# 3. SITE 33

The Shipboard Scientific Party[1]

## SITE BACKGROUND

The proposed location of Site 33 was over north-south Magnetic Anomaly 10 (Pittman-Heirtzler, 32 million years) in order (a) to provide a basis for comparison of the age of the basal sediments with the age based on the magnetic anomaly, (b) to provide a basis for evaluation of relative movement along the Pioneer and Mendocino Fracture Zones, and (c) by being paired with Site 34, to provide comparison of basement materials for adjacent positive and negative magnetic anomalies.

The site survey was conducted by *Argo* (Appendix III) during March, 1969. The sea floor in the area is generally made up of abyssal hills of several tens of meters relief. The acoustic basement has slightly higher relief and, consequently, average depths to bottom and to the acoustic basement are only generally representative. At the site, the water depth is 4284 meters and the acoustic basement is at about 0.4 second below the sea floor. Most of the sediment section in the area is acoustically transparent, but some non-continuous reflectors were recorded near the base of the section during the *Argo* survey.

The surface sediment collected during the site survey is a soft grayish-brown mud with underlying brittle olive-green mud, all of which contains Pleistocene microfossils. The heat flow measurement obtained at the same time was $1.3 \times 10^{-6}$ cal cm$^{-2}$ sec$^{-1}$.

The final location of the site by the *Glomar Challenger* was made by approaching from the west and monitoring for the magnetic high. The magnetometer was monitored until values peaked at about 51,300 gammas, at which time the occupation of the site was begun. The site was located west of the base of the Delgada Fan on the upper slope of an abyssal hill which lies adjacent to a small abyssal plain-like area.

### Location

Site 33 is located at latitude 39° 28.48'N, longitude 127° 29.81'W on the upper slope of an abyssal hill.

## OPERATIONS

The drilling summary for Site 33 is presented in Table 1. Coring began on the morning of 20 April in 4284 meters of water. The first core represented the first 9 meters of sediment for comparison with that in the 10-meter piston core taken by *Argo*. Because of the rich fossil content in this core, another core was taken immediately below.

Cores 3, 4 and 5 were spotted down the section. The first reflector was anticipated at a depth of about 260 meters (0.375 second), and continuous coring was begun with Core 6 at a depth of 219 meters. Core 10 (256 to 265 meters) contained the first cherty red mudstone fragment. These fragments were found in all the remaining cores. Consequently, the 0.375-second reflector is presumed to represent the top of the chert-bearing sediment. In the core catcher of Core 11 (about 275 meters) the chert nodules were more lithified, showing conchoidal fracture; and, in Core 12 (275 to 284 meters), the coring rate decreased considerably. Similar low rates of penetration characterized all the remaining cores. In Core 14 (293 meters), only one foot of hole was made, yet the core liner contained 16 feet of sediment. During the coring for Core 15 (293 to 295 meters), penetration ceased and the coring operations were stopped, while the bit was still in the chert-bearing sediments.

An on-site seismic reflection profile (Figure 1) shows a strong reflector at a depth of 0.375 second below the sea floor. This depth was correlated with the basement depths observed during the site survey and was originally thought to be basement, although additional reflectors appeared below it. Subsequent coring recovered cherty nodules from this depth (262 meters) and the 0.375-second reflector is now presumed to represent cherty siliceous mudstones. As this section could not be penetrated, it is impossible to state which of the lower reflectors represents basement; the 0.475-second (350 meters) reflector is the present estimate.

### Logging

A gamma-ray log was made of the hole, and first inspection showed little variation with depth. The attempt to

[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.

**TABLE 1**
**Drilling Summary of Leg 5, Site 33**

| 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 April | 1 | 0-9 | 14,091-14,121 | 30 | 9.1 | 30.0 | 9.1 | 100 |
| | 2 | 9-18 | 14,121-14,151 | 30 | 9.1 | 30.0 | 9.1 | 100 |
| | 3 | 47-56 | 14,245-14,275 | 30 | 9.1 | 30.0 | 9.1 | 100 |
| | 4 | 95-104 | 14,403-14,433 | 30 | 9.1 | 25.0 | 7.6 | 83 |
| | 5 | 152-161 | 14,558-14,588 | 30 | 9.1 | 30.0 | 9.1 | 100 |
| | 6 | 219-228 | 14,780-14,810 | 30 | 9.1 | 30.0 | 9.1 | 100 |
| | 7 | 228-237 | 14,810-14,840 | 30 | 9.1 | 30.0 | 9.1 | 100 |
| 21 April | 8 | 237-246 | 14,840-14,870 | 30 | 9.1 | 30.0 | 9.1 | 100 |
| | 9 | 247-256 | 14,872-14,902 | 30 | 9.1 | 25.3 | 7.7 | 84 |
| | 10[a] | 256-265 | 14,902-14,932 | 30 | 9.1 | 30.0 | 9.1 | 100 |
| | 11 | 265-275 | 14,932-14,962 | 30 | 9.1 | 10.0 | 3.1 | 33 |
| | 12 | 275-284 | 14,962-14,992 | 30 | 9.1 | 30.0 | 9.1 | 100 |
| | 13 | 284-293 | 14,992-15,022 | 30 | 9.1 | 30.0 | 9.1 | 100 |
| | 14[b] | 293-293 | 15,022-15,023 | 1 | 0.3 | 1.0 | 0.3 | 100 |
| | 15 | 293-295 | 15,023-15,028 | 7 | 2.1 | 6.0 | 1.8 | 86 |
| | | | Totals | 398 | 120.7 | 367.3 | 111.5 | 92 |

[a]First appearance of cherty nodules.
[b]Although only 1 foot of hole was made, 16 feet of core were recovered.

Note: Sonic water depth (corrected): 4284 meters; 14,051 feet; 2342 fathoms.
Driller's depth: 14,091 feet.

obtain an electric log failed when the circuit shorted out due to a broken conductor in the cable. The acoustic sonde was only a short distance out of the bit when an open circuit was apparent. Subsequent examination of the tool suggested that it had stopped at a bridge shortly below the bit and that the cable had then been pinched by the heave of the bit. The swell was producing considerable heave in the drill string. Examination of the gamma-ray log indicated that this sonde may also have been stopped at about the same depth, at which time the conductor was broken, preventing the electric logging. The "log" obtained from the gamma ray sonde, therefore, is thought to represent statistical variation at the bridge rather than an actual log of the hole.

## LITHOLOGY

At Site 33, a total of 112 meters of sediment was recovered from the interval between the sea floor and the bottom of the hole at 295 meters. A good sampling of the lithologies was obtained from the upper 18 meters (Cores 1 and 2), from 47 to 56 meters (Core 3), from 95 to 104 meters (Core 4), from 153 to 161 meters (Core 5) and from 219 meters to the bottom of the hole (Cores 6 through 15). With the exception of those from the deeper cores, the samples generally were badly deformed during coring operations, and it was difficult to interpret sedimentary structures and fabrics.

The cores from the upper part of the sedimentary section (Cores 1 through 5) are dominantly a dark green-gray mud with interbeds of siliceous- and calcareous-fossil muds of the same color. A distinct volcanic ash bed occurs at the base of Core 1 (about 8 to 9 meters), and there are traces of pyrite spherules and rare siliceous and calcareous microfossils in Cores 1 and 2 (0 to 18 meters). The cores from the lower part of the section (Cores 3, 4 and 5) have traces of zeolites, pyrite spherules and silt-size fresh feldspar.

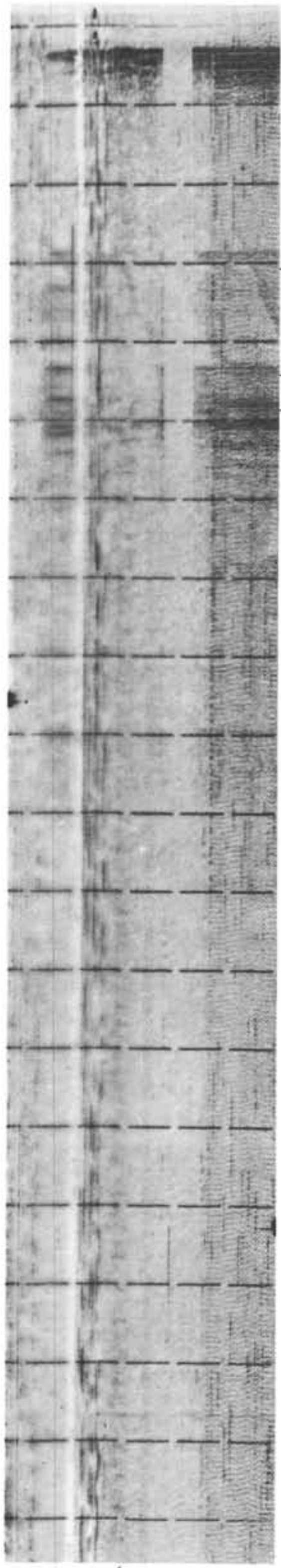


Figure 1. *On-site seismic reflection profile, Site 33.*

In Cores 6 through 9 (219 to 256 meters), mud, siliceous-fossil ooze is the dominant lithologic unit with mud and nannofossil mud as interbeds. Core 9 (247 to 256 meters) has a thin nannofossil siliceous ooze near its base and thin beds of nannofossil ooze occur in Core 10 (256 to 265 meters). A round dark green cherty mudstone concretion, containing minor slightly pyritized and recrystallized fossil remains, was recovered from a depth of 257 meters. This may be from a horizon of cherty nodules within the siliceous-fossil mud.

Cores 11 through 15 (265 to 295 meters) are dominantly siliceous-fossil mud with significant quantities of dark green cherty fragments. These fragments in the bottom of Core 11 (about 275 meters) together with the sudden decrease in coring rate between Cores 11 and 12, suggest that the top of the main cherty formation lies approximately at the top of Core 12 (275 meters). From this horizon to the bottom of the hole, the coring rate was much slower, with minor fluctuations, suggesting the presence of cherty layers alternating with softer sediments. Where sampled, these softer units are siliceous-fossil muds.

The lowermost core (Core 15, 293 to 295 meters) recovered cherty fragments, nannofossil-siliceous ooze and mud siliceous-fossil ooze.

## PALEONTOLOGY

### Nannofossils

With the exception of a few short intervals in Cores 1 and 2, nannofossils are found throughout the recovered sequence at Site 33 ranging in age from Pleistocene to Middle Miocene. Siliceous nannofossils are fairly frequent to common in the recovered material below Core 4, including a number of displaced forms. These displaced siliceous nannofossils are forms considered representative of neritic or littoral environments (Cupp, 1943; Hendey, 1937 and 1964; and, Hustedt, 1930), and 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 matrix in Cores 3 through 15 contains frequent to common fine fragments and debris of siliceous skeletal material. Parts and fragments of siliceous nannofossils are often coated with a fine-grained iron and/or manganese oxide and these appear to become more common at intervals associated with more frequent occurrences of micronodules and displaced siliceous forms. Some parts and pieces of siliceous nannofossils occur in Cores 3 and 4, and, especially 5; the majority probably represent reworked material. The siliceous nannofossil assemblages are quite diverse in the more siliceous skeletal-rich sediments of Cores 5 through 15. A few representatives of this extensive suite of nannofossils which occur through this interval include: *Ebria antiqua* Schulz; *E. a. rectangularis* Schulz; *Coscinodiscus asteromphalus* Ehrenberg; *C. lineatus* Ehrenberg; *C. marginatus* Ehrenberg; *C. oculus-iridis* Ehrenberg; *C. radiatus* Ehrenberg; *C. vetustissimus* Pantocsek – form with coarser and heavier areolae found below Core 9; *Denticula hustedtii* Simonsen and Kanaya–probably including its base within Core 15; *D. lauta* Bailey–higher scattered occurrences probably due to reworking; fragments of *Ethmodiscus rex* (Rattray) Hendey; *Hemidiscus cuneiformis* Wallich; *Thalassiosira decipiens* (Grunow) Jørgensen and related forms; and, *Thalassiothrix longissima* Cleve and Grunow and related forms. *Actinocyclus octonarius* Ehrenberg, *Actinoptychus senarius* Ehrenberg, and *Melosira sulcata* (Ehrenberg) Kützing also occur through this interval, and their occurrences may include some displaced specimens.

Calcareous nannofossils are also absent from samples in parts of Cores 9 and 11, and most of Core 12. Calcareous nannofossils are quite common to abundant in the more calcareous intervals of Cores 4, 5 and 9, and throughout the more calcareous Cores 10, 14 and 15. Preservation of the calcareous nannofossils is reasonably good at this site, though etched and partly disaggregated specimens are evident in the less calcareous parts of some cores. The background of some samples from this site contains common to abundant fine calcareous and coccolith fragments and very fine coccolith debris. This condition is evident in parts of Cores 2, 3, 5, 6 and 7 and throughout most of Cores 11, 14 and 15. Scattered reworked older calcareous nannofossils occur in Cores 1, 3, 4, 5 and, possibly, 6.

The Pleistocene (*Coccolithus carteri* Zone) is represented by Cores 1, 2 and 3. Identifiable calcareous or siliceous nannofossils are lacking in the upper-most part of Core 1 and at intervals in Core 2. The more calcareous intervals in Cores 1 and 2 contain a calcareous nannofossil assemblage of *Coccolithus carteri* (Wallich), *C. doronicoides* Black and Barnes?, *C. pelagicus* (Walich), *Cyclococcolithus leptoporus* (Murray and Blackman)–mostly var. B. of McIntyre, Bé, and Preikstas, and *Gephyrocapsa* spp. Less frequent or scattered occurring forms include *Discolithina japonica* Takayama, *Helicopontosphaera kamptneri* Hay and Mohler, and *Pseudoemiliania lacunosa* (Kamptner). The samples from Core 3 contain the same assemblage with the addition of *Cyclococcolithus leptoporus macintyrei* Bukry and Bramlette and an increase in the frequency of *Coccolithus doronicoides?*.

The fragmented siliceous skeletal material in these Pleistocene cores becomes large enough to identify representative forms in the lower part of Section 6, Core 1, and at intervals in Core 3, especially in Sections 1, 3 and 6. Most, if not all, of these siliceous nannofossils are probably reworked as indicated by their fragmented condition in these sediments, their more consistent stratigraphic occurrence at various sites on this leg, and their reported occurrence or range in the North Pacific area (Kanaya, 1959; Loeblich *et al.*, 1968; Wornardt, 1967); and, some of the forms are also indicative of displacement. These include: *Actinocyclus tsugaruensis* Kanaya; *Campyloneis grevillei* vars., *Coscinodiscus vetustissimus; Denticula hustedtii; D. lauta; Dictyocha fibula* Ehrenberg; *D. pseudofibula* (Schulz); *Distephanus aculeatus* (Ehrenberg) vars. A, B and D; *D. diommata* (Ehrenberg); *D. gracilis* (Kützing) – heavy form; *D. speculum* (Ehrenberg); *Endictya oceanica* Ehrenberg; *Fragilariopsis* sp. aff. *F. pliocena* (Brun) Sheshuk.; *Melosira granulata* – in Core 1; *Navicula lyra* Ehrenberg in Core 1; *Stephanopyxis appendiculata* Ehrenberg; *S.* cf. *S. nipponica* Gran and Yendo of Kanaya; *S. turris* (Greville and Arnott) Ralfs; resting spores of *Chaetoceros cinctum* Gran and *C. subsecundum* (Grunow) Hustedt; *Xanthiopyxis oblonga* Ehrenberg; *X. ovalis* Lohman; *X.* sp. A, B, and C of Wornardt; and, *X.* sp. 5 of Kanaya. The association in Core 1 with a fair number of *Melosira sulcata* may represent a similar depositional episode as found in Core 1 at Site 32.

Some reworked older calcareous nannofossils are evident in the lower part of Core 1 and scattered through Core 3. Most are in a poor state of preservation, but include *Cyclococcolithus neogammation* Bramlette and Wilcoxon, *Discoaster* spp. indet., and *Reticulofenestra pseudoumbilica* (Gartner). Two specimens complete enough to identify as *Discoaster brouweri* Tan and var. occur in the basal part of Core 3.

Part of the Upper and Lower Pliocene is represented by the sediments of Core 4. The greater portion of this core belongs to the Upper Pliocene *Discoaster brouweri* Zone. The calcareous assemblage is dominated by common occurrences of *Coccolithus doronicoides?* and *Cyclococcolithus leptoporus* and vars. including *C. l. macintyrei,* plus the distinctive forms *Ceratolithus rugosus* Bukry and Bramlette var. and *Discoaster brouweri* and var. Less frequent or consistent are the occurrences of *Ceratolithus cristatus* Kamptner, *Coccolithus pelagicus, Discolithina japonica, Discoaster brouweri rutellus* Gartner, *D.* cf. *D. challengeri* Bramlette and Riedel–with short and weak bifurcations, *D. pentaradiatus* Tan, *D. surculus* Martini and Bramlette – most with weak trifurcations, *D.* sp. aff. *D. exilis* Martini and Bramlette, *Helicopontosphaera kamptneri, H. sellii* Bukry and Bramlette, and *Pseudoemiliania lacunosa.* The basal-most part of Core 4 represents the *Ceratolithus rugosus-Cyclococcolithus leptoporus Subzone of* the Lower Pliocene with the presence of *Ceratolithus tricorniculatus* Gartner in association with the calcareous forms above. Reworked older calcareous forms are evident in Sections 1, 3 and 5 of Core 4. These include incomplete or etched specimens of *Discoaster exilis* and var. and *D.* cf. *D. divaricatus* Hay indicative of a lower Upper to Middle Miocene source. In addition, larger parts of siliceous nannofossils are evident in Sections 3, 5 and the base of 6 which are most probably reworked from a lowest Lower Pliocene or Upper Miocene to Middle Miocene source, and some are displaced. These include: *Actinocyclus tsugaruensis, Campyloneis grevillei* and vars., *Denticula hustedtii, D. lauta, Distephanus aculeatus* var. B and C, *D. gracilis*–heavy form, *Mesocena diodon* Ehrenberg, *Rhaphoneis amphiceros* var. *angularis* (Lohman), *Stephanopyxis appendiculata, S.* cf. *S. nipponica, Xanthiopyxis ovalis, X.* sp. B and C of Wornardt.

The nannofossil assemblage in the sediments of Core 5 exhibit unusual characteristics. The more calcareous samples from Sections 1, 2, 4, 5 and part of 6 are dominantly composed of common-to-abundant fine calcareous-coccolith debris and fragments. These samples, as well as the less calcareous samples, contain quite frequent or common small fragments and parts of siliceous skeletal material. Most of these samples contain few, if any, larger specimens of coccoliths; and, when present, they usually are broken and incomplete, pitted, etched or partly coated. A few samples do contain some well-preserved larger coccolith specimens, particularly specimens of *Cyclococcolithus leptoporus* and vars. Many specimens of the asteroliths in these samples are also incomplete or not well-preserved. Complete and well-preserved specimens of siliceous nannofossils are also quite rare in these samples. They are usually represented by broken, coated or only parts of specimens.

The general nannofossil assemblage in a number of samples from Core 5 exhibits a Miocene aspect. However, a number of the species, both calcareous and siliceous, are incompatible stratigraphically and represent different parts of the Upper and Middle Miocene. Three samples, from sections 2, 5 and the upper part of 6, contain better preserved larger coccoliths and a few specimens of *Ceratolithus rugosus* var. and *Discolithina japonica.* These species, in addition to the presence of *Ceratolithus tricorniculatus* and *Reticulofenestra pseudoumbilica* (mostly medium to small forms with narrower central area), are indicative of the *Ceratolithus rugosus-Reticulofenestra pseudoumbilica* Subzone of the Lower Pliocene. From the conditions enumerated, it is concluded that a large proportion of the nannofossil specimens in Core 5 represent reworked material, some more obvious than others. On comparing the sequence and age of Cores 4 and 5 from this site with Cores 3 through 7 from nearby Site 34, by depth, Core 5 at this site approximates the position of the sandy interval or associated finer sediments containing a higher frequency of reworked and displaced nannofossil material at Site 34.

The remainder of the calcareous nannofossil suite from Core 5–which may represent indigenous specimens–includes: *Coccolithus doronicoides?, C. pelagicus, Cyclococcolithus leptoporus* and vars., *Discoaster brouweri* and var., *D. b. rutellus, D. challengeri, D.* sp. aff. *D. exillis, D. surculus, D. variabilis* Martini and Bramlette var., and *Sphenolithus abies* Deflandre. The more obvious reworked forms include: *Discolithina vigintiforata* (Kamptner), *Discoaster* cf. *D. divaricatus, D. divaricatus, D. exilis, D. exilis* var., *D. stellulus* Gartner, and *D. variabilis s.s.*–including the more massive forms with slightly larger discs transitional to the heavy form. These reworked forms are fairly frequent in some intervals of this core.

Siliceous forms represented in Core 5 by specimens which were complete enough to be identified include: *Actinocyclus octonarius* var. *tenellus* (Brébisson) Hustedt, *Coscinodiscus lineatus* var. *leptopus* Grunow, *C. rothii* (Ehrenberg) Grunow, *Denticula kamtschatica* Zabelina, *Dichtyocha fibula, D. f. aspera* Lemmermann, *D. f. pentagonalis* Aurivillius, *D. f. rhombica* Schulz–large form, *D. pseudofibula, Distephanus aculeatus* var. B, C, and D, *D. binoculus* (Ehrenberg), *D. gracilus*–heavy form, *Lithodesmium californicum* Grunow, *L. minusculum* Grunow, *Mesocena diodon* and the displaced forms *Melosira granulata,* resting spores of *Chaetoceros lorenzianum* Grunow and *C. subsecundum, Xanthiopyxis ovalis, X.* sp. B, C and D of Wornardt, and *X.* sp. 5 of Kanaya. The distinctive reworked siliceous forms include *Actinocyclus ingens* Rattray and vars., *Denticulata lauta, Distephanus ornamentum* (Ehrenberg) *D.* cf. *D. pseudocrux* Schulz–heavy transitional form characteristic of the lowest part of its range, and *Rhabdonema japonicum* var. *sparsicostatum* Tempère and Brun.

The essentially continuously cored sequence from Core 6 to Core 15 provides an excellent section from the lower part of the Upper Miocene to the lower part of the Middle Miocene. The base of the *Discoaster variabilis* Zone is in the uppermost part of Core 9, and the calcareous assemblage that characterizes the sediments in Cores 6 to 8 is dominated by *Reticulofenestra pseudoumbilica, Discoaster challengeri* and *D. variabilis* along with the rather constant occurrence of *D. brouweri* and var., *D. b. rutellus, D. exilis* var., *D.* sp. aff. *D. exilis,* and *D. stellulus* Gartner. Less consistent occurring forms include *D.* aff. *D. bollii* Martini and Bramlette, *D. calcaris* Gartner, *D. neohamatus* Bukry and Bramlette, *D. subsurculus* Gartner–Core 8, *Coccolithus pelagicus, Cyclococcolithus leptoporus* and vars., and *Sphenolithus abies.* The occurrence of *Discoaster exilis s.s.*–with offset ridges on the majority of rays–below the basal part of Core 6 defines the

*D. variabilis-D. exilis* Subzone in this sequence. In the lower part of Core 8 the asteroliths, including those representing the species *D. challengeri* and *D. variabilis,* show a number of specimens tending to have larger central discs, which become more confluent with the rays. Others have longer narrow rays with short-forked bifurcations to weak U-shaped terminations transitional to the form *D.* cf. *D. divaricatus* (with weak terminations), which has its highest occurrence in the basal part of Core 8. There are parts and fragments of somewhat heavier asteroliths with larger discs and fragments of other calcareous forms in Section 5 and the upper part of Core 6, which probably represent reworked specimens. Associated in these same samples are a few specimens of *Denticula lauta* which also are probably reworked.

The fairly consistently occurring siliceous forms in the *Discoaster variabilis* Zone are: *Actinocyclus ingens* and vars.–with more frequent and distinctly corrugated valves below Core 7; *A. tsugaruensis*–with larger and more distinctly quadrate areolae below the middle of Core 7; *Asteromphalus moronensis* (Greville) Rattray and var.–top of *s.s.* form in Section 6 of Core 6; *Coscinodiscus endoi* Kanaya; *C. rothii*–considerably less frequent below Core 7; the finer areolate form of *C. vetustissimus; Denticula hustedtii; Dictyocha fibula aspera; D. f. brevispina* Lemmermann; *D. f. rhombica; D. pseudofibula; Distephanus aculeatus* vars. A, B, and D–var. B becomes less frequent and consistent below mid Core 7; *D. crux* (Ehrenberg); *D. pseudocrux* Schulz; *D. speculum; Fragilariopsis* sp. aff. *F. pliocena; Lithodesmium californicum;* and, *Mesocena circulus apiculata* Lemmermann. Less consistently occurring siliceous forms include: *Actinocyclus ellipticus* Grunow; *A. e.* var. *javanica* Reinhold–highest occurrence in the lower part of Core 6; *A. octonarius* var. *tenellus; Dictyocha fibula; D. f. pentagonalis*–small and rare in Core 6 and its lowest occurrence in Core 8; *Distephanus crux longispina* Schulz; *D. diommata; D. ornamentum; Mesocena circulus* (Ehrenberg); *M. diodon;* and, *Rutilaria epsilon* (Kitton) Greville–mostly parts and occurring more frequently above the middle of Core 7 but the lowest occurrence is in Section 6 of Core 8 (displaced?). Besides the changes already stated, the limits in the stratigraphic occurrence of other siliceous nannofossils indicate a general change at this site in the siliceous assemblage near the middle of Core 7, although some of these are recorded ranging higher at other sites. These include: *Coscinodiscus curvatulus* var. *odontodiscus* (Grunow) Hustedt–highest occurrence in the lower part of Core 7; *C. lineatus* var. *leptopus* Grunow–only in the upper part of Core 6; *C. yabei* Kanaya–highest occurrence in the lower part of Core 7; *Denticula lauta*–highest continuous occurrence in top of Core 8; *Distephanus aculeatus* var. C–base in Core 7; *D. gracilis*–heavy form with lowest occurrence in the bottom of Core 6; *Fragilariopsis* cf. *F. pliocena*–smaller forms but near typical with quite narrowly rounded ends occurring in Core 6; *Triceratium cinnamomeum* Greville–highest occurrence near middle of Core 8; and, *T condecorum* Brightwell–upper limit in the top of Core 8 (displaced?). Other forms which have occurrences in singular samples of Core 8 are *Coscinodiscus lewisianus* Greville–Section 1, *C. paleaceus* (Grunow) Rattray–Section 4; *Endicta japonica* Kanaya–Section 6; and, *Triceratium montereyi* Brightwell–Section 4 (displaced?). Quite frequent displaced siliceous nannofossils are present in Cores 6 and 7, and become less frequent in Core 8; some forms have their lowest occurrence within this zone. The displaced forms include: *Arachnoidiscus ehrenbergii* Bailey and vars.; *Actinoplychus splendens* var. *incisa* (Grunow) Wornardt; *Buddulphia* spp., including *B. aurita* (Lyngbye) Brébisson and Godey and *B. aurita* var. *obtusa* (Kützing) Hustedt; *Campyloneis grevillei* and vars.; *Cocconeis antiqua* Tempère and Brün; *Melosira granulata; Navicula optima* Hanna; *Rhaphoneis amphiceros* var. *angularis* (Lohman); *Stephanopyxis appendiculata; S.* cf. *S. nipponica; S. turris;* resting spores of *Chaetoceros* spp., including *C. cinctum*–lowest occurrence in Section 4 of Core 8; *C. lorenzianum*–lowest occurrence in the base of Core 6; *C. subsecundum*–lowest occurrence in the base of Core 6; *Xanthiopyxis acrolopha* Forti; *X. diaphana* Forti–Core 6; *X. lacera* Forti; *X. oblonga; X. ovalis*–Core 6; *X.* sp. B, C and D of Wornardt; and, *X.* sp. 3 and 5 of Kanaya.

The *Discoaster exilis–Reticulofenestra pseudoumbilica* Subzone of the Middle Miocene is represented by the sediments in most of Core 9 down to the uppermost part of Core 13. The calcareous part of this sequence is characterized by an assemblage dominated by *R. pseudoumbilica* and the *Discoaster exilis* group, including *D. exilis s.s., D. exilis* var. and *D.* sp. aff. *D. exilis.* Other less frequent but characteristic calcareous nannofossils include: *D. brouweri rutellus; D. challengeri*–a few still fairly typical but most with shorter bifurcations or slightly larger disc; *D.* cf. *D. divaricatus*–with weak U-shaped ray terminations; *D. variabilis* and var.; small *D. kugleri* var.–most evident in mid-subzone (Cores 10 and 11); and, *Sphenolithus abies.* Less consistently occurring calcareous species are: *Coccolithus pelagicus; Cyclococcolithus leptoporus* and vars.; *Discoaster* cf. *D. brouweri*–quite small with a larger central nob and flatter rays with irregular enlarged ends; *D.* cf. *D. calcaris*–transitional forms with only some of the weak spike-like terminations tending to be asymmetrical (Cores 9 and 10); and, *Discolithina vigintiforata*–Core 10.

The assemblage of siliceous nannofossils is quite diverse in the sediments of this Middle Miocene subzone, expecially in the less calcareous intervals. Some of the more distinctive forms include: *Actinocyclus ellipticus*–infrequent; *A. e. javanica*–less frequent below the middle of Core 11; *A. ingens* and vars.–*s.s.* from becoming quite frequent; *A. tsugaruensis; Asteromphalus moronensis s.s.*–var. form in upper Core 9; *Coscinodiscus curvatulus* var. *odontodiscus*–infrequent; *C. endoi; C. yabei, Denticula hustedtii; D. lauta*–becoming the dominant denticulid below Core 9; *Dictyocha fibula; D. f. aspera; D. f. brevispina; D. f. rhombica* (a number of the *D. fibula* group exhibit longer radial spines); *D. pseudofibula*–less frequent below the middle of Core 11; *Distephanus aculeatus* vars. A and B–infrequent; *D. crux; D. crux longispina*–becoming quite frequent and also dominated below the middle of Core 11 by the form with very long radial spines and a smaller or more rounded basal ring; *D. diommata; D. ornamentum*–infrequent; *D. speculum; Fragilariopsis* sp. aff. *F. pliocena*–less frequent below Core 11; *Mesocena circulus apiculata;* and, *M. diodon*–including heavy forms. A number of siliceous nannofossils have their lowest and highest occurrence within this subzone at this site, or occur at limited intervals. These are: *Actinocyclus octonarius* var. *tenellus*–lowest at base of Core 9; *Coscinodiscus rothii*–lowest at base of Core 10; *Dictyocha paradistiphanus* Tsumura–this distinctive form is essentially restricted to the lower part of Core 12; *D. triommata* Ehrenberg–highest occurrence is in the basal-most part of Core 12; *Distephanus pseudocrux*–lowest occurrence of unquestionable specimens in the upper part of Core 10 and with transitional forms evident below to Core 12; *D. speculum pentagonus*–heavy forms with lowest occurrence in the base of Core 9; *Lithodesmium californicum*–lowest in the base of Core 9; *Mesocena circulus*–lowest possible occurrence observed in the upper part of Core 10; *M. hexagona* Haeckel–highest occurrence in the top of Core 11; *Plagiogramma antillarum* Cleve–Section 6 of Core 9 (probably displaced); *Stephanogonia hanzawae* Kanaya–basal part of Core 9; *Triceratium cinnamomeum*–lowest at base of Core 10; *T. condecorum*–lowest in the upper part of Core 9; and, *T. margaritiferum* Cleve–Section 6 of Core 9 and Section 3 of Core 10 (displaced?). The number of displaced siliceous forms in this subzone is fairly limited, and they are generally rare below Core 10. However, a few more obvious accumulations are evident at intervals where more diverse displaced suites are present (lower part of Core 9 and the basal part of Core 11) or where slightly diverse displaced assemblages occur (base of Core 10 and base of Core 12). Some of the displaced forms have their lowest occurrences in this subzone. The infrequent displaced forms evident in the samples of this interval include: *Arachnoidiscus ehrenbergii* and vars.; *Biddulphia* spp., including *B. aurita; Campyloneis grevillei* and vars.; *Cocconeis antiqua; Diploneis major* Cleve–Section 5 of Core 10; *Melosira granulata; Rhaphoneis amphiceros; R. elegans* Pantocsek and Grunow; *Stephanopyxis appendiculata; S.* cf. *S. nipponica; S. turris*–lowest occurrence at the base of Core 10; *Xanthiopyxis lacera; X. umbonata* Greville; *X.* cf. *X.* sp. A; *X.* sp. B–base in Core 10; *X.* cf. *X.* sp. C–large; *X.* sp. D of Wornardt; and, *X.* sp. 2, 3 and 5 of Kanaya.

The Middle Miocene *Discoaster exilis-Cyclococcolithus neogammation* Subzone is the age of the oldest sediments recovered at this site in Cores 13, 14 and 15. The calcareous nannofossil assemblage of this subzone is characterized by *C. neogammation*–becoming quite frequent or common in the lower part (Core 15), *Reticulofenestra pseudoumbilica*–becoming less frequent in the lower part (Core 15), *Discoaster divaricatus*, the *D. exilis* group, and *Cyclococcolithus leptoporus* and vars.–becoming quite frequent or common in the lower part with some specimens (just above eight microns in size) probably representing early forms of *C. l. macintyrei.* Other less consistent or less frequently occurring calcareous species, as well as forms with their stratigraphic limits within this subzone, are: *Coccolithus pelagicus; C. eopelagicus* (Bramlette and Riedel)–infrequent in Core 15; *Discoaster aulakos* Gartner–Core 15; *D.* cf. *D. brouweri* and *D. b. rutellus*–base of both in uppermost Core 15; *D. challengeri; D. deflandrei* Bramlette and Riedel–Core 15; *D. variabilis*–lowest occurrence in Core 14; *D.* cf. *D. variabilis*–heavy form transitional to *D. deflandrei* in Cores 14 and 15; *Discolithina vigintiforata*–Core 14; and, *Sphenolithus abies.*

The siliceous nannofossils become less frequent in the lower part of Core 15, and are quite rare and poorly preserved at the base of this core which limits the distribution of some forms. Others exhibit lower or confined limits well above this lowest core; and, it probably represents their lowest occurrence at this site, in light of what is evident at the closely adjacent Site 34. The siliceous assemblage is characterized by *Actinocyclus ingens*–quite frequent; *A. tsugaruensis; Coscinodiscus endoi; C. yabei; Denticula hustedtii*–lowest unquestionable occurrence in the upper part of Core 15; *D. lauta; Dictyocha triommata; Distephanus crux; D. crux longispina*–quite frequent; and, *Halicalyptra virginica* Ehrenberg. Others with a more variable or restricted occurrence are: *Actinocyclus ellipticus* and *A. e. javanica*–base of both in the lower part of Core 13; *Asteromphalus moronensis*–base in the lower part of Core 13; *Coscinodiscus curvatulus* var. *odontodiscus*–lowest at the base of Core 13; *Craspedodiscus coscinodiscus* Ehrenberg–occurs in the lower half of Core 13; *Dictyocha fibula; D. f. aspera; D. f. brevispina. D. pseudofibula*–lowest in Core 14; *Distephanus aculeatus* vars. A, B, and D–lowest at the base of Core 13; *D. diommata*–lowest at the base of Core 13; *D. ornamentum*–upper part Core 13; *D. speculum*–Core 13; *Fragilariopsis* sp. aff. *F. pliocena*–lowest near middle of Core 13; *Mesocena circulus apiculata*–lowest in

Core 14; *M. diodon*–base in the lower part of Core 13; *M. elliptica* (Ehrenberg)–heavy form occurring in Section 5 of Core 13; *M. hexagona*–base in the lower part of Core 13; and, the closely allied form *M. septenaria* Schulz–occurring in Section 1 of Core 13.

The displaced siliceous representatives are fairly rare in this subzone, but do show a slight increase in diversity in Section 3 of Core 13. The displaced forms include parts of *Arachnoidiscus ehrenbergii* and vars.; *Melosira granulata; Navicula hennedyi* Wm. Smith and *N. lyra*–both in Section 3 of Core 13; *Stephanopyxis appendiculata; S.* cf. *S. nipponica; Xanthiopyxis lacera; X. umbonata; X.* cf. *X.* sp. C-large and *X.* sp. D of Wornardt; and, *X.* sp. 5 of Kanaya.

**Foraminifera**

Foraminifera occur sporadically, sometimes in fair abundance, throughout the first four core barrels. Foraminifera are very rare in cores below, and are absent below Core 9. Throughout most of these core samples selective solution has eliminated the majority of small or thin-walled species.

Identification of Species:

Sample 33-1-1, 130-132 cm:
*Globigerina bulloides* d'Orbigny, *Globigerina pachyderma* (Ehrenberg).

Sample 33-1-2, 21-23 cm:
*Orbulina universa* d'Orbigny, *Globigerina pachyderma.*

Sample 33-1-3, 20-22 cm:
*Globogerina bulloides, Globigerina pachyderma.*

Sample 33-1-3, 117-119 cm:
*Globigerina bulloides, Globigerina pachyderma, Orbulina universa.*

Sample 33-1-4, 23-25 cm:
*Globigerina bulloides, Globigerina pachyderma, Globigerinita glutinata* (Egger).

Sample 33-1-4, 85-87 cm:
*Globigerina bulloides.*

Sample 33-1-6, 24-26 cm:
Planktonic foraminifera absent.

Sample 33-1-6, 113-115 cm:
*Globigerina bulloides, Globigerinita glutinata, Globorotalia crassaformis* s.l.

Sample 33-2-1, 20-22 cm:
*Globigerina pachyderma, Globigerinita glutinata.*

Sample 33-2-1, 100-102 cm:
Planktonic foraminifera absent.

Sample 33-2-2, 23-25 cm:
*Globigerina pachyderma.*

Sample 33-2-2, 91-93 cm:
*Globigerina bulloides, Globigerina pachyderma, Globorotalia* cf. *G. acostaensis pseudopima* Blow.

Sample 33-2-3, 24-26 cm:
*Globerigerina bulloides, Globigerina dutertrei* d'Orbigny, *Globigerina pachyderma, Globerigerina quinqueloba* Natland, *Globigerinita glutinata, Globorotalia acostaensis pseudopima* Blow, *Globorotalia hirsuta praehirsuta* Blow.

Sample 33-2-3, 106-108 cm:
*Globigerina bulloides, Globigerina pachyderma, Globorotalia acostaensis pseudopima, Globorotalia crassaformis* s.l., *Globorotalia hirsuta praehirsuta.*

Sample 33-2-4, 20-22 cm:
*Globigerina bulloides, Globigerina dutertrei* and variants, *Globigerina pachyderma, Globorotalia* cf. *G. acostaensis pseudopima.*

Sample 33-2-5, 53-55 cm:
*Globigerina bulloides, Globigerina pachyderma, Globigerina quinqueloba, Globigerinita glutinata, Globorotalia acostaensis pseudopima.*

Sample 33-2-5, 101-103 cm:
Planktonic foraminifera absent.

Sample 33-2-6, 20-22 cm:
*Globigerina bulloides, Globigerina dutertrei, Globigerina pachyderma.*

Sample 33-2-6, 103-105 cm:
Planktonic foraminifera absent.

Sample 33-3-1, 12-14 cm:
*Globigerina bulloides, Globigerina dutertrei, Globigerina pachyderma, Globigerina quinqueloba, Globigerinita glutinata, Globigerinita uvula* (Ehrenberg), *Globorotalia acostaensis acostaensis* Blow, *Globorotalia acostaensis humerosa* takayanagi and Saito, *Globorotalia acostaensis pseudopima, Globorotalis crassaformis* s.l., *Globorotalia inflata* (d'Orbigny), *Globorotalia* cf. *G. scitula* (Brady).

Sample 33-3-1, 102-104 cm:
*Globigerina bulloides.*

Sample 33-3-2, 22-24 cm:
*Globigerina bulloides, Globigerina pachyderma.*

Sample 33-3-3, 24-26 cm:
*Globigerina bulloides, Globigerina conglomerata* Schwager, *Globigerina pachyderma, Globigerinoides trilobus* (Reuss), *Globorotalia acostaensis acostaensis, Globorotalia acostaensis humerosa, Globorotalia acostaensis pseudopima, Globorotalia crassaformis* s.l.

Sample 33-3-3, 94-96 cm:
Globigierina bulloides, Globigierina *dutertrei*–4 chambered variant, *Globorotalia crassaformis ronda.*

Sample 33-3-4, 18-20 cm:
*Globigerina bulloides, Globigerina pachyderma, Globorotalia acostaensis acostaensis, Globorotalia crassaformis* s.l., *Globorotalia inflata.*

Sample 33-3-4, 103-105 cm:
Planktonic foraminifera absent.

Sample 33-3-5, 10-12 cm:
*Globigerina bulloides, Globigerina dutertrei, Globorotalia acostaensis acostaensis, Globorotalia acostaensis pseudopima, Globorotalia crassaformis* s. l., *Globorotalia crassaformis ronda, Globorotalia hirsuta praehirsuta, Globorotalia inflata.*

Sample 33-3-5, 100-102 cm:
*Globigerina bulloides, Globigerina dutertrei*–4-5 chambered variants, *Globigerina quinqueloba, Globorotalia acostaensis acostaensis, Globorotalia acostaensis pseudopima, Globorotalia crassaformis* s.l., *Globigerinita glutinata.*

Sample 33-3-6, 37-39 cm:
*Globigerina bulloides, Globigerina dutertrei, Globigerina pachyderma, Globigerinita glutinata, Globorotalia acostaensis acostaensis, Globorotalia crassaformis* s.l., *Globorotalia inflata, Orbulina universa.*

Sample 33-3-6, 100-102 cm:
*Globorotalia crassaformis ronda.*

Sample 33-4-1, 20-22 cm:
*Globigerina bulloides, Globigerina dutertrei, Globigerina pachyderma, Globorotalia crassaformis, Orbulina universa.*

Sample 33-4-1, 100-102 cm:
Planktonic foraminifera absent.

Sample 33-4-3, 25-27 cm:
*Globigerina bulloides, Globigerina dutertrei, Globigerina quinqueloba, Globorotalia acostaensis acostaensis, Globorotalia acostaensis pseudopima, Globorotalia crassaformis crassaformis* Galloway and Wissler, *Globorotalia* cf. *G. subscitula* Conato, *Orbulina universa, Sphaeroidinella dehiscens* (Parker and Jones) immatura form.

Sample 33-4-3, 102-104 cm:
Planktonic foraminifera absent.

Sample 33-4-5, 22-24 cm:
*Globigerina bulloides, Globigerina dutertrei, Globorotalia crassaformis crassaformis, Orbulina universa.*

Sample 33-4-5, 100-102 cm:
Planktonic foraminifera absent.

Sample 33-5-3, 16-18 cm:
*Globigerina bulloides, Globigerina pachyderma, Orbulina universa.*

Sample 33-5-3, 100-102 cm:
Planktonic foraminifera absent.

Sample 33-5-6, 20-22 cm:
*Globigerina pachyderma, Globigerina parabulloides,* Blow, *Globigerina quinqueloba, Globorotalia acostaensis acostaensis, Globorotalia hirsuta praehirsuta, Globorotalia puncticulata* (Deshayes), *Orbulina universa.*

Sample 33-5-6, 98-100 cm:
Planktonic foraminifera absent.

Sample 33-6-1, υ-2 cm:
Planktonic foraminifera absent.

Sample 33-6-2, 0-2 cm:
*Globigerina bulloides.*

Sample 33-6-4, 0-2 cm:
*Globigerina bulloides, Globigerina parabulloides, Orbulina universa, Sphaeroidinellopsis subdehiscens* (Blow).

Sample 33-6-6, 70-72 cm:
*Globigerina bulloides, Globigerina parabulloides, Glogerina nepenthes* Todd, *Orbulina universa.*

Sample 33-7-3, 24-26 cm:
Planktonic foraminifera absent.

Sample 33-7-3, 104-106 cm:
Planktonic foraminifera absent.

Sample 33-8-1, 43-45 cm:
*Globigerina bulloides, Globigerina parabulloides, Globoquadrina* cf. *G. larmeui* Akers.

Sample 33-8-1, 102-104 cm:
Planktonic foraminifera absent.

Sample 33-8-2, 27-29 cm:
*Globigerina bulloides, Globorotalia* cf. *G. miozea miozea* s.l. Finaly.

Sample 33-8-2, 100-102 cm:
Planktonic foraminifera absent.

Sample 33-8-3, 26-28 cm:
Planktonic foraminifera absent.

Sample 33-8-4, 30-32 cm:
*Orbulina universa.*

Sample 33-8-5, 28-30 cm:
*Globigerina praebulloides* Blow, *Orbulina universa.*

Sample 33-8-6, 20-22 cm:
*Globigerina decoraperta* Takayanagi and Saito, *Globigerina praebulloides, Globoquadrina altispira globosa* Bollii.

Sample 33-9-3, 20-22 cm:
Planktonic foraminifera absent.

Sample 33-9-6, 20-22 cm:
*Globigerina praebulloides, Globigerinoides subquadratus* Bronnimann, *Globorotalia* cf. *G. zealindica pseudomiozea* Walters "reworked Cretaceous" *Globotruncana fornicata* Plummer, *Globotruncana linneiana* d'Orbigny).

Sample 33-10-2, 100-102 cm:
Small globigerinid forms.

Sample 33-10-5, 25-27 cm:
Planktonic foraminifera absent.

Sample 33-11-2, 18-20 cm:
*Orbulina universa.*
Note: last sample with planktonic foraminifera present.

**Radiolaria**

Radiolaria are present in all the cores of this hole except Cores 1 and 2. They are common to abundant in Core 15 and the interval including Cores 6 and 10, but their abundance declines to scarce or rare in the remaining cores. The assemblage is restricted, and few age-daignostic Radiolaria were observed. Orosphaerid fragments are present in Core 15, but special preparations were not made for their indentification. Species that are listed below were not included on the Biostratigraphy Chart.

Sample 33-3-6, 19-21 cm:
*Pterocanium trilobum, Tholospyris scaphipes, Dendrospyris damaecornis.*

Sample 33-4-5, 1-3 cm:
*Dendrospyris damaecornis, Pterocanium trilobum.*

Sample 33-5-3, 5-7 cm:
*Pterocanium trilobum, Eucyrtidium acuminatum, Tholospyris scaphipes.*

Sample 33-6-6, 55-57 cm:
*Pterocanium trilobum, Dendrospyris stabilis, Eucyrdidium acuminatum, Dendrospyris damaecornis, Tholospyris scaphipes.*

Sample 33-8-1, 5-7 cm:
*Tholospyris infericosta, Liriospyris ovalis, Pterocanium trilobum.*

Sample 33-8-5, 13-15 cm:
*Tholospyris scaphipes, Dendrospyris damaecornis, Dendrospyris stabilis, Eucyrtidium acuminatum.*

Sample 33-9-3, 7-9 cm:
*Tholospyris scaphipes, Eucyrtidium acuminatum, Liriospyris ovalis.*

## SUMMARY

The sediment section penetrated at Site 33 can be divided into five main stratigraphic units ranging from Middle Miocene to Pleistocene in age (Table 2). The section below 295 meters was not penetrated. The depth of the basement, therefore, is uncertain but on the basis of the seismic reflection profile, it appears to be at 350 meters. This suggests that 55 meters of unpenetrated sediments lie above basement. According to the magnetic anomaly at this site (Number 10; 32 million years), the age of the basal sediments would be within the Upper Oligocene. If sediments of this age exist here, one would have to postulate a depositional rate of 3m/m.y. years for the unpenetrated interval. Such a rate is much lower than that observed in the penetrated interval. However, when compared with rates for sediments of this age at surrounding sites, it becomes a realistic value.

The lowest unit cored, unit 5, extends only through Core 15 (293 to 295 meters). As penetration ceased with this unit, its total thickness is unknown. This unit has an abundance of microfossils, and consists of dark gray and green-gray mud siliceous-fossil ooze interbedded with nannofossil-siliceous ooze. Cherty fragments found at the top of the core are Middle Miocene age.

Unit 4 encompasses part of Cores 11 through Core 14 (270 to 293 meters). It is characterized by its rare nannofossils and only moderate amounts of siliceous fossils. The lithology is dark green-gray siliceous-fossil mud. Thin cherty siliceous-fossil mudstone beds and/or fragments are a minor feature in all cores. Thin volcanic ash beds occur at the base of Cores 12 and 13. Only Middle Miocene fossils were encountered in this unit.

**TABLE 2**
**Stratigraphic Units at Site 33**

| Unit | Depth (m) | Cores | Age | Description |
|---|---|---|---|---|
| 1 | 0-170 ± | 1-5 | Pleistocene Lower Pliocene | Dark greenish-gray dominantly clay-mud unit. Muds with some siliceous-fossils and rare nanno-fossils. Rare silty mud and ash in Core 1. |
| 2 | 170±-256 | 6-9 | Upper Miocene Middle Miocene | Dark greenish-gray mud siliceous-fossil ooze with thin nannofossil-siliceous ooze near middle and base. |
| 3 | 256-270 | 10.0-11.2 | Middle Miocene | Dark greenish to greenish-gray nannofossil rich interval. Mostly mud nannofossil ooze, siliceous-nannofossil ooze, and nannofos-sil-siliceous ooze. Thin streaks cherty siliceous-fossil mudstone. |
| 4 | 270-293 | 11.3-14.0 | Middle Miocene | Dark greenish-gray mud unit with moderate siliceous-fossils. Mostly siliceous-fossil mud with several streaks and chips cherty siliceous-fossil mudstone. Several ash beds. |
| 5 | 293-295 | 15 | Middle Miocene | Dark to light green-gray fossil-rich unit, consisting of siliecous-fossil ooze, and nannofossil sili-ceous-ooze. Some chert chips. |
| | 295-350 | | Middle Miocene Upper Oligocene? | |

Unit 3 (parts of Cores 10 and 11, 256 to 270 meters) is also entirely Middle Miocene in age. It is marked by a high nannoplankton content. Dominant are mud nannofossil ooze, siliceous nannofossil ooze and nannofossil siliceous ooze. Also present is siliceous-fossil mud. All strata are dark greenish to greenish-gray. Core 10 contains some cherty mudstone nodules with microfossil ghosts. This chert apparently represents the upper limit of silicification. It is at approximately this depth (262 meters) that the first reflector on the seismic profile is represented, suggesting that the reflector source is the silicified part of the section.

Unit 2 (between Cores 5 and 6 through Core 9, 170 to 256 meters[1]) ranges from Middle Miocene to Late Miocene age. A high siliceous fossil content dominates the unit. The dark greenish-gray beds are mostly a mud siliceous-fossil ooze. Thin nannofossil-siliceous ooze layers are found near the middle and base of unit 2.

Unit 1 extends from between Cores 5 and 6 (170± meters) to the sea floor, and is dominated by dark greenish-gray (Pliocene to Pleistocene) clay-mud. Some siliceous-fossil mud occurs in Cores 3 and 5. Minor amounts of siliceous-fossil and nannofossils occur throughout unit 1. Ash is found at the bottom of Core 1. A few silty muds represent the only coarse terrigenous debris at Site 33. As this site is in the abyssal hills west of the Delgada Fan the origin of the silt is uncertain. It may represent the results of various depositional agents, possibly largely the nepheloid layer.

The part of the section containing silt also contains a cold water forminiferal fauna. The sedimentation rate

[1]Interval was obtained by extrapolation from Site 34.

for the Pleistocene part of the section with a cold water foraminiferal fauna is 29 m/m.y.

Various admixtures of green terrigenous mud were deposited throughout the section at Site 33. The lower part of the Middle Miocene interval is marked by high calcareous nannoplankton production at the top and bottom. In between are moderate amounts of siliceous fossils. The greatest amount of siliceous fossil deposition, however, began in the upper part of the Middle Miocene and persisted at least into the Late Miocene (possibly even into Early Pliocene as there is a 58 meter uncored interval here). Following this period of biogenous deposition, the number of fossils declined abruptly as the terrigenous muds began to dominate. This condition persisted to the present.

## 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, Bacillariophycaee (Diatoms). *Fishery Invest., Ser. IV.*

Hustedt, Frederich, 1930. Die Kieselalgen Deutschlands, Oesterrichs und der Schweiz mit Berücksichtigung der übrigen Länder Europas sowie der angrenzenden Meeresgebiedt. **In** *Kryptogammen–Flora von Deutschland, Oesterrich und der Schweig.* L. Rabenhorsts (Ed.). Leipzig (Akad. Verlag, Geest Portig K-G) VII, **1**, 609.

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

Loeblich, A. R., III, Loeblich, L. A., Tappan, H. 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. W., Jr., 1967. Miocene and Pliocene marine diatoms from California. *Calif. Acad. Sci.* Occ. Paper **63**, 1.

## THE CORES RECOVERED FROM SITE 33

The following pages present a graphic summary of the results of drilling and coring at Site 33. Fig. 2, a summary of Site 33 is at the back of the book. Figures 3 to 17 are summaries of the individual cores recovered. A key to the lithologic symbols is given in the Introduction (Chapter 1).

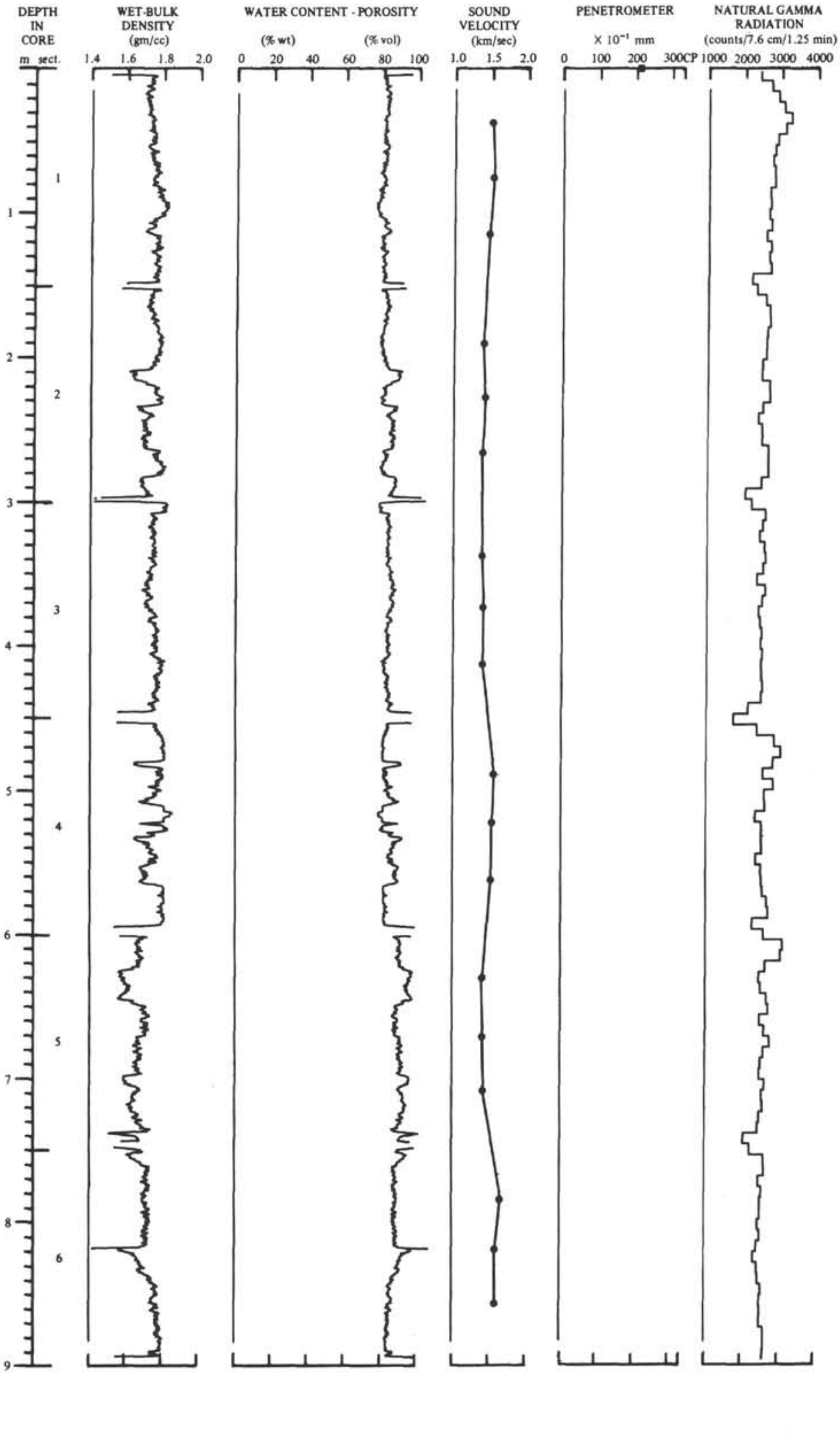


Figure 3A. *Physical Properties of Core 1, Hole 33*

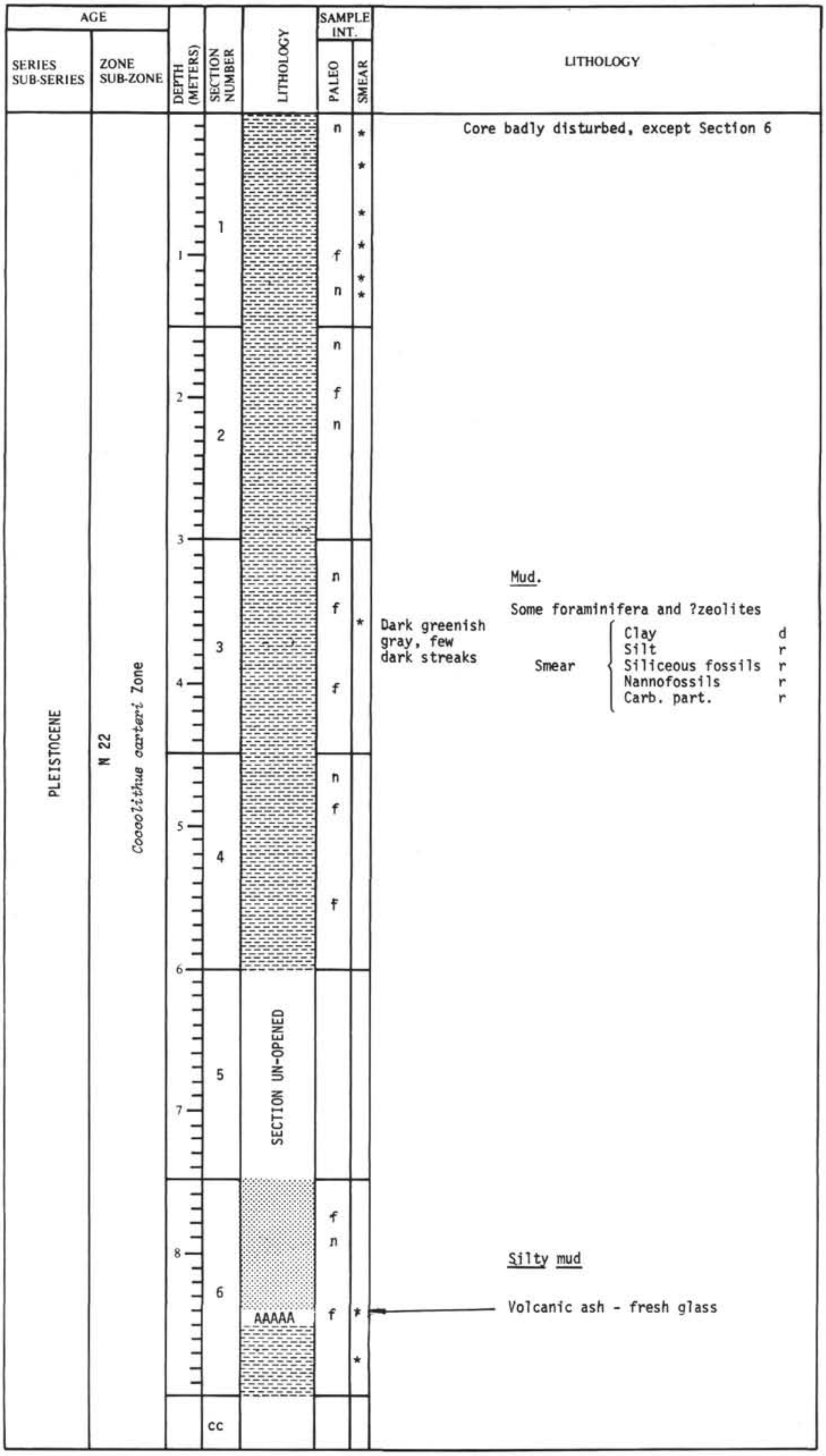


Figure 3B. *Core 1, Hole 33 (0-9 m Below Seabed)*

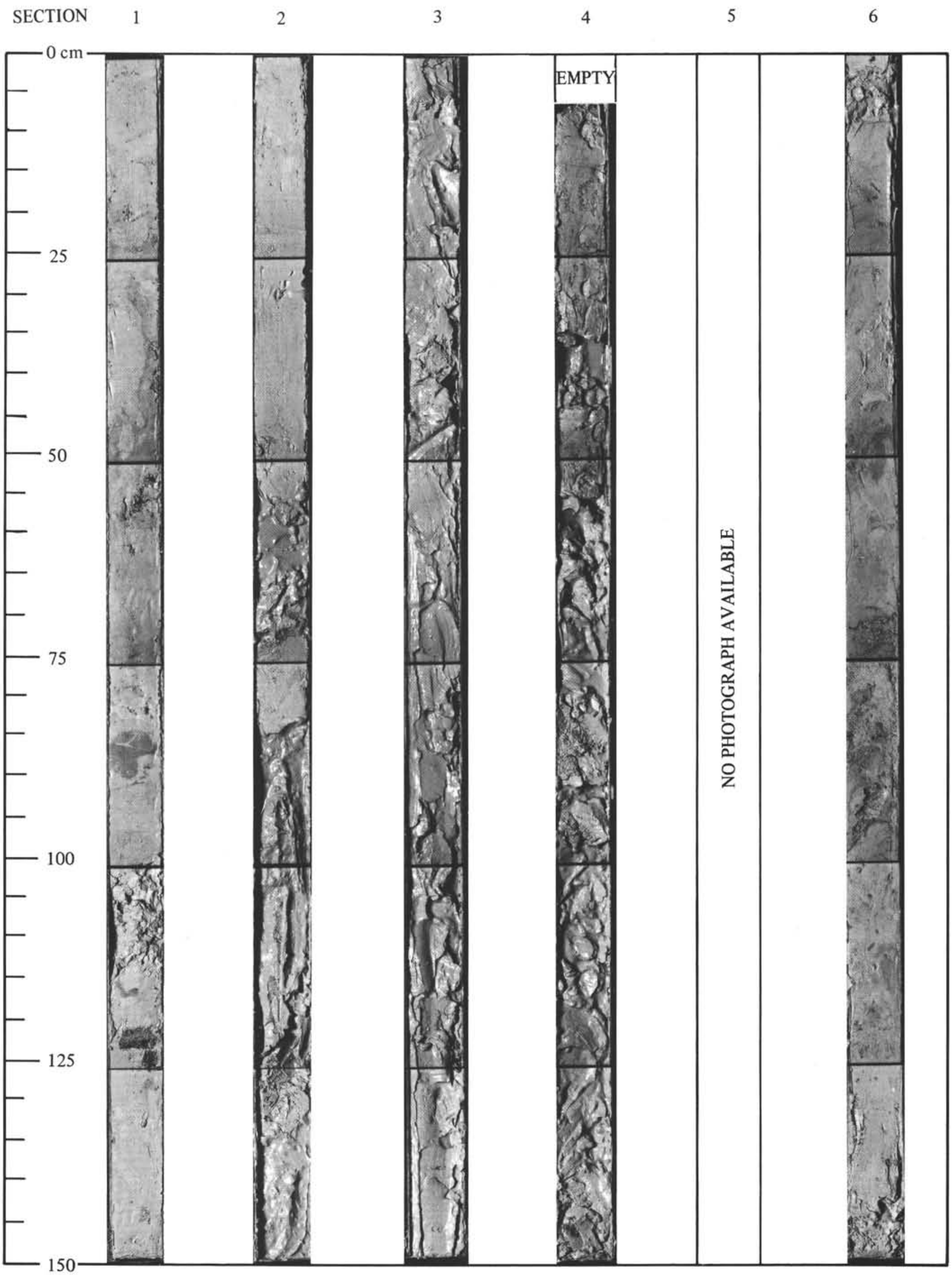


Plate 1. *Core 1, Hole 33*

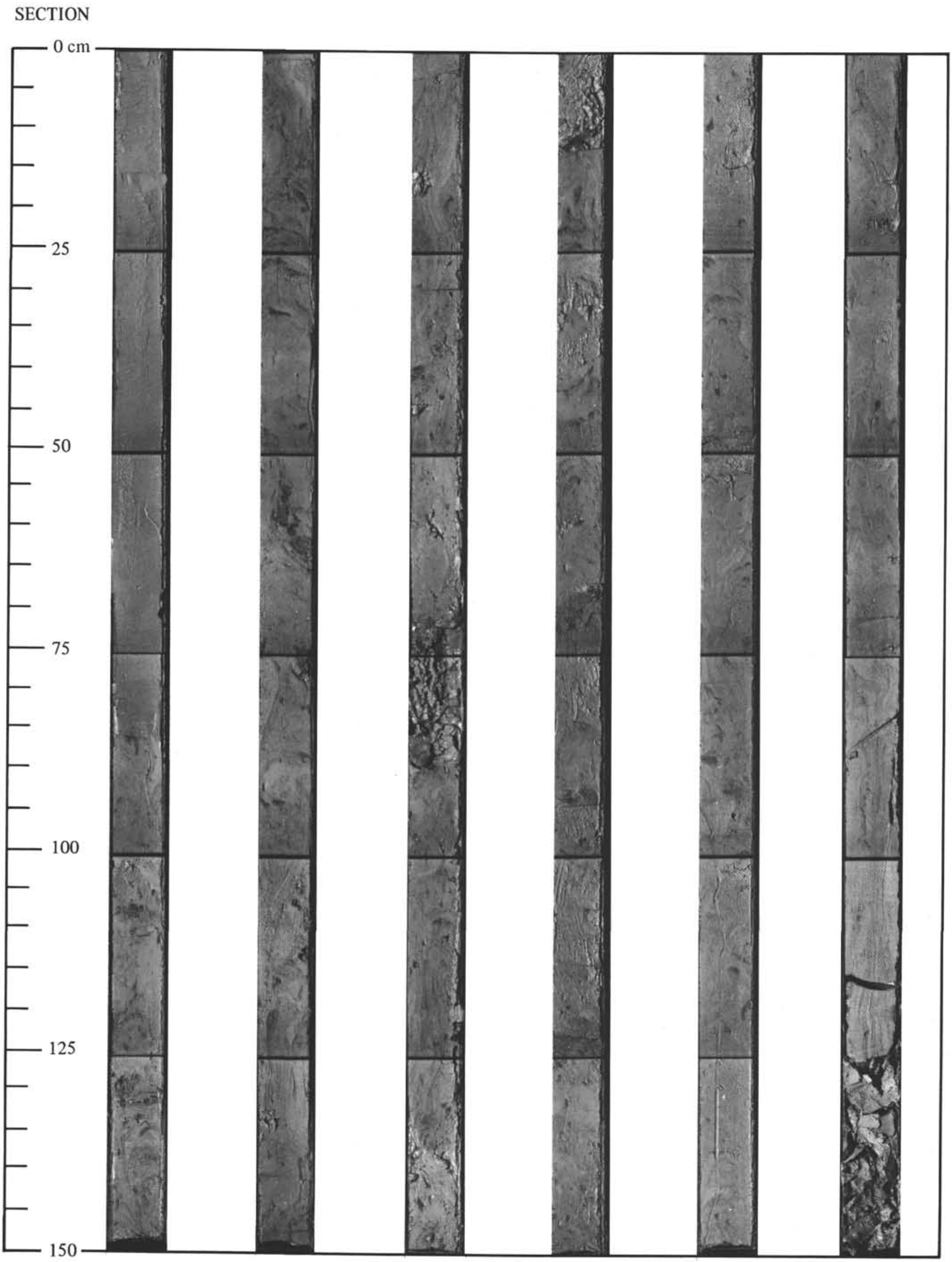

Plate 2. *Core 2, Hole 33*

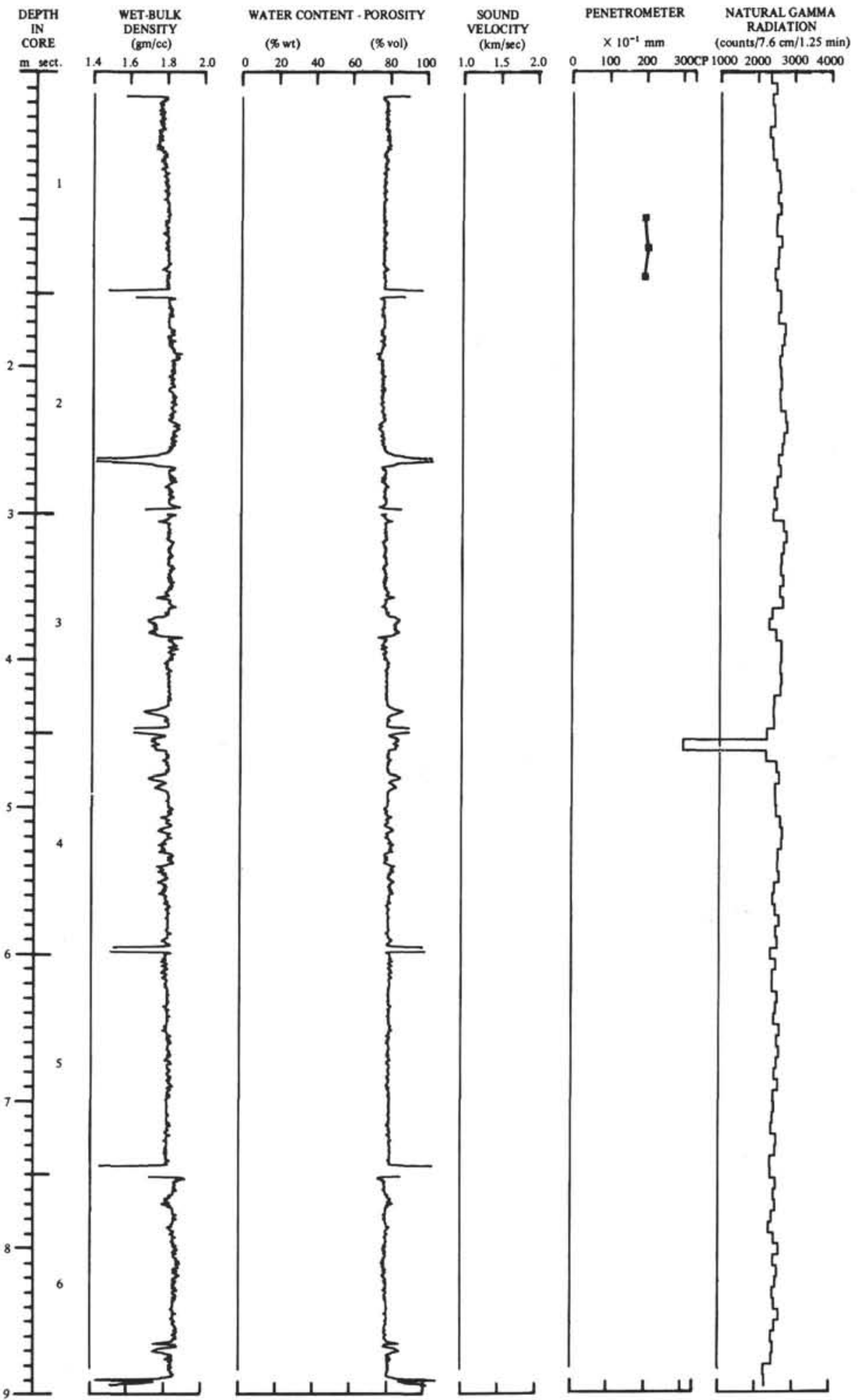


Figure 4A. *Physical Properties of Core 2, Hole 33*

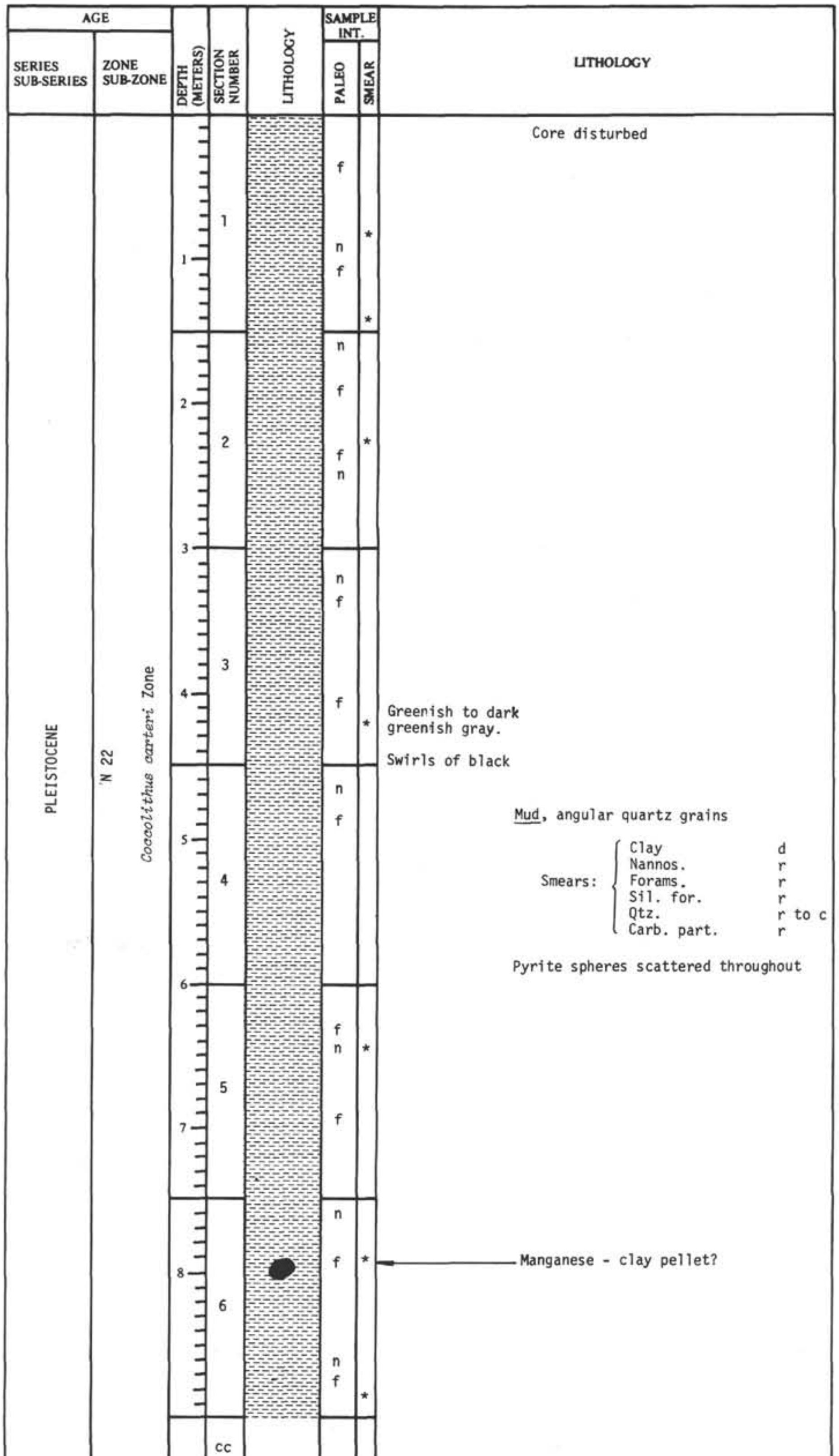


Figure 4B. *Core 2, Hole 33 (9-18 m Below Seabed)*

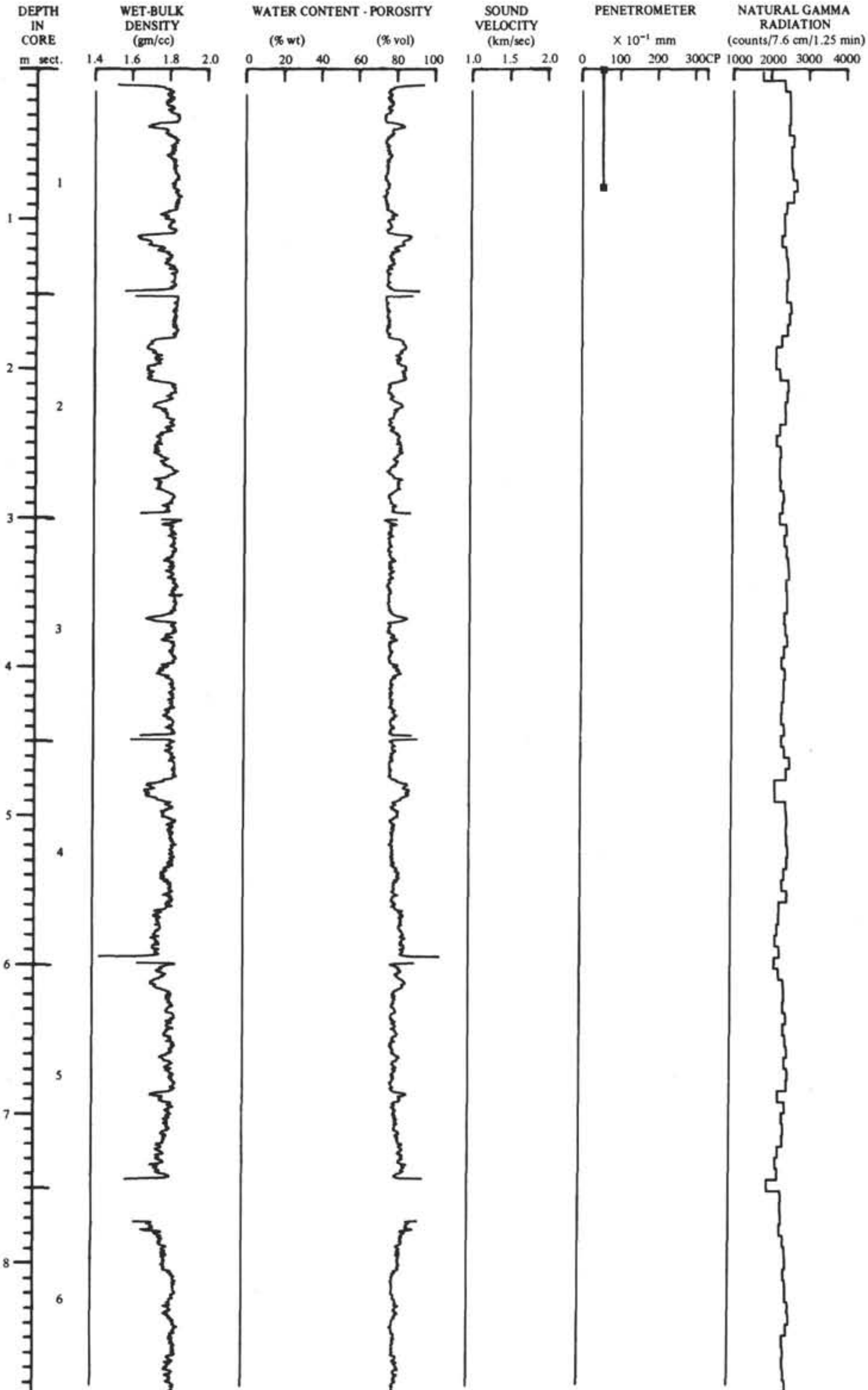


Figure 5A. *Physical Properties of Core 3, Hole 33*

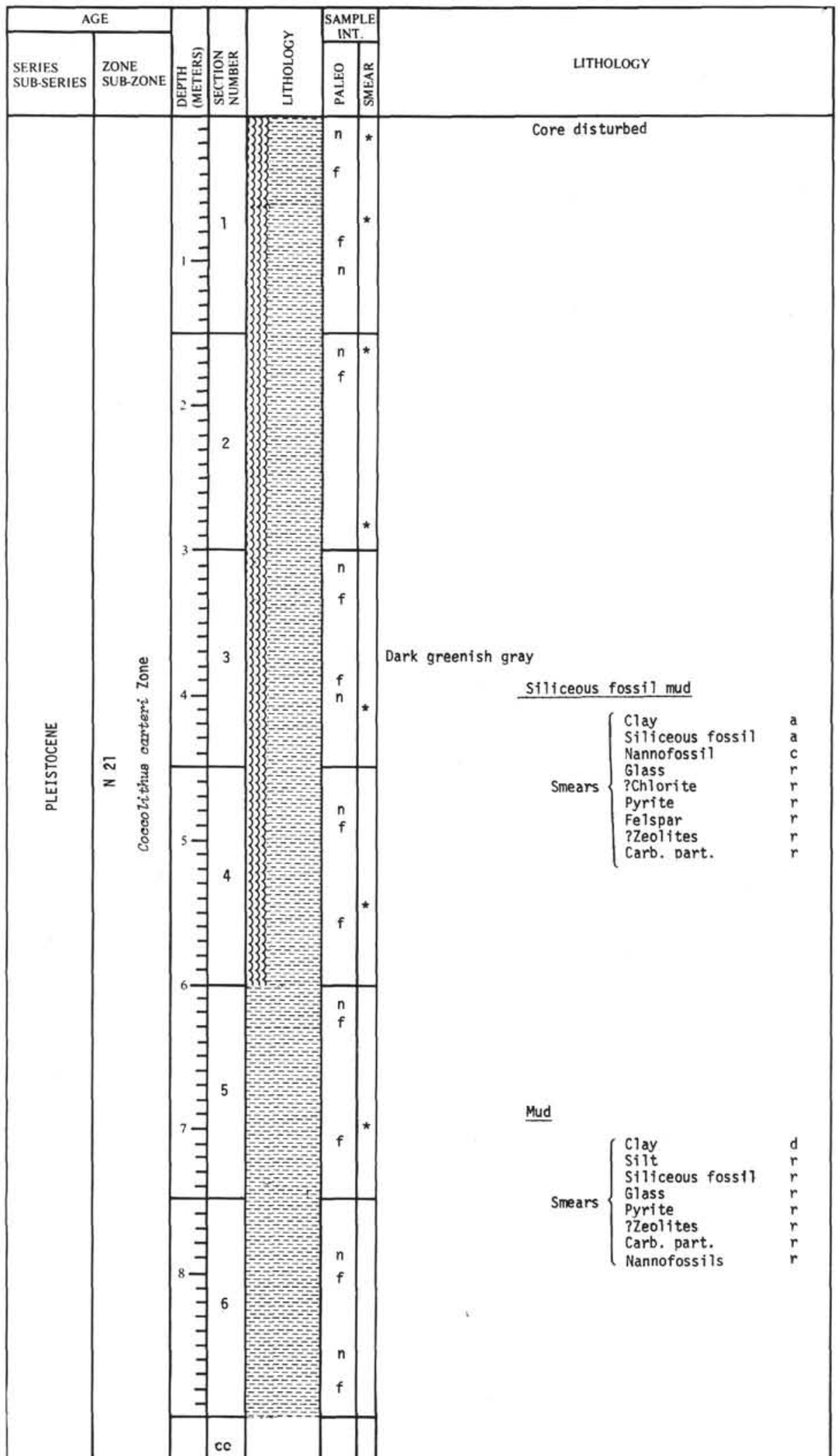


Figure 5B. *Core 3, Hole 33 (47-56 m Below Seabed)*

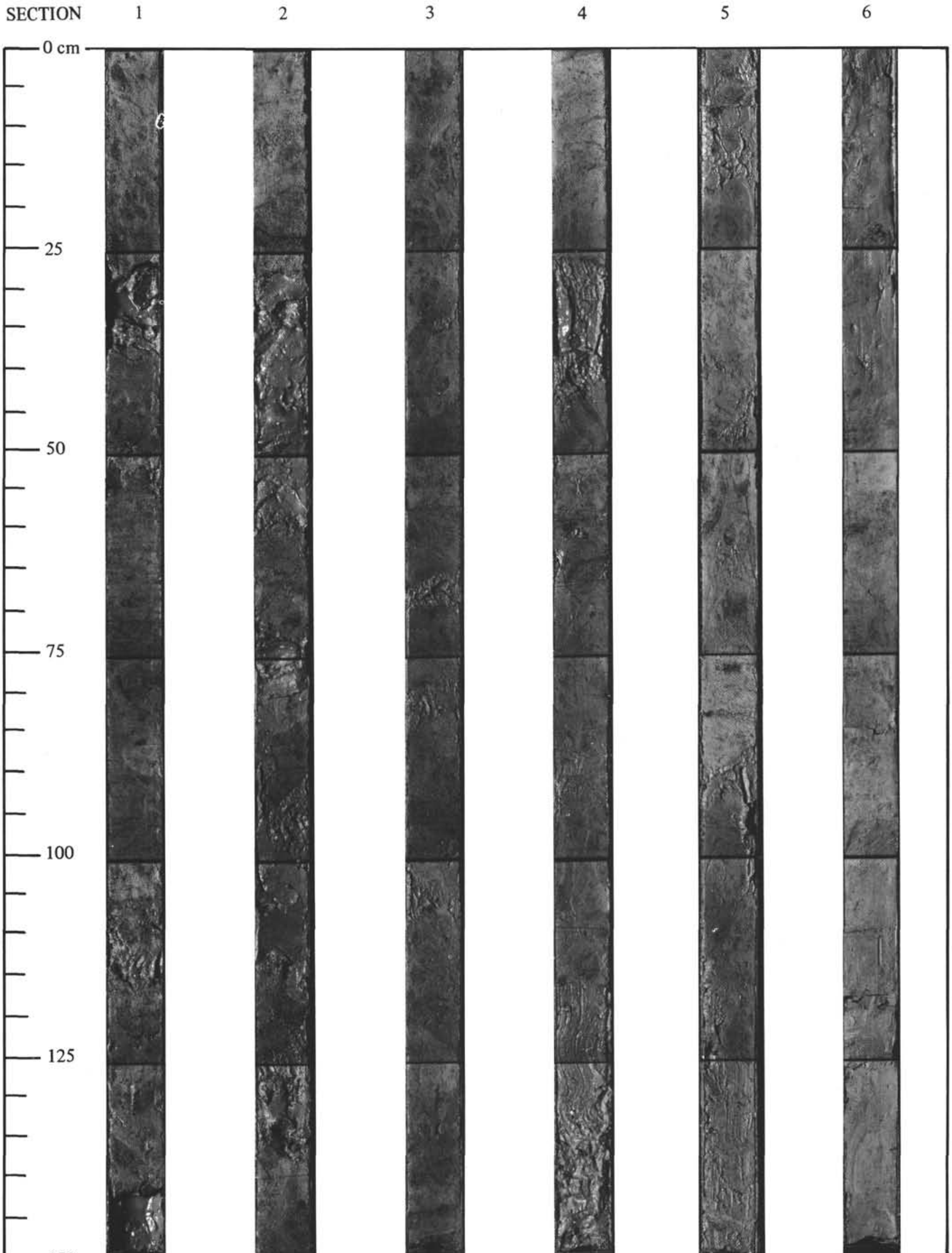

Plate 3. *Core 3, Hole 33*

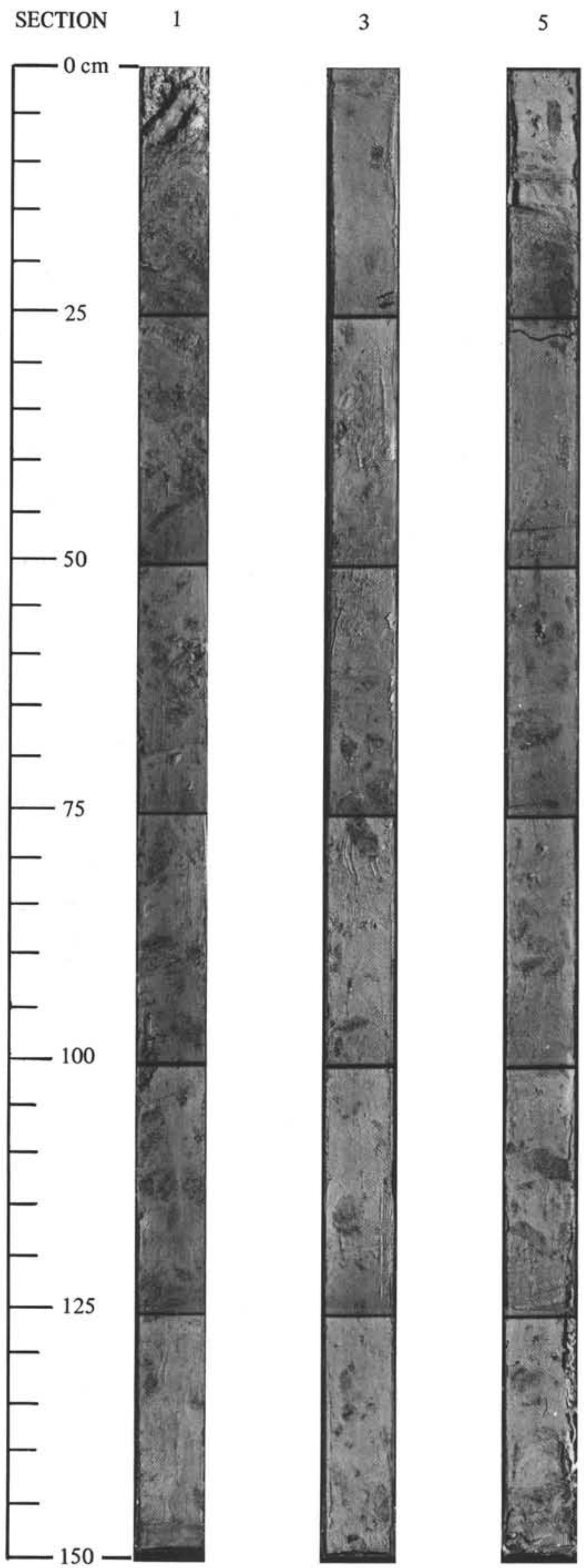

Plate 4. *Core 4, Hole 33*

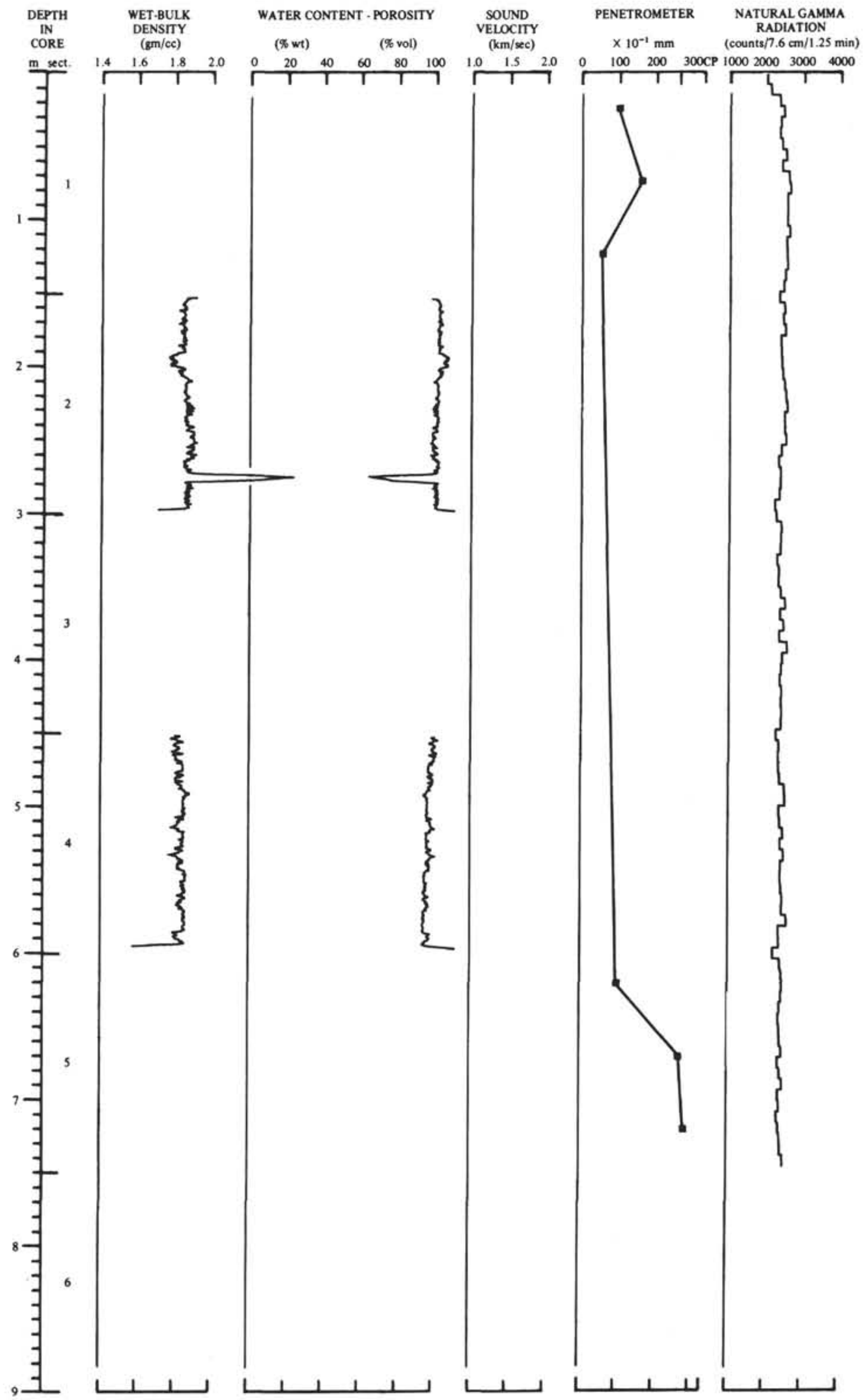


Figure 6A. *Physical Properties of Core 4, Hole 33*

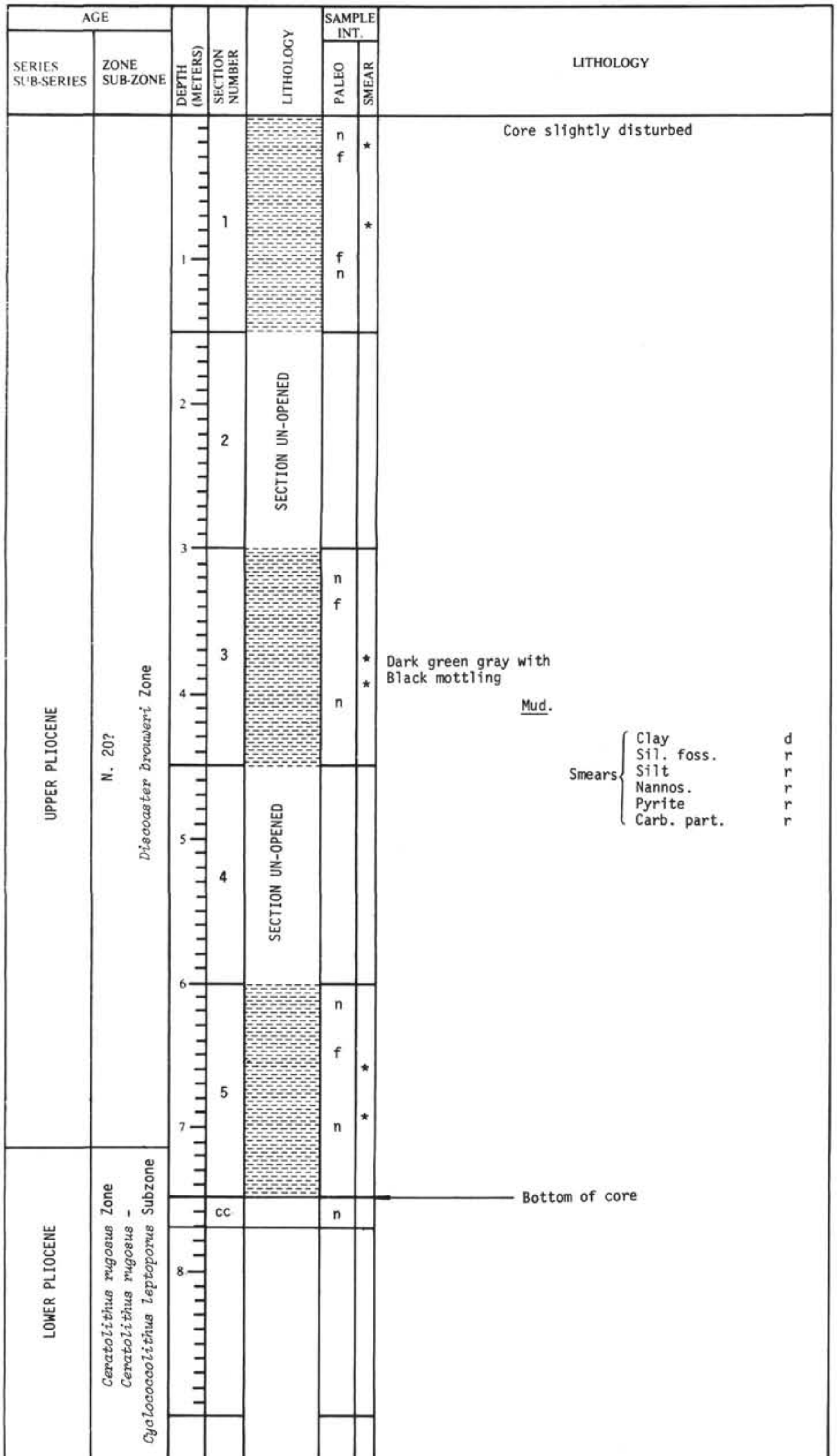


Figure 6B. *Core 4, Hole 33 (95-104 m Below Seabed)*

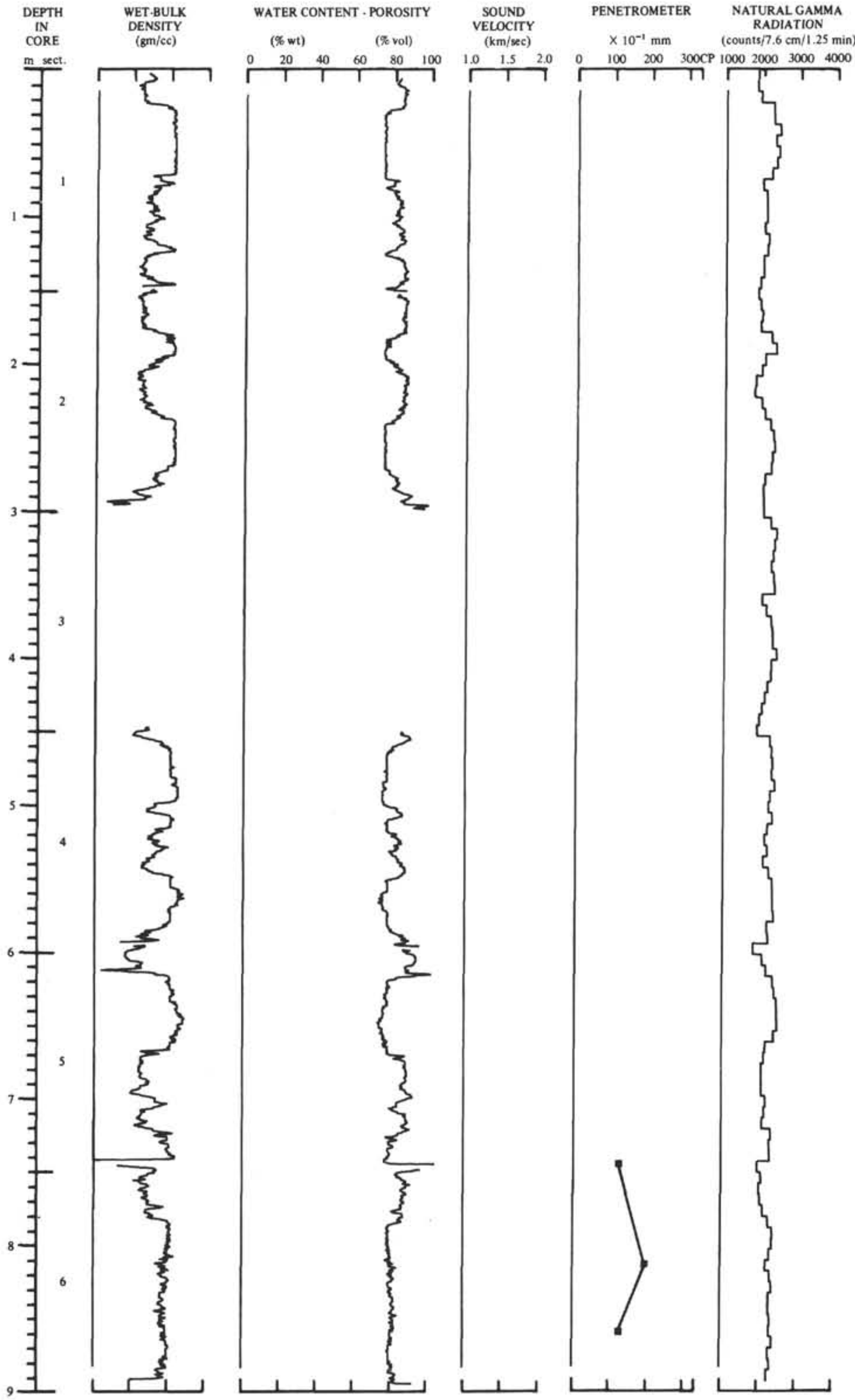


Figure 7A. *Physical Properties of Core 5, Hole 33*

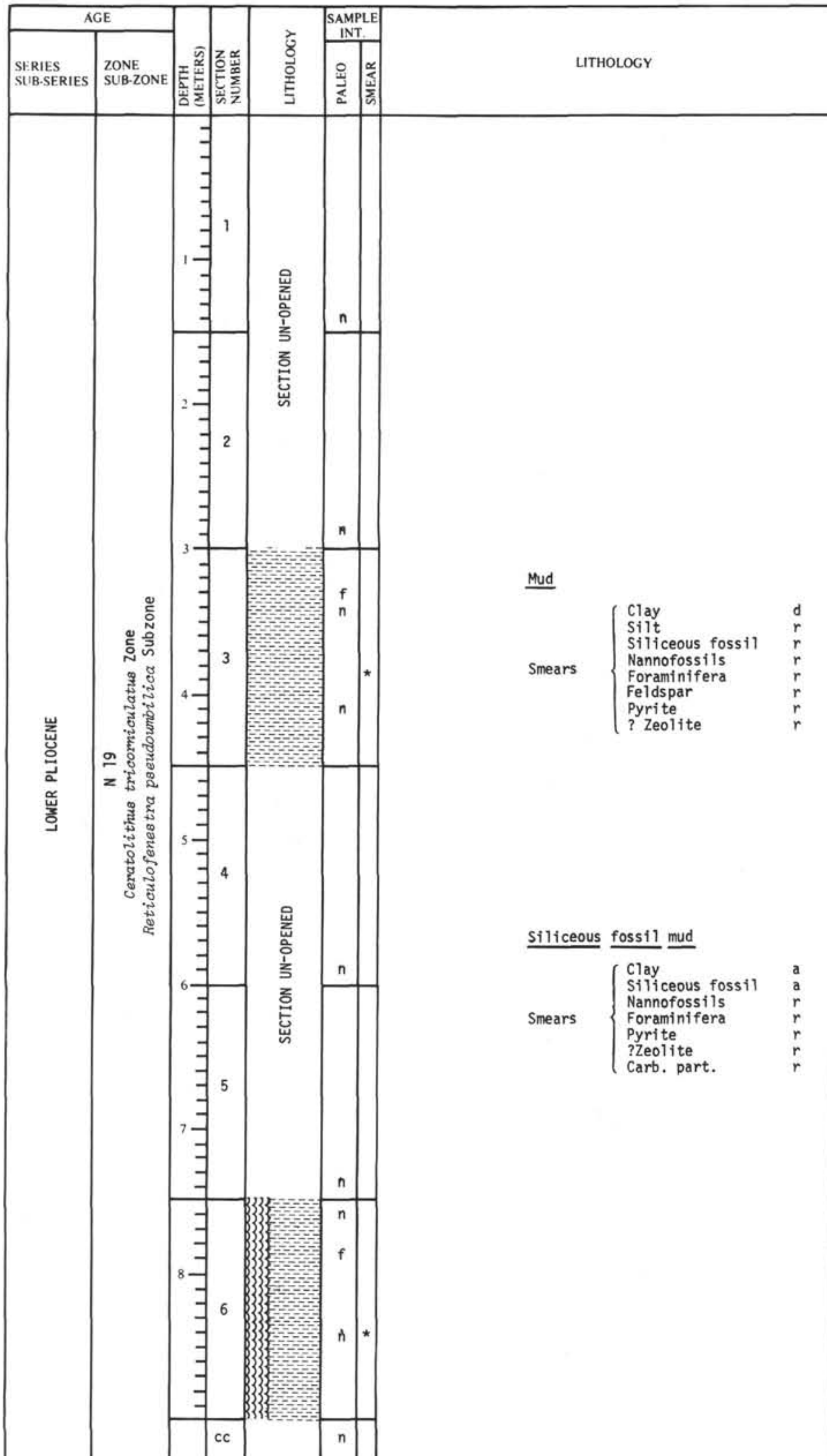


Figure 7B. *Core 5, Hole 33 (152-161 m Below Seabed)*

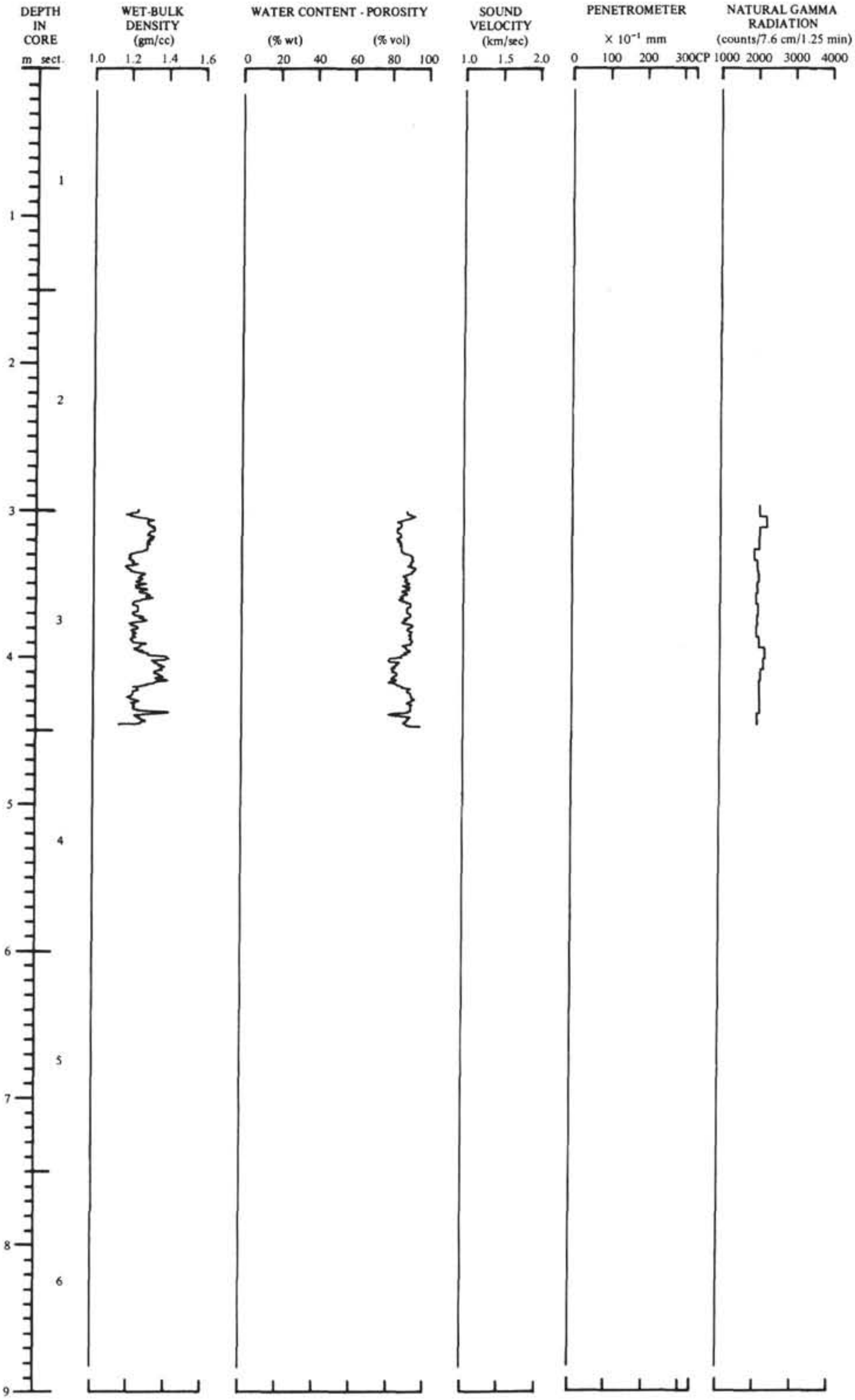


Figure 8A. *Physical Properties of Core 6, Hole 33*

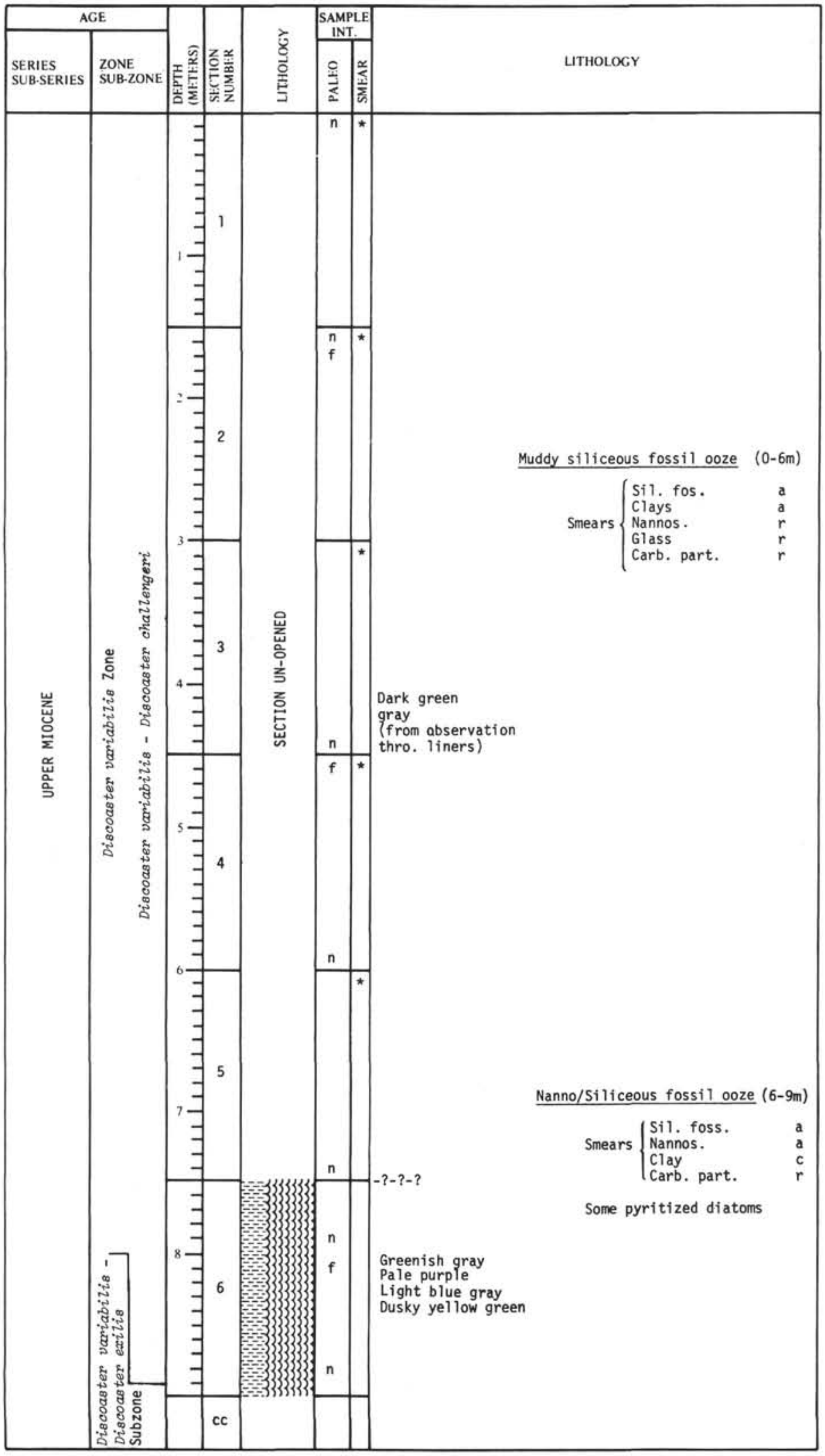


Figure 8B. *Core 6, Hole 33 (219-228 m Below Seabed)*

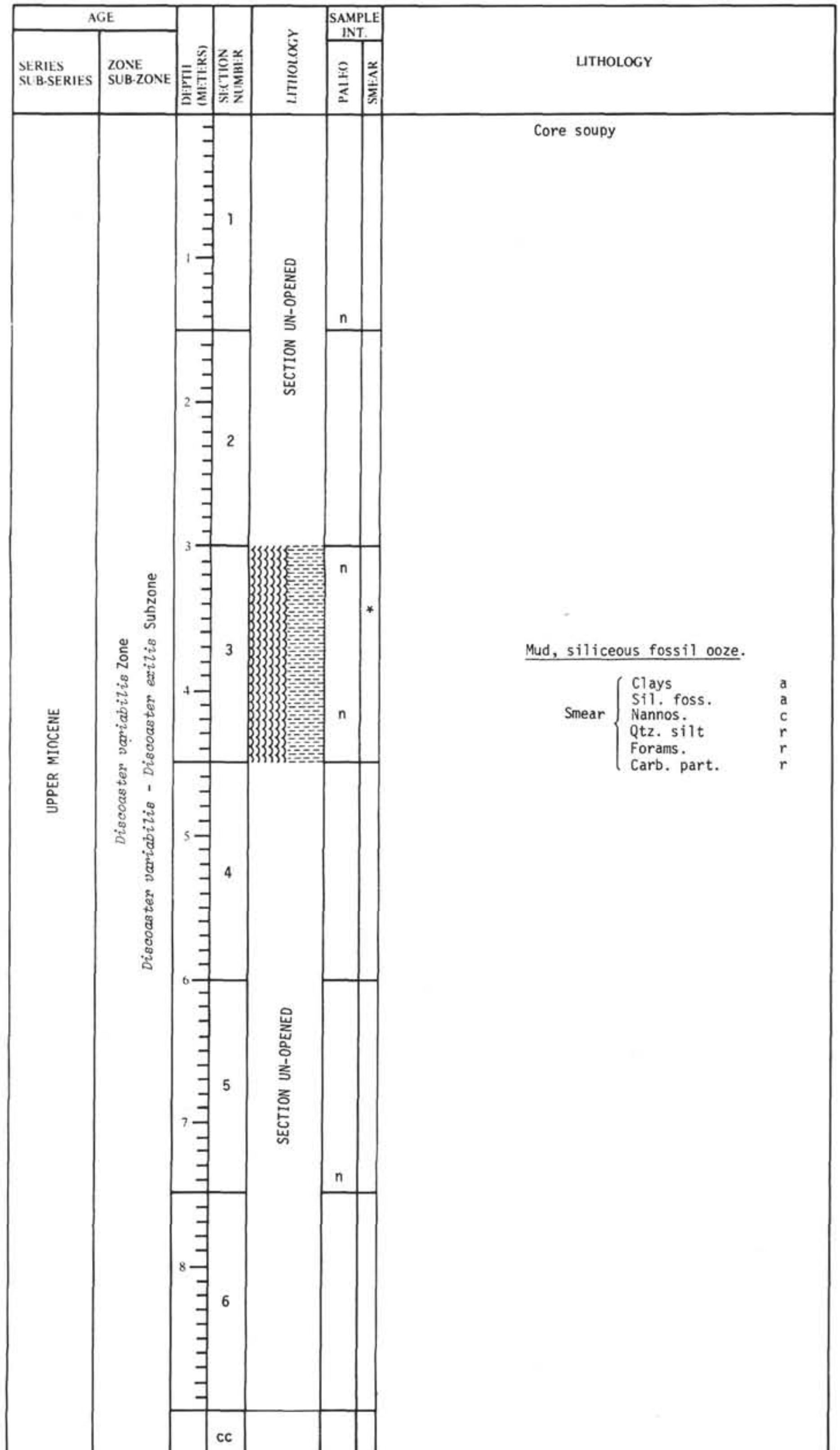


Figure 9. *Core 7, Hole 33 (228-237 m Below Seabed)*

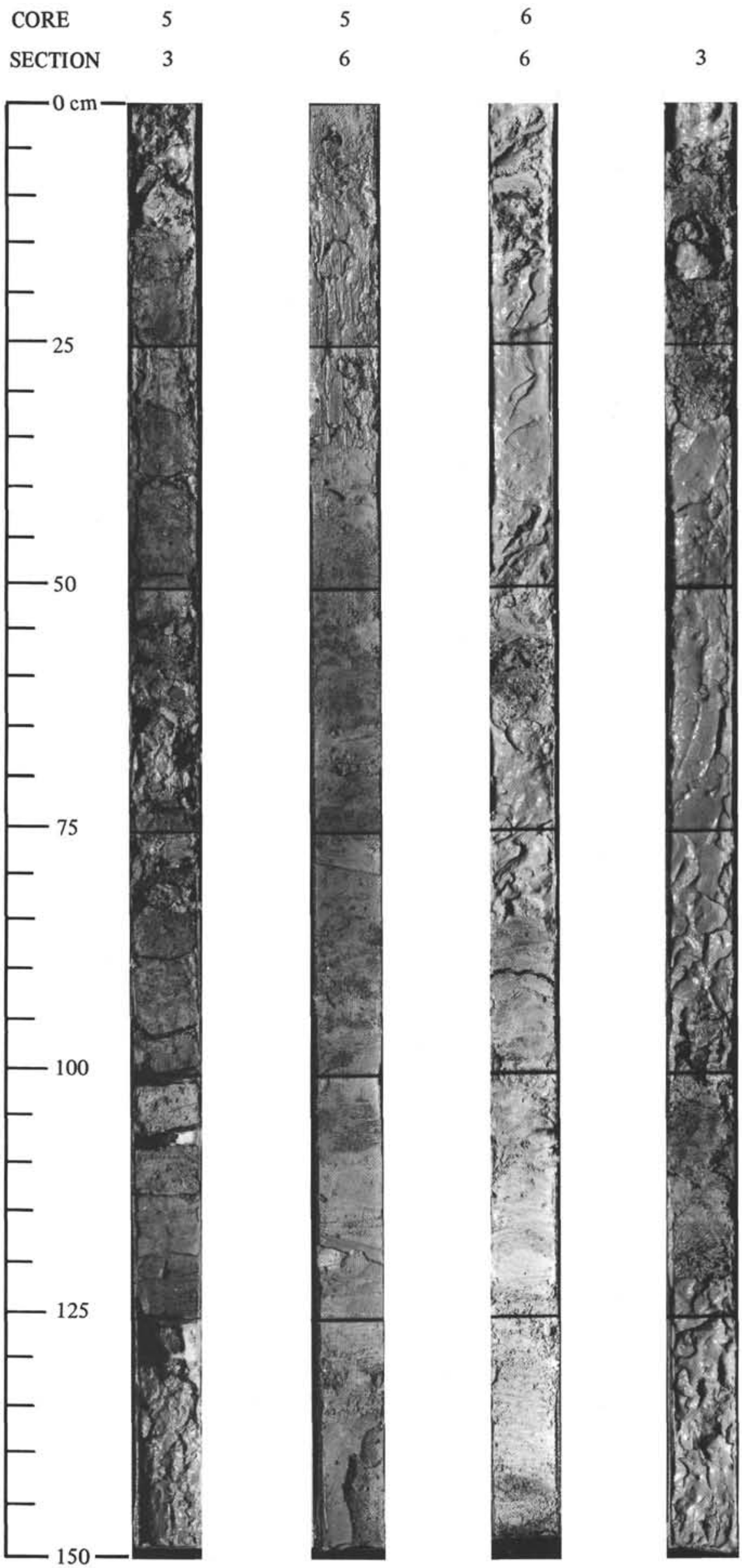


Plate 5. *Sections of Cores 5, 6 and 7, Hole 33*

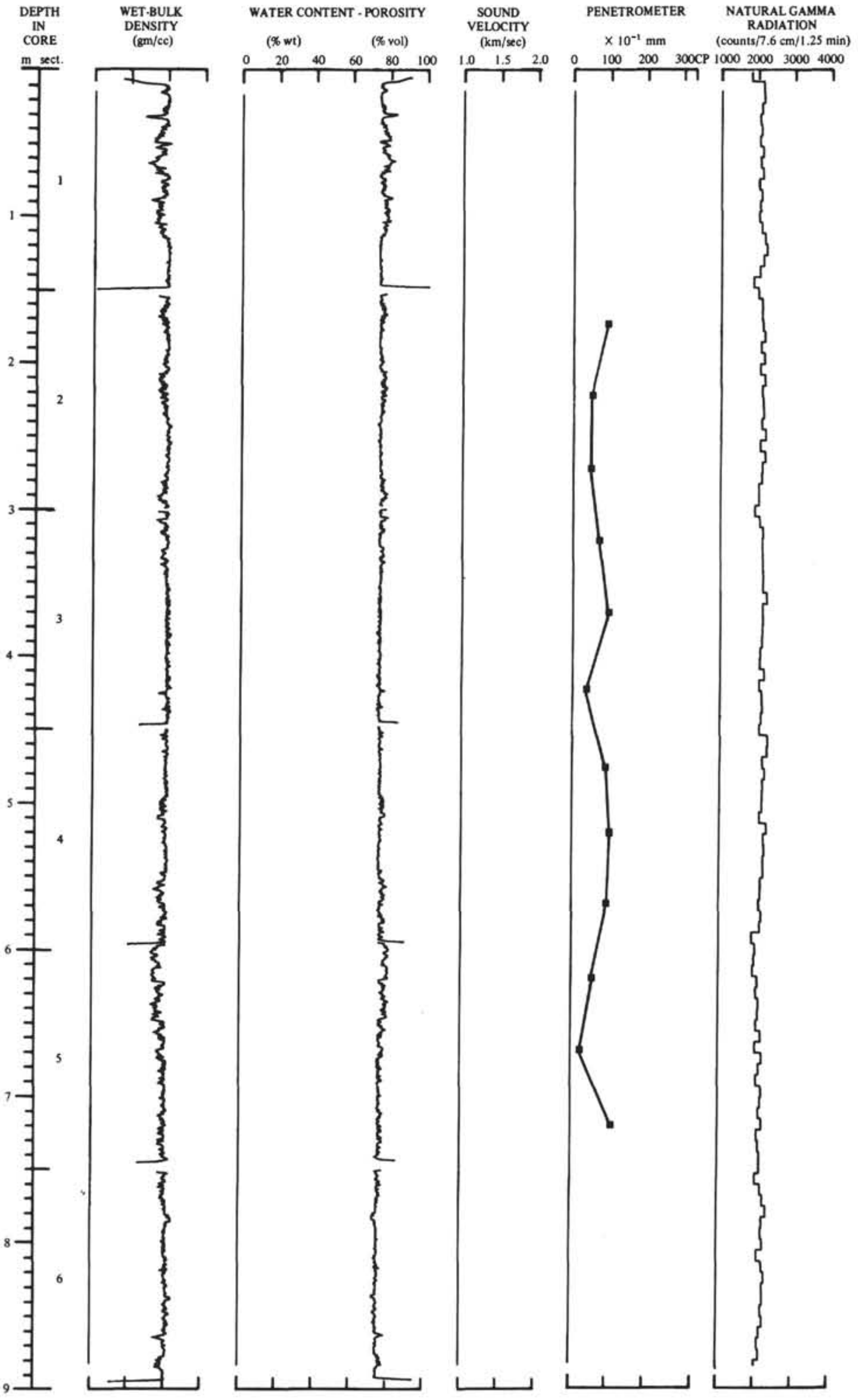


Figure 10A. *Physical Properties of Core 8, Hole 33*

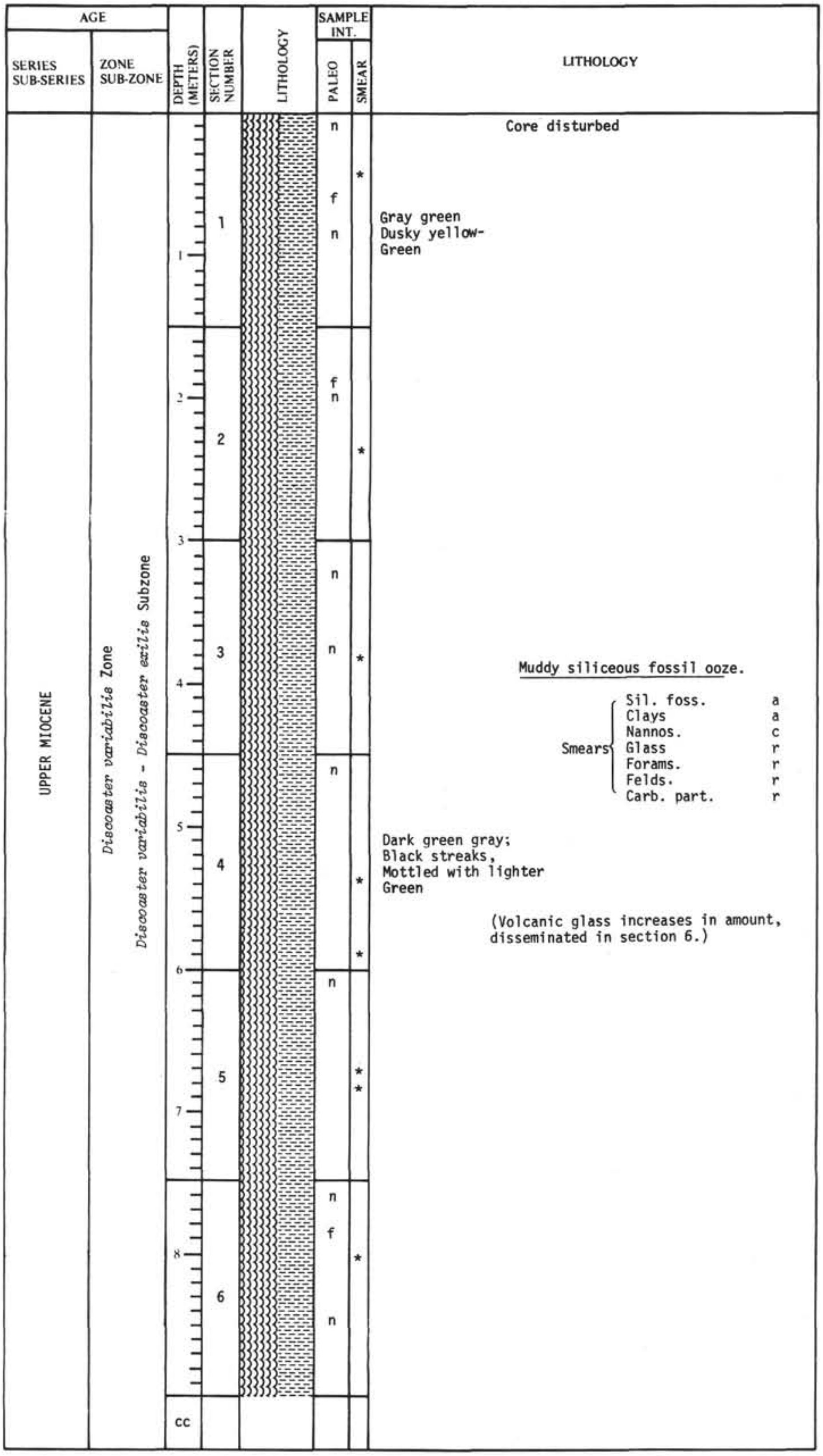


Figure 10B. *Core 8, Hole 33 (237-246 m Below Seabed)*

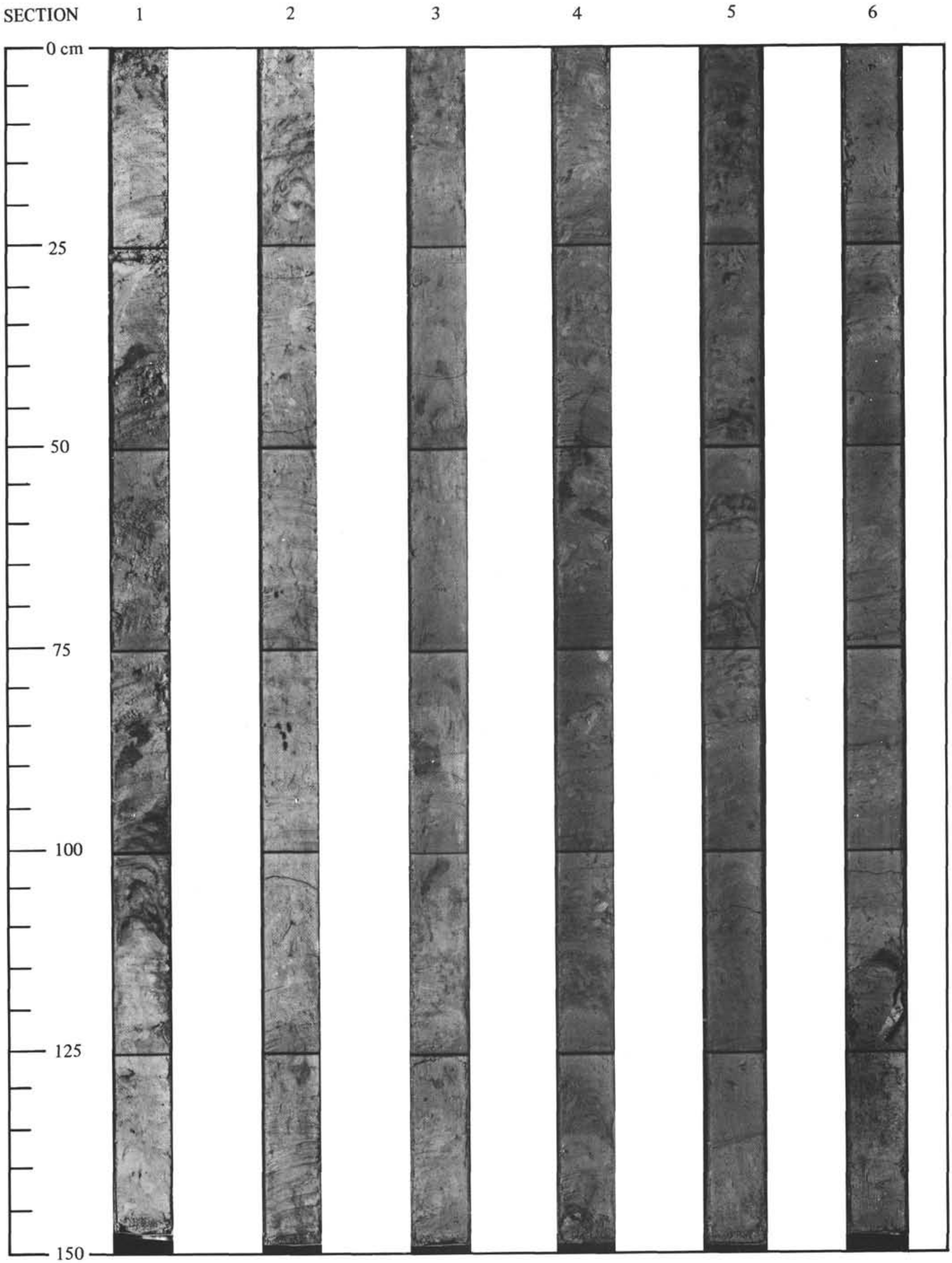


Plate 6. *Core 8, Hole 33*

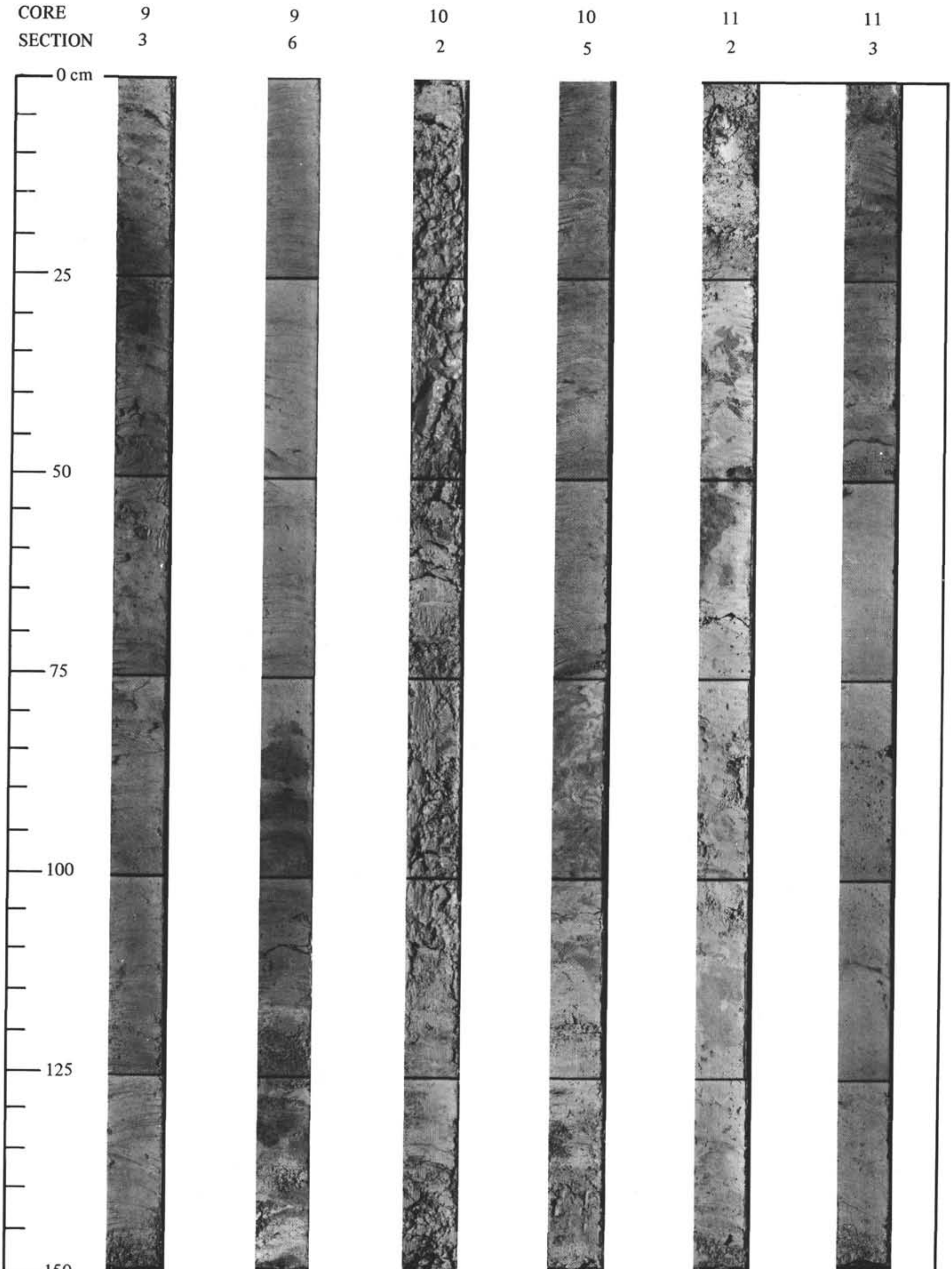


Plate 7. *Sections of Cores 9, 10 and 11, Hole 33*

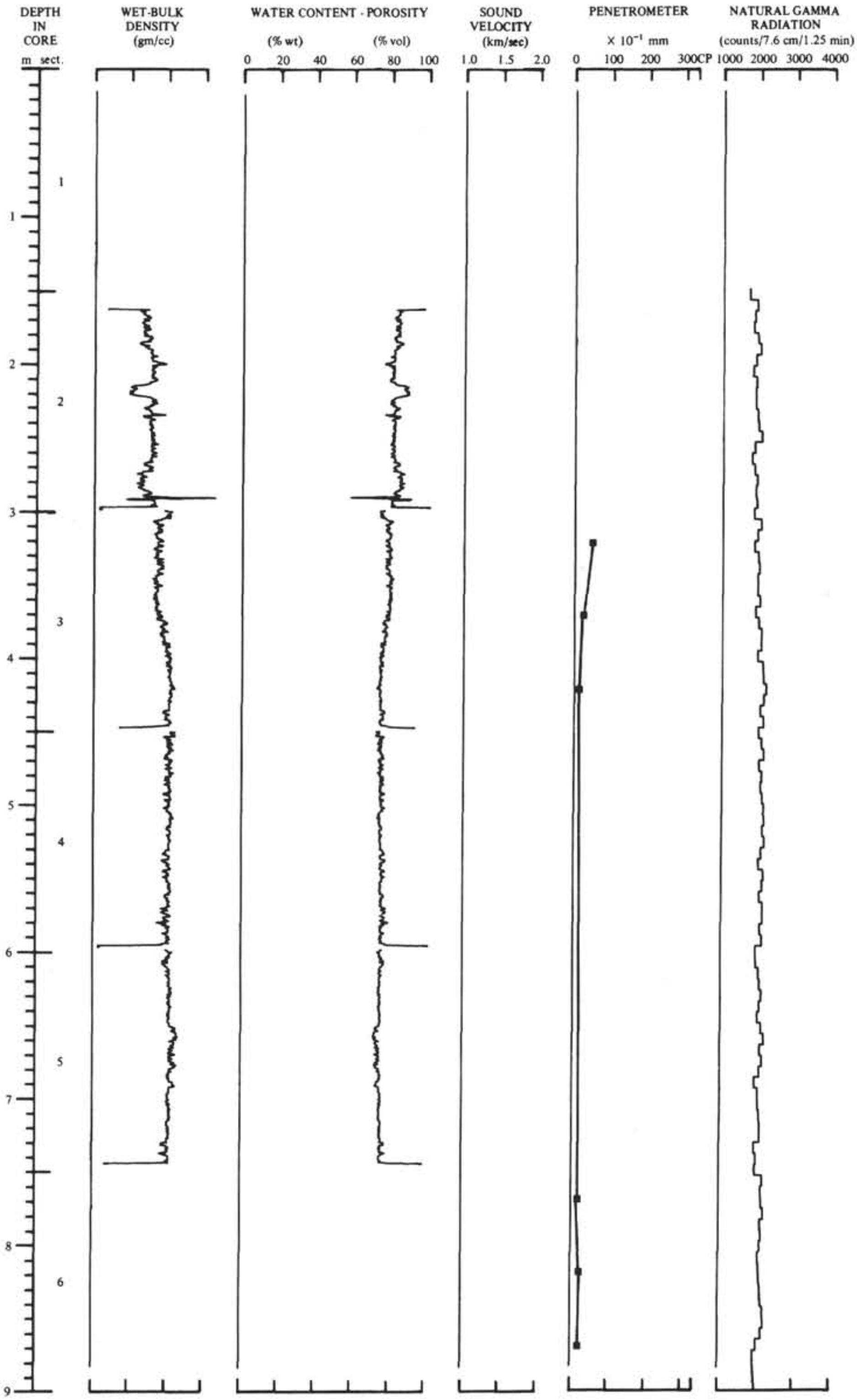


Figure 11A. *Physical Properties of Core 9, Hole 33*

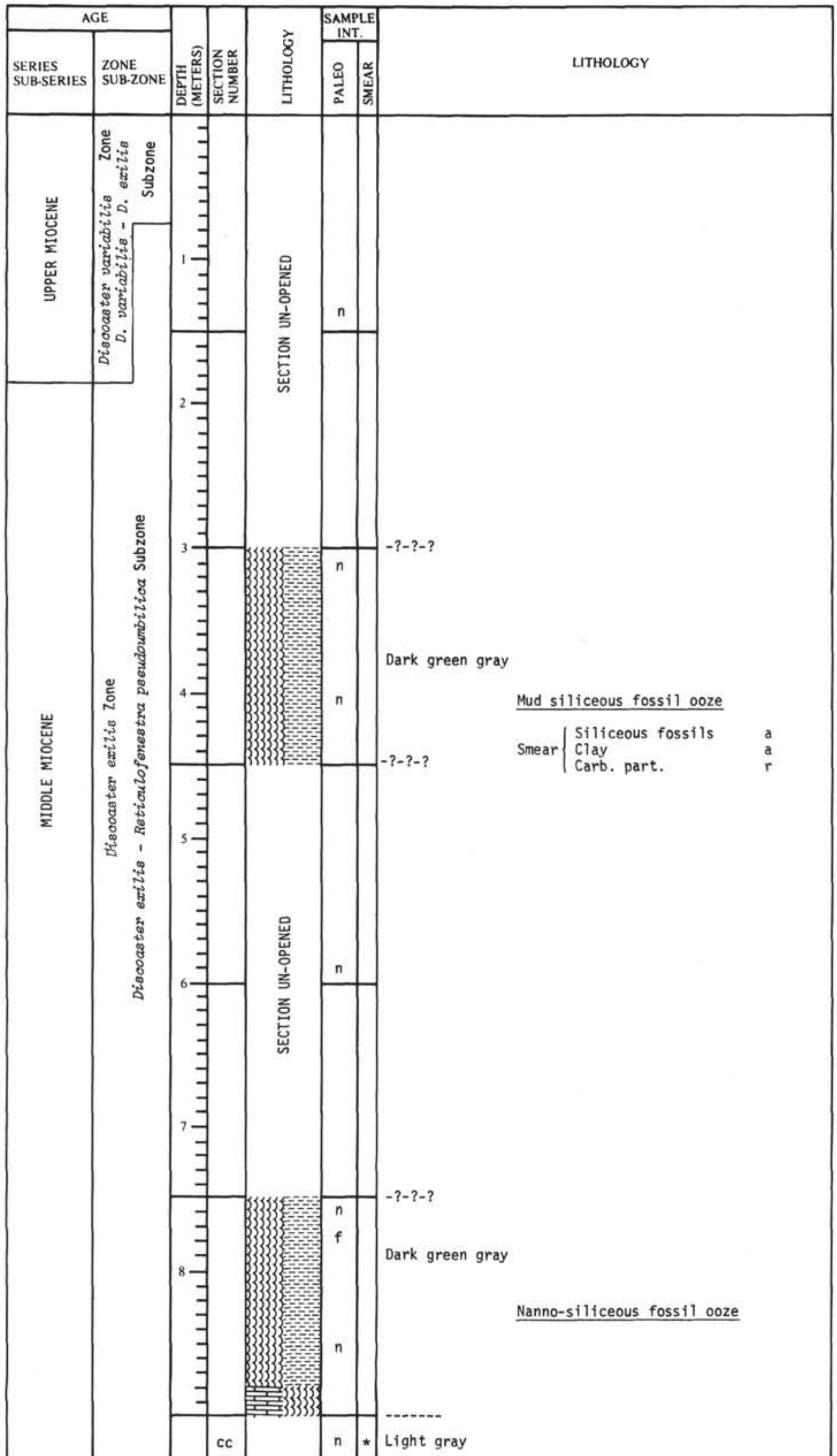


Figure 11B. *Core 9, Hole 33 (247-256 m Below Seabed)*

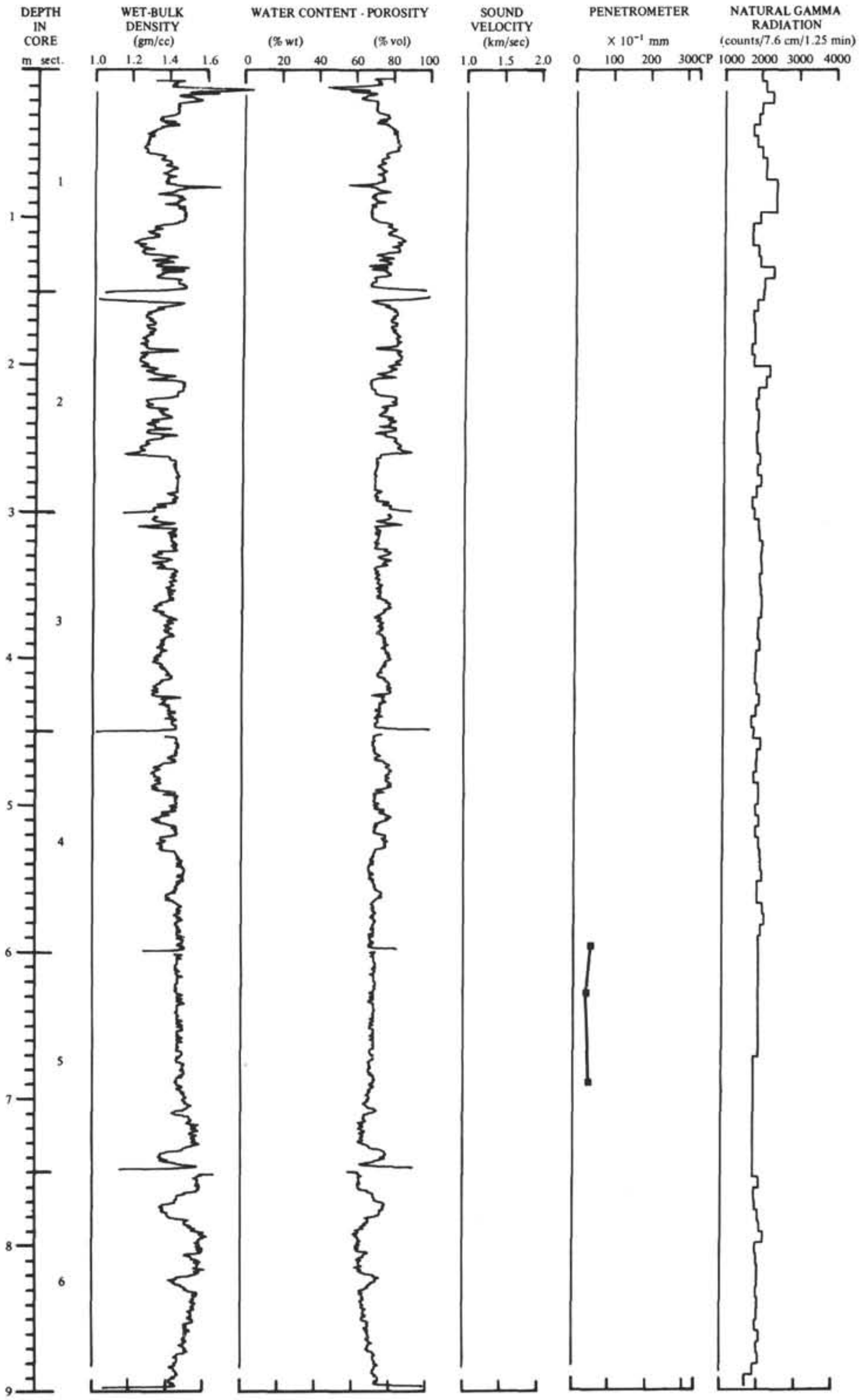


Figure 12A. *Physical Properties of Core 10, Hole 33*

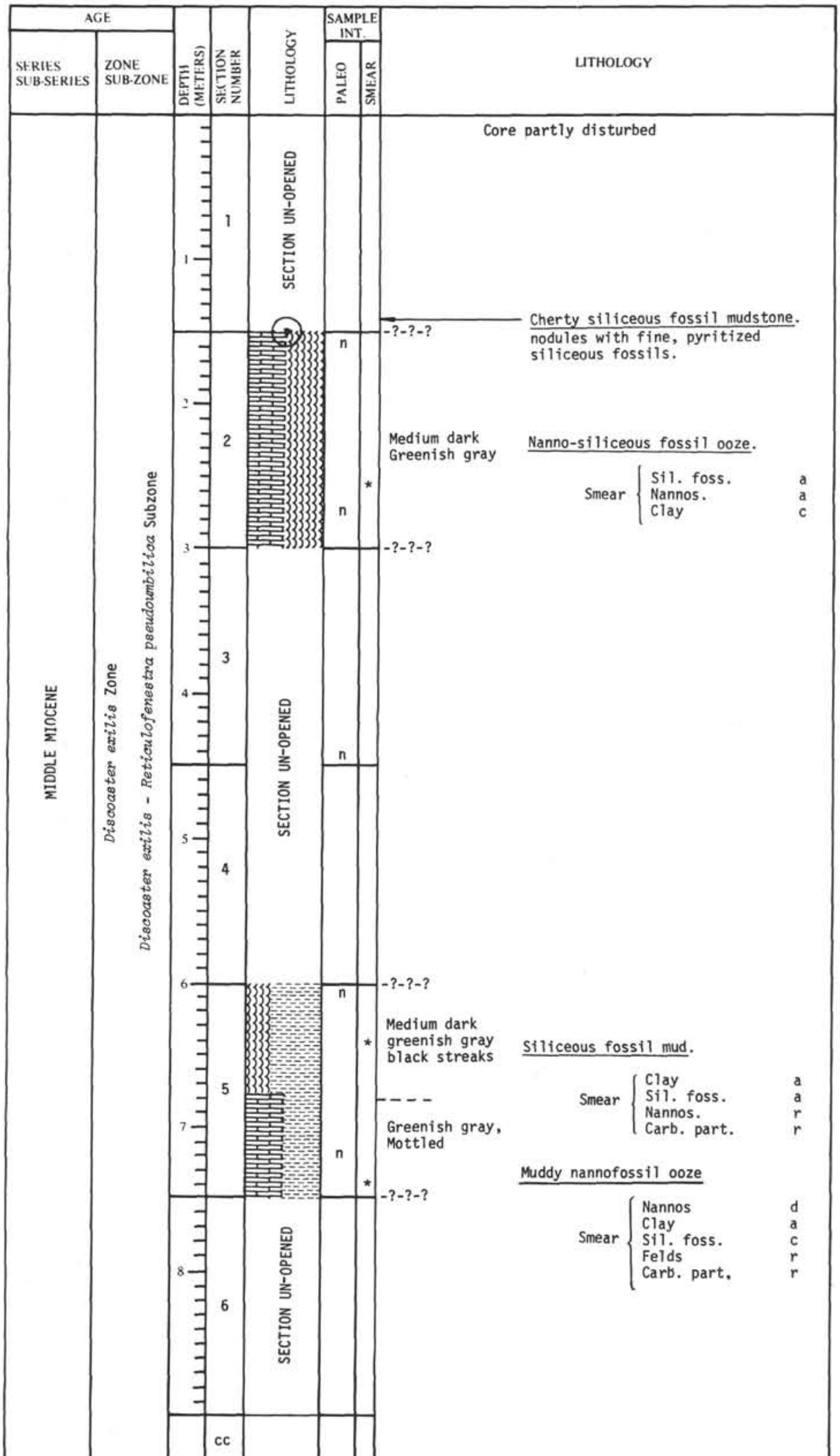


Figure 12B. *Core 10, Hole 33 (256-266 m Below Seabed)*

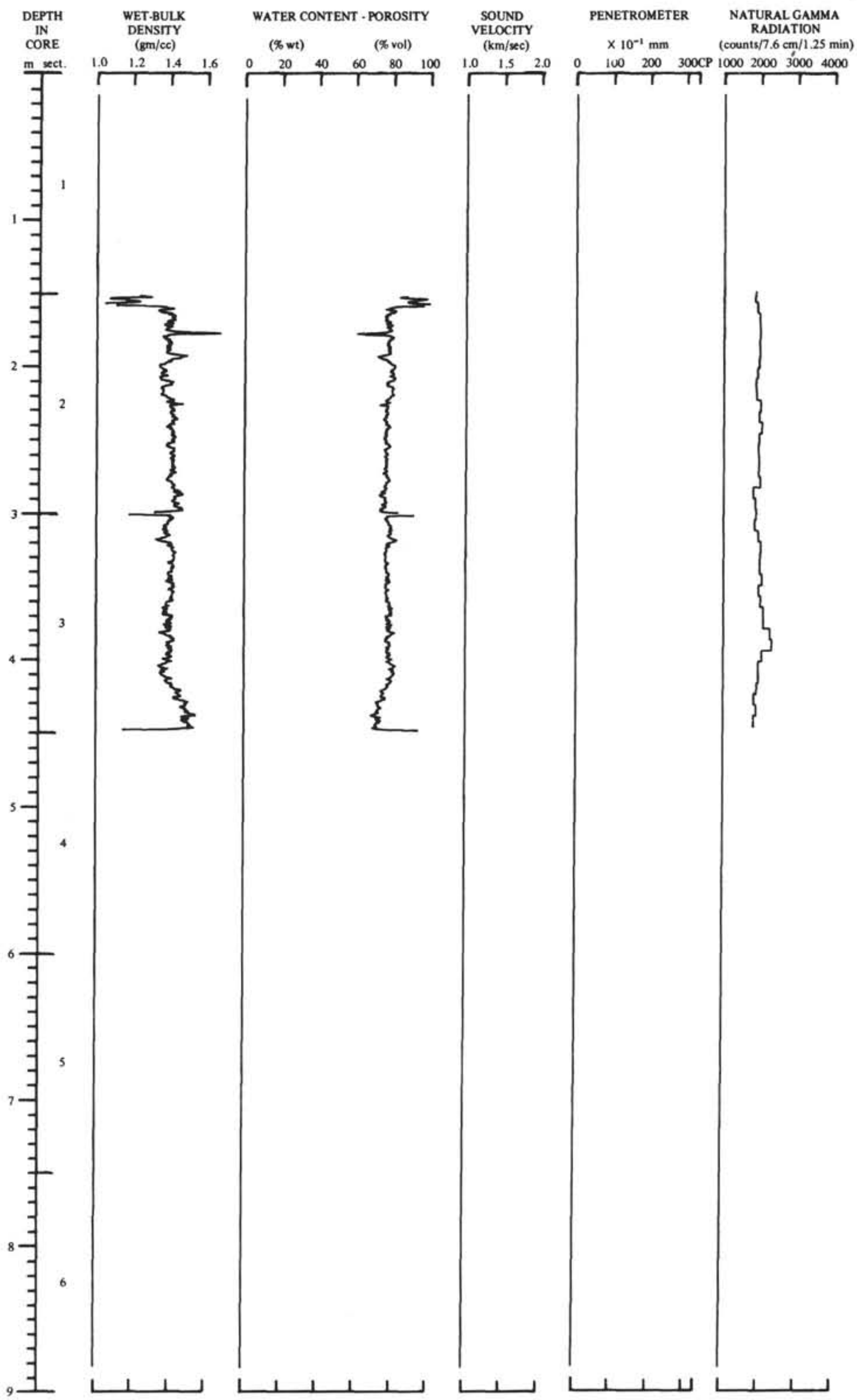


Figure 13A. *Physical Properties of Core 11, Hole 33*

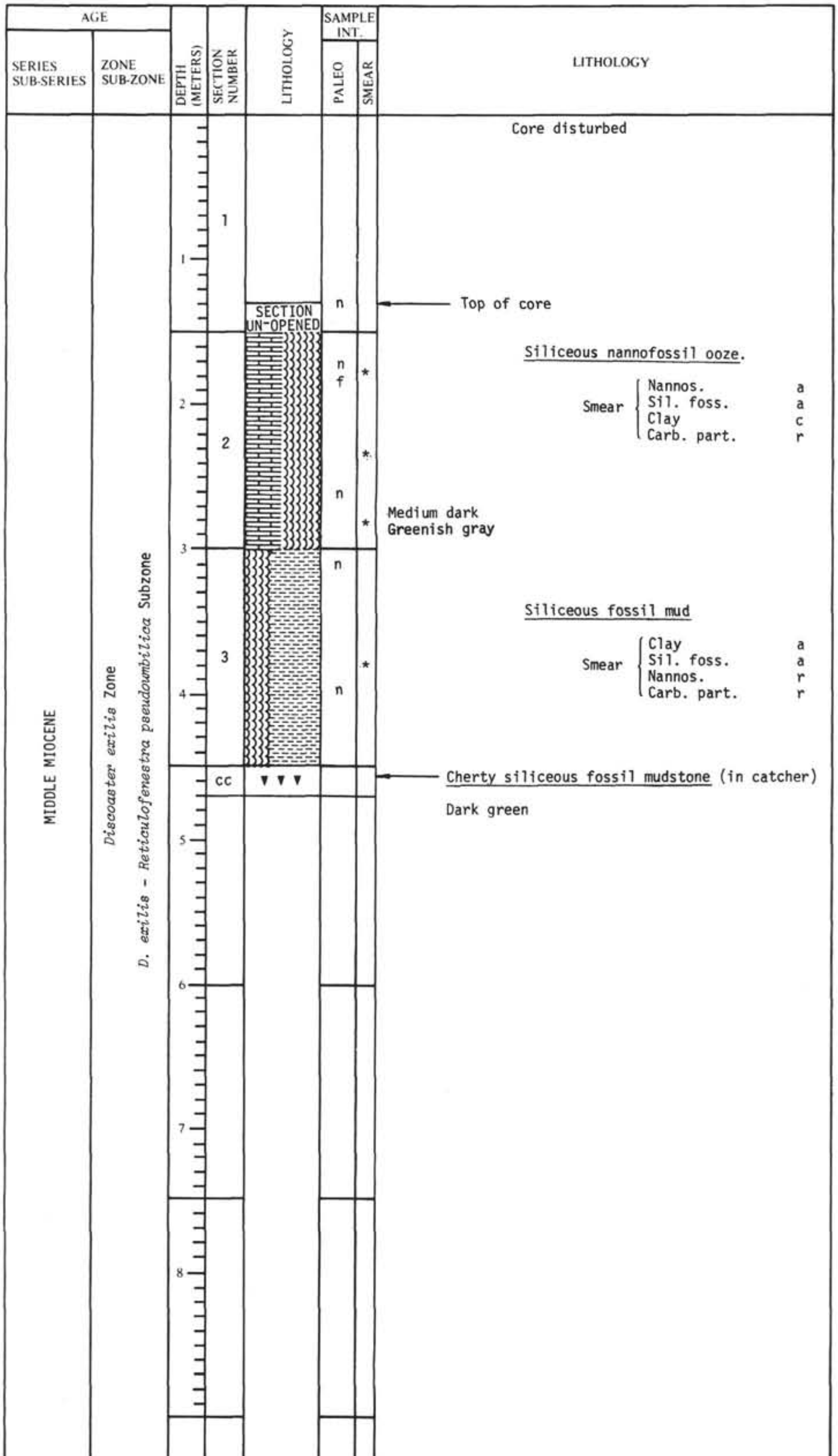


Figure 13B. *Core 11, Hole 33 (265-275 m Below Seabed)*

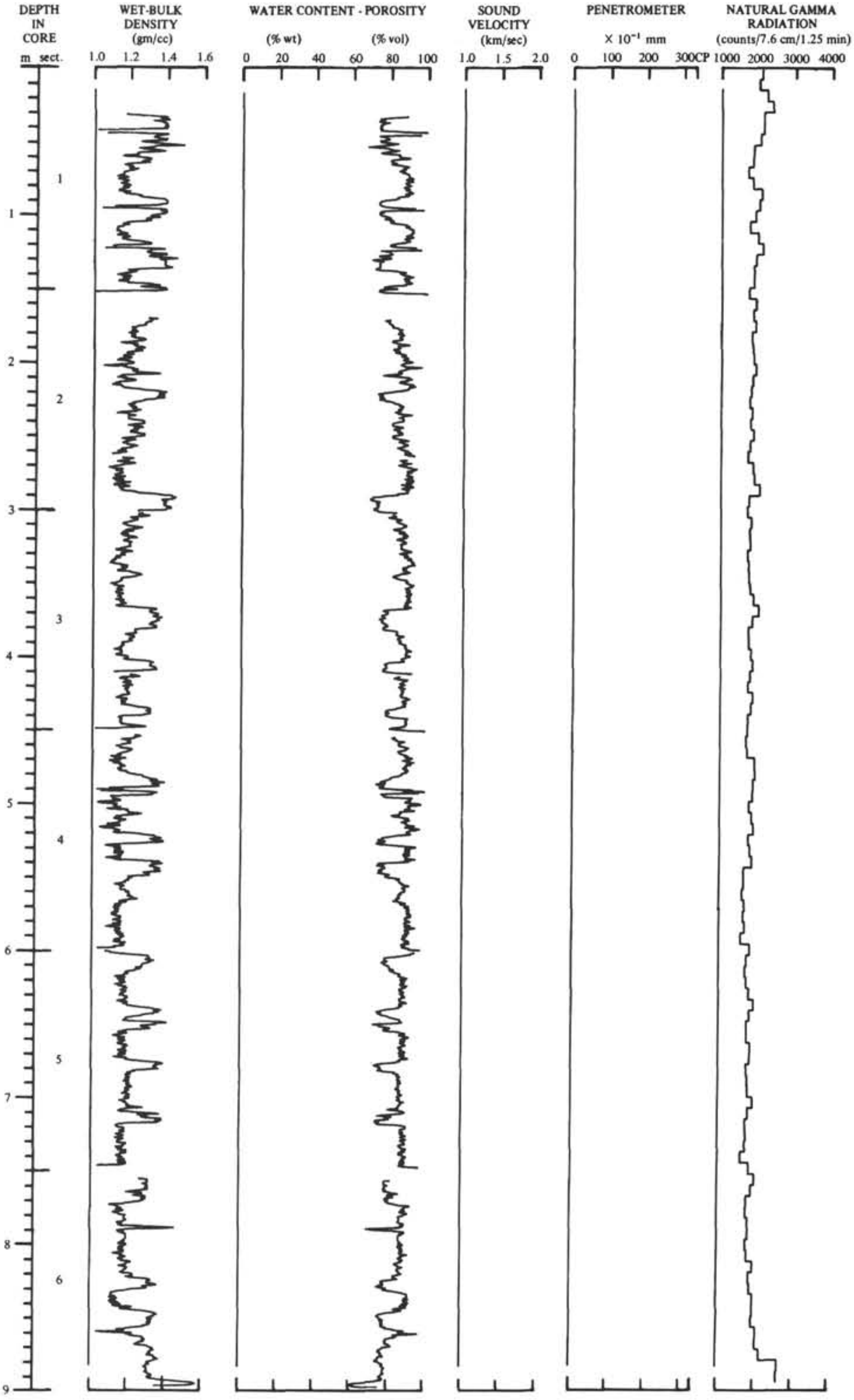


Figure 14A. *Physical Properties of Core 12, Hole 33*

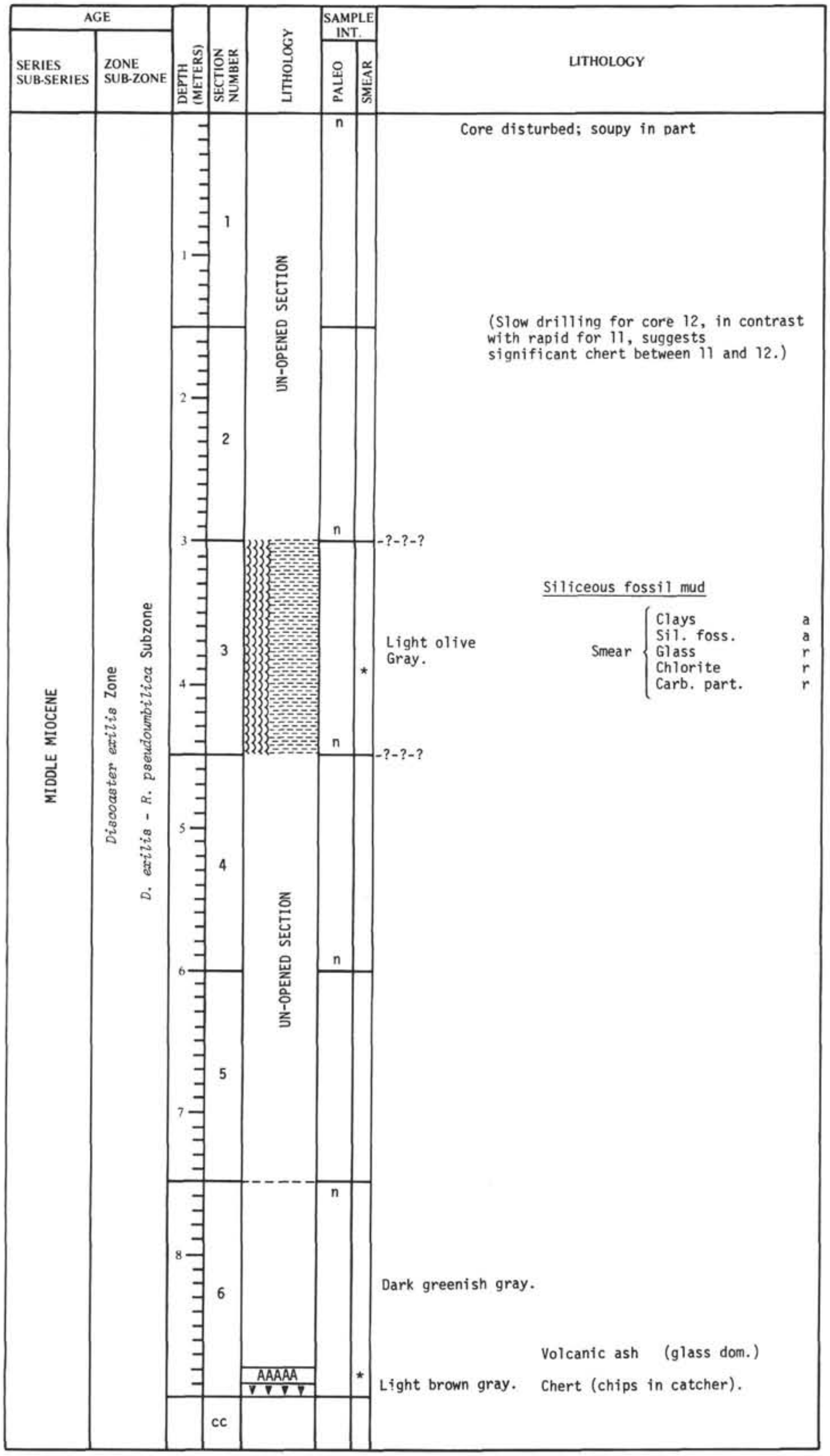


Figure 14B. *Core 12, Hole 33 (275-284 m Below Seabed)*

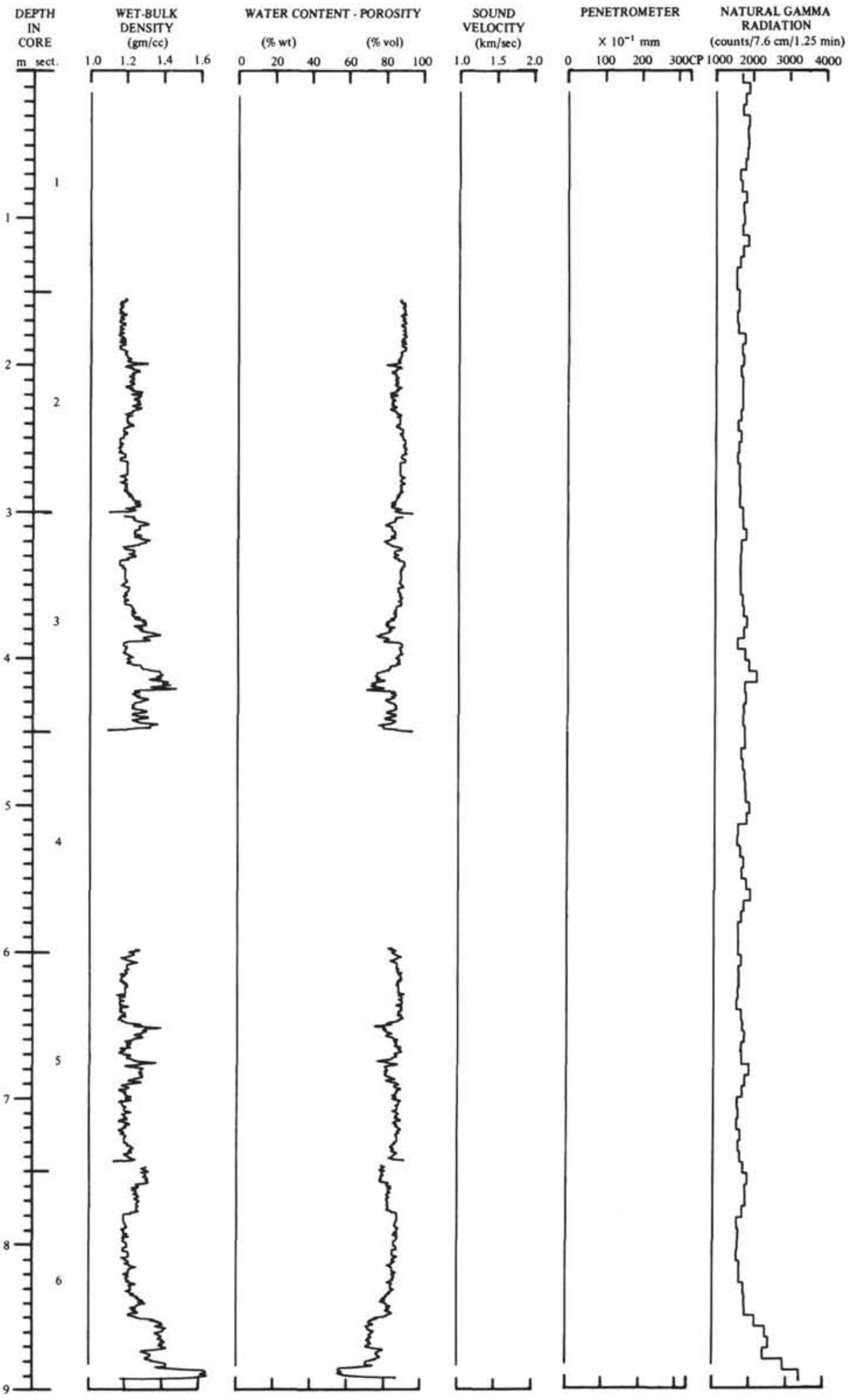


Figure 15A. *Physical Properties of Core 13, Hole 33*

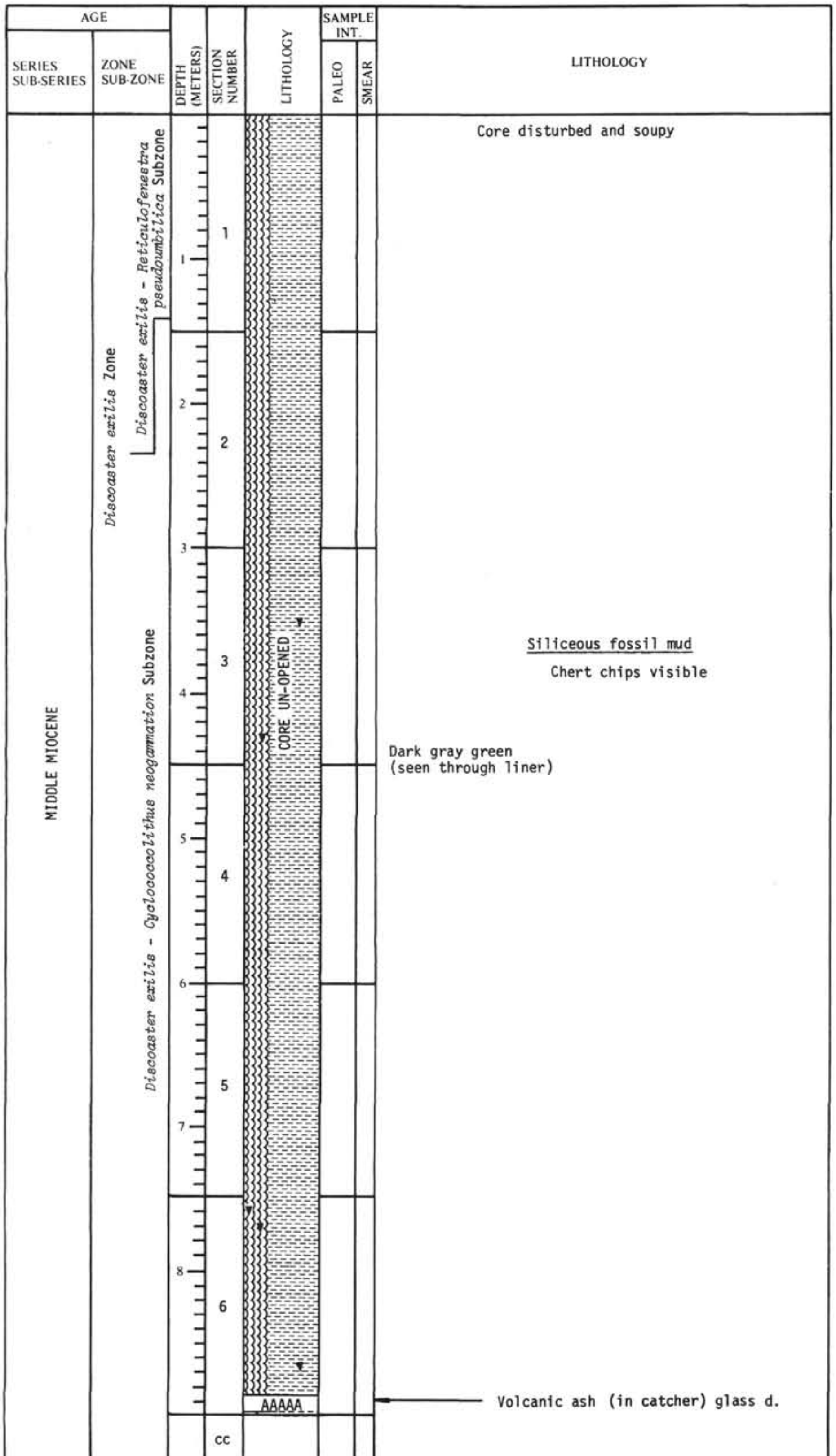


Figure 15B. *Core 13, Hole 33 (284-293 m Below Seabed)*

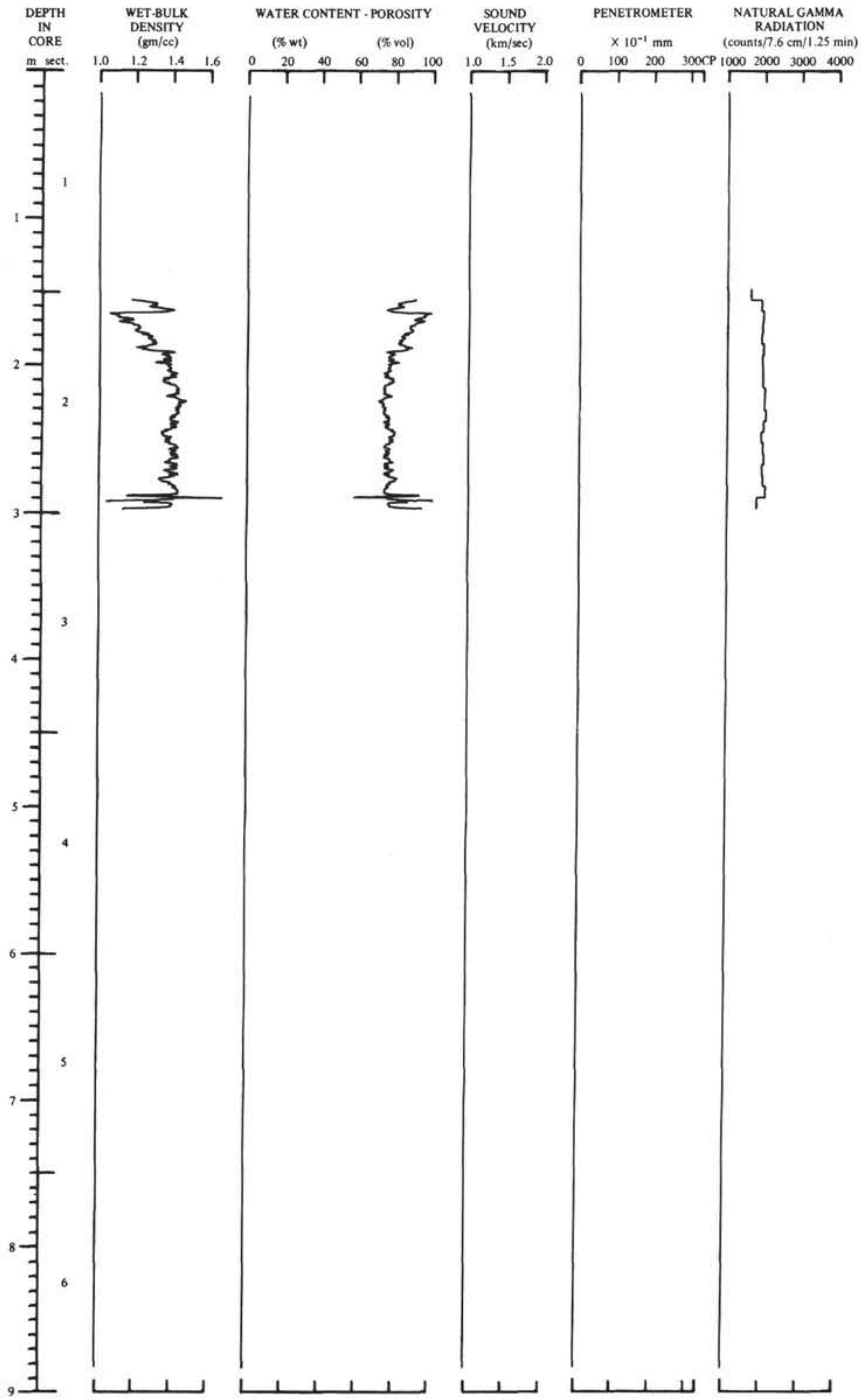


Figure 16A. *Physical Properties of Core 14, Hole 33*

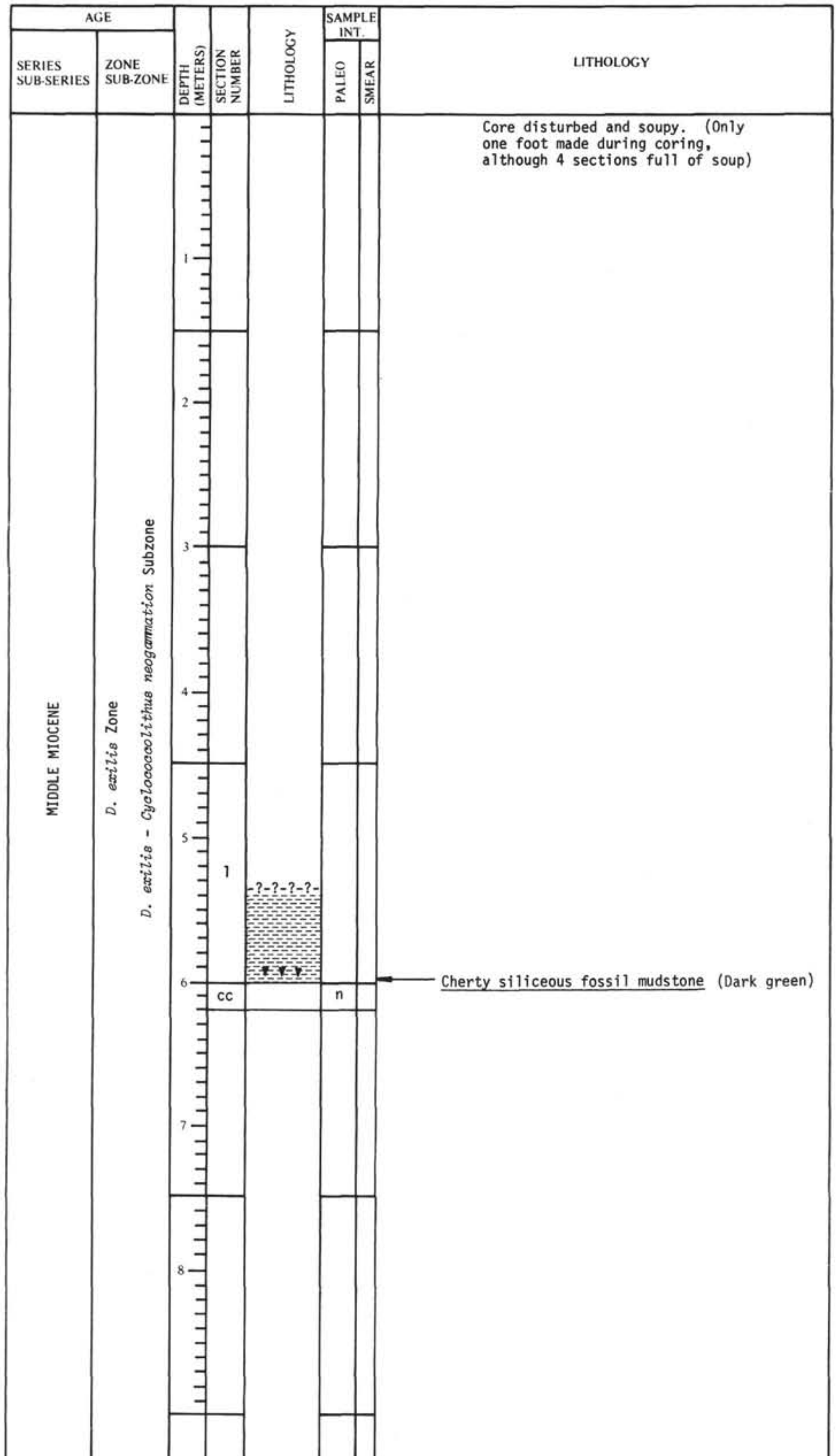


Figure 16B. *Core 14, Hole 33 (292-293 m Below Seabed)*

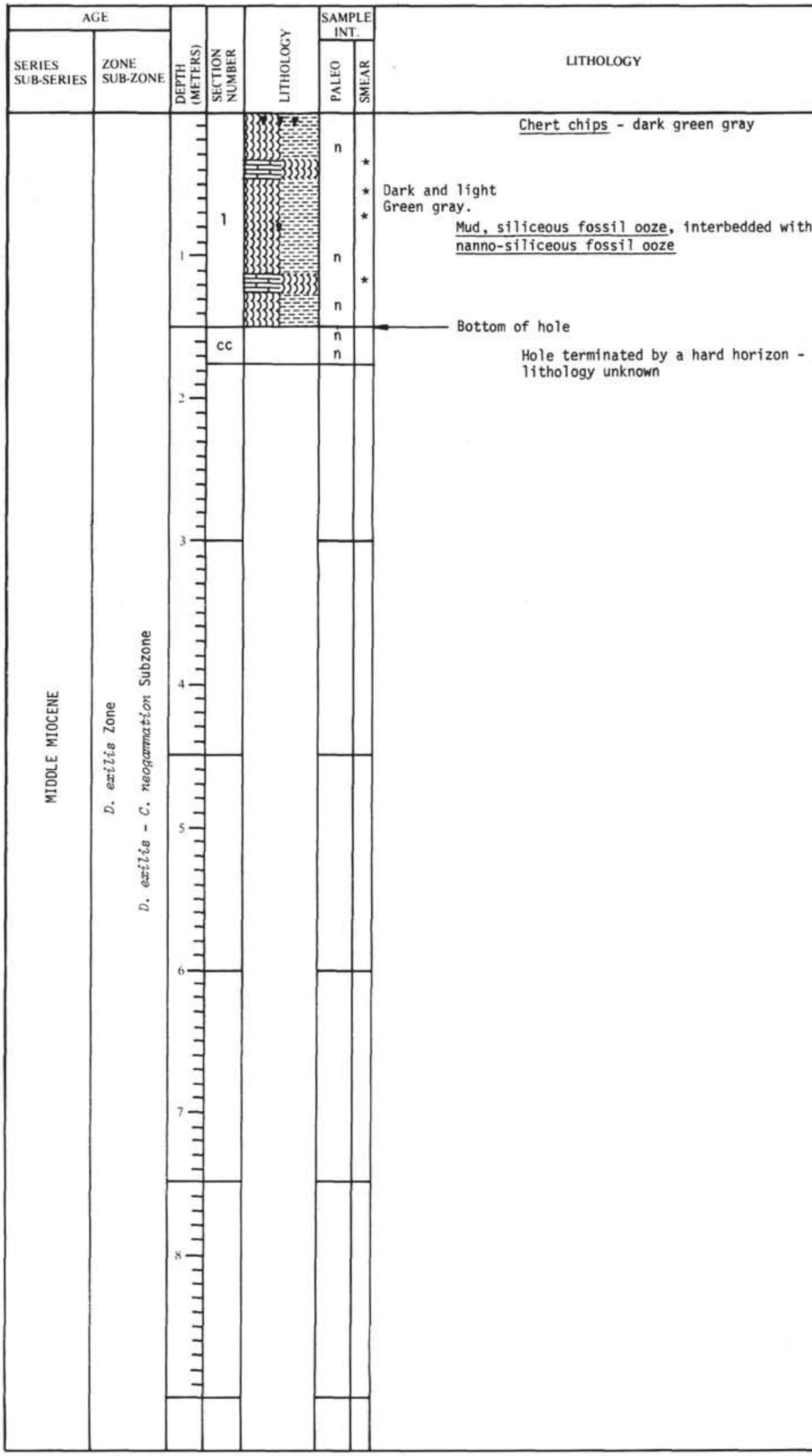


Figure 17. *Core 15, Hole 33 (293-295 m Below Seabed)*

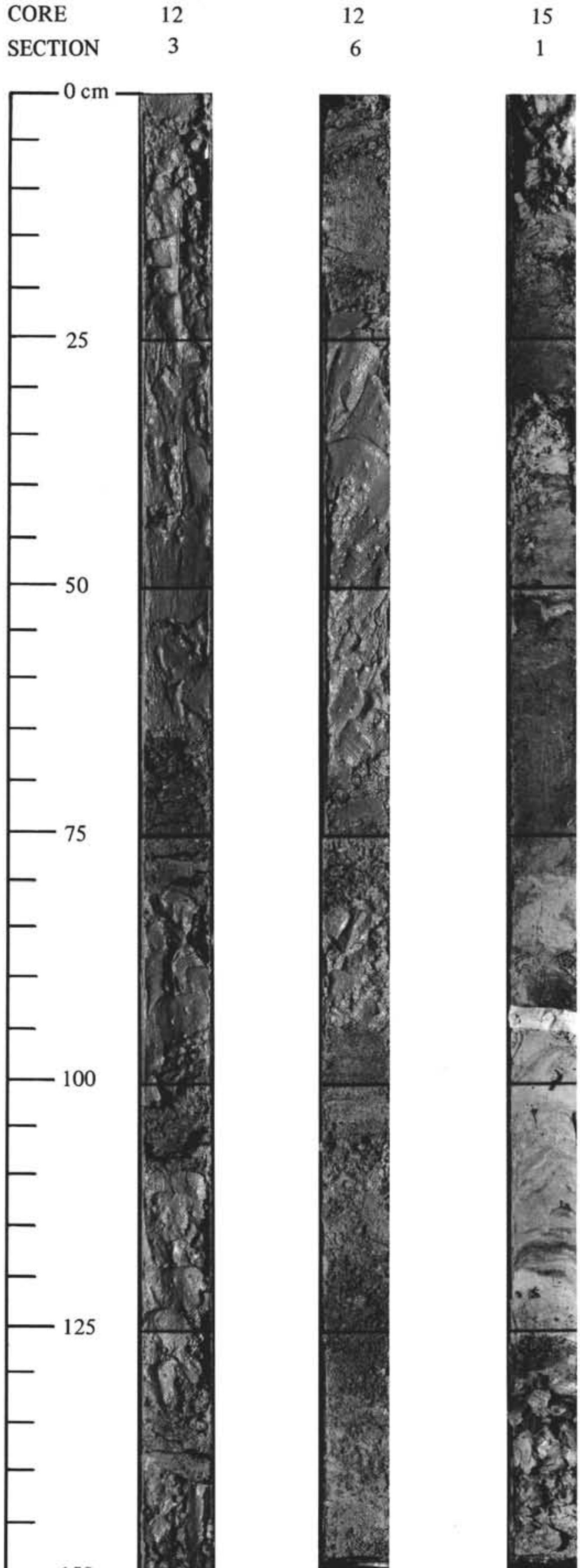


Plate 8. *Sections of Cores 12 and 15, Hole 33*