4. SITE 233

The Shipboard Scientific Party[1]

SITE DATA

Date Occupied: 13 May 1972

Date Departed: 16 May 1972

Time on Site: 48 hours, 30 minutes

Position:
Latitude: 14°19.68′N
Longitude: 52°08.11′E

Water Depth: 1839 corrected meters (echo sounding)

Bottom Felt At:
Hole 233: 1859.5 meters (drill pipe)
Hole 233A: 1858 meters (drill pipe)

Penetration: 271 meters

Holes Drilled: 2

Number of Cores: 32

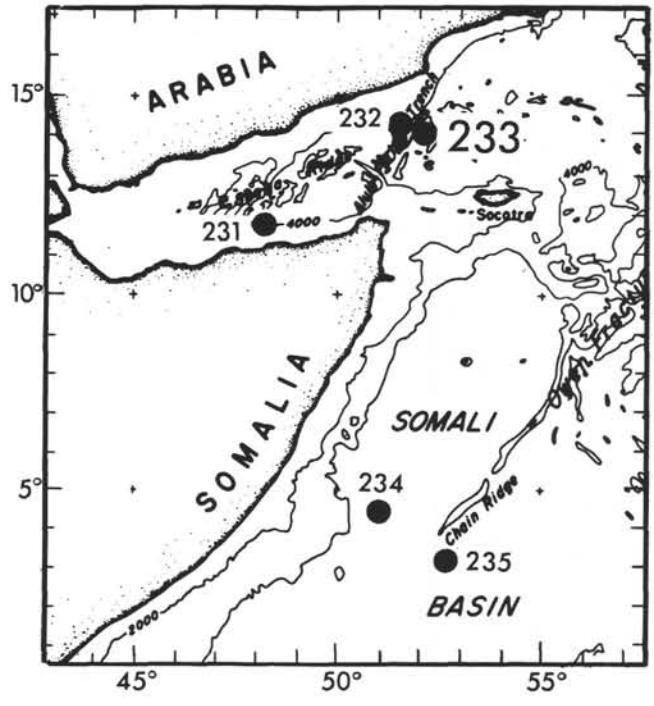
Total Length of Cored Section: 271 meters

Total Core Recovered: 173 meters

Acoustic Basement:
Hole 233: Not reached
Hole 233A:
Depth: 234.5 meters
Nature: Diabase
Inferred vertical velocity to basement: 2.1 km/sec

Age of Oldest Sediment:
Hole 233: Upper Pliocene
Hole 233A: Upper Pliocene

Principal Results: This site is located on the back slope of the eastern flank of the Alula-Fartak Trench. Two penetrations were made at the same beacon location; the second was cored to overlap the first in the interval between 168 and 176 meters so that the section is a composite. Continuous drilling and coring penetrated 271 meters of sediments into well-defined acoustic basement and possibly through it. A total of 173 meters of core was recovered. The inferred section consists of 52.5 meters of nanno ooze and 182.3 meters of micarb-bearing to micarb-rich nanno ooze. The acoustic basement material in unfragmented diabase with a minimum thickness of 8.2 meters and a maximum thickness of 37.5 meters. A total of 2.6 meters of diabase core was recovered. From subsequent marked increase in drilling speed, the drill may have penetrated through the probable sill into sediments. Diabase found wedged in the drill bit precluded core recovery of material between 243 and 271 meters, where the hole was terminated. Age of the sediments are: Pleistocene, 0-81 meters; upper Pliocene, 81 meters to base of sediment.



BACKGROUND AND OBJECTIVES

See Background and Objectives of Sites 232 and 233, Chapter 3.

OPERATIONS

Near-Site Activities

At the conclusion of sampling operations at Hole 232A, *Glomar Challenger* ran northwest while streaming the hydrophone array, came about and headed east-southeast for the 18 mile run to Site 233. (See Figure 1 for Site 232 which is based on both R.R.S. *Discovery* and D/V *Glomar*

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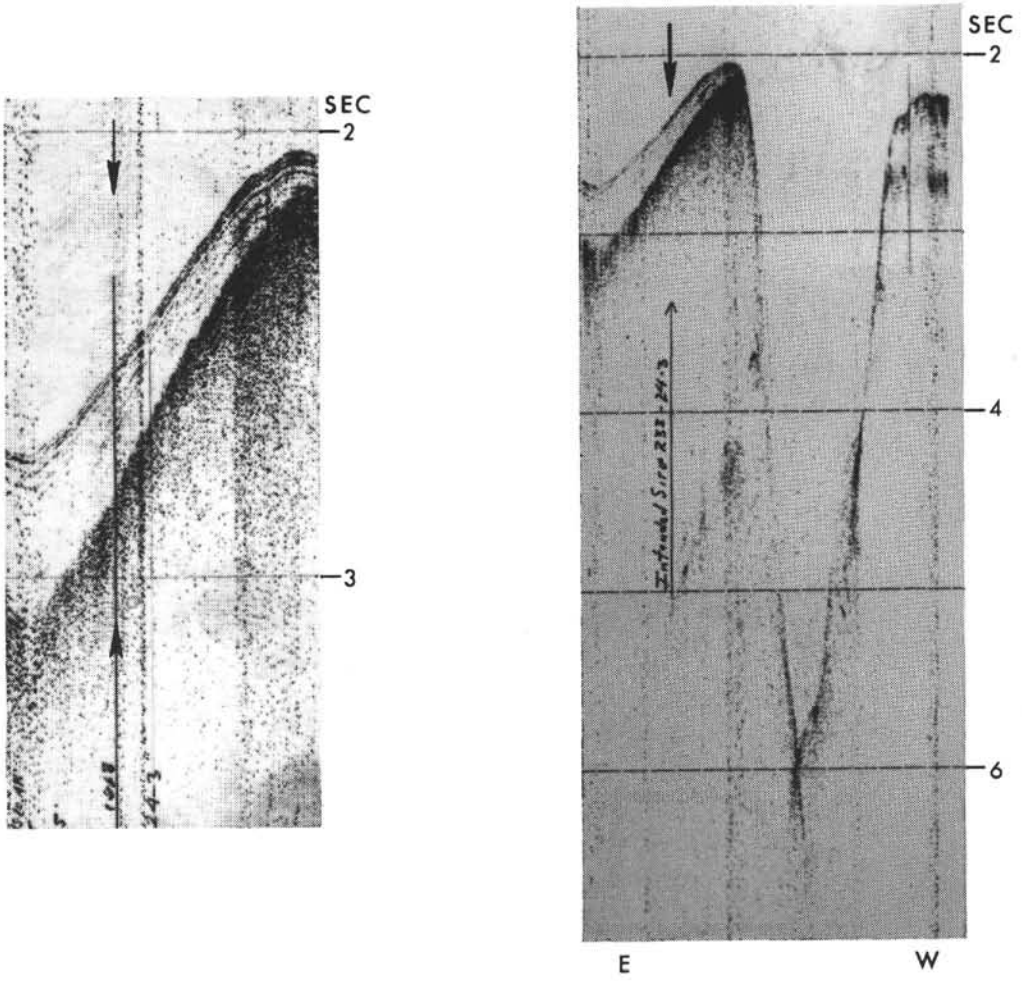

Figure 1. *Site 233: right-Alula-Fartak Trench, east-west crossing; left-expanded scale presentation of on-site profile; arrows indicate site location.*

Challenger surveys.) The magnetometer was not used on this traverse; the reflection profiler and echo sounder were employed to select the proper site. A spar buoy was dropped (1917Z, 13 May); the ship shortly thereafter doubled back and retrieved the seismic gear. The beacon was dropped 3.4 nautical miles north-northeast at Site 233 (Figure 1), in a water depth of 1839 meters (corrected).

At the close of drilling operations on Site 233, *Glomar Challenger* proceeded north-northeast to stream all gear, came about to pass near Site 233, and then ran a reflection profile nearly parallel to, and over, *Discovery's* 1967 seismic refraction profiles 6215 and 6219.

Drilling Program

The first three cores were punch cored. From Cores 3 to 13 the drill string was rotated at 35 rpm, with just enough pump to clean the clay off the bit. While retrieving Core 19, the bearing shaft in the Hycalog core barrel latch broke. A wire line overshot was lowered on the sand line in an attempt to fish out the core barrel, but this attempt failed because the bearing stub on top of the core barrel was too short. Pipe was pulled to recover Core 19 and the broken bearing shaft. Total depth was at 2035.5 meters; 176 meters were cored and 135.3 meters recovered (Table 1).

Hole 233A water depth (drill pipe) was established at 1858.0 meters and drilled to 2026.0 meters. Since the upper portion of Site 233 had already been cored and determined to be free of hydrocarbon, the first core was taken at 2026.0 to 2035.5 meters. This provided a short overlap between Holes 233 and 233A.

Diabase was encountered at 2092.5 meters. A few pieces of diabase were found in the bottom of Core 7. In Core 8, the recovery was 2.5 meters of igneous rocks. In Core 9 only 0.85 meters was recovered. The next four coring attempts had no recovery. While retrieving Core 9, a piece of diabase slipped through the core catcher and fell back to the bottom on the drill string and lodged on top of the support bearing. On the following coring attempts, the core barrel could not be latched into its coring position. An attempt to dislodge or break up the piece of diabase by dropping the center bit just prior to Core 13 was unsuccessful. Hole 233A was abandoned at 2128.5 meters.

TABLE 1
Coring Summary – Site 233

Core	Date (May 1972)	Time	Depth Below Sea Floor (m)	Depth From Drill Floor (m)	Cored (m)	Recovered (m)	Recovered (%)
Hole 233							
1	14	0529	0.0-5.0	1859.5-1864.5	5.0	5.0	100
2	14	0624	5.0-14.5	1864.5-1874.0	9.5	5.5	58
3	14	0710	14.5-24.0	1974.0-1883.5	9.5	8.0	84
4	14	0751	24.0-33.5	1883.5-1893.0	9.5	3.9	41
5	14	0834	33.5-43.0	1893.0-1902.5	9.5	7.9	83
6	14	0914	43.0-52.5	1902.5-1912.0	9.5	8.2	86
7	14	1002	52.5-62.0	1912.0-1921.5	9.5	8.7	92
8	14	1058	62.0-71.5	1921.5-1931.0	9.5	6.0	63
9	14	1202	71.5-81.0	1931.0-1940.5	9.5	9.0	95
10	14	1248	81.0-90.5	1940.5-1950.0	9.5	9.5	100
11	14	1325	90.5-100.0	1950.0-1959.5	9.5	9.5	100
12	14	1406	100.0-109.5	1959.5-1969.0	9.5	8.1	85
13	14	1506	109.5-119.0	1969.0-1978.5	9.5	8.6	91
14	14	1606	119.0-128.5	1978.5-1988.0	9.5	2.9	31
15	14	1659	128.5-138.0	1988.0-1997.5	9.5	9.5	100
16	14	1758	138.0-147.5	1997.5-2007.0	9.5	8.5	90
17	14	1904	147.5-157.0	2007.0-2016.5	9.5	3.1	33
18	14	1950	157.0-166.5	2016.5-2026.0	9.5	6.2	65
19	15	0200	166.5-176.0	2026.0-2035.5	9.5	7.2	76
Hole 233A							
1	15	1002	168.0-177.5	2026.0-2035.5	9.5	5.2+	55
2	15	1050	177.5-187.0	2035.5-2045.0	9.5	2.3	24
3	15	1138	187.0-196.5	2045.0-2054.5	9.5	8.3	87
4	15	1219	196.5-206.0	2054.5-2064.0	9.5	5.1	53
5	15	1315	206.0-215.5	2064.0-2079.5	9.5	4.8	50
6	15	1405	215.5-225.0	2079.5-2083.0	9.5	1.9	20
7	15	1516	225.0-234.5	2083.0-2092.5	9.5	7.1	75
8	15	1758	234.5-237.0	2092.5-2095.0	2.5	1.77	70
9	15	2051	237.0-243.0	2095.5-2101.0	6.0	0.85	14
10	15	2300	243.0-245.5	2101.0-2103.5	2.5	0	0
11	16	0145	245.5-254.0	2103.5-2111.5	8.0	0	0
12	16	0317	254.0-263.5	2111.5-2121.0	9.5	0	0
13	16	0431	263.5-271.0	2121.0-2128.5	7.5	0	0

LITHOLOGIC SUMMARY

Hole 233 was continuously cored from the sediment surface down to a depth of 176.0 meters. Hole 233A was cored from 166.0 down to 271.0 meters, providing 10 meters of overlap with Hole 233. The lithologic units are summarized in Table 2.

The greater part of the sequence consists of nanno ooze as shown in Table 2, and, based on the micarb content, different units can be distinguished. The colors of the sediments do not generally serve to identify different facies. However, at the bottom of the sequence a dark gray color does characterize one unit.

Unit 1 (0.0-52.5 m; Cores 1-6)

Unit 1 extends from 0 to 52.5 meters and is characterized by a variation of colors from grayish olive to pale olive and light olive gray. Calcareous nannofossils form 80 to 90 percent of the sediments, while other minor components vary from 0 to 5 percent (foraminifera, diatoms, volcanic ash, pyrite, and dolomite rhombs). Large miliolid forams occur in the upper part of the unit. The texture does not vary greatly and is characteristically 5 to 10 percent sand, 5 to 10 percent silt, and 80 to 90 percent clay. Burrows occur occasionally. Pyritiferous streaks are frequently present.

Units 2, 4, and 6 (52.5-100.0 m; 128.0–157.0 m; 169.5-206.0 m; Cores 7-11; 15-17; 19, Section 3-4A)

Units 2, 4, and 6 are found between 52.5 and 100.0 meters, 128.0 and 157.0 meters, and 169.5 and 206.0 meters, respectively. Calcareous nannofossils form 60 to 70 percent of the sediments and micarb forms 10 to 20 percent. The minor components do not differ from those found in Unit 1 although the texture is slightly coarser, being typically 5 percent sand, 10 to 25 percent silt, and 60 to 80 percent clay. Pyrite streaks are common and the odor of H_2S was very strong. Few burrows are present. Volcanic ash is rare but is present at 206.0 meters depth in a core catcher sample. Its refractive index of 1.51 is indicative of an acid composition (65 to 70% SiO_2).

TABLE 2
Lithologic Units – Site 233

Depth Below Sea Floor (m)	Unit	Lithology	Thickness (m)	Cores
	1	Grayish-olive nanno ooze	52.5	1-6
52.5				
	2	Grayish-olive micarb-bearing nanno ooze	47.5	7-11
100.0				
	3	Grayish-olive micarb-rich nanno ooze	28.0	12-14
128.0				
	4	Grayish-olive micarb-bearing nanno ooze	29.0	15-17
157.0				
	5	Grayish-olive micarb-rich nanno ooze	12.5	18-19, 2[a]
169.5				
	6	Grayish-olive micarb-bearing nanno ooze	36.5	19 3[b]-4A
206.0				
	7	Grayish-olive micarb-rich nanno ooze	23.5	5A-7A, 5
229.5				
	8	Dark gray micarb nanno chalk	5.3	7A, 5-7A, 6
234.8				
	9	Diabase	>8.2	8A-13A
271.0				

[a]Core 19, Section 2.
[b]Core 19, Section 3.

Units 3, 5, and 7 (100.0-128.0 m; 157.0-169.5 m; 206.0-229.5 m; Cores 12-14; 18-19, Section 2; 5A-7A, Section 5)

Units 3, 5,. and 7 are found between 100.0 and 128.0 meters, 157.0 and 169.5 meters, and 206.0 and 229.5 meters, respectively. Calcareous nannofossils make up from 50 to 70 percent of the sediments and micarb from 30 to 40 percent. Among the minor constituents, quartz varies from 2 to 10 percent and pyrite from 2 to 5 percent. Sponge spicules vary from 2 to 3 percent. The texture, 2 to 10 percent sand, 10 to 25 percent silt, and 60 to 80 percent clay, does not differ from that of other units. Pyrite streaks occur frequently and the H_2S odor is strong. In Unit 7 at 299.5 meters, there is a sandy layer with 60 percent quartz and 30 percent micarb.

Unit 8 (229.5-234.8 m; Core 7A, Section 6)

Unit 8, with a probable thickness of 5.3 meters, is found at the bottom of the sedimentary sequence at 234.8 meters, overlying diabase. The color becomes darker towards the bottom. Micarb varies from 40 to 50 percent, calcareous nannos are about 40 percent, quartz 5 percent, and pyrite 5 percent. The texture is 2 percent sand, 30 to 40 percent silt, and 60 to 70 percent clay. This unit is characterized by its greater hardness, suggesting baking or lithification.

Unit 9 (234.8-271.0 m; Cores 8A-13A)

Unit 9 is described in the appendix to this chapter.

Conclusions

The microfossils and lithology indicate that slight changes in conditions of sedimentation are responsible for the facies variations distinguished at this site.

1) The nanno ooze represents hemipelagic sedimentation.

2) The micarb nanno ooze probably represents hemipelagic sedimentation with a large contribution of detrital eolian material. In addition, the increase in silt fraction in Units 2 to 7 tends to support this suggestion.

3) The micarb nanno chalk has been metamorphosed by the diabase.

4) The volcanic ash layer at 206.0 meters, at the base of Unit 6, may correlate with similar layers at Sites 231 (170.0-203.0 m) and 232 (160.0-170.0 m).

BIOSTRATIGRAPHIC SUMMARY

Introduction

The 235 meters of sediment continuously cored at Site 233 represent an apparently uninterrupted sequence from Quaternary to late Pliocene. Sediments just above the diabase at 235 meters are late Pliocene with an approximate age of 3 m.y.

The sediments yielded common and well-preserved calcareous nannofossils as well as common to abundant and well-preserved radiolarian fauna throughout the section. Foraminifera are common and well to moderately preserved in the upper 100 meters, whereas they are rare and poorly preserved below this level.

Zonations of fossil groups and age assignments are summarized on the site summary form at the end of this chapter. The Pliocene/Pleistocene boundary was placed at 81 meters, between Cores 9 and 10, on the basis of nannofossil data. This is the same as for the other sites of the Gulf of Aden. However, both radiolarian and foraminiferal zonations indicate higher positions for the boundary.

Calcareous Nannoplankton

Nannofossils are common throughout the section, and there are fewer reworked forms than in other sites in the Gulf of Aden. Cores 1 and 2 recovered the *Gephyrocapsa oceanica* Zone with *Gephyrocapsa oceanica, G. caribbeanica,* and *Umbilicosphaera sibogae. Pseudoemiliania lacunosa* only occurs in Core 2. Cores 4 and 5 belong to the *Gephyrocapsa caribbeanica* Zone and contain assemblages including *Gephyrocapsa caribbeanica, Crenalithus doronicoides,* and *Pseudoemiliania lacunosa.* Assemblages typical of the *Pseudoemiliania lacunosa* Zone were found in Cores 7 through 9. The Pliocene/Pleistocene boundary based on calcareous nannofossils lies between Cores 9 and 10. Cores 10 through 14 are assigned to the *Cyclococcolithina macintyrei* Zone based on the presence of *Discoaster brouweri* and *Cyclococcolithina macintyrei.* The *Discoaster pentaradiatus* Zone is present in Cores 15 through 19 and Cores 1A through 4A and probably appears thicker due to some overlap of the two holes drilled at this site. The

assemblages include *Discoaster brouweri, D. pentaradiatus,* and *D. surculus.* The last mentioned species disappears below the top of this zone, i.e., in Core 16. Cores 5A through 7A recovered the *Discoaster tamalis* Zone with *Discoaster tamalis, D. pentaradiatus, D. surculus,* and *D. brouweri.*

Preservation: As at all of the other Gulf of Aden sites, slight etching was observed in all the assemblages. The margin of placoliths are often serrate; sometimes central areas are enlarged or central structures dissolved. *Pontosphaera* was observed throughout the section but *Scyphosphaera*, which is another delicate form, was not found.

Foraminifera

Foraminifera are the dominant component of the coarse fraction (>63μ) in Cores 1 to 6 (Unit 1), in which they are well to moderately preserved. They are common and moderately to poorly preserved in Cores 7 to 11 (Unit 2). They are rare and poorly preserved throughout the remainder of the section (Units 3 to 8) while small subangular quartz grains and radiolarians become the dominant components of the coarse fraction. The major factor responsible for the marked downward decrease in the abundance of foraminifera appears to be solution of calcium carbonate as evidenced by (1) the poorer preservation with increasing depth, (2) an increase in the relative frequency of benthic foraminifera with increasing depth, and (3) an increase in the relative frequency of radiolarians with increasing depths. Planktonic foraminifera, which are less resistant to solution than calcareous benthics, comprise usually more than 80 percent of the total foraminiferal fauna in the upper 52 meters (Cores 1 to 6) and constitute only 30 to 70 percent of the fauna in the remainder of the section. These trends are similar to those observed at Site 232. At both Sites 232 and 233, at water depths of 1755 and 1860 meters, respectively, calcium carbonate solution is significant in the late Pliocene and remains to be explained.

The interval Core 1 to Core 3, Section 2 is assigned to the Quaternary (N.23–N.22), as indicated by the presence of *Globorotalia truncatulinoides*, and the remainder of the section, which contains *Globorotalia tosaensis* only, is assigned to the late Pliocene Zone N.21. Several foraminiferal events correlate with similar events in the two other sites of the Gulf of Aden. The lowest occurrence of *Globigerina tenella* was found in Core 3, Section 2 at the same level as the base of *Globorotalia truncatulinoides*; an horizon with dextrally coiled *Globorotalia tumida tumida* was observed in Core 5, CC; the highest occurrence of *Globorotalia limbata* lies in Core 8, Section 3; and the highest appearance of *Globoquadrina altispira* s.s. occurs in Core 2A, Section 2 (the occurrence of this species in Core 8, Section 3 is probably due to displacement).

Radiolarians

In all samples examined from Holes 233 and 233A, radiolarians are common to abundant and moderately to excellently preserved.

The base of the Quaternary is between 233-5-6 and 233-7-5; the base of the *Pterocanium prismatium* Zone is between 233-16-6 and 233-18-5; and the uncertain base of the *Spongaster pentas* Zone appears to lie below 233A-4-4.

SEDIMENT ACCUMULATION RATES

Average accumulation rates were calculated as follows:

Series	Thickness (m)	Average Accumulation Rate (m/m.y.)
Pleistocene	81.0	45.0
Upper Pliocene	153.5	117.1

The Pleistocene accumulation rate is comparable to the values obtained at Sites 231 and 232 for this time interval, while the upper Pliocene rate is approximately twice as high as those at the other two Gulf of Aden sites.

PHYSICAL PROPERTIES

Bulk Density and Porosity

The bulk density of the 229.5 meters of nanno ooze in lithologic Units 1 through 7 has a smoothly decreasing trend from 1.78 g/cm^3 at 20 meters to 1.70 g/cm^3 at 229 meters (Figure 2). A corresponding porosity increase from 55 to 60 percent is present over this interval. These trends are contrary to those expected for hemipelagic muds undergoing normal consolidation processes. They may be partially explained as: (1) the cored sediment being disturbed during drilling, resulting in higher porosity values, or (2) the 229.5 meters of nanno ooze might be slightly "underconsolidated," i.e., a slight excess pore water pressure may exist in situ. This would occur if the sedimentation rate was sufficient to impede the upward movement of pore water. The latter seems a justifiable explanation for the upper Pliocene section since Site 233 had approximately twice the sedimentation rate in the upper Pliocene as compared to Site 232.

Unit 8 (micarb nanno chalk) is characterized by a bulk density of 1.96 g/cm^3 and a corresponding porosity of 44 percent. These values are attributed to the "baking" action of the underlying diabase intrusive (Unit 9). Bulk densities of the diabase rock were obtained by the GRAPE device on block samples approximately 1.5 cm × 1.5 cm × 2.5 cm. Bulk densities of the diabase samples measured in the vertical direction (long axis) range from 2.79 to 2.85 g/cm^3 and those measured in the horizontal direction range from 2.80 to 2.82 g/cm^3 (Table 3).

TABLE 3
Bulk Density of Diabase – Site 233

Sample[a]	Bulk Density (g/cm^3)		Velocity (km/sec)		Rock Description
	Vertical	Horizontal	Vertical	Horizontal	
9-1 (1)	2.85	2.80	5.07	5.19	Diabase
9-1 (2)	2.79	2.82	4.99	5.11	Diabase
13-1 (1)	2.82		4.76		Diabase
13-1 (2)	2.81		4.81		Diabase

[a]Figures in parentheses are the sequence of rocks in the section.

Sonic Velocity

The velocity profile of the nanno ooze shows a smooth increase from 1.53 km/sec near the surface to 1.61 km/sec

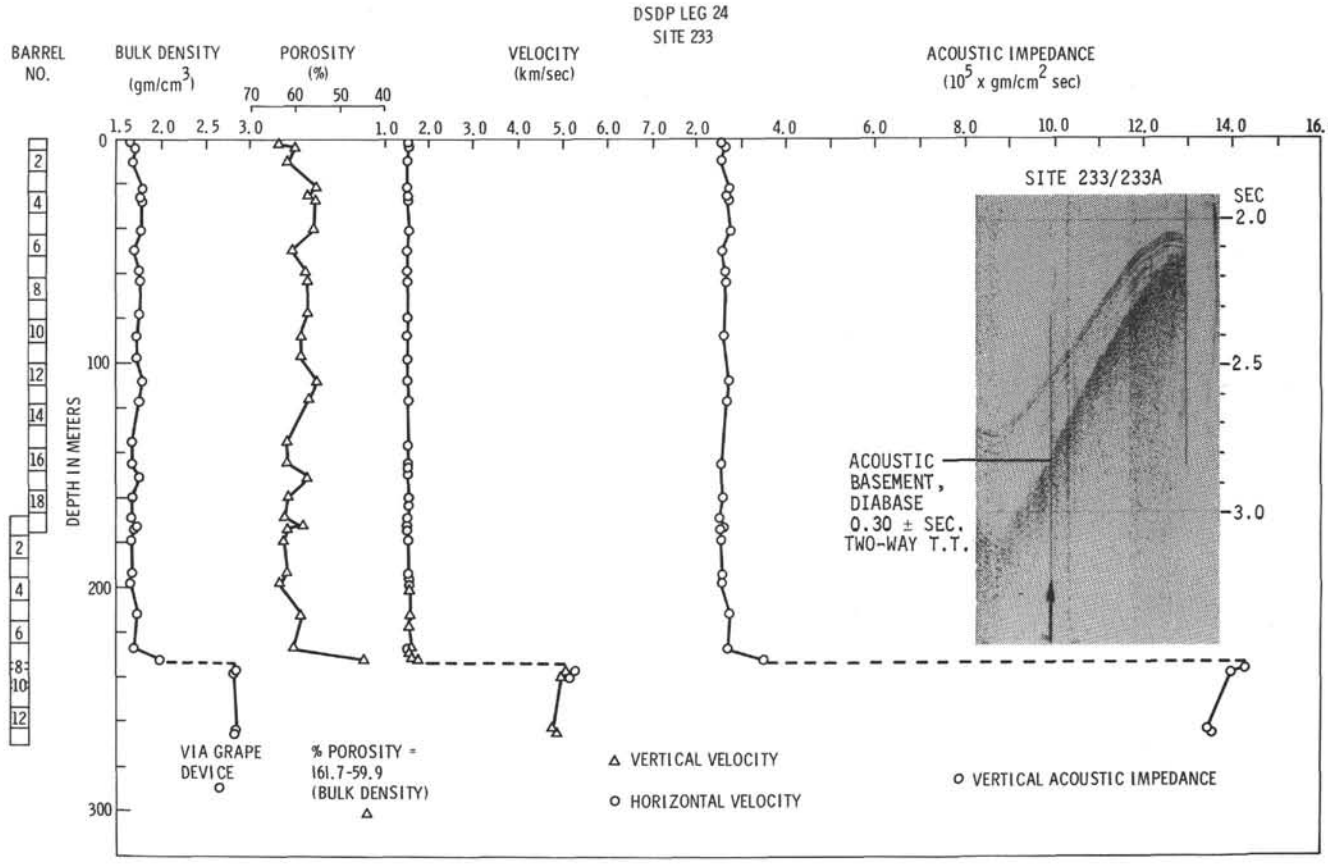

Figure 2. *Physical properties, Site 233.*

just above Unit 8 (Figure 2). The latter material (micarb nanno chalk) is characterized by a velocity of 1.78 km/sec. This relatively high velocity is probably also due to the "baking" action of the diabase intrusive that caused a decrease in porosity.

The major velocity change occurs in the diabase rock. Four randomly chosen basalt samples from Cores 9 and 13 of the second hole have vertical velocities ranging from 4.76 to 5.07 km/sec and horizontal velocities ranging from 5.11 to 5.19 km/sec (Table 3). Significant velocity anisotropism is not apparent in the measurements.

A maximum one-way travel time for seismic energy traveling from the sediment-water interface to the diabase basement can be calculated as follows:

Depth Interval (m)	Average Velocity (km/sec)	Travel Time (sec)
0-200	1.53	131
200-229	1.58	0.018
229-235	1.78	0.003
		0.152

Thus, maximum one-way travel time at Site 233 for the basement reflection should be 0.152 sec.

Acoustic Impedance

The acoustic impedance profile appears to mirror the bulk density trend from 20 to 229 meters, decreasing from 2.75 to 2.70 g/cm^2 sec. The dominant reflector is represented by the diabase rock, Unit 9, which has an average vertical velocity of 4.91 km/sec and an average bulk density of 2.82 g/cm^3. Thus, the acoustic impedance is about 13.8 $\times$ 10^5 g/cm^2 sec or 5.1 times that of the overlying sediment layer. The previously calculated travel time for the basement reflection (0.152 sec one-way or 0.304 sec two-way travel time) does agree readily with the ±0.30 sec two-way travel time determined from the seismic reflection profile in Figure 2. The latter time, however, may vary from 0.24 to 0.30 sec two-way travel time, depending upon the actual location of Hole 233A on the seismic profiles.

INTERSTITIAL WATER CHEMISTRY

Depth below the sediment-water interface, salinity, *p*H, and alkalinity are recorded in Table 4 for pore waters squeezed from core samples at Site 233. In Table 5 are recorded data on water content, porosity, and bulk density.

Salinity: Bottom seawater salinity at this site is 35.0°/$_{oo}$ (Wyrtki, 1971). Salinity distribution with depth is shown in Figure 3. Salinities decrease over the interval 5 to 80 meters and increase between 80 and 230 meters. The total variation is close to 3°/$_{oo}$. This variation could be caused entirely by partial reduction of $SO_4^{=}$ and changes in alkalinity and cation concentrations.

TABLE 4
Interstitial Water Chemistry – Site 233

Depth Below Sea Floor (m)	Salinity (°/oo)	pH[a]	Alkalinity (meq/kg)
Surface seawater	36.3		
4	36.3	7.38.(7.45)	2.44
23	34.6	7.28 (7.01)	5.86
42	34.1	7.10 (6.90)	7.62
61	35.5	7.03 (6.79)	5.44
80	33.6	7.08 (7.02)	7.17
108	33.8	6.91	5.29
137	34.4	7.42	1.81
162	34.9	6.93 (6.32)	3.36
193[b]	35.8	6.93	2.64
228[b]	35.8	7.29	1.36

[a] *p*H values in parentheses are corrected (see Chapter 1 Explanatory Notes).
[b] These samples are from Hole 233A, others are from Hole 233.

TABLE 5
Water Content, Porosity, and Bulk Density of Sediments – Site 233

Core, Section, Top of Interval (cm)	Water (%)	Porosity (%)	Density (g/cm^3)
Hole 233			
1-2, 20	13.34	20.44	1.5320
1-2, 77	42.02	66.84	1.5908
1-2, 120	39.48	65.61	1.6619
1-4, 66	34.53	60.29	1.7458
1-4, 96	36.21	65.21	1.8008
1-4, 132	40.91	71.63	1.7808
2-4, 41	38.52	57.95	1.5042
2-4, 75	40.56	71.89	1.7126
2-4, 132	37.70	68.21	1.8092
3-5, 52	36.61	63.53	1.7353
3-5, 95	39.45	69.00	1.7490
3-5, 134	32.59	58.79	1.8037
4-2, 27	36.93	62.71	1.6975
4-2, 90	36.74	66.24	1.8029
4-3, 101	36.44	67.61	1.8553
4-3, 135	40.26	68.79	1.7084
5-4, 23	36.37	65.29	1.7950
5-4, 113	42.17	71.39	1.6929
5-5, 94	42.28	72.42	1.7232
5-5, 117	31.03	57.58	1.8558
6-5, 42	36.34	63.89	1.7584
6-5, 100	39.87	67.89	1.7029
7-5, 20	34.05	61.55	1.8076
7-5, 120	35.59	64.00	1.7982
7-3, 132	40.79	71.97	1.7642
8-2, 74	42.15	75.08	1.7813
8-2, 117	35.09	64.68	1.8124
8-3, 88	36.75	66.65	1.8136
9-6, 58	37.47	67.13	1.7915
9-6, 122	37.15	65.71	1.7687
9-6, 134	32.61	60.88	1.8669
10-4, 126	35.82	67.16	1.8749
10-5, 11	35.43	64.09	1.8089
10-5, 120	37.32	64.55	1.7296
10-6, 108	39.65	67.63	1.7056
11-3, 100	36.79	69.29	1.8833
11-6, 82	37.86	68.67	1.8137
11-6, 106	38.92	69.15	1.7767
12-5, 110	36.05	66.63	1.8482
12-6, 75	39.66	69.52	1.7528
12-6, 118	38.17	70.05	1.8352
13-5, 134	36.98	66.71	1.8039
13-6, 83	39.15	68.57	1.7514
13-6, 102	38.91	69.09	1.7751
15-1, 12	43.28	71.89	1.6610
15-6, 60			
15-6, 117	38.48	67.34	1.7500
16-5, 90	37.37	64.78	1.7334
16-6, 68	37.94	69.09	1.8210
17-2, 64	37,68	64.39	1.7088
18-3, 82	38.15	66.31	1.7381
18-5, 62	39.58	68.58	1.7321
18-5, 92	36.98	66.09	1.7871
19-2,78	40.10	67.42	1.6812
19-5, 81	37.68	65.16	1.7282
15-1, 99	43.65		
18-4, 68	45.97		
Hole 233A			
1-2, 91	38.71	69.20	1.7876
1-4, 36	36.52	66.52	1.8214
2-2, 94	35.95	66.28	1.8436
3-5, 78	38.22		
4-2, 124	39.26		
4-3, 75	38.49		
4-3, 109	37.87		
5-2, 123	37.30		
5-4, 11	39.11		
6-1, 58	35.44		
7-2, 63	32.41		
7-3, 137	34.60		
7-4, 132	28.73		
7-5, 64	24.96		

pH and Alkalinity: *p*H measurements were made as at Site 232. The distribution of *p*H and alkalinity with depth is shown in Figure 4. *p*H shows no trend and varies between 7.4 and 6.9. Alkalinity values show the same general trend found at Sites 231 and 232; a large increase in the upper sediment section followed in depth by a decrease to values below that of seawater.

Water Content, Porosity, and Bulk Density: Water content averages 35-40 percent, porosity 60-70 percent, and bulk density 1.7-1.9 g/cm^3, with no strong trend being observed of any parameter with depth.

CORRELATION OF SEISMIC REFLECTION PROFILES AND LITHOLOGIES

Both the seismic reflection profile and the structure it portrays are simple on this eastern margin of the Alula-Fartak Trench. Here again, an acoustically transparent layer overlies acoustic basement, but, unlike the western margin, there is no obvious evidence of either sea-floor or basement deformation. The possible reflector mid-depth in the transparent layer (Figure 5) proves to be part of the reflected-source pulse.

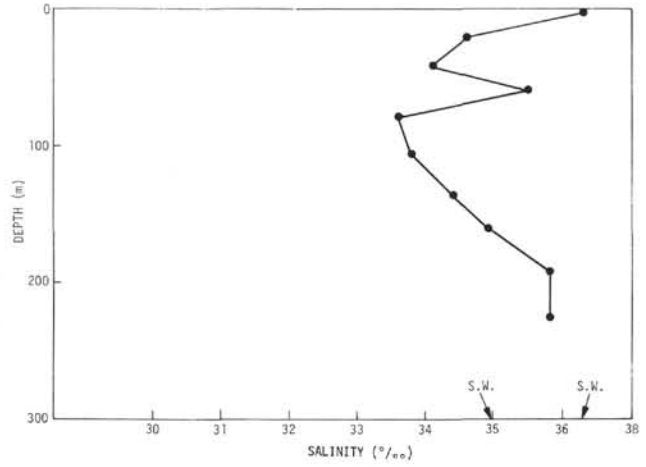

Figure 3. *Interstitial pore water salinities, Site 233.*

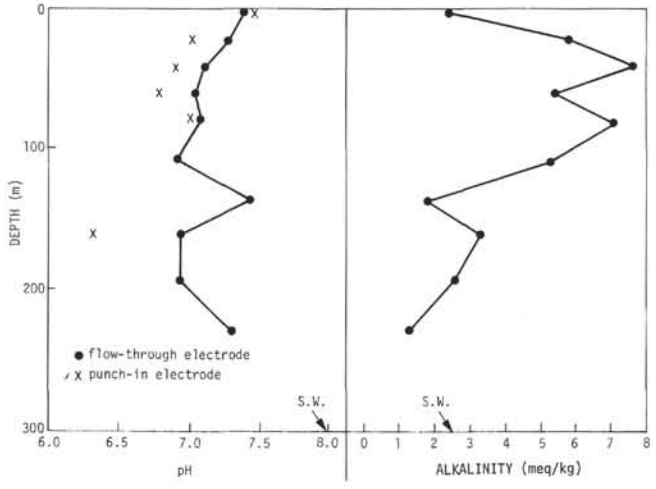

Figure 4. *pH and alkalinity of interstitial pore water, Site 233.*

The acoustically transparent layer correlates to the nanno ooze and the acoustic basement to the diabase. Agreement between the observed reflectors and the lithologic section is excellent. Also excellent is the agreement between the computed and observed seismic sections based on the measured physical properties. Laughton and Tramontini (1969) also reported a reversed refraction profile on the backslope of this ridge, its northeast end about 10 miles away. Considering the slope and distance, the site results of 4.91 km/sec average basement velocity and 235 meters depth are in excellent agreement with the reported 4.81 km/sec at 350 meters depth.

SUMMARY, CONCLUSIONS, AND SPECULATIONS

Site 233 is located at a depth of 1839 meters on the back slope of the eastern flank of the Alula-Fartak Trench. The Alula-Fartak Trench lies at the eastern entrance to the Gulf of Aden and has a north-northeast south-southwest direction (see Figure 1).

Two penetrations were made at the same beacon location. Hole 233 was continuously cored from the

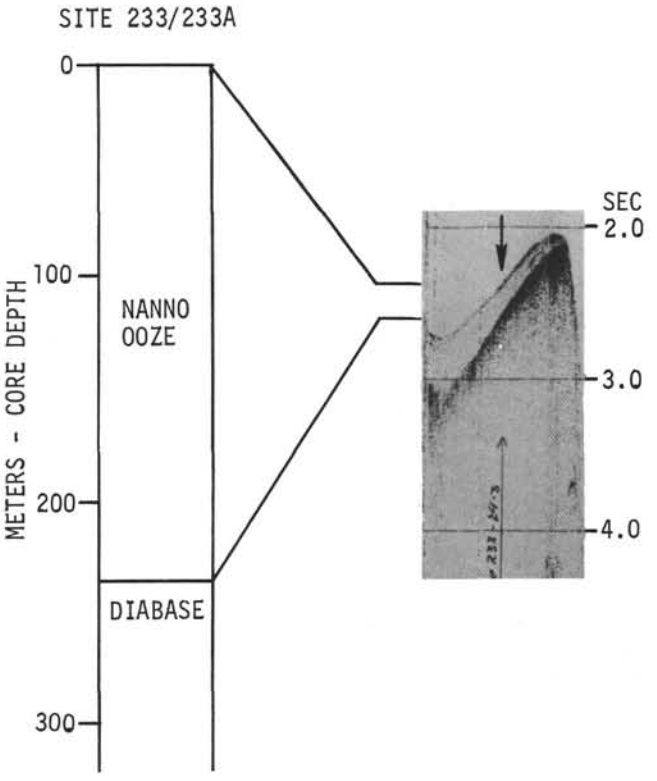

Figure 5. *Site 233, arrow indicates site location on backslope of eastern margin.*

sediment surface to a depth of 176 meters; Hole 233A was cored from 166 meters down to 271 meters, providing 10 meters of overlap with Hole 233. A total composite section of 235 meters was cored before acoustic basement was reached; this comprised diabase with a minimum thickness of 8.2 meters and a maximum thickness of 37.5 meters. In the final core, increased drilling rates possibly indicate further soft sediments below the diabase sill.

The greater part of the sedimentary sequence consists of nanno ooze, and, based on variations in the micarb percentage, it has been possible to distinguish seven units. Unit 1 and the upper part of Unit 2 are Pleistocene in age and comprise nanno ooze and micarb-bearing nanno ooze, respectively (Figure 1). Sedimentation during the Pleistocene was dominated by calcareous nannofossils and shows an average rate of 45 m/m.y. From 0 to 80 meters, interstitial pore water salinity decreases from 36.3 °/₀₀ to 33.6 °/₀₀. Microfossil content and lithology indicate that through the Pleistocene the sedimentation pattern was constant, being dominated by intense biogenic activity, with minor amounts of terrigenous material.

From Unit 2 through Unit 7 (Cores 233-7 through 233A-7; 52.5 to 229.5 m) there is an alternation of micarb-bearing silty nanno ooze and micarb-rich silty nanno ooze. A volcanic glass-rich layer is found at 206 meters at the base of Unit 6, while a quartzose sandy layer is found at 209.5 meters in Unit 7. These sediments are Pliocene in age and accumulated with an average high rate of 117.1 m/m.y. yr. Planktonic foraminifers become rare throughout the

lower part of the section. Interstitial pore water salinity increases between 80 and 230 meters to a maximum of 35.8 °/₀₀, close to the basement.

Throughout the sedimentary section, bulk density exhibits a smoothly decreasing trend from 1.78 g/cm^3 to 1.70 g/cm^3 with increasing depth, while the corresponding porosities increase from 55 to 60 percent (see Figure 2). This trend may either be caused by simple disturbance during drilling, or the sediment at depth may possibly be unconsolidated. The velocity profile shows a smooth increase from 1.53 km/sec, near the surface, to 1.61 km/sec just above Unit 8. Units 2 through 7 probably represent the results of hemipelagic sedimentation with a varying contribution of detrital eolian material. The acid volcanic ash at the base of Unit 6 may correlate with volcanic ashes found at Sites 231 and 232. However, this correlation does not entirely agree with biostratigraphical correlations. The quartzose sandy layer in Unit 7 may correlate with the sandy layers of Unit 1 of Site 232 and suggests the opening of the Alula-Fartak Trench to post date the lower Pliocene.

Between 229.5 and 234.8 meters (Core 233A-7) the sediment overlying the acoustic basement was recovered. The sediment of Unit 8 is a micarb nanno chalk. It is fairly hard, suggesting baking by the sill. The bulk density is 1.96 g/cm^3 with a corresponding porosity of 47 percent, the sonic velocity is 1.78 km/sec for this unit.

The diabase was found at a depth of 237.5 meters. This is a greenish-gray, dense, massive, fine-grained rock with sparse tiny fractures. The petrographic characteristics show that the diabase is typical of intrusive dikes or sills of small thickness and intermediate depth. Minor alteration suggests that the rock is not very old. Physical properties show this to be the dominant reflector of the sequence, with an average vertical velocity of 4.91 km/sec and an average bulk density of 2.82 g/cm^3.

Sediments and basement rock recovered at both sites of the Alula-Fartak Trench may enable the following general problems to be solved:

1) Paleoclimatology and paleooceanography of the Gulf of Aden since later Tertiary times.

2) Time of opening of the Alula-Fartak Trench.

3) Nature and age of basement at both sites (see Figure 1.)

The data for the western site are discussed elsewhere. Site 233 gave a positive result for point 1, where preliminary data show a marked downward decrease in the abundance of foraminifers. This is due to solution of calcium carbonate, evidenced by poorer preservation with increasing depth, and by an increase in the relative frequency of benthic foraminifers with increasing depth. Point 2 may be discussed, while point 3 was not achieved because the diabase found at the base of the Hole 233 is presumably not true basement.

REFERENCES

Laughton, A. S. and Tramontini, G., 1969. Recent studies of the crustal structure in the Gulf of Aden: Tectonophysics, v. 8, p. 359-375.

Wyrtki, K., 1971. Oceanographic Atlas of the International Indian Ocean Expedition: Washington (U. S. Government Printing Office), 531 p.

APPENDIX A
PRELIMINARY OBSERVATIONS ON THE IGNEOUS ROCKS SAMPLED AT HOLE 233A

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At Hole 233A, drilling encountered an igneous body at a depth of 234.5 meters below the sea floor. Although penetration was continued for another 36.5 meters, to hole termination at 271 meters, only 2.6+ meters of igneous rock (all from the first two cores attempted) were recovered. The failure to recover samples from the lower 28 meters drilled was explained on recovery of the bit; several stubby fragments of diabase were wedged athwart the opening. Prior to cessation of drilling because of zero sample recovery, penetration was rapid, suggesting nonigneous horizons were being traversed, but the lower boundary of the diabase body was not determined. The visual core description columns summarize the observations, and the "location" of samples.

Megascopic Description

The diabase recovered in two cores of Hole 233A is a dense greenish-gray, massive rock with sparse tiny fractures and a crystalline texture clearly apparent on freshly broken surfaces. Near its upper boundary are irregular vugs or cavities up to 10 cm in length; their walls are encrusted with aggregates of calcite-chlorite crystals.

Preliminary Petrographic Description

Examination of four thin sections, from the upper part of 233A-9-1 and from the fragments subsequently extricated from the bit, suggest the rock has a uniform doleritic (diabasic) texture, and it is equigranular over the interval sampled, so far as can be surmised. The texture consists of serrated to euhedral prismatic crystals of fresh plagioclase 1.0-1.5 mm long and smaller (0.2-0.3 mm) subhedral grains of augite, with chloritized and carbonatized felted aggregates comprising 20-25 percent of the rock (Figure 6, typical section).

Plagioclase displays a maximum extinction angle of 30°-36° for albite twinning ⊥ 010 zone; it is labradorite, An_{55-60}. A minor change in composition, to andesine An_{40}, occurs at the margins of larger crystals.

Augite, colorless here, has an extinction angle $c \wedge Z$ = 46°-52°. Individual grains of hypersthene, also colorless but with parallel extinction, are found in several samples.

An **opaque mineral**, possibly ilmenite, in skeletal crystals or amorphous masses, make up 2-3 percent of the diabase.

Alteration: Chlorite, pleochoric from green to pale yellow green, is present in fibrous aggregates. Isolated serpentine masses have the customary habit, a 0.2-0.5 mm size, and apparently are pseudomorphic after olivine.

The petrographic characteristics of the diabase recovered at Hole 233A are typical of intrusive sills or dikes of little thickness and intermediate depth. Furthermore, the minor degree of alteration apparent suggests that in geological terms this sill(?) is of no great age.

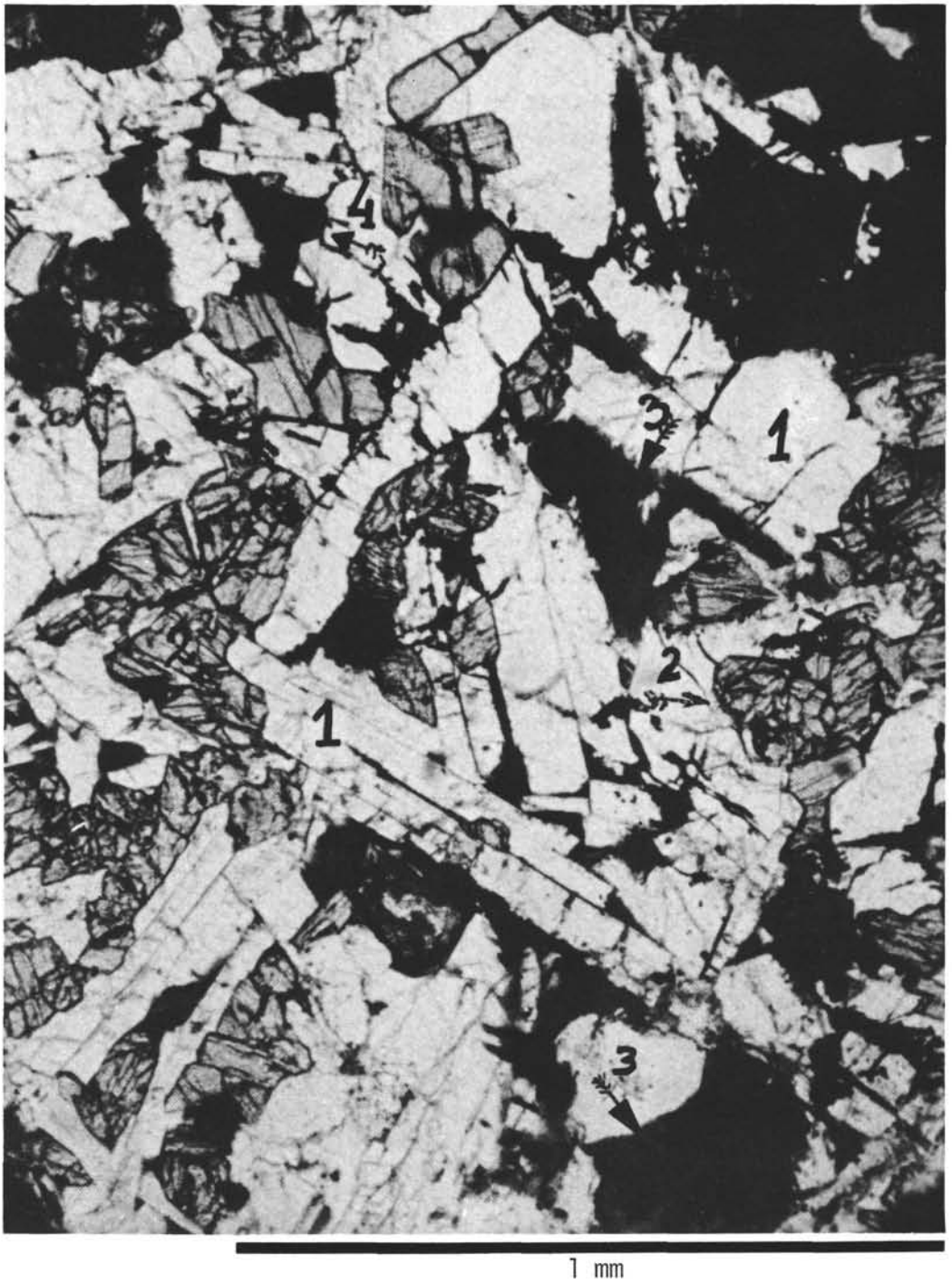
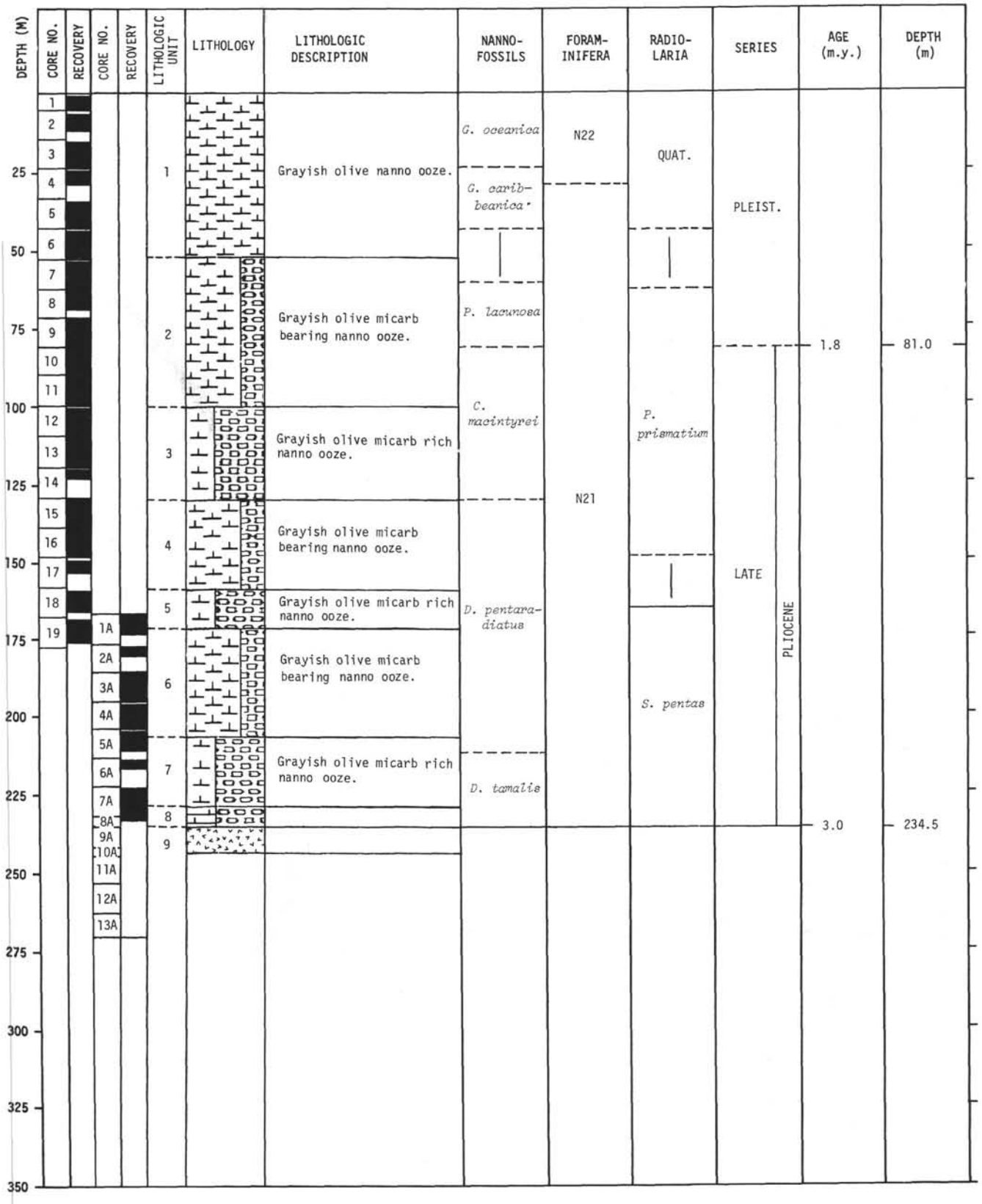


Figure 6. *Typical thin section of Site 233 diabase:* (1) *plagioclase*, (2) *pyroxene*, (3) *glass?*; (4) *opaques.*


DEPTH (M)
CORE NO.
RECOVERY
CORE NO.
RECOVERY
LITHOLOGIC UNIT
LITHOLOGY
LITHOLOGIC DESCRIPTION
NANNO-FOSSILS
FORAM-INIFERA
RADIO-LARIA
SERIES
AGE (m.y.)
DEPTH (m)
Grayish olive nanno ooze.
Grayish olive micarb bearing nanno ooze.
Grayish olive micarb rich nanno ooze.
Grayish olive micarb bearing nanno ooze.
Grayish olive micarb rich nanno ooze.
Grayish olive micarb bearing nanno ooze.
Grayish olive micarb rich nanno ooze.
G. oceanica
G. carib-beanica
P. lacunosa
C. macintyrei
D. pentara-diatus
D. tamalis
N22
N21
QUAT.
P. prismatium
S. pentas
PLEIST.
LATE
PLIOCENE
1.8
3.0
81.0
234.5

Site 233 Hole Core 1 Cored Interval: 0.0-5.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLEISTOCENE	QUATERNARY N23-N22 Gephyrocapsa oceanica	C/G	A/G A/G A/G	A/G	1 2 3 4 Core Catcher	0.5 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2); in the upper part of 1-2 some grayish yellow green (5GY7/2) lenses. Pale olive (10Y6/2) from 1-3-0. A few pyrite streaks. Smear 1-3-90 Sand 10-15% Nannos 80-90% Quartz 5% Silt 10% Forams 5% Dolo. Rhombs 1% Clay 70-80% Rads <1% Sponge Spic. <1% Thin sandy lens (grayish olive 10Y4/2) at 1-3-125, sandy horizon (grayish yellow green (5GY7/2) 1-3-140 to 1-4-50. Light olive gray (5Y5/2) grading to pale olive (10Y6/2) at 1-4-80 and to grayish yellow green (5GY7/2) at 1-4-120. Smear 1-4-140 Sand 5-10% Nannos 80-90% Quartz 2- 3% Silt 5-10% Forams 3- 5% Clay 80-90% Diatoms 2- 3%

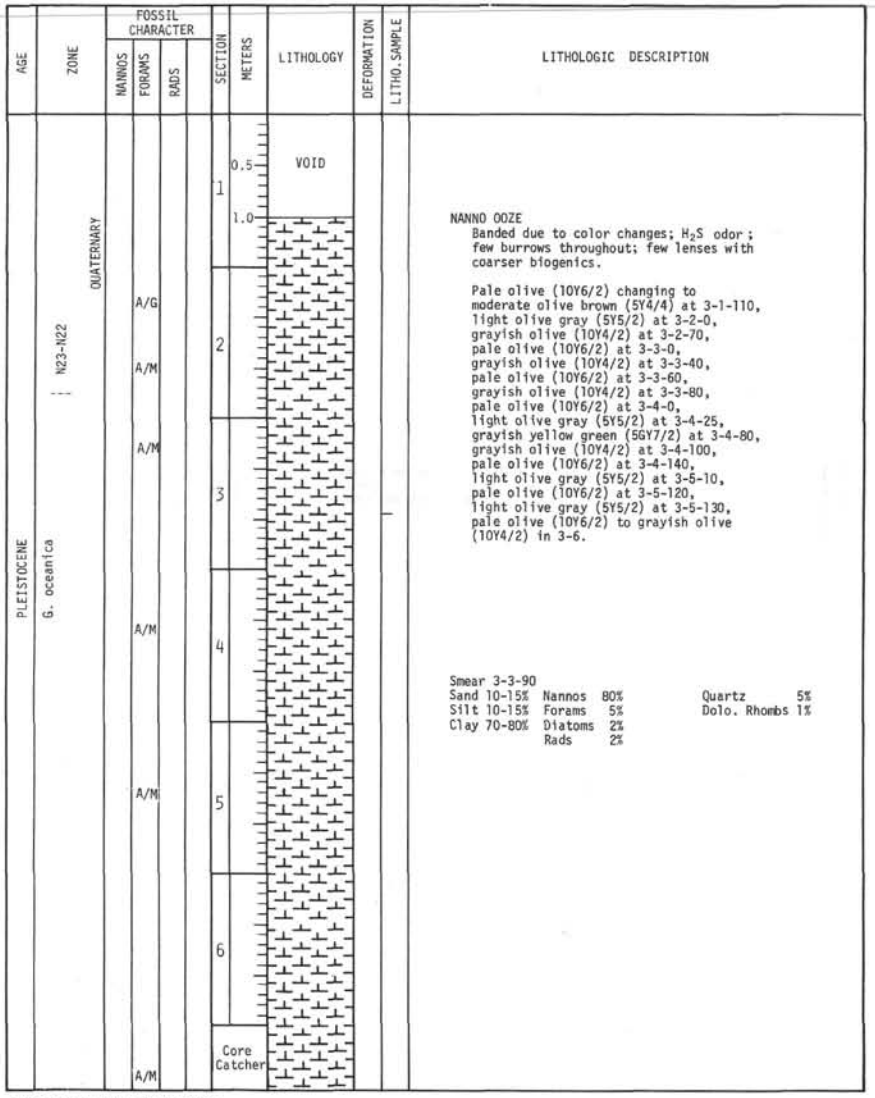
Explanatory notes in chapter 1

Site 233 Hole Core 2 Cored Interval: 5.0-14.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLEISTOCENE	QUATERNARY N23-N22 C. oceanica	C/G	A/G A/M A/M	F/M	1 2 3 4 Core Catcher	0.5 1.0	VOID		GZ, C	NANNO OOZE Grayish olive (10Y4/2) changing to dusky yellow green (5GY5/2) at 2-1-80, pale olive (10Y6/2) at 2-1-90, yellowish gray (5Y7/2) at 2-1-100, pale olive (10Y6/2) at 2-1-110, dusky yellow (5Y6/4) at 2-2-0, moderate olive brown (5Y4/4) at 2-2-40, pale olive (10Y6/2) at 2-2-50. Thin sandy horizon at 2-1-80 to 90. Some burrows and pyrite stripes throughout. light olive gray (5Y5/2) from 2-3-0 changing to pale olive (10Y6/2) at 2-3-30, light olive gray (5Y5/2) at 2-3-100, pale olive (10Y6/2) at 2-3-125, light olive gray (5Y5/2) at 2-4-0, pale greenish yellow (10Y8/2) at 2-4-25, light olive gray (5Y5/2) at 2-4-35, pale greenish yellow (10Y8/2) at 2-4-80, moderate olive brown (5Y4/4) at 2-4-90, dusky yellow green (5GY5/2) in 2-cc. Grain Size Sand 12% Silt 44% Clay 46% H_2S odor. $CaCO_3$ 66%

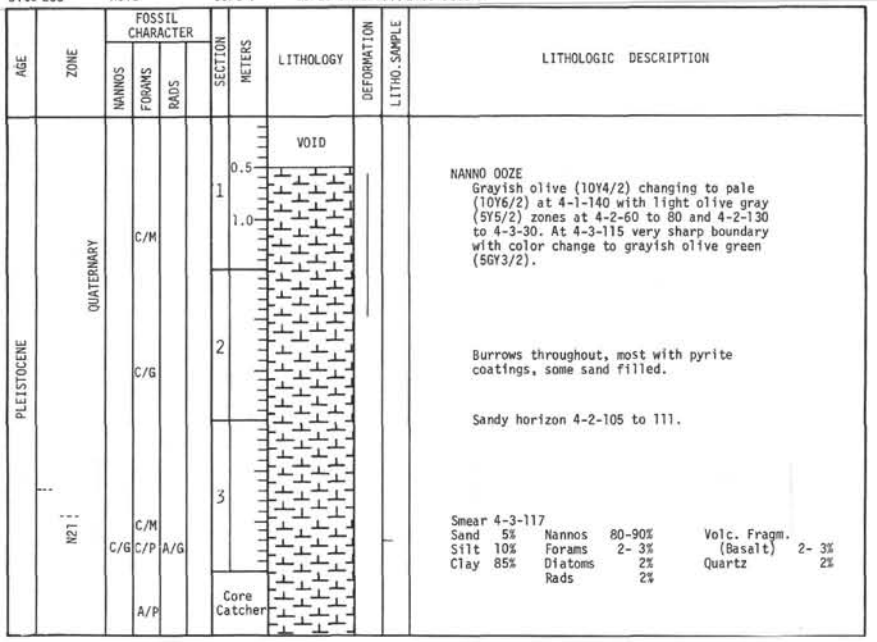
Explanatory notes in chapter 1

Site 233 Hole Core 3 Cored Interval: 14.5-24.0 m



Explanatory notes in chapter 1

Site 233 Hole Core 4 Cored Interval: 24.0-33.5 m



Explanatory notes in chapter 1

Site 233 Hole Core 5 Cored Interval: 33.5-43.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLEISTOCENE	QUATERNARY N21 G. caribbeanica	C/G	A/M C/G A/M	A/G	1 2 3 4 5 6 Core Catcher	0.5 1.0	VOID		GZ, C GZ, C	NANNO OOZE Light olive gray (5Y5/2) grading to grayish olive (10Y4/2) at 5-2-40 and back to light olive gray (5Y5/2) in 5-3. Some burrows in 5-3. H_2S - odor . Smear 5-3-80 Sand 5% Nannos 90% Quartz 2% Silt 10% Diatoms 2% Dolo. Rhombs 2% Clay 80-90% Rads 2% Pale olive (10Y6/2) zones at 5-4-20 to 70, 5-5-20 to 40, 5-6-15 to 20, 5-6-70 to 80, 5-6-125 to 5-cc. Burrows sometimes pyrite coated. $CaCO_3$ 49% 44% Sandy horizon 5-5-110 to 120 Smear 5-5-115 Sand 23% Nannos 80% Quartz 15% Silt 56% Dolo. Rhombs 2% Clay 22% Grain Size Sand 4% Silt 57% Clay 39%

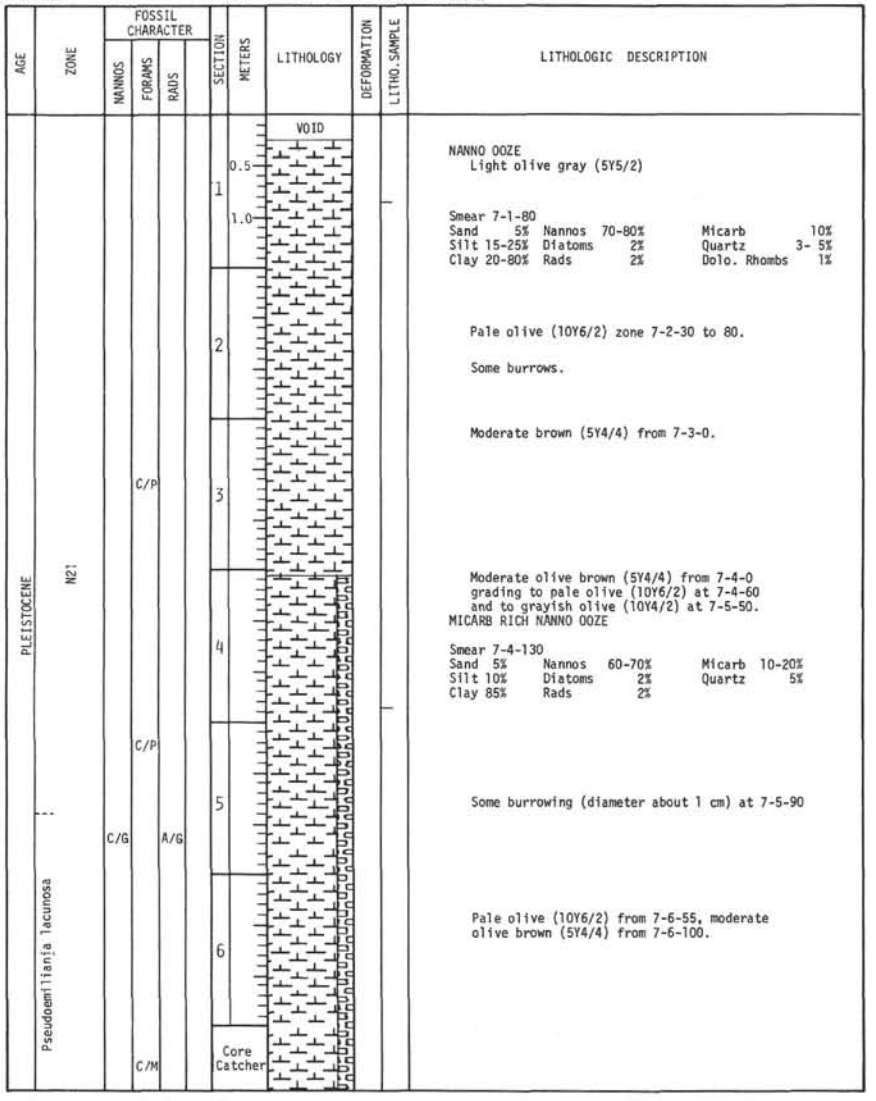
Explanatory notes in chapter 1

Site 233 Hole Core 6 Cored Interval: 43.0-52.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLEISTOCENE	N21		A/M C/M A/M		1 2 3 4 5 6 Core Catcher	0.5 1.0	VOID			NANNO OOZE Grayish olive (10Y4/2) Smear 6-2-80 Sand 5% Nannos 90% Quartz 2% Silt 10% Diatoms 2% Pyrite 2% Clay 85% Dolo. Rhombs 2% Smear 6-4-80 Sand 5% Nannos 90% Quartz 5% Silt 15% Diatoms 2% Dolo. Rhombs 3% Clay 80% Pale olive (10Y6/2) zones at 6-6-18 to 20, 6-6-60 to 62, 6-6-79 to 81, 6-6-123 to 150.

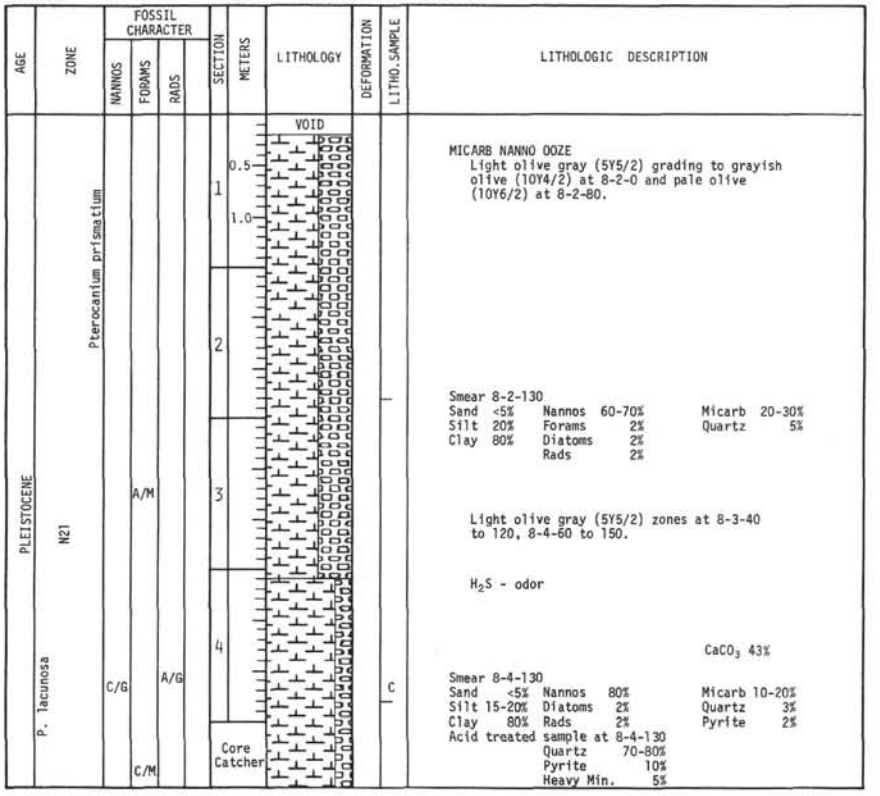
Explanatory notes in chapter 1

Site 233 Hole Core 7 Cored Interval: 52.5-62.0 m



Explanatory notes in chapter 1

Site 233 Hole Core 8 Cored Interval: 62.0-71.5 m



Explanatory notes in chapter 1

Site 233 Hole Core 9 Cored Interval: 71.5-81.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLEISTOCENE	N21 P. prismatium / P. lacunosa	C/G	C/M C/P C/P	A/G	1 2 3 4 5 6 Core Catcher	0.5 1.0				NANNO OOZE Grayish olive (10Y4/2). H_2S odor. Large miliolids. Pale olive (10Y6/2) bands at 9-4-15 to 20, 9-4-57 to 67, 9-4-105 to 120, 9-5-15 to 40. Slightly layered. Pyrite stripes from burrow coatings. Smear 9-4-80 Sand 5% Nannos 80-90% Micarb 10% Silt 10% Diatoms 2% Quartz 5% Clay 85% Rads 2% Dolo. Rhombs 2% Strong H_2S odor. Zone of light olive gray (5Y5/2) grading down to pale olive (10Y6/2) at 9-6-90 to 135.

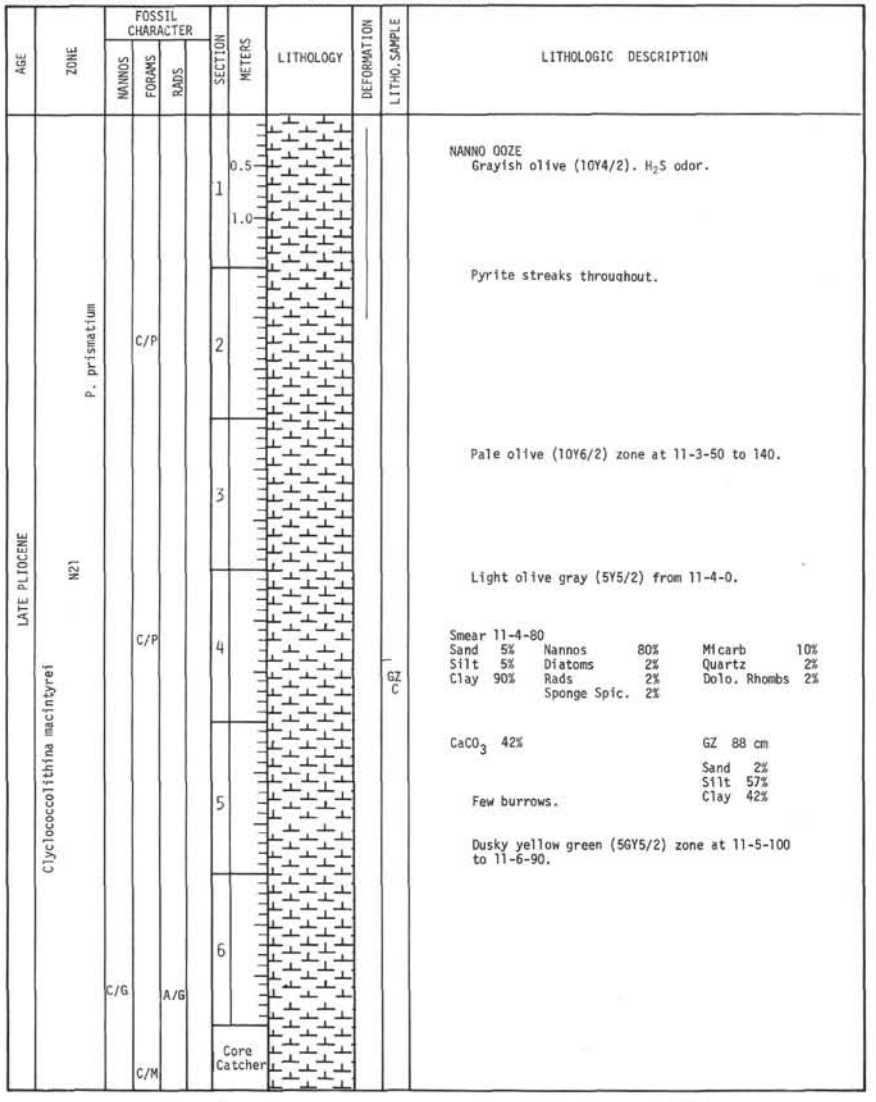
Explanatory notes in chapter 1

Site 233 Hole Core 10 Cored Interval: 81.0-90.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	N21 P. prismatium / P. lacunosa / C. macintyrei	C/G C/P	C/P C/P C/P	A/E	1 2 3 4 5 6 Core Catcher	0.5 1.0				NANNO OOZE Light olive gray (5Y5/2). H_2S odor. Pyrite streaks from burrow coatings. Color grading to pale olive (10Y6/2) Light olive gray (5Y5/2). H_2S odor. Pyrite streaks. Few burrows diameter up to 1 cm. Smear 10-4-80 Sand 5% Nannos 80% Micarb 15% Silt 10% Diatoms 2% Quartz 2- 3% Clay 85% Rads 2% Sponge Spic. 1% Color grading slowly to greenish yellow green (5GY7/2). Sharp boundary in color at 10-6-130: below grayish olive (10Y4/2).

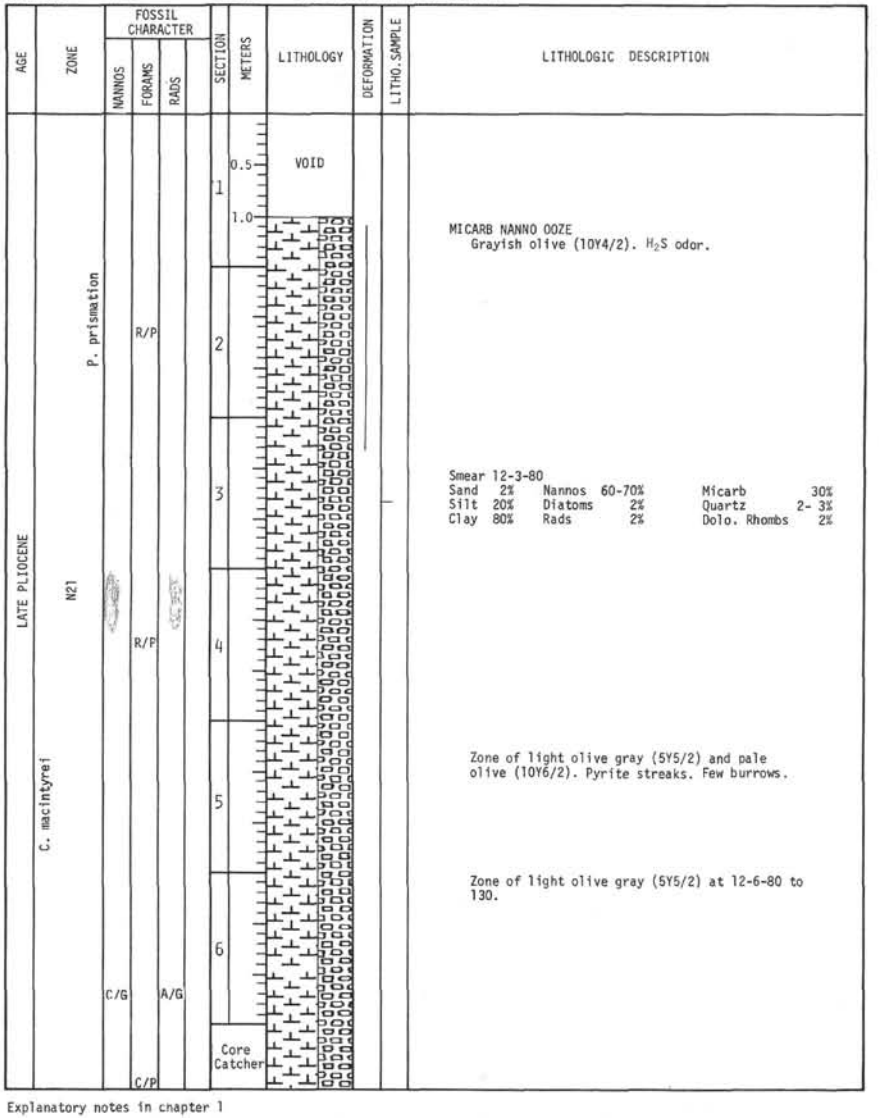
Explanatory notes in chapter 1

Site 233 Hole Core 11 Cored Interval: 90.5-100.0 m



Explanatory notes in chapter 1

Site 233 Hole Core 12 Cored Interval: 100.0-109.5 m



Explanatory notes in chapter 1

Site 233 Hole Core 13 Cored Interval: 109.5-119.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	N21 C. macintyrei / P. prismatium	C/G	R/P R/p C/P	A/G	1 2 3 4 5 6 Core Catcher	0.5 1.0	VOID			MICARB NANNO OOZE Light olive gray (5Y5/2). H_2S - smell. Pyrite streaks. Smear 13-3-80 Sand 10% Nannos 50-60% Micarb 30-40% Silt 15-20% Diatoms 2% Quartz 5-10% Clay 70-80% Rads 2% Dolo. Rhombs 2% Sponge Spic. 2%

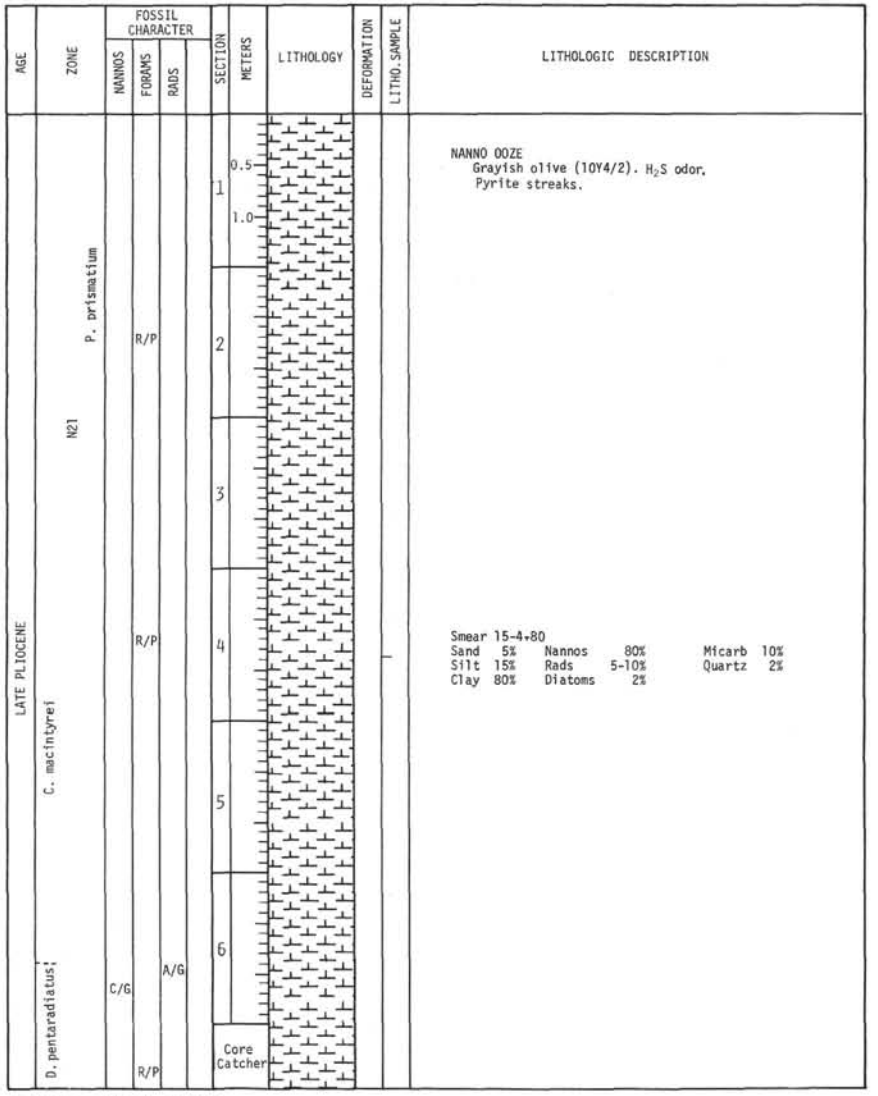
Explanatory notes in chapter 1

Site 233 Hole Core 14 Cored Interval: 119.0-128.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	N21 C. macintyrei / P. prismatium	C/G	R/P R/P	A/G	1 2 Core Catcher	0.5 1.0	VOID			MICARB NANNO OOZE Olive gray (5Y3/2). H_2S odor. Pyrite streaks. Grayish olive (10Y4/2) from 14-2-40

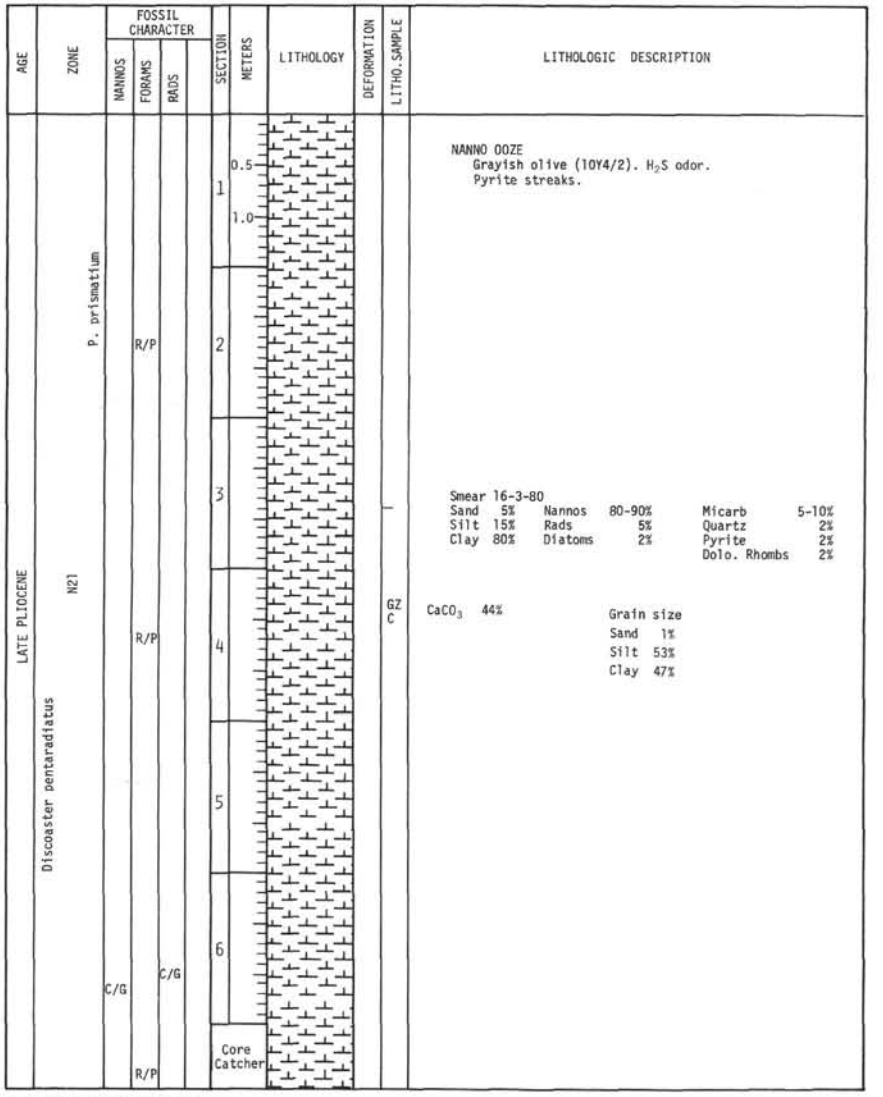
Explanatory notes in chapter 1

Site 233 Hole Core 15 Cored Interval: 128.5-138.0 m



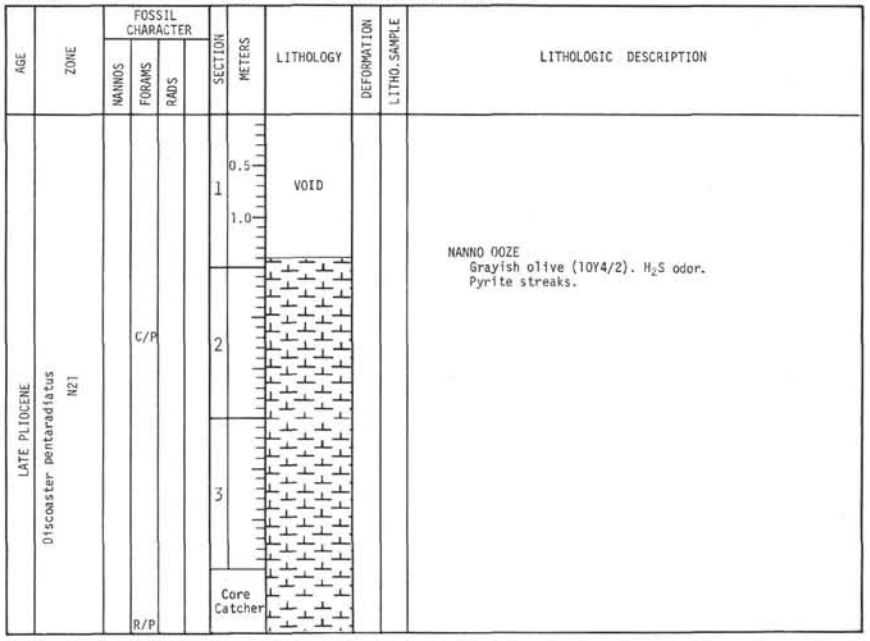
Explanatory notes in chapter1

Site 233 Hole Core 16 Cored Interval: 138.0-147.5 m



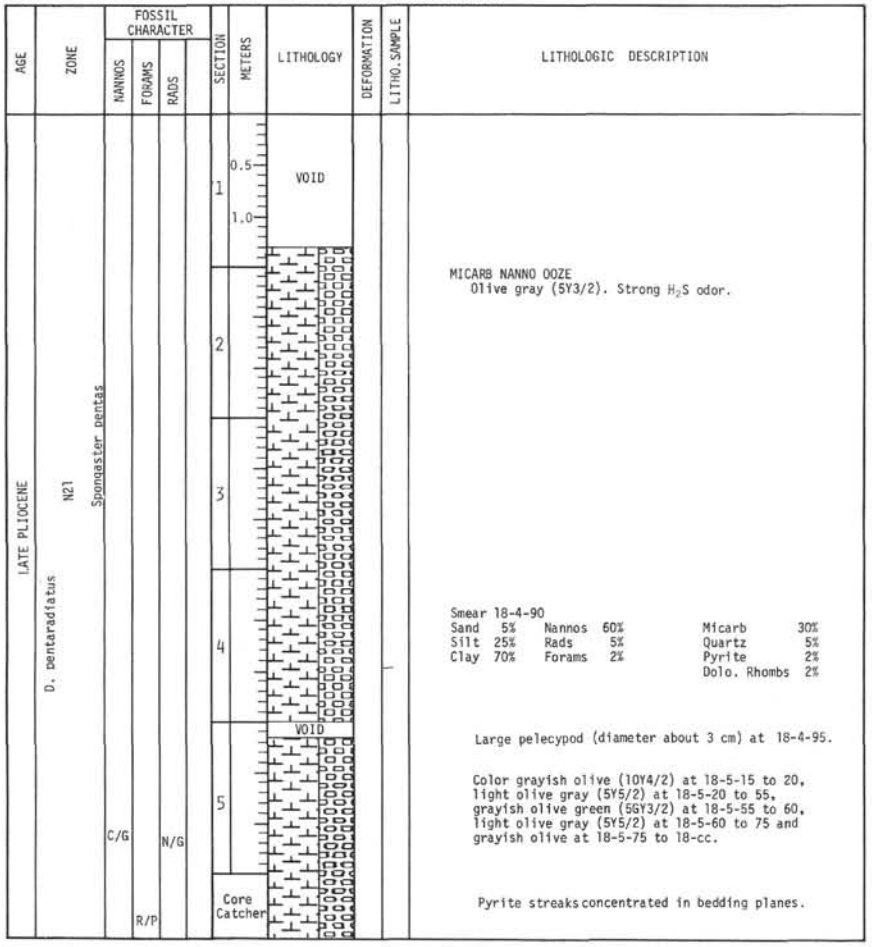
Explanatory notes in chapter 1

Site 233 Hole Core 17 Cored Interval: 147.5-157.0 m



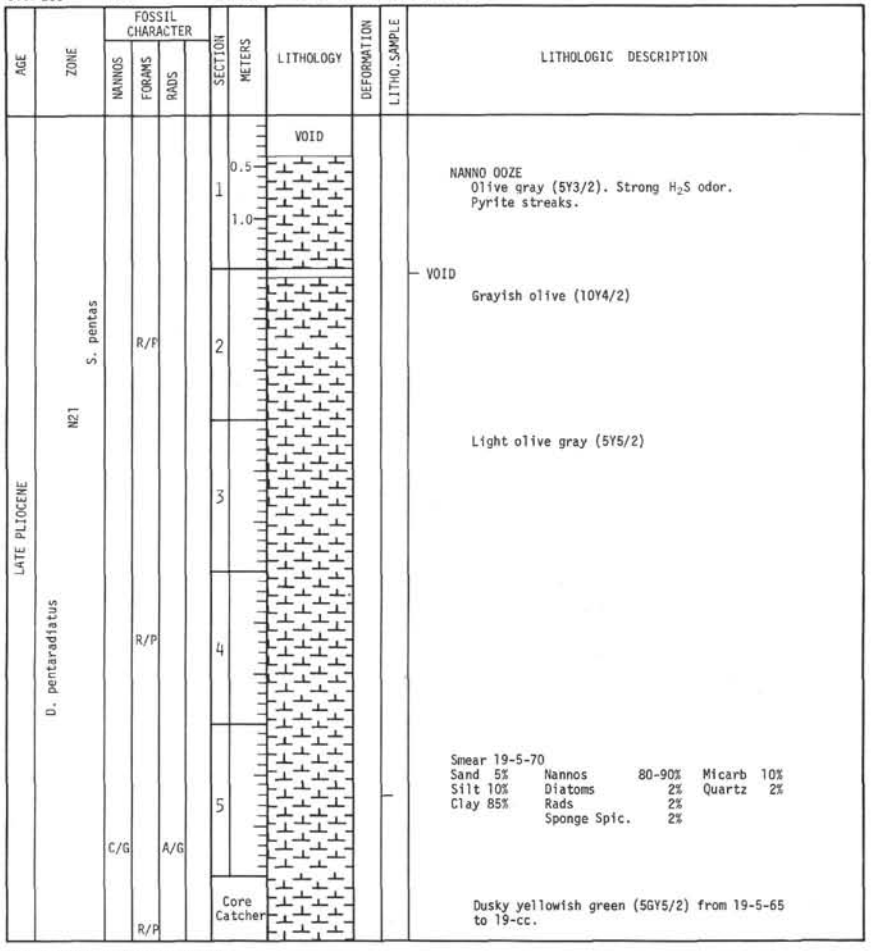
Explanatory notes in chapter 1

Site 233 Hole Core 18 Cored Interval: 157.0-166.5 m



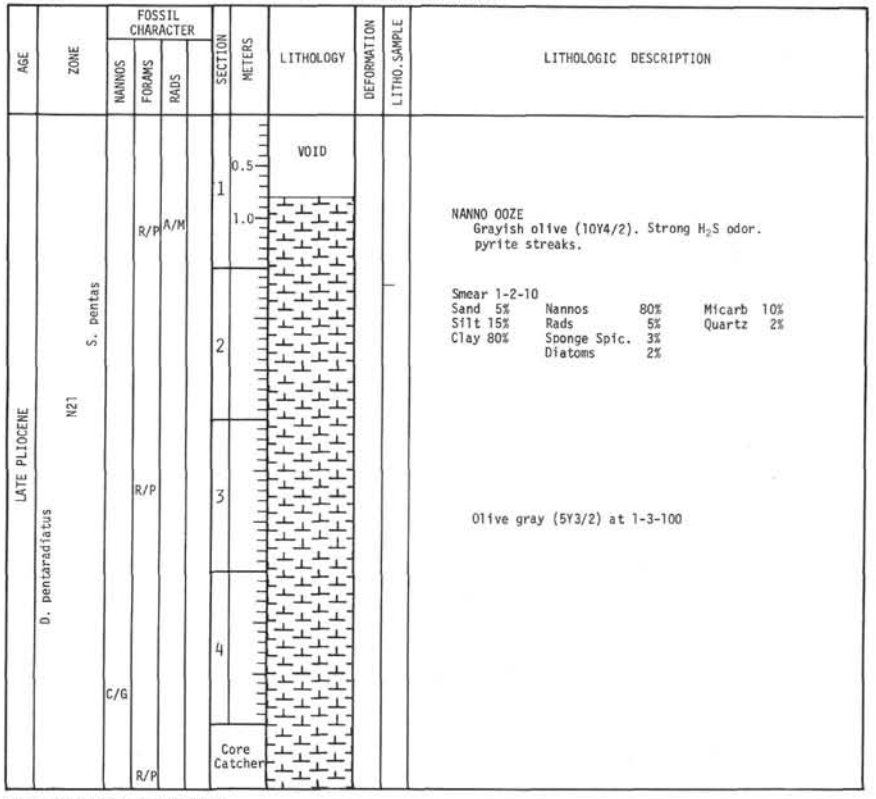
Explanatory notes in chapter 1

Site 233 Hole Core 19 Cored Interval:166.5-176.0 m



Explanatory notes in chapter 1

Site 233 Hole A Core 1 Cored Interval:168.0-177.5 m



Explanatory notes in chapter 1

Site 233 Hole A Core 2 Cored Interval: 177.5-187.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	D. pentaradiatus N21 S. pentas	C/G	C/P	C/M	1	0.5, 1.0	VOID			NANNO OOZE Grayish olive (10Y4/2). Strong H_2S odor. Pyrite streaks.
					2					
					Core Catcher					
			R/P							

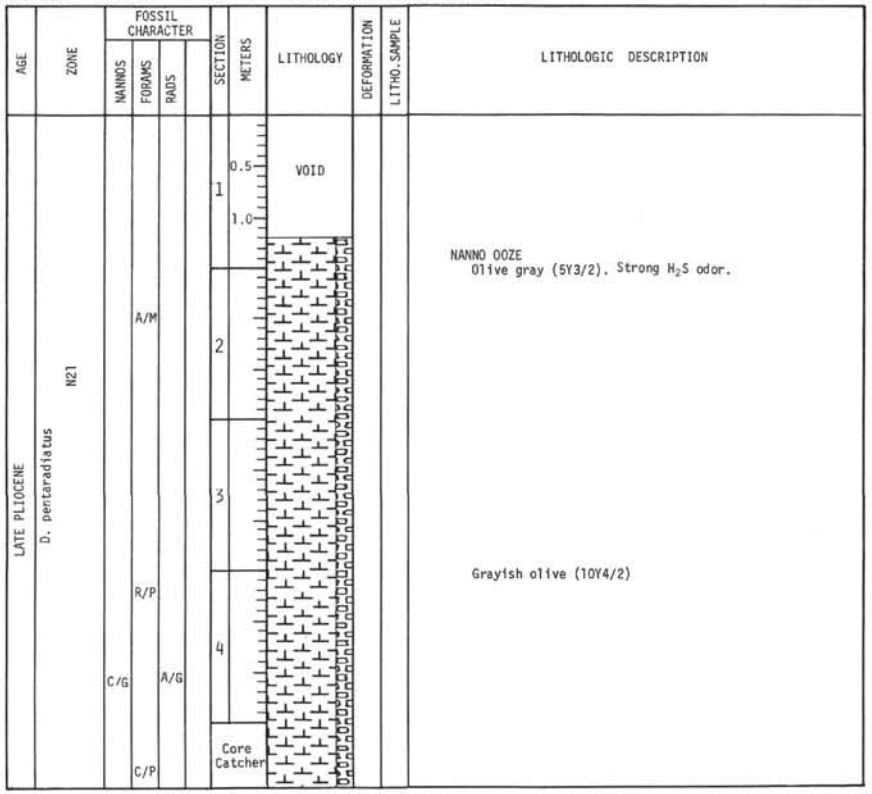
Explanatory notes in chapter 1

Site 233 Hole A Core 3 Cored Interval: 187.0-196.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	D. pentaradiatus N21 S. pentas		C/P		1	0.5, 1.0	VOID			NANNO OOZE Grayish olive (10Y4/2). Strong H_2S - odor. Scattered shell fragments throughout darker sediment.
					2					
					3					
			R/P		4					Light olive gray (5Y5/2) at 3-4-45 to 3-6-75.
					5					
		C/G		A/G	6					Olive gray (5Y3/2) at 3-6-75 to 3-cc.
			R/P		Core Catcher					

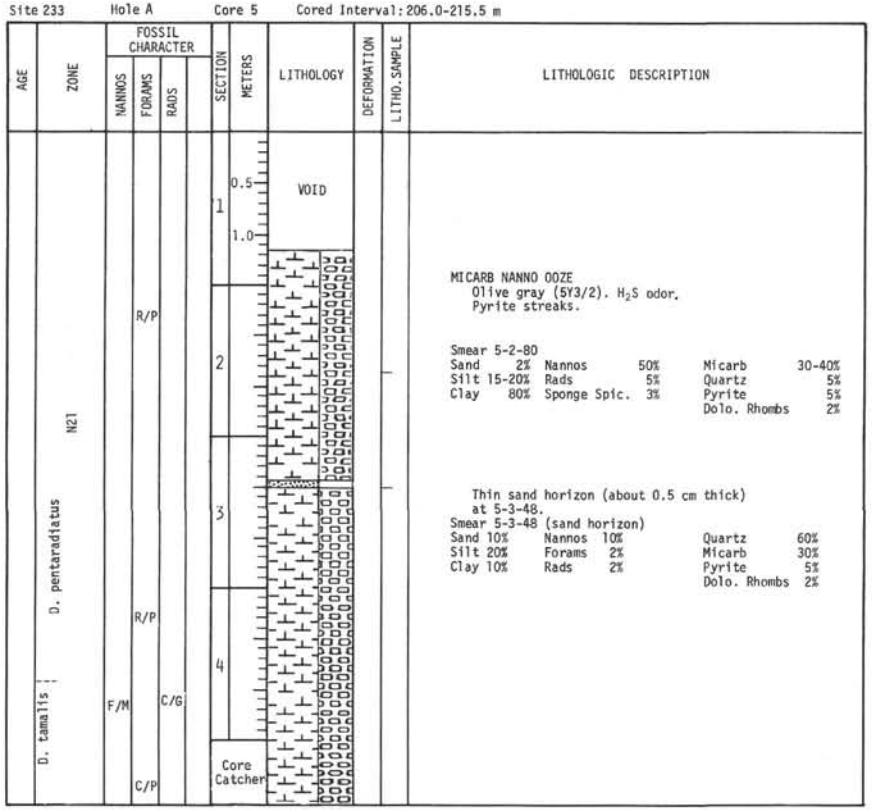
Explanatory notes in chapter 1

Site 233 Hole A Core 4 Cored Interval: 196.5-206.0 m



Explanatory notes in chapter 1

Site 233 Hole A Core 5 Cored Interval: 206.0-215.5 m



Explanatory notes in chapter 1

Site 233 Hole A Core 6 Cored Interval: 215.15-225.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	D. tamalis N21	F/M	C/P	A/G	1	0.5	VOID			MICARB NANNO OOZE Olive gray (5Y3/2). H_2S odor Pyrite streaks.
						1.0				
					2					
			R/P		Core Catcher					

Explanatory notes in chapter 1

Site 233 Hole A Core 7 Cored Interval: 225.0-234.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	D. tamalis N21						VOID			
					1	0.5				MICARB NANNO OOZE Grayish olive (10Y4/2)
						1.0				
			C/P		2					
					3					Olive gray (5Y3/2)
			C/P		4					gradually grading to olive black (5Y2/1)
		F/P	R/P	C/M	5					Smear 7-5-80 Sand 2% Nannos 40% Micarb 40-50% Silt 15% Rads 2% Quartz 5% Clay 80% Sponge Spic. 2% Pyrite 5%
										Color grading gradually to dark gray (N2). From 7-5-96 downwards very indurated.
			C/P		Core Catcher					Smear 7-CC Sand 2% Nannos 40% Micarb 50% Silt 30-40% Pyrite 5-10% Clay 60-70%

Explanatory notes in chapter 1

Site 233 Hole A Core 8 Cored Interval: 234.5-237.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
					1	0.5	VOID			DIABASE Dark gray (N3). Homogenous, relatively coarse grained; druses with cover of whity crystals; thin veins of same material.
						1.0				
					2		VOID			
					Core Catcher					

Site 233 Hole A Core 9 Cored Interval: 237.0-243.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
					1	0.5	VOID			DIABASE Dark gray (N3). Homogenous, relatively coarse grained.
						1.0				

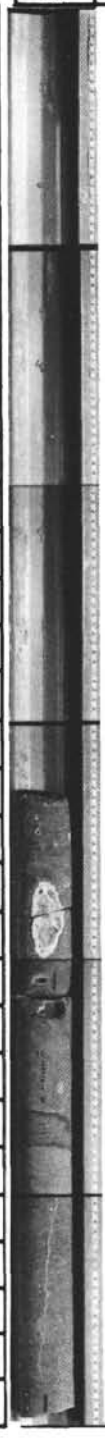
Site 233 Hole A Core Cored Interval:

AGE	ZONE	FOSSIL CHARACTER	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
			1	0.5				Cores 10 243.0-245.5 m 11 245.0-254.0 m 12 254.0-263.5 m 13 263.5-271.0 m NO RECOVERY
				1.0				
			2					

Explanatory notes in chapter 1

DETAILED CORE DESCRIPTIONS

Site 233 A Core 8 Section 1

Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description
0–150					Dark gray (N3) massive uniform diabase (dolerite): fresh euhedral plagioclase crystals 1.0-1.5 mm, subhedral pyroxene (augite, minor hypersthene) 0.2-0.3 mm, opaques 2-3% throughout section. Alteration: fibrous chlorite, and isolated serpentine, after olivine(?). Upper portion contains vugs or cavities with walls incrusted by calcite-chlorite aggregates, and a thin vein of calcite-chlorite.

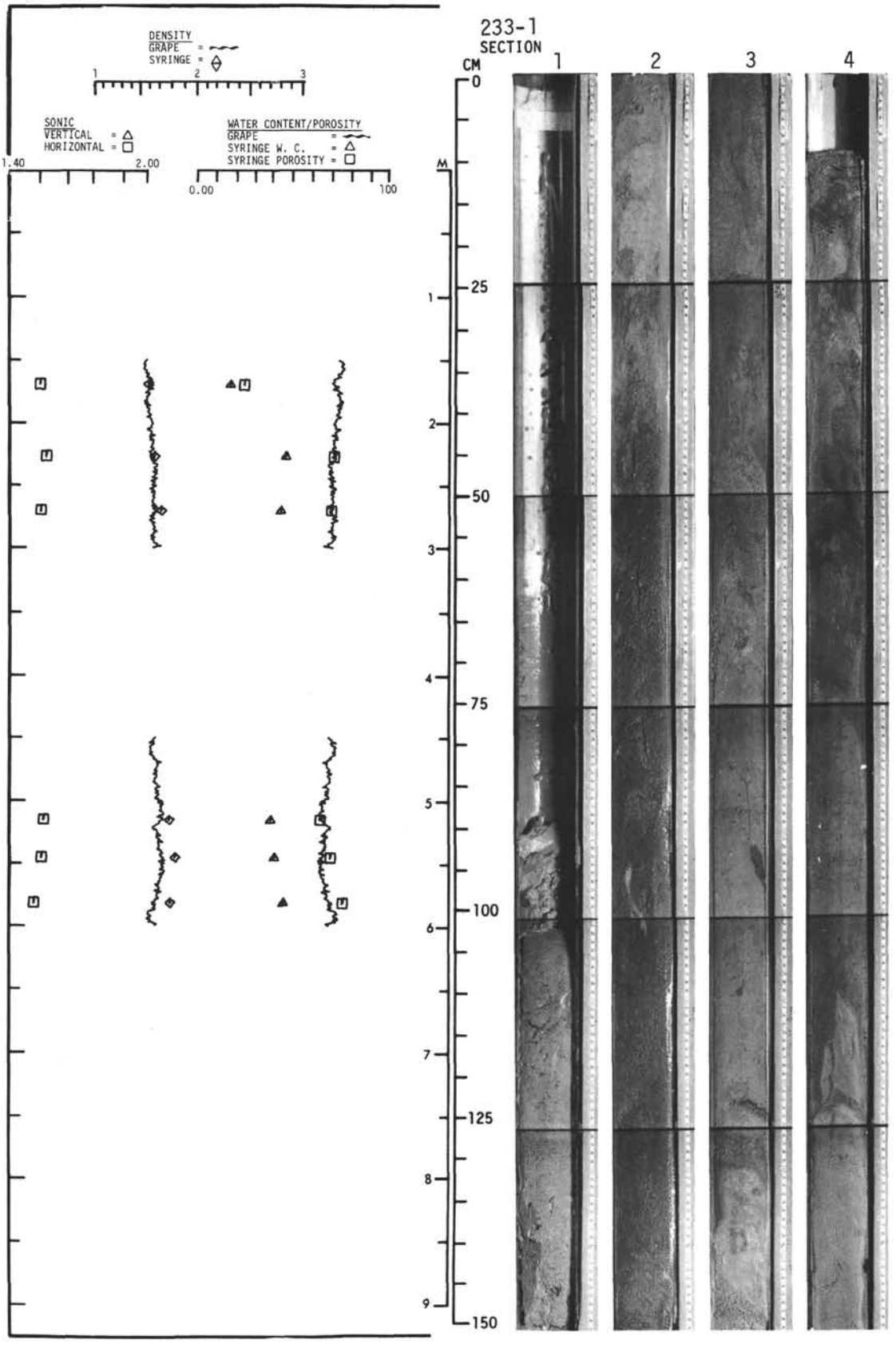
Site 233 A Core 8 Section 2

Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description
0–150					Dark gray massive diabase as above.

DETAILED CORE DESCRIPTIONS

Site 233 A Core 9 Section

Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description
0–150					Dark gray massive diabase as above.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SONIC
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HORIZONTAL = □
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GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
233-1
SECTION
CM
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2
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M
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100
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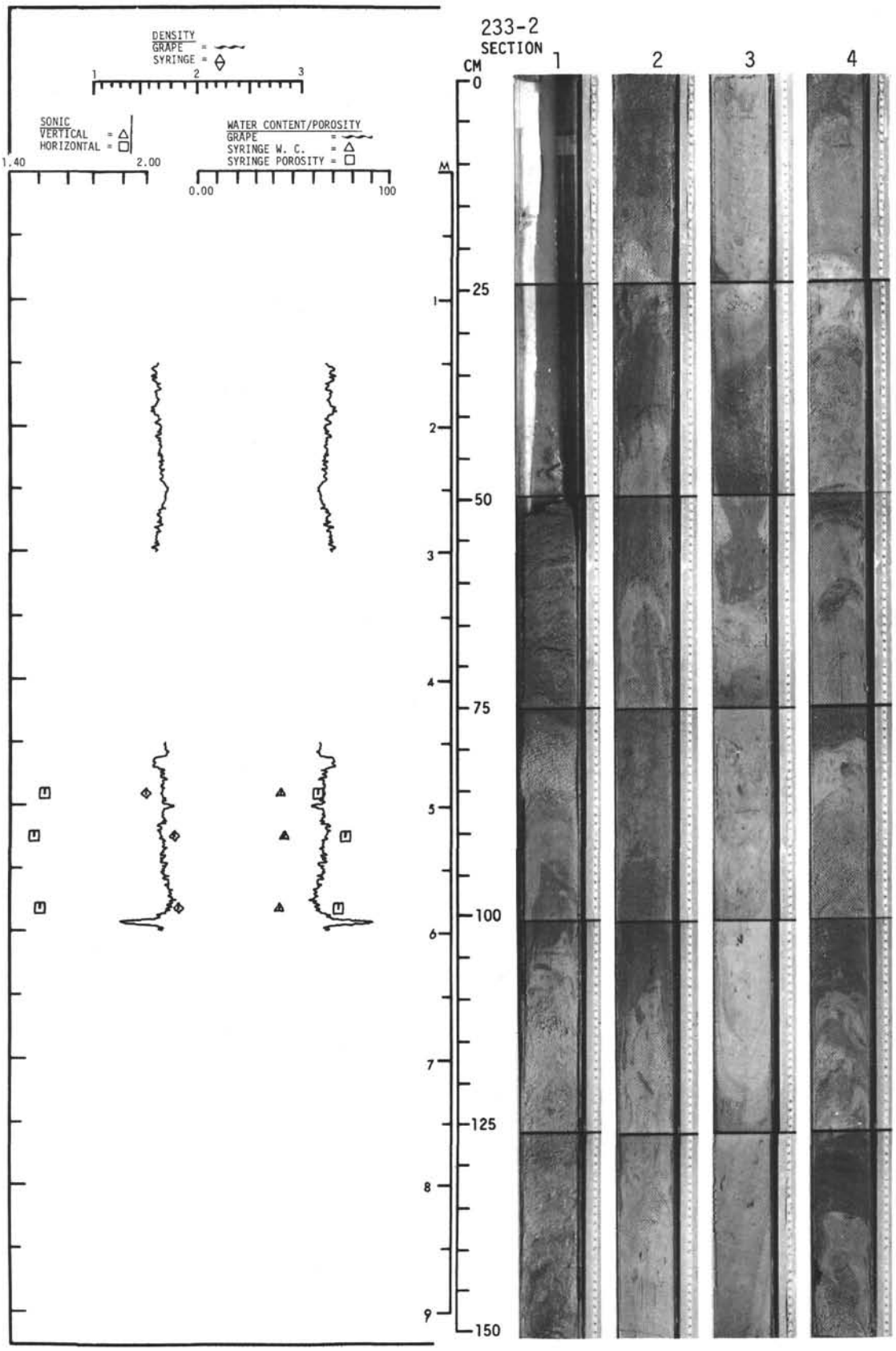
1
2
3
4
5
6
7
8
9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SYRINGE POROSITY = □
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4
CM
M
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100
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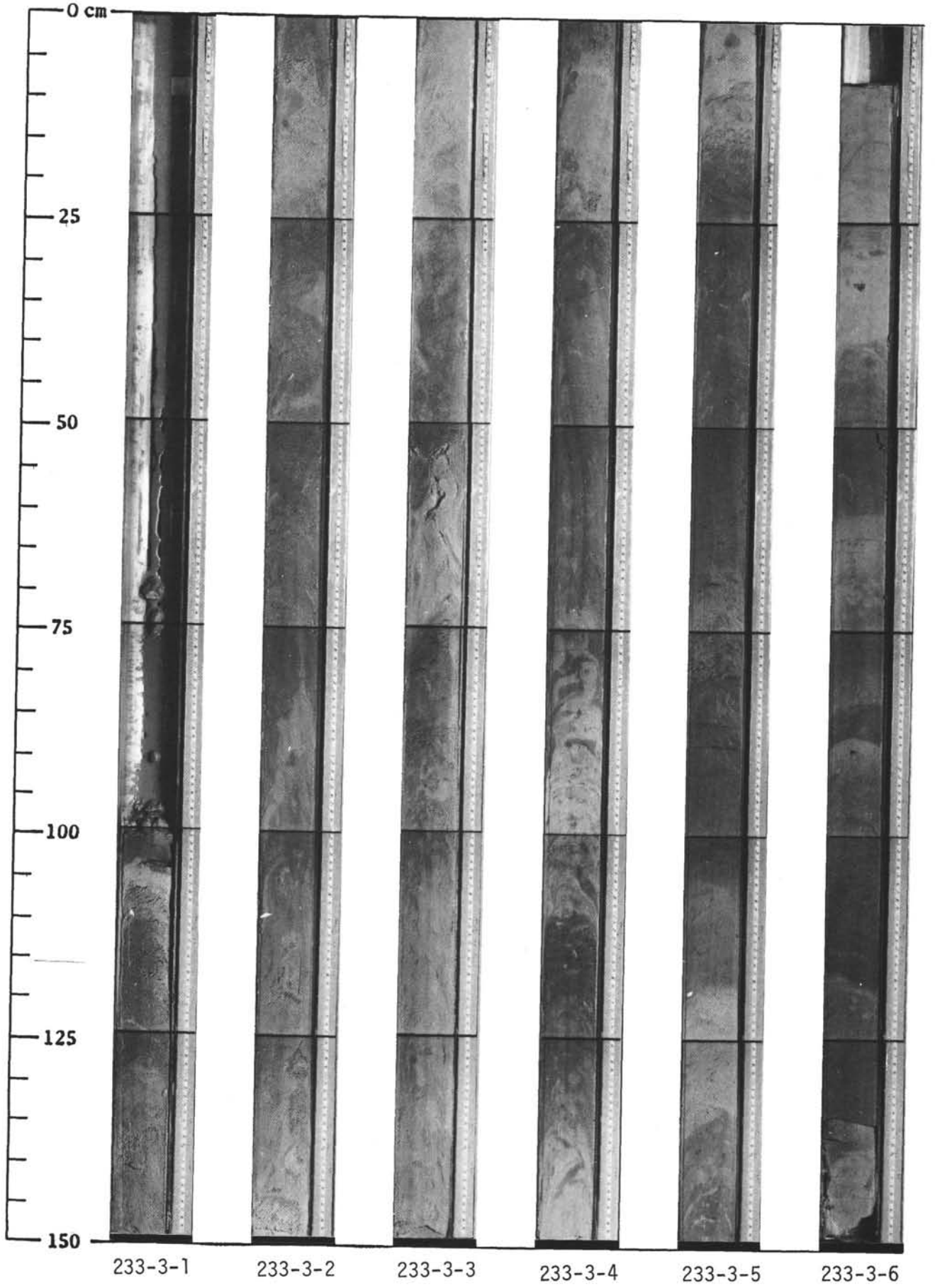
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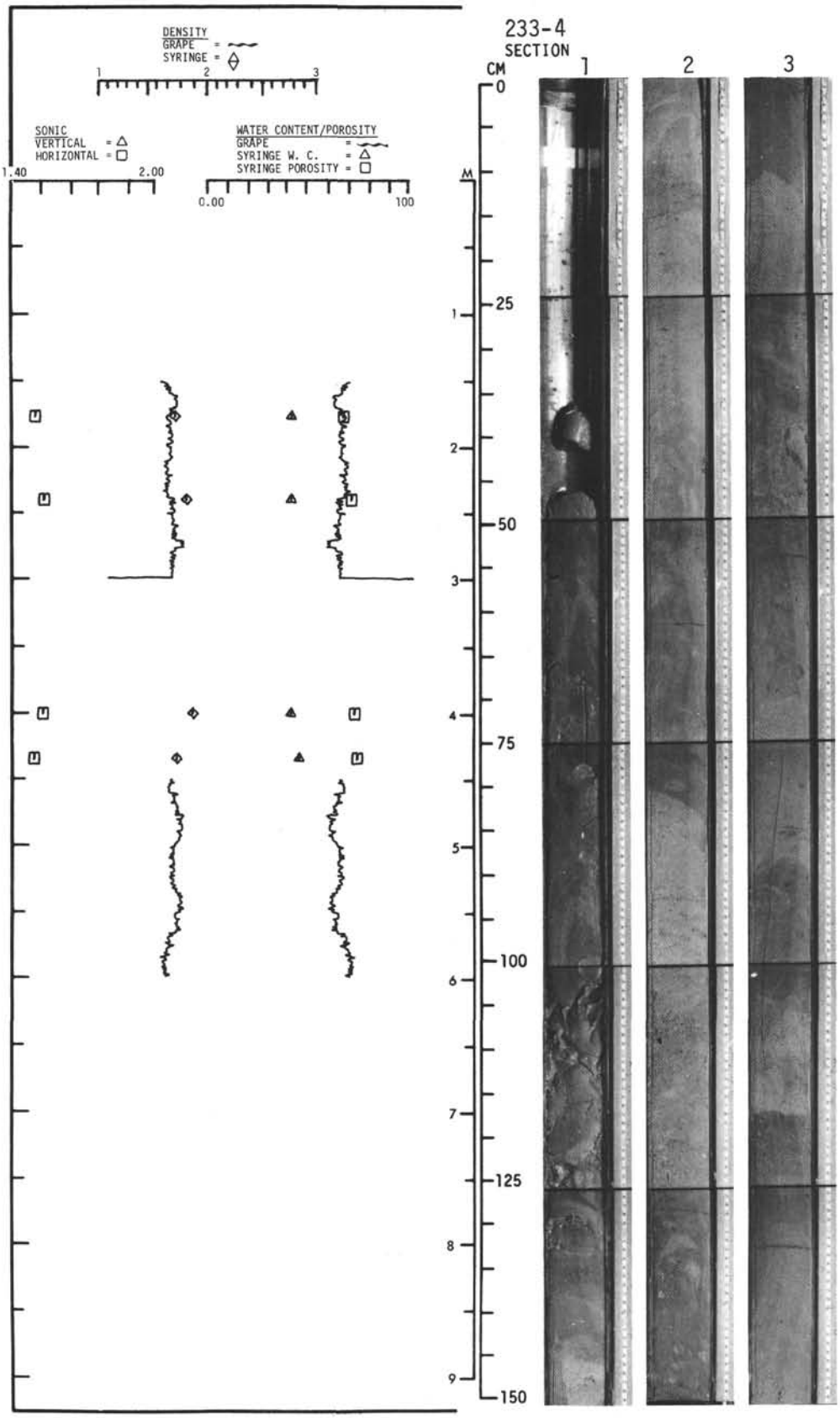
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SYRINGE W. C. = △
SYRINGE POROSITY = □
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233-4
SECTION
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CM
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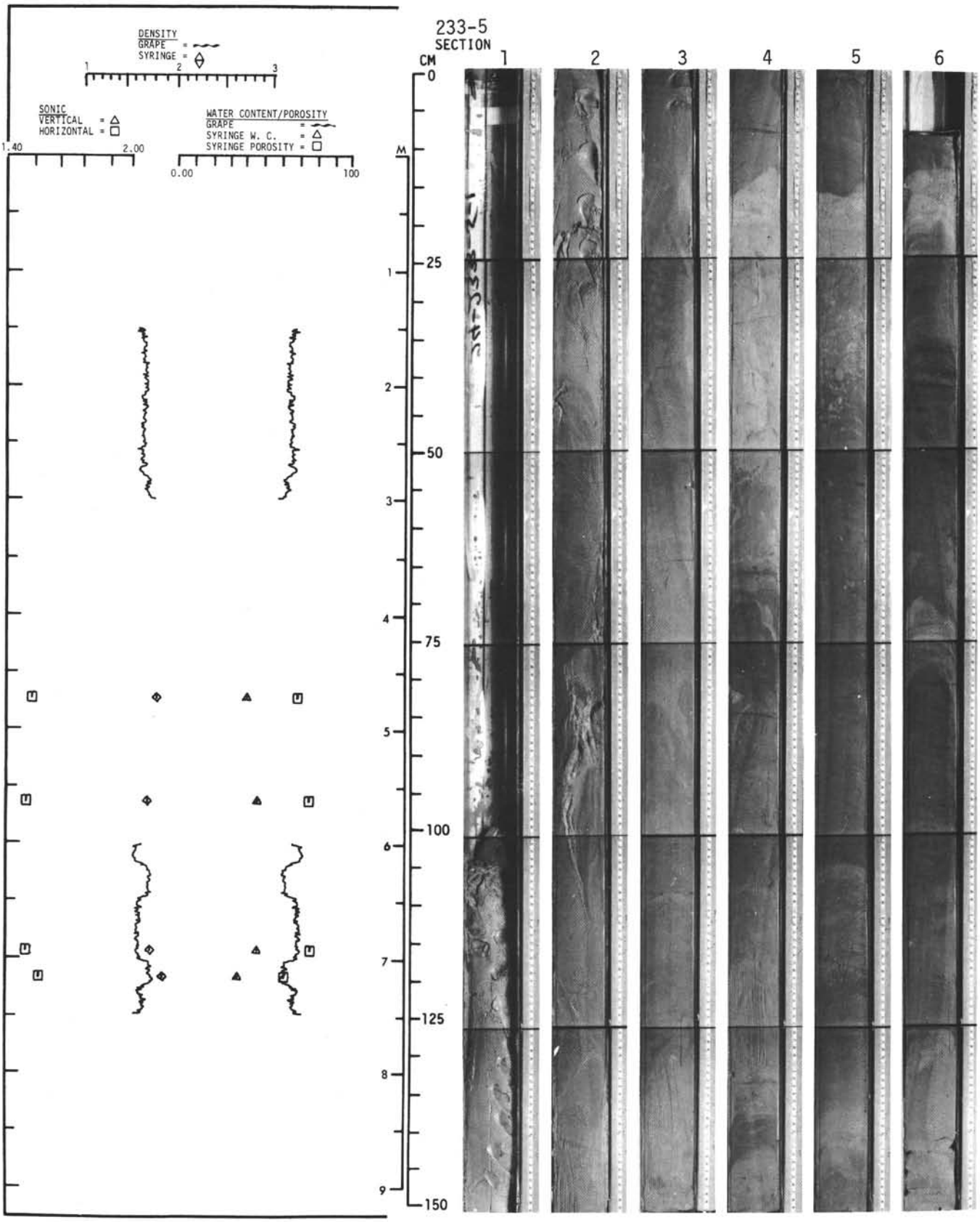
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SYRINGE POROSITY = □
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233-5
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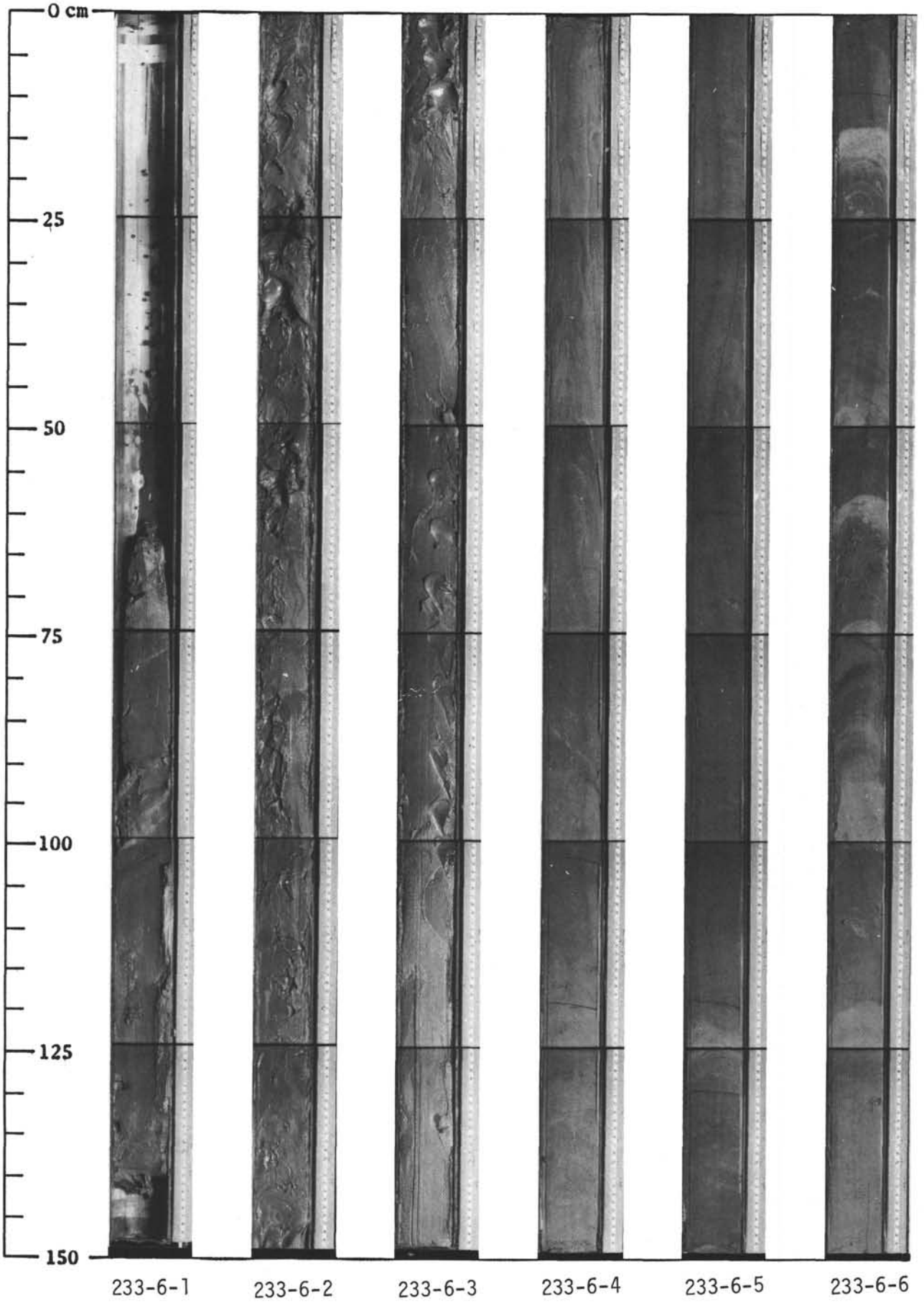
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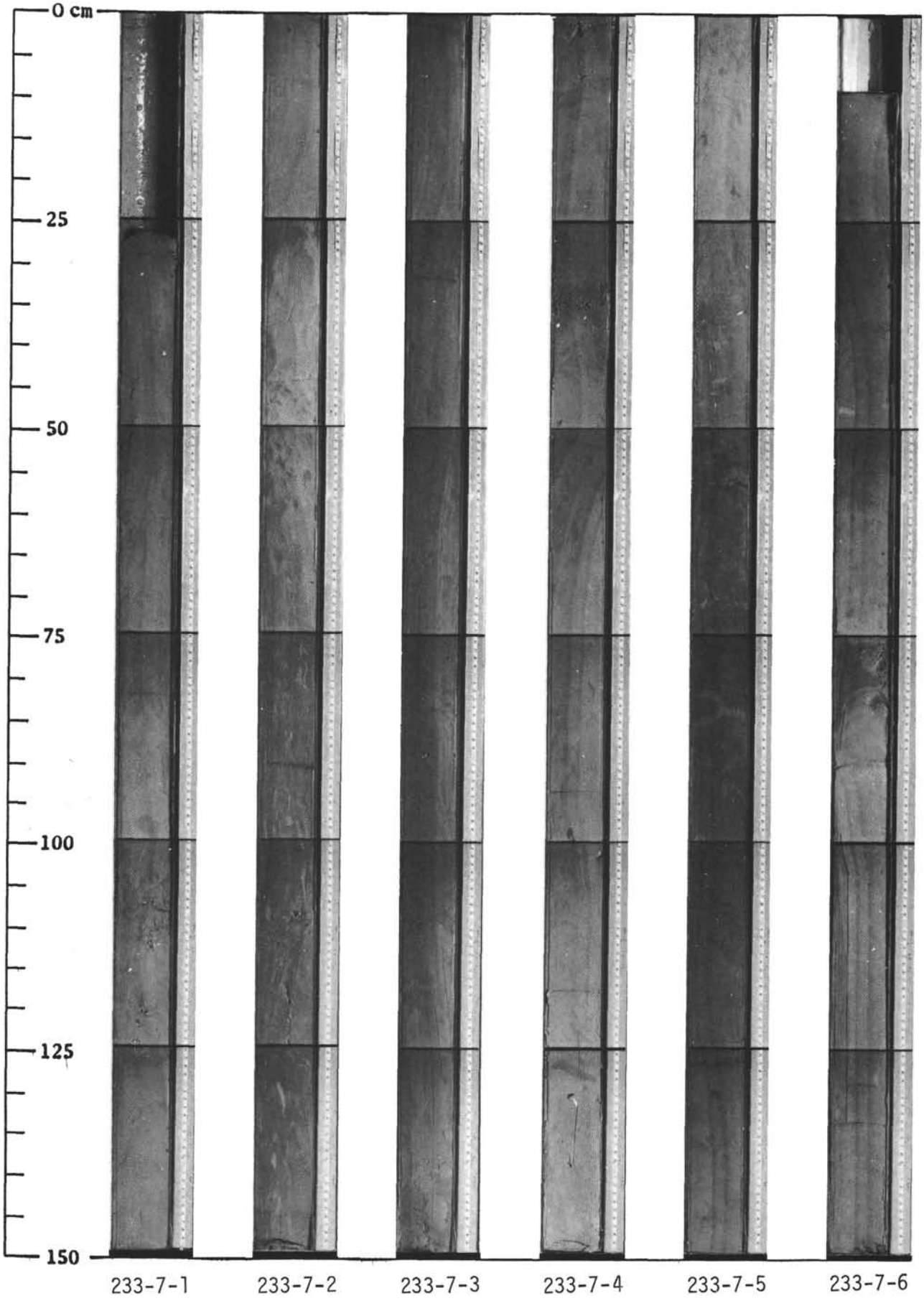
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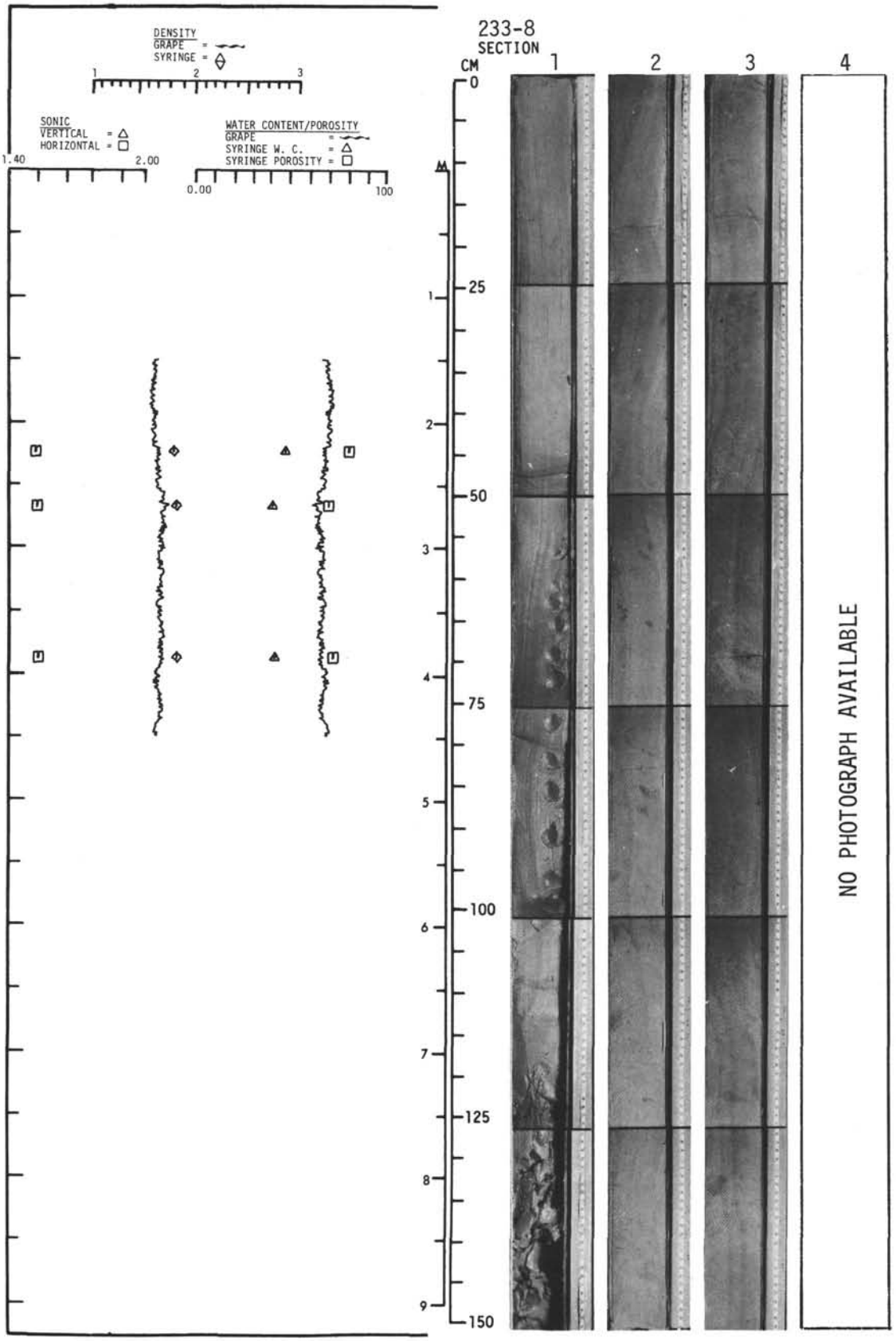
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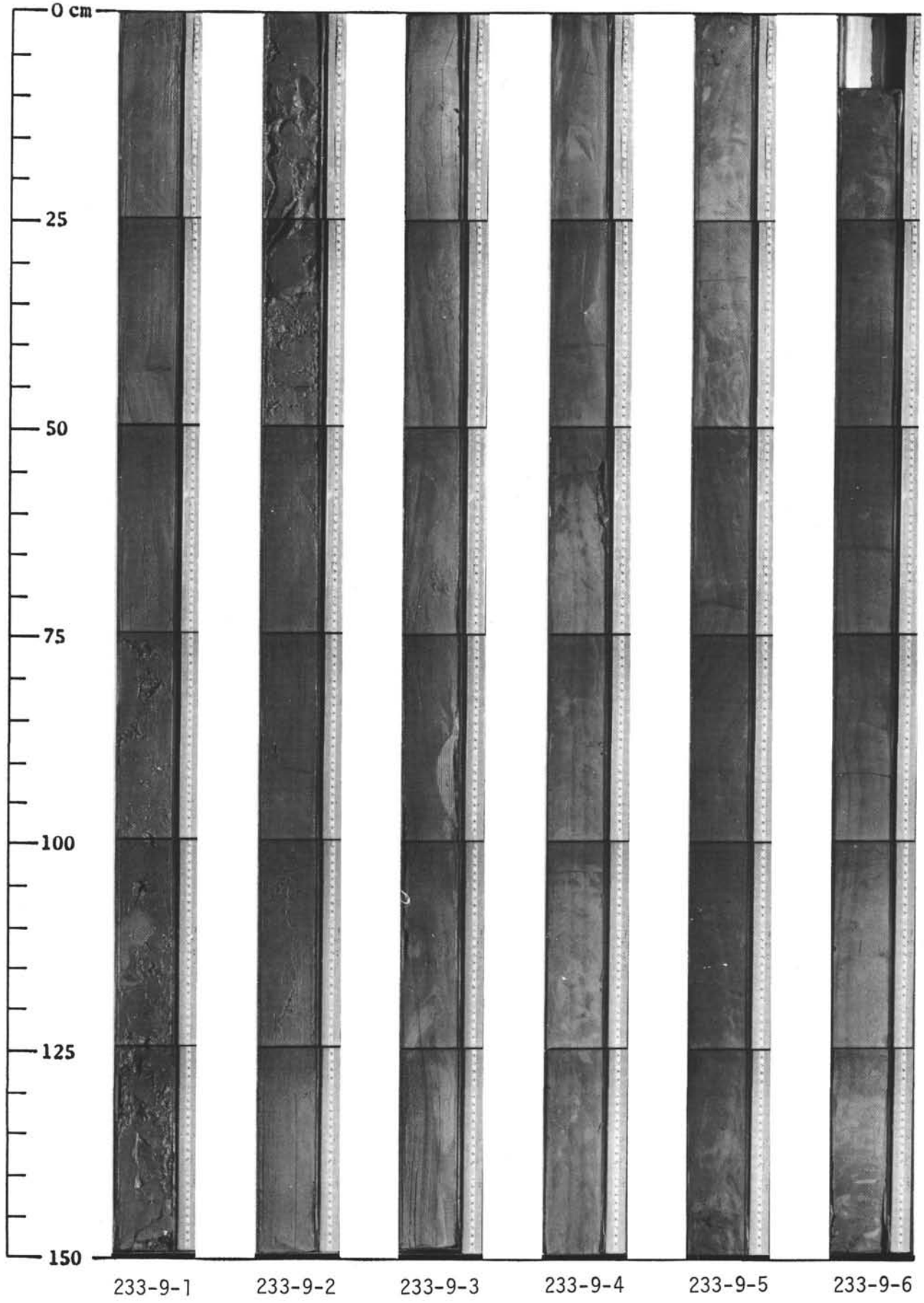
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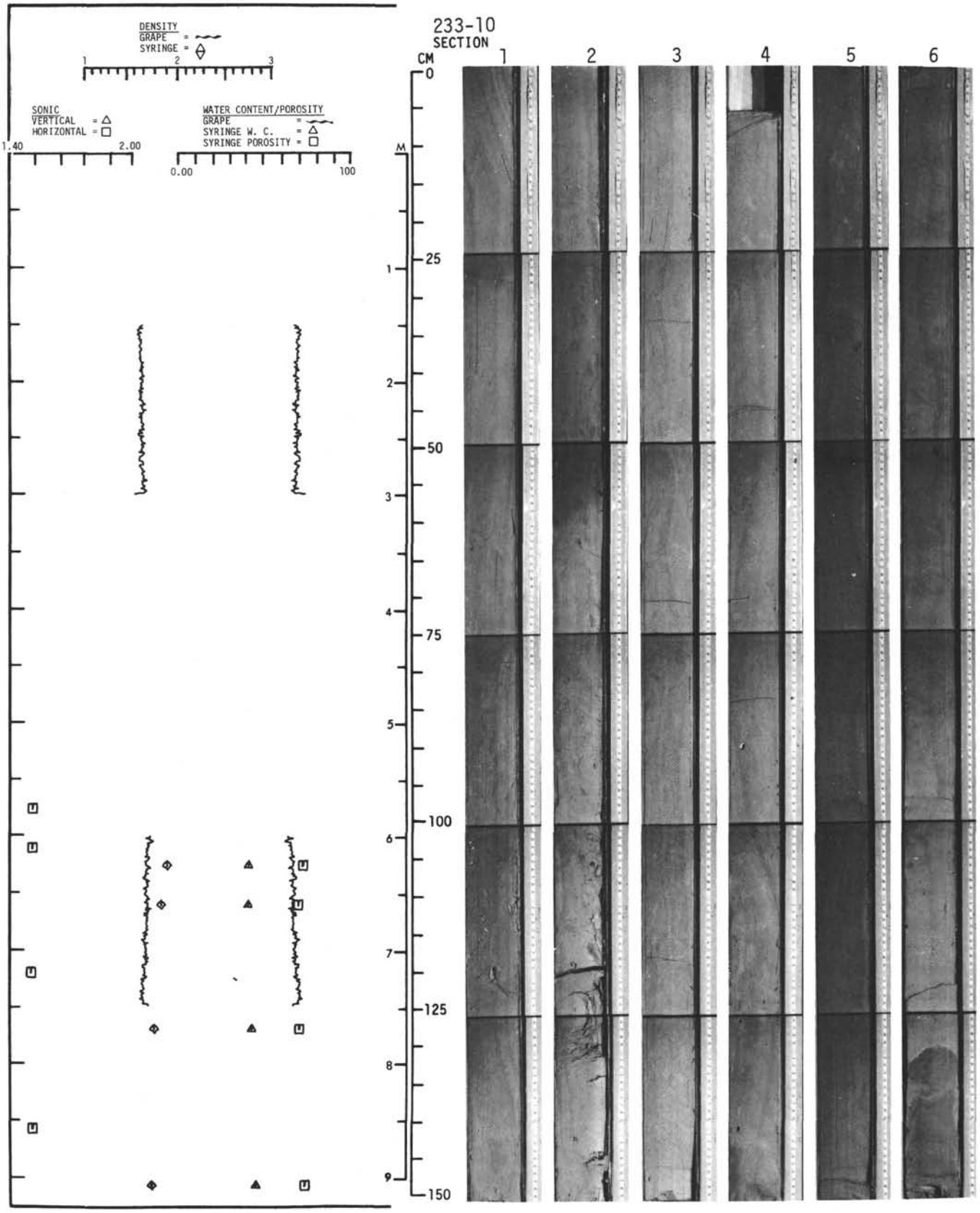
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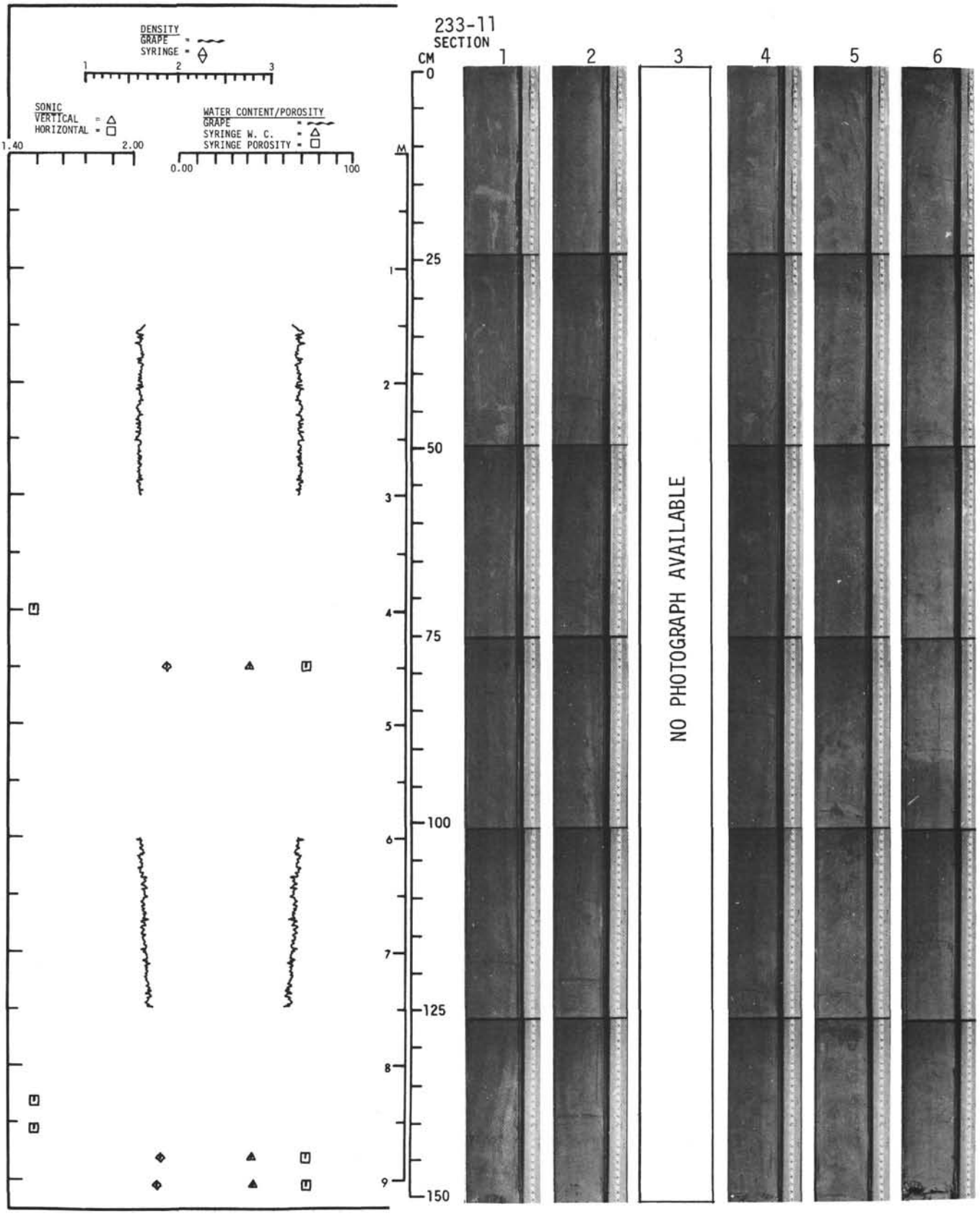
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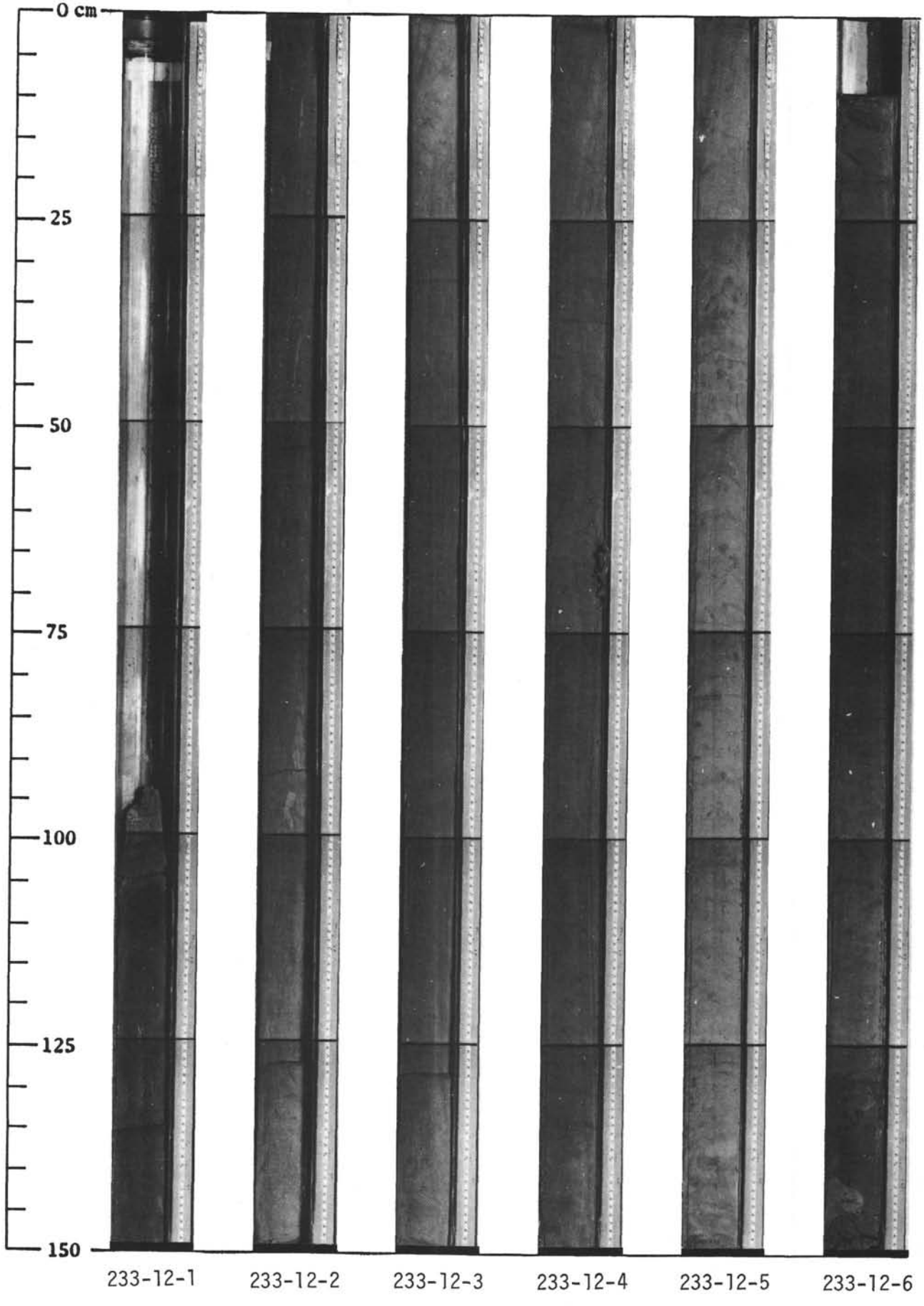
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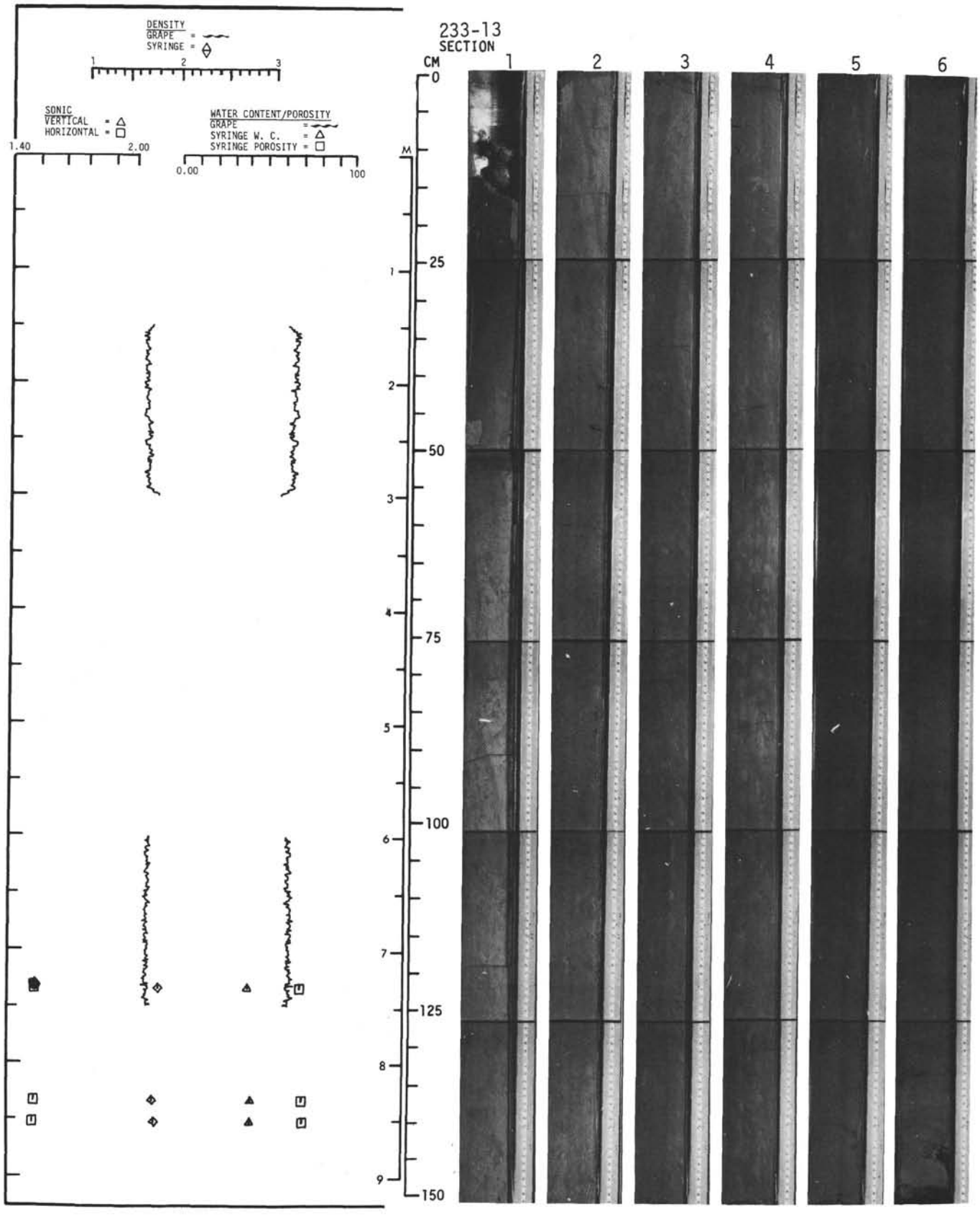
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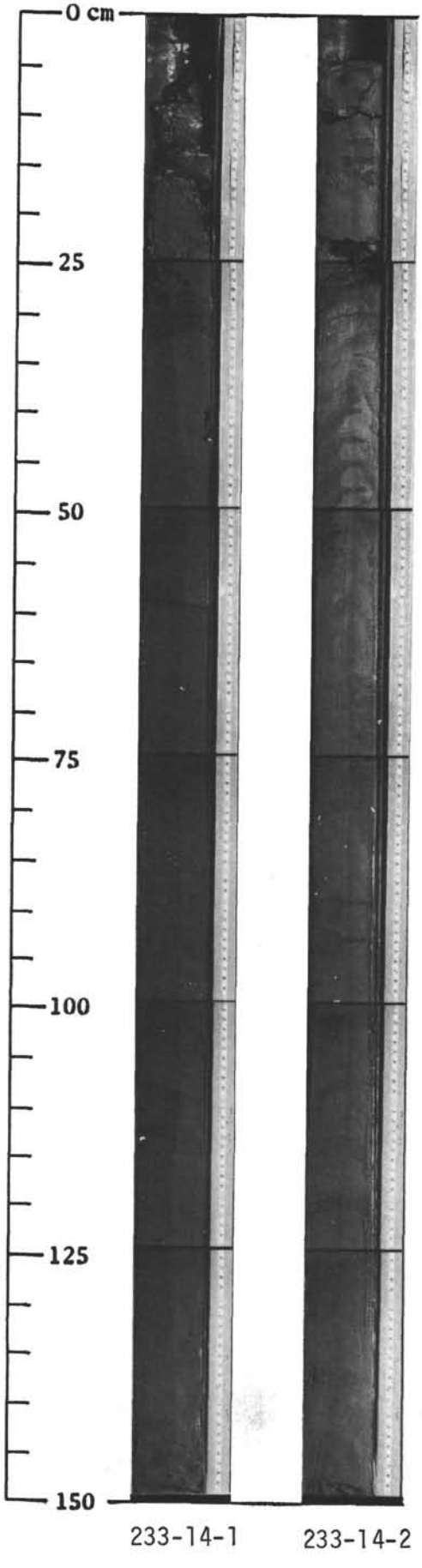
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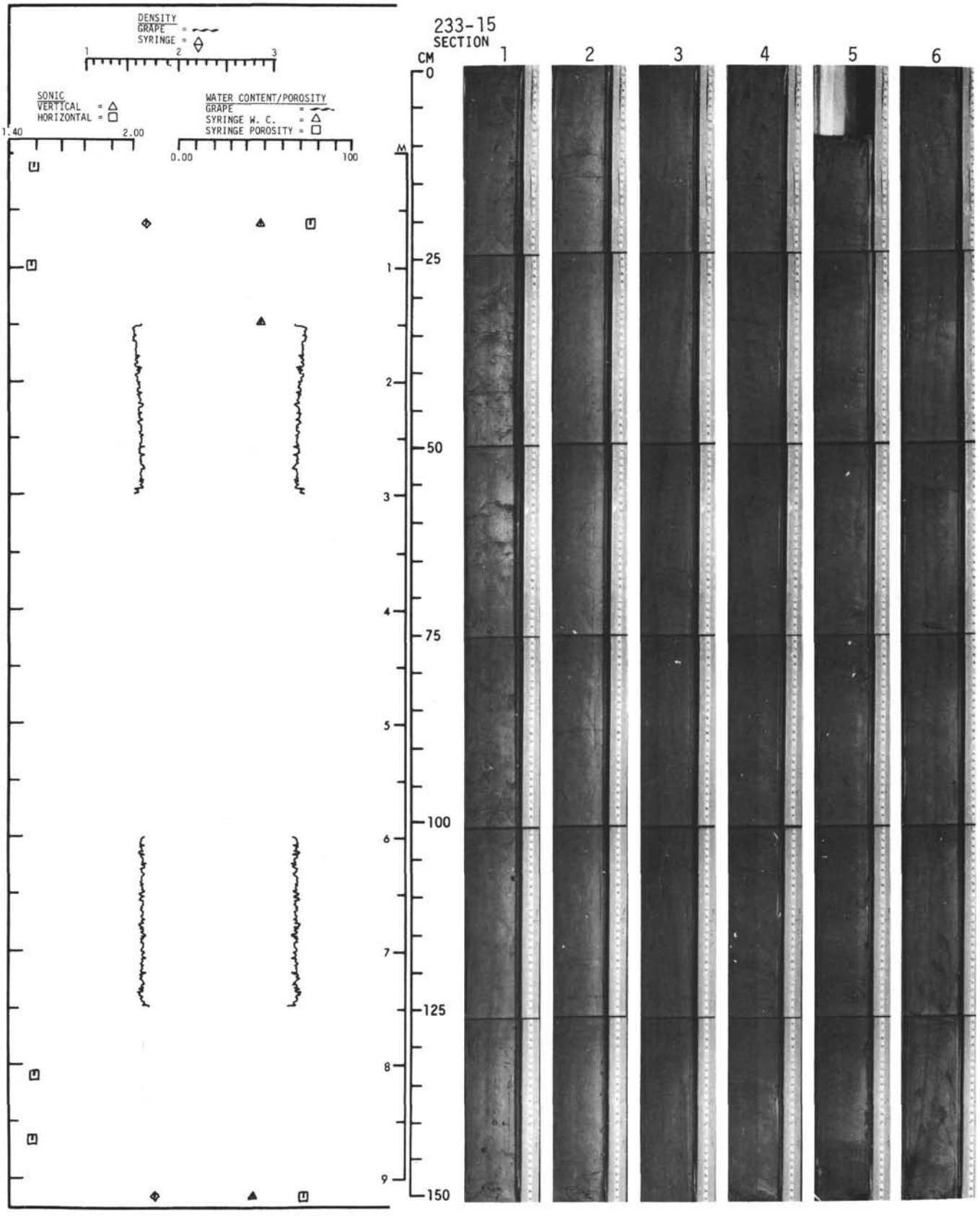
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150
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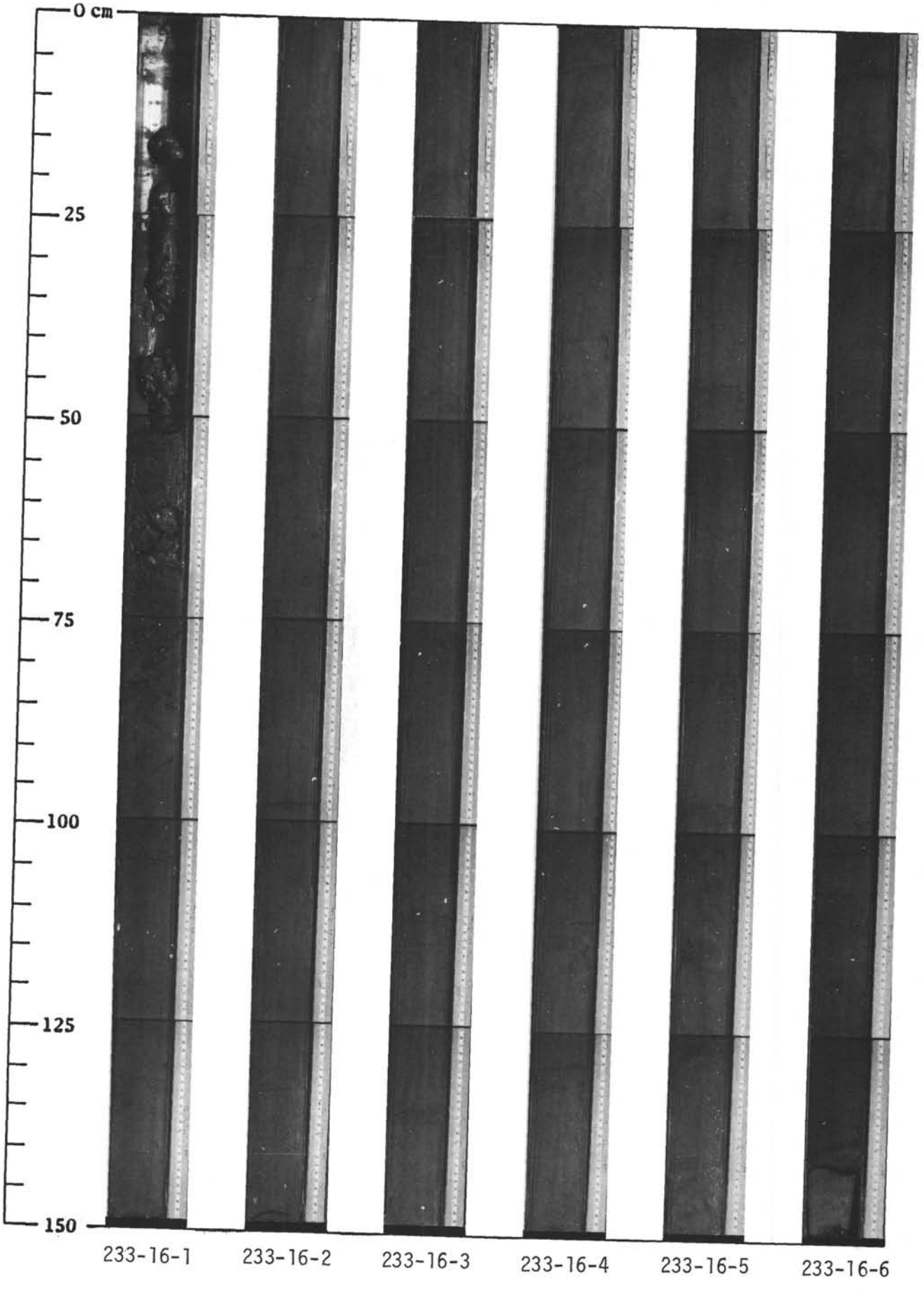
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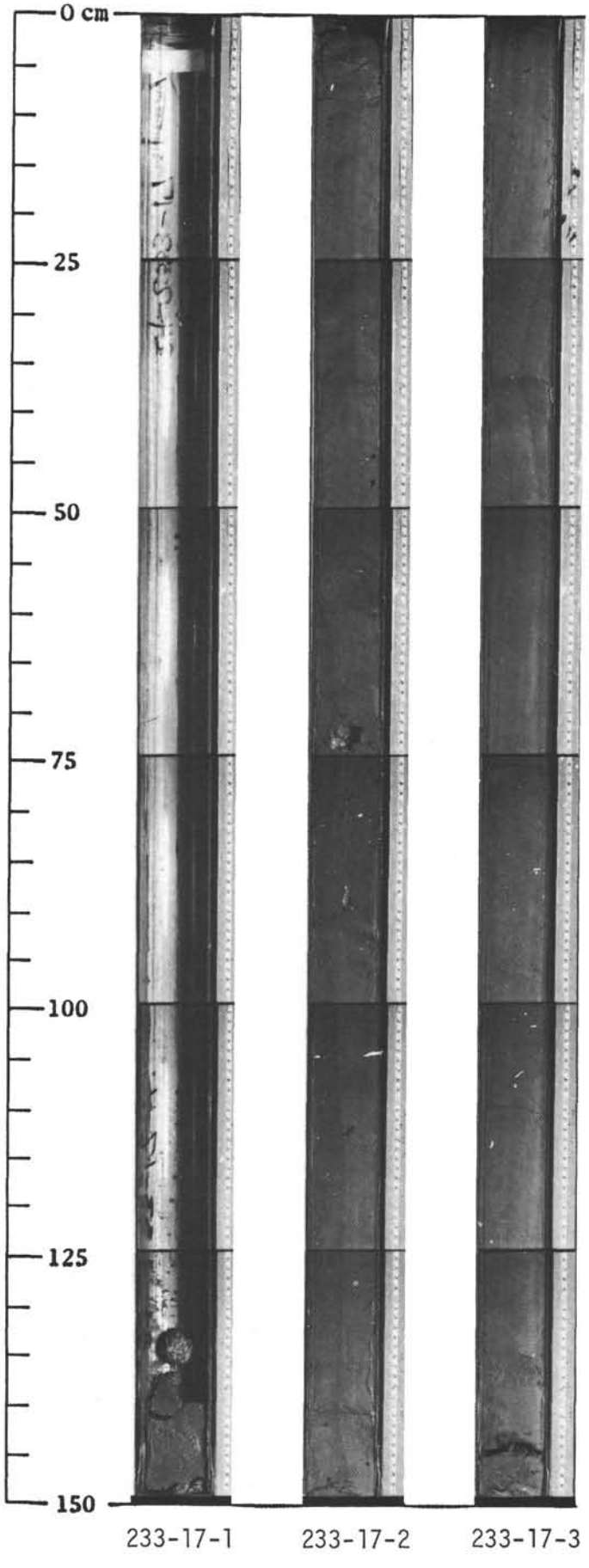
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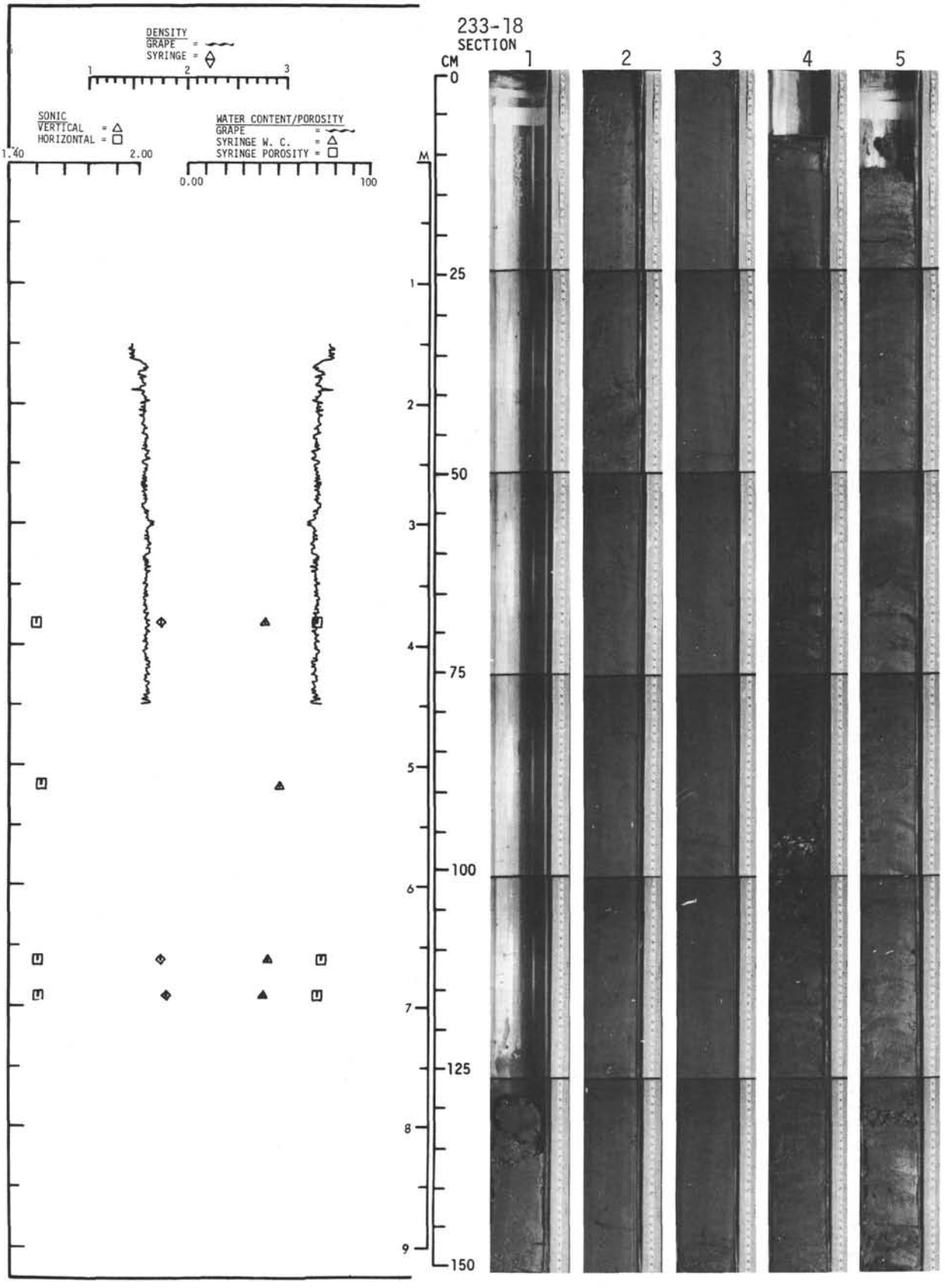
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SYRINGE POROSITY = □
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233-18
SECTION
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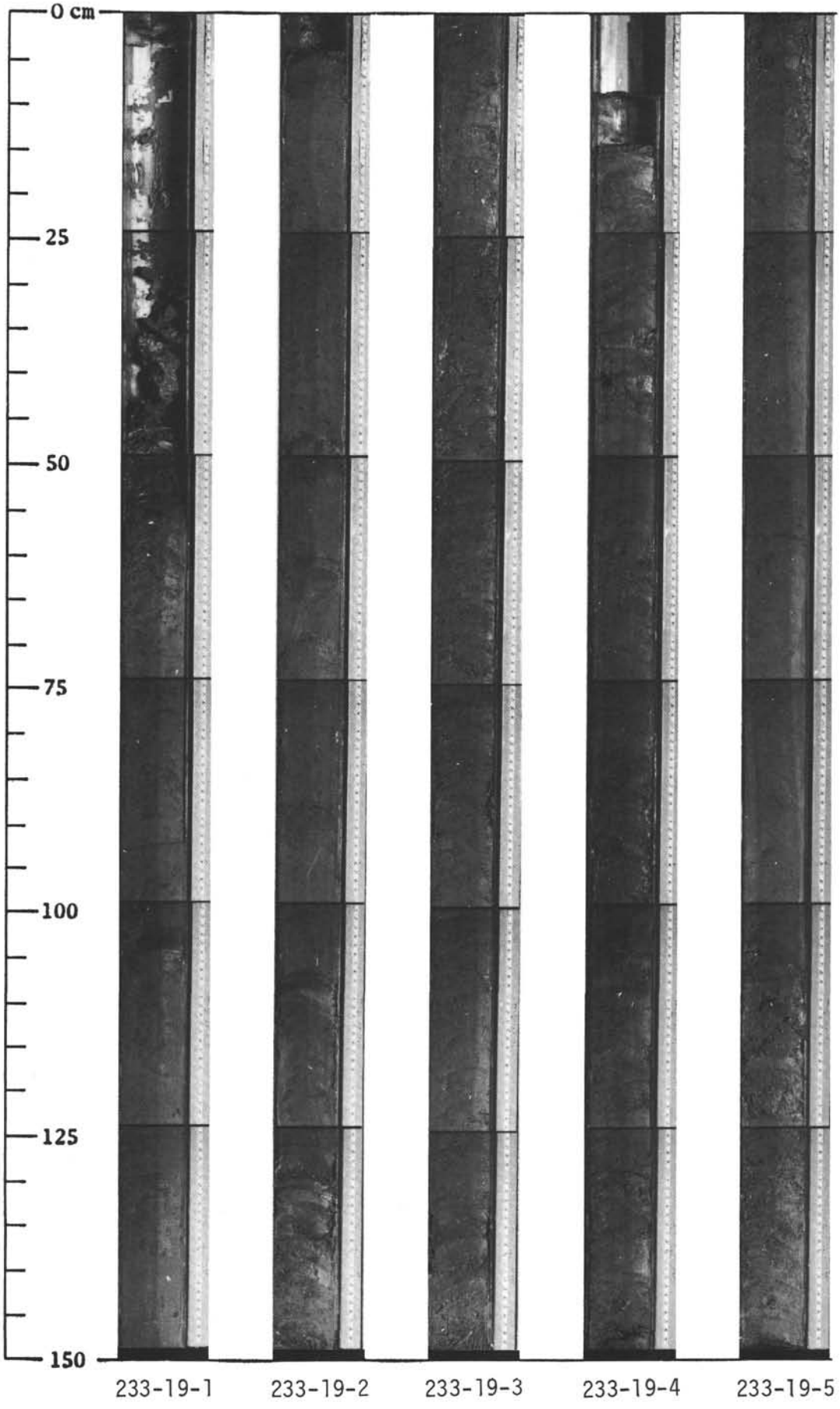
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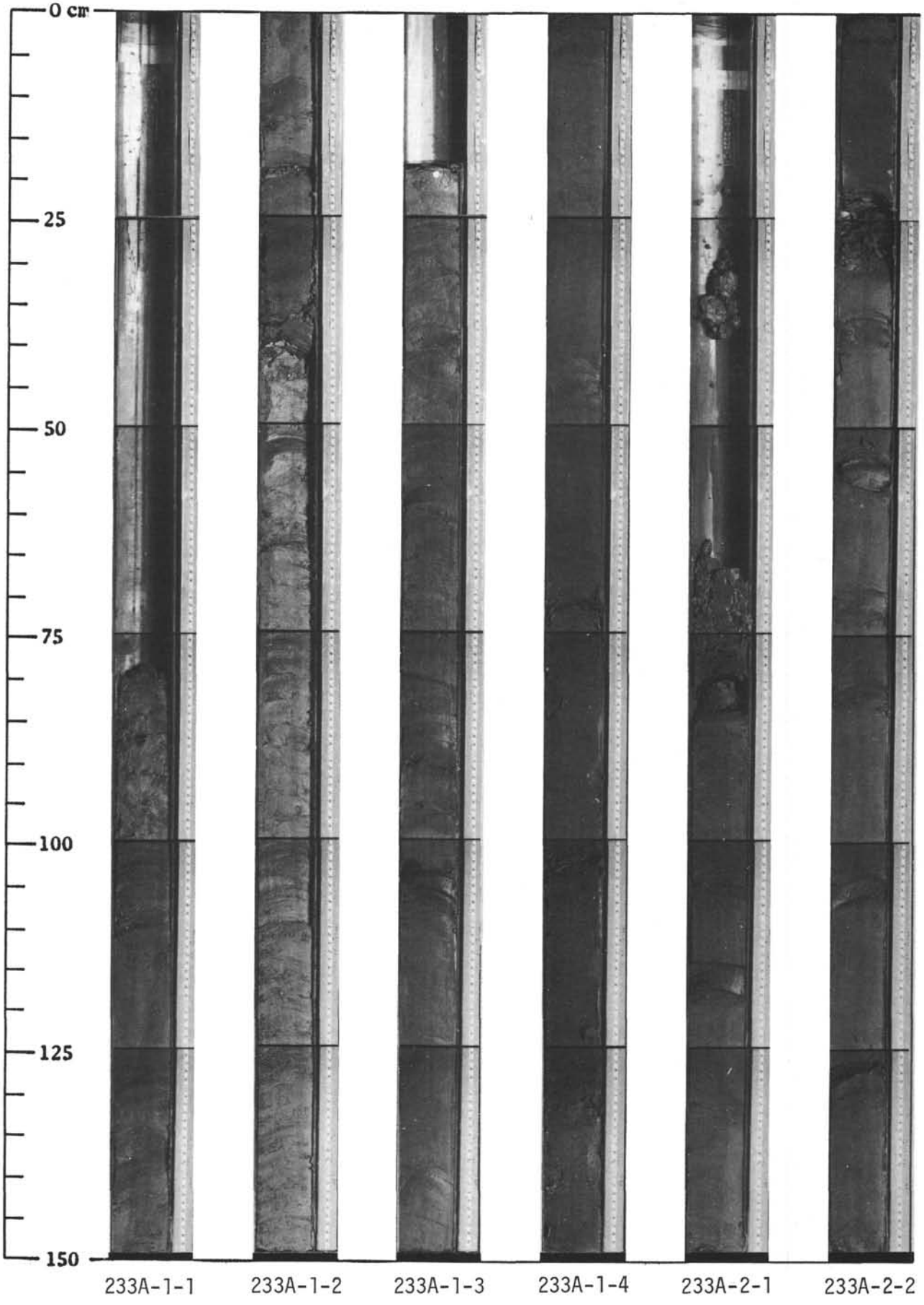
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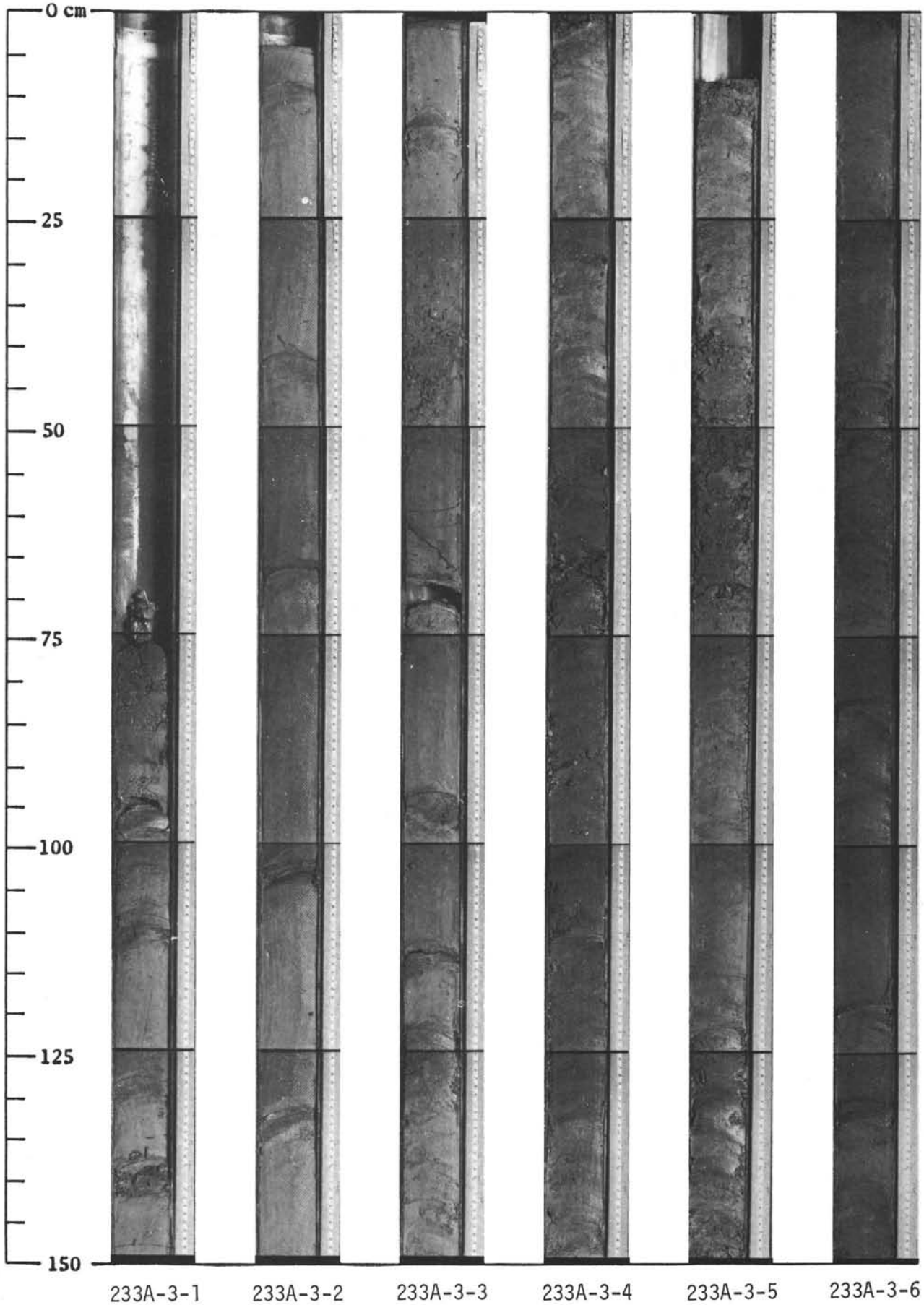
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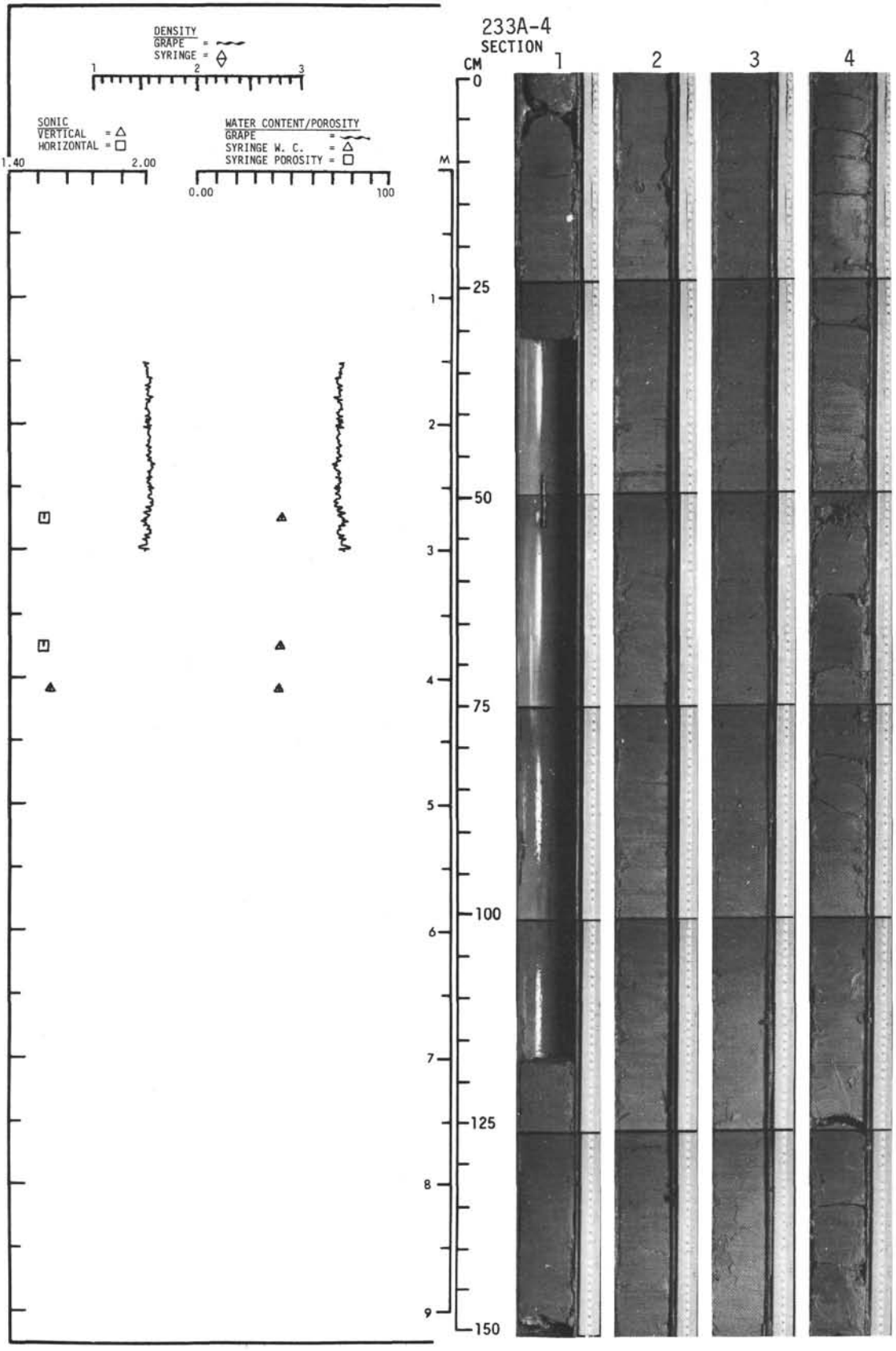
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VERTICAL = △
HORIZONTAL = □
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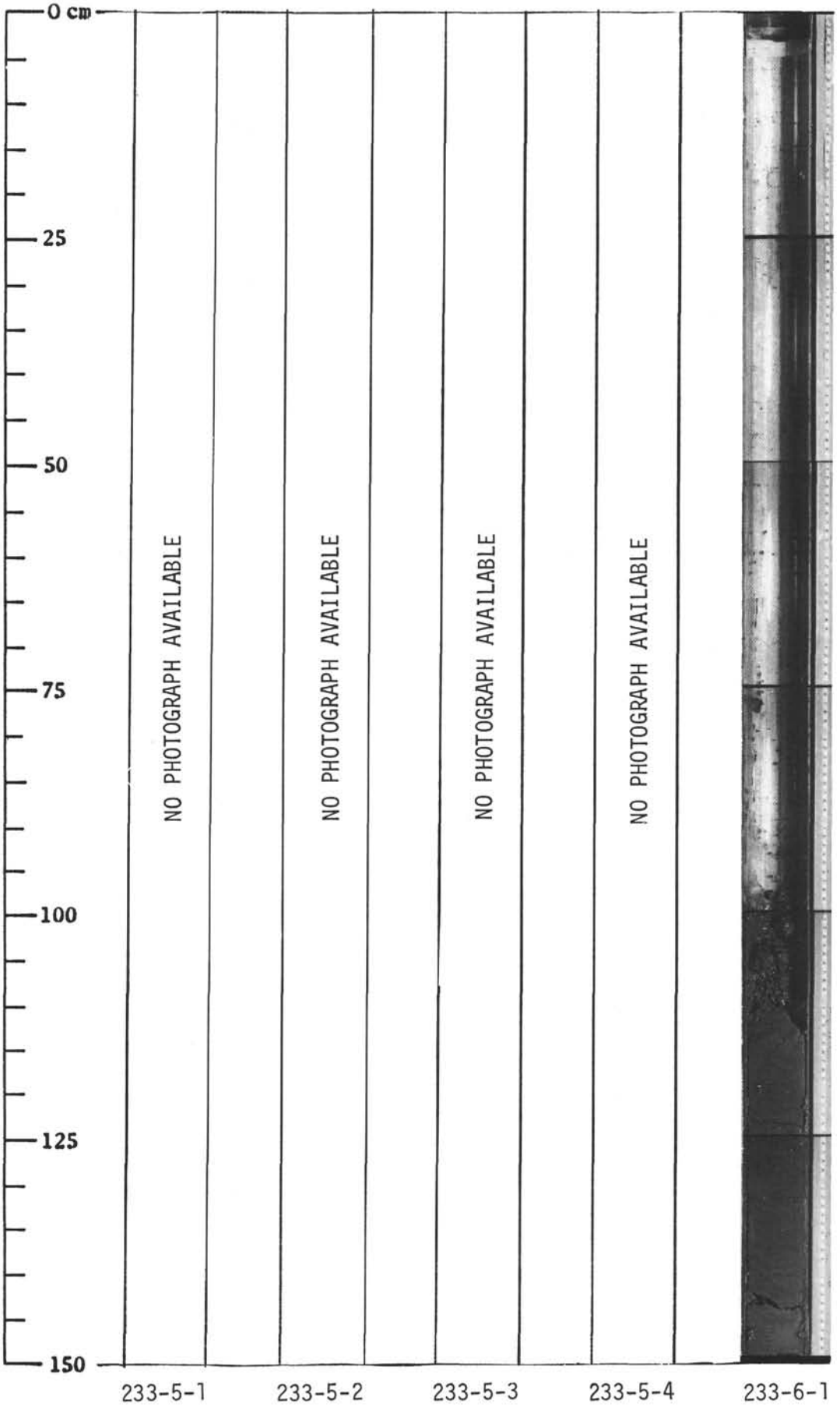
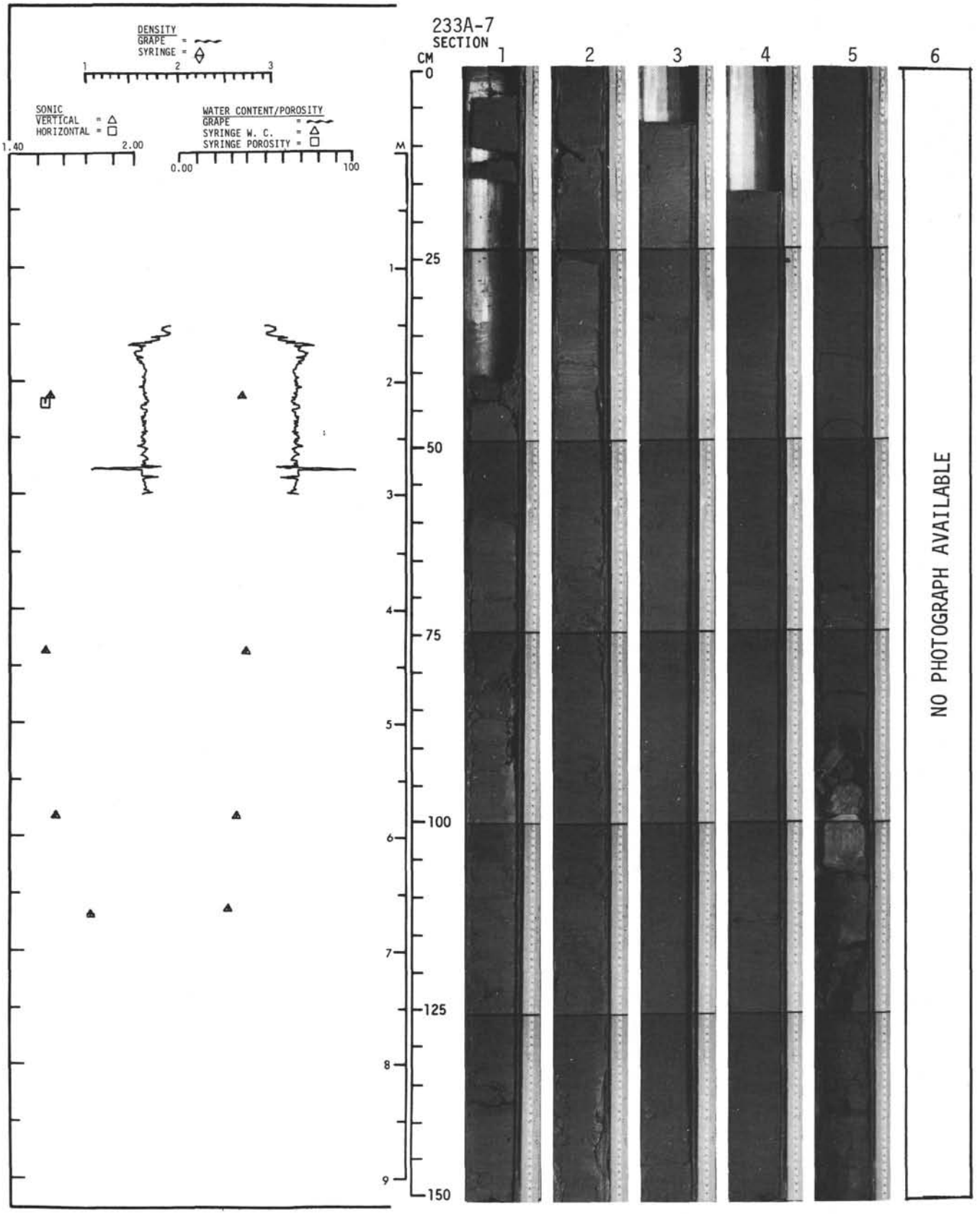
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
233A-4
SECTION
CM
M
1
2
3
4
0
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
NO PHOTOGRAPH AVAILABLE
NO PHOTOGRAPH AVAILABLE
NO PHOTOGRAPH AVAILABLE
NO PHOTOGRAPH AVAILABLE
233-5-1
233-5-2
233-5-3
233-5-4
233-6-1


DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = □
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
233A-7
SECTION
CM
M
1
2
3
4
5
6
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25
50
75
100
125
150
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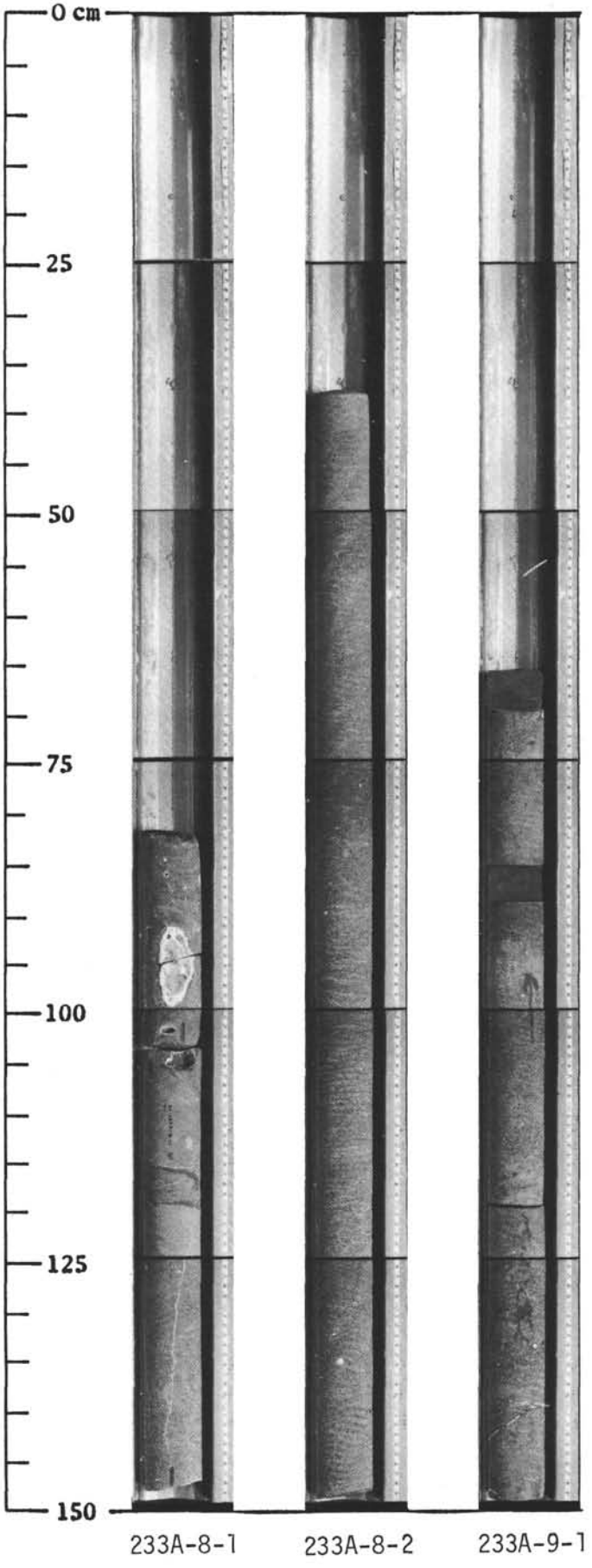
0 cm
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50
75
100
125
150
233A-8-1
233A-8-2
233A-9-1