2. SITE 32

The Shipboard Scientific Party[1]

SITE BACKGROUND

Site 32 was proposed by the Pacific Advisory Panel at a location over a strong positive magnetic anomaly (Number 13 on the Pittman-Heirtzler scale, 38 million years) where samples of the basement and the basal sediment would be of value in testing hypotheses for origin of the linear magnetic anomalies from this part of the Pacific. Comparison of this site, south of the Pioneer Fracture Zone, with later sites north of the Fracture Zone would be the basis for evaluating the discontinuity formed by the Pioneer.

The proposed site location was near the seaward margin of Delgada Fan. Sediment obtained at this site would represent one of the few samples of continental rise material to be cored in the Pacific, and possibly would provide a means for estimating the age of the Fan more closely than previously had been possible. South of the Pioneer Fracture Zone, the outer margin of the Fan consists of moderately regular topography formed by approximately 200 meters of stratified sediment covering a rough basement topography. A short distance to the west, the absence of Fan sediment is reflected by moderately rough topography of the abyssal hills province.

During the site survey (Appendix III), a buried ridge was defined which runs approximately north-northwest through the surveyed area. The ridge is expressed topographically as a prominent (80 to 100 meter) surface ridge at the south, which broadens northward and becomes a minor (40 meter) scarp. A strong positive magnetic axis with total field intensity in excess of 53,000 gammas runs almost parallel to and west of the surface ridge and is paralleled by the axis of a weak negative anomaly in the eastern part of the surveyed area. The topographic ridge separates two abyssal plains. To the east, the shallower plain lies at a depth of about 4650 meters and is the seaward extension of Delgada Fan. The western plain, at a depth of about 4830 meters, apparently is connected with the Fan around the ridge some distance north of the surveyed area.

A piston core taken by *Argo* during the site survey consists of soft green silty mud with coarser turbidite layers. Foraminifera were the only microfossils present, and they had an age range from Early Pliocene to Recent. The heat flow measurement yielded a normal value of 1.6×10^{-6} cal cm^{-2} sec^{-1}.

A tentative drilling site was based on the site survey data, and was easily located by approaching from the east over the shallower abyssal plain, crossing the ridge and moving westward over the deeper abyssal plain. This latter plain formed the surface for the drilling site. Final location was based on the magnetometer, which was monitored to a peak positive value of 50,372 gammas total field intensity.

The on-site seismic reflection profile (Figure 1) indicates acoustic basement at a depth of 0.31 second (214 meters). Several reflection horizons in the upper half of the section were initially interpreted as representing turbidite deposits associated with the abyssal plain. Subsequent coring confirmed this. A somewhat stronger reflector at 0.13 second had also been observed by the *Argo*. This reflector apparently represents a series of sands in the Pliocene turbidite deposits.

Location

Site 32 is located at latitude 37° 07.63'N, longitude 127° 33.38'W on a small plain forming the distal part of Delgada Fan.

OPERATIONS

The drilling summary for Site 32 is presented in Table 1. Coring began at 0600 on 16 April in 4758 meters of water. An initial core of the upper 9 meters was taken for comparison with the piston core taken by *Argo* during the site survey. The second core, at a depth of 33 meters below the sea floor, contained only liquid with a trace of sediment. Most of this sediment was lost while recovering the core barrel, but a small amount was collected from the core liner for preparation of a smear slide.

Cores 3 through 6 represent a continuously cored section in the depth range of the 0.13 second reflective horizon on the seismic profile. Cores 3 and 4 required

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Figure 1. *On-site seismic reflection profile, Site 32.*

added weight for coring, and in Core 4 the driller reported two distinct times of requisite additional weight, suggesting two somewhat harder layers. Some relatively stiff mud layers were found in Core 4. Core 5 was characterized by thick sand beds, including one almost a meter in thickness.

Core 7 was a spot core ostensibily below the 0.13 second reflective horizon. The core recovery was poor, however, and as a note, this core was taken after 21 meters of washing.

Cores 8 through 13 represent continuous coring of the basal sediments in the section. Core 8 is below the contact between overlying greenish sediment and the underlying red clay sediment section. Below this contact, additional weight was required for the coring operation because of the dryness of the sediment as compared to the overlying sediment. In Core 10, the sediment is obviously disturbed since the core liner was twisted and crumpled during coring, and the core had to be extruded. In Core 13, basement was encountered; the consequent increased circulation resulted in most of the sediment being washed out of the core. Only about 0.5 foot of core was recovered, most of which was basalt fragments caught in the core catcher and the lower part of the core liner. A final core, Core 14 was attempted in the basalt with a hard rock core catcher in the core barrel. The result was approximately 1 foot of basalt fragments.

LITHOLOGY

At Site 32 a total of 87 meters of sediment was recovered from the interval between the sea floor and the bottom of the hole at a depth of 215 meters. A good sampling of the lithologies was obtained from the upper 9 meters (Core 1), from between 80 to 117 meters (Cores 3 to 6), and from 166 meters to the bottom of the hole (Cores 8 through 14). Generally, the cores were badly deformed during coring operations making it difficult to interpret sedimentary structures and fabric. In the lower section of the hole (below Core 8) firmer sediments yielded some relatively undisturbed samples.

The uppermost sediment, as sampled by Core 1 (0 to 9 meters), is a green-gray silty mud with interbedded silty sand. The sands are moderately well-sorted and occur in beds up to 40 centimeters thick. Where undisturbed contacts occur, sand layers have sharp basal contacts with the underlying muds. Grading was observed in the sand layers, in their uppermost portions, where they grade into silts and muds.

Although Core 2 (33 to 42 meters) consisted of only a slurry of muddy water, past experience with this type of recovery suggests presence of sands and silts.

TABLE 1
Drilling Summary of Leg 5, Site 32

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
16 April	32-1	0-9	15,643-15,673	30	9.1	30.0	9.1	100
	32-2	33-42	15-750-15,780	30	9.1	0.0	0.0	0
	32-3	80-90	15,907-15,937	30	9.1	30.0	9.1	100
	32-4	90-99	15,937-15,967	30	9.1	30.0	9.1	100
	32-5	99-108	15,967-15,997	30	9.1	30.0	9.1	100
	32-6	108-117	15,997-16,027	30	9.1	30.0	9.1	100
17 April	32-7	138-147	16,095-16,125	30	9.1	15.0	4.6	50
	32-8	166-176	16,190-16,220	30	9.1	30.0	9.1	100
	32-9	176-185	16,220-16,250	30	9.1	30.0	9.1	100
	32-10	185-194	16,250-16,280	30	9.1	16.0	4.9	53
	32-11	194-203	16,280-16,310	30	9.1	12.0	3.7	40
	32-12	203-212	16,310-16,340	30	9.1	30.0	9.1	100
	32-13[a]	212-214	16,340-16,345	5	1.5	0.5	1.5	10
18 April	32-14[b]	214-215	16,346-16,349	3	0.9	1.0	0.3	33
			Totals	368	111.6	284.5	87.8	77[c]

[a]Core 13 consisted of 0.5 foot of basalt.
[b]Core 14 consisted of approximately 1 foot of basalt fragments.
[c]Recovery percentage excluding cores in basalt is 79 per cent.

Note: Sonic water depth (corrected): 4758 meters; 15,605 feet; 2600 fathoms.
Driller's depth: 15,643 feet.

Consequently, sediment in this interval may be similar to Core 1, but with an observed addition of a trace of possible zeolites.

Siliceous-fossil muds and silty muds, interbedded with silty sands, were cored through the intervals from 80 to 117 meters (Cores 3 to 6) and 138 to 147 meters (Core 7), and are presumed to be continuous between 80 and 147 meters. The color of this unit is basically olive-gray with some shades of olive-gray to olive-black. The silts are predominantly quartz and weathered feldspars, with traces of devitrified glass and zeolites. In the upper portion (Core 3, 80 to 85 meters), there are prominent interbeds of nannofossil mud. Rare glass shards are present in the mud. Between 99 to 108 meters (Core 5), there are significant interbeds of well-sorted silty sand containing quartz, altered feldspar, and ferromagnesian minerals.

Core 8 (166 to 176 meters) is a pale yellow siliceous-fossil "red" clay with pockets of volcanic ash and scattered glass shards near its base.

At a depth of 180 meters (Core 9), the siliceous-fossil "red" clay has graded into a brown color. Silt-sized ferromagnesian minerals are common throughout most of this interval. Thin volcanic ash beds are interbedded with the "red" clay in Core 11 (194 to 203 meters). Near the base of Core 12 (210 to 212 meters), thin altered ash layers are associated with a thin bed of nannofossil ooze. Throughout the "red" clay section (below 190 meters), the occurrence of zeolites generally increases irregularly with depth. Dolomite rhombs are present in trace quantities near the base of Core 12 (210 to 212 meters), and become abundant near the base of the "red" clay section where they are associated with the basement contact.

The actual basement contact was not cored, but basalt fragments were recovered in Cores 13 and 14 (212 to 215 meters). Parts of these fragments are mantled with rinds of palagonite.

PALEONTOLOGY

Nannofossils

Nannofossils, both calcareous and siliceous, are lacking in samples from parts of Cores 1, 8 and most of 12, and they are not evident throughout Cores 9, 10, 11 and 13 at Site 32. At other intervals, calcareous nannofossils are absent or quite rare, though siliceous nannofossils (diatoms and silicoflagellates) are present. These intervals embrace most of Core 1, the topmost and lower portion of Core 4, the mid and part of the upper sandy portion of Core 5, a large part of Core 7, and essentially all of Core 8. Calcareous nannofossils are quite frequent to common at other intervals including Core 3–particularly the upper part, the upper portion of Core 4, the bottom-most part of Core 5, and the basal portions of Cores 6 and 12. The matrix of some samples at selected positions is composed of frequent fine calcareous grains and coccolith fragments and debris. This is particularly evident in Cores 3, 5 and 6, near the sandy parts of the recovered sequence. Reworked older calcareous nannofossils are quite evident in the samples from Core 3, and are also present in some of the samples from Cores 4 and 5.

Siliceous nannofossils as well as siliceous skeletal parts of other organisms (mostly radiolarians and sponges) form a significant part of the sediments in part of Core 1, in the limited recovery of Core 2, and in Cores 3 through 8, becoming quite common in the lower part of Core 4 through Core 7. Part of the siliceous assemblage in this interval is represented by displaced forms which are generally considered representative of neritic to benthonic or epiphytic littoral or even brackish to fresh water environments (Cupp, 1943; Hendey, 1937 and 1964; Hustedt, 1930). Some of the more frequent displaced forms include: *Arachnoidiscus ehrenbergii* Bailey and vars., *Actinoptychus splendens* (Shadbolt) Ralfs vars., *Biddulphia* spp., *Campyloneis grevillei* (Wm. Smith) Grunow and vars., *Cocconeis* spp., *Diploneis* spp., *Melosira granulata* (Ehrenberg) Ralfs, *Navicula* spp., *Rhaphoneis amphiceros* (Ehrenberg) Ehrenberg and vars., *Stephanopyxis* spp., and, the resting spores of *Chaetoceros* spp., and *Xanthiopyxis* spp. The suite of displaced forms is more frequent to common in the samples from the lowest part of Core 3 through Core 7. Most of the samples from Core 1 through Core 8 contain fragments or parts of siliceous nannofossils and/or fine siliceous skeletal debris forming a portion of the matrix. This form of siliceous biogenous material constitutes a greater portion of the sediment in the lower part of Core 3 through the upper part of Core 8. This fragmental material or fine debris is the only biogenous constituent in some samples, particularly in Core 1, and in a number of cases is not large enough to be specifically identified. Associated with these siliceous skeletal-bearing sediments in Cores 1 to 8 are fragments or parts of siliceous hard parts that are coated with a fine-grained iron and/or manganese oxide, and occur together with oxide micronodules. They are more frequent in the upper part of Core 1, the lower part of Core 3 and especially in Cores 4 through 7. Reworked siliceous nannofossils, usually broken or incomplete and coated, corroded, or exhibiting some other characteristics indicating a different state of preservation, are quite frequently associated with the coarser sediments in most of the samples from Cores 1 through 5, and a few occur in some of the samples from Cores 6 and 7. Besides their state of preservation indicating their incompatible nature, these occurrences differ from their reported occurrences or stratigraphic range in the North Pacific area (Kanaya, 1959; Loeblich *et al.,* 1968; Wornardt, 1967), and their distribution and more continuous occurrences at other sites in this study. Some specimens of other species of siliceous nannofossils, notably the larger coscinodiscids, may also be reworked and/or displaced from their original site of accumulation as indicated by their state of preservation and their greater frequency within and adjacent to the coarser clastic sediments. However, these forms occur at this site within their known stratigraphic range and environmental distribution so that they are not obvious indicators of such a depositional history. A few representatives of the rather diverse siliceous assemblages found throughout Cores 1 through 8 include: *Actinocyclus octonarius* Ehrenberg, rather frequent at intervals, and *Actinoptychus senarius* Ehrenberg–both are probably partly displaced; *Coscinodiscus asteromphalus* Ehrenberg; *C. lineatus* Ehrenberg; *C. marginatus* Ehrenberg; *C. oculus-iridis* Ehrenberg; *C. radiatus* Ehrenberg; *Ebria antiqua* Schulz; *E. a. rectangularis* Schulz; fragments and parts of *Ethmodiscus rex* (Rattray) Hendey; *Hemidiscus cuneiformis* Wallich; *Melosira sulcata* (Ehrenberg) Kutzing–probably partly displaced; *Thalassiosira decipiens* (Grunow) Jφrgensen and related forms; and, *Thalassiothrix longissima* Cleve and Grunow and related forms. Some scattered palynomorphs, plant parts and woody fragments are evident in Cores 1, 3 and the uppermost part of Core 4.

Difficulty was encountered in determining the age of all of the recovered sediments at this site due to large intervals which were void of nannofossils, especially, calcareous nannofossils, and the high degree of reworked forms, especially, the siliceous nannofossils in the upper part of the sequence. Stratigraphic control was achieved by direct comparison and contemporization with the assemblages and sequences recovered from the other sites on this leg.

An hiatus is evident between the Lower and Upper Pliocene at this site with the *Ceratolithus rugosus–Cyclococcolithus leptoporus* Subzone missing and probably part of the underlying subzone as well. The sediments immediately above this hiatus in the base of Core 3 are quite coarse and decrease in size toward the middle and upper parts of this core. Reworked nannofossils are also quite evident in the lower and mid-portions of Core 3, and diminish substantially toward the top of this core.

The Pleistocene *Coccolithus carteri* Zone is represented in the intervals of Cores 1 and 2. Calcareous nannofossils are absent in most of the samples from Core 1, except for rare scattered specimens of *Coccolithus doronicoides* Black and Barnes? and *Cyclococcolithus leptoporus* (Murray and Blackman) in Section 4. Though the majority of sediment was lost from the interval of Core 2, small amounts of sediment were collected from the core liner and exhibit what is considered a representative nannofossil assemblage. The few to frequent calcareous forms present include: *Coccolithus carteri* (Wallich), *C doronicoides?, C. pelagicus* (Wallich), *Cyclococcolithus leptoporus, Gephyrocapsa* spp., and *Helicopontosphaera kamptneri* Hay and Mohler. Fragmental siliceous biogenous debris is quite evident in the material from Cores 1 and 2 with larger identifiable parts present in Core 2. It is associated with the more silty or sandy intervals in the upper part of Section 1, and the lower part of Sections 4 through 6 of Core 1. Besides the presence of the longer-ranging forms listed above, a number of siliceous forms occur in these cores which indicate reworking from older sediments of Pliocene or Miocene age and/or displaced from a different environment. These include: *Actinocyclus ingens* Rattray and vars., *A. tsugaruensis* Kanaya, *Actinoptychus splendens* var. *incisa* (Grunow) Wornardt, *Arachnoidiscus ehrenbergii* and vars., *Coscinodiscus vetustissimus* Pantocsek, *Denticula hustedtii* Simonsen and Kanaya, *D. lauta* Bailey, *Dictyocha fibula aspera* Lemmermann, *Distephanus aculeatus* (Ehrenberg) vars. A, B and D, *D. binoculus* (Ehrenberg), *D. crux* (Ehrenberg), *D. gracilis* (Kutzing)–heavy from, *Entopya australis* var. *gigantea* (Greville) Fricke, *Fragilariopsis pliocena* (Brun) Sheshuk., *Melosira granulata, M. clavigera* Grunow, *Navicula* sp. indet., *Stephanopyxis appendiculata* Ehrenberg, *S.* cf. *S. nipponica* Gran and Yendo of Kanaya, *Xanthiopyxis diaphana* Forti, *X. ovalis* Lohman, and *X.* sp. C and D of Wornardt. Specimens of *Melosira* spp., including *M. sulcata,* are quite frequent in these intervals of Core 1.

The Upper Pliocene *Discoaster brouweri* Zone is represented by Core 3, where the calcareous portions are dominated by the common small coccolith *Coccolithus doronicoides?,* as well as, *Cyclococcolithus leptoporus* and vars. (including, *C. l. macintyrei* Bukry and Bramlette). Other distinctive and consistently occurring calcareous forms are *Ceratolithus rugosus* Bukry and Bramlette var., *Coccolithus pelagicus, Discolithina japonica* Takayama, and *Discoaster brouweri* Tan and var. Less frequent forms include: *D. pentaradiatus* Tan, *D.* sp. aff. *D. exilis* Martini and Bramlette, *D. surculus* Martini and Bramlette–most with weak trifurcations, *D. variabilis* Martini and Bramlette var., *Ceratolithus cristatus* Kamptner, *Helicopontosphaera kamptneri, H. sellii* Bukry and Bramlette, and *Thoracosphaera* spp. Reworked older calcareous nannofossils occur in this core and are usually less well-preserved or incomplete. The identifiable specimens include: *Discoaster exilis* and var., *D.* cf. *D. calcaris* Gartner, *D. variabilis s.s.*, *Reticulofenestra pseudoumbilica* (Gartner), and large *Sphenolithus abies* Deflandre. Besides the presence of a fair number of the longer-ranging siliceous nannofossils in Core 3, a few others are present which may be representative as indicated by their preservation and repeated occurrence. These include: *Actinocyclus octonarius* var. *tenellus* (Brébisson) Hustedt, *Coscinodiscus rothii* (Ehrenberg) Grunow, *C. vetustissimus, Distephanus gracilis, D. binoculus, D. speculum pentagonus* Lemmermann, *Mesocena elliptica* (Ehrenberg), *M. triangula* (Ehrenberg); and, the displaced forms *Actinoptychus splendens* var. *solisi* Hanna and Grant, *Campyloneis grevillei* and vars.; the resting spores of *Chaetoceros lorenzianum* Grunow and *C. subsecundum* (Grunow) Hustedt, and *Stephanopyxis turris* (Greville and Arnott) Ralfs. A large number of the other distinctive siliceous nannofossils are most probably reworked, and the majority have singular occurrences within this core. These include: *Actinocyclus ingens* and vars., *A. tsugaruensis, Denticula hustedtii, D. kamtschatica* Zabelina, *Dictyocha fibula aspera, D. f. rhombica* Schulz, *D. f. brevispina* Lemmermann, *D. f. pentagonalis* Aurivillius, *D. pseudofibula* (Schulz), *Distephanus aculeatus* var. B, C, and D, *D. crux, Hyalodiscus valens* Schmidt, *Lithodesmium californicum* Grunow, *L. minusculum* Grunow, *Stephanogonia hanzawae* Kanaya; and, the reworked displaced forms *Actinoptychus stella* var. *clevi* (Schmidt) Wornardt, *Stephanopyxis appendiculata, S.* cf. *S. nipponica, Xanthiopyxis diaphana, X. lacera* Forti, *X. ovalis,* and *X.* sp. A and C of Wornardt.

The Lower Pliocene *Ceratolithus rugosus–Reticulofenestra pseudoumbilica* Subzone is represented by Cores 4 and 5. Calcareous nannofossils are absent from several sampled intervals in the recovered portion of this subzone. These include the lower part of Section 1 and all samples in Sections 4 and 5 of Core 4. Calcareous nannofossils are absent, as well, in Section 4 of Core 5, and they are quite rare in Section 2 of Core 5. Where present, the calcareous nannofossils are dominated by rather frequent occurrences of *Reticulofenestra pseudoumbilica, Cyclococcolithus leptoporus* and vars., and *Coccolithus pelagicus,* including the highest sample of Core 4. Other less frequent, but consistently occurring and distinctive calcareous forms include: *Ceratolithus rugosus* var., *C. tricorniculatus* Gartner, *Coccolithus doronicoides?, Discolithina japonica, Discoaster brouweri* and var., *D. challengeri* Bramlette and Riedel, *D.* sp. aff. *D. exilis,* and *D. variabilis* var. Calcareous forms with scattered occurrences include: *D. pentaradiatus, Helicopontosphaera kamptneri, H. sellii, Sphenolithus abies,* and *Thoracosphaera* spp. The highest continuous occurrence of well-preserved *Discoaster variabilis s. s.* is in the lower part of this subzone. The few specimens of *Ceratolithus rugosus* var. in the lowest part of Core 5 are the early forms transitional to *C. tricorniculatus* with the truncate arch lower than the connecting arms or rays, and one or both arms are often slightly bent or twisted out of the plane of the ceratolith; this may be a reflection of the change in orientation of the crystallites within the forms of this lineage. This position is comparable with that in mid-Core 7 at Site 34 and the lower part of Core 11 at Site 36. Some reworked older calcareous nannofossils from a Miocene-to-Oligocene source are evident in Sections 2 and 3 of Core 4 and Section 6 of Core 5. The discernable species include: *Coccolithus* cf. *C. scissurus* (Hay, Mohler and Wade) of Bramlette and Wilcoxon, *Cycloccolithus neogammation* Bramlette and Wilcoxon, and *Discoaster exilis* and var.

A noticeable increase in the diversity and frequency of siliceous microfossils occurs in this Lower Pliocene subzone below Section 3 of Core 4. This general characteristic approximates the highest continuous occurrence of a number of forms, and it is comparable to a similar change below Section 5 of Core 5 at Site 34. Some of the characteristic siliceous nannofossils of this subzone include: *Actinocyclus ellipticus* Grunow–Core 5; *A. octonarius* var. *tenellus; Coscinodiscus lineatus* var. *leptopus* Grunow; *C. rothii; C. vestustissimus; Denticula hustedtii, D. kamtschatica*–quite frequent in the lower part; *Dictyocha fibula* Ehrenberg; *D. f. aspera* and *D. f. brevispina*–both ranging slightly higher at this site (partly reworked?); *D. f. rhombica; D. f. pentagonalis*–top in Core 4; *D. pseudofibula*–top in Core 4; *Distephanus aculeatus* vars. B, C–quite frequent, and D; *D. binoculus; D. gracilis; D. speculum pentagonus*–quite frequent; *Fragilariopsis pliocena; Lithodesmium californicum*–ranging higher at this site (partly reworked?); *L. cornigerum* Brun–highest in Core 4; L. *minusculum; Mesocena diodon* Ehrenberg–top in Core 4; *M. elliptica*–lowest occurrence in Core 5; *M. quadrangula* Ehrenberg–restricted to this subzone; and, *M. triangula.* Large and heavy forms of coscinodiscids are quite prevalent in the finer sediments associated with the sands in Core 5. Displaced siliceous forms are quite frequent, becoming more common in the lower part of this subzone. A representative suite includes: *Actinoptychus splendens* var. *solisi; Arachnoidiscus ehrenbergii* and vars.; *Biddulphia* spp., including *B. aurita* var. *obtusa* (Kützing) Hustedt; *Campyloneis grevillei* and vars.; *Diploneis major* Cleve; *Melosira clavigera; M. granulata; Rhaphoneis amphiceros* var. *angularis* (Lohman); *R. a.* var. *elongata* Peragallo; *R. elegans* Pantocsek and Grunow; *Stephanopyxis* cf. *S. nipponica; S. turris;* resting spores of *Chaetoceros* spp., including, *C. cinctum* Gran, *C. lorenzianum,* and *C. subsecundum; Xanthiopyxis* spp., including, *X. oblonga* Ehrenberg, *X. ovalis,* and *X.* sp. A, B, C and D of Wornardt. A number of reworked siliceous forms are scattered through the samples of Cores 4 and 5, and most have singular occurrences within this interval. These include: *Actinocyclus ellipticus* var. *javanica* Reinhold; *A. ingens* and vars., *A. tsugaruensis; Anaulus mediterraneus* var. *intermedia* Grunow–also displaced; *Coscinodiscus endoi* Kanaya; *Denticula lauta; Distephanus crux; D. c. longispina* Schulz; *D. diommata* (Ehrenberg); *D. pseudocrux* Schulz; *Mesocena circulus apiculata* Lemmermann; and, *Rhabdonema japonicum* var. *sparsicostatum* Tempère and Brun.

Cores 6 and 7 represent the Upper Miocene *Ceratolithus tricorniculatus* Zone. Of the limited samples available from these cores, only those from the upper part of Section 6 and the basal part of Core 6 contain frequent-to-common calcareous nannofossils representing a fairly diverse assemblage. One sample from the upper part of Section 1 of Core 7 contains a somewhat diverse assemblage of near frequent calcareous nannofossils. The remaining samples contain few specimens, which represent a limited number of calcareous species, or essentially lack calcareous nannofossils. The calcareous assemblage in the three more calcareous samples is characterized by *Cyclococcolithus leptoporus* and vars., *Reticulofenestra pseudoumbilica, Coccolithus pelagicus, Ceratolithus tricorniculatus–rare, Discoaster brouweri* var., *D. challengeri,* and *D. variabilis* and var. Less consistent forms include: *D. calcaris* Gartner–Core 7; *D.* sp. aff. *D. exilis; D. quinquerimus* Gartner–Core 6; *D. pentaradiatus; Discolithina vigintiforata* (Kamptner)–Core 7; *Helicopontosphaera sellii;* and, *Sphenolithus abies.*

The *Ceratolithus tricorniculatus* Zone contains a rich and diverse siliceous nannofossil assemblage at this site, including the highest and lowest occurrences of a number of distinctive forms in the recovered material. Part of the assemblage includes: *Actinocyclus ellipticus; A. octonarius* var. *tenellus; Coscinodiscus lineatus* var. *leptopus*–quite frequent; *C. rothii, C. vetustissimus; Denticulata hustedtii*–Core 7; *D. kamtschatica, Dictyocha fibula; D. f. aspera; D. f. brevispina; D. f. rhombica*–large form; *D. f. pentagonalis; D. pseudofibula; Distephanus aculeatus* vars. A–highest in Core 7, B, C and D; *D. binoculus; D. crux; D. gracilis*–heavy form; *D. ornamentum* (Ehrenberg)–highest in Core 7; *D. speculum* (Ehrenberg)–highest in Core 7; *D. s. pentagonus*–becoming the heavy form in Core 7; *Fragilariopsis pliocena; F.* sp. aff. *F. pliocena*–highest in Core 7; *Litho-*

desmium californicum; L. cornigerum; L. minusculum; Rouxia californica Peragallo–highest in lower part of Core 7; and, *Triceratium cinnamomeum* Greville–highest in Core 7. The displaced siliceous forms are quite frequent to common in the sediments of this zone and include: *Arachnoidiscus ehrenbergii* and vars.; *Biddulphia* spp., including *B. aurita* (Lyngbye) Brébisson and Godey; *Campyloneis grevillei* and vars.; *Cocconeis antiqua* Tempère and Brun–highest in Core 7; *C. formosa* Brun–Core 6; parts of *Diploneis* spp., including *D. major, Hyalodiscus valens*–probably displaced; *Melosira clavigera; Navicula opima* Hanna–Core 7; *Plagiogramma antillarum* Cleve–Core 7 and probably displaced; *Rhaphoneis amphiceros* var. *angularis; R. a.* var. *elongata; Stephanopyxis appendiculata*–highest in the lower part of Core 7; *S.* cf. *S. nipponica; S. turris; Stictodiscus buryanus* Grunow–probably displaced; resting spores of *Chaetoceros* spp., including *C. cinctum, C. lorenzianum* and *C. subsecundum; Xanthiopyxis diaphana, X. oblonga, X. ovalis, X.* sp. A, B, C and D of Wornardt, and *X.* sp. 5 of Kanaya. A few scattered reworked older siliceous forms are present in Cores 6 and 7, mostly represented by broken (or fragments of) specimens of *Actinocyclus ingens* and vars. and *Denticula lauta.* Close comparison can be made between the siliceous nannofossil associations in the recovered portion of this zone at this site with comparable assemblages at Sites 33 and 34. The siliceous assemblage in Core 6 of Site 32 corresponds quite well with the lowest part of Core 7 at Site 34. The assemblage in Core 7 of Site 32 is comparable to the upper to mid-parts of Core 8 at Site 34.

Core 8 essentially lacks calcareous nannofossils, except for rare specimens of *Cyclococcolithus leptoporus* at the base of the core. Fairly diverse siliceous nannofossil assemblages are present at intervals in Core 8. The correlation and contemporization of the better assemblages in Sections 1, 3, 6 and at the base of the core with the sequences recovered at the other sites results in the assignment of part of this core to the Upper Miocene *Discoaster variabilis* Zone, with the remainder essentially embracing the *D. exilis–Reticulofenestra pseudoumbilica* Subzone of the Middle Miocene. The distinctive siliceous forms in the upper part of Section 1 include: *Actinocyclus ellipticus* var. *javanica; A. ingens* var.; *A. tsugaruensis; Coscinodiscus endoi; C. vetustissimus*–including finely areolate form; *C. yabei* Kanaya; *Denticula hustedtii; D. lauta; Dictyocha fibula*–fairly frequent and some with fairly long radial spines; *D. f. aspera*–fairly frequent; *D. f. brevispina; D. f. rhombica; Distephanus aculeatus* vars. A, B, C and transitional forms as cf. var. C; *D. crux*–fairly frequent; *D. c. longispina*–mostly latest form with larger straight-sided basal ring and with radial spines just long enough to belong to this subspecies, and one specimen with somewhat rounded basal ring; *D. speculum; D. s. pentagonus* –small form; *Lithodesmium californicum; Mesocena circulus* (Ehrenberg); *M. c. apiculata; M. diodon*–fairly frequent; *M. triangula;* and few to frequent displaced forms, including, *Campyloneis grevillei* and vars.; *Diploneis major; Melosira granulata; Rhaphoneis amphiceros; Stephanopyxis* cf. *S. nipponica;* and, *Xanthiopyxis* spp., including, *X.* sp. A, *X.* cf. *X.* sp. B, and *X.* sp. C of Wornardt. On comparing their distribution at Sites 33 and 34, this siliceous assemblage is no younger than the lower part of the *Discoaster variabilis–D. challengeri* Subzone or no older than the mid-to-lower mid part of the *D. variabilis–D. exilis* Subzone. It most likely fits into this latter subzone based on some of the species present and the stage of development represented by some of the silicoflagellates. The sample from the upper part of Section 3 contains: *Actinocyclus ellipticus; A. ingens* and vars.–fairly frequent including *s.s.* forms with corrugated valves; *Asteromphalus moronensis* (Greville) Rattray and var.; *Coscinodiscus endoi; C. vetustissimus*–a few are tending to finely areolate form; *Denticula hustedtii* and *D. lauta*–including long forms; *Dictyocha fibula; D. f. aspera*–some with longer radial spines; *D. f. brevispina; Distephanus crux*–with rounded basal ring; *D. c. longispina*–fairly frequent with smaller rounded basal ring forms dominating over angled forms; *D. speculum; Mesocena circulus apiculata;* and, rare to few displaced forms, such as, *Melosira granulata* and *Xanthiopyxis* spp. including *X. acrolopha* Forti. The characteristics of this assemblage compare well with the mid-to-upper mid portion of the *Discoaster exilis–Reticulofenestra pseudoumbilica* Subzone. A limited suite of siliceous forms are present in the top of Section 6, but they are quite characteristic of the lower part of this subzone. They are *Actinocyclus ingens s.s., Denticula hustedtii, D. lauta*–dominates here, *Distephanus speculum, Mesocena circulus apiculata,* and *M. hexagona* Haeckel. The sample from the core catcher of Core 8 contains a siliceous assemblage typical of the basal-most part of the *Discoaster exilis-Reticulofenestra pseudoumbilica* Subzone recovered at Sites 33 and 34. The forms present include: *Actinocyclus ingens* and var.; *A. tsugaruensis; Asteromphalus moronensis; Coscinodiscus endoi; C. vetustissimus*–coarse areolate form; *Denticula hustedtii; D. lauta*–dominant form; the distinctive *Dictyocha paradistephanus* Tsumura; *Distephanus crux; D. c. longispina*–mostly the form with rounded basal ring and quite long radial spines; *Mesocena circulus apiculata, M. hexagona,* and a few displaced *Xanthiopyxis* spp.

Common calcareous nannofossils are present in very thin calcareous lenses or streaks in the basal part of Section 6 of Core 12. Many of the coccoliths show evidence of etching, and disassociated parts or small coccolith fragments are quite frequent-to-common in the matrix. The calcareous assemblage characterizes the upper-most part of the *Coccolithus bisectus–Reticulofenestra umbilica* Subzone of Lower Oligocene age. The assemblage is composed of *Coccolithus bisectus* (Hay, Mohler and Wade), *C.* cf. *C. scissurus, C. eopelagicus* (Bramlette and Riedel), *C. pelagicus, Discoaster adamanteus* Bramlette and Wilcoxon, *D. deflandrei* Bramlette and Riedel, *D. tani tani* Bramlette and Riedel, *D. tani nodifer* Bramlette and Riedel, *Pontosphaera vadosa* of Hay, Mohler and Wade, *Reticulofenestra umbilica* (Levin), *Sphenolithus moriformis* (Bronnimann and Stradner), *S. predistentus* Bramlette and Wilcoxon, *S. pseudoradians* Bramlette and Wilcoxon, and *Zygrhablithus* sp. aff. *Z. bijugatus* (Deflandre)–equals *Lucianorhabdus dispar* Stradner of Levin and Joerger.

Foraminifera

Foraminifera occur only in Core 3 and, for the most part, are rare and poorly preserved.

Identification of Species:

Sample 32-3-1, 40-42 cm:
Globorotalia tosaensis Takayanagi and Saito, *Globigerina bulloides* d'Orbigny, *Globorotalia* cf. *G. inflata* (d'Orbigny).

Sample 32-3-1, 127-129 cm:
Globorotalia crassaformis ronda Blow, *Globigerina bulloides, Orbulina universa* d'Orbigny.

Sample 32-3-2, 21-23 cm:
Orbulina universa, Globorotalia cf. *G. acostaensis pseudopima* Blow, rare benthonic foraminifera.

Sample 32-3-4, 21-23 cm:
Orbulina universa.

Sample 32-3-4, 120-122 cm:
Globigerina bulloides, Globigerina pachyderma (Ehrenberg), *Globorotalia crassaformis* s.l. (Galloway and Wissler).

Sample 32-3-5, 20-22 cm:
Globorotalia acostaensis pseudopima Blow, *Globorotalia crassaformis ronda, Globorotalia* cf. *G. hirsuta* (d'Orbigny), *Globigerina bulloides, Globigerina pachyderma, Orbulina universa.*

Radiolaria

Radiolaria are present in the interval between Cores 3 and 9, inclusive. They are common in Cores 6 and 8, and their abundance declines above and below this sequence. Less than one hundred species constitute the total assemblage, which includes many undescribed forms and few age-diagnostic species. Orosphaerid fragments occur commonly in Cores 8 and 9, but special preparations were not made for their identification. Species, which were identified, but not included on the Biostratigraphy Chart, are listed below:

Sample 32-3-2, 12-14 cm:
Pterocanium trilobum, Eucyrtidium acuminatum.

Sample 32-3-4, 3-5 cm:
Pterocanium trilobum, Dorcadospyris pentagona.

Sample 32-3-5, 1-3 cm:
Dendrospyris damaecornis, Tholospyris scaphipes.

Sample 32-6-6, 16-18 cm:
Dendrospyris damaecornis, Tholospyris scaphipes, Eucyrtidium acuminatum.

Sample 32-7-1, 11-13 cm:
Pterocanium trilobum.

Sample 32-8-1, 6-8 cm:
Panarium penultimum, Tholospyris kantiana, Liriospyris ovalis.

Sample 32-8-3, 8-10 cm:
Tholospyris kantiana.

Sample 32-8, Core Catcher:
Tholospyris scaphipes, Dendrospyris stabilis.

Sample 32-9-6, 1-3 cm:
Liriospyris mutuaria, Dorcadospyris pentagona.

SUMMARY

At Site 32, the sediment column is 214 meters thick and ranges in age from Lower Oligocene to Pleistocene. The contents of the fourteen cores recovered from this site have been divided into five stratigraphic units (Table 2).

The basement basalt, unit 5 (part of Core 13 through Core 14, 214 to 217 meters), is partly glassy with microvesicles and carbonate rinds.

Unit 4 extends from Core 9 through part of Core 13 (176 to 214 meters). The basal part of unit 4 (parts of Cores 12 and 13, 211 to 214 meters) consists of black-brown "red" clay with dolomite rhombs, overlying the basalt but separated from it by a 2-meter unsampled zone. This dolomite-rich clay is overlain by "red" clay containing nannoplankton remains of Lower Oligocene age. The remainder of unit 4 (Core 9 through part of Core 12, 176 to 211 meters) consists of "red" clay (with common zeolites) which is dark yellow-brown in the lower part and becomes progressively lighter in color towards the top of the unit. Several thin beds of ash occur in the lower part of the unit. Radiolaria near the upper part of unit 4 indicate a Middle Miocene age.

TABLE 2
Stratigraphic Units at Site 32

Unit	Depth (m)	Cores	Age	Description
1	0-90	1-3	Pleistocene Upper Pliocene	Greenish-gray dominantly silty mud unit grading to siliceous-fossil mud at base. Nannofossil-rich zone in Core 3. Some silty sands in Core 1.
2	90-156	4-7	Lower Pliocene Upper Miocene	Olive-gray to olive-green mostly siliceous-fossil mud and siliceous-fossil silty mud. Silty sands in Core 5.
3	156±-176	8	Upper Miocene Middle Miocene	Pale yellow siliceous-fossil "red" clay with pockets of ash.
4	176-214	9-13	Middle Miocene Lower Oligocene	Light, moderate to dark brown "red" clay with common zeolites. Dolomite rhombs and nannofossil "red" clay near base.
5	214-217	13-14	?	Basalt, partly glassy with microvesicles and manganese rinds.

Unit 3 (Core 8, 156 to 176 meters) is a Middle and Upper Miocene pale yellow siliceous-fossil "red" clay with pockets of volcanic ash and disseminated shards of fresh glass.

The most pronounced change in sediment lithology at Site 32 occurs between units 2 and 3. Unit 2 (Cores 4 through 7, 90 to 156 meters) is an olive-green sequence of siliceous-fossil mud and siliceous-fossil silty mud with interbeds of silty sand. The sands and silts are feldspathic and contain traces of glass shards. The thickest sands (2 to 3 meters) occur in Core 5 (99 to 108 meters). The unit is Late Miocene to Early Pliocene in age. The thick Lower Pliocene sand was initially correlated with the 0.13-second reflector on the seismic reflection profile. Re-evaluation of the seismic velocities, however, suggests that the source of this reflector lies above Core 3 (80 to 90) meters. Consequently, other thick sands may be present in the Upper Pliocene part of the section.

Unit 1 (Cores 1, 2 and 3, 0 to 90 meters) is a greenish-gray silty mud with a few interbeds of silty sand. Some nannofossil muds occur in Core 3 (80 to 90 meters). The coarser sediments as well as the silty muds are believed to be of turbidite origin. Reworked fossils are prominent in the terrigenous interval encompassing units 1 and 2. Fresh water diatoms and small carbonized wood fragments are also present.

Site 32 is located on Magnetic Anomaly 13, which is indicated as having an age of 38 million years. The oldest fossils recovered at the site are within a thin laminated interval of sediments 2 meters above the basement. These fossils indicate an age comparable to the highest Lower Oligocene, about 32 million years.

The basalt at this site, in spite of the presence of manganese rinds, may have been intruded into the sediments. This interpretation is based on the presence of the black-brown dolomitic mud recovered from Core 13. No further evaluation of this question can be made here.

During latest Early Oligocene time, sedimentation commenced with the deposition of a thin nannofossil "red" clay. This was followed by zeolite-rich "red" clays and several ash beds.

In the early Miocene, either organic productivity increased to permit the appearance of siliceous plankton, or else the sedimentary environment permitted their preservation as fossils. By Middle Miocene, siliceous-fossil beds began accumulating. Volcanic ash was still a common constituent. Sometime in the Late Miocene, the fine terrigenous detritus of the siliceous-fossil mud began to have coarser detritus associated with it, probably resulting from activity of the Delgada Fan. By Early Pliocene time, intermittent influxes of silt had been augmented by the deposition of thick sands, both apparently of turbidite origin. Significant sand deposition may have continued sporadically into the Late Pliocene. By Pleistocene time, only thin silty sands were being deposited among the silty clays and clayey silts.

REFERENCES

Cupp, Easter, 1943. Marine plankton diatoms of the west coast of North America. *Bull. Scripps Inst. Oceanog. Univ. Calif.* **5**, 1.

Hendey, I. N., 1937. The plankton diatoms of the southern seas. *Discovery Reports.* **16**, 151.

———, 1964. An introductory account of the smaller algae of British coastal waters. Pt. V, Bacillariophyceae (Diatoms). *Fishery Invest., Ser. IV.*

Hustedt, Fredrich, 1930. Die Kieselalgen Deutschlands, Oesterreichs und der Schweiz mit Berucksightigung der ubrigen Lander Europas sowie der angrenzenden Meeresgebiedt. **In** Kryptogammen–Flora von Deutschland, *Oesterreich und der Schweiz.* L. Rabenhorsts (Ed.). Leipzig (Akad. Verlag, Geest Portig K–G) VII, **1**, 609.

Kanaya, Taro, 1959. Miocene diatom assemblages from the Onnagawa Formation and their distribution in the correlative formations in Northeast Japan. *Sci. Rept. Tohoku Univ. Second Sr. (Geol.).* **30**, 1.

Loeblich, A. R., III, Loeblich, L. A., Tappan, and Loeblich, A. R., Jr., 1968. Annotated index of fossil and recent silicoflagellates and ebridians with descriptions and illustrations of validly proposed taxa. *Geol. Soc. Am., Mem.* 106, 1.

Wornardt, W. E., Jr., 1967. Miocene and Pliocene marine diatoms from California. *Calif. Acad. Sci.,* Occ. Paper 63, 1.

THE CORES RECOVERED FROM SITE 32

The following pages present a graphic summary of the results of drilling and coring at Site 32. Fig. 2, a summary of Site 32 is at the back of the book. Figures 3 to 15 are summaries of the individual cores recovered. A key to the lithologic symbols is given in the Introduction (Chapter 1).

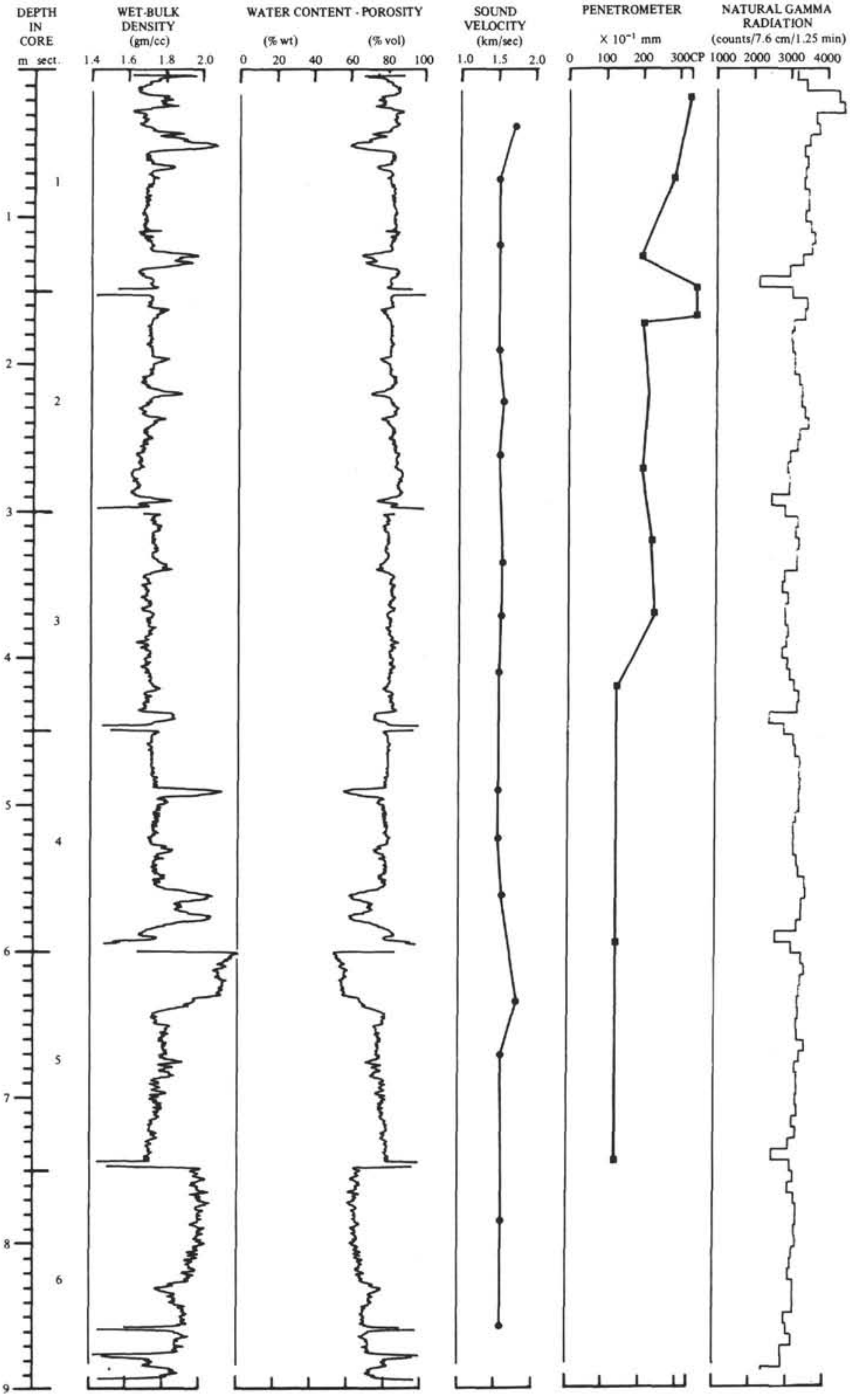

Figure 3A. *Physical Properties of Core 1, Hole 32*

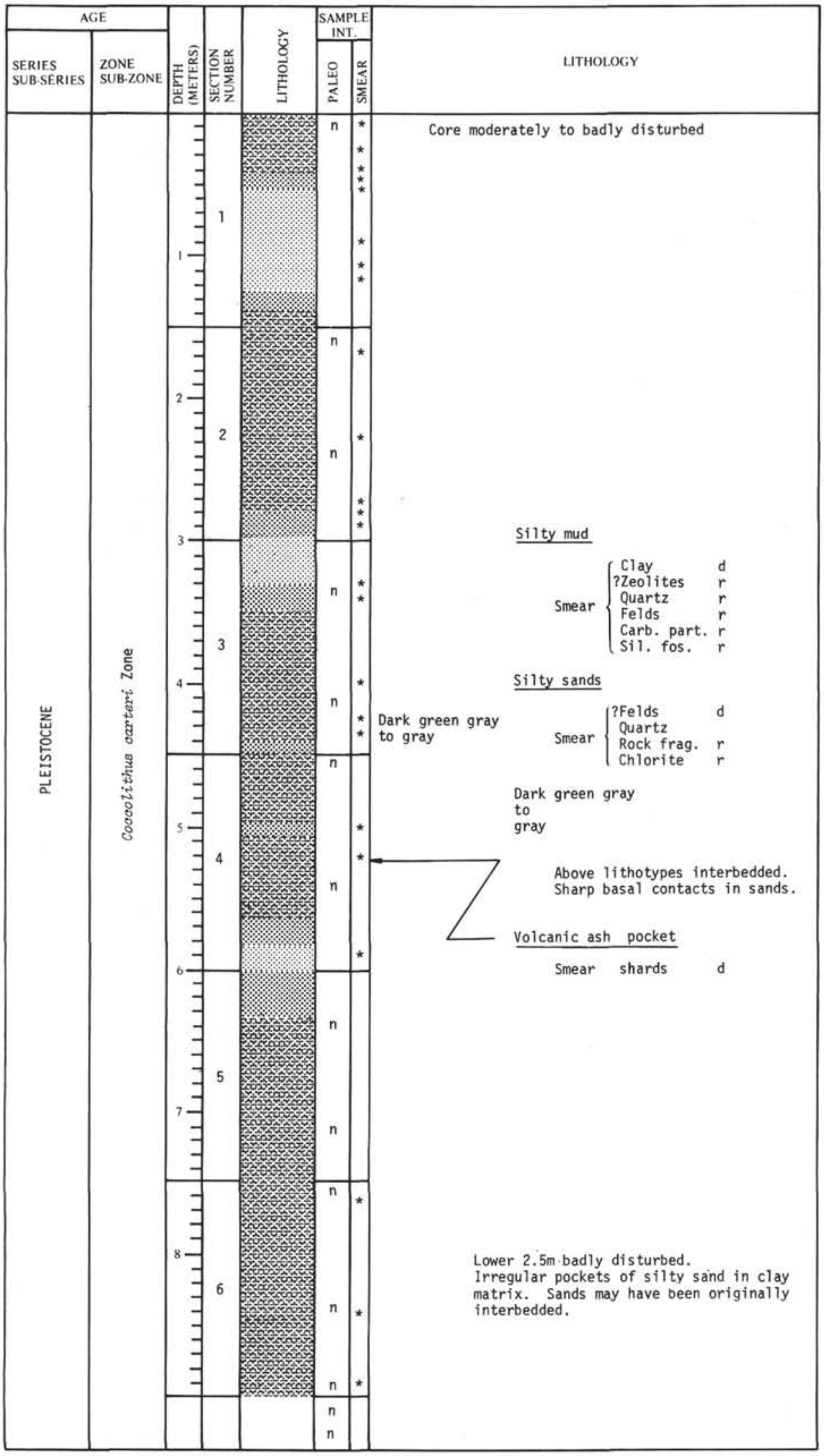

Figure 3B. *Core 1, Hole 32. (0-9 in Below Seabed)*

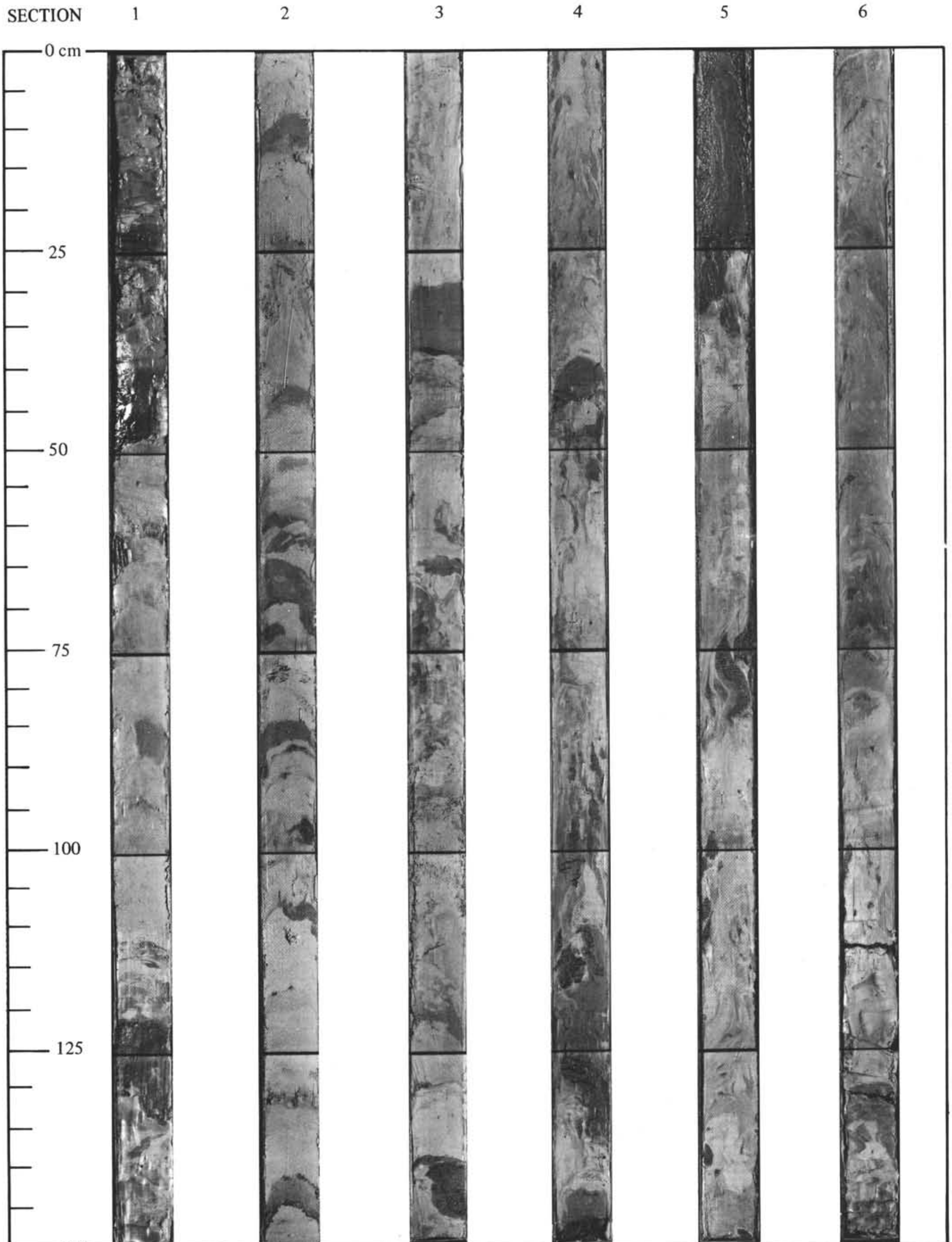

Plate 1. *Core 1, Hole 32*

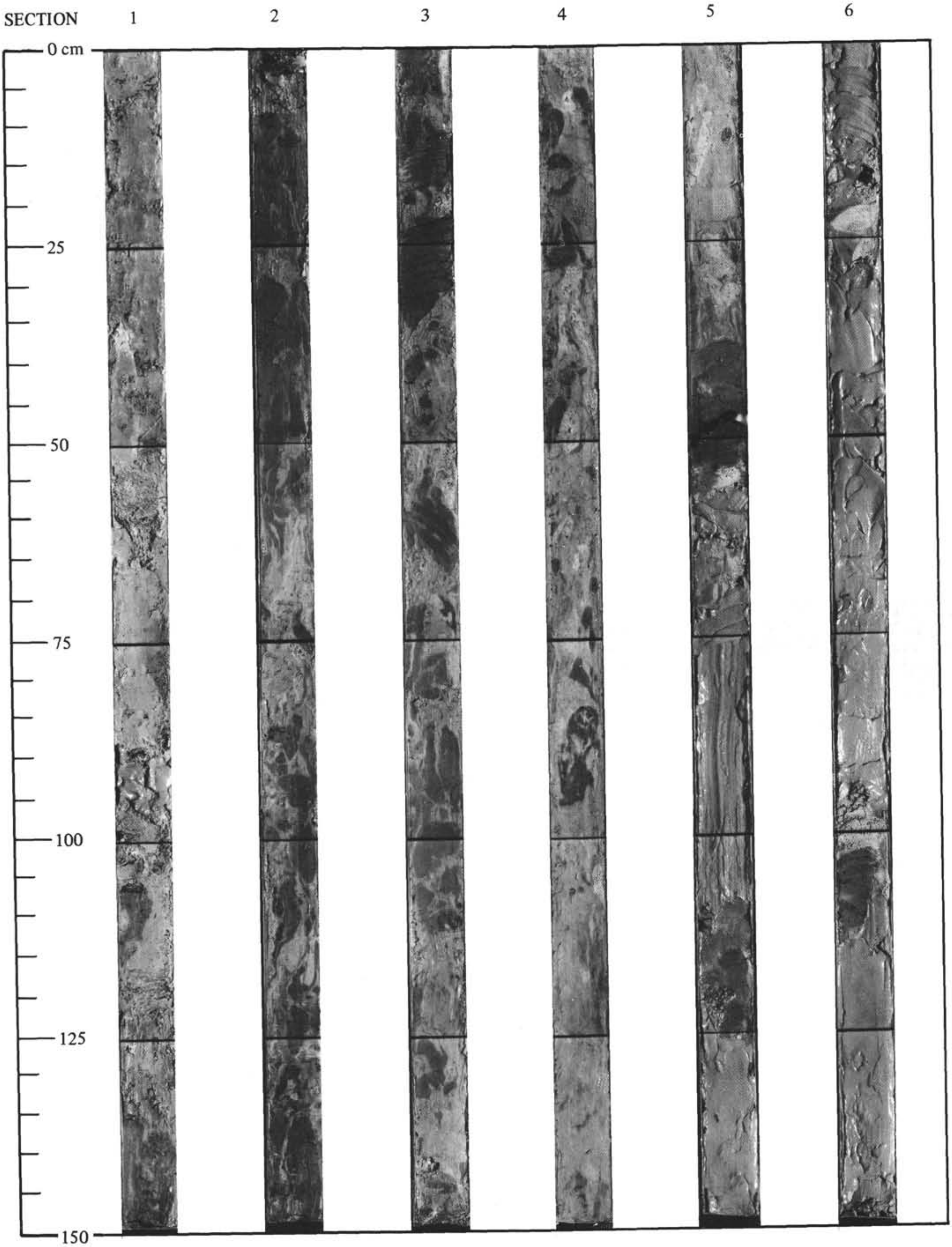

Plate 2. *Core 3, Hole 32*

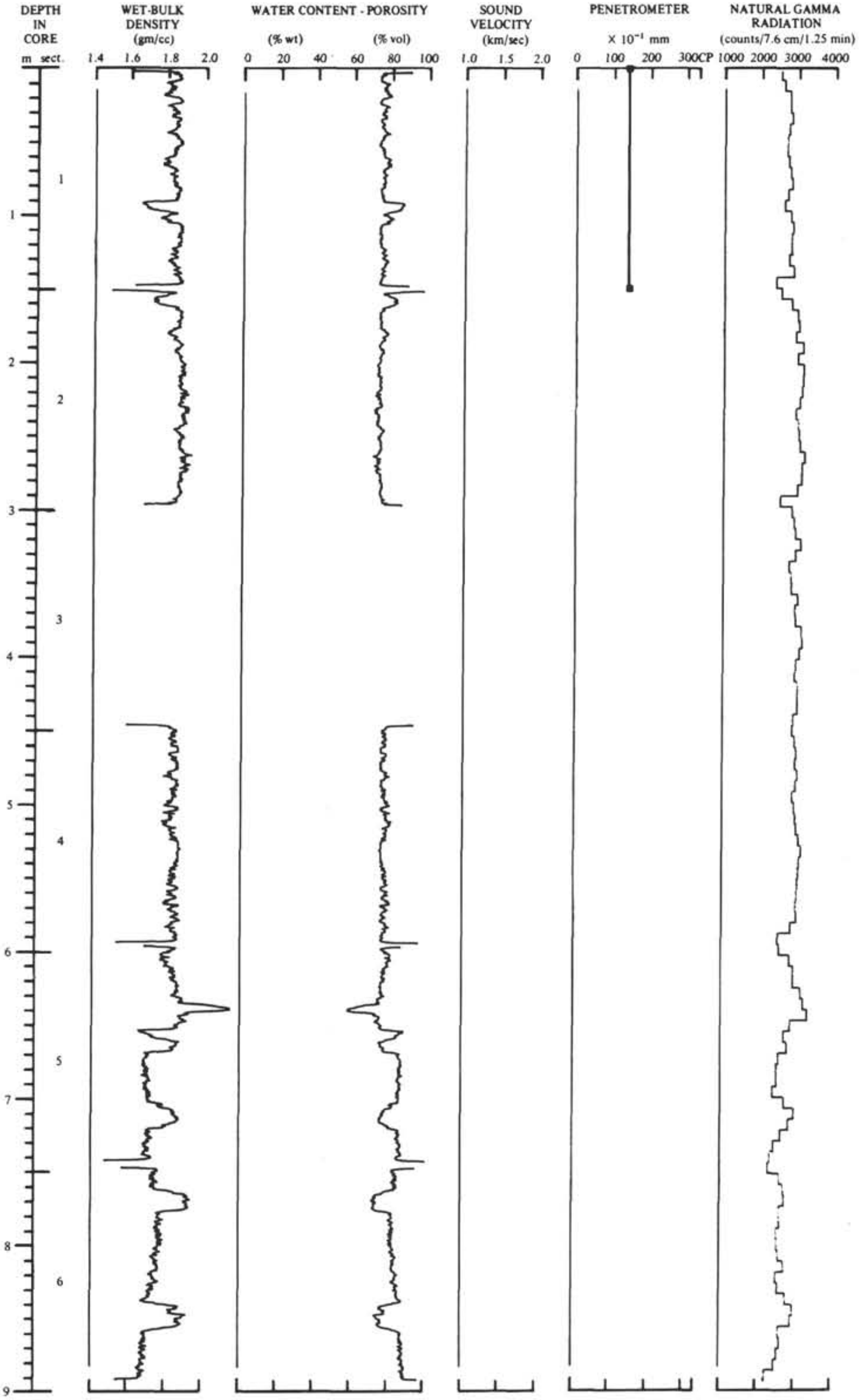

Figure 4A. *Physical Properties of Core 3, Hole 32*

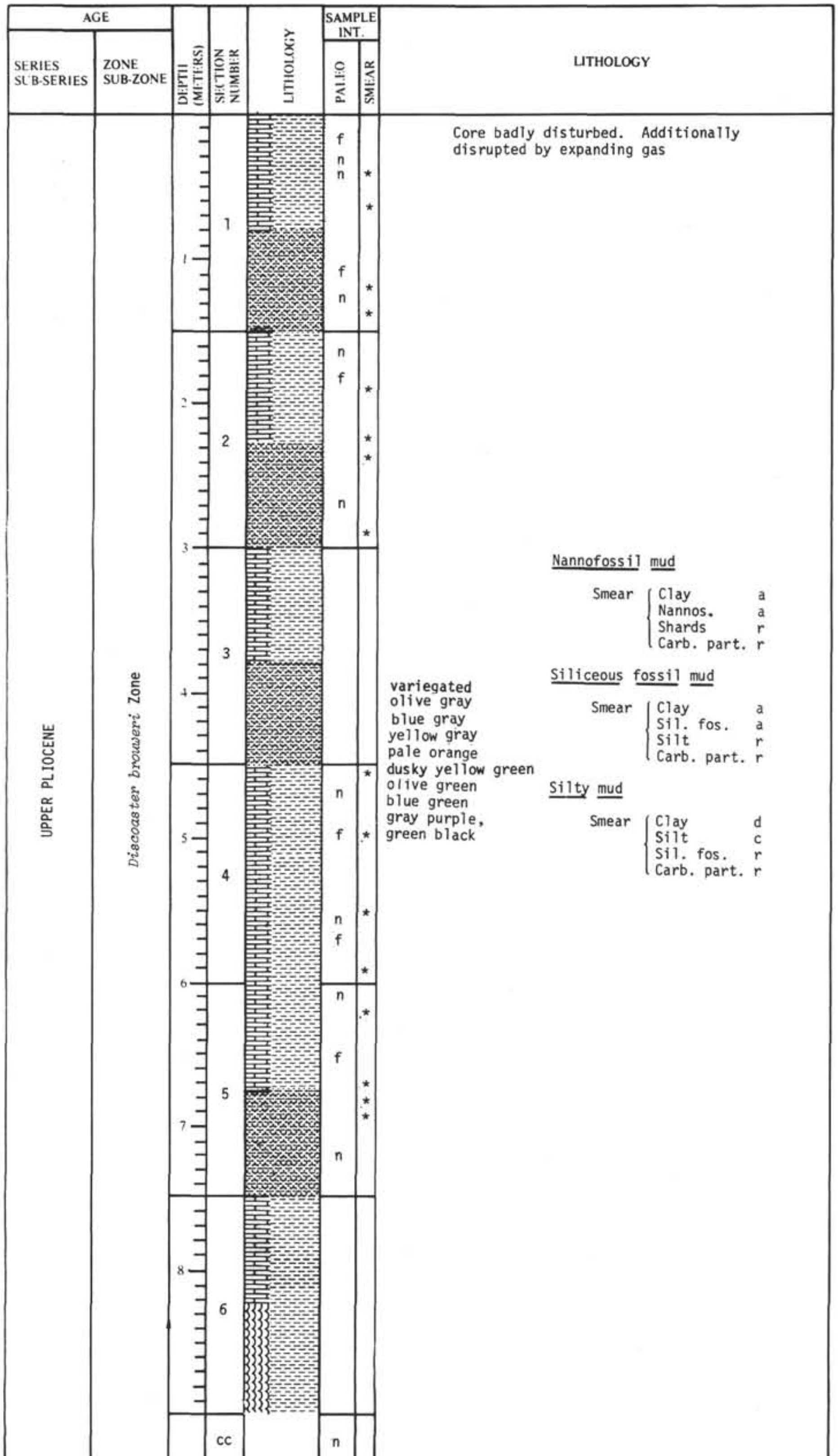

Figure 4B. *Core 3, Hole 32 (80-90 in Below Seabed).*

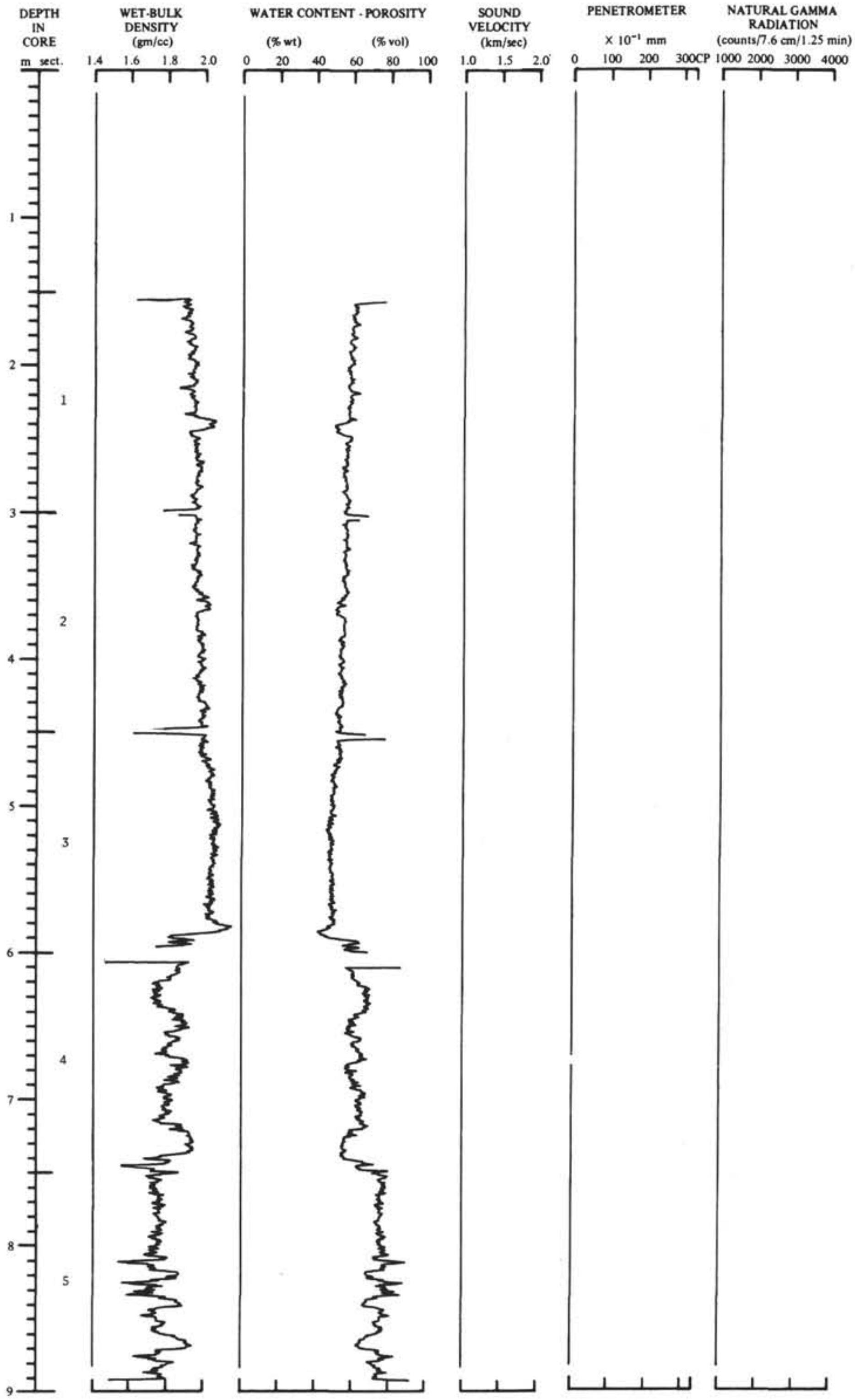

Figure 5A. *Physical Properties of Core 4, Hole 32*

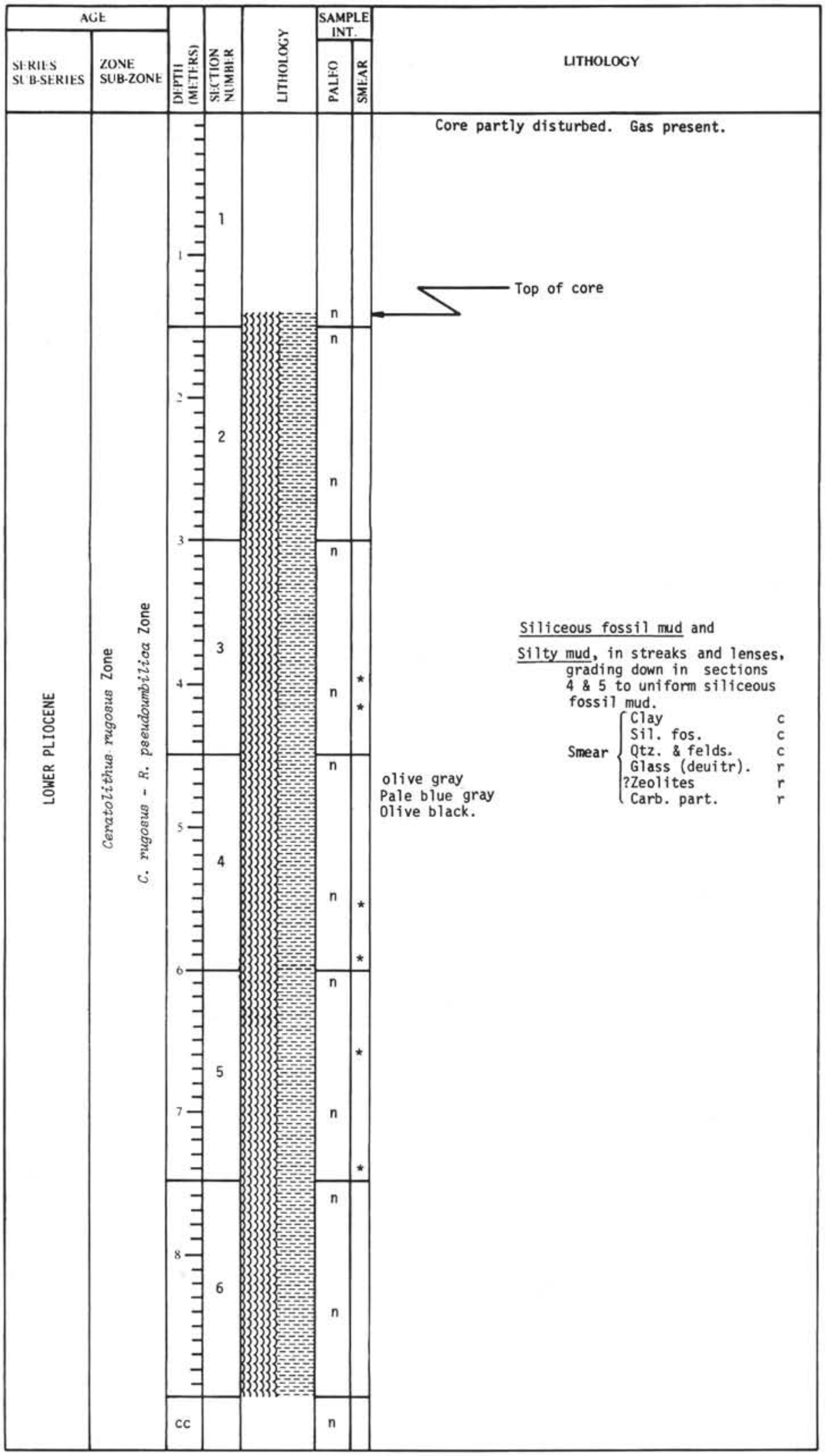

Figure 5B. *Core 4, Hóle 32. (90-99 m Below Seabed)*

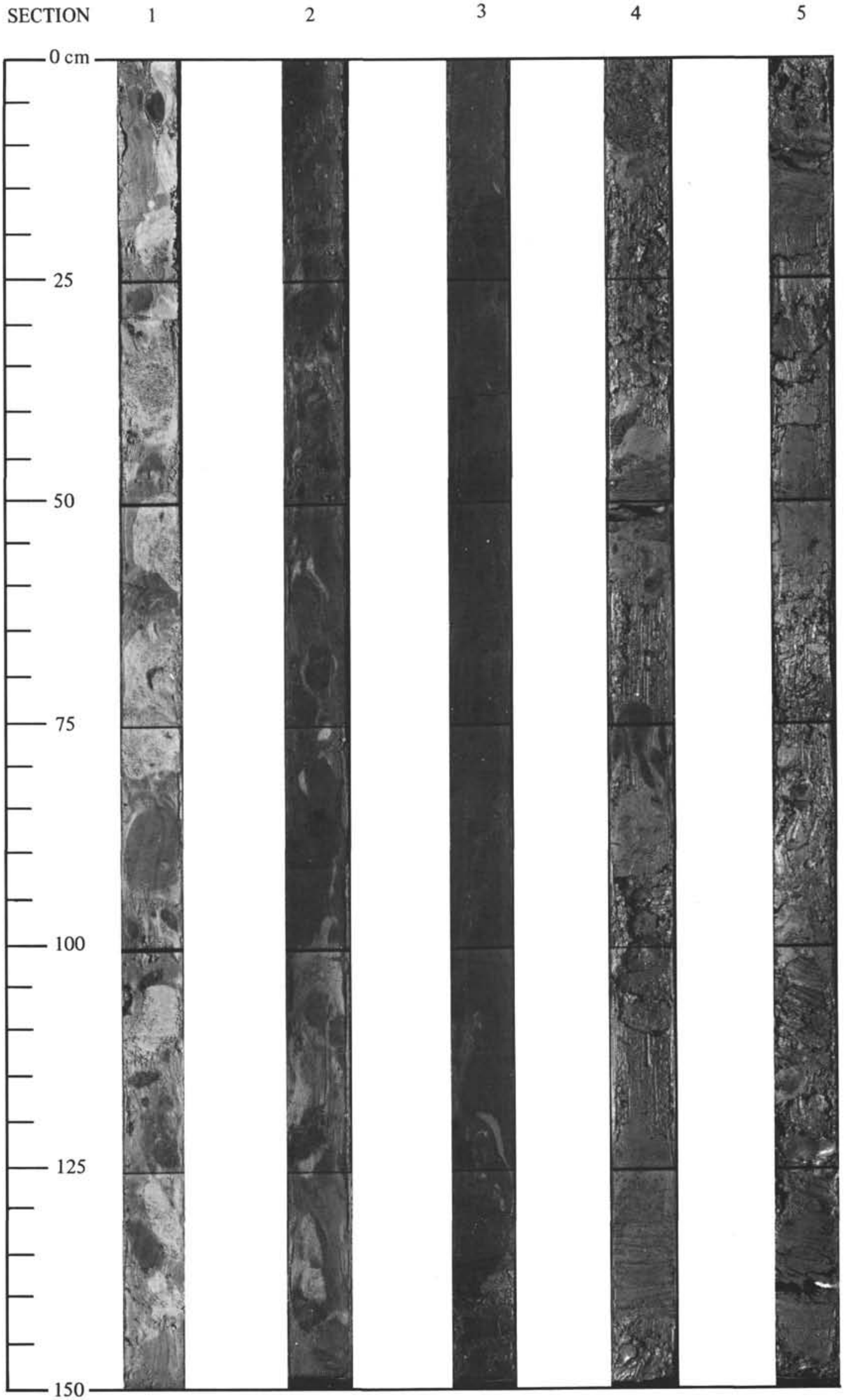

Plate 3. *Core 4, Hole 32*

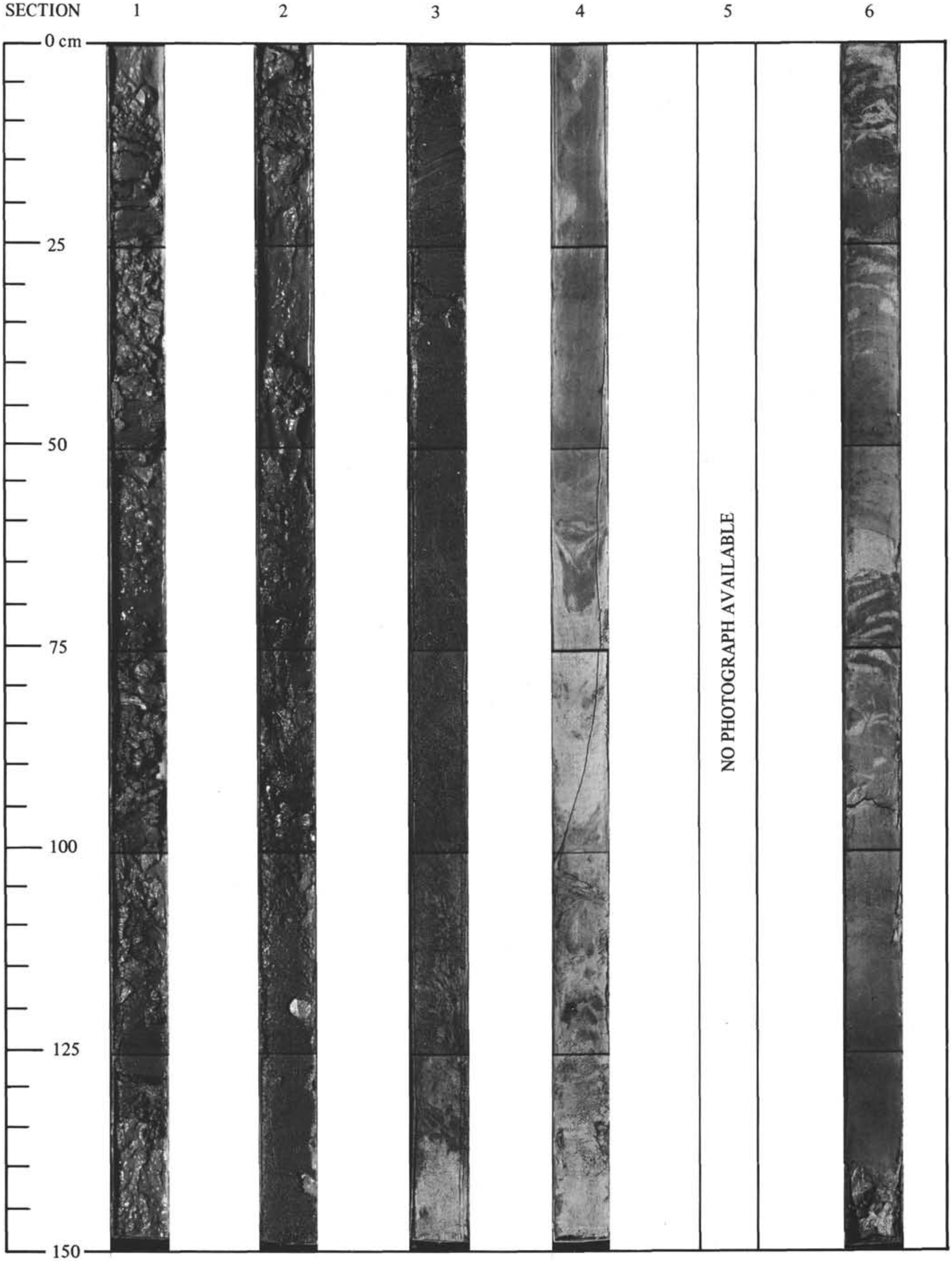

Plate 4. *Core 5, Hole 32*

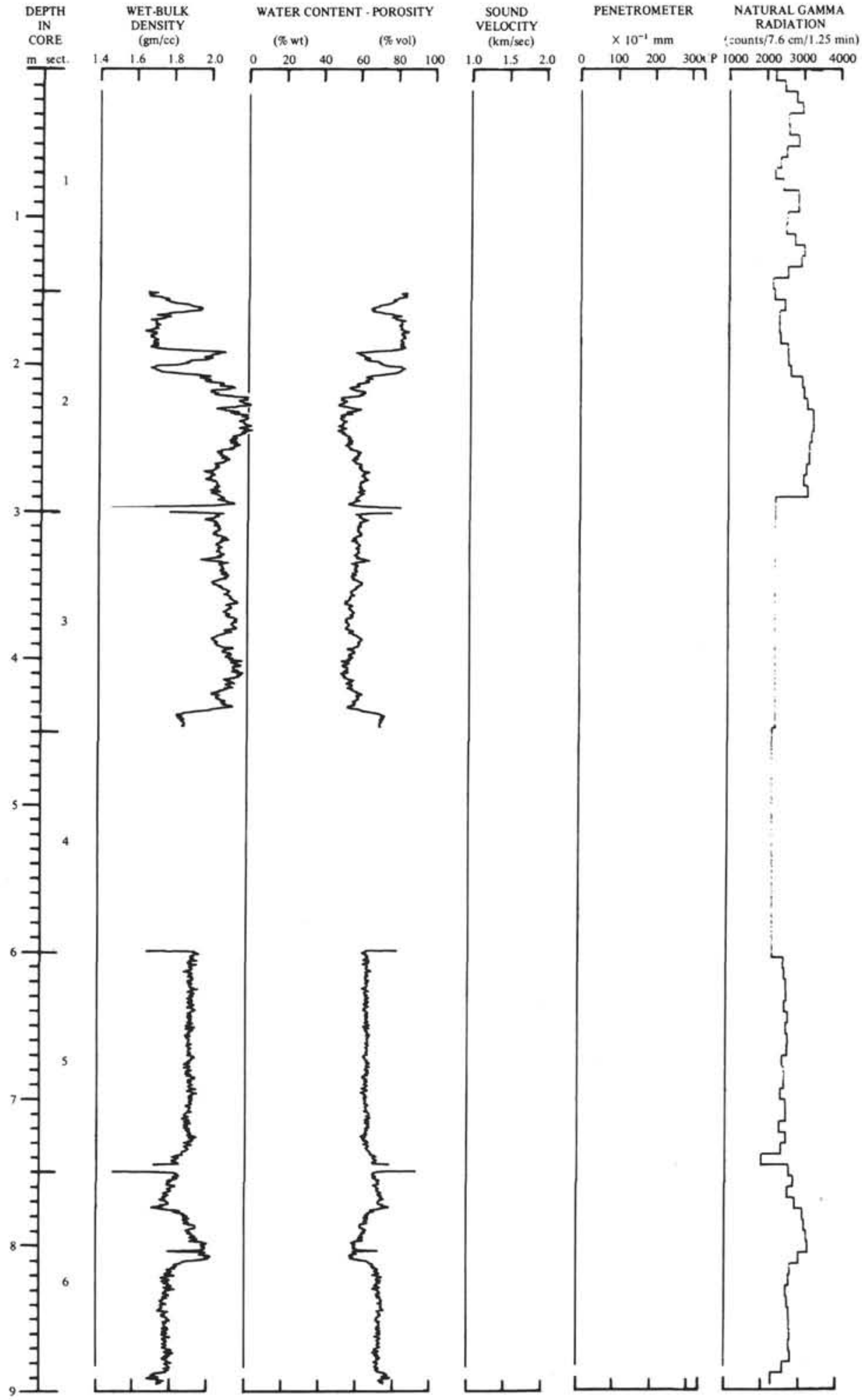

Figure 6A. *Physical Properties of Core 5, Hole 32*

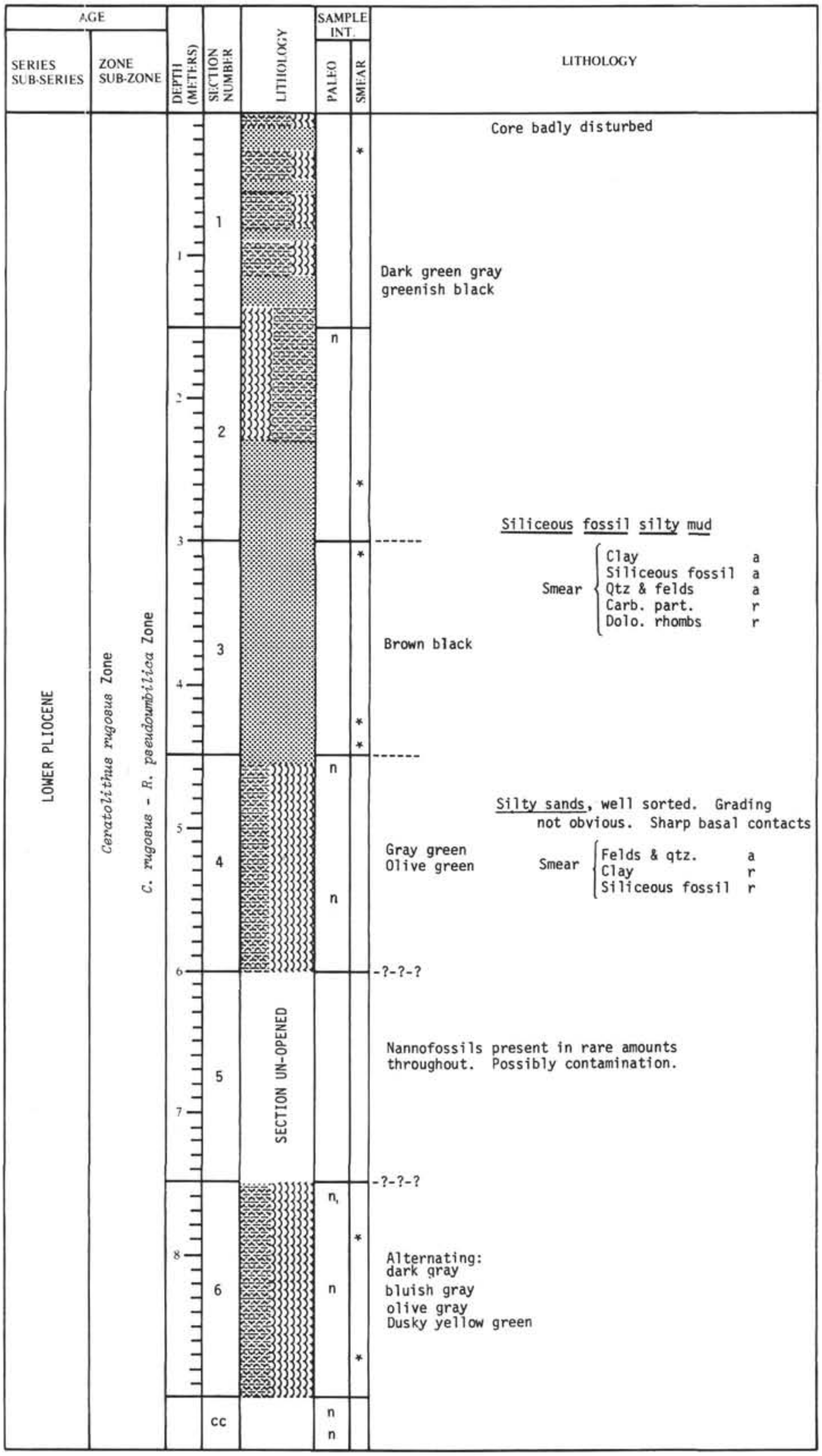

Figure 6B. *Core 5, Hole 32 (99-108 m Below Seabed)*

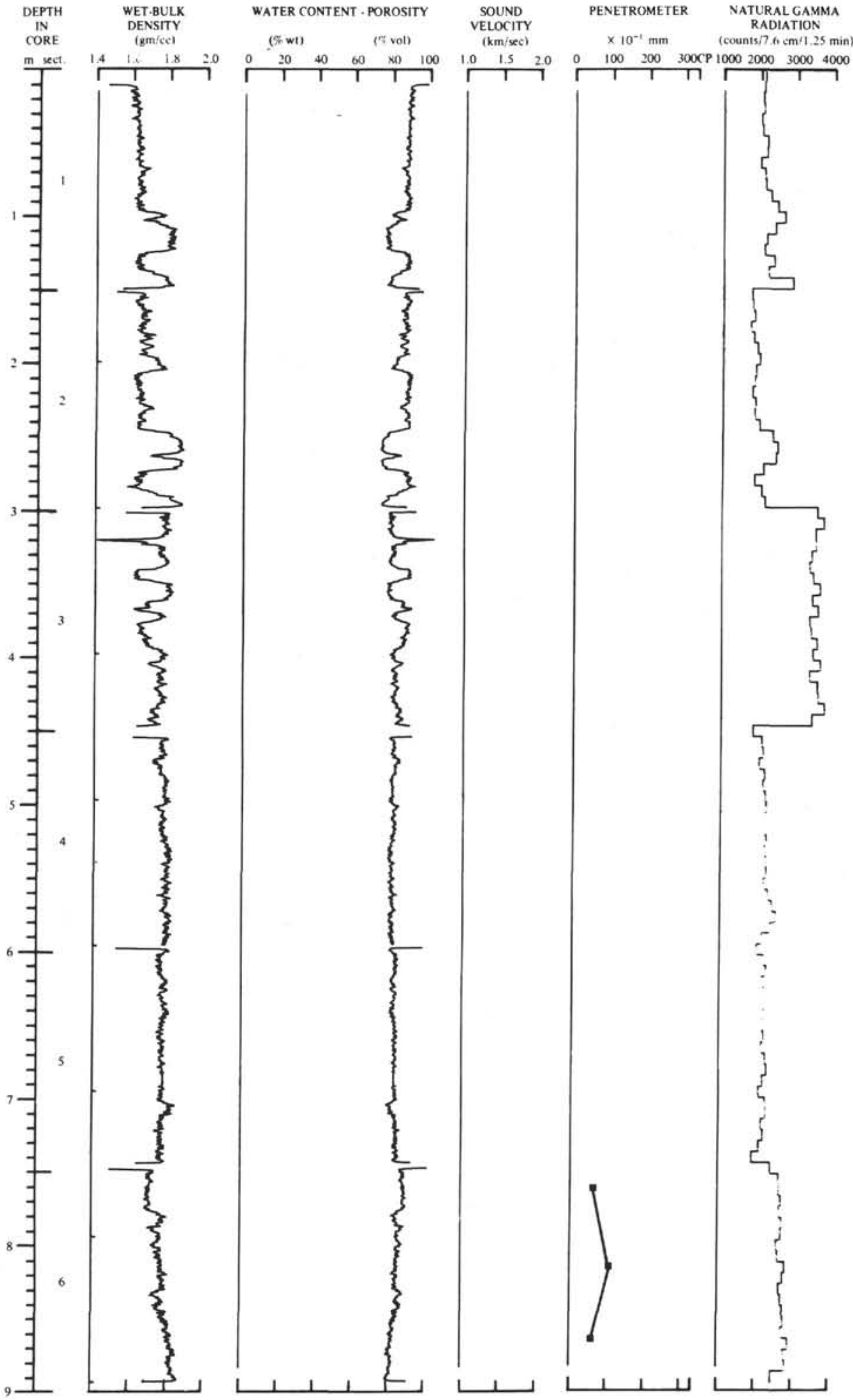

Figure 7A. *Physical Properties of Core 6, Hole 32*

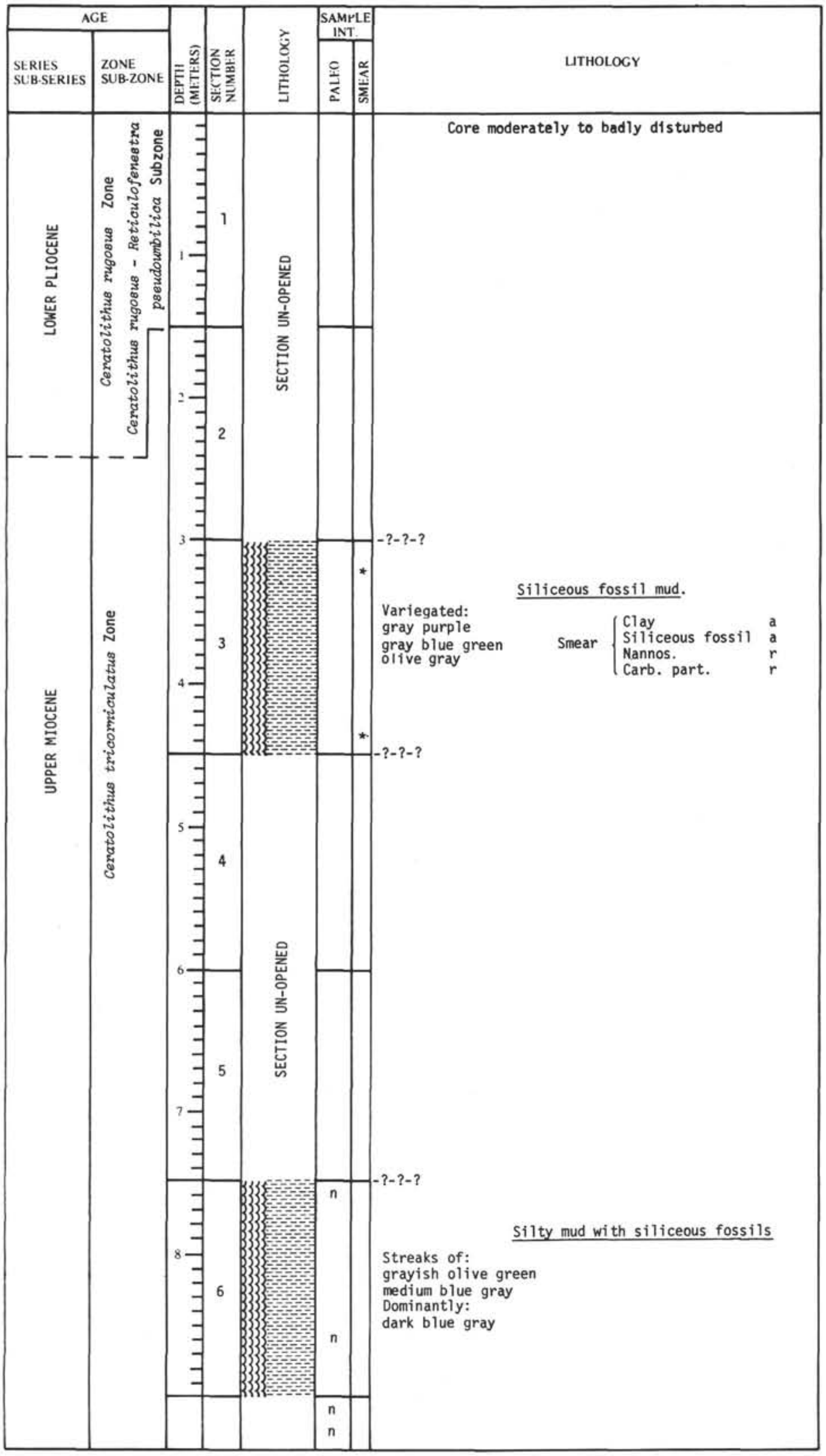

Figure 7B. *Core 6, Hole 32 (108-117 m Below Seabed)*

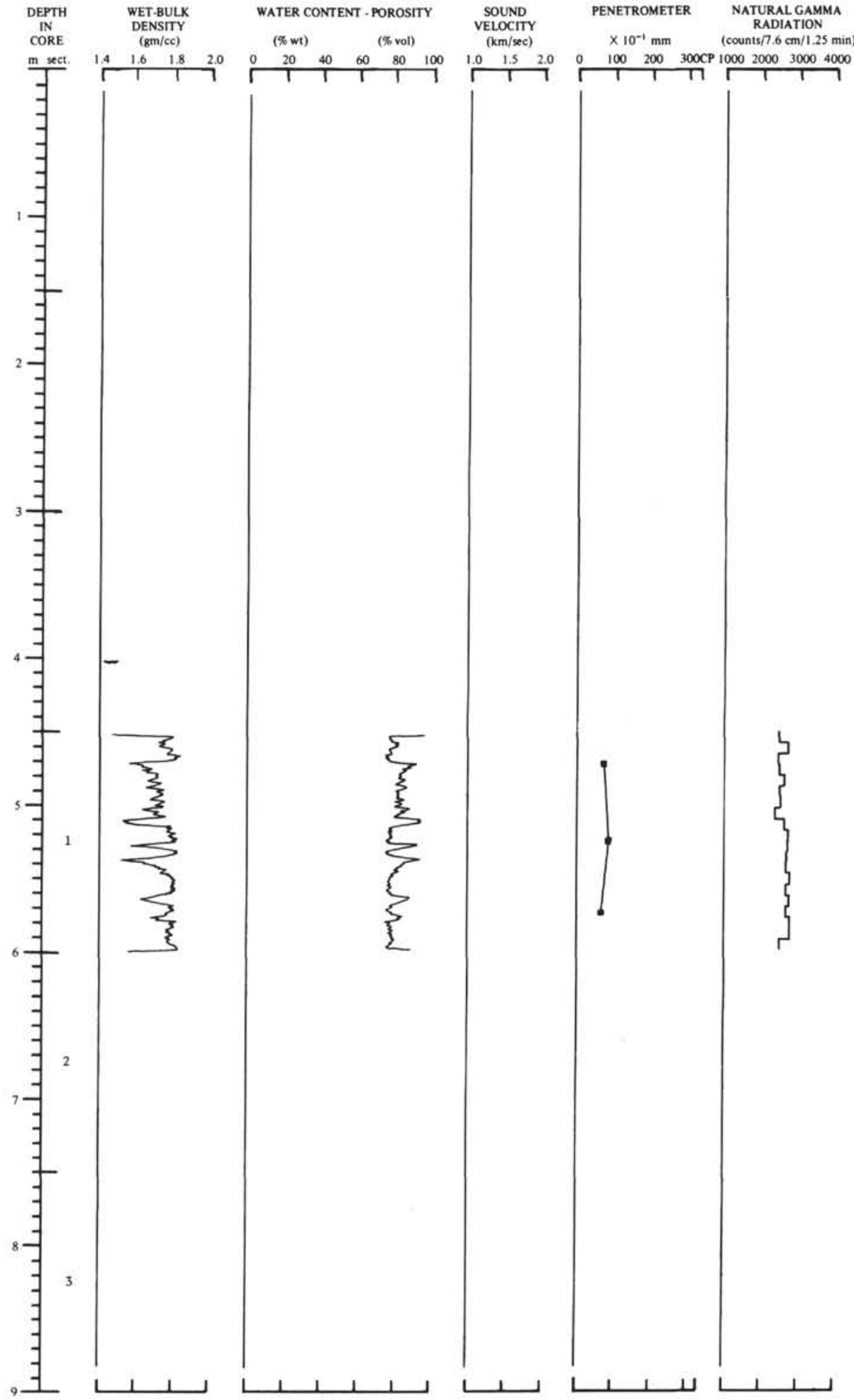

Figure 8A. *Physical Properties of Core 7, Hole 32*

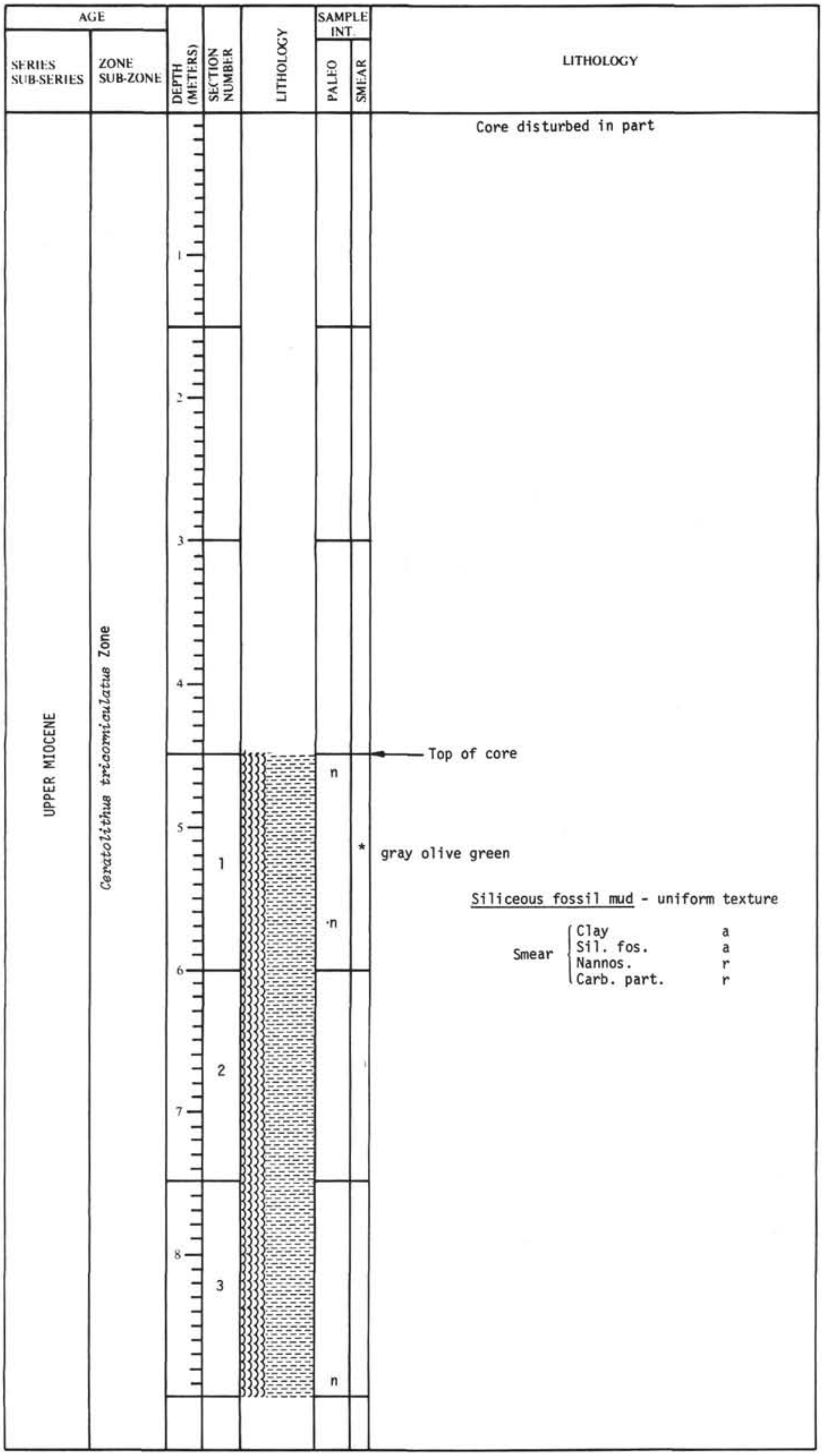

Figure 8B. *Core 7, Hole 32 (138-147 m Below Seabed)*

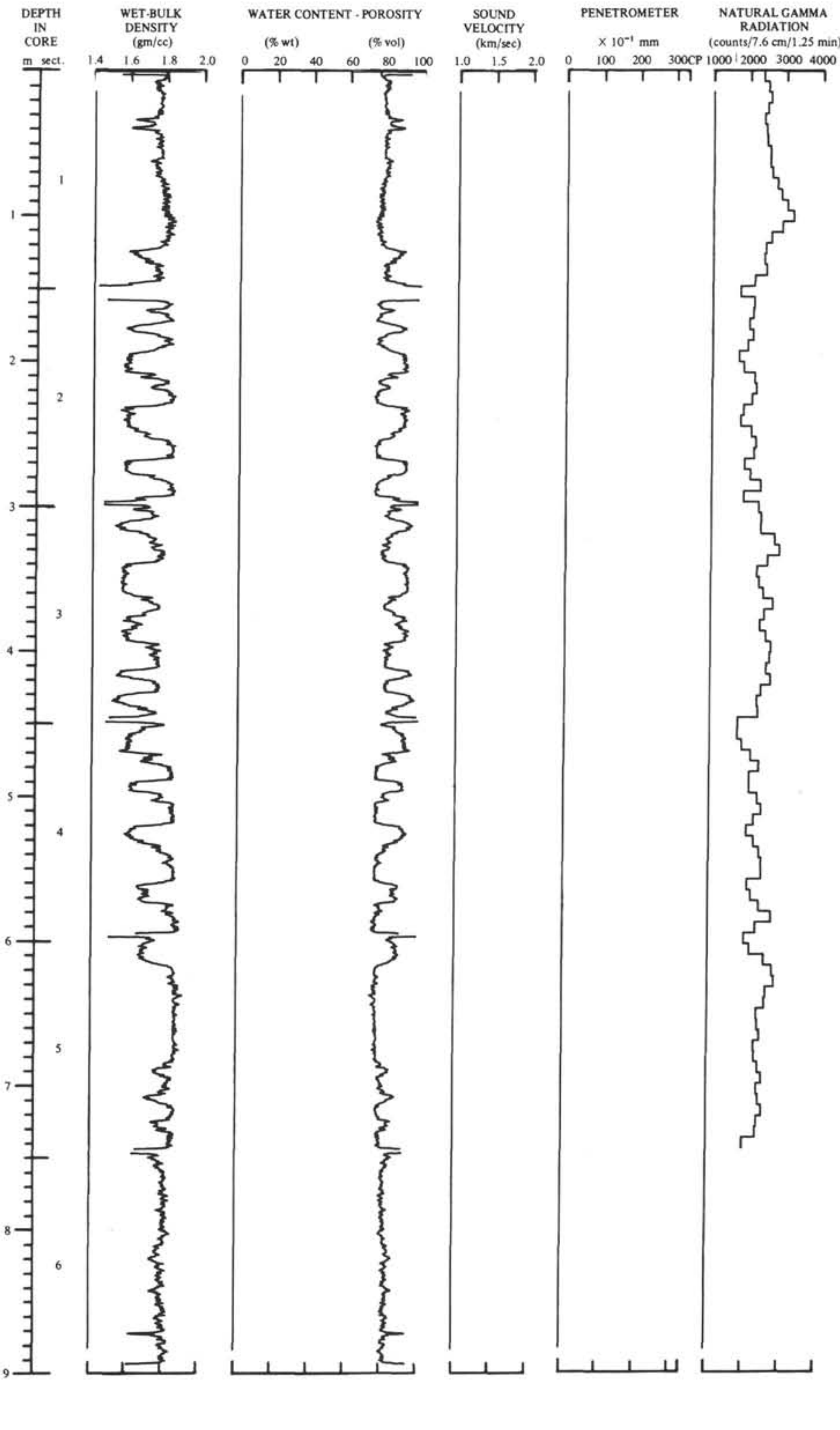

Figure 9A. *Physical Properties of Core 8, Hole 32*

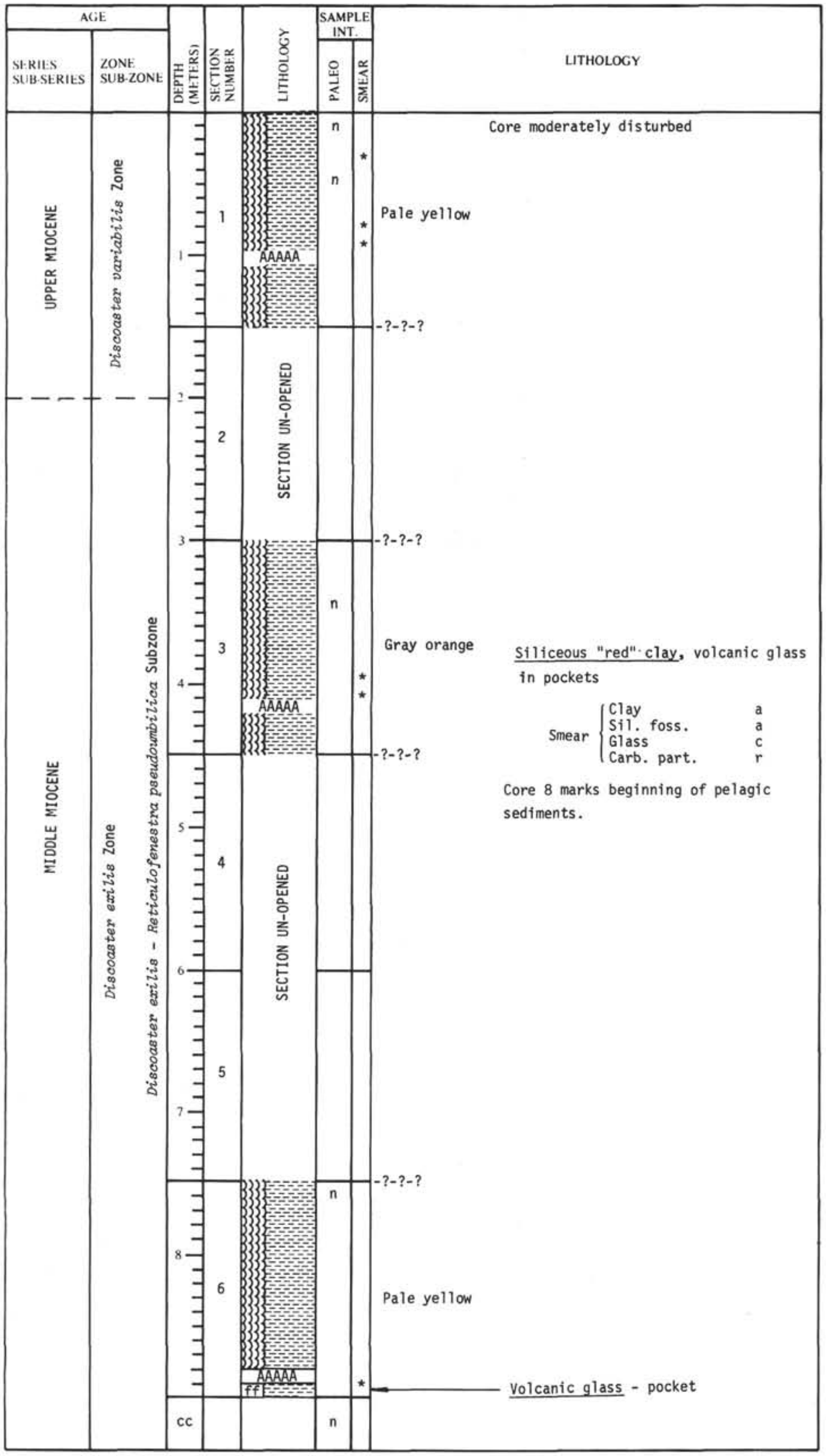

Figure 9B. *Core 8, Hole 32 (166-176 m Below Seabed)*

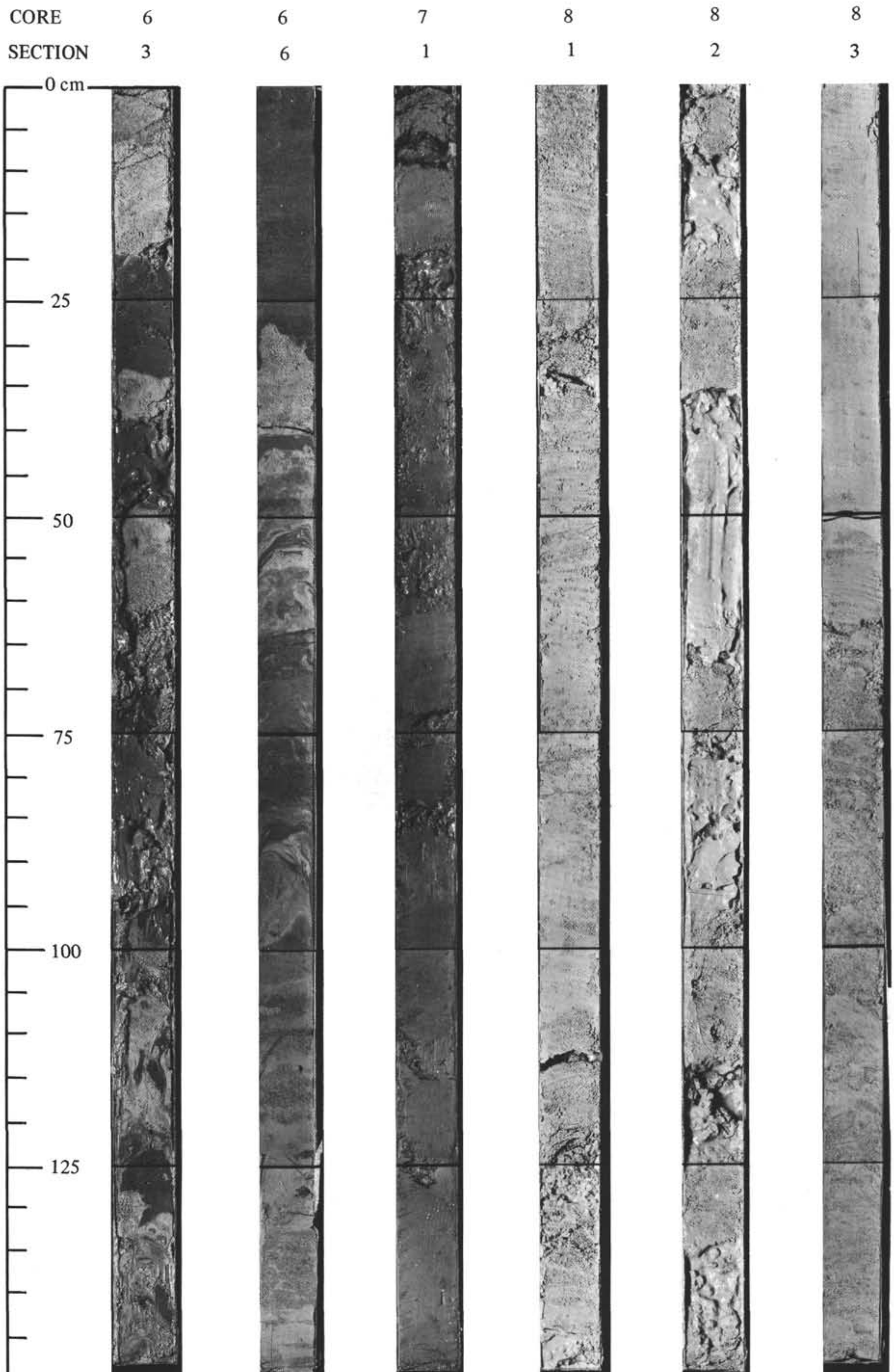

Plate 5. *Sections of Cores 6, 7 and 8, Hole 32*

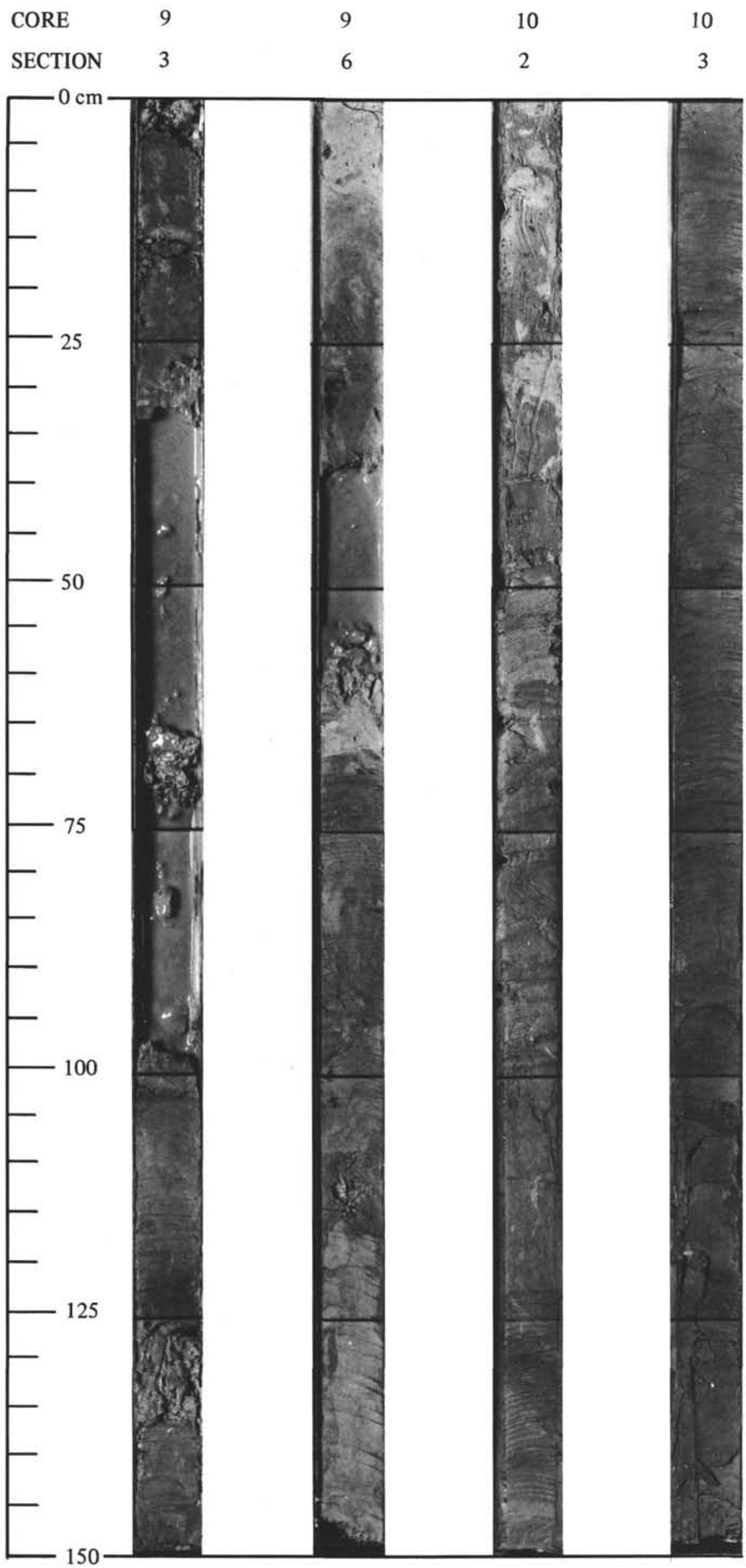

Plate 6. *Sections of Core 9 and 10, Hole 32*

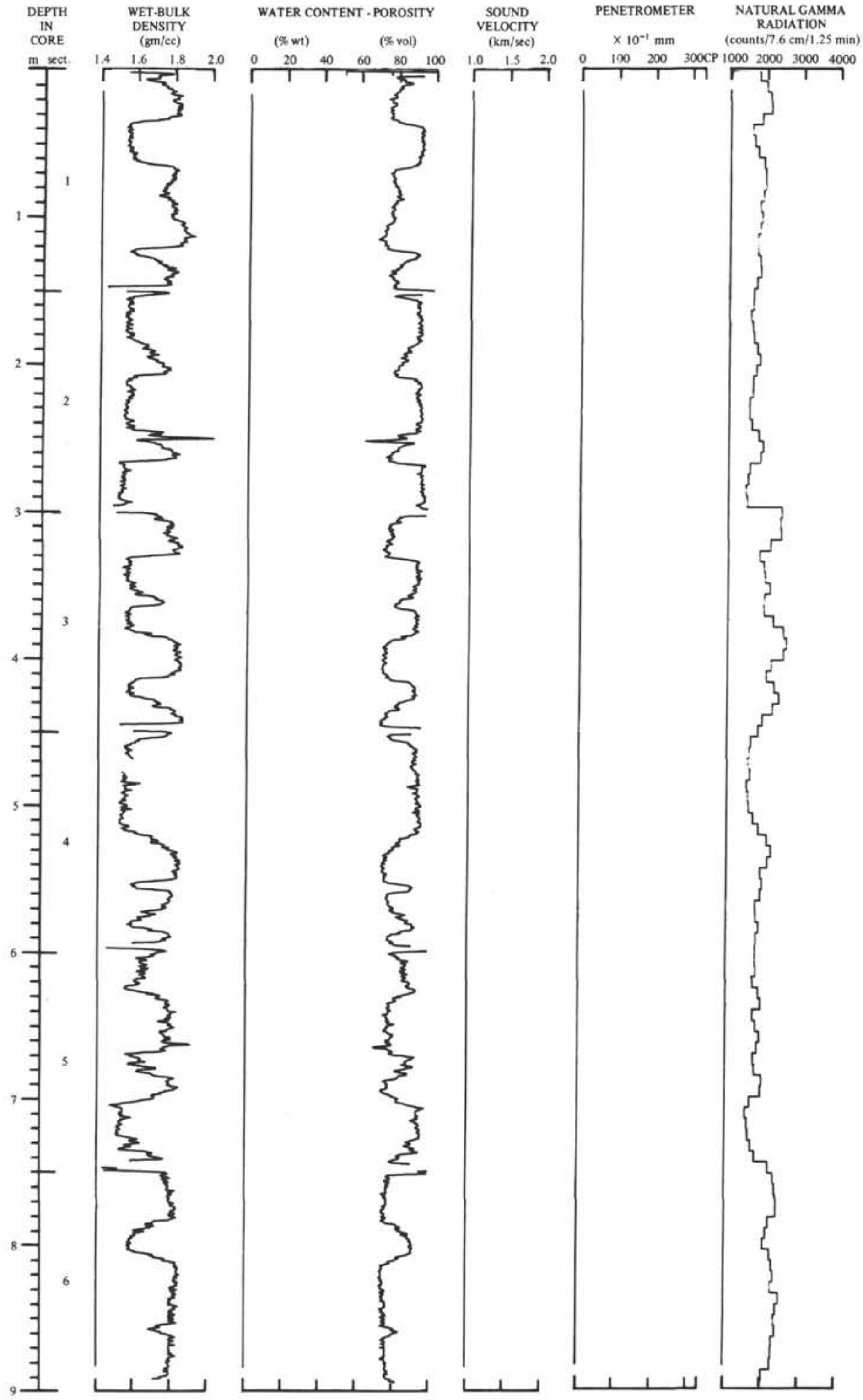

Figure 10A. *Physical Properties of Core 9, Hole 32*

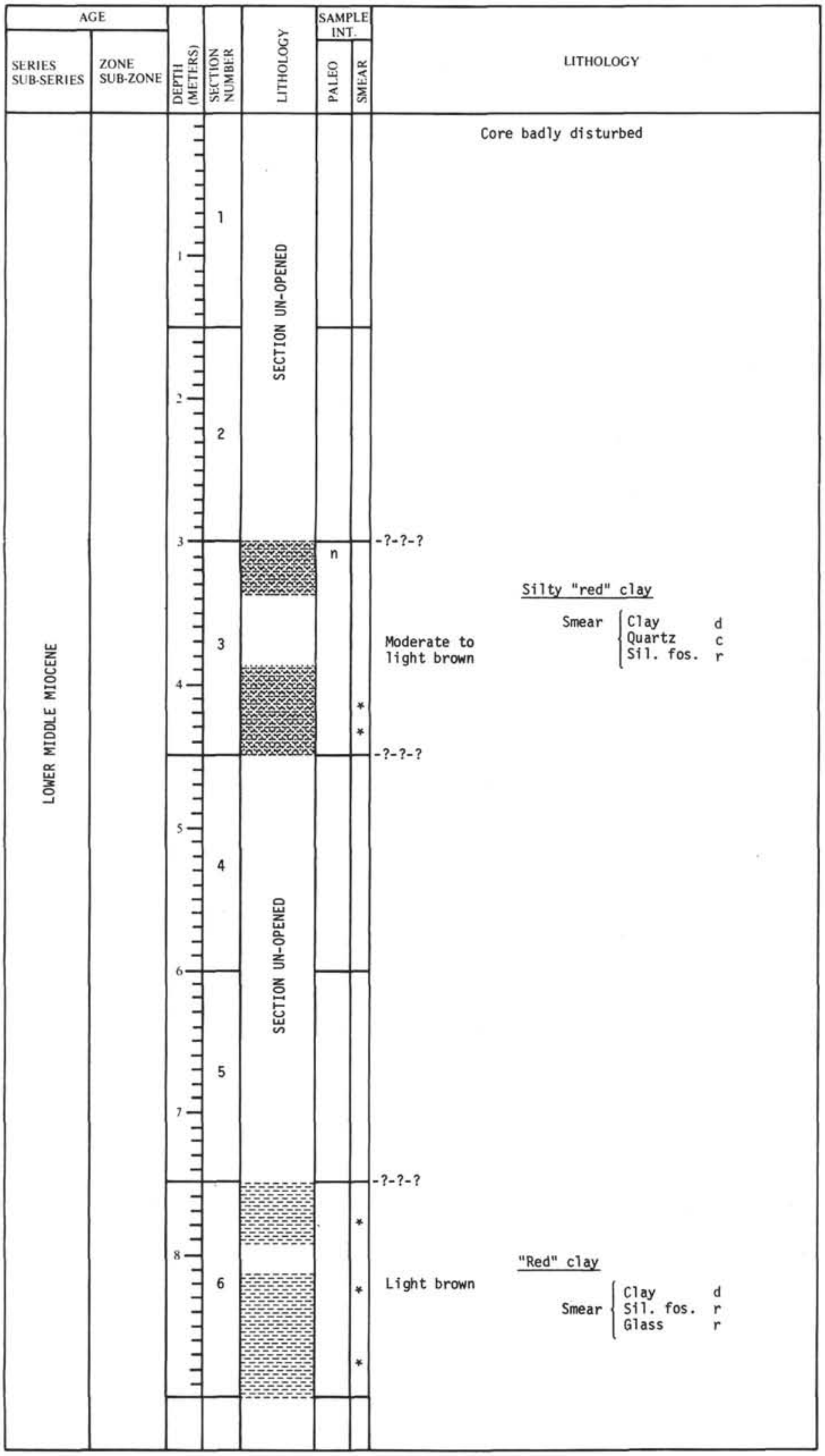

Figure 10B. *Core 9, Hole 32 (176-185 m Below Seabed)*

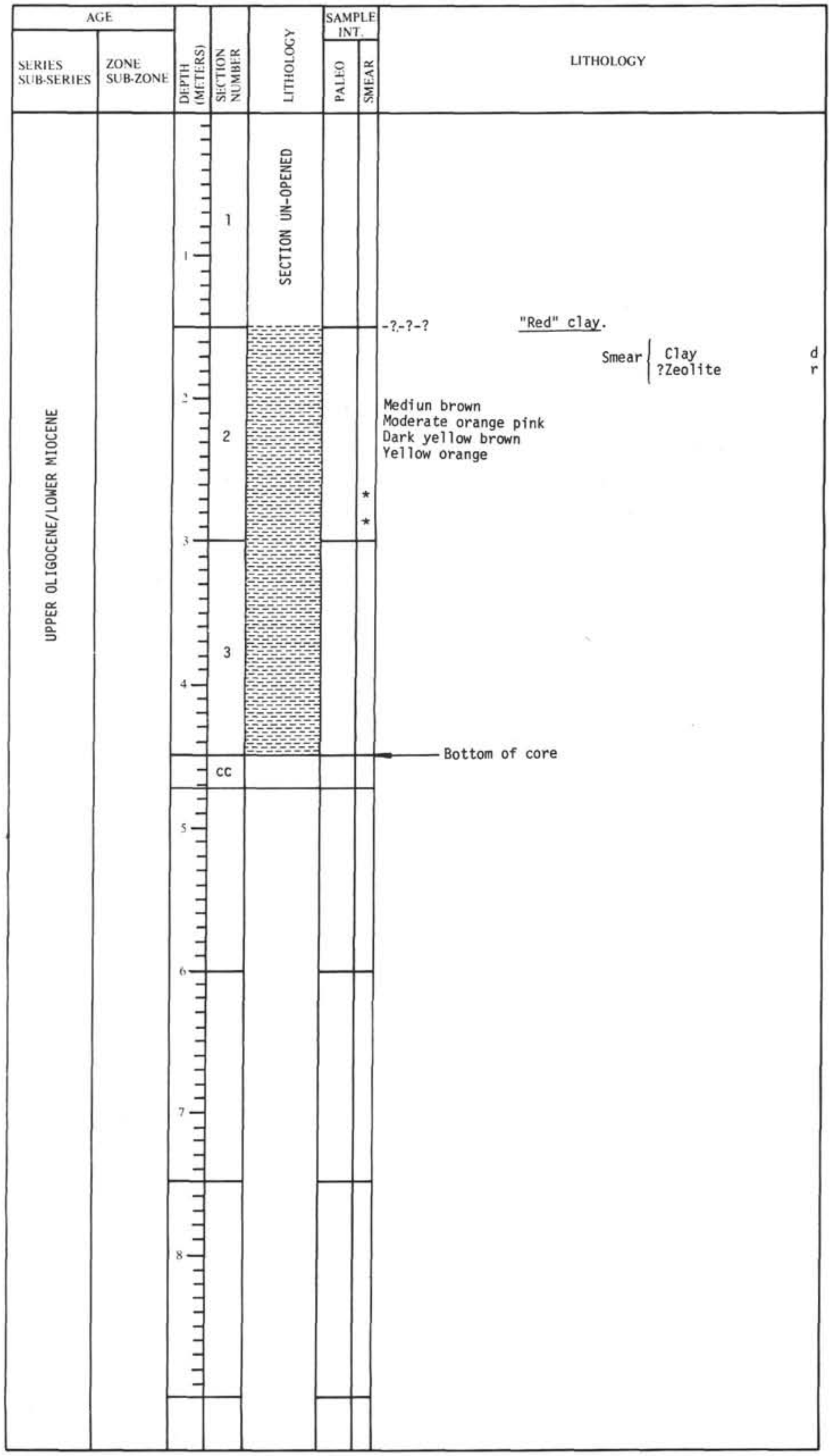

Figure 11. *Core 10, Hole 32 (185-194 m Below Seabed)*

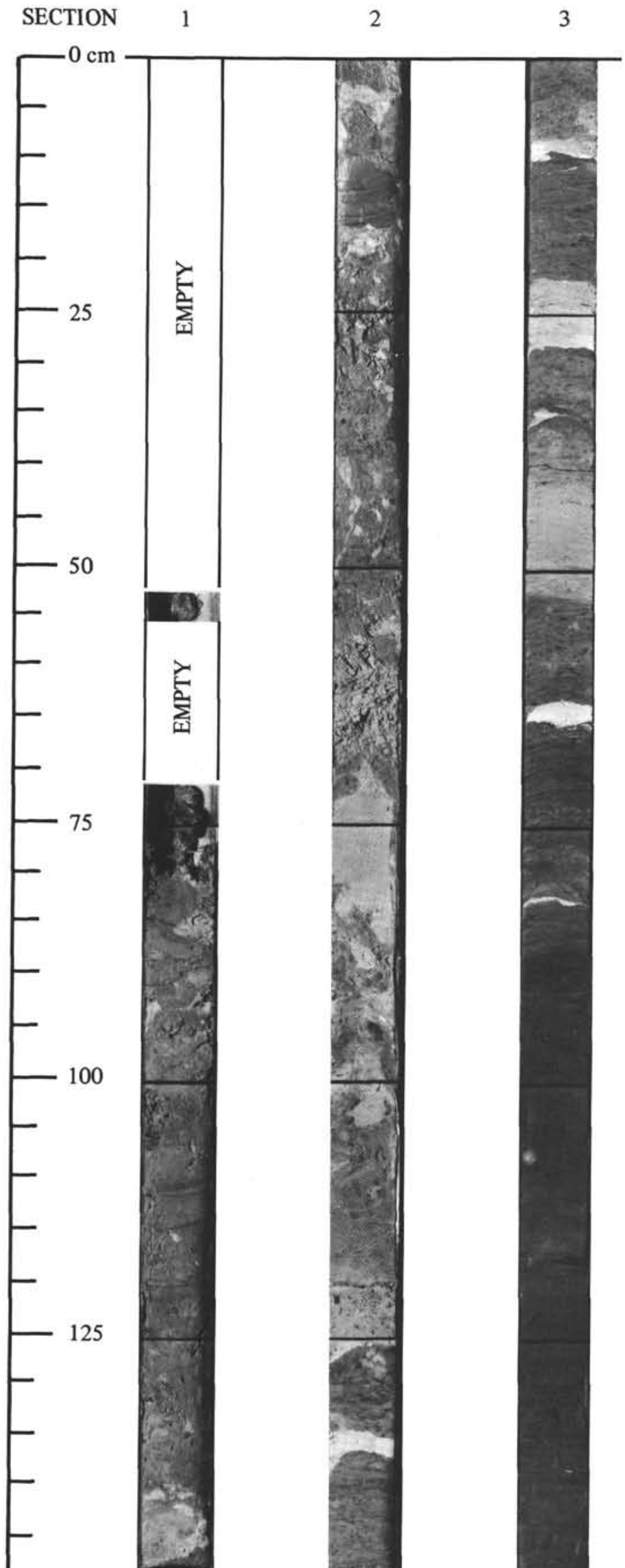

Plate 7. *Sections of Core 11, Hole 32*

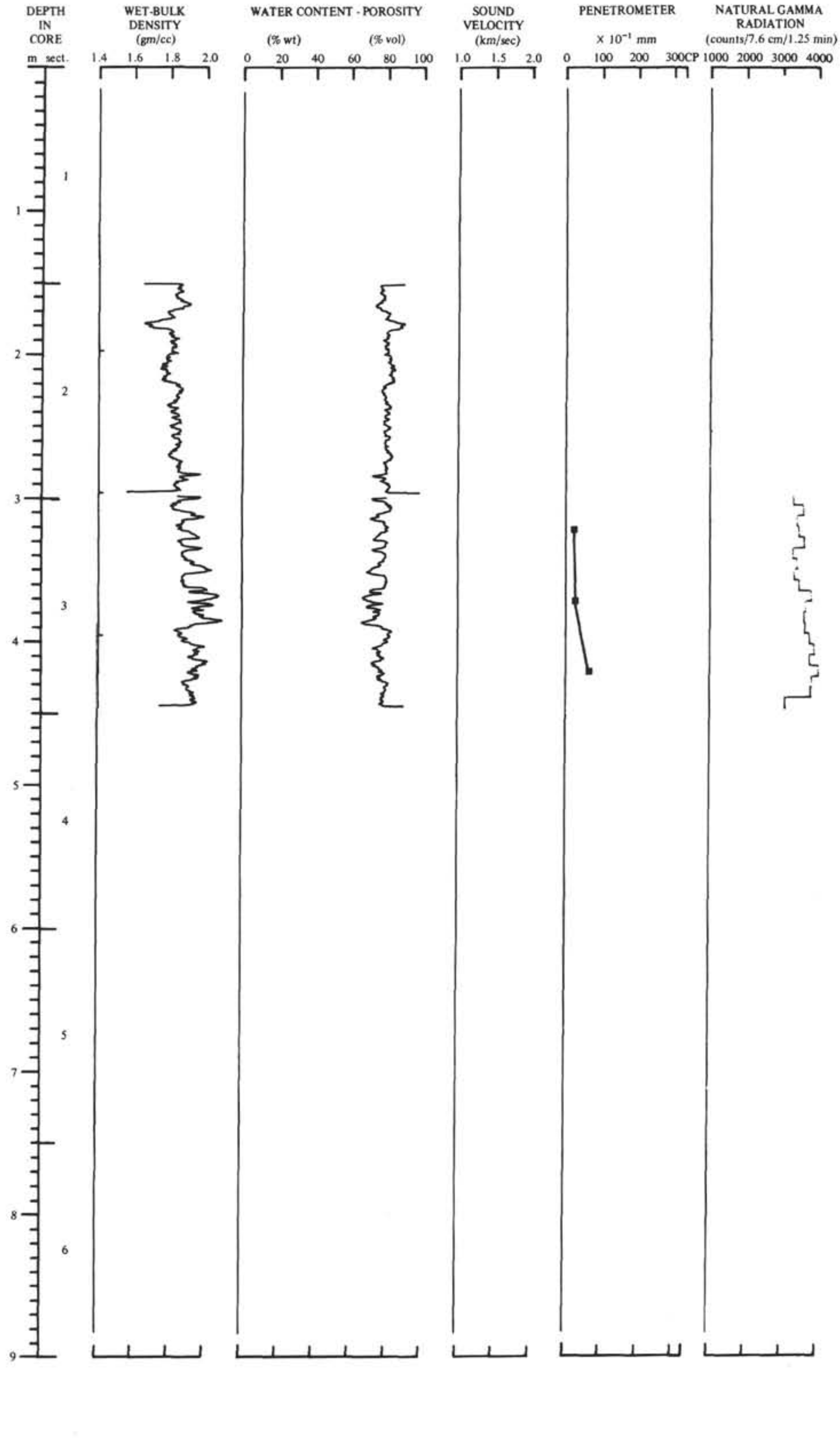

Figure 12A. *Physical Properties of Core 11, Hole 32*

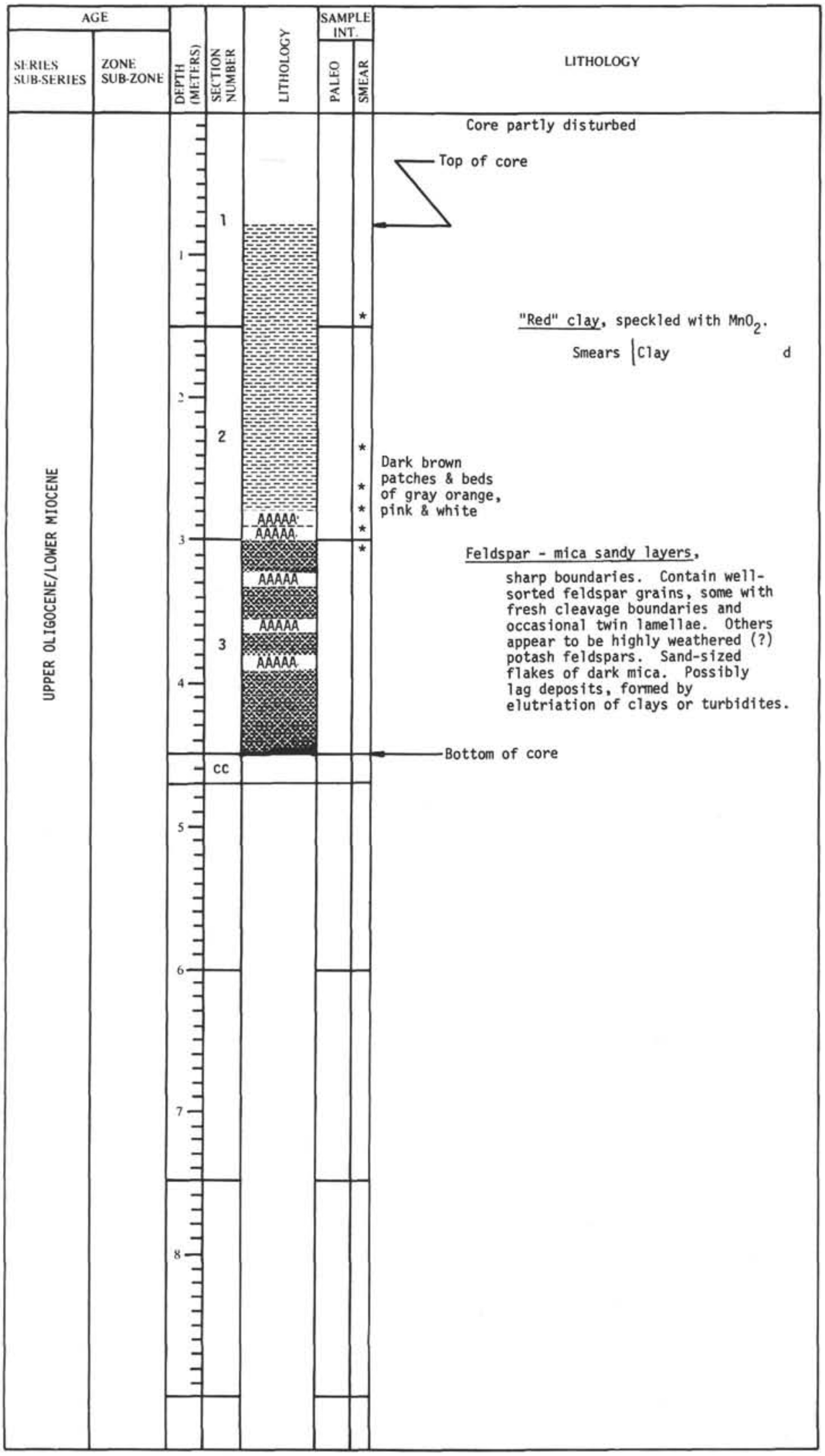

Figure 12B. *Core 11, Hole 32 (194-203 m Below Seabed)*

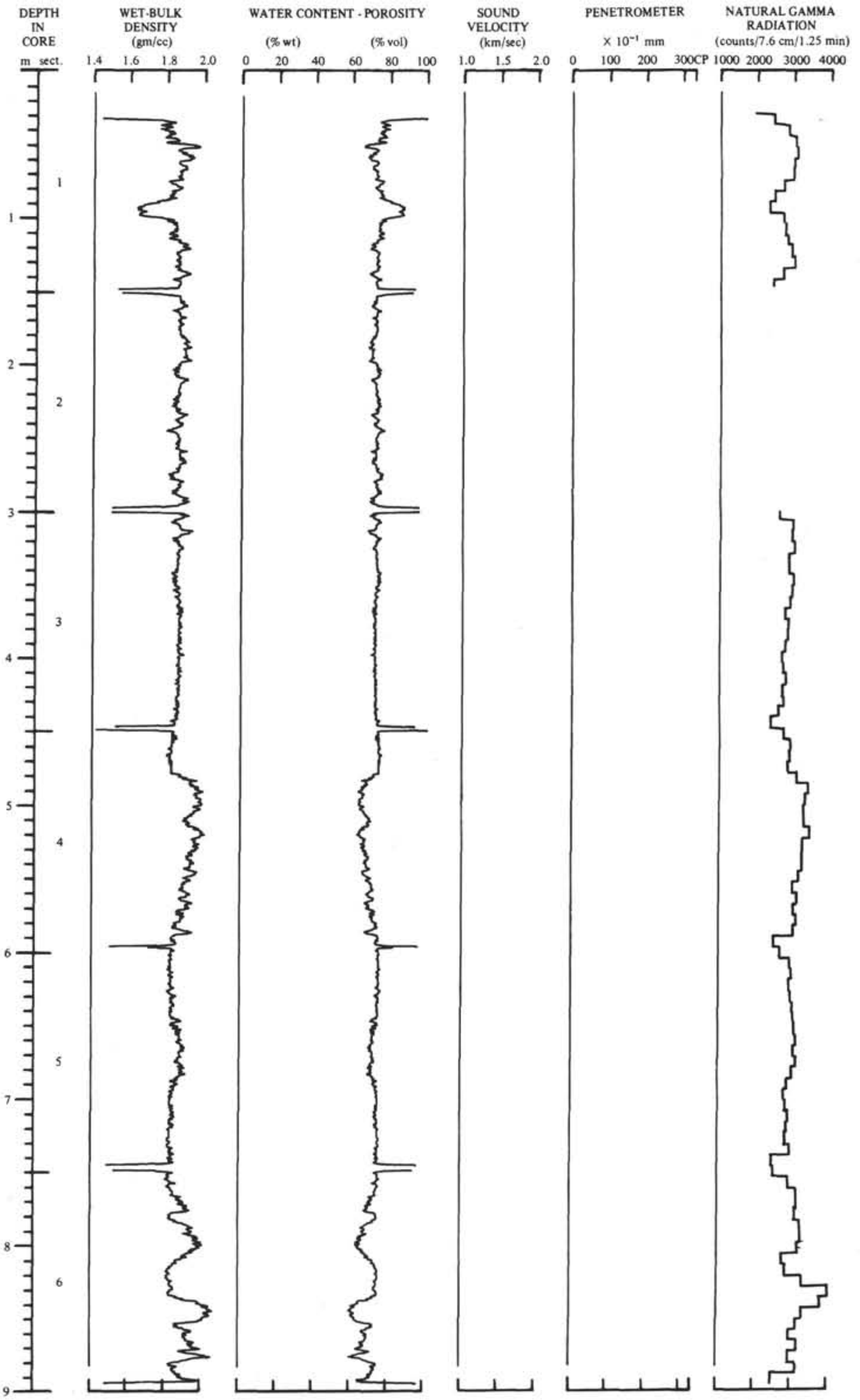

Figure 13A. *Physical Properties of Core 12, Hole 32*

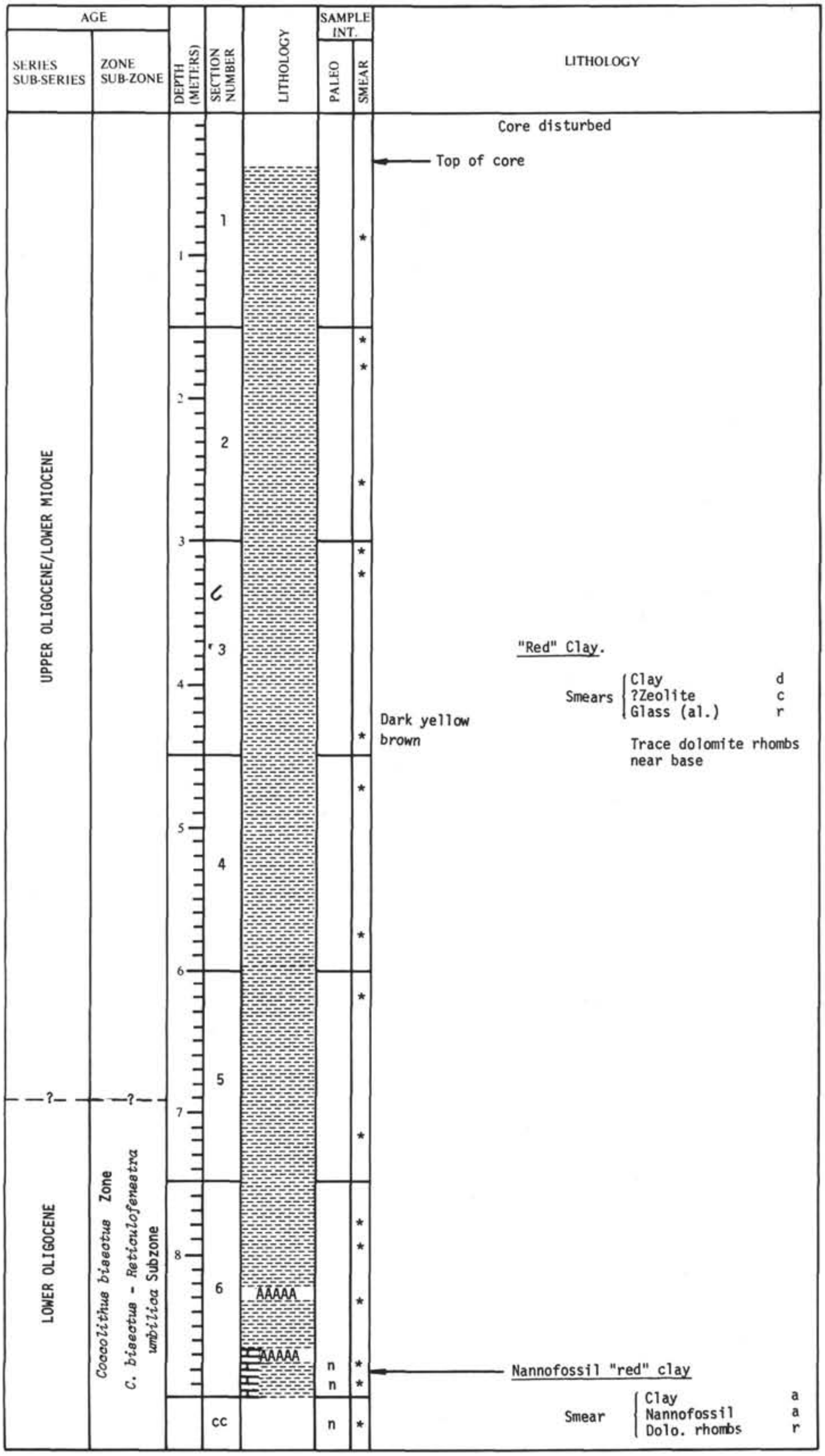

Figure 13B. *Core 12, Hole 32 (203-212 m Below Seabed)*

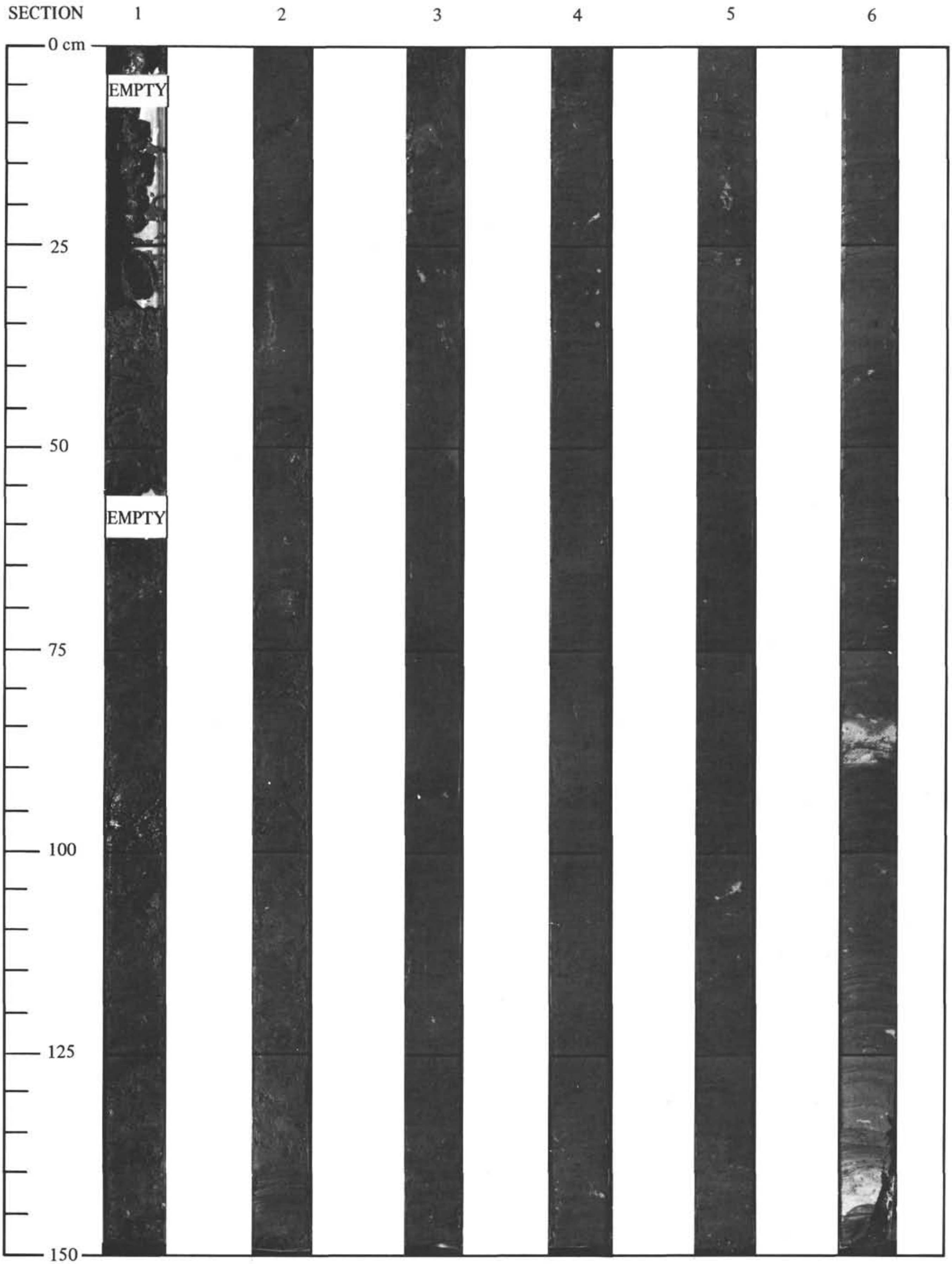

Plate 8. *Core 12, Hole 32*

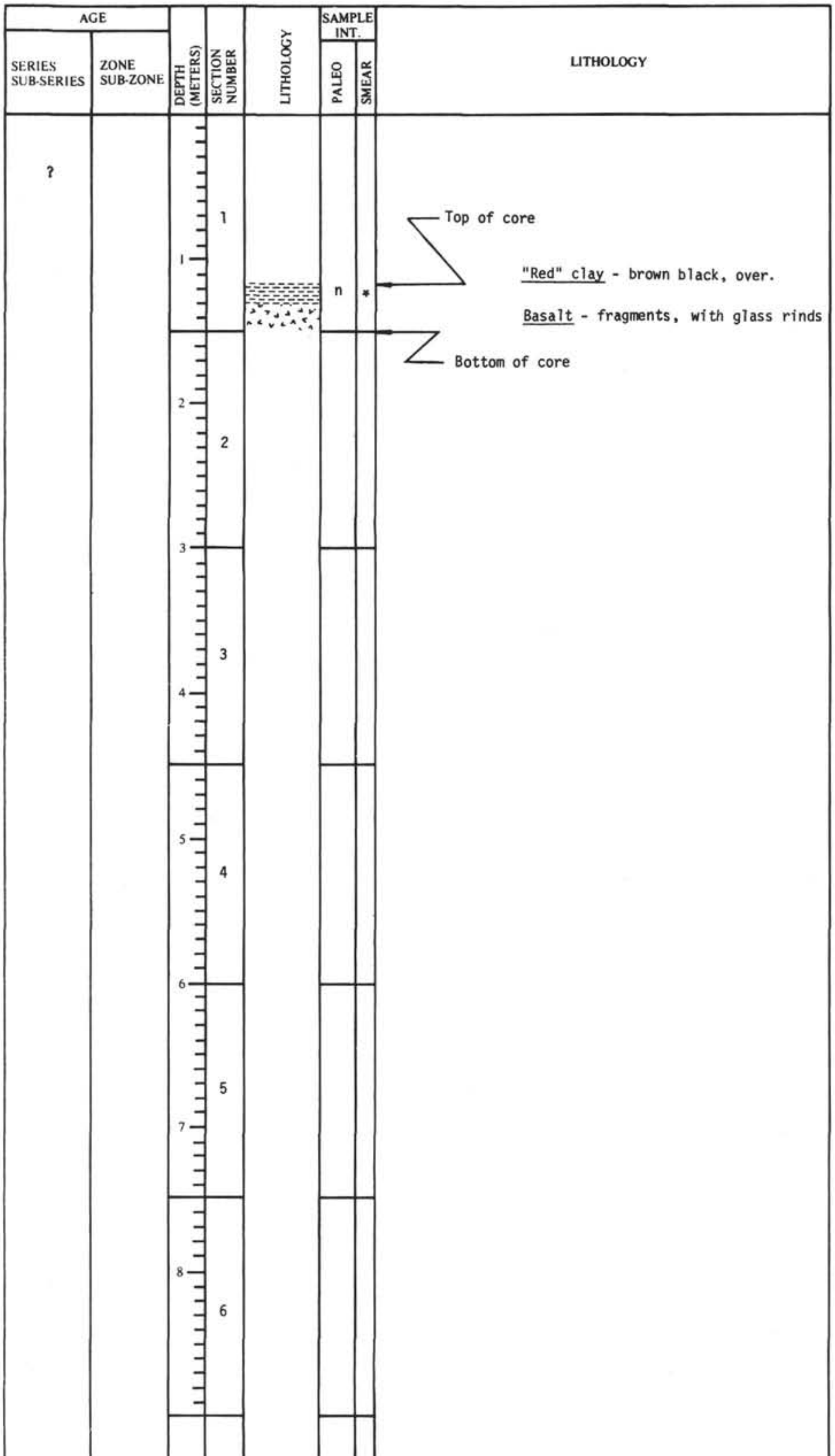

Figure 14. *Core 13, Hole 32 (212-215 m Below Seabed)*

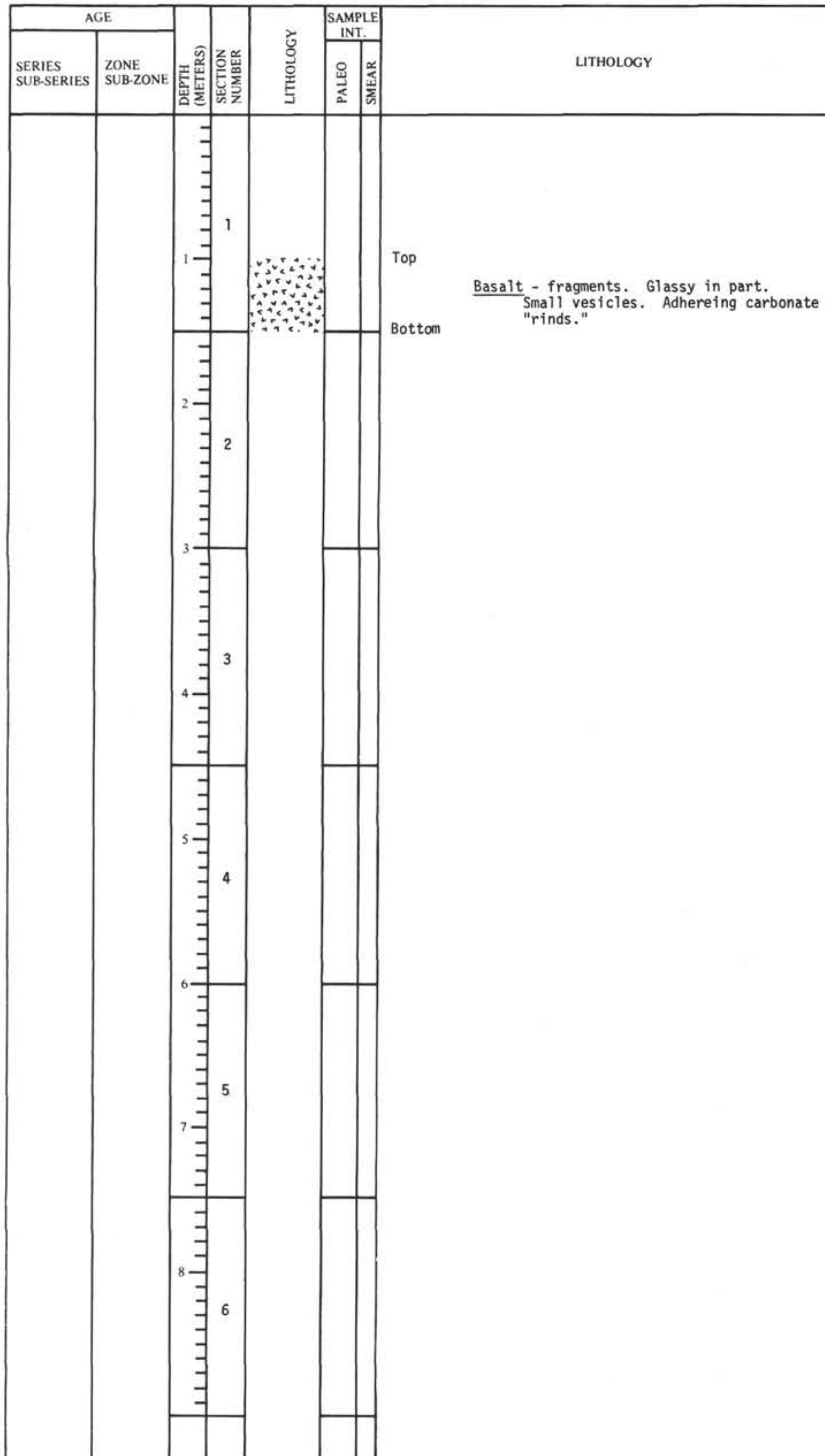

Figure 15. *Core 14, Hole 32 (216-217 m Below Seabed)*