10. SITE 40

The Shipboard Scientific Party[1]

SITE BACKGROUND

Site 40 was located by the JOIDES Pacific Advisory Panel in the region between the Molokai and Clarion Fracture Zones with the objective of recovering a continuous sediment core for the paleontologic and biostratigraphic study of the variation in sediment components at the transition between the North Pacific gyral and the Equatorial Current System.

Based upon the Site Survey by *Argo*, little sediment was present for coring in the area. Most of the area had thin sediment sections similar to those found at Sites 37, 38 and 39. Around the base of a large abyssal hill or ridge, however, a 0.2-second thick pond of sediment was reported. Although the ponded sediment may not have been regionally representative, priority was given to locating the site in this thicker section because fossiliferous sediment, other than at the bottom of the section, might be present—thus, providing dates within the sequence. The adjacent thin sediment section was later drilled as Site 41.

Site 40 is located in a region of abyssal hills having 80 to 150 meters relief and a regional north-south lineation, according to the Site Survey by *Argo*. The ponded sediment of Site 40 is at the base of a hill having approximately 400 meters relief. This hill is isolated from the smaller hills by the smooth surface of the ponded sediment (Figure 1). As much as 0.2 second of sediment with a few weak reflectors was recorded above a smooth acoustic basement. Piston cores taken by *Argo* consisted of nonfossiliferous light to dark brown "red" clay. The seismic reflection profile made aboard *Glomar Challenger* while on Site 40 is shown in Figure 2. Although, essentially, the sequence of sediment is acoustically transparent, a few reflectors are present. The strongest reflector is at 0.21 second. This reflector corresponds to the acoustic basement reflector reported by *Argo;* and, it is present as a smooth layer, running from the outer abyssal hills to the central large hill. Subsequent coring encountered chert at 143 meters depth which, apparently, is the source of this reflector. At least two additional reflectors are identifiable beneath the 0.21-second horizon: 0.31 and 0.42 seconds. Presumably the deeper reflector is basement, but the signal is weak and possible reflectors can be seen beneath it.

Because of a southerly course on approaching the site, the magnetometer record could not be used to identify the anomaly at Site 40. If the location of the site is plotted on the magnetic anomaly chart of Hayes and Pittman (in press), both Sites 40 and 41 appear to be located on Magnetic Anomaly 27 (67 million years).

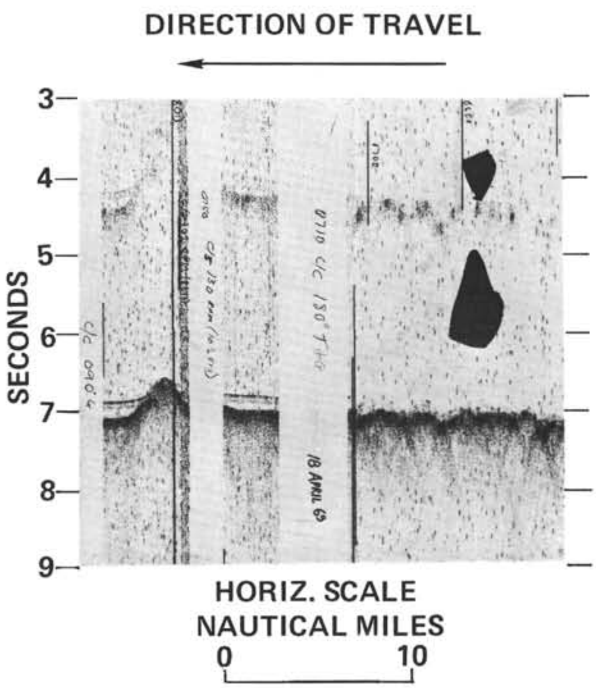

Figure 1. *Seismic reflection profile from* Argo *Site Survey (Appendix III) showing thicker sediment section around isolated hill.*

[1]D. A. McManus, University of Washington, Seattle, Washington; R. E. Burns, ESSA–University of Washington, Seattle, Washington; C. von der Borch, Scripps Institution of Oceanography, La Jolla, California; R. Goll, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York; E. D. Milow, Scripps Institution of Oceanography, La Jolla, California; R. K. Olsson, Rutgers University, New Brunswick, New Jersey; T. Vallier, Indiana State University, Terre Haute, Indiana; O. Weser, Chevron Oil Field Research Company, La Habra, California.

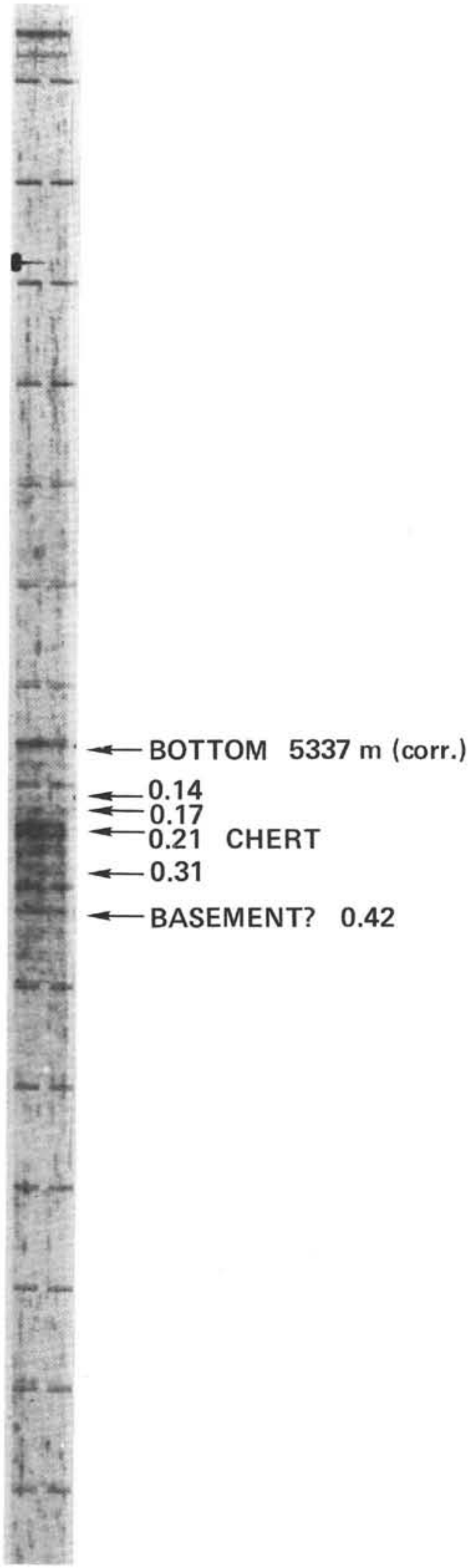

Figure 2. *On-site seismic reflection profile at Site 40 (5-second sweep).*

Location

Site 40 is located at latitude 19°47.57'N, longitude 139°54.08'W in the ponded sediment at the base of an isolated, large abyssal hill or ridge.

OPERATIONS

The drilling summary of Site 40 is presented in Table 1. The sediment was continuously cored to a depth of 156 meters below the sea floor. The rate of penetration during the coring operation was exceedingly high, even without circulation and with only a minor amount of rotation. The ease of coring and the "soupy" nature of most of the cores indicate that the radiolarian ooze is a very porous and soft material for coring. When chert was encountered at 143 meters, Core 16 was retrieved and a barrel with a hard rock core catcher was lowered for coring in the chert. Core 17 was cut in the chert, and coring was halted when the bit passed into the underlying softer material. Subsequent cores were attempted in alternating hard and soft material, suggesting interbedded chert and softer material. Coring was terminated with Core 19 because the bit became plugged. A massive diamond bit was used at this site.

The absence of recovery in Core 7 was caused by a failure of the core catcher and does not reflect any change in lithology.

LITHOLOGY

At Site 40.0, coring was continuous between the sea floor and a total depth of 156 meters. From this interval, 129 meters of sediment were recovered in 19 cores.

Recovery percentage (84 per cent) was good except for no recovery in Core 7 and only 8 per cent recovery in Cores 17, 18 and 19 (143 to 156 meters). Cores were deformed during coring operations which destroyed most sedimentary structures. However, color contacts remained quite sharp. Thirty-four of 87 sections were cut and 69 smear slides were described.

Three recognizable sedimentary units occur with depth. A zeolitic "red" clay (0 to 10 meters), a radiolarian ooze (10 to 143 meters), and a calcareous (?) ooze-chert unit (143 to 156 meters). The color of the zeolitic "red" clay is dark reddish-brown. Zeolites comprise as much as 45 per cent of some smear slides. The upper part of Core 1 contains scattered manganese nodules of small size. The radiolarian ooze in Cores 2 through 16 (10 to 143 meters) is characterized by moderate brown and dark reddish-brown colors with infrequent streaks and beds of yellow. The upper contact of the ooze is gradational through three meters, where the clay content decreases downward from the zeolitic "red" clay. Below 13 meters, the radiolarian ooze has only small admixtures of clay, hematitic iron oxides, and other minerals. Radiolarians comprise from

TABLE 1
Drilling Summary of Leg 5, Site 40

Date	Core	Depth Below Sea Floor (m)	Depth Below Rig Floor (ft)	Core Cut (ft)	Core Cut (m)	Core Recovered (ft)	Core Recovered (m)	Per cent Recovered
20 May	1	0-9	17,047-17,076	29	8.8	29.0	8.8	100
	2	9-18	17,076-17,106	30	9.1	30.0	9.1	100
	3	18-27	17,106-17,136	30	9.1	29.0	8.8	97
21 May	4	27-36	17,136-17,166	30	9.1	28.0	8.5	93
	5	36-45	17,166-17,196	30	9.1	28.0	8.5	93
	6[a]	48-57	17,203-17,233	30	9.1	30.0	9.1	100
	7	57-66	17,233-17,263	30	9.1	0.0	0.0	0
	8	66-75	17,263-17,293	30	9.1	28.0	8.5	93
	9	75-84	17,293-17,323	30	9.1	30.0	9.1	100
	10	84-93	17,323-17,353	30	9.1	30.0	9.1	100
	11	93-102	17,353-17,383	30	9.1	30.0	9.1	100
	12	102-112	17,383-17,413	30	9.1	29.0	8.8	97
	13	112-121	17,413-17,443	30	9.1	30.0	9.1	100
	14	121-130	17,443-17,473	30	9.1	29.0	8.8	97
	15	130-139	17,473-17,503	30	9.1	30.0	9.1	100
	16	139-143	17,503-17,516	13	4.0	10.0	3.1	77
	17	143-150	17,516-17,538	22	6.7	0.7	0.2	3
	18	150-153	17,538-17,549	11	3.4	2.0	0.6	18
	19	153-156	17,549-17,559	10	3.1	0.5	0.2	5
			Totals	505	153.4	423.2	128.5	84

[a]Gap between Cores 5 and 6 is merely a depth correction of 7 feet upon entering the hole for Core 6. No section lost.

Note: Sonic water depth (corrected): 5176 meters; 16,999 feet, 2833 fathoms.
Driller's depth: 17,047 feet.

85 to 100 per cent of the samples. Other siliceous fossils occur but are not abundant. The third unit, between 143 and 156 meters (Cores 17, 18 and 19), probably consists mostly of gray calcareous mud with interlayered beds of black and brown chert. Although only a small percentage of the cores were recovered, a study of the driller's log greatly assisted in stratigraphic inteprretations. The uncored intervals may represent radiolarian ooze beds. Apparently, three chert beds were penetrated. The first was encountered at 143 meters, the second probably at 150 meters, and a third at 153 meters. Drilling stopped on the fourth chert bed at 156 meters. Black chert with thin brown calcareous mudstone lenses was recovered from the core catcher of Core 17. The brown chert from Core 18 was associated with gray calcareous mud, and black chert from Core 19 contained vugs filled with calcareous mud. The calcareous muds consist mostly of calcite fragments with some dolomite rhombs and rare calcareous nannoplankton. Basement was not reached but probably lies at about 300 meters below the sea floor.

Major authigenic components are manganese nodules, zeolites and dolomite rhombs. Most zeolites are phillipsite characterized by euhedral elongate crystals, low birefringence and penetration twinning. Phillipsite occurs as streaks, as nodules, and in irregularly-shaped pockets. Some concentrations may represent altered volcanic ashes. The dolomite rhombs occur in what may be a recrystallized chalk ooze.

Pumice also occurs in the sediments. The core catcher of Core 7 contained fragments of pumice as did Core 12

(102 meters) and Core 15 (132 meters). The largest fragment observed measures about 2 centimeters in length.

PALEONTOLOGY

Nannoplankton

Calcareous nannoplankton occur in very thin, hard, chalk laminae intercolated in a section of chert at the bottom of this hole; this is in the recovered portion of Cores 18 and 19. The preservation is only fair, and the nannofossils are somewhat heavily calcified but suitable for the identification of a fair sized assemblage of diagnostic nannofossils, representing the *Discoaster diastypus* Zone.

The samples from Core 18 represent the lower part of the *Discoaster diastypus-Marthasterites tribrachiatus* Subzone, Lower Eocene. In Core 19, the coccolith-discoaster assemblage represents the *Discoaster diastypus-Marthasterites contortus* Subzone, the basal-most Lower Eocene. Some of the species found in these cores have not been encountered in previous holes of this leg. These are: *Discoaster multiradiatus* Bramlette and Riedel, *D. perpolitus* Martini, *Fasciculithus involutus* Bramlette and Sullivan, and *Marthasterites contortus* (Stradner).

Foraminifera

Foraminifera were not found in any of the cores in this hole.

Radiolaria

Radiolaria are present in great abundance in Cores 2 to 6 and 8 to 16, and they are absent in the remaining cores. The assemblage is well-preserved; diversity is high and typical of low latitudes. Additional species, which are not included on the Biostratigraphy Chart, are listed below with their occurrence by cores.

	Core
Dendrospyris stylophora	2-6
Liriospyris spinulosa	3-4
Dendrospyris inferispina	2-6; 8-16
Dorcadospyris argisca	2-6; 8-16
Giraffospyris didiceros	2-6; 8-16
Dendrospyris confluens	4-6; 8-16
Giraffospyris haeckelii	8-16

SUMMARY

At Site 40, 156 meters of sediment were penetrated. Drilling was terminated in a gray calcareous (?) ooze-chert unit and basement was not sampled. Apparently, the last rock drilled was chert. The fossils recovered range in age from Early to Late Eocene. Sediment cover at the site is anomalously thick relative to most of the surrounding region. Identification of acoustic basement on the seismic profiles is uncertain. However, as much as 0.42-second of sediment may overlie the basement rocks.

The sediment column is composed of three distinct units which reflect different conditions of deposition (Table 2). The bottom unit is a calcareous (?) ooze with some thin ash beds of siliceous mudstone and chert. At 143 meters, there is a change to relatively uniform radiolarian ooze: unit 2 (Cores 2 through 16, 10 to 143 meters). At 13 meters, the clay content

TABLE 2
Stratigraphic Units at Site 40

Unit	Depth (m)	Cores	Age	Description
1	0-10	1-2 pt.	?	Zeolitic "red" clay (dark reddish-brown). Small manganese nodules in first meter. Zone of phillipsite nodules (altered volcanic ash ?) at 2 meters.
2	10-143	2 pt.-16	Upper Eocene Middle Eocene Lower Eocene	Radiolarian ooze (moderate brown and dark reddish-brown). Clayey radiolarian ooze 10 to 13 meters. Pumice fragments in Core 7 (Core catcher), Core 12 (102 meters), and Core 15 (132 meters).
3	143-156	17-19	Lower Eocene	Calcareous (?) ooze-chert (black and brown chert with gray calcareous ooze). Thin chert and siliceous mudstone beds interbedded with gray calcareous oozes is interpreted from drilling record. Basement was not cored.

increases, and at 10 meters (unit 1, Cores 1 and 2, 0 to 10 meters), the lithology changes gradually to zeolitic "red" clay. Phillipsite nodules and streaks probably represent altered ash layers. Scattered fragments of pumice also reflect the influence of volcanic contributions. Dolomite rhombs in the lower cores emphasize the importance of diagenetic changes during lithification of deep-sea sediments.

This site was chosen to be representative of possible high tropical productivity during Eocene time; and, to date it has provided the best record of Eocene radiolarian evolution in the Pacific Ocean Basin. The reasons for the changes from calcareous (?) ooze to radiolarian ooze and from radiolarian ooze to zeolite "red" clay are not clear. It is apparent, however, that very little sediment has accumulated since Late Eocene time.

REFERENCE

Hayes, D. E. and Pitman III, W. C., (in press). Magnetic lineations in the North Pacific. *Geol. Soc. Am. Memoir.*

THE CORES RECOVERED FROM SITE 40

The following pages present a graphic summary of the results of drilling and coring at Site 40. Fig. 3, a summary of Site 40 is at the back of the book. Figures 4 to 21 are summaries of the individual cores recovered. A key to the lithologic symbols is given in the Introduction (Chapter 1).

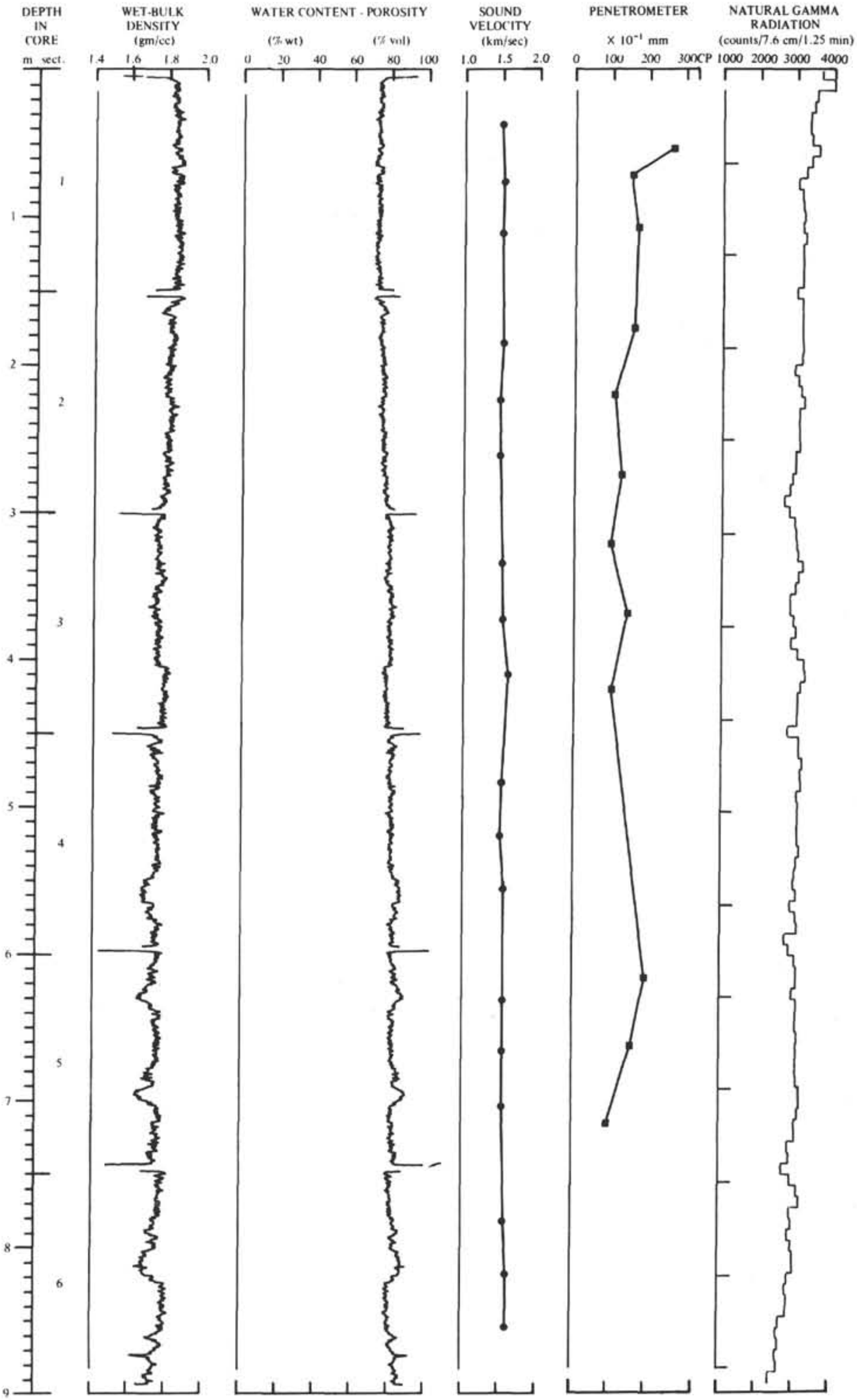

Figure 4A. *Physical Properties of Core 1, Hole 40*

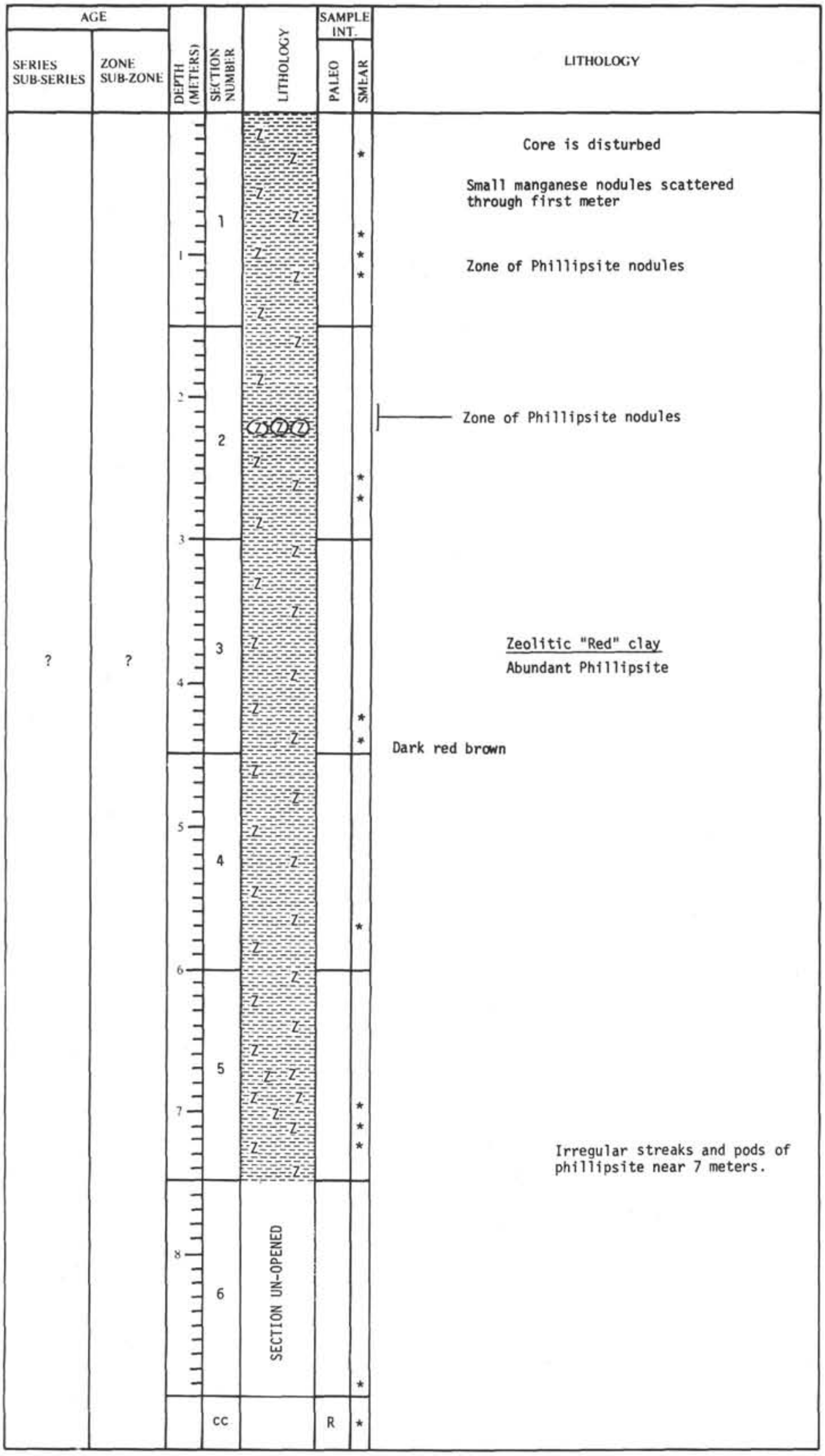

Figure 4B. *Core 1, Hole 40 (0-9 m Below Seabed)*

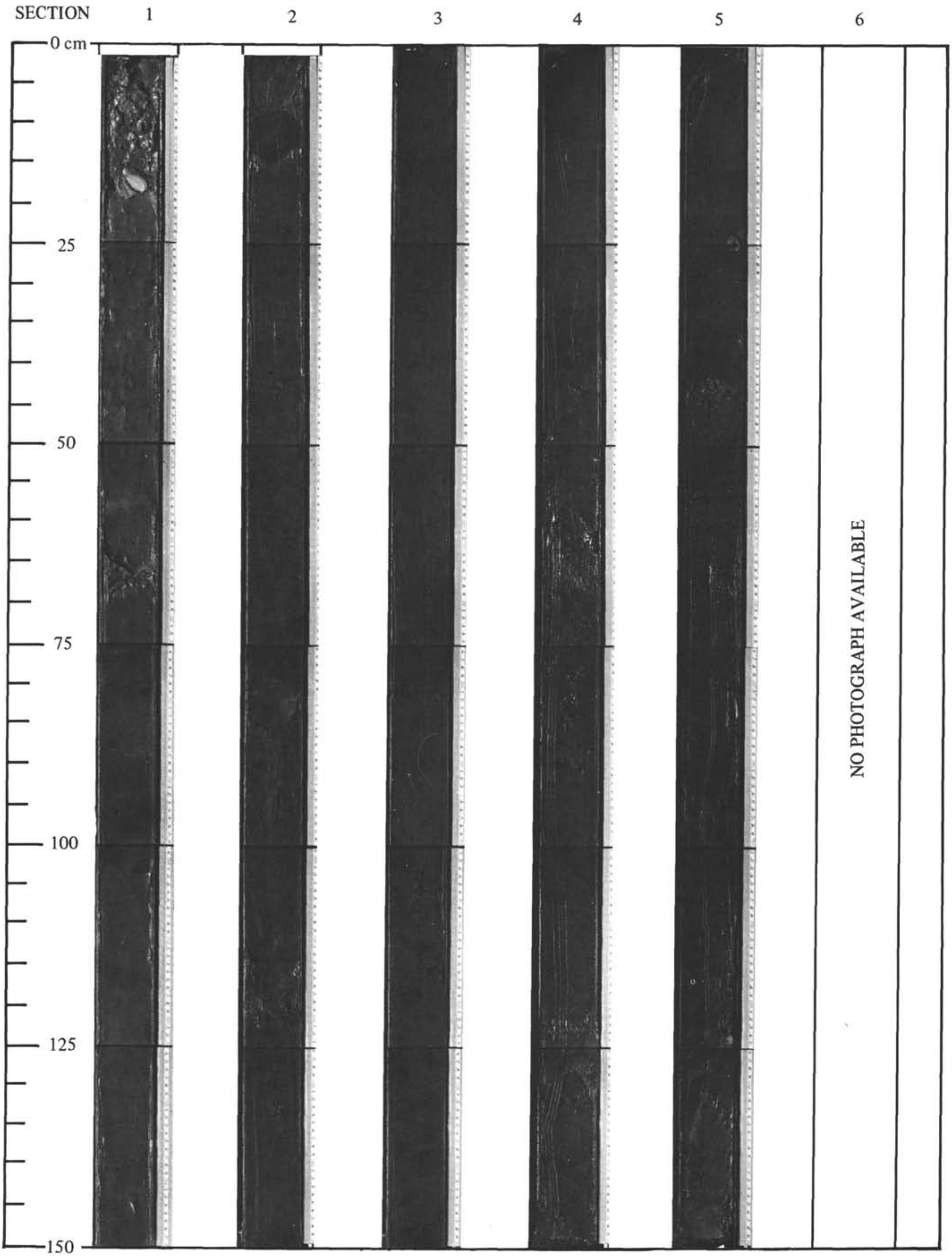

Plate 1. *Core 1, Hole 40*

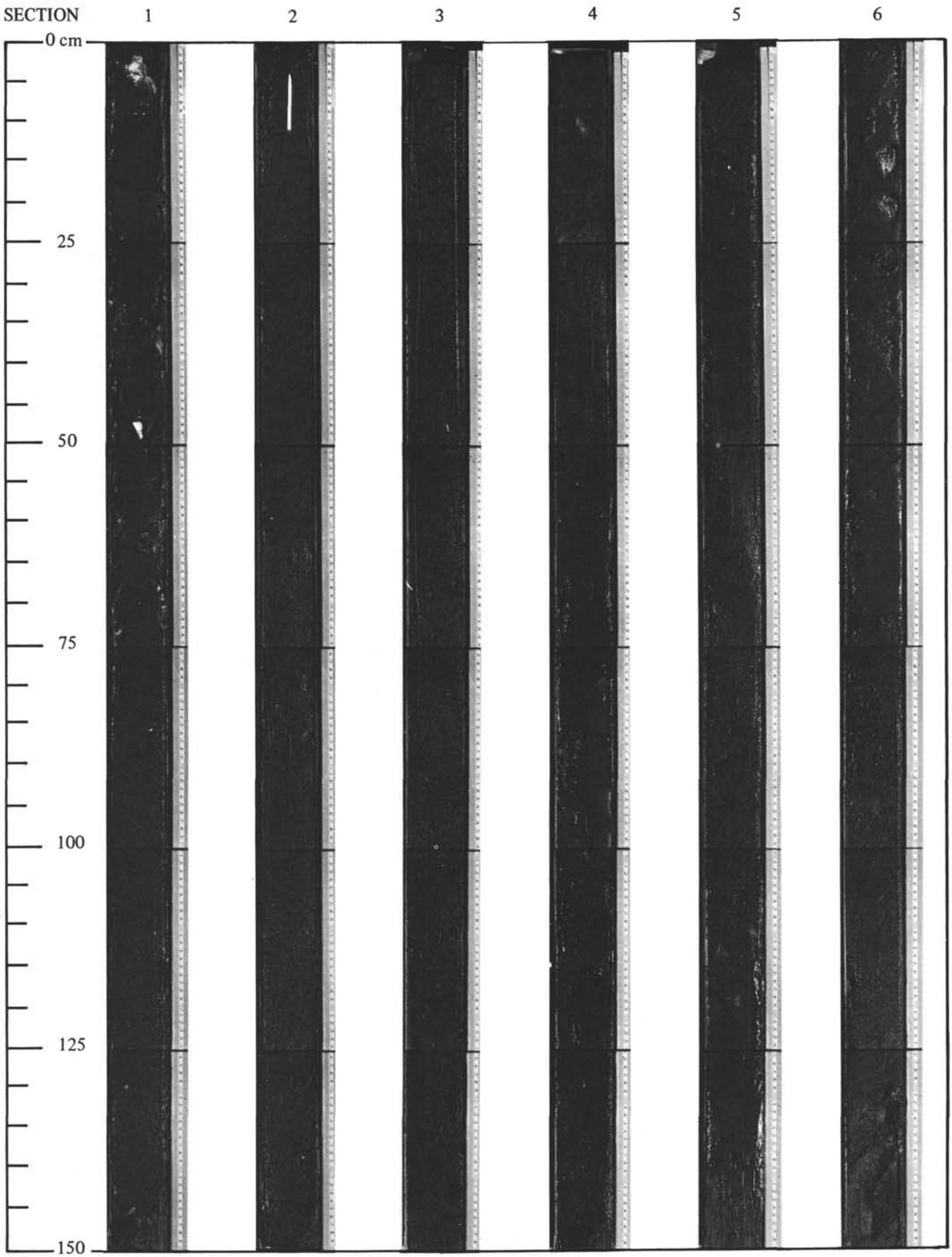

Plate 2. *Core 2, Hole 40*

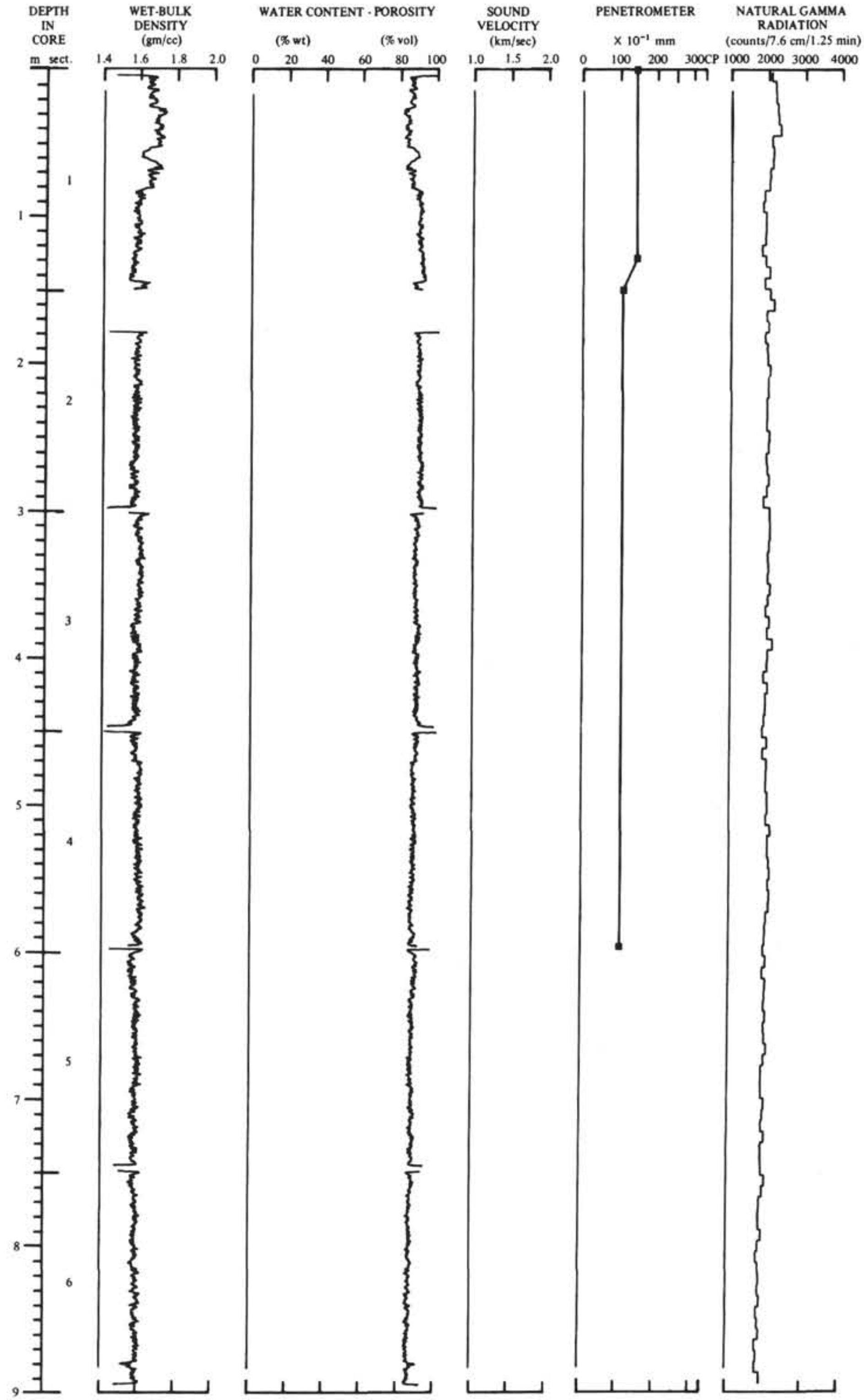

Figure 5A. *Physical Properties of Core 2, Hole 40*

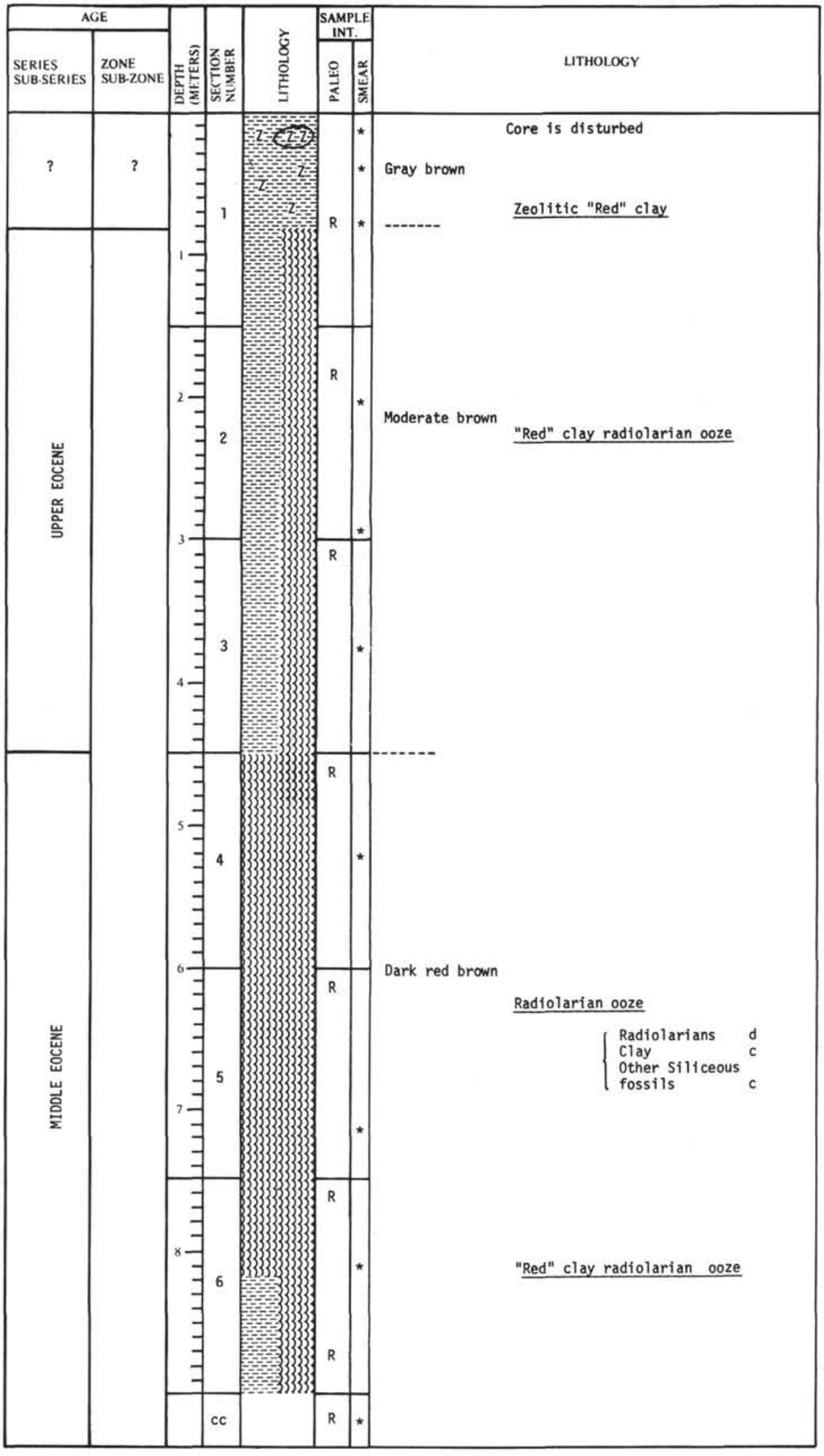

Figure 5B. *Core 2, Hole 40 (9-18 m Below Seabed)*

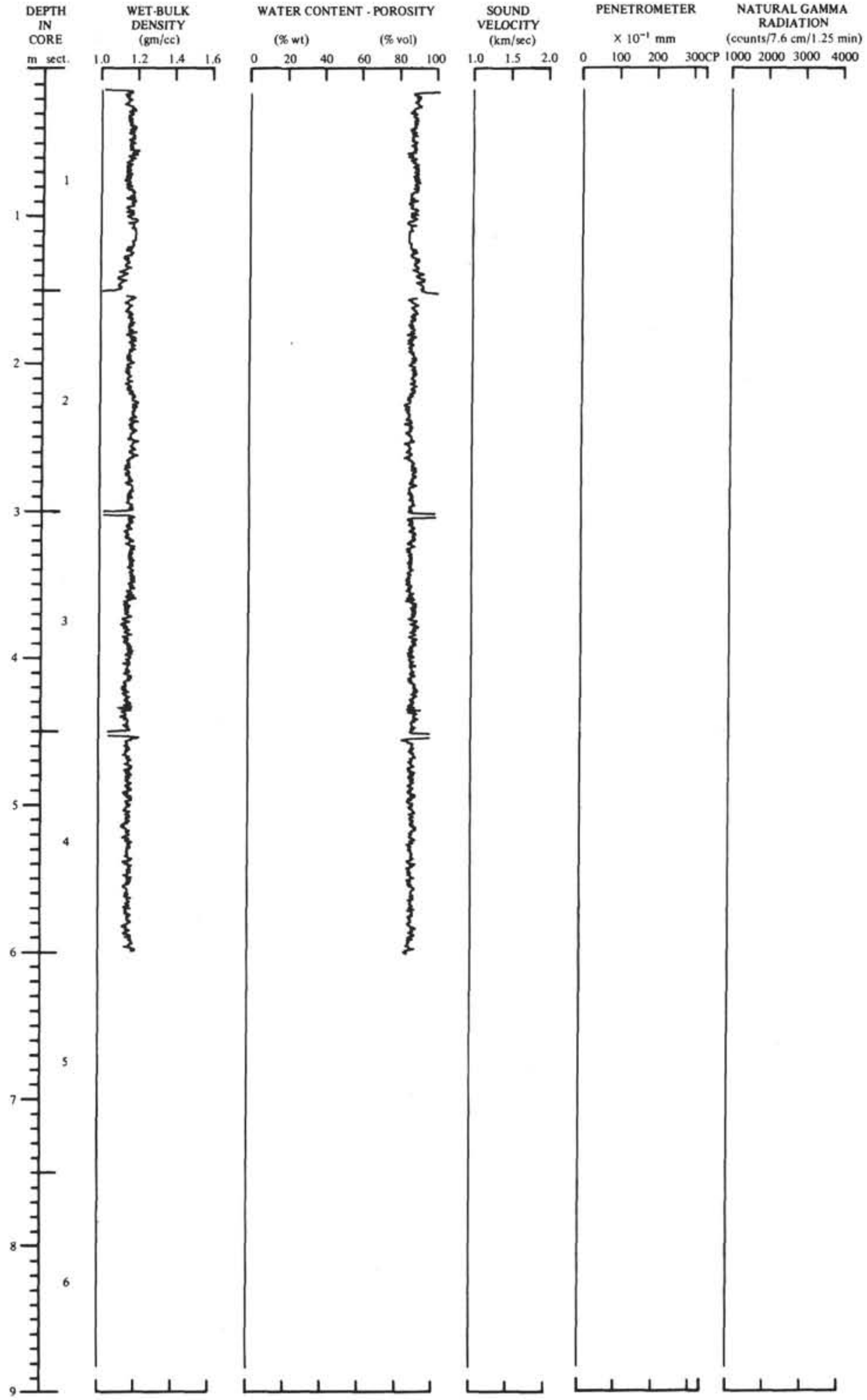

Figure 6A. *Physical Properties of Core 3, Hole 40*

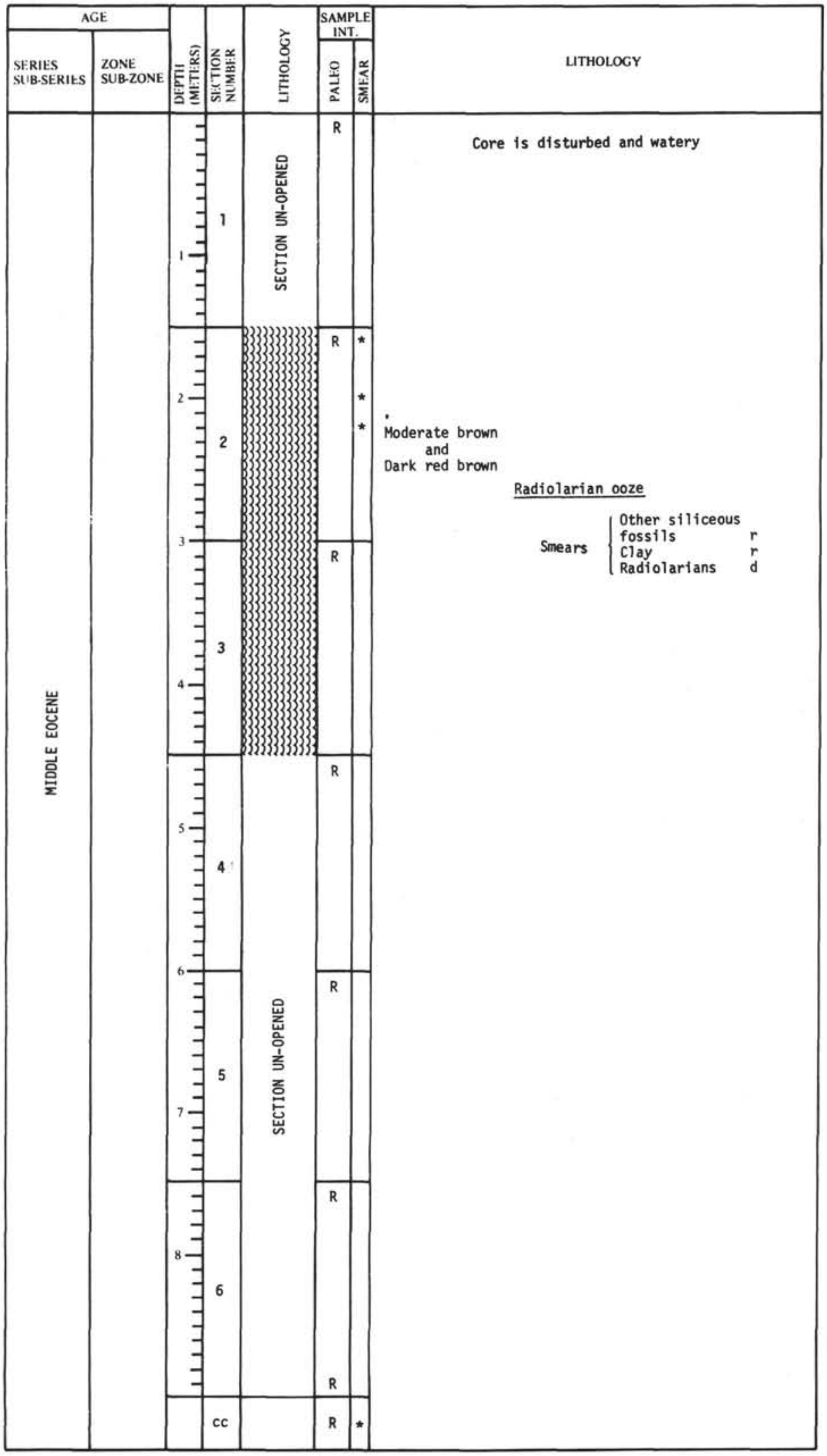

Figure 6B. *Core 3, Hole 40 (18-27 m Below Seabed)*

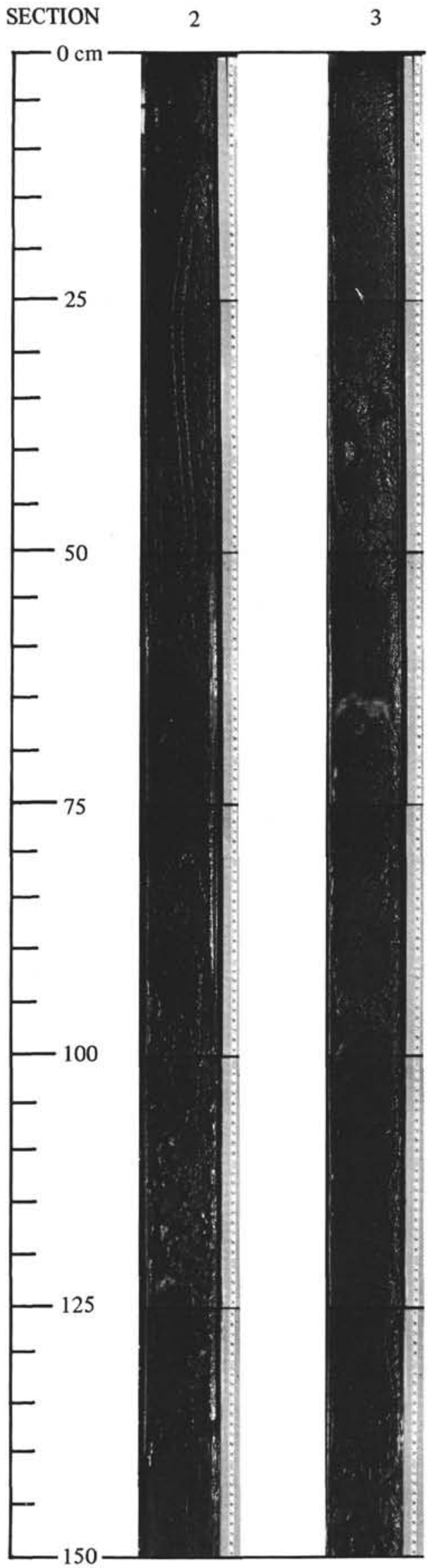

Plate 3. *Sections from Core 3, Hole 40.*

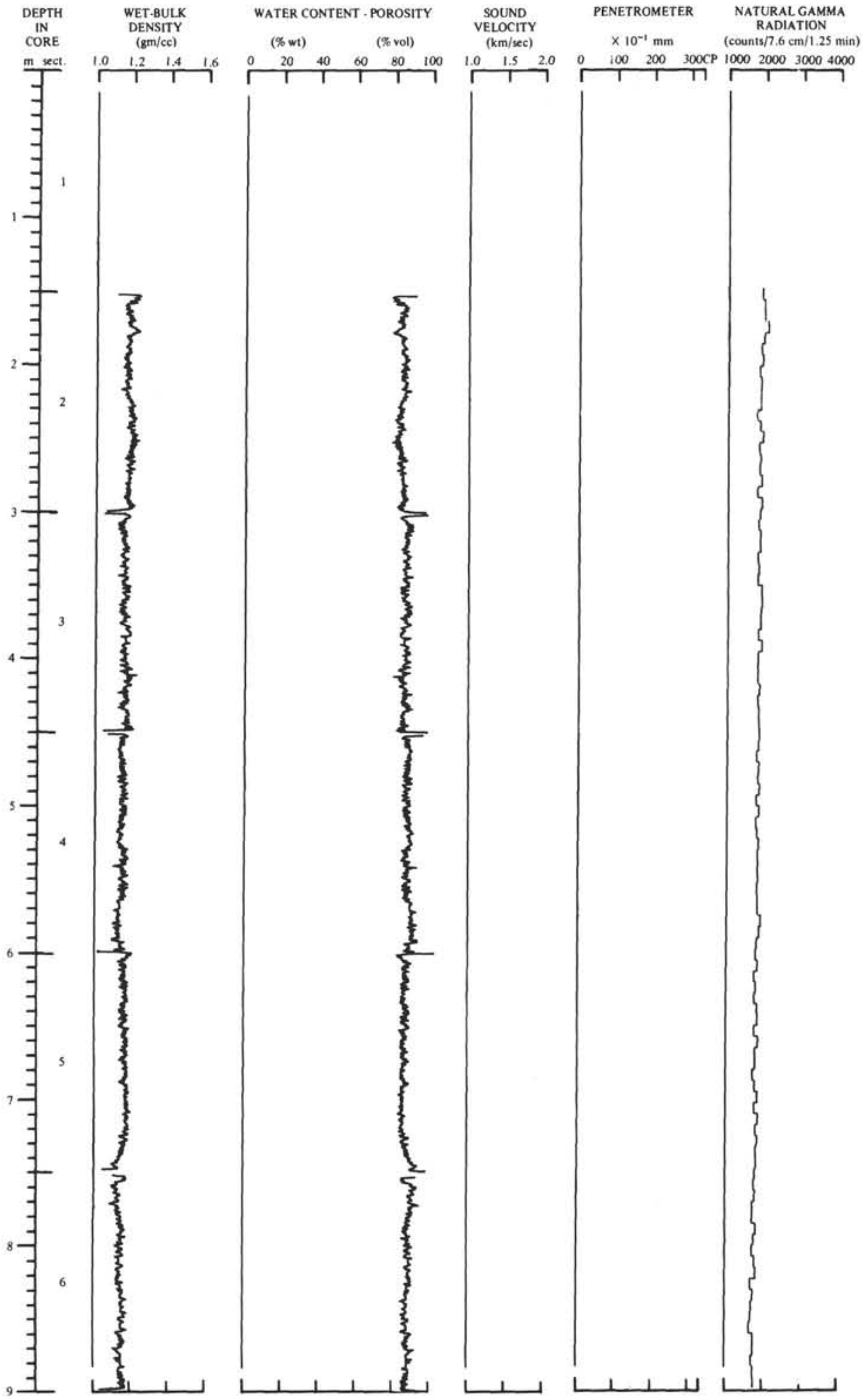

Figure 7A. *Physical Properties of Core 4, Hole 40*

AGE		DEPTH (METERS)	SECTION NUMBER	LITHOLOGY	SAMPLE INT.		LITHOLOGY
SERIES SUB-SERIES	ZONE SUB-ZONE				PALEO	SMEAR	
MIDDLE EOCENE		1	1	CORE UN-OPENED	R	*	Core is disturbed and water injected
		2, 3	2		R		
		4	3		R	*	Dark red brown
		5, 6	4		R		Radiolarian ooze
		7	5		R	*	
		8	6		R		
			cc		R		

Figure 7B. *Core 4, Hole 40 (27-36 m Below Seabed)*

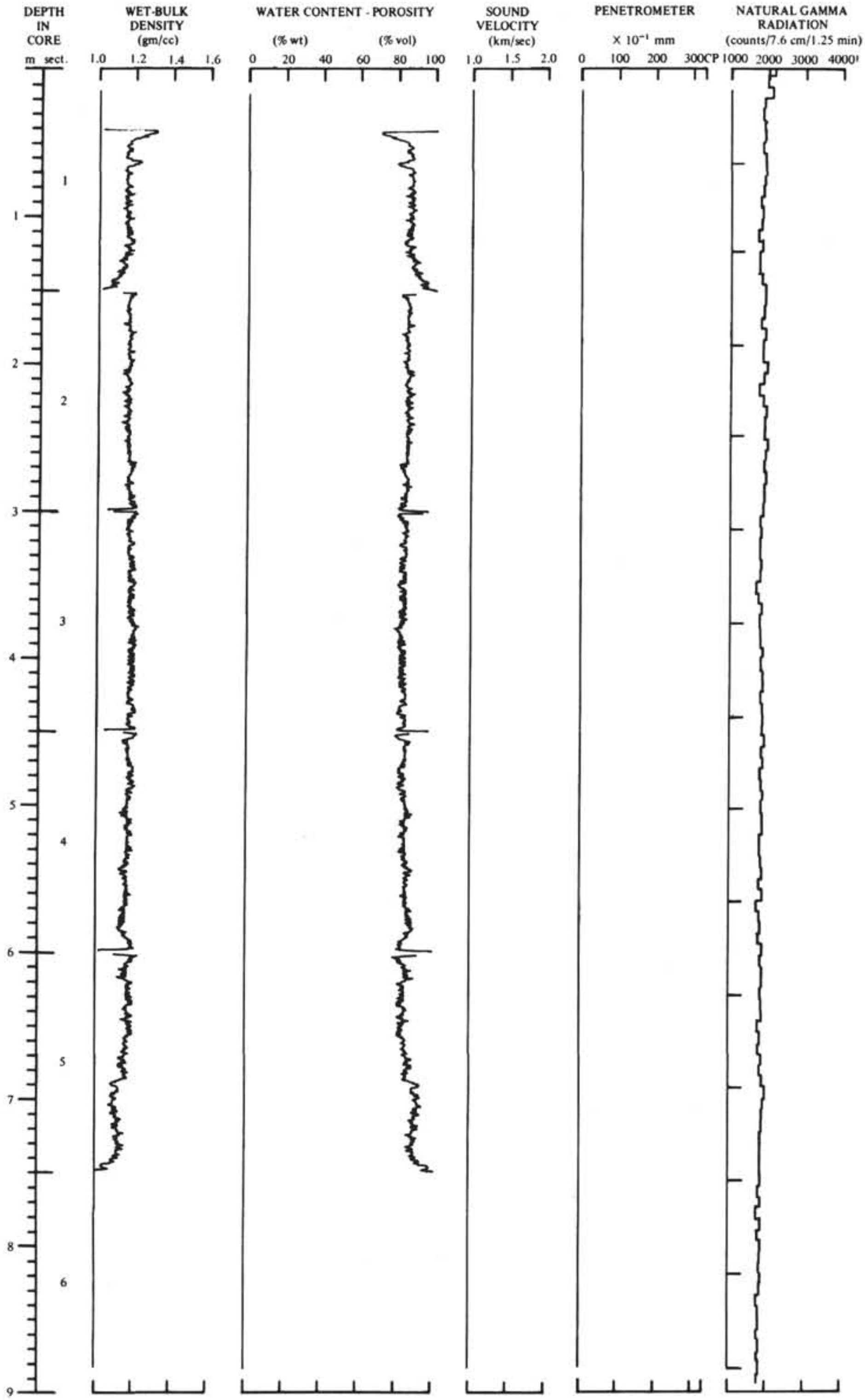

Figure 8A. *Physical Properties of Core 5, Hole 40*

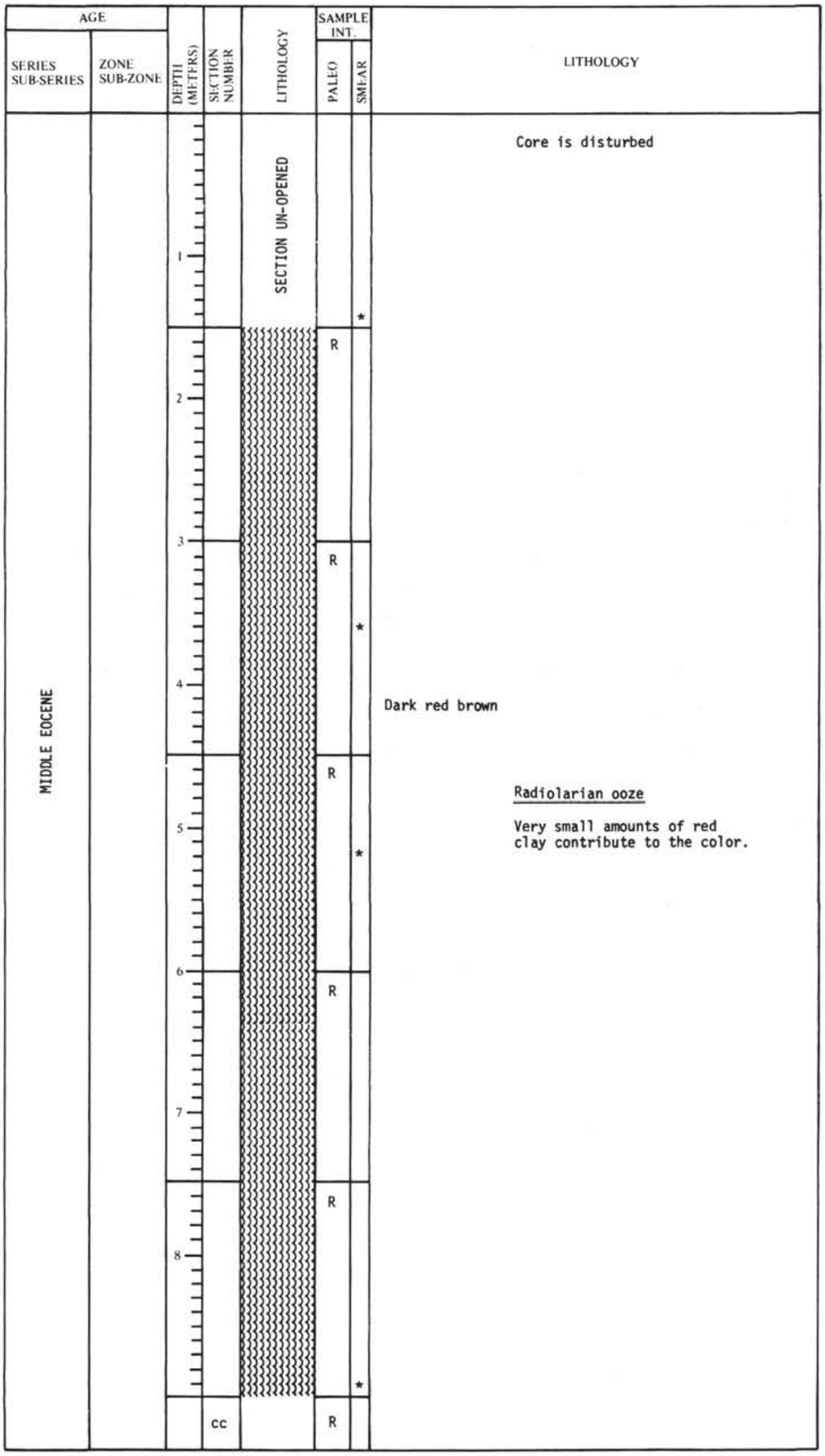

Figure 8B. *Core 5, Hole 40 (36-45 m Below Seabed)*

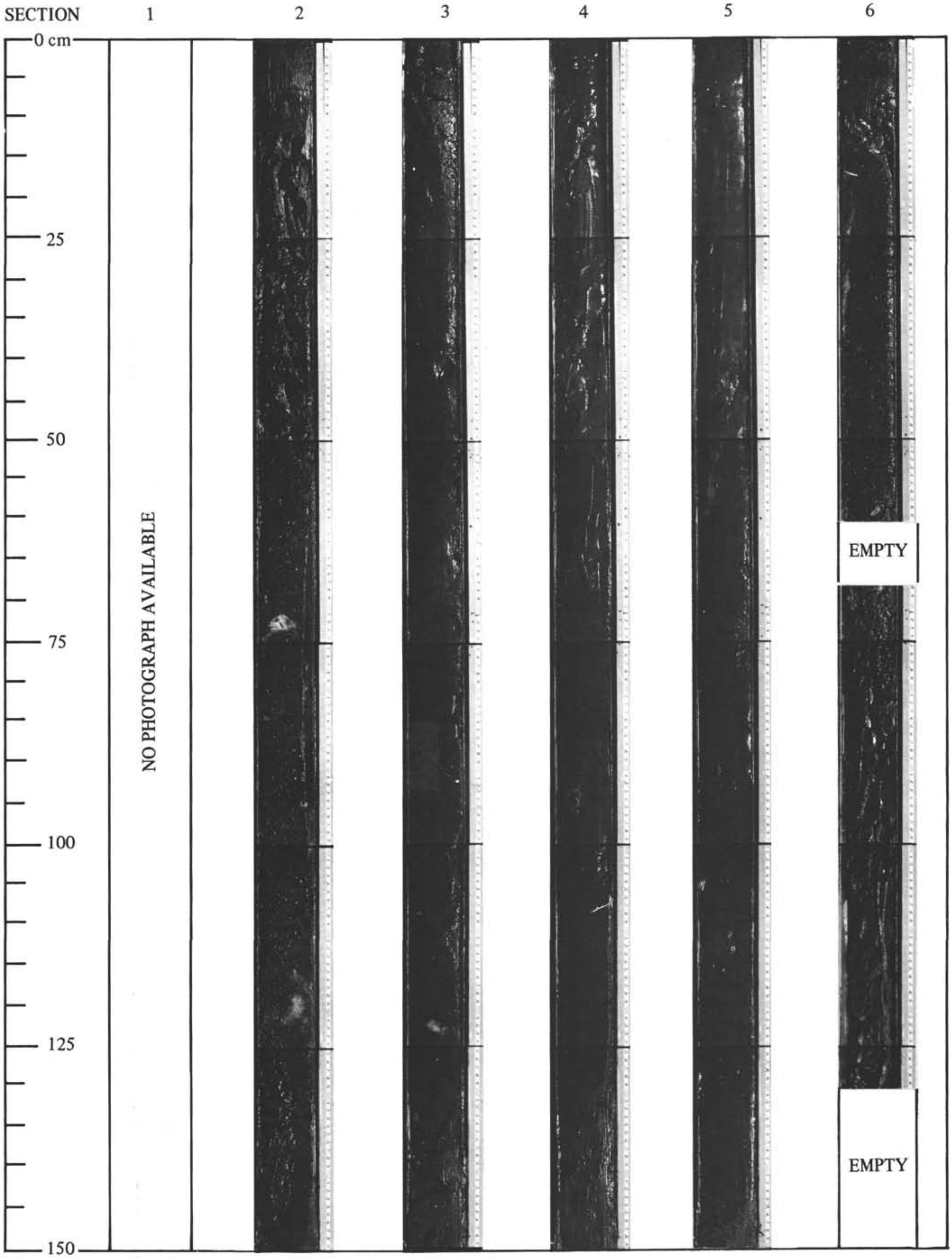

Plate 4. *Core 5, Hole 40*

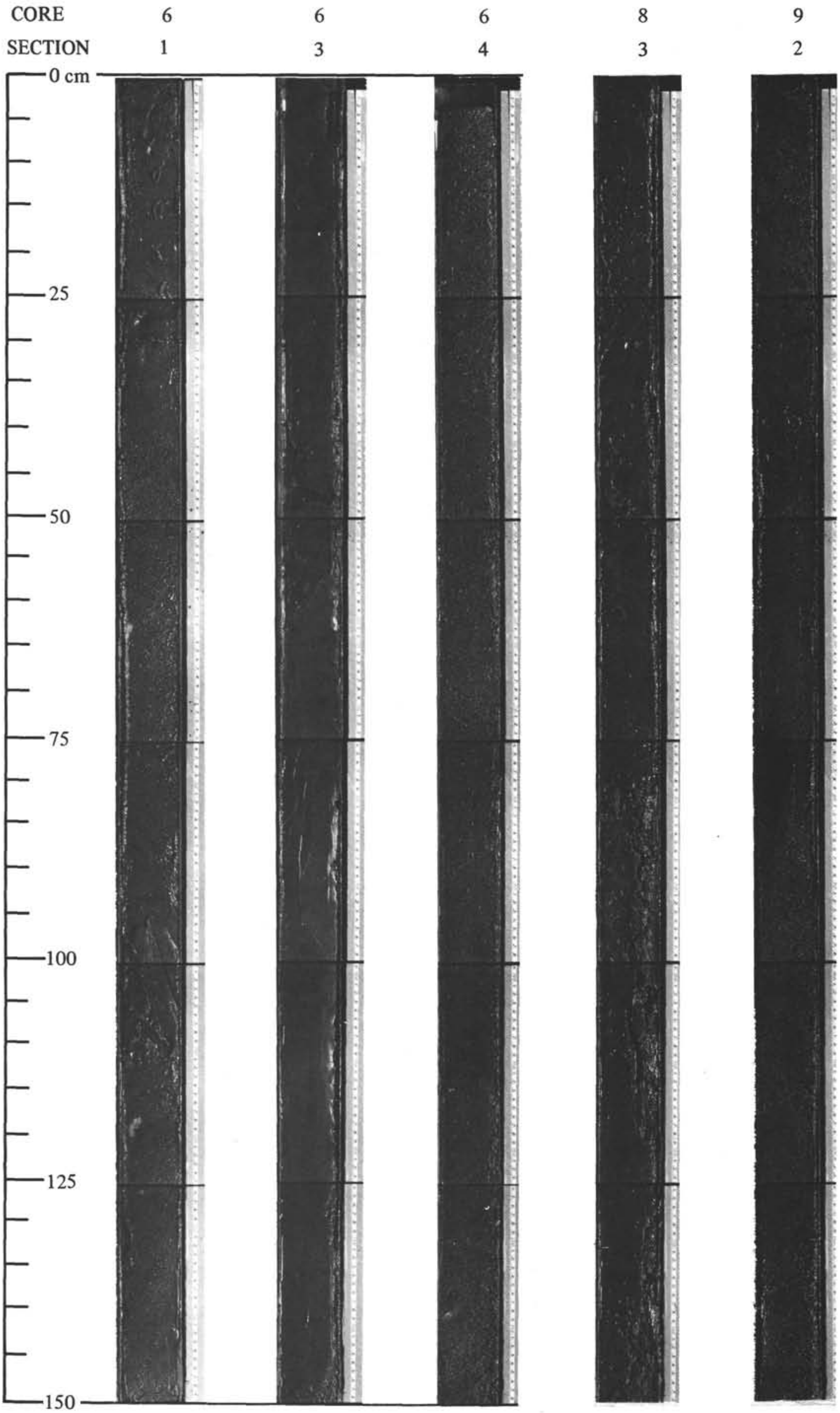

Plate 5. *Sections of Cores from Hole 40 (Cores 6, 8, and 9)*

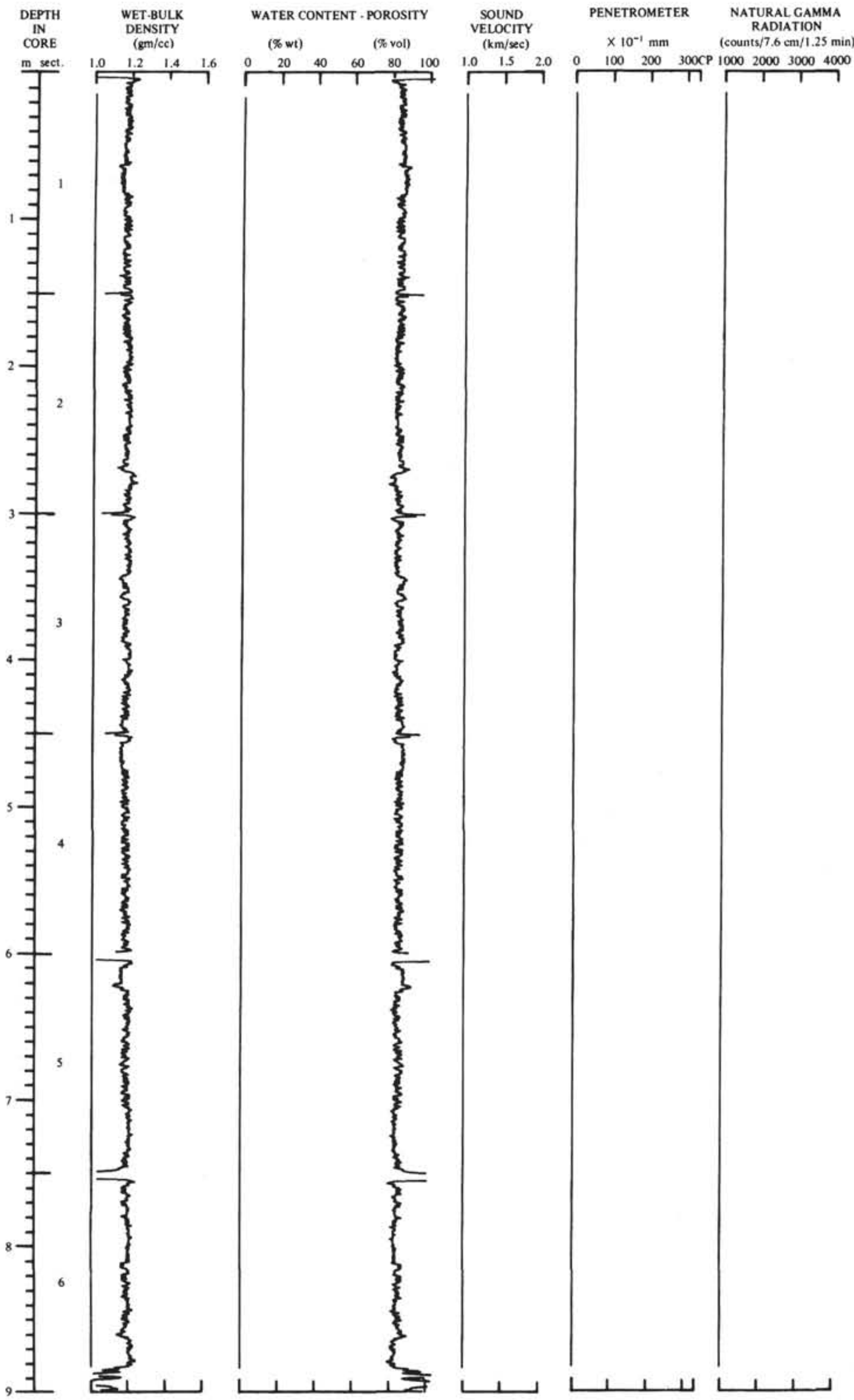

Figure 9A. *Physical Properties of Core 6, Hole 40*

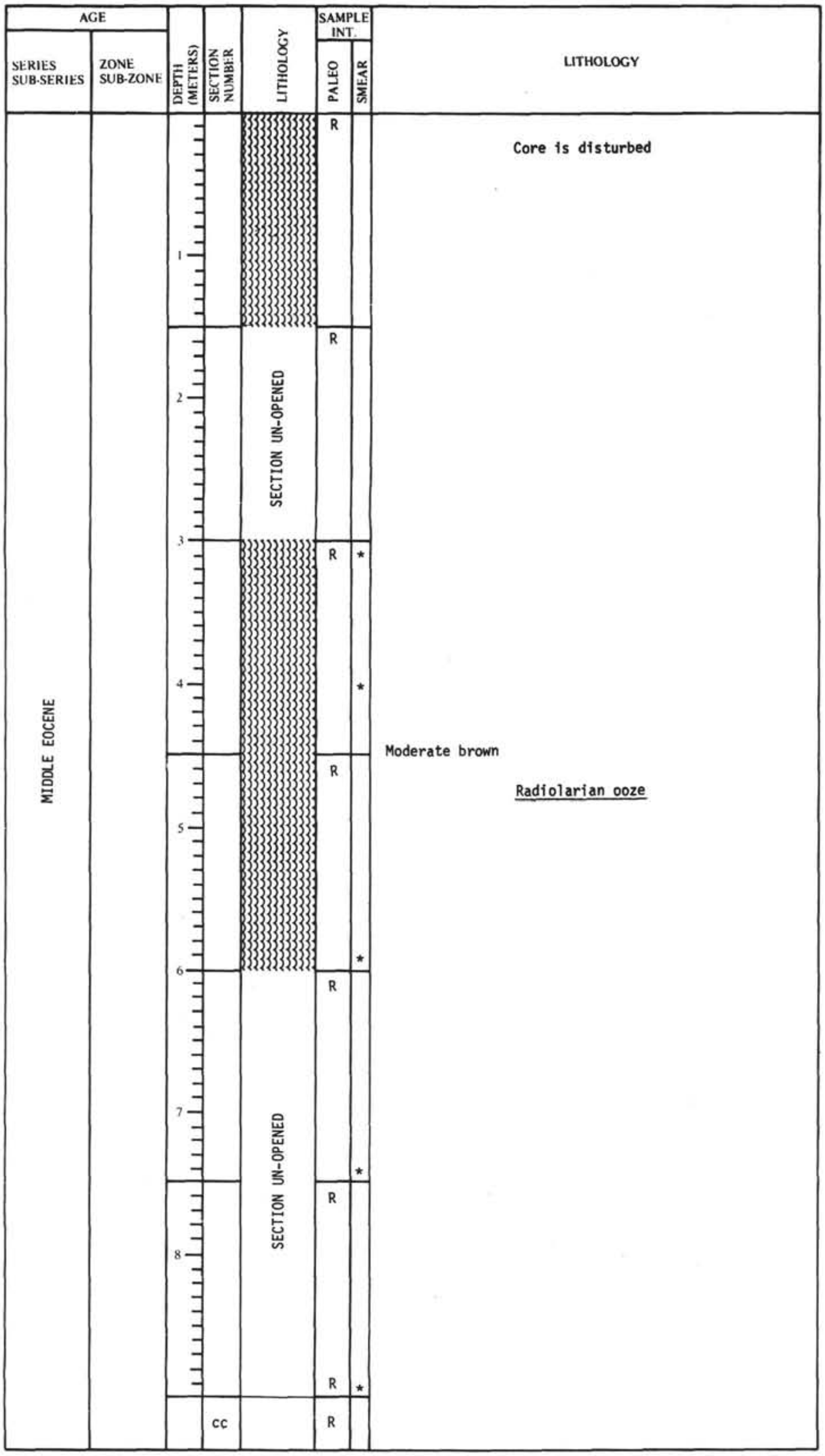

Figure 9B. *Core 6, Hole 40 (48-57 m Below Seabed)*

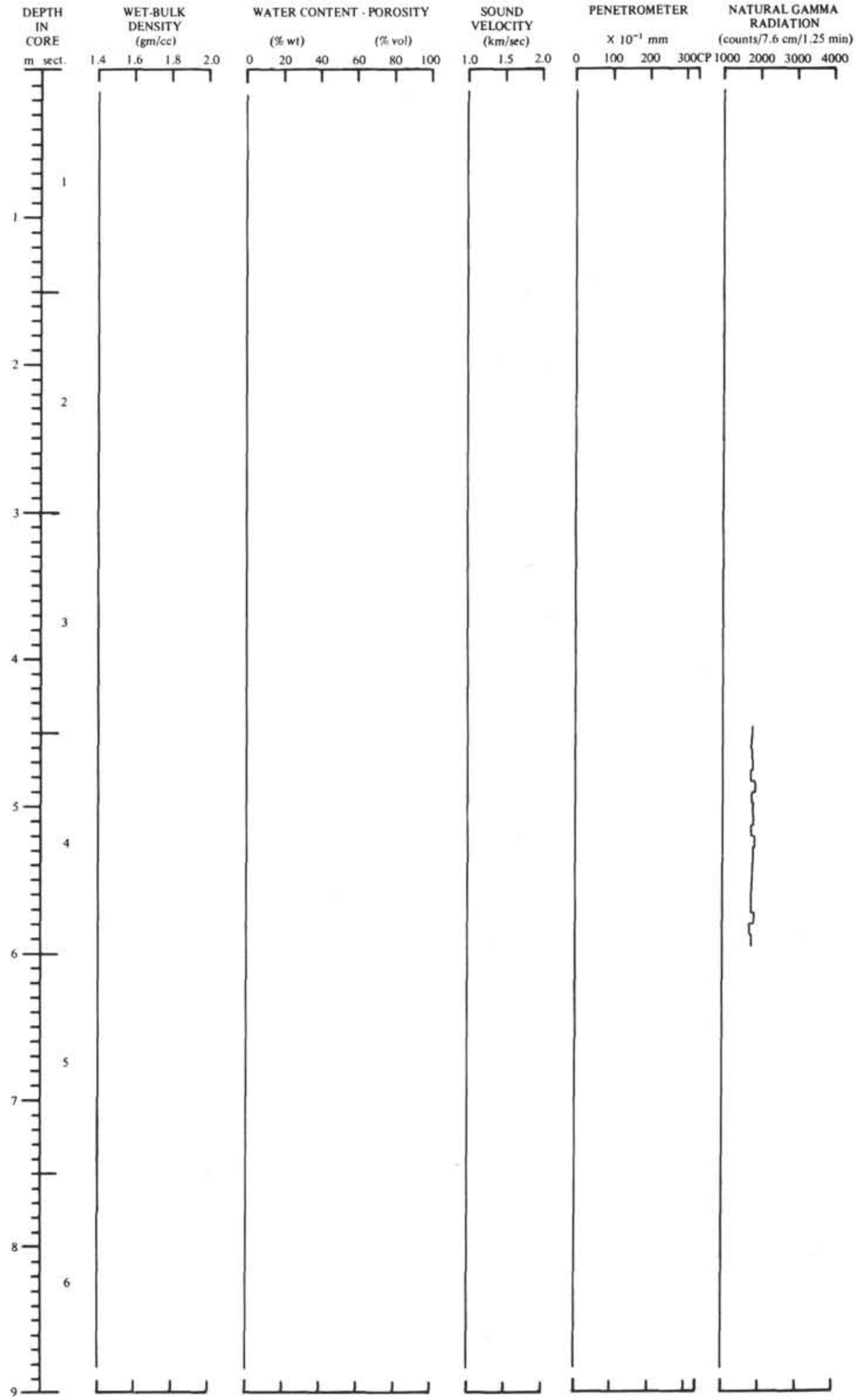

Figure 10A. *Physical Properties of Core 8, Hole 40*

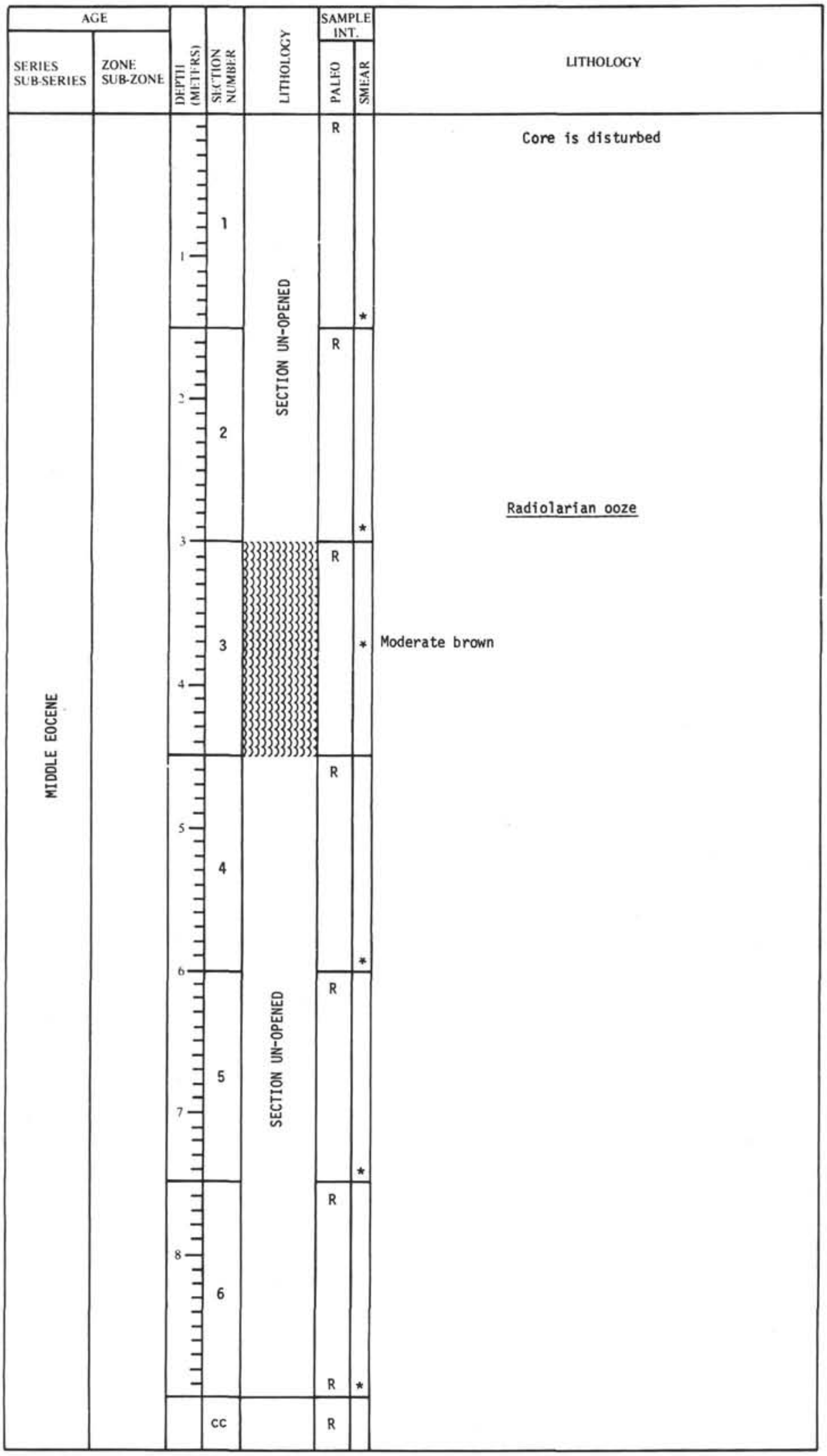

Figure 10B. *Core 8, Hole 40 (66-75 m Below Seabed)*

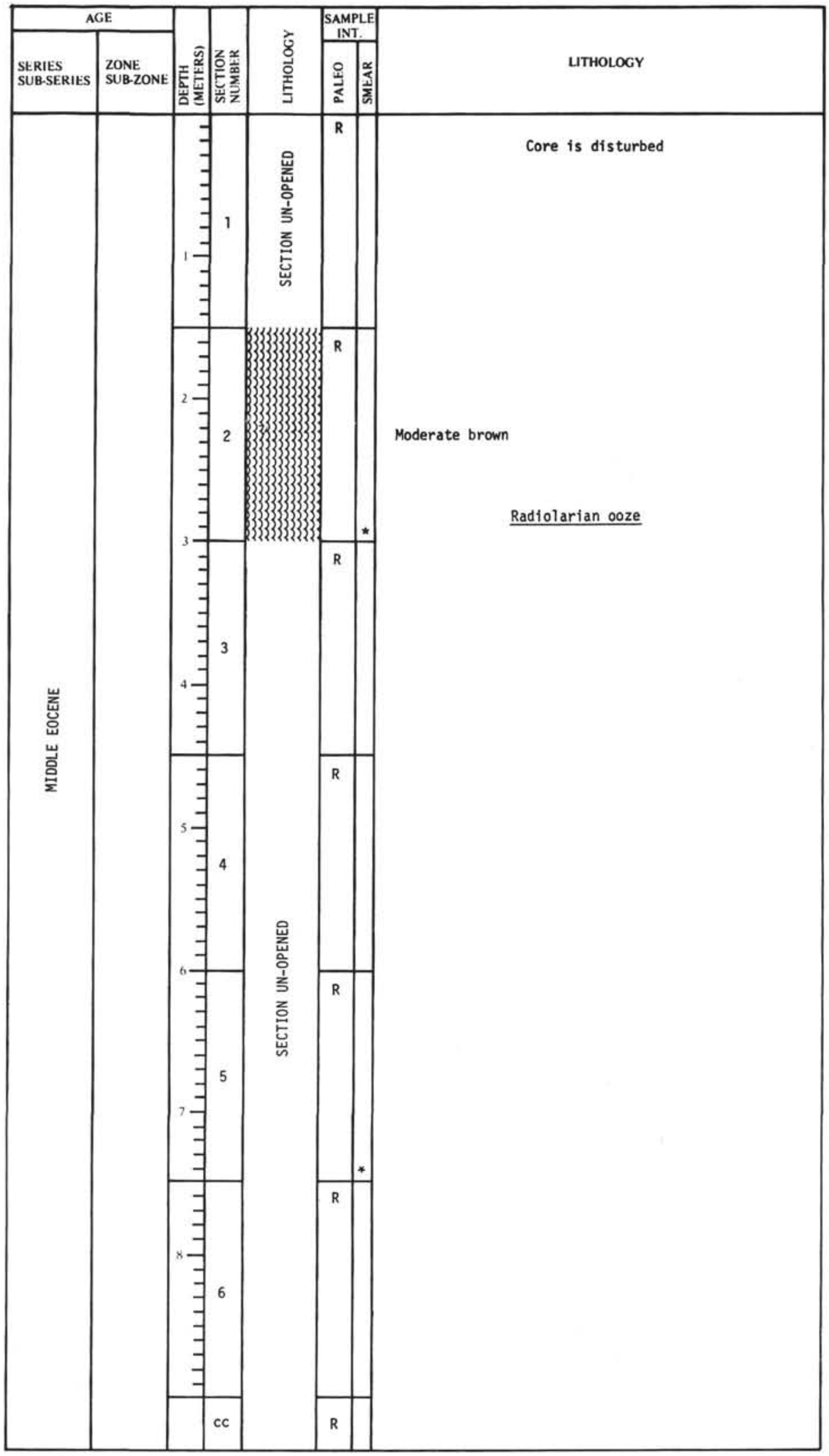

Figure 11. *Core 9, Hole 40 (75-84 m Below Seabed)*

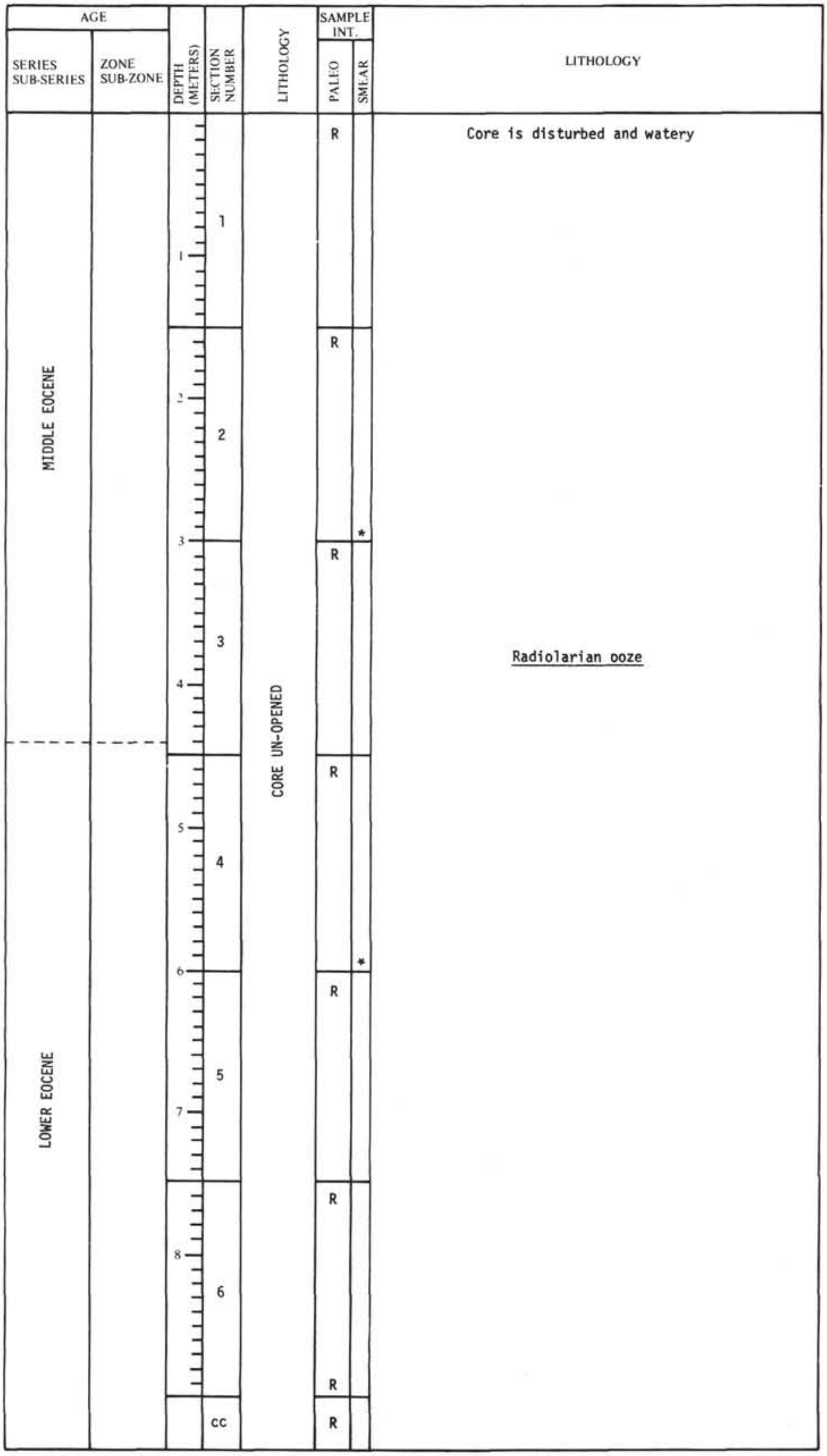

Figure 12. *Core 10, Hole 40 (84-93 m Below Seabed)*

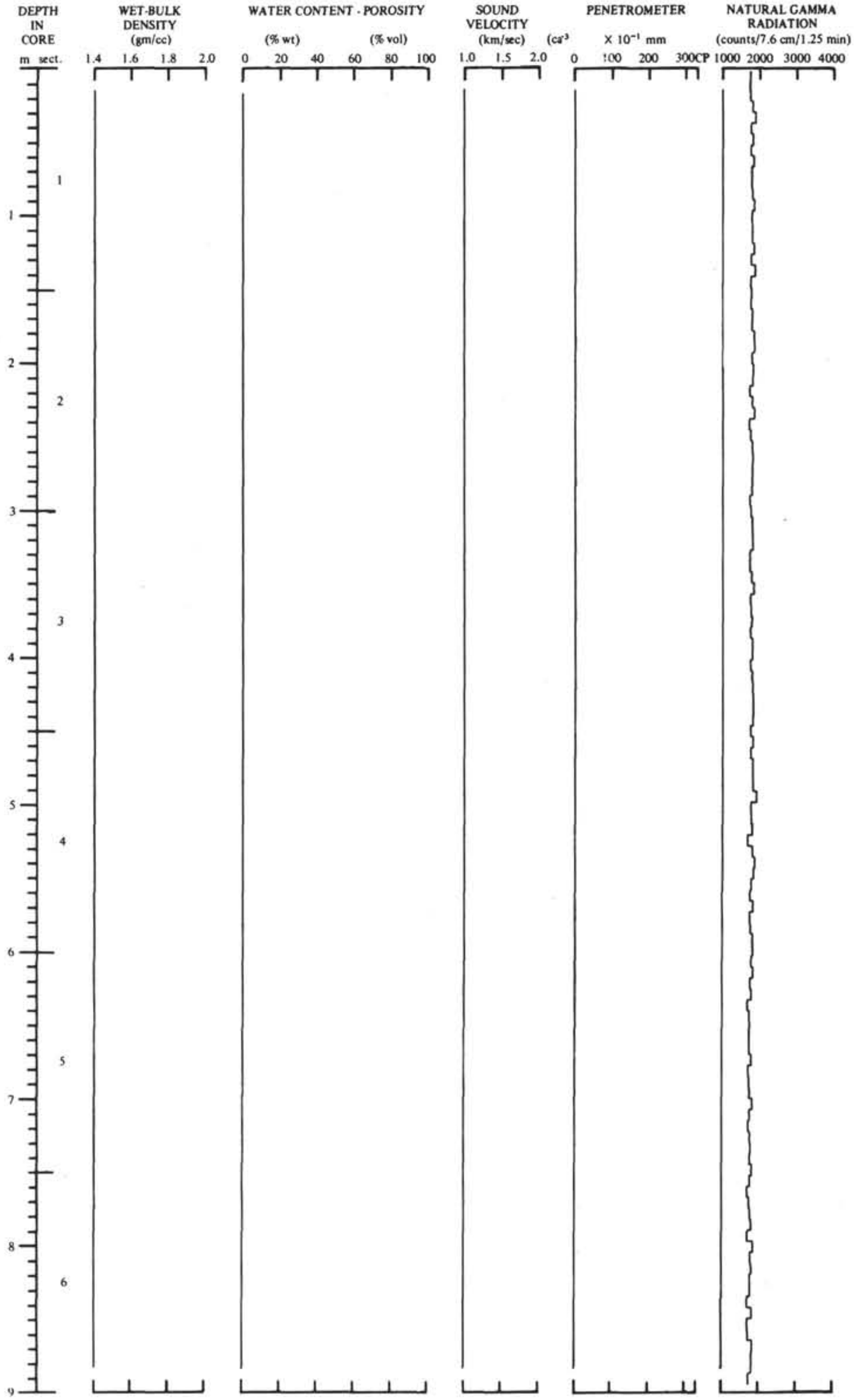

Figure 13A. *Physical Properties of Core 11, Hole 40*

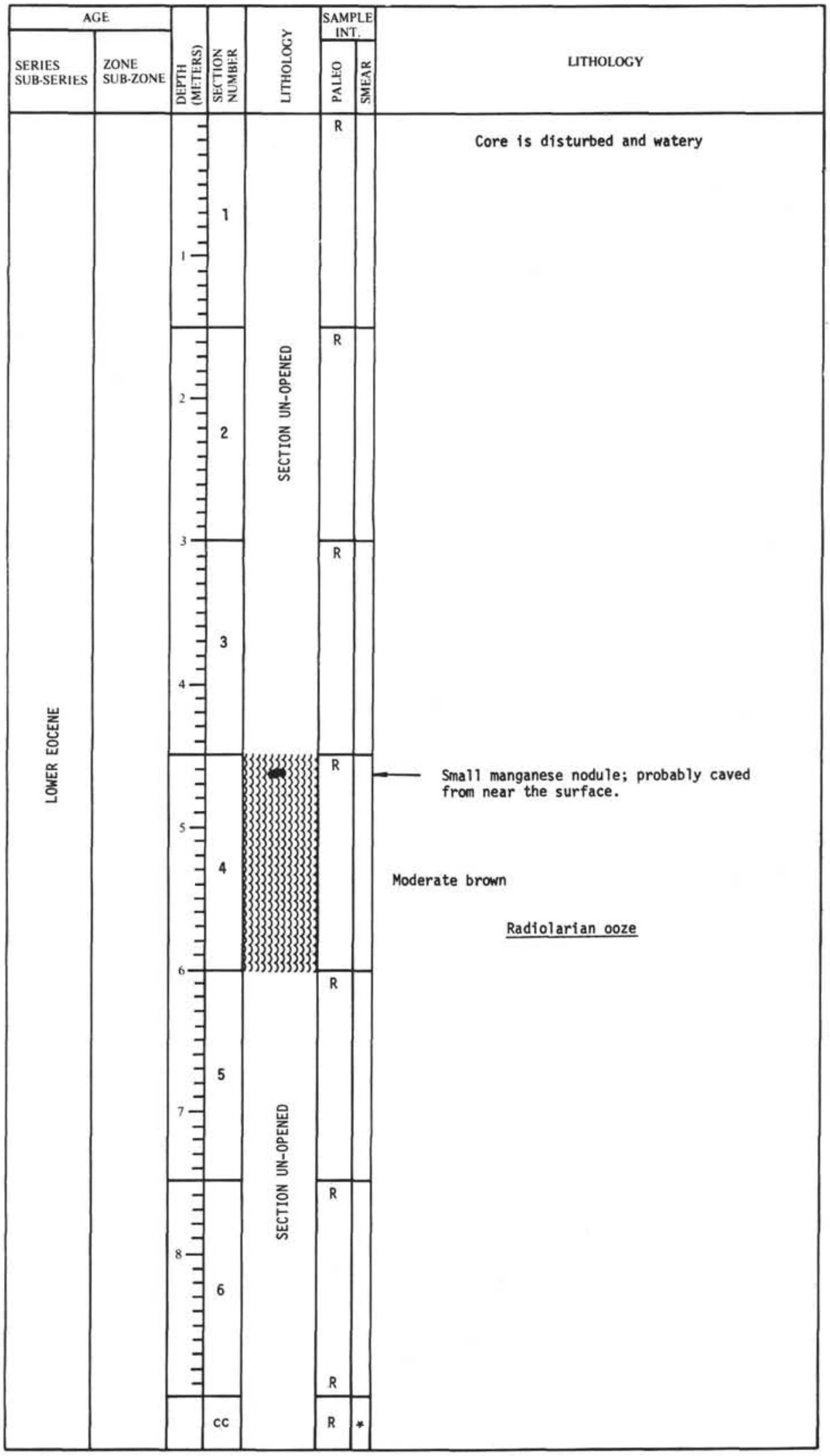

Figure 13B. *Core 11, Hole 40 (93-102 m Below Seabed)*

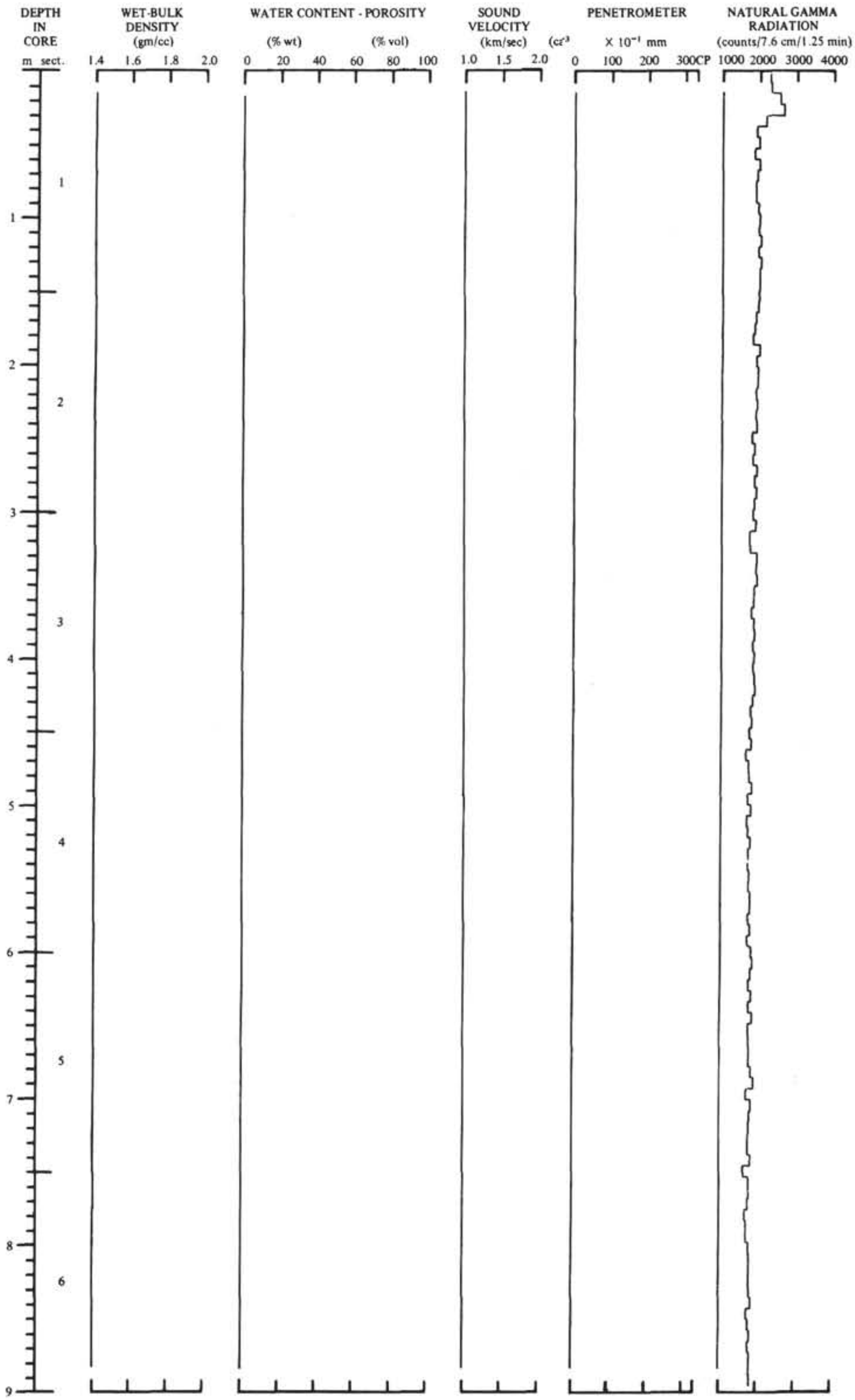

Figure 14A. *Physical Properties of Core 12, Hole 40*

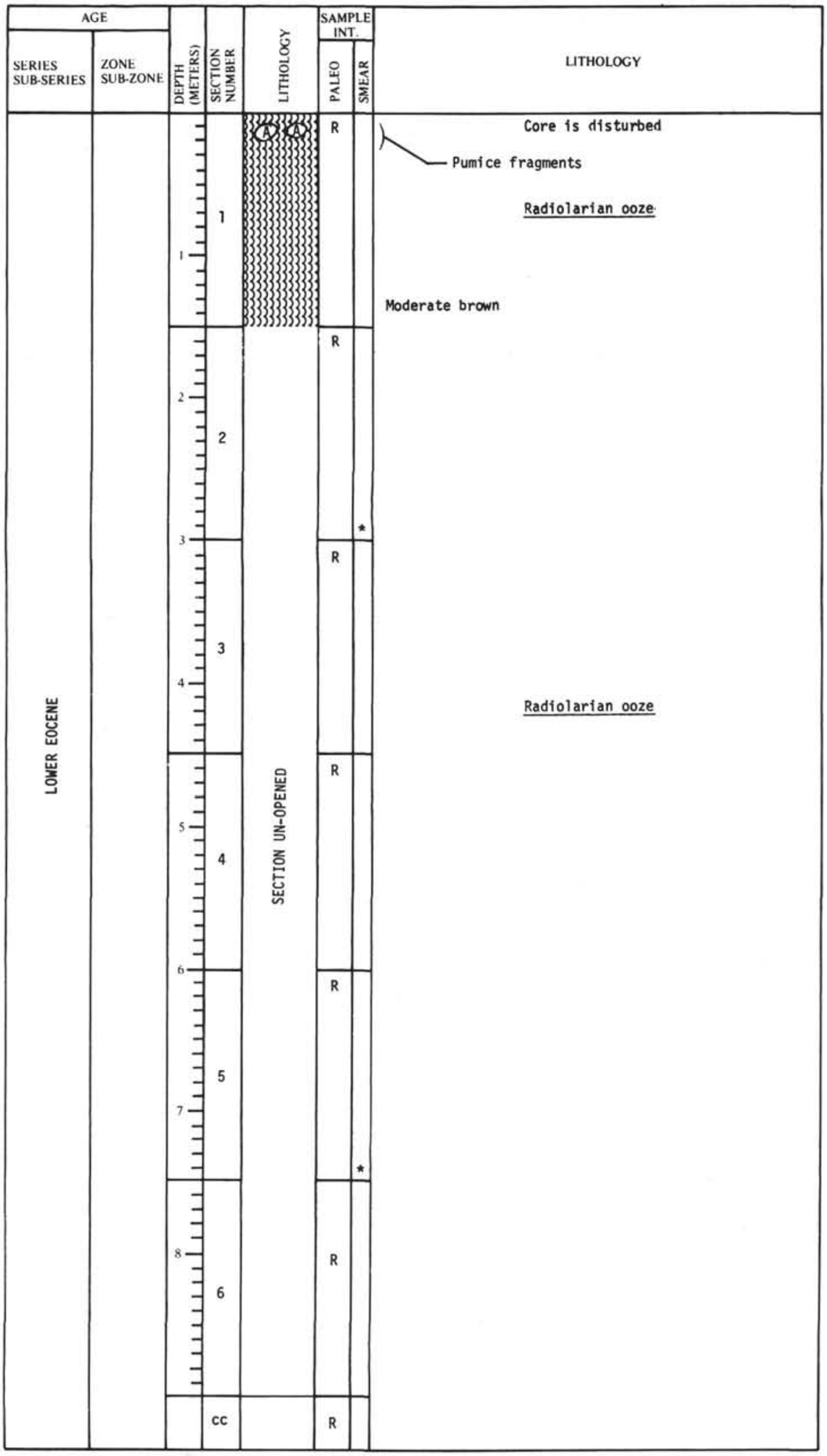

Figure 14B. *Core 12, Hole 40 (102-112 m Below Seabed)*

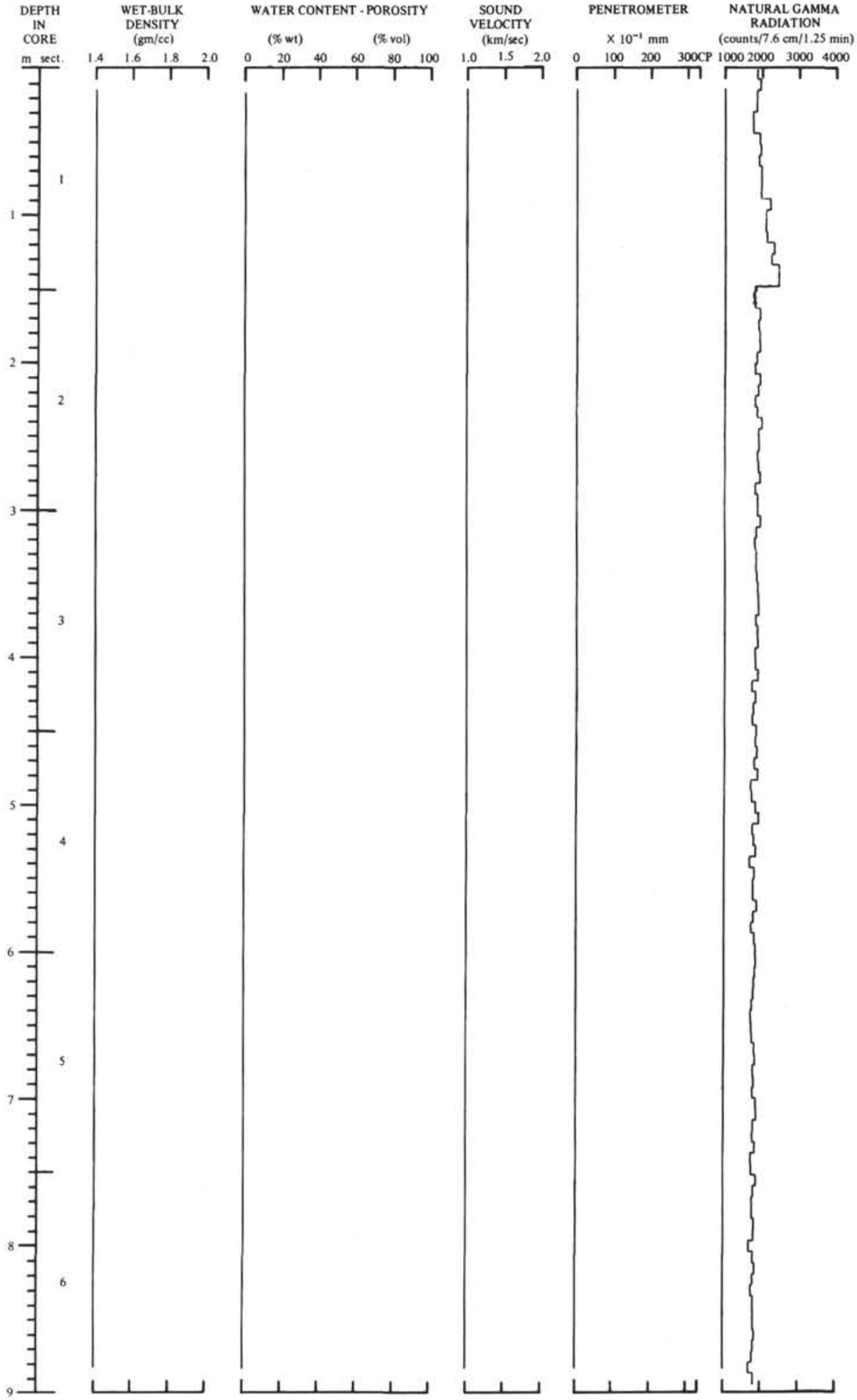

Figure 15A. *Physical Properties of Core 13, Hole 40*

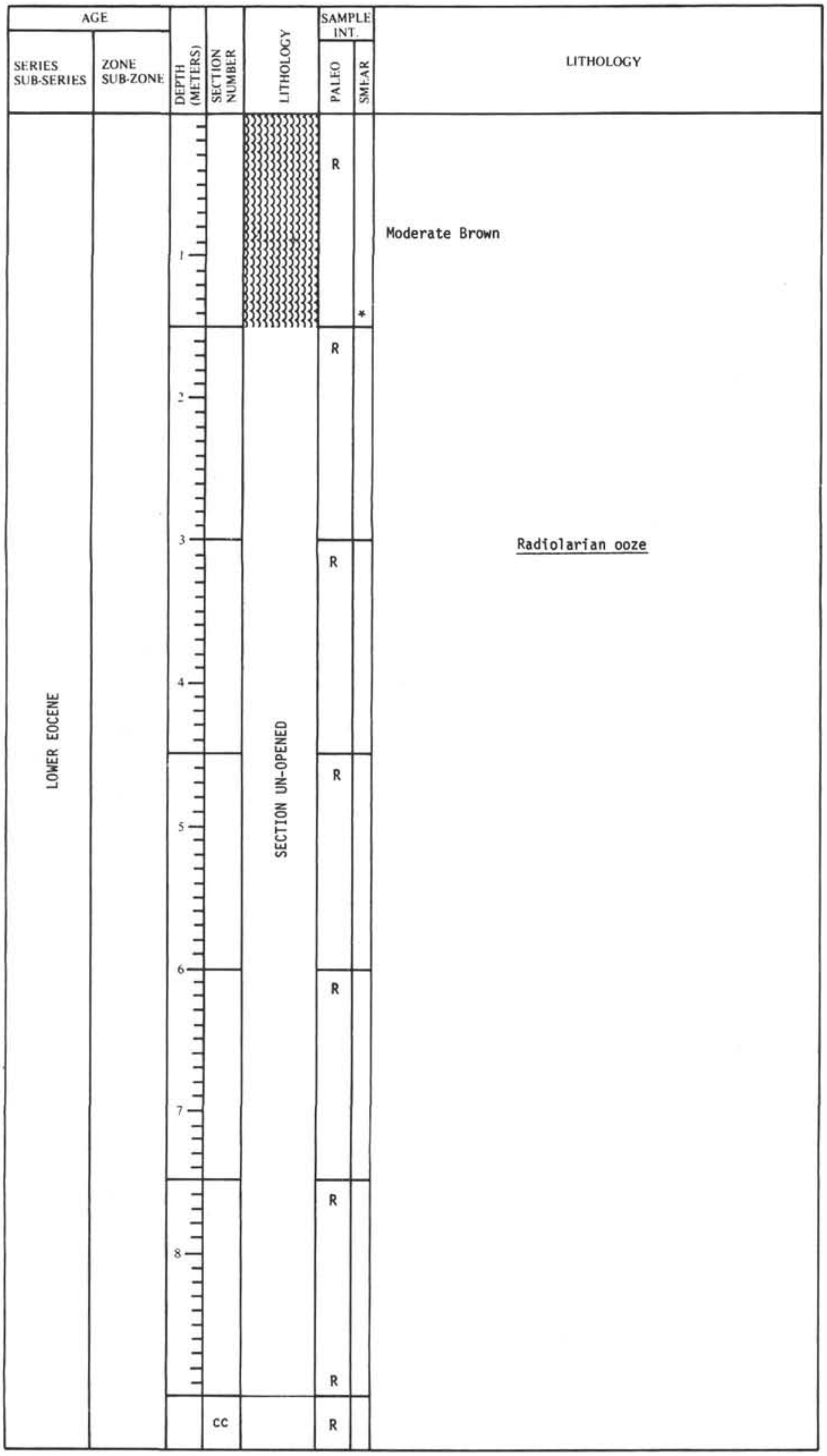

Figure 15B. *Core 13, Hole 40 (112-121 m Below Seabed)*

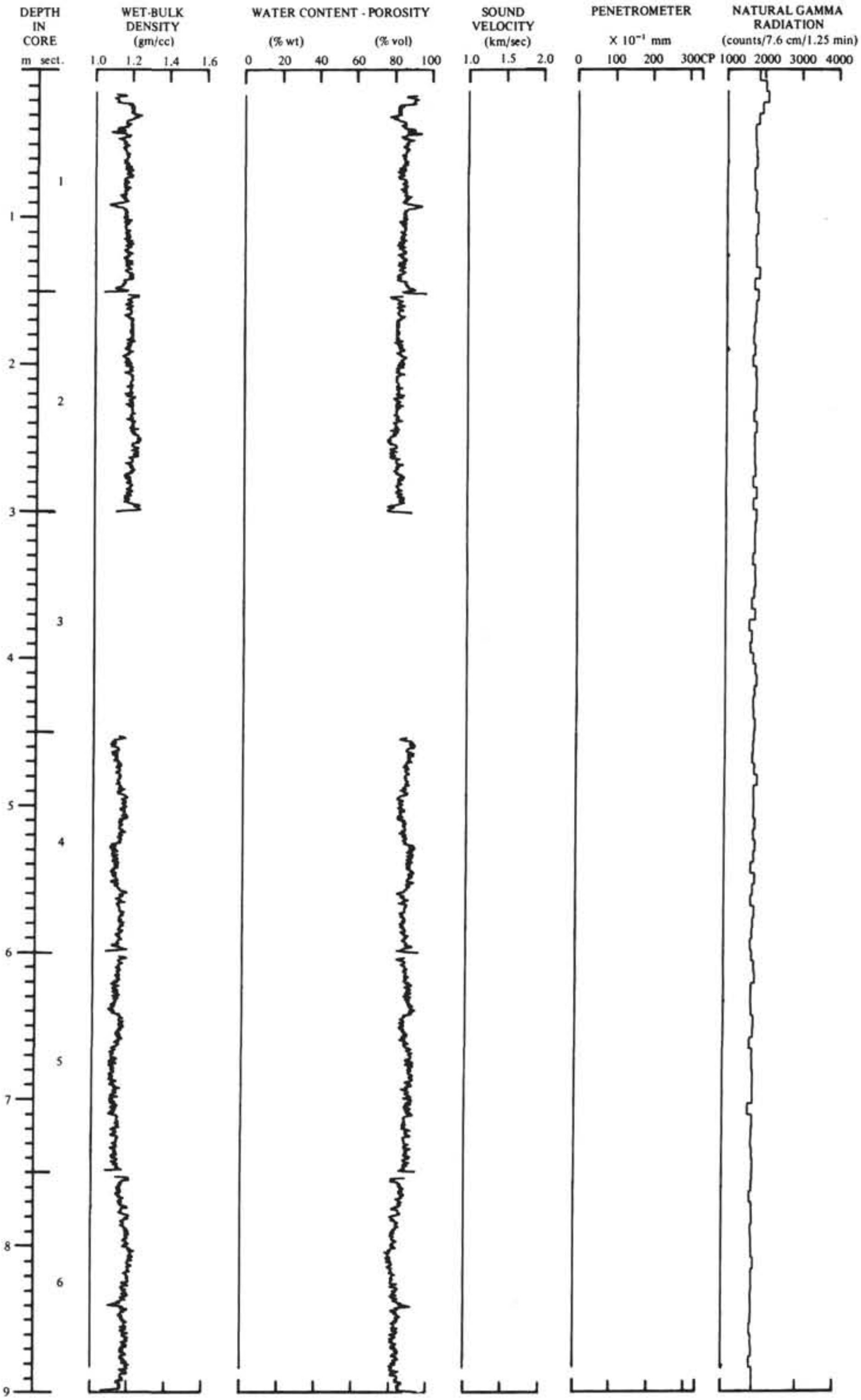

Figure 16A. *Physical Properties of Core 14, Hole 40*

AGE					SAMPLE INT.		
SERIES SUB-SERIES	ZONE SUB-ZONE	DEPTH (METERS)	SECTION NUMBER	LITHOLOGY	PALEO	SMEAR	LITHOLOGY
LOWER EOCENE		1	1	SECTION UN-OPENED	R		Core is disturbed and watery
		2	2	SECTION UN-OPENED	R		
		3, 4	3		R	*	Moderate brown Radiolarian ooze
		5	4	SECTION UN-OPENED	R		
		6, 7	5	SECTION UN-OPENED	R		
		8	6	SECTION UN-OPENED	R, R		
			CC		R		

Figure 16B. *Core 14, Hole 40 (121-130 m Below Seabed)*

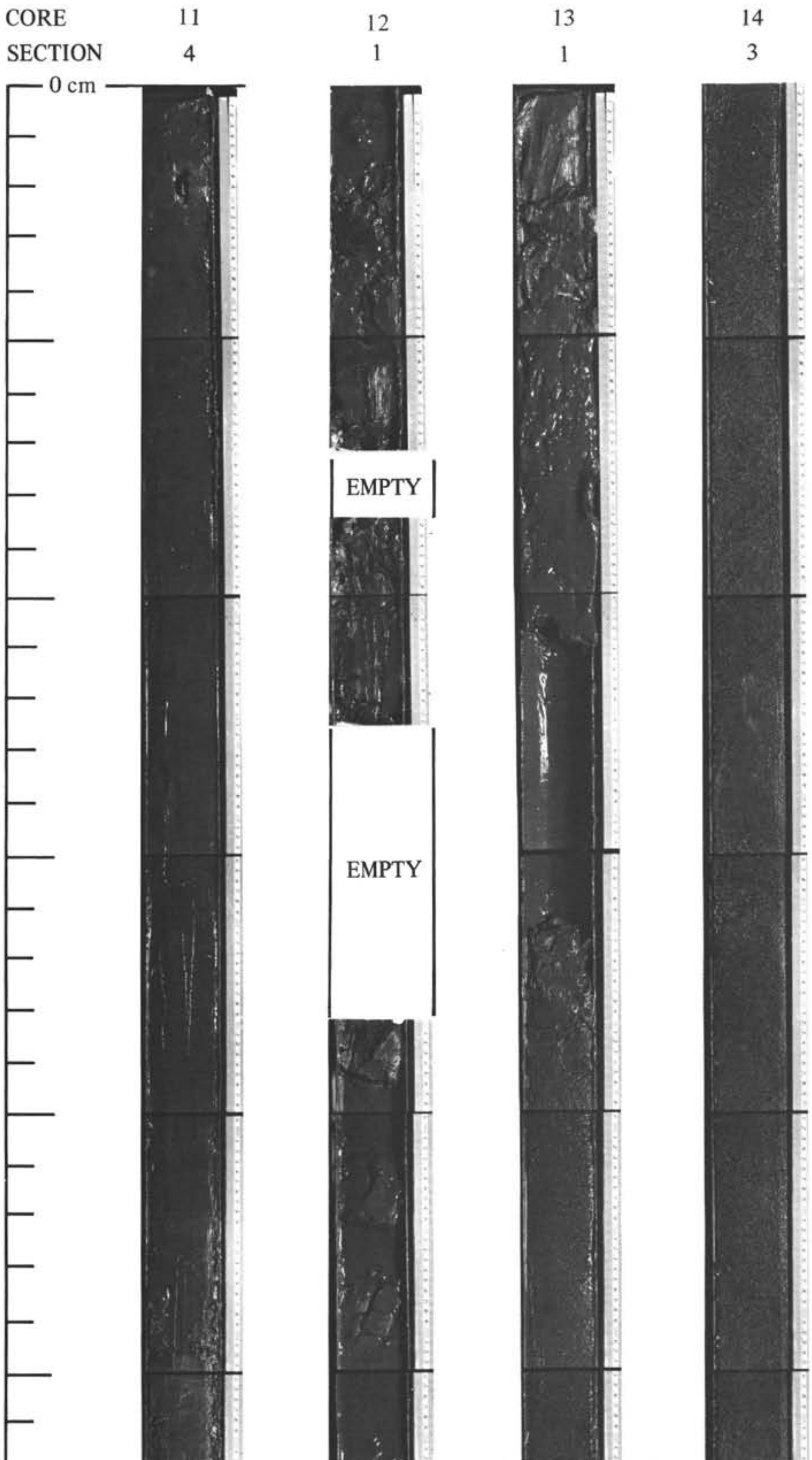

Plate 6. *Sections of cores from Hole 40.*

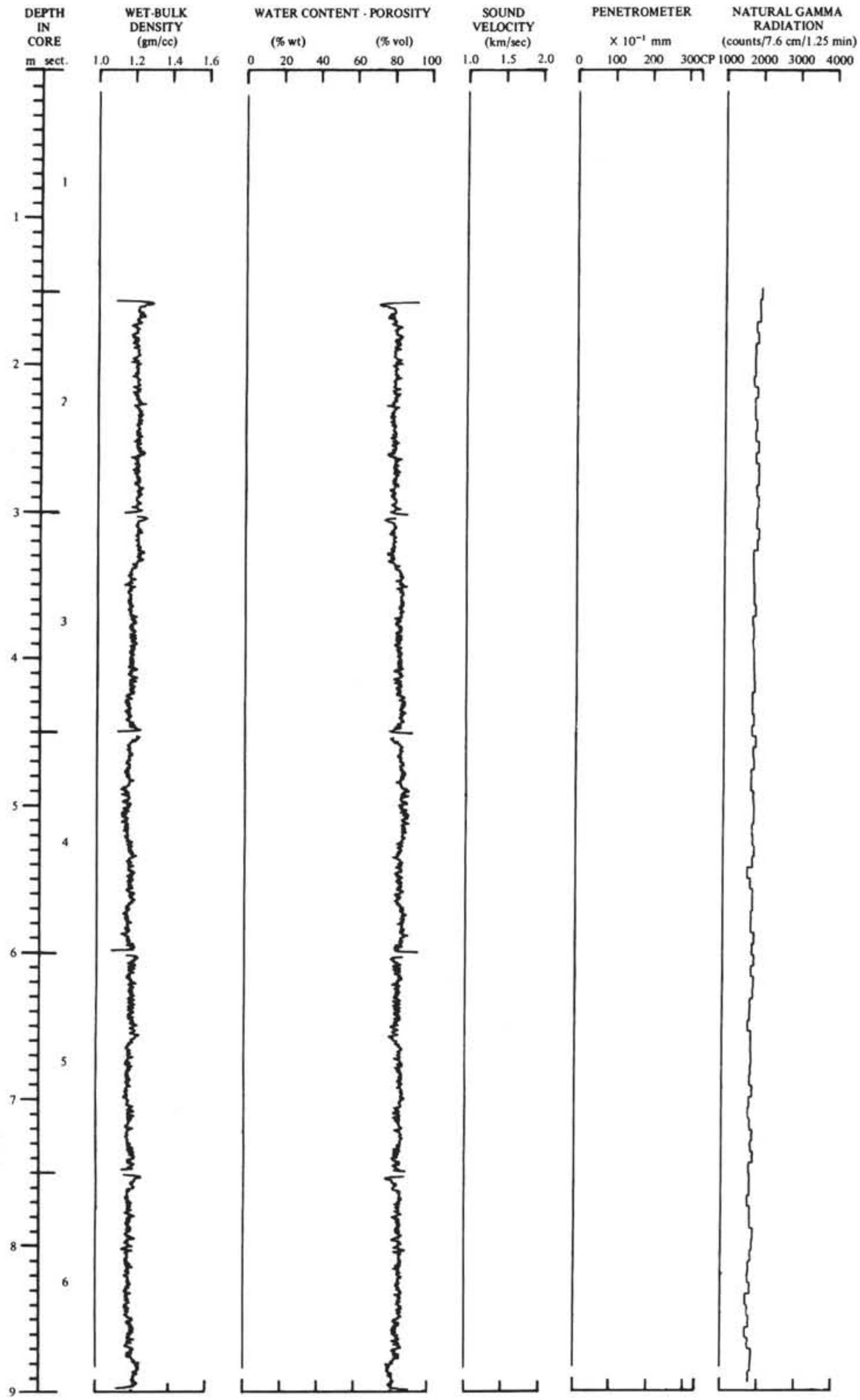

Figure 17A. *Physical Properties of Core 15, Hole 40*

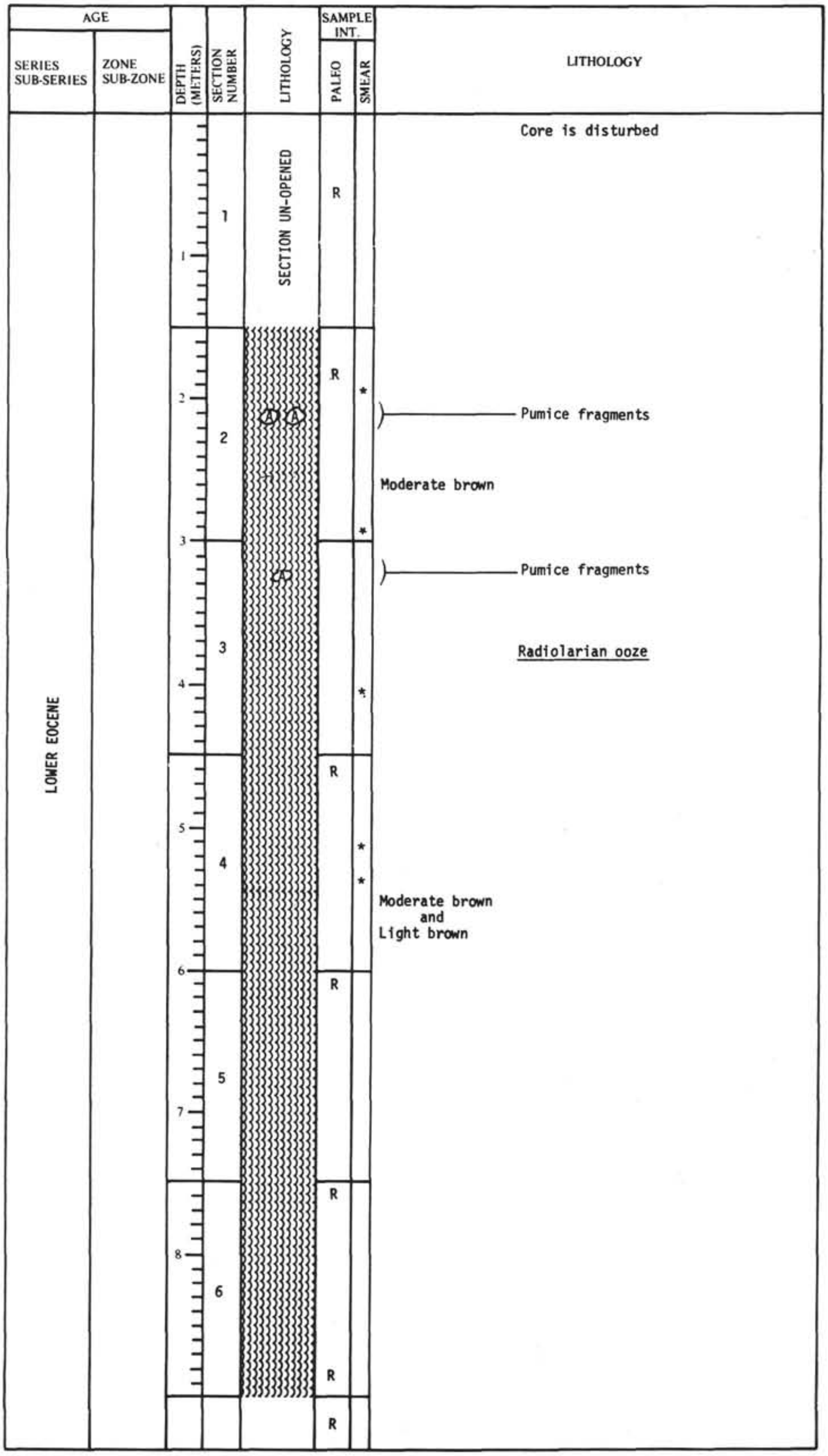

Figure 17B. *Core 15, Hole 40 (130-139 m Below Seabed)*

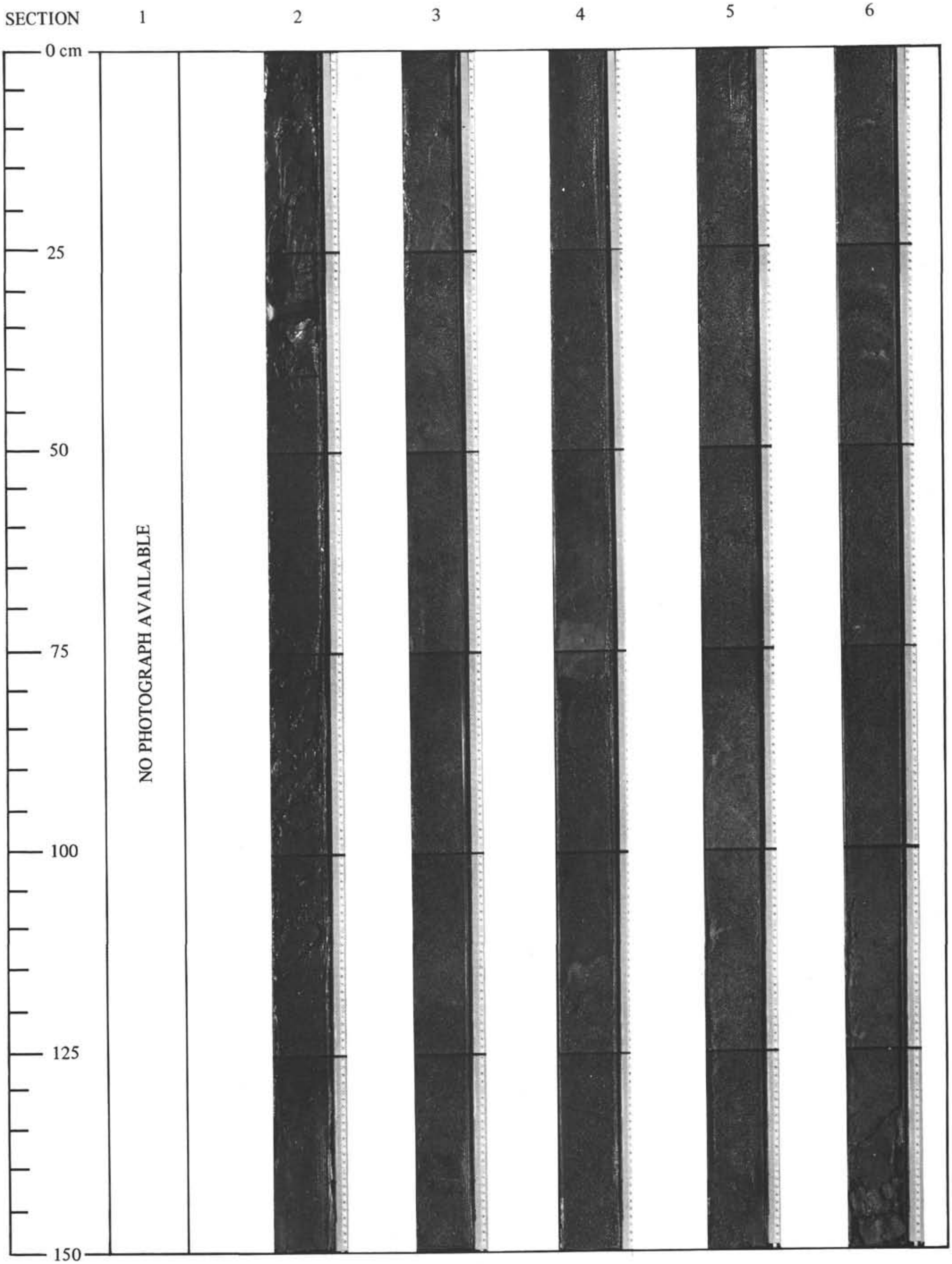

Plate 7. *Core 15, Hole 40*

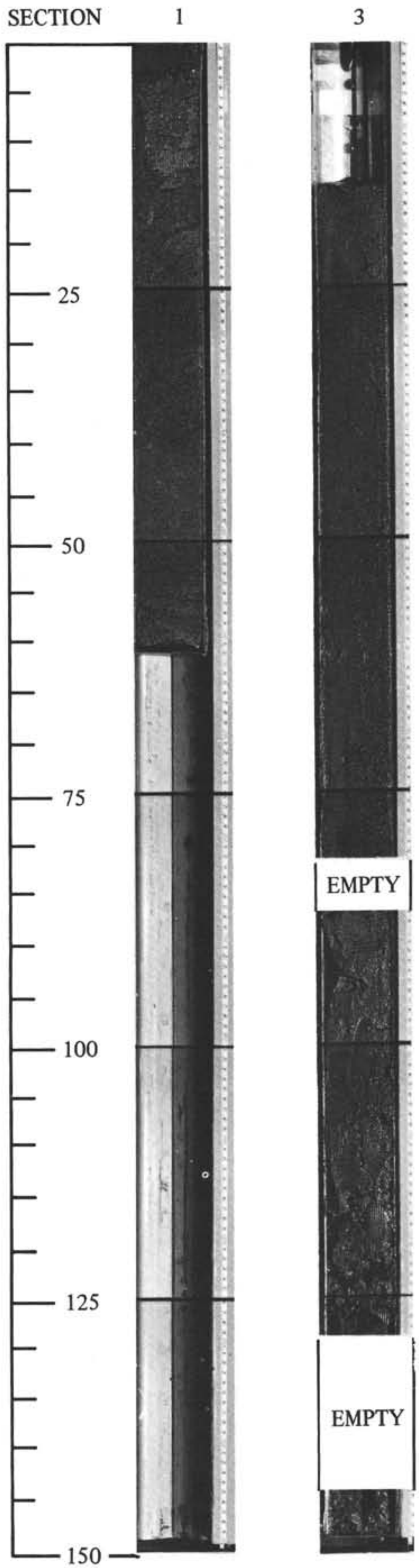

Plate 8. *Sections of Core 16, Hole 40*

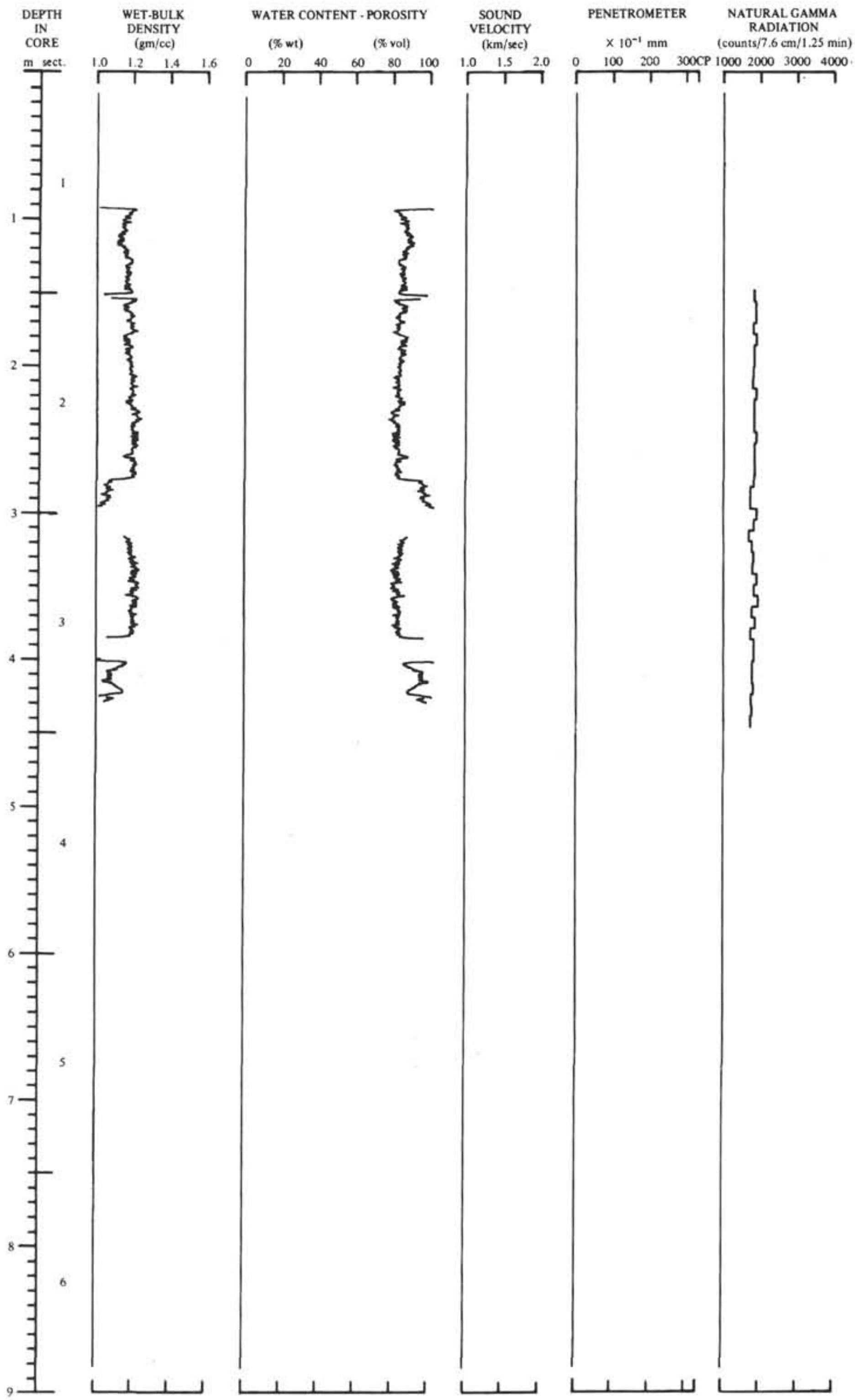

Figure 18A. *Physical Properties of Core 16, Hole 40*

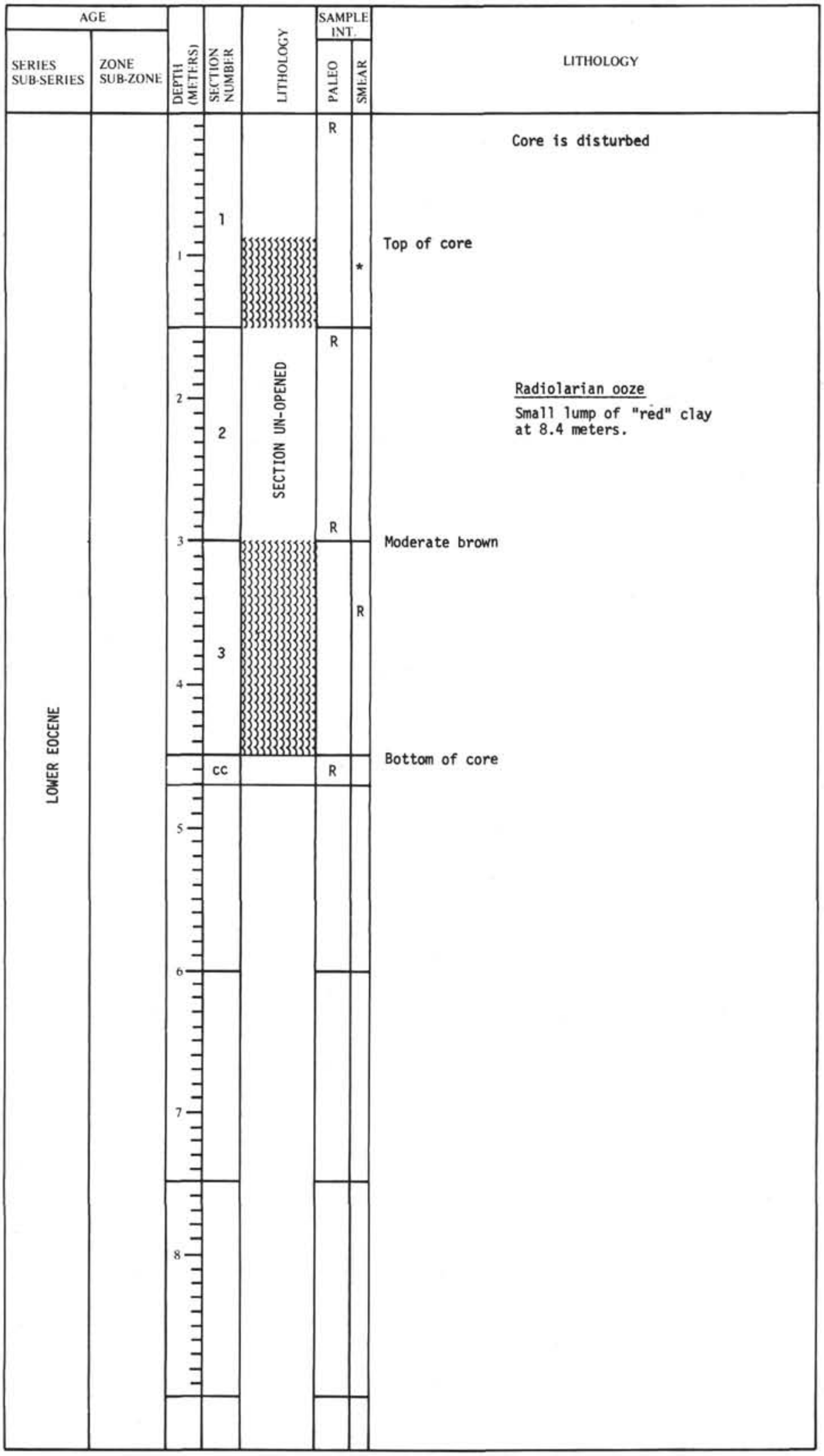

Figure 18B. *Core 16, Hole 40 (139-143 m Below Seabed)*

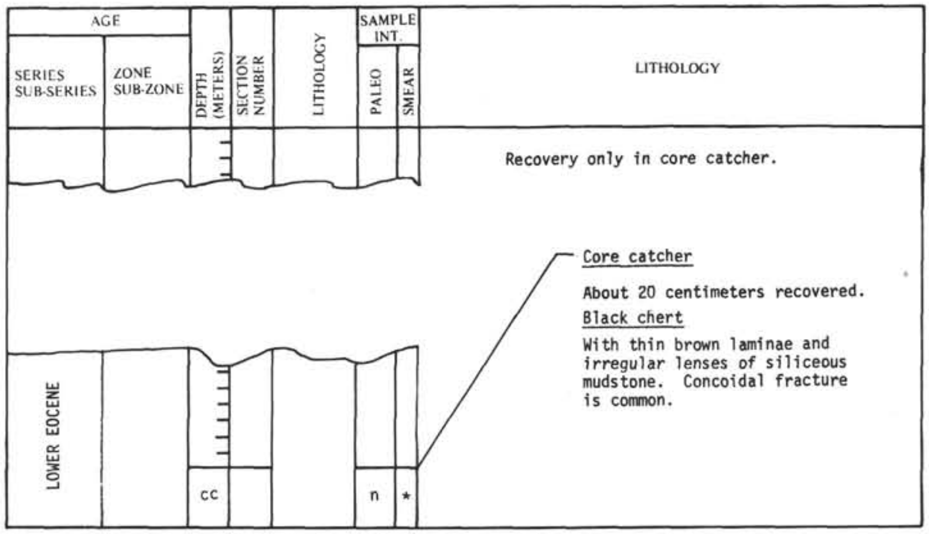

Figure 19. *Core 17, Hole 40 (143-150 m Below Seabed)*

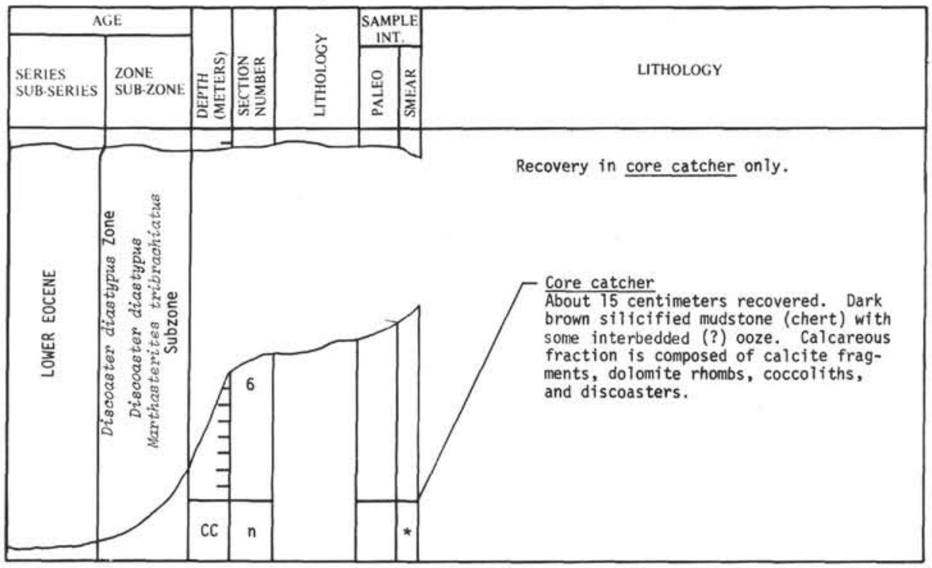

Figure 20. *Core 18, Hole 40 (150-153 m Below Seabed)*

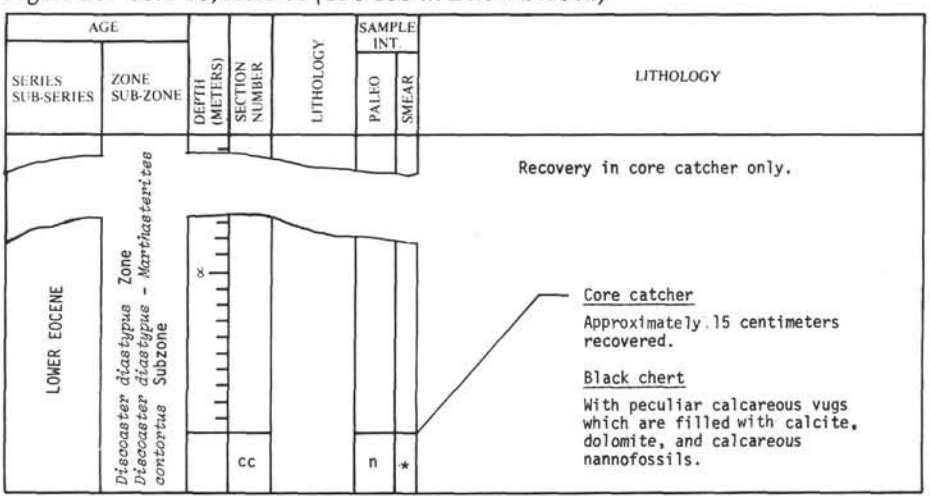

Figure 21. *Core 19, Hole 40 (153-156 m Below Seabed)*