5. SITE 15

The Shipboard Scientific Party[1]

SURVEY DATA AND SITE BACKGROUND

The location of this site, on Magnetic Anomaly 6 west of the Mid-Atlantic Ridge crest, was assisted by a preliminary detailed survey of the region by *R/V Vema*. This positive magnetic anomaly has an age of about 21 million years in the hypothesized geomagnetic time scale. Coring of the upper Tertiary sediments and basement rock sampling were the major objectives at this site.

The general topography and magnetic contours both have a pronounced N-S lineation approximately parallel to the Ridge crest. The detailed topography has a roughness of 40 to 200 meters (131 to 656 feet) amplitude, consisting for the most part of small hills 1 to 2 kilometers in width (Figure 1). According to the *Vema* survey, the variability in bottom depth and sediment thickness is noticeably greater in the E-W direction than in the N-S, implying N-S lineation of these smaller scale features also.

The topographic roughness near the site is generally conformable to the prominent "basement" reflector. The reflection time from bottom to "basement" reflector varies from about zero on the flanks of the steep slopes to about 0.15 seconds within the area. For the most part, it is within the range 0.10 to 0.15 seconds. The drilling site (lat. 30° 53.38'S, long. 17° 58.99'W) is located on a small (30 to 40 meter) hill where the reflection time from bottom to basement is about 0.15 second. Water depth was recorded as 3938 meters (12,917 feet) corrected (2093 fathoms, uncorrected). The site is on the western side of the positive magnetic anomaly, which has a width of 20 to 30 kilometers.

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OPERATIONS

Positioning

The marker beacon for Site 15 was dropped over the side at 0400 hours on 24 December, 1968. After it reached the bottom around 0445 hours, the ship was placed in automatic positioning. However, around 0800 on 25 December the wind picked up to about 30 knots, and it was necessary to shift to the semi-automatic mode. By 1800 hours the wind had abated sufficiently so that it was possible to shift back into automatic. No particular difficulties were experienced, although on occasion the ship strayed as much as 60 meters (196 feet) off location.

Drilling

The only significant drilling break at Site 15 occurred at a depth of 141 meters (463 feet), where basalt basement was encountered. The drilling rate changed from about 18 m/hr to 0.5 m/hr at this horizon. It is to be noted that while drilling in the basalt the ship wandered off position by about 60 meters (196 feet), at which time 4 meters (13 feet) of pipe were lowered into the hole. This gave a false impression that a substantial penetration had been made into the basalt. But as the ship returned to a more accurate position over the hole, it was necessary to pull in the extra pipe. There were no substantive drilling problems at Site 15.

Coring

A list of the cores collected, the time of arrival on deck, the interval cored and length is shown in Table 1. It should be noted that virtually 100 per cent of the sediment cored was recovered. Recovery of basalt was not as successful. A 50-minute coring period yielded about 0.3 meter (1 foot) of basalt and a second 3.5-hour coring period, which penetrated 1.5 meters (4.9 feet), gave only a 0.15 meter core. None of the basalt recovered was in pieces larger than 5 centimeters in length.

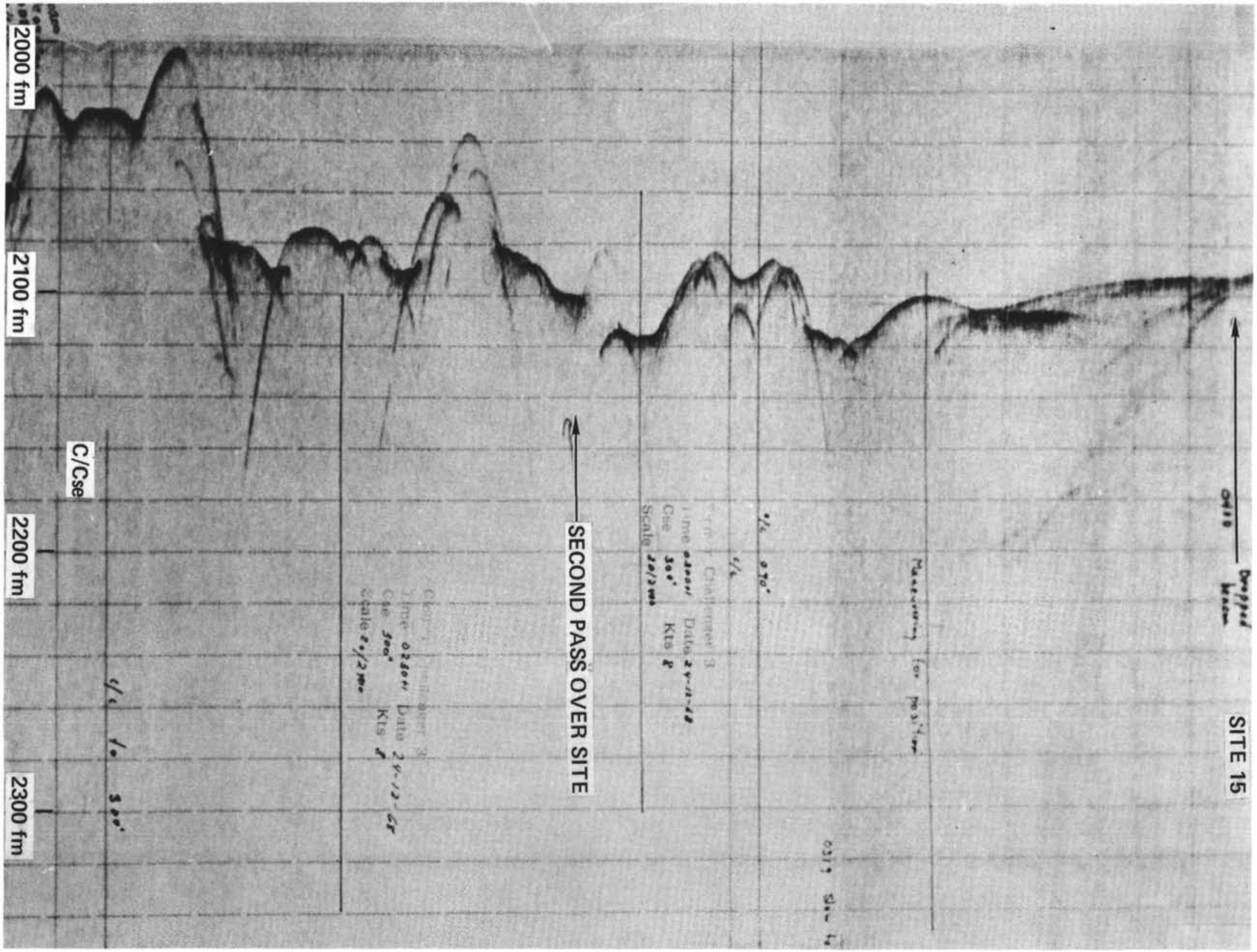


Figure 1. *Precision depth recording in the vicinity of Site 15.*

TABLE 1
Summary of Coring

Core No.	Date/Time	Interval Cored (m below sea floor)	Core Retrieved (m)	Remarks
15-1	12-24-68 1345	0-9	9.00	--
15-2	1630	18-27	9.00	--
153-	1915	37-46	9.00	--
15-4	2145	47-56	9.00	--
15-5	12-25-68 0015	77-86	9.00	--
15-6	0345	105-114	9.00	--
15-7	0615	114-123	9.00	--
15-8	0745	123-132	8.00	--
15-9	0935	132-141	9.00	Recovered one small chip of basalt from bottom of core.
15-10	1200	141-141.3	0.3	--
15-11	1700	141.3-143	0.15	--
	Totals	82.7	80.2	98 per cent

PALEONTOLOGY

Pleistocene, Upper Pliocene, Lower Pliocene, Upper Miocene and Lower Miocene sediments were recovered in nine out of the eleven barrels cored. Cores 10 and 11 recovered small amounts of basalt. Coring was discontinuous in the upper 105 meters (346 feet)—Cores 1 through 5—of the hole and continuous below that depth into the basalt (Cores 6 through 11). The only major boundary cored was the Pliocene/Pleistocene boundary in Core 2. The Aquitanian/Burdigalian boundary of the Lower Miocene occurs between Cores 7 and 8 and is repeated in Core 9. The Lower Miocene boundary is recognized in Core 6, but is poorly developed. In addition, the Miocene/Pliocene boundary was probably cored on the basis of calcareous nannoplankton evidence.

One of the purposes in drilling the hole on this site was to test the hypothesis of sea floor spreading and the interpretation of the linear magnetic anomalies. The hole was drilled on the positive anomaly associated with Magnetic Anomaly 6 which has a suggested age of 21 million years based on the Heirtzler *et al.* (1968) time scale. The oldest sediments above the basalt include fauna and flora characteristic of the *Globigerinita dissimilis* Zone of Bolli (1957c) and the upper part of the *Triquetrorhabdulus carinatus* Zone of Bramlette and Wilcoxon (1967) and are of early Miocene (Aquitanian) age. Examination of some white chalk and a soft sediment associated with basalt in Core 10 for calcareous nannoplankton disclosed a flora probably no older than the upper part of the *Triquetrorhabdulus carinatus* Zone of Bramlette and Wilcoxon (1967). This indicates that the sediments above the basalt have an equivalent radiometric age of 24 million years (see Chapter 2, Figure 3). This is in fairly close agreement with the suggested age of 21 million years based on the magnetic anomaly data.

Another purpose of drilling this hole was to study Cenozoic floral and faunal changes which took place at 30° South Latitude. The planktonic foraminiferal faunas in the Pleistocene, Upper Pliocene, Lower Pliocene and Upper Miocene sediments (Cores 1 through 5) are quite distinct from those known from the tropical regions. Throughout this stratigraphic interval, the warm-water species group of *Globorotalia menardii* and its related forms are almost entirely absent and are replaced by temperate or high latitude forms such as *Globorotalia conoidea* Walters and *G. conomiozea* Kennett, both of which were originally described from New Zealand. Furthermore, the lowermost Pliocene and Upper Miocene planktonic foraminiferal faunas are very impoverished, consisting of only several species. A close similarity of the present faunas with faunas from New Zealand and other higher latitudes suggests that in this area temperate rather than tropical waters prevailed during that time. The middle Miocene and lower Miocene sediments (Cores 6 through 9), on the other hand, contain many species characteristic of tropical regions.

Throughout most of the stratigraphic sequence, the calcareous nannoplankton appears to be more eurytopic. Most of the species found are those reported by Bramlette and Wilcoxon (1967) from the Caribbean region and Indonesia and by Hay *et al.* (1967) from the Caribbean and Gulf Coast regions. The Pleistocene flora is a possible exception, but it has not been studied in detail.

The sediments cored at this site consist predominantly of plates of calcareous nannoplankton with varying amounts of planktonic foraminifera and varying amounts of clay and opaque minerals. The amounts of accessories vary from lithologic unit to lithologic unit and are discussed in the section on Stratigraphy.

Pleistocene sediments are found in Core 1, 0 to 9 meters (0 to 29 feet), and the uppermost part of Core 2, 18 to 27 meters (60 to 88 feet), based on the planktonic foraminifera. Rare reworked specimens of *Discoaster* spp. occur in all the samples studied. The Pliocene/Pleistocene boundary is placed in Section 1 of Core 2 between 0 to 2 centimeters and 110 to 112 centimeters depth based on the planktonic foraminifera. The foraminiferal criteria for the boundary are: 1) the first geologic appearance of *Globorotalia truncatulinoides* in the 0 to 2 centimeter sample; 2) left to right coiling preference change of species of the genus *Pulleniatina* across the boundary; and, 3) the extinction of *Globigerina praedigitata* Parker at this horizon. The first criterion is analogous to that discussed by Philips *et al.* (1968). The second has been described by Hay *et al.* (1969) in the Olduvai section of several deep-sea sediment cores; and, the third has been recognized by Parker (1967) as one of the foraminiferal changes which took place near the Pliocene/Pleistocene boundary. The nannoplankton floras from both samples are similar to those described from Core 1 except that *Discoaster brouweri* is more abundant. Thus, no marked floral change takes place at the boundary. Below the boundary in the sample from 105 to 107 centimeters depth of Section 6, a major floral change occurs. This change is marked by the first appearance of *Discoaster surculus, D. challengeri,* and *D. pentaradiatus* with *D. brouweri.* These forms are associated with *Ceratolithus rugosus* Bukry and Bramlette, *Cyclococcolithus leptoporus* (Murray and Blackman) and *Coccolithus pelagicus.*

The sediments in Core 3, from 37 to 46 meters (121 to 157 feet), and most of Core 4, from 47 to 56 meters (154 to 183 feet), are Early Pliocene (Zanclian) in age based on the calcareous nannoplankton. The flora in Core 3 consists of *Discoaster brouweri, D. surculus, D. pentaradiatus, D. challengeri, Reticulofenestra pseudoumbilica, Ceratolithus rugosus, C. tricorniculatus* Gartner and *Cyclococcolithus leptoporus.* The Miocene/Pliocene boundary is placed in Section 5 of Core 4 between samples from 12 to 14 centimeters of Section 5 and from 12 to 14 centimeters in Section 6. The flora above the boundary is similar to that reported for Core 3 and below the boundary *Ceratolithus rugosus* is absent. According to Bukry and Bramlette (1968) this species is more commonly found in the Lower Pliocene, however, they do report it from the Upper Miocene of Lamont Core V3-153. The planktonic foraminifera do not show any marked change throughout Core 4. The fauna consists of *Globigerina nepenthes* Todd, *G. bulloides* d'Orbigny, *Globorotalia conoidea, G. crassaformis* (Galloway and Wissler), *G. acostaensis* Blow and *Sphaeroidinellopsis seminulina.*

An Late Miocene (Tortonian) age is assigned to Core 5, from 77 to 86 meters (253 to 282 feet), based on the calcareous nannoplankton. The flora consists of *Discoaster brouweri, D. challengeri, D. pentaradiatus, Cyclococcolithus leptoporus, Coccolithus pelagicus* and *Reticulofenestra pseudoumbilica.* This age assignment is based on the report by Bukry and Bramlette (1968) where the first geologic occurrence of *Ceratolithus tricorniculatus* is in the Messinian portion of the type Tortonian section. The fact that this species which abounds in the younger sediments of this hole is absent in Core 5 strongly suggests that this interval is Tortonian in age. The planktonic foraminifera occurring in Core 5 are: *Globigerina nepenthes, Globigerinoides ruber cyclostomus* (Galloway and Wissler), *G. bollii* Blow, *Globorotalia conoidea* and *Sphaeroidinellopsis seminulina.*

Core 6, from 105 to 114 meters (344 to 374 feet), contains the Lower Miocene (Burdigalian)/Middle Miocene (Langhian) boundary based on the planktonic foraminifera. The boundary occurs immediately above the core catcher and is the boundary between *Globigerinatella insueta/Globigerinoides sicanus* and the *Globorotalia fohsi barisanensis* Zones of Blow (1959). The fauna below the boundary is characterized by *Globigerinoides sicanus* and *Praeorbulina glomerosa* (Blow). The fauna in Sections 1 and 2, above the boundary, apparently represents younger Neogene contaminants from uphole because most of the *in situ* fauna consists of broken tests which also show effects of solution. The faunas in Sections 3 through 6 are characterized by *Globoquadrina dehiscens* (Chapman, Parr and Collins), *G. dehiscens advena* Bermudez, *G. conglomerata* (Schwager), *Sphaeroidinellopsis seminulina, Globigerina druryi* Akers, *G. woodi, Globorotalia conoidea* and *G. miozea.* The first geologic appearance of *Orbulina universa* d'Orbigny is in Section 4 at 108 to 110 centimeters depth, but a poor state of preservation of the faunas below precludes the possibility of finding the complete *Orbulina* evolutionary series in this hole. The flora above the boundary consists of

Sphenolithus heteromorphus Deflandre, *Discoaster challengeri, D. exilis* Martini and Bramlette (Rare), *D. deflandrei, Cyclococcolithus neogammation,* and *C. leptoporus* (Rare) which indicates the *Sphenolithus heteromorphus* Zone of Bramlette and Wilcoxon (1967). The absence of *Discoaster exilis* in the core catcher sample suggests its equivalence to the *Helicopontosphaera ampliaperta* Zone of Bramlette and Wilcoxon (1967).

The sediments in Core 7, from 114 to 123 meters (374 to 403 feet), are assigned to the *Globigerinatella insueta/Globigerinoides trilobus* and *Globigerinita stainforthi* Zones of Blow (1959), and are Burdigalian in age. The boundary between these two zones is placed near the sample of 102 to 104 centimeters of Section 6 where the first appearance of *Globigerinita stainforthi* is noticed. The calcareous nannoplankton flora from this core represents the *Helicopontosphaera ampliaperta* Zone of Bramlette and Wilcoxon (1967). The Aquitanian/Burdigalian boundary of the Lower Miocene appears to occur between Cores 7 and 8 but was not cored.

In Core 8, from 123 to 132 meters (404 to 433 feet), the sediments are Aquitanian (lower Miocene) in age based on the planktonic foraminifera and calcareous nannoplankton. They represent the *Globigerinita dissimilis-Globigerinita stainforthi* planktonic foraminiferal Zones (undifferentiated) of Bolli (1957c) and the upper part of the *Triquetrorhabdulus carinatus* calcareous nannoplankton Zone of Bramlette and Wilcoxon (1967). The fauna includes: *Globigerinita dissimilis, G. stainforthi, Globoquadrina dehiscens, Globorotalia denseconnexa* Subbotina, *G. praescitula* Blow, *G. peripheroronda* Blow and Banner, *G. nana pseudocontinuosa* Jenkins, and *Globorotaloides variabilis* Bolli. The flora consists of *Cyclococcolithus neogammation, Sphenolithus belemnos?, Discoaster deflandrei, D. druggi* and *Orthorhabdulus serratus* Bramlette and Wilcoxon.

In Core 9, from 132 to 141 meters (433 to 462 feet), the Aquitanian/Burdigalian sequence as cored in Cores 6 through 8 is repeated. Sections 1 through 4 contain floras and faunas similar to those from the core catcher sample of Core 7; Sections 5 and 6, and the core catcher contain those similar to Core 8. The calcareous nannoplankton data suggest that the *Sphenolithus belemnos* Zone of Bramlette and Wilcoxon (1967) appears to be missing in the cored section, which could result from removal of this zonal interval by strong currents, or a slumping of these sediments after deposition or solution.

Repetition of the Aquitanian/Burdigalian section in Core 9 may be the result of drilling or of slumping of soft unconsolidated Lower Miocene sediments shortly after their deposition. It is possible, although the bumper subs are designed to compensate for all movements of the ship, that the drill string could move both vertically and horizontally in such soft sediments. Such movement would not have to be much and could result in a repeated section. Another alternative is that such soft sediments may actually flow into the core barrel once overburden pressures are released.

In Core 10, from 141 to 141.3 meters (462 to 463 feet), two sediment samples–white chalk and soft sediment, associated with the basalt–were examined for their calcareous nannoplankton floras. The soft sediment might be contaminant from uphole. Both samples contained a flora characterized by *Discoaster deflandrei, Cyclococcolithus neogammation* and *Coccolithus pelagicus.* This flora is probably no older than the upper part of the *Triquetrorhabdulus carinatus* Zone of Bramlette and Wilcoxon (1967).

STRATIGRAPHY

The section at Site 15 has been divided into six subsurface lithologic units, representing six formations on the Mid-Atlantic Ridge. They are in descending order:

3-15-1-1	Albatross Ooze	Foraminiferal nannofossil chalk oozes.
3-15-3-3	Blake Ooze	Nannofossil chalk oozes.
3-15-4-5	Challenger Ooze	Marly nannofossil chalk oozes.
3-15-6-1	Discovery Clay	Dark brown marl oozes and red clays.
3-15-6-4	Endeavor Ooze	Marly nannofossil chalk oozes.
3-15-8-1	Grampus Ooze	Foraminiferal nannofossil chalk oozes.

Two of the six could be correlated with those at Site 14 as the Endeavor and the Grampus Oozes. The others are younger and are not present there.

The Plio-Pleistocene Albatross Formation is represented by the chalk oozes of the Unit 3-15-1-1. These oozes include some 5 to 20 per cent identifiable foraminiferan tests. These microfossils constitute the sand fraction of the sediments, which ranges from 22.7 per cent in a top core (3-15-1-4) to 4.0 per cent (3-15-3-1-2) near the transitional lower boundary. In comparison, the underlying Mio-Pliocene 3-15-3-3 Unit consists of nannofossil chalk oozes which include less than 5 per cent of identifiable foraminifera. In addition, a significant difference was noted between the very pale brown color of the upper unit and the chalky white color which typifies the Blake Ooze of the South Mid-Atlantic Ridge.

TABLE 2
Stratigraphy Site 15

Age	Cored Interval (m)	Formation Name	Probable Interval (m)	Probable Thickness (m)	Description
Upper Pleistocene to Lower Pliocene	0-9 18-27 37-40	Albatross Ooze 3-15-1-1	0-40	40	Very pale brown to white foraminiferal nannofossil chalk oozes, with 5 to 30 per cent foraminifera. A few light yellow brown intervals present with 5 to 10 per cent clay minerals.
Lower Pliocene	40-54	Blake Ooze 3-15-3-3	40-54	14	White nannofossil chalk oozes. Less than 5 per cent foraminifera.
Upper Miocene	54-56 77-86	Challenger Ooze 3-15-4-5	54-96	42	Yellow brown to dark yellow brown mottled marl and marly chalk oozes. 10 to 30 per cent clay minerals; 0 to 10 per cent hematite; 0 to 20 per cent zeolites.
Middle Miocene	105-110	Discovery Clay 3-15-6-1	96-110	14	Dark red brown marl ooze and red clays, with 1 to 10 per cent phosphates.
Middle to Lower Miocene	110-123	Endeavor Ooze 3-15-6-4	110-123	13	Light yellow brown, yellow brown, and brownish-yellow nannofossil marly chalk oozes. 1 to 10 per cent opaques and hematite. Zeolites and phosphates present. Foraminifera $<$ 2 per cent.
Lower Miocene	123-132	Grampus Ooze 3-15-8-1	123-132	9	Dark brown to dark reddish-gray nannofossil marly chalk oozes. 10 to 25 per cent opaques and hematite. Foraminifera – 10 per cent.
?	140.6-142	Basement 3-15-10-1	140.6-?	?	Dark gray aphanitic basalt with a few plagioclase phenocrysts and vesicles. A few fragments of white marble recovered. Steeply oriented calcite veins are present in the basalt.

The Upper Miocene Unit 3-15-4-5 consists of brown marly chalk oozes and includes considerable non-carbonate impurities (20 to 25 per cent). Although the bulk of the sediments is still made of nannofossils, with a few per cent foraminifera, other components are: 0 to 20 per cent zeolites, 10 to 30 per cent clay minerals, and up to 10 per cent hematite. The presence of considerable non-carbonate minerals, in fact, is a characteristic feature of the Challenger Ooze, distinguishing this formation from the lighter and purer Blake Ooze above. The authors placed the contact between the two formations at 3-15-4-5, 100 centimeters where they observed a change from white to pale brown chalk ooze, accompanying a faunal break. Also, the bottom of Core 4 consists of a brown marly chalk ooze typical of the Challenger Ooze. The lower boundary of the Challenger Ooze is not represented by cores. In such an instance the authors resorted to an arbitrary practice of placing the boundary at the midpoint of the uncored interval, or about 96 meters (315 feet) BOB.

The Unit 3-15-6-1 includes dark brown nannofossil marl oozes and dark reddish-brown nannofossil clays, and represents the Discovery Clay at Site 15. Aside from nannofossils and traces of foraminifera, clay minerals, hematite, opaque iron minerals, phosphates, and, as in some beds, zeolites, are present. The terrigenous and diagenetic minerals constitute the bulk of the lower part of the unit, where the calcium carbonate content drops below 35 per cent. The red clays at this site typically contain 1 to 10 per cent phosphates, which may account for the unusually high natural gamma counts of some cores. Some nannofossils have been phosphatized.

Underlying the red clays are brown marly chalk oozes. The color varies from a very pale brown, to light yellowish-brown, to brownish-yellow, to yellowish-brown, to dark yellowish-brown, to dark brown, to dark reddish-brown, and to dark reddish-gray. The shades of colors are related to the content of hematite and opaque iron minerals, which ranges up to 25 per cent in the darkest interbeds. Two units were recognized. The upper 3-15-6-4 Unit is somewhat lighter; zeolites and phosphates are present in small amounts in these nannofossil chalk oozes. In contrast, the lower 3-15-8-1 Unit is darker, and contains some 10 per cent foraminifera. These units were correlated with those at Sites 14, 17 and 18, as the Endeavor and Grampus Oozes. The facies represented by the Fram Ooze cannot be recognized as a separated unit at this site. The sediments of 3-15-9 represent a repeatedly cored section (see section on Paleontology).

Underlying the Grampus Ooze is the basalt basement. This dark gray aphanitic rock is probably a flow. A few small vesicles are present; also, the overlying sediments do not seem to be altered by any contact metamorphic effects. Found were a few white friable chalk chips, somewhat recrystallized, mixed with basalt chips in Core 3-15-10; they may represent recrystallized calcareous sediments entrapped in a basalt flow. In addition, the basalt core is traversed by steeply oriented calcite veins.

The sedimentation rates for the six formations at this site are estimated as follows:

Albatross Ooze	40m/3.5 m.y.,	or	1.2 cm/t.y.
Blake Ooze	14m/2.5 m.y.,	or	0.6 cm/t.y.
Challenger Ooze	42m/7.5 m.y.,	or	0.6 cm/t.y.
Discovery Clay	14m/4.5 m.y.,	or	0.3 cm/t.y.
Endeavor and Grampus Oozes	22m/7 m.y.,	or	0.3 cm/t.y.

The stratigraphy is summarized in Table 2.

PHYSICAL PROPERTIES

Natural Gamma Radiation

Gamma radiation counts spanned from 50 to 1500 counts, averaging about 300 counts/1.25 minutes/7.6-centimeter core segment. A systematic change with depth was not apparent, although an apparent inverse correlation to the penetrometer measurements was observed (Figures 2A and 3A-12A). (See Site 13 penetrometer summary for discussion.) High gamma counts were apparently associated with clay, zeolite and phosphate minerals. The highest counts occurred where two or more of these components were present in the sediment, such as a count of 1500 where phosphate and clay minerals were combined in Core 6 of the Discovery Clay, and to a much lesser extent in Core 7, Endeavor Ooze, which contained clay minerals with traces of phosphate minerals. Cores 5, 8 and 9 (parts of the Discovery Clay, Endeavor Ooze and Grampus Ooze) were rich in clays and, also, zeolites in some intervals, and emitted intermediate gamma counts.

Porosity, Wet-Bulk Density and Water Content

Site 15 porosities and wet-bulk densities ranged from 44 to 78(?) per cent, and 1.38(?) to 2.00 g/cc with averages about 52 per cent and 1.82 g/cc (Figures 2A and 3A-12A). Water contents ranged from 29 to 44 per cent, with a mean of 33 per cent. Core barrel averaged porosities decreased from about 58 to 49 per cent from the sediment surface to about 40 meters (131 feet) (Albatross Ooze). Below 40 meters, in the Blake Ooze, Challenger Ooze and Discovery Clay, average porosities were roughly 48, 52, and 57 per cent, respectively, with the Discovery Clay having a wide porosity range of 46 to 78(?) per cent. The Endeavor Ooze and Grampus Ooze averaged about 52 per cent. Wet-bulk densities are inversely related to the porosities and roughly correlate directly to sound velocity.

Sediment Sound Velocity

Site 15 sound velocities spanned 1.48 to 1.57 km/sec with a norm of 1.53 km/sec (Figures 2A and 3A-12A). Sound velocities increased 0.02 to 0.04 km/sec within each core from its top to bottom. The sound velocities in the top of some cores were also lower than the velocities in the bottom of the previous core. This occurred in Cores 1 through 6. The error in the measurement of the sediment velocity in an elliptically-shaped core may be attributed to this phenomenon, or it could indicate a higher degree of disturbance toward the top of each core. In general, there is little overall variance of sound velocity with increasing depth at Site 15, except for slightly lower velocities at the boundary of the Albatross Ooze and Blake Ooze and the upper part of the Endeavor Ooze.

Penetrometer

Penetrometer measurements of sediments from Site 15 spanned from complete penetration to 20×10^{-1} mm (Figures 2A and 3A-12A). Sediments of Cores 1 through 4 were completely penetrated. Sediments from Cores 5 through 9 averaged 59 mm $\times 10^{-1}$. Generally these measurements decreased with depth and were inversely correlated to the natural gamma radiation which was also observed at Site 13, and discussed in the Site 13 summary.

Thermal Conductivity

Thermal conductivity at Site 15 varied from about 2.7 to 3.0×10^{-3} cal/°C cm sec. (Figure 2A). A general increase in values occurred between the surface and 81 m. depth, where the highest value was measured. Measurements on cores between 110 m. and the bottom of the hole gave relatively constant value at about 2.9×10^{-3} cal/°C cm sec.

Interstitial Water Salinity

Two interstitial salinity samples were processed at Site 15 which had identical salinities of 35.2 ppt. These two samples were selected at 44 meters (144 feet) and 139 meters (456 feet) within the hole, which were from the upper Miocene Blake Ooze and a repeatedly cored Blake Ooze section, respectively.

REFERENCES

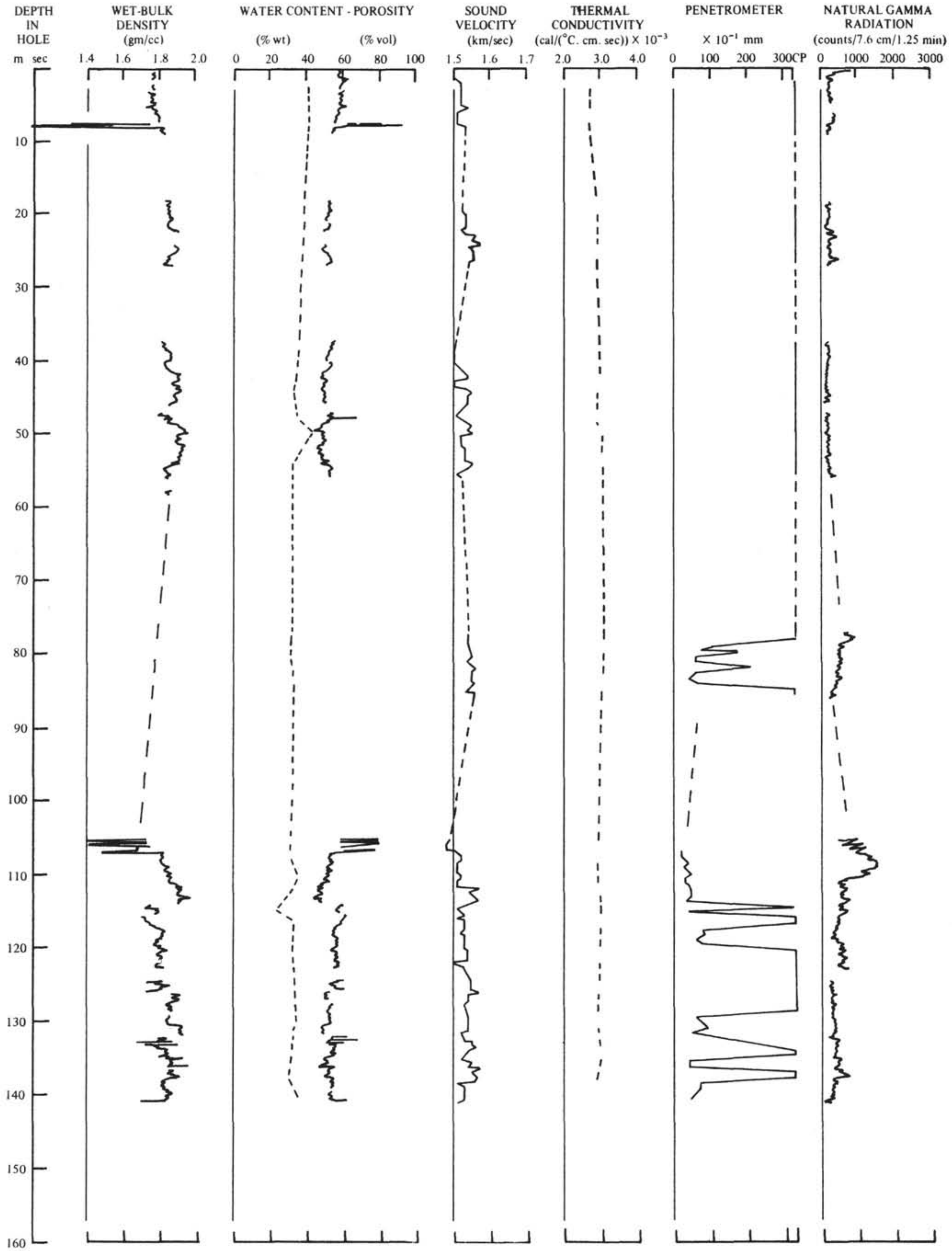
See consolidated list at the end of Chapter 13.

THE CORES RECOVERED FROM SITE 15

The following pages present a graphic summary of the results of drilling and coring at Site 15.

The first illustrations show a summary of the physical properties of the cores, the positions of the cores and cored intervals and some notes on the lithology and ages of the cores recovered from the holes.

Following this summary are more detailed displays of the individual cores recovered from Site 15. These two-page displays show the physical properties of the cores, the age assignments made on the basis of paleontology, a graphic representation of the lithology of the cores, some notes on the lithology, and notes regarding the diagnostic fossil species present. Symbols have been used for graphic display of lithology to give a general impression only, rather than a detailed representation, and these are supplemented by the lithology notes. For this reason, a detailed key has not been prepared. Interspersed among the core descriptions are photographs of the cores, where photographs are available. In general, every attempt has been made to locate photographs of the cores adjacent to, or as close as practicable to, the relevant Core Summaries. Where sections of core are of special interest, detailed Section Summaries are inserted.



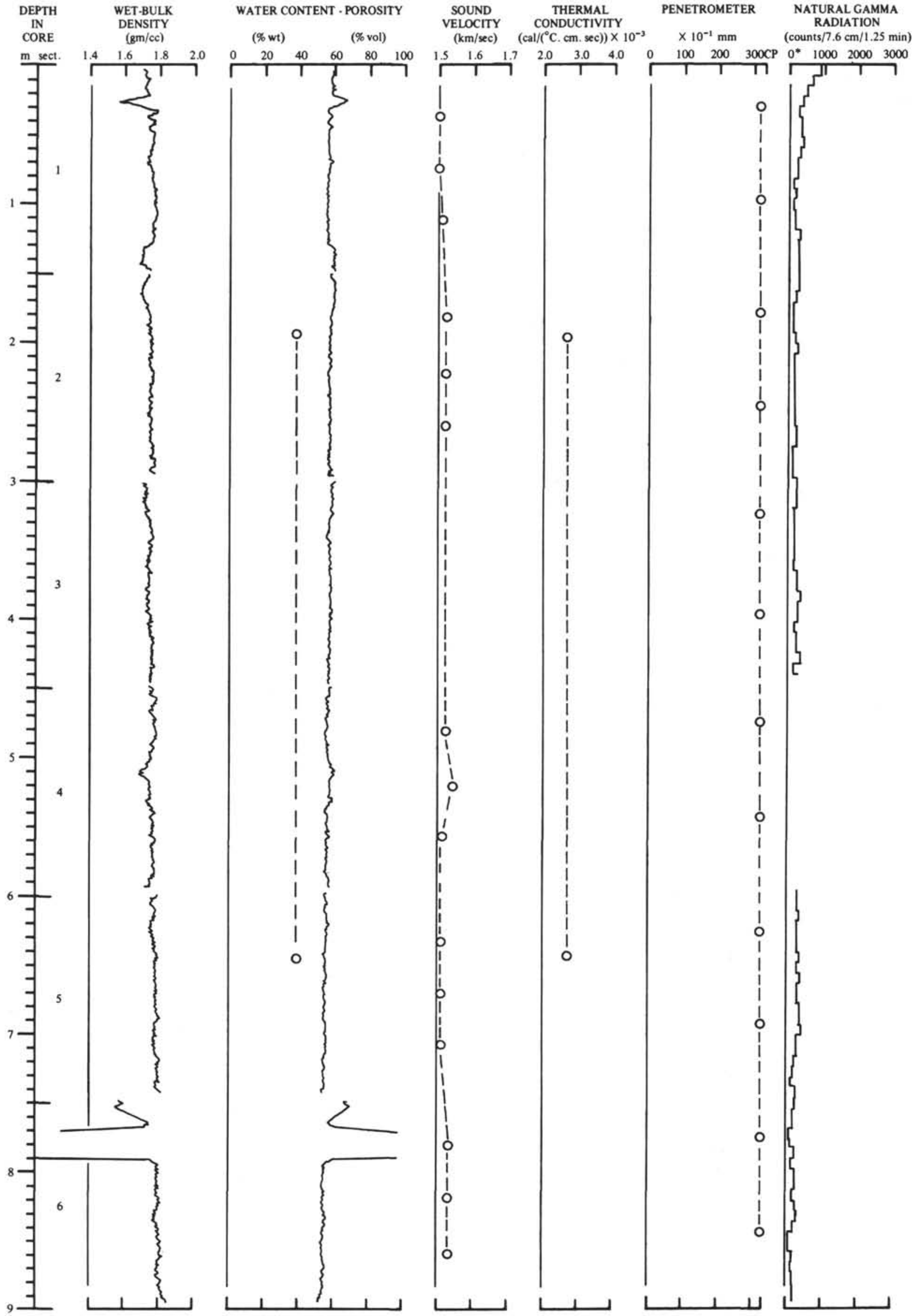
*"0" = laboratory atmospheric background count of 1550.

Figure 2A. *Summary of the Physical Properties of cores recovered from Hole 15.*

DEPTH	CR.	CI.	FORMATION	LITHOLOGY	AGE
0	1, 2, 3		Albatross Ooze 3-15/1/1	Very pale brown to white foraminiferal nannofossil chalk oozes. 5-30% foraminifera. A few light yellow brown more marly intercalations are present.	PLEISTOCENE LOWER PLEISTOCENE Calabrian UPPER PLIOCENE Astian Piacenzian
50	4		Blake Ooze 3-15/3/3	White nannofossil chalk oozes. <5% foraminifera.	LOWER PLIOCENE Zanclian
	5		Challenger Ooze 3-15/4/5	Yellow brown to dark yellow brown, mottled marl and marly chalk oozes. Zeolitic, hematitic.	UPPER MIOCENE Messinian UPPER MIOCENE Tortonian
100	6		Discovery Clay 3-15/6/1	Dark red brown marl oozes and red clays, phosphatic.	MIDDLE MIOCENE Langhian
	7		Endeavor Ooze 3-15/6/4	Yellowish brown nannofossil marly chalk oozes. Foraminifera very rare, zeolitic.	LOWER MIOCENE Burdigalian
	8		Grampus Ooze 3-15/8/1	Dark brown marly chalk oozes Foraminifera and hematitic contents increase with depth.	LOWER MIOCENE Aquitanian
	9		Endeavor Ooze	Section cored repeatedly.	LOWER MIOCENE Burdigalian*
	10		Grampus Ooze		LOWER MIOCENE Aquitanian*
150	11		Basement 3-15/10/1	Basalt	

* These stratigraphic intervals are repeated by coring.

Figure 2B. *Summary of the cores from Hole 15. (Depth below sea bed in meters; C.R. = core recovered; C.I. = cored interval.)*



* "0" = laboratory-atmospheric background count of 1550.

Figure 3A. *Physical properties of Core 1, Hole 15.*

AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
PLEISTOCENE		1	1		N F		Calcareous nannoplankton: *Coccolithus pelagicus, Gephyrocapsa oceanica, Helicopontosphaera kamptneri, Cycloccolithus leptoporus, Ceratolithus cristatus, Scapholithus fossilis.* Sample 103-105 cm: Planktonic foraminifera: *Globorotalia inflata, G. tumida, G. truncatulinoides, G. scitula, Globigerinoides ruber, G. conglobatus, Globigerina pachyderma, Sphaeroidinella dehiscens, Globigerinella aequilateralis.*
		2	2		N		Flora similar to above.*
		3 4	3		N	ALBATROSS OOZE Very pale brown to white (10YR 8/2-3 to 7/4) foram - nannofossil chalk oozes, 10-20% foram 80-90% nannofossils with a few light yellow brown (10YR5/4) intervals, with ~2% hematite.	Flora similar to above
		5	4		N		Flora similar to above.*
		6 7	5		N F		Flora similar to above.* Planktonic foraminifera: *Globorotalia inflata, G. crassaformis, G. truncatulinoides, G. scitula, Pulleniatina finalis* (R), *P. obliquiloculata* (R), *Globigerinoides sacculifer.*
		8	6		FN		Flora and fauna similar to above.* Core catcher: Flora and fauna similar to above.*

* This sample contains rare reworked *Discoaster* spp.

Figure 3B. *Core 1, Hole 15.*

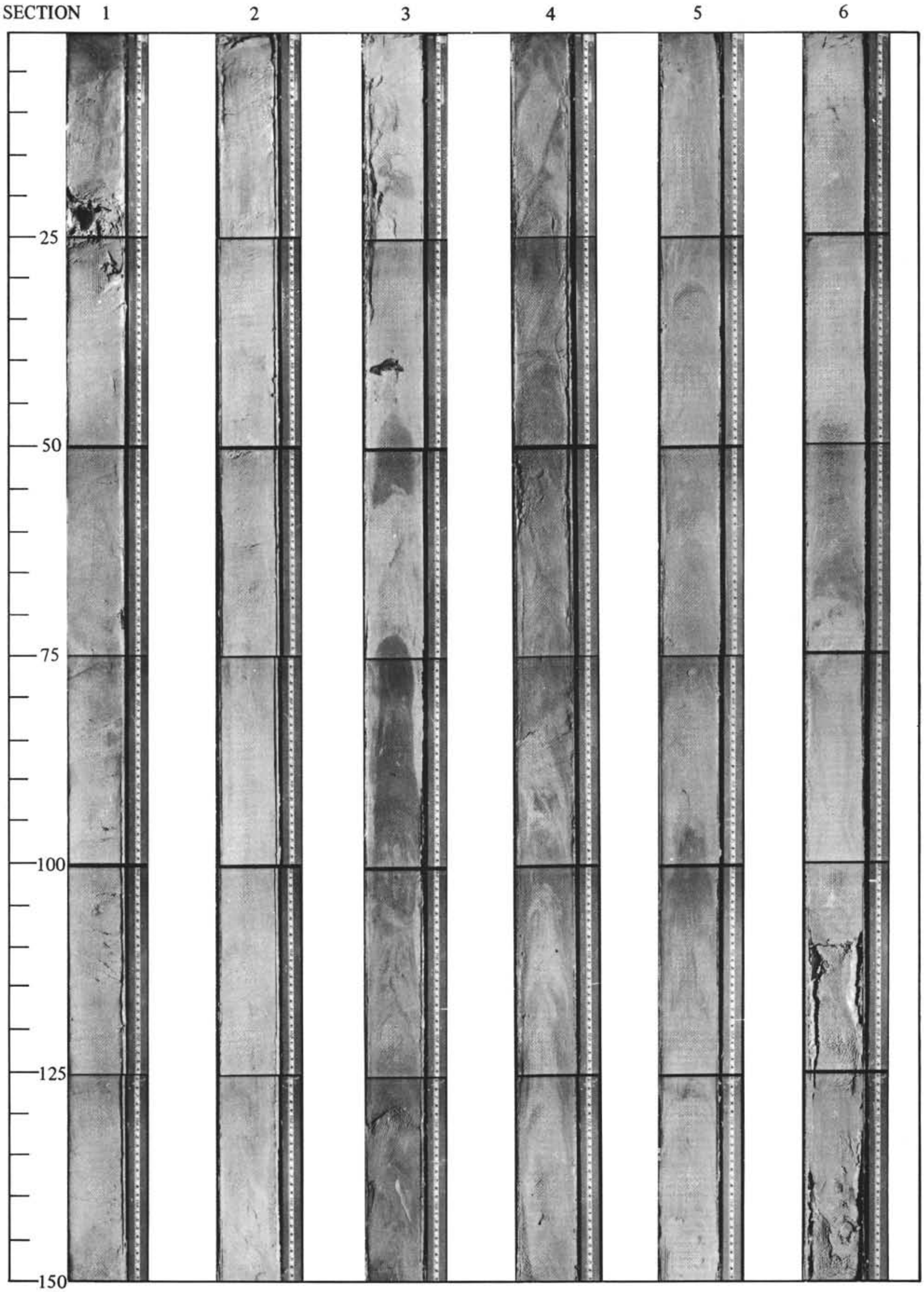


Plate 1. *Hole 15, Core 1.*

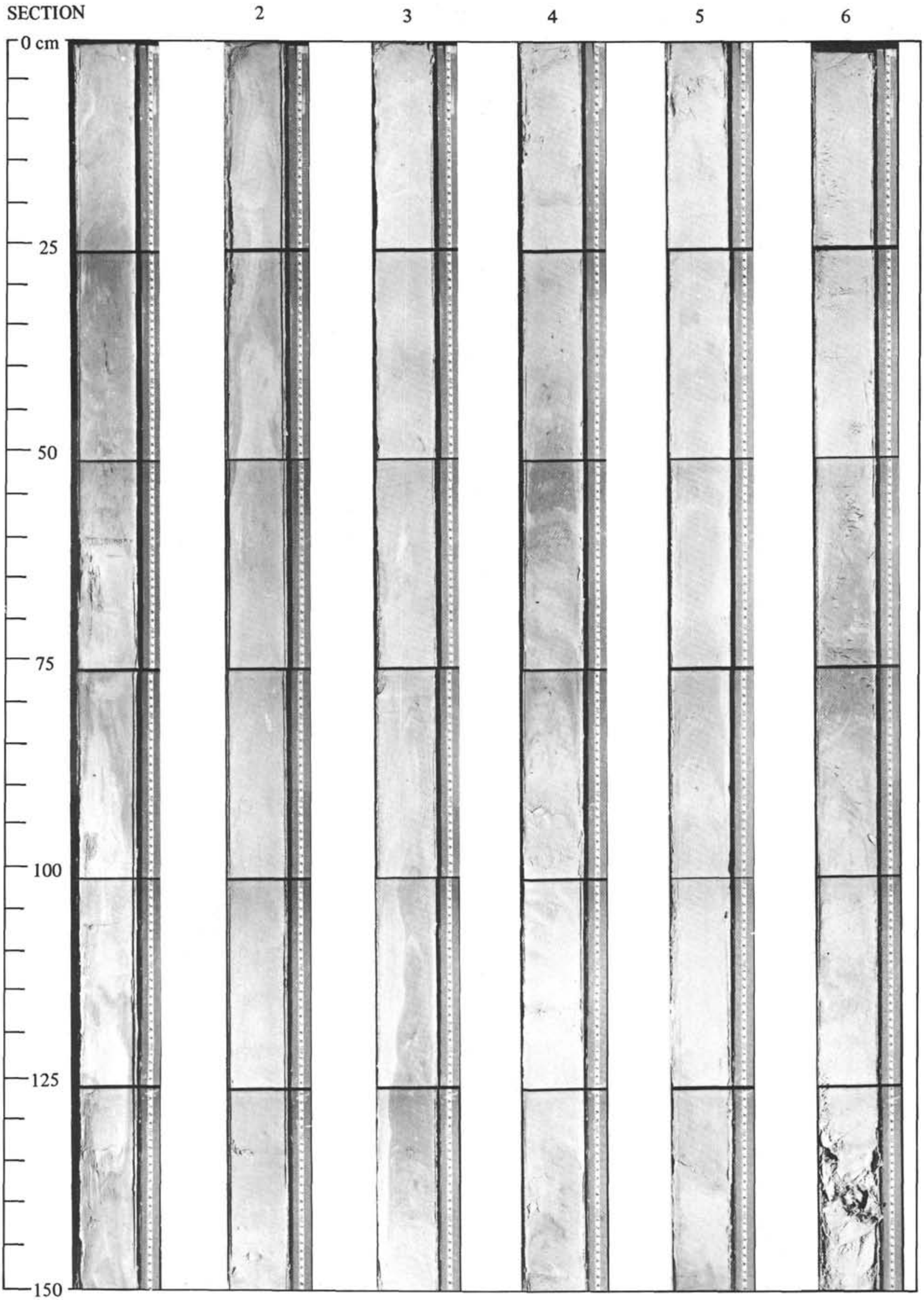
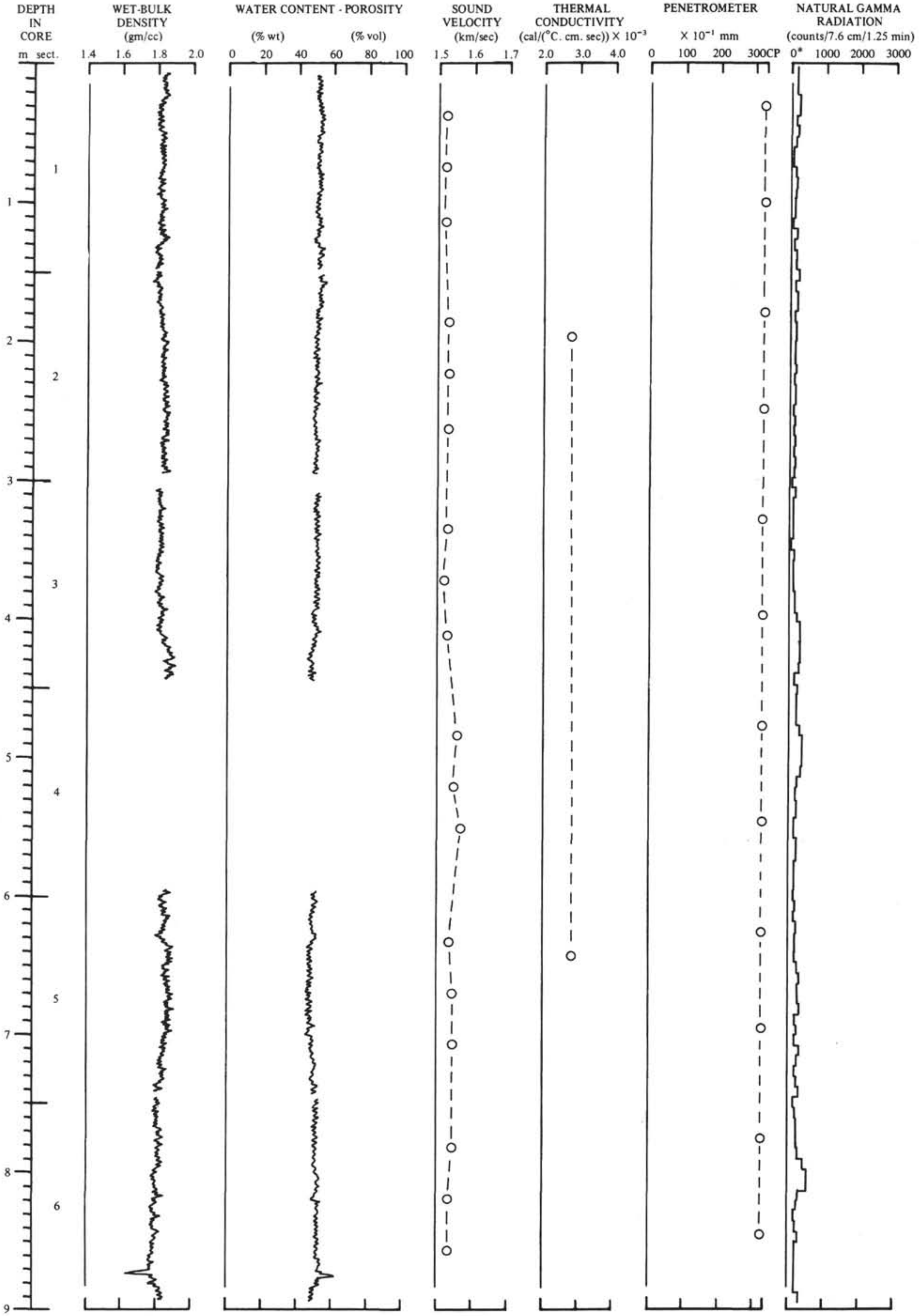


Plate 2. *Hole 15, Core 2.*

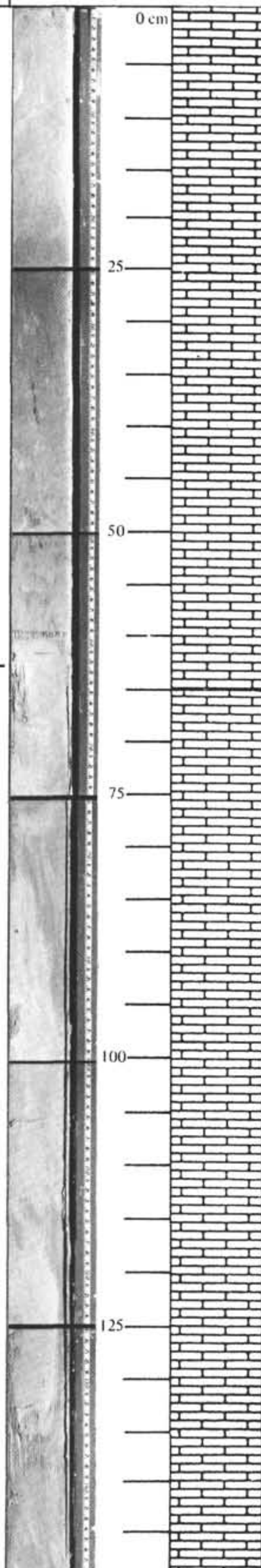


* "0" = laboratory-atmospheric background count of 1550.

Figure 4A. *Physical properties of Core 2, Hole 15.*

AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LOWER PLEISTOCENE / UPPER PLIOCENE	CALABRIAN / ASTIAN - PIACENZIAN	0–1.5	1		FN, FN	ALBATROSS OOZE Foram - nannofossil chalk ooze, white to very pale brown (10YR8/2-10YR7/4) with light yellow brown (10YR6/4) intervals 5-15% foram	For flora and fauna description see Section Sheet.
UPPER PLIOCENE	ASTIAN - PIACENZIAN	1.5–3	2		N, F		Calcareous nannoplankton: *Discoaster browweri* (abundant), *Helicopontosphaera kamptneri*, *Cyclococcolithus leptoporus*, *Ceratolithus rugosus*, *C. cristatus*, *Gephyrocapsa oceanica*, *Coccolithus pelagicus*. Planktonic foraminifera: *Globorotalia crassula*, *G. tumida*, *G. inflata*, *G. scitula*, *Globigerina praedigitata*, *Globigerinoides ruber*, *Sphaeroidinella dehiscens*.
UPPER PLIOCENE	ASTIAN - PIACENZIAN	3–4.5	3		N		Flora similar to above.
UPPER PLIOCENE	ASTIAN - PIACENZIAN	4.5–6	4		FN		Flora and fauna similar to above.
UPPER PLIOCENE	ASTIAN - PIACENZIAN	6–7.5	5		N, F		Flora similar to above. Fauna similar to above.
UPPER PLIOCENE	ASTIAN - PIACENZIAN	7.5–9	6		FN, FN		Sample 10-12 cm: Flora similar to above. Sample 105-107 cm: Calcareous nannoplankton: *Discoaster browweri*, *D. pentaradiatus*, *D. surculus*, *Coccolithus pelagicus*, *Cyclococcolithus leptoporus*, *Ceratolithus rugosus*. Fauna similar to above. Core catcher: Flora similar to above. Fauna similar to above with *Globorotalia menardii miocenica* (rare).

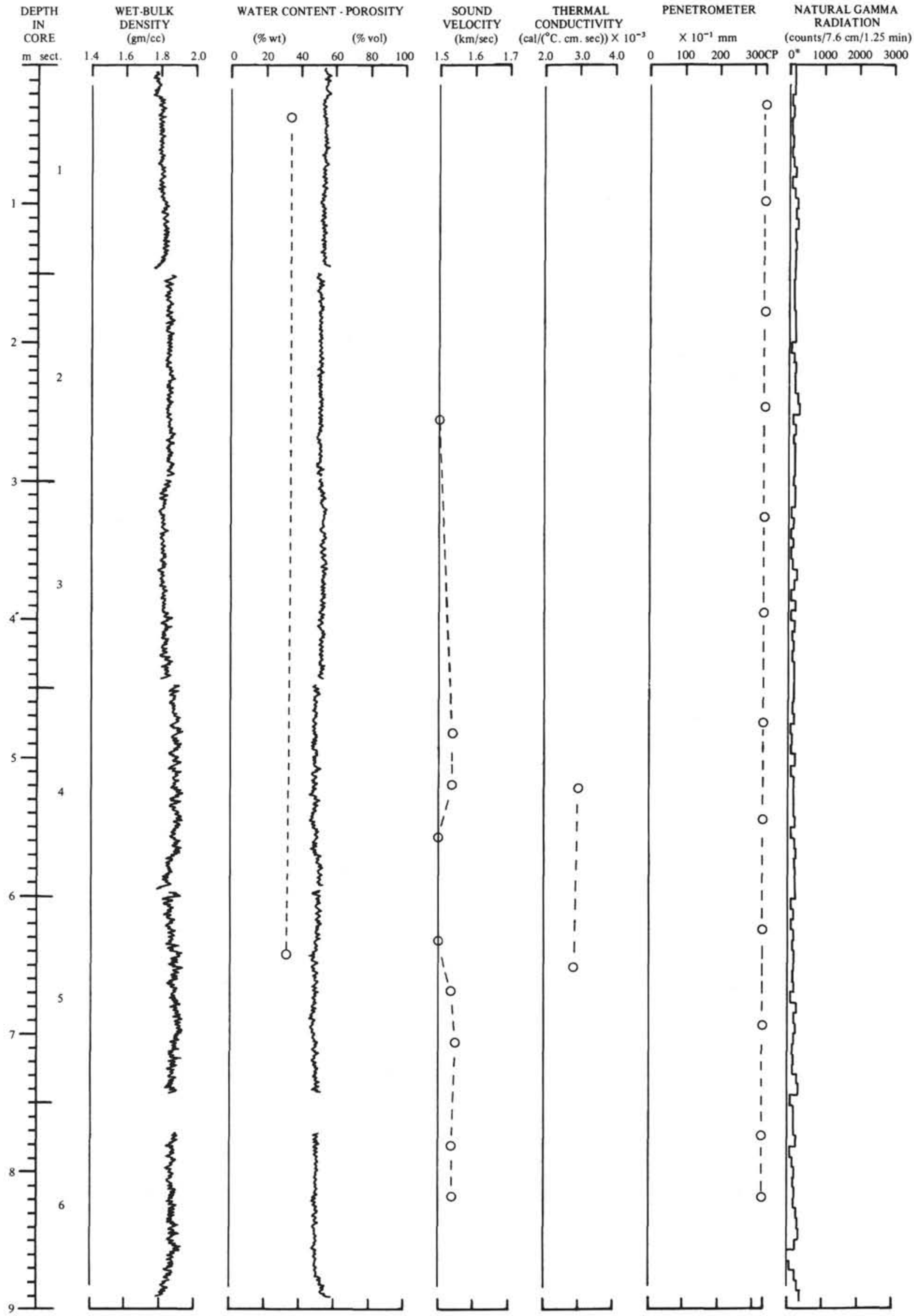
Figure 4B. *Core 2, Hole 15.*



AGE	STAGE	LITHOLOGY	SAMP. INT.	LITHOLOGY	DIAGNOSTIC FOSSILS
LOWER PLEISTOCENE	CALABRIAN		FN	Fm. ALBATROSS OOZE Foram-nannofossil chalk ooze. 8% foram 0-57 cm. Very pale brown (10YR7/4) with white (10YR8/2) mottling. 57-150 cm. White (10YR8/2) with very pale brown (10YR7/4) and light yellow brown (10YR6/4) mottling.	Planktonic foraminifera: *Globorotalia tosaensis, G. truncatulinoides, G. inflata, G. crassaformis, Candeina nitida, Globigerinoides obliquus, G. conglobatus, Globigerina praedigitata, Pulleniatina praecursor, Sphaeroidinella dehiscens.* Calcareous nannoplankton: *Discoaster brouweri* (Common) *Helicopontosphaera carteri, Cyclococcolithus leptoporus, Ceratolithus rugosus, Coccolithus pelagicus.*
UPPER PLIOCENE	ASTIAN-PIACENZIAN		FN	Core disturbed; boundaries irregular; diapiric and squeezed structures present.	Planktonic foraminifera: *Globorotalia crassula, G. tumida* (L), *G. inflata, G. crassaformis, Sphaeroidinella dehiscens, Globigerinoides obliquus, G. gomitulus, G. ruber, Pulleniatina primalis* (L), *P. praecursor* (L). Calcareous nannoplankton: Flora similar to above with *Discoaster brouweri* (Abundant).

Figure 5. *Summary of Section 1, Core 2, Hole 15.*

Plate 3. *Hole 15, Core 3.*

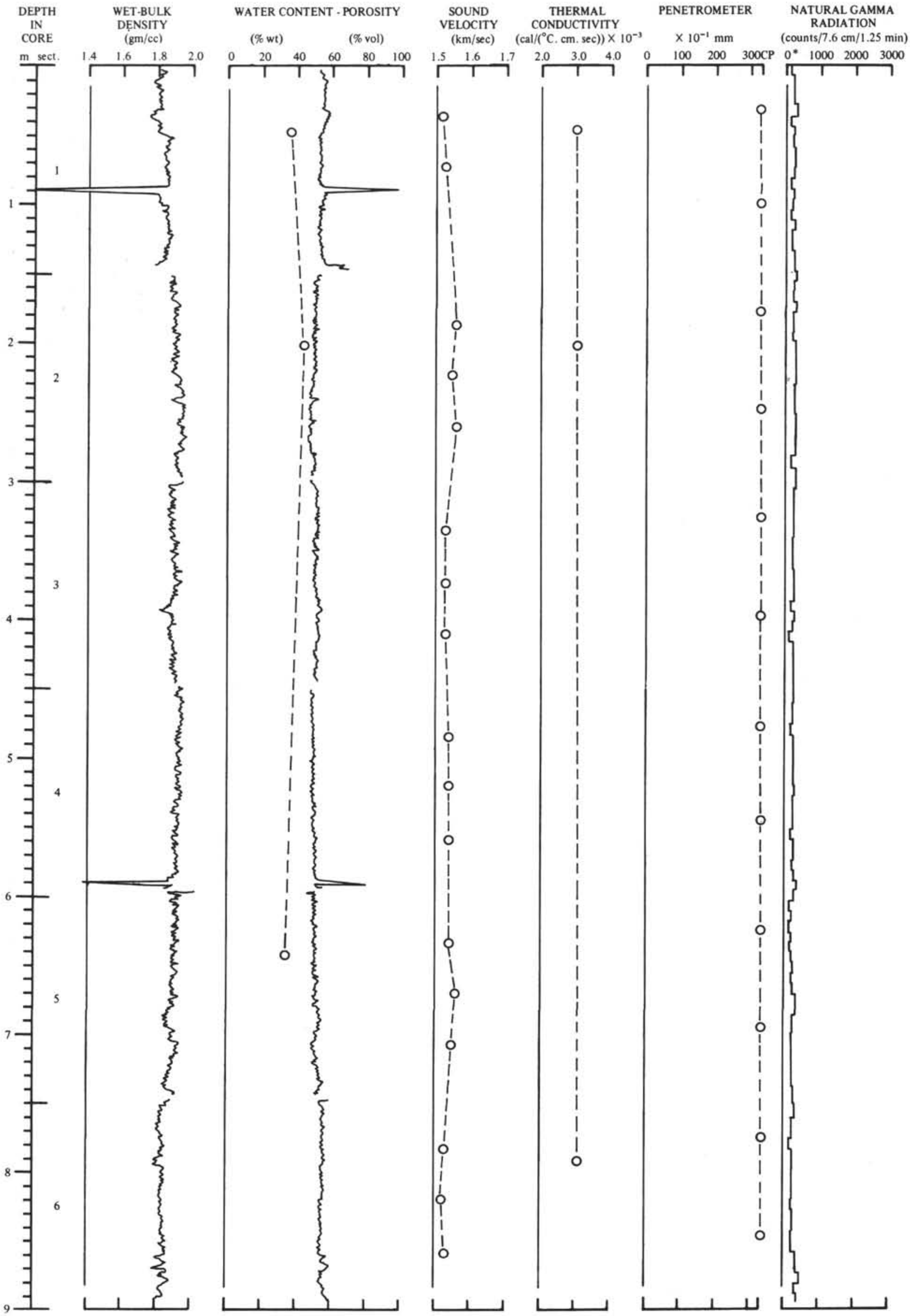


* "0" = laboratory-atmospheric background count of 1550.

Figure 6A. *Physical properties of Core 3, Hole 15.*

AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LOWER PLIOCENE	ZANCLAIN	0–1.5	1		FN	ALBATROSS OOZE Very pale brown (10YR8/4) to white (10YR8/2), foram-nannofossil chalk ooze. 8-10% foram	Planktonic foraminifera: *Globorotalia margaritae, G. inflata, G. conoidea, G. conomiozea, G. scitula, G. menardii miocenica, Globigerinoides obliquus, Globigerina decoraperta, Sphaeroidinellopsis seminulina.* Calcareous nannoplankton: *Discoaster brouweri, D. challengeri, D. surculus, D. pentaradiatus, Cyclococcolithus leptoporus, Ceratolithus rugosus, C. tricorniculatus, Reticulofenestra pseudoumbilica.*
		1.5–3	2		N		Flora similar to above.
		3–4.5	3		N F	BLAKE OOZE White (2.5Y8/2-8/1), nannofossil chalk ooze (< 5% foram) with light yellow brown zone at 125 cm. in Section 6.	Flora similar to above. Planktonic foraminifera: *Globorotalia crassaformis, G. crassaformis oceanica, G. conoidea, Globigerina praedigitata, Globoquadrina altispira, Globigerinoides obliquus.*
		4.5–6	4		N		Flora similar to above.
		6–7.5	5		FN		Flora and fauna similar to above.
		7.5–9	6		FN F		Flora and fauna similar to above. Sample 110-112 cm: Fauna similar to above. First appearance of *Globigerina nepenthes.* Core catcher: Flora similar to above. Planktonic foraminifera: *Globigerina nepenthes, Globoquadrina altispira, Globigerinoides obliquus, Globorotalia oceanica, G. miotumida, Sphaeroidinella dehiscens, Sphaeroidinellopsis seminulina, S. subdehiscens.*

Figure 6B. *Core 3, Hole 15.*



* "0" = laboratory-atmospheric gackground count of 1550.

Figure 7A. *Physical properties of Core 4, Hole 15.*

AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LOWER PLIOCENE	ZANCLIAN	1	1		FN		Planktonic foraminifera: *Globigerina nepenthes, G. bulloides, Globorotalia conoidea. G. crassaformis, G. acostaensis, Sphaeroidinellopsis seminulina.* Calcareous nannoplankton: *Discoaster browseri, D. surculus, D. challengeri, D. pentaradiatus, Reticulofenestra pseudoumbilica, Cyclococcolithus leptoporus, Ceratolithus tricorniculatus, C. rugosus* (rare).
		2	2		N		Flora similar to above.
		3, 4	3		N, F	BLAKE OOZE White (2.5Y8/2-8/1-10YR8/2) nannofossil chalk ooze 2% foram	Flora similar to above. Fauna similar to above.
		5	4		N		Flora similar to above.
?	?	6, 7	5		N		Flora and fauna similar to above.
UPPER MIOCENE	MESSINIAN	8	6		N, FN	CHALLENGER OOZE Dark yellow brown (10YR4/3), nannofossil chalk ooze 10% hematite 2% foram.	Calcareous nannoplankton: *Discoaster browseri, D. pentaradiatus D. surculus, D. challengeri, Ceratolithus tricorniculatus, Reticulofenestra pseudoumbilica, Cyclococcolithus leptoporus.* Core catcher: Flora and fauna similar to above.

Figure 7B. *Core 4, Hole 15.*

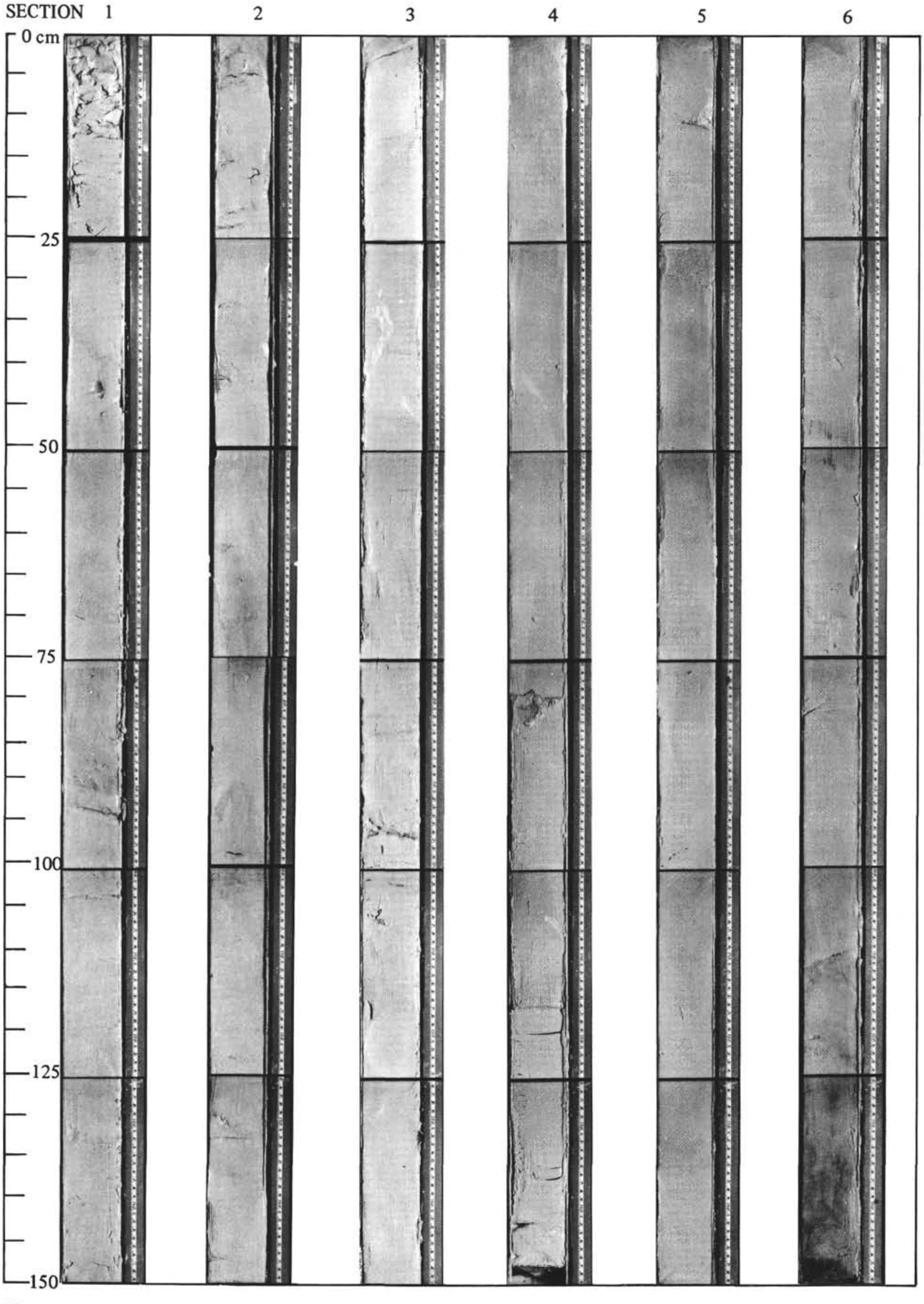


Plate 4. *Hole 15, Core 4.*

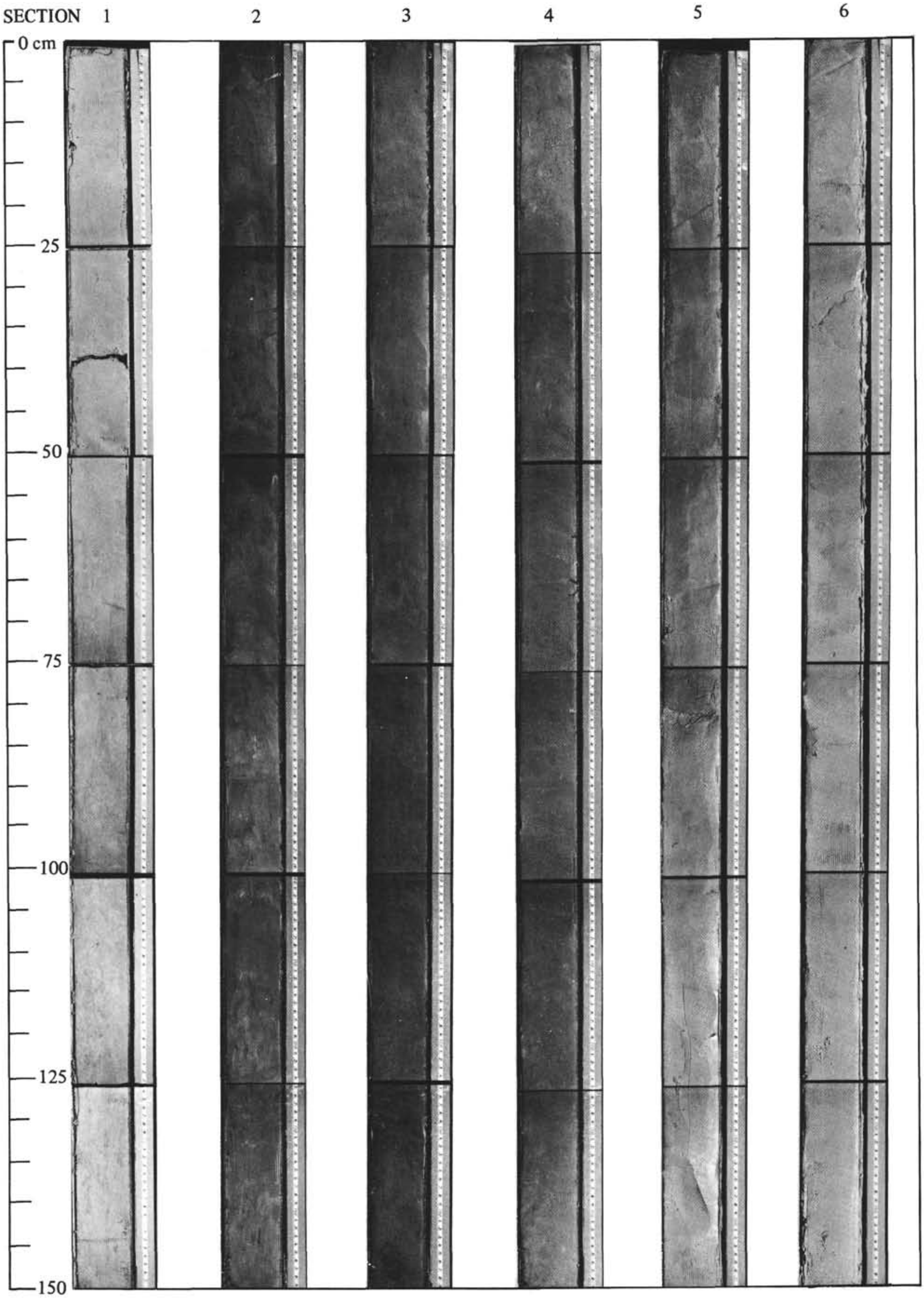


Plate 5. *Hole 15, Core 5.*

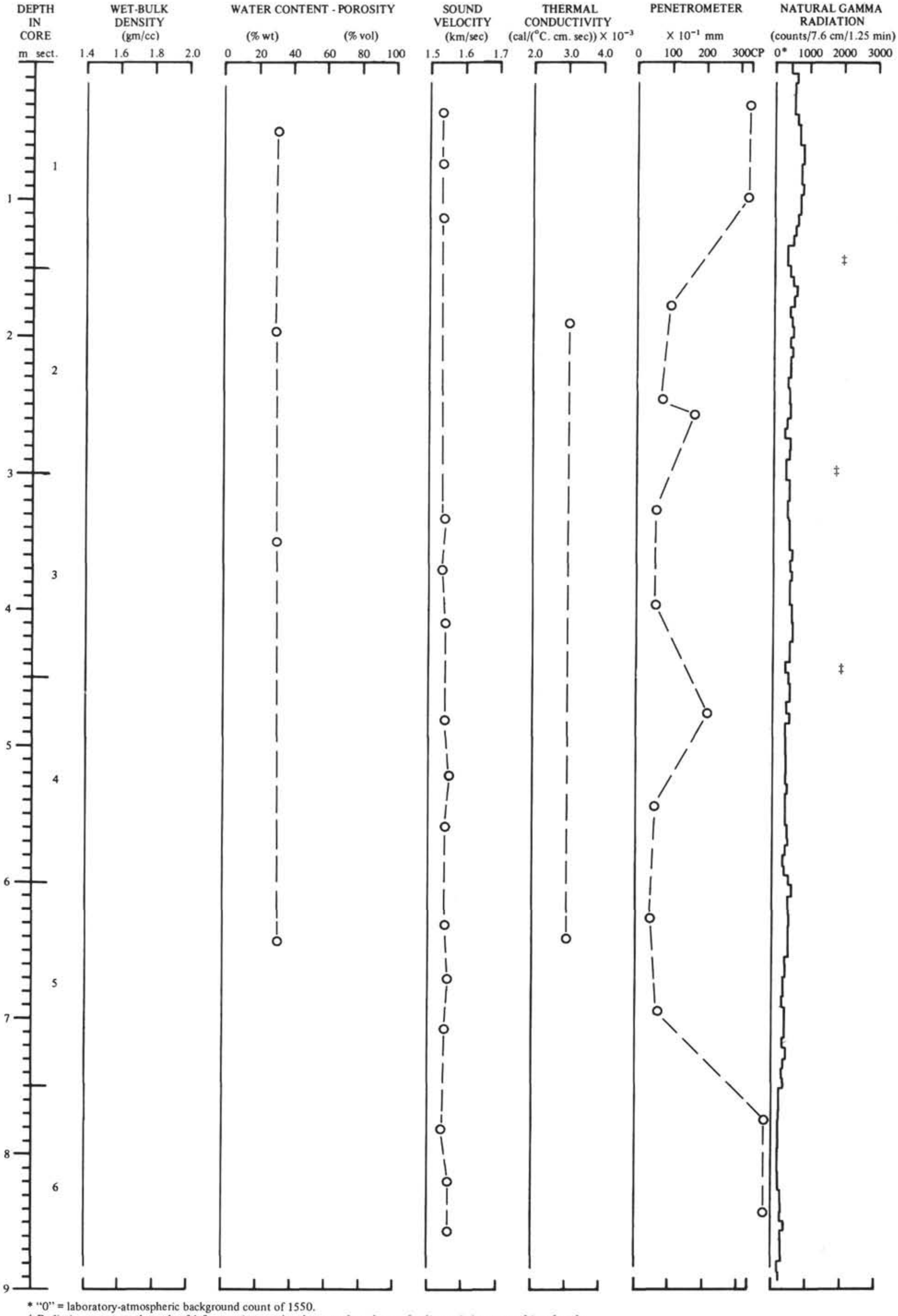
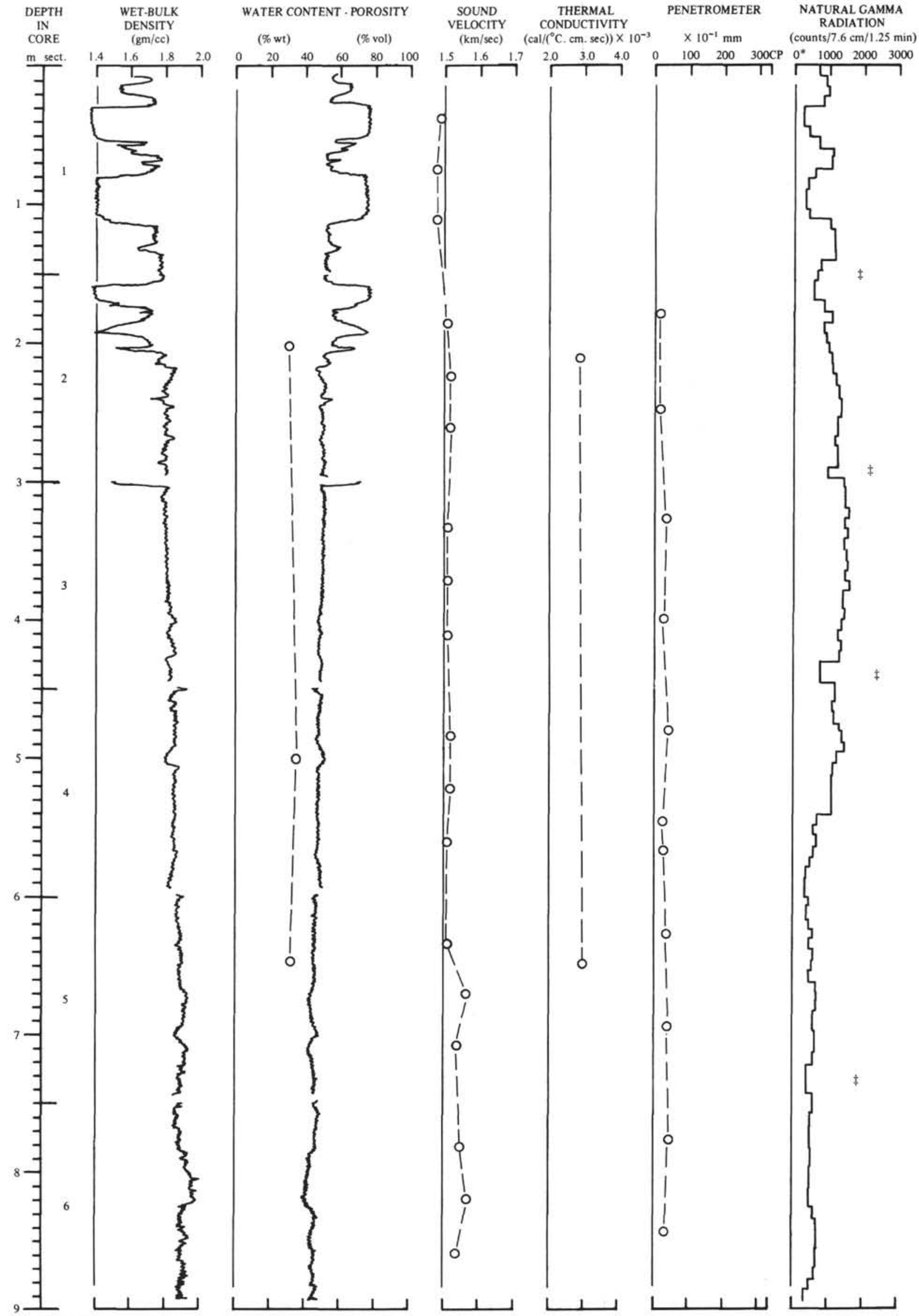


Figure 8A. *Physical properties of Core 5, Hole 15.*

AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
UPPER MIOCENE	TORTONIAN	1	1		FN		Planktonic foraminifera: *Globigerina nepenthes, Globigerinoides bollii, Sphaeroidinellopsis seminulina, Orbulina universa, Globorotalia conoidea.* Calcareous nannoplankton: *Discoaster brouweri, D. challengeri, D. pentaradiatus, Coccolithus pelagicus, Cyclococcolithus leptoporus, Reticulofenestra pseudoumbilica.*
		2	2		N		Flora similar to above.
		3, 4	3		FN	CHALLENGER OOZE Yellow brown (10YR5/4) to dark brown (10YR4/3), mottled, marl oozes and marly chalk oozes 30-50% clay minerals 0-20% zeolite Grades to lower concentrations and light yellow brown/very pale brown towards bottom of core.	Flora and fauna similar to above.
		5	4		N		Flora similar to above.
		6, 7	5		FN		Flora and fauna similar to above.
		8	6		N F		Flora similar to above. Planktonic foraminifera: *Globigerina nepenthes, Globorotalia conoidea, Globigerinoides cyclostoma, G. gomitulus, G. bollii.* Core catcher: Flora and fauna similar to above.

Figure 8B. *Core 5, Hole 15.*



* "0" = laboratory-atmospheric background count of 1550.
‡ Radiation counts at the ends of 1.5 m sections are low because the volume of sediment being scanned is reduced.

Figure 9A. *Physical properties of Core 6, Hole 15.*

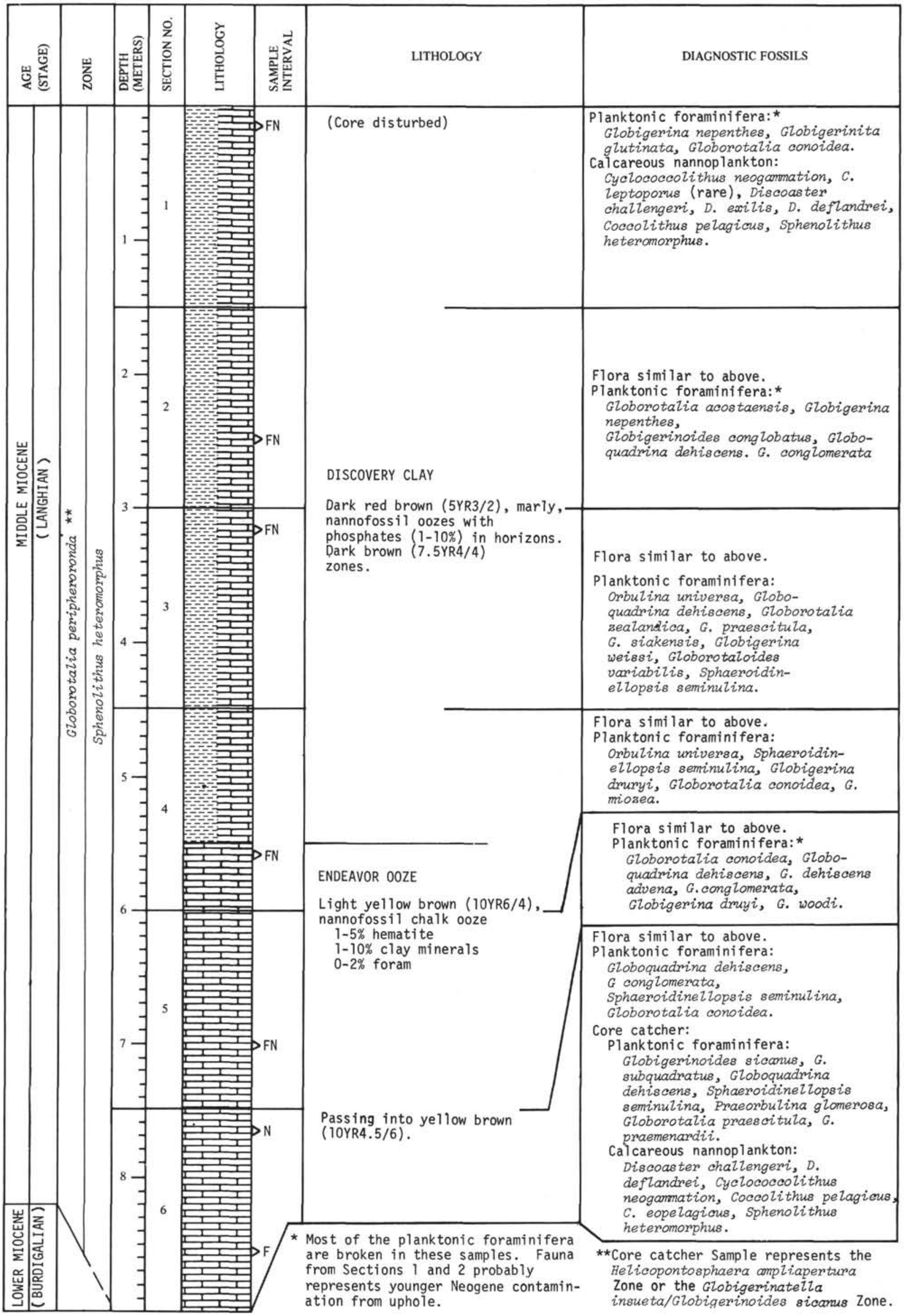
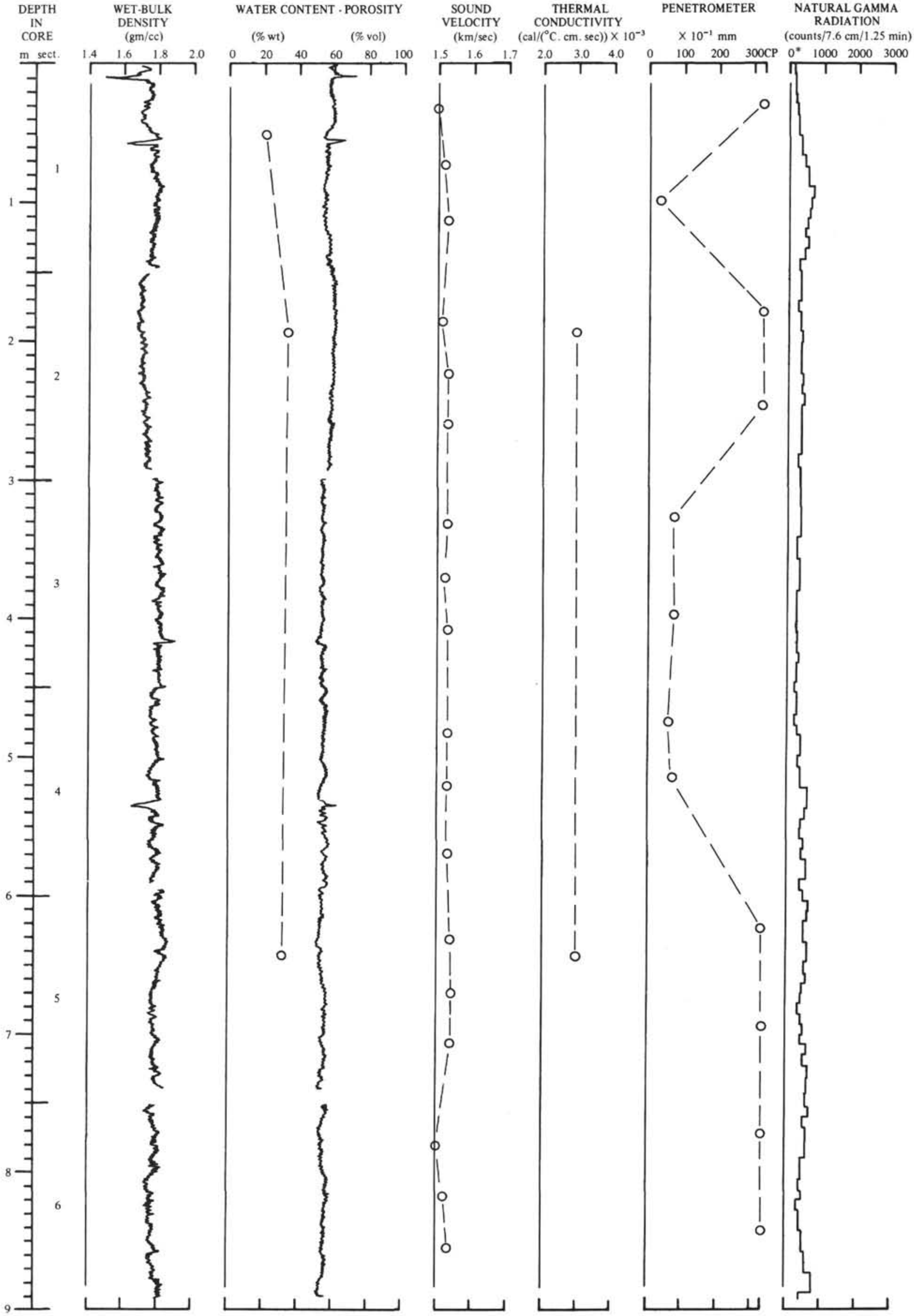


Figure 9B. *Core 6, Hole 15.*

Plate 6. *Hole 15, Core 6.*

Plate 7. *Hole 15, Core 7.*



* "0" = laboratory-atmospheric background count of 1550.

Figure 10A. *Physical properties of Core 7, Hole 15.*

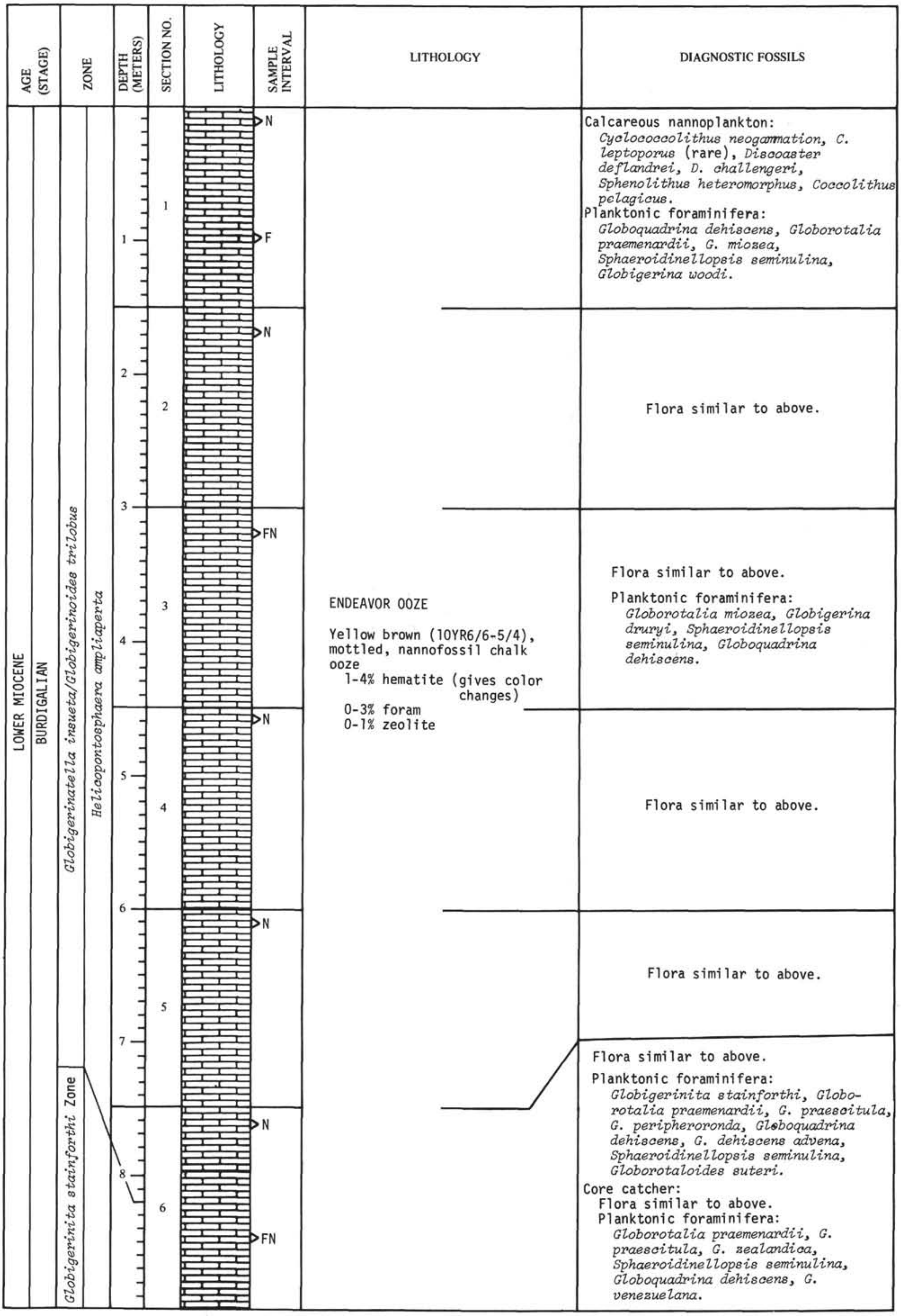


Figure 10B. *Core 7, Hole 15.*

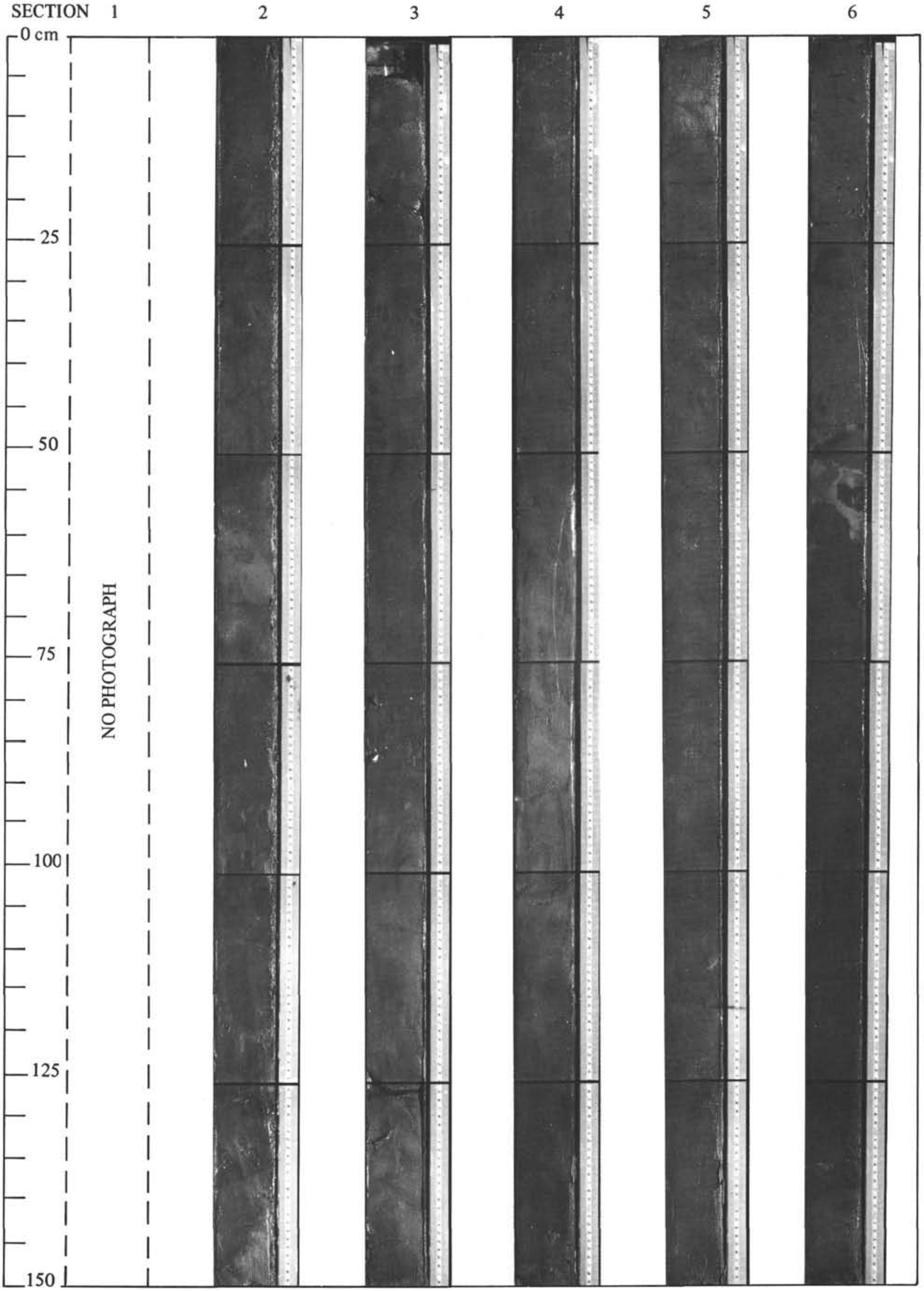
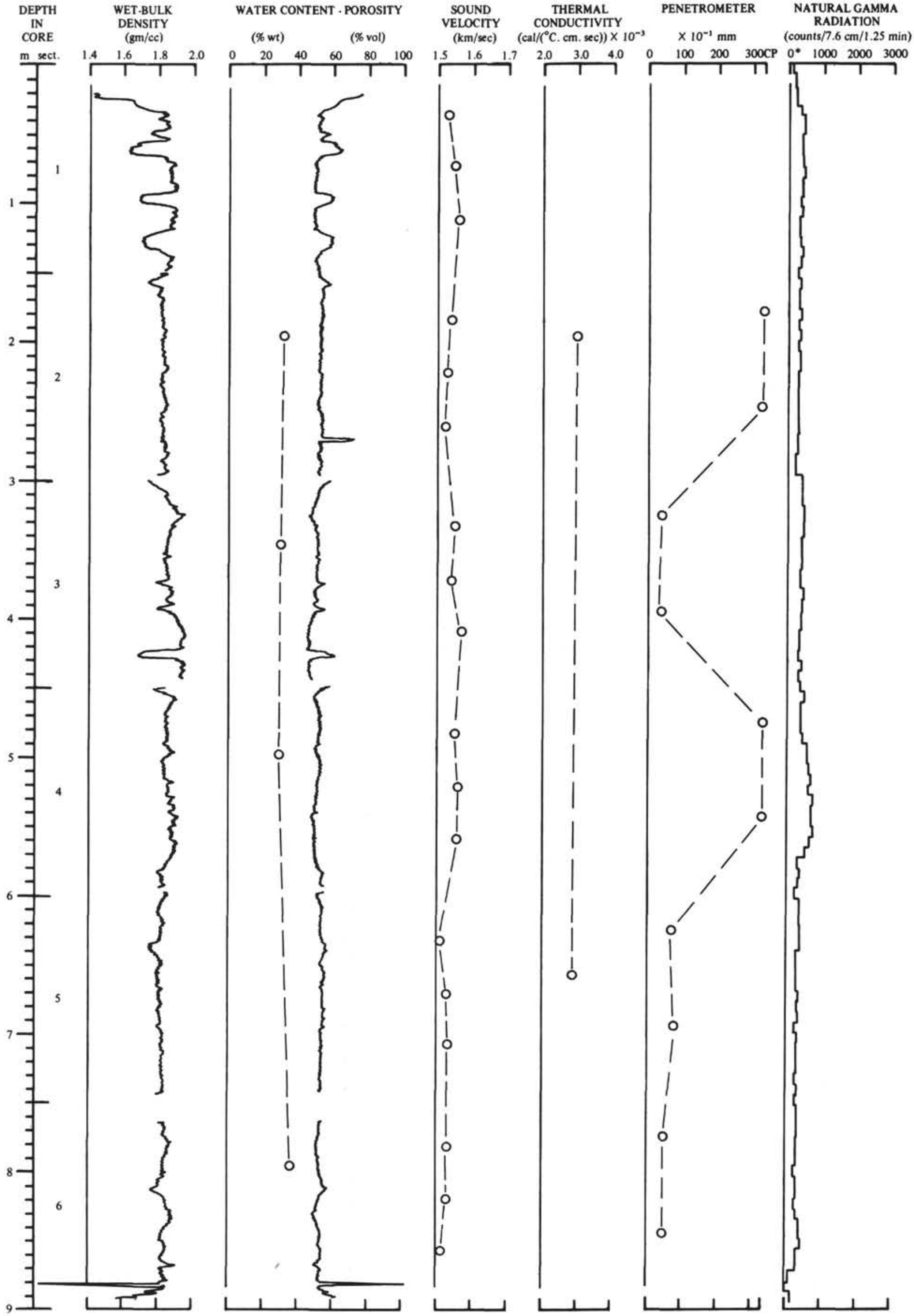


Plate 8. *Hole 15, Core 8.*

AGE (STAGE)	ZONE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LOWER MIOCENE AQUITANIAN	*Globigerinita dissimilis - Globigerinita stainforthi*; *Triquetrorhabdulus carinatus*	1	1		OPENED AT END; FN	(Core disturbed)	Planktonic foraminifera: *Globigerinita dissimilis, G. stainforthi, Globoquadrina dehiscens, Globorotalia denseconnexa, G. praescitula, G. peripheroronda, G. nana pseudocontinuosa, Globorotaloides variabilis.* Calcareous nannoplankton: *Cyclococcolithus neogammation, Sphenolithus belemnos, Discoaster deflandrei, D. druggi, Orthorhabdus serratus, Coccolithus pelagicus, C eopelagicus.*
		2	2		N		Flora similar to above.
		3, 4	3		FN	GRAMPUS OOZE Dark brown (10YR3/3-4/4), mottled, marly, nannofossil chalk ooze 5-25% hematite and opaques Tr. zeolite 2-5% foram	Flora and fauna similar to above.
		5	4		N		Flora similar to above.
		6, 7	5		FN		Flora and fauna similar to above.
		8	6		N; FN	Dark red brown (5YR3/2)	Flora and fauna similar to above. Core catcher: Flora and fauna similar to above.*

* This sample contains younger Lower Miocene floral contaminants from uphole.

Figure 11. *Core 8, Hole 15.*



* "0" = laboratory-atmospheric background count of 1550.

Figure 12A. *Physical properties of Core 9, Hole 15.*

AGE (STAGE)	ZONE	DEPTH (METERS)	SECTION NO	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LOWER MIOCENE BURDIGALIAN	*Globigerinatella insueta/Globigerinoides sicanus - Globigerinatella insueta/Globigerinoides trilobus* *Helicopontosphaera ampliaperta*	0–1	1	N, FN	(Repeat coring of sections above)	Calcareous nannoplankton: *Discoaster deflandrei, D. challengeri, Cyclococcolithus neogammation, Sphenolithus heteromorphus, Coccolithus pelagicus.* Plankton foraminifera: *Globigerinoides sicanus, G. trilobus, G. subquadratus, Globoquadrina dehiscens, Globorotalia praemenardii, G. praescitula, G. peripheroronda.*
		2	2	N	GRAMPUS OOZE	Flora similar to above.
		3–4	3	FN	Light yellow brown (10YR6/4), mottled, nannofossil chalk ooze. 1-2% opaques 5% clay minerals 2-5% foram	Flora and fauna similar to above.
		5	4	N		Flora similar to above.
LOWER MIOCENE AQUITANIAN	*Globigerinita dissimilis-Globigerinita stainforthi* *Triquetrorhabdulus carinatus*	6–7	5	FN	Dark brown (10YR3/4) mottled and marly intervals. Increase to 15% hematite and opaques.	Planktonic foraminifera: *Globigerinita dissimilis, G. stainforthi, Globorotaloides suteri, Globigerina woodi, Globorotalia siakensis, G. mayeri, G. nana pseudocontinuosa.* Calcareous nannoplankton: *Cyclococcolithus neogammation, Sphenolithus belemnos, Discoaster deflandrei, D. druggi, Coccolithus pelagicus, C. eopelagicus, Orthorhabdulus serratus.*
		8	6	FN		Flora and fauna similar to above. Core catcher: Flora and fauna similar to above.

* This core repeats stratigraphic interval found in cores 7 and 8. For discussion see Chapter 5, Paleontology sections.

Figure 12B. *Core 9, Hole 15.*

Plate 9. *Hole 15, Core 9.*

AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
		1	1			Basalt: Aphanitic basalt, with chips ot white friable chalk and basaltic glass. Some vesicles and amygdules; calcite vein in the basalt.	White chalk. Calcareous nannoplankton: *Coccolithus pelagicus*, *Helicopontosphaera parallela*, *Cyclococcolithus neogammation*, *Discoaster deflandrei*. Soft sediment, probably contamination from uphole. Calcareous nannoplankton: *Coccolithus pelagious*, *Cyclococcolithus neogammation*, *Discoaster deflandrei*.
		2	2				
		3, 4	3				
		5	4				
		6, 7	5				
		8	6				

Figure 13. *Core 10, Hole 15.*

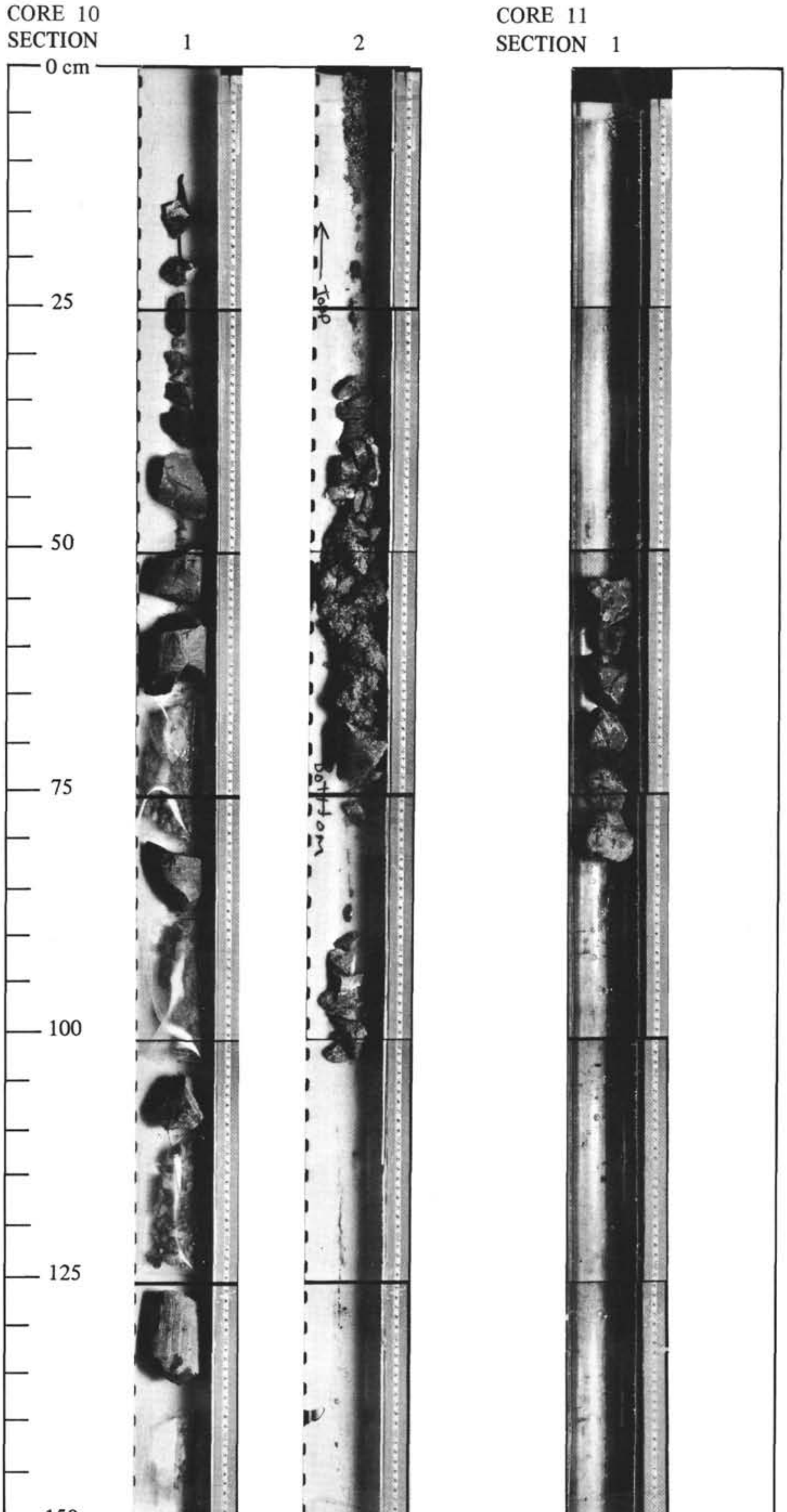


Plate 10. *Sections from Cores 10 and 11, Hole 15.*