9. SITE 19

The Shipboard Scientific Party[1]

SURVEY DATA AND SITE BACKGROUND

The principal consideration for the general location of this site was that it be over the identified Magnetic Anomaly 21, hypothesized to have an age of 53 million years in the extrapolated geomagnetic time scale. Prior to arrival of the drilling vessel in the site vicinity, the only survey information available was the *Vema-20* track and a few details of topography and sediment thickness near the site obtained from another very recent *Vema* crossing in the site vicinity.

The drilling vessel conducted a small box survey near the site before commencing drilling. The site (28° 32.08'S, 23° 40.63'W) is located on the east flank of a N-S trending ridge, 10 to 15 kilometers wide and 350 to 450 meters (1149 to 1477 feet) high. The minimum depth measured on this ridge during the survey is 4200 meters (13,776 feet), corrected (2230 fathoms, uncorrected) (Figure 1). The highest peaks have diffuse echos, possibly indicating that they are sediment-free, although sharper echos are obtained from small peaks at greater depths. The depth at the site is 4685 meters (15,367 feet), corrected (2483 fathoms, uncorrected), in a region of irregular topography and some diffuse reflectors.

The sediment cover at and near the site was poorly recorded by the air-gun, probably resulting for the most part from the irregular topography and poorly-reflecting bottom. Another record obtained on the site after drilling had commenced provided no better results. The magnetometer record showed that the site was located several kilometers east of the relatively broad maximum of a positive magnetic anomaly.

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OPERATIONS

Positioning

After a preliminary survey of the area, at 0900 hours on 7 January, 1969, the ship was stopped and the beacon was dropped to the ocean bottom. At the site there was a 15-knot wind from the northwest and about a 1-knot current from the same direction; however, a large, long period swell (2 to 4 meters, 10-second period) from the south required that the ship keep its axis oriented in a north-south direction. By keeping the wind off the bow and the swell from the stern, the ship was able to maintain position and yet keep the roll to an acceptable amount, although considerable heave motion was experienced. It was possible to keep the ship in the automatic position-keeping mode most of the time while on the site.

Drilling

A minor drilling break was encountered at a depth of 4763 meters (15,623 feet) during the time Core 6 was being cut. At this depth, coring was reduced to a rate of about 10 m/hr, whereas above that depth it had been nearly 30 m/hr. The bottom of the core was noted to be much firmer and drier than previous cores, and this probably accounts for the change in rate. On the other hand, when this core was split it was found to have a high water content and a soupy texture. It is not known whether this condition reflects an artificial thinning due to the coring process or whether it is a natural property of the sediment. Succeeding cores were cut at a rate closer to 30 m/hr even though Core 7 appeared to be as firm as Core 6. At a depth of 4818 meters (15,803 feet), basalt was encountered and the drilling rate was reduced to about 1.3 m/hr.

Coring

The drill pipe was started over the side about 0915 hours, shortly after the beacon had been dropped, and it reached bottom around 1800 hours. Because the seismic profiler gave an ambiguous measurement of the sediment thickness, two consecutive cores were taken immediately below the sea floor in order to get an estimate of the rate of sedimentation. This knowledge, along with an anticipated age of the bottom sediments, allowed the authors to predict the thickness of the sediments. From these cores, the sediment-basement interface was estimated to be 150 meters (492 feet) below the sea floor, which proved to be

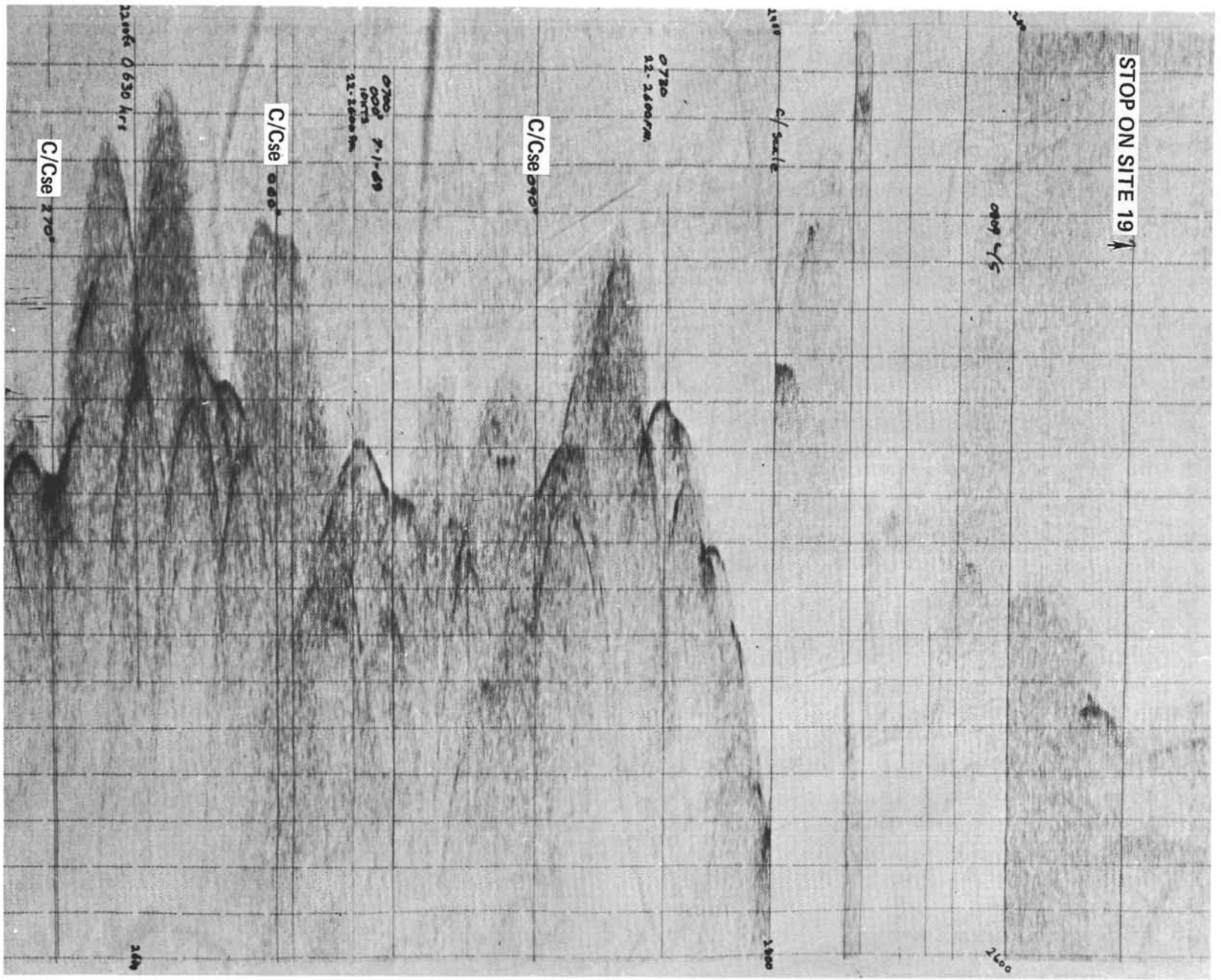


Figure 1. *Precision depth recording in the vicinity of Site 19.*

TABLE 1
Summary of Coring at Site 19

Core No.	Date/Time	Interval Cored (m below sea floor)	Core Retrieved (m)	Remarks
19-1	1-7-69 2050	0-9.1	9.0	--
19-2	2215	9.1-18.3	9.0	--
19-3	1-8-69 0205	36.6-45.7	8.8	Overshot failed to latch first attempt.
19-4	0430	56.7-65.9	8.4	--
19-5	0645	75.6-84.8	9.0	--
19-6	0900	86.0-95.1	9.0	Drilling break this depth.
19-7	1045	95.1-104.3	9.0	--
19-8	1215	104.3-113.4	8.7	--
19-9	1415	113.4-122.6	9.0	--
19-10	1630	123.8-133.0	9.0	--
19-11	1745	133.0-140.9	5.5	Basalt fragments in bottom of core.
19-12	2300	140.9-145.2	2.1	Basalt.
	Totals	103.7	97.5	94%

correct within 5 per cent. Twelve cores were collected at Site 19, and they are summarized in Table 1. Core recovery at Site 19 was very successful with the exception of the last two cores, both of which were in basalt. On Core 3 there was a failure of the overshot to latch onto the core barrel necessitating a second trip with the sand line. Despite a greater water depth than on the previous few holes, the average time to retrieve a core was less than 2 hours.

PALEONTOLOGY

Pleistocene, Upper Oligocene, Lower Oligocene, Upper Eocene and Middle Eocene sediments were recovered from eleven out of the twelve cores. Basalt with some sediments was recovered from Core 12. Coring was discontinuous in the upper 75.6 meters (248 feet), with a recovery of four cores. Coring was practically continuous from 75.6 meters (248 feet) to the top of the basalt at 140.9 meters (459 feet). Three stratigraphic boundaries, the Lower Oligocene/Upper Oligocene in Core 4, the Eocene/Oligocene in Core 5 and the Middle Eocene/Upper Eocene in Core 7, were cored. Time limitations aboard the ship and the soupy nature of many of the sediments cored resulted in many of the cores not being slabbed and sampled in detail for geologic and paleontologic studies.

The major purpose in drilling this hole was to test the hypothesis of sea-floor spreading and the interpretation of linear magnetic anomalies. The hole was drilled on a positive anomaly associated with Magnetic Anomaly 21 and had a suggested age of 53 million years according to the work of Heirtzler *et al.* (1968). The oldest sediments found above the basalt are Middle Eocene (Lutetian) in age and represent the *Hantkenina aragonensis* Zone of Bolli (1957b), and the *Chiphragmolithus quadratus* Zone of Hay in Hay *et al.* (1967). In addition, a sample of hard buff sediment associated with the basalt contained a similar calcareous nannoplankton flora. On the basis of Chapter 2 Figure 1 an equivalent radiometric age of 49 million years is suggested for these zones. This paleontologically derived age is in agreement with the 53-million years age based on the interpretation of the magnetic anomalies.

Another purpose in drilling this hole was to study any floral or faunal changes which may take place at 30° South Latitude. The floras and faunas found in the Paleogene are typical of those described from tropical areas. The Pleistocene section is too thin to allow for much interpretation of the Pleistocene floras and faunas.

The sediments of Cores 1 and 2 consist mostly of zeolite clay with only the upper half of Section 1

of Core 1 containing planktonic microfossils. The remaining sediments are barren of these fossil groups. Those of Cores 3 through 11 consist predominantly of plates of calcareous nannoplankton with minor amounts of planktonic foraminifera and opaque minerals. Most of the planktonic foraminiferal tests in Cores 3 through 8 are broken and show the effects of solution. The variations with lithology are discussed in the following section on Stratigraphy.

A thin Pleistocene section, less than 80 centimeters thick, occurs in Section 1 of Core 1, from 0 to 9.1 meters (0 to 30 feet). The fauna is represented by *Globorotalia truncatulinoides, G. inflata,* and *G. crassaformis;* and, the flora consists of *Helicopontosphaera kamptneri, Cyclococcolithus leptoporus, Gephyrocapsa oceanica* and *Ceratolithus cristatus.* Rare specimens of *Discoaster* spp. are also present in this interval, but they are considered reworked. The remainder of Core 1 and all of Core 2, from 9.1 to 18.3 meters (30 to 60 feet), is barren of planktonic microfossils, and contains fish teeth only sporadically. Thus, the age is indeterminate for this interval.

In Core 3, from 36.6 to 45.7 meters (120 to 149 feet), the sediments are of the Late Oligocene (Chattian) age based on the calcareous nannoplankton and the planktonic foraminifera. The foraminiferal fauna is poor and consists of very few species. Most of the foraminiferal tests are broken and show the effects of solution. However, benthonic foraminifera are common. The planktonic species present are *Globorotalia opima nana, Globorotaloides suteri* and *Globigerinita dissimilis.* These forms suggest a general correlation of the sediments with the *Globorotalia opima opima-Globigerina ciperoensis* Zones (undifferentiated) of Bolli (1957c). The flora in Section 1 and the sample from 14 to 16 centimeters of Section 2 consists of *Coccolithus bisectus, C.* aff. *bisectus, Cyclococcolithus neogammation, Sphenolithus ciperoensis* and *Discoaster deflandrei* which indicate the *Sphenolithus ciperoensis* Zone of Bramlette and Wilcoxon (1967). The sample from 105 to 107 centimeters of Section 2 and those from the remainder of the core have a flora containing *Sphenolithus distentus* and *S. predistentus* which indicates the *Sphenolithus distentus* Zone of Bramlette and Wilcoxon (1967).

The Lower Oligocene/Upper Oligocene boundary in Core 4, from 56.7 to 65.9 meters (186 to 216 feet), occurs between the sample from 148 to 150 centimeters of Section 4 and the one from 148 to 150 centimeters of Section 6 based on the planktonic foraminifera. The fauna of this core is similar to that of Core 3 in the interval from the top of the core to the sample from 148 to 150 centimeters of Section 3, and is of Late Oligocene (Chattian) age. Like that in Core 3, the fauna is a poor one consisting of a few whole specimens. Most of the foraminiferal tests are broken and show the effects of solution. The fauna in the sample from 148 to 150 centimeters of Section 6 is richer and includes *Pseudohastigerina micra, Chiloguembelina cubensis, Globorotalia postcretacea, Globigerina yeguaensis, G. sellii* and *Globorotaloides suteri,* which suggest correlation with the *Globigerina selli/Pseudohastigerina barbadiensis* Zone of Banner and Blow (1965) of the Lower Oligocene (Lattorfian-Rupelian Stage, undifferentiated). The calcareous nannoplankton species occurring throughout the core are *Coccolithus bisectus, Sphenolithus predistentus, S. distentus, S. pseudoradians, Discoaster tani* s. l., *D. deflandrei, Cyclococcolithus neogammation* and *Reticulofenestra umbilica.* This flora is characteristic of the *Sphenolithus predistentus* Zone of Bramlette and Wilcoxon (1967).

The Eocene/Oligocene boundary is in Core 5, from 75.6 to 84.8 meters (248 to 278 feet), based mainly on the calcareous nannoplankton. It occurs in the middle of Section 3 between the samples from 8 to 10 centimeters and from 100 to 102 centimeters depth. As previously mentioned for Cores 3 and 4, the planktonic foraminifera are mostly broken and show the effects of solution. The fauna is dominated by benthonic species. However, the planktonic faunas from the interval above Section 3 include *Pseudohastigerina micra, Globigerina tapuriensis* Blow and Banner, *G. angiporoides* Hornibrook, *G. gortanii* Borsetti, *Globorotalia opima nana* and *G. postcretacea* which are indicative of the *Globigerina tapuriensis* Zone of Banner and Blow (1965). The fauna from 8 to 10 centimeters depth of Section 3, above the Eocene/Oligocene boundary consists only of benthonic foraminifera and the one from 100 to 102 centimeters contains a very poor fauna but is characterized by the first appearance of *Globigerapsis index* a common Eocene species. The calcareous nannoplankton indicate that the boundary occurs between these two samples. The flora above is characterized by: *Discoaster tani* s.l., *D. deflandrei, Sphenolithus predistentus, S. pseudoradians, Coccolithus bisectus, Cyclococcolithus neogammation, C. lusitanicus, Isthmolithus recurvus* and *Reticulofenestra umbilica* which are characteristic of the *Helicopontosphaera reticulata* Zone of Bramlette and Wilcoxon (1967). Below the boundary, *Discoaster barbadiensis* Tan Sin Hok and *D. saipanensis* Bramlette and Riedel first appear, and the flora is assigned to the *Isthmolithus recurvus* Zone of Hay in Hay *et al.* (1967), as is the remainder of the core.

Core 6, from 86 to 95.1 meters (282 to 312 feet), and the uppermost part of Core 7, from 95.1 to 104.3 meters (312 to 341 feet), are Late Eocene (Bartonian) in age based on the planktonic foraminifera and the calcareous nannoplankton. The planktonic foraminiferal fauna is extremely poor in these cores showing

the effects of solution and consists almost exclusively of *Globigerapsis index.* The calcareous nannoplankton of this interval are those characteristic of the *Discoaster tani nodifera* Zone of Hay in Hay *et al.* (1967) which lacks *Isthmolithus recurvus,* but contains *Discoaster tani nodifera* Bramlette and Riedel.

The boundary between the Middle Eocene (Lutetian)/ Upper Eocene (Bartonian) is located in Section 2 of Core 7 between samples from 11 to 13 centimeters and from 100 to 102 centimeters depth based on the planktonic foraminifera. The first appearance of *Globigerina senni* (Beckmann), which becomes extinct near the top of the Middle Eocene, is found in the lower sample. In some of the samples examined, the planktonic foraminiferal tests are broken and show the effect of solution. Most of the core represents the *Discoaster tani nodifera* Zone of Hay in Hay *et al.* (1967) and is characterized by: *Discoaster barbadiensis, D. saipanensis, D. tani* s.l., *Coccolithus bisectus, Cyclococcolithus lusitanicus* and *Reticulofenestra umbilica.* The boundary of this zone and the subjacent *Chiphragmolithus quadratus* Zone of Hay in Hay *et al.* (1967) occurs in Section 5 below the sample from 9 to 11 centimeters. The flora of the latter zone is characterized by *Chiphragmolithus quadratus, Sphenolithus furcatolithoides* Locker, *Chiasmolithus grandis* (Bramlette and Riedel), *Reticulofenestra umbilica* and *Campylosphaera dela.*

Below the depth of 64 centimeters in Section 6 of Core 7, both the planktonic foraminifera and calcareous nannoplankton indicate the presence of an anomalous stratigraphic sequence. The foraminiferal faunas from 62 to 64 centimeters and 148 to 150 centimeters depth are correlated with the *Globigerapsis kugleri* Zone of Bolli (1957b) based on the associated occurrence of *Globorotalia aragonensis* Nuttall, *G. centralis* Cushman and Bermudez, *Globigerina frontosa* Subbotina and *"Globigerinoides" higginsi* Bolli. Immediately below, in the first five sections of Core 8, from 104.3 to 113.4 meters, the *Orbulinoides beckmanni* (= *Porticulasphaera mexicana*) Zone of Bolli (1957c) a much younger Middle Eocene is found. The marker species *Orbulinoides beckmanni* (Saito) occurs associated with *Globigerina senni, G. yeguaensis, Globigerapsis index* and *Acarinina densa* (Cushman). Most of the planktonic foraminiferal tests are broken and show the effects of solution in the younger zone. However, Section 6 and the core catcher of this core represent the *Globigerapsis kugleri* Zone. The calcareous nannoplankton reveal a similar stratigraphic sequence, the flora typical of *Discoaster tani nodifera* Zone is repeated in the upper five sections of Core 8, with a flora typical of the *Chiphragmolithus quadratus* Zone occurring in the lowermost part of Cores 7 and 8. In addition both the planktonic foraminifera and calcareous nannoplankton suggest that the stratigraphic interval at the bottom of this core represents a younger part of the *Globigerapsis kugleri* Zone than that occurring in the bottom of Core 7.

Core 9, from 113.4 to 122.6 meters (371 to 402 feet), Core 10, from 123.8 to 133 meters (406 to 437 feet) and Core 11, from 133 to 140.9 meters (437 to 462 feet), are Middle Eocene (Lutetian) in age. They represent the *Globigerapsis kugleri* Zone of Bolli (1957b), and the *Chiphragmolithus quadratus* Zone of Hay in Hay *et al.* (1967). Characteristic planktonic species found in the upper two cores are *Globigerapsis kugleri, G. index, Globigerina bolivariana* (Petters), *G. senni, G. linaperta* Finlay, *"Globigerinoides" higginsi, "Catapsydrax" echinatus* Bolli, *Acarinina densa, A. pseudotopilensis* Subbotina and *A. rotundimarginata* Subbotina. Associated with these forms in Core 11 are *Globorotalia aragonensis, Globigerina frontosa* Subbotina, and *Hantkenina dumblei* Weinzierl and Applin. In Core 9 the flora consist of: *Chiphragmolithus quadratus, Chiasmolithus grandis, Cyclococcolithus lusitanicus, Sphenolithus furcatolithoides, S. radians, Reticulofenestra umbilica* and *Campylosphaera dela.* The floras in the other two cores are similar but lack *Reticulofenestra umbilica.*

In Core 12, from 140.9 to 145.2 meters (462 to 476 feet), a hard buff sediment was found associated with the basalt. Although no planktonic foraminifera were found, a flora typical of the Middle Eocene *Chiphragmolithus quadratus* Zone of Hay in Hay *et al.* (1967), was found. Diagnostic species present are *Chiphragmolithus quadratus, Chiasmolithus grandis, C. gigas* (Bramlette and Sullivan), *Sphenolithus furcatolithoides, S. radians* Deflandre, *Campylosphaera dela* and *Cyclococcolithus lusitanicus.*

STRATIGRAPHY

Six subsurface lithologic units have been recognized in Hole 19, of which five could be traced regionally as formations. These units are:

3-19-1-1	Local Unit	Brown nannofossil clays.
3-19-1-2	Discovery Clay	Zeolitic red clays.
3-19-3-1	Endeavor Ooze	Marly nannofossil oozes, with *Braarudosphaera* Chalk Subunit (3-19-3-6).
3-19-4-1	Fram Ooze	Nannofossil chalk oozes.
3-19-5-3	Gazelle Ooze	Brown chalk and marl oozes.
3-19-7-6	Grampus Ooze	Foraminiferal nannofossil chalk oozes.

The Unit 3-19-1-1 is a local facies of a thin late Cenozoic veneer which is present on the lower flanks of the Mid-Atlantic Ridge. This brown clay, 10 centimeters

thick, consists of 20 per cent nannofossils in a zeolitic clay matrix and could be dated as Pleistocene. Although this unit could be considered a lithostratigraphic correlative of the surface veneer—a Pliocene nannofossil ooze at the adjacent Site 14—the authors have chosen not to complicate the already complex stratigraphy by elevating such thin local units to a formational rank. Such veneers of late Cenozoic sediments are obviously the time-stratigraphic equivalents, in regions below the carbonate-compensation depths, of the Albatross, Blake and possibly Challenger Oozes.

The Unit 3-19-1-2 consists of zeolitic red clays, deposited below the carbonate-compensation depth. Neither planktonic foraminifera nor nannofossils are present, and the calcium carbonate content is not discernable (less than 0.0 per cent) in all the samples analysed. Clay minerals, as X-ray analyses show, are mainly micas and kaolinite. Quartz and feldspars are also common. The zeolite content is variable, ranging from 5 to 50 per cent. Phosphate, in amounts of a few percentages, is present in some intervals. Red iron mineral, probably cryptocrystalline hematitic mineral, ranges from 15 to 30 per cent, and is responsible for the dark red brown or red gray colors of these clays. This unit can be correlated to the Unit 3-15-6-1 at Site 15, as the Discovery Clay. This formation at Site 15 includes marl ooze interbeds in addition to the red clays.

The Unit 19-3-1 consists of brown zeolitic nannofossil marl oozes, with some dark brown and dark reddish-brown nannofossil clays. This unit apparently includes sediments deposited either just above or just below the carbonate-compensation depth, so that the calcium carbonate content of the sediments varies from about 20 to over 65 per cent. Aside from nannofossils and clays, the sediments may include zeolites in percentages from traces to 5 per cent, some hematitic material, and traces of phosphates. Foraminifera are practically absent (sand fraction < 0.2 per cent). This unit is similar to the Discovery Clay at Site 14 on the one hand, and to the Endeavor Ooze at Site 15 on the other, being somewhat transitional in character. The authors chose to interpret the Unit 3-19-3-1 as the more marly facies of the Endeavor Ooze.

Intercalated within the Endeavor Ooze is the remarkable *Braarudosphaera* Chalk Subunit, serving as a middle Oligocene time marker. This 3-19-3-6 Subunit is only 0.5 centimeter thick here and consists of the same white crystalline chalk as that found at Sites 14 and 17.

Below the Endeavor Ooze is a sequence of nannofossil chalk and marl oozes, in various shades of brown. The subdivision of this sequence posed a considerable problem. The upper very pale brown oozes, relatively homogeneous in lithology, are obviously a correlative of the Fram Ooze. The lower foraminiferal oozes, directly overlying the basement and with colors darkening with depth, have all the characters of the Grampus Ooze. However, the interbedded chalk and marl oozes in the middle are sufficiently different from both. Only after studying the stratigraphy of Site 20, did the authors realize that this middle interval should be separated as a unit to be correlated with the Unit 3-20C-3-1 as the Gazelle Formation.

The authors included in the Unit 3-19-4-1 only the upper very pale brown and light yellowish-brown nannofossil chalk oozes. Aside from terrigenous components, which average less than 25 per cent, the oozes are made up of calcareous nannofossils. Foraminifera are very rare, and the sand fraction is commonly less than 1 per cent. Thus defined, the unit can be readily correlated with the Fram Ooze at Sites 14 and 17.

The middle Unit 3-19-5-3 includes the sequence of interbedded chalk and marl oozes. This unit is separated from above by a sharp contact at 3-19-5-3, 43 centimeters, where a light yellowish-brown chalk ooze of the Fram Formation overlies a yellow brown zeolitic marl ooze. The lower contact is sharp at 3-19-7-6, 57 centimeters, between a yellowish-brown and an Eocene brownish-yellow chalk ooze. The oozes of this unit are mainly yellowish-brown or light yellowish-brown in color, although some intercalations of very pale brown ooze are present. Nannofossils still constitute the bulk of the sediments, the non-carbonate content varies from about 50 per cent in a marl ooze to 20 per cent in a chalk ooze. The color is related to the presence of a few percentages of hematitic materials. Zeolite is recognized, together with traces of phosphate, in the marl ooze just below the sharp top contact. As mentioned above, this unit constitutes the Gazelle Formation at Site 19, where it is more calcareous than its correlative at Site 20 farther away from the axis of the Mid-Atlantic Ridge.

The underlying Unit 3-19-7-6 consists mainly of nannofossil chalk oozes, colored in various shades of brown. Except for the top meter of brownish-yellow nannofossil chalk ooze just below the unconformity, the sequence shows a gradual color change from very pale brown, to light yellowish-brown, to yellowish-brown. This increase in the darkness of shades, accompanied by a parallel increase of the foraminiferal content with depth, is characteristic of the Grampus Ooze, which is almost invariably the oldest formation above the basalt basement. The color shades reflect the amount of cryptocrystalline hematitic material, which ranges from traces to 10 per cent. Although this unit is, on the whole, slightly darker than the overlying Fram Ooze, there is not much difference in the non-carbonate content between these two formations. Yet, the foraminifera content is appreciably different; 1 to 5 per cent identifiable foraminifera could commonly

TABLE 2
Stratigraphy Site 19

Age	Cored Interval (m)	Formation Name	Probable Interval (m)	Probable Thickness (m)	Description
Pleistocene	0-0.8	Local unnamed Unit 3-19-1-1	0-0.8	0.8	Brown nannofossil clay, 20 per cent nannofossils.
?	0.8-18.3	Discovery Red Clay 3-19-1-2	0.8-26.0	25.2	Dark red brown and red gray zeolitic clay, barren of fossils. 30 to 70 per cent clay, 5 to 50 per cent zeolite, 15 to 30 per cent hematite and opaques, trace to 5 per cent phosphates.
Upper Oligocene	36.6-45.7	Endeavor Ooze 3-19-3-1 with 3-19-3-6 Subunit	26-50	24.0	Brown zeolitic nannofossil marly chalk oozes, marl oozes with dark brown and red brown interbeds of zeolitic clays, hematite and clay common, zeolite 1 to 5 per cent. 3-19-3-6 Subunit consists of platelets and fragments of the nannofossil *Braarudosphaera rosa*–color white, 0.5 centimeters thick.
Upper to Lower Oligocene	56.7-65.9 75.6-79.1	Fram Ooze 3-19-4-1	50.0-79.1	29.1	Very pale brown and light yellow brown chalk oozes. Foraminifera very rare.
Upper and Middle Eocene	79.1-103.4	Gazelle Formation 3-19-5-3	79.1-103.4	24.3	Brown nannofossil chalk and marl oozes. Foraminifera extremely rare. Zeolitic at top. 20 to 50 per cent non-carbonate matter.
Middle Eocene	103.4-140.9	Grampus Ooze 3-19-7-6	103.4-140.9	37.5	Very pale brown, light yellow brown and yellow brown nannofossil chalk oozes with hematite and opaques 0 to 10 per cent, foraminifera 1 to 5 per cent with 12 centimeters of foraminiferal sand at 122.6 meters b.o.b.
?	140.9-145.2	Basement 3-19-12-1	140.9-?	?	Very dark gray vesicular aphanitic basalt, pillow basalts, and pillow breccias, with euhedral calcite growing in veins and openings.

be seen under microscope in the lower unit. One foraminiferal ooze layer, 12 centimeters thick, containing some 50 per cent foraminifera in addition to nannofossils and clays, is present in 3-19-9, core catcher. Also noted was the presence of a large nannofossil, *Thorasosphaera* sp., spherical or oblong in shape, in these Middle Eocene deposits, making up 10 per cent of the bulk volume of some intervals.

Directly underlying the Grampus Ooze is the basalt basement. This basalt is definitely an extrusive flow. The rock has been deeply weathered with an irregular upper surface, the depressions being filled by soft sediments. The randomly oriented, steeply dipping contacts are apparently chilled margins of basalt pillows. Intercalated pillow breccias consist of angular glass and aphanitic basalt fragments in a crystalline calcite matrix. The latter may represent recrystallized sediments trapped by the flow.

The formational boundaries were drawn on the basis of the data presented below:

Base of Local Unit	at	0.1 meters	Base of nannofossil clay.
Base of Discovery Clay	at	26.0 meters	Mid-point of uncored interval.
Base of Endeavor Ooze	at	50.0 meters	Mid-point of uncored interval.
Base of Fram Ooze	at	79.1 meters	Lithological change described in text.
Base of Gazelle Ooze	at	103.4 meters	Disconformity described in text.
Base of Grampus Ooze	at	140.9 meters	Basement.

Such a subdivision permits the following estimates of the sedimentation rates:

Local Unit plus Discovery Clay	26m/26 m.y.,	or	0.1 cm/t.y.
Endeavor Ooze	24m/7 m.y.,	or	0.35 cm/t.y.
Fram Ooze	29.1m/5 m.y.,	or	0.6 cm/t.y.
Gazelle Formation	24.3m/8 m.y.,	or	0.3 cm/t.y.
Grampus Ooze	37.5m/3.1 m.y.,	or	1.2 cm/t.y.

These rates are comparable to those at other sites, and the general pattern of about 1 cm/t.y. for foraminiferal calcareous oozes and 0.1 cm/t.y. for red clays is confirmed by the data here.

A summary of the stratigraphy at Site 19 is included in Table 2.

PHYSICAL PROPERTIES

Natural Gamma Radiation

Natural gamma radiation at Site 19 spanned zero to 2100 counts, with a norm of 700 counts/1.25 minutes/7.6-centimeter core segment (Figures 2A and 3A-15A). In general, averaged counts from each core decreased irregularly with increasing depth. Highest gamma counts of 2100, with an average of 1900 counts, were obtained from the Discovery Clay, which contained gamma ray emitting phosphates in addition to clay minerals and zeolites. Endeavor Ooze emitted intermediate gamma counts, and it contained clay minerals and zeolites, with only a trace of phosphates. Below these formations, in the Fram and Gazelle Oozes, was a sequence of nannoplankton oozes with little or no clays, zeolites, or phosphates; thus, they emitted low gamma counts averaging 600 to 700. In general, the Grampus Ooze, averaging about 300 to 400 counts, had smaller radiation values than the Fram and Gazelle Oozes.

Porosity, Wet-Bulk Density and Water Content

At Site 19 the wet-bulk densities, water contents, and porosities ranged from 1.25(?) g/cc to 1.98 g/cc, 26 per cent to 56 per cent, and 36 per cent to 84(?) per cent, averaging about 1.73 g/cc, 41 per cent, and 55 per cent (Figures 2A and 3A-15A). In general, core averaged porosities irregularly decreased with increasing depth through the Discovery Clay, the Endeavor and Fram Oozes, and the upper part of the Gazelle Ooze. Porosities varied irregularly in the remaining Gazelle and Grampus Oozes. This may be in part caused by compaction, but for the most part it is a lithological change from fine-grained to slightly coarser-grained sediments with a different grain size distribution.

Low sediment wet-bulk densities (about 1.50 g/cc) were observed in some of the clay bearing formations. The nanno chalk oozes had higher wet-bulk densities ranging up to 2.00 g/cc. Porosity inversely correlated to wet-bulk density and sound velocity. Penetrometer measurements and natural gamma radiation had a very crude direct correlation to porosity.

Sediment Sound Velocity

Sediment sound velocities at Site 19 ranged from 1.49 to 1.61 km/sec, with an average of 1.53 km/sec (Figures 2A and 3A-15A). In general, core averaged velocities increased with increasing depth through the Discovery Clay, Endeavor Ooze, Fram Ooze, and Gazelle Ooze; and, it decreased slightly in the Grampus Ooze. Averaged velocities had an apparent direct correlation with wet-bulk density, and an indirect correlation with porosity, and to a lesser extent, the penetrometer measurements and (questionably) natural gamma radiation. The high porosity red clay formations tended to have lower velocities, near that of sea water. The nanno

chalk oozes, with high wet-bulk densities and lower porosities, typically had higher velocities of 1.53 to 1.61 km/sec. These cores were disturbed during coring; thus, these velocities may not be representative of *in situ* values after temperature-pressure corrections.

Penetrometer

Penetrometer measurements at Site 19 had a scope of 25×10^{-1} millimeters to complete penetration (Figures 2A and 3A-15A). The mean of the values with incomplete penetration was 88×10^{-1} millimeters. In general, core averages lessened with greater depth and had an apparent indirect relationship to wet-bulk density and sound velocity, and an apparent direct correlation to porosity, and (questionably) natural gamma radiation. A direct correlation to natural gamma radiation, of course, is contradictory to that observed at some previous sites.

Thermal Conductivity

As was inferred for Site 18, values for Site 19 also increased with depth over most of the hole. From the surface to a depth of 100 m. the measured values increased relatively uniformly from 2.0 to 3.2×10^{-3} cal/°C cm sec. Somewhat lower values, about 2.9 to 3.0×10^{-3} cal/°C cm sec, were measured from 110 to 130 m. The highest value was measured on a core taken near 140 m. depth.

Interstitial Water Salinity

At Site 19 the interstitial water salinities of four samples were measured. These ranged from 34.7 to 35.2 ppt. With increasing depth they were 35.2, 34.9, 35.2 and 34.7 ppt, which were collected at the respective depths of 7, 80, 110 and 137 meters (23, 262, 361 and 449 feet). Stratigraphically, these samples were from the Pleistocene to upper Oligocene Discovery Clay, upper Eocene Fram Ooze, middle Eocene Gazelle Ooze, and middle Eocene Grampus Ooze, respectively. Again, these samples had only small salinity variations.

REFERENCES

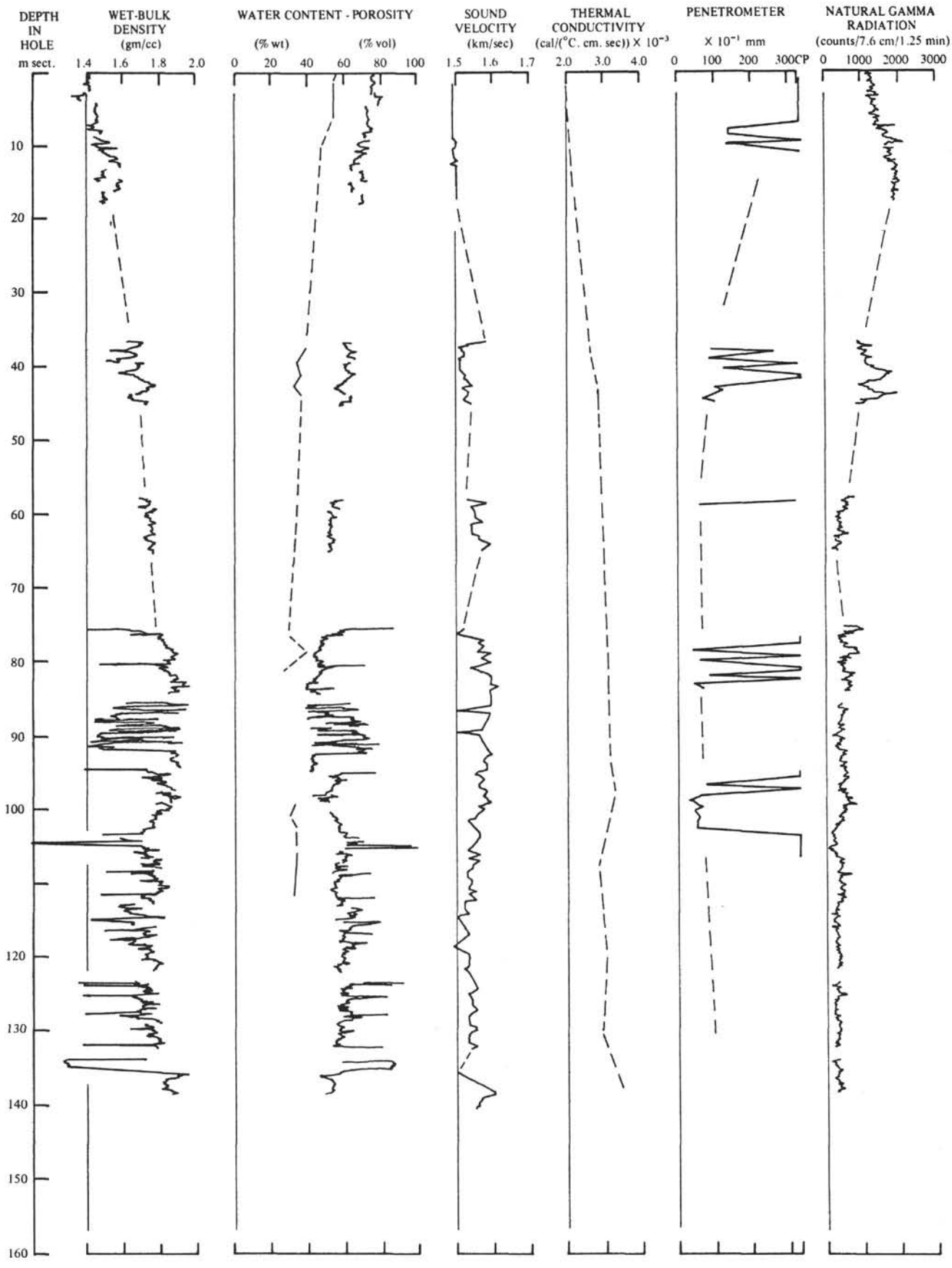
See consolidated list at the end of Chapter 13.

THE CORES RECOVERED FROM SITE 19

The following pages present a graphic summary of the results of drilling and coring at Site 19.

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 19. 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 the cores recovered from Hole 19.*

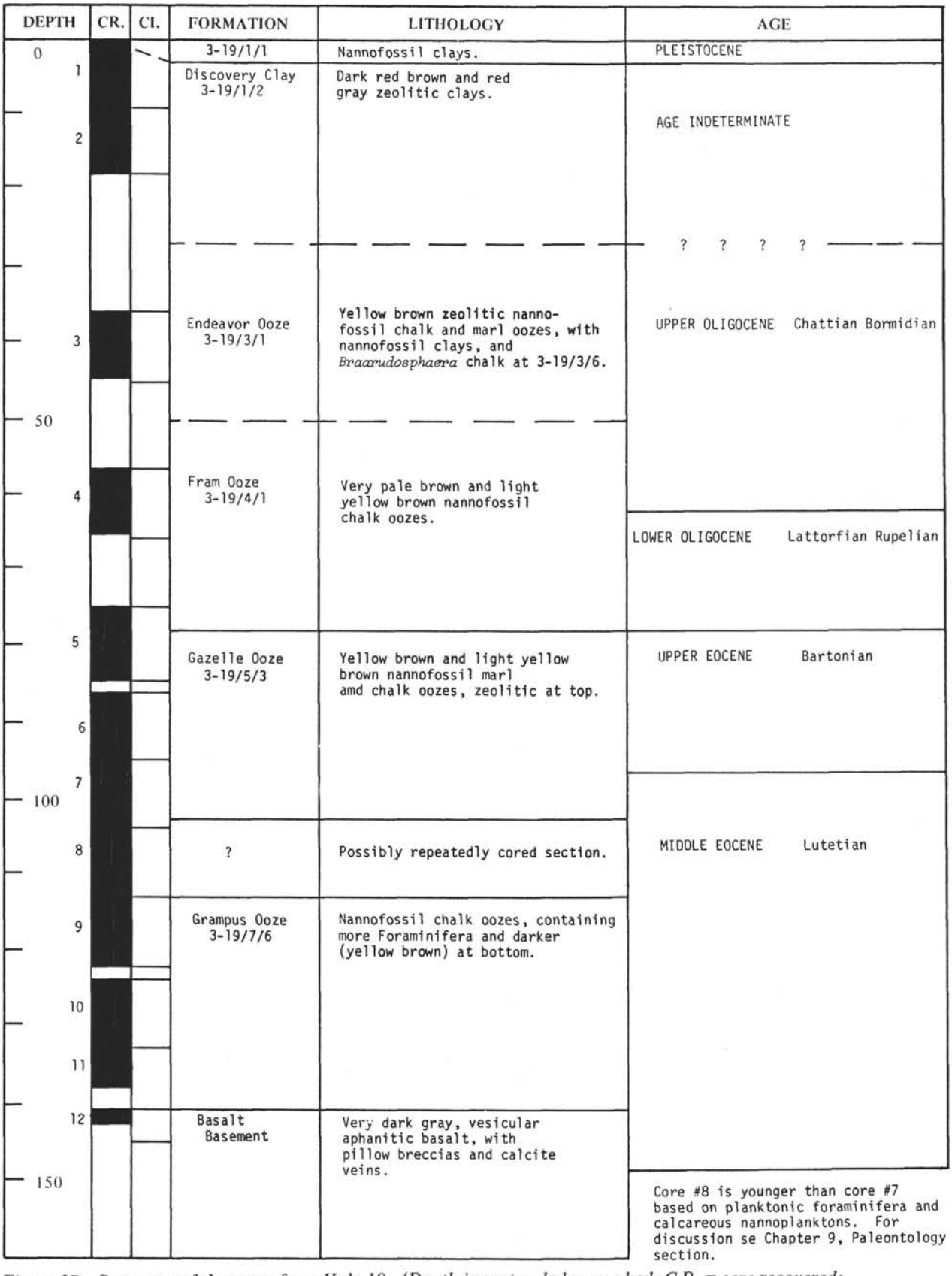
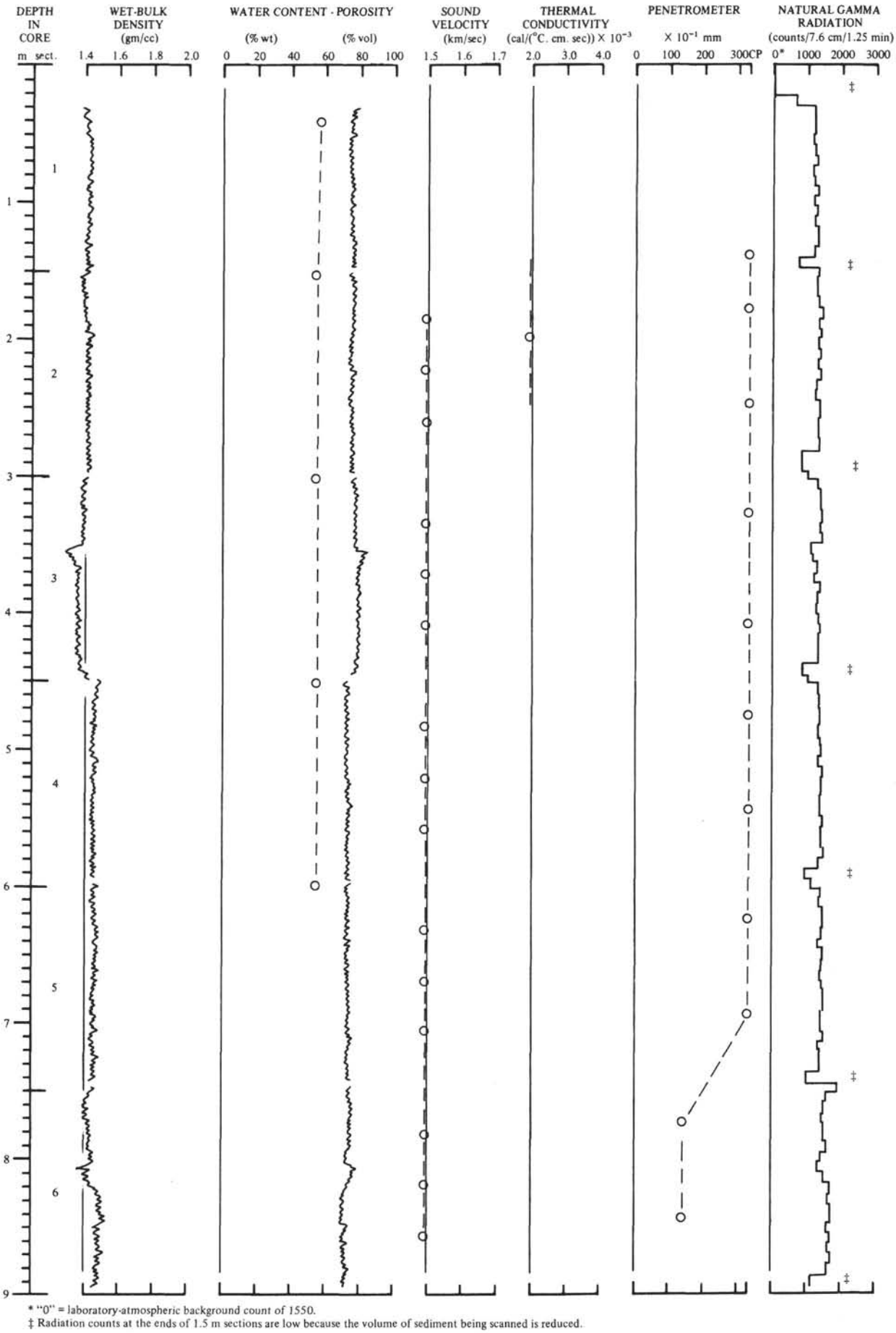


Figure 2B. *Summary of the cores from Hole 19. (Depth in meters below sea bed; C.R. = core recovered; C.I. = cored interval.)*



* "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 3A. *Physical properties of Core 1, Hole 19.*

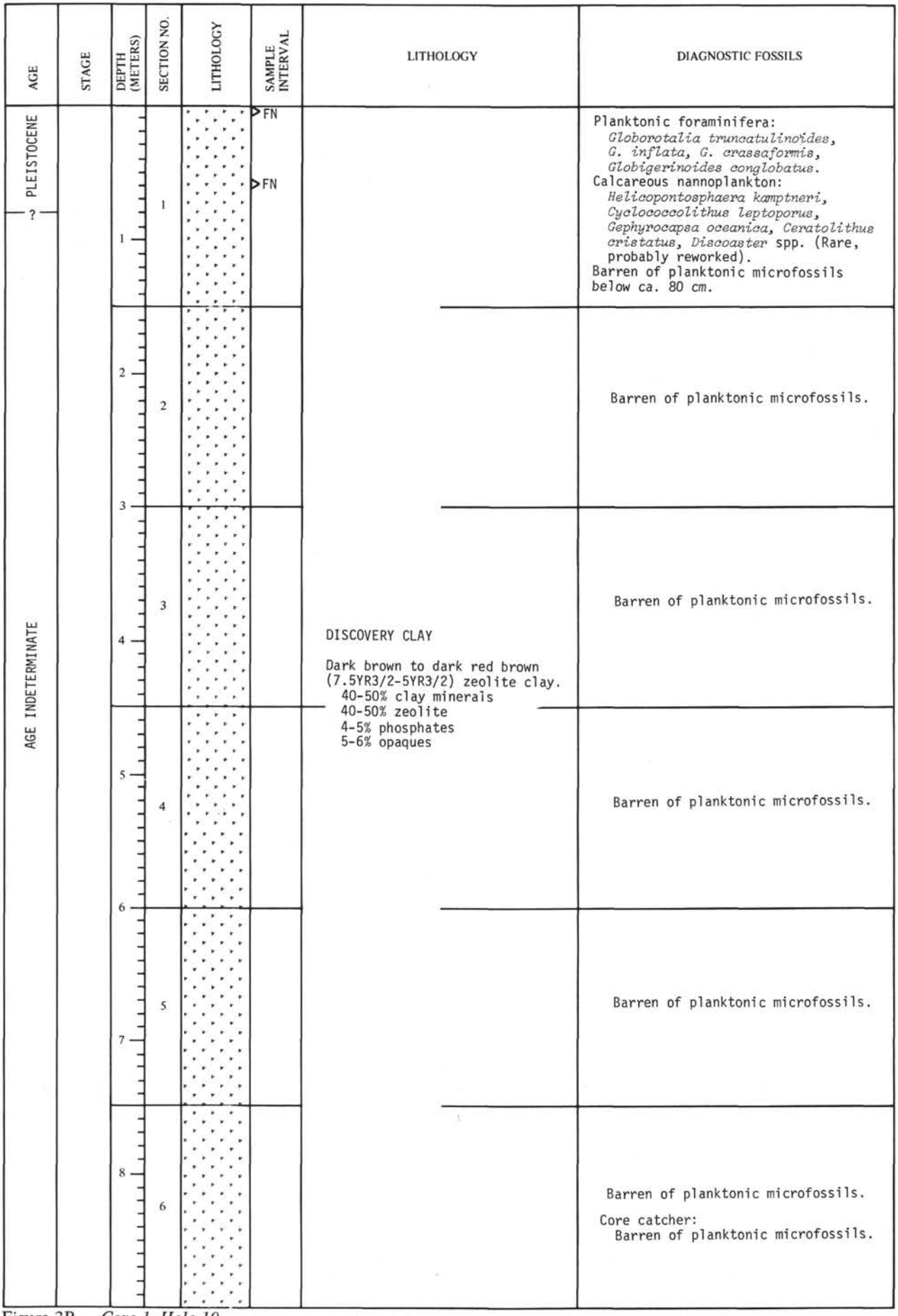


Figure 3B. *Core 1, Hole 19.*

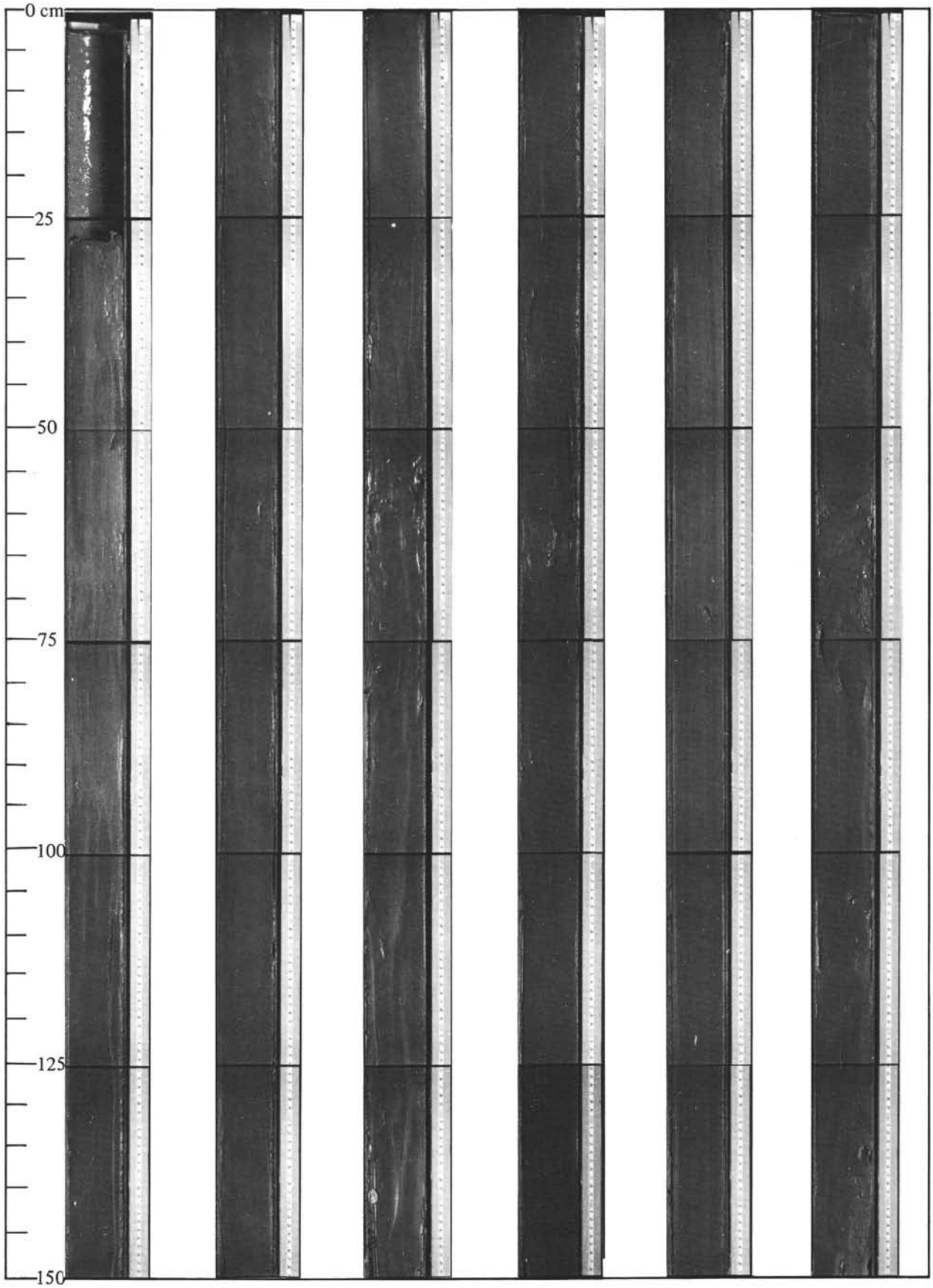


Plate 1. *Core 1, Hole 19.*

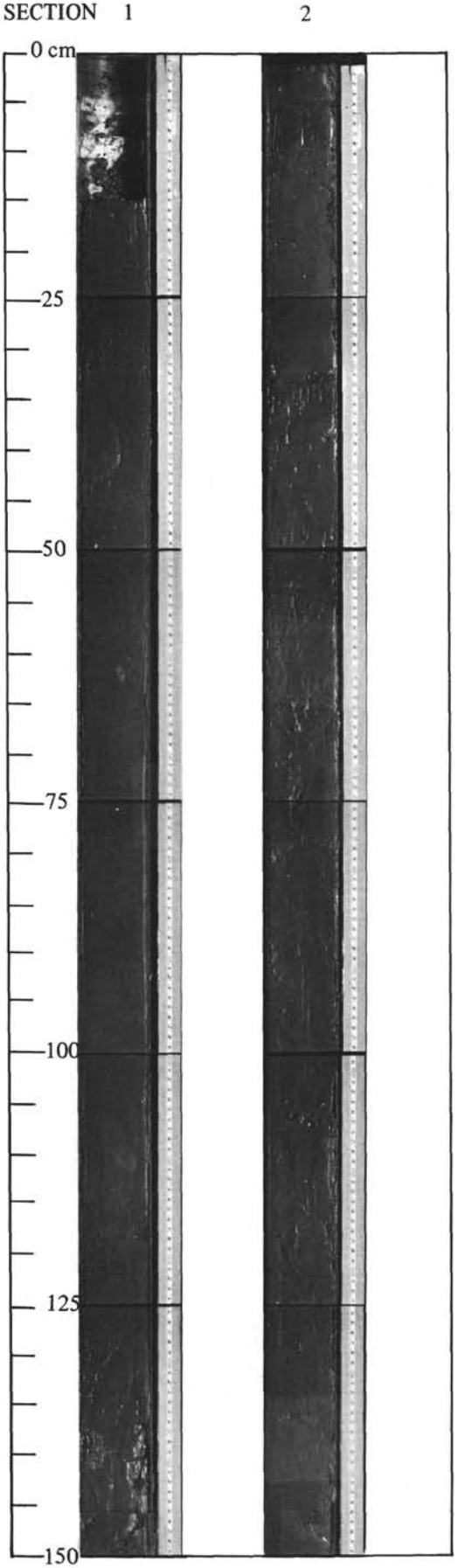
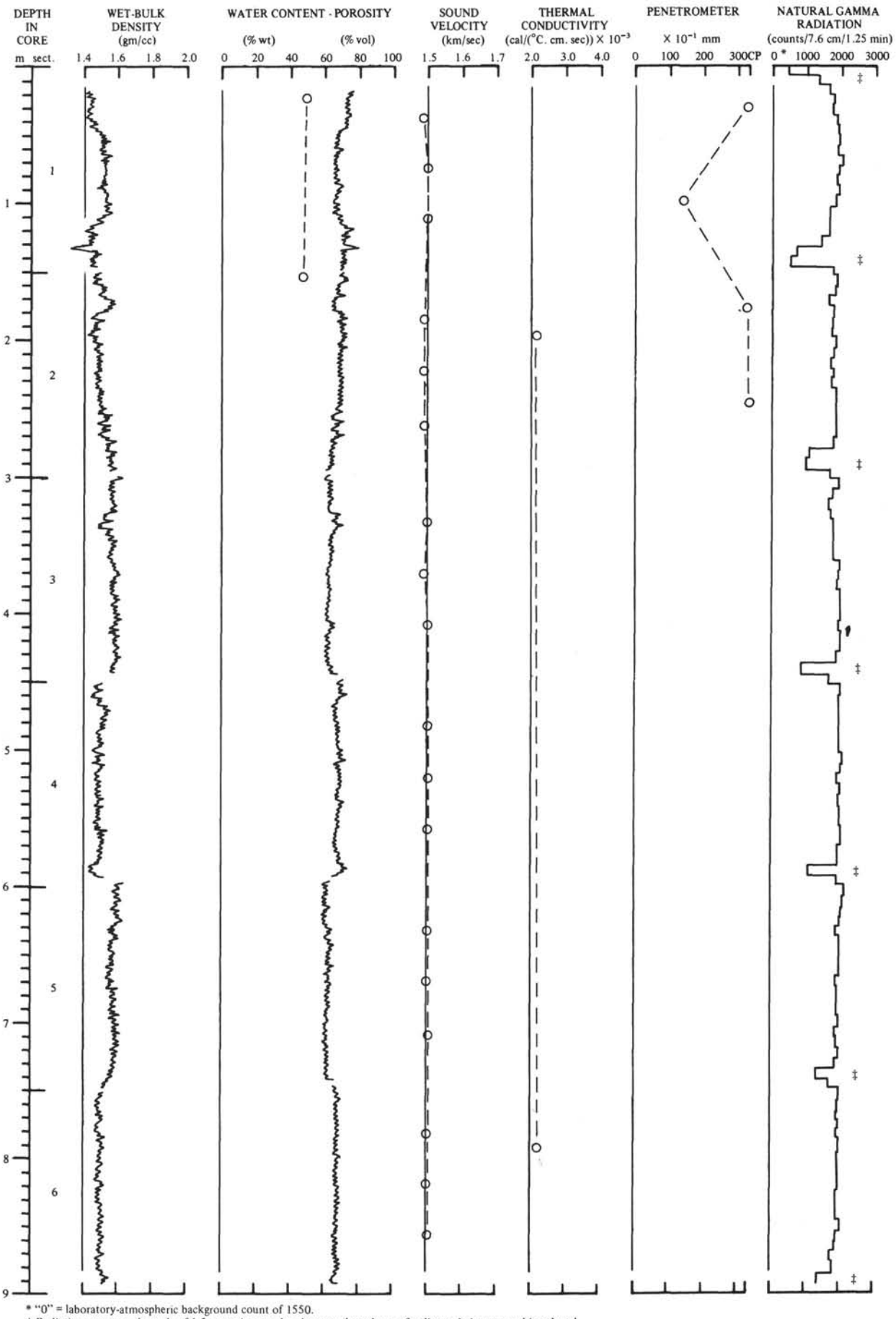


Plate 2. *Core 2, Hole 19.*



* "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 4A. *Physical properties of Core 2, Hole 19.*

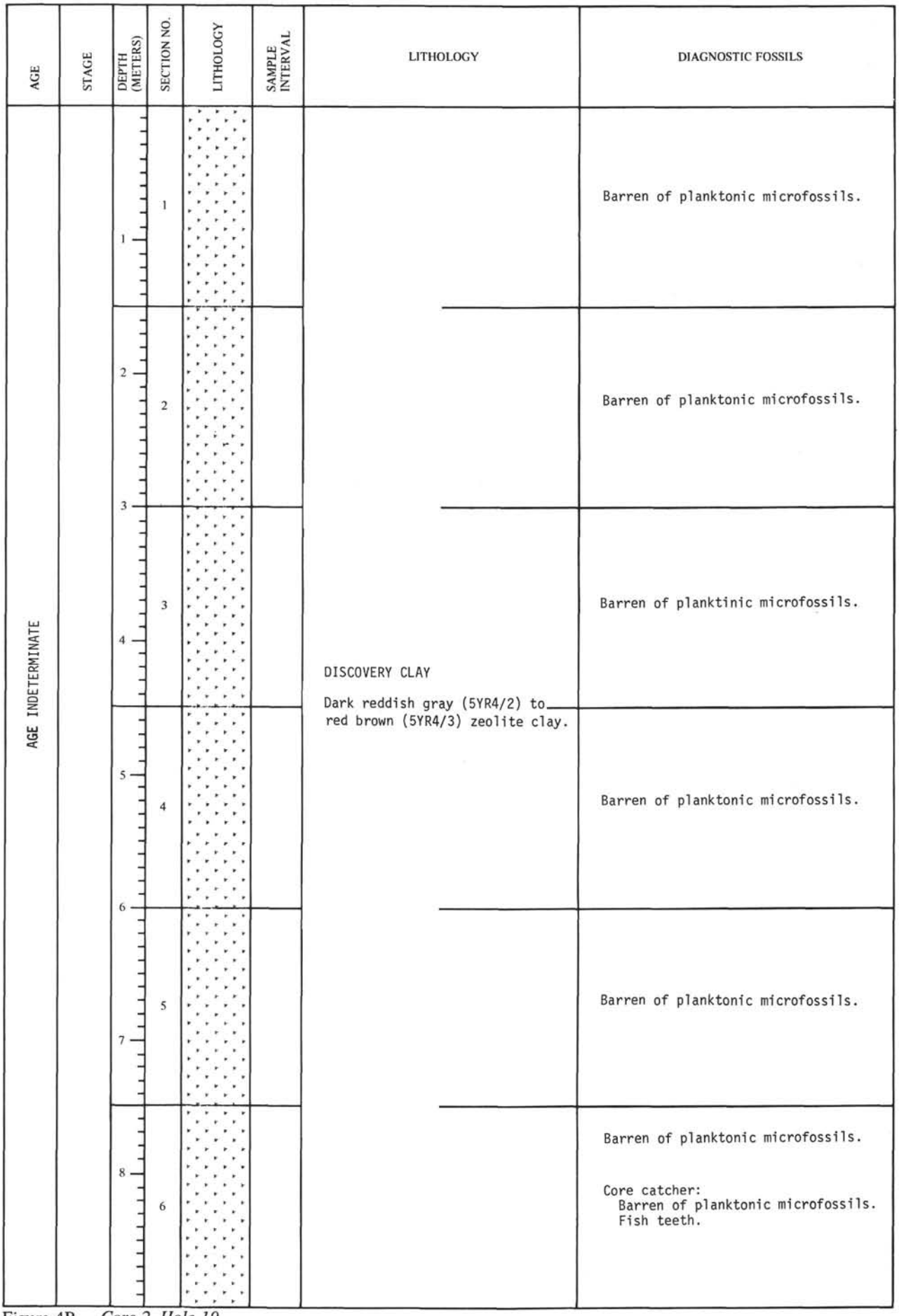
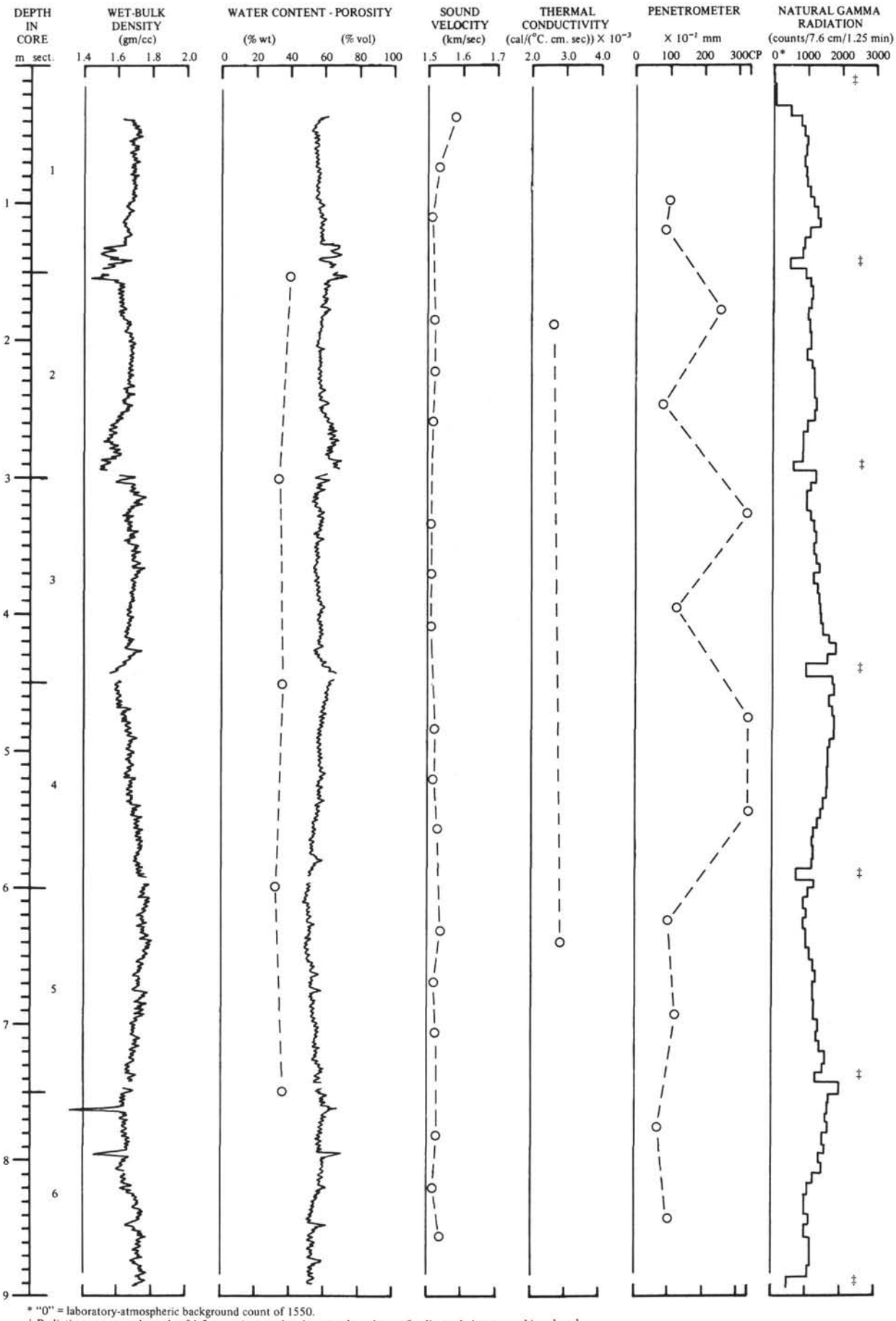


Figure 4B. *Core 2, Hole 19.*



* "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 5A. *Physical properties of Core 3, Hole 19.*

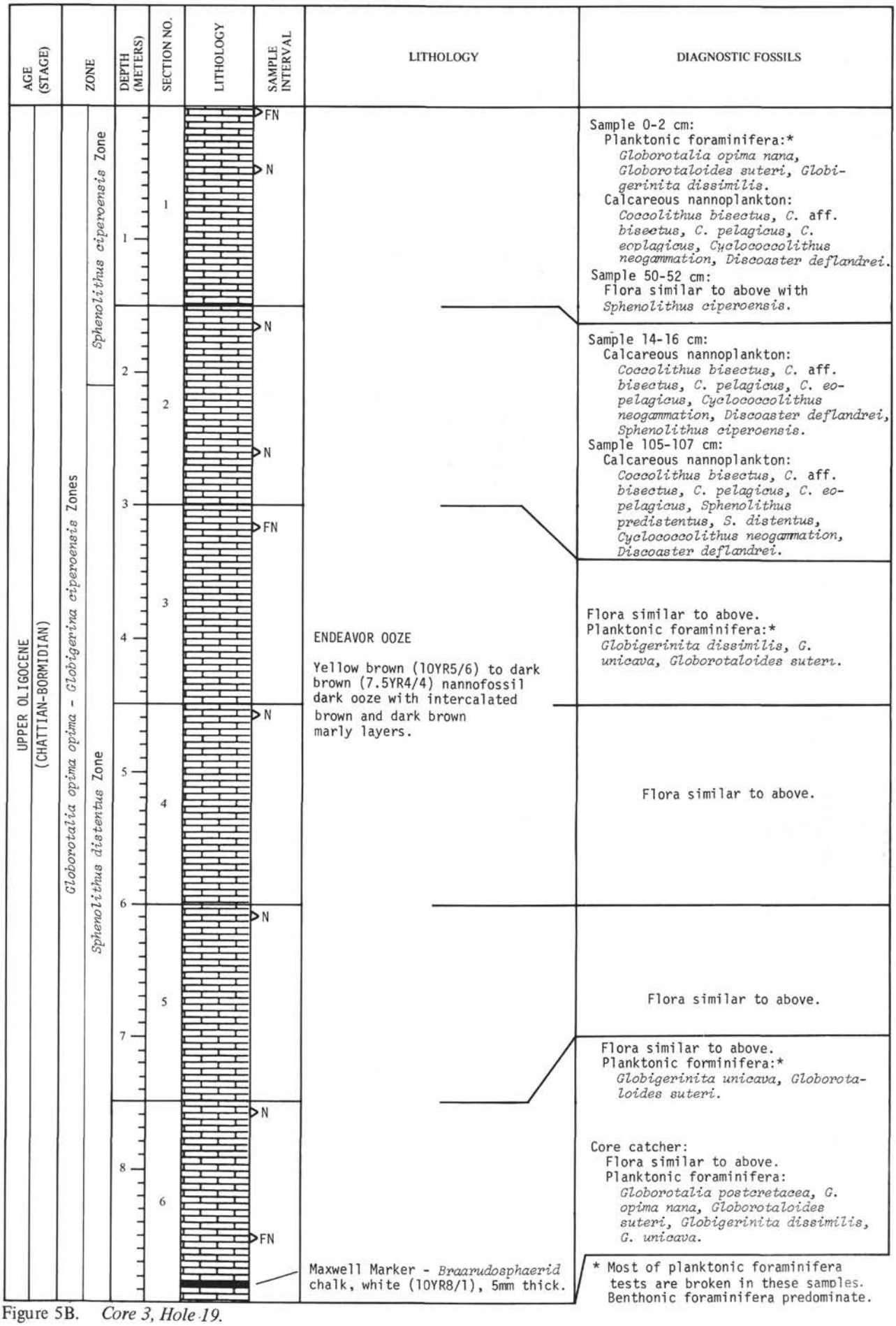


Figure 5B. *Core 3, Hole 19.*

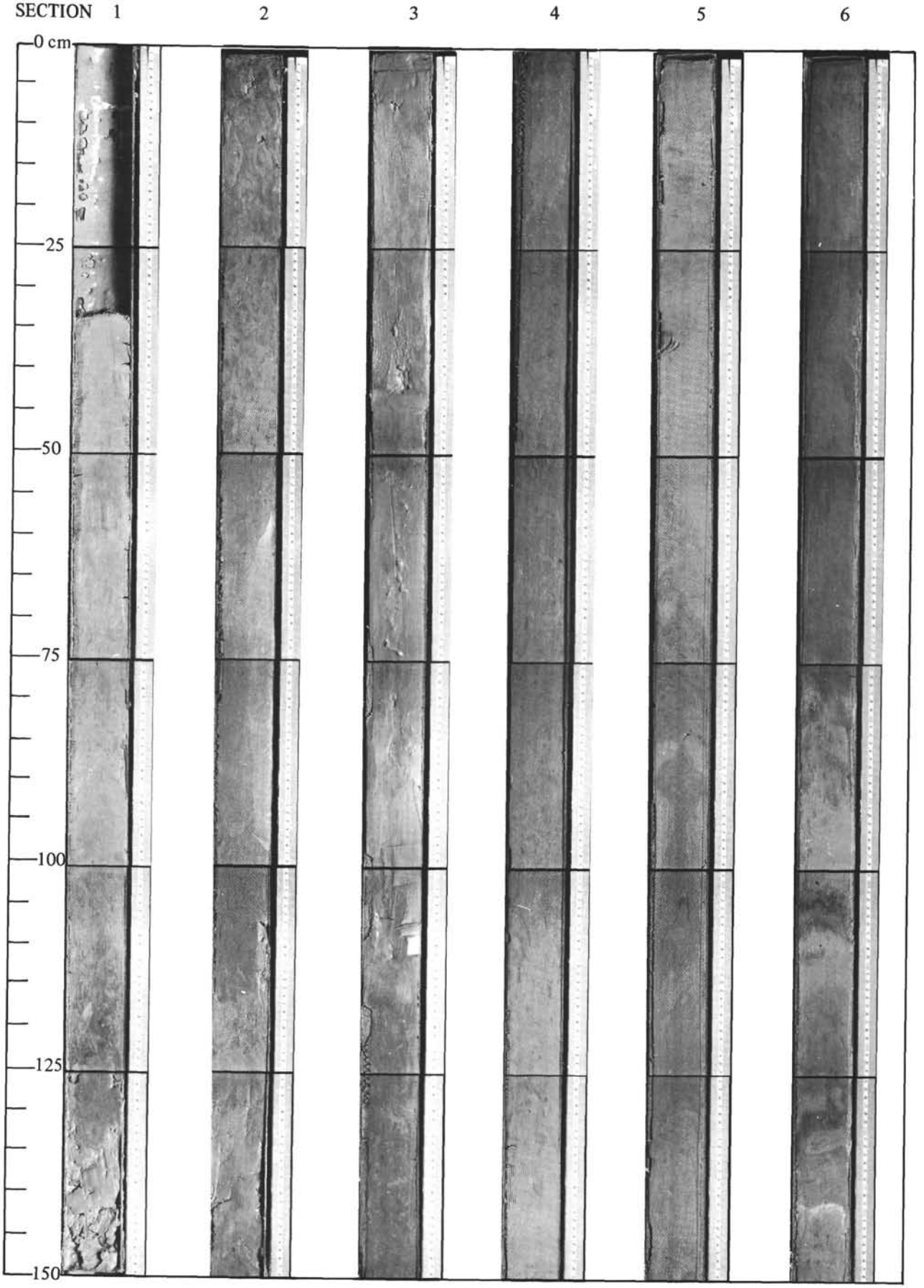


Plate 3. *Core 3, Hole 19.*

SECTION 2

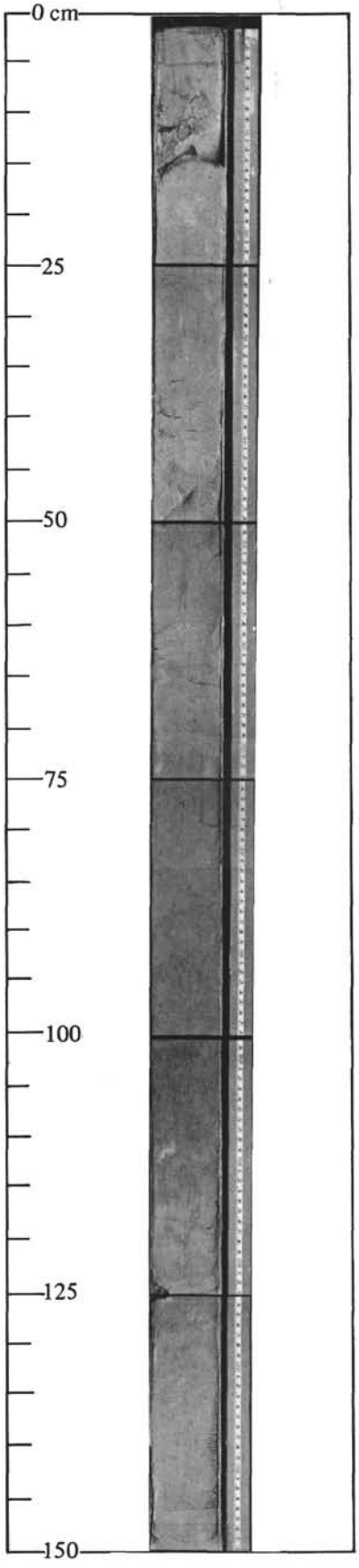


Plate 4. *Core 4, Hole 19.*

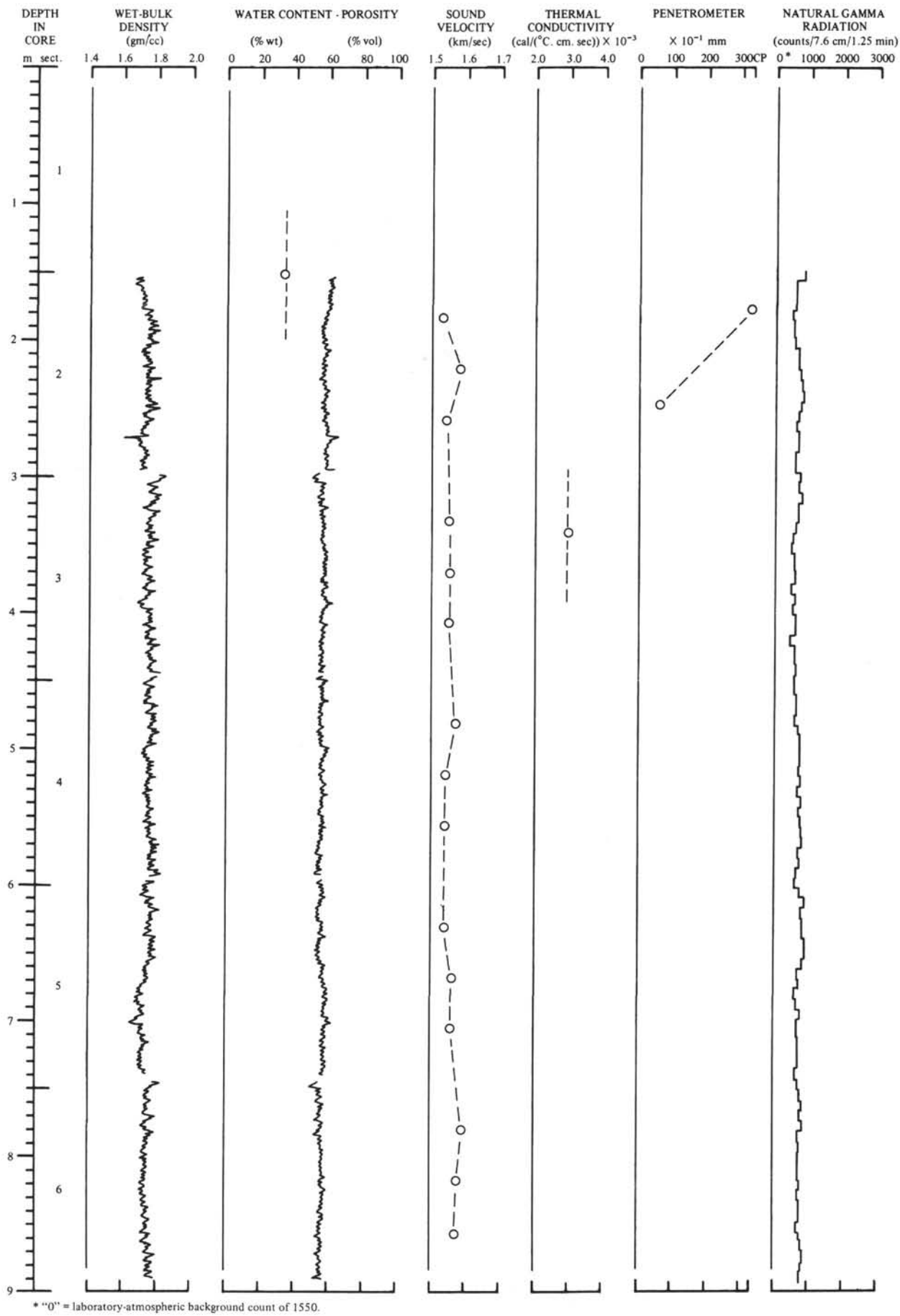


Figure 6A. *Physical properties of Core 4, Hole 19.*

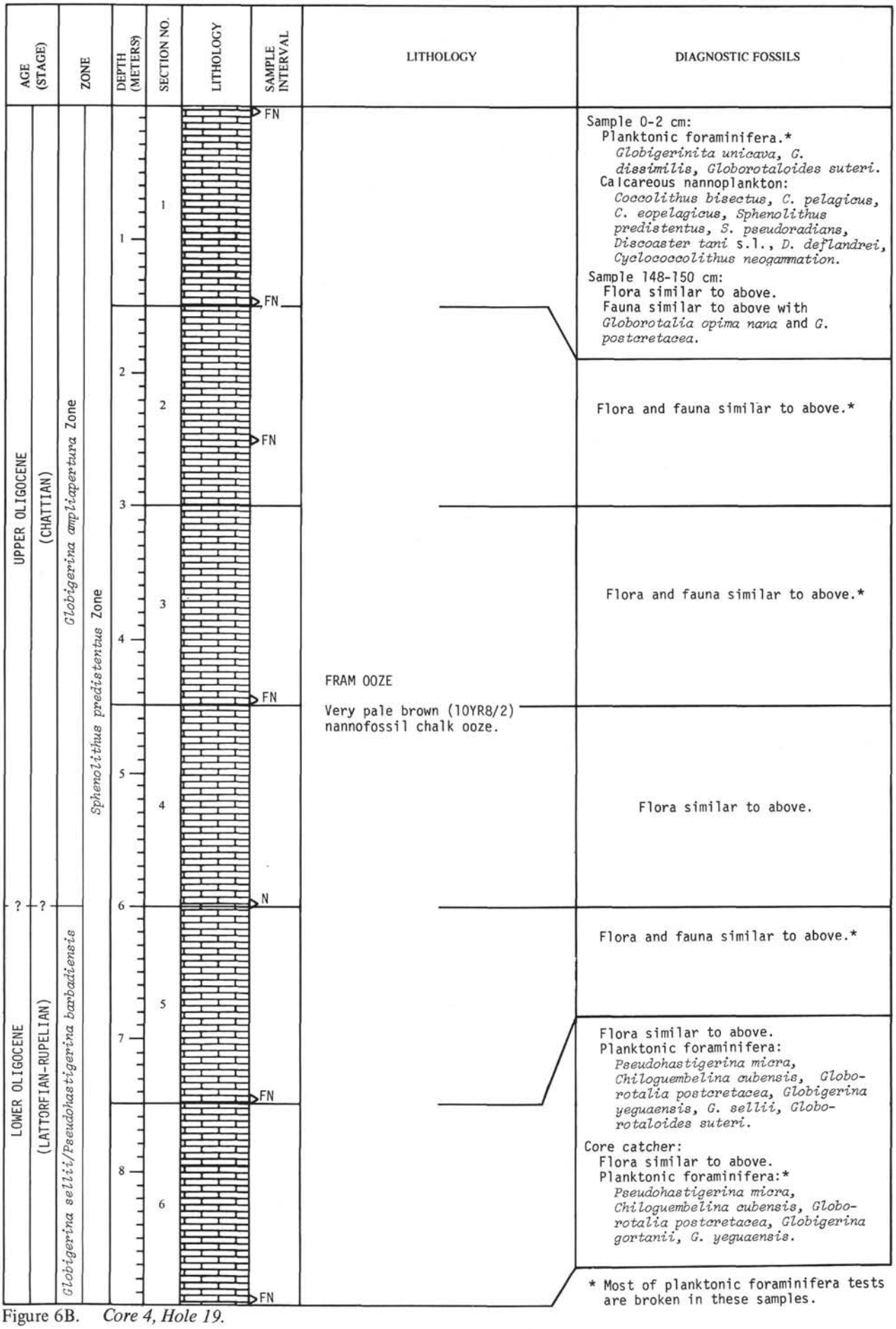
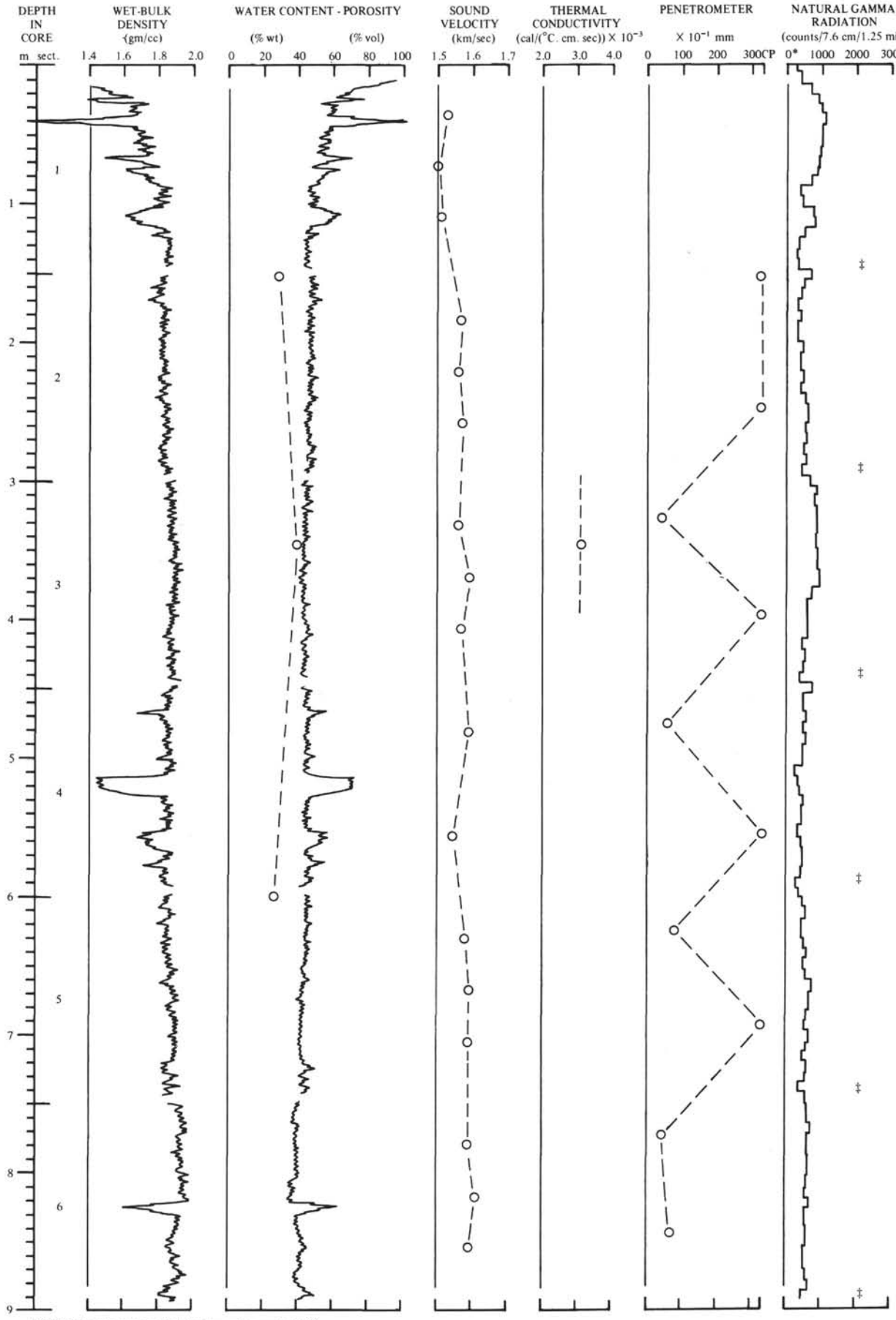


Figure 6B. *Core 4, Hole 19.*



* "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 7A. *Physical properties of Core 5, Hole 19.*

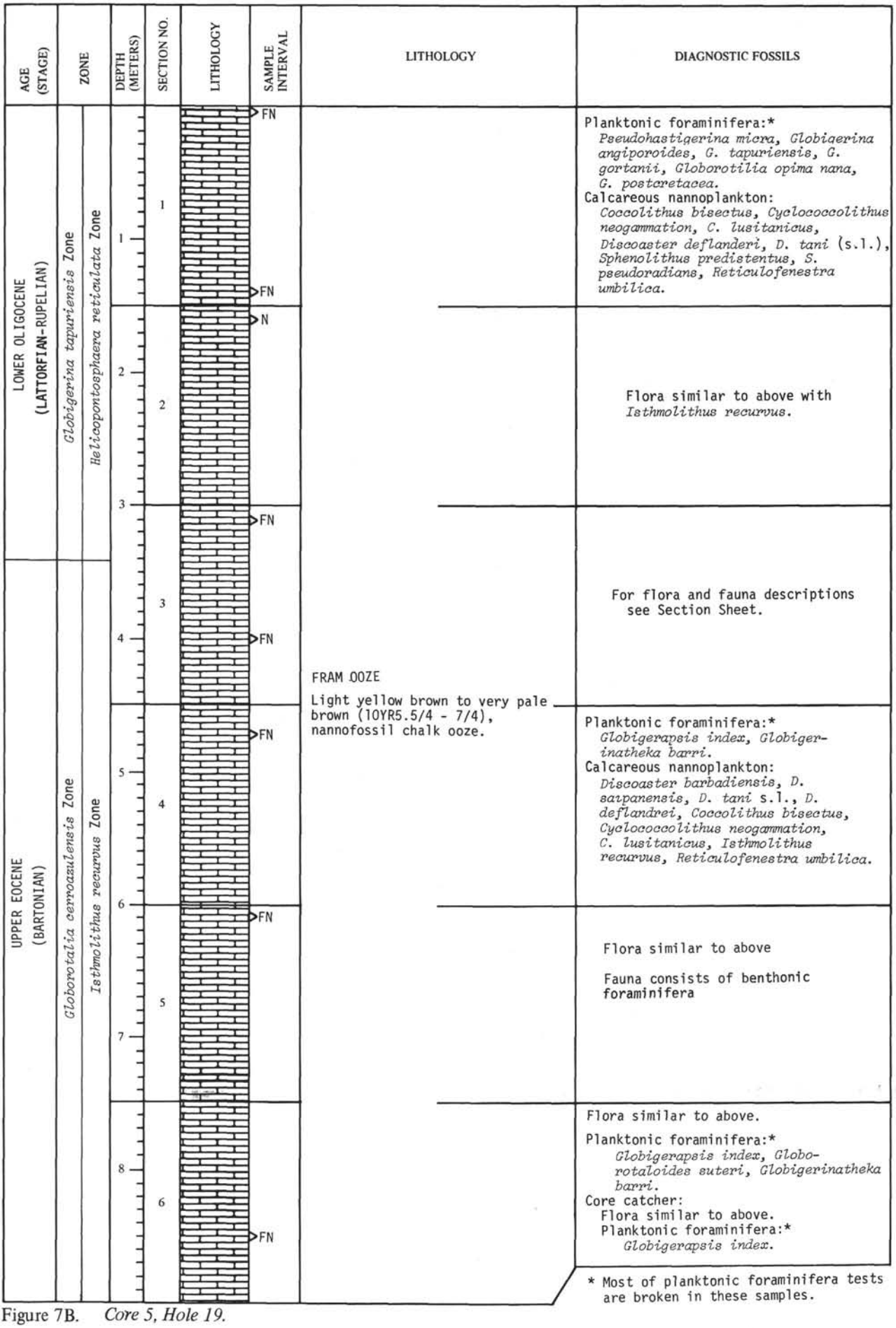


Figure 7B. *Core 5, Hole 19.*

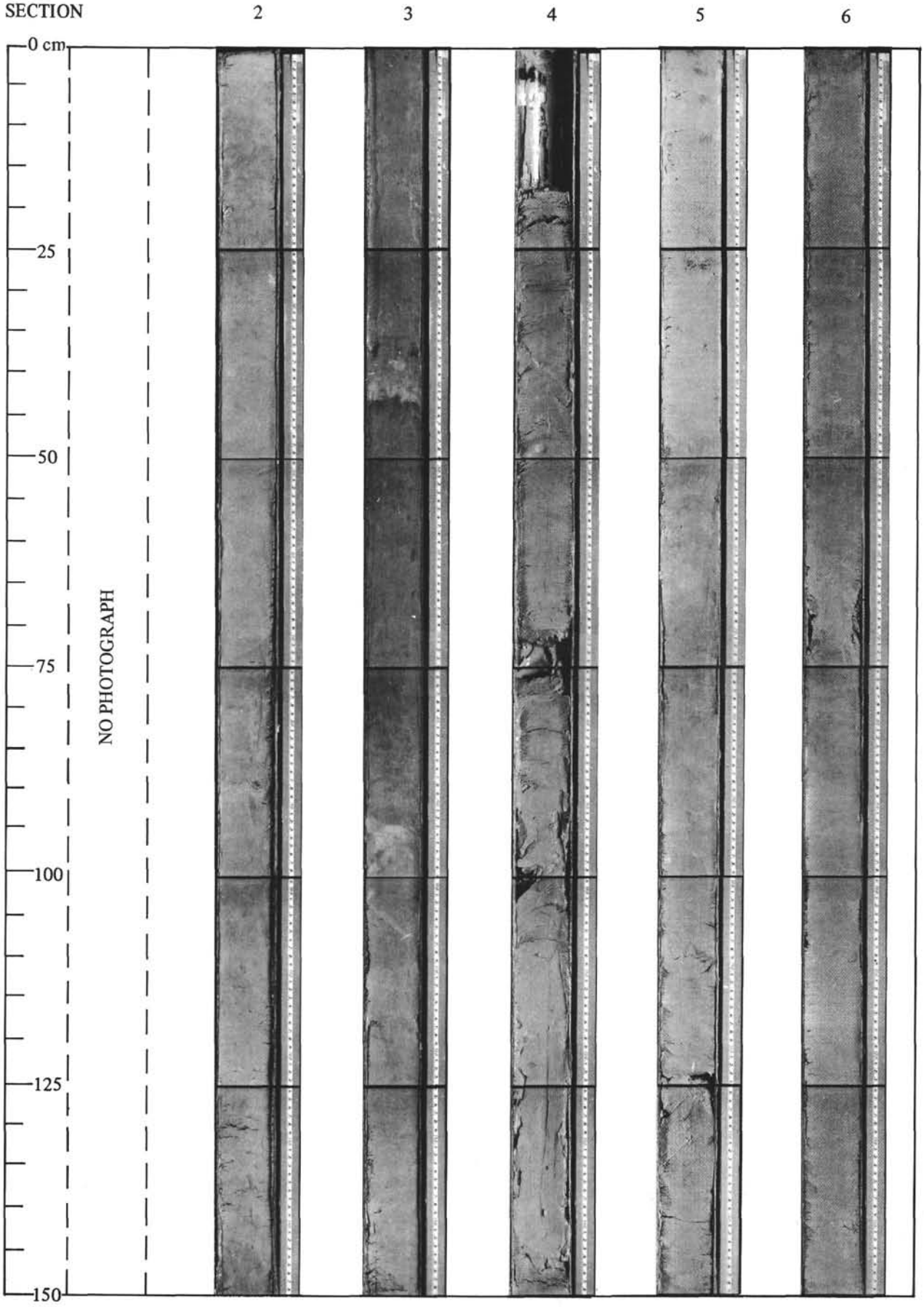


Plate 5. *Core 5, hole 19.*

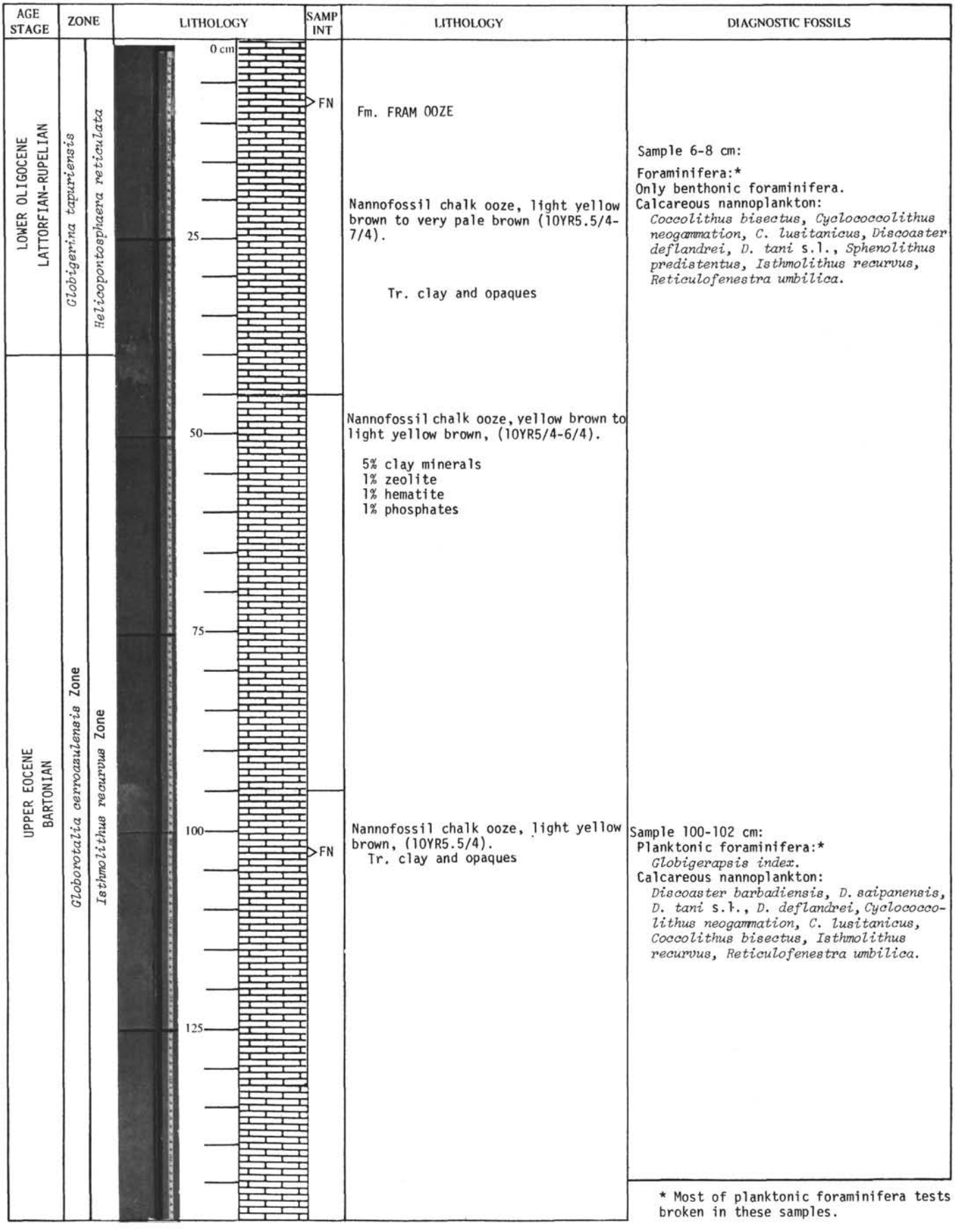
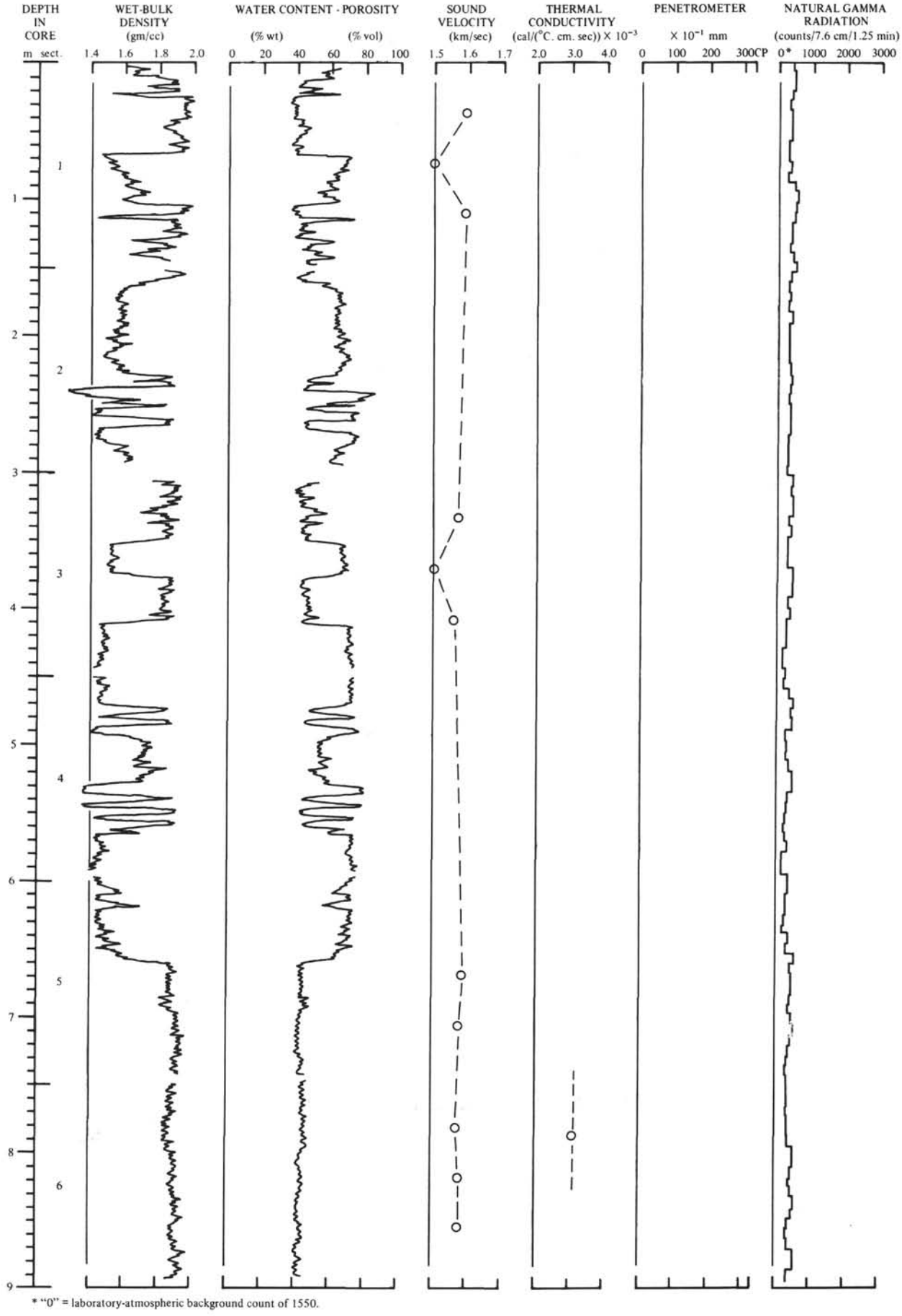


Figure 8. *Summary of Section 3, Core 5, Hole 19.*



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

Figure 9A. *Physical properties of Core 6, Hole 19.*

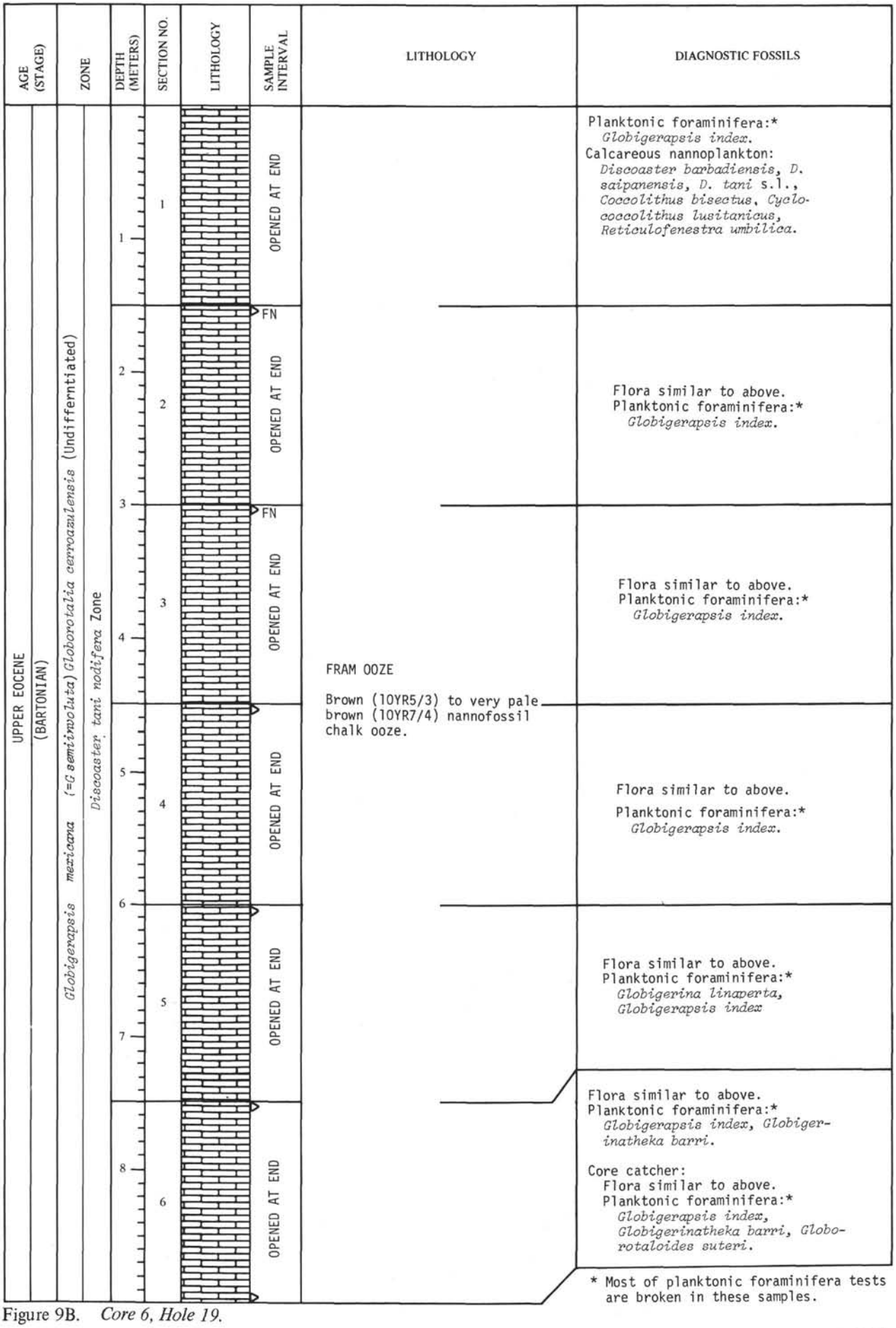
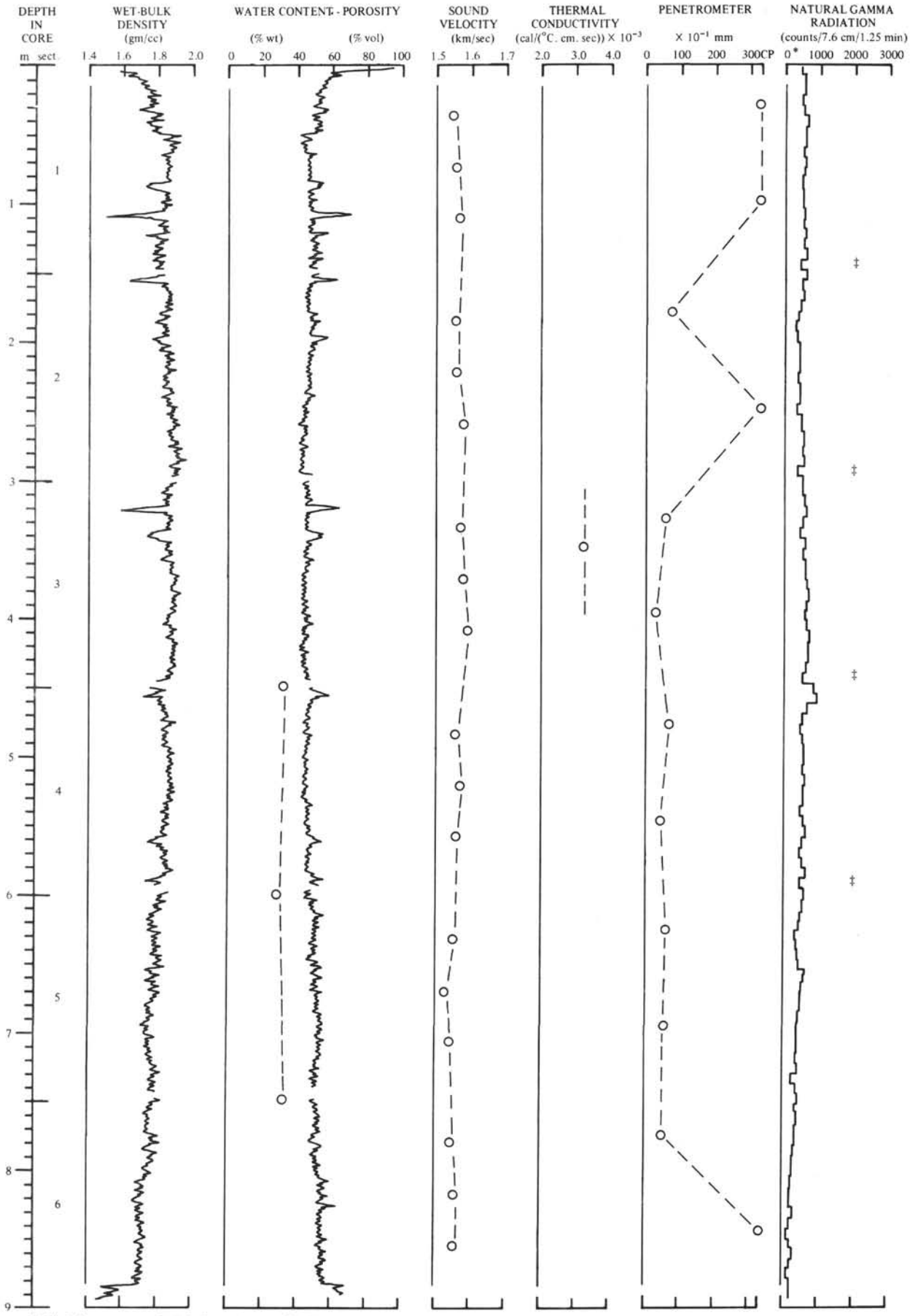


Figure 9B. *Core 6, Hole 19.*



* "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 10A. *Physical properties of Core 7, Hole 19.*

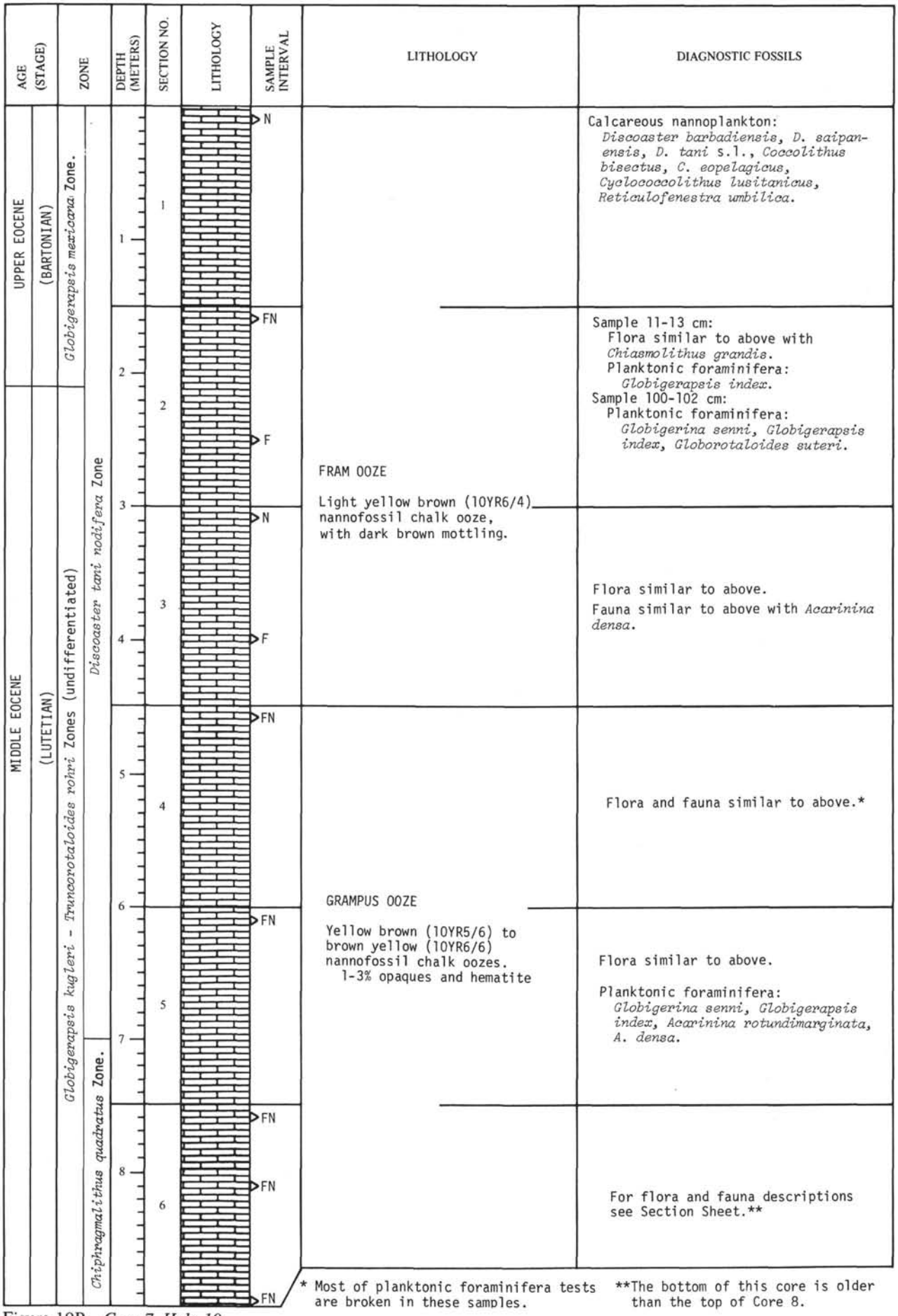


Figure 10B. *Core 7, Hole 19.*

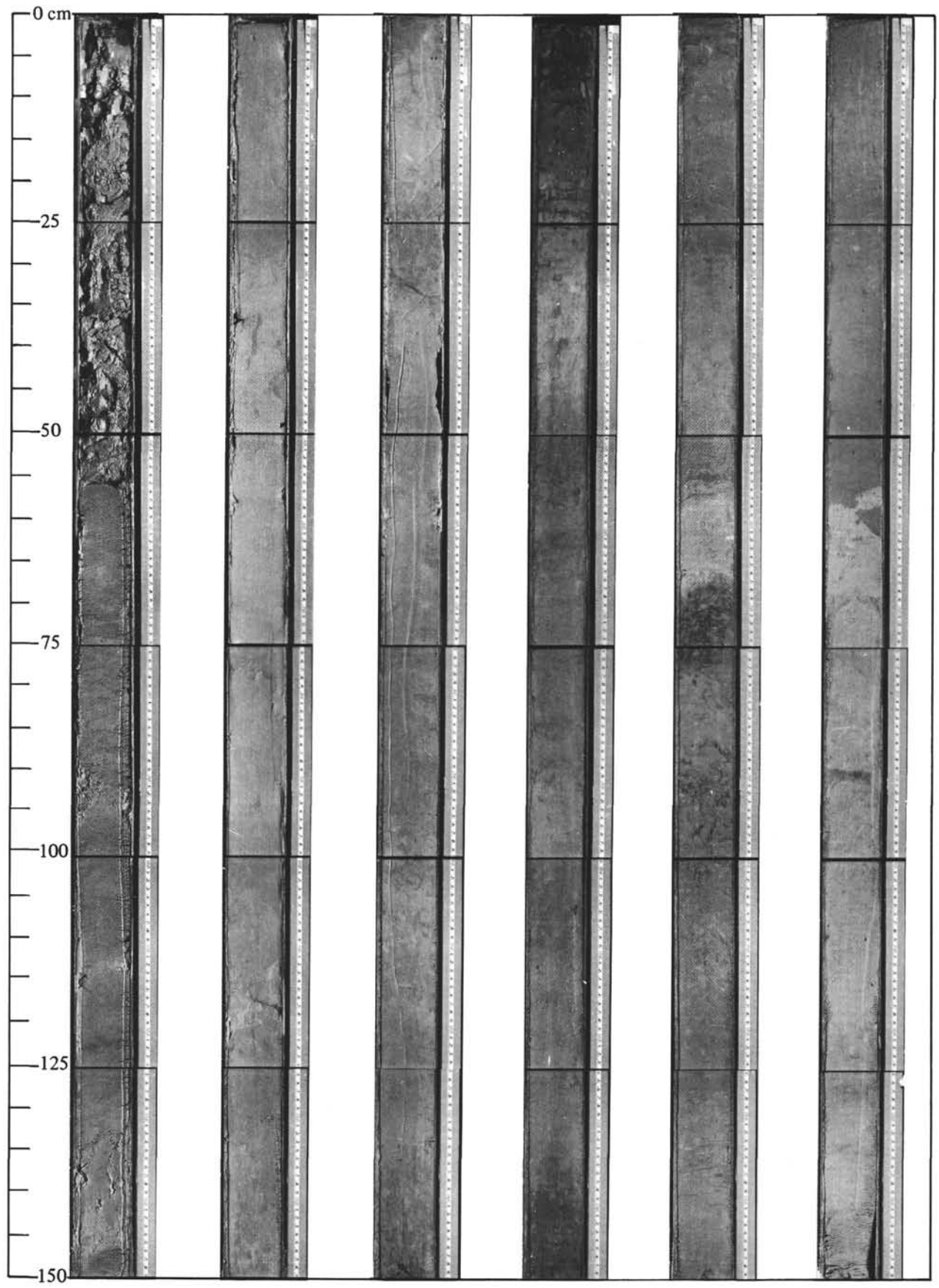


Plate 6. *Core 7, Hole 19.*

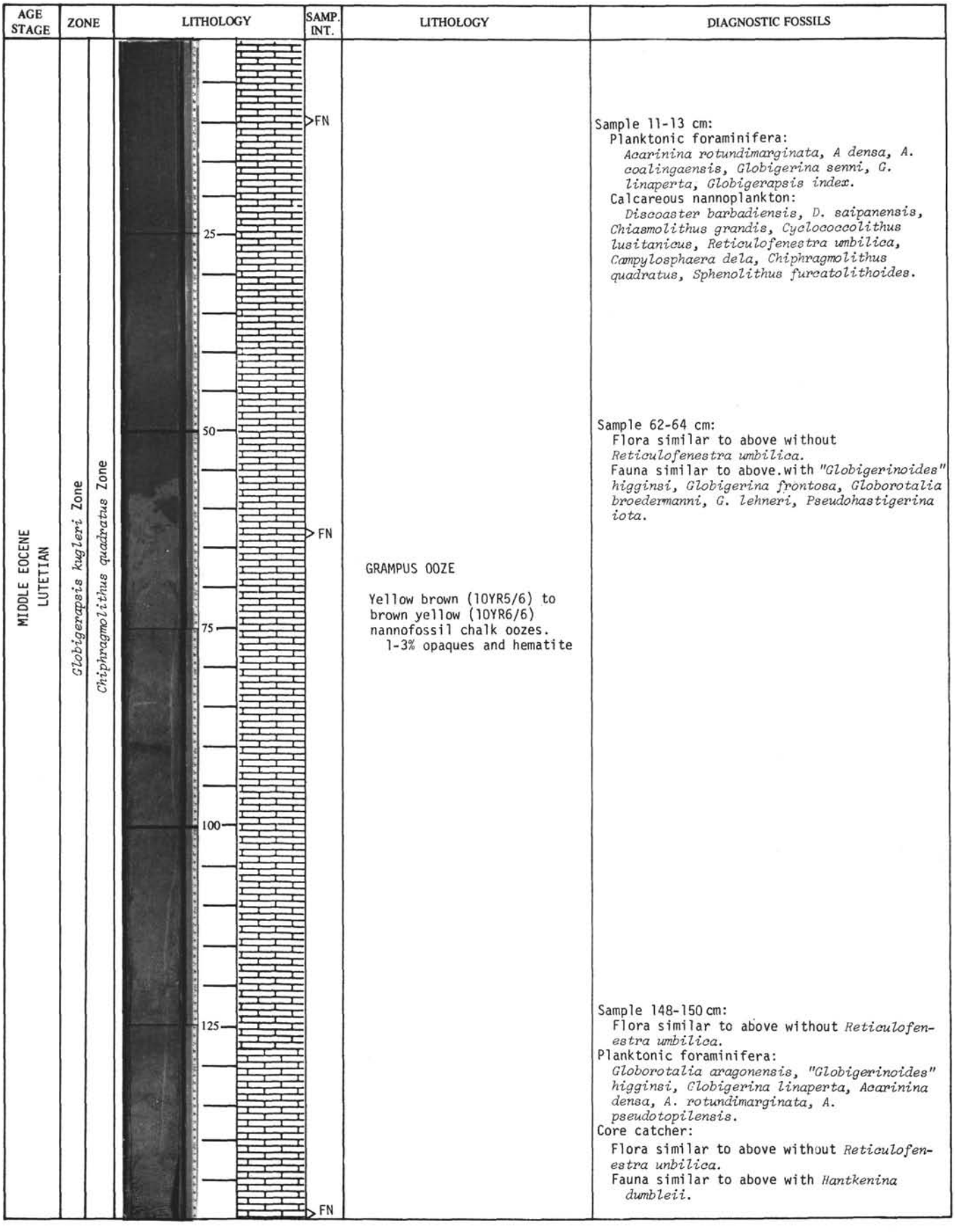
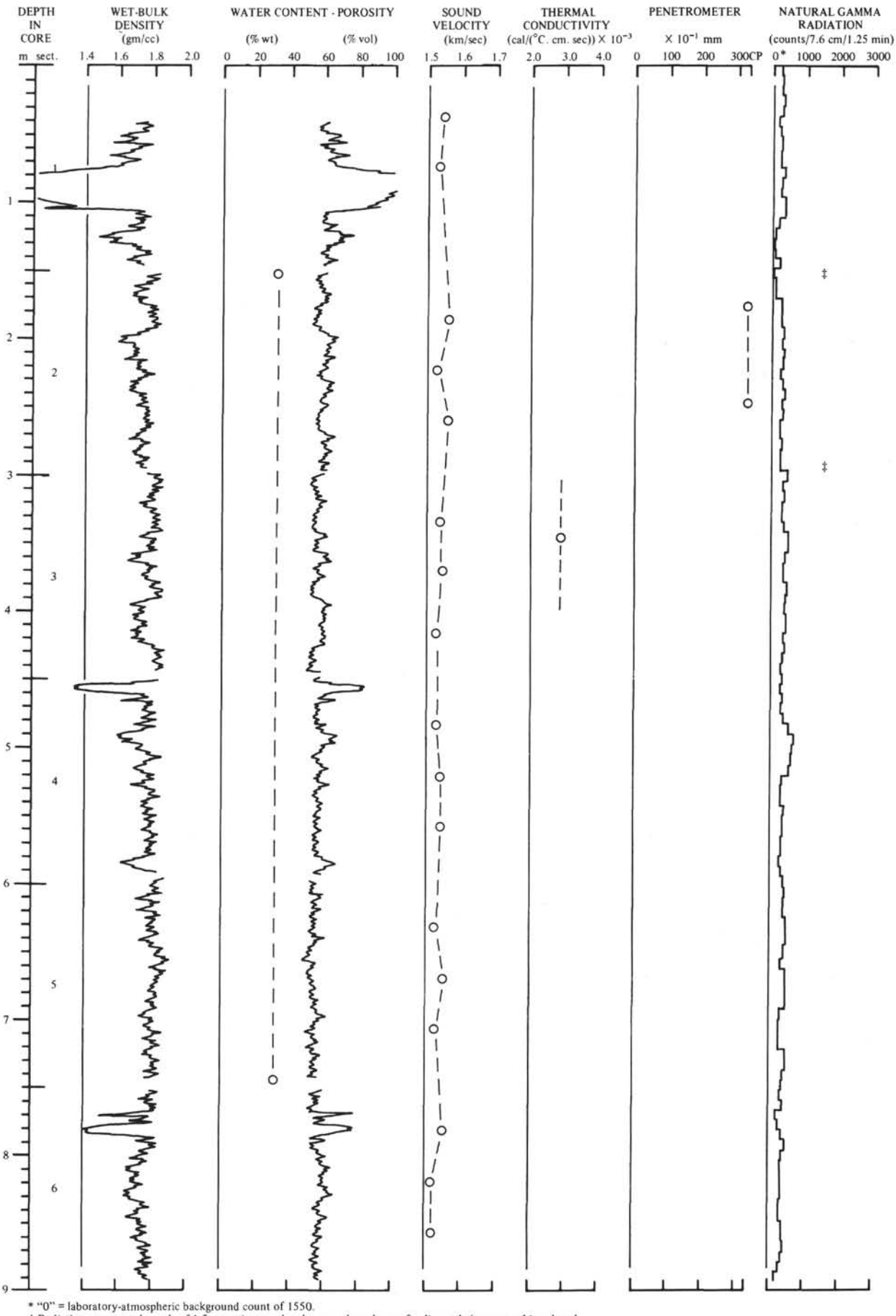


Figure 11. *Summary of Section 6, Core 7, Hole 19.*



* "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 12A. *Physical properties of Core 8, Hole 19.*

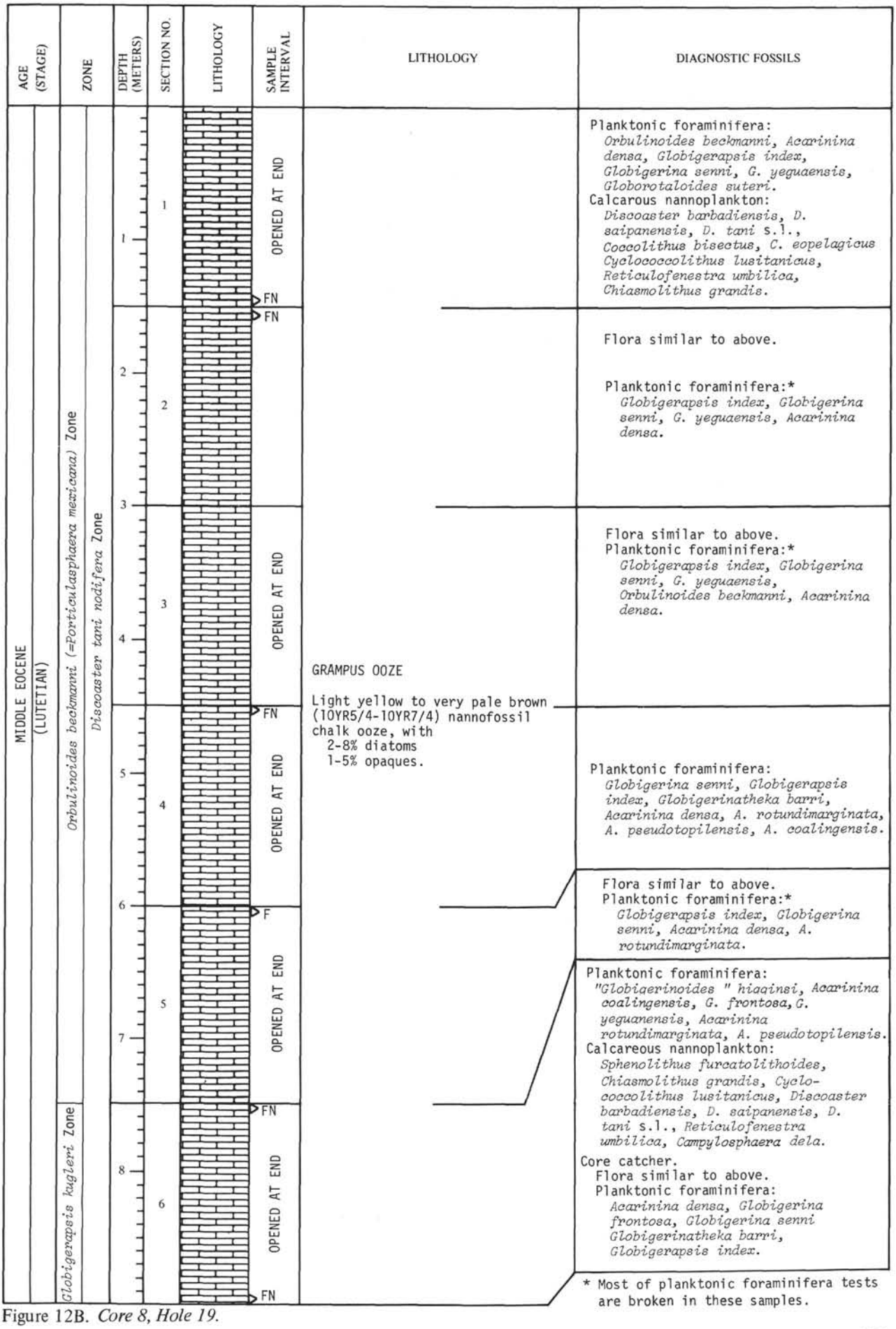
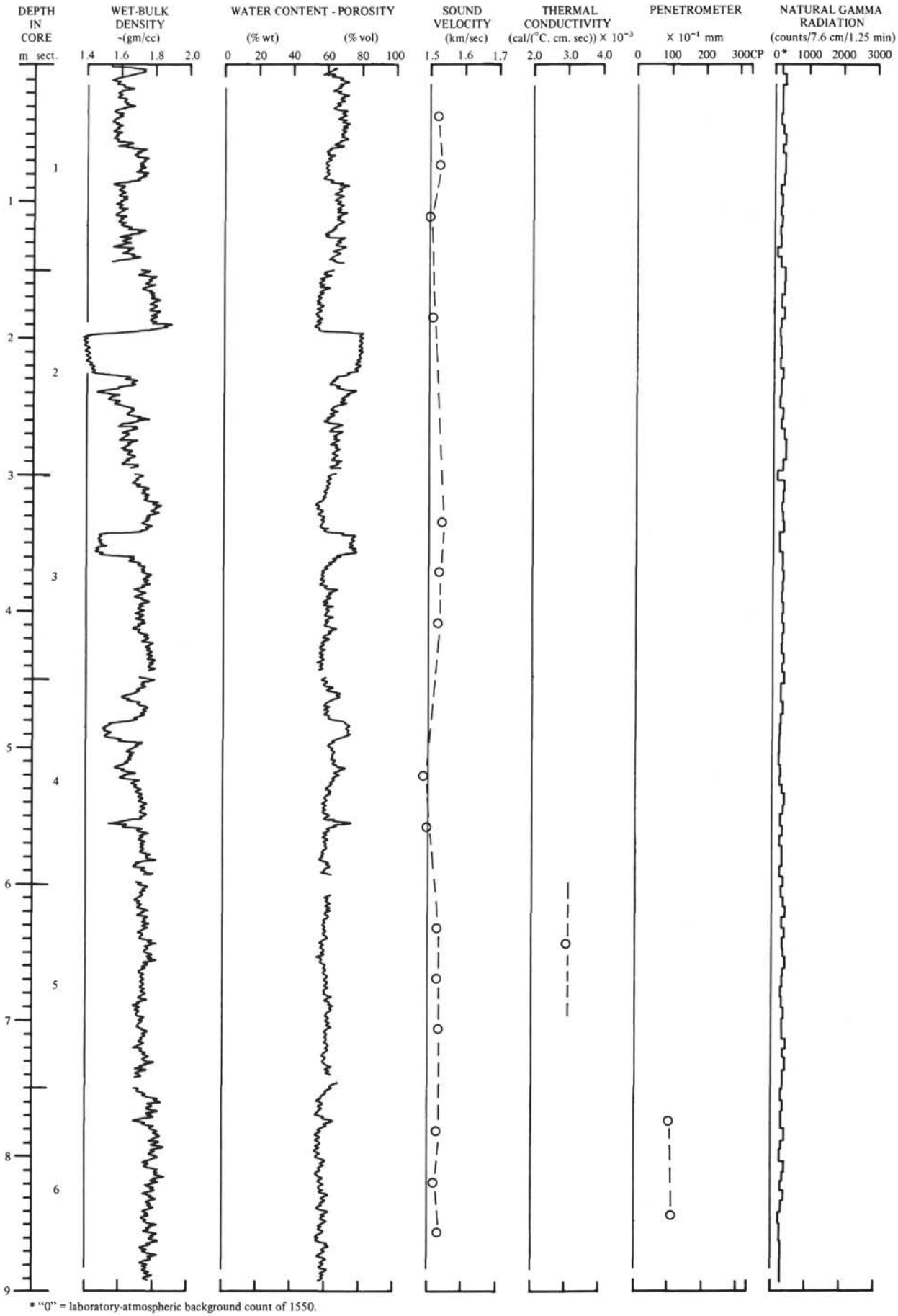


Figure 12B. *Core 8, Hole 19.*



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

Figure 13A. *Physical properties of Core 9, Hole 19.*

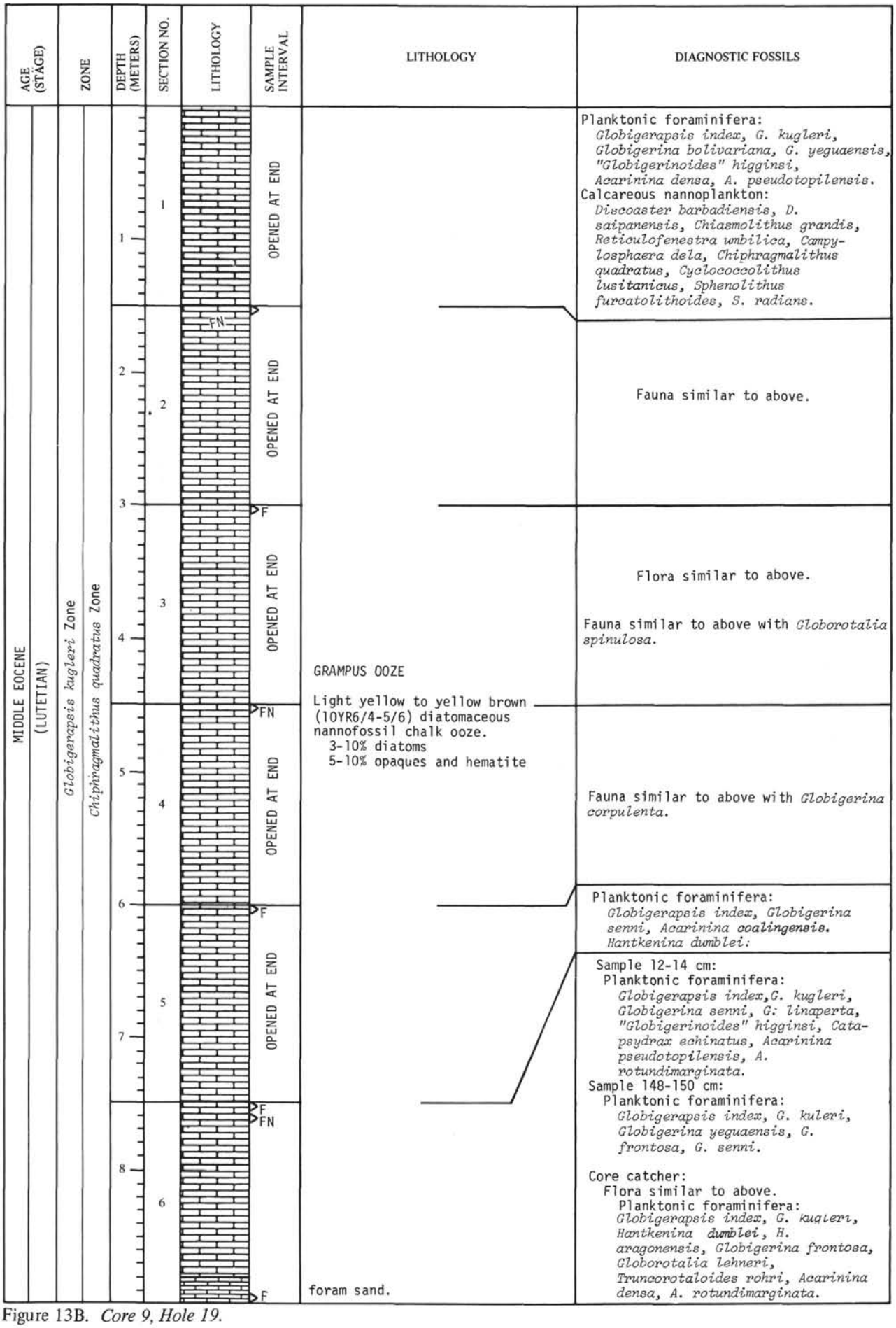
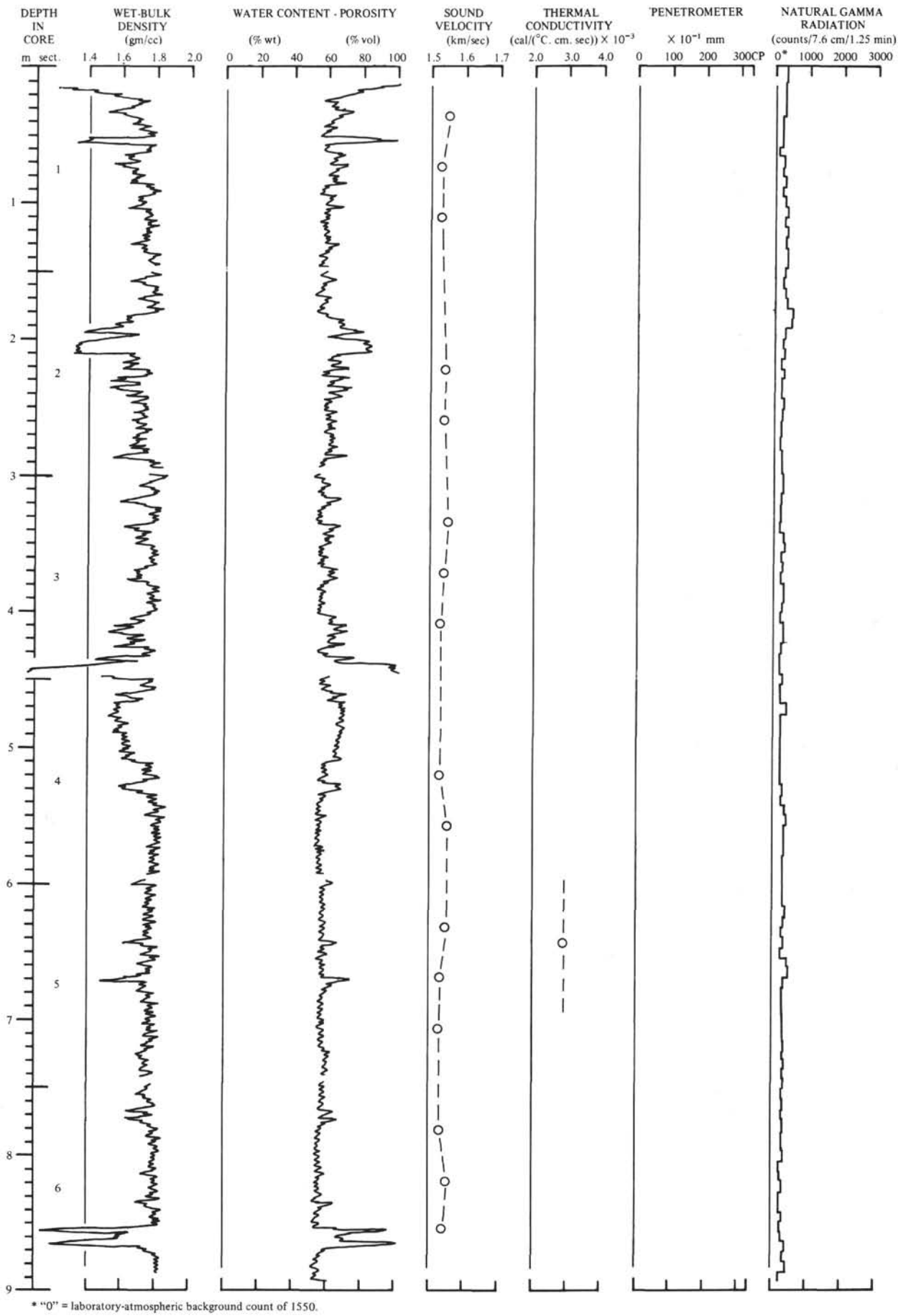


Figure 13B. *Core 9, Hole 19.*



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

Figure 14A. *Physical properties of Core 10, Hole 19.*

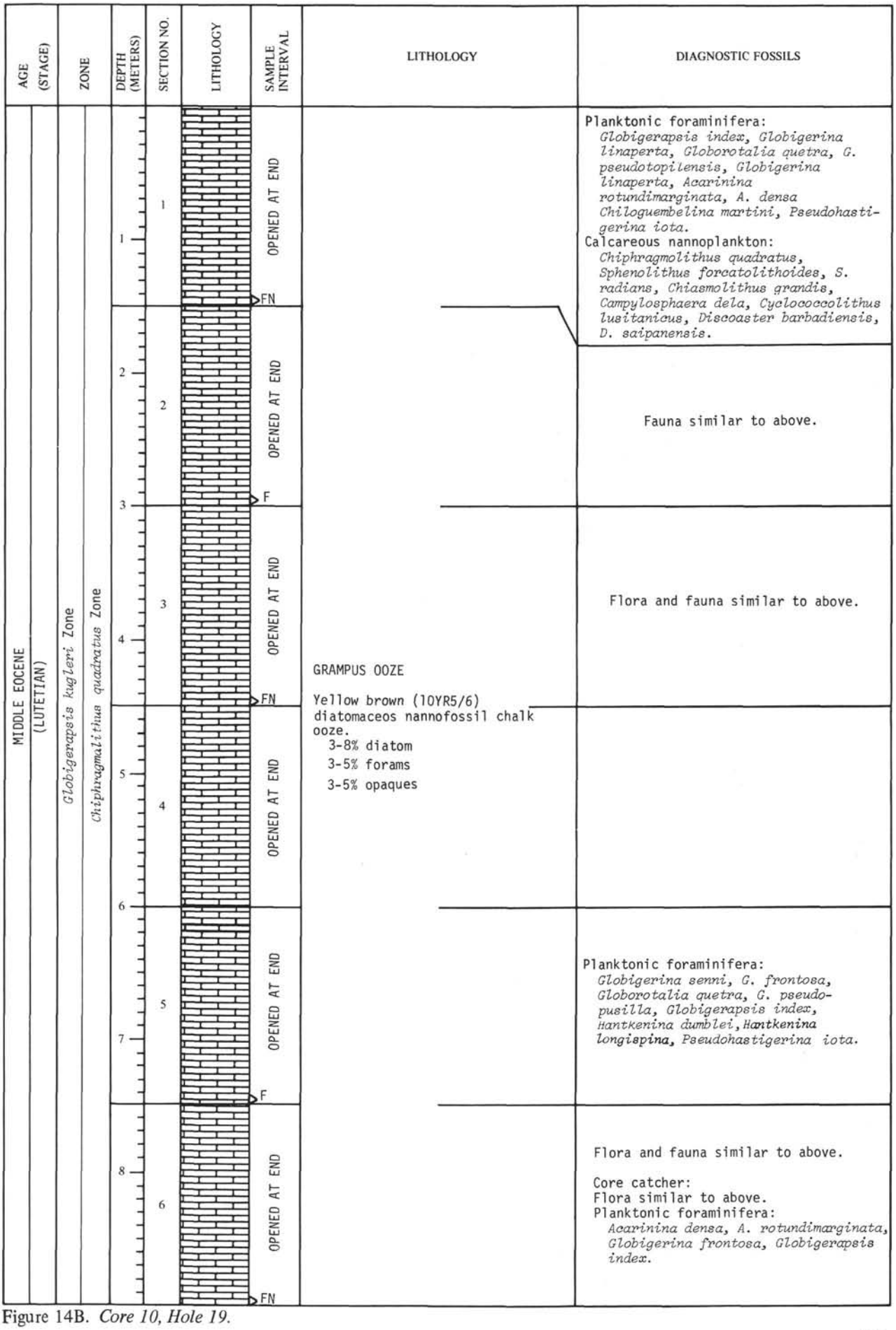
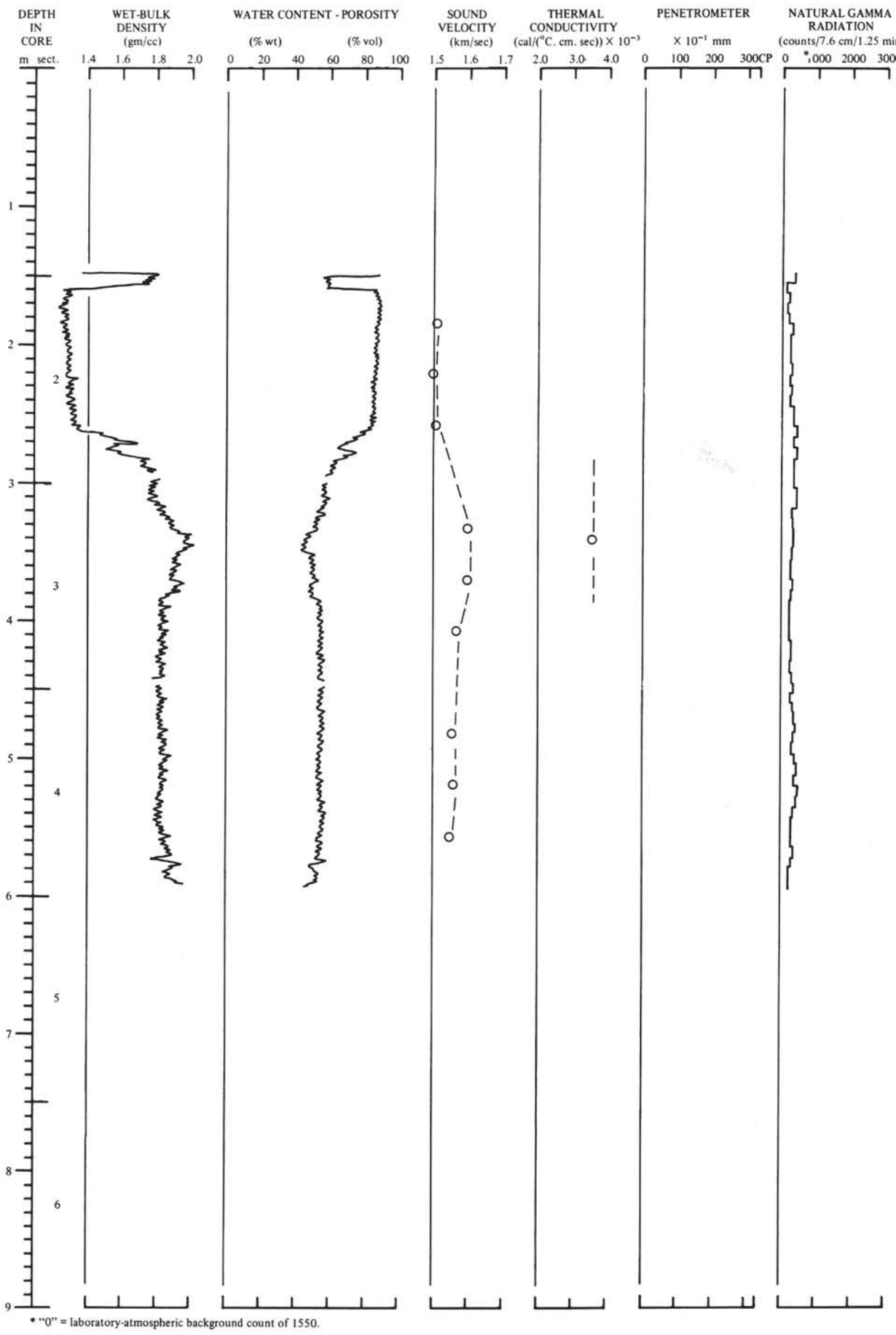


Figure 14B. *Core 10, Hole 19.*



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

Figure 15A. *Physical properties of Core 11, Hole 19.*

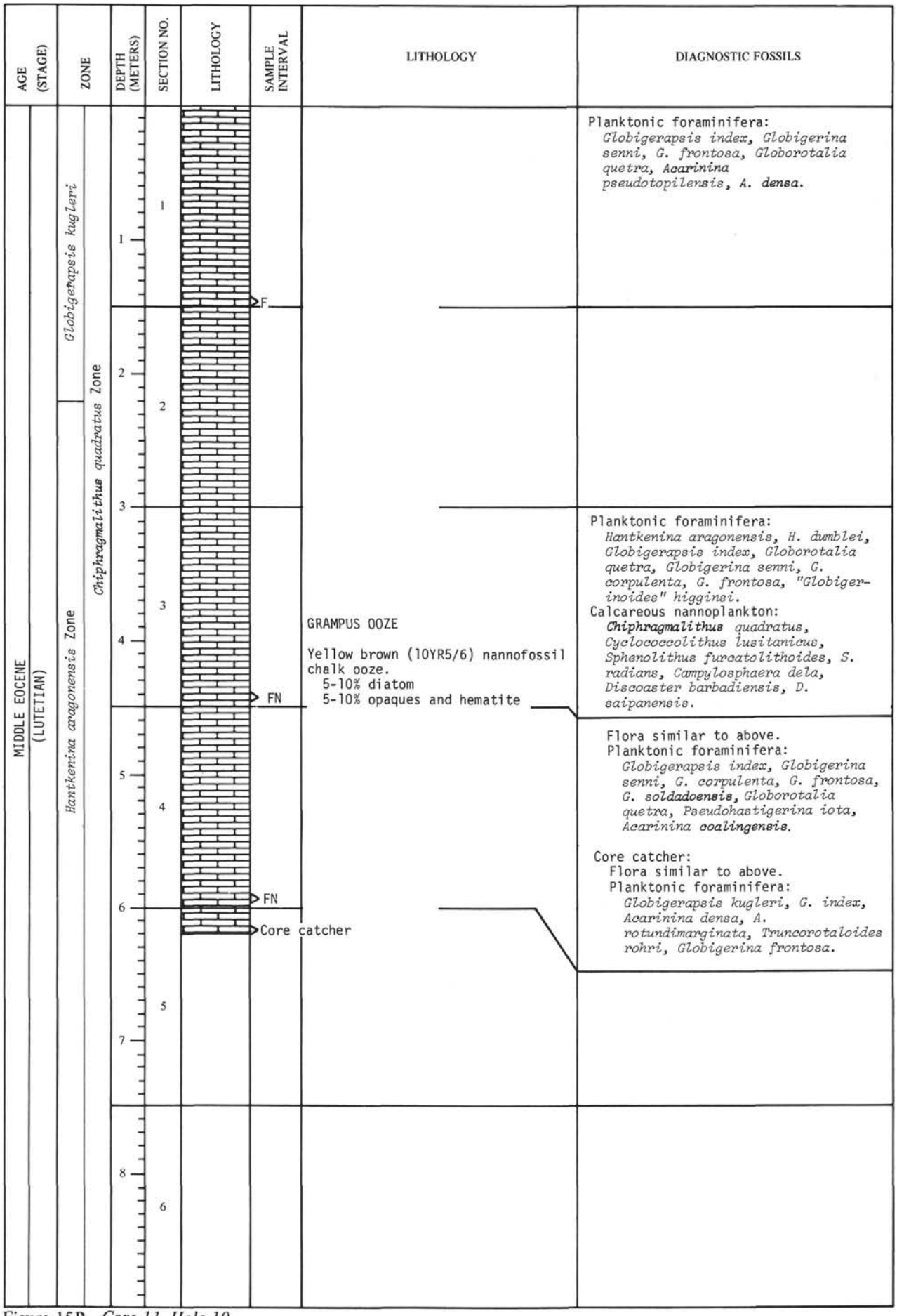


Figure 15B. *Core 11, Hole 19.*

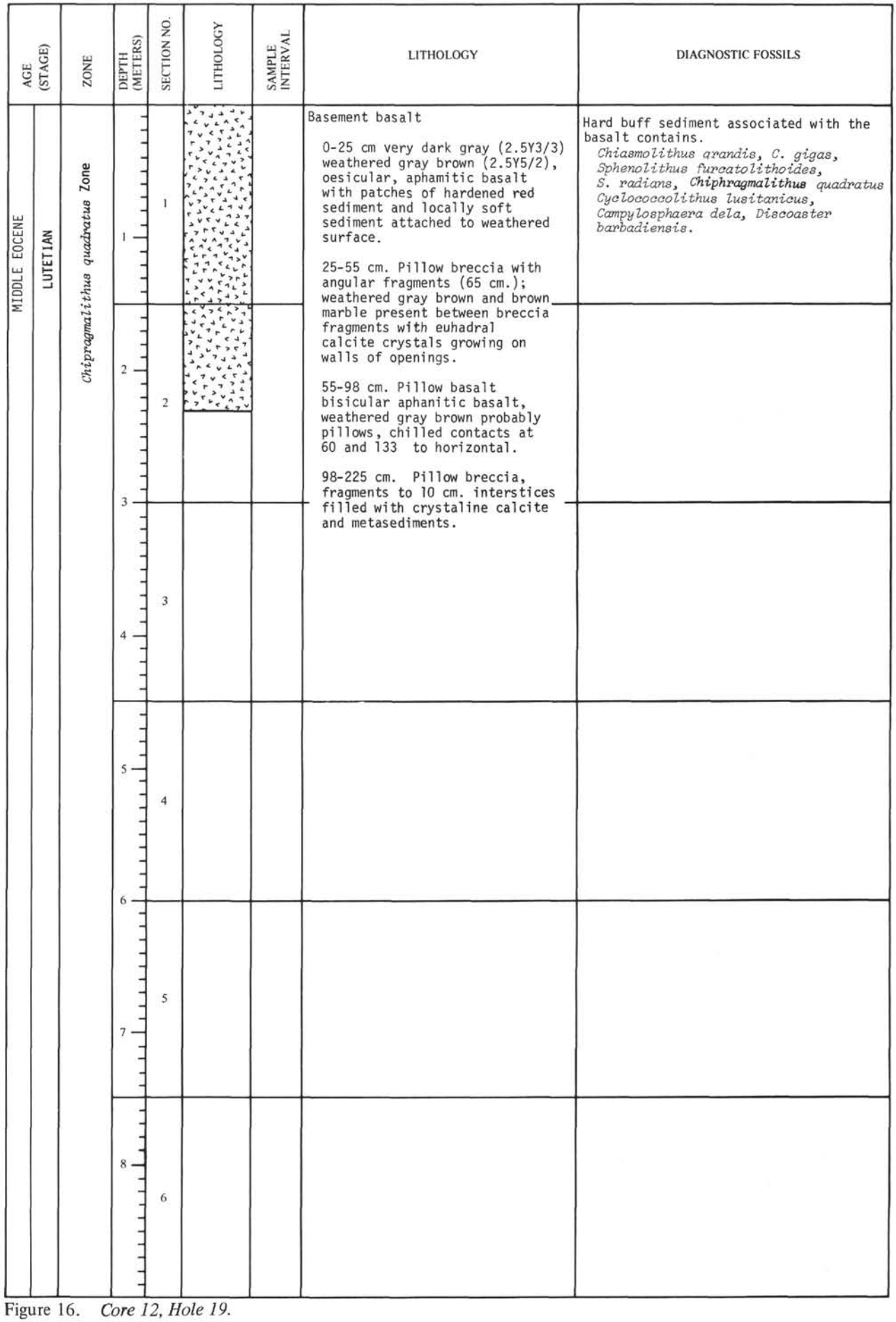


Figure 16. *Core 12, Hole 19.*

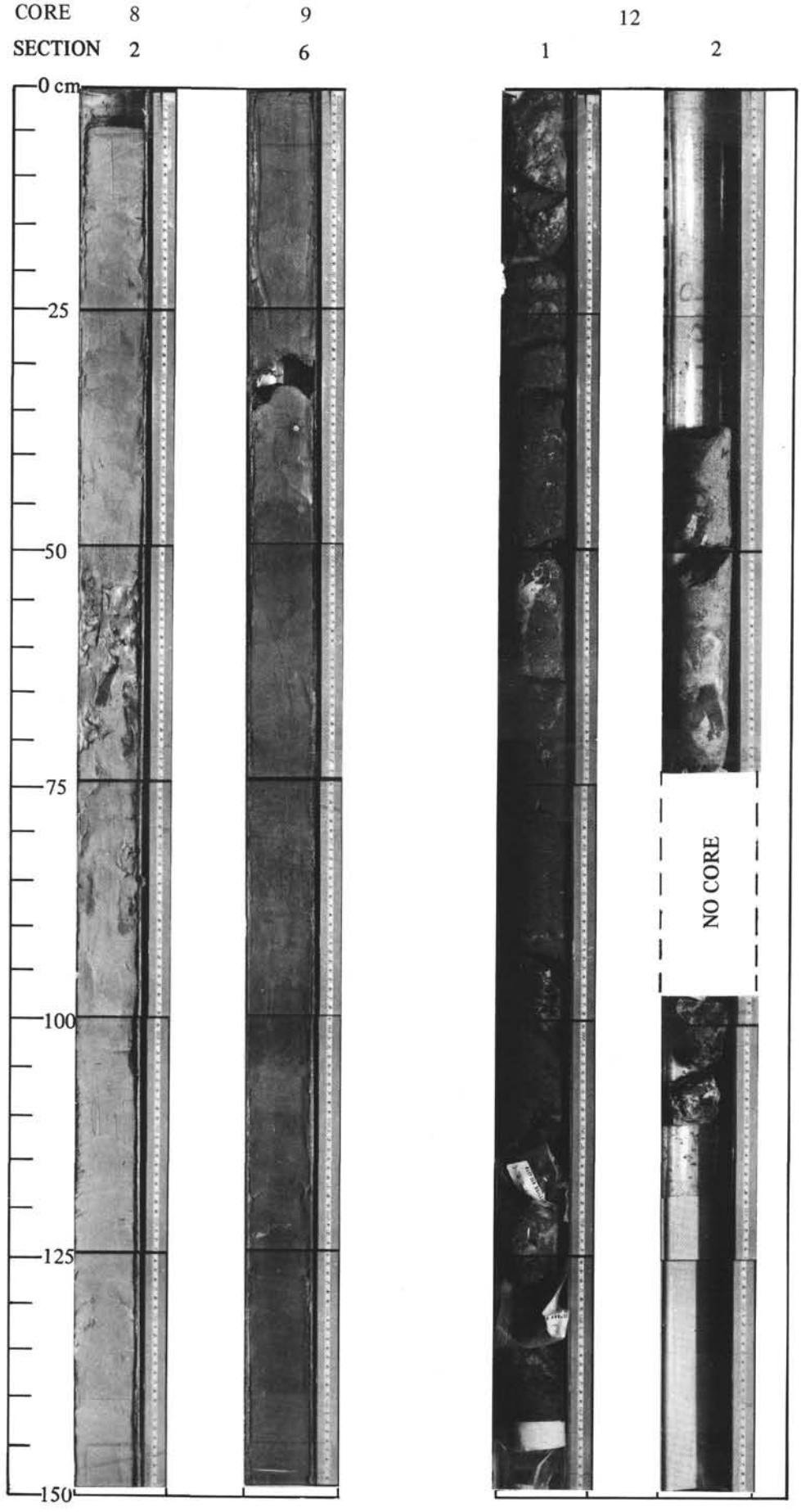


Plate 7. *Sections of Cores from the Lower Part of Hole 19.*