5. SITE 158

The Shipboard Scientific Party[1]

SYNOPSIS

Area: Cocos Ridge, eastern equatorial Pacific

Date Occupied: 18-20 February, 1971

Position:
Lat. 06°37.36′N
Long. 85°14.16′W

Water Depth: 1953 meters (corrected)

Penetration: 323 meters

Number of Holes: 1

Number of Cores: 36

Core Recovery: 249.9 meters

Acoustic Basement:
Depth: 0.37 second
Nature: Chert
Inferred acoustic velocity for sedimentary section: 1649 m/sec

Age of Oldest Sediment: Middle Miocene

Basement: Basalt

Three sedimentary units can be distinguished above basalt: 0-30 meters – Marly calcareous ooze containing abundant microfossils, terrigenous detritus and volcanic ash.
Age: Quaternary.

30-305 meters – Chalk ooze grading to chalk over the interval 135 to 171 meters. Foraminifers grade from abundant at the top to sparse at the bottom; diatoms are abundant in the late Miocene interval 207 to 243 meters. Volcanic ash is present. This unit is separated from the overlying one by a hiatus covering most of the late Pliocene.
Age: Early Pliocene to middle Miocene.

305-323 meters – Chalk with nodules and irregular masses of chert.
Age: Middle Miocene.

323 meters – Extrusive basalt.

The sedimentation rate for the upper unit is probably close to 40 m/m.y. There is a hiatus of about 1.4 m.y. above the chalk ooze and chalk section where the rate decreases from about 50 m/m.y. in the middle Miocene to about 20 m/m.y. in the upper chalk oozes.

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REGIONAL SETTING AND OBJECTIVES

DSDP 158 is located on the Cocos Ridge at the western edge of the Panama Basin (Figure 1). The Panama Basin is bordered on the north and east by the continental margin of eastern Central America and northern South America, and on the south and west by the Carnegie and Cocos ridges. These ridges enclose a central basin which contains the active east-west trending Galapagos Rift Zone and is crossed by several north-south trending fracture zones. As is shown in Chapter 2 (see also van Andel et al., 1971), the acoustic character of the basement and sediment cover of the ridges and some high blocks in the eastern part of the basin is similar. Based in part upon this similarity, van Andel et al. (1971) have suggested that all high blocks originally formed part of a single, east-west trending ancestral Carnegie Ridge located approximately at the latitude of the present one. This ridge was split by the formation of the Galapagos Rift Zone, which started in the east and proceeded westward in a stepwise fashion, affecting the block west of the Coiba Fracture Zone approximately 10 m.y. ago. The southern half of the split ridge remained stationary, whereas successive northern blocks migrated northward until, one by one, they reached and sealed the eastern extension of the Middle Americas Trench. The most recent block to do so is the portion of the Cocos Ridge between the Coiba and 85° fracture zones.

Three sites in the Panama Basin (one each on the Coiba, Carnegie, and Cocos ridges) were selected by the Pacific Site Selection Panel to test this hypothesis through a comparison of the sedimentary sections and basement ages of the three ridges. In addition, the sites were chosen to determine the late Cenozoic biostratigraphy of the eastern equatorial Pacific in locations shallow enough to insure preservation of calcareous microfossils. DSDP 158 might shed more light on earlier findings of the Deep Sea Drilling Project which indicated Caribbean rather than Pacific affinities in part of the late Tertiary microfauna.

TOPOGRAPHIC AND GEOLOGIC SETTING

The Cocos Ridge is divided into a series of en echelon blocks by north-south and east-west trending faults which are located progressively farther north in an eastward direction. This displacement appears to have taken place along a series of fracture zones. DSDP 158 lies in the block just west of the 85° Fracture Zone.

The site lies on the crest of the Cocos Ridge. Initial uplift of this ridge as part of the ancestral Carnegie Ridge may have produced the east-west trending faults that are similar to those that border the Carnegie Ridge. The pronounced north-south fault system extends the fracture zones of the Galapagos Rift Zone. The site is located just south of the northern boundary fault of its segment.

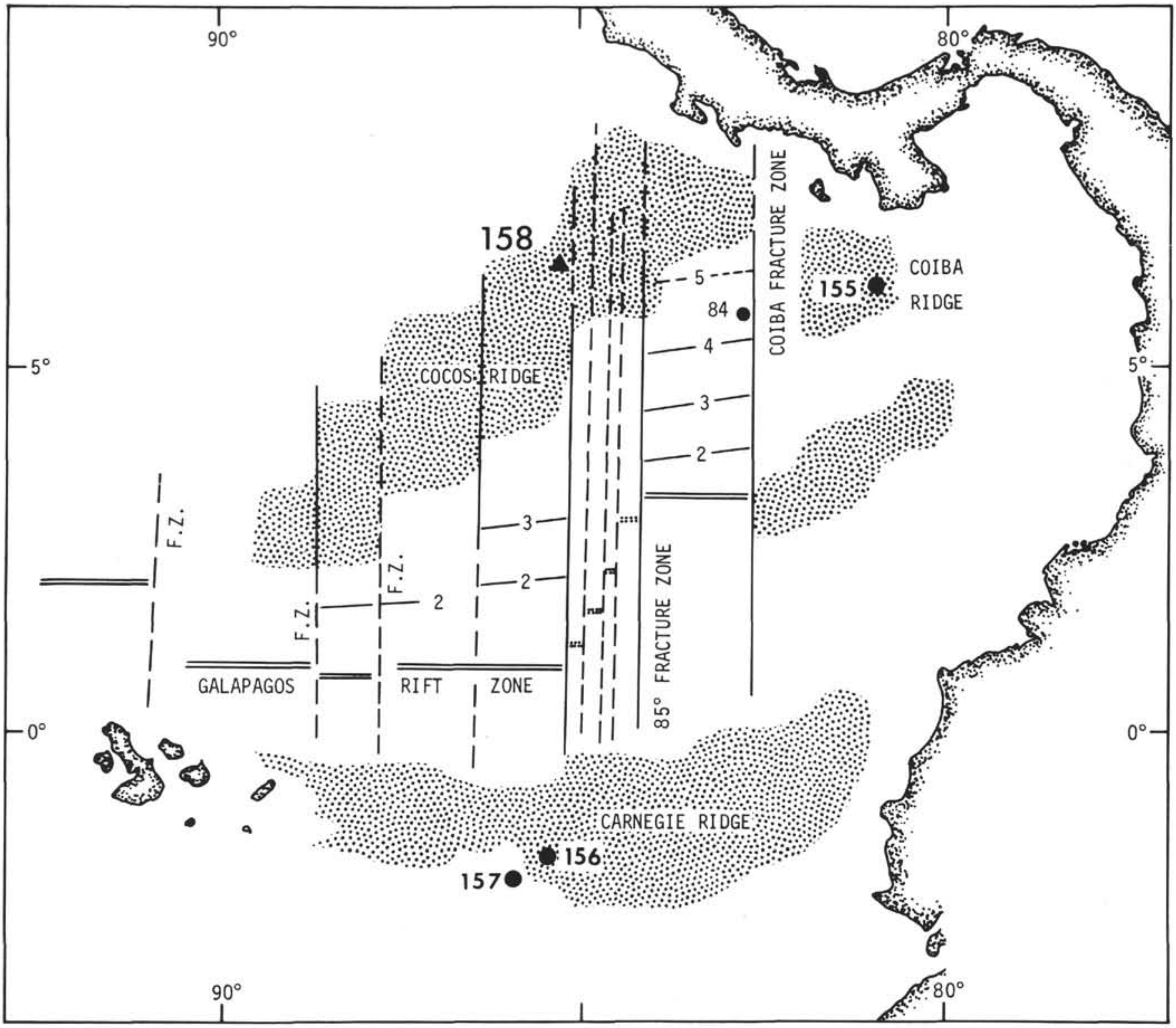


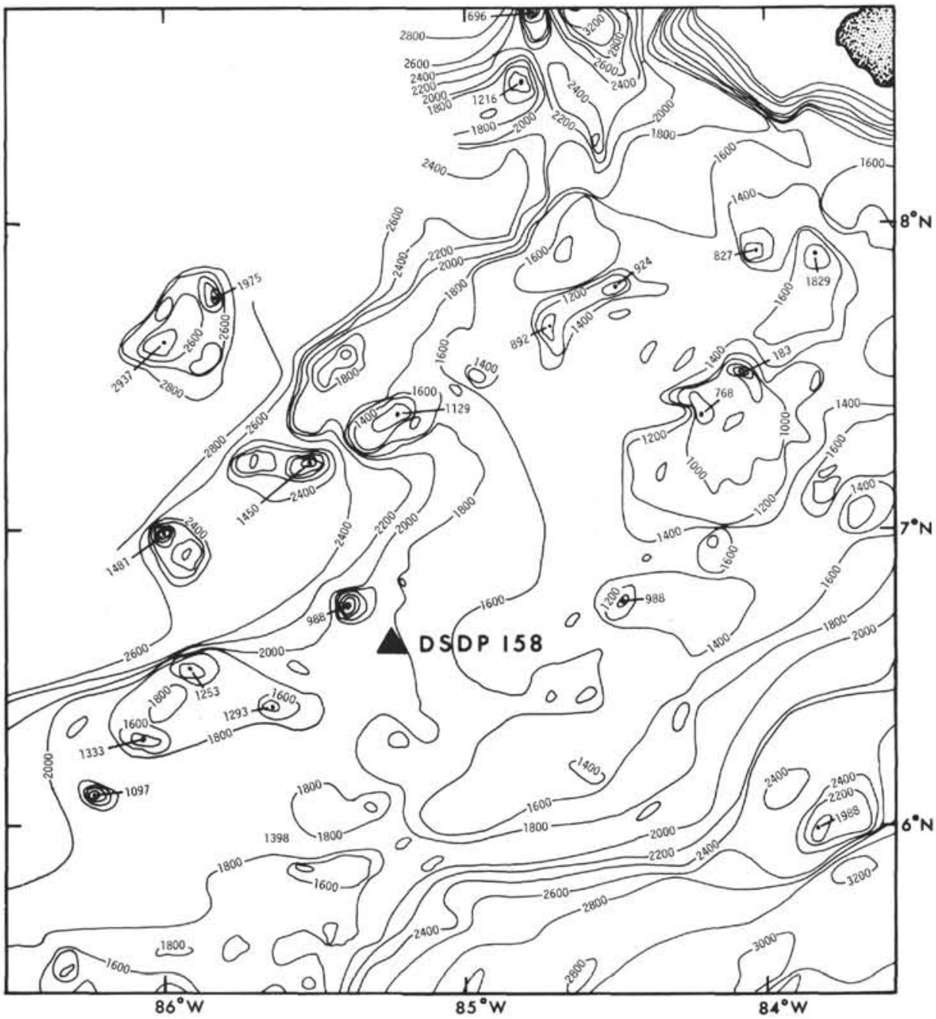
Figure 1. *Tectonic map of the Panama Basin (after van Andel et al., 1971) with locations of drill sites. Numbered contours are magnetic anomalies.*

The small-scale structure of the crest and flanks of the Cocos Ridge is quite complex (Figure 2). Numerous small basins, bordered by the two principal fault systems and perhaps a third which trends southwest-northeast, occupy the crestal area. Available data suggest that these basins are small grabens bordered by clusters of normal faults with cumulative displacements of several hundred meters. They are separated by narrow, rather rugged basement ridges. Superimposed on this block-faulted terrain are numerous steep and quite high volcanic pinnacles which result from point eruptions rather than flow from rifts. Cocos Island, located southwest of the site, is a volcanic edifice of this type on the west flank of the ridge.

Internally, the small basins are relatively uncomplicated and filled with a series of deposits which remains very constant in acoustic character across the entire ridge crestal area. Normal faults within the basin sediments are common but the offsets of the basin floors are small and the vertical separations of the younger deposits range only from 10 to 50 meters. These separations indicate that the faults are still active or have been active until quite recently. Since the acoustic basement is usually chert, the small offsets of the upper section may correspond locally to much larger displacements below the acoustically opaque zone.

A site survey of DSDP 158 was carried out in January 1971 during Cruise 28 of R/V *Vema*. A bathymetric chart based on this and some other data is presented in Figure 3 and a sediment thickness map in Figure 4. A more complete discussion of the nature of the site area can be found in Chapter 11.

Within the site basin, the upper part of the acoustic section (Figure 5) is semitransparent and contains only a small number of faint and discontinuous reflectors. This semitransparent section overlies a highly stratified zone in



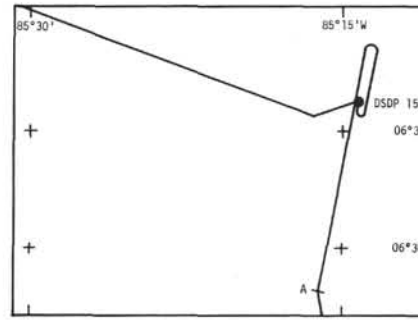


Figure 2. *Location of DSDP 158 on the Cocos Ridge. Depth contours in uncorrected meters after van Andel et al. (1971). Insert: site approach track; A – 158 is location of acoustic reflection profile of Figure 5.*

which the closely spaced reflectors become more prominent with depth. This part of the section is similar to the stratified sequence of the Carnegie Ridge and, in general, to the deposits of the equatorial zone of high biological productivity of the eastern equatorial Pacific (Ewing et al., 1968). Similar stratified deposits from the lower part of the section in the adjacent Guatemala Basin. Within the stratified series of the site area, two zones can be distinguished, each marked with a well-defined top reflector. A similar sequence is found everywhere on the Cocos Ridge. The site is thus typical for a large portion of the Panama Basin.

Underneath the lowest stratified sediments, the acoustic basement is relatively smooth and horizontal within the basin, and is quite unlike the irregular basement reflector of the surrounding ridges and peaks. This smooth acoustic basement is present in all basins of the Cocos Ridge and its flanks, and continues far into the Guatemala Basin to the west. It resembles the acoustic basement of the Carnegie Ridge.

The acoustic section is quite uniform within the survey area, with only minor variations in the thickness of the individual units. The deposits thin onto the surrounding ridges, usually by progressive loss of the upper semitransparent zone, implying that erosion after uplift is the cause. Occasionally, onlap of only the upper layer onto basement can be observed (Figure 5). The upper stratified zone is somewhat less constant than the lower one and tends to fade in and out of the records presumably as a result of minor changes in acoustic impedance. It is, for example, well defined on the approach track to the site but is not as distinctly seen on the traverse across the beacon upon departure (Figure 5), when the recorder gain was set low to bring out the acoustic basement more sharply. Table 1 presents a summary of acoustic data and a comparison with the results obtained by drilling.

OPERATIONS

Because a site survey was available, the final location was determined by a double pass across the site and the beacon was set at 1100 hours on February 18. The site was cored continuously using a Smith 10 3/8", 3-cone button bit. A summary of coring operations at DSDP 158 is given in Table 2. After completion, an attempt was made to obtain sidewall cores from the Plio-Pleistocene boundary using a new multiple corer. The attempt failed and the vessel departed at 1800 hours on February 20.

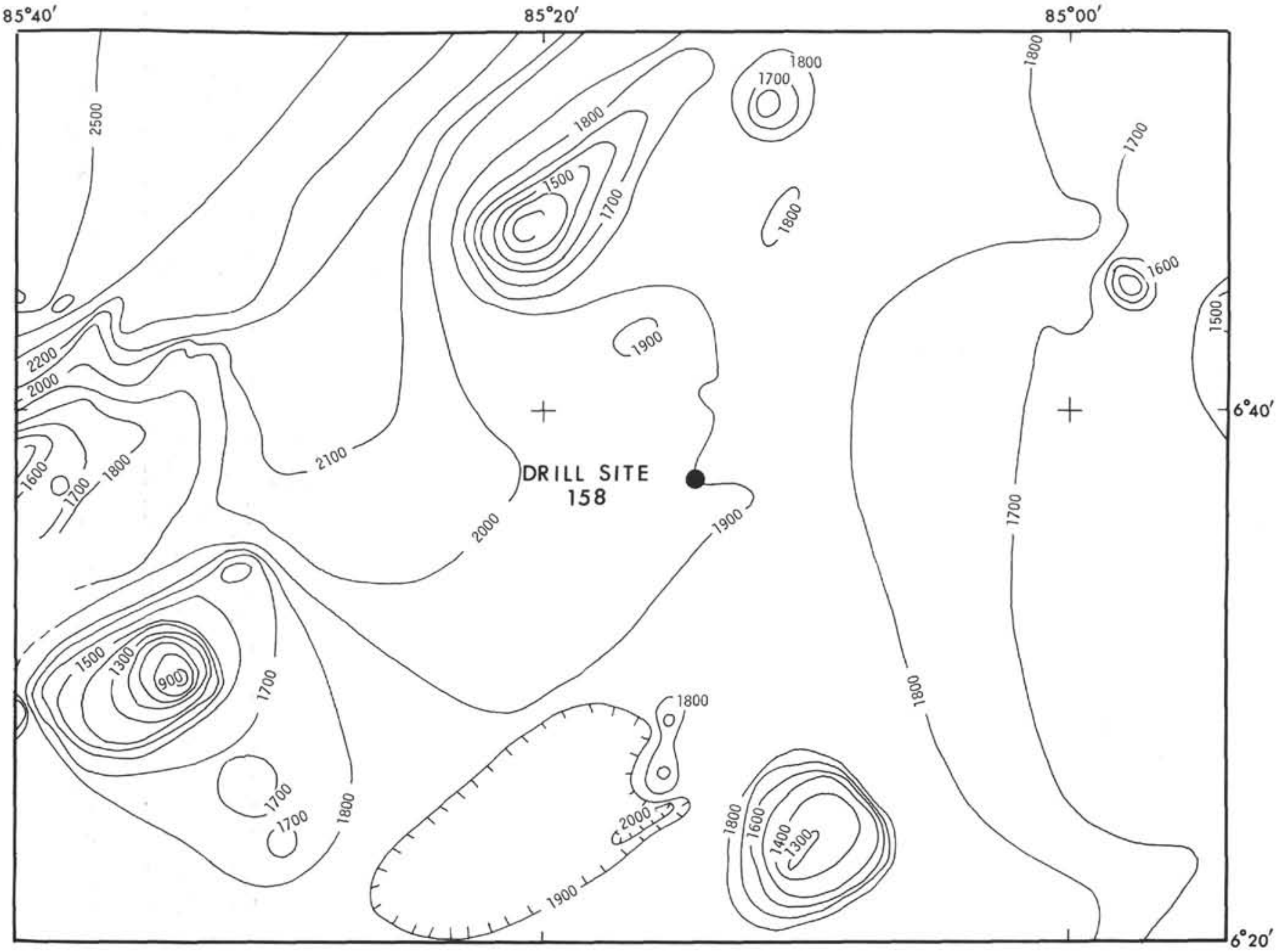


Figure 3. *Bathymetric map of the site survey area around DSDP 158. Depths in uncorrected meters. Based on data from R/V Vema cruise 28 (Lamont-Doherty Geological Observatory), R/V Yaquina (Oregon State University) and D/V Glomar Challenger.*

LITHOLOGY

The section at DSDP 158 consists of chalk oozes grading downward into chalks with basal chert beds. Basalt basement was encountered 322 meters below the sea floor. The following lithologic units can be distinguished: (1) nannofossil chalk ooze with three subtypes (a) foraminiferal, ashy, marly, (b) foraminiferal, and (c) pure; (2) nannofossil chalk with two subtypes (a) pale yellow and olive gray, and (b) grayish yellow green, well indurated; (3) nannofossil chalk and interbedded chert, and (4) augite basalt.

158-1a

From 0 to 30 meters the section is foraminiferal, ashy and marly nannofossil ooze with common radiolarians. Diatoms are present to 23 meters. A 10-cm thick layer of white angular volcanic glass, of silt to fine sand size, occurs 2 meters from the top. Silt-sized volcanic glass containing pyrite occurs in an olive black bed 5 cm thick at 15 meters and in a 2-cm thick light olive layer at 20 meters. Ashy laminations several millimeters thick, and a few ash lumps isolated by the drilling process are scattered throughout this unit. Small quantities of silt-sized, light-colored glass and, less commonly, dark glass, palagonite, quartz, feldspar, and some pyroxene, occur in smear slides from Unit 158-1a. Dominant colors are dusky yellow green at the top grading to lighter grayish to dusky yellow green and pale to grayish olive. The uppermost 4 cm are oxidized and yellowish to light olive gray. Mottling in this interval is slight to moderate, with grayish olive burrows up to 5 cm long which are locally enriched in pyrite and foraminiferal tests. On fresh surfaces, the sediment has a faint H_2S odor.

158-1b

Between 30 and 70 meters the sediments consist of foraminiferal nannofossil ooze virtually free of quartz and feldspar and with only small amounts of light and dark glass. Silt-sized pyrite granules are ubiquitous in small amounts and locally abundant in streaks. Foraminifers are abundant and radiolarians common. Diatoms are absent in the upper one-third but present in small amounts below. Colors lighten downward from dusky to grayish yellow green to pale yellow. Mottling is almost entirely absent. A faint H_2S odor is present.

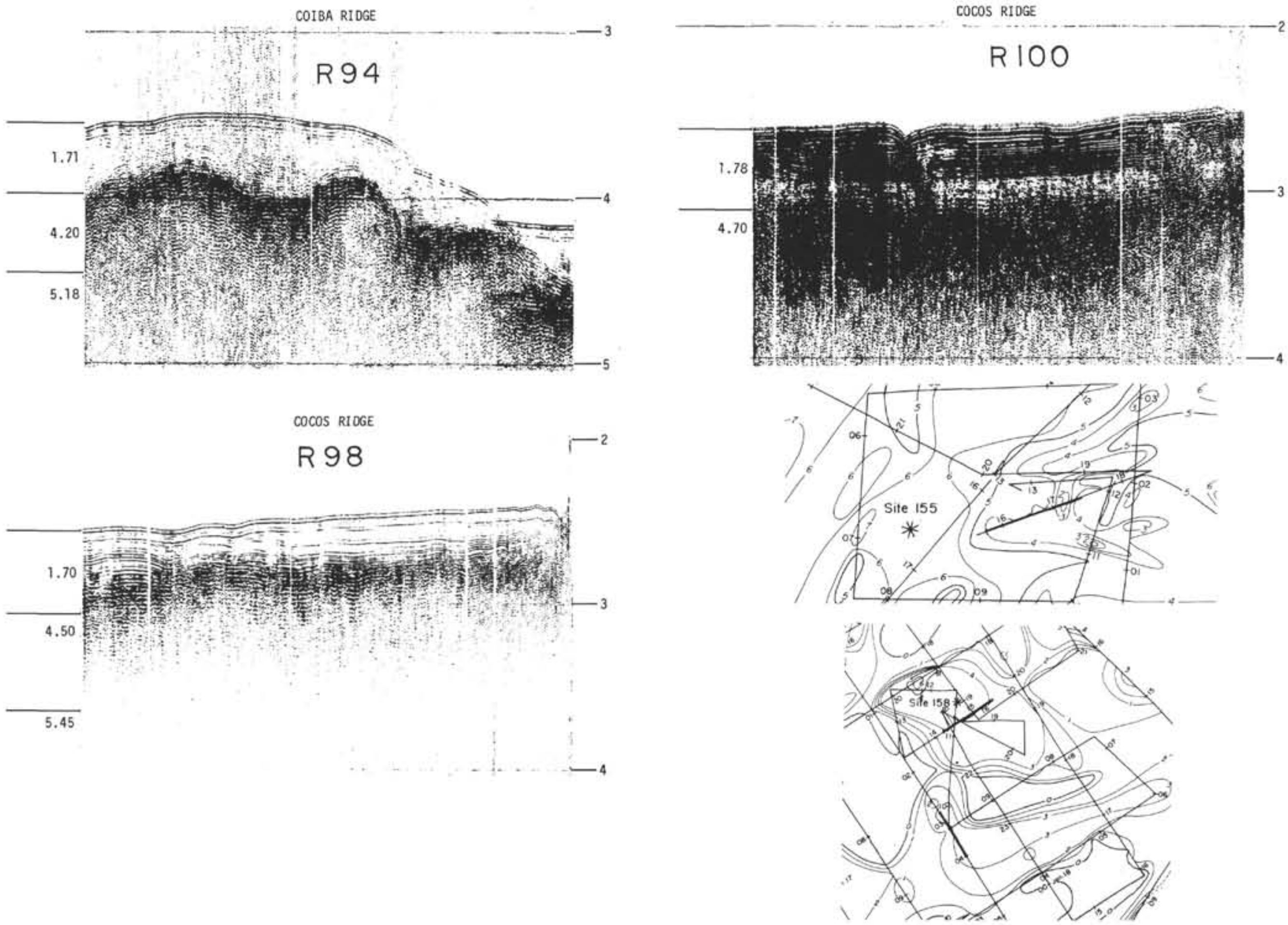


Figure 4. *Sediment thickness in the site survey area around DSDP 158 (after Chapter 11, Figure 10). Sediment thickness in meters assuming a velocity of 2 km/sec.*

158-1c

From 72 to 135 meters the sediment is a nannofossil chalk ooze containing small amounts of silt-sized feldspar along with slightly more glass and palagonite than the overlying section. At 102 meters, a 20 cm interval contains 1 to 5 cm burrows with abundant glass and associated pyrite framboids. Silt-sized pyrite is scattered throughout the section in small amounts. Residues of acid-treated coarse fraction commonly contain glauconite molds of foraminiferal tests. The abundance of foraminifers decreases downward, accompanied by an increase in diatoms which become abundant near the bottom of the interval. The radiolarian content fluctuates with a maximum in the middle of the unit. At this point, silicoflagellates make their first appearance and continue downward in small amounts. The dominant color changes from pale yellow green at the top to light to greenish gray and lesser yellowish to light olive gray. Mottling increases and becomes dominant in the lower part with burrows typically up to 1 cm wide and 4 to 6 cm long. H_2S odor is noticeable in the upper part but not near the bottom of the interval.

Gradational Transition

The interval from 135 to 171 meters is transitional between nannofossil ooze and nannofossil chalk. The increase in consolidation is reflected in a reduction of the drilling rate despite increased rotation and weight. Cores above the interval are easily cut with a wire; below, they could be cut only with a bandsaw. Slight minima in the foraminiferal and radiolarian contents and a light maximum in the silicoflagellate abundance mark the transition zone. Volcanic constituents, principally light-colored glass, palagonite, and feldspar, are present in trace amounts. The transition is also one of color from the dominant light yellow green and light greenish gray of the ooze to the pale yellow and light olive gray of the chalk.

158-2a

From 135 to 243 meters, the sediment is a nannofossil chalk with an increasing number of burrows. The burrows contain concentrations of pyrite and sometimes also greater amounts of glass than the surrounding material. Silt-sized

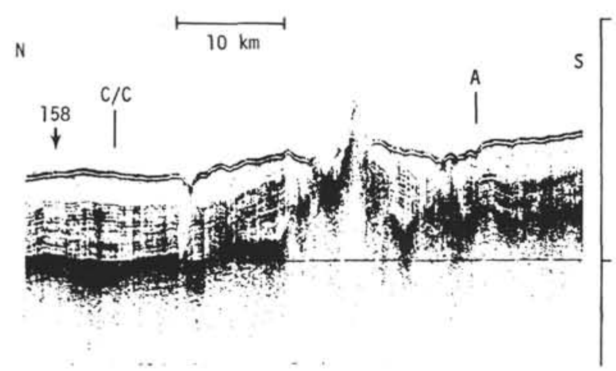


Figure 5. *Acoustic reflection profile of DSDP 158. Location on Figure 2. Depths in seconds 2-way travel time. Horizontal scale approximate.*

TABLE 1
Comparison of Acoustic Section and Drill Data, DSDP 158

Reflectors	Depth[a] (sec)	Drilling Results[a]	Interval (sec)	Velocity (m/sec)	Calculated[b] Depth (m)
Top upper stratified zone	0.10	(72 m Plioc-Mioc hiatus ?)			77
Top lower stratified zone	0.21	162 m top chalk	0.0-0.21	1540	
Top acoustic basement	0.37	305 m top chert	0.0-0.37	1650	
	(0.37)	321 m (top basalt)	0.0-0.37	1735	

[a]Underlined–correlation accepted; ( )–correlation not accepted (partly on grounds of smoothness and character of acoustic basement).

[b]Based on a velocity of 1540 m/sec.

TABLE 2
Coring Summary, DSDP 158

Core	Depth Below Sea Level (m)	Depth Below Sea Floor (m)	Cored (cm)	Recovered (cm)	Recovered (%)
1	1953-1962	0-9	900	295	32.8
2	1962-1971	9-18	900	485	53.9
3	1971-1980	18-27	900	924	102.7
4	1980-1989	27-36	900	566	62.9
5	1989-1998	36-45	900	900	100.0
6	1998-2007	45-54	900	900	100.0
7	2007-2016	54-63	900	878	97.6
8	2016-2025	63-72	900	855	95.0
9	2025-2034	72-81	900	890	98.9
10	2034-2043	81-90	900	821	91.2
11	2043-2052	90-99	900	906	100.7
12	2052-2061	99-108	900	895	99.4
13	2061-2070	108-117	900	866	96.2
14	2070-2079	117-126	900	894	99.3
15	2079-2088	126-135	900	919	102.1
16	2088-2097	135-144	900	912	101.3
17	2097-2106	144-153	900	924	102.7
18	2106-2115	153-162	900	875	97.2
19	2115-2124	162-171	900	926	102.9
20	2124-2133	171-180	900	918	102.0
21	2133-2142	180-189	900	730	81.1
22	2142-2151	189-198	900	800	88.9
23	2151-2160	198-207	900	710	78.9
24	2160-2169	207-216	900	355	39.4
25	2169-2178	216-225	900	753	83.7
26	2178-2187	225-234	900	883	98.1
27	2187-2196	234-243	900	881	97.9
28	2196-2205	243-252	900	901	100.0
29	2205-2214	252-261	900	288	32.0
30	2214-2223	261-270	900	895	99.4
31	2223-2232	270-279	900	111	12.3
32	2232-2240	279-287	800	511	63.9
33	2240-2249	287-296	900	253	28.1
34	2249-2258	296-305	900	110	12.2
35	2258-2267	305-314	900	0	0.0
36	2267-2276	314-323	900	62	6.9

volcanic constituents and pyrite are disseminated throughout the chalk in abundances similar to those of the chalk ooze. Acid-treated coarse fractions show an increase in glauconitic foraminiferal molds and irregular glauconite particles which may be fecal pellets. Radiolarians and foraminifers decrease irregularly with depth.

Gradational Transition

The interval from 243 to 287 meters forms a transition between Units 158-2a and 158-2b. This transitional character is somewhat enhanced by reduced core recovery.

158-2b

Between 287 and 305 meters the sediment is a well indurated nannofossil chalk, distinctly harder than the overlying chalk as a result of minor silicification. The chalk is yellowish green and intensely mottled with light olive gray burrows. Mottles and pyritic streaks in this interval are not randomly oriented as elsewhere in the section but are mainly subhorizontal and possibly somewhat compressed. Feldspar and light-colored glass and pyrite remain scarce, but dark glass, palagonite and glauconite increase distinctly downward and are fairly common.

158-3

From 305 to 322 meters the sediment consists of nannofossil chalk with interbedded chert. The uppermost chert was cored at 305 meters from this depth to basement, short-period fluctuations in torque indicate the presence of other chert beds not represented in the rather poor core recovery. Approximately 40 cm of interbedded chert and chalk were recovered immediately above basalt and consist of 12 to 20 cm layers of chalk interbedded with 1 to 5 cm of chert. At the top and bottom of the unit, the chalk is identical to the overlying beds except for a greater abundance of feldspar, palagonite, and glauconite, and the nearly complete absence of glass. In a sample at 314 meters, the rock is a siliceous limestone, thinly laminated and light olive gray in color. There is no microscopic evidence for recrystallization of the carbonate even close to the basalt.

Chert occurs in two forms, and is found in contact both with the grayish yellow green chalks and with olive gray limestone. The contact with the yellow green chalks is very sharp and the chert consists of microcrystalline cristobalite, pseudomorphic after nannofossil chalk. The chert contains 10 to 15 per cent calcite as rounded microcrystalline aggregates averaging 150 microns in diameter and as crystals up to 5 microns in size. Both the chert and the associated chalk contain ovoid yellowish green microcrystalline aggregates which possibly are chlorite-smectite with carbonate admixture. Foraminiferal tests are common both in the chalk and in the chert. In the chert, the tests are filled with fibrous chalcedonic quartz, sometimes with small calcite nuclei. The tests in the chalk are mostly empty, although a few are filled with fine-grained carbonate or chalcedonic quartz.

Silicification has progressed farther in the olive black cherts in contact with the limestone. The olive black chert is composed almost entirely of interlocking 10 to 20 micron grains of chalcedonic quartz; the larger grains occur in stretched, ragged-ended lenticular aggregates suggesting some control of recrystallization by laminations such as those seen in the associated limestone which contains isolated chalcedonic segregations with similar size, shape, and orientation. The contact between the chalcedonic chert and the limestone is a zone of isotropic cristobalite ranging in width from 500 to 700 microns. Both the limestone and the chert contain small amounts of fine, disseminated pyrite, and some pyrite framboids and foraminiferal test fillings up to 30 microns. Small amounts of yellowish clay are disseminated throughout the limestone and chert.

158-4

The basement, at 322 meters, consists of a fine-grained augite basalt containing augite grains which are anhedral with respect to labradorite laths which are normally zoned. The groundmass appears once to have been glassy but has been completely devitrified to spherulitic chlorite which also fills round and ovoid amygdules up to 1.5 cm in diameter. The texture of the basalt, the complete absence of metasomatic and metamorphic features in the overlying sediments, and the downward increasing concentration of detrital feldspar in these sediments all suggest an extrusive origin for the basalt. Only one meter of basalt was cored, of which a few centimeters were recovered in a single section and in the core catcher of core 36. A drastic reduction in the drilling rate at a depth of 322 meters is interpreted as the sediment-basalt contact.

GEOCHEMISTRY

Interstitial water samples and shipboard observations for DSDP 158 are listed in Table 3.

TABLE 3
Interstitial Water Samples and Shipboard Observations, DSDP 158

Core	Section	Sampled Interval (cm)	pH	Eh (mv)	Lab. Temp. (°C)	Salinity (%)	Squeeze Pressure (psi)
1	3	0-9	7.51	93	25.4	34.7	1523
2	5	0-8	7.39	92	24.3	34.7	1015
3	6	0-8	7.46	147	25.8	34.7	1523
4	4	0-6	7.37	166	24.7	34.1	1015
5	3	0-7	7.22	105	24.9	34.7	2436
6	4	0-6	7.22	92	24.8	34.1	1015
7	5	0-9	7.18	-32	24.8	34.7	2436
8	5	0-8	7.21	-2	24.9	34.7	2436
9	6	0-6	7.18	2	24.1	34.1	1015
10	6	0-6	7.17	38	25.3	34.1	1523
11	5	0-5	7.26	115	25.8	34.1	1015
12	5	0-6	7.23	129	25.8	34.1	2030
13	5	0-5	7.15	116	25.2	34.1	1523
14	5	0-6	7.18	80	26.0	34.7	1015
15	4	0-8	7.20	88	24.3	34.7	2436
16	6	0-6	7.19	128	24.2	34.1	1523
17	6	0-8	7.26	131	24.0	34.1	2436
18	6	0-5	7.19	140	23.8	34.7	1523
19	6	0-5	7.12	140	25.3	34.1	2436
20	6	0-5	7.19	136	25.2	34.1	1523
21	5	0-6	7.18	122	25.1	34.1	1523
22	6	0-5	7.34	144	26.0	34.7	1523
23	5	0-5	7.31	129	25.8	34.1	1523
24	3	0-5	7.30	120	25.7	34.1	2436
25	6	0-5	7.18	133	25.8	34.1	1523
26	0	20-25	7.22	136	25.8	34.1	1015
27	6	0-6	7.26	142	25.6	34.1	1523
28	5	0-3	7.13	90	26.0	33.0	2030
29	3	0-4	7.23	128	25.8	34.1	1523
30	6	0-7	7.16	130	25.6	34.1	2030
32	4	0-6	7.22	140	25.5	34.1	1523
33	2	0-5	7.09	126	25.7	34.1	1523

BIOSTRATIGRAPHY

Foraminifera, coccoliths, and radiolarians indicate the presence of a nearly complete middle Miocene to Pleistocene section at DSDP 158. The uppermost Pleistocene is missing, as evidenced by the absence of the *Buccinosphaera invaginata* radiolarian zone, and a hiatus at approximately 30 meters has removed a portion of the upper Pliocene (the uppermost part of the *Globorotalia limbata* Zone is superimposed on the lower part of the *Globoquadrina altispira* Zone).

Foraminifera are generally well-preserved throughout but are not abundant, averaging not more than a few per cent by weight. A zone of carbonate dissolution occurs in Cores 24 through 27; as at Site DSDP 155, this zone straddles the *Globorotalia menardii/G. acostaensis* zonal boundary. The hole bottoms in the *Globorotalia fohsi robusta* zone of middle Miocene age.

Nannofossils show superior preservation as compared to Site DSDP 157, and the presence of *Ceratolithus rugosus, Discoaster perplexus, Scyphosphaera globulata, Thoracosphaera* sp., and common discoasters in the lower Pliocene indicate well-preserved, warm-water associations. Diversity is poorer in the upper Miocene. The middle Miocene assemblages are well-preserved at the top, but deteriorate noticeably downward.

Middle Miocene to Pleistocene radiolarians are present throughout and moderately well-preserved except in Cores 1 through 4, in which preservation is poor, and where reworked upper Miocene and lower Pliocene taxa occasionally dominate the fauna. Radiolarian biostratigraphy also recognizes the hiatus at 30 meters (between Sections 2 and 3 of Core 4), where the *Anthocyrtidium angulare* Zone directly overlies the *Spongaster pentas* Zone, with most or all of the *Pterocanium prismatium* Zone missing. This hiatus also marks the separation between well and poorly preserved radiolarian faunas.

The section at DSDP 158 bottoms in the *Globorotalia fohsi robusta, Discoaster exilis,* and *Cannartus laticonus* zones. Foraminifera and nannofossils both indicate deposition of this section at warmer-water conditions than at Site DSDP 157.

PHYSICAL PROPERTIES

As a result of core disturbance at several levels, mass physical properties determined by laboratory techniques reflect changes of lithology with depth more reliably than do the GRAPE data. Extreme disturbance between 65 and 95 meters forced elimination of both GRAPE and laboratory analysis in that interval, and GRAPE data were not obtained between 216 and 243 meters for the same reason. Natural gamma radiation were not obtained in either interval.

Bulk Density

GRAPE bulk density values increase markedly with depth in the upper 36 meters of marly foraminiferal nannofossil chalk ooze from 1.36 g/cc to 1.52 g/cc (average value is 1.5 g/cc). Below the disconformity in Core 4, bulk densities average 1.62 g/cc to a depth of 296 meters. Between 36 and 171 meters, the predominant sediment type is a nannofossil chalk ooze that grades into nannofossil chalk between 135 and 171 meters. The general homogeneity of the chalk ooze corresponds to rather uniform GRAPE densities.

The highest GRAPE densities, up to 1.77 g/cc, occur in the nannofossil chalk below 171 meters to about 190 meters, but densities again decrease below 190 meters where they average 1.62 g/cc. This absence of a gradual increase in bulk density with depth, which would normally be expected as a result of increasing consolidation, is probably due to extreme disturbance masking variations that may originally have been present. This disturbance, in the absence of megascopic primary structures in the homogeneous chalk ooze and chalk, cannot be easily evaluated.

The numerous 10 to 15 g subsamples collected in the least disturbed areas indicate significant variations in the mass physical properties with depth. Laboratory bulk densities show a sharp increase with depth in the upper 65 meters from a low of 1.31 g/cc to a high of 1.65 g/cc. Values of 1.60 to 1.64 g/cc are common in the nannofossil chalk ooze between 60 and 135 meters. A relatively high variability in bulk density, 1.44 to 1.65 g/cc, occurs in the chalk ooze-chalk transition in the interval of 135 to 170 meters. The highest bulk densities, 1.68 g/cc, occur in the nannofossil chalk between 170 to 185 meters, while between 185 and 200 meters, they are again lower (1.51–1.59 g/cc). A very low value of 1.31 g/cc at a depth of 208 meters may be due to the abundance of Radiolaria. The abundance of Radiolaria in the nannofossil chalk is probably a contributing factor to the lower bulk densities in contrast to the slightly higher bulk densities characteristic of the overlying chalk ooze.

Porosity

GRAPE porosities decrease with depth in the upper 36 meters from 77 per cent to 68 per cent. Lower porosities, averaging 63 per cent, occur in the nannofossil chalk ooze and chalk between 36 and 296 meters, except for somewhat lower values of 54 to 60 per cent in the interval between 171 and 190 meters, which correspond to the high bulk densities of this interval. With depth, GRAPE porosities decrease in the foraminiferal nannofossil chalk ooze and indurated chalk and increase in the transition from nannofossil chalk ooze to chalk.

Laboratory porosities vary with depth in the upper 65 meters where they decrease from 80 to 63 per cent. The highest porosities occur in the upper ooze. Between 65 and 95 meters there are no data, while from 95 to 135 meters the porosity is relatively constant at 62 per cent. In the chalk ooze to chalk transition, values as high as 72 per cent are found together with low bulk densities. In the nannofossil chalk below 170 meters the porosity increases with depth, to decrease again slightly in the indurated chalk below 250 meters. Only a minor variation to 66 to 64 per cent occurs in the indurated chalk in marked contrast with the high variability in the overlying chalk and chalk ooze to chalk transition between 135 and 210 meters.

Water Content

In the marly foraminiferal chalk ooze the water content is quite high, decreasing from 62 per cent at 9 meters to 38 per cent at 63 meters. In the lower chalk ooze the water content decreases slowly with depth, then increases again with high variability in the chalk ooze to chalk transition between 135 and 170 meters. The lowest values, 35 to 37 per cent, occur in the upper chalk, but the water content increases again with depth to 58 per cent at 208 meters, corresponding to low bulk density and low grain density at this depth. In the indurated chalk, water content decreases slightly with depth from 43 to 38 per cent.

Grain Density

Throughout the lithologic sequence the average grain density is quite variable in response to changing concentrations of microfossils, volcanic ash and perhaps pyrite. Volcanic ash and opaline biogenous silica are almost surely significant factors in many of the observed low grain density values. The foraminiferal nannofossil chalk ooze is characterized by the highest grain density, averaging 2.68 g/cc with a range of 2.59 to 2.81 g/cc. Densities in the lower chalk ooze average 2.67 g/cc to a depth of 135 meters. In the chalk ooze and chalk between 135 and 210 meters, the grain density is highly variable, averaging 2.62 g/cc, with a range of 2.28 to 2.72 g/cc. The low value of 2.28 g/cc occurs at 208 meters; throughout the sequence, higher values are more common. In the indurated chalk, grain densities average 2.61 g/cc, with a range of 2.46 to 2.68 g/cc.

Sonic Velocity

Sonic velocities were measured in numerous sections of Cores 1 through 33. One measurement was made on basalt from Core 36 at 315 meters. Velocities range from 1.39 km/sec to 1.56 km/sec and average 1.46 km/sec for the entire sedimentary sequence. Basalt measured at 3.61 km/sec, considerably lower than the basalt velocity from Site DSDP 152 and slightly lower than the sonic velocities at DSDP-155. The values are not corrected for temperature and pressure.

Natural Gamma Radiation

Natural gamma radiation, shown as the average per section of 1.5 meters, indicates the presence of radionuclide concentrations in the upper 36 meters which are substantially higher than elsewhere in the core, notwithstanding the high porosity. The shift from high to low concentration occurs above the stratigraphic disconformity in Core 4 and may indicate a change in depositional environment. High percentages of terrigenous material present in the upper 36 meters may account for the high natural radiation. With depth, the radiation shows a slight decrease.

Shear Strength

Vane shear strength was measured in the upper 175 meters of nannofossil chalk ooze and in the chalk ooze to chalk transition using samples from core catcher and sleeve. Values range from 18 g/cm^2 in the chalk ooze at 9 meters to 738 g/cm^2 at 162 meters in the transition zone. Shear strengths of 64 g/cm^2 to 162 g/cm^2 are found in the nannofossil chalk ooze between 36 and 135 meters. High values of 254 to 735 g/cm^2 occur in the transition from chalk ooze to chalk. In the upper chalk between 170 and 175 meters, shear strengths are 259 and 320 g/cm^2. Glauconite and pyrite occur in the sediment with the highest shear strength value of 738 g/cm^2, so that incipient cementation might be a contributing factor.

SUMMARY

The single hole drilled at DSDP 158 penetrated 322 meters of calcareous pelagic sediment before entering basalt basement.

From 0 to about 30 meters, the sediment is a marly calcareous ooze rich in nannofossils and foraminifers of Quaternary age. Terrigenous detritus is prominent throughout, and volcanic ash, both dispersed and forming three well defined beds, is common. Siliceous microfossils are common, but diatoms are notably less abundant than at DSDP 157. This section is distinctly more radioactive than the underlying units, with natural gamma activity in the range of 12 to 1500 counts/75 sec/7.6 cm (in contrast to 600-1000 counts for deeper sediments). GRAPE porosities exceed 70 per cent. The sedimentation rate for this section is undefined owing to lack of dated horizons. It probably exceeds 20 m/10^6 yrs.

The base of the top unit is marked by a hiatus covering most of the late Pliocene.

The lithologic character of the section from 30 to 305 meters lacks abrupt changes. The sediment is chalk ooze grading to chalk over the interval 135 to 171 meters. Foraminifera are abundant at the top of the section, but decrease downward. Nannofossils are dominant throughout. Radiolaria and diatoms are of variable abundance. Diatoms in particular are most abundant in the upper Miocene interval of 207 to 243 meters (apparently reflecting an influx of cold water to the region) but are rare elsewhere. The diatom-rich section is marked by poorly preserved calcareous microfossil assemblages of low diversity. Volcanic ash is present in most of the chalk ooze and chalk samples, but is much less abundant than it is above the hiatus. All sediments above 305 meters are pyritic.

The GRAPE porosity of the sediments below 30 meters decreases from about 70 per cent at the top to 54 per cent at 187 meters. Deeper values are variable from 60 to 70 per cent, and may be suspect due to disturbance of the cores. Measured acoustic velocities above 305 meters average 1.57 km/sec, in good agreement with the value of 1.65 km/sec calculated from the seismic profiler records. The sedimentation rate in the chalk ooze-chalk section (uncorrected for compaction) decreases from about 40 m/m.y. in the Middle Miocene to about 22 m/m.y. in the Pliocene.

Below 305 meters, the chalk contains irregular masses of cristobalite and chalcedonic quartz chert. These masses do not exceed a centimeter or two in thickness, and probably form less than 5 per cent of the sediment section from 305 to 322 meters. This chert-chalk sequence is correlated with the smooth reverberating acoustic basement of the seismic profiler records.

Volcanic basement at DSDP 158 consists of fine-grained augite basalt. Only a few centimeters of this material were recovered. The rock consists of labradorite laths and interstitial augite in a groundmass of spherulitic ?chlorite (probably altered glass). As with the other Panama Basin sites, the lack of evidence for metasomatism and metamorphism of the overlying sediments, and the texture of the basalt point to an extrusive rather than intrusive origin for the volcanic basement.

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Ewing, John L., Ewing, M., Aitken, T. and Ludwig, W. J., 1968. North Pacific sediment layers measured by seismic profiling. Am. Geophys. Union. Geophys. Mon. 12, 147.

van Andel, Tj. H., Heath, G. R., Malfait, B. T., Heinrichs, D. F. and Ewing, J. I., 1971. Tectonics of the Panama Basin. Bull. Geol. Soc. Amer. 82(6), 1489.

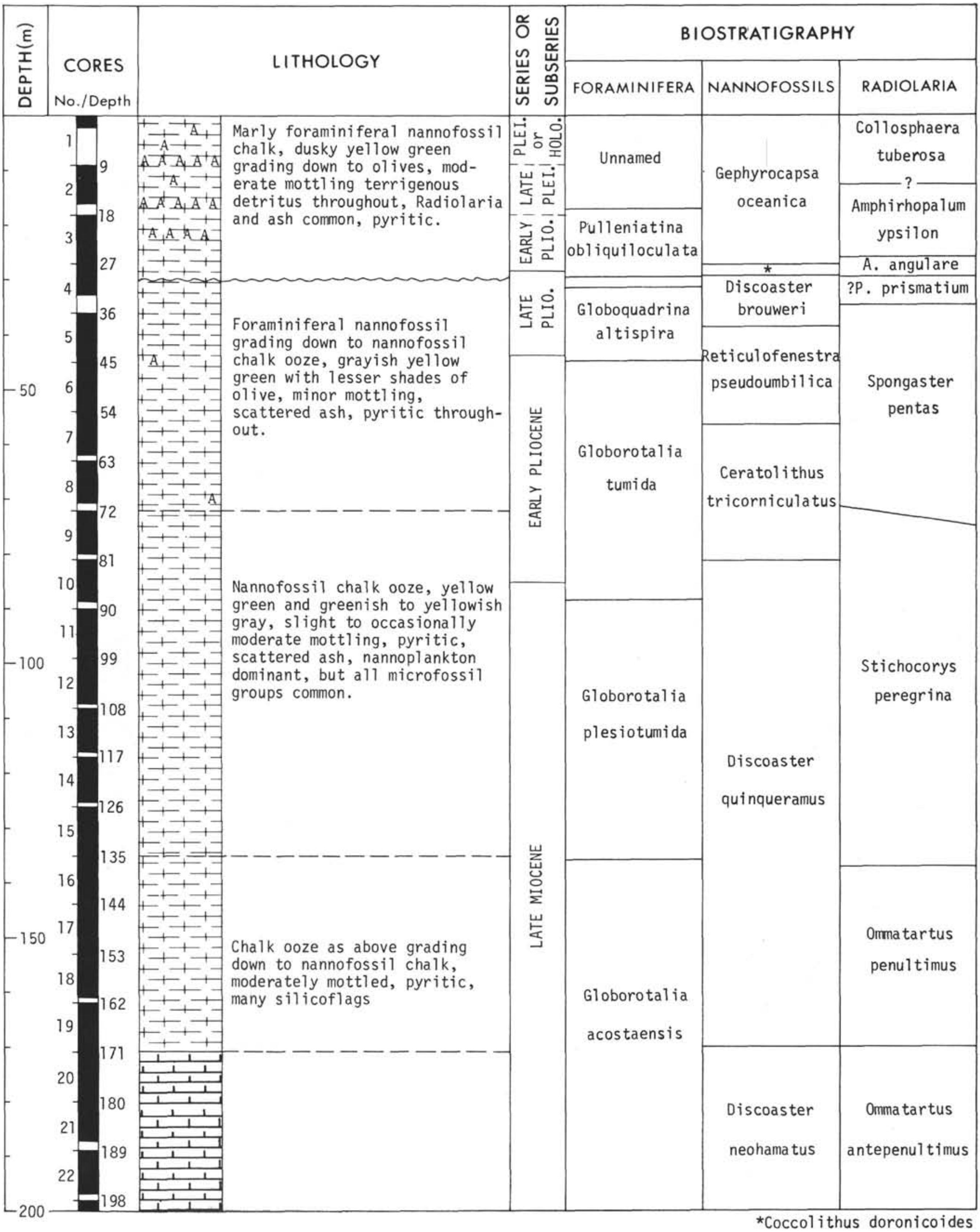
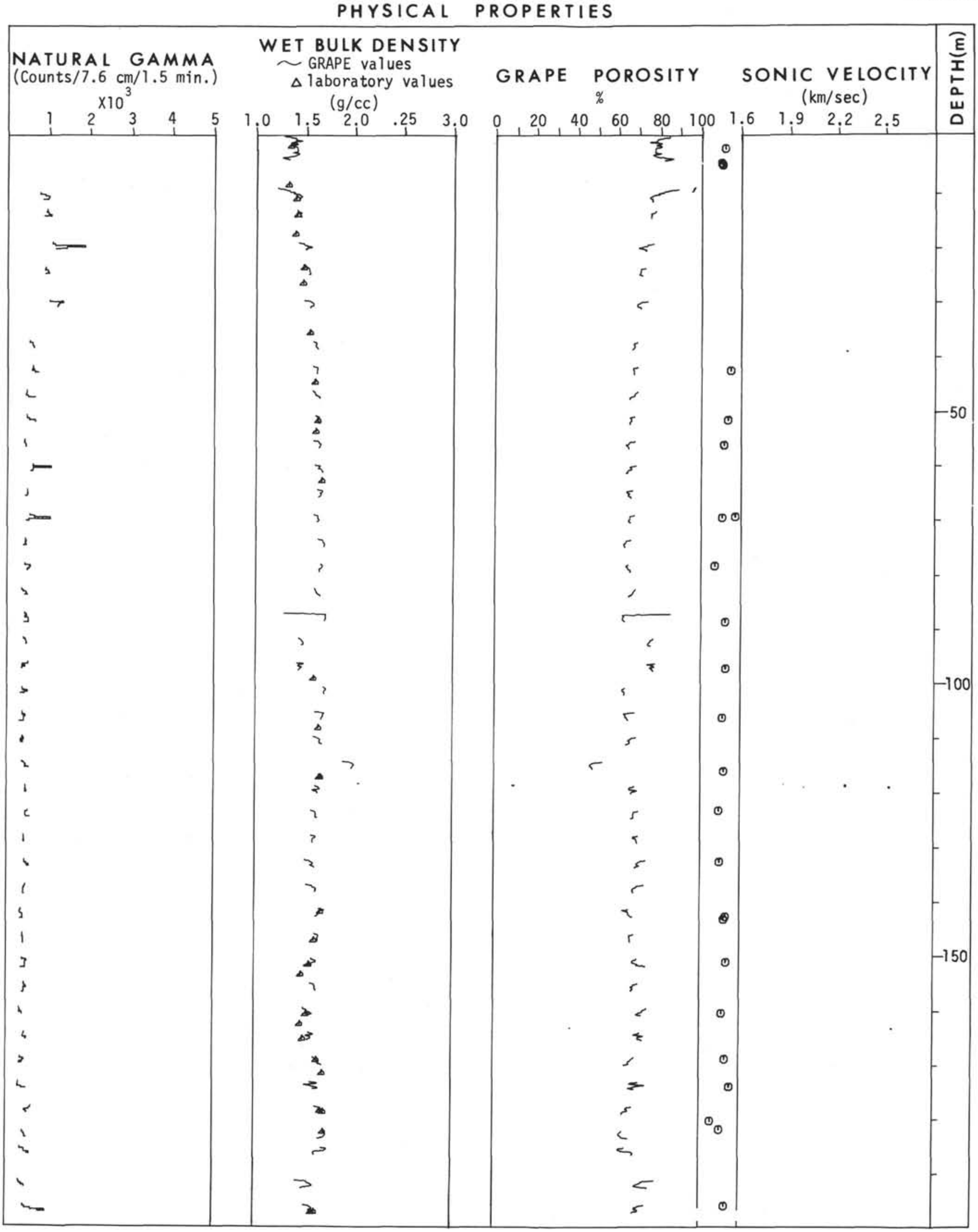


Figure 6. *DSDP 158, graphic hole summary. Vertical scale 1 cm = 10 m (1:1000).*


PHYSICAL PROPERTIES
NATURAL GAMMA
(Counts/7.6 cm/1.5 min.)
X10^3
1 2 3 4 5
WET BULK DENSITY
GRAPE values
laboratory values
(g/cc)
1.0 1.5 2.0 .25 3.0
GRAPE POROSITY
%
0 20 40 60 80 100
SONIC VELOCITY
(km/sec)
1.6 1.9 2.2 2.5
DEPTH(m)
50
100
150

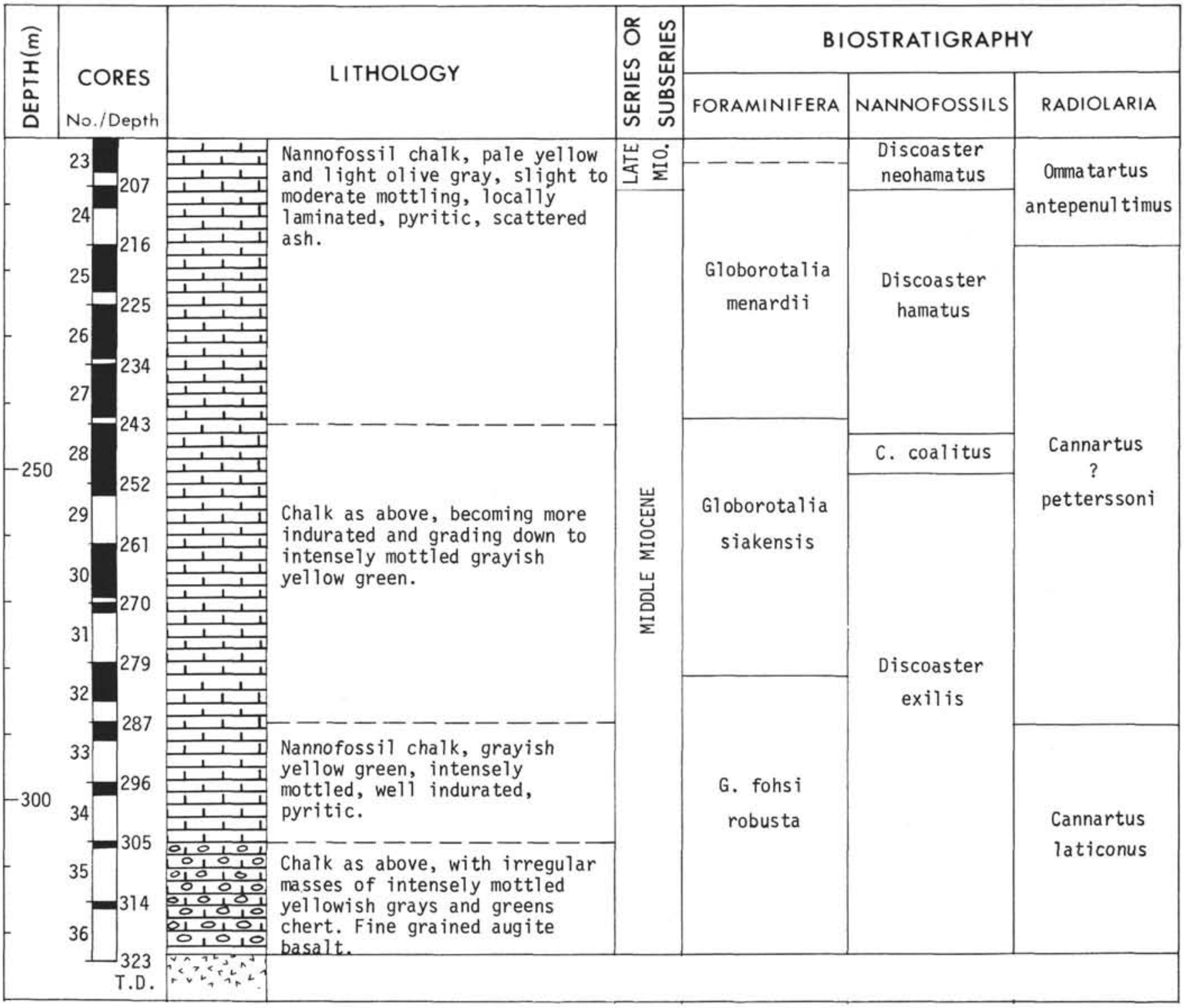
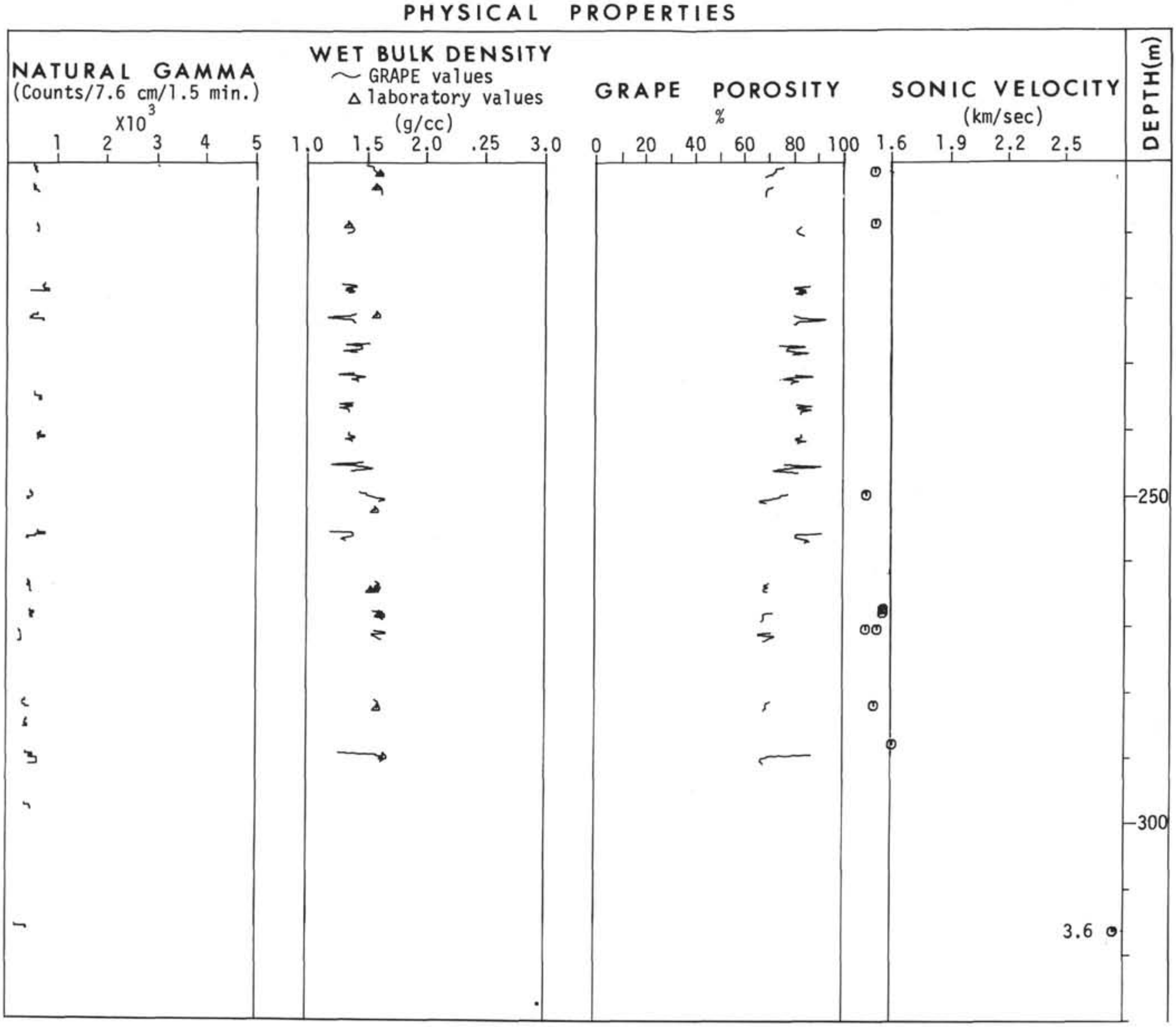


Figure 6. *(Continued).*


PHYSICAL PROPERTIES
NATURAL GAMMA
(Counts/7.6 cm/1.5 min.)
X10^3
1 2 3 4 5
WET BULK DENSITY
GRAPE values
laboratory values
(g/cc)
1.0 1.5 2.0 .25 3.0
GRAPE POROSITY
%
0 20 40 60 80 100
SONIC VELOCITY
(km/sec)
1.6 1.9 2.2 2.5
DEPTH(m)
250
300
3.6

SITE: 158 HOLE: CORE: 1 Cored Interval: 0-9 m

SERIES	AGE / ZONE: Foram	Nanno	Rad	DEPTH (Meters)	SECTION	DESCRIPTION
UPPER PLEISTOCENE	Not named	*Emiliania huxleyi*		0–1.5	1	Nannofossil foraminiferal chalk ooze, radiolaria common; mostly grayish olive, but top 4 cm oxidized surface layer is yellowish to light olive gray; also, mottles and layers present which are dusky yellow to moderate olive brown, containing finely disseminated light glass and pyrite 0.5-1.0 cm lumps of 20-100μ light glass
				1.5–3	2	Volcanic glass; light, some admixed quartz, pyrite. Same nannofossil foram ooze, grading in color from dusky yellow green at top to grayish olive at bottom. Light and dark glass, and rare pyroxene and quartz present. 3-4 mm marly lamina with ~~quartz~~, feldspar. Nannofossil marly chalk ooze, forams common to abundant, radiolaria common to present, dusky yellow green.
				3–4.5	3	obscure mottles enriched in foraminifera. 1 cm. diameter lumps of white ash
					CC	Glassy marly chalk ooze, grayish olive; containing glauconite.

LITHOLOGY | Disturbance | Smear Slide | Paleo. sample

MICROFOSSIL Abund/Pres: Foram | Nanno | Rad

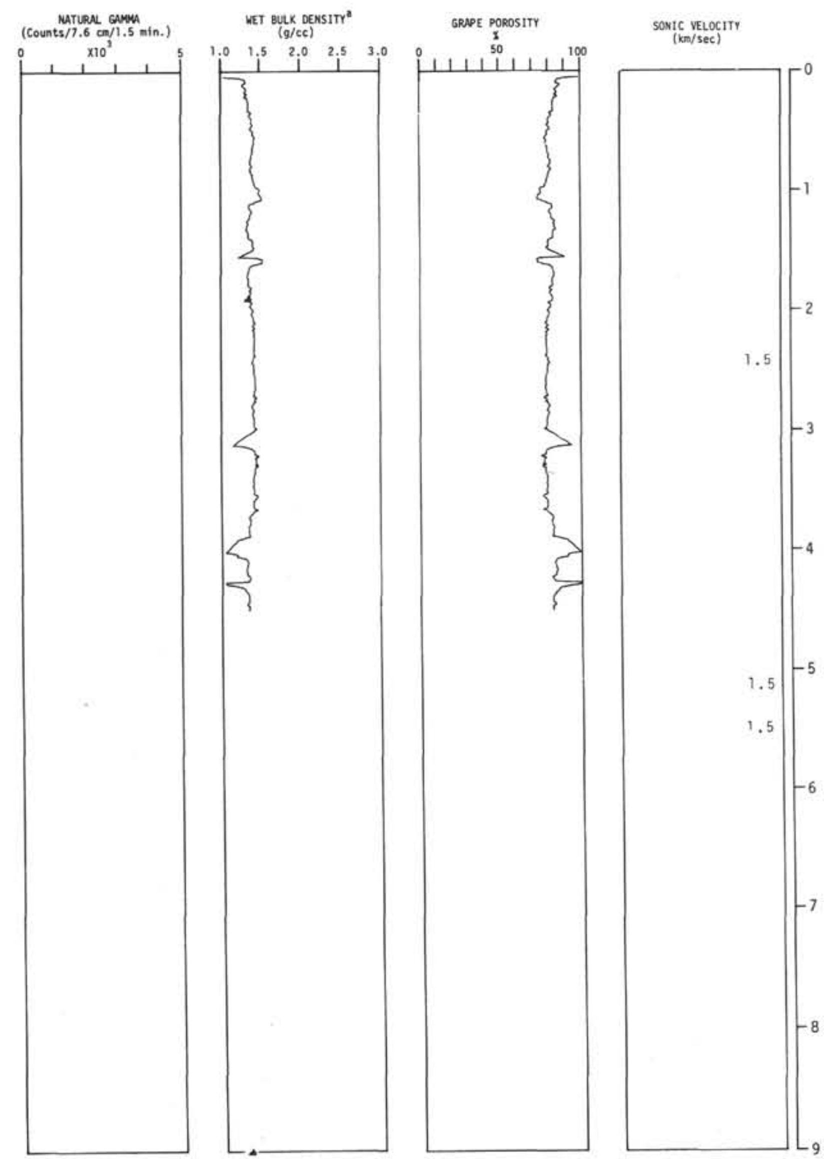
% $CaCO_3$: 0 50 100

C G

C Pd C* M F G

PHYSICAL PROPERTIES

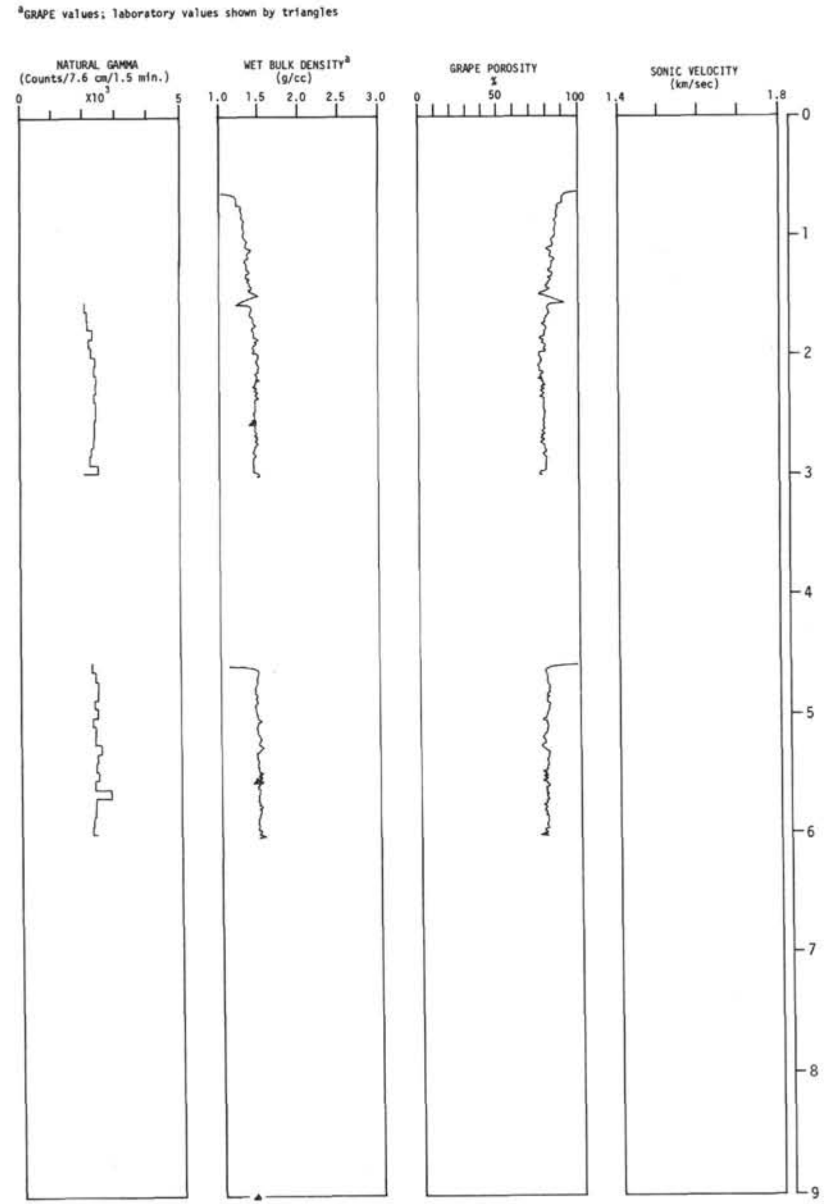
[a]GRAPE values; laboratory values shown by triangles



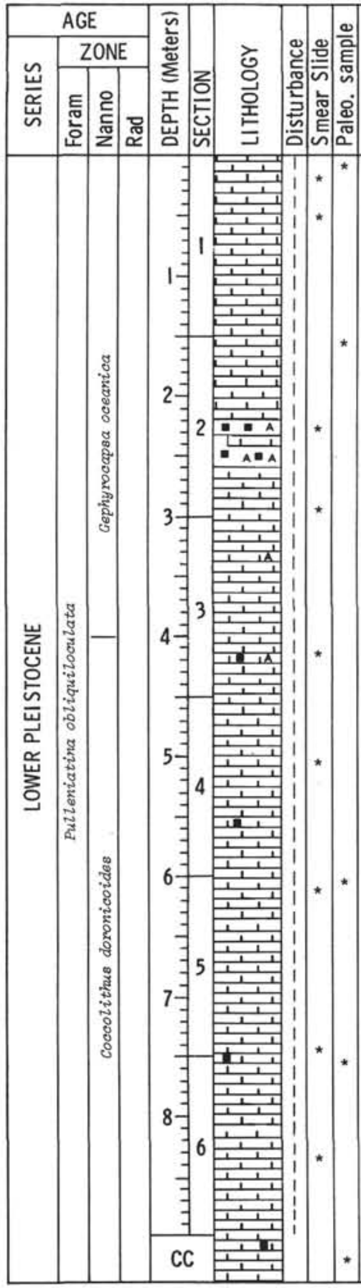
SITE: 158 HOLE: CORE: 2 Cored Interval: 9-18 m

SERIES	AGE ZONE Foram	AGE ZONE Nanno	AGE ZONE Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres Foram / Nanno / Rad; % $CaCO_3$ 0 50 100
UPPER PLEISTOCENE	Not named	*Emiliania huxleyi*		0–1	1	VOID		*		Nannofossil foraminiferal ooze, grayish at top, dusky yellow green at bottom.	
				1–2				*		Fine olive gray pyritic streaks	
								* *		2 2-cm lumps of olive gray glassy marl Nannofossil foraminiferal marly chalk ooze; common glass, diatoms and radiolarian grayish to dusky yellow green	
				2–3	2			* *		Nannofossil foraminiferal chalk ooze, radiolaria common; pale to grayish olive at top, dusky yellow green in middle, grading between 86 and 132 into next unit. Minor pyritic gray streaks from 40 to 60 and 86 to 132.	
				3						1 cm lump of brownish black pyritic marl	
				3–4.5	3			* *	*	Nannofossil foraminiferal chalk ooze, radiolaria common, diatoms present or locally common; locally marly as indicated; glass present and locally common; typically dusky yellow green to grayish-dusky yellow green; also pale to grayish olive where glass is more abundant.	A G
				4.5–6	4					Nannofossil foraminiferal marly chalk ooze, radiolaria common to present; grayish to dusky yellow green; streaks of grayish-olive somewhat richer in glass and pyrite	
		Gephyrocapsa oceanica		6		A■A■A		* * *	*	10 cm thick pyritic marly ash, olive gray to black	A M
				6–7.5	5			*		Nannofossil foraminiferal chalk ooze, grayish to dusky yellow green, with grayish-olive streaks containing glass and finely disseminated pyrite.	
					CC			*	*	Nannofossil foraminiferal chalk ooze, with glass and pyrite fromboids and foram casts. Light glass, quartz and feldspar present.	A M A G F

PHYSICAL PROPERTIES



SITE: 158 HOLE: CORE: 3 Cored Interval: 18-27 m



DESCRIPTION

Nannofossil foraminiferal chalk ooze; predominantly olive; also grayish to dusky yellow green where poorer in forams, or dusky yellow to moderate olive brown where richer in forams; dark glass usually present; probably mottled to low degree; locally rich in pyritic volcanic ash as indicated; frequent olive gray pyritic streaks. Radiolaria common; diatoms present at top.

2 x 8 cm volcanic ash, pyritic, mostly light glass, brownish
2 cm gray

Disturbed layer of pyritic volcanic ash; quartz, feldspar and pyroxene present; brownish gray

2 x 8 cm lump of same pyritic volcanic ash

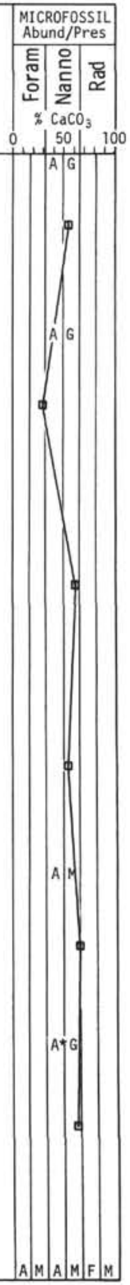
2 cm lump of same pyritic volcanic ash

Pyrite-rich gray lump and deformed lamina

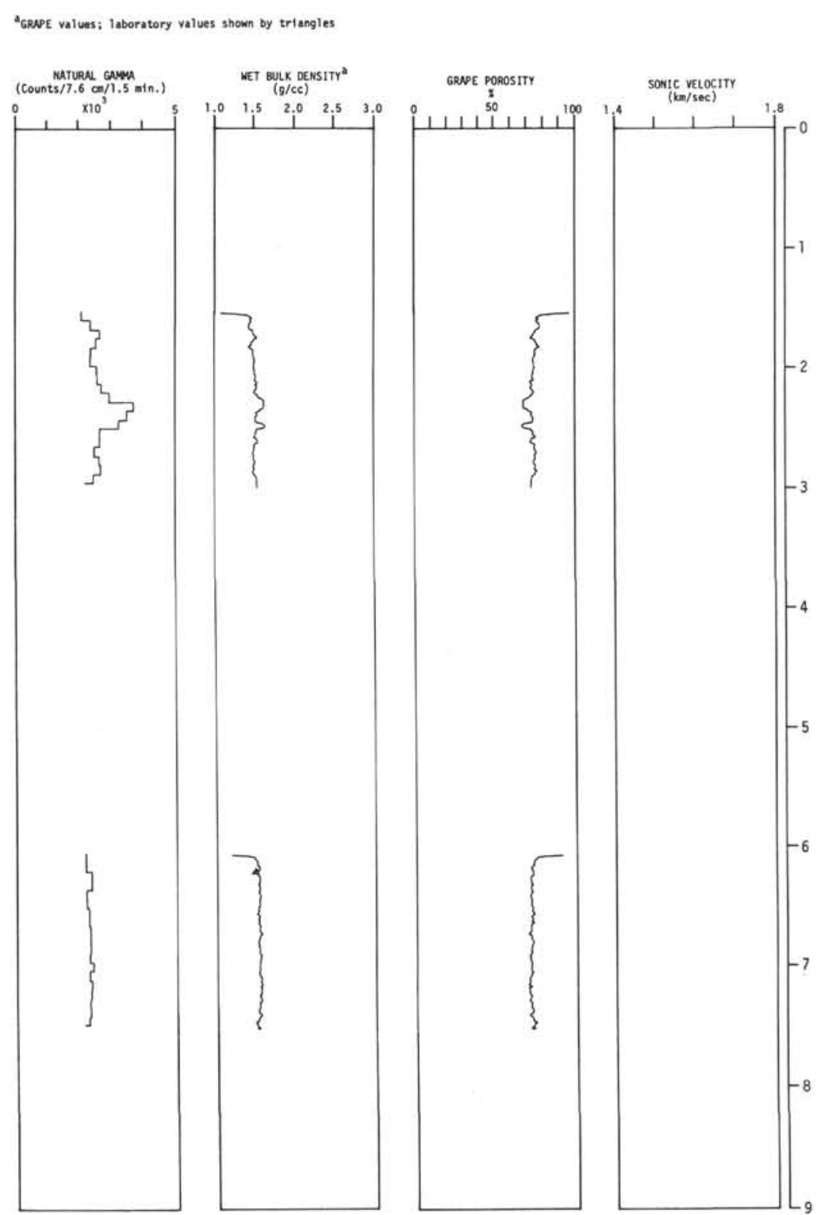
1 cm pyritic gray lump

1 cm pyritic gray lump

3 pyritic lumps 0.3 to 1 cm diameter. Light glass common; pyroxene, quartz, feldspar and dark glass present



PHYSICAL PROPERTIES



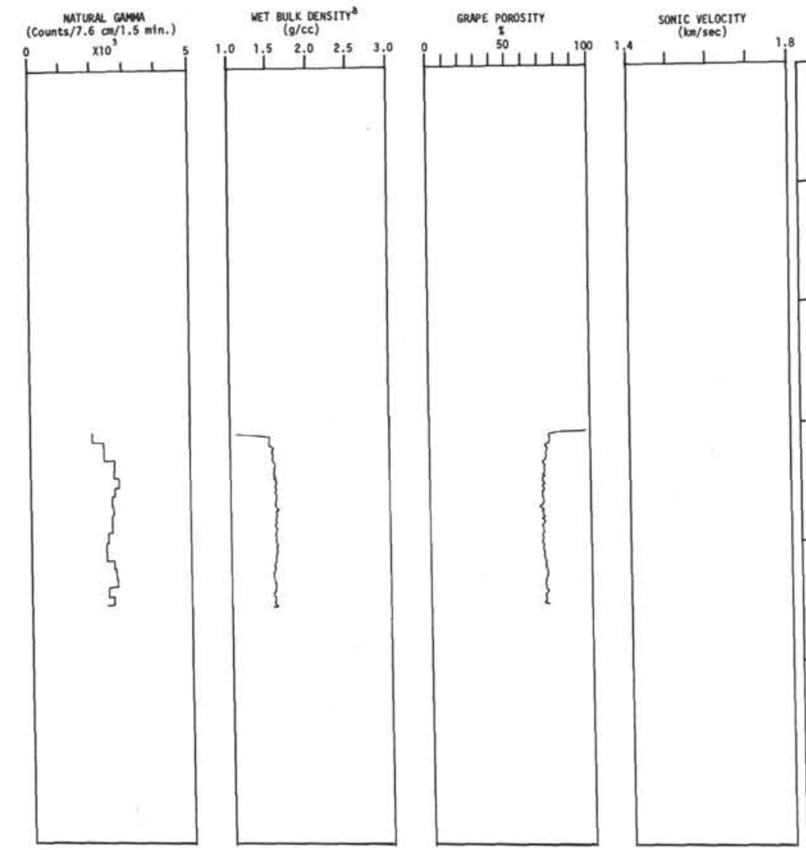
SITE: 158 HOLE: CORE: 4 Cored Interval: 27-36 m

SERIES	Foram zone	Nanno zone	Rad zone	DEPTH (Meters)	SECTION	LITHOLOGY	DESCRIPTION	MICROFOSSIL Abund/Pres (Foram / Nanno / Rad)
LOWER PLEISTOCENE	*P. obliquiloculata*	*Coccolithus doronicoides*		0–1.5	1	VOID	Nannofossil foraminiferal chalk ooze, radiolaria common; predominant colors grayish-to-dusky yellow green at top grading to grayish yellow green in section 3's lower half; pyrite present in varying amounts in every smear slide; faint H_2S odor. Low to moderate mottling; mottles are various yellow-green shades plus yellowish gray where pyrite contents are higher. Dark glass also ubiquitous in small amounts.	A G / A M / A G
UPPER PLIOCENE	*Globorotalia limbata* / *Globoquadrina altispira*	*Discoaster brouweri*	*Spongaster pentas*	1.5–6	2, 3, 4			A M; A P
					CC		Light and dark glass, feldspar and glauconite present in coarse fraction.	A M / A M / C M

% $CaCO_3$: 0, 50, 100

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles

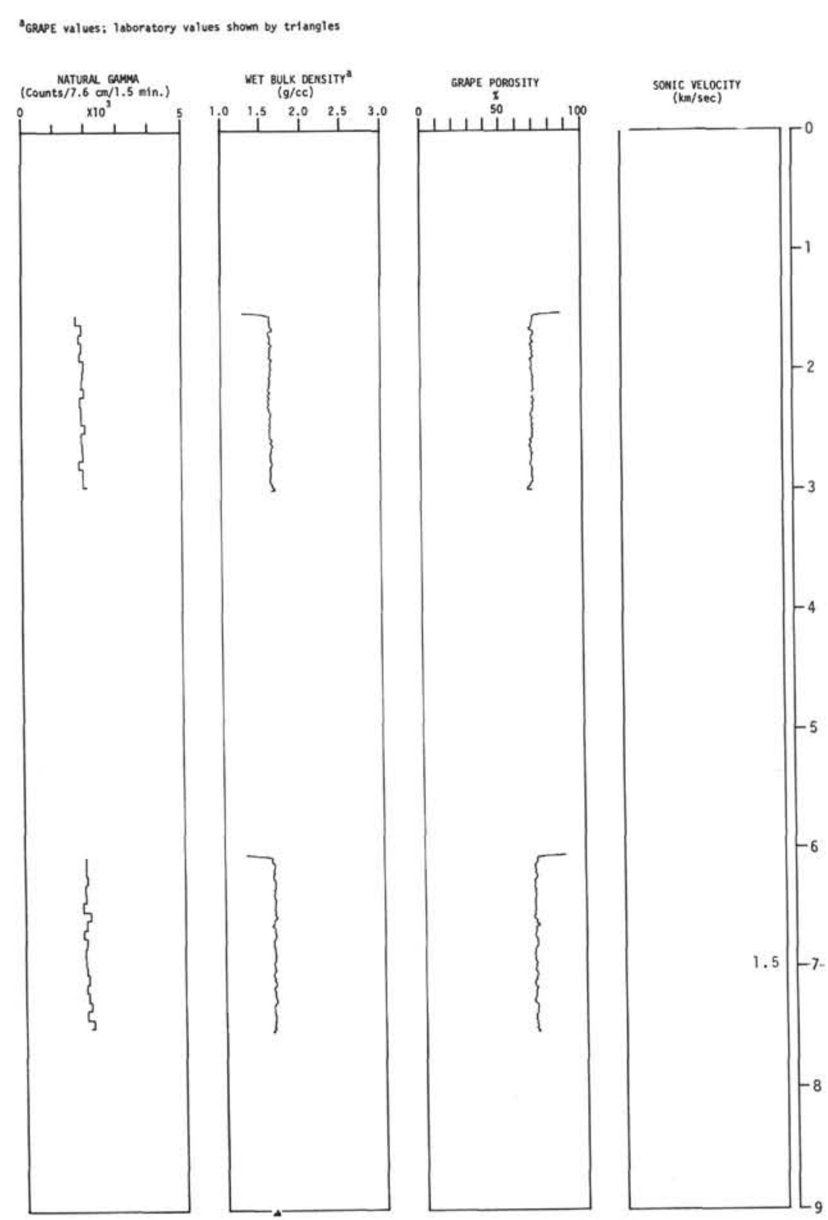


SITE: 158 HOLE: CORE: 5 Cored Interval: 36-45 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	DESCRIPTION	MICROFOSSIL Abund/Pres
UPPER PLIOCENE	*Globoquadrina altispira*	*Discoaster brouweri* / *Reticulofenestra pseudoumbilica*	*Spongaster pentas*	0–9	1–6	Nannofossil foraminiferal chalk ooze, grayish yellow green; radiolaria common; with minor pyritic streaks about 2 mm wide and 10-20 mm long; few minor 3 mm thick layers of same. Few scattered gray lumps of pyritiferous chalk ooze about 2 to 5 mm in diameter; larger ones indicated separately.	
						Light glass and clay usually present.	A G
							A G
						1 x 2 cm pyritic streak 4 mm x 1 cm pyritic streak	
						0.5 x 1 cm pyritic lump	
LOWER PLIOCENE	*G. tumida*				CC	Glauconite present in acid-treated coarse fraction.	C M A M A M

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



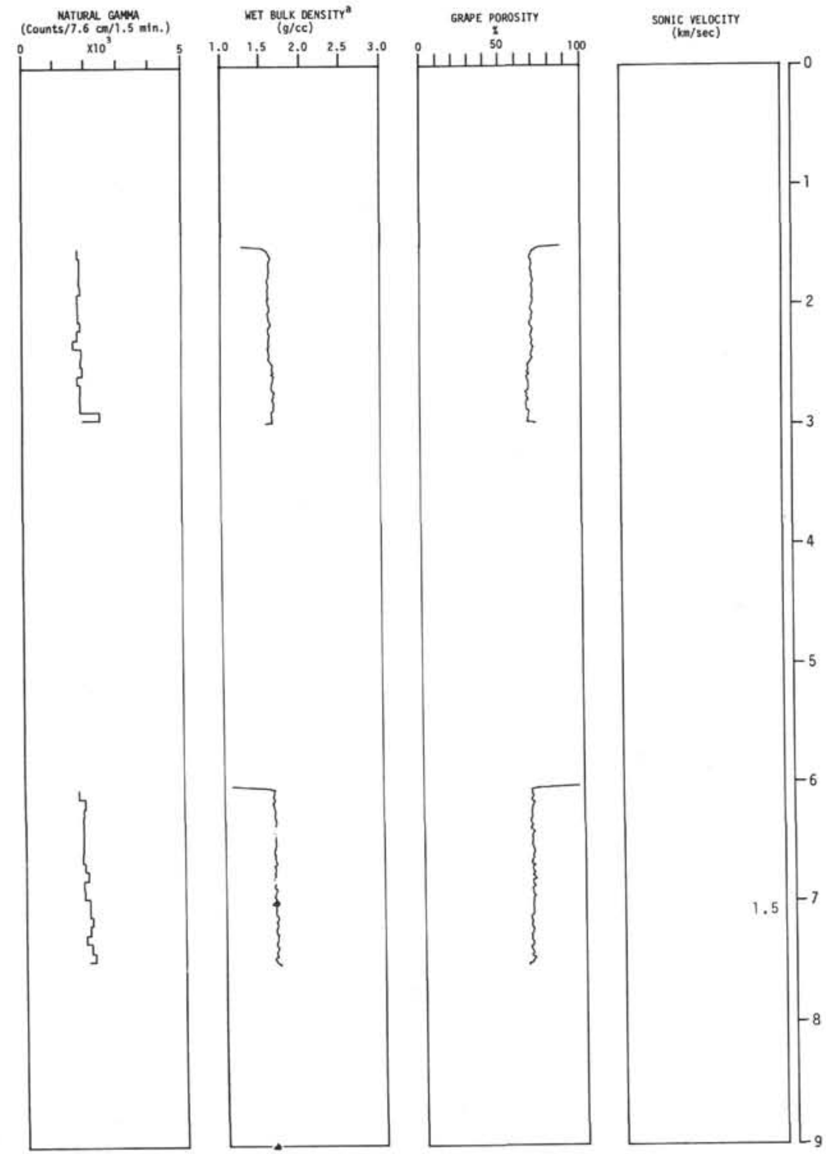
SITE: 158 HOLE: CORE: 6 Cored Interval: 45-54 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
LOWER PLIOCENE	*Globorotalia tumida*	*Reticulofenestra pseudoumbilica*	*Spongaster pentas*	0	1				*	Nannofossil foraminiferal chalk ooze, radiolaria common, diatoms present; grayish yellow green, minor pyritic gray streaks and lumps as in core 5; some suggestion of either layering or mottling (light olive, but too deformed to evaluate at op, missing in lower sections.	A	Md	
				1						streak of gray pyritic chalk ooze			
				2	2					Light glass and clay usually present.			
				3					*		A	M	
				4	3			*		Diatoms increasing			
				5	4								
				6									
				7	5								
				8	6			*		First noted appearance of silicoflagellates			
					CC				*	Light and dark glass and palagonite in acid-treated coarse fraction.	C M	A M	A G

% $CaCO_3$: 0 50 100

PHYSICAL PROPERTIES

[a] GRAPE values; laboratory values shown by triangles

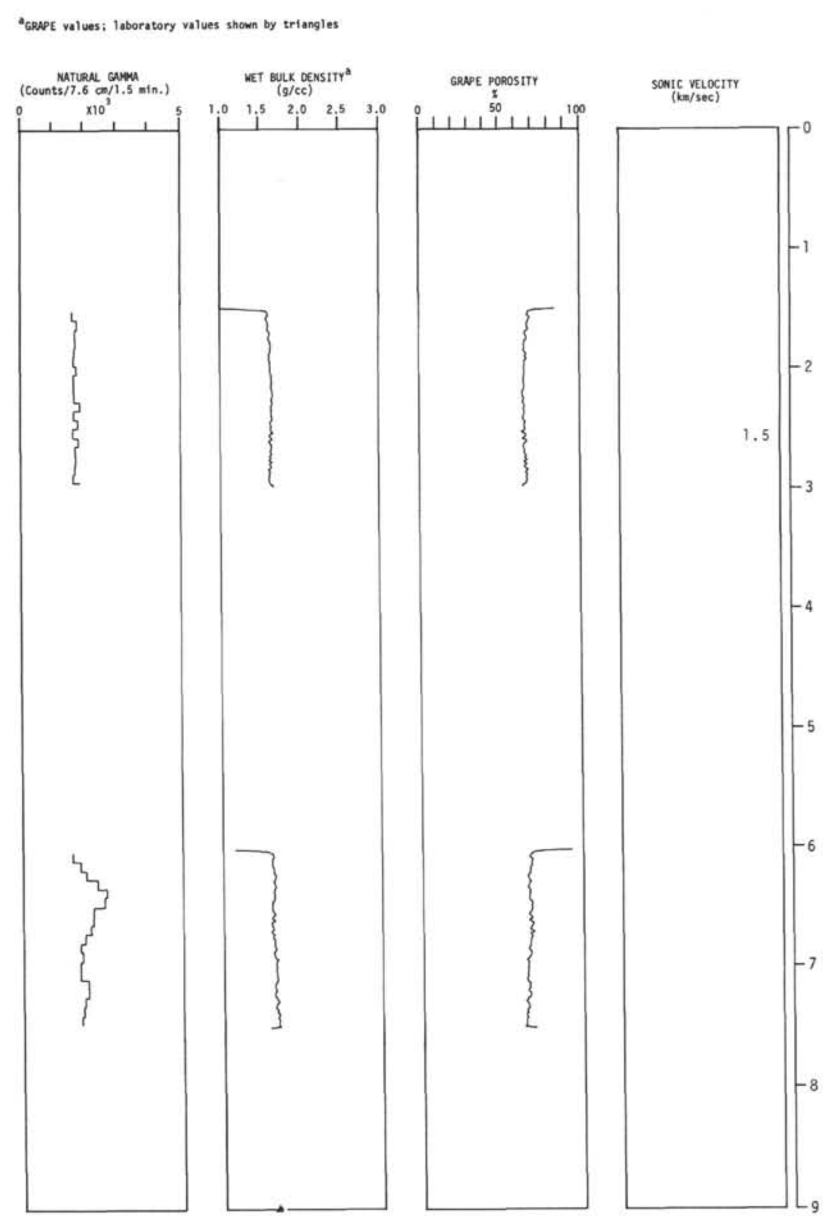


SITE: 158 HOLE: CORE: 7 Cored Interval: 54-63 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION
LOWER PLIOCENE	*Globorotalia tumida*	*Reticulofenestra pseudoumbilica*	*Spongaster pentas*	0–1.5	1	VOID		*		Nannofossil chalk ooze; forams common to abundant, diatoms common, radiolaria common to present; lighter in color than core 6 by 0.5 value (light grayish yellow green); light glass usually present, dark glass less so. Fine pyrite usually present.
				1.5–3	2					Few minor yellowish-gray streaks suggest disturbed layering; also same gray pyritic streaks as in Core 6.
				3–4.5	3			*		Pyritic gray streak 3 mm x 40 mm 2-3 mm pyritic lumps
				4.5–6	4					
				6–7.5	5			*		30 x 50 mm dusky to grayish olive green pyritic lump, containing light and dark glass
				7.5–9	6					4 mm pyritic lump Deformed into 3-5 cm "biscuits" separated by 1-2 cm of flowed homogenized material
					CC			*	*	Dark glass, palegonite, quartz, feldspar present in acid treated coarse fractions.

MICROFOSSIL Abund/Pres: Foram, Nanno, Rad — % $CaCO_3$ (0, 50, 100) — F M A M A G

PHYSICAL PROPERTIES



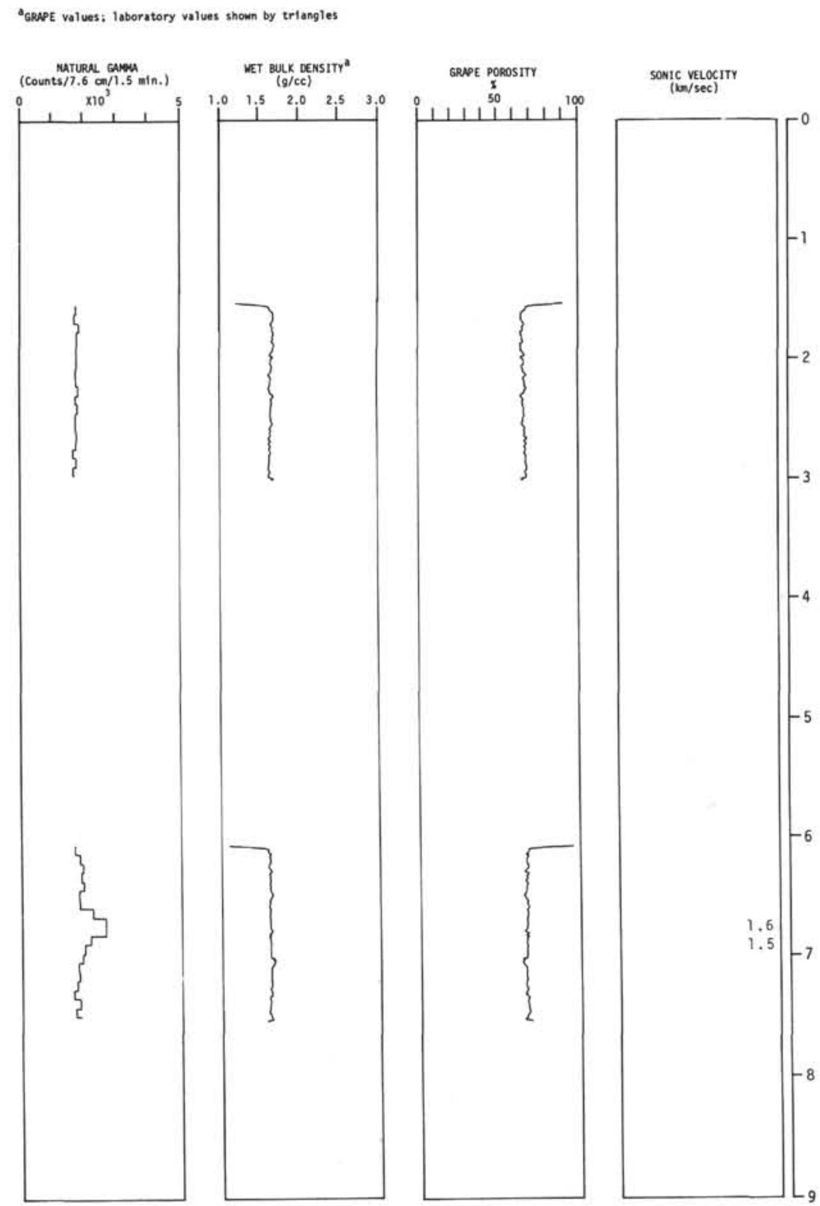
SITE: 158 HOLE: CORE: 8 Cored Interval: 63-72 m

SERIES	AGE ZONE: Foram	AGE ZONE: Nanno	AGE ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION
LOWER PLIOCENE	*Globorotalia tumida*	*Reticulofenestra pseudoumbilica*	*Spongaster pentas*	0–1.5	1	VOID; VOID				Nannoplankton chalk ooze, forams and radiolaria common, diatoms present; light grayish yellow green; finely disseminated dark and light glass present. Pyrite still present as fine grains, but gray streaks which characterize higher sections are very rare.
				1.5–3	2			*		Top half of core homogenized by deformation. few small unhomogenized lumps
		Ceratolithus tricorniculatus		3–4.5	3			*		8 cm unhomogenized lump
				4.5–6	4					
				6–7.5	5					
			Stichocorys peregrina	7.5–9	6					
					CC				*	No detritals noted in acid-treated coarse fraction.

MICROFOSSIL Abund/Pres: Foram C M; Nanno A M; Rad A G

% $CaCO_3$ 0 50 100

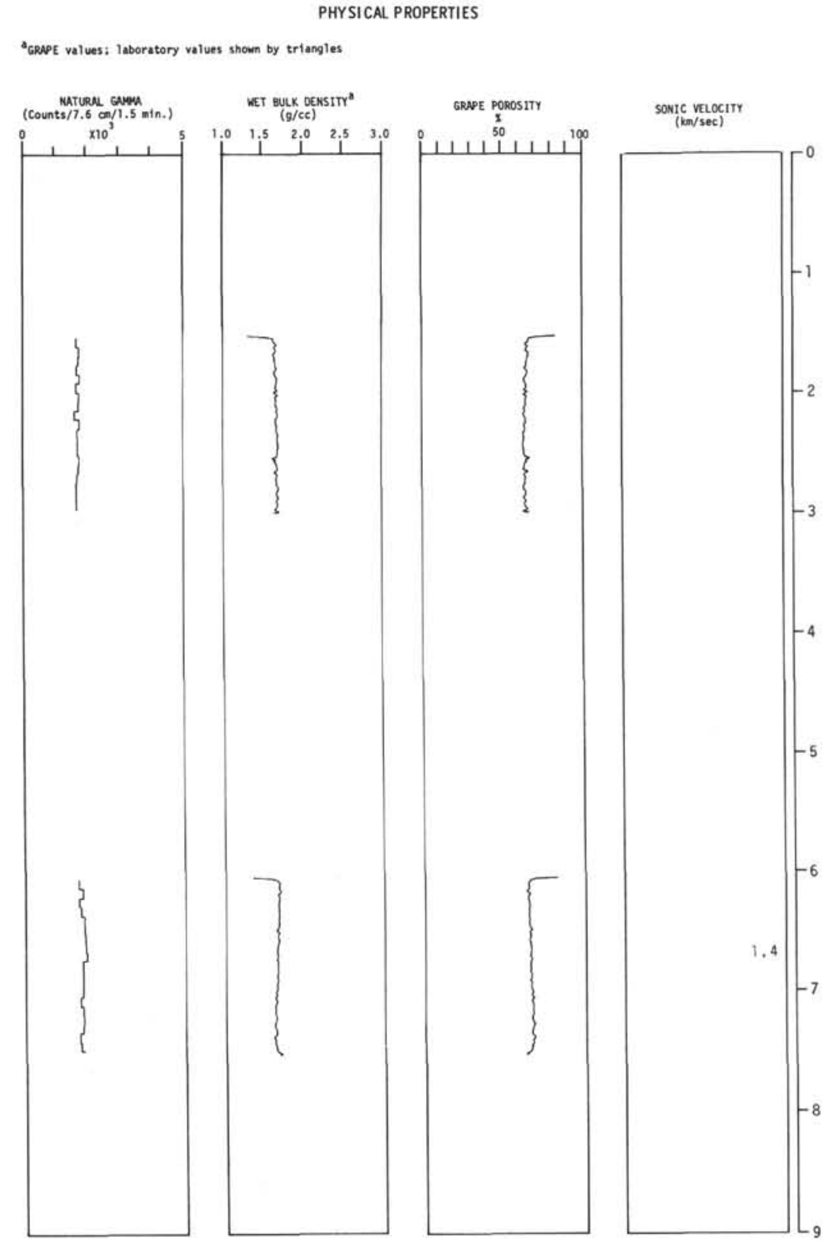
PHYSICAL PROPERTIES



SITE: 158 HOLE: CORE: 9 Cored Interval: 72-81 m

SERIES	Foram zone	Nanno zone	Rad zone	SECTION	DESCRIPTION
LOWER PLIOCENE	*Globorotalia tumida*	*Ceratolithus tricorniculatus*	*Stichocorys peregrina*	1	VOID. Nannoplankton chalk ooze, forams and radiolaria common, diatoms present; light grayish yellow green. Palagonite, dark glass, quartz and feldspar present locally
				1	minor olive gray layer, distorted
				2	
				3	
				4	
				5	
				6	3 x 10 mm foram and pyrite-enriched lump
				CC	Glauconite present, no detritals noted in acid-treated coarse fraction.

MICROFOSSIL Abund/Pres (Foram, Nanno, Rad); % $CaCO_3$ (0, 50, 100): C M A ?M A G

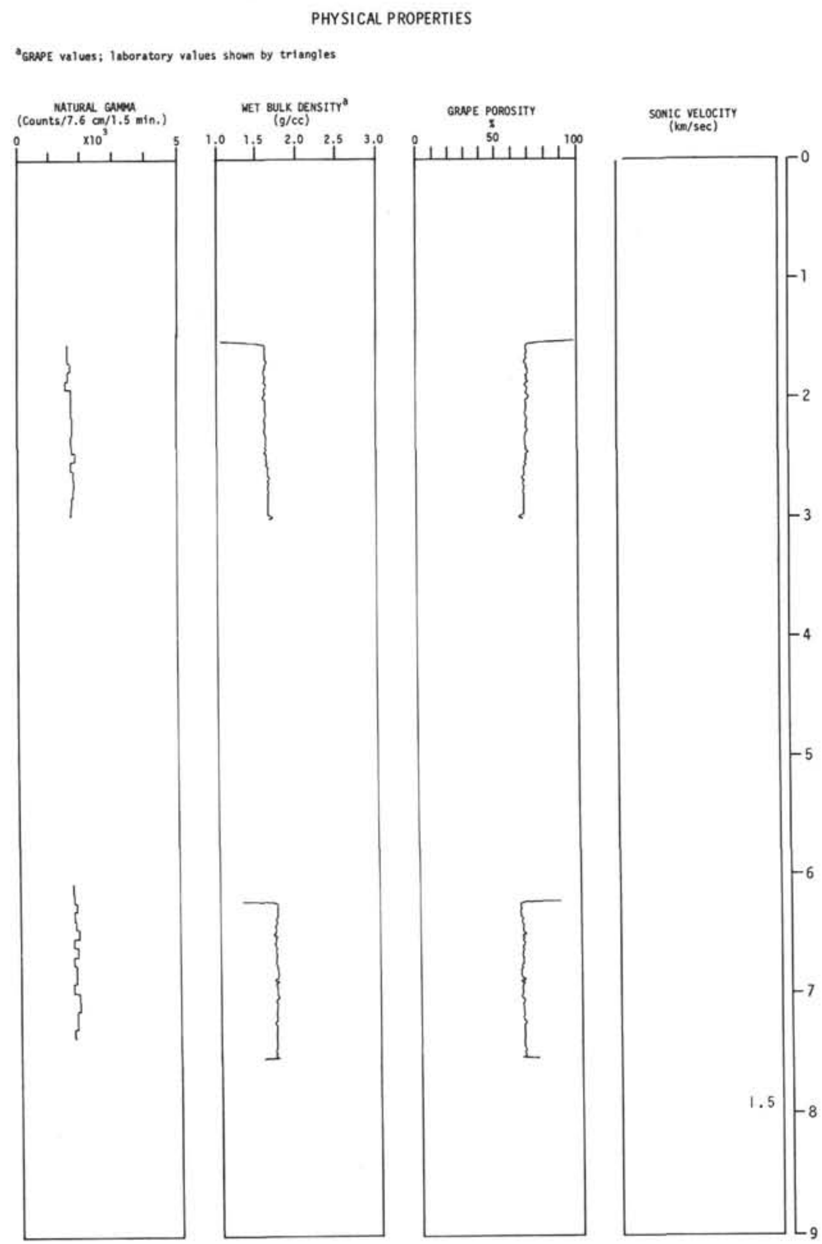


SITE: 158 HOLE: CORE: 10 Cored Interval: 81-90 m

SERIES	Foram zone	Nanno zone	Rad zone	DEPTH (Meters)	SECTION	LITHOLOGY	Smear Slide	Paleo. sample	DESCRIPTION
LOWER PLIOCENE				0–1	1	VOID			Nannofossil chalk ooze; foraminifera and radiolaria common, diatoms present to common, silicoflagellates present; light grayish yellow green; obscure deformed yellowish to light olive gray mottling or layering, few gray deformed lamina. Color grading to medium greenish gray in bottom third of section
UPPER MIOCENE	*Globorotalia tumida*	*Ceratolithus tricorniculatus*	*Stichocorys peregrina*	1–1.5		VOID			
				2					2 x 8 mm pyritic gray streak
				2–3	2		*		pyrite and light glass present
				3–4.5	3				
		Discoaster quinqueramus		4.5–6	4				
				6–7.5	5		*		Dark glass and palagonite present; also clay
	G. plesiotumida			7.5–9	6				3 mm pyritic lump
					CC			*	Dark and light glass, palagonite and feldspar in acid-insoluable coarse fraction.

MICROFOSSIL Abund/Pres: Foram C M; Nanno A M; Rad A G

% $CaCO_3$ 0 50 100

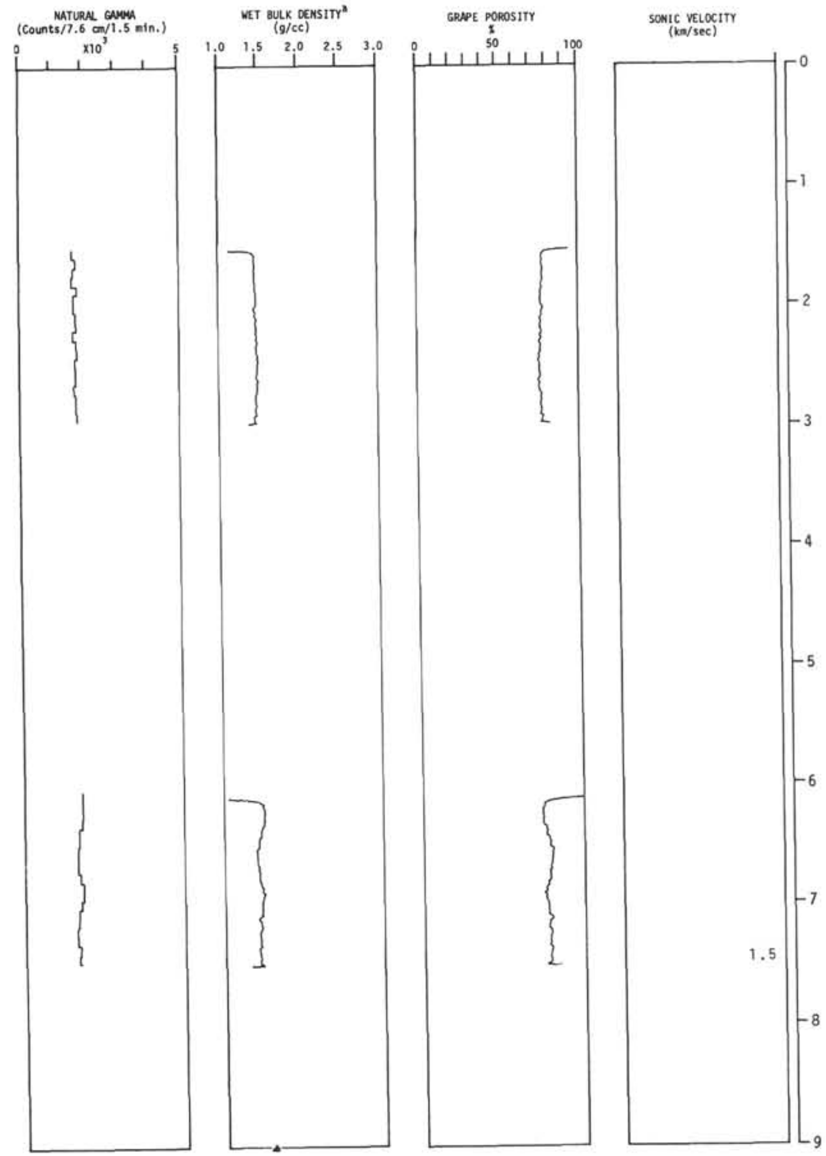


SITE: 158 HOLE: CORE: 11 Cored Interval: 90-99 m

SERIES	AGE ZONE: Foram	Nanno	Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram, Nanno, Rad; % $CaCO_3$ (0, 50, 100)
UPPER MIOCENE	*Globorotalia plesiotumida*	*Discoaster quinqueramus*	*Stichocorys peregrina*	1	1					Nannofossil chalk ooze, radiolaria common to abundant, foraminifera common, diatoms increasing to abundant in 5th section; predominant color medium greenish gray, light grayish green mottling, rare in uppermost 3 sections, increases in section 4 so the 2 core colors become intimately intermingled.	
				2	2			* *		Pyrite is ubiquitous in small amounts; dark and light glass, clay and feldspar also locally present.	
				3, 4	3						
				5, 6	4						
				7	5			*		Distinct increase in diatom and radiolaria contents	
								*		Silicoflagellates common	
				8	6						
					CC				*	Glauconite in coarse fraction.	C M A P A G

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



SITE: 158 HOLE: CORE: 12 Cored Interval: 99-108 m

SERIES: UPPER MIOCENE

AGE / ZONE: Foram: *Globorotalia pleisotumida*; Nanno: *Discoaster quinqueramus*; Rad: *Stichocorys peregrina*

Columns: DEPTH (Meters), SECTION, LITHOLOGY, Disturbance, Smear Slide, Paleo. sample, DESCRIPTION, MICROFOSSIL Abund/Pres (Foram, Nanno, Rad), % $CaCO_3$ (0, 50, 100)

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

DESCRIPTION

Nannofossil chalk ooze, radiolaria and diatoms common to abundant, foraminifera common to abundant; predominant color yellow gray at top, grading down through grayish olive green to light grayish yellow green at bottom; obscurely mottled yellow gray and medium greenish gray. Pyrite and associated light glass locally abundant.

1 to 5 cm yellow to light olive gray mottles containing abundant light glass, pyrite inclusions in glass, and pyrite framboids

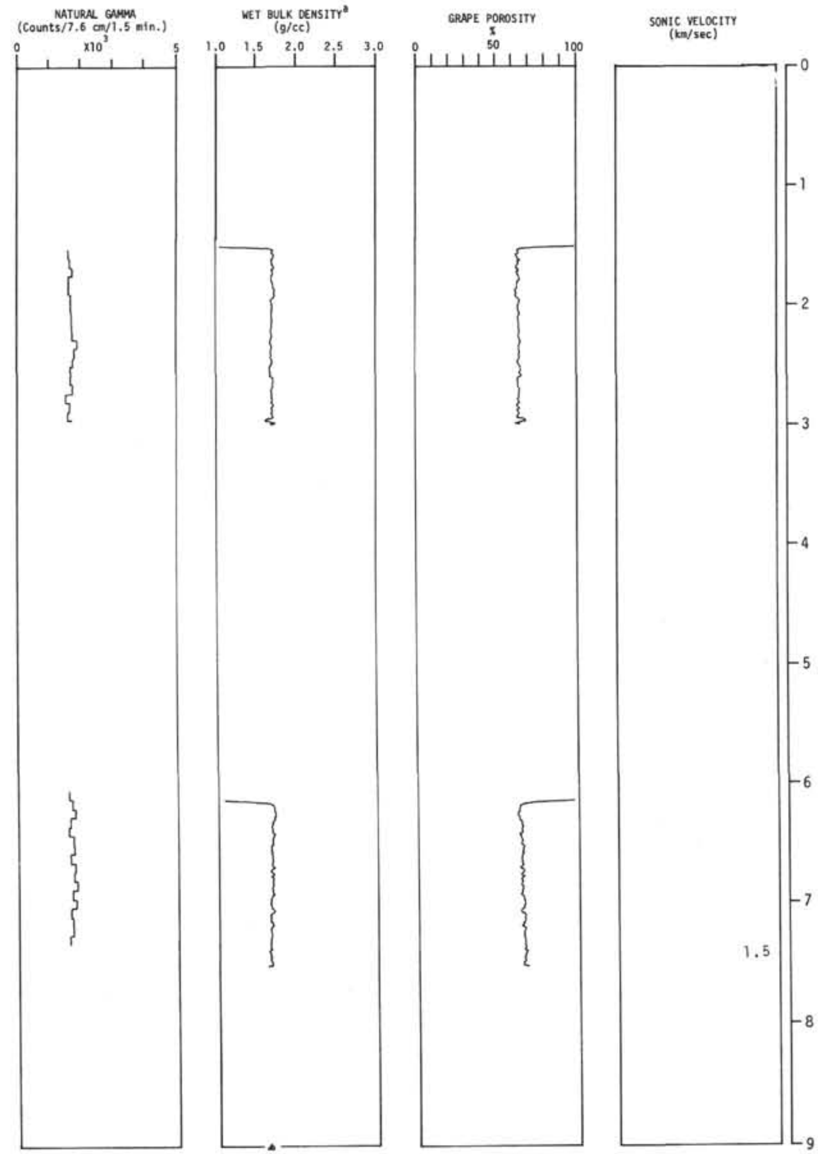
Light glass common, palagonite, feldspar and glauconite present in acid-treated coarse fraction.

MICROFOSSIL Abund/Pres (Section 1): A M

MICROFOSSIL Abund/Pres (CC): C M A M A G

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles

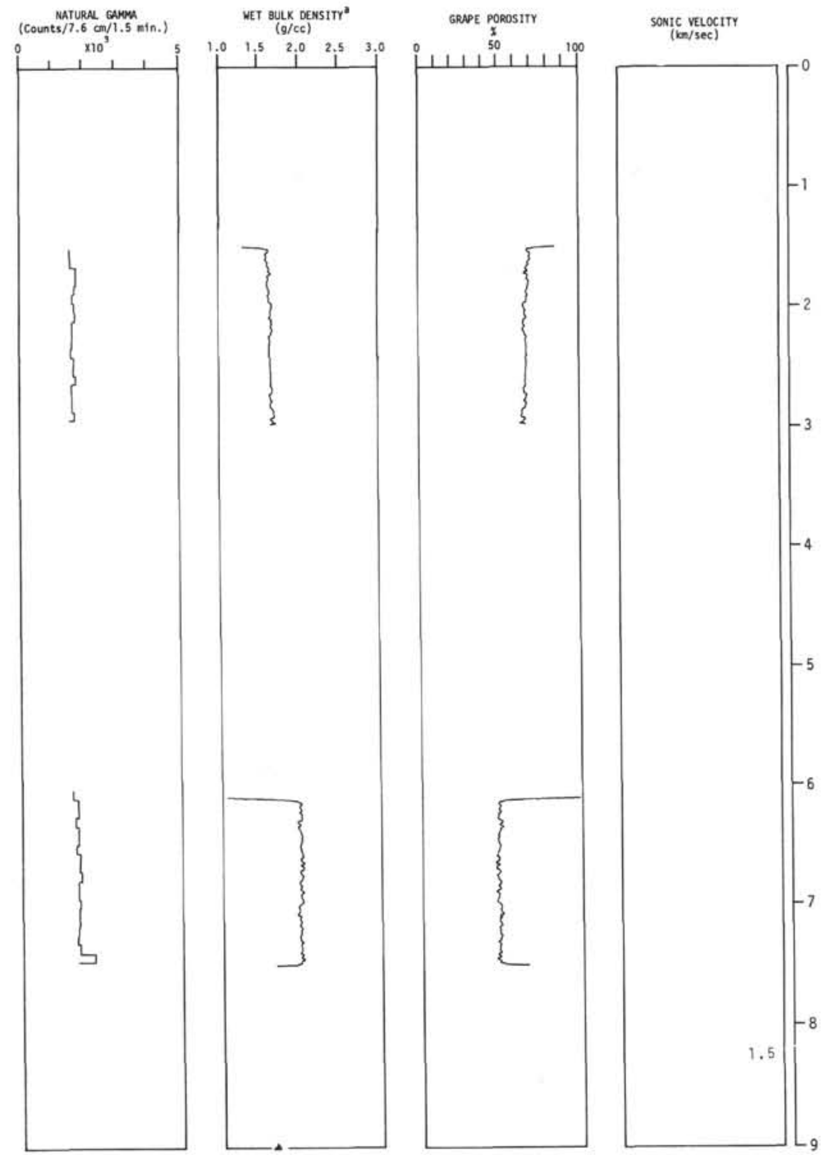


SITE: 158 HOLE: CORE: 13 Cored Interval: 108-117 m

SERIES	Foram zone	Nanno zone	Rad zone	SECTION	DESCRIPTION	MICROFOSSIL Abund/Pres
UPPER MIOCENE	*Globoratalia pleisotumida*	*Discoaster quinqueramus*	*Stichocorys peregrina*	VOID; 1	Nannofossil chalk ooze, foraminifera and radiolaria abundant, diatoms common to present; medium greenish gray with light olive gray mottling (mottling moderate). Dark glass present, also (locally) rare glauconite, palagonite and feldspar. Fine pyrite ubiquitous in small amounts, especially in olive gray mottles.	Nanno A M
				2		
				3		Nanno A M
				4		
				5		
				6		
				CC	In acid-treated coarse fractions: diatoms present, sponge spicules rare; also rare feldspar, dark glass, palagonite and glauconite.	Foram C M; Nanno A M; Rad A G

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



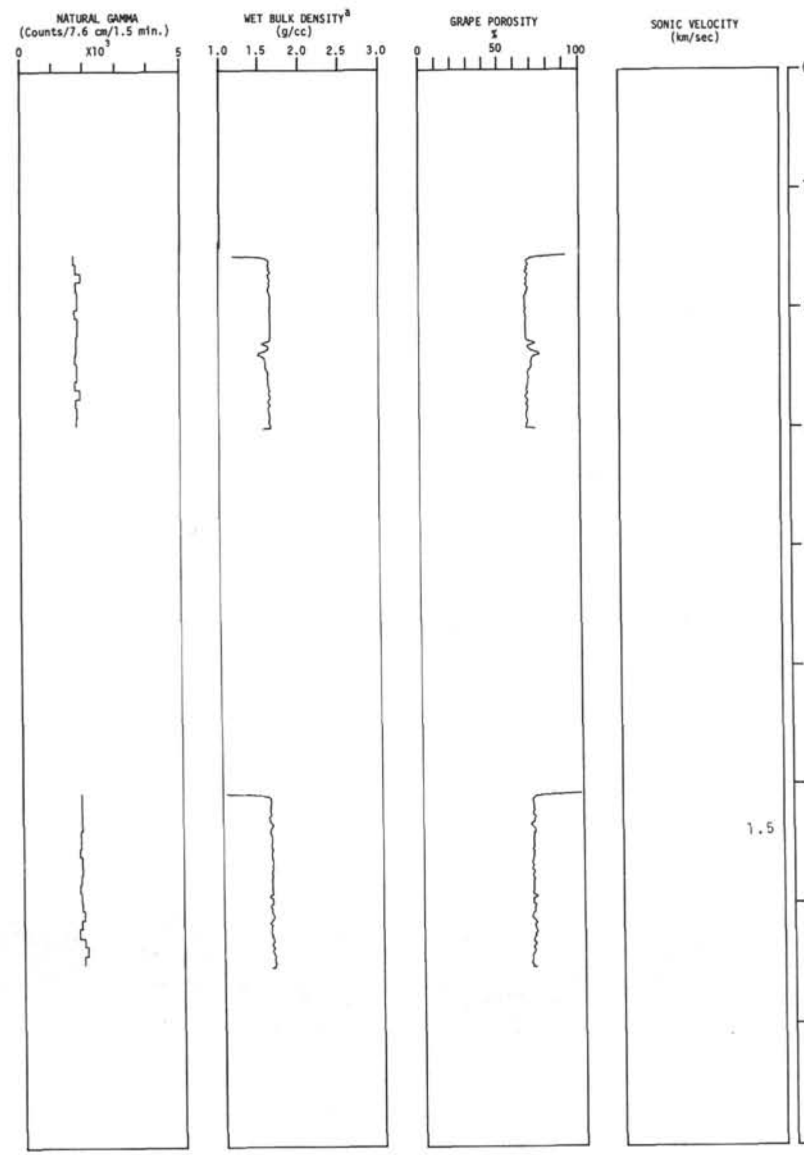
SITE: 158 HOLE: CORE: 14 Cored Interval: 117-126 m

SERIES	AGE / ZONE: Foram	Nanno	Rad	DEPTH (Meters)	SECTION	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
UPPER MIOCENE	*Globorotalia pleisotumida*	*Discoaster quinqueramus*	*Stichocorys peregrina*	0–1.5	1		*	Nannofossil chalk ooze, foraminifera and radiolaria common to abundant, diatoms present to common; yellowish-to-light olive gray and medium greenish gray alternating as dominant and mottle colors; pyrite common as fine grains in olives, also present in greenish grays; dark glass and palagonite locally present. Moderately well mottled.		A M	
				1.5–3	2	*					
				3–4.5	3	*	*			A M	
				4.5–6	4	*					
				6–7.5	5	*					
				7.5–9	6						
					CC	*	*	In acid-treated coarse fraction: diatoms present, radiolaria abundant.	C M	A M	A G

% $CaCO_3$: 0 50 100

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



SITE: 158 HOLE: CORE: 15 Cored Interval: 126-135 m

AGE: SERIES — UPPER MIOCENE

ZONE: Foram — *Globorotalia pleisotumida*; Nanno — *Discoaster quinqueramus*; Rad — *Stichocorys peregrina*

DEPTH (Meters): 0–9; SECTIONS: 1, 2, 3, 4, 5, 6, CC

LITHOLOGY | Disturbance | Smear Slide | Paleo. sample

DESCRIPTION

Nannofossil chalk ooze, radiolaria abundant to common, diatoms, and silicoflagellates common, foraminifera present to common. Dominant colors: top half, pale grayish yellow green; lower half medium greenish gray. Moderately well mottled pale yellow gray in entire core, also pale grayish yellow green toward bottom.

Pyrite fine grains ubiquitous, especially in grays; only other mineral noted in smears is rare dark glass and palagonite.

Glauconite rare in acid-treated coarse fraction.

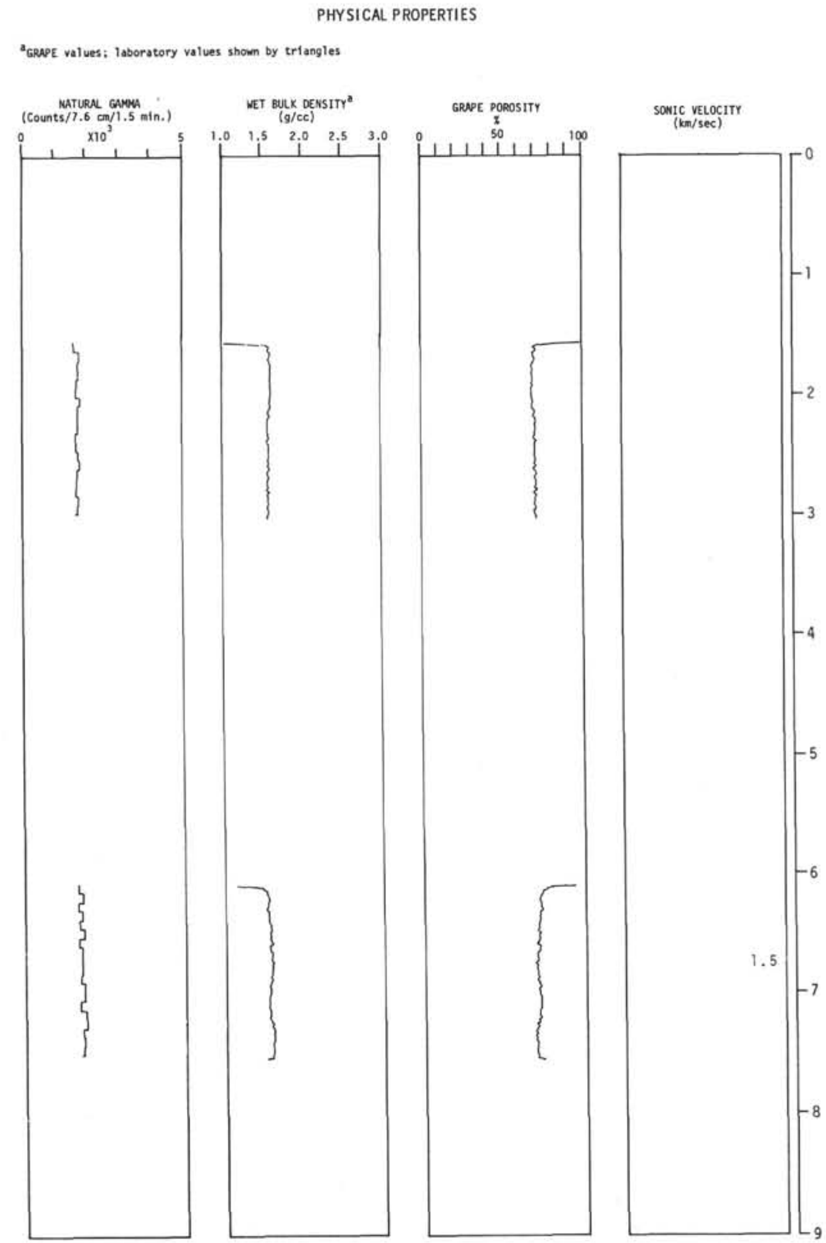
MICROFOSSIL Abund/Pres: Foram, Nanno, Rad; % $CaCO_3$ (0, 50, 100)

A M (Section 1); A M (Section 3)

CC: C M A M A G

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles

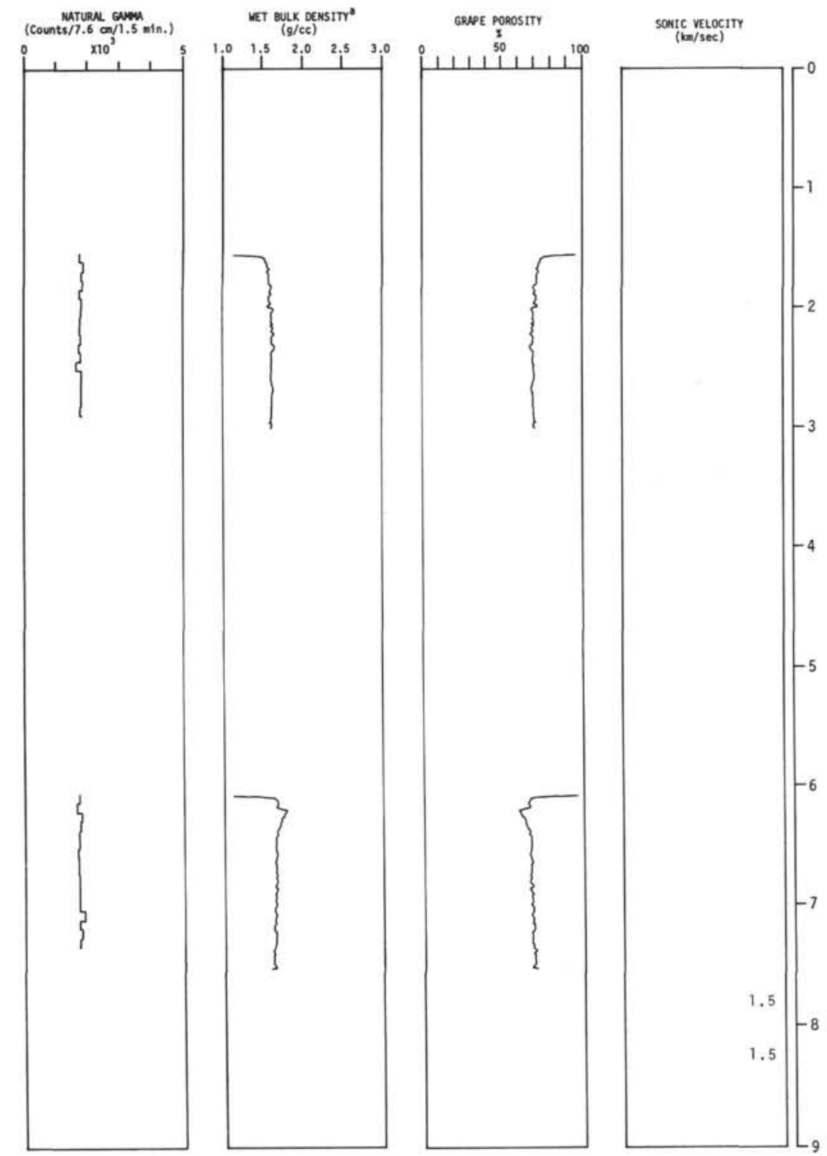


SITE: 158 HOLE: CORE: 16 Cored Interval: 135-144 m

SERIES	AGE ZONE: Foram	Nanno	Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres (Foram, Nanno, Rad); % CaCO3
UPPER MIOCENE	*Globorotalia acostaensis*	*Discoaster quinquerwmus*	*Ommatartus penultimus*		1				*	Nannofossil chalk ooze, radiolaria common, silicoflagellates common to present, foraminifera and diatoms present; moderately to strongly mottled, colors various yellowish and light olive gray hues; also gray mottles present containing abundant pyrite	A M
				1				*		many discoasters	
				2	2				*		A ?M
				3, 4	3				*		A M
				5	4			*	*	rare dark glass and palagonite; 3 mm pyritic lump	A P
				6, 7	5			*			A P
				8	6			*	*	Many 1-5 cm gray mottles	A Md
					CC				*		

C M A M A G

PHYSICAL PROPERTIES



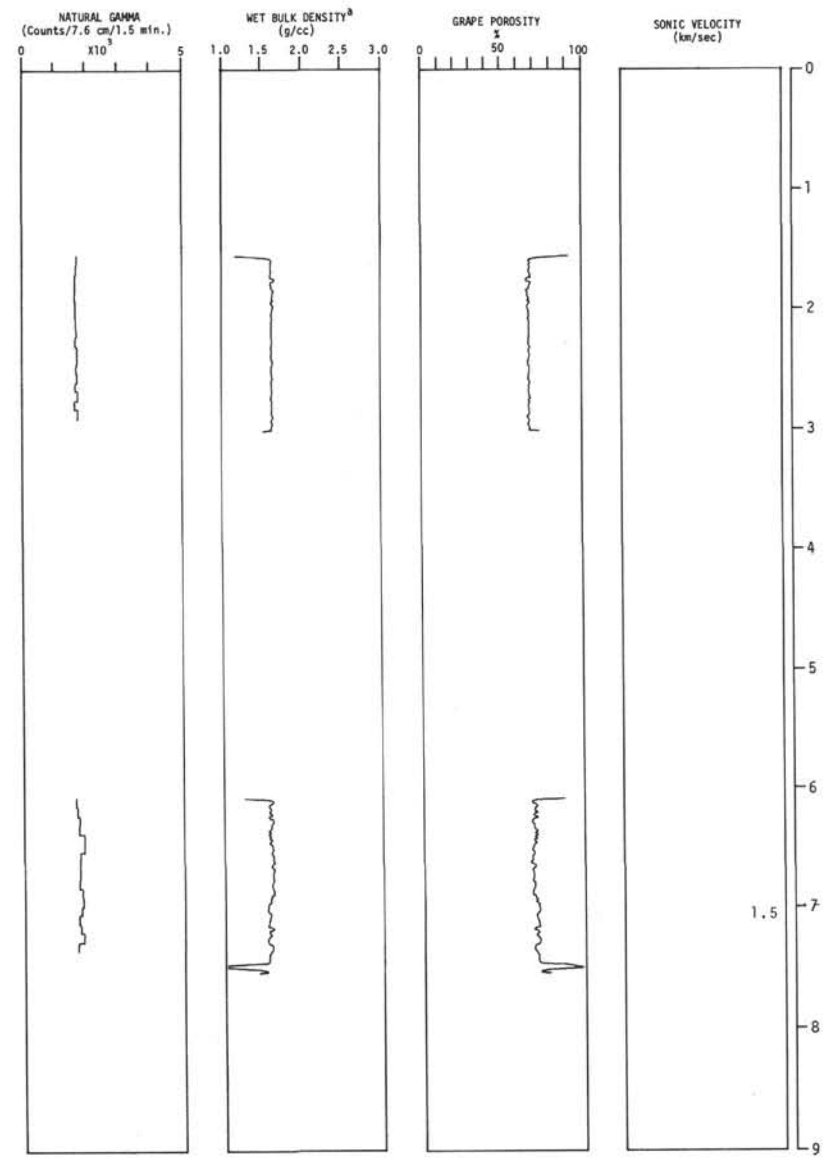
SITE: 158 HOLE: CORE: 17 Cored Interval: 144-153 m

SERIES	AGE ZONE: Foram	AGE ZONE: Nanno	AGE ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres
UPPER MIOCENE	*Globorotalia acostaensis*	*Discoaster quinqueramus*	*Ommatartus penultimus*	0–1.5	1				*	Nannofossil chalk ooze, diatoms and radiolaria common, foraminifera and silicoflagellates common to present, dominant colors pale olive in top and bottom thirds, yellow to light olive gray in middle. Mottled distinctly various yellowish and light olives (5Y8/1, 5Y7/2)	A M
				1.5–3	2				*	Fine pyrite still present in all smear slides; locally dark glass.	A M
				3–4.5	3			* *	*	rare dark glass	A P
				4.5–6	4				*		A P
				6–7.5	5			*	*	Material becoming more cohesive and less disturbed; commonly in discrete 10-15 cm pieces	A P
				7.5–9	6				*		A ?M
					CC				*	Glauconite present; also rare quartz and dark glass in acid-treated coarse fraction.	C M A M A G

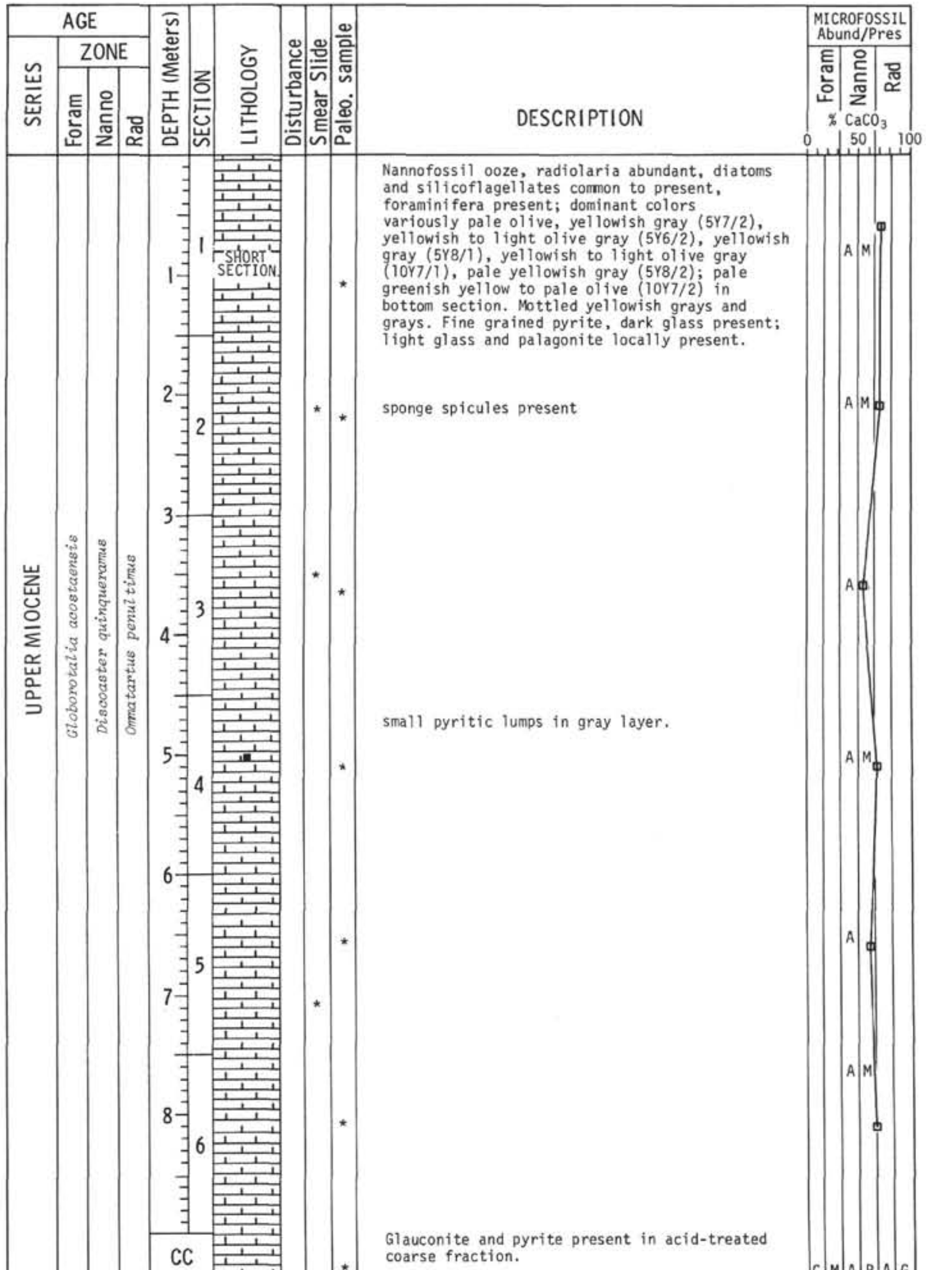
% $CaCO_3$: 0 50 100

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



SITE: 158 HOLE: CORE: 18 Cored Interval: 153-162 m



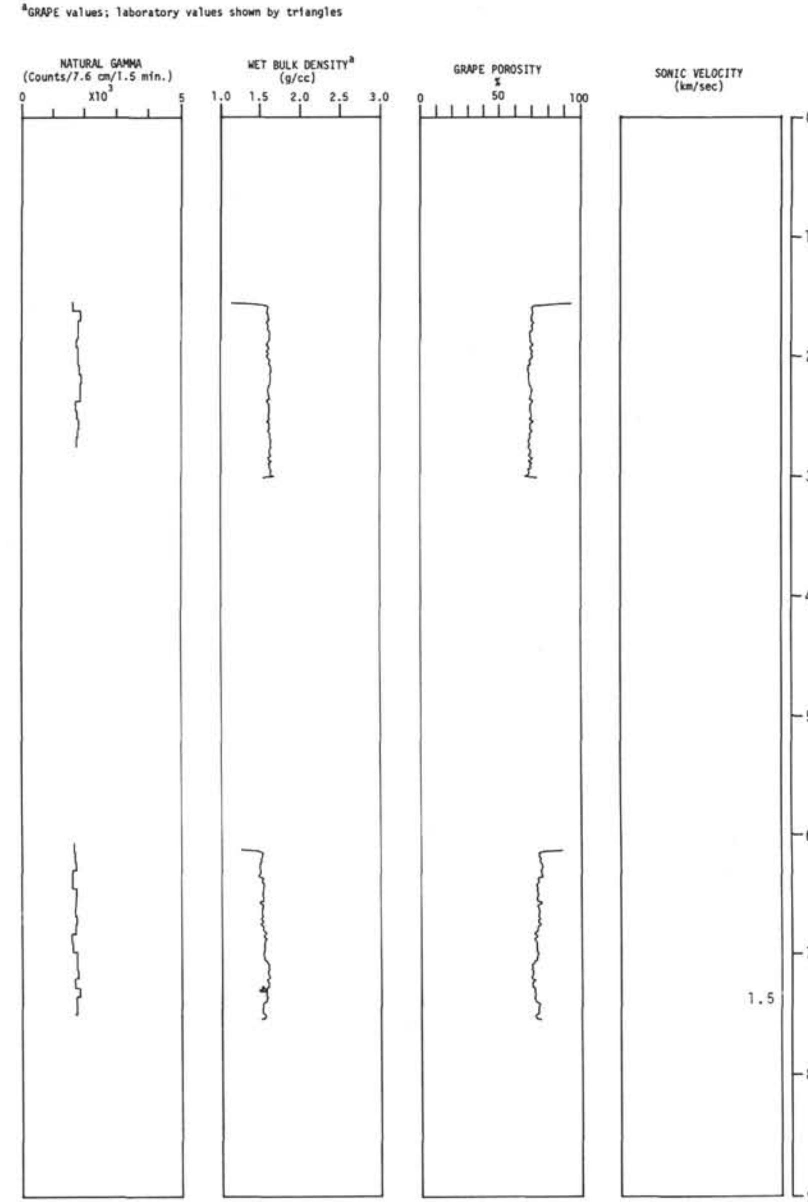
Nannofossil ooze, radiolaria abundant, diatoms and silicoflagellates common to present, foraminifera present; dominant colors variously pale olive, yellowish gray (5Y7/2), yellowish to light olive gray (5Y6/2), yellowish gray (5Y8/1), yellowish to light olive gray (10Y7/1), pale yellowish gray (5Y8/2); pale greenish yellow to pale olive (10Y7/2) in bottom section. Mottled yellowish grays and grays. Fine grained pyrite, dark glass present; light glass and palagonite locally present.

sponge spicules present

small pyritic lumps in gray layer.

Glauconite and pyrite present in acid-treated coarse fraction.

PHYSICAL PROPERTIES



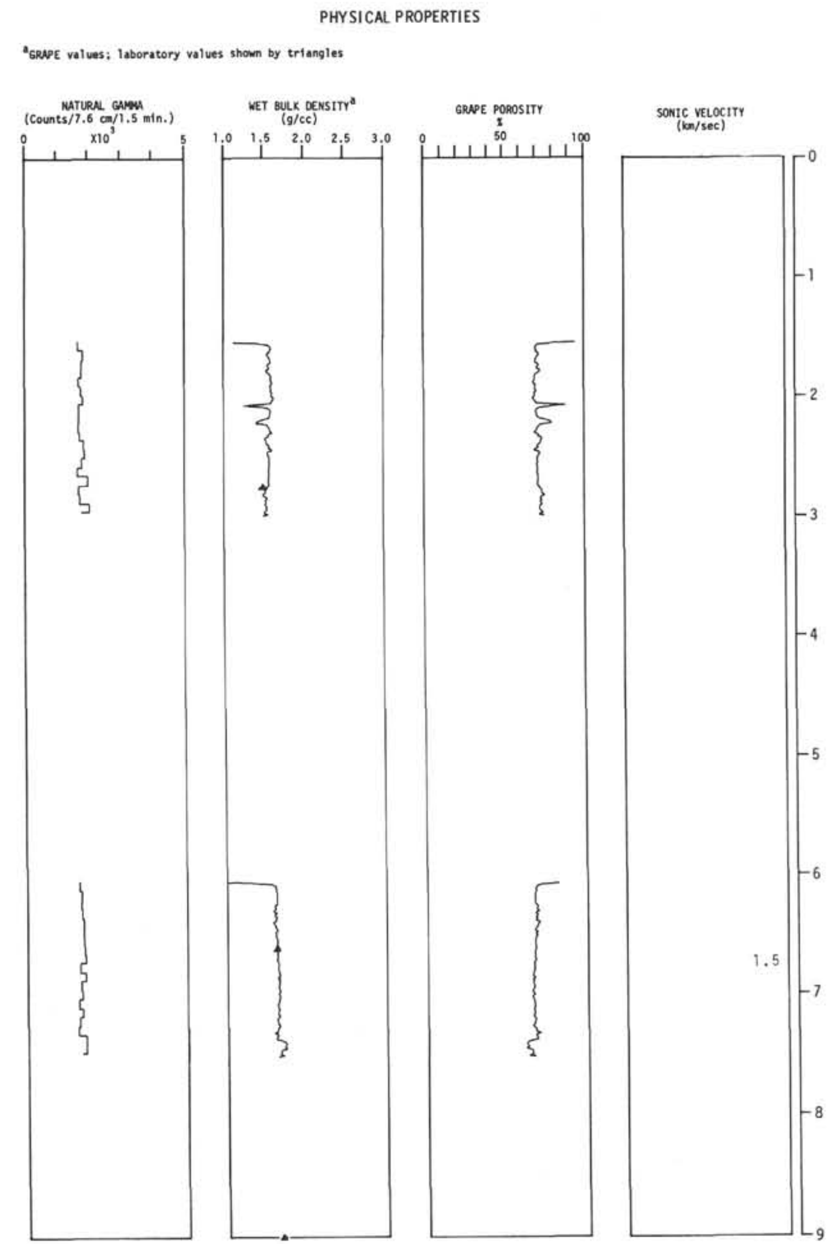
SITE: 158 HOLE: CORE: 19 Cored Interval: 162-171 m

SERIES	AGE ZONE: Foram	Nanno	Rad	DEPTH (Meters)	SECTION	DESCRIPTION	MICROFOSSIL Abund/Pres
UPPER MIOCENE	*Globorotalia acostaensis*	*Discoaster quinqueramus*	*Ommatartus penultimus*	0–1	1	Nannofossil chalk; radiolaria abundant to common, foraminifera, diatoms and silico-flagellates present to common; dominant color at top pale greenish yellow to olive; rest variously pale yellow gray (5Y8/2), yellowish gray (5Y7/2, or 5Y8/1) and yellowish to light olive gray (5Y6/2 or 5Y7/1). Mottled similar colors.	A M
				2	2	Fine pyrite ubiquitous, slightly more common in darker mottles. Dark glass, palagonite and rare light glass present locally.	
				3–4	3		A P ? ?
				5	4		
		Discoaster neohamatus	*Ommatartus antepenultimus*	6–7	5		
				8	6		
					CC	Rare quartz, dark glass and palagonite in acid-treated coarse fraction.	

% $CaCO_3$: 0 50 100

C M A Mc A G

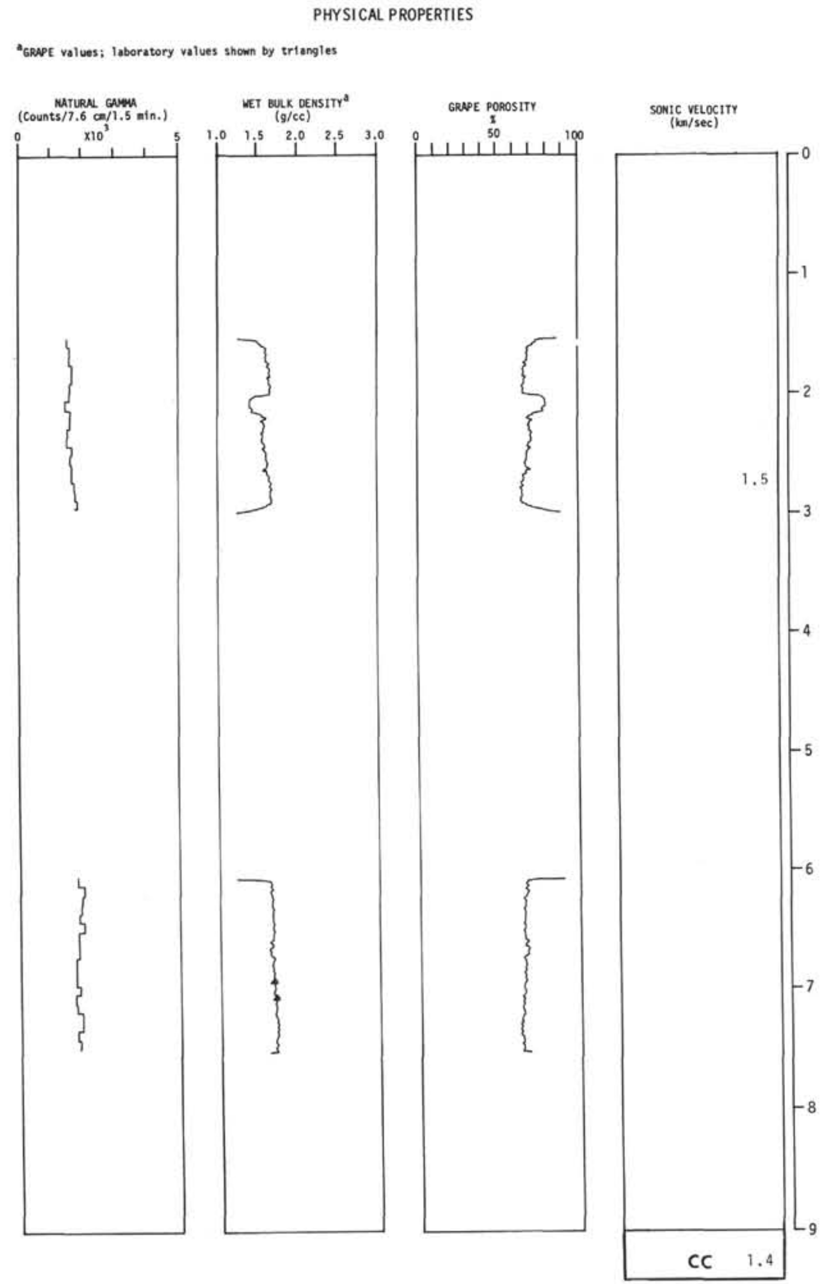
PHYSICAL PROPERTIES



SITE: 158 HOLE: CORE: 20 Cored Interval: 171-180 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	DESCRIPTION	MICROFOSSIL Abund/Pres (Foram, Nanno, Rad)
UPPER MIOCENE	*Globorotalia acostaensis*	*Discoaster neohamatus*	*Ommatartus antepenultimus*	0–1.5	1	VOID	Nannofossil chalk, radiolaria abundant to common, foraminifera common, diatoms common to present, silicoflagellates present; dominant colors yellow gray (5Y8/1), yellowish to light olive gray (5Y7/1) and light yellow gray (5Y8/2). Mottles light and medium light gray, yellowish to light olive gray, light yellow gray (5Y8/2) and yellowish to light olive gray (5Y7/1). Finely disseminated pyrite ubiquitous, especially in gray mottles; dark and light glass and palagonite present locally.	A P
				1.5–3	2			
				3–4.5	3			A P
				4.5–6	4			
				6–7.5	5		prominent light and medium light gray mottles	
							1 cm mottle surrounded by 2 mm grayish green "aureole"	
				7.5–9	6		bedded alternations several mm to several cm thick of yellowish gray and light olive gray	
					CC		Rare feldspar, dark glass and palagonite.	A P A G

% $CaCO_3$: 0, 50, 100



SITE: 158 HOLE: CORE: 21 Cored Interval: 180-189 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
UPPER MIOCENE	*Globorotalia acostaensis*	*Discoaster neohamatus*	*Ommatartus antepenultimus*	0–7	1, 2, 3, 4, 5, CC	VOID	Nannofossil chalk, radiolaria abundant, foraminifera common to abundant, diatoms present to common, silicoflagellates present; colors change downward from white to pale yellowish gray, yellowish to light olive gray (5Y6/2 and 5Y7/1); mottles and laminations pale to grayish green and pale green (diffuse), medium light gray, and yellowish to light olive gray (5Y6/2). 3 mm thick pale green laminae and pyritic streaks Dark and light glass, palagonite, feldspar and rare pyroxene present in smear slides. Pyrite associated with glass especially abundant in gray mottles and laminae. Dark and light glass and palagonite rare in acid-treated coarse fractions.		A P / A P / A M	A G

% $CaCO_3$: 0, 50, 100

PHYSICAL PROPERTIES

SITE: 158 HOLE: CORE: 22 Cored Interval: 189-198 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	DESCRIPTION
UPPER MIOCENE	*Globorotalia acostaensis*	*Discoaster neohamatus*	*Ommatartus antepenultimus*	0–1.5	1	VOID	
				1–3	1–2		Nannofossil chalk, radiolaria common to abundant, foraminifera present to common, diatoms and silicoflagellates present; dominant color yellowish to light olive gray (5Y7/1), grading into medium greenish gray and grayish yellow green in the 50 cm near the pyritic glassy chalk. Mottles yellowish to light olive gray (5Y6/2) and medium light gray.
				7	5		Pyritic glassy nannofossil chalk, olive gray to black. Light and dark glass with pyrite inclusions common.
				8	6		Same nannofossil chalk as top of core; yellowish to light olive gray, grading down to pale yellowish gray (5Y8/2).
					CC		Feldspar present, also rare dark and light glass, palagonite and glauconite.

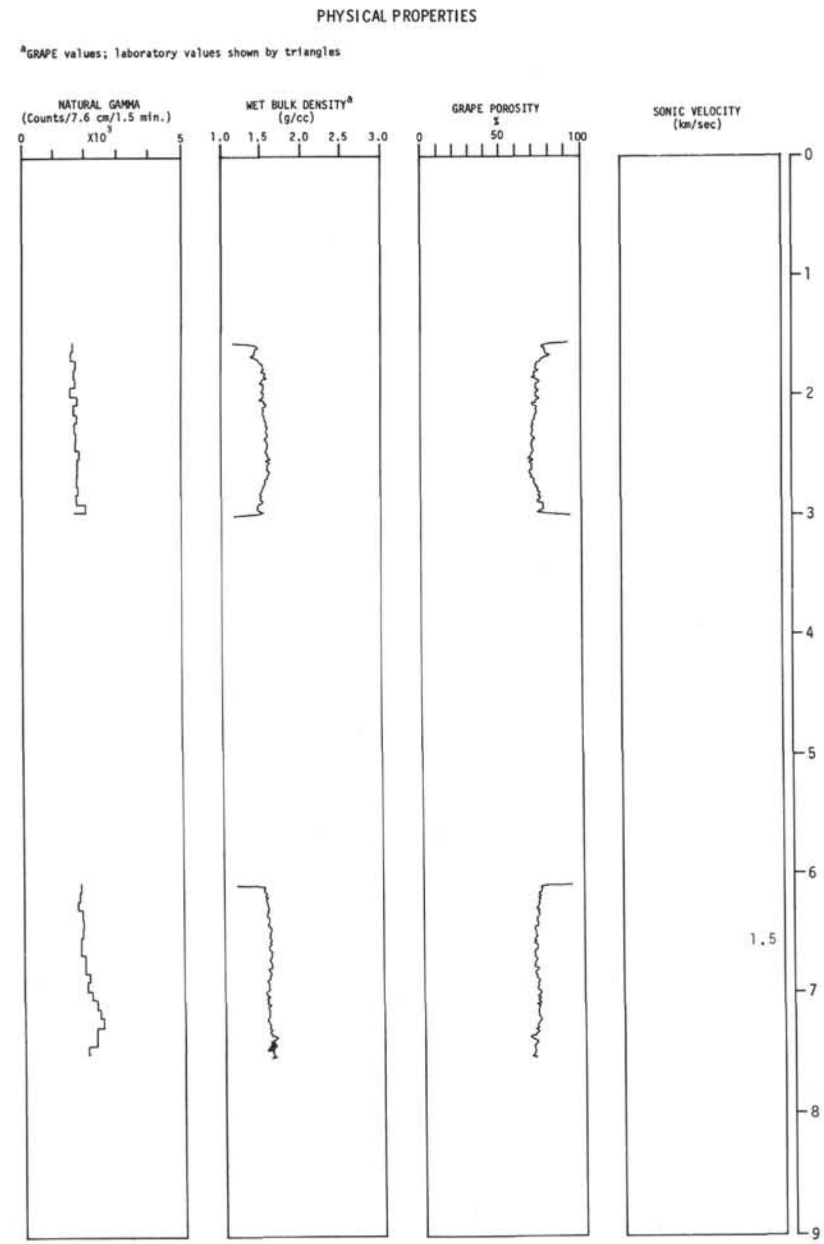
MICROFOSSIL Abund/Pres: Foram, Nanno, Rad; % $CaCO_3$ (0, 50, 100)

Nanno: A M (approx. 4.2 m); A M (approx. 4.4 m); A M (approx. 7.5 m)

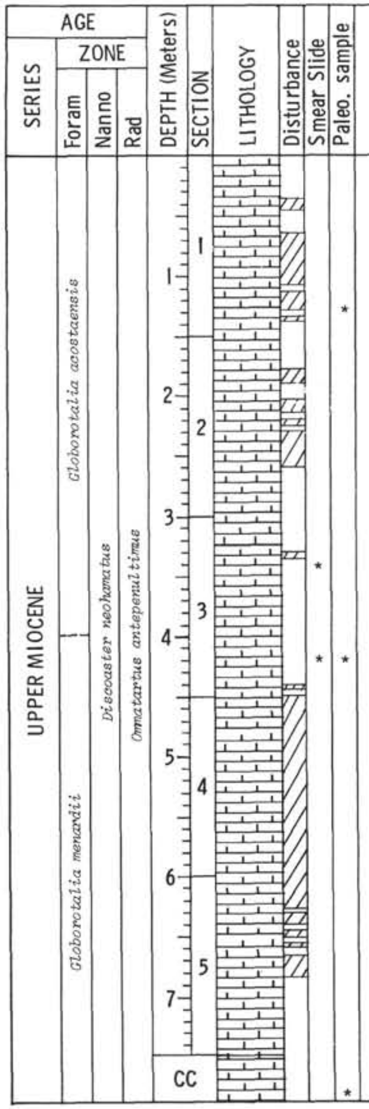
Key: F M A M A G

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



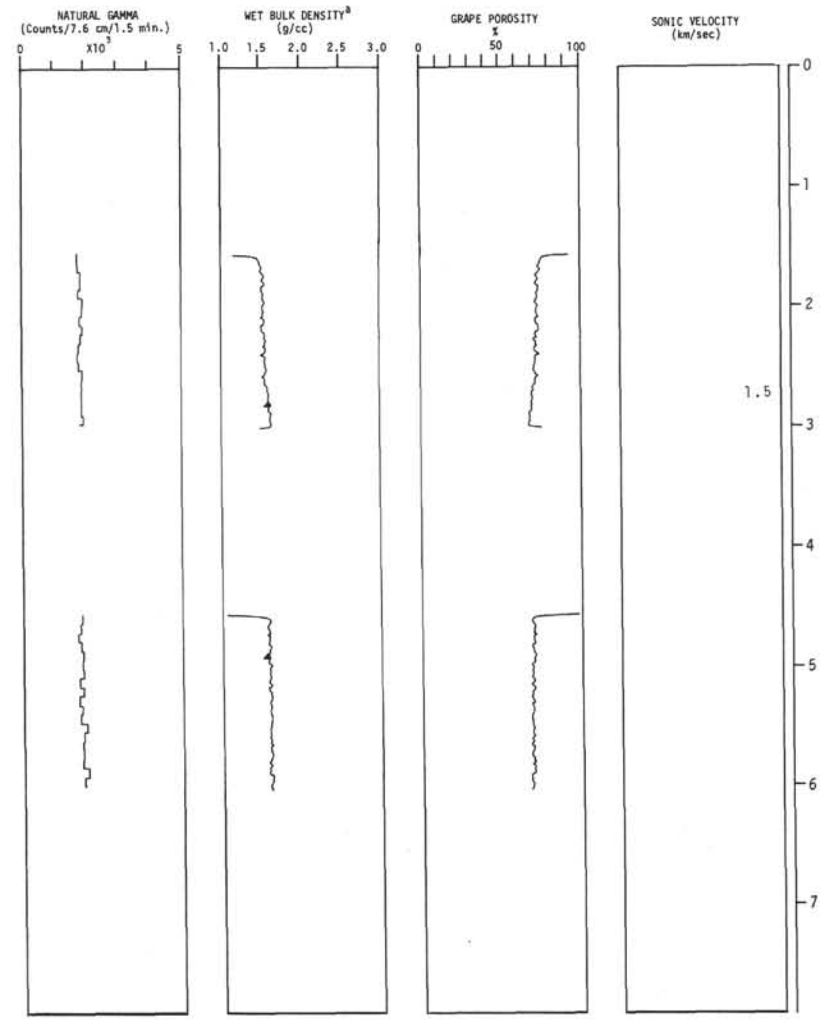
SITE: 158 HOLE: CORE: 23 Cored Interval: 198-207 m



DESCRIPTION

Nannofossil chalk, radiolaria common to abundant, foraminifera and diatoms present; light to medium greenish gray becoming darker down core; moderately mottled yellowish to light olive gray and medium light gray with purplish aureoles around some mottles; toward bottom (section 5), scattered diffusely pale green patches. Pyrite ubiquitous, especially in dark mottles; dark glass, light glass, palagonite and feldspar locally rare.

PHYSICAL PROPERTIES



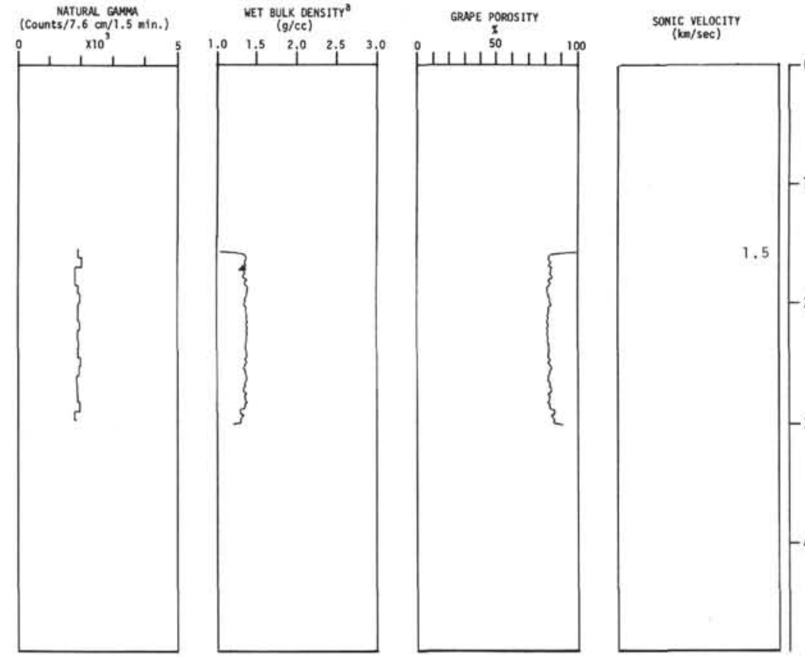
SITE: 158 HOLE: CORE: 24 Cored Interval: 207-216 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
MIDDLE MIOCENE	*Globorotalia menardii*	*Discoaster hamatus*	*Ommatartus antepenultimus*	0–4	1, 2, 3, CC	VOID; chalk		* * * *	* * * * * *	Pyritic glassy nannofossil chalk, radiolaria abundant to common, foraminifera common; diatoms and silicoflagellates present; dominant color moderate olive brown, also olive, becoming lighter down core to grayish dusky yellow green, olive and pale greenish yellow to pale olive; slightly to moderately mottled yellowish to light olive gray. Glass mostly dark, but light glass also present in catcher. Feldspar also present.	F Pd	A M; A M; A M; A M; A ?M	A G

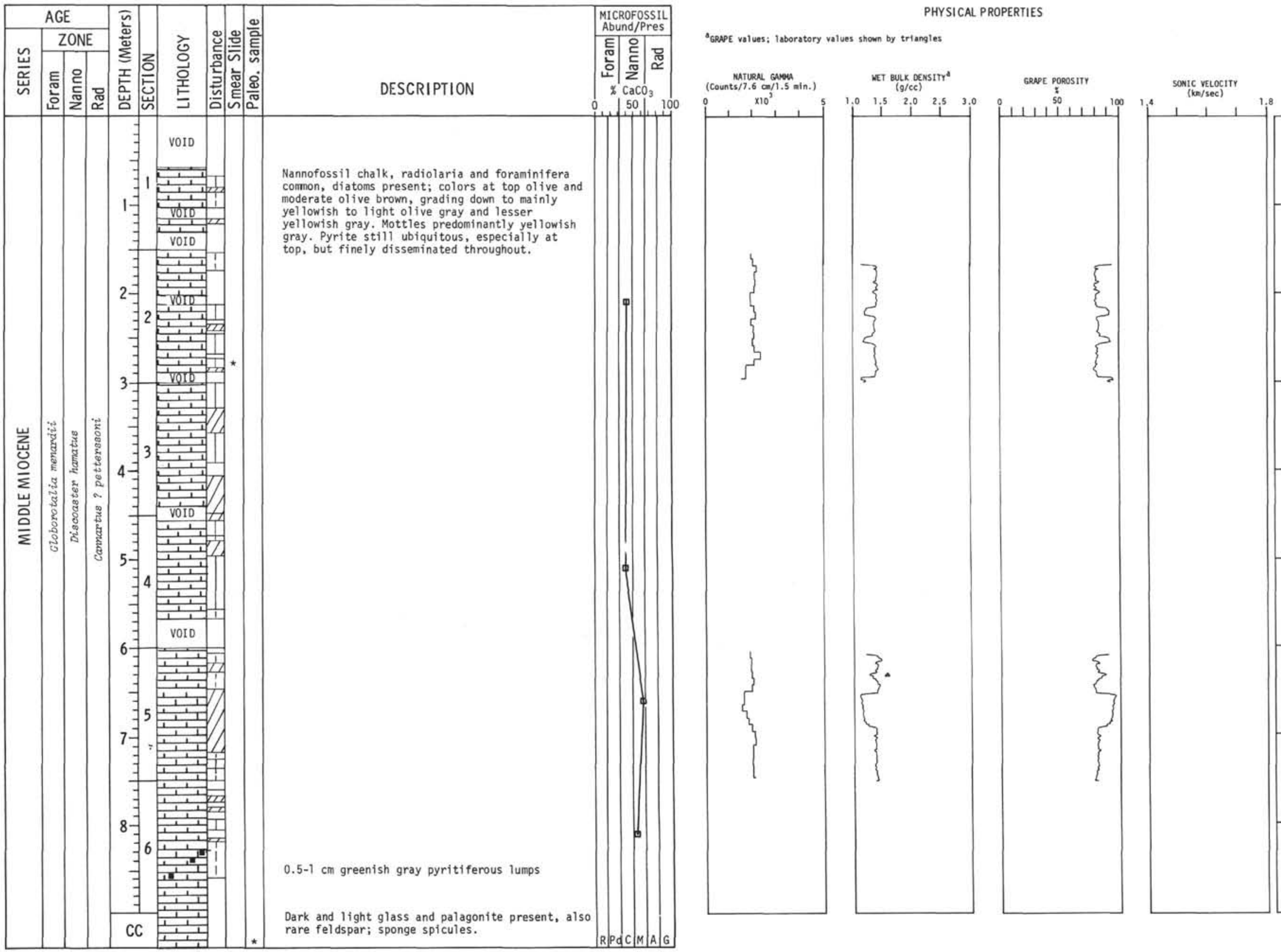
% $CaCO_3$ 0 50 100

PHYSICAL PROPERTIES

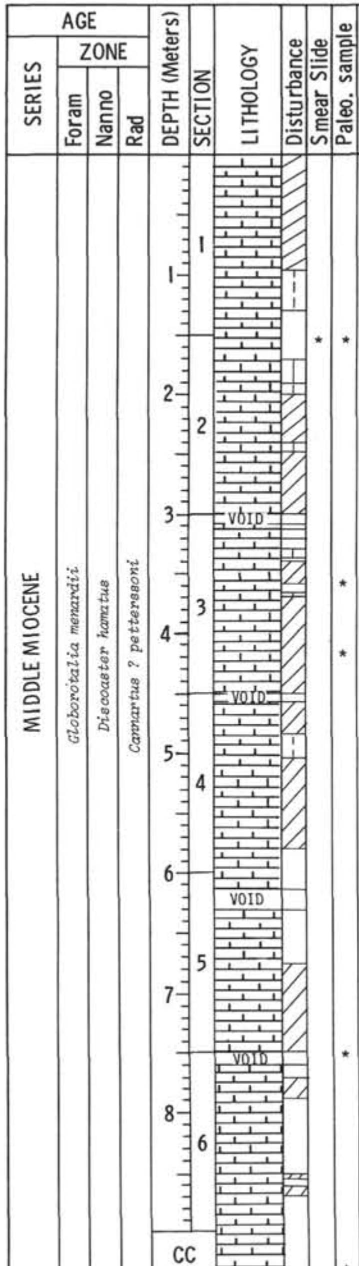
[a]GRAPE values; laboratory values shown by triangles



SITE: 158 HOLE: CORE: 25 Cored Interval: 216-225 m



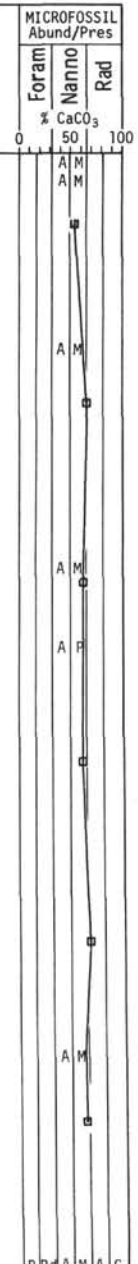
SITE: 158 HOLE: CORE: 26 Cored Interval: 225-234 m



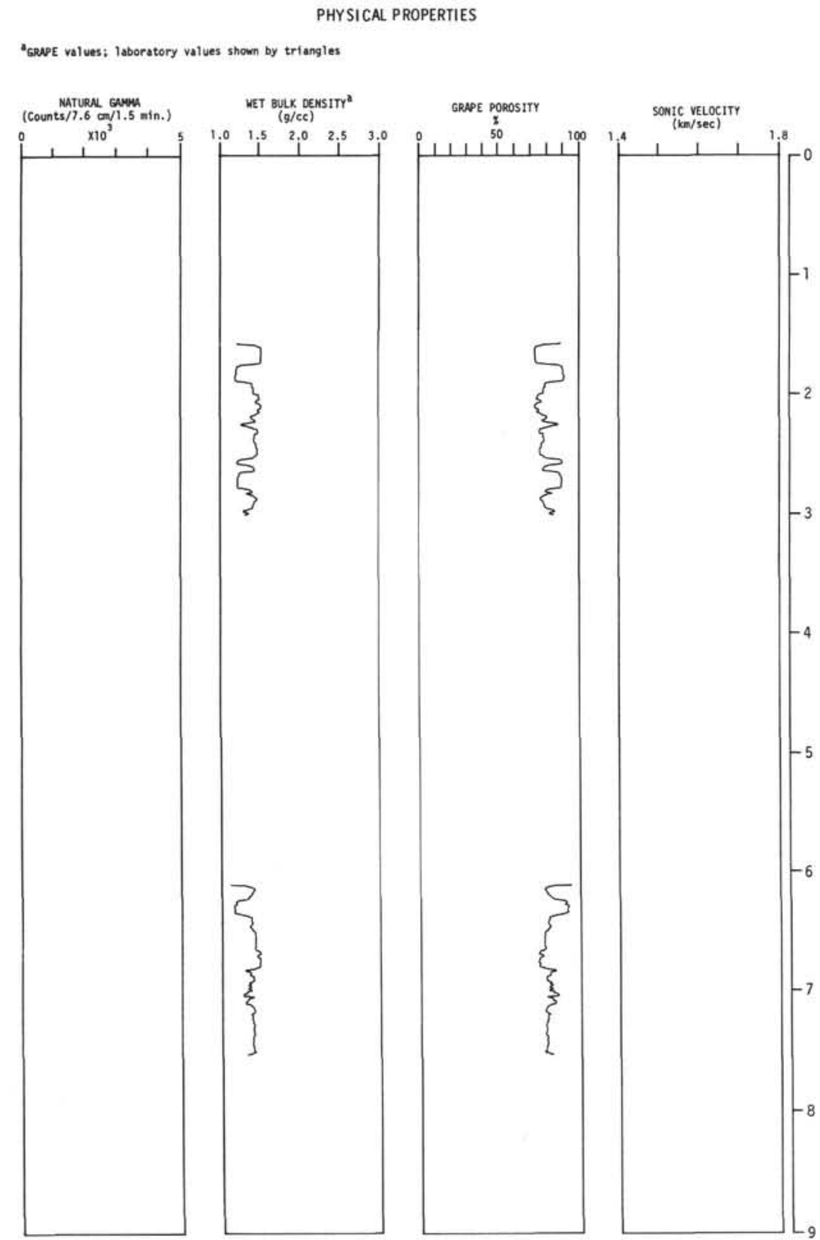
DESCRIPTION

Nannofossil chalk; foraminifera, radiolaria, diatoms and silicoflagellates present; yellowish to light olive gray and lesser yellowish gray and light olive gray; mottled, but degree difficult to evaluate due to disturbance; fine pyrite scattered throughout, dark and light glass present.

Rare feldspar in acid-treated coarse fraction; also sponge spicules.



PHYSICAL PROPERTIES

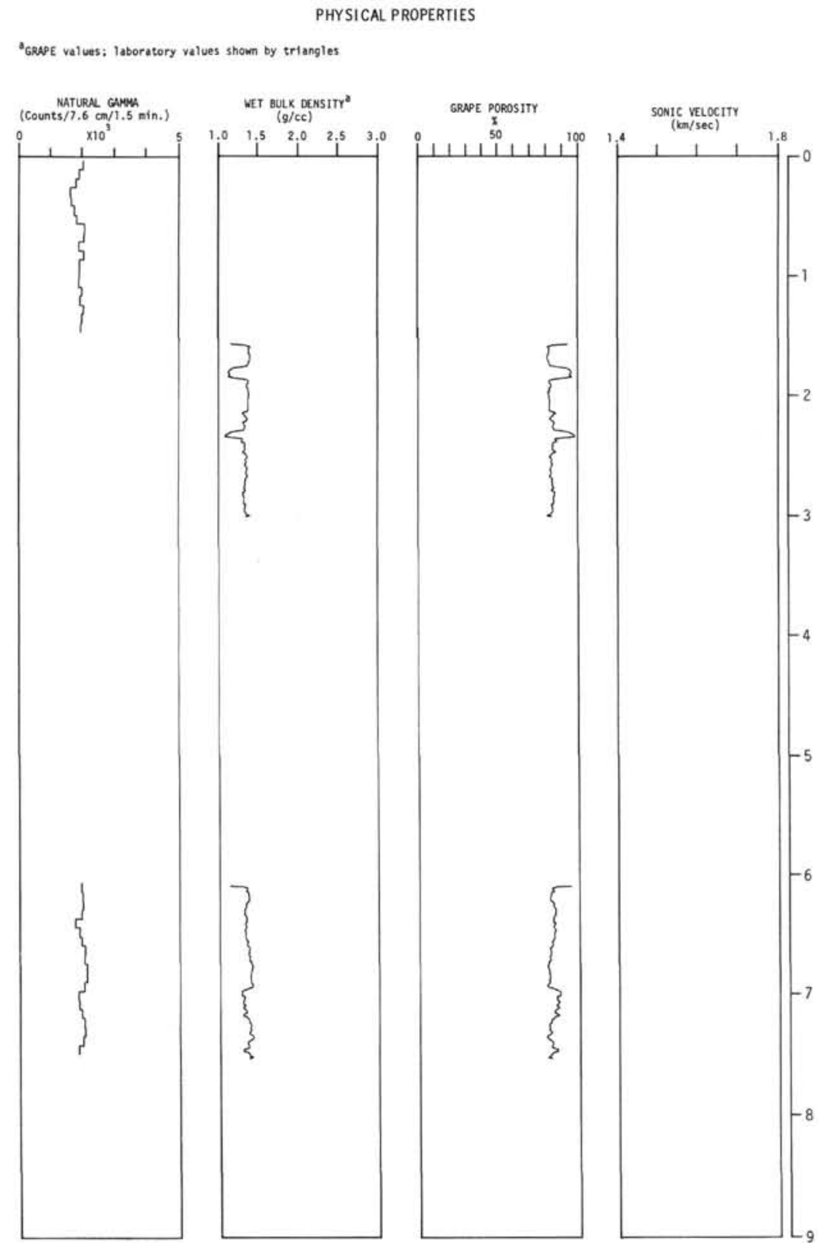


SITE: 158 HOLE: CORE: 27 Cored Interval: 234-243 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	DESCRIPTION	MICROFOSSIL Abund/Pres
MIDDLE MIOCENE	*Globorotalia menardii*	*Discoaster hamatus*	*Cannartus ? pettersoni*	0–1.5	1	VOID	Nannofossil chalk; foraminifera, radiolaria, diatoms and silicoflagellates present; yellowish-to-light-olive gray and lesser yellowish gray and light olive gray mottles; degree of mottling difficult to evaluate due to disturbance; pyrite ubiquitous (finely disseminated); dark glass, palagonite and feldspar rare.	A M; A M
				1.5–3	2			
				3–4.5	3			A M
				4.5–6	4			
				6–7.5	5			
				7.5–9	6			A M
					CC		Rare feldspar in acid-treated coarse fractions; sponge spicules present.	R Pd ? ? C G

Microfossil columns: Foram, Nanno, Rad; % $CaCO_3$ (0, 50, 100)

PHYSICAL PROPERTIES



SITE: 158 HOLE: CORE: 28 Cored Interval: 243-252 m

SERIES	AGE: ZONE Foram	Nanno	Rad	DEPTH (Meters)	SECTION	DESCRIPTION	MICROFOSSIL Abund/Pres
MIDDLE MIOCENE	*Globorotalia mayeri*	*Discoaster hamatus*	*Cannartus ? pettersoni*	0–1.5	1	Nannofossil chalk, radiolaria common to present, foraminifera and diatoms present; dominant color grading down core from light greenish gray to medium greenish gray to grayish yellow green to light olive gray and yellowish gray; variously mottled grayish green and pale yellow green.	A M; A P
		Catinaster coalitus		1.5–3	2	Dark and light glass, palagonite and rare feldspar present. Fine pyrite ubiquitous. Rubbly 5 cm thick green bed	A M
				3–4.5	3		A M
				4.5–6	4	Green layers and mottles up to 5 cm thick present. 2 cm thick pale to grayish green mottle.	A M
		Discoaster exilis		6–7.5	5		A M
				7.5–9	6		A Pd
					CC	Light glass common, dark glass and feldspar present in acid-treated coarse fractions.	

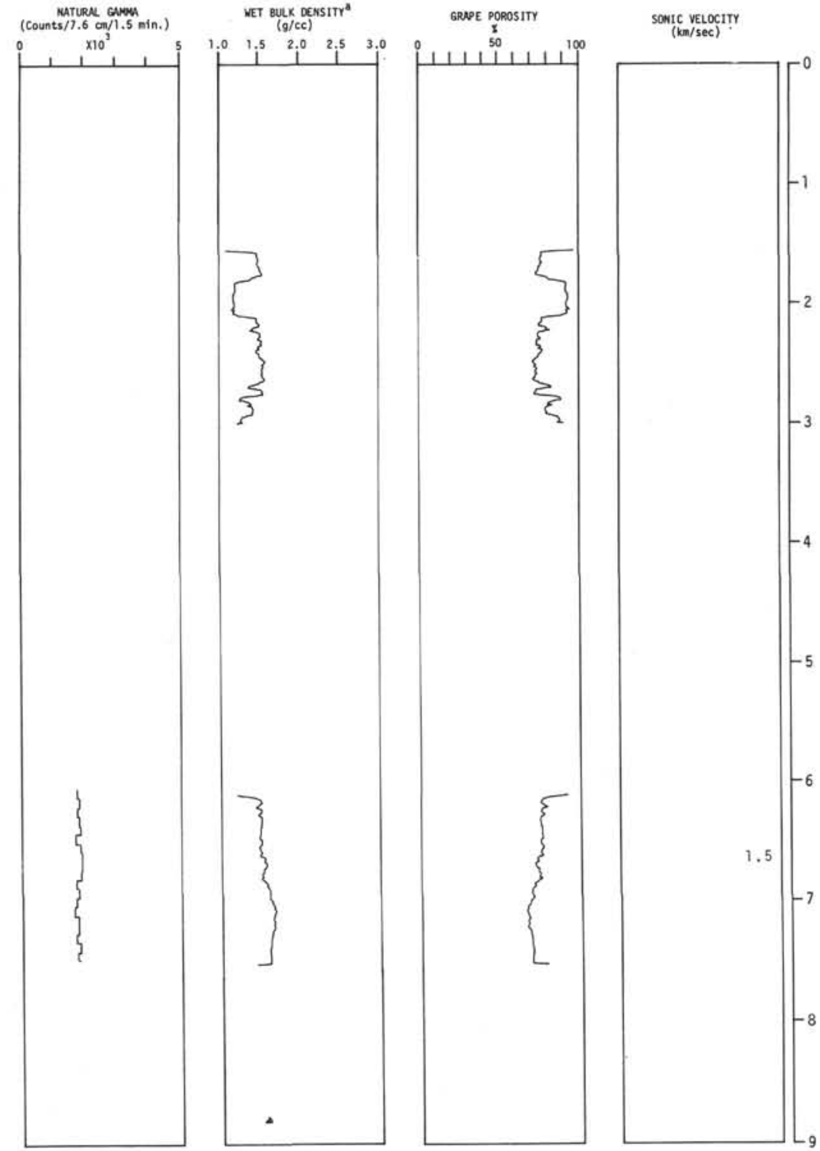
VOID intervals in sections 1, 2, 3 and 4.

% $CaCO_3$: 0, 50, 100

F P A M A G

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles

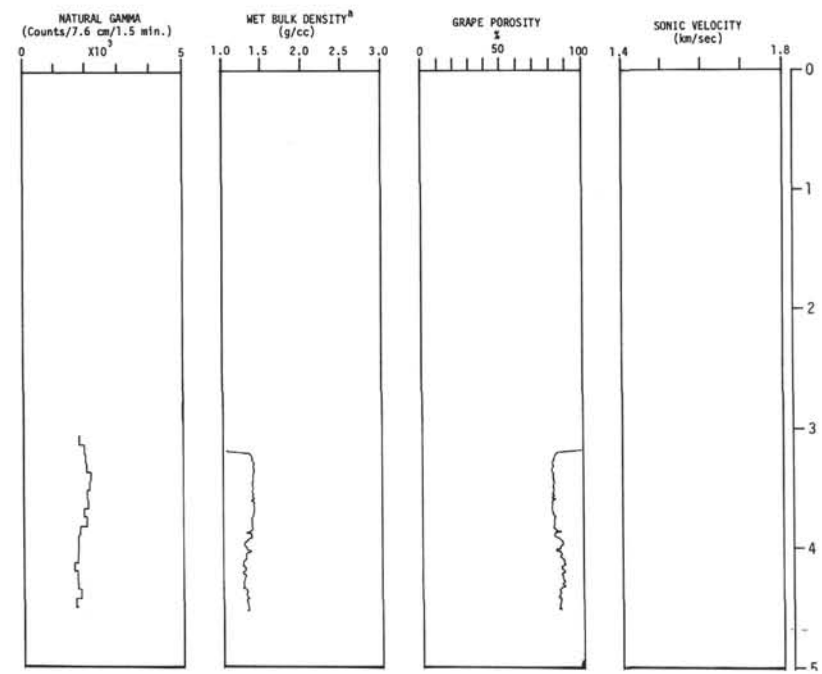


SITE: 158 HOLE: CORE: 29 Cored Interval: 252-261 m

SERIES	AGE ZONE: Foram	AGE ZONE: Nanno	AGE ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram / Nanno / Rad; % $CaCO_3$ (0, 50, 100)
MIDDLE MIOCENE	*Globorotalia mayeri*	*Discoaster exilis*	*Cannartus ? pettersoni*	0–4	1, 2, 3	VOID; VOID		*		Nannofossil chalk, foraminifera, radiolaria and diatoms present, yellowish to light olive gray, few yellowish gray mottles; finely disseminated pyrite ubiquitous, palagonite present. Homogenized "ooze" or badly shattered but obviously formerly well indurated.	
					CC				*	Only radiolaria and diatoms (present) found in acid residues of coarse fractions.	F M C M F M

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles

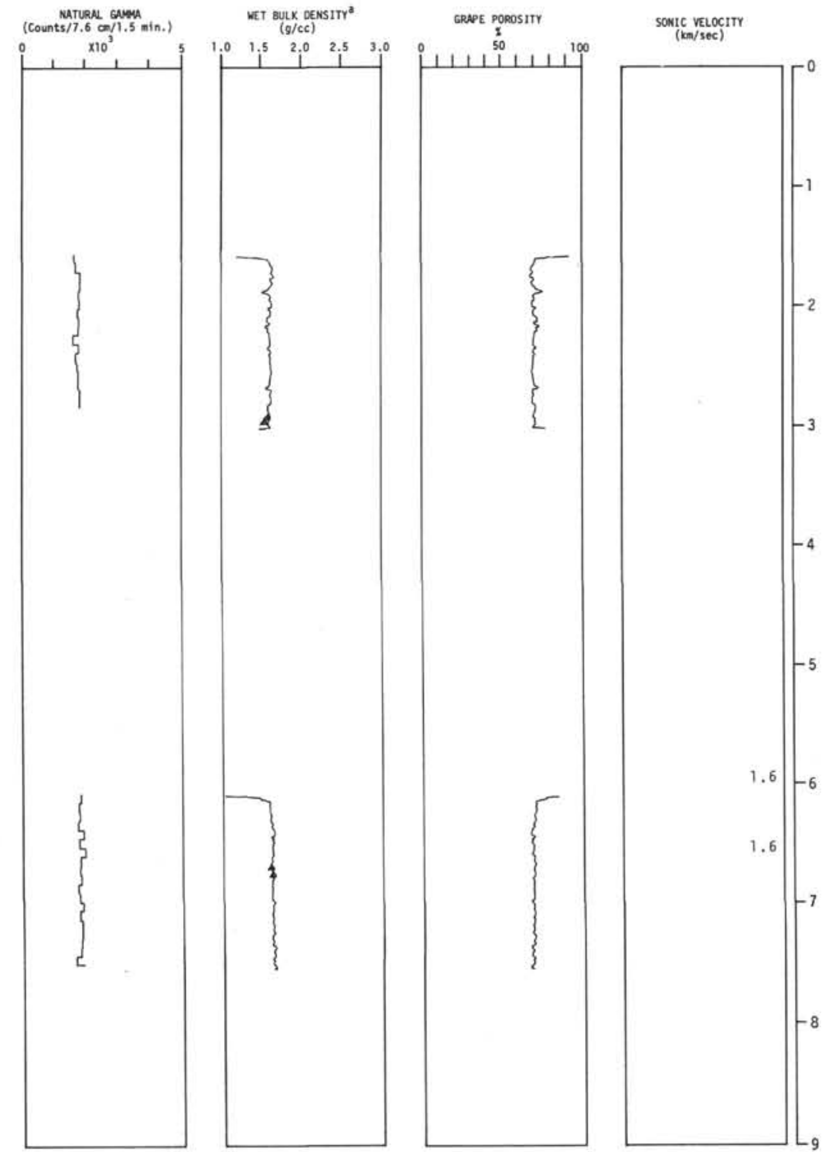


SITE: 158 HOLE: CORE: 30 Cored Interval: 261-270 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres (Foram, Nanno, Rad); % $CaCO_3$
MIDDLE MIOCENE	*Globorotalia mayeri*	*Discoaster exilis*	*Cannartus ? pettersoni*	0–1.5	1			* *	*	Nannofossil chalk, foraminifera, radiolaria and diatoms present; yellowish gray, medium light gray mottles increasing down core to abundant in lower half; also scattered grayish yellow green mottles. Pyrite (fine) ubiquitous; dark glass and palagonite present.	A M
				1.5–3	2						
				3–4.5	3						
				4.5–6	4					2 cm black pyritic lump	
				6–7.5	5						
				7.5–9	6					0.8 cm coherent pyrite nodule	
					CC				*	Dark glass, palagonite and glauconite present.	A P C A G

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



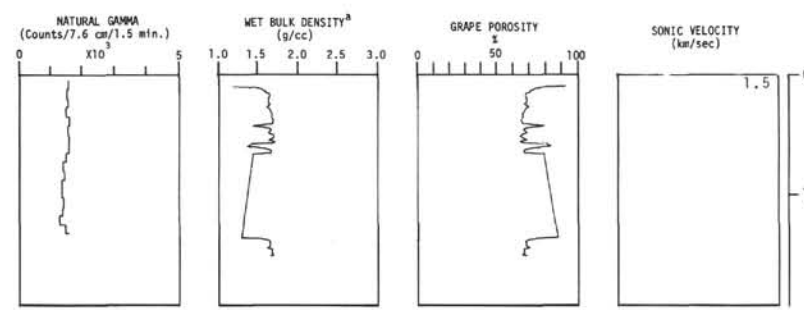
SITE: 158 HOLE: CORE: 31 Cored Interval: 270-279 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
MIDDLE MIOCENE	*Globorotalia mayeri*	*Discoaster exilis*	*Cannartus ? pettersoni*	1	1	VOID		*	*	Nannofossil chalk, foraminifera, radiolaria and diatoms present, also silicoflagellates; yellowish gray; pyritic medium light gray mottles; also scattered yellowish to light olive gray mottles. Dark and light glass, palagonite and feldspar present.		A P	
					CC				*	Feldspar, palagonite, dark glass and glauconite present in acid residue.	C G	A M	A G

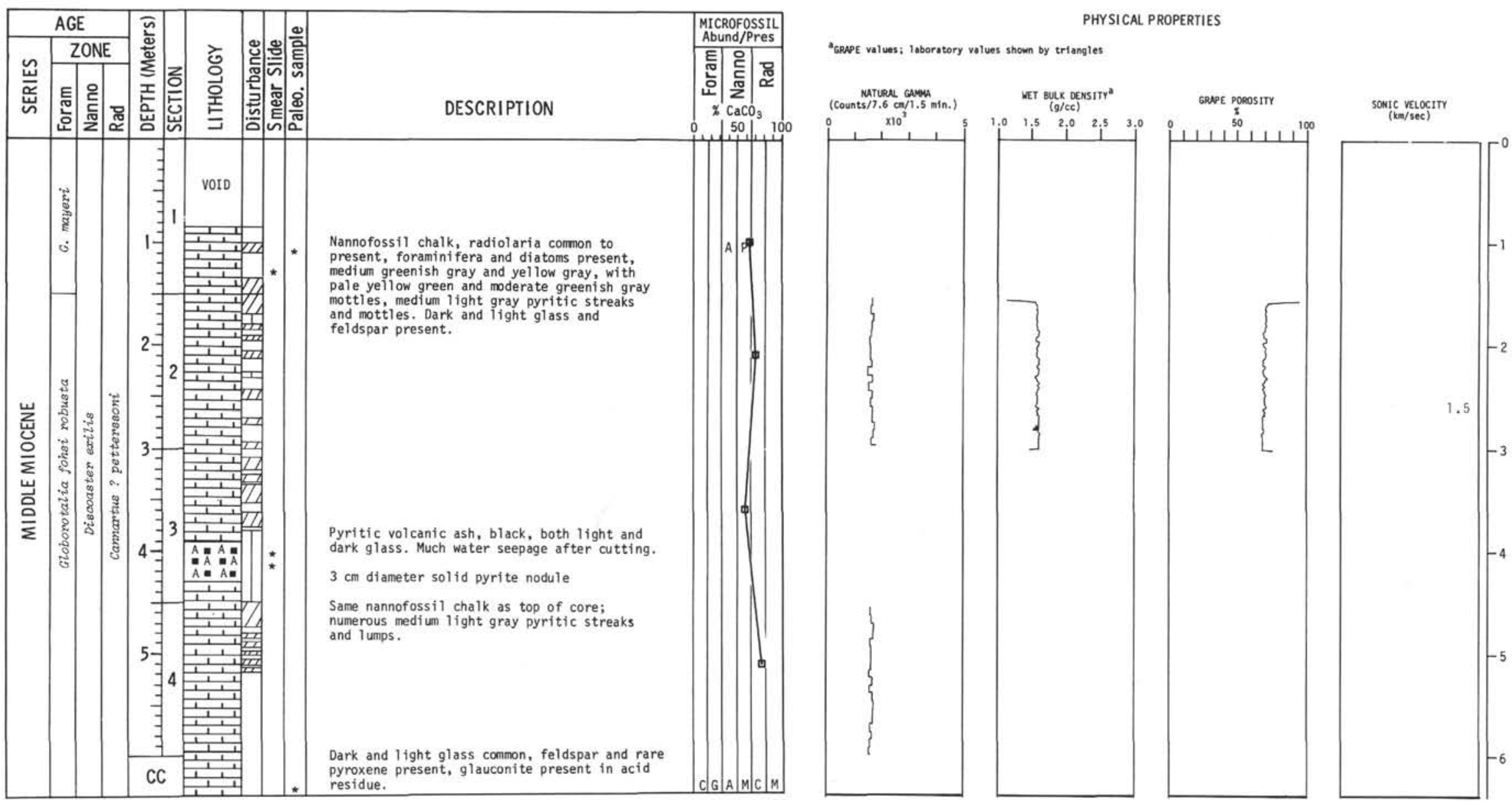
% $CaCO_3$: 0, 50, 100

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



SITE: 158 HOLE: CORE: 32 Cored Interval: 279-287 m



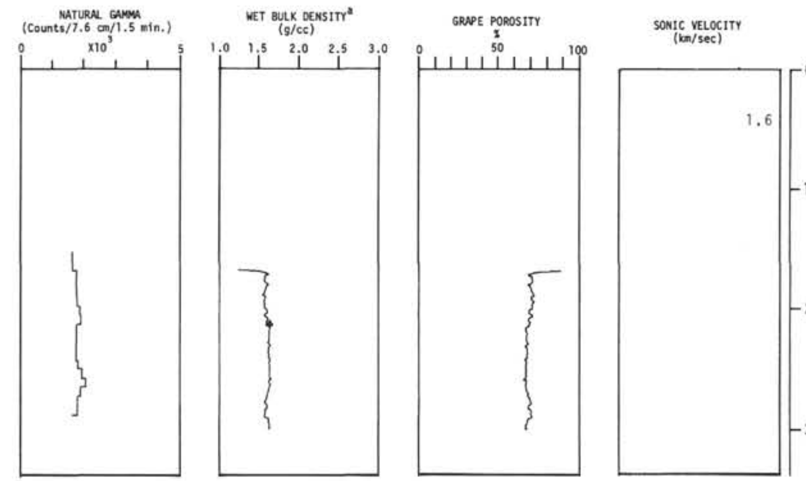
SITE: 158 HOLE: CORE: 33 Cored Interval: 287-296 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
MIDDLE MIOCENE	*Globorotalia fohsi robusta*	*Discoaster exilis*	*Cannartus laticonus*	1, 2	1, 2	VOID	Nannofossil chalk, foraminifera, radiolaria, diatoms and silicoflagellates present, grayish to dusky yellow green; yellowish to light olive gray and medium grayish green mottles; distinctly better indurated than previous cores. White nannofossil chalk 4 cm thick; few pale green mottles. Ubiquitous fine pyrite.	A	M	
					CC		Dark glass, palagonite, glauconite present in acid residues. Also rare feldspar and pyroxene.	A	M	A G

% $CaCO_3$: 0 50 100

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



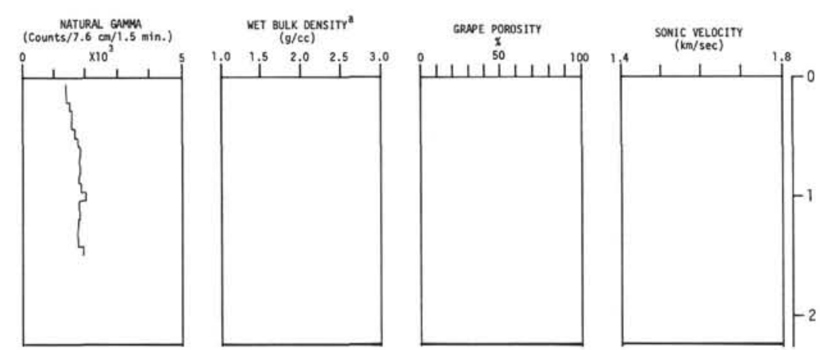
SITE: 158 HOLE: CORE: 34 Cored Interval: 296-305 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
MIDDLE MIOCENE	*G. fohsi robusta*	*Discoaster exilis*	*Cannartus laticonus*	1	1	VOID	Nannofossil chalk; foraminifera, radiolaria and diatoms present, mostly homogenized, but small undisturbed pieces are greenish to dusky yellow green with yellowish to light olive gray mottles. Fine pyrite is present in smear slide. 4 cm fragment of chert, yellowish to light olive gray, with yellowish gray mottle.	A	M	C G
					CC		Same chalk and chert. Palagonite and glauconite common, dark glass, feldspar and pyroxene present.	A	P	F M

% $CaCO_3$: 0 50 100

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



SITE: 158 HOLE: CORE: 35 Cored Interval: 305-314 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
MIDDLE MIOCENE	*G. fohsi robusta*	*Discoaster exilis*	*Cannartus laticonus*		CC				*	Catcher sample only. Siliceous limestone and chalcedonic chert; limestone light olive gray and olive gray, thinly bedded. Chert olive black, chalcedonic. Limestone is nannofossiliferous micrite with few forams.			

% $CaCO_3$: 0, 50, 100

C G A Pc F M

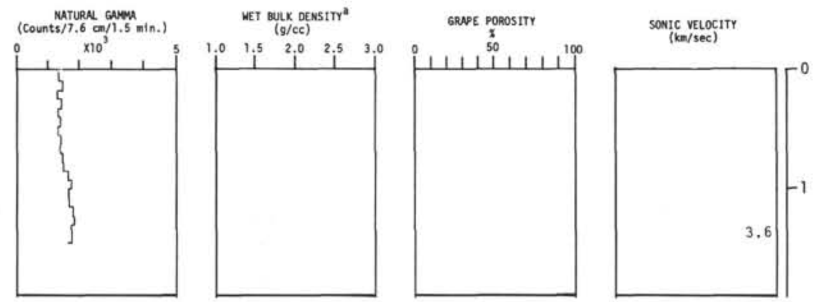
SITE: 158 HOLE: CORE: 36 Cored Interval: 314-323 m

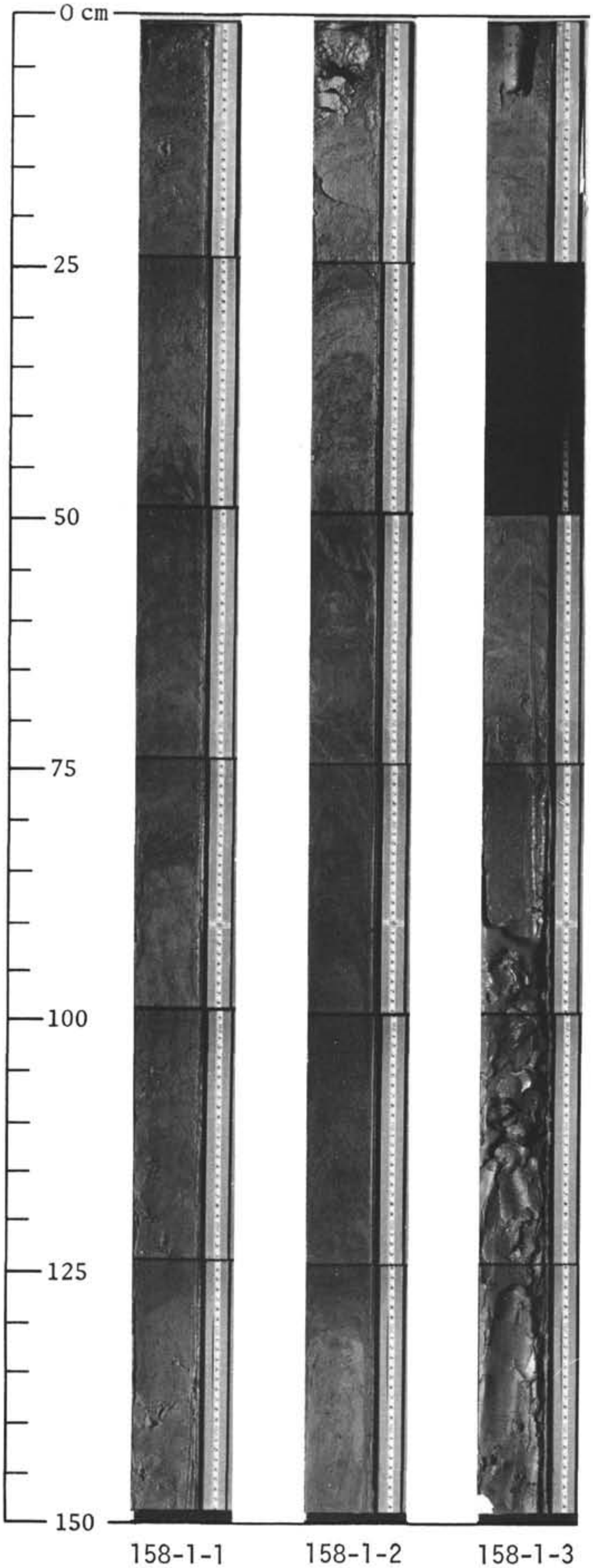
AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide *	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
MIDDLE MIOCENE	*G. fohsi robusta*	*Discoaster exilis*	*Cannartus laticonus*	1	1	VOID			* * * *	Chalk, grayish green, with medium olive gray mottling separate 2-8 cm fragments. At 98 to 103, piece of chalk has Basal 0.5 cm thickness of chert, dusky yellow green. At 122, 2 2 cm fragments of mottly chert, medium and dusky yellow green. 145 to 150, Basalt, aphanitic, equigranular, bottom surface of 1 piece lined with crystalline calcite. Augite Basalt.	A A A	Pc P M	R Pd
					CC					Same chloritized or serpentinized Augite basalt.			

% $CaCO_3$: 0, 50, 100

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles

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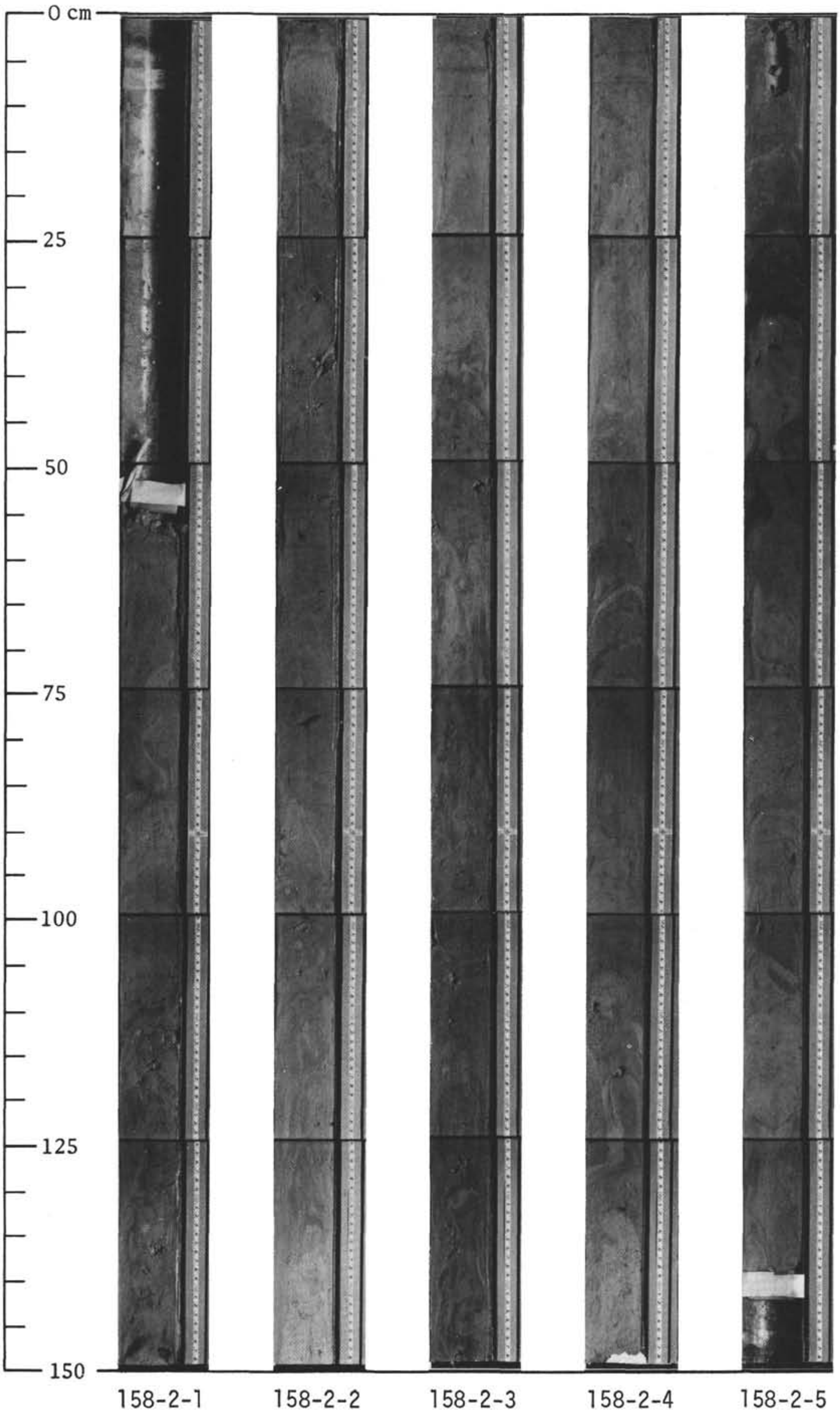
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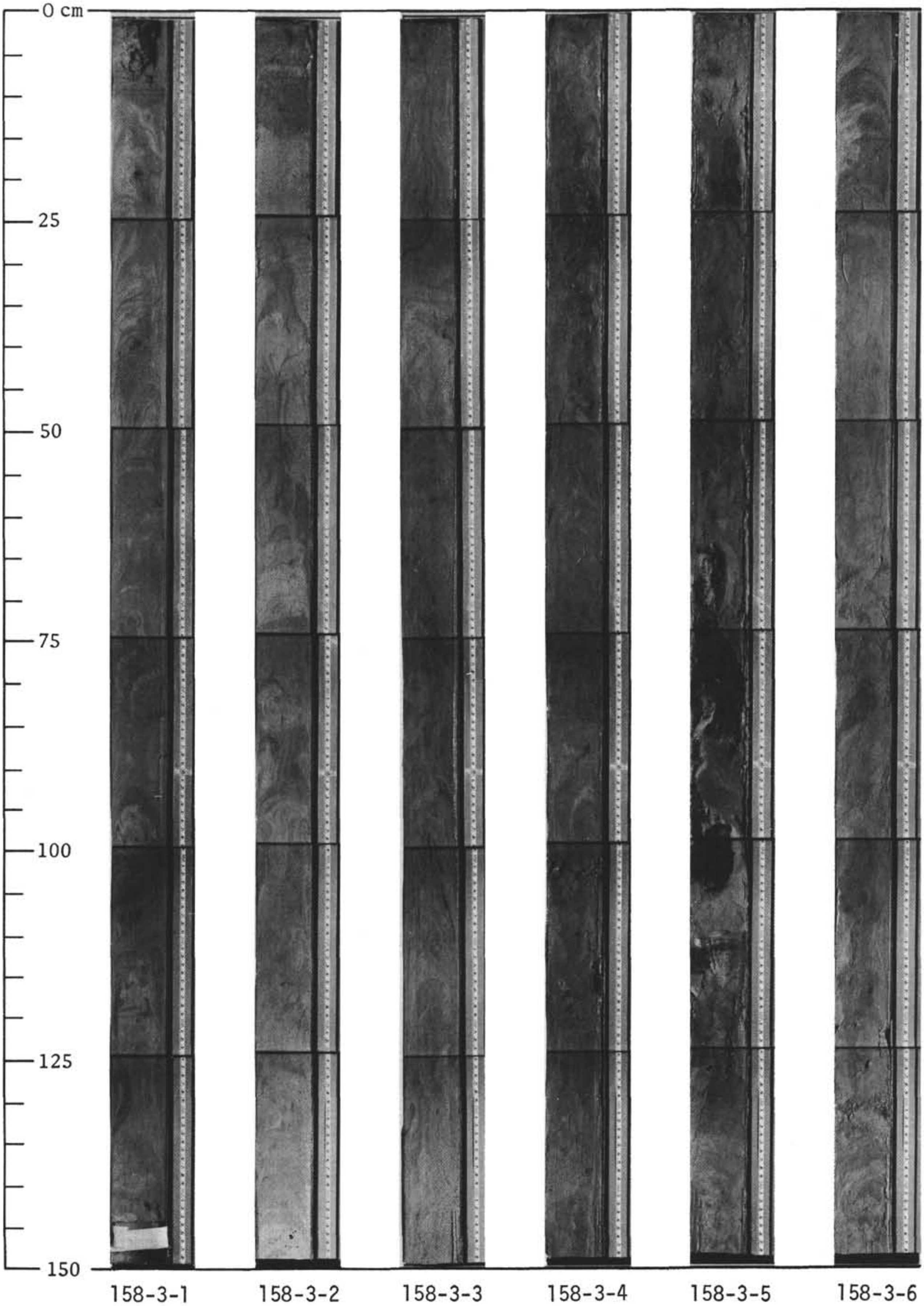
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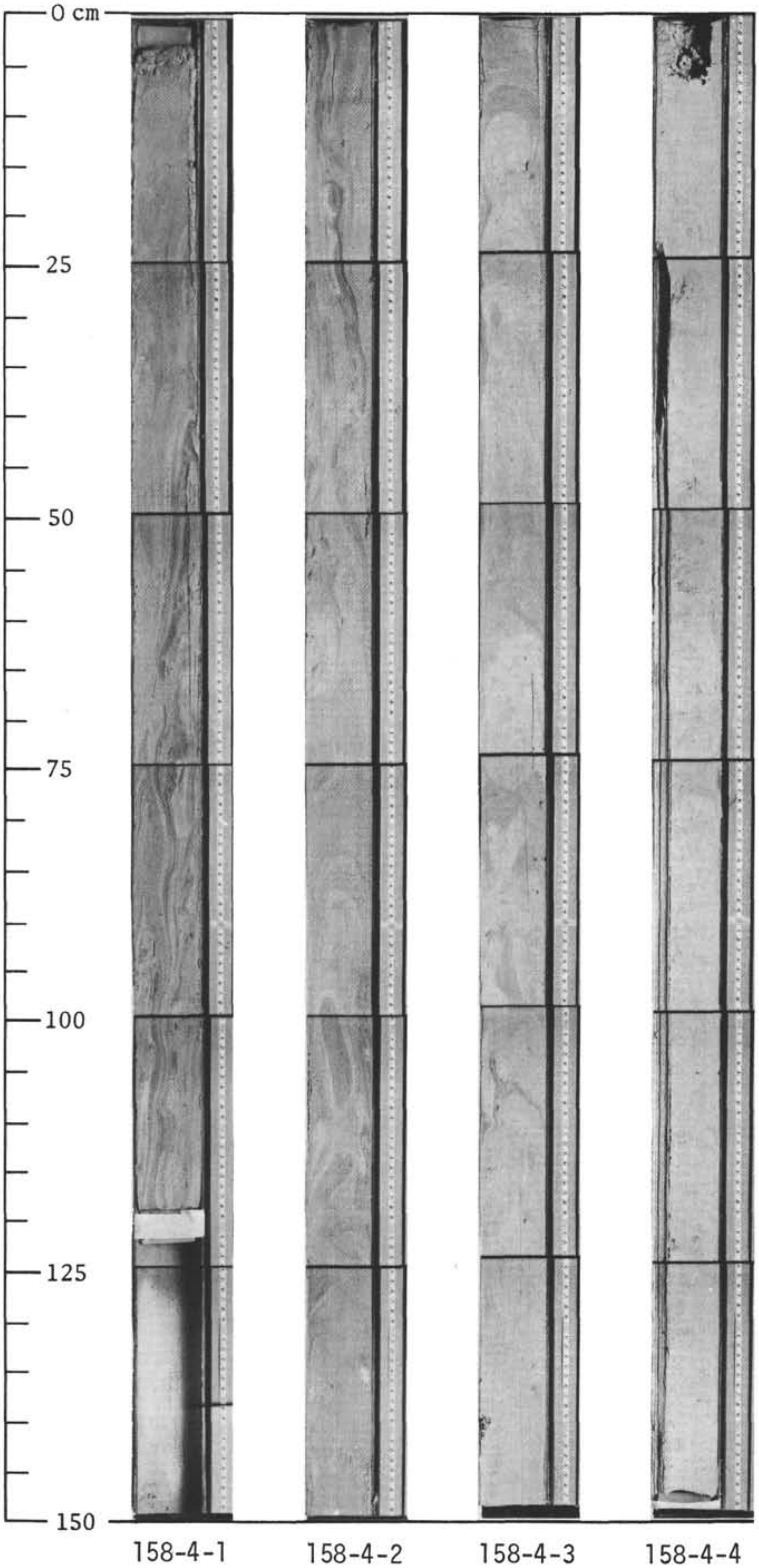
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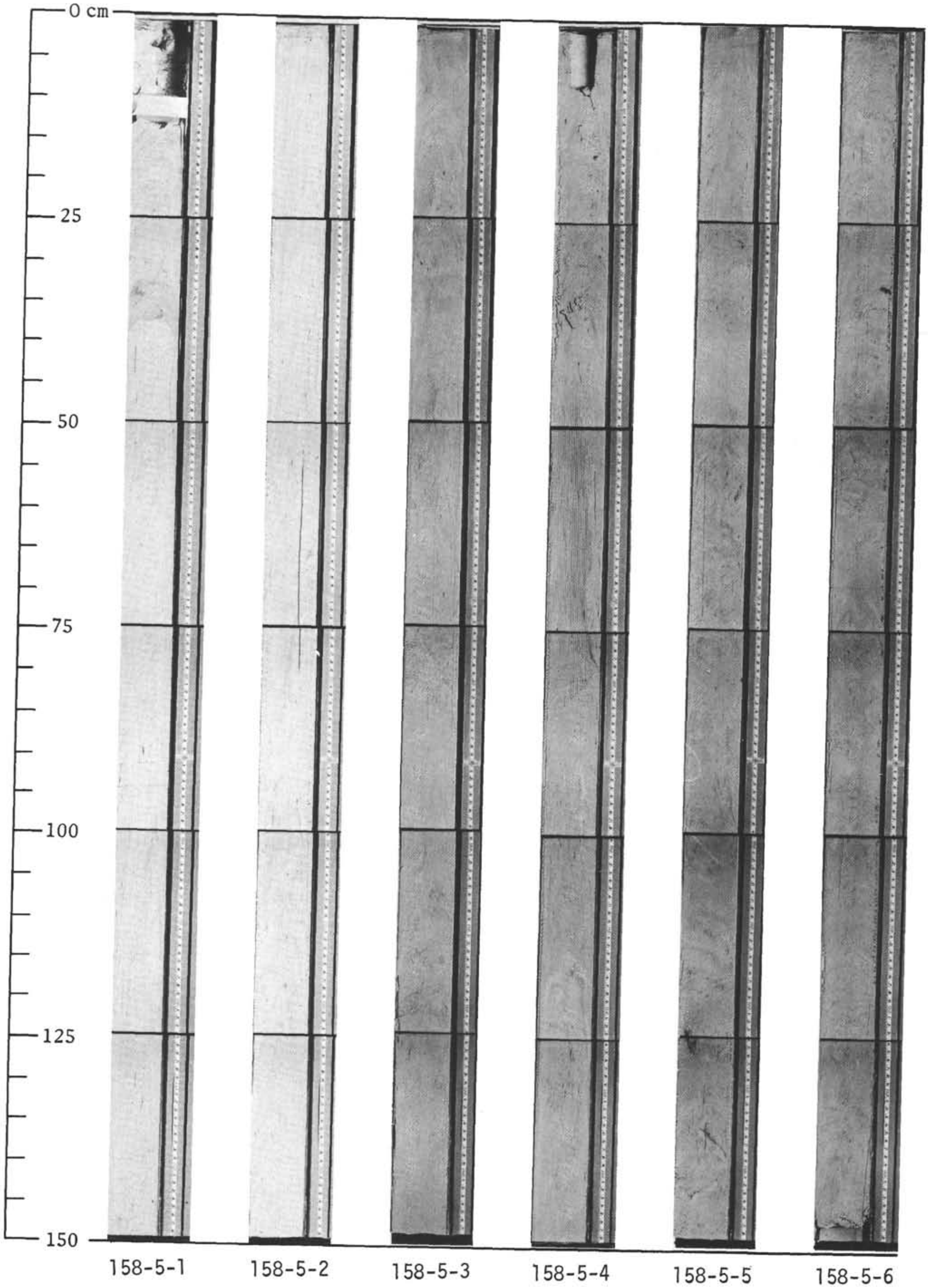
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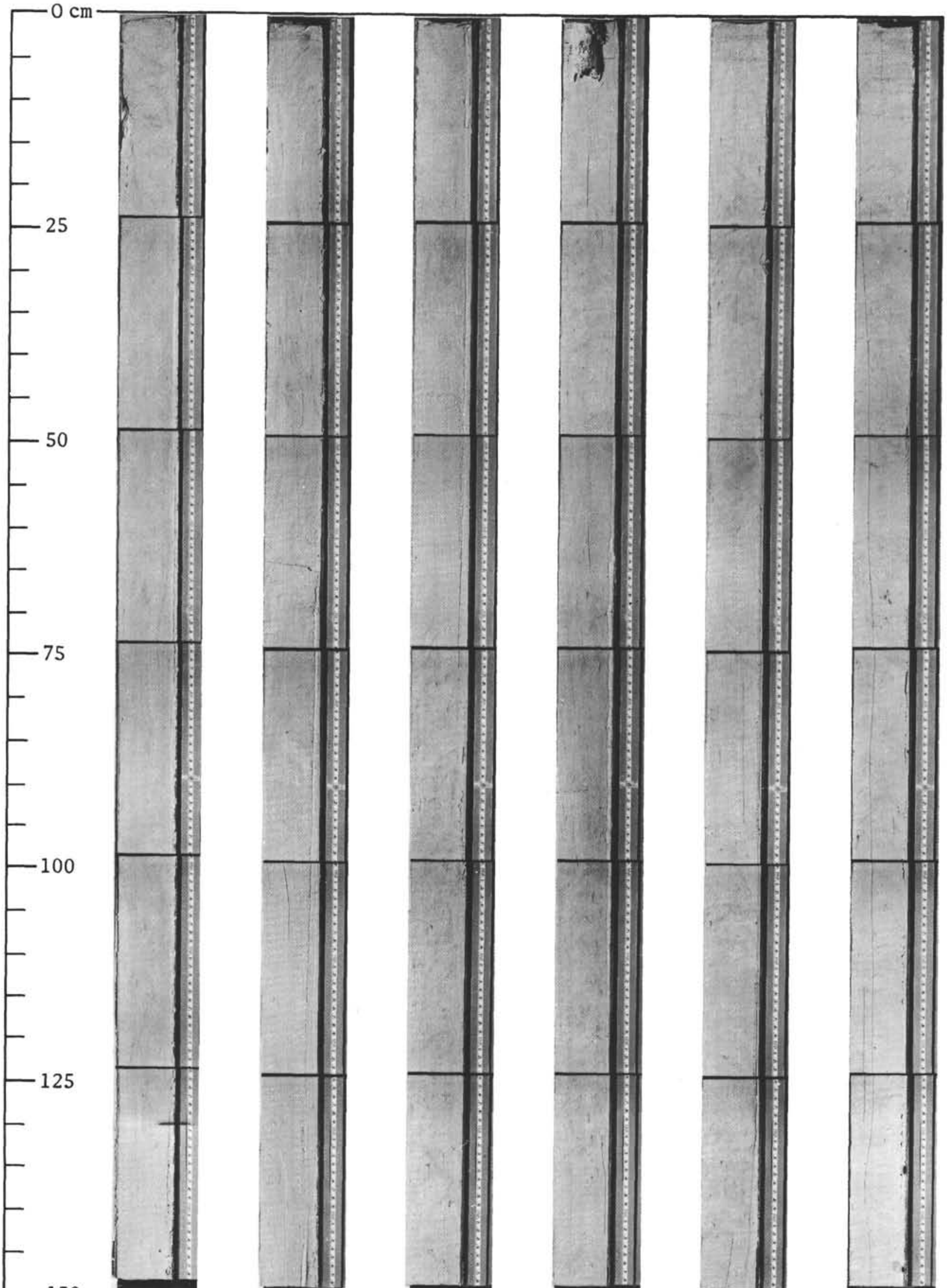

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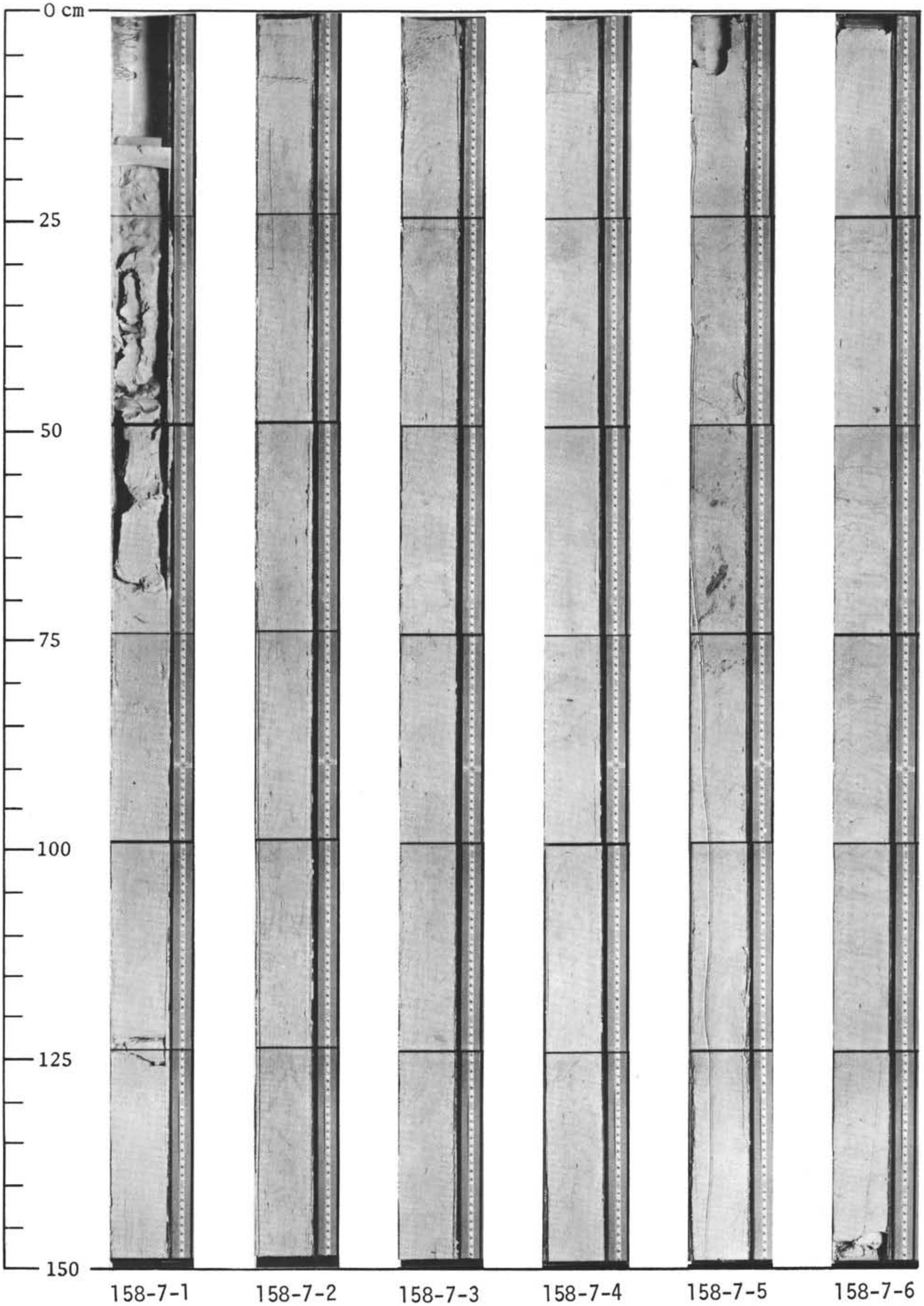
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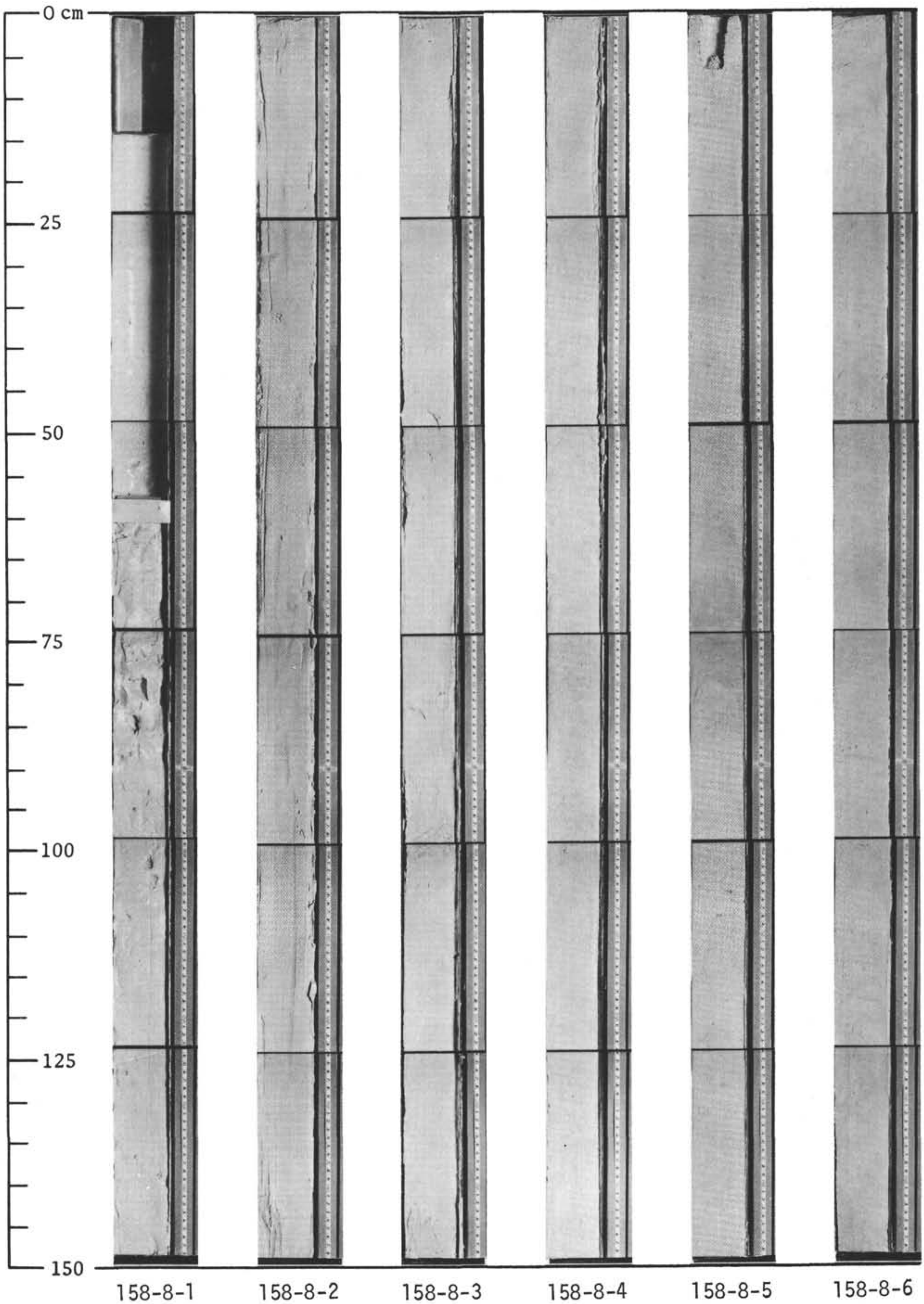
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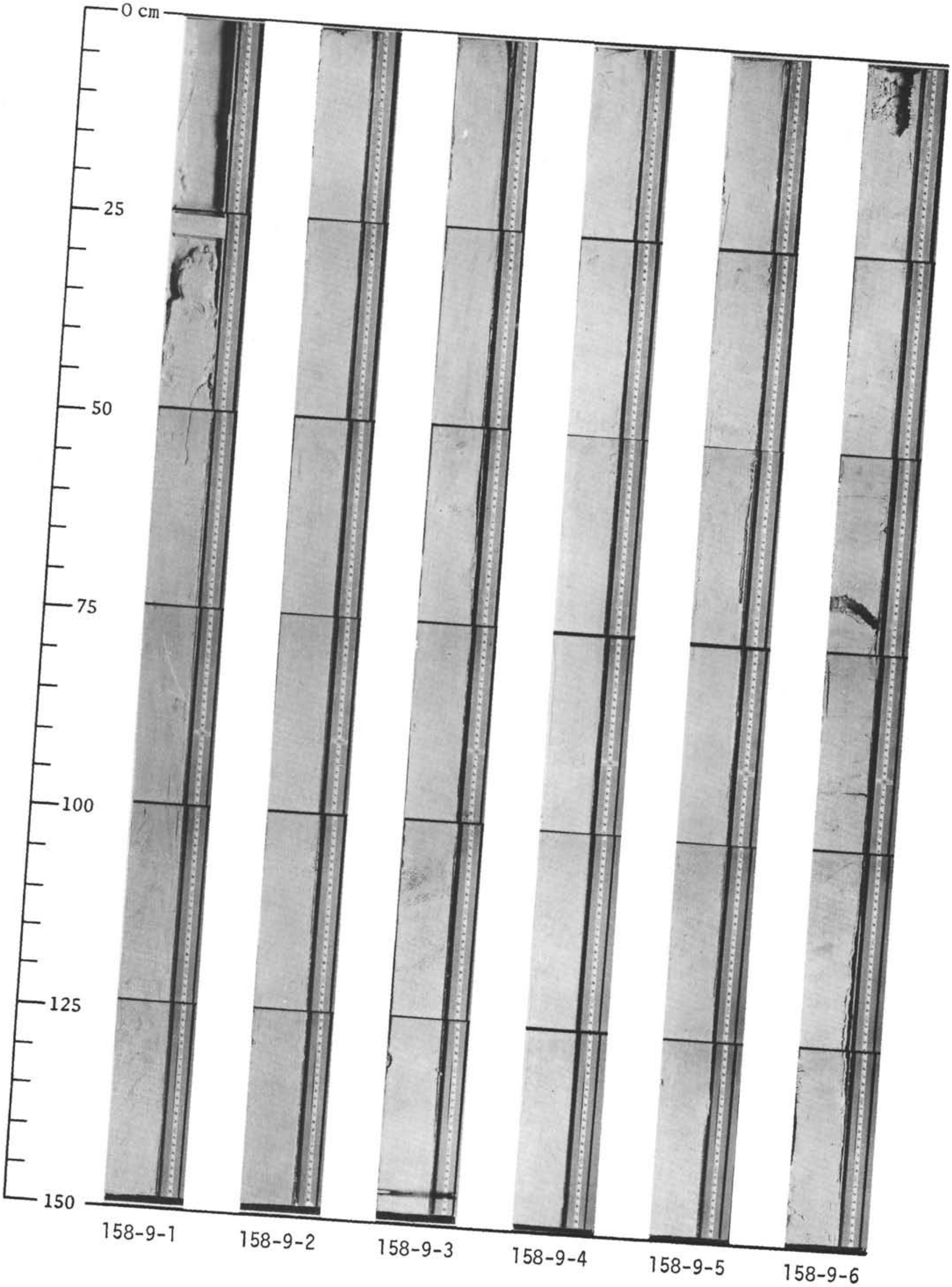
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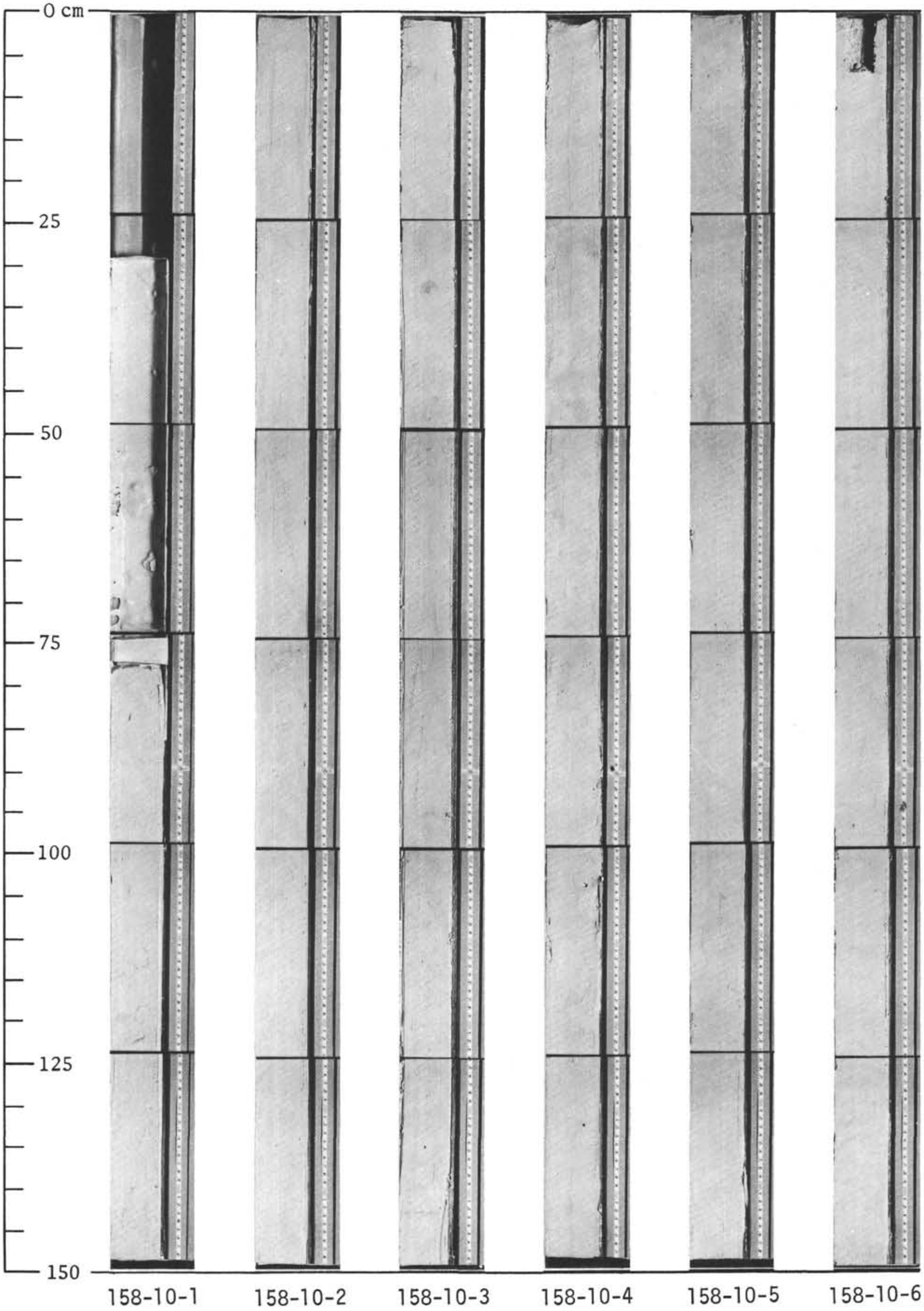
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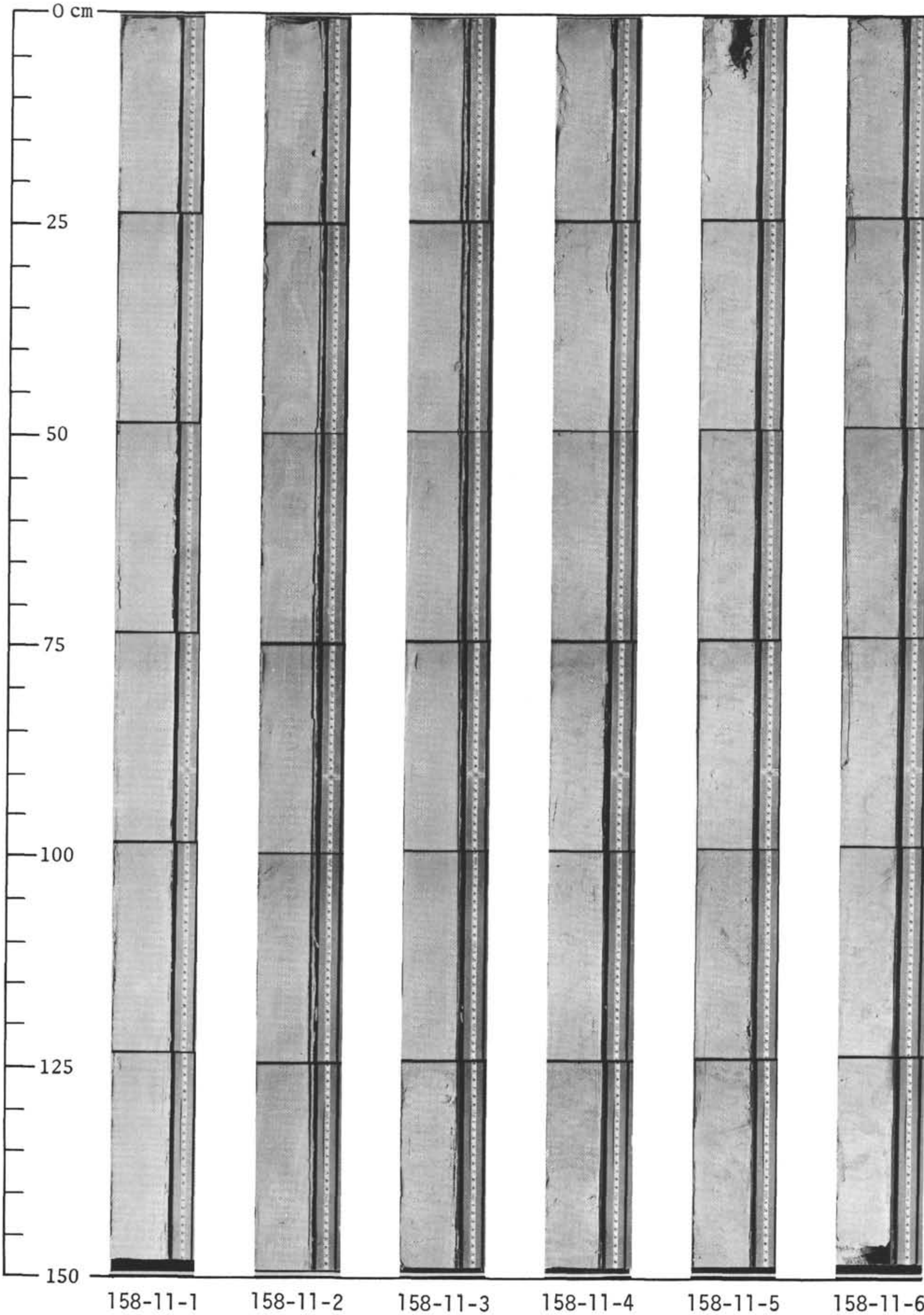
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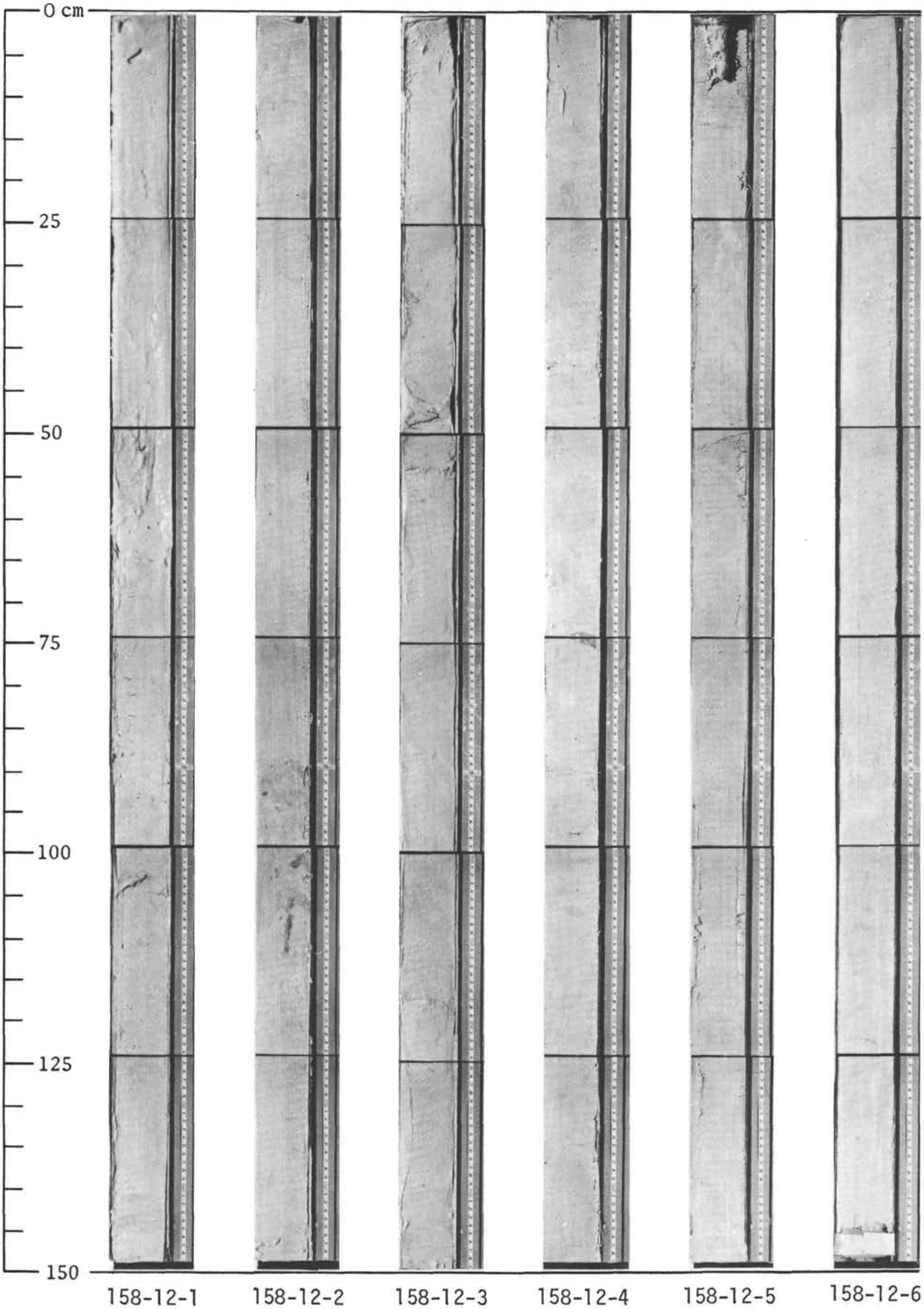
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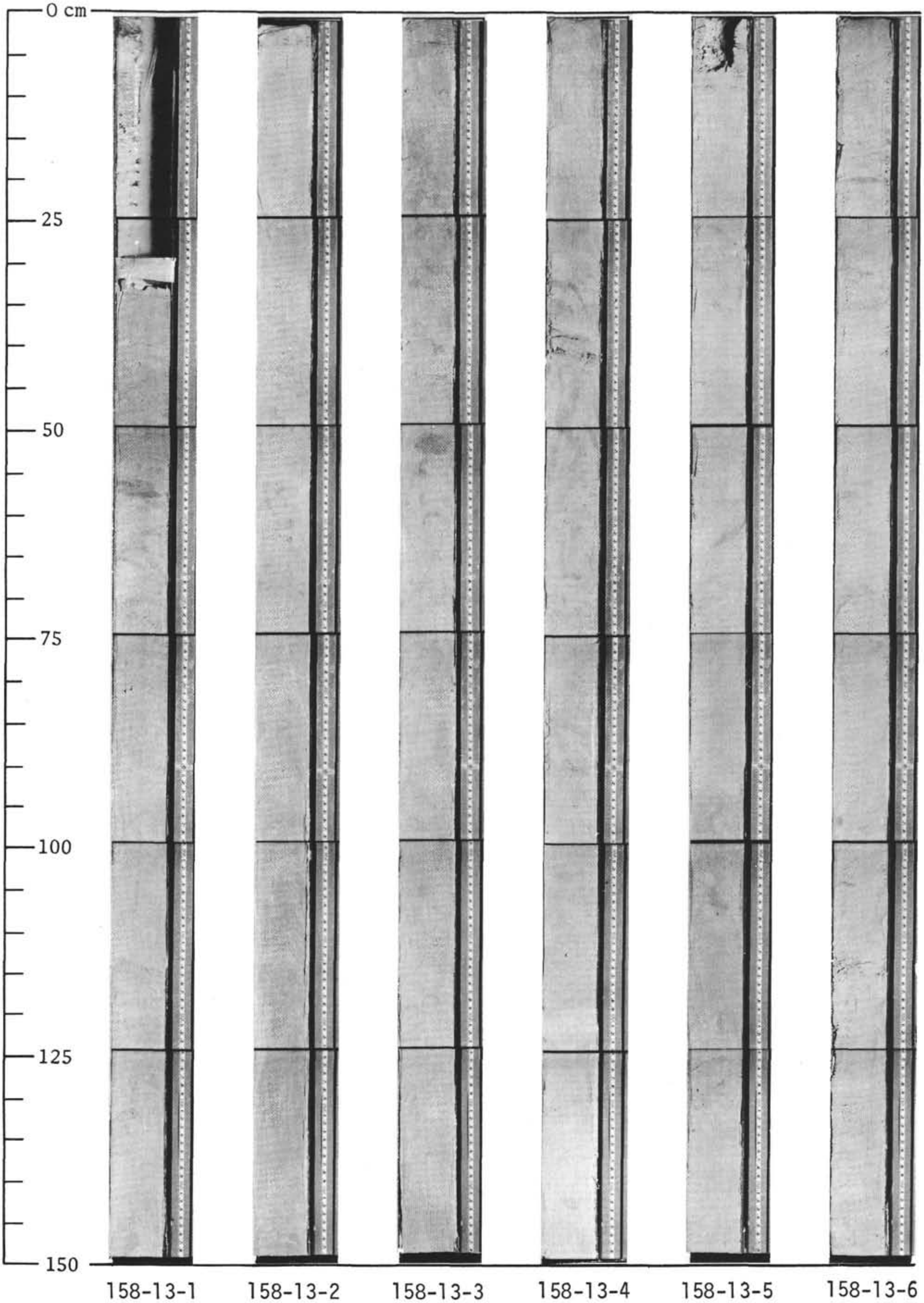
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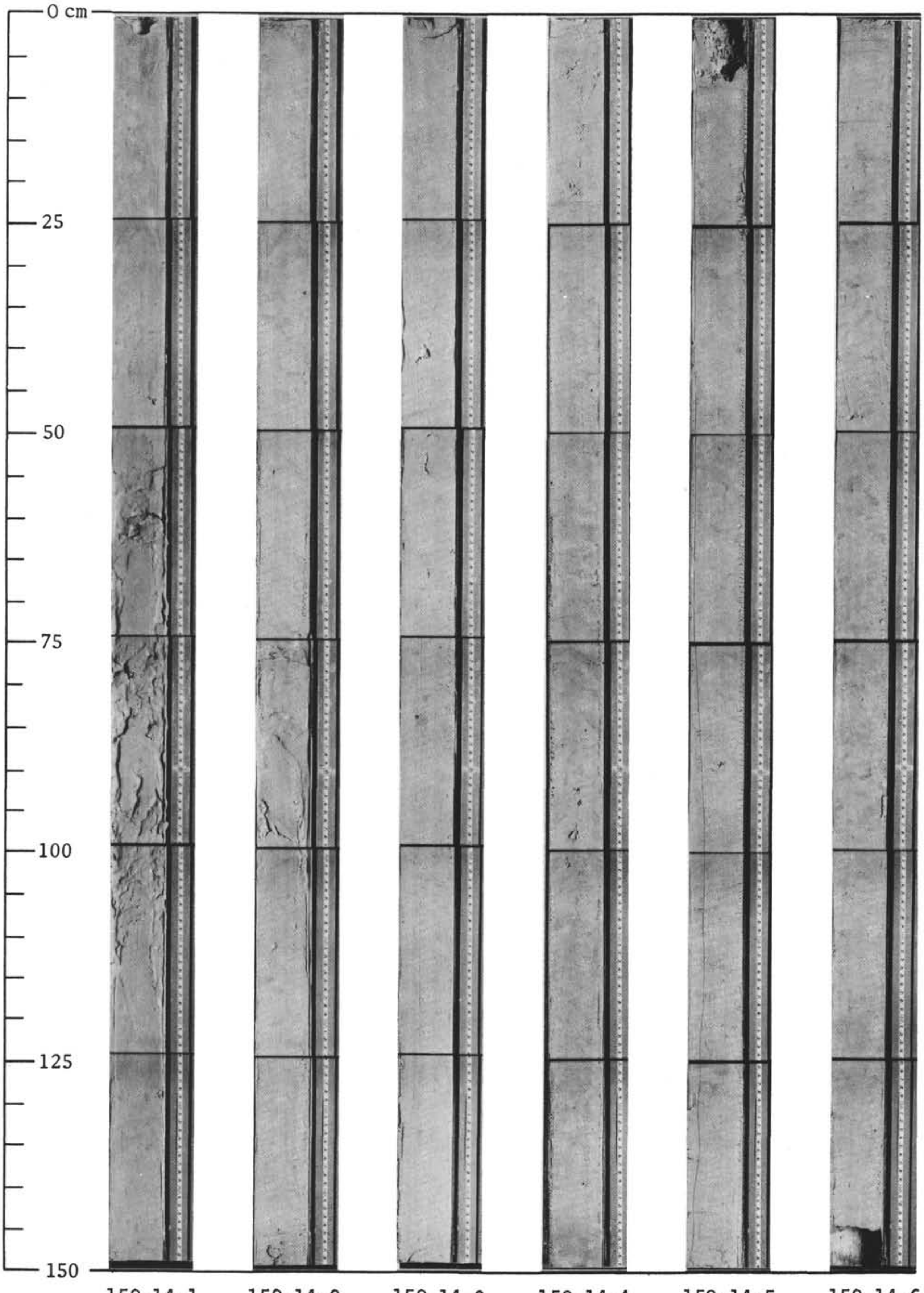
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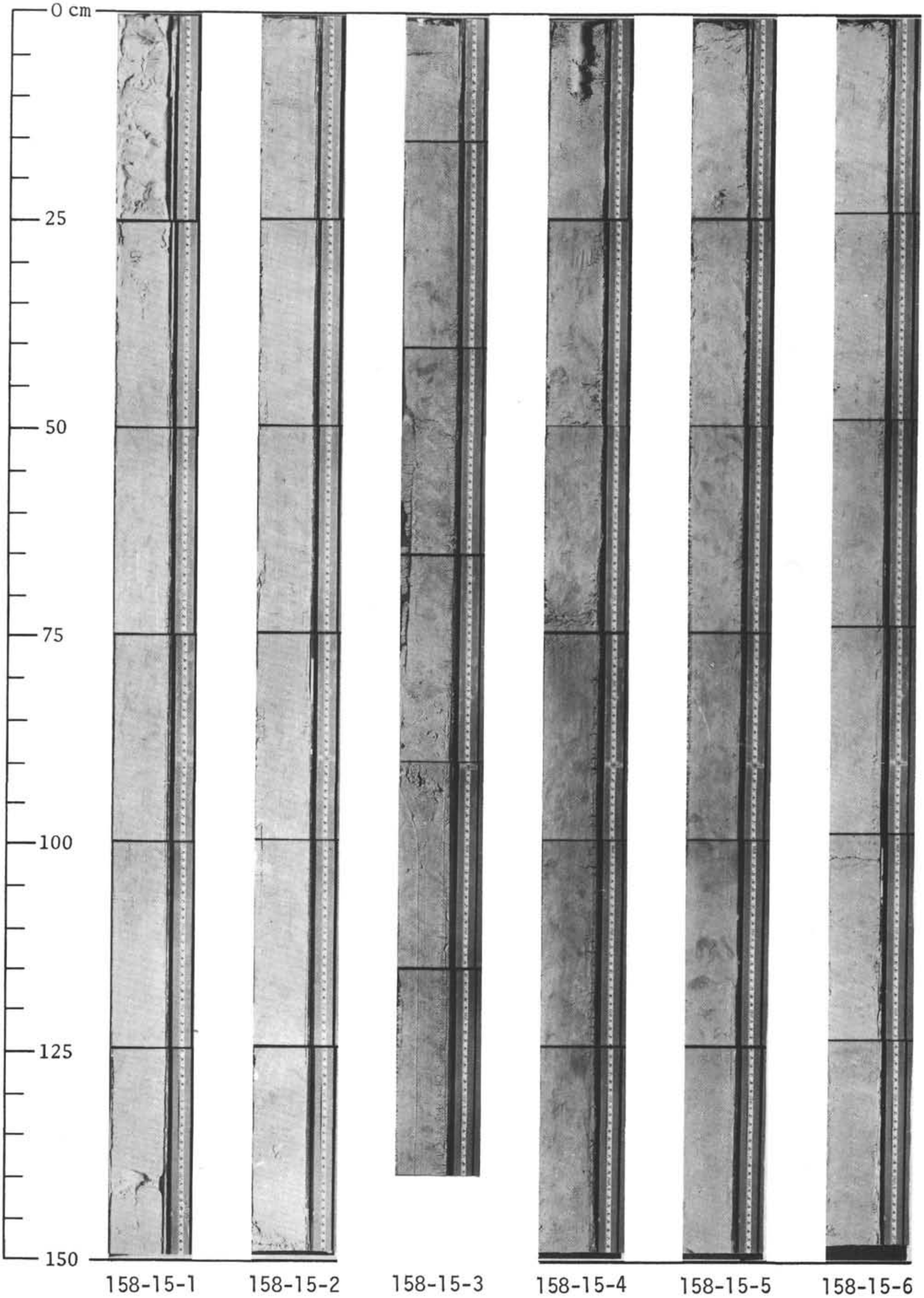
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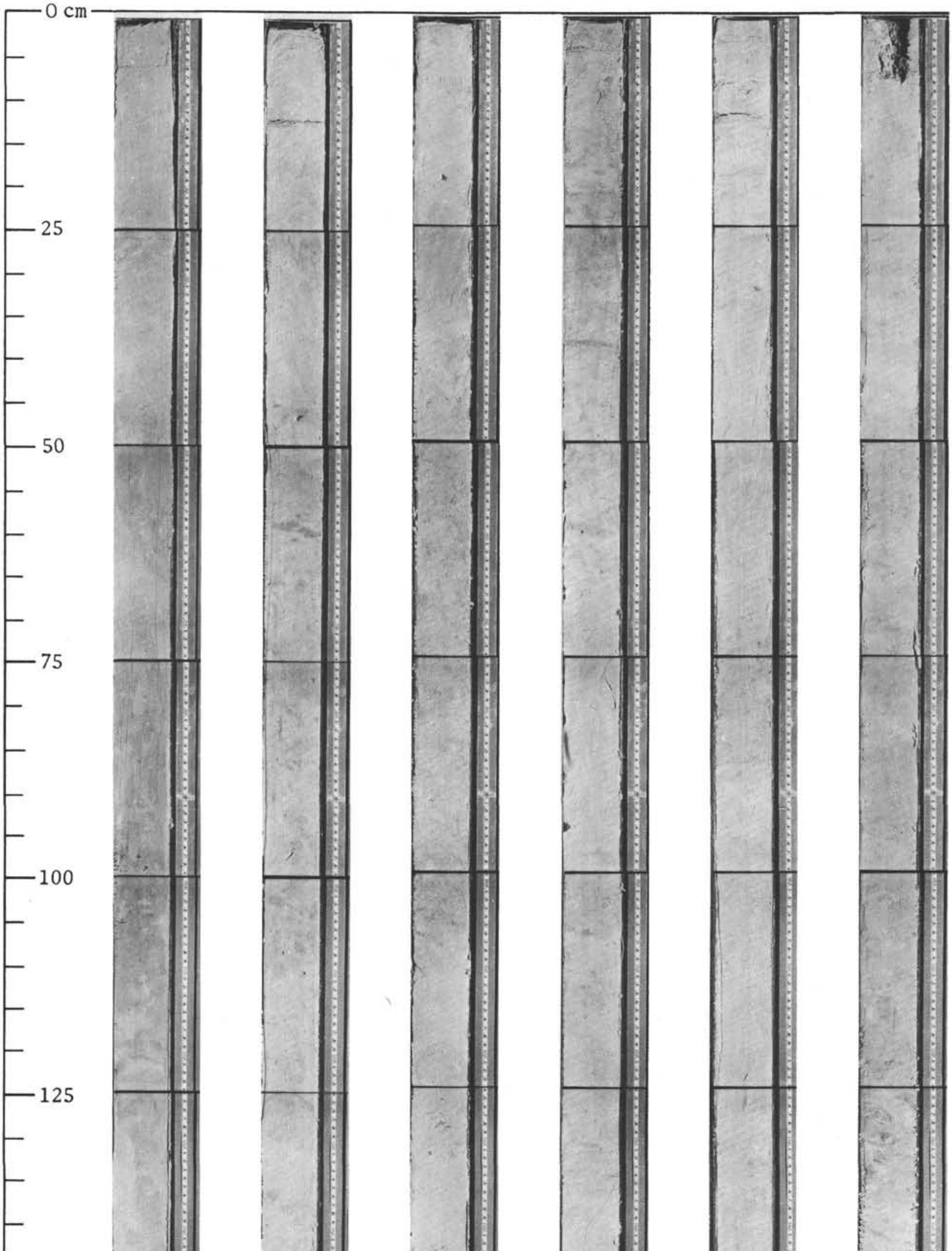
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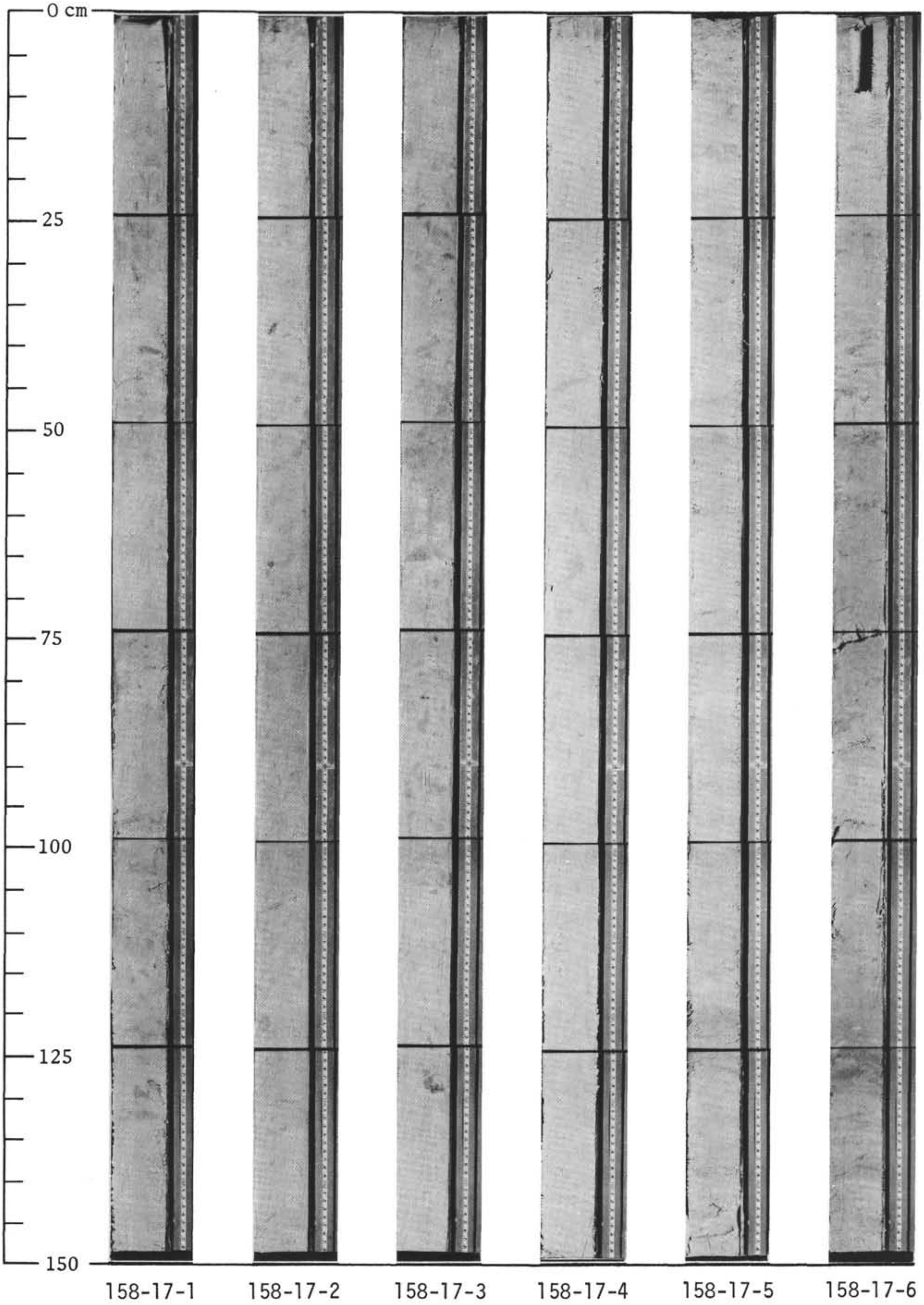
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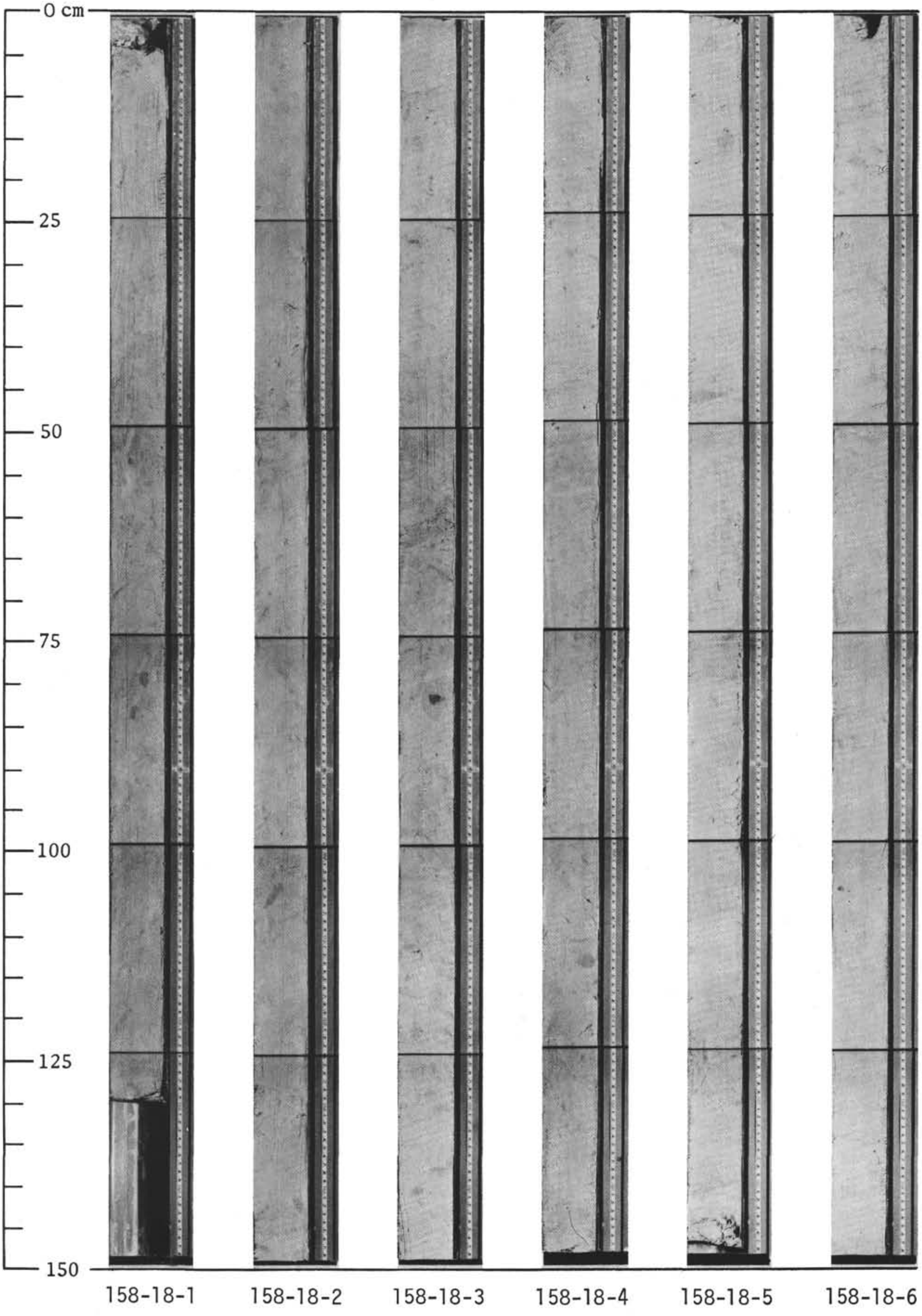
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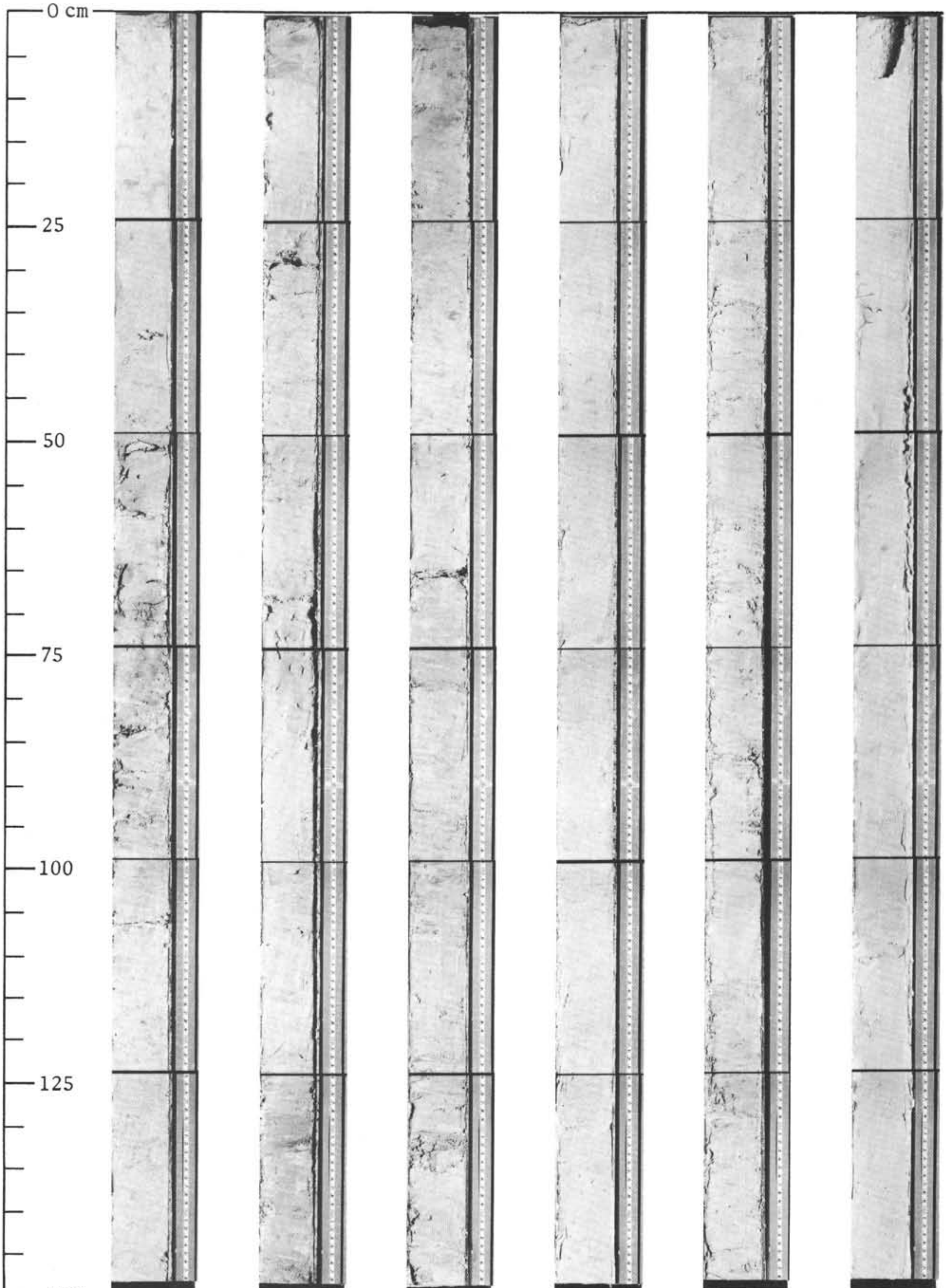

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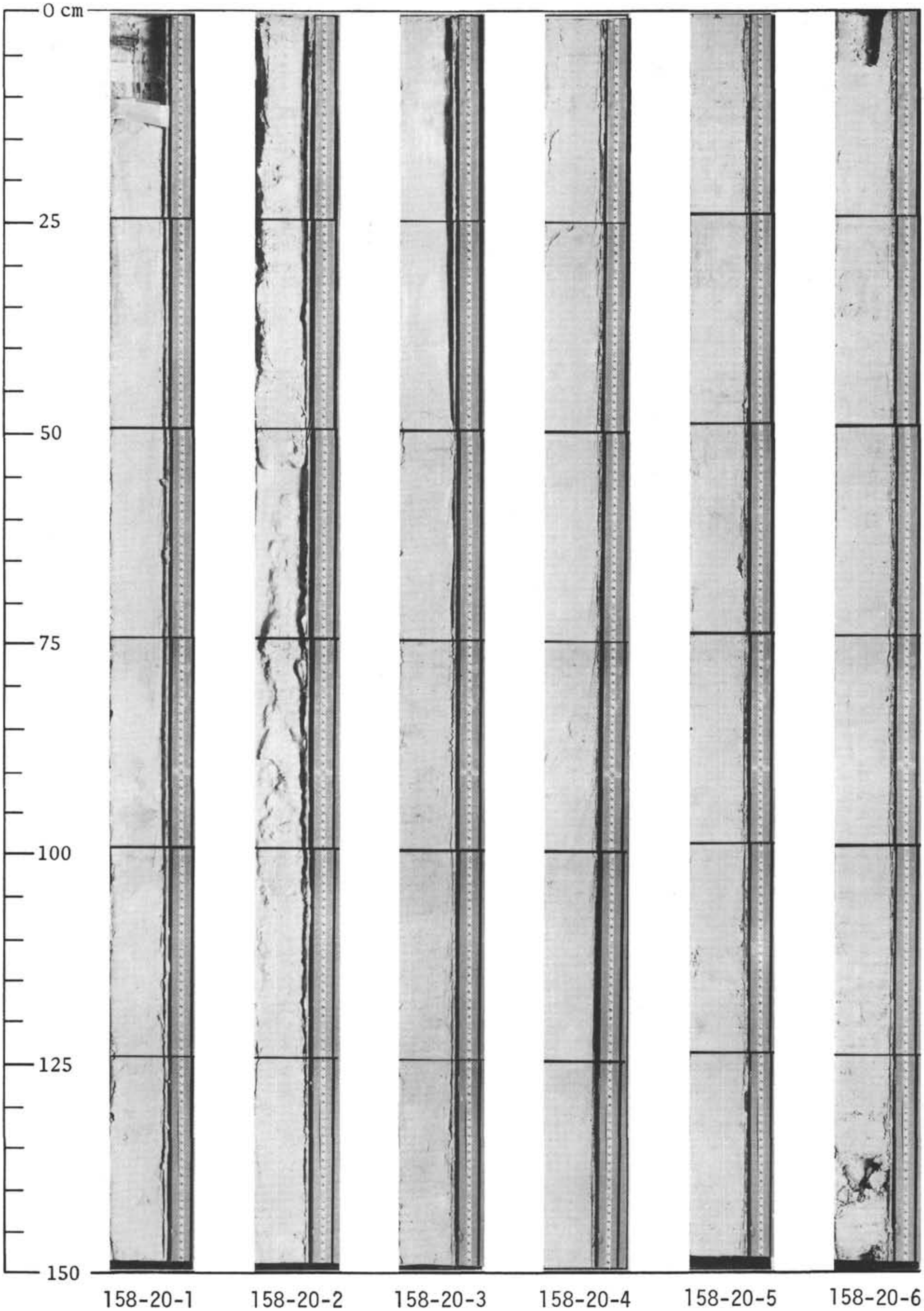
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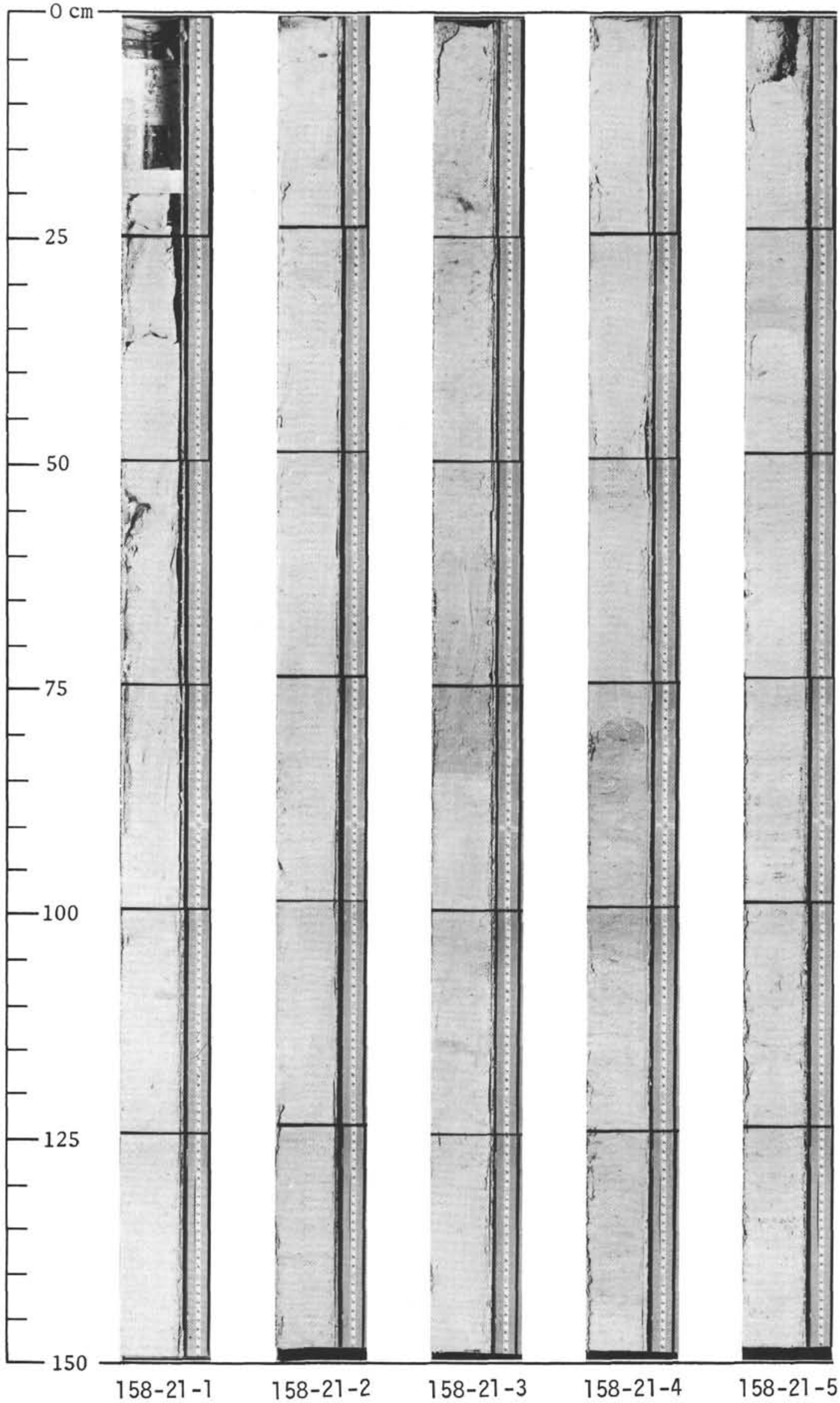
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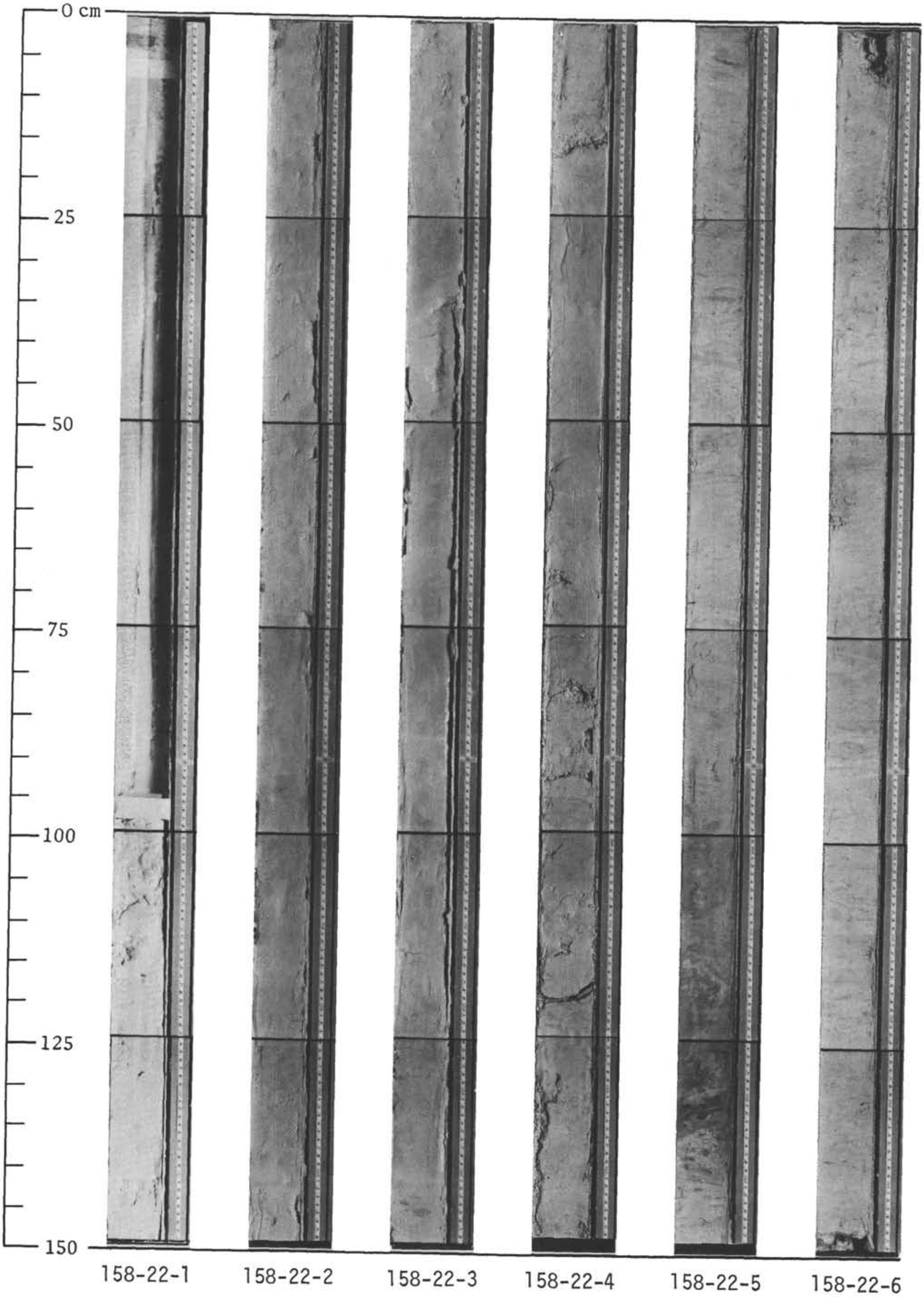
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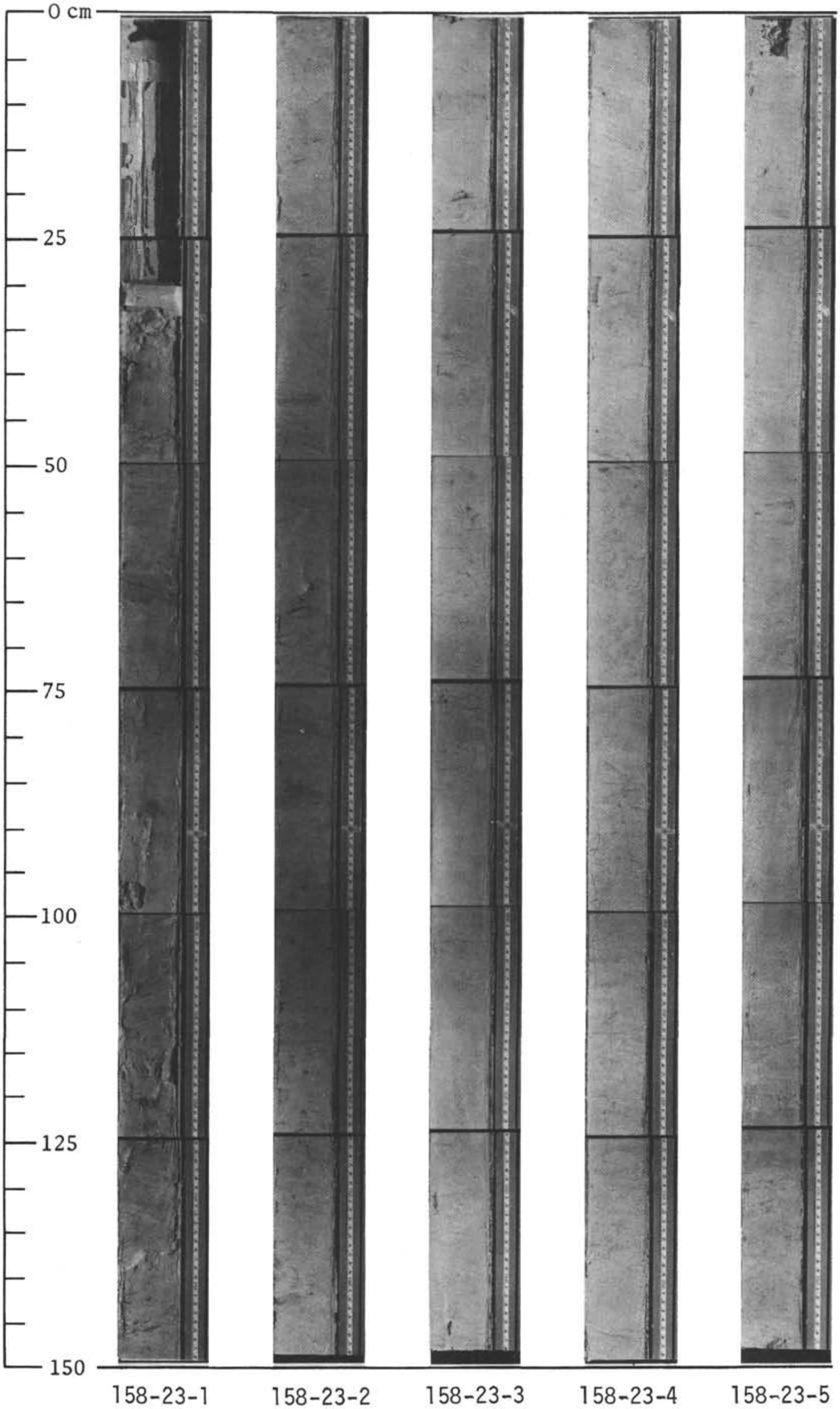
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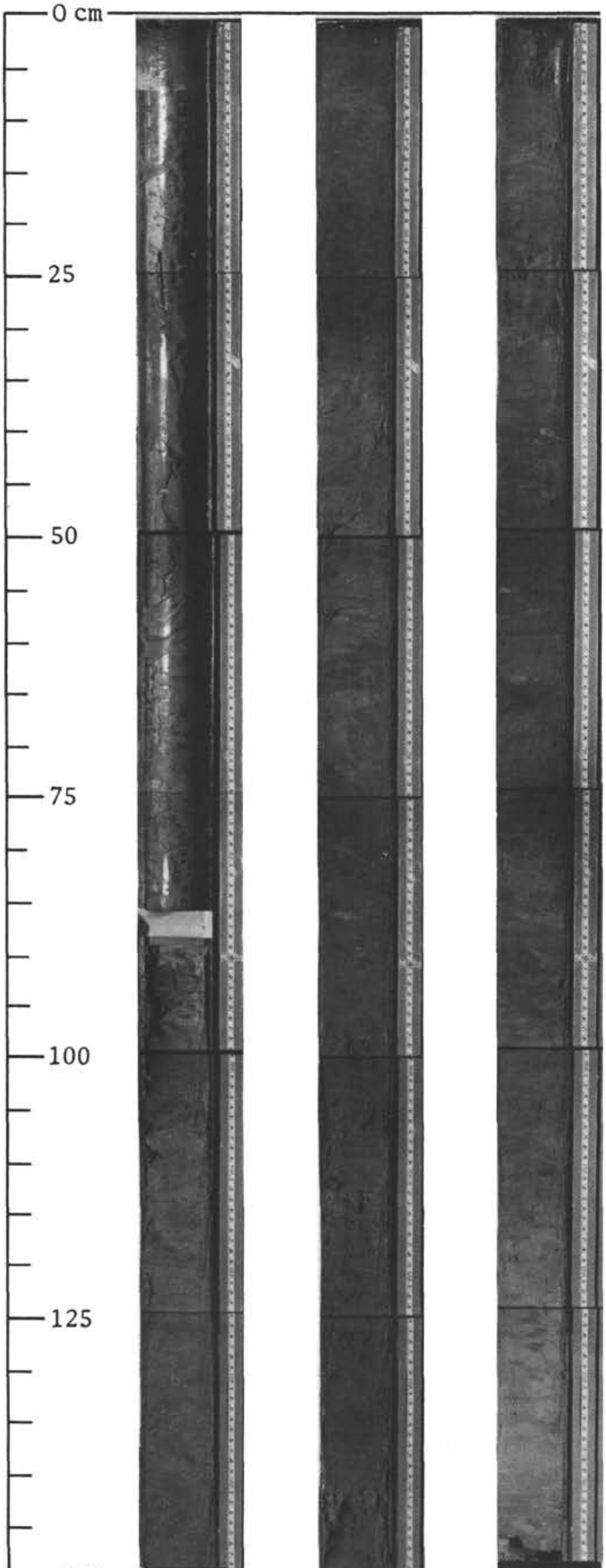

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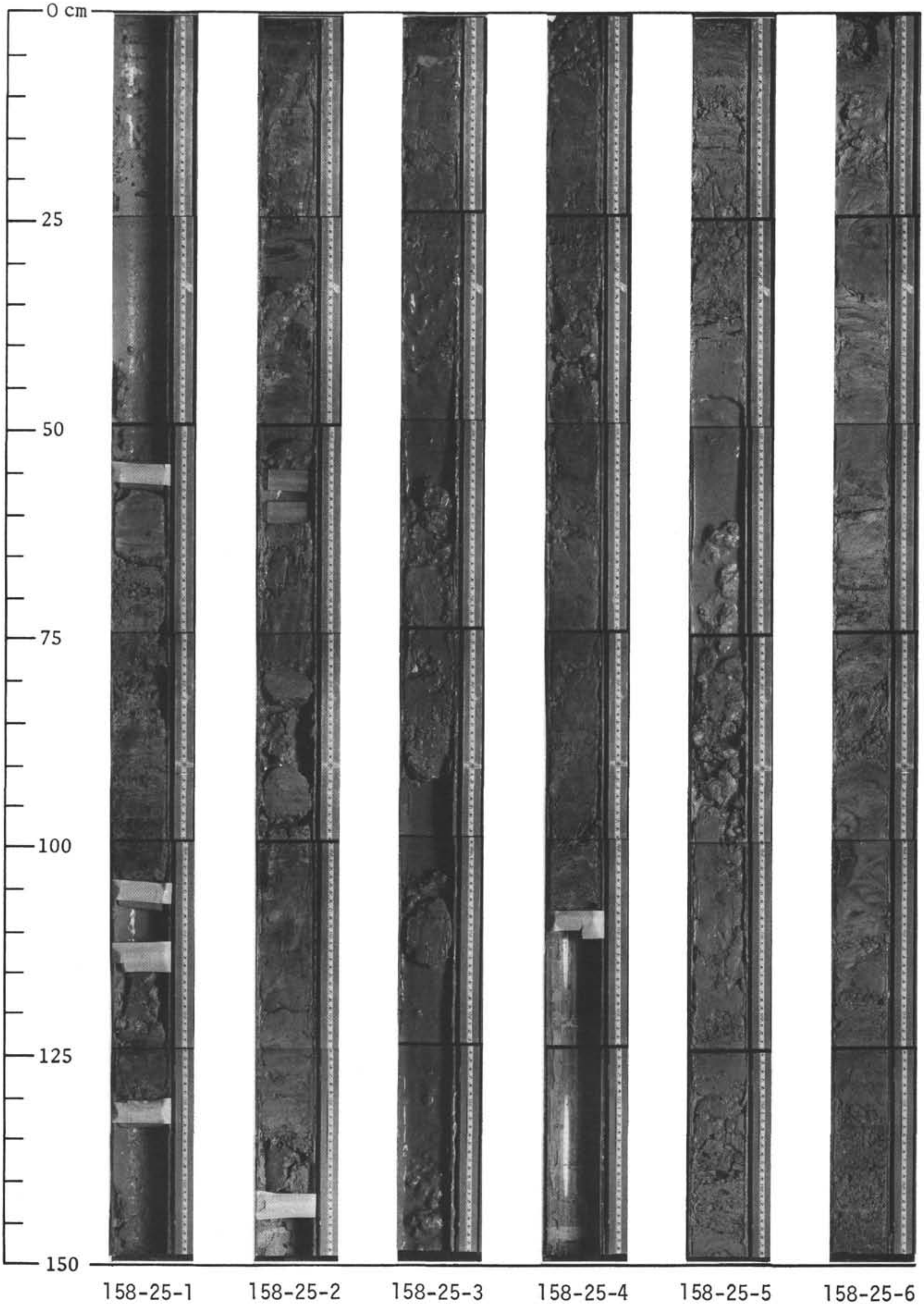
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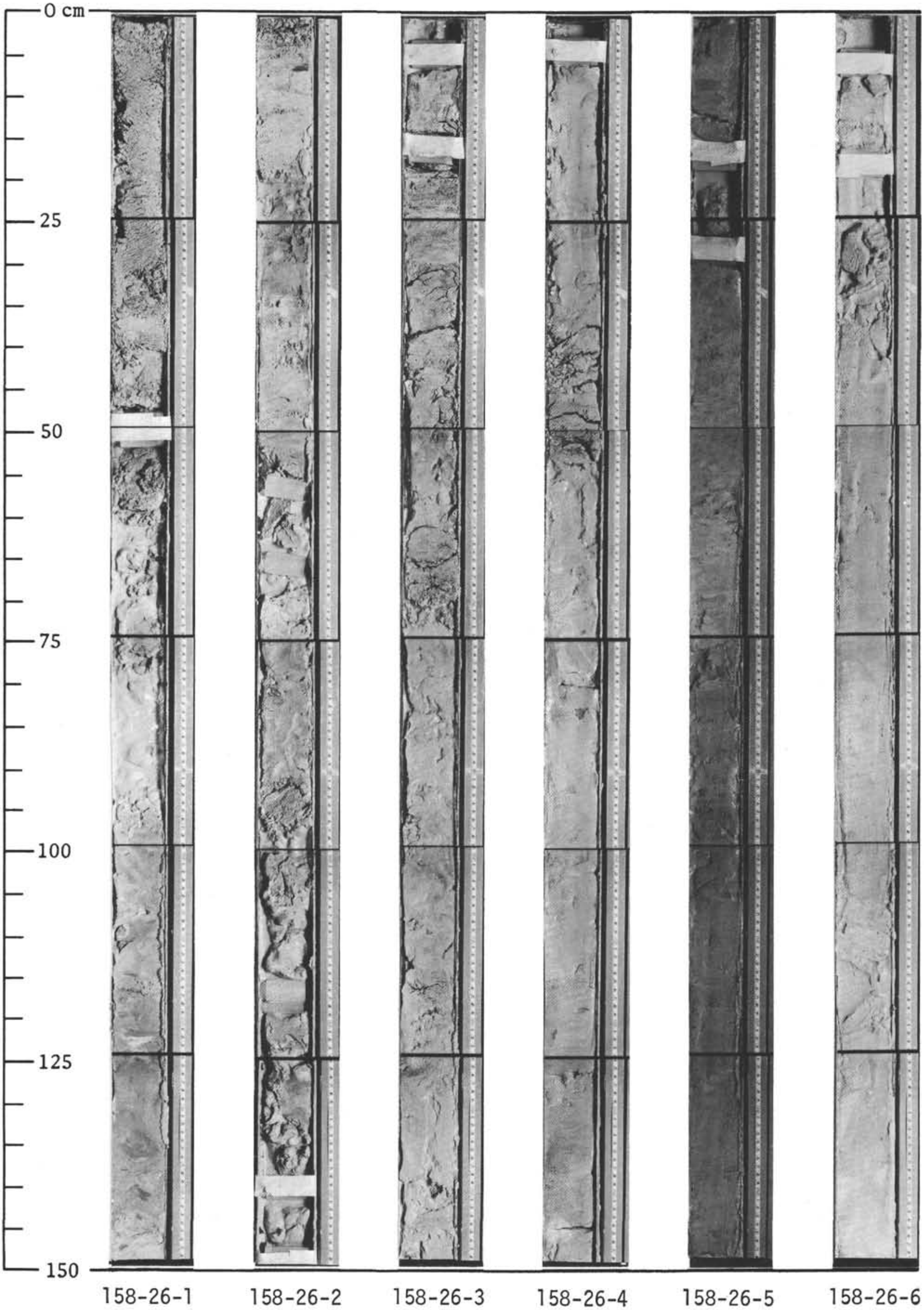
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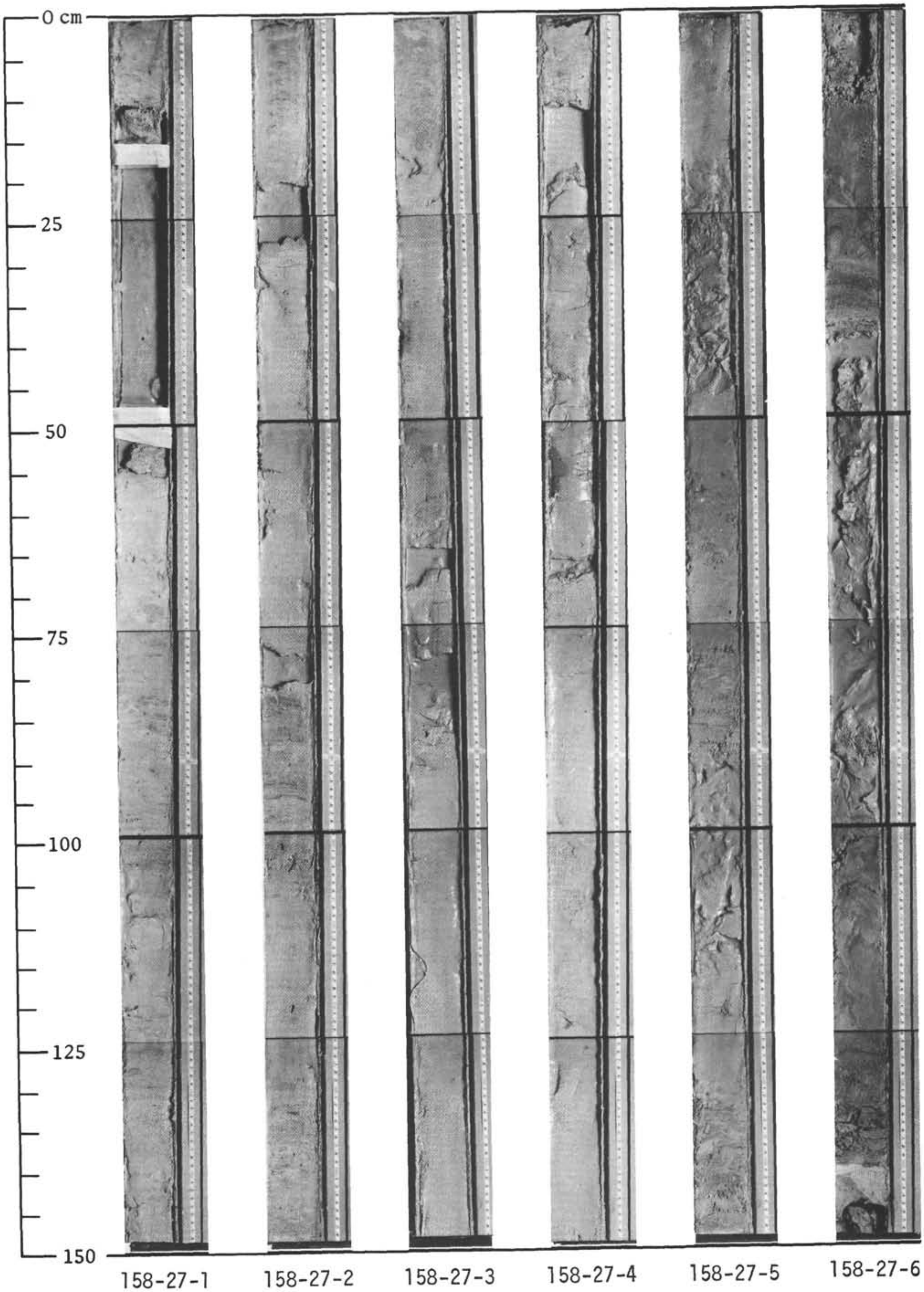
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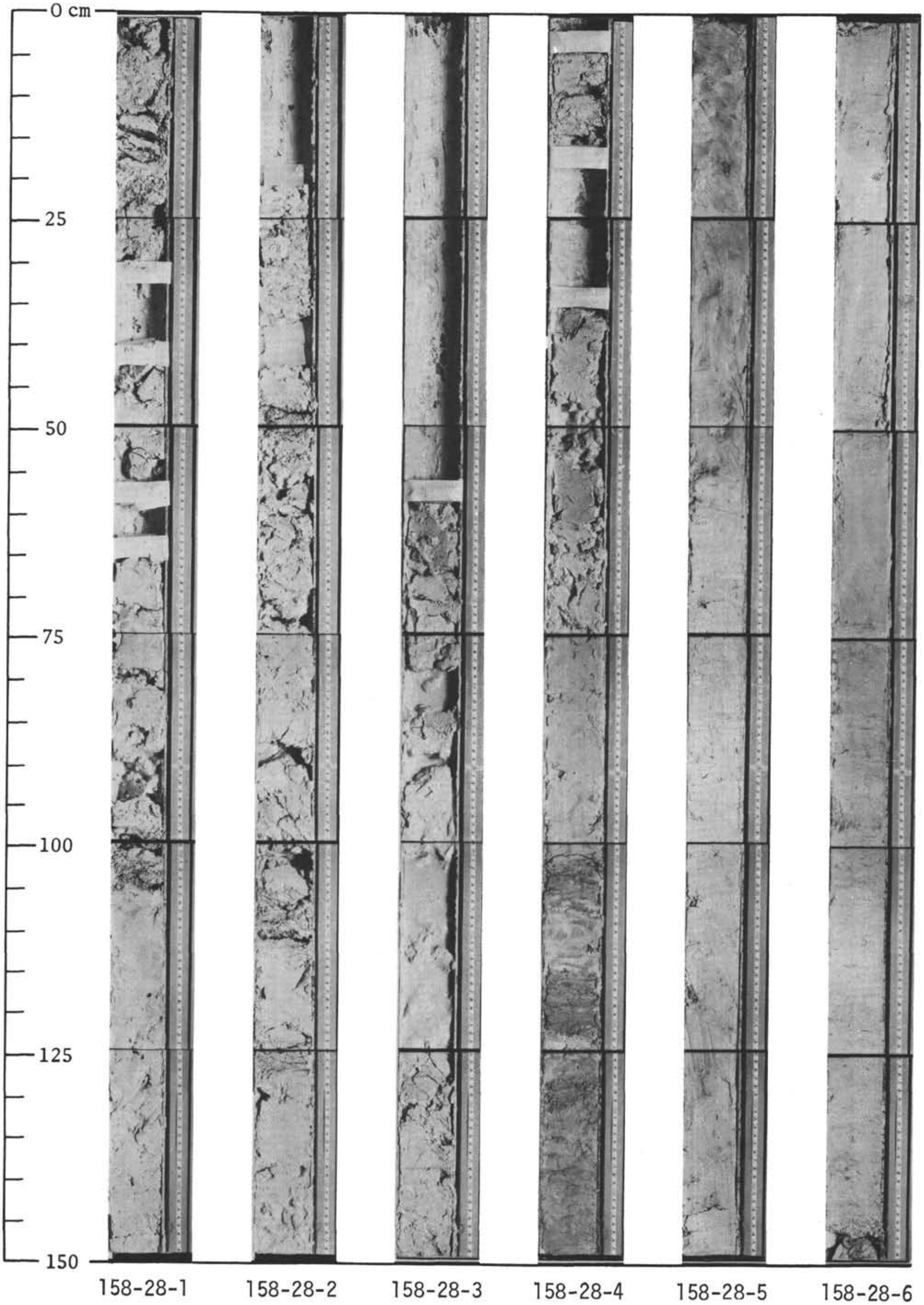
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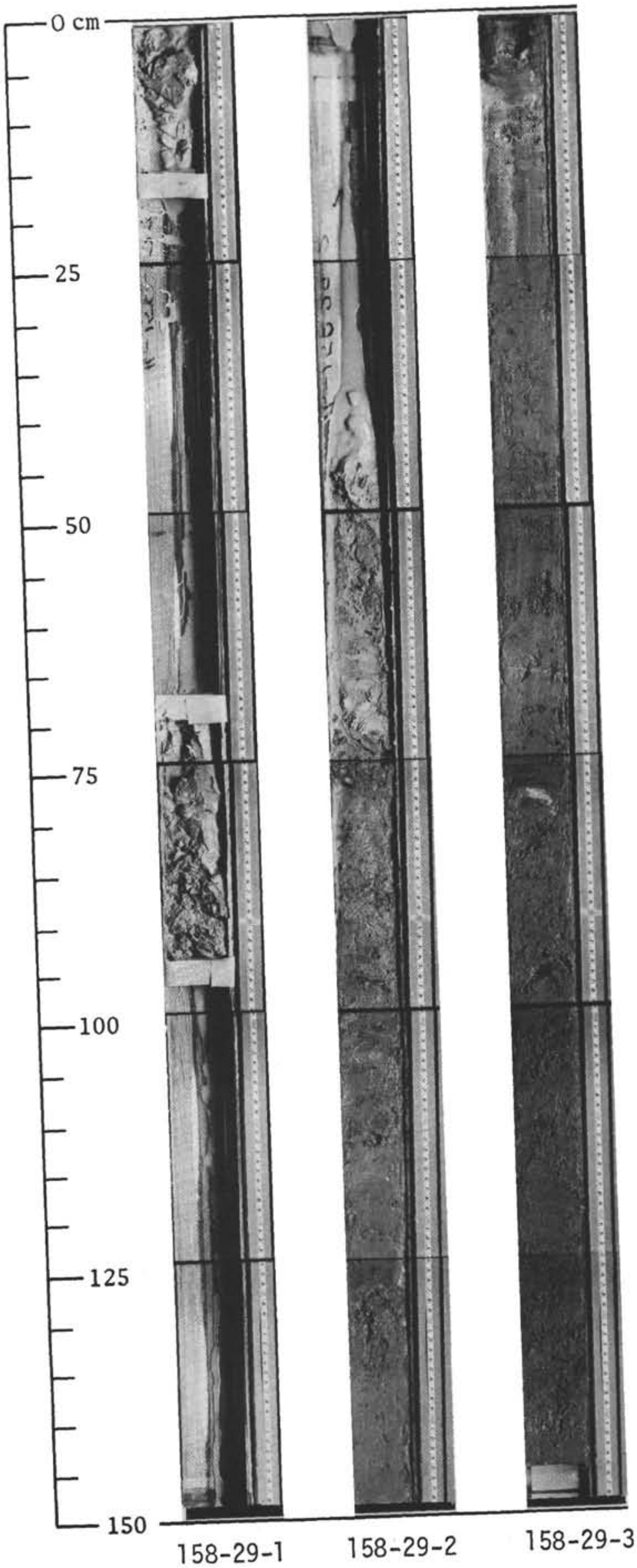
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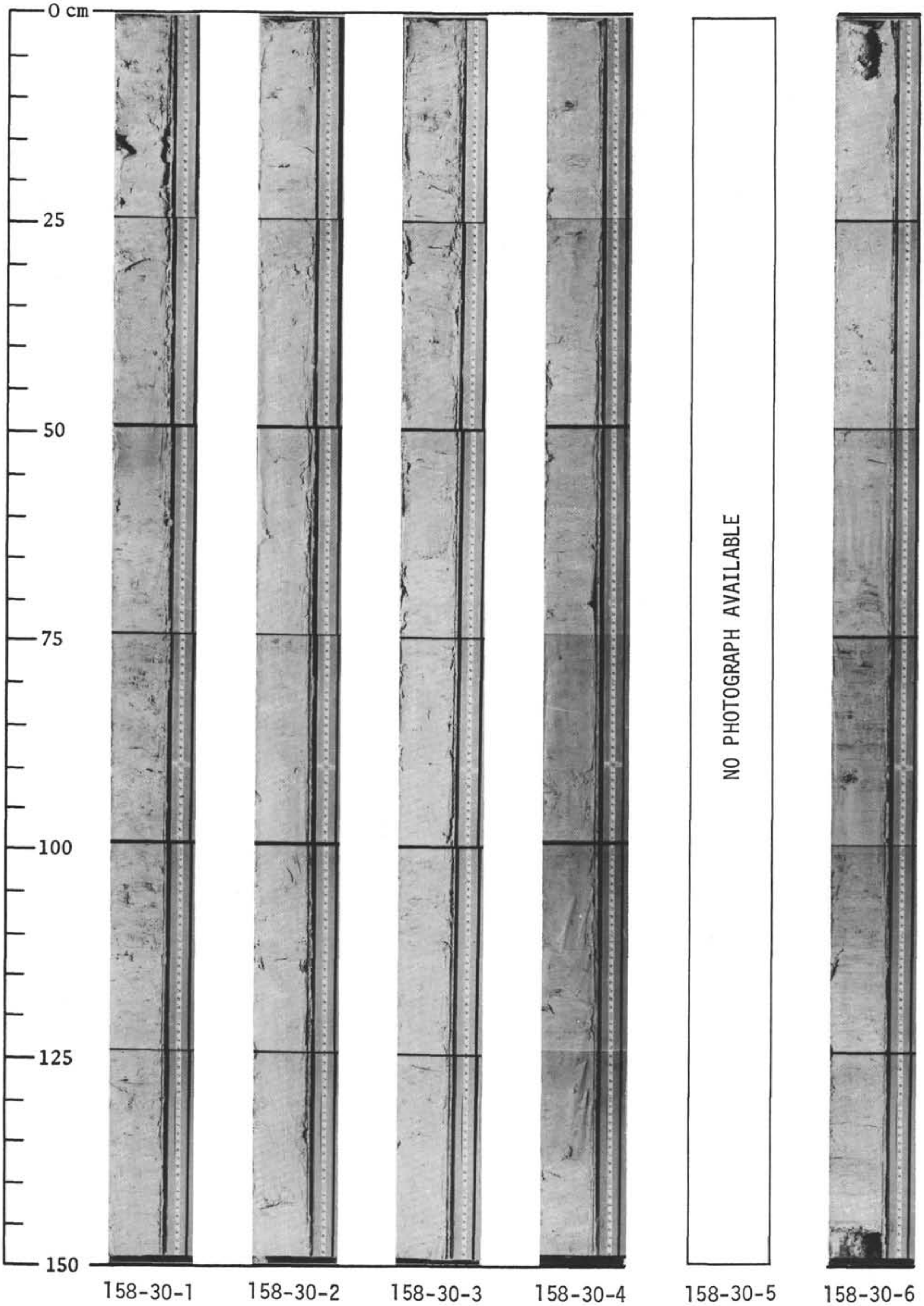
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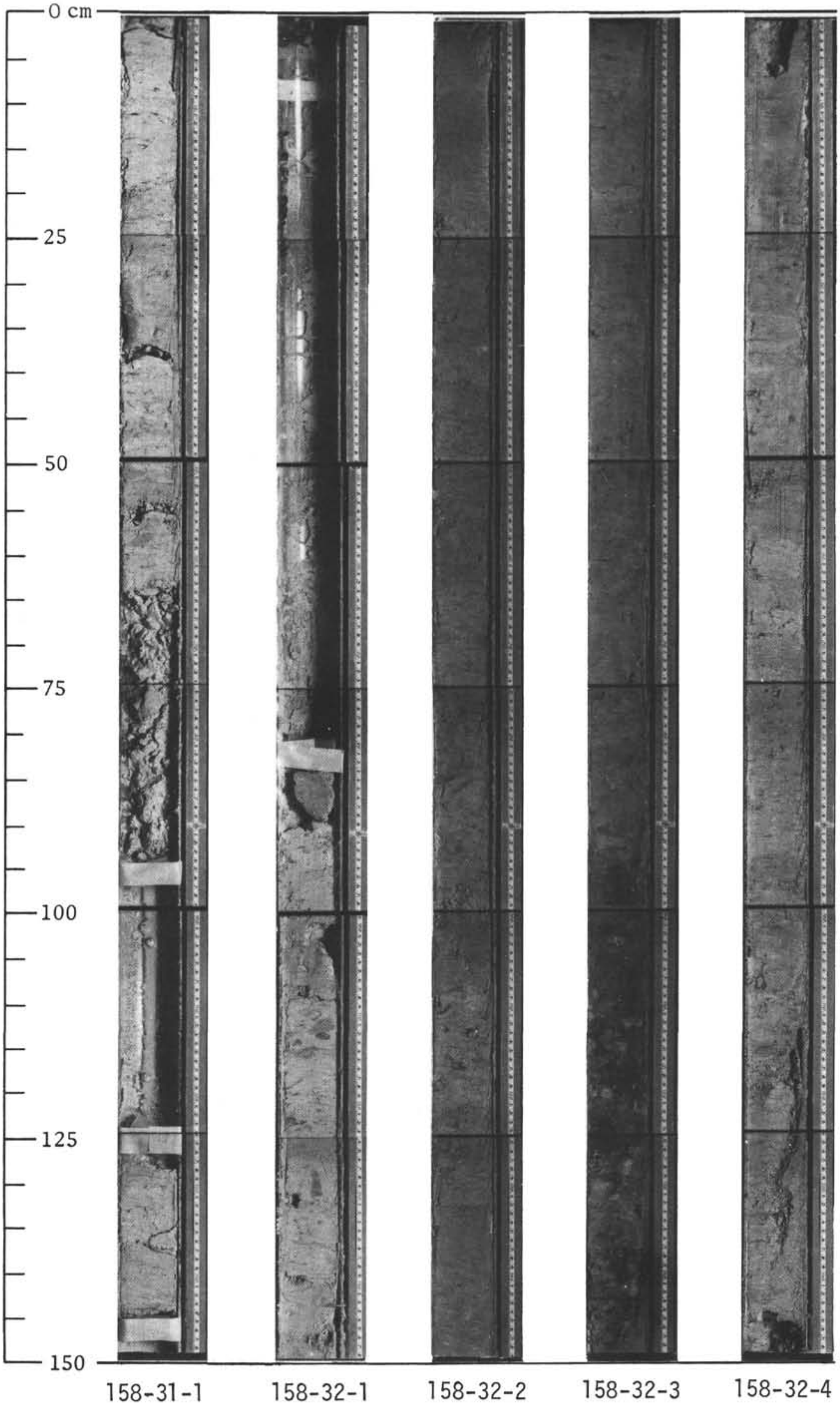
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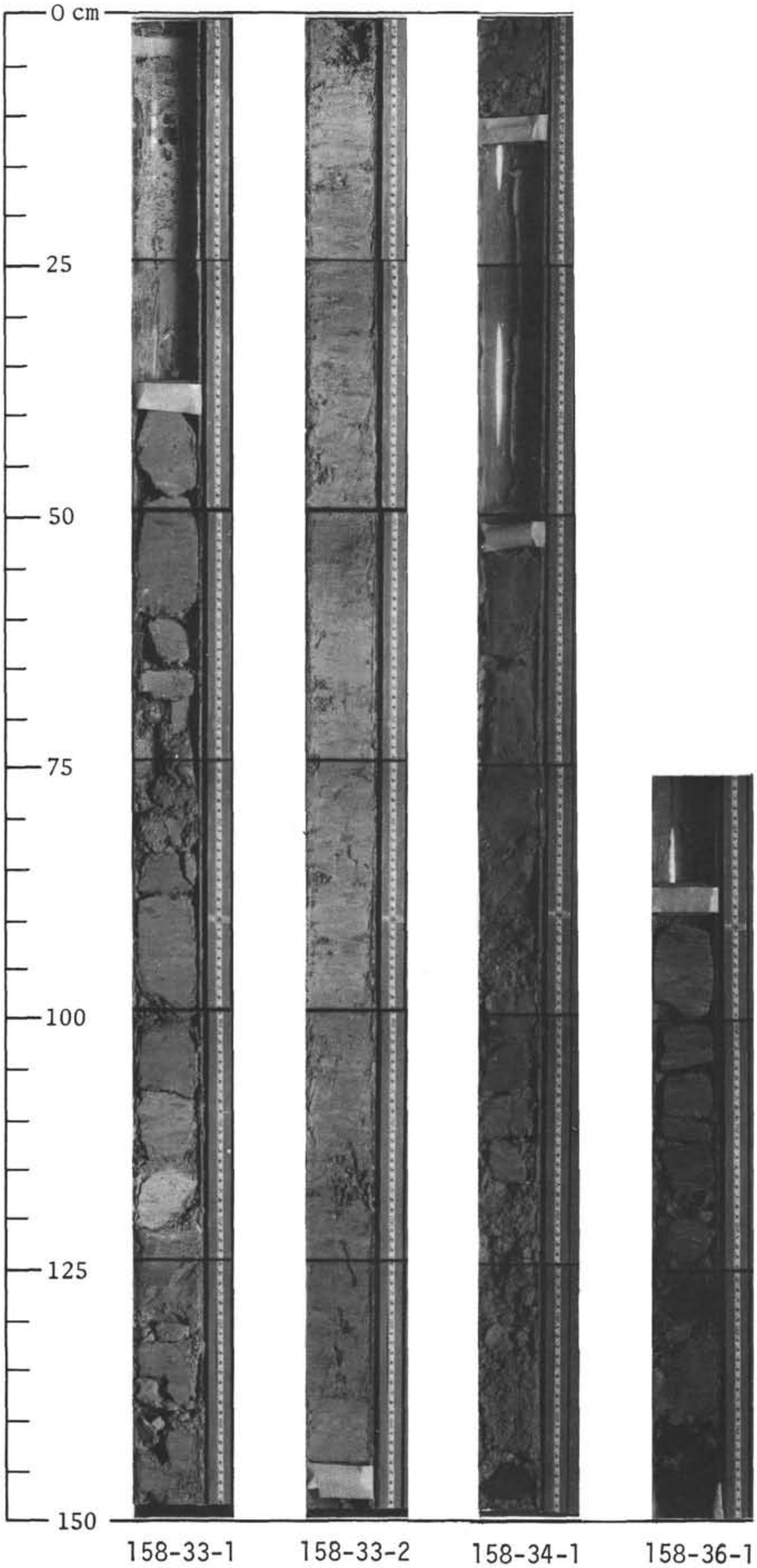
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