5. SITE 234

The Shipboard Scientific Party[1]

SITE DATA

Date Occupied: 19 May 1972

Date Departed: 21 May 1972

Time on Site: 56 hours

Position:
Latitude: 04°28.96′N
Longitude: 51°13.48′E

Water Depth: 4721 corrected meters (echo sounding)

Bottom Felt At: 4738 meters (drill pipe)

Penetration: 247 meters

Holes Drilled: 2

Number of Cores: 16

Total Length of Cored Section: 142.5 meters

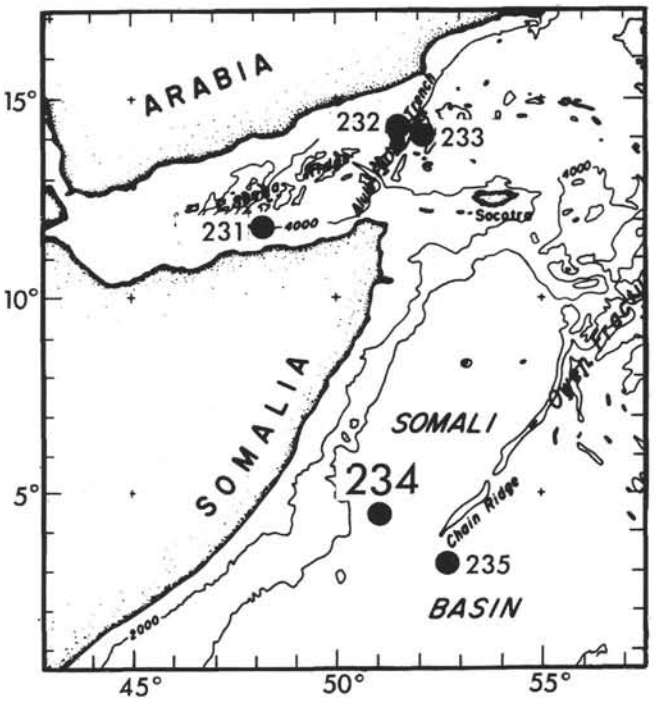
Total Core Recovered: 90.1 meters

Acoustic Basement: Not reached

Age of Oldest Sediment: Oligocene

Principal Results: This site is located on a ridge flanking the western margin of the abyssal plain of the northwest Somali Basin. Two holes were drilled using the same beacon, but 234A aborted after a single core. Hole 234 was cored intermittently to 247 meters with 142.5 meters cored and 90.1 meters recovered. Of 15 cores, it was possible to date eight using nannofossils, but the section was almost barren of foraminifera. The hole did not reach basement. The sedimentary section is mainly blue green gray nanno clay and nanno ooze. The uppermost nanno ooze contains manganese nodules and is Pliocene in age. Deeper sections contain volcanic glass, detrital minerals, and pyrite. The section from 161.5 to 196.4 meters is upper Oligocene. The bottom core, at 247 meters, is tentatively dated as lower Oligocene. Hole 234A was abandoned when the drill string repeatedly seized.

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



BACKGROUND AND OBJECTIVES (SITES 234 AND 235)

Northwest Somali Basin

The northwest portion of the Somali Basin, between the Seychelles Archipelago and the African coast, is an abyssal plain bounded on the west and north by the African continental slope, on the east by southward trending Chain Ridge, and on the south, in the subsurface, by shallow basement structure that apparently is a buried continuation of Chain Ridge. The ridge is possibly also a southerly extension of Owen Fracture Zone, a transform fault.

The sediments ponded by these structures are in general uniformly layered, and divided into upper and lower sequences by an acoustically transparent member. Presumably, the stratified sequences are in part turbidites. The top of the lower sequence is a prominent reflector traceable throughout the basin.

A rock sample dredged from the east flank of Chain Ridge (Bunce et al., 1967) has the composition of a typical "oceanic" volcanic rock and a K-Ar age of 89.6 ± 4.5 m.y., which should be considered a minimum age. While the reflection profiles shown the basement material to the east as being obviously the same as that forming Chain Ridge, it is difficult to draw the same conclusions regarding that to the west, beneath the almost 3.0 seconds of ponded sediment. The basement here may also be older. The topographically rough basement east of Chain Ridge lies

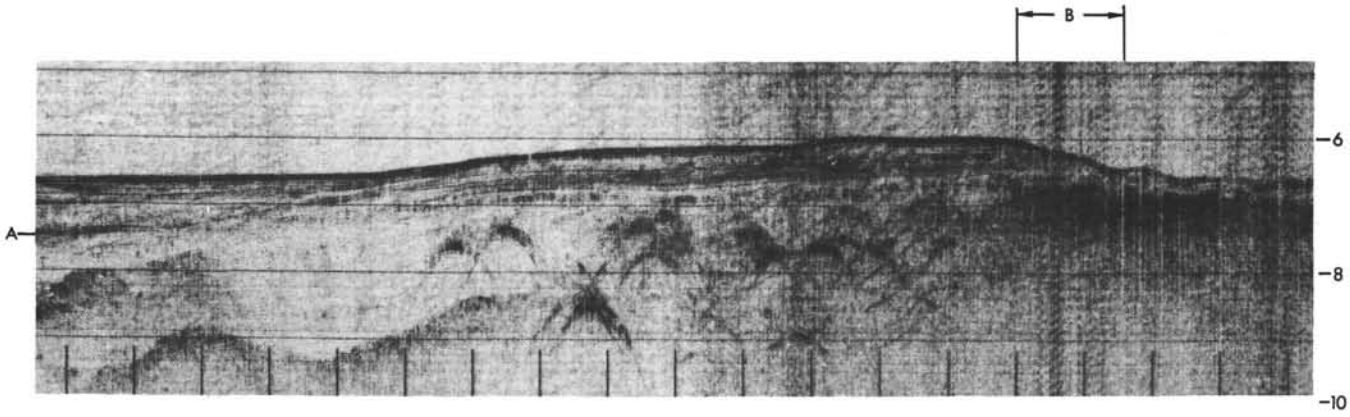


Figure 1. *Site survey profile,* R/V Chain *100, April 1971. Sparker (about 90,000 j) and airgun (40 in^3) fired simultaneously, 10 sec repetition rate; two summed hydrophone arrays (Woods Hole Type AQ-1); filter bandpass 37.5-77 Hz.* B *indicates site area;* A *, reflector of interest. Increased background noise over right side of figure is supertanker passing nearby.*

beneath a very slightly deeper sea floor and is not as deep as that to the west. The assumed turbidites are the same depth on the two sides of the ridge, suggesting it may mark an age discontinuity.

On the western border of the abyssal plain, the sediment sequence onlaps the flanking ridge (Figure 1) so that the deeper older sediments, including that forming the distinctive basin reflector, crop out, offering a drilling target.

The drilling objectives in this area were to obtain samples of sediments and basement east and west of Chain Ridge in order to compare them, to core, identify, and date the lithologic units overlying the basement in order to obtain information on the turbidites, to identify, if possible, the source areas of clastic material on the African margin and to obtain a low-latitude faunal assemblage to complement that to be obtained on other sites. East of the Chain Ridge, identification and dating of the material of the acoustically transparent layers was accomplished. Basement samples were to be obtained deep enough to recover unweathered material in quantity for use in petrologic examination and dating.

By obtaining these various dates and chronologies, we should be able to determine the significance, if any, of Chain Ridge in the tectonic history of the basin, the possible sources of the sediments to its east and west, and the role of this northwest basin in the sea-floor spreading history of the western Indian Ocean.

OPERATIONS

Near-Site Activities

Site 234, western of a pair of sites designed to sample the westernmost portion of the Northwest Somali Basin, lies about 175 km west of Chain Ridge. R/V *Vema* (Lamont-Doherty Geological Observatory) has crossed the area in 1963 and R/V *Chain* (Woods Hole Oceanographic Institute) crossed, first in 1964 (Bunce et al., 1967) and then early in 1971 to conduct a drilling site survey (Figure 1). *Glomar Challenger* approached the region from north-northeast to cross a knoll just northwest of the proposed site (24-4 on Figure 2) and to complement the primarily east-west and north-south line of *Chain*. No truly suitable locality correlative in basement depth and overlying structure to that based on the *Chain* survey record (Figure 1) was found near 24-4. A brief reconnaissance to the east turned into a long detour because of maneuvering constraints imposed by the presence of an oncoming supertanker.[2]

Enroute east, however, a favorable site was encountered, and *Glomar Challenger* returned, slowing to 4 kn to get a documenting reflection. The beacon was dropped at Site 234 (Figure 2) in a water depth of 4721 meters (corrected). It is 7.2 nmi east-southeasterly of 24-4, on a sedimentary apron bordering the knoll (Figure 3). The seismic streamer and magnetometer were retrieved and the vessel doubled back over the beacon to commence drilling operations. Figure 2 incorporates the sounding data of *Chain's* 1971 pattern and that of *Glomar Challenger.*

On leaving Site 234, *Glomar Challenger* ran west-northwest for a short distance to stream gear and reversed heading to pass near the beacon on a southeasterly course. About five miles southeast of Site 234, a sonobuoy was dropped to set up a wide-angle reflection profile. A plague of troubles with airguns and recorders forced its termination after half an hour, and *Glomar Challenger* departed the region for Chain Ridge and Site 235.

Drilling Program

The water depth from drill rig floor to mud line at Site 234 was 4738 meters by drill pipe measurements, and basement was estimated at 600 meters below the mud line; in order to save time, only certain intervals were cored.

[2]Site 234, and to a lesser degree Site 235, lay within or very near the Cape of Good Hope–Persian Gulf shipping lanes.

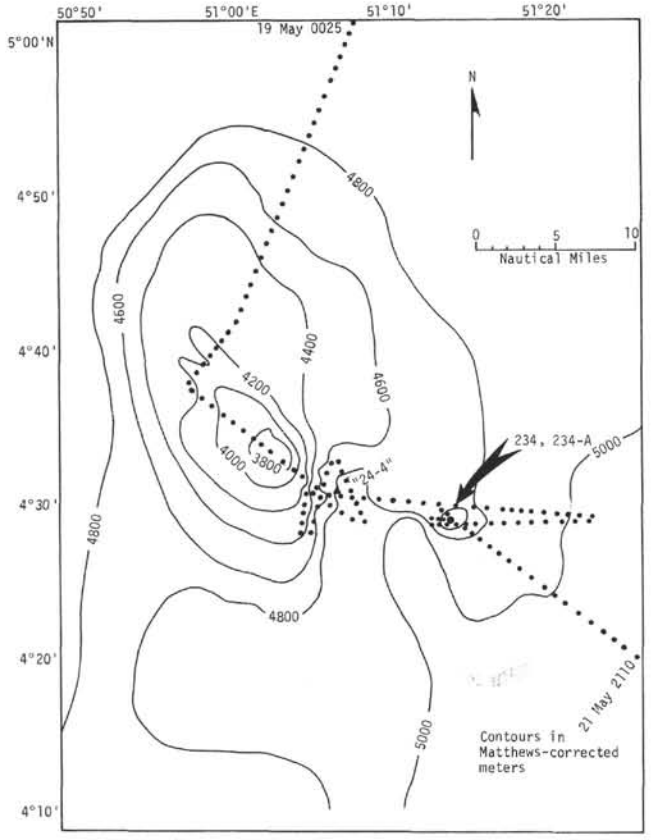


Figure 2. *Site survey track of* Glomar Challenger *showing location of prospective site 24-4 and Site 234.*

From 4899.5 to 4909.9 meters (Core 10), there was a noticeable increase in the drill pipe torque and pump pressure. At 4937.0 meters, the drill string was sticking on all connections or anytime the hole was not being pumped. To help free the pipe and clean the hole, 30 barrels of mud was circulated, but this did not improve hole conditions. After freeing the stuck drill pipe a number of times, the hole was abandoned at 4985 meters, for one or all of the following: (1) the clay was swelling, causing the bit and bottom hole assembly to stick, (2) mud cake on bottom hole assembly, and (3) crooked hole, causing tool joints to hang up in a key seat. There were 104.5 meters drilled, 142.5 meters cored, and 90.1 meters recovered (Table 1).

Hole 234A was drilled from 4738.0 to 4975.5 meters. To drill a straight hole, both pumps were used. With 1750 psi of pump pressure and the drill string turning at 60 rpm, the bit would not slide when different formations were encountered. Only one core was attempted at this hole. Core 1 was from 4975.5 to 4985.0 meters with 1.4 meters recovery. The drill string was stuck while retrieving the core barrel. The hole was abandoned at 5015 meters after 70 barrels of mud failed to improve conditions. When the drill string was retrieved, a 1/2" mud cake was found to cover the bottom hole assembly. All plans for drilling on the west side of the basin were dismissed since the swelling clay plus the BHA balling up would have resulted in a stuck drill string. A total of 9.5 meters was cored, 1.4 meters recovered, and 237.5 meters drilled (Table 1).

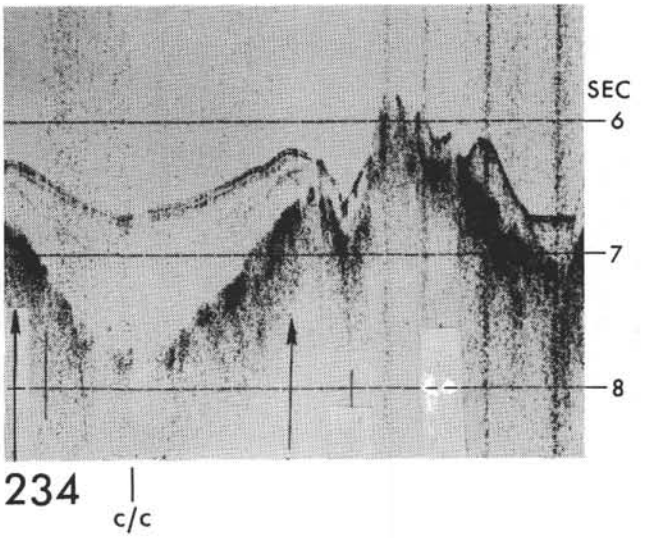


Figure 3. *Site 234; approach, final survey, and site. Arrow on right marks first crossing, followed by course and speed changes to final position (second arrow); c/c (center) indicates major course change, responsible for apparent valley due to length of hydrophone.*

LITHOLOGIC SUMMARY

At Site 234, coring and drilling were carried out from the sediment surface to a depth of 247 meters. Fifteen cores (spot coring) were obtained from Hole 234 and only one from Hole 234A. Both holes had to be abandoned before reaching basement because of difficult drilling conditions in the stiff, clayey sediments. The sediment can be grouped into six lithologic units (Table 2).

Unit 1 (0.0-9.5 m; Core 1)

Nanno clay and nanno ooze throughout. At the surface sediments are moderate yellowish brown changing with depth to grayish orange, dusky yellow, and in the lowermost part of the unit, to grayish green. The following components were found in the smear slides in decreasing abundance: calcareous nannofossils, clay minerals, micarb, terrigenous detrital minerals (mainly quartz and a few heavy mineral grains), traces of volcanic glass, dolomite rhombs, siliceous fossils, and foraminifera (very fragmented). In addition, X-ray data indicate the presence of feldspar and mica. Manganese nodules (up to 7 X 6 X 6 cm) were found at the top of the section.

Unit 2 (9.5-38.0 m; Cores 2, 3, 4)

The sediments consist of grayish-green to dusky yellow-green clay with black pyritic streaks throughout. They contain 80-90 percent clay minerals, traces of detrital terrigenous minerals (quartz, feldspars, mica, heavy minerals), pyrite, micronodules, volcanic glass, and fish remains. The whole of Unit 2 is mottled.

Unit 3 (66.5-85.5 m; Cores 5, 6)

This unit consists of clay and is pale green to pale olive and dusky yellow green. The main components are

TABLE 1
Coring Summary – Site 234

Core	Date (May 1972)	Time	Depth Below Sea Floor (m)	Depth From Drill Floor (m)	Cored (m)	Recovered (m)	Recovered (%)
Hole 234							
1	20	0101	0.0-9.5	4738.0-4747.5	9.5	9.5	100
2	20	0225	9.5-19.0	4747.5-4757.0	9.5	6.7	70
3	20	0341	19.0-28.5	4757.0-4766.5	9.5	8.7	92
4	20	0456	28.5-38.0	4766.5-4776.0	9.5	8.1	85
Drilled (4776.0-4804.5)							
5	20	0643	66.5-76.0	4804.5-4814.0	9.5	3.9	41
6	20	0804	76.0-85.5	4814.0-4823.5	9.5	8.0	84
Drilled (4823.5-4852.0)							
7	20	1115	114.0-123.5	4852.0-4861.5	9.5	9.4	99
8	20	1258	123.5-133.0	4861.5-4871.0	9.5	3.4	36
Drilled (4871-4890)							
9	20	1445	152.0-161.5	4890.0-4899.5	9.5	3.8	40
10	20	1615	161.5-171.0	4899.5-4909.0	9.5	5.1	53
11	20	1750	171.0-180.5	4909.0-4918.5	9.5	3.8	40
12	20	1930	180.5-190.0	4918.5-4928.0	9.5	6.8	71
13	20	2110	190.0-199.5	4928.0-4937.5	9.5	7.5	78
14	20	2243	199.5-209.0	4937.5-4947.0	9.5	1.9	20
Drilled (4947-4975.5)							
15	21	0210	237.5-247.0	4975.5-4985.0	9.5	3.7	39
Hole 234A							
1	21	0949	237.5-247.0	4975.5-4985.0	9.5	1.4	15
Drilled (4985-5015) – abandoned							

TABLE 2
Lithologic Units – Site 234

Depth Below Sea Floor (m)	Unit	Lithology	Thickness (m)	Cores
	1	Nanno clay to nanno ooze	9.5	1
9.5				
	2	Clay	29.0	2-4
38.0				
	3	Clay to nanno clay	19.0	5-6
85.5				
	4	Clay	47.5	7-9
161.5				
	5	Clay to nanno ooze	28.5	10-12
190.0				
	6	Clay	67.0	13A
247.0				

calcareous nannofossils, clay minerals in varying high percentages, traces of terrigenous and detrital minerals including quartz, mica, and heavy minerals, volcanic glass, pyrite, and siliceous fossils. Black pyritic streaks and mottles occur throughout.

Unit 4 (114.0-161.5 m; Cores 7, 8, 9)

This unit is composed of clay with some quartz-rich horizons. The color is light to medium bluish gray, pale to grayish green, and greenish gray. The sediment is composed mainly of clay minerals with traces of detrital terrigenous minerals (quartz, mica, heavy minerals), volcanic glass, palagonite, fish remains, dolomite rhombs, micronodules, pyrite, black pyritic streaks, and is mottled throughout. Smear slide taken at 234-9-1, 82 cm shows a quartz nanno-rich clay with scarce siliceous fossils.

Unit 5 (161.5-190.0 m; Cores 10, 11, 12)

This unit consists of clays and nanno oozes, light bluish gray, greenish and olive in color. The main components are calcareous nannofossils and clay minerals with traces of quartz, feldspars, mica, heavy minerals, dolomite rhombs, micronodules, zeolites, pyrite, and siliceous fossils. Zeolitic sand layers at 173 meters and 174 meters are notable. Black pyritic streaks and mottling occur throughout.

Unit 6 (190.0-247.0 m; Cores 13, 14, 15, 1A)

Light to medium bluish, greenish, olive-gray, and olive-black clay composed mainly of clay minerals and traces of terrigenous detrital minerals, volcanic glass, pyrite, micronodules, dolomite rhombs, zeolites, and fish remains make up the bulk of Unit 6. The lower part of this unit contains 5-10 percent calcareous nannofossils. Black pyritic streaks and mottles are found throughout.

Conclusions

1. Unit 1 represents the normal distal hemipelagic nanno clay to nanno ooze facies, deposited close to the calcium carbonate compensation depth (CCD). Manganese nodules are indicative of an oxidizing environment and low sedimentation rates.

2. Units 2 through 6 are dominated by clay minerals of unknown origin, while the bulk of the fossils ($CaCO_3$ and SiO_2) seem to be dissolved (with the exception of some nanno-bearing to nanno-rich horizons in Units 3, 5, and 6).

3. Small percentages of glass in nearly all smear slides point to an important volcanic input to this area.

4. Nowhere in the sediments of Site 234 were indications of a high input of terrigenous detrital or of shallow-water material found nor were there any indications of turbidite deposition. This suggests that the depositional area of these sediments was always far from land, and always on a topographic high that was not reached by turbidity currents.

BIOSTRATIGRAPHIC SUMMARY

Introduction

The paucity of microfossils in the sediments recovered at Site 234, in a water depth of 4738 meters, makes age assignment difficult. Poorly preserved foraminifera showing extensive signs of dissolution are present in the upper 10 meters; they are rare or absent below this level. Moderately to poorly preserved nannofossils are present in a number of horizons but are absent in others. Poorly to moderately preserved radiolarians, mostly pyritized, are present in the upper 38 meters and almost totally absent below. This site must have been close to the CCD throughout the time of deposition of the recovered sediments.

The upper 196.4 meters of the sequence range from late Oligocene to Pliocene. The lower 45.6 meters could not be dated; however, assuming a constant sediment accumulation rate for the lower part of the section, the lowermost sediments at 242 meters would be of early Oligocene age (approximately 34 m.y.). Fossil zonations and age assignments are summarized on the site summary form at the end of this chapter.

Calcareous Nannoplankton

Core 1, Section 1, recovered a poor assemblage belonging to the *Reticulofenestra pseudoumbilica* Zone with a few specimens of *Reticulofenestra pseudoumbilica* together with *Discoaster brouweri, D. pentaradiatus, D. surculus,* and *D. variabilis.* Section 6 of the same core belongs to the late Miocene *Discoaster bellus* Zone with *Discoaster neohamatus, D. bellus, D. calcaris,* and *D. asymmetricus.* Cores 2, 3, and 5 lack nannofossils. Core 5 is middle Miocene with a poor assemblage of *Sphenolithus heteromorphus, Cyclicargolithus floridanus,* and *Discoaster exilis,* which are characteristic of the *Sphenolithus heteromorphus* Zone. Cores 6, 7, and 8 are barren of nannofossils. Core 9 contains a poor assemblage belonging to the early Miocene *Triquetrorhabdulus carinatus* Zone with *Triquetrorhabdulus carinatus, Discoaster deflandrei,* and rare, small *Sphenolithus belemnos.* Cores 10 and 11 yield a similar assemblage which also includes *Reticulofenestra abisecta* and is thus assigned to the upper Oligocene *Reticulofenestra abisecta* Zone. Recovered in Core 12 was the *Sphenolithus ciperoensis* Zone with rare *Triquetrorhabdulus carinatus, Sphenolithus ciperoensis,* and *Reticulofenestra bisecta.* Core 13 contains only long ranging species like *Reticulofenestra abisecta, R. bisecta,* and *Discoaster deflandrei.* It cannot be assigned to any zone but is of late Oligocene age. Core 15 yields only *Cyclicargolithus floridanus* and cannot be dated.

All assemblages are strongly etched and only solution resistant species are common. This site must have been close to the CCD throughout the time of deposition of the recovered sediments.

Foraminifera

Only Core 1 (lithologic Unit 1) yielded a significant amount of coarse sediment fraction (>63μ). Poorly preserved foraminifera are common in the horizons 0-10 cm, 2.26 meters, and 9.5 meters, and are rare in the other horizons of Core 1. They show extensive signs of dissolution, being poorly diversified and highly fragmented, and including only species with robust tests resistant to solution. The remaining components of Core 1 coarse fraction include quartz grains, mica flakes, sponge spicules, fish teeth, echinoderm debris, and radiolarians.

The planktonic assemblage in the interval of Core 1, Section 1 to Section 4, contains modern species ranging back at least to the Pliocene. No diagnostic species were found for differentiation between Quaternary and Pliocene. However, the presence of primitive forms of *Sphaeroidinella dehiscens* indicate a probable early Pliocene age (N.20-N.19). The planktonic faunas from Core 1, Sections 5 and 6 appear to be lowermost early Pliocene (N.18) as indicated by the presence of *Sphaeroidinellopsis* spp., *Globorotalia tumida tumida, G. tumida plesiotumida, Globoquadrina altispira,* and *Globigerina nepenthes.*

Below Core 1, no residue coarser than 63 μ was recovered except in a few horizons. The latter yielded a very small amount of coarse fraction containing benthic foraminifera, unidentifiable planktonic foraminiferal debris, quartz grains, fish teeth, sponge spicules, and radiolarians, often pyritized.

Benthic foraminifera consist mainly of deep-water calcareous species. Because of their lower susceptibility to solution than planktonic species, they constitute a large percentage of the foraminiferal fauna. They comprise 4 to 28 percent of the total foraminiferal fauna in Core 1, and 37 to 93 percent in the other horizons of the section which yielded calcareous material (2, CC; 5, CC; 8, CC; 9, CC; 10-3, 24 cm; 10, CC; 13, CC).

Radiolarians

Radiolarians are poorly preserved to moderately preserved, most pyritized, in all samples examined from 234-1-1 through 234-4-6. They are absent from samples examined from 234-5-3 through 234-15-3 with the exception that a sample from 234-7-1 contains few, poorly preserved radiolarians, and 234-15-3 contains very rare, poorly preserved, and pyritized radiolarians. The assemblages are not adequate for stratigraphic interpretation. No samples were examined from Hole 234A.

SEDIMENT ACCUMULATION RATES

Average sediment accumulation rates at Site 234 were calculated as follows:

Series	Thickness (m)	Average Accumulation Rate (m/m.y.)
Pliocene-Upper Miocene	11.0	1.0
Middle Miocene	60.0	20.0
Lower Miocene	90.5	10.6
Upper Oligocene	34.9	7.0

The Pliocene to upper Miocene sediments at the top of the section consist of slowly accumulating, well-oxidized, calcareous sediments grading down into greenish, more reduced deposits. The slow sedimentation was conducive to manganese nodule formation at the sediment surface; this was confirmed by the occurrence of a large nodule in Core 1. Lower and middle Miocene sediments, which consist of alternating clay and calcareous muds with minor amounts of pyrite, palagonite, volcanic glass, and terrigenous materials, accumulated more rapidly, with an average rate of 13.0 m/m.y.

The late Oligocene rate is a minimum value, as the base of the epoch was not determined. However, assuming a continuous rate of accumulation of 7 m/m.y. for the lower sediments, the maximum age at the base of the section (242 m) would be early Oligocene (approximately 34 m.y.).

PHYSICAL PROPERTIES

The reader is cautioned that due to the intermittent coring procedure used at Site 234, many of the recovered cores (particularly the uppermost of each series) are markedly disturbed. Thus, data presented here are restricted to those cores, and sections most representative of fairly undisturbed sediments.

Bulk Density and Porosity

The bulk density and porosity of the 247 meters of nanno ooze and various clays increases from 1.48 to 1.83 g/cm^3 and decreases from 73.1 to 52.7 percent, respectively, from near the sediment-water interface to the bottom of the hole (Figure 4). Significant variations occur throughout the 247-meter depth of the hole. However, the gaps of data for the uncored sections preclude any definite conclusions concerning the physical properties.

The 1.85 g/cm^3 bulk density value and corresponding 50.9 percent porosity value in Core 1, at approximately 7 meters depth, defines a large manganese nodule (7 X 6 X 6 cm). Otherwise Units 1 and 2 of the lithologic description are characterized by a rather uniform 1.50 g/cm^3 bulk density and corresponding 71.8 percent porosity. A bulk density and porosity change occurs somewhere between Cores 4 and 9 (35 to 157 m). However, since few control points fall within this interval, no definite conclusions should be made. It appears that one change occurs at approximately 40 to 60 meters and another at 158 meters.

Lithologic Units 5 and 6 (161 to 247 m) are represented by bulk densities of 1.69 to 1.83 g/cm^3 and porosities ranging from 60.5 to 52.7 percent.

Sonic Velocity

The velocity profile of the nanno ooze and various clays has a uniform increase from 1.48 km/sec near the sediment-water interface to 1.57 km/sec at 245 meters (Figure 4). The velocity of 1.88 km/sec at approximately 7 meters is representative of the aforementioned manganese nodule. No potential reflection surfaces may be discerned from the velocity profile.

Acoustic Impedance

The acoustic impedance profile increases from 2.19 X 10^5 g/cm^2 sec near the sediment-water interface to 2.85 X 10^5 g/cm^2 sec at 245 meters. The manganese nodule is characterized by an acoustical impedance of 3.48 X 10^5 g/cm^2 sec. An acoustical impedance mismatch sufficient to cause a reflection possibly exists at 40 to 80 meters and also at approximately 185 meters. Because of the discontinuous coring procedure used at Site 234 and the marked disturbance of the recovered sediments, no interpretation based on physical properties can be safely made for the two sedimentary reflectors at 0.15 and 0.20 seconds two-way travel time shown on the seismic profiles (Figure 4).

INTERSTITIAL WATER CHEMISTRY

Depth below the sediment water interface, salinity, *p*H, and alkalinity are recorded in Table 3 and Figure 5 for pore waters squeezed from core samples at Site 234. In Table 4 are recorded data on water content, porosity, and bulk density.

TABLE 3
Interstitial Water Chemistry – Site 234

Depth Below Sea Floor (m)	Salinity (°/$_{oo}$)	*p*H[a]		Alkalinity (meq/kg)
Surface seawater	35.2	8.23		2.32
8	35.3	7.53	(7.42)	2.74
28	35.5	8.44	(7.62)	4.24
70	36.0	7.56		3.06
122	35.8	7.48		3.75
165	35.8	7.49		2.20
195	35.8	7.34		3.06
241	34.4	7.54		3.47

[a] *p*H values in parentheses are corrected (see Chapter 1, Explanatory Notes).

Salinity: Bottom seawater at Site 234 has a salinity of 34.7 °/$_{oo}$. Interstitial water salinities are essentially constant, being in the range 35.2 ± 0.8 °/$_{oo}$ (Figure 5). This near constancy stands in contrast to the distribution found in the Gulf of Aden sites and suggests rather limited $SO_4^=$ reduction to have occurred.

***p*H and Alkalinity**: *p*H measurements were made as at Site 232. Values of *p*H show no trend with depth and average 7.5 ± 0.2 except for one value at 28 meters which is difficult to reconcile and is most probably a measurement error. Similarly, alkalinities show little or no consistent trend with depth and except for one sample (at 165 meters) are in excess of the sea-water value.

Water Content, Porosity, and Bulk Density: These data are contained in Table 4. Water content decreases with depth from values of 50-60 percent near the surface to around 30-35 percent below 190 meters. Porosity decreases irregularly from 80 percent near the surface to 60 percent at the base of the cored sequence. Bulk density varies inversely with porosity, from values of 1.5 g/cm^3 near the surface to 1.85 g/cm^3 below 180 meters.

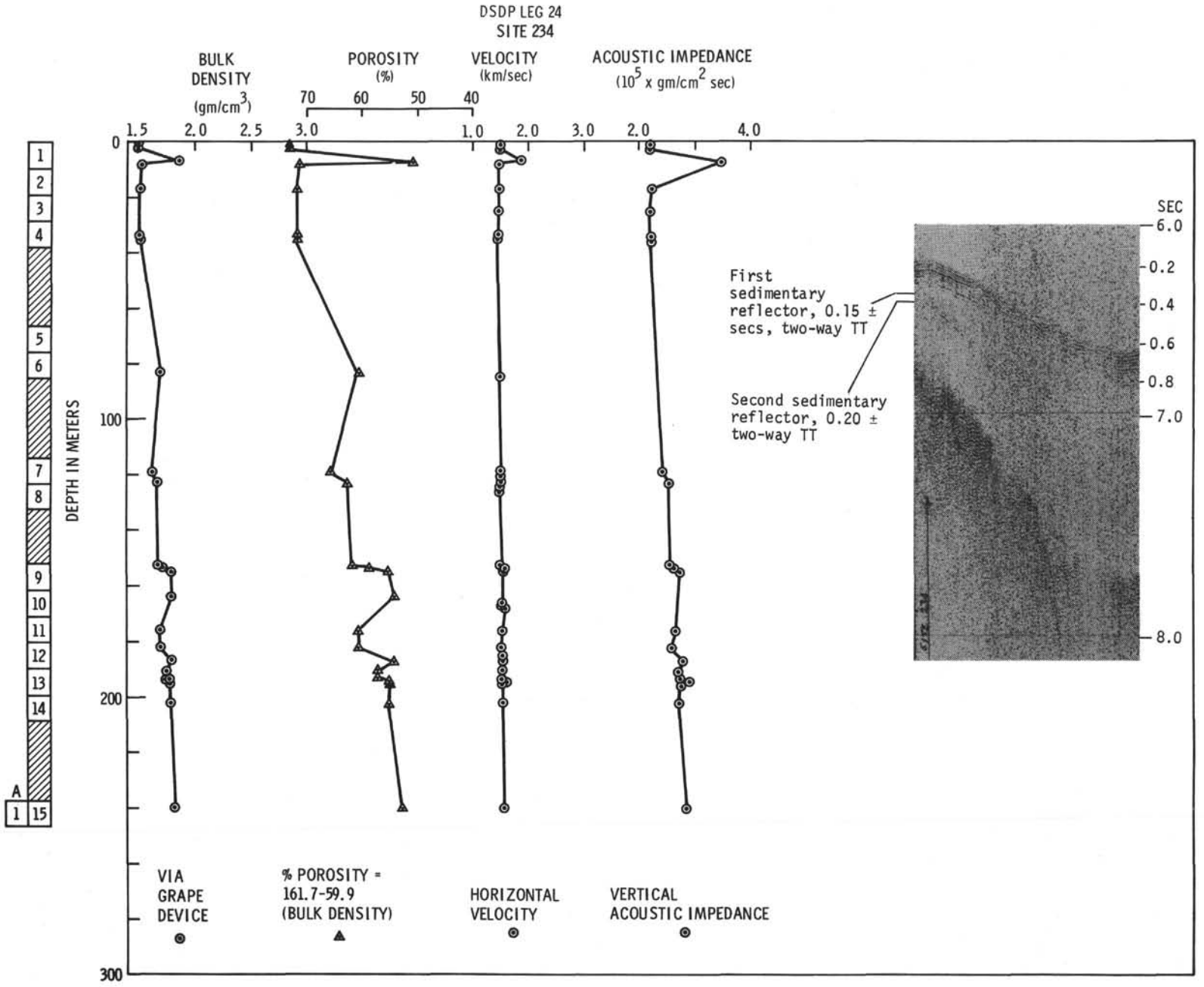


Figure 4. *Physical properties, Site 234.*

TABLE 4
Water Content, Porosity, and Bulk Density of Sediments – Site 234

Core, Section, Top of Interval (cm)	Water (%)	Porosity (%)	Density (g/cm^3)
1-1, 30	51.24	78.26	1.5273
1-2, 85	54.01	82.39	1.5254
1-5, 30	60.45	84.21	1.3930
2-5, 135	53.21	81.36	1.5290
3-4, 97	55.72	82.10	1.4734
4-3, 50	53.09	81.36	1.5324
4-4, 62	51.95	79.97	1.5393
4-4, 89	52.94	80.52	1.5209
4-4, 115	52.33	78.34	1.4970
6-6, 108	42.55	73.52	1.7278
6-6, 140	40.56	71.94	1.7736
7-4, 99	50.54	77.26	1.5286
7-5, 24	42.04	69.26	1.6474
7-6, 93	42.63	71.26	1.6715
8-2, 81	42.01	71.68	1.7062
8-2, 108	46.81	73.28	1.5654
8-2, 127	41.59	69.52	1.6715
9-1, 62	40.42	69.47	1.7187
9-1, 90	40.39	69.47	1.7199
9-1, 120	38.14	66.57	1.7454
9-1, 138	33.72	60.89	1.8057
9-2, 108	32.49	61.26	1.8855
9-2, 130	33.53	62.18	1.8544
10-3, 128	40.46	70.21	1.7352
10-3, 143	36.18	64.89	1.7935
10-4, 17	39.69	71.00	1.7888
10-4, 120	39.62	69.31	1.7493
11-3, 81	39.44	62.81	1.5925
11-3, 129	38.33	67.28	1.7552
12-2, 45	39.41	69.05	1.7520
12-2, 132	38.45	66.10	1.7191
12-3, 60	41.59	71.15	1.7107
12-3, 120	32.50	61.57	1.8944
12-4, 58	38.50	70.63	1.8345
12-4, 114	33.94	63.80	1.8797
12-5, 70	36.99	65.86	1.7804
13-1, 116	36.81	66.52	1.8071
13-3, 62	36.77	68.60	1.8656
13-3, 77.5	30.94		
13-3, 106	35.64	67.26	1.8872
14-2, 39	34.49	60.65	1.7584
14-2, 109	35.27	63.73	1.8069
15-3, 44	31.37	60.57	1.9308

CORRELATION OF REFLECTION PROFILES AND LITHOLOGY

The correlation of seismic and lithologic information is confined to the upper sedimentary section because of the limited coring at this site.

The onsite profile (Figure 6) shows the sloping sea floor and an acoustic basement sandwiching a semitransparent sequence. Within this sequence are two layers that thicken downslope; witness the diverging reflections (Figure 6, a, b). Identification of the lithologic units is restricted to those cored, so that the 247 meters of nanno ooze and clay shown might not be strictly representative of the entire section. The same argument applies to the measured physical properties, described earlier, in which there is little direct evidence for existence of the impedance

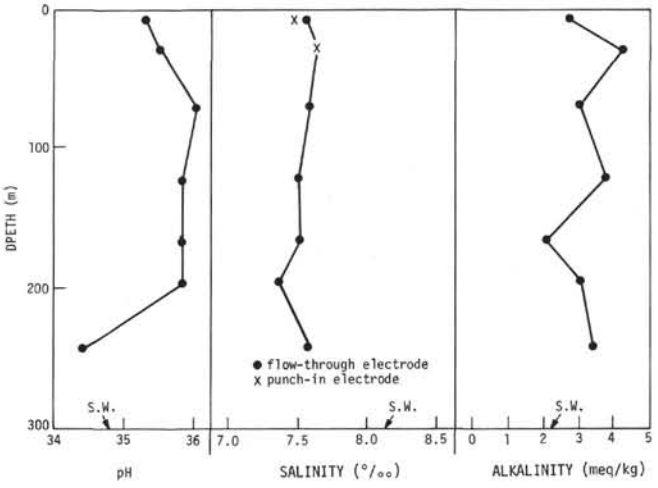


Figure 5. *Salinity, pH and alkalinity of interstitial pore water, Site 234.*

contrasts necessary for reflecting horizons. Using the average velocity and the final drill depth to derive an equivalent travel time results in an ambiguous value of 0.33 sec midway between the second reflection and the acoustic basement. Speculatively, the drilling ended in the second of the two units seen as reflectors in the semitransparent sequence (Figure 6, b). Acoustic basement should be the distinctive reflector which, though of initial interest at this site, was not reached by the drill.

SUMMARY, CONCLUSIONS, AND SPECULATIONS

The site (at 04°28.96′N, 51°13.48′E) is located on the flank of the marginal ridge forming the western border of the Somali Abyssal Plain at these latitudes. This section of the northwest Somali Basin is a magnetic quiet zone, its eastern border being Chain Ridge and its subsurface continuation (Bunce et al., 1967). Rocks dredged from the Ridge have been assigned by K-Ar dating a minimum age of Cenomanian (Lower Upper Cretaceous) while the nearest magnetic anomaly is Paleocene. The extreme thickness of the ponded sediments (at least 3 sec) prevents drilling a section in the plain itself. However, the deeper sediments onlap the ridge beneath upward thinning younger layers so that drilling should obtain a relatively thin, possibly incomplete, younger section, above an older sequence and the underlying basement.

This site was selected with three basic objectives in mind: (1) to provide the basis for comparison of basement characteristics with that of the eastern marginal Chain Ridge; (2) to examine as much as possible of the older sediments of the Somali Abyssal Plain, particularly the mid-column acoustically transparent layer and a distinctive reflector at its base, both traceable across the plain; and (3) to determine (African) source areas and their tectonic history relevant to the turbidite mineralogy.

A summary of the scientific information obtained appears in the conclusions at the end of this chapter. The information ends rather abruptly at 247 meters depth,

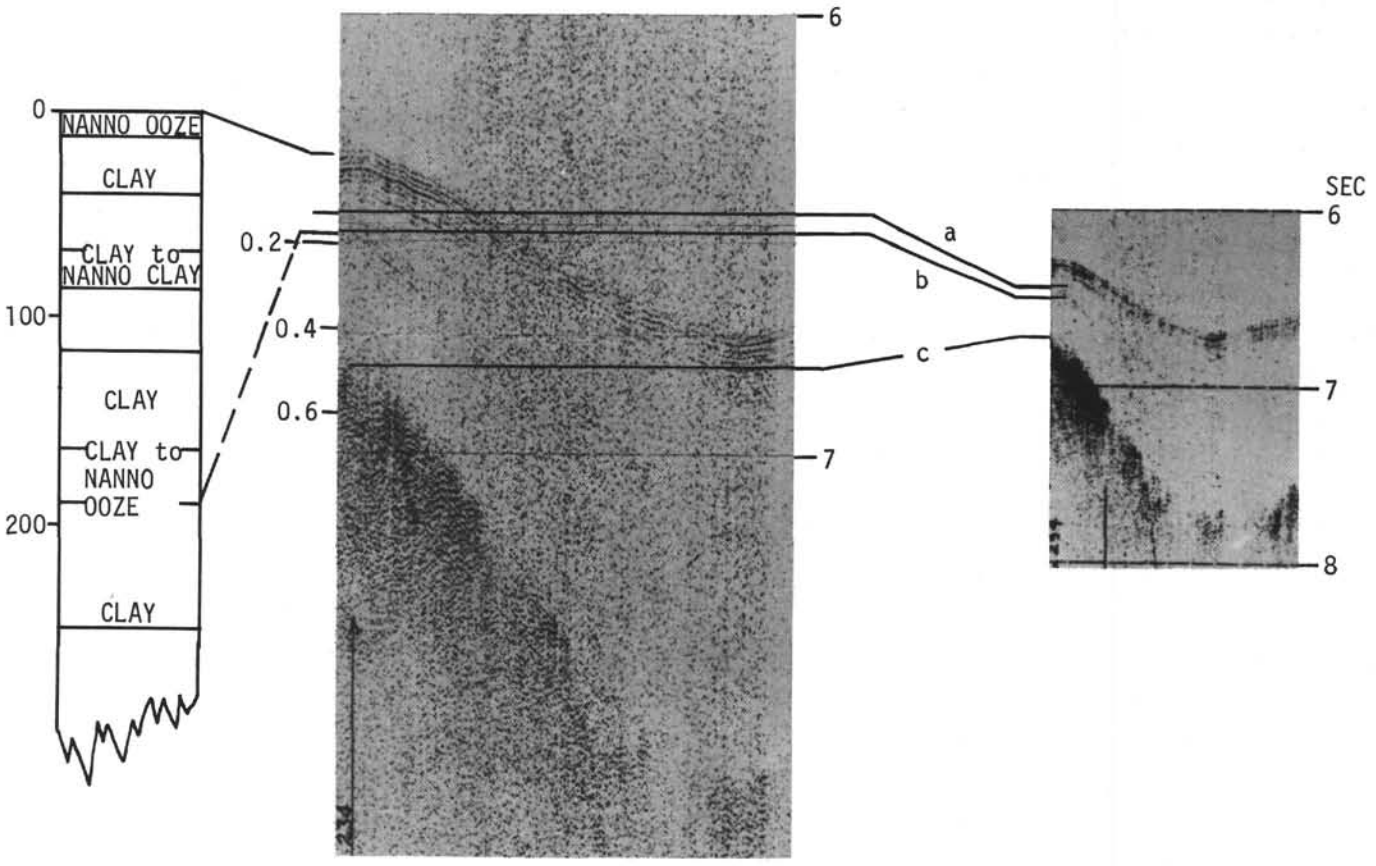


Figure 6. *Onsite profiler record;* a, b, *mark two shallow sedimentary reflectors;* c, *the "distinctive" reflector of interest. Seconds are two-way travel time, both records.*

when we were forced to abandon the site because of unfavorable drilling conditions.

Two holes were drilled, the first being cored at varying intervals to its terminal depth of 247.0 meters, the second overlapping in the last depth interval.

The cored sediments consist largely of grayish clays with rare nannofossils, and are generally lacking in sand-sized components. The uppermost 9.5 meters of nanno clay to nanno ooze are yellowish brown at the surface, becoming grayish orange, dusky yellow, and finally grayish green. Components found in the smear slides include clay minerals, calcareous nannofossils, terrigenous detrital minerals (mainly quartz), and a trace of volcanic glass. Manganese nodules are found at the top of this section. The second unit is grayish green to dusky yellow silt-bearing clay, mottled and with black pyritic streaks throughout. Clay minerals comprise 80-90 percent of this unit and again there are traces of the same detrital terrigenous minerals, pyrite, and volcanic glass. The third unit is a clay to nanno clay, pale green, pale olive, and dusky yellow green in color. Main components here are the same as for the previous unit with the addition of a thin zeolitic horizon. The fourth unit is silt-bearing clay, light to medium bluish gray, pale to grayish green and greenish gray, containing the same minor components as that above it, black pyritic streaks and two zeolitic sandy layers. The sixth and last unit, also silt-bearing clay, is light to medium bluish, greenish, olive gray and olive black. In addition to the ubiquitous clay minerals, terrigenous mineral traces, and pyrite, there is a small percentage (5-10%) of nannofossils in the lower part.

Foraminifera and radiolarians, both poorly preserved, are present only in the upper 10 meters. They are almost totally absent in the remainder of the section. Nannofossils are found, fairly well-preserved, in four horizons, but like the other fossil groups are corroded or absent elsewhere. These nannofossil remains are largely responsible for the biostratigraphy. Sediments accumulated with an average rate of 1.0 m/m.y. during post middle Miocene time, 13.0 m/m.y. during early and middle Miocene, and a minimum of 7.0 m/m.y. during the late Oligocene. The low Pliocene-late Miocene sedimentation rate coincides with the occurrence of manganese nodules indicative of an oxidizing environment as well as slow sedimentation.

The significant comments with regard to the sediments and their depositional environment appear to be: (1) the calcareous nannofossils and poorly preserved foraminifers indicate fluctuations of the position of the CCD; (2) minor amounts of volcanic glass and thin zeolitic sandy horizons indicate an important volcanic input into this area; (3) clay minerals of undetermined origin dominate the lithology;

and (4) based on the small percentage of terrigenous detritus, the lack of turbidites and shallow-water material, this area seems to have been well removed from any landmass, as well as having been a topographic high inaccessible to turbidity currents during the time interval sampled by these cores.

Conclusions

1) Inability to reach basement results in still ambiguous knowledge concerning the nature of this material.

2) Coarse turbidites were not encountered in the cored section, eliminating the possibility of determining African source areas.

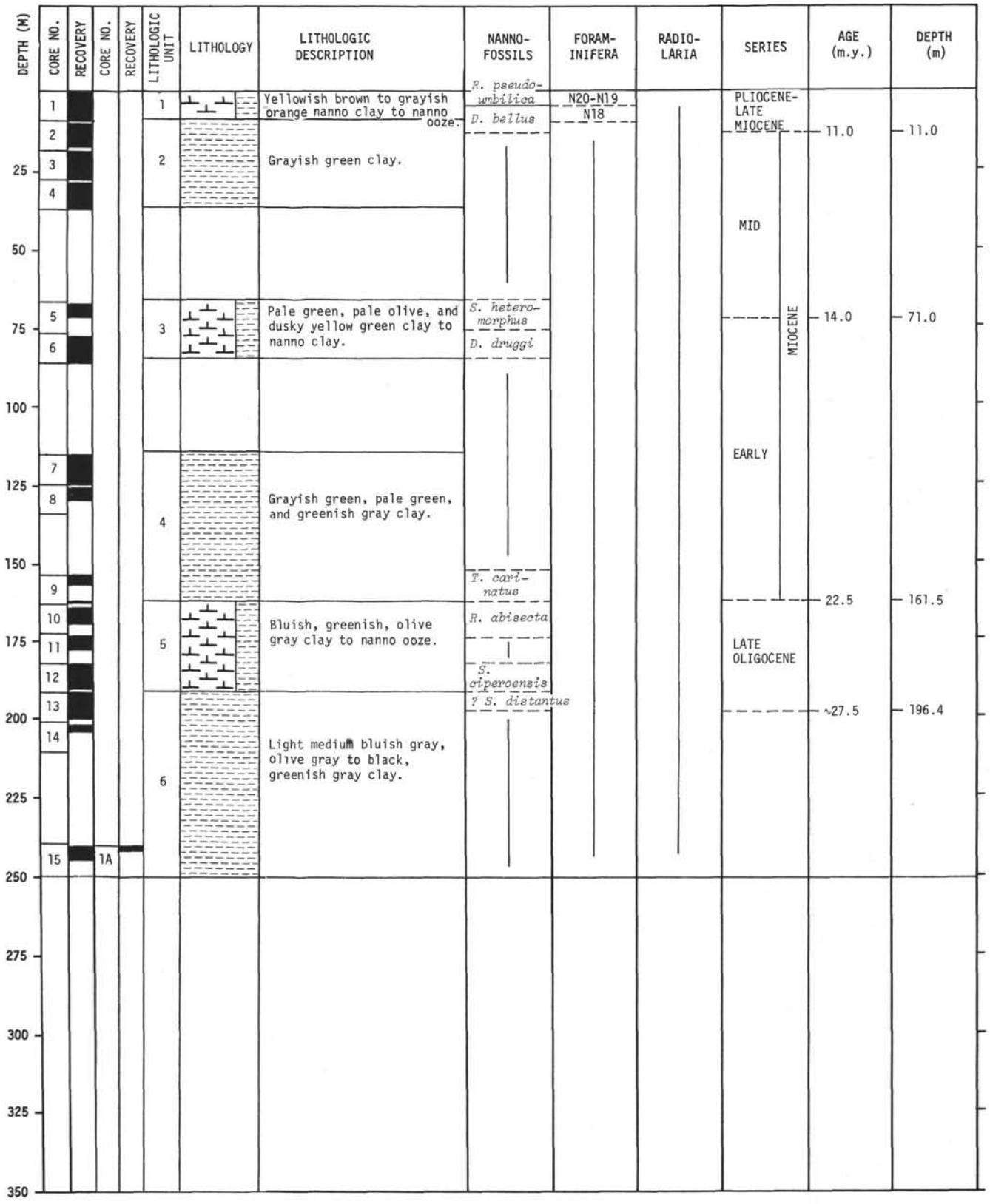
3) The lithologic units of the cored sections and seismic reflectors do not correlate uniquely.

It is difficult at this time to reach significant conclusions for lack of such fundamental data as age of the sediments adjacent to basement and basement composition. However, the fact that drilling cessation was caused by apparent clogging or swelling of sediments within the hole could suggest the presence of a product of the decomposition of volcanic ash–bentonite.[3]

REFERENCE

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

[3]Note: The split cores of these lithologic units have swelled noticeably in their "D-tubes." This suggests that Tertiary volcanic activity, adjacent to the basin or with adequate wind propulsion for its products, must have been prominent. The lack of major amounts of terrigenous material due to lack of a landmass might also be attributed (by skeptics) to a fortuitous feature of this site, in that the sediment onlap is too selective, eliminating both the very deep layers as well as portions of the younger.


DEPTH (M)
CORE NO.
RECOVERY
CORE NO.
RECOVERY
LITHOLOGIC UNIT
LITHOLOGY
LITHOLOGIC DESCRIPTION
NANNO-FOSSILS
FORAM-INIFERA
RADIO-LARIA
SERIES
AGE (m.y.)
DEPTH (m)
Yellowish brown to grayish orange nanno clay to nanno ooze.
Grayish green clay.
Pale green, pale olive, and dusky yellow green clay to nanno clay.
Grayish green, pale green, and greenish gray clay.
Bluish, greenish, olive gray clay to nanno ooze.
Light medium bluish gray, olive gray to black, greenish gray clay.
R. pseudo-umbilica
D. bellus
S. hetero-morphus
D. druggi
T. cari-natus
R. abisecta
S. ciperoensis
? S. distantus
N20-N19
N18
PLIOCENE-LATE MIOCENE
MID
EARLY
MIOCENE
LATE OLIGOCENE
11.0
14.0
22.5
~27.5
11.0
71.0
161.5
196.4
1A

Site 234 Hole Core 1 Cored Interval: 0.0-9.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLIOCENE-LATE MIOCENE	Reticulofenestra pseudoumbilica N20-N19 / N18 / D. bellus	C/P	R/P		1	0.5				NANNO CLAY OOZE Moderate yellowish brown (10YR5/4) Smear 1-1-80 Sand 5% Nannos 30-40% Clay Min. 30% Silt 20-25% Fish Debris<1% Quartz 10% Clay 75-80% Dolo. Rhombs 1- 2%
						1.0				
			C/P		2				CC	Color change to grayish orange (10YR7/4) at 1-2-70, to moderate yellowish brown (10YR5/4) at 1-2-95. Manganese nodule at 1-2-80. Smear 1-2-80 Sand 12% Nannos 40% Micarb 30% Silt 31% Rads 5% Quartz 5% Clay 57% Sponge Spic. 3- 5% Heavy Min. 1% Diatoms 2% Fish Debris 1%
			R/P		3					$CaCO_3$ 45% Dusky yellow (5Y6/4) at 1-3-0 manganese nodules at 1-3-10, 1-3-90, 1-3-125.
			R/P		4					NANNO OOZE Grayish orange at 1-4-0, grayish green (5G5/2 and 10GY5/2). Smear 1-4-80 Sand 2- 3% Nannos 80-90% Quartz 3% Silt 5-10% Rads 2% Volc. Glass 2% Clay 90% Dolo. Rhombs 1%
			R/P		5					Manganese nodule (7x6x6 cm) at 1-5-3
			R/P		6					
		C/P	C/P		Core Catcher					

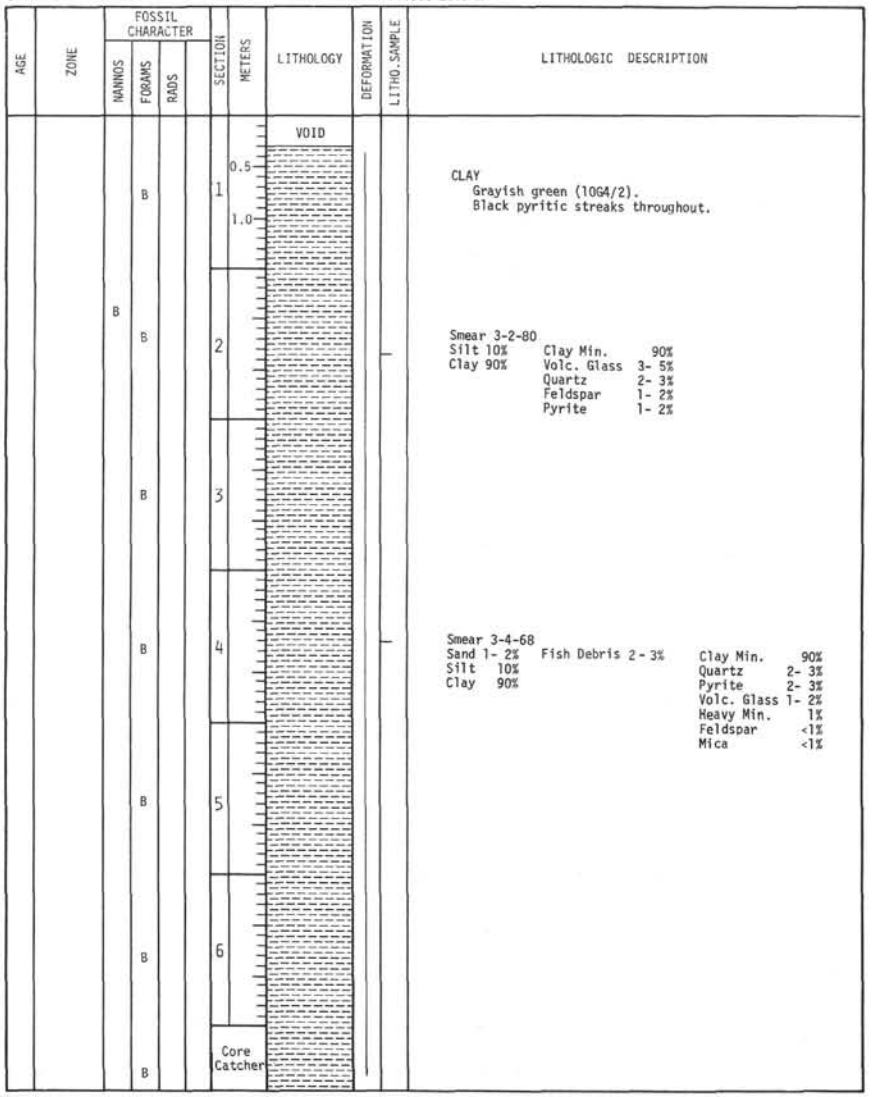
Explanatory notes in chapter 1

Site 234 Hole Core 2 Cored Interval: 9.5-19.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLIOCENE-LATE MIOCENE	D. bellus				1	0.5	VOID			CLAY Grayish green (5G5/2) Pyrite streaks throughout
						1.0				
		B	B		2					
			B		3					Smear 2-3-80 Sand 2- 3% Diatoms <1% Clay Min. 80-90% Silt 10-15% Quartz 3% Clay 85-90% Pyrite 2- 3% Heavy Min. 1- 2% Volc. Glass 1%
			B		4					Large black streaks 2-4-100 to 2-4-115.
			B		5					Lighter patch 2-5-40.
			R/P		Core Catcher					Color change to dusky yellow green (5GY5/2) at 2-5-130.

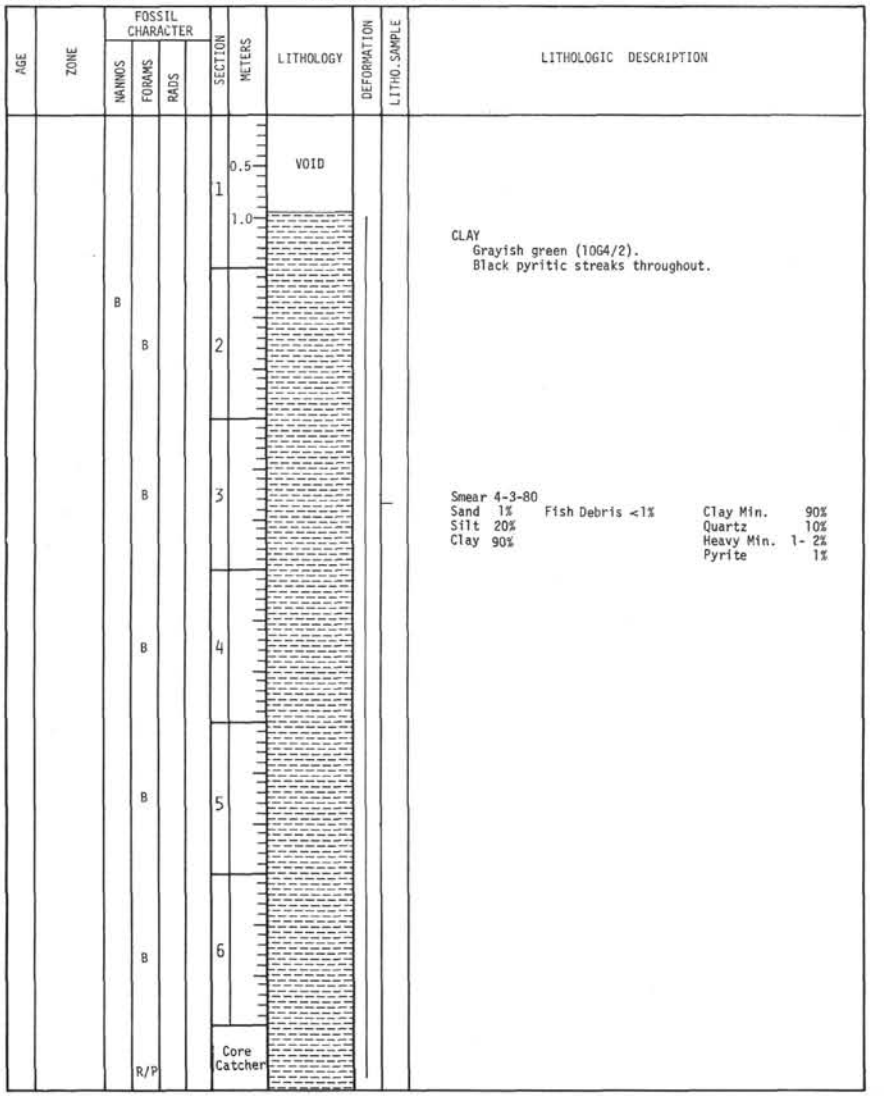
Explanatory notes in chapter 1

Site 234 Hole Core 3 Cored Interval: 19.0-28.5 m



Explanatory notes in chapter 1

Site 234 Hole Core 4 Cored Interval: 28.5-38.0 m



Explanatory notes in chapter 1

Site 234 Hole Core 5 Cored Interval:66.5-76.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	S. heteromorphus	C/P	R/P	R/P	1	0.5, 1.0	VOID			NANNO RICH CLAY Pale green (10G6/2). Mottled and streaked with very pale green (10G8/2). Grading down to pale olive (10Y6/2) to 5-2. Smear 5-2-80 Sand 1% Nannos 10-15% Clay Min. 80% Silt 10% Sponge Spic. 1% Quartz 5% Clay 90% Fish Debris 1% Pyrite 2% Heavy Min. 1% Dolo. Rhombs 1% Mica <1%
					2					
					3					
					Core Catcher					

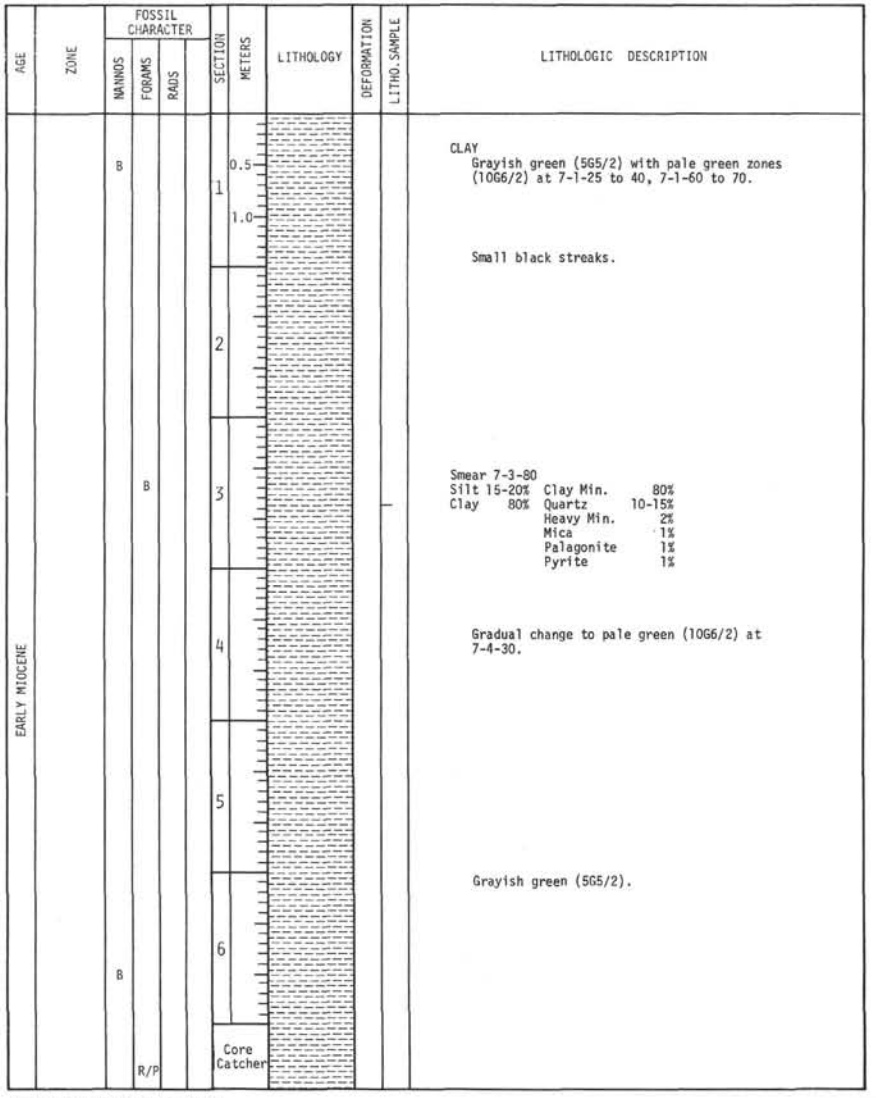
Explanatory notes in chapter 1

Site 234 Hole Core 6 Cored Interval:76.0-85.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
M. MIOCENE	S. heteromorphus				1	0.5, 1.0	VOID			CLAY NANNO OOZE Dusky yellow green (5GY5/2). Streaked throughout with very light patches. Smear 6-2-80 Sand 1% Nannos 50-60% Clay Min. 20-30% Silt 10-15% Quartz 5- 7% Clay 85-90% Heavy Min. 2- 3% Mica 1% Dolo. Rhombs 1% Streaks of dusky yellow (5Y6/4) at 6-6-0 to 50 and bands of this color at 6-6-120 to 150. $CaCO_3$ 2% Grain Size Sand 0% Silt 7% Clay 93%
		C/P			2					
EARLY MIOCENE	Discoaster druggi		B		3					
					4					
					5					
		B			6				GZ CC	
			R/P		Core Catcher					

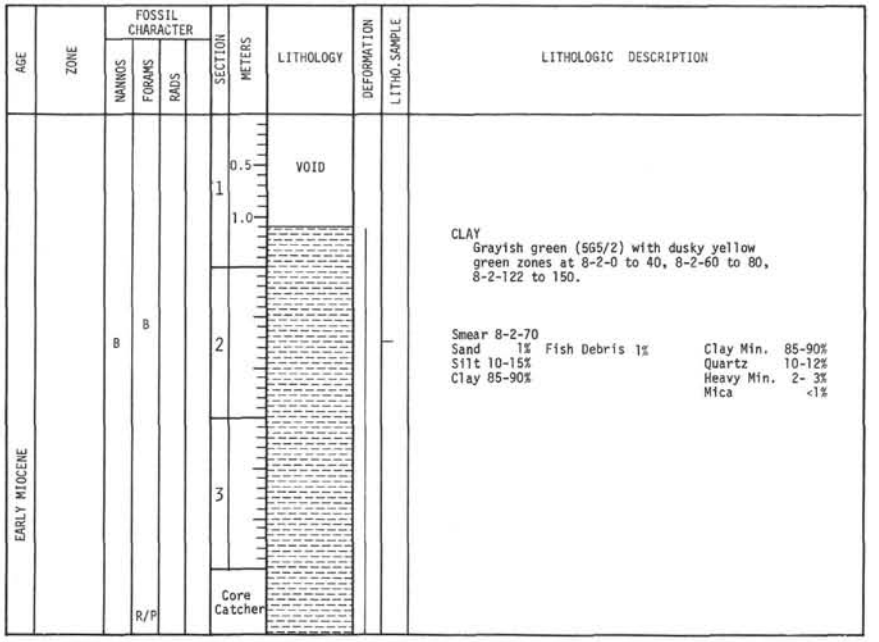
Explanatory notes in chapter1

Site 234 Hole Core 7 Cored Interval: 114.0-123.5 m



Explanatory notes in chapter 1

Site 234 Hole Core 8 Cored Interval: 123.5-133.0 m



Explanatory notes in chapter 1

Site 234 Hole Core 9 Cored Interval: 152.0-161.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY MIOCENE	Triquetrorhatdulus carinatus	B			1	0.5				CLAY Medium bluish gray (5B5/1) changing to light bluish gray (5B7/1) at 9-1-10, to medium bluish gray (5B5/1) at 3-1-43, to olive gray (5Y4/1) at 9-1-65, to medium bluish gray (5B5/1) at 9-1-82, to greenish gray (5GY6/1) at 9-1-100.
						1.0			CC GZ	
					2					$CaCO_3$ 28% Mottled in lower part of 9-1 and 9-2. Smear 9-1-37 Sand 1% Fish Debris 1% Clay Min. 95% Silt 5% Quartz 4- 5% Clay 95% Volc. Glass 1- 2% Smear 9-1-82 Silt 10-15% Nannos 10% Clay Min. 75-80% Clay 85-90% Fish Debris 1% Quartz 10% Heavy Min. 2% Volc. Glass 1% Pyrite 1%
		C/P			3					
					4		VOID			Color changing to medium bluish gray (5B5/1) at 9-2-0, to light bluish gray (5B7/1) at 9-2-30, to medium bluish gray at 9-2-70, to light bluish gray at 9-1-120. Grain Size Sand 0% Clay 9% Sand 91%
					5					
					6					Highly mottled.
			R/P		Core Catcher					

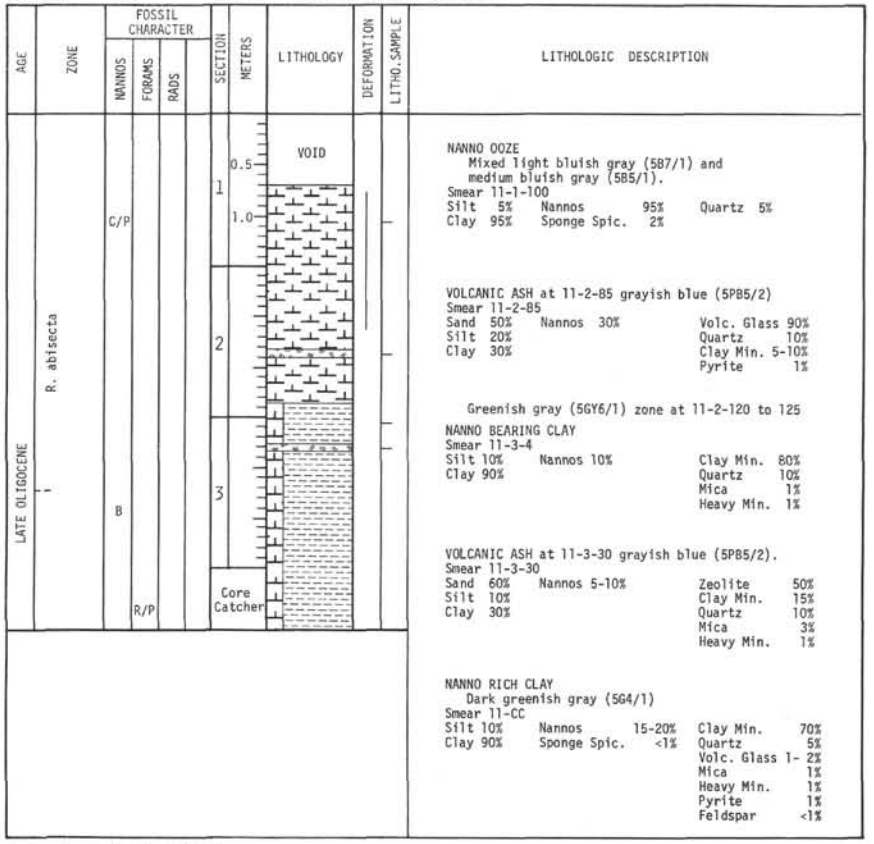
Explanatory notes in chapter 1

Site 234 Hole Core 10 Cored Interval: 161.5-171.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE OLIGOCENE	Reticulofenestra abisecta				1	0.5	VOID			
						1.0				NANNO OOZE Medium (5B5/1) and light bluish gray (5B7/1) Smear 10-1-130 Silt 5% Nannos 90-95% Quartz 5% Clay 95% Sponge Spic. 1% Heavy Min. 1% Mica <1% Dolo. Rhombs <1%
					2					
		C/P	R/P		3					Color changing to greenish gray (5G6/1) with zones of medium bluish gray (5B5/1) at 10-3-110 to 140, light bluish gray at 10-3-140 to 150, medium bluish gray (5B5/1) at 10-4-0 to 25 and 10-4-55 to 60, light bluish gray at 10-4-90 to 95 and medium bluish gray (5B5/1) at 10-4-95 to 10-cc.
									GZ CC	$CaCO_3$ 7% Smear 10-3-90 Silt 7-10% Nannos 90% Quartz 3% Clay 90-95% Sponge Spic. 3- 5% Mica 1% Heavy Min. 1% Dolo. Rhombs <1%
					4					
		B								CLAY Smear 10-4-120 Silt 10% Nannos 10% Clay Min. 80% Clay 90% Quartz 10% Heavy Min. 1% Mica <1%
					Core Catcher					
			R/P							CLAY NANNO OOZE Smear 10-CC Silt 10% Nannos 50% Clay Min. 40% Clay 90% Fish Debris 1% Quartz 5% Heavy Min. 1% Grain Size 10-4-14 Volc. Glass 1% Sand 0% Pyrite 1% Silt 9% Mica <1% Clay 91%

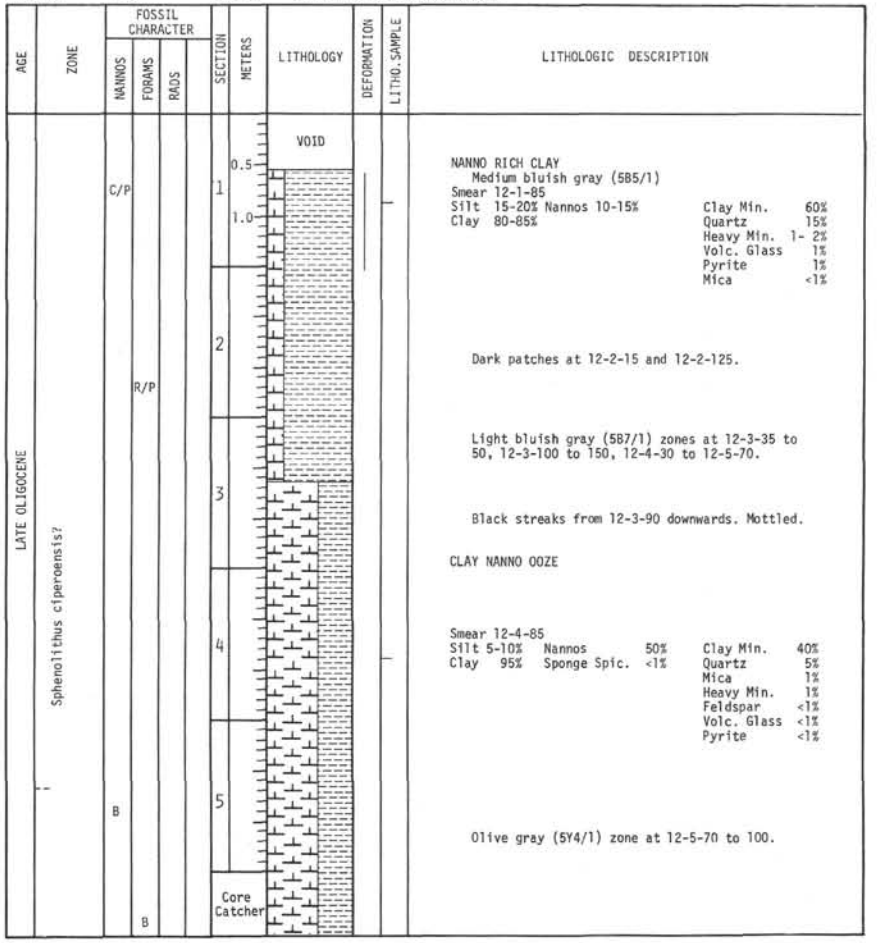
Explanatory notes in chapter 1

Site 234 Hole Core 11 Cored Interval: 171.0-180.5 m



Explanatory notes in chapter 1

Site 234 Hole Core 12 Cored Interval: 180.5-190.0 m



Explanatory notes in chapter 1

Site 234 Hole Core 13 Cored Interval: 190.0-199.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE OLIGOCENE		C/P			1	0.5 1.0				CLAY Medium bluish gray (5B5/1) mixed with olive gray (5Y4/1). Light bluish gray (5B7/1) patches at 13-1-40. Smear 13-1-80 Silt 15% Fish Debris 1- 2% Clay Min. 80-85% Clay 85% Quartz 10% Mica 3% Heavy Min. 1%
					2					Olive black (5Y2/1) zones at 13-2-57 to 60 and at 13-2-65. Color grading down to dark greenish gray (5GY4/1). Black streaks throughout. Smear 13-2-58 Sand 1% Fish Debris 1% Clay Min. 90% Silt 10% Sponge Spic. <1% Quartz 5% Clay 90% Mica 2- 3% Heavy Min. 1% Pyrite 1%
			B		3					VOLCANIC ASH at 13-3-76 to 83 Smear 13-3-78 Sand 1% Volc. Glass 70% Silt 70% Clay Min. 25% Clay 30% Quartz 2- 3% Mica 2% Pyrite 2%
					4					Mottles. Greenish gray (5GY6/1) horizon at 13-4-125.
		R/P			5		VOID			Dark greenish gray (5GY4/1) zone at 13-5-0 to 50.
							VOID			
					Core Catcher					
			R/P							

Explanatory notes in chapter 1

Site 234 Hole Core 14 Cored Interval: 199.5-209.0 m

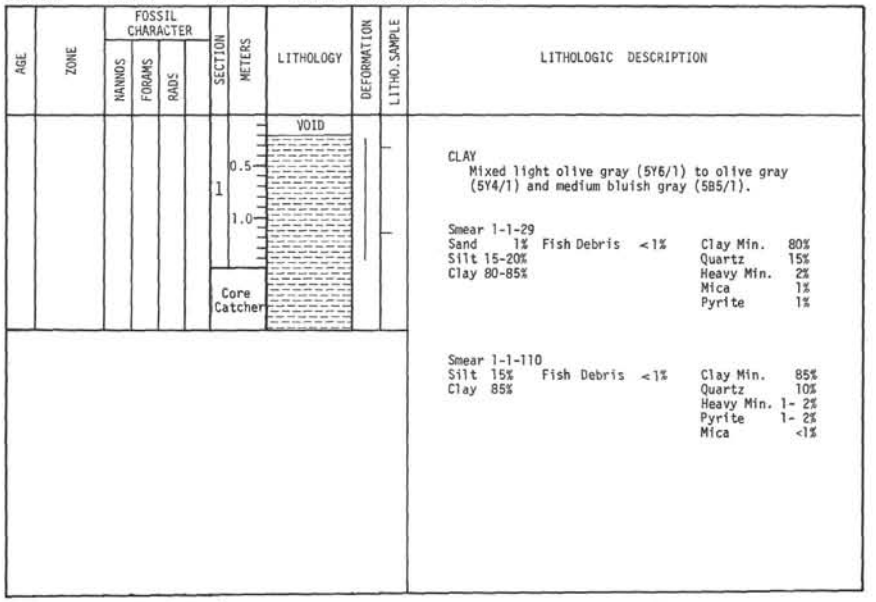
AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					1	0.5 1.0	VOID			CLAY Mixed olive gray (5Y4/1) and medium bluish gray (5B5/1). Black streaks.
			B		2					Smear 14-2-80 Silt 10% Clay Min. 90% Clay 90% Quartz 7- 9% Heavy Min. 1% Pyrite 1%
			B		Core Catcher					

Site 234 Hole Core 15 Cored Interval: 237.5-247.0 m

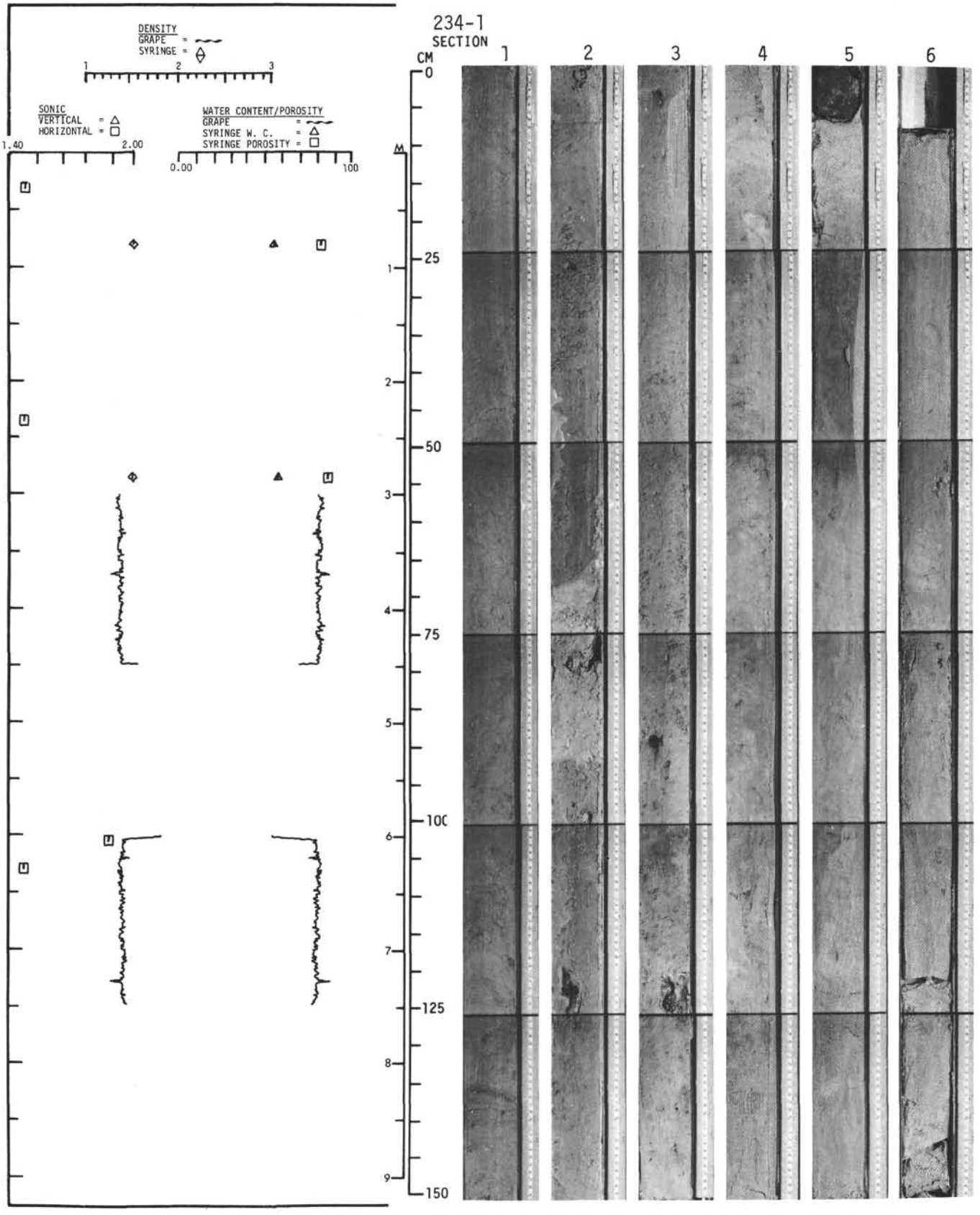
AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					1	0.5 1.0	VOID			CLAY Mixed olive gray (5Y4/1) and medium bluish gray (5B5/1). Smear 15-1-88 Sand 2- 3% Nannos 20% Clay Min. 70% Silt 15% Quartz 5% Clay 80-85% Heavy Min. 1- 2% Pyrite 1- 2% Mica <1% Volc. Glass <1%
			B		2					$CaCO_3$ 0% Smear 15-1-132 Silt 10% Clay Min. 90% 15-3-44 Clay 90% Quartz 5- 7% Grain Size Mica 1- 2% Sand 0% Heavy Min. 1% Silt 6% Clay 94%
					3				GZ CC	
			B		Core Catcher					Smear 15-3-140 Sand 1% Nannos 5-10% Clay Min. 80% Silt 10% Quartz 5% Clay 90% Mica 1- 2% Heavy Min. 1- 2% Pyrite 1- 2%

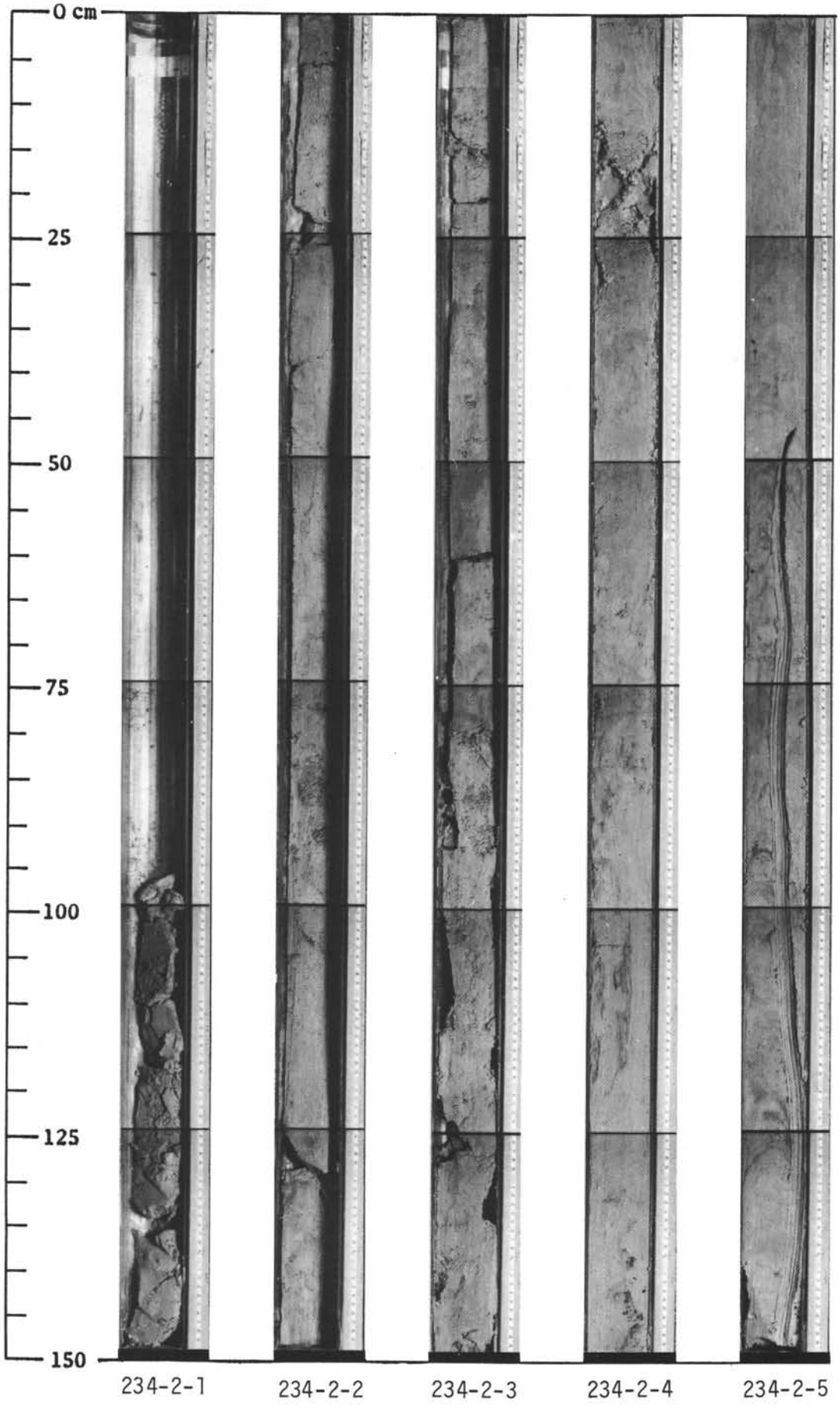
Explanatory notes in chapter 1

Site 234 Hole A Core 1 Cored Interval: 237.5-247.0 m



Explanatory notes in chapter 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
234-1
SECTION
1
2
3
4
5
6
CM
0
25
50
75
100
125
150
M
1
2
3
4
5
6
7
8
9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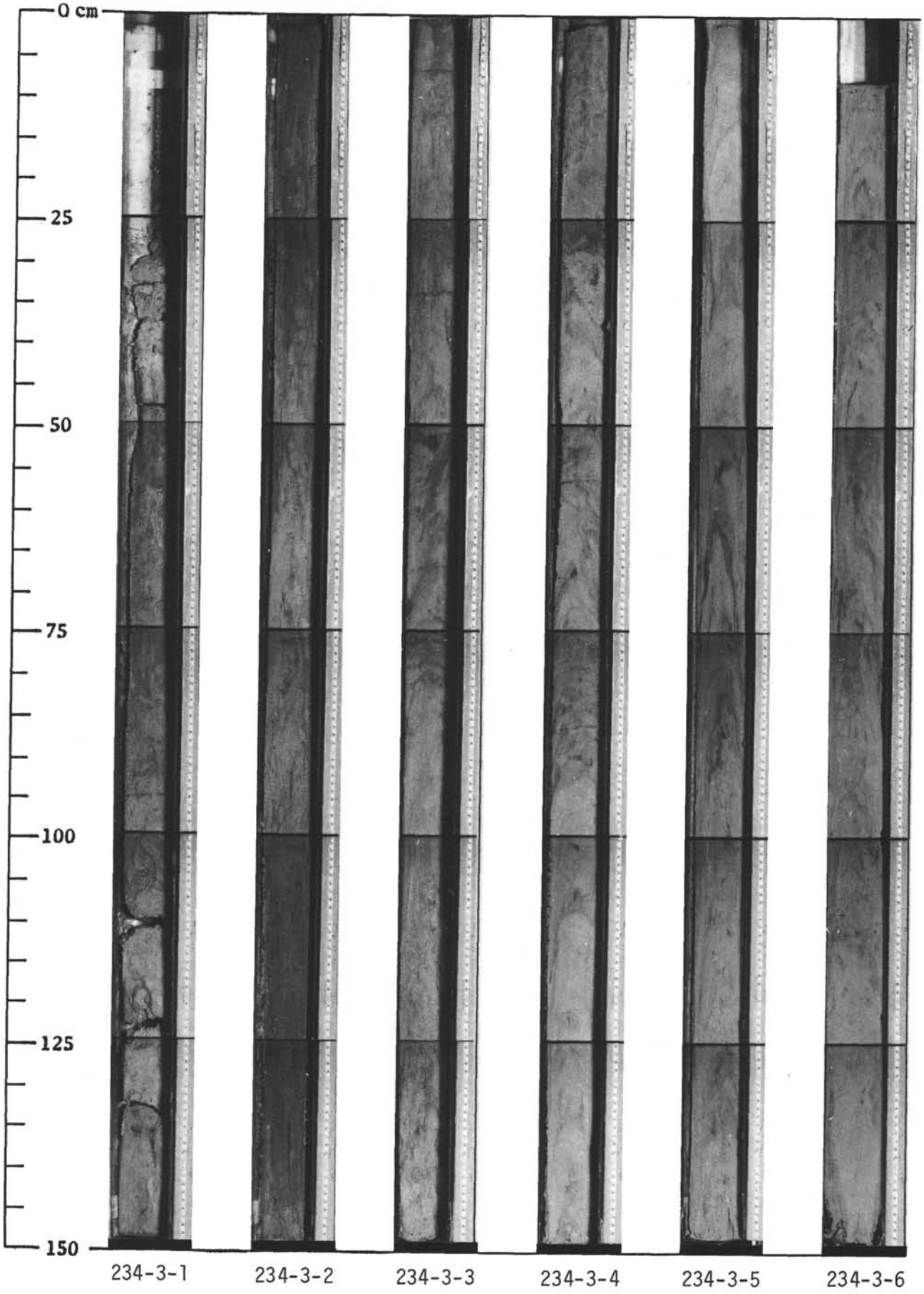
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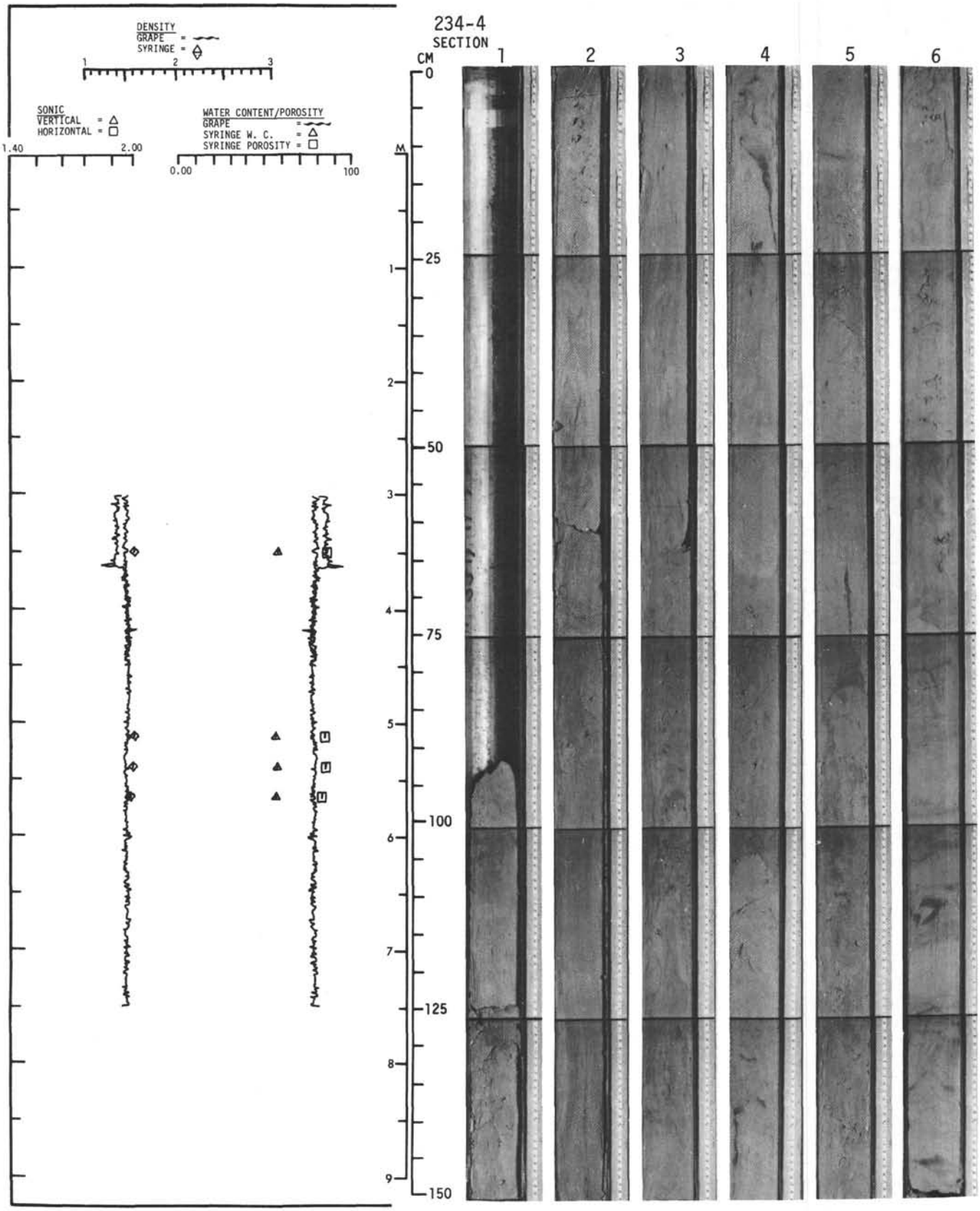
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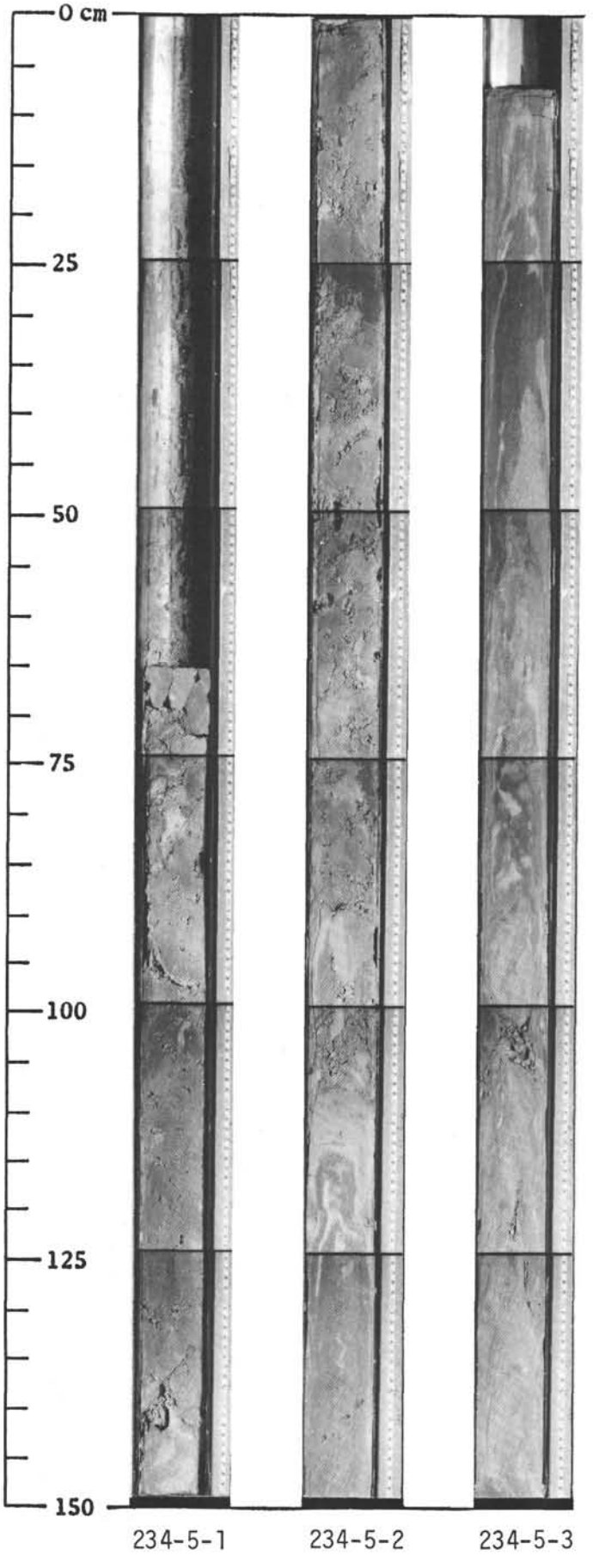
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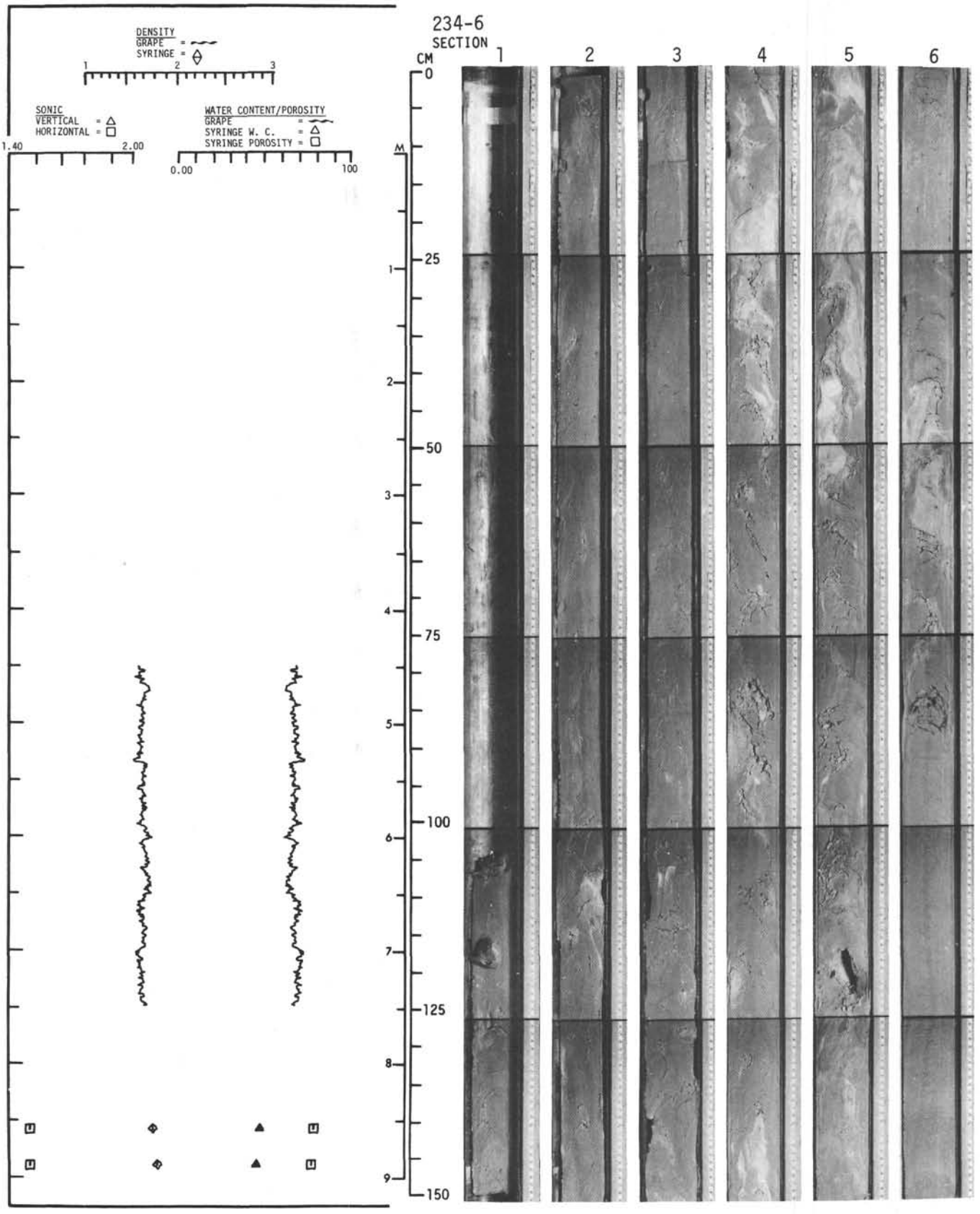
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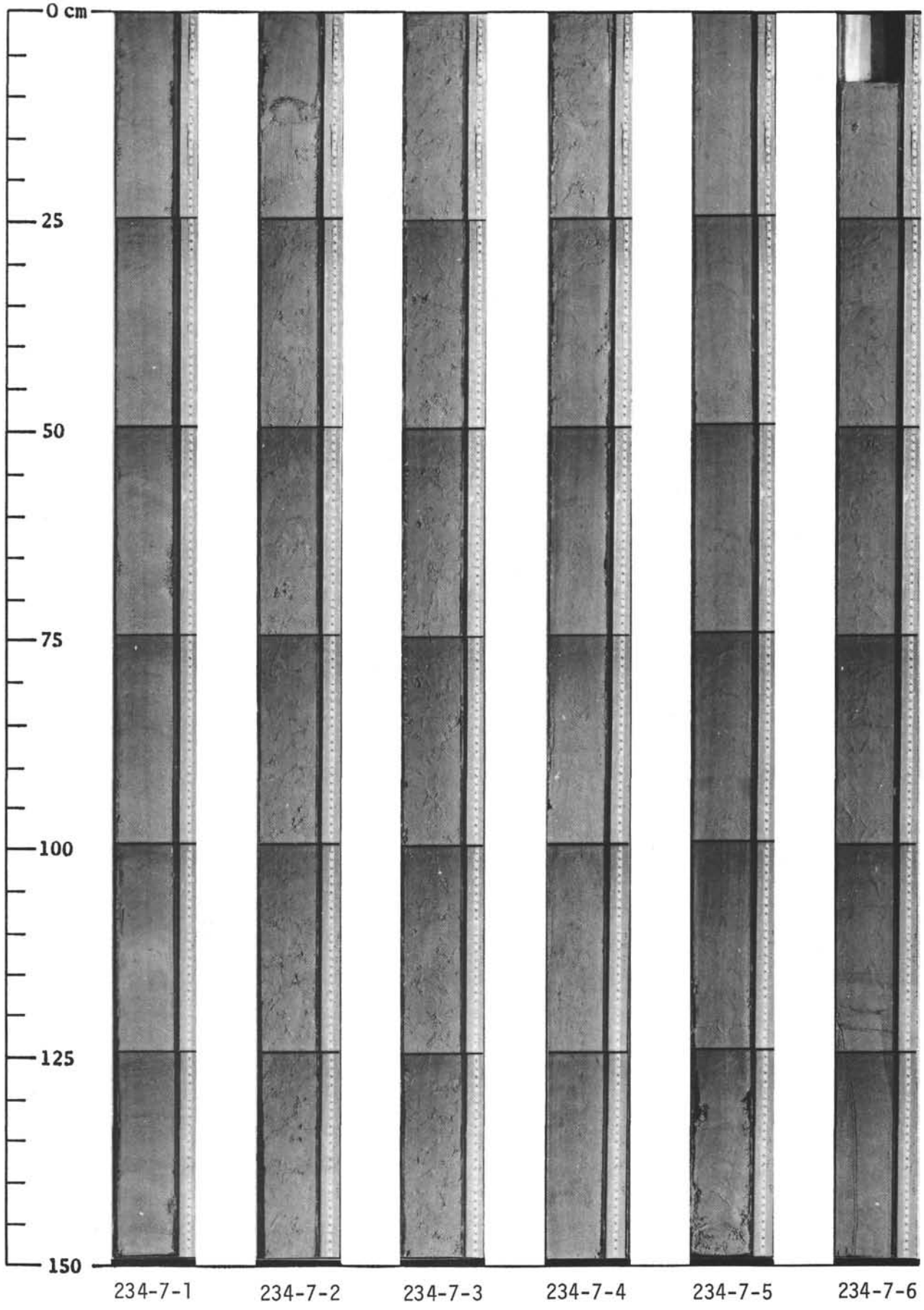
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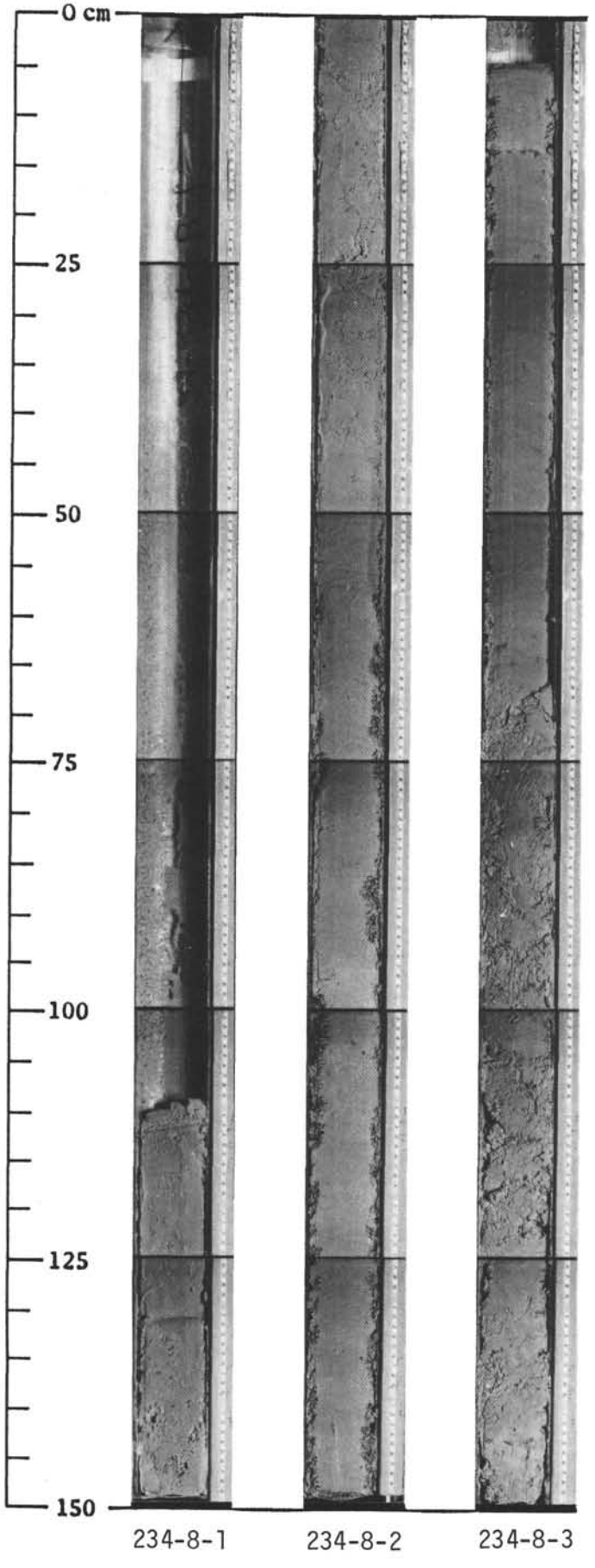
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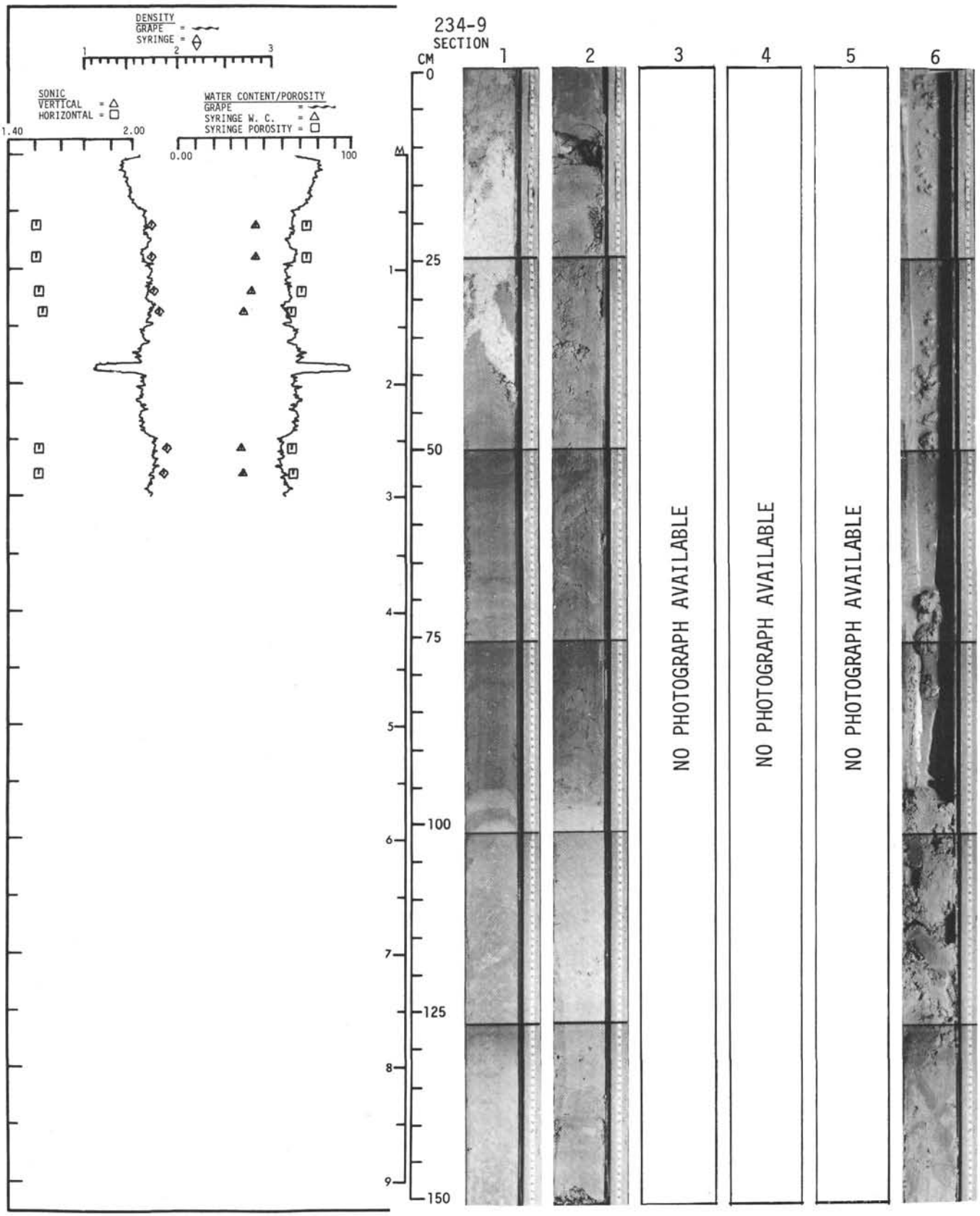
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SECTION
CM
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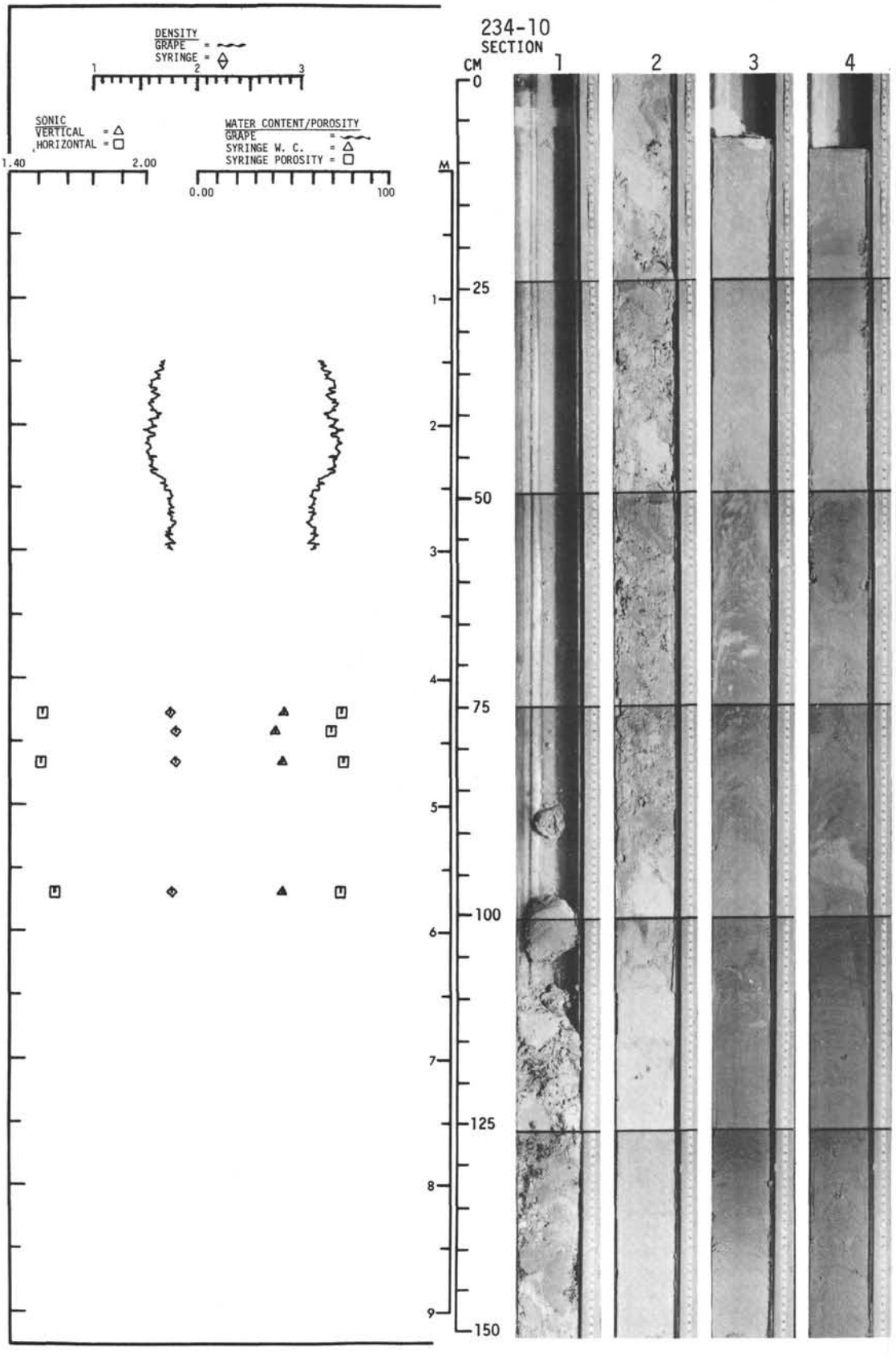
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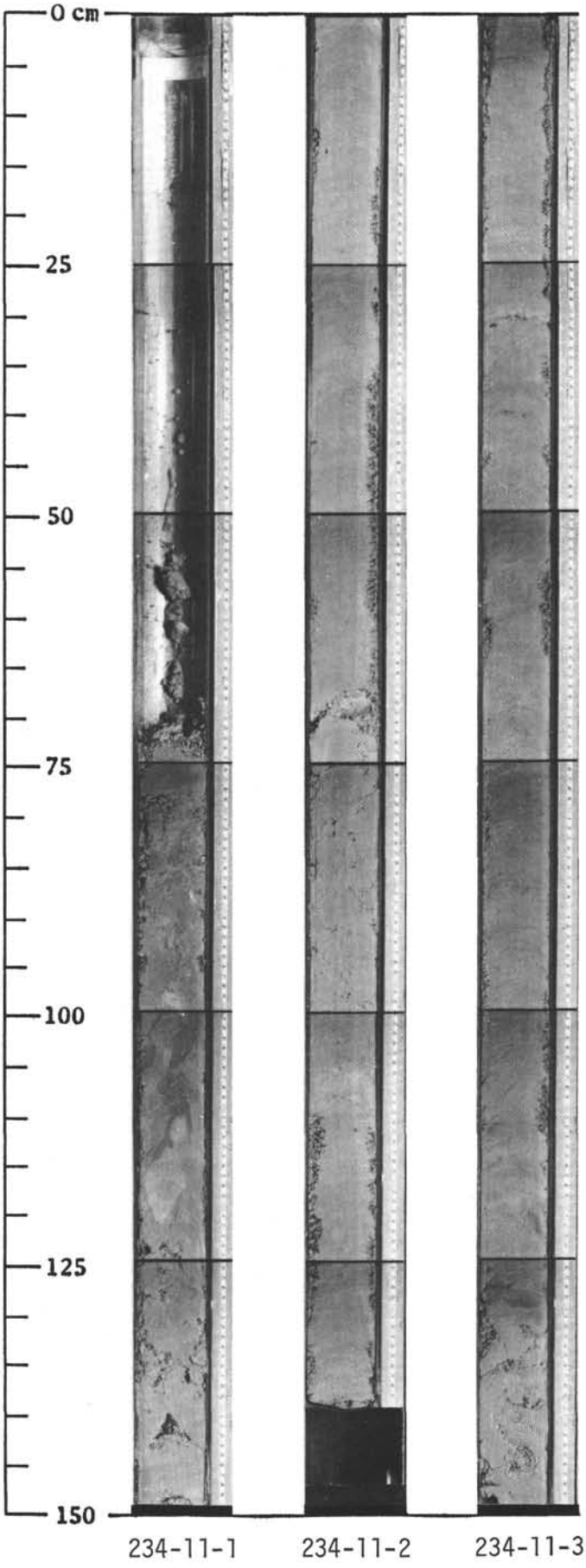
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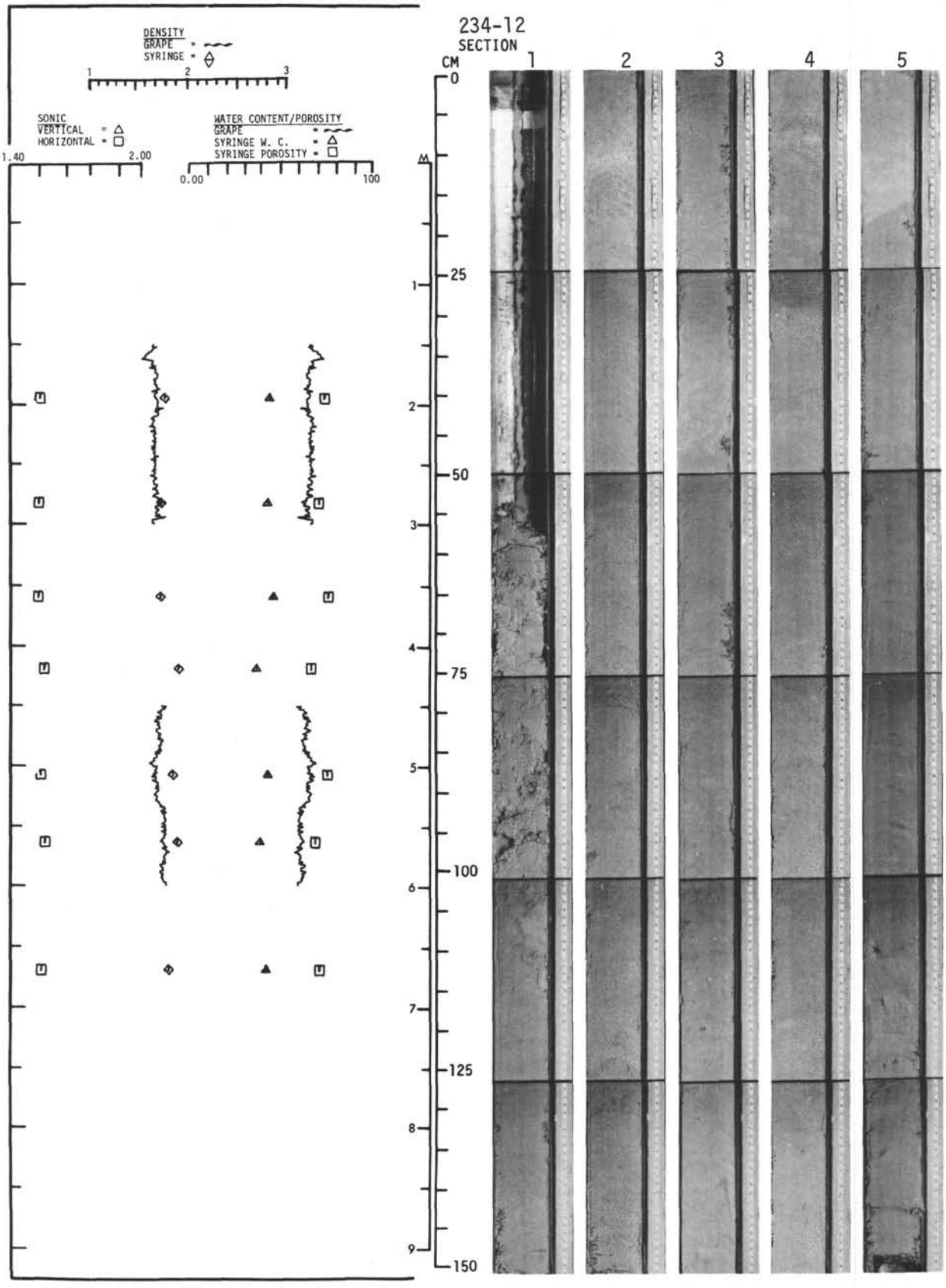
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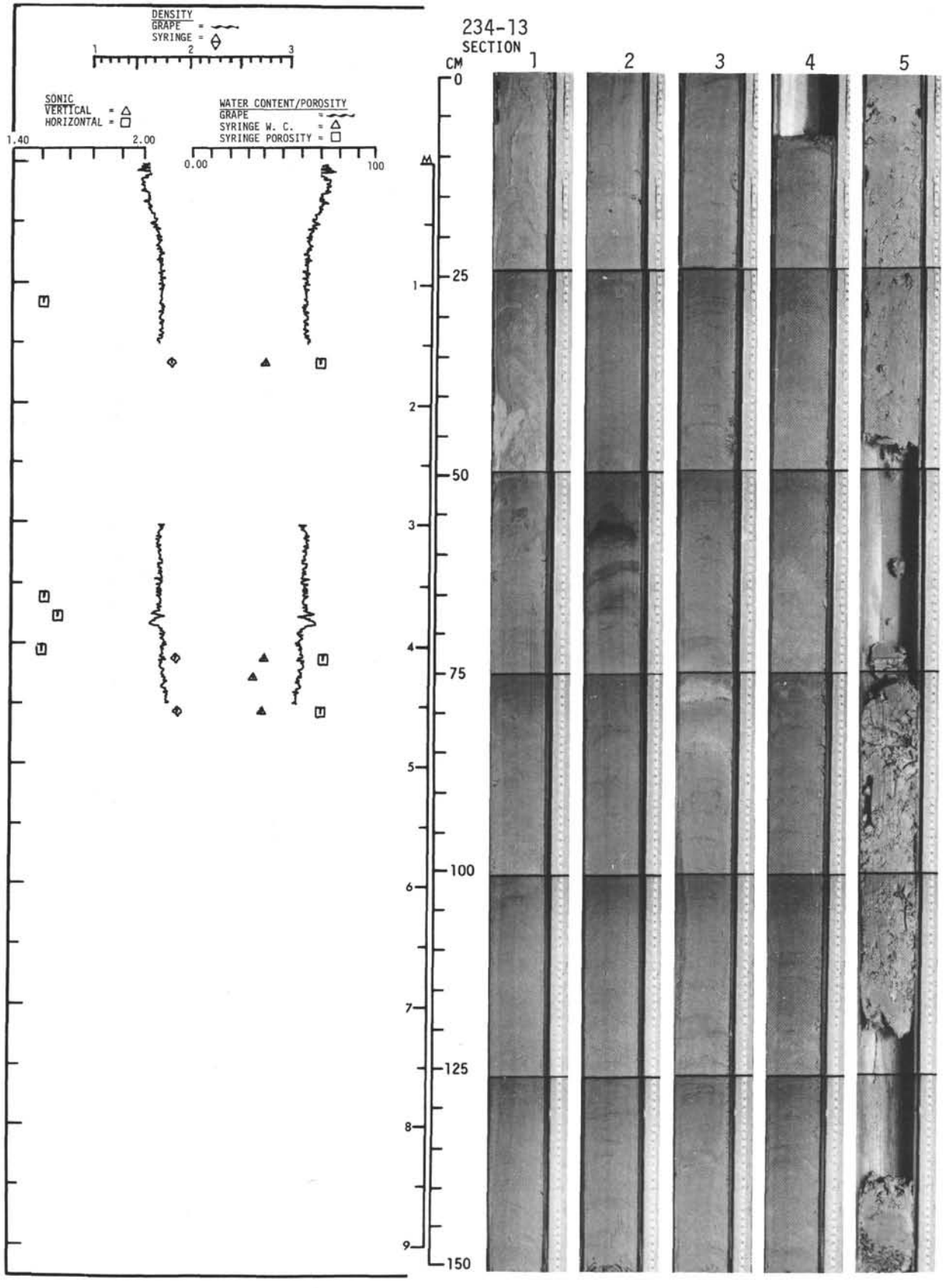
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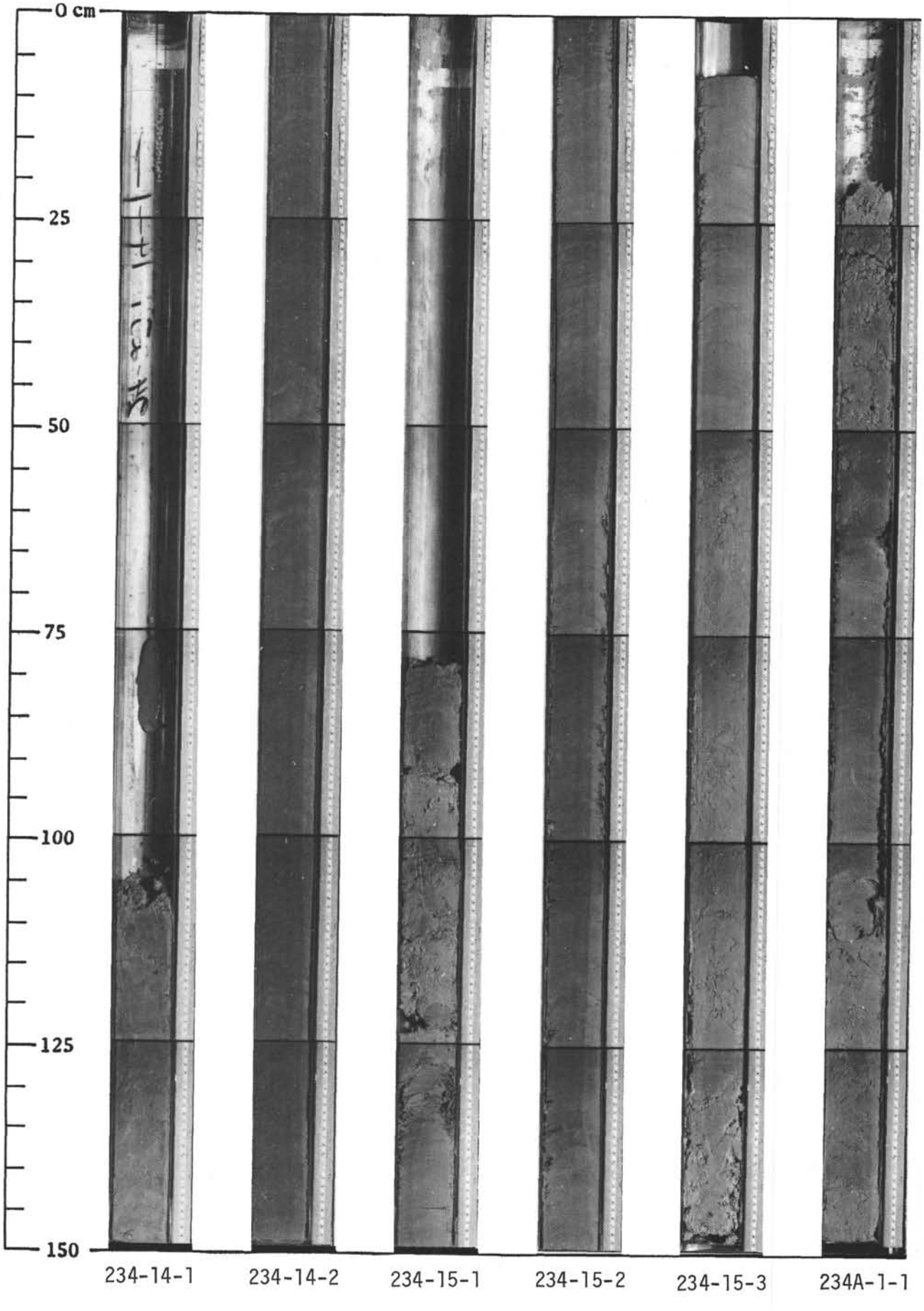
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