10. SITE 163

The Shipboard Scientific Party[1]

SYNOPSIS

Area: Abyssal hill area between Clipperton and Clarion fracture zones

Date Occupied: 20-26 March, 1971

Position:
Lat. 11°14.66′N
Long. 150°17.52′W

Water Depth: 5230 meters (corrected)

Penetration:
163: 294 meters
163A: 151 meters

Number of Holes: 2

Number of Cores:
163: 29
163A: 2

Core Recovery:
163: 155.7 meters
163A: 5.0 meters

Acoustic Basement:
Depth: 0.33 second
Nature: Basalt
Inferred acoustic velocity in sedimentary section: 1670 m/sec

Age of Oldest Sediment: Early Campanian

Basement: Basalt

The site was cored from 0-111 meters, 140-144 meters, 150-151 meters, and 162-294 meters; to yield the following section:
0-28 meters – Zeolitic brown clay becoming radiolarian and less zeolitic with depth.
Age: Early and early late Oligocene.
28-95 meters – Clayey radiolarian ooze with numerous thin porcellaneous cherts, particularly below 91 meters.
Age: middle and late Eocene.
95-?136 meters – Thin chert beds with soft sediment (not recovered; ? radiolarian ooze).
Age: Unknown.
?137-?150 meters – Zeolitic stiff clay, cherty.
Age: early Maestrichtian.
?150-176 meters – Nannofossil chalk, in part mottled. Flinty cherts throughout. Some dolomite at base.
Age: Early Maestrichtian to late early or middle Campanian.
276-294 meters – Extrusive basalt; seven flow units with glassy altered margins and diabasic interiors.

Sedimentation rates are 5 m/m.y. for the Eocene-Oligocene radiolarian ooze and clay, and 11 m/m.y. for the Campanian and early Maestrichtian chalk. The oldest sediment is from the Campanian *Eiffellithus augustus* nannofossil zone, giving an estimated age of more than 72 m.y.

REGIONAL SETTING AND OBJECTIVES

DSDP 163 is located in the abyssal hill region of the central equatorial Pacific, between the Clipperton and Clarion fracture zones. The tectonic position of the site, which lies about 5000 km from the crest of the East Pacific Rise (Figure 1), is not clear. The foot of the rise lies to the east and the Line Islands to the west. Only the Clarion Fracture Zone to the north is well defined at this longitude. The Clipperton Fracture Zone is represented by a band of broad, rather indistinct ridges and swales which is much wider than the corresponding zone farther east. In addition, the sediment-covered abyssal-hill terrain of the flank of the East Pacific Rise is separated from the thick sediments and subdued topography of the DSDP 163 area by a distinctive zone between approximately 142°W and 149°W in which the sediment cover is very thin.

The site was selected by the Pacific Site Selection Panel to examine the unusually thick sedimentary section of this area and to provide a tie between the sites drilled on the flanks of the East Pacific Rise and those of the central and western equatorial Pacific examined on Legs 7 and 17 (Winterer, Riedel et al., 1971; Winterer, Ewing et al., in preparation). Prior to Leg 16 no sediments older than middle Eocene had been cored or found at the surface east of the Line Islands, and all Eocene deposits had been sparsely calcareous or non-calcareous. Thus, either the Eocene equatorial belt of calcareous sediments had not been located or Eocene oceanographic conditions differed markedly from those prevailing from the Oligocene to Recent times. Furthermore, the upper and middle Eocene sections cored previously are incomplete and coring rarely penetrated to the Paleocene. Thus, DSDP 163 was selected to try to sample the missing section as well as to allow construction of an east-west stratigraphic profile through the equatorial Pacific, based on sites from Legs 7, 8, 9, 16, and 17, to complement the north-south profile along 140°W.

TOPOGRAPHY AND GEOLOGIC SETTING

DSDP 163 is separated from the typical abyssal-hill terrain of the lower East Pacific Rise (for example at DSDP

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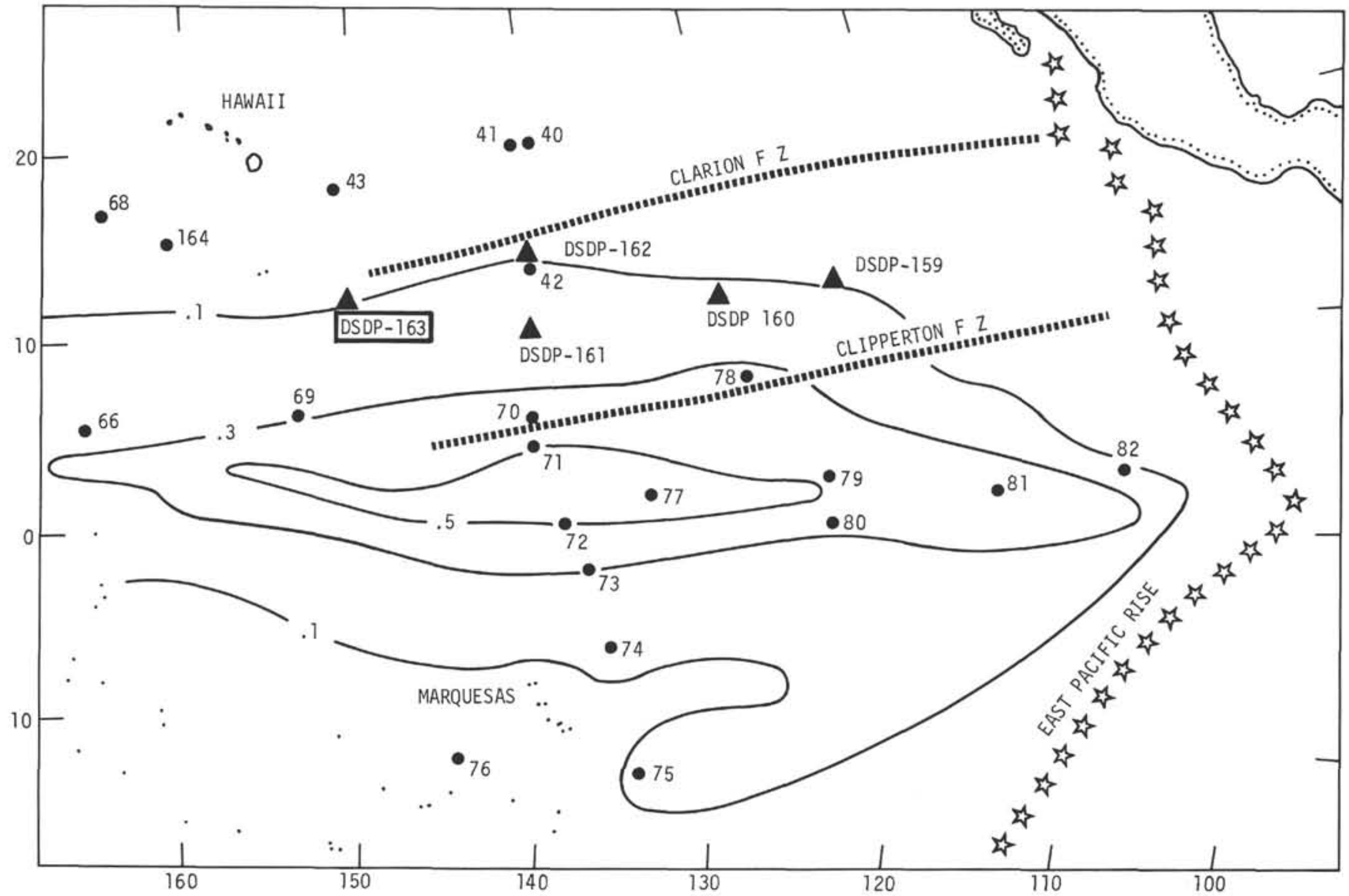


Figure 1. *Location of Leg 16 sites (large triangles) in the eastern equatorial Pacific on the west flank of the East Pacific Rise. Small dots are sites from Legs 5, 8, 9, and 17. Contours indicate sediment thickness above acoustic basement in seconds (approximately equivalent to 800 meters).*

161 and DSDP 162) by a zone of unusual and unexplained topography. At approximately 142°W, the lineated, sediment-covered hills and valleys of the lower flank are abruptly replaced by very narrow V-shaped valleys and sharp basement peaks. These features have wavelengths of no more than 4.8 km and vertical relief of 100 meters. The jagged local terrain is superimposed upon a larger scale topography of broad rises and depressions with 200-400 meters of relief and wavelengths of a hundred kilometers or more. Rather large normal faults with vertical separations of a hundred meters and spacing of 50-100 km characterize the larger scale features. Seamounts appear occasionally and the track of the *Glomar Challenger* may have crossed a few minor fracture zones. Regional bathymetric charts indicate that the trend of the large topographic features is parallel to the Clarion and Clipperton fracture zones.

East of 142°W, the typical sediment cover is generally 150-200 meters thick and overlies smooth acoustic basement. West of this longitude the sediment is acoustically transparent, very patchy, and is generally less than 100 meters thick. Smooth acoustic basement does not occur in the western area.

To the west, the extreme jaggedness of the topography diminishes somewhat as a result of broadening of the individual hills and valleys, but the vertical relief increases. The highly transparent sediment cover thins to about 50 meters, and becomes very discontinuous.

Another abrupt change occurs near 149°W. Over a short distance the jagged terrain is replaced by broad gentle hills and valleys 10-20 km wide having 100 meters or less of relief. The rolling topography is covered by a continuous sediment blanket which rests on a reasonably well-defined, smooth acoustic basement. The sediments are 200-300 meters thick and consist of an acoustically transparent surface layer overlying a strongly stratified sequence which in turn rests on a transparent basal layer. The smooth acoustic basement, unlike the one observed west of 142°W, can be seen on the hills as well as in the valleys. Faults are not numerous and are of small throw. DSDP 163, approximately 100 km west of the 149°W boundary, lies in terrain which is representative of the entire area.

The significance of the drastic changes in surface morphology and sediment cover at 142°W and 149°W are unfortunately not clear. Data to establish whether the topography observed on the *Glomar Challenger* crossing is typical of the entire block between the Clipperton and Clarion fracture zones are lacking. What is clear, however, is that DSDP 163 does not lie on a direct structural continuation of the west flank of the East Pacific Rise.

Because of the drastic changes in morphology, structure, and sediment cover immediately to the east, the site area was surveyed in some detail. The location was originally selected on the basis of a seismic reflection record obtained on Cruise 11 of R/V *Conrad.* This record shows shallow, nearly flat-bottomed valleys separated by low rounded ridges of unknown trend and extent.

The site survey (Figure 2) shows that the area consists of small rounded hills and broad flat basins with typical dimensions of 4-10 km and relief of 50-100 meters. Faults are uncommon (Figure 3); the few that are observed are normal faults with vertical separations of a few tens of meters. The surveyed area is too small to reveal any lineation of the topography, but at least some of the hills are very nearly equidimensional. If a trend exists, it is probably approximately northeast, quite different from the nearly northerly trends prevailing east of 142°W. A thick sediment blanket covers the entire area. With the exception of one small seamount north of the survey area and another one about 40 km to the east, there is no significant area of basement outcrop. Some of the hill slopes appear to result from normal faults. Commonly, a small basement pinnacle invariably covered by sediment occurs on the upthrown side of the fault.

The upper layer of the acoustic section is highly transparent, and contains one single, thin, but sharp reflector close to the surface (Figure 3). Where this reflector is absent, the entire transparent section is invisible or almost so on the profiler records, even though still detected by the 12 kHz echosounding system. The transparent layer is thickest in the immediate vicinity of DSDP 163 in a small area between two hills (Figure 2). Elsewhere, it thins drastically to the west and, judging from the approach track, also to the east. Even where the layer is thin, however, the thin reflector near the top is generally present, suggesting that the thinning is probably not due to recent erosion.

The next deeper acoustic unit is probably stratified throughout, although the strength and reverberation of the signal from the top reflector largely conceal the internal structure of the layer and the position of its base. Underneath, there is another more transparent layer which, however, is not nearly as transparent as the top zone. This basal unit contains many thin, rather discontinuous and diffuse reflectors, which give the impression of fine stratification, somewhat similar to but not nearly as distinct as the stratification observed in late Cenozoic deposits of the equatorial region. The thickness of sediment between the upper strong reflector and the acoustic basement is very constant on hills as well as in valleys. Only rarely is the section interrupted by small basement pinnacles. Table 1 is a comparison of acoustic section and drill data.

OPERATIONS

The vessel arrived in the site area in the early morning of 20 March and, after completing the site survey, dropped the beacon at 0500 hours. At 0600 hours it became evident that the beacon had failed. During this period, the vessel had drifted out of the small area of thick upper transparent sediment so that a supplementary survey was necessary. Around noon the final beacon was dropped, after which the re-entry cone was prepared, lowered over the side and keelhauled, and the string was made up. In the early morning of the 21st of March, the casing latch in the bottom-hole assembly gave way, leaving the cone and casing supported only by a sling. It was decided to go ahead and spud the hole and to lower the cone assembly only when the need for re-entry became apparent. The hole was spudded and cored continuously using a 10-1/8″ Smith 3-cone shaped insert bit which performed well, except for difficulties in recovering core in interbedded soft sediment and chert. Blocked circulation resulted in a decision to drill ahead from 111 meters to the last chert detectable by means of torque and drilling rate changes. From 162 meters the hole was cored satisfactorily to basalt at 276 meters and then a further 18 meters into basement. At 294 meters progress was stopped by basalt lost from the previous core. The core loss resulted from failure of the core catchers to hold and break a fresh column of basalt. The string was tripped and the bit found to be totally worn. It appears that the debris in the hole broke off the cones during the attempt to obtain a final basement core. Since the re-entry cone and casing had already been dropped, re-entry was attempted as an exercise. The attempt was abandoned when the EDO acoustic re-entry tool failed to function properly. A second hole, offset from the first, was then drilled in an attempt to core the section from 111-162 meters. This hole recovered two cores of chert and Maestrichtian zeolitic clay. Pressure of time forced abandonment of the site after an unsuccessful attempt to obtain a sidewall core (the tool would not pass through the bit). At 0800 hours on 27 March the gear was secured and the vessel departed for Honolulu. A coring summary for Site 163 is given in Table 2.

LITHOLOGY

In Hole DSDP 163, fourteen cores were taken from 0-111 meters and fifteen from 162-292 meters. Two cores were taken in the interval 140-515 meters in Hole DSDP 163A. The uncored interval (111-140 m) contains the boundary between lower Tertiary radiolarian ooze and Maestrichtian clay, while the boundary between the Maestrichtian clay and chalk lies in the unsampled interval of 144-162 meters. The following lithologic types can be recognized at this site:

Unit 163-1 – Dark yellowish brown zeolitic clay.

Unit 163-2 – Moderate brown clayey radiolarian ooze.

Unit 163-3 – Dusky brown, light brown, and dark brown chert.

Unit 163-4 – Light olive gray to very pale orange nannofossil chalk, with intense mottling of pale yellowish brown to orange pink and dusky brown. Contains thin chert beds.

Unit 163-5 – Very pale orange to very pale pinkish orange nannofossil chalk grading into and alternating with Unit 163-4 and containing interbedded chert layers.

Unit 163-6 – Extrusive basalt.

Dark yellowish brown zeolitic clay with radiolarian fragments (Unit 163-1) is found at the surface; its color

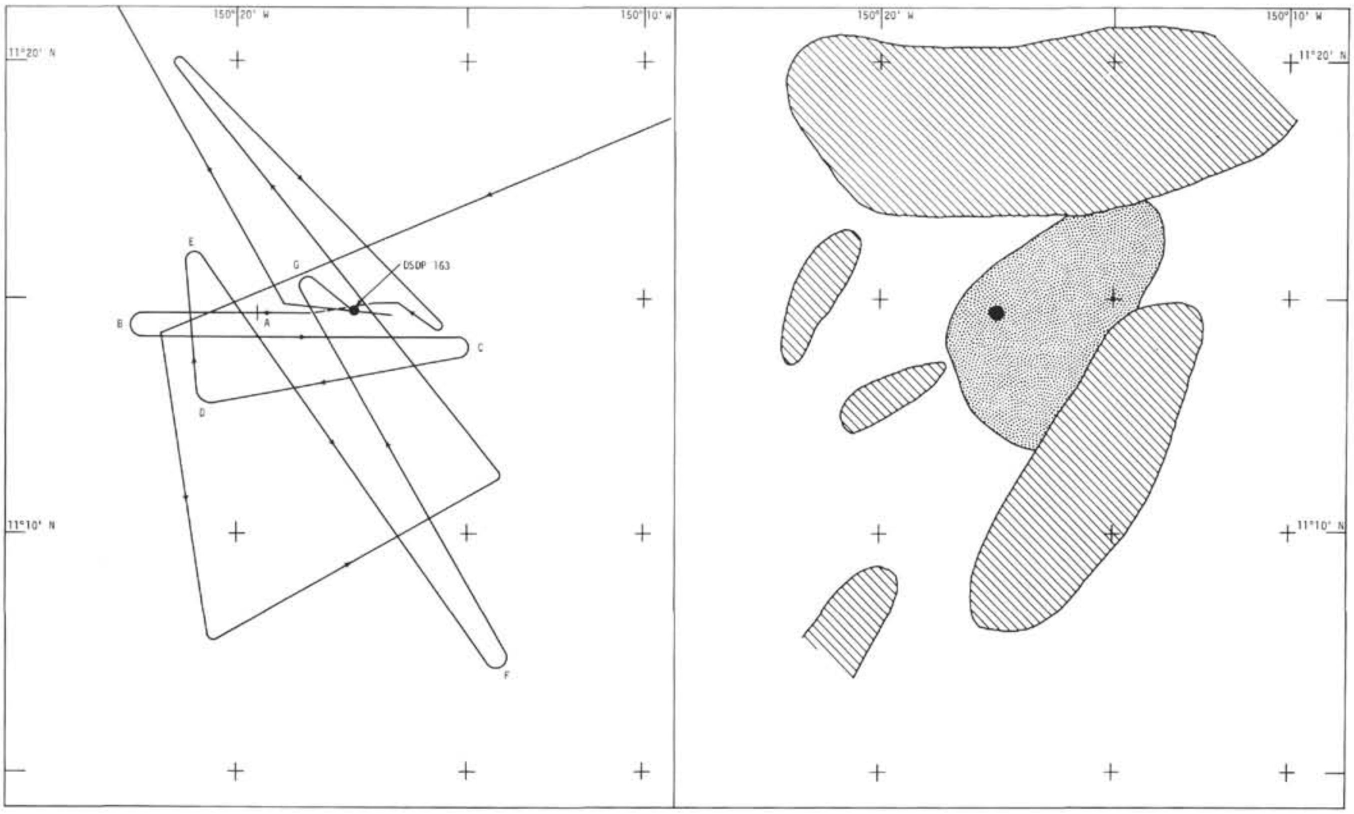


Figure 2. *Site survey and diagrammatic sketch of topography and sediment cover near DSDP 163. Stippled: upper transparent zone more than 100 meters thick; shaded: abyssal hills. A-163 is location of profile of Figure 3.*

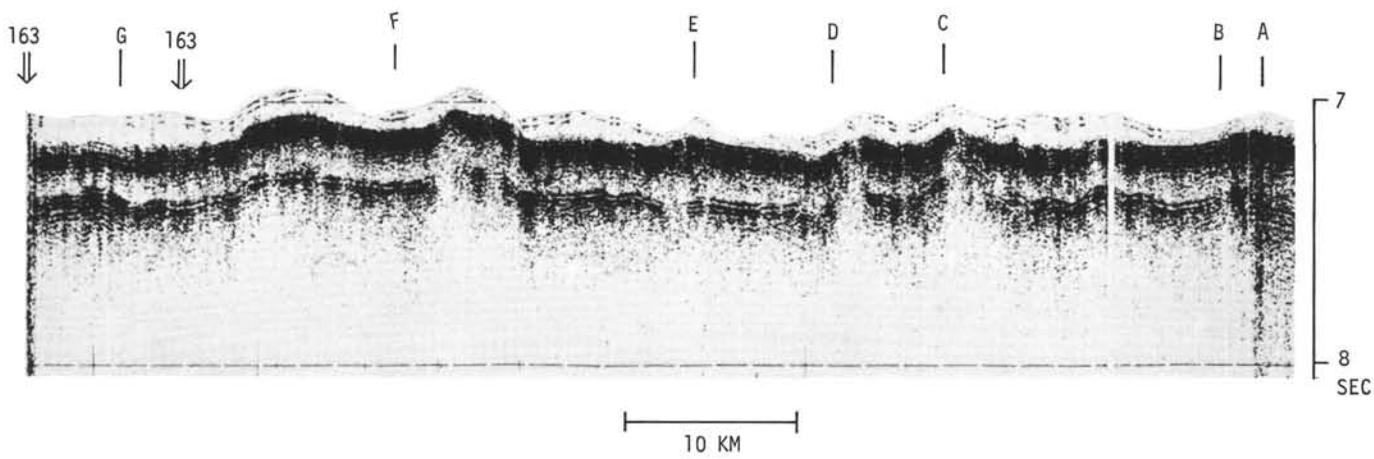


Figure 3. *Acoustic reflection profile in vicinity of Site DSDP 163. Depths in seconds two-way travel time. Horizontal scale approximate.*

comes from abundant micronodules and amorphous ferruginous aggregates. With depth, the zeolite and clay contents decrease, the radiolarian content increases, and the formation grades into a clayey radiolarian ooze (Unit 163-2) in its lower part. Grayish orange mottles from 2 to 10 mm across, consisting of relatively pure radiolarian ooze with greatly reduced concentrations of clay, manganese micronodules, and amorphous ferruginous aggregates, are found throughout. Diatoms, sponge spicules, and fish debris are present, but the section is not calcareous. Light volcanic glass and barite are found near the surface.

The first chert (Unit 163-3) occurs near 28 meters judging from drilling rate data and the appearance of fragments in Core 5. In the interval from 28-111 meters, the drilling rate shows abrupt decreases at 28-32, 44-45, 77-78, 91-92, 100-101, 105-106, and 109-111 meters, indicating thin layers of chert. In general, these eight layers can be recognized in the cores, although incomplete

TABLE 1
Comparison of Acoustic Section and Drill Data, DSDP 163

Reflectors	Depth (sec)	Drilling Results	Velocity (m/sec)
First thin reflector	0.035	28 m base of brown clay	1600
Top stratified zone	0.12	95 m top closely spaced cherts	1580
Base stratified zone[a]	0.20	155 m top Cretaceous chalk?	1550
Acoustic basement	0.33	276 m top basalt	1670

[a]Transitional, approximate depth.

TABLE 2
Coring Summary, DSDP 163

Core	Depth Below Sea Level (m)	Depth Below Sea Floor (m)	Cored (cm)	Recovered	
				(cm)	(%)
1	5320-5321	0-1	100	15	15.0
2	5321-5330	1-10	900	490	54.4
3	5330-5539	10-19	900	803	89.2
4	5339-5348	19-28	900	807	89.7
5	5348-5357	28-37	900	725	80.6
6	5357-5366	37-46	900	910	101.1
7	5357-5375	46-55	900	903	100.3
8	5375-5384	55-64	900	38	4.2
9	5384-5393	64-73	900	355	39.4
10	5393-5402	73-82	900	819	91.0
11	5402-5411	82-91	900	900	100.0
12	5411-5420	91-100	900	540	50.0
13	5420-5429	100-109	900	3	0.3
14	5429-5431	109-111	200	45	22.5
15	5431-5491	162-171	900	150	16.7
16	5491-5500	171-180	900	862	95.8
17	5500-5509	180-189	900	918	102.0
18	5509-5518	189-198	900	928	103.1
19	5518-5527	198-207	900	864	96.0
20	5527-5536	207-216	900	888	98.7
21	5536-5545	216-225	900	766	85.1
22	5545-5554	225-234	900	797	88.6
23	5554-5563	234-243	900	912	101.3
24	5563-5572	243-252	900	53	5.9
25	5572-5581	252-261	900	85	9.4
26	5581-5590	261-270	900	205	22.8
27	5590-5596	270-276	600	120	21.7
28	5596-5605	276-285	900	127	15.2
29	5605-5614	285-294	900	614	68.2
1A	5460-5464	140-144	400	485	121.3
2A	5470-5471	150-151	100	10	10.0

recovery prevents precise correlation. The softer sediments are similar to those above 28 meters and consist of slightly diatomaceous clayey radiolarian ooze (Unit 163-2), which is rich in micronodules and amorphous ferruginous aggregates, and contains grayish orange and pale yellowish orange mottles of clay-poor radiolarian ooze. Zeolitic clay (Unit 163-1) layers are found at 88 meters and 96 meters. The highest chert at 28 meters is dusky brown with 1-5 mm streaks of light brown. Some chert fragments from greater depths are similar in appearance and may in part be cavings, but others, such as those from the chert layer at 44-45 meters are dark brown and dusky yellowish brown in color.

The deepest radiolarian ooze recovered is at 95 meters. Between 95 and 111 meters only dusky yellowish brown and moderate brown chert, with 1-10 mm moderate yellowish brown, grayish orange, and very pale orange laminations, was recovered (Unit 163-3). This recovered material probably corresponds, at least in part, to the chert layers at 100, 105, and 109 meters inferred from the drilling record.

The transition between the radiolarian ooze and the underlying clay which lies between 111 and 140 meters was not cored. A slight change in drilling character suggests that the boundary is at about 137 meters. From 140-151 meters, cores from DSDP 163A contain a dark yellowish brown zeolitic clay of Maestrichtian (?) age. This zeolitic clay (Unit 163-1) contains manganese micronodules, amorphous ferruginous aggregates, corroded radiolarians, fish debris, and at 144 meters, small quantities of calcareous nannofossils. Dark yellowish brown to moderate yellowish brown chert fragments are common. Since the deeper core contains only cavings, the calcareous microfossils at 144 meters may mark the upper limit of the underlying calcareous sequence. Hard drilling from 149 to 153 meters probably indicates chert.

The top of the carbonate sequence may be as deep as 169 meters, but the data from DSDP 163A imply that it is not far below 144 meters. The drilling record indicates that there are no chert beds in the interval 153-171 meters. The calcareous sequence consists of nannofossil chalk (Unit 163-4). The highest cores are light olive gray with intense mottling of dusky yellowish brown, grayish orange, and pale orange. The darker colored mottles are nannofossil marl and nannofossil clay and are rich in micronodules and amorphous ferruginous aggregates. From 170-207 meters, the chalk is characterized by striking mottling, with the dominant colors of pale yellowish brown, grayish orange, and brownish gray interspersed with 2-20 mm spots of orange pink, very pale orange, dusky yellowish brown, and dusky brown. The drilling record points to thin chert beds at 171, 175, 177, and 195 meters, all of which, except the layer at 195 meters, can be correlated with thin layers of pale orange, pale yellowish brown, and dusky yellowish brown chert layers with burrows 2-10 mm across in the cores. Fish debris and foraminifera are present in the sediments, but siliceous fossils are rare.

The nannofossil chalk gradually loses its high-contrast intense mottling, best described as "leopard spot" mottling, down the section. The first low-contrast mottling (Unit 163-5) appears at 175 meters, where it alternates with the "leopard spot" type, before becoming dominant below 207 meters. The chalk in the interval 207-245 meters shows low-contrast mottling (Unit 163-5) and is very pale orange to very pale pinkish orange and pale yellowish brown. Foraminifera, fish debris, micronodules, and ferruginous aggregates are present in small amounts. Thin beds of dusky yellowish brown and moderate brown chert, locally mottled with light brown, are associated with the chalk. Such cherts appear at numerous levels, as indicated by the drilling record, but are often difficult to identify in cores due to poor recovery. From 243 to 276 meters the lithology appears to remain unchanged as far as can be determined from the small amount of material recovered.

The chalk shows increasing consolidation with depth as a result of silicification and compaction; locally it is classed as siliceous limestone. Dolomite rhombs appear from 261 to 285 meters, and palagonite occurs in the interval 270-285 meters. The deepest part of the section is very light colored to locally white.

The chalk overlies basalt which occupies the section from 276-295 meters. Eighteen meters of basalt were cored for a recovery of 7.4 meters. The basalt can be divided into at least seven flow units, separated by intervening 1-2 cm zones of black glass (see Yeats et al., this volume, Chapter 22). Unit 3, the thinnest of these units (14 cm thick) has bounding glass zones dipping at 50° and 65°, suggesting that it is a basalt pillow. The thickest unit, assuming that recovery was complete, is about 470 cm thick and may represent a separate flow. Alteration, calcite veining, and glassy groundmass all decrease away from the glassy border zone of this unit.

Adjacent to the glassy borders, the altered basalt is dusky yellow, moderate yellowish brown, and olive gray. Farther away, less altered rock is greenish gray and medium light gray. Close to the glass, anastomosing calcite veins are common. Much of the discoloration of the basalt parallels these veins. Farther into the flow, calcite veins are rare, and in the center of the thickest unit, they are absent. Even in the freshest areas, however, the basalt has undergone alteration; natural fractures are greenish gray or greenish black and are talcose to the touch.

Close to the glass, the basalt is aphanitic, probably indicating a glassy groundmass. Farther away, it is characterized by a felty texture produced by interlocking needle-like plagioclase laths which apparently formed in place. These laths are largest and most prominently developed in the center of the largest flow unit. Small, more equant microphenocrysts of plagioclase, 1-3 mm across, appear to be unrelated to the distance from the glass, and were probably formed prior to extrusion. The basalt is clearly extrusive, with local pillow structure and zones of glass. No dikes are apparent. Alteration is related to glass boundaries rather than to depth below the chalk, suggesting either that much of the alteration is deuteric rather than halmyrolytic, or that the flow units are separate events.

In thin section, the glassy margin is seen to consist of light brown glass, isotropic with conchoidal fractures, and dark brown to opaque glass. The opaque glass tends to form around plagioclase nuclei. The phenocrysts are fresh euhedral laths of sodic bytownite zoned to labradorite, 100-600 microns long, and olivine largely pseudomorphed by calcite, serpentine, and iron oxide, in euhedral grains 100-700 microns long. As the fresh interior of a flow unit is approached, the labradorite laths are larger, up to 1500 microns, and pyroxene progresses from variolitic crystallites to well-developed augite sheafs and skeletal "pseudographic" crystals up to 1.2 mm long. Olivine grain size is the same throughout the unit, suggesting crystallization prior to emplacement; it is much less altered in the interior of the units. The olivine is Mg-rich with a large positive 2V. The groundmass is coarser grained toward the interior of the units.

GEOCHEMISTRY

Interstitial water samples and shipboard operations for DSDP 163 are listed in Table 3.

TABLE 3
Interstitial Water Samples and Shipboard Observations, DSDP 163

Core	Section	Sampled Interval (cm)	pH	Eh (mv)	Lab. Temp. (°C)	Salinity (%)	Squeeze Pressure (psi)
2	4	0-9	7.34	150	25.7	34.7	1015
3	4	0-9	7.32	138	26.7	35.2	508
4	5	0-9	7.37	142	26.2	35.2	508
6	6	0-7	7.27	155	26.9	35.2	2436
7	2	0-9	7.43	161	27.0	35.2	508
10	3	141-150	7.46	151	26.8	35.2	508
11	6	0-9	7.44	164	26.1	35.8	1015
16	5	0-9	7.46	163	26.2	34.1	2436
17	6	0-8	7.44	164	26.0	34.1	2436
18	6	0-5	7.34	184	25.8	34.7	2436
19	5	0-8	7.45	191	25.0	34.1	2436
20	4	0-9	7.37	194	25.3	34.1	2436
21	4	0-8	7.45	188	25.9	34.1	2436
22	5	0-6	7.39	191	25.7	34.1	3000
23	6	0-7	7.41	201	26.0	34.1	3000
1A	4	0-8	7.37	172	25.4	34.7	3000

BIOSTRATIGRAPHY

The upper 160 meters of section at Site DSDP 163 is barren of calcareous fossils, except for traces of upper middle and middle Eocene nannofossils. However, the upper 100 meters of section contains a nearly continuous radiolarian sequence of early Tertiary age. Preservation of radiolarians is poor to moderately good in Cores 1 through 3, and good, with diverse faunas, in the rest of the radiolarian sequence. A veneer of Quaternary sediment is indicated by the presence of corroded specimens of *Ommatartus tetrathalamus* and *Spongaster tetras* in Core 1. However, the upper Tertiary is condensed or missing because Core 2 contains an upper Oligocene assemblage of the *Dorcadospyris papilio* Zone. Below this, a nearly continuous sequence down to the lowest part of the *Theocampe mongolfieri* Zone (lowermost middle Eocene) in Core 12, occurs.

Sediments cored in Cores 1A and 2A, taken in the uncored interval of Site 163, are unfossiliferous, though late Maestrichtian nannofossils, probably reworked from the underlying calcareous Cretaceous sections were found.

The calcareous sequence from 162 to 275 meters contains both coccoliths and foraminifera of Cretaceous age. Radiolarians in this section are scarce, very poorly preserved, and difficult to identify to the species level. A Campanian to early Maestrichtian age is indicated for this part of the section by nannofossils. Cores 15 through 22 are in the *Tetralithus trifidus* Zone of the late Campanian and early Maestrichtian age. The lower part of Core 22 and Core 23 contain the *Broinsonia parca* Zone. The oldest nannofossil zone sampled is the *Eiffellithus augustus* Zone, still of Campanian age.

The planktonic foraminiferal fauna in the Cretaceous part of the section is very sparse and rather uniform in composition throughout. Because of the lack of diagnostic planktonic species, no zonal assignments could be made. Though small, the benthonic foraminiferal fauna is highly diverse and appears to be well preserved. A Campanian age is indicated. The planktonic assemblages are remarkably undiversified, consisting mainly of species of *Hedbergella* and *Globigerinelloides*. *Globotruncanids* are absent throughout most of the section; deformed specimens, not identifiable to species, were seen in Core 27. *Globotruncanids* were also seen in the core catcher sample of Core 26 and are tentatively identified as *G. fornicata*, *G. elevata*, and *G. stuartiformis*. The overall aspect of this assemblage places it in the *Globotruncana elevata* Zone of late Campanian age.

PHYSICAL PROPERTIES

Core disturbance was evident throughout most of the sedimentary sequence; however, subsamples collected for the determination of the mass physical properties as well as samples used in the sound velocity measurements were all carefully selected from the least disturbed portions of the section. A few Swedish Fall Cone penetrometer and vane shear tests were made at selected intervals.

Bulk Density

Low GRAPE bulk densities of 1.14 to 1.26 g/cc are characteristic of the zeolitic clay and radiolarian ooze in the upper 100 meters. Densities of 1.49 to 1.55 g/cc are found in the zeolitic radiolarian brown clay between 141 and 150 meters. Considerably higher GRAPE densities of 1.71 to 1.86 g/cc are displayed by the nannofossil chalk from 174 to 243 meters. Laboratory bulk densities of 1.21 to 1.36 g/cc are observed for the zeolitic clay in the upper 28 meters, whereas values of 1.18 to 1.25 g/cc are associated with the radiolarian ooze above 100 meters. Values of 1.36 to 1.42 g/cc are characteristic of the zeolitic clay from 141 to 150 meters. The highest observed laboratory densities of 1.66 to 1.92 g/cc are found in the nannofossil chalk below 162 meters.

Porosity

High GRAPE porosities ranging from 83 to 92 per cent are characteristic of the upper 100 meters with a lower range (69 to 73%) prevailing in the underlying interval of 141 to 150 meters. The lowest GRAPE porosities (60 to 51%) occur below 174 meters. High laboratory porosities of 76 to 87 per cent are observed for the zeolitic clay with yet higher overall values of 80 to 84 per cent for the radiolarian ooze above 100 meters. The lower zeolitic clay (141 to 150 m) displays porosities ranging from 71 to 76 per cent. The lowest laboratory porosities of 62 to 47 per cent occur in the nannofossil chalk from 162 to 271 meters.

Water Content

Water contents of 56 to 74 per cent in the zeolitic clay (0 to 28 m) are the highest values observed throughout the sedimentary sequence with the exception of relatively high values of 65 to 68 per cent which occur in the radiolarian ooze above 100 meters. Water contents decrease with depth from values of 50 to 56 per cent in the interval of 141 to 150 meters to 25 to 37 per cent for the underlying sequence down to 271 meters.

Grain Density

Grain density is highly variable with depth averaging 2.58 g/cc in the upper 28 meters but decreasing significantly to 2.22 g/cc from 28 to 100 meters. Between 141 and 150 meters grain densities average 2.49 g/cc increasing to 2.73 g/cc at 271 meters.

Sound Velocity

Sonic velocities averaging 1.50 km/sec in the upper radiolarian ooze are generally lower than those of the nannofossil chalk (162 to 271 m) which average 1.57 km/sec. The highest velocities, averaging 1.83 km/sec, are found in the zeolitic radiolarian brown clay. High velocities of 3.29 to 4.94 km/sec are recorded for the chert of Cores 6 and 25 respectively. Velocity measurements of the basalt are higher than any observed at previous DSDP Leg 16 sites, averaging 7.03 km/sec and ranging from 6.98 to 7.12 km/sec.

Natural Gamma Radiation

The lowest natural gamma activity occurs in the radiolarian ooze in contrast to the highest values which are found in the zeolitic brown clay. These high values are evidently due to the occurrence of clay with high concentrations of radionuclides per unit volume even in the presence of relatively high porosities. The upper nannofossil chalk shows activity that is lower than the zeolitic radiolarian brown clay but higher than the radiolarian ooze. Natural gamma activity decreases with depth in the lower nannofossil chalk probably reflecting the relative increase in carbonate content.

Shear Strength

A few vane shear and Swedish Fall Cone penetrometer tests were made in the radiolarian ooze, lower zeolitic clay, and nannofossil chalk. A single vane shear strength of 278 g/cm^2 was recorded for the radiolarian ooze at a depth of 55 meters. A vane shear of 660 g/cm^2 and fall cone measurements averaging 604 g/cm^2 are in fairly close agreement for the ferruginous zeolitic clay (141 to 150 m). Fall cone shear strengths increase considerably in the nannofossil chalk. Average values range from 726 to 1233 g/cm^2 from 162 to 216 meters.

SUMMARY AND DISCUSSION

Two holes were drilled at Site DSDP 163. The first cored the sections from 0-111 meters and from 162-294 meters, while the second attempted, with partial success, to recover the section from 111-162 meters. The coring program ran into a problem that has plagued many previous sites—that of effectively sampling soft sediment containing chert beds. The soft sediment can only be sampled by drilling without circulation, but penetration of the chert requires substantial pump pressures. Attempts at intermittent circulation led to plugging of the circulation ports of the bit, which were fortunately cleared at DSDP 163, but have led to loss of the hole in the past. Other procedures, such as spotting mud before attempting a soft core were not effective in clearing out the chert debris. In order to be sure of reaching the deeper sediments, we decided to drill through the main lower Tertiary chert sequences and to attempt to core it in a second hole (DSDP 163A). This plan was partially effective, although pressure of time, failure of the sidewall corer, and plugging of the bit with chert cuttings still prevented recovery of the Cretaceous-Tertiary boundary.

The top 28 meters of the section consist of slightly radiolarian zeolitic brown clay, becoming more radiolarian-rich and less zeolitic with depth. The section is Oligocene in age with a surface age of about 26 m.y. The radiolarian assemblages are noteworthy for the presence of abundant reworked Eocene taxa. The surface sediment, like the underlying radiolarian ooze, has a porosity of about 90 per cent and tends to release water under the influence of the ship's vibration.

From 28-95 meters, the sediment is clayey, brown radiolarian ooze of middle and late Eocene age. Two thin beds of zeolitic clay occur near the base of the section. Scattered through the unit, and becoming abundant below 91 meters, are thin beds of porcellaneous brown chert. The youngest of these is at the Eocene-Oligocene boundary; others occur at 20-30 meter intervals throughout the Eocene section before becoming closely spaced in the lower middle Eocene. The upper cherts must be thin and areally restricted, since they do not destroy the acoustically transparent character of the ooze section. The closely spaced cherts starting at 91 meters form the prominent central opaque unit of the profiler records. The measured acoustic velocity in the radiolarian ooze and clay above 95 meters averages about 1.5 km/sec. A value of 3.3 km/sec was measured on the uppermost chert. The accumulation rate for the Oligocene-Eocene sequence was about 5 m/m.y. The absence of the *Thyrsocyrtis tetracantha* and *Podocyrtis goetheana* radiolarian zones points to a hiatus between the middle and late Eocene sections, a conclusion supported by reworked forms above this boundary.

From 95 meters to about 137 meters, closely spaced cherts, identified from the drilling record, and intervening soft sediment were drilled using high pump pressure and were not recovered.

A change in drilling character at about 137 meters suggests that the ooze gives way to the compact clay sampled in DSDP 163A at 140-144 meters. This clay, of early Maestrichtian age, is yellow brown and zeolitic (rich in both phillipsite and clinoptilolite). Its GRAPE porosity is about 70 per cent and its measured acoustic velocity above 1.8 km/sec. The natural gamma activity is much greater than that of the lower Tertiary oozes or underlying chalk.

The presence of a few calcareous nannofossils at the base of this core interval (144 m) suggests that in the early Maestrichtian the site lay precisely at the calcite compensation depth. The boundary between the zeolitic clay and the underlying chalk was not sampled; it is probably gradational and is arbitrarily placed at 150-155 meters.

The Cretaceous-Tertiary boundary was not sampled. The nature of the deepest Eocene sediments suggests that the 20 m.y. gap is too large for the 40 meters of missing section. Thus, either basal Tertiary or uppermost Cretaceous sediments are absent, or the middle Eocene radiolarian ooze must overlie less biogenous deposits that accumulated at an average rate of 2 m/m.y.

From about 150 to 276 meters, the sediment is nannofossil chalk of early to middle Campanian to early Maestrichtian age. The upper part of this section is light olive gray with grayish orange mottling. This grades to a section from 170 to about 207 meters characterized by distinctive intense "leopard spot" mottling of orange pink and related hues on brownish gray. The appearance is reminiscent of the Cretaceous clay at DSDP 66 to the west. Below 207 meters, the mottling is more subdued and grades to white chalk at the base of the section. Scattered through the chalk is flinty chert, usually pale or dusky yellow brown, and often bearing the typical white patina of chert nodules in limestones. A sample from 252 meters has an acoustic velocity of 4.9 km/sec.

The chalk contains few radiolarians or planktonic foraminifera. It appears to have been laid down between the contemporary lysocline and calcite compensation depth, a conclusion supported by the accumulation rate of about 11 m/m.y. which is close to modern rates when allowance is made for compaction.

The GRAPE porosity of the chalk decreases slightly from about 53 per cent at 160 meters, to about 43 per cent at 260 meters. The acoustic velocity is fairly uniform at 1.53 km/sec above 200 meters, but then increases to about 1.7 km/sec over the interval from 200 to 250 meters.

The chalk overlies extrusive basalt. DSDP 163 penetrated 18 meters into basement and recovered 7.4 meters belonging to at least seven flow units, each bounded by glassy margins. The abundance of calcite veins and brown alteration parallel to the veins decreases away from these margins. The flow units range from 13 to 470 cm in thickness and may be constituents of a single flow or be separate extrusive events. Apart from olivine and sparse plagioclase microphenocrysts scattered indiscriminately throughout the rock, the size of the plagioclase laths and augite crystals increases toward the center of flow units to produce a texture that becomes diabasic in the thicker units. An acoustic velocity of 7.05 km/sec ± 0.07 sec was measured in fresh basalt at 290 meters.

The average measured acoustic velocity for the section above the chalk is about 1.51 km/sec, which agrees well with the value of 1.55 km/sec to the base of the opaque layer estimated from the seismic profiler records. The strong velocity gradient in the chalk makes comparisons for deeper zones rather uncertain although it does appear that the value inferred from correlation of the profiler records with the stratigraphic column is perhaps 10 per cent greater than the measured velocity.

REFERENCES

Winterer, E.L., Riedel, W. R. et al., 1971. Initial Reports of the Deep Sea Drilling Project, Volume VII. Washington (U.S. Government Printing Office).

Winterer, E.L., Ewing, J.I. et al., in preparation. Initial Reports of the Deep Sea Drilling Project, Volume XVII. Washington (U.S. Government Printing Office).

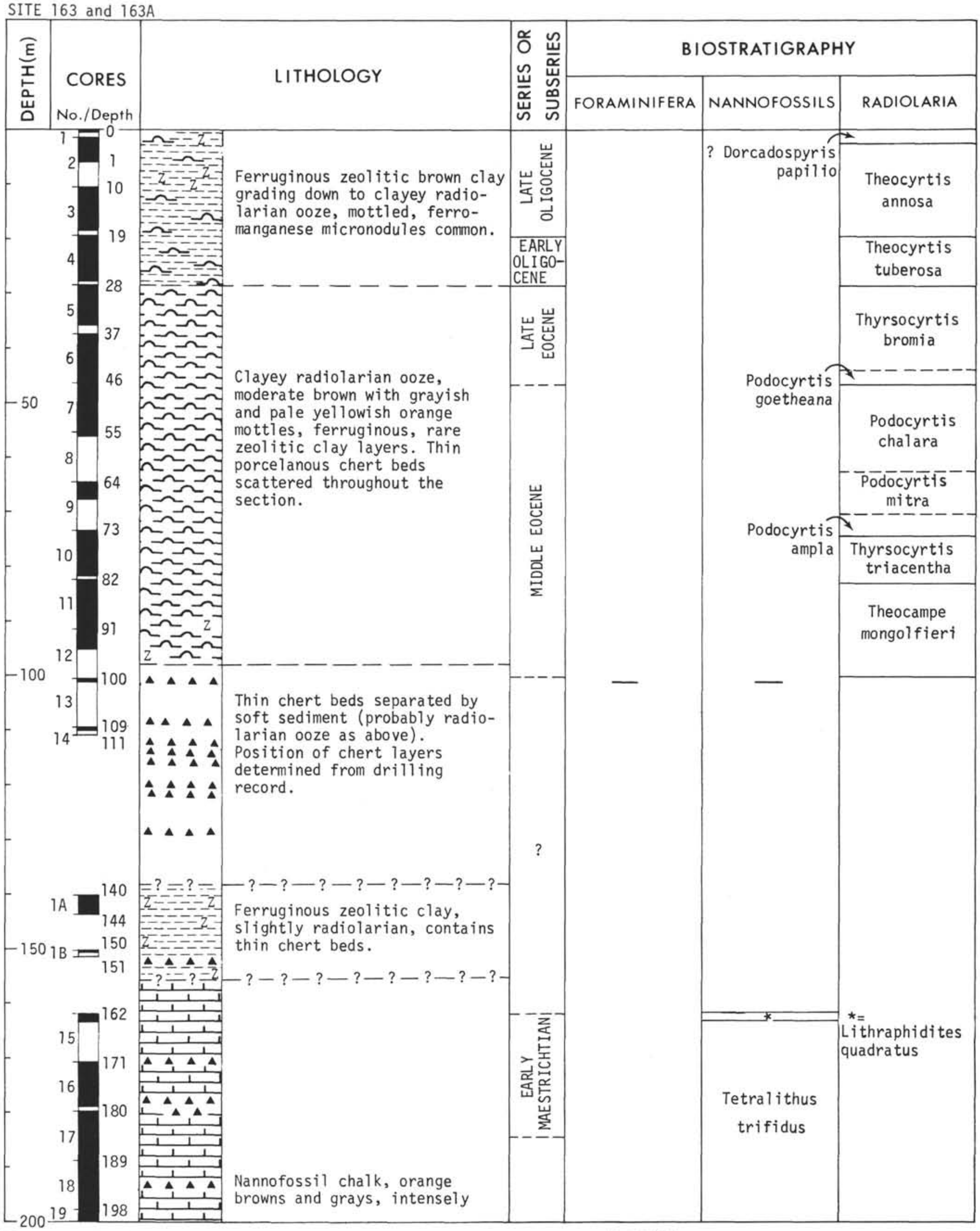
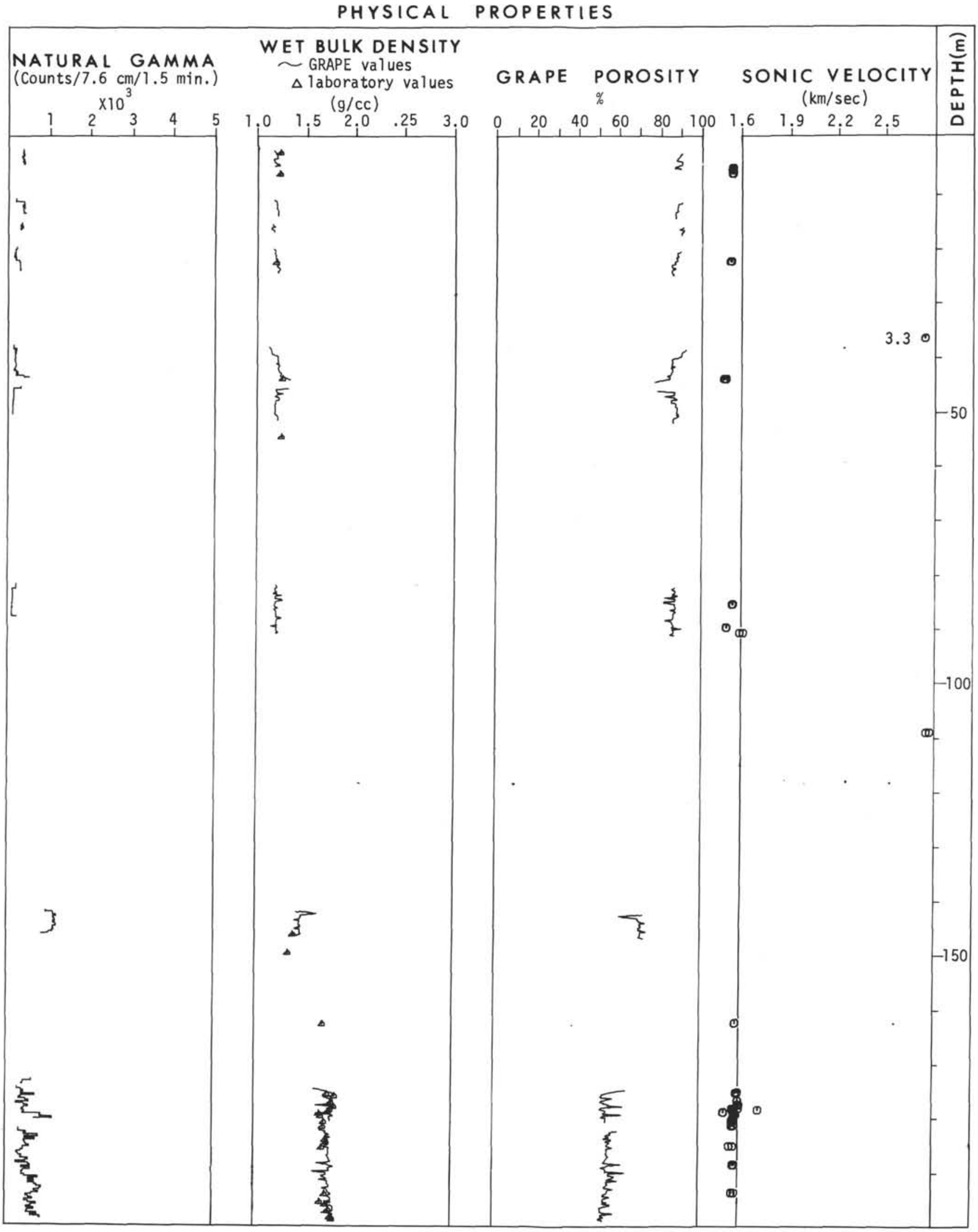


Figure 4. *DSDP 163, graphic hole summary. Vertical scale 1 cm = 10 m (1:1000).*


PHYSICAL PROPERTIES
NATURAL GAMMA
(Counts/7.6 cm/1.5 min.)
X10^3
1 2 3 4 5
WET BULK DENSITY
GRAPE values
laboratory values
(g/cc)
1.0 1.5 2.0 .25 3.0
GRAPE POROSITY
%
0 20 40 60 80 100
SONIC VELOCITY
(km/sec)
1.6 1.9 2.2 2.5
DEPTH(m)
50
100
150
3.3

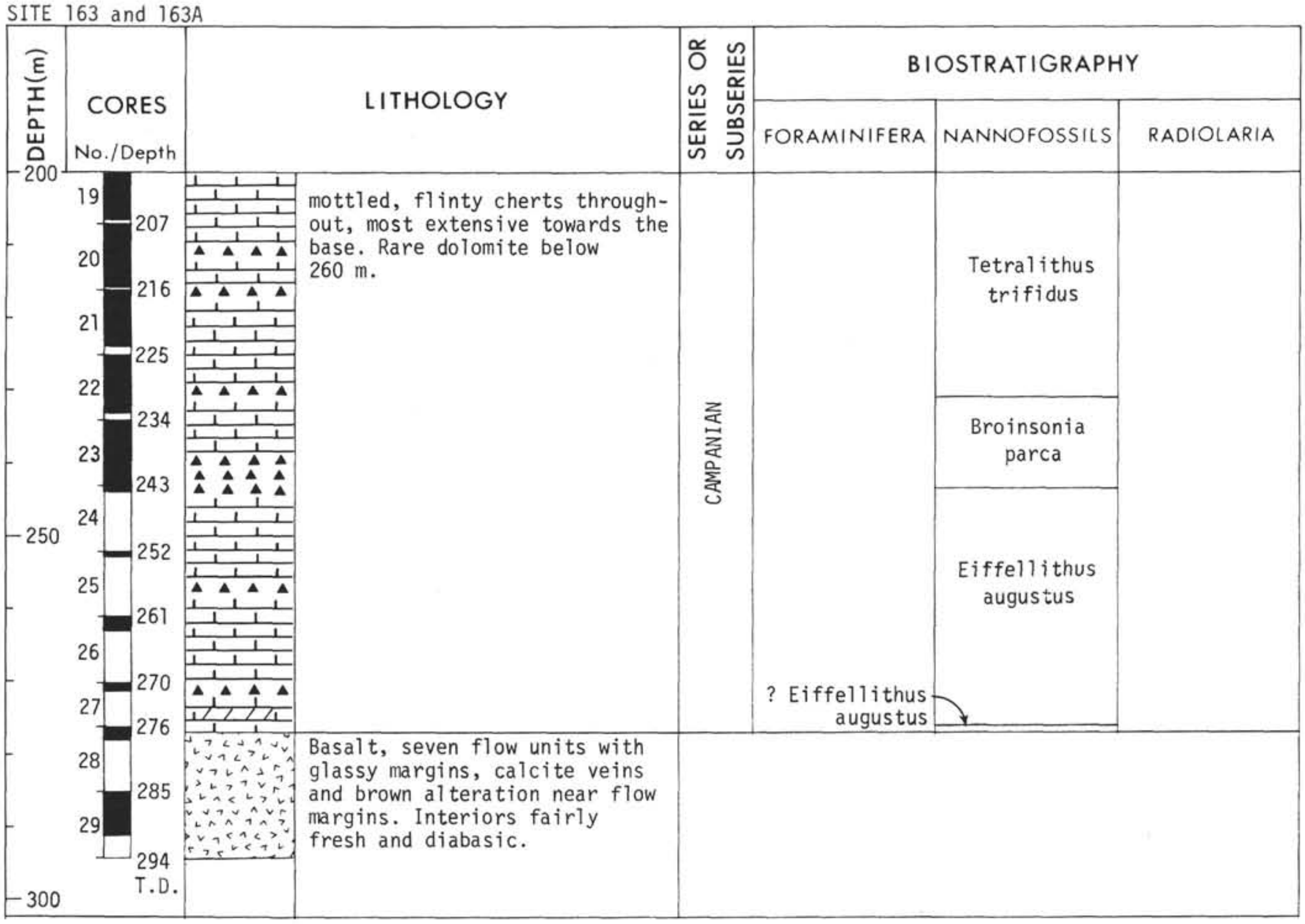
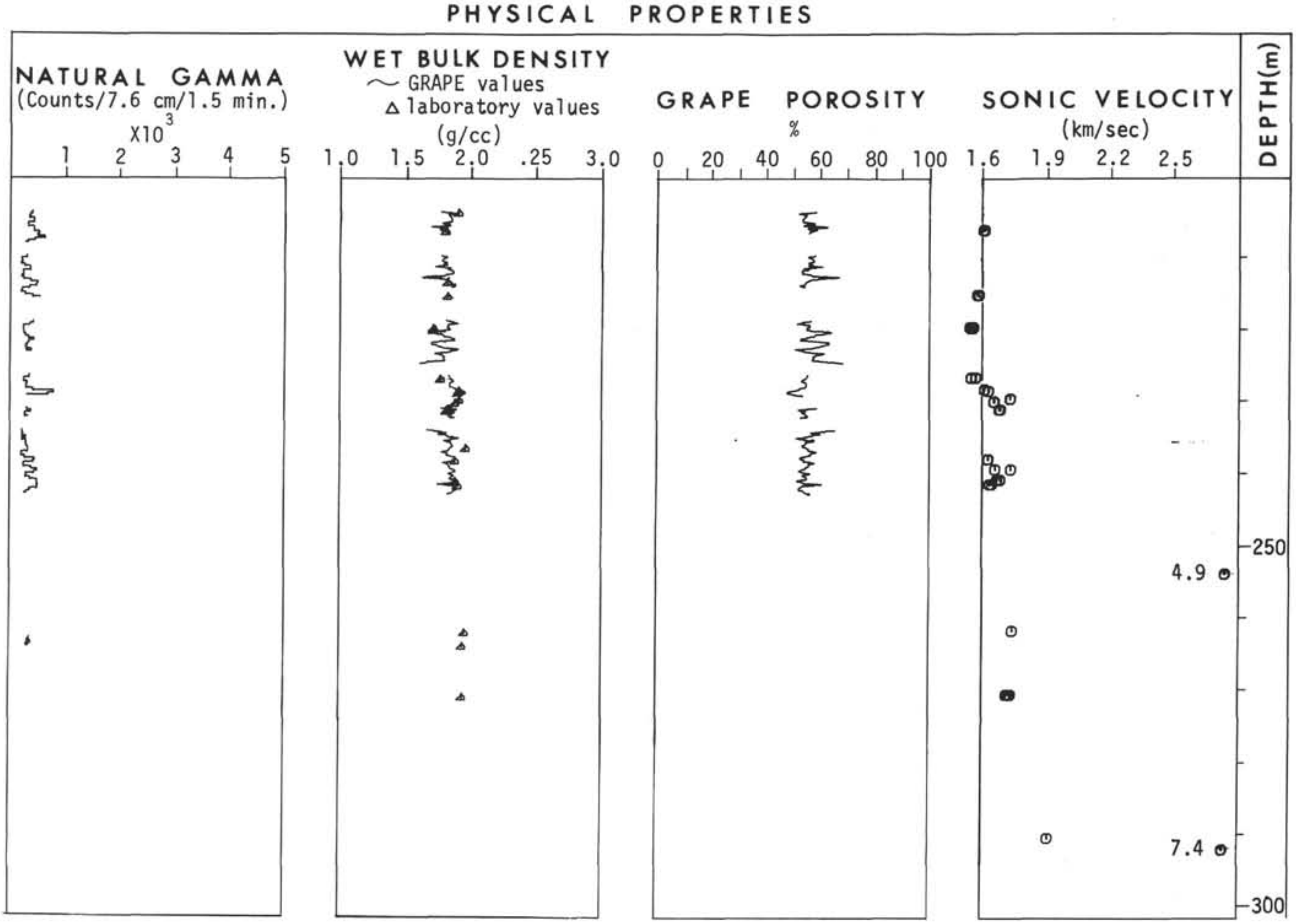


Figure 4. *(Continued).*


PHYSICAL PROPERTIES
NATURAL GAMMA
(Counts/7.6 cm/1.5 min.)
X10^3
1 2 3 4 5
WET BULK DENSITY
GRAPE values
laboratory values
(g/cc)
1.0 1.5 2.0 .25 3.0
GRAPE POROSITY
%
0 20 40 60 80 100
SONIC VELOCITY
(km/sec)
1.6 1.9 2.2 2.5
DEPTH(m)
250
300
4.9
7.4

SITE: 163 HOLE: CORE: 1 Cored Interval: 0-1 m

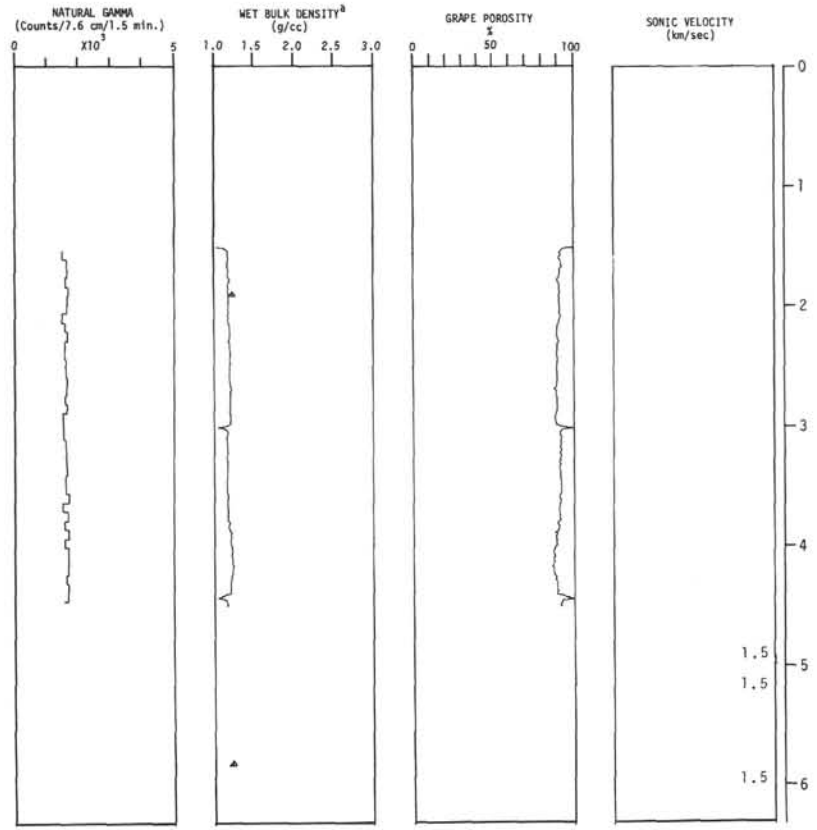
AGE SERIES	ZONE Foram	ZONE Nanno	ZONE Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres Foram	Nanno	Rad
PLEISTOCENE	|	|	*Quaternary*		CC			* *	* * *	Zeolitic clay with radiolarian fragments, dark yellowish brown (10YR 4/2) with micronodules and brown amorphous ferruginous aggregates; grayish orange (10YR 7/4) mottles as above but less common micronodules; diatoms, fish debris, barite, light glass present. Core Catcher Zeolitic clay as above.	— —	— —	A* M A* M

SITE: 163 HOLE: CORE: 2 Cored Interval: 1-10 m

AGE SERIES	ZONE Foram	ZONE Nanno	ZONE Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres Foram	Nanno	Rad
UPPER OLIGOCENE	|	|	*? Dorcadospyris papilio*	0–1	1	VOID							
				1				*		Slightly zeolitic clay, moderate brown (5YR 3/4), radiolarian fragments, micronodules, amorphous ferruginous aggregates common, diatoms, light glass present.			
						VOID							
				2	2					Zeolitic radiolarian clay with micronodules and amorphous ferruginous aggregates (a.f.a.)			
								*	*				C* M
			Theocyrtis annosa	3					*	Same, 5YR 3/4, few streaks grayish orange (10YR 7/4); lighter streaks have fewer a.f.a. and micronodules; local zeolitic palagonite.	—	—	
				4	3			*					
				5	4			*	* *	Zeolitic radiolarian clay, moderate brown (5YR 3/4), micronodules, a.f.a. common, fish debris present. Mottles, 5-10 mm across, are grayish orange (10YR 7/4) and have fewer micronodules and a.f.a.			A* M
					CC				*				A* M

PHYSICAL PROPERTIES

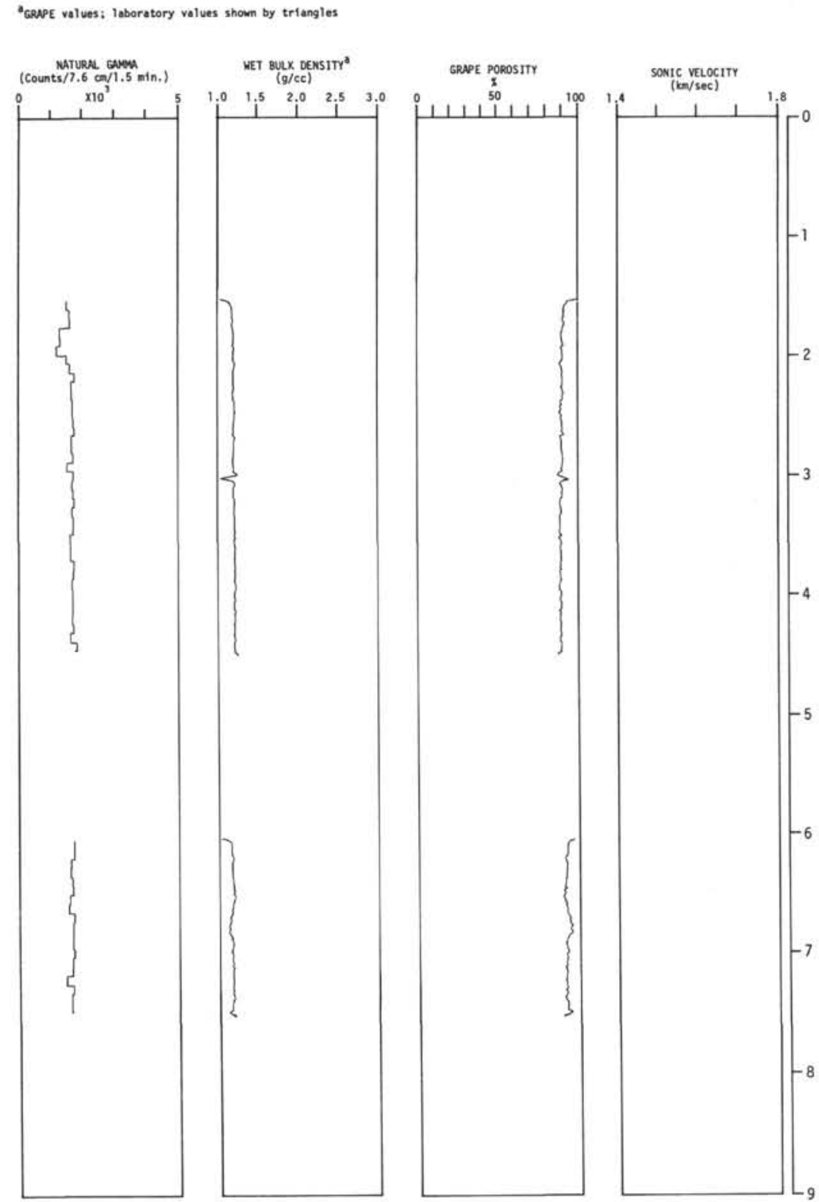
*GRAPE values; laboratory values shown by triangles



SITE: 163 HOLE: CORE: 3 Cored Interval: 10-19 m

SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	SECTION	DESCRIPTION	MICROFOSSIL Abund/Pres: Rad
UPPER OLIGOCENE	—	—	*Theocyrtis annosa*	1	Zeolitic radiolarian clay, moderate brown (5YR 3/4); few mottles of grayish orange (10YR 7/4). Micronodules and a.f.a. common, diatoms present.	A* G
				2	Slightly zeolitic radiolarian clay, 5YR 3/4; rare 2 mm mottles of 10YR 7/4. Micronodules and a.f.a. common, fish debris and diatoms present.	
				3	Radiolarian clay, moderate brown (5YR 3/4); grayish orange mottles (10YR 7/4) with fewer micronodules and a.f.a.	A* G
				4	Slightly zeolitic radiolarian clay, moderate brown (5YR 2/4 and 3/4), fish debris present.	
				5	Radiolarian clay, moderate brown (5YR 3/4); diatoms, fish debris present.	A* G
				6	Same, 5YR 3/4 and 2/4.	
				CC		A* G

PHYSICAL PROPERTIES



SITE: 163 HOLE: CORE: 4 Cored Interval: 19-28 m

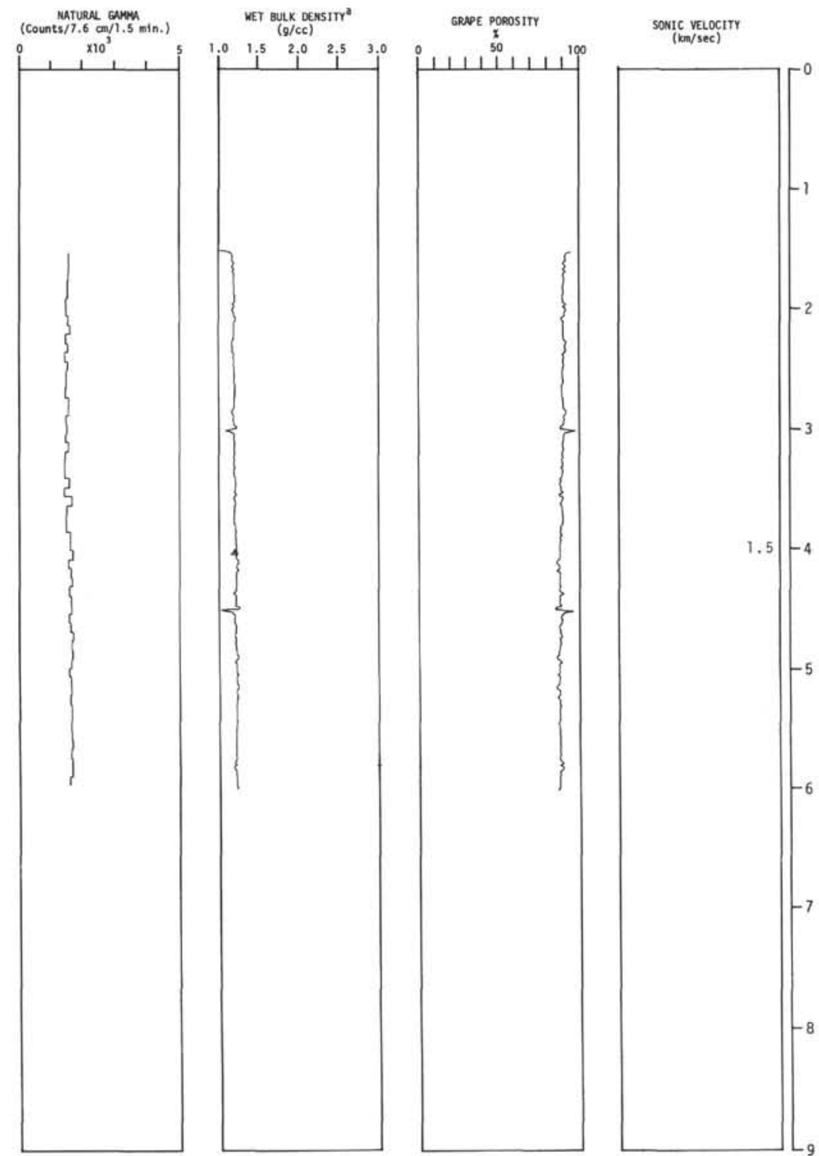
SERIES: LOWER OLIGOCENE

ZONE (Rad): *Theocyrtis tuberosa*

Depth (m) / Section	Description	Microfossil Abund/Pres (Rad)
0–1.5 / Section 1 (VOID at top and base)	Clayey diatomaceous radiolarian ooze, moderate brown (5YR 3/4); amorphous ferruginous aggregates common, micronodules, sponge spicules, fish debris present. 5-10 mm mottles of grayish orange (10YR 7/4) to pale yellowish orange (10YR 8/6).	A G
1.5–3 / Section 2	Same, 5YR 4/4, mottles are 10YR 7/4.	
3–4.5 / Section 3	Same, 5YR 4/4 to 3/4.	A* G
4.5–6 / Section 4	Same, 5YR 3/3; 1-33 mm mottles of pale yellowish orange (10YR 8/6) radiolarian ooze.	
6–7.5 / Section 5	Same, 5YR 3/4; mottles 10YR 7/4. Streaks of 5YR 3/3 and 3/2.	A G
7.5–9 / Section 6 (VOID at base)	Clayey, slightly diatomaceous radiolarian ooze, moderate brown (5YR 4/4). Same mixed with 5YR 2/2 and 3/3. Same, all 5YR 3/3, some 2/2.	
CC		A* G

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



SITE: 163 HOLE: CORE: 5 Cored Interval: 28-37 m

SERIES	AGE ZONE: Foram	AGE ZONE: Nanno	AGE ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
UPPER EOCENE			*Thyrsocyrtis bromia*	0–1.5	1			*		Radiolarian clay, moderate brown (5YR 3/4); diatoms, sponge spicules, fish debris present; micronodules and amorphous ferruginous aggregates common; chert interbeds, dusky brown (5YR 2/2) with 1-5 mm streaks of light brown (5YR 6/4).			
				1.5–3	2			*	*	Radiolarian ooze, dark yellowish brown (10YR 3/3), micronodules and a.f.a. common; diatoms and fish debris present.			A G
				3–4.5	3	VOID		*	*				A G
				4.5–6	4			*	*				A G
				6–7.5	5			*	*	Same, dark yellowish brown (10YR 4/3); rare patches of grayish orange (10YR 7/4). Fragments of chert, dusky yellowish brown (10YR 2/2).			A G
					CC				*		–	–	A G

% $CaCO_3$: 0 50 100

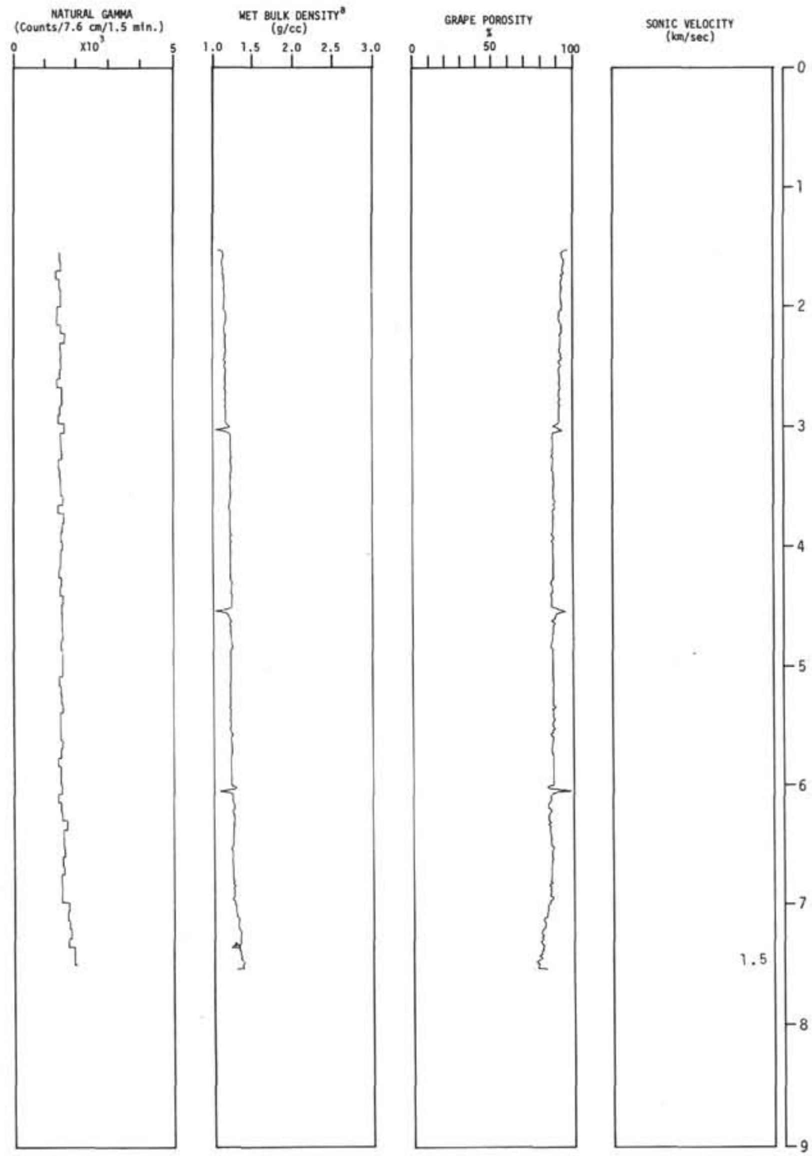
427

SITE: 163 HOLE: CORE: 6 Cored Interval: 37-46 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	DESCRIPTION	MICROFOSSIL Abund/Pres: Rad
UPPER EOCENE			*Thyrsocyrtis bromia*	0–3	1, 2	Clayey slightly diatomaceous radiolarian ooze, moderate brown (5YR 3/4); micronodules, and amorphous ferruginous aggregates common, fish debris present; grayish orange (10YR 7/4) mottles 2-5 mm across lower in clay, sponge spicules present.	A* G
				3–4.5	3	Same, mottles are 10YR 7/4 and pale yellowish orange (10YR 8/6).	A G (Nanno: R M)
				4.5–6	4	Fragments of chert, dusky brown (5YR 2/2) may be contamination; rest is radiolarian ooze as above.	
			Podocyrtis goetheana	6–9	5, 6		A G
					CC		A G

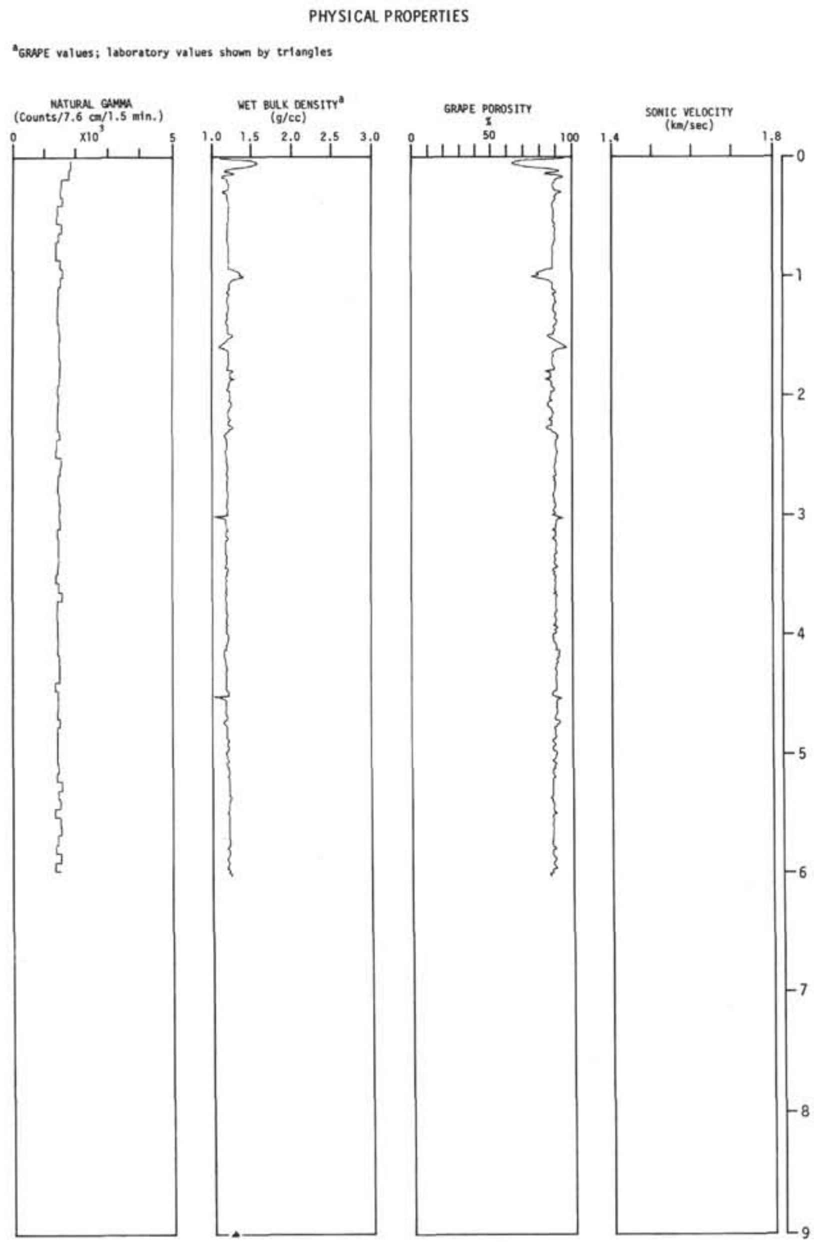
PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



SITE: 163 HOLE: CORE: 7 Cored Interval: 46-55 m

SERIES	AGE / ZONE: Foram	Nanno	Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
MIDDLE EOCENE	—	—	*Podocyrtis chalara*	0–1.5	1			* *	*	Chert, dusky brown (5YR 2/2), 1-2mm streaks moderate yellowish brown (10YR 5/4). Clayey radiolarian ooze, moderate brown (7.5YR 4/4 to 5YR 3/3); micronodules and amorphous ferruginous aggregates, diatoms, sponge spicules present; mottles of grayish orange (10YR 7/4) radiolarian ooze very low in clay content.			A G
				1.5–3	2			* *	*			— —	
				3–4.5	3			*					A G
				4.5–6	4			* * *	*	Same, with darker area 5YR 2/4, mottles up to 10 mm of grayish orange (10YR 7/4) which are nearly pure radiolarian ooze.		— —	
				6–7.5	5			*	*				A G
				7.5–9	6			*					
					CC				*		—	— —	A G



SITE: 163 HOLE: CORE: 8 Cored Interval: 55-64 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
MIDDLE EOCENE	—	—	*P. chalara*	1	1	VOID		*	*	Chert, dark brown (5YR 2/3), streaks of light brown (5YR 6/4) 2-3mm across; clayey radiolarian ooze, moderate brown (5YR 4/4), streaks of grayish orange (10YR 7/4), micronodules, amorphous ferruginous aggregates common, diatoms, sponge spicules, fish debris present.	—	—	A G
			1						*	[1] *Podocyrtis mitra*	—	—	A G

% $CaCO_3$ 0 50 100

SITE: 163 HOLE: CORE: 9 Cored Interval: 64-73 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
MIDDLE EOCENE	—	—	*Podocyrtis mitra*	1	1	VOID		*		Very clayey radiolarian ooze, dark yellowish brown (10YR 3/3); micronodules and amorphous ferruginous aggregates common; diatoms and fish debris present.			
						VOID				Chert fragments, dusky yellowish brown (10YR 2/2).			
				2, 3	2								
				4	3			*		Chert fragments, dusky yellowish brown (10YR 2/2) mottled irregularly to light brown (5YR 5/6).			
			1		CC				*	[1] *Podocyrtis ampla*	—	—	A G

% $CaCO_3$ 0 50 100

SITE: 163 HOLE: CORE: 10 Cored Interval: 73-82 m

SERIES	AGE ZONE: Foram	Nanno	Rad	DEPTH (Meters)	SECTION	LITHOLOGY	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
MIDDLE EOCENE	—	—	*Thyrsocyrtis triacantha*	0–1.5	1		Radiolarian ooze, dark yellowish brown (10YR 3/3); micronodules, amorphous ferruginous aggregates, fish debris present; mottles of grayish orange (10YR 7/4) which are nearly pure radiolarian ooze; fragments of chert, dusky yellowish brown (10YR 2/2).		— —	A G
				1.5–3	2					
				3–4.5	3				— —	A G
				4.5–6	4	VOID	Same, no mottles.			
				6–7.5	5	VOID			— —	A G
				7.5–9	6	VOID				
					CC			— —	R M	A G

% CaCO3: 0, 50, 100

SITE: 163 HOLE: CORE: 11 Cored Interval: 82-91 m

AGE: MIDDLE EOCENE

ZONE: Foram: — ; Nanno: — ; Rad: *Theocampe mongolfieri*

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

LITHOLOGY | Disturbance | Smear Slide | Paleo. sample

DESCRIPTION

Chert, dusky yellowish brown (10YR 2/2); radiolarian ooze, dark yellowish brown (10YR 4/4), micronodules common, amorphous ferruginous aggregates, diatoms, fish debris present; 5-20 mm mottles of grayish orange (10YR 7/4) radiolarian ooze.

Light mottles very pale orange (10YR 8/3).

Zeolitic clay, dark yellowish brown (10YR 3/2); micronodules and a.f.a. common, radiolarians and fish debris present; mottles of grayish orange (10YR 7/4) radiolarian ooze. Radiolarian ooze, moderate yellowish orange (10YR 5/6), mottles and burrows of grayish orange (10YR 7/4) and very pale orange (10YR 8/3).

Same, moderate yellowish orange (7.5YR 4/4).

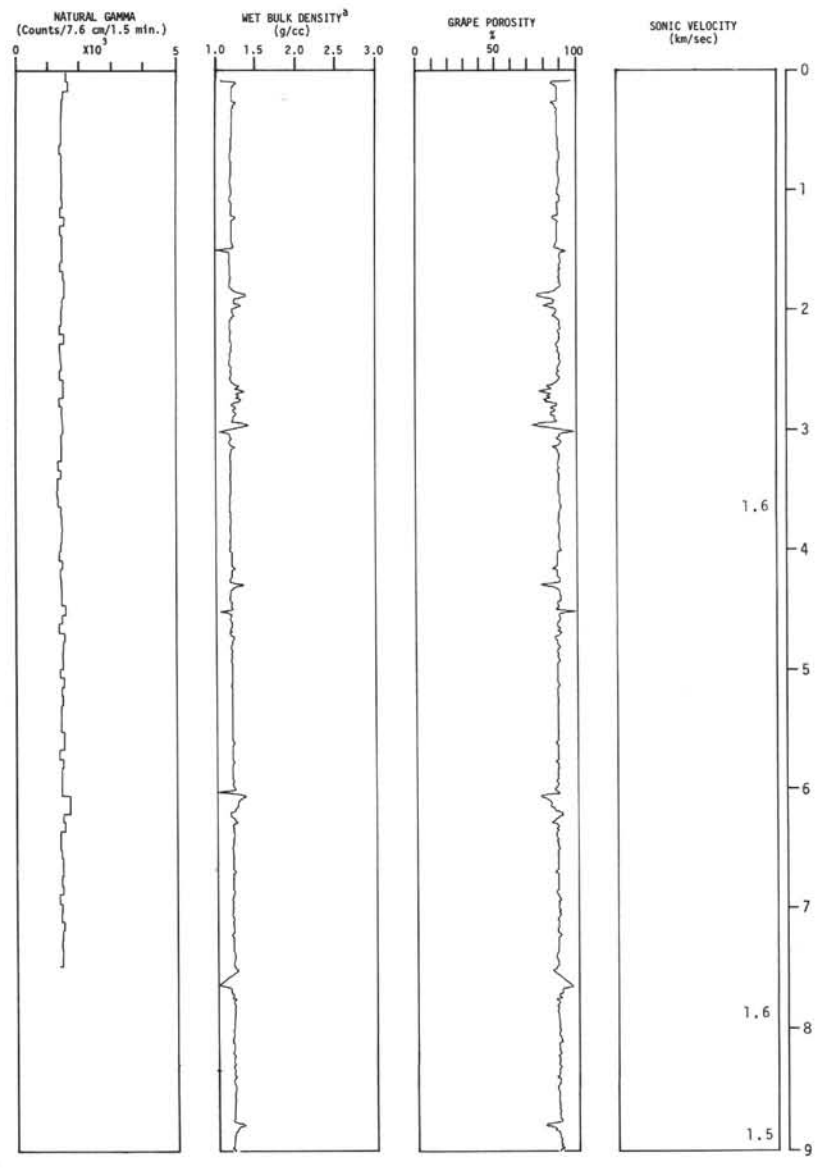
Same, moderate yellowish brown (10YR 5/4); thin long burrows of dark yellowish brown (10YR 4/2), rare grayish orange (10YR 7/4); chert fragments.

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

Rad: A G (Section 1); A G (Section 3); A G (Section 5); A G (CC)

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



SITE: 163 HOLE: CORE: 12 Cored Interval: 91-100 m

SERIES	AGE ZONE Foram	AGE ZONE Nanno	AGE ZONE Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres Foram	MICROFOSSIL Abund/Pres Nanno	MICROFOSSIL Abund/Pres Rad
MIDDLE EOCENE			*Theocampe mongolfieri*	1	1			*	*	Chert, dusky yellowish brown (10YR 2/2); laminae up to 3 mm across are moderate yellowish brown (10YR 5/4). Radiolarian ooze, moderate yellowish brown (10YR 5/4), micronodules, amorphous ferruginous aggregates, diatoms, fish debris present; grayish orange (10YR 7/4) mottles; chert fragments.			
				2	2			*					A G
				3						Radiolarian ooze as above, alternating with moderate brown (5YR 4/4), mottles and 1-4 mm laminae of pale yellowish orange (10YR 8/3).			
				4	3			*	*				
								*	*	Zeolitic clay, laminated grayish brown (5YR 3/2) and dark yellowish brown (10YR 4/2), micronodules, a.f.a., radiolarians common.			A G
					CC			*	*				A G

% $CaCO_3$: 0 50 100

SITE: 163 HOLE: CORE: 13 Cored Interval: 100-109 m

AGE: SERIES	AGE: ZONE Foram	AGE: ZONE Nanno	AGE: ZONE Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad	% $CaCO_3$ 0 50 100
?	|	|	|		CC				*	Chert, dusky yellowish brown (10YR 2/2), diffusely laminated moderate yellowish brown (10YR 5/4), lams. 1-3 mm thick.				

SITE: 163 HOLE: CORE: 14 Cored Interval: 109-111 m

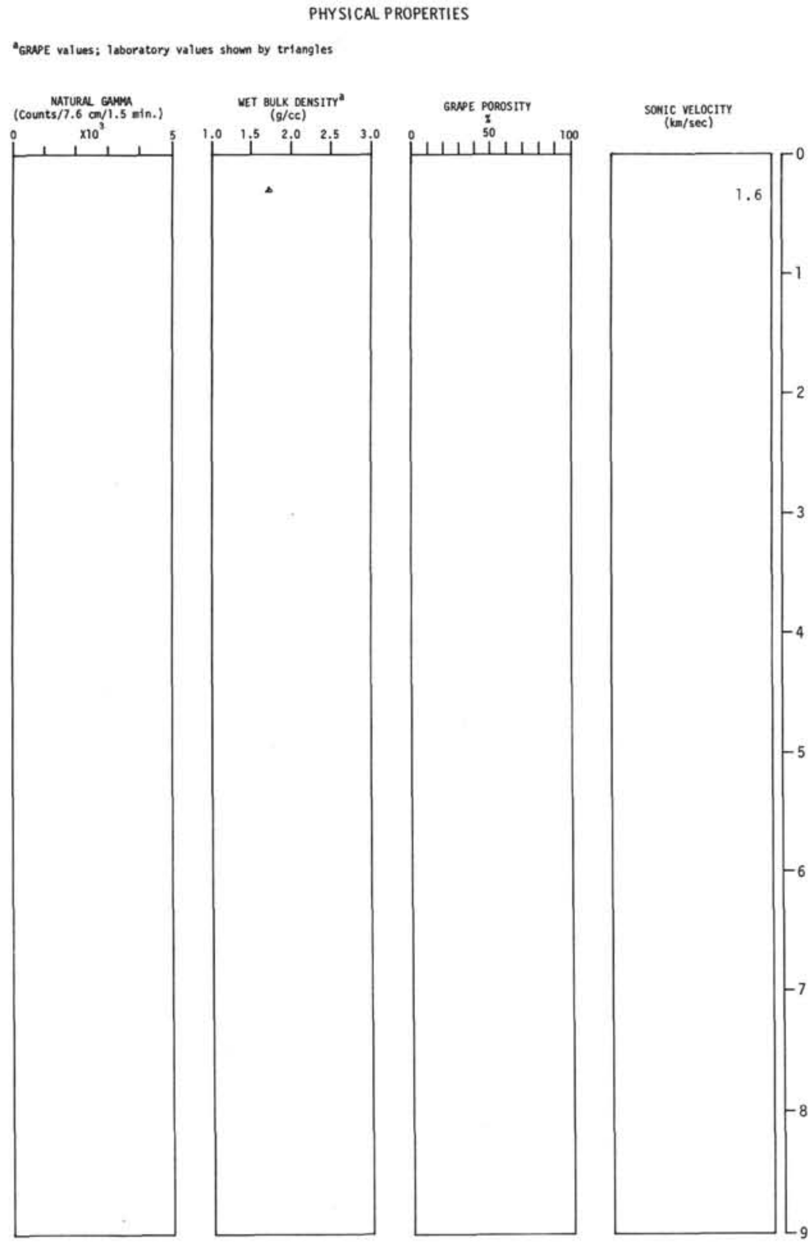
AGE: SERIES	AGE: ZONE Foram	AGE: ZONE Nanno	AGE: ZONE Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad	% $CaCO_3$ 0 50 100
?	|	|	|	1	1	VOID				Chert, dusky yellowish brown (10YR 2/2), laminations of moderate yellowish brown (10YR 5/4) 1-10 mm thick; local grayish orange (10YR 7/4) and very pale orange (10YR 8/2).				
					CC					Chert, moderate brown (5YR 3/4), diffusely laminated to dark yellowish brown (10YR 4/2), grayish orange (10YR 7/4), dusky yellowish brown (10YR 2/2).				

SITE: 163 HOLE: CORE: 15 Cored Interval: 141-171 m

SERIES: LOWER MAESTRICHTIAN

AGE / ZONE: Foram: Not zoned; Nanno: *Tetralithus trifidus*; Rad: —

Depth (Meters)	Section	Lithology	Smear Slide	Paleo. sample	DESCRIPTION	Microfossil Abund/Pres (Foram / Nanno / Rad)
0–1.5	1	Chalk and chert	* * * * * *	*	Nannofossil chalk, light olive gray (5Y 6/1), yellowish brown (10YR 5/2), and chert, dusky yellowish brown (10YR 2/2), and ovoid masses grayish orange (10YR 7/4). Nannofossil clay, laminated dark yellowish brown (10YR 4/1), dusky yellowish brown (10YR 2/2), compressed mottles and burrows of very pale orange (10YR 8/3), local grayish, orange (10YR 7/4) nannofossil marl.	Nanno A P
1.5–3.0	2	VOID; chalk at base	*		Nannofossil chalk, light olive gray (5Y 6/1), 2-5 mm laminations very pale orange (10YR 8/2), mottles of dusky yellowish brown (10YR 2/2).	
3.0–4.5	3	VOID; chalk at base	* *	*	Same, very pale orange (10YR 8/2) laminated to brown gray (5YR 4/1), and light olive gray (5Y 6/1), clayey, intensely burrowed and mottled, locally compressed.	Nanno A M
4.5–6.0	4	VOID				
6.0–7.5	5					
7.5–9.0	6	VOID; chalk at base	* *			
	CC	Chalk	* * *	*	Nannofossil chalk, laminated with variable amounts of clay, pale yellowish brown (10YR 6/2), very pale orange (10YR 8/2), and pale yellowish brown (10YR 6/2), local nannofossil clay, dusky yellowish brown (10YR 2/2).	R P / A M / R P; A P



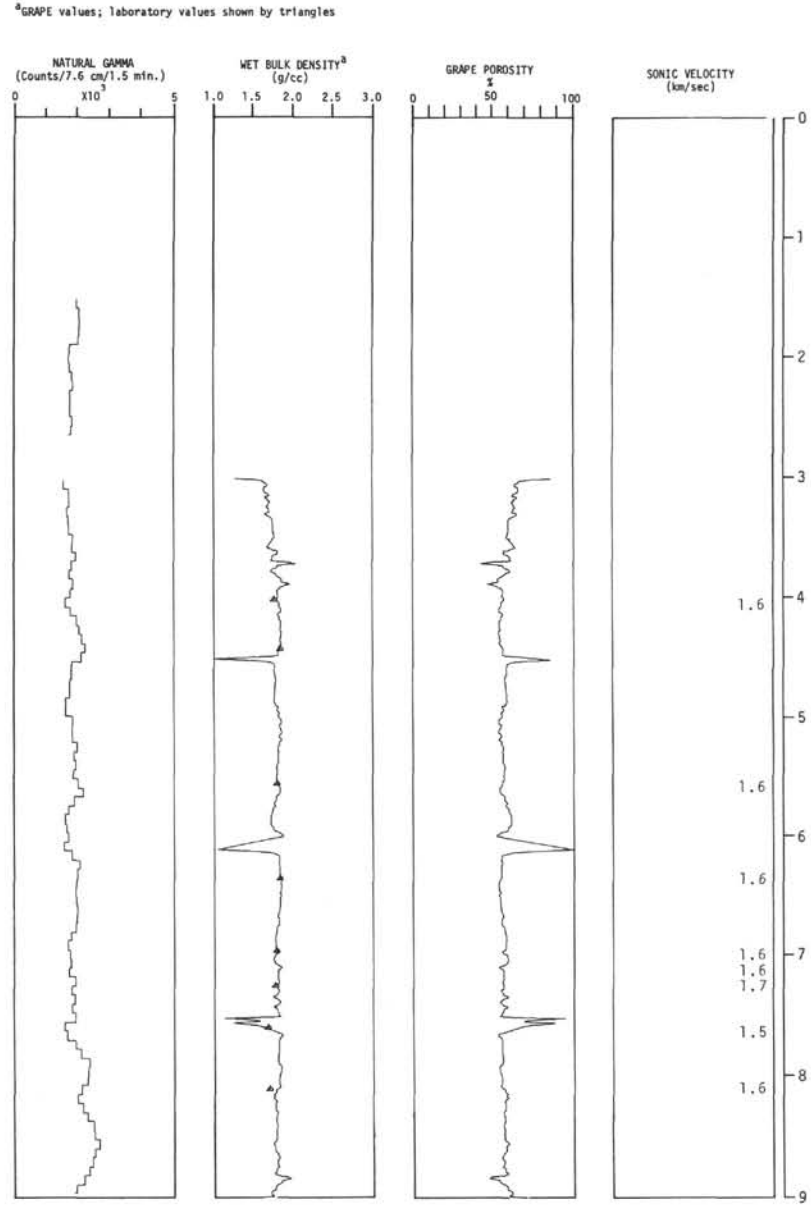
SITE: 163 HOLE: CORE: 16 Cored Interval: 171-180 m

AGE: SERIES: LOWER MAESTRICHTIAN; ZONE: Foram: Not zoned; Nanno: *Tetralithus trifidus*; Rad: —

MICROFOSSIL Abund/Pres: Section 1: Nanno A M; Section 3: Nanno A M; CC: Foram R ?, Nanno A M, Rad R P

DEPTH (Meters)	SECTION	LITHOLOGY	DESCRIPTION
0	1	VOID	Chert, dusky yellowish brown (10YR 2/2) to very pale orange (10YR 8/2), burrows 2-10 mm across. Nannofossil chalk, strongly mottled, laminated; mainly pale yellow brown (10YR 6/2) to dark yellow brown (10YR 4/2) or very pale orange (10YR 8/2); locally dusky yellowish brown (10YR 2/2). Color variation due to variable content of clay, micronodules, and a.f.a.
1.5	2	VOID	Same, intensely mottled.
			Chert, dusky yellowish brown (10YR 2/2) mottled moderate brown (5YR 3/4).
3	3	VOID	Nannofossil chalk, pale yellowish brown (10 YR 6/2) intensely mottled 10YR 8/2, 5YR 6/1, and brown gray (5YR 4/1).
			Chert fragment, dusky brown (5YR 2/2), laminated very pale orange (10YR 8/2), dull light brownish gray (5YR 6/1).
			Nannofossil chalk, moderate orange pink (5YR 8/4) and 10YR 8/2, 10YR 6/2.
			Same, intensely mottled.
4.5	4		Same, less mottled, low color contrast; pale yellowish brown (10YR 6/2-5/2), very pale orange (10YR 8/2).
			Same, intense mottling and color contrast; dark yellowish brown (10YR 4/2), dusky yellowish brown (10YR 2/2), very pale orange (10YR 8/2), light olive gray (5Y 6/1).
6	5		
7.5	6		Same, strongly mottled and laminated, 10YR 8/2 to 5YR 6/1 to dusky brown (5YR 2/2).
			Chert, pale yellowish brown (10Y 6/2), very pale orange (10YR 8/2).
9	CC		

PHYSICAL PROPERTIES



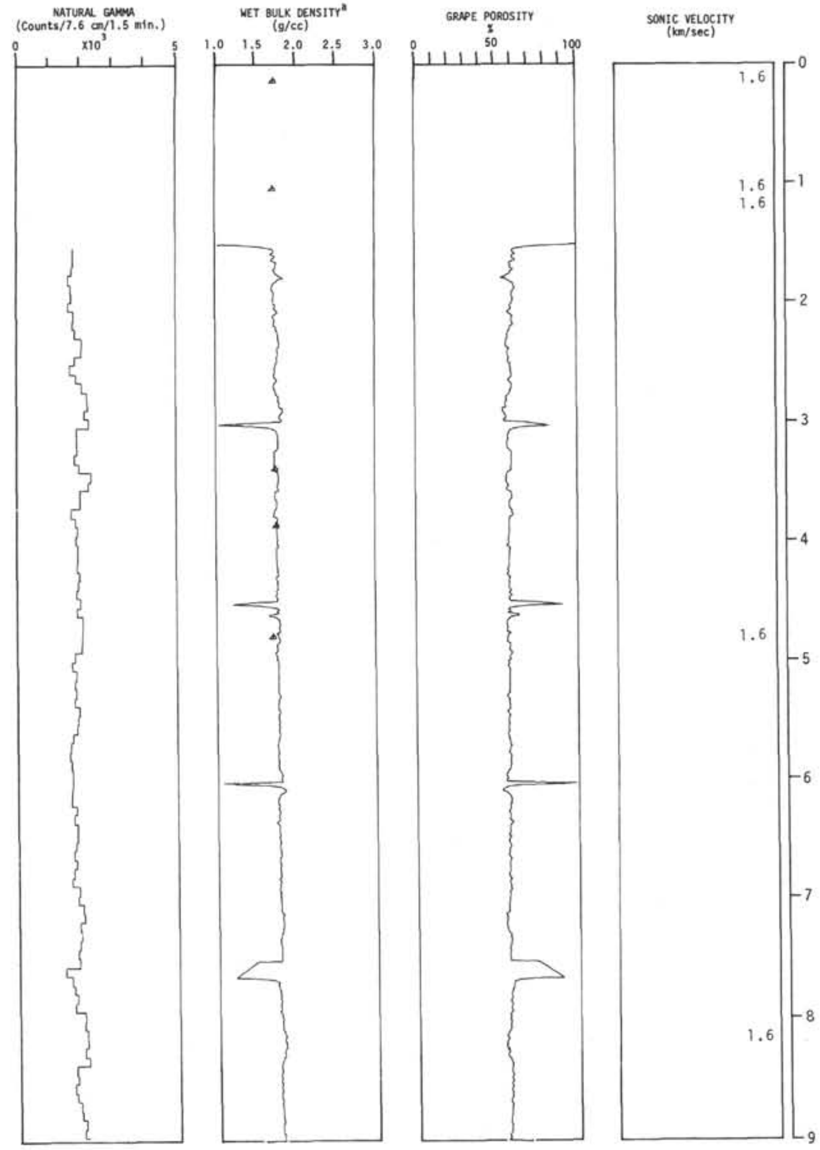
SITE: 163 HOLE: CORE: 17 Cored Interval: 180-189 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
LOWER MAESTRICHTIAN	Not zoned	*Tetralithus trifidus*		0–1.5	1			* *		Nannofossil chalk, predominantly light olive gray (5Y 6/1) and pale yellowish brown (10YR 6/2), micronodules, amorphous ferruginous aggregates, fish debris present. Intensely laminated and mottled orange pink (5YR 8/4), brown-gray (5YR 7/1), dusky yellowish brown (10YR 2/2), very pale orange (10YR 8/2).			
				1.5–3	2			* *		Same, main colors pale yellowish brown (10YR 6/2), gray orange (10YR 7/4), brown-gray (5YR 4/1); mottled to very pale orange (10YR 8/2) and dusky brown (5YR 2/2), leopard spot and tiger stripe mottling; darkest mottles are nannofossil marl.			
				3–4.5	3			* *				A M	
CAMPANIAN				4.5–6	4			* *		Same, no large dark mottles.			
				6–7.5	5			* *		Same, tiger stripe and leopard spot mottling, pale brown (5YR 5/1), very pale orange (10YR 8/2), light brown gray (5YR 6/1), brown black (5YR 2/1); darkest areas nannofossil marl. Intensely, prevasively mottled and burrowed, 2 mm - 2 cm across, local hard areas of chalky limestone.			
				7.5–9	6			* *					
					CC				* *		R ?	A P	R P

% $CaCO_3$: 0 50 100

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



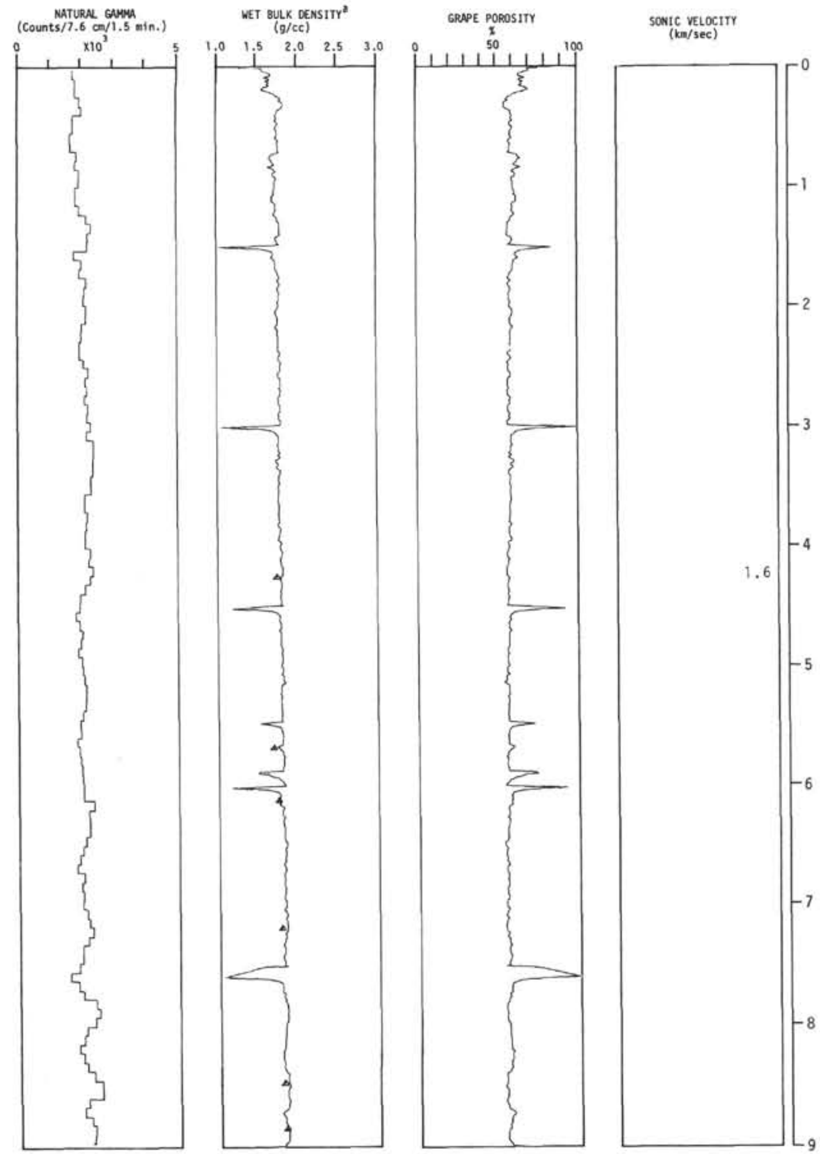
SITE: 163 HOLE: CORE: 18 Cored Interval: 189-198 m

SERIES	AGE ZONE: Foram	AGE ZONE: Nanno	AGE ZONE: Rad	DEPTH (Meters)	SECTION	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
CAMPANIAN	Not zoned	*Tetralithus trifidus*		0–1.5	1	Nannofossil chalk, grayish orange (10YR 7/4) mottled light brown gray (5YR 6/1), brown gray (5YR 4/1), rare very pale orange (10YR 8/2). Same, leopard spot mottling, light brown gray (5YR 6/1), very pale orange (10YR 8/2), with ovoid burrows 5-8 mm across of nannofossil marl; dusky yellowish brown (10YR 2/2).			
				1.5–3	2	Alternating leopard spot mottled nannofossil chalk and less mottled dark yellowish brown nannofossil chalk (10YR 4/2); forams and fish debris present.			
				3–4.5	3			A M	
				4.5–6	4	Leopard spot mottling as above. Intensely mottled, but no dark mottles. Nannofossil chalk, dark yellowish brown (10YR 4/2) mottled very pale orange (10YR 8/2) and rare dusky yellowish brown (10YR 2/2).			
				6–7.5	5	Nannofossil chalk, alternatingleopard spot mottling and low contrast mottling.			
				7.5–9	6				
					CC		R P	A M A P	P P

% CaCO3: 0 50 100

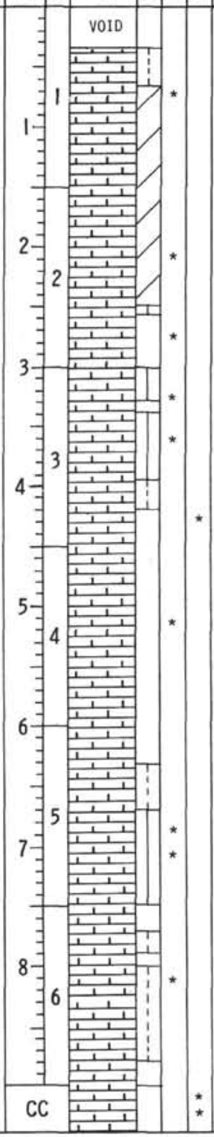
PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



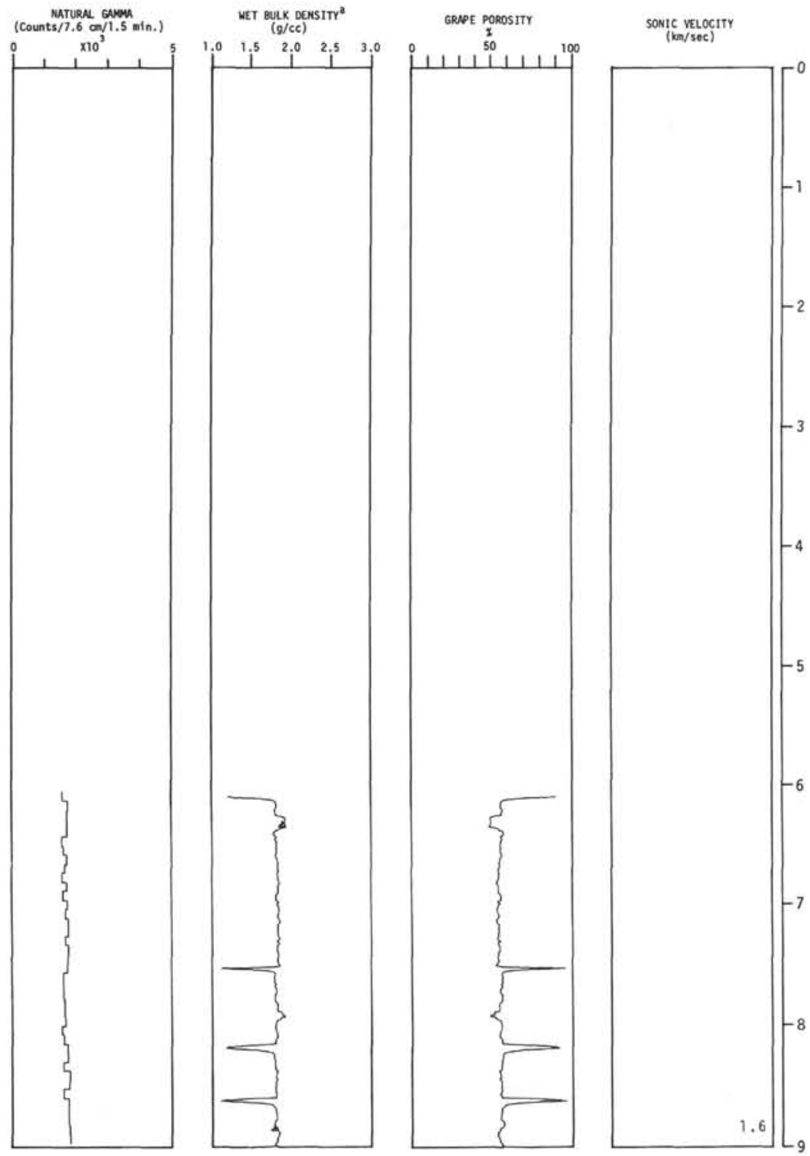
SITE: 163 HOLE: CORE: 19 Cored Interval: 198-207 m

SERIES	AGE ZONE: Foram	AGE ZONE: Nanno	AGE ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
CAMPANIAN	Not zoned	*Tetralithus trifidus*	—	0–9	1–6, CC	VOID				Nannofossil chalk, pale yellowish brown (10YR 6/2), forams, fish debris, micronodules present; intensely mottled very pale orange (10YR 8/2), dark yellowish brown (10YR 4/2), very locally dusky yellowish brown (10YR 2/2), pinkish gray (5YR 8/3), and medium gray (N6).		A M	
										Same, nearly massive, grayish orange (10YR 7/3), faintly mottled very pale orange (10YR 8/2), alternates with light olive gray (5Y 6/1), medium light gray (N6), and grayish orange pink (5YR 8/2).			
										Same, 5 mm leopard spot mottles, dusky yellowish brown (10YR 2/2). Same, light borwn-gray (5YR 6/1) mottled very pale orange (10YR 8/3), pale yellowish brown (10YR 6/2). Alternating leopard spot mottling and low contrast mottling.	R P	A P	R P

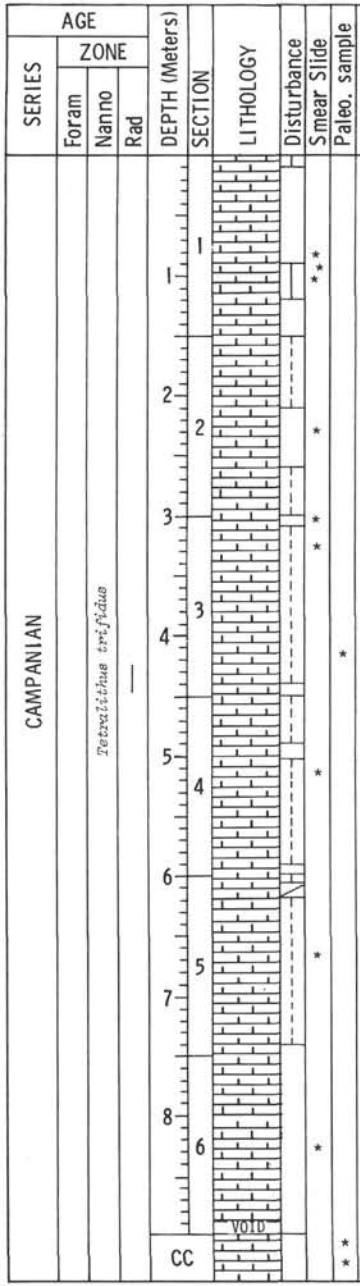


PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



SITE: 163 HOLE: CORE: 20 Cored Interval: 207-216 m



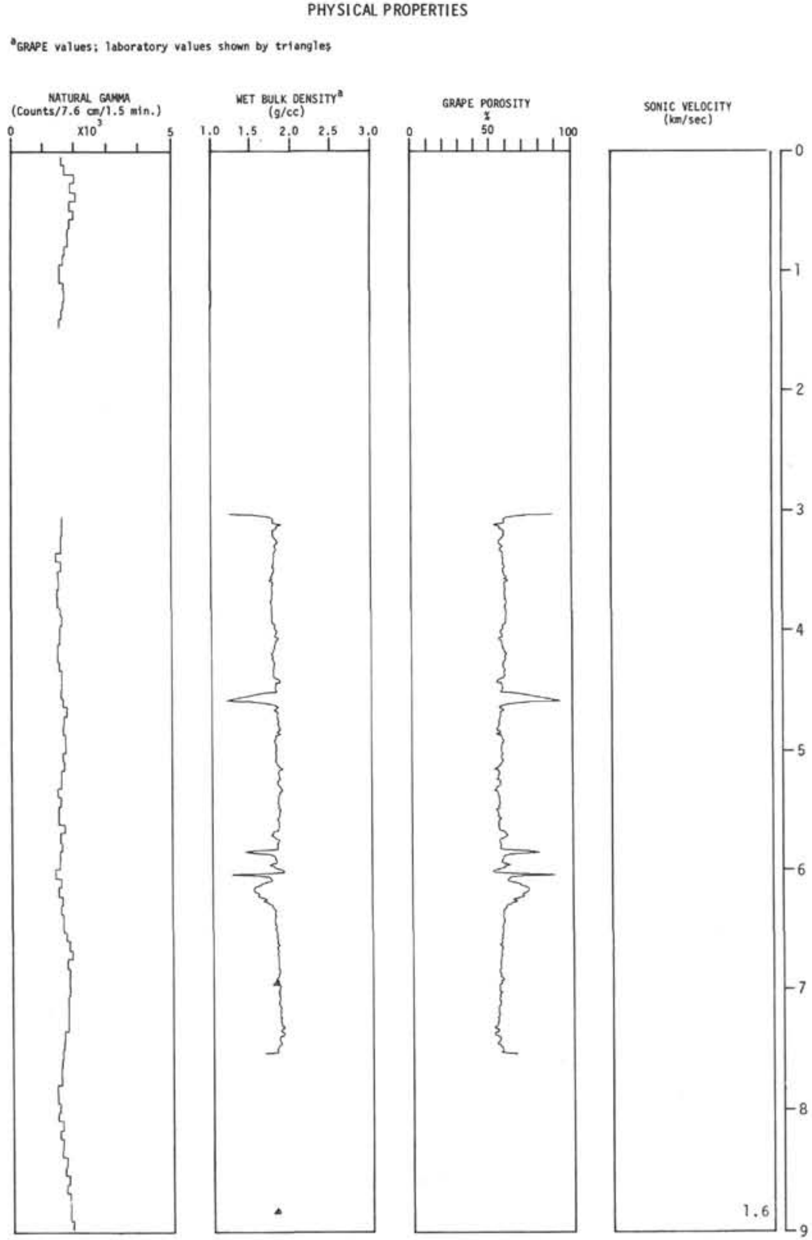
DESCRIPTION

Nannofossil chalk, very pale pinkish orange (7.5YR 8/2), slightly mottled to very pale orange (10YR 8/2), light gray (N7), pale yellowish brown (10YR 7/2); forams, micronodules, amorphous ferruginous aggregates present.

Chert, dusky yellowish brown (10YR 2/2) rimmed with chalk limestone patina, very pale orange (10YR 8/2).

Nannofossil chalk, pinkish gray (5YR 8/1) slightly mottled to pale yellowish brown (10YR 6/2), locally mottled light gray (N7), light olive gray (5Y 6/1), medium gray (5YR 4/1), brown gray (5YR 4/1).

PHYSICAL PROPERTIES

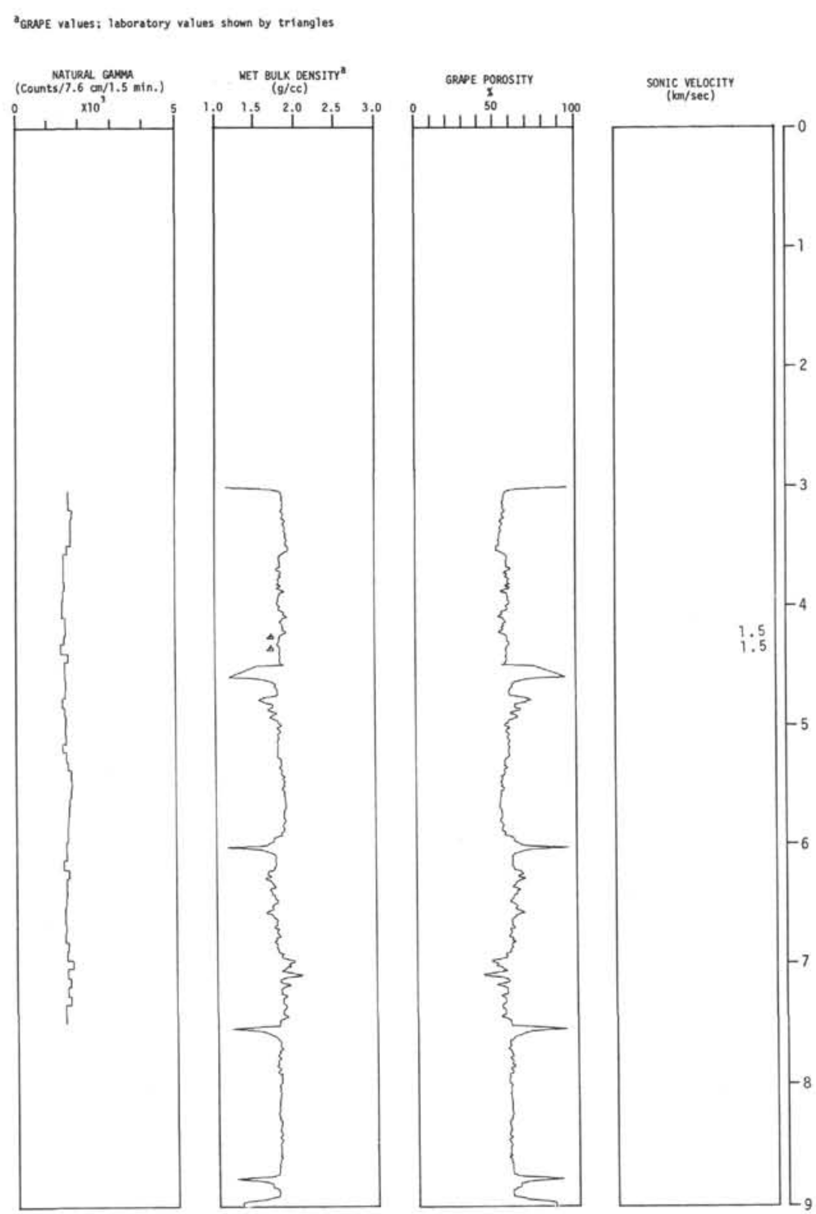


SITE: 163 HOLE: CORE: 21 Cored Interval: 216-225 m

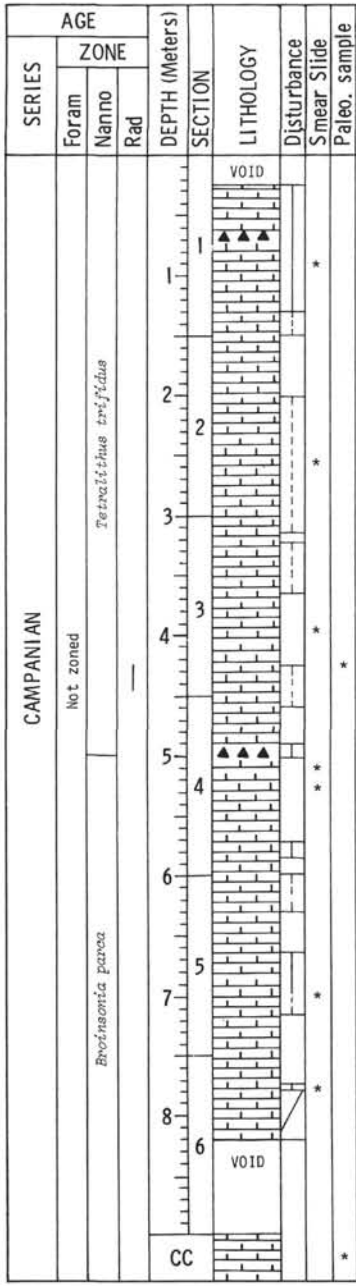
SERIES	AGE ZONE Foram	Nanno	Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres Foram / Nanno / Rad; % CaCO3
CAMPANIAN	Not zoned	*Tetralithus trifidus*		0–1	1	VOID					
				1–3	2					Nannofossil chalk, very pale orange (10YR 8/2), forams, fish debris, micronodules present. Chert, moderate brown (5YR 3/3) rimmed with limestone, very pale orange (10YR 8/4).	
				3						Same, with few light olive gray (5Y 6/1) mottles.	
				4	3					Same, pale yellowish brown (10YR 6/2) mottled 10YR 8/2; sharp 1 mm mottles medium dark gray (N4).	A M
				5–6	4						
				7	5						
				7.5–9	6					Nannofossil chalk intercalated with chert dusky yellowish brown (10YR 2/2), locally mottled moderate orange pink (5YR 8/4).	
					CC						R P A M R P

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



SITE: 163 HOLE: CORE: 22 Cored Interval: 225-234 m

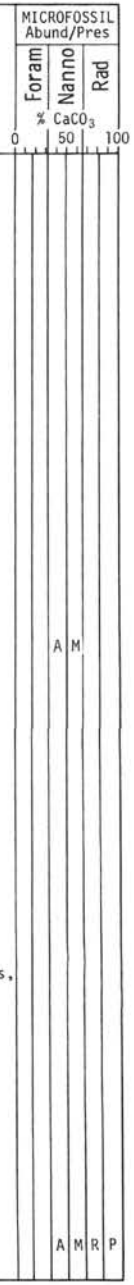


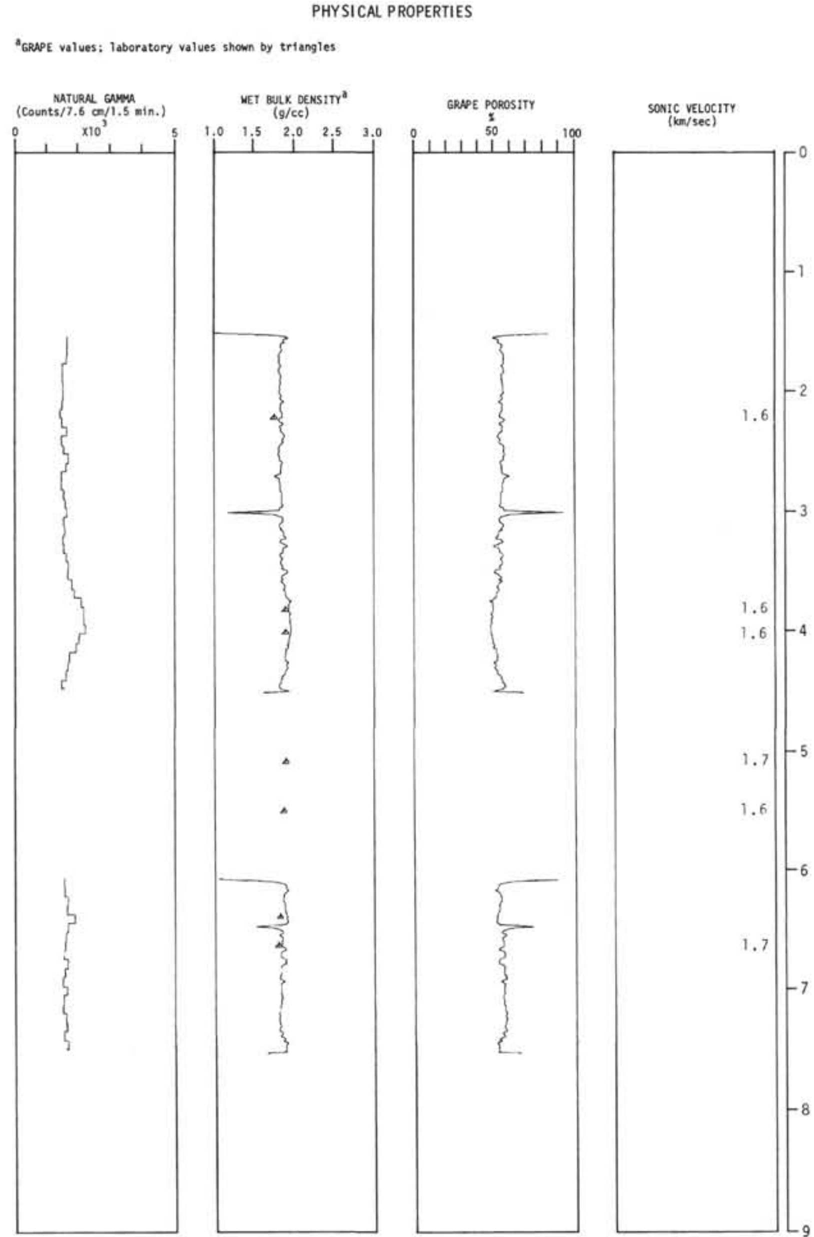
DESCRIPTION

Nannofossil chalk, very pale orange (10YR 8/2), low color contrast mottling to pale yellowish brown (10YR 7/2).
Chert, dusky yellowish brown (10YR 2/2) mottled dark yellowish brown (10YR 4/2).

Chert, moderate brown (5YR 3/4 and 4/4).

Same, very pale yellowish brown (10YR 7/1) mottled pale yellowish brown (10YR 6/2) and very pale orange (10YR 8/1), grading to pale yellowish brown (10YR 6/2 and 10YR 8/2); forams, micronodules, fish debris present.



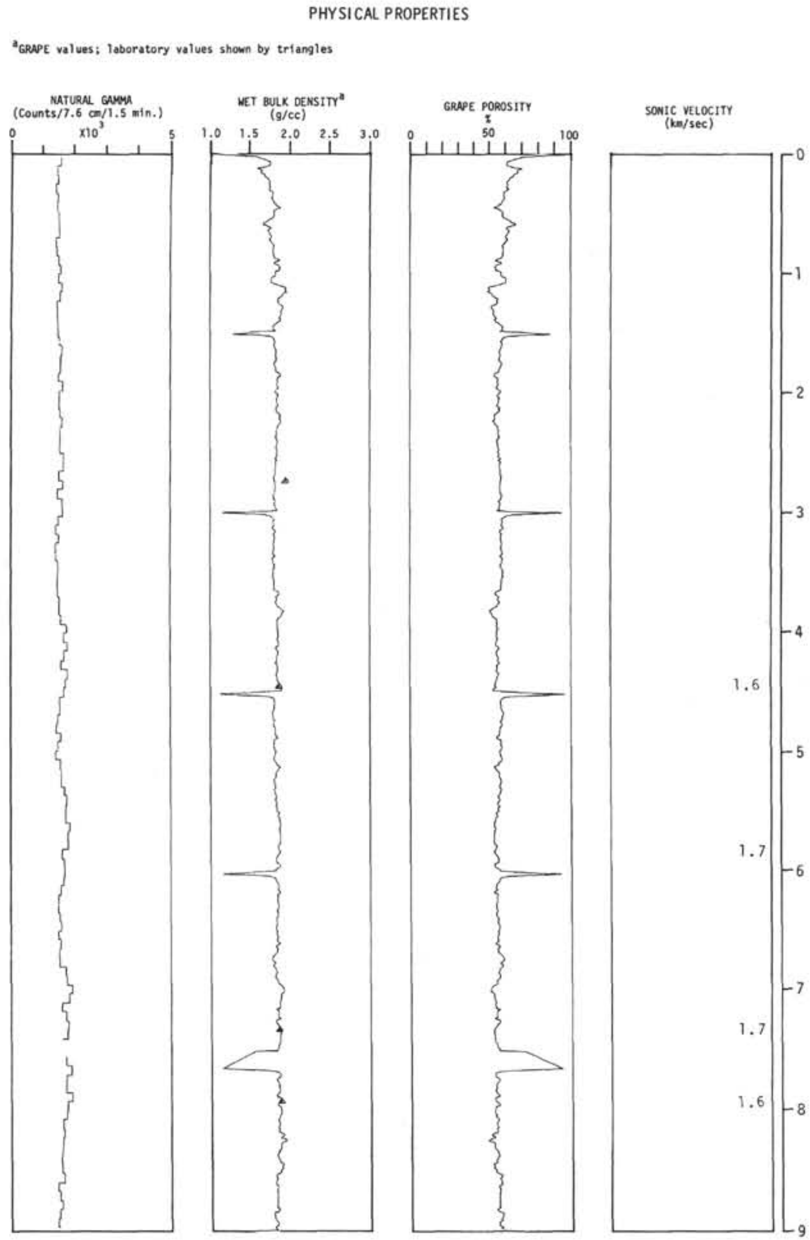


SITE: 163 HOLE: CORE: 23 Cored Interval: 234-243 m

SERIES	AGE: ZONE Foram	Nanno	Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres Foram	Nanno	Rad
CAMPANIAN	Not zoned	*Broinsonia parva*		0–1.5	1			*		Nannofossil chalk, very pale orange (10YR 7/1), slightly mottled to 10YR 8/1, forams, fish debris, micronodules present.			
										Chert, moderate brown (5YR 3/4) locally mottled light brown (5YR 6/4).			
				1.5–3	2			*		Nannofossil chalk, pinkish gray (5YR 8/1), weakly mottled to very pale orange (10YR 8/1).			
				3–4.5	3			*	*	Few mottles of pale yellowish brown (10YR 7/1 and 7/2).		A M	
				4.5–6	4			*		Nannofossil chalk, very pale yellowish brown (10YR 7/2), mottles to 10YR 8/1 and 10YR 6/2.			
				6–7.5	5			* * *		Same, pinkish gray (5YR 8/1), mottled yellowish brown (10YR 6/2), large mottles of chalky limestone, moderate yellowish brown (10YR 5/4).			
										Chalky limestone areas, partly silicified.			
				7.5–9	6			* *					
					CC				* *		R P	A P	R P

% $CaCO_3$: 0, 50, 100

PHYSICAL PROPERTIES



SITE: 163 HOLE: CORE: 24 Cored Interval: 243-252 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
CAMPANIAN	Not zoned	*Eiffellithus augustus*	—	1	1	VOID		* *	*	Nannofossil chalk, very pale orange (10YR 7/1), (10YR 8/1), burrows of light brown-gray (10YR 6/1) and light olive gray (5Y 6/1); forams, fish debris, micronodules present.		A M	
					CC						R ?	A ?	R P

SITE: 163 HOLE: CORE: 25 Cored Interval: 252-261 m

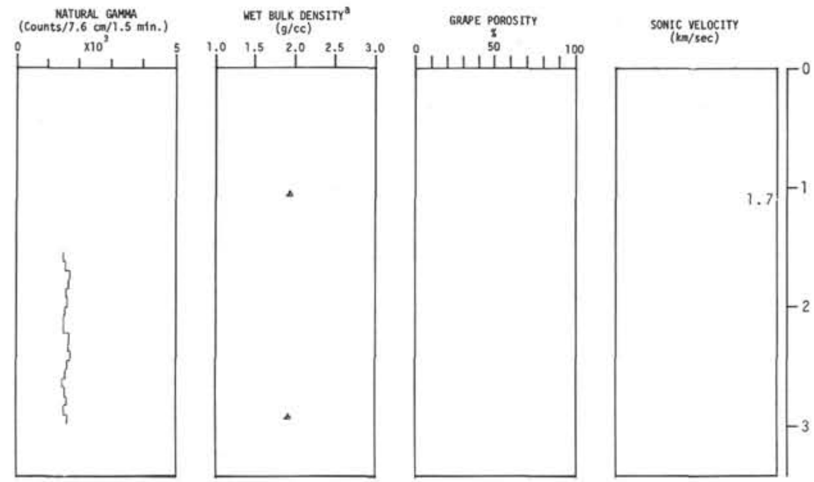
AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
CAMPANIAN	Not zoned	*Eiffellithus augustus*	—	1	1					Nannofossil chalk, white (N9), yellowish gray (5Y 8/1), mottled faintly to greenish gray (5GY 6/1); micronodules present.		A M	
					CC					Chert, yellowish brown (10YR 4/3) mottled grayish orange (10YR 7/4).			
										Limestone, yellowish gray (5Y 8/1), silicified, grading to chert, moderate yellowish brown (10YR 5/4) and dark yellowish orange (10YR 6/6).	R P	A P	R P

Sonic Velocity (km/sec) 4.9; Depth 1.36 m

SITE: 163 HOLE: CORE: 26 Cored Interval: 261-270 m

SERIES	Foram zone	Nanno zone	Rad zone	DEPTH (Meters)	SECTION	LITHOLOGY	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
CAMPANIAN	Not zoned	*Eiffellithus augustus*	—	0–3	1, 2	VOID	Chert, dusky brown (5YR 2/2) with moderate brown (5YR 4/4) mottles. Nannofossil chalk, yellowish gray (5Y 8/1), mottled very light gray; micronodules, fish debris, dolomite rhombs present. Same, pinkish gray (5YR 8/1) with very pale orange (10YR 8/1) mottles. Limestone, light olive gray (5Y 6/1) and greenish gray (5GY 6/1), compressed mottles; light brown gray (5YR 6/1), sharp horizontal contact with moderate yellow brown chert (10YR 5/4). Nannofossil chalk as above.			
					CC		Chalk, very pale orange (10YR 8/2).	F D	A M	R P

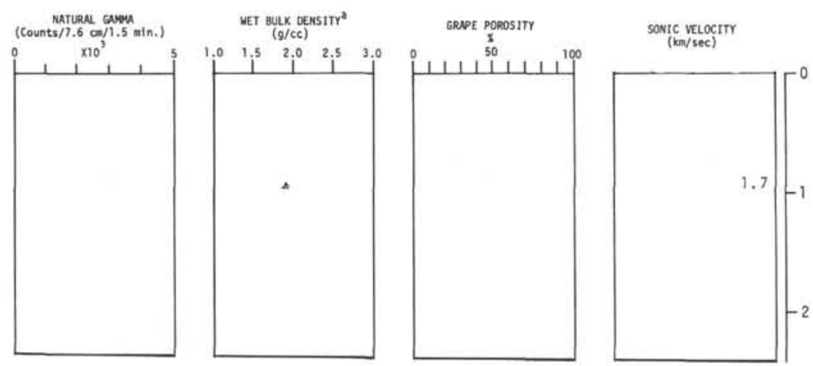
PHYSICAL PROPERTIES



SITE: 163 HOLE: CORE: 27 Cored Interval: 270-276 m

SERIES	Foram zone	Nanno zone	Rad zone	DEPTH (Meters)	SECTION	LITHOLOGY	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
CAMPANIAN	Not zoned	*Eiffellithus augustus*	—	0–2	1	VOID	Nannofossil chalk, very pale orange (10YR 8/2), micronodules, dolomite rhombs, palagonite, fish debris present. Same, with light gray (N/7) mottles. Chert nodule, grayish orange pink (5YR 7/2), mottled pale brown (5YR 5/2) and grayish orange (10YR 7/4).			
					CC		Same.	R P	A F / M P	R P

PHYSICAL PROPERTIES



SITE: 163 HOLE: CORE: 28 Cored Interval: 276-285 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
1	2	3		1	1			* T.S T.S T.S	*	Nannofossil chalk, very pale orange (10YR 8/2) and harder areas of gray orange (10YR 7/3); forams, fish debris, micronodules, dolomite rhombs, palagonite present. Basalt, altered, fine grained to glassy, cut by calcite veins. Black glassy zones 1-2 cm thick dip 20-65°, vitreous, cut by veins of dark greenish yellow (10Y 6/6) and pale olive (10Y 6/2); may be pillow boundaries. Basalt alteration greatest adjacent to glassy borders, very light olive gray (5Y 6/1), dusky yellow (5Y 6/4), and moderate yellowish brown (10YR 5/4). Farther from glass, basalt is medium gray to medium dark gray (N/6-N/5) to brownish black (5YR 2/1). Basalt most aphanitic near glass borders, with few subsequent plagioclase microphenocrysts; interiors appear holocrystalline with pronounced felty texture formed by needle-like plagioclase laths up to 1 mm long. Glass zones at top of basalt (18-20 cm), at 47 cm, 112-115 cm, and 122-126 cm.		A/D, R/P	
					CC								

% $CaCO_3$: 0 50 100

[1] CAMPANIAN [2] Not zoned [3] *?Eiffellithus augustus*

SITE: 163 HOLE: CORE: 29 Cored Interval: 285-294 m

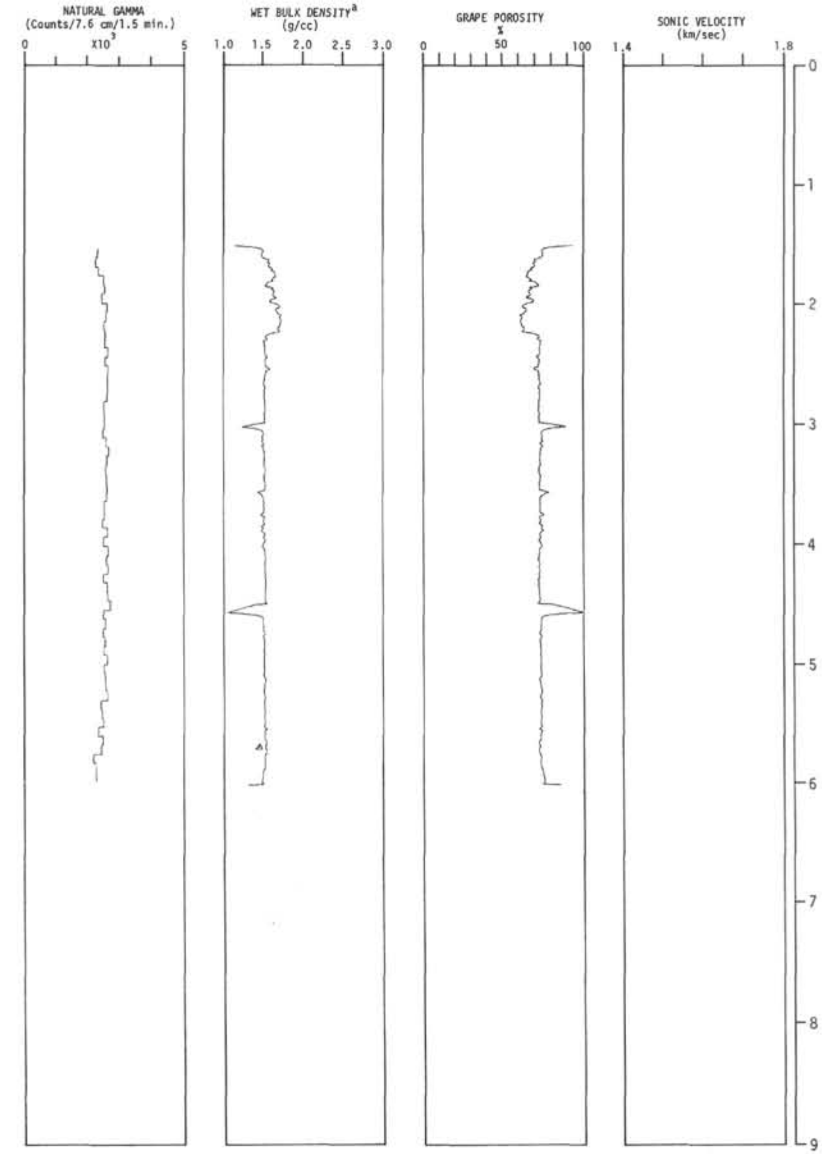
AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
						VOID							
				1	1		T.S T.S			Basalt, medium light gray (N/6) to light olive gray (5Y 6/1) cut by calcite veins. Black, glassy zone 1 cm thick at 102 cm; Sec. 1 dips 15°, glass zone at 120-135 cm incorporated in 4 cm thick calcite vein; basalt altered to moderate yellowish brown (10YR 5/1) near glass zones and calcite veins; veins most common near glass zones; also basalt aphanitic there with micro-phenocrysts of plagioclase. Away from glass, felty texture due to needle-like plagioclase laths; fracture surfaces coated with chlorite and ?talc.			
				2	2		T.S			Basalt, light gray (N/7), medium dark gray (N/4), green gray (5GY 6/1), cut by thin calcite veins; felty plagioclase needles and more equant plagioclase. Felty textured baslat, thin needle-like plagioclase laths 1-2 mm long, less common equant phenocrysts 1-3 mm long. No calcite veins but natural fractures are alteration surfaces with talcose feel; green gray (5G 6/1-8/1)) or green black (5GY 2/1).			
				3	3		T.S						
				4									
				5	4		T.S T.S			Felty textured basalt as above. Altered basalt cut by calcite veins up to 3 mm, no felty texture, few equant plagioclase phenocrysts 1 cm black glass zone dips 30° 1.5 cm horizontal calcite vein. Altered			
				6			T.S		*	basalt, pale yellowish brown (10YR 6/2), green gray (5GY 6/1), aphanitic except equant plagioclase, many calcite veins.			
					CC								

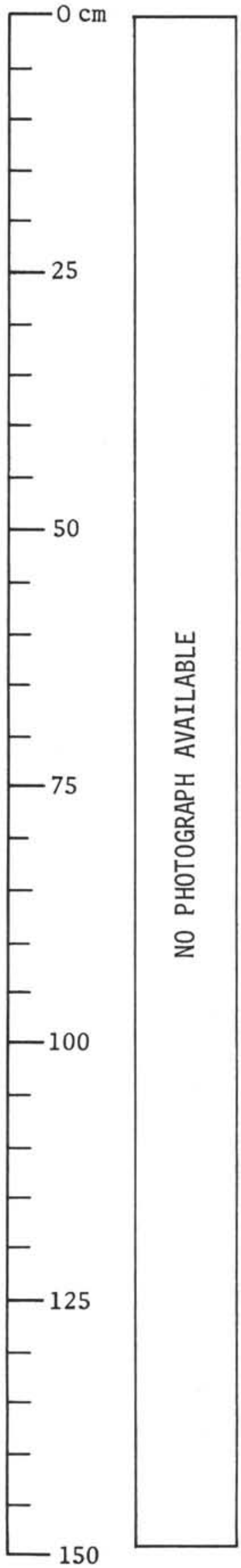
% $CaCO_3$: 0 50 100

Sonic Velocity (km/sec) 7.0; Depth 6.17 m

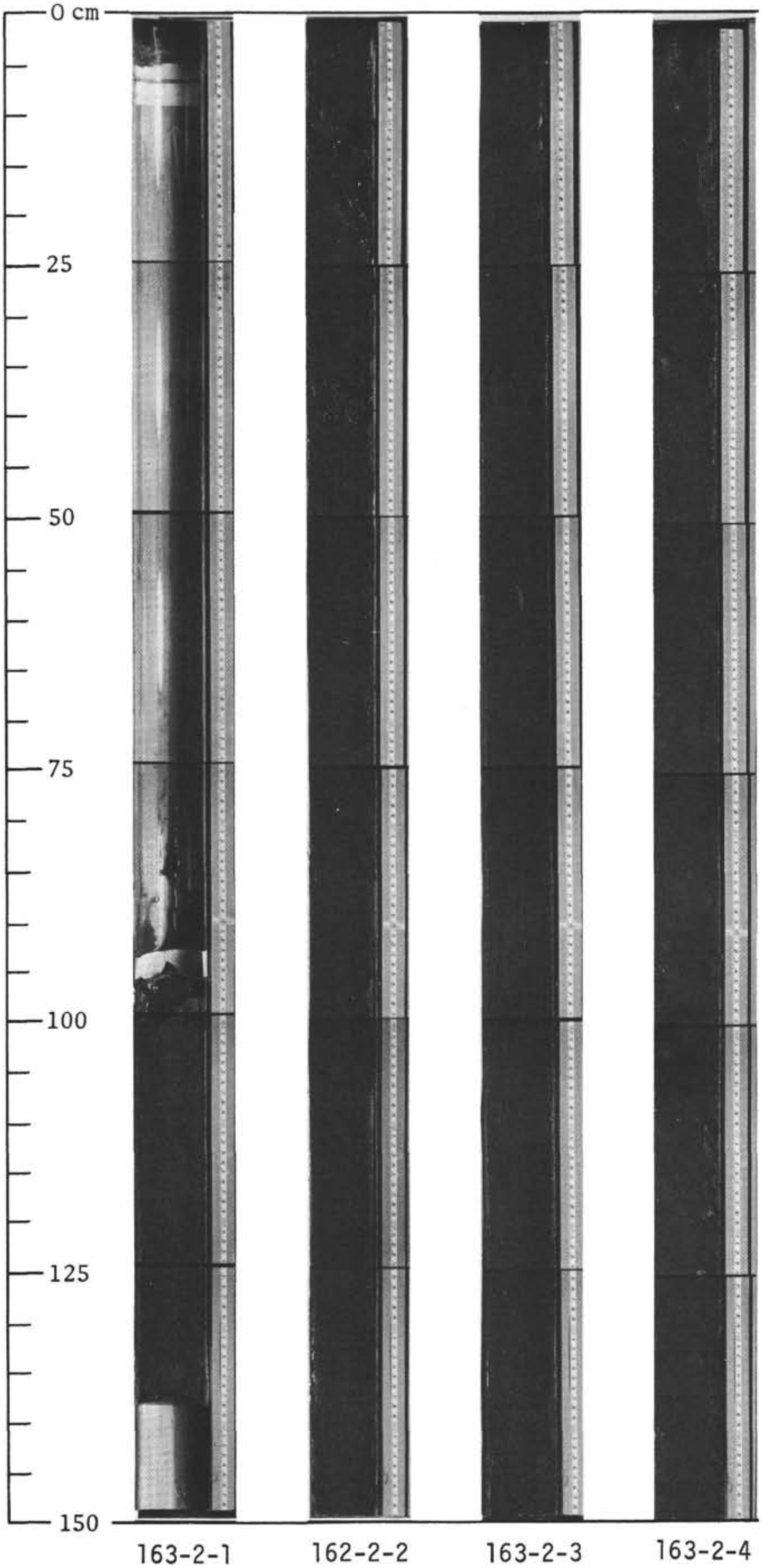
163A PHYSICAL PROPERTIES

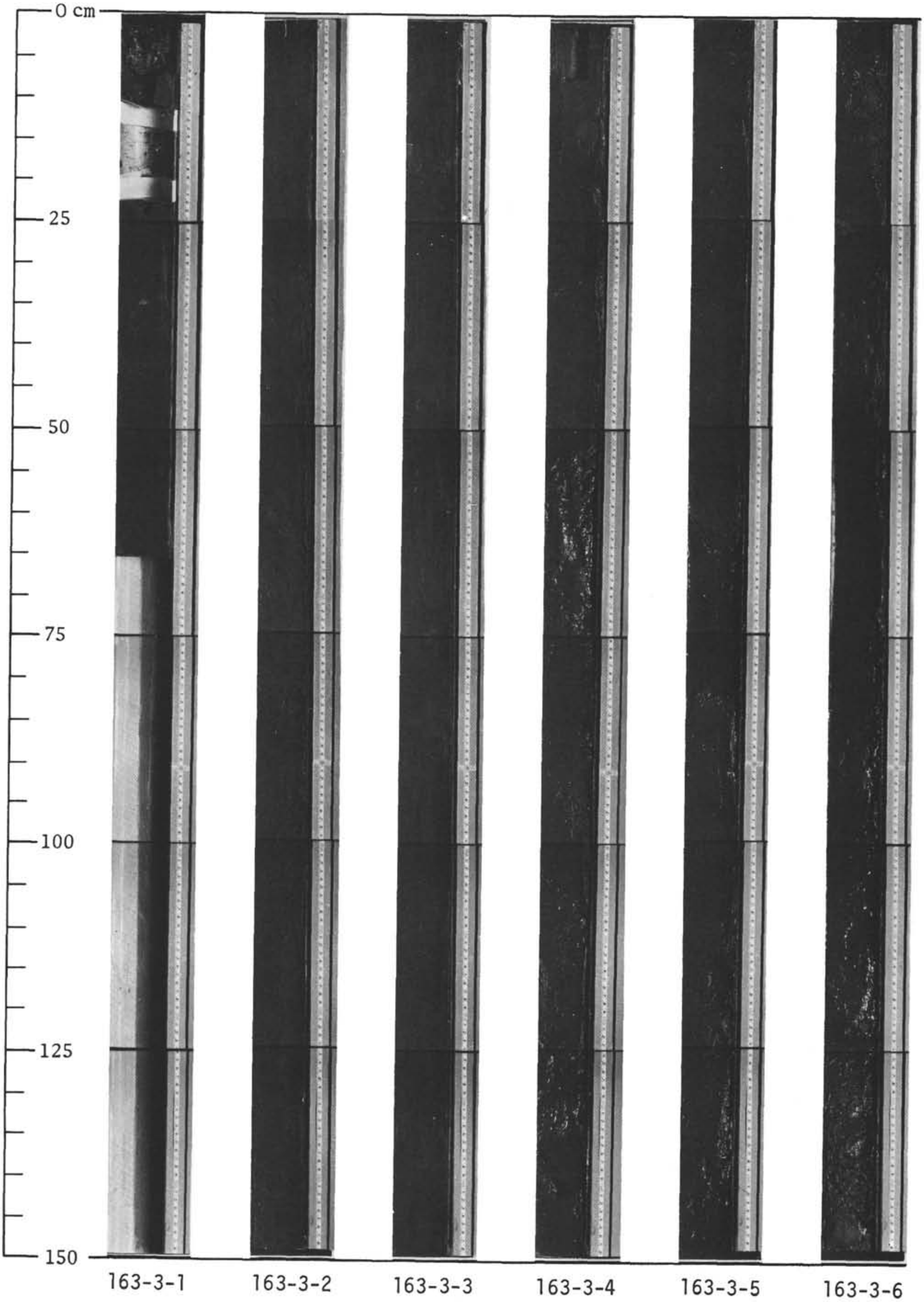
[a]GRAPE values; laboratory values shown by triangles





163-1-1


0 cm
25
50
75
100
125
150
163-2-1
162-2-2
163-2-3
163-2-4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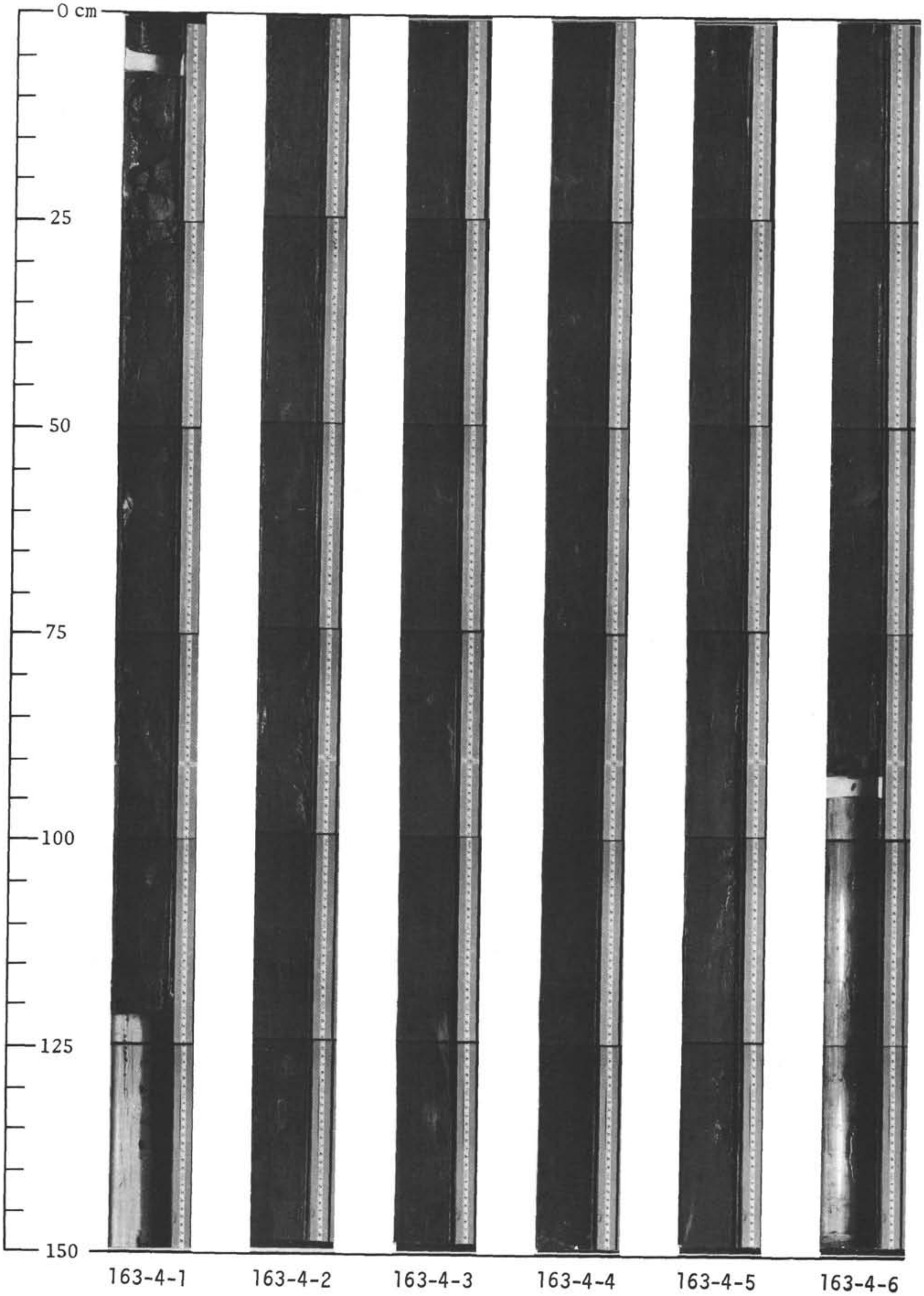
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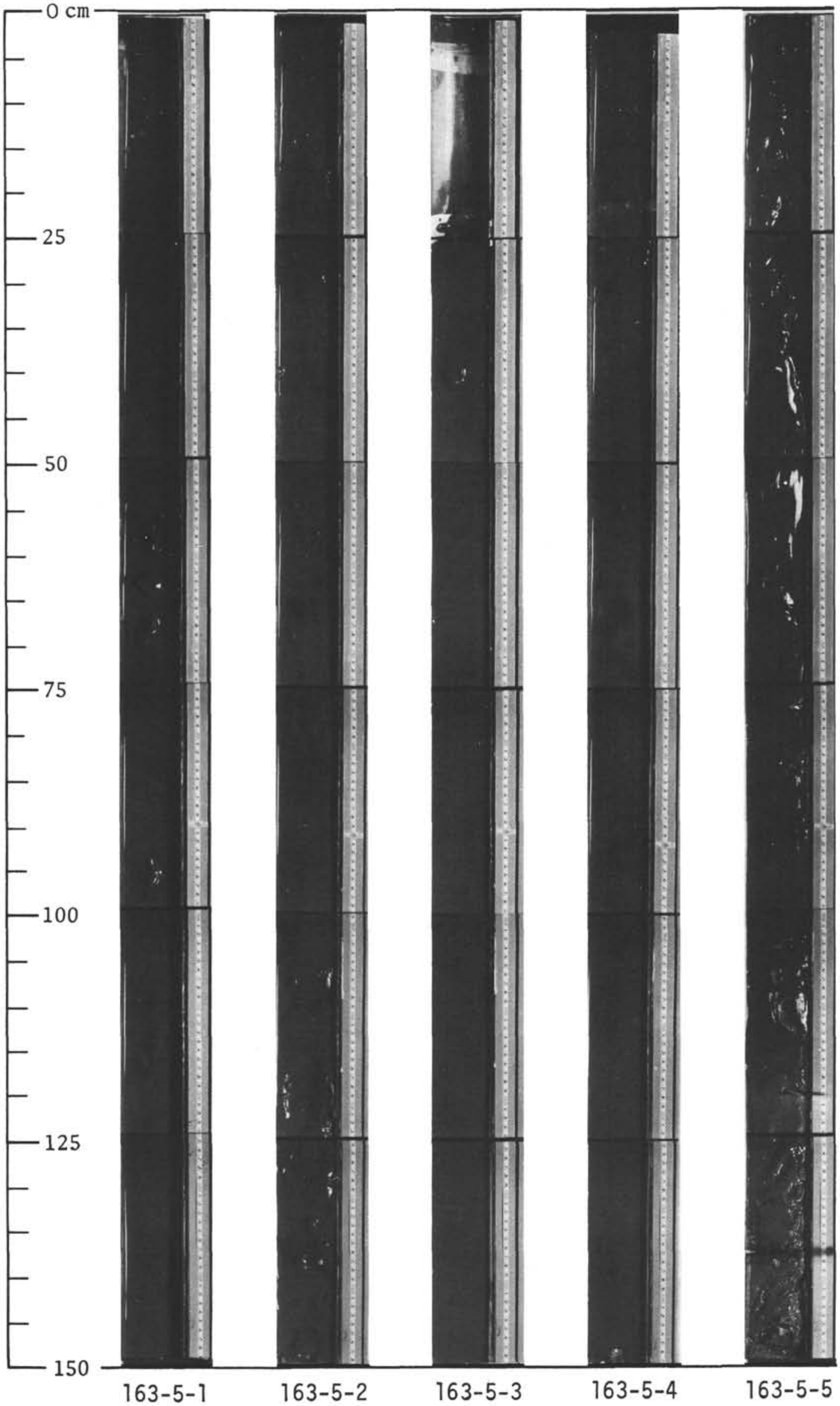
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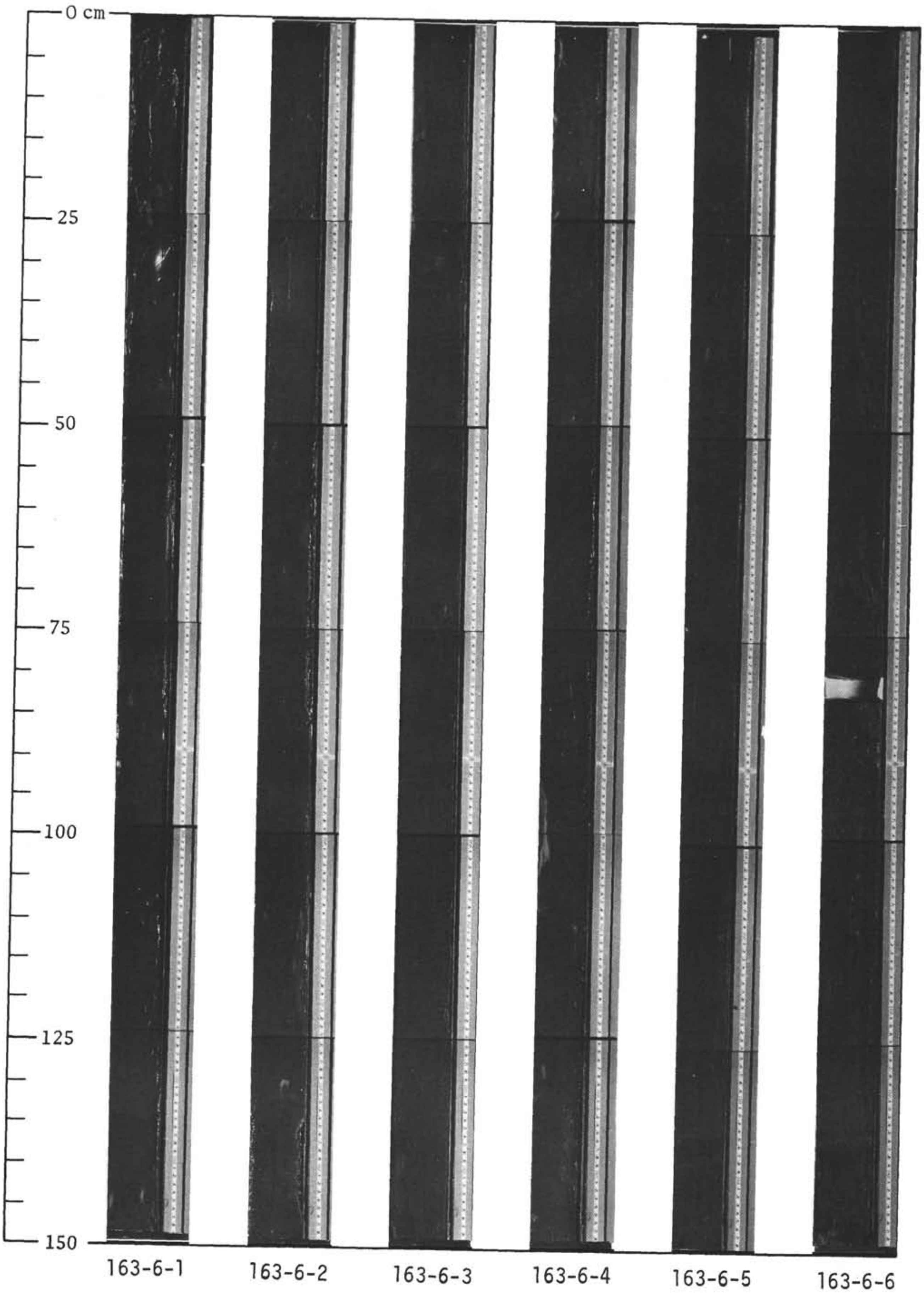
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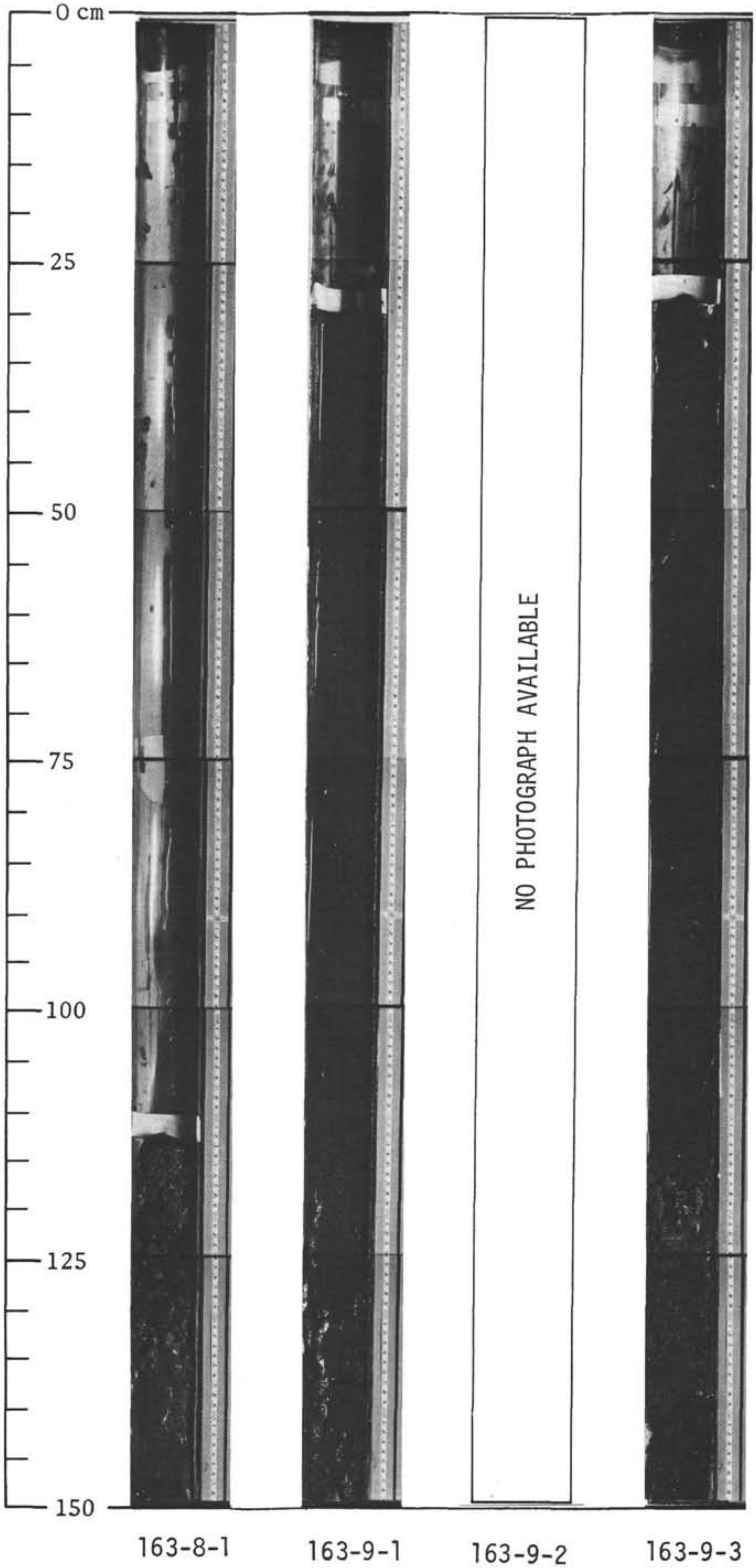
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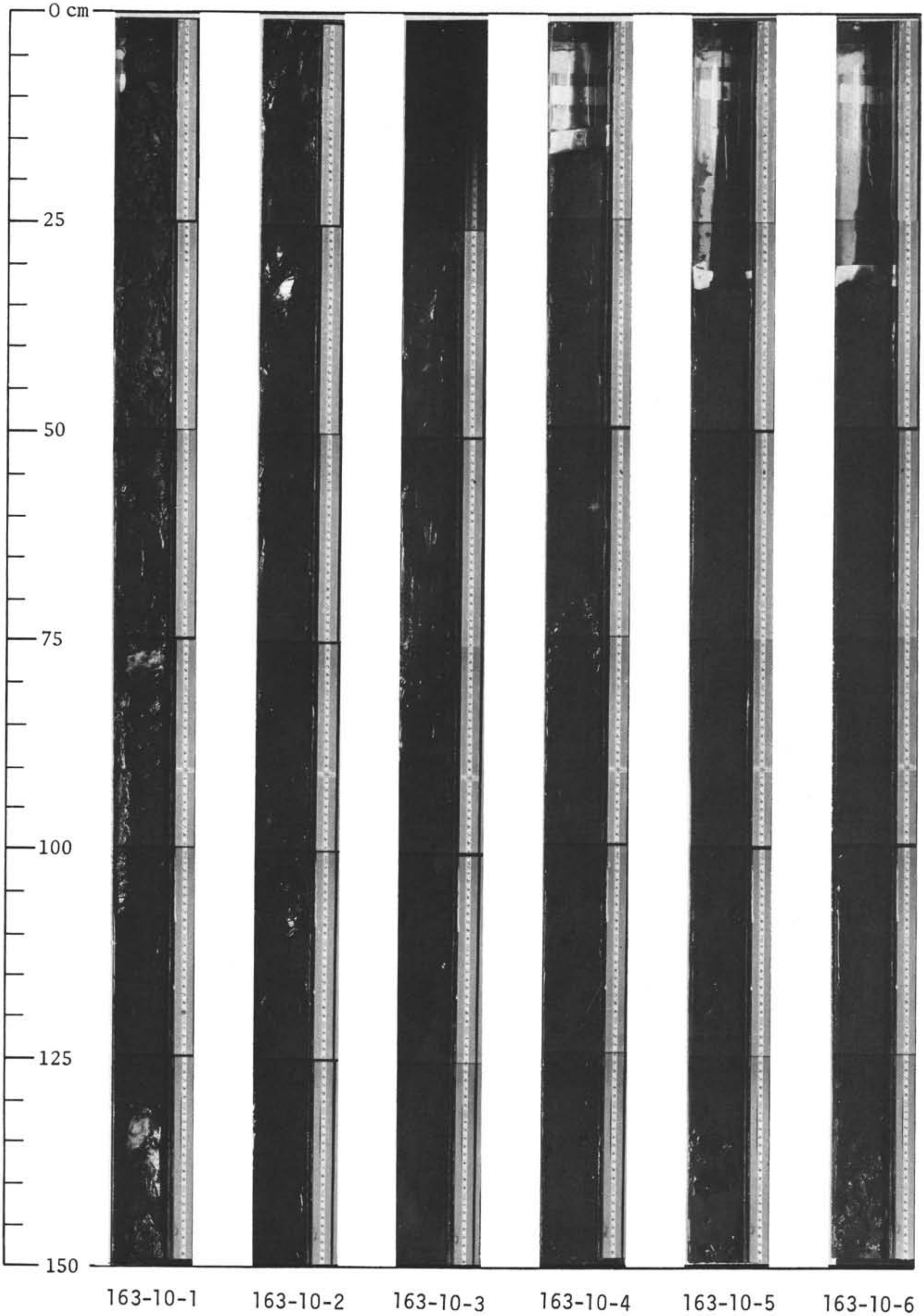
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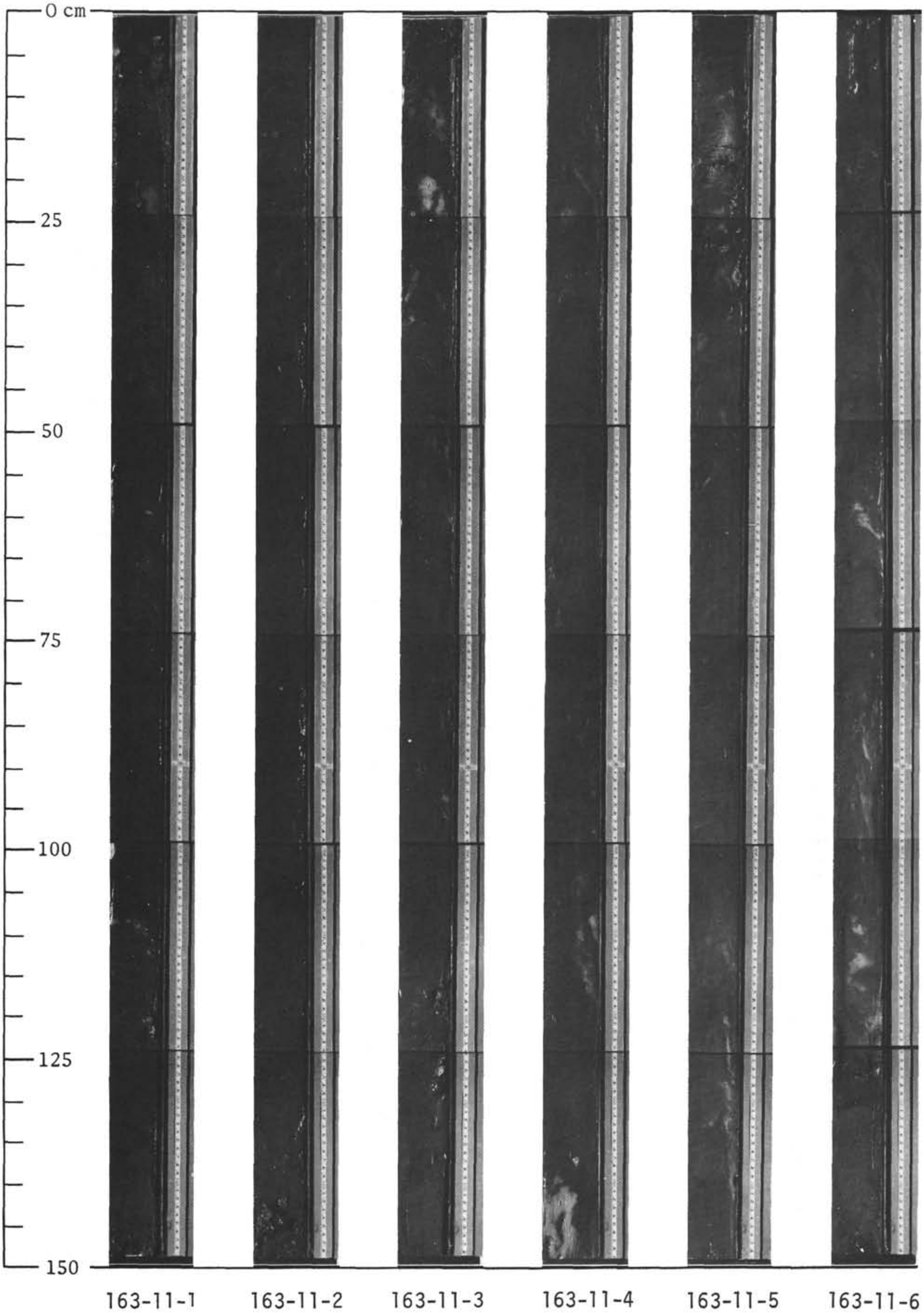
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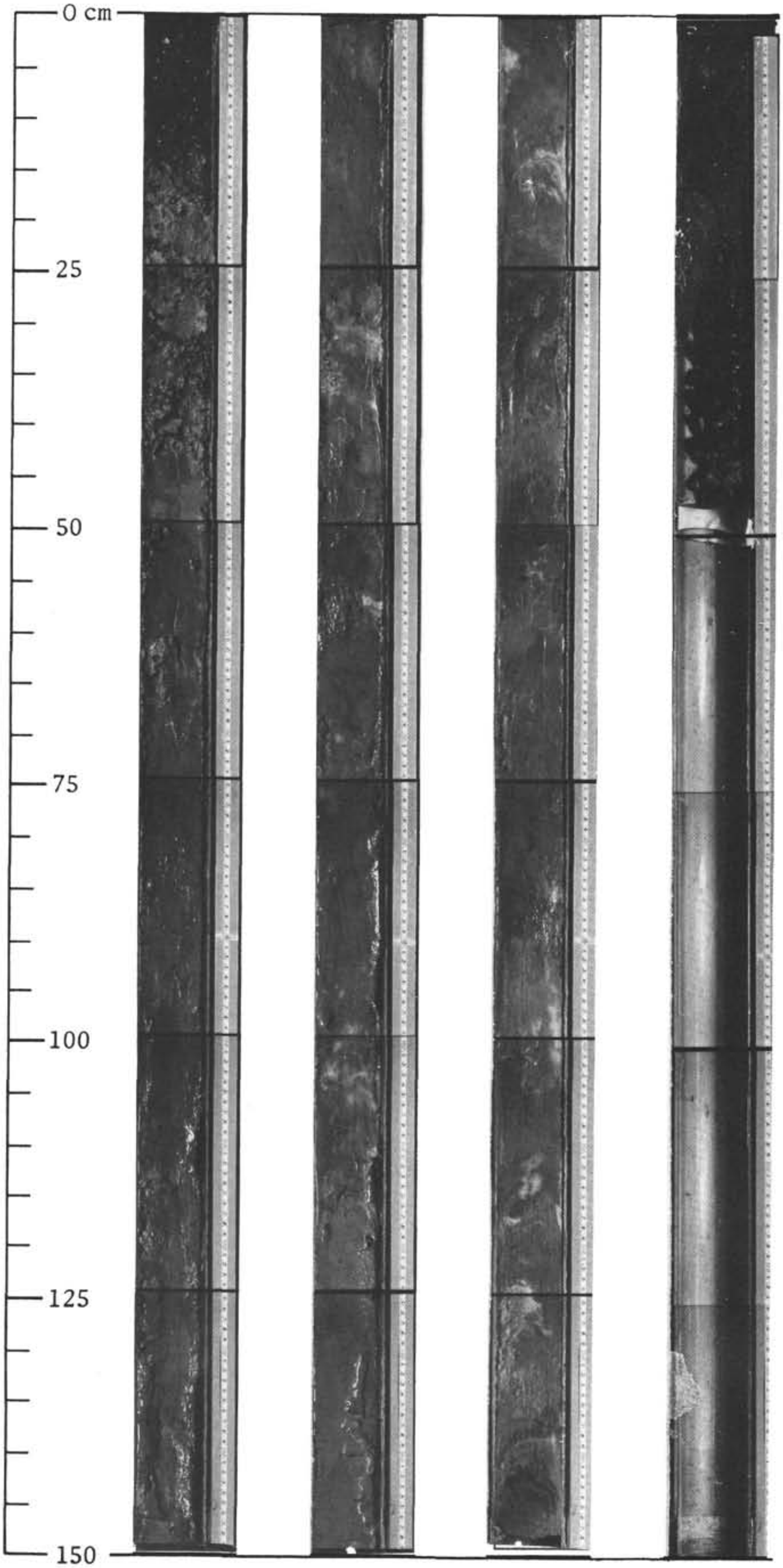

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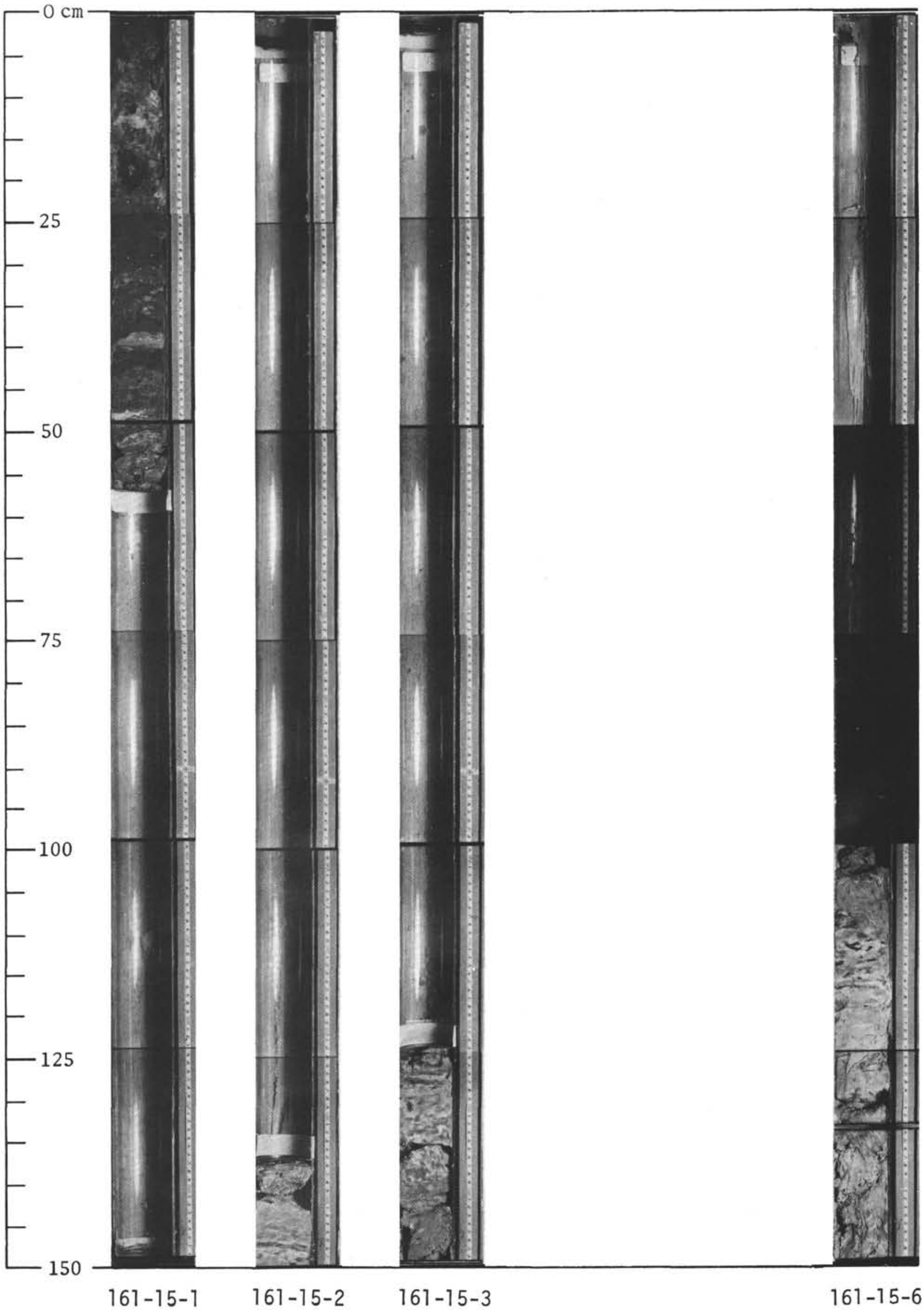
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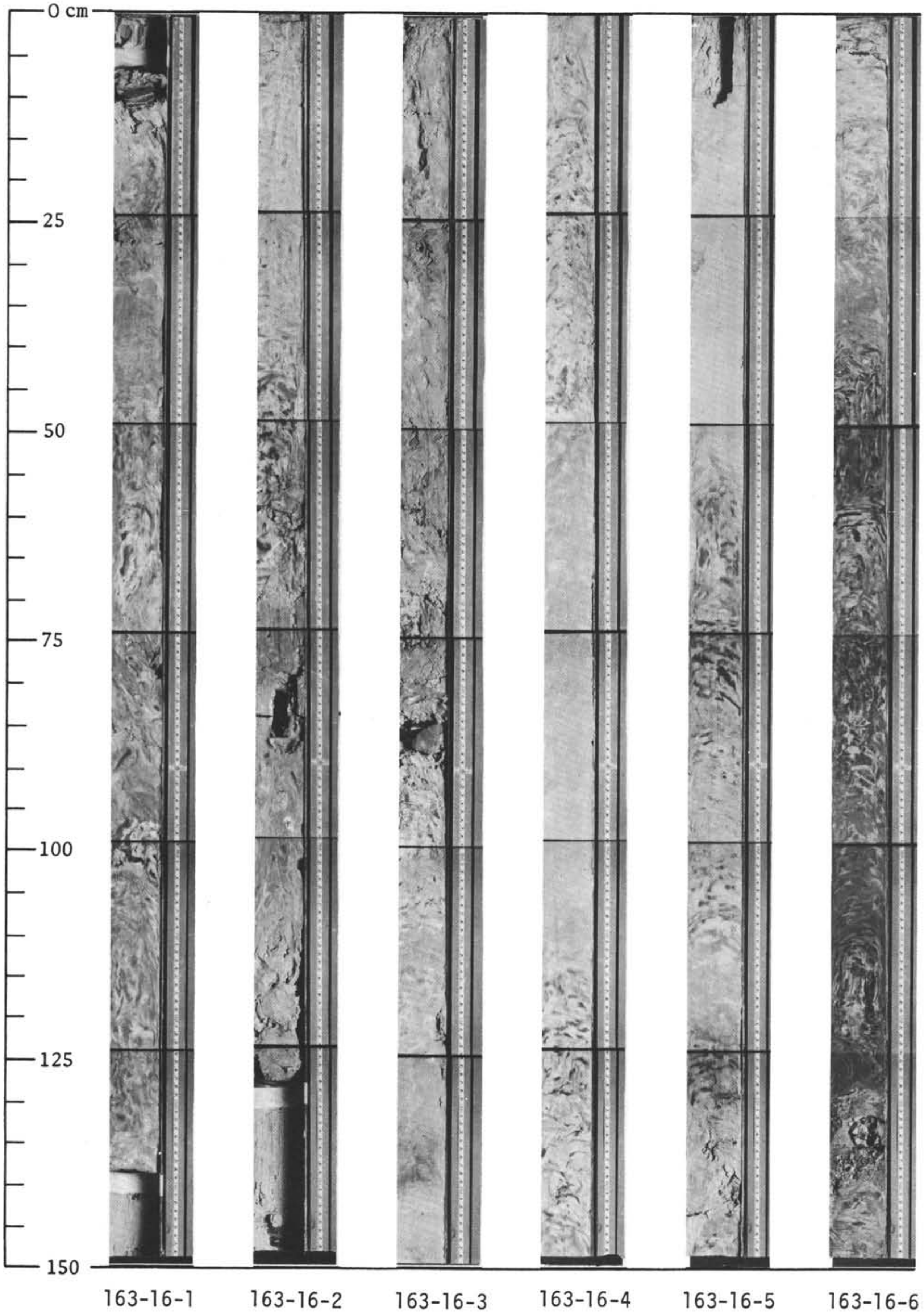
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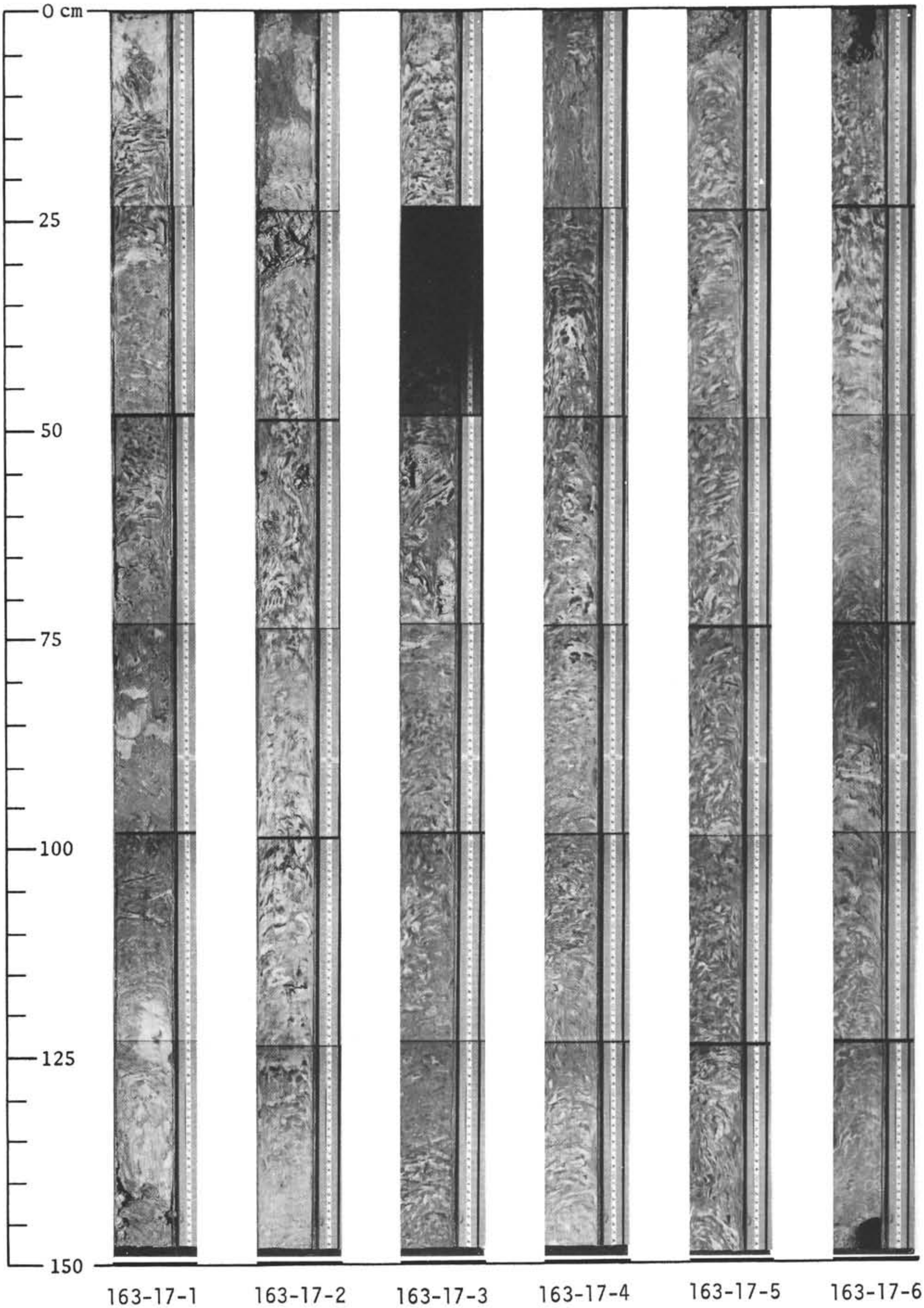
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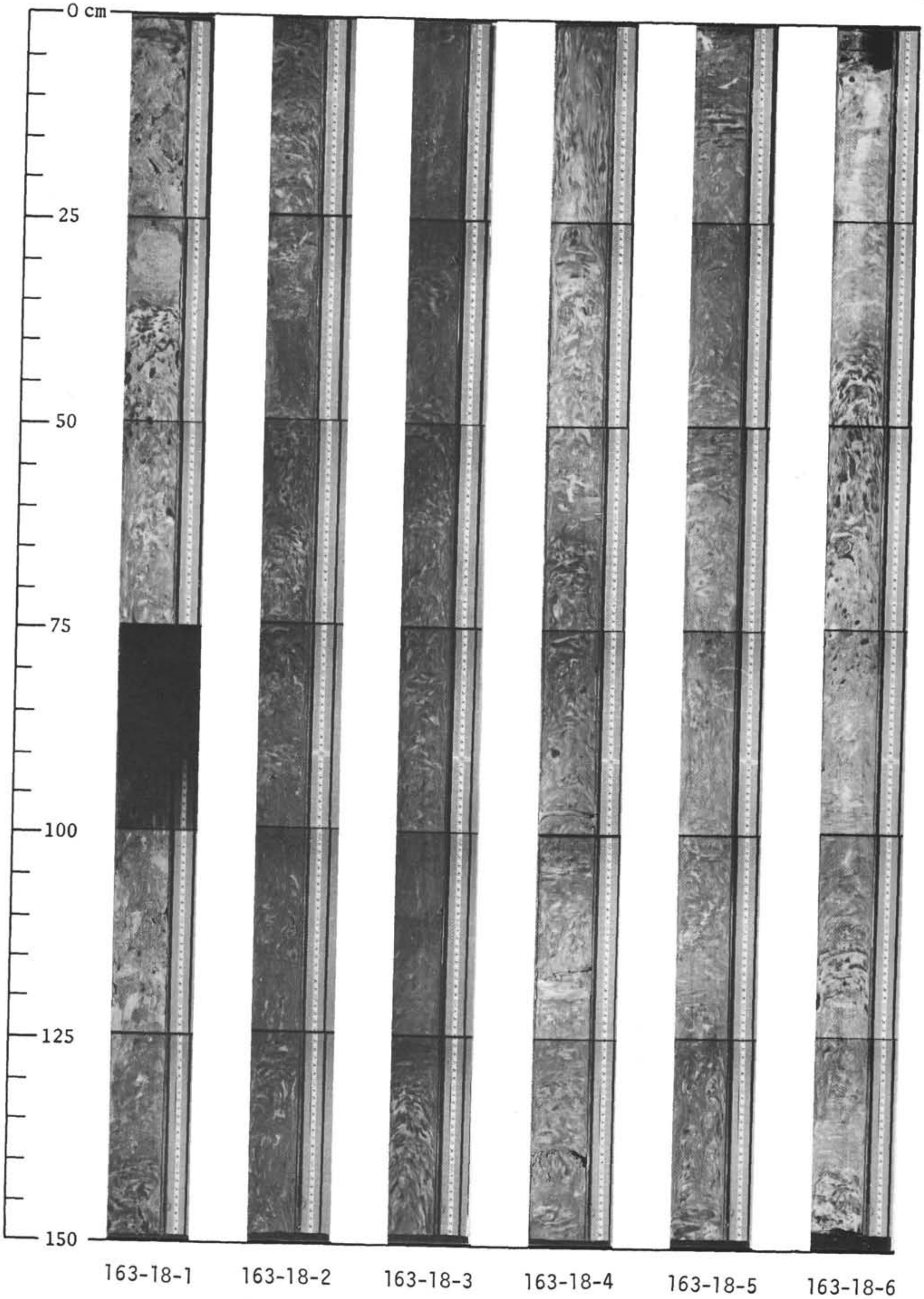
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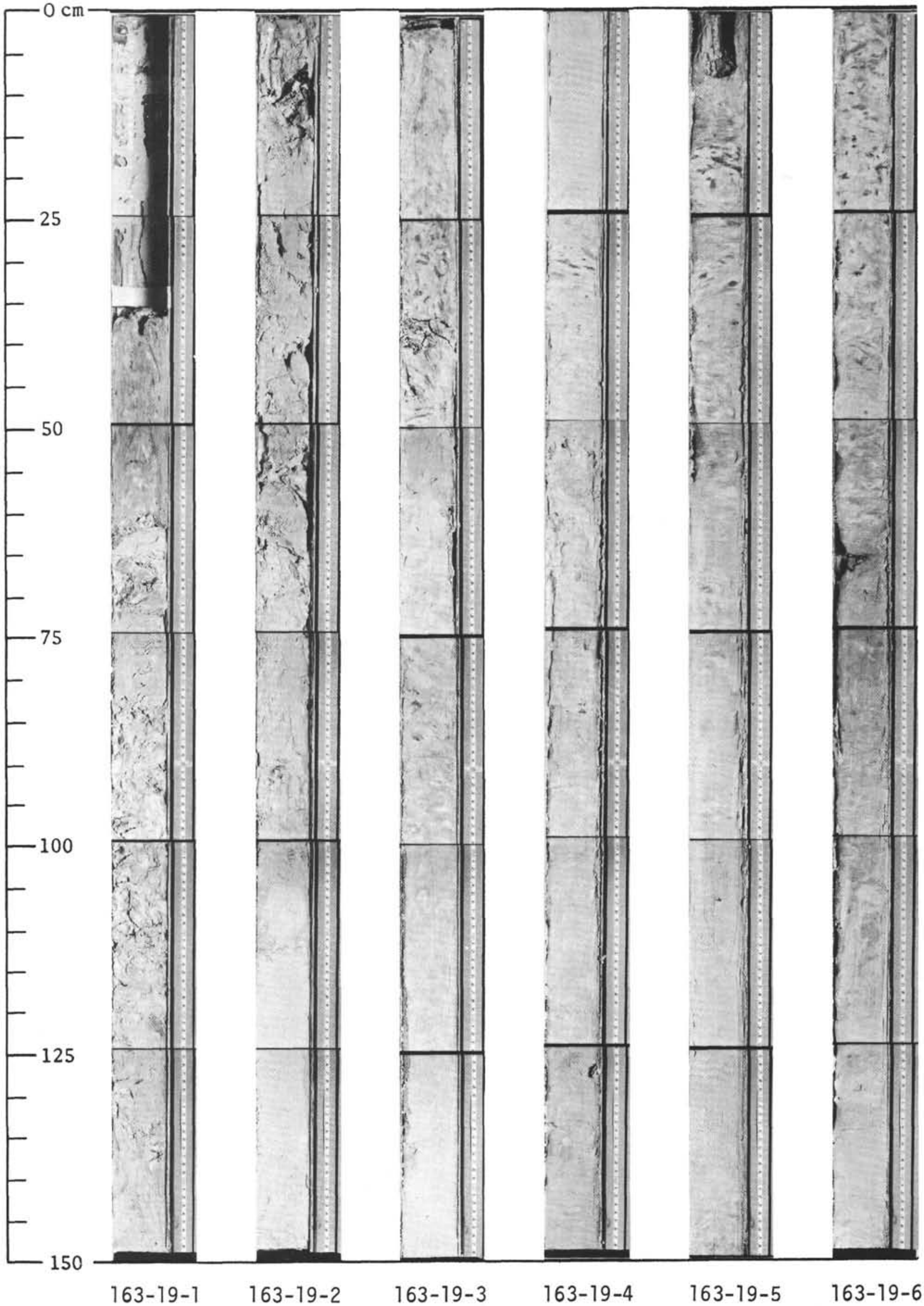
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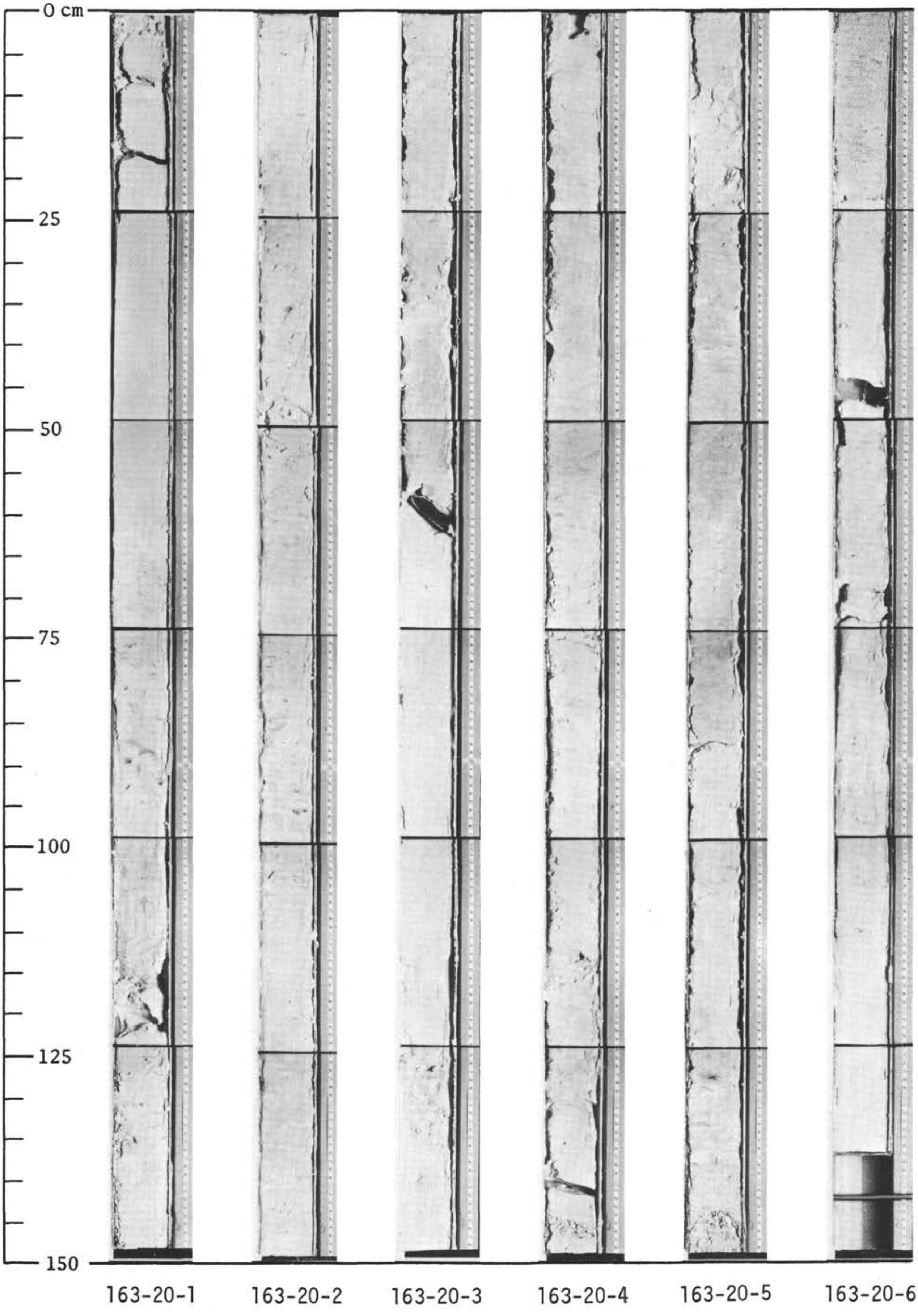
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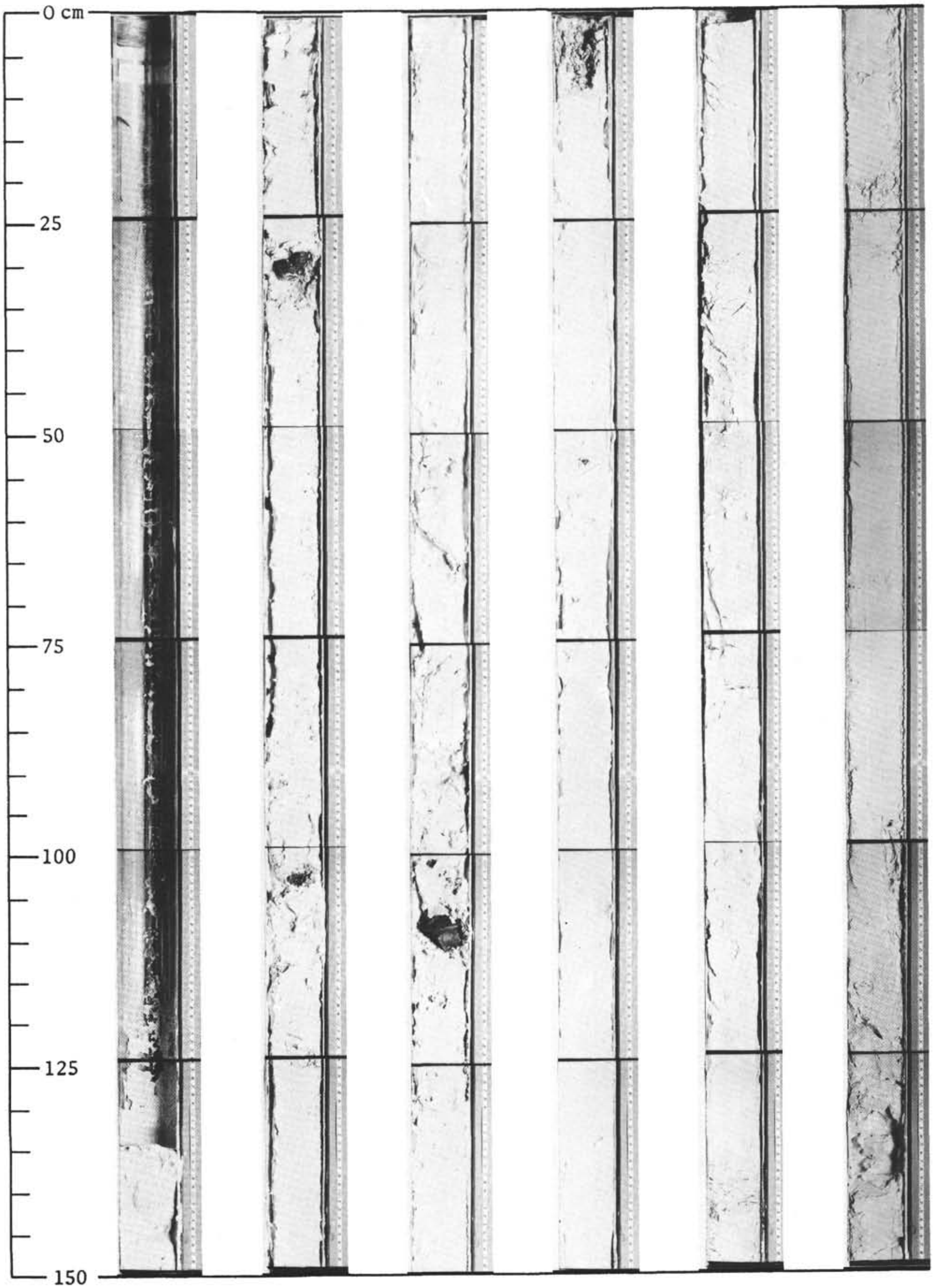
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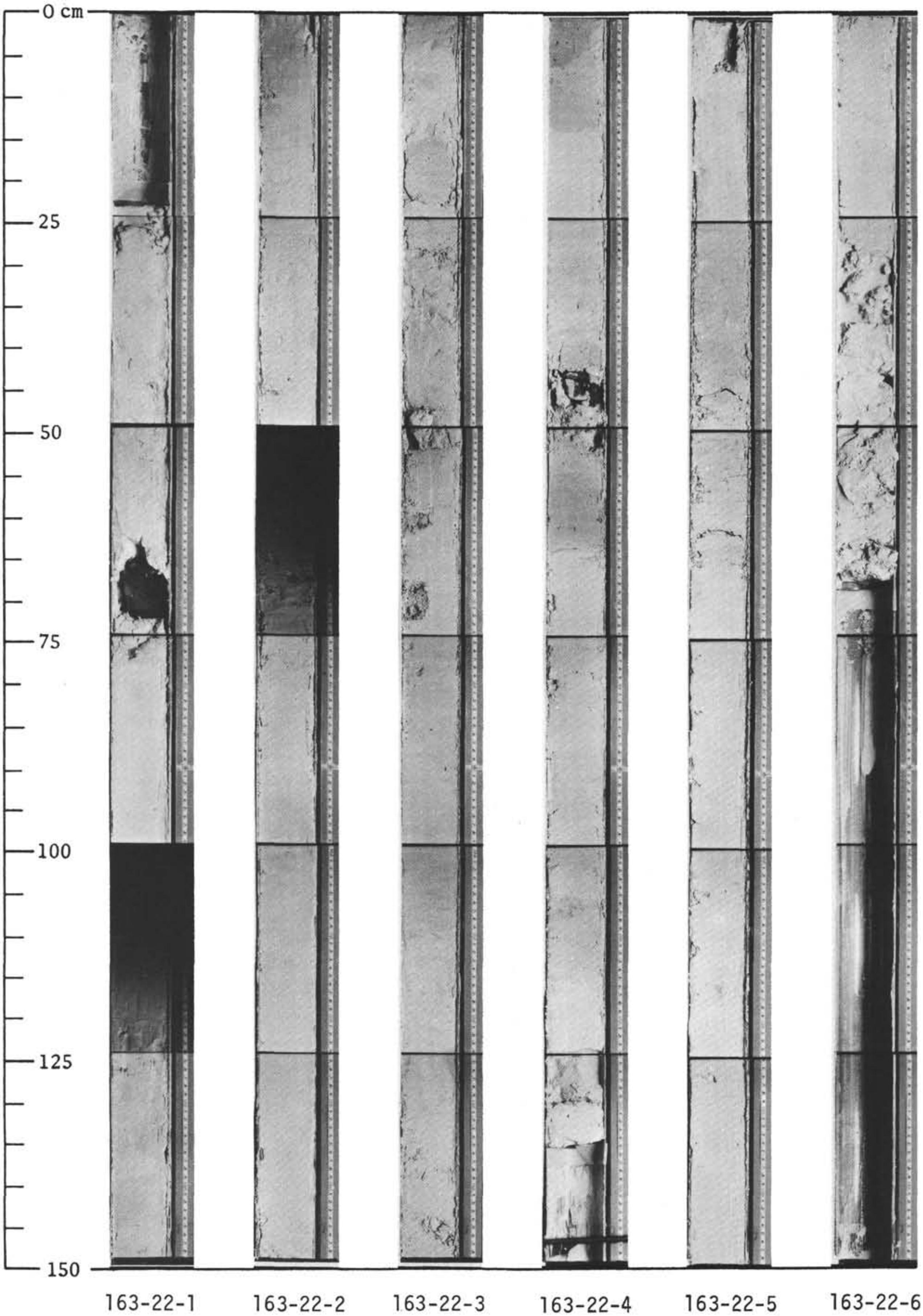
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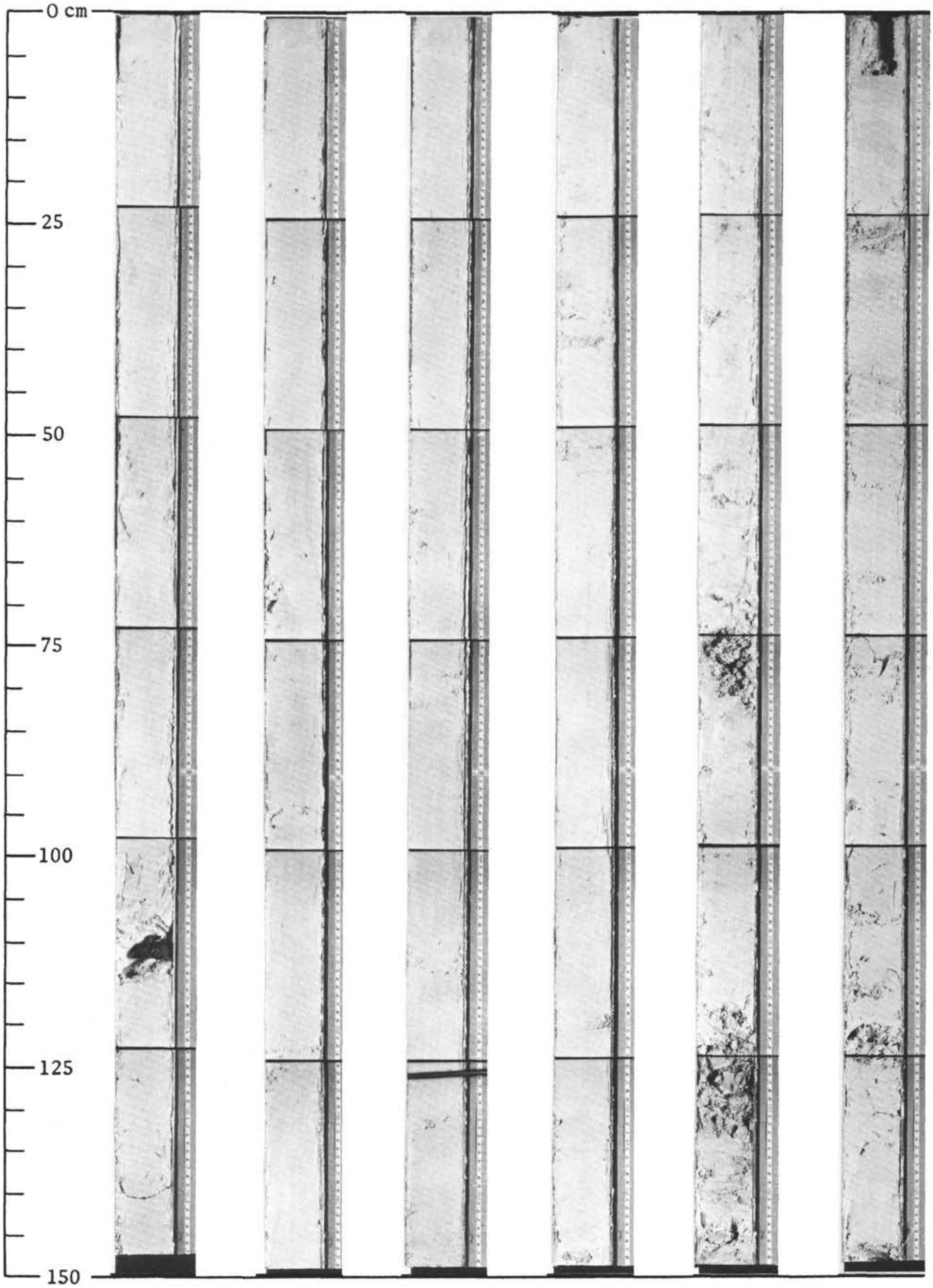

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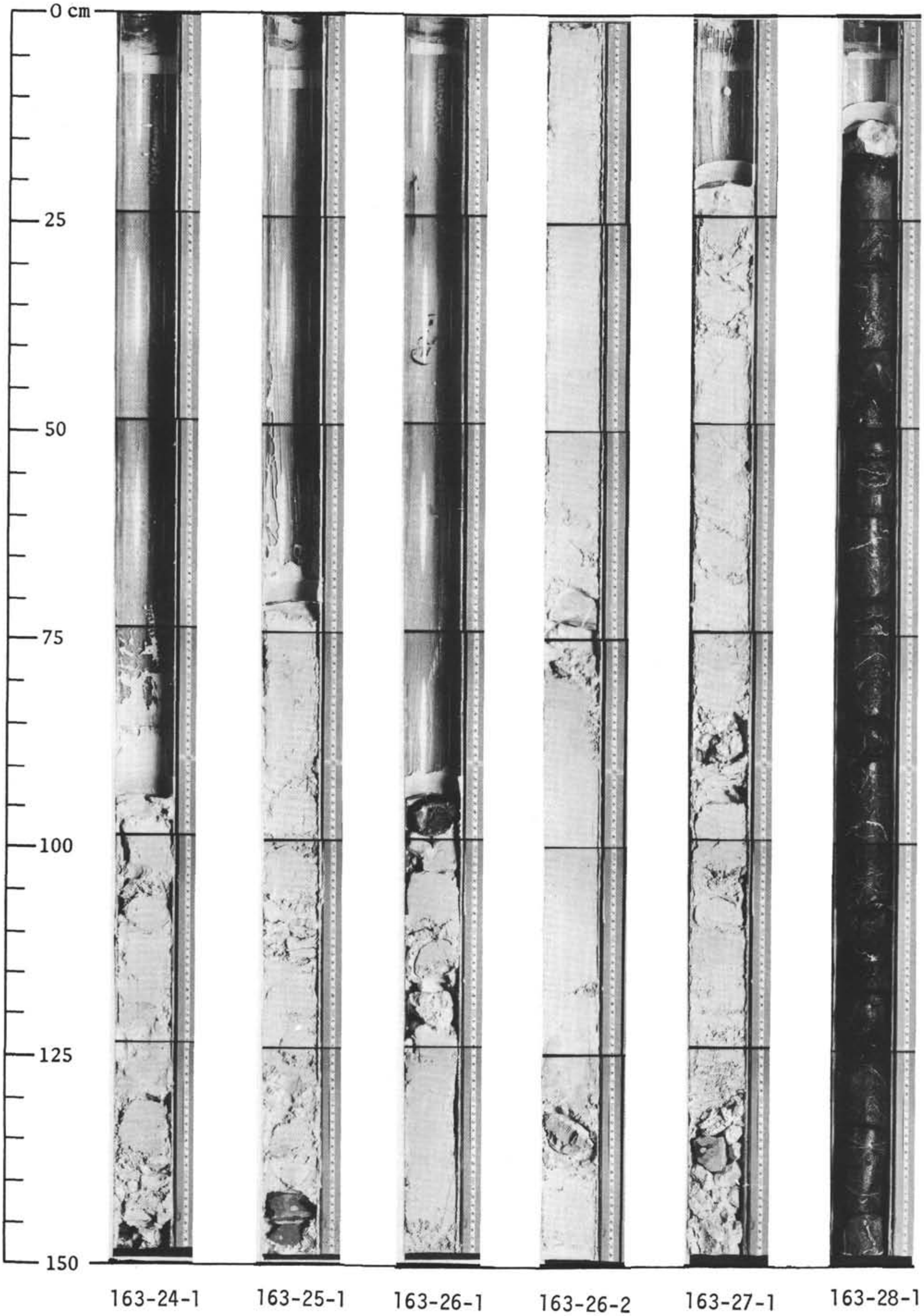
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163-26-2
163-27-1
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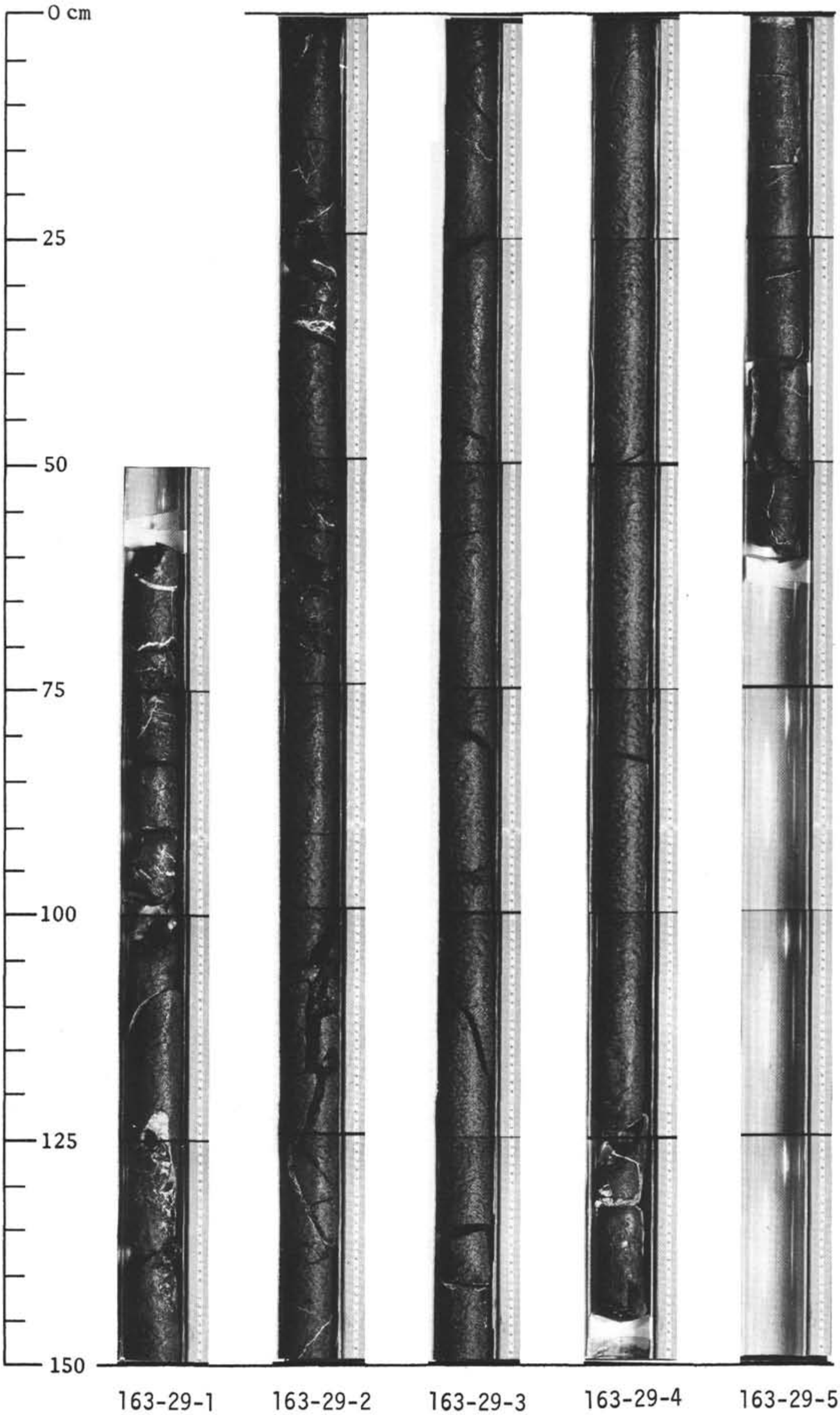
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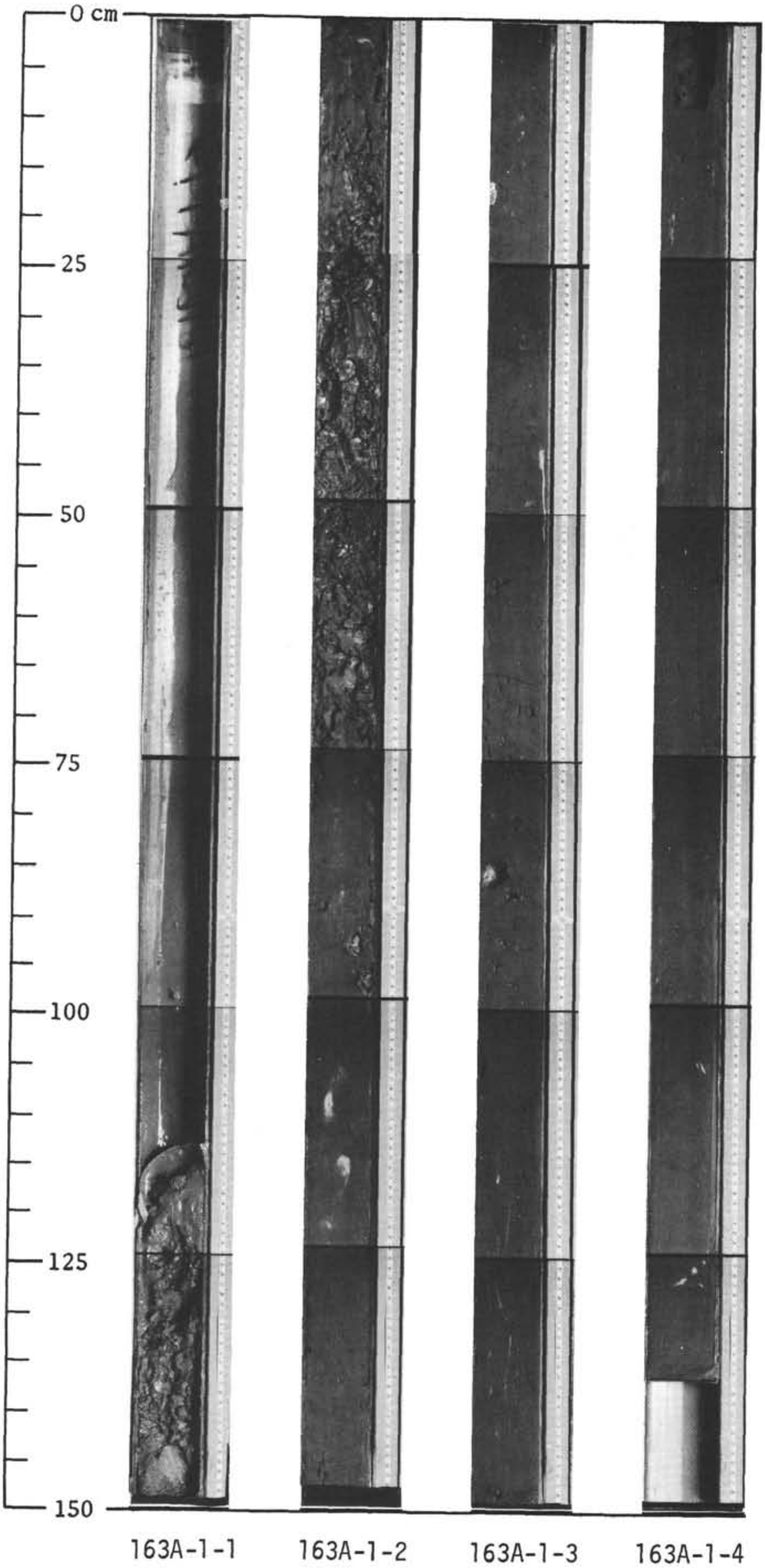
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163A-1-1
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163A-1-4