6. SITE 235

The Shipboard Scientific Party[1]

SITE DATA

Date Occupied: 22 May 1972

Date Departed: 26 May 1972

Time on Site: 119 hours

Position:
Latitude: 03°14.06′N
Longitude: 52°41.64′E

Water Depth: 5130 corrected meters (echo sounding)

Bottom Felt At: 5146 meters (drill pipe)

Penetration: 684 meters

Holes Drilled: 1

Number of Cores: 20

Total Length of Cored Section: 190 meters

Total Core Recovered: 98.1 meters

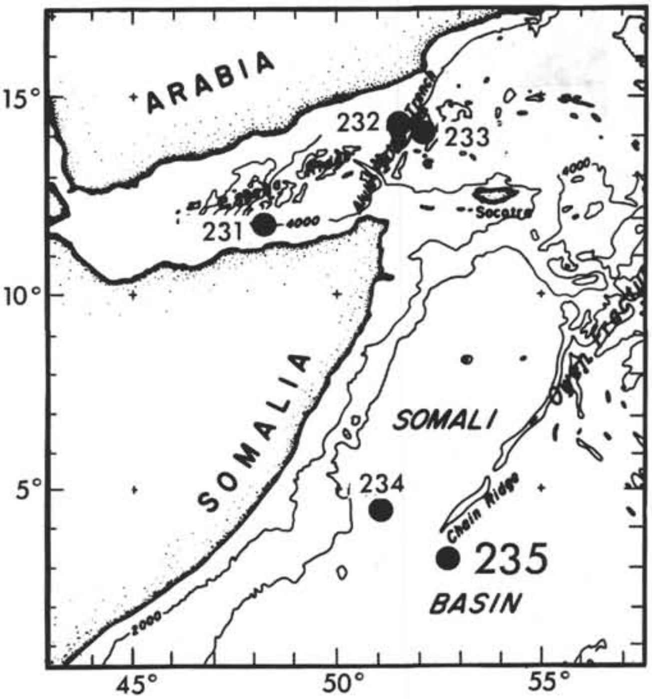
Acoustic Basement:
Depth: 651.5 meters
Nature: Basalt (diabase)
Inferred vertical velocity to basement: 1.63 km/sec

Age of Oldest Sediment: Upper Cretaceous

Basement: Cretaceous? from K-Ar date Chain Ridge dredge haul (Bunce et al., 1967)

Principal Results: This site was located on the westernmost edge of the abyssal plain bordering the east flank of Chain Ridge. The single penetration was intermittently cored to basaltic basement. Total penetration was 684 meters with 190 meters cored and 98.1 recovered. The sediment section consisted mainly of pale blue-gray nanno ooze. Forams are rare to missing throughout the column.

Age of sediments are: Pleistocene 0-45 meters; Pliocene 45-195 meters; and Miocene 195-500 meters. The last sediment core at 579.5 meters consists of laminated clay and calcareous silty clay and is devoid of nannos and forams. Sediment pods at sediment-basalt contact contain Late Cretaceous nannos but there are no fossils in the filled veins at the base of the section. Total penetration into basement was 32.5 meters. Coring recovery was 12.94 meters of basalt glass breccia, a rather fresh dense gray black porphyritic extrusive. The flows become massive at the hole base.



BACKGROUND AND OBJECTIVES

See Background and Objectives of Sites 234 and 235, Chapter 5.

OPERATIONS

Near-Site Activities

Site 235, on the Somali Abyssal Plain just east of Chain Ridge, was approached on a southeasterly run crossing the deep-lying southwest extremity of the ridge. The proposed site (24-5) had been reconnoitered by R/V *Chain* in 1971 (Figure 1), and only moderate additional exploration was required. Southeast of the 5120 meter contour the sea floor lies at 5122 ± 2 meters throughout the region (Figure 2) so the chief criterion was favorable depth to "hummocky" basement. A slow speed run northeast near 24-5 revealed acoustic basement well developed below an intermediate reflector underlain by layered returns (Figure 3). The beacon was dropped while underway on this course, streamers were retrieved, and *Glomar Challenger* returned to occupy Site 235 in a water depth on 5130 meters (corrected). This locality is 1.9 nmi northeast of 24-5.

---

[1] Elizabeth T. Bunce, Department of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts (Co-chief scientist); Robert L. Fisher, Geological Research Division, Scripps Institution of Oceanography, La Jolla, California (Co-chief scientist); Paul J. Cernock, Producing Department, Texaco Inc., New Orleans, Louisiana; David C. Clegg, Scripps Institution of Oceanography, La Jolla, California; David S. Cronan, Department of Geology, University of Ottawa, Ottawa, Ontario, Canada (Present address: Department of Geology, Imperial College, London SWT, England); Vincenzo Damiani, Instituto Italiano de Idrobiologia, Italy (Present address: Canada Centre for Inland Waters, Burlington, Ontario, Canada); Leonid V. Dmitriev, Institute of Geochemistry, Academy of Sciences of the USSR, Moscow, USSR; David J. J. Kinsman, Department of Geological and Geophysical Sciences, Princeton University, Princeton, New Jersey; Peter H. Roth, Geological Research Division, Scripps Institution of Oceanography, La Jolla, California, Jörn Thiede, Universitet I Bergen, Geologisk Institut, Bergen, Norway (Present address: School of Oceanography, Oregon State University, Corvallis, Oregon); Edith Vincent, Department of Geological Sciences, University of Southern California, Los Angeles, California.

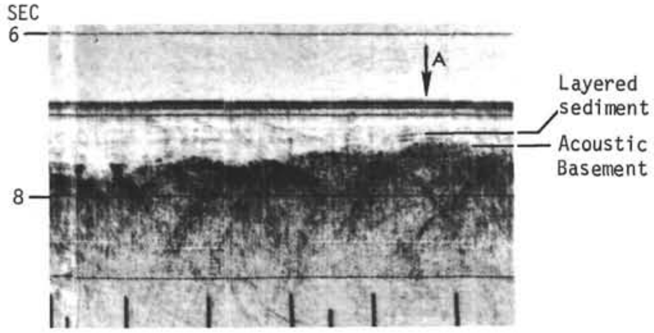


Figure 1. *Site survey profile,* Chain *100, April, 1971. Equipment as for Site 234.* A *indicates proposed site.*

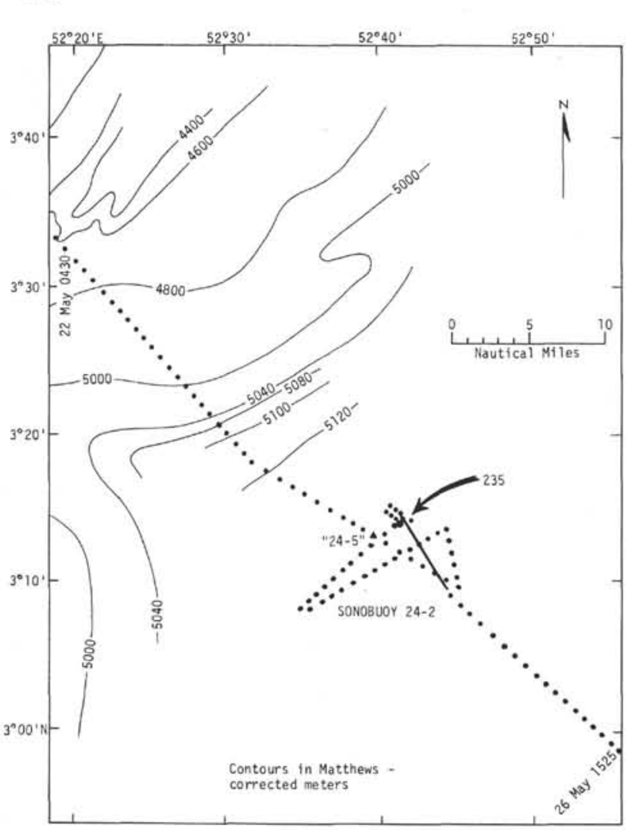


Figure 2. *Site survey track of* Glomar Challenger *showing location of prospective site 24-5 and Site 235.*

Figure 2 incorporates the *Chain* and *Glomar Challenger* sounding data.

On leaving Site 235, *Glomar Challenger* ran northwesterly at 4 knots to stream gear and check out systems. She then came about to a southeasterly course to pass near the beacon, dropping a sonobuoy (SB 24-2) for a wide-angle reflection run. With a course change to south-southeast, *Glomar Challenger* made a 6-mile seismic profile, then came up to standard speed and proceeded in broad zig-zags toward Site 236 (24-7).

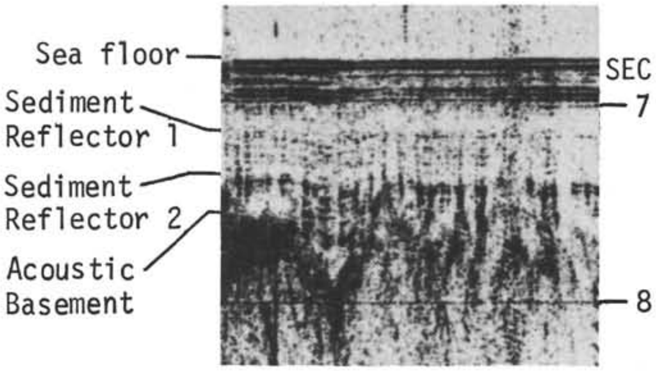


Figure 3. *On-site reflection profile showing two sedimentary reflection horizons above acoustic basement.*

Drilling Program

The bottom at Site 235 was difficult to detect on the weight indicator since the soft chalk did not provide enough resistance to the core bit to enable the driller to detect any definite change in drill string weight.

The top 28.5 meters were continuously cored. The hole was then intermittently cored and drilled to 646 meters (Table 1). Minor sticking and ball-up problems were noticed but were not nearly as severe as those encountered at Site 234. A trace of basalt was recovered in Core 17; the drilling rate recorder indicating a sudden change of drilling at 5801 meters. Basalt was cored to a total depth of 5830 meters, with 13 meters recovered. Total penetration was 684 meters, 494 meters drilled and 190 meters cored, with 98.1 meters recovered.

LITHOLOGIC SUMMARY

Site 235 was cored at varying intervals from the sediment surface down to a depth of 684.0 meters (Table 1). Twenty cores were obtained: Cores 1-16 (0.0-651.5 m below the sea floor) penetrated sediments; Cores 17-20 (651.5-684.0 m below the sea floor) penetrated basalt. The cored section comprises four lithologic units (Table 2).

Unit 1 (0.0-38.0 m; Cores 1-4)

This unit consists of dusky yellow-green nanno ooze. At the surface, the sediments are very soupy, becoming soft below. The color is quite uniform except towards the bottom where it changes to a grayish olive green. The composition of the sediments is very uniform with 80-95 percent calcareous nannoplankton; minor components are foraminifera (0-2%), diatoms (2-3%), radiolarians (1-2%), sponge spicules (1-2%), and detrital components such as quartz (0-3%), heavy minerals (0-2%), and volcanic ash (0-3%). The texture is 1-5 percent sand, 20-30 percent silt, and 70-80 percent clay. A sandy layer 2-3 cm thick is found in Core 3 at a depth of 22.7 meters with 60 percent sand, 20 percent silt, and 20 percent clay. Towards the bottom of the unit there is occasional burrow mottling.

TABLE 1
Coring Summary – Site 235

Core	Date (May 1972)	Time	Depth Below Sea Floor (m)	Depth From Drill Floor (m)	Cored (m)	Recovered (m)	Recovered (%)
1	23	0617	0-9.5	5146.0-5155.5	9.5	8.5	89
2	23	0738	9.5-19.0	5155.5-5165.0	9.5	8.3	87
3	23	0857	19.0-28.5	5165.0-5174.5	9.5	4.8+	50+
4	23	1015	28.5-38.0	5174.5-5184.0	9.5	6.0+	63
Drilled (5184.0-5212.5)							
5	23	1208	66.5-76.0	5212.5-5222.0	9.5	9.3+	98
6	23	1334	76.0-85.5	5222.0-5231.5	9.5	0	0
Drilled (5231.5-5260.0)							
7	23	1450	114.0-123.5	5260.0-5269.5	9.5	5.4	57
8	23	1718	123.5-133.0	5269.5-5279.0	9.5	1.4	15
Drilled (5279.0-5317.0)							
9	23	2010	171.0-180.5	5317.0-5326.5	9.5	8.8	93
Drilled (5279.0-5364.5)							
10	23	2318	218.5-228.0	5364.5-5374.5	9.5	9.5+	100
Drilled (5374.0-5412.0)							
11	24	0215	266.0-275.5	5412.0-5421.5	9.5	6.9	73
Drilled (5421.5-5459.5)							
12	24	0522	313.5-323.0	5495.5-5469.0	9.5	3.9	41
Drilled (5469.0-5507.0)							
13	24	0814	368.0-377.5	5507.0-5516.5	9.5	4.3	45
14	24	1402	427.5-437.0	5573.5-5583.0	9.5	2.5	26
Drilled (5583-5640)							
15	24	1939	494.0-503.5	5640.0-5649.5	9.5	5.7	60
Drilled (503.5-579.5)							
16	25	0435	579.5-589.0	5725.5-5735.0	9.5	0.3	3
Drilled (5735.0-5792.0)							
17	25	0930	646.0-655.5	5792.0-5801.5	9.5	0.4	4
18	25	1406	655.5-665.0	5801.5-5811.0	9.5	0.94	10
19	25	1928	665.0-674.5	5811.0-5820.5	9.5	4.3	45
20	26	0029	674.5-684.0	5820.5-5830.0	9.5	6.9	73

TABLE 2
Lithologic Units – Site 235

Depth Below Sea Floor (m)	Unit	Lithology	Thickness (m)	Cores
38.0	1	Dusky yellow-green Nanno ooze	38	1-4
66.5 503.5	2	Yellow-gray Nanno ooze to Greenish-black Nanno clay	437	5-15
579.5 589.0	3	Moderate brown clay	9.5	16
646.0 684.0	4	Basalt	38	17-20

Unit 2 (66.5-503.5 m; Cores 5-15)

The sediments recovered showed alternations of yellow-gray to grayish-green nanno ooze and greenish-black to dark greenish-gray nanno clay. The nanno ooze is characterized by calcareous nannoplankton (60-95%) with minor components similar to those of Unit 1 but with more clay minerals (0-15%). Foraminifera gradually disappear with increasing depth in the unit. The nanno clay is characterized by clay minerals (50-95%), nannoplankton fossils (1-30%), volcanic glass (0-3%), and pyrite (0-3%). The texture does not change between the two facies, 0-5 percent sand, 10-30 percent silt, 70-90 percent clay. Some 3-cm-thick sandy layers are found at 73.2 meters in Core 5. A very finely laminated sandy layer with a thickness of 12-15 cm was found at 369.4 meters. The latter is characterized by 30 percent micarb, 30 percent foraminifera, and 30 percent calcareous nannos. Its texture is 50 percent sand, 30 percent silt, and 20 percent clay. Towards the bottom of the unit, there are fragments of pyrite nodules (1-3 cm) and burrows from 1-2 mm to 2-3 cm in diameter. Color changes on the scale of 5-10 cm to meters are common.

Unit 3 (579.5-589.0 m; Core 16)

Unit 3 consists of moderate brown clay. This unit is represented only by 30 cm of sediments obtained from Core 16. The main components are clay minerals (80-95%) and traces of calcareous nannoplankton (1%), quartz (1-5%), and heavy minerals (1%). Typical in this unit are aggregates of iron oxides. The texture is 1-3 percent sand, 20-30 percent silt, and 70-80 percent clay.

Unit 4 (646.0-684.0 m; Cores 17-20)

Unit 4 is comprised of basalt and lava breccias with layers and veins of fine-grained metamorphosed sediment. This unit is described in Appendix A.

Conclusions

1. Unit 1 represents distal hemipelagic sedimentation with a high biogenic input, close to the carbonate compensation depth.

2. The finely laminated silt-sand horizon of Unit 2 (Core 13) may represent turbidites, probably derived from the Chain Ridge.

3. The sedimentary environment evolved with time from oxidizing to more reducing conditions while the preservation of carbonate materials improved.

4. The absence of volcanic ash layers may be related to the greater distance from land, protection of the area by Chain Ridge, or absence of volcanoes.

BIOSTRATIGRAPHIC SUMMARY

Introduction

The upper 500 meters of sediments discontinuously cored at Site 235 range in age from Quaternary to middle Miocene. Sediments between 500 and 646 meters below sediment water interface are of undetermined age; the only core recovered in this interval did not yield any fossils. Sediment inclusions in the basalt between 662 and 665 meters indicate a late Maestrichtian age (65-67 m.y. B.P.).

Nannofossils are moderately to well preserved and while common throughout the upper 500 meters are absent below this level, with the exception of rare poorly preserved specimens in the sediment inclusions in the basalt. Foraminifera are rare and poorly preserved. They show a significant degree of dissolution throughout the section. Radiolarians are abundant and well preserved in the upper 76 meters, whereas they are less common and poorly preserved or absent below.

Sequences of fossil zones and age assignment are summarized on the site summary form at the end of this chapter. Epoch boundaries which fall within unrecovered intervals are located on the basis of sedimentation rates. The Pliocene/Pleistocene boundary is placed between Cores 4 and 5 at approximately 45 meters; the Miocene/Pliocene boundary between Cores 9 and 10 at approximately 195 meters; and the middle/late Miocene boundary between Cores 12 and 13 at about 340 meters.

Calcareous Nannoplankton

Core 1 belongs to the *Gephyrocapsa oceanica* Zone with *Gephyrocapsa oceanica* and *Umbilicosphaera sibogae*. Core 2 recovered the *Gephyrocapsa caribbeanica* Zone with *Gephyrocapsa caribbeanica* and *Crenalithus doronicoides*. Cores 3 and 5 are assigned to the *Pseudoemiliania lacunosa* Zone and yield an assemblage with *Pseudoemiliania lacunosa* and *Crenalithus doronicoides*. The Pliocene/Pleistocene boundary lies between Cores 4 and 5. Core 5 belongs to the late Miocene *Cyclococcolithina macintyrei* Zone with *Discoaster brouweri* and *Cyclococcolithina macintyrei*. Core 7 recovered the *Discoaster tamalis* Zone with *Discoaster tamalis, D. surculus, D. pentaradiatus,* and *D. variabilis.* The *Reticulofenestra pseudoumbilica* Zone is present in Core 8 with *Reticulofenestra pseudoumbilica* and *Sphenolithus abies.* Core 9 yields an assemblage characteristic of the *Ceratolithus rugosus* Zone with *Ceratolithus rugosus* and *C. tricorniculatus.* The Miocene/Pliocene boundary lies between Cores 9 and 10. Cores 10 and 11 recovered the *Ceratolithus primus* Zone with *Ceratolithus primus* and *Discoaster quinqueramus.* The *Discoaster bellus* Zone with *Discoaster neohamatus* and *D. bellus* occurs in Core 12. Core 13 contains the *Discoaster hamatus* Zone with *Discoaster hamatus, D. neohamatus,* and rare *D. blackstockae.* Core 14 belongs to the *Discoaster kugleri* Zone with *Discoaster kugleri* and *D. exilis.* Core 15 recovered the *Sphenolithus heteromorphus* Zone with *Sphenolithus heteromorphus, Discoaster exilis,* and *Coccolithus eopelagicus.* Core 16 is barren of nannofossils. Sediment inclusions in the basalt in Cores 17, 18, and 20 contain rare nannofossils including *Micula decussata, M. mura, Markalius inversus,* and *Prediscosphaera cretacea,* which indicate a late Maestrichtian age.

Preservation: Assemblages are moderately to well preserved with slight etching and overgrowth throughout the sedimentary section. The inclusions in the basalt contain strongly overgrown nannofossils.

Foraminifera

Abundance and Preservation

The sediments of Site 235 yielded an extremely small coarse fraction (>63μ) throughout the section. A larger amount of coarse fraction was recovered in some silty and sandy horizons of lithologic Units 1 and 2. In these horizons, uniformly minute foraminifera are common to abundant. Despite the great depth of water at the site (5146 m), this fauna is well preserved; it is probably displaced from shallower depths and may represent the distal parts of turbidite layers.

Except for this distinct, well-sorted foraminiferal fauna, foraminifera show a significant degree of dissolution. The fauna is poorly diversified, the tests are highly fragmented, and only those species resistant to solution are present.

The sediment inclusions in the basalt between 662 and 665 meters were too indurated to be disaggregated. Four thin sections at 662 and 665 meters (Core 18, Section 1 and 18, CC) show a recrystallized sediment without foraminifera.

Planktonic Foraminiferal Zonation

Due to the paucity and poor preservation of the planktonic foraminifera recovered at Site 235, biostratigraphic investigation could be conducted only at a few horizons.

The presence of *Globorotalia truncatulinoides* in Cores 1 to 5 indicate a Quaternary age for this interval. Core 7 appears to be late Pliocene in age (N.21) as shown by the cooccurrence of *Neogloboquadrina dutertrei* and *Pulleniatina primalis.* Core 8 and the upper part of Core 9, which contain *Globorotalia tumida, Globoquadrina altispira,* and *Pulleniatina* spp., are assigned to the early Pliocene Zones N.20-N.19, and Sample 9, CC, which includes *Globorotalia tumida plesiotumida,* is assigned to N.18. Core 10 yielded a similar planktonic assemblage but without *G. tumida.* Because of the absence of this species, Core 10 is attributed to N.17.

The debris of planktonic foraminifera (mainly fragmented keels of *Globorotalia*) found in Core 6 and below 228 meters (Cores 11 to 16) do not permit a zonal assignment for these intervals.

Benthic Foraminifera

Benthic foraminifera are rare, generally constituting less than 1 percent of the total foraminiferal fauna, except in some horizons of Cores 3, 5, and 8 to 12, where they comprise a larger proportion of the fauna (usually 10 to 25%). Only deep-water calcareous species were found.

The small proportion of benthic foraminiferal species, which are less susceptible to solution than planktonic species, probably reflects a shallower origin for part of the sediment of Site 235. This conclusion is supported by the lower benthic/planktonic ratio at Site 235 than at Site 234 even though the water depth is greater at the latter. The lower benthic/planktonic ratio at Site 235 is also associated with a sedimentation rate much higher than at Site 234. Displacement of sediment from a shallower source is also indicated by the presence in some horizons of pteropods and bivalve debris.

Radiolaria

Samples from 235-1-1 through 235-5-6 contain common to abundant, well to excellently preserved radiolarians. Below this, radiolarians are much less common, generally pyritized, and not sufficiently well preserved for stratigraphic interpretation. Occurrences in Site 235 samples are as follows: 7-1, 106-110 cm (R, M); 7-4, 96-100 cm (R, P); 8-1, 96-100 cm (R, P); 9-1, 57-62 cm (R, P); 9-6, 93-99 cm (R, P); 10-1, 50-52 cm (F, P); 10-6, 101-105 cm (R, P); 11-6, 110-112 cm (F, M); 12-1, 93-96 cm (R, P); 12-3, 89-93 cm (C, M); 13-1, 49-51 cm (R, P); 13-3, 109-111 cm (R, P); 14-2, 34-40 cm (R, P); 15-1, 60-62 cm (None); 15-4, 108-110 cm (None); 16-1, 136-138 cm (None).

The section from the top of the hole through the sample at 235-5-1, 68-74 cm contains Quaternary radiolarians, and the assemblage in 235-5-6, 99-103 cm is in the *Pterocanium prismatium* Zone.

SEDIMENT ACCUMULATION RATES

Average accumulation rates of the sediments of Site 235 were calculated as follows:

Series	Thickness (m)	Average Accumulation Rate (m/m.y.)
Pleistocene	45	25
Upper Pliocene	78.5	65.4
Lower Pliocene	71.5	27.5
Upper Miocene	145	24.2
Middle Miocene	160	53.3

The middle Miocene rate is a minimum value as the base of the series was not determined.

Rates of accumulation of the upper 500 meters of sediment average 37.0 m/m.y., a very high value compared to the average rate of 5.0 m/m.y. for the equivalent strata at Site 234. The high rate of accumulation at Site 235 probably results from the influx of displaced shallower sediments, as evidenced by the better preservation of the calcareous material than would normally be expected in a water depth greater than 5000 meters.

The undated lower 147 meters of the sedimentary sequence above basement correspond to an interval of time of at least 51.5 m.y. between early middle Miocene (approximately 13.5 m.y.) and late Maestrichtian (65 m.y. or older). The average accumulation rate for this interval is, therefore, 0.4 m/m.y. This low value indicates that breaks in sedimentation have probably occurred during that interval.

PHYSICAL PROPERTIES

Because of the intermittent coring procedure used at Site 235, the data gaps for the uncored sections within the hole preclude any definite conclusions concerning the physical properties.

Bulk Density and Porosity

The bulk density and porosity of the 646 (?) meters of nanno ooze and nanno clays increases from 1.53 to 1.91 g/cm^3 and decreases from 70.1 to 47.3 percent, respectively, from near the sediment-water interface to 500 meters. Lithologic Unit 1 and the uppermost portion of Unit 2 (0-75 m) are characterized by a rather uniform 1.56 g/cm^3 bulk density and corresponding porosity of 68.3 percent (Figure 4).

Bulk densities of the basement rocks were obtained by the GRAPE device on block samples approximately 1.5 cm × 1.5 cm × 2.5 cm. Bulk densities of the basalt samples measured in the vertical direction (long axis) range from 2.75 to 2.84 g/cm^3 and those measured in the horizontal direction range from 2.73 to 2.84 g/cm^3. A sample of volcanic breccia from Core 19 has a vertical bulk density of 2.39 g/cm^3 and a horizontal bulk density of 2.29 g/cm^3 (see Table 3).

Sonic Velocity

The velocity profile of the nanno ooze and nanno clays increases from 1.47 km/sec near the sediment-water interface to 1.74 km/sec at approximately 587 meters. Lithologic Unit 1 and the uppermost portion of Unit 2 (0-75 m) are characterized by a uniform 1.48 km/sec (Figure 4).

The upper 323 meters of sediments were measured for only horizontal velocities due to the cohesiveness of the sediment. However, the small degree of velocity anisotropism in Core 13, Section 1 (369 m) suggests that the measured horizontal velocities are also valid representations of the vertical velocities. Velocity anisotropism increases from 0.07 km/sec at 369 meters to approximately 0.13 km/sec at about 500 meters. For this reason, horizontal velocities are plotted above 369 meters and vertical velocities at 369 meters and deeper. Velocity anisotropism decreases to practically zero for a sample at about 587 meters. If this measurement is considered representative of the sediment section (Unit 3) above the acoustic basement, it may be inferred that proximity to the basaltic basement brought about the decrease in velocity anisotropism, either by baking, hydrothermal cementation processes, or some other factor.

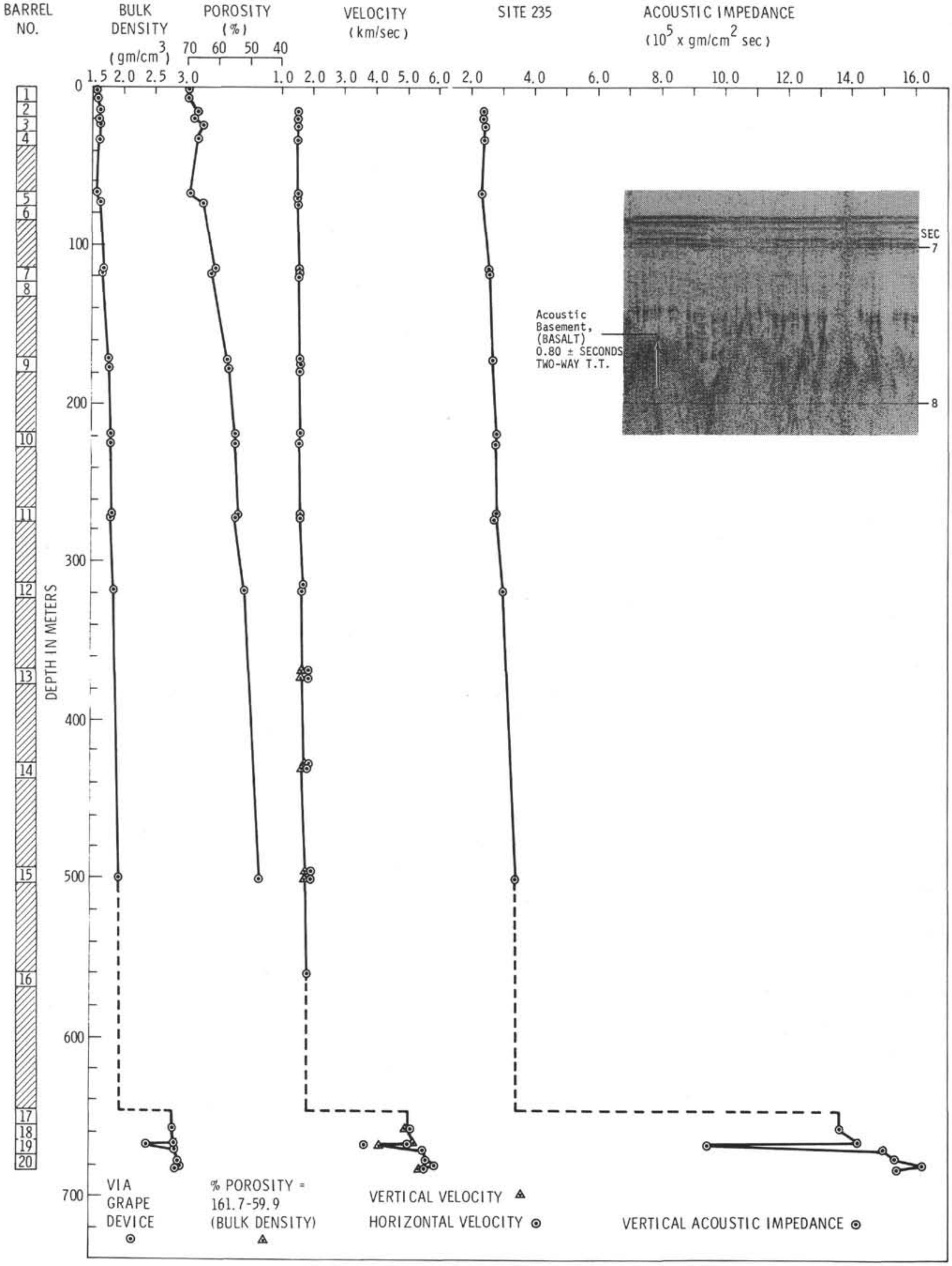


Figure 4. *Physical properties, Site 235.*

TABLE 3
Bulk Density of Basalt – Site 235

Sample[a]	Bulk Density (g/cm^3)		Velocity (km/sec)		Rock Description
	Vertical	Horizontal	Vertical	Horizontal	
18-1 (7)	2.75	2.73	4.95	5.02	Basalt
19-1 (10)	2.76	2.78	5.12	5.01	Basalt
19-2 (4)	2.39	2.29	4.00	3.59	Glassy breccia
19-3 (21)	2.79	2.76	5.37	5.34	Basalt
20-2 (21)	2.80	2.82	5.45	5.47	Basalt
20-4 (21)	2.84	2.84	5.69	5.73	Basalt
20-5 (8)	2.80	2.84	5.44	5.34	Basalt

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

The major velocity change occurs at approximately 646 meters (Unit 4), where basaltic basement is encountered. Six randomly chosen basalt samples from Cores 18, 19, and 20 have vertical velocities ranging from 4.95 to 5.69 km/sec and horizontal velocities ranging from 5.01 to 5.73 km/sec. Significant velocity anisotropism is not apparent in the measurements. A sample of volcanic breccia from Core 19 has a vertical velocity of 4.00 km/sec and a horizontal velocity of 3.59 km/sec (see Table 3).

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

Depth Interval (m)	Average Velocity (km/sec)	Travel Time (sec)
0-70	1.48	0.047
70-175	1.51	0.070
175-270	1.53	0.062
270-450	1.62	0.111
450-646	1.73	0.113
		0.403

Thus, maximum one-way travel time at Site 235 for the basement reflection should be 0.403 sec.

Acoustic Impedance

The acoustic impedance value increases from 2.33×10^5 g/cm^2 sec near the sediment-water interface to 3.34×10^5 g/cm^2 sec at approximately 500 meters. An acoustical impedance mismatch sufficient to cause a reflection cannot justifiably be picked from the sparse amount of data. It is suggested that a reflection surface may exist between 272 and 316 meters, where the velocity increases from approximately 1.55 to 1.64 km/sec. Another surface might be present between 432 and 496 meters, where the velocity increases from approximately 1.62 to 1.70 km/sec.

The major reflector is the basaltic acoustic basement (Unit 4) at about 646 meters. This basalt has an average velocity (V_p) of 5.0 km/sec and an average bulk density of 2.78 g/cm^3. Thus, the acoustic impedance is about 13.9×10^5 g/cm^2 sec or 4.2 times that of the overlying sediment layer. The previously calculated travel time for the basement reflection (0.403 sec one-way or 0.806 sec two-way travel time) agrees handsomely with the ±0.80 seconds two-way travel time determined from the seismic reflection profiles in Figures 3 and 4.

INTERSTITIAL PORE WATER CHEMISTRY

Salinity, *p*H, and alkalinity of surface seawater and pore waters squeezed from sediments cored at Site 235 are presented in Table 4.

Salinity: Salinity data are plotted in Figure 5. Pore water salinities average 33 ± 2°/oo compared with a measured surface water value of 36.3°/oo and a published value at 4-5000 meters of 34.7°/oo (Wyrtki, 1971). The 2-3°/oo decrease between pore water and bottom salinities could be entirely caused by SO_4 = reduction.

TABLE 4
Interstitial Water Chemistry – Site 235

Depth Below Sea Floor (m)	Salinity (°/oo)	*p*H	Alkalinity (meq/kg)
Surface seawater	36.3	8.00	2.32
18	34.9	7.28	10.12
32	34.6	7.30	11.51
73	33.8	7.18	12.43
117	33.3	7.62	11.25
179	31.9	8.28	8.21
227	33.0	7.87	3.86
273	32.7	7.73	2.30
315	31.4	8.03	2.66
371	32.7	7.85	1.36
429	32.2	7.58	0.75
497	33.6	7.78	0.65

***p*H and Alkalinity**: Data are plotted in Figure 6. Some *p*H values below 179 meters are unusually high for pore waters and are rather suspect. Alkalinity shows the usual subsurface trend, increasing rapidly below the surface to rather high values, then decreasing with depth to values lower than that of seawater.

Water Content, Porosity, and Bulk Density: These data are presented in Table 5. Water content decreases from 50 percent to almost 20 percent down the core. Porosity decreases from 75-80 percent in the upper part of the cored section, to around 65 percent at 227 meters; bulk density increases from 1.55 g/cm^3 to 1.85 g/cm^3 over the interval 0 to 227 meters.

CORRELATION OF REFLECTION PROFILES AND LITHOLOGY

The reflection profile shows three major horizons: an acoustically semitransparent layer immediately beneath the

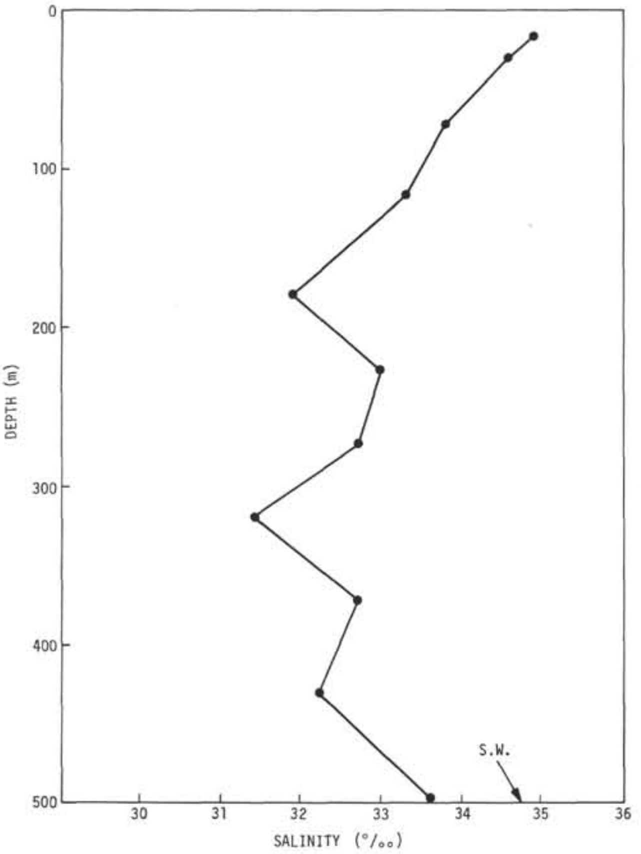


Figure 5. *Interstitial pore water salinity, Site 235.*

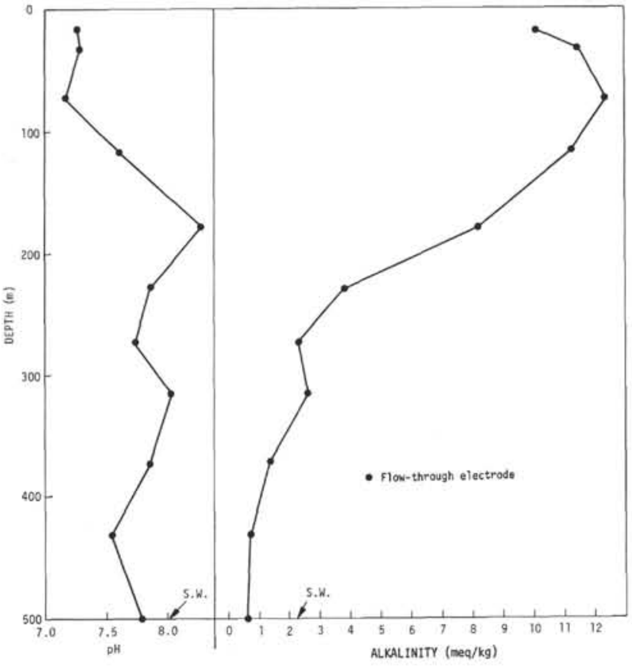


Figure 6. *Interstitial pore water* pH *and alkalinity, Site 235.*

sea floor; a relatively uniform, but intermittent reflector that in places appears to be part of the basement reflector and in others to top a thin (0.2 sec) transparent section; and acoustic basement. The last is topographically rough with hyperbolae indicative of side echos. In addition to these major units, a faint reflecting horizon can be seen at about 0.35 sec beneath the sea floor in the semitransparent layer, Figure 7.

The majority of the lithologic section consists of nanno ooze and slightly calcareous clay that extend to a depth of 579.5 meters. Between this and the basement is a layer of moderate brown clay. Basaltic basement lies at 651.5 meters.

Good acoustic-lithologic correlation is possible only for the basement. There are no observed boundaries in the intermittently cored section to correlate with either of these reflectors.

Because of the relatively high proportion of uncored to cored sediments, it is not possible to establish reliable datum points from which to calculate possible reflectors – the unknowns outweigh the knowns.

SUMMARY, CONCLUSIONS, AND SPECULATIONS

Site 235, in the northwest Somali Basin (03°14.06'N, 52°41.64'E), lies on the westernmost edge of the abyssal plain that onlaps the eastern flank of Chain Ridge. Although the floor of this plain is very slightly deeper than that of the Somali Plain west of the ridge, the basement surface is shallower, while the supposed turbidites lie at the same level on either side. These features, considered with the geographical relations of Chain Ridge and Owen Fracture Zone, suggest the former may be a continuation of the latter transform fault and demark an age discontinuity in the basin.

The primary objectives of drilling this site were: (1) to obtain basement material for comparison of age and composition with that of Site 234; (2) to identify and date the acoustically transparent material overlying basement; and (3) to supplement and/or extend the faunal sequence obtained at Site 234.

The scientific results are summarized in Figure 7. The one hole drilled at this site was cored at varying intervals (20 cores obtained) to its terminal depth of 684 meters. The last depth interval (651.5-684 m), in basement basalt, was continuously cored. The sediments as sampled consist of alternating nanno oozes and clays with a few intercalated sand layers and some traces of volcanic glass. They are divided into three lithologic units. The uppermost unit is dusky yellow-green nanno ooze, soupy at the surface, soft beneath. Its composition is uniform, 80-95 percent calcareous nannoplankton. Minor components include foraminifera, diatoms, radiolarians, and sponge spicules together with detritus as quartz, volcanic glass, and heavy minerals. A 2-3-cm sand layer occurs in the lower third, and there is occasional burrow mottling near the bottom. The second major unit has two facies, alternations of yellow gray to grayish green nanno ooze and greenish black to dark greenish gray nanno clay. Calcareous nannoplankton characterize the nanno ooze, which has minor components similar to Unit 1 except that it includes a larger percentage of clay minerals. Foraminifera gradually disappear as the depth of the section increases. The minor constituents of the nanno clays are diatoms, radiolarians, quartz, pyrite, and volcanic glass. Texture is the same for the two facies. Thin (3 cm) sand layers are found in the upper facies, and

TABLE 5
Water Content, Porosity, and Bulk Density of Sediments – Site 235

Core, Section Top of Interval (cm)	Water (%)	Porosity (%)	Density (g/cm^3)
1-2, 40	51.70	79.63	1.5402
1-5, 50	52.26	78.50	1.5021
2-2, 60	48.72	75.31	1.5457
2-4, 56	46.14	74.26	1.6094
3-2, 48	57.99	82.97	1.4307
3-2, 96	46.26	73.13	1.5808
3-4, 38	45.95	74.73	1.6263
5-1, 105	39.92	71.54	1.7920
5-1, 124	45.64	74.63	1.6351
4-4, 32	44.15	72.39	1.6396
5-2, 28	46.09	72.18	1.5660
5-2, 128	35.08	63.15	1.8001
5-4, 68	37.71	68.61	1.8194
5-6, 51	47.48	78.10	1.6449
5-6, 66	38.94	68.87	1.7686
5-6, 79	37.80	66.16	1.7502
5-6, 88	44.77	74.34	1.6604
5-6, 110	36.85	64.77	1.7576
5-6, 124	42.53	71.42	1.6792
7-1, 84	34.30	63.10	1.8396
7-1, 130	38.99	69.34	1.7784
7-2, 60	38.30	64.18	1.6757
7-2, 120	38.38	66.23	1.7256
7-4, 110	34.45	62.05	1.8011
7-3, 40	39.20	68.23	1.7405
7-3, 110	35.06	63.18	1.8020
9-2, 70	33.19	62.51	1.8833
9-2, 120	33.01	60.23	1.8245
9-4, 14	33.13	60.13	1.8149
9-4, 130			
9-5, 90	33.86	61.78	1.8245
9-6, 22	36.12	64.71	1.7915
9-6, 115	33.03	61.10	1.8498
10-2, 50	33.57	63.51	1.8918
10-2, 125	23.25	41.47	1.7836
10-5, 40	34.23	63.26	1.8480
10-5, 110	35.41	65.02	1.8362
11-3, 25	27.53		
11-3, 41	38.08		
11-3, 82	29.49		
11-4, 48	32.69		
11-4, 142	31.03		
12-2, 122	25.72		
12-3, 46	30:35		
12-3, 99	31.35		
12-3, 132	30.03		
13-1, 119	27.83		
13-3, 101	27.95		
14-2, 71	23.98		
14-2, 98	26.34		
15-2, 125	21.76		
15-3, 118	22.20		
15-4, 89	21.19		
16-1, 138	23.87		

thicker (12-15 cm) finely laminated sand layers, near the central section. Burrows and fragmentary pyrite nodules occur toward the bottom of the unit. The third sedimentary unit, of moderate brown clay, contains traces of calcareous nannoplankton, quartz, and heavy minerals, as well as aggregates of iron oxides. The fourth unit is solid to somewhat fractured greenish-gray basalt with obvious porphyritic structure, having veins and layers of fine-grained metamorphosed sediments.

Foraminifera are rare and poorly-preserved throughout most of the sediment column, the result of extensive calcium carbonate solution, although some minute well-sorted forms are common in some sandy horizons. However, the calcareous sediment fractions throughout the upper 500 meters contain common moderately well-preserved nanno fossils. Radiolarians occur abundantly in the upper 76 meters but as poorly-preserved fragments or rare poorly-preserved whole specimens below. Except for the upper part of the section, the biostratigraphy rests for the most part on nannofossil data.

The physical properties of the sediments show smoothly increasing values with depth, of density, porosity, and acoustic velocity. Minor excursions of density and porosity values at 75 meters are not reflected in the velocity nor the reflection profile. The only firm acoustic-lithologic correlation is that of basement basalt and acoustic basement.

Sediment accumulation rates of dated sediments average 37 m/m.y., a high value compared to accumulation rate at Site 234, which probably results from the influx of displaces shallower sediments.

Significant features of the sediments are (1) the high clay mineral content (2) the appearance of finely laminated silty sand horizons, and (3) the evidence of oxidizing conditions.

Conclusions

1. The area is one in which fluctuations of carbonate compensation depth have occurred while the sedimentary sequence has evolved from an oxidizing environment toward more reducing conditions.

2. Minor turbidite deposits occur that may have originated on the northern slope of the abyssal plain or from Chain Ridge.

3. The incidence of clay minerals, although no volcanic ash appeared in the cores recovered, may be related to the Tertiary volcanic activity as at Site 234.

4. Major conclusions are: (a) basalt material was recovered at depth in agreement with the seismic-acoustic basement; (b) the floral assemblage (nannofossils only) of Site 234 is supplemented but not really extended; and (c) the transparent layer of the abyssal plain east of Chain Ridge appears to be formed of nanno ooze and nanno clay.

REFERENCES

Bunce, E. T., Langseth, M. G., Chase, R. L., and Ewing, M., 1967. Structure of the western Somali Basin: J. Geophys. Res., v. 72, p. 2547-2555.

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

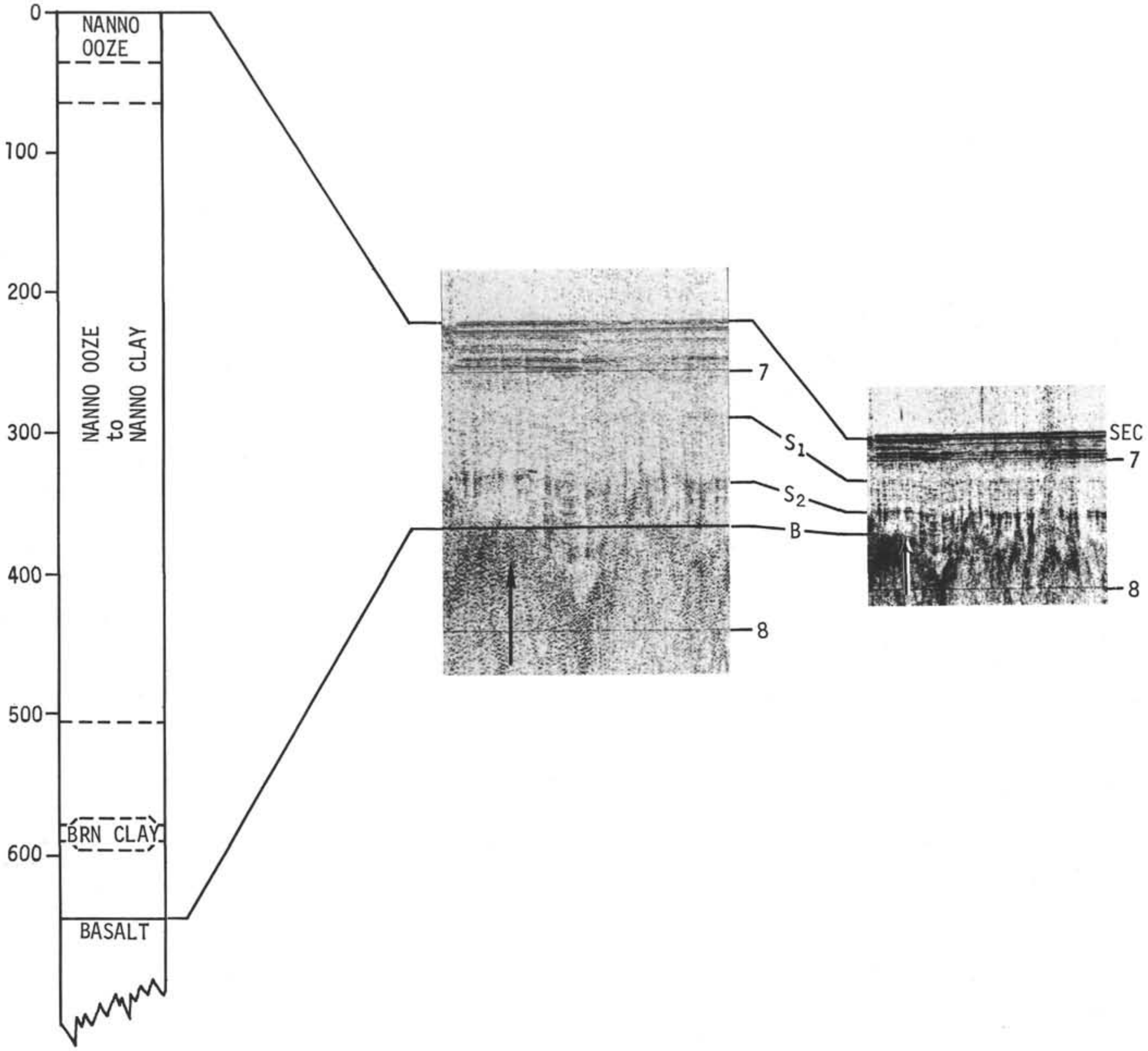


Figure 7. *Generalized lithology and seismic reflection profiles, Site 235. Arrows indicate site location;* B, *acoustic basement*; S_1, S_2, *sedimentary reflection horizons.*

APPENDIX A
PRELIMINARY OBSERVATIONS ON THE IGNEOUS ROCKS SAMPLED AT SITE 235

Leonid V. Dmitriev, Vernadsky Institute of Geochemistry,
Academy of Sciences of the USSR, Moscow
and
Robert L. Fisher, Scripps Institution of Oceanography,
University of California San Diego, La Jolla, California

Basaltic rocks, the acoustic basement at Site 235, were encountered at a depth of 651.5 meters below the sea floor and were penetrated for 32.5 meters to hole bottom at 684 meters. Volcanic rock, brecciated glass, and slightly to considerably metamorphosed sediment inclusions and seams, totaling 12.9+ meters, were recovered. The section is summarized in the visual core descriptions, and the positions of sampling are indicated there.

Megascopic Description

Most of this rock, believed to be basement, the top of the igneous crustal material, is massive to somewhat fractured greenish-gray basalt with obvious porphyritic texture. Iron hydroxides color the upper portion of the basalt pile yellowish gray to brownish red, and a similar oxidized zone occurs at a depth of 23.5 meters below the upper contact (235-20-1, a flow surface?). Zones of brecciated volcanic glass (Figure 8: 235-19-2, No. 11) are present in the middle part of the section (235-19-1, No. 2). Thin veins of calcite-chlorite-zeolite traverse the basalt everywhere, but are most common close to the zones of brecciated glass. Inclusions of slightly metamorphosed sediments, here carbonatized clays, occur principally in the upper part of the section (235-17-1, -18-1, -19-1).

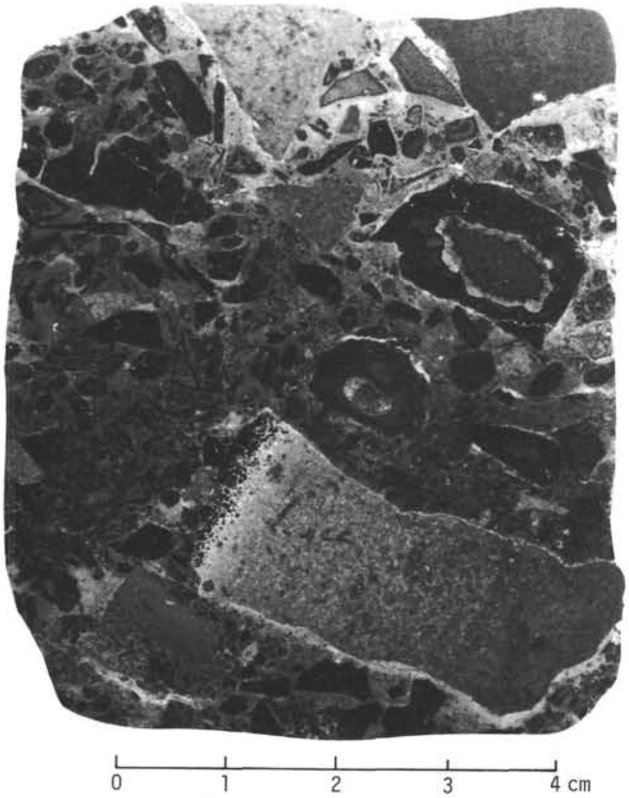


Figure 8. *Brecciated glass: 235-19-2, no. 11.*

Preliminary Petrographic Description

About 24 or 25 thin sections, from specimens distributed along the igneous section, were prepared aboard ship. The basalts examined in thin section can be assigned to one of three groups on the basis of texture and overall structure:

(1) Most of the section has porphyritic texture, with phenocrysts of plagioclase and olivine (as pseudomorphs) in a variolitic groundmass. Plagioclase phenocrysts make up 5 to 15 percent of the rock, and olivine about 3 percent. Long prismatic phenocrysts of plagioclase are twinned, with maximum extinction angles of 30°-38° in the zone ⊥ 010, labradorite, An_{50-70}. Length of phenocrysts ranges from 0.5 to 3 mm, with the larger ones being single and the smaller forming aggregates (Figure 9a, b). Most of these phenocrysts are replaced by sericite and chloritic aggregates; remnants of plagioclase are well preserved only in 235-20-2, -3, -5.

In the variolitic groundmass, plagioclase occurs as microlite needles assembled in radial or fibrous groups. The microlites, averaging about 0.2 mm in length, have a composition An_{55-60}, and, except in the oxidized zones, are essentially unaltered. The interstices are filled with palagonitized, chloritized, or carbonatized glass.

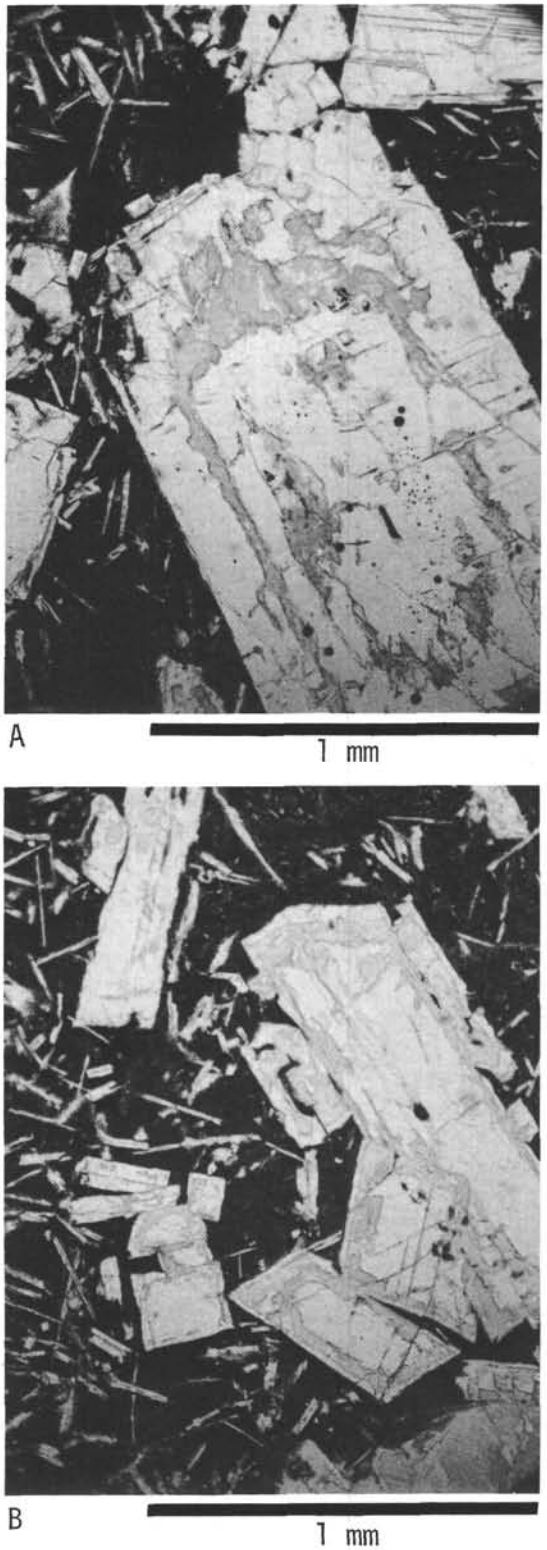


Figure 9. *Phenocrysts of altered plagioclase* (a) *and glomerophyric texture* (b) *in basalt; 235-20-4, no. 21; unpolarized light.*

Olivine is nowhere preserved in these rocks; there are only pseudomorphs with the customary habit and ranging in size from 0.1 to 1.0 mm (Figure 10).

Figure 10. *Pseudomorphs of chlorite-serpentine-carbonate after phenocrysts of olivine, 235-20-2, no. 21A, unpolarized light.*

Figure 11. *Fibrous structure in variolitic basalt; 235-18-1, CC; unpolarized light.*

(2) The second group consists of common variolitic basalt with skeletal microlites of plagioclase and olivine (Figures 11, 12). Such rocks occur rarely with the porphyritic basalts, but they predominate in the upper part of this basement section (235-17-1, 125-18-1). Varieties intermediate in texture between porphyritic and variolitic occur in the middle of the section (Figure 13; 235-19-1).

(3) Glassy basalt with phenocrysts of plagioclase and olivine, commonly replaced by palagonite-chlorite-carbonate, occurs in the zone of fracturing (Figure 14; 235-19-2) and mylonization. Angular fragments of variolitic basalt and palagonitized glass are associated in breccia and cemented by carbonate-chlorite; they range in size from 0.01 mm in the thin mylonite zones to 2 to 20 mm in the adjacent breccias.

One significant characteristic of the basalts from Site 235 is the presence of dark red-brown spinel as an accessory mineral. Spinel occurs in regular, euhedral crystals (Figure 15; 235-19-2, No. 7) from 0.001 to more than 0.2 mm in size. The association of olivine and spinel suggests origin at high pressure for the magma-yielding basalts at this locality.

Discussion and Implications

The porphyritic basalts suggest cooling and some crystal solidification at depth of magma en route to the sea floor. The variolitic groundmass and the glassy selvages were formed by chilling at the end of its rise to the sea floor. The occurrence of spinel with olivine, and the overall porphyritic texture of this basalt section indicate a source depth of more than 50 km for the magma.

The absence of massive rocks in the upper cores of the section penetrated suggests that this part of the igneous "basement" was disrupted or destroyed by submarine weathering or that, possibly, it consists of a scree or talus of fragmental variolitic basalt and metamorphosed sediment.

Finally, basement rocks at Site 235 showed considerable range in C_p apparently correlatable with the size and abundance of phenocrysts and vesicularity, and inversely to degree of chloritization. However, these promising shipboard petrographic-sound velocity comparisons, by Dmitriev and Paul Cernock, are too preliminary to review here.

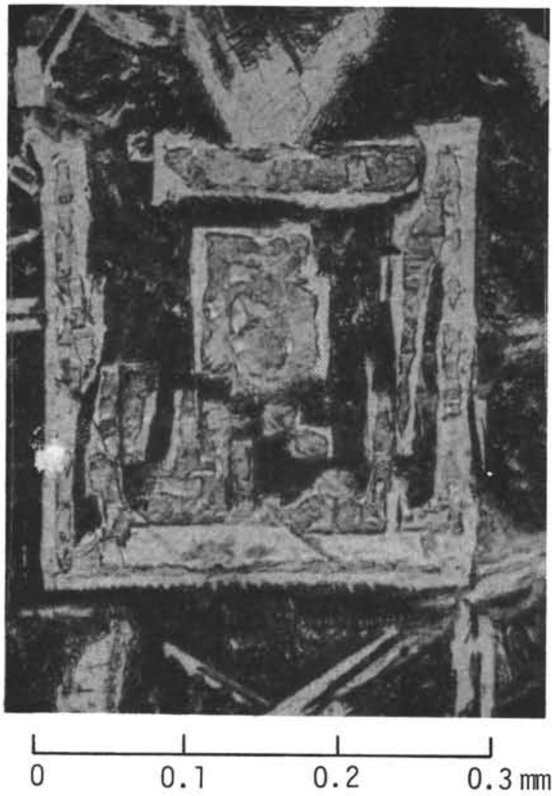


Figure 12. *Skeletal forms of plagioclase microlites; glomerophyric texture (closed clusters of equant crystals); 235-20-2, no. 21B; unpolarized light.*

Figure 13. *Texture intermediate between variolitic and porphyritic basalt; 235-19-1, no. 10; unpolarized light.*

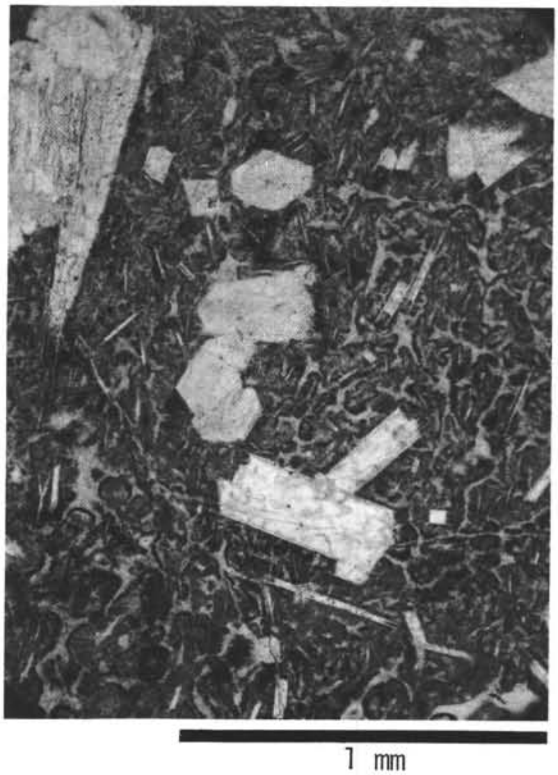


Figure 14. *Phenocrysts of plagioclase in palagonitized glass; 235-19-2, no. 7A; unpolarized light.*

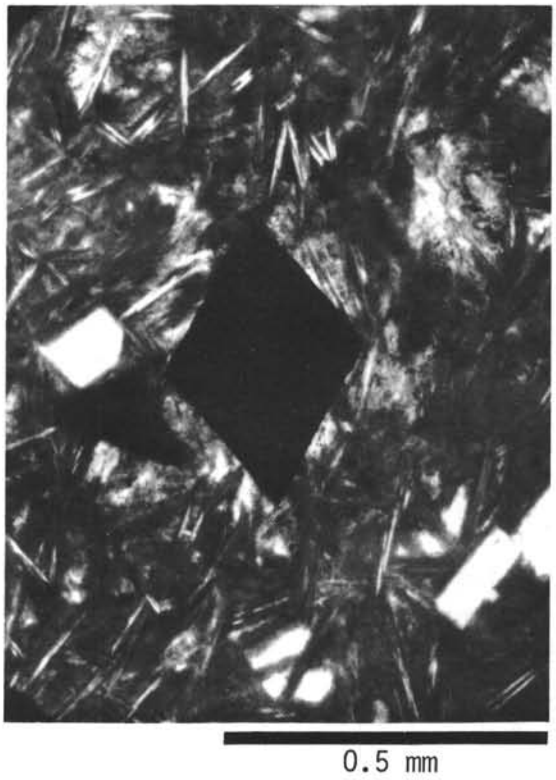
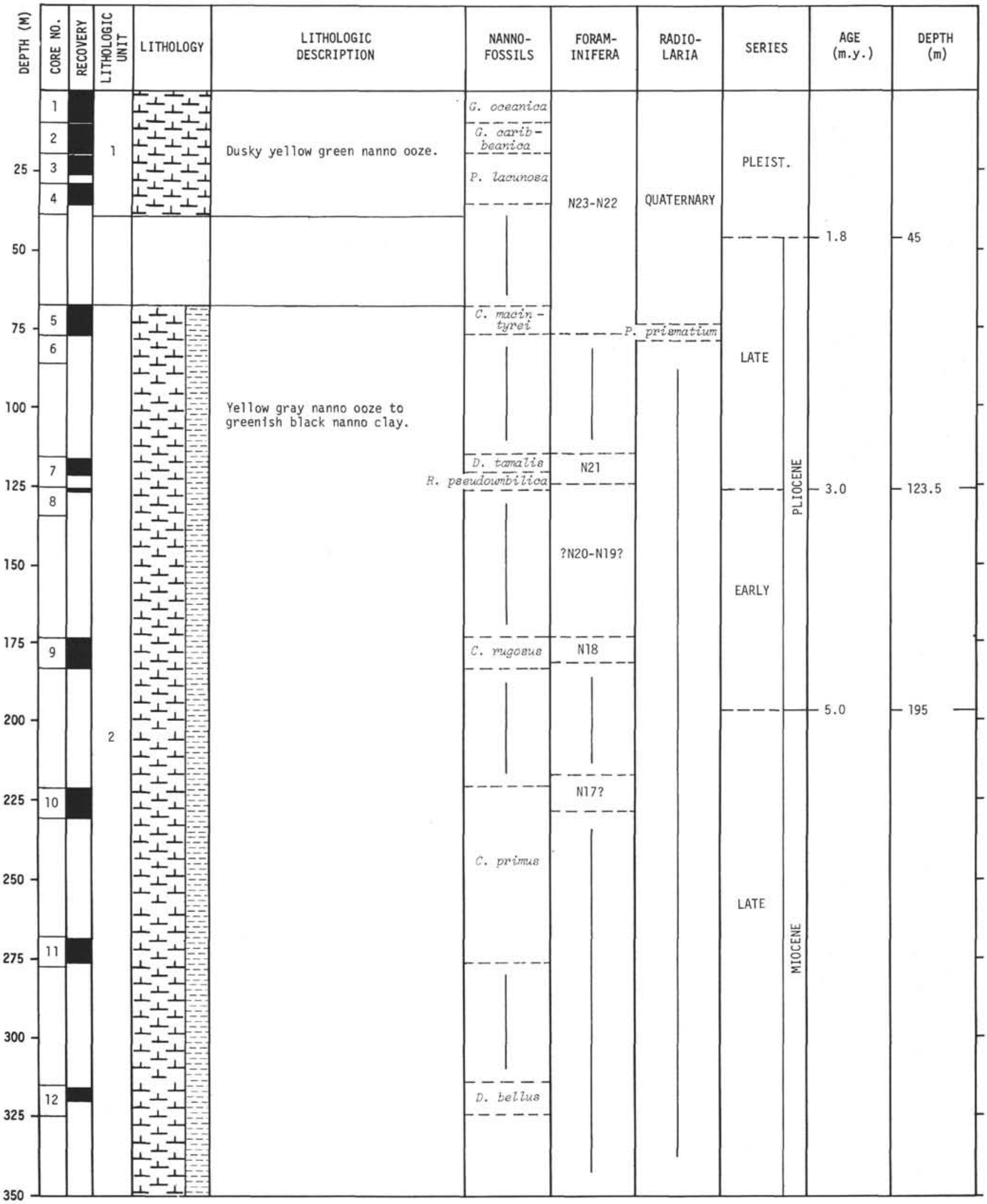
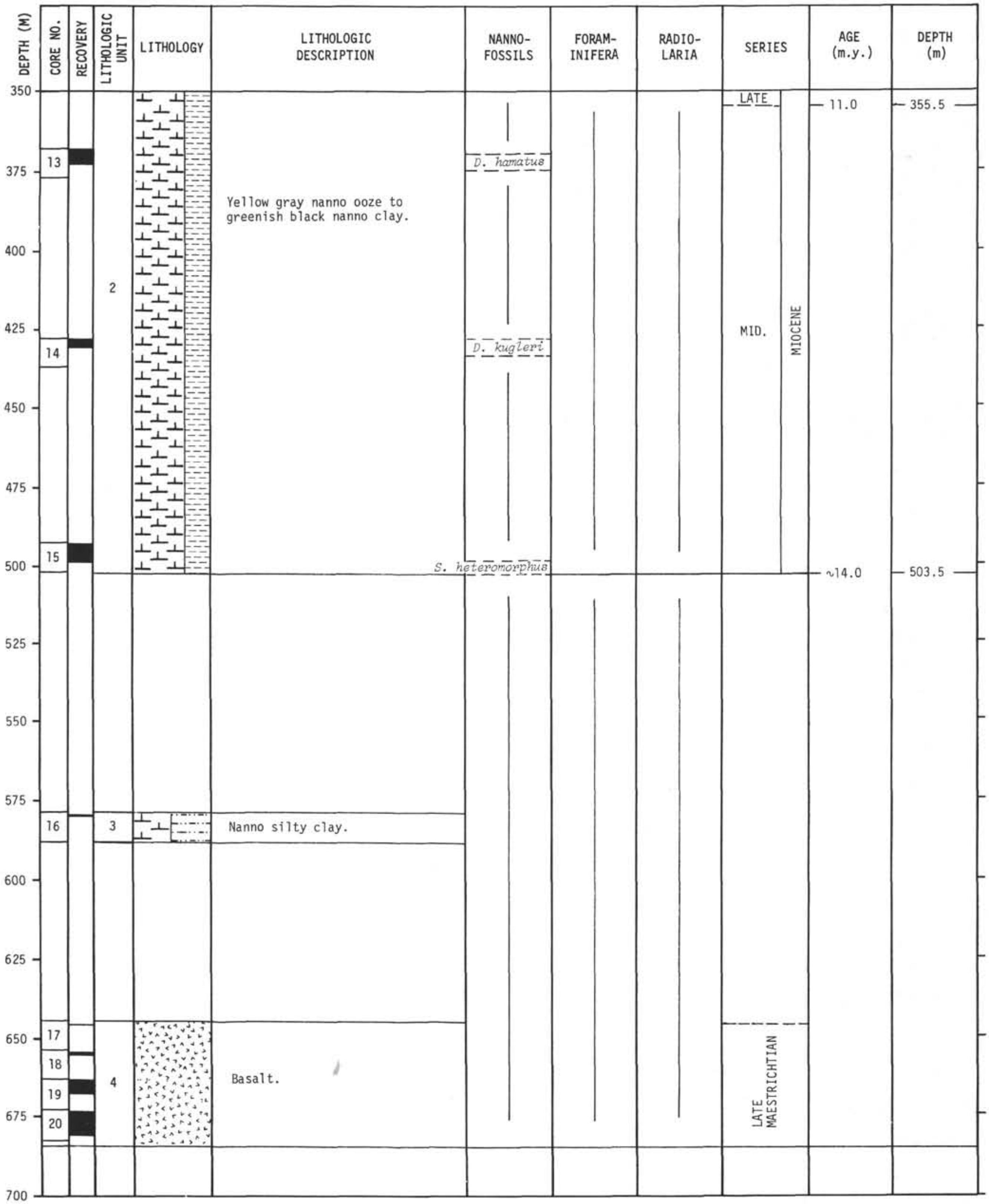
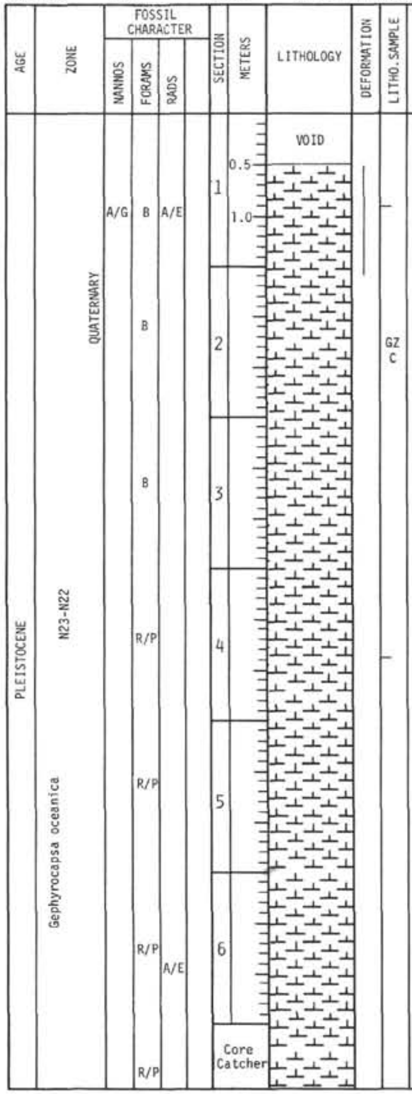


Figure 15. *Euhedral (diamond-shaped) crystal of spinel (dark); 235-19-2, no. 7; unpolarized light.*


DEPTH (M)
CORE NO.
RECOVERY
LITHOLOGIC UNIT
LITHOLOGY
LITHOLOGIC DESCRIPTION
NANNO-FOSSILS
FORAM-INIFERA
RADIO-LARIA
SERIES
AGE (m.y.)
DEPTH (m)
25
50
75
100
125
150
175
200
225
250
275
300
325
350
1
2
3
4
5
6
7
8
9
10
11
12
1
2
Dusky yellow green nanno ooze.
Yellow gray nanno ooze to greenish black nanno clay.
G. oceanica
G. caribbeanica
P. lacunosa
C. macintyrei
D. tamalis
R. pseudoumbilica
C. rugosus
C. primus
D. bellus
N23-N22
N21
?N20-N19?
N18
N17?
QUATERNARY
P. prismatium
PLEIST.
LATE
PLIOCENE
EARLY
LATE
MIOCENE
1.8
3.0
5.0
45
123.5
195


DEPTH (M)
CORE NO.
RECOVERY
LITHOLOGIC UNIT
LITHOLOGY
LITHOLOGIC DESCRIPTION
NANNO-FOSSILS
FORAM-INIFERA
RADIO-LARIA
SERIES
AGE (m.y.)
DEPTH (m)
350
375
400
425
450
475
500
525
550
575
600
625
650
675
700
13
14
15
16
17
18
19
20
2
3
4
Yellow gray nanno ooze to greenish black nanno clay.
Nanno silty clay.
Basalt.
D. hamatus
D. kugleri
S. heteromorphus
LATE
MID.
MIOCENE
LATE MAESTRICHTIAN
11.0
~14.0
355.5
503.5

Site 235 Hole Core 1 Cored Interval: 0.0-9.5 m



LITHOLOGIC DESCRIPTION

NANNO OOZE

Dusky yellow green (5GY5/2). Soupy.

Smear 1-1-80

Sand	1- 5%	Nannos	80-90%	Quartz	1%
Silt	25%	Rads	1- 2%FP	Heavy Min.	<1%
Clay	70%	Forams	1%	Volc. Glass	<1%
		Diatoms	1%		
		Sponge Spic.	1%		
		Silicoflag.	<1%		

$CaCO_3$ 55%

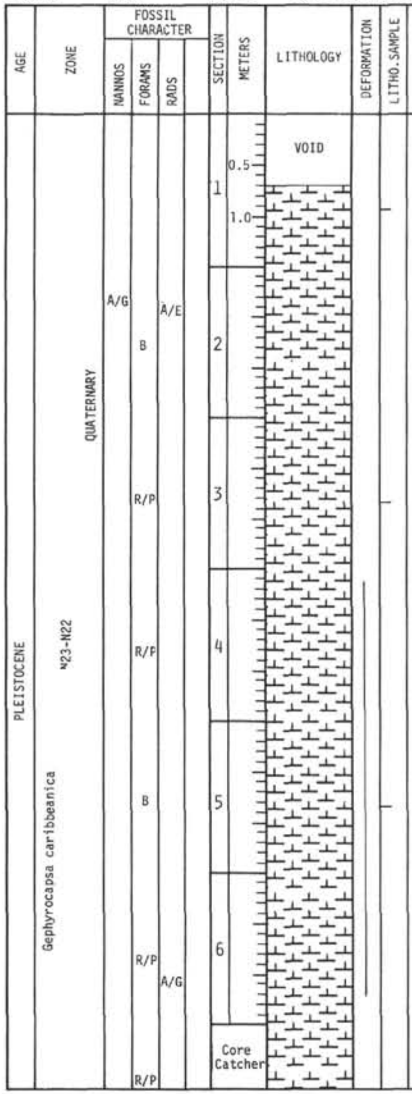
Grain Size
Sand 0%
Silt 22%
Clay 80%

Smear 1-4-80

Sand	1- 5%	Nannos	80-90%	Quartz	1%
Silt	25%	Diatoms	2%	Volc. Glass	1%
Clay	70%	Rads	1%	Dolo. Rhombs	1%
		Sponge Spic.	1%		
		Silicoflag.	1%		

Explanatory notes in chapter 1

Site 235 Hole Core 2 Cored Interval: 9.5-19.0 m



LITHOLOGIC DESCRIPTION

NANNO OOZE

Dusky yellow green (5GY5/2). Soupy.

Smear 2-1-80

Sand	5%	Nannos	80-90%	Volc. Glass	1%
Silt	25-30%	Diatoms	2- 3%		
Clay	70%	Rads	1- 2%		
		Sponge Spic.	1- 2%		

Smear 2-3-80

Sand	1- 2%	Nannos	80-90%	Heavy Min.	1%
Silt	30%	Forams	1- 2%	Volc. Glass	1%
Clay	70%	Diatoms	1- 2%		
		Rads	1- 2%		
		Silicoflag.	1%		

Sediment soft.

Grayish olive green (5GY3/2) zone at 2-4-120 to 2-5-15 with darker patches.

Smear 2-5-80

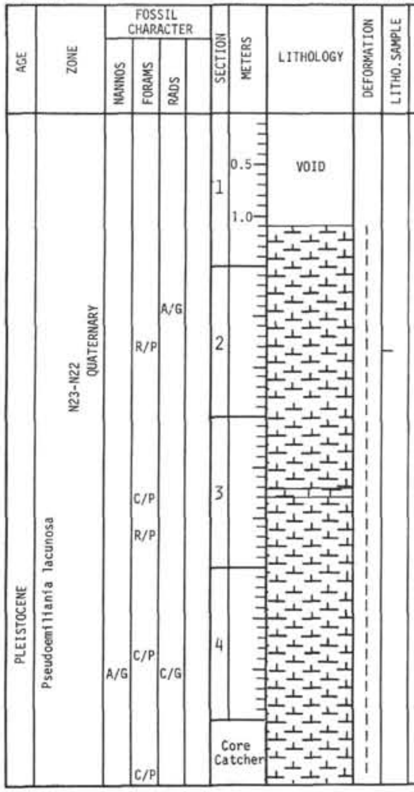
Sand	1- 3%	Nannos	90-95%	Volc. Glass	<1%
Silt	25%	Diatoms	2%		
Clay	70%	Rads	2%		
		Sponge Spic.	2%		
		Forams	1%		
		Silicoflag.	1%		

Smear 2-CC

Sand	1%	Nannos	90%	Quartz	1%
Silt	25%	Diatoms	2%	Volc. Glass	1%
Clay	75%	Rads	2%FG		
		Sponge Spic.	2%		
		Forams	1%		
		Silicoflag.	1%		

Explanatory notes in chapter 1

Site 235 Hole Core 3 Cored Interval: 19.0-28.5 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Dusky yellow green (5GY5/2) with grayish olive green (5GY3/2) zones at 3-1-140 to 150, 3-2-30 to 60, 3-3-80 to 90.

Smear 3-2-80

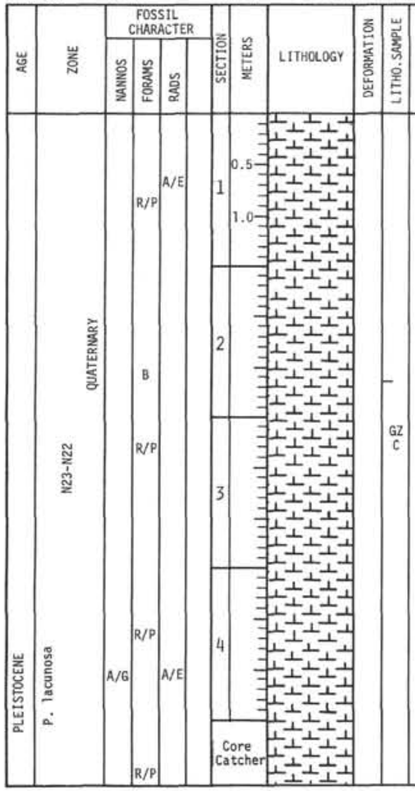
Sand	1- 3%	Nannos	90%	Quartz	1%
Silt	25%	Diatoms	2%	Heavy Min.	1%
Clay	70%	Sponge Spic.	1- 2%	Volc. Glass	1%
		Silicoflag.	1- 2%	Dolo. Rhombs	1%
		Forams	1%		
		Rads	1%		

Sand layer at 3-3-75
Smear 3-3-75

Sand	60%	Nannos	40%	Quartz	5%
Silt	20%	Plank. Forams	20%FG	Volc. Glass	5%
Clay	20%	Benth. Forams	1- 2%	Dolo. Rhombs	1%
		Diatoms	1- 2%		
		Rads	1- 2%		
		Sponge Spic.	1- 2%		
		Silicoflag.	1%		

Explanatory notes in chapter 1

Site 235 Hole Core 4 Cored Interval: 28.5-38.0 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Dusky yellow green (5GY5/2).
Occasional burrows.

Smear 4-2-110

Sand	1- 3%	Nannos	80%	Quartz	1%
Silt	30%	Diatoms	3%	Heavy Min.	1%
Clay	70%	Rads	3%	Volc. Glass	1%
		Sponge Spic.	2%		
		Silicoflag.	1%		

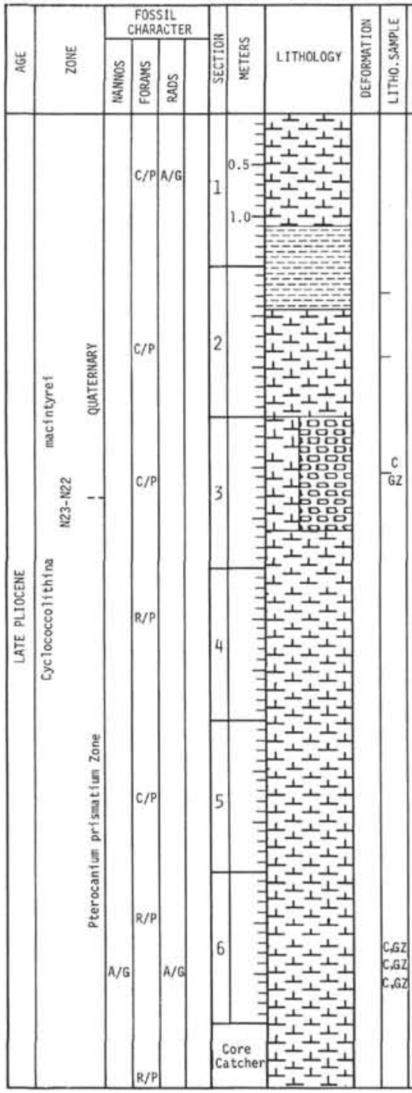
Grayish olive green (5GY3/2) zone at 4-3-80.

$CaCO_3$ 51%

Grain Size
Sand 0%
Silt 17%
Clay 83%

Explanatory notes in chapter 1

Site 235 Hole Core 5 Cored Interval: 66.5-76.0 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Yellowish gray (5Y8/1) changing to dusky olive green (5GY5/2) at 5-1-70, to grayish olive green (5GY3/2) at 5-1-110 to 5-2-48.

CLAY
Smear 5-2-25
Sand 1- 3% Nannos 1- 2% Clay Min. 90%
Silt 25-30% Diatoms 2% Quartz 2%
Clay 70% Rads 2%
Sponge Spic. 2%
Silicoflag. 1%

NANNO OOZE
Yellowish gray (5Y8/1) at 5-2-48 downwards.
Smear 5-2-85
Sand <1% Nannos 90% Quartz 2%
Silt 25% Forams 1- 2%
Clay 75% Diatoms 1- 2%FP
Rads 1- 2%FP CaCO$_3$ 90%
Sponge Spic. 1- 2%
Silicoflag. 1%
Grain Size
Sand 1%
Silt 78%
Clay 21%

NANNO MICARB OOZE
Smear 5-3-60
Sand 20% Nannos 30-40% Micarb 50%
Silt 60% Plank. Forams. 1- 5% Quartz 3%
Clay 20% Benth. Forams 1- 2% Feldspar 2%
Diatoms 1% Heavy Min. 1%
Rads 1% Pyrite 1%
Sponge Spic. 1% Dolo. Rhombs 1%
Silicoflag. 1%

Color changing to dusky yellow green (5GY5/2) at 5-3-110, to grayish olive green (5GY3/2) at 5-5-80,
to grayish green (10G4/2) at 5-6-0,
to dusky yellow green (5GY5/2) at 5-6-30,
to grayish green (10G4/2) at 5-6-45,
to dusky yellow green (5GY5/2) at 5-6-55,
to grayish yellow green (5GY7/2) at 5-6-75,
to grayish green (10G4/2) at 5-6-80,
to dusky yellow green (5GY5/2) at 5-6-98,
to grayish green (10G4/2) at 5-6-115,
to dusky yellow green (5GY5/2) at 5-6-135.

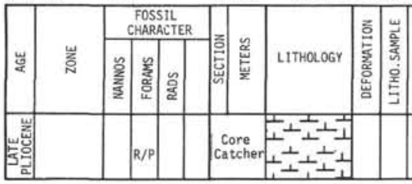
Smear 5-6-90
Sand 1- 5% Nannos 60-70% Clay Min. 10%
Silt 30% Diatoms 2% Quartz 1- 2%
Clay 65% Rads 2% Volc. Glass 1- 2%
Sponge Spic. 1%
Silicoflag. 1%
Fish Debris 1%

GZ	Sand	Silt	Clay
78 cm	0%	12%	88%
89 cm	1%	19%	80%
110 cm	0%	17%	83%

CaCO$_3$	
78 cm	59%
89 cm	8%
110 cm	53%

Explanatory notes in chapter 1

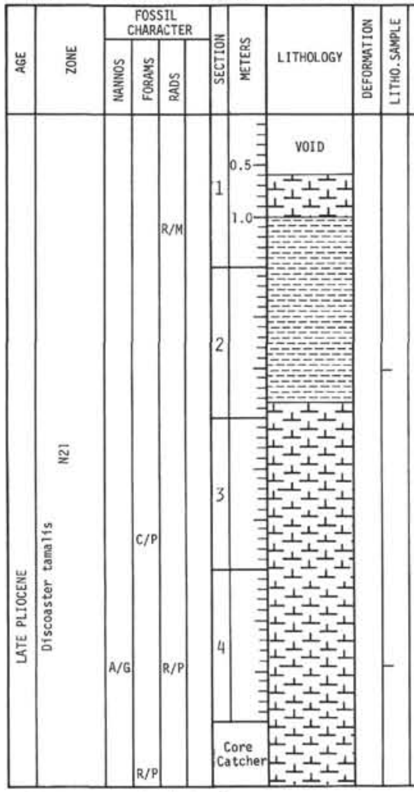
Site 235 Hole Core 6 Cored Interval: 76.0-85.5 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Dusky yellow green (5GY5/2).

Site 235 Hole Core 7 Cored Interval: 114.0-123.5 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Dusky yellow green (5GY5/2) grading to greenish black (5G2/1).

CLAY

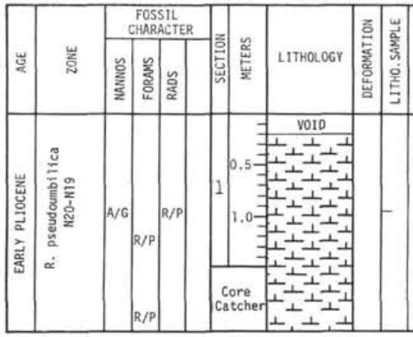
Smear 7-2-90
Silt 10-20% Nannos 10% Clay Min. 70%
Clay 80% Quartz 1- 2%
Volc. Glass 1- 2%
Heavy Min. 1%

Patch of coarse pyrite at 7-2-107.
Color change to olive gray (5Y4/1) at 7-2-135, to dusky yellow green (5GY5/2).

Smear 7-4-90
Silt 10-20% Nannos 95% Quartz 1- 2%
Clay 80-90% Heavy Min. 1%
Dolo. Rhombs 1%

Explanatory notes in chapter 1

Site 235 Hole Core 8 Cored Interval:123.5-133.0 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Dusky yellow green (5GY5/2)

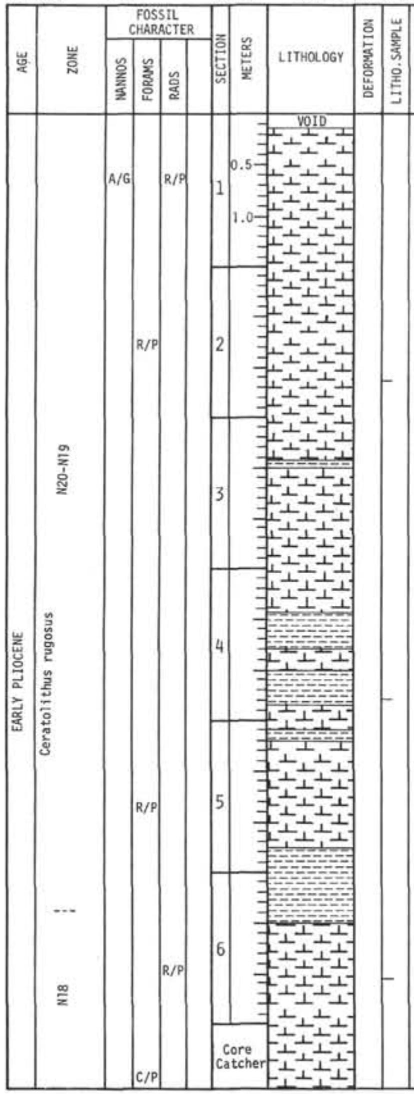
Smear 8-1-90

Sand	0- 1%	Nannos	90%	Heavy Min.	1%
Silt	10-20%	Forams	1%FP	Volc. Glass	1%
Clay	80-90%	Rads	1%FP	Dolo. Rhombs	1%
		Pteropods	1%		

Greenish black (5G2/1) horizon 8-1-145 to 150.

Explanatory notes in chapter 1

Site 235 Hole Core 9 Cored Interval:171.0-180.5 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Dusky yellow green (5GY5/2).

Smear 9-2-100

Silt	10-20%	Nannos	95%	Mica	1%
Clay	80-90%	Forams	1%FP	Heavy Min.	1%

Olive gray (5Y4/1) 9-3-45 to 50.

Grayish olive green (5GY3/2) 9-3-50.

CLAY Greenish black (5G2/1)

NANNO OOZE Grayish olive green (5GY3/2)

Smear 9-4-130

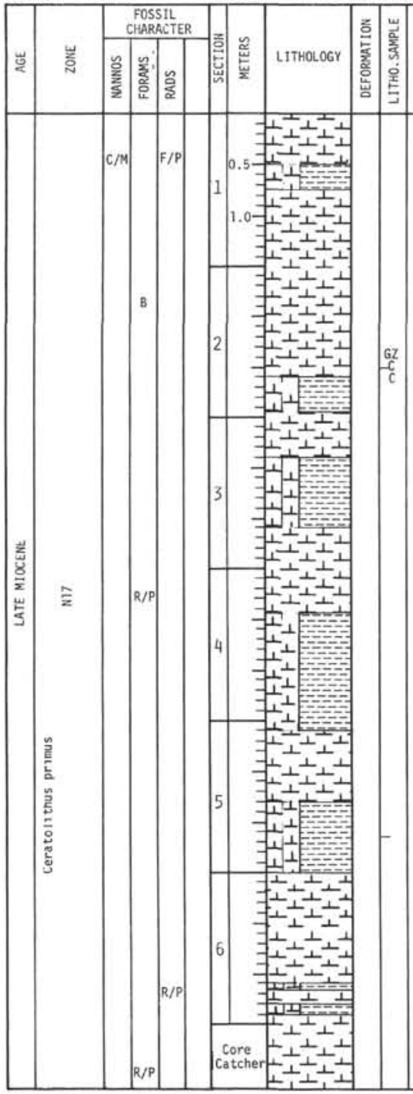
Sand	<1%	Nannos	1- 2%	Clay Min.	80-90%
Silt	10-20%	Forams	1%FP	Volc. Glass	1- 2%
Clay	80-90%			Quartz	1%
				Mica	1%
				Heavy Min.	1%
				Pyrite	1%

Smear 9-6-100

Silt	10%	Nannos	95%	Heavy Min.	1%
Clay	90%	Rads	1%FP	Volc. Glass	1%
				Pyrite	1%
				Dolo. Rhombs	1%

Explanatory notes in chapter 1

Site 235 Hole Core 10 Cored Interval: 218.5-228.0 m



LITHOLOGIC DESCRIPTION

NANNO OOZE Grayish green (10GY5/2) and
NANNO CLAY Dusky green (5G3/2).

Smear 10-2-100
Sand 1- 2% Nannos 90% Feldspar 1%
Silt 10-20% Forams 1% Heavy Min. 1%
Clay 80-90% Rads 1%F Volc. Glass 1%
Pyrite 1%

Grain Size
Sand 0%
Silt 14%
Clay 86%

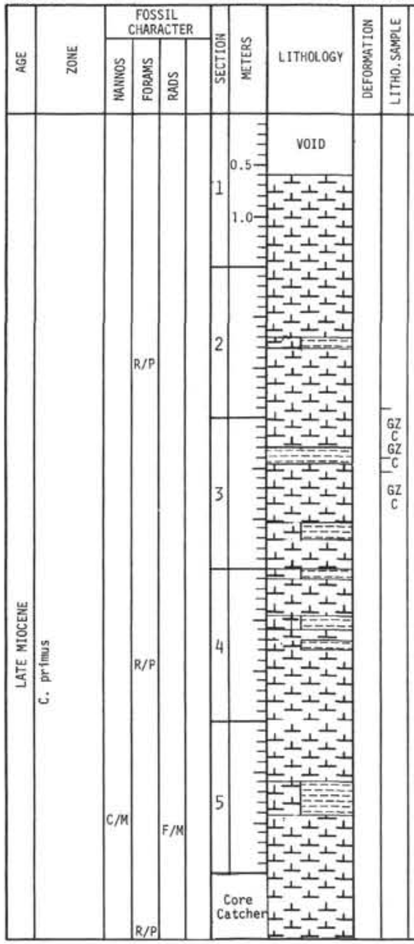
$CaCO_3$
112 cm 2%
116 cm 44%

Smear 10-5-100
Sand <1% Nannos 20-30% Clay Min. 50-70%
Silt 10% Quartz 1- 2%
Clay 90% Volc. Glass 1%
Pyrite 1%
Dolo. Rhombs 1%

Light gray (N7) horizon at 10-6-140.

Explanatory notes in chapter 1

Site 235 Hole Core 11 Cored Interval: 266.0-275.5 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Grayish green (10GY5/2) with thin horizons of yellowish gray (5Y8/1), dusky yellow green (5GY5/2) and light gray (N7).
NANNO CLAY Dusky green (5G3/2).

Smear 11-2-135
Silt 10% Nannos 95% Volc. Glass 1%
Clay 90% Forams 1%FP Pyrite 1%
Rads 1%FP

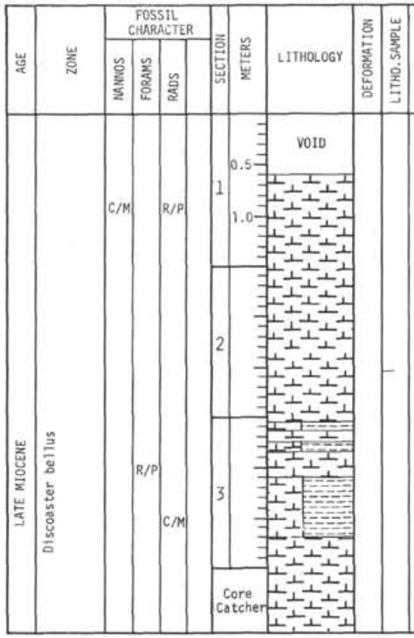
Smear 11-3-40
Sand 10% Nannos 5% Clay Min. 90-95%
Silt 20% Quartz 1%
Clay 70% Dolo. Rhombs 1%
Smear 11-3-50
Sand 2% Nannos 80-90% Volc. Glass 2- 3%
Silt 30% Rads 1%FP Dolo. Rhombs 1- 2%
Clay 70% Quartz 1%
Pyrite 1%

Grain Size	Sand	Silt	Clay
23 cm	0%	28%	72%
38 cm	0%	9%	91%
80 cm	0%	11%	89%

$CaCO_3$	
25 cm	81%
40 cm	2%
84 cm	54%

Explanatory notes in chapter 1

Site 235 Hole Core 12 Cored Interval: 313.5-323.0 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Grayish green (5G5/2) to (10G4/2)

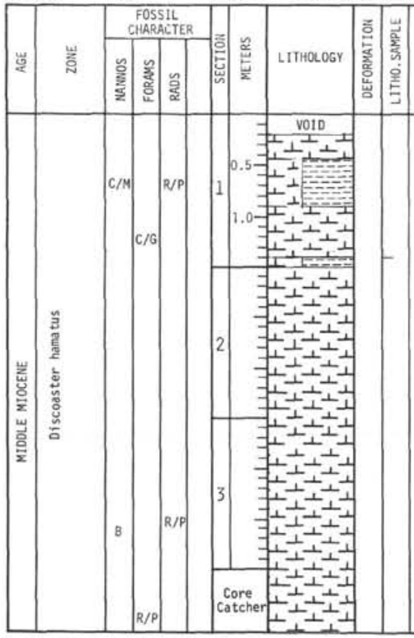
Smear 12-2-105

Sand 1%	Nannos 95%	Quartz 5%
Silt 20%		Heavy Min. 1%
Clay 80%		Volc. Glass 1%

NANNO CLAY
Grayish green (10G4/2) to dark greenish gray (5G4/1).

NANNO OOZE
Light gray (N7) and dusky yellow green (5GY5/2).

Site 235 Hole Core 13 Cored Interval: 368.0-377.5 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Grayish green (5G5/2) to (10G4/2).

NANNO CLAY
Dark greenish gray (5G4/1).

Yellowish gray (5Y8/1) horizon with burrows 13-1-87 to 94.

Smear 13-1-140 (thin sand horizon)

Sand 50%	Nannos 20-30%	Micarb 30%
Silt 30%	Plank. Forams 20%	Pyrite 5%
Clay 20%	Benth. Forams 2- 5%	Quartz 2%
		Volc. Glass 2%
		Dolo. Rhombs 1%

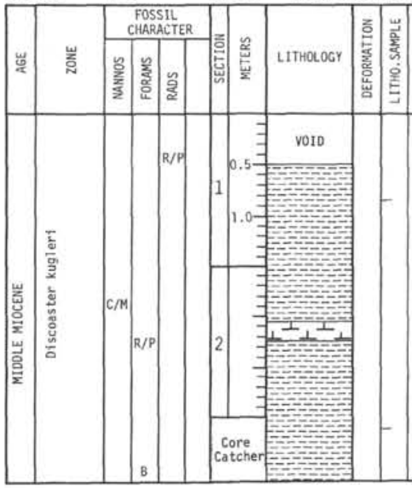
Smear 13-2-80

Sand 1%	Nannos 95%	Dolo. Rhombs 2%
Silt 20-30%		Quartz 1- 2%
Clay 70%		Volc. Glass 1%
		Pyrite 1%

Occasional pyrite nodules in 13-2 and 13-3.

Explanatory notes in chapter 1

Site 235 Hole Core 14 Cored Interval: 427.5-437.0 m



LITHOLOGIC DESCRIPTION

NANNO CLAY to CLAY
Medium dark gray (N4) changing to dark greenish gray (5GY4/1) at 14-2-0.

Horizon of light brownish gray (5YR6/1) NANNO OOZE 14-2-57 to 75, burrows in upper part.

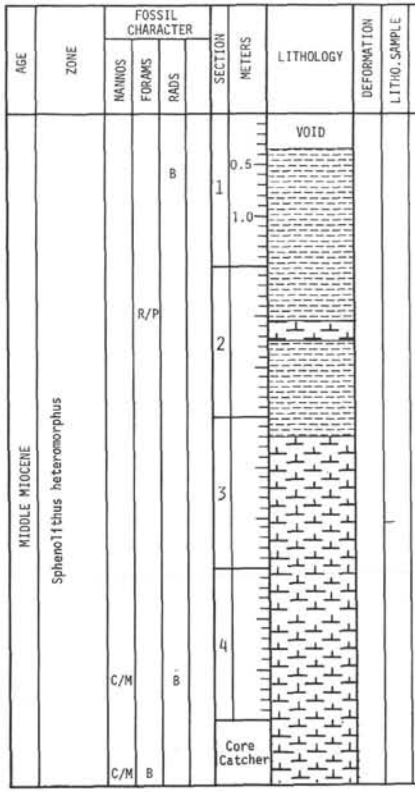
Smear 14-2-70

Silt 20%	Nannos 95%	Volc. Glass 1%
Clay 80%	Forams 1%	Pyrite 1%

Smear 14-CC

Sand 1%	Nannos 5%	Clay Min. 80-90%
Silt 20%		Quartz 2%
Clay 80%		Pyrite 1%

Site 235 Hole Core 15 Cored Interval: 494.0-503.5 m



LITHOLOGIC DESCRIPTION

CLAY
Grayish green (5G5/2) to (10GY5/2).

Greenish gray (5G6/1) 15-2-40 to 55.

NANNO OOZE horizon 15-2-55 to 77, light olive gray (5Y6/1).

NANNO OOZE
Light olive gray (5Y6/1) changing to grayish green (5GY5/2). Burrows throughout.

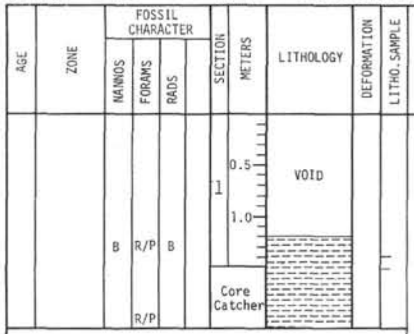
Smear 15-3-100

Silt 20%	Nannos 90-95%	Volc. Glass 1%
Clay 80%		Dolo. Rhombs 1%

Light olive gray (5Y6/1) horizons at 15-4-40 to 55, 15-4-105 to 120.

Explanatory notes in chapter 1

Site 235 Hole Core 16 Cored Interval: 579.5-585.0 m



LITHOLOGIC DESCRIPTION

CLAY
Moderate brown (5YR3/4), laminated (2-5 mm).

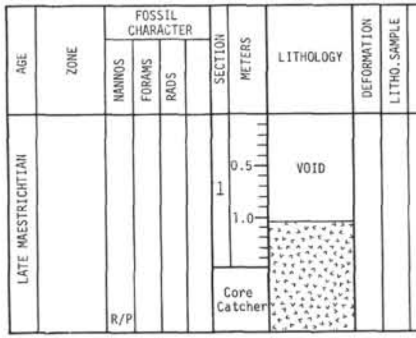
Smear 16-1-140

Sand	1%	Nannos	<1%	Clay Min.	95%
Silt	10%			Quartz	1%
Clay	90%			Feldspar	1%

Smear 16-1-143

Sand	1- 3%	Nannos	1%	Clay Min.	80-90%
Silt	20-30%	Forams	1%	Quartz	5%
Clay	70%			Pyrite	2%
				Dolo. Rhombs	1%

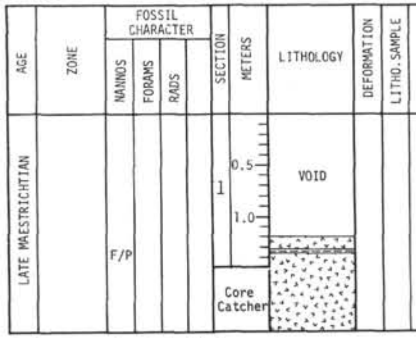
Site 235 Hole Core 17 Cored Interval: 646.0-655.5 m



LITHOLOGIC DESCRIPTION

BASALT

Site 235 Hole Core 18 Cored Interval: 655.5-665.0 m

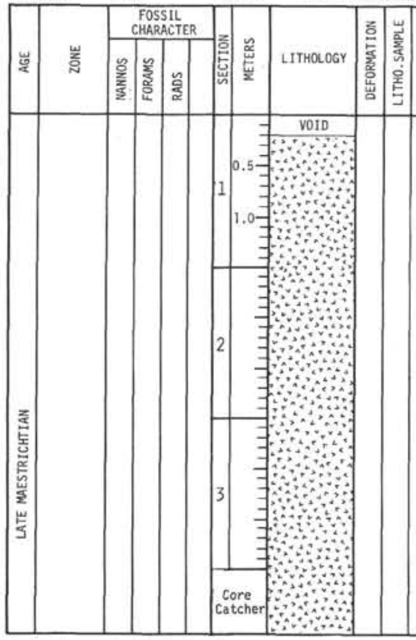


LITHOLOGIC DESCRIPTION

BASALT
Slightly altered and 3 thin bands of slightly metamorphosed sediments (moderate orange pink 5YR8/4 CLAY).

Explanatory notes in chapter 1

Site 235 Hole Core 19 Cored Interval: 665.0-674.0 m

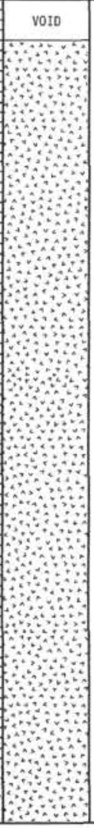


LITHOLOGIC DESCRIPTION

BASALT
Solid variolitic with inclusions of metamorphosed sediments and layers of breccia consisting of basalt and basaltic glass fragments.

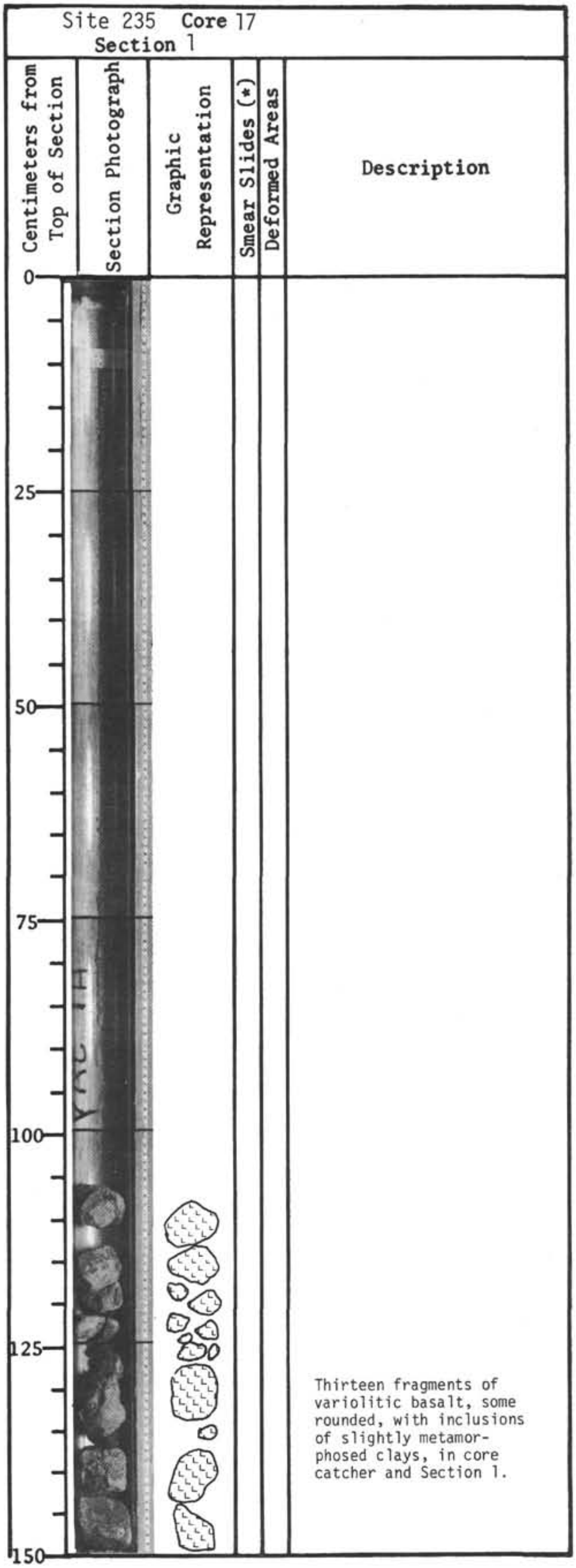
Explanatory notes in chapter 1

Site 235 Hole Core 20 Cored Interval: 674.5-684.0 m

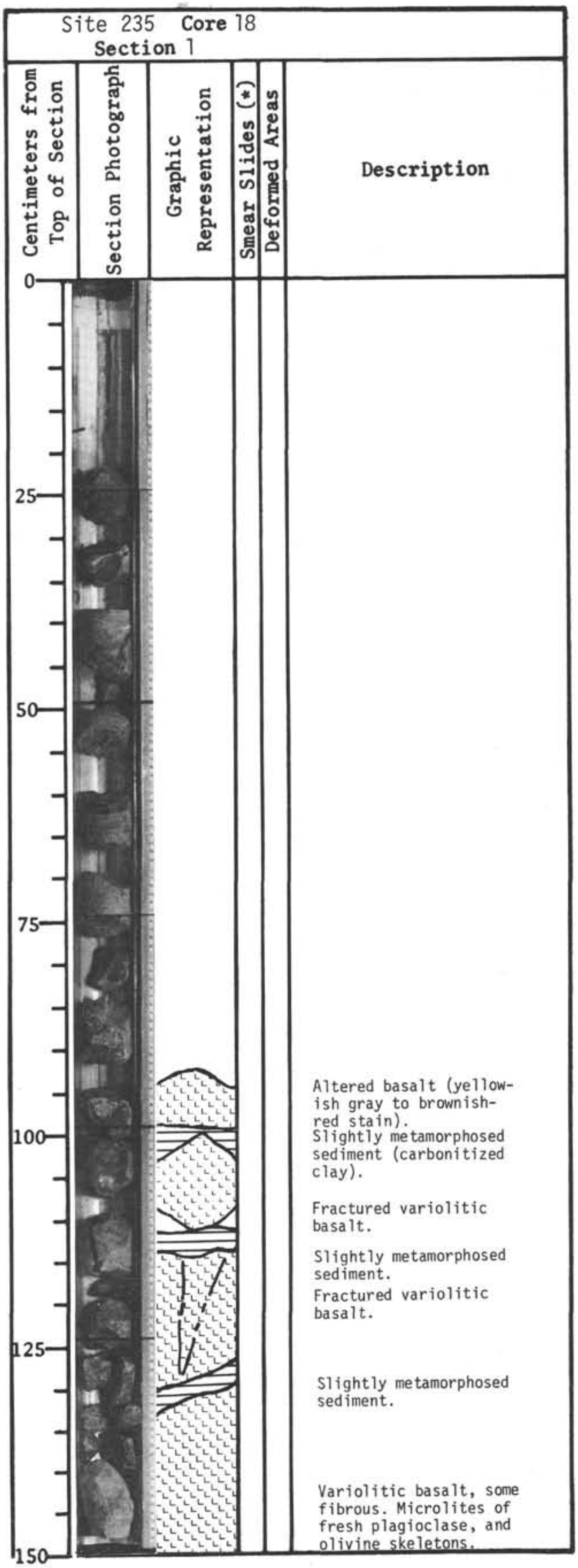
AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		NANNOS	FORAMS	RADS						
LATE MAESTRICHTIAN		R/P R/P			1	0.5 1.0	VOID 			BASALT Structure changing from variolitic to porphyritic. Narrow zones of breccia.
					2					
					3					
					4					
					5					
					Core Catcher					

Explanatory notes in chapter 1

DETAILED CORE DESCRIPTIONS



Thirteen fragments of variolitic basalt, some rounded, with inclusions of slightly metamorphosed clays, in core catcher and Section 1.



Altered basalt (yellowish gray to brownish-red stain).

Slightly metamorphosed sediment (carbonitized clay).

Fractured variolitic basalt.

Slightly metamorphosed sediment.

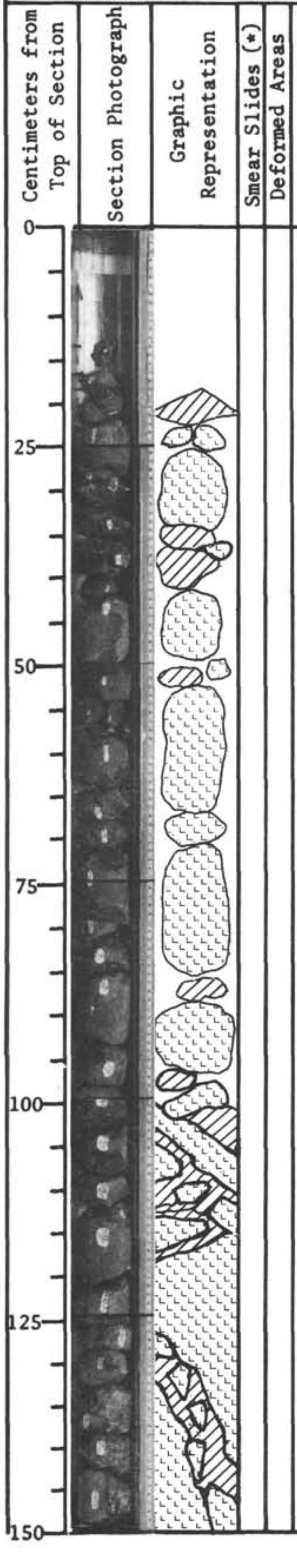
Fractured variolitic basalt.

Slightly metamorphosed sediment.

Variolitic basalt, some fibrous. Microlites of fresh plagioclase, and olivine skeletons.

DETAILED CORE DESCRIPTIONS

Site 235 Core 19
Section 1



Description

Uniform variolitic basalt interspersed with inclusions of metamorphosed sediments (scree?).

▨ Basalt.

▤ Metamorphosed sediments.

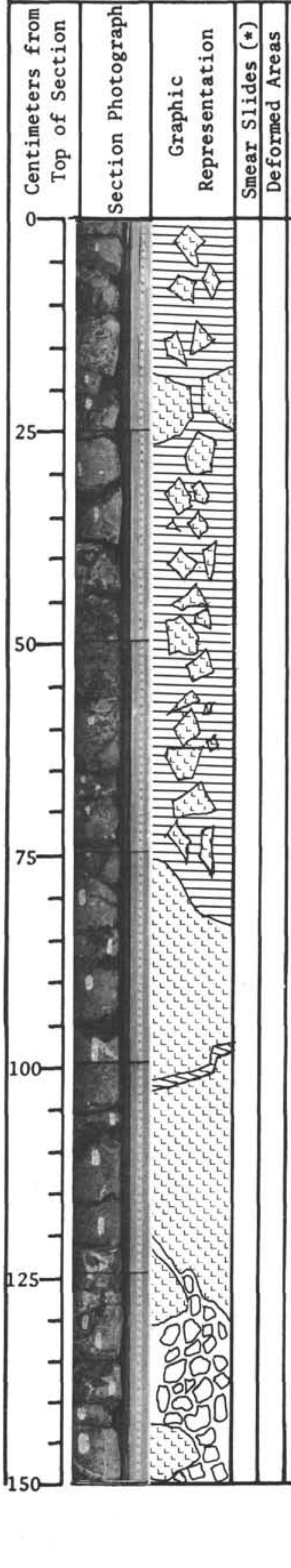
▨ Breccia.

Angular fragments (2-20 mm) of variolitic basalt and palagonitized basaltic glass in breccia cemented with carbonate-chlorite(?).

Variolitic basalt with skeletal microlites of plagioclase and olivine.

Breccia, as above, with carbonate groundmass.

Site 235 Core 19
Section 2



Description

Breccia of variolitic basalt and palagonitized basaltic glass (with altered or replaced phenocrysts of plagioclase and olivine) in a predominant groundmass of carbonate-chlorite(?) derived from metamorphosed sediment.

Zone of mylonite (fragments <<1.0 mm).

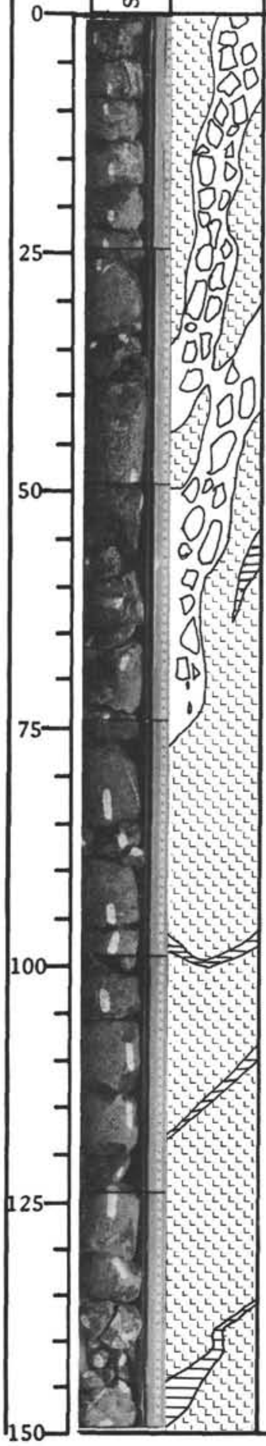
Zone of mylonite, as above.

Spinel-bearing vesicular variolitic basalt, with phenocrysts of plagioclase 1-2 mm, and vesicles incrusted or filled by chlorite. Several thin veins in this massive basalt are filled by chlorite and calcite and one by silica.

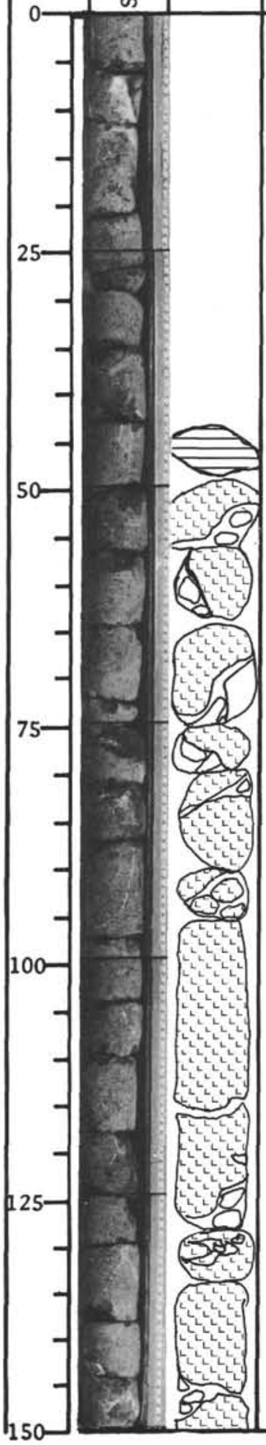
Breccia with components as above, but here variolitic basalt and glass fragments predominate over groundmass.

DETAILED CORE DESCRIPTIONS

Site 235 Core 19 Section 3

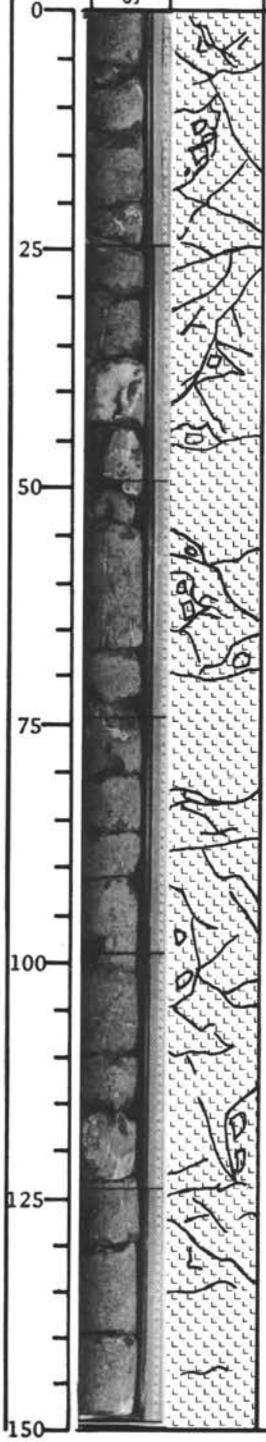
Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description
					Fractured and brecciated basalt, with ruptures nearly vertical. "Fresh" to somewhat altered variolitic basalt, with plagioclase phenocrysts partially replaced by sericite-chlorite and olivine phenocrysts replaced by serpentine. Vesicles filled.

Site 235 Core 20 Section 1

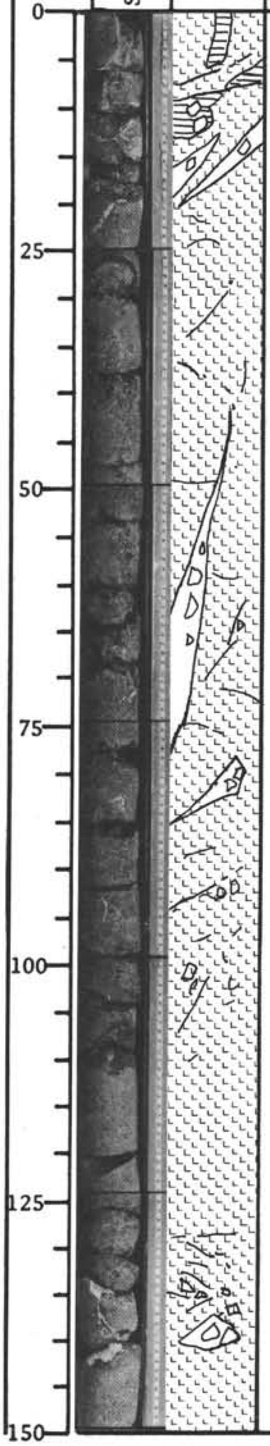
Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description
					Fragment of metamorphosed sediment: top of flow? Fracture zone (scree?): brecciated and rolled(?) basalt with oxidation stains, and with a structure primarily porphyritic rather than variolitic below this level. Porphyritic and variolitic basalt, greenish gray, with filled round vesicles. Veins or cracks filled with carbonate. Phenocrysts altered to chlorite-carbonate and serpentine.

DETAILED CORE DESCRIPTIONS

Site 235 **Core** 20
Section 2

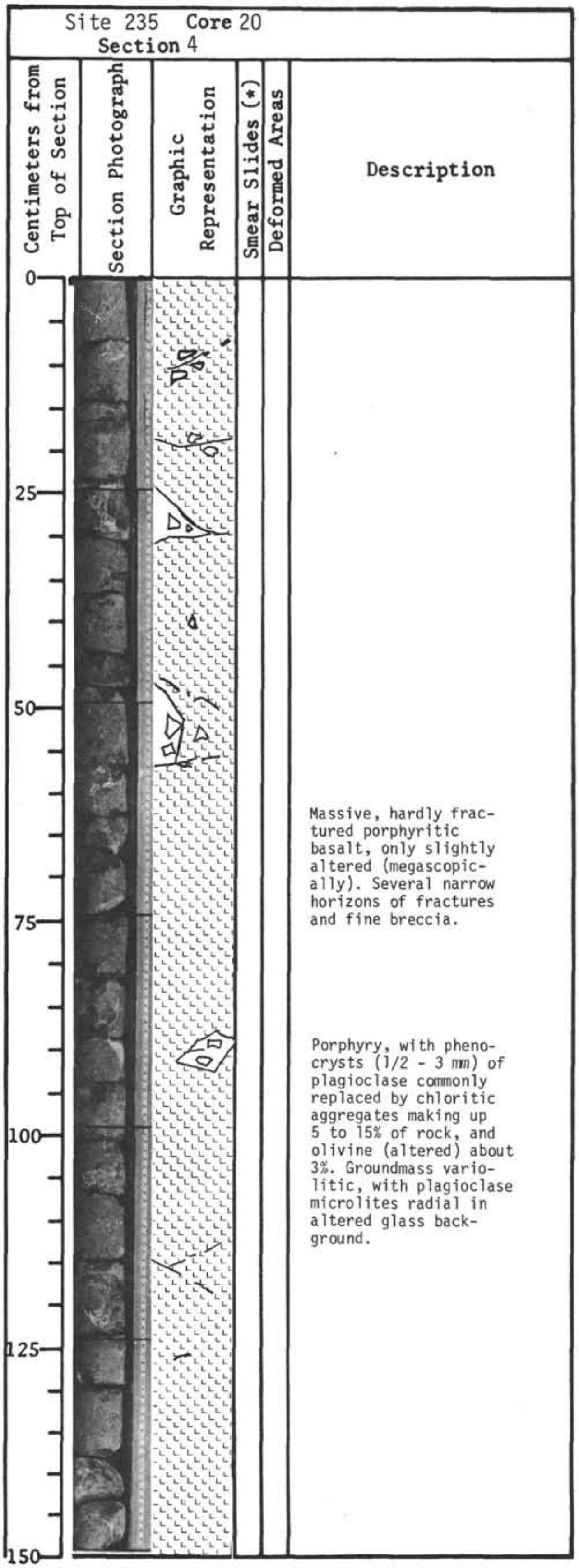
Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description
					Three horizons of slightly altered and little-fractured porphyritic basalt occurring within a dominantly fractured to locally brecciated section. Pockets of carbonate in groundmass and vesicles filled with carbonate and fibrous zeolites(?). Plagioclase phenocrysts crushed and skeletal to euhedral and fresh.

Site 235 **Core** 20
Section 3

Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description
					Fractured variolitic to porphyritic basalt, locally with breccia layers, and with two relatively unshattered basalt horizons near its base.

DETAILED CORE DESCRIPTIONS

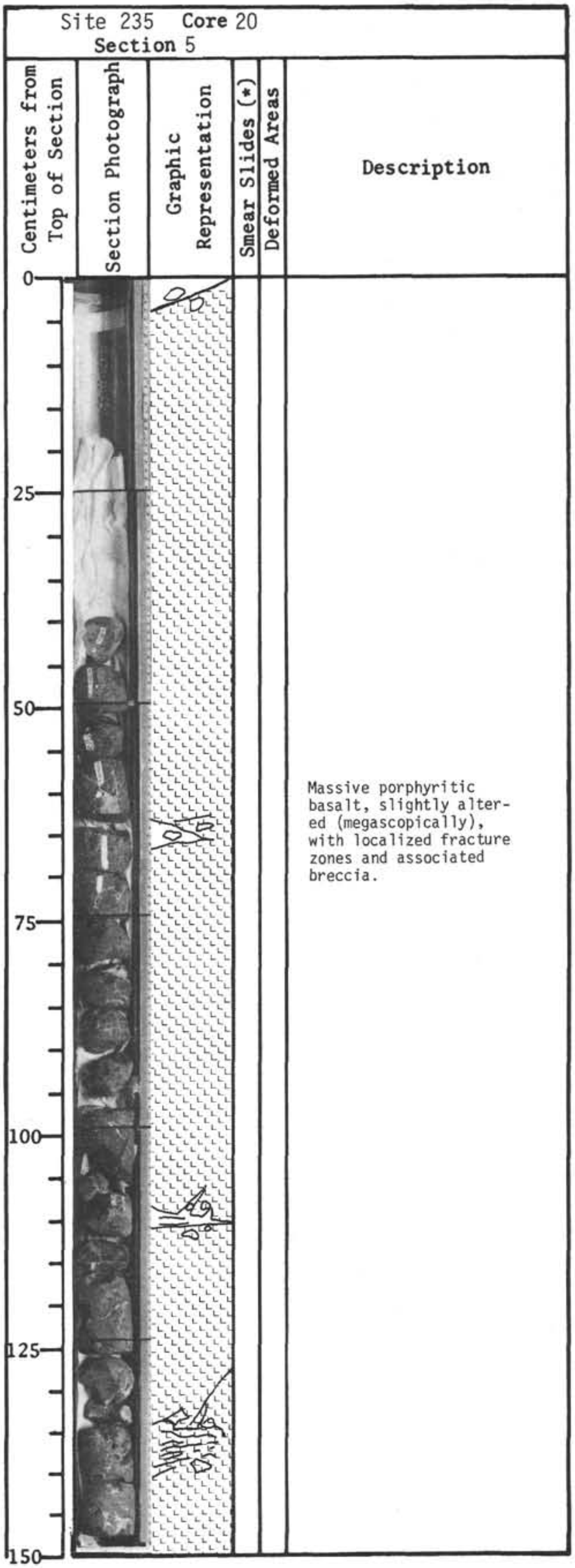
Site 235 **Core** 20
Section 4



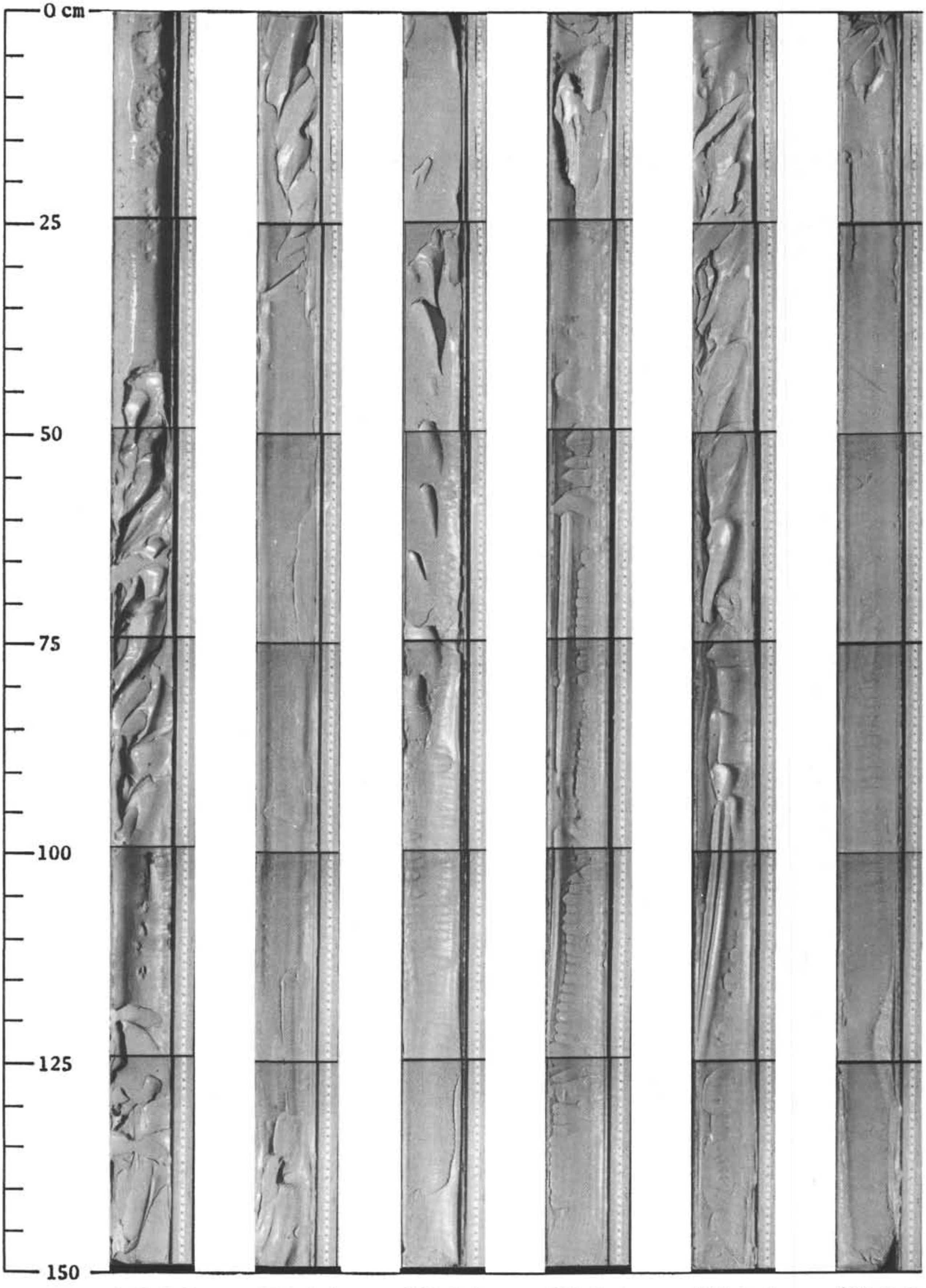
Massive, hardly fractured porphyritic basalt, only slightly altered (megascopically). Several narrow horizons of fractures and fine breccia.

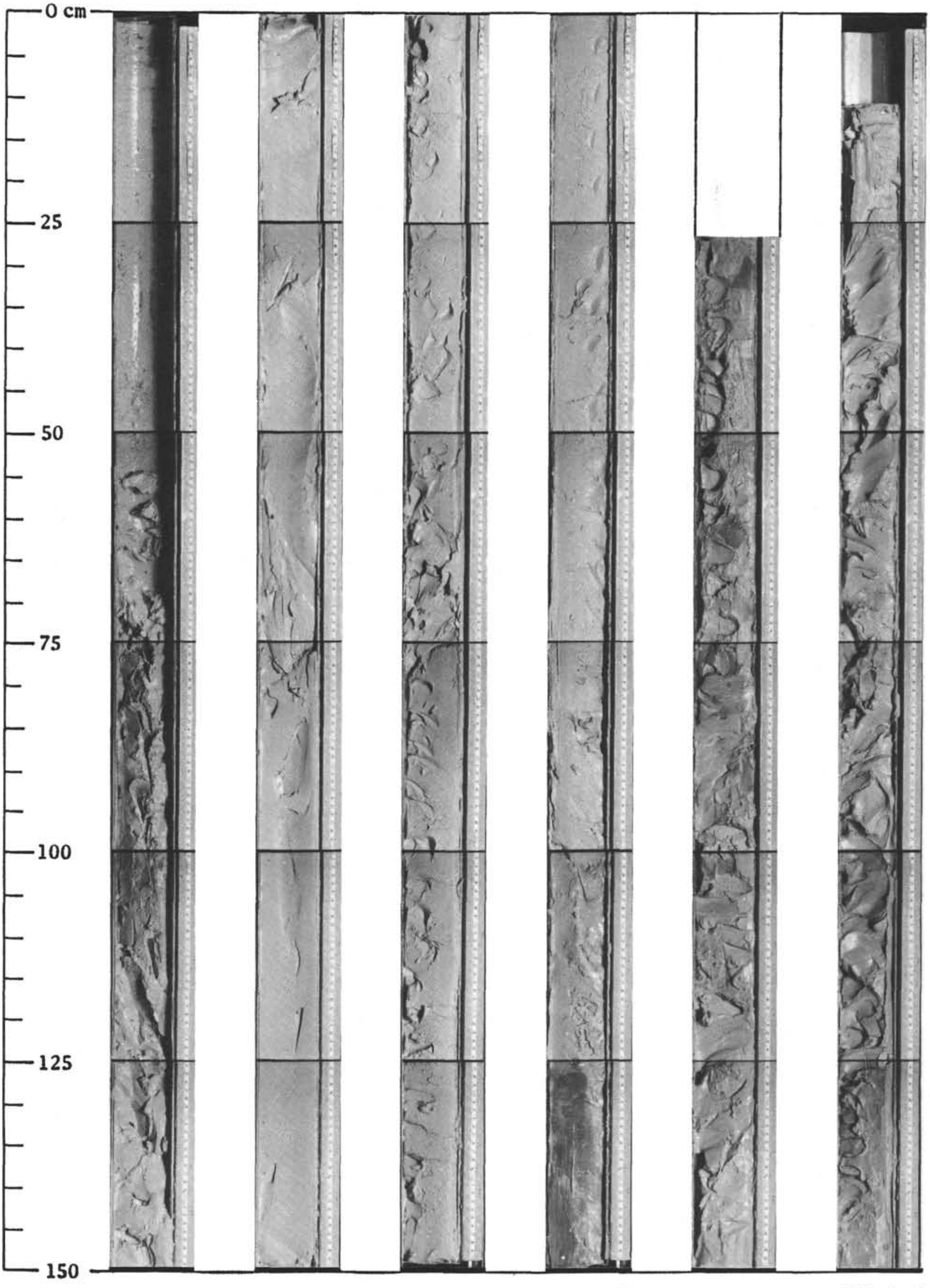
Porphyry, with phenocrysts (1/2 - 3 mm) of plagioclase commonly replaced by chloritic aggregates making up 5 to 15% of rock, and olivine (altered) about 3%. Groundmass variolitic, with plagioclase microlites radial in altered glass background.

Site 235 **Core** 20
Section 5

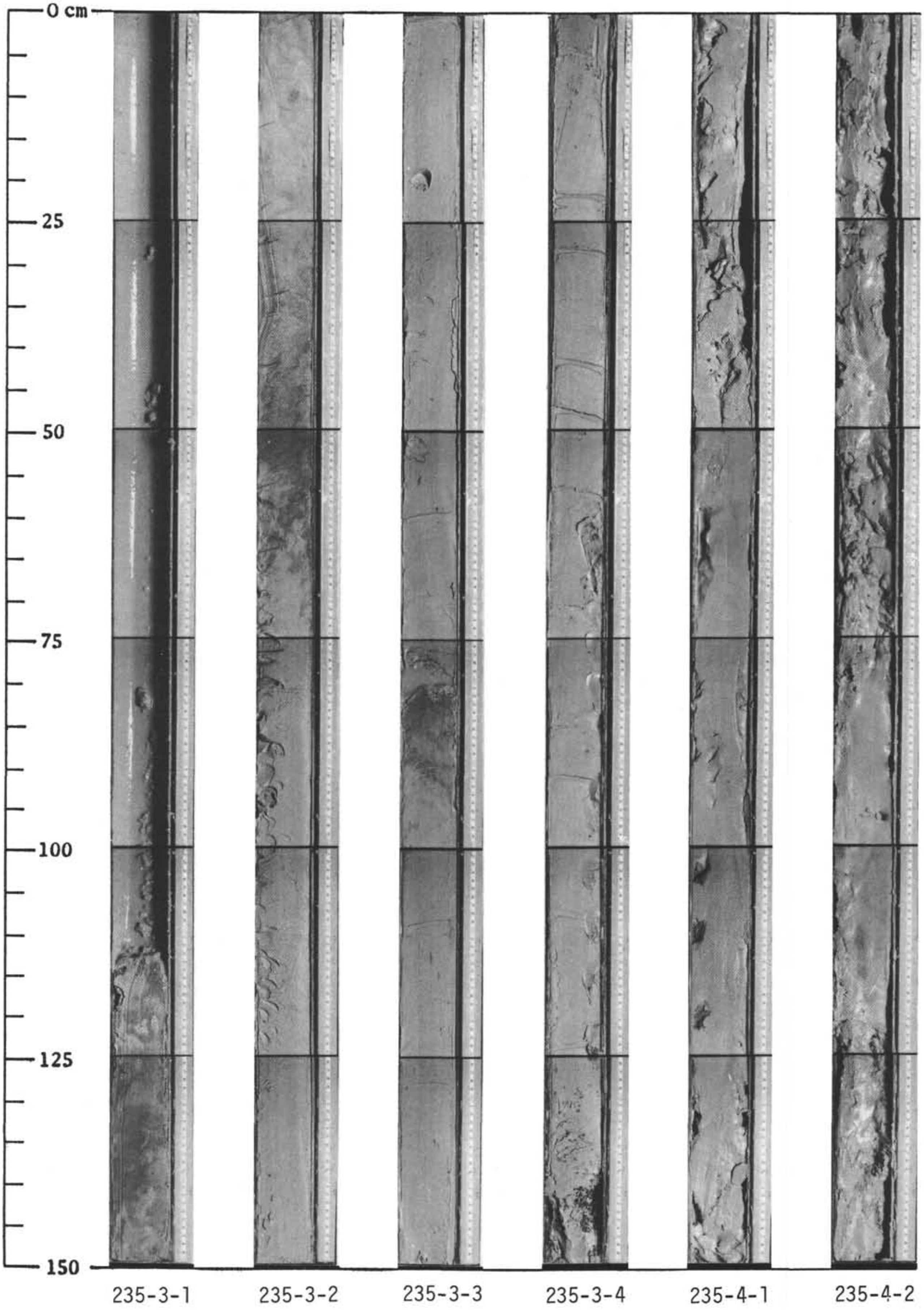


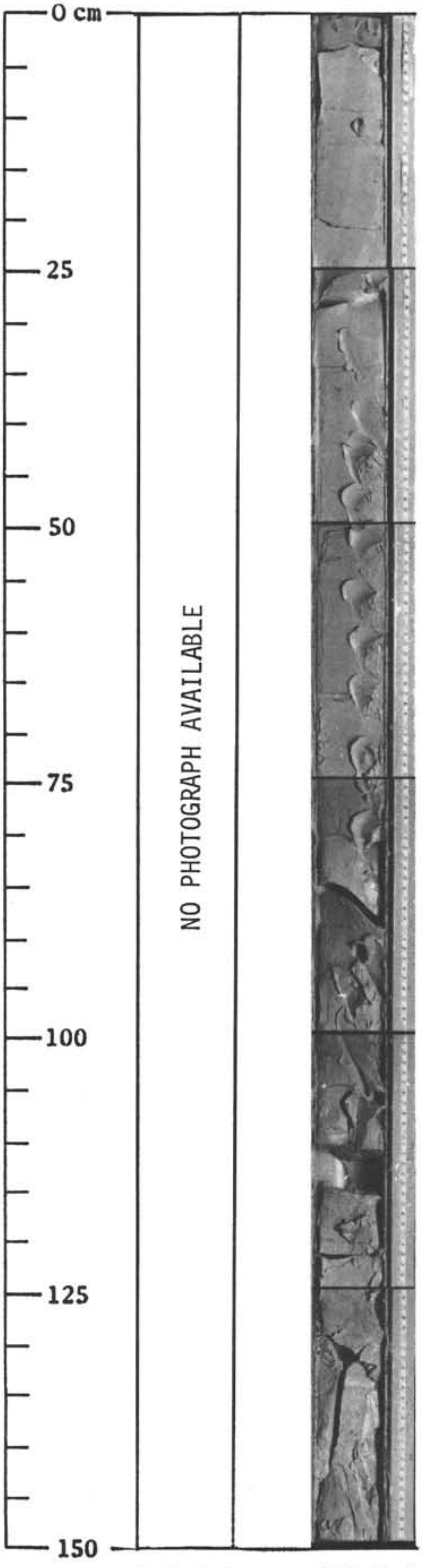
Massive porphyritic basalt, slightly altered (megascopically), with localized fracture zones and associated breccia.

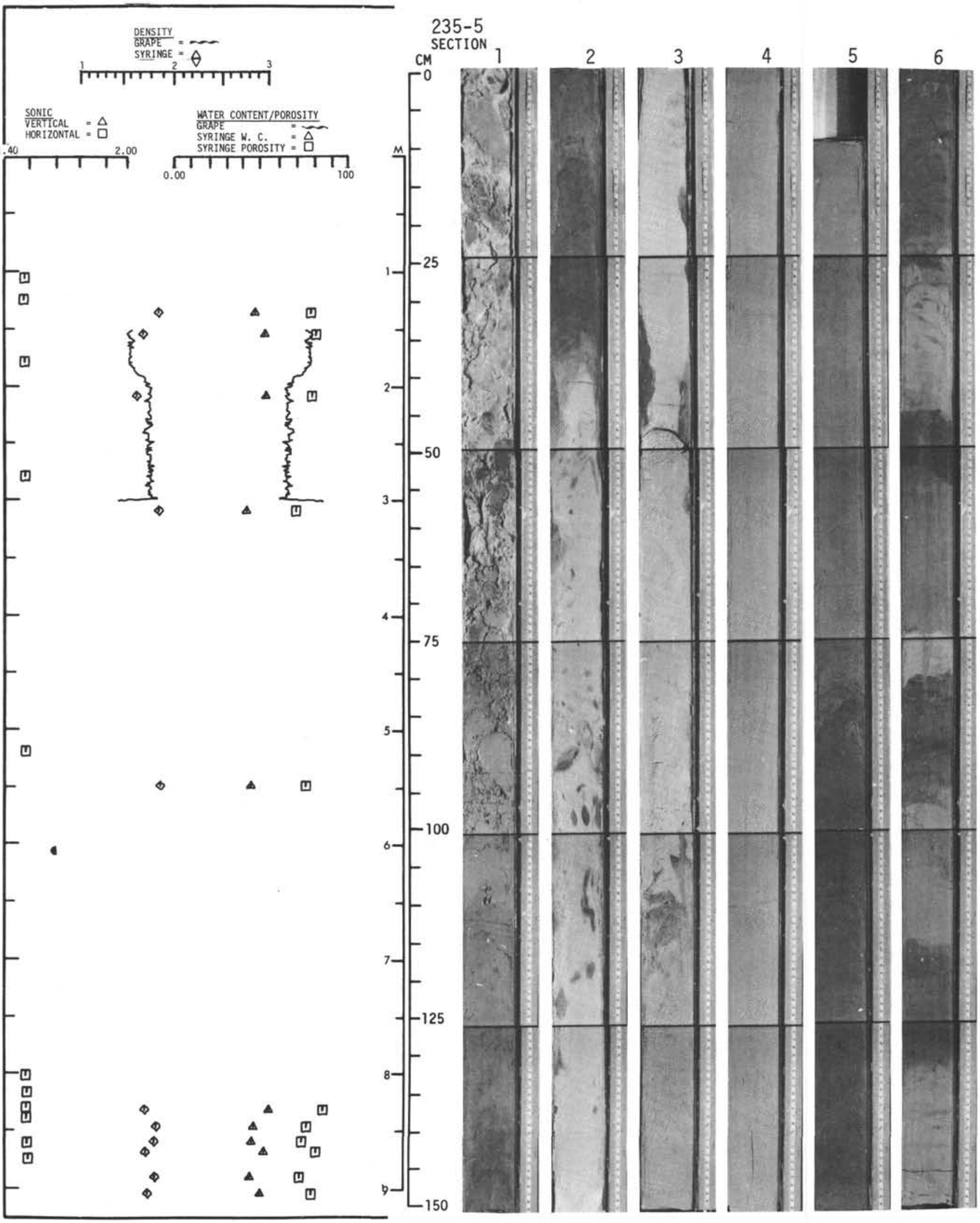

0 cm
25
50
75
100
125
150
235-1-1
235-1-2
235-1-3
235-1-4
235-1-5
235-1-6



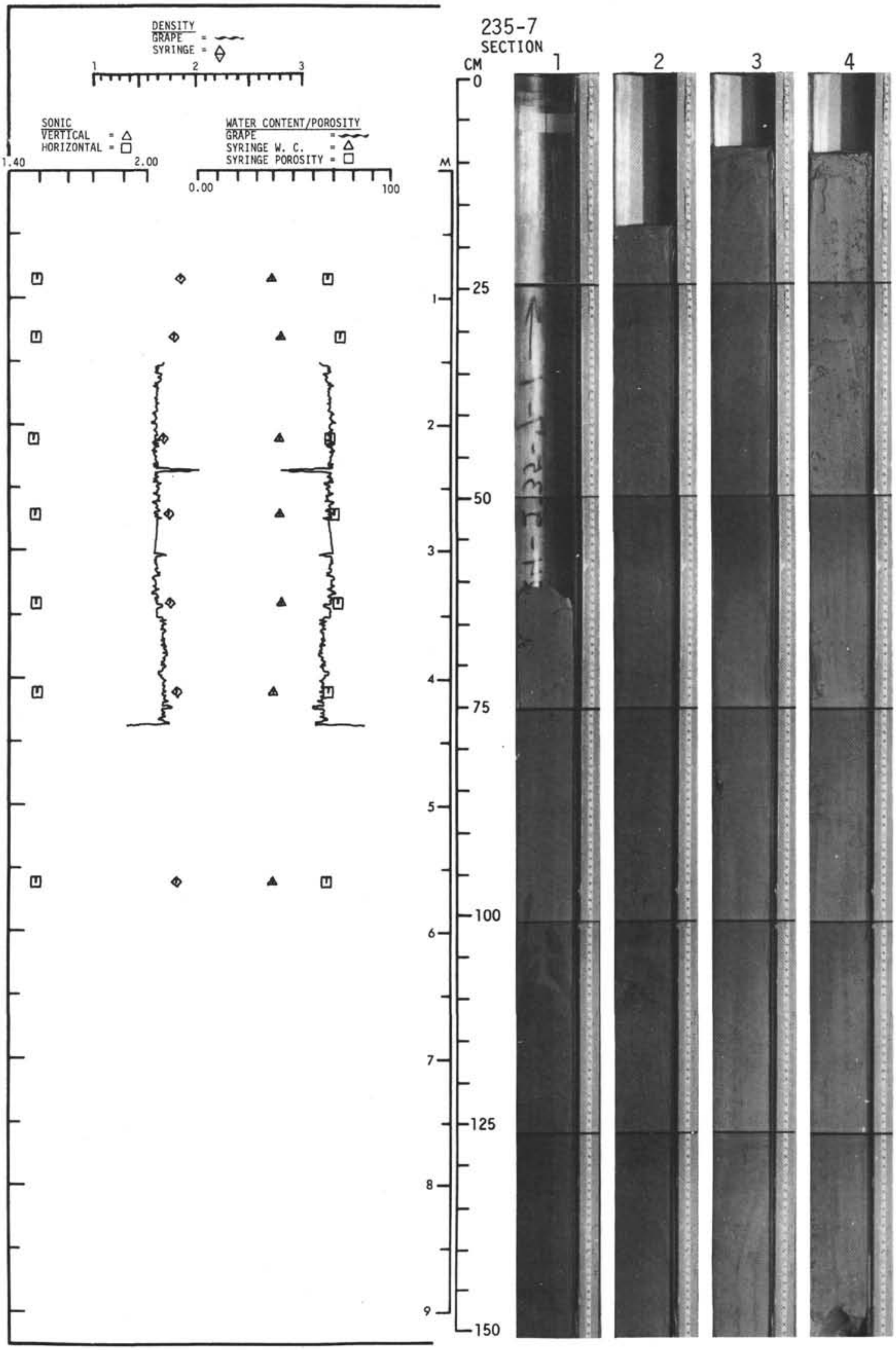
0 cm
25
50
75
100
125
150
235-2-1
235-2-2
235-2-3
235-2-4
235-2-5
235-2-6

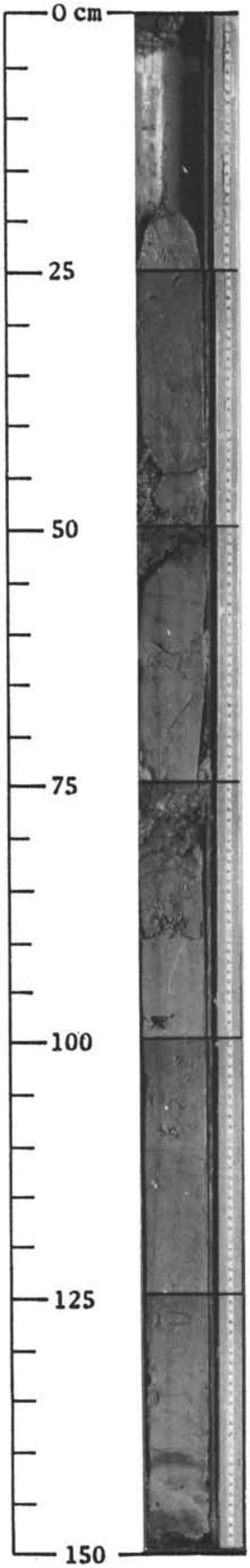

0 cm
25
50
75
100
125
150
235-3-1
235-3-2
235-3-3
235-3-4
235-4-1
235-4-2


0 cm
25
50
75
100
125
150
NO PHOTOGRAPH AVAILABLE
235-4-3
235-4-4

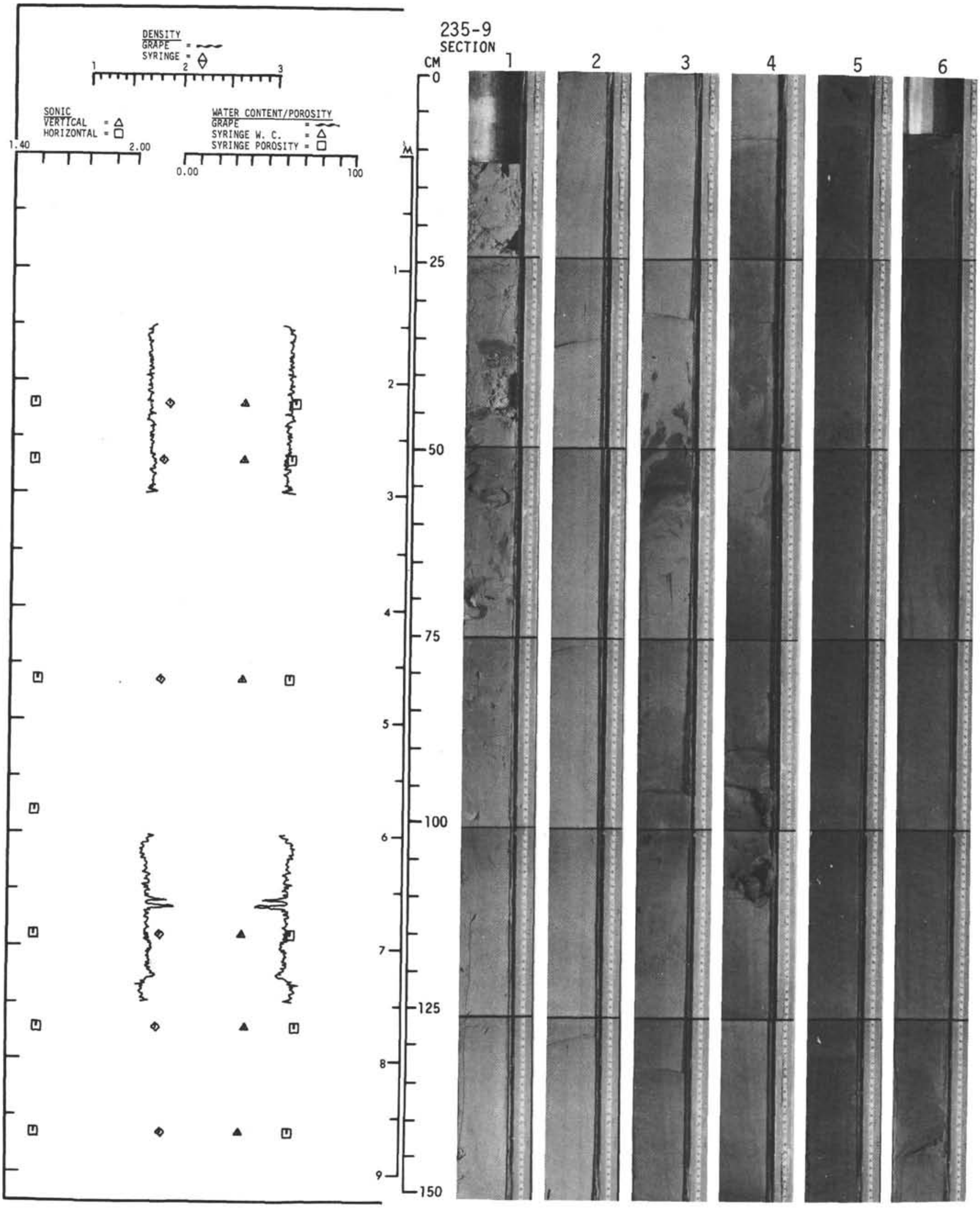

DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = □
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
M
1
2
3
4
5
6
7
8
9
235-5
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6

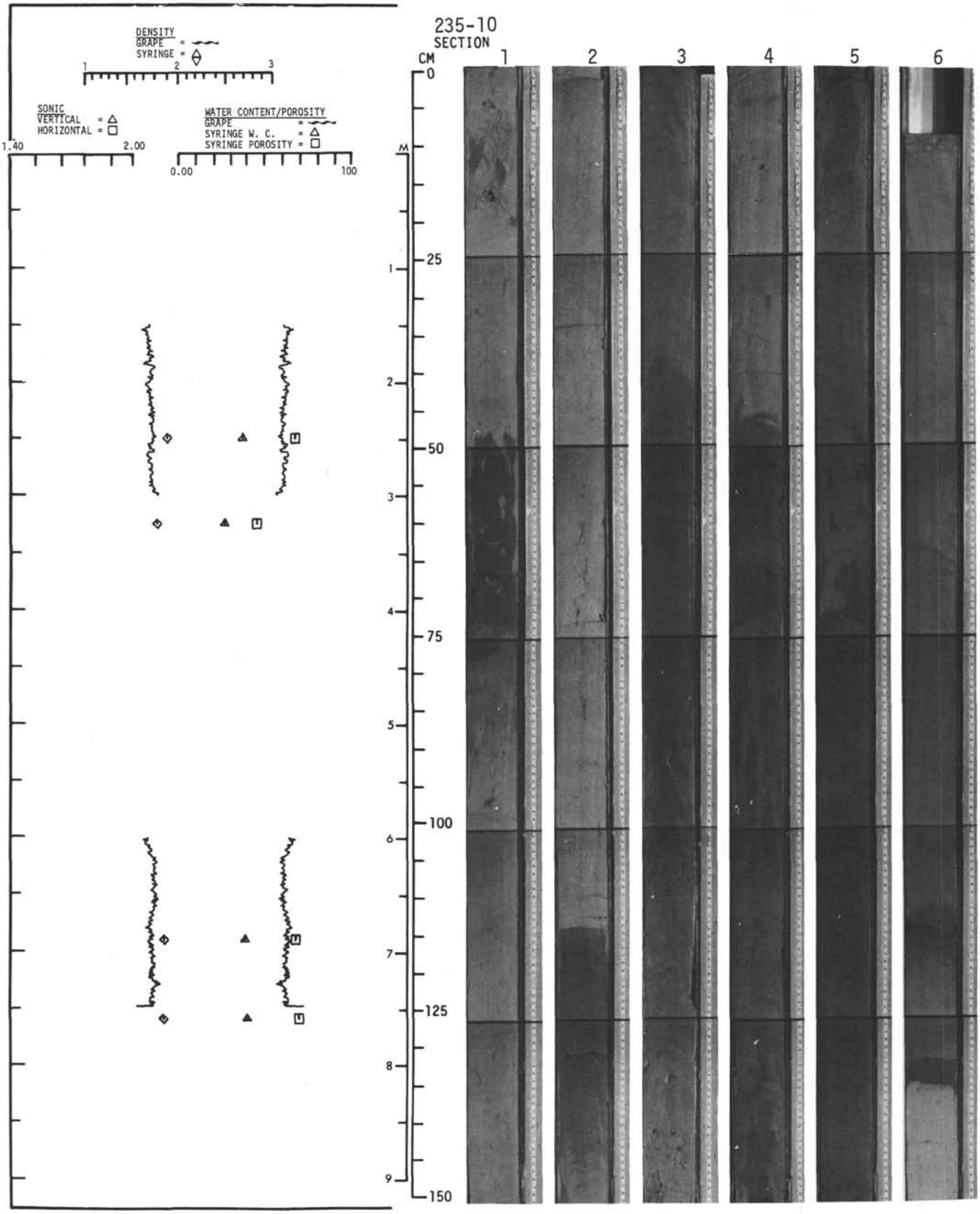
There is no Core 6 (CC only)

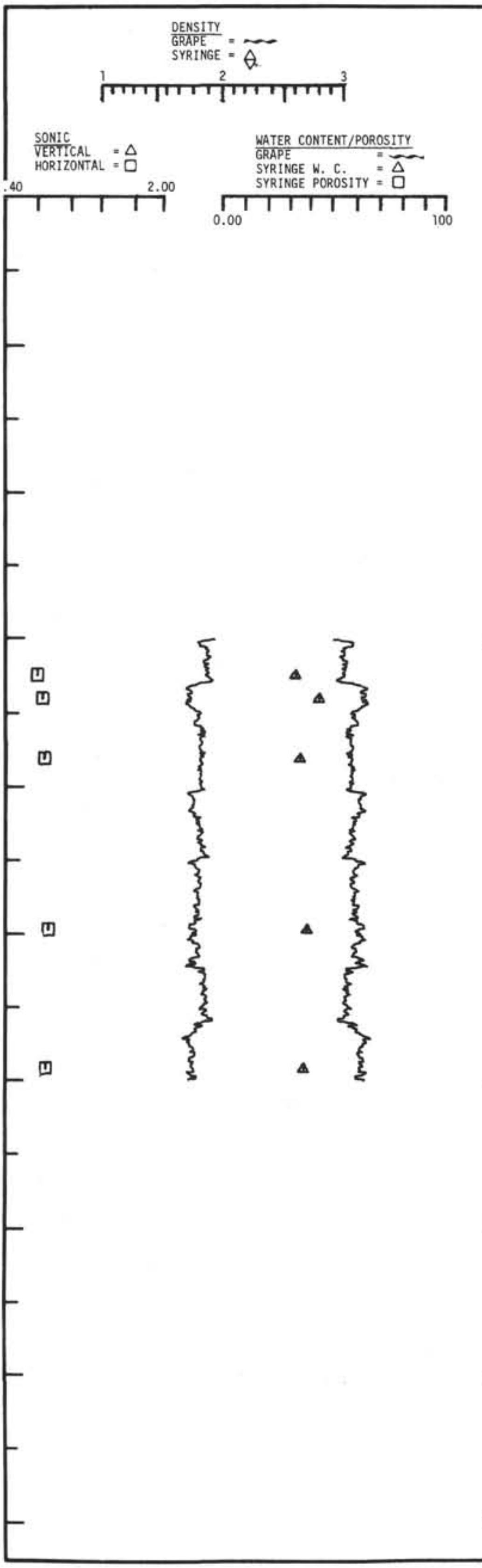


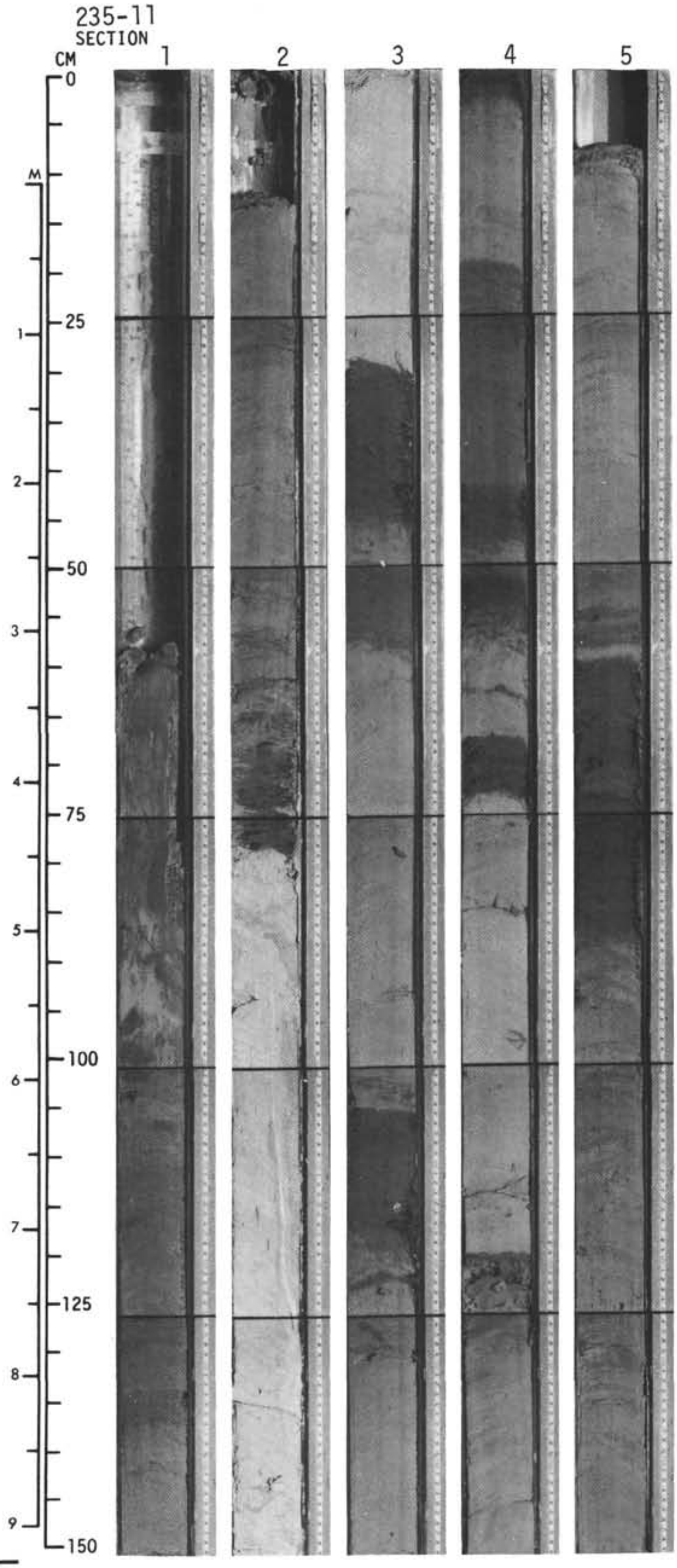


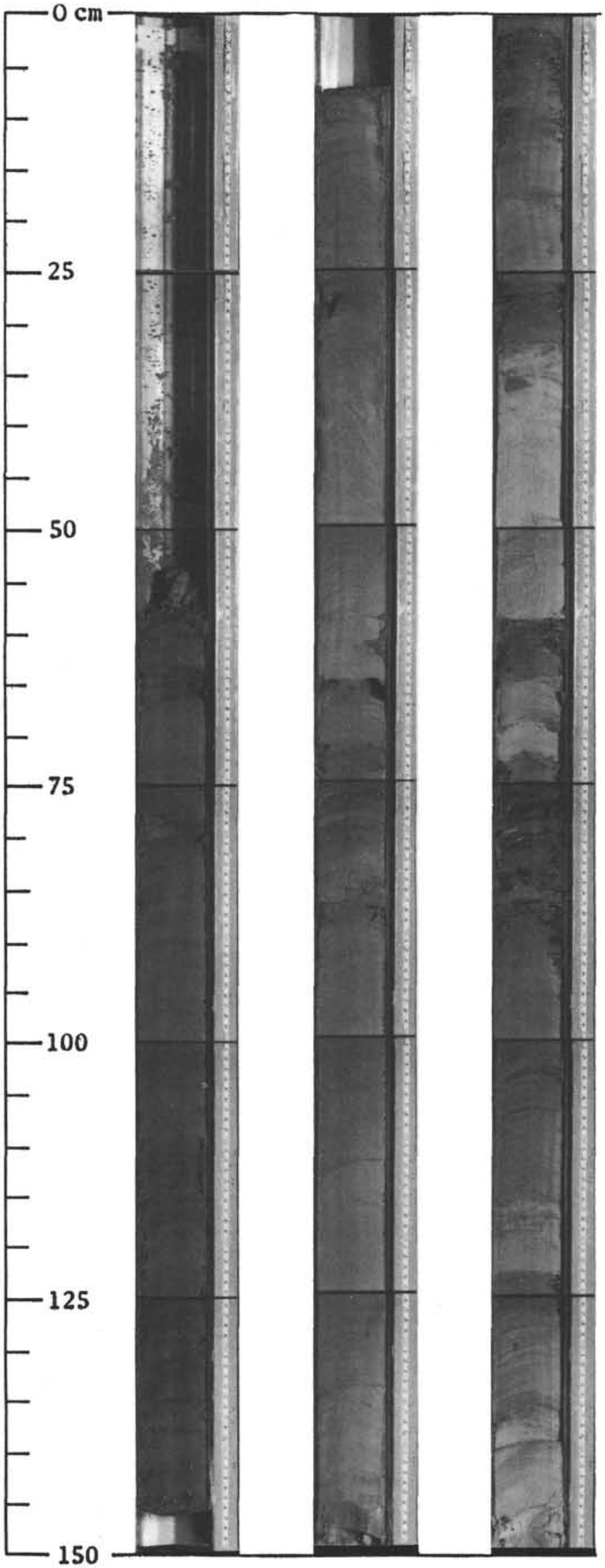
235-8-1


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
235-9
SECTION
CM
M
1
2
3
4
5
6
0
25
50
75
100
125
150
1
2
3
4
5
6
7
8
9

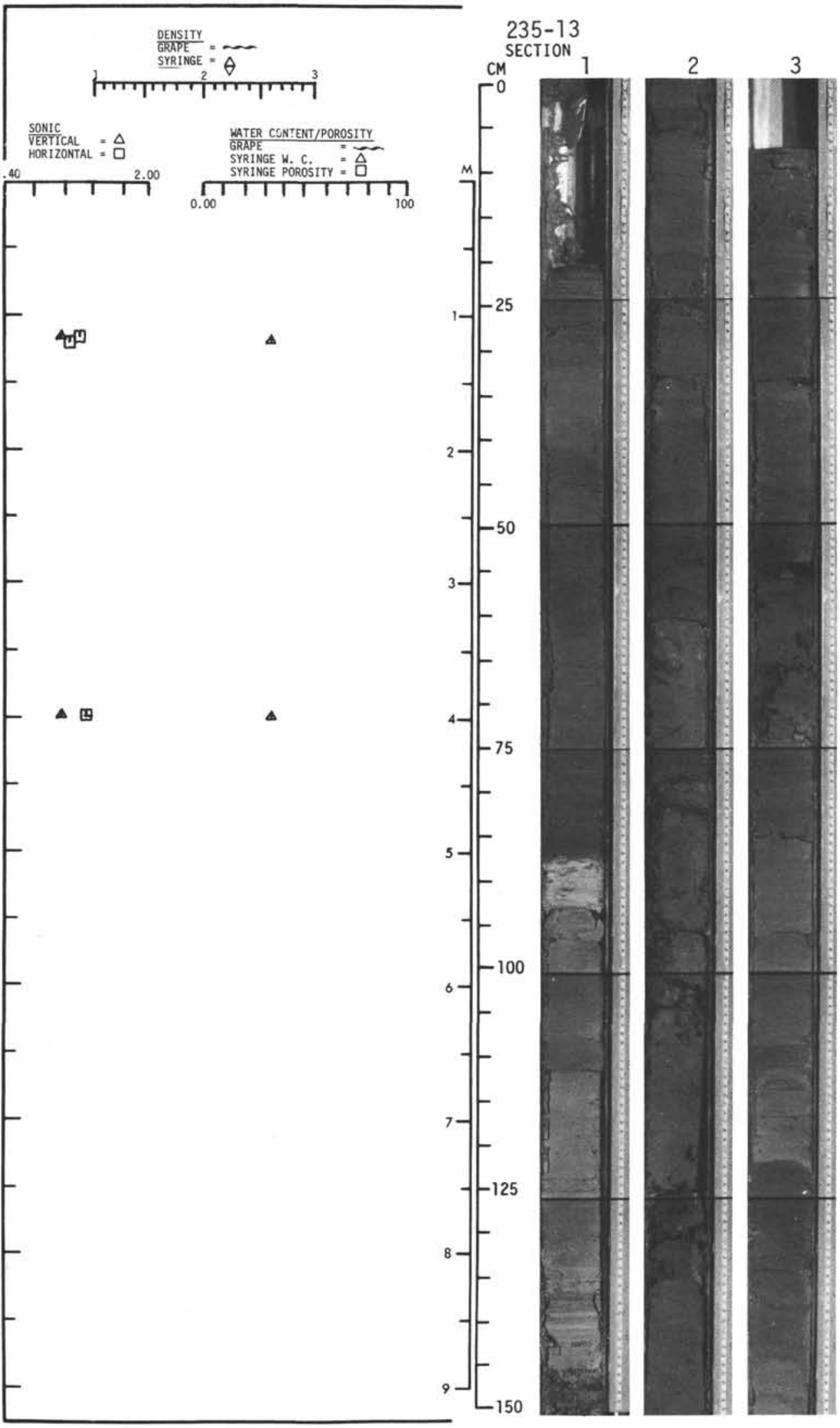

DENSITY
GRAPE =
SYRINGE = ◊
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = □
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
M
1
2
3
4
5
6
7
8
9
235-10
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6

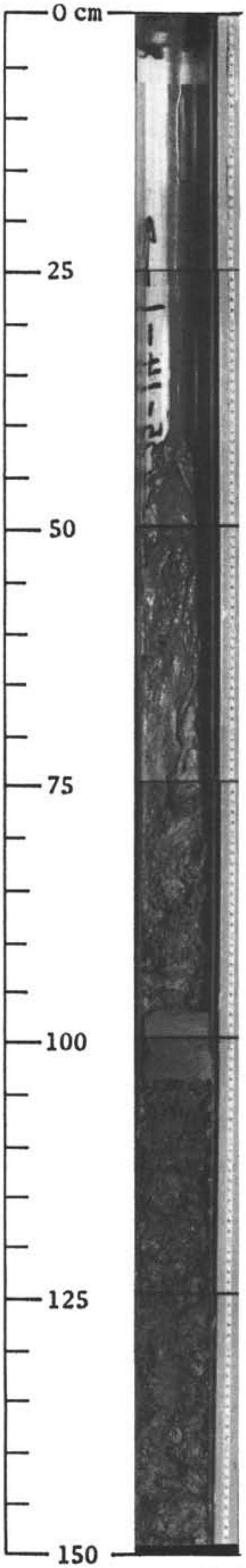

DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = □
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100


235-11
SECTION
1
2
3
4
5
CM
0
25
50
75
100
125
150
M
1
2
3
4
5
6
7
8
9

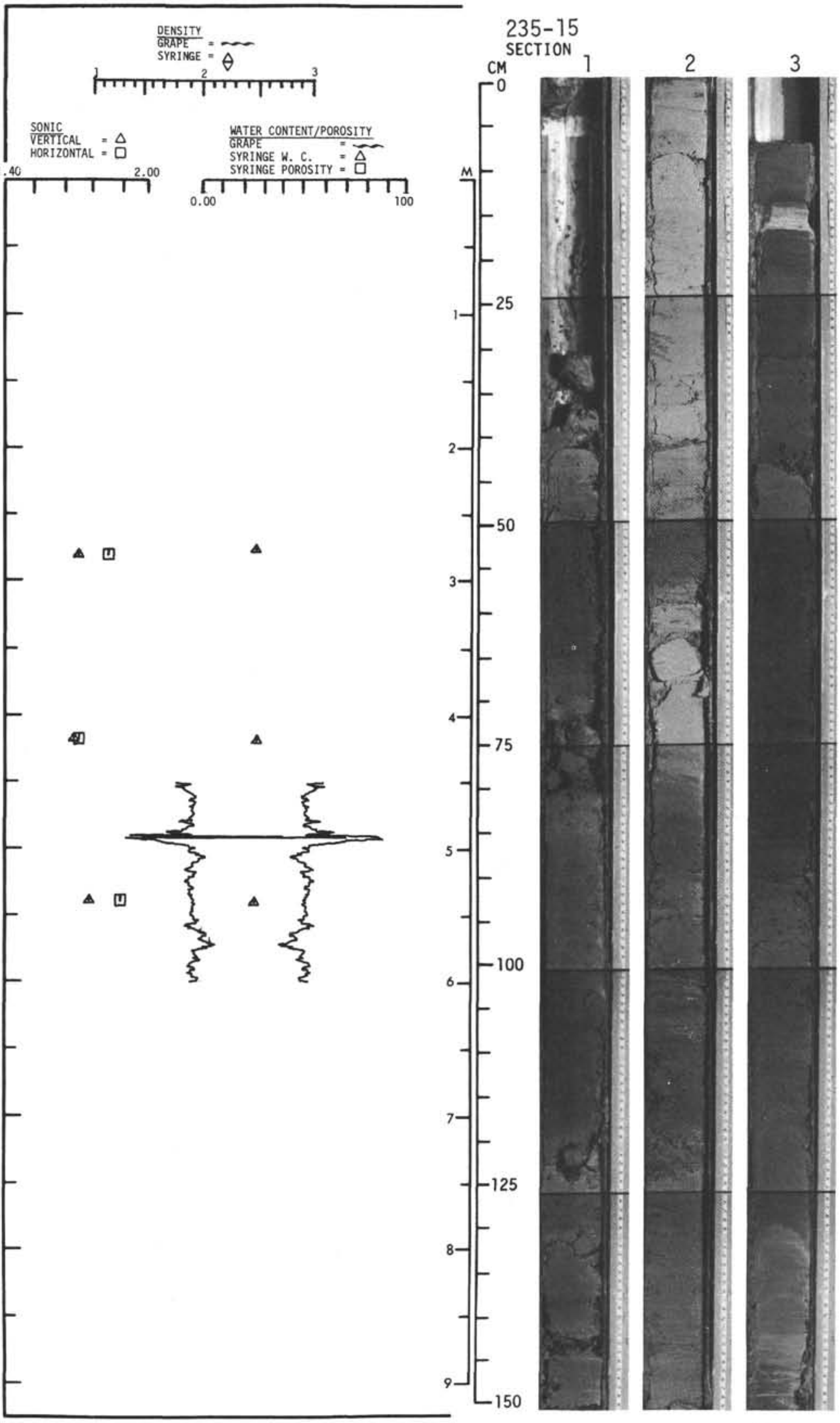


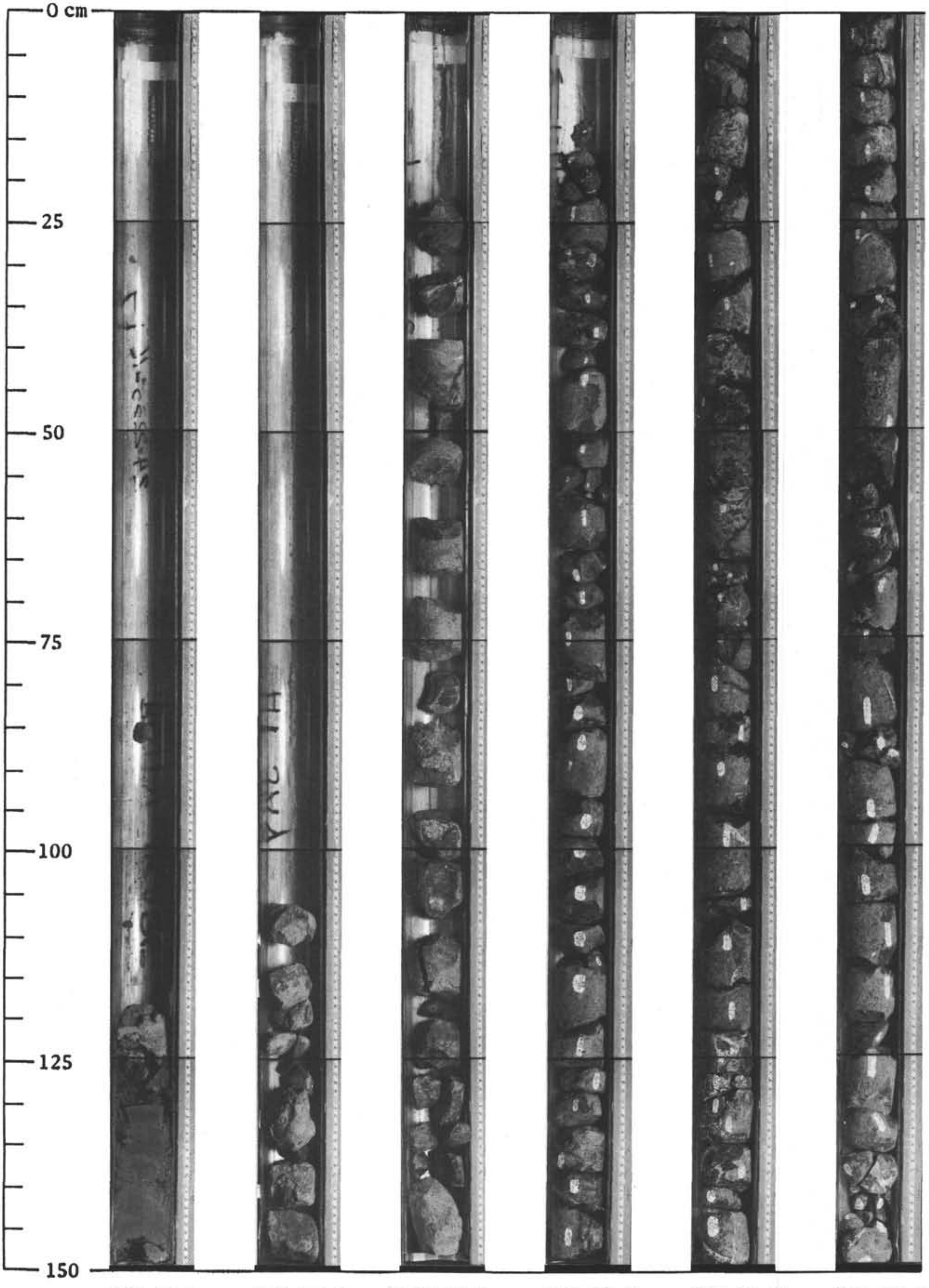
235-12-1 235-12-2 235-12-3

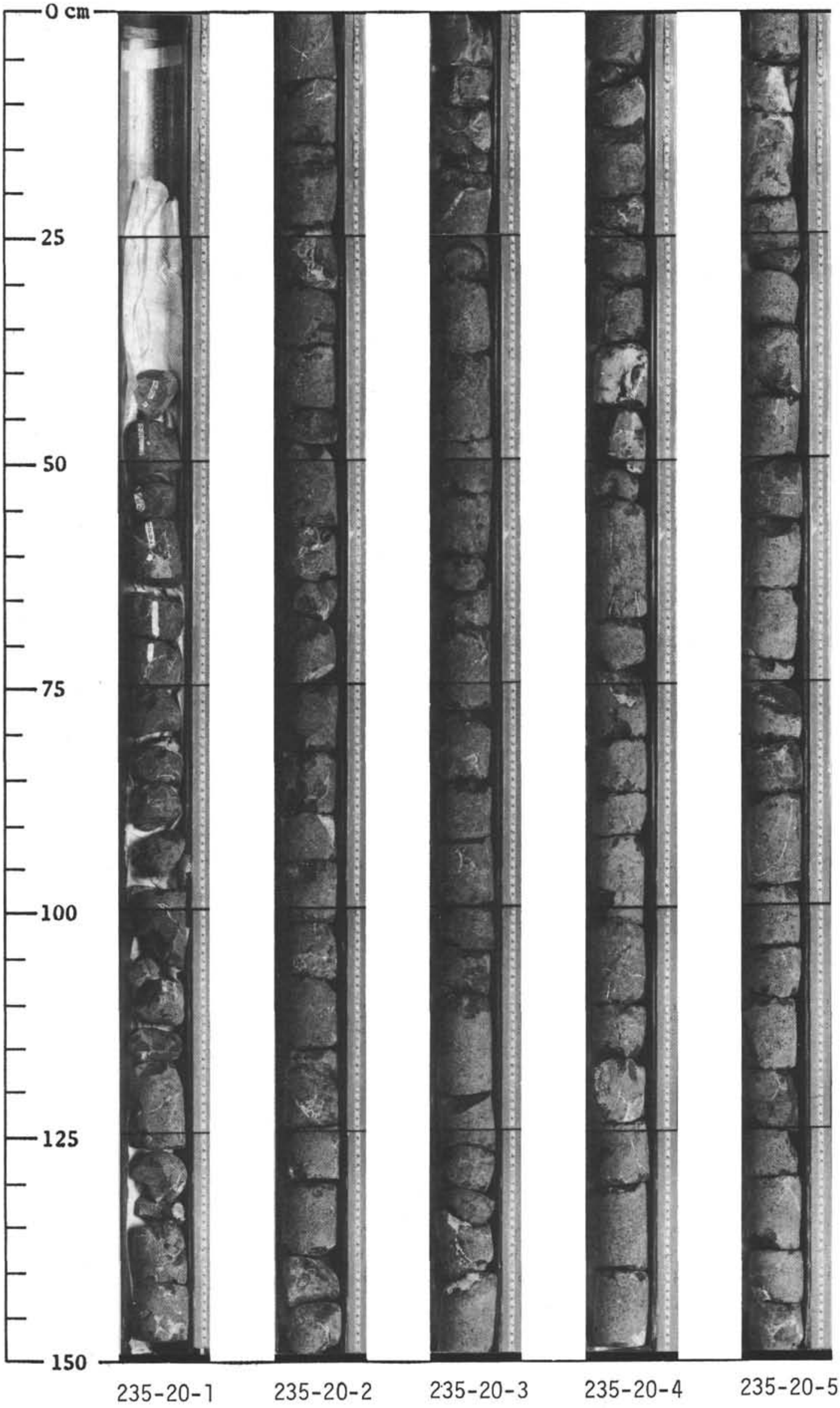

DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = □
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
M
1
2
3
4
5
6
7
8
9
235-13
SECTION
CM
0
25
50
75
100
125
150
1
2
3



235-14-1


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
235-15
SECTION
1
2
3
CM
0
25
50
75
100
125
150
M
1
2
3
4
5
6
7
8
9


0 cm
25
50
75
100
125
150
235-16-1
235-17-1
235-18-1
235-19-1
235-19-2
235-19-3


0 cm
25
50
75
100
125
150
235-20-1
235-20-2
235-20-3
235-20-4
235-20-5