8. SITE 161

The Shipboard Scientific Party[1]

SYNOPSIS

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

Date Occupied: 9-13 March, 1971

Position:
Lat. 10°~~14~~40.25′N
Long. 139°57.21′W

Water Depth: 4939 meters (corrected)

Penetration:
161: 126 meters
161A: 245 meters

Number of Cores:
161: 14
161A: 15

Core Recovery:
161: 94.5 meters
161A: 87.8 meters

Acoustic Basement:
Depth: 0.20-0.22 second
Nature: Top of chert

Age of Oldest Sediment: Middle Eocene.

DSDP 161 continuously cored the top 126 meters; DSDP 161A, the section from 126 meters to basement. The following sequence was encountered:

0-2 meters – Brown radiolarian clay with very minor nannofossil chalk ooze.
Age: Quaternary.

2-45 meters – nannofossil chalk ooze with radiolarian nannofossil chalk ooze and marl. Absence of foraminifers suggests severe dissolution before burial.
Age: Latest Oligocene and early Miocene.

45-155 meters – Nannofossil chalk ooze; foraminifers rare and poorly preserved suggesting that the sea floor at this site has been never shallower than the lysocline.
Age: Early to Late Oligocene.

155-200 meters – Nannofossil chalk with some radiolarian nannofossil chalk to marl.
Age: Early Oligocene.

200-244 meters – Dark brown clayey ferruginous indurated radiolarian ooze rich in ferruginous aggregates. A brief hiatus may exist between the middle and late Eocene.
Age: Middle and late Eocene.

244-245 meters – Extrusive basalt.

No sedimentation rate can be established for the upper few meters of Miocene. The rate for the underlying chalk ooze is low, 6 m/m.y., supporting deposition near the compensation depth. The rate for the Oligocene is 13 m/m.y. A lower rate of 5 m/m.y. prevails in the Eocene, in accord with the nature of the sediment. The oldest sediment is from the *Reticulofenestra umbilica* (nannofossil) and *Podocyrtis mitra* (radiolarian) zones, giving an estimated age of 44 to 45 m.y.

REGIONAL SETTING AND OBJECTIVES

DSDP 161 is located on the lower west flank of the East Pacific Rise about midway between the Clipperton and Clarion fracture zones which define the boundaries of a large structural block in the eastern Pacific. The site is about 4,000 km west of the present crest of the Rise. It is located near the northern edge of a zone of thick Cenozoic sediments (Figure 1) which marks the general location of the equatorial zone of high biological productivity (Ewing et al., 1968).

On Legs 5 and 8 of the Deep Sea Drilling Project, a series of holes was drilled along 140°W to provide a stratigraphic traverse across the zone of equatorial sedimentation into the zone of slow deposition of red clay in the central North Pacific. This traverse was designed to determine the shift of the zone of high productivity with time during the Cenozoic; to study the nature of the depositional transition from the high productivity zone to the area of low biological productivity associated with the central water mass of the North Pacific; and to investigate postulated changes in the depth of the calcite compensation level during the Cenozoic (Heath, 1969). DSDP 161 was intended to fill the gap between DSDP 70 and DSDP 42 of this traverse. In addition, prior to Leg 16, nearly all sites on the traverse terminated in middle Eocene chert rather than in basement, due to the capability of bits then available. Since this is also true for most of the other sites occupied in the equatorial Pacific, they provided little knowledge regarding the nature and position of the equatorial zone of high productivity during the latest Cretaceous and earliest Cenozoic. With better means for penetrating the chert, DSDP 161 to 163 were intended to cast light on this part of the section.

The results of Legs 5 and 8 show that the equatorial zone of rapid calcareous sedimentation is displaced increasingly farther north with increasing age, presumably as a result of northward migration of the Pacific plate of as much as 30 degrees of latitude since the late Cretaceous (Francheteau et al., 1970). In addition, the results show that during the Cenozoic the width, carbonate content, and sedimentation rate of the biogenous deposits have fluctuated considerably (Tracey et al., 1971) and suggest that the calcite compensation depth has varied markedly with time. DSDP 161 and DSDP 162 farther to the north were

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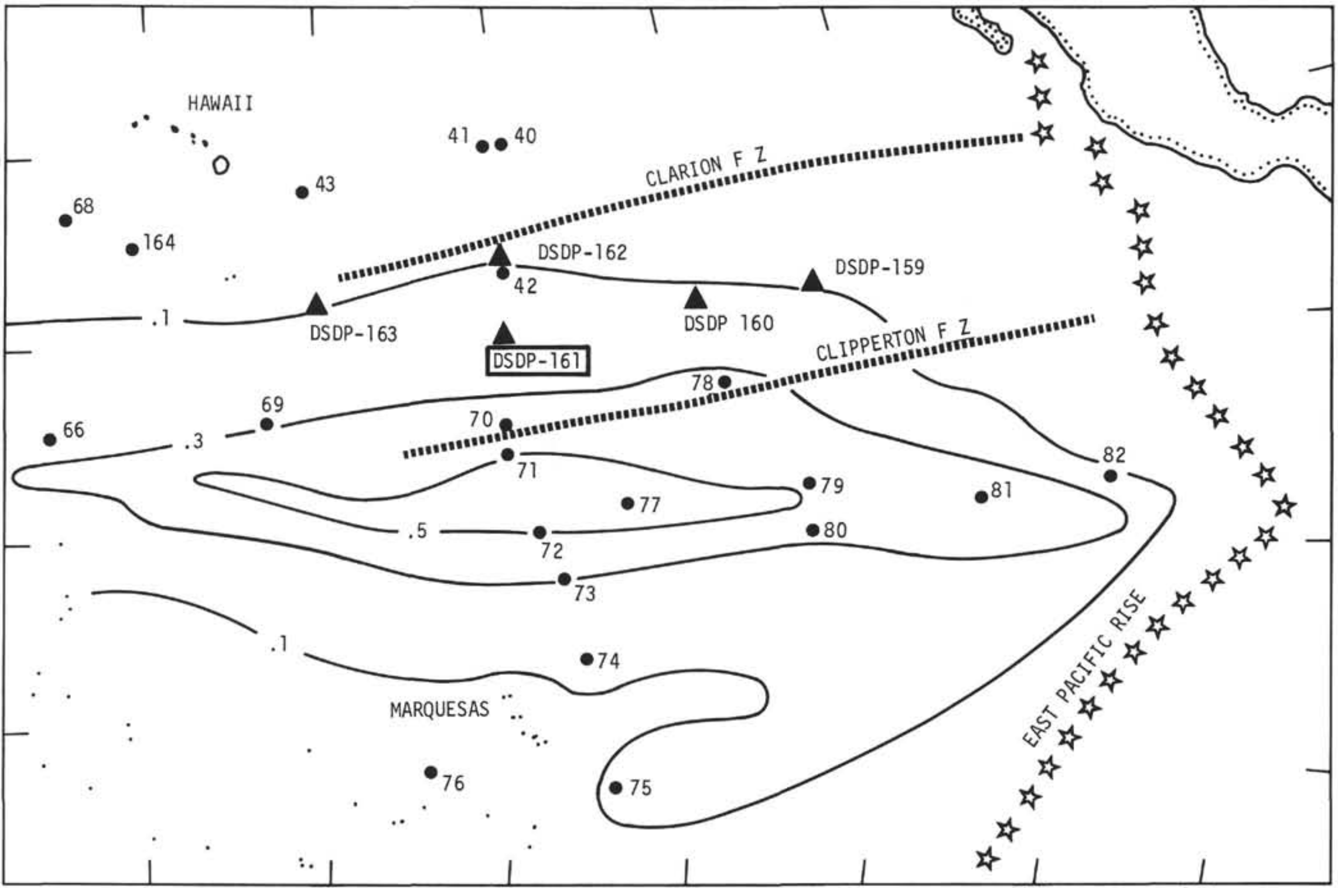

Figure 1. *Location of Leg 16 sites (large triangles) in the eastern equatorial Pacific on the west flank of the East Pacific Rise. Small dots are sites from Legs 5, 8, 9 and 17. Contours indicate sediment thickness above acoustic basement in seconds (approximately equivalent to 800 meters).*

designed to clarify the nature of the fluctuations in a portion of the 140°W traverse where facies boundaries fluctuated markedly during the early and middle Tertiary.

Additionally, DSDP 161 in combination with DSDP 159 and DSDP 160, and several sites drilled on Leg 9, was intended to determine the nature and age of the volcanic basement, thereby better defining the spreading rate of the west flank of the East Pacific Rise, and to establish whether iron-oxide-rich sediments occur immediately above basement over a large portion of the rise flank (see Chapters 6 and 7, this volume).

TOPOGRAPHIC AND GEOLOGIC SETTING

The site is located in an extensive region of abyssal hills occasionally interrupted by isolated or clustered small seamounts. The marked difference in local relief observed between north-south and east-west oriented seismic reflection profiles (Figure 3) supports a north-south structural trend similar to that observed elsewhere on the flanks of the East Pacific Rise (Luyendyk, 1970). In a north-south direction, the topography is broad and gentle with a relief of a few hundred meters and wavelength of 20 to 40 km. On the slightly south-of-west profile approaching the site (Figure 3), the relief is similar, but crest-to-crest distances are considerably shorter.

The topography appears to be controlled primarily by normal faulting. Ridges and troughs are bordered by groups of small normal faults spaced a few kilometers apart and with vertical separations of a few tens of meters. Crests and troughs are generally symmetrical and of similar dimensions. A few basement peaks protrude at the surface, but most of the area is covered with a sediment blanket of rather uniform thickness. The faults mentioned above extend to the surface of the sediment and give rise to a rather sharp minor relief of 10 to 20 meters, suggesting that the faults are either still active or have been active during most of the depositional history of the region.

The site was selected on the basis of a north-south seismic reflection profile made by R/V *Conrad* (records 1402-1405, Cruise 11) in connection with site surveys for Leg 8. In view of the general uniformity and small scale of the local relief, no extensive site survey was conducted by the *Challenger* and the final location was selected and confirmed with a double seismic reflection profile across the selected site (Figure 2). The approach profiles were typical for the region, but another profile made while crossing the beacon on departure showed the presence of a window less than 1 km wide in the regional acoustic basement. During Leg 8, this acoustic basement, inexplicably absent at DSDP 161, was found to represent the top of

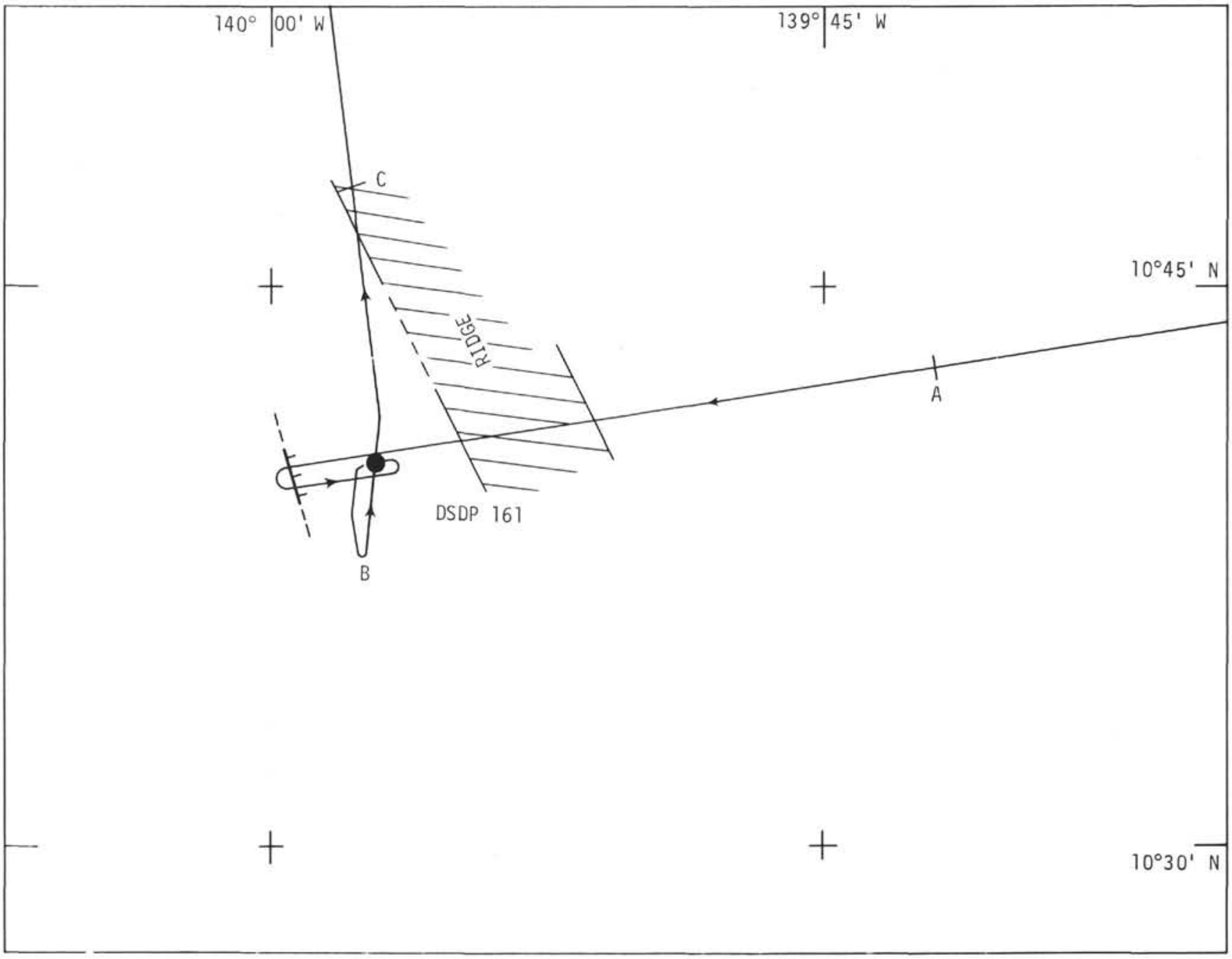

Figure 2. *Site location map. A-161 and B-161-C are locations of profiles of Figure 3. Approximate positions of eastern ridge and western boundary fault of drilled trough are shown.*

a sequence of chert beds of middle and upper Eocene age. The accidental location of the site over such a window was fortunate since it permitted a good recovery of the soft Eocene sediments that are usually washed out between chert beds.

A sediment layer of rather uniform thickness, ranging from 0.15 to 0.20 sec, almost blankets the area. This layer is underlain by a rather smooth and strongly reverberating acoustic basement that is nearly horizontal between step faults and abuts sharply against the occasional volcanic peaks and pinnacles that protrude through it and into and through the sediment overlying it. The acoustic basement, identified as chert on Leg 8, is generally parallel to the sea floor. The thickness of sediment varies little between troughs and ridges. Only occasionally can slight thickening in the valleys, probably resulting from downslope displacement of sediment, be observed.

The sediment column is distinctly stratified (Figure 3), especially in the upper part. The fine stratification is laterally continuous and parallel to both the sea floor and the acoustic basement. It is similar to the stratification observed in thick calcareous deposits near the equator (Ewing et al., 1968). The sea floor itself is a rather strong reflector, only locally overlain by a thin transparent zone about 0.01 sec thick. This surface zone is somewhat indistinct at the site itself.

Underneath the upper stratified sequence, the sediment becomes somewhat more transparent but still contains faint, discontinuous closely spaced reflectors.

Although the profile is generally clear and easily interpreted for large distances around the site, it is evident from the departure profile (Figure 3) that the situation is rather more complex at the precise location of the hole. The smooth reflector, well developed both to the east and west, becomes indistinct near the site itself and seems to disappear over it. A faint reflector may persist, but the correlation is less than certain. Reflections tailing off a basement pinnacle, which rises east of the site, dip beneath the location at a considerable depth, but deeper parts are almost certainly side echos. Above this rather marked reflector lie two others which are less distinct and may or may not be volcanic basement. Thus, at DSDP 161, the

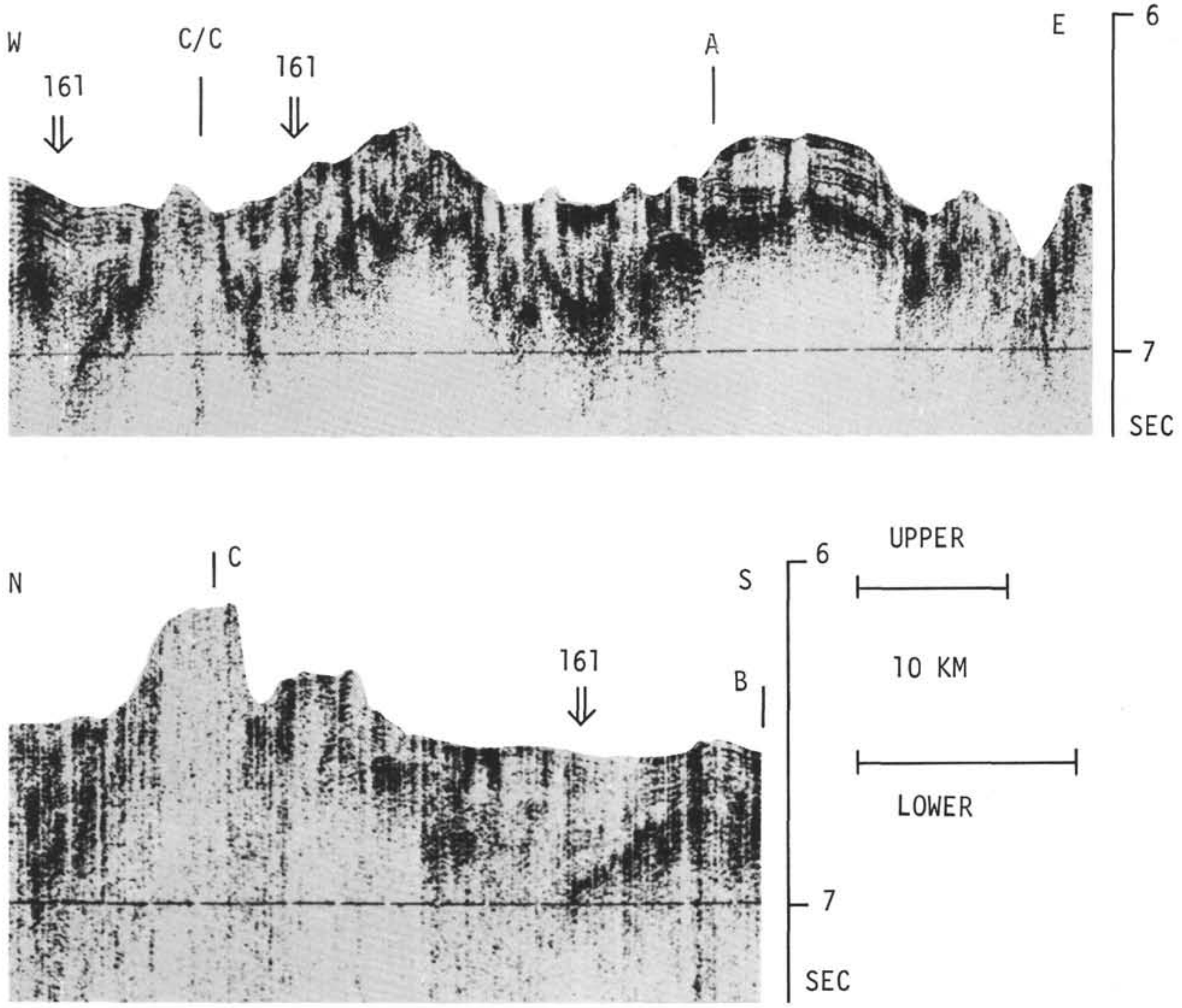

Figure 3. *Acoustic reflection profiles in the vicinity of DSDP 161. Depths in seconds of two way travel time. Locations on Figure 2. Horizontal scale is approximate.*

correlation between reflection data and drilling results (Table 1) is very tentative.

OPERATIONS

The vessel arrived at the site area on the morning of 9 March 1971, and after completing a double approach pass, dropped the beacon at 1345 hours. The hole was continuously cored using a Smith 10 3/8" sealed bearing 3-cone button bit. No difficulties with weather or positioning were experienced, but after pulling Core 14, the sand line parted. After recovering the sand line and core barrel by pulling the greater part of the string, the string was run in again and hole DSDP 161A spudded, using the same bit. This hole was drilled to the approximate terminal depth of DSDP 161 without coring and cored continuously into basement from that point. Core 16 was attempted in the basalt but the bit stuck immediately after touching bottom and problems were experienced with the hydraulic supply to the power swivel. Since repairs were time-consuming, the bit was worked loose, and the hole was terminated. After completing a reflection profile across the beacon the vessel departed at 2130 hours on 13 March. A summary of coring operations is given in Table 2.

TABLE 1
Comparison of Acoustic Section and Drill Data, DSDP 161

Reflectors	Depth (sec)	Drilling Results	Velocity (m/sec)
Base upper stratified zone	0.15		
Top smooth acoustic basement (?)	0.20-0.22	155 m top chalk	1550
First basement (?)	0.28	245 m top basalt	1710
Second basement (side echo?)[a]	0.37	(245 m top basalt)[a]	(1330)[a]

[a] Correlation not accepted.

LITHOLOGY

DSDP 161 and 161A continuously cored the sedimentary section to basement. Six lithostratigraphic units are distinguished (Figure 4).

TABLE 2
Coring Summary, DSDP 161

Core	Depth Below Sea Level (m)	Depth Below Sea Floor (m)	Cored (cm)	Recovered	
				(cm)	(%)
1	4939-4948	0-9	900	924	102.7
2	4948-4957	9-18	900	796	88.4
3	4957-4966	18-27	900	715	79.4
4	4966-4975	27-36	900	916	101.8
5	4975-4984	36-45	900	837	93.0
6	4984-4993	45-54	900	523	58.1
7	4993-5002	54-63	900	570	63.3
8	5002-5011	63-72	900	0	00.0
9	5011-5020	72-81	900	862	95.8
10	5020-5029	81-90	900	850	94.4
11	5029-5038	90-99	900	883	98.1
12	5038-5047	99-108	900	742	82.4
13	5047-5056	108-117	900	835	92.8
14	5056-5065	117-126	900	0	00.0
1A	5002-5011	63-72	900	758	84.2
2A	5067-5076	128-137	900	874	97.1
3A	5076-5085	137-146	900	742	82.4
4A	5085-5094	146-155	900	924	102.7
5A	5094-5103	155-164	900	895	99.4
6A	5103-5112	164-173	900	916	101.8
7A	5112-5121	173-182	900	885	98.3
8A	5121-5130	182-191	900	348	38.7
9A	5130-5139	191-200	900	663	73.7
10A	5139-5148	200-209	900	722	80.2
11A	5148-5157	209-218	900	612	68.0
12A	5157-5166	218-227	900	140	15.6
13A	5166-5174	227-235	800	70	8.8
14A	5174-5183	235-244	900	228	25.3
15A	5183-5184	244-245	100	5	5.0

Unit 161-1 – Brown radiolarian clay (0-2 m).
Unit 161-2 – Nannofossil chalk ooze interbedded with radiolarian nannofossil chalk ooze (2-45 m).
Unit 161-3 – White nannofossil chalk ooze (45-155 m)
Unit 161-4 – White nannofossil chalk(155-200 m)
Unit 161-5 – Brown indurated radiolarian ooze (200-244 m).
Unit 161-6 – Basalt (244-245 m)

Unit 161-1

The uppermost unit is a predominantly yellowish brown radiolarian clay interbedded with several thin laminations of white nannofossil chalk ooze. Mottling is present and ferruginous-looking aggregates are fairly common throughout the interval. In the upper part, nannofossil chalk ooze, nannofossil radiolarian ooze, and nannofossil radiolarian marl are interbedded. This variability is the result of the varying proportions of radiolarians, ferruginous aggregates, and clay.

Unit 161-2

Two distinct sediment types are interbedded in this unit: very pale orange and grayish orange nannofossil chalk ooze and yellowish brown radiolarian nannofossil chalk ooze. Mottling is generally present. Clay minerals and ferruginous-looking aggregates are restricted to the second sediment type.

Unit 161-3

The overlying mixed nannofossil chalk ooze passes abruptly to this unit. Its most striking characteristic is its white color, due to a virtual absence of clay minerals and ferruginous-looking components. Several thin beds of pale orange nannofossil chalk ooze are interbedded with the white chalk ooze. Occasionally, diatoms and fragments of foraminifers are encountered.

Unit 161-4

Lithologically, this unit is similar to 161-3, differing only in the greater degree of induration and the presence of several thin intervals of very pale orange nannofossil chalk and nannofossil radiolarian chalk. Diatoms are fairly common.

Unit 161-5

This unit is characterized by silica-rich sediments. Lithologically, it consists of an indurated radiolarian ooze. The dominant color is dark yellowish brown. Ferruginous aggregates and clay minerals are common constituents. Mottling and burrowing are fairly intense. Although the unit is dominantly siliceous, a thin calcareous bed is present in the upper portion.

Unit 161-6

This unit consists of fine-grained to glassy microporphyritic basalt. Plagioclase occurs as laths of calcic labradorite up to 1.2 mm long with faint euhedral oscillatory or normal zoning, and as moderately aligned thin labradorite laths 100 to 700 microns long. Augite with $2V_Z$ near 60 degrees occurs as variolitic sheafs or as anhedral grains up to 200 microns across, associated with labradorite in phenocryst clusters. Euhedral olivine phenocrysts 100 to 700 microns long are mostly altered to bowlingite. Vesicles, 50 to 175 microns in diameter, are filled with chlorophaeite, iddingsite, and bowlingite. The groundmass is glassy and devitrified to a variolitic mass of pyroxene, magnetite, and chlorophaeite.

GEOCHEMISTRY

Interstitial water samples and shipboard operations for DSDP 161 are listed in Table 3.

BIOSTRATIGRAPHY

At DSDP 161, a continuous middle Miocene to lower Miocene section was recovered.

The section is largely barren of foraminifera and, where present, they are very poorly preserved. Cores 5 through 7 contain poorly diversified assemblages characterized by *Catapsydrax* spp. and *Globorotalia opima* (in the core catcher of Core 7); the latter occurrence marks the top of the *Globorotalia opima* Zone. The biostratigraphy below this point is unclear. Maximum diversity occurs in Cores 10 and 11, still in the *Globorotalia opima* Zone; the base of this zone could not be located. The only specimens of *Globigerina ampliapertura* were found in Cores 4A and 5A. Diversity and preservation decline from Core 12 downward, and below Core 5A the section is virtually barren (except for a small, low-diversity assemblage in Core 8A which

TABLE 3
Interstitial Water Samples and Shipboard Observations, DSDP 161

Core	Section	Sampled Interval (cm)	pH	Eh (mv)	Lab. Temp. (°C)	Salinity (%)	Squeeze Pressure (psi)
DSDP 161							
1	2	0-6	7.62	147	25.0	34.7	508
1	6	0-6	7.53	146	25.0	34.7	1523
2	5	0-9	7.54	149	25.0	34.7	1015
3	3	0-6	7.50	152	25.0	35.2	1015
4	6	0-8	7.53	152	25.2	35.2	1015
5	3	0-7	7.50	152	25.8	35.2	1523
6	1	143-150	7.49	160	25.8	35.2	1523
7	3	0-8	7.46	149	26.0	35.2	2436
9	4	0-8	7.49	129	25.0	35.2	2436
10	3	0-8	7.53	148	25.1	34.7	1523
11	6	0-8	7.57	156	25.3	34.7	2436
12	6	0-8	7.53	161	25.2	35.2	2436
13	4	0-8	7.46	173	25.3	34.7	2436
DSDP 161A							
1	6	0-8	7.58	154	25.6	34.7	1015
2	6	0-8	7.48	161	25.5	34.1	2436
3	3	0-9	7.60	155	25.4	34.7	2436
4	6	0-8	7.53	167	25.9	34.7	2030
5	6	0-8	7.51	155	26.0	34.7	2436
6	6	0-8	7.49	157	26.0	34.7	2436
7	6	0-8	7.52	172	26.0	34.7	2436
8	3	0-8	7.55	166	26.0	34.7	2436
9	3	0-8	7.54	172	25.8	34.7	2436
10	6	0-8	7.55	173	25.8	34.7	1523
11	4	0-7	7.54	171	25.7	34.7	2436

includes *Catupsydrax dissimilis* and *Globigerina ?psuedovenezuelana*).

Middle Eocene to lower Miocene nannofossils are abundant, but preservation is only moderate to poor and diversity is low. It was possible to recognize the sequence of zones from the *Triquetrorhabdulus carinatus* Zone at the top. Easily soluble taxa such as *Rhabdosphaera, Helicopontosphaera* and holococcoliths, are absent.

Radiolarians are present throughout and are abundant. There is moderate solution in the upper part of the section, but preservation improved downward. The presence of a thin veneer of Quaternary is indicated by the presence in Cores 1 and 2 of corroded specimens of *Spongaster tetras*, *Authocyrtidium* sp., and *Ommatartus tetrathalamus*. Aside from these taxa, and the frequent occurrence of reworked Eocene and Oligocene, Cores 1 and 2 belong in the *Calocycletta virginis* Zone of the lower Miocene. From Core 3 down, a nearly continuous sequence to the upper middle Eocene *Podocyrtis mitra* Zone was recognized; some stratigraphic breaks may be present at the Eocene-Oligocene boundary and in the uppermost Oligocene. Abundant reworked middle Eocene radiolarians occur in the Oligocene and lower Miocene of this site.

PHYSICAL PROPERTIES

Megascopic examination of sediment cores indicated varying degrees of disturbance throughout most of the section. However, subsamples collected for laboratory determination of physical properties in addition to samples used for acoustic measurements were carefully selected from the least disturbed intervals. Vane shear and Swedish Fall Cone penetrometer tests were made in a few selected intervals. A total of 272 velocity measurements were made at this site. Insufficient recovery of basement rock precluded a velocity measurement of the basalt.

Bulk Density

Physical properties data reveal that the lowest bulk densities and highest porosities occur in the uppermost and lowermost portions of the section, corresponding to the radiolarian-rich clays. A rapid increase with depth in GRAPE bulk densities (average value per section), from 1.37 to 1.78 g/cc, is found in the upper 113 meters of nannofossil chalk ooze (1.5 to 114.5 meters). Within the interval of 114.5 to 155 meters density decreases from 1.82 to 1.58 g/cc, apparently reflecting the increase in radiolarian concentration. Bulk densities in the nannofossil chalk (155 to 200 meters) range from 1.63 to 1.79 g/cc reflecting the varying abundances of Radiolaria, coccoliths and diatoms. Extremely low GRAPE densities (1.31 to 1.43 g/cc) were found in the radiolarite sequence (200 to 220 meters) relative to the overlying sediment.

Laboratory bulk densities display considerable variation with depth. Bulk density is remarkably low (1.12 g/cc) in the 0 to 1.5 meter interval of ferruginous radiolarian clay but increases from 1.38 to 1.80 g/cc at a depth of 130 meters in the nannofossil chalk ooze. Density ranges from 1.52 to 1.82 g/cc in the lower chalk ooze and chalk within the 130 to 200 meter interval. Within the radiolarite section (200 to 220 meters), laboratory densities of 1.30 to 1.42 g/cc were recorded. Two samples taken from a depth of 236 meters, in the basal radiolarian nannofossil chalk, reveal densities of 1.61 and 1.65 g/cc.

Porosity

GRAPE porosities decrease sharply from 79 to 56 per cent to a depth of 113 meters and then increase to 66 per cent at 155 meters. Within the interval of 155 to 200 meters, porosity varies from 51 to 65 per cent increasing from 71 to 80 per cent in the radiolarite section. Laboratory determined porosities, like the densities, are highly variable with depth. A high porosity of 90 per cent is associated with the uppermost ferruginous radiolarian clay. Porosities range from 54 to 76 per cent within the upper 130 meters, but show a general decrease with depth. Laboratory porosities are quite variable within the 130 to 100 meter interval, ranging from 50 to 66 per cent. Higher porosities of 69 to 79 per cent are found in the section, 200 to 220 meters. The basal chalk at 136 meters displays a porosity of 57 per cent.

Water Content

Water content is highly variable throughout the entire sequence with the highest values found in the upper radiolarian-rich clay (0 to 1.5 meters) and in the radiolarite sequence (200 to 220 meters). A water content of 81 per cent in the ferruginous radiolarian-rich clay at 0.5 meters is the highest encountered at this site. Within the remainder of the upper 45 meters of the section, water content varies from 35 to 56 per cent. Varlues decrease from 47 to 30 per cent in the nannofossil chalk ooze (45 to 130 meters), but in the interval 130 to 200 meters an overall increase from 29 to 43 per cent is found. Water content increases from 48 to 58 per cent in the radiolarite, but decrease sharply to 35 per cent in the basal nannofossil chalk.

Grain Density

A relatively low average grain density of 2.26 g/cc is found associated with the radiolarian-rich clay (0 to 1.5 meters). Low values of 2.07 to 2.40 g/cc were also observed in the radiolarite with the exception of one high grain density of 2.70 g/cc, sampled in an area of ferruginous aggregates and pyrite grains (219 meters). Variable grain densities of 2.42 to 2.77 g/cc are characteristic of the nannofossil chalk ooze and chalk, with an overall average of 2.59 g/cc.

Natural Gamma Radiation

Natural gamma activity (average per section) is significantly higher in the radiolarian-rich clay (0 to 1.5 meters) and in the radiolarite (200 to 220 meters) than in the intermediate nannofossil chalk ooze and chalk. The gamma radiation profile indicates a steady decrease in activity with depth in the chalk ooze and chalk reflecting the overall decrease in radionuclide concentration.

Sound Velocity

A total of 272 velocity measurements averaged 1.50 km/sec and ranged from 1.30 to 1.63 km/sec for the entire sedimentary sequence. In spite of the exceptionally high degree of variation in the measurements, the data appear to indicate that velocities are relatively constant in the upper 190 meters and increase sharply with depth in the lower chalk and radiolarite. This sharp increase in velocity may be due to greater induration of the chalk relative to the chalk ooze and to an increase in apparent rigidity of the radiolarite.

Shear Strength

Although a high degree of disturbance was found throughout much of the section, it was possible to make a limited number of reliable vane shear and fall cone measurements. Vane shear strengths of 44 and 88 g/cm^2 were recorded at depths of 81 and 99 meters, respectively. At 86 meters, shear strengths determined by the fall cone averaged 283 g/cm^2, considerably higher than values obtained with the vane shear apparatus for essentially the same lithology.

SUMMARY AND DISCUSSION

Two holes were drilled at DSDP 161. The first one cored the upper 126 meters; the second one, an additional 116 meters to basement for a total section of 244 meters.

From 0 to 2 meters, the sediment is a highly porous brown radiolarian clay, mostly of early Miocene age but containing a few Quaternary radiolarians at the surface. Calcareous nannofossil chalk forms a minor part of the section. The sediment has moderate natural gamma ray activity, higher than in the underlying calcareous deposits and comparable to the basal indurated radiolarian ooze. The estimated age of the surface sediment exclusive of the small Quaternary contribution is about 18 m.y.

From 2 to 45 meters the sediment is mottled pale orange and grayish orange nannofossil chalk ooze of latest Oligocene and earliest Miocene age. Yellow brown radiolarian nannofossil chalk ooze and lesser marl forms a subordinate part of the section. Although calcareous, these sediments lack foraminifera, suggesting severe dissolution before burial. The deposition rate for the top 25 meters, about 6 m/m.y., supports this conclusion.

From 45 to 155 meters, the sediment is nannofossil chalk ooze, mostly very uniform white in color ("toothpaste-like"), but with pale orange and yellow brown tints above 82 meters. The natural gamma activity of this Oligocene section decreases fairly uniformly with depth, suggesting a gradual decrease in clay content. At the same time, the GRAPE porosity decreases from 70 to 50 per cent. Despite the high carbonate content of the unit, foraminifers are rare and poorly preserved. Apparently, the sea floor at the site has never been shallower than the lysocline. For the Oligocene section (25-200 m), the sedimentation rate was about 13 m/m.y.

Below 130 meters, the chalk ooze becomes more indurated with depth; from 155 to 200 meters, it is classified as a nannofossil chalk. This section, of early Oligocene age, includes some minor grayish orange radiolarian nannofossil chalk to marl, but mostly resembles the overlying chalk ooze. Like the entire sediment column, this unit includes reworked Eocene radiolarians. It also contains reworked nannofossils.

The deepest sediment, from 200 to 244 meters, is dark yellow brown clayey indurated radiolarian ooze of early and middle Eocene age. This sediment is clayey, intensely mottled, and rich in ferruginous aggregates. It is more porous (about 75%) and has a higher natural gamma activity than the overlying chalk. Measured acoustic velocities show considerable scatter but generally increase from 1.52 to 1.62 km/sec from the top to the bottom of the radiolarian ooze. The *Thyrsocyrtis tetracantha* (radiolarian) zone is absent, possibly suggesting a brief hiatus between the middle and late Eocene. The sedimentation rate is about 5 m/m.y.

Basement at DSDP 161 is extrusive basalt. This altered rock was originally glassy and vesicular, with microphenocrysts of olivine, augite, and calcic labradorite. The glass and olivine have largely been altered while the vesicles have been filled with iddingsite.

The measured acoustic velocity of the sediments averages about 1.52 km/sec in reasonable agreement with the value of 1.5 km/sec for the section above the chalk deduced from correlation with the seismic profiler records. The alternative profiler values of 1.33 and 1.71 km/sec for the complete section differ markedly from the measured average, casting doubt on either the identification of reflectors or on the assumed correlations.

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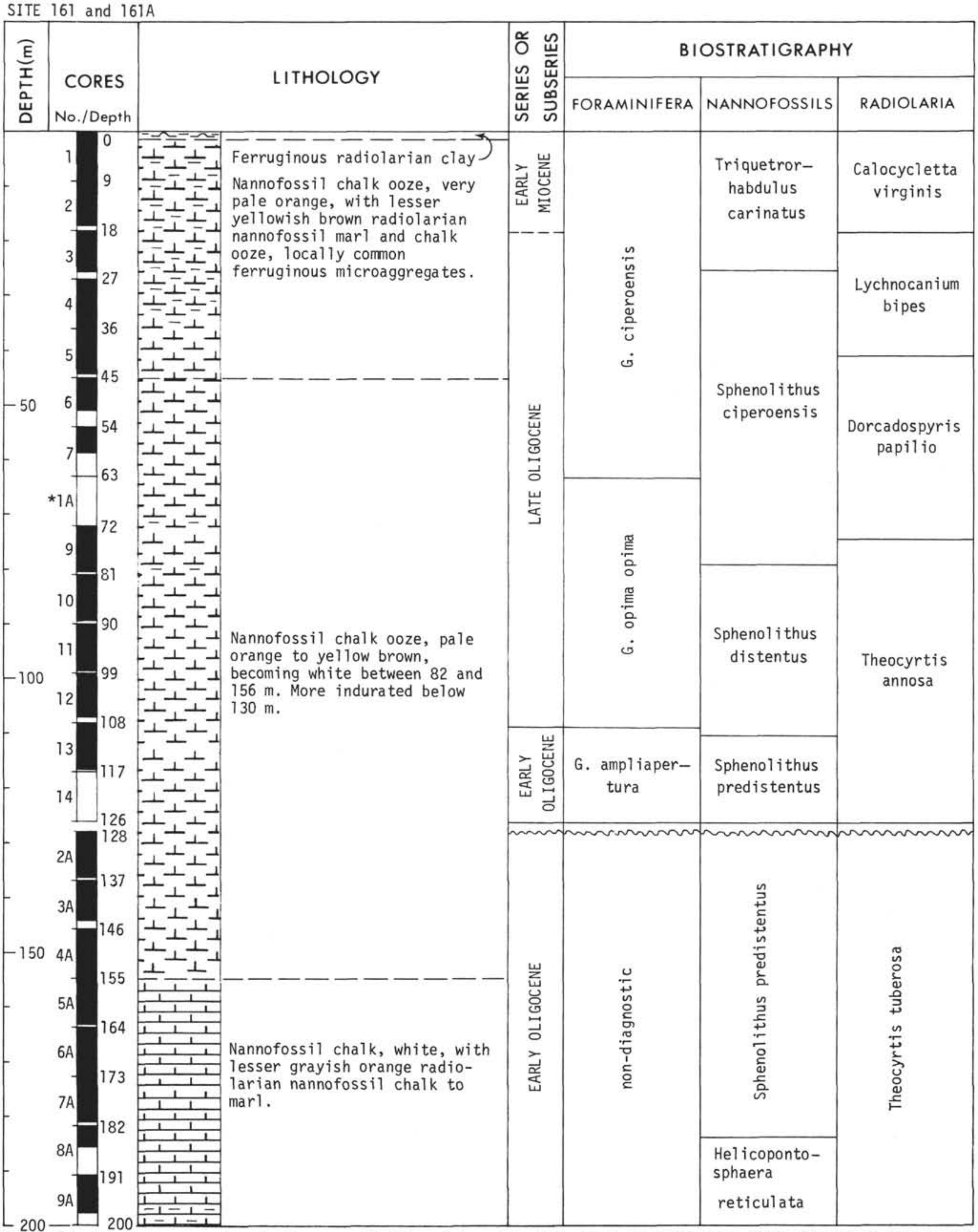
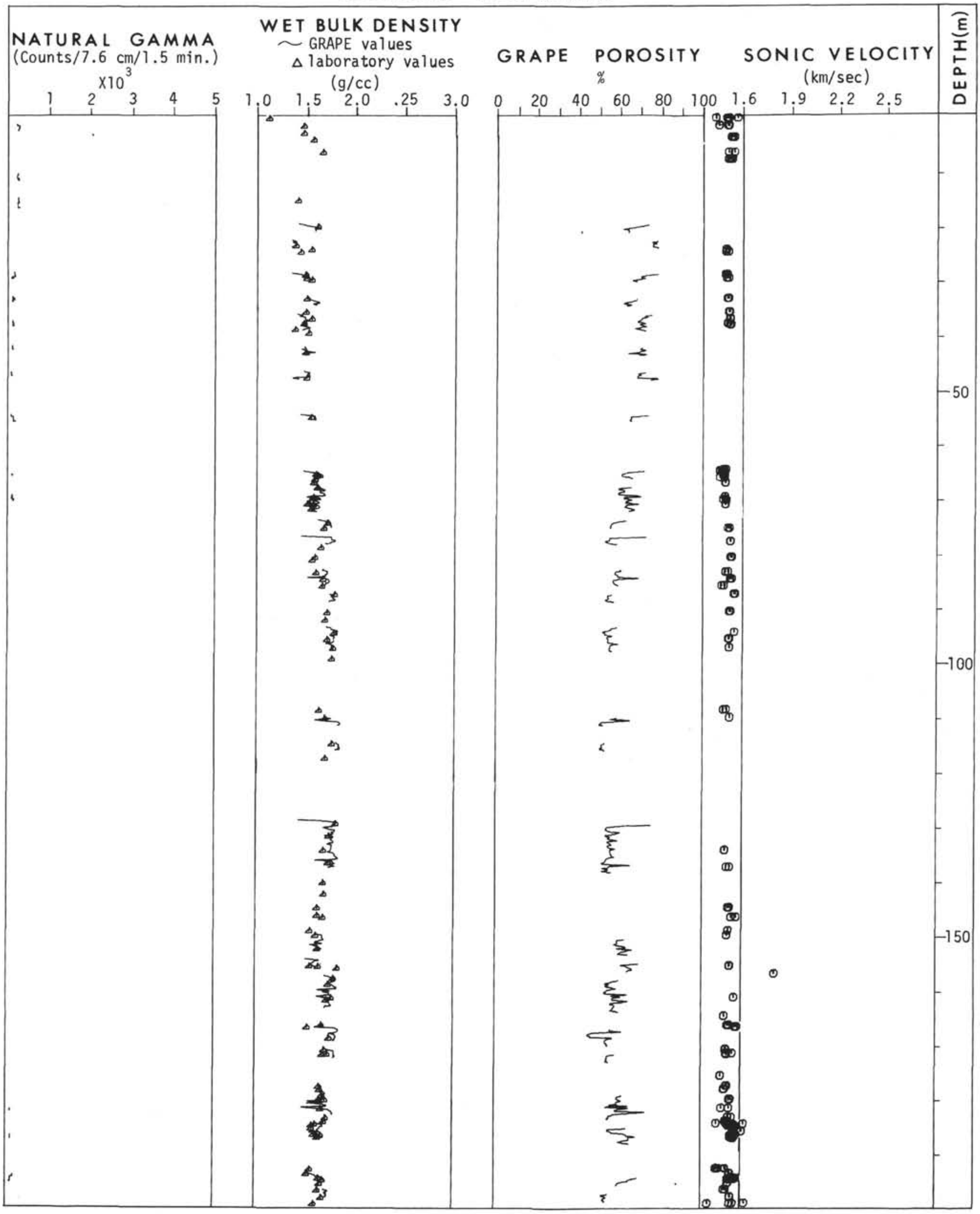


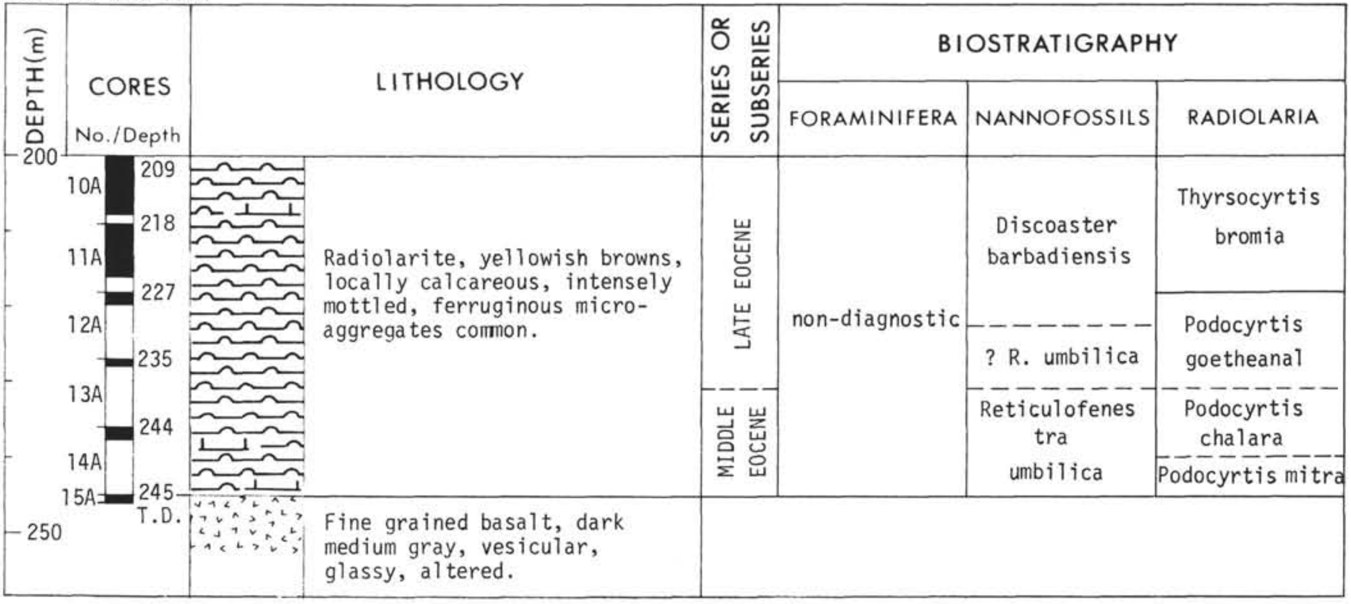
*Core 1A, taken to cover the depth range 63-72 m, (missed in Hole 161), contained the following zonal boundaries: foram: entire core is in the G. opima Zone nanno: boundary between the Sphenolithus ciperoensis and Sphenolithus distensus Zones is between sections 4 and 5 ; rad: boundary between the Dorcadospyris papilio and Theocyrtis annos Zones

Figure 4. *DSDP 161, graphic hole summary. Vertical scale 1 cm = 10 m (1:1000).*

PHYSICAL PROPERTIES



SITE 161 and 161A

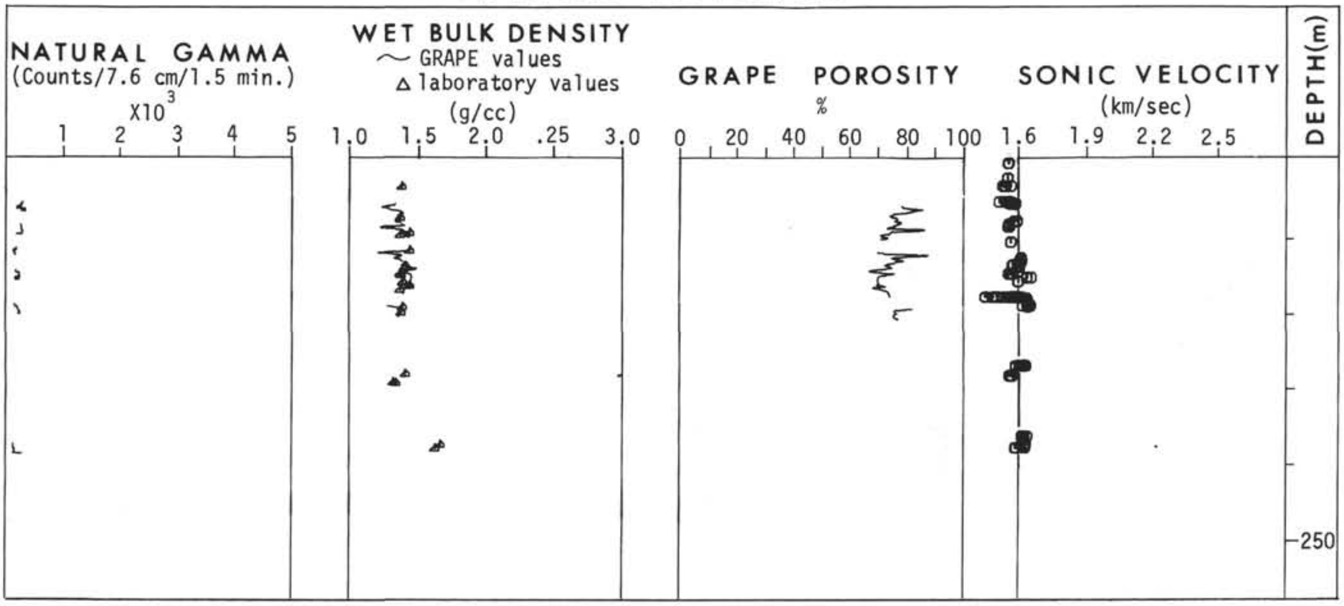


Radiolarite, yellowish browns, locally calcareous, intensely mottled, ferruginous micro-aggregates common.

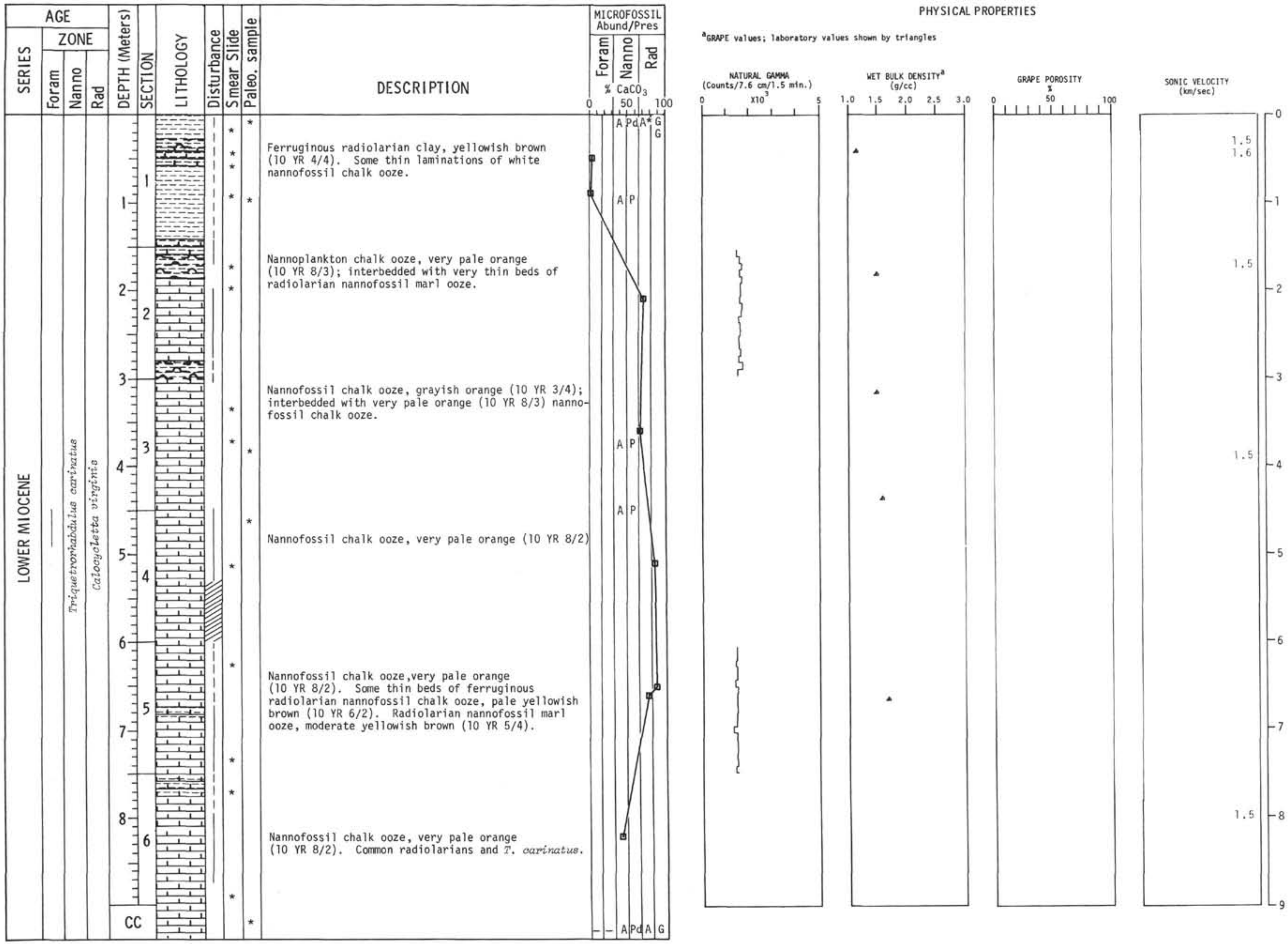
Fine grained basalt, dark medium gray, vesicular, glassy, altered.

Figure 4. *(Continued).*

PHYSICAL PROPERTIES



SITE: 161 HOLE: CORE: 1 Cored Interval: 0-9 m



Ferruginous radiolarian clay, yellowish brown (10 YR 4/4). Some thin laminations of white nannofossil chalk ooze.

Nannoplankton chalk ooze, very pale orange (10 YR 8/3); interbedded with very thin beds of radiolarian nannofossil marl ooze.

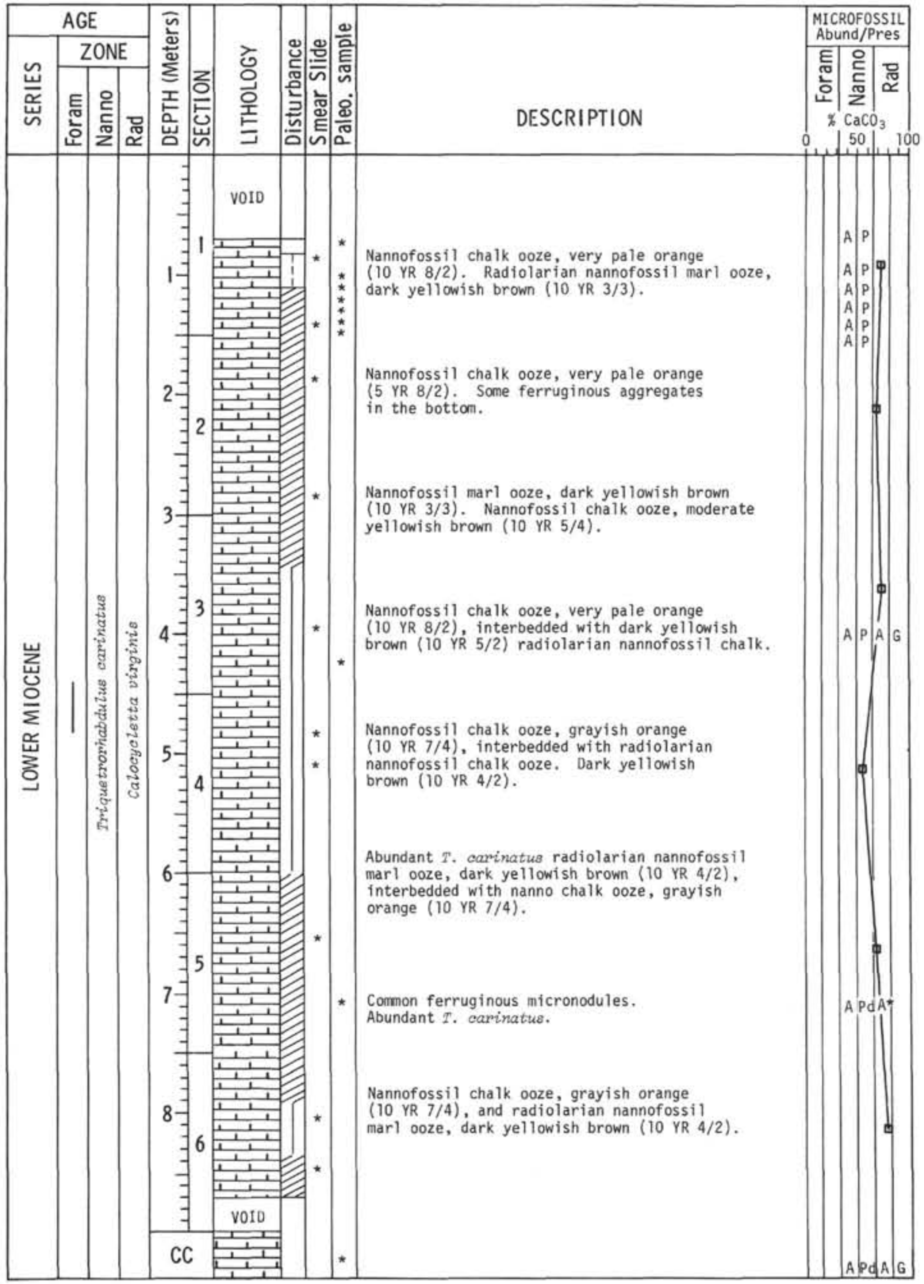
Nannofossil chalk ooze, grayish orange (10 YR 3/4); interbedded with very pale orange (10 YR 8/3) nannofossil chalk ooze.

Nannofossil chalk ooze, very pale orange (10 YR 8/2)

Nannofossil chalk ooze, very pale orange (10 YR 8/2). Some thin beds of ferruginous radiolarian nannofossil chalk ooze, pale yellowish brown (10 YR 6/2). Radiolarian nannofossil marl ooze, moderate yellowish brown (10 YR 5/4).

Nannofossil chalk ooze, very pale orange (10 YR 8/2). Common radiolarians and *T. carinatus*.

SITE: 161 HOLE: CORE: 2 Cored Interval: 9-18 m



Nannofossil chalk ooze, very pale orange (10 YR 8/2). Radiolarian nannofossil marl ooze, dark yellowish brown (10 YR 3/3).

Nannofossil chalk ooze, very pale orange (5 YR 8/2). Some ferruginous aggregates in the bottom.

Nannofossil marl ooze, dark yellowish brown (10 YR 3/3). Nannofossil chalk ooze, moderate yellowish brown (10 YR 5/4).

Nannofossil chalk ooze, very pale orange (10 YR 8/2), interbedded with dark yellowish brown (10 YR 5/2) radiolarian nannofossil chalk.

Nannofossil chalk ooze, grayish orange (10 YR 7/4), interbedded with radiolarian nannofossil chalk ooze. Dark yellowish brown (10 YR 4/2).

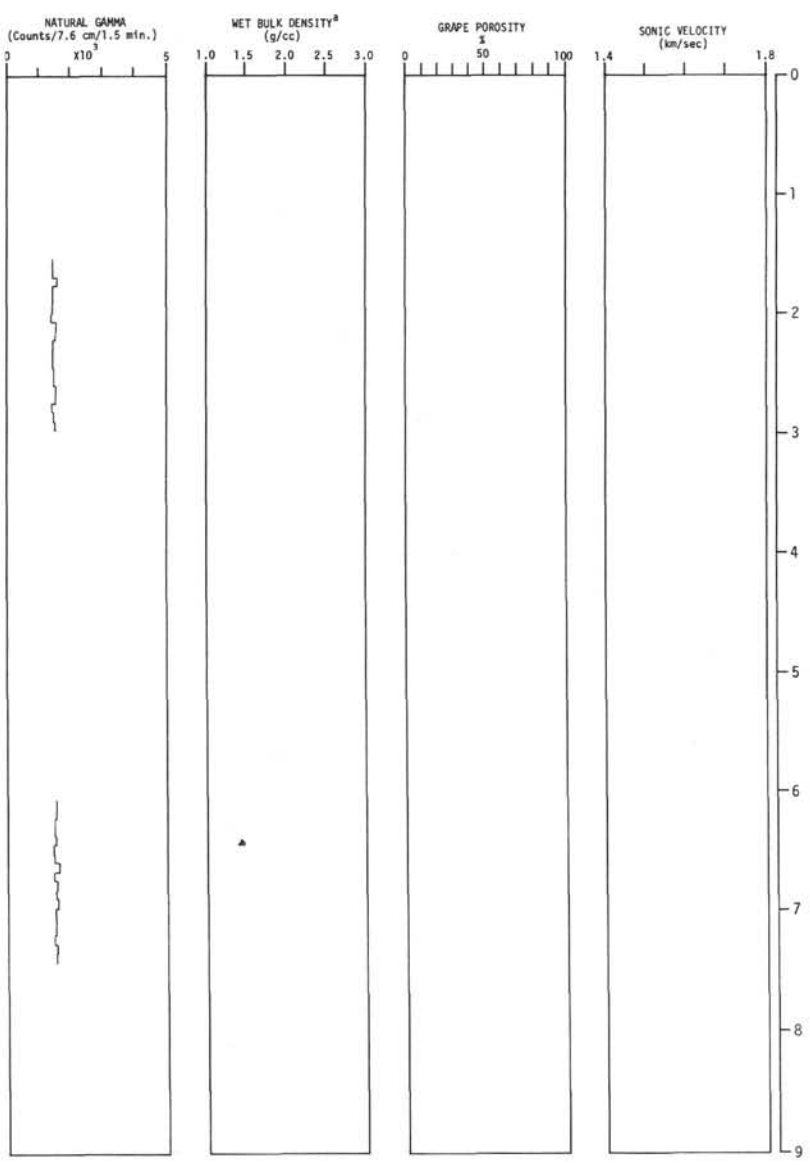
Abundant *T. carinatus* radiolarian nannofossil marl ooze, dark yellowish brown (10 YR 4/2), interbedded with nanno chalk ooze, grayish orange (10 YR 7/4).

Common ferruginous micronodules. Abundant *T. carinatus*.

Nannofossil chalk ooze, grayish orange (10 YR 7/4), and radiolarian nannofossil marl ooze, dark yellowish brown (10 YR 4/2).

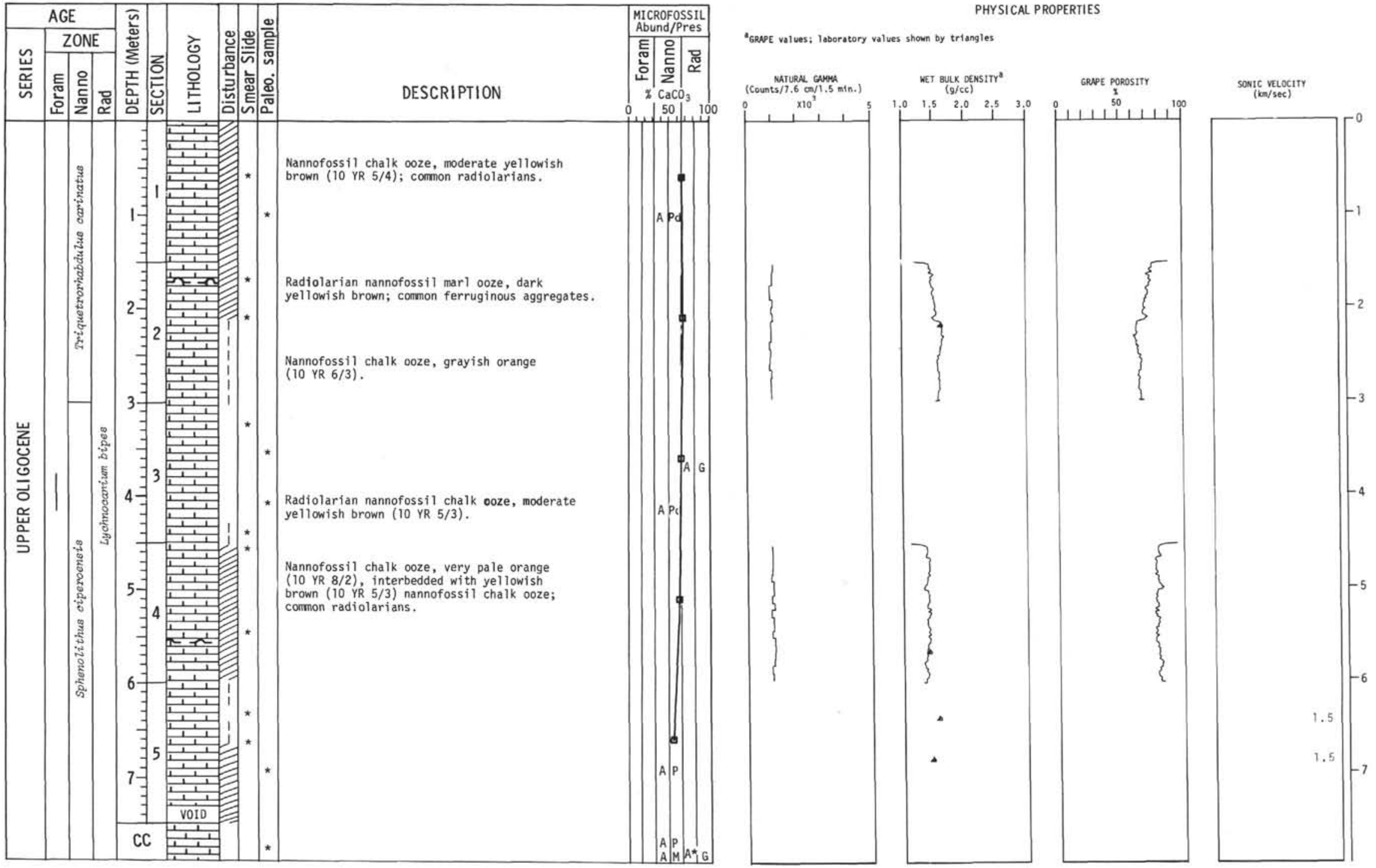
PHYSICAL PROPERTIES

aGRAPE values; laboratory values shown by triangles



1.5

SITE: 161 HOLE: CORE: 3 Cored Interval: 18-27 m



Nannofossil chalk ooze, moderate yellowish brown (10 YR 5/4); common radiolarians.

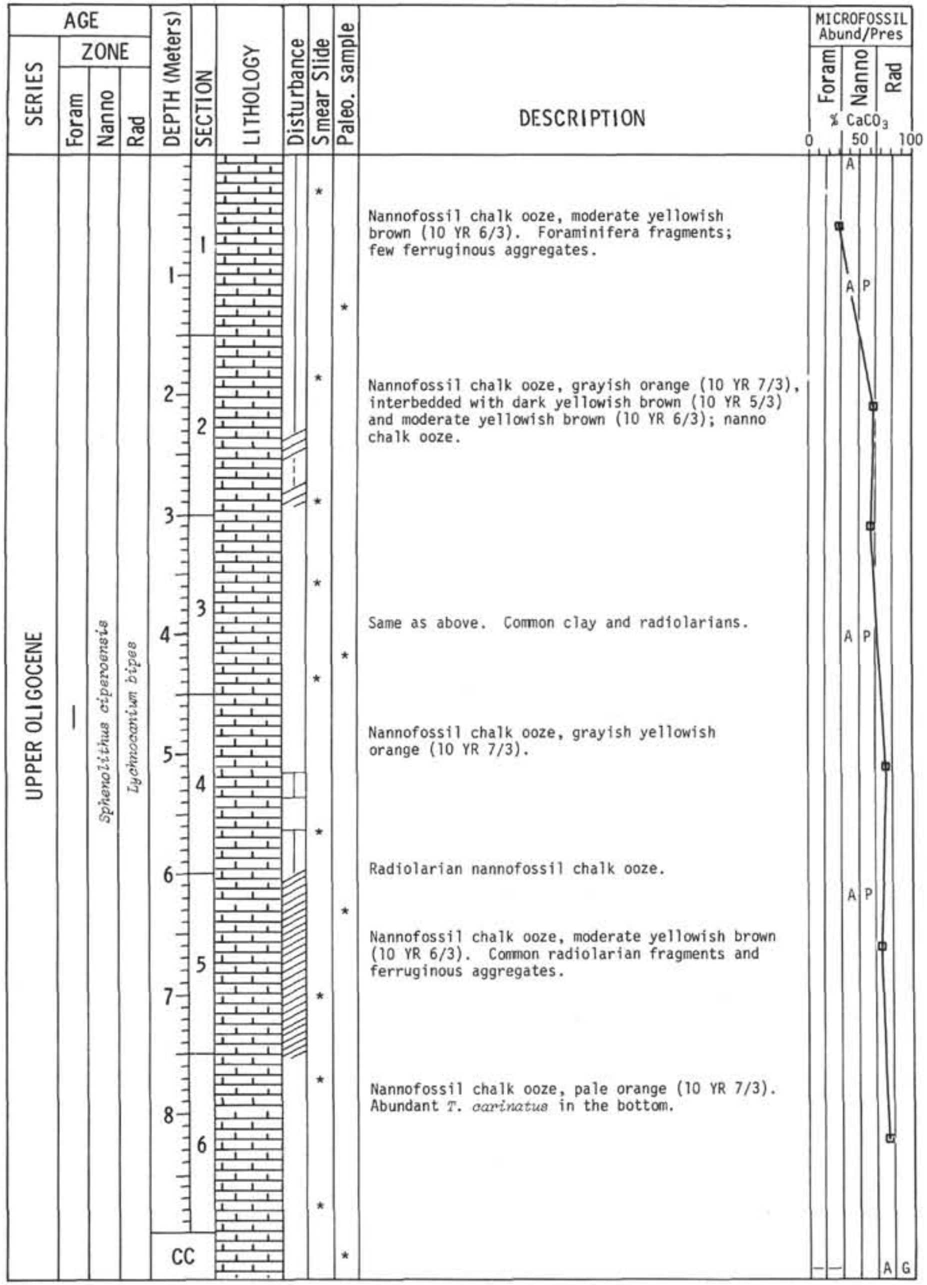
Radiolarian nannofossil marl ooze, dark yellowish brown; common ferruginous aggregates.

Nannofossil chalk ooze, grayish orange (10 YR 6/3).

Radiolarian nannofossil chalk ooze, moderate yellowish brown (10 YR 5/3).

Nannofossil chalk ooze, very pale orange (10 YR 8/2), interbedded with yellowish brown (10 YR 5/3) nannofossil chalk ooze; common radiolarians.
]

SITE: 161 HOLE: CORE: 4 Cored Interval: 27-36 m



Nannofossil chalk ooze, moderate yellowish brown (10 YR 6/3). Foraminifera fragments; few ferruginous aggregates.

Nannofossil chalk ooze, grayish orange (10 YR 7/3), interbedded with dark yellowish brown (10 YR 5/3) and moderate yellowish brown (10 YR 6/3); nanno chalk ooze.

Same as above. Common clay and radiolarians.

Nannofossil chalk ooze, grayish yellowish orange (10 YR 7/3).

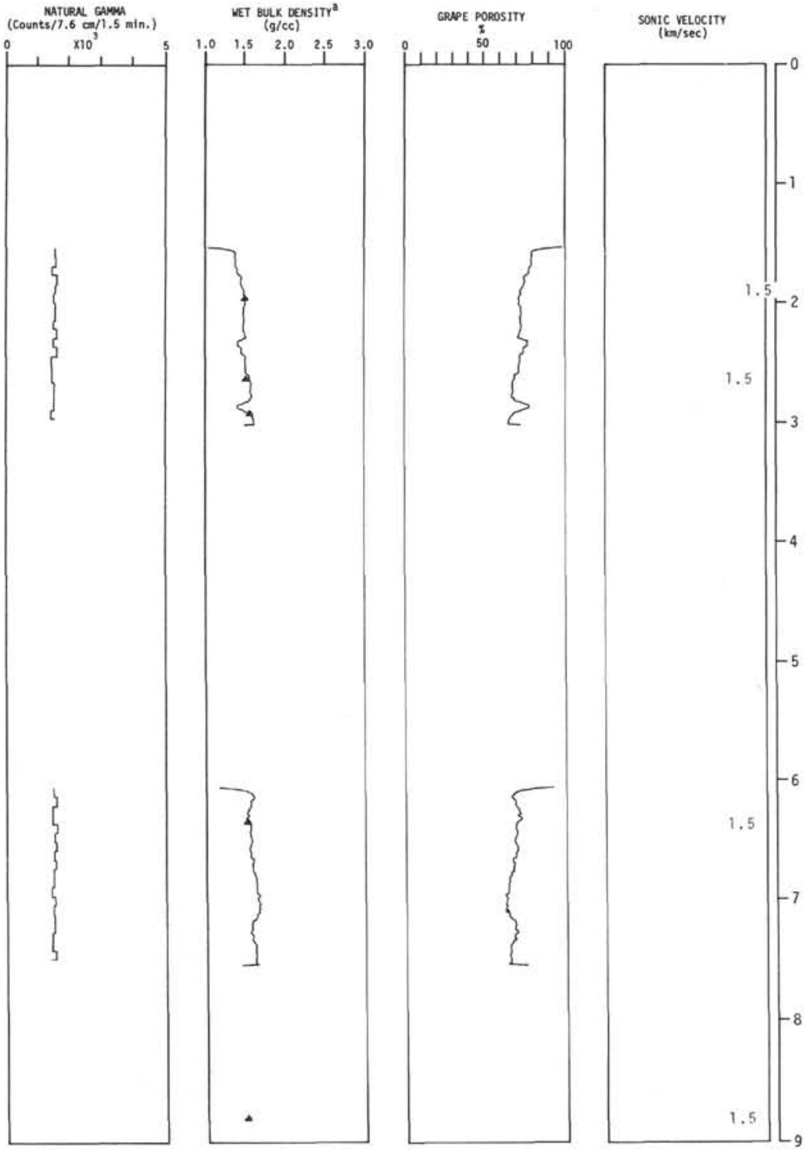
Radiolarian nannofossil chalk ooze.

Nannofossil chalk ooze, moderate yellowish brown (10 YR 6/3). Common radiolarian fragments and ferruginous aggregates.

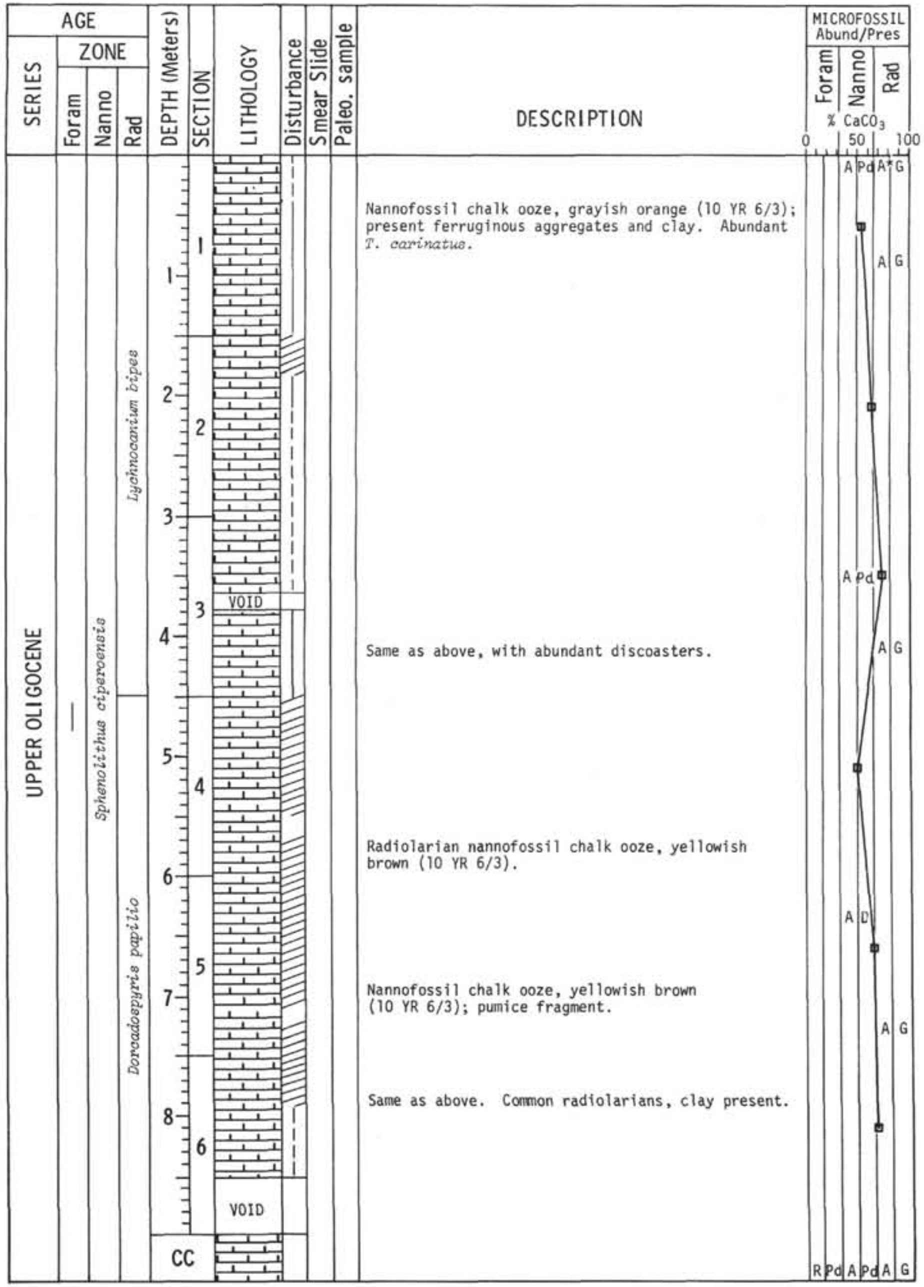
Nannofossil chalk ooze, pale orange (10 YR 7/3). Abundant *T. carinatus* in the bottom.

PHYSICAL PROPERTIES

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



SITE: 161 HOLE: CORE: 5 Cored Interval: 36-45 m



Nannofossil chalk ooze, grayish orange (10 YR 6/3); present ferruginous aggregates and clay. Abundant *T. carinatus*.

Same as above, with abundant discoasters.

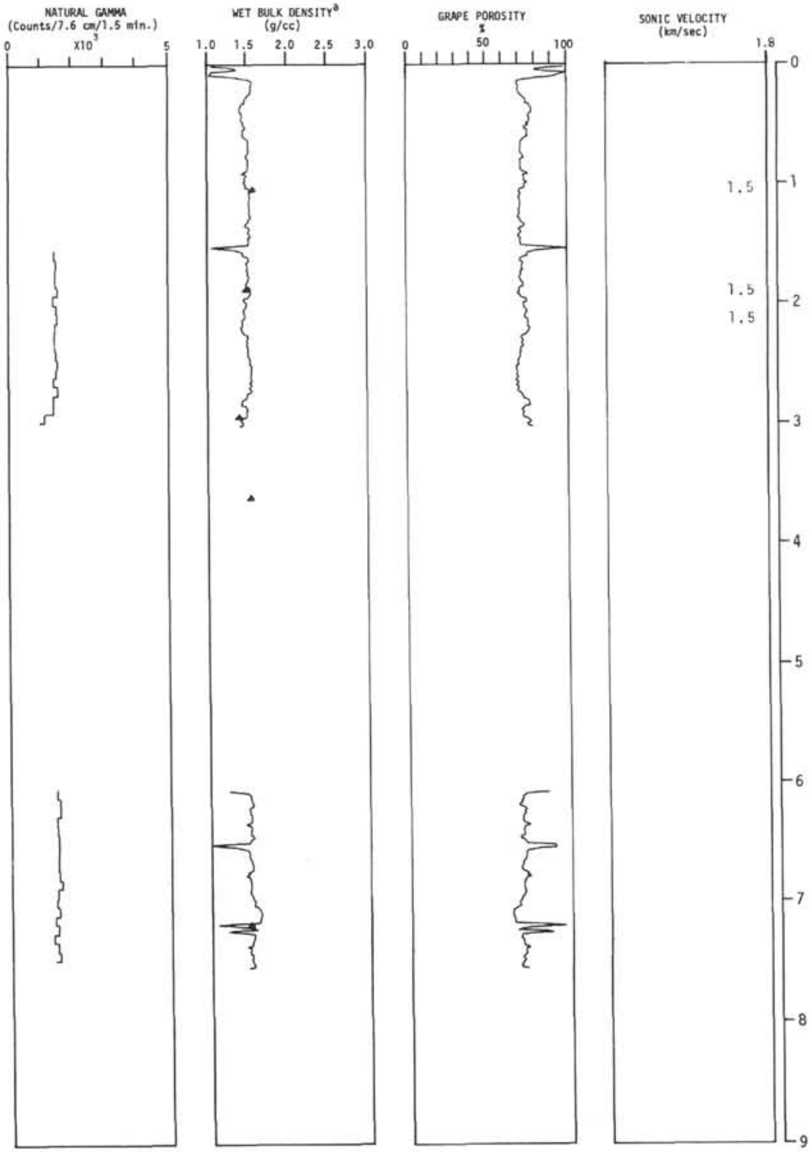
Radiolarian nannofossil chalk ooze, yellowish brown (10 YR 6/3).

Nannofossil chalk ooze, yellowish brown (10 YR 6/3); pumice fragment.

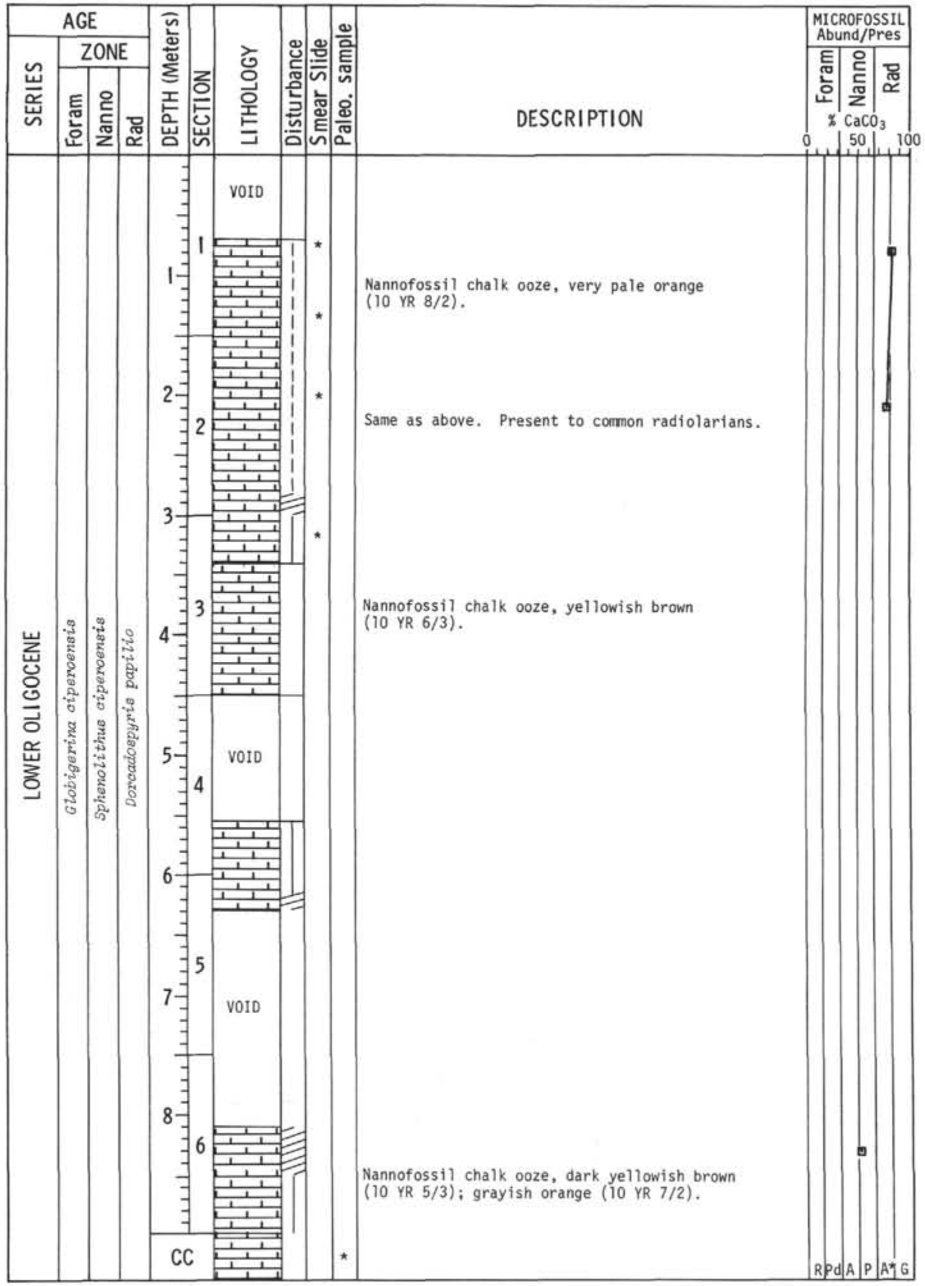
Same as above. Common radiolarians, clay present.

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



SITE: 161 HOLE: CORE: 6 Cored Interval: 45-54 m



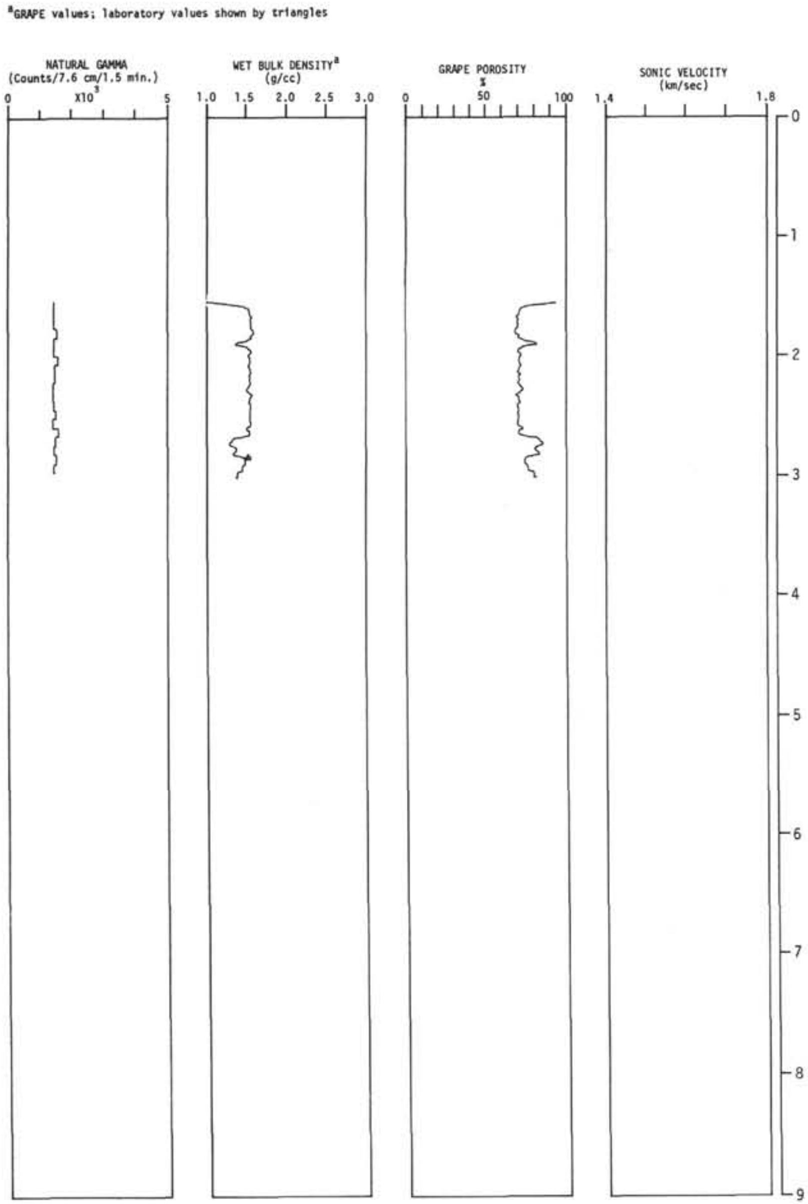
Nannofossil chalk ooze, very pale orange (10 YR 8/2).

Same as above. Present to common radiolarians.

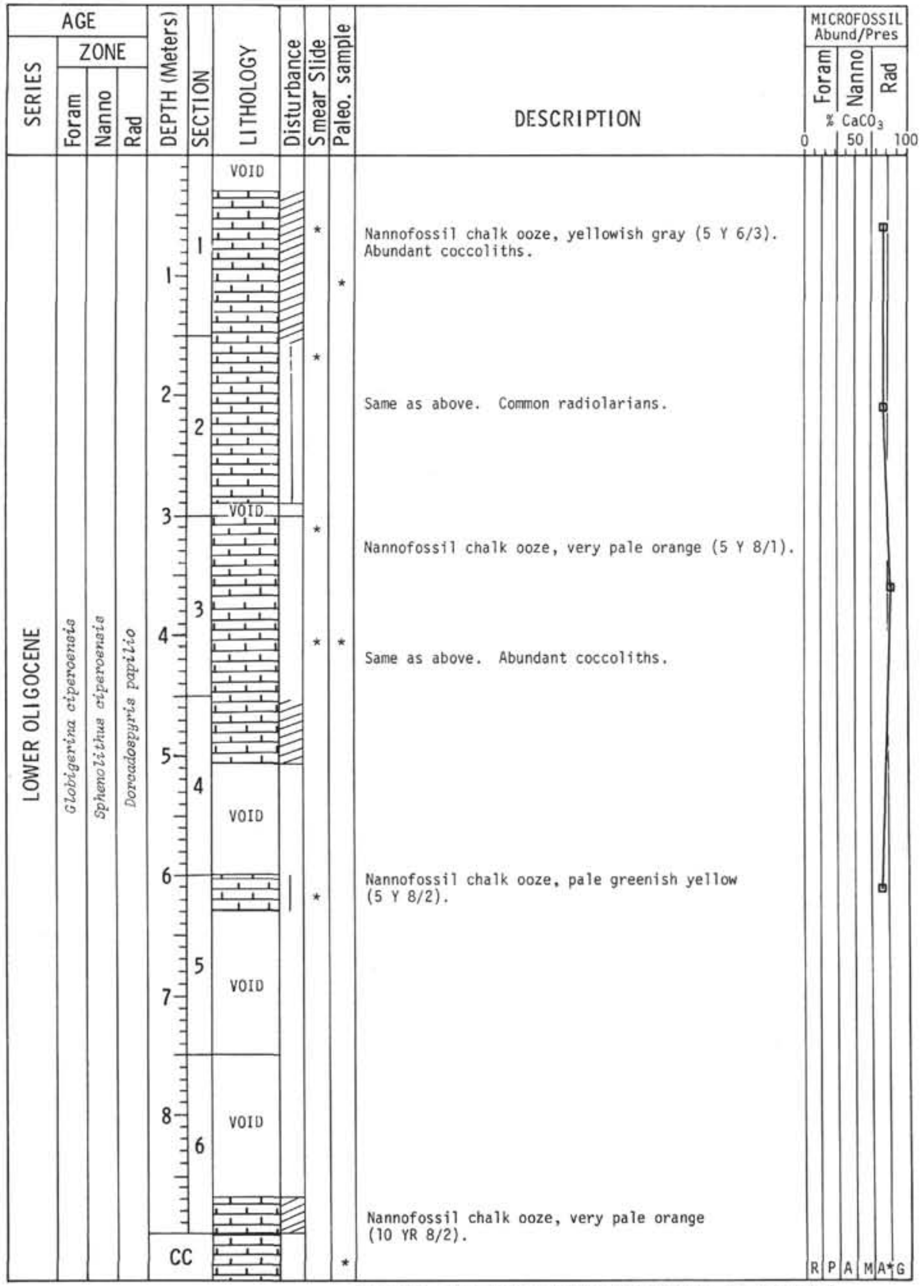
Nannofossil chalk ooze, yellowish brown (10 YR 6/3).

Nannofossil chalk ooze, dark yellowish brown (10 YR 5/3); grayish orange (10 YR 7/2).

PHYSICAL PROPERTIES



SITE: 161 HOLE: CORE: 7 Cored Interval: 54-63 m



Nannofossil chalk ooze, yellowish gray (5 Y 6/3). Abundant coccoliths.

Same as above. Common radiolarians.

Nannofossil chalk ooze, very pale orange (5 Y 8/1).

Same as above. Abundant coccoliths.

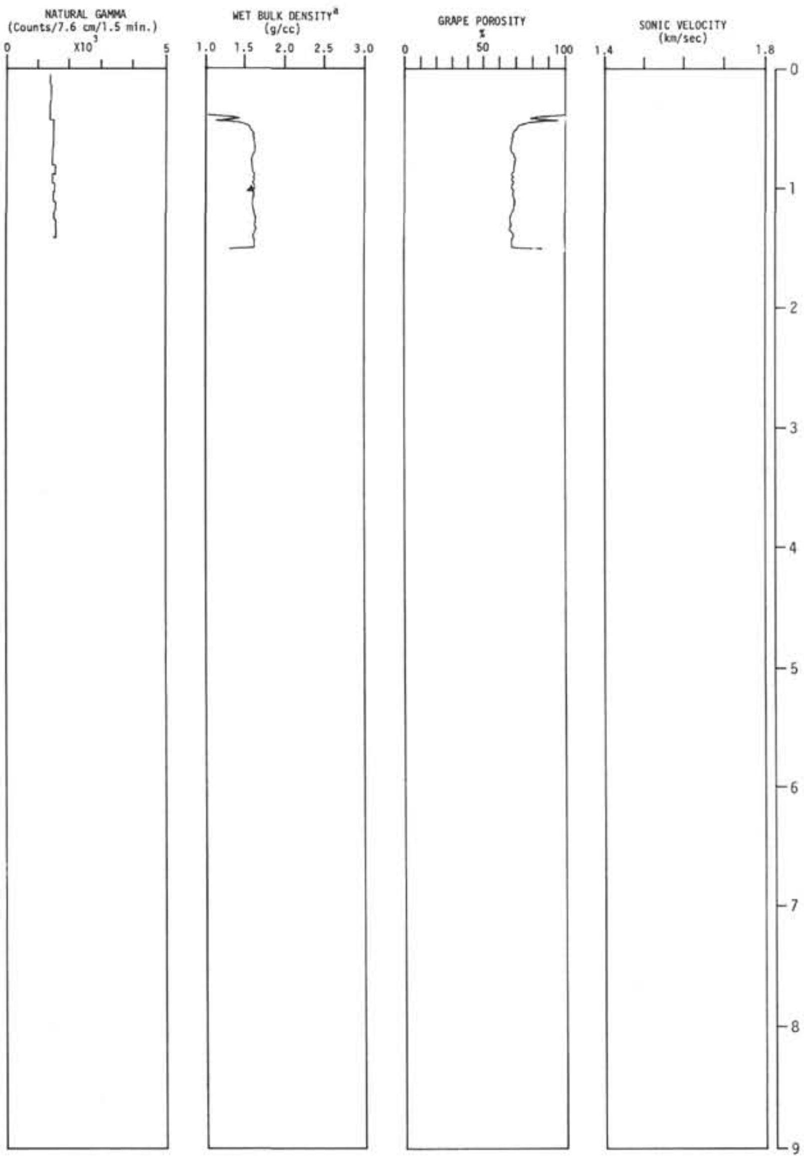
Nannofossil chalk ooze, pale greenish yellow (5 Y 8/2).

Nannofossil chalk ooze, very pale orange (10 YR 8/2).

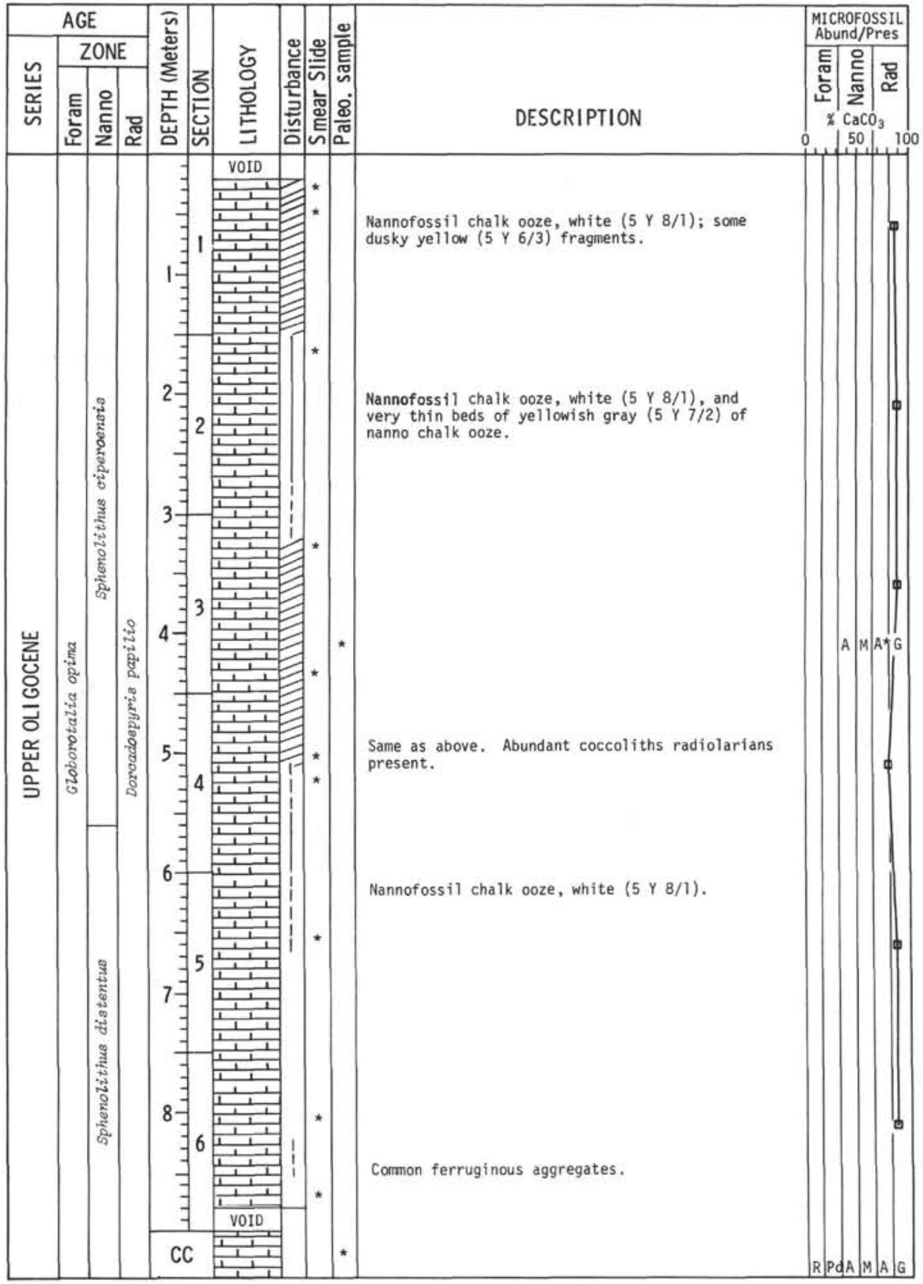
(Site 161, Core 8; Cored Interval: 63-72 m. No recovery.)

PHYSICAL PROPERTIES

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



SITE: 161 HOLE: CORE: 9 Cored Interval: 72-81 m



Nannofossil chalk ooze, white (5 Y 8/1); some dusky yellow (5 Y 6/3) fragments.

Nannofossil chalk ooze, white (5 Y 8/1), and very thin beds of yellowish gray (5 Y 7/2) of nanno chalk ooze.

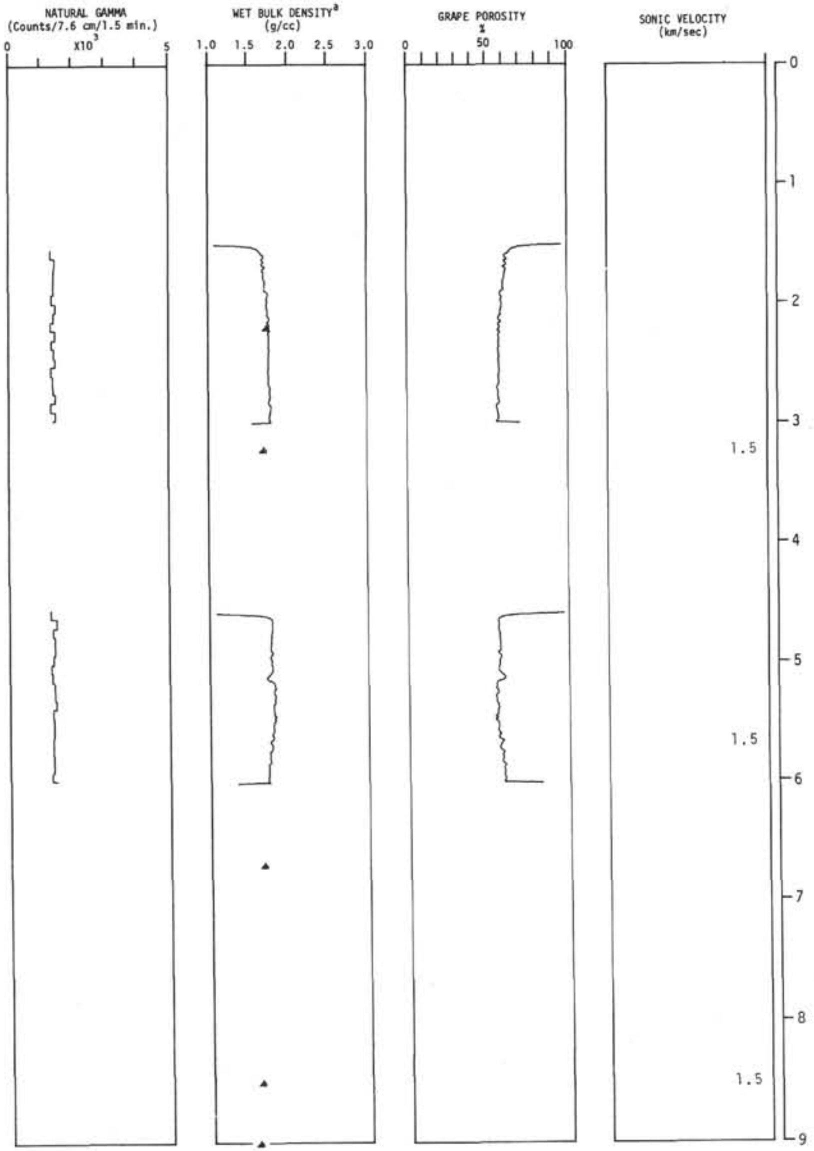
Same as above. Abundant coccoliths radiolarians present.

Nannofossil chalk ooze, white (5 Y 8/1).

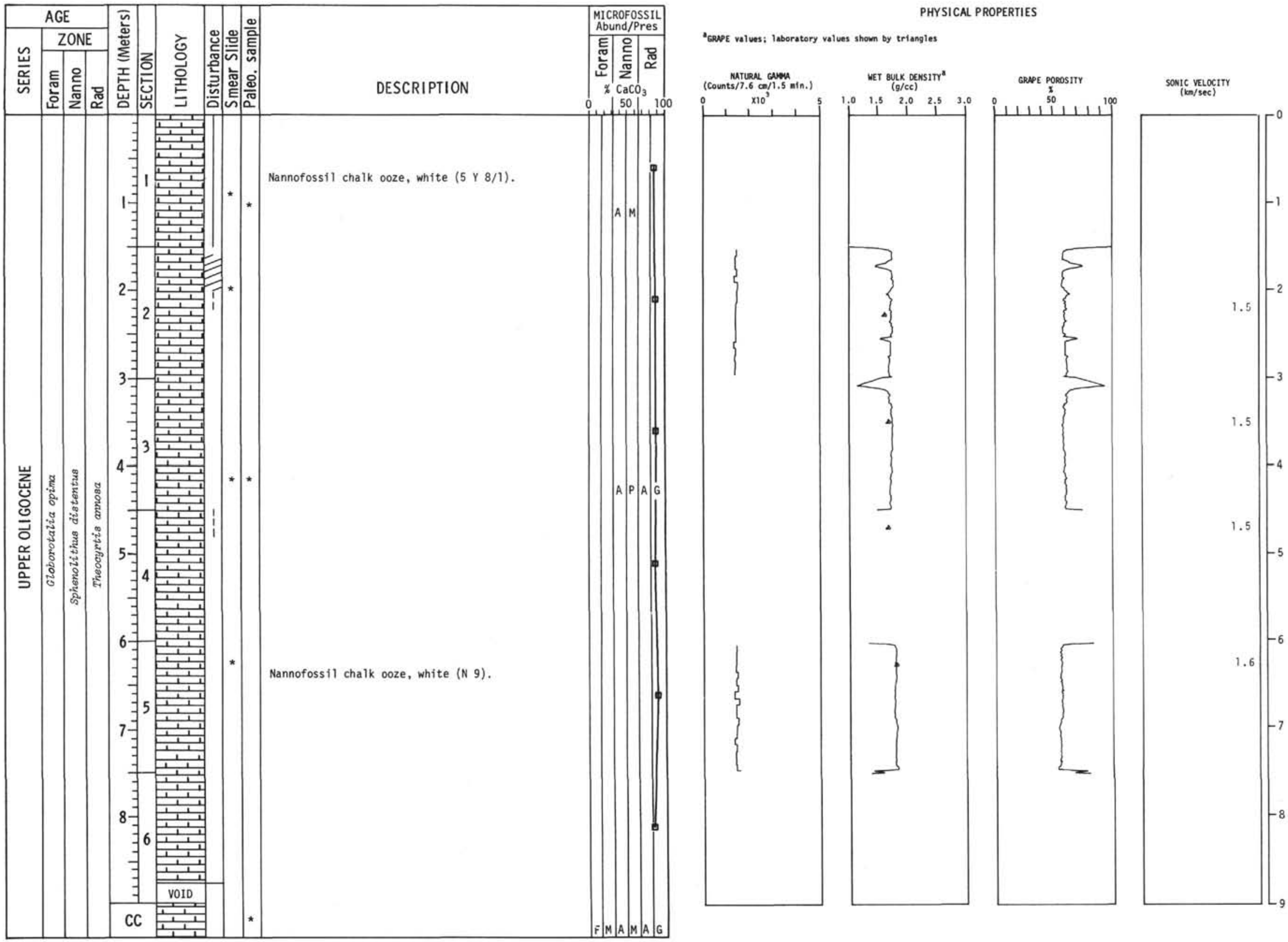
Common ferruginous aggregates.

PHYSICAL PROPERTIES

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



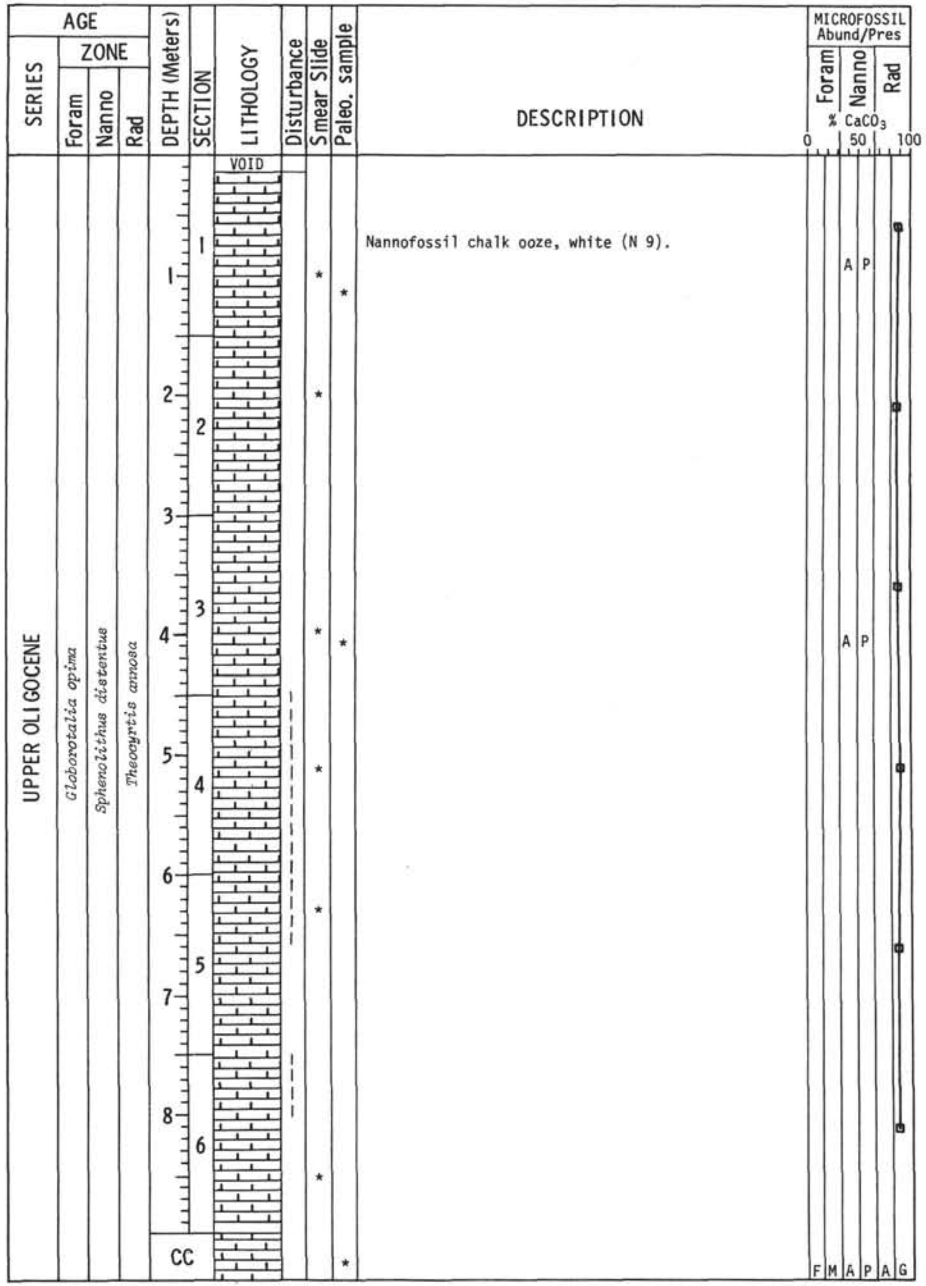
SITE: 161 HOLE: CORE: 10 Cored Interval: 81-90 m



Nannofossil chalk ooze, white (5 Y 8/1).

Nannofossil chalk ooze, white (N 9).

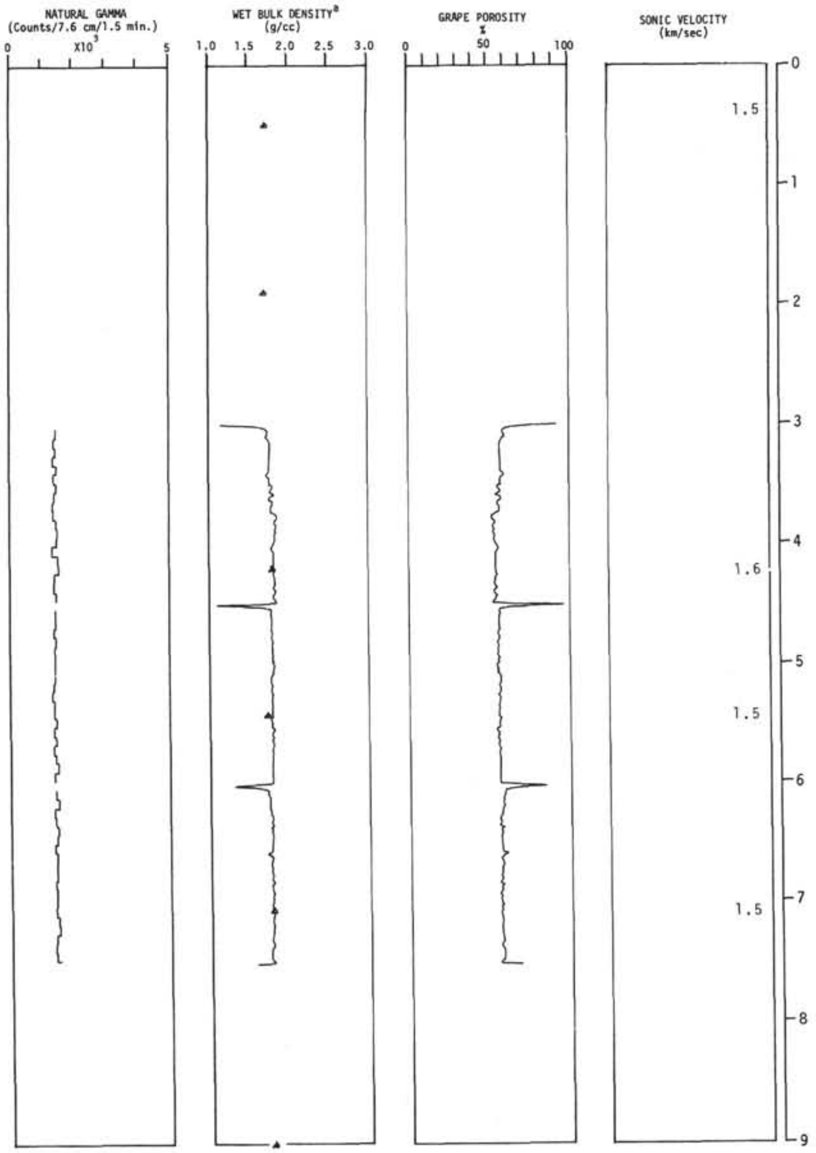
SITE: 161 HOLE: CORE: 11 Cored Interval: 90-99 m



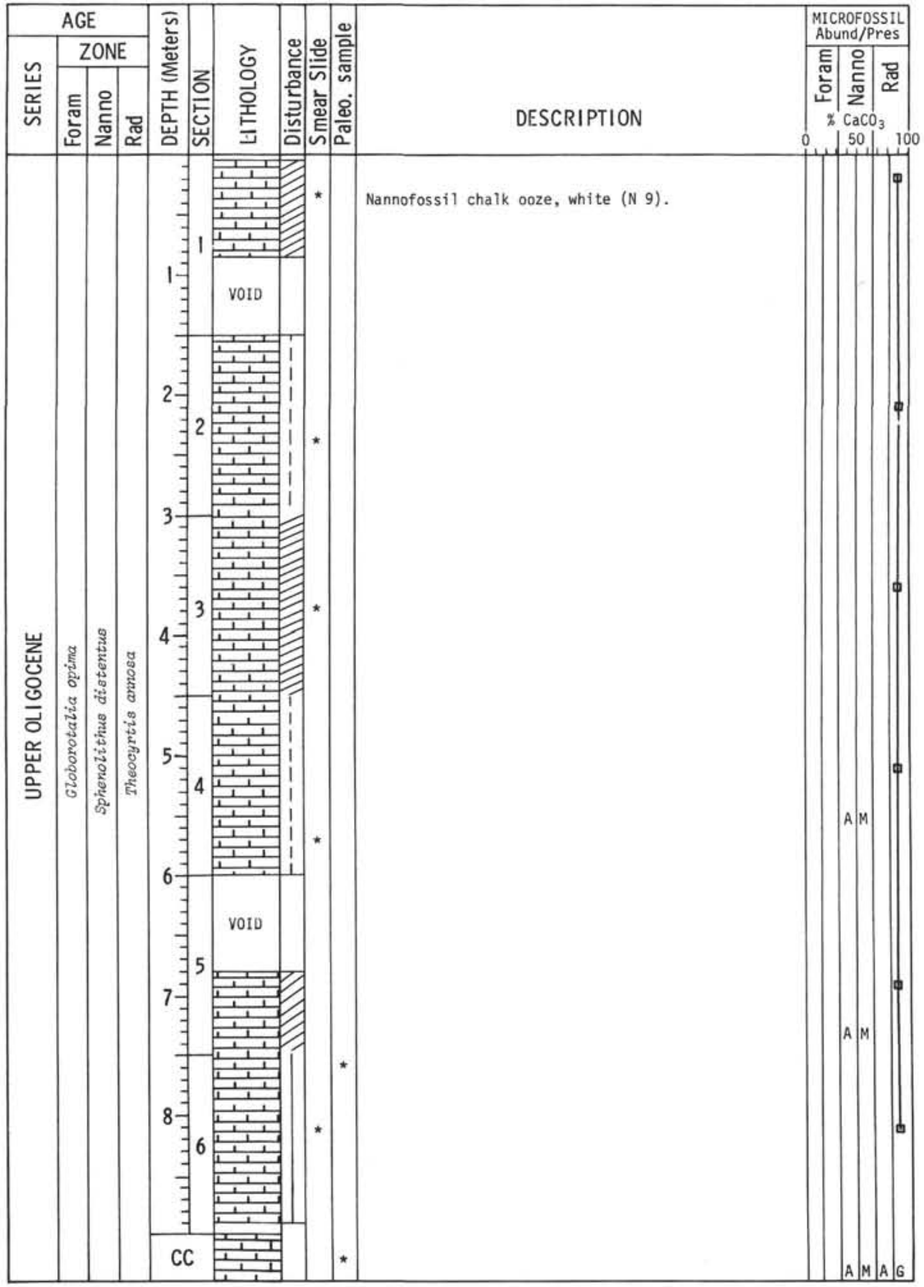
Nannofossil chalk ooze, white (N 9).

PHYSICAL PROPERTIES

ᵃGRAPE values; laboratory values shown by triangles

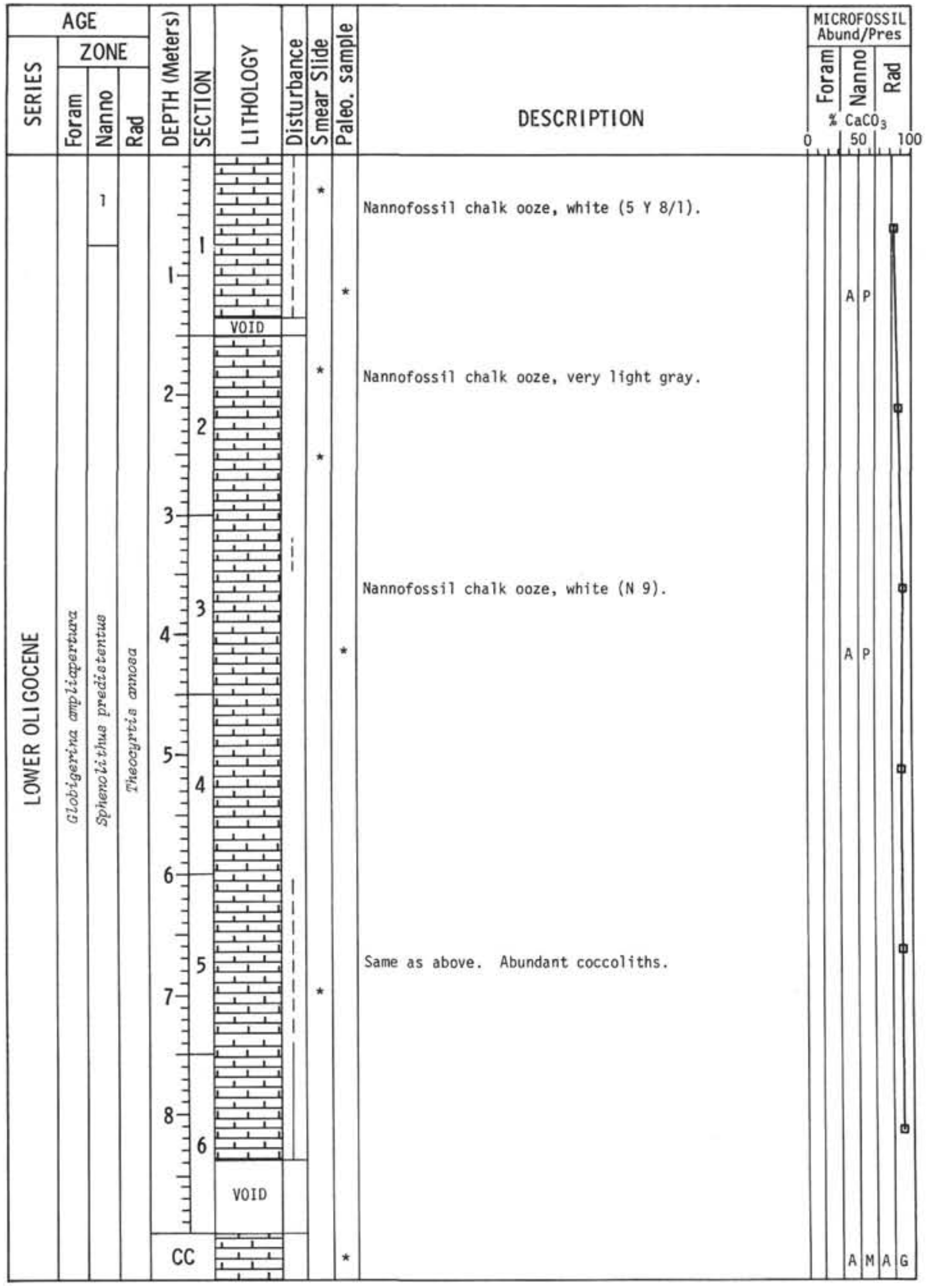


SITE: 161 HOLE: CORE: 12 Cored Interval: 99-108 m



Nannofossil chalk ooze, white (N 9).

SITE: 161 HOLE: CORE: 13 Cored Interval: 108-117 m



Nannofossil chalk ooze, white (5 Y 8/1).

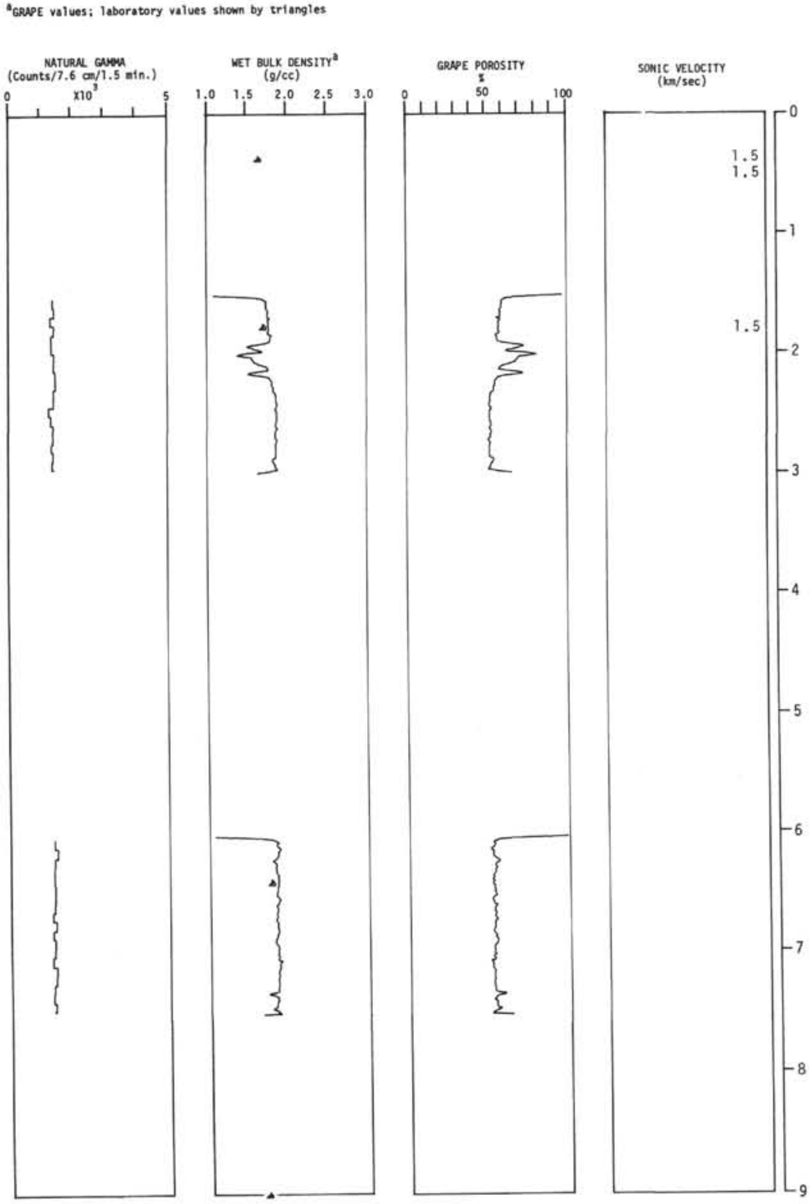
Nannofossil chalk ooze, very light gray.

Nannofossil chalk ooze, white (N 9).

Same as above. Abundant coccoliths.

[1] *Sphenolithus distentus*

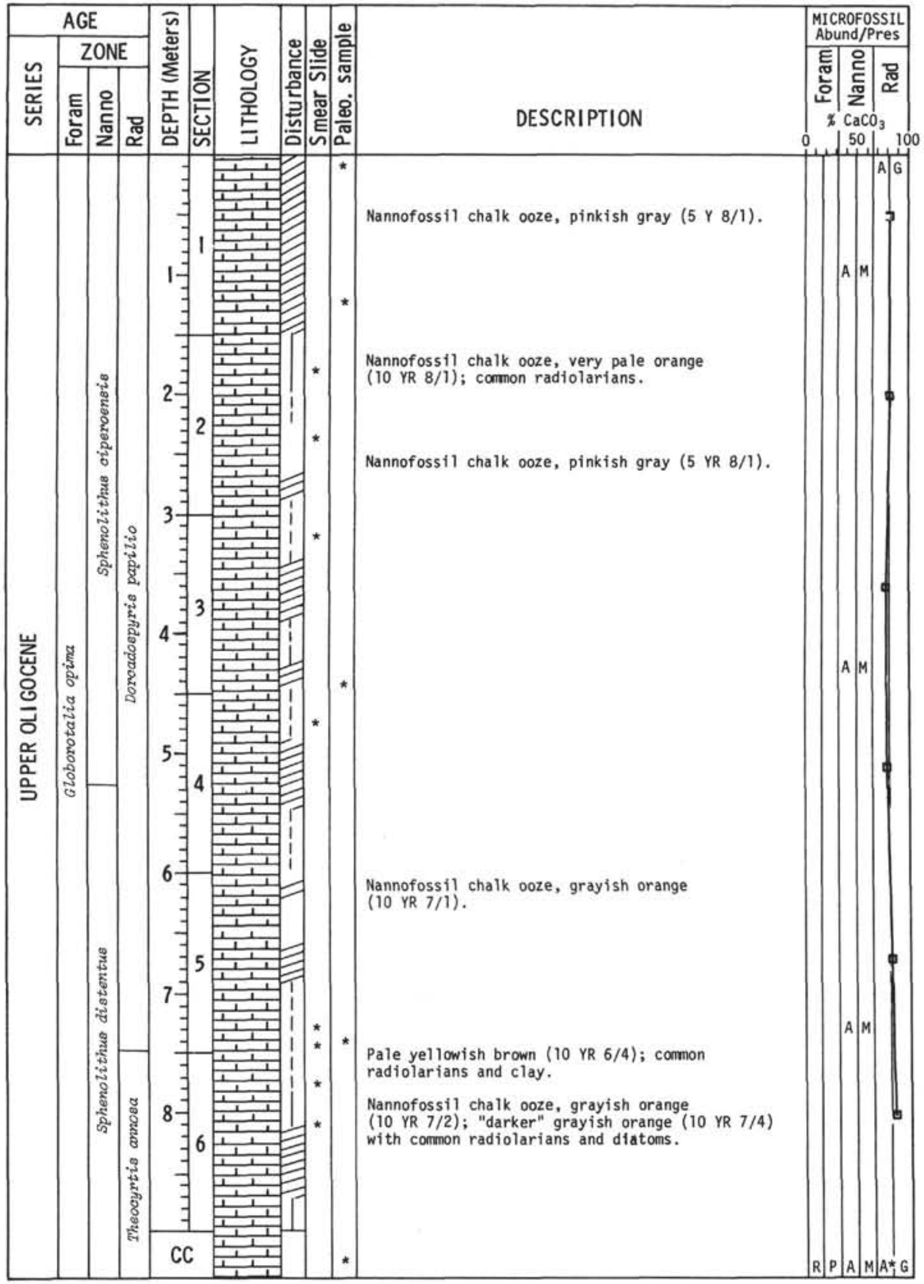
PHYSICAL PROPERTIES



SITE: 161 HOLE: CORE: 14 Cored Interval: 117-126 m

AGE											MICROFOSSIL Abund/Pres		
SERIES	ZONE			DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	Foram	Nanno	Rad
	Foram	Nanno	Rad								% CaCO$_3$ 0 50 100		
LOWER OLIGOCENE	*G. ampliapertura*	*S. predistentus*	*T. annosa*	1	1	No recovery							
				CC		▦				Nannofossil chalk ooze	R Pd	A A P M	A G

SITE: 161 HOLE: A CORE: 1 Cored Interval: 63-72 m



Nannofossil chalk ooze, pinkish gray (5 Y 8/1).

Nannofossil chalk ooze, very pale orange (10 YR 8/1); common radiolarians.

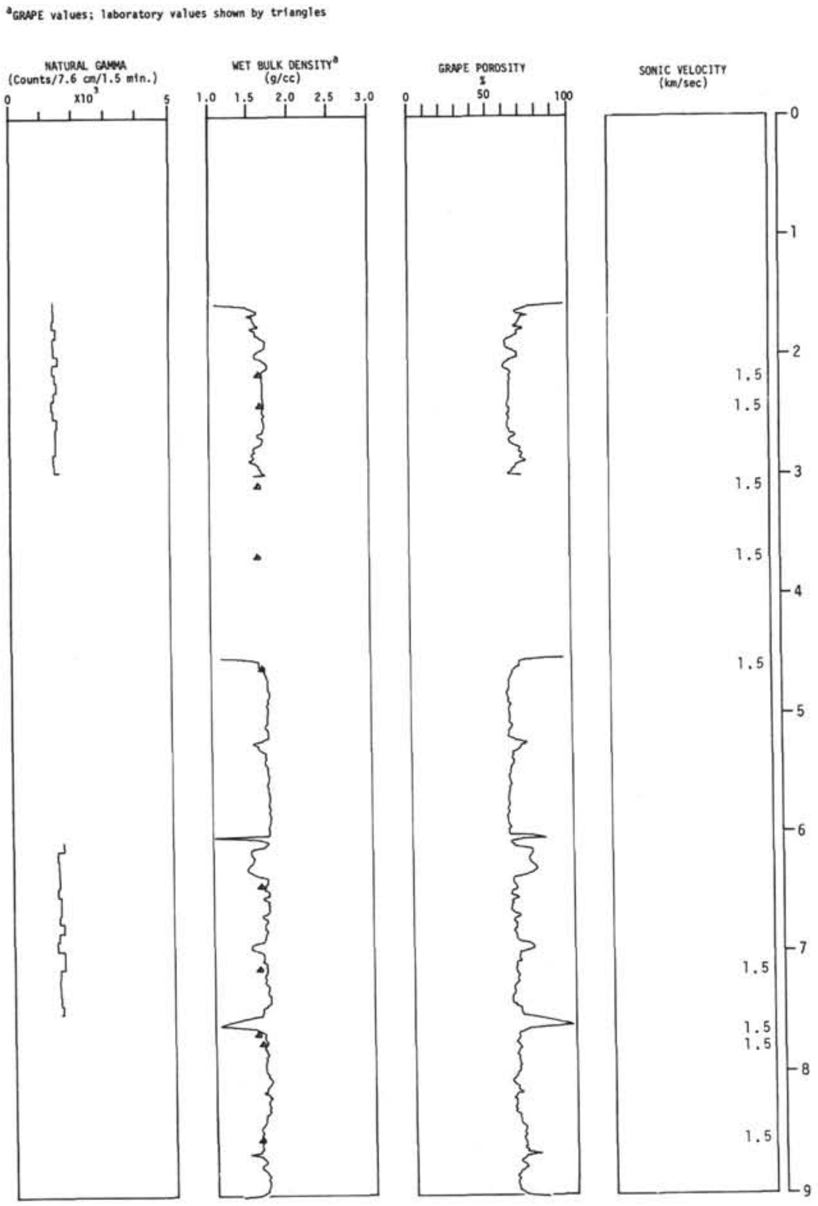
Nannofossil chalk ooze, pinkish gray (5 YR 8/1).

Nannofossil chalk ooze, grayish orange (10 YR 7/1).

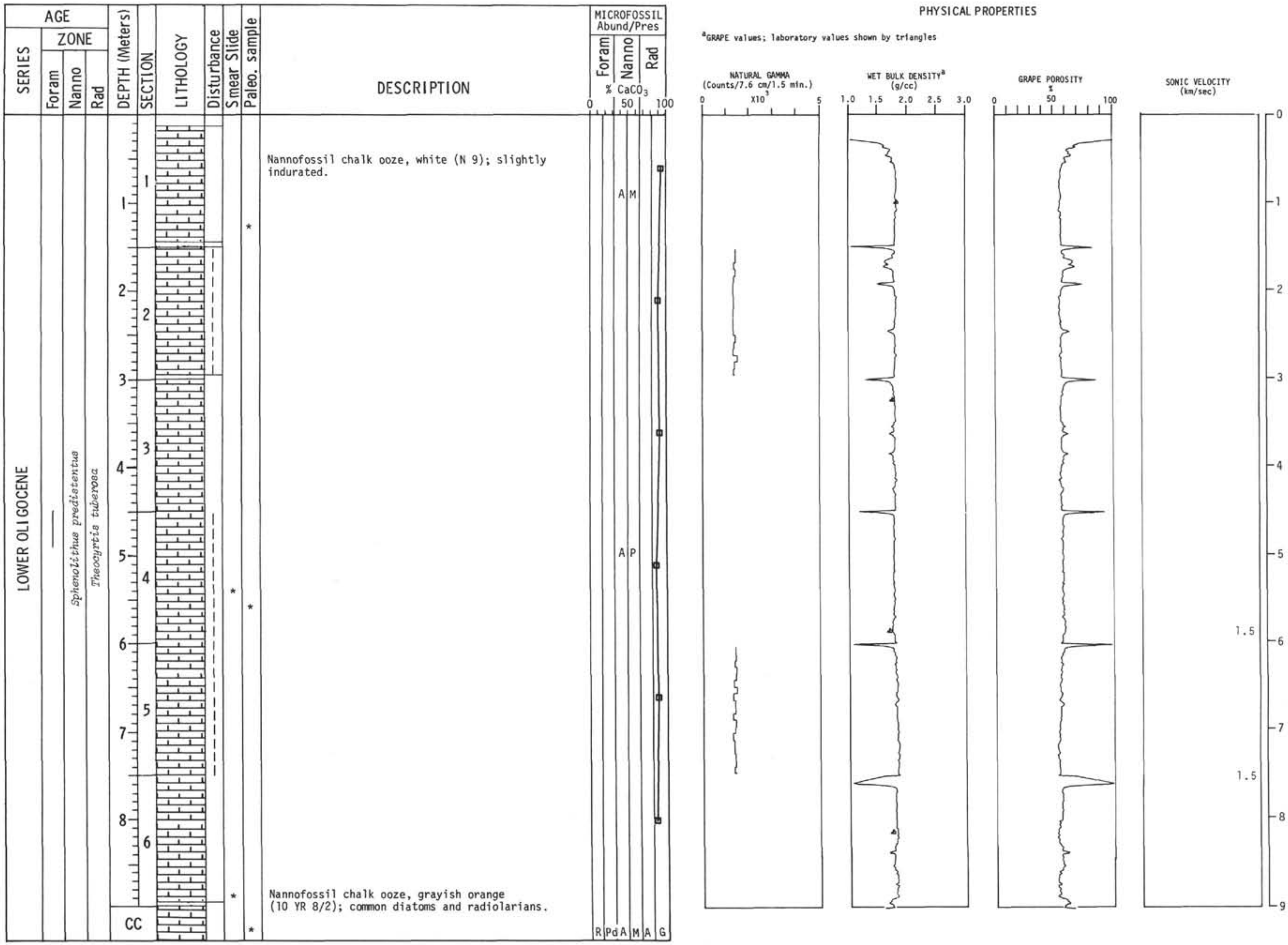
Pale yellowish brown (10 YR 6/4); common radiolarians and clay.

Nannofossil chalk ooze, grayish orange (10 YR 7/2); "darker" grayish orange (10 YR 7/4) with common radiolarians and diatoms.

PHYSICAL PROPERTIES



SITE: 161 HOLE: A CORE: 2 Cored Interval: 128-137 m

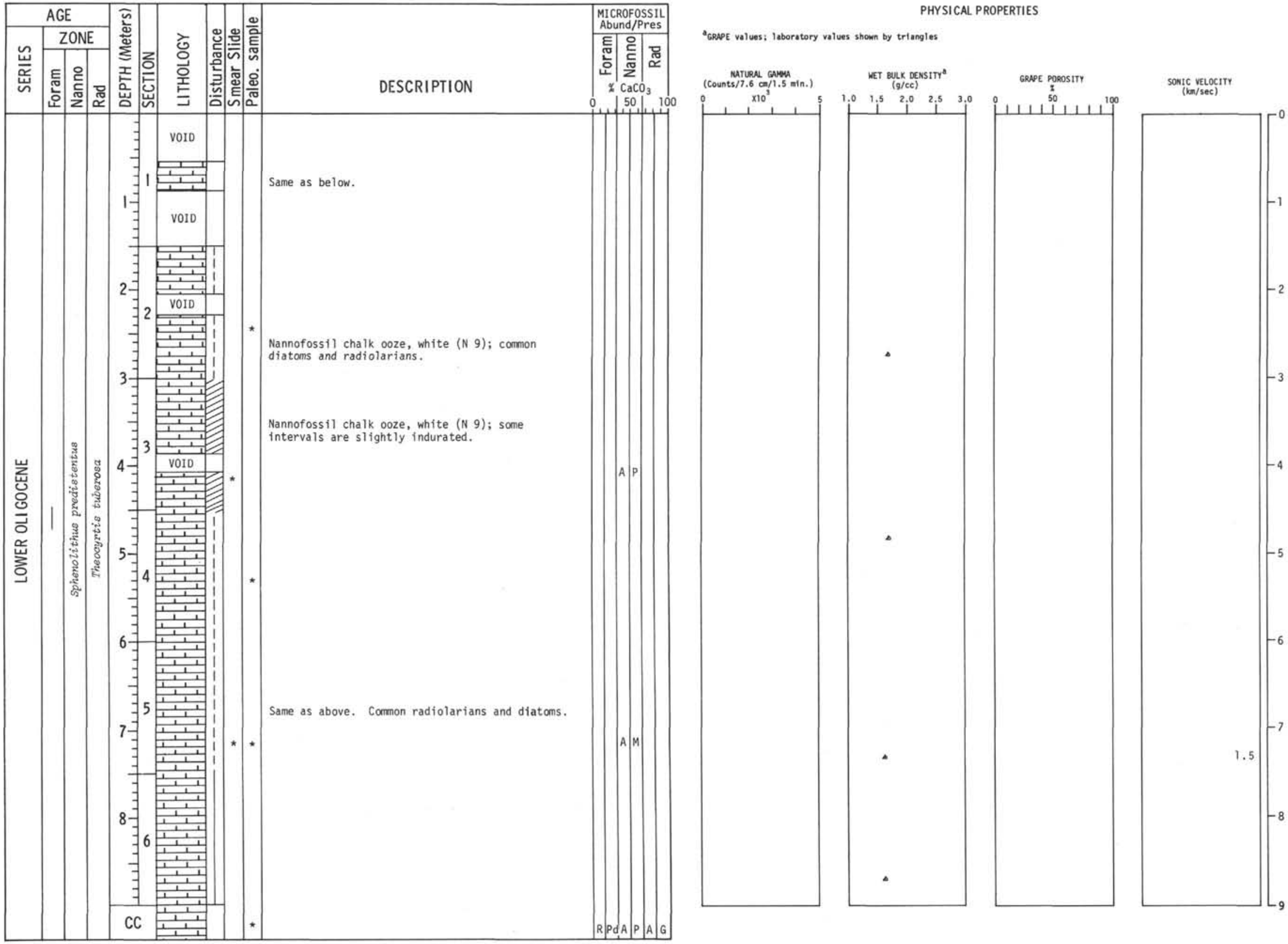


Nannofossil chalk ooze, white (N 9); slightly indurated.

Nannofossil chalk ooze, grayish orange (10 YR 8/2); common diatoms and radiolarians.

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

SITE: 161 HOLE: A CORE: 3 Cored Interval: 137-146 m



Same as below.

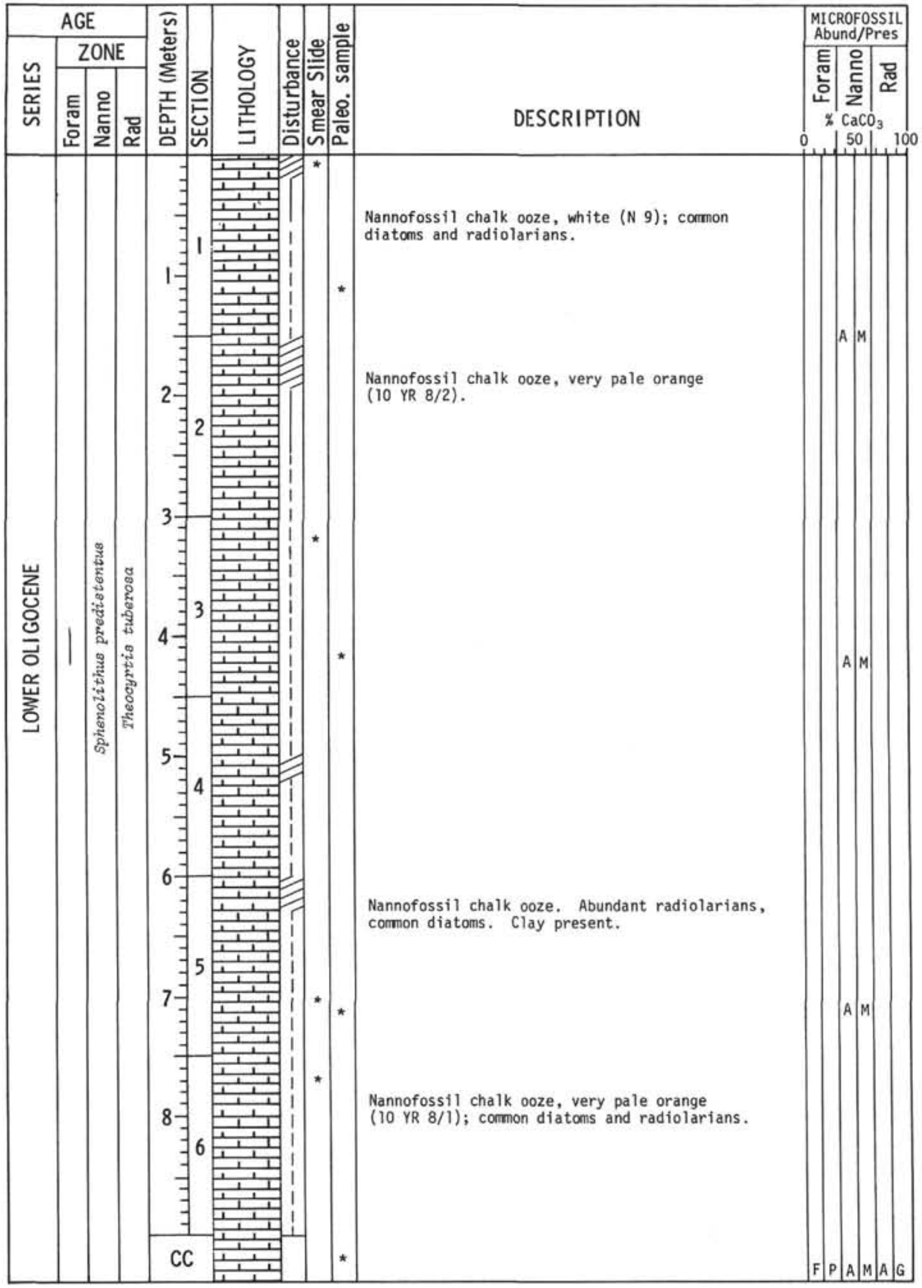
Nannofossil chalk ooze, white (N 9); common diatoms and radiolarians.

Nannofossil chalk ooze, white (N 9); some intervals are slightly indurated.

Same as above. Common radiolarians and diatoms.

[a] GRAPE values; laboratory values shown by triangles

SITE: 161 HOLE: A CORE: 4 Cored Interval: 146-155 m



Nannofossil chalk ooze, white (N 9); common diatoms and radiolarians.

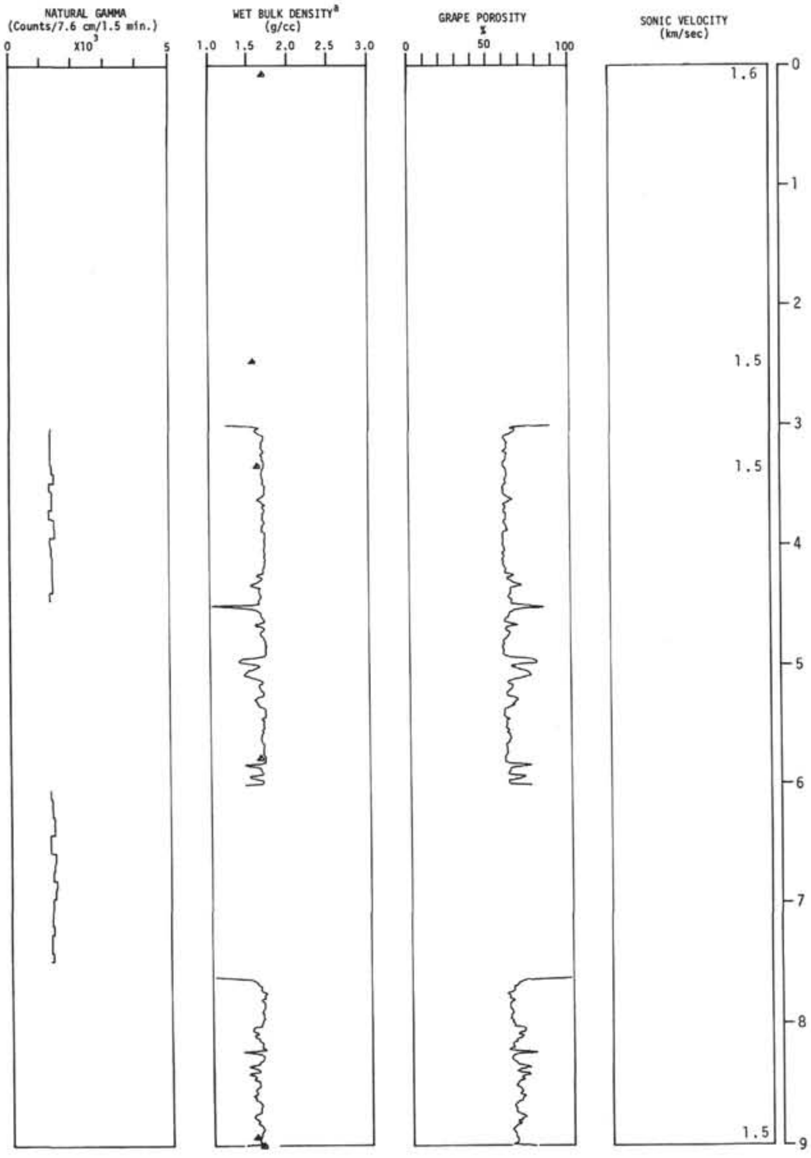
Nannofossil chalk ooze, very pale orange (10 YR 8/2).

Nannofossil chalk ooze. Abundant radiolarians, common diatoms. Clay present.

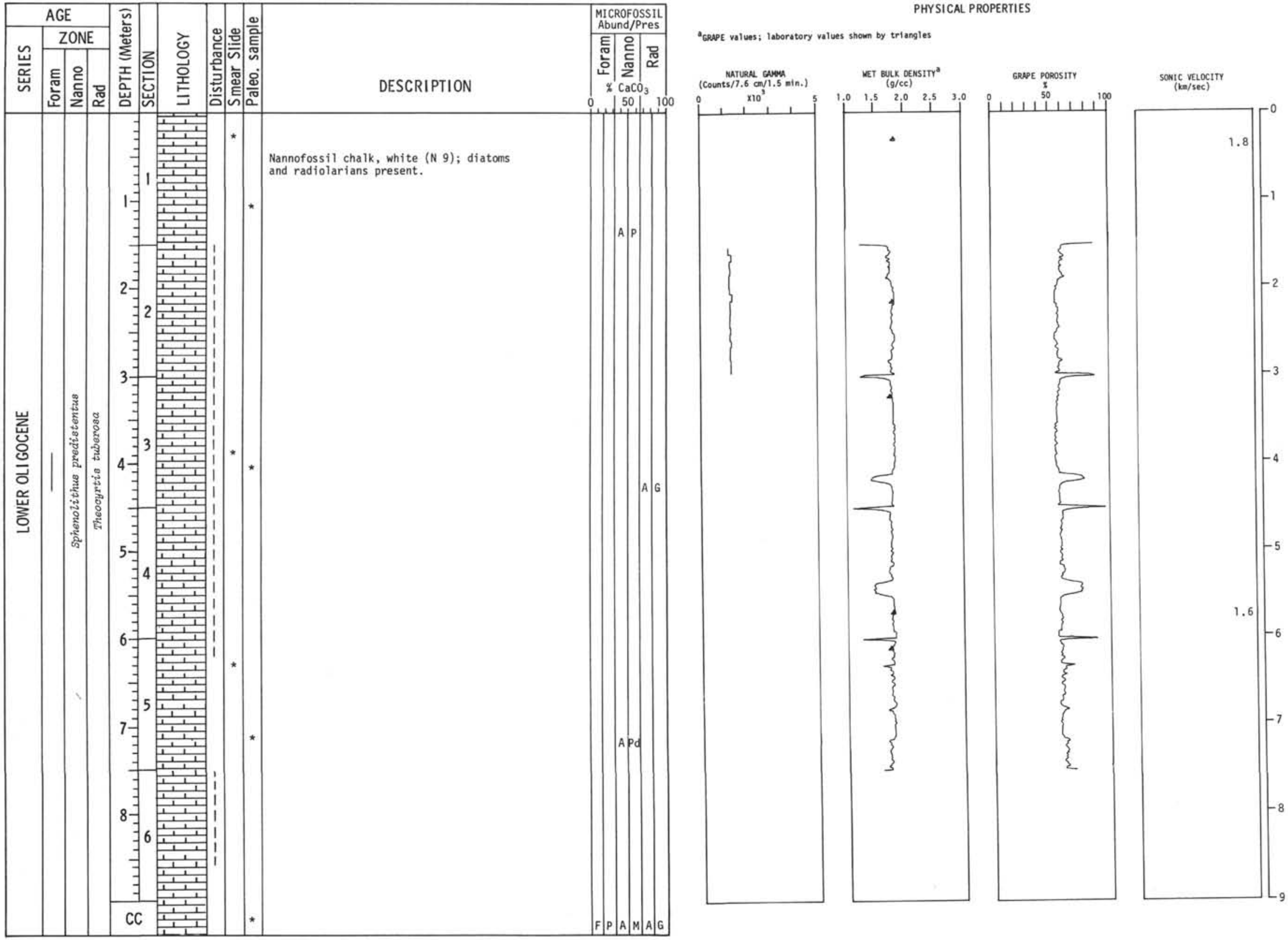
Nannofossil chalk ooze, very pale orange (10 YR 8/1); common diatoms and radiolarians.

PHYSICAL PROPERTIES

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

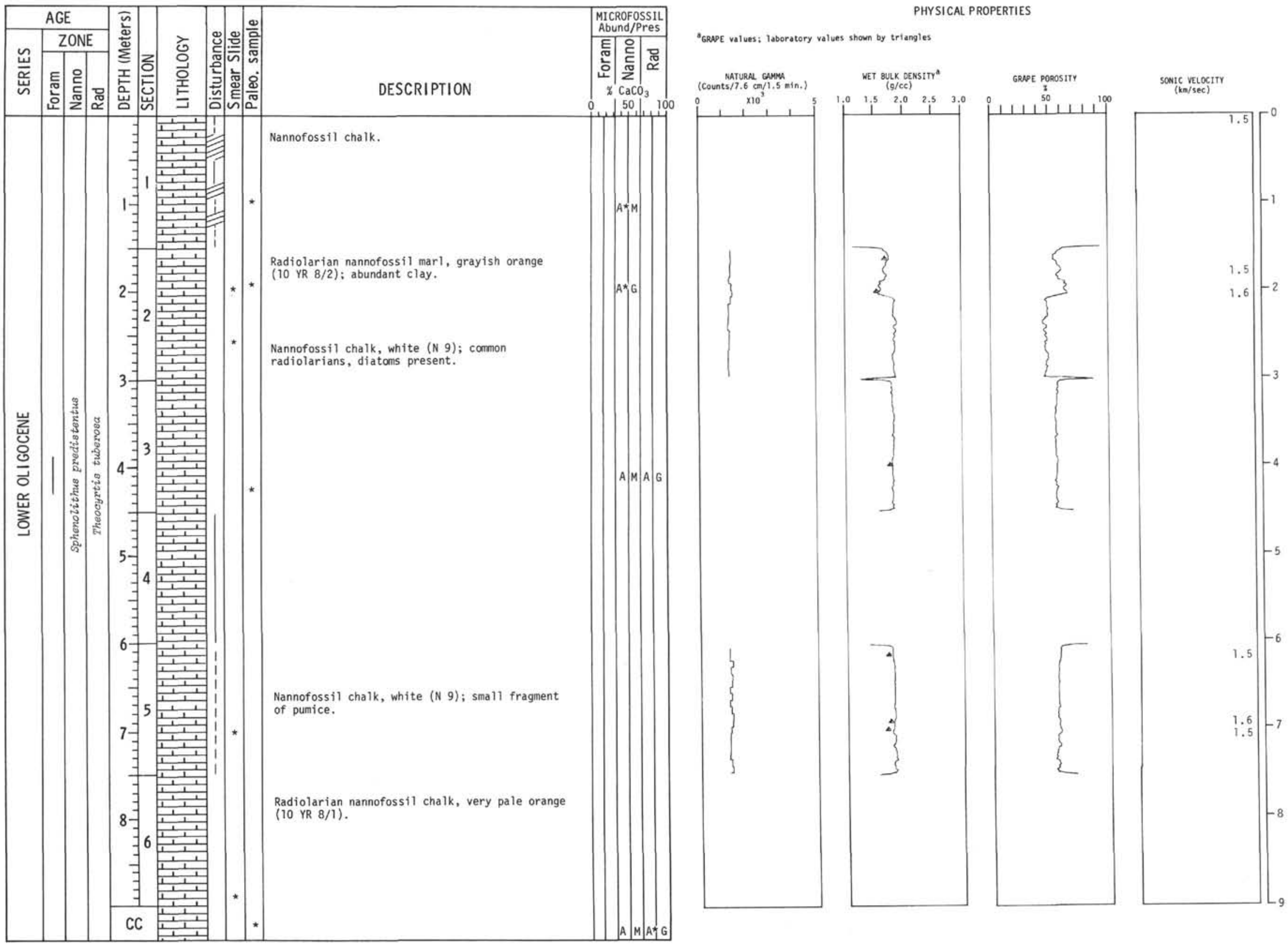


SITE: 161 HOLE: A CORE: 5 Cored Interval: 155-164 m



Nannofossil chalk, white (N 9); diatoms and radiolarians present.

SITE: 161 HOLE: A CORE: 6 Cored Interval: 164-173 m



^a GRAPE values; laboratory values shown by triangles

Nannofossil chalk.

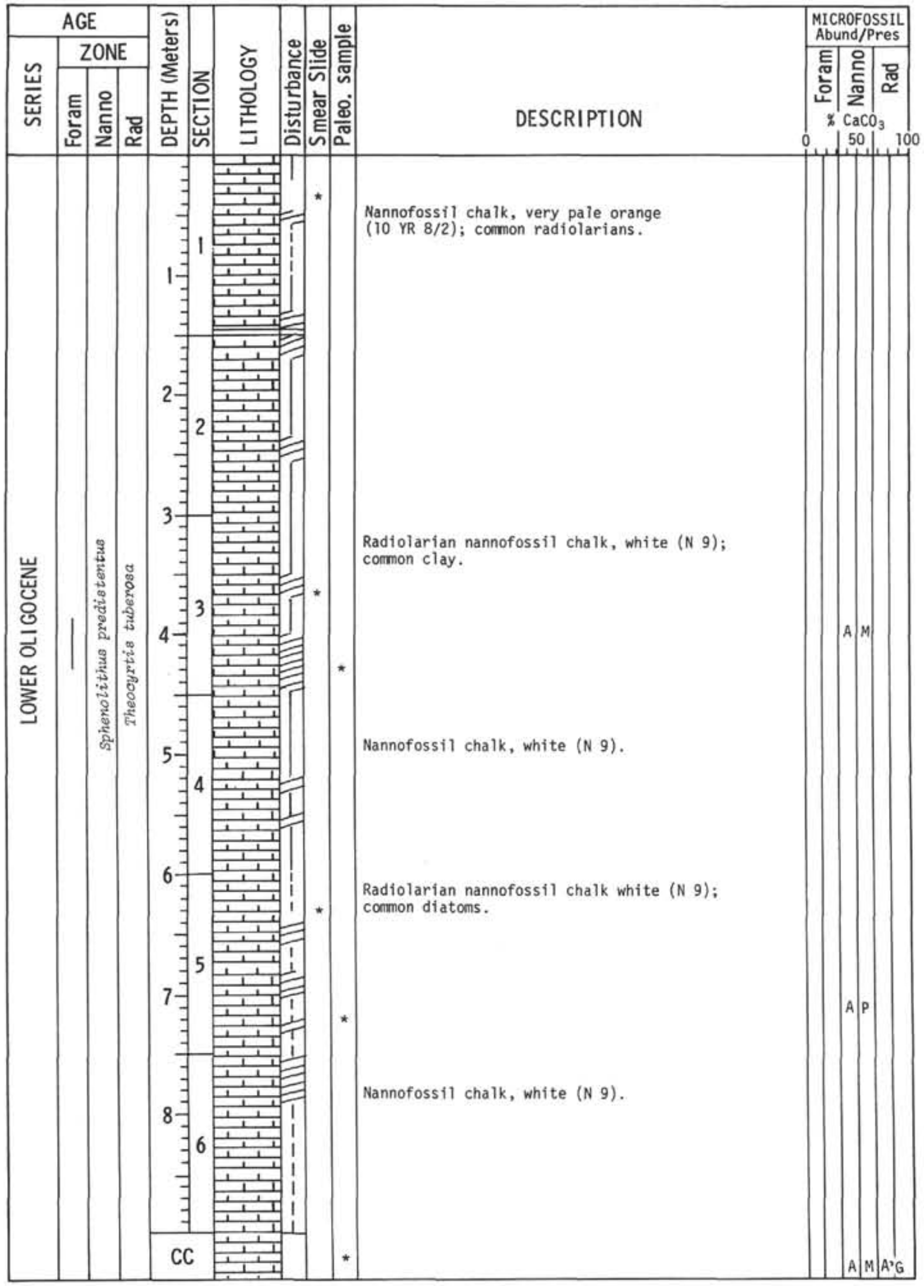
Radiolarian nannofossil marl, grayish orange (10 YR 8/2); abundant clay.

Nannofossil chalk, white (N 9); common radiolarians, diatoms present.

Nannofossil chalk, white (N 9); small fragment of pumice.

Radiolarian nannofossil chalk, very pale orange (10 YR 8/1).

SITE: 161 HOLE: A CORE: 7 Cored Interval: 173-182 m



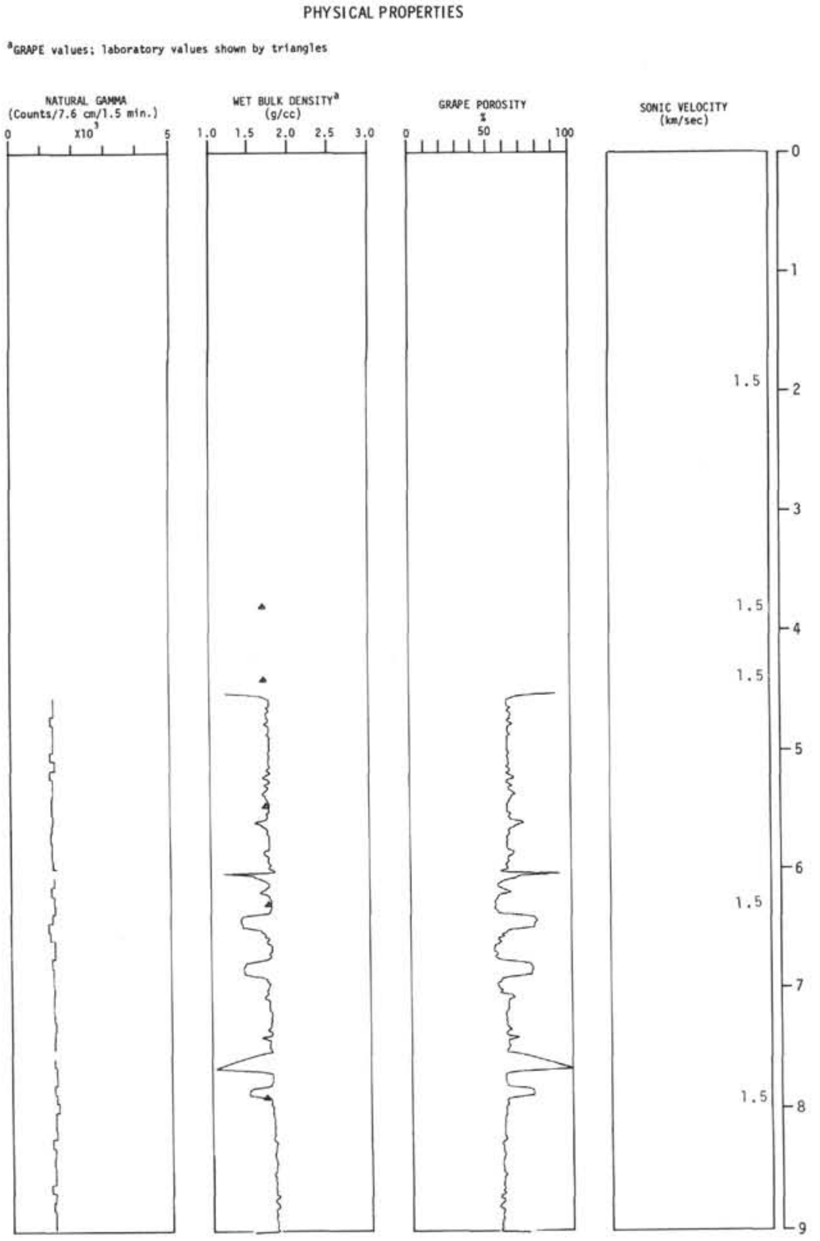
Nannofossil chalk, very pale orange (10 YR 8/2); common radiolarians.

Radiolarian nannofossil chalk, white (N 9); common clay.

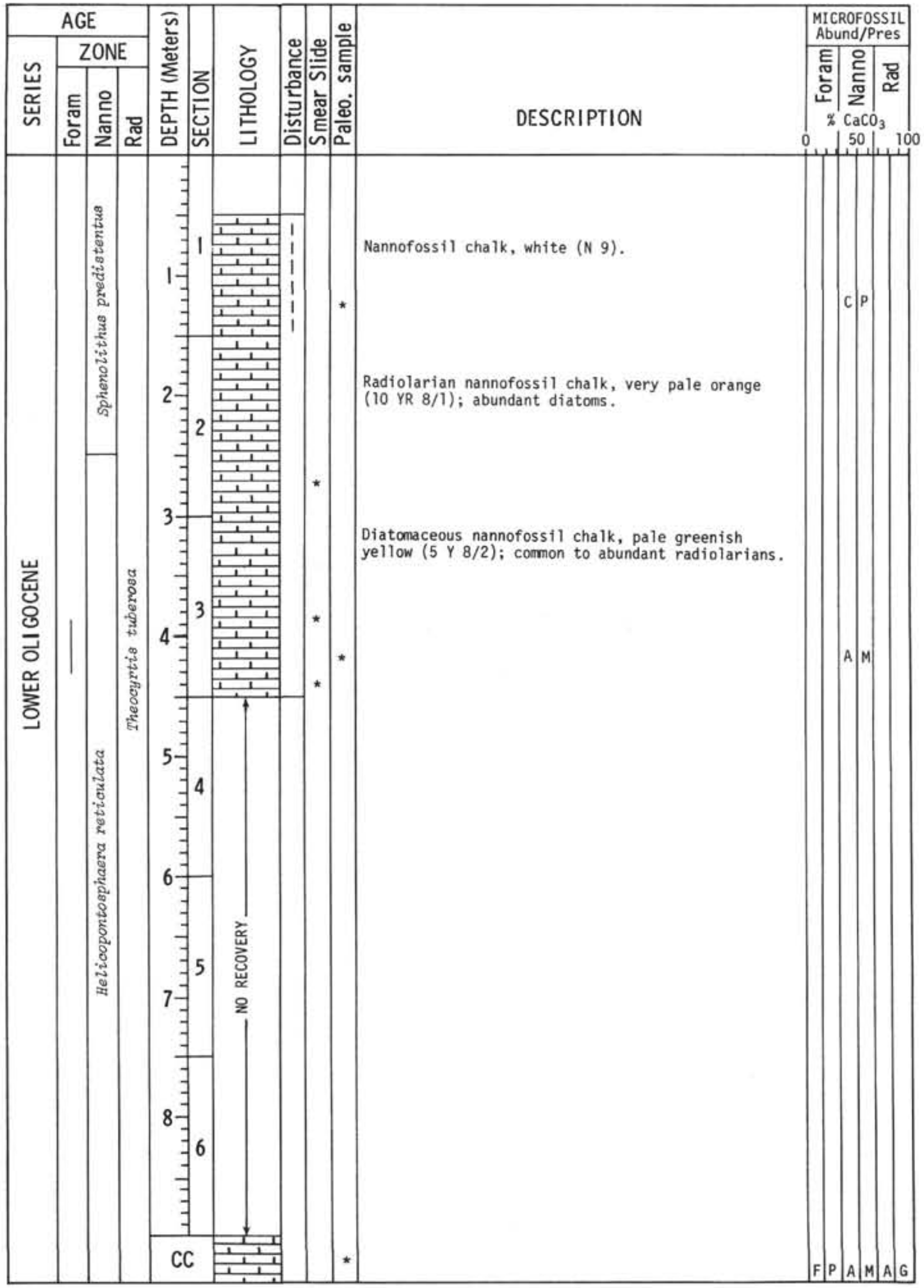
Nannofossil chalk, white (N 9).

Radiolarian nannofossil chalk white (N 9); common diatoms.

Nannofossil chalk, white (N 9).



SITE: 161 HOLE: A CORE: 8 Cored Interval: 182-191 m

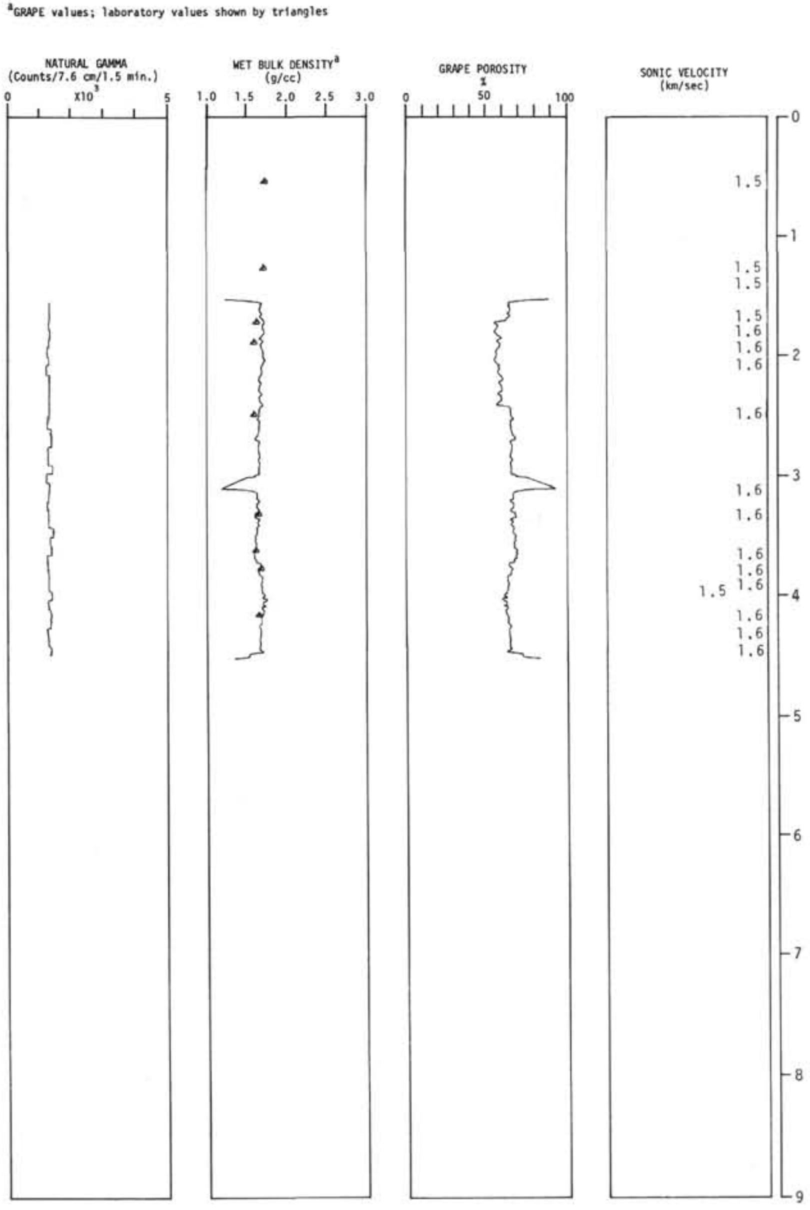


Nannofossil chalk, white (N 9).

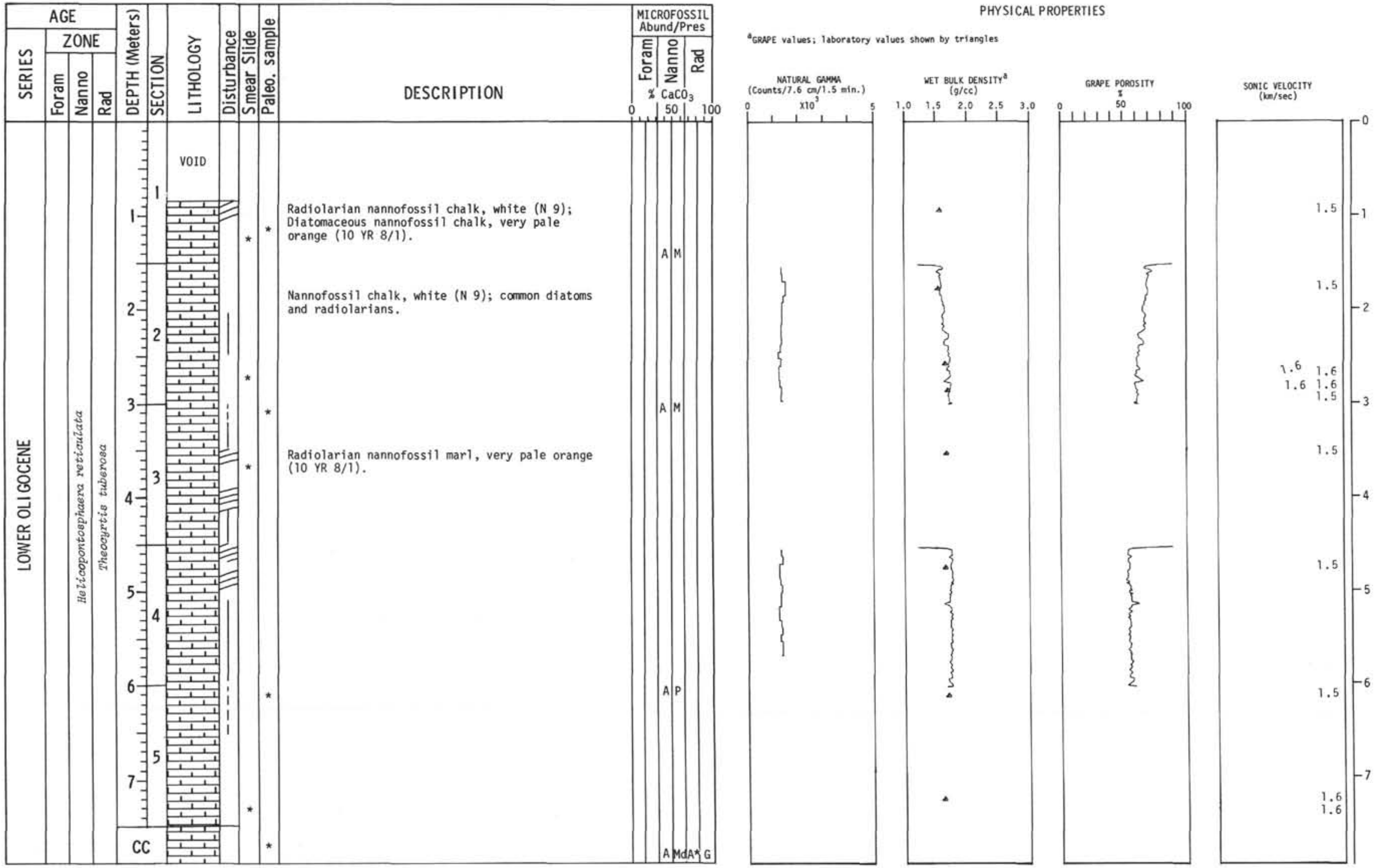
Radiolarian nannofossil chalk, very pale orange (10 YR 8/1); abundant diatoms.

Diatomaceous nannofossil chalk, pale greenish yellow (5 Y 8/2); common to abundant radiolarians.

PHYSICAL PROPERTIES



SITE: 161 HOLE: A CORE: 9 Cored Interval: 191-200 m

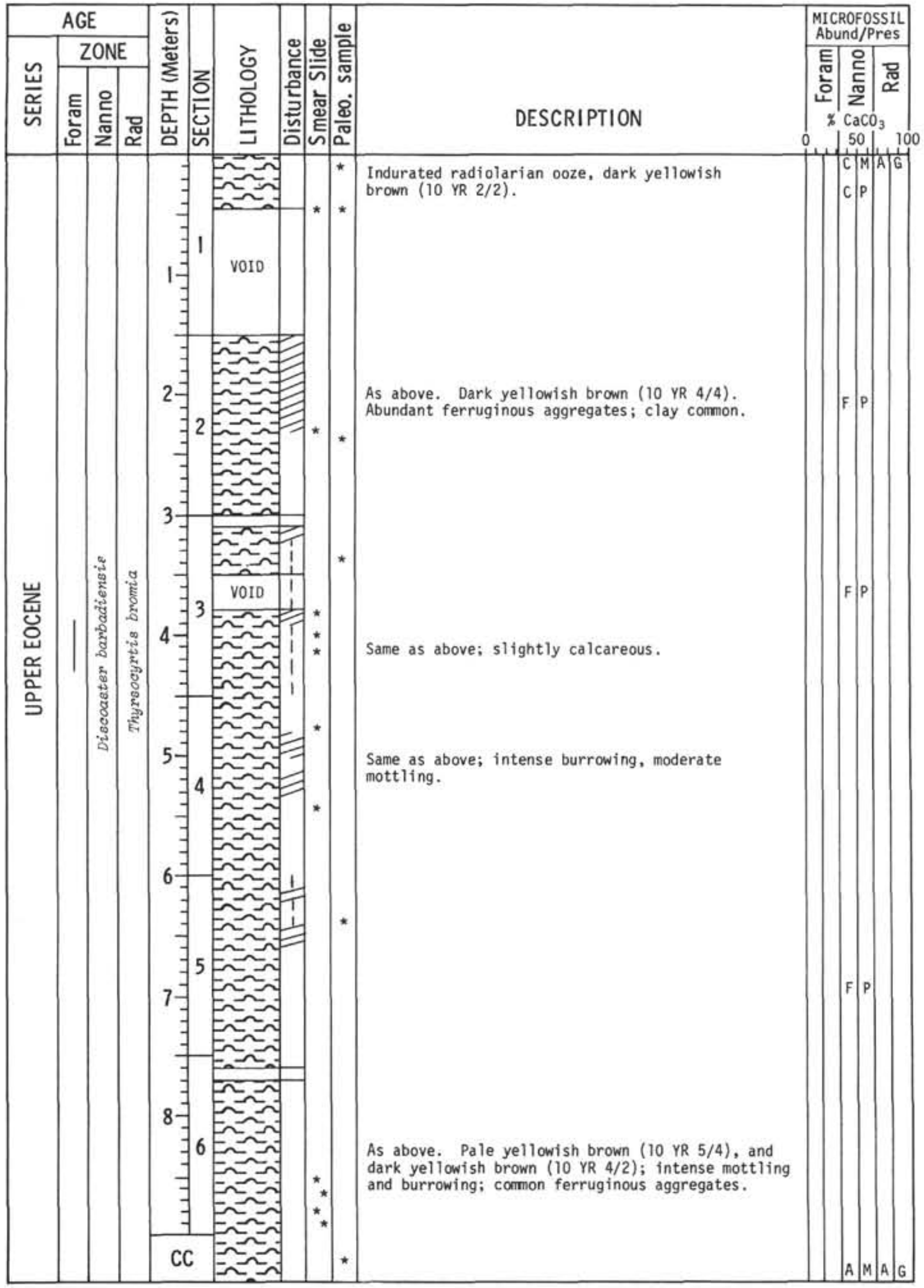


Radiolarian nannofossil chalk, white (N 9); Diatomaceous nannofossil chalk, very pale orange (10 YR 8/1).

Nannofossil chalk, white (N 9); common diatoms and radiolarians.

Radiolarian nannofossil marl, very pale orange (10 YR 8/1).

SITE: 161 HOLE: A CORE: 10 Cored Interval: 200-209 m



Indurated radiolarian ooze, dark yellowish brown (10 YR 2/2).

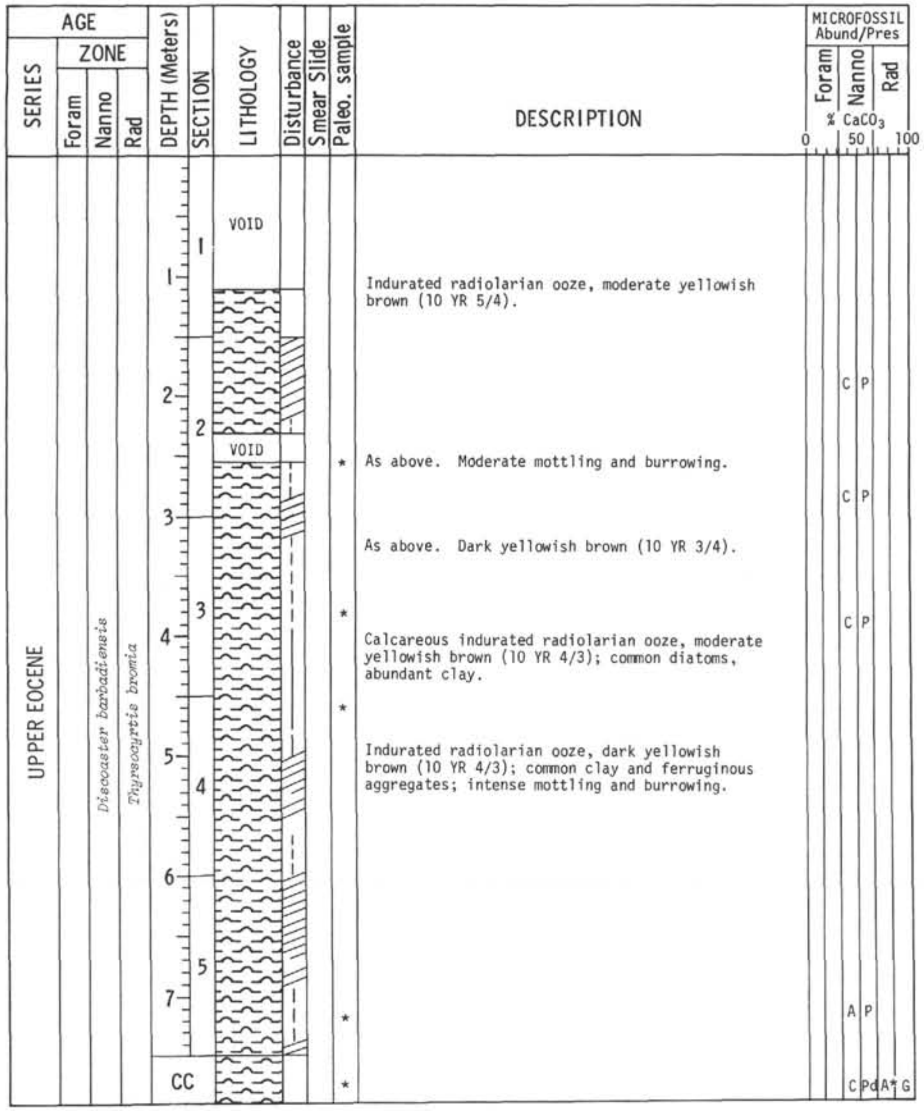
As above. Dark yellowish brown (10 YR 4/4). Abundant ferruginous aggregates; clay common.

Same as above; slightly calcareous.

Same as above; intense burrowing, moderate mottling.

As above. Pale yellowish brown (10 YR 5/4), and dark yellowish brown (10 YR 4/2); intense mottling and burrowing; common ferruginous aggregates.

SITE: 161 HOLE: A CORE: 11 Cored Interval: 209-218 m



Indurated radiolarian ooze, moderate yellowish brown (10 YR 5/4).

As above. Moderate mottling and burrowing.

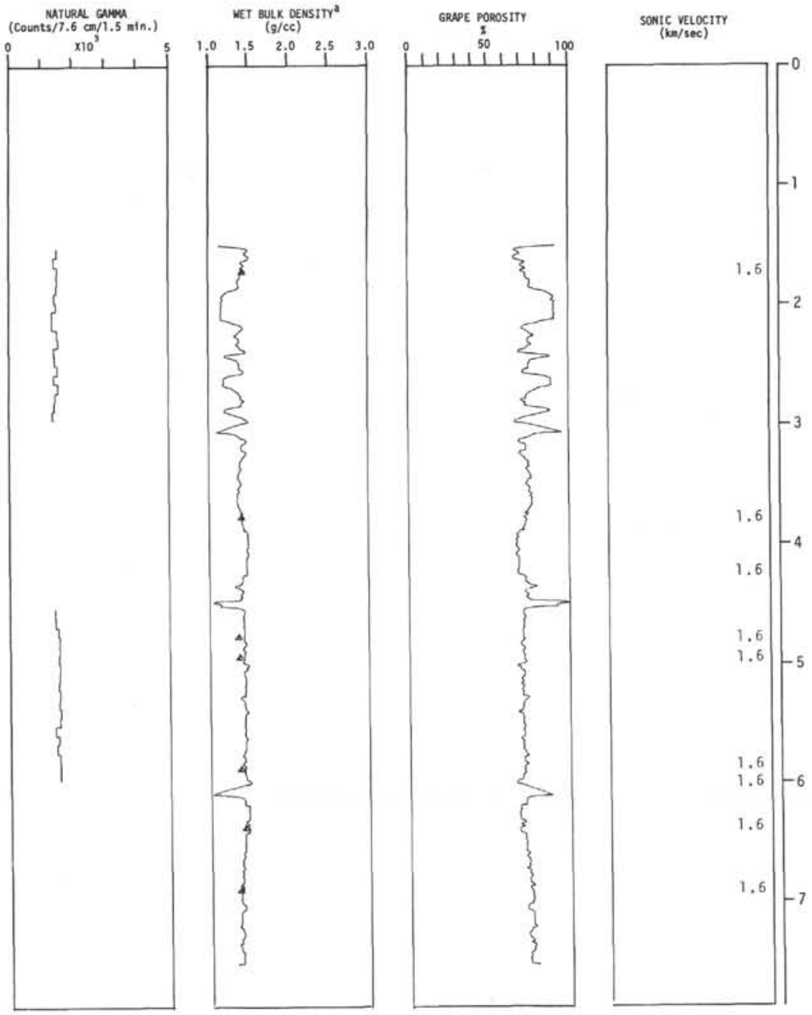
As above. Dark yellowish brown (10 YR 3/4).

Calcareous indurated radiolarian ooze, moderate yellowish brown (10 YR 4/3); common diatoms, abundant clay.

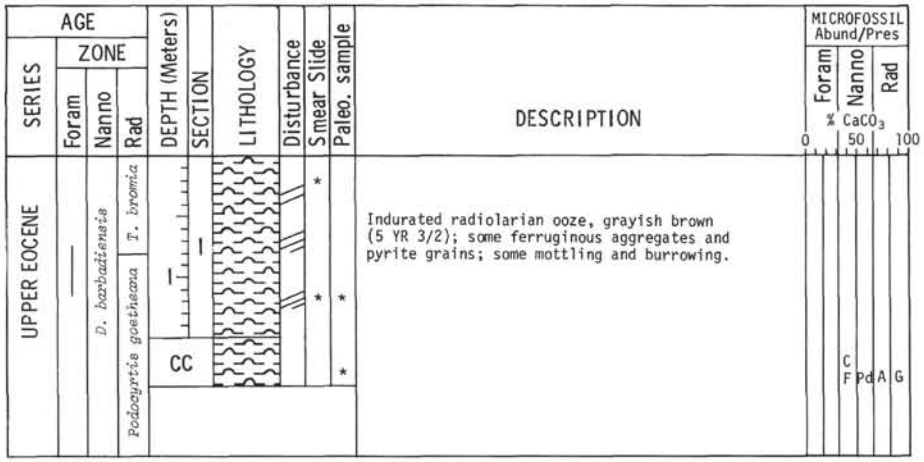
Indurated radiolarian ooze, dark yellowish brown (10 YR 4/3); common clay and ferruginous aggregates; intense mottling and burrowing.

PHYSICAL PROPERTIES

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



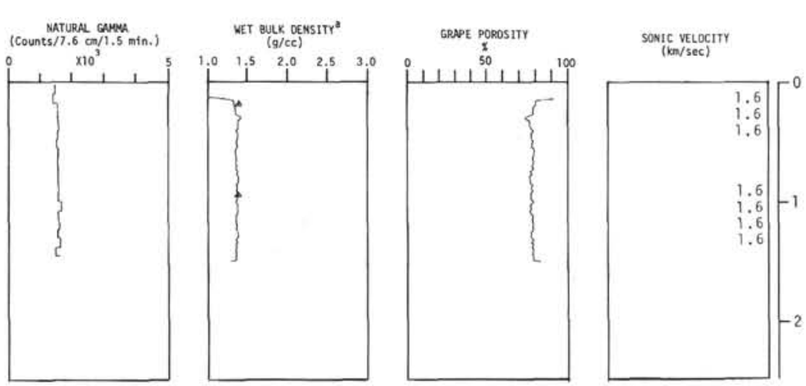
SITE: 161 HOLE: A CORE: 12 Cored Interval: 218-227 m



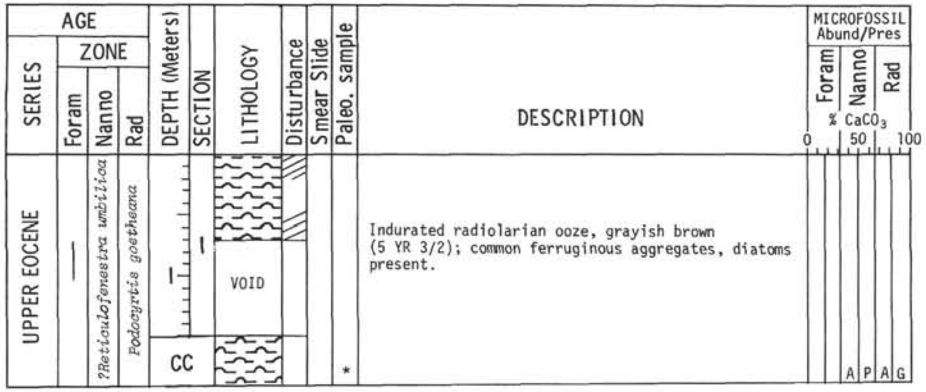
Indurated radiolarian ooze, grayish brown (5 YR 3/2); some ferruginous aggregates and pyrite grains; some mottling and burrowing.

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



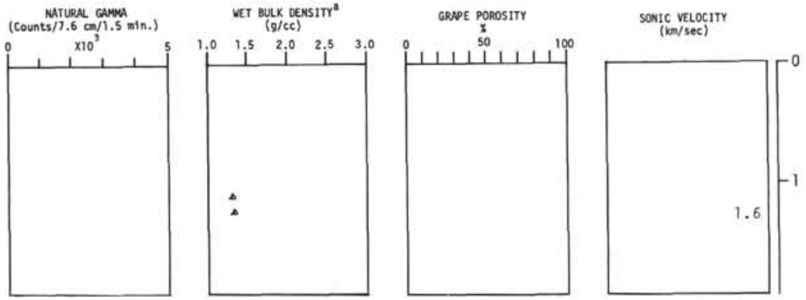
SITE: 161 HOLE: A CORE: 13 Cored Interval: 227-235 m



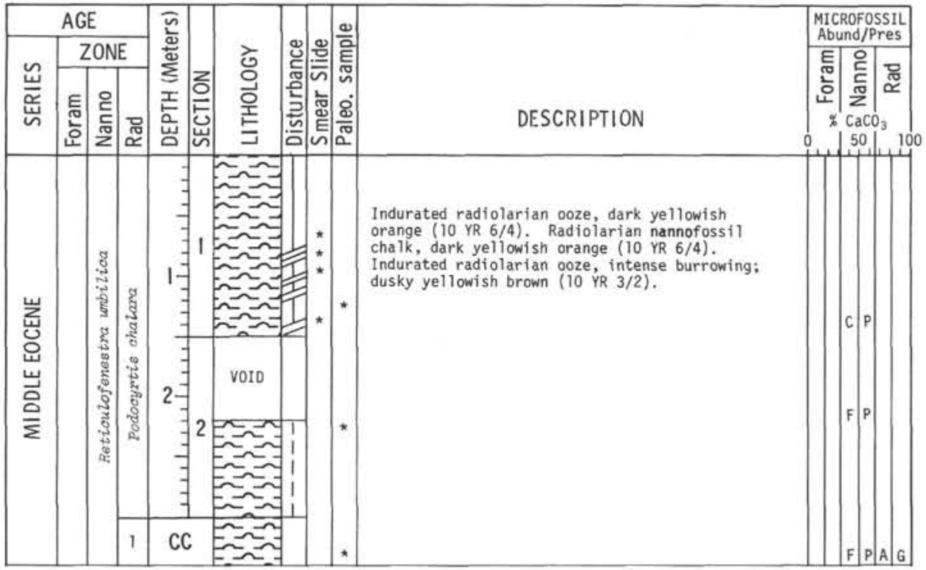
Indurated radiolarian ooze, grayish brown (5 YR 3/2); common ferruginous aggregates, diatoms present.

PHYSICAL PROPERTIES

^aGRAPE values; laboratory values shown by triangles



SITE: 161 HOLE: A CORE: 14 Cored Interval: 235-244 m

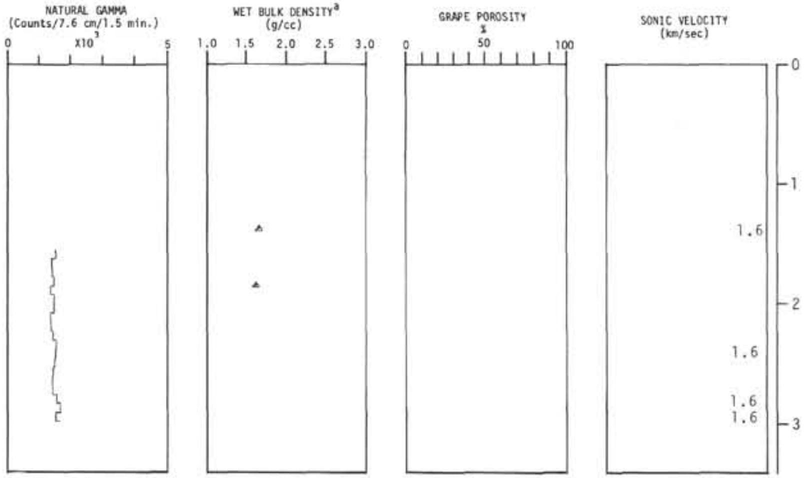


Indurated radiolarian ooze, dark yellowish orange (10 YR 6/4). Radiolarian nannofossil chalk, dark yellowish orange (10 YR 6/4). Indurated radiolarian ooze, intense burrowing; dusky yellowish brown (10 YR 3/2).

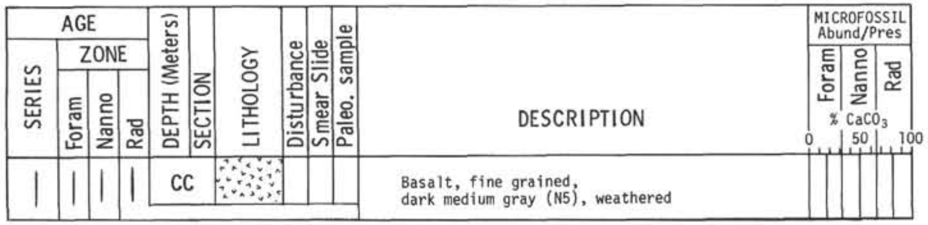
[1] *Podocyrtis mitra*

PHYSICAL PROPERTIES

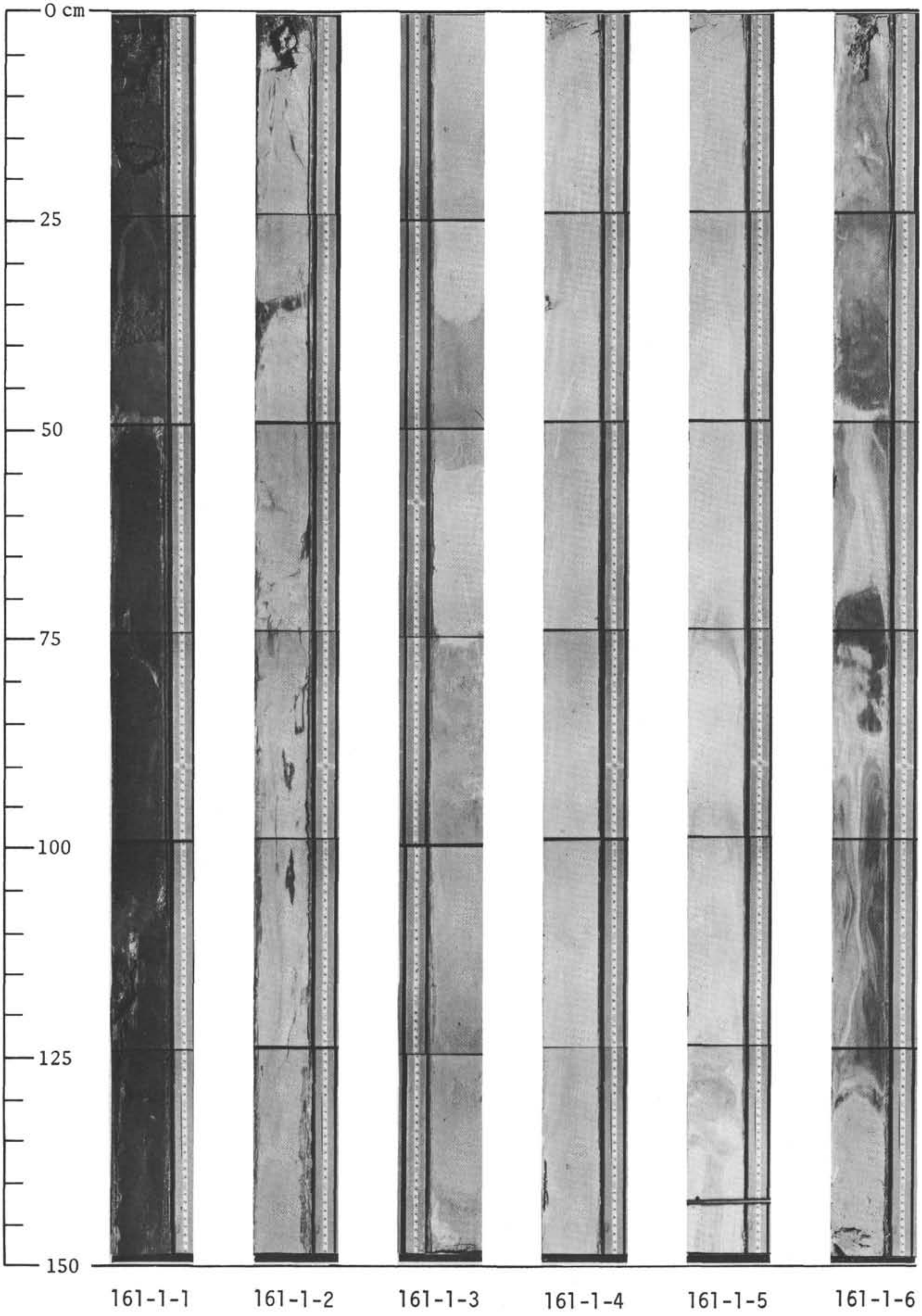
[a] GRAPE values; laboratory values shown by triangles



SITE: 161 HOLE: A CORE: 15 Cored Interval: 244-245 m



Basalt, fine grained, dark medium gray (N5), weathered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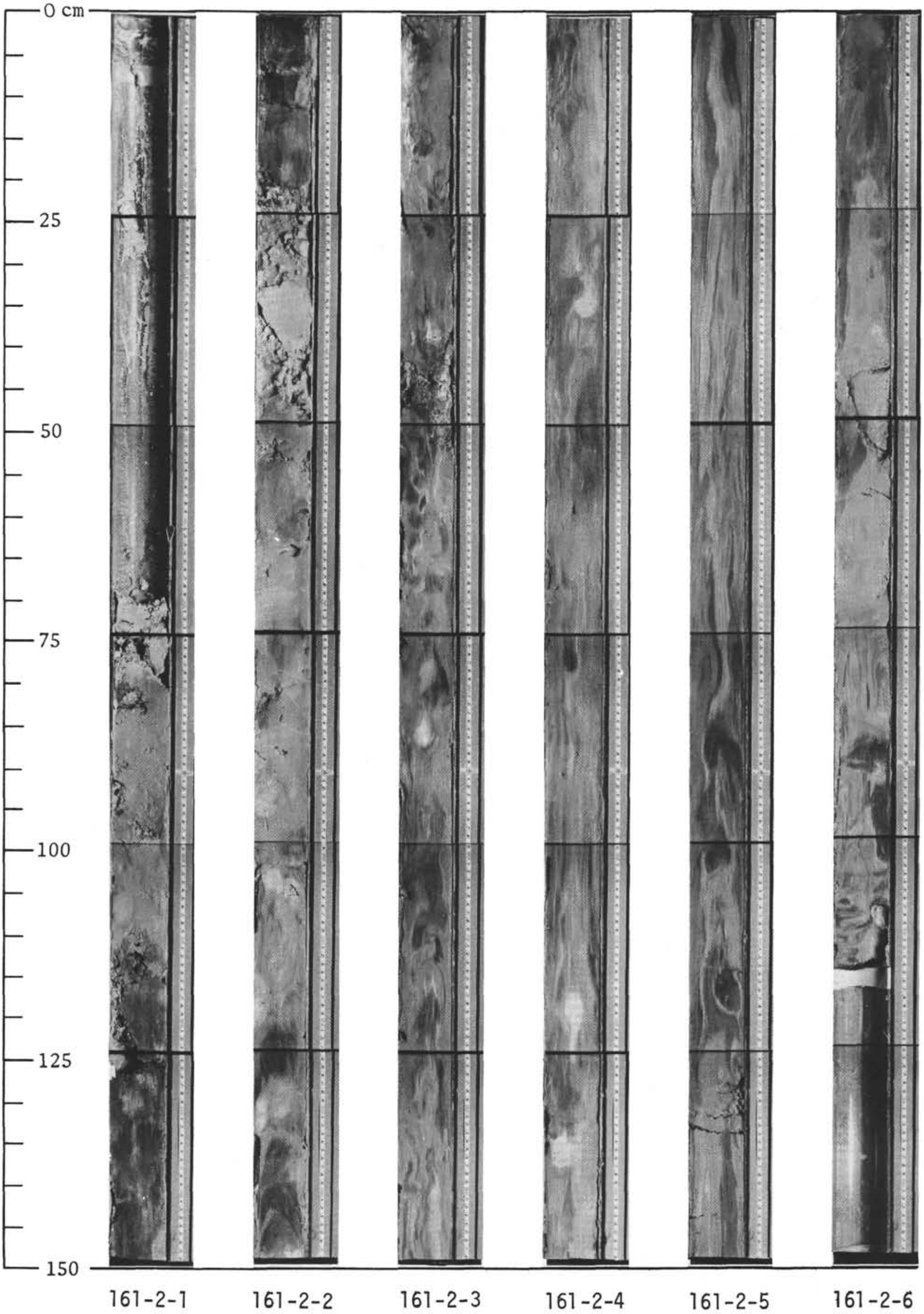
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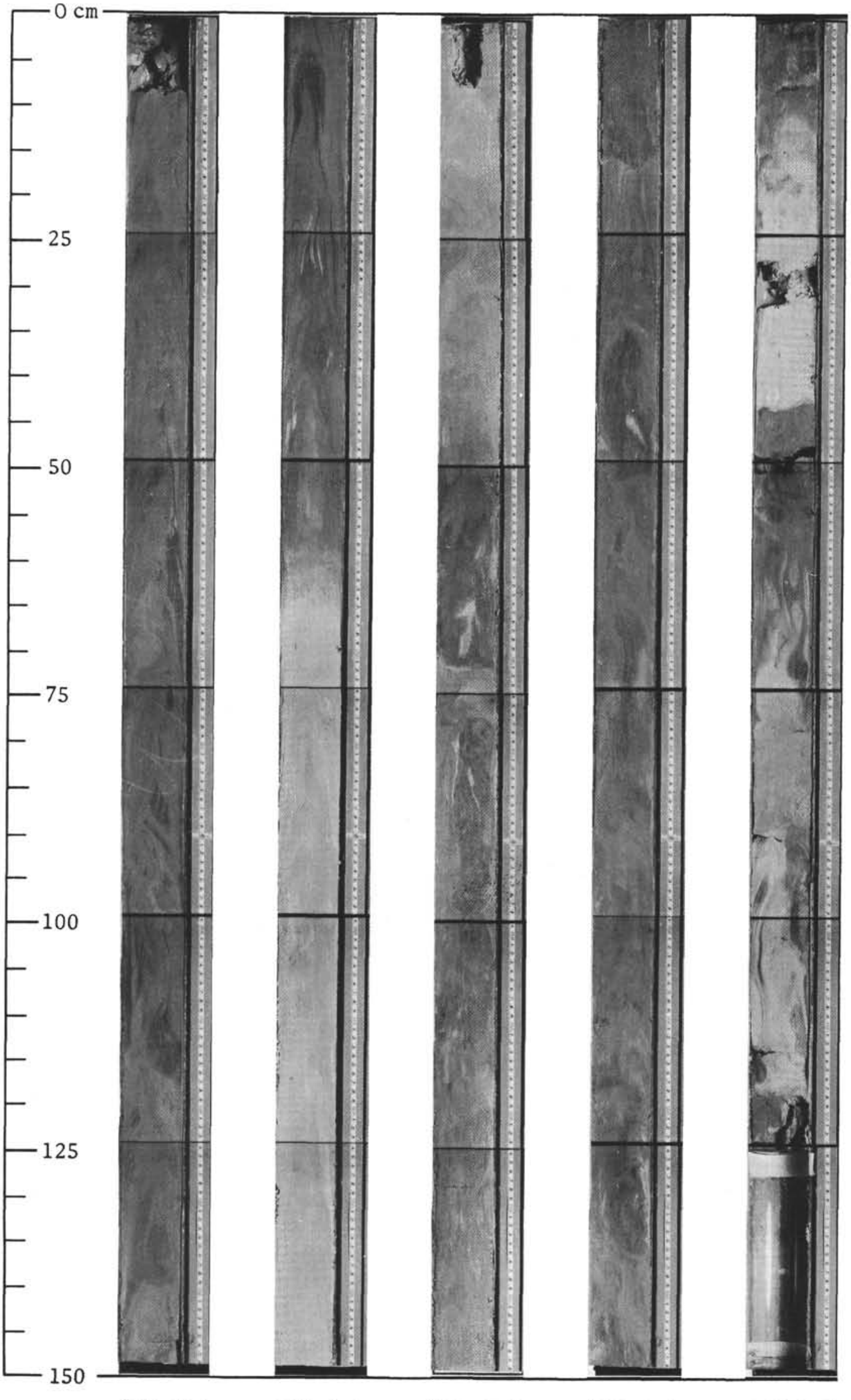
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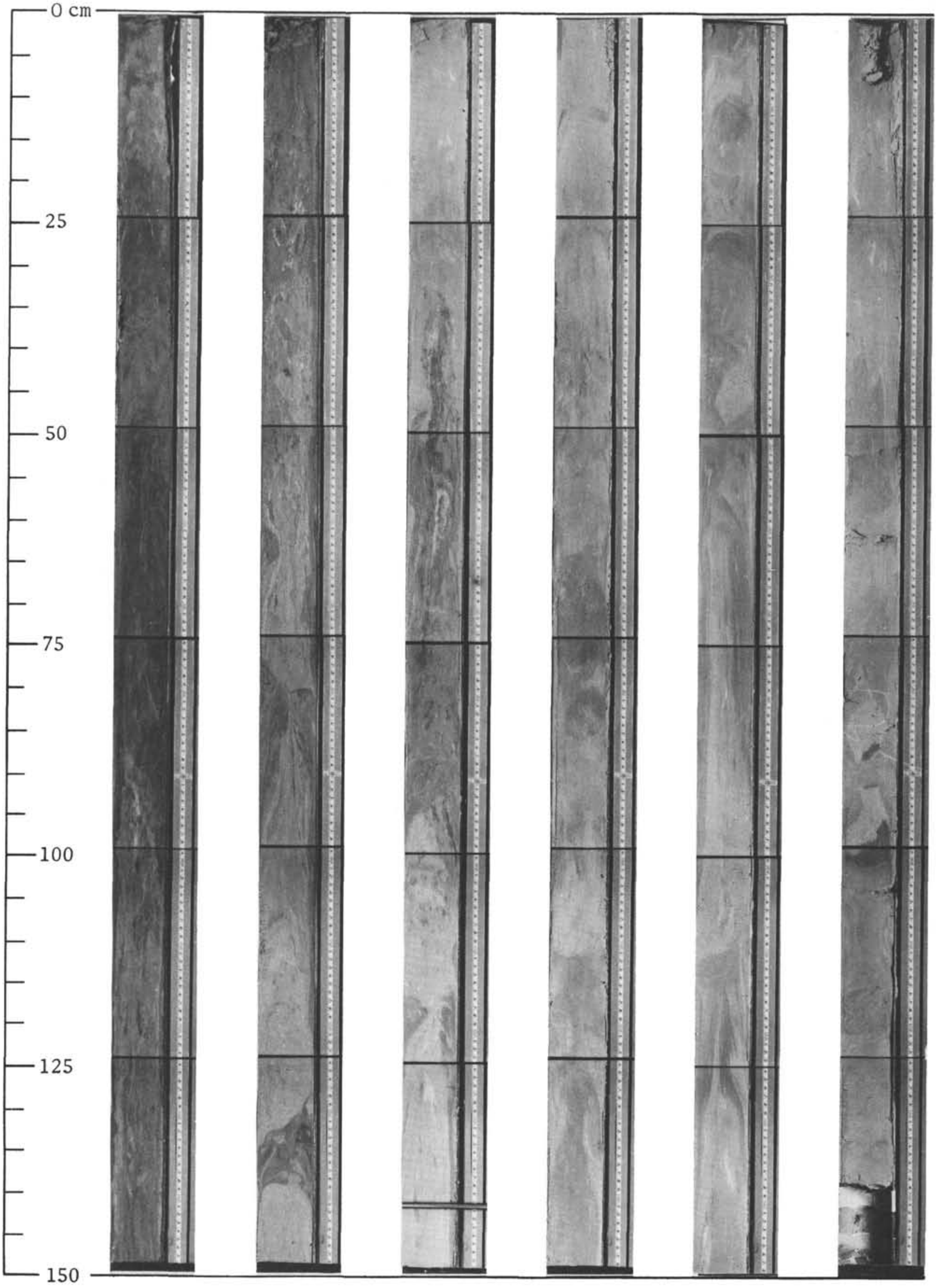
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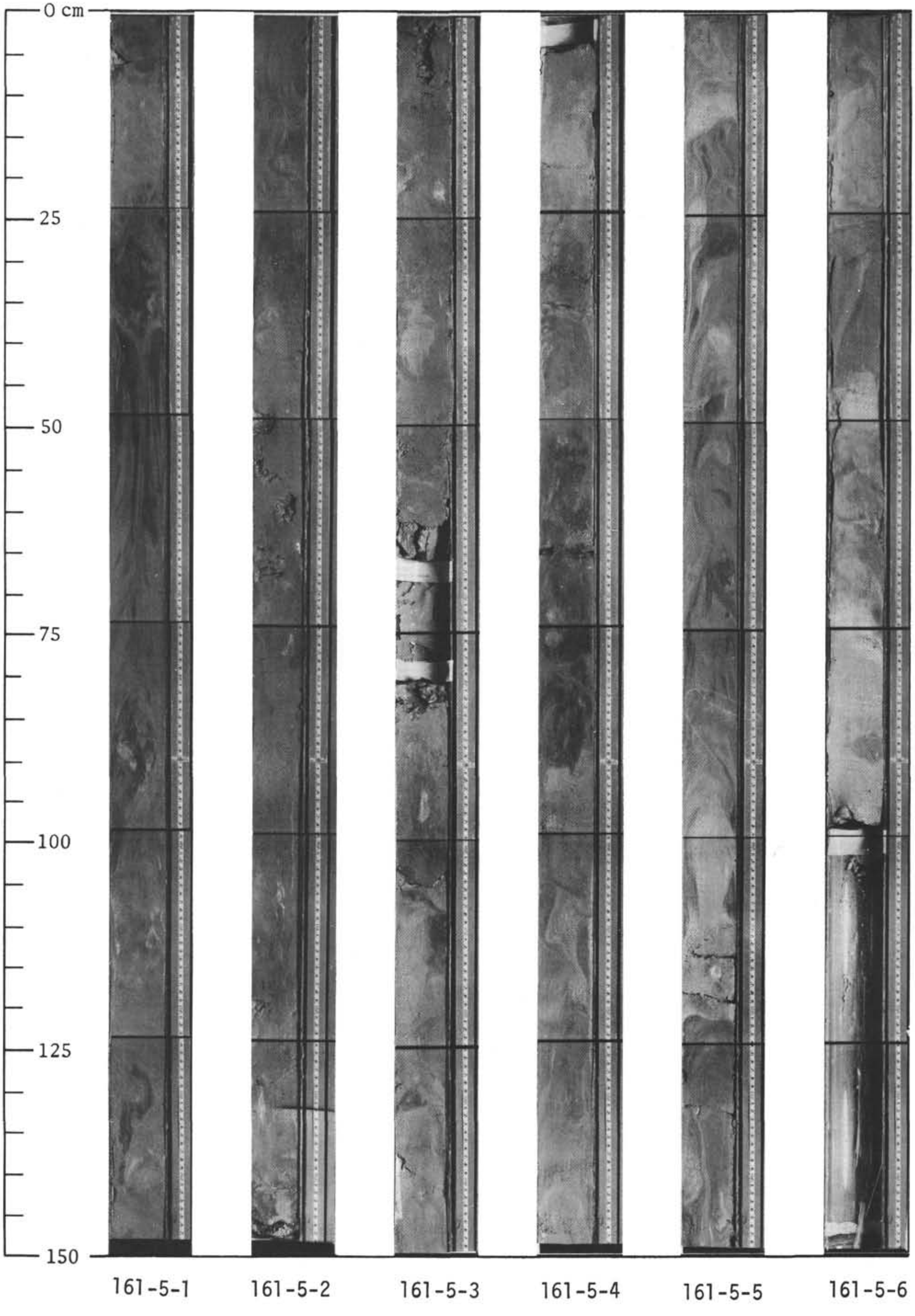
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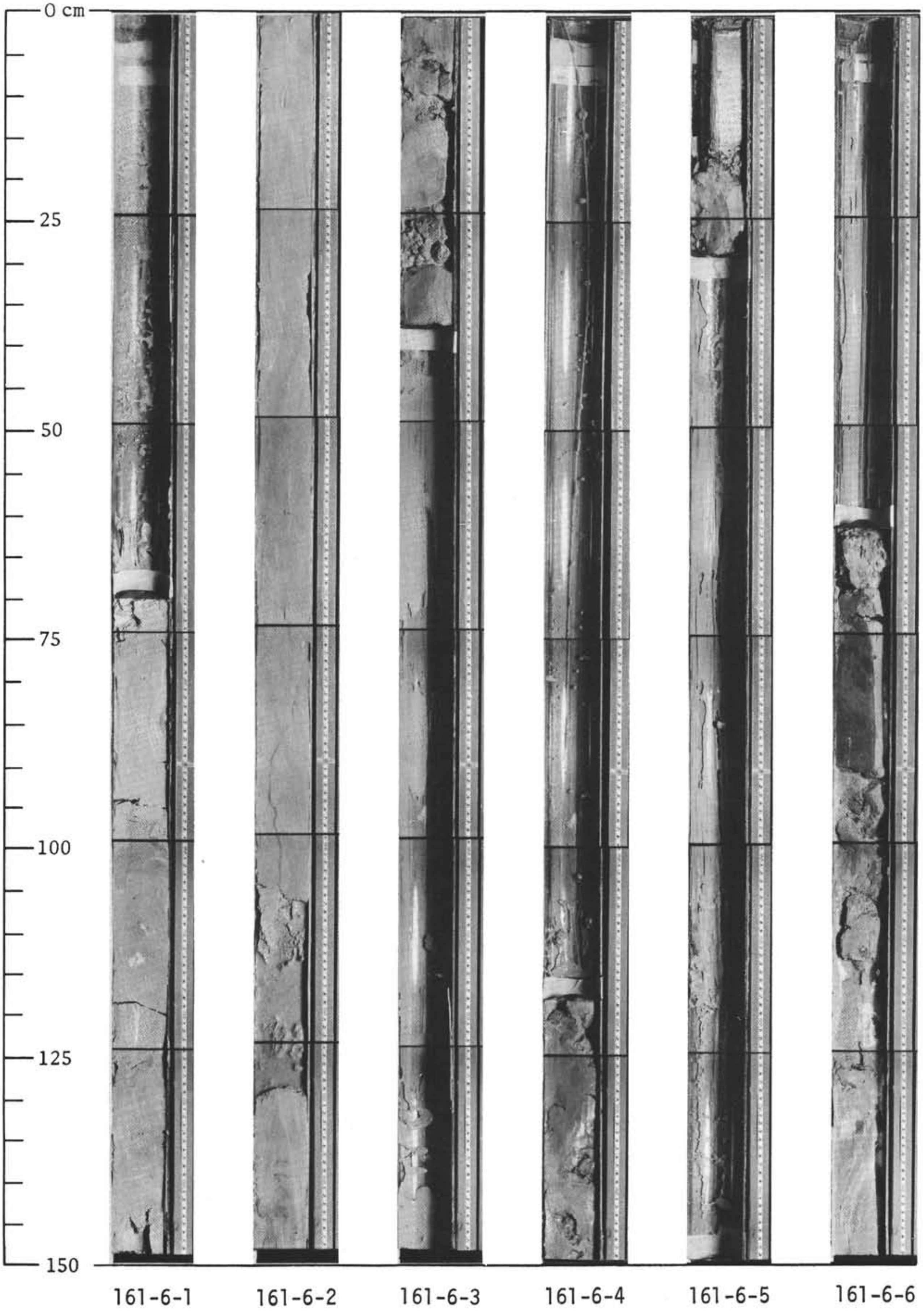
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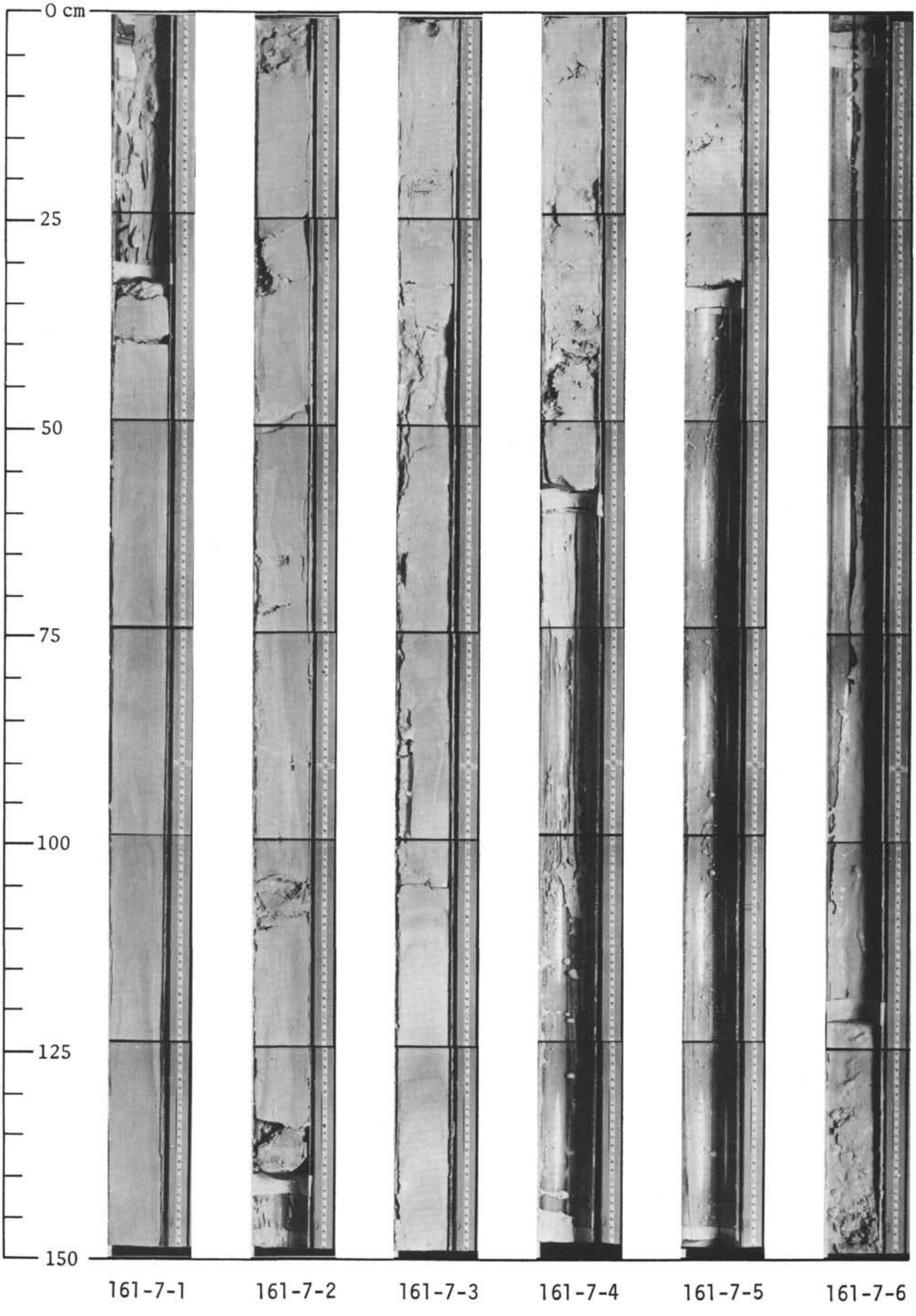
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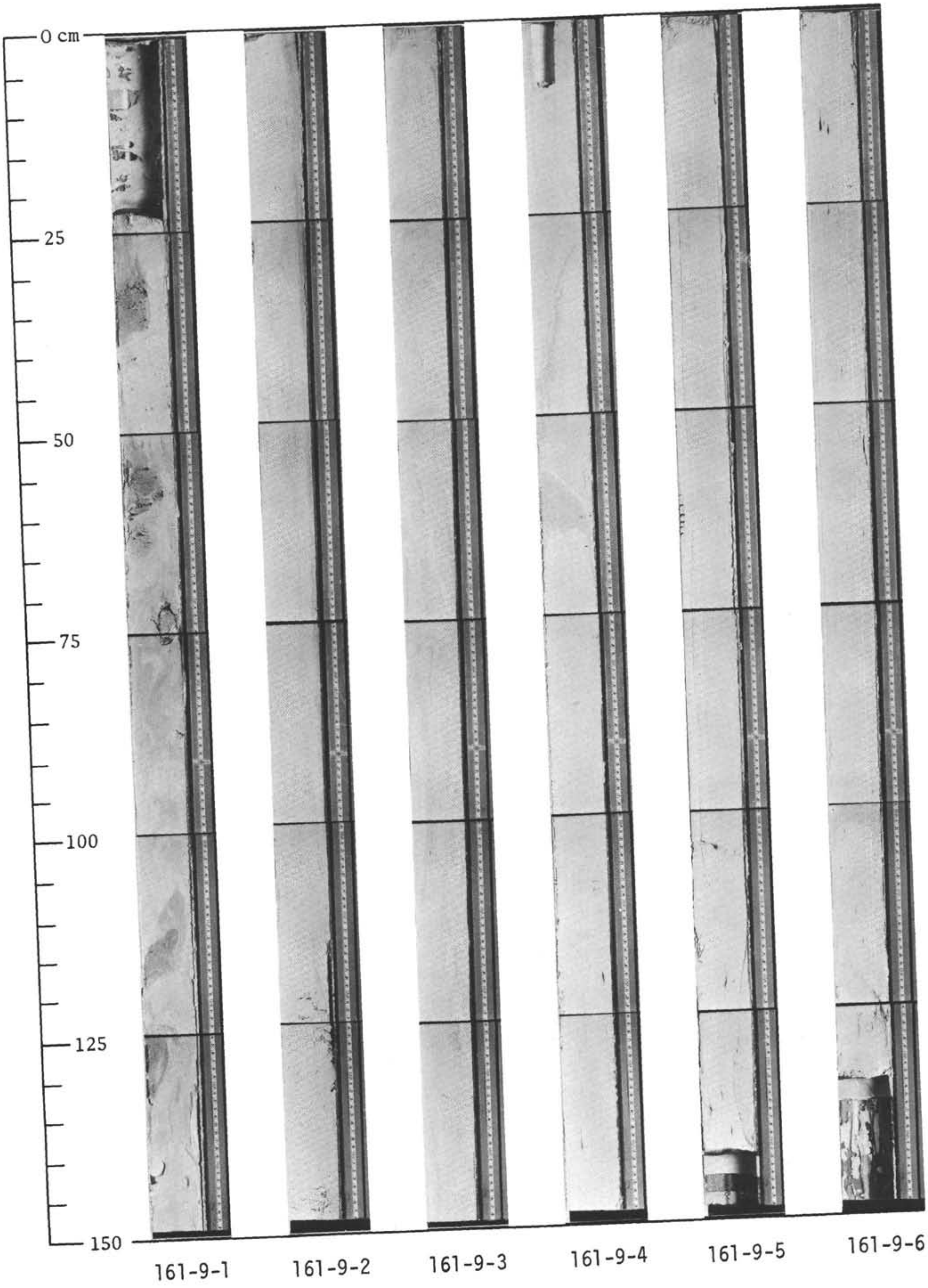
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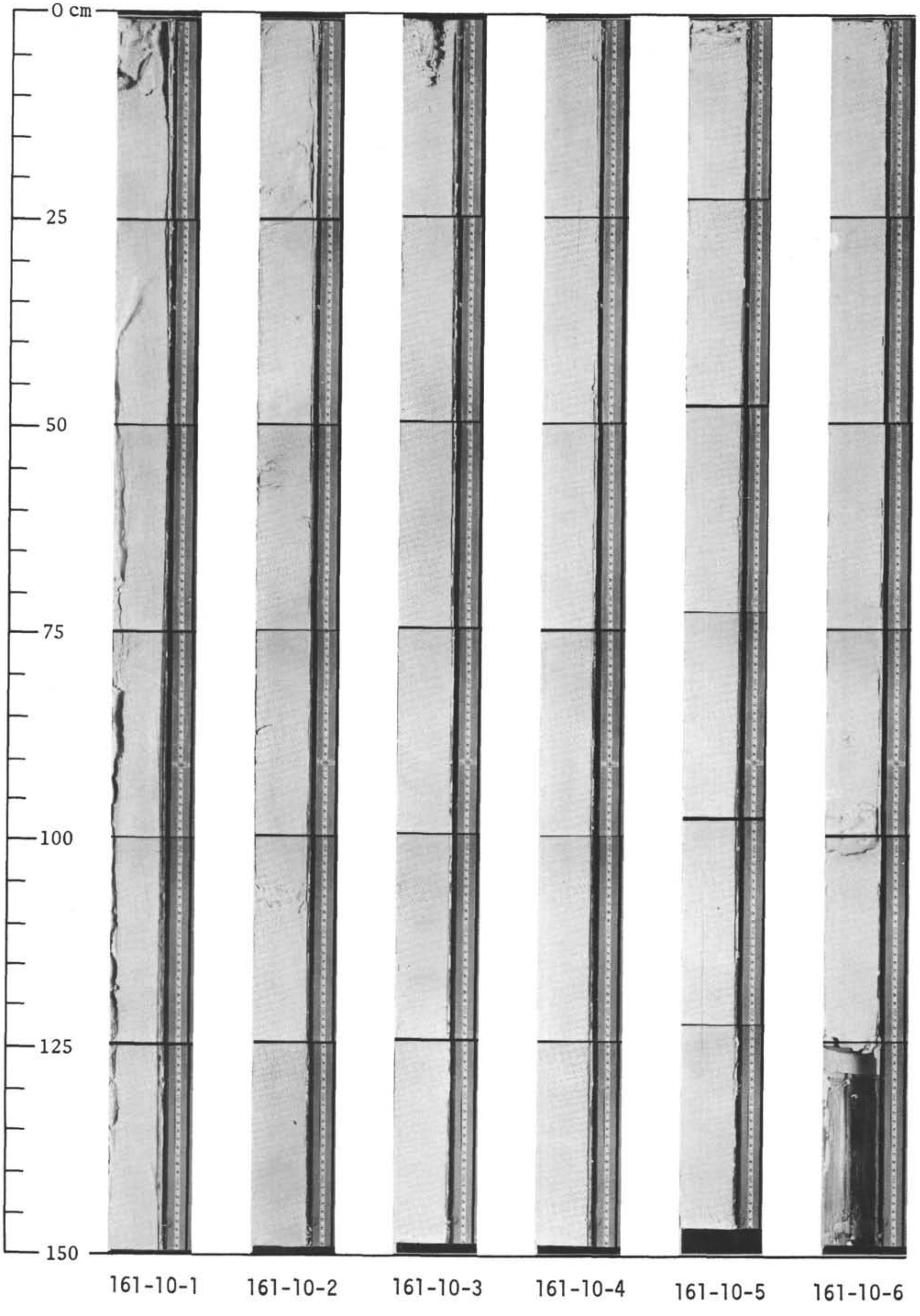
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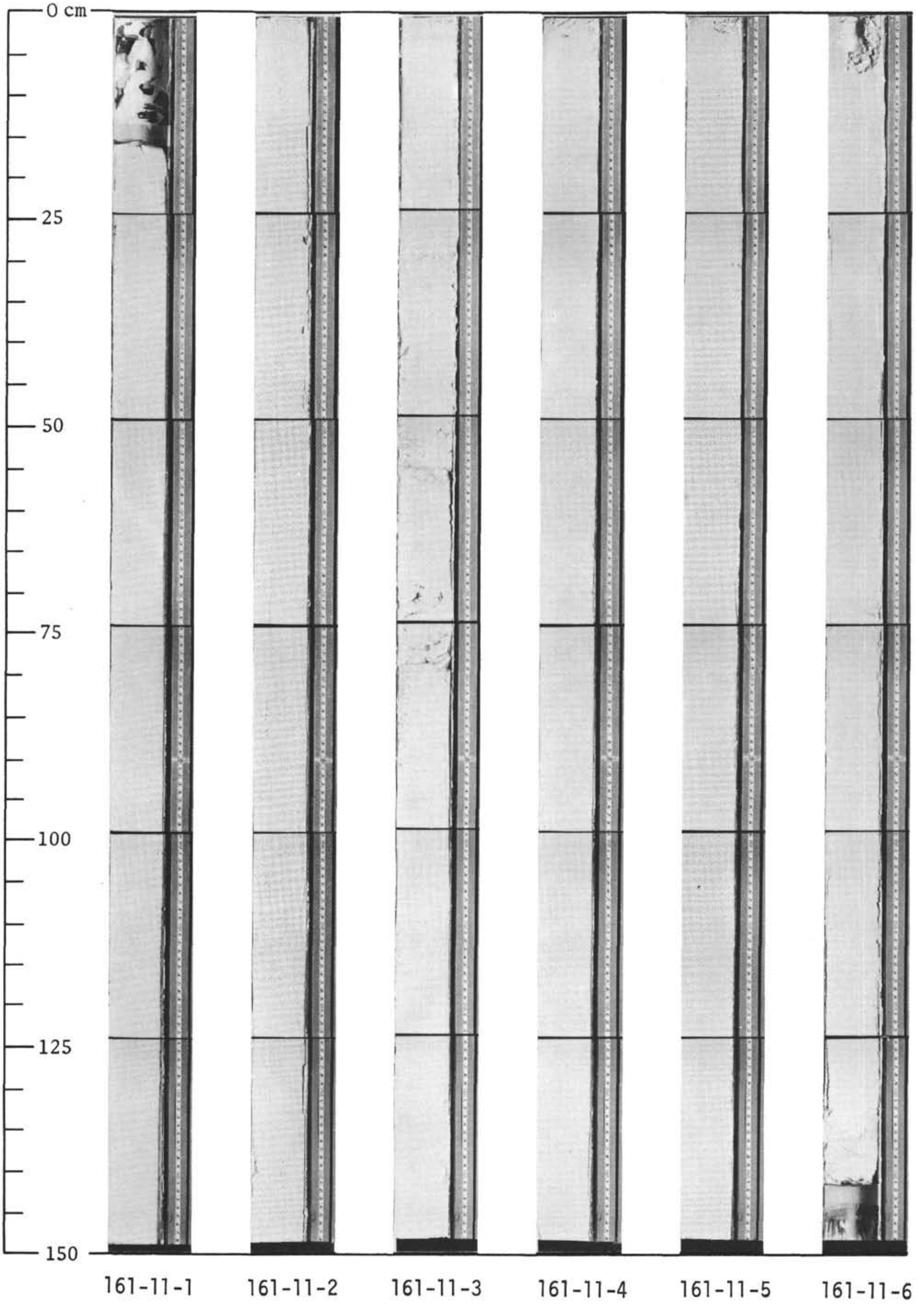
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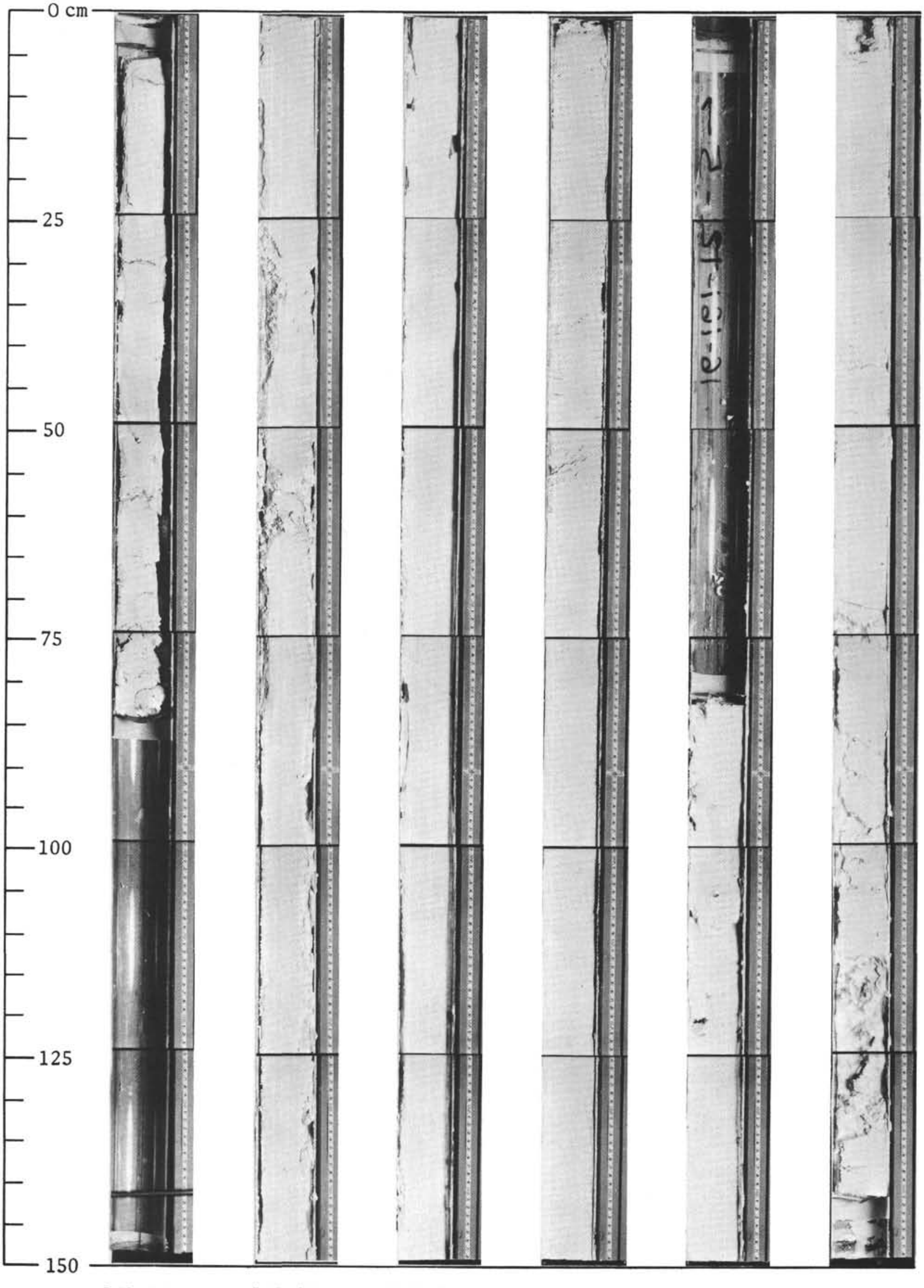
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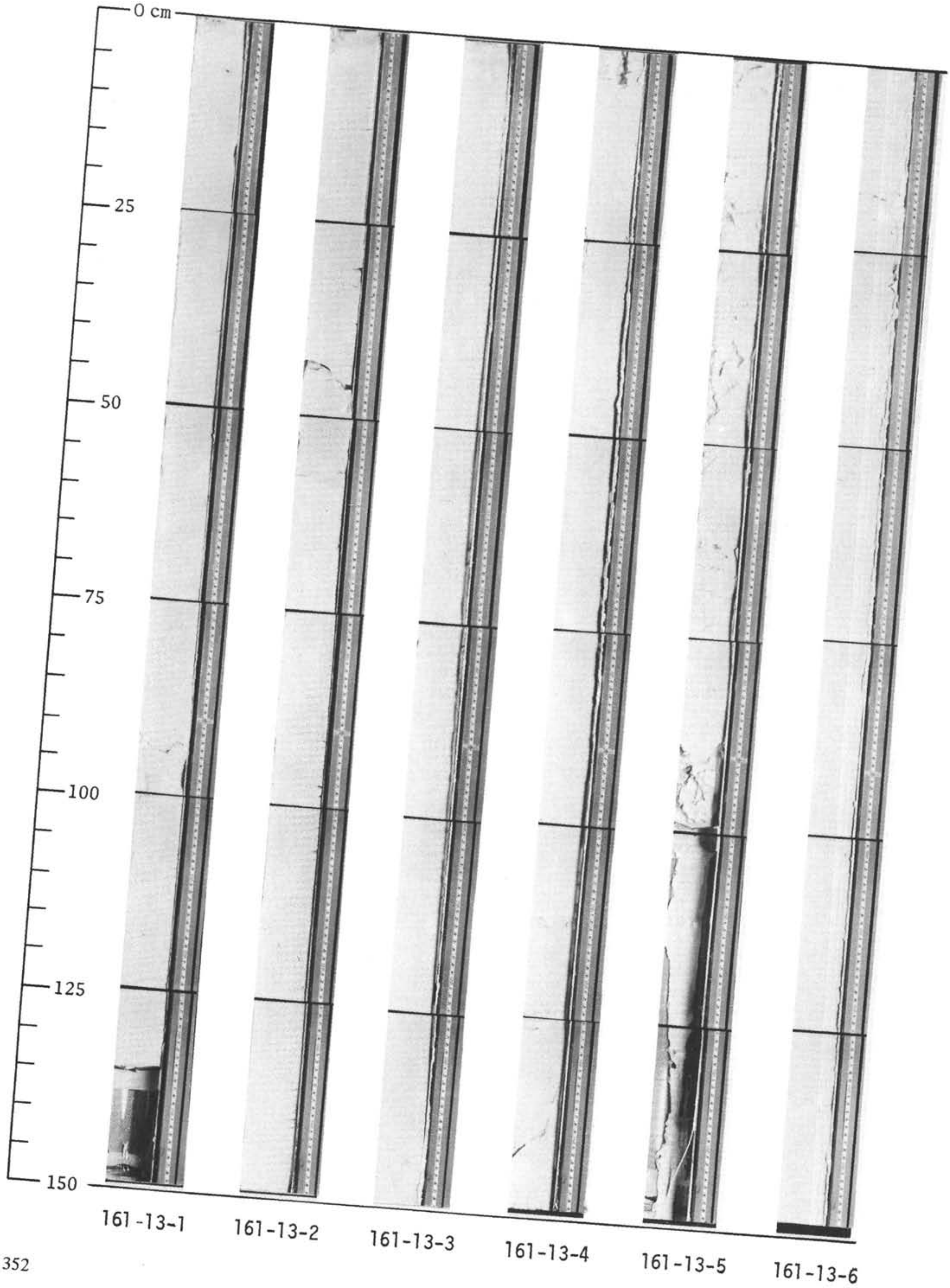
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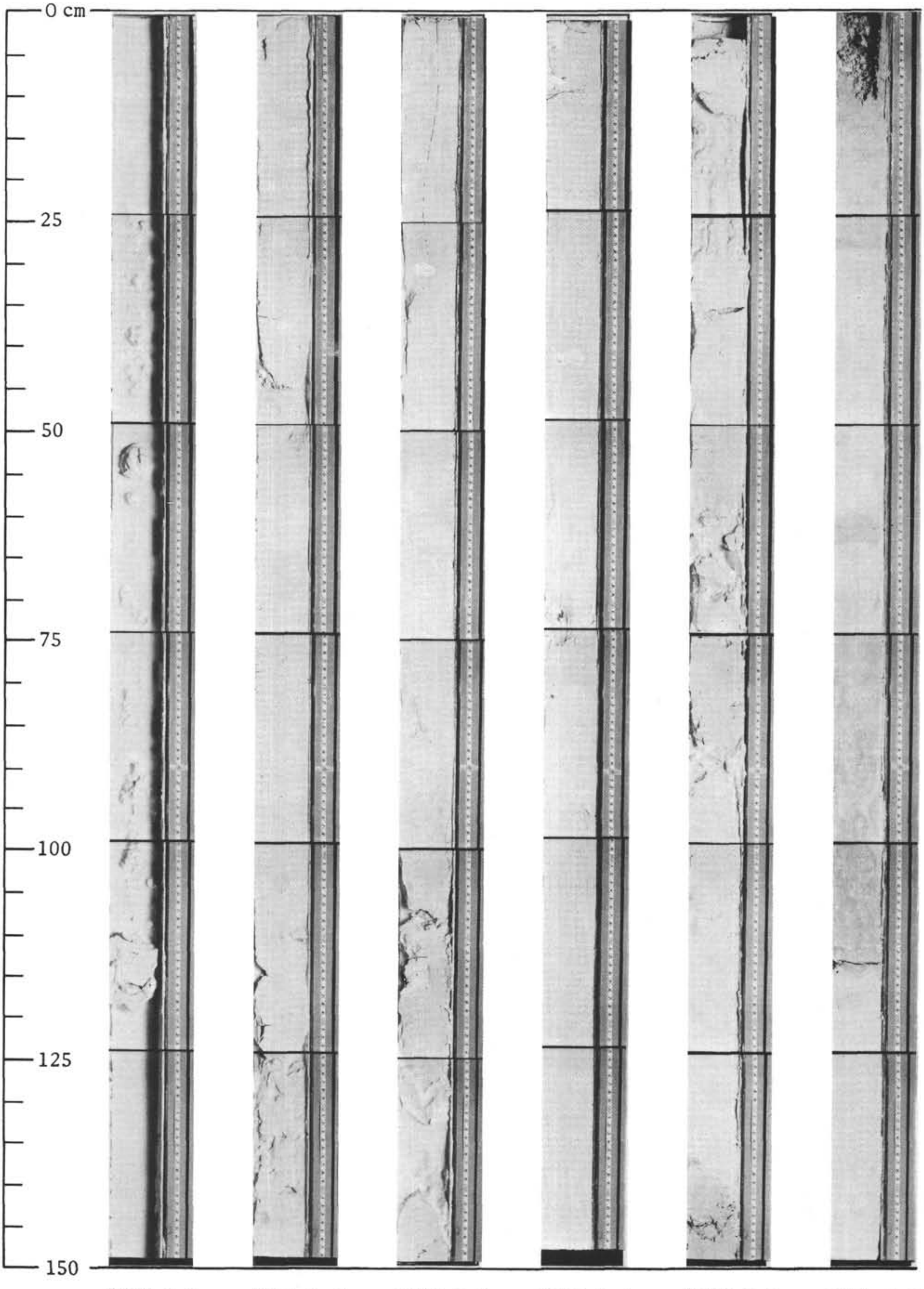
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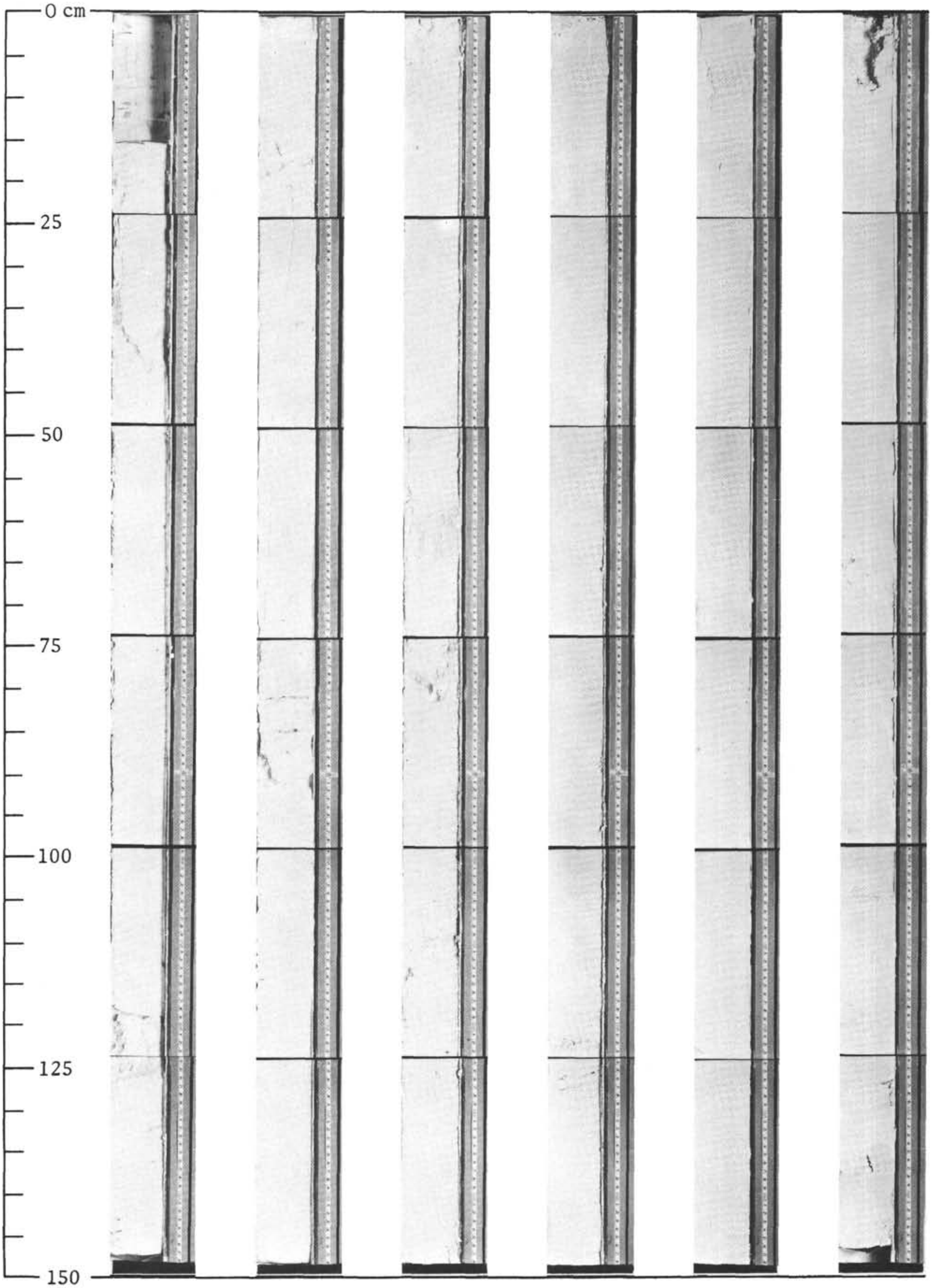
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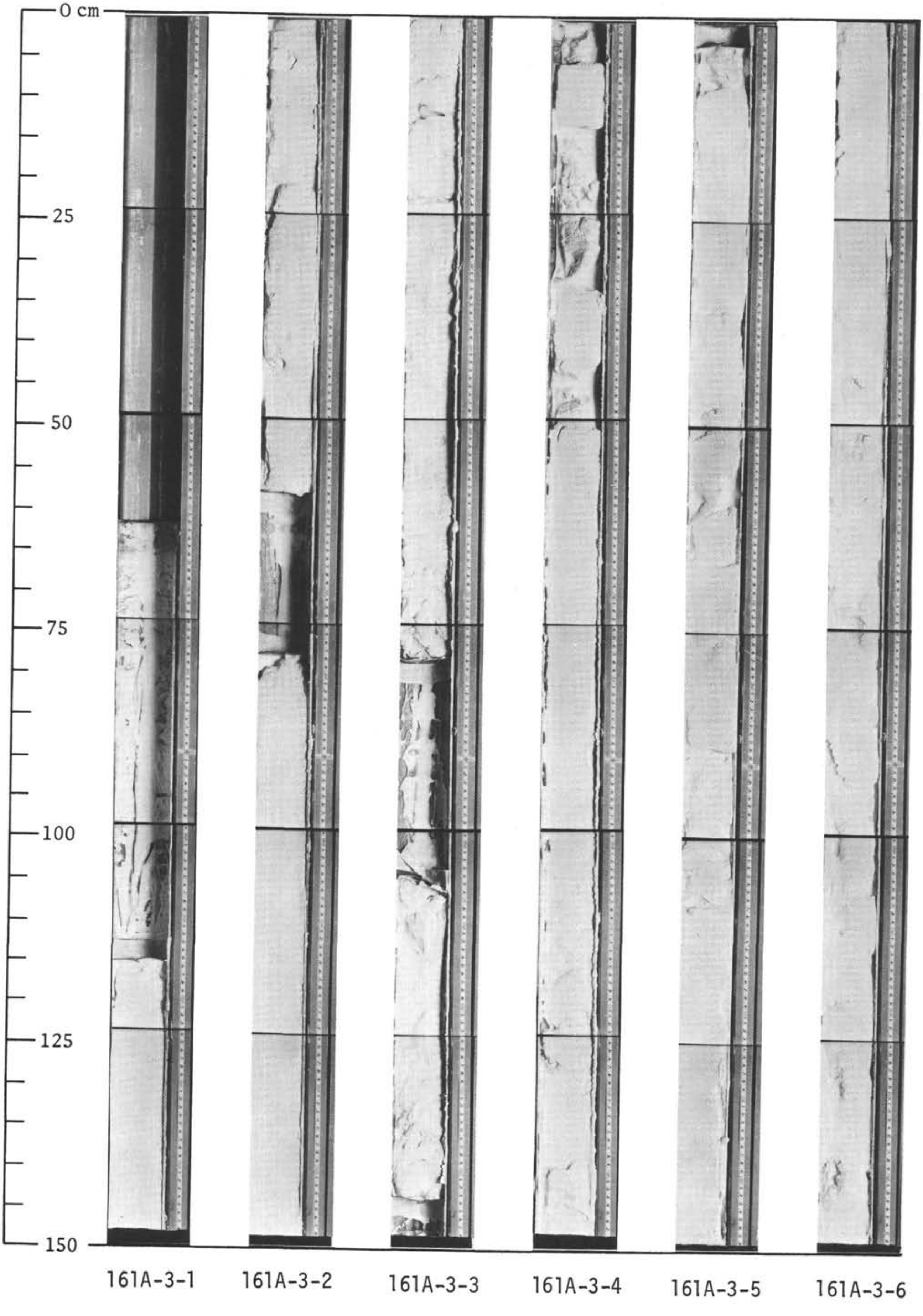
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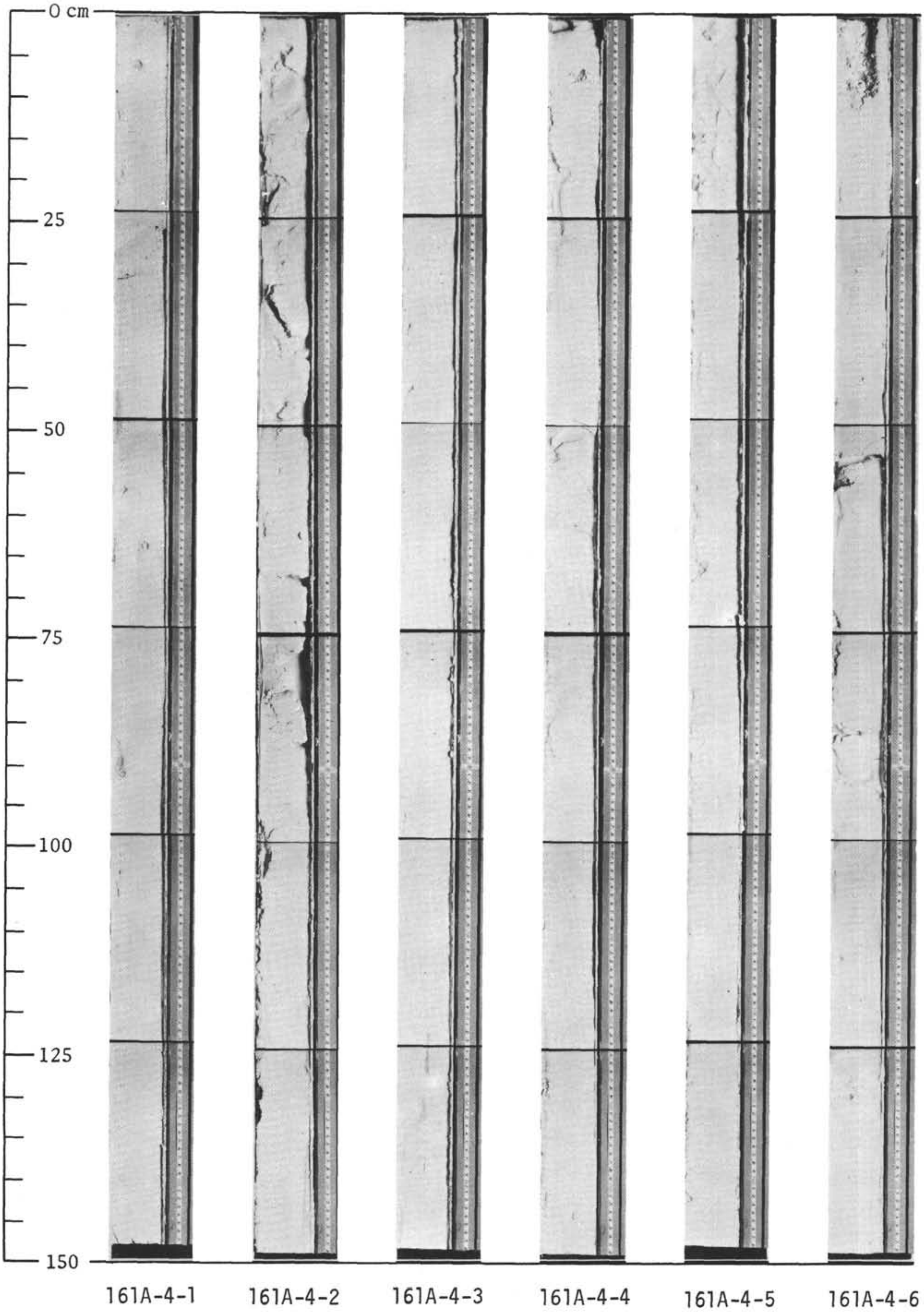
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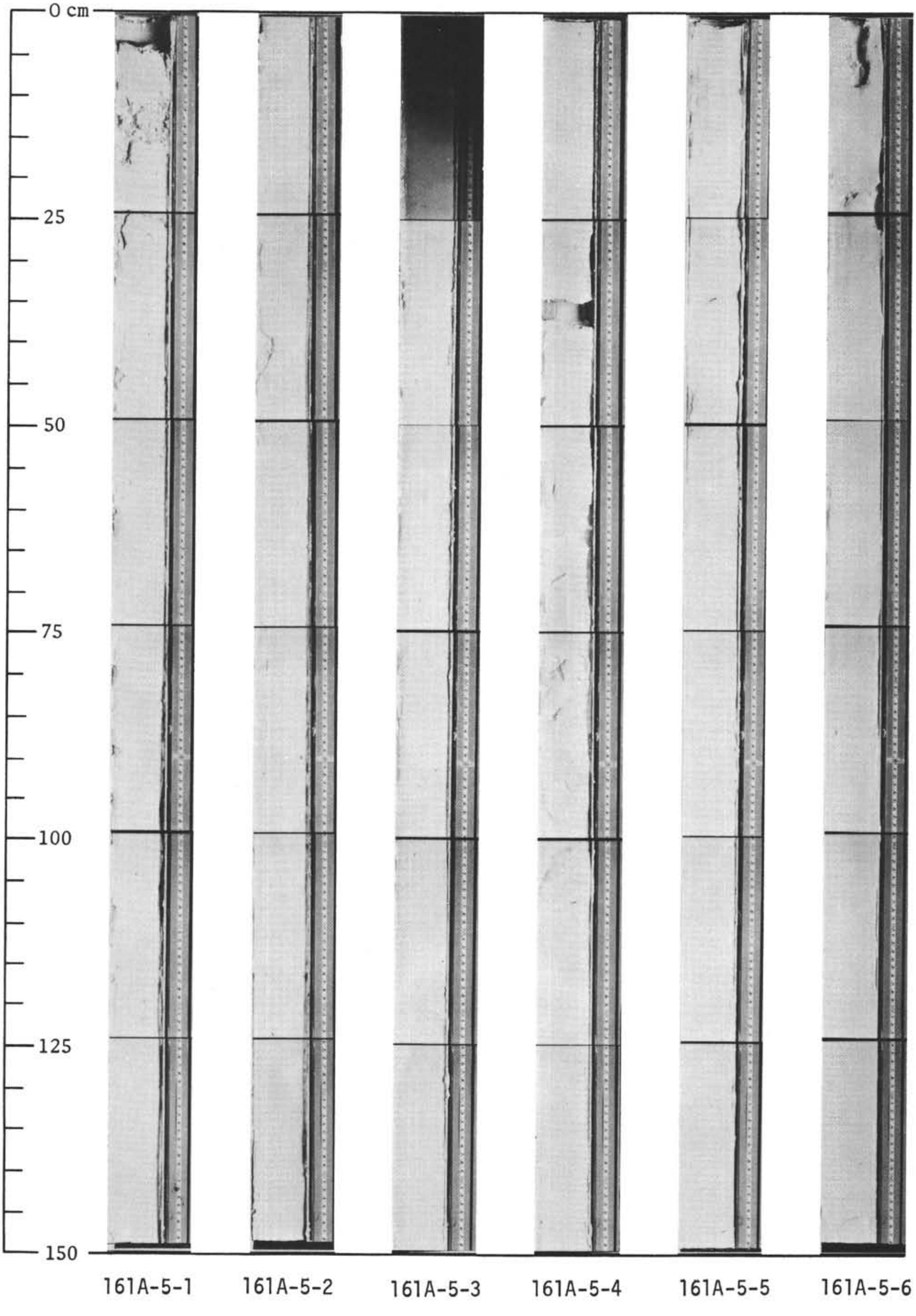
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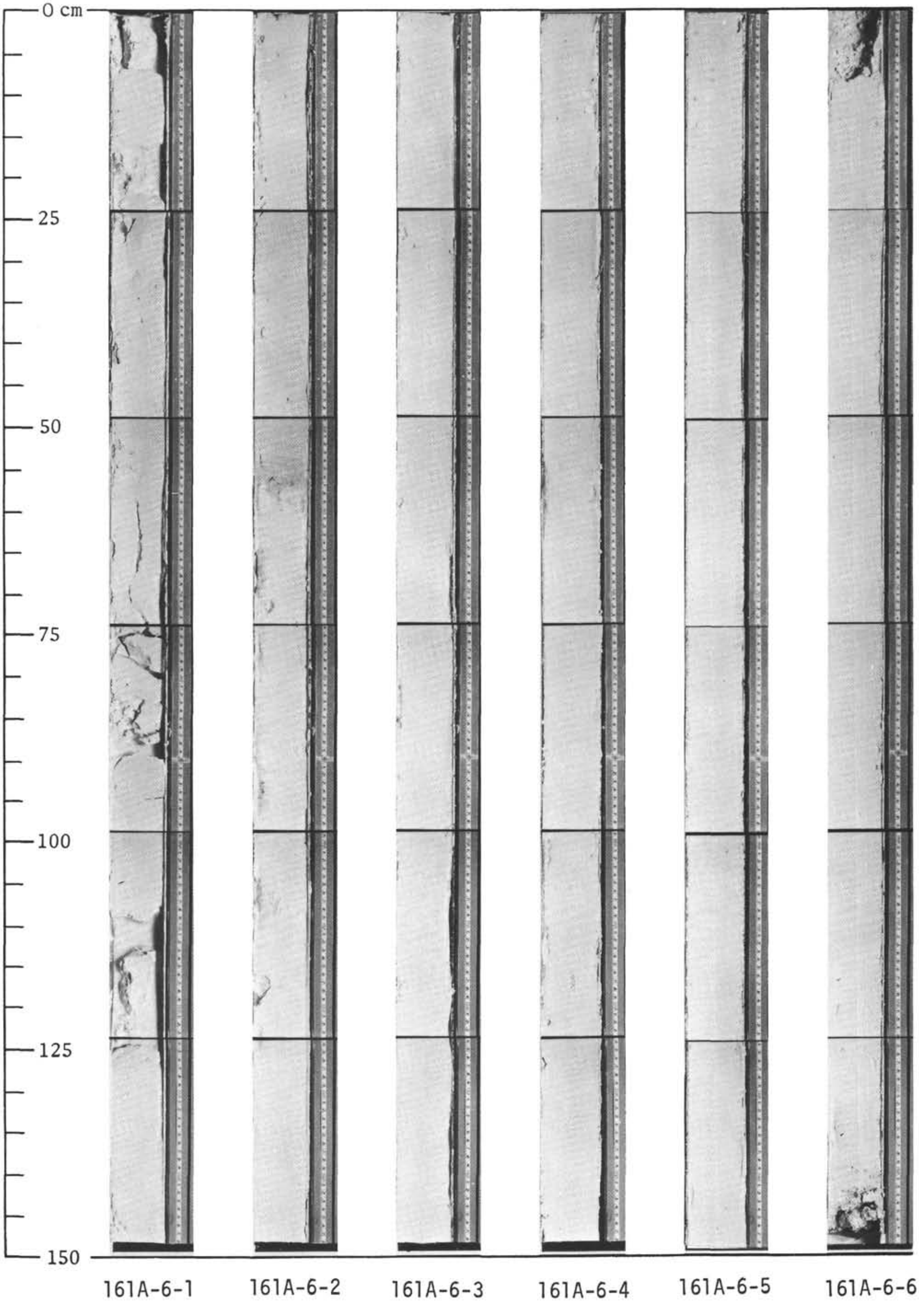
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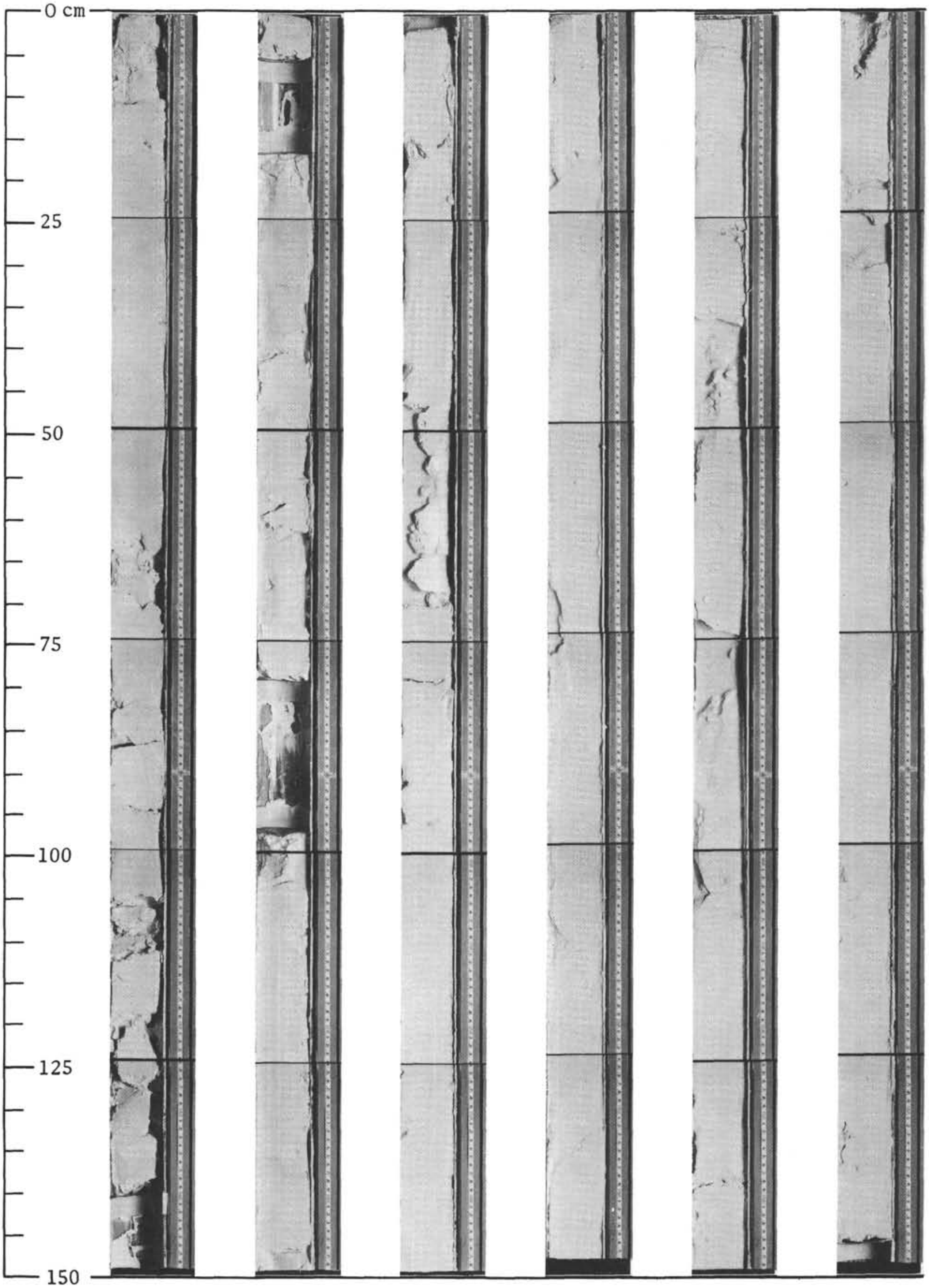
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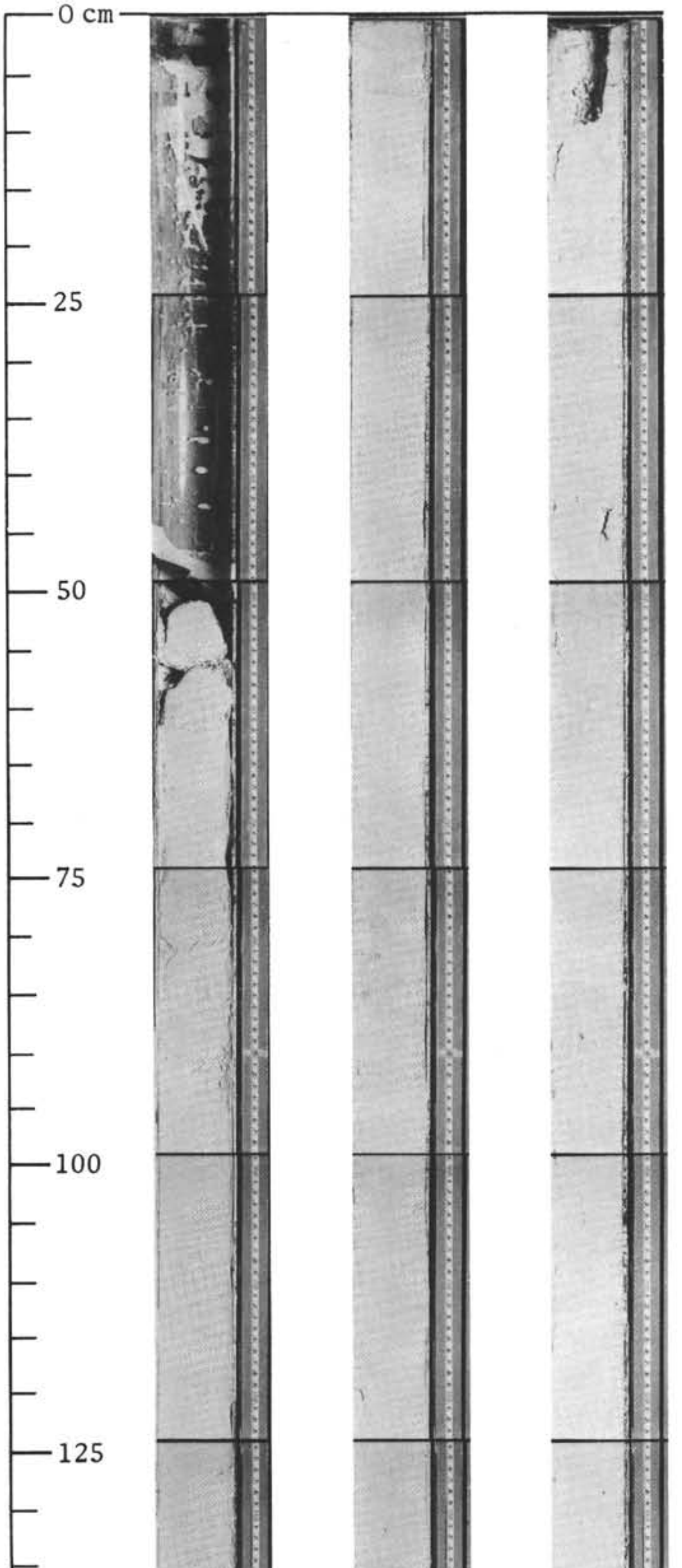
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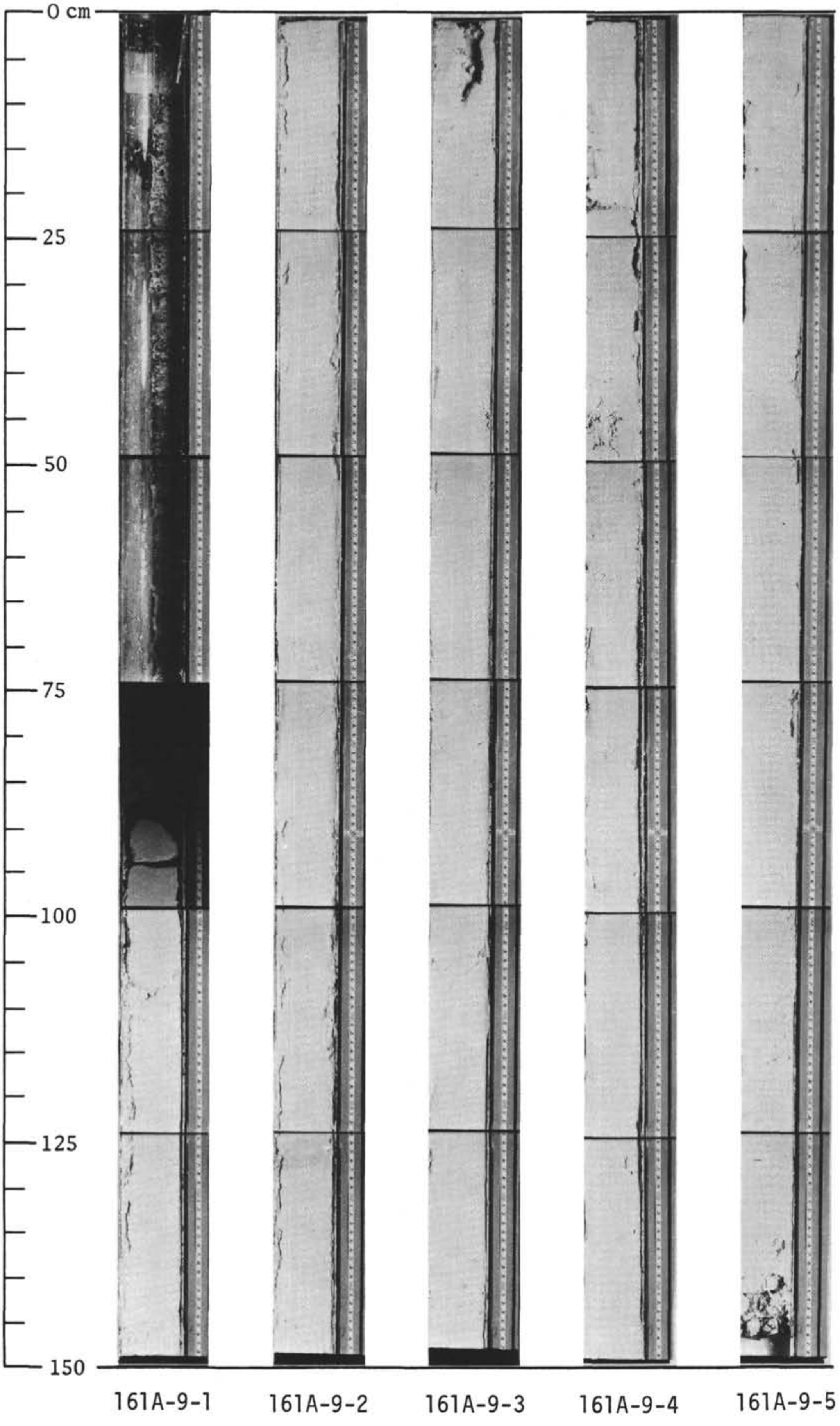
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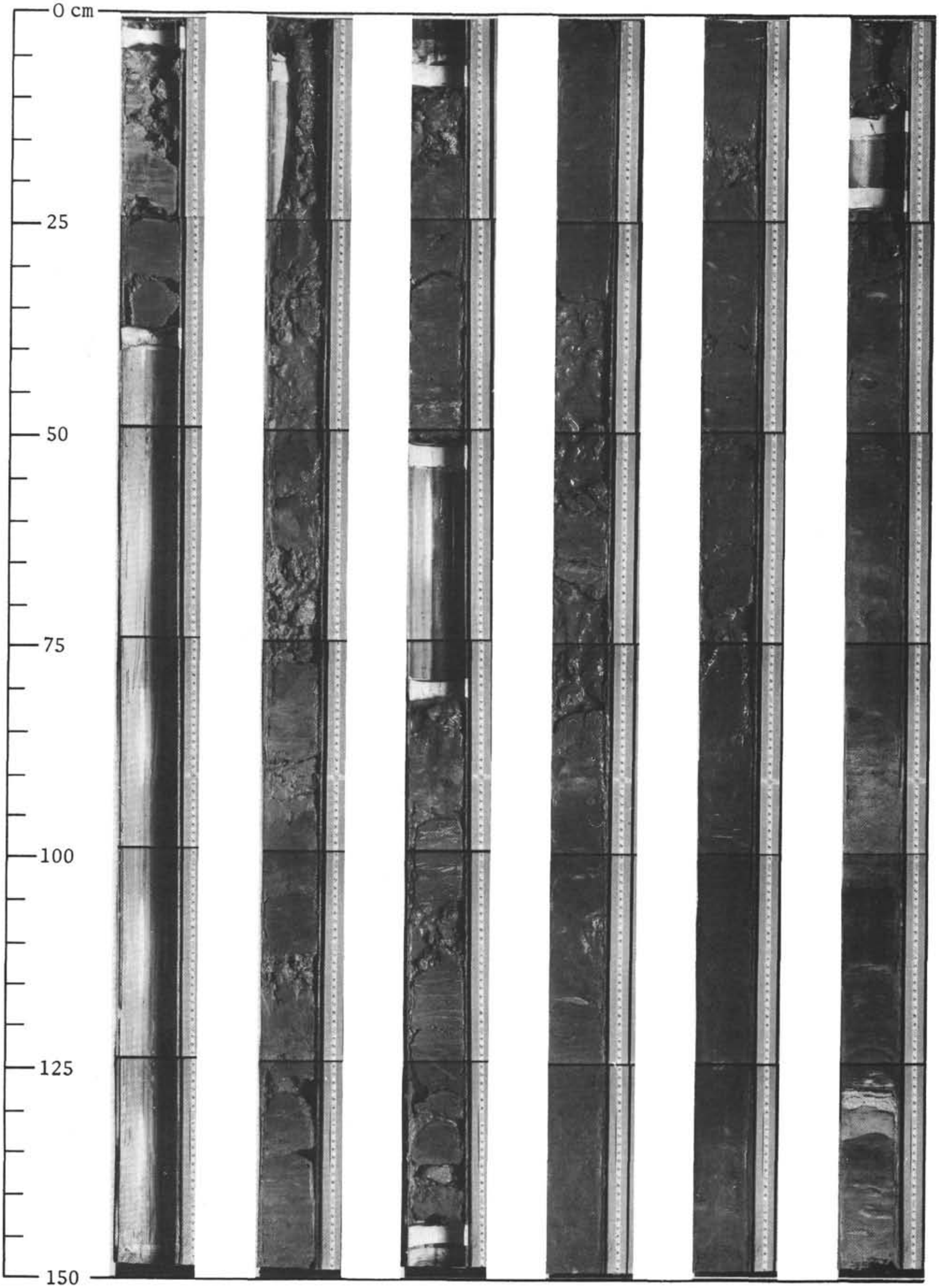

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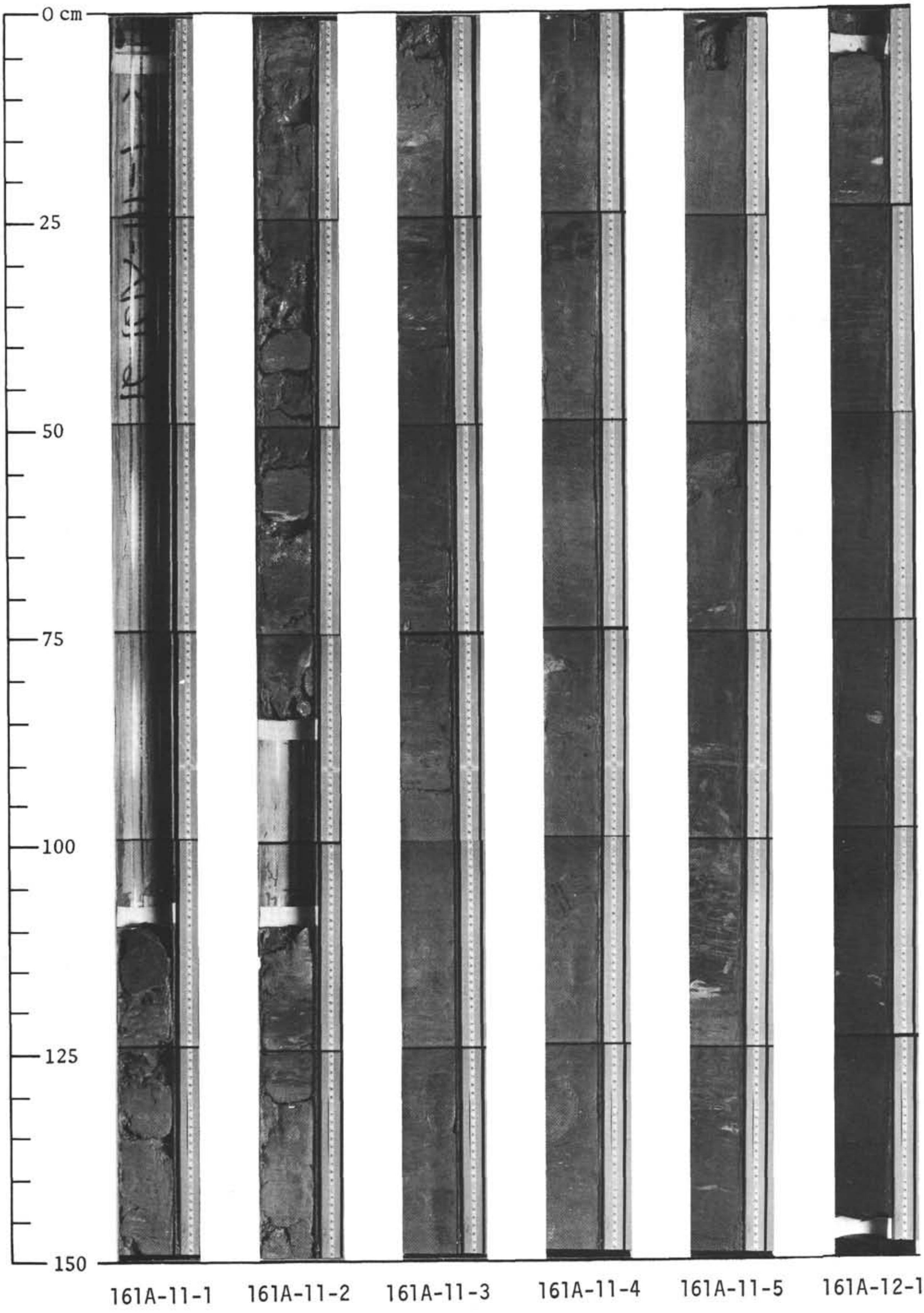
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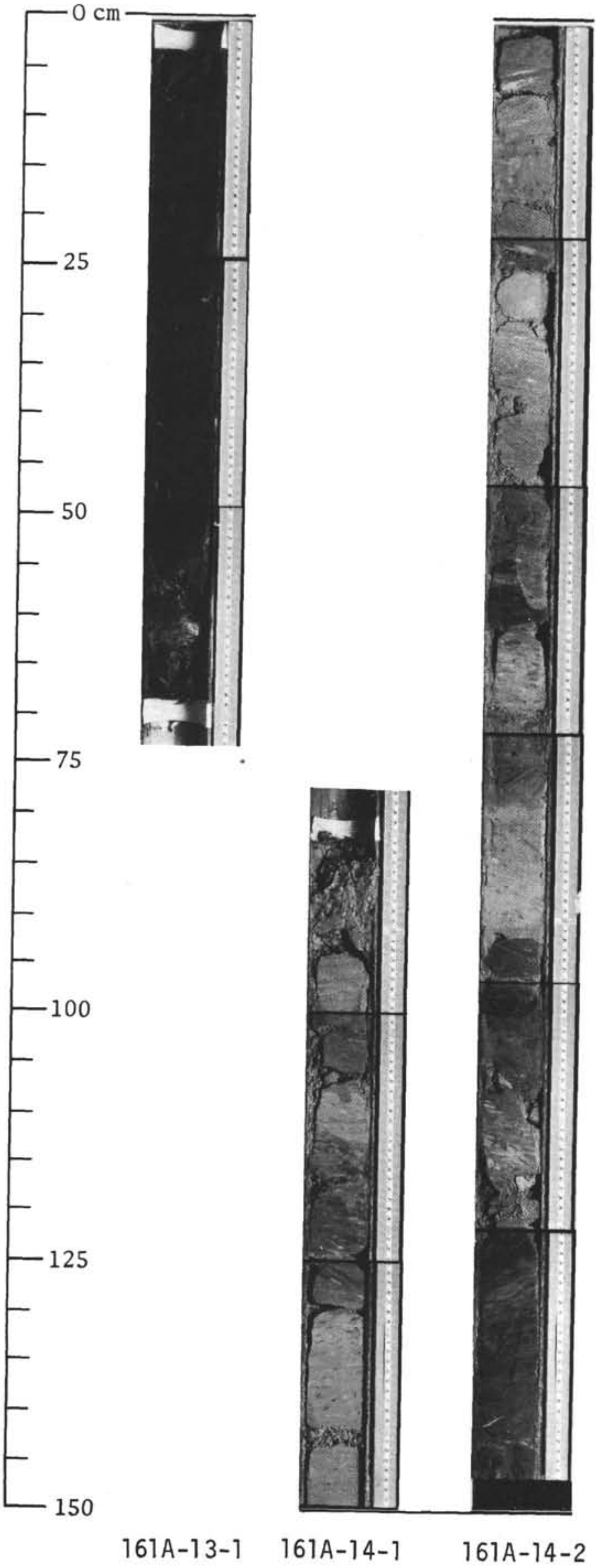
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