7. SITE 236

The Shipboard Scientific Party[1]

SITE DATA

Date Occupied: 28 May 1972

Date Departed: 1 June 1972

Time on Site: 96 hours, 25 minutes

Position:
Latitude: 01°40.62'S
Longitude: 57°38.85'E

Water Depth: 4487 corrected meters (echo sounding)

Bottom Felt At: 4504 meters (drill pipe)

Penetration: 327.5 meters

Holes Drilled: 1

Number of Cores: 37

Total Length of Cored Section: 327.5 meters

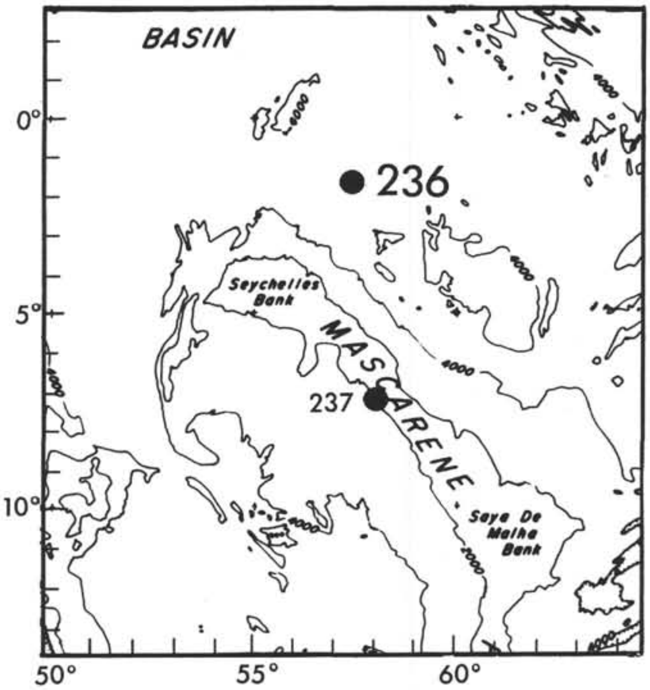
Total Core Recovered: 218.5 meters

Acoustic Basement:
Depth: 306 meters
Nature: Basalt: veined, chloritized, serpentinized
Inferred vertical velocity to basement: 1.75 km/sec

Age of Oldest Sediment: Upper Paleocene

Basement: Older than Paleocene

Principal Results: This site is located 270 km northeast of the Seychelles Islands block in characteristic oceanic structure. Single penetration was drilled and cored continuously to a total depth of 327.5 meters, with 218.5 meters, of core recovery. Sediment section consists of 14 meters of nanno ooze; 37 meters of brown clay, calcareous ooze, and zeolitic clay; 67 meters of nanno ooze; and 62 meters of cherty chalky clay which extends to basement at 306.0 meters. Basement was penetrated to a depth of 21.5 meters and 10.5 meters of chloritized veined basalt was recovered. Ages of sediments are: Pleistocene 0-19 meters; Pliocene 19-47.5 meters; upper Miocene 47.5-133 meters; middle Miocene 133-158.5 meters; lower Miocene 158.5-177.5 meters; upper Oligocene 177.5-210 meters; lower Oligocene 210-253.5 meters; upper Eocene 253.5-263 meters; lower Eocene 263-294.5 meters; and upper Paleocene 294.5 meters to base of sediment.



BACKGROUND AND OBJECTIVES

Site 236 is a high priority locality selected to examine long-term pelagic sedimentation, in near-equatorial latitudes and on fairly deep smooth sea floor, near the oldest portion of an ancient magnetic anomaly pattern. The pattern is associated with Carlsberg Ridge, or a proto-Carlsberg Ridge, the postulated agency by which the Seychelles block separated from India (?).

A single track by R/V *Vema* in 1963 provided clues that the deep region a few hundred km northeast of Seychelles Bank might yield the pelagic sequence desired by paleontologists. Furthermore, magnetic compilations (for example, Fisher et al., 1968) showed the area to be characterized by old high-amplitude, widely spaced magnetic anomalies whose overall lineation is west-northwest, more or less paralleling the present or ancestral Carlsberg Ridge.

Early in 1971, on ANTIPODE Expedition, R/V *Melville* made an extensive bathymetric, seismic, and magnetic site survey for this site, took a piston core (Quaternary at base) and measured heat flow (1.4 μcal/cm^2/sec). Figure 1 (modified to include *Glomar Challenger* results) is based primarily on *Melville's* survey. From the 1971 work, the

---

[1] Robert L. Fisher, Geological Research Division, Scripps Institution of Oceanography, La Jolla, California (Co-chief scientist); Elizabeth T. Bunce, Department of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts (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.

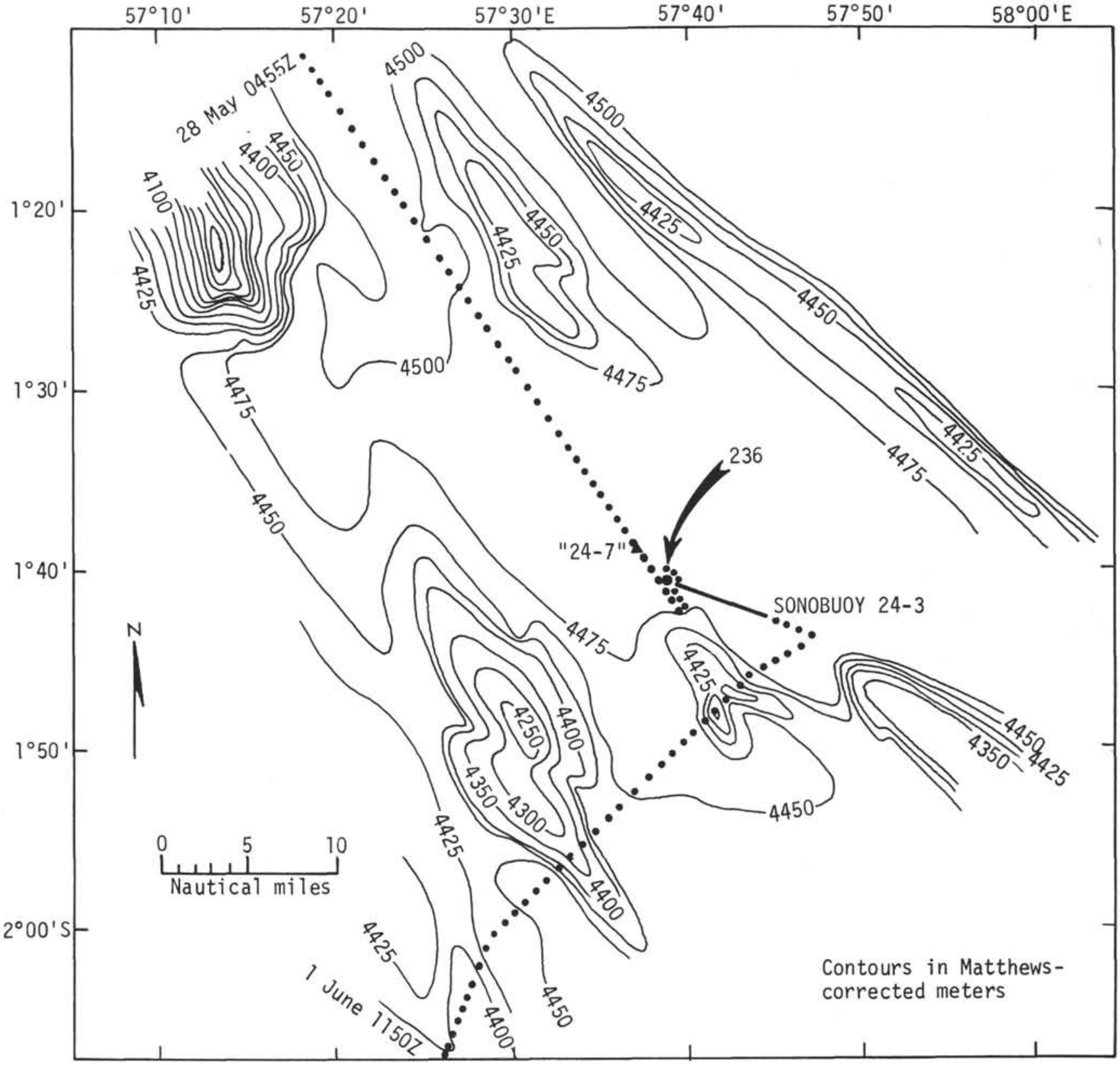


Figure 1. *Location of Site 236 and proposed site 24-7. Bathymetry based primarily on* Melville *1971 survey, Dotted line is track of* Glomar Challenger.

deepest recognizable reflector lies at 0.35 to 0.38 seconds; it, or at least what appears to be a volcanic surface, does approach and break through the overlying sediments in several portions of the area surveyed. The overall topographic grain, both surface and basement, is northwesterly, more or less paralleling Carlsberg Ridge. The site is subject to strong but variable currents in a zonal direction.

The objectives of drilling this site were several and various:

1) To continuously core and recover as much as possible of the expected deepwater pelagic section, to establish a long term low-latitude fossil zonation for Late Cretaceous(?)-early Tertiary (if anomaly 26-27 age assignment is correct) strata, and to provide a paleontological Rosetta Stone for foram-nanno-radiolarian Tertiary zones in this part of the Indian Ocean;

2) to penetrate deeply enough into any igneous rock encountered to establish that it is basement, to determine age, mineralogical composition, and petrologic affinity of basement, and to recover and examine in some detail the sediment-basement contact;

3) to provide direct evidence as to when India (?) and the Seychelles block were sundered, and to date by overlying or included fossil aggregates almost the oldest anomaly recognizable northeast of the 600+ million-year-old Seychelles block.

OPERATIONS

Near-Site Activities

Site 236, in the sedimented outermost foothills southwest of Carlsberg Ridge and 270 km northeast of Seychelles

Bank, was approached on a southeasterly course that approximately parallels the surface and basement topography. Since the environs had been extensively explored by R/V *Melville* in February 1971, no additional survey was required. Slowing to improve seismic records, and finding suitable structure easily available, *Glomar Challenger* reversed course; the seismic arrays and magnetometer were retrieved and the beacon was dropped. The point selected lies 2.3 nmi southeast of proposed Site "24-7" at a water depth of 4479 meters (corrected). Figure 1 incorporates both *Glomar Challenger* and *Melville's* ANTIPODE data.

At the close of the drilling program, *Glomar Challenger* got underway on a northwesterly course, streamed gear, then came about to a southeasterly heading and dropped a sonobuoy (24-3, Figure 2) just prior to passing close abeam the beacon. Following the wide-angle reflection profile, *Glomar Challenger* headed southwest at standard speed to make a brief call at Port Victoria to pick up a ship's computer trainee.

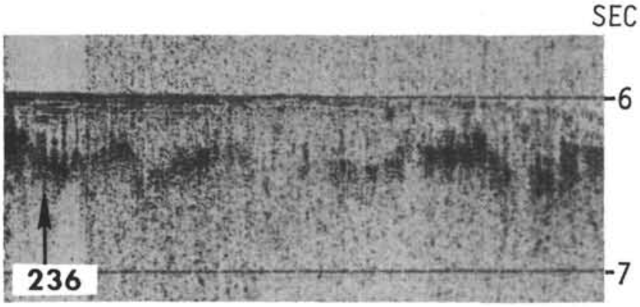


Figure 2. *On-site profile, Site 236. Arrow indicates site.*

Drilling Program

A 3-cone button bit was lowered on the same bottom hole assembly as had been used on the previous sites. Prior to touching the mudline, the draw works' low drum clutch became inoperative and seven hours were used effecting repairs.

Site 236 coring summary is shown in Table 1. Core 1 indicated that the upper sediments are a soft chalk. No pump was used while coring until Core 9 was recovered. Coring continued from 82 to 139 meters by only breaking circulation. Core recovery was excellent to 244 meters where chert was encountered. Of the next 57 meters cored, 263 to 306, only 12 (21%) were recovered. Basalt was cored from 306 meters to the total depth of 327.5 meters, with 21.5 meters cored and 10.3 meters recovered. Drilling was stopped at 327.5 meters because the drill string commenced torquing excessively, indicating the bearings in the bit were gone.

LITHOLOGIC SUMMARY

Site 236 was continuously cored from the sediment surface to a depth of 327.5 meters. Sediments were recovered in Cores 1 to 32; in Core 33, the sediment-basalt contact was found at a depth of 305 meters. Cores 34-37 penetrated basalt. The sediments can be grouped into six lithologic units, while Unit 7 includes all the basaltic rocks (Table 2). These igneous rocks are described in Appendix A.

Unit 1 (0.0-17.5 m; Cores 1, 2, and Core 3, Section 1)

This unit comprises yellowish or light to moderate to dark gray (frequent slightly changing hues) nanno ooze, with thin moderate brown radiolarian ooze layers. The nanno oozes consist predominantly of nannofossils (80-90%) with few foraminifera (0-5%) and traces of quartz, feldspar, radiolarians, fish debris, and pyrite. The radiolarian ooze layers contain up to 60 percent radiolarians, 20 percent diatoms, traces of foraminifera, and nannofossils. All cores show a high degree of deformation and no primary sedimentary structures are preserved. However, it seems most likely that the radiolarian oozes are intercalated as thin beds with the nanno oozes.

Unit 2 (17.5-139.5 m; Core 3, Section 2, through Core 15)

Unit 2 is the thickest lithological unit (122 m) found at Site 236. It consists mainly of nanno ooze, foram ooze, and foram nanno ooze with a few intercalated, relatively thin clay layers.

The moderate orange-pink, greenish-yellow, grayish-yellow-green, and light gray nanno oozes contain, in addition to nannofossils, traces of foraminifera, radiolarians, fish debris, dolomite rhombs, quartz, and pyrite. The grayish-yellow-green to moderate orange-pink foram oozes or foram nanno oozes are intercalated with the nanno oozes and reach a maximum thickness of 6 meters. However, most of them measure only a few decimeters. The sandy layers are infrequent and relatively thin in the lower part (Cores 12-15) of this unit, whereas they are more abundant and thicker in the middle part (Cores 5-11); only a few thin ones occur in the uppermost part. The sandy layers consist of 40 to 60 percent planktonic foraminifera, 20 to 50 percent nannofossils with traces of fish debris, micarb, quartz, and clay minerals. Some of the sandy layers have a very characteristic grayish-red-purple zone at their base. Nanno-rich clays and nanno clays are found intercalated with the sediments. They are mostly greenish to bluish gray in color and consist of clay minerals, micarb, nannofossils, and foraminifera with traces of radiolarians, fish debris, dolomite rhombs, and quartz. Burrows seem to be more frequent or better preserved in some of the clay and nanno clay layers.

Unit 3 (139.5-180.5 m; Core 16 through Core 20, Section 2)

The sediments of Unit 3 consist of light olive-gray to pale brown nanno-bearing clays with thin intercalations of nanno clay and nanno ooze. The proportion of $CaCO_3$-rich sediments increases in the lower part of this unit. The nanno-bearing clays consist of clay minerals (up to 80%) with traces of foraminifera, nannofossils, fish debris, volcanic glass, dolomite rhombs, and pyrite. Small amounts of Fe oxide (up to 3%) are common, and the clays of Core 18 contain up to 5 percent zeolites.

Unit 4 (180.5-244.0 m; Core 20, Section 3, through Core 26)

The bulk of Unit 4 consists of very homogeneous pale orange to white nanno ooze to nanno chalk, comprising 60-95 percent nannofossils, 2-25 percent foraminifera, and

TABLE 1
Coring Summary – Site 236

Core	Date (May-June 1972)	Time	Depth Below Sea Floor (m)	Depth From Drill Floor (m)	Cored (m)	Recovered (m)	Recovered (%)
1	29	0628	0.0-6.5	4504.0-4510.5	6.5	6	93
2	29	0746	6.5-16.0	4510.5-4520.0	9.5	1	10
3	29	0902	16.0-25.5	4520.0-4529.5	9.5	4.2	44
4	29	1012	25.5-35.0	4529.5-4539.0	9.5	7.5	78+
5	29	1146	35.0-44.5	4539.0-4548.5	9.5	7.2+	76
6	29	1314	44.5-54.0	4548.5-4558.0	9.5	9.5	100
7	29	1434	54.0-63.5	4558.0-4567.5	9.5	9.5	100
8	29	1556	63.5-73.0	4567.5-4577.0	9.5	9.4	98
9	29	1720	73.0-82.5	4577.0-4586.5	9.5	6.5	68
10	29	1858	82.5-92.0	4586.5-4596.0	9.5	6.6	69
11	29	2023	92.0-101.5	4596.0-4605.5	9.5	3.0	32
12	29	2153	101.5-111.0	4605.5-4615.0	9.5	9.5	100
13	29	2325	111.0-120.5	4615.0-4624.5	9.5	9.5	100
14	30	0113	120.5-130.0	4624.5-4634.0	9.5	4.1	43
15	30	0327	130.0-139.5	4634.0-4643.5	9.5	9.5	100
16	30	0517	139.5-149.0	4643.5-4653.0	9.5	8.8	93
17	30	0653	149.0-158.5	4653.0-4662.5	9.5	9.5	100
18	30	0817	158.5-168.0	4662.5-4672.0	9.5	9.0	95
19	30	0938	168.0-177.5	4672.0-4681.5	9.5	3.9	41
20	30	1053	177.5-187.0	4681.5-4691.0	9.5	6.2	65
21	30	1220	187.0-196.5	4691.0-4700.5	9.5	8.8	93
22	30	1346	196.5-206.0	4700.5-4710.0	9.5	5.1	54
23	30	1537	206.0-215.5	4710.0-4719.5	9.5	9.4	99
24	30	1710	215.5-225.0	4719.5-4729.0	9.5	9.5	100
25	30	1846	225.0-234.5	4729.0-4738.5	9.5	9.5	100
26	30	2030	234.5-244.0	4738.5-4748.0	9.5	9.5±	100
27	30	2210	244.0-253.5	4748.0-4757.5	9.5	1.8	19
28	30	2355	253.5-263.0	4757.5-4767.0	9.5	1.2	13
29	31	0132	263.0-272.5	4767.0-4776.5	9.5	1.2	13
30	31	0306	272.5-282.0	4776.5-4786.0	9.5	1.8	19
31	31	0444	282.0-291.5	4786.0-4795.5	9.5	2.6	28
32	31	0613	291.5-301.0	4795.5-4805.0	9.5	3.3	35
33	31	0743	301.0-306.5	4805.0-4810.5	5.5	3.7+	68
34	31	1106	306.5-312.5	4810.5-4816.5	6.0	2.85	47
35	31	1513	312.5-322.0	4816.5-4826.0	9.5	3.15	33
36	31	1917	322.0-326.0	4826.0-4830.5	4.0	3.0	75
37	1	0012	326.0-327.5	4830.0-4831.5	1.5	1.5	100

5-10 percent radiolarians. Pale yellowish to pale orange hues coincide with small amounts of Fe oxide (up to 1%).

In contrast to the chalks of Unit 5 (below), no cherts were found in Unit 4. Thin grayish-orange to pale yellowish volcanic ash layers occur at depths of 204.7, 212.0, and 214.0 meters (80-85% volcanic glass and traces of quartz, feldspar, Fe oxides, nannofossils, foraminifera, radiolarians, and fish debris).

Unit 5 (244.0-301.0 m; Cores 27-32)

The sediments of Unit 5 consist of very pale orange to pale yellowish-brown sometimes clay-rich nanno chalk with pale brown cherts. Nannofossils (80-90%), foraminifera (10-20%), and Radiolaria (2-4%) are the most common components. In the pale yellowish-brown horizons, small amounts of clay minerals are found in addition to the biogenic fraction.

Many burrows are preserved in partially silicified zones of the chalk, adjacent to the cherts. In other parts of this unit, burrows are usually not readily discerned, presumably because the sediments are too homogeneous.

Unit 6 (301.0-305.1 m; Core 33, Sections 1-3)

The nanno chalk of Unit 6 overlies, possibly conformably, basalt basement. It is pale green, grayish-olive green, dusky brown, and moderate yellowish-brown colored due to its content of clay minerals (10-30%) and Fe oxides (1-5%). The main components of these sediments are nannofossils (60-80%) and foraminifera (5-15%), with traces of quartz.

The sediments directly above the basement rocks seem to be more compact than higher up in this unit. Pyrite is found in small fissures, Fe oxides are concentrated more highly than usual in a dusky brown to moderate orange pink horizon about 2 meters above the basement. These observations might indicate hydrothermal activity.

Unit 7 (305.1-327.5 m; Core 33, Sections 3 and 4, through Core 37)

The basement rocks consist of dark gray, veined, chloritized, and serpentinized basalt. A detailed description is given in Appendix A.

TABLE 2
Lithologic Units – Site 236

Depth Below Sea Floor (m)	Unit	Lithology	Thickness (m)	Cores
	1	Yellowish to gray nanno ooze with brown-rad ooze layer	7.5	1-3
17.5				
	2	Yellow to gray nanno and foram ooze with thin clay layers	22.0	3-15
139.5				
	3	Olive gray to pale brown clay with thin layers of nanno clay and ooze	41.0	16-20
180.5				
	4	Pale orange to white nanno ooze to chalk	63.5	20-26
244.0				
	5	Pale orange to pale brown nanno chalk with chert	57.0	27-32
301.0				
	6	Pale green to brown nanno chalk	4.1	33
306.0				
	7	Basalt	>22.4	33-37
327.5				

Conclusions

1. The bulk of the sediment found at Site 236 is of biogenic origin, comprising the skeletons of pelagic organisms. The sediments overlie basaltic basement. Sediments a few centimeters above the basalt are fossiliferous and could therefore provide a minimum age for the underlying basement.

2. The lower half of the sedimentary sequence is dominated by pure nanno chalks or nanno oozes; in the upper half, foram nanno ooze and radiolarian ooze layers are found intercalated with the nanno oozes. These three different facies are typical of the highly productive, low-latitude, open-oceanic environment.

3. Terrigenous matter is represented by small amounts of clay minerals (and sometimes quartz) distributed throughout the whole sedimentary sequence. However, the terrigenous input was fairly high during sedimentation of the zeolite-bearing pale brown ferruginous clays of Unit 3. A few thin, distinct, volcanic ash layers found in the nanno chalks in the upper part of Unit 4 are mainly composed of glass (colorless, or nearly so).

BIOSTRATIGRAPHIC SUMMARY

Introduction

The sediments continuously cored at Site 236 represent a sequence from late Paleocene to Quaternary with substantial hiatuses in the Eocene and uppermost Paleocene and condensed series in the early Miocene. The late Pliocene sequence appears also to be condensed. Sediments are chiefly pelagic and contain common to abundant calcareous plankton. In Quaternary to upper Eocene sediments, nannofossils are well to moderately preserved, whereas planktonic foraminifera are poorly to moderately preserved with a significant degree of fragmentation. In lower Eocene sediments, nannofossils show considerable alteration and foraminifera are commonly recrystallized. Throughout the section, radiolarians are well preserved and common in some horizons but poorly preserved or absent in others.

Fossil zonations and age assignments are summarized on the site summary form at the end of this chapter. The biostratigraphic age of the oldest sediment immediately overlying basement in Core 33, Section 3 is 57-58 m.y. old (P.4 foraminiferal zone and *Discoaster mohleri* nannofossil zone). Reworking of older sediments into younger material was commonly observed in the three fossil groups in many horizons.

Calcareous Nannoplankton

Core 1 contains assemblages typical of the *Gephyrocapsa oceanica* Zone with the zonal marker and some reworked Oligocene. Core 2 belongs to the *Gephyrocapsa oceanica* Zone with *Gephyrocapsa caribbeanica, Pseudoemiliania lacunosa,* and *Crenalithus doronicoides.* Core 3 yields assemblages indicating the *Pseudoemiliania lacunosa* Zone in the upper part (Section 1) with *Pseudoemiliania lacunosa* and *Crenalithus doronicoides.* Core 3, Section 3 belongs to the late Pliocene *Cyclococcolithina macintyrei* Zone with *Discoaster brouweri* and *Cyclococcolithina macintyrei.* The Pliocene/Pleistocene boundary lies within Core 3. Core 4, Section 1 recovered the early Pliocene *Reticulofenestra pseudoumbilica* Zone with *Reticulofenestra pseudoumbilica* and *Sphenolithus abies.* The lower part of Core 4 contains *Ceratolithus rugosus* together with *C. tricorniculatus* and *C. primus*, indicating the *Ceratolithus rugosus* Zone. Core 6 recovered the *Ceratolithus tricorniculatus* Zone with *Ceratolithus tricorniculatus, C. primus*, and *Triquetrorhabdulus rugosus*. The Miocene/Pliocene boundary, based on nannofossils, lies between Cores 5 and 6. Cores 7 through 12 belong to the *Ceratolithus primus* Zone with assemblages including *Ceratolithus primus, Discoaster quinqueramus,* and *D. surculus*. Core 13 is assigned to the *Discoaster berggrenii* Zone based on the presence of *Discoaster berggrenii, D. quinqueramus,* and *D. surculus.* Core 14 recovered good *Discoaster bellus* Zone assemblages including *Discoaster neohamatus* and *D. bellus.* Core 15 belongs to the middle Miocene *Discoaster hamatus* Zone with *Discoaster hamatus, D. neohamatus,* and *D. calcaris* as the most important species. Core 16 lacks calcareous nannofossils, and Core 17 is already in the lowermost part of middle Miocene, the *Sphenolithus heteromorphus* Zone, with *Sphenolithus heteromorphus* and *Discoaster exilis*. Lower Miocene was recovered in Cores 18 and 19. The upper part of Core 18 contains *Sphenolithus belemnos* and *S. heteromorphus* and is probably best assigned to the *Helicopontosphaera ampliaperta* Zone although the marker is absent. The lower part of Core 18 and Core 19 contain *Discoaster druggi* and *Triquetrorhabdulus carinatus* and therefore belong to the *Discoaster druggii* Zone. The Oligocene/Miocene boundary, based on nannofossils, is drawn between Cores 19 and 20. Core 20 yields assemblages typical of the *Reticulofenestra abisecta* Zone with *Triquetrorhabdulus carinatus* and *Reticulofenestra abisecta*. Core 21 recovered the *Sphenolithus ciperoensis* Zone with *Sphenolithus ciperoensis, Triquetrorhabdulus carinatus,* and

Reticulofenestra bisecta. Core 22 and the upper part of Core 23 belong to the *Sphenolithus distentus* Zone with common *Sphenolithus distentus*, rare *S. ciperoensis* and *Reticulofenestra abisecta* and, in the lower part, with rare *Braarudosphaera bigelowii.* Cores 23 and 24 are assigned to the early Oligocene *Sphenolithus predistentus* Zone with assemblages including *Sphenolithus predistentus, S. distentus* and *Sphenolithus pseudoradians.* Core 25 contains *Reticulofenestra umbilica, Discoaster nodifer, Helicopontosphaera reticulata, Sphenolithus predistentus* and *Braarudosphaera bigelowii,* together with some reworked Eocene discoasters. It belongs to the *Helicopontosphaera reticulata* Zone. Cores 26 and 27 recovered the *Ericsonia subdisticha* Zone with assemblages including *Cyclococcolithina formosa, Reticulofenestra umbilica, Ericsonia subdisticha,* and *Braarudosphaera bigelowii.* The Eocene/Oligocene boundary, based on nannofossils, lies between Cores 27 and 28. Core 28 yields assemblages typical of the late Eocene *Discoaster barbadiensis* Zone with *Discoaster saipanensis, D. barbadiensis,* and *Reticulofenestra reticulata.* Core 29 belongs to the *Discoaster sublodoensis* Zone and contains an assemblage including *Discoaster sublodoensis, D. lodoensis,* and *Discoaster kuepperi.* Most of the middle Eocene seems to be missing, and we have to assume the presence of an unconformity between Cores 28 and 29. Cores 30 and 31 recovered the *Discoaster lodoensis* Zone with *Discoaster lodoensis, Coccolithus crassus,* and *Chiasmolithus consuetus.* Parts of the lower Eocene are also missing because Core 32 belongs to the late Paleocene *Discoaster multiradiatus* with poor assemblages including *Discoaster multiradiatus* Zone and *D. nobilis.* The Paleocene/Eocene boundary is marked by an unconformity and lies between Cores 31 and 32. Core 33 recovered the *Discoaster mohleri* Zone with *Discoaster mohleri, Sphenolithus anarrhopus, Fasciculithus tympaniformis,* and *Chiasmolithus danicus.*

Preservation: The Quaternary assemblages are slightly etched and the Pliocene to upper middle Miocene assemblages show slight etching and overgrowth. Below a barren interval, the lower middle and upper lower Miocene assemblages are moderately etched. The assemblages from the lower part of the lower Miocene, the Oligocene, and the middle and upper Eocene are slightly etched and show moderate overgrowths. Some layers in the lower Eocene contain nannofossils which are considerably altered by overgrowths and only discoasters are preserved. Other parts of the lower Eocene and the upper Paleocene are characterized by assemblages with slight etching and moderate overgrowths.

Foraminifera

Abundance and Preservation

Planktonic foraminifera are the dominant component of the coarse sediment fraction ($>63\mu$) at Site 236. Their state of preservation throughout the section is poor to moderate with a significant degree of fragmentation. In Core 1 (lithologic Unit 1), planktonic foraminifera are poorly preserved, whereas siliceous components (radiolarians and sponge spicules) are well preserved. In Cores 2 to 15 (base of Unit 1 and Unit 2), foraminiferal preservation varies depending on the lithologic horizon. The fine-grained nanno ooze contains planktonic foraminifera which are more poorly preserved than those found in the coarse-grained foraminiferal ooze layers. The latter may be derived from transported sediment; this suggestion is supported by the occurrence of a few transported shallow-water foraminifera in some of the coarse layers. The age of the planktonic foraminifera in the coarse layers is essentially the same as that of the associated nanno oozes. However, the evidence of some reworking of older sediments was observed in several horizons.

In Cores 15 to 21 (Unit 3 and the upper part of Unit 4) the fine-grained ooze and chalk contained only a small coarse fraction, which is composed of very small foraminifera. Fish teeth are rare to common in this interval. In Cores 22 to 28 (lower part of Unit 4 and uppermost part of Unit 5), the coarse residue is dominated by siliceous biogenic components and the foraminiferal species of minute size.

Below Core 26 (Units 5 and 6), sediments are indurated and difficult to disaggregate, and the coarse fractions yielded common chert debris. In Cores 29 to 33 the coarse fraction is composed of common recrystallized calcareous debris, rare chert fragments, and common to abundant foraminifera of normal size, which are partly recrystallized.

Planktonic Foraminiferal Zonation

Core 1 to Core 3, Section 1 are Quaternary in age, as indicated by the occurrence of *Globorotalia truncatulinoides.* The evolutionary transition of *G. truncatulinoides* from *Globorotalia tosaensis*, which marks the N.22/N.21 zonal boundary, is not well represented at this site due to the rare occurrence of *G. truncatulinoides.* This species is common only in Core 2, Section 1. The rare presence, however, of *G. truncatulinoides* in Core 3, Section 1 is the lowest observed occurrence of the species, and the zonal boundary N.22/N.21 is placed at this level. This determination is supported by the occurrence of *Globigerinoides quadrilobatus fistulosus* in the same horizon.

The base of Zone N.21, as defined by the lowest occurrence of *G. tosaensis*, lies in Core 5, Section 1. The lowest occurrence of *Neogloboquadrina dutertrei* and the lowest common occurrence of *Globigerina rubescens,* both noted in Core 5, Section 1, support this assignment; however, *Globoquadrina altispira altispira*, normally found in the lower part of Zones N.21 and N.20-N.19, occurs as high as Core 3, Section 2. It is possible that this species is here reworked into younger sediments. The highest occurrence of *Globorotalia margaritae*, which normally lies within Zone N.20/N.19, is found in Core 5, Section 1 at the same level as the lowest occurrence of *G. tosaensis*, which delineates the base of Zone N.21. This co-occurrence may result from reworking or may reflect condensing of the Pliocene sequence. The base of Zone N.19 cannot be conclusively determined because the index species *Sphaeroidinella dehiscens* first appears in Core 5, Section 1 at the same level as the base of *G. tosaensis*. The N.19/N.18 zonal limit is tentatively drawn at the highest occurrence of *Globorotalia tumida plesiotumida* in Core 5, Section 6. The base of Zone N.18, the lowermost Pliocene zone, lies in Core 6, Section 2, as indicated by the lowest occurrence of *Globorotalia tumida tumida.*

The zonal boundary N.17/N.16, based on the initial appearance of *G. tumida plesiotumida*, lies in Core 10, Section 3. An apparent unconformity separating N.16 from lower N.13 occurs between Core 13, Section 6, and Core 15, Section 3. It is possible, however, that a condensing of zones N.15 and upper N.13 occurs in this interval which contains a mixed fauna.

Core 15, Section 3 to Core 16, Section 3 are assigned to the lower part of Zone N.13 as indicated by the co-occurrence of *Globorotalia fohsi* and *Sphaeroidinellopsis subdehiscens*. Core 17, which contains a poor planktonic fauna composed essentially of *Globoquadrina dehiscens* and *Globigerina druryi*, could not be dated with certainty but is tentatively assigned to Zone N.11. Core 18, which includes common *Catapsydrax stainforthi* and *Globorotalia peripheroronda*, is assigned to Zones N.7-N.6. Throughout the middle and lower Miocene, the foraminiferal fauna is poorly preserved, with low diversity and considerable fragmentation. Mixed faunas were often found, and several intervals yielded inadequate faunas for age determination.

The Oligocene/Miocene boundary lies between Core 18, Section 4 and Core 20, Section 3. Core 20, Section 3, which contains common *Globorotalia opima nana* and *Turborotalia siakensis*, is assigned to the lowermost part of Zone P.22. Cores 21 to 28 contain a minor fauna of minute planktonic tests, making species indentification and zonal assignment difficult. Cores 29 to 31, which contain common *Morozovella aragonensis* and *Acaranina soldadoensis*, are assigned to the early Eocene Zones P.8/P.7. Cores 32 and 33 yielded *Globanomalina pseudomenardii* and common *Morozovella velascoensis* and belong to the late Paleocene Zone P.4. Core 33, Section 3, 105-107 cm, just above basement which contain *Globanomalina pseudomenardii, Morozovella pusilla* s.l., *Subottina pseudobulloides* (without *Morozovella angulata*) belongs to the lower part of P.4 Zone and is 57-58 million years old. Middle Eocene Zones as well as lowermost Eocene and uppermost Paleocene zones are missing.

Benthic Foraminifera

Throughout the section, benthic foraminifera are rare. They constitute less than 1 percent of the total foraminiferal fauna and are indicative of deep water. Some evidence of downslope transport of shallow-water species (*Elphidium*) is found in several of the coarse foraminiferal ooze layers of Unit 2.

Radiolaria

Samples from 236-1-1 through 236-3-1 contain abundant well-preserved radiolarians; those from 236-3-3 through 236-4-5 contain radiolarians progressively fewer and more corroded; those from 236-5-1 through 236-7-6 contain no radiolarians; those from 236-8-1 through 236-14-2 contain rare to common, poorly to moderately well-preserved radiolarians, and those from 236-20-2 through 236-33-2 contain rare to abundant, poorly to well-preserved radiolarians. The following were examined and found to contain no radiolarians: 14-3, 109-112 cm; 15-1, 49-52 cm; 15-6, 28-32 cm; 15-6, 94-97 cm; 16-1, 58-60 cm; 16-6, 102-105 cm; 17-1, 59-62 cm; 17-6, 98-102 cm; 18-1, 45-50 cm; 18-6, 108-111 cm; 19-1, 88-93 cm; 19-3, 95-105 cm; and 33-3, 68-73 cm.

All of the radiolarian assemblages at this site include reworked older radiolarians – often in such high proportions as to obscure the autochthonous component. Therefore, the zonal assignments indicated are only tentative and approximate. The upper limit of the *Pterocanium prismatium* Zone appears to lie approximately between 236-2-1 and 236-3-1. Assemblages from 236-10-2 through 236-14-2 seem probably assignable to the *Ommatartus antepenultimus* Zone, and those from 236-20-2 through 236-33-2 are approximately in the *Theocyrtis tuberosa* Zone.

SEDIMENT ACCUMULATION RATE

Average accumulation rates of the sediments of Site 236 are shown as follows:

Series	Thickness (m)	Average Sedimentation Rate (m/m.y.)
Pleistocene	19	10.6
Pliocene	28.5	8.9
Upper Miocene	85.5	14.3
Middle Miocene	25.5	8.5
Lower Miocene	19.0	2.2
Upper Oligocene	32.5	4.3
Lower Oligocene	43.5	5.8
Upper Eocene	9.5	11.7
Middle Eocene	0	
	(missing; break in sedimentation)	
Lower Eocene	31.5	12.6
Upper Paleocene	10.6	5.3

During the late Neogene (middle Miocene through Pleistocene) accumulation rates averaged 11.3 m/m.y. The higher upper Miocene value of 14.3 m/m.y. is possibly due to the presence of coarse-grained foraminiferal layers intercalated with the nanno oozes.

The lower sedimentation rates of the Paleocene through lower Miocene, which average 3.3 m/m.y., coincide also with the occurrence of cherts and with extensive recrystallization of the nanno chalk fraction. Both diagenetic processes, origin of the chert and recrystallization of the chalks, result in a filling of primary pore space and an increase in bulk density. These changes require a diagenetic thinning of the sedimentary section unless the excess silica and $CaCO_3$ are derived entirely from outside sources, which is extremely unlikely. For example, an apparent decrease in sedimentation rate from 10 m/m.y. to 6 m/m.y. would be associated with diagenetic recrystallization and concomitant increase in bulk density from 1.5 g/ to 1.85 g/cm^3 (70% porosity decreasing on diagenesis to 50% porosity). These bulk density variations with depth are close to those measured from samples from this site.

PHYSICAL PROPERTIES

Bulk Density and Porosity

The bulk density and porosity of the ±140 meters of nanno ooze in Units 1 and 2 increases from 1.56 to 1.94 g/cm^3 and decreases from 68.3 to 45.5 percent, respectively. The higher density values within Unit 2 (20 to 140 m) are attributed to the abundance of foram ooze layers. The foram- and nanno-bearing clays and nanno ooze of Units 3 and 4 (140 to 214 m) have bulk densities ranging from 1.67 to 1.85 g/cm^3 and corresponding porosities of 61.7 to 50.9 percent (Figure 3).

Bulk densities of a chert and basaltic basement rocks were obtained by the GRAPE device on block samples approximately 1.5 cm × 1.5 cm × 2.5 cm. The bulk density of the chert sample from Unit 5 is 2.14 g/cm^3 measured in the vertical direction (long axis) and 2.06 g/cm^3 in the horizontal direction. A chloritized basalt sample near the top of Unit 6 (basaltic basement) has a bulk density of 2.47 g/cm^3 measured in the vertical direction. Six fresher basalt samples have bulk densities ranging from 2.77 to 2.83 g/cm^3 measured in the vertical direction and 2.74 to 2.86 g/cm^3 measured in the horizontal direction (see Table 3).

Sonic Velocity

The nanno ooze in Units 1 and 2 (0 to 140 m) is represented by an average velocity of 1.53 ±0.05 km/sec (Figure 3). Velocity fluctuations to higher values (1.69 km/sec) are indicative of the foram ooze layers in Unit 2. The foram- and nanno-bearing clays of Unit 3 (140 to 180 m) are defined by velocities near 1.54 km/sec. An increase in velocity from 1.56 to 1.72 km/sec near 200 meters defines the top of the consolidated nanno chalk in Unit 4. This higher velocity layer represents a potential reflector of seismic energy. The nanno chalk and chert sequence in Unit 5 and the clay-bearing nanno chalk of Unit 6 are characterized by vertical velocities ranging from 1.85 to 3.19 km/sec. The high velocity chert (3.19 km/sec) at approximately 256 meters also represents a potential reflector of seismic energy.

The major velocity change occurs at approximately 305 meters (Unit 7) where the acoustic basement of basalt was encountered. A chloritized basalt sample near the top of this layer has a velocity of 3.84 km/sec measured in the vertical direction. Six fresher basalt samples from Cores 34 through 37 (see Table 3) have sonic velocities ranging from 4.69 to 5.43 km/sec in the vertical direction and from 4.89 to 5.43 km/sec in the horizontal direction. The basaltic basement appears to have a general increase in velocity and a decrease in velocity anisotropism with depth (Figure 3 and Table 3).

A maximum one-way travel time for seismic energy propagating between the sediment/water interface and the basaltic basement can be calculated as follows:

Depth Interval (m)	Average Velocity (km/sec)	Travel Time (sec)
0-200	1.55	0.129
200-255	1.75	0.031
255-306	2.25	0.022
		0.182

Thus, maximum one-way travel time at Site 236 for the basement reflection should be 0.182 sec.

Acoustic Impedance

The acoustic impedance profile appears to mirror the bulk density trend from 18 to 214 meters by having a general increase from approximately 2.29 to 3.17 × 10^5 g/cm^2 sec. It is suggested that a reflection surface probably exists near the top of the nanno chalk layer (Unit 4) at about 200 meters, where the velocity increases from 1.56 to 1.72 km/sec. The calculated travel time for this reflector is 0.129 sec one-way or 0.258 sec two-way, which readily agrees with a reflection at about 0.25 sec two-way travel time from the seismic profiles (Figure 3).

A reflection surface is expected at about ±255 meters (the chert layers within Unit 5) where the acoustic impedance is approximately 6.8 × 10^5 g/cm^2 sec. The calculated travel time for this potential reflector is 0.16 sec one-way or 0.32 sec two-way. No corresponding reflection is apparent on the seismic profiles. This could be explained if the chert layers in place are of small thickness. It would then be doubtful that a reflection would be observed from these horizons in recordings made with normal seismic frequency bandwidths.

The dominant reflector is represented by the basaltic basement in Unit 7, which has an average vertical velocity of 5.00 km/sec and a bulk density of approximately 2.80 g/cm^3. Thus, the acoustic impedance is about 14 × 10^5 g/cm^2 sec. The previously calculated travel time for the basement reflection (0.182 sec one-way or 0.364 sec two-way travel time) agrees with the ±0.35 sec two-way travel time for the acoustic basement determined from the seismic reflection profiles (Figure 3).

INTERSTITIAL WATER CHEMISTRY

Data on the interstitial pore water salinity, *p*H, and alkalinity are given in Table 4. Water content, porosity, and bulk chemistry data are given in Table 5.

Salinity: Surface seawater at this site has a salinity of 36.0°/oo compared with a published bottom water value of 34.7°/oo (Wyrtki, 1971). Pore water salinities show little variation with depth; a value of 36.0 ±0.5°/oo brackets all but a single measurement at 293 meters (Figure 4). Major losses or additions of ions during diagenesis of these pore waters is unlikely to have occurred in the light of these data.

***p*H and Alkalinity**: *p*H values are near constant with depth; (7.5 ±0.3); one measurement, at 93 meters, is rather low and is suspect. Pore water alkalinities are close to twice the seawater value, and show little variation down to 243 meters; below this depth, alkalinities decrease to values less than that of seawater.

Water Content, Porosity, and Bulk Density: The weight percent water values are rather variable, perhaps because of the disturbed nature of many of the cores; values average 45-55 percent in the upper part of the cored section and decrease to 20-30 percent near the base. Porosity values are in the range 75-85 percent near the top, and fall to 60-70 percent near the base of the cored section. Bulk density increases irregularly with depth from about 1.7 g/cm^3 near the surface to about 1.7 g/cm^3 at the base of the section.

CORRELATION OF REFLECTION PROFILES AND LITHOLOGIES

Correlation of these seismic and lithologic sections is rather good. Basalt is the acoustic basement material, while the nanno ooze-chalk-chert sequences appear logical candidates for the semicontinuous reverberative sequence

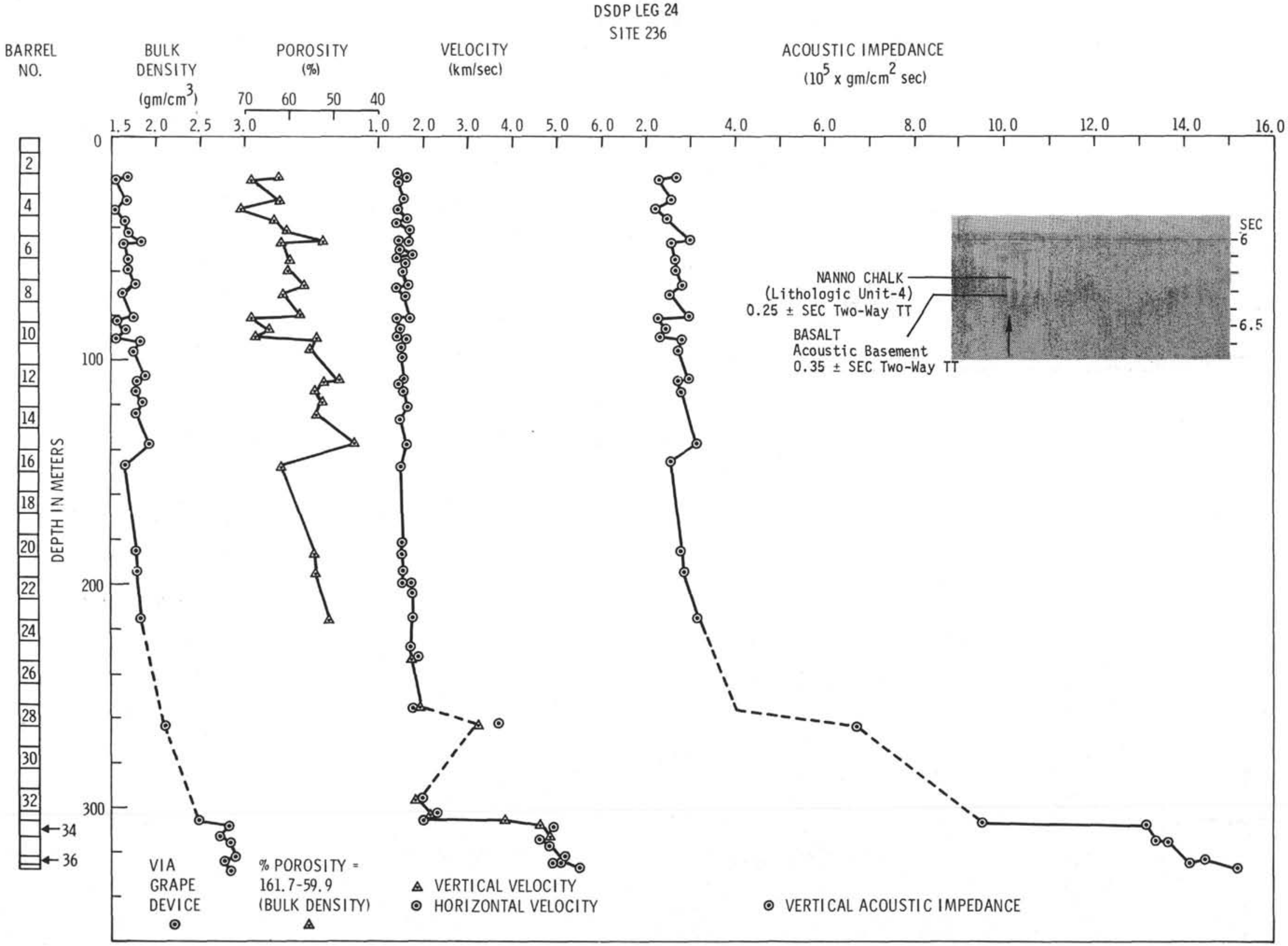


Figure 3. *Physical properties, Site 236.*

TABLE 3
Bulk Density of Basalt – Site 236

	Bulk Density (g/cm^3)		Velocity (km/sec)		
Sample[a]	Vertical	Horizontal	Vertical	Horizontal	Rock Description
28, CC	2.14	2.06	3.19	3.68	Chert
33-3A (4)	2.47		3.84		Chloritized basalt
34-2 (11)	2.81	2.81	4.69	4.89	Basalt
35-1 (1)	2.77	2.74	4.84	4.61	Basalt
35-2 (8)	2.78	2.82	4.84	4.79	Basalt
36-1 (2)	2.83	2.86	5.09	5.08	Basalt
36-2 (7)	2.80	2.80	5.04	4.95	Basalt
37-1 (15)	2.81	2.80	5.43	5.43	Basalt (enriched pyroxene)

[a]Numbers in parentheses are the sequence of the specific rock sample in the section.

TABLE 4
Interstitial Pore Water Chemistry – Site 236

Depth Below Sea Floor (m)	Salinity (°/oo)	*p*H	Alkalinity (meq/kg)
Surface seawater	36.0	8.27	2.37
7	35.8	7.50	4.54
32	35.8	7.72	3.89
48	35.5	7.53	3.34
70	36.0	7.43	4.23
93	35.8	6.54	4.80
124	35.8	7.41	5.15
156	35.5	7.17	4.94
184	36.0	7.23	4.94
210	35.5	7.39	3.79
243	35.8	7.31	4.52
264	36.3	7.64	2.02
293	36.8	7.53	1.15
304	36.3	7.37	0.86

TABLE 5
Water Content, Porosity, and Bulk Density of Sediments – Site 236

Core, Section, Top of Interval (cm)	Water (%)	Porosity (%)	Density (g/cm^3)
2-1, 98	45.07	74.76	1.6589
2-1, 106	58.22	85.67	1.4714
3-1, 46	54.65	81.86	1.4978
3-1, 55	55.44	82.63	1.4904
3-2, 70	43.14		
3-2, 83	40.65	69.55	1.7109
3-2, 126	49.12	77.23	1.5722
4-1, 140	50.50	79.18	1.5679
4-2, 118	31.57	58.76	1.8612
4-3, 122	52.04	80.60	1.5488
4-3, 135	22.63	40.89	1.8068
4-4, 56	48.85	79.38	1.6249
4-4, 106	54.18	82.60	1.5245
5-1, 96	36.96		
5-1, 129	48.91	78.61	1.6072
5-2, 83	44.99	74.60	1.6581
5-3, 41	35.38		
5-3, 69	28.14		
5-6, 90	40.91		
5-6, 130	48.79	77.00	1.5781
6-1, 30	34.35	61.86	1.8008
6-1, 58	34.32		
6-2, 66	31.59		
6-2, 120	35.86		
6-3, 80	49.18	78.34	1.5929
6-5, 24	32.41		
6-5, 120	24.03		
7-1, 105	38.90		
7-3, 46	36.26		
7-5, 52	47.79	74.68	1.56
7-6, 74	48.38	75.86	1.56
8-3, 30	34.35		
8-3, 53	48.27	77.81	1.61
8-4, 40	34.45		
8-5, 80	46.04	73.81	1.6
8-5, 131	38.85		
8-6, 68	33.54	60.65	1.8
8-6, 122	37.99	65.73	1.73
9-5, 16	43.95		
9-5, 30	50.28	78.65	1.56
10-3, 48	46.38	77.25	1.66
10-4, 44	34.22	61.50	1.7
10-4, 97	34.58	61.13	1.7
10-4, 118	48.04	77.71	1.61
10-4, 125	31.29	57.65	1.8

seen at varying intervals above it. It is tempting to attempt correlation of the apparently well-defined reflections in the remainder of the section with the diverse lithology of the nanno ooze and nanno clay. However, closer scrutiny shows the source pulse structure obscuring any details (Figure 5).

The hummocky or hilly character of the basement results in some reasonable doubt as to our exact location on it. We probably drilled a slightly deeper basement location, or on a slope, a reasonable assumption in view of the observed structure. Correlation of the reverberant reflection above basement with a lithologic unit is also made difficult by the variations of the reflector. Vertical velocity values suggest it is related to the nanno ooze to chalk of Unit 4 and/or to the nanno chalk with chert (Unit 5). It is fairly obvious that this will in turn depend upon the position of the chalk or chert surfaces in the sedimentary section.

SUMMARY, CONCLUSIONS, AND SPECULATIONS

Hole 236 (01°40.6′S, 57°38.9′E) was drilled in the sedimented outermost foothills southwest of Carlsberg Ridge and about 270 km northeast of Seychelles Bank, It is on, or near, the oldest sector of an ancient magnetic

TABLE 5 – *Continued*

Core, Section, Top of Interval (cm)	Water (%)	Porosity (%)	Density (g/cm3)
7-2, 133	35.39	65.09	1.8
8-2, 136	32.61		
11-1, 54	34.91		
11-2, 42	33.95		
12-4, 72	30.30		
12-5, 100	30.77	57.34	1.86
12-5, 132	34.58	64.23	1.85
12-6, 41	32.57		
12-6, 92	43.62	73.34	1.69
13-2, 96	37.13		
13-2, 126	32.24	59.44	1.8436
13-6, 128	36.57		
13-6, 137	44.55	72.60	1.6296
14-3, 76	32.51	62.42	1.9200
15-5, 135	29.96		
15-6, 120	41.63	72.05	1.7307
16-5, 126	39.14	66.84	1.7077
20-3, 32	38.08		
20-3, 59	32.71		
20-3, 140	39.84		
20-4, 26	37.69		
20-4, 115	32.77		
20-5, 50	34.51		
20-5, 88	33.66		
20-5, 120	32.05		
21-5, 102	34.65		
21-6, 83	34.41		
22-2, 38	30.99		
22-3, 110	30.92		
22-3, 135	35.86		
22-4, 92	29.04		
23-5, 13	44.40		
23-6, 132	27.63		
25-2, 73	38.11	64.76	1.6992
25-5, 103	32.64		
26-2, 49	24.34		
26-5, 12	25.24		
27-2, 131	24.21		
28-1, 68	19.03		
32-3, 136	24.07		
33-1, 80	19.41		
33-3, 117	23.24		

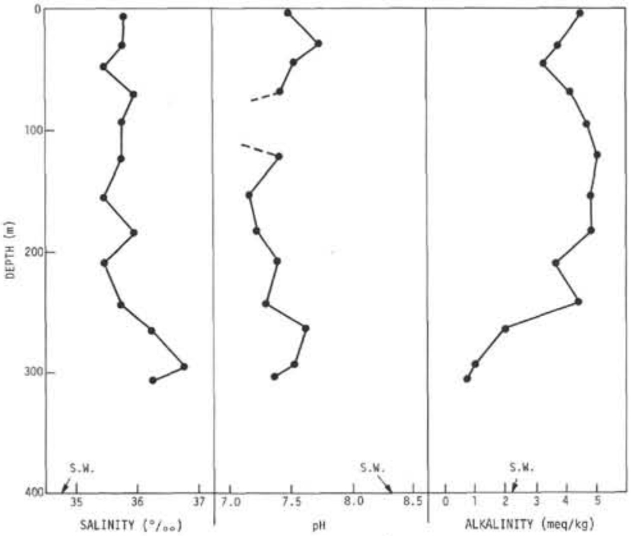


Figure 4. *Interstitial pore water salinity,* p*H and alkalinity.*

anomaly pattern associated with Carlsberg Ridge or a proto-Carlsberg Ridge. Water depth at the site was 4487 meters (corrected). The hole, a single penetration, was cored continuously from seafloor to basement, which here is a chloritized veined basalt. Penetration was 327.5 meters, as was the total length of cored section, with a total core recovery of 218.5 meters. The age of the oldest sediment immediately overlying basement is late Paleocene, perhaps 57-58 m.y.

Six sedimentary lithologic units were distinguished (Table 2); all are of pelagic origin, typical of a low-latitude, open-oceanic environment. In the upper half of the section, to about 180.5 meters near the Miocene-Oligocene boundary, foraminiferal and radiolarian ooze layers are intercalated into the nanno oozes that are the common sediment type at this site. The lower half of the section, to upper Paleocene, is dominantly pure nanno chalks or nanno oozes. Small quantities of clay, and occasionally quartz, of terrigenous origin occur throughout the section, particularly in lower Miocene strata; thin volcanic ash layers, mainly colorless glass, are found in the nanno chalk unit of Eocene age. The clayey nanno chalks that overlie basement basalt, possibly conformably, are higher in clay minerals and iron oxides. Iron gives the oxidized lower section a dusky brown to orange pink color, and pyrite is found in fissures; such occurrences suggest weak, post-eruptive, hydrothermal activity.

The sediment section continuously cored at Site 236 (Figure 1) ranges from Quaternary to late Paleocene with substantial hiatuses in the Eocene and late Paleocene. Condensed sections occur during early Miocene and Pliocene. Calcareous plankton is common throughout the section. For the first four lithologic units (from the present back through Oligocene time), nannofossils are well preserved while planktonic foraminifers show significant degrees of solution. In the Eocene and upper Paleocene sediments, nannofossils and foraminifers show considerable alteration and are recrystallized. Occurrence and preservation of radiolarians varies from common and well preserved to absent or fragmented.

Average accumulation rates increase from 3.3 m/m.y. for the interval late Paleocene through early Miocene to 11.3 m/m.y. for the interval middle Miocene to Pleistocene. This increase is not alone a function of lesser compaction of the more recent sediments but also reflects the presence of foraminifera and SiO_2 fossils in quantity in the later strata.

Basement was penetrated to a depth of 21.5 meters, with 11.0 meters of core recovered. The upper portion of the column is common olivine-bearing tholeiitic basalt. The lower unit, almost the entire section, consists of melanobasalts of sub-alkali type enriched in clinopyroxene, in this case augite. In these sub-alkali basalts, plagioclase has been replaced in large part by analcite. The sequence indicates an early clinopyroxene-rich phase that required a considerable depth of magma chamber and quiet tectonic conditions being supplanted by tholeiites having a lower melting temperature.

Bulk density and sonic velocity increase, and porosity decreases, irregularly with depth into the sediment column. Density and porosity curves mirror one another throughout the nanno chalk-ooze sequence. Sonic velocities (P_V) remain

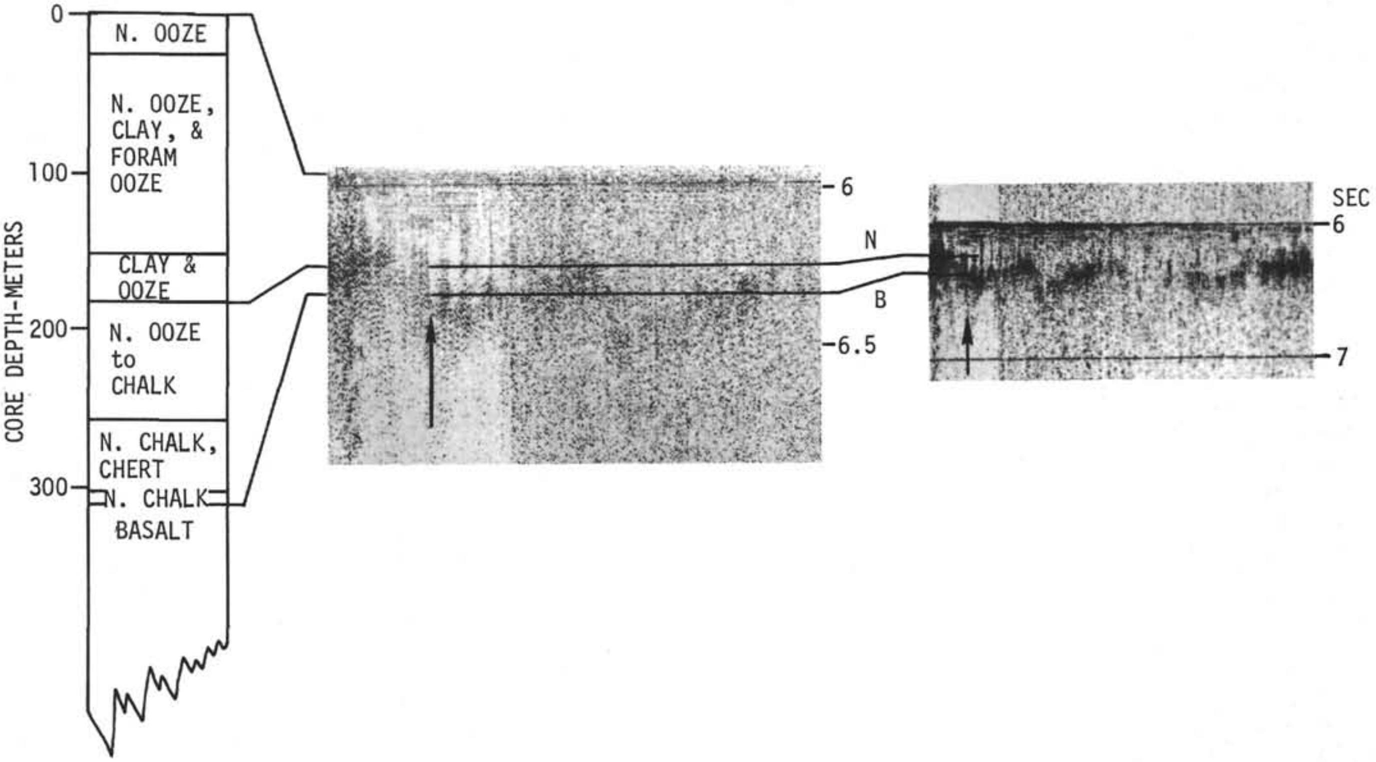


Figure 5. *Generalized lithology and seismic section, Site 236.* N, B *reflections correlated with nanno ooze-chalk-chert sequence and basalt, respectively.*

rather constant (1.55 ± km/sec) to the top of the Oligocene nanno chalk; sporadic chert occurrences in the lower layers yield velocities up to 3.2 km/sec. The major velocity change occurs as basalt is encountered; basement velocities range from 4.6 to 5.4 km/sec. The dominant reflector in the section is the basaltic basement, which has an acoustic impedance about four times that of the overlying sediment layer.

Correlation of the seismic and lithologic sections is rather good; basalt, with a high acoustic impedance, is the acoustic basement and the Oligocene nanno chalk or Eocene nanno chalk-chert sequence is the intermittent reflecting horizon above basement.

With respect to aims for this hole, the objectives were met admirably as indicated below and speculations are hardly in order.

1) A deepwater low-latitude pelagic fossil sequence was collected; it extends from Quaternary back through upper Paleocene time, at which level basement was encountered.

2) True basement was reached and sampled to some depth, and the sediment-basement contact was recovered. A compositional change from pyroxene-rich melano-basalt to tholeiites at this very early site—in terms of ridge development and compared with other rock dredged nearer the ridge axis—suggests that in the earliest stages, the ridge basalts were produced by deeper, higher-temperature sources.

3) The oldest recognizable magnetic anomaly northeast of Seychelles Bank, taken at about number 28 in the standard scale of magnetic "dendrochronology," appears to be of about Paleocene age rather than Cretaceous. Some reexamination of profiles is indicated, but these data suggest that India and the Seychelles-Mascarene Plateau (?) region may have been sundered—if at all—rather later than currently held.

REFERENCES

Fisher, R. L., Engel, C. G., and Hilde, T. W. C., 1968. Basalt dredged from the Amirante Ridge, western Indian Ocean: Deep-Sea Res., v. 15, p. 521-534.

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 SITE 236

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

At Site 236, igneous rock, the acoustic basement and believed to be top of the true igneous crust, was encountered at a depth below the mudline of 306 meters, underlying discolored upper Paleocene nanno chalk. Penetration into basement was continued for another 21.5

meters, and 11.0 meters of basalt, of two varieties, was recovered. Details of layering, brecciation, structure, and fracture orientation are indicated on the visual core description.

Megascopic Description

The upper part of the igneous section (236-33-3A) contains massive dark gray, slightly porphyritic, and lightly altered basalt with several glassy seams. Unfortunately, the contact between this basalt and the overlying nanno chalk was destroyed in drilling. Greenish-gray, slightly porphyritic basalts occur at intervals to the bottom of the hole, but in general, color changes to gray with increasing depth.

The upper part of the volcanic section (236-34-1, -2) is varied. It contains basaltic breccia fragments 5-10 cm in size and glassy components cemented by only slightly metamorphosed carbonate sediment containing well-preserved foraminifera and Radiolaria. Similar zones occur, too, at 320 meters and 324 meters, and these contain abundant chlorite as cement.

Preliminary Petrographic Description

At least 12 igneous or contact specimens were thin sectioned aboard ship, and the basalts can be separated into two groups by their petrographic characteristics. One, present in minor amount as the upper part of the section (236-33A), is common olivine-tholeiitic basalt, similar to that of Site 235. The second group, the main part of the basement recovered here, consists of melano-basalts enriched by clinopyroxene, specifically augite.

Olivine-tholeiitic basalts–These rocks display some porphyritic texture with phenocrysts of plagioclase, augite, and olivine, the latter completely replaced by serpentine, chlorite, and carbonates.

Plagioclase–Phenocrysts occur as short prismatic twinned crystals, 1-2 mm in length; maximum extinction angle of 30°-35° $\perp 010$ indicates plagioclase here is labradorite, An_{55-60}. It is the major component in phenocrysts in this basalt, by a 3:1 ratio over clinopyroxene, while olivine, as pseudomorphs, exists as isolated aggregates.

Augite–Short prismatic crystals, averaging about 0.5 mm, show extinction $c \wedge Z \approx 50°$.

The groundmass consists of needly microlites of fibrous or radial labradorite, about 0.3-0.4 mm in length, and interstitial augite (Figure 6), with plagioclase making up 60-70 percent. Palagonitized or chloritized glass comprises 10-15 percent of the remainder.

Sub-alkali basalts–The second, and principal, group of basalts in the igneous basement section at Site 236 is characterized by an abundance of augite, particularly in the groundmass of these porphyritic basalts.

Plagioclase–Labradorite, An_{50-55}, occurs as long (0.5-1.5 mm) prismatic crystals, occasionally somewhat zoned; extinction angle in the zone $\perp 010$ is 30°-35°.

Augite–Short prismatic grains of augite, of similar size to the plagioclase, have an extinction $c \wedge Z$ = 50°-55°. The ratio of plagioclase to augite phenocrysts varies from 1:1 to 1:1.5, and both minerals form simple accretions (Figure 7).

Figure 6. *Texture of the olivine-tholeiitic basalt groundmass: 236-33-3A, no. 4 (without analyzer).*

Figure 7. *Accretions of plagioclase (1), and pyroxene (2) as phenocrysts: 236-35-1, no. 1 (without analyzer).*

Olivine—Small regular single crystals of olivine are generally replaced by aggregates of serpentine, chlorite, and carbonate.

In the groundmass, pyroxene predominates, ranging from 50 to 80 percent, and glass comprises no more than 10-15 percent. In specimens where augite composes 80 percent of the groundmass, analcite has replaced plagioclase (Figure 8). The texture of the groundmass in these melano-basalts is markedly different from that of the olivine-tholeiites: pyroxene microlites form smaller needles than do the plagioclase microlites, and they make spherolitic accretions. The development of this texture is shown in Figure 9a, b, c.

Conclusions From This Preliminary Examination and Description

The basement at Site 236 displays the products of crystal differentiation of a low-alkali basaltic magma unusually high in silica. In the igneous series here displayed, the early stages, with higher temperature of crystallization, are represented by the sub-alkali analcite-bearing basalts rich in pyroxene. The latter, lower melting temperature products are deposited in the upper part of the section; these consist of the olivine-tholeiitic basalts with less pyroxene. The occurrence, overall, suggests a great depth for magma generation and relatively stable or tranquil conditions permitting differentiation.

As at Site 235, specimens were analyzed and examined for co-variation of C_p and characteristics of mineralogy and mineral ratios, both in groundmass and phenocrysts. Those results, by Dmitriev and Paul Cernock, will be reported elsewhere.

Figure 8. *Replacement of plagioclase by analcite in phenocrysts: 236-37-1, no. 15 (without analyzer).*

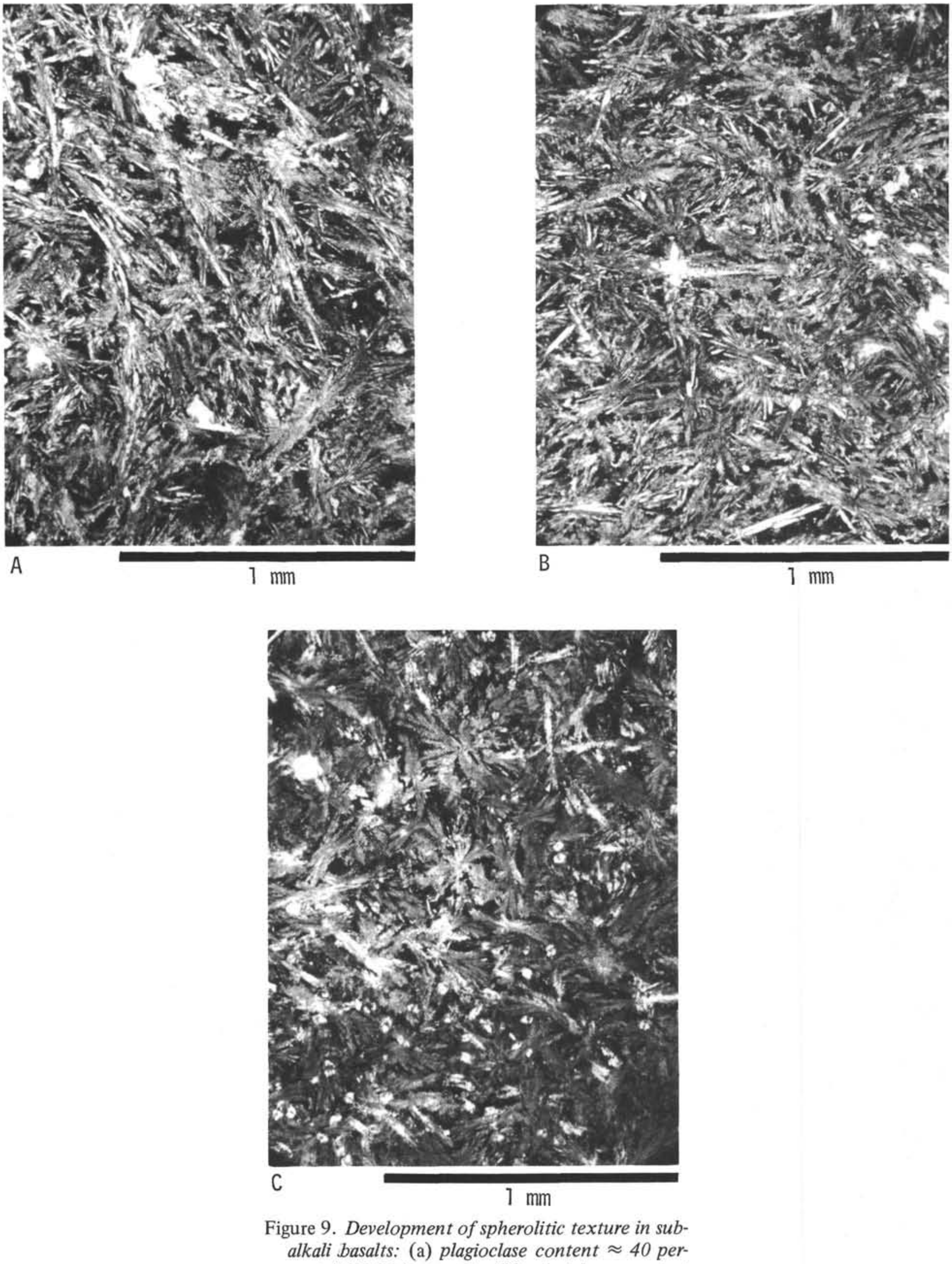
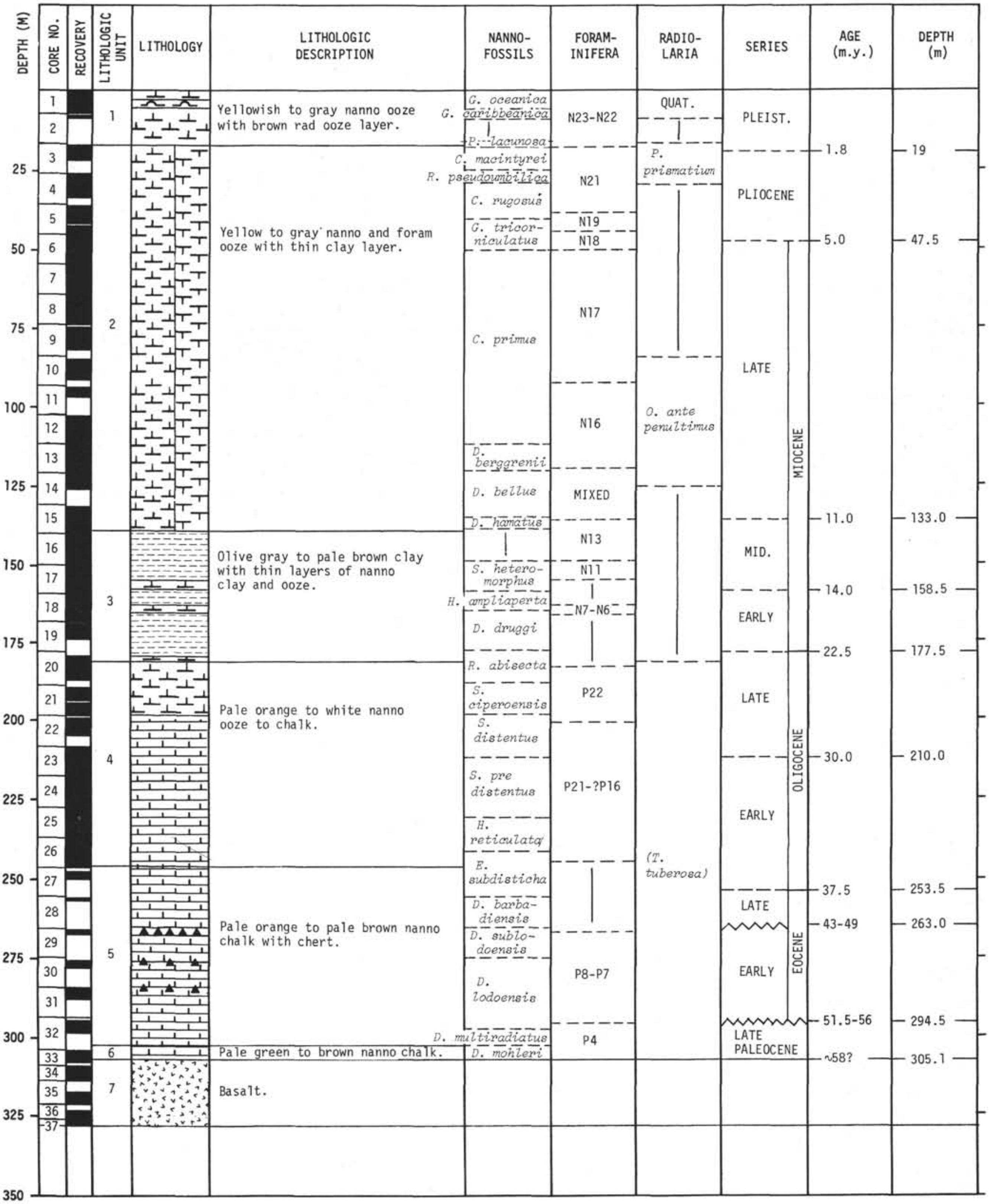
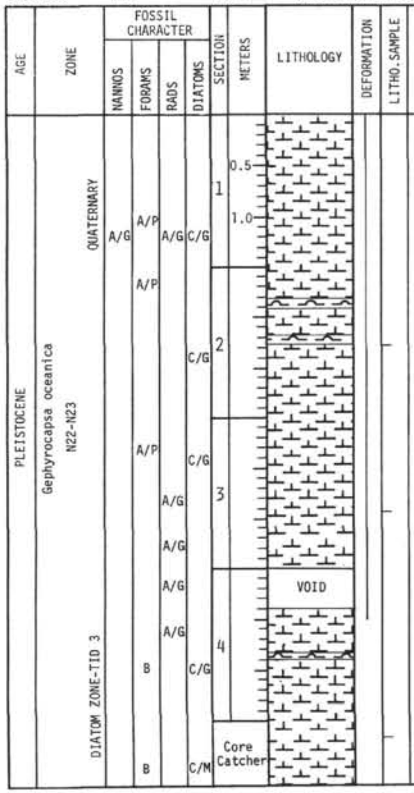


Figure 9. *Development of spherolitic texture in subalkali basalts:* (a) *plagioclase content ≈ 40 percent (236-36-2, no. 7)*; (b) *plagiolcase content ≈ 25 percent (236-35-2, no. 8)*; (c) *plagioclase content ≈ 10 percent (236-37-1, no. 15) (all without analyzer).*


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
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
1
2
3
4
5
6
7
Yellowish to gray nanno ooze with brown rad ooze layer.
Yellow to gray nanno and foram ooze with thin clay layer.
Olive gray to pale brown clay with thin layers of nanno clay and ooze.
Pale orange to white nanno ooze to chalk.
Pale orange to pale brown nanno chalk with chert.
Pale green to brown nanno chalk.
Basalt.
G. oceanica
G. caribbeanica
P. lacunosa
C. macintyrei
R. pseudoumbilica
C. rugosus
G. tricorniculatus
C. primus
D. berggrenii
D. bellus
D. hamatus
S. heteromorphus
H. ampliaperta
D. druggi
R. abisecta
S. ciperoensis
S. distentus
S. pre distentus
H. reticulata
E. subdisticha
D. barbadiensis
D. sublodoensis
D. lodoensis
D. multiradiatus
D. mohleri
N23-N22
N21
N19
N18
N17
N16
MIXED
N13
N11
N7-N6
P22
P21-?P16
P8-P7
P4
QUAT.
P. prismatium
O. ante penultimus
(T. tuberosa)
PLEIST.
PLIOCENE
LATE
MIOCENE
MID.
EARLY
LATE
OLIGOCENE
EARLY
LATE
EOCENE
EARLY
LATE PALEOCENE
1.8
5.0
11.0
14.0
22.5
30.0
37.5
43-49
51.5-56
~58?
19
47.5
133.0
158.5
177.5
210.0
253.5
263.0
294.5
305.1

Site 236 Hole Core 1 Cored Interval: 0.0-6.5 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Yellowish gray (5Y7/2). Sediment liquid to soupy.

with many thin layers of moderate brown (5YR4/4).
RAD OOZE

Smear 1-2-72 (Rad Ooze)

Sand	25%	Rads	60%	Quartz	2%
Silt	60%	Diatoms	20%		
Clay	15%	Forams	5%		
		Nannos	5%		
		Fish Debris	2%		

Smear 1-3-80

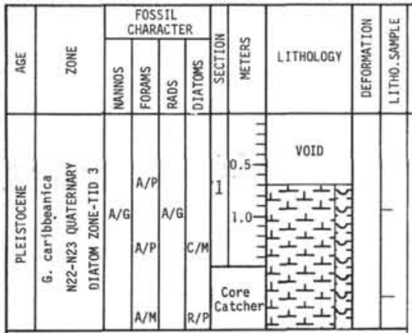
Sand	10%	Rads	50%	Quartz	2%
Silt	50%	Nannos	30%	Palagonite	1%
Clay	40%	Diatoms	15%		
		Forams	5%		
		Fish Debris	3%		

Smear 1-CC

Sand	5%	Nannos	80%	Quartz	2%
Silt	10%	Rads	10%	Feldspar	1%
Clay	85%	Forams	5%		
		Diatoms	3%		
		Fish Debris	1%		

Explanatory notes in chapter 1

Site 236 Hole Core 2 Cored Interval: 6.5-16.0 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Yellow gray (5Y7/2) changing to very light gray (N8) at 2-1-75, to moderate light gray (N6) at 2-1-90, to very light gray (N8) at 2-1-95, to moderate light gray (N6) at 2-1-100, to moderate dark gray (N4) at 2-1-110, to moderate light gray (N6) at 2-1-120, to very light gray (N8) at 2-1-125.

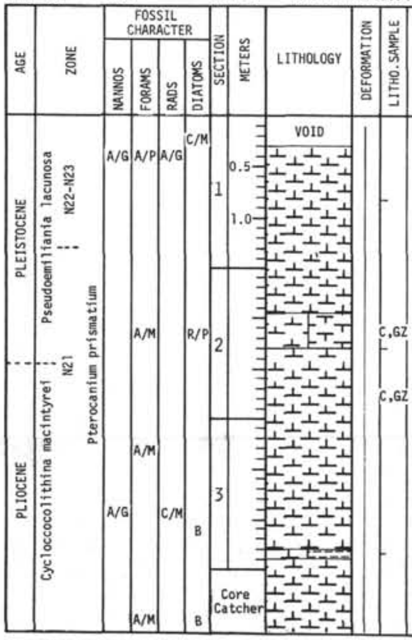
Smear 2-1-120

Sand	5%	Nannos	75%	Pyrite	1%
Silt	20%	Rads	15%		
Clay	75%	Forams	5%		
		Fish Debris	1%		

Smear 2-CC

Sand	5%	Nannos	75%	Quartz	1%
Silt	10%	Forams	10%	Palagonite	1%
Clay	85%	Rads	10%		
		Diatoms	1%		
		Fish Debris	1%		

Site 236 Hole Core 3 Cored Interval: 16.0-25.5 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Very light gray (N8) and moderate light gray (N6) hues changing frequently. Layers 5-30 cm thick. Sediment liquid to soupy.

Thin moderate orange pink (5YR8/4) horizons at 3-1-35, 3-1-130.

Smear 3-1-80 $CaCO_3$ 78%

Sand	5%	Nannos	90%
Silt	25%	Forams	8%
Clay	70%	Rads	2%

FORAM NANNO OOZE 3-2-45 to 80, grayish red purple (5RP4/2) horizon at the base.

Smear 3-2-77

Sand	30%	Nannos	50%	Quartz	1%
Silt	40%	Forams	40%		
Clay	30%	Fish Debris	2%		

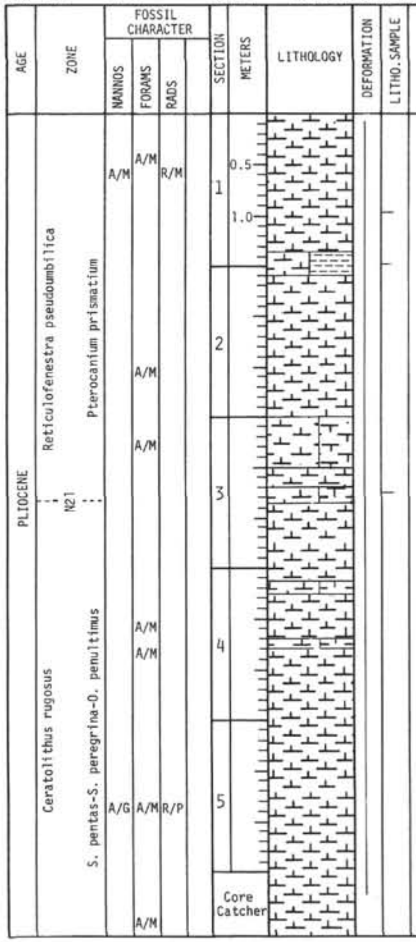
Grain Size	Sand	Silt	Clay
3-2-68 cm	68%	15%	20%
3-2-126 cm	8%	16%	76%

Smear 3-3-133 (bit of medium dark gray [N4] NANNO CLAY)

Sand	10%	Nannos	30%	Clay Min.	40%
Silt	20%	Forams	10%	Micarb	10%
Clay	70%	Rads	2%	Dolo. Rhombs	3%
		Fish Debris	2%	Quartz	1%

Explanatory notes in chapter 1

Site 236 Hole Core 4 Cored Interval: 25.5-35.0 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Grayish yellow green (5GY7/2) with thin sandy foram bearing layers.

Smear 4-1-90

Sand	5%	Nannos	90%	Quartz	1%
Silt	15%	Forams	5%		
Clay	80%	Fish Debris	1%		

Color change to dusky yellow green (5GY5/2) at 4-1-115.

NANNO CLAY dusky blue (5PB3/2) 4-1-135 to 4-2-10

Smear 4-1-145

Sand	5%	Nannos	50%	Clay Min.	35%
Silt	15%	Forams	10%	Quartz	2%
Clay	80%				

Color changing to dusky yellow green (5GY5/2) at 4-2-10 with very light gray (N8) horizons of

NANNO FORAM OOZE at 4-3-0 to 50, 4-3-70 to 85, 4-4-5 to 15, 4-4-70 to 80.

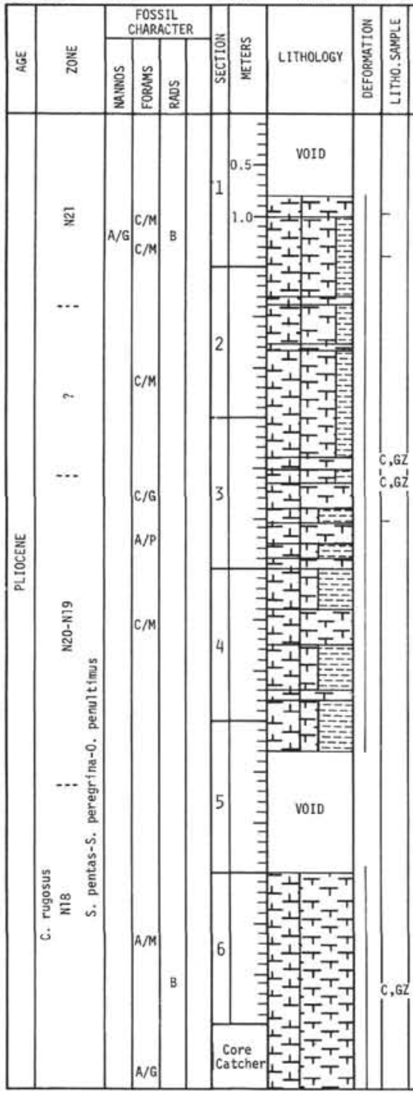
Smear 4-3-78 (grayish red purple [5RP5/2] base of horizon)

Sand	50%	Forams	60%	Quartz	2%
Silt	30%	Nannos	30%	Feldspar	1%
Clay	20%			Pyrite	1%

Very light gray (N8) 4-5-0 to 60.

Explanatory notes in chapter 1

Site 236 Hole Core 5 Cored Interval: 35.0-44.5 m



LITHOLOGIC DESCRIPTION

NANNO FORAM OOZE
Yellowish gray (5Y8/1) intercalated with dusky yellow green (5GY5/2) CLAY rich horizons.

Smear 5-1-95

Sand	50%	Forams	60%	Clay Min.	5%
Silt	30%	Nannos	30%	Quartz	1%
Clay	20%				

Smear 5-1-145 (Grayish purple [5P4/2] horizon)

Sand	20%	Forams	40%	Clay Min.	20%
Silt	40%	Nannos	30%	Micarb	5%
Clay	40%			Dolo. Rhombs	2%

NANNO FORAM OOZE horizons always pale red purple (5RP6/2) at their base.

$CaCO_3$ 41 cm 81%
71 cm 94%

Smear 5-3-100

Sand	10%	Nannos	40%	Clay Min.	40%
Silt	25%	Forams	10%	Pyrite	3%
Clay	65%	Fish Debris	1%		

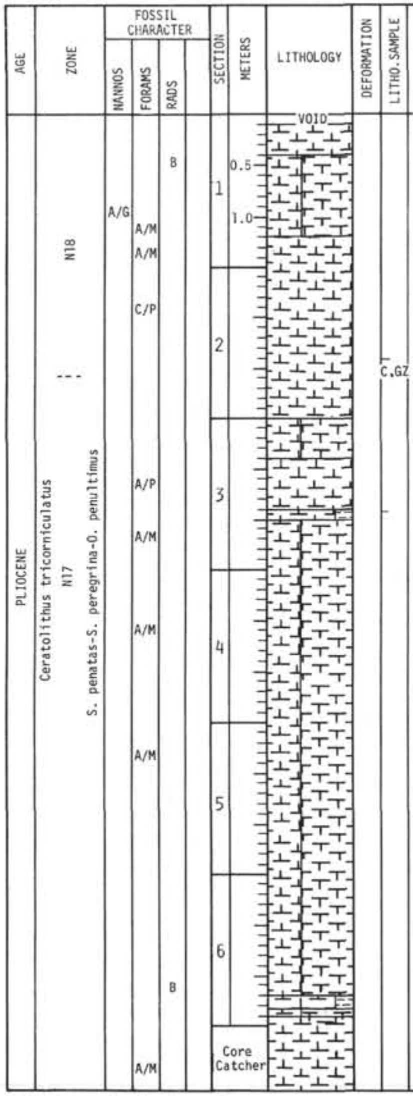
Grain Size	Sand	Silt	Clay
5-3-41 cm	20%	49%	31%
4-3-71 cm	85%	8%	8%

$CaCO_3$ 88%

Grain Size
Sand 49%
Silt 30%
Clay 21%

Explanatory notes in chapter 1

Site 236 Hole Core 6 Cored Interval: 44.5-54.0 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Grayish yellow green (5GY7/2)
NANNO FORAM OOZE
Grayish purple (5P4/2) at 6-1-40 to 70, below yellowish gray (5Y8/1). With intercalations of NANNO OOZE.

Many burrows.

Dusky yellow green (5GY5/2) to light greenish gray (5GY8/1) at 6-1-125 to 6-2-150.

$CaCO_3$ 55%

Smear 6-2-80

Sand	5%	Nannos	90%	Quartz	1%
Silt	10%	Forams	5%		
Clay	85%				

Dusky yellow green (5GY5/2) at 6-3-40 to 90, dark gray (N3) at 6-3-90 to 100.

Smear 6-3-90

Sand	5%	Nannos	60%	Clay Min.	25%
Silt	10%	Forams	5%	Micarb	2%
Clay	85%	Fish Debris	2%	Dolo. Rhombs	2%

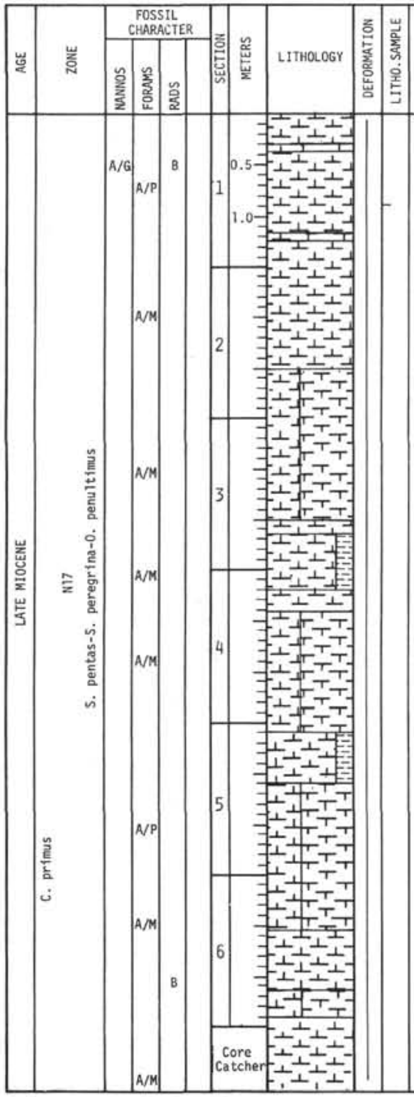
Grain Size

Sand	2%
Silt	32%
Clay	67%

Dusky yellow green (5GY5/2) at 6-6-80 to 100 and 6-6-140 to 6-cc, grayish olive green (5GY3/2) at 6-6-120 to 135.

Explanatory notes in chapter 1

Site 236 Hole Core 7 Cored Interval: 54.0-63.5 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Dusky yellow green (5GY5/2) with yellowish gray (5Y8/1) NANNO FORAM OOZE inclusions.

Smear 7-1-80

Sand	5%	Nannos	80%	Clay Min.	10%
Silt	10%			Quartz	2%
Clay	80%			Pyrite	2%

Frequent color changes at 7-2-70 to 105 from dark gray (N3) to very light gray (N8) to dusky yellow green (5GY5/2). Intensively layered.
NANNO FORAM OOZE
Yellowish gray (5Y8/1)

NANNO OOZE
Very light gray (N8) at 7-3-100 to 115, medium bluish gray (5B5/1) at 7-3-115 to 150 and medium dark gray (N4) at 7-4-0 to 20.
NANNO OOZE Very light gray (N8)
NANNO FORAM OOZE
Yellowish gray (5Y8/1)

NANNO OOZE Medium dark gray (N4)

NANNO FORAM OOZE
Yellowish gray (5Y8/1)

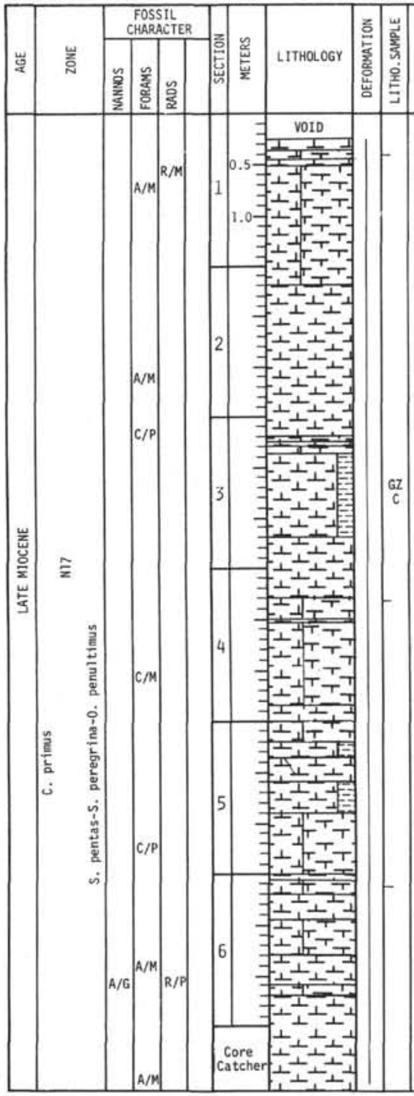
NANNO OOZE Dusky yellow green (5GY5/2) with burrows.

NANNO FORAM OOZE Very light gray (N8) grading to yellowish gray (5Y8/1).

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

Explanatory notes in chapter 1

Site 236 Hole Core 8 Cored Interval: 63.5-73.0 m



LITHOLOGIC DESCRIPTION

NANNO OOZE Dusky yellow green (5GY5/2) and
NANNO FORAM OOZE Yellowish gray (5Y8/1)
Smear 8-1-28
Sand 5% Nannos 90% Quartz 2%
Silt 10% Forams 5% Dolo. Rhombs 1%
Clay 85%

Many burrows.
Very light gray (N8) at 8-2-110 to 8-3-20.

Two thin horizons of pale purple (5P6/2) NANNO FORAM OOZE.

Greenish gray (5G6/1) at 8-3-33 to 120.

$CaCO_3$ 23%

Very light gray (N8) at 8-3-120 to 8-4-30.
Smear 8-4-35
Sand 30% Nannos 45% Micarb 10%
Silt 40% Forams 40% Quartz 2%
Clay 30%

Grain Size
Sand 1%
Silt 11%
Clay 88%

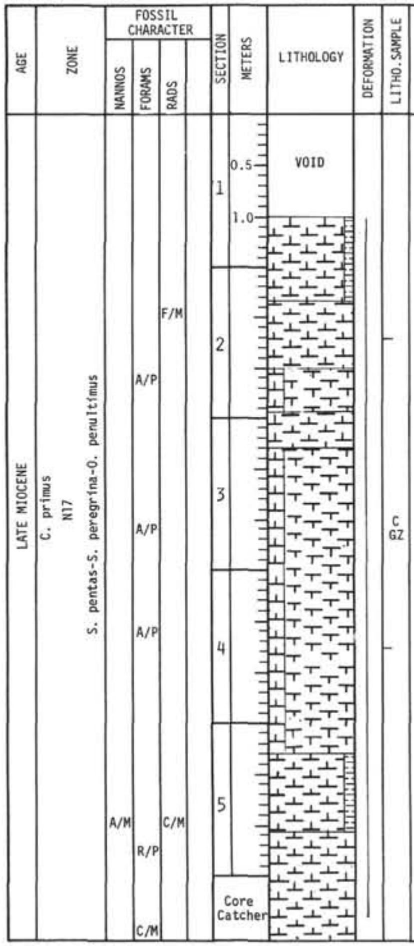
Very light gray (N8) at 8-5-35 to 60.

Pale red purple (5RP6/2) at 8-5-95 to 8-6-20.

Very light gray (N8) at 8-6-20 to 45 and 8-6-80 to 110, light greenish gray (5GY8/2) at 8-6-120 to 8-cc.
Smear 8-6-15
Sand 50% Forams 60%
Silt 30% Nannos 35%
Clay 20% Rads 3%

Explanatory notes in chapter 1

Site 236 Hole Core 9 Cored Interval: 73.0-82.5 m



LITHOLOGIC DESCRIPTION

Layers of
NANNO OOZE
with greenish gray (5G6/2), medium bluish gray (5B5/2) and very light gray (N8) hues,
and
NANNO RICH FORAM OOZE
Yellowish gray (5Y8/2)
Smear 9-2-70
Sand 5% Nannos 80% Quartz 2%
Silt 15% Forams 15% Volc. Glass 1%
Clay 80%

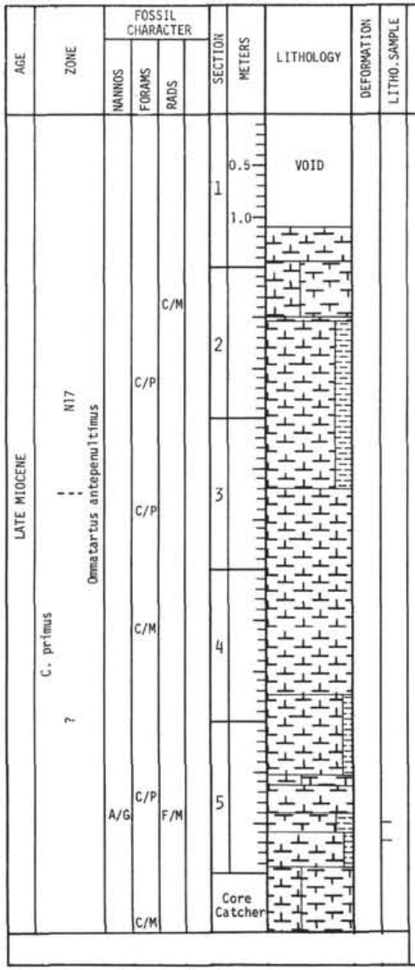
$CaCO_3$ 90%

Grain Size
Sand 44%
Silt 35%
Clay 21%

Smear 9-4-70
Sand 40% Forams 60% Micarb 10%
Silt 30% Nannos 20% Dolo. Rhombs 3%
Clay 30% Rads 5%
Fish Debris 2%

Explanatory notes in chapter 1

Site 236 Hole Core 10 Cored Interval: 82.5-92.0 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Greenish gray (5G6/2) to yellowish gray (5Y8/2) to very light gray (N8). Clay mineral bearing horizon dark to medium gray (N3 to N5) or dusky yellow green (5GY5/2).
NANNO FORAM OOZE
Yellow gray (5Y8/2).

Some burrowing.

Frequently layered and banded.

Smear 10-5-96

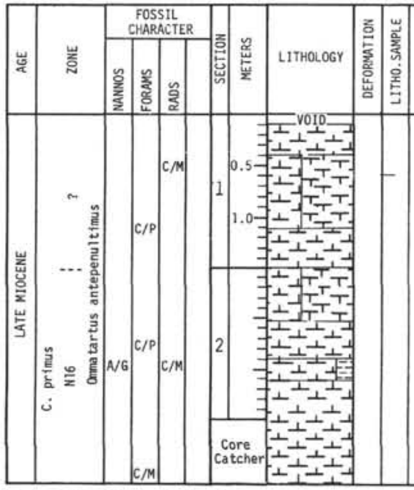
Sand 10%	Nannos 70%	Quartz 1%
Silt 30%	Forams 20%	
Clay 60%	Rads 5%	
	Fish Debris 1%	

Smear 10-5-116

Sand 10%	Nannos 80%	Pyrite 2%
Silt 30%	Forams 15%	
Clay 60%	Rads 2%	

Explanatory notes in chapter 1

Site 236 Hole Core 11 Cored Interval: 92.0-101.5 m



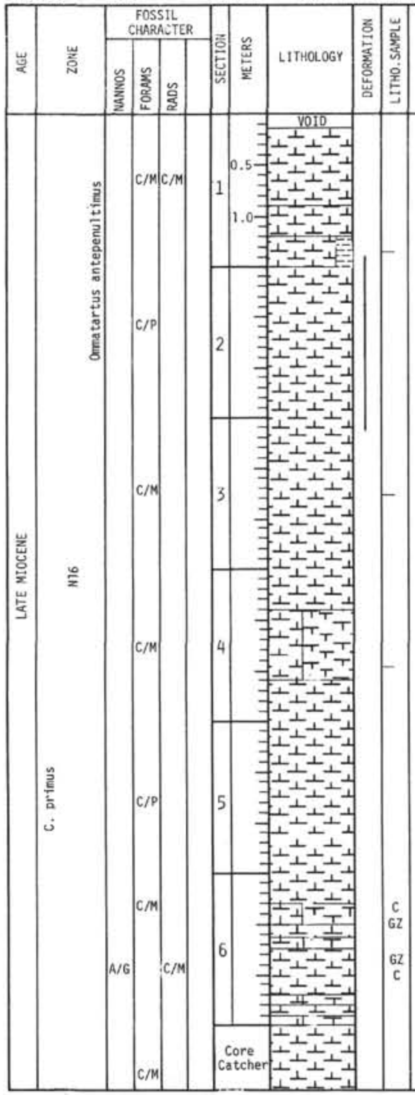
LITHOLOGIC DESCRIPTION

NANNO OOZE
Dusky yellow green (5GY5/2), very light gray (N8), clay mineral bearing to rich horizons dark gray (N3)
NANNO FORAM OOZE Yellowish gray (5Y8/1)
Smear 11-1-43 (Pale red purple [5RP6/2] horizon)

Sand 5%	Nannos 90%	Pyrite 1%
Silt 10%	Forams 5%	Dolo. Rhombs 1%
Clay 80%	Rads 2%	

Explanatory notes in chapter 1

Site 236 Hole Core 12 Cored Interval: 101.5-111.0 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Very light gray (N8), clay mineral bearing horizons dark gray (N3).
Dusky yellow green (5GY5/2) with burrows.

Smear 12-1-100

Sand 1%	Nannos	85%	Pyrite 2%
Silt 20%	Forams	5%	
Clay 80%	Rads	5%	
	Fish Debris	1%	

Intense deformed NANNO OOZE, dark gray (N3), dusky yellow green (5GY5/2) and very light gray (N8).

Very light gray (N8) with many dusky yellow green mottles (5GY5/2).

Smear 12-3-84

Sand	10%	Nannos	80%
Silt	20%	Forams	10-12%
Clay	70%	Rads	5%

FORAM NANNO OOZE Yellowish gray (5Y8/1)

Smear 12-4-90

Sand	20%	Nannos	65%	Volc. Glass 1%
Silt	30%	Forams	25%	
Clay	50%	Rads	10%	

NANNO OOZE
Dusky yellow green (5GY5/2) with very light gray (N8) horizon at 12-5-20 to 115.

FORAM NANNO OOZE horizons
Yellowish gray (5Y8/1).

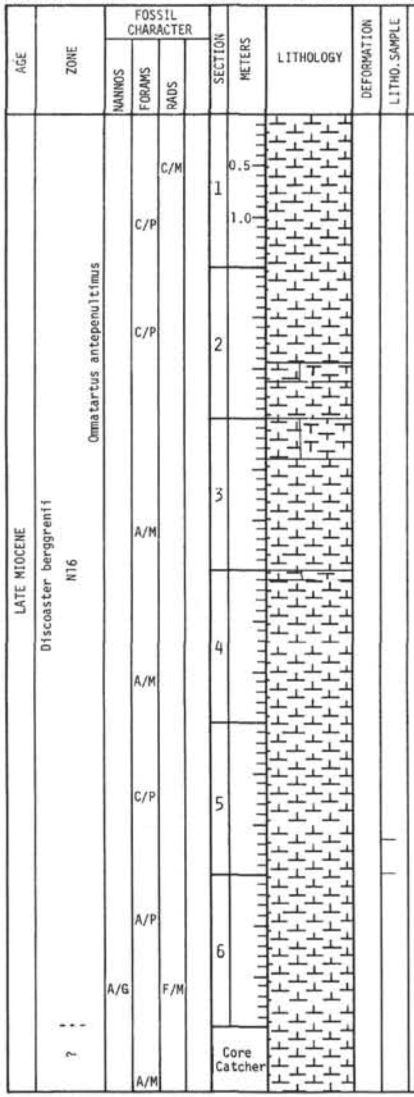
$CaCO_3$ 92%

$CaCO_3$ 35%

Grain Size	Sand	Silt	Clay
12-6-38 cm	55%	26%	20%
12-6-90 cm	0%	13%	87%

Explanatory notes in chapter 1

Site 236 Hole Core 13 Cored Interval: 111.0-120.5 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Very light gray (N8) with horizons of pale red purple (5RP6/2) at 13-1-30 to 65, dusky yellow green (5GY5/2) at 13-1-65 to 75, 13-2-0 to 95, 13-3-40 to 80, 13-4-7 to 30, 13-4-120 to 150.

FORAM NANNO OOZE 13-2-95 to 108
Greenish gray (5GY6/2).

FORAM NANNO OOZE 13-3-0 to 40
Yellowish gray (5Y8/1).

Color grading to pale red purple (5RP6/2) with dusky yellow green (5GY5/2) horizons at 13-6-60 to 125 and 13-6-130 to 13-cc.

Smear 13-5-130

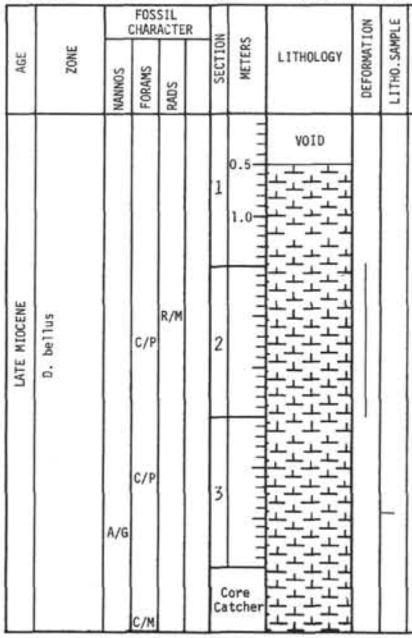
Sand	20%	Nannos	70%	Clay Min. 3%
Silt	30%	Forams	15%	
Clay	50%	Rads	10%	

Smear 13-5-140

Sand	15%	Nannos	60%	Pyrite 10%
Silt	30%	Forams	15%	
Clay	55%	Rads	10%	
		Fish Debris	1%	

Explanatory notes in chapter 1

Site 236 Hole Core 14 Cored Interval: 120.5-130.0 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Dusky yellow green (5GY5/2) with dark gray (N3) and very light gray (N8) mottles.

Intensively deformed, grayish yellow green (5GY7/2), very light gray (N8) and pale red purple (5RP6/2).

Grayish yellow green (5GY7/2) with burrows.

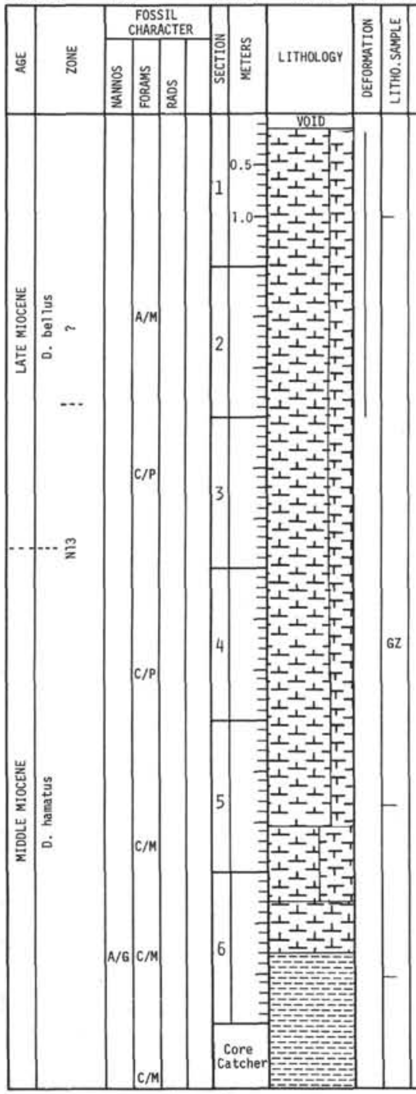
Smear 14-3-92

Sand	5%	Nannos	90%	Feldspar	1%
Silt	10%	Forams	5%		
Clay	85%	Fish Debris	1%		

Dusky yellow green (5GY7/2).

Explanatory notes in chapter 1

Site 236 Hole Core 15 Cored Interval: 130-139.5 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Grayish yellow green (5GY7/2).

Smear 15-1-90

Sand	5%	Nannos	90%	Volc. Glass	1%
Silt	10%	Forams	5%	Fe-oxid.	1%
Clay	85%	Fish Debris	1%		

Dusky yellow green (5GY5/2) horizon at 15-3-20 to 15-4-150 with mottles.

$CaCO_3$ 41%

Grain Size 15-4-94

Sand	0%
Silt	23%
Clay	77%

Smear 15-5-90

Sand	2%	Nannos	90%
Silt	15%	Forams	5%
Clay	85%	Rads	1%

FORAM NANNO OOZE Yellowish gray (5Y8/1)
Smear 15-6-14

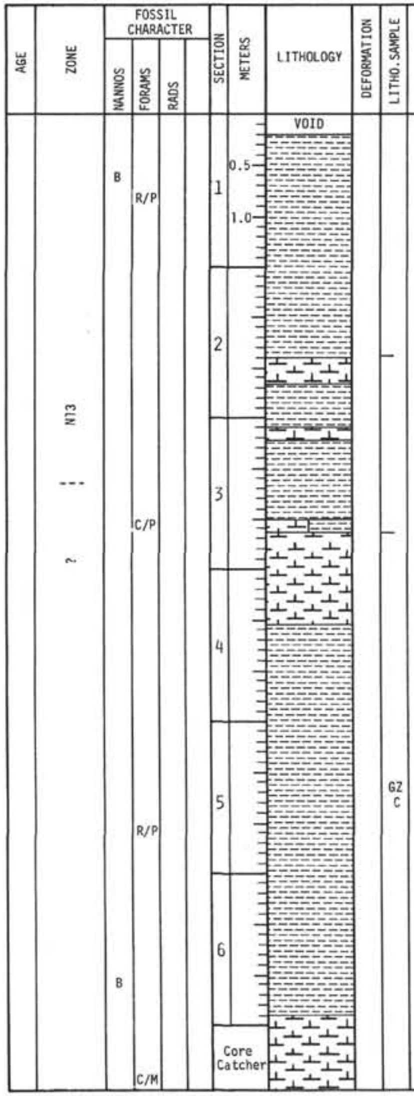
Sand	20%	Nannos	70%	Volc. Glass	1%
Silt	30%	Forams	25%		
Clay	50%	Rads	2%		
		Fish Debris	1%		

NANNO OOZE Dusky yellow green (5GY5/2)
CLAY Light olive gray (5Y6/2)
Smear 15-6-102

Sand	5%	Forams	5%	Clay Min.	80%
Silt	10%	Nannos	5%	Fe-oxides	5%
Clay	85%	Fish Debris	2%	Quartz	3%

Explanatory notes in chapter 1

Site 236 Hole Core 16 Cored Interval: 139.5-149.0 m



LITHOLOGIC DESCRIPTION

CLAY
Light olive gray (5Y6/1).

Smear 16-2-80

Sand	2%	Forams	5%	Clay Min.	80%
Silt	10%	Nannos	5%	Fe-oxides	2%
Clay	88%	Fish Debris	2%	Volc. Glass	1%
				Dolo. Rhombs	1%

Dusky yellow green (5GY5/2) NANNO OOZE horizons at 16-2-90 to 115, 16-3-10 to 20.

Smear 16-3-110

Sand	5%	Nannos	50%	Clay Min.	30%
Silt	10%	Forams	10%	Quartz	2%
Clay	85%	Fish Debris	1%	Fe-oxides	1%
				Dolo. Rhombs	1%

NANNO OOZE
Dusky yellow green (5GY5/2) grading to yellowish gray (5Y7/2).

CLAY
Light olive gray (5Y6/2).

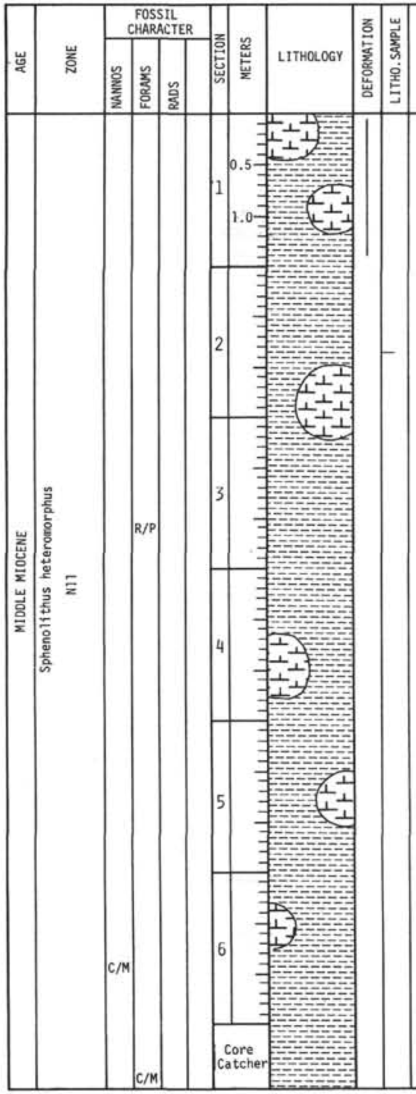
$CaCO_3$ 0%

Grain Size
Sand 0%
Silt 4%
Clay 96%

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

Explanatory notes in chapter 1

Site 236 Hole Core 17 Cored Interval: 149.0-158.5 m



LITHOLOGIC DESCRIPTION

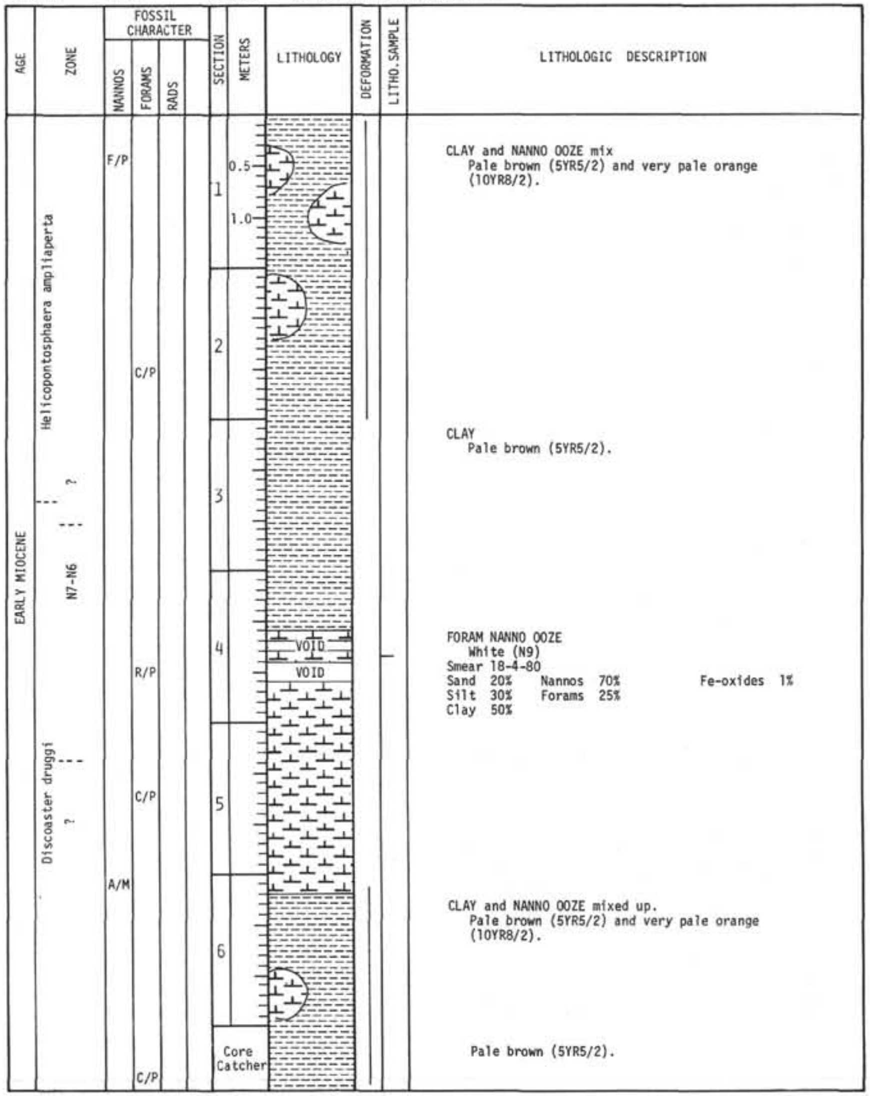
CLAY and NANNO OOZE mix
Pale brown (5YR5/2) and very pale orange (10YR8/2).

Smear 17-2-80

Sand	5%	Nannos	65%	Clay Min.	20%
Silt	10%	Forams	5%	Fe-oxides	3%
Clay	85%	Fish Debris	1%	Quartz	1%
				Dolo. Rhombs	1%

Explanatory notes in chapter 1

Site 236 Hole Core 18 Cored Interval: 158.5-168.0 m



CLAY and NANNO OOZE mix
Pale brown (5YR5/2) and very pale orange (10YR8/2).

CLAY
Pale brown (5YR5/2).

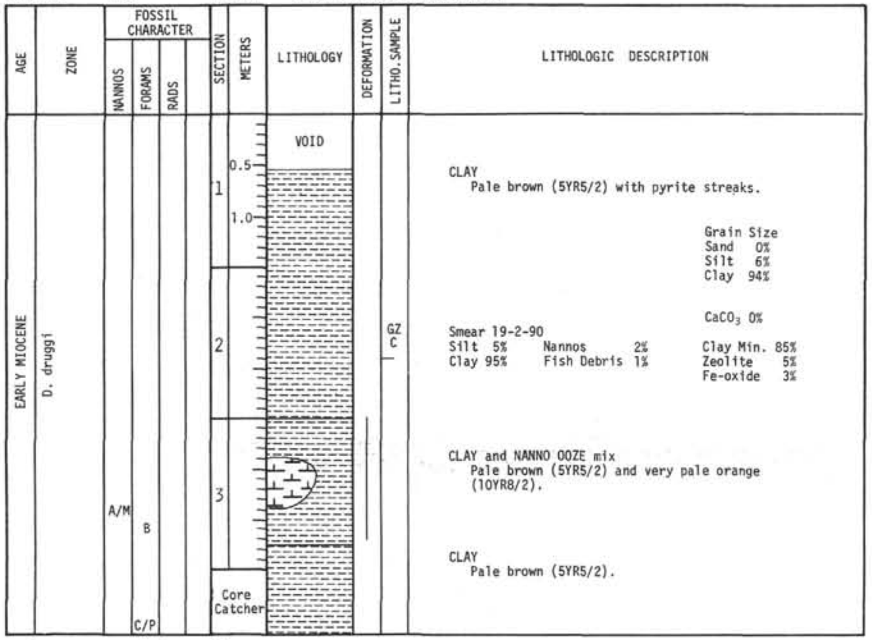
FORAM NANNO OOZE
White (N9)
Smear 18-4-80
Sand 20% Nannos 70% Fe-oxides 1%
Silt 30% Forams 25%
Clay 50%

CLAY and NANNO OOZE mixed up.
Pale brown (5YR5/2) and very pale orange (10YR8/2).

Pale brown (5YR5/2).

Explanatory notes in chapter 1

Site 236 Hole Core 19 Cored Interval: 168.0-177.5 m



CLAY
Pale brown (5YR5/2) with pyrite streaks.

Grain Size
Sand 0%
Silt 6%
Clay 94%

$CaCO_3$ 0%

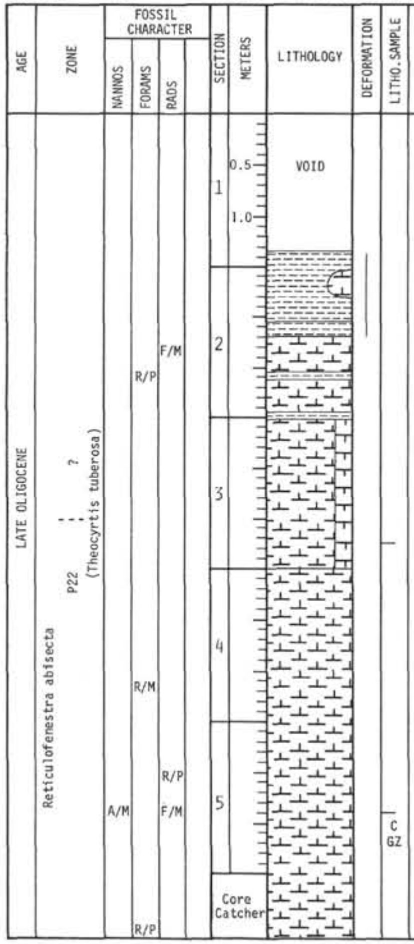
Smear 19-2-90
Silt 5% Nannos 2% Clay Min. 85%
Clay 95% Fish Debris 1% Zeolite 5%
Fe-oxide 3%

CLAY and NANNO OOZE mix
Pale brown (5YR5/2) and very pale orange (10YR8/2).

CLAY
Pale brown (5YR5/2).

Explanatory notes in chapter 1

Site 236 Hole Core 20 Cored Interval:177.5-187.0 m



LITHOLOGIC DESCRIPTION

NANNO OOZE
Very pale orange (10YR8/2) and
CLAY
Pale brown (5YR5/2).

Smear 20-3-120
Sand 30% Nannos 60% Volc. Glass 1%
Silt 20% Forams 25%
Clay 50% Rads 10%

Pinkish gray (5YR8/2) horizon at 20-3-20 to 40.

Pale greenish yellow (10YR8/2) horizon at 20-3-85 to 150.
White (N9) horizons at 20-4-0 to 20, 20-4-130 to 20-5-60.

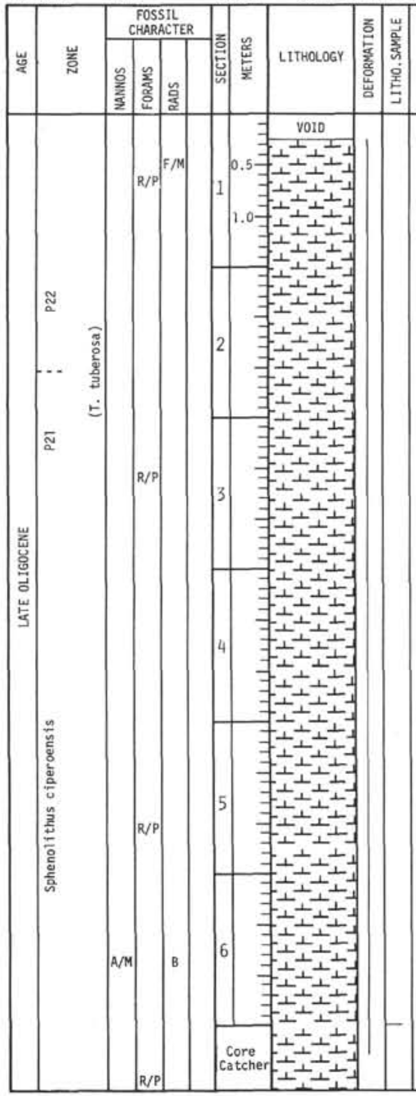
$CaCO_3$ 81%

Smear 20-5-80
Silt 10% Nannos 95% Fe-oxide 1%
Clay 90% Forams 3%

Grain Size
Sand 0%
Silt 44%
Clay 56%

Explanatory notes in chapter 1

Site 236 Hole Core 21 Cored Interval: 187.0-196.5 m



LITHOLOGIC DESCRIPTION

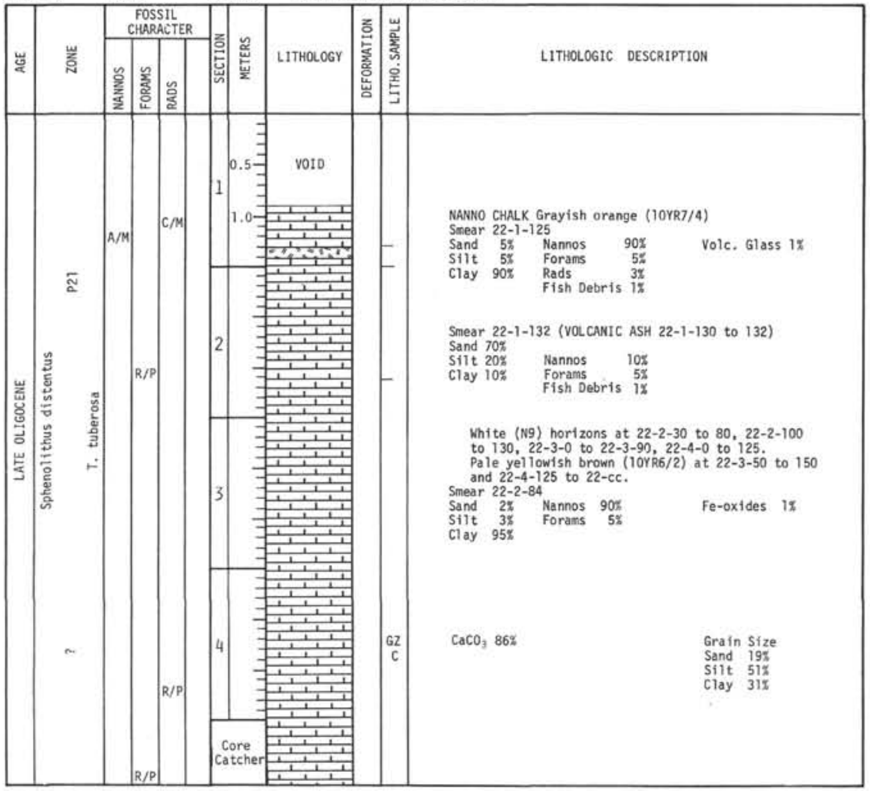
NANNO OOZE
Very orange pale (10YR8/2).

White (N9) horizons at 21-5-70 to 130, 21-6-45 to 135 and 21-6-140 to 21-cc.

Moderate yellowish brown (10YR5/4) horizon at 21-6-135 to 140.
Smear 21-6-140
Silt 15% Nannos 90% Fe-oxides 2%
Clay 85% Forams 5%

Explanatory notes in chapter 1

Site 236 Hole Core 22 Cored Interval: 196.5-206.0 m



NANNO CHALK Grayish orange (10YR7/4)
Smear 22-1-125

Sand	5%	Nannos	90%	Volc. Glass 1%
Silt	5%	Forams	5%	
Clay	90%	Rads	3%	
		Fish Debris	1%	

Smear 22-1-132 (VOLCANIC ASH 22-1-130 to 132)

Sand	70%		
Silt	20%	Nannos	10%
Clay	10%	Forams	5%
		Fish Debris	1%

White (N9) horizons at 22-2-30 to 80, 22-2-100 to 130, 22-3-0 to 22-3-90, 22-4-0 to 125. Pale yellowish brown (10YR6/2) at 22-3-50 to 150 and 22-4-125 to 22-cc.

Smear 22-2-84

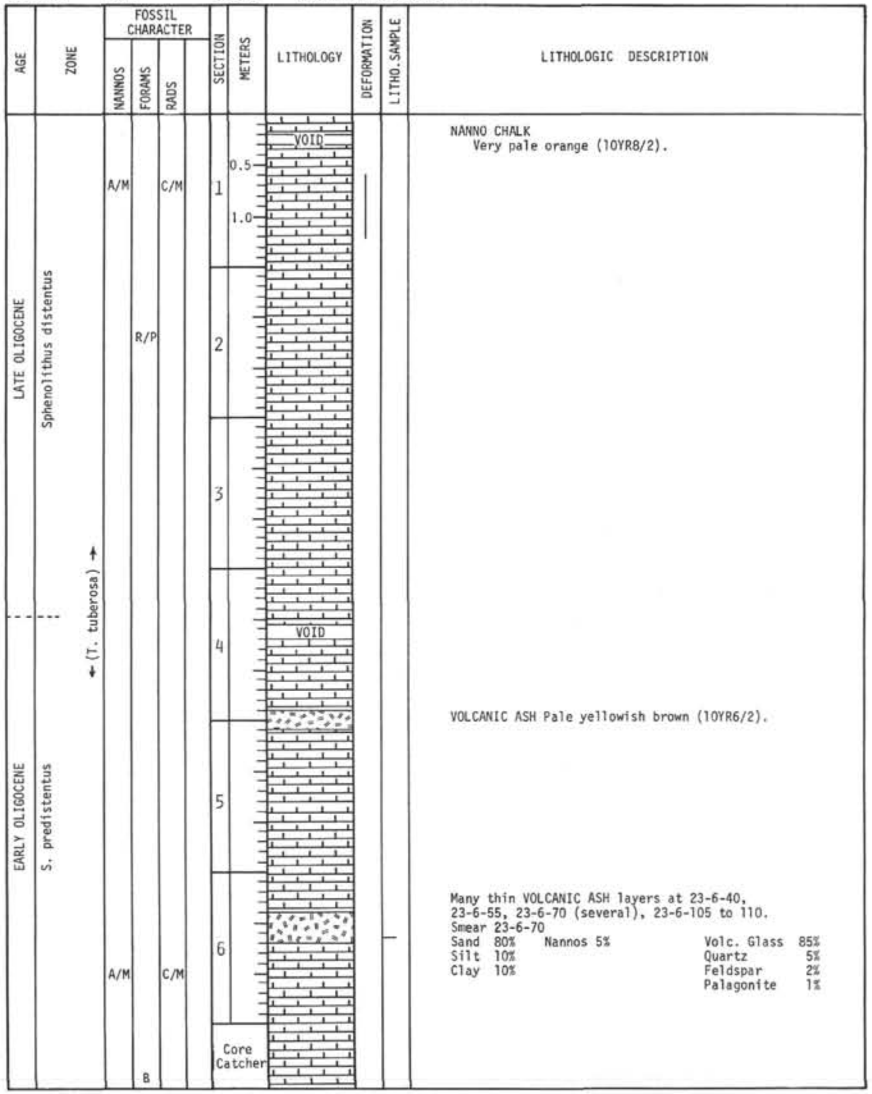
Sand	2%	Nannos	90%	Fe-oxides 1%
Silt	3%	Forams	5%	
Clay	95%			

$CaCO_3$ 86%

Grain Size
Sand 19%
Silt 51%
Clay 31%

Explanatory notes in chapter 1

Site 236 Hole Core 23 Cored Interval: 206-215.5 m



NANNO CHALK
Very pale orange (10YR8/2).

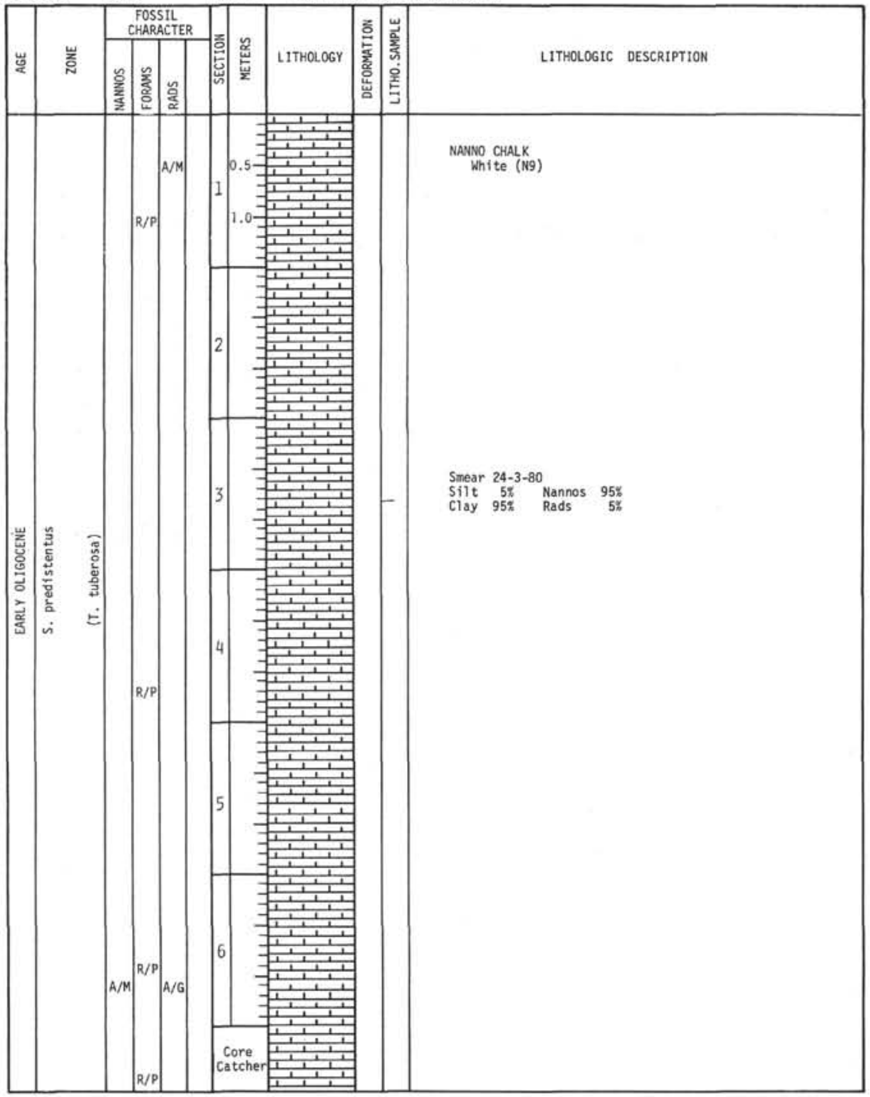
VOLCANIC ASH Pale yellowish brown (10YR6/2).

Many thin VOLCANIC ASH layers at 23-6-40, 23-6-55, 23-6-70 (several), 23-6-105 to 110.
Smear 23-6-70

Sand	80%	Nannos 5%		Volc. Glass	85%
Silt	10%			Quartz	5%
Clay	10%			Feldspar	2%
				Palagonite	1%

Explanatory notes in chapter 1

Site 236 Hole Core 24 Cored Interval:215.5-225.0 m

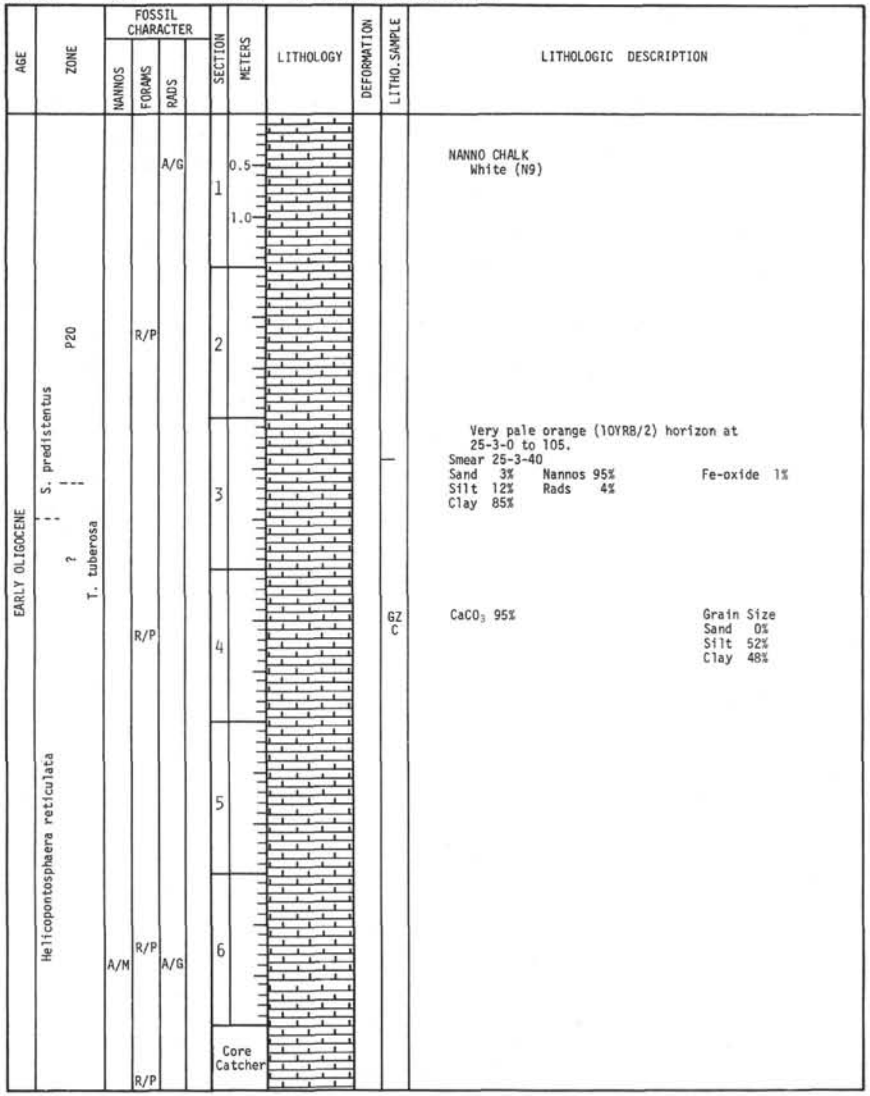


NANNO CHALK
White (N9)

Smear 24-3-80
Silt 5% Nannos 95%
Clay 95% Rads 5%

Explanatory notes in chapter 1

Site 236 Hole Core 25 Cored Interval:225.0-234.5 m



NANNO CHALK
White (N9)

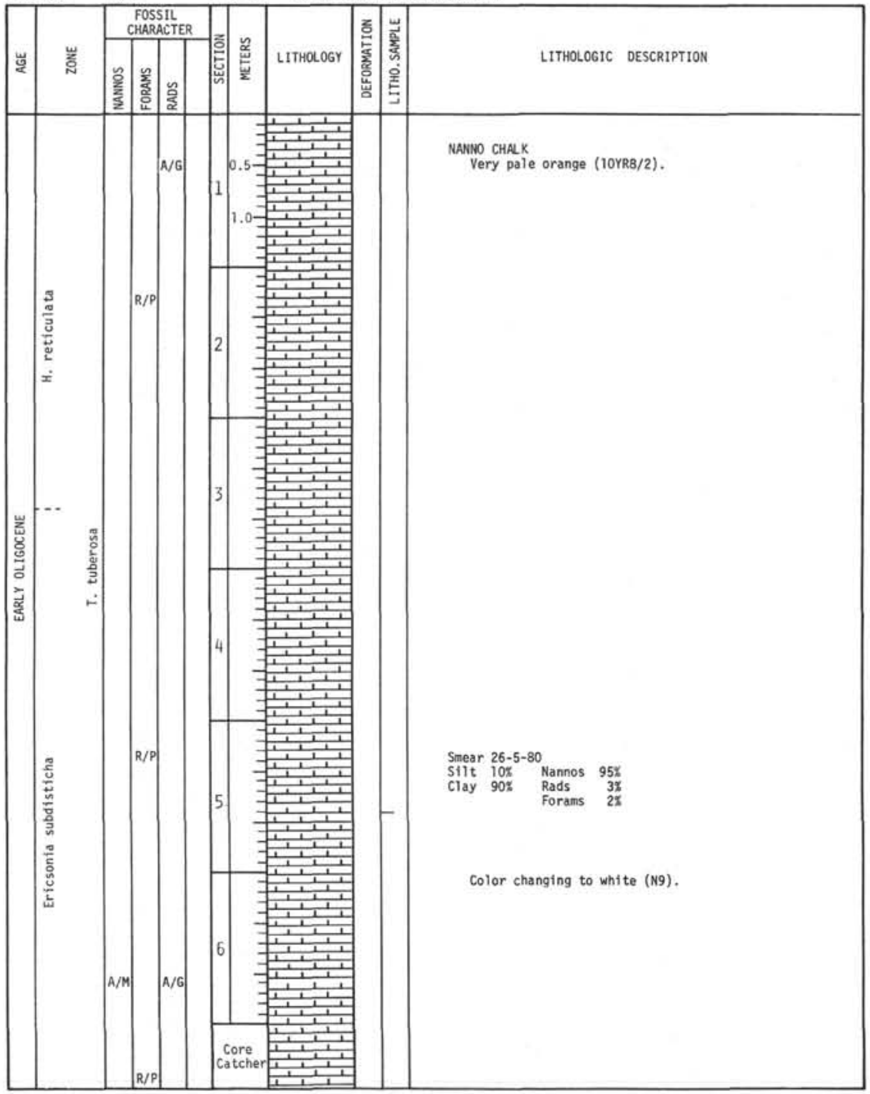
Very pale orange (10YR8/2) horizon at 25-3-0 to 105.
Smear 25-3-40
Sand 3% Nannos 95% Fe-oxide 1%
Silt 12% Rads 4%
Clay 85%

CaCO₃ 95%

Grain Size
Sand 0%
Silt 52%
Clay 48%

Explanatory notes in chapter 1

Site 236 Hole Core 26 Cored Interval: 234.5-244.0 m



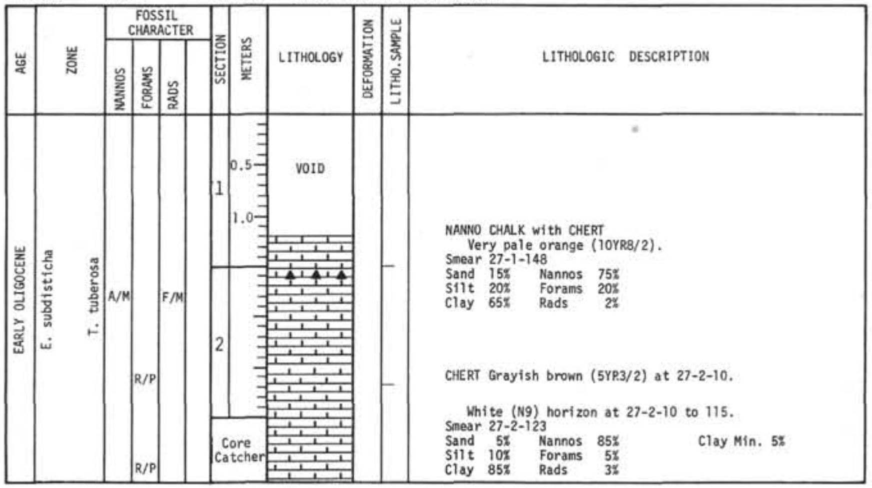
NANNO CHALK
Very pale orange (10YR8/2).

Smear 26-5-80
Silt 10% Nannos 95%
Clay 90% Rads 3%
Forams 2%

Color changing to white (N9).

Explanatory notes in chapter 1

Site 236 Hole Core 27 Cored Interval: 244.0-253.5 m

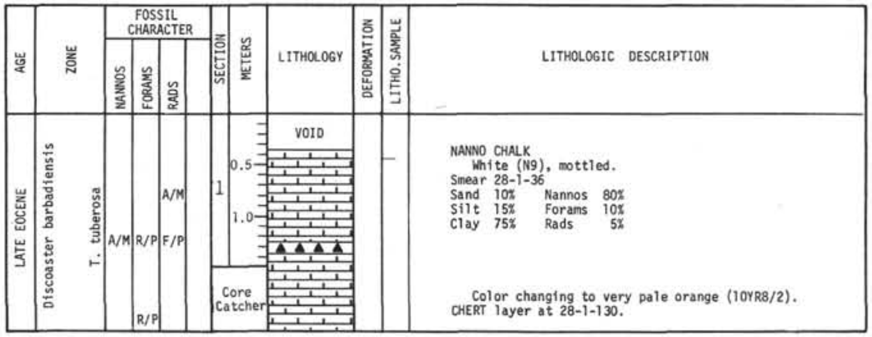


NANNO CHALK with CHERT
Very pale orange (10YR8/2).
Smear 27-1-148
Sand 15% Nannos 75%
Silt 20% Forams 20%
Clay 65% Rads 2%

CHERT Grayish brown (5YR3/2) at 27-2-10.

White (N9) horizon at 27-2-10 to 115.
Smear 27-2-123
Sand 5% Nannos 85% Clay Min. 5%
Silt 10% Forams 5%
Clay 85% Rads 3%

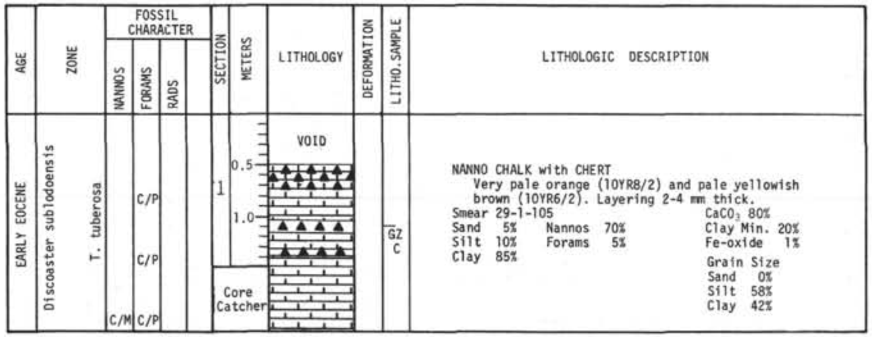
Site 236 Hole Core 28 Cored Interval: 253.5-263.0 m



NANNO CHALK
White (N9), mottled.
Smear 28-1-36
Sand 10% Nannos 80%
Silt 15% Forams 10%
Clay 75% Rads 5%

Color changing to very pale orange (10YR8/2).
CHERT layer at 28-1-130.

Site 236 Hole Core 29 Cored Interval: 263.0-272.5 m



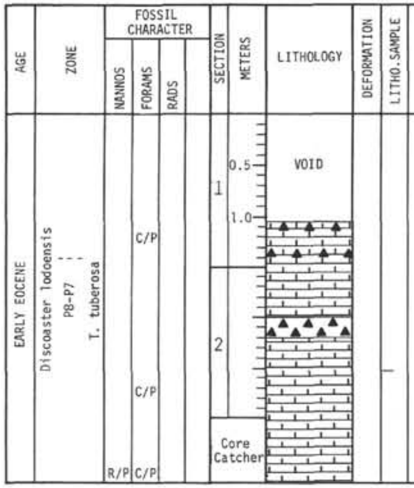
NANNO CHALK with CHERT
Very pale orange (10YR8/2) and pale yellowish brown (10YR6/2). Layering 2-4 mm thick.
Smear 29-1-105
Sand 5% Nannos 70%
Silt 10% Forams 5%
Clay 85%

CaCO$_3$ 80%
Clay Min. 20%
Fe-oxide 1%

Grain Size
Sand 0%
Silt 58%
Clay 42%

Explanatory notes in chapter 1

Site 236 Hole Core 30 Cored Interval: 272.5-282.0 m

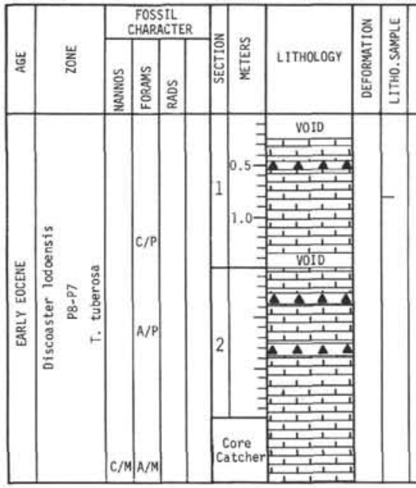


LITHOLOGIC DESCRIPTION

NANNO CHALK with CHERT layers
Very pale orange (10YR8/2).

Smear 30-2-100
Sand 10% Nannos 70% Clay Min. 20%
Silt 20% Forams 10%
Clay 70%

Site 236 Hole Core 31 Cored Interval: 282.0-291.5 m

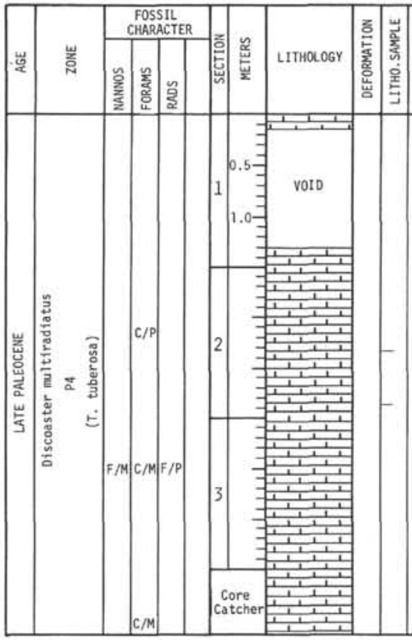


LITHOLOGIC DESCRIPTION

NANNO CHALK with some CHERT layers
Very pale orange (10YR8/2). Chert layers at 31-1-50, 31-1-60, 31-1-100, 31-1-130, 31-2-30, 31-2-80.
Smear 31-1-80
Sand 5% Nannos 90% Clay Min. 5%
Silt 15% Forams 5%
Clay 80%

Explanatory notes in chapter 1

Site 236 Hole Core 32 Cored Interval: 291.5-301.5 m



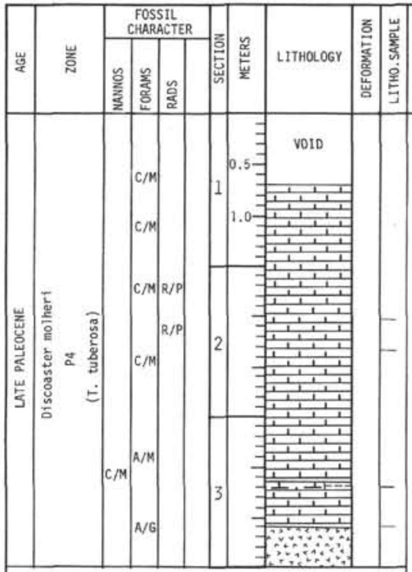
LITHOLOGIC DESCRIPTION

NANNO CHALK
Grayish orange (10YR7/4)

Very pale orange (10YR8/2) horizon at 32-2-75 to 115.
Smear 32-2-80
Sand 2% Nannos 95% Dolo. Rhombs 1%
Silt 8% Forams 3%
Clay 90% Rads 1%
Smear 32-2-140
Sand 5% Nannos 85% Fe-oxide 1%
Silt 10% Forams 10%
Clay 85%

Explanatory notes in chapter 1

Site 236 Hole Core 33 Cored Interval: 301.0-306.5 m



LITHOLOGIC DESCRIPTION

NANNO CHALK
Moderate yellowish brown (10YR5/4)
Smear 33-1-100

Sand	5%	Nannos	60%	Clay Min.	20%
Silt	10%	Forams	15%	Quartz	1%
Clay	85%				

Dusky brown (5YR2/2) to moderate orange pink (5YR8/4) at 33-2-35 to 45.
Smear 33-2-43

Sand	5%	Nannos	80%	Fe-oxide	5%
Silt	10%	Forams	10%	Quartz	1%
Clay	85%				

Color changing to grayish yellow green (5GY7/2) at 33-2-45.

Smear 33-2-68

Sand	5%	Nannos	80%	Clay Min.	10%
Silt	15%	Forams	5%	Fe-oxide	2%
Clay	80%				

Color grading to grayish olive green (5GY3/2) at 33-3-67, to pale green (10G6/2) at 33-3-75 to 110.
Smear 33-3-67

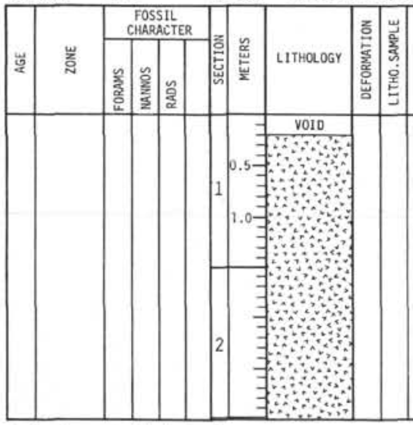
Sand	5%	Nannos	50%	Clay Min.	30%
Silt	15%	Forams	5%	Fe-oxide	10%
Clay	80%				

Smear 33-3-102

Sand	10%	Nannos	85%	Fe-oxide	3%
Silt	10%	Forams	10%		
Clay	80%				

BASALT Greenish black (5G2/1).

Site 236 Hole Core 34 Cored Interval: 306.5-312.5 m

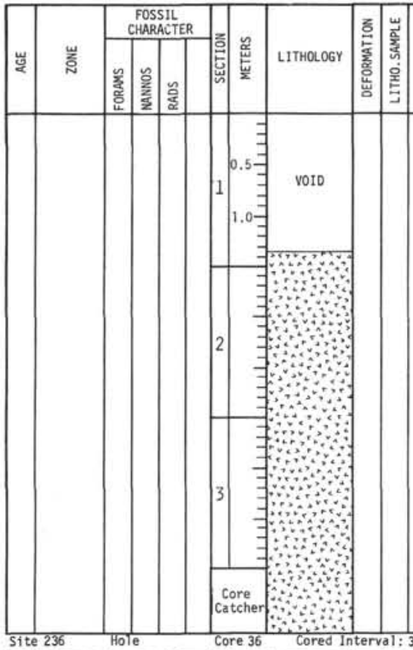


LITHOLOGIC DESCRIPTION

BASALT with layers of volcanic breccia and basaltic glass. Main color greenish black (5G2/1).

Explanatory notes in chapter 1

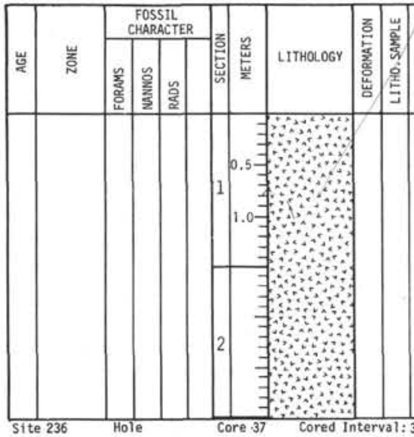
Site 236 Hole Core 35 Cored Interval: 312.5-322.0 m



LITHOLOGIC DESCRIPTION

BASALT with glassy breccias and veins. Main color greenish black (5G2/1).

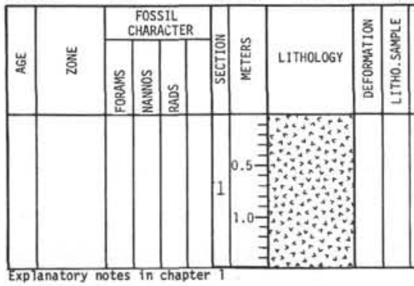
Site 236 Hole Core 36 Cored Interval: 322.0-326.0 m



LITHOLOGIC DESCRIPTION

BASALT
Greenish black (5G2/1). With layers of volcanic glass.

Site 236 Hole Core 37 Cored Interval: 326.0-327.5 m



LITHOLOGIC DESCRIPTION

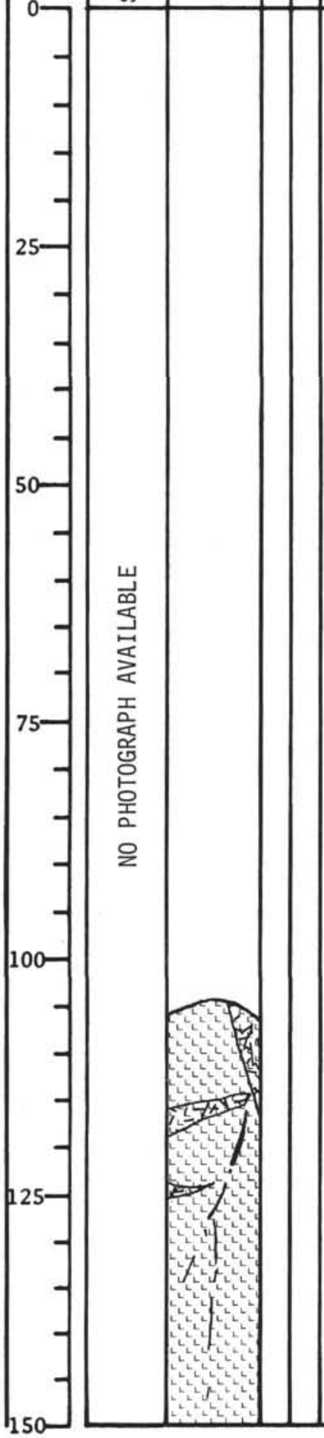
BASALT
Grayish black (N2) with zones of volcanic glass.

Explanatory notes in chapter 1

DETAILED CORE DESCRIPTIONS

Site 236 Core 33
Section 3A

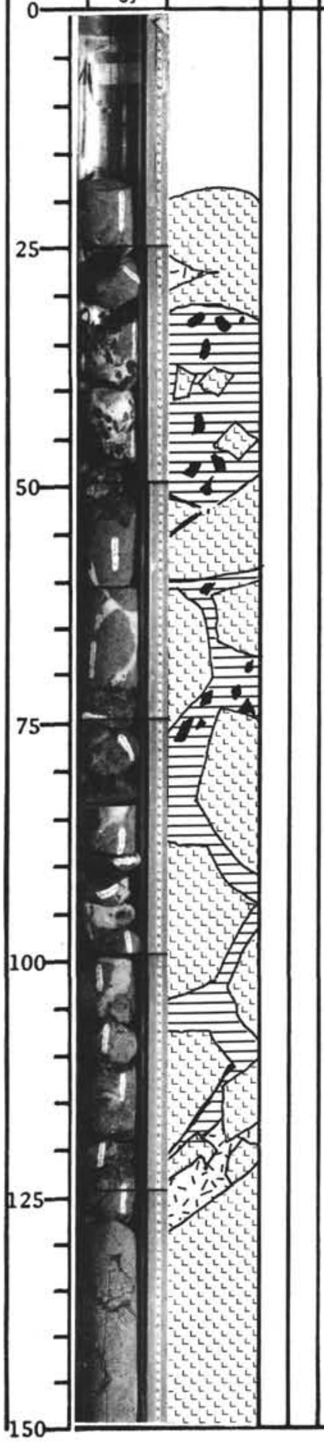
Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description



Porphyritic vesicular basalt, greenish-gray to filled. Phenocrysts sparse: chiefly plagioclase.

Site 236 Core 34
Section 1

Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description



Porphyritic basalt; vesicular.

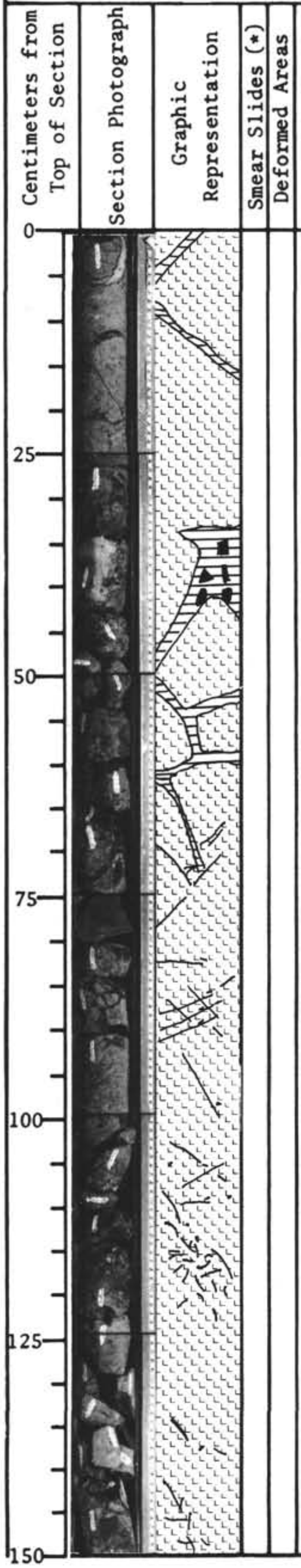
Volcanic breccia: large fragments of variolitic and porphyritic basalt and smaller fragments of basaltic glass and greenish zones of altered glass cemented by seams of slightly altered to unaltered calcareous microfossil aggregates; veins or seams of carbonate. Varying proportions of basalt-glass-carbonate.

Basaltic glass.

Porphyritic basalt; massive.

DETAILED CORE DESCRIPTIONS

Site 236 **Core** 34
Section 2



Description

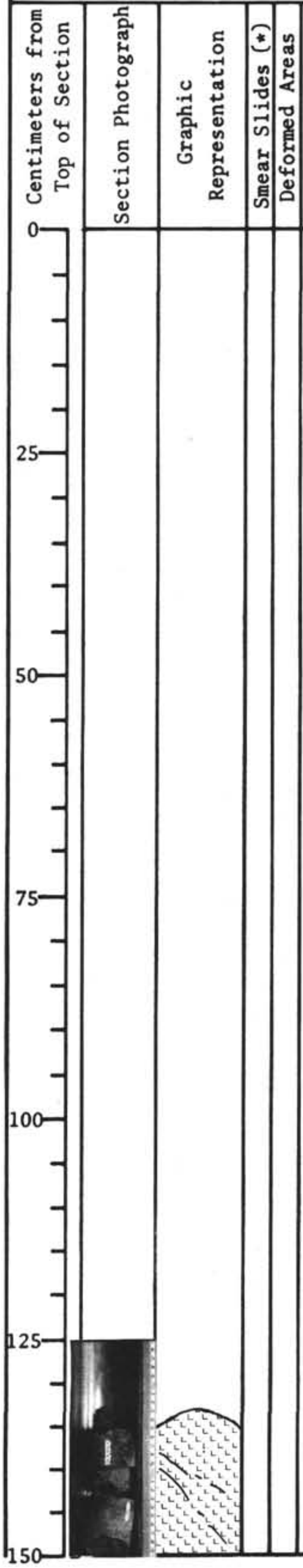
Massive basalt, with filled fractures.

Extensively fractured basalt. Upper portion has brecciated basalt and glass with calcite-chlorite cement. Glasses have fresh phenocrysts or plagioclase and augite; vesicular.

Altered (oxidized) basalt horizon.

Porphyritic basalt: plagioclase phenocrysts in a variolitic groundmass high in augite. Round vesicles, filled.

Site 236 **Core** 35
Section 1

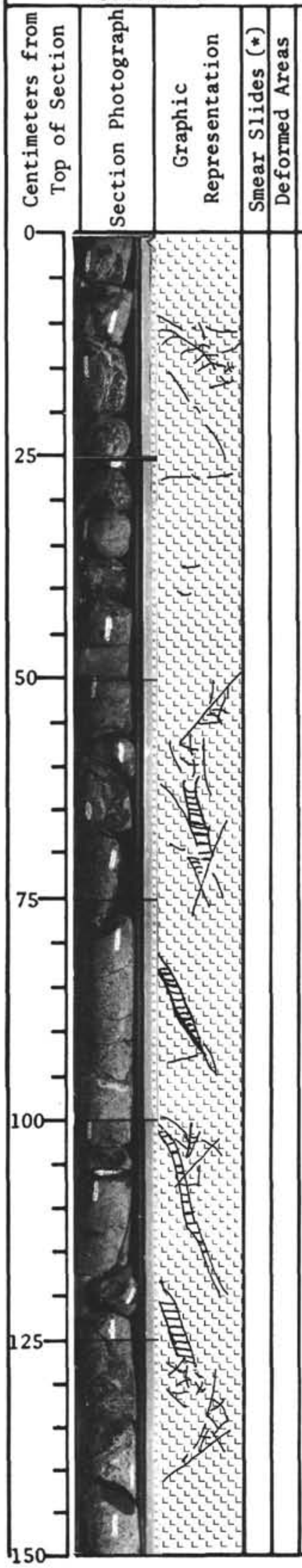


Description

Greenish-gray vesicular porphyritic basalt. Phenocrysts of augite and plagioclase, in aggregates. Vesicles filled.

DETAILED CORE DESCRIPTIONS

Site 236 Core 35
Section 2



Description

Vesicular porphyritic basalt; alteration to chlorite. Calcite locally.

Brecciated glass cemented by calcite-chlorite.

Porphyritic basalt: plagioclase phenocrysts corroded, chloritic; augite. Abundant round vesicles, filled. Chlorite abundant in variolitic groundmass.

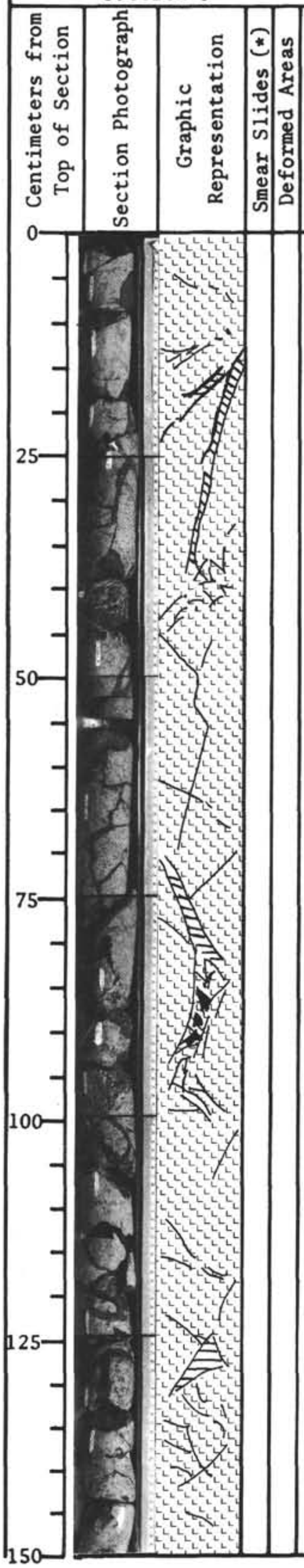
Glassy breccia with chlorite cement.

Fractured basalt veins incrusted with chlorite.

Brecciated basalt and glass; chlorite cement.

Brecciated glass. Chlorite in cement.

Site 236 Core 35
Section 3



Description

Fractured basalt.

Brecciated glass.

Fractured porphyritic variolitic basalt. Plagioclase phenocrysts replaced by analcite; groundmass chloritic. Large vesicles, filled with "fibrous" chlorite. Veins of chlorite and partially-preserved calcareous microfossils. Carbonate in veins also; sometimes principal vein material.

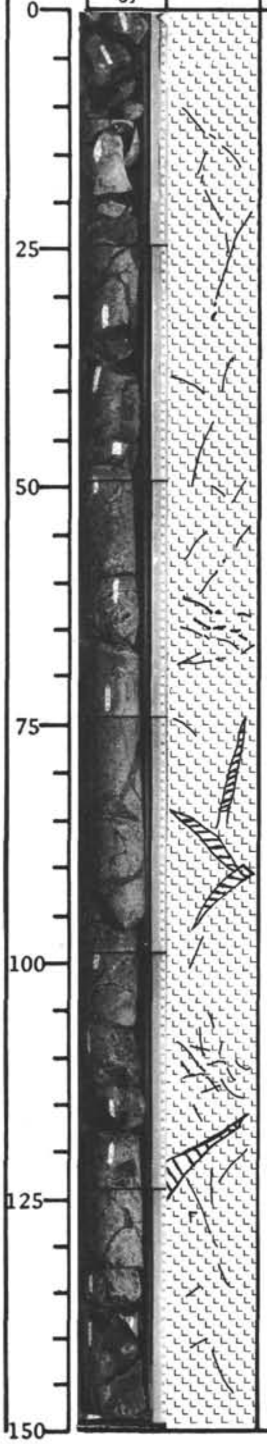
Brecciated glass.

Fractured porphyritic basalt: plagioclase phenocrysts somewhat chloritized; augite phenocrysts fresher. Augite abundant in variolitic groundmass. Vesicles filled with chlorite.

DETAILED CORE DESCRIPTIONS

Site 236 Core 36
Section 1

Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description



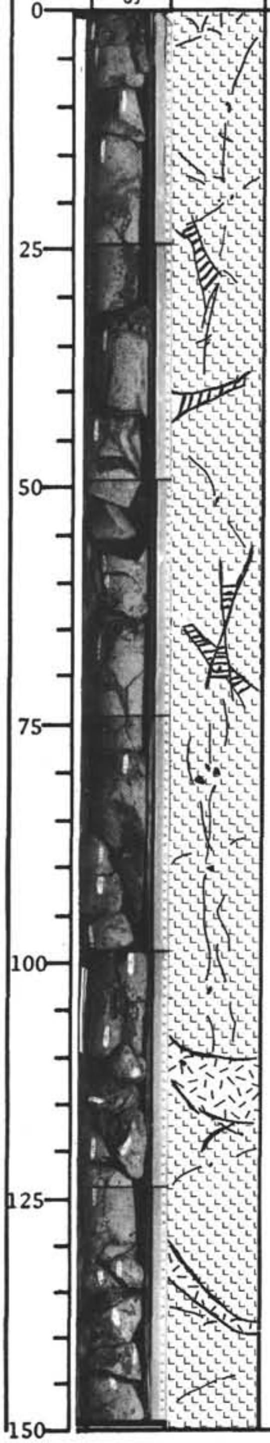
Massive greenish-gray porphyritic variolitic basalt. Augite and plagioclase phenocrysts; augite abundant in groundmass. Vesicles filled. Chlorite as aggregates in groundmass and as fracture fillings, and replacing plagioclase.

Glassy horizon.

Porphyritic basalt.

Site 236 Core 36
Section 2

Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description



Glassy zone.

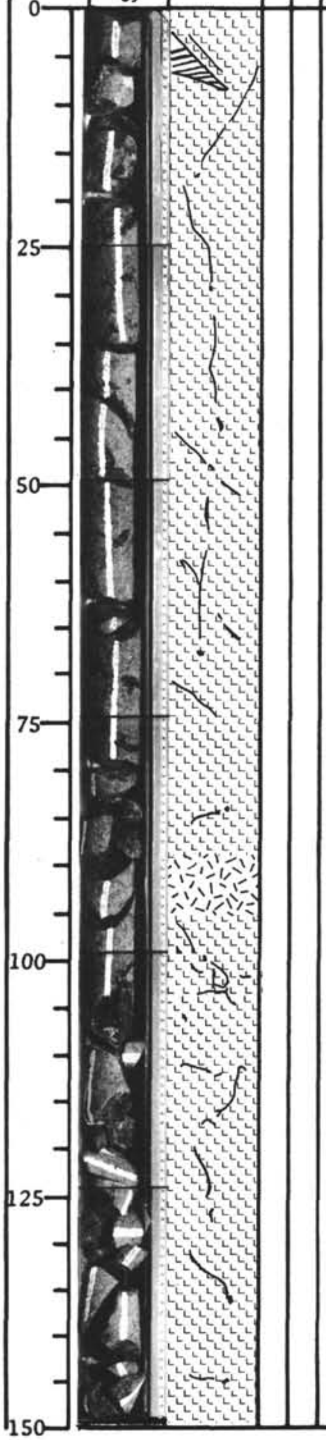
Fractured massive porphyritic basalt, greenish-gray at top, becoming gray-black at base; large plagioclase, small augite phenocrysts: plagioclase phenocrysts chloritized. Chlorite aggregates in groundmass, which is high in pyroxene. Chlorite in fractures, and filling small round vesicles.

Glassy horizon.

DETAILED CORE DESCRIPTIONS

Site 236 **Core** 37
Section 1

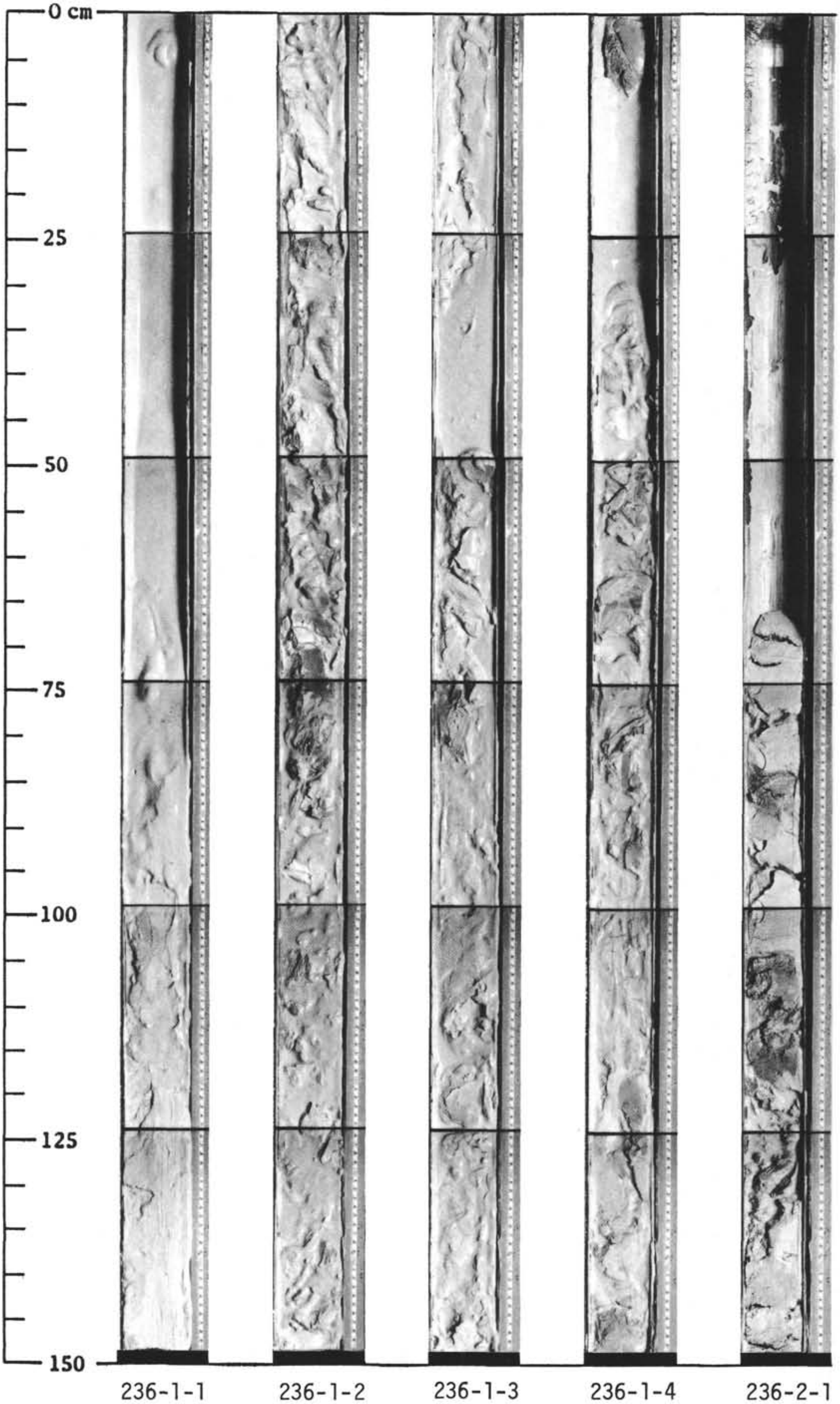
Centimeters from Top of Section
Section Photograph
Graphic Representation
Smear Slides (*)
Deformed Areas
Description

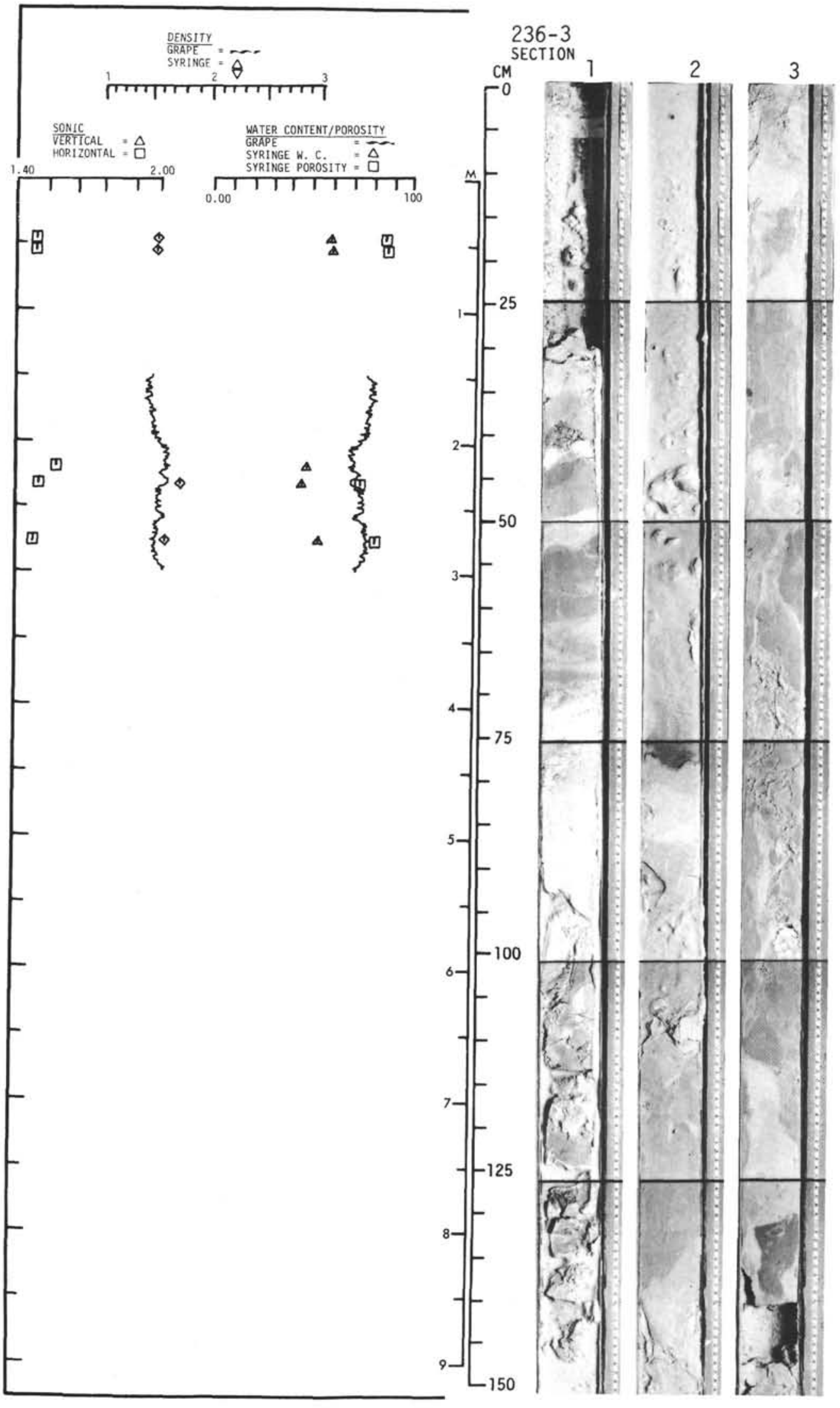


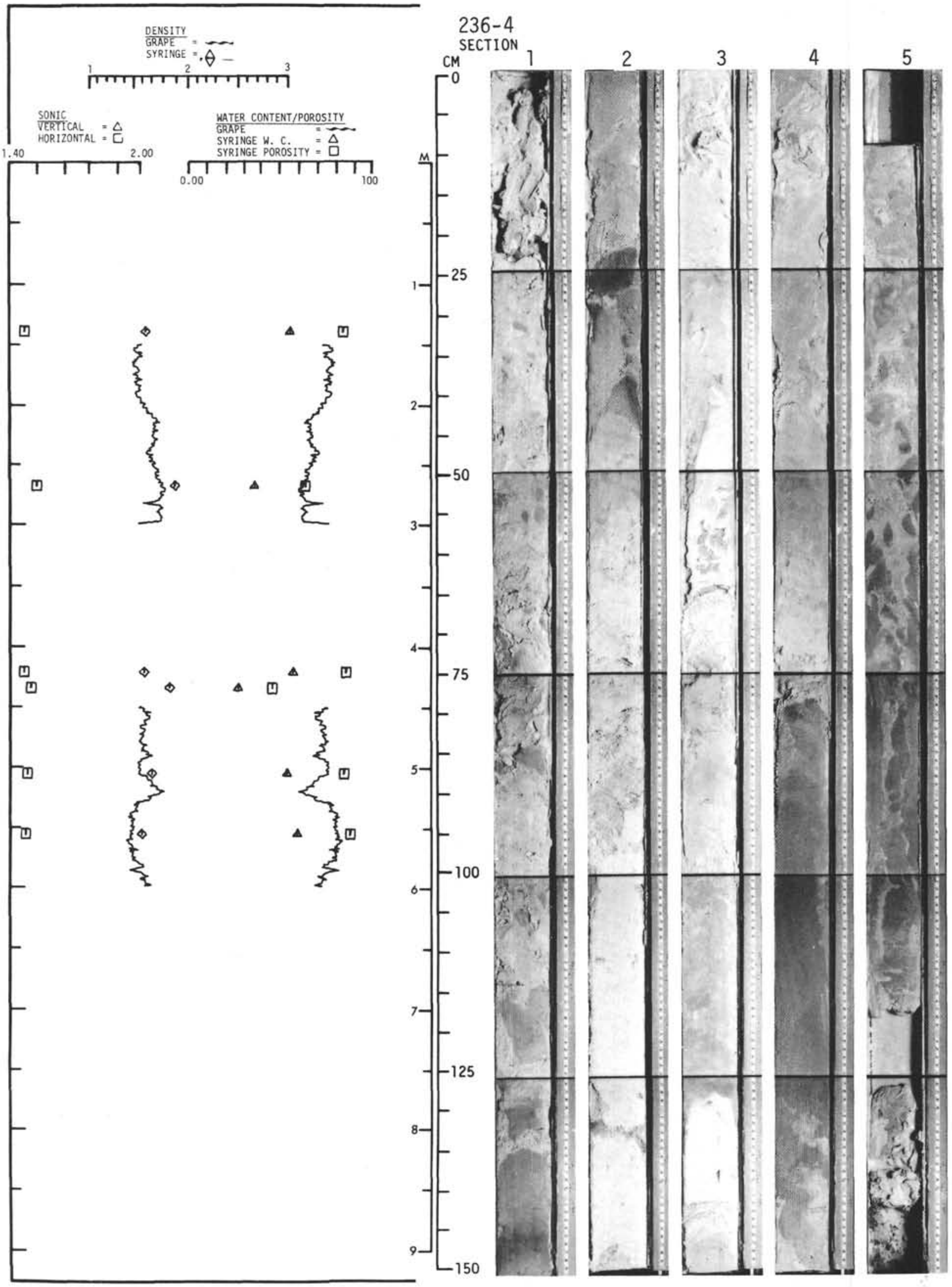
Fractured fine-grained variolitic basalt, with altered phenocrysts. Chlorite (green) and fibrous gray-green as alteration and vein and vesicle filling. Basalt massive except for fractures. Plagioclase altered in part of analcite. Some carbonate crack or vein fillings between rims or borders of finer-grained chlorite.

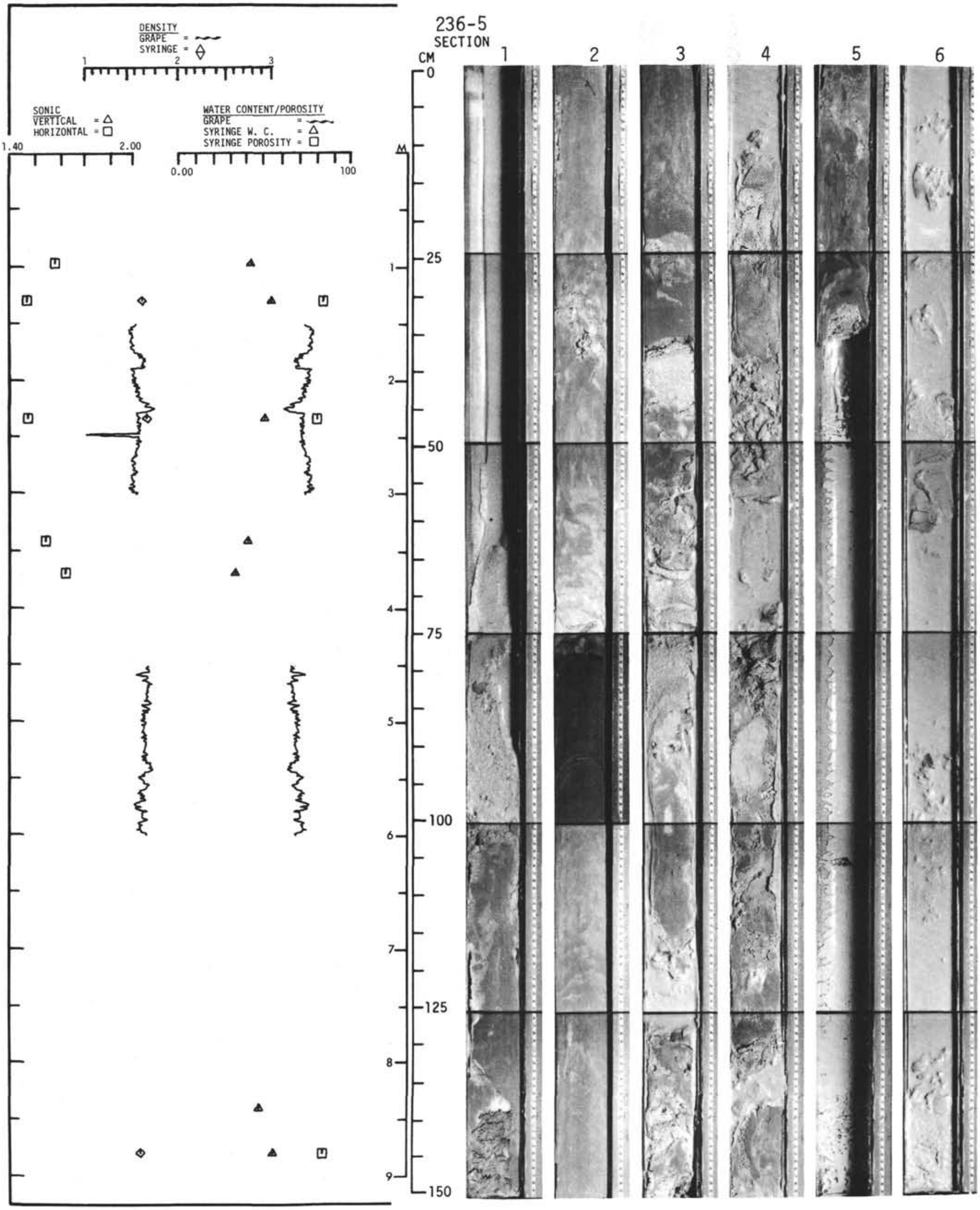
Glassy horizon: grayish green to brown spherulitic glass with very fresh phenocrysts of plagioclase and augite. Vesicles round, filled with chlorite.

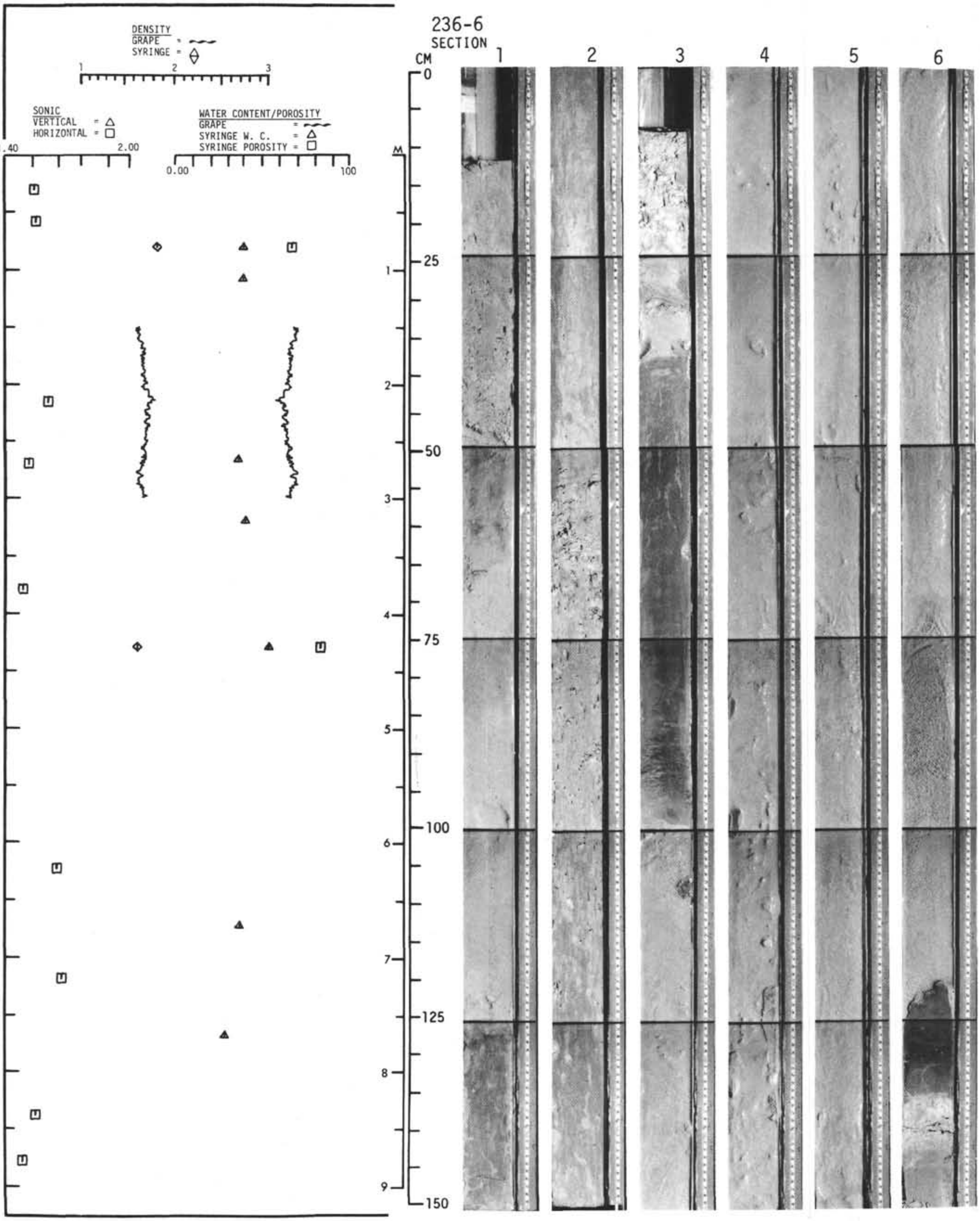
Massive porphyritic basalt; finely variolitic groundmass with abundant augite. Plagioclase phenocrysts corroded; finer-grained augite less so. Round vesicles, filled with chlorite.

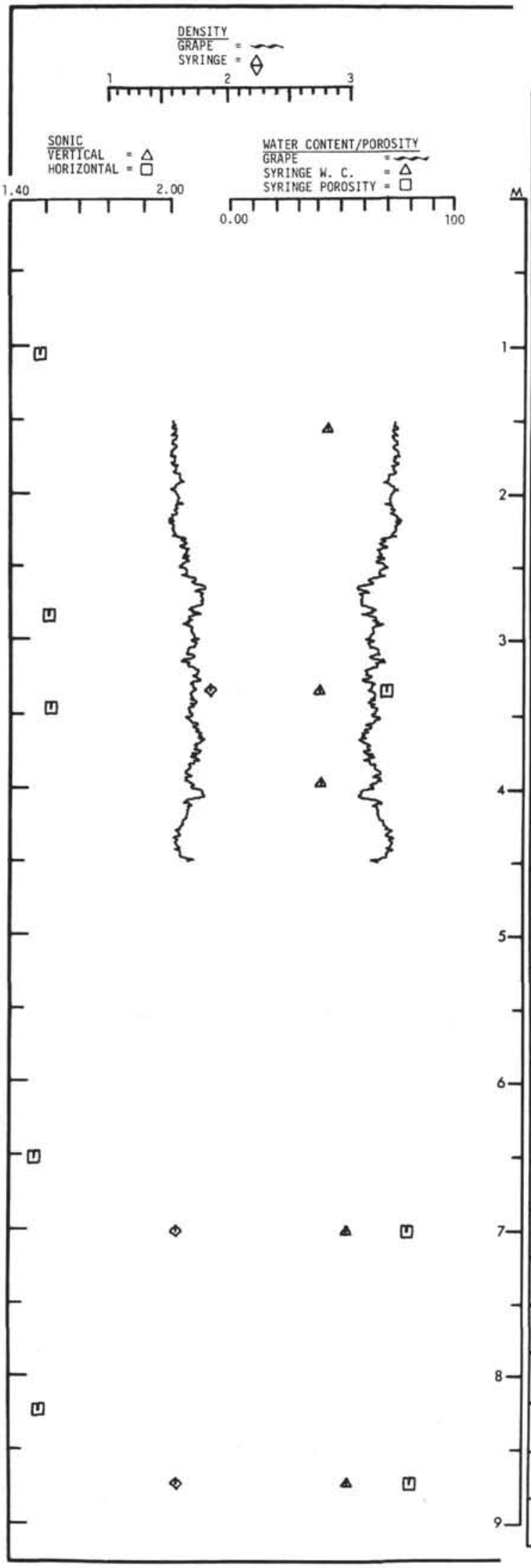

0 cm
25
50
75
100
125
150
236-1-1
236-1-2
236-1-3
236-1-4
236-2-1

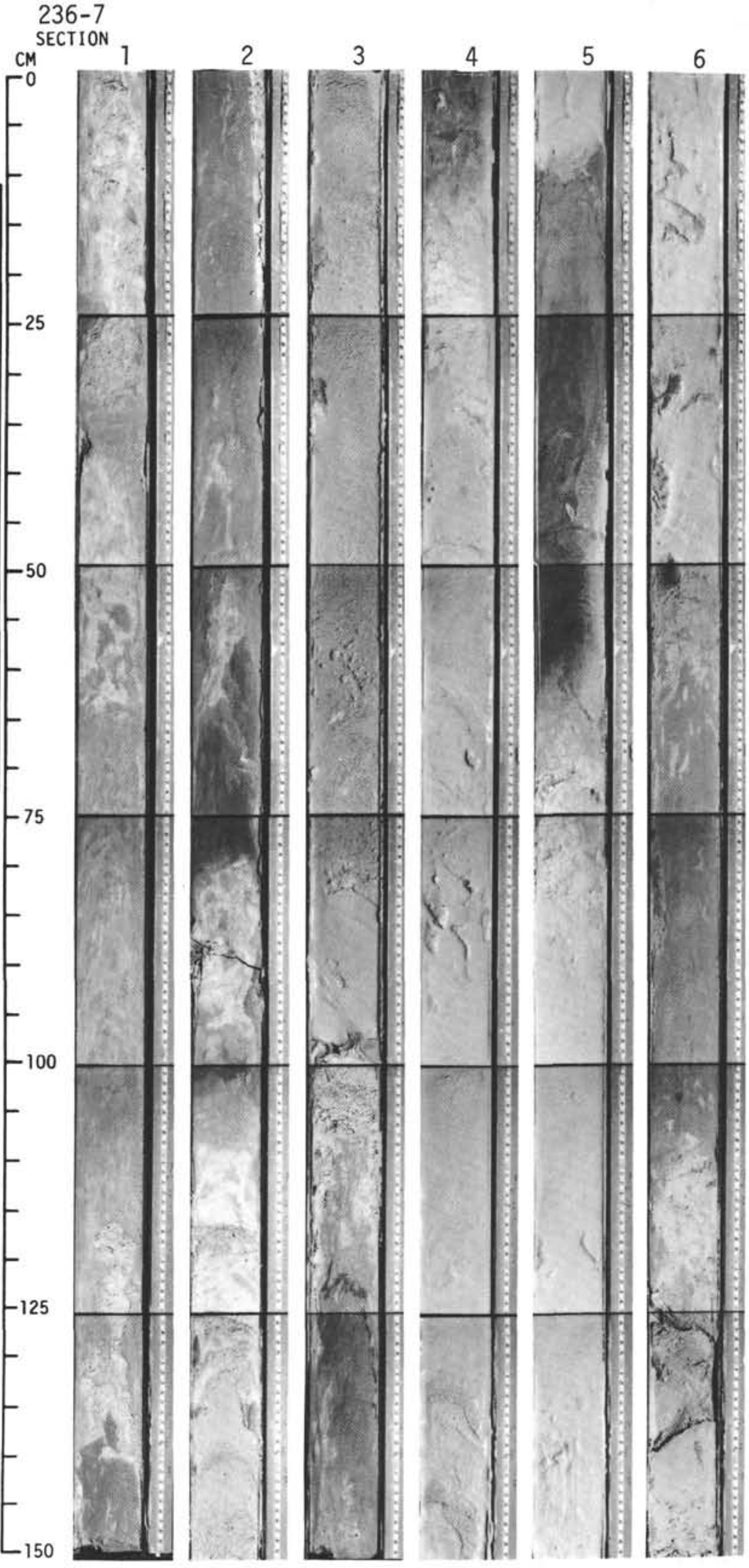

DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = □
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
M
1
2
3
4
5
6
7
8
9
236-3
SECTION
1
2
3
CM
0
25
50
75
100
125
150

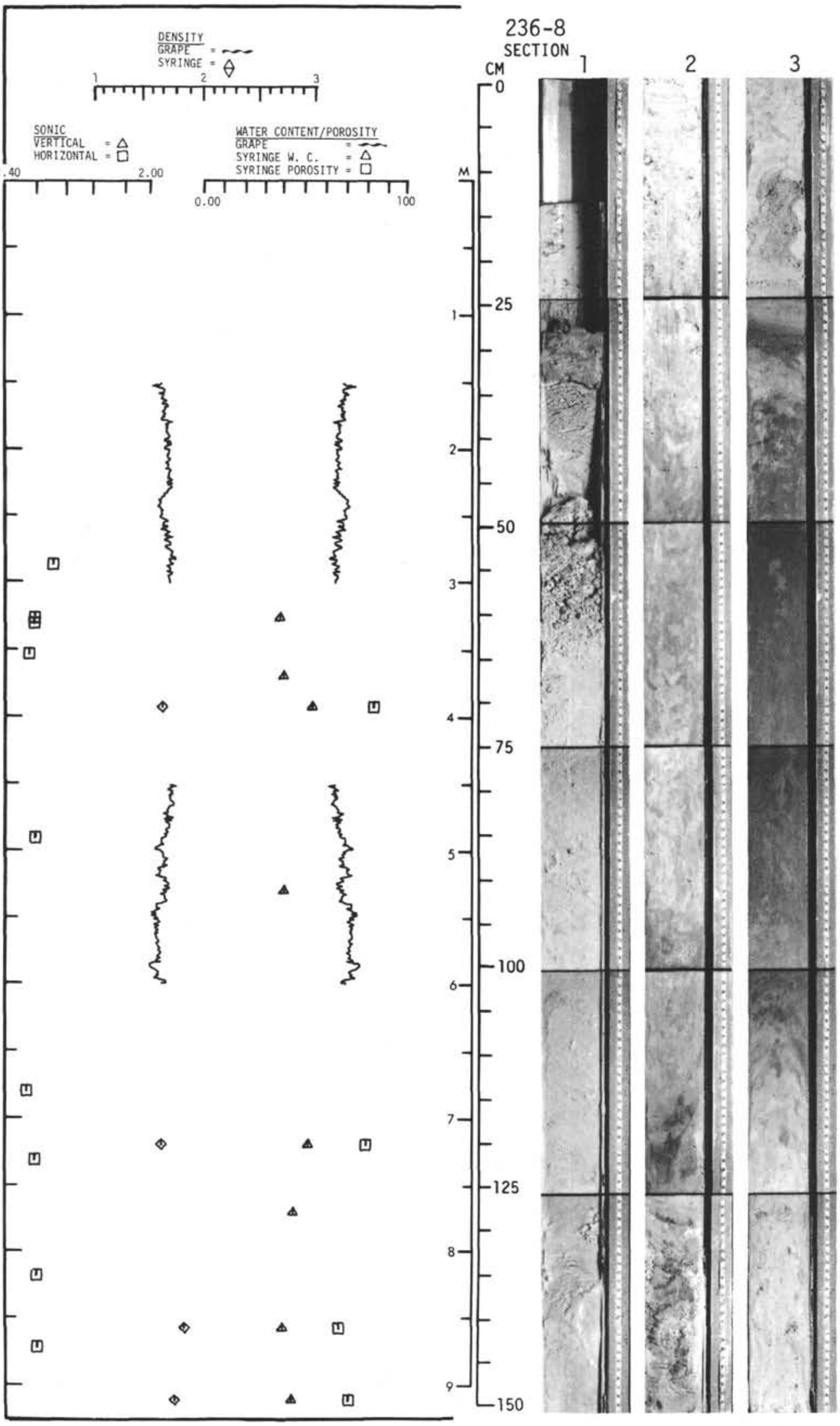

DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = ⊏
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
M
1
2
3
4
5
6
7
8
9
236-4
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5

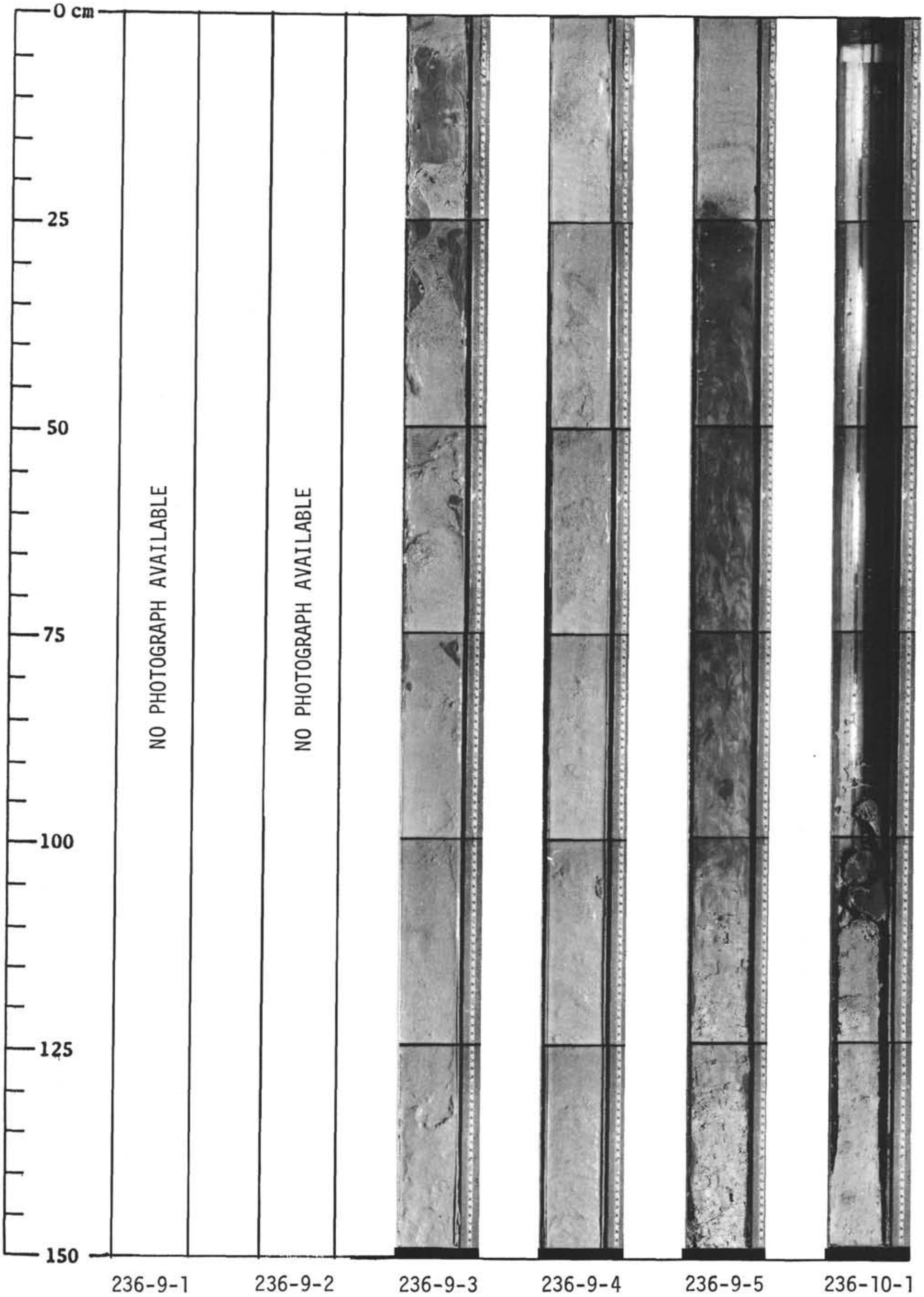

DENSITY
GRAPE = 〰
SYRINGE = ◊
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = □
1.40
2.00
WATER CONTENT/POROSITY
GRAPE = 〰
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
M
1
2
3
4
5
6
7
8
9
236-5
SECTION
1
2
3
4
5
6
CM
0
25
50
75
100
125
150

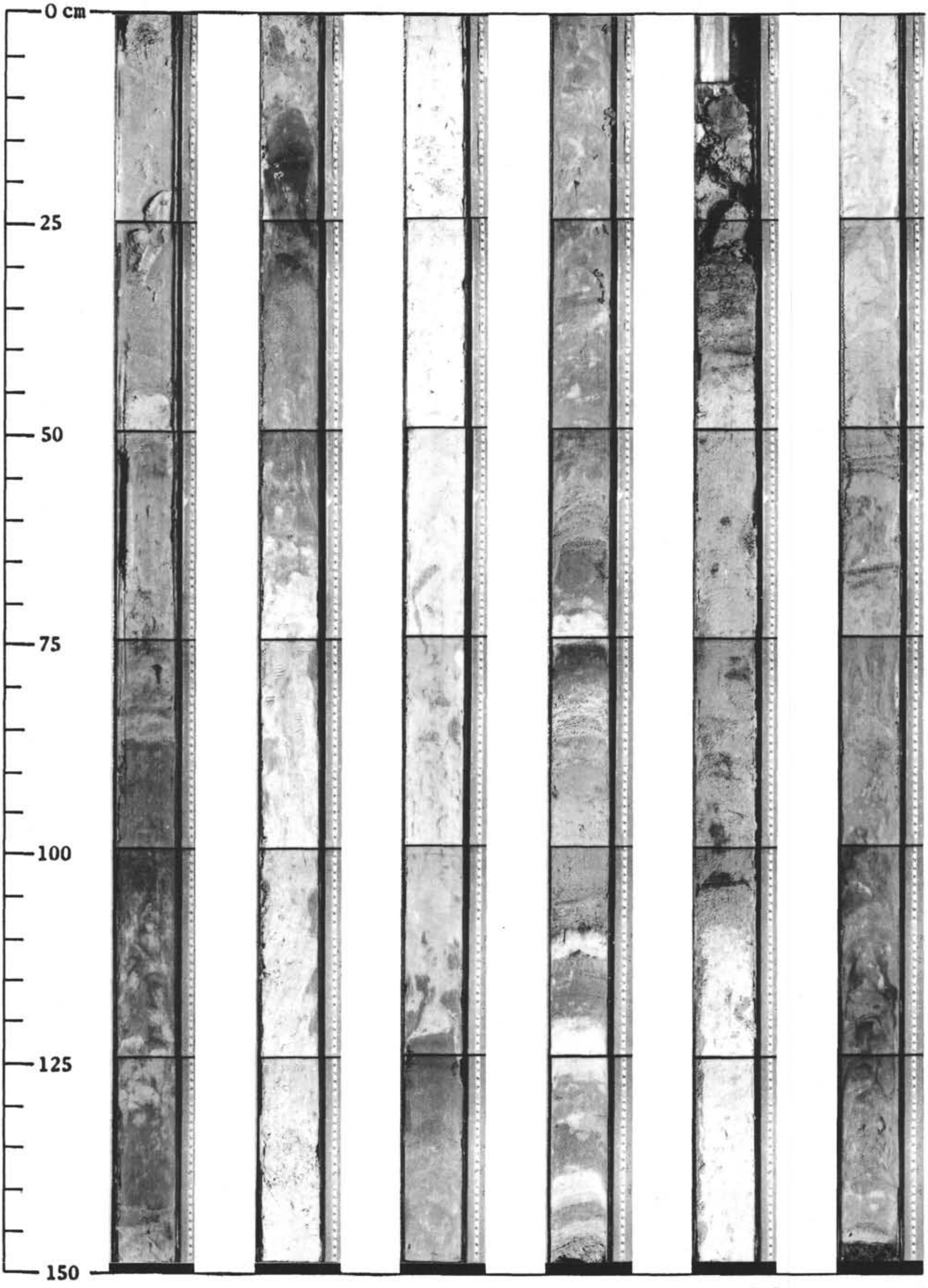

DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = □
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
M
1
2
3
4
5
6
7
8
9
236-6
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6

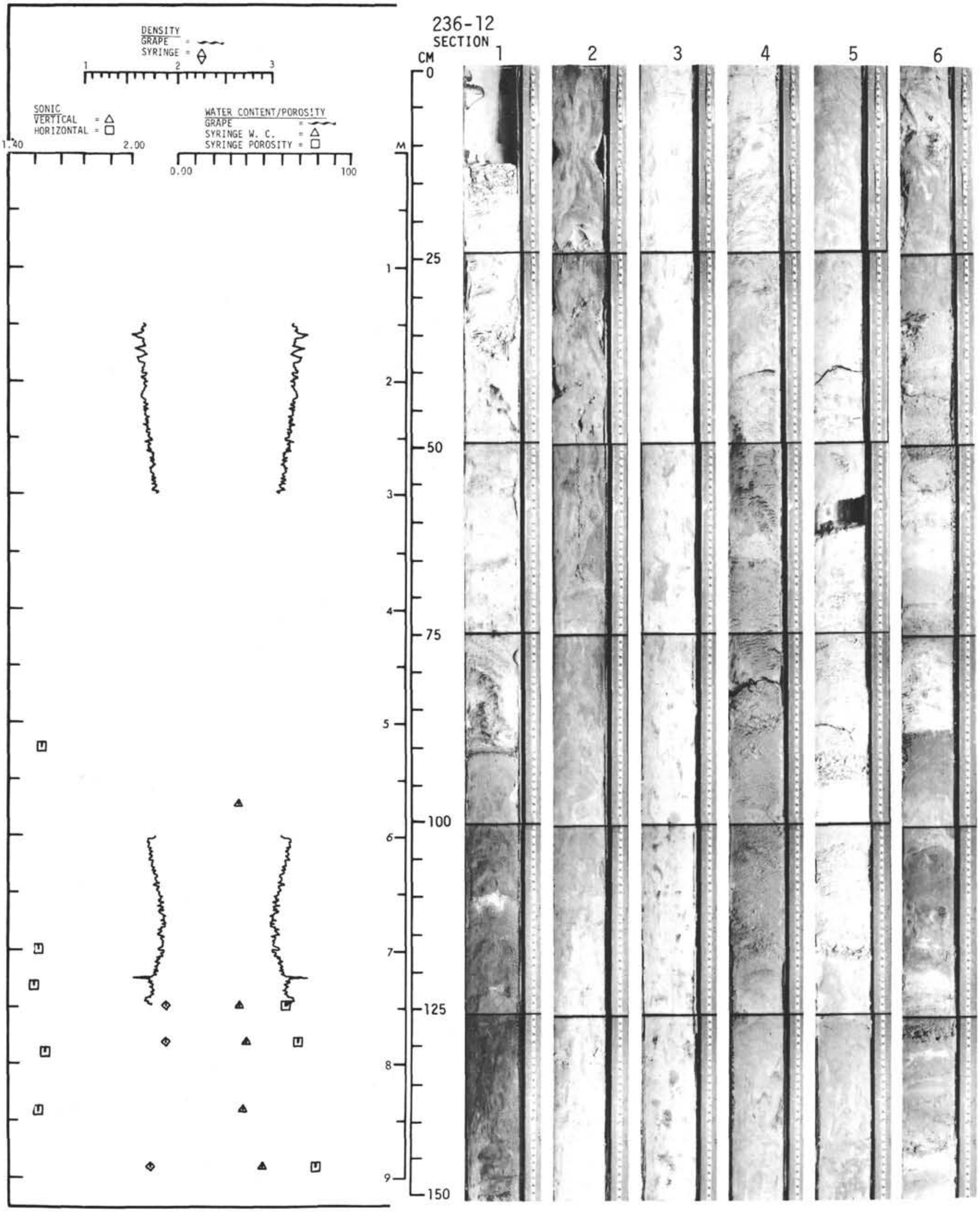

DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = □
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
M
1
2
3
4
5
6
7
8
9

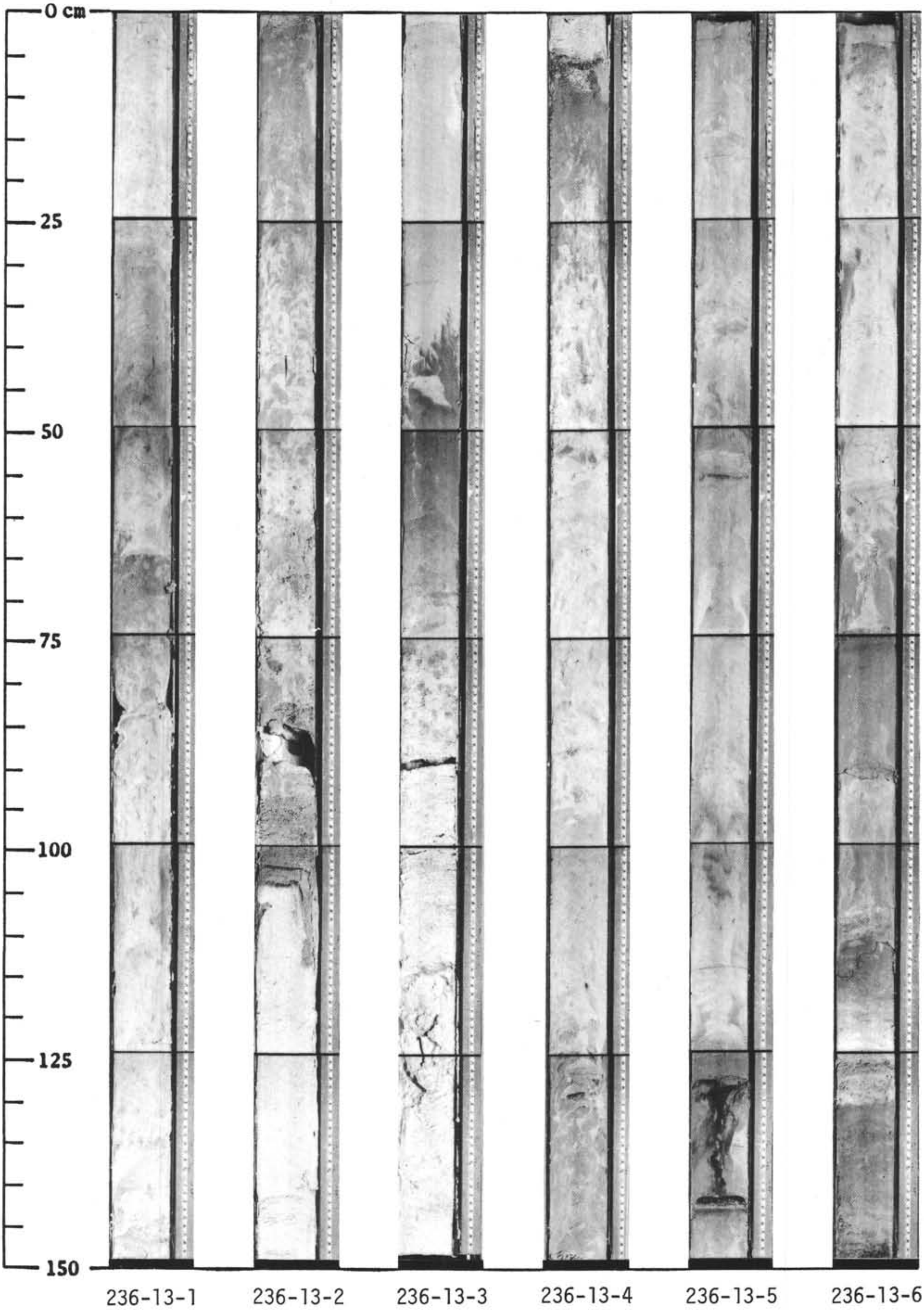

236-7
SECTION
1
2
3
4
5
6
CM
0
25
50
75
100
125
150

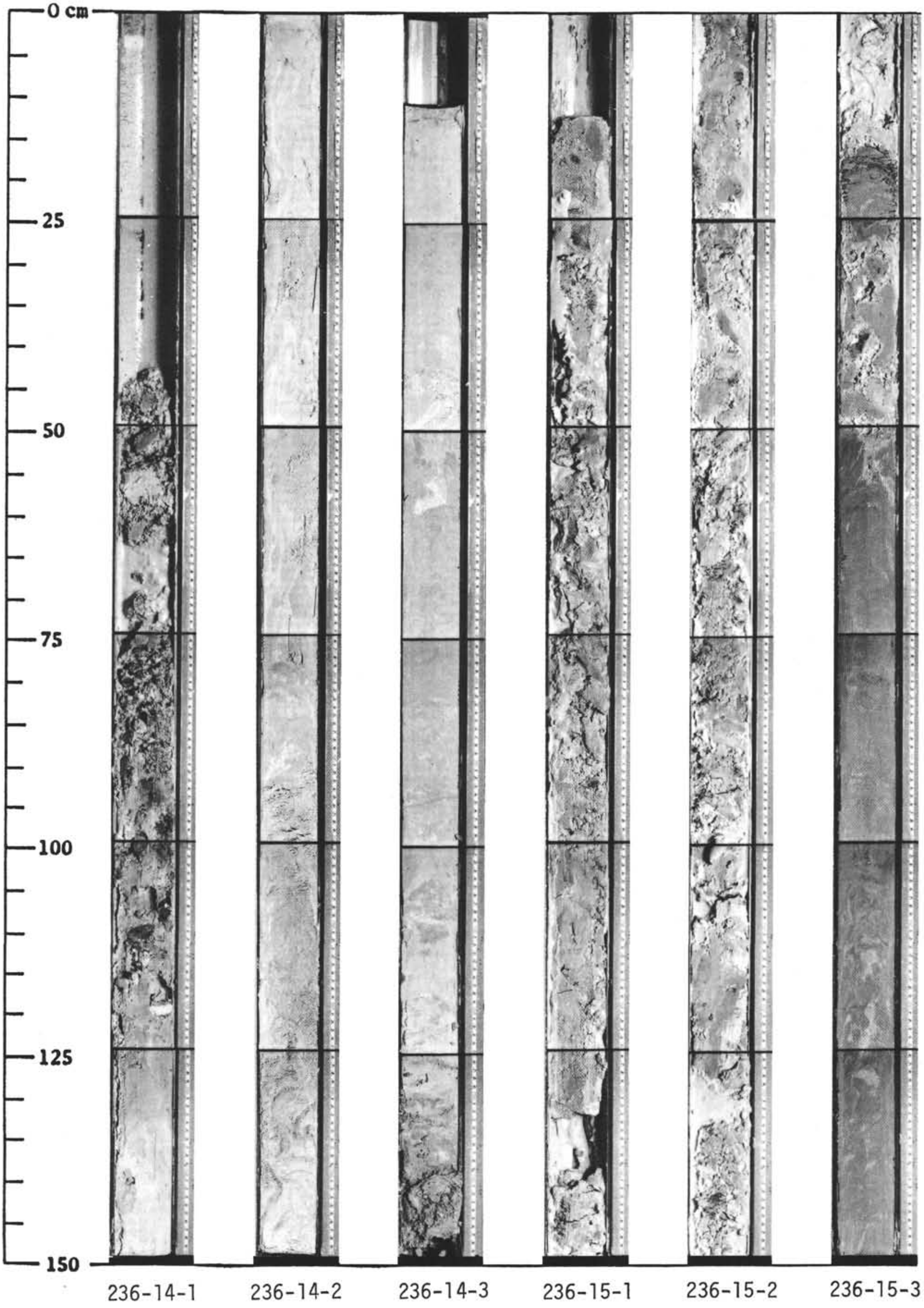

DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = □
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
236-8
SECTION
1
2
3
CM
0
25
50
75
100
125
150
M
1
2
3
4
5
6
7
8
9

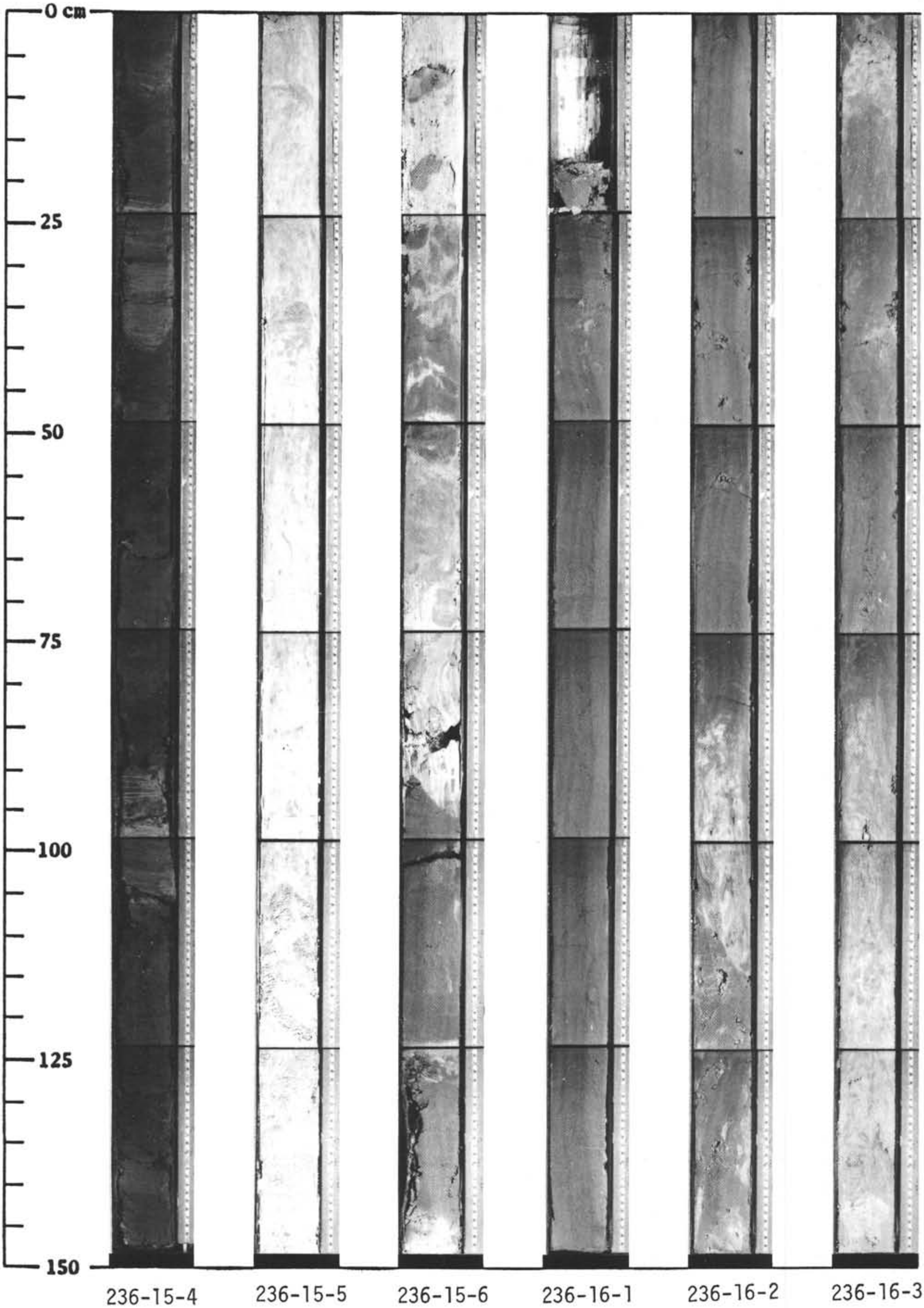

0 cm
25
50
75
100
125
150
NO PHOTOGRAPH AVAILABLE
NO PHOTOGRAPH AVAILABLE
236-9-1
236-9-2
236-9-3
236-9-4
236-9-5
236-10-1

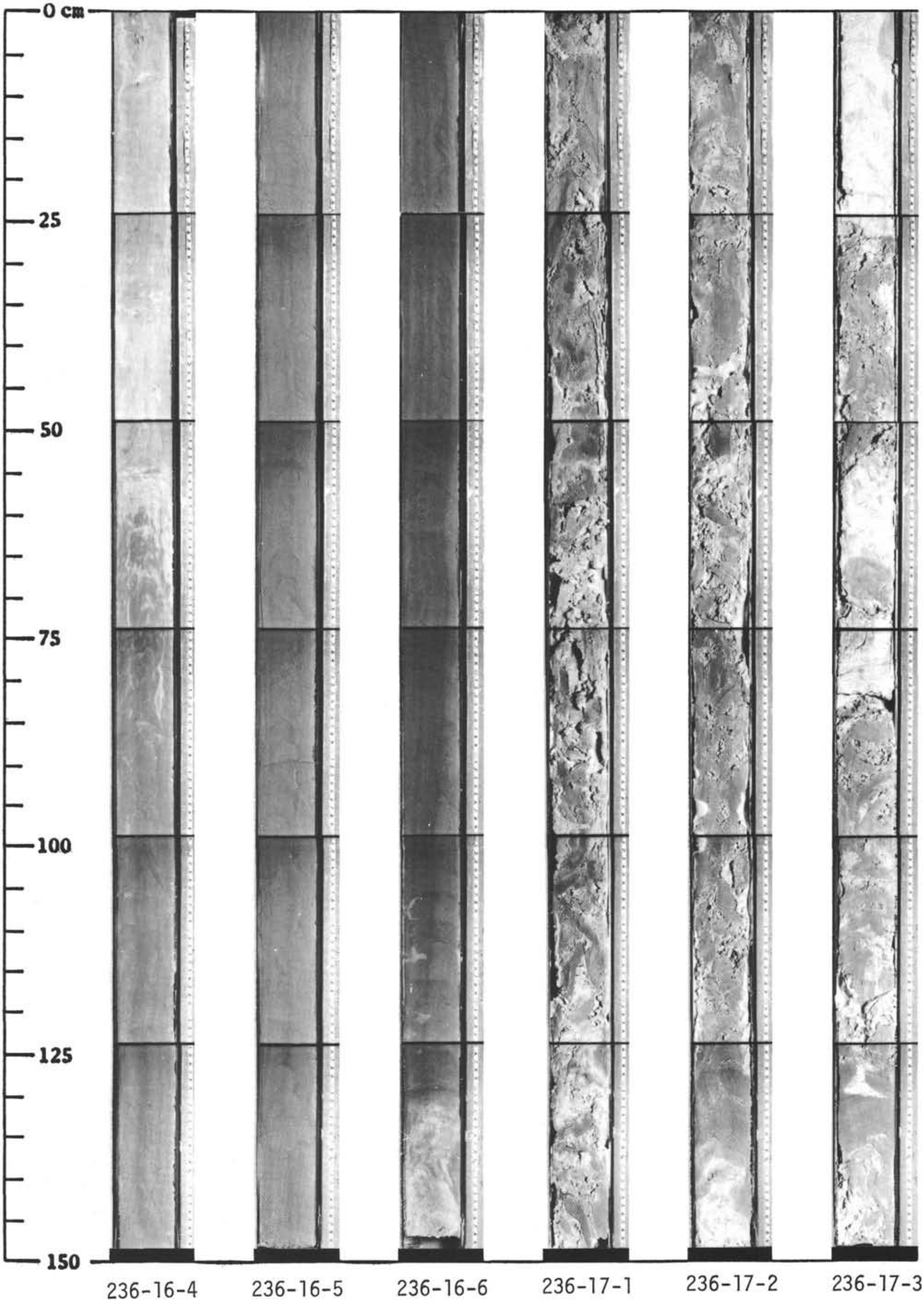

0 cm
25
50
75
100
125
150
236-10-2
236-10-3
236-10-4
236-10-5
236-11-1
236-11-2

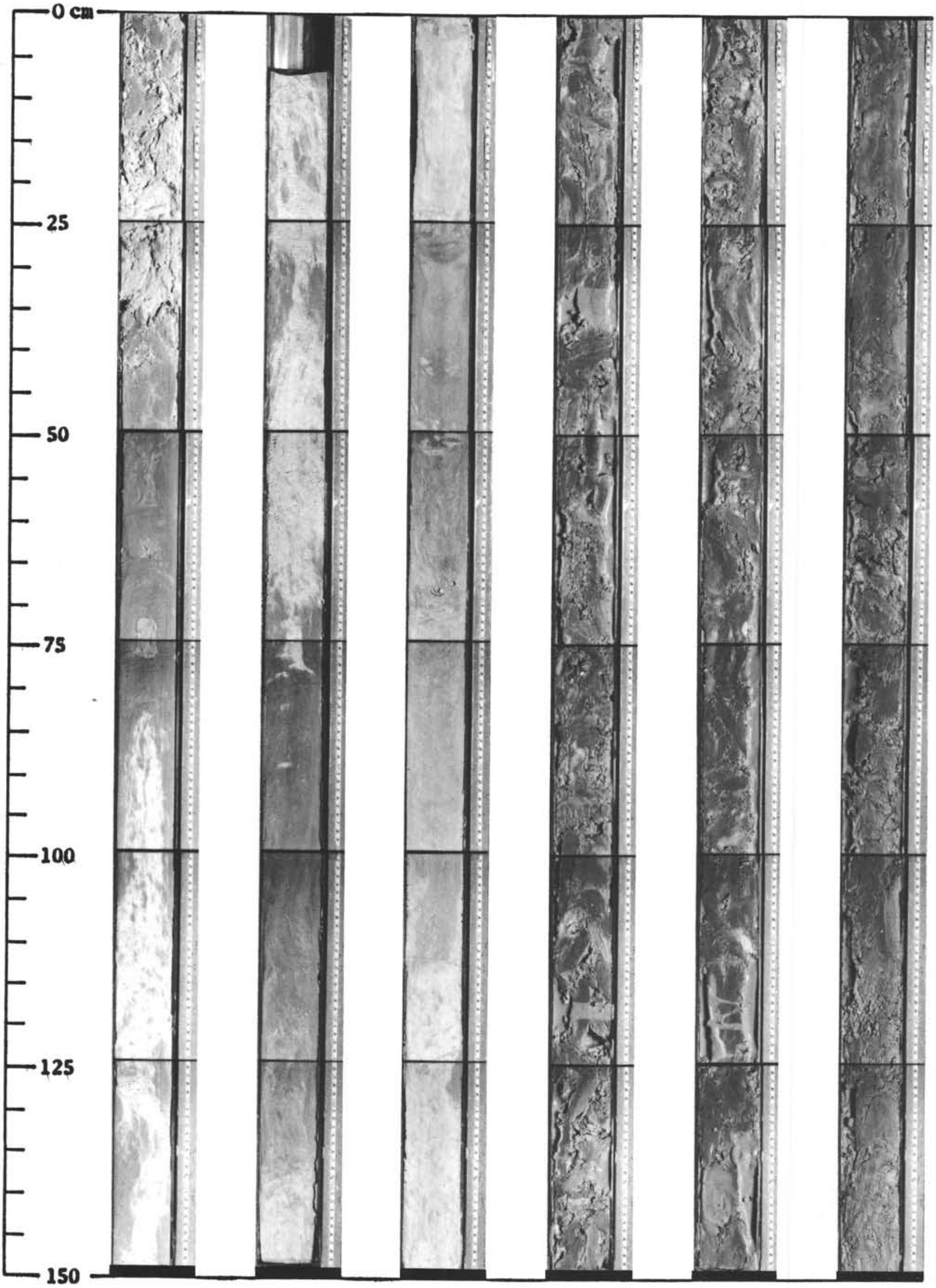

DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL =
HORIZONTAL =
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. =
SYRINGE POROSITY =
0.00
100
M
1
2
3
4
5
6
7
8
9
236-12
SECTION
1
2
3
4
5
6
CM
0
25
50
75
100
125
150

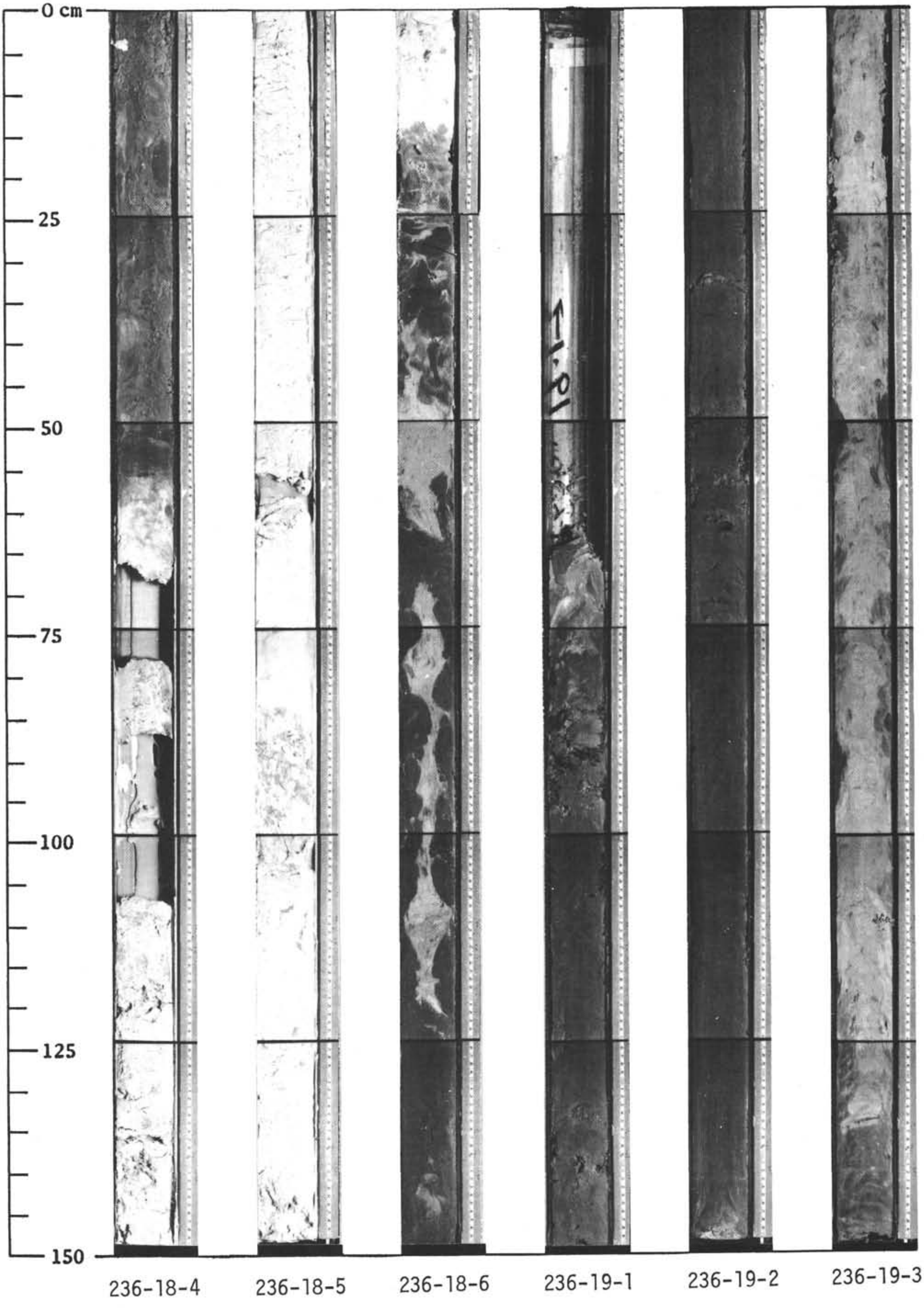

0 cm
25
50
75
100
125
150
236-13-1
236-13-2
236-13-3
236-13-4
236-13-5
236-13-6

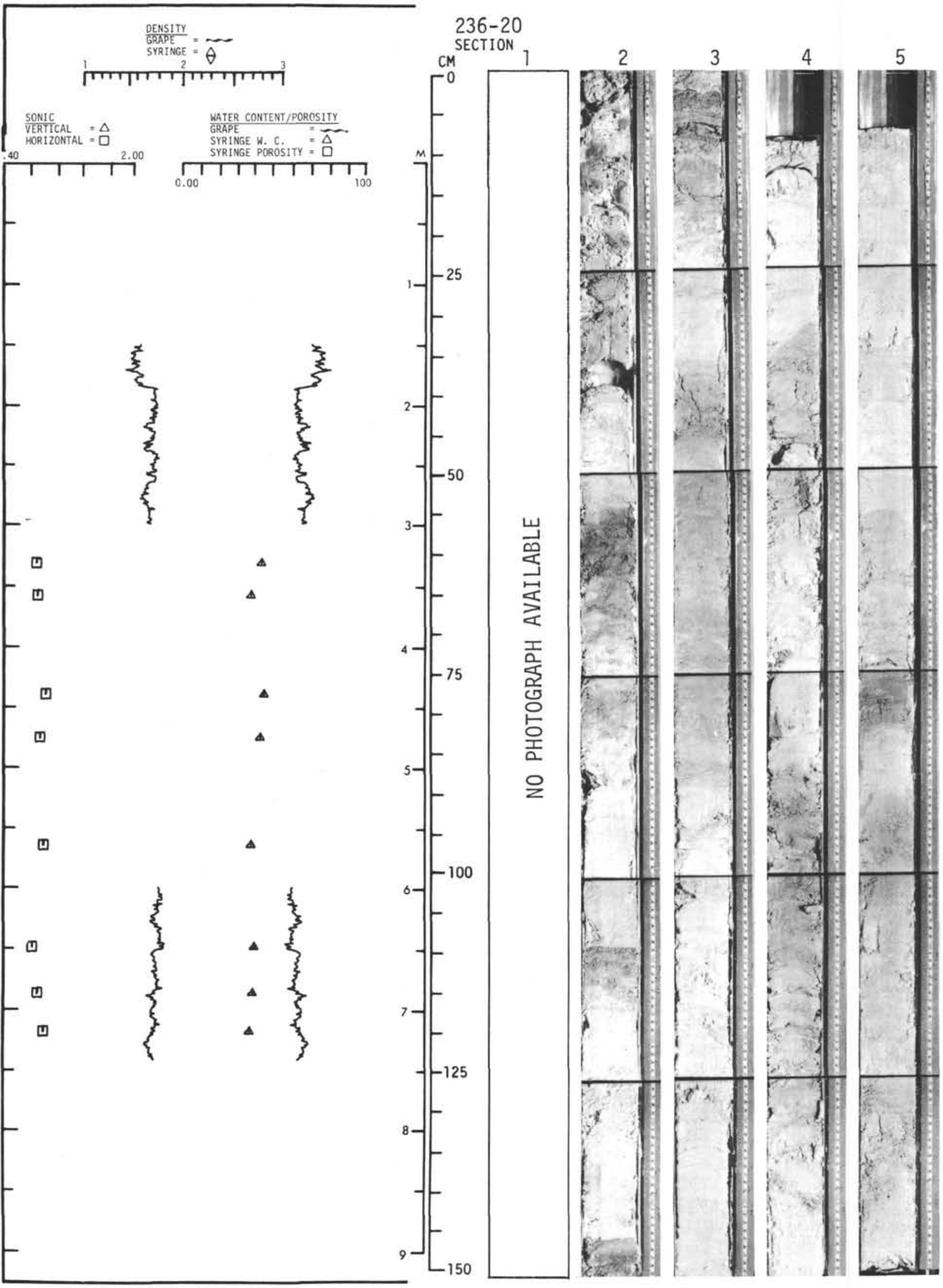

0 cm
25
50
75
100
125
150
236-14-1
236-14-2
236-14-3
236-15-1
236-15-2
236-15-3

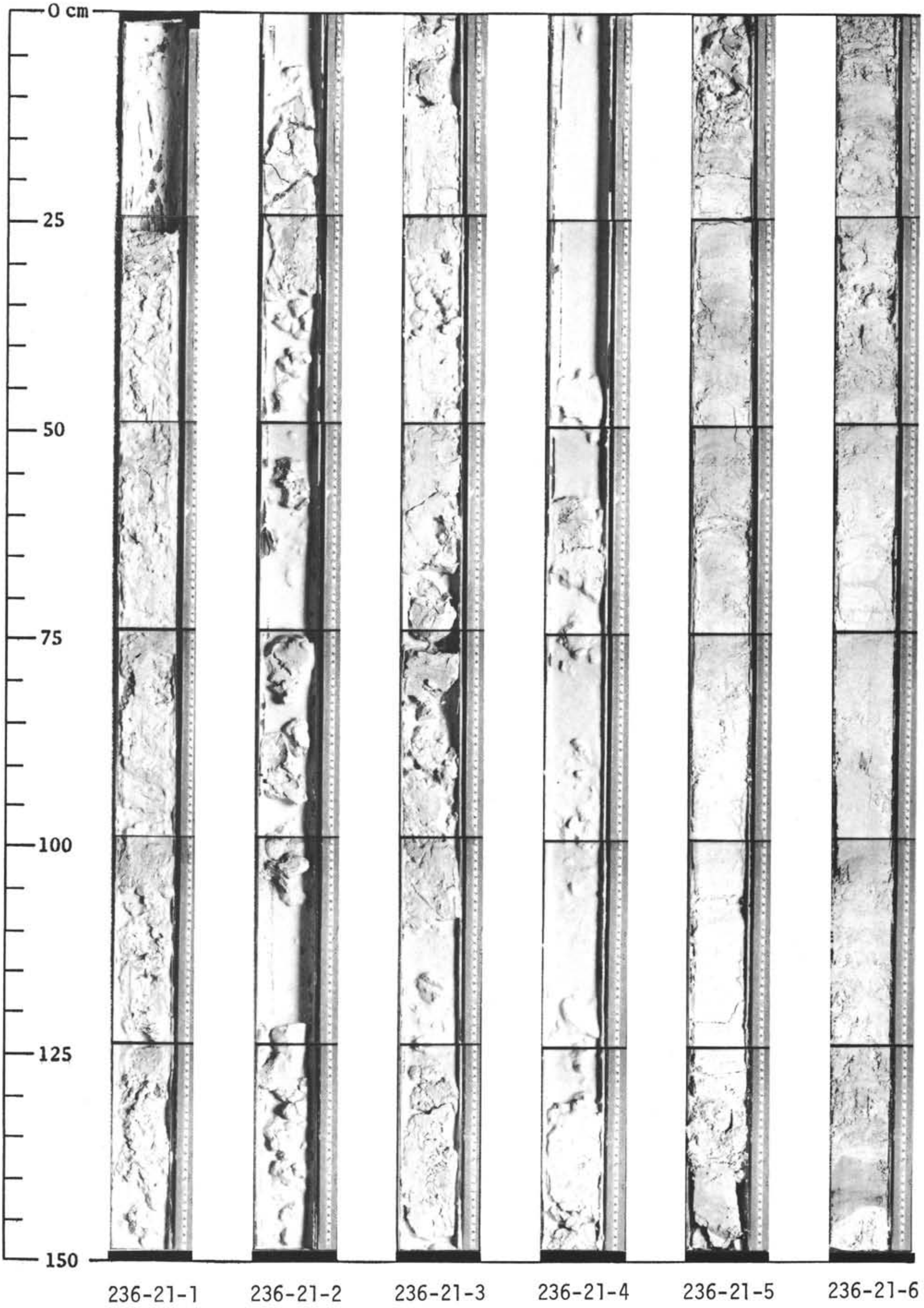

0 cm
25
50
75
100
125
150
236-15-4
236-15-5
236-15-6
236-16-1
236-16-2
236-16-3

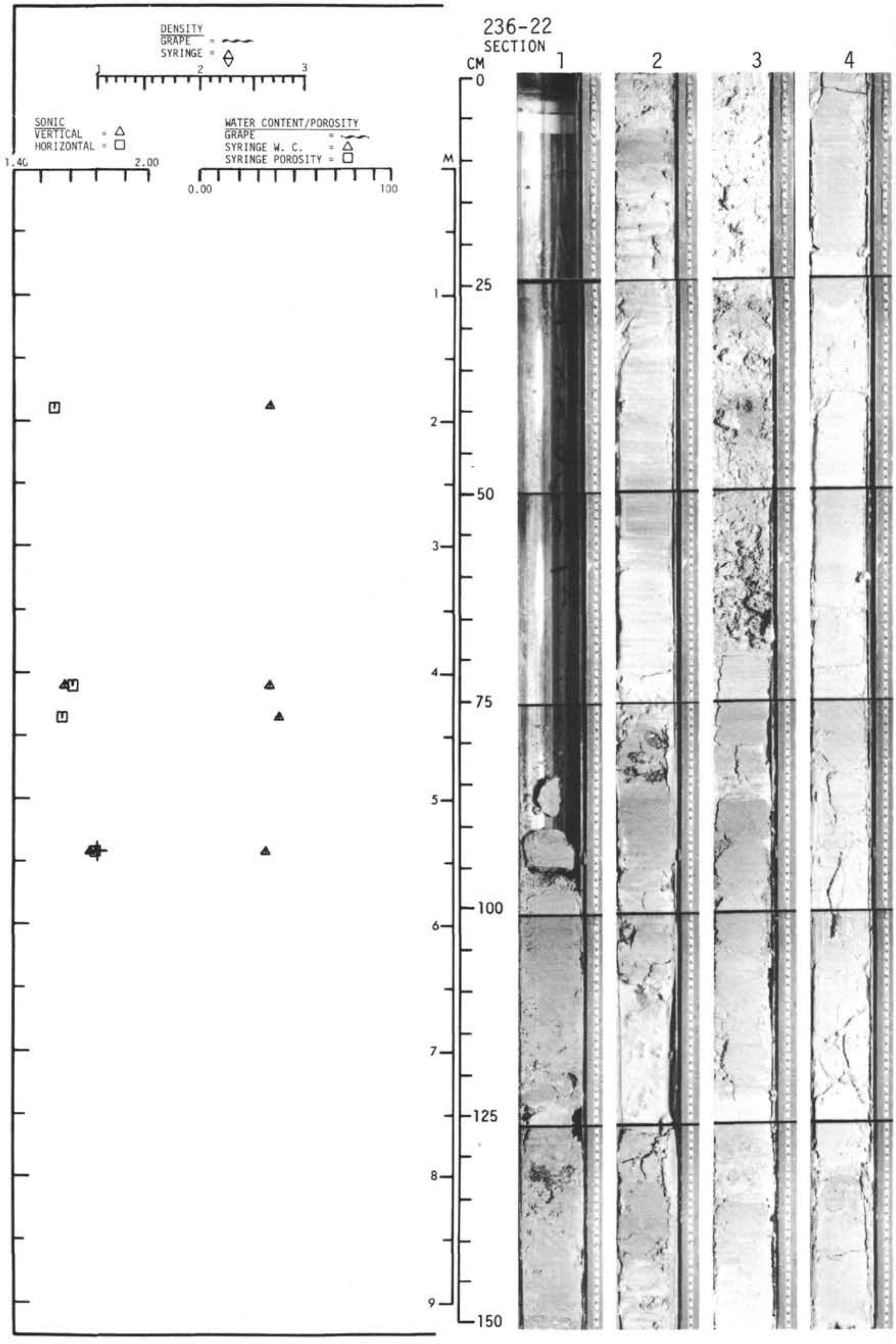

0 cm
25
50
75
100
125
150
236-16-4
236-16-5
236-16-6
236-17-1
236-17-2
236-17-3

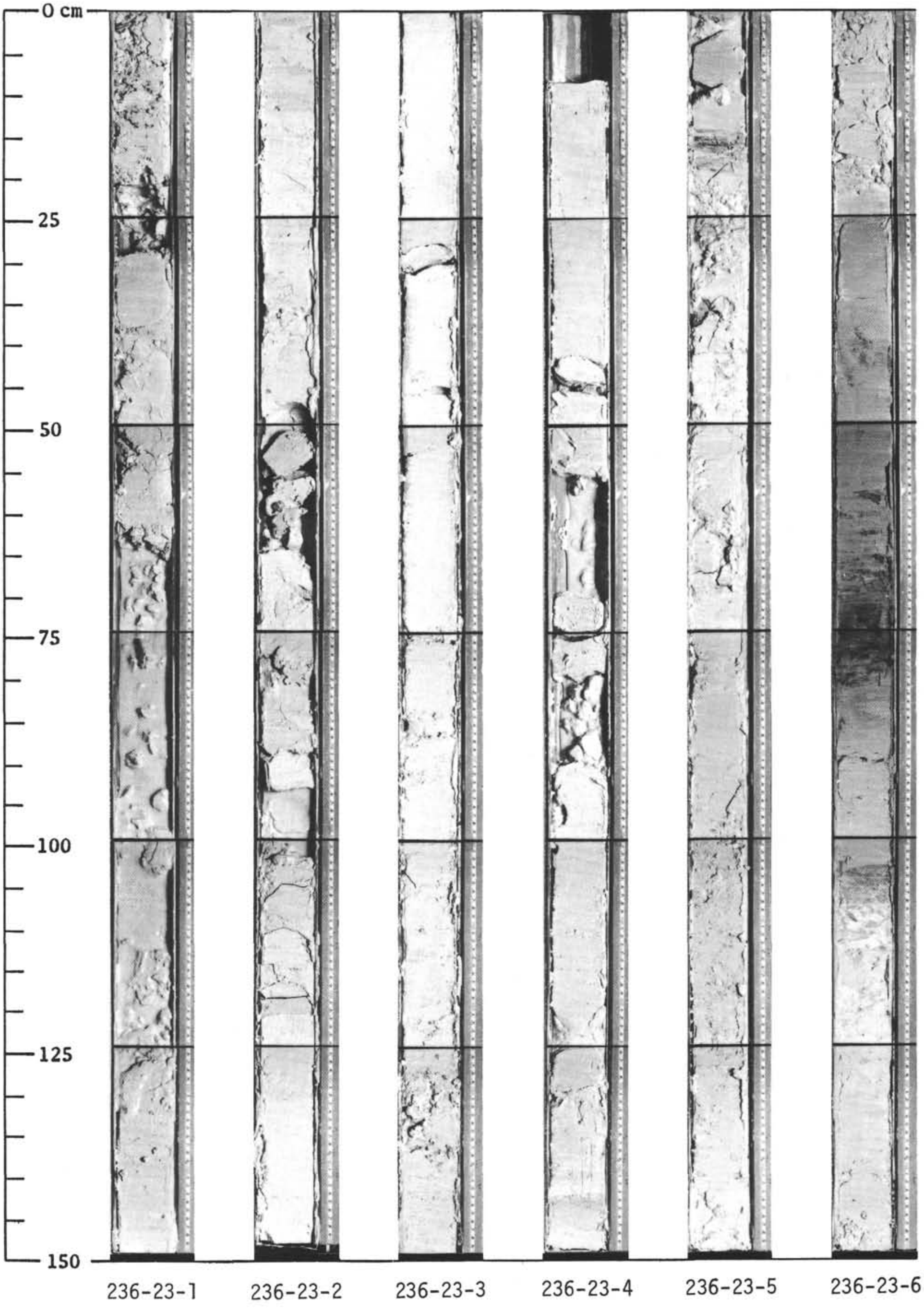

0 cm
25
50
75
100
125
150
236-17-4
236-17-5
236-17-6
236-18-1
236-18-2
236-18-3

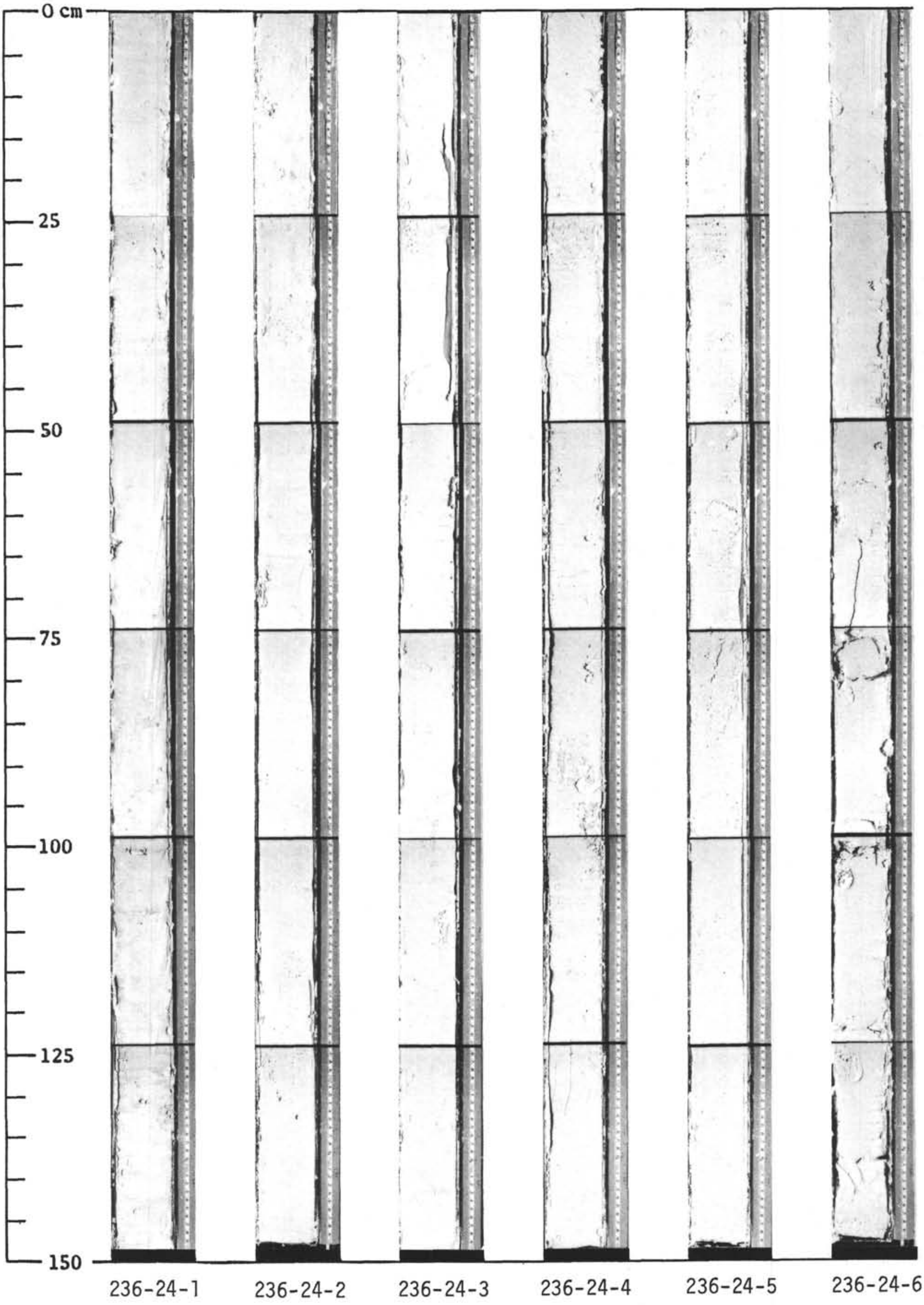

0 cm
25
50
75
100
125
150
236-18-4
236-18-5
236-18-6
236-19-1
236-19-2
236-19-3

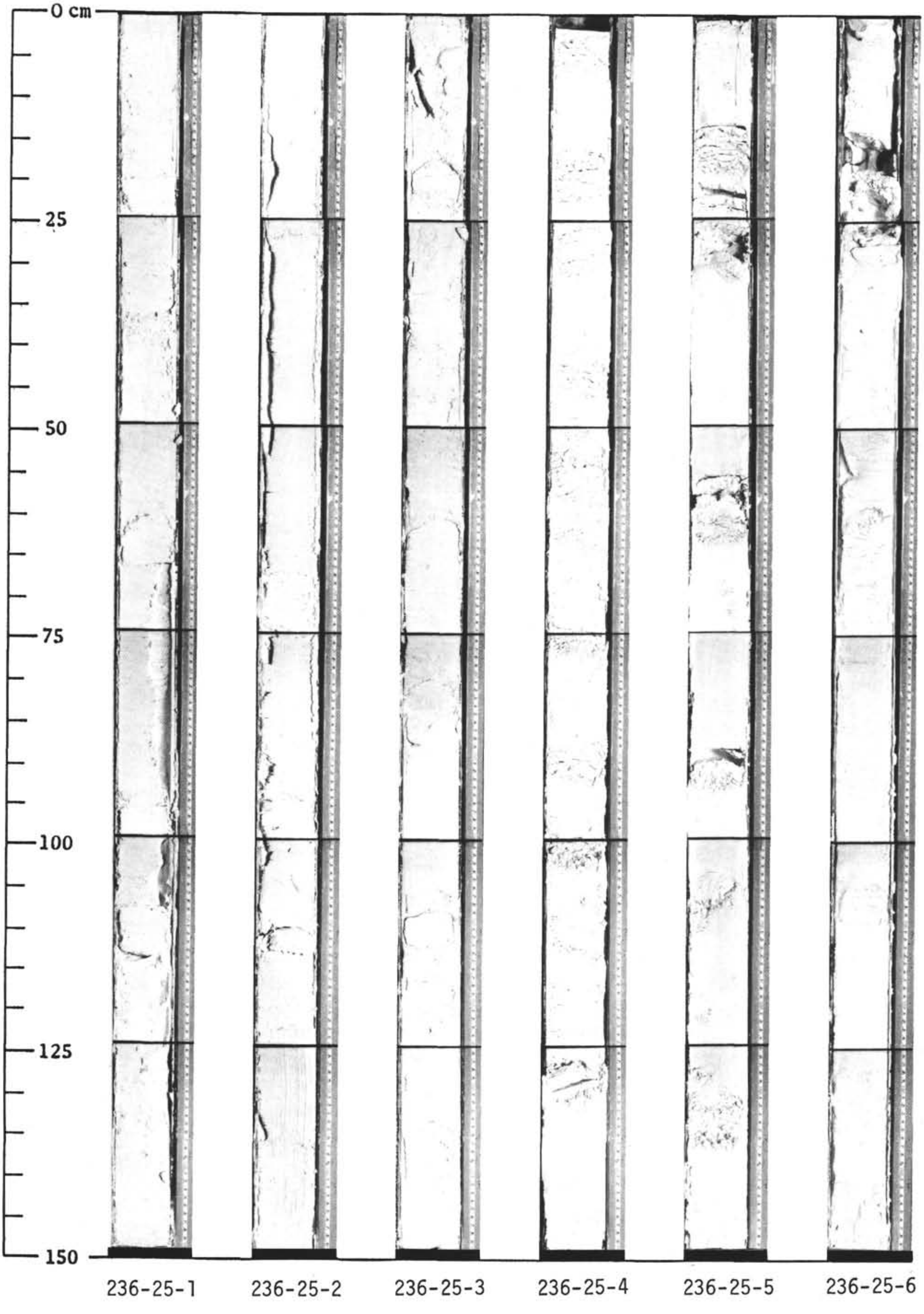

DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL =
HORIZONTAL =
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. =
SYRINGE POROSITY =
0.00
100
M
1
2
3
4
5
6
7
8
9
236-20
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
NO PHOTOGRAPH AVAILABLE

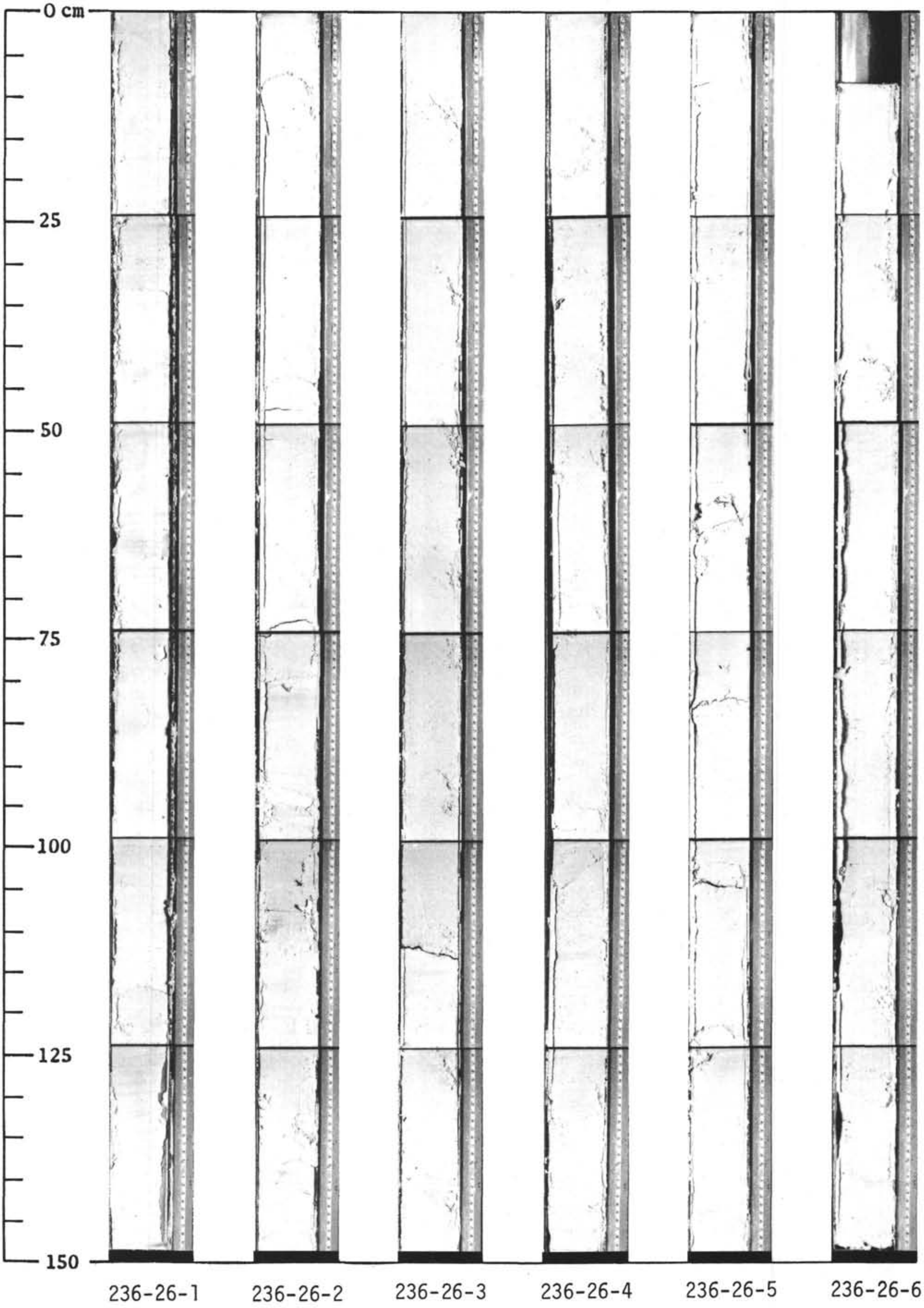

0 cm
25
50
75
100
125
150
236-21-1
236-21-2
236-21-3
236-21-4
236-21-5
236-21-6

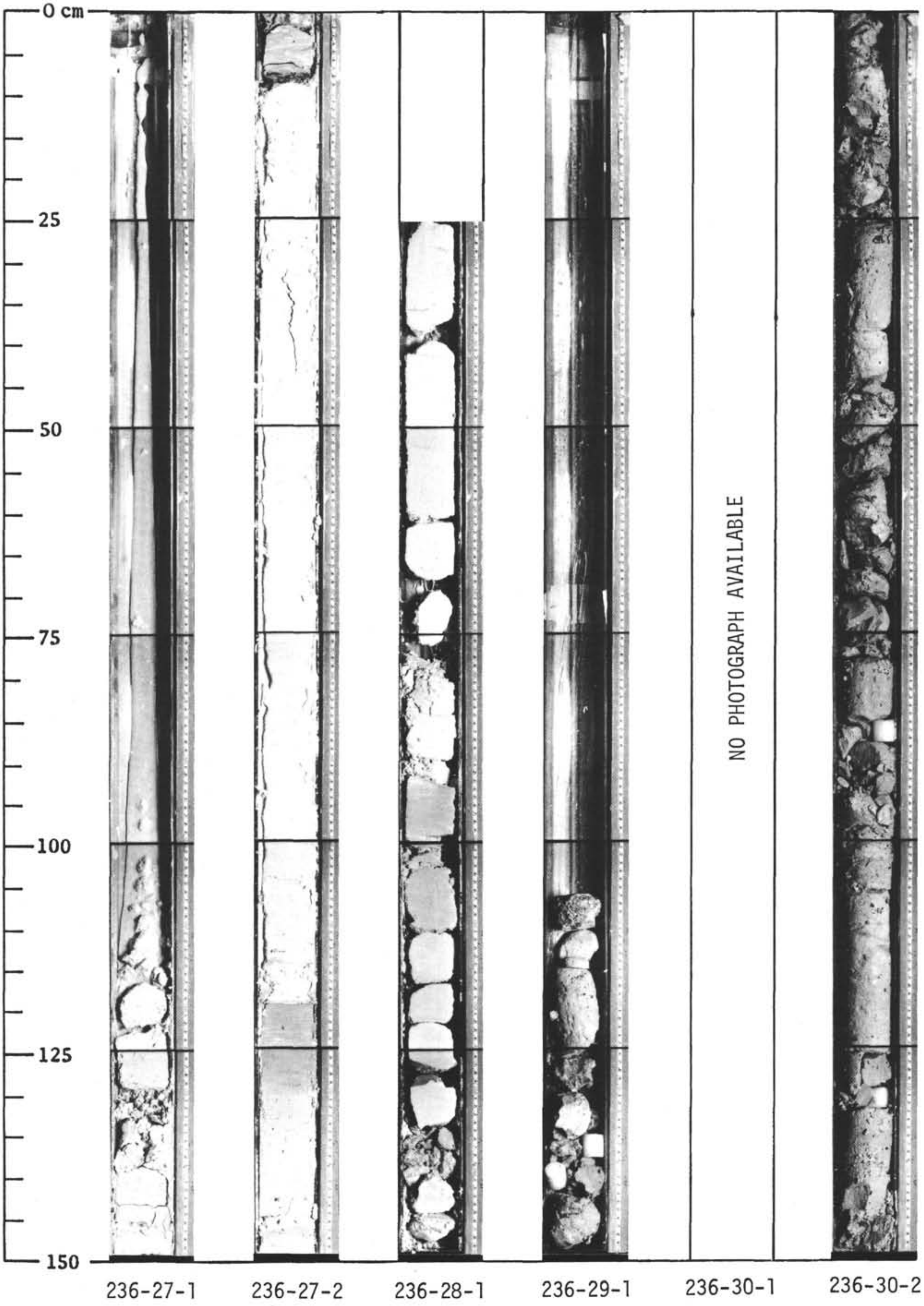

DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = □
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
M
1
2
3
4
5
6
7
8
9
236-22
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4

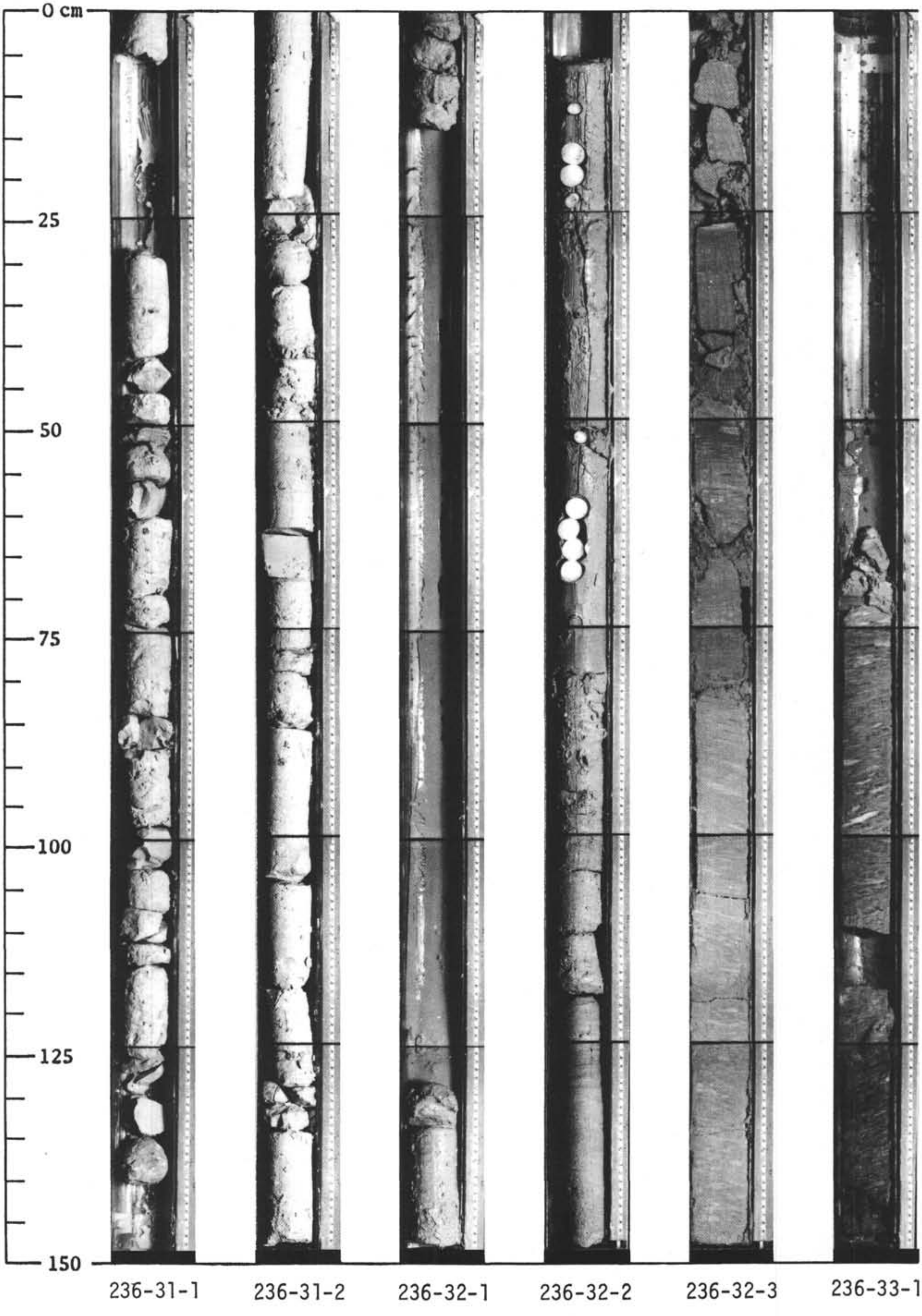

0 cm
25
50
75
100
125
150
236-23-1
236-23-2
236-23-3
236-23-4
236-23-5
236-23-6

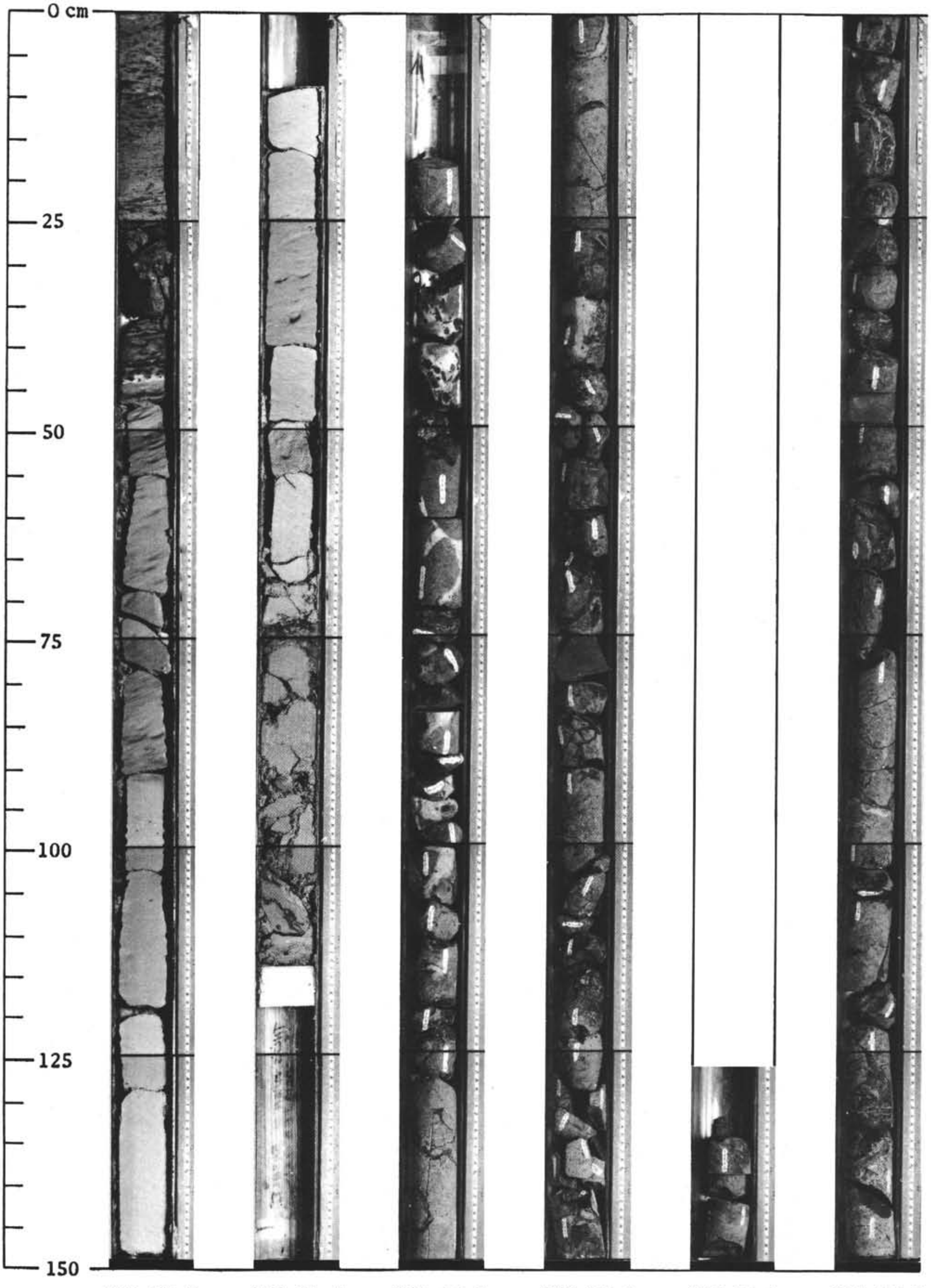

0 cm
25
50
75
100
125
150
236-24-1
236-24-2
236-24-3
236-24-4
236-24-5
236-24-6


0 cm
25
50
75
100
125
150
236-25-1
236-25-2
236-25-3
236-25-4
236-25-5
236-25-6

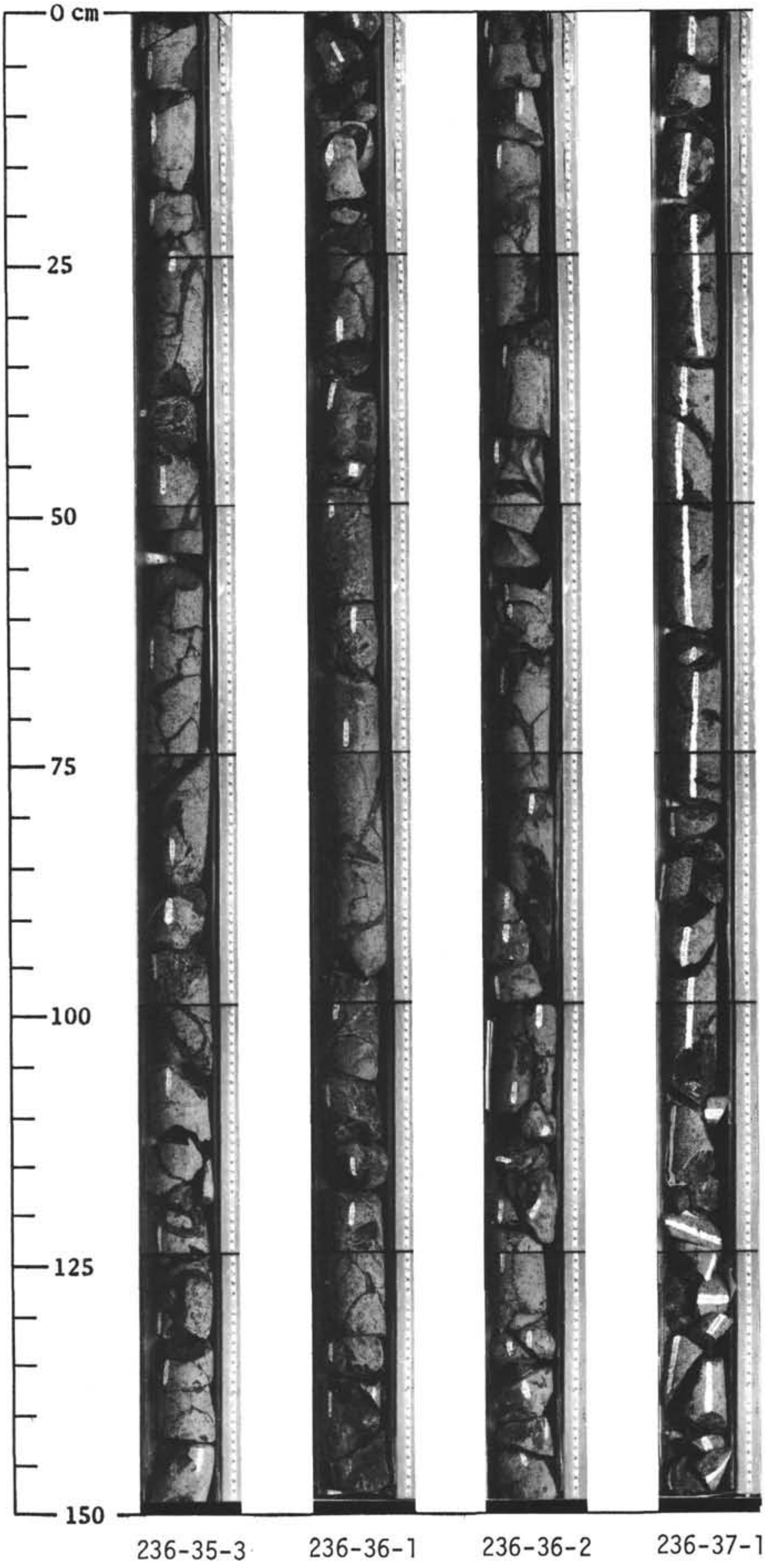

0 cm
25
50
75
100
125
150
236-26-1
236-26-2
236-26-3
236-26-4
236-26-5
236-26-6


0 cm
25
50
75
100
125
150
NO PHOTOGRAPH AVAILABLE
236-27-1
236-27-2
236-28-1
236-29-1
236-30-1
236-30-2


0 cm
25
50
75
100
125
150
236-31-1
236-31-2
236-32-1
236-32-2
236-32-3
236-33-1



236-33-2 236-33-3 236-34-1 236-34-2 236-35-1 236-35-2


0 cm
25
50
75
100
125
150
236-35-3
236-36-1
236-36-2
236-37-1