11. SITE 21

The Shipboard Scientific Party[1]

SURVEY DATA AND SITE BACKGROUND

Around this site, located on the north-eastern edge of the Rio Grande Rise, a considerable amount of geophysical survey data was made available from previous tracks of *R/V Vema*. These data consisted of seismic reflection profiles and contour maps of bottom depth and types of sediment at the sea floor.

On the north-eastern edge of the Rio Grande Rise, the slope from the crest of the rise at 1800 meters depth (uncorrected) to the 3600 meters (uncorrected) depth contour is gentle, about 5 degrees on the average. Drilling sites were considered near the base and the crest of this slope, where sediment thicknesses are less and hence the chances of sampling old sediments are greater. Sediments of Cretaceous age had been obtained with piston coring techniques from the lowest site. However, at this site it appeared that hard basement rocks nearly cropped out and that the slope steepened locally, both of which might make it difficult to spud in the drill bit. Also, the relatively thin (<0.1 second reflection time, bottom to basement) sediments there may imply hiatuses in the depositional sequence.

Therefore, the shallower site (28°35.10′S, 30°35.85′W) was selected at a depth of 2102 meters, corrected (Figure 1). The slope there appears less than 5 degrees, with only minor undulations. The air-gun records (Figure 2) show the sediment thickness to be 0.20 to 0.25 second above a rough reflector which is probably basalt basement, or perhaps 150 to 200 meters (492 to 656 feet) of sediment. The *Vema* records showed a strong reflector occurring 0.1 second or less above the rough "basement" reflector, which appears unresolved on Figure 2. By analogy with previous sites, it was thought that this might indicate chert layers, but none were encountered.

Magnetic anomalies are observed over the Rio Grande Rise, but they are not related to sea-floor spreading and are quite different in character.

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OPERATIONS

Positioning

After completion of the site survey, a beacon was dropped over the side at 1016 hours on 15 January, 1969. Initial difficulty was experienced in positioning the ship over the beacon. This probably resulted from the excessive side thrust being used which deteriorated the signal from the beacon. By rotating the ship 90 degrees, the problem was resolved. The wind was light at this site – less than 10 knots – and there was an apparent 1-knot current from the southwest. No further positioning difficulties were encountered at this site.

Drilling

While breaking and resetting the joints on the drill collars prior to their being lowered into the hole, a collar was sheared off at the threads. This required additional time, because it was necessary to machine the core barrel to fit the new assembly. The drill string was on bottom and ready to start coring at 2400 hours on 15 January. The first two cores which were lowered recovered only a handful of foraminiferal sand. Either failure to reach bottom or the sandy bottom was thought to be the reason that no sediments were retrieved. The first core was brought aboard at 0400 hours, 16 January. There were no significant drilling breaks until limestone was encountered at 130 meters (427 feet).

Coring

Two separate holes (21, 21A) were drilled. A total of 101 meters (331 feet) of core were collected from the 98 meters (321 feet) cored, yielding a return of 102 per cent. This anomalous percentage results from Core 21-8, in which 9 meters (30 feet) of core were collected although only 6.4 meters (21 feet) were cored. With the exception of Core 21A-2, in which 8.8 meters (29 feet) were recovered out of an attempted 9 meters (30 feet), there was 100 per cent recovery. The coring results are summarized in Table 1.

The second hole was drilled at this site in order to: (1) check whether zeolites were present in the Oligocene; (2) to recover a dolomite layer thought to exist around 65 meters (213 feet) and, (3) to sample, if possible, the Tertiary-Cretaceous boundary which fell between two cores in the first hole.

Several of the cores from this site were soupy and contained contamination from Recent sediments. This was

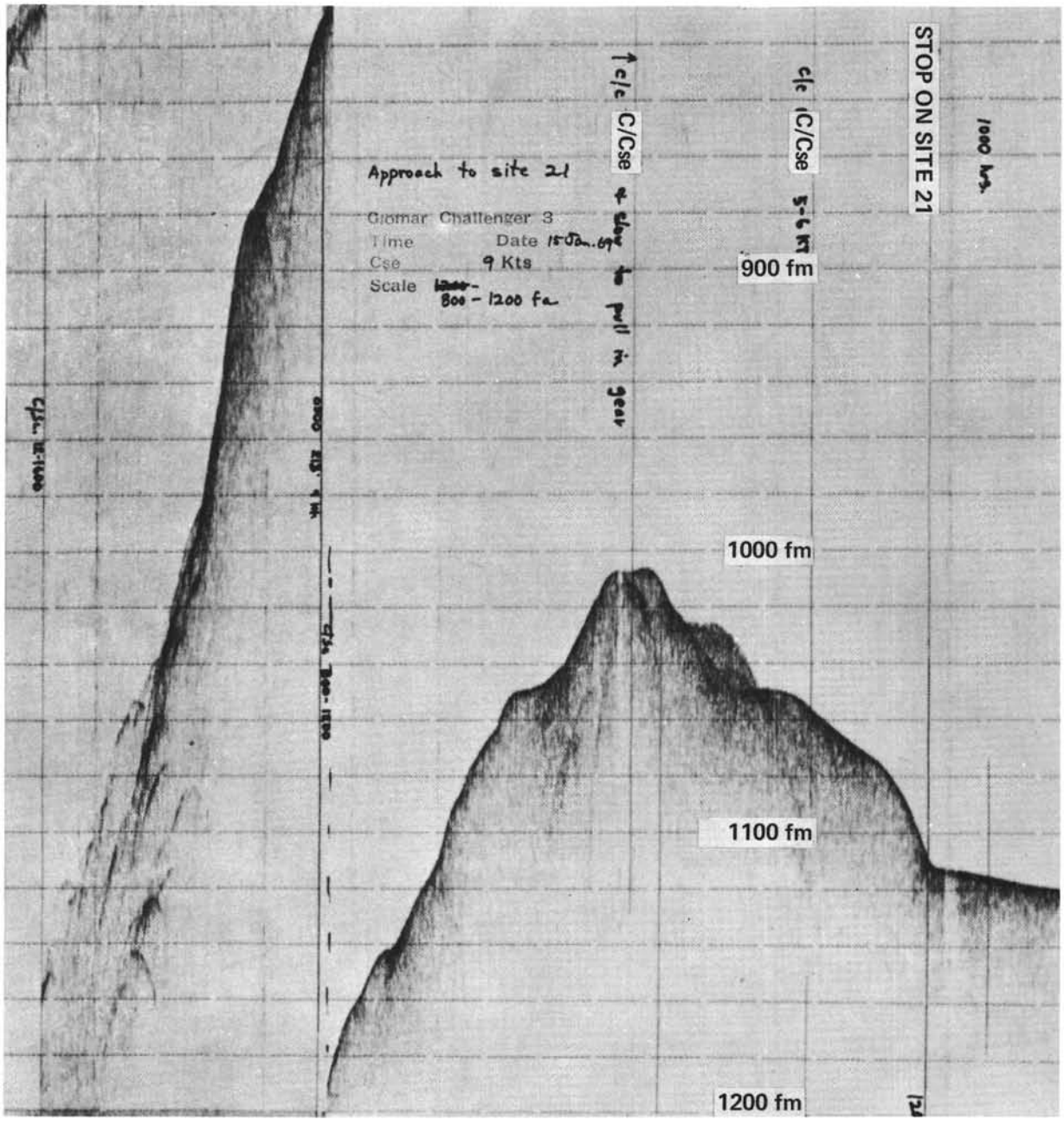


Figure 1. *Precision depth recording in the vicinity of Site 21.*

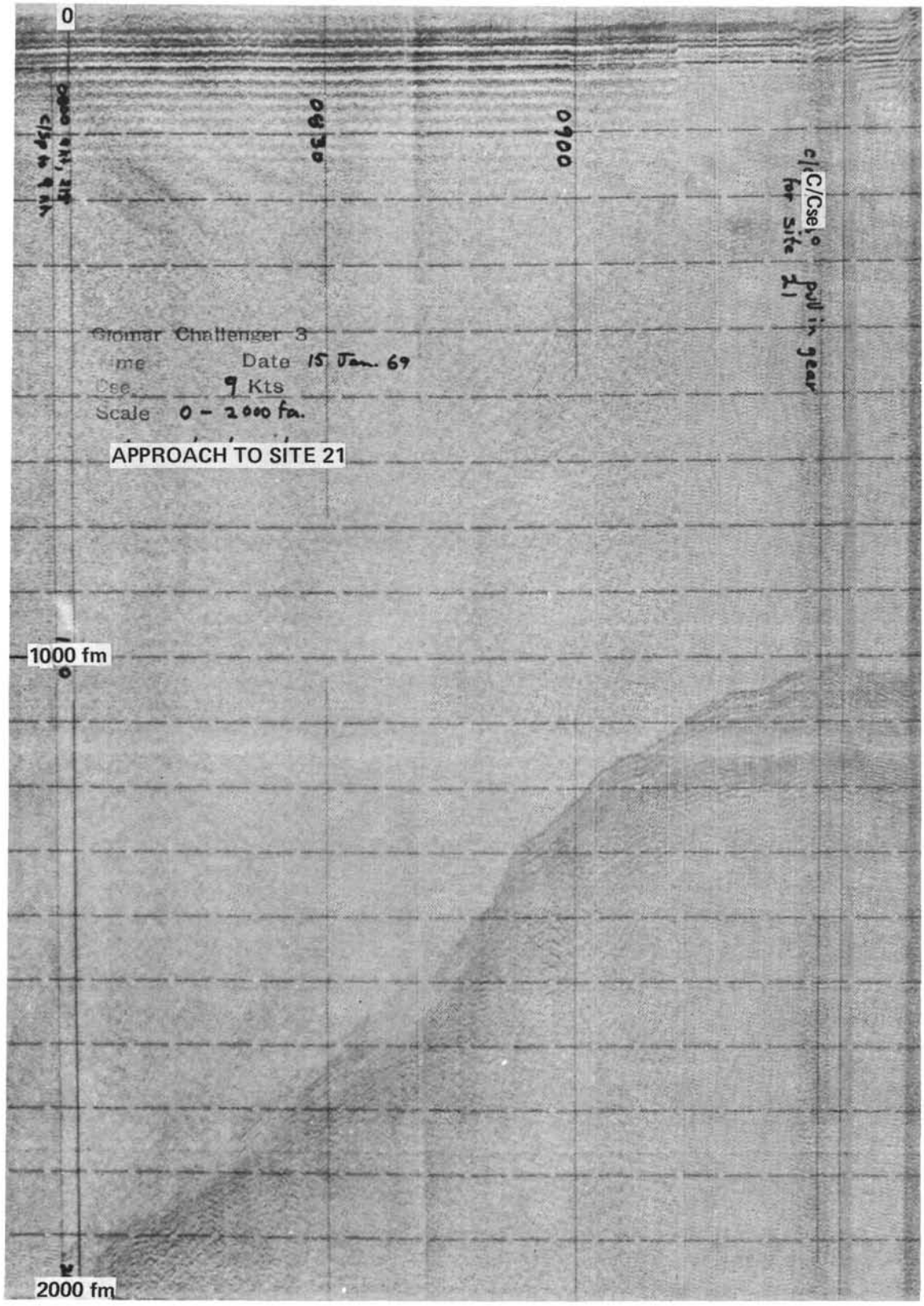


Figure 2. *Continuous seismic profiler record in the vicinity of Site 21.*

TABLE 1
Summary of Coring At Site 21

Core No.	Date/Time	Interval Sampled (m below sea floor)	Core Retrieved (m)	Remarks
21-1	1-16-69 0400	20.2-29.3	9.0	---
21-2	0630	67.1-76.3	9.0	---
21-3	0815	76.3-85.4	9.0	---
21-4	0945	85.4-94.6	9.0	---
21-5	1130	96.7-105.9	9.0	---
21-6	1300	105.9-115.0	9.0	Extruded from liner.
21-7	1530	115.0-124.2	9.0	---
21-8	1845	124.2-130.6	9.0	143 per cent recovery.
21-9	2145	130.6-131.0	0.5	---
21A-1	1-17-69 0130	46.4-55.6	9.0	---
21A-2	0330	61.0-70.2	8.8	---
21A-3	0515	70.2-79.3	9.0	---
		Total	99.3	

probably due to a hole cave-in near the surface which was brought about by the necessity of pumping vigorously, in order to keep the pipe from sticking.

PALEONTOLOGY

Two holes were drilled at Site 21. The stratigraphic relationships of the two holes, 21 and 21A, are shown in Figure 3. Upper Pliocene, Lower Pliocene, Upper Paleocene, Maestrichtian and Campanian sediments were recovered from the nine cores in Hole 21. This hole did not reach basement. Core 1 was taken between the sea floor and 67.1 meters (220 feet); coring was practically continuous from that depth to 131 meters (430 feet) where the hole was abandoned. Middle Eocene, Lower Eocene, Upper Paleocene, Lower Paleocene and Maestrichtian sediments were recovered from the three cores in Hole 21A. Since this hole was an attempt to core the Cretaceous/Tertiary boundary, coring was restricted to an interval calculated to contain the boundary. Three stratigraphic boundaries were cored at Site 21. These are the Lower Pliocene/Upper Pliocene, the Cretaceous/Tertiary and the Campanian/Maestrichtian boundaries. The Lower Pliocene/Upper Pliocene boundary is found in Core 1 of Hole 21. The Campanian/Maestrichtian boundary is in Core 5 of Hole 21 immediately above the core catcher, and the Cretaceous/Tertiary boundary which is not continuous is in the core catcher of Core 3 of Hole 21A. 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 purpose of drilling at this site was to recover the oldest sediments in this part of the South Atlantic and to obtain stratigraphic information of the sediments constituting the Rio Grande Rise. The stratigraphic results are shown in Figures 4B and 5B below.

The lithology of the sediments in Core 1 of Hole 21 is variable, and consists of some sediments in which the plates of calcareous nannoplankton are the major constituents and others in which planktonic foraminiferal tests dominate. In Cores 2 through 8 of Hole 21 the sediments consist predominantly of the plates of calcareous nannoplankton with minor amounts of planktonic foraminifera. Core 9 of Hole 21 contains an indurated coquina. In Hole 21A, the sediments of Cores 1, 2 and 3 consist predominantly of the plates of calcareous nannoplankton with minor amounts of planktonic foraminifera. The variations from lithologic unit to lithologic unit are discussed under the Stratigraphy section.

Hole 21, Core 1, from 20.2 to 29.3 meters (66 to 97 feet), contains sediments of Late Pliocene (Astian-Piacenzian, undifferentiated) and Early Pliocene (Zanclian) age. The boundary between these two epochs is placed in Section 2 between the sample from 148 to 150 centimeters of that section and the one from 148 to 150 centimeters of Section 1, based on the first appearance of *G. margaritae*. The fauna in the upper sample is characterized by *Globorotalia menardii miocenica, G. inflata, G. crassaformis, G. multicamerata* and *Globigerinoides obliquus*. The calcareous nannoplankton

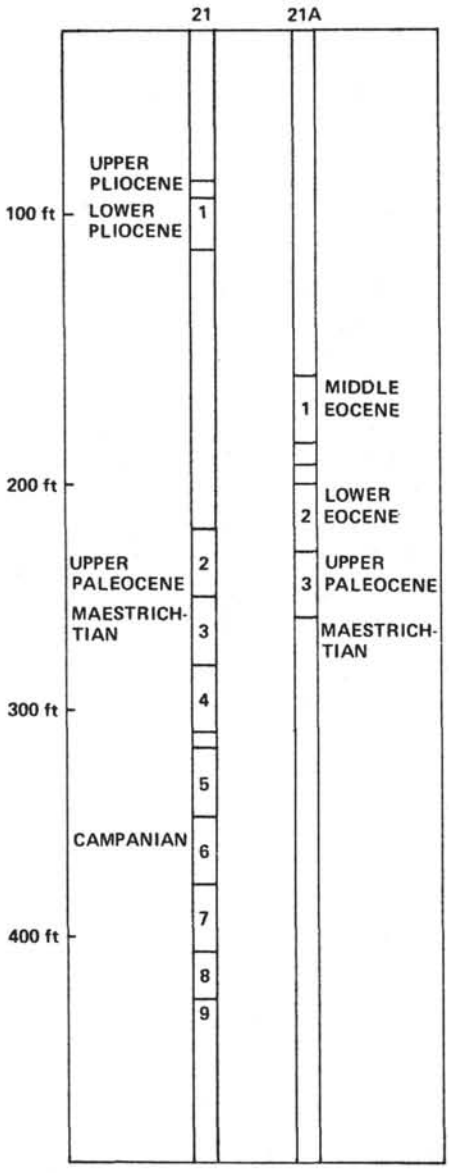


Figure 3. *Stratigraphic relationships between Holes 21 and 21A.*

throughout the core consists of *Discoaster brouweri, D. pentaradiatus, D. surculus, Ceratolithus cristatus* and *C. rugosus.* The first appearance of *Reticulofenestra pseudoumbilica* occurs in the sample from Section 2. Although this species occurs rarely in all samples where found, it suggests a probable Early Pliocene age as recorded previously for Sites 13, 15 and 16.

Sediments of Late Paleocene (Thanetian) age are present in Core 2, from 67.1 to 76.3 meters (220 to 250 feet), in Hole 21 based on the planktonic foraminifera and calcareous nannoplankton. The planktonic foraminifera are characteristic of the *Globorotalia pseudomenardii* Zone of Bolli (1957a). The Core catcher sample of Core 2 represents the *Globorotalia pusilla pusilla* Zone based on the first appearance of *Globorotalia pseudobulloides* and *Globigerina triloculinoides.* Most of the core represents the *Discoaster multiradiatus* Zone of Bramlette and Sullivan (1961), except for the sample from 143 to 145 centimeters of Section 6 and the core catcher sample, based on the occurrence of *Discoaster multiradiatus, Toweius eminens, Coccolithus cavus, Chiasmolithus consuetus* and *Fasciculolithus tympaniformis.* The latter samples belong to the *Cruciplacolithus tenuis* Zone of Hay and Mohler in Hay *et al.* (1967), based on the occurrence of *Coccolithus cavus, Cruciplacolithus tenuis, Ericsonia subpertusa, Markalius astroporus* and *Zyogdiscus sigmoides.*

In Hole 21, Core 3, from 76.3 to 85.4 meters (250 to 280 feet), Core 4, from 85.4 to 94.6 meters (280 to 310 feet), and most of Core 5, from 96.7 to 105.9 meters (287 to 347 feet), are assigned to Maestrichtian Stage of the Upper Cretaceous based on the planktonic foraminifera. Core 3, represents the *Abathomphalus mayaroensis* Zone of Bolli (1957) based on the occurrence of *Abathomphalus mayaroensis, Globotruncana elevata* (Brotzen), *G. contusa, Racemiguembelina fructicosa* and *Pseudotextularia elegans* (Rzehak). The calcareous nannoplankton also are of Maestrichtian age and consist of *Arkhangelskiella cymbiformis, Lithraphadites quadratus, Tetralithus murus, Micula decussata, Microrhabdulus decoratus* and *M. stradneri.* In Core 4, from 85.4 to 94.6 meters (280 to 310 feet), two zones are present: the *Globotruncana gansseri* Zone of Bolli (1957) and the *Rugotruncana circumnodifera* Subzone of Pessagno (1967). The boundary of these two zones is placed between the samples from 148 to 150 centimeters in Section 1 and from 148 to 150 centimeters in Section 3, based on the first appearance of *Globotruncana fornicata* Plummer in the lower sample. The fauna above the contact consists of *Globotruncana arca* (Cushman), *G. plummerae* Gandolfi, *G. contusa* (primitive), *G. ganserri* Bolli, *G. elevata, G. stuartiformis, G. rosetta, Globotruncanella havanensis* and *Rugoglobigerina rugosa.* The study of the calcareous nannoplankton, however, suggests that these sediments are Campanian in age based on the work of Stradner (1963) in Europe and Gartner (1968) in the Gulf Coast. The flora consists of *Tetralithus nitidus T. nitidus trifidus?* (not typical), *Broinsonia parca, Lucianorhabdus cayeuxi* Deflandre, *Microrhabdulus decoratus* and *Micula decussata.* This same flora with more typical *Tetralithus nitidus trifidus* occurs in Core 5, where it is again associated throughout most of the core with planktonic foraminifera typical of *Rugotruncana subcircumnodifera* Subzone. However, the core catcher sample contains abundant *Globotruncana calcarata* Cushman and represents the *Globotruncana elevata* Subzone of Pessagno (1967) of Campanian age.

The sediments in Core 6, from 105.9 to 115.9 meters (347 to 380 feet), Core 7, from 115.9 to 124.2 meters

(380 to 408 feet), and Core 8, from 124.2 to 130.6 meters (408 to 428 feet), in Hole 21 are assigned to the Campanian Stage of the Upper Cretaceous based on the planktonic foraminifera and calcareous nannoplankton. These sediments represent the *Globotruncana elevata* Subzone of Pessagno (1967). Planktonic foraminifera species found throughout these cores are *Globotruncana fornicata, G. ventricosa* White, *G. arca, G. elevata, G. stuartiformis, G. linneiana* (d'Orbigny) and *Pseudotextularia elegans.* The flora is similar to that reported for Core 5, except that *Tetralithus nitidus trifidus* is absent from Core 6. In Cores 7 and 8, *Inoceramus* shell fragments and prisms are abundant in many of the sections studied; for their location see the Core Summary Sheets. The coquina in Core 9, from 130.6 to 131 meters (428) to 430 feet, is well cemented and it appears to be partially recrystallized. No planktonic foraminifera or calcareous nannoplankton were recovered from these processed samples. Future studies by thin section may reveal more information concerning its age; but, for the present, because of its gradational contact with the overlying Campanian sediments, it is dated as Campanian in age.

In Hole 21A, Core 1, from 46.4 to 55.6 meters (152 to 182 feet), is assigned to the Middle Eocene (Lutetian) based on the planktonic foraminifera and calcareous nannoplankton. Two planktonic foraminiferal Zones of Bolli (1957b) are recognized in this core, namely, the *Hantkenina aragonensis* Zone and the *Globigerapsis kugleri* Zone. The contact of the two is placed between samples from 148 to 150 centimeters of Section 4 and from 148 to 150 centimeters of Section 5. The fauna above the contact consists of *Truncorotaloides topilensis* (Cushman), *T. rohri* Bronnimann, *"Globigerinoides" higginsi, Globigerapsis kugleri, G. index, Globigerina frontosa, G. senni, Globorotalia centralis* and *G. lehneri,* Below the contact *Globorotalia broedermanni* Cushman and Bermudez and *G. pseudomayeri* Bolli make their first appearance. The flora is typical of the *Chiphragmolithus quadratus* Zone of Hay (1967), and it consists of *Chiphragmolithus quadratus, Chiasmolithus grandis, Sphenolithus furcatolithoides, Cyclococcolithus lusitanicus* and *Campylosphaera dela.*

The sediments in Core 2, from 61 to 70.2 meters (200 to 230 feet), in Hole 21A are Early Eocene in age. The planktonic foraminifera present in all samples studied from this core represent the *Globorotalia aragonensis-Globoortalia formosa formosa* (undifferentiated) Zone of Bolli (1957a) of the Early Eocene (Ypresian) age. Most of the core, except for the lowermost part of Section 6, belongs to the *Discoaster lodoensis* Zone of Bramlette and Sullivan (1961), which is Lower Eocene (Ypresian) in age. The lower part of Section 6 and the core catcher represent the *Discoaster tribrachiatus* Zone of Bramlette and Sullivan (1961), also of Early Eocene age.

The planktonic foraminifera present throughout most of the core are: *Globorotalia aragonensis, G. pseudoscitula, Globigerina soldadoensis angulosa, G. soldadoensis* and *Acarinina coalingaensis.* The calcareous nannoplankton present throughout most of the core are: *Discoaster sublodoensis, D. lodoensis, D. barbadiensis, Sphenolithus radians, Chiasmolithus grandis* and *Campylosphaera dela.* In the lowermost part of Section 6 and in the core catcher sample, *Marthasterites tribrachiatus* is present. The sample from 0 to 2 centimeters of Section 6 contains a few Middle Eocene calcareous nannoplankton species which are interpreted as contamination from uphole.

The sediments in Core 3, from 70.2 to 79.3 meters (230 to 260 feet) of Hole 21A, except for the core catcher, are Late Paleocene (Thanetian) in age based on the planktonic foraminifera and calcareous nannoplankton. The Cretaceous/Tertiary boundary, although not continuous, occurs in the core catcher. Three planktonic foraminiferal zones of Bolli (1957b) are present in the core from Sections 1-6; namely, in ascending order, the *Globorotalia pusilla pusilla, Globorotalia pseudomenardii* and *Globorotalia velascoensis* Zones. Because of an artificial mixing of faunas of the different ages, it is difficult to place exact zonal boundaries. However, the contact between the last two zones is placed between the samples from 121 to 124 centimeters of Section 5 and from 10 to 12 centimeters of Section 6, based on the first appearance of *Globorotalia pusilla laevigata* in the lower sample. The contact between the *Globorotalia pusilla pusilla* and *Globorotalia pseudomenardii* Zones occurs in Section 6 between the samples from 125 to 127 centimeters and from 136 to 138 centimeters based on the first appearance of *Globorotalia pseudobulloides* and *Globigerina triloculinoides in the* lower sample. All samples studied from this core, except for those from the core catcher, are from the *Discoaster multiradiatus* Zone of Bramlette and Sullivan (1961), and they contain: *Chiasmolithus consuetus, Toweius eminens* and *Fasciculithus tympaniformis.*

The core catcher sample contains the Cretaceous/Tertiary boundary, but the boundary does not represent a continuous stratigraphic sequence. This boundary is placed at 9 centimeters below the top of the 18-centimeter long sample which was carefully extruded from the core catcher. This assignment is based on a study of the calcareous nannoplankton. The flora above the boundary represents the *Fasciculithus tympaniformis* Zone of Hay in Hay *et al.* (1967) and contains: *Fasciculithus tympaniformis, Cruciplacolithus tenuis, Coccolithus cavus, Ericsonia subpertusa* and *Zygodiscus sigmoides.* The Maestrichtian flora below the boundary consists of *Arkhangelskiella cymbiformis, Lithraphidites quadratus, Micula decussata* and *Eiffellithus turriseiffeli* (Deflandre). The foraminiferal fauna below the boundary consists of *Abathomphalus mayaroensis, Globotrun-*

STRATIGRAPHY

The sedimentary section of Site 21, located on the Rio Grande Rise, is, on the whole, more foraminiferal and less terrigenous than those on the flanks of the Mid-Atlantic Ridge. Five lithological units were recognized, of which only two were correlated with those at the Ridge sites. The units, in descending order, are:

3-21-1-1	Albatross Ooze	White foraminiferal chalk oozes.
-------	Disconformity	----------
3-21-2-1	Hirondelle Ooze	Pale nannofossil chalk oozes.
3-21-4-1	Local Unit	Pink chalk oozes with *Inoceramus.*
3-21-7-1	Local Unit	White chalk oozes.
3-21-9-1	"Basement"	White coquina.

The sediments of Unit 3-21-1-1 consist mainly of calcareous planktons. Foraminifera predominate; sand-size fraction ranges from 40 to 60 per cent. Nannofossils are commonly present in a subordinate amount. The non-carbonate content constitutes 5 to 35 per cent of the sediment bulk. Like the Albatross Ooze on the Mid-Atlantic Ridge, this Quaternary unit is characterized by a foraminifera-content greater than any of the underlying units. The authors have, therefore, made the correlation, although they recognize that the oozes here are more arenaceous than their correlative on the Ridge crest.

After a short uncored interval, Eocene nannofossil chalk oozes were encountered. The Pliocene, Miocene, and Oligocene sediments are either absent or they are represented by a much reduced section with a total thickness of less than 17 meters (56 feet).

The sequence of white, very pale brown and pink chalk oozes, some 46 meters (151 feet) thick and ranging in age from late Maestrichtian to Middle Eocene, was grouped together because of their similarity in texture and composition. Nannofossils predominate. Foraminifera are invariably present, and the content commonly varies between 10 to 20 per cent. The oozes have been recrystallized in part so that 5 to 35 per cent of the very fine matrix can no longer be positively identified as nannofossils under the light microscope. The non-carbonate content, on the whole, varies between 15 to 25 per cent, including in some samples traces of zeolite. The pink interbeds are characterized by the presence of euhedral rhombs of dolomite and/or rhodochrosite, which range up to 5 per cent in a few of the smear slides examined. Dolomite chalk oozes at certain horizons have been sufficiently lithified to constitute an acoustic reflector at this site (RGR-2, <0.1 second). Chips of such pink friable chalk rock have been found on top of 3-21-2-1 at about 67 meters (220 feet) BOB of Hole 21. The authors have designated the chalk sequence Unit 3-21-2-1, and they have correlated it with the basal sedimentary unit at Site 20 as the Hirondelle Ooze Formation. In making the correlation, it was noted that the foraminifera content here (10 to 20 per cent) is considerably greater than that of its correlative (1 to 5 per cent) in the Mid-Atlantic Ridge province, a variation trend parallel to that observed in correlating the Albatross Ooze.

The Unit 3-21-4-1 consists of pink, foraminiferal nannofossil chalk oozes, characterized by the presence of *Inoceramus* fragments. The foraminifera content is similar to that of the overyling unit; the larger percentages of sand-size fraction in some of the samples are related to the presence of megafossils; Aside from *Inoceramus,* fragments of other small megafossils were found. The oozes are recrystallized in part. The fine-grained matrix includes both recrystallized nannofossils and terrigenous detritus; the latter commonly ranges from 20 to 35 per cent. Traces of zeolite are present in some samples. This local unit ranges from Campanian to Maestrichtian in age, and thus, is older than all of the sediments cored from the Mid-Atlantic Ridge province.

The Unit 3-21-7-1 is a white to grayish-white foraminiferal nannofossil chalk ooze. Foraminifera content increases from about 10 to 20 per cent to about 35 per cent in sediments near the base of this unit (which overlies here, not a basalt basement, but a coquina "basement"). The oozes are also somewhat more calcareous than the overlying unit, including only about 20 per cent of terrigenous detritus. Zeolite is present in small amounts. The oozes have been recrystallized to such an extent that only a small fraction of the fine-grained matrix could be identified as nannofossils (10 to 40 per cent). In fact, some are no longer unconsolidated pelagic oozes, but friable rocks.

The lowest sample cored at Site 21 is a coquina rock. The rock is porous well-sorted biosparite. Fragments of pelecypods, echinoderms, red algae, and other megafossils were cemented by sparry calcite. Some green stains are present, probably a glauconite. The top of this hard coquina layer could be identified as the "basement reflector" at Site 21. The thickness of this coquina layer is unknown, since it was not possible to drill through this formation to reach the crystalline basement.

All but one of the boundaries between the units were accurately placed, on the basis of cored information, The exception was the major disconformity separating the Albatross and Hirondelle Formations; this was arbitrarily placed at the mid-point of a 17-meter uncored

TABLE 2
Stratigraphy Site 21

Age	Cored Interval (m)	Formation Name	Probable Interval (m)	Probable Thickness (m)	Description
Pleistocene	20-29	Albatross Ooze 3-21-1-1	0-38	38.0	White foraminiferal chalk oozes - 30 to 80% foraminifera, 20 to 70% nannofossils.
Middle Eocene to Upper Cretaceous (Maestrichtian)	67.0-85.4 (46.4-55.6) (61.0-79.3)	Hirondelle Ooze 3-21-2-1	38.0-85.4	46.4	White, very pale brown, and pink chalk oozes. 10 to 20% foraminifera. 5 to 35% fine-grained calcite in a nannofossil matrix. 0 to 5% dolomite.
Upper Cretaceous (Maestrichtian-Campanian)	85.4-115.0	Local Unit 3-21-4-1	85.4-115.0	29.6	Pink foraminiferal nannofossil chalk oozes, with 10 to 20% foraminifera. *Inoceramus* fragments are common throughout the zone (105.9 to 115 meters).
Upper Cretaceous (Campanian)	115-130	Local Unit 3-21-7-1	115-130	15.0	White foraminiferal nannofossil chalk oozes. 20 to 40% foraminifera, 10 to 40% nannofossils, in fine-grained calcareous matrix.
?	130.0-130.5	3-21-9-1 (Basement) White Coquina	130- ?	?	White porous coquina consisting of megafossil fragments.

interval, or at 38 meters (125 feet) BOB. The sedimentation rates are estimated as follows:

Albatross Ooze	38 m/	1.9 m.y., or 2	cm/t.y.
Hirondelle Ooze	46.4 m/	20 m.y., or 0.23	cm/t.y.
Local Unit 3-21-4-1	29.6 m/	7 m.y., or 0.4	cm/t.y.
Local Unit 3-21-7-1	15 m/	3 m.y., or 0.5	cm/t.y.

The stratigraphy at Site 21 is summarized by Table 2. All figures refer to cored intervals, probably intervals, and probable thicknesses at Hole 21; cored intervals at Hole 21A are given in parentheses.

PHYSICAL PROPERTIES

Natural Gamma Radiation

Natural gamma radiation at Site 21 ranged from zero to 1200 counts/1.25 minutes/7.6 centimeter core segment, with a mean of 350 counts (Figure 4A and 5A and 6A-17A). Core averaged gamma counts were about 100 to 300 at depths of 20 to 76 meters (66 to 249 feet) (Tertiary). Below 76 to 106 meters (249 to 348 feet) (Maestrichtian), gamma radiation averages increased to about 400 to 600 counts, and below 106 meters (348 feet) (Campanian) they decreased again to about 250 counts. The high radiation counts below 76 meters (249 feet) appear to correlate to the occurrence of zeolites, and possibly dolomites and hematites.

Porosity, Wet-Bulk Density, and Water Content

Porosities, wet-bulk densities and water contents ranged from 11 per cent to 80(?) per cent, 1.35(?) g/cc to and 22 per cent to 37 per cent, respectively, averaging 52 per cent, 1.82 g/cc, and 29 per cent (Figures 4A and 5A and 6A-17A). Site 21 porosity, in general, irregularly decreases with depth. It has an unnatural variation about the Tertiary-Cretaceous contact which is probably related to lithology and compaction. Wet-bulk density, of course, is the inverse of the porosity variations.

The lowest porosity of 10 per cent occurred in Section 21-5-4, which was unopened. A low porosity of about 20 per cent occurred over a short interval in Core 8, Section 6, which is a pale gray to white rocky mud. The rock was 95 per cent clay-size material comprised of calcareous fragments, dolomite(?) and, nannoplankton.

Sediment Sound Velocity

Sediment sound velocities at Site 21 range from 1.51 to 1.71 km/sec with an average of about 1.57 (Figures 4A and 5A and 6A-17A). Sound velocity core averages of Tertiary sediments are lower than those of the Cretaceous sediments. The highest average velocities occur in the pink calcareous nannoplankton-foraminiferal chalk ooze, especially in Core 4. (Core 6, the *Inoceramus* megafossil Zone, and the Coquina in Core 9 were not measured.) The lack of correlation between the higher

Penetromenter

Penetrometer measurements at Site 21 extended from 84×10^{-1} millimeters to complete penetration (Figures 4A and 5A and 6A-17A). The only section which was not completely penetrated was 3-21-2-6. This core is the bottom of the pale dolomitic nanno-foraminiferal chalk ooze at a depth of 75 meters (246 feet). Many of the cores at this site were disturbed to a soupy condi-

Thermal Conductivity

At Site 21, low values were measured in the upper 25 m. of the hole. From 25 to 70 m. values were relatively uniform at about 2.9×10^{-3} cal/°C cm sec. A decrease from about 3.0 to 2.6×10^{-3} cal/°C cm sec was measured between 70 m. and 90 m. depth in the hole. The highest value, about 3.3×10^{-3} cal/°C cm sec, was measured at a depth of about 100 m. From there to the bottom of the hole values decreased somewhat to about 3.0×10^{-3} cal/°C cm sec at the bottom of the hole.

Interstitial Water Salinity

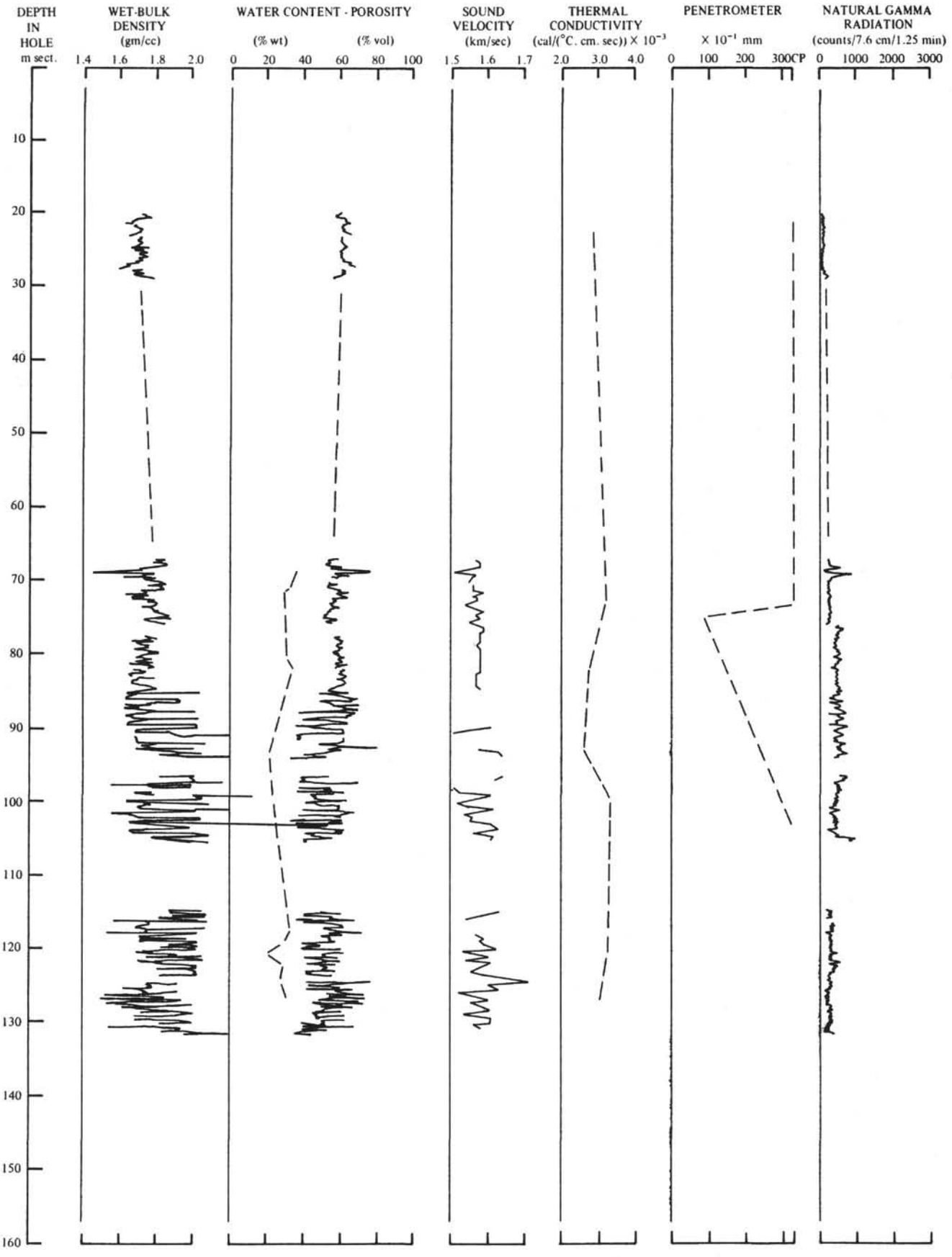
Interstitial salinities at Site 21 of 34.4, 36.0, 35.5 ppt were measured at 77, 97, and 128 meters (253, 318 and 420 foot) depths, respectively. These samples were Campanian ,and younger sediments within the Cretaceous System. The highest salinity of 36.0 ppt was collected near the lithified *Inoceramus* Zone. Site 21 had the greatest salinity variations measured on Leg 3, which were probably caused by lithification processes.

THE CORES RECOVERED FROM SITE 21

The following pages present a graphic summary of the results of drilling and coring at Site 21.

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 21. 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 4A. *Summary of the Physical Properties of the cores recovered from Hole 21.*

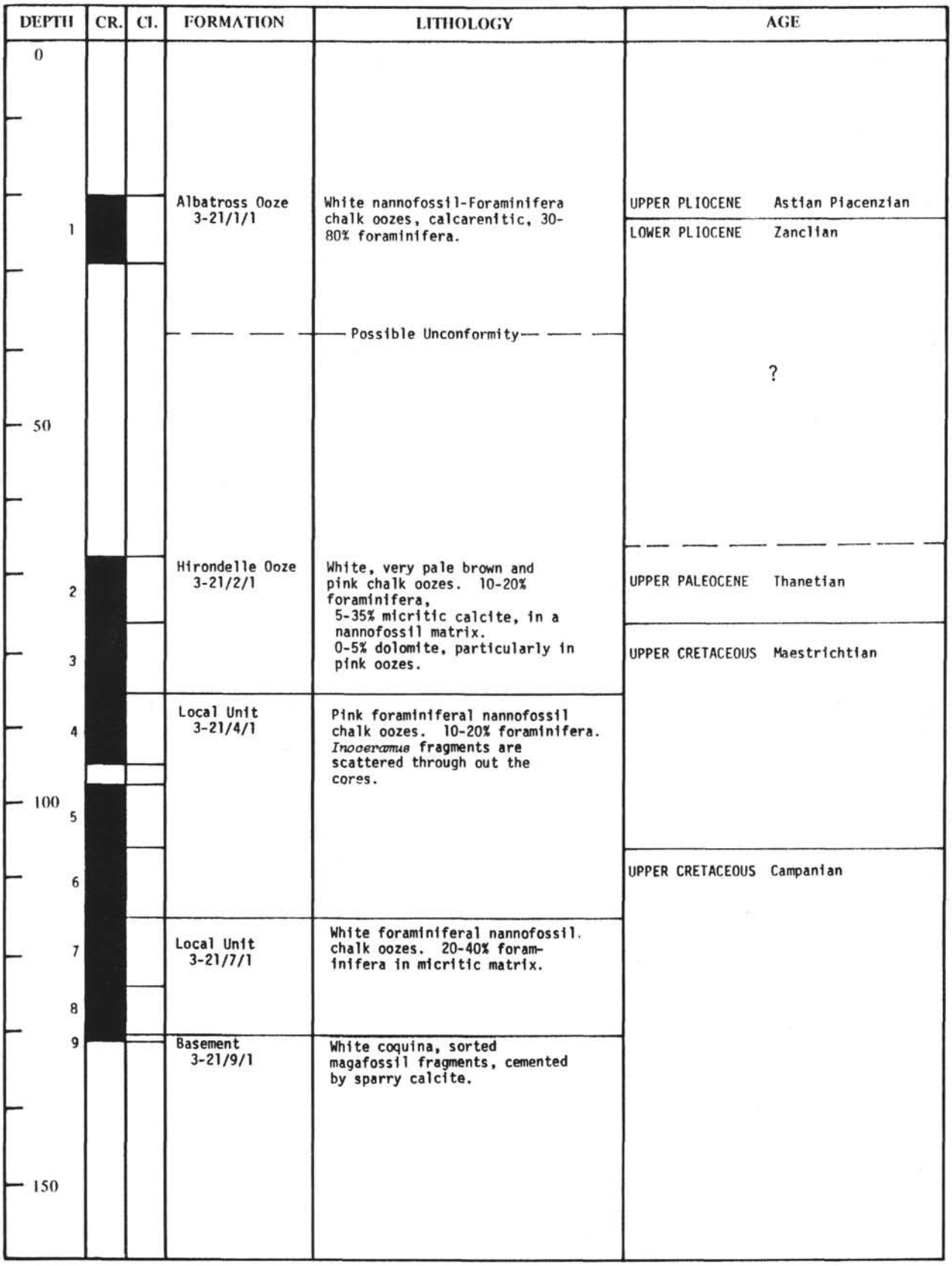
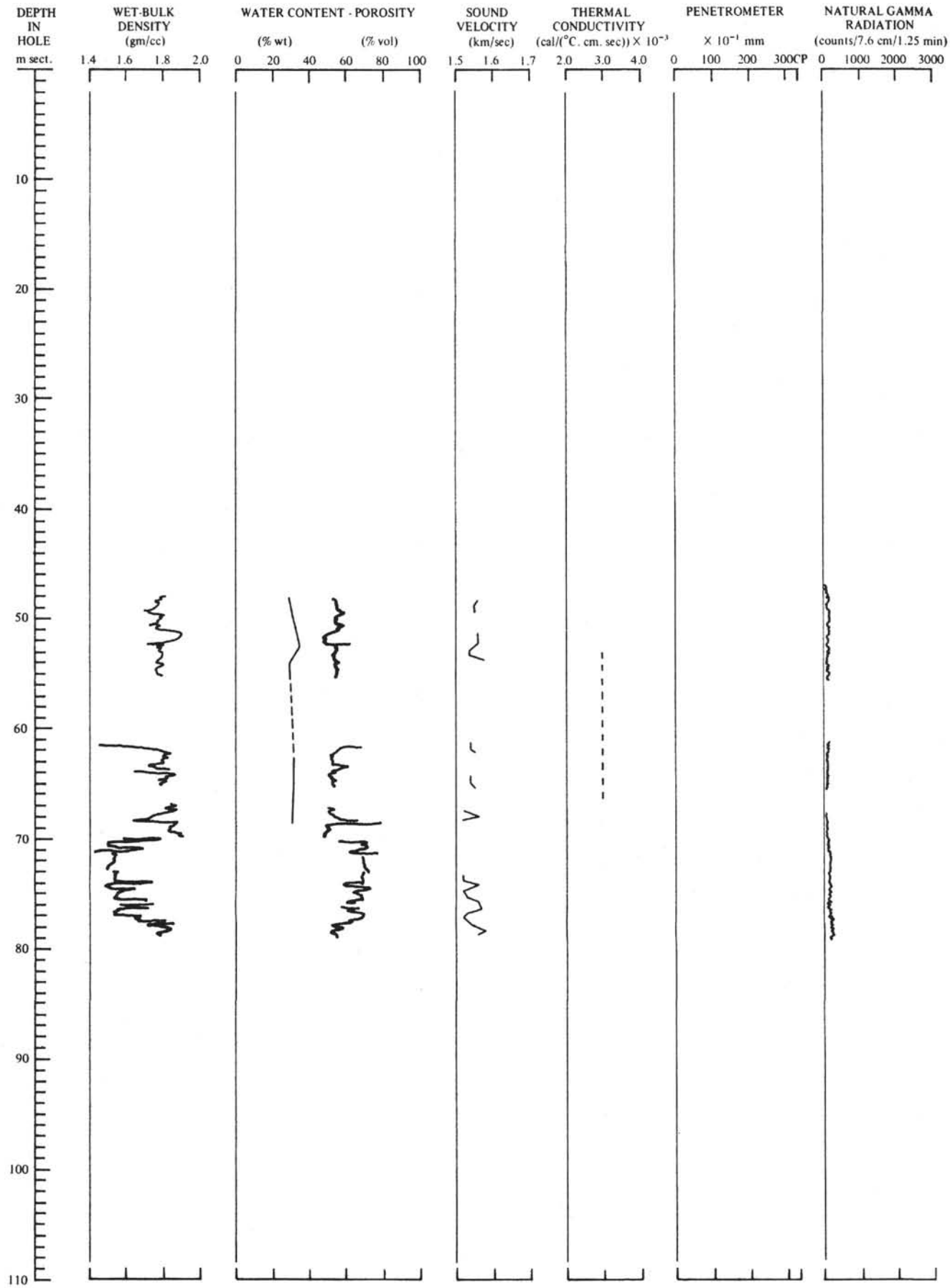


Figure 4B. *Summary of the cores from Hole 21. (Depth in meters below sea bed; C.R. = core recovered; C.I. = cored interval.)*



*"0" = laboratory atmospheric background count of 14

Figure 5A. *Summary of the Physical Properties of the cores recovered from Hole 21A.*

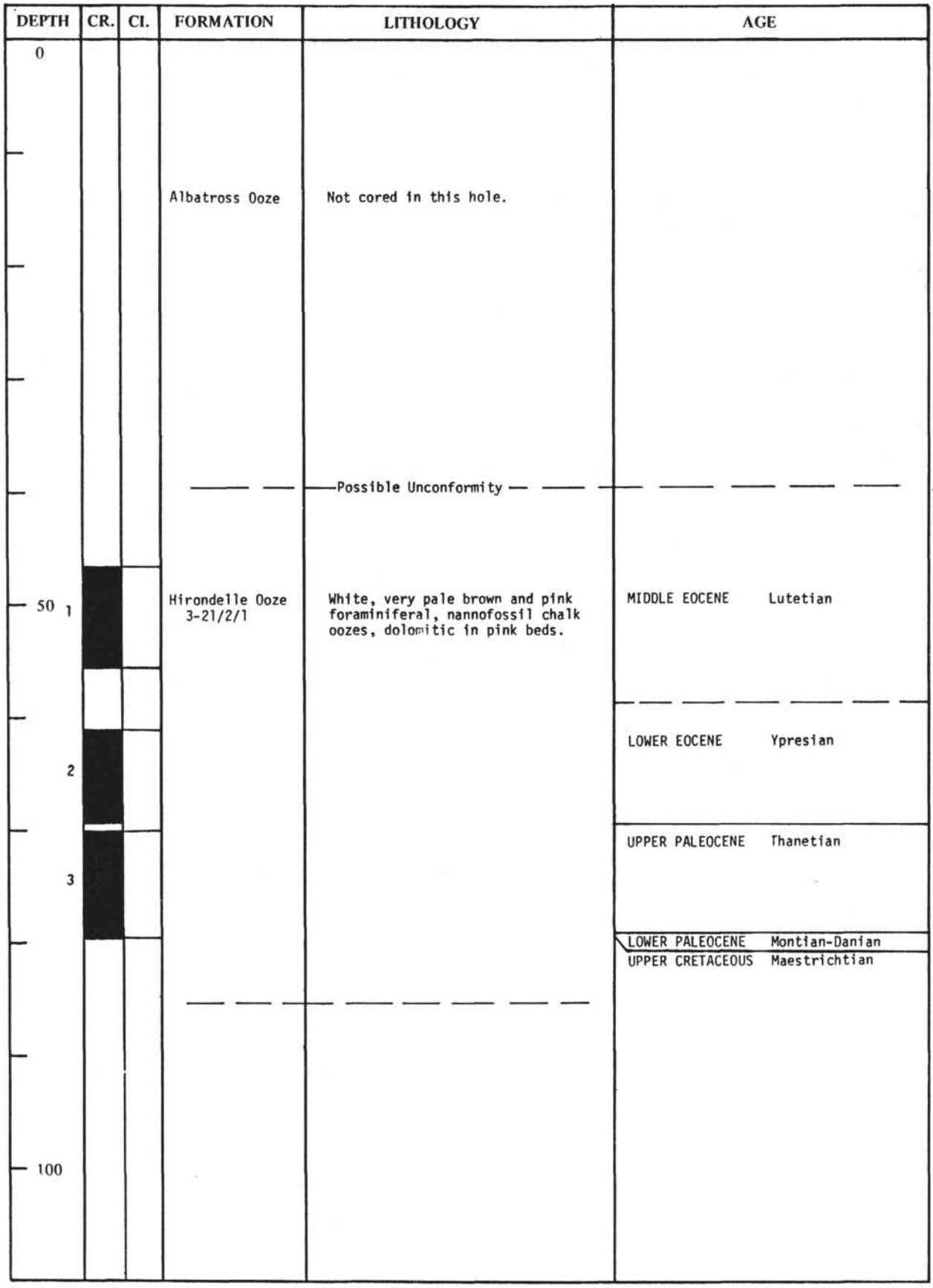
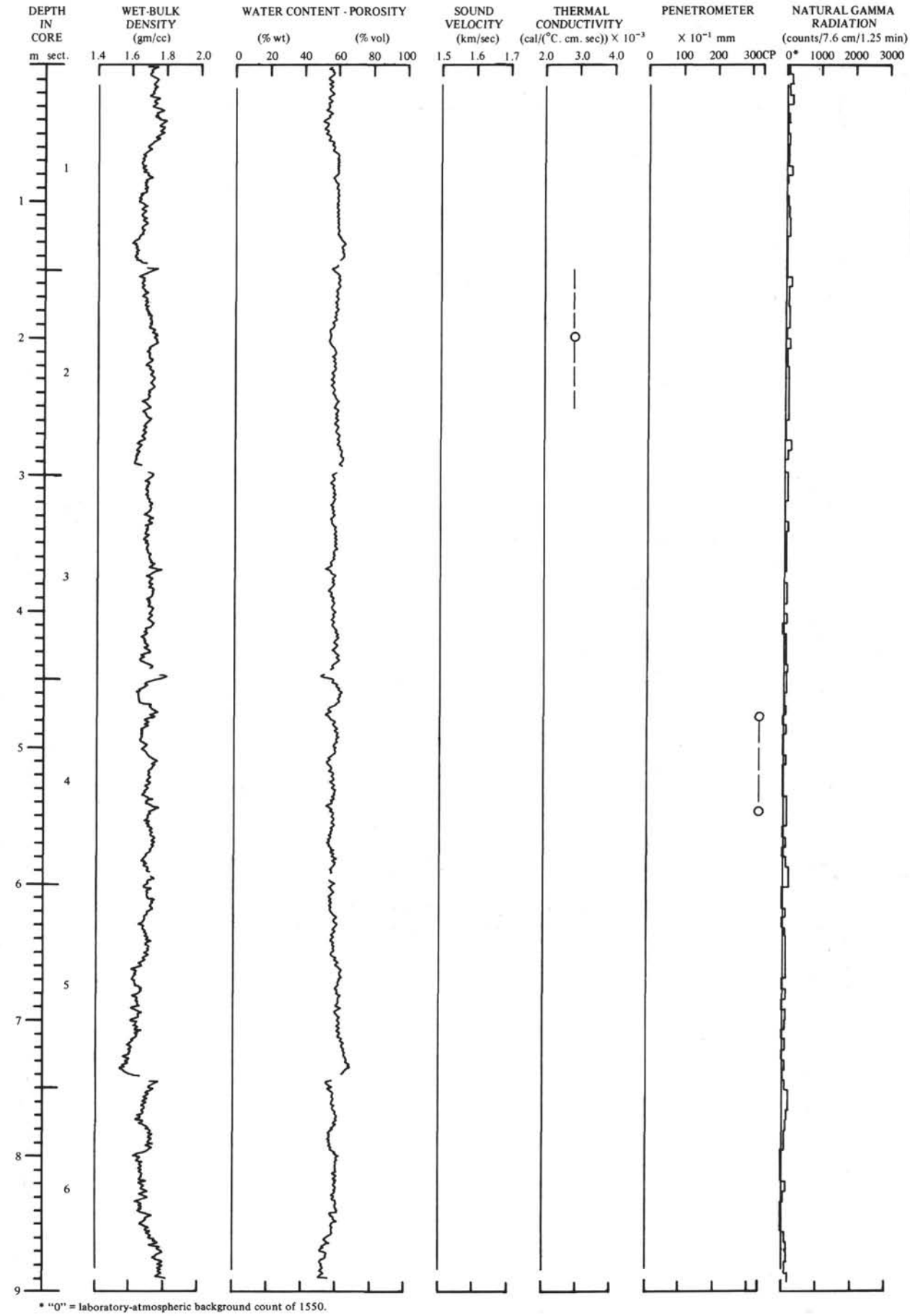


Figure 5B. *Summary of the cores from Hole 21A. (Depth in meters below sea bed; C.R. = core recovered; C.I. = cored interval.)*



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

Figure 6A. *Physical properties of Core 1, Hole 21.*

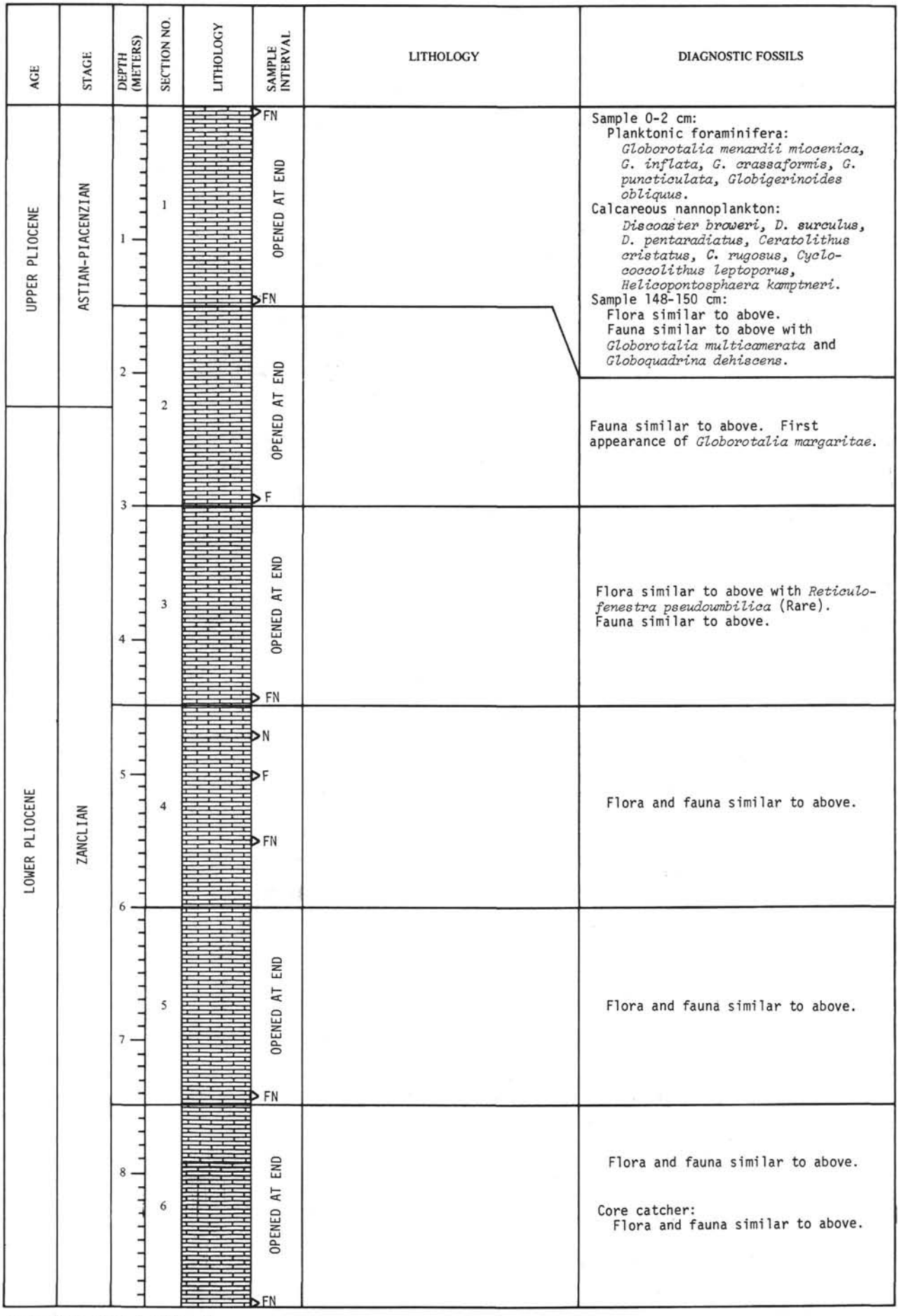


Figure 6B. *Core 1, Hole 21.*

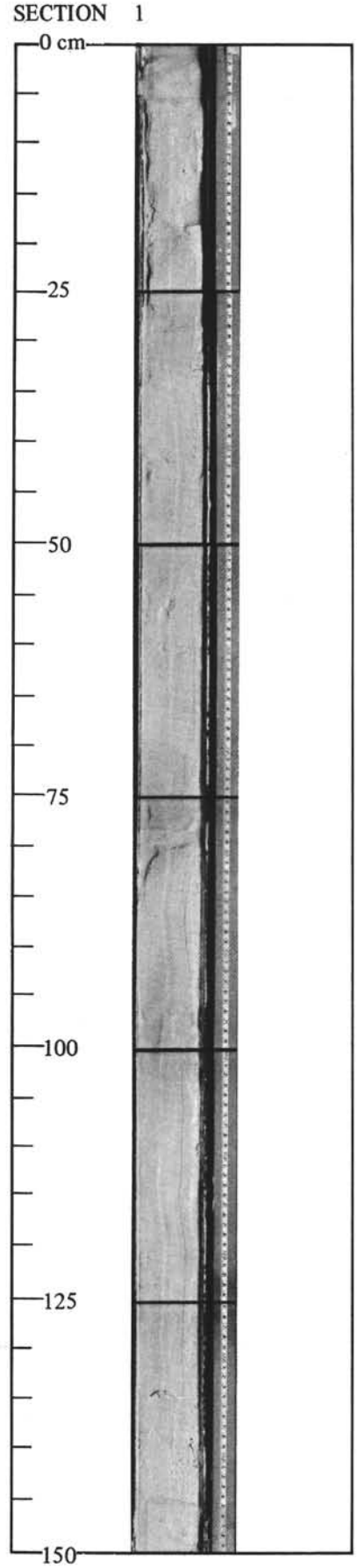


Plate 1. *Core 1, Hole 21.*

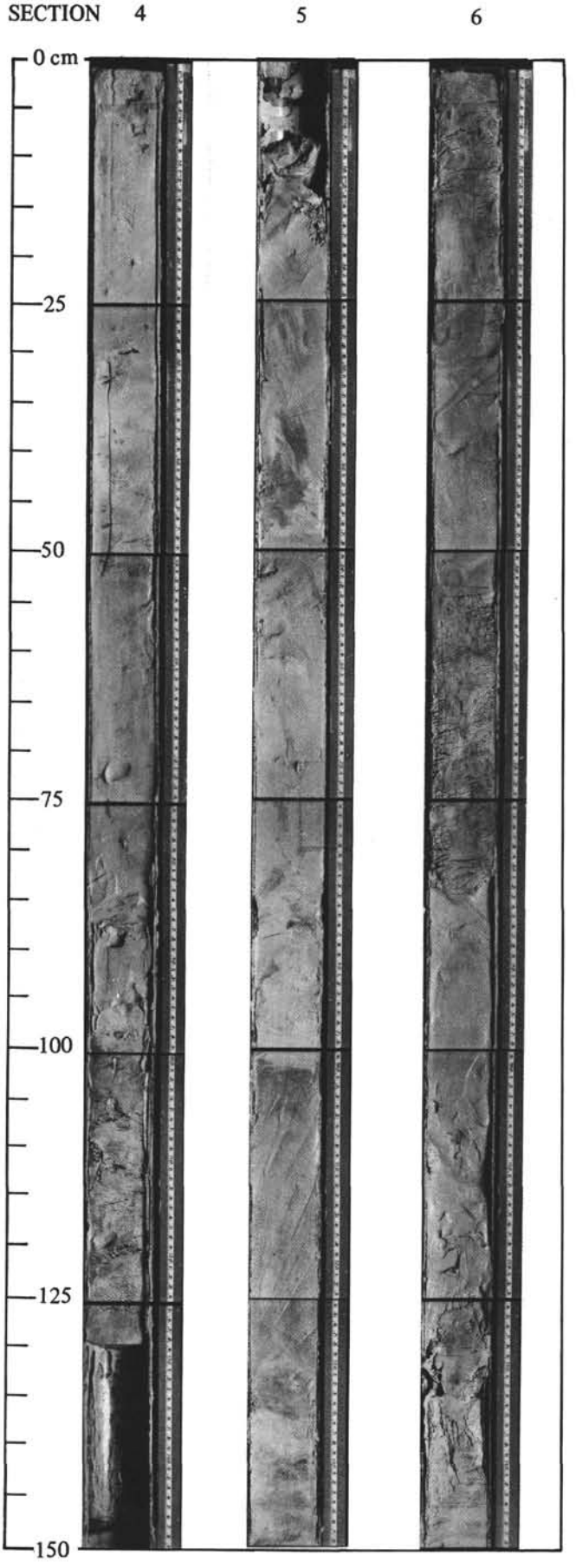
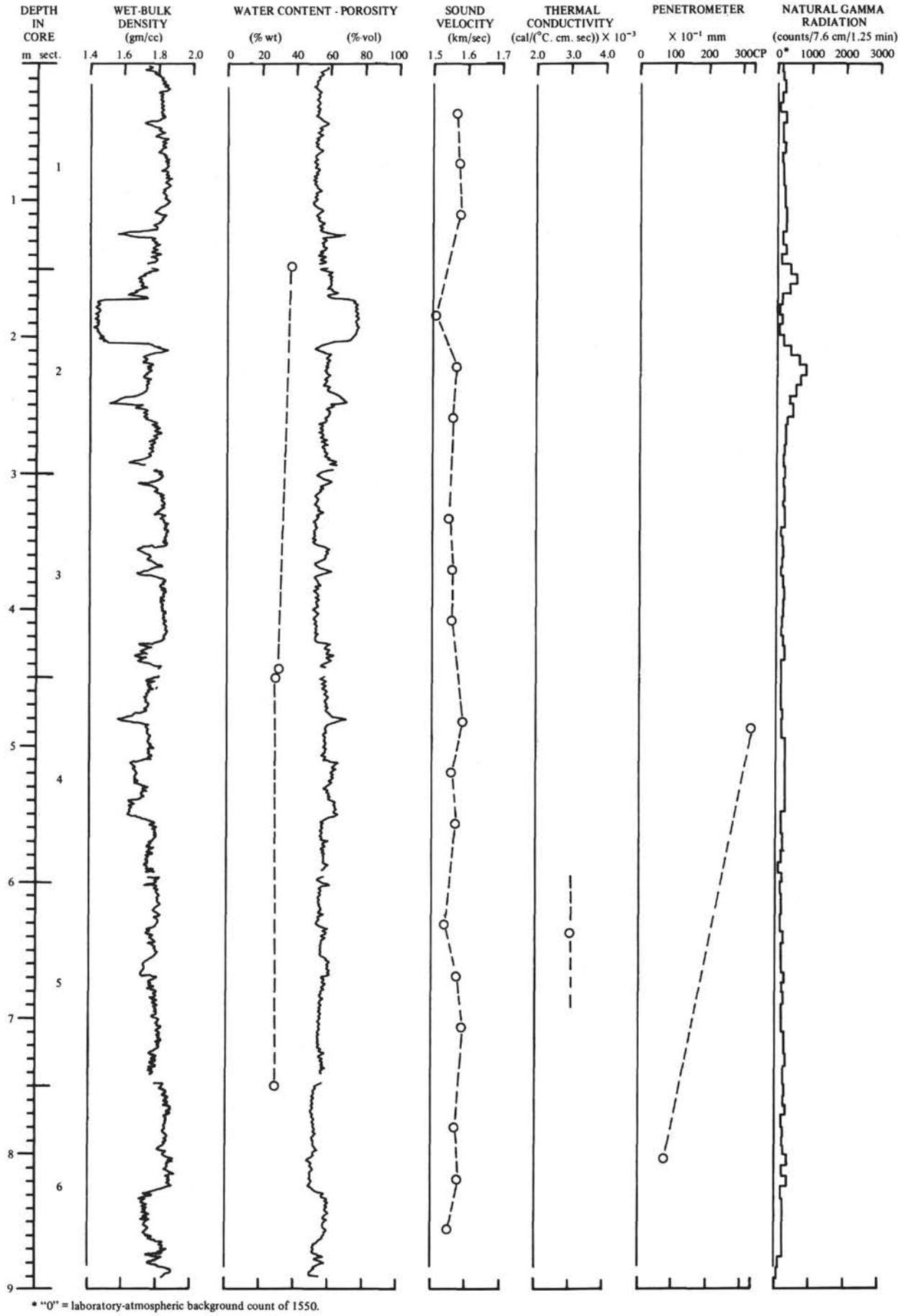


Plate 2. *Core 2, Hole 21.*



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

Figure 7A. *Physical properties of Core 2, Hole 21.*

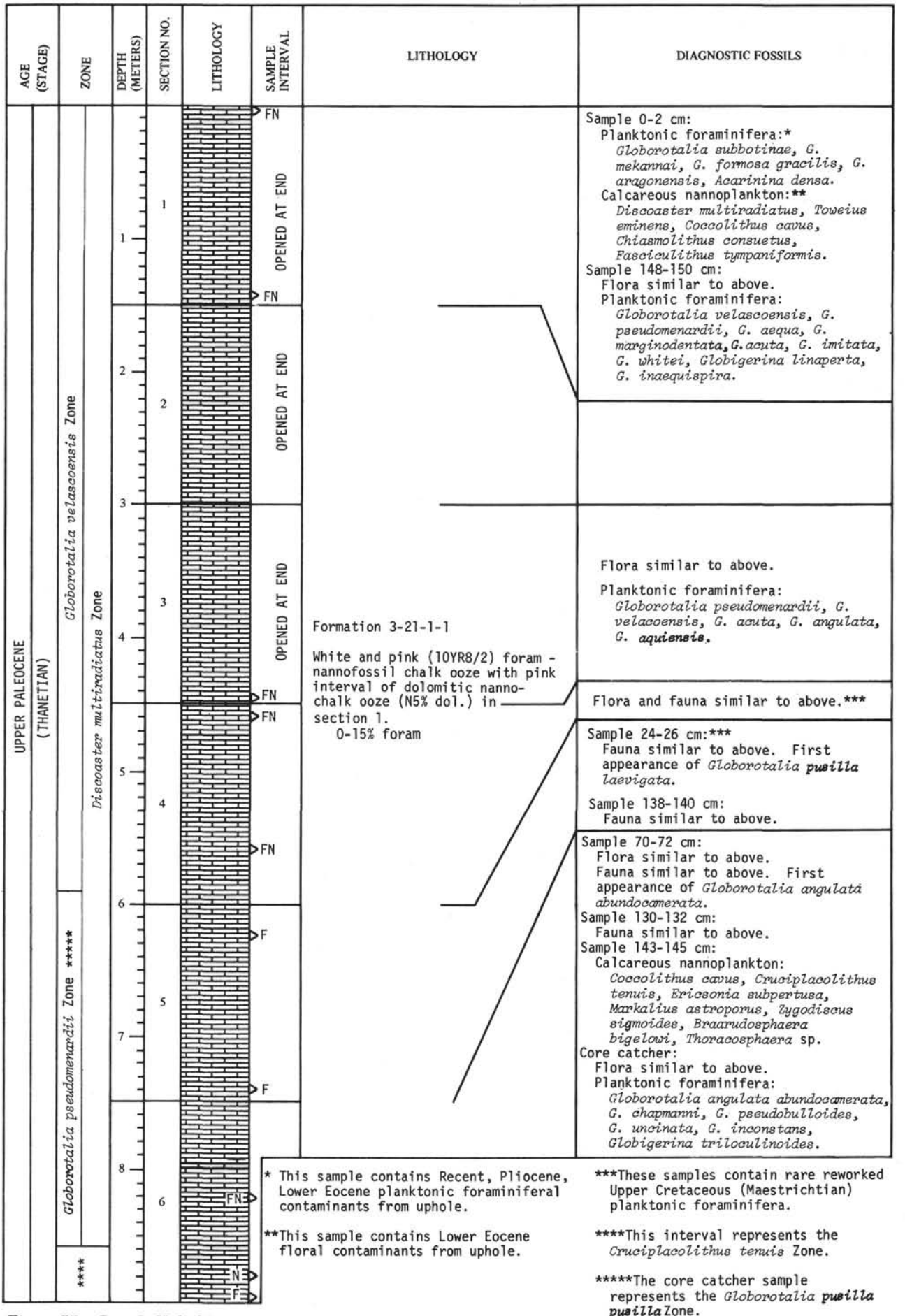
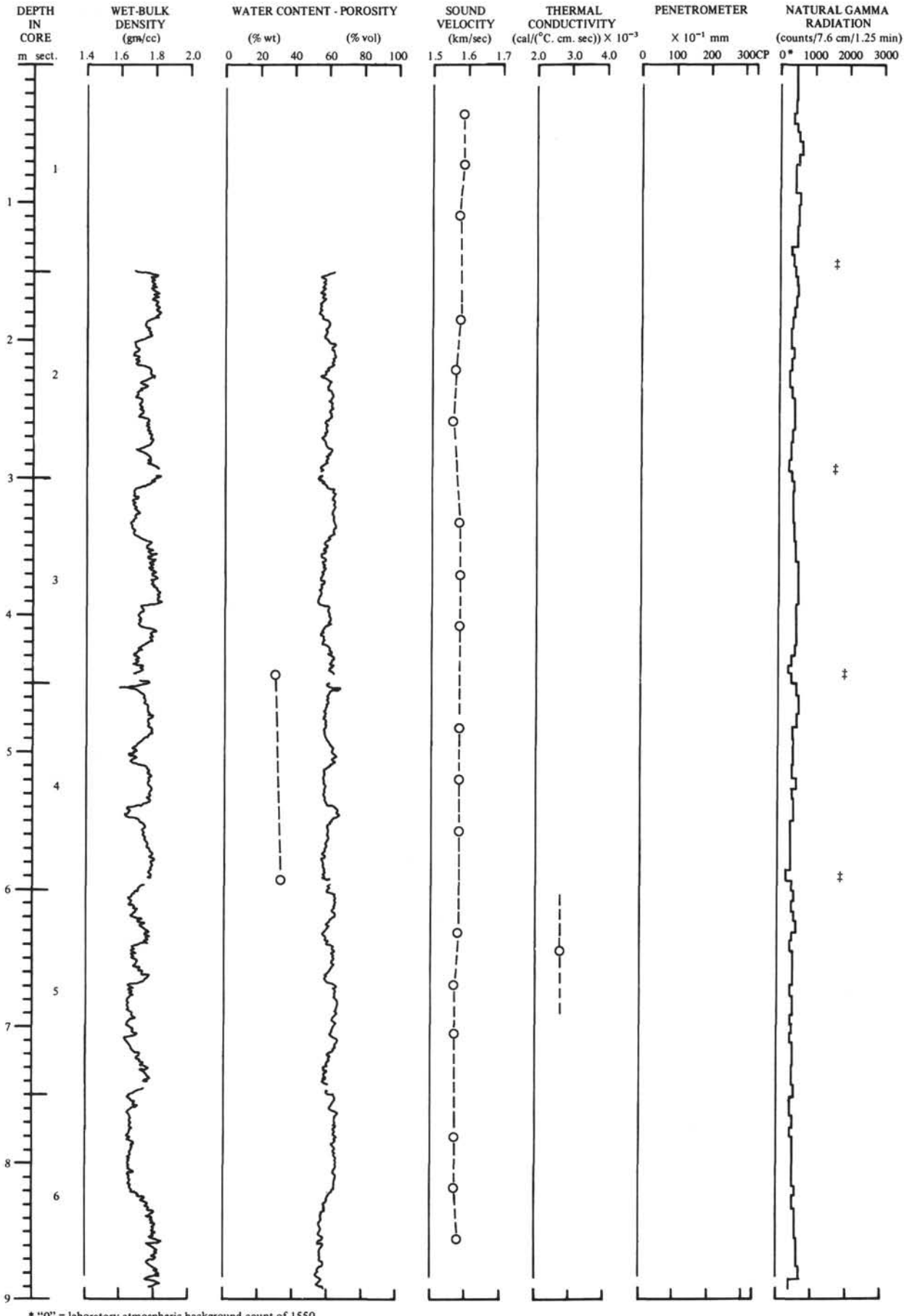


Figure 7B. *Core 2, Hole 21.*



* "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 8A. *Physical propetries of Core 3, Hole 21.*

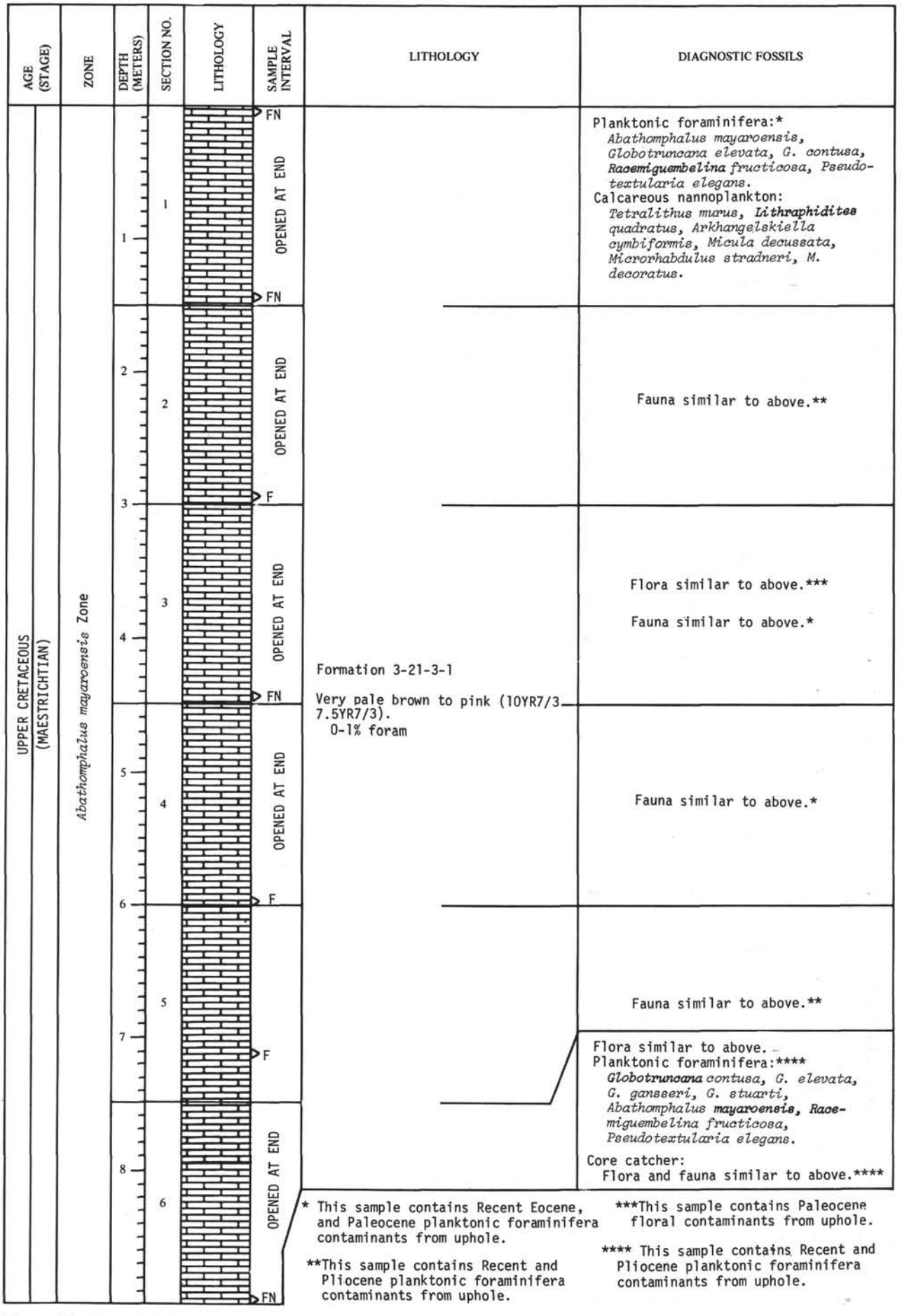
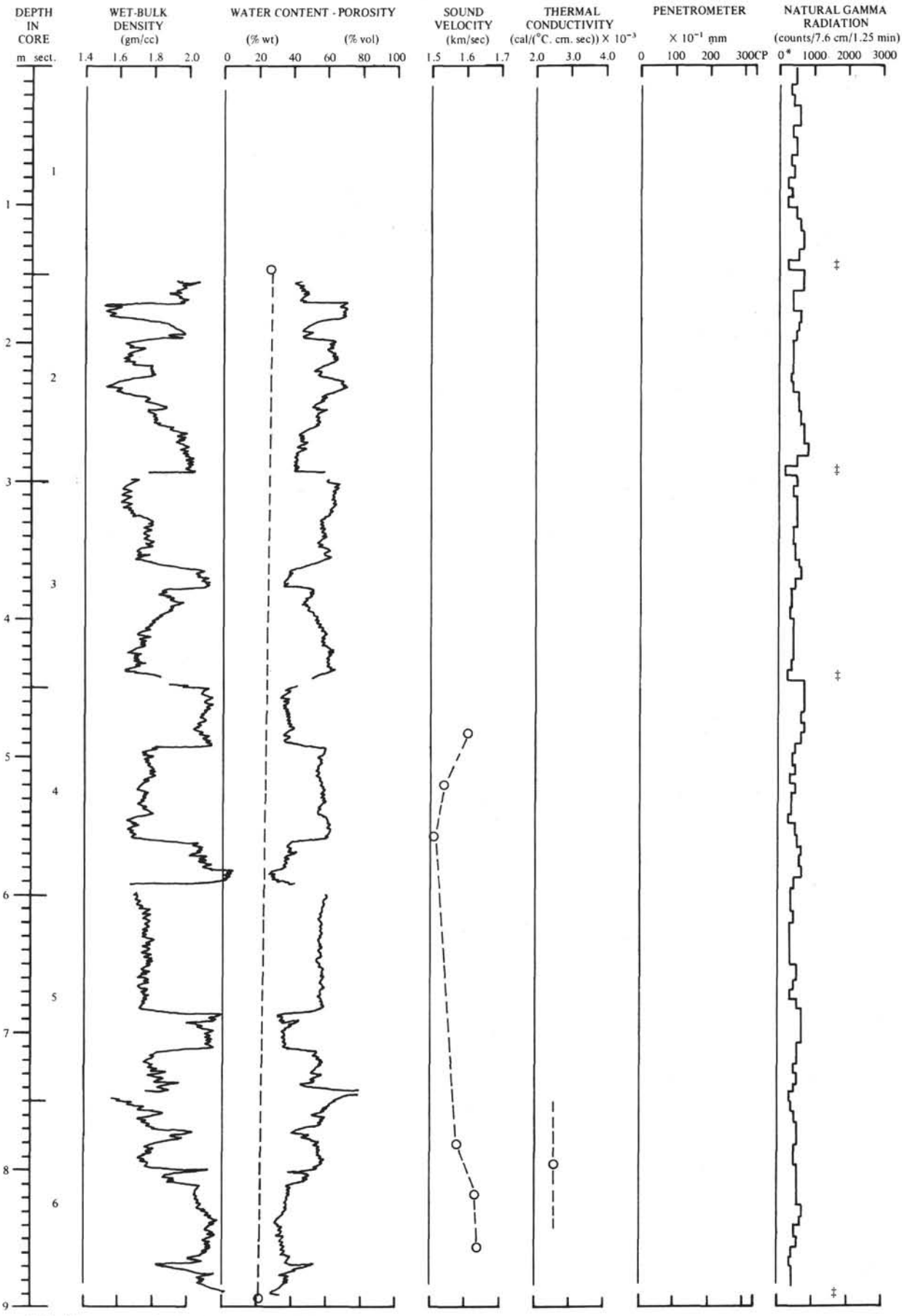


Figure 8B. *Core 3, Hole 21.*



* "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 4, Hole 21.*

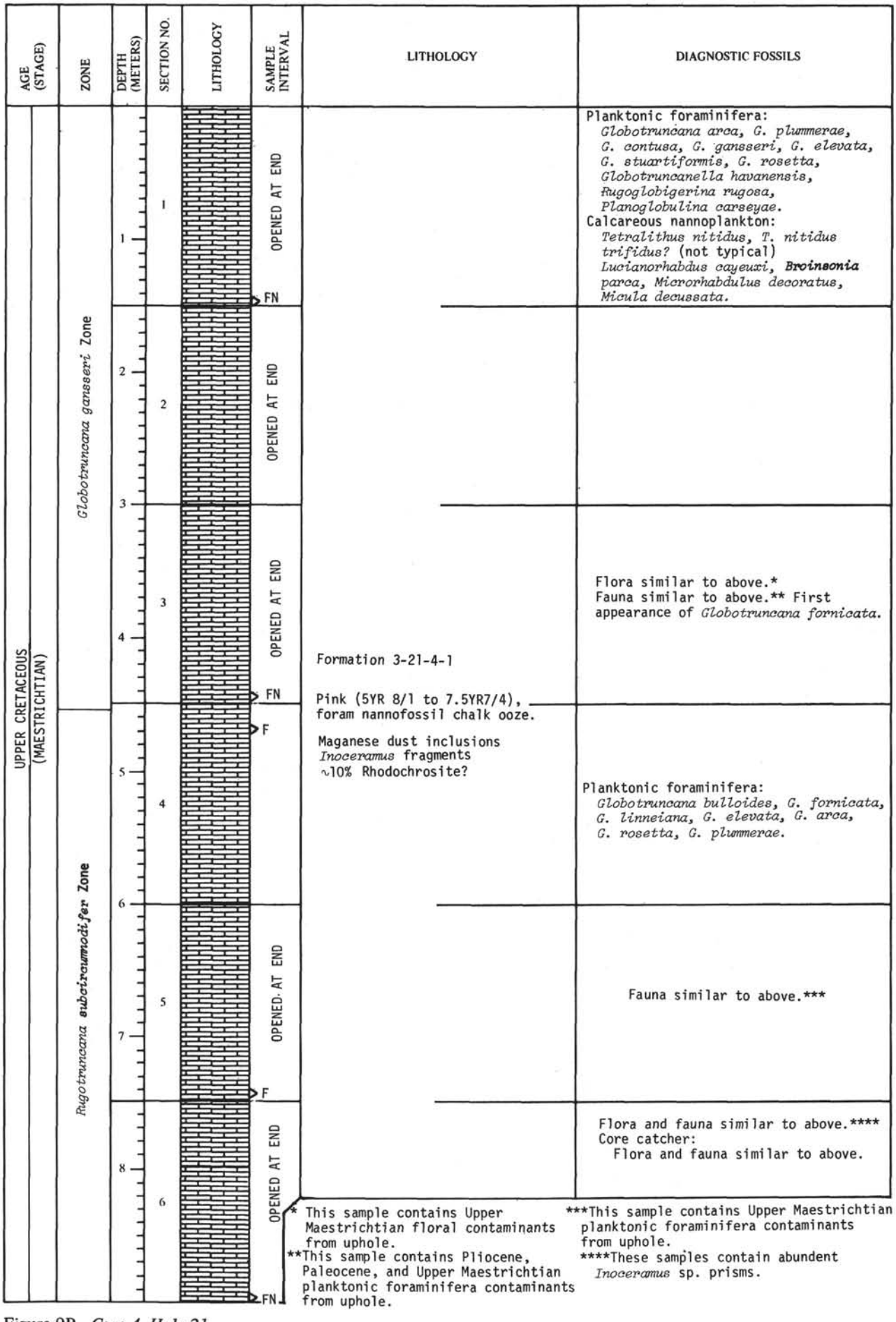
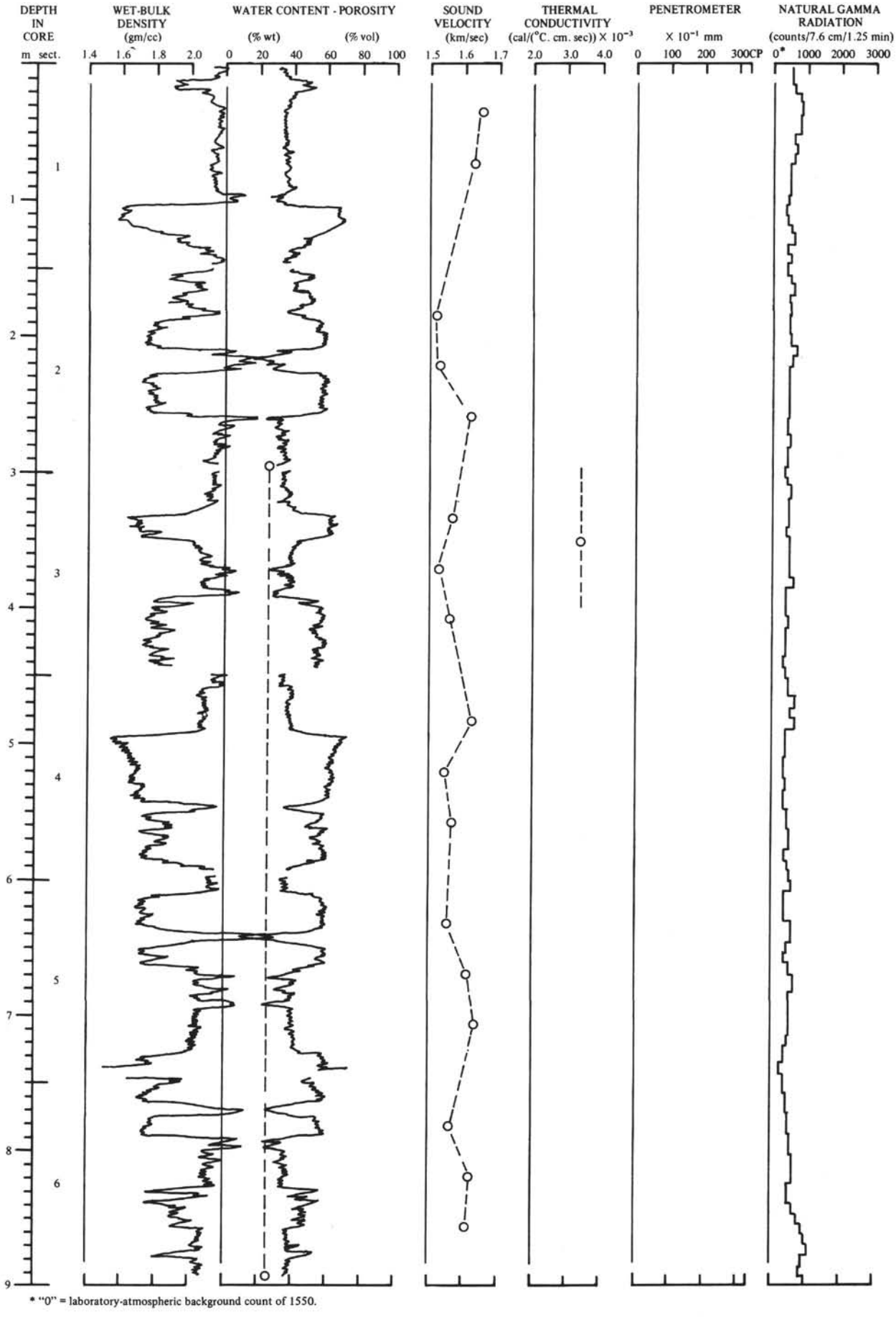


Figure 9B. *Core 4, Hole 21.*



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

Figure 10A. *Physical properties of Core 5, Hole 21*

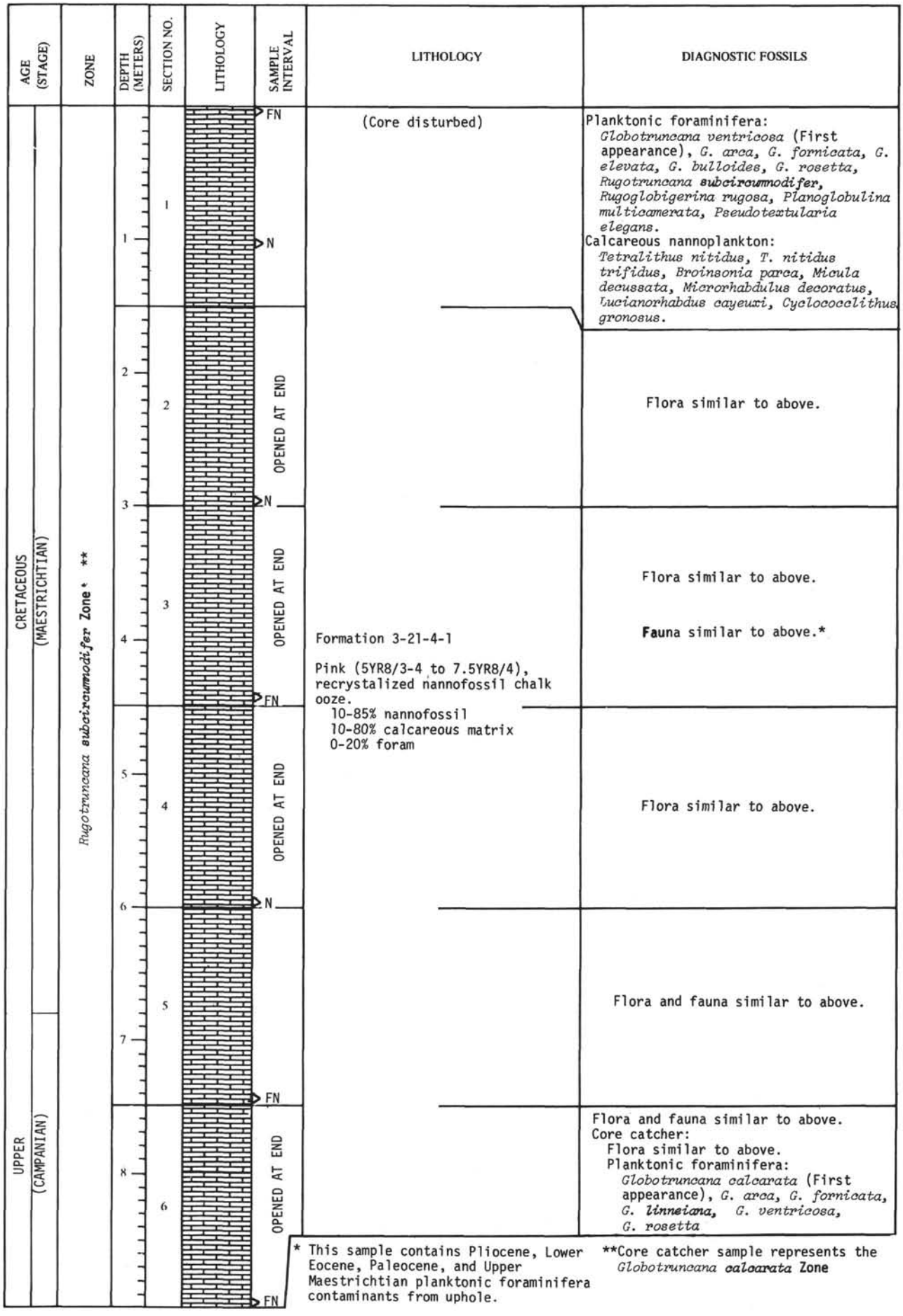


Figure 10B. *Core 5, Hole 21.*

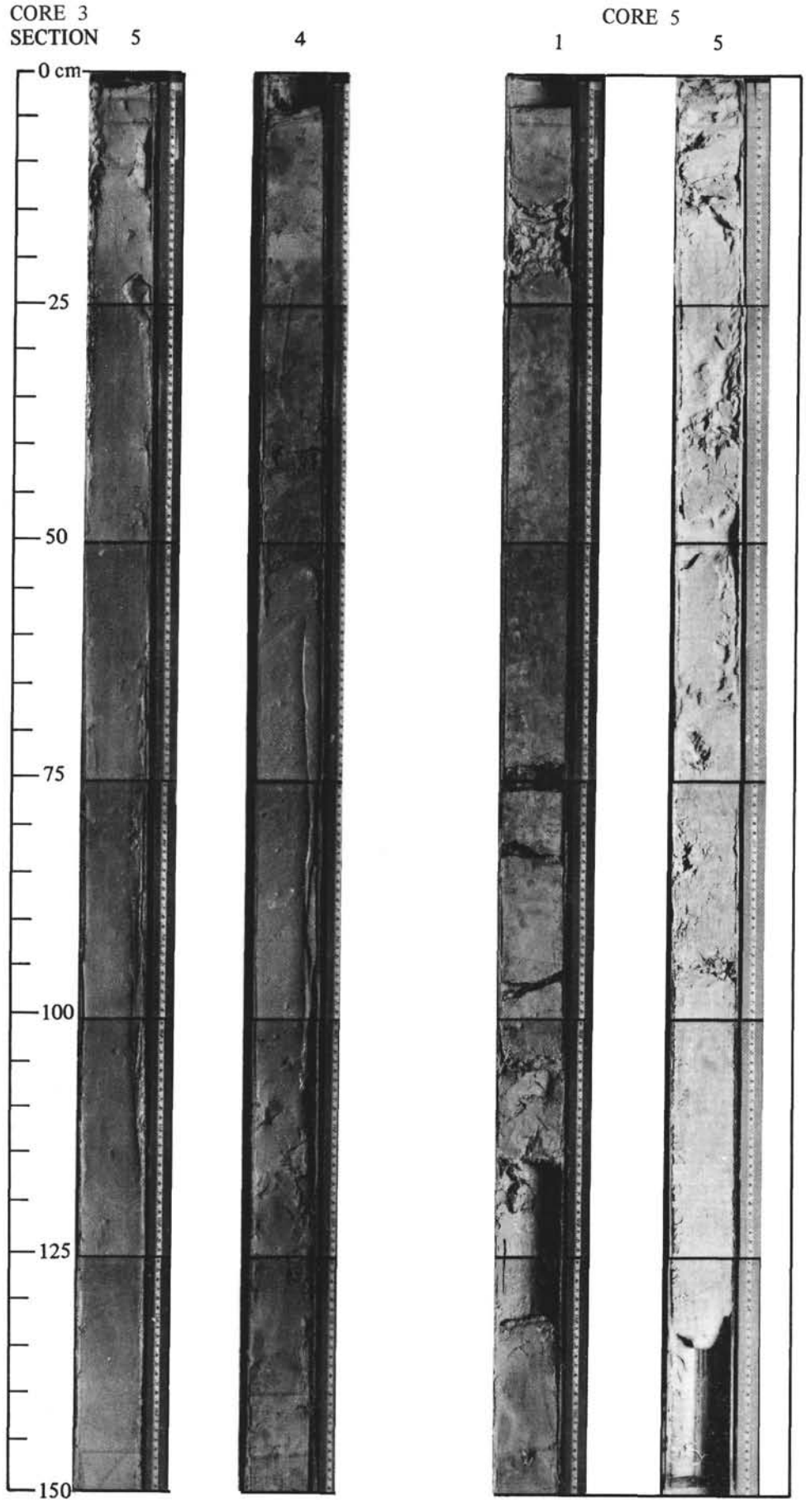


Plate 3. *Sections of Cores 3, 4 & 5, Hole 21.*

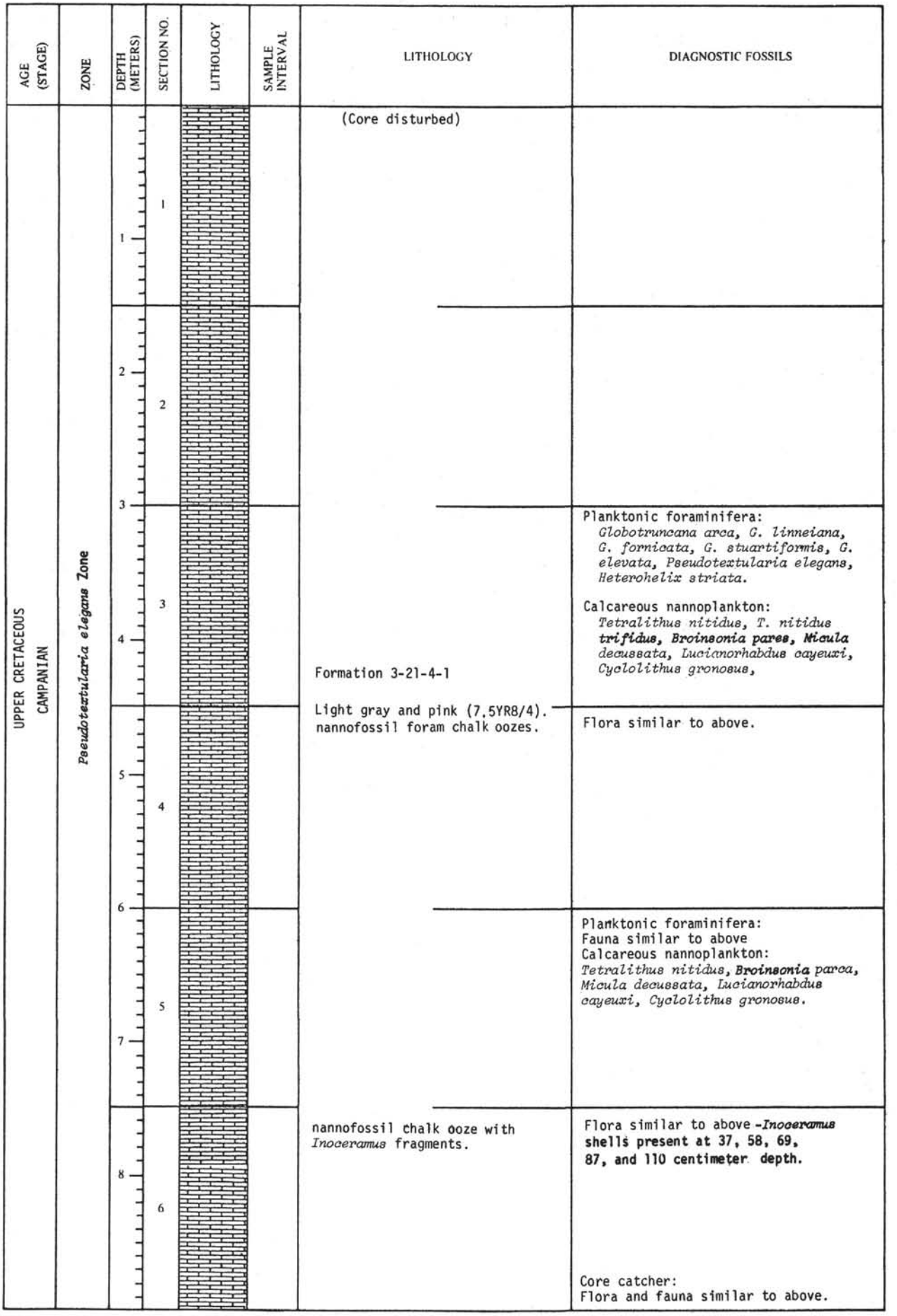
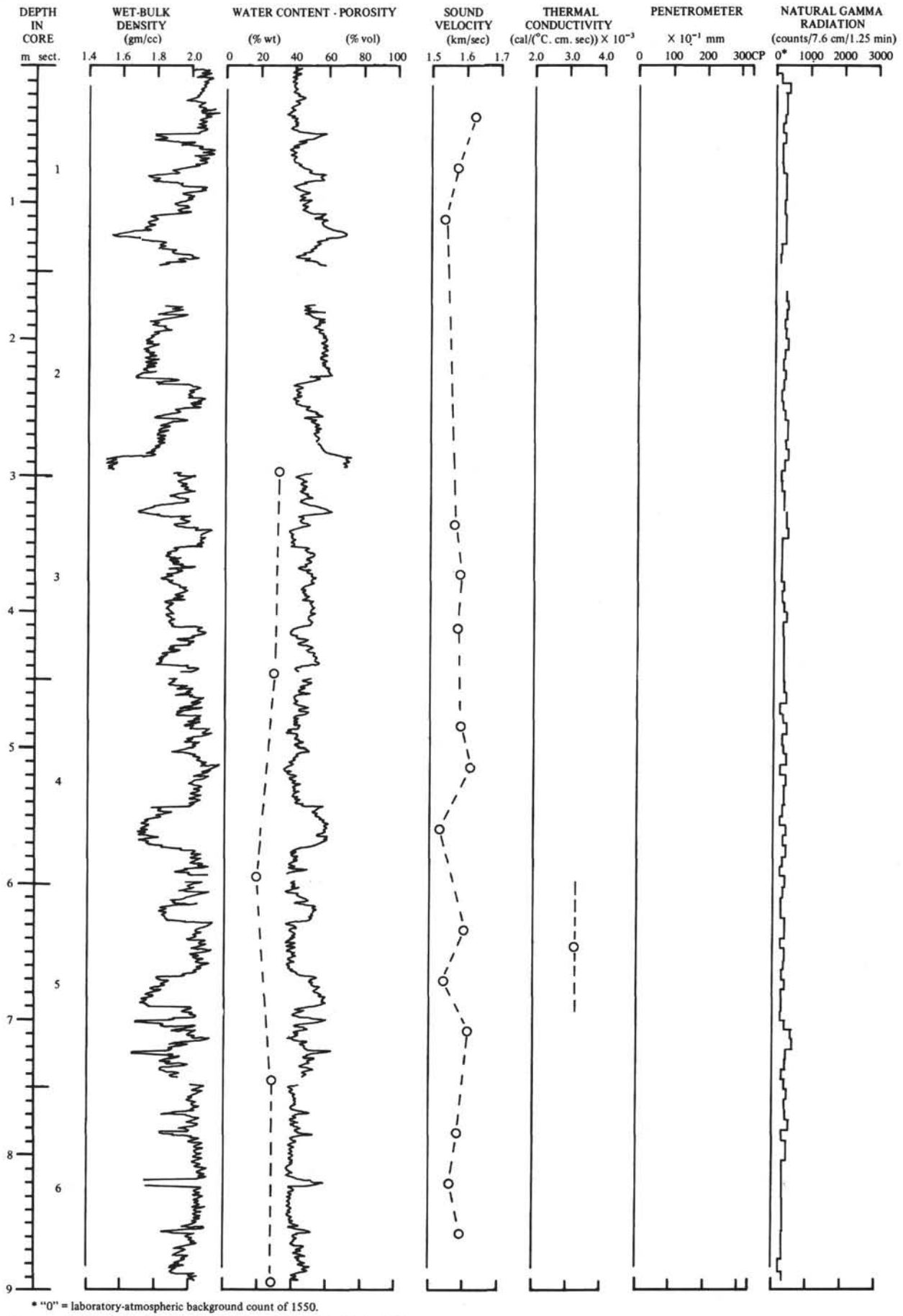


Figure 11. *Core 6, Hole 21.*



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

Figure 12A. *Physical properties of Core 7, Hole 21.*

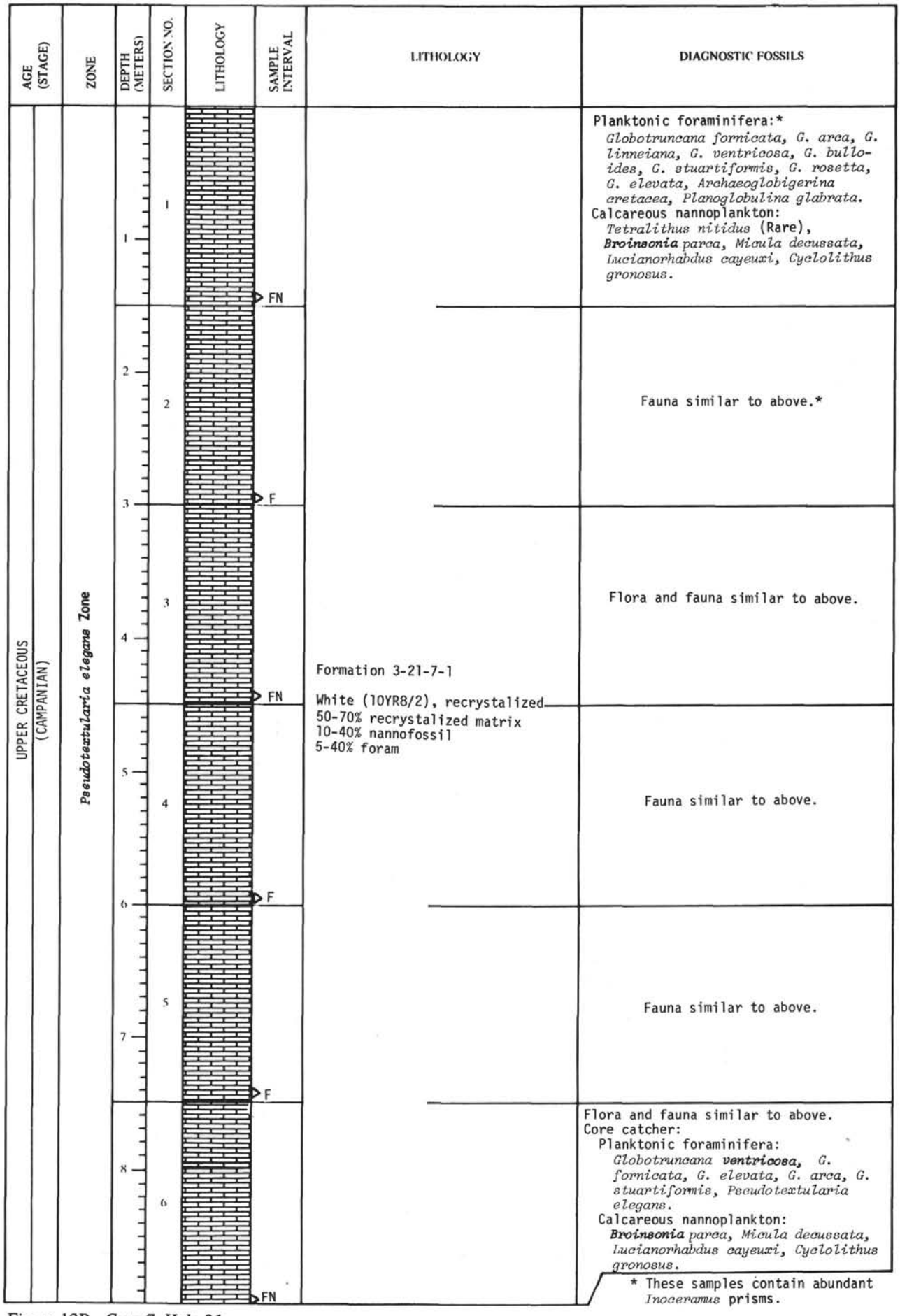
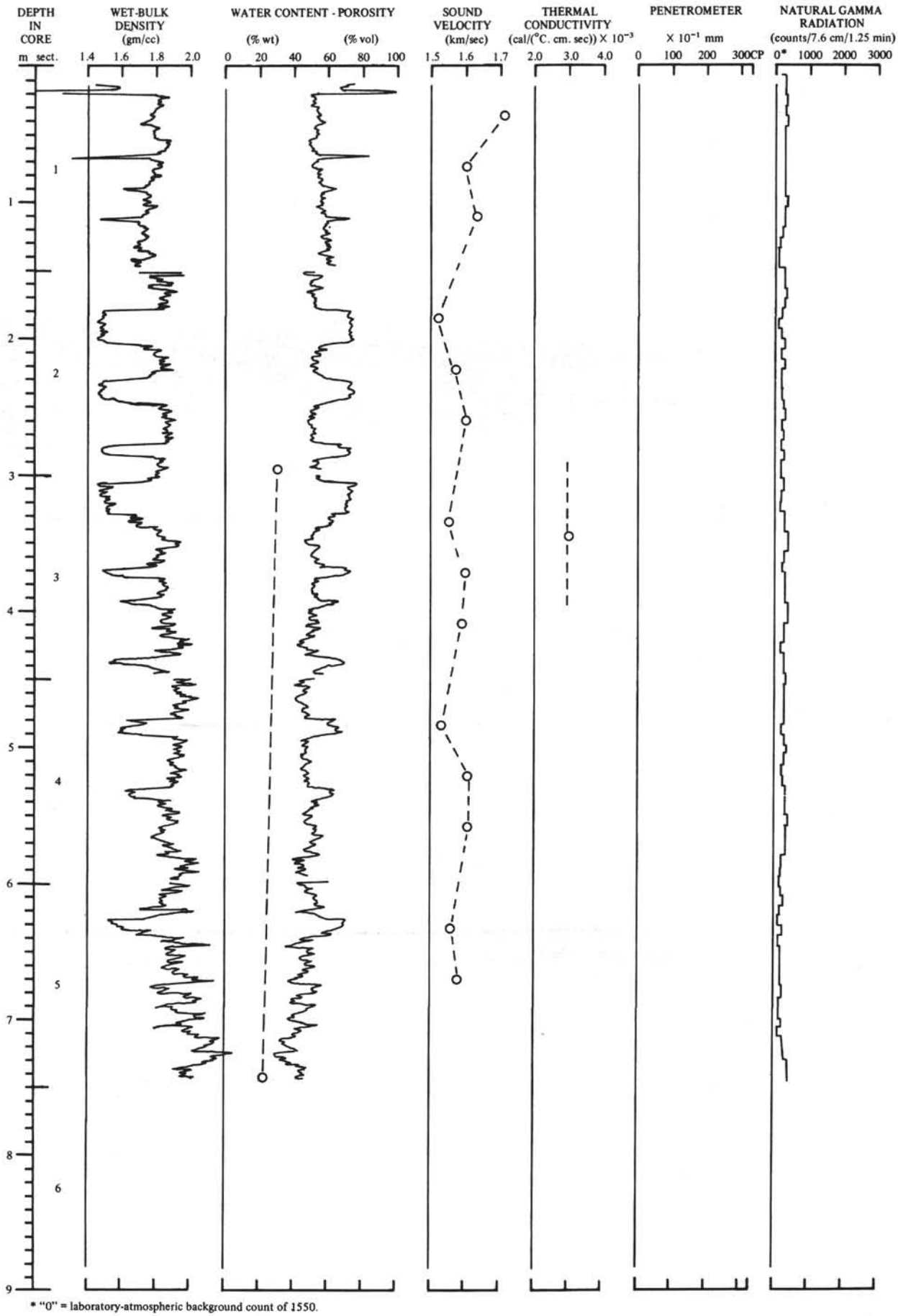


Figure 12B. *Core 7, Hole 21.*



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

Figure 13A. *Physical properties of Core 8, Hole 21.*

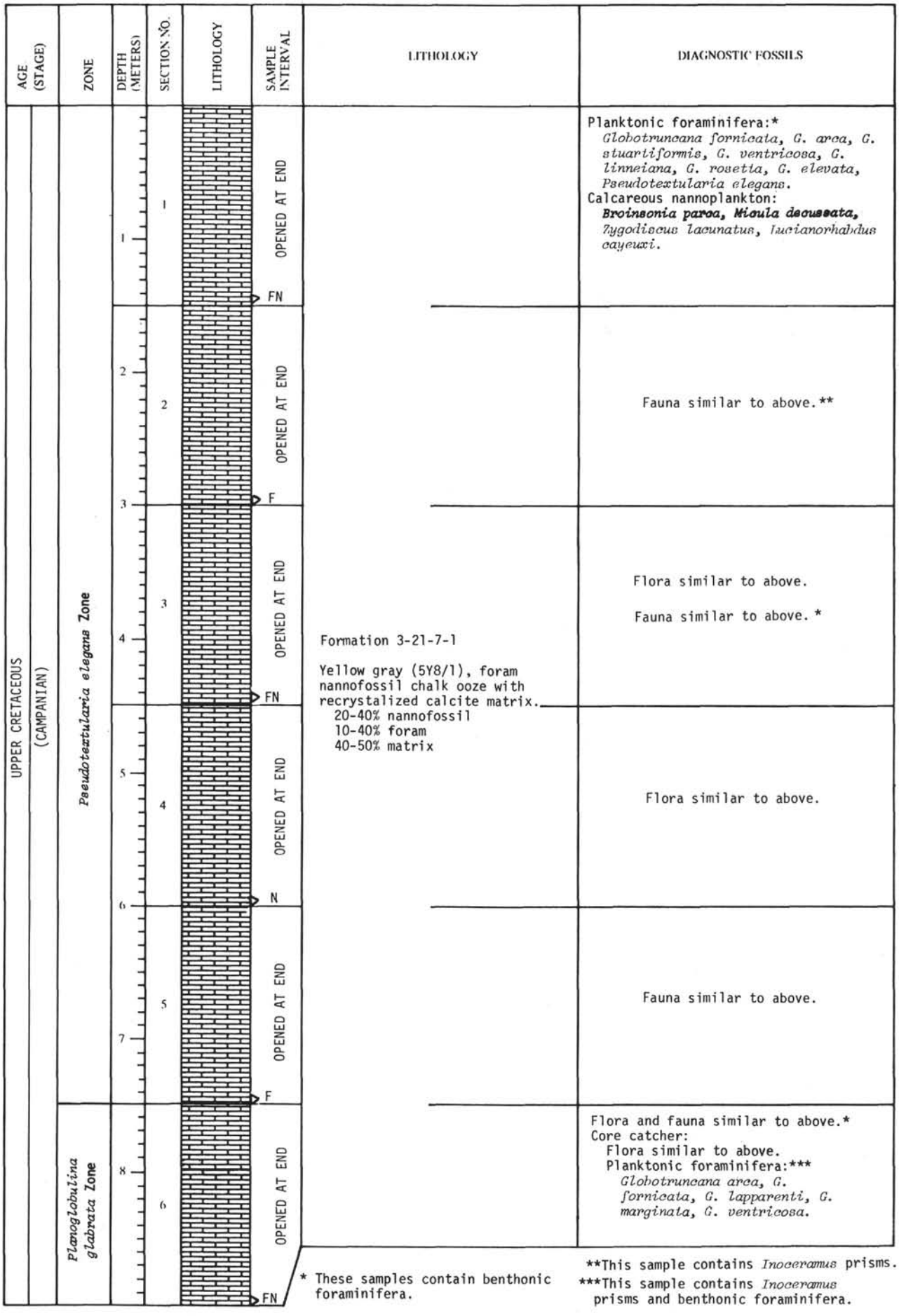


Figure 13B. *Core 8, Hole 21.*

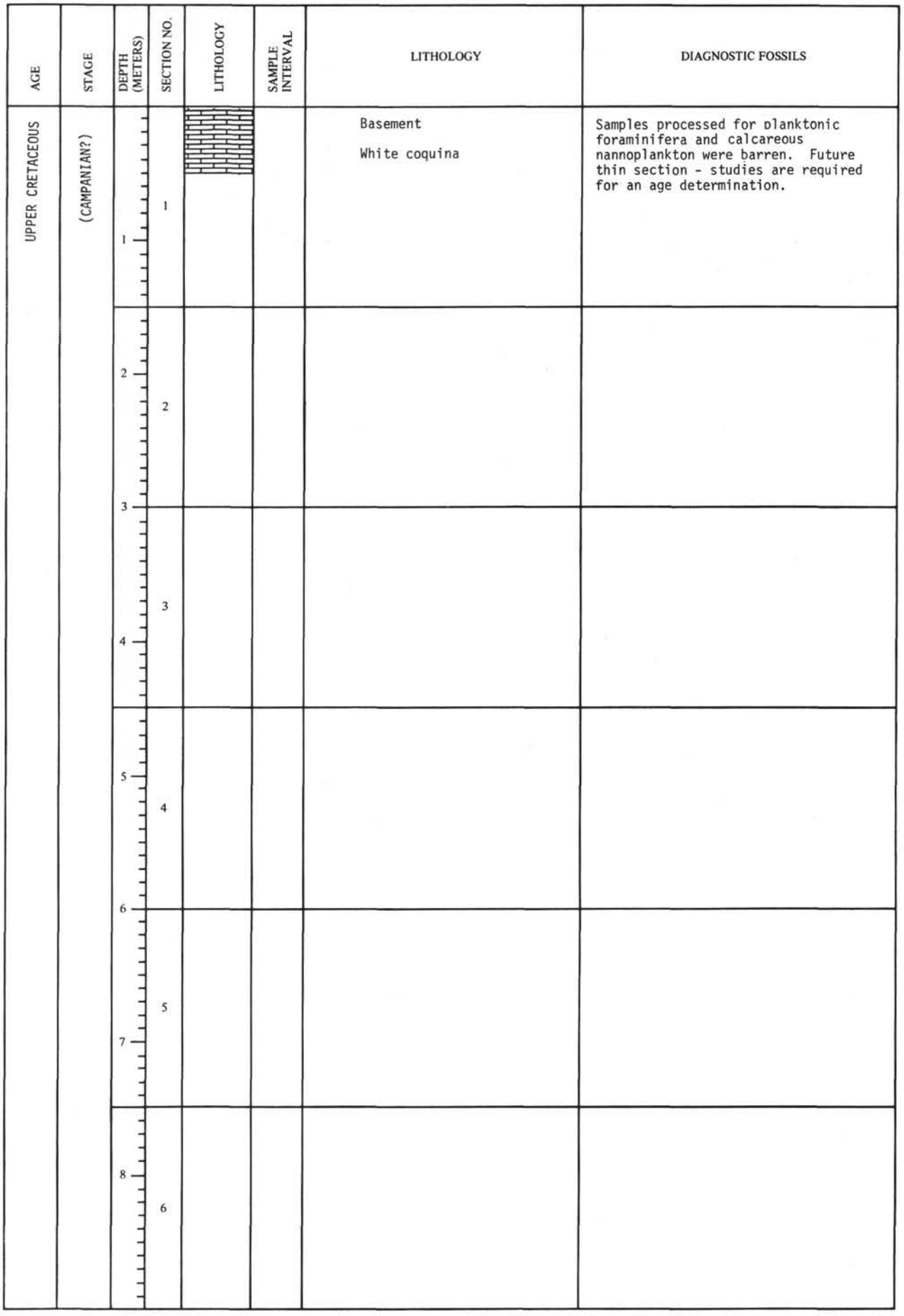


Figure 14. *Core 9, Hole 21.*

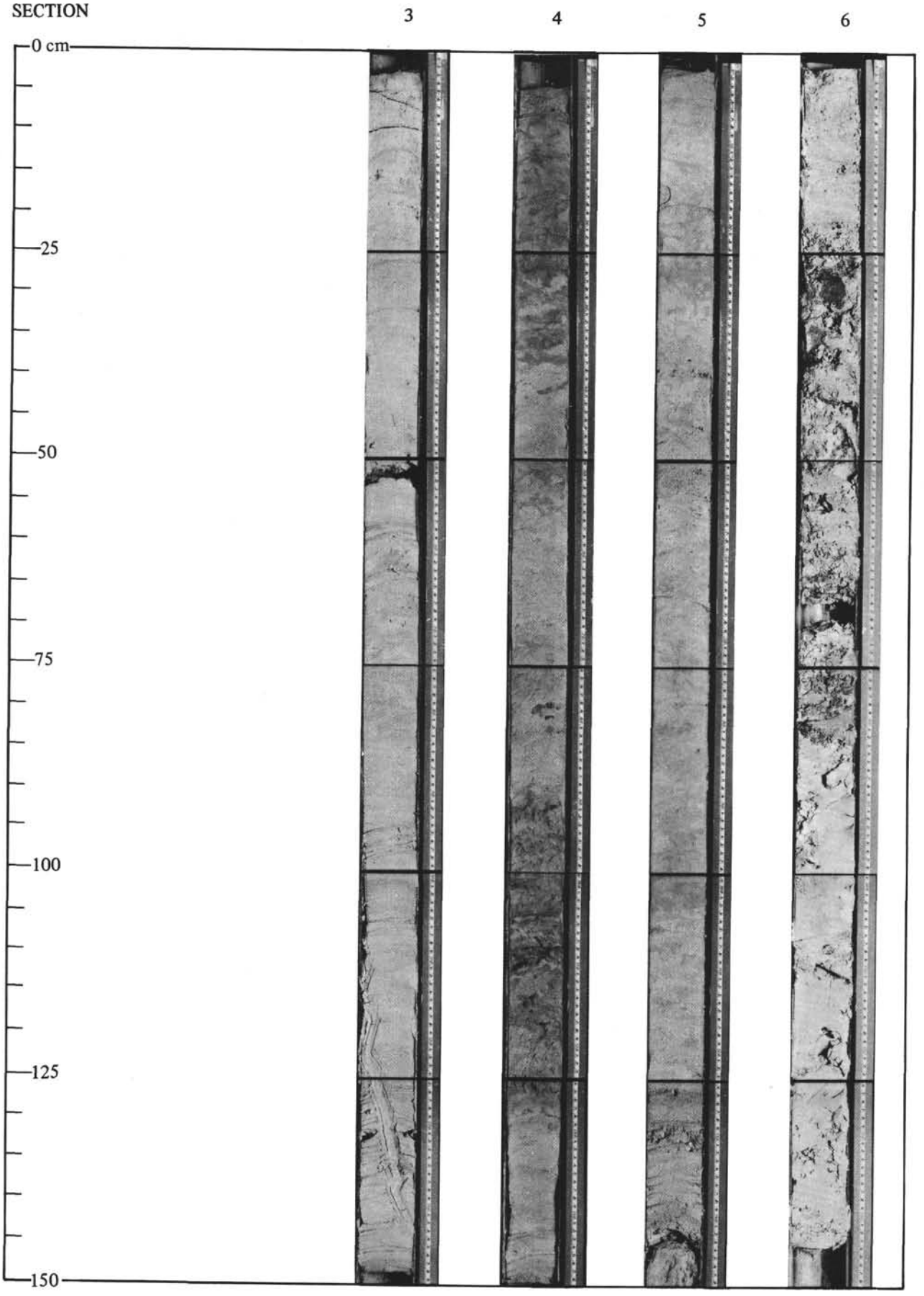


Plate 4. *Core 6, Hole 21.*

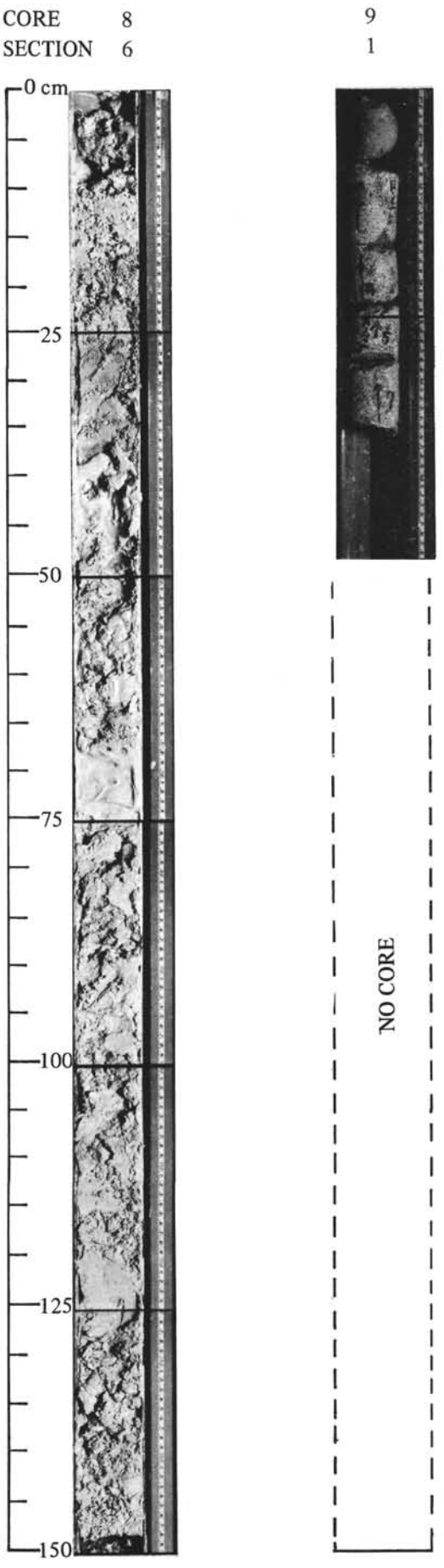


Plate 5. *Sections of Cores 8 and 9, Hole 21.*

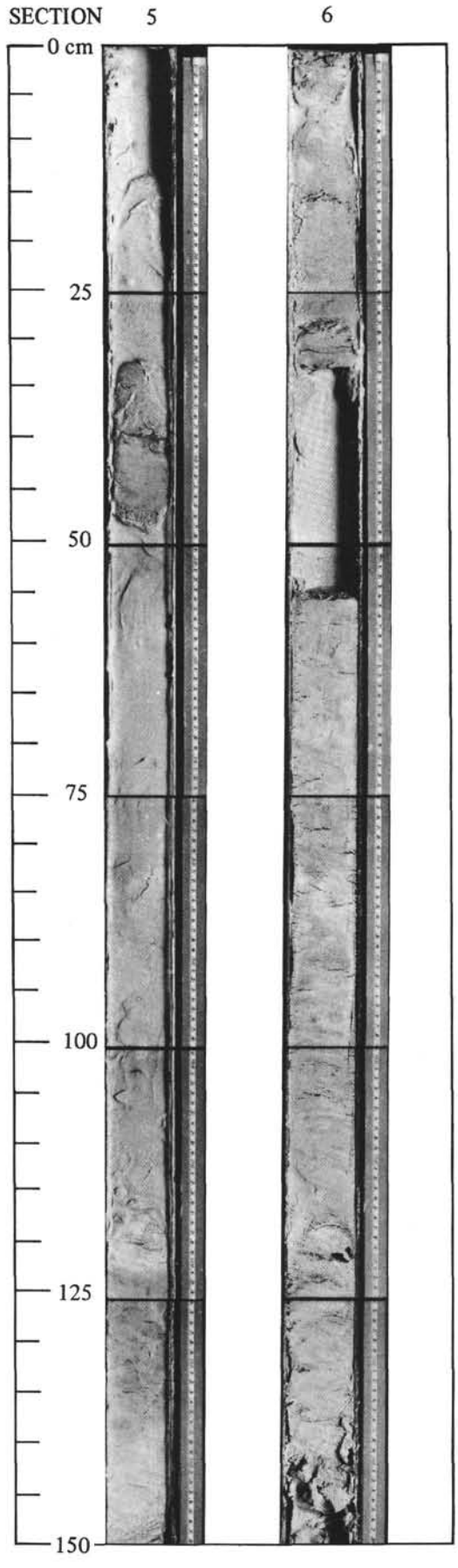
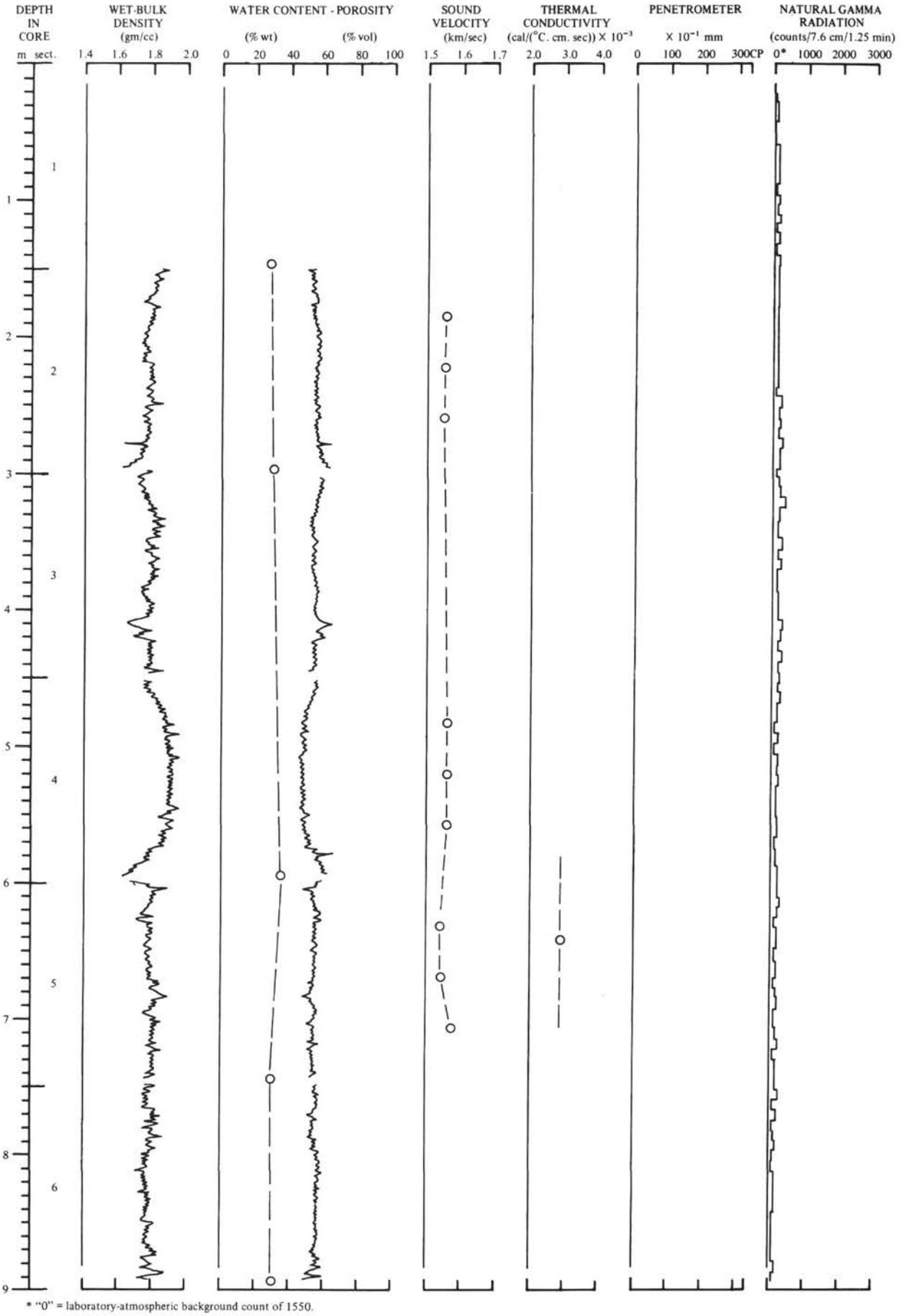


Plate 6. *Core 3, Hole 21A.*



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

Figure 15A. *Physical properties of Core 1, Hole 21A.*

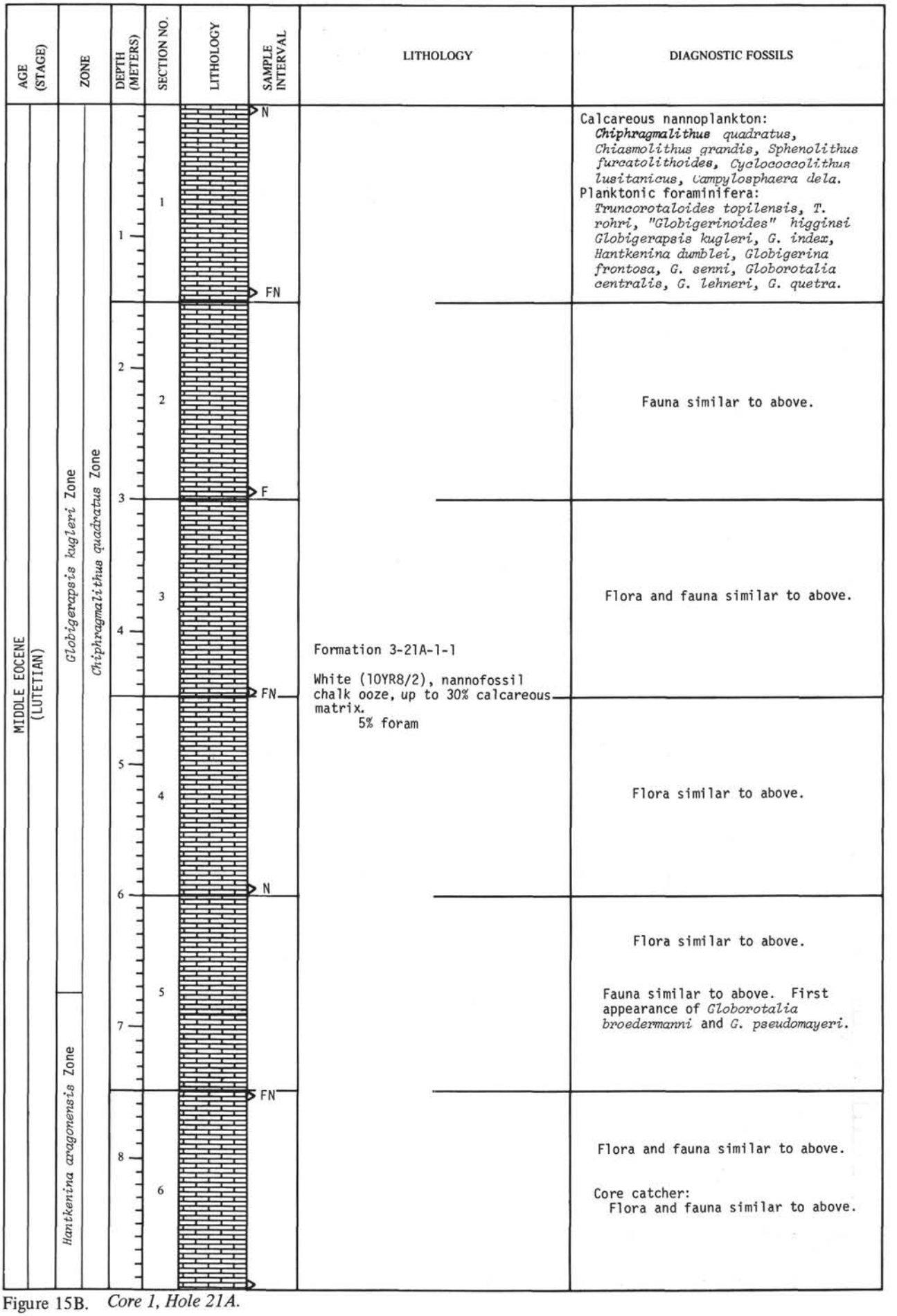
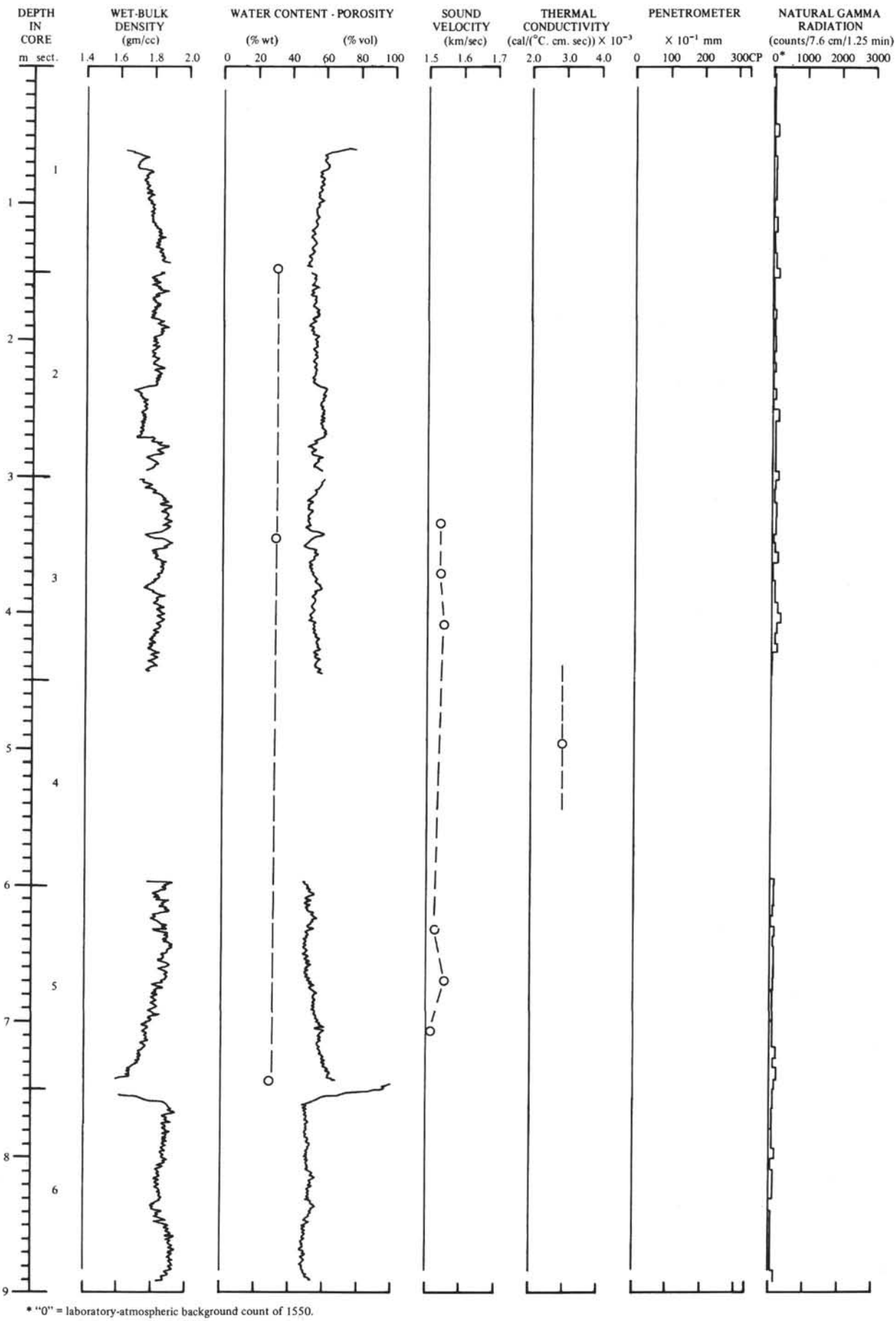


Figure 15B. *Core 1, Hole 21A.*



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

Figure 16A. *Physical properties of Coer 2, Hole 21A.*

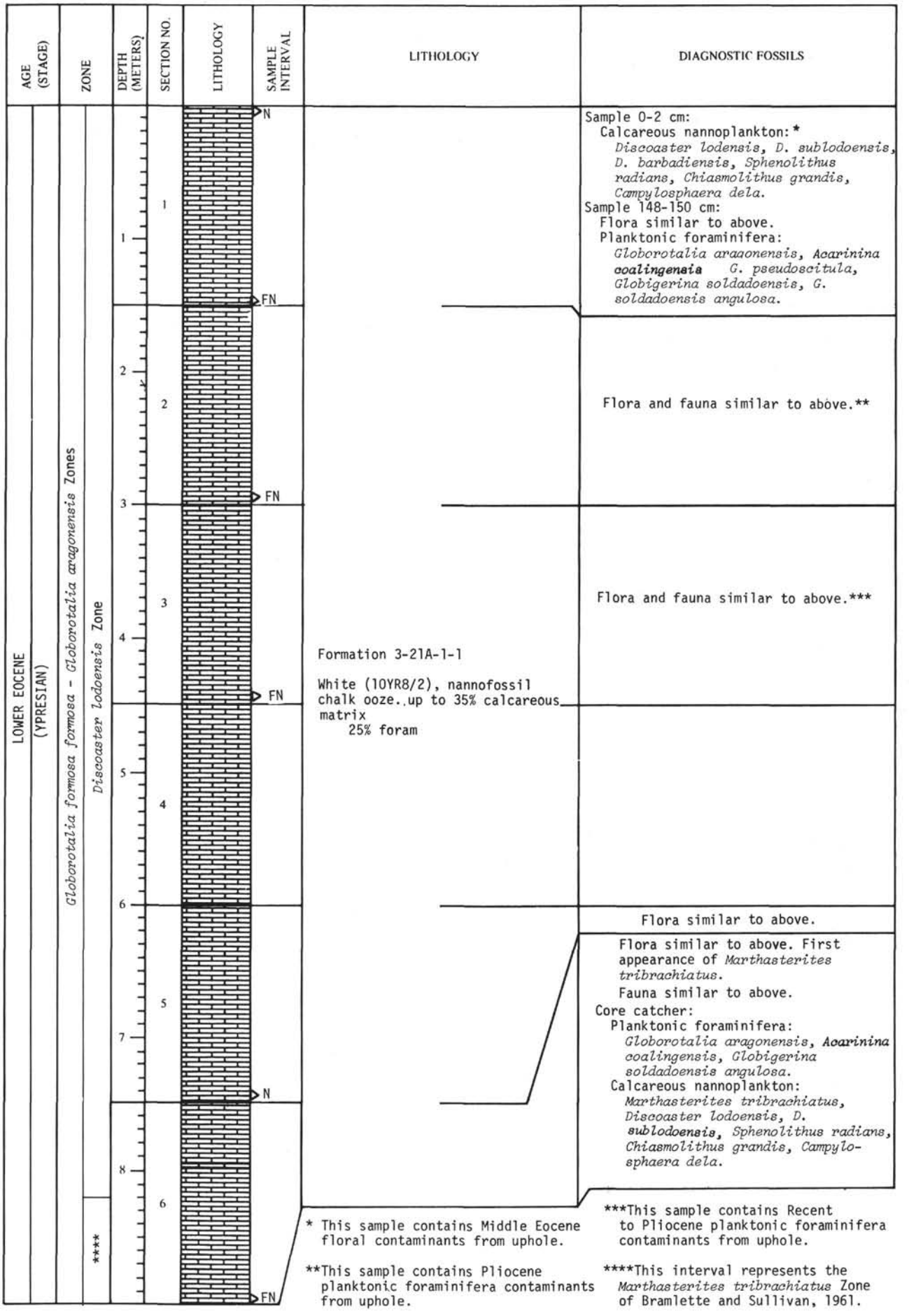
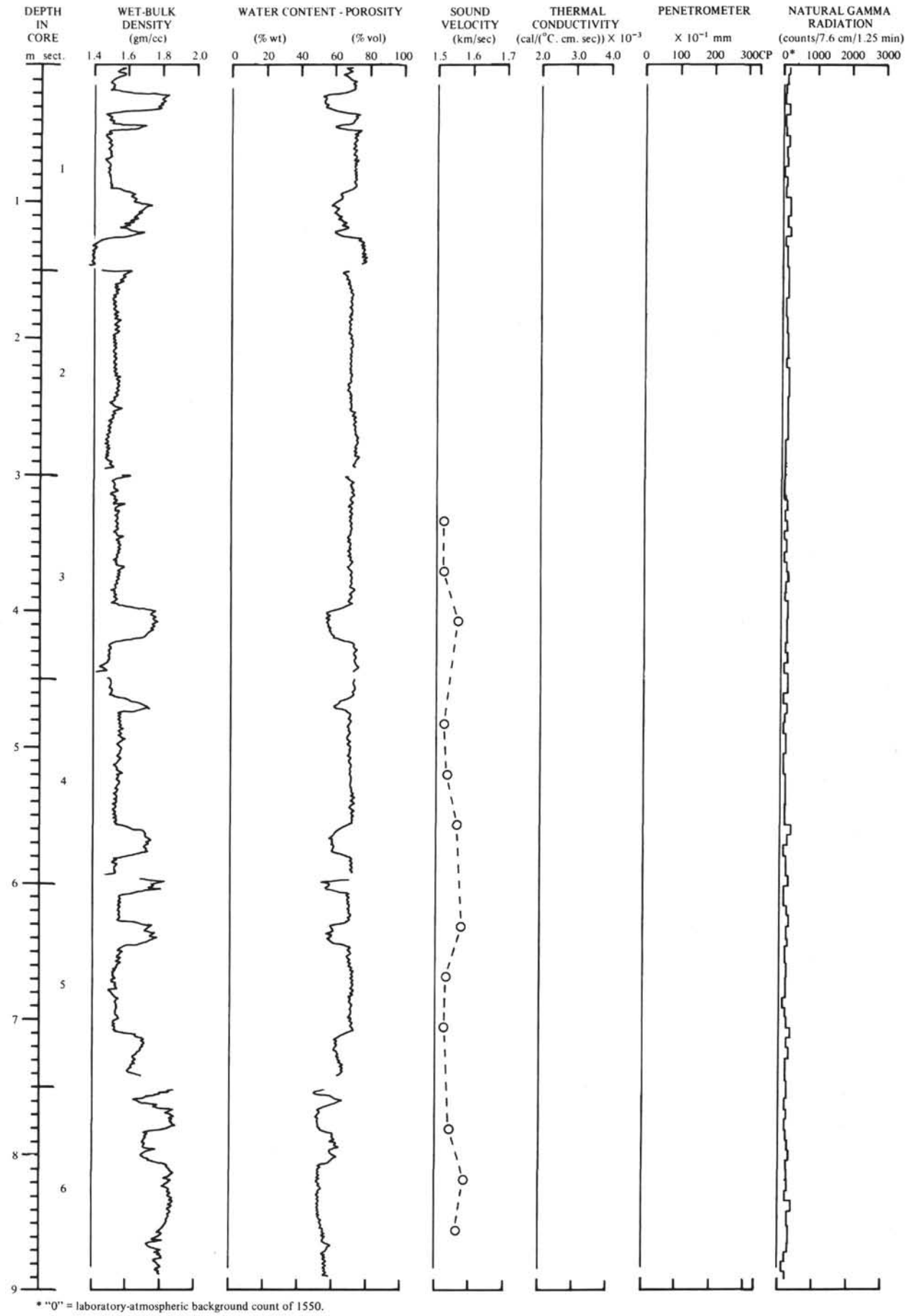


Figure 16B. *Core 2, Hole 21A.*



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

Figure 17A. *Physical properties of Core 3, Hole 21A.*

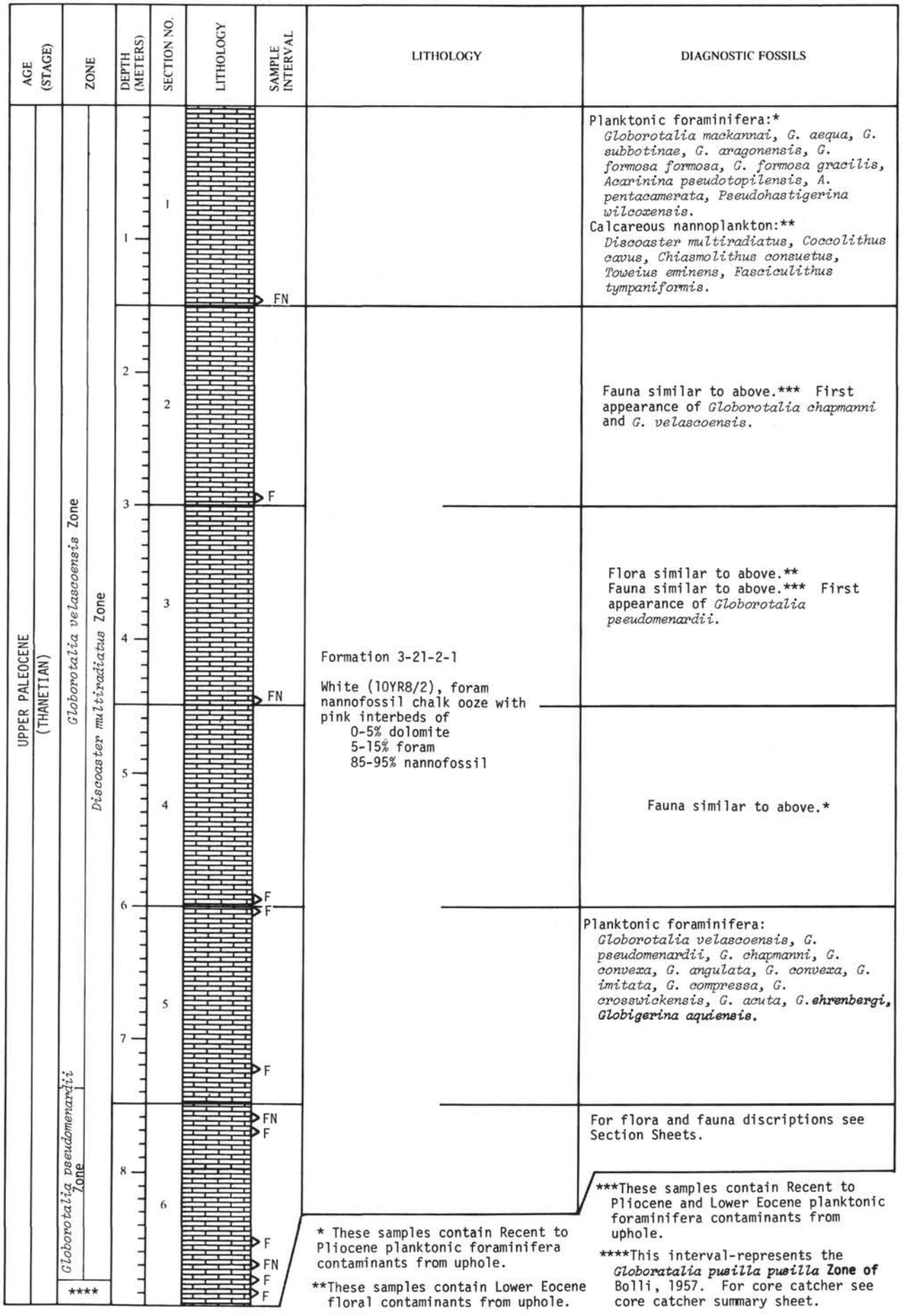


Figure 17B. *Core 3, Hole 21A.*

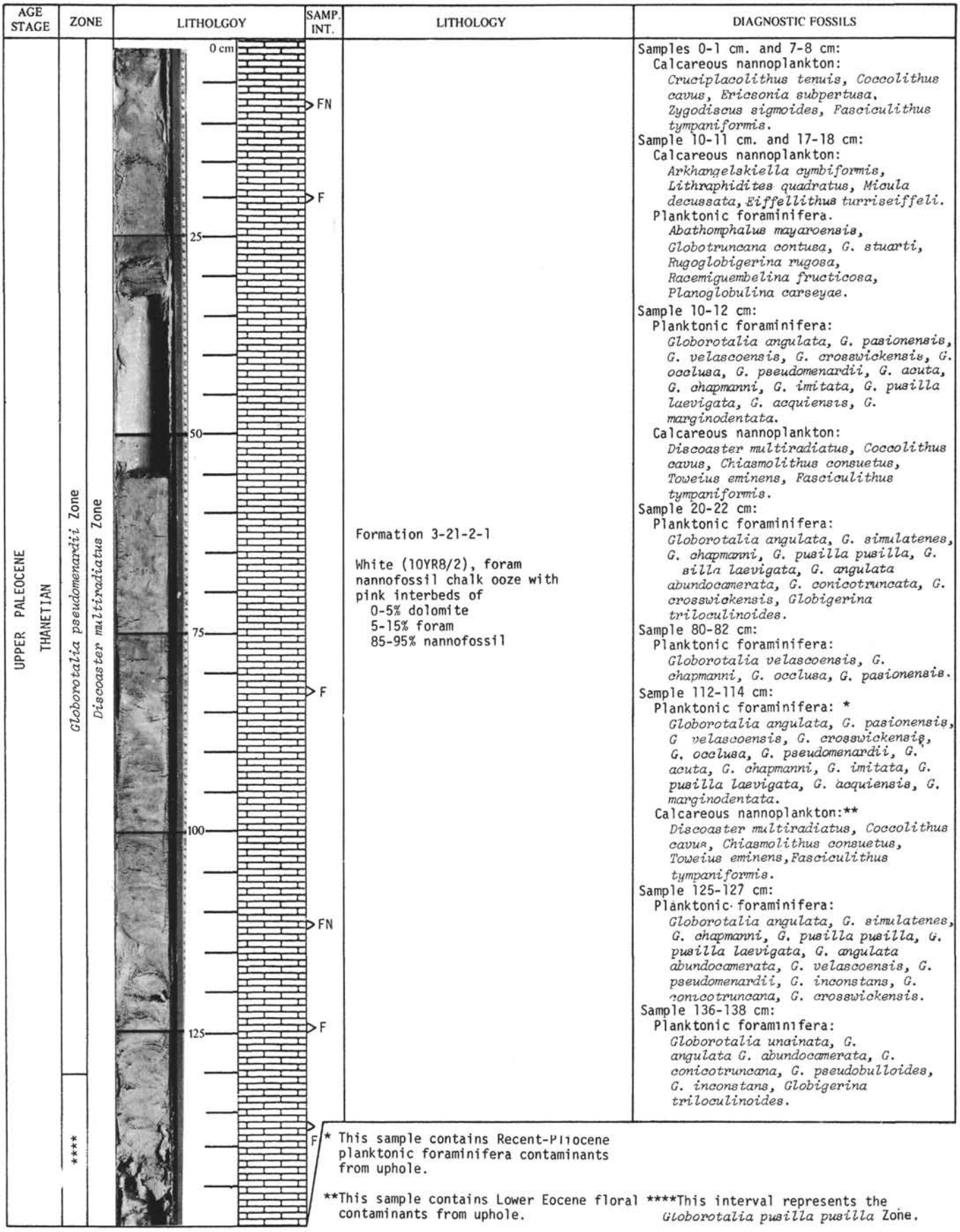


Figure 18. *Summary of Section 6, Core 3, Hole 21A.*

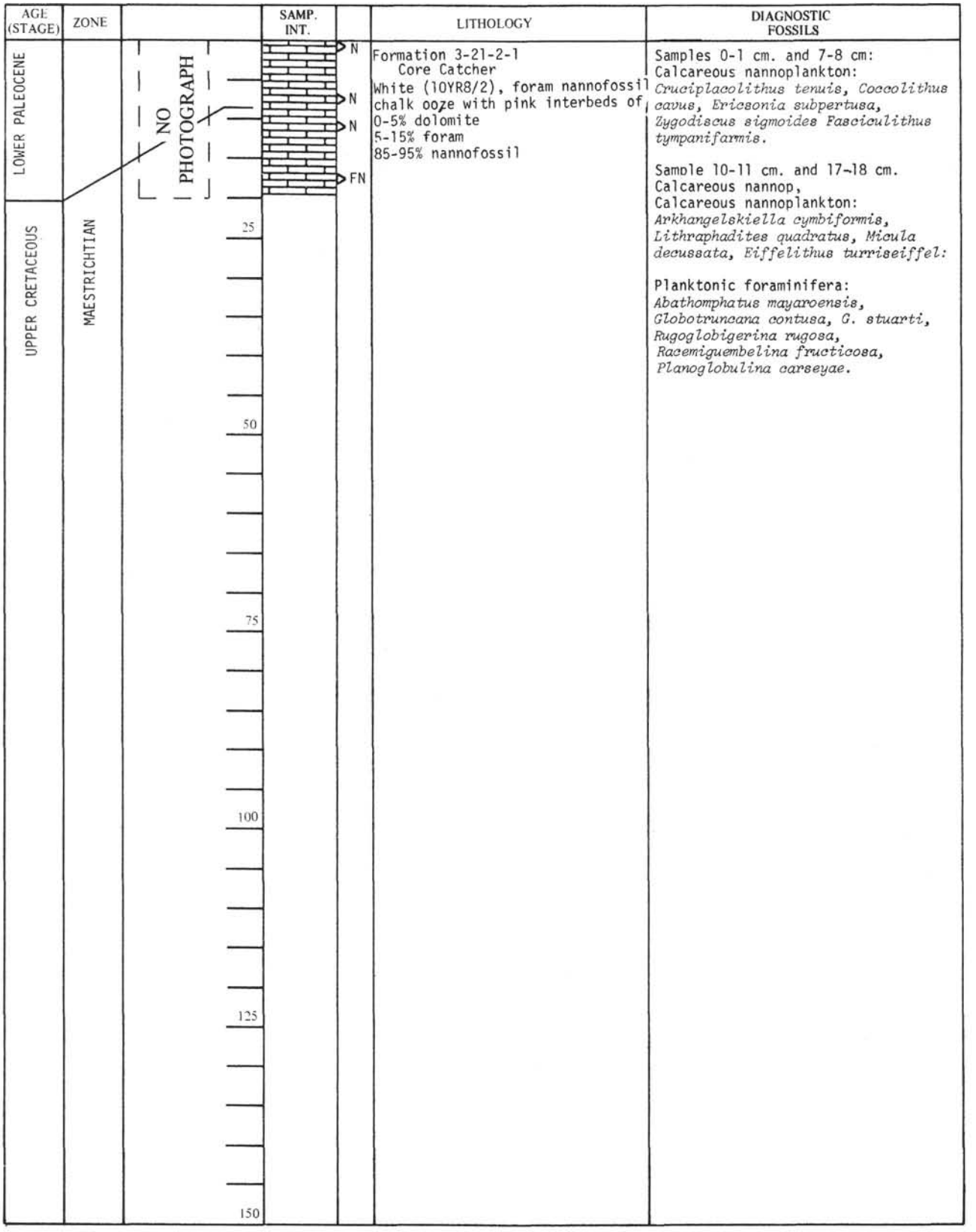


Figure 19. *Summary of Section 5, Core 6, Hole 20C.*