2. SITE 231

The Shipboard Scientific Party[1]

SITE DATA

Date Occupied: 5 May 1972

Date Departed: 8 May 1972

Time on Site: 95 hours, 40 minutes

Position:
Latitude: 11°53.41′N
Longitude: 48°14.71′E

Water Depth: 2152 corrected meters (echo sounding)

Bottom Felt At: 2161 meters (drill pipe)

Penetration: 584.0 meters

Holes Drilled: 1

Number of Cores: 64

Total Length of Cored Section: 584.0 meters

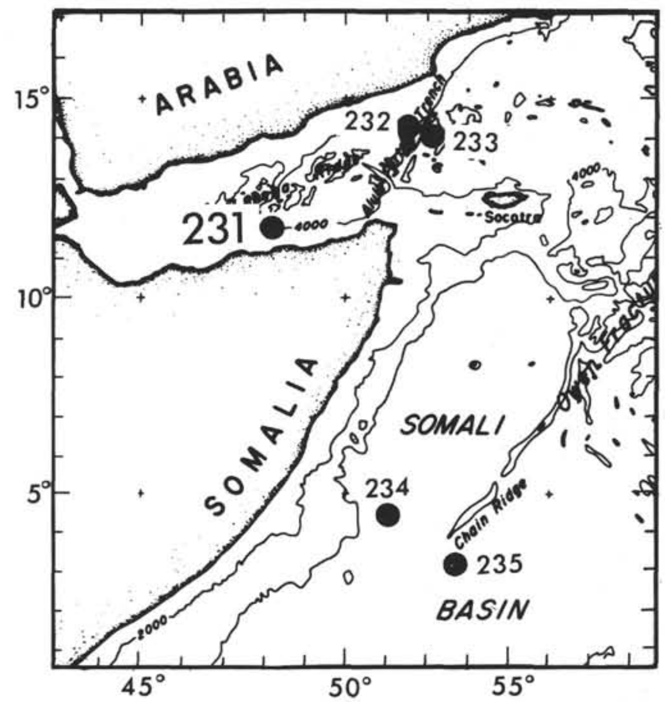
Total Core Recovered: 424.9 meters

Acoustic Basement:
Depth: 566.5 meters
Nature: Basalt and nanno chalk
Inferred vertical velocity to basement: 1.9 km/sec

Age of Oldest Sediment: Middle Miocene

Basement: Middle Miocene (intercalated sediments)

Principal Results: This site, in the Gulf of Aden south of the Sheba Ridge and 70 km north of the Somalia Coast, was drilled and cored continuously to a depth of 584 meters, and 424.9 meters of sediment were obtained. These are hemipelagic with sands at intervals in the upper 220 meters; the remainder is acoustically transparent, consisting of nanno clay and nanno ooze as follows: Pleistocene 0-102 meters; upper Pliocene 102-178 meters; lower Pliocene 178-254 meters; upper Miocene 254-482 meters; and middle Miocene 482-566.5 meters (base of sediments). Sediments intercalated with basement are middle Miocene. There is little evidence for sediments being baked above the basaltic basement. Basement was drilled to 17.5 meters with 7.5 meters recovered.



BACKGROUND AND OBJECTIVES

Site 231 was the first of three localities accepted for drilling the Gulf of Aden in order to investigate this apparently young oceanic area and to elucidate sedimentary processes in the earliest stages of ocean development by rifting. Situated between southern Arabia and the Horn of Africa, the gulf is at the focus of a topographically and tectonically complex and mobile region.

Southeast of Socotra the axis of the northwest-trending Carlsberg Ridge, part of the seismically active mid-ocean ridge system, is offset right laterally at Owen Fracture Zone (a transform fault) for a distance of 310 km. West of Owen Fracture Zone the active ridge crest, there termed Sheba Ridge, continues along the axis of the gulf and into the East African rift system at a triple junction located in the Afar Depression. Sheba Ridge is offset by several minor transform faults within the gulf and by one major one, the linear 5360-meter-deep Alula-Fartak Trench, that extends across the mouth of the gulf.

Geophysical evidence suggests that the Gulf of Aden is a young oceanic area with new mafic crust forming the central region (Sheba Ridge) for the past 10 m.y. as Arabia has moved away from Somalia. South of the complex, deformed, and active central ridge, the magnetic anomaly amplitudes, basement relief, and sea-floor topography itself all become subdued; an acoustically transparent layer overlies smooth basement and underlies turbidites of variable thickness.

[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.

Site 231 lies in the "Half-Degree Square", which is south of West Sheba Ridge and was the object of an intensive geophysical survey by R.R.S. *Discovery* in 1967 (Laughton et al., 1970). Our stated objectives in drilling here were to date and determine the composition of the smooth basement that seems to correlate acoustically with volcanic igneous material at Sheba Ridge, but in the southern region, does not have a marked magnetic signature; to determine the age, lithology, and, perhaps, origin of the transparent layer (evaporites?); to examine the time and extent of changes in level and sedimentary regime in the Somalia continental margin, which presumably is the source area for the upper turbidites.

Hence, it was obvious that we should core the hemipelagic sediment section continuously, penetrate the acoustic basement as far as necessary to establish it as true basement, not a sill, and obtain unweathered igneous rock, expectably basalt, for petrologic analysis and possible dating.

OPERATIONS

Near-Site Activities

Site 231, in the "Half Degree Square" of Laughton et al. (1970), was approached on a course of 079° followed by a westerly run a few miles southward to provide two nearly east-west bathymetric, reflection, and magnetic lines to complement the closely spaced north-south dan-buoy controlled sounding and magnetic lines run by R.R.S. *Discovery* in 1967. Upon heading for, and surveying near, the proposed locality ("24-1" on Figure 1a), it was learned that more favorable structure was present somewhat to the south, and a spar buoy was dropped to mark the new locality. *Glomar Challenger* continued her traverse south-southeast to provide equally good reflection context south of the site. Upon doubling north-northwest, the hydrophone streamers were retrieved and the beacon was dropped (1956Z) at a point, very near the buoy drop, marked 231 on Figure 1b, with a water depth of 2146 meters (corrected) by sounder. It is 3.6 miles south of the proposed 24-1, at the southwest extremity of a small transform fault zone offsetting Sheba Ridge and just north of the continental slope off Somalia. Figure 1a incorporates the sounding data of *Discovery* and *Glomar Challenger.*

At the close of the drilling program, *Glomar Challenger* streamed gear, passed northerly through both 231 and 24-1 to the vicinity of 12°10′N, 48°10′E and then easterly en route to Sites 232 and 233. The latter two runs provide reflection data to supplement–by two crossings–a seismic refraction profile (No. 6228) reported by Laughton and Tramontini (1969).

Drilling Program

Water depth was established at 2161 meters by drill pipe measurements. A total penetration of 584 meters was reached. Basalt was cored from 566.5 to 584 meters, and 7.7 meters was recovered (Table 1).

The first 50 meters of sediment was cored without pumping water or rotating the drill pipe. From 50 to 160 meters the drill pipe was rotated at 30 rpm and some seawater was pumped down the drill pipe to keep the bit clean and to prevent the drill from torquing. From 160 to 567 meters (top of basalt), the pipe was rotated at 30 to 35 rpm and with 150 psi of pump pressure and 20,000 pounds of weight on the bit. The basalt was cored with 30,000 pounds of bit weight and 150 to 200 psi of pump pressure.

A total of 64 cores was taken at Site 231. Each core was checked for the presence of gas. The methane-ethane ratio was monitored from Cores 13 to 62. Before leaving the site, the hole was filled with 190 barrels of heavy (12.5 PPG) drilling mud.

LITHOLOGIC SUMMARY

Hole 231 was continuously cored from the sediment surface down to basalt at a depth of 566.5 meters and then 17.5 meters into the basalt. The sedimentary sequence can be divided into five units (Table 2), with the underlying basalt constituting a sixth unit.

Unit 1 (0.0-7.0 m; Cores 1-2)

Unit 1 is a light gray nanno ooze. It contains up to 70 percent calcareous nannoplankton, together with minor quantities of foraminifera, radiolarians, and diatoms. Inorganic constituents include quartz, feldspar, volcanic glass, dolomite, calcite, and mica.

Unit 2 (7.0-64.0 m; Cores 3-8)

This unit consists of light olive-gray nanno ooze with intercalated sandy horizons. The ooze contains more than 60 percent calcareous nannoplankton together with some foraminifera. The sandy layers are somewhat variable in composition and some contain materials of reef origin (including *Acropora* fragments). The first 11 meters contains 50 percent sand-sized material of which 50 percent is quartz, and the remainder detrital and biogenous carbonate together with minor constituents. Other sandy layers with their principal characteristics are as follows: (a) 18 meters, nanno-rich foraminiferal sand; (b) 28 meters, quartz-rich shelly sand; (c) 34 meters, shelly sand; (d) 38 meters, shelly sand; (e) 48 meters, shelly sand; and (f) 59 meters quartz-rich shelly sand. Minor constituents in this unit include pyrite 1 to 5 percent, mica 1 to 5 percent, feldspar, dolomite, calcite, and quartz.

Unit 3 (64.0-121.0 m; Cores 9-14)

Unit 3 consists of a rather uniform nanno ooze predominantly light olive gray in color. Burrow mottling is common in this unit but does not attain the intensity found lower in the section. Some of the burrows are filled with mud, others with sand. Between 92 and 102 meters, a nanno clay with somewhat less than 60 percent nannos was recovered. One striking characteristic of this unit is that between 73 and 83 meters there are a number of reworked shallow-water fossils which indicate slumping. These include a gastropod, a scaphopod, a cerithid, and several foraminiferal limestone fragments. A sandstone fragment was also found in this interval. Minor constituents in this unit include pyrite, dolomite rhombs, detrital calcite, mica, quartz, foraminifera, radiolarians, and sponge spicules. Towards the base of the unit there is a thin sand layer.

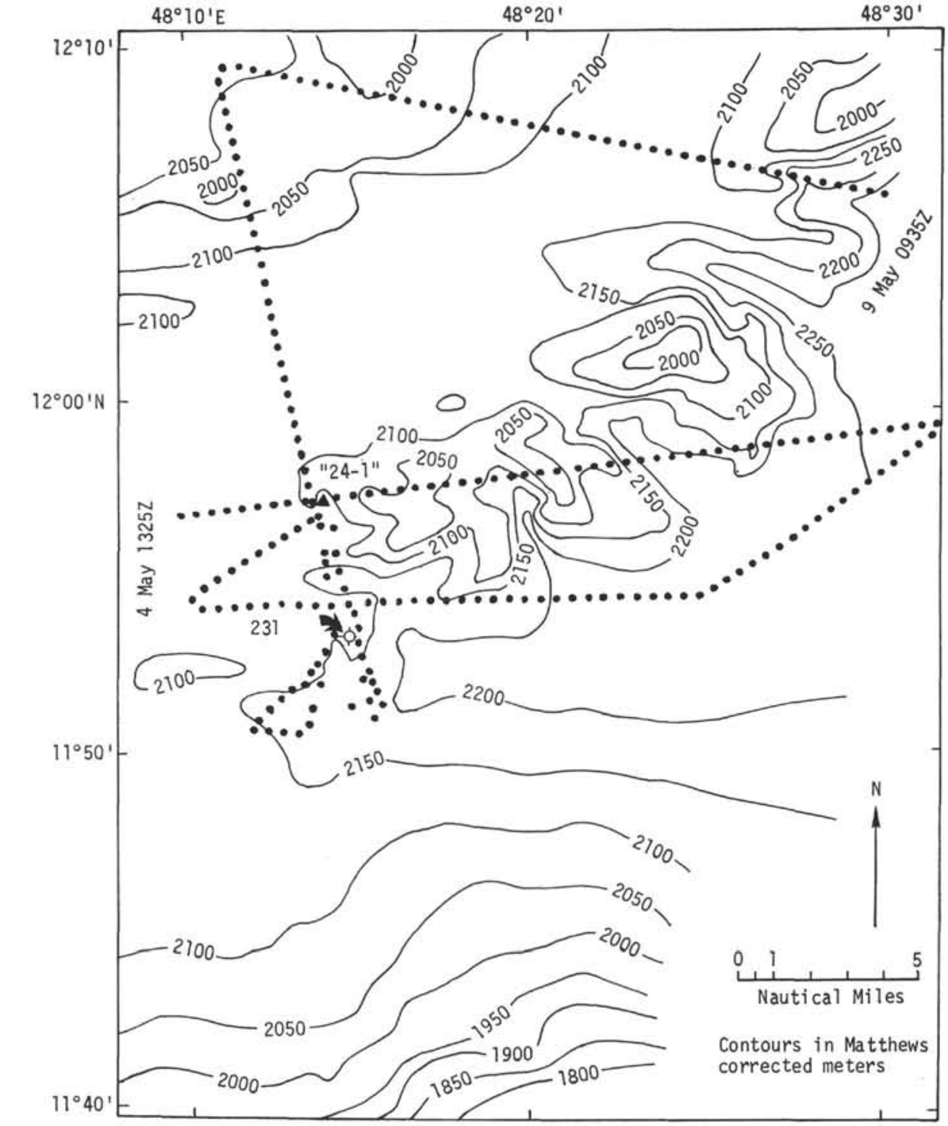


Figure 1a. *Site survey track of* Glomar Challenger *showing proposed Site 24-1 and Site 231. Contours in Matthews-corrected meters.*

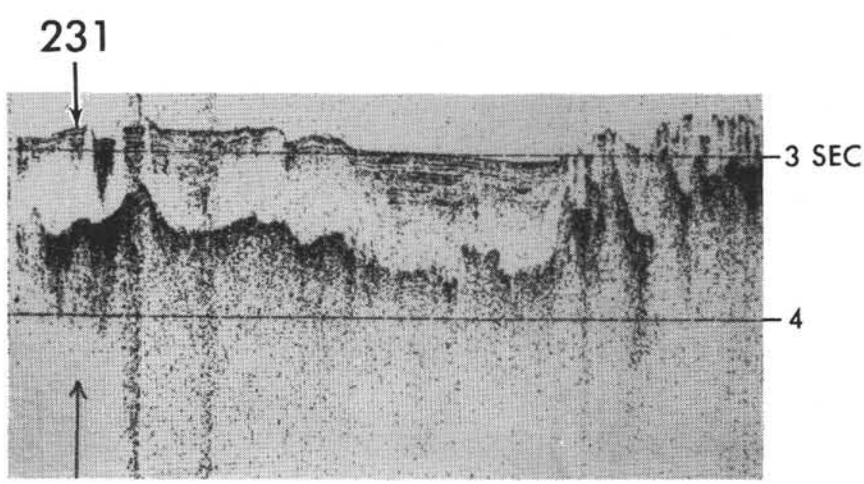


Figure 1b. *Profile showing location of Site 231.*

TABLE 1
Coring Summary–Site 231

Core	Date (May 1972)	Time	Depth Below Sea Floor (m)	Depth From Drill Floor (m)	Cored (m)	Recovered (m)	Recovered (%)
1	5	0753	0.0-0.5	2161.0-2161.5	0.5	0.5	100
2	5	0830	0.5-7.0	2161.5-2168.5	6.5	1.6	24
3	5	0925	7.0-16.5	2168.5-2177.5	9.5	5.5+	58
4	5	1015	16.5-26.0	2177.5-2187.0	9.5	4.5	47
5	5	1102	26.0-35.5	2187.0-2196.5	9.5	9.0+	94
6	5	1201	35.5-45.0	2196.5-2206.0	9.5	8.6+	91
7	5	1310	45.0-54.5	2206.0-2215.5	9.5	3.7+	39
8	5	1410	54.5-64.0	2215.5-2225.0	9.5	9.7	96
9	5	1507	64.0-73.5	2225.0-2234.5	9.5	8.8	92
10	5	1609	73.5-83.0	2234.5-2244.0	9.5	6.7	70
11	5	1715	83.0-92.5	2244.0-2253.5	9.5	3.9	41
12	5	1819	92.5-102.0	2253.5-2263.0	9.5	5.8	61
13	5	1926	102.0-111.5	2263.0-2272.5	9.5	7.7	81
14	5	2030	111.5-121.0	2272.5-2282.0	9.5	7.2	76
15	5	2147	121.0-130.5	2282.0-2291.5	9.5	3.7	39
16	5	2247	130.5-140.0	2291.5-2301.0	9.5	7.7	81
17	5	2347	140.0-149.5	2301.0-2310.5	9.5	7.0+	74
18	6	0052	149.5-159.0	2310.5-2320.0	9.5	4.0±	42
19	6	0150	159.0-168.5	2320.0-2329.5	9.5	5.5	58
20	6	0249	168.5-178.0	2329.5-2339.0	9.5	8.8	93
21	6	0346	178.0-187.5	2339.0-2348.5	9.5	8.7+	91
22	6	0442	187.5-197.0	2348.5-2358.0	9.5	6.7+	70
23	6	0537	197.0-206.5	2358.0-2367.5	9.5	7.8–	82
24	6	0647	206.5-216.0	2367.5-2377.0	9.5	9.0	94
25	6	0738	216.0-225.5	2377.0-2386.5	9.5	8.7	91
26	6	0833	225.5-235.0	2386.5-2396.0	9.5	7.9	83
27	6	0938	235.0-244.5	2396.0-2405.5	9.5	7.8+	82
28	6	1041	244.5-254.0	2405.5-2415.0	9.5	9.0	94
29	6	1140	254.0-263.5	2415.0-2424.5	9.5	9.1	96
30	6	1246	263.5-273.0	2424.5-2434.0	9.5	7.8	82
31	6	1345	273.0-282.5	2434.0-2443.5	9.5	6.3	66
32	6	1452	282.5-292.0	2443.5-2453.0	9.5	8.7	91
33	6	1605	292.0-301.5	2453.0-2462.5	9.5	7.2+	76
34	6	1705	301.5-311.0	2462.5-2472.0	9.5	9.2	97
35	6	1813	311.0-320.5	2472.0-2481.5	9.5	4.5	47
36	6	1922	320.5-330.0	2481.5-2491.0	9.5	8.2	86
37	6	2040	330.0-339.5	2491.0-2500.5	9.5	7.2	76
38	6	2213	339.5-349.0	2500.5-2510.0	9.5	5.3+	56
39	6	2331	349.0-358.5	2510.0-2519.5	9.5	6.0	63
40	7	0047	358.5-368.0	2519.5-2529.0	9.5	6.4	67
41	7	0200	368.0-367.5	2529.0-2538.5	9.5	7.3	77
42	7	0318	377.5-387.0	2538.5-2548.0	9.5	7.8	82
43	7	0434	387.0-396.5	2548.0-2557.5	9.5	9.5	100
44	7	0601	396.5-406.0	2557.5-2567.0	9.5	2.3	24
45	7	0720	406.0-415.5	2567.0-2576.5	9.5	9.3	97
46	7	0833	415.5-425.0	2576.5-2586.0	9.5	9.5	100
47	7	0950	425.0-434.5	2586.0-2595.5	9.5	8.9	94
48	7	1122	434.5-444.0	2595.5-2605.0	9.5	4.2	44
49	7	1313	444.0-453.5	2605.0-2614.5	9.5	3.5	37
50	7	1429	453.5-463.0	2614.5-2624.0	9.5	8.3+	87
51	7	1605	463.0-472.5	2624.0-2633.5	9.5	9.4+	99
52	7	1729	472.5-482.0	2633.5-2643.0	9.5	7.6	80
53	7	1912	482.0-491.5	2643.0-2652.5	9.5	8.5	90
54	7	2102	491.5-501.0	2652.5-2662.0	9.5	4.0	42
55	7	2245	501.0-509.5	2662.0-2670.5	8.5	4.5	53
56	8	0006	509.5-519.0	2670.5-2680.0	9.5	7.7	81
57	8	0145	519.0-528.5	2680.0-2689.5	9.5	3.7	39
58	8	0326	528.5-538.0	2689.5-2699.0	9.5	8.8	93
59	8	0500	538.0-547.5	2699.0-2708.5	9.5	9.5	100
60	8	0618	547.5-557.0	2708.5-2718.0	9.5	3.9+	41
61	8	0753	557.0-566.5	2718.0-2727.5	9.5	8.3–	86
62	8	0905	566.5-568.5	2727.5-2729.5	2.0	1.0	50
63	8	1158	568.5-574.5	2729.5-2735.5	6.0	2.2	36
64	8	1551	574.5-584.0	2735.5-2745.0	9.5	4.5	47

TABLE 2
Lithologic Units – Site 231

Depth Below Sea Floor (m)	Unit	Lithology	Thickness (m)	Cores
	1	Nanno ooze	7	1-2
7.0				
	2	Nanno ooze intercalated sandy horizons	57	3-8
64.0				
	3	Nanno ooze	57	9-14
121.0				
	4	Nanno ooze with intercalated horizons	114	15-26
235.0				
	5	Uniform grayish-olive nanno ooze	331.5	27-61
566.5				
	6	Volcanic basement with thin nanno chalk layers		62-64
584.0				

Unit 4 (121.0-235.0 m; Cores 15-26)

This unit consists predominantly of grayish-olive to light olive-gray nanno ooze and nanno clay with intercalated coarse sediments, some of them volcanic ash deposits. The coarse horizons are as follows: (a) 123 meters, quartz-rich nanno ooze; (b) 142 meters, nanno dolomitic clayey silt; (c) 161 meters, foram-rich nanno ooze; (d) 170 meters, volcanic ash; (e) 180 meters, volcanic ash; (f) 181 meters, nanno- and foram-rich silty quartz sand; (g) 188.5 meters, volcanic ash; (h) 203 meters, volcanic ash; (i) 208 meters, nanno detrital silty sand; (j) 231 meters, nanno detrital silty sand.

Within this unit, the calcareous nannofossils vary from about 40 percent up to about 90 percent. Other constituents are foraminifera, radiolarians, dolomite rhombs, detrital calcite, quartz, feldspar, and pyrite, all usually in minor quantities.

Unit 5 (235.0-566.5 m; Cores 27-61)

Unit 5, lowest in the sediment column, consists of a fairly uniform grayish-olive nanno ooze. Burrow mottling becomes increasingly apparent down the unit. The degree of lithification also increases downwards. Gas was evident in most of the cores, and bitumen occurs at 397 meters. At 425 meters, there is a thin layer consisting of quartz nanno ooze containing 30 percent quartz, 5 percent feldspar, 5 percent shell, and 50 percent nannos. Towards the bottom of the unit, color variation between grayish olive and light olive gray becomes common. Calcareous nannoplankton commonly comprise between 80 and 90 percent of the sediment. H_2S was detected throughout much of the lower part of the unit.

Unit 6 (Below 566.5 m; Cores 62-64)

This unit consists of volcanic rocks, principally basalt and volcanic glass, together with layers and veins of lithified nanno chalk. The volcanics are discussed in Appendix A and the sediments enclosed in them have not been examined in detail.

Conclusions

1. The gross characteristics of the entire sediment section are surprisingly uniform, the sediments being nannoplankton-rich hemipelagic ooze. There is little or no variation even close to the basalt basement. This uniformity suggests near constant conditions of water depth, pelagic carbonate production, and detrital sediment input.

2. Reef and other very shallow-water carbonate grains are largely limited to Units 1 and 2. The accession of shelf facies sediments to deep water may be related to Pleistocene low sea level periods, when the outer shelf edge became the reef growth locale.

3. The fairly abundant very fine and silt-sized quartz, dolomite, calcite, and other detrital mineral grains found dispersed throughout the section may well be of eolian origin. Aridity in the potential detrital sediment source area of Somalia probably precluded large inputs of waterborne terrigenous sediment.

4. In the basalt unit, nanno chalk layers are generally associated with chilled basaltic glass and may be indicative of continued sediment deposition between eruptive events or represent xenoliths.

BIOSTRATIGRAPHIC SUMMARY

Introduction

The 567.6 meters of sediments continuously cored at Site 231 represents an apparently uninterrupted sequence from Quaternary to middle Miocene. Sediments at 567.4 meters (Sample 62-1, 85-90 cm), above the basalt, and below the altered volcanic ash, are approximately 12.5 to 12.8 m.y. old (foraminiferal Zone N.12), and the nanno chalk inclusions in the basalt at 567.8 and 569.4 meters (Samples 62-1, 130 cm and 63-1, 90 cm) indicate an age of approximately 13 to 14 m.y. (*Sphenolithus heteromorphus* nannofossil zone). These dates permit a reliable age assignment of approximately 13 m.y. for the basalt/sediment contact.

Calcareous nannofossils are common and slightly etched throughout the sedimentary sequence and considerably altered in the basalt inclusions. Planktonic foraminifera are common and moderately well preserved throughout most of the upper 225 meters of the section but are less common and poorly preserved in the lower 342.6 meters (below Core 25). Radiolarians are abundant and well preserved only in the uppermost core and are present but poorly preserved throughout the remainder of the hole.

The zonation of the various fossil groups are summarized on the site summary form at the end of this chapter. Because of the uncertainty of the position in the section of the evolutionary appearance of the foraminiferal Quaternary index species *Globorotalia truncatulinoides*, the Pleistocene/Pliocene boundary was placed on the basis of nannofossil data. This boundary, placed at the highest occurrence of *Discoaster brouweri* (*Pseudoemiliania lacunosa*/*Cyclococcolithina macintyrei* zonal boundary), lies at 102 meters, between Cores 12 and 13. The late/middle Miocene boundary was placed on the basis of nannofossil data at 482 meters (between Cores 52 and 53 at the *Discoaster neohamatus*/*Discoaster bellus* zonal boundary), although the foraminiferal zonation indicates a higher position for the boundary (between Core 46, Section 5 and Core 48, Section 3).

Calcareous Nannoplankton

Nannofossils are common throughout the sedimentary section.

Core 1 contains an assemblage consisting of *Gephyrocapsa oceanica* and many small placoliths which belong, most probably, to *Emiliania huxleyi*. This core is tentatively assigned to the *Emiliania huxleyi* Zone, but only electron microscopy could give definitive proof of this age assignment. Cores 2 through 9 recovered the *Gephyrocapsa oceanica* Zone with common *G. oceanica* and *G. caribbeanica*. The last occurrence of *Pseudoemiliania lacunosa* in Core 4 could be used to further subdivide this interval. The *Gephyrocapsa caribbeanica* Zone is thin and was recovered only in Core 10. *Crenalithus doronicoides* and *Gephyrocapsa caribbeanica* overlap in that interval. The *Pseudoemiliania lacunosa* Zone is present in Cores 11 and 12 with assemblages including common *Crenalithus doronicoides* and *Pseudoemiliania lacunosa; Ceratolithus cristatus* and *C. rugosus* occur in the lower part of this zone, and *Cyclococcolithina macintyrei* ranges throughout this interval. Reworked *Discoaster brouweri* is present in small numbers throughout this zone. The upper Pliocene *Cyclococcolithina macintyrei* Zone was found in Cores 13 through 16 with assemblages including *Cyclococcolithina macintyrei* and *Discoaster brouweri*. Cores 17 through 19 yield assemblages belonging to the *Discoaster pentaradiatus* Zone with *Discoaster brouweri, D. pentaradiatus*, and, in the lower part, *D. surculus*. The *Discoaster tamalis* Zone occurs in Core 20 only. The *Reticulofenestra pseudoumbilica* Zone was recovered in Cores 21 through 27 with assemblages including common *Reticulofenestra pseudoumbilica* and *Sphenolithus abies*. Cores 23 through 27 contain reworked Miocene discoasters and placoliths in small numbers. Core 28 yielded *Ceratolithus acutus* together with rare *C. tricorniculatus*, which indicates the basal Pliocene *Ceratolithus acutus* Zone. The *Ceratolithus rugosus* Zone was not found in any of the samples studied.

The Pliocene/Miocene boundary, based on calcareous nannofossils, would fall between Cores 28 and 29. Core 29 belongs to the upper Miocene *Ceratolithus tricorniculatus* Zone and contains an assemblage including *Ceratolithus tricorniculatus* and *C. primus*. The *Ceratolithus primus* Zone is quite thick at this site and occurs in Cores 30 through 42. *Ceratolithus primus, C. amplificus*, and *Discoaster quinqueramus* are characteristic for this interval. Cores 43 through 46 are assigned to the *Discoaster berggrenii* Zone based on assemblages including *Discoaster berggrenii, D. quinqueramus*, and *D. surculus*. Cores 47 and 48 contain *Discoaster* sp. cf. *D. neorectus* (somewhat smaller), *D. bellus, D. neohamatus*, and *D. pseudovariabilis* and is thus assigned to the *Discoaster neohamatus* Zone. Cores 49 through 52 yield assemblages typical of the *Discoaster bellus* Zone including *Discoaster neohamatus, D. bellus, D. calcaris*, and *D. pseudovariabilis*. The boundary between the upper and the middle Miocene, based on nannofossils, lies between Cores 52 and 53. Cores 53 through 56 contain rich assemblages characteristic of the *Discoaster hamatus* Zone with *Discoaster hamatus, D. neohamatus, D. calcaris*, rare *Discoaster bollii, Catinaster coalitus*, and *C. mexicanus*. The next lower zone present at this site is the *Discoaster kugleri* Zone, recovered in Cores 57 through 60, with assemblages including *Discoaster kugleri, D. exilis*, and *Coccolithus eopelagicus*. Cores 61 and the top of 62 contain impoverished assemblages with *Discoaster exilis* and *Coccolithus eopelagicus*, which are assigned to the *Discoaster exilis* Zone. Nannoplankton chalk layers interbedded with basalt in Cores 62 and 63 yield moderately recrystallized assemblages including early forms of *Cyclococcolithina macintyrei* (slightly elliptical), *Coccolithus eopelagicus, Cyclicargolithus floridanus, Discoaster deflandrei*, and *Reticulofenestra pseudoumbilica* (with covered central areas). This assemblage is typical of the *Discoaster exilis* to *Sphenolithus heteromorphus* Zone.

Preservation: All the assemblages recovered from soft sediments at this site show slight etching resulting in serrate margins of coccoliths and sometimes destruction of central area elements. Delicate forms like *Pontosphaera* and *Scyphosphaera* are preserved. The sediment interbedded with basalt contains highly overgrown nannofossils with almost unrecognizable discoasters and considerably altered placoliths. *Reticulofenestra pseudoumbilica* has a strongly overgrown central area, giving it an appearance similar to *Reticulofenestra bisecta*.

Foraminifera

Abundance and Preservation

Moderately to poorly preserved foraminifera are the dominant component of the coarse fraction (>63μ) throughout the sediments recovered at Site 231 except in the interval between Cores 47 and 57 in Unit 5. Terrigenous components are common throughout the section and increase in relative percentage down the hole; they are abundant in some sandy horizons and dominate the coarse fraction between Cores 47 and 57. Pyrite is rare to common below Core 9 and abundant in some horizons. Skeletal debris of pelecypods, gastropods, pteropods, and echinoderms are rare throughout the section. These are common in the sandy horizons of Unit 2 together with bryozoan and coral debris and transported shallow-water benthic foraminifera.

Foraminiferal faunas exhibit signs of dissolution, especially below Core 15. Planktonic faunas show an increasingly high degree of fragmentation below Core 8, and in many horizons, the planktonic species are predominantly forms with robust solution-resistant tests. Dissolution of planktonic foraminifera is also reflected by the high relative frequency of benthic species, which are more resistant to solution and which sometimes dominate the assemblages. Planktonic foraminifera are dominant in Cores 1 to 25; they constitute from 80 to over 99 percent of the total foraminiferal fauna in Cores 1 to 15, and 50 to 80 percent of the fauna in Cores 16 to 25. Below Core 25, relative proportions of planktonics and benthics are variable. Planktonic species make up 30 to 80 percent of the fauna, and are very rare in some intervals (especially in Core 47 and in the interval between Cores 50 and 57).

Planktonic Foraminiferal Zonation

The interval Core 1 to Core 6, Section 5 is assigned to the Quaternary (Zones N.23 and N.22) as indicated by the common presence of *Globorotalia truncatulinoides*. The N.23/N.22 zonal boundary is tentatively drawn between Sections 2 and 3 of Core 3, at the lowest occurrence of *Globigerinella adamsi*. Specimens of pink colored *Globigerina rubescens* occur commonly above this level in the interval Core 1 to Core 3, Section 2, rarely in the interval between Core 3, Section 3 to Core 5, Section 3, and they were not found below.

The N.22/N.21 zonal limit (Pleistocene/Pliocene boundary) is placed in Core 6, Section 5 at the base of the common occurrence of *G. truncatulinoides*. The exact level of the evolutionary appearance of this species from its direct ancestor *Globorotalia tosaensis* cannot be easily determined. Specimens intermediate between *G. truncatulinoides* and *G. tosaensis* (with a rounded edge but with an imperforate band) occur occasionally throughout the interval between Core 3, Section 4 and Core 12, Section 1. The highest occurrence of *G. tosaensis* (specimens with a perforate rounded edge) is in Core 5, Section 2. The latter species occurs rarely in the interval between Core 5, Section 2 and Core 6, Section 1, commonly between Core 6, Section 3 and Core 9, Section 4, and rarely below. The base of the common occurrence of *G. truncatulinoides* (in Core 6, Section 5) approximates the highest occurrence of *Globigerinoides quadrilobatus fistulosus*, the lowest appearance of *Globigerina tenella* (in Core 6, Section 4), and the highest occurrence of *Globigerinoides obliquus extremus* (in Core 6, Section 6).

An interval with dextrally coiled *Globorotalia tumida tumida* was found between Core 9, Section 4 and Core 10, CC. A horizon containing *Globoquadrina sp.* A (a new species to be described in a subsequent paper) occurs in Sample 12, CC, slightly above the highest occurrence of *Globorotalia limbata* and *Turborotalia humerosa* in Core 13, Section 3. The N.21/N.20-N.19 zonal limit is drawn between Cores 19 and 20 at the lowest occurrence of *G. tosaensis*. The N.19/N.18 boundary is placed between Cores 27 and 28, at the lowest occurrence of *Sphaeroidinella dehiscens*, although the scarcity of this species at this site makes it an unreliable biostratigraphic indicator for the Gulf of Aden. The N.18/N.17 limit (Pliocene/Miocene boundary), based on the lowest occurrence of *Globorotalia tumida tumida*, lies between Cores 28 and 29.

Cores 30 to 46 are assigned to the late Miocene Zones N.17 to N.15. The N.17/N.16 boundary is placed at the base of *Globorotalia tumida plesiotumida*, between Cores 34 and 35, and Zones N.16 and N.15 were not differentiated. The lowest occurrence of *Turborotalia acostaensis* lies in Core 43, but *Globorotalia merotumida* ranges lower; as low as Core 46, Section 5. Preservation of planktonic foraminifera is inadequate between Core 46, Section 5 and Core 48, Section 3, and no biostratigraphic data was obtained from this interval.

The lower part of the section from Core 48, Section 3 to the bottom of the hole contains common *Turborotalia siakensis* and is assigned to middle Miocene Zones N.14 to N.12. In this interval, many horizons did not yield biostratigraphically valuable data because of the poor preservation of planktonic foraminifera, especially in Core 49 and between Cores 51 and 57. The N.14/N.13 boundary was not determined. Rare forms referable to *Globigerina nepenthes*, which is known to define the base of N.14, occur as far down as Core 59, Section 2; however, forms known to become extinct within N.13 are present higher in the section. The highest occurrences of *Globigerinoides subquadratus* and *Turborotalia mayeri* lie, respectively, in Core 50, Section 6 and Core 58, Section 2. The N.13/N.12 boundary is placed at the lowest occurrence of *Sphaeroidinellopsis subdehiscens* in Core 61, Section 2, which is also the level of highest appearance of *Globorotalia fohsi fohsi* and *Globorotalia peripheroacuta*. The lowest sample, just above the basalt and below the altered volcanic ash (Sample 62-1, 85-90 cm), contains a rich but altered planktonic fauna including *Globorotalia fohsi fohsi, G. fohsi lobata, G. fohsi robusta, Globorotalia peripheroacuta, Globorotalia peripheroronda*, and *Globorotalia praefohsi*. This assemblage belongs to the faunal Zone N.12 and is 12.5 to 12.8 m.y. old according to the Berggren scale.

Benthic Foraminifera

Benthic foraminifera are common throughout the section, but their relative frequency varies. In the Pleistocene sediments, they constitute from less than 1 to 20 percent of the total foraminiferal fauna and are especially common in the sandy layers of Unit 2 because of dilution of planktonic foraminifera by displaced elements of shallow origin. In Pliocene sediments, benthic foraminifera comprise 20 to 50 percent of the foraminiferal fauna and in the Miocene 20 to 70 percent. They are especially abundant in the lower part of the section where they often dominate the foraminiferal assemblages because of dissolution of planktonic foraminiferal tests.

Benthic foraminiferal assemblages in most cores are characteristic of deep water; however, mixing with displaced shallower water elements was observed in various horizons. The assemblages commonly include deep-water species characteristic of a lower bathyal, or deeper, environment, such as *Cibicides wuellerstorfi, Epistominella exigua, Gyroidina soldanii, Laticarinina pauperata, Melonis pompiliodes,* and *Pullenia quinqueloba*. Species usually found at upper to middle bathyal depths, such as *Chilostomella oolina, Eggerella bradyi, Globocassidulina subglobosa, Hoeglundina elegans, Melonis barleeanus,* and *Sphaeroidina bulloides*, were also found associated with the deep-water fauna. Some horizons include species typical of outer neritic to upper bathyal depth, such as *Cassidulina carinata, Hyalinea balthica*, and *Textularia* spp., which have probably been transported downslope. Shallow-water species with abraded tests, such as *Amphistegina lessonii, Asterigerina* sp., *Ammonia gaimardii compressiuscula,* and *Elphidium* spp., are common in the sandy layers of Unit 2 (upper Pleistocene) and in some lower Pleistocene and upper Pliocene horizons (especially in Core-Sections 9-3 to 9-5; 13-3 to 13-5, 15-3, 17-1 to 17-3, 18-3). These are frequently associated with skeletal debris of pelecypods, gastropods, bryozoans, echinoderms, and corals, suggesting slumping from shelf areas.

Radiolarians

The only sample with abundant well-preserved radiolarians is 231-1-1, 145-147 cm, which is Quaternary in age. Below that, most of the samples from Cores 2 to 16 contain radiolarians, which are, however, somewhat dissolved and therefore inadequate for biostratigraphic interpretation.

Radiolarian abundances and preservation in all samples examined from Site 231 are as follows: 1-1, 145-147 cm (A, G); 2-2, 49-51 cm (R, M); 3-1, 58-60 cm (R, M); 3-4, 53-55 cm (R, M); 4-1, 50-52 cm (R, M); 4-3, 50-52 cm (R, M); 5-1, 49-51 cm (C, M); 5-6, 50-52 cm (F, M); 5-6, 115-117 cm (None); 6-1, 50-52 cm (R, M); 6-6, 50-52 cm (F, M); 7-3, 130-132 cm (None); 8-1, 59-61 cm (F, M); 8-6, 110-112 cm (C, M); 9-1, 49-51 cm (C, M); 9-6, 120-122 cm (None); 10-3, 29-31 cm (C, M); 10-5, 130-132 cm (C, M); 11-2, 50-52 cm (C, M); 11-3, 110-112 cm (C, M); 12-1, 50-52 cm (R, M); 12-4, 130-132 cm (F, M); 13-2, 30-32 cm (F, M); 13-6, 108-110 cm (F, M); 14-1, 49-51 cm (F, M); 14-5, 118-120 cm (F, M); 15-2, 83-85 cm (R, M); 16-2, 19-21 cm (R, M); 16-6, 119-121 cm (None); 17-1, 58-60 cm (None); 17-5, 119-121 cm (None); 18-2, 29-31 cm (None); 19-2, 29-31 cm (F, M); 19-4, 110-112 cm (None); 20-1, 44-46 cm (None); 20-6, 119-121 cm (None); 21-1, 59-61 cm (None); 21-6, 109-111 cm (None); 22-1, 84-86 cm (+, M); 23-6, 119-121 cm (None); 24-5, 119-120 cm (None); 25-6, 120-122 cm (None); 26-6, 110-112 cm (None); 27-6, 110-112 cm (R, pyritized); 28-6, 110-112 cm (R, pyritized); 29-6, 110-112 cm (+, pyritized); 30-6, 110-112 cm (None); 31-5, 110-112 cm (None); 32-6, 110-112 cm (None); 33-5, 110-112 cm (None); 34-6, 110-112 cm (None); 35-2, 50-52 cm (None); 36-6, 100-102 cm (None); 37-5, 100-102 cm (None); 38-4, 60-62 cm (None); 39-4, 100-102 cm (None); 40-5, 104-106 cm (None); 41-5, 120-122 cm (None); 42-6, 120-122 cm (None); 43-6, 120-122 cm (None); 44-2, 110-112 cm (None); 45-6, 40-42 cm (None); 47-1, 60-62 cm (None); 47-6, 120-122 cm (None); 48-1, 119-121 cm (None); 49-2, 40-42 cm (None); 50-6, 110-112 cm (None); 51-6, 110-112 cm (None); 52-5, 130-132 cm (R, M); 53-6, 120-122 cm (R, M); 54-2, 56-58 cm (None); 55-1, 70-72 cm (R, P); 56-2, 30-32 cm (None); 57-1, 107-109 cm (None); 58-6, 50-52 cm (None); 59-6, 102-104 cm (None); 60-2, 70-72 cm (R, pyritized); 61-6, 117-119 cm (None); and 62-1, 85-90 cm (None).

SEDIMENT ACCUMULATION RATES

Average accumulation rates were calculated as follows:

Series	Thickness (m)	Average Accumulation Rate (m/m.y.)
Pleistocene	102.0	56.7
Upper Pliocene	76.0	63.3
Lower Pliocene	76.0	38.0
Upper Miocene	228.0	38.0
Middle Miocene	85.6	47.8

The average accumulation rate for the entire sedimentary sequence is 43.7 m/m.y. The higher rate for the Pleistocene and upper Pliocene series (average of 59.3 m/m.y.) probably reflects the input of coarse shell and skeletal debris slumped from shelf areas in Unit 2 and the upper part of Unit 4.

PHYSICAL PROPERTIES

Bulk Density and Porosity

Only one slight variation in bulk density and porosity occurs in the 566.5 meters of nanno ooze overlying the basaltic basement. In Core 5, a 0.21 g/cm^3 increase in bulk density and a corresponding 13 percent decrease in porosity is attributed to the quartz-rich shell sand layer at 28 meters which is described in the section on lithology (see also Core 5, physical property data). The various sandy layers described in Unit 2 (7-64 m) of the lithologic description are grossly reflected in the density and porosity data in Figure 2. The plots of bulk density and porosity are remarkably smooth, the former showing a steady increase from 1.64 g/cm^3 near the surface to 1.97 g/cm^3 near 550 meters while over the same interval, the porosity generally decreases from approximately 63 to 44 percent. The trends of these properties are attributed to normal consolidation of the sediments, i.e., an escape of pore water in an upward direction due to an increasing overburden pressure by sedimentation.

Bulk densities of the basaltic basement rocks were obtained by the GRAPE device on block samples approximately 1.5 cm × 1.5 cm × 2.5 cm. Bulk densities measured in the vertical direction (long axis) ranged from 2.67 to 2.86 g/cm^3 and those measured in the horizontal direction from 2.72 to 2.86 g/cm^3 (See Table 3).

Sonic Velocity

The velocity profile of the nanno ooze in Figure 2 shows a smooth increase from 1.50 km/sec near the surface to 1.80 km/sec just above the basaltic basement. Lithologic Unit 2 is represented by a velocity of 1.66 km/sec for the

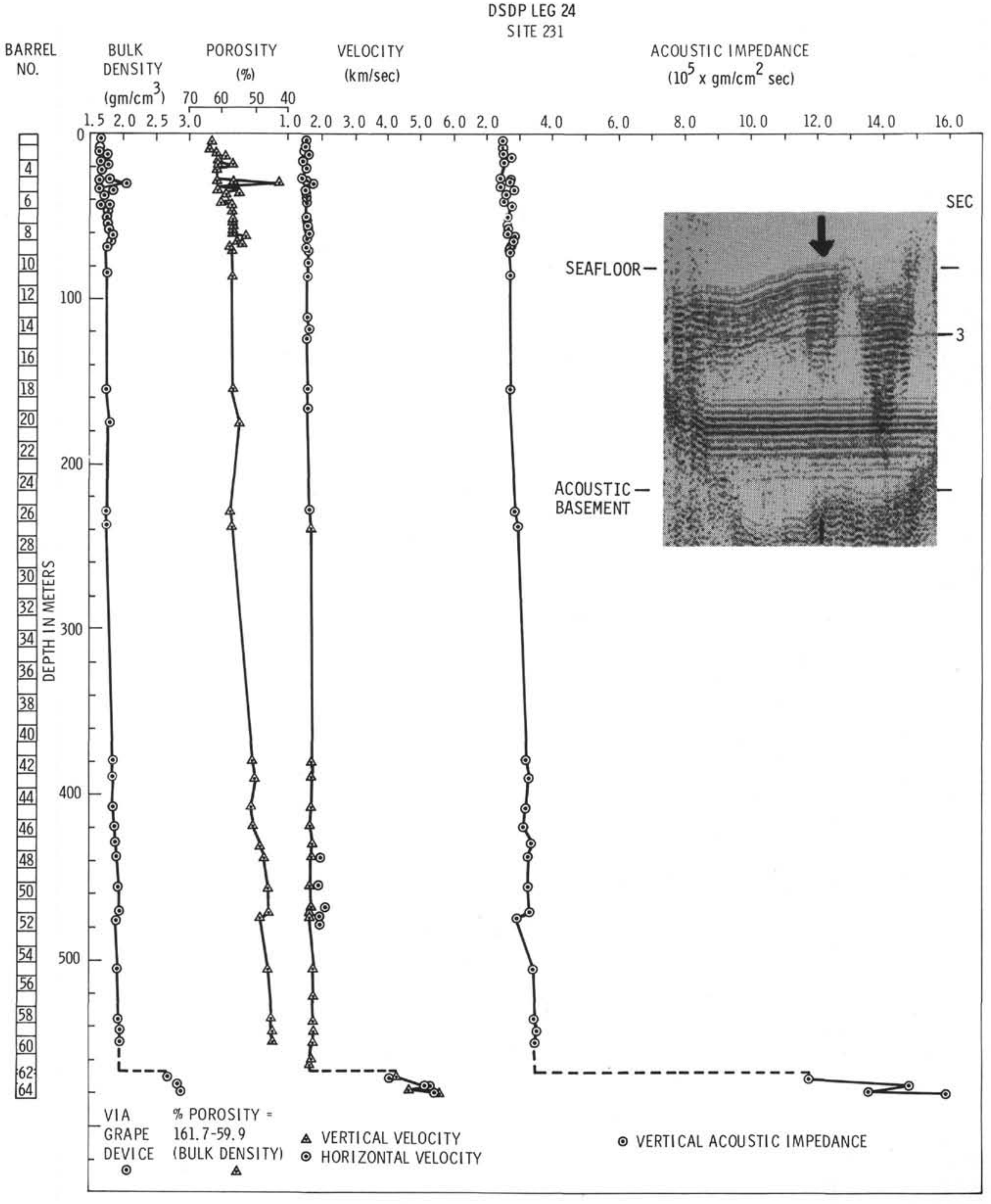


Figure 2. *Physical properties, Site 231.*

TABLE 3
Bulk Density of Basalt–Site 231

Sample[a]	Bulk Density (g/cm^3)		Velocity (km/sec)		Rock Description
	Vertical	Horizontal	Vertical	Horizontal	
62-1 (CC)				3.74	Vesicular basalt
63-1 (1)	2.67	2.72	4.37	4.13	Basalt
64-1 (2)	2.81	2.84	5.21	5.28	Basalt
64-2 (2)	2.79	2.82	5.12	5.22	Oxidated basalt
64-2 (4)	2.83	2.86	4.78	5.17	Basalt
64-3 (3)	2.86	2,86	5.54	5.49	Basalt

[a]Figures in parentheses are sequence numbers of basalt pieces in the section.

sandy interval in Core 5. Other sandy layers within Unit 2 were not measured for sonic velocities because of the degree of disturbance of the layers and the high attenuation of the received measuring signal.

Although attempts were made to calculate velocities for Cores 12 through 41, few reliable values were obtained. Core disturbance, gas bubbles, and cracks caused by the expanding gases precluded accurate measurements. However, the smoothness of both the bulk density and porosity curves over this depth interval suggests that no significant velocity changes have occurred.

Ideally, horizontal and vertical velocity values should be obtained for the sediments for application to, and interpretation of, seismic refraction and reflection measurements. The upper 430± meters of sediments were measured only for horizontal velocities due to the consistency of the sediment. However, the small degree of velocity anisotropism in Cores 48 and 50 suggests that the measured horizontal velocities are also valid representations of the vertical velocities. Velocity anisotropism increases from 0.09 km/sec near 440 meters to approximately 0.58 km/sec at about 505 meters. Therefore, horizontal velocities are plotted above 430 meters and vertical velocities from 430 meters to basement contact. It must be emphasized at this time that all sediment velocity measurements are probably minimum values due to: (1) release of overburden pressure, (2) release of hydrostatic pressure, and (3) changes of temperature from in situ values (see Hamilton, 1965 or Cernock, 1970 for a detailed explanation).

The major velocity change occurs at 566.5 meters (Unit 6) where basaltic basement is encountered. An altered, fractured, vesicular basalt sample from the core catcher of Core 62 has a horizontal sonic velocity of 3.74 km/sec (Table 3). A more homogeneous basalt sample from Core 63 has a vertical velocity of 4.37 km/sec and a horizontal velocity of 4.13 km/sec. The deepest basalt samples measured are from Sections 1, 2, and 3 of Core 64. These samples have velocities of 5.12 to 5.54 km/sec in the vertical direction and 5.22 to 5.49 km/sec in the horizontal direction. These samples appear to be the most homogeneous tested and best represent basaltic velocities at this site.

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

Depth Interval (m)	Average Velocity (km/sec)	Travel Time (sec)
0-25	1.50	0.017
25-70	1.58	0.028
70-150	1.54	0.052
150-480	1.70	0.194
480-566	1.80	0.048
		0.339

Thus maximum one-way travel time at Site 231 for the basement reflection should be 0.339 seconds.

Acoustic Impedance

The reflection coefficient is inherently related to the acoustic impedance. Thus, sharp acoustic impedance changes should be associated with the major reflectors. The acoustic impedance profile is smooth throughout the 566.5 meters of nanno chalk mud, increasing from 2.5×10^5 g/cm^2 sec near the surface to $3.5 \times g/cm^2$ sec directly above the basaltic basement. Unit 2 has an acoustic impedance increase from 2.64 to 3.25×10^5 g/cm^2 sec. Due to the small thickness of the included sandy layers, it is doubtful that a reflection would be observed from these horizons in recordings made with normal seismic frequency bandwidths. However, individual sandy layers within Unit 2 could be observed if high frequency-short pulses were employed.

The only major reflector observed on the acoustic impedance profile is Unit 6 (basaltic basement). The basalt has a velocity of approximately 5.3 km/sec and a bulk density of about 2.8 g/cm^2. Thus, the acoustic impedance is about 14.8×10^5 g/cm^2 sec or 4 times that of the overlying sediment layer. The previously calculated travel time for the basement reflection (0.34 seconds one-way travel time) agrees well with the ±0.60 seconds two-way travel time determined from the seismic reflection profiles in Figure 2.

INTERSTITIAL WATER CHEMISTRY

Salinity: Gulf of Aden bottom water at this site has a salinity close to 35 °/oo (Wyrtki, 1971). Pore waters show a fairly rapid decrease in salinity from 35.5 °/oo at 5 meters to 32 °/oo at 60 meters; values between 60 and 550 meters are in the range 32.5 ± 1 °/oo (Table 4 and Figure 3). Depletion of $SO_4^{=}$ by sulfate reducing bacteria could account entirely for this salinity trend.

TABLE 4
Interstitial Water Chemistry–Site 231

Depth Below Sea Floor (m)	Salinity (‰)	pH[a]	Alkalinity (meq/kg)
Surface seawater	36.2		
5	35.5	7.55(7.54)	2.09
20	35.2	7.51(7.39)	2.71
45	34.6	7.53(7.34)	4.62
63	32.2	7.62	6.54
80	32.2	7.50	6.05
110	32.2	7.49	5.96
123	32.2	7.48	4.90
150	32.2	7.39	3.54
175	31.6	7.40	2.90
194	31.6	7.51	2.44
215	33.8[b]	7.94	1.35
243	31.4	7.47	1.43
262	32.2	7.54	1.36
299	31.9	7.66	1.50
329	31.9	7.57	1.11
365	31.6	7.89	0.95
405	31.6	7.80	0.95
436	32.4	7.39	1.04
479	32.4	7.36	0.81
495	33.5	7.14	0.86
551	32.7	6.85	0.35

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

[b]Contaminated.

***p*H and Alkalinity**: *p*H measurements are recorded in Table 4 and were made with a combination electrode; values in parentheses were made with a punch-in electrode. Values between 5 and 400 meters are 7.6 ± 0.2, but between 400 and 500 meters they decrease to 6.9 (Figure 4). These are fairly typical ranges of values found in marine sediment pore waters and are indicative of equilibration with CO_2 pressures greater than atmospheric, the excess CO_2 being a by product of bacterial metabolism.

Alkalinities are given in Table 4 and the data plotted versus depth in Figure 4. A fairly rapid increase occurs between 5 and 60 meters, followed by a fairly rapid decrease from 60 to 215 meters; from 215 to 550 meters a further small decrease occurs. Below 205 meters, alkalinities are lower than that of seawater. The great increase in alkalinity below the sediment-water interface is presumably related to bacterial CO_2 production; the deeper decrease in alkalinity may reflect cessation of bacterial activity and slow consumption of the alkalinity by mineral-pore water reactions.

Water Content, Porosity, and Bulk Density: These data comprise Table 5. Water content decreases from 35 to 40 weight percent in the upper core sections to 20-25 weight percent near the base of the cored sequence. Porosity and bulk density data are only available for the interval 0-90 meters and show little trend in their variation.

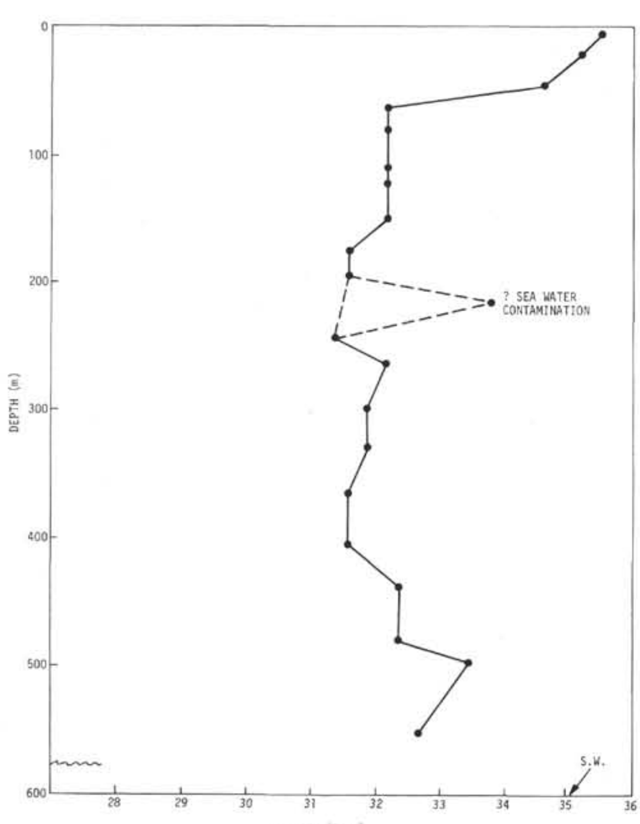


Figure 3. *Interstitial pore water salinity, Site 231.*

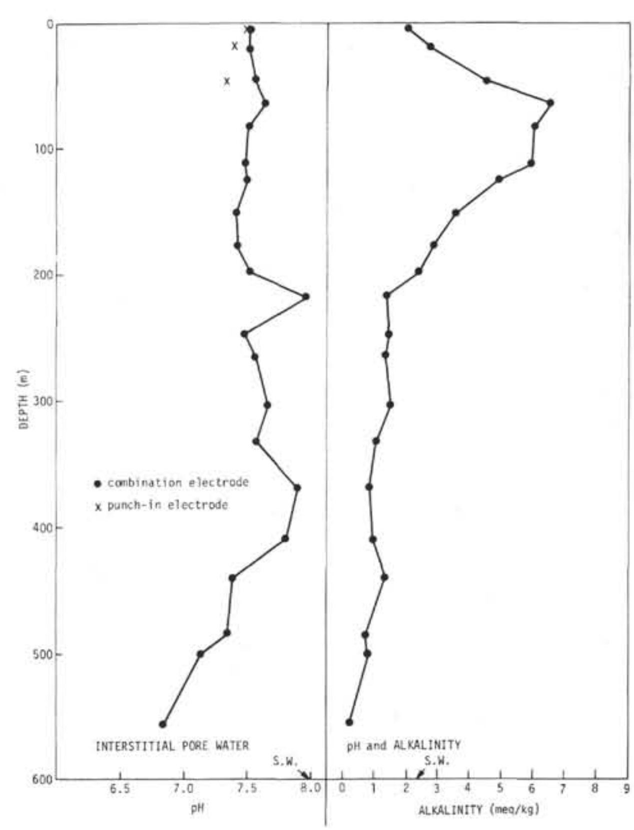


Figure 4. *Interstitial pore water* p*H and alkalinity, Site 231.*

TABLE 5
Water Content, Porosity, and Bulk Density of Sediments – Site 231

Core, Section, Top of Interval (cm)	Water (%)	Porosity (%)	Density (g/cm³)
1-1, 137	46.31	66.50	1.4359
2-2, 34	35.22	53.06	1.5065
2-2, 72	37.32	56.93	1.5254
2-2, 100	35.37	54.21	1.5326
2-2, 127	38.46	58.61	1.5239
3-1, 141	38.15	57.65	1.5111
3-2, 20	35.44	54.50	1.5378
3-2, 53	38.59	59.68	1.5465
3-2, 74	38.06	58.98	1.5496
3-2, 95	36.39	57.76	1.5872
3-2, 115	38.86	58.56	1.5069
3-2, 132	38.83	58.48	1.5060
3-2, 144	36.13	55.76	1.5433
3-3, 24	37.29	58.18	1.5596
3-4, 48	37.28	57.17	1.5335
3-3, 66	32.38	50.96	1.5738
3-3, 89	35.06	54.96	1.5675
3-3, 109	38.29	56.85	1.4847
3-3, 132	29.08	48.02	1.6513
3-4, 113	40.13	61.06	1.5215
3-4, 139	35.45	54.85	1.5472
3-4, 146	31.79		
4-1, 34	35.78	56.61	1.5821
4-1, 73	36.74	57.62	1.5683
4-1, 102	35.66	54.58	1.5305
4-1, 126	36.66	57.76	1.5755
4-2, 17	37.11	57.04	1.5370
4-2, 88	37.23	55.52	1.4912
4-2, 111	33.05	52.66	1.5933
4-2, 134	34.04	54.88	1.6122
5-4, 132	34.96	55.12	1.5766
4-3, 37	38.33	64.96	1.6947
4-3, 63	40.22	65.33	1.6243
4-3, 88	39.96	65.30	1.6341
4-3, 112	39.91	65.62	1.6441
4-3, 133	37.31	64.93	1.7402
5-2, 46	42.75	70.77	1.6554
5-2, 77	40.01	66.88	1.6715
5-4, 80	41.33	68.16	1.6491
5-2, 109	36.78	64.82	1.7623
5-3, 127	38.80	68.93	1.7765
5-4, 35	40.39	68.37	1.6927
5-5, 26	37.81	66.61	1.7617
5-5, 72	36.98	66.88	1.8085
5-5, 132	36.94	66.42	1.7980
5-6, 47	41.55	71.22	1.7140
5-6, 86	38.91	69.14	1.7769
5-6, 112	34.55	64.10	1.8552
6-1, 120	38.93	67.54	1.7349
6-3, 72	36.94	102.71	2.7804
6-3, 127	36.90	66.63	1.8056
6-4, 30	38.34	69.32	1.8080
6-4, 83	38.96	69.12	1.7741
6-4, 142	36.25	57.97	1.5991
6-5, 61	36.49	65.87	1.8051
6-5, 138	35.27	64.72	1.8349
6-6, 28	39.05	80.26	2.0553
7-3, 98	34.12	53.88	1.5791
7-3, 134	34.59	64.80	1.8733
8-1, 77	35.71	64.43	1.8042
8-2, 42	35.52	66.00	1.8581
8-3, 133	35.01	63.93	1.8260
8-4, 46	32.66	57.23	1.7522
8-4, 122	33.39	63.46	1.9005
8-6, 65	43.41	72.73	1.6754
9-3, 77	38.03	67.63	1.7783

TABLE 5 – *Continued*

Core, Section Top of Interval (cm)	Water (%)	Porosity (%)	Density (g/cm³)
9-4, 100	34.39	61.70	1.7941
11-2, 83	34.62	68.03	1.9650
5-2, 140	31.39		
5-3, 31	17.36		
5-3, 58	26.14		
5-6, 24	38.73		
5-6, 69	35.84		
6-2, 14	28.44		
6-2, 139	36.30		
7-3, 143	23.06		
8-5, 33	31.85		
9-3, 138	36.42		
9-4, 14	40.06		
9-5, 99	35.00		
10-3, 142	35.97		
10-4, 127	31.31		
11-3, 92	37.00		
12-4, 118	35.78		
13-5, 135	19.45		
13-6, 84	34.73		
14-4, 67	34.72		
14-5, 128	33.15		
15-1, 126	37.34		
15-2, 130	30.97		
16-6, 58	37.95		
17-2, 72	26.98		
17-4, 100	33.37		
17-5, 55	32.18		
18-3, 142	33.76		
19-2, 84	33.39		
19-4, 77	35.77		
20-2, 92	36.62		
20-4, 117	32.03		
20-6, 113	31.66		
21-2, 136	31.04		
21-4, 124	28.68		
21-6, 98	30.06		
22-2, 84	30.73		
22-4, 124	29.36		
23-2, 108	28.66		
23-4, 66	32.97		
23-6, 82	30.61		
24-4, 105	31.05		
24-6, 78	31.02		
25-2, 100	32.30		
25-4, 76	33.91		
25-6, 79	30.85		
26-2, 106	32.69		
26-4, 122	30.75		
26-6, 82	33.29		
27-2, 55	32.41		
27-4, 104	29.27		
27-6, 96	32.32		
28-2, 86	34.15		
28-4, 104	33.69		
28-6, 82	31.55		
29-2, 114	31.09		
29-5, 112	29.47		
30-2, 84	31.97		
30-5, 76	28.12		
31-2, 75	31.35		
32-2, 50	32.93		
32-3, 80	27.08		
33-2, 86	30.54		
33-3, 75	29.97		
34-2, 114	29.32		
34-3, 110	27.00		
35-1, 98	27.96		
35-3, 103	30.58		

TABLE 5 – *Continued*

Core, Section, Top of Interval (cm)	Water (%)	Porosity (%)	Density (g/cm^3)
36-3, 94	27.76		
36-4, 106	28.17		
37-2, 78	27.87		
38-2, 90	31.48		
39-2, 90	24.57		
41-4, 100	24.87		
42-2, 4	23.77		
42-5, 86	32.94		
43-2, 70	28.89		
43-2, 4	32.11		
43-2, 84	29.64		
43.5, 95	25.78		
45-2, 71	25.93		
45-2, 148	25.00		
46-2, 52	24.07		
46-5, 81	23.45		
47-3, 128	22.59		
48-2, 95	27.84		
50-2, 118	22.83		
51-4, 94	22. 37		
51-6, 48	24.27		
51-6, 59	24.25		
52-2, 119	26.70		
54-2, 93	28.46		
55-3, 134	22.91		
57-2, 111	23.35		
58-5, 37	22.08		
59-3, 94	20.83		
60-2, 141	23.36		
61-6, 95	21.20		

CORRELATION OF REFLECTION PROFILES AND LITHOLOGIES

The characteristics of the reflection profiles obtained in the near-site area and onsite can be summarized rather briefly. The sequence observed consists of three units: (1) possibly stratified or layered sediments of variable thickness resting on (2) acoustically transparent material also of variable thickness which in turn overlies (3) acoustic basement. The thickness of the stratified sediments ranges between 0.1 and 0.4 sec (two-way travel time); the thicker sections apparently are ponded in the acoustically transparent layer by basement hills. The description of stratified or layered sediments is not wholly based on these particular records (Figure 5) where the reflected source pulse obscures any such character, but on other observations from R.R.S. *Discovery*; R/V *Chain*, and R/V *Conrad* (unpublished data). Since the total depth to basement surface varies between 0.35 and 0.60 sec, and the base of the transparent layer is conformable with it (as are all but the uppermost sediments), the thickness of this intermediate depth material depends on the surface relief of the basement, being roughly between 0.25 and 0.55 sec.

The basement topography is subdued by comparison with that of the nearby West Sheba Ridge; the relief is on the order of 0.05 sec. While this is not a large change in absolute depth, it amounts to about 130 meters of surface relief. (This is calculated using the velocity value reported by Laughton and Tramontini [1969, Sta. 6228], of 5.22 km/sec for the Layer 2 basement material.)

Laughton and Tramontini (1969) described the stratified sediments as turbidites and further suggested that the transparent layer might be of evaporitic composition. These are questions that should be resolved by the drilling. In this light, it seemed expedient to attempt continuous coring of this site. Figure 5 shows the relation between the recorded reflection profile and the generalized lithology; the relation to physical properties is shown in Figure 2. The sediment sequence that extends to the acoustic basement surface is acoustically transparent except in the upper 0.3 sec portion, where the source pulse appears. This pulse is here elongated enough to suggest that some part might represent a reflecting horizon within the layer. The remainder of the acoustically transparent material appears to be represented by the nanno chalk mud. The acoustic and the volcanic basement depths are in excellent agreement.

SUMMARY, CONCLUSIONS, AND SPECULATIONS

The single hole drilled at Site 231 was continuously cored through 566.5 meters of sediment extending down to middle Miocene in age, and into 17.5 meters of basalt basement.

The Pleistocene and Pliocene parts of the section are more variable in lithology than is the Miocene. From 0 to 7 meters the sediment is a light olive-gray nanno ooze. Between 7 and 64 meters, the sediment is a nanno ooze with intercalated sandy horizons. The sands are variable in composition, and some include material of reef origin, possibly as a result of the erosion of reefs on the continental shelf during periods of lowered sea level during the Pleistocene. From 64 to 121 meters, the sediment consists of a relatively uniform nanno ooze. Some derived shallow-water fossils were obtained between these depths, indicating slumping of material down the continental slope. Within this interval, the Pliocene/Pleistocene boundary has been placed at 102 meters at the highest occurrence of *Discoaster brouweri.* Below 121 meters and down to a depth of 236 meters, nanno oozes contain more layers of intercalated coarse sediments, including four volcanic ash layers associated with the eruption of Pliocene rhyolites. The base of the Pliocene is at approximately 254 meters. Lithologically, the lower Pliocene sediments are very similar to the upper Miocene deposits below. The Miocene sediments between 254 meters and basement consist of a very uniform grayish-olive nanno ooze. The monotony of this sequence is broken only by patches of bitumen and a shelly quartzose sand layer at 425 meters. Hydrogen sulphide was detected throughout much of this section.

Throughout the section, calcareous plankton is common, with calcareous nannoplankton slightly etched and planktonic foraminifera moderately to poorly preserved. Radiolarians are abundant and well preserved in the uppermost core only; they are present but poorly preserved throughout the remainder of the section. The sedimentary sequence is apparently uninterrupted from middle Miocene to Quaternary and the average sediment accumulation rate for the entire series is 43.7 m/m.y. Pleistocene and upper Pliocene sediments accumulate with a rate higher than the other series, averaging 59.3 m/m.y., reflecting slumping of coarse elements from shelf areas during these epochs.

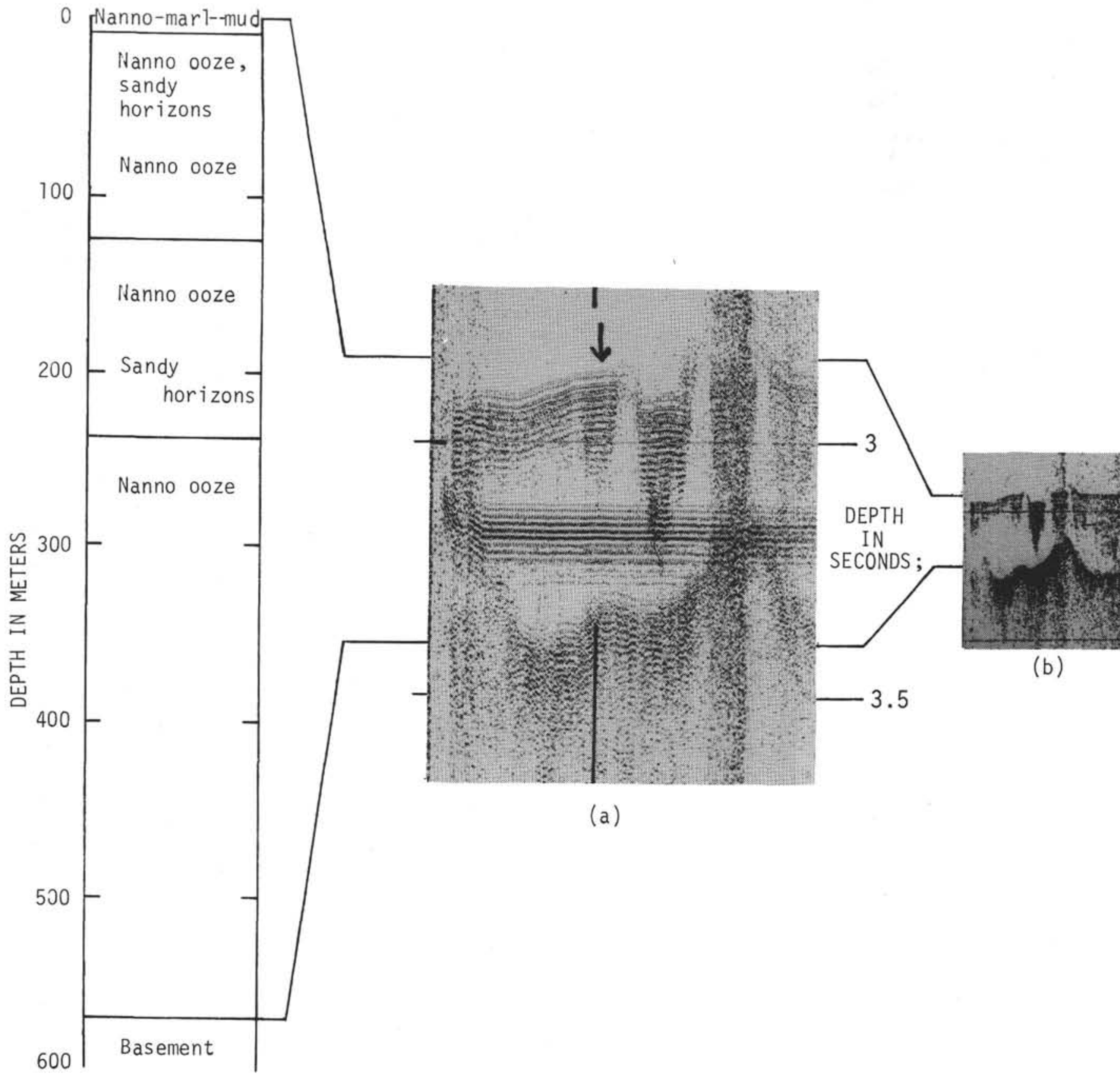


Figure 5. *Generalized lithology and seismic sections; core length is in meters, the seismic section in seconds of two-way travel time. In the delayed sweep recording the outgoing pulse obscures the transparent layer, center of record (a).*

The physical properties of the sediments are, like the lithology, fairly uniform throughout the section. Only one slight variation in bulk density and porosity occurs; it is associated with a sandy layer in Core 5. Overall trends in both these properties can be attributed to normal consolidation of the sediment. The sonic velocity profile of the section shows a smooth increase from 1.50 km/sec near the surface to 1.80 km/sec just above basement, also reflecting the uniformity of the sediment throughout the section.

Basalt basement was reached at a depth of 566.5 meters, the basalt being similar to standard oceanic tholeiite and extrusive in origin.

In summary, the gross characteristics of the entire section, excluding the basalt, are very uniform. This suggests near constant conditions of depth, carbonate productivity, and detrital input in this area since the inception of deposition in middle Miocene times. Some of the fine-grained detrital material in the sediments may be eolian in origin; aridity in the potential source areas of Somalia probably precluding a large input of water transported sediment.

Most of the principal aims of this site were met. The age and lithology of the entire sedimentary sequence has been established, but the speculation that the basal transparent layer might be evaporites has proved to be false. The age and lithology of the basement have been established. The inhomogeneities in the upper part of the section result from the intercalation of coarse sediment, as suggested from the seismic profiles.

REFERENCES

Cernock, P. J., 1970. Sound velocities in Gulf of Mexico sediments as related to physical properties and simulated overburden pressures: Texas A&M Univ. Tech. Rept. 70-5-T, Naval Res. Contract N000 14-68-A-0308 (0002) Oceanography, 114 p.

Hamilton, E. L., 1965. Sound speed and related physical properties of sediments from Experimental Mohole (Guadalupe Site): Geophysics, v. 30, p. 257-261.

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

Laughton, A. S., Whitmarsh, R. B., and Jones, M. T., 1970. The evolution of the Gulf of Aden, Roy. Soc. London Phil. Trans., v. 267, p. 227-266.

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

ADDITIONAL SELECTED REFERENCES

Bennett, R. H., and Keller, G. H., 1973. Initial Reports of the Deep Sea Drilling Project, Volume XVI: Washington (U. S. Government Printing Office).

Peterson, M. N. A., Edgar, N. T. et. al., 1970. Initial Reports of the Deep Sea Drilling Project, Volume II: Washington (U. S. Government Printing Office).

Whitmarsh, R. B., 1972. Initial Reports of the Deep Sea Drilling Project, Volume XII: Washington (U. S. Government Printing Office).

APPENDIX A
PRELIMINARY OBSERVATIONS ON THE IGNEOUS ROCKS SAMPLED AT SITE 231

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

Drilling at Site 231 encountered igneous rock, here acoustic basement, at a depth of 566.5 meters below the mudline. It was continued 17.5 meters into extrusive material, considered to be flows signifying the top of the basement, 7.7 meters of basaltic rock were recovered. Details of layering, fracturing, and structure are indicated on the visual core description columns.

Megascopic Description

The igneous rock recovered between 566.5 and 584 meters at Site 231 is predominantly dense, gray-black, slightly altered uniform basalt with small seams of glassy materials that generally coincide with steeply dipping fractures (Figure 6: 231-62-1, CC). The glassy zones, and brecciated glasses, are only 2-5 cm thick; but there are 14

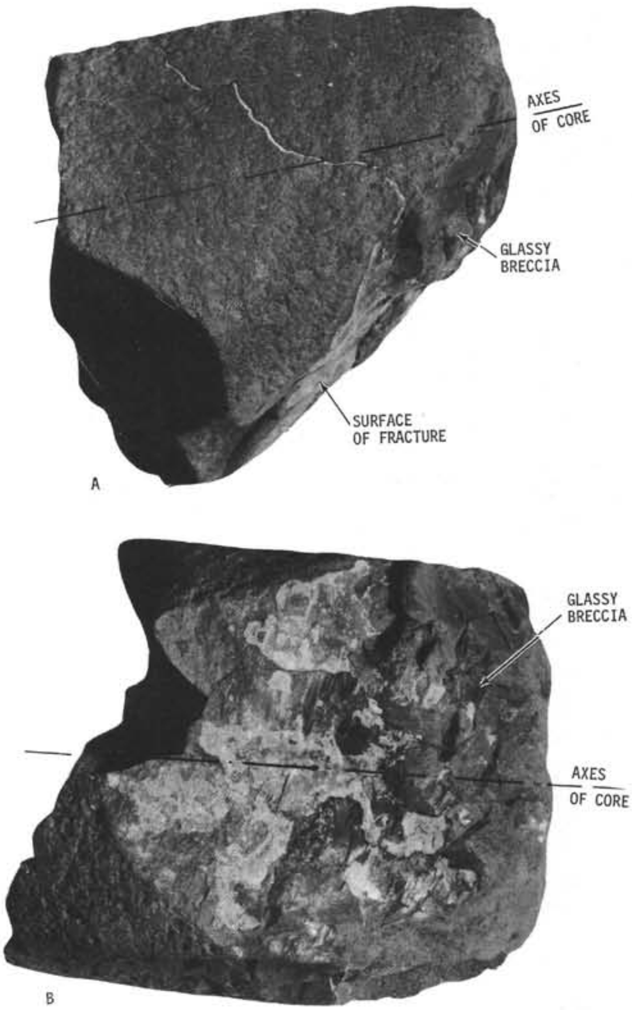


Figure 6. *Core catcher sample from 231-62-1, magnified 2X. Note dip of fracture and seam of brecciated glass.*

such seams within the 7.7 meters of core recovered. In the core catcher sample pictured, the fractured surface shows remains of glassy breccia and evidence of scratches made by movements during emplacement. The breccias commonly are cemented by fine-grained carbonate material, principally relics of foraminifers but also some Radiolaria, that has lodged in cracks in the basalt, forming veins up to 3-4 cm thick.

Two inclusions of slightly metamorphosed sediment are present in the upper part (231-62-1) of the basalt section. These sediments display vestiges of layering and fossils. The upper of these inclusions is 10-15 cm thick; that of the lower is not known because it was partially destroyed during drilling. Altered or baked zones are clearly distinguishable in both inclusions; in each, the upper altered zone is 1-1.5 cm thick, and the lower is 3-4 cm. The contact between the uppermost glassy layer of basalt and the base of the overlying carbonate sediment was recovered in Section 231-62-1; the contact is marked by a zone of baking or alteration about 3 cm thick, containing fine grains of pyrite. The contact itself is almost horizontal, and the layered sediments above it dip less than 15°.

Preliminary Petrographic Description

At least fourteen thin sections prepared from Hole 231 "basement" were examined at sea. This inspection determined that the majority of these rocks are slightly altered variolitic basalts of tholeiitic composition, and contain variously olivine, plagioclase, magnetite, and both clinopyroxene and orthopyroxene.

Olivine occurs in small isolated skeletal crystals less than 0.1 mm long, colorless to pale yellow green (Figure 7,b). It is commonly replaced by serpentine or chlorite, and remains fresh only in the glass.

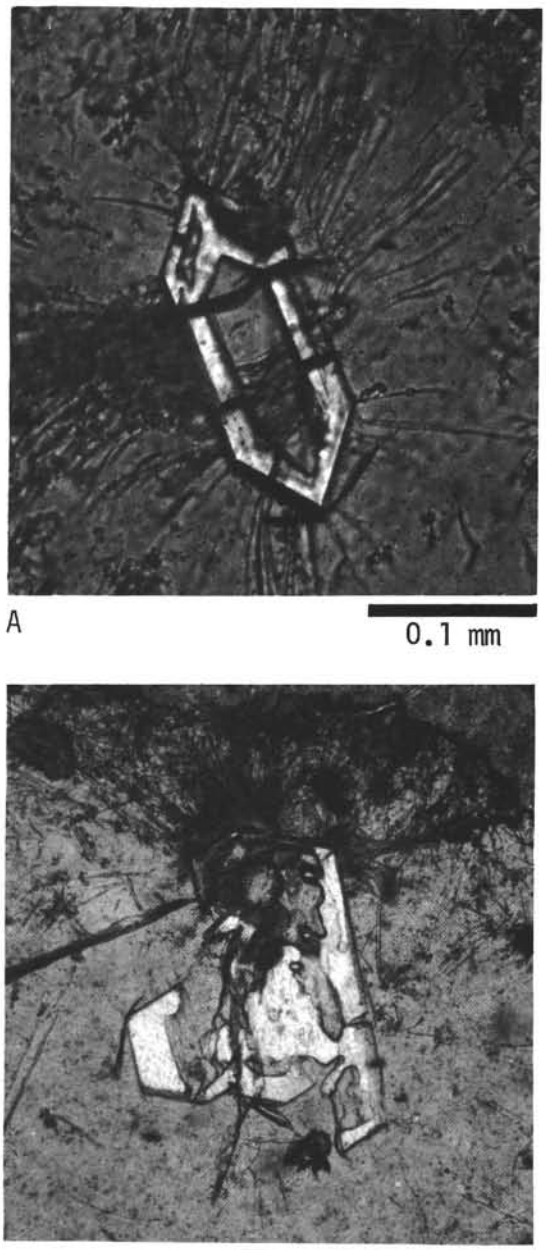


Figure 7. *Skeletal crystals of olivine in fresh glass; 231-64-1-1; unpolarized light.*

Plagioclase, identified as labradorite An_{65} ($\perp$ 010 $\approx$ 40°), occurs as needle-like crystals, about 0.5 mm long, grouped in radial structures or fibrous aggregates (Figure 8). Skeletal forms predominate.

Pyroxene, both clinopyroxene and orthopyroxene, interstitial among plagioclase crystals, is found only in the granular basalts. It forms xenomorphs of colorless grains that display characteristic cleavage. Hypersthene is distinguishable by parallel extinction and augite by $c \lambda Z \approx 50^\circ$.

Magnetite is disseminated in the glass as finely dispersed dusty grains.

At Site 231, the basalt section consists principally of dense massive fragments, with typical variolitic texture, that contain 40-50 percent palagonitized or fresh glass (Figure 9). Granular basalts are rare; in the lower part of the drill hole, such rocks are present and contain pyroxene and 5-10 percent glass (Figure 10). The porosity of the basalts is constant at about 2 percent but is about half that in the granular basalts. Vesicles generally have a regular sphenoidal shape and average 0.3 mm in diameter; there is one zone with oval vesicles and tachylitic structure in the same section (231-64-2-3). Chilled zones, averaging 3-4 cm thick, are similar to those in typical pillow lavas of submarine origin. The external surfaces are typically brown unaltered glass, with isolated crystals of olivine (Figure 11a). Further toward the interior small dark brown spots appear, as the first stages of devitrification (Figure 11b). Further inside, these spots or nuclei give way to common variolitic basalt.

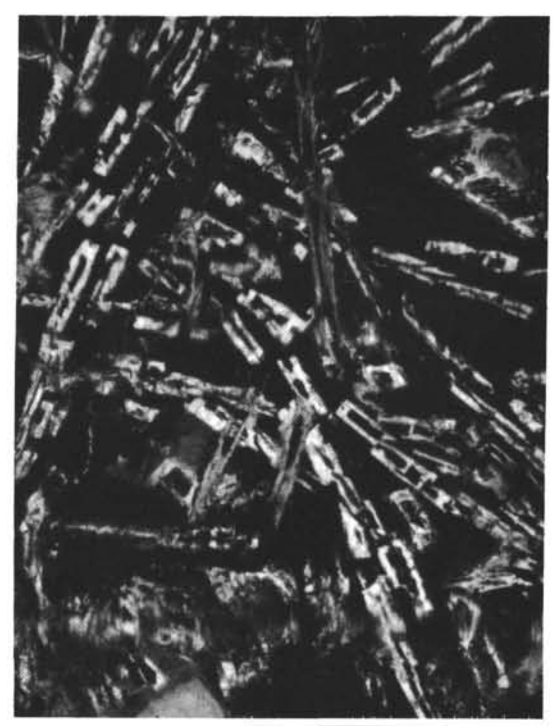


Figure 8. *Skeletal crystals of plagioclase in variolitic basalt; 231-64-2-4; unpolarized light.*

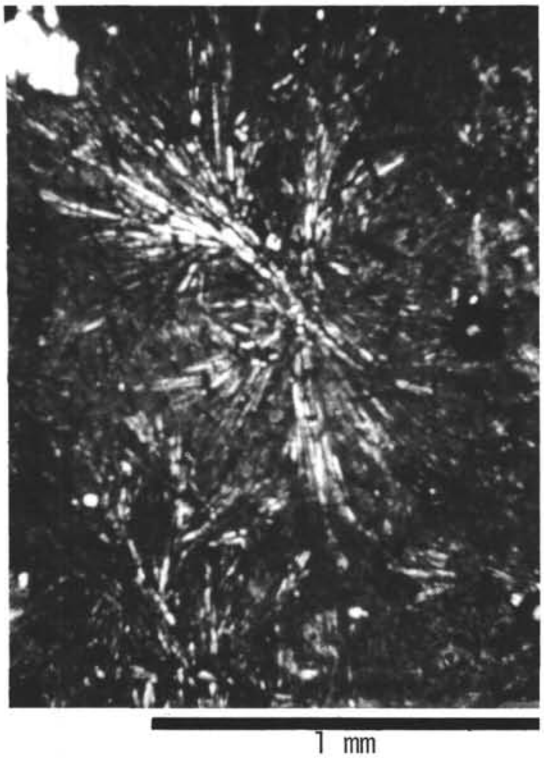


Figure 9. *Radial structure of plagioclase needles in variolitic basalt; 231-64-2-2; unpolarized light.*

Figure 10. *Microdoleritic texture in basalt; 231-64-2-4; unpolarized light.*

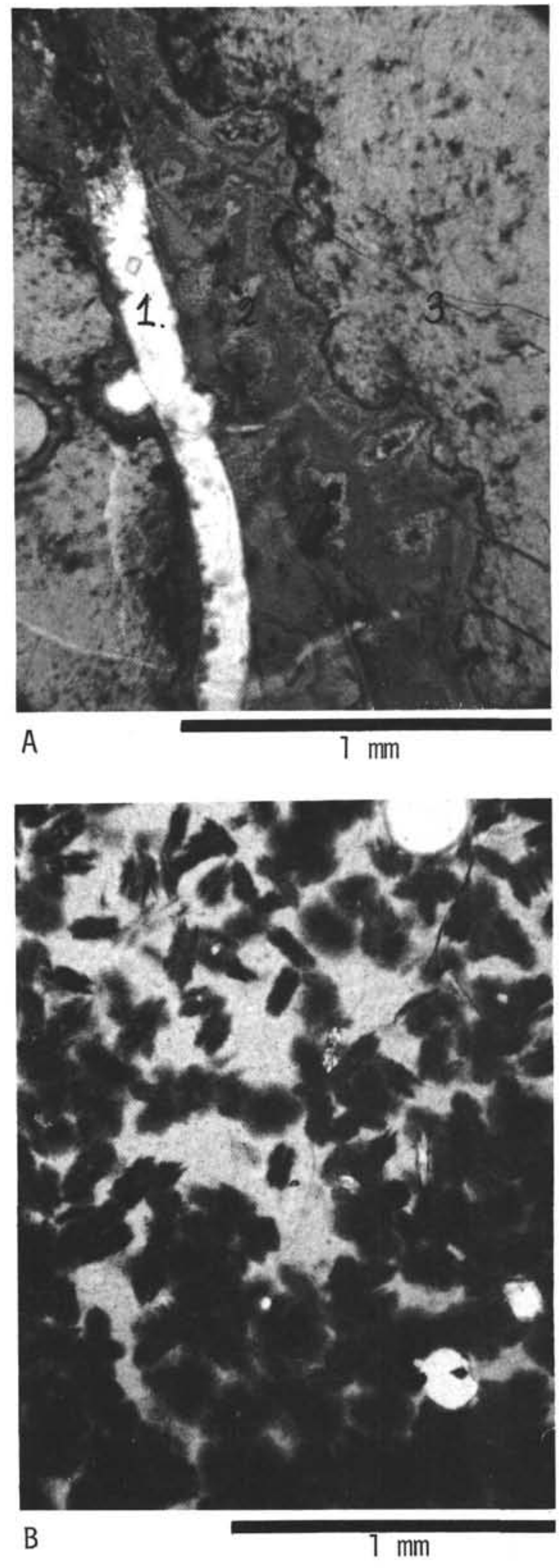


Figure 11. *Glassy margin on a pillow surface; 231-64-1-1:* (a) *external zone, fresh glass with palagonitization around fracture:* (1) *fracture filled by carbonate-chlorite-zeolite material,* (2) *palagonite,* (3) *fresh glass;* (b) *initiation of devitrification.*

The majority of this basalt pile is only slightly altered; such alteration includes palagonization of glass, serpentinization or chloritization of olivine, and chloritization of pyroxenes.

1) Glassy rind is everywhere fresh. Palagonization, in zones thinner than 1.5-2.0 mm, spreads from thin fractures filled by the chlorite-zeolite-carbonate material cementing glassy breccias.

2) Vesicles are lined with carbonates, chlorite, and zeolites. When the filling is zoned, the exterior layer is chlorite and the center of the vesicle contains carbonate or zeolites.

3) Oxidation along thin fractures represents the most recent alteration; it results in formation of dark brown iron hydroxides which are adsorbed on plagioclase grains and the inside of vesicles. The oxidized zone or aureole extends 1.0-1.5 cm outside the fracture.

Discussion and Implications

1. The structure and composition of this basalt within the present Gulf of Aden is characteristic of oceanic tholeiite, and the glassy zones mantling the outer surfaces, variolitic texture, and skeletal form of crystals suggest it was formed by eruption under water.

2. The uniformity in composition and structure throughout the section recovered suggests that this hole was drilled through only one group of lava flows, which was the product of just one eruption.

3. The abundant interlayering of brecciated glass and dense basalt suggests that these components are part of a lava flow which moved down a steep slope and cooled rapidly. The numerous glassy zones suggest a very fluid magma. Internal fragmentation in the flow would result from incorporation or over-riding of the solidified crust to mix with the fluid lava. In this way, some fragments of sediments could be introduced into the moving mass, be metamorphosed, and their constituents cement fracture zones containing the brecciated glasses. Sediments, as chips or fragments resting on the lava surface, have their primary character preserved; some of this material may have trickled into cracks and been little affected. Figure 12 portrays a schematic cross-section through such a sediment-lava pile.

4. The minor alteration of the basalts from Site 231 may indicate absence here of conditions causing greenstone metamorphism, or of hydrothermal activity.

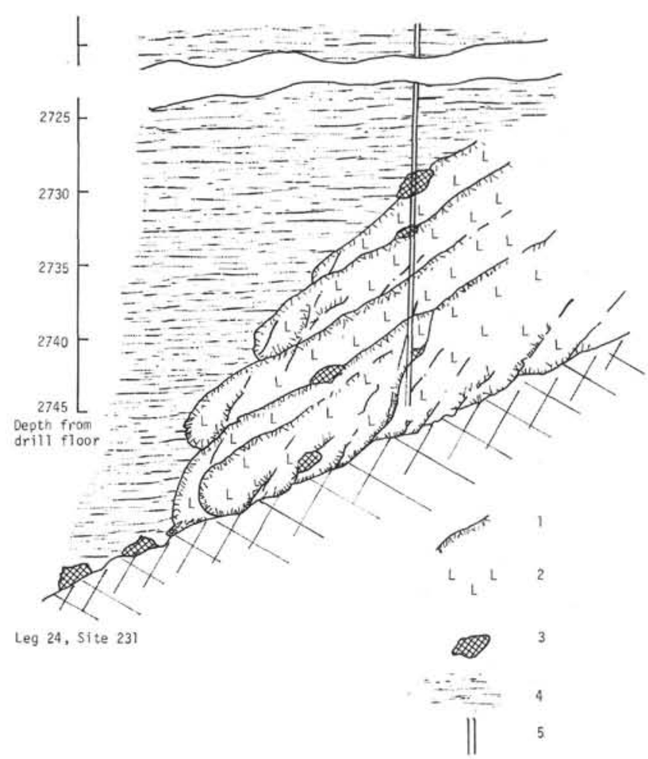
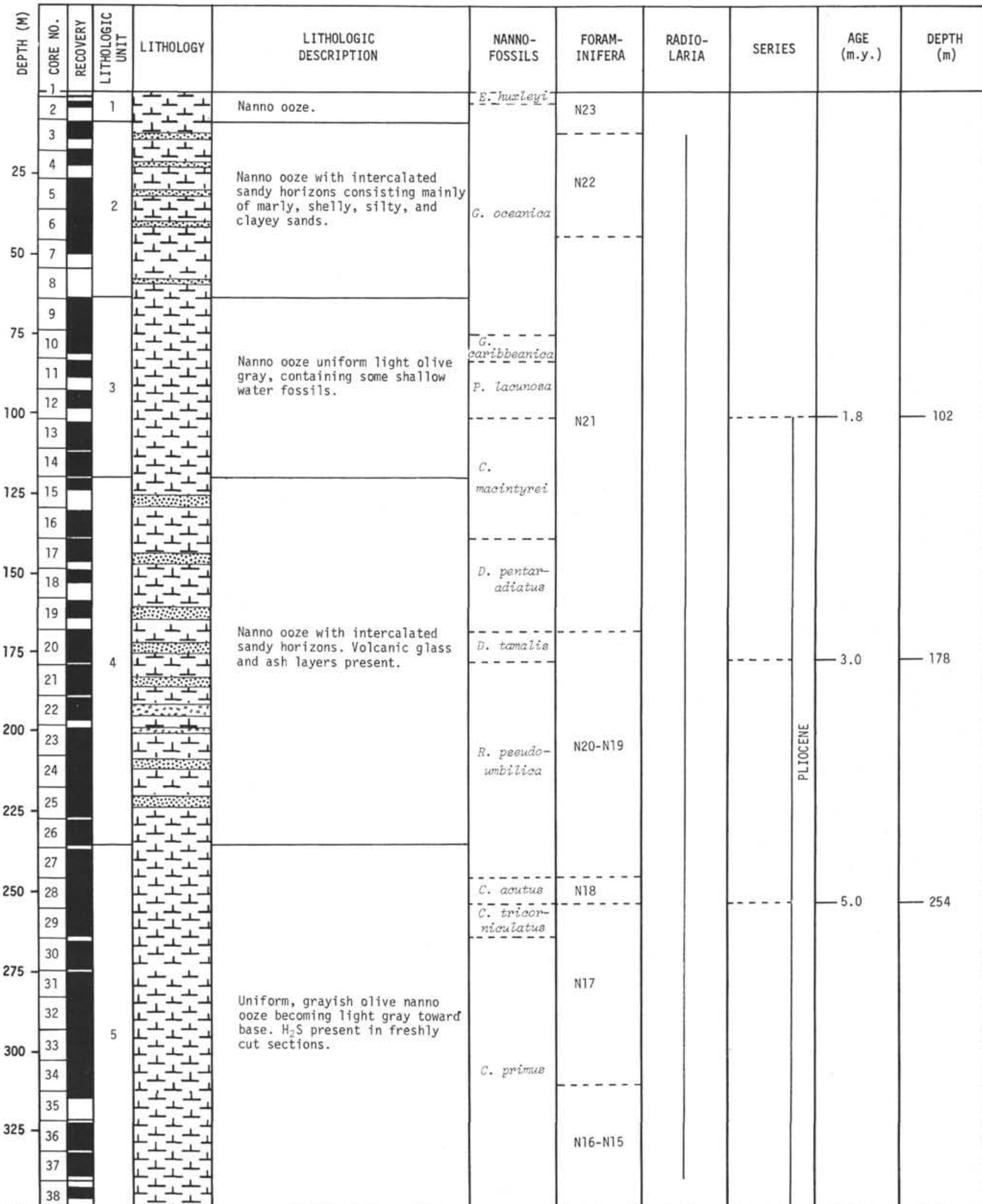
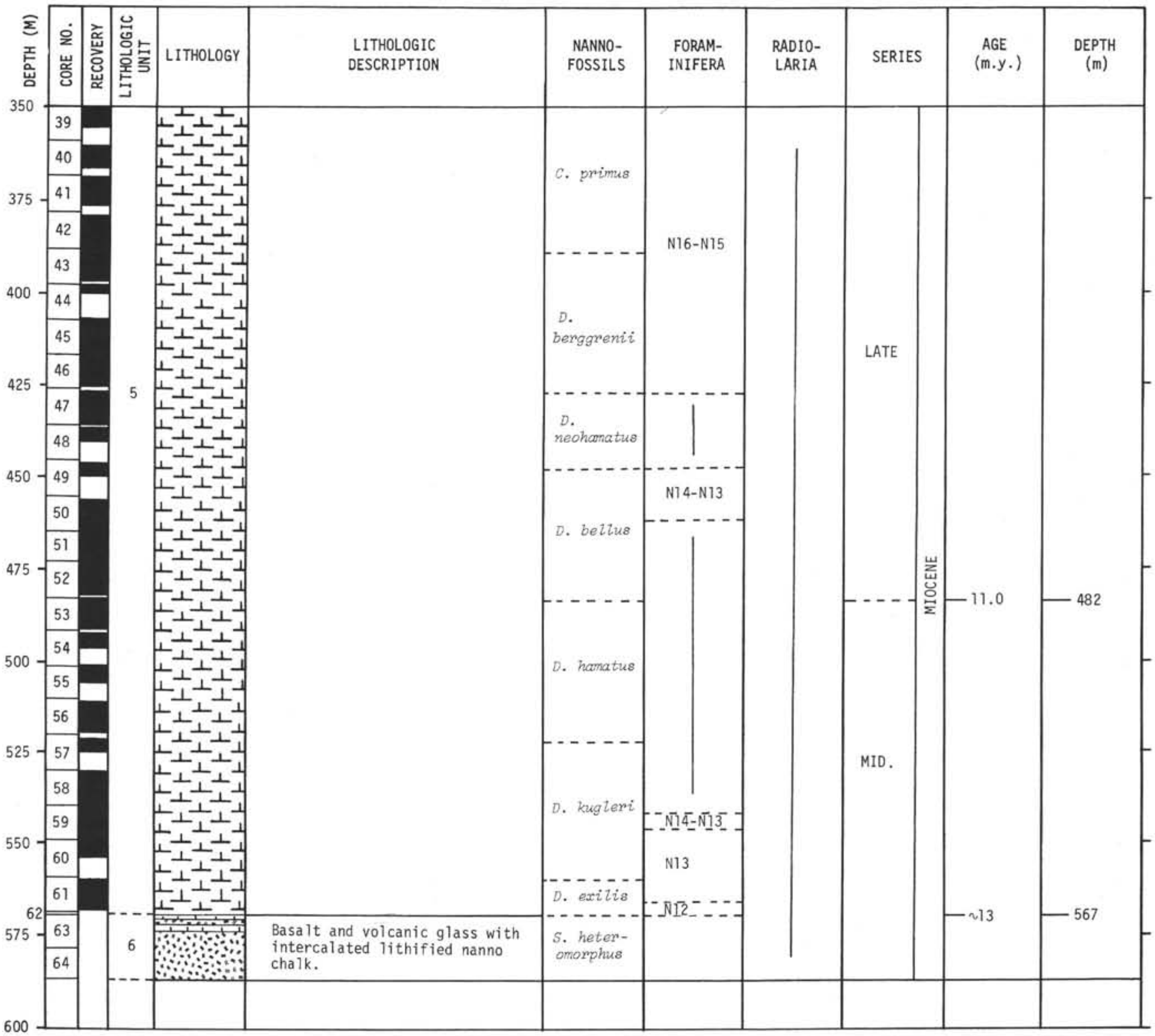


Figure 12. *Schematic cross-section through lava flow on a steep slope:* (1) *glass,* (2) *variolitic basalt,* (3) *inclusions of sediments,* (4) *later sediments,* (5) *drill hole.*


DEPTH (M)
CORE NO.
RECOVERY
LITHOLOGIC UNIT
LITHOLOGY
LITHOLOGIC DESCRIPTION
NANNO-FOSSILS
FORAM-INIFERA
RADIO-LARIA
SERIES
AGE (m.y.)
DEPTH (m)
Nanno ooze.
Nanno ooze with intercalated sandy horizons consisting mainly of marly, shelly, silty, and clayey sands.
Nanno ooze uniform light olive gray, containing some shallow water fossils.
Nanno ooze with intercalated sandy horizons. Volcanic glass and ash layers present.
Uniform, grayish olive nanno ooze becoming light gray toward base. H_2S present in freshly cut sections.
E. huxleyi
G. oceanica
G. caribbeanica
P. lacunosa
C. macintyrei
D. pentaradiatus
D. tamalis
R. pseudoumbilica
C. acutus
C. tricorniculatus
C. primus
N23
N22
N21
N20-N19
N18
N17
N16-N15
PLIOCENE
1.8
3.0
5.0
102
178
254
25
50
75
100
125
150
175
200
225
250
275
300
325
350
1
2
3
4
5


DEPTH (M)
CORE NO.
RECOVERY
LITHOLOGIC UNIT
LITHOLOGY
LITHOLOGIC DESCRIPTION
NANNO-FOSSILS
FORAM-INIFERA
RADIO-LARIA
SERIES
AGE (m.y.)
DEPTH (m)
350
375
400
425
450
475
500
525
550
575
600
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
5
6
Basalt and volcanic glass with intercalated lithified nanno chalk.
C. primus
D. berggrenii
D. neohamatus
D. bellus
D. hamatus
D. kugleri
D. exilis
S. heter-omorphus
N16-N15
N14-N13
N14-N13
N13
N12
LATE
MID.
MIOCENE
11.0
~13
482
567

Site 231 Hole Core 1 Cored Interval: 0.0-0.5 m

AGE	ZONE	NANNOS	FORAMS	RADS	DIATOMS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
PLEISTOCENE	E. huxleyi ? N23 QUATERNARY	C/G	A/M	A/G		1	0.5, 1.0	VOID		

LITHOLOGIC DESCRIPTION

MICARB BEARING NANNO OOZE
Light olive gray (5Y5/2) becoming grayer towards the base

Smear 1-1-115

Sand 5%	Nannos	60%	Micarb	5-10%
Silt 40%	Forams	5%FG	Quartz	1- 2%
Clay 55%	Diatoms	1%FP	Feldspar	<1%
	Rads	1%FP	Heavy Min.	<1%
	Sponge Spic.	<1%	Dolo. Rhombs	<1%
	Silicoflag.	<1%		

Site 231 Hole Core 2 Cored Interval: 0.5-7.0 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
PLEISTOCENE	Gephyrocapsa oceanica N23	C/G	A/M	R/M	1	0.5, 1.0	VOID		
					2				C GZ
			A/M		Core Catcher				

LITHOLOGIC DESCRIPTION

FORAM BEARING NANNO OOZE
Light olive gray (5Y5/2)

Smear 2-2-72

Sand 5%	Nannos	70%	Quartz	2%
Silt 30%	Forams	5%FG	Micarb	1-2%
Clay 65%	Diatoms	2%FP	Feldspar	1%
	Rads	2%FP	Mica	1%
	Sponge Spic.	<1%	Dolo. Rhombs	1%
	Fish Debris	<1%		

NANNO OOZE
Light olive gray (5Y5/2)

Smear CC

Sand 5%	Nannos	60%	Quartz	5%
Silt 45%	Forams	5%FG	Feldspar	2%
Clay 50%	Rads	5%FP	Heavy Min.	2%
	Pteropods	2%	Dolo. Rhombs	2%
	Diatoms	1%	Volc. Glass	1%
	Sponge Spic.	1%	Pyrite	1%

Grain Size
Sand 3%
Silt 45%
Clay 52%

$CaCO_3$ 51%

Explanatory notes in chapter 1

Site 231 Hole Core 3 Cored Interval: 7-16.5 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
PLEISTOCENE	N23		A/G	R/M	1	0.5, 1.0	VOID		
			A/M		2				
	Gephyrocapsa oceanica --- N22		A/G		3				
		C/G	A/M	R/M	4				
			A/G						
			A/M		Core Catcher				

LITHOLOGIC DESCRIPTION

NANNO OOZE
Light olive gray (5Y5/2)

Smear 3-2-80

Sand 10%	Nannos	70%	Quartz	5%
Silt 30%	Plank. Forams	5%FG	Micarb	1-2%
Clay 60%	Benth. Forams	1%	Glauconite	1%
	Rads	1%FP	Pyrite	1%
			Dolo. Rhombs	1%

Bands slightly more olive and gray. Thickness of bands 30-40 cm.

NANNO RICH QUARTZ SAND

Smear 3-4-120

Sand 50%	Nannos	20%	Quartz	50%
Silt 25%	Plank. Forams	10%	Micarb	5%
Clay 25%	Pteropods	5%	Pyrite	2%
	Benth. Forams	1%	Feldspar	1%
	Rads	1%	Mica	1%
	Sponge Spic.	1%	Dolo. Rhombs	1%
	Echinoid Debris	1%		
	Fish Debris	1%		

Smear 3-4-146

Sand 30%	Nannos	50%FG	Micarb	20%
Silt 35%	Forams	5%FG	Quartz	5%
Clay 35%	Rads	2%FP	Feldspar	1%
	Sponge Spic.	1%	Heavy Min.	1%
	Pteropods	1%	Pyrite	1%

Explanatory notes in chapter 1

Site 231 Hole Core 4 Cored Interval: 16.5-26.0 m

AGE: PLEISTOCENE

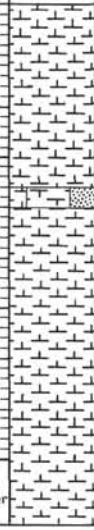
ZONE: Gephyrocapsa oceanica N22

FOSSIL CHARACTER (NANNOS / FORAMS / RADS): C/G, R/M, A/M; A/M; A/G; A/M, R/M; A/M

SECTION: 1, 2, 3, Core Catcher

METERS: 0.5, 1.0

LITHOLOGY



LITHO. SAMPLE: GZ

LITHOLOGIC DESCRIPTION

NANNO OOZE
Light olive gray (5Y5/2), H_2S odor.

NANNO RICH FORAM SAND LAYERS (4-2-30 to 35 and 4-2-44 to 54)
Smear 4-2-54

Sand 40%	Plank. Forams	40%FG	Quartz	10%
Silt 30%	Nannos	20%FG	Micarb	10%
Clay 30%	Pteropods	10%FM	Mica	1%
	Benth. Forams	5%	Heavy Min.	1%
	Rads	5%FM	Pyrite	1%
	Sponge Spic.	1%	Dolo. Rhombs	1%

Smear 4-2-120

Sand 5%	Nannos	80%FG	Quartz	5%
Silt 40%	Forams	5%FG	Heavy Min.	1-2%
Clay 55%	Rads	1%FP	Mica	1%

Grain Size
Sand 38%
Silt 40%
Clay 23%

Explanatory notes in chapter 1

Site 231 Hole Core 5 Cored Interval: 26.0-35.5 m

AGE: PLEISTOCENE

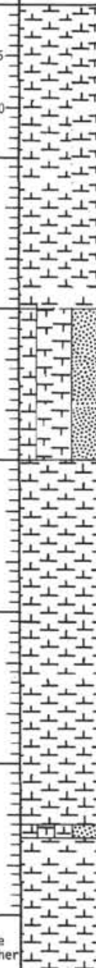
ZONE: Gephyrocapsa oceanica N22

FOSSIL CHARACTER (NANNOS / FORAMS / RADS): C/G, C/M, A/M; A/P; A/M; A/G; A/M; A/M; A/M, F/M; N; A/M

SECTION: 1, 2, 3, 4, 5, 6, Core Catcher

METERS: 0.5, 1.0

LITHOLOGY



LITHO. SAMPLE: GZ

LITHOLOGIC DESCRIPTION

MICARB RICH NANNO OOZE
Light olive gray (5Y5/2)
Smear 5-1-95

Sand 5%	Nannos	50%	Micarb	20%
Silt 40%	Forams	5%	Quartz	5%
Clay 55%			Mica	2%
			Volc. Glass	2%
			Pyrite	2%
			Dolo. Rhombs	2%
			Heavy Min.	1%

Smear 5-2-120

Sand 5%	Nannos	60%	Micarb	20%
Silt 45%	Forams	5%FG	Quartz	2%
Clay 50%	Rads	2%FP	Pyrite	2%
	Diatoms	1%	Dolo. Rhombs	2%
	Sponge Spic.	1%		

QUARTZ RICH SHELL SAND
Grayish olive (10Y4/2)
Smear 5-2-145

Sand 70%	Nannos	20%	Quartz	20%
Silt 15%	Indet. Shell Detrit.	20%	Feldspar	5%
Clay 15%	Forams	15%	Heavy Min.	5%
	Pteropods	15%	Mica	2%
	Rads	1%		
	Sponge Spic.	1%		

Smear 5-3-90

Sand 50%	Forams	30%FG	Quartz	10%
Silt 25%	Indet. Shell Detrit.	30%	Heavy Min.	5%
Clay 25%	Nannos	10-15%	Feldspar	2%
	Pteropods	5%FG	Dolo. Rhombs	2%
	Rads	5%FP		
	Sponge Spic.	2%		

NANNO OOZE
Light olive gray (5Y5/2)
Smear 5-5-80

Sand 5%	Nannos	80%	Quartz	5%
Silt 20%	Forams	5%FG	Dolo. Rhombs	1%
Clay 75%	Rads	2%FP	Heavy Min.	<1%

Alternate bands (10-30 cm thick) of predominantly greenish and olive gray respectively (Section 5 and 6)

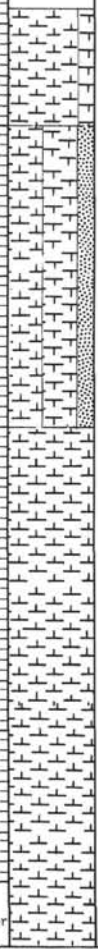
SHELL SAND 5-6-60 to 75
Olive black (5Y2/1)

Grain Size
Sand 1%
Silt 56%
Clay 43%

Explanatory notes in chapter 1

Site 231 Hole Core 6 Cored Interval: 35.5-45.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
PLEISTOCENE	Gephyrocapsa oceanica N22	C/G	A/M	R/M	1	0.5, 1.0	VOID		
			C/P		2				
			A/P		3				
			A/G		4				
			A/M		5				
	N21		A/M	F/M	6				
			A/M		Core Catcher				



LITHOLOGIC DESCRIPTION

FORAM RICH NANNO OOZE
Light olive gray (5Y5/2)
Smear 6-1-105

Sand 30%	Nannos 50%	Quartz 10%
Silt 30%	Forams 20%	Pyrite 2%
Clay 40%	Indet. Shell Detrit. 10%	Mica 1%
	Rads 2%FP	Heavy Min. 1%
	Sponge Spic. 1%	

SHELL SAND
Grayish olive (10Y4/2)
Smear 6-2-100

Sand 60%	Nannos 30%	Quartz 5%
Silt 20%	Plank. Forams 20%FG	Feldspar 2%
Clay 20%	Indet. Shell Detrit. 20%	Heavy Min. 2%
	Benth. Forams 10%FG	Dolo. Rhombs 1%
	Pteropods 5%	
	Lamellibr. 5%	
	Sponge Spic. 2%	

FORAM NANNO OOZE
Light olive gray (5Y5/2)
(disturbed layer dark reddish brown [10R3/4])
Smear 6-2-144

Sand 10%	Nannos 40%	Quartz 10%
Silt 40%	Plank. Forams 20%FG	Heavy Min. 2%
Clay 50%	Benth. Forams 10%FG	Pyrite 2%
	Pteropods 5%	Dolo. Rhombs 1%
	Rads 2%FP	
	Sponge Spic. 1%	
	Fish Debris 1%	

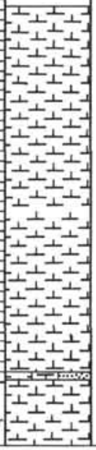
NANNO OOZE
Light olive gray (5Y5/2)
Smear 6-4-100

Sand 2%	Nannos 80%	Mica 2%
Silt 40%	Forams 5%	Quartz 1%
Clay 58%	Rads 1%	Pyrite 1%
	Sponge Spic. 1%	Dolo. Rhombs 1%

Explanatory notes in chapter 1

Site 231 Hole Core 7 Cored Interval: 45.0-54.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
PLEISTOCENE	Gephyrocapsa oceanica N21		R/M		1	0.5, 1.0	VOID		
			C/P		2				
			A/G		3				
		C/G		B					
			C/P		Core Catcher				



LITHOLOGIC DESCRIPTION

NANNO OOZE
Light olive gray (5Y5/2)

Smear 7-3-80

Sand 5%	Nannos 80%FG	Quartz 2%
Silt 40%	Forams 5%FG	Mica 1%
Clay 55%	Rads 1%FP	Heavy Min. 1%
	Sponge Spic. 1%	Pyrite 1%
		Dolo. Rhombs 1%

SHELL SAND
Smear 7-3-142

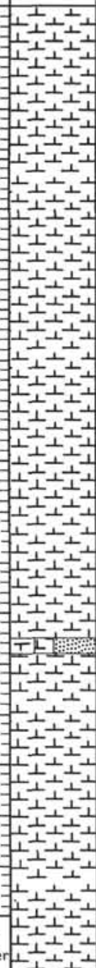
Sand 60%	Nannos 30%	Quartz 5%
Silt 20%	Forams 30%	Pyrite 5%
Clay 20%	Indet. Shell Detrit. 20%	
	Pteropods 5%	
	Lamellibr. 5%	

NANNO OOZE
Light olive gray (5Y5/2)

Explanatory notes in chapter 1

Site 231 Hole Core 8 Cored Interval: 54.5-64.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
PLEISTOCENE	Gephyrocapsa oceanica N21		A/M	F/M	1	0.5, 1.0			–
			C/P		2				–
			A/P		3				–
			A/M		4				–
			A/M		5				–
			A/P		6				
		C/G		C/M					
			A/M		Core Catcher				



LITHOLOGIC DESCRIPTION

NANNO OOZE
Light olive gray (5Y5/2), burrow mottling between 1 m and 3 m

Smear 8-1-80

Sand 10%	Nannos 70%	Quartz 5%
Silt 40%	Forams 5%	Feldspar 2%
Clay 50%	Sponge Spic. 1%	Pyrite 2%
		Dolo. Rhombs 2%
		Mica 1%
		Heavy Min. 1%

Smear 8-2-80

Sand 5%	Nannos 80%	Micarb 10%
Silt 40%	Forams 1%	Quartz 1%
Clay 50%		Pyrite 1%
		Dolo. Rhombs 1%

8-3-0 to 30 some burrow mottling

Smear

Sand 5%	Nannos 70%	Quartz 2%
Silt 45%	Pteropods 2%	Feldspar 1%
Clay 50%	Rads 1%FP	Mica 1%
	Silicoflag. 1%	Heavy Min. 1%
	Fish Frags. 1%	Pyrite 1%

8-4-75 to 95 sand filled burrows

Smear 8-4-91 (from burrow)

Sand 40%	Plank. Forams 40%	Quartz 5%
Silt 30%	Nannos 30%	Pyrite 5%
Clay 30%	Indet. Shell Detrit. 5%	Feldspar 2%
	Benth. Forams 2-5%	Dolo. Rhombs 2%
	Pteropods 2%	Heavy Min. 1%

8-5-0 to 90 sand filled burrows, 8-5-90 to 8 cc ooze filled burrows

QUARTZ RICH SHELL SAND 8-5-27 to 36
Smear 8-5-35

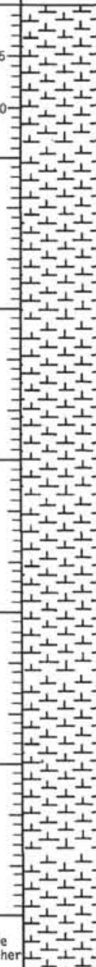
Sand 40%	Nannos 30%	Quartz 20%
Silt 30%	Forams 20%	Feldspar 5%
Clay 30%	Rads 5%	Pyrite 5%
	Echinoid Debris 5%	Heavy Min. 1%
	Fish Debris 1%	

Occasional coarse shell detritus throughout.

Explanatory notes in chapter 1

Site 231 Hole Core 9 Cored Interval: 64.0-73.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
PLEISTOCENE	Gephyrocapsa oceanica N21	C/G	A/P	C/M	1	0.5, 1.0			
			A/M		2				–
			A/M		3				
			A/M		4				
			A/M		5				–
			A/P	B	6				
			C/M		Core Catcher				



LITHOLOGIC DESCRIPTION

NANNO OOZE
Light olive gray (5Y5/2) with ooze filled burrows throughout.

Smear 9-2-90

Sand 5%	Nannos 80%	Quartz 5%
Silt 40%	Forams 5%	Pyrite 2%
Clay 55%	Sponge Spic. 5%	Feldspar 1%
	Rads 1%FP	Dolo. Rhombs 1%

Some sand filled burrows 9-4-5 to 30.

Smear 9-5-90

Sand 3%	Nannos 80%	Quartz 5%
Silt 45%	Forams 5%	Feldspar 2%
Clay 52%	Sponge Spic. 2%	Mica 2%
	Rads 1%FP	Pyrite 2%
		Dolo. Rhombs 1%

Explanatory notes in chapter 1

Site 231 Hole Core 10 Cored Interval: 73.5-83.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLEISTOCENE	G. oceanica / N21 / G. caribbeanica	C/G	A/P, C/P, A/M, A/M	C/M, C/M	1, 2, 3, 4, 5, Core Catcher	0.5, 1.0	VOID			

FORAM RICH NANNO OOZE
Light olive gray (5Y5/2)
Large Gastropod at 10-1-110
Smear 10-1-100

Sand 3%	Nannos	80%	Quartz	2%
Silt 40%	Plank. Forams	10%	Dolo. Rhombs	2%
Clay 57%	Benth. Forams	2%		
	Rads	2%FP		
	Sponge Spic.	2%		
	Pteropods	1%		

10-2-5 Foram limestone fragment
10-2-55 Sandstone fragment
10-2-95 Large Scaphopod
10-2-112 Large 'Cerithid'

10-3-145 Sandstone fragment
10-4-10 Foram limestone fragment
Some mottling in 10-4 and 10-5

Smear 10-4-80

Sand 3%	Nannos	80%	Quartz	5%
Silt 35%	Sponge Spic.	3%	Feldspar	1%
Clay 62%	Forams	1%FG	Pyrite	1%
	Rads	1%FP	Dolo. Rhombs	1%
	Fish Debris	1%		

Explanatory notes in chapter 1

Site 231 Hole Core 11 Cored Interval: 83.0-92.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLEISTOCENE	G. caribbeanica / Pseudoemiliania lacunosa N21	C/G	C/P, C/P, A/P	C/M, C/M	1, 2, 3, Core Catcher	0.5, 1.0	VOID			

NANNO OOZE
Light olive gray (5Y5/2); some mottling in 11-2 and 11-3

Smear 11-3-80

Sand 5%	Nannos	70%	Quartz	10%
Silt 45%	Forams	5%FG	Mica	2%
Clay 50%	Rads	2%FP	Pyrite	2%
	Sponge Spic.	2%	Dolo. Rhombs	2%
	Diatoms	1%FP	Feldspar	1%
	Pteropods	1%		

Explanatory notes in chapter 1

Site 231 Hole Core 12 Cored Interval: 92.5-102.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLEISTOCENE	P. lacunosa N21	C/G	A/M	R/M	1	0.5, 1.0	VOID			QUARTZ RICH NANNO OOZE Light olive gray (5Y5/2)
			C/M		2					Smear 12-2-80 Sand 5% Silt 40% Clay 55%; Nannos 60%, Forams 5%, Sponge Spic. 2%, Rads 1%, Pteropods 1%, Fish Debris 1%; Quartz 10-20%, Heavy Min. 2%, Dolo. Rhombs 2%, Feldspar 1%, Volc. Glass 1%, Pyrite 1%
			A/M		3					Grayish olive (10Y4/2) Zone 12-3-0 to 45
			A/P	F/M	4					Smear 12-4-40 Sand 5% Silt 20% Clay 75%; Nannos 50%, Forams 5%, Rads 1%, Sponge Spic. 1%; Quartz 10-20%, Heavy Min. 2- 5%, Volc. Glass 2%, Pyrite 2%, Dolo. Rhombs 1%. Yellowish gray from 12-4-143 (5Y7/2)
			A/P		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 13 Cored Interval: 102.0-111.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLEISTOCENE	P. lacunosa				1	0.5, 1.0	VOID			QUARTZ RICH NANNO OOZE Light olive gray (5Y5/2)
LATE PLIOCENE	Cyclococcolithina macintyrei N21	C/G	C/P	F/M	2					Sand filled burrows at 13-3-100 and 13-3-145
			A/P		3					Smear 13-3-80 Sand 5% Silt 25% Clay 70%; Nannos 60-70%, Forams 2%, Rads 2%, Sponge Spic. 2%; Quartz 10-20%, Feldspar 2%, Dolo. Rhombs 1%
			A/P		4					Some burrow mottling in 13-4
			C/P		5					Occasional sand filled burrows at 13-5-100
			A/M	F/M	6					
			A/M		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 14 Cored Interval: 111.5-121.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	C. macintyrei N21		A/P	F/M	1	0.5, 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2); structureless
			A/P		2					Smear 14-2-80
			A/P		3					
			A/P		4					Smear 14-4-80
		C/G	A/P	F/M	5					2 cm thick sand layer at 14-5-112; Grayish olive (10Y4/2) Zone 14-5-125 to 135
			A/M		Core Catcher					

NANNO OOZE
Light olive gray (5Y5/2); structureless

Smear 14-2-80

Sand 2%	Nannos	80%	Quartz	5%
Silt 28%	Forams	2%	Heavy Min.	1%
Clay 70%	Rads	1%	Pyrite	1%
	Sponge Spic.	1%	Dolo. Rhombs	1%

Smear 14-4-80

Sand 5%	Nannos	80%	Micarb	10%
Silt 20%	Sponge Spic.	2%	Quartz	5%
Clay 75%	Forams	1%	Pyrite	2%
	Rads	1%	Dolo. Rhombs	1%

2 cm thick sand layer at 14-5-112

Grayish olive (10Y4/2) Zone 14-5-125 to 135

Explanatory notes in chapter 1

Site 231 Hole Core 15 Cored Interval: 121.0-130.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	C. macintyrei N21	C/G			1	0.5, 1.0	VOID		GZ	QUARTZ RICH NANNO OOZE
			C/P	R/M	2				GZ	QUARTZ RICH NANNO OOZE (15-2-120 to 15-3-30)
			C/P		3					
			A/M		Core Catcher					

QUARTZ RICH NANNO OOZE
Grayish olive (10Y4/2), slowly grading to light olive gray (5Y5/2)

Smear 15-1-90

Sand 5%	Nannos	40-50%	Quartz	10-20%
Silt 25%	Rads	3%	Micarb	5%
Clay 70%	Sponge Spic.	2%	Feldspar	5%
	Forams	1%	Volc. Glass	5%
			Heavy Min.	2- 5%
			Pyrite	2%
			Dolo. Rhombs	2%

QUARTZ RICH NANNO OOZE (15-2-120 to 15-3-30)
Grayish olive (10Y4/2)

Smear 15-3-20

Sand 40%	Nannos	50%	Quartz	10%
Silt 30%	Rads	10%FP	Feldspar	2%
Clay 30%	Plank. Forams	5%	Heavy Min.	2%
	Benth. Forams	5%		
	Sponge Spic.	1%		
	Echinoid Debris	1%		

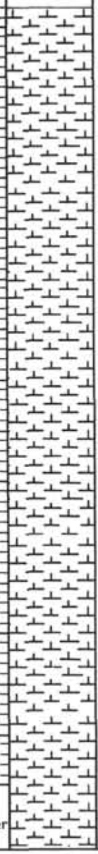
Light olive gray (5Y5/2) Zone (15-3-35 to 85) with sand filled burrows at 15-3-60

Grain Size	Grain Size
Sand 1%	Sand 41%
Silt 56%	Silt 38%
Clay 43%	Clay 21%

Explanatory notes in chapter 1

Site 231 Hole Core 16 Cored Interval: 130.5-140.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	C. macintyrei N21		R/M		1	0.5, 1.0	VOID			
		C/G		R/M	2					NANNO OOZE Light olive gray (5Y5/2) Occasional sand filled burrows
			C/M		3					
			C/M		4				—	Smear 16-4-80
			A/M		5					
			A/P	B	6					
			C/M		Core Catcher					



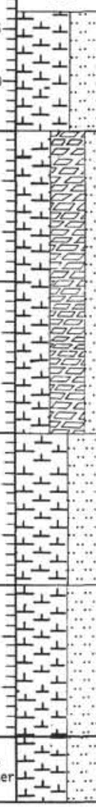
Smear 16-4-80

Sand	3%	Nannos	80%	Quartz	5%
Silt	27%	Rads	1%	Pyrite	5%
Clay	70%	Sponge Spic.	1%	Volc. Glass	2%
				Mica	1%
				Dolo. Rhombs	1%

Explanatory notes in chapter 1

Site 231 Hole Core 17 Cored Interval: 140.0-149.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	Discoaster pentaradiatus N21	C/G	A/P	B	1	0.5, 1.0	VOID		—	QUARTZ RICH NANNO OOZE Grayish olive (10Y4/2)
			A/P, R/P		2				—	NANNO DOLOMITIC CLAYEY SILT Light olive gray (5Y5/2); Grayish olive (10Y4/2) Large clayball at 17-2-125
			R/P, C/P		3					
			R/P		4					Mottled burrows QUARTZ RICH NANNO OOZE Color grading to light olive gray (5Y4/2)
			R/P	B	5					
			C/P		Core Catcher					



QUARTZ RICH NANNO OOZE
Grayish olive (10Y4/2)
Smear 17-1-100

Sand	3%	Nannos	50%	Quartz	10-20%
Silt	27%	Forams	5%	Feldspar	5%
Clay	70%	Rads	2%	Pyrite	5%
		Sponge Spic.	1%	Dolo. Rhombs	5%
				Heavy Min.	2%

NANNO DOLOMITIC CLAYEY SILT
Light olive gray (5Y5/2)
Smear 17-2-100

Sand	25%	Nannos	20-30%	Dolo. Rhombs	20-30%
Silt	40%	Forams	5%	Quartz	10%
Clay	35%	Rads	5%	Heavy Min.	1%
		Sponge Spic.	2%		

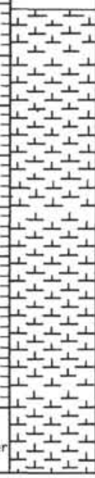
Grayish olive (10Y4/2)
Large clayball at 17-2-125

Mottled burrows
QUARTZ RICH NANNO OOZE
Color grading to light olive gray (5Y4/2)

Explanatory notes in chapter 1

Site 231 Hole Core 18 Cored Interval: 149.5-159.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	D. pentaradiatus N21	C/G	C/P, A/M, C/M	B	1, 2, 3, Core Catcher	0.5, 1.0	VOID		–	see below



NANNO OOZE
Light olive gray (5Y5/2)

Smear 18-2-80

Sand	5%	Nannos	70-80%	Quartz	5%
Silt	35%	Rads	3%	Pyrite	2%
Clay	60%	Forams	2%	Heavy Min.	1%
				Dolo. Rhombs	1%

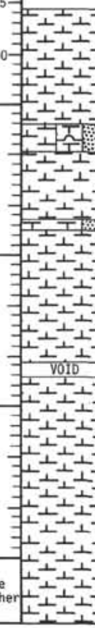
Occasional burrow mottling

Color change to grayish olive (10Y4/2)

Explanatory notes in chapter 1

Site 231 Hole Core 19 Cored Interval: 159.0-168.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	D. pentaradiatus N21	C/G	C/M, R/M, C/P, C/P, C/P	F/M, B	1, 2, 3, 4, Core Catcher	0.5, 1.0	VOID, VOID		–, –	see below



NANNO OOZE
Light olive gray (5Y5/2)

FORAM RICH NANNO OOZE
Smear 19-2-44

Sand	30%	Nannos	30-40%	Quartz	10%
Silt	35%	Plank. Forams	10%	Feldspar	5%
Clay	35%	Benth. Forams	10%	Heavy Min.	2- 5%
		Rads	10%	Dolo. Rhombs	2%
		Sponge Spic.	2%		

NANNO OOZE

Smear 19-3-90

Sand	5%	Nannos	80%	Quartz	5%
Silt	35%	Forams	2%	Mica	1%
Clay	60%	Rads	1%FP	Heavy Min.	1%
		Sponge Spic.	1%	Pyrite	1%
				Dolo. Rhombs	1%

Explanatory notes in chapter 1

Site 231 Hole Core 20 Cored Interval: 168.5-178.0 m

AGE: LATE PLIOCENE

ZONE: Discoaster tamalis N20-N19

FOSSIL CHARACTER: NANNOS C/G; FORAMS A/M, C/P, C/P, A/P, R/P, A/M, C/M; RADS B, B

SECTION: 1, 2, 3, 4, 5, 6, Core Catcher

METERS: 0.5, 1.0

LITHOLOGY: VOID

LITHOLOGIC DESCRIPTION

NANNO OOZE
Light olive gray (5Y5/2)

VOLCANIC ASH
Dark gray (N3)
Smear 20-2-31

Sand 50%	Rads 1%	Volc. Glass 90%
Silt 25%		Feldspar 5%
Clay 25%		Quartz 1%

Color grading into grayish olive (10Y4/2) at 20-2-115 and light olive gray (5Y5/2) at 20-3-5

Smear 20-3-80

Sand 5%	Nannos 80%	Quartz 2%
Silt 35%	Forams 2%	Feldspar 2%
Clay 60%	Rads 2%	Dolo. Rhombs 2%
		Heavy Min. 1%
		Pyrite 1%

Color grading into grayish olive (10Y4/2) at 20-3-140

NANNO OOZE
Light olive gray (5Y5/2); occasional thin sandy layers

Color grading to grayish olive (10Y4/2) at 20-5-40

Color grading to light olive gray (5Y5/2) at 20-5-90

Explanatory notes in chapter 1

Site 231 Hole Core 21 Cored Interval: 178.0-187.5 m

AGE: EARLY PLIOCENE

ZONE: Reticulofenestra pseudoumbilica N20-N19

FOSSIL CHARACTER: NANNOS C/G; FORAMS C/P, C/M, A/M, C/P, R/P, A/M, C/M; RADS B, B

SECTION: 1, 2, 3, 4, 5, 6, Core Catcher

METERS: 0.5, 1.0

LITHOLOGY: VOID

LITHOLOGIC DESCRIPTION

NANNO OOZE
Light olive gray (5Y5/2)

VOLCANIC ASH
Medium dark gray (N4)
Smear 21-2-22

Sand 50%	Volc. Glass 95%	Colorless Glass 60%
Silt 30%	Quartz 2%	Palagonitized and Recryst. Glass 30%
Clay 20%	Feldspar 2%	Zeolites 1%
	Heavy Min. 1%	Feldspathoids 1%

NANNO AND FORAM RICH SILTY QUARTZ SAND
Olive gray (5Y3/2)
Smear 21-2-108

Sand 40%	Nannos 20%	Quartz 50%
Silt 30%	Forams 10-20%	Feldspar 10%
Clay 30%	Rads 1- 5%	Pyrite 5%
		Heavy Min. 2%
		Micarb 2%
		Dolo. Rhombs 2%

Smear 21-4-100

Sand 5%	Nannos 80%	Quartz 5%
Silt 35%	Forams 2%	Feldspar 2%
Clay 60%	Rads 1%FP	Dolo. Rhombs 2%
		Mica 1%
		Volc. Glass 1%
		Pyrite 1%

Explanatory notes in chapter 1

Site 231 Hole Core 22 Cored Interval: 187.5-197.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY PLIOCENE	R. pseudoumbilica N20-N19	F/G	C/P	+/M	1	0.5, 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2) VOLCANIC ASH in light olive gray (5Y5/2) sandy silty zone Smear 22-1-88 Sand 60% Volc. Glass (Colorless) 90-95% Silt 25% Quartz 1- 3% Clay 15% Feldspar 2% Heavy Min. 1%
			R/P		2					
			A/M		3					
			C/M		4					
			C/P		5					NANNO OOZE Smear 22-5-40 Sand 2- 5% Nannos 90% Quartz 2% Silt 25% Rads 2% Feldspar 2% Clay 70% Sponge Spic. 1% Volc. Glass 2% Dolo. Rhombs 1%
			C/P		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 23 Cored Interval: 197.0-206.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY PLIOCENE	R. pseudoumbilica N20-N19				1	0.5, 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2) with sandy zones at 23-3-20
			A/P		2					
			C/P		3					
			A/P		4					
			A/P		5					VOLCANIC ASH Medium gray (N5) Smear 23-5-19 Sand 5% Nannos 5% Clay Min. (Palagonite Tuff) 90% Silt 60% Quartz 2% Clay 35% Feldspar 2%
		C/G	C/M	B	6					Occasional sand filled burrows
			R/M		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 24 Cored Interval: 206.5-216.0 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY PLIOCENE	R. pseudoumbilica N20-N19		C/P		1	0.5 1.0				NANNO OOZE Light olive gray (5Y5/2), at 24-1-132 1 cm sand layer
			C/P		2				—	NANNO DETRITAL SILTY SAND Smear 24-2-10 Sand 30% Nannos 40% Quartz 20% Silt 40% Forams 10-20% Feldspar 10% Clay 30% Rads 5% Heavy Min. 2% Sponge Spic. 1% Dolo. Rhombs 2% Pyrite 1%
			R/P		3					
			C/P		4					Smear 24-4-100 Sand 1- 5% Nannos 80% Quartz 5% Silt 30-40% Forams 2% Feldspar 2% Clay 50-60% Heavy Min. 2% Pyrite 2% Dolo. Rhombs 2%
		C/G	C/P	B	5					
			R/P		6					
			C/P		Core Catcher					

Explanatory notes in chapter 1

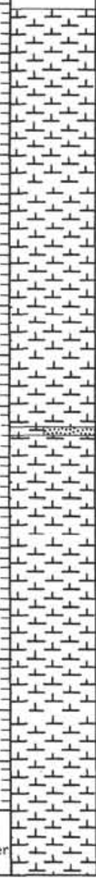
Site 231 Hole Core 25 Cored Interval: 216.0-225.5 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY PLIOCENE	R. pseudoumbilica N20-N19		A/M		1	0.5 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2)
			A/M		2					
			C/P		3					
			C/P		4				—	Smear 25-4-100 Sand 1- 5% Nannos 90% Quartz 2% Silt 30% Forams 2% Pyrite 1-2% Clay 65% Rads 1% Feldspar 1% Dolo. Rhombs 1%
			C/P		5					
		C/G	C/P	B	6					
			C/M		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 26 Cored Interval: 225.5-235.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY PLIOCENE	R. pseudoumbilica N20-N19				1	0.5, 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2); 1 cm sandy layer at 26-1-140
			C/P		2					
			C/P		3					
			C/M		4					NANNO DETRITAL QUARTZ SAND grayish brown (5YR3/2) grading down to brown
			A/M		5					NANNO OOZE Light olive gray (5Y5/2)
		C/G	A/P	B	6					
			A/P		Core Catcher					



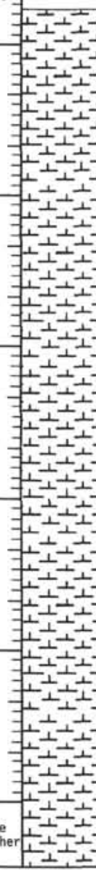
Smear 26-4-75

Sand	40%	Nannos	40%	Quartz	30%
Silt	30%	Forams	5%	Heavy Min.	5%
Clay	30%	Rads	2%	Opaque Min.	5%
		Sponge Spic.	1%	Dolo. Rhombs	2- 5%

Explanatory notes in chapter 1

Site 231 Hole Core 27 Cored Interval: 235.0-244.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY PLIOCENE	R. pseudoumbilica N20-N19				1	0.5, 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2)
			C/P		2					
			R/P		3					
			C/M		4					
			A/M		5					Olive gray (5Y3/2) layer 27-5-126 to 130
		C/G	C/M	R	6					
			A/M		Core Catcher					



Explanatory notes in chapter 1

Site 231 Hole Core 28 Cored Interval: 244.5-254.0 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY PLIOCENE	Ceratolithus aculus N18		A/M		1	0.5, 1.0				NANNO OOZE Light olive gray (5Y5/2)
			C/P		2					
			R/P		3					
			C/P		4				–	Smear 28-4-80
			C/P		5					
		C/G	R/P	R	6					
			A/M		Core Catcher					

Smear 28-4-80

Sand	2%	Nannos	90%	Quartz	1%
Silt	45%	Rads	2%	Feldspar	1%
Clay	53%	Forams	1%	Dolo. Rhombs	1%
				Zeolite	1%

Explanatory notes in chapter 1

Site 231 Hole Core 29 Cored Interval: 254.0-263.5 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	Ceratolithus tricorniculatus N17		C/P		1	0.5, 1.0				NANNO OOZE Light olive gray (5Y5/2)
			C/P		2					
			A/M		3					
			C/P		4				–	Smear 29-4-100
			C/P		5					
		C/G	C/P	+	6					
			R/P		Core Catcher					

Smear 29-4-100

Sand	5%	Nannos	80%	Quartz	5%
Silt	45%	Forams	1%	Feldspar	2%
Clay	50%	Diatoms	1%	Heavy Min.	1%
				Pyrite	1%
				Dolo. Rhombs	1%
				Zeolite	1%

Explanatory notes in chapter 1

Site 231 Hole Core 30 Cored Interval: 263.5-273.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	Ceratolithus primus N17				1	0.5, 1.0	VOID			
			A/M		2					NANNO OOZE Light olive gray (5Y5/2)
			A/M		3				—	Smear 30-3-90
			R/P		4					
			C/P		5					
		C/G	A/M	B	6					
			C/P		Core Catcher					

Smear 30-3-90

Sand	5-10%	Nannos	80%	Quartz	2%
Silt	30-50%	Forams	2%	Pyrite	2%
Clay	50%	Rads	2%	Feldspar	1%
				Heavy Min.	1%
				Dolo. Rhombs	1%
				Zeolite	1%

Explanatory notes in chapter 1

Site 231 Hole Core 31 Cored Interval: 273.0-281.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	C. primus N17				1	0.5, 1.0	VOID			
			A/M		2					NANNO OOZE Light olive gray (5Y5/2)
			C/M		3				C	$CaCO_3$ 62%
			C/P		4				GZ —	Smear 31-4-100
		C/G	C/M	B	5					Grain Size
			R/M		Core Catcher					

Smear 31-4-100

Sand	2- 5%	Nannos	90%	Pyrite	2%
Silt	30%	Forams	1%	Quartz	1%
Clay	65%			Feldspar	1%
				Mica	1%
				Heavy Min.	1%
				Dolo. Rhombs	1%

Grain Size
Sand 1%
Silt 28%
Clay 71%

Explanatory notes in chapter 1

Site 231 Hole Core 32 Cored Interval: 282.5-292.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	C. primus N17		A/M		1	0.5 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2)
			A/M		2					
			R/P		3					
			R/P		4				–	Smear 32-4-80 Sand 5% Nannos 90% Quartz 1% Silt 45% Sponge Spic. 1% Feldspar 1% Clay 50% Mica 1% Pyrite 1% Dolo. Rhombs 1%
			C/P		5					
		C/G	C/P	B	6					
			C/M		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 33 Cored Interval: 292.0-301.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	C. primus N17		A/M		1	0.5 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2)
			C/M		2					
			C/P		3					
			A/M		4		VOID			
		C/G	R/P	B	5				–	Smear 33-5-100 Sand 2% Nannos 90% Quartz 1% Silt 25% Forams 1% Mica 1% Clay 70% Rads 1%FP Heavy Min. 1% Pyrite 1% Dolo. Rhombs 1% Zeolite 1%
			R/M		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 34 Cored Interval: 301.5-311.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	C. primus N17		R/P		1	0.5, 1.0				NANNO OOZE Light olive gray (5Y5/2)
			R/P		2					
			C/P		3					
			C/P		4				–	Smear 34-4-100
			C/M		5					
		C/G	C/P	B	6					
			A/M		Core Catcher					

Smear 34-4-100

Sand	5%	Nannos	80%	Quartz	2%
Silt	25%	Forams	2%	Heavy Min.	2%
Clay	70%			Dolo. Rhombs	2%
				Volc. Glass	1%
				Zeolite	1%

Explanatory notes in chapter 1

Site 231 Hole Core 35 Cored Interval: 311.0-320.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	C. primus N16-N15		C/M		1	0.5, 1.0				NANNO OOZE Light olive gray (5Y5/2); Grading into very light olive gray
		C/G	A/P	B	2				–	Smear 35-2-80
			C/M		3					
			C/M		Core Catcher					

Smear 35-2-80

Sand	5%	Nannos	90%	Quartz	2%
Silt	25%	Rads	1%FP	Feldspar	2%
Clay	70%			Heavy Min.	1%
				Volc. Glass	1%
				Pyrite	1%
				Dolo. Rhombs	1%
				Zeolite	1%

Explanatory notes in chapter 1

Site 231 Hole Core 36 Cored Interval: 320.5-330.0 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	C. primus N16-N15				1	0.5, 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2); slight color changes to very light olive gray at 2-80 and back to light olive gray at 2-140
			C/M		2				–	Smear 36-2-110 Sand 1- 3% Nannos 90% Heavy Min. 1% Silt 20-30% Forams 1% Dolo. Rhombs 1% Clay 70% Rads 1%
			C/M		3					
			A/M		4					
			C/M		5					
		C/G	C/M	B	6					
			C/M		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 37 Cored Interval: 330.0-339.5 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	C. primus N16-N15		C/P		1	0.5, 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2)
			C/P		2					
			C/M		3				–	Smear 37-3-73 Sand 1- 2% Nannos 90% Pyrite 2% Silt 25% Rads 2% Quartz 1% Clay 70% Forams 1% Feldspar 1% Heavy Min. 1% Volc. Glass 1% Dolo. Rhombs 1% Zeolite 1%
			A/M		4					
		C/G	C/P	B	5					
			R/M		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 38 Cored Interval: 339.5-349.0 m

AGE	ZONE	FOSSIL CHARACTER NANNOS	FOSSIL CHARACTER FORAMS	FOSSIL CHARACTER RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	C. primus N16-N15		C/P		1	0.5 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2), mottled in Section 1
			C/P		2					
			C/P		3					Smear 38-3-100 Sand 1- 5% Nannos 90% Quartz 2%; Silt 25% Forams 1% Heavy Min. 1%; Clay 70% Rads 1% Volc. Glass 1%; Dolo. Rhombs 1%
		C/G	C/P	B	4					
			C/M		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 39 Cored Interval: 349.0-358.5 m

AGE	ZONE	FOSSIL CHARACTER NANNOS	FOSSIL CHARACTER FORAMS	FOSSIL CHARACTER RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	C. primus N16-N15		C/P		1	0.5 1.0				NANNO OOZE Light olive gray (5Y5/2)
			C/P		2					
			C/P		3				—	Smear 39-3-100 Sand 1- 2% Nannos 80-90% Quartz 2%; Silt 25-30% Rads 1% Heavy Min. 1-2%; Clay 70% Sponge Spic. 1% Pyrite 1-2%; Mica 1%; Volc. Glass 1%; Dolo. Rhombs 1%
		C/G	C/P	B	4					
			C/P		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 40 Cored Interval: 358.5-368.0 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	C. primus N16-N15				1	0.5 1.0	VOID			
			C/P		2					NANNO OOZE Light olive gray (5Y5/2) with very light olive gray zone from 40-2-60 to 140 and 40-3-40 to 90
			A/M		3				—	Smear 40-3-80 Sand 1- 5% Nannos 90% Silt 20-30% Forams 1% Clay 65% Rads 1%FP; Dolo. Rhombs 2% Quartz 1- 2% Feldspar 1% Heavy Min. 1% Pyrite 1%
			C/P		4					
		C/G	C/P	B	5					
			A/M		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 41 Cored Interval: 368.0-377.5 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	C. primus N16-N15		C/P		1	0.5 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2); small scale burrow mottling
			C/P		2					
			C/M		3					Smear 41-3-100 Sand 1- 3% Nannos 80-90% Silt 20-30% Forams 1% Clay 70% Rads 1%; Quartz 2% Pyrite 2% Dolo. Rhombs 1- 2% Feldspar 1% Heavy Min. 1%
			C/M		4					Burrows at 41-4-110 to 120
		C/G	C/M	B	5					
			C/P		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 42 Cored Interval: 377.5-387.0 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	C. primus N16-N15				1	0.5, 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2)
			A/M		2					Many small burrows in 42-2, 42-3 and 42-4.
			R/P		3					
			C/P		4					
			R/P		5				—	Smear 42-5-100
			C/P		6					
		C/G		B						
			C/P		Core Catcher					

Smear 42-5-100

Sand	1- 2%	Nannos	90%	Quartz	1%
Silt	25-30%	Forams	1%	Heavy Min.	1%
Clay	70%	Rads	1%FP	Pyrite	1%
				Dolo. Rhombs	1%

Explanatory notes in chapter 1

Site 231 Hole Core 43 Cored Interval: 387.0-396.5 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	Discoaster berggrenii N16-N15		C/M		1	0.5, 1.0				NANNO OOZE Light olive gray (5Y5/2); burrowed throughout
			C/P		2					
			C/P		3					
			C/P		4					
			C/P		5				—	Smear 43-5-100
			C/P		6					
		C/G		B						
			C/P		Core Catcher					

Smear 43-5-100

Sand	1- 3%	Nannos	80-90%	Dolo. Rhombs	2%
Silt	30%	Forams	1%	Quartz	1- 2%
Clay	65%	Rads	1%FP	Mica	1%
				Pyrite	1%

Explanatory notes in chapter 1

Site 231 Hole Core 44 Cored Interval: 396.5-406.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	D. berggrenii N16-N15	C/G	R/P, R/P	B	1, 2, Core Catcher	0.5, 1.0	VOID		–	QUARTZ AND FORAM BEARING NANNO OOZE

QUARTZ AND FORAM BEARING NANNO OOZE
Grayish olive (10Y4/2), slightly consolidated. Bitumen streaks 44-1-80 to 95
Smear 44-1-90

Sand 5%	Nannos	30-50%	Opaque matter (oiled or bitumenous?)	5-10%
Silt 30%	Forams	5%	Quartz	5%
Clay 65%	Sponge Spic.	1%	Pyrite?	5%
			Feldspar	2%
			Heavy Min.	1%
			Dolo. Rhombs	1%

Color change to pale olive (10Y6/2) at 44-2-80 and back to grayish olive (10Y4/2) at 44-2-105

Explanatory notes in chapter 1

Site 231 Hole Core 45 Cored Interval: 406.0-415.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	D. berggrenii N16-N15	C/G	C/P, C/P, R/P, C/P, C/P, C/P, C/P	B	1, 2, 3, 4, 5, 6, Core Catcher	0.5, 1.0			–	NANNO OOZE

NANNO OOZE
Light olive gray (5Y5/2) with some small burrows.

Smear 45-3-120

Sand 1- 2%	Nannos	90%	Feldspar	1%
Silt 20%	Forams	1%	Heavy Min.	1%
Clay 75%	Rads	1%		
	Sponge Spic.	1%		

Explanatory notes in chapter 1

Site 231 Hole Core 46 Cored Interval: 415.5-425.0 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	D. berggrenii; N16-N15		R/P		1	0.5, 1.0				NANNO OOZE Light olive gray (5Y5/2) with burrows throughout.
			R/M		2					
			R/P		3					
			R/M		4					
			C/P		5					
			C/P		6				–	NANNO DETRITAL SILTY SAND Smear 46-6-90 Sand 30-40% Silt 30% Clay 30% Nannos 50%, Shell debris 5%, Forams 2%, Rads 2% Quartz 30%, Feldspar 5%, Pyrite 2%, Dolo. Rhombs 2%, Heavy Min. 1%
		C/G	A/P		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 47 Cored Interval: 425.0-434.5 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	D. berggrenii		C/P	B	1	0.5, 1.0	VOID			NANNO OOZE Light olive gray (5Y5/2), burrowed throughout
			C/P		2					
			A/P		3				–	Smear 47-3-100 Sand 1- 3% Silt 25-30% Clay 70% Nannos 90%, Forams 1%, Rads 1%, Sponge Spic. 1% Quartz 1%, Pyrite 1%, Dolo. Rhombs 1%, Heavy Min. <1%
			R/P		4					
			C/P		5					
			C/P		6					
	D. neohamatus	C/G		B						
			C/P		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 48 Cored Interval: 434.5-444.0 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	D. neohamatus N14-N13	C/G	C/P, C/P, A/P, C/P	B	1, 2, 3, Core Catcher	0.5, 1.0	VOID			

NANNO OOZE
Olive gray (5Y3/2) and color changes
to light olive gray (5Y5/2) at 48-1-70
to grayish olive (10Y4/2) at 48-2-20
to light olive gray (5Y5/2) at 48-2-80
to grayish olive (10Y4/2) at 48-2-110
to olive gray (5Y3/2) at 48-3-0

Burrowed throughout.

to light olive gray (5Y5/2) at 48-3-25
to olive gray (5Y3/2) at 48-3-50
grading to light olive gray (5Y5/2)
to grayish olive (10Y4/2) at 48-3-130

Smear 48-3-80

Sand	1- 2%	Nannos	80-90%	Quartz	1%
Silt	20-25%	Forams	1%	Mica	1%
Clay	75%	Rads	1%FP	Pyrite	1%

Site 231 Hole Core 49 Cored Interval: 444.0-453.5 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	Discoaster bellus / D. neohamatus N14-N13	C/G	C/P, R/M	B	1, 2, 3, Core Catcher	0.5, 1.0	VOID			

NANNO OOZE
Olive gray (5Y3/2) grading to grayish
olive (10Y4/2) with some burrows.

Explanatory notes in chapter 1

Site 231 Hole Core 50 Cored Interval: 453.5-463.0 m

AGE	ZONE	NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	D. bellus N14-N13	C/G	C/P, A/M, R/P, C/P, C/P, C/P	B	1, 2, 3, 4, 5, 6, Core Catcher	0.5, 1.0	VOID			

NANNO OOZE
Grayish olive (10Y4/2) with burrows.
Burrows in part filled with coarser material:
Smear 50-1-97 (from burrow)

Sand	10-30%	Nannos	30-50%	Quartz	10-15%
Silt	30-40%	Forams	5%	Feldspar	2- 5%
Clay	30%	Rads	3- 5%FP	Heavy Min.	1- 3%
				Pyrite	1- 2%
				Mica	1%

Color change to pale olive (10Y6/2) at 50-2-50
and to grayish olive (10Y4/2) at 50-2-100

Smear 50-3-100

Sand	1- 3%	Nannos	90%	Quartz	2%
Silt	15-20%	Forams	1%	Dolo. Rhombs	1- 2%
Clay	80%			Feldspar	1%
				Volc. Glass	1%
				Zeolite	1%

Explanatory notes in chapter 1

Site 231 Hole Core 51 Cored Interval: 463.0-472.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	D. bellus		C/P		1	0.5 1.0				NANNO OOZE Grayish olive (10Y4/2) with burrows throughout.
					2					
					3					Color change to light olive gray (5Y5/2) at 51-3-50 and to grayish olive (10Y4/2) at 51-3-110
			R/P		4					Thin sandy layer at 51-4-38 to 45
					5					
		C/G		B	6				—	Thin sandy layer at 51-6-48 to 52
			A/P		Core Catcher					

Smear 51-6-50

Sand 30%	Nannos	30-40%	Quartz	15-20%
Silt 35%	Forams	3- 5%	Feldspar	1- 5%
Clay 35%	Rads	2- 3%FP	Pyrite	1- 5%
	Sponge Spic.	1%	Heavy Min.	1- 3%
			Volc. Glass	1- 3%
			Dolo. Rhombs	2%
			Mica	1%
			Zeolite	1%

Explanatory notes in chapter 1

Site 231 Hole Core 52 Cored Interval: 472.5-482.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	D. bellus				1	0.5 1.0				NANNO OOZE Olive gray (5Y3/2) grading to grayish olive (10Y4/2) at 52-1-60. Burrows throughout.
			C/P		2					
					3				—	Smear 52-3-80
			C/P		4					
		C/G		R/M	5					
			R/P		Core Catcher					

Smear 52-3-80

Sand 1- 3%	Nannos 90%		Quartz	1- 2%
Silt 30%	Forams 1%		Heavy Min.	1%
Clay 70%			Volc. Glass	1%
			Pyrite	1%
			Dolo. Rhombs	1%
			Zeolite	1%

Explanatory notes in chapter 1

Site 231 Hole Core 53 Cored Interval: 482.0-491.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	D. bellus		C/P		1	0.5, 1.0	VOID			NANNO OOZE Burrows throughout. Grayish olive (10Y4/2) grading to olive gray (5Y3/2) at 53-1-100 to grayish olive (10Y4/2) at 53-2-20 to olive gray (5Y3/2) at 53-2-60 to light olive gray (5Y5/2) at 53-2-120 to grayish olive (10Y4/2) at 53-3-0
					2					
					3				—	Smear 53-3-80 Sand 1- 2% Silt 25% Clay 75% Nannos 90% Sponge Spic. 1% Quartz 1% Heavy Min. 1% Volc. Glass 1% Pyrite 1% Dolo. Rhombs 1% Zeolite 1%
					4					
			C/P		5					
					6					
MIDDLE MIOCENE	D. hamatus	C/G	R/P	R/M	Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 54 Cored Interval: 491.5-501.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	D. hamatus				1	0.5, 1.0	VOID			NANNO OOZE Grayish olive (10Y4/2) grading to light olive gray (5Y5/2) at 54-1-90 to grayish olive (10Y4/2) at 54-1-135 to light olive gray (5Y5/2) at 54-2-0 to grayish olive (10Y4/2) at 54-2-30
		C/G	C/P	B	2				—	Burrows throughout. Smear Sand 1- 2% Silt 30% Clay 70% Nannos 80-90% Sponge Spic. 1% Quartz 1% Heavy Min. 1% Dolo. Rhombs 1% Pyrite <1%
					3					
			C/P		Core Catcher					

Site 231 Hole Core 55 Cored Interval: 501.0-509.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	D. hamatus	C/G		R/P	1	0.5, 1.0				NANNO OOZE Grayish olive (10Y4/2) with burrows.
			C/P		2				—	Smear 55-2-80 Sand 1- 5% Silt 40% Clay 60% Nannos 80-90% Rads 1% Quartz 1- 2% Heavy Min. 1% Volc. Glass 1% Dolo. Rhombs 1%
					3					
			C/P		Core Catcher					

Explanatory notes in chapter 1

Site 231 Hole Core 56 Cored Interval: 509.5-519.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	D. hamatus	C/G	C/P, C/P, C/P	B	1, 2, 3, 4, 5, 6, Core Catcher	0.5, 1.0	VOID			

NANNO OOZE
Grayish olive (10Y4/2) with burrows.

Color grading to light olive gray (5Y5/2) at 56-3-75
to grayish olive (10Y4/2) at 56-3-110
to light olive gray (5Y5/2) at 56-4-10
to grayish olive (10Y4/2) at 56-4-40
to light olive gray (5Y5/2) at 56-4-80
to grayish olive (10Y4/2) at 56-5-85

Smear 56-3-90

Sand	1- 3%	Nannos	>90%	Quartz	1%
Silt	50%	Forams	1%	Mica	1%
Clay	50%	Rads	1%FP	Heavy Min.	1%
				Pyrite	1%
				Dolo. Rhombs	1%

Explanatory notes in chapter 1

Site 231 Hole Core 57 Cored Interval: 519.0-528.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	D. hamatus / D. kugleri	C/G	R/P, R/P	B	1, 2, 3, Core Catcher	0.5, 1.0	VOID			NANNO OOZE Grayish olive (10Y4/2) with burrows throughout.

Explanatory notes in chapter 1

Site 231 Hole Core 58 Cored Interval: 528.5-538.0 m

AGE | ZONE | FOSSIL CHARACTER (NANNOS, FORAMS, RADS) | SECTION | METERS | LITHOLOGY | DEFORMATION | LITHO. SAMPLE | LITHOLOGIC DESCRIPTION

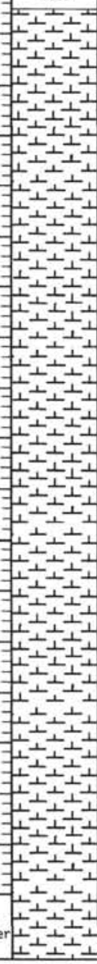
AGE: MIDDLE MIOCENE

ZONE: D. kugleri; N14-N13

FOSSIL CHARACTER: FORAMS C/M (Section 2); FORAMS C/M (Section 4); NANNOS C/G, FORAMS R/P, RADS B (Section 6); FORAMS A/M (Core Catcher)

SECTION: 1 (0.5, 1.0), 2, 3, 4, 5, 6, Core Catcher

LITHOLOGY: VOID



LITHOLOGIC DESCRIPTION

NANNO OOZE
Light olive gray (5Y5/2) grading
to grayish olive (10Y4/2) at 58-1-75
to light olive gray (5Y5/2) at 58-2-40
to grayish olive (10Y4/2) at 58-2-120
to light olive gray (5Y5/2) at 58-4-0
to grayish olive (10Y4/2) at 58-4-15
to light olive gray (5Y5/2) at 58-4-50
to grayish olive (10Y4/2) at 58-4-70

Burrows throughout.

to light olive gray (5Y5/2) at 58-4-110
to grayish olive (10Y4/2) at 58-5-0

Smear 58-3-80

Sand 1- 3%	Nannos 90%	Quartz 1- 2%
Silt 30-40%	Forams 1%FP	Feldspar 1%
Clay 60-70%	Rads 1%FP	Pyrite 1%
	Sponge Spic. 1%	Dolo. Rhombs 1%

Explanatory notes in chapter 1

Site 231 Hole Core 59 Cored Interval: 538.0-547.5 m

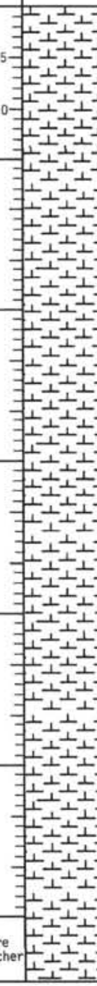
AGE | ZONE | FOSSIL CHARACTER (NANNOS, FORAMS, RADS) | SECTION | METERS | LITHOLOGY | DEFORMATION | LITHO. SAMPLE | LITHOLOGIC DESCRIPTION

AGE: MIDDLE MIOCENE

ZONE: N14-N13; D. kugleri N13

FOSSIL CHARACTER: FORAMS C/M (Section 2); FORAMS A/M (Section 4); NANNOS C/G, FORAMS C/P, RADS B (Section 6); FORAMS A/M (Core Catcher)

SECTION: 1 (0.5, 1.0), 2, 3, 4, 5, 6, Core Catcher



LITHOLOGIC DESCRIPTION

NANNO OOZE
Grayish olive (10Y4/2) to pale olive
(10Y6/2) with burrows throughout.
Semilithified.

Smear 59-3-120

Sand 5%	Nannos 80-90%	Quartz 1%
Silt 30%	Rads 1- 2%FP	Volc. Glass 1%
Clay 65%	Forams 1%	Pyrite 1%

Explanatory notes in chapter 1

Site 231 Hole Core 60 Cored Interval: 547.5-557.0 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	D. kugleri N13	C/G	C/M, C/M	R	1, 2, 3, Core Catcher	0.5, 1.0	VOID			NANNO OOZE Grayish olive (10Y4/2) to pale olive (10Y6/2)

Explanatory notes in chapter 1

Site 231 Hole Core 61 Cored Interval: 557.0-566.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	N13 --- N12 D. kugleri --- D. exilis	C/G	C/M, A/M, C/P, A/M	B	1, 2, 3, 4, 5, 6, Core Catcher	0.5, 1.0	VOID		GZ C	NANNO OOZE Grayish olive (10Y4/2) with burrows throughout. Smear 61-4-80 Sand 1- 3% Nannos 70-80% Pyrite 5% Silt 20-30% Rads 1% Quartz 2% Clay 70% Feldspar 2% Dolo. Rhombs 1% Color grading to light olive gray (5Y5/2) at 61-4-90 and back to grayish olive (10Y4/2) at 61-4-140 Grain Size Sand 2% Silt 23% Clay 75% $CaCO_3$ 33%

Explanatory notes in chapter 1

Site 231 Hole Core 62 Cored Interval: 566.5-568.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	D. exilis-S. heteromorphus?; D. exilis; N12	C/M, C/M	A/M	B	1; Core Catcher	0.5, 1.0	VOID			

NANNO CHALK
Greenish gray (5G6/1) 62-1-60 to 65
Smear 62-1-60 (ea. 5 cm over Basalt!)
Sand 1% Nannos >95% Quartz 1%
Silt 25% Feldspar 1%
Clay 75%

BLACK VOLCANIC GLASS 62-1-65 to 85
NANNO CHALK 62-1-85 to 102
Greenish gray (5G6/1)
Smear 62-1-89
Sand 1% Nannos 95% Quartz 1%
Silt 30% Feldspar 1%
Clay 70%

VOLCANIC GLASS AND BASALT 62-1-102 to 125 with intrusional contacts

NANNO CHALK 62-1-125 to 135
Greenish gray (5G6/1)
Smear 62-1-130
Sand 1% Nannos 90-95%
Silt 30% Heavy Min. 1%
Clay 70% Volc. Glass 1%

VESICULAR BASALT 62-1-135 to 150

Site 231 Hole Core 63 Cored Interval: 568.5-574.5 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	D. exilis-S. heteromorphus	C/P			1; 2; Core Catcher	0.5, 1.0	VOID			

BLACK VESICULAR BASALT

BLACK VOLCANIC GLASS
BLACK VESICULAR BASALT
with brownish gray (5YR4/1) vein.

BLACK VOLCANIC GLASS
BLACK VESICULAR BASALT with brownish gray vein (5YR4/1) consisting of muscovite, talc and serpentine aggregates.

Explanatory notes in chapter 1

Site 231 Hole Core 64 Cored Interval: 574.5-584 m

AGE	ZONE	FOSSIL CHARACTER: NANNOS	FORAMS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE					1; 2; 3; Core Catcher	0.5, 1.0				

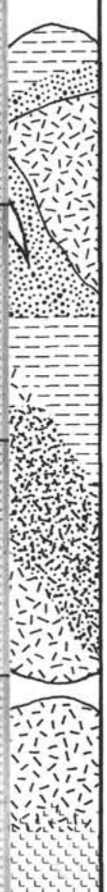
BLACK BASALT
with glass breccias and veins.
See detailed descriptions on 'Visual Core Descriptions'.

Explanatory notes in chapter 1

DETAILED CORE DESCRIPTIONS

Site 231 Core 62 Section 1

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



0
25
50
75
100
125
150

Layered sediments.

Baked zone in sediments, with pyrite: Contact.

Fractured zone in glass

Brecciated glass.

Tempered upper margin in sediments.

Slightly metamorphosed sediment inclusions without layering.

Glassy breccia cemented by tempered metamorphosed sediments lodged in cracks.

Fractured glass.

Slightly metamorphosed sediment inclusion.

Tempered zone in sediments.

Glassy rind overlying black massive basalt.

Site 231 Core 62 Section CC

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

NO PHOTOGRAPH AVAILABLE

0
25
50
75
100
125
150

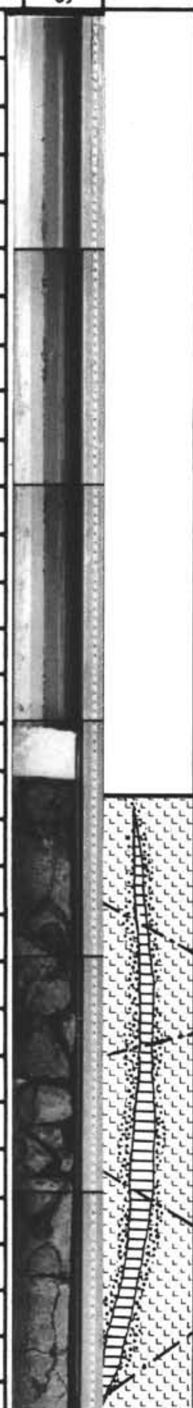
Mylonitized zone.

Black massive vesicular basalt.

DETAILED CORE DESCRIPTIONS

Site 231 Core 63 Section 1

Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description
0, 25, 50, 75, 100, 125, 150					

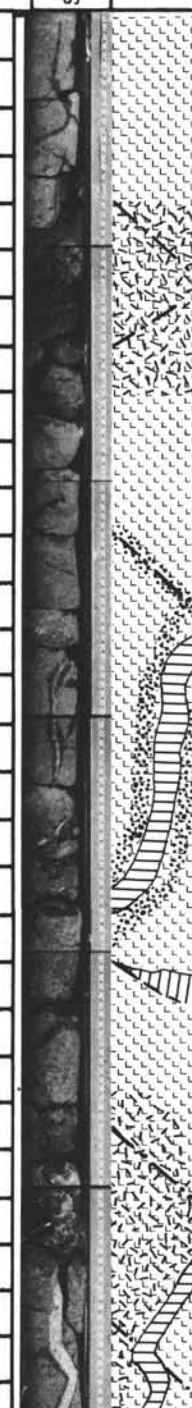


Black massive vesicular doleritic basalt, slightly altered, with minor fracturing and oxidation along fractures.

Thin vertical vein incrusted with fine-grained aggregates of talc, sericite, chlorite, and an oxidized zone bordering vein.

Site 231 Core 63 Section 2

Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description
0, 25, 50, 75, 100, 125, 150					



Massive black basalt: slightly fractured with narrow zones of oxidation around tiny veins and fractures.

Fragmented glass.

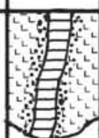
Variolitic vesicular basalt.

Chlorite-sericite-talc-aragonite veins (thickness from 1 mm to 1.5 cm) in variolitic, vesicular basalt.

Glassy breccia.

DETAILED CORE DESCRIPTIONS

Site 231 Core 63 Section CC

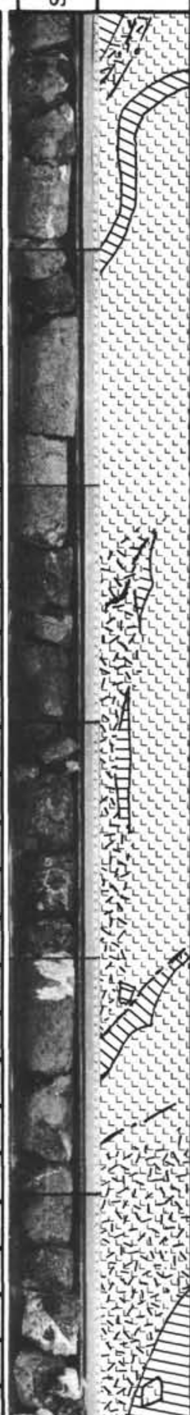
Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description
0	NO PHOTOGRAPH AVAILABLE				Black vesicular basalt, with vein of talc-sericite-chlorite, and narrow zone of oxidation around vein.
25					
50					
75					
100					
125					
150					

Site 231 Core 64 Section 1

Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description
0					Black massive basalt.
					Fragmented volcanic glass with thin veins of aragonite (?).
25					
50					Massive basalt; slightly fractured.
					Vein of aragonite, chlorite, sericite.
75					Massive basalt.
100					Fractured zone of glass and glassy breccia impregnated with aragonite, sericite, chloritic material in irregular veins.
125					Massive vesicular basalt.
150					Massive basalt.

DETAILED CORE DESCRIPTIONS

Site 231 Core 64 Section 2

Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description
0–150					

Massive basalt, slightly fractured and altered.

Chlorite, sericite, quartz (?) veins along small fractures.

Massive variolitic basalt, only slightly fractured, and altered.

Brecciated glass; veins.

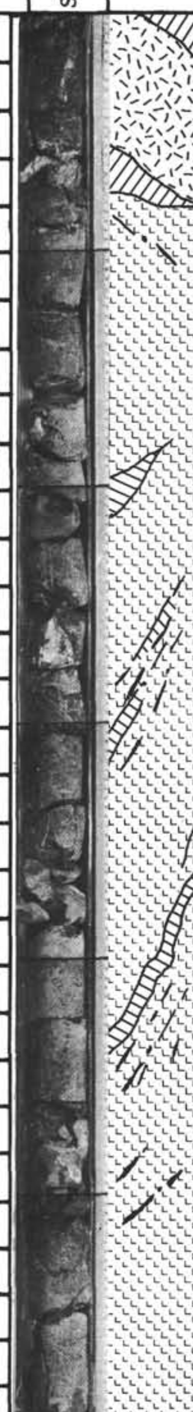
Variolitic basalt.

Fractured zone: upper part fragmented glass; lower part talc, calcite, sericite vein as fine-grained aggregates.

Doleritic basalt.

Brecciated volcanic glass impregnated with chlorite-sericite-talc aggregates, cemented to vein of such material.

Site 231 Core 64 Section 3

Centimeters from Top of Section	Section Photograph	Graphic Representation	Smear Slides (*)	Deformed Areas	Description
0–150					

Fragments of vein of talc-chlorite-sericite.

Fragmented glass along fracture zone.

Vein of chlorite-sericite-talc mixture.

Massive vesicular basalt.

Vein of chlorite-sericite-talc material.

Basalt.

Fracture zone with basalt fragments bonded by chlorite-sericite-talc vein material.

Vesicular basalt.

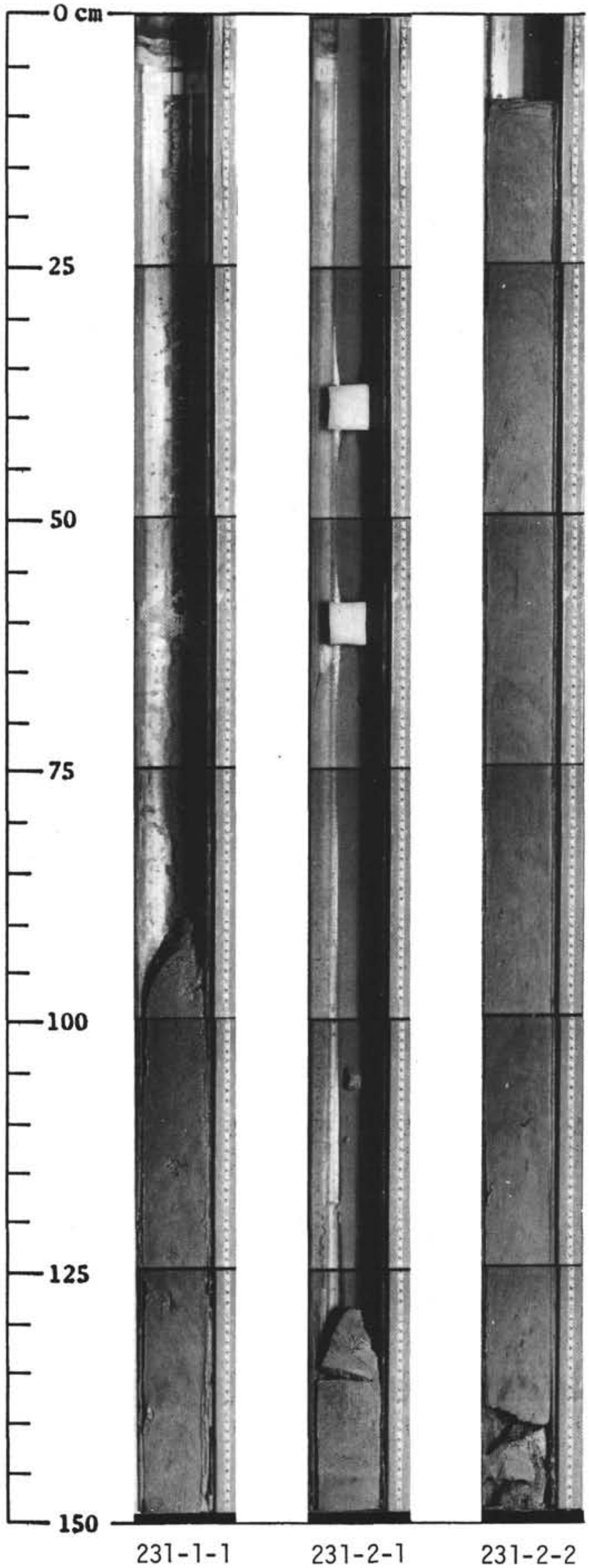
Fracture zone in basalt: upper part, brecciated more than lower, contains thin veins of chlorite-sericite-talc.

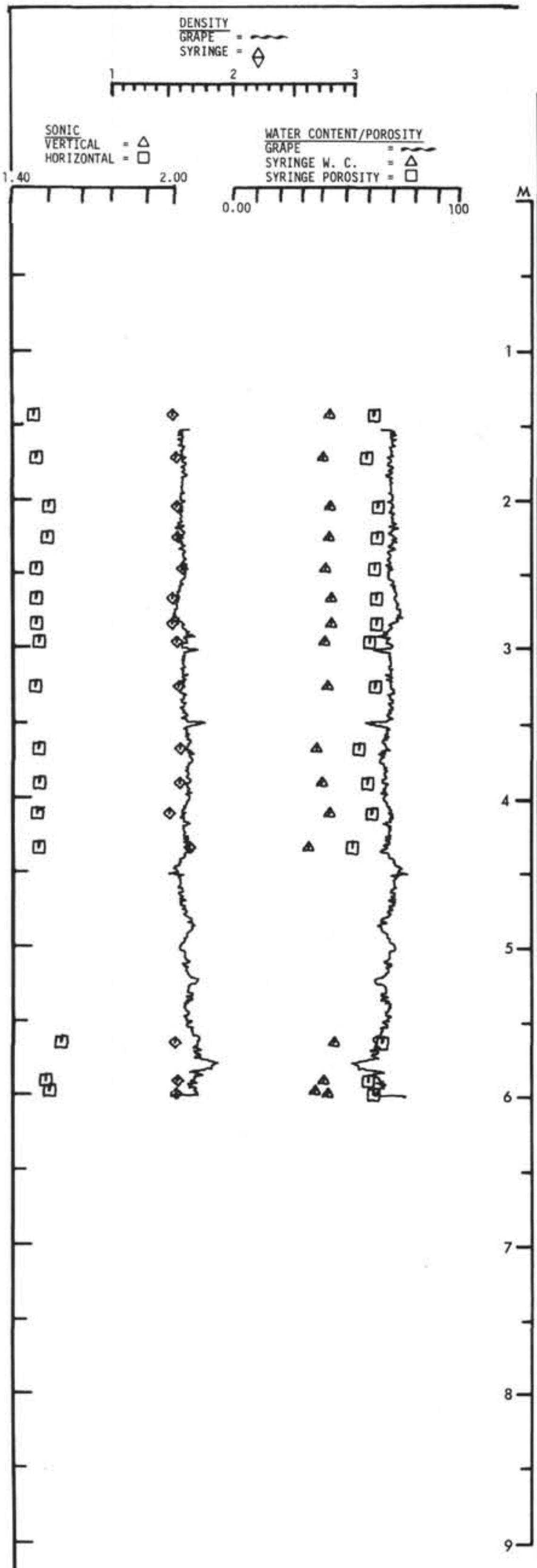
Vesicular basalt.

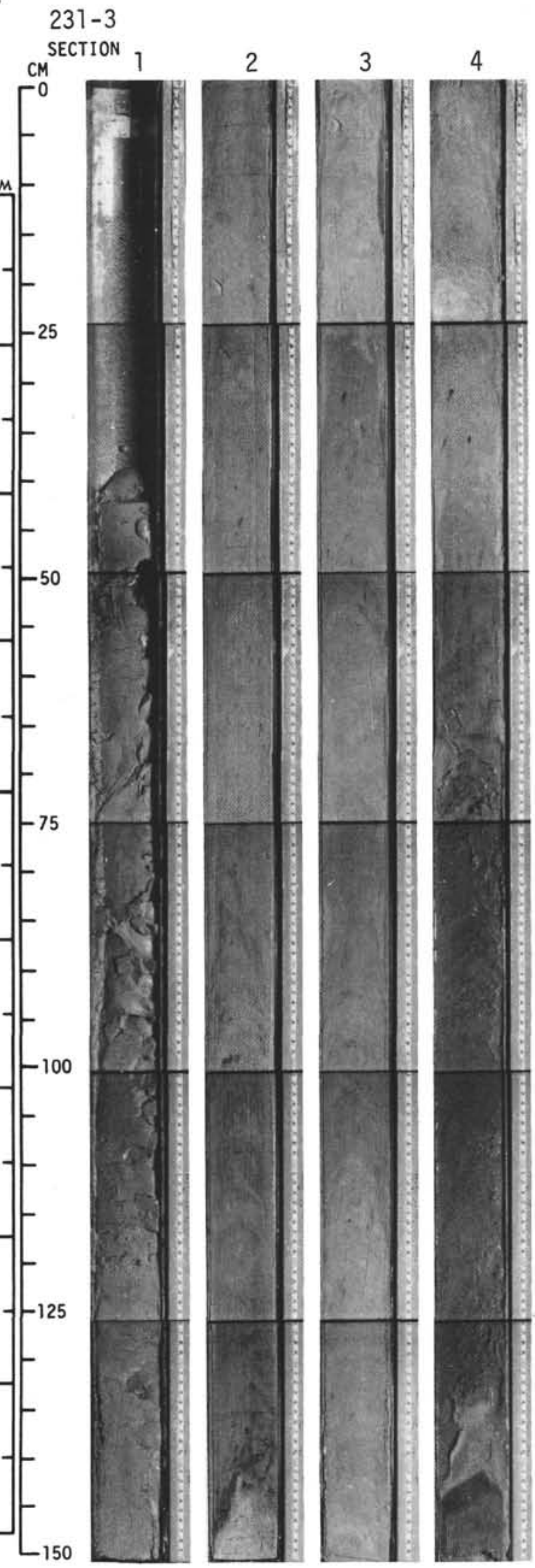
DETAILED CORE DESCRIPTIONS

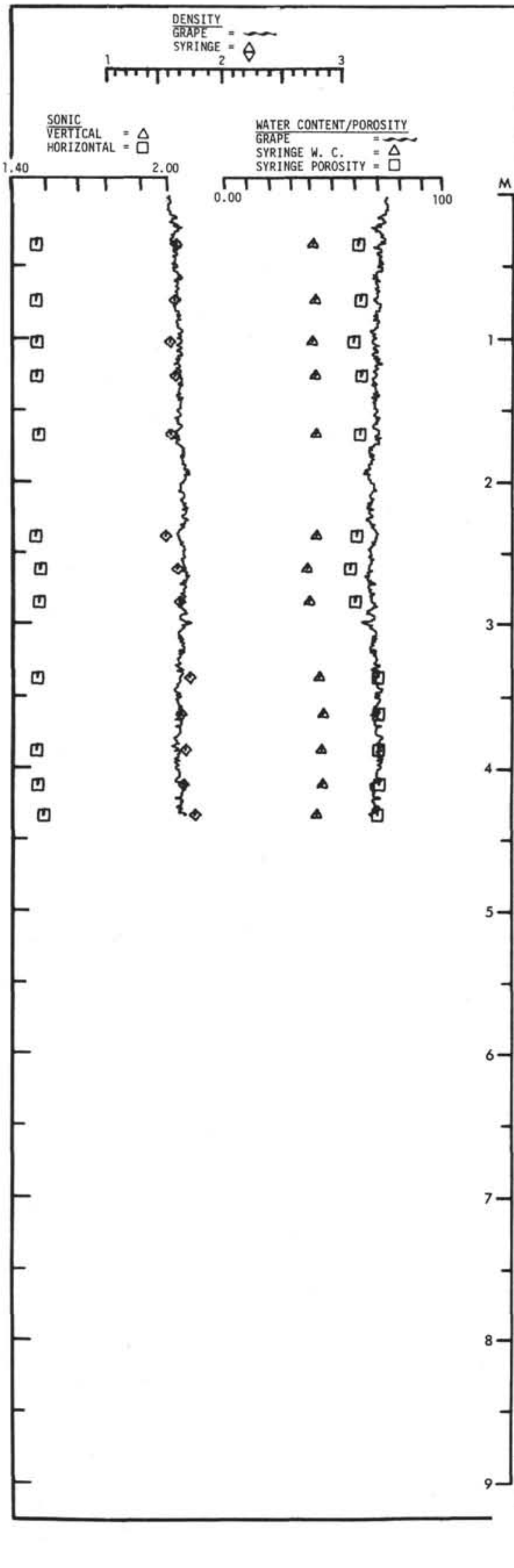
Site 231 **Core** 64
Section CC

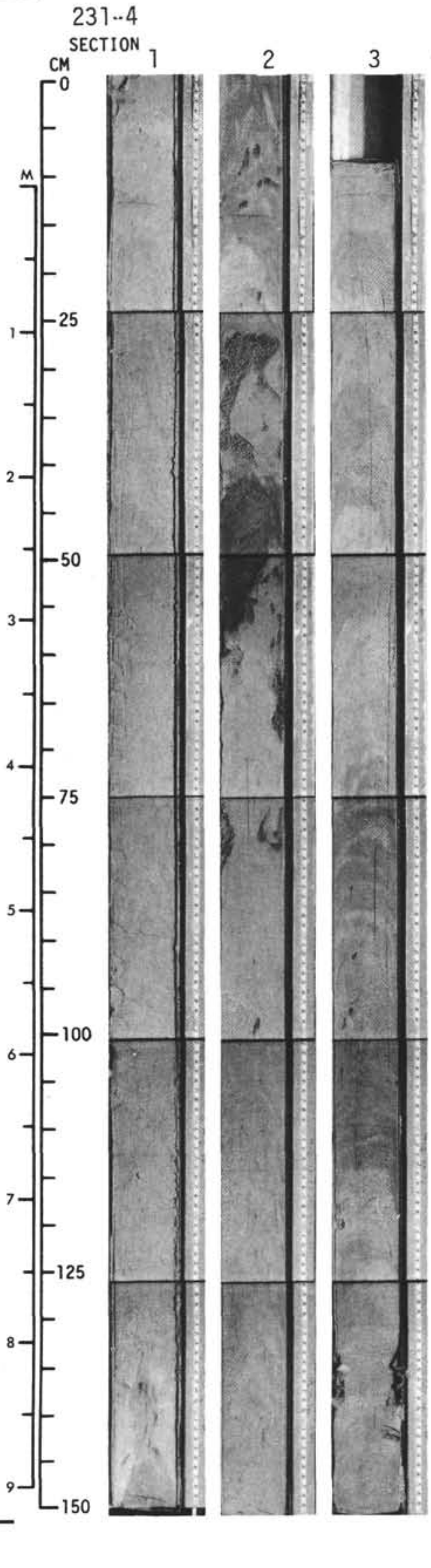
Centimeters from Top of Section	**Section Photograph**	**Graphic Representation**	**Smear Slides (*)**	**Deformed Areas**	**Description**
0–25	NO PHOTOGRAPH AVAILABLE				Massive vesicular basalt, slightly altered and fractured. Some brecciated glass, impregnated with talc-chlorite-sericite vein material, occurs in the fractures.
25					
50					
75					
100					
125					
150					

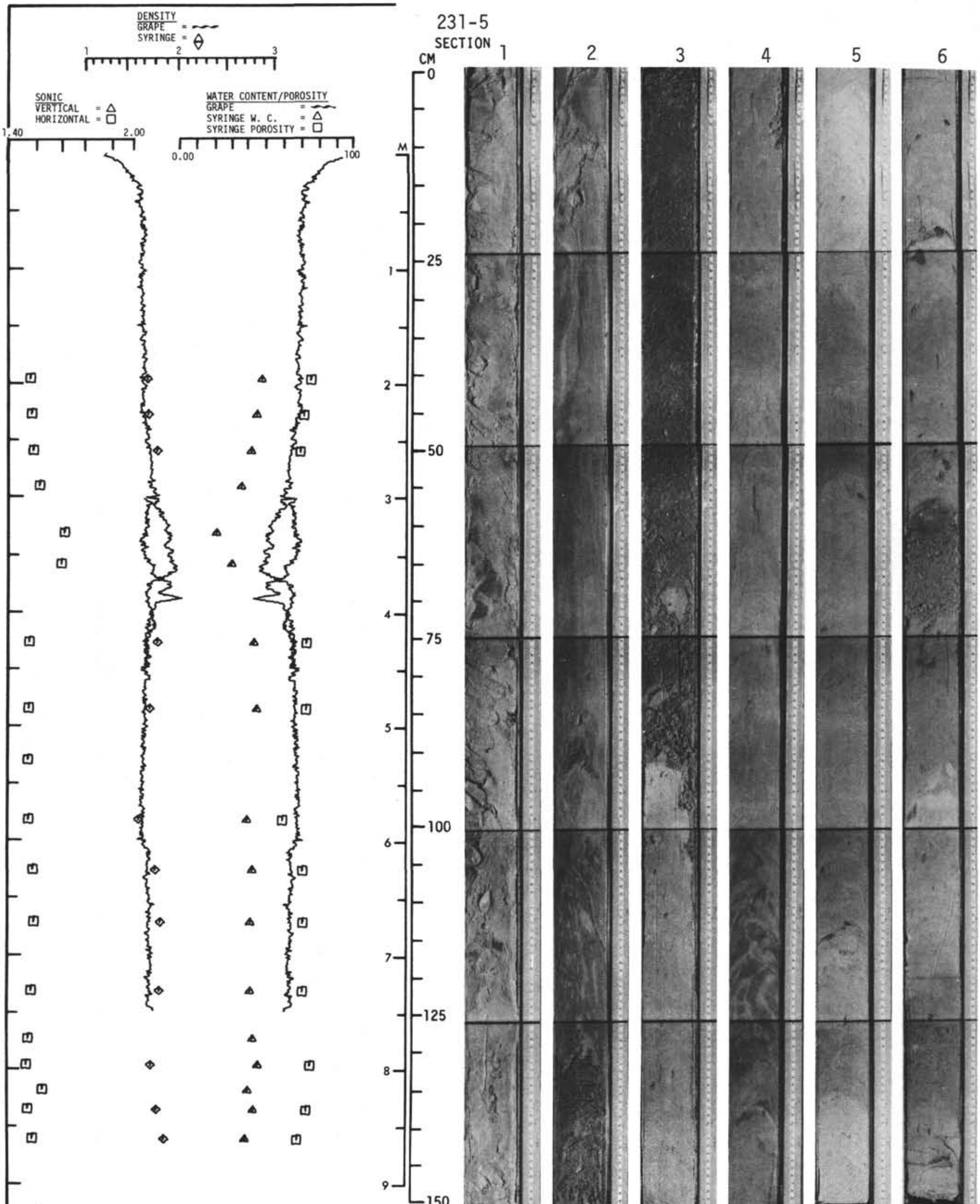

0 cm
25
50
75
100
125
150
231-1-1
231-2-1
231-2-2

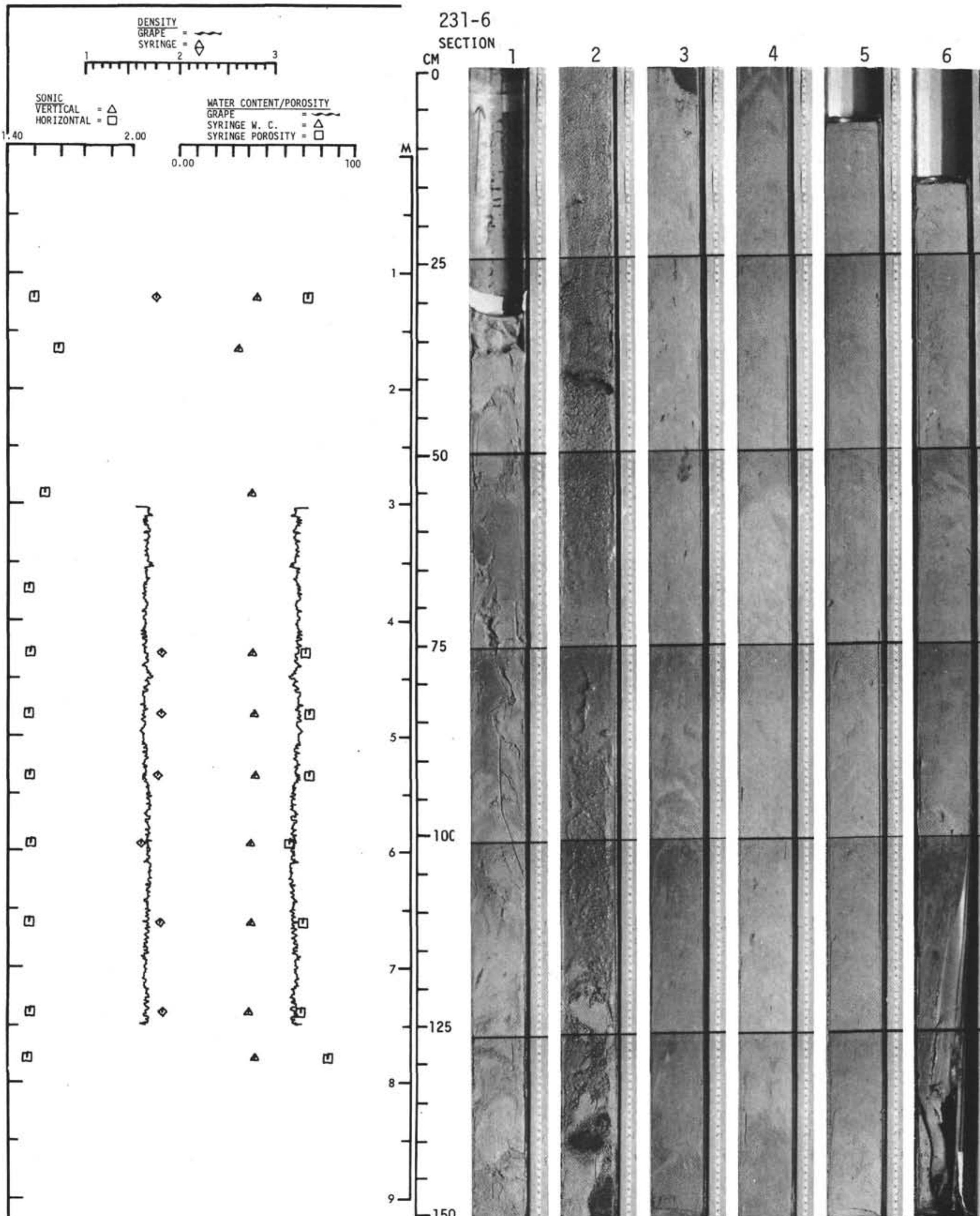

DENSITY
GRAPE
SYRINGE
1
2
3
SONIC
VERTICAL
HORIZONTAL
1.40
2.00
WATER CONTENT/POROSITY
GRAPE
SYRINGE W. C.
SYRINGE POROSITY
0.00
100
M
1
2
3
4
5
6
7
8
9

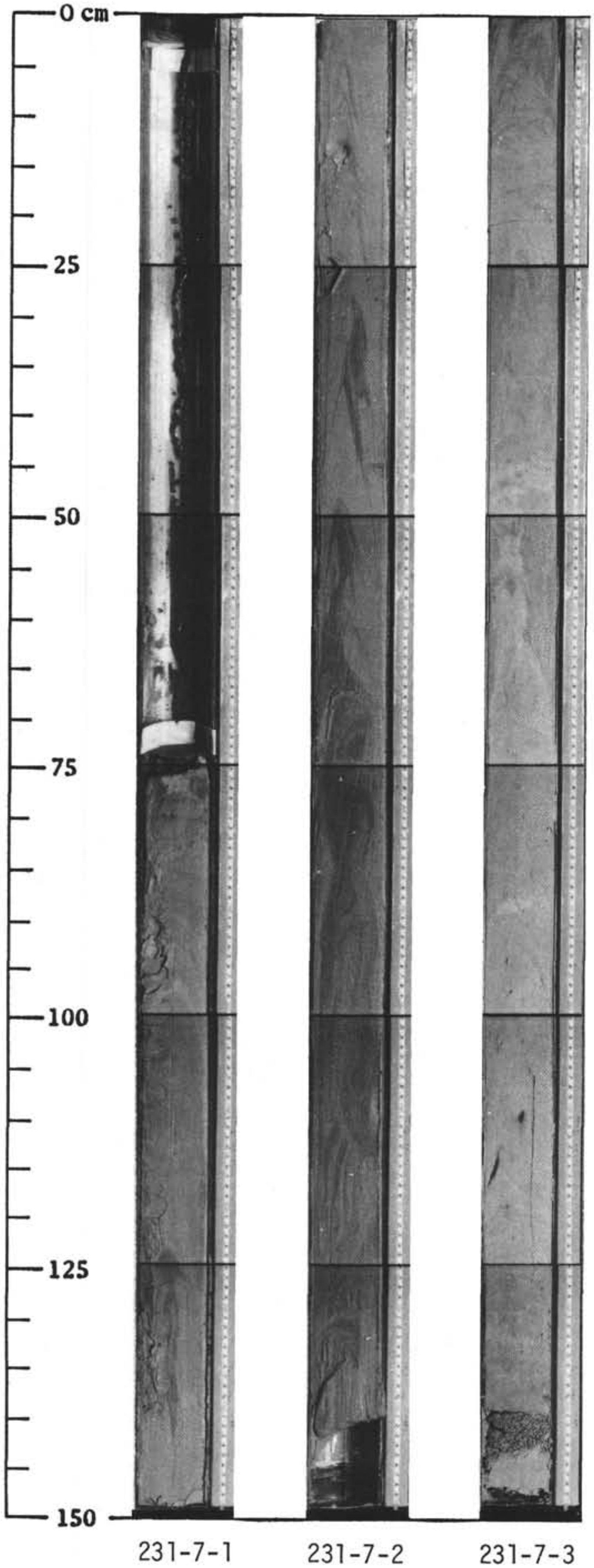

231-3
SECTION
1
2
3
4
CM
0
25
50
75
100
125
150

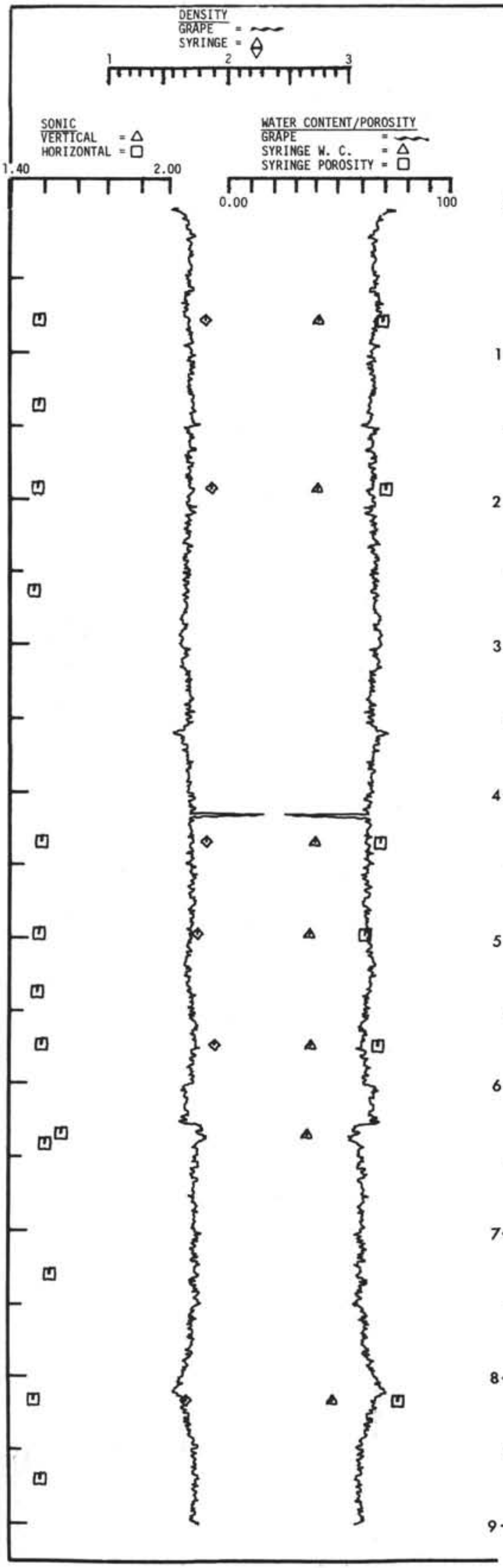

DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = □
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100

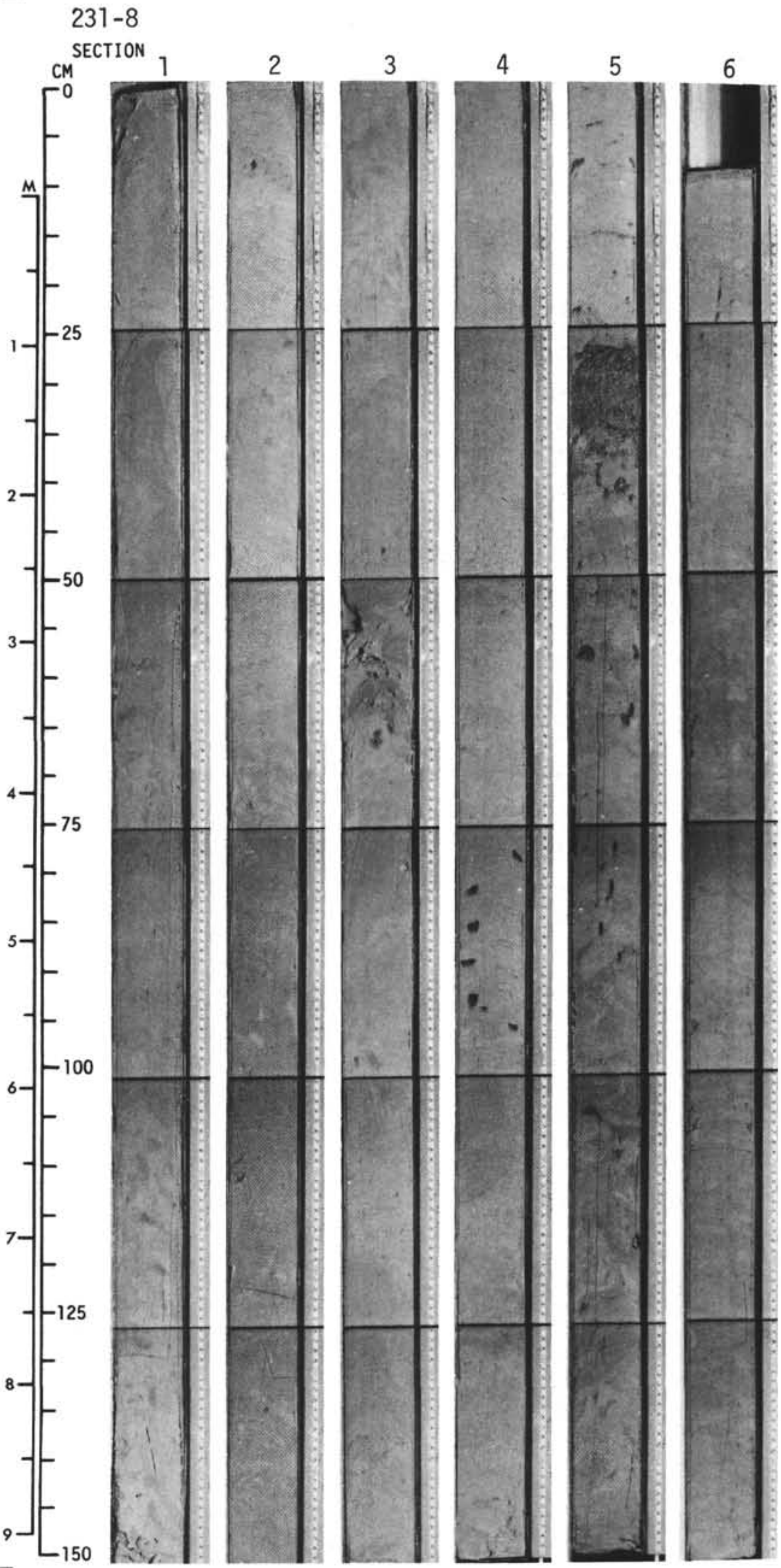

231-4
SECTION 1
2
3
CM
0
25
50
75
100
125
150
M
1
2
3
4
5
6
7
8
9

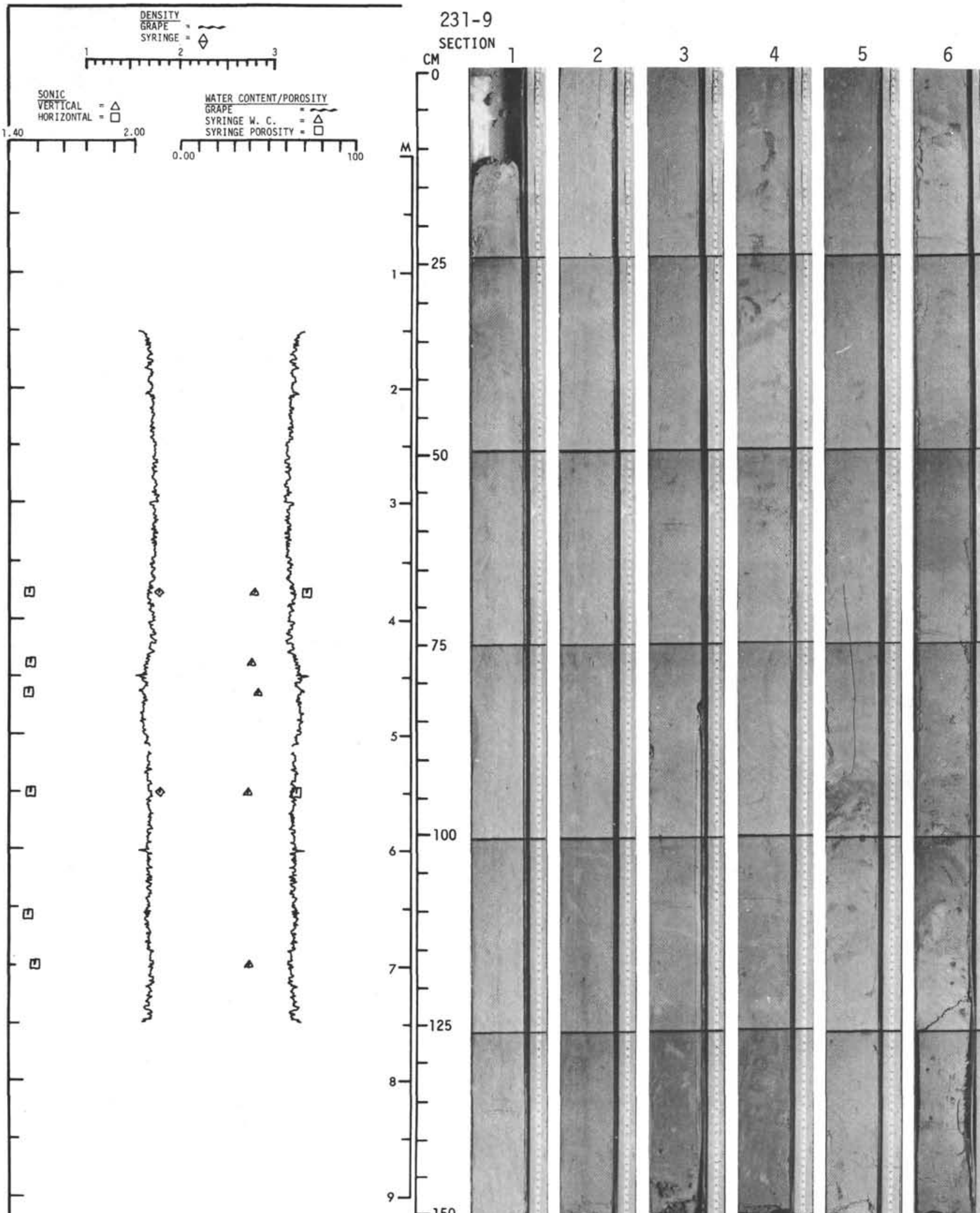

DENSITY
GRAPE
SYRINGE
1
2
3
SONIC
VERTICAL
HORIZONTAL
1.40
2.00
WATER CONTENT/POROSITY
GRAPE
SYRINGE W. C.
SYRINGE POROSITY
0.00
100
M
1
2
3
4
5
6
7
8
9
231-5
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6

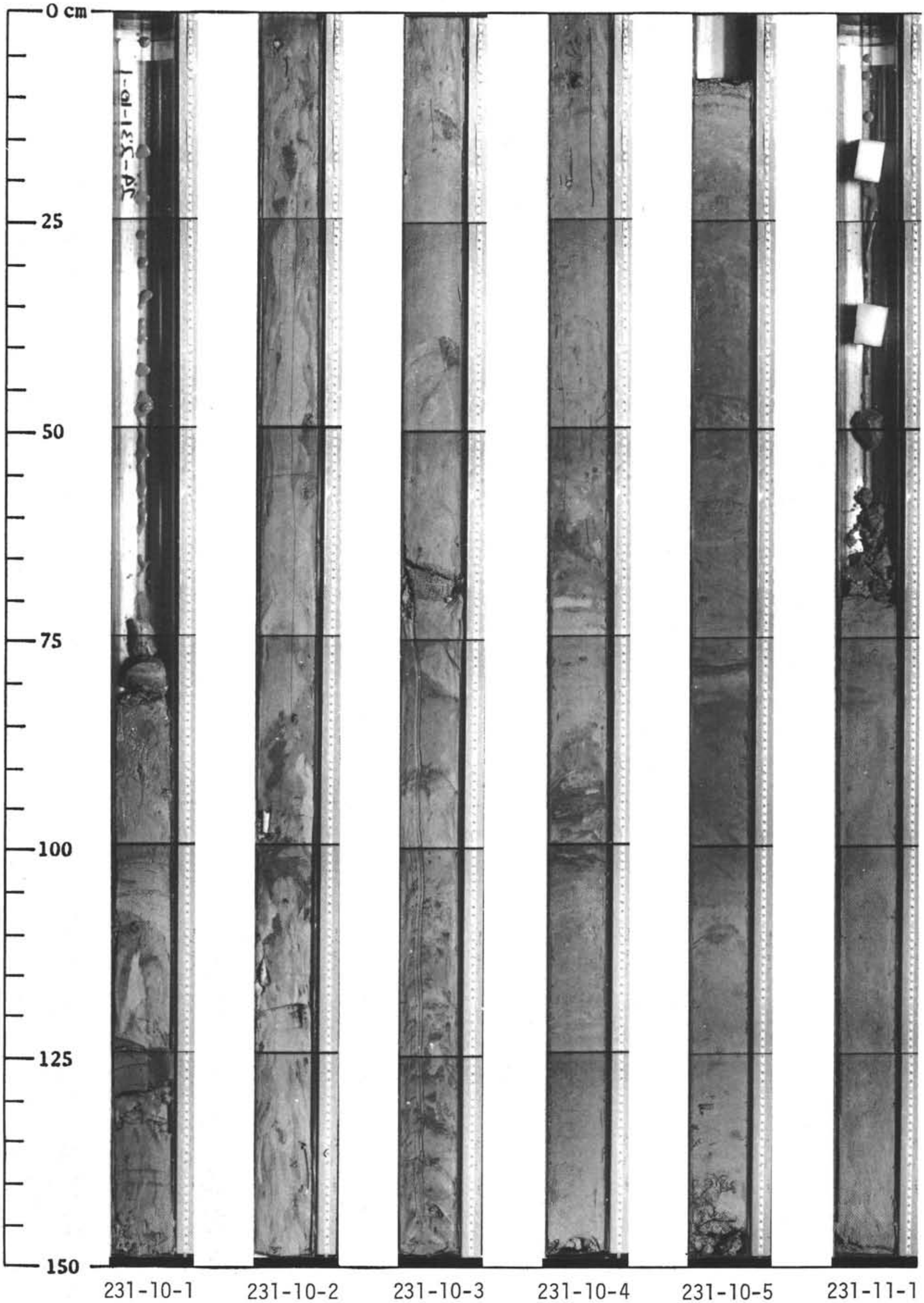

DENSITY
GRAPE
SYRINGE
1
2
3
SONIC
VERTICAL
HORIZONTAL
1.40
2.00
WATER CONTENT/POROSITY
GRAPE
SYRINGE W. C.
SYRINGE POROSITY
0.00
100
M
1
2
3
4
5
6
7
8
9
CM
0
25
50
75
100
125
150
231-6
SECTION
1
2
3
4
5
6

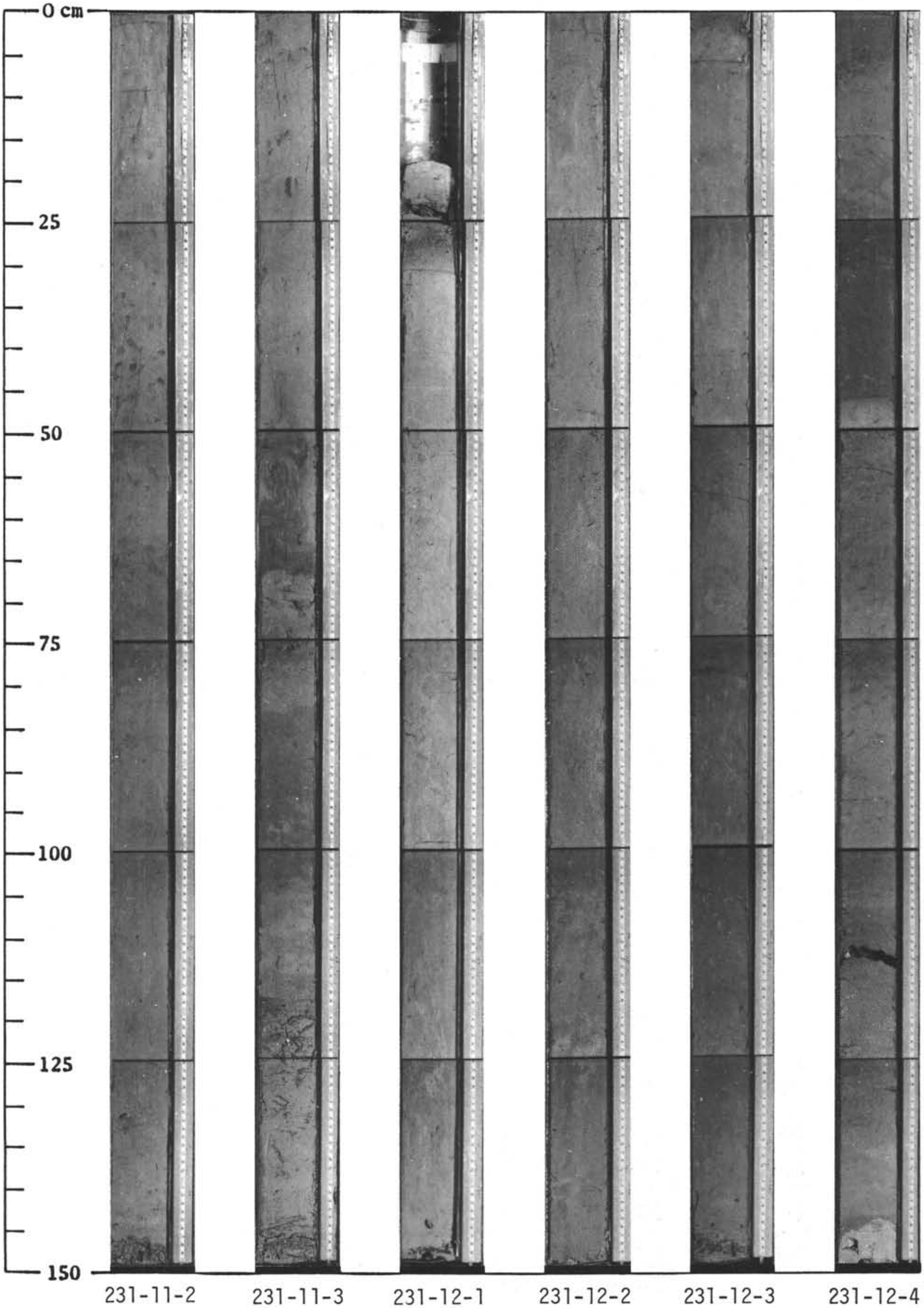

0 cm
25
50
75
100
125
150
231-7-1
231-7-2
231-7-3

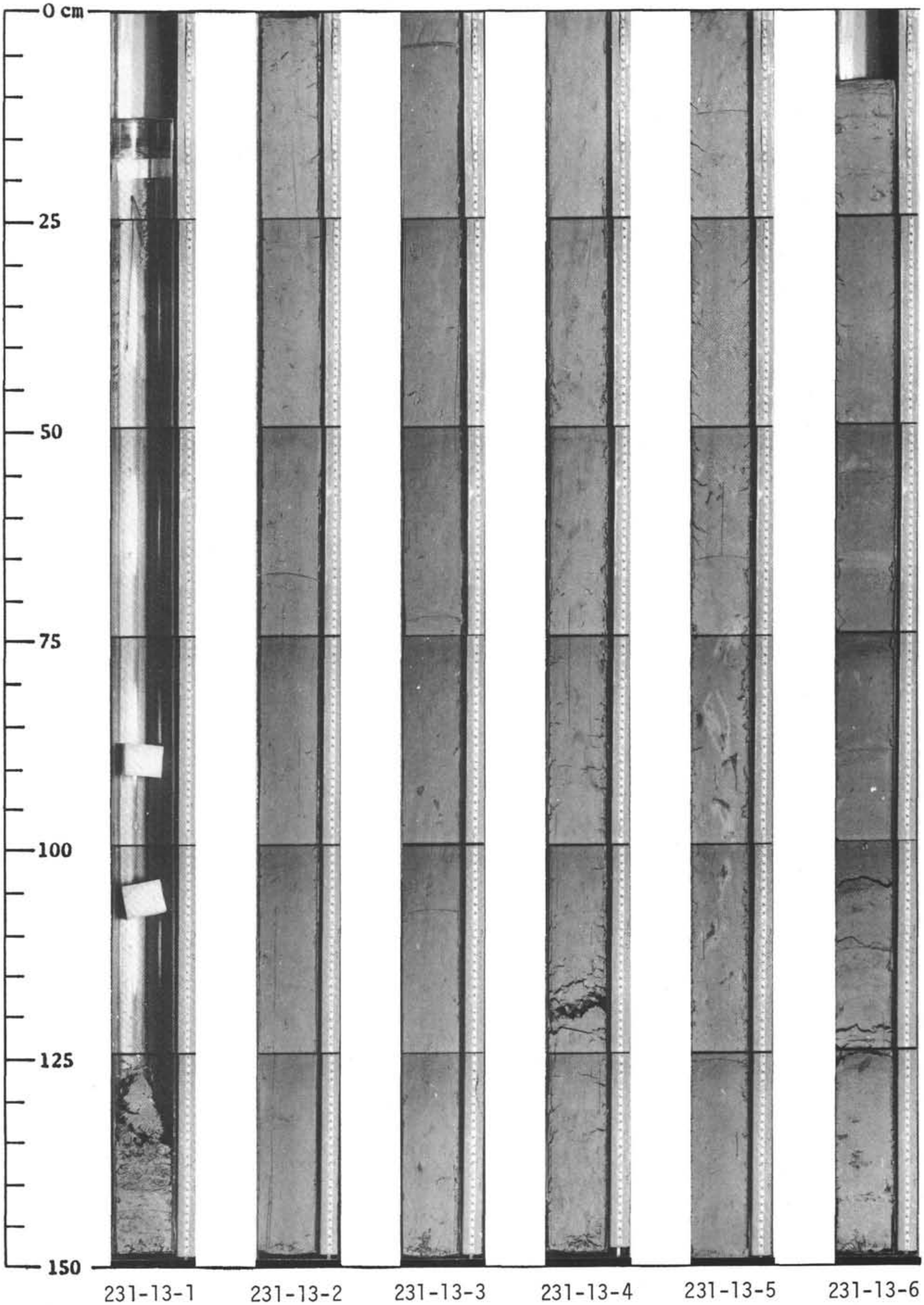

DENSITY
GRAPE
SYRINGE
1
2
3
SONIC
VERTICAL
HORIZONTAL
1.40
2.00
WATER CONTENT/POROSITY
GRAPE
SYRINGE W. C.
SYRINGE POROSITY
0.00
100
M
1
2
3
4
5
6
7
8
9

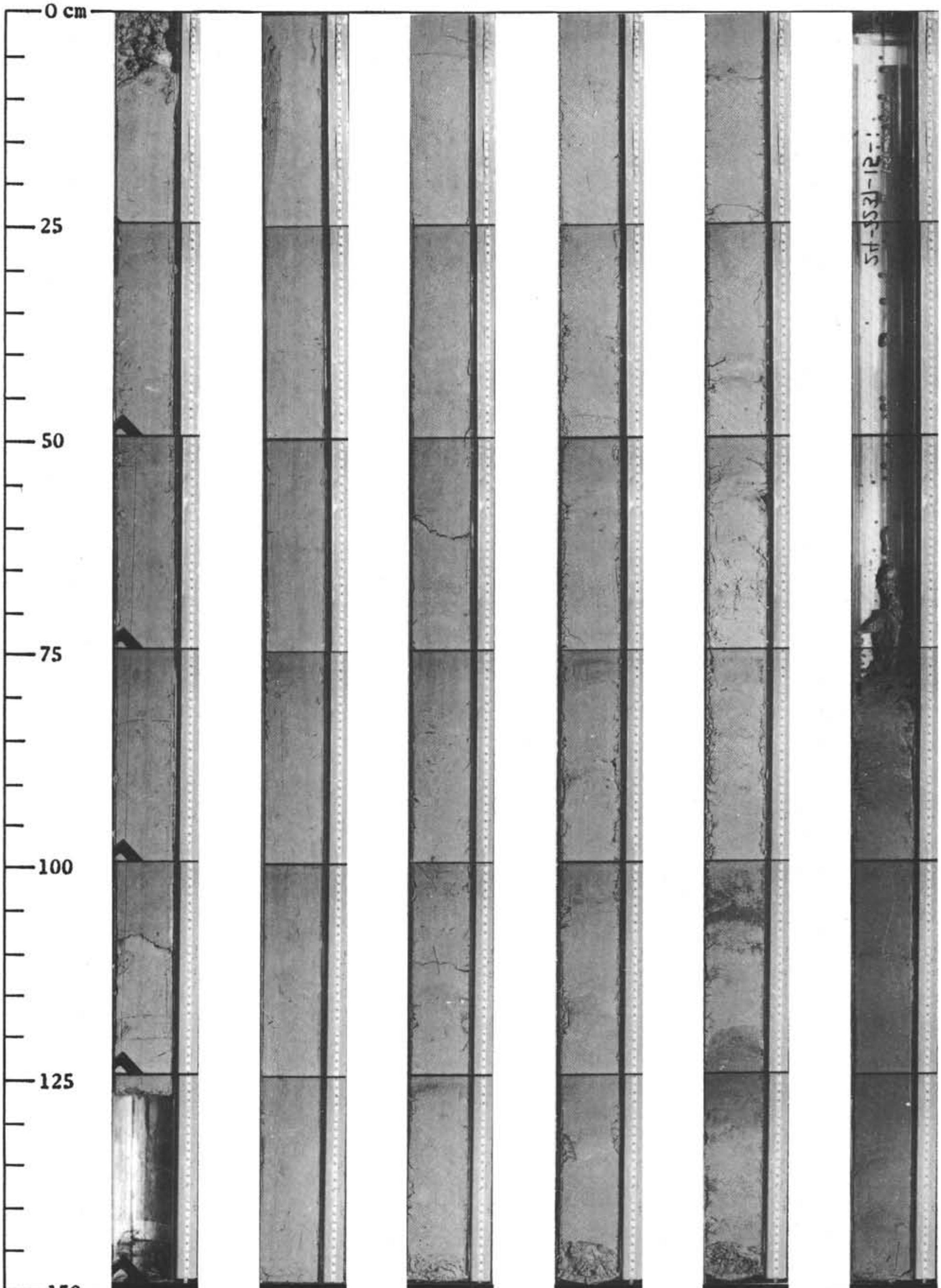

231-8
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6


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
CM
0
25
50
75
100
125
150
231-9
SECTION
1
2
3
4
5
6

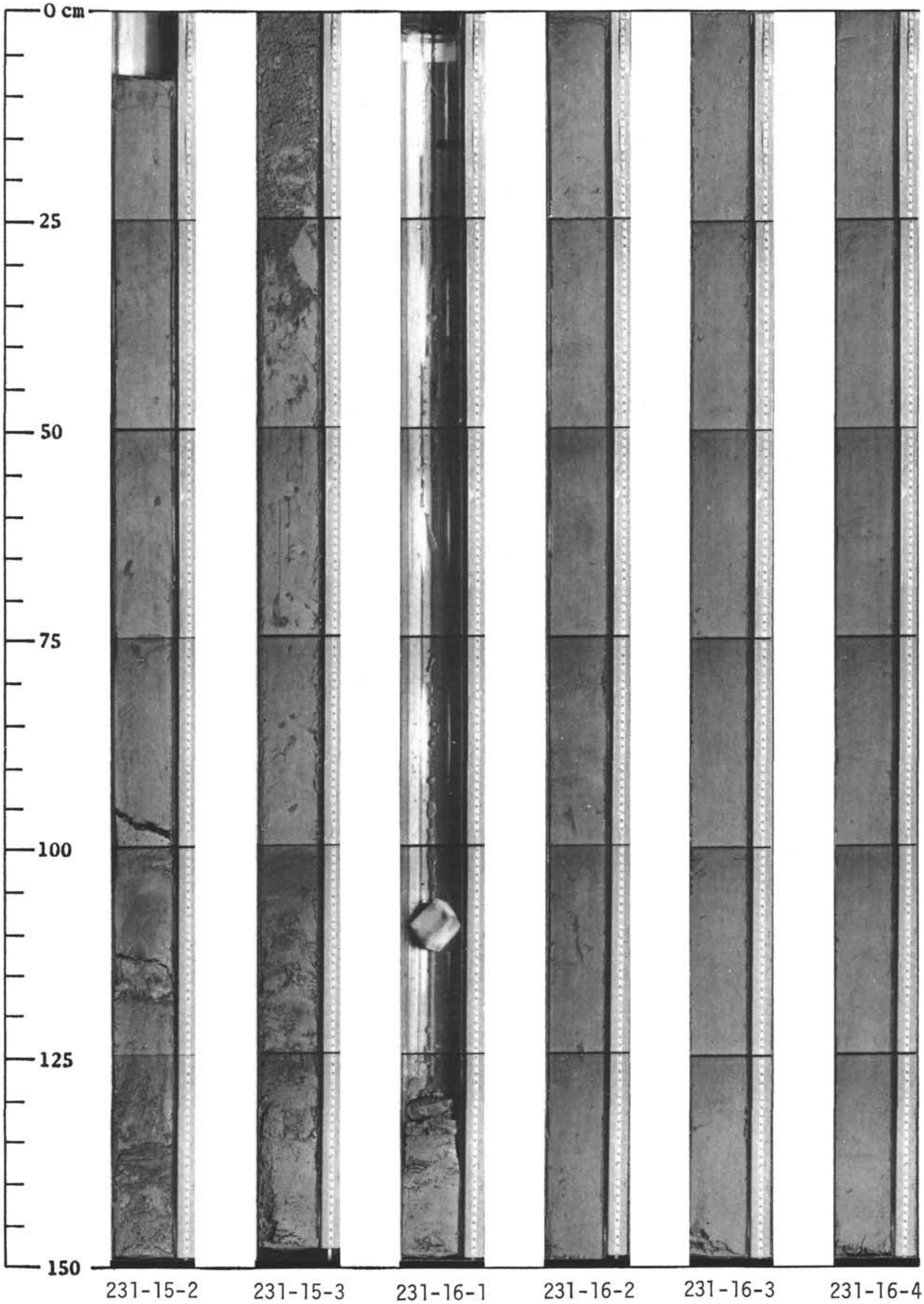

0 cm
25
50
75
100
125
150
231-10-1
231-10-2
231-10-3
231-10-4
231-10-5
231-11-1

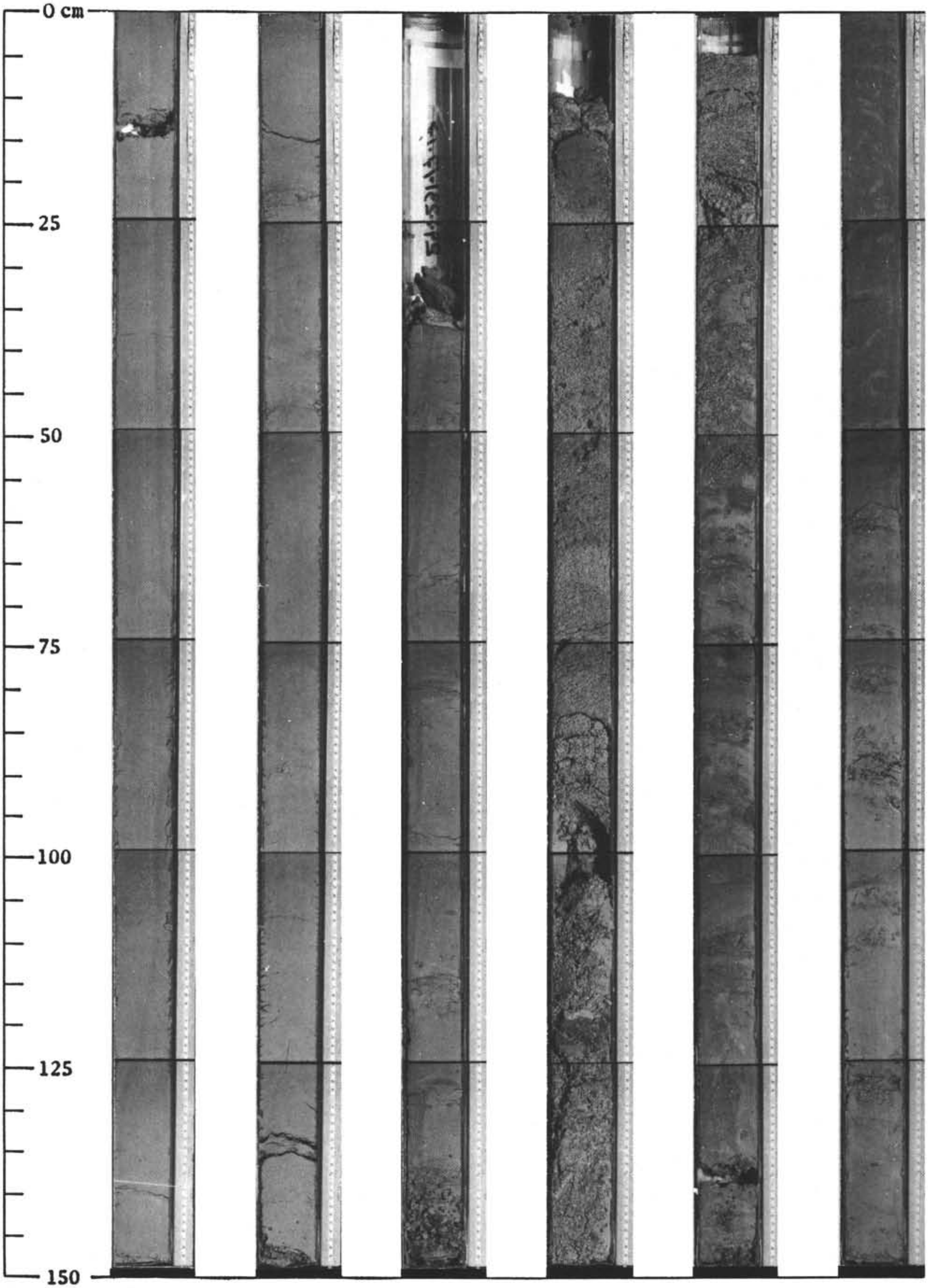

0 cm
25
50
75
100
125
150
231-11-2
231-11-3
231-12-1
231-12-2
231-12-3
231-12-4


0 cm
25
50
75
100
125
150
231-13-1
231-13-2
231-13-3
231-13-4
231-13-5
231-13-6

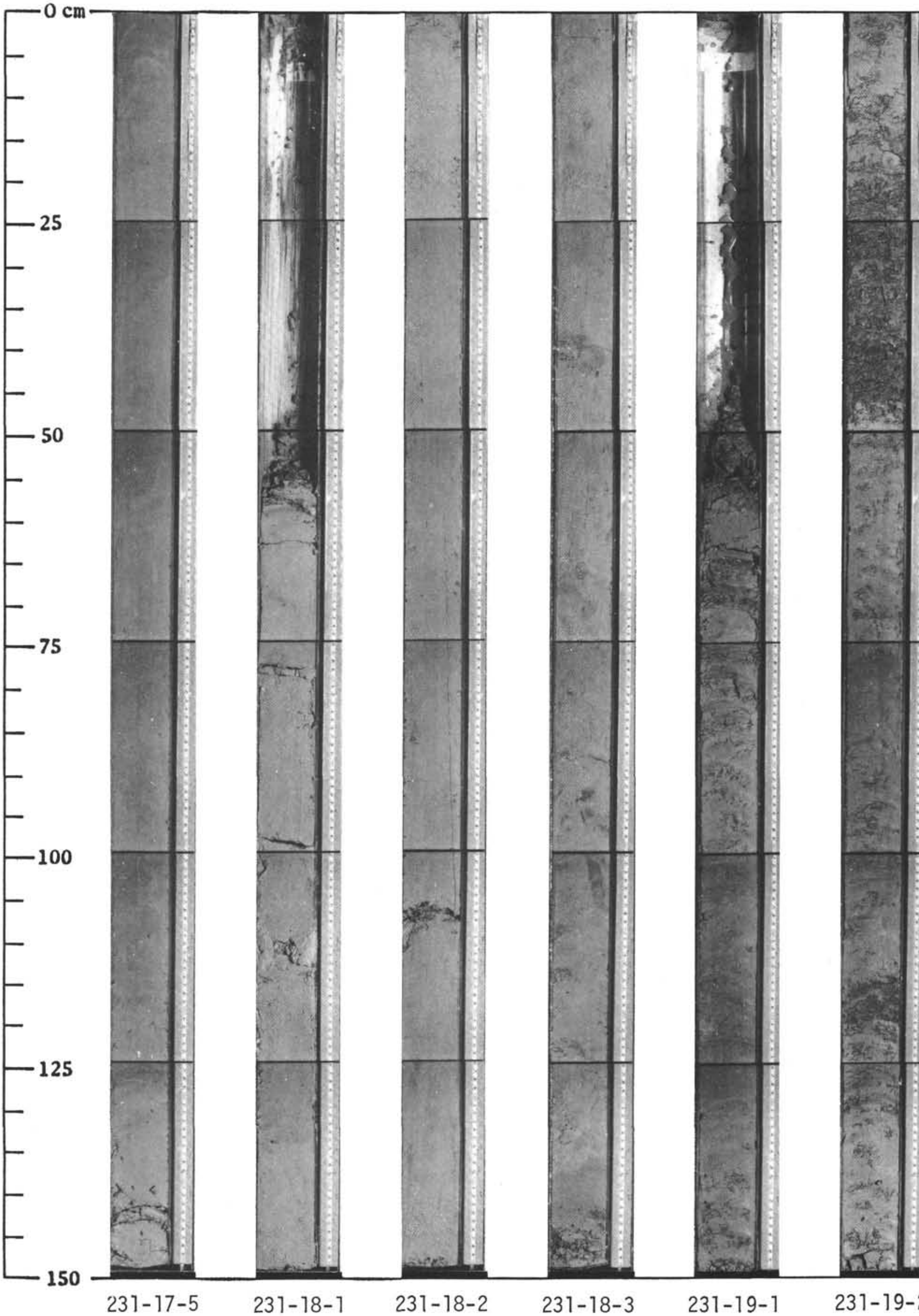


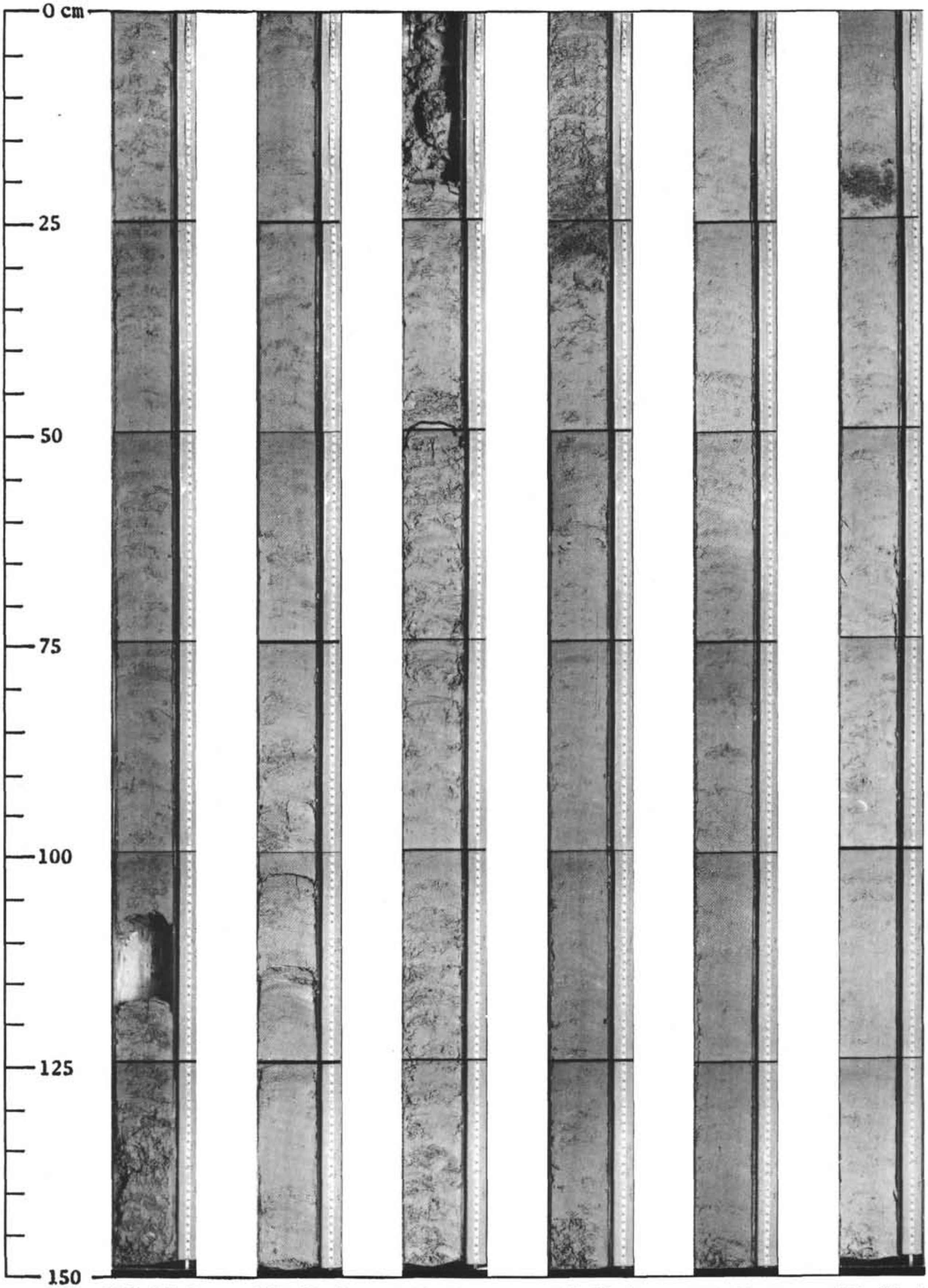
231-14-1 231-14-2 231-14-3 231-14-4 231-14-5 231-15-1

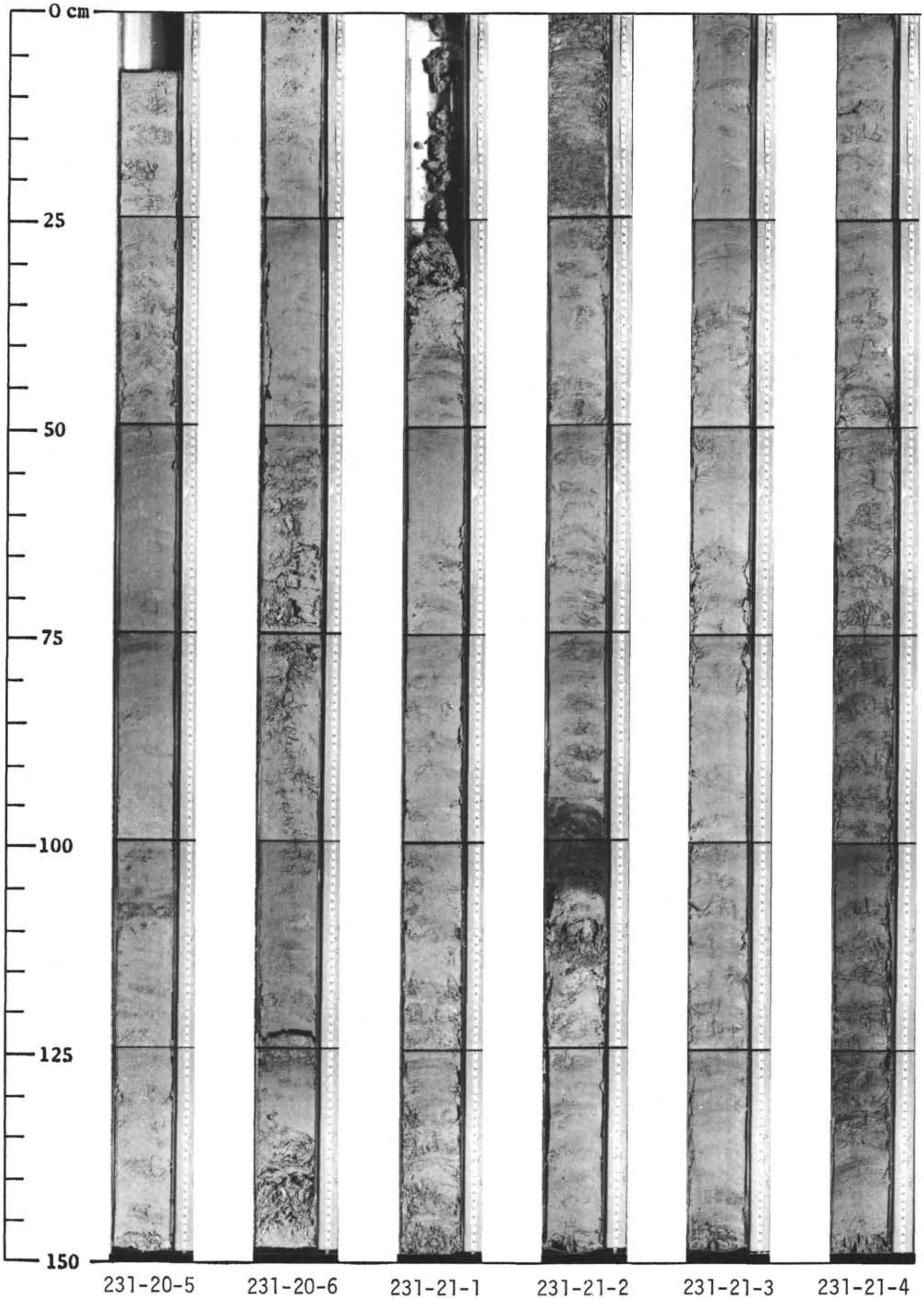

0 cm
25
50
75
100
125
150
231-15-2
231-15-3
231-16-1
231-16-2
231-16-3
231-16-4

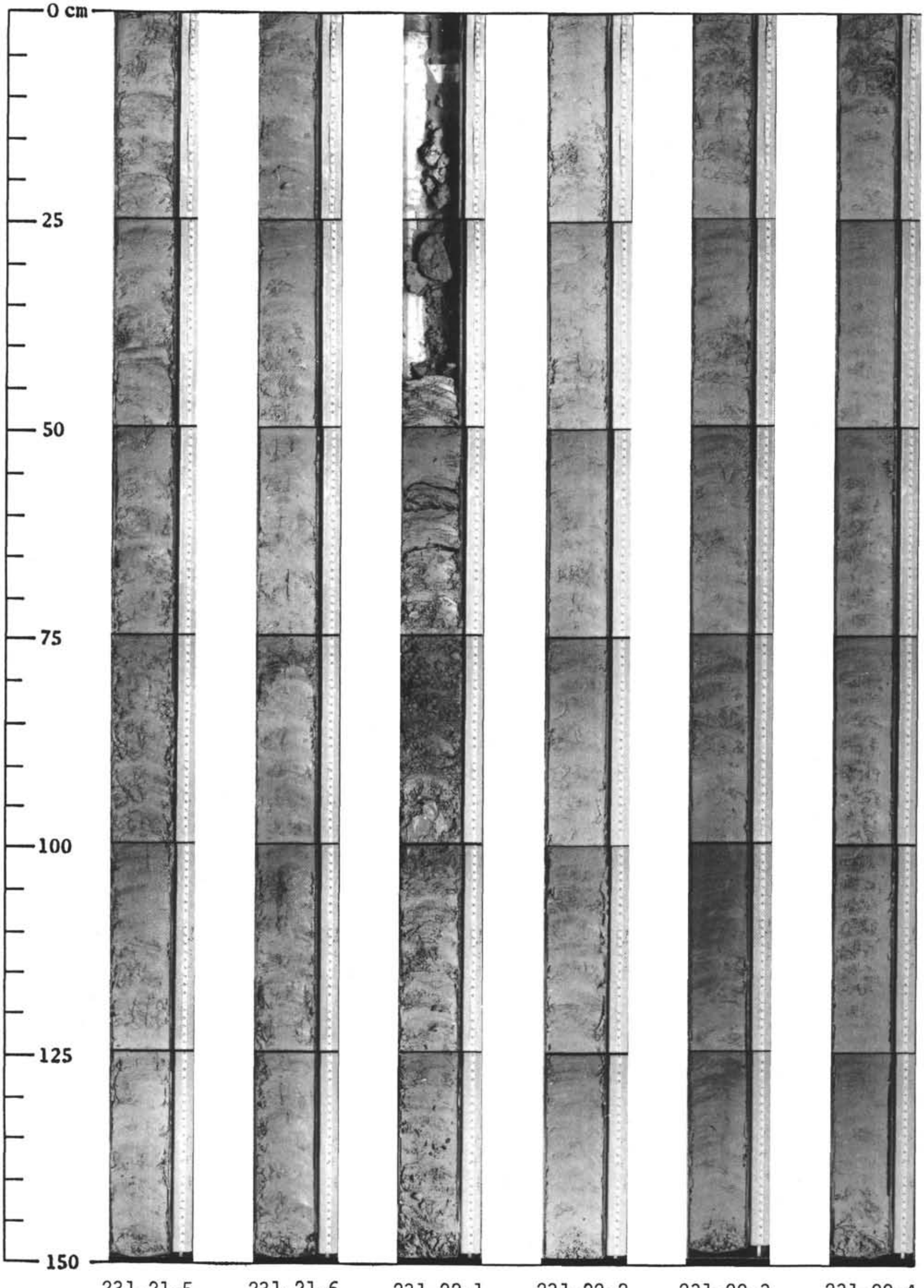


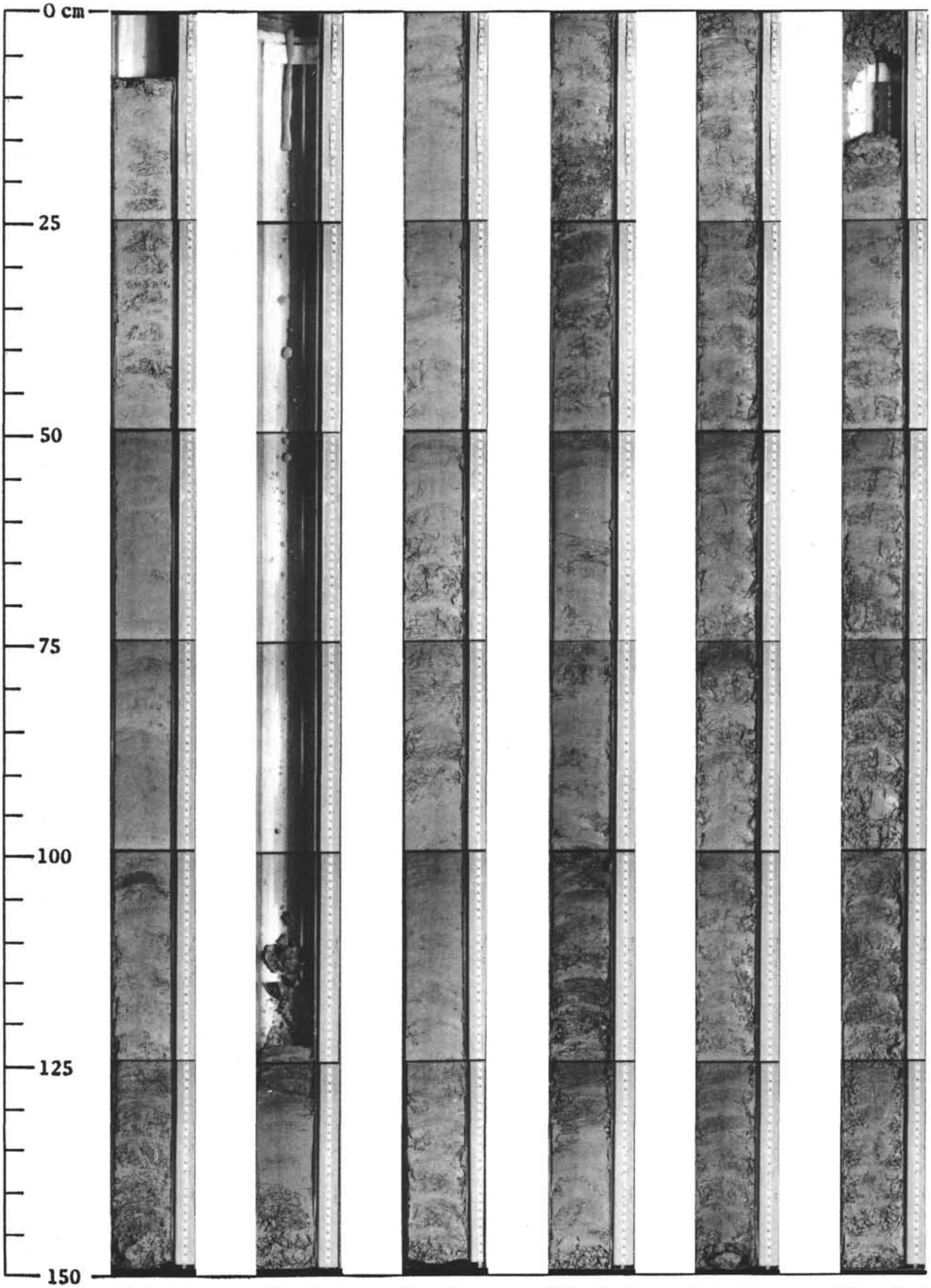
231-16-5 231-16-6 231-17-1 231-17-2 231-17-3 231-17-4

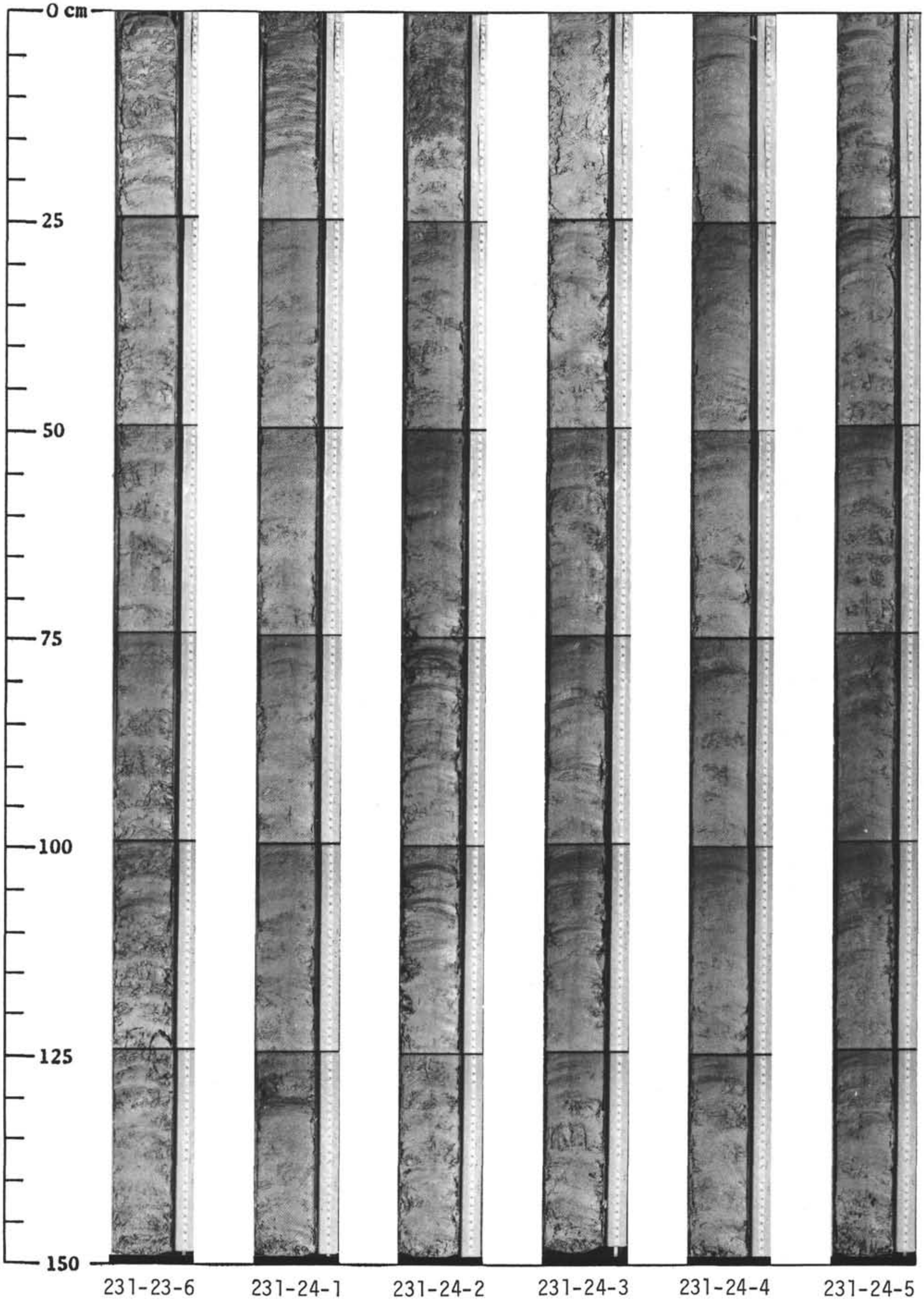

0 cm
25
50
75
100
125
150
231-17-5
231-18-1
231-18-2
231-18-3
231-19-1
231-19-2

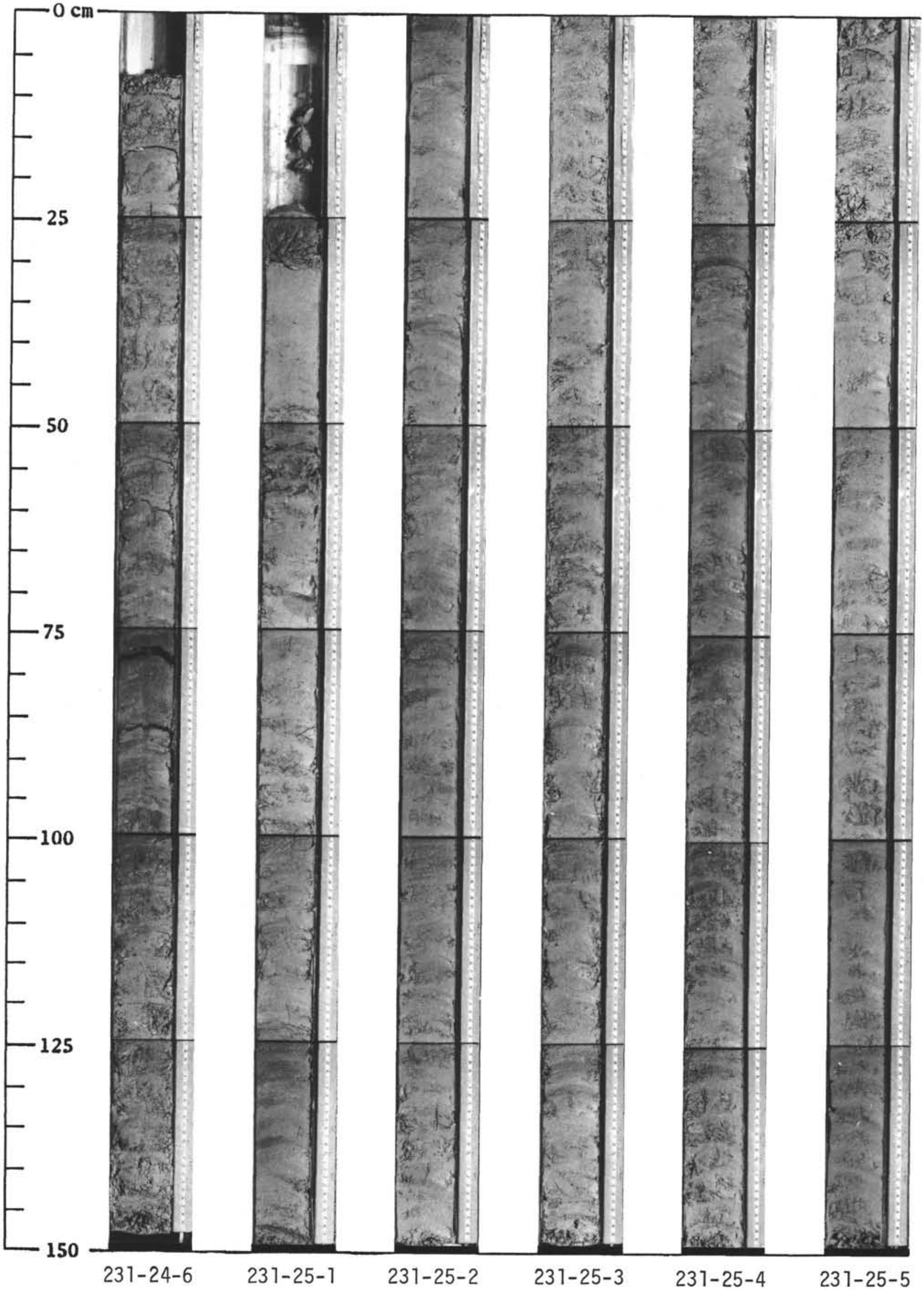

0 cm
25
50
75
100
125
150
231-19-3
231-19-4
231-20-1
234-20-2
234-20-3
234-20-4

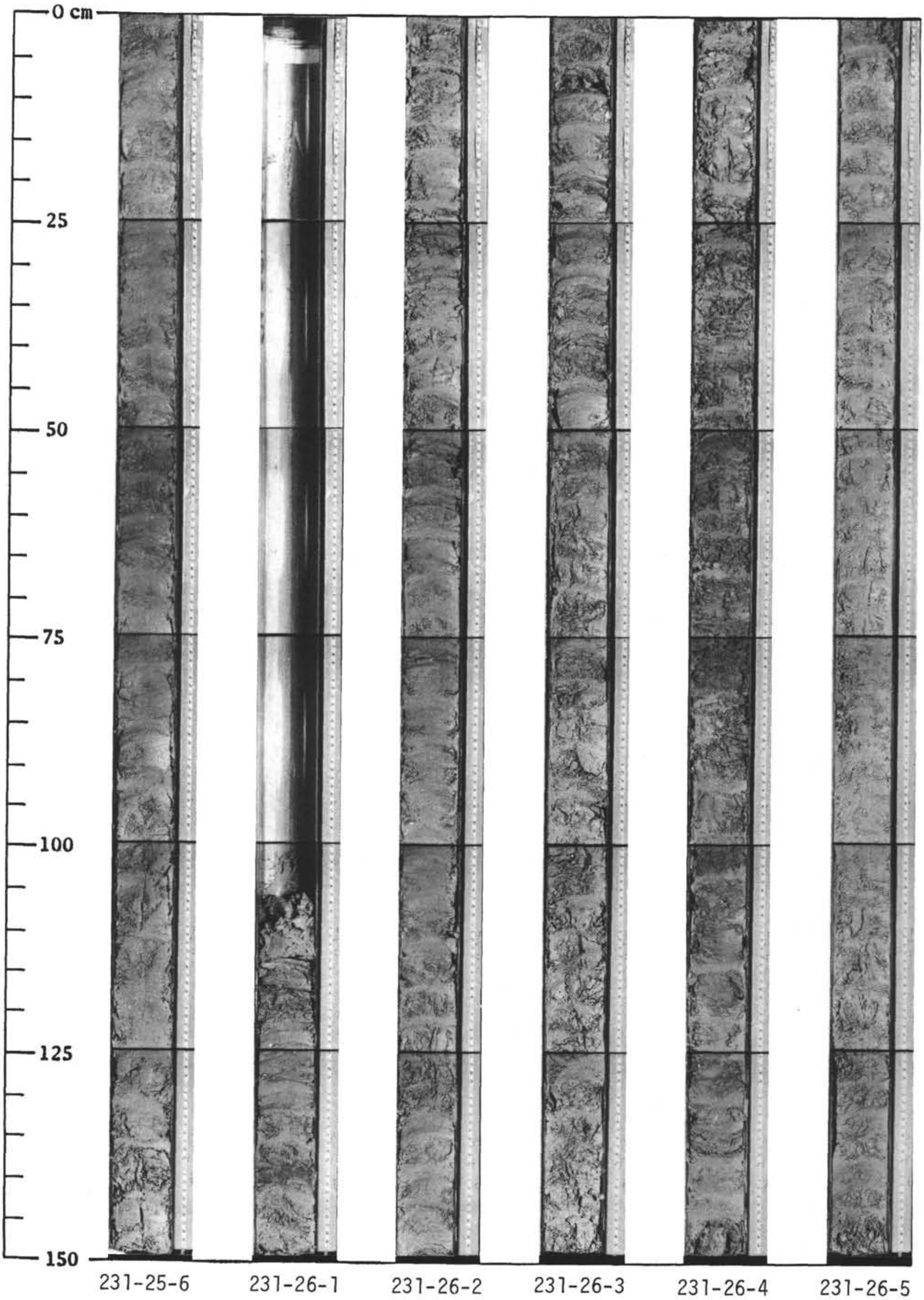

0 cm
25
50
75
100
125
150
231-20-5
231-20-6
231-21-1
231-21-2
231-21-3
231-21-4

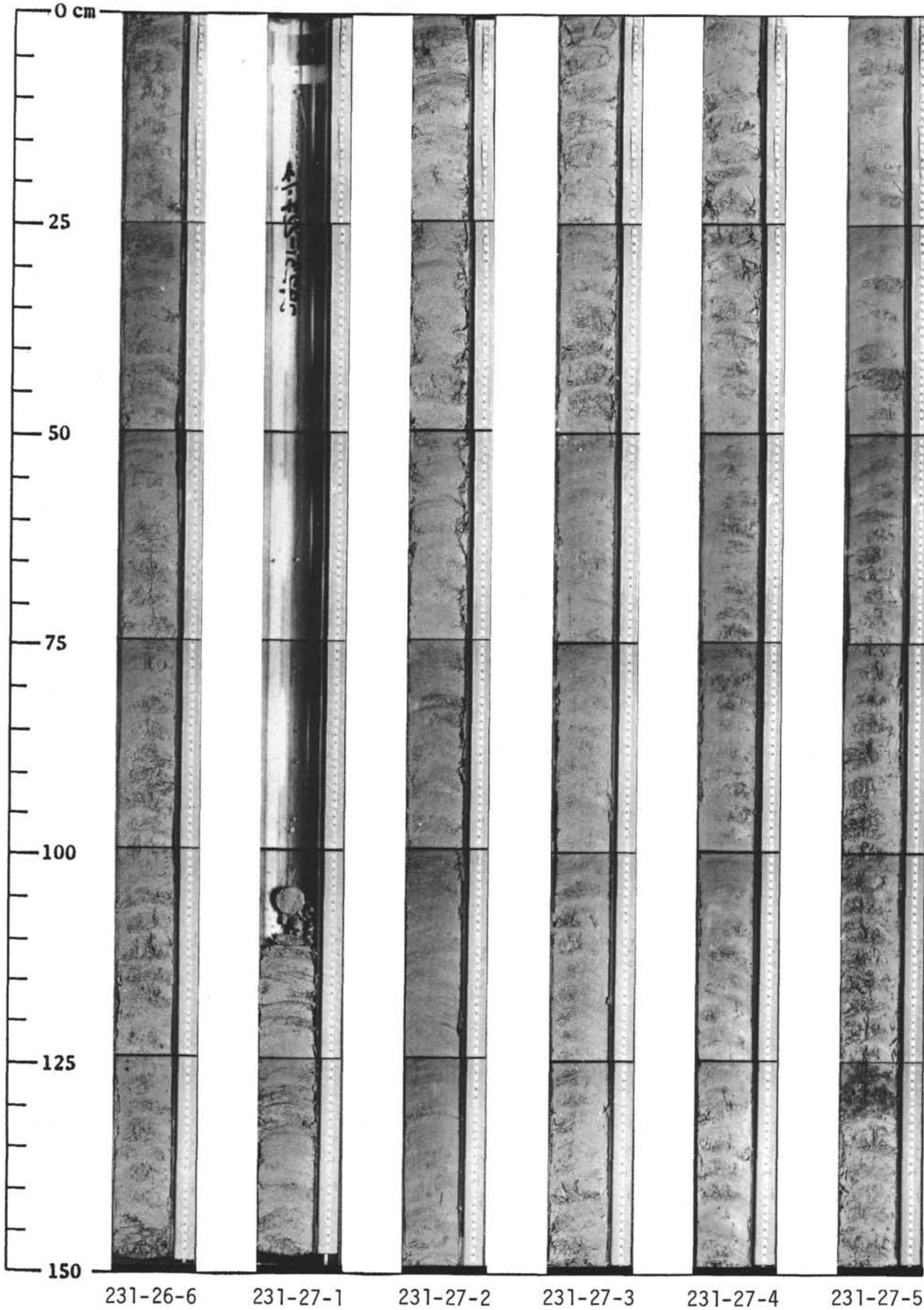

0 cm
25
50
75
100
125
150
231-21-5
231-21-6
231-22-1
231-22-2
231-22-3
231-22-4

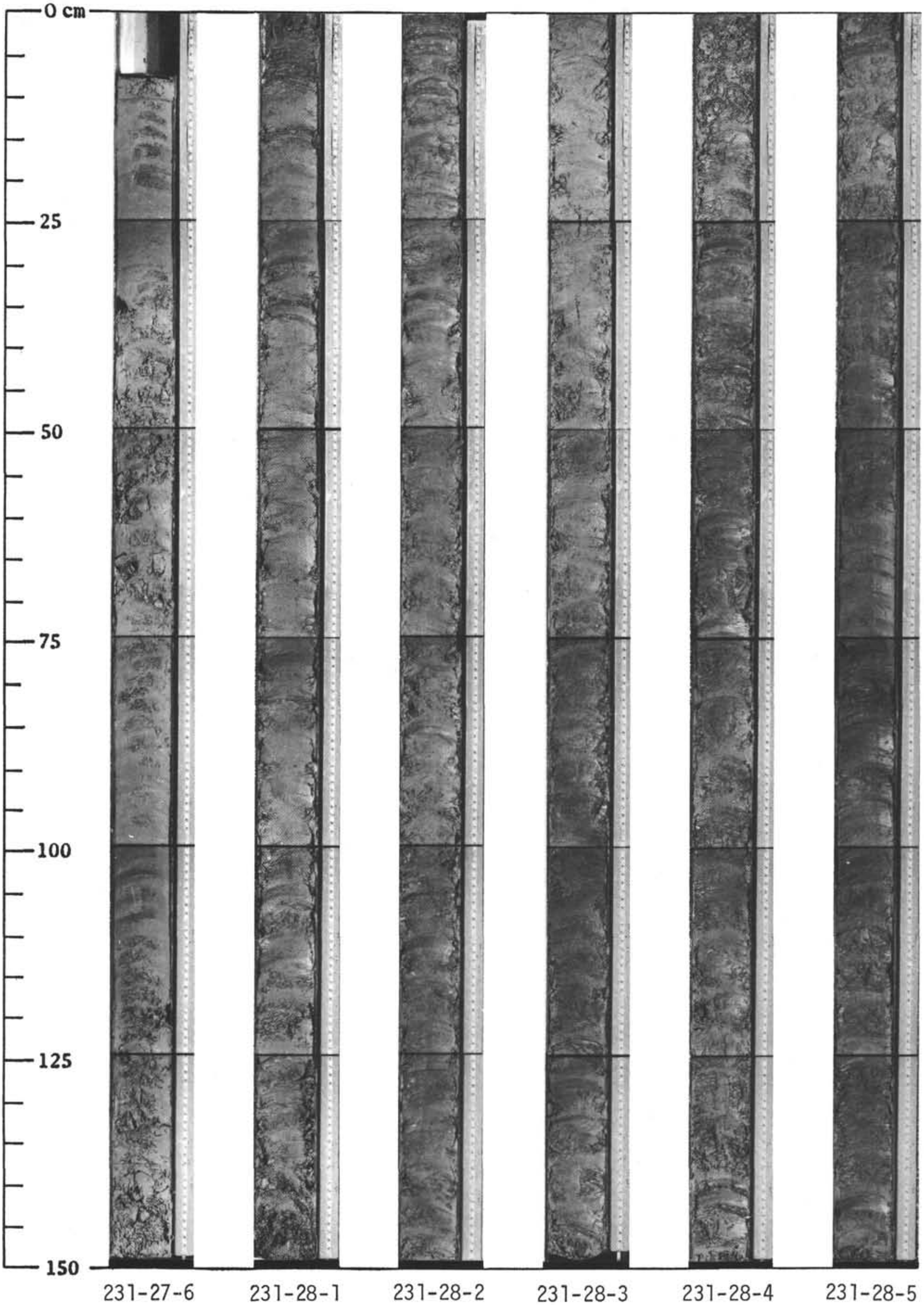

0 cm
25
50
75
100
125
150
231-22-5
231-23-1
231-23-2
231-23-3
231-23-4
231-23-5

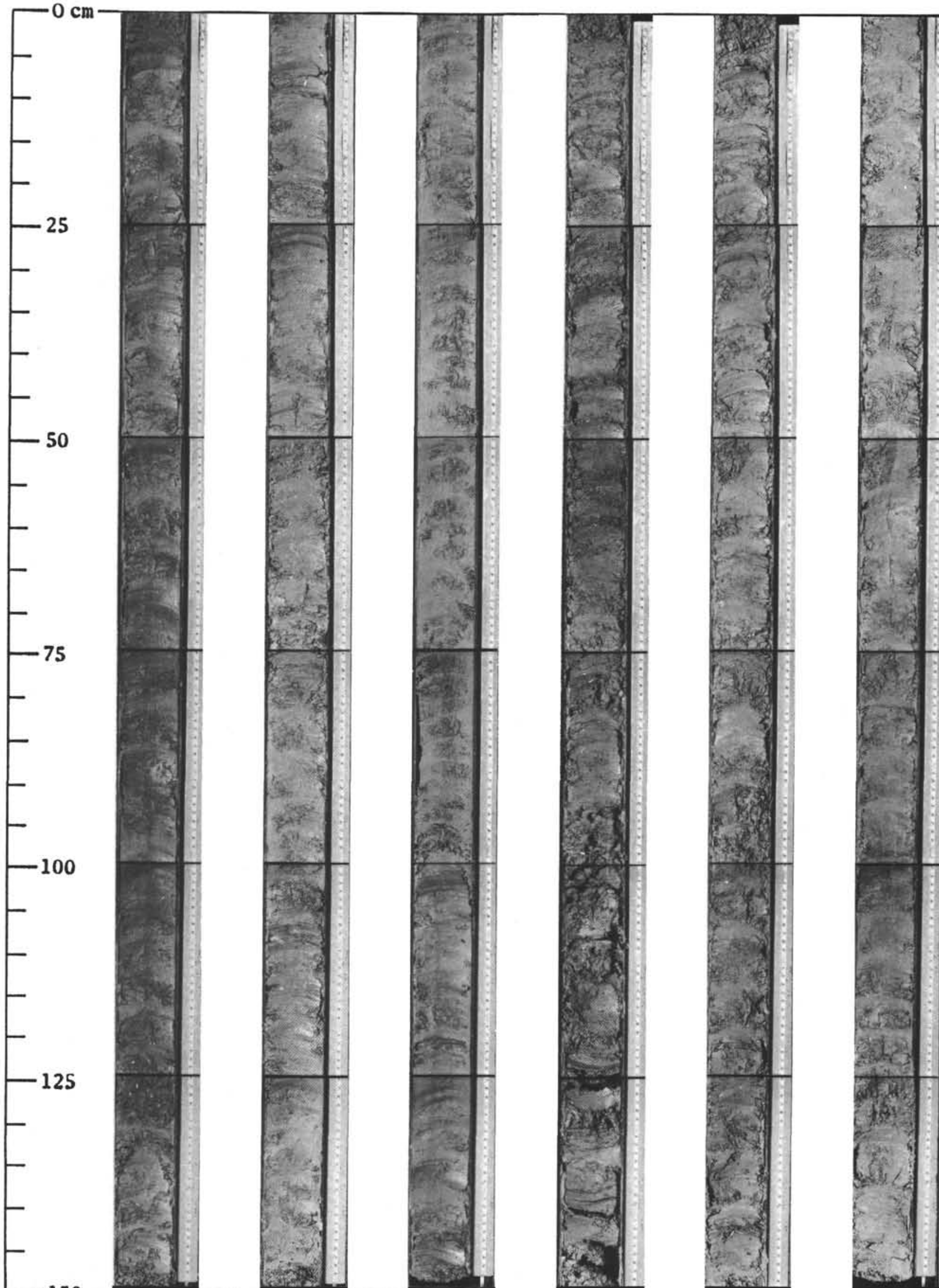

0 cm
25
50
75
100
125
150
231-23-6
231-24-1
231-24-2
231-24-3
231-24-4
231-24-5


0 cm
25
50
75
100
125
150
231-24-6
231-25-1
231-25-2
231-25-3
231-25-4
231-25-5

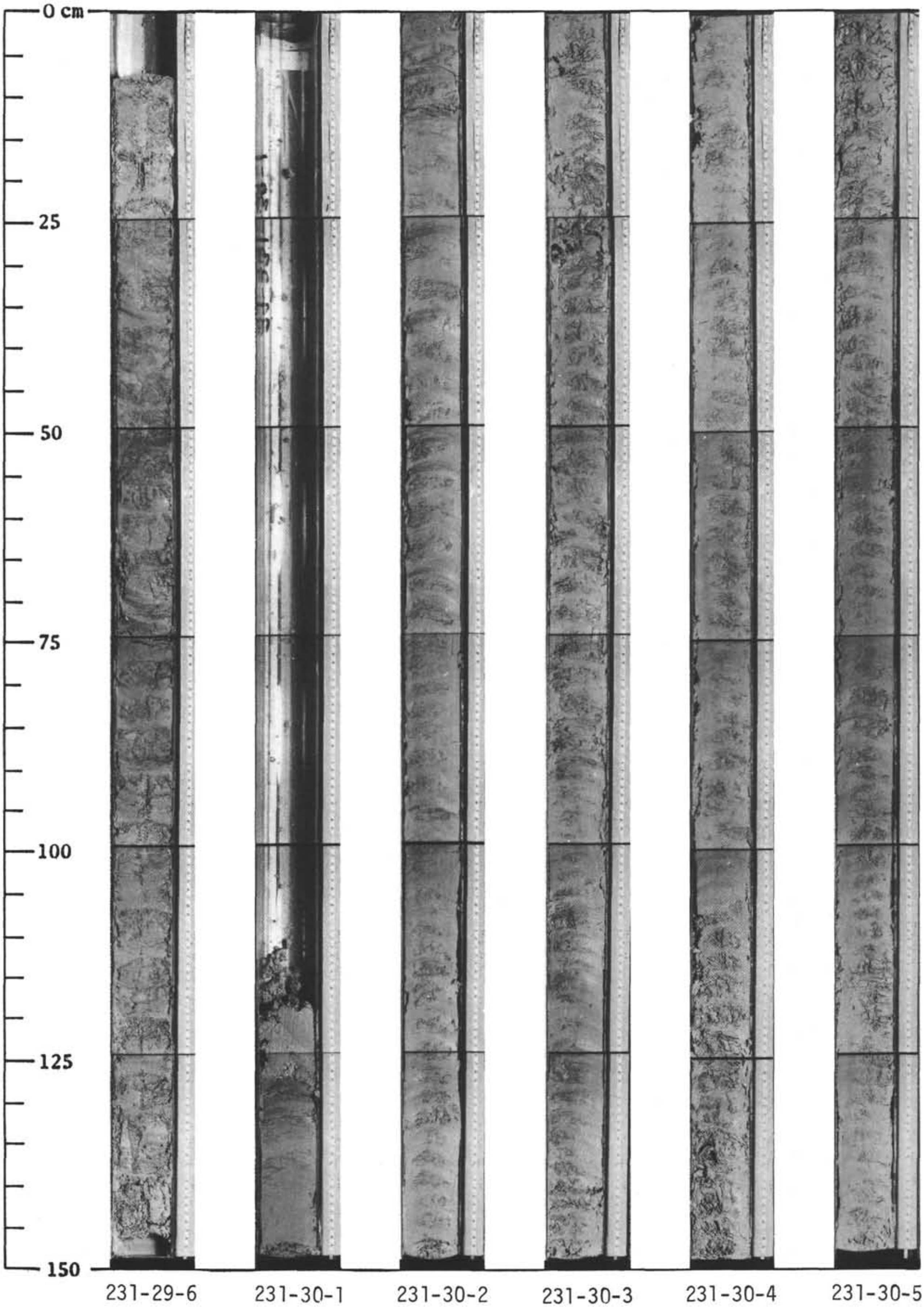

0 cm
25
50
75
100
125
150
231-25-6
231-26-1
231-26-2
231-26-3
231-26-4
231-26-5

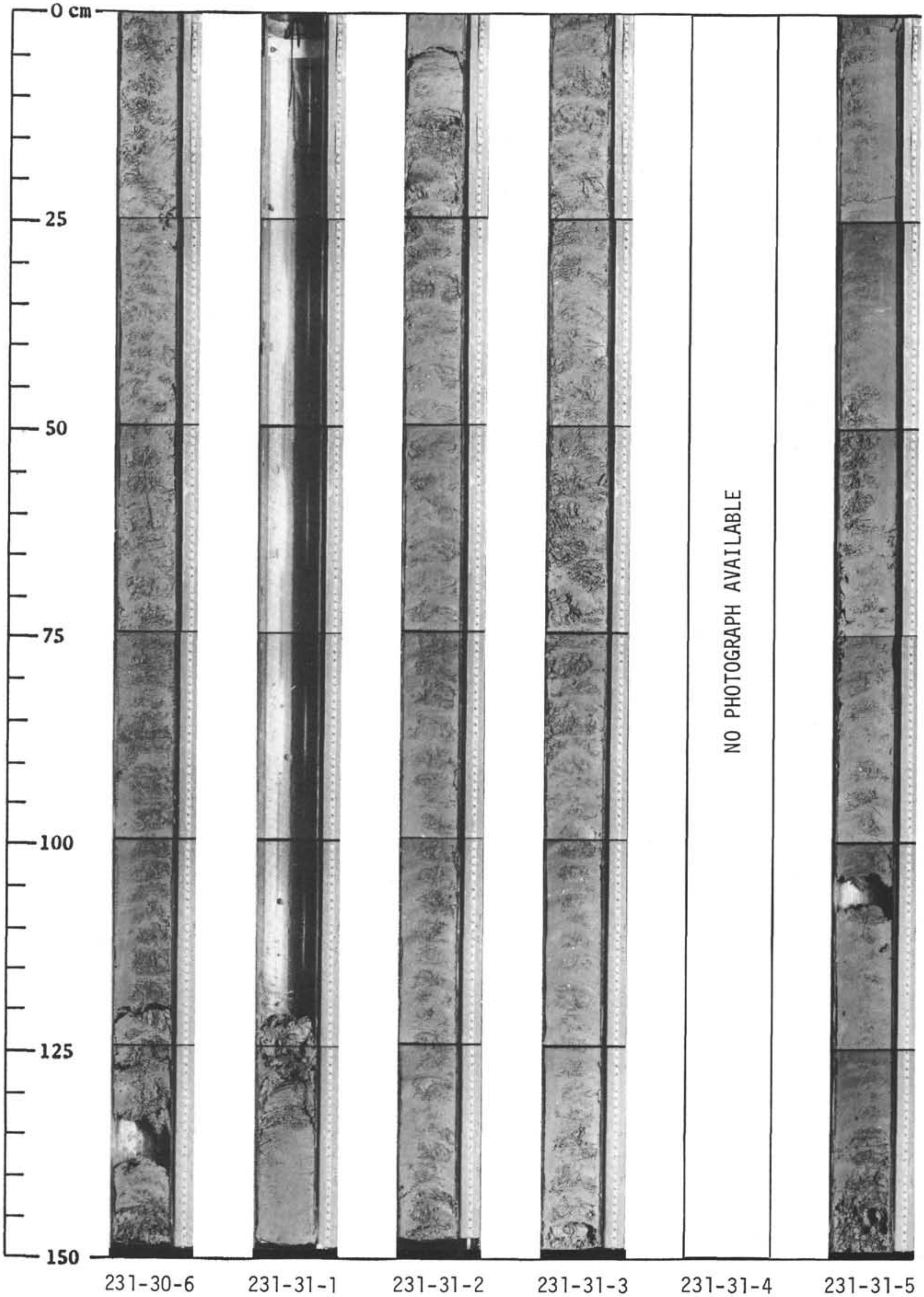

0 cm
25
50
75
100
125
150
231-26-6
231-27-1
231-27-2
231-27-3
231-27-4
231-27-5

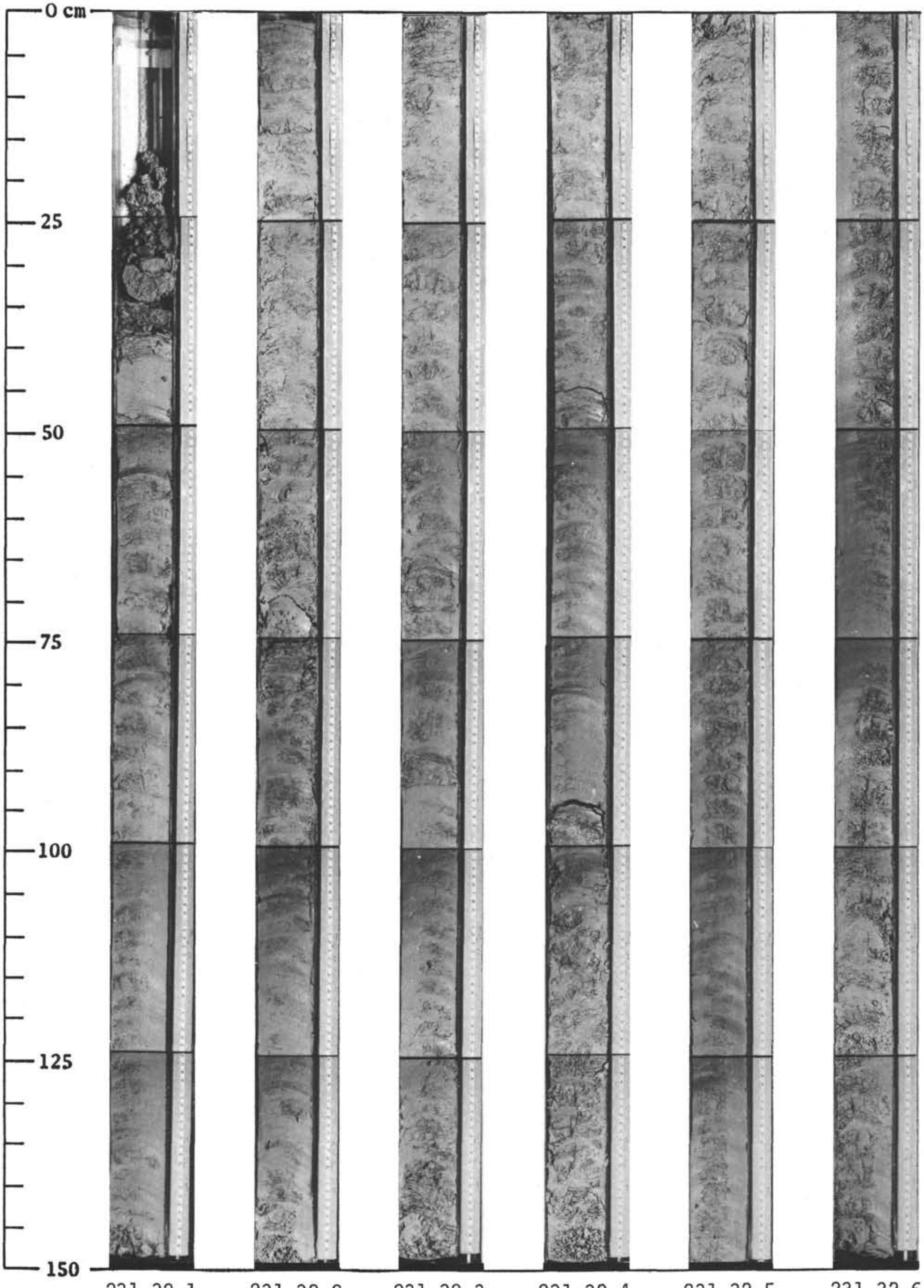

0 cm
25
50
75
100
125
150
231-27-6
231-28-1
231-28-2
231-28-3
231-28-4
231-28-5

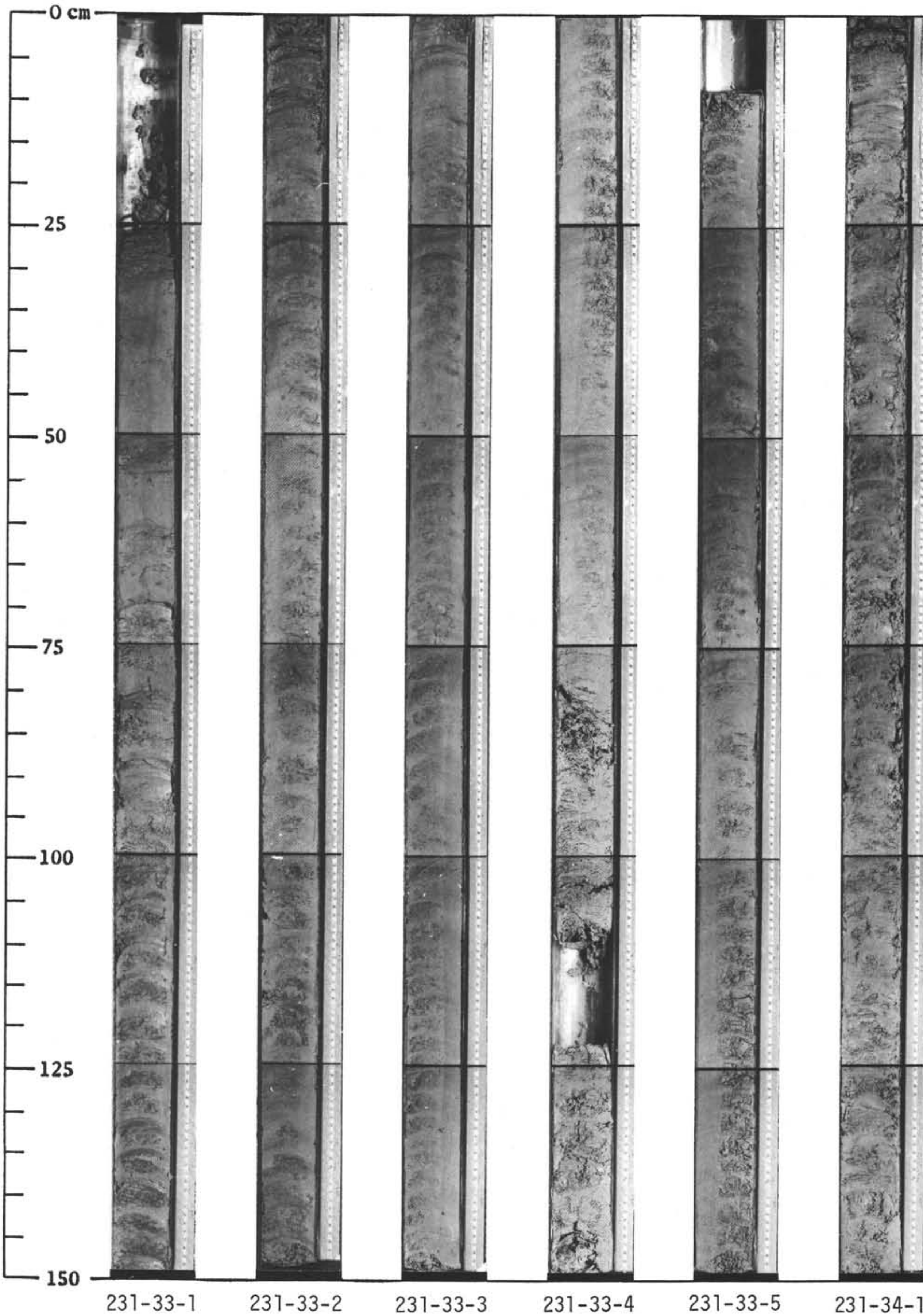


231-28-6 231-29-1 231-29-2 231-29-3 231-29-4 231-29-5

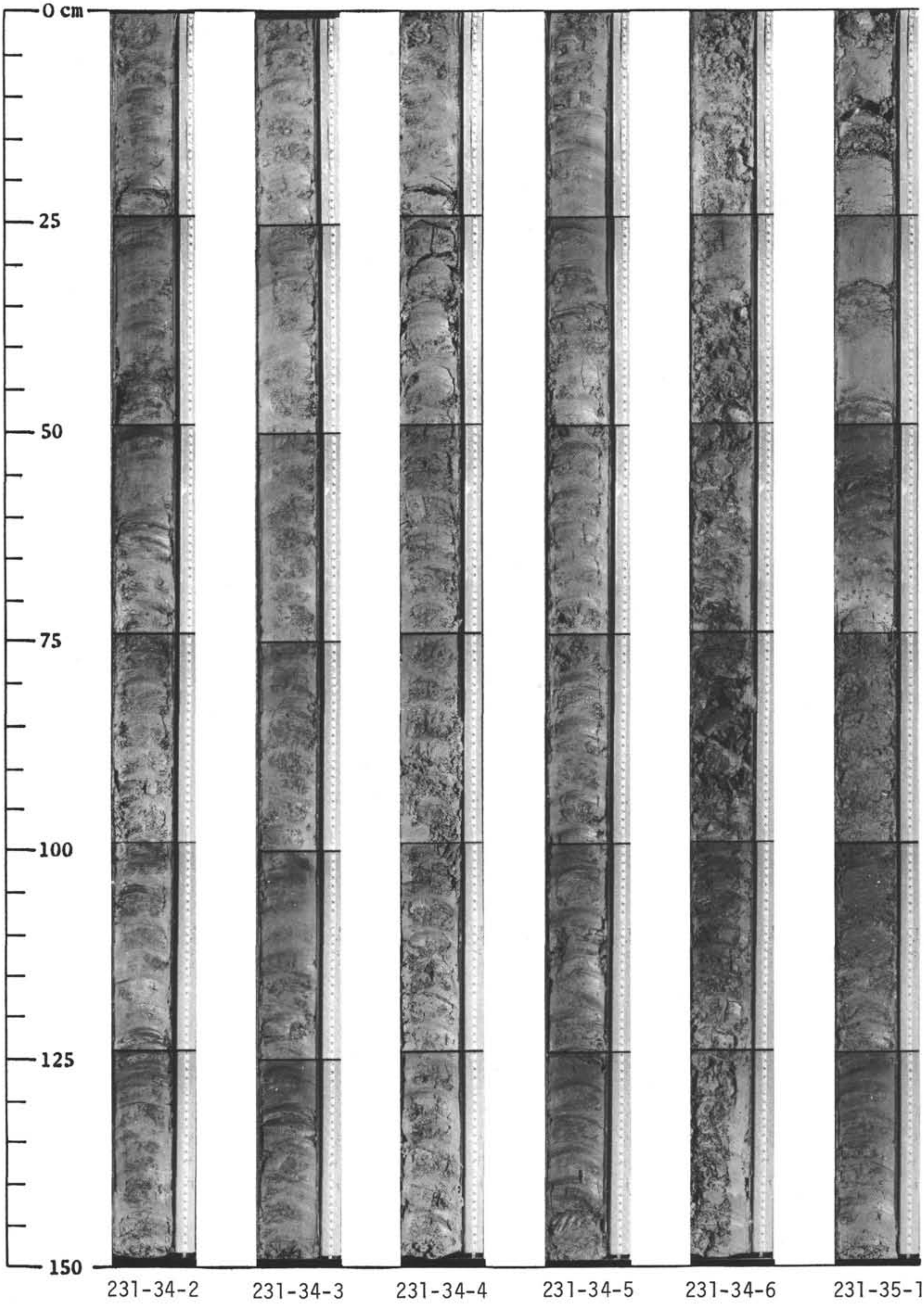

0 cm
25
50
75
100
125
150
231-29-6
231-30-1
231-30-2
231-30-3
231-30-4
231-30-5

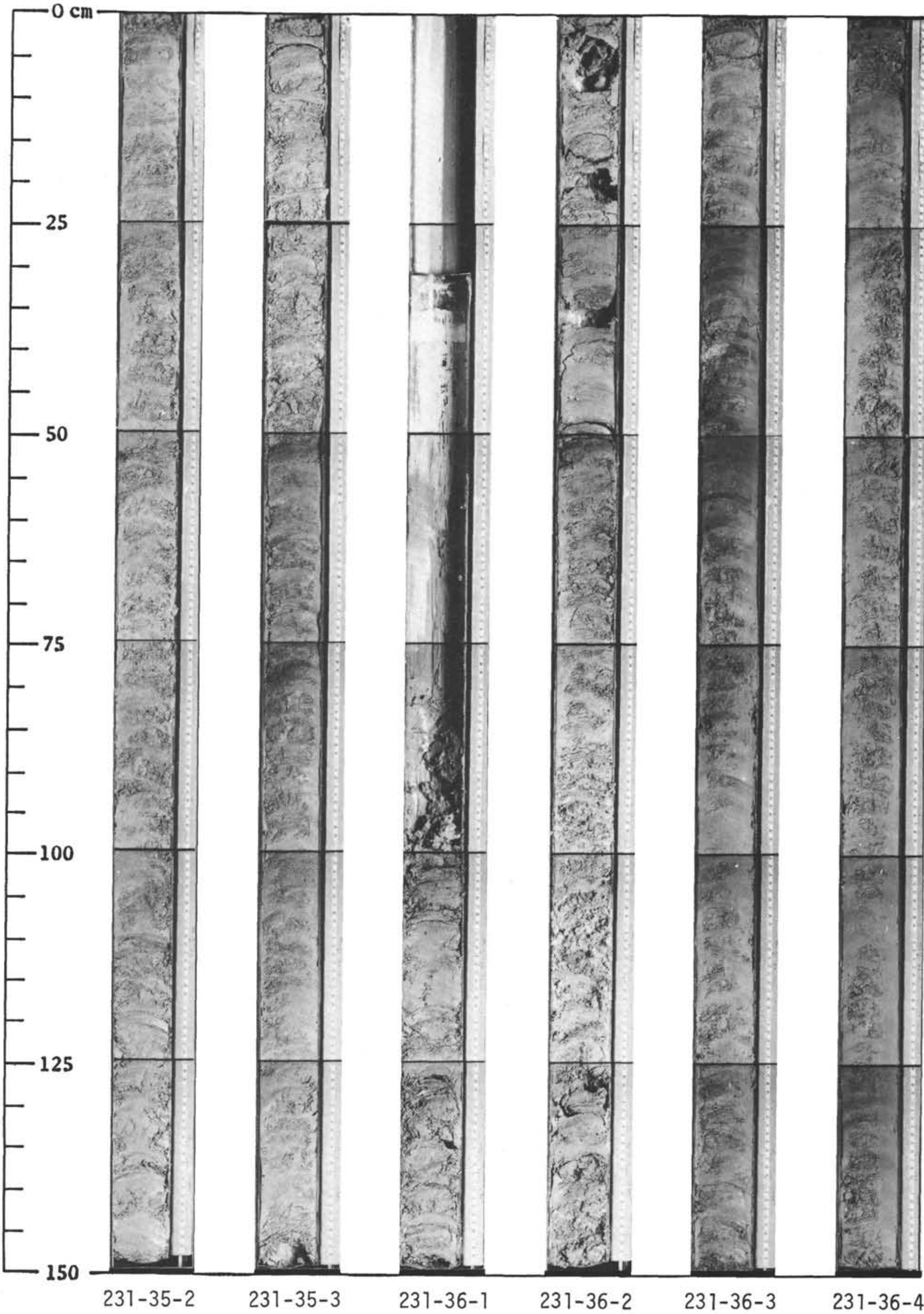

0 cm
25
50
75
100
125
150
NO PHOTOGRAPH AVAILABLE
231-30-6
231-31-1
231-31-2
231-31-3
231-31-4
231-31-5

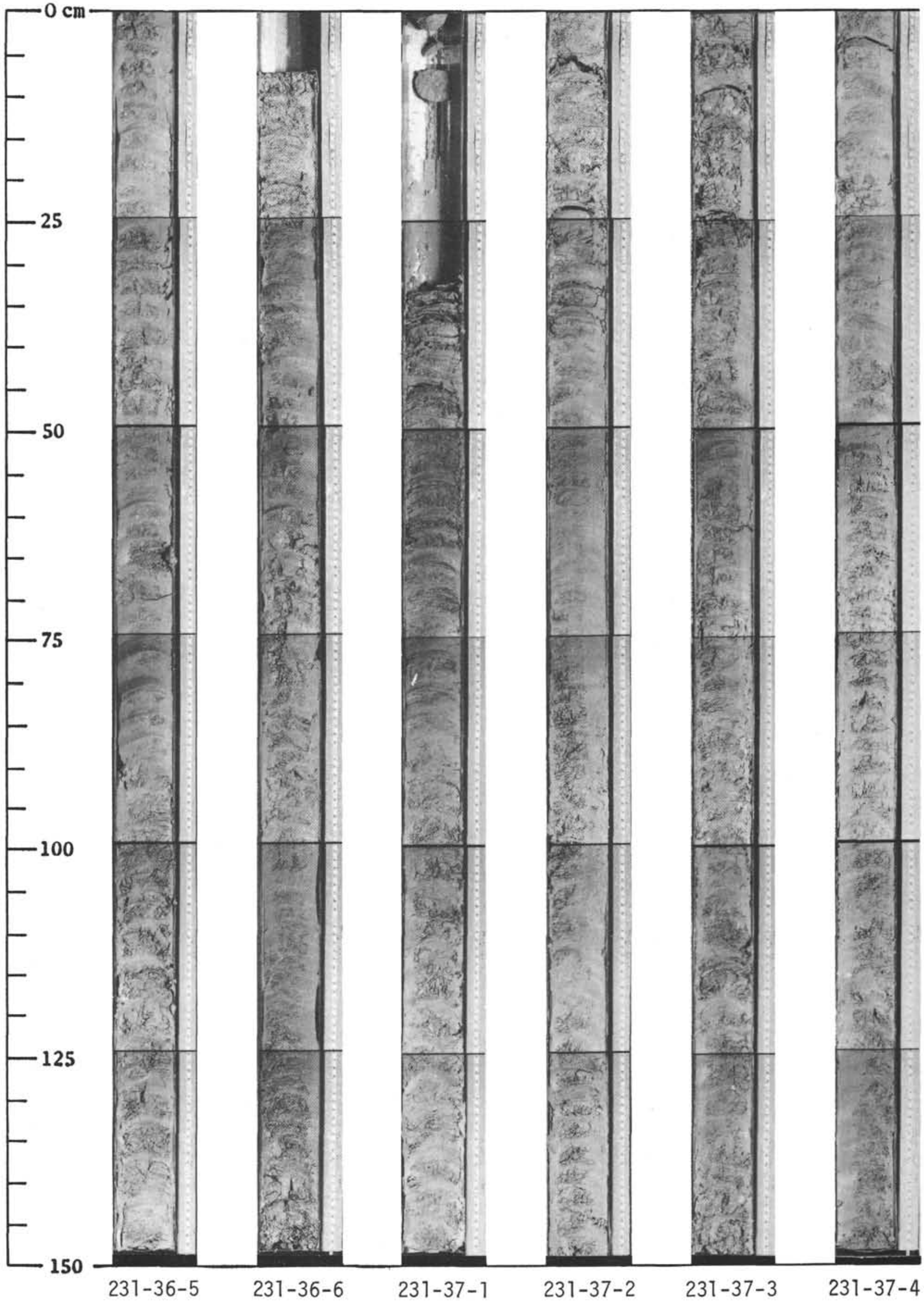

0 cm
25
50
75
100
125
150
231-32-1
231-32-2
231-32-3
231-32-4
231-32-5
231-32-6

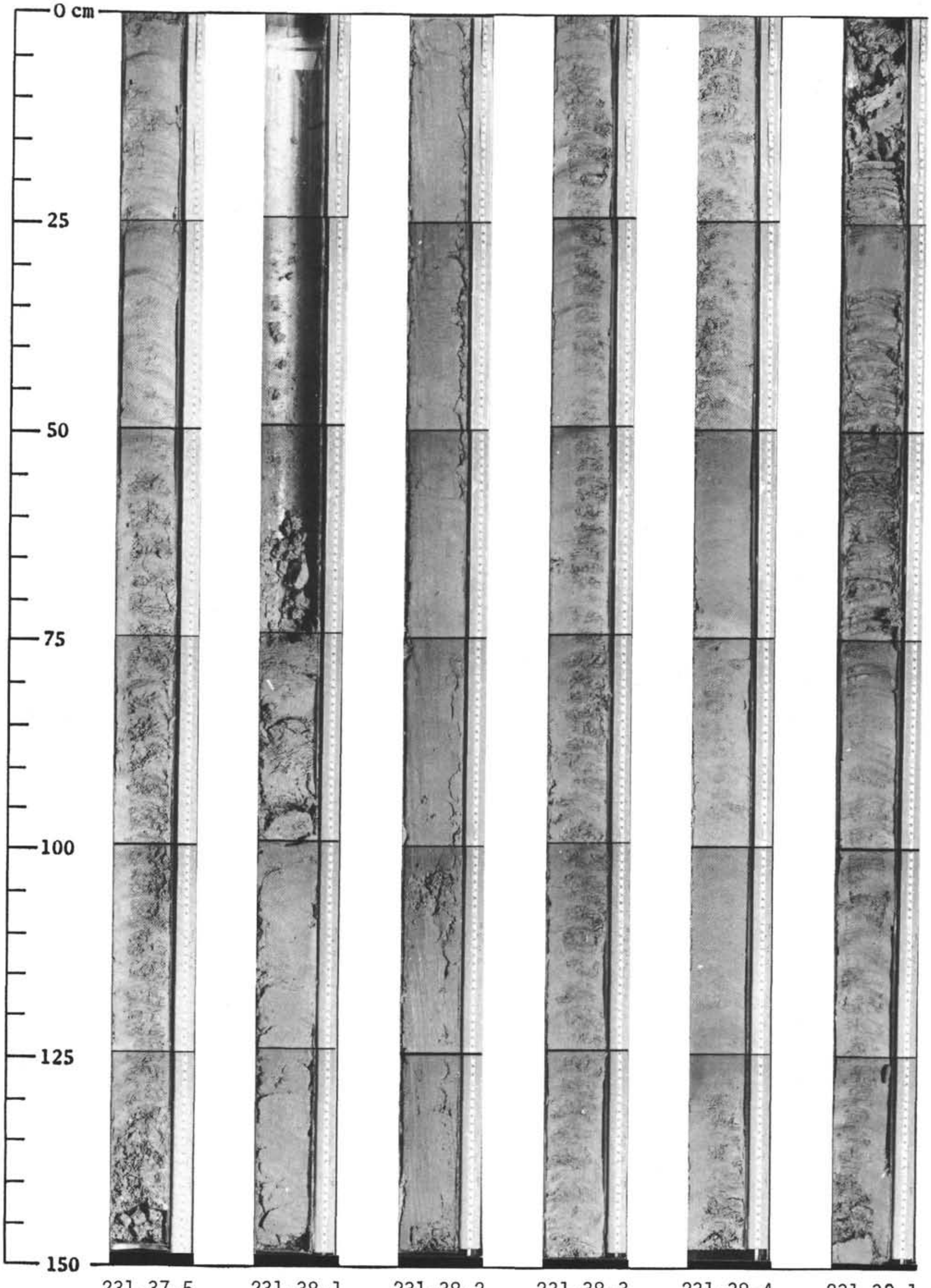


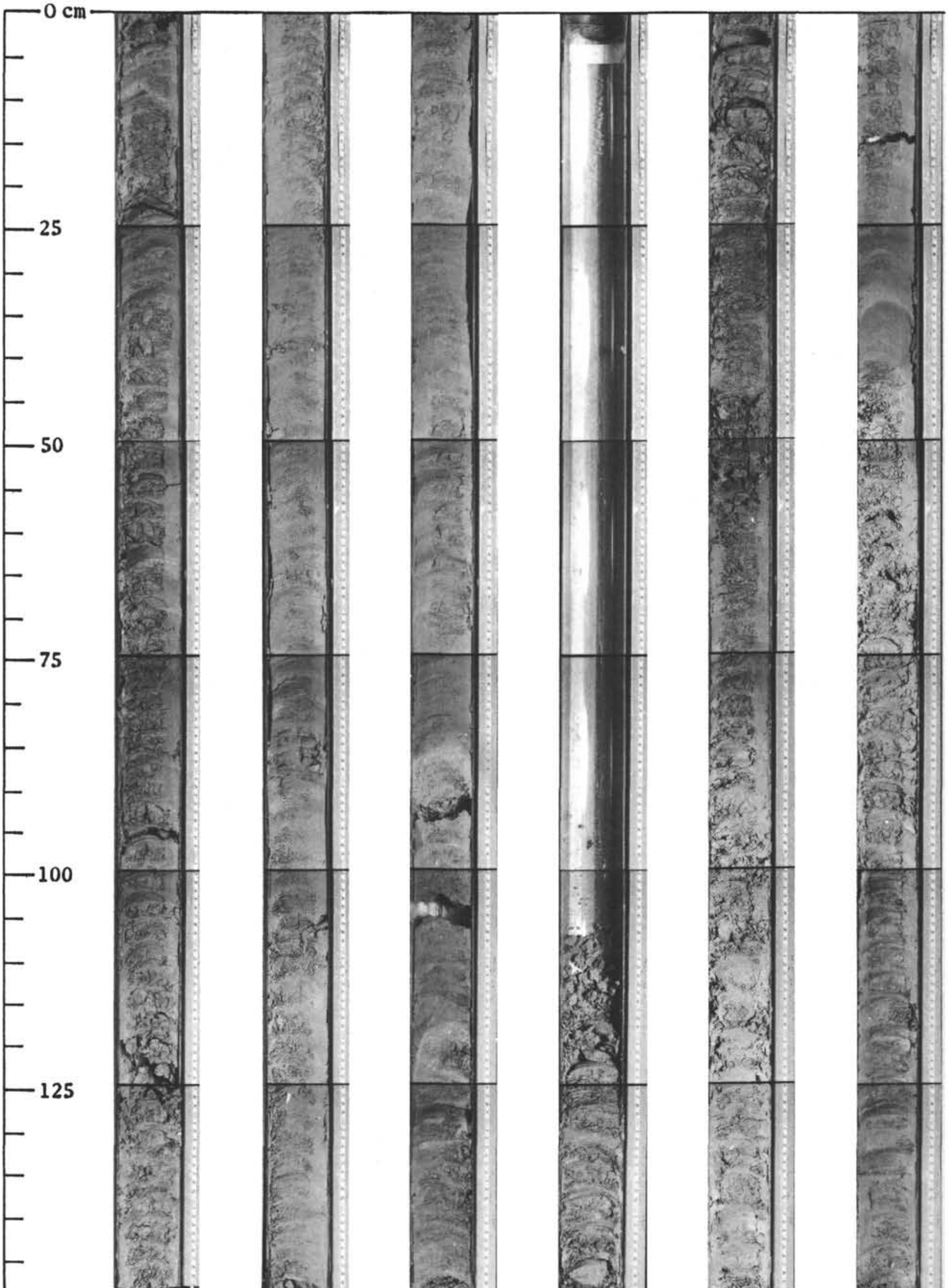
0 cm
25
50
75
100
125
150
231-33-1
231-33-2
231-33-3
231-33-4
231-33-5
231-34-1

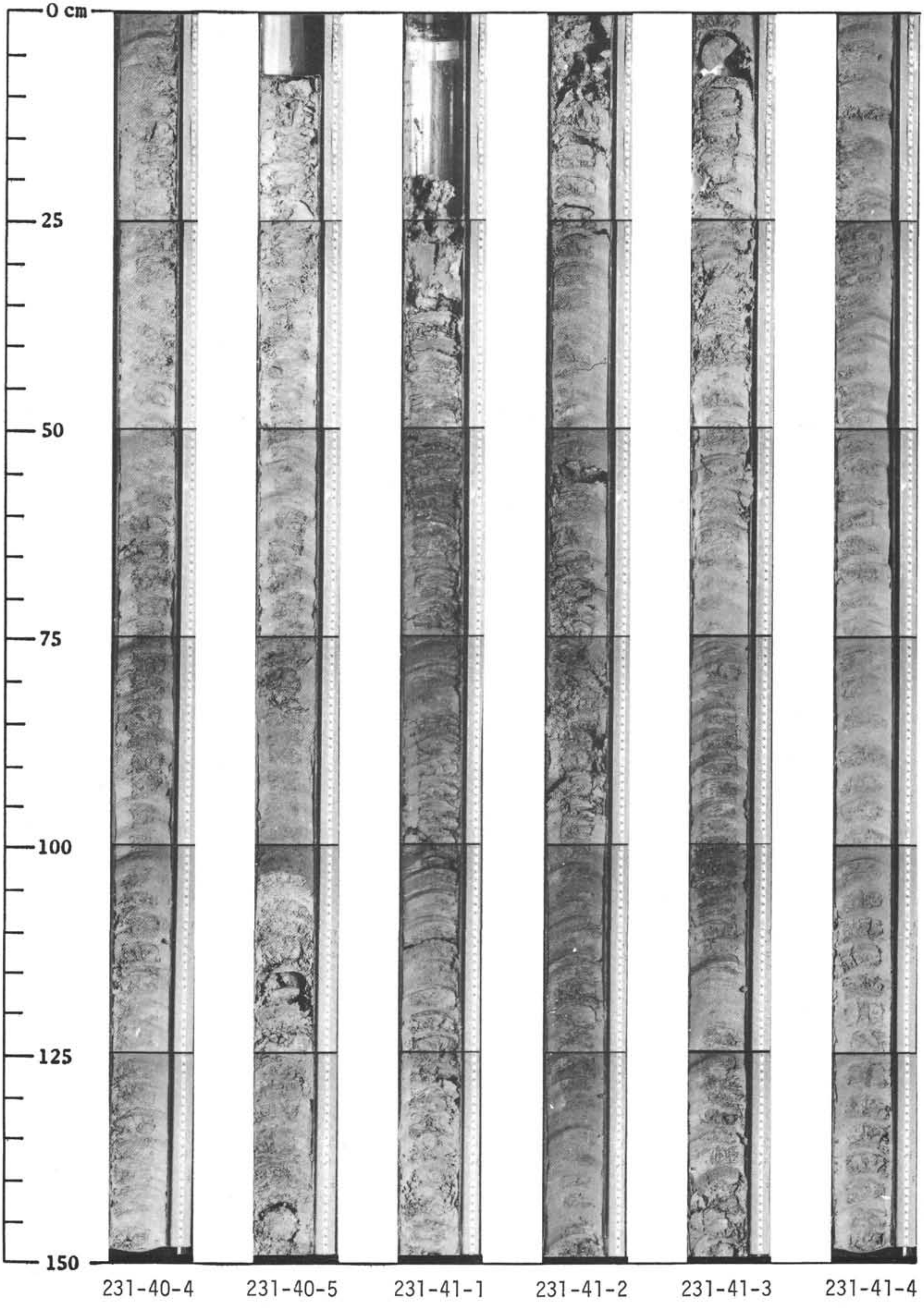

0 cm
25
50
75
100
125
150
231-34-2
231-34-3
231-34-4
231-34-5
231-34-6
231-35-1

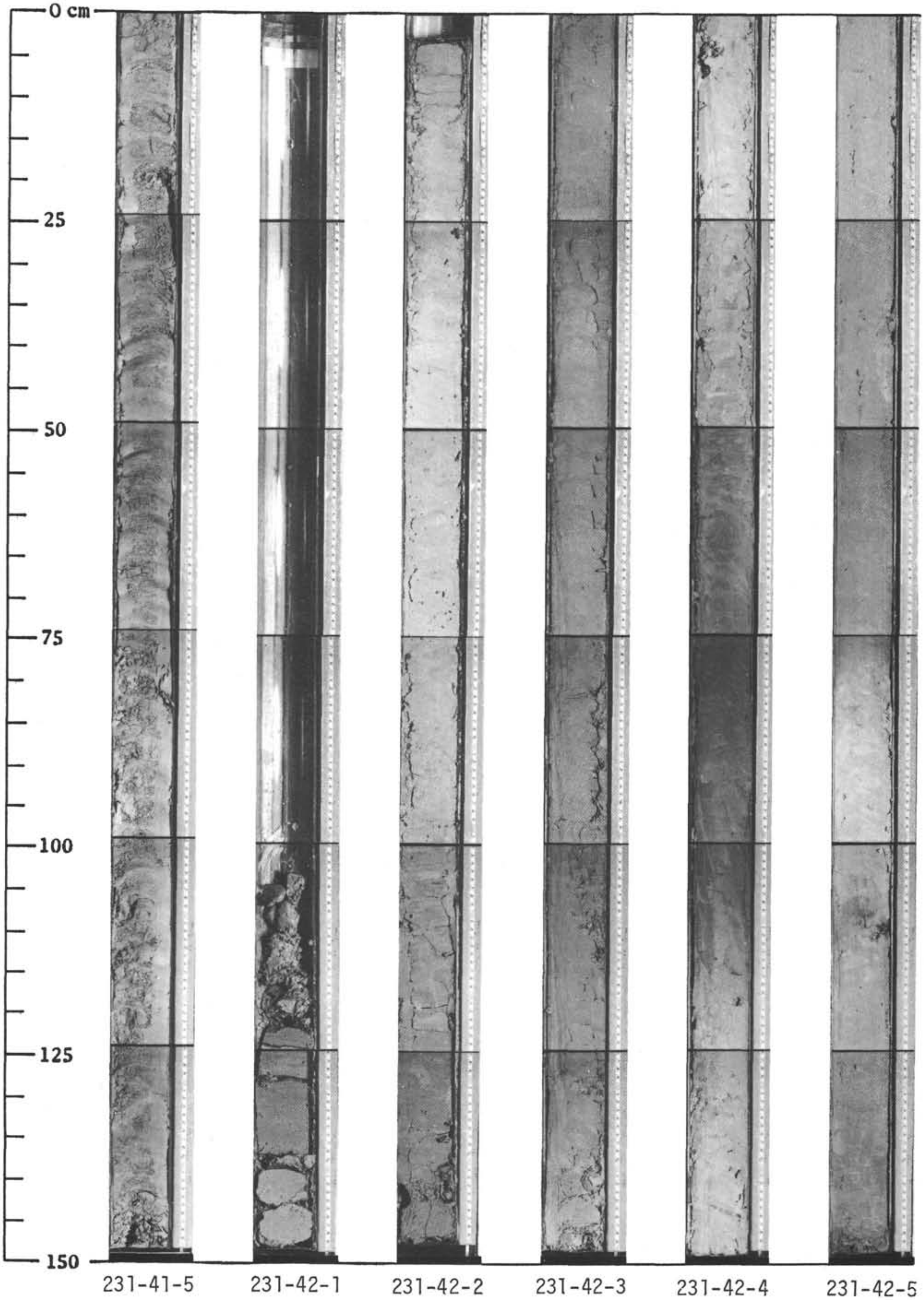

0 cm
25
50
75
100
125
150
231-35-2
231-35-3
231-36-1
231-36-2
231-36-3
231-36-4

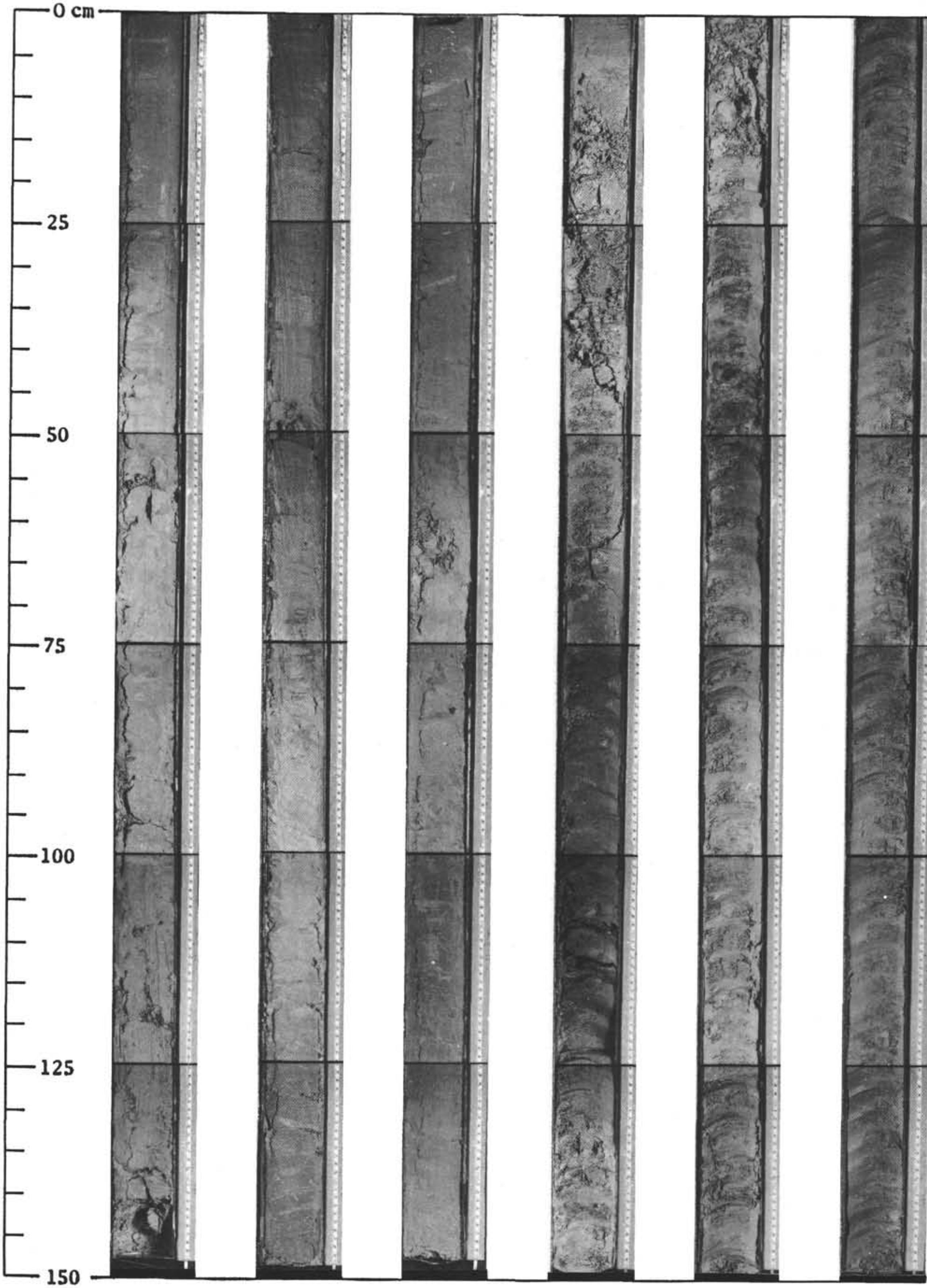

0 cm
25
50
75
100
125
150
231-36-5
231-36-6
231-37-1
231-37-2
231-37-3
231-37-4

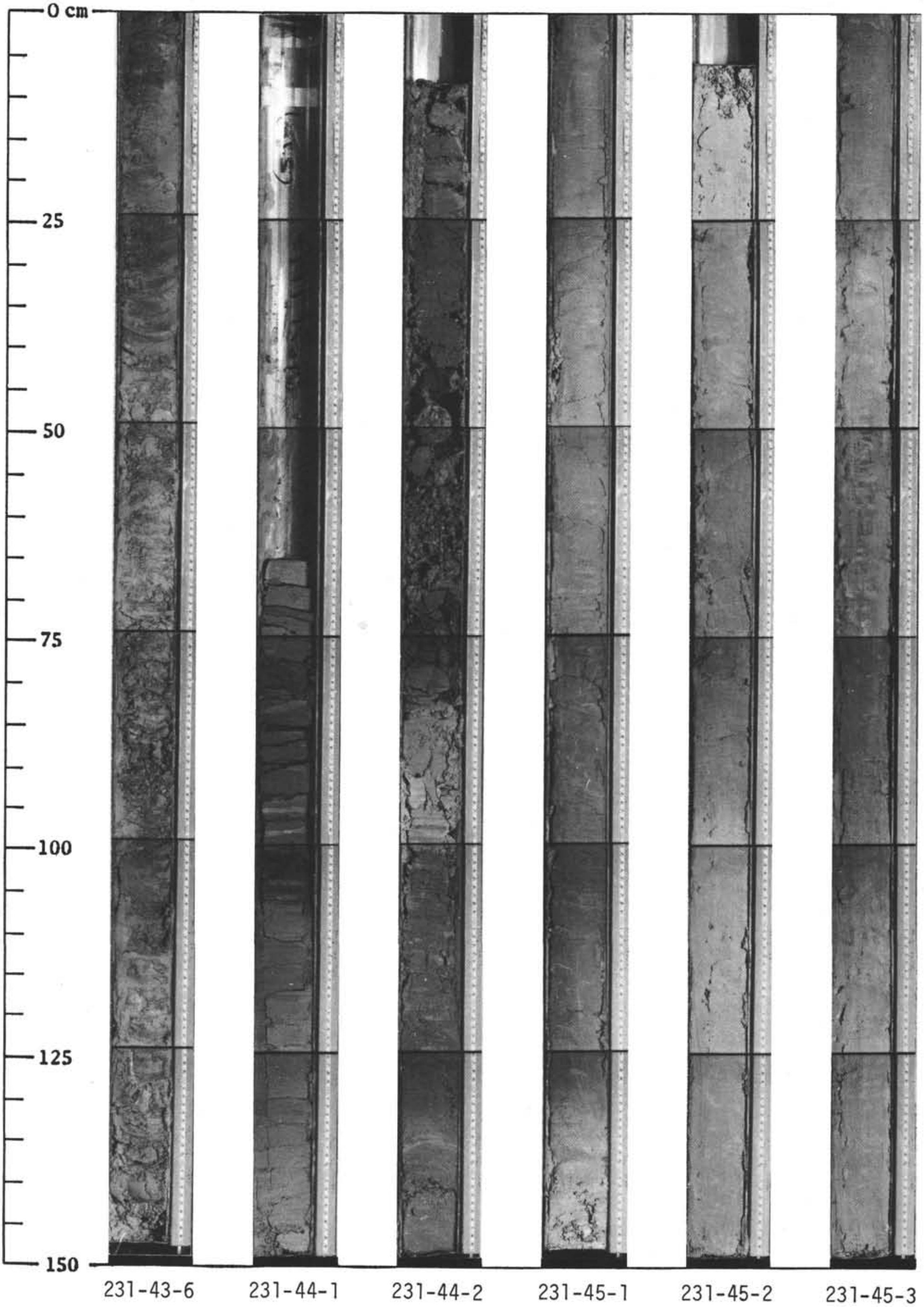

0 cm
25
50
75
100
125
150
231-37-5
231-38-1
231-38-2
231-38-3
231-38-4
231-39-1

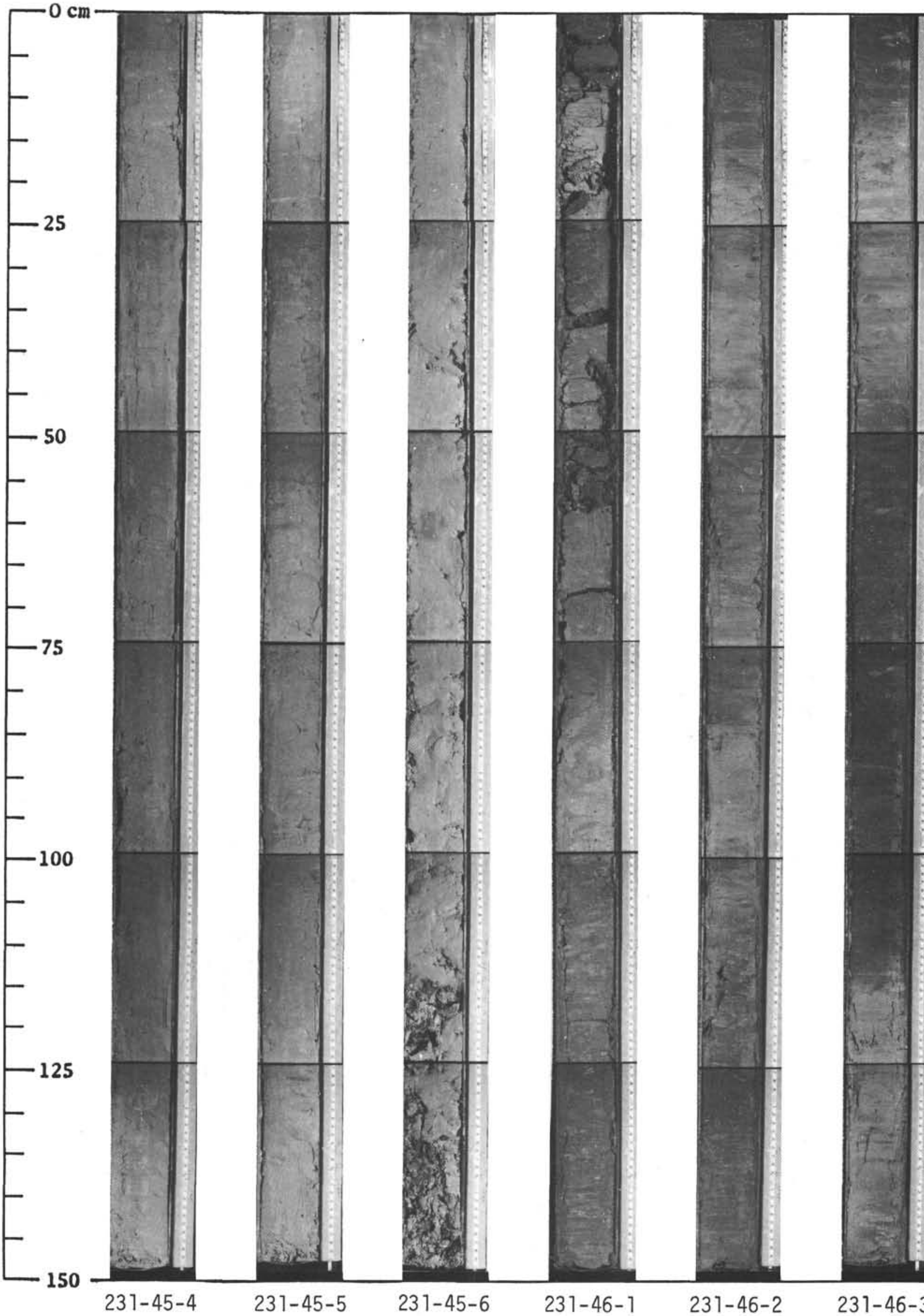

0 cm
25
50
75
100
125
150
231-39-2
231-39-3
231-39-4
231-40-1
231-40-2
231-40-3

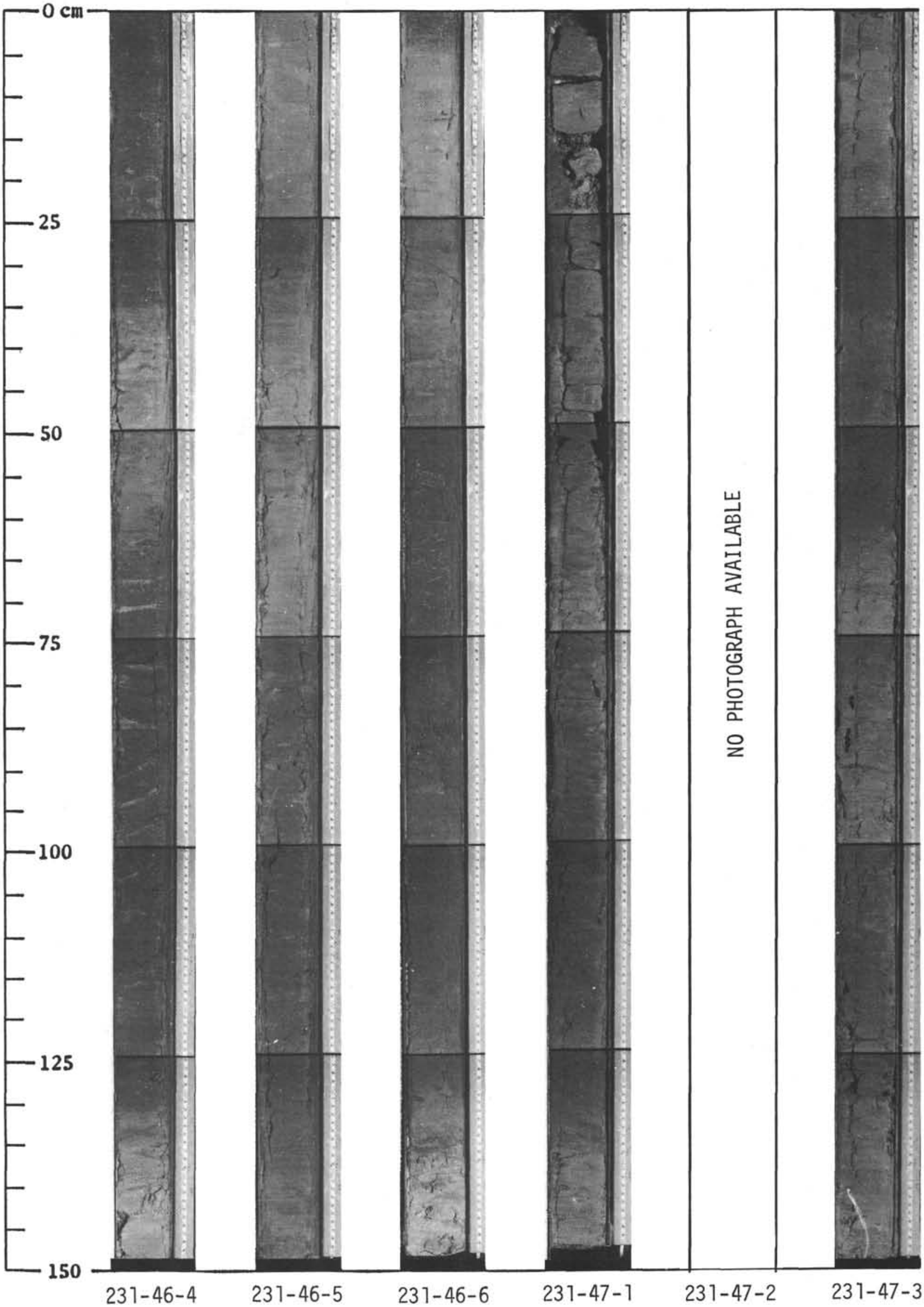

0 cm
25
50
75
100
125
150
231-40-4
231-40-5
231-41-1
231-41-2
231-41-3
231-41-4

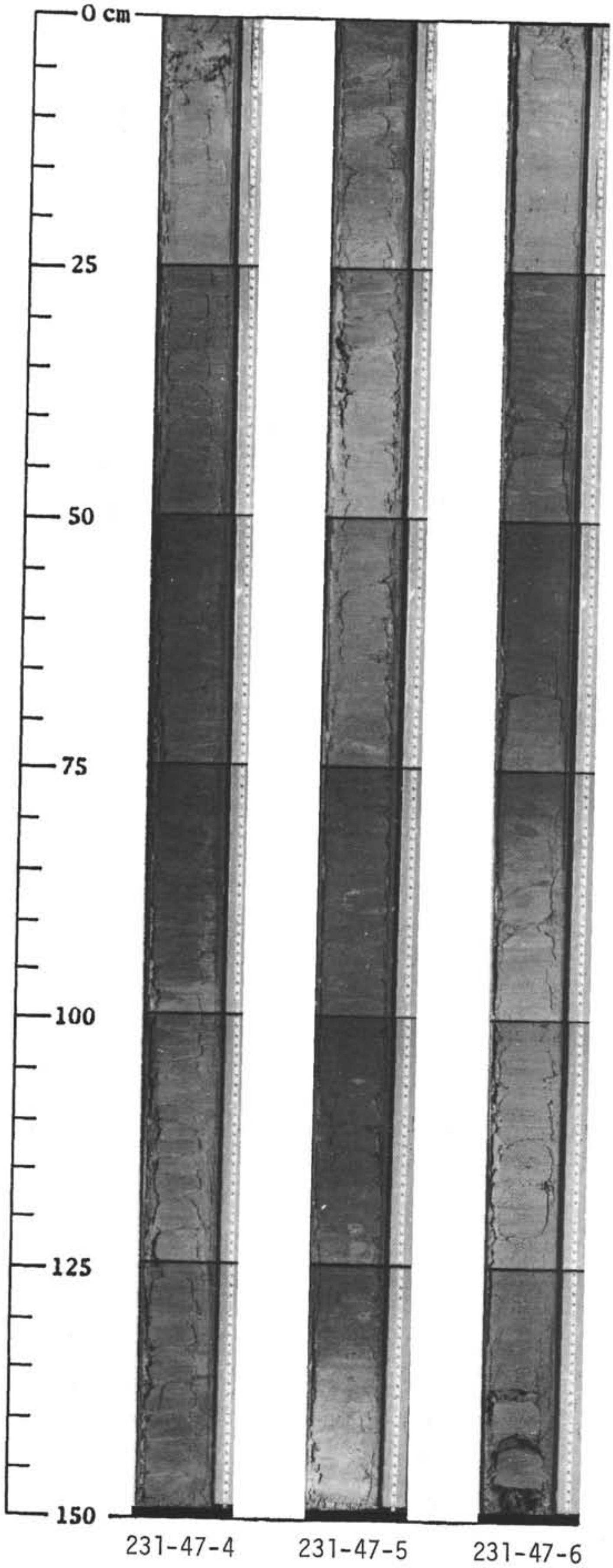

0 cm
25
50
75
100
125
150
231-41-5
231-42-1
231-42-2
231-42-3
231-42-4
231-42-5

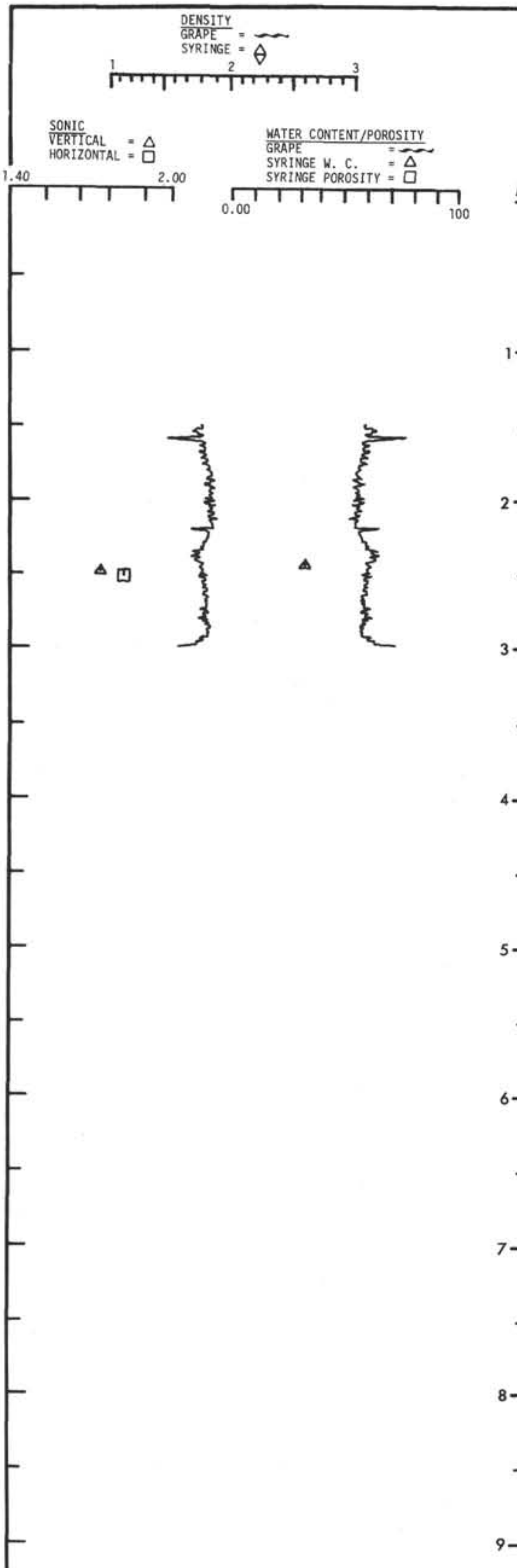

0 cm
25
50
75
100
125
150
231-42-6
231-43-1
231-43-2
231-43-3
231-43-4
231-43-5

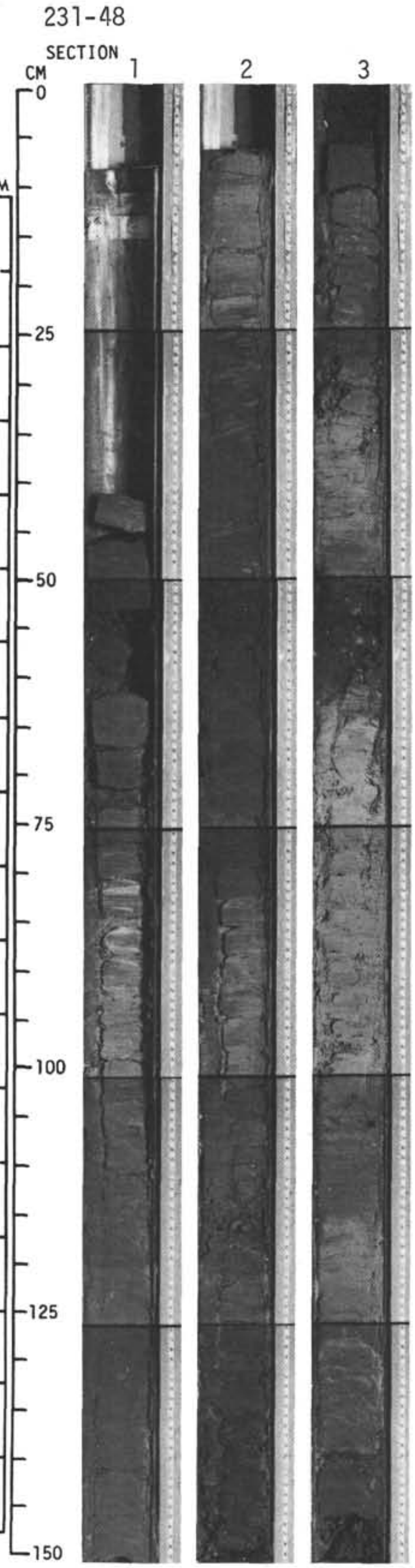

0 cm
25
50
75
100
125
150
231-43-6
231-44-1
231-44-2
231-45-1
231-45-2
231-45-3

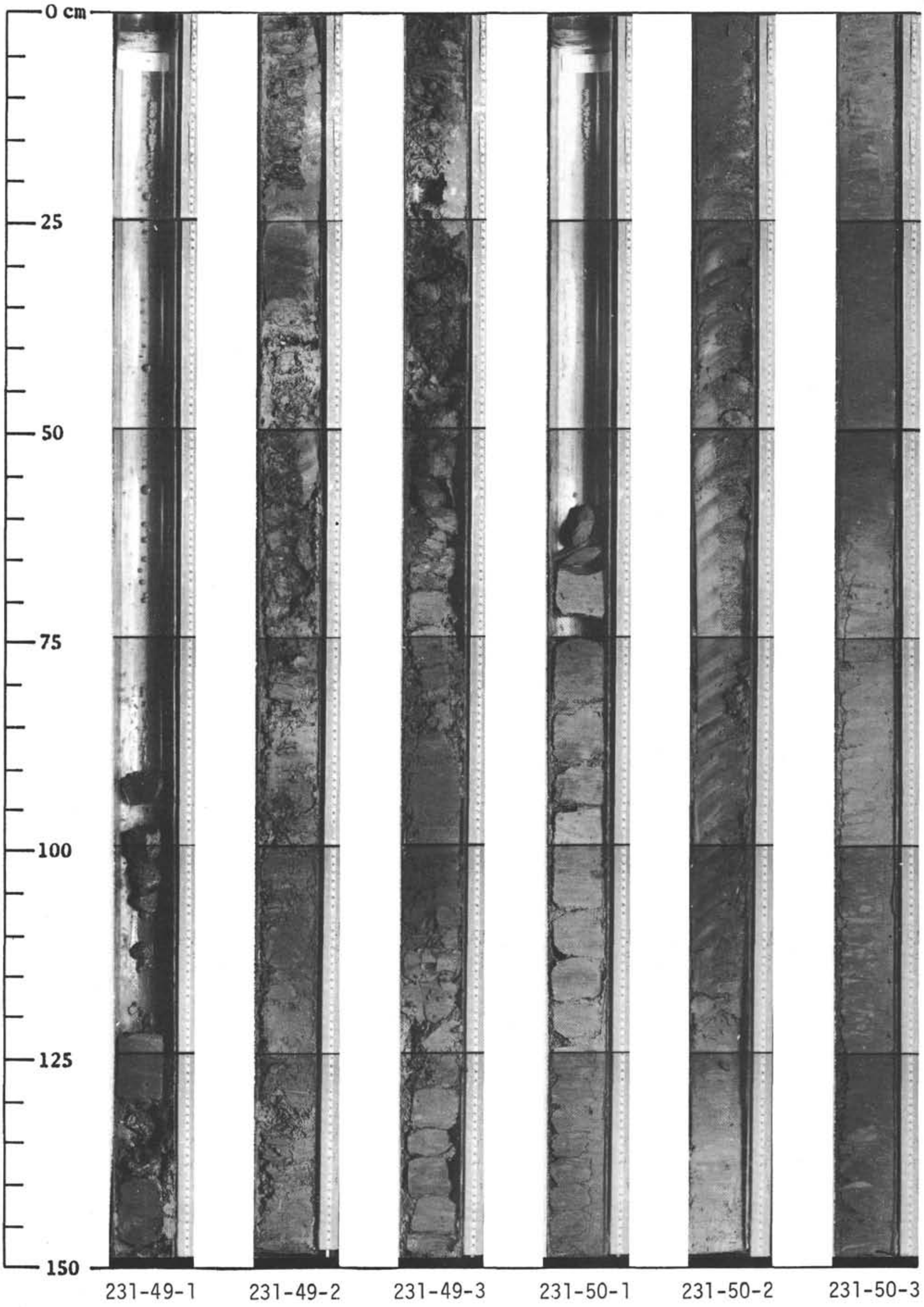

0 cm
25
50
75
100
125
150
231-45-4
231-45-5
231-45-6
231-46-1
231-46-2
231-46-3

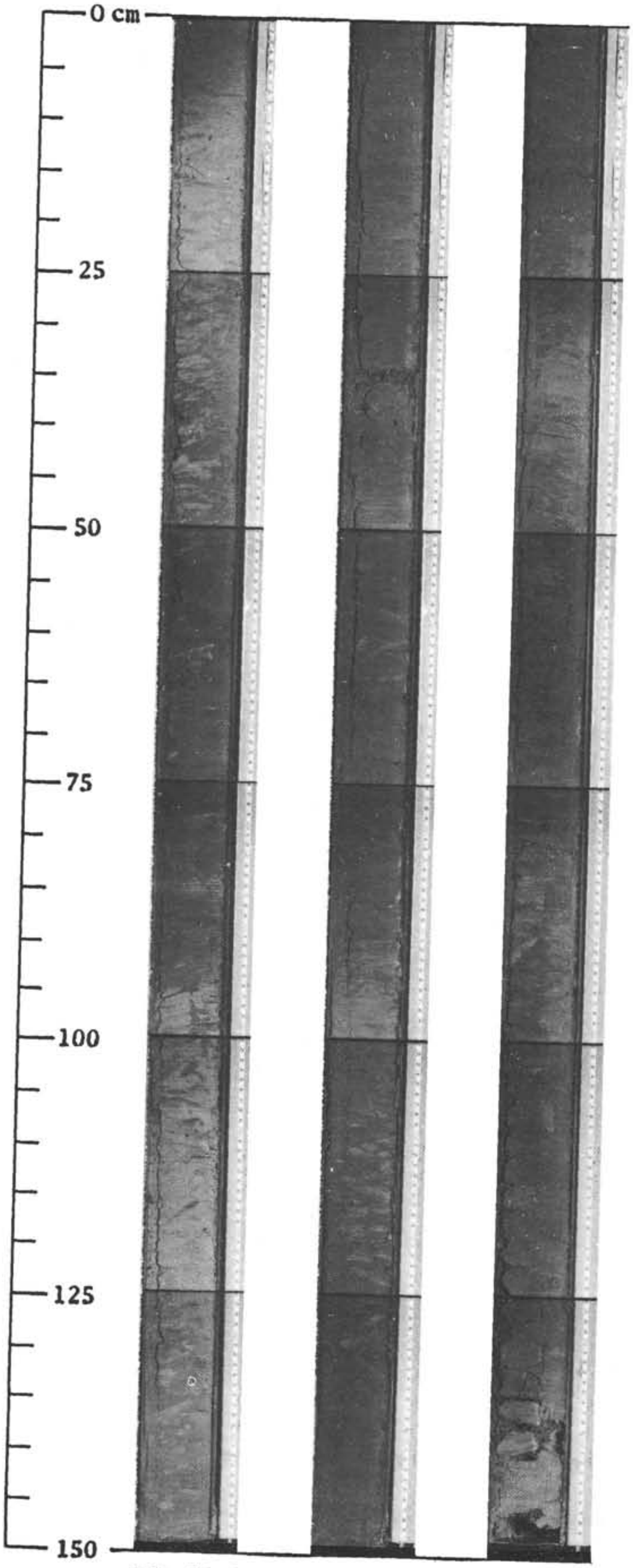

0 cm
25
50
75
100
125
150
NO PHOTOGRAPH AVAILABLE
231-46-4
231-46-5
231-46-6
231-47-1
231-47-2
231-47-3


0 cm
25
50
75
100
125
150
231-47-4
231-47-5
231-47-6

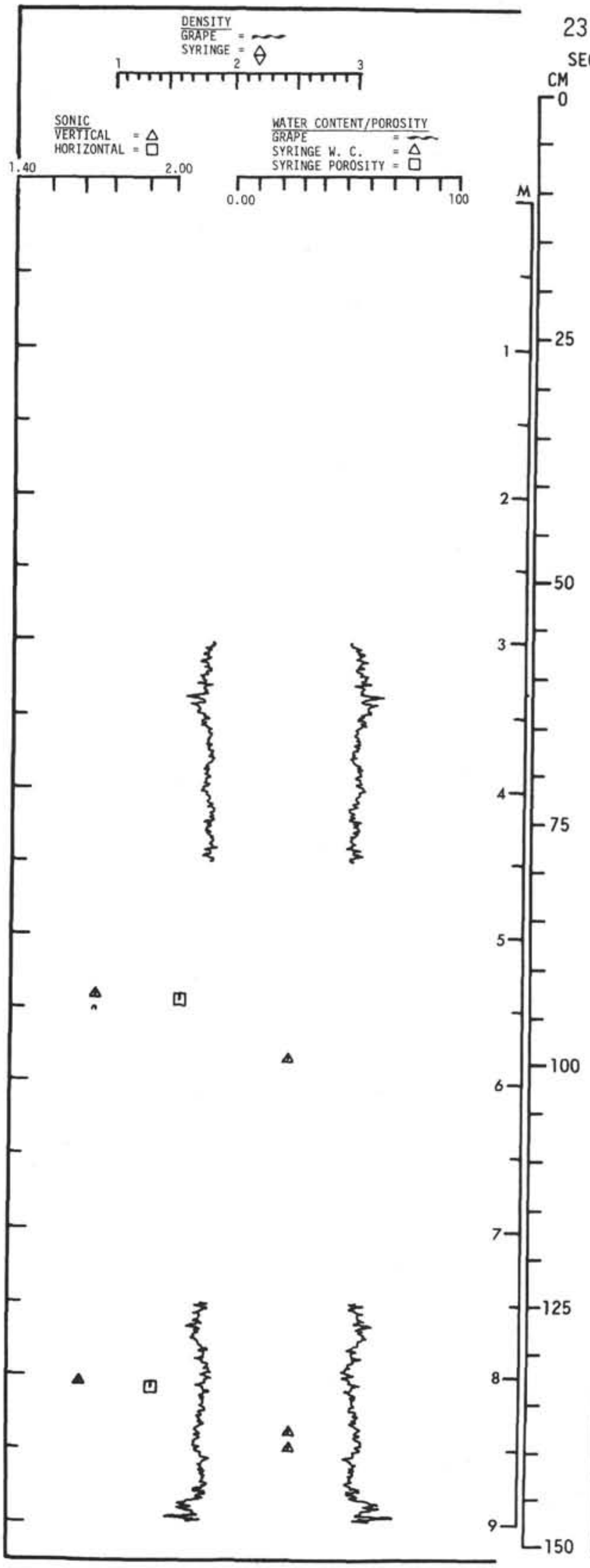

DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = □
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
M
1
2
3
4
5
6
7
8
9

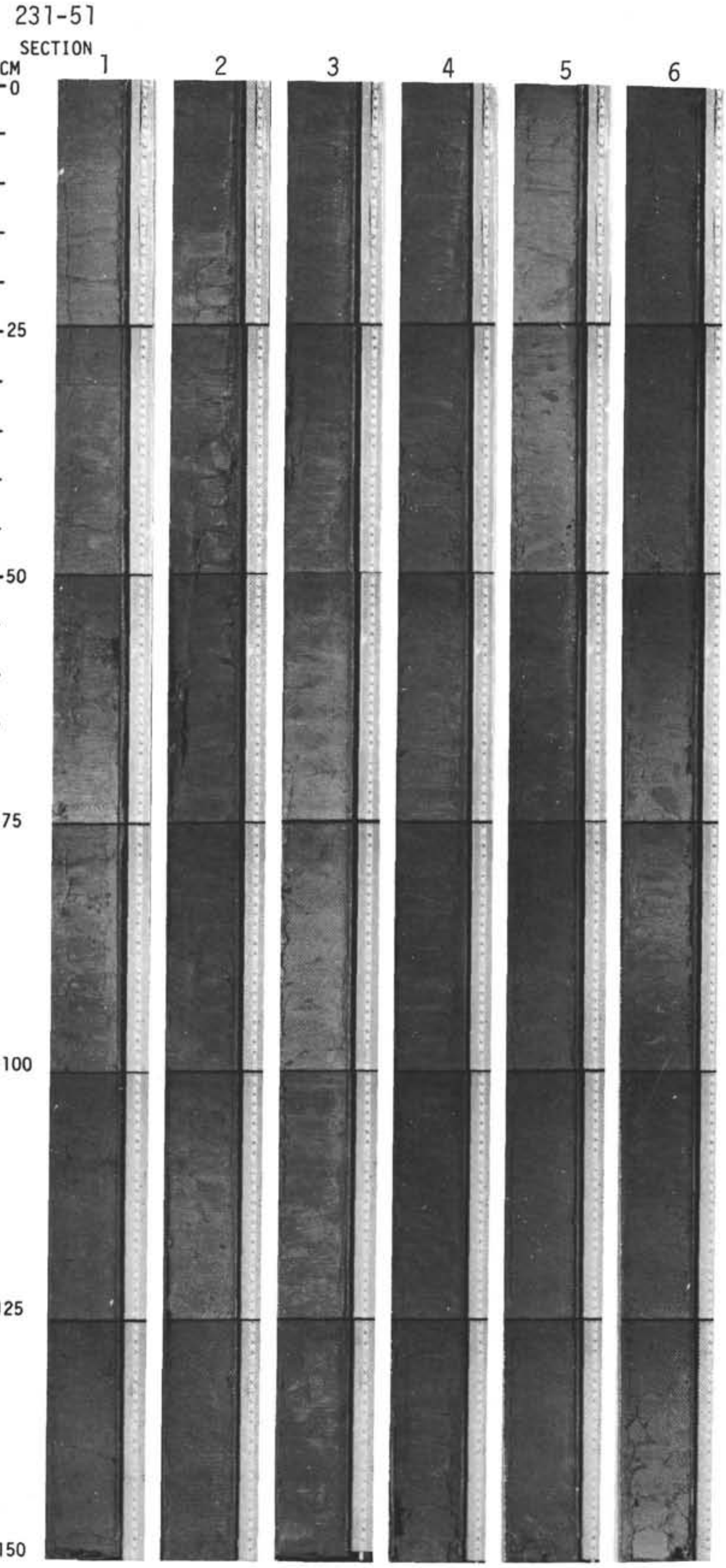

231-48
SECTION
CM
1
2
3
0
25
50
75
100
125
150

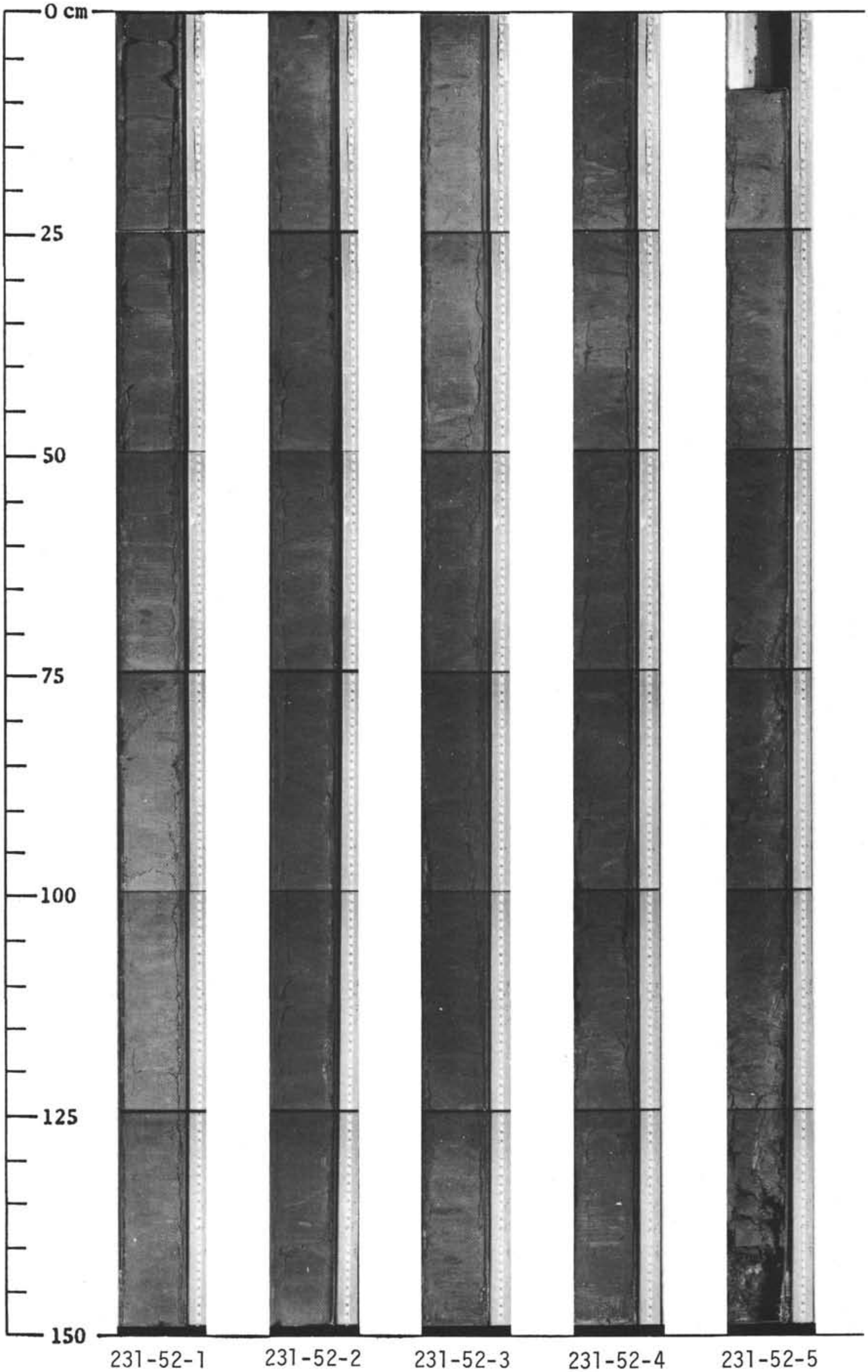

0 cm
25
50
75
100
125
150
231-49-1
231-49-2
231-49-3
231-50-1
231-50-2
231-50-3

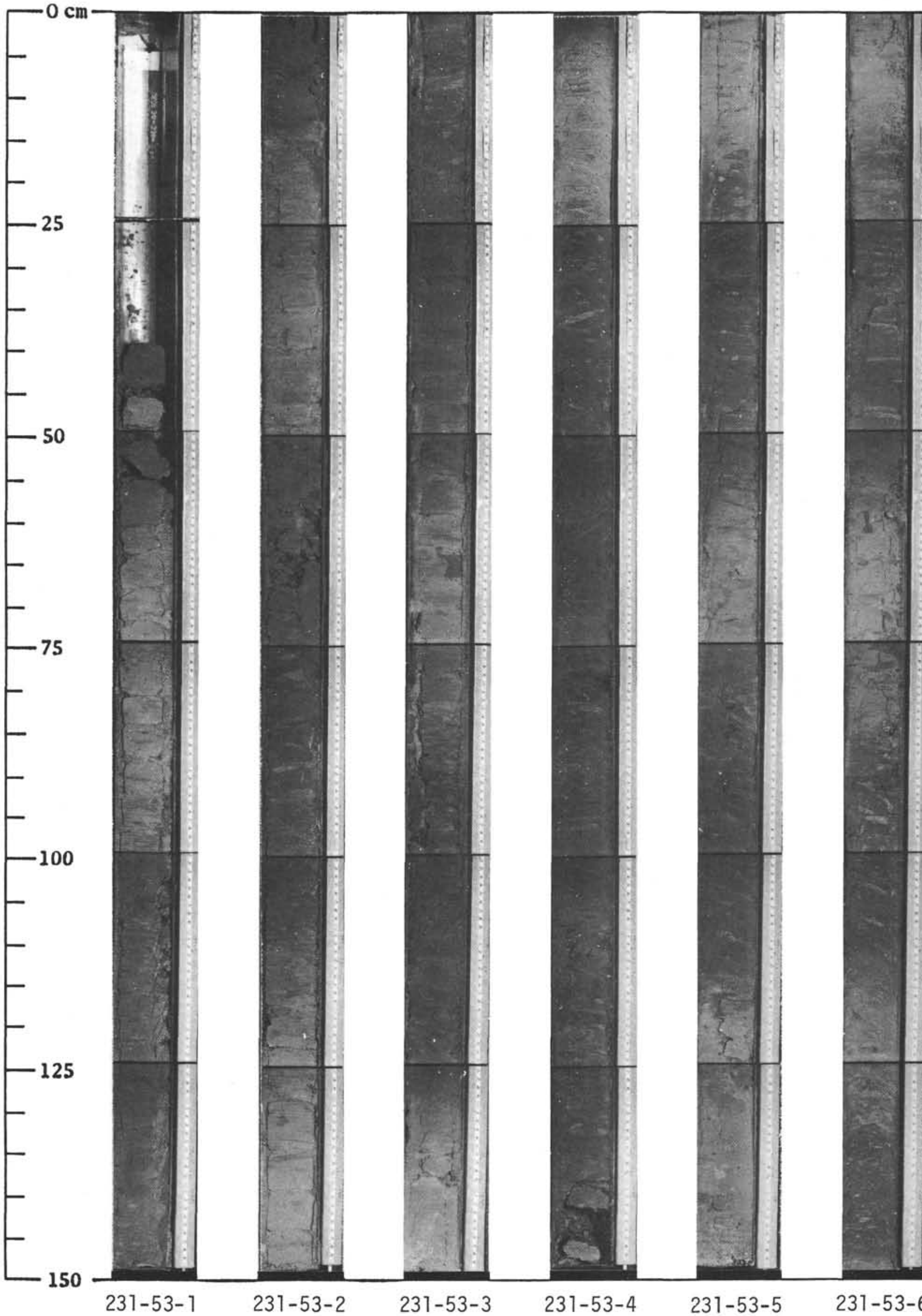


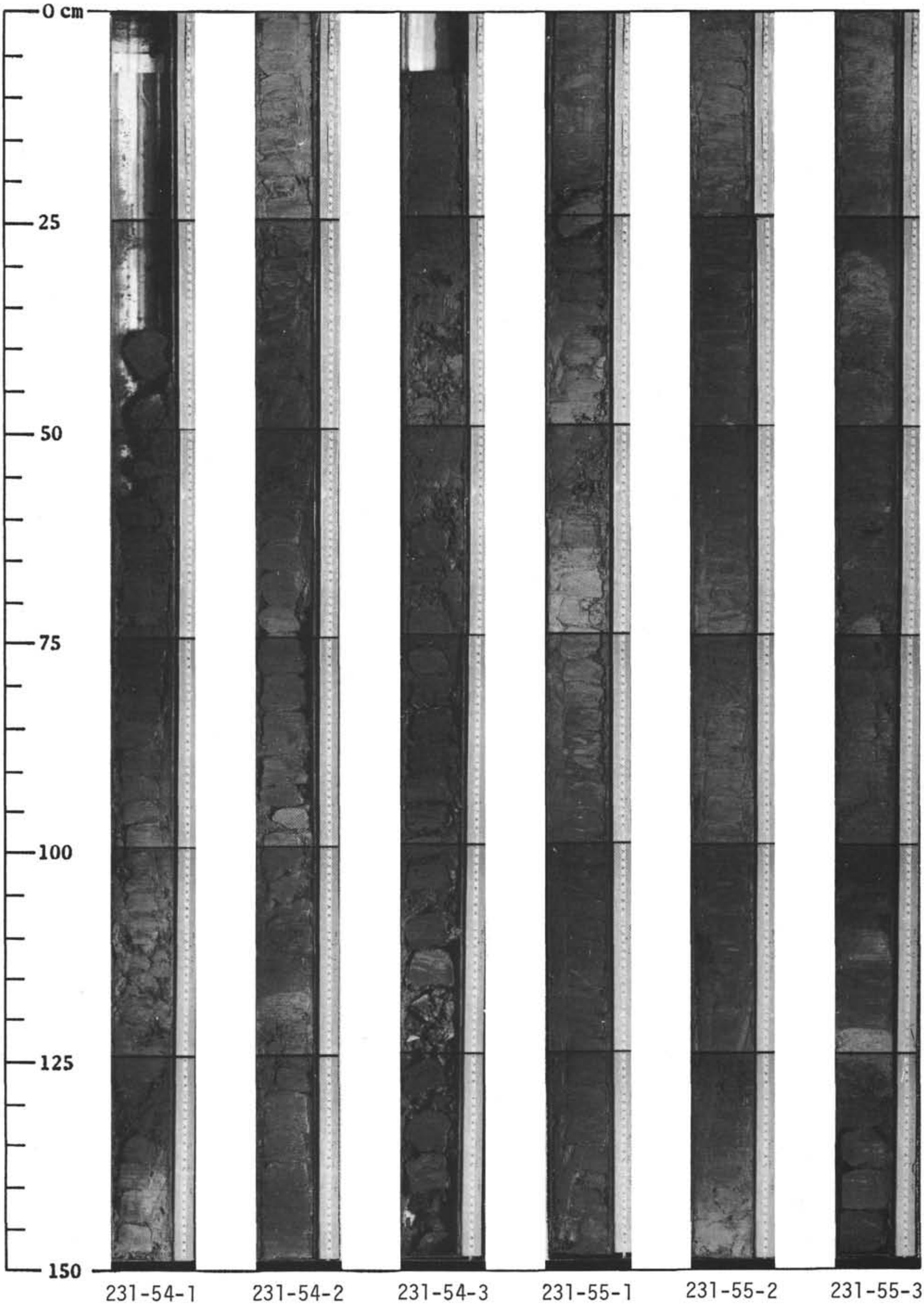
231-50-4 231-50-5 231-50-6

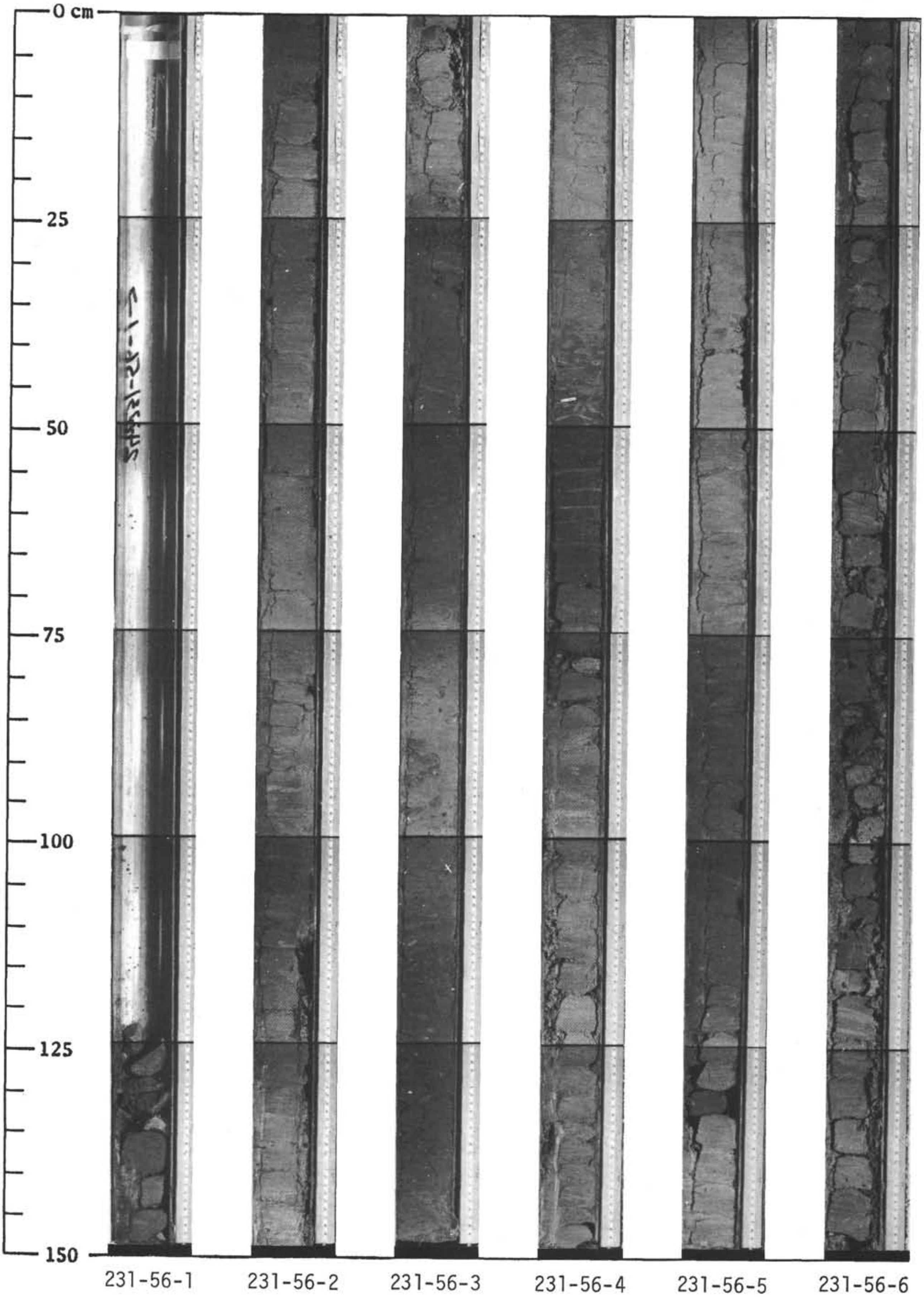

DENSITY
GRAPE =
SYRINGE =
1
2
3
SONIC
VERTICAL = △
HORIZONTAL = □
1.40
2.00
WATER CONTENT/POROSITY
GRAPE =
SYRINGE W. C. = △
SYRINGE POROSITY = □
0.00
100
M
1
2
3
4
5
6
7
8
9
CM
0
25
50
75
100
125
150

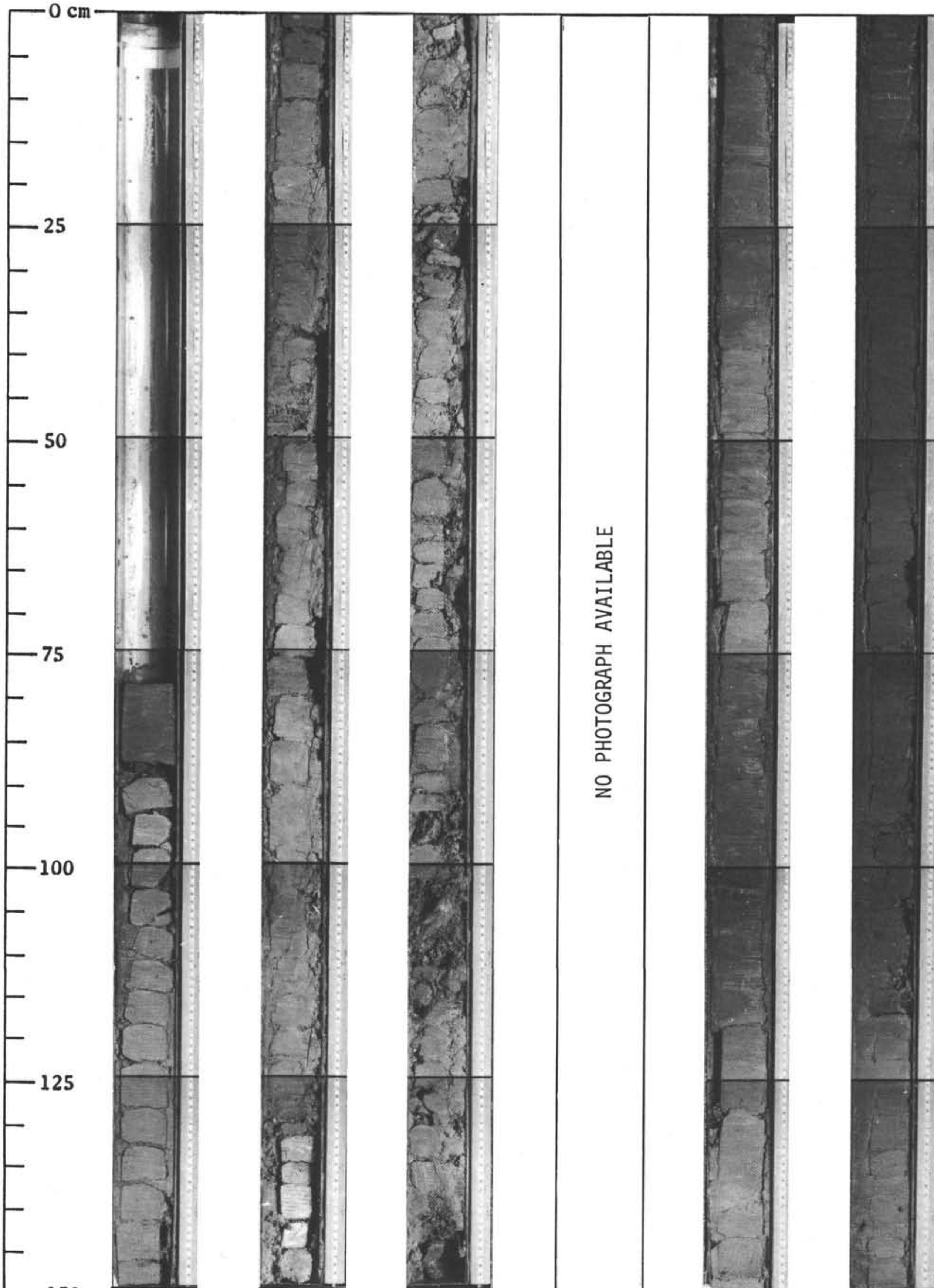

231-51
SECTION
1
2
3
4
5
6


0 cm
25
50
75
100
125
150
231-52-1
231-52-2
231-52-3
231-52-4
231-52-5

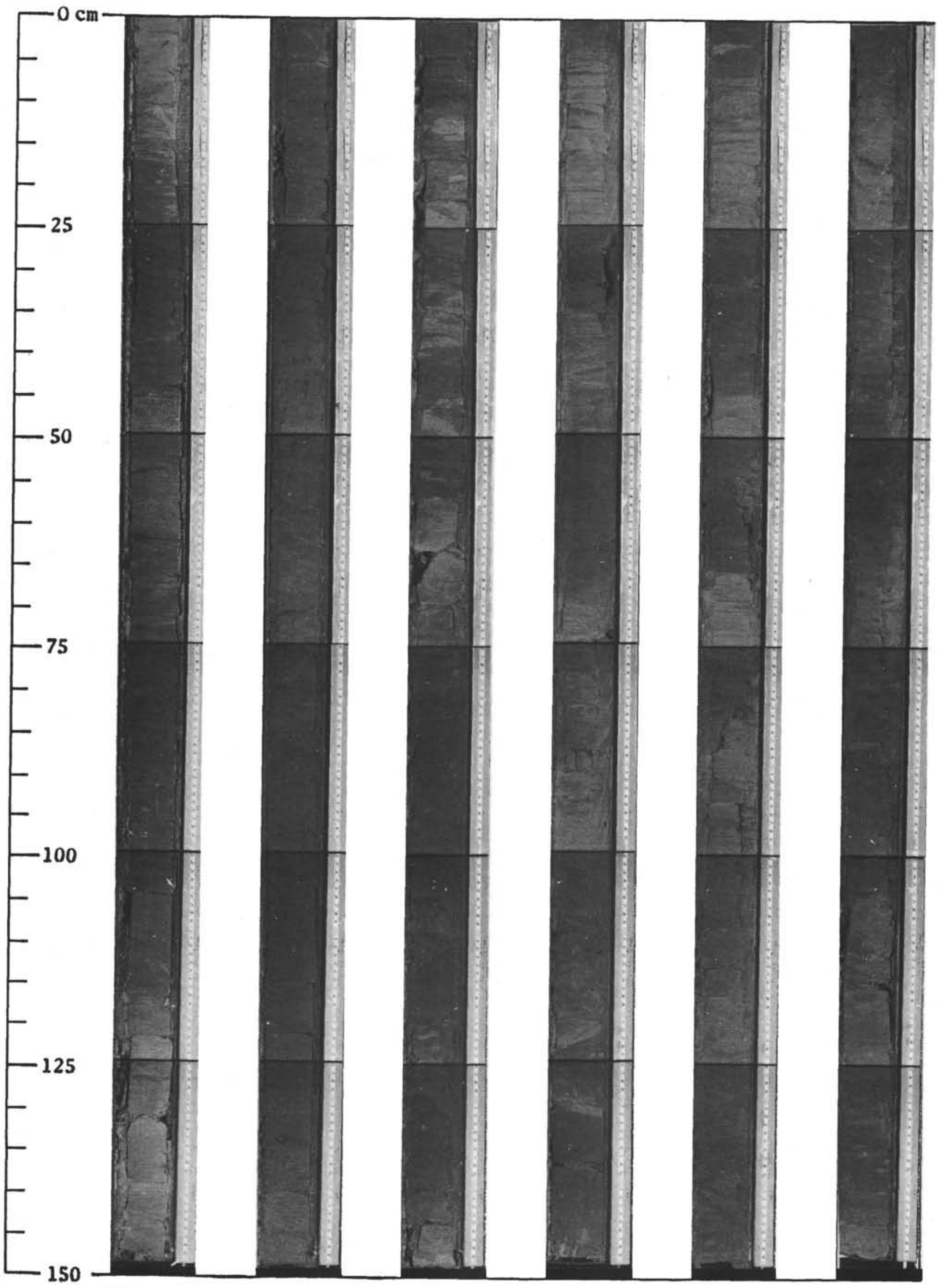

0 cm
25
50
75
100
125
150
231-53-1
231-53-2
231-53-3
231-53-4
231-53-5
231-53-6

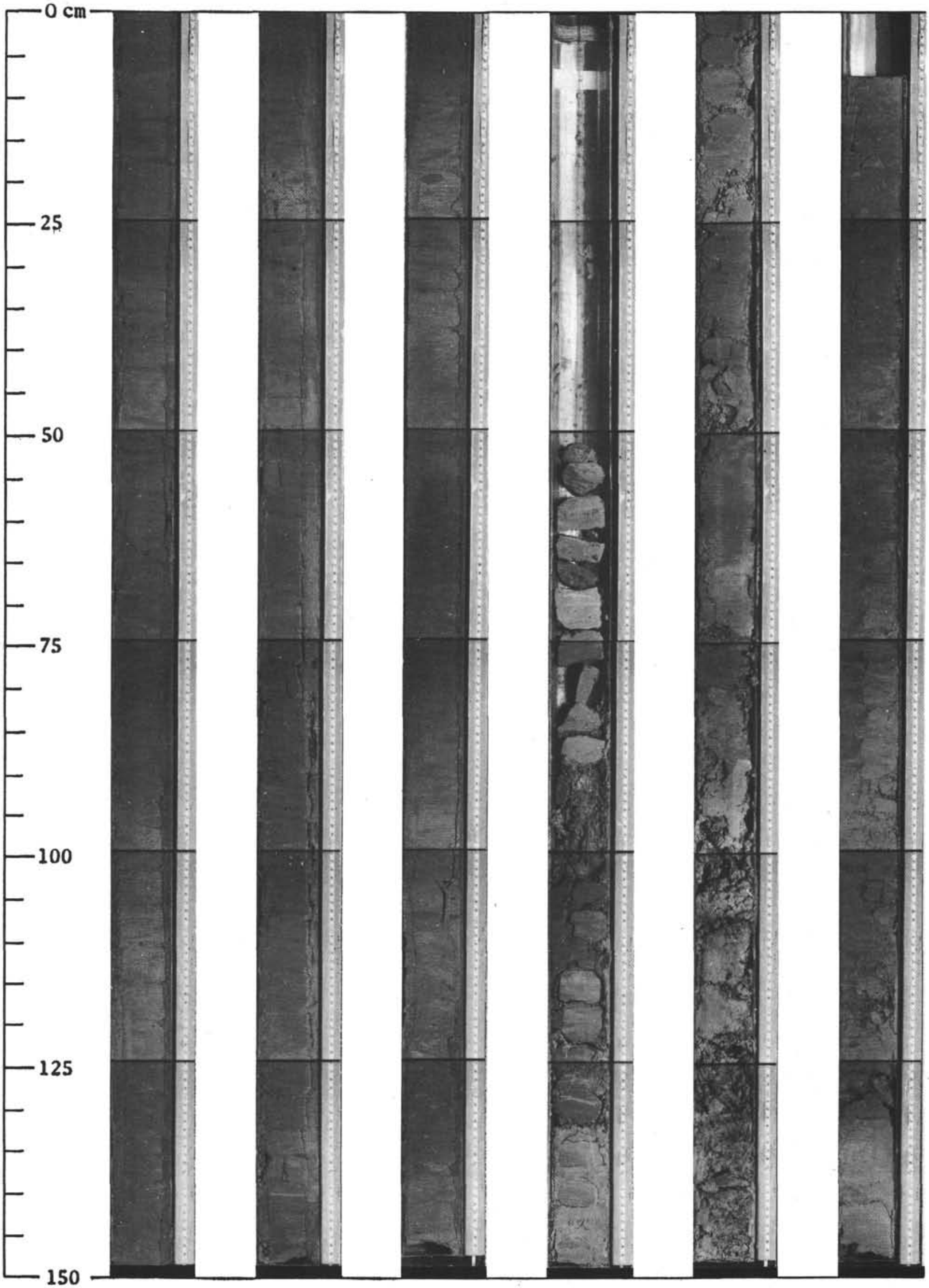

0 cm
25
50
75
100
125
150
231-54-1
231-54-2
231-54-3
231-55-1
231-55-2
231-55-3

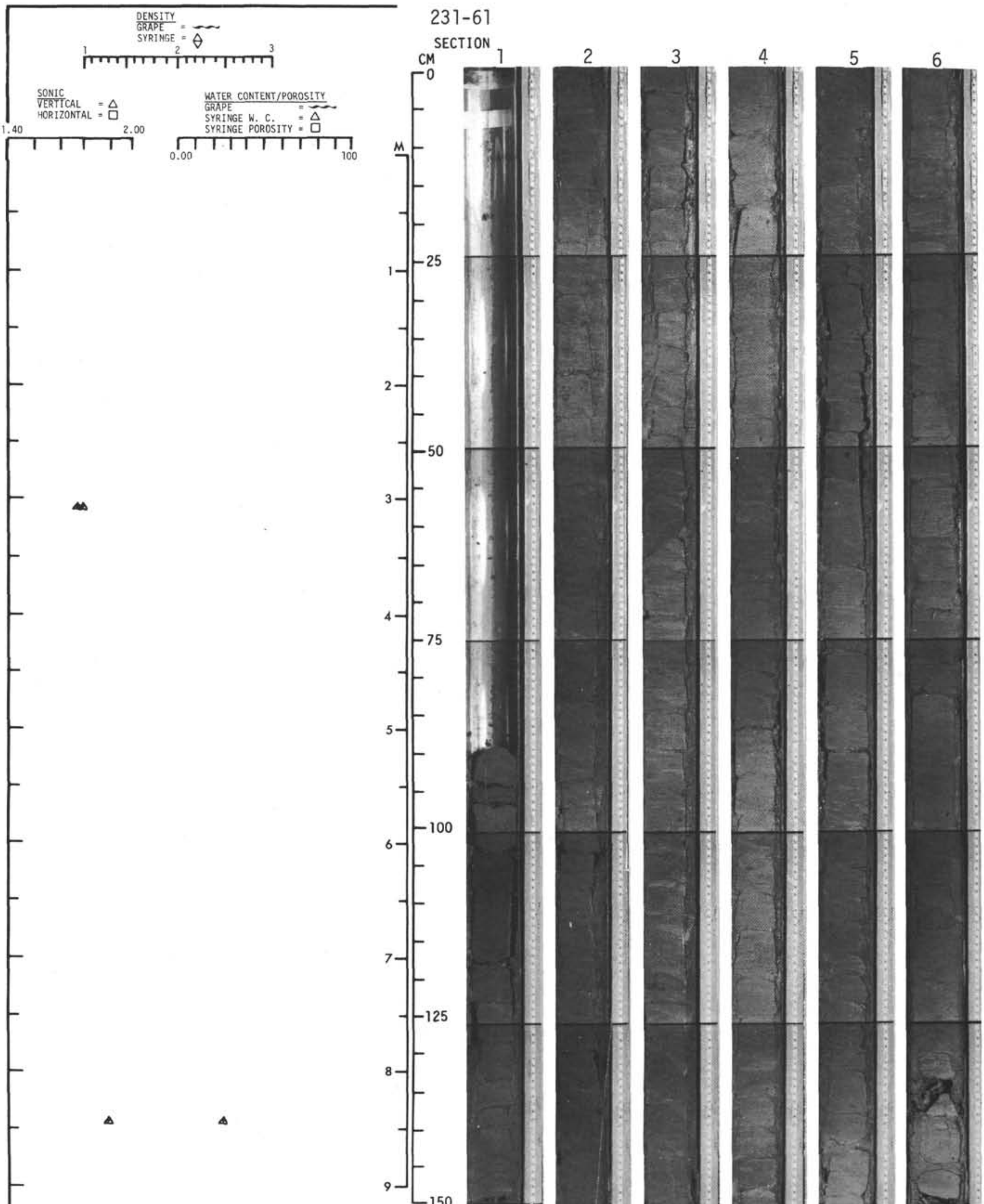

0 cm
25
50
75
100
125
150
231-56-1
231-56-2
231-56-3
231-56-4
231-56-5
231-56-6

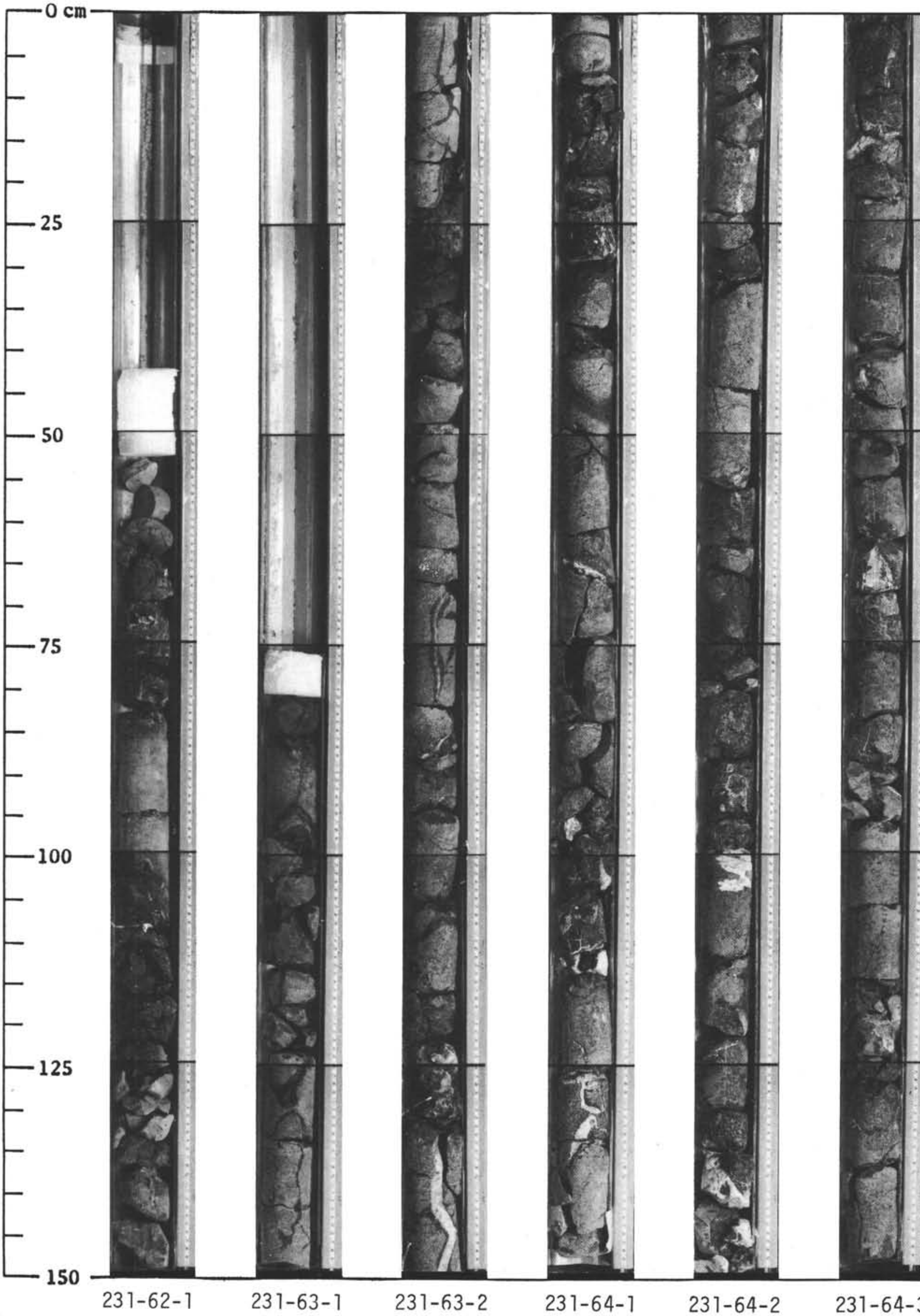


231-57-1 231-57-2 231-57-3 231-58-1 231-58-2 231-58-3


0 cm
25
50
75
100
125
150
231-58-4
231-58-5
231-58-6
231-59-1
231-59-2
231-59-3


0 cm
25
50
75
100
125
150
231-59-4
231-59-5
231-59-6
231-60-1
231-60-2
231-60-3


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
231-61
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6


0 cm
25
50
75
100
125
150
231-62-1
231-63-1
231-63-2
231-64-1
231-64-2
231-64-3