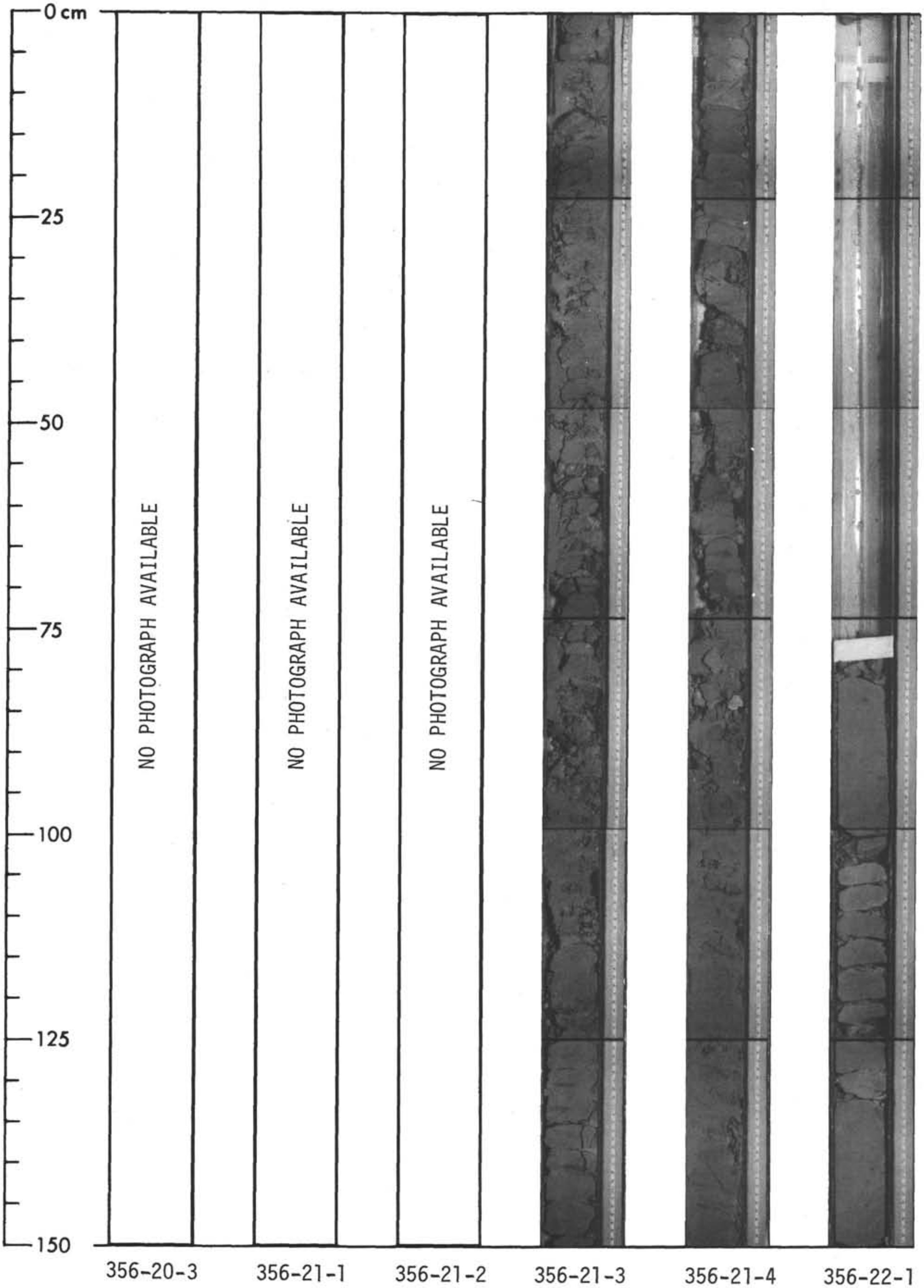
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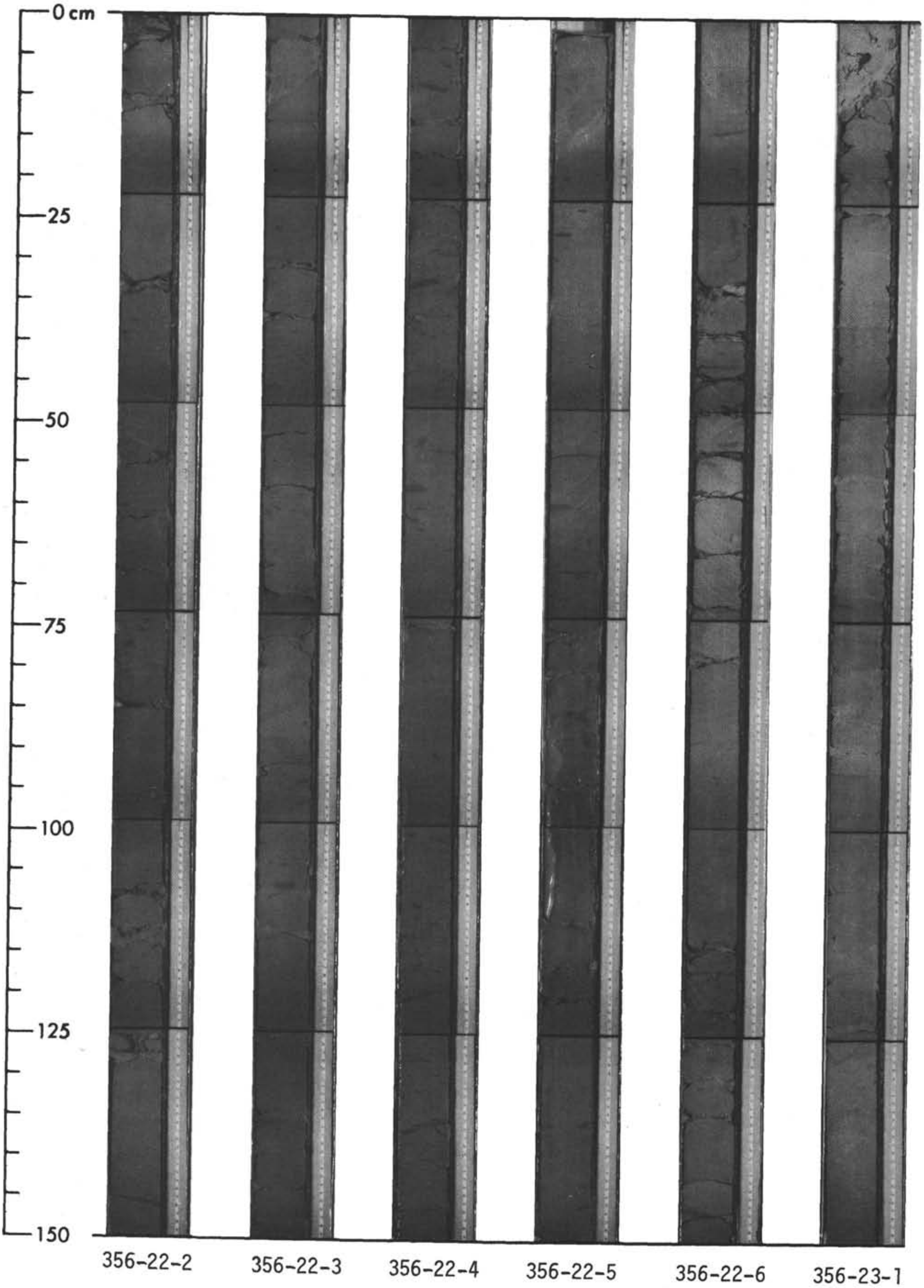
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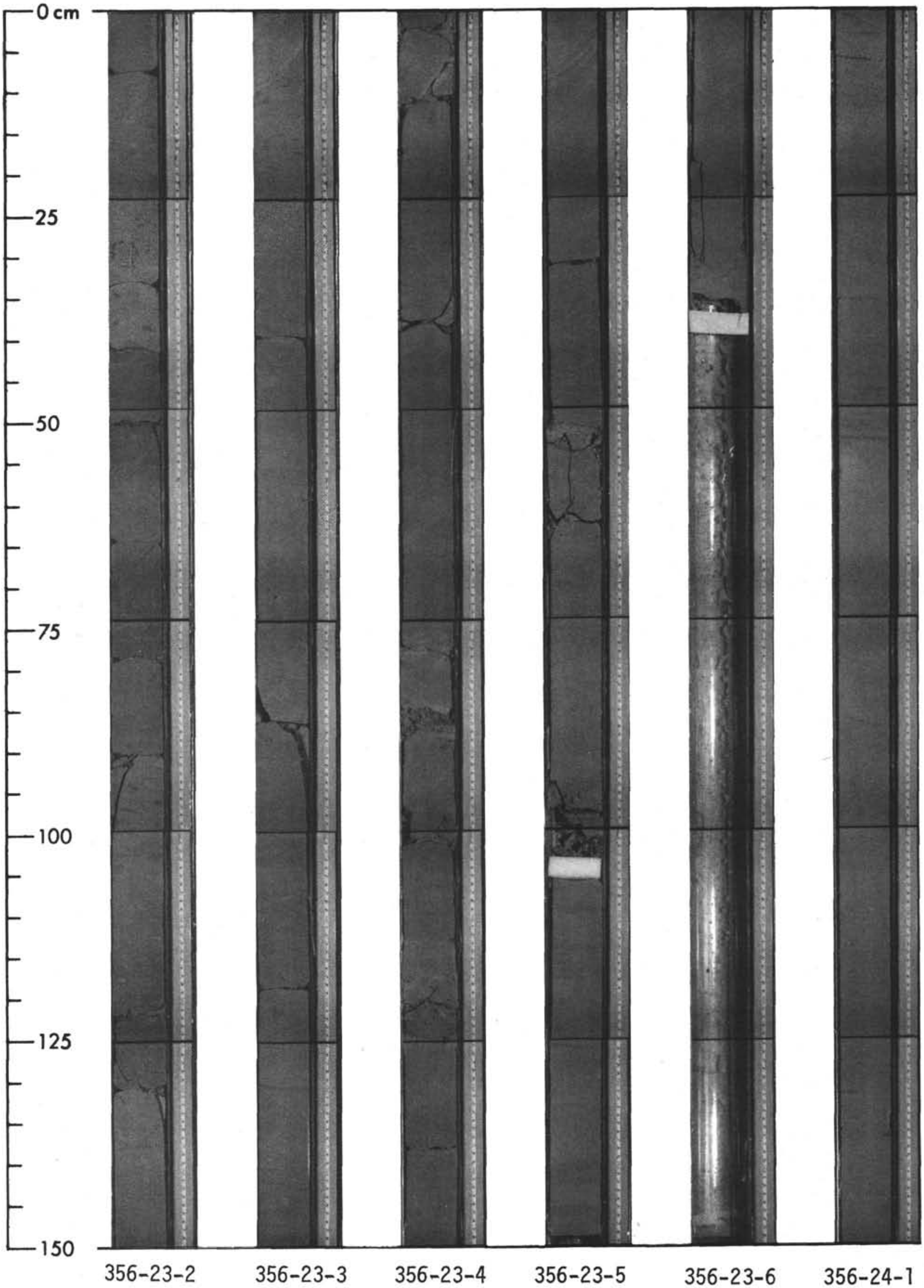
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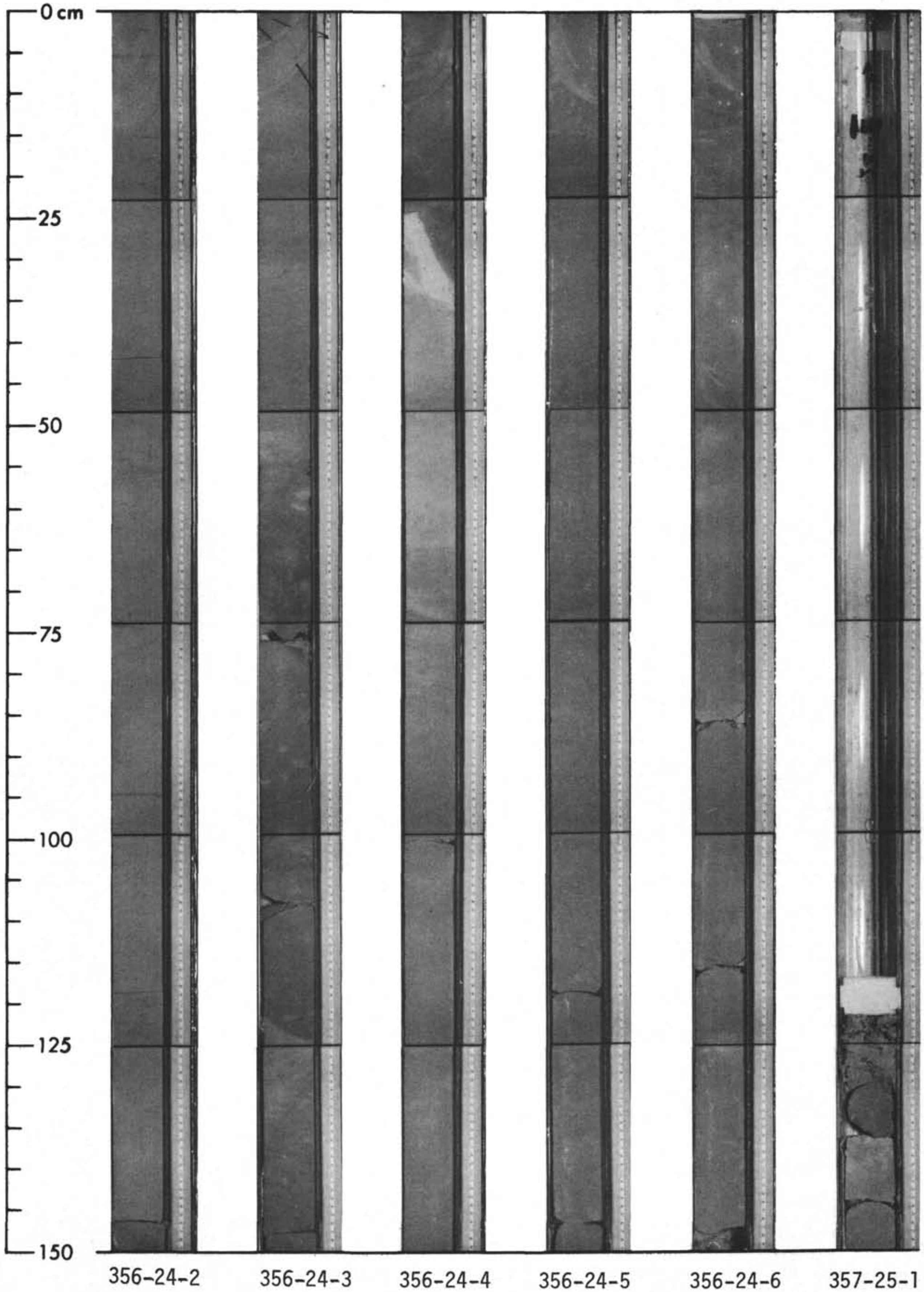
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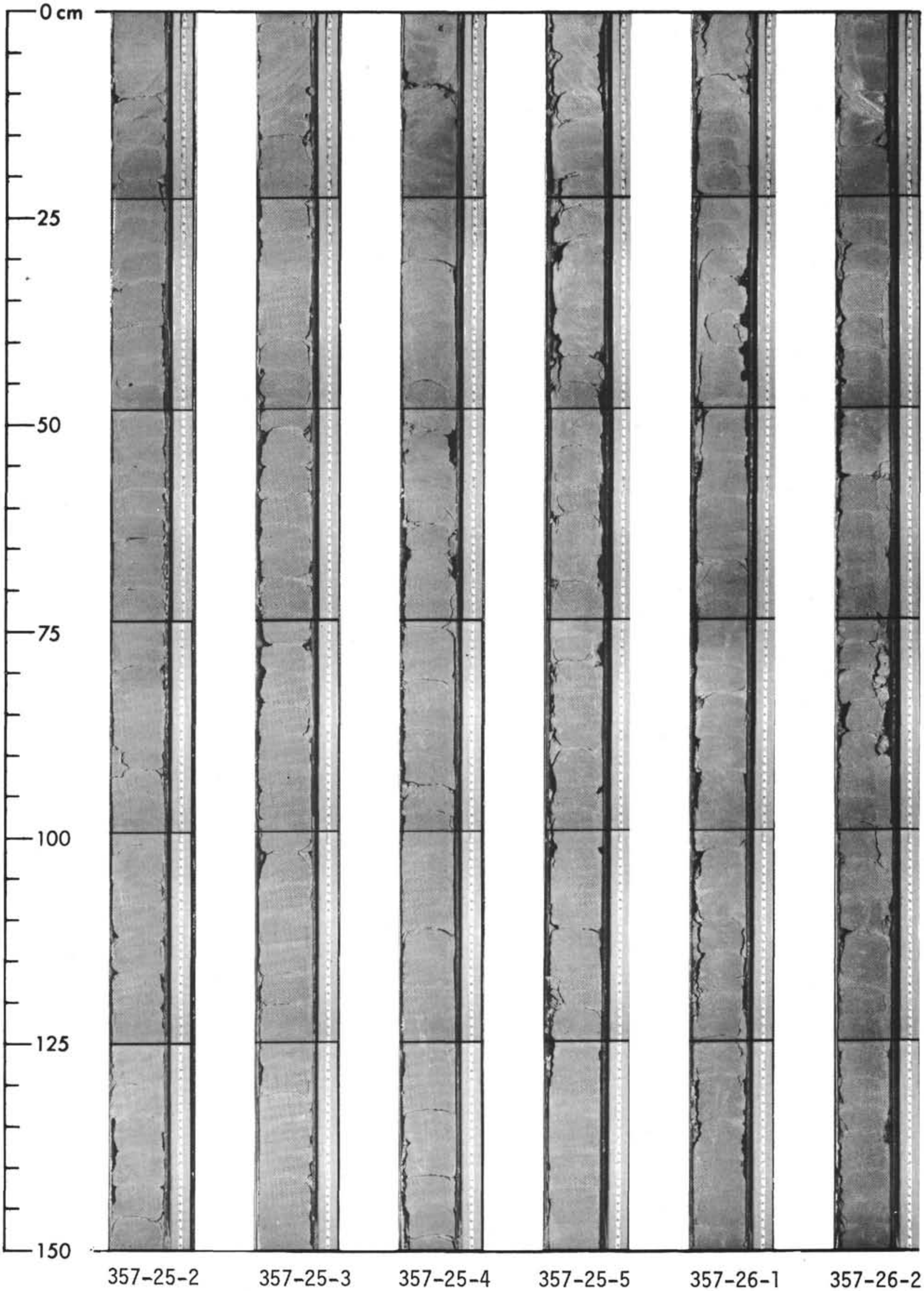
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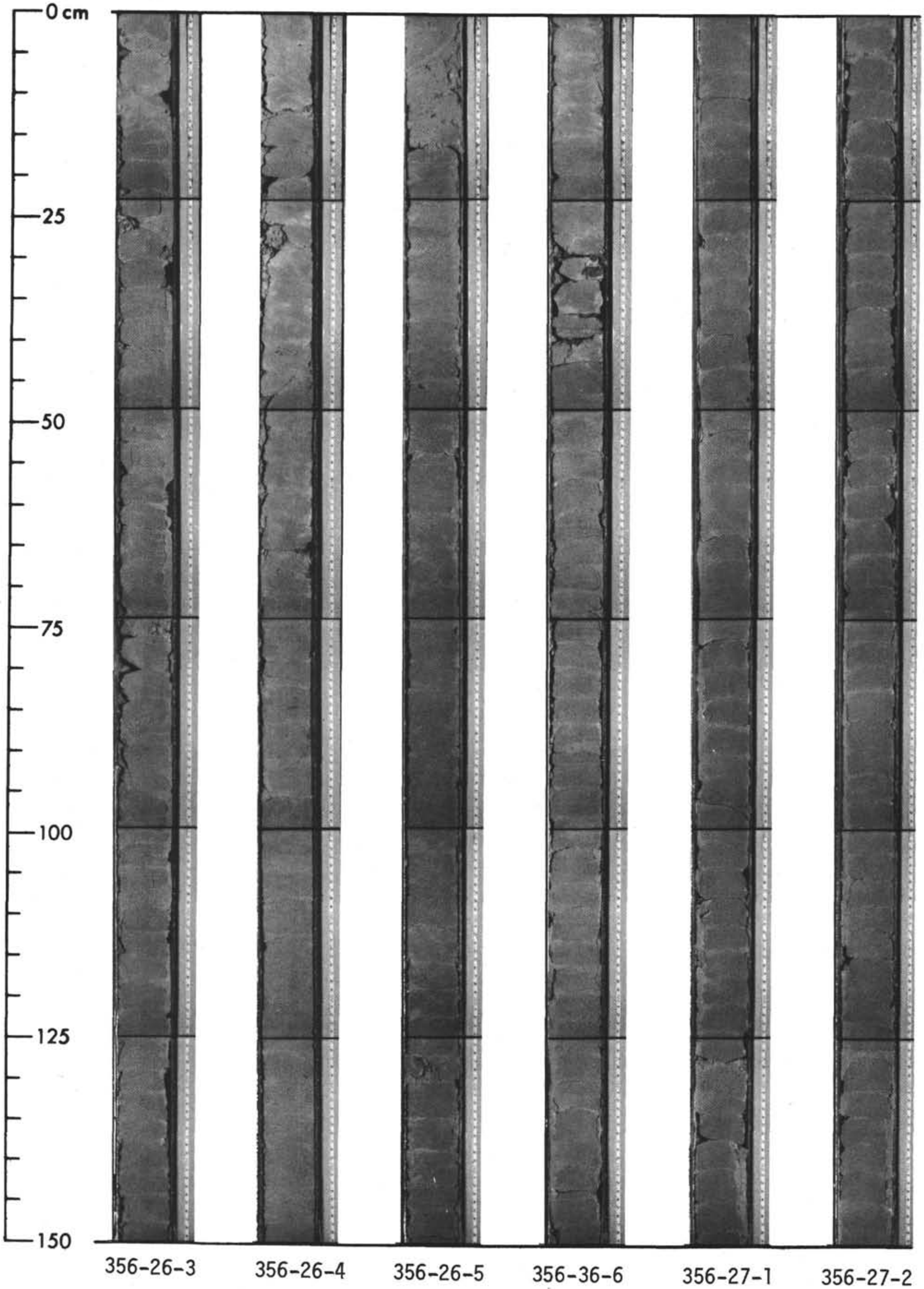
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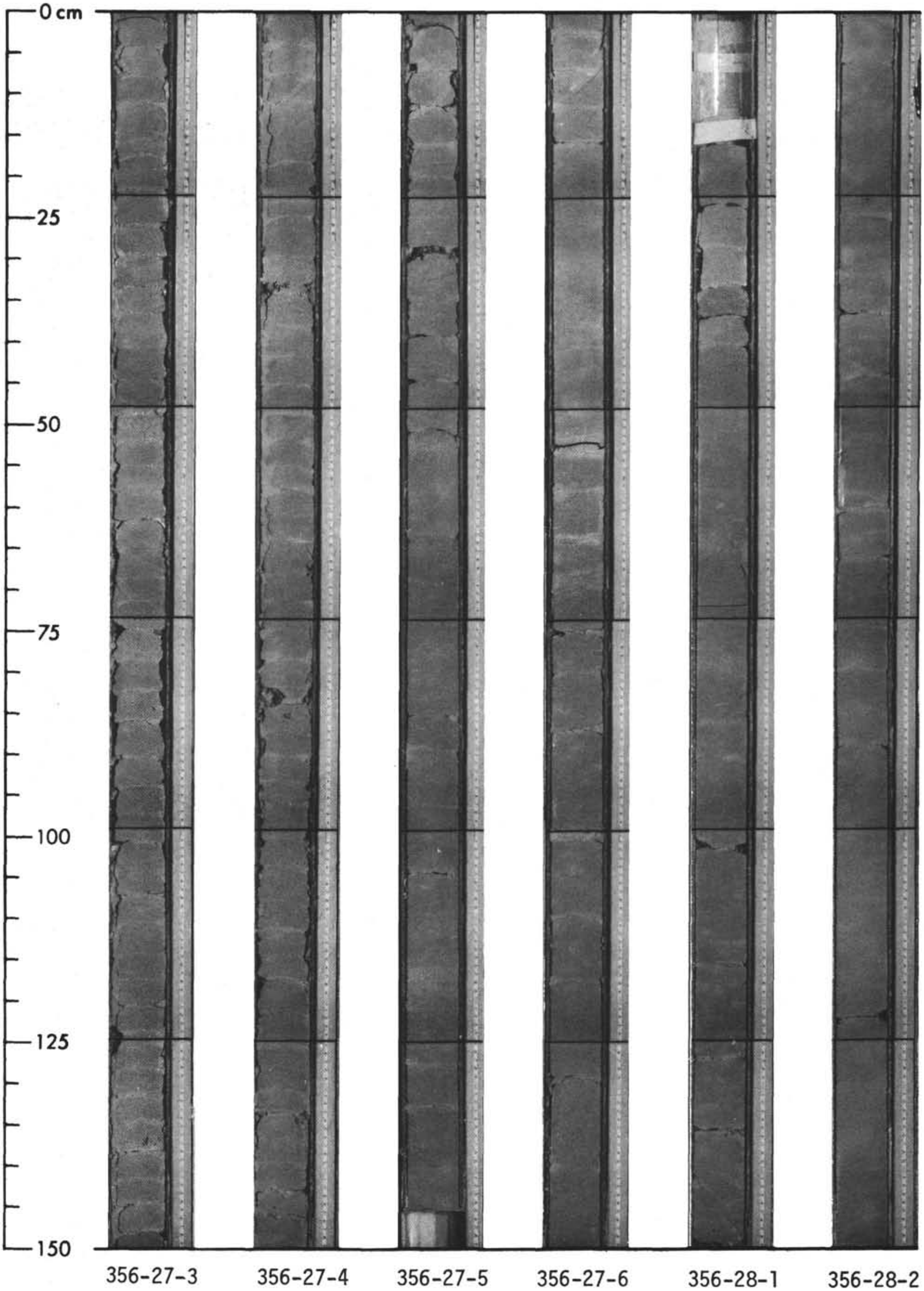
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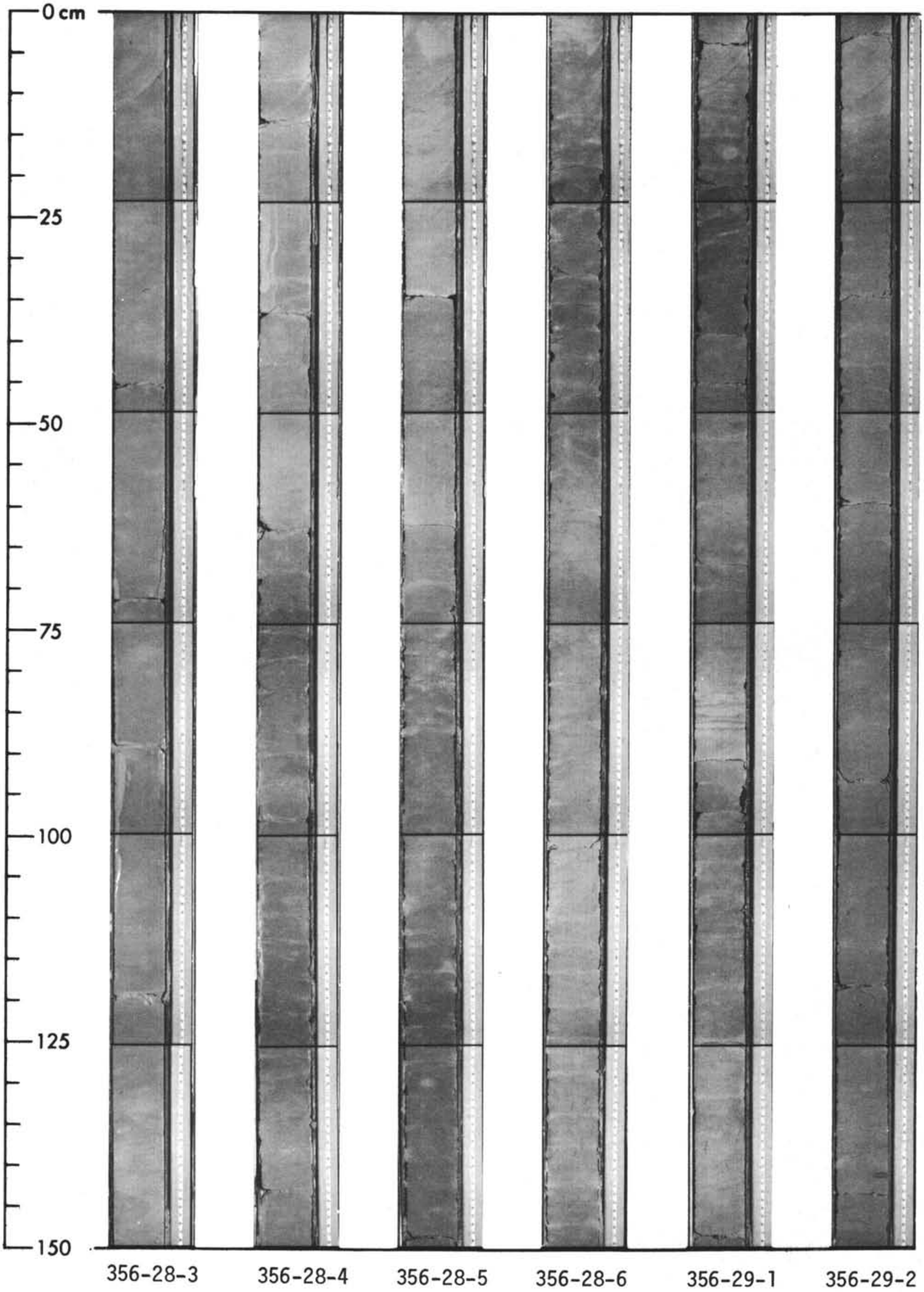
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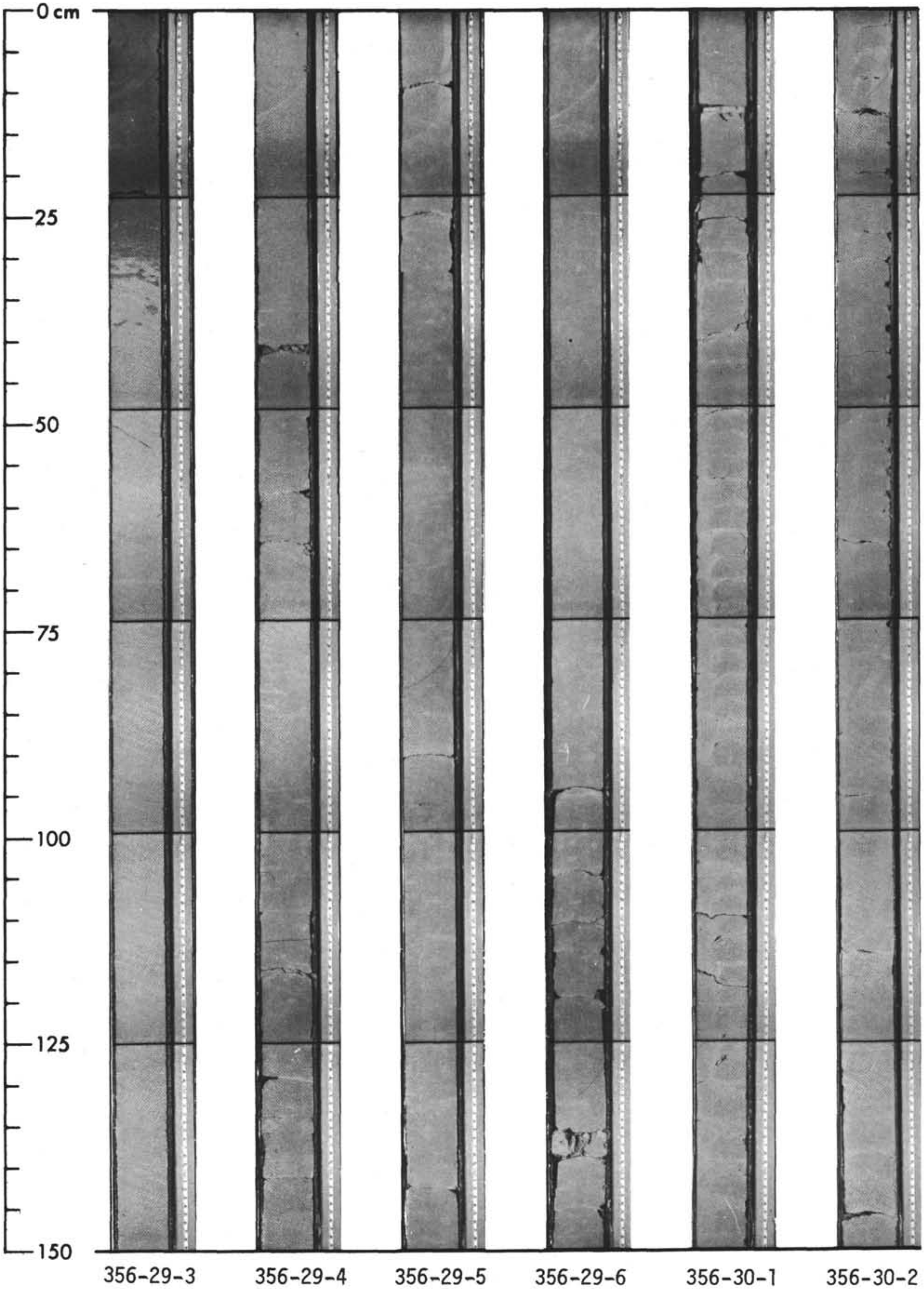
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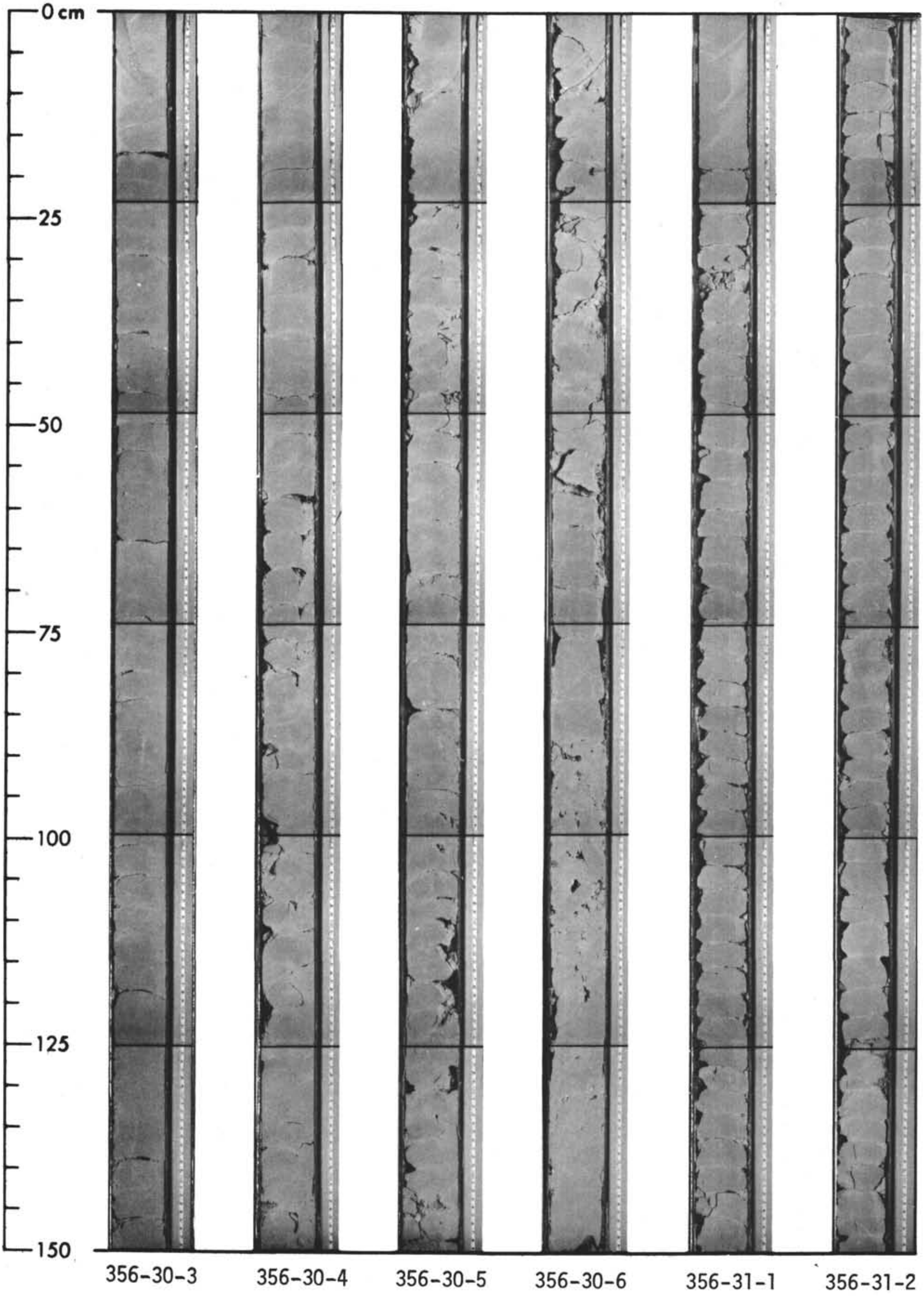
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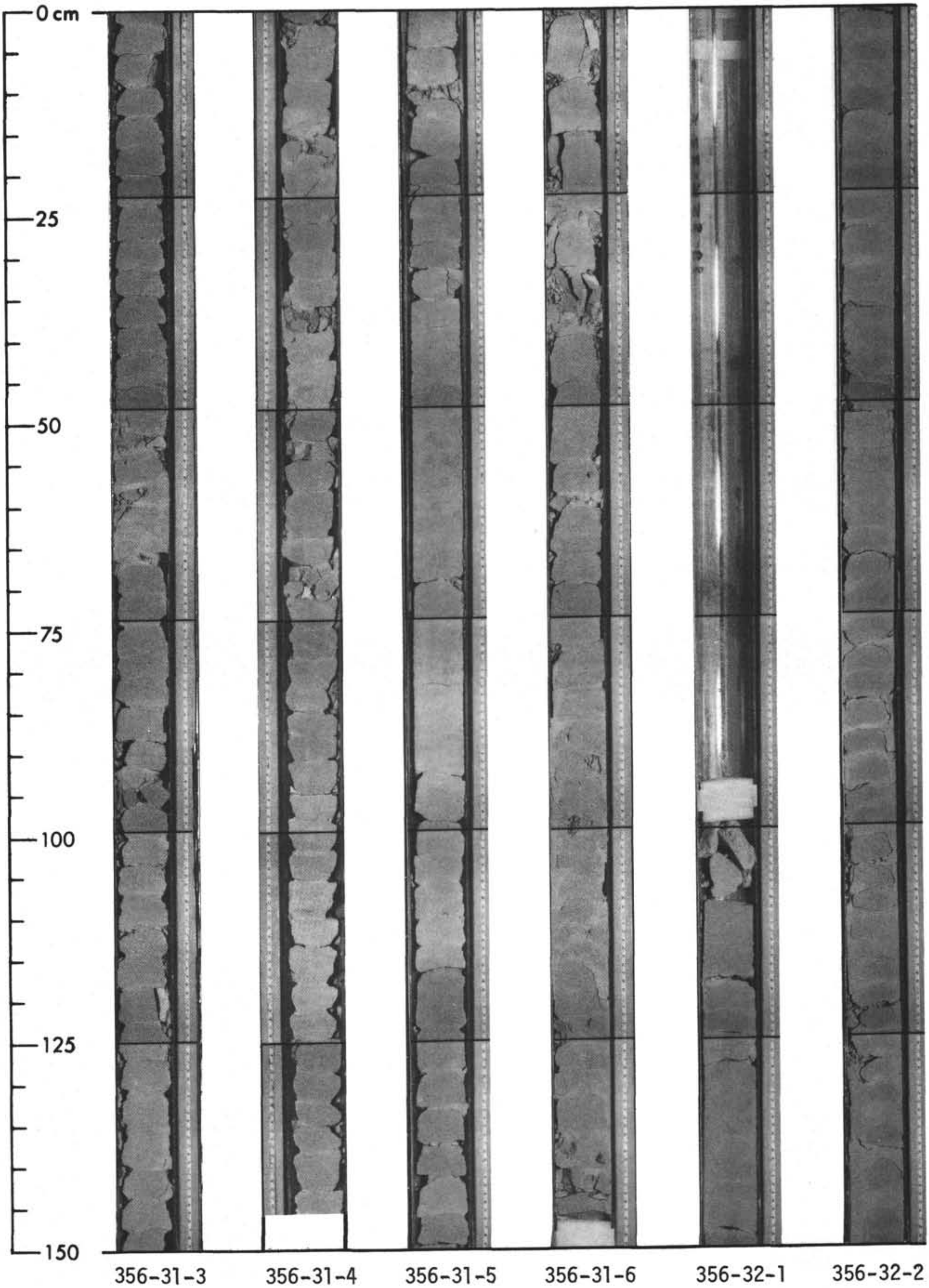
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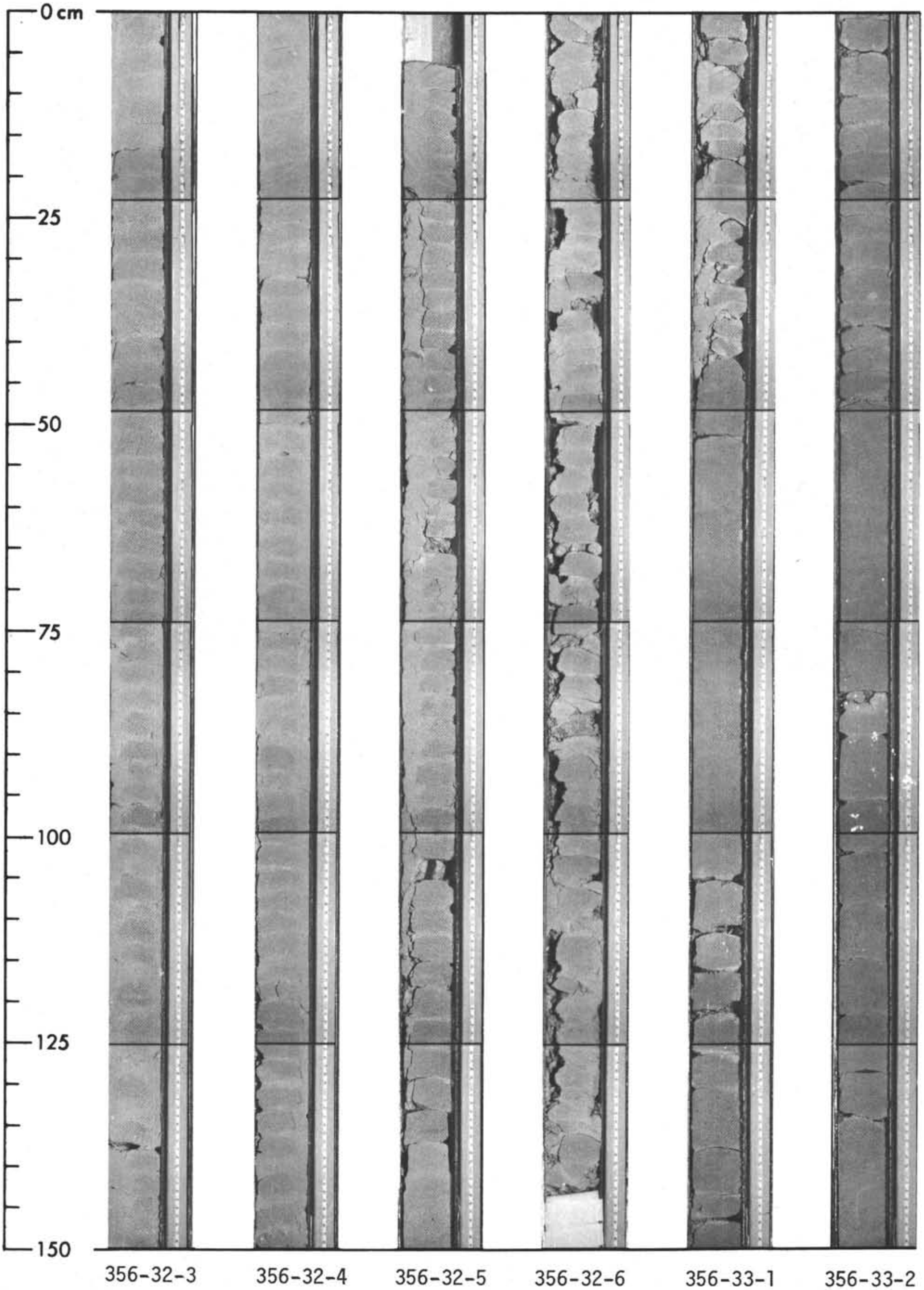
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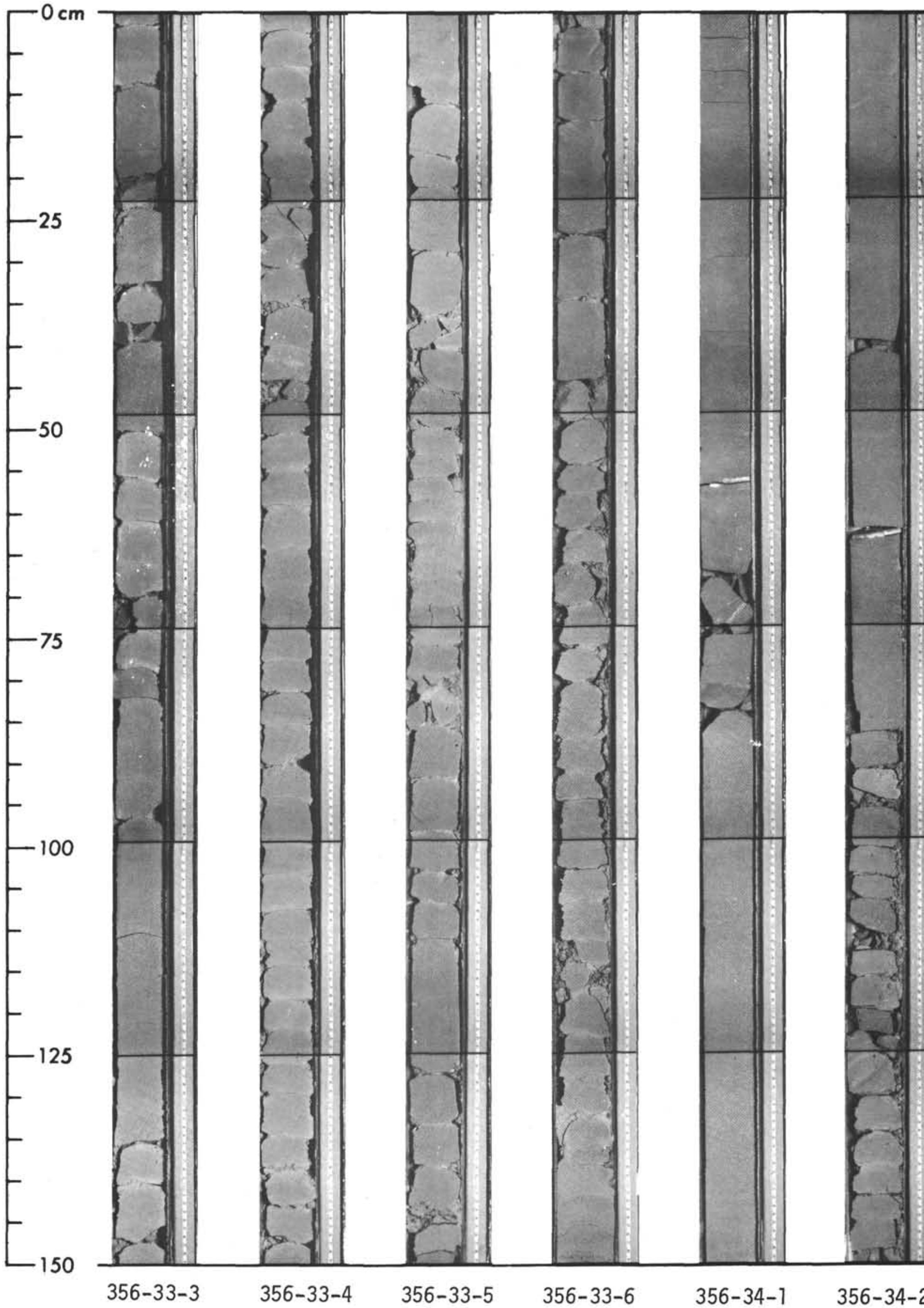
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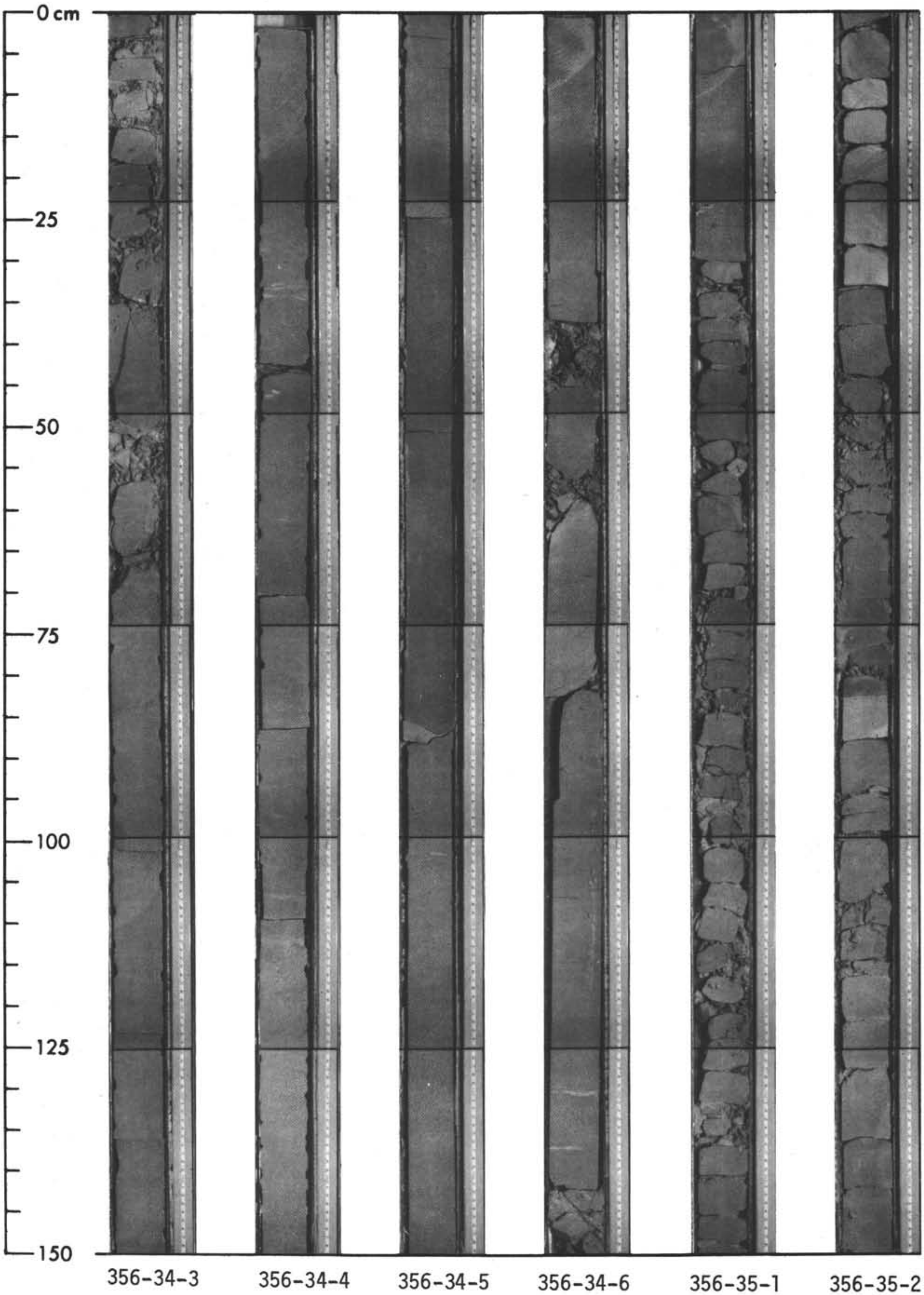
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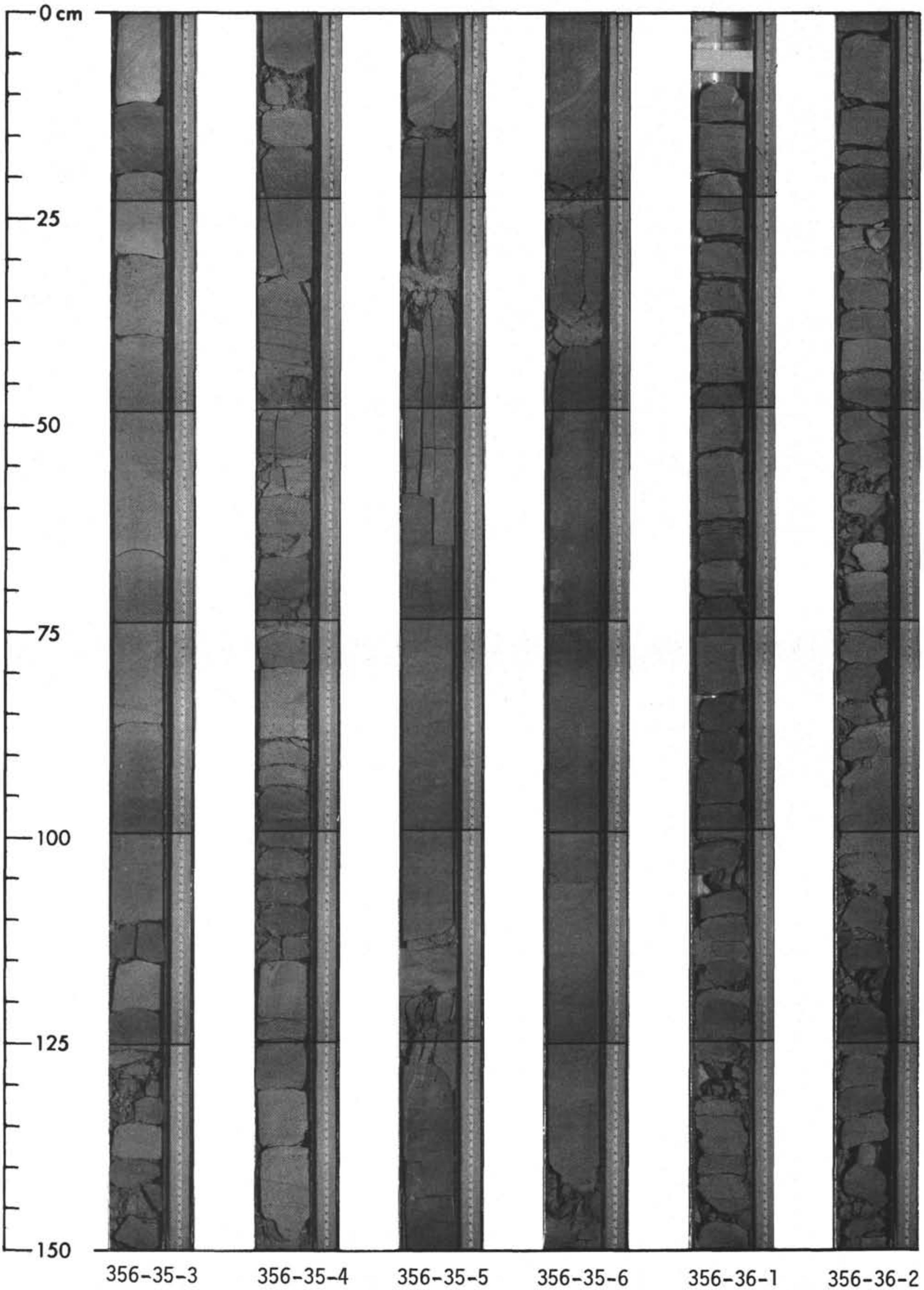
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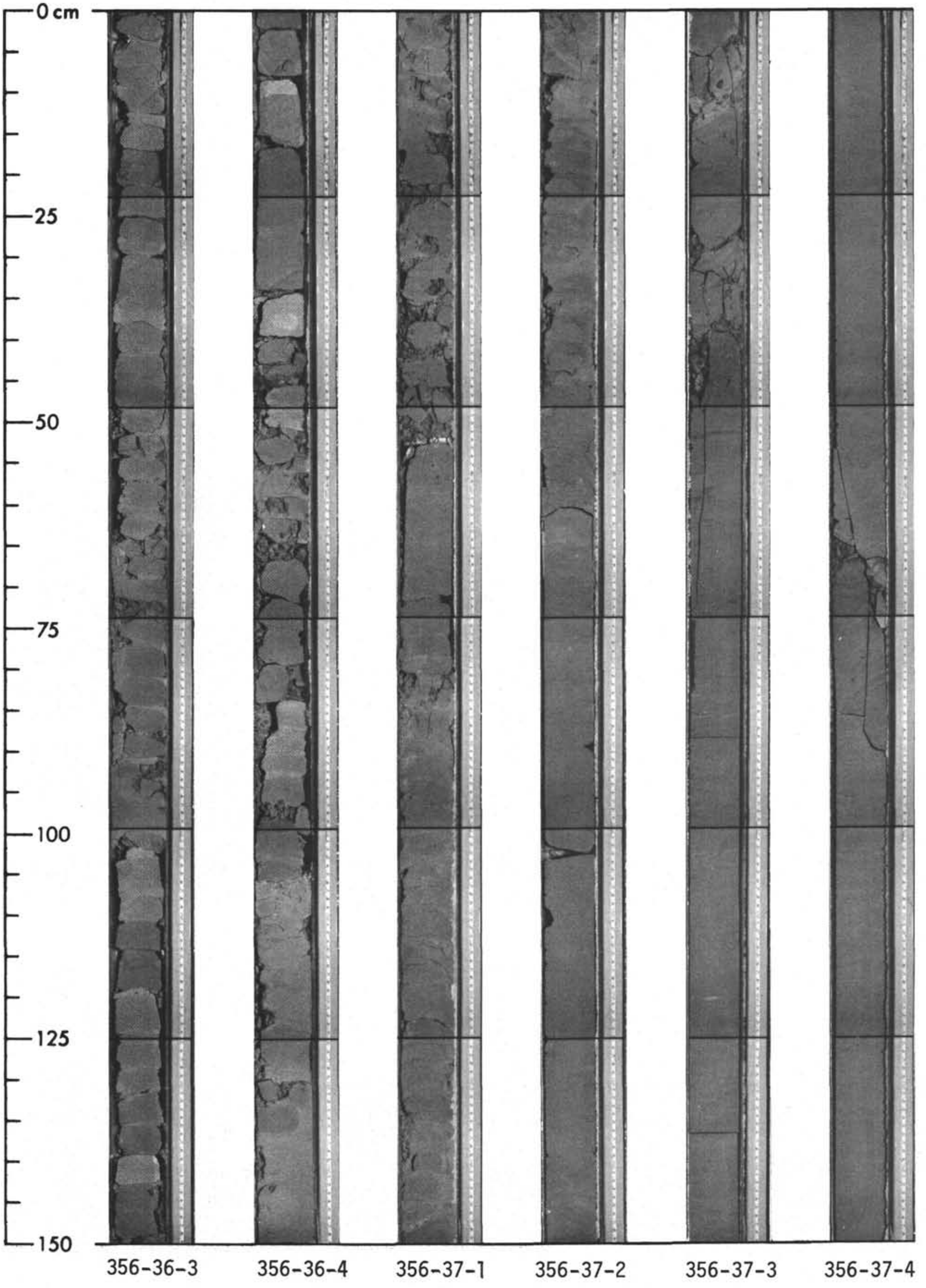
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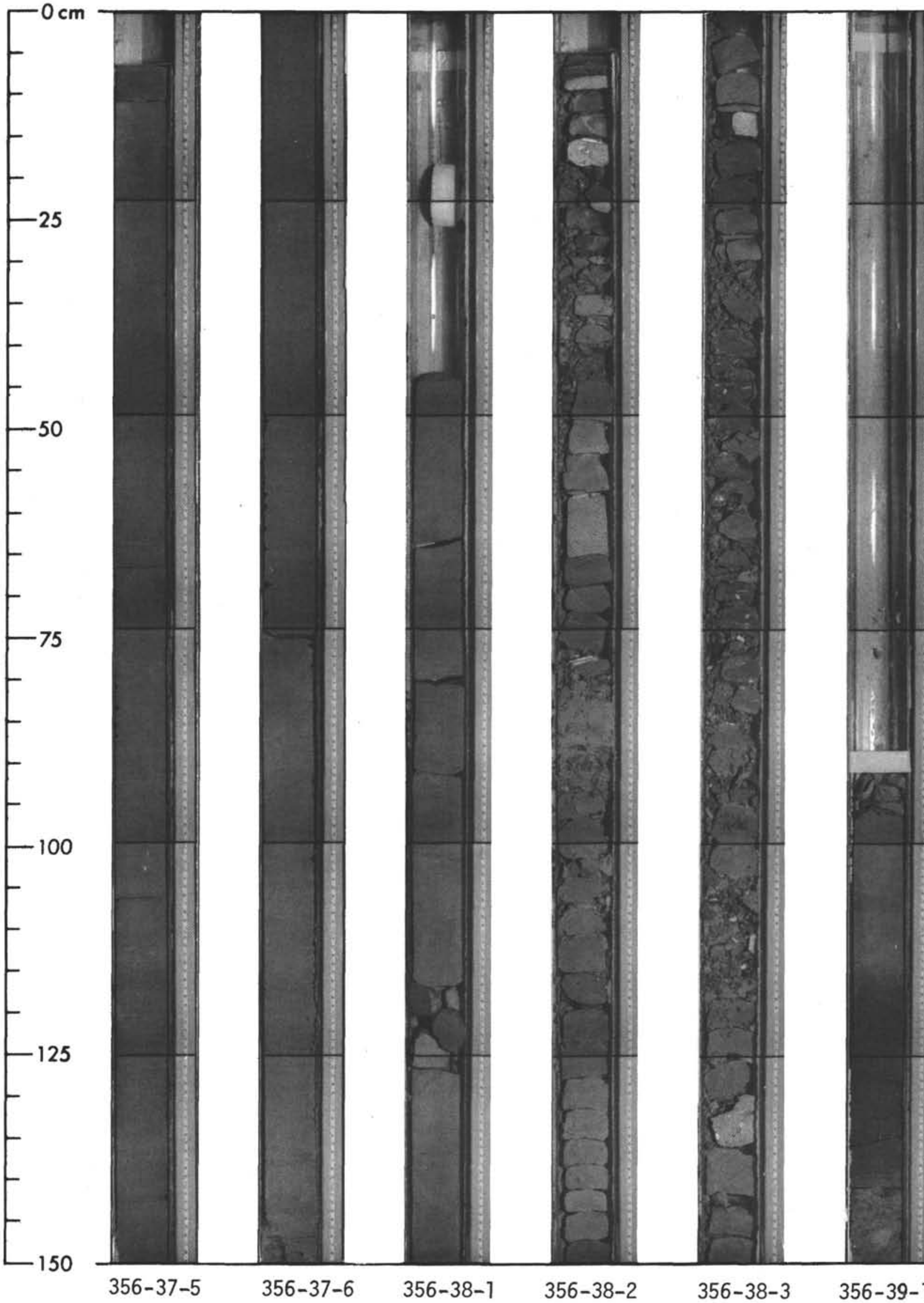
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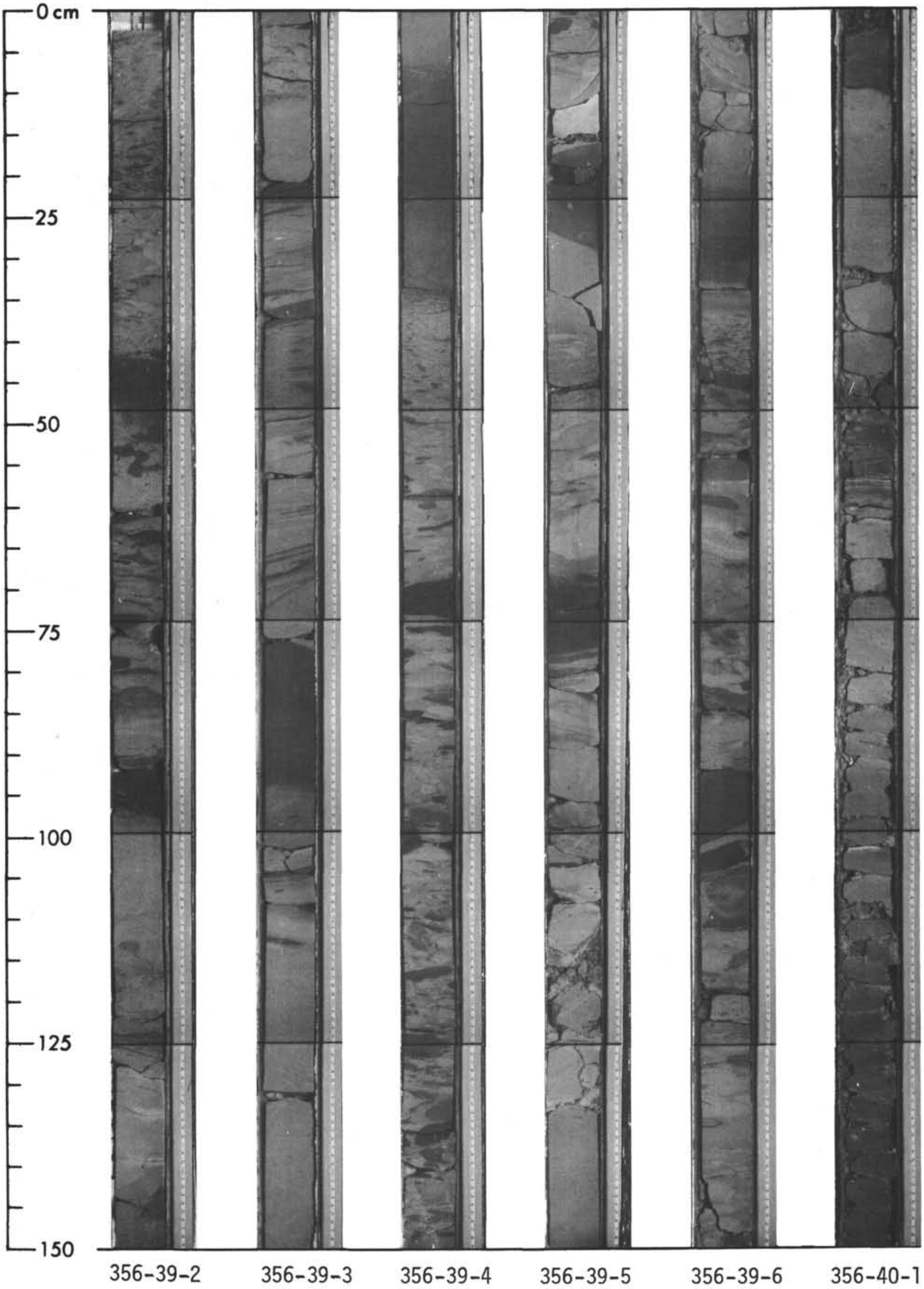
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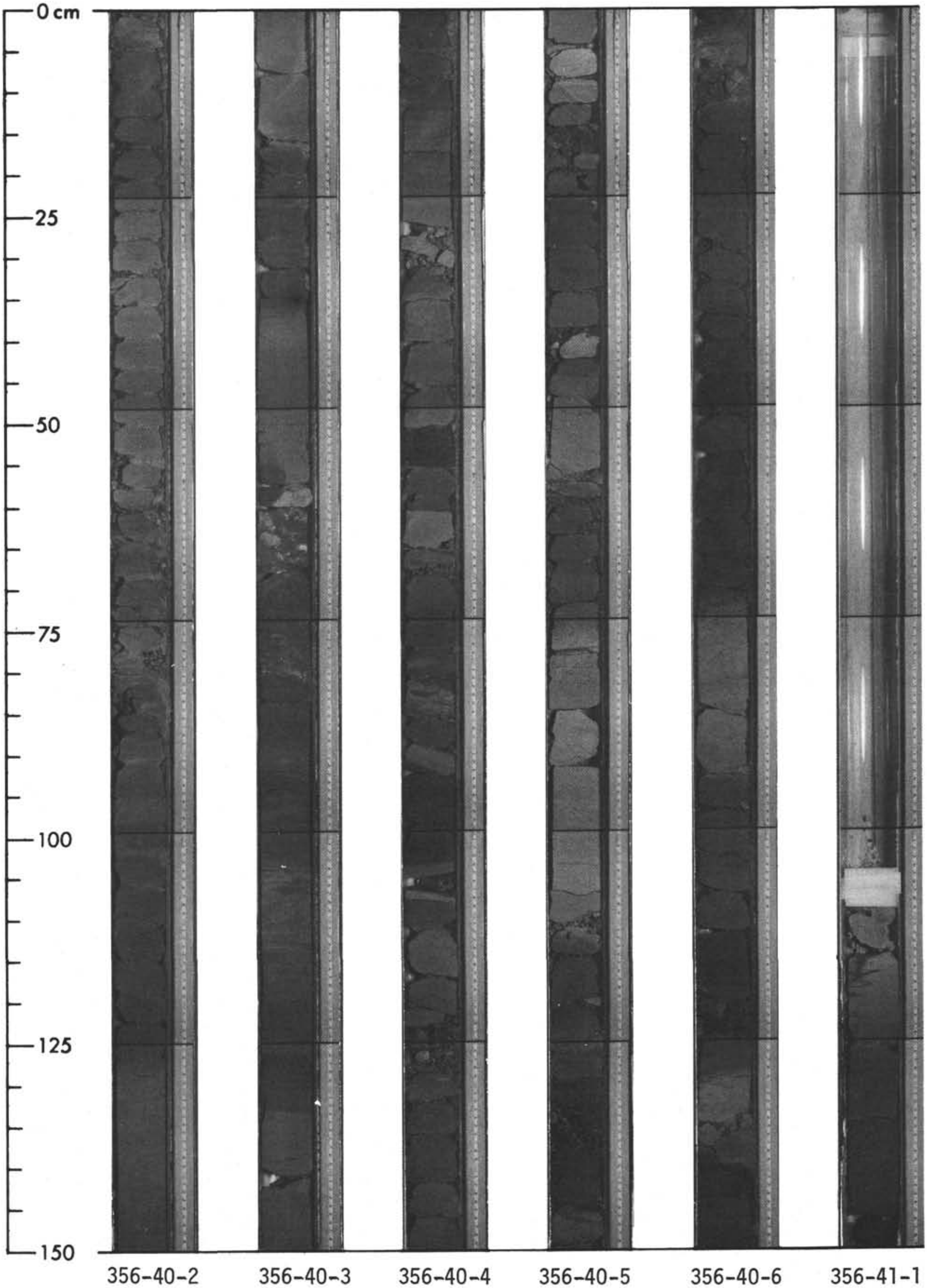
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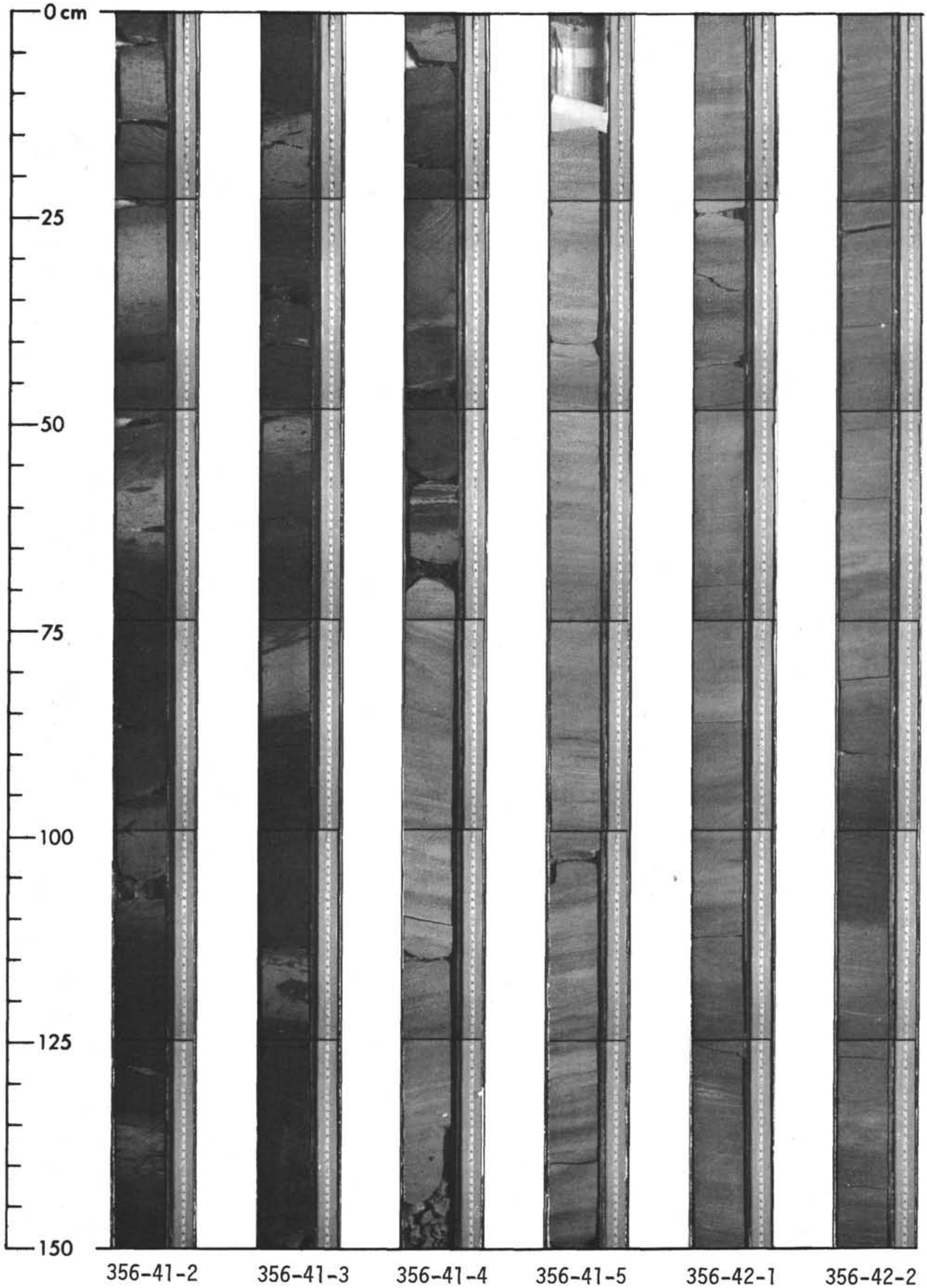
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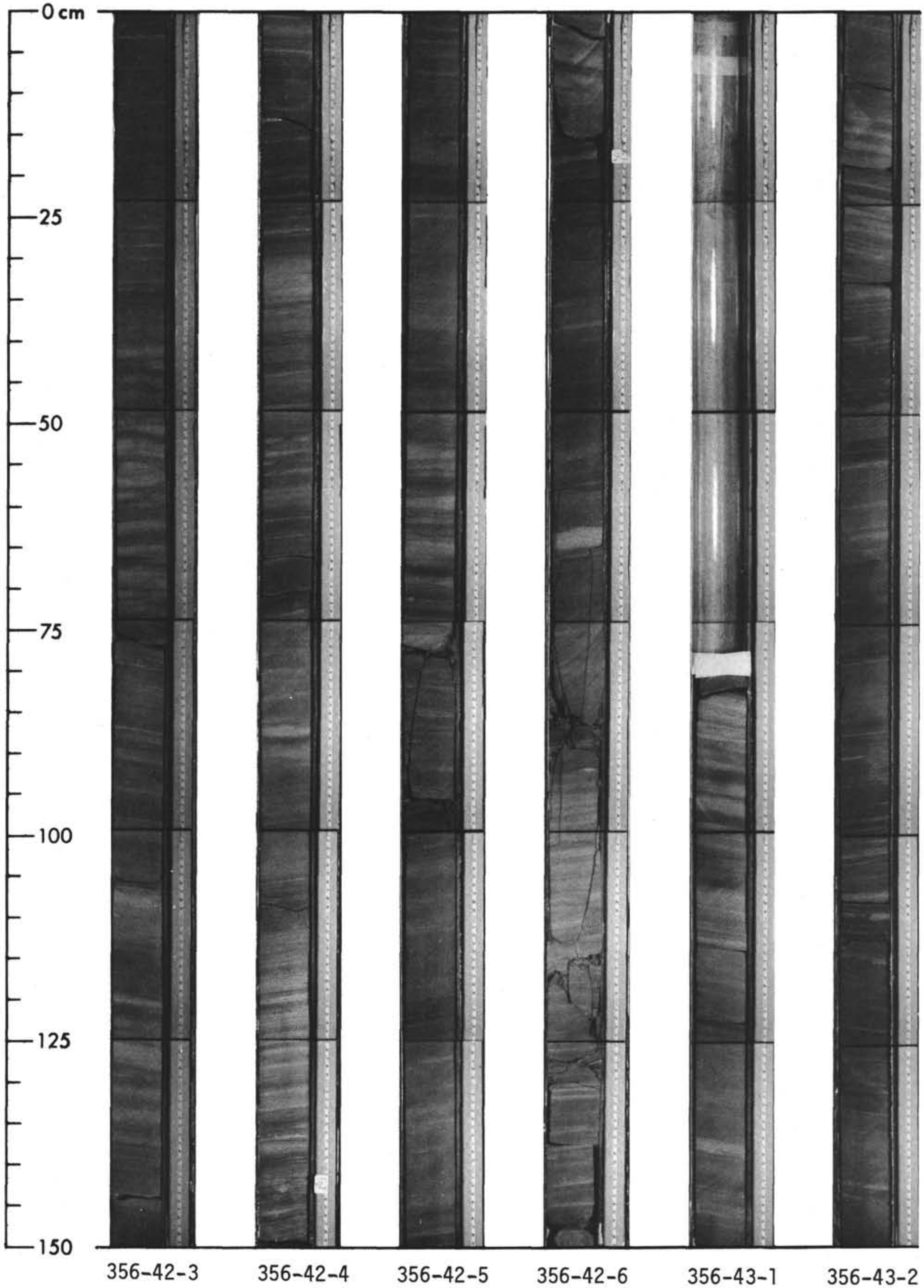
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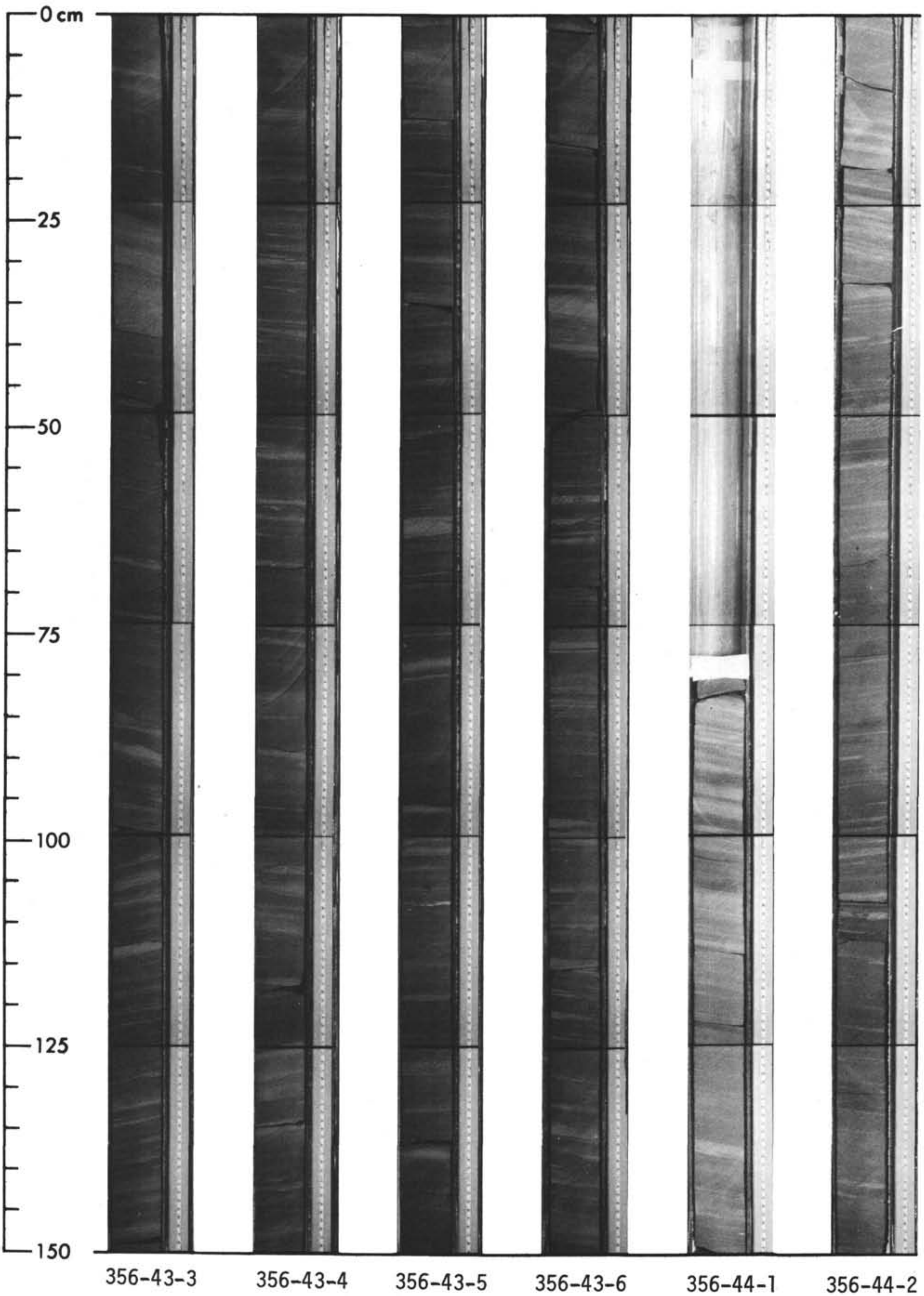
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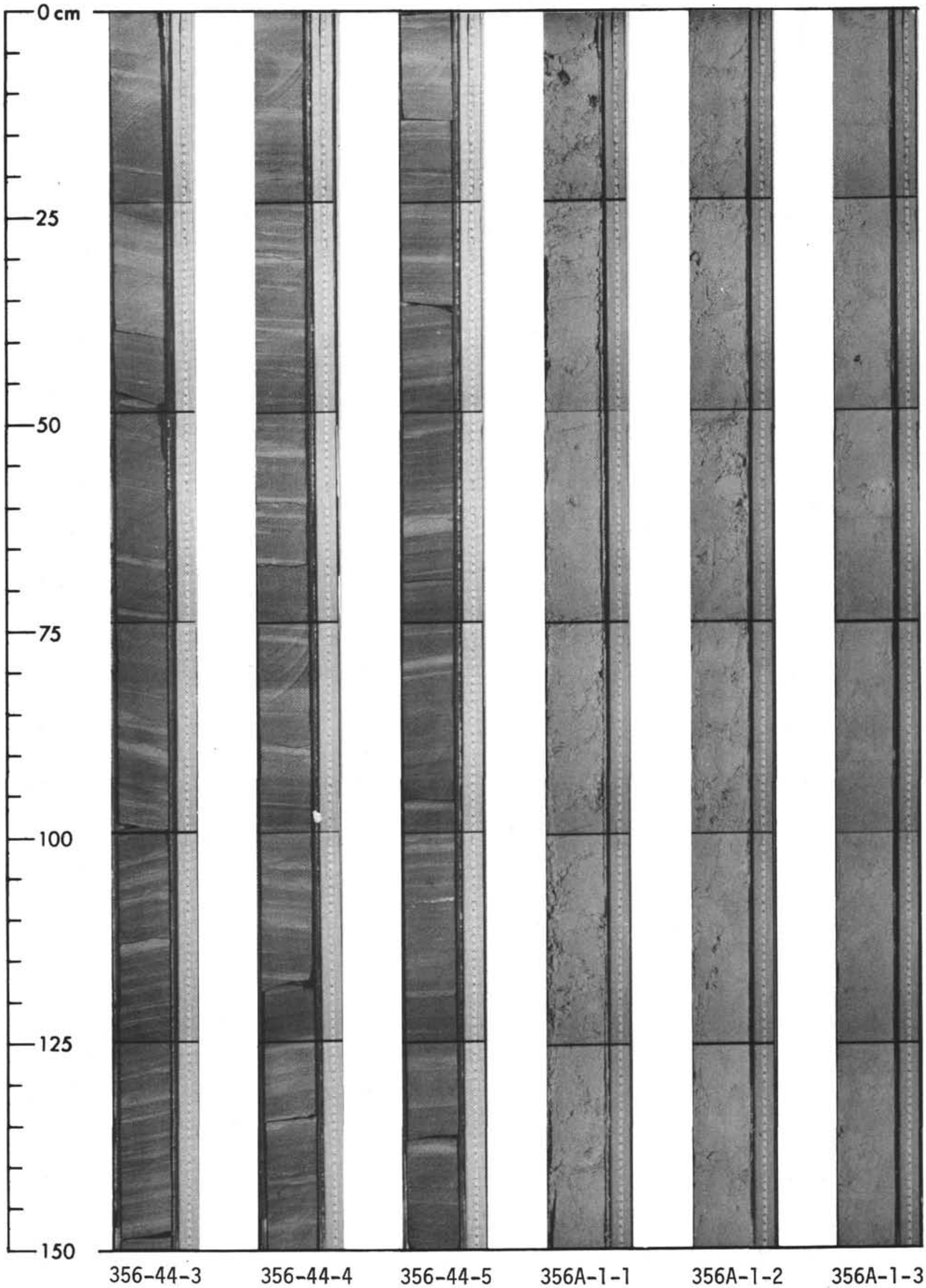
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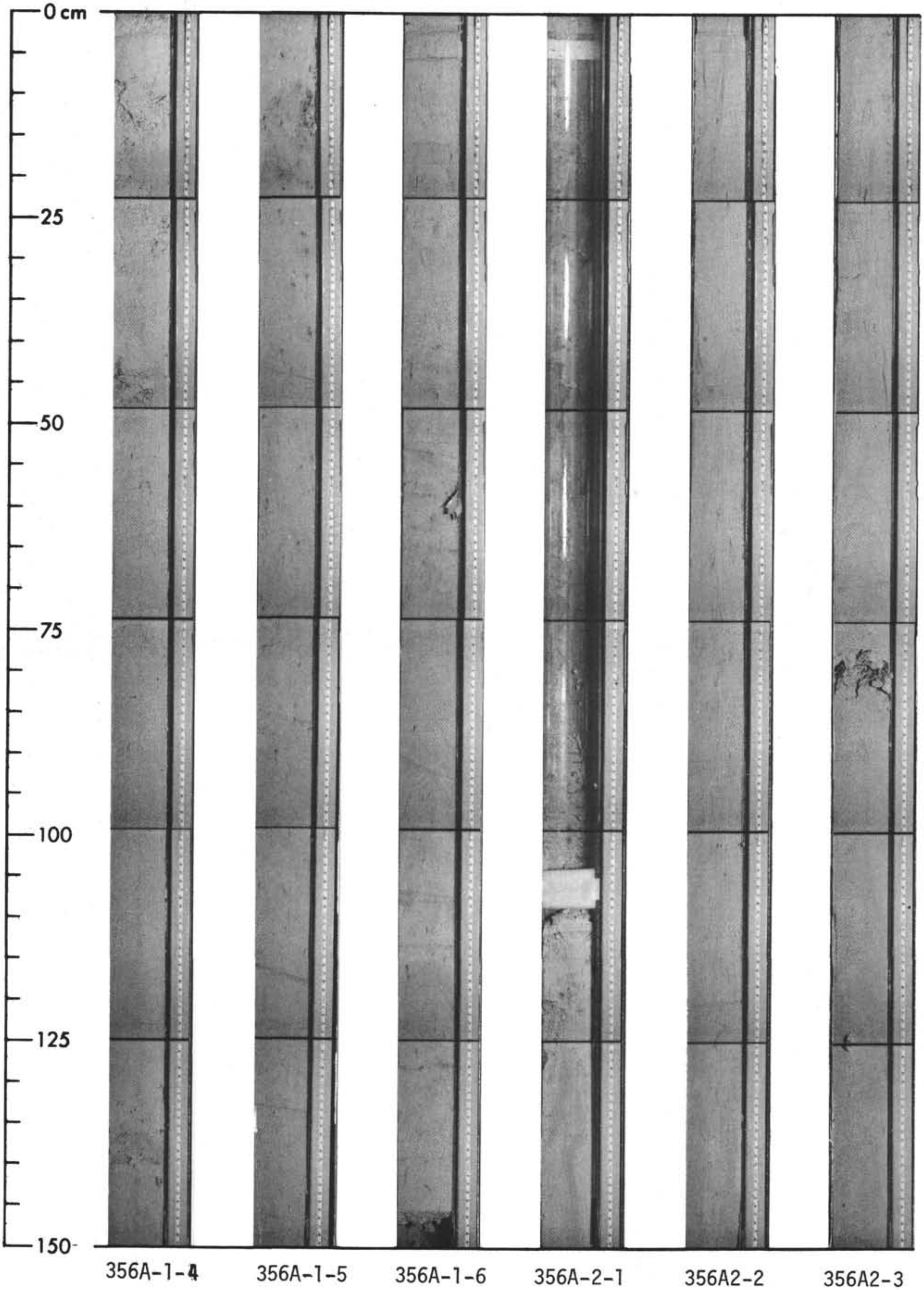
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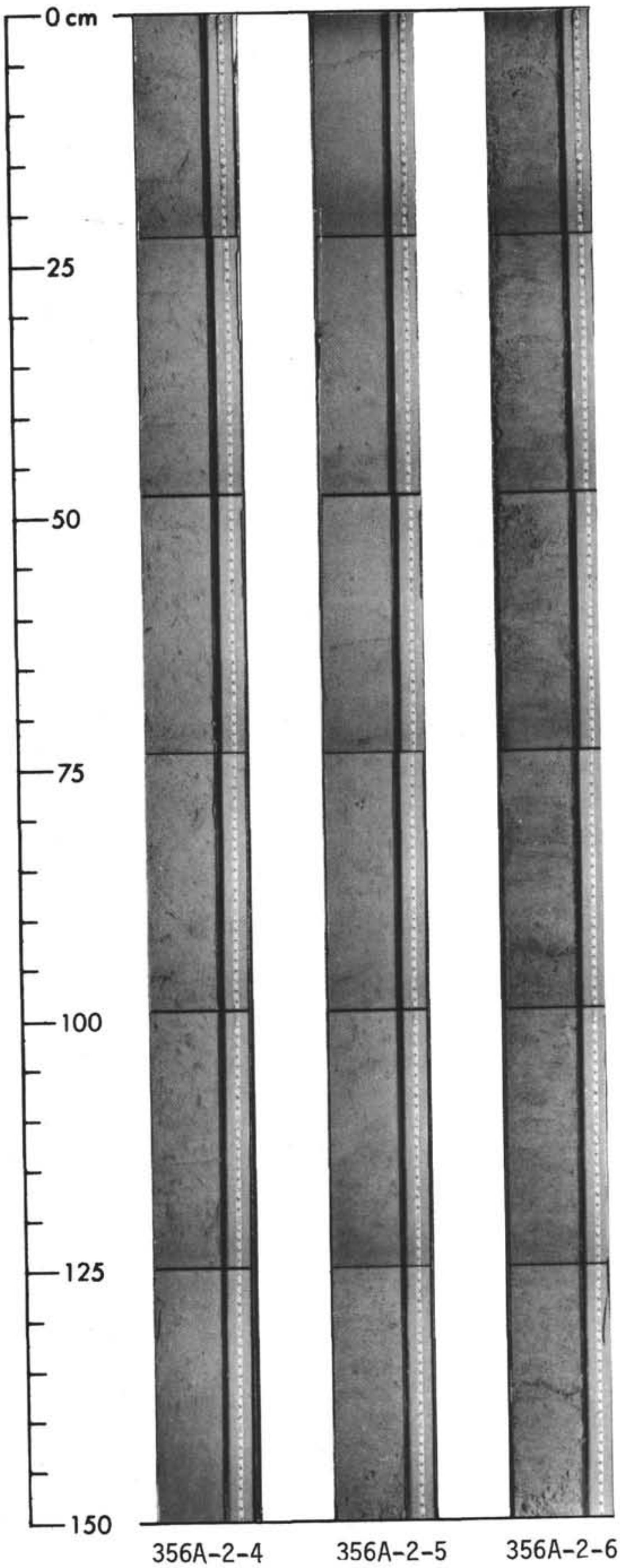
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