6. SITE 159

The Shipboard Scientific Party[1]

SYNOPSIS

Area: West flank East Pacific Rise between Clarion and Clipperton fracture zones

Date Occupied: 1-3 March, 1971

Position:
Lat. 12°19.92′N
Long. 122°17.27′W

Water Depth: 4484 meters (corrected)

Penetration: 109 meters

Number of Holes: 1

Number of Cores: 14

Core Recovery: 96.8 meters

Acoustic Basement:
Depth: 0.13 second
Nature: Basalt
Inferred acoustic velocity of sedimentary section: 1646 m/sec

Age of Oldest Sediment: Late Oligocene

The site was continuously cored to yield the following sequence of deposits:

0-18 meters – Slightly siliceous pelagic brown clay. Upper 9 meters contain Quaternary radiolarians.
Age: Middle Miocene at bottom.

18-70 meters – Gradual change from calcareous clay with some pelagic brown clay to nannofossil marl. Microfossils suggest brief hiatus at 47 meters in early Miocene.
Age: Middle to early Miocene.

70-108 meters – Nannofossil marl ooze rich in ferromanganese aggregates.
Age: Early Miocene and late Oligocene.

108-109 meters – Altered basalt, extrusive.

A sedimentation rate for the Quaternary of 5 m/m.y. follows a rate of 1.0 m/m.y. during the Pliocene and late Miocene. The average rate for the late Oligocene to late Miocene (18-108 m) is 7 to 8 m/m.y., which is low for a calcareous sequence. The oldest sediment is from the *Globigerina ciperoensis* (foraminiferal) and *Triquetrorhabdulus carinatus* (nannofossil) zones, giving an estimated age of 22 to 23 m.y.

REGIONAL SETTING AND OBJECTIVES

DSDP 159 is one of a series of sites in the eastern equatorial Pacific on the west flank of the East Pacific Rise (Figure 1). During Legs 5 and 9 of the Deep Sea Drilling Project, sediments rich in oxides of iron and perhaps other transition metals were recovered just above basement at several sites in the eastern Pacific (McManus et al., 1970; Hays et al., 1972). These deposits have been compared (von der Borch and Rex, 1970) to the iron-rich oozes of the deep thermal holes in the Red Sea. Because of the limited chemical data available, their genesis, the details of their geochemistry, and their tectonic relationships are still unclear. The oxide-bearing sites of Legs 5 and 9 occupy a broad zone on the west flank of the East Pacific Rise; DSDP Sites 159 and 160 are located on this trend. They were selected by the Pacific Site Selection Panel on the premise that if hydrothermal processes on the crest of the East Pacific Rise supply the transition metals, a broad zone of such deposits should be present immediately above basement over the entire flank of the Rise. This assumption is supported by the fact that the number of sites on which these deposits have been found among the total number drilled in the area is far larger than can be ascribed to accidental penetration of localized deposits. Sediments containing relatively large concentrations of iron, manganese, and trace metals, similar to those recovered on Legs 5 and 9, have been found in surface layers on the crest of the East Pacific Rise (Böstrom and Peterson, 1966, 1969; Boström et al., 1969) and have been attributed to somewhat vaguely defined hydrothermal processes. Potentially, such highly mineralized sediments are of economical value, mainly because of their trace metals which appear to be present in concentrations equivalent to those of many currently exploited ore bodies on land. At present, technology for the recovery of the marine deposits does not exist, but these deposits are attractive because of the limited overburden of unconsolidated sediment, the softness of the ore, and its probable ease of processing.

DSDP 159 is located in the red clay region of the north central Pacific, just below the calcite compensation depth. The site is delicately poised on the northern edge of the equatorial zone of high biological productivity which, farther south, yields calcareous sediments that are preserved at depths exceeding those encountered near the site. Reflection profiles have shown that an elongate mound of sediments has formed in the equatorial Pacific stretching from the eastern Pacific westward along two degrees north latitude (Ewing et al., 1968). This mound has been extensively sampled by the Deep Sea Drilling Project during Legs 7, 8, and 9 and contains a record of migrating, expanding and contracting equatorial sedimentation during the Cenozoic. These data show that with increasing age the equatorial zone of rapidly deposited calcareous sediments

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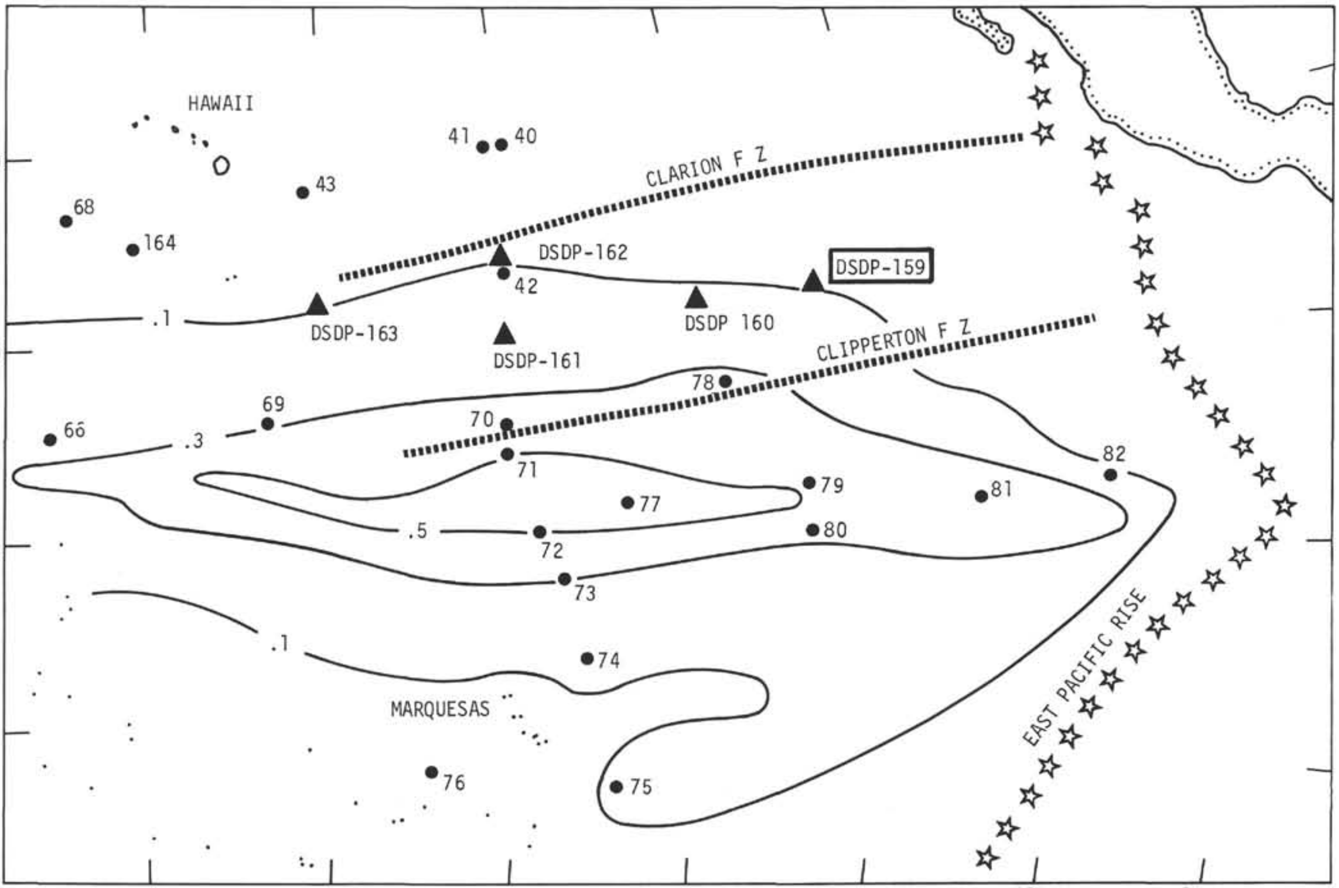

Figure 1. *Location of Leg 16 sites (large triangles) in the eastern equatorial Pacific on the west flank of the East Pacific Rise. Small dots are sites from Legs 5, 8, 9, and 17. Contours indicate sediment thickness above acoustic basement in seconds (approximately equivalent to 800 meters).*

lies progressively farther northward, and also that at different times the width and accumulation rate of this zone have varied (Tracey et al., 1971). DSDP 159 and the later sites of Leg 16 were selected to contribute further to an understanding of the history of equatorial sedimentation in the Pacific and of its dependence on tectonic, oceanographic, and climatic factors.

The site lies on the west flank of the East Pacific Rise about halfway between the Clipperton and Clarion fracture zones which define a major structural block of the eastern Pacific floor. The present spreading axis is approximately 2,000 km east of the site. Data from Burckle et al. (1967) and Riedel (1967), recently supported by results from Leg 9 (Hays et al., 1972), indicate that during most of the Cenozoic, spreading in this block was parallel to these fracture zones and occurred at a rate of approximately 8 cm/yr. Sclater, Anderson and Bell (1971) have suggested that the spreading axis for this period was not the present one but instead was one located in the Mathematicians Seamounts. The present spreading rate of 5 to 6 cm/yr and spreading direction are somewhat different from the earlier ones (Heirtzler, 1968).

TOPOGRAPHIC AND GEOLOGIC SETTING

The site lies several hundred kilometers west of the moderately rugged relief of the central portion of the East Pacific Rise and the Mathematicians Seamount cluster. The regional slope is very gentle and the small-scale local relief is only occasionally interrupted by small seamounts grouped in clusters which are spaced 100 km or so apart, and by occasional escarpments, 100 to 200 meters high, which probably result from normal faulting. These large faults delineate rather extensive basement plateaus with a width in the east-west direction of several tens of kilometers and a height of about one hundred meters above the surrounding terrain. Otherwise, the local relief is small and consists of numerous small faults with a vertical separation of 10 to 50 meters and spaced from 1 to 10 km apart. Detailed examinations of this type of abyssal hill terrain elsewhere on the flank of the East Pacific Rise has shown that the topographic elements formed by these faults are strongly lineated parallel to the spreading axis (Luyendyk, 1970).

The area is rather uniformly blanketed by a thin layer of sediment averaging about 0.1 to 0.15 sec (80-120 cm) in thickness and draped over the irregularities of the basement (Figure 3). Basement outcrops, in the form of small pinnacles and the upper edges of fault scarps, are common, but by far the larger part of the sea floor is sediment covered.

The site itself is located in the eastern part of a small depression about 5 km wide and bordered on both sides by boundary scarps of uplifted basement (Figures 2 and 3). The data obtained during site selection are not adequate to determine whether this valley is elongate in a north-south direction, but the similarity between the two profiler crossings made on site and the evidence cited above for a regional lineation of this abyssal hill terrain renders this probable.

The site originally proposed was selected on the basis of a single crossing made during the *Seventow* Expedition of Scripps Institution of Oceanography in 1970. This proposed site was located approximately 80 km east of DSDP 159. As the terrain and its sediment cover appear to be highly uniform over great distances, the final site is thought to incorporate all the characteristics of the originally selected one. Because of this great uniformity and in view of the very small scale of the topographic grain (10 km or less), the only site survey made was the usual double pass on approach (Figure 2).

The acoustic section consists of highly transparent sediment (Figure 3) containing only a few faint internal reflectors. The sediment is rather uniform in thickness with only a slight increase in the valley in which the site was located. The valley itself, which appears to be a small graben, lies approximately 100 meters below the crests of the two boundary ridges on the east and west. The basement within the valley is quite sharply defined and nearly horizontal although slightly undulating. A few small faults, in addition to the boundary faults, are present within the valley but do not produce significant vertical separations of the sediment column although they seem to affect the sediments up to the sea floor and thus to postdate, at least in part, their deposition. The sediment thickness in the valley varies from 0.11 to 0.14 sec; the site itself is in a location where the sediment is about 0.13 sec thick. A thin transparent zone here overlies a slightly stratified sequence which in turn rests on acoustic basement. The acoustic profile at the drill site is summarized in Table 1.

OPERATIONS

The vessel arrived in the site area on March 1, 1971, and after a double pass across the selected location dropped the beacon at approximately 1400 hours. Although some difficulty was experienced with positioning as a result of sustained winds of 20 to 25 kt, seas of 6 to 8 ft from a different direction and some current, drilling was accomplished without mishap and the hole cored continuously with a Smith 3-cone button bit left over from DSDP 158. Roll and pitch of the vessel forced termination of the hole after one meter of core had been obtained from the basement. A summary of coring operations is given in Table 2.

LITHOLOGY

The sediments at DSDP 159 can be divided into three main units overlying basalt. The middle unit consists of alternating lithologic types (Figure 4).

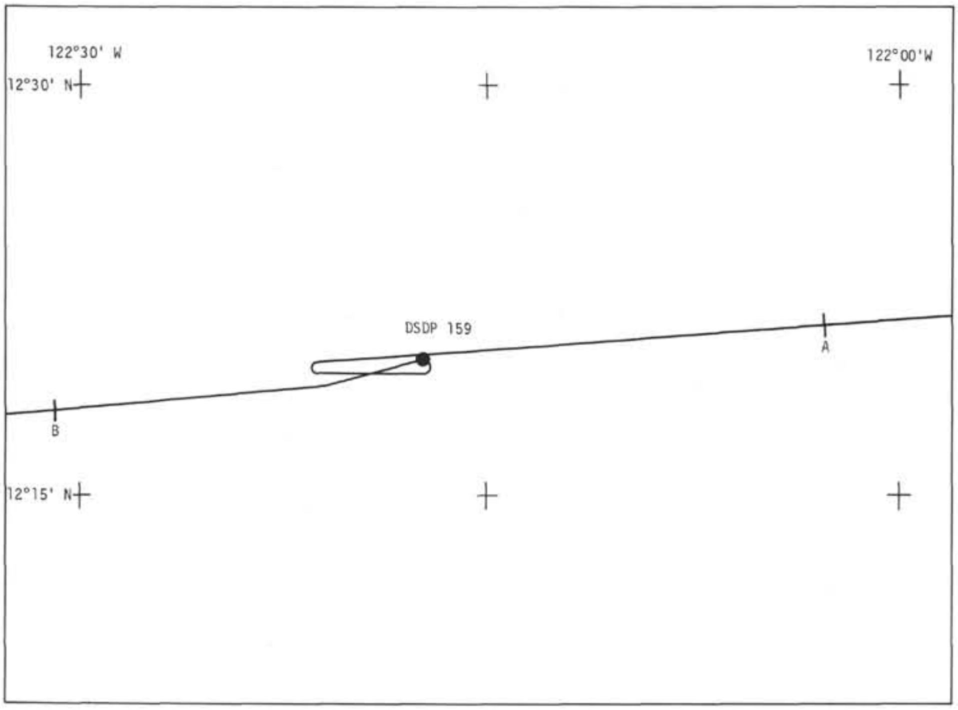

Figure 2. *Site location map. A-159 and 159-B are locations of profiles of Figure 3.*

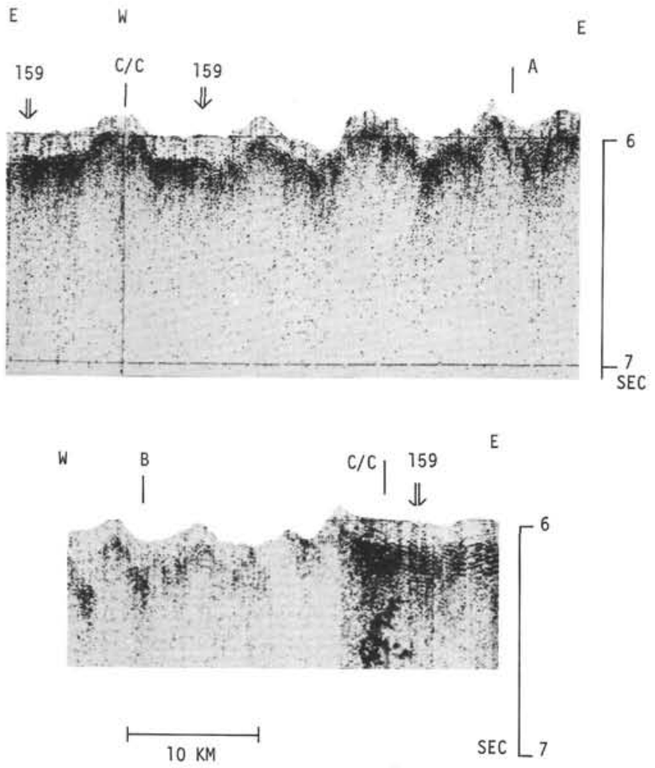

Figure 3. *Acoustic reflection profiles in vicinity of DSDP 159. Depths in seconds of two-way travel time. Horizontal scale is approximate. Locations are on Figure 2.*

TABLE 1
Comparison of Acoustic Section and Drill Data, DSDP 159

Reflectors	Depth (sec)	Drilling Results	Velocity (m/sec)
Top stratified zone	0.02-0.03	18 m base radiolarian clay	(1440)[a]
Top acoustic basement	0.13	107 m top basalt	1646

[a] Uncertain because of thinness of the interval.

TABLE 2
Coring Summary, DSDP 159

Core	Depth Below Sea Level (m)	Depth Below Sea Floor (m)	Cored (cm)	Recovered	
				(cm)	(%)
1	4484-4493	0-9	900	375	41.7
2	4493-4502	9-18	900	910	101.1
3	4502-4511	18-27	900	926	102.9
4	4511-4520	27-36	900	870	96.7
5	4520-4529	36-45	900	928	103.1
6	4529-4538	45-54	900	440	48.9
7	4538-4547	54-63	900	890	98.9
8	4547-4556	63-72	900	905	100.6
9	4556-4565	72-81	900	923	102.6
10	4565-4574	81-90	900	909	101.0
11	4574-4583	90-99	900	0	0.0
12	4583-4591	99-107	800	911	113.9
13	4591-4592	107-108	100	680	680.0
14	4592-4593	108-109	100	10	10.0

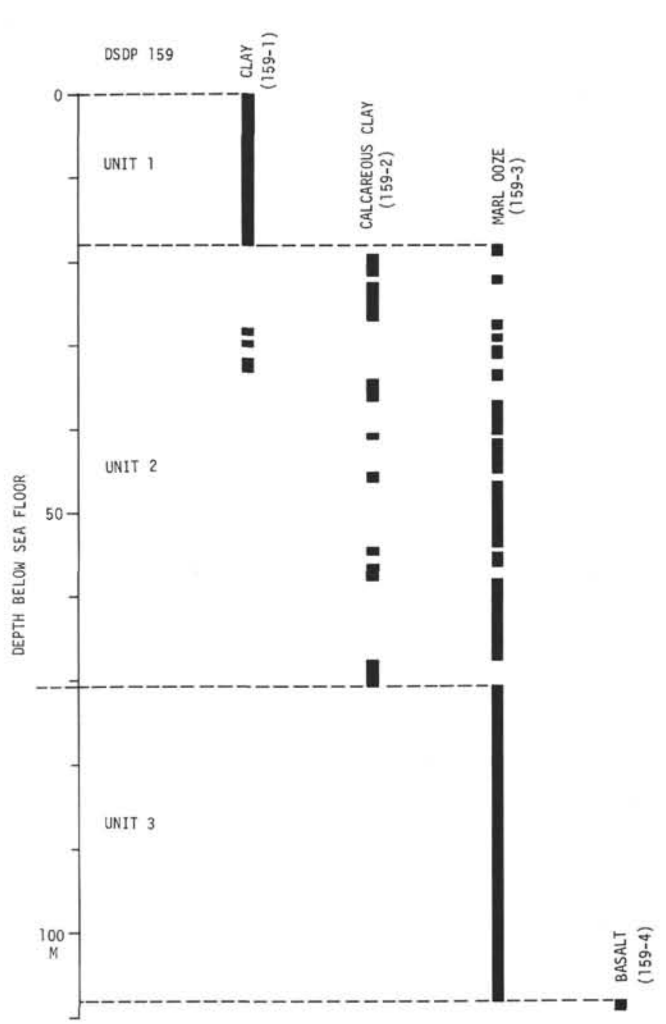

Figure 4. *Sequence of lithologic types at DSDP 159. For explanation see text.*

Unit 159-1: Grayish orange to moderate yellow brown clay containing common to abundant radiolarians with lesser quantities of diatoms (0-18 m).
Unit 159-2: Alternations of clay, calcareous clay, and nannofossil marl ooze (18-70.5 m).
Unit 159-3: Nannofossil marl ooze (70.5-108 m).
Unit 159-4: Basalt.

Unit 159-1

This unit begins at the top with grayish orange to moderate yellow brown radiolarian clay, containing diatoms, small concentrations of feldspar, volcanic glass, and palagonite. At about 9 meters depth, the clay grades into a dark yellowish brown clay with abundant dark yellow, amorphous, seemingly ferruginous aggregates up to about 100 microns in diameter. This clay is variously mottled in shades of grayish orange and dark yellow brown and contains significant numbers of radiolarians. A few calcareous nannofossils occur, but only in very small concentrations. They are probably contaminants.

Unit 159-2

This unit consists of alternating clay, calcareous clay, and nannofossil marl ooze. The alterations are rarely in the form of well defined beds, but more commonly as streaks, lenticles, and patches of one or two lithologies in the third, probably resulting from disturbances of thin alternating beds during the coring process. The upper part is dominated by clays and calcareous clays which are moderate brown and show various degrees of mottling. The marls are also moderate brown and mottled in dark yellowish orange and various shades of moderate brown. Below 36 meters, the proportion of marl ooze exceeds that of clay. These marls are predominantly grayish orange to moderate brown and contain abundant nannofossils with subordinate amounts of radiolarians. The sediment is moderately to heavily mottled and shows various flow structures as a result of severe disturbance by the coring process. Nannofossils are most abundant in the light-colored zones.

Unit 159-3

Below 70.5 meters in this unit, moderate yellowish brown to grayish orange nannofossil ooze is the only sediment type. The ooze is mottled in pale yellowish orange in the upper part (70.5 - 80 m); the mottles become darker with depth until from 100 to 108 meters they are uniform dark moderate brown. These basal sediments contain very abundant dark aggregates of amorphous dark brown ferruginous-looking globules. These may be the equivalent of the amorphous dark iron oxides found just above basement in some Leg 5 and 9 holes. However, they are heavily diluted with calcium carbonate and do not merit distinction as a separate lithologic unit as in the Leg 5 and 9 holes.

Unit 159-4

This unit consists of altered basalt, directly underlying unmetamorphosed sediments, suggesting extrusive emplacement. Only a few centimeters of basalt were recovered. Amygdaloidal reddish orange basalt glass found in drill cuttings apparently represents the top of the unit. The basalt is fine grained, locally vesicular, and considerably altered. Laths of sodic to calcic labradorite are mostly 100 to 300 microns long in the matrix and up to 700 microns long as phenocrysts; the largest seen is 1300 microns long. These locally contain faint euhedral oscillatory zoning; most have normally zoned rims of calcic andesine. Pyroxene is 50 to 200 microns across and is probably augite with $2V_z$ 30 to 40°. The low 2V is suggestive of pigeonite, but the crystals have lower birefringence and a higher extinction angle than pigeonite. The pyroxene occurs as elongate sheafs associated with plagioclase, and as subhedral prisms. Aggregates of bowlingite and iddingsite have the form of olivine phenocrysts and are probably psuedomorphs. Vesicles are 300 to 700 microns in diameter and are filled with fine-grained devitrified basalt and zeolite. The opaque minerals are most common in the glassy areas and consist of octahedra and short octahedral chains of a spinellid mineral, probably magnetite, but locally brown-tinged like chromite.

Manganese micronodules occur throughout the core. They vary from common to very abundant, and range in size up to about 100 microns. They are commonly spherical although other shapes occur. These dark brown opaque phases markedly darken the sediment wherever they are abundant, and reach their greatest concentration in the dark brown marl ooze immediately above basement. Macro-nodules are also present at several horizons in the cores. One nodule was found in the topmost section and fragments of others at lower levels; three whole nodules occur between 99 and 107 meters. There is no conclusive evidence for their in situ information, however, and they may have been emplaced by the cave-in of surface material.

GEOCHEMISTRY

Interstitial water samples and shipboard observations for DSDP 159 are listed in Table 3.

TABLE 3
Interstitial Water Samples and Shipboard Observations, DSDP 159

Core	Section	Sampled Interval (cm)	pH	Eh (mv)	Lab. Temp. (°C)	Salinity (%)	Squeeze Pressure (psi)
1	5	0-4	7.26	176	25.9	34.7	1523
2	6	0-9	7.43	153	26.0	35.2	1015
3	5	0-8	7.55	150	26.0	35.2	1523
4	6	0-5	7.51	157	26.0	35.2	508
5	6	0-6	7.54	165	26.1	35.2	1015
6	3	0-9	6.81	155	26.7	35.2	508
7	5	0-6	7.50	152	26.0	35.2	1015
8	6	0-5	7.40	154	26.0	35.2	1015
9	6	0-6	7.47	146	26.0	35.2	1523
10	6	0-5	7.32	154	26.3	35.2	1015
12	5	0-6	7.49	151	26.4	34.7	1523

BIOSTRATIGRAPHY

A mainly mid-Tertiary section (upper Oligocene to middle Miocene), with some Quaternary (Core 1) and questionable upper Miocene (Core 2) is present at DSDP 159. For all three fossil groups (foraminifera, nannofossils, and radiolarians) preservation is highly variable, though not synchronously.

Foraminifera are absent from Cores 1 through 3 and most of 4. They appear in the lower part of Core 4 and gradually increase in diversity to a peak in Core 10; diversity again decreases downward to the bottom of the hole. Nowhere are foraminifera well preserved, and even the most diverse assemblages do not comprise more than about ten taxa. The foraminifer-bearing section encompasses the zones from the *Globigerina ciperoensis* Zone at the base through the *Globigerinatella insueta* Zone at the top. The preservation and diversity maximum occurs in the *Globorotalia kugleri* Zone. Faunas throughout are dominated by solution-resistant forms such as *Catapsydrax dissimilis* and *Globorotalia siakensis*.

Early and middle Miocene nannofossil assemblages are abundant in Cores 3 through 13, though preservation and diversity are highly variable. Some dissolution is evidenced by scarcity and etching of specimens of *Helicopontosphaera* and *Discolithina* and the absence of *Scyphosphaera*. The section bottoms in the *Dictyococirtes abisectus* Subzone of the *Triquetrorhabdulus carinatus* Zone and is continuous into the *Discoaster exilis* Zone of the middle Miocene.

Radiolarians are present only in Cores 1 through 6. Core 1 contains moderately abundant lower Quaternary radiolarians of the *Anthocyrtidium angulare* Zone. Core 2 contains a few corroded specimens of *Ommatartus penultimus* (Section 4) and *O. antepenultimus* (CC) of late Miocene age, but the assemblages consist mostly of Orosphaerid spines and fragments. Core 3 is devoid of siliceous microfossils. However, Core 4 contains a well-preserved and diverse assemblage of the *Calocycletta costata* Zone (middle Miocene). Cores 5 and 6 are in the Calocycletta virginis zones, but preservation is poor again.

PHYSICAL PROPERTIES

The upper 9 to 19 meters of section from DSDP 159 was disturbed to such a degree that measurement of physical properties was not feasible. In the least disturbed portions of the remainder of the section a number of subsamples were collected for laboratory measurement of physical properties. A few vane shear and fall cone penetrometer tests were also made to complement the standard shipboard tests.

Bulk Density

GRAPE bulk densities (average value per section) range from 1.25 to 1.38 g/cc in the radiolarian and nannofossil clay from 10 to 64 meters, but are commonly lower than 1.30 g/cc. Bulk densities vary from 1.33 to 1.46 g/cc in a transitional zone of nannofossil clay which grades to a nannofossil marl between 54 and 75 meters. The highest GRAPE densities of 1.50 to 1.54 g/cc occur in the nannofossil marl ooze below 75 meters. Low laboratory bulk densities of 1.19 to 1.36 g/cc are found in the upper 54 meters, but increase to 1.44 to 1.52 g/cc in the transitional zone (54 to 75 meters). A slight increase in laboratory bulk density of 1.53 to 1.55 g/cc is found in the nannofossil marl ooze below 75 meters.

Porosity

High GRAPE porosities of 80 to 87 per cent are observed in the upper 54 meters, decreasing from 83 to 76 per cent in the transitional zone between 54 to 75 meters. The lowest GRAPE porosities of 71 to 73 per cent are found below 75 meters. Laboratory porosities of 77 to 89 per cent are highest in the upper 58 meters but decrease slightly from 75 to 72 per cent in the interval, 58 to 75 meters. The lowest laboratory porosities of 69 to 70 per cent are found below 75 meters.

Water Content

Water content is highly variable in the upper 58 meters ranging from 43 to 75 per cent. Below 58 meters, values vary from 45 to 52 per cent. The high variability observed in most of the physical properties in the upper 58 meters of sediment reflects the numerous alternating sequences of radiolarian and nannofossil clay and marl ooze.

Grain Density

The greatest variation in average grain density, 2.59 to 2.88 g/cc, is found in the radiolarian clay and upper nannofossil clay. It is considerably less variable, 2.71 to 2.85 g/cc, below 58 meters in the nannofossil marl ooze. Grain density averages 2.74 g/cc in the upper 58 meters and 2.78 g/cc in the remainder of the section.

Natural Gamma Radiation

Natural gamma radiation (average value per section) measurements indicate that the gamma activity is significantly higher in the upper 27 meters of the section where porosities are relatively higher than even in the lower porosity material below. If volume corrections were made, the gamma readings would be even higher than those shown in the section logs. High radiation counts above 27 meters correlates with the almost total absence of nannofossil and foraminiferal carbonates. The decreasing natural gamma radiation with depth below 27 meters reflects the overall increase in total carbonates with depth.

Sound Velocity

A relatively high degree of scatter exists in the sonic velocity data. This scatter suggests operator error and the use of an inconsistent technique (see Physical Properties Evaluation, this volume). Using only the most reliable data, velocities averaged 1.47 km/sec for the entire sedimentary sequence, but ranged from 1.40 to 1.52 km/sec. The velocity profile indicates an overall decrease with depth through the 107 meter section. The average sonic velocity of 4.89 km/sec for the basalt is based on six measurements.

Shear Strength

A few vane shear and Swedish Fall Cone penetrometer tests were performed on a limited basis due to sediment disturbance throughout much of the section. A vane shear strength of 53 g/cm^2 was recorded for the calcareous clay at a depth of 27 meters. Fall cone measurements average 464 g/cm^2 in the nannofossil clay, 56 to 58 meters, and 605 g/cm^2 in the nannofossil marl ooze at a depth of 58.5 to 59 meters. At a depth of 87 to 88 meters, fall cone measurements averaged 417 g/cm^2 in the nannofossil marl ooze. Four vane shear tests in the nannofossil clay (56 to 58 meters) averaged 357 g/cm^2, revealing significantly lower values than the average fall cone measurements in the same section.

SUMMARY AND DISCUSSION

The single hole drilled at DSDP 159 penetrated 108 meters of pelagic clay and calcareous sediment before entering basaltic basement.

From 0 to 18 meters, the sediment is somewhat siliceous pelagic brown clay, rich in dispersed ferromanganese oxides. Quaternary radiolarians occur throughout the upper 9 meters, but are absent at greater depths. Late Miocene radiolarians at 18 meters provide the only clue to the age of the basal part of the pelagic clay. The paleontologic data suggest a sedimentation rate of about 5 m/m.y. years for the Quaternary, but this value may be too low if the entire Quaternary is not present and is suspect as it is based on a single core. The rate for the Pliocene and Late Miocene is no more than 1.0 m/m.y. years. The abrupt increase in the sedimentation rate at the end of the Tertiary, which at DSDP 159 may be accentuated by one or more hiatuses, is common in the North Pacific. The pelagic clay is characterized by a high natural gamma activity compared to the underlying marl ooze.

From 18 to 71 meters, the sediment changes gradually from calcareous clay with some pelagic brown clay and nannofossil marl to nannofossil marl with subordinate calcareous clay. In contrast to the lithology, both the physical properties and the micropaleontological data indicate a change in character at about 47 meters. All three microfossil groups record zone boundaries at this depth, pointing to a brief hiatus in the late early Miocene, with no radiolarians found at greater depth. This depth also corresponds to slight increases in acoustic velocity and bulk density and slight decreases in natural gamma activity and GRAPE porosity of the sediments.

The lowest portion of the sediment section, from 71 to 108 meters, is a fairly uniform nannofossil marl ooze rich in dark brown ferromanganese aggregates. These aggregates are most abundant just above basement and appear to represent the local equivalent of the "amorphous iron-oxide facies" reported for Legs 5 and 9 (von der Borch and Rex, 1970; Cook, 1972; Cronan, this vol., chapter 18). The basal sediment, of possible latest Oligocene to earliest Miocene age, shows little variation in physical properties. The sedimentation rate, averaged over the entire calcareous interval from 18 to 108 meters, is 7 to 8 m/m.y. yrs. This is low for calcite-rich sediments and emphasizes the influence of dissolution, evident in the depleted microfossil assemblages in this area on the fringe of the equatorial zone of high biological productivity and close to the calcite compensation depth. The evidence points to a rise of the compensation depth at this site about 18 m.y. ago, or a corresponding subsidence of the site area, so that it moved from a position above the compensation depth during the first part of its history to a position below during the latest Cenozoic.

Volcanic basement at this site is a fine-grained altered augite-plagioclase basalt. The samples recovered were originally vesicular and probably glassy so that an extrusive origin is inferred. Such an origin is supported by the absence of evidence of metasomatism and metamorphism of the overlying sediments.

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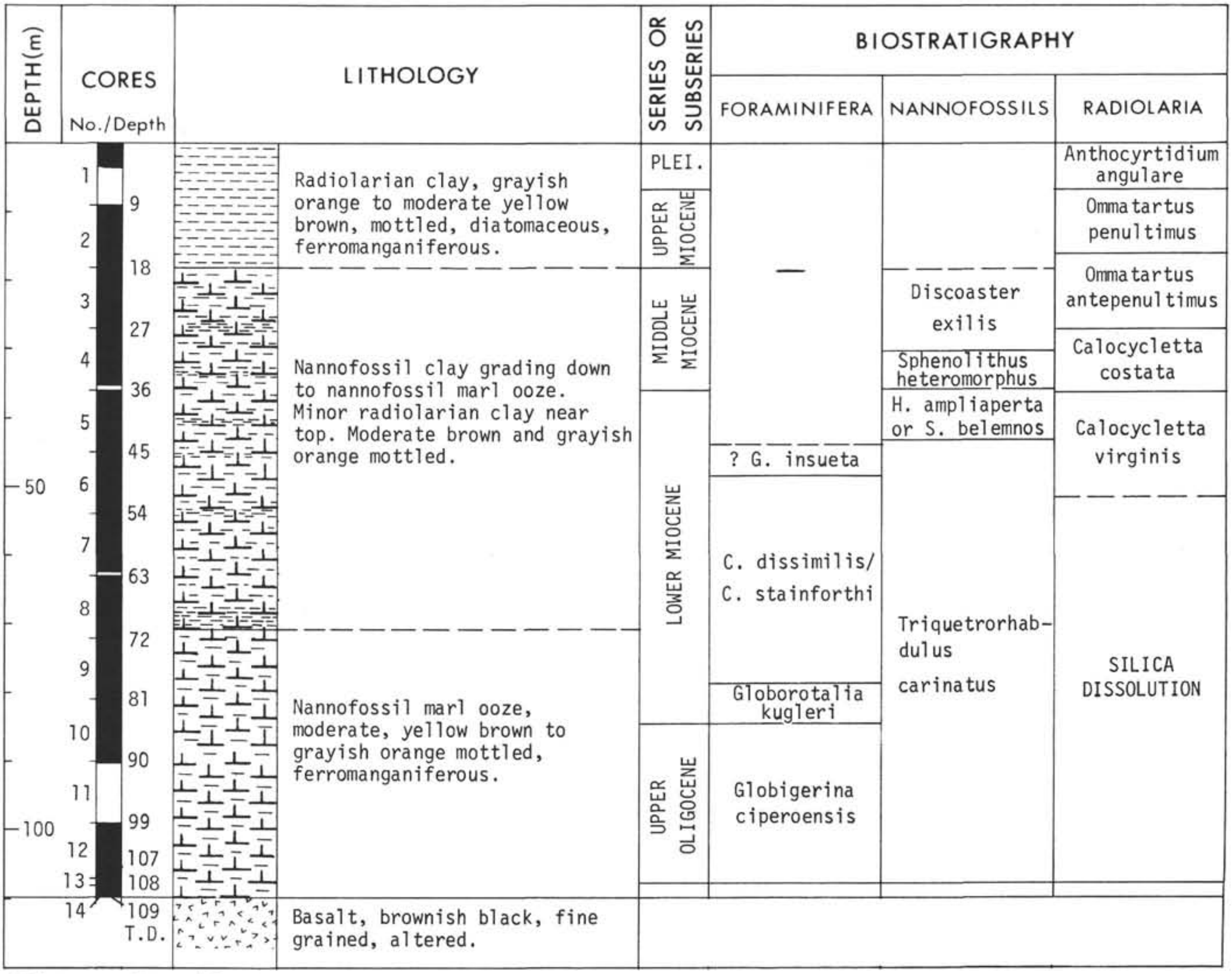
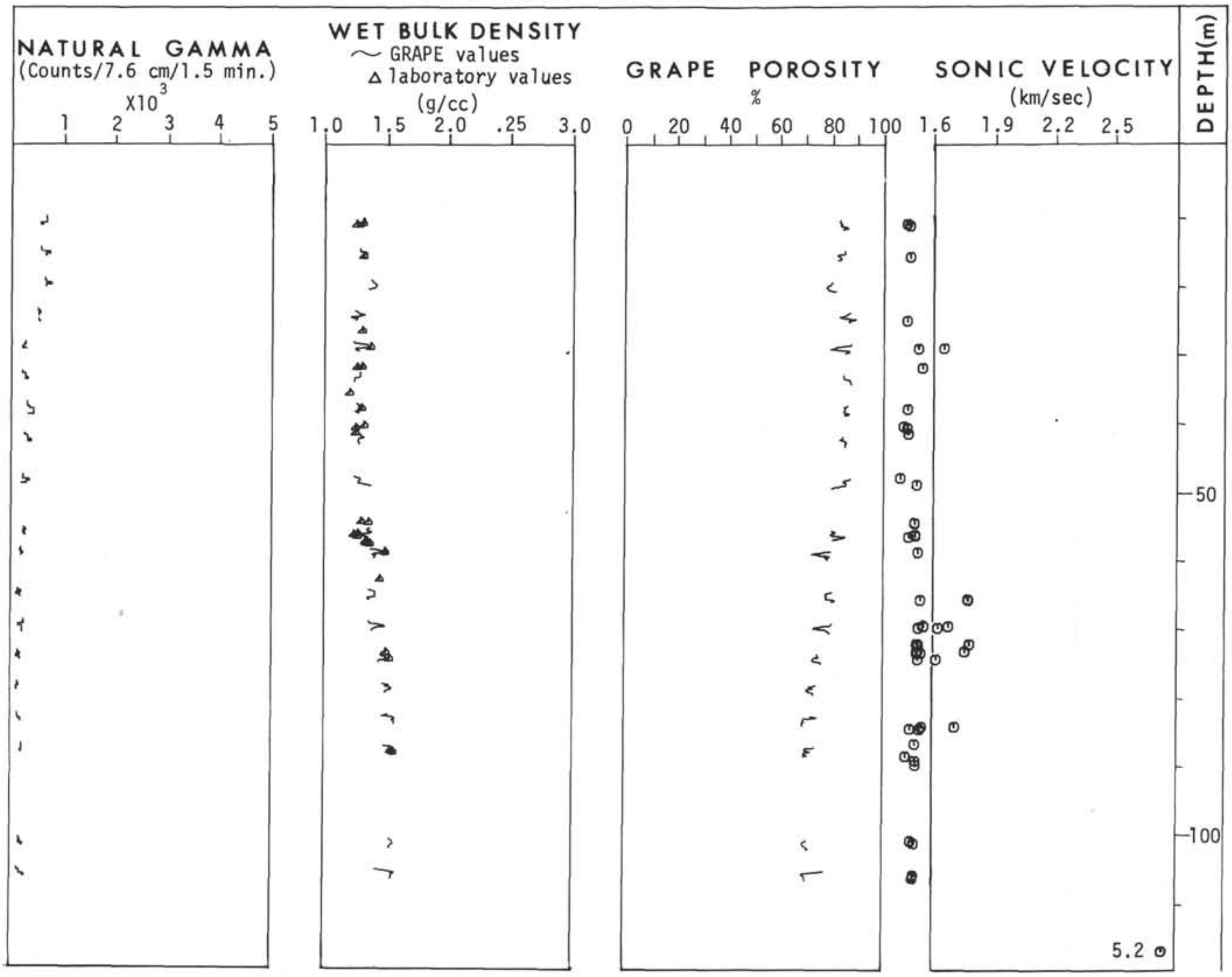


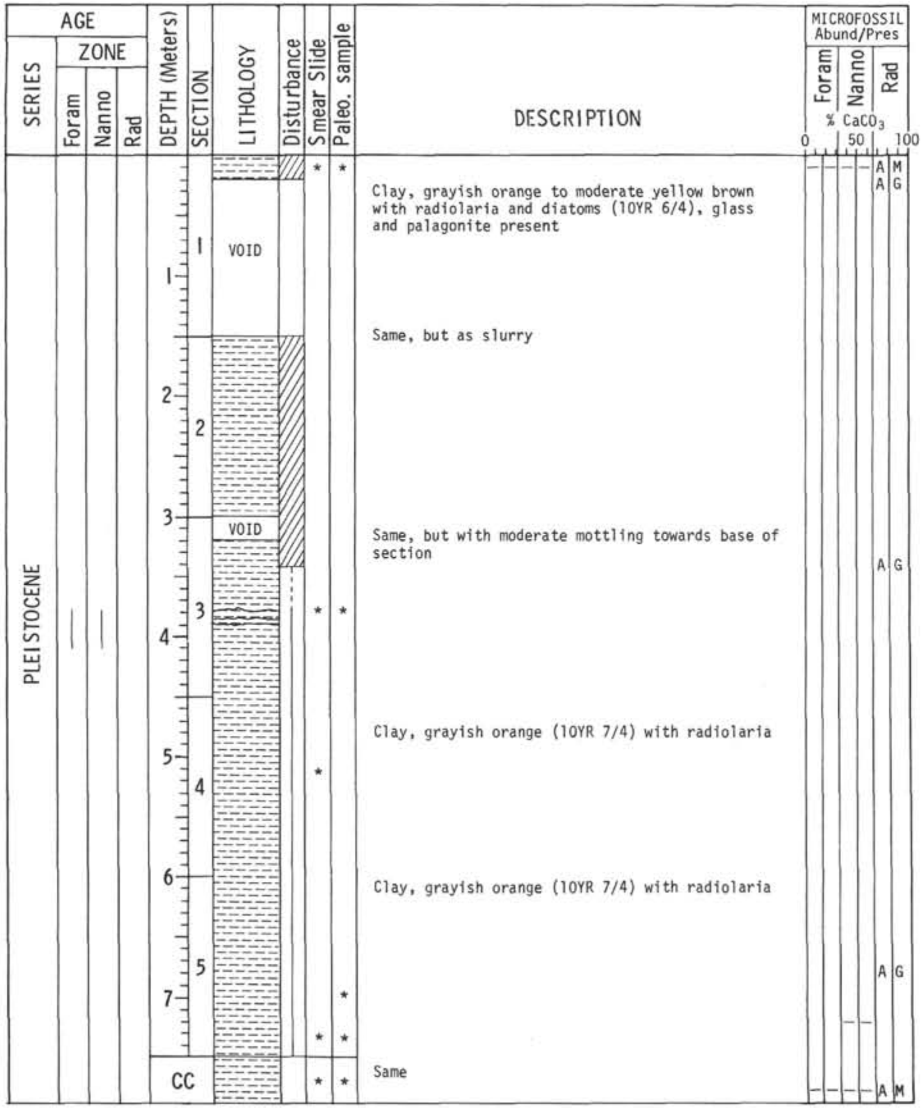
*Dictyococcites abisectus

Figure 5. *DSDP 159, graphic hole summary. Vertical scale 1 cm = 10 m (1:1000).*

PHYSICAL PROPERTIES



SITE: 159 HOLE: CORE: 1 Cored Interval: 0-9 m



Clay, grayish orange to moderate yellow brown with radiolaria and diatoms (10YR 6/4), glass and palagonite present

Same, but as slurry

Same, but with moderate mottling towards base of section

Clay, grayish orange (10YR 7/4) with radiolaria

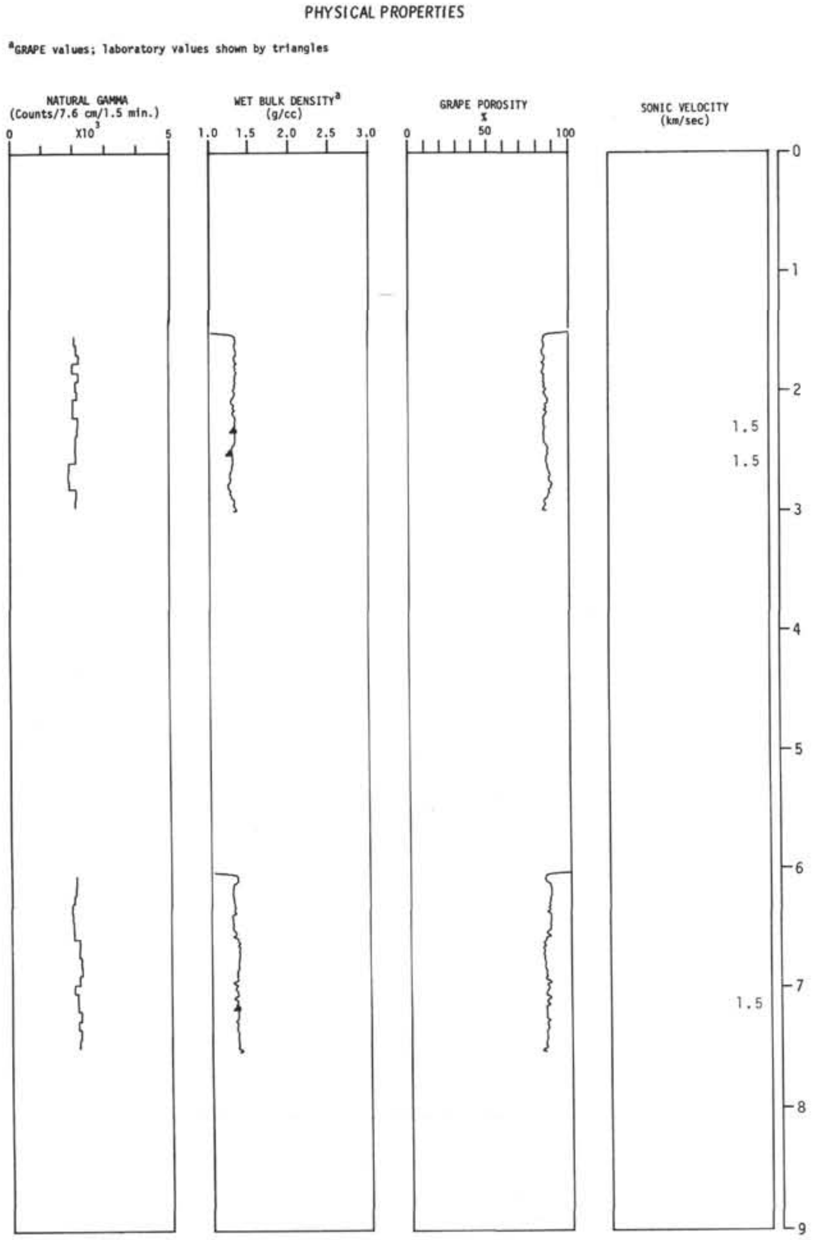
Clay, grayish orange (10YR 7/4) with radiolaria

Same

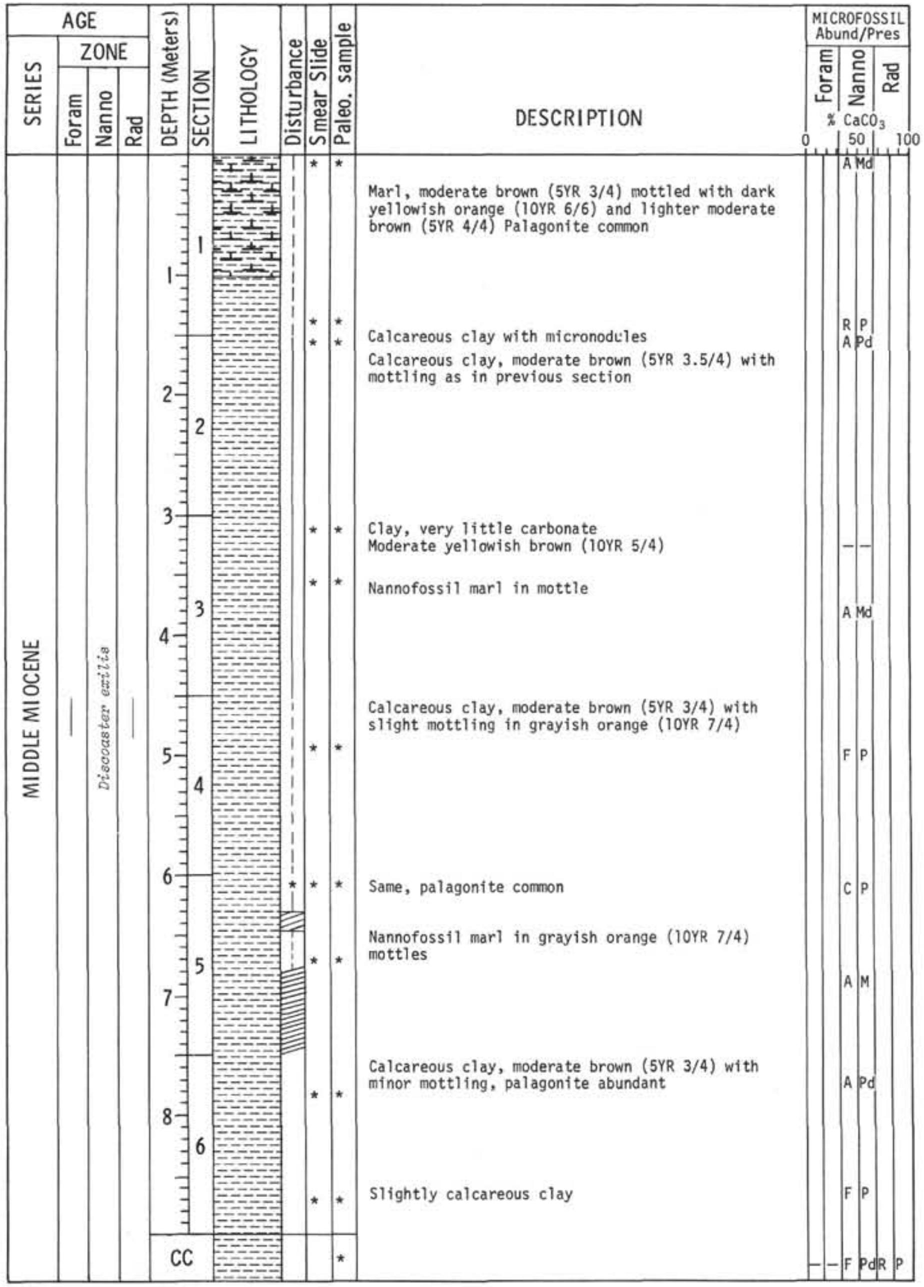
SITE: 159 HOLE: CORE: 2 Cored Interval: 9-18 m

SERIES: UPPER MIOCENE

SECTION	DESCRIPTION	Foram	Nanno	Rad
1	Clay, dark yellowish brown (10YR 4/2) radiolarian, grayish orange mottles (10YR 7/4)		R P	
2	Same, but with less mottling			R Pd
2	Clay, grayish orange (10YR 7/4) with radiolarian fragment			
3	Radiolarian clay, dark yellowish brown (10YR 4/2) with some micronodules and yellowish brown aggregates mottled in grayish orange (10YR 7/4), Palagonite present		R M	R Pd
3–4	Radiolarian clay, grayish orange (10YR 7/4) with streaks and mottles of dark yellow brown (10YR 4/2)		- -	
5	Same, but with several large mottles			
5	Micronodules and amorphous aggregates common		- -	R Pd
6	Clay, dark to dusky yellowish brown (10YR 3/2) amorphous yellow brown aggregates and grayish orange (10YR 7/4) mottles		- -	
6	VOID			
CC	Same, together with abundant aggregates	- -	- -	R P



SITE: 159 HOLE: CORE: 3 Cored Interval: 18-27 m



Marl, moderate brown (5YR 3/4) mottled with dark yellowish orange (10YR 6/6) and lighter moderate brown (5YR 4/4) Palagonite common

Calcareous clay with micronodules

Calcareous clay, moderate brown (5YR 3.5/4) with mottling as in previous section

Clay, very little carbonate
Moderate yellowish brown (10YR 5/4)

Nannofossil marl in mottle

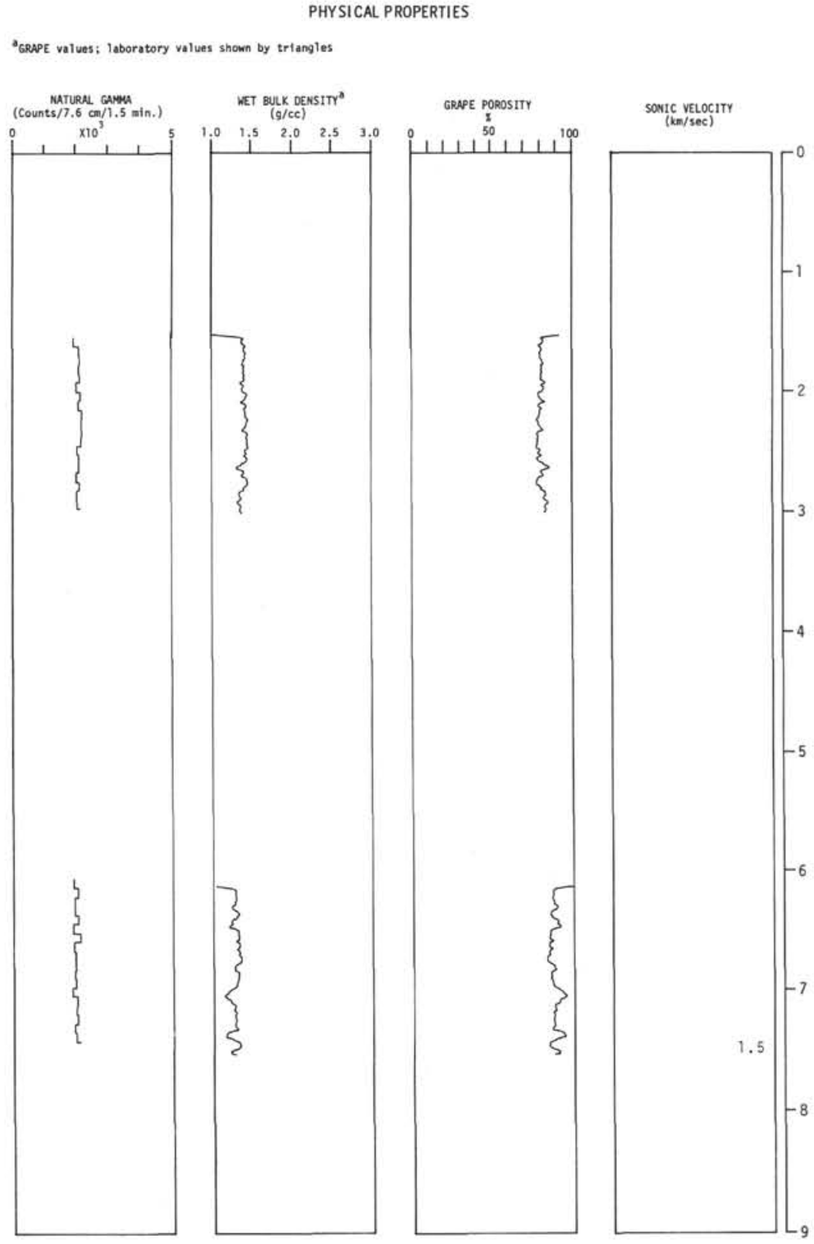
Calcareous clay, moderate brown (5YR 3/4) with slight mottling in grayish orange (10YR 7/4)

Same, palagonite common

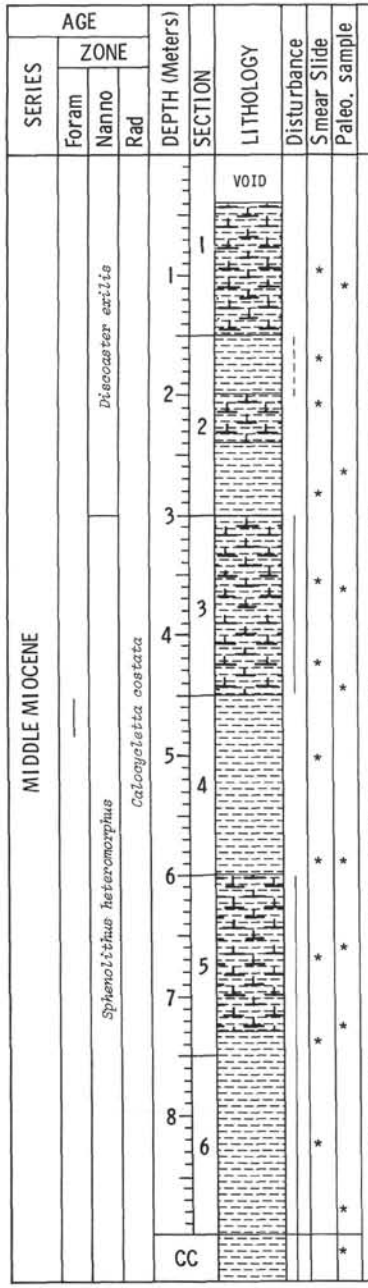
Nannofossil marl in grayish orange (10YR 7/4) mottles

Calcareous clay, moderate brown (5YR 3/4) with minor mottling, palagonite abundant

Slightly calcareous clay



SITE: 159 HOLE: CORE: 4 Cored Interval: 27-36 m



DESCRIPTION

Nannofossil marl, moderate brown (5YR 4/4)

Nannofossil marl, yellowish brown (10YR 5/4), with radiolaria

Clay, moderate brown (5YR 3/4) with radiolarian

Nannofossil marl, grayish orange (10YR 7/4) with minor mottling

Clay, moderate brown (5YR 3/4)

Nannofossil marl, grayish orange (10YR 7/4) mixed with moderate brown (5YR 4/4)

Streaks of nannofossil clay with radiolaria

Radiolarian clay, moderate brown (5YR 3/4) slightly calcareous

Clay, moderate yellowish brown (10YR 5/4) with some mottling. Glass common

Clay, dark yellowish orange (10YR 6/6)

Nannofossil marl, moderate yellowish brown (10YR 5/4) to moderate brown (5YR 3/4) with radiolaria

Nannofossil clay, moderate brown (5YR 3/4) with radiolaria

Yellow-brown aggregates common

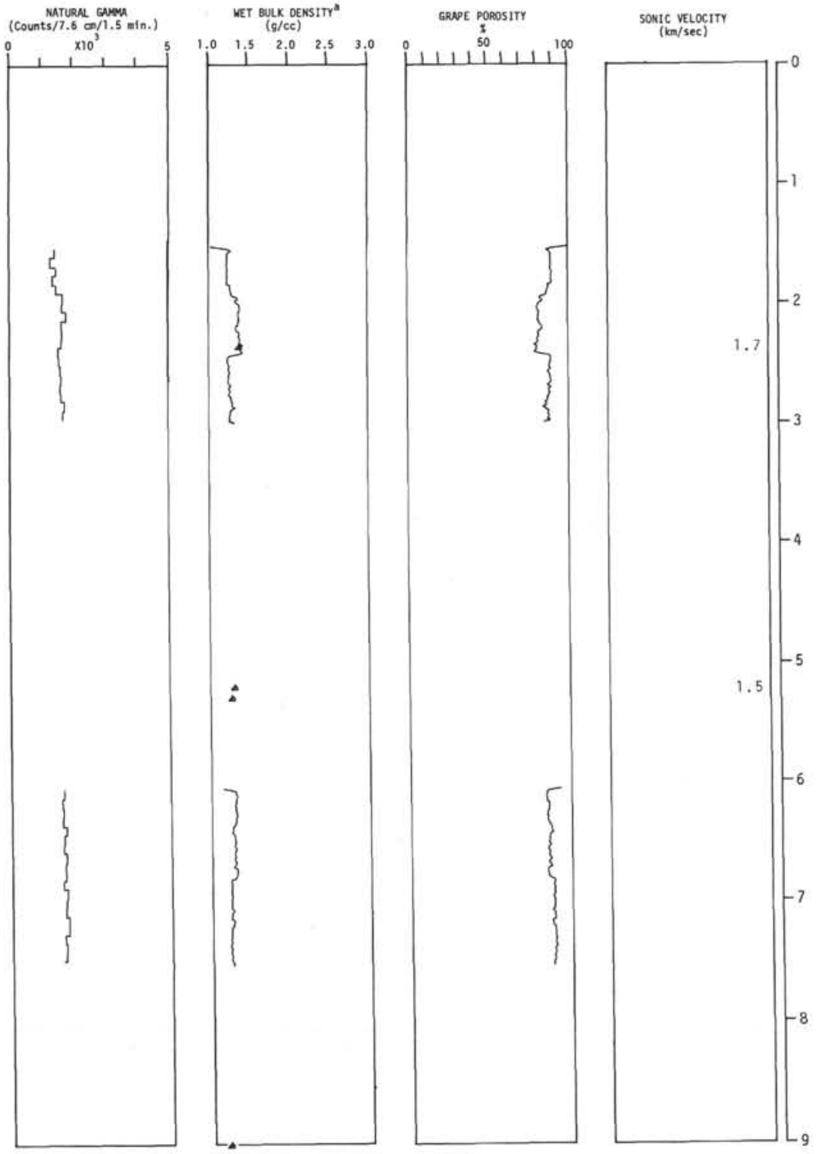
MICROFOSSIL Abund/Pres

Foram		Nanno		Rad	
		F	M	A	G
		A	M		
				A	M
		A	G		
		F	P		
				A	M
		A	P		
		A	P		
R	Pd	A	M	A	G

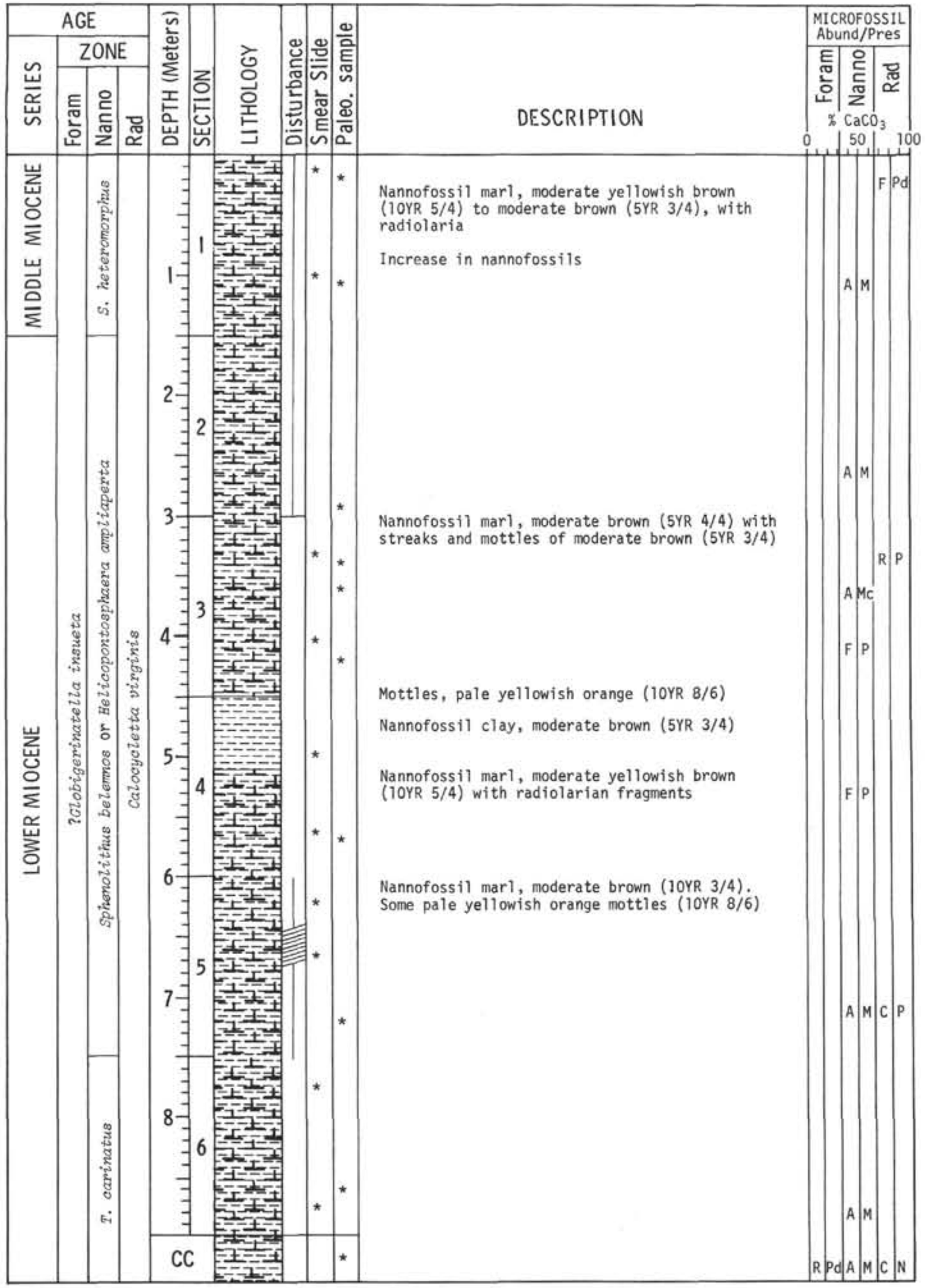
% CaCO$_3$ 0 50 100

PHYSICAL PROPERTIES

^{a}GRAPE values; laboratory values shown by triangles



SITE: 159 HOLE: CORE: 5 Cored Interval: 36-45 m



Nannofossil marl, moderate yellowish brown (10YR 5/4) to moderate brown (5YR 3/4), with radiolaria

Increase in nannofossils

Nannofossil marl, moderate brown (5YR 4/4) with streaks and mottles of moderate brown (5YR 3/4)

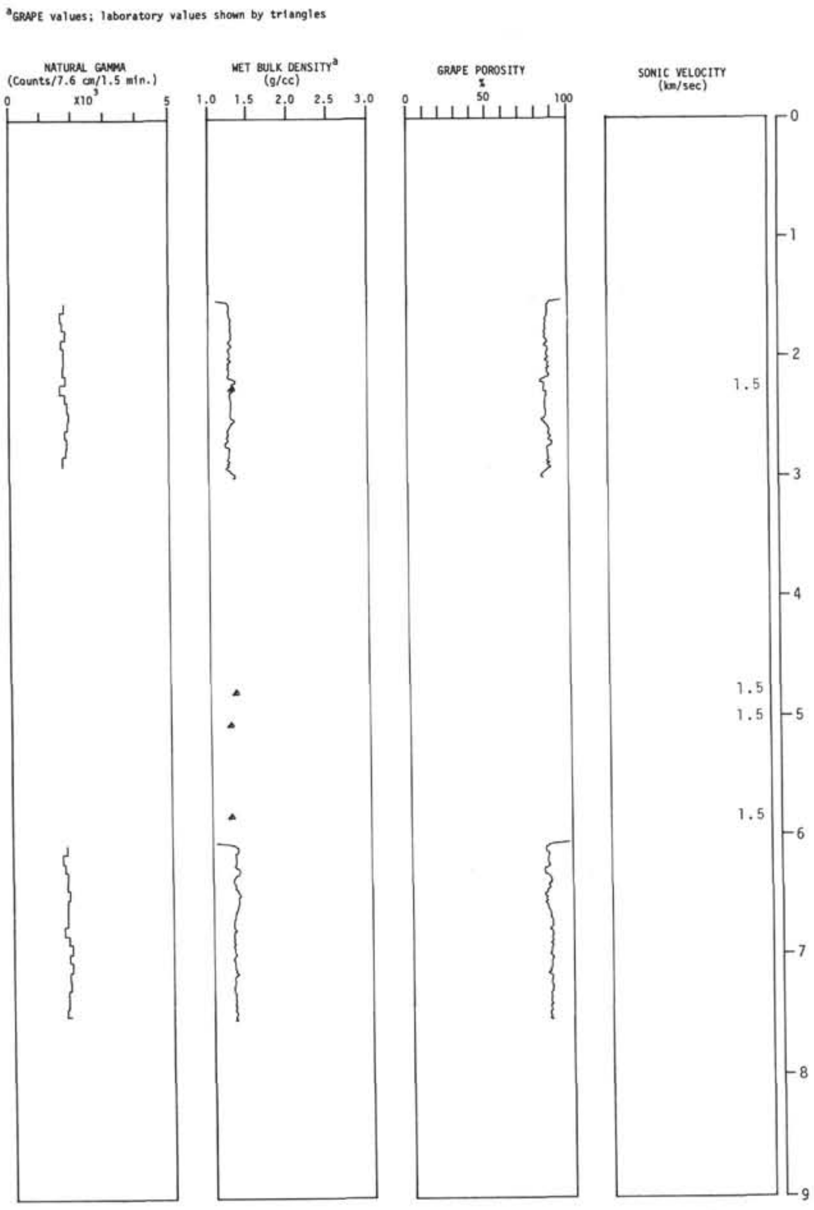
Mottles, pale yellowish orange (10YR 8/6)

Nannofossil clay, moderate brown (5YR 3/4)

Nannofossil marl, moderate yellowish brown (10YR 5/4) with radiolarian fragments

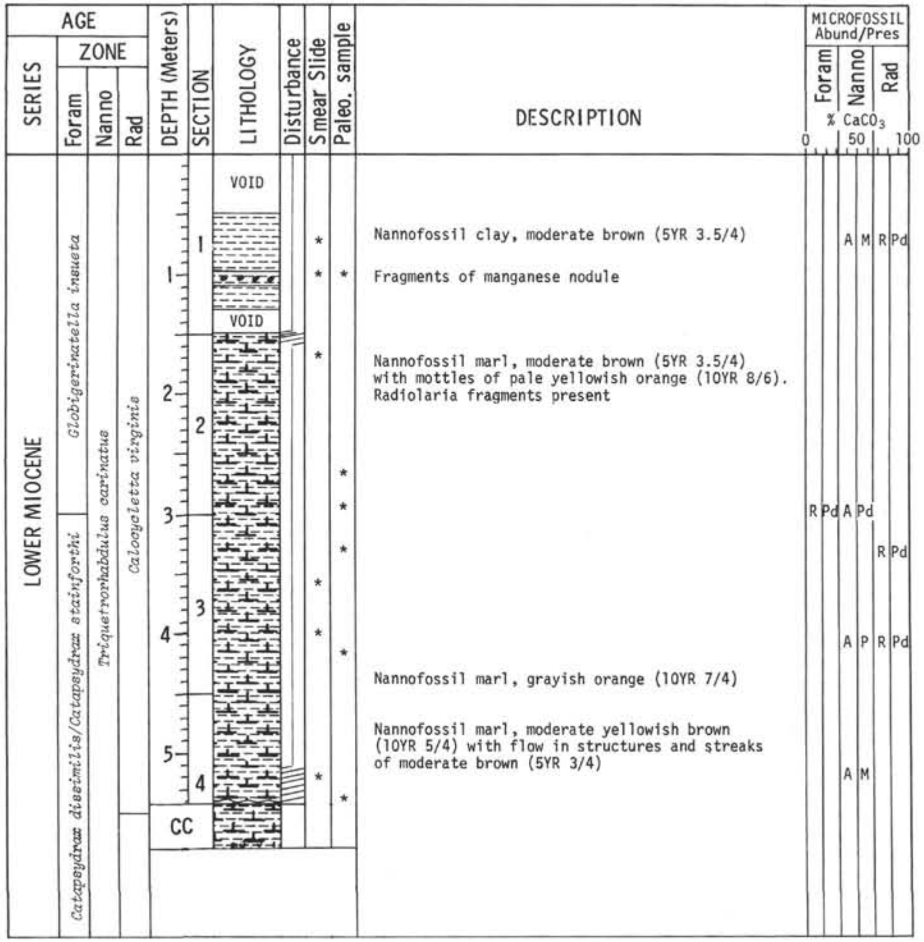
Nannofossil marl, moderate brown (10YR 3/4). Some pale yellowish orange mottles (10YR 8/6)

PHYSICAL PROPERTIES



^a GRAPE values; laboratory values shown by triangles

SITE: 159 HOLE: CORE: 6 Cored Interval: 45-54 m



Nannofossil clay, moderate brown (5YR 3.5/4)

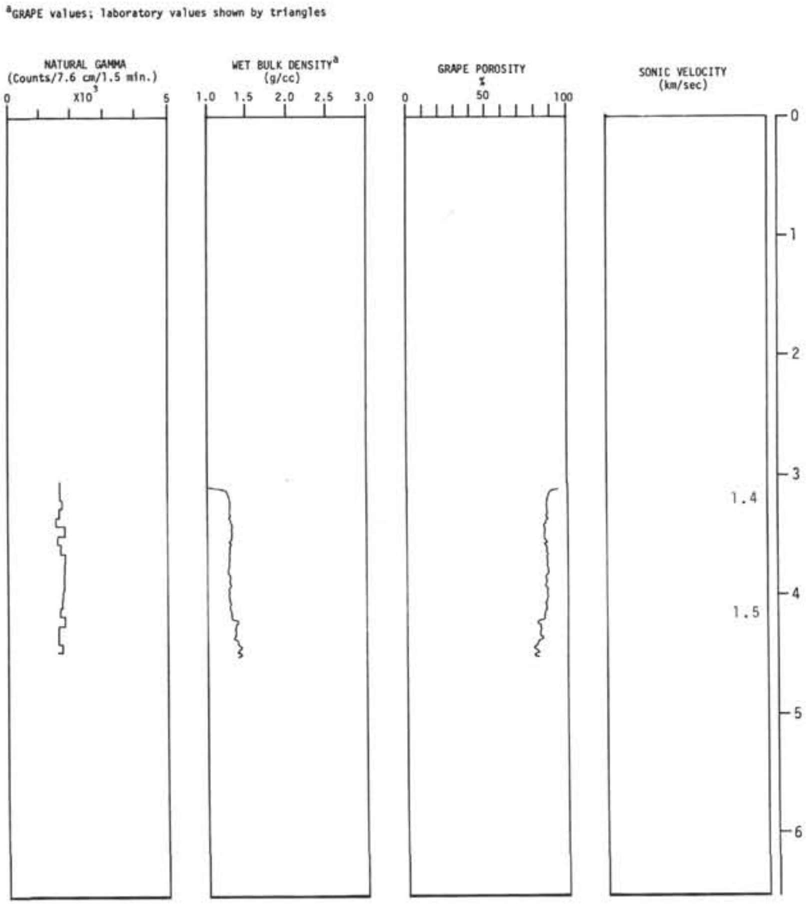
Fragments of manganese nodule

Nannofossil marl, moderate brown (5YR 3.5/4) with mottles of pale yellowish orange (10YR 8/6). Radiolaria fragments present

Nannofossil marl, grayish orange (10YR 7/4)

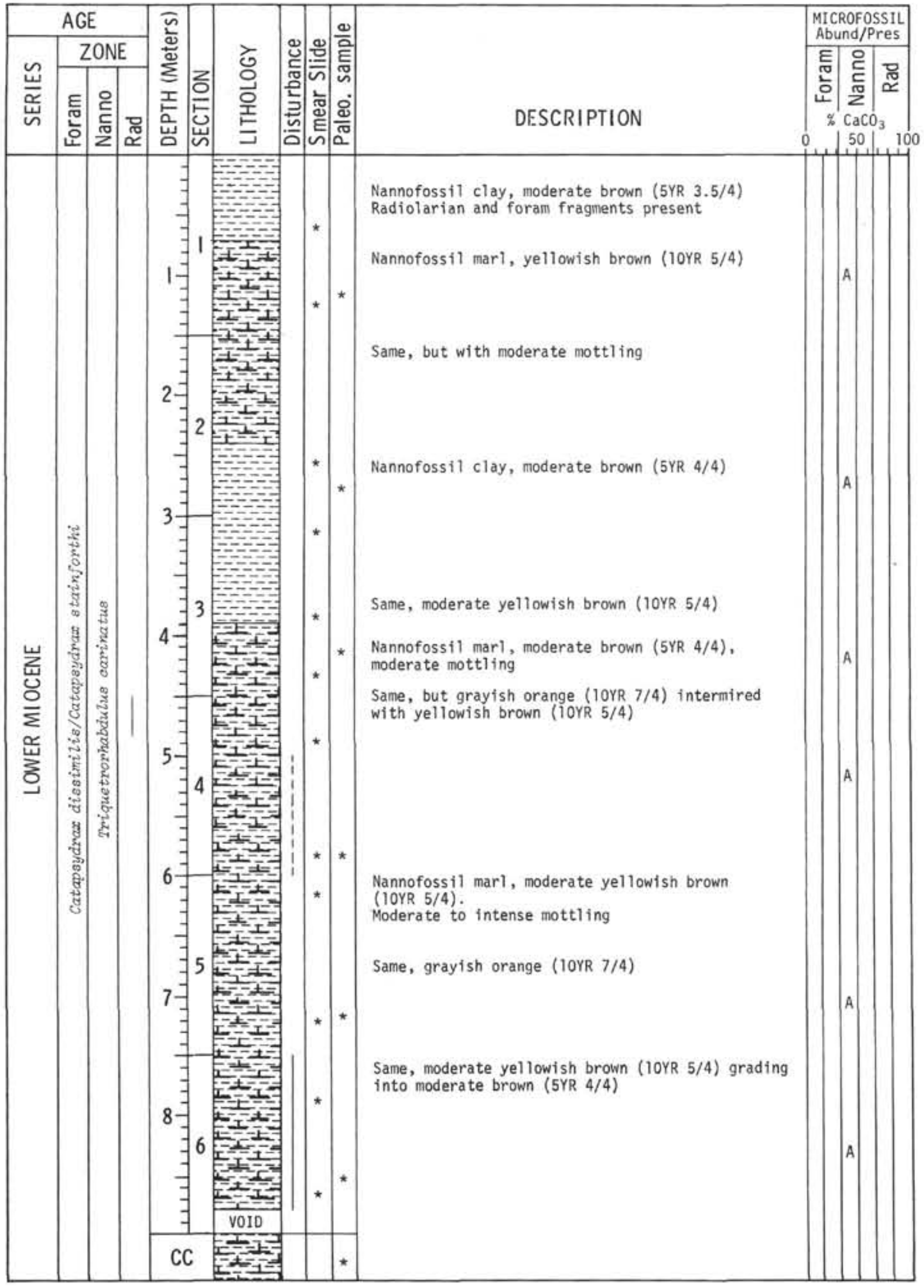
Nannofossil marl, moderate yellowish brown (10YR 5/4) with flow in structures and streaks of moderate brown (5YR 3/4)

PHYSICAL PROPERTIES



^{a}GRAPE values; laboratory values shown by triangles

SITE: 159 HOLE: CORE: 7 Cored Interval: 54-63 m



Nannofossil clay, moderate brown (5YR 3.5/4)
Radiolarian and foram fragments present

Nannofossil marl, yellowish brown (10YR 5/4)

Same, but with moderate mottling

Nannofossil clay, moderate brown (5YR 4/4)

Same, moderate yellowish brown (10YR 5/4)

Nannofossil marl, moderate brown (5YR 4/4), moderate mottling

Same, but grayish orange (10YR 7/4) intermired with yellowish brown (10YR 5/4)

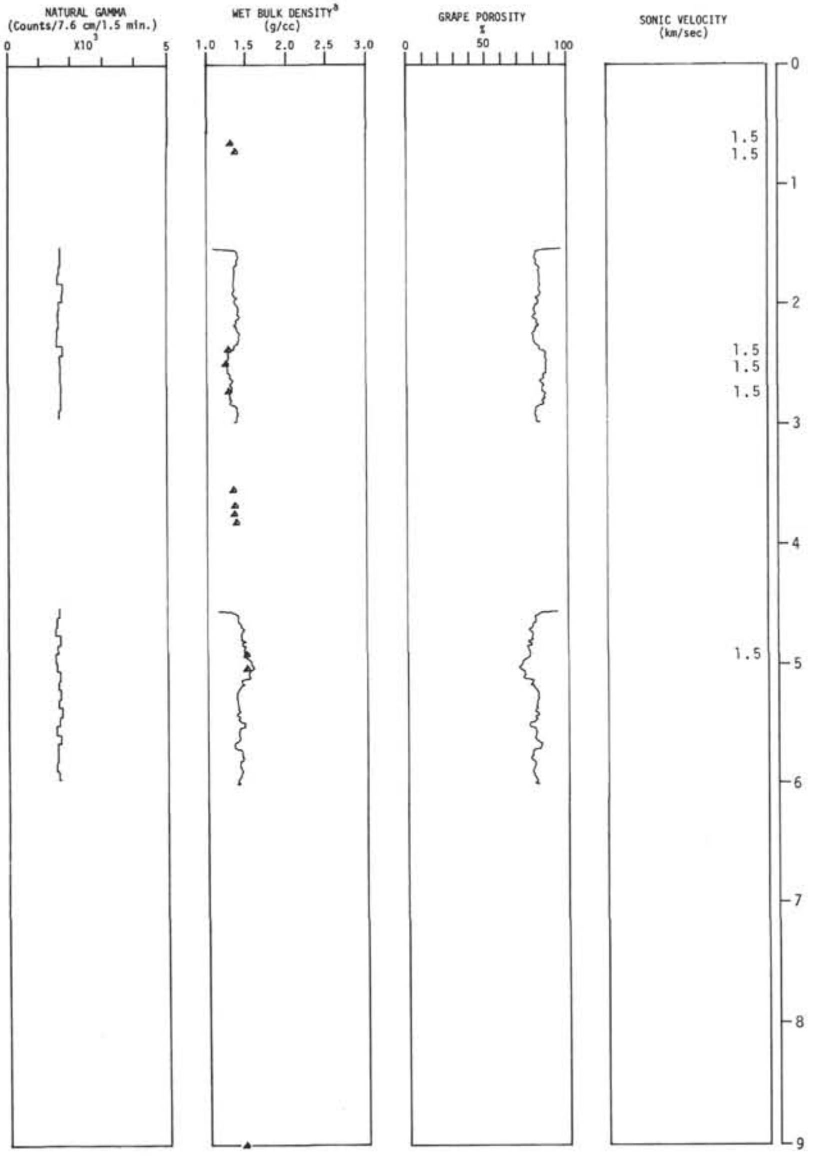
Nannofossil marl, moderate yellowish brown (10YR 5/4).
Moderate to intense mottling

Same, grayish orange (10YR 7/4)

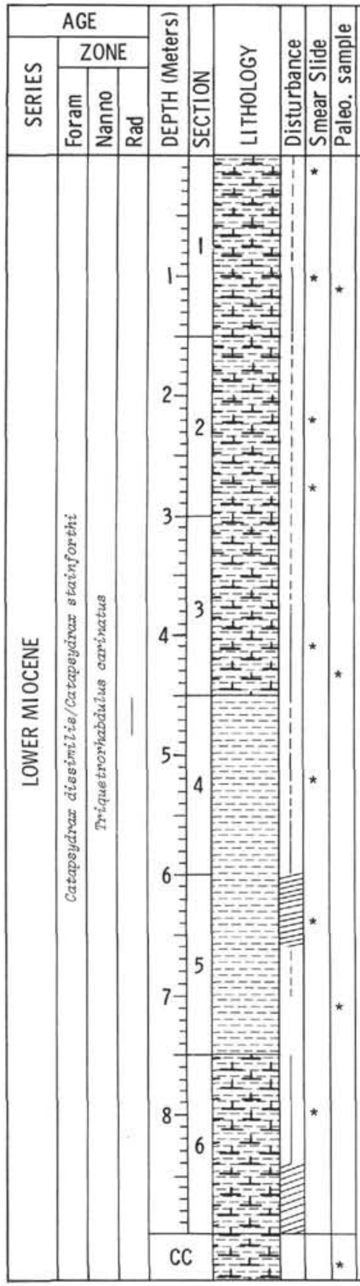
Same, moderate yellowish brown (10YR 5/4) grading into moderate brown (5YR 4/4)

PHYSICAL PROPERTIES

[a] GRAPE values; laboratory values shown by triangles



SITE: 159 HOLE: CORE: 8 Cored Interval: 63-72 m



DESCRIPTION

Nannofossil marl, grayish orange (10YR 7/4)

Same, moderate yellowish brown (10YR 5/4) with streaks and flow in structures

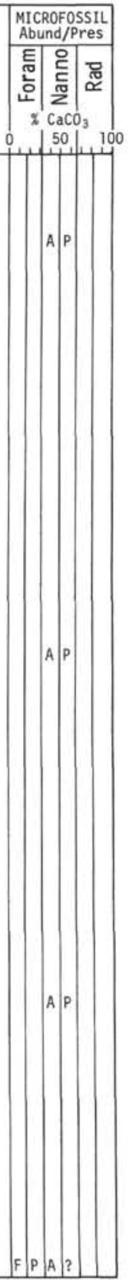
Same, but with patches of moderate brown (5YR 3/4)

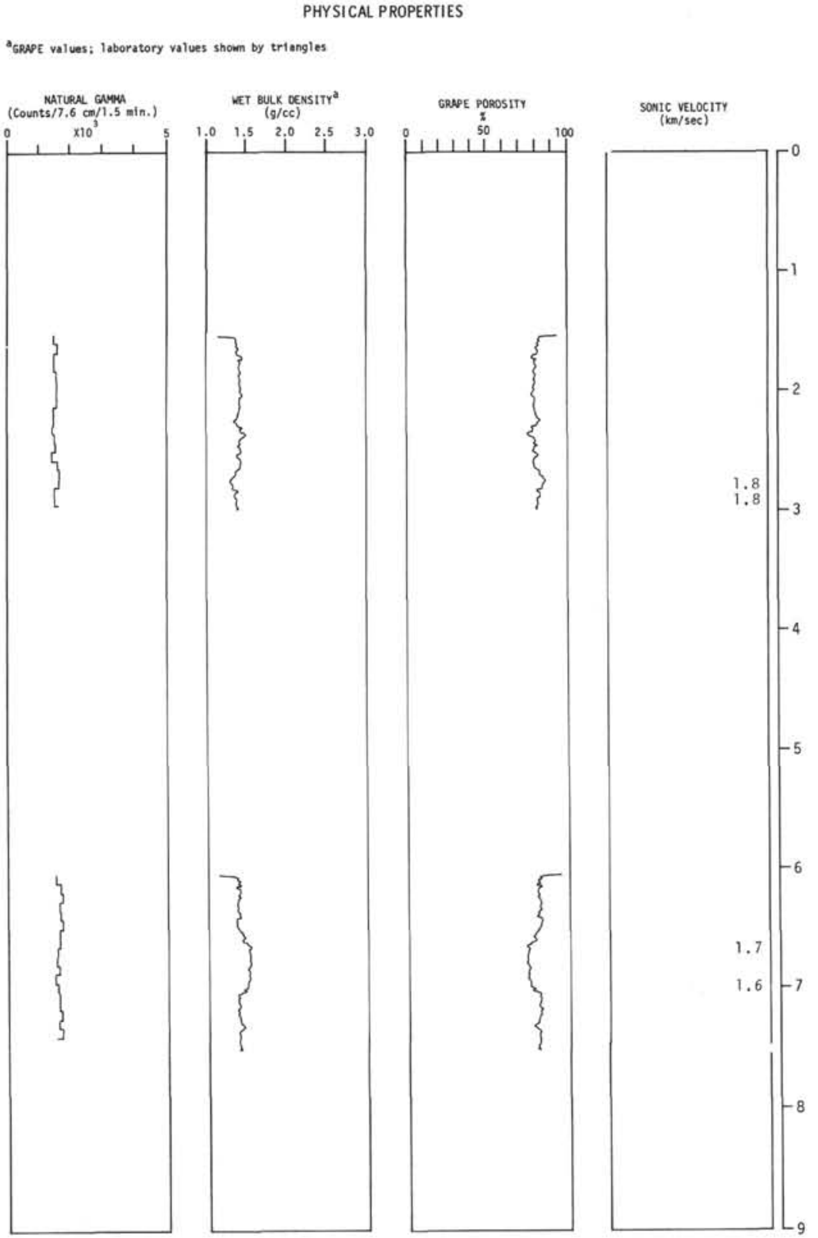
Nannofossil marl, alternations of moderate brown (5YR 4/4) and moderate yellowish brown (10YR 5/4) with mottles and streaks of nannoplankton clay

Nannofossil clay, moderate yellowish brown (10YR 5/4) to moderate brown (5YR 4/4) grading down into grayish orange (10YR 7/4). Patches of nannofossil marl.

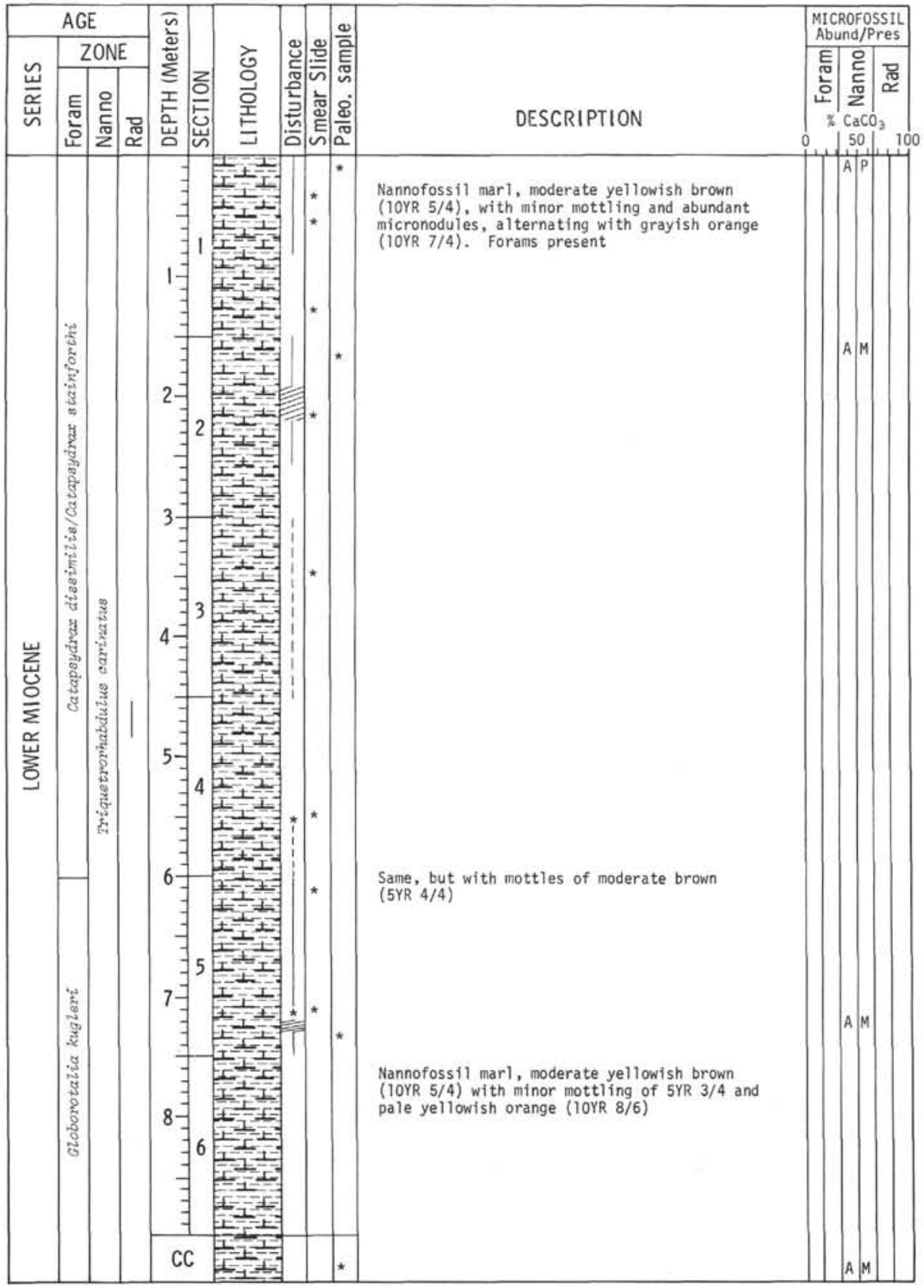
Nannofossil marl, moderate yellowish brown (10YR 5/4), grading down through moderate brown (5YR 4/4) and back to (10YR 5/4). Mixed 5YR 4/4 and 10YR 10/4

Mixed 5YR 4/4 and 10YR 10/4
Light glass present





SITE: 159 HOLE: CORE: 9 Cored Interval: 72-81 m



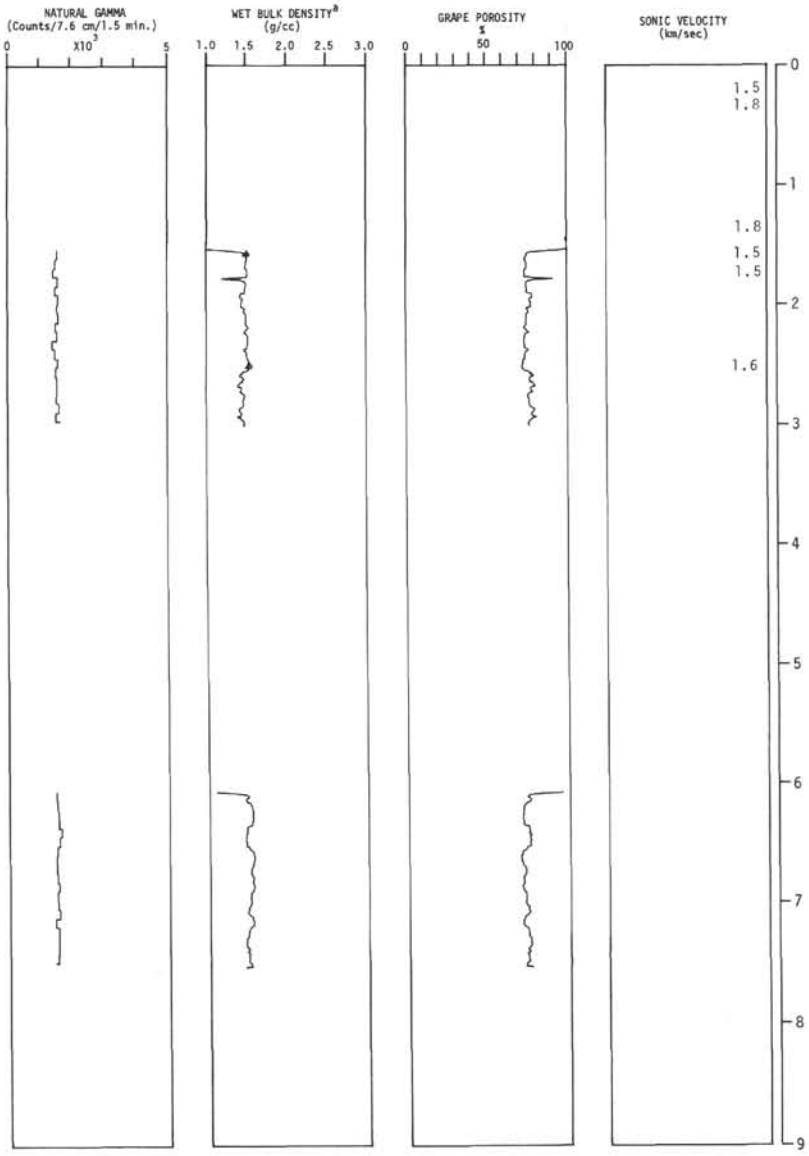
Nannofossil marl, moderate yellowish brown (10YR 5/4), with minor mottling and abundant micronodules, alternating with grayish orange (10YR 7/4). Forams present

Same, but with mottles of moderate brown (5YR 4/4)

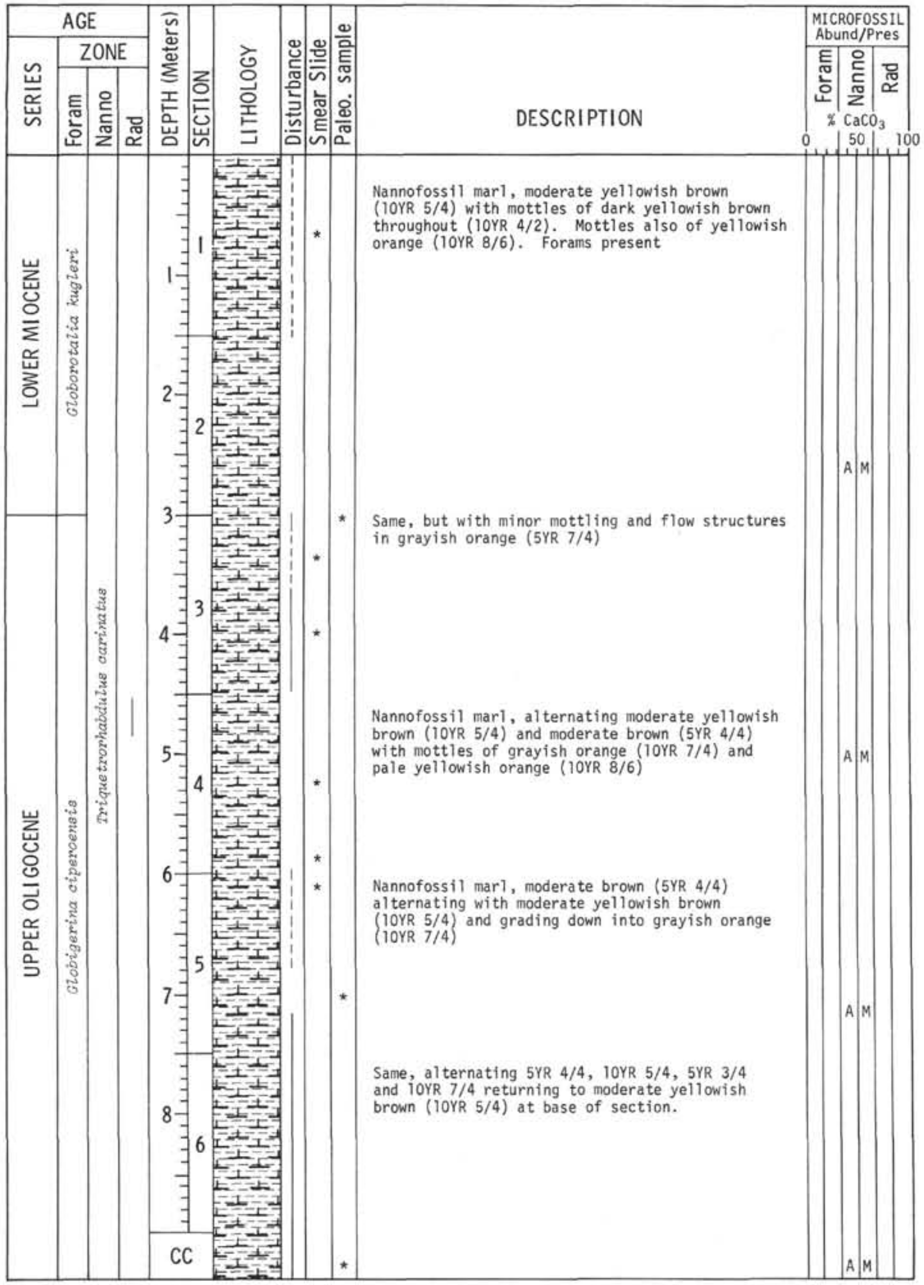
Nannofossil marl, moderate yellowish brown (10YR 5/4) with minor mottling of 5YR 3/4 and pale yellowish orange (10YR 8/6)

PHYSICAL PROPERTIES

aGRAPE values; laboratory values shown by triangles



SITE: 159 HOLE: CORE: 10 Cored Interval: 81-90 m



Nannofossil marl, moderate yellowish brown (10YR 5/4) with mottles of dark yellowish brown throughout (10YR 4/2). Mottles also of yellowish orange (10YR 8/6). Forams present

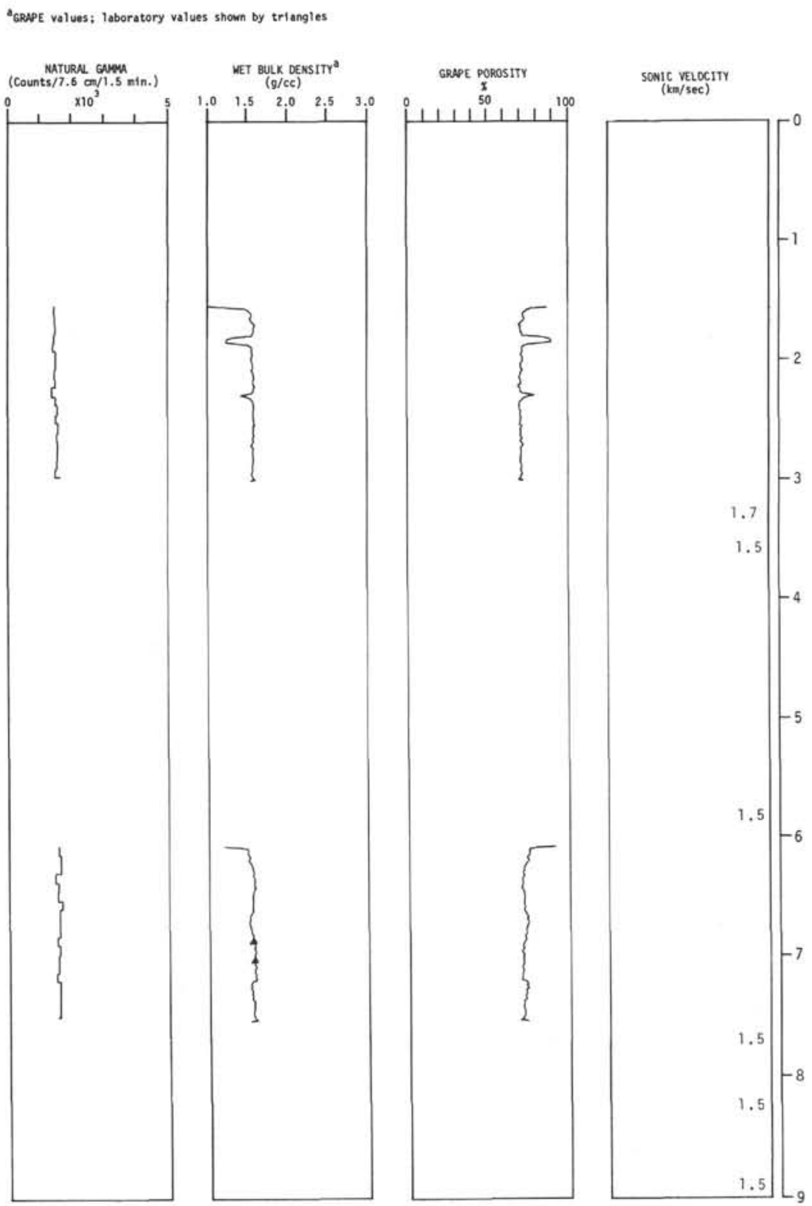
Same, but with minor mottling and flow structures in grayish orange (5YR 7/4)

Nannofossil marl, alternating moderate yellowish brown (10YR 5/4) and moderate brown (5YR 4/4) with mottles of grayish orange (10YR 7/4) and pale yellowish orange (10YR 8/6)

Nannofossil marl, moderate brown (5YR 4/4) alternating with moderate yellowish brown (10YR 5/4) and grading down into grayish orange (10YR 7/4)

Same, alternating 5YR 4/4, 10YR 5/4, 5YR 3/4 and 10YR 7/4 returning to moderate yellowish brown (10YR 5/4) at base of section.

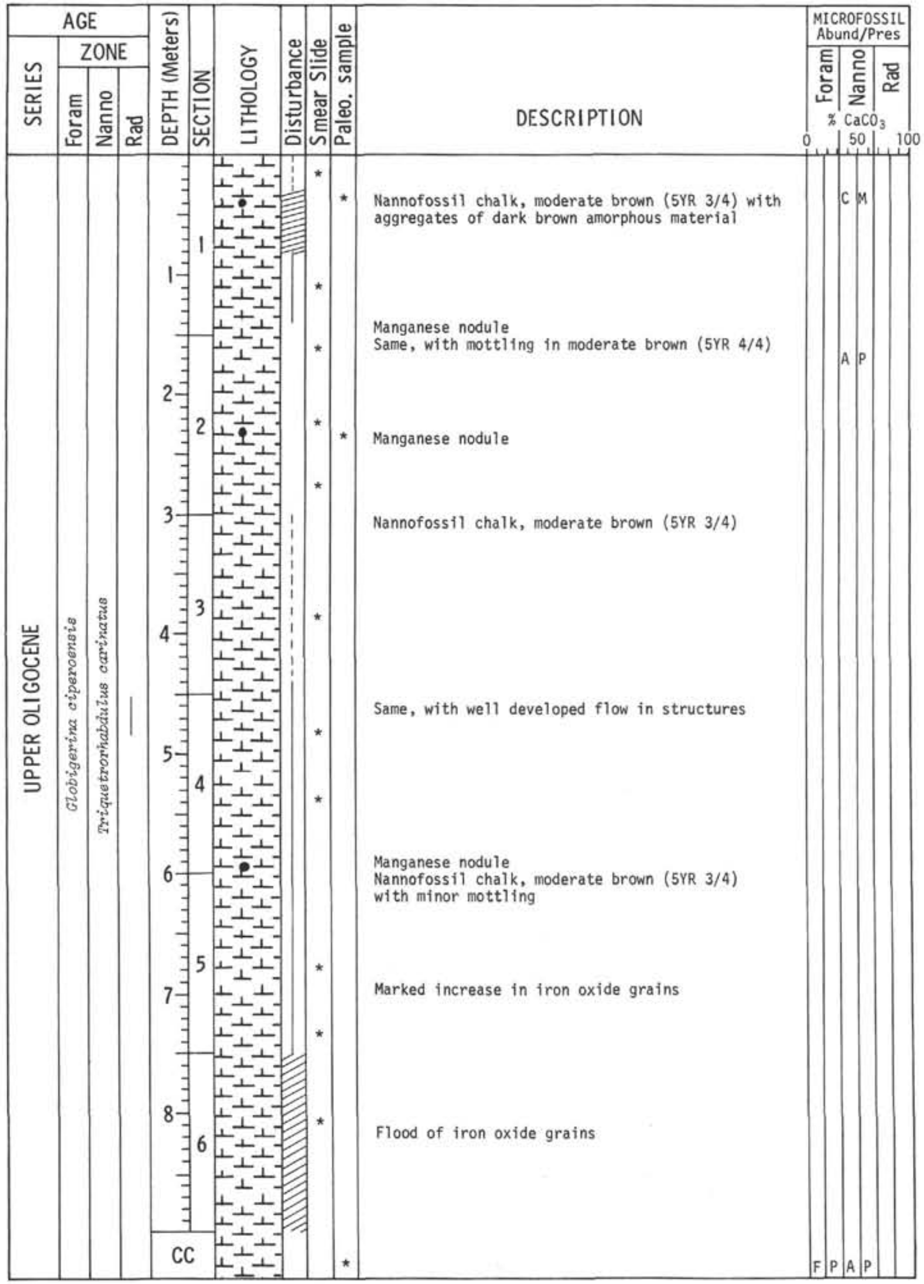
PHYSICAL PROPERTIES



SITE: 159 HOLE: CORE: 11 Cored Interval: 90-99 m

AGE				DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres		
SERIES	ZONE										Foram	Nanno	Rad
	Foram	Nanno	Rad								% $CaCO_3$ 0	50	100
U. OLIGOCENE	*G. ciperoensis*	*T. carinatus*	—	CC	▨			*	*	Nannofossil marl, dark yellowish brown (10YR 4/2) to moderate yellowish brown (10YR 5/4). Iron oxide grains common, and some small macronodules present		A M	

SITE: 159 HOLE: CORE: 12 Cored Interval: 99-107 m



Nannofossil chalk, moderate brown (5YR 3/4) with aggregates of dark brown amorphous material

Manganese nodule
Same, with mottling in moderate brown (5YR 4/4)

Manganese nodule

Nannofossil chalk, moderate brown (5YR 3/4)

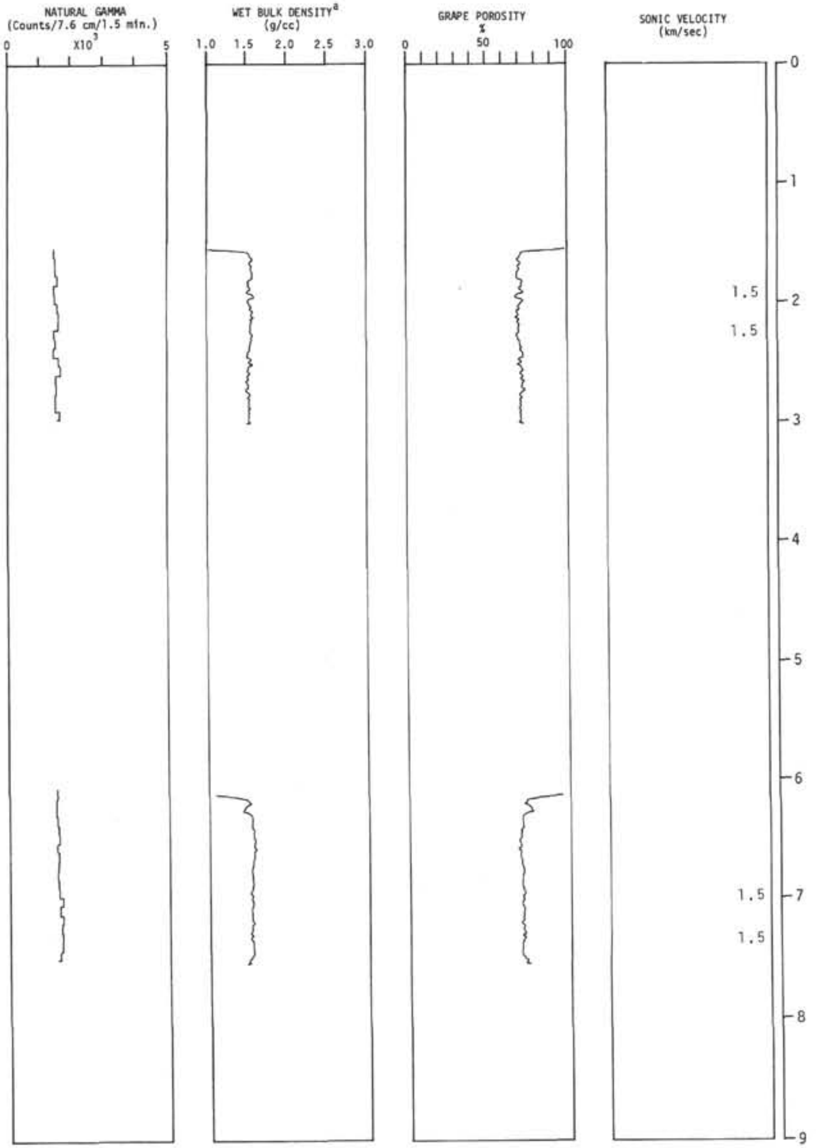
Same, with well developed flow in structures

Manganese nodule
Nannofossil chalk, moderate brown (5YR 3/4) with minor mottling

Marked increase in iron oxide grains

Flood of iron oxide grains

PHYSICAL PROPERTIES



^a GRAPE values; laboratory values shown by triangles

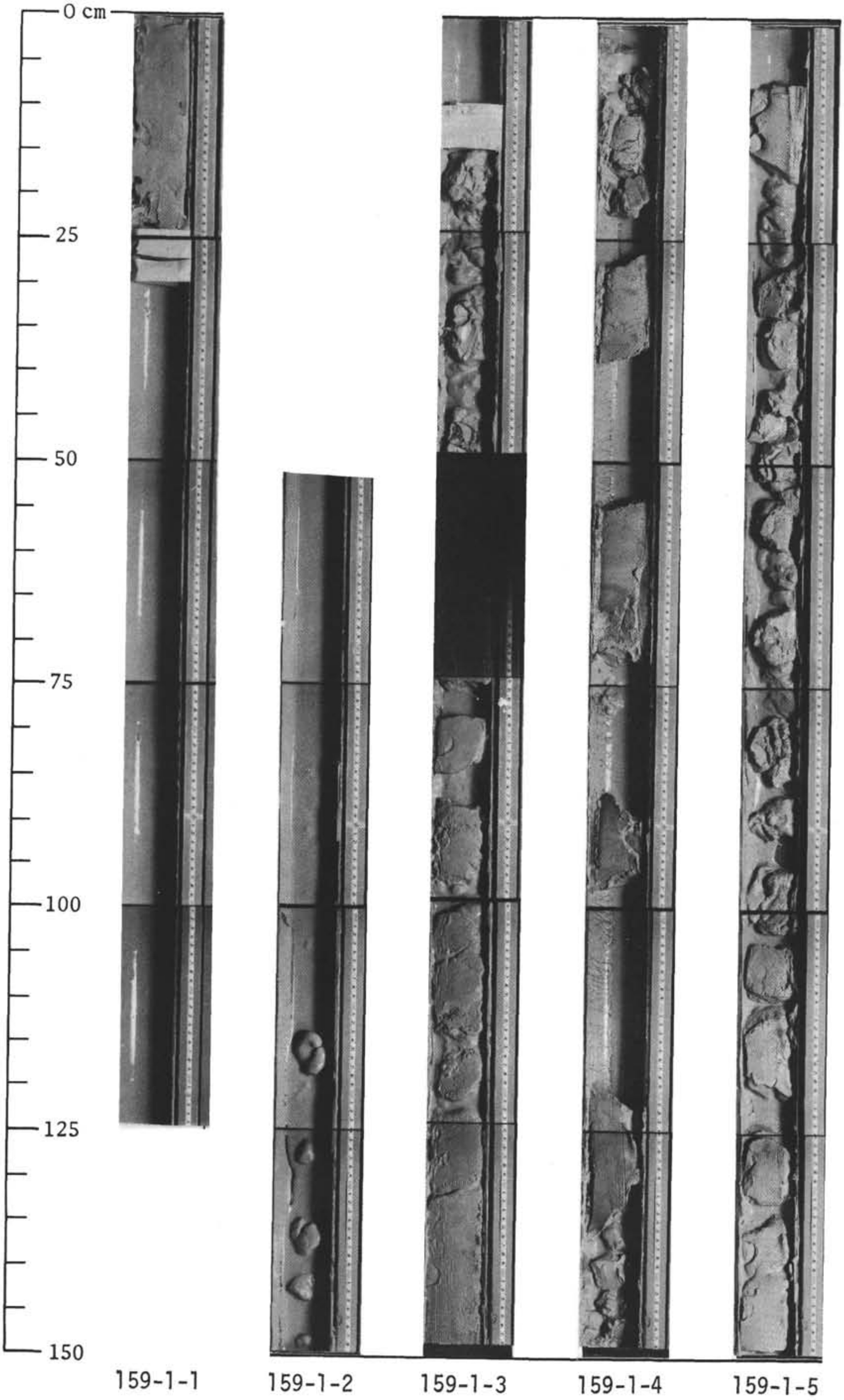
SITE: 159 HOLE: CORE: 13 Cored Interval: 107-108 m

AGE				DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres		
SERIES	ZONE										Foram	Nanno	Rad
	Foram	Nanno	Rad								% $CaCO_3$ 0 50 100		
UPPER OLIGOCENE	—	*S. ciperoensis* or *T. carinatus*		CC						Drill cuttings and slurry, moderate brown (5YR3/4). No core Coarse fraction, amygdaloidal glass, calcite, basalt	R P	A M	A P

SITE: 159 HOLE: CORE: 14 Cored Interval: 108-109 m

AGE				DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres		
SERIES	ZONE										Foram	Nanno	Rad
	Foram	Nanno	Rad								% $CaCO_3$ 0 50 100		
				CC						Basalt, color between brownish gray (5YR 4/1) and brownish black (5YR 2/1)			

Sonic Velocity (km/sec) 5.3; CC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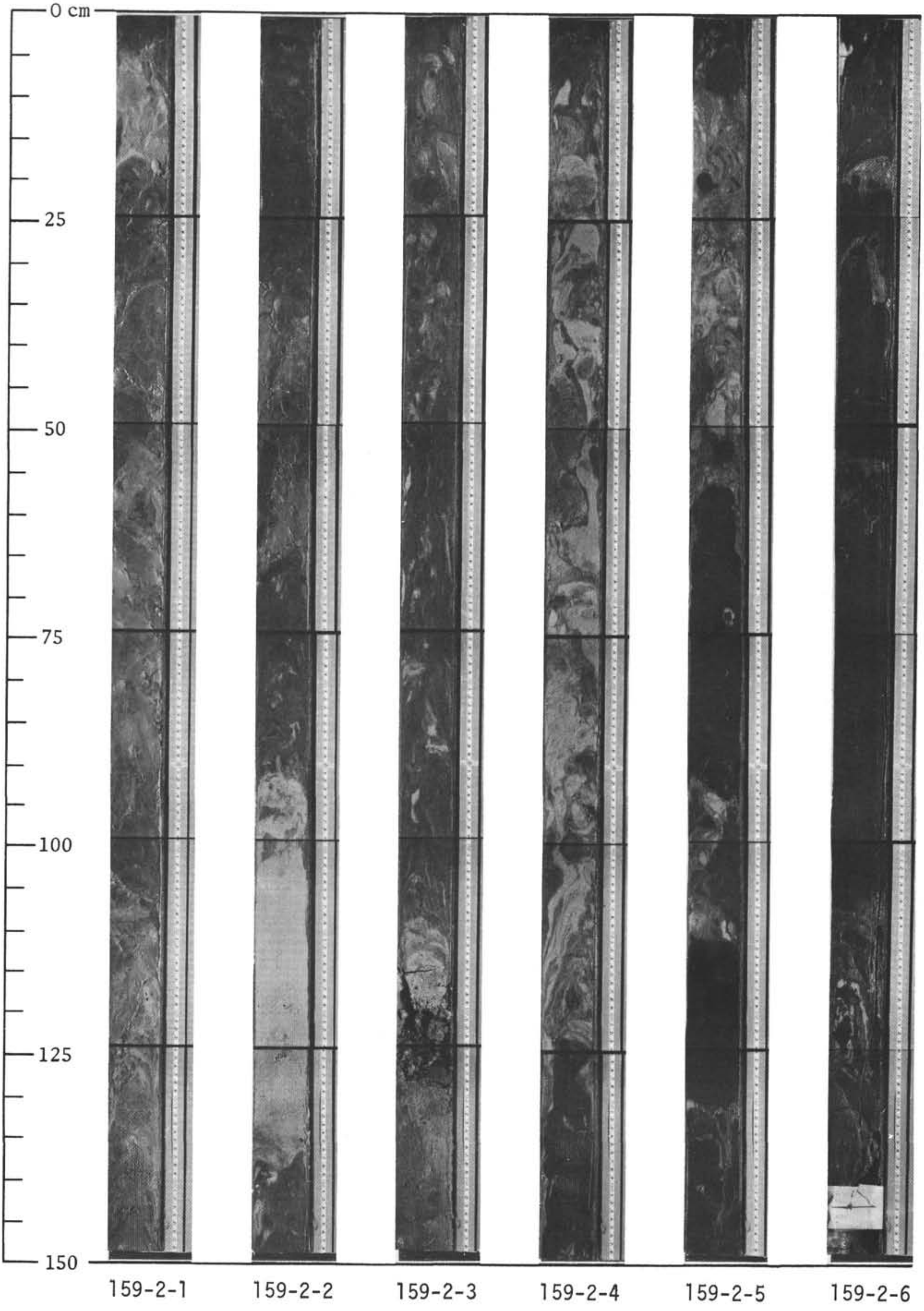
159-1-5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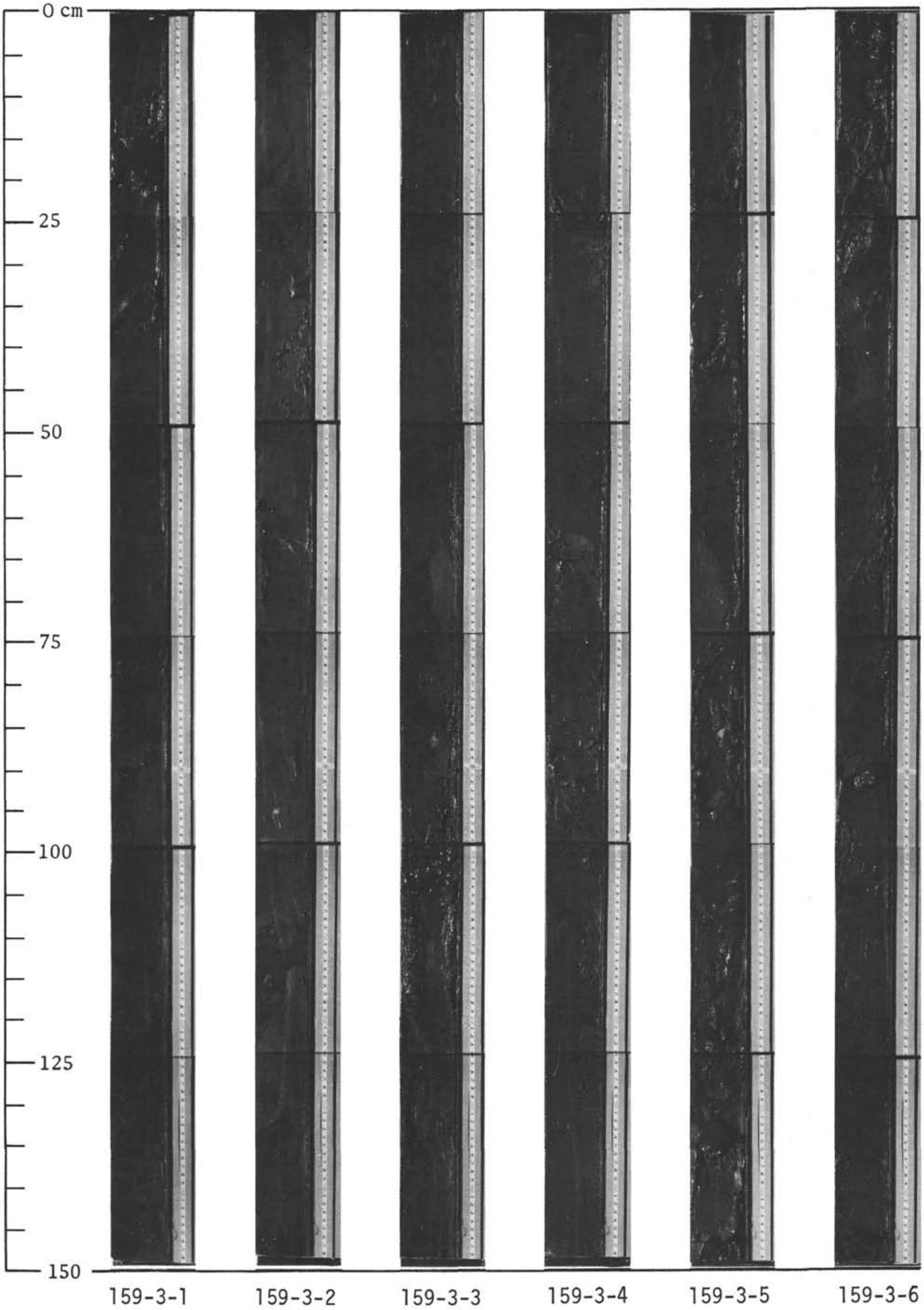
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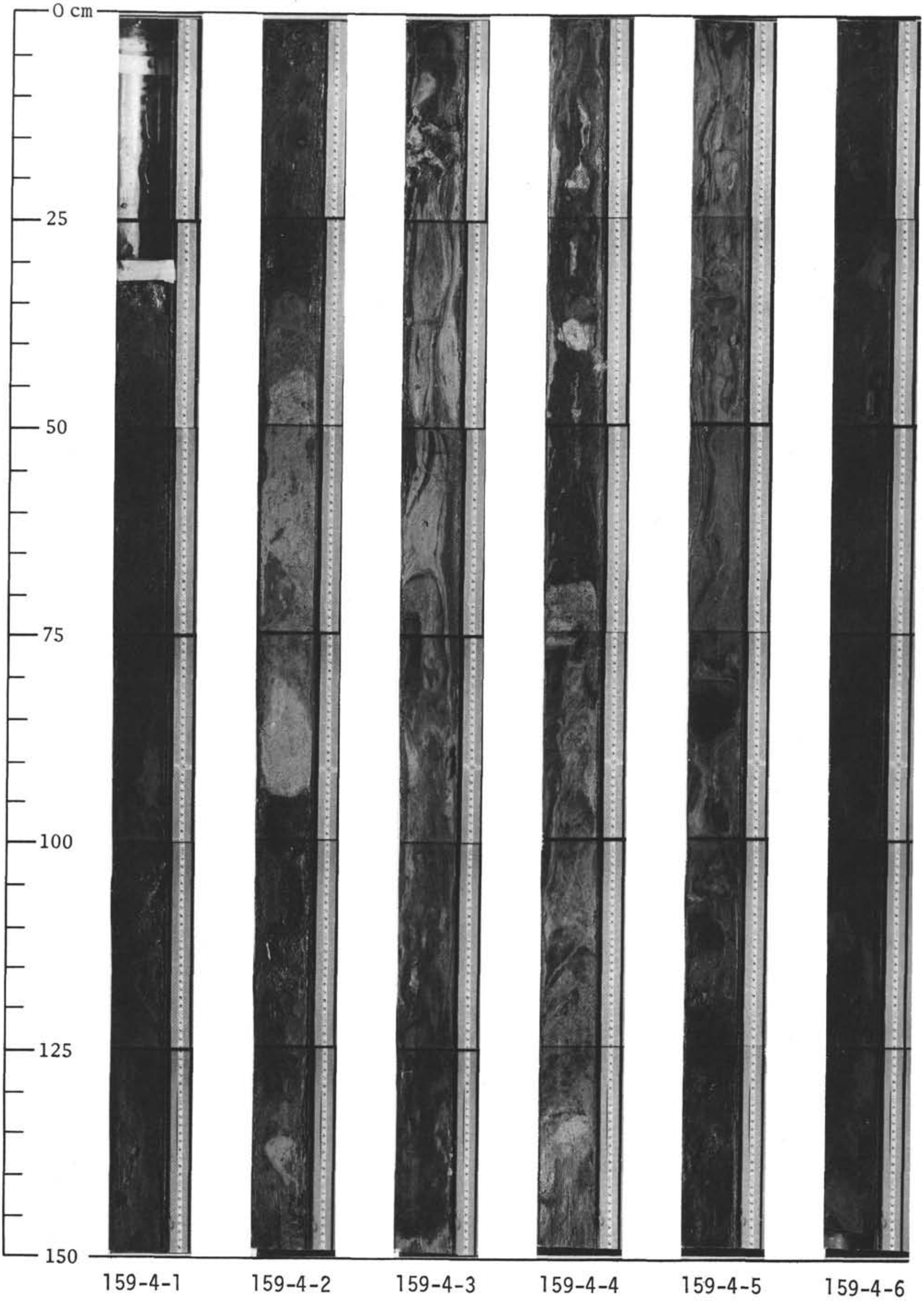
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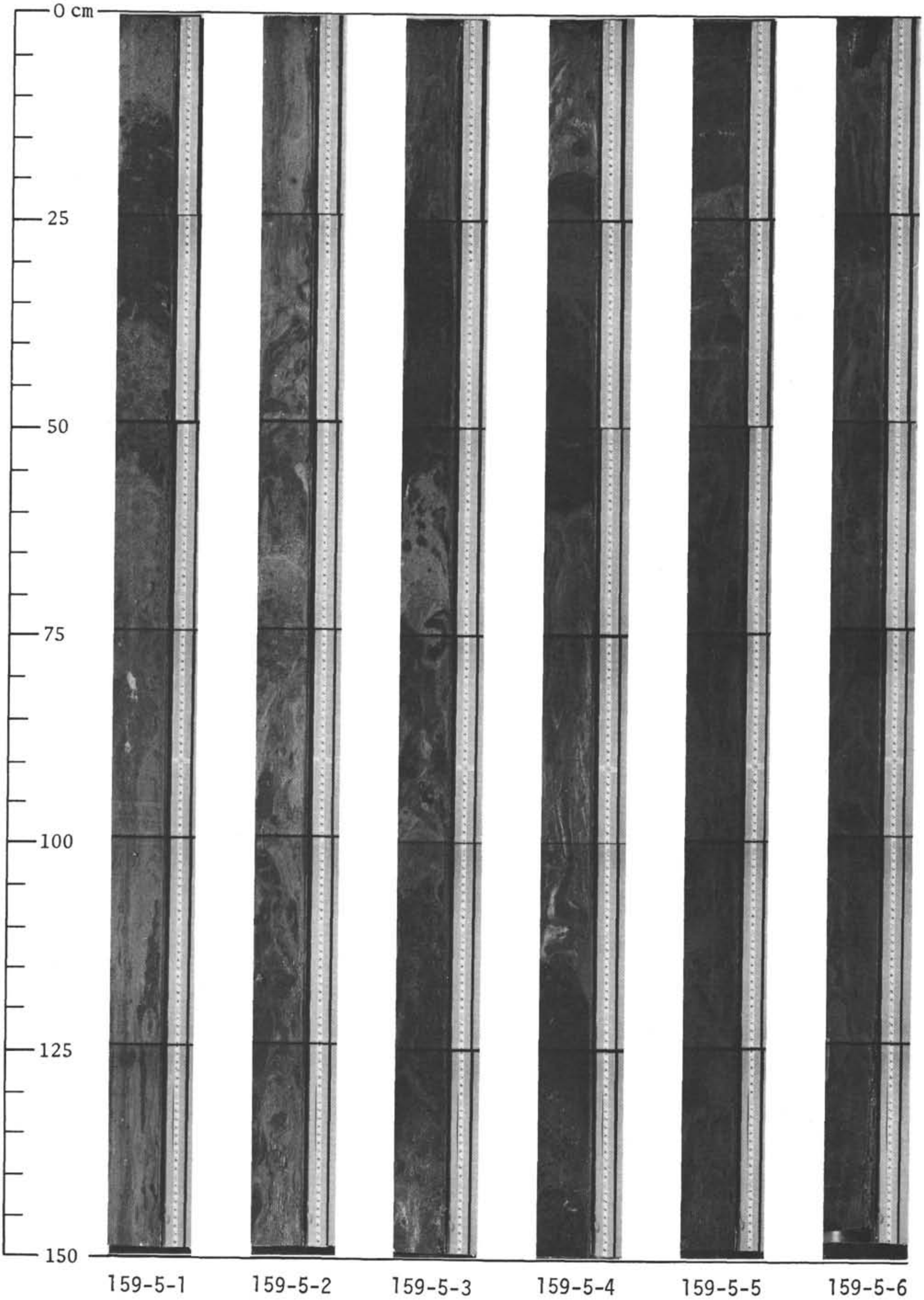
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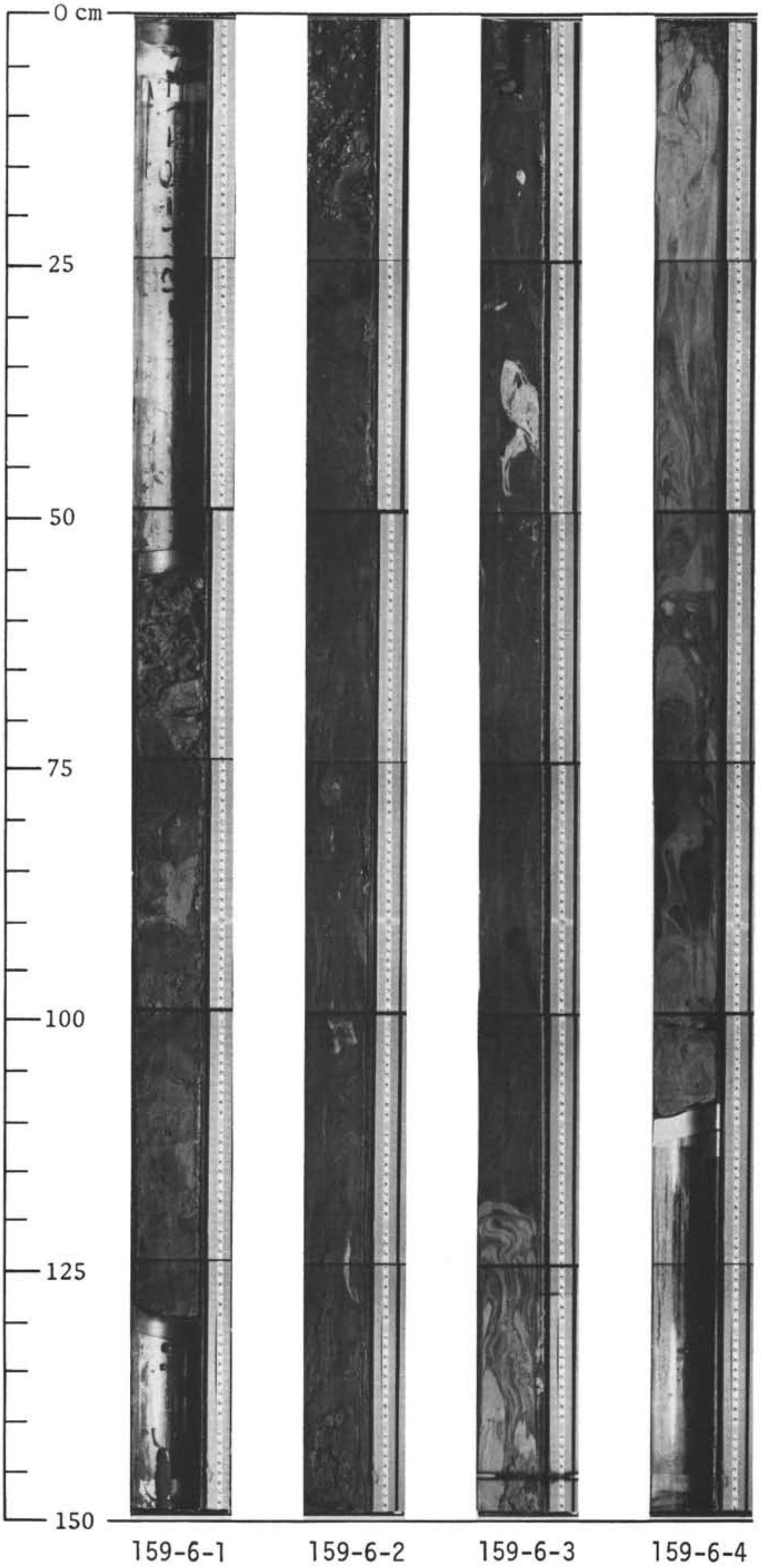
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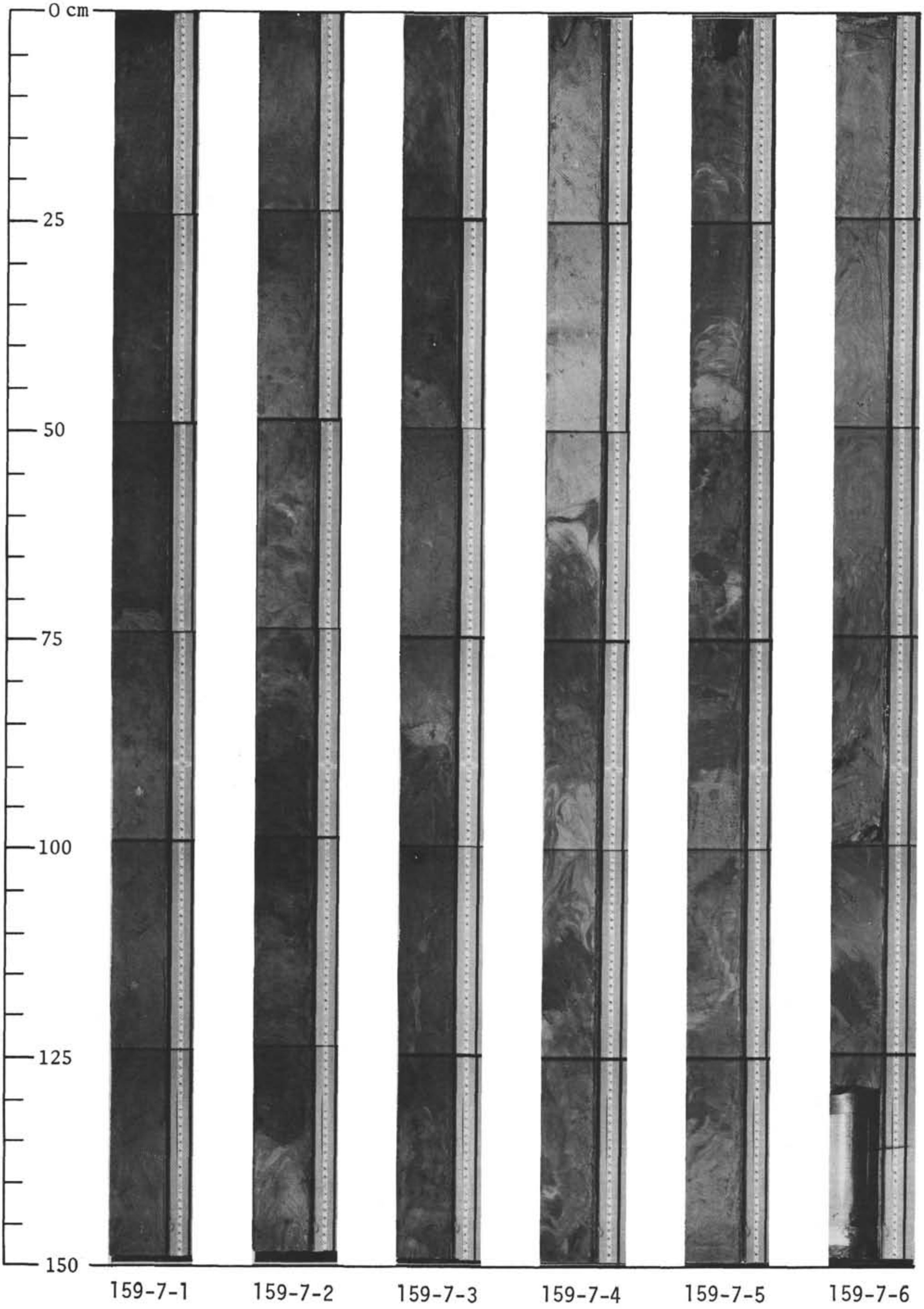
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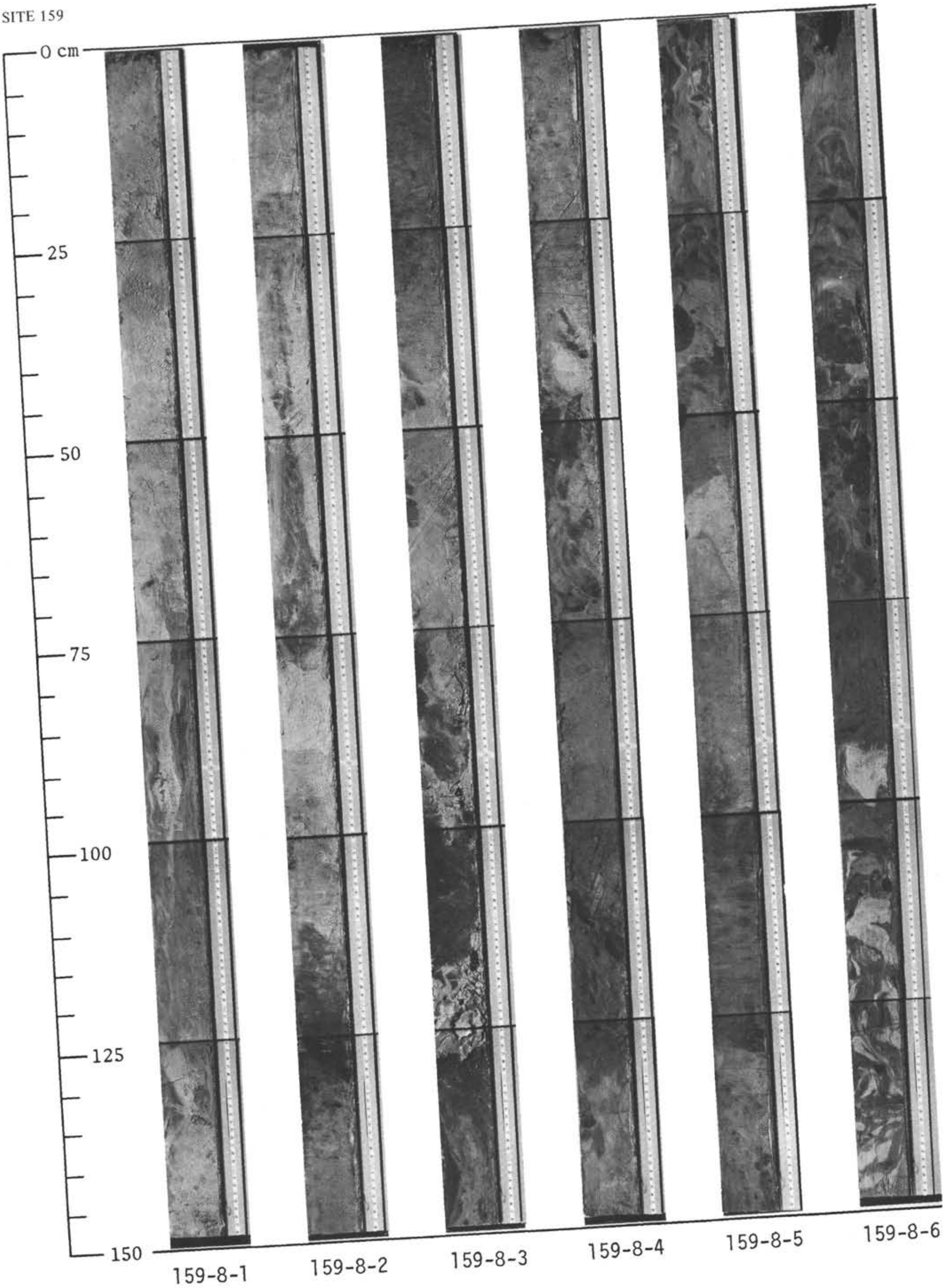
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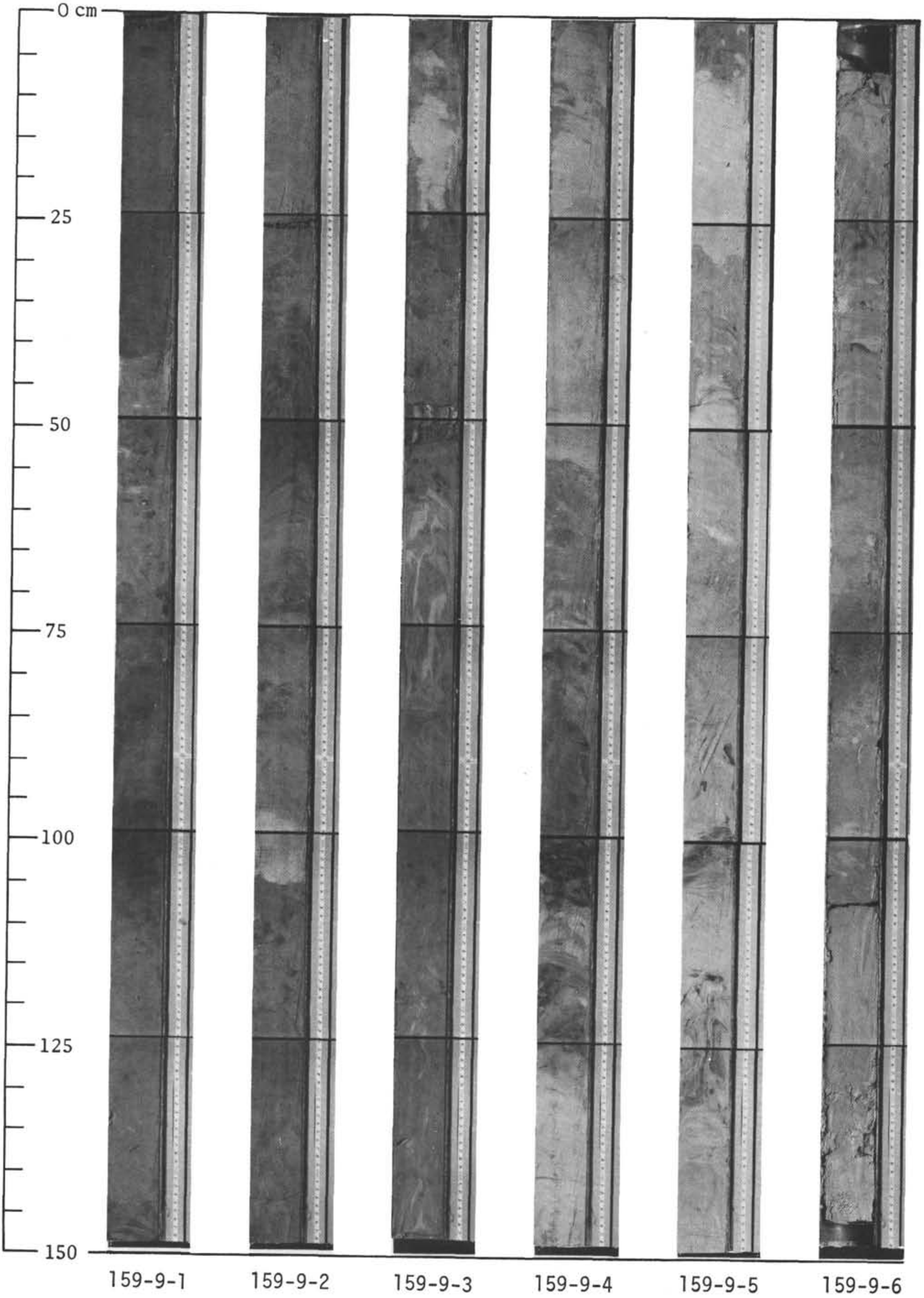
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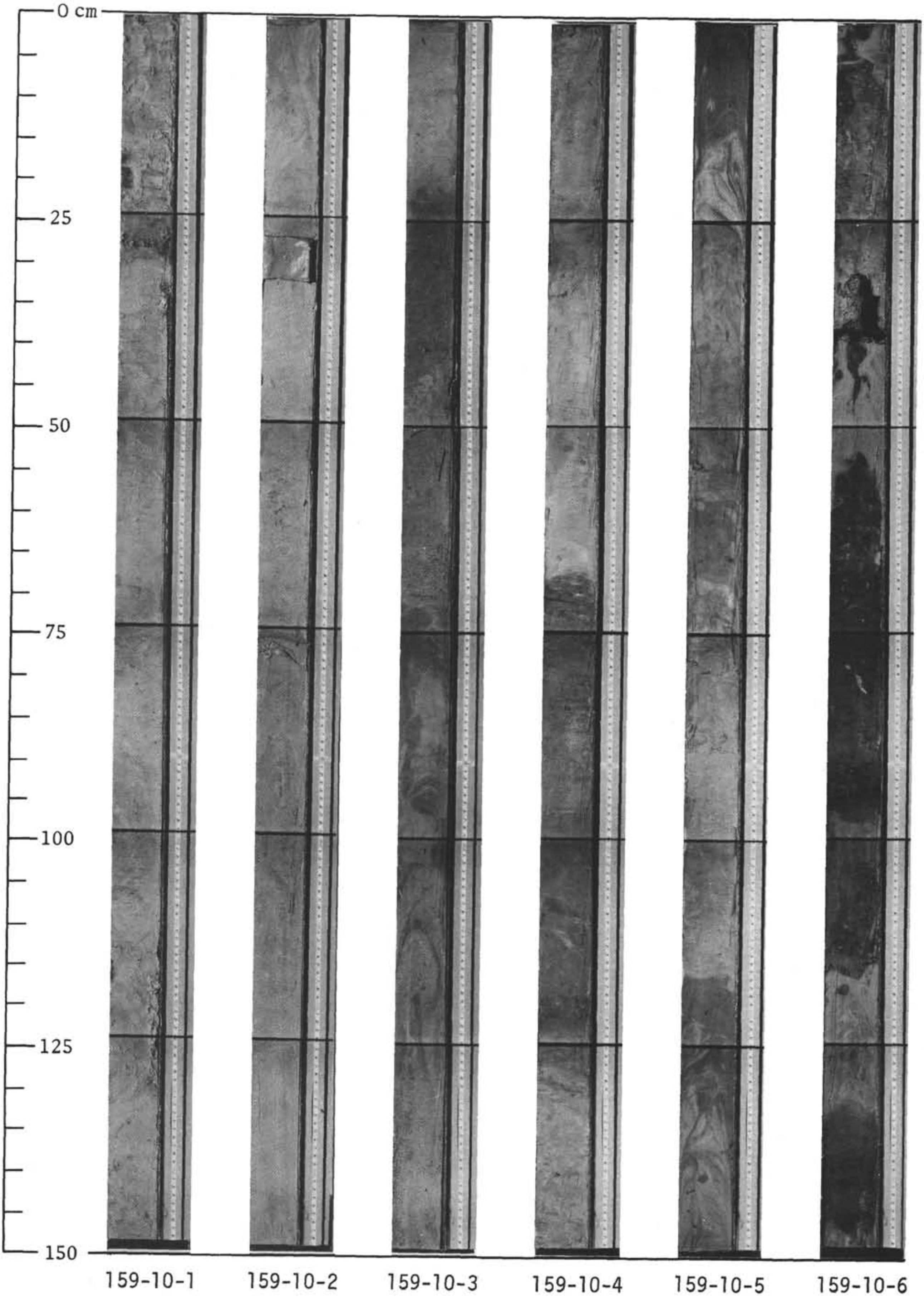
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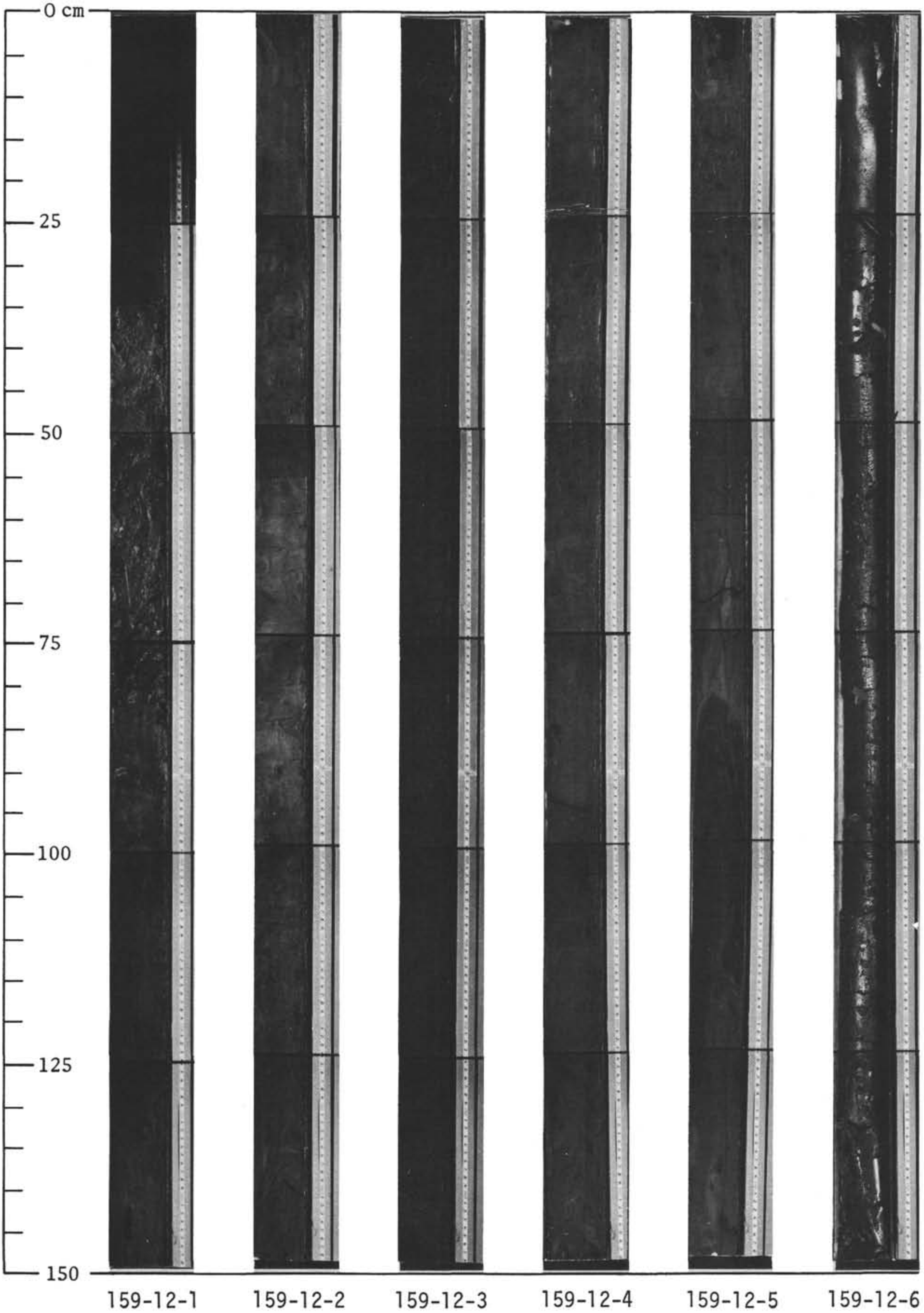
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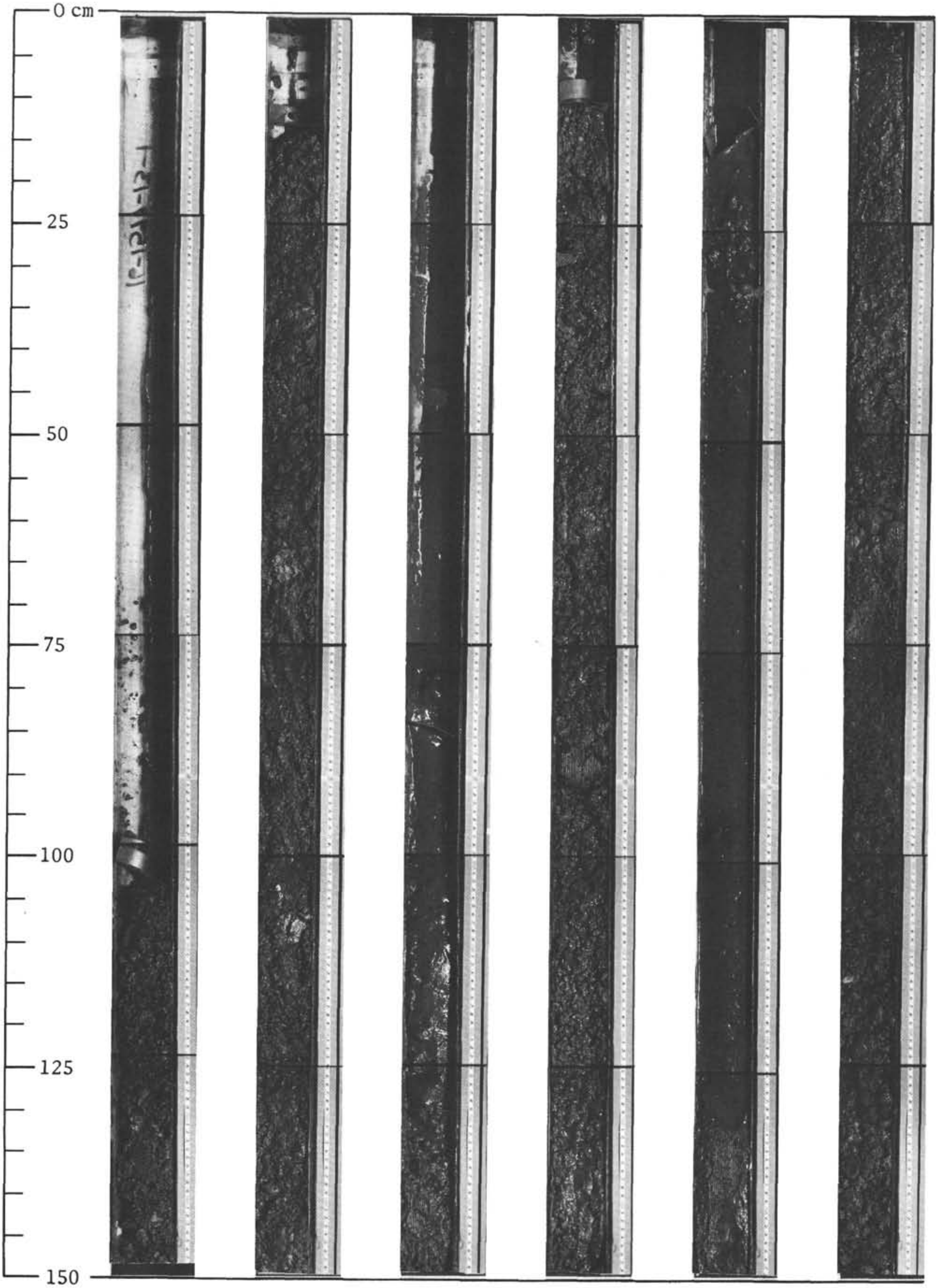
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