12. SITE 22

The Shipboard Scientific Party[1]

SURVEY DATA AND SITE BACKGROUND

This site is similar to Site 21 in that it is also located on the Rio Grande Rise, and it had an extensive pre-site survey by *R/V Vema*. From the previous survey data, it appeared that the Tertiary sediments were of greater thickness than at Site 21, and one of the objectives here was to sample parts of the Tertiary section in greater detail.

A primary site was selected on the northern edge of the *Vema* survey where the bottom slopes gently (<5°) to the north, and at a location where the sedimentary section appears to thin but not pinch out. Due to operational constraints, a shallower drilling site was initially chosen several kilometers south of the primary site, but this site was abandoned before drilling to return to the primary site.

The primary site (30° 00.31'S, 35° 15.00'W) is located in deeper water (1124 fathoms, uncorrected; 2106 meters (6908 feet), corrected) on the same northward slope as the first site attempt. The average northward slope at the site is about 80 m/km, on which small hills (20 to 40 meters high) (66 to 131 feet) are superimposed (Figure 2). The *Vema* survey indicated that this slope is cut in some places by what appear to be submarine canyons, but it is not believed that the drilling site is located over any such feature. The CSP records (Figure 1) showed two or three relatively smooth subbottom reflectors, the deepest of which was represented by more than 0.5 second reflection time below bottom at the site.

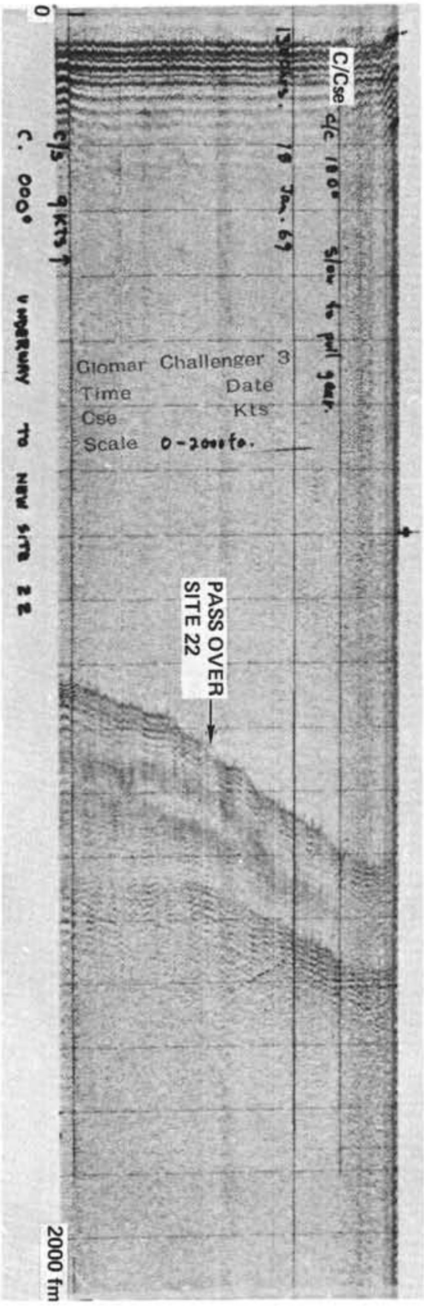


Figure 1. *Continuous seismic profiler record in the vicinity of Site 22.*

---

[1] A. E. Maxwell and R. P. von Herzen, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts; J. E. Andrews, University of Hawaii, Honolulu, Hawaii; R. E. Boyce and E. D. Milow, Scripps Institution of Oceanography, La Jolla, California; K. J. Hsu, Geologisches Institut, Zurich, Switzerland; S. F. Percival, Princeton University, Princeton, New Jersey; and, T. Saito, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York.

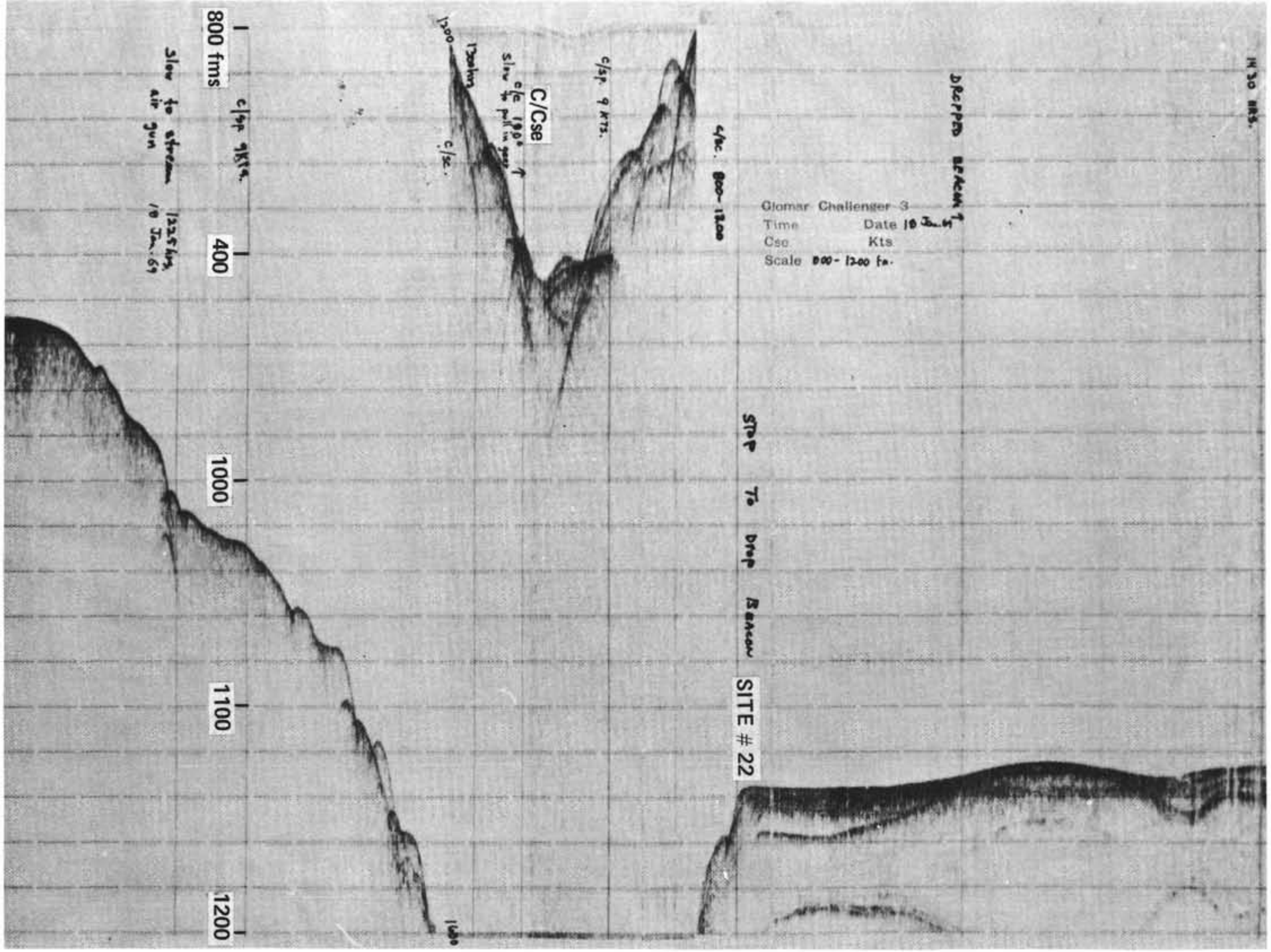


Figure 2. *Precision depth recording in the vicinity of Site 22.*

OPERATIONS

Positioning

At 1010 hours on 18 January, the beacon was dropped over the side in 935 meters (3067 feet) of water. A great deal of difficulty was encountered in trying to maintain position over this beacon, and at 1200 hours it was decided to abandon the beacon and to select a new site. A suitable location was found about 12 kilometers to the north, and at 1355 hours another beacon was lowered into the water. The phase-comparison system (PCS) of the beacon stopped functioning as the beacon was falling to the bottom–thus depriving the ship of a backup signal for position keeping.

During the time at this site, the wind velocity varied from 10 to 20 knots from a northerly direction. A relatively strong current from the north-northwest (about 1 knot) was present during the entire time spent on site. No large swells were observed.

The positioning system did not function properly in automatic while at Site 22 and most of the time was spent with the ship in semi-automatic operation. This might be attributed to either the large current or shallow depth–possibly a combination of both. The ship rarely moved more than 25 meters (82 feet) from directly over the beacon.

Drilling

Although two acoustic reflectors were penetrated at this site, there was only one significant drilling break. This occurred in the interval between 234 to 245 meters (768 to 804 feet), where at least four separate hard layers were encountered. Samples retrieved from Core 5 showed these layers to be Eocene dolomitic limestone and chert stringers embedded in a stiff nannochalk ooze. A shallower reflector from Core 4 at 134 meters (440 feet) was identified as a crystalline Oligocene chalk, but this reflector was not apparent as a break in the drilling rate. Hole 22 had to be terminated when the inner core barrel became lodged in the bottom of the string after coring the dolomite. It was necessary to pull the drill string to retrieve the core.

A second hole, 22A, was started with an objective of penetrating the two acoustic reflectors and obtaining a core of the Tertiary-Cretaceous boundary. This hole was abandoned without taking any cores because of repeated cave-ins and the necessity to cease operations in order to meet the scheduled port call.

Coring

Five cores were collected at Site 22, which are summarized in Table 1. Two of these, Cores 4 and 5, sampled both of the acoustic reflectors observed on the seismic profiler. Although there was an attempt to sample below the second acoustic reflector, this was not successful because of hole conditions and lack of time.

TABLE 1
Summary of Coring at Site 22

Core No.	Date/Time	Interval Cored (m below sea floor)	Core Retrieved (m)	Remarks
1	1-19-69 0100	0-9.1	9.0	--
2	0330	47.0-56.1	9.0	--
3	0710	104.6-113.8	9.0	--
4	0920	133.3-142.4	9.0	Hard chalk layer.
5	1-20-69 0030	234.2-242.2	2.4	Dolomite, chert–hole abandoned.
	Total		38.4	

PALEONTOLOGY

Pleistocene, Upper Pliocene, Lower Pliocene, Upper Oligocene and Middle Eocene sediments were recovered from the five cores at this site. This hole did not reach basement. Coring was discontinuous from the sea floor bottom to 242.5 meters (795 feet), where the hole was abandoned. Only one boundary, the Pliocene/Pleistocene boundary, was recovered in Core 1. Time limitations aboard the ship and a repetition of stratigraphic intervals (cored many times in other holes) resulted in some of the cores not being slabbed and sampled in detail for geologic and paleontologic studies.

The purpose in drilling this hole was to obtain stratigraphic knowledge of the sediments constituting the Rio Grande Rise. The stratigraphic results of this hole are shown in Figure 3B and are described below.

The sediments found throughout most of Core 1 consist predominantly of planktonic foraminifera with moderate amounts of calcareous nannoplankton plates and varying amounts of calcareous matrix. In the lower part of Core 1 and throughout Cores 2, 3 and 4 the sediments consist predominantly of calcareous nannoplankton plates with minor amounts of planktonic foraminifera. Minor amounts of Radiolaria also occur in these cores. Core 4 contains many layers of *Braarudosphaera rosa* Chalk. Core 5 contains dolomite and chert. The variations from lithologic unit to lithologic unit are discussed in the section on Stratigraphy.

Core 1, from 0 to 9.1 meters (0 to 30 feet), contains sediments of three ages: Pleistocene, Late Pliocene and Early Miocene. The Pliocene/Pleistocene boundary is found in Section 5 between samples from 148 to 150 centimeters of Section 4 and 60 to 62 centimeters in Section 6, based on the planktonic foraminifera. This determination is based on the first appearance of right coiling *Globorotalia menardii,* right coiling *G. miocenica* and *Globigerinoides obliquus.* This faunal change is accompanied by the first appearance of the calcareous nannoplankton species *Discoaster brouweri.* Immediately below this sample in Section 6, a sample from 100 to 102 centimeters depth contains typical Lower Miocene (Aquitanian) planktonic foraminifera and calcareous nannoplankton. It is not possible to explain the origin of the stratigraphic hiatus with just one core, but many explanations, such as, slumping or removal by strong currents of sediments of the intervening age, are possible. The Lower Miocene fauna is characterized by *Globigerinita dissimilis, G. stainforthi, Globorotalia birnagae* Blow, *G. peripheroronda* Banner and Blow, *G. praescitula,* and *Globigerinoides subquadratus*, which represents the *Globigerinita dissimilis* Zone of Bolli (1957c). The flora represents the upper part of the *Triquetrorhabdulus carinatus* Zone of Bramlette and Wilcoxon (1967), and consists of *Sphenolithus belemnos?, Discoaster druggi, D. deflandrei* and *Cyclococcolithus neogammation.*

The Lower Miocene (Aquitanian) sediments continue into Core 2, from 47 to 56.1 meters (154 to 184 feet). The planktonic foraminiferal study shows that two zones, the *Globorotalia kugleri* and *Globigerinita dissimilis* Zones of Bolli (1957c), are present. The calcareous nannoplankton study reveals that both the lower and upper part of the *Triquetrorhabdulus carinatus* Zone of Bramlette and Wilcoxon (1967) are represented. The contact of the two planktonic foraminiferal zones is placed between Sections 4 and 5 and is based upon the occurrence in the sample from 6 to 8 centimeters in Section 6 of *Globorotalia kugleri, G. postcretacea, Globigerinoides primordius, Globigerina sellii* and *G. tripartita.* The boundary between the calcareous nannoplankton zonal subdivision would probably occur near that of the planktonic foraminifera based on the first appearance of *Coccolithus* aff. *bisectus* in the samples from Section 6.

Radiolaria are also found in this core associated with the calcareous microfossils. In addition to numerous other diagnostic radiolarians listed in the Section Summary, two forms which are probably ancestral to *Calocyclas virginis* Haeckel were found in sequence in Cores 2 and 3 of this hole. One form, *C.* aff. *virginis* has a thin continuous veil-like abdomen termination or an incomplete ragged edge to the abdomen. This gives rise to another form in the lower part of the Lower Miocene which has the abdomen terminated by up to six or seven broad spatulate feet. Both of these differ from the typical form, which has an abdomen terminated by eleven to sixteen small, narrow lamellate feet. This typical form is characteristic of a slightly younger horizon (Riedel, 1959) than the highest radiolarian-bearing material cored in Hole 22.

The Upper Oligocene (Chattian) is present in Core 3, from 104.6 to 113.8 meters (342 to 373 feet). The planktonic foraminifera occurring throughout the core are representative of the *Globorotalia opima opima* Zone of Bolli (1957c). Species present are: *Globorotalia opima opima, G. opima continuosa, Globigerina ciperoensis, G. angulisuturalis* and *Cassigerinella chipolensis.* The calcareous nannoplankton study reveals that two zones are present, namely, the *Sphenolithus ciperoensis* and the lower part of the *Triquetrorhabdulus carinatus* Zones of Bramlette and Wilcoxon (1967). The contact of these two zones probably occurs in the middle of Section 4. The flora above consists of *Coccolithus* aff. *bisectus, Discoaster deflandrei, D. adamenteus* and *Cyclococcolithus neogammation* which is typical of the younger zone. The first appearance of *Coccolithus bisectus* occurs in the sample from 148 to 150 centimeters depth of Section 4 which suggests the top of the *Sphenolithus ciperoensis* Zone.

Core 4, from 133.3 to 142.4 meters (438 to 467 feet), is Late Oligocene (Chattian) in age based on the planktonic foraminifera and is represented by the *Globigerina ampliapertura* Zone of Blow (1969). Diagnostic species present in the upper part of the core are: *Globorotalia opima opima, G. opima nana, G. postcretacea* and *Chiloguembelina cubensis*, and in the lower part *Globigerina ampliapertura* occurs. The associated calcareous nannoplankton belong to the *Sphenolithus distentus* Zone of Bramlette and Wilcoxon (1967), and they are characterized by *Coccolithus bisectus, C.* aff. *bisectus, Sphenolithus distentus, S. predistentus, Cyclococcolithus neogammation* and *Discoaster deflandrei.* Numerous layers of *Braarudosphaera rosa* Chalk are found in this core and they contain a flora similar to the above mentioned one, except for the abundance of *Braarudosphaera rosa*, both complete and as isolated fragments. The level of occurrence of these chalks is stratigraphically lower than those reported from Sites 14, 17 and 19, but younger than that from Site 20.

The Middle Eocene (Lutetian) sediments occur in Core 5, from 234.2 to 242.2 meters (768 to 794 feet), based on the planktonic foraminifera and calcareous nannoplankton. This core represents the *Globorotalia lehneri* Zone of Bolli (1957b), and *Discoaster tani nodifera* Zone of Hay in Hay *et al.* (1967). The diagnostic planktonic foraminifera include: *Globigerapsis kugleri, Acarinina coalingensis, Truncorotaloides rohri, Hantkenina dumblei, Globorotalia lehneri,* and *Globorotalia bolivariana.* The diagnostic calcareous nannoplankton are: *Reticulofenestra umbilica, Discoaster saipanensis, D. barbadiensis, D. tani nodifera, Coccolithus bisectus, Cyclococcolithus neogammation* and *Chiasmolithus grandis.*

STRATIGRAPHY

Although two holes were drilled at Site 22, no cores were retrieved from Hole 22A. Some 242 meters (794 feet) of sedimentary section were penetrated, but the "basement-reflector" was not reached because of time limitations and drilling problems. The Tertiary section penetrated by the drill can be divided into three lithologic units; they are:

3-22-1-1	Albatross Ooze	Foraminiferal chalk oozes.
-------	Disconformity	-------------------
3-22-1-6	Local Unit	Nannofossil chalk oozes.
3-22-5-1	Local Unit	Cherty nannofossil chalk.

The very pale brown chalk oozes which constitute Unit 3-22-1-1 consist of 40 to 60 per cent foraminifera, 20 to 30 per cent nannofossils, and 15 to 20 per cent non-carbonate detritus. These sediments are thus lithologically almost identical to those of the Unit 3-21-1-1 at the adjacent Rio Grande Rise, and can be identified as the Albatross Ooze. The authors noted, however, that the formation here, which is only 8.4 meters (28 feet) thick, is thinner than its correlative elsewhere.

Unit 3-22-1-6 underlies the Albatross Ooze disconformably. Lower Miocene and Upper Oligocene pink chalk oozes, some 200 meters (656 feet) thick, are made up largely of nannofossils. Well preserved Radiolaria tests are present in amounts up to 5 per cent, as well as some siliceous sponge parts and a few diatoms. Foraminifera are also very common. However, its content decreases with age, ranging from 15 to 25 per cent in the Lower Miocene to less than 10 per cent in Upper Oligocene sediments. The lowest Upper Oligocene chalk oozes cored include less than 1 per cent foraminifera and are, thus, lithologically very similar to the Oligocene Fram Ooze of the Mid-Atlantic Ridge province. Yet, the unit as a whole is considerably more variable in lithology and richer in foraminifera content than the Fram Ooze. The authors have thus assigned this chalk ooze sequence the rank of a local unit.

Included in this local unit is the widespread *Braarudosphaera* Chalk, which constitutes the Subunit 3-22-4-1. This member consists of several layers of *Braarudosphaera* Chalk. The main bed, some 80 centimeters thick (3-22-4-1 and 2), consists almost exclusively of *Braarudosphaera* pentelets and fragments; and, it is a white, crystalline, friable chalk, which serves as an acoustical reflector (RGR-1, 0.15 second at 134 meters–440 feet, Hole 22). Several other thin chalk layers occur in 3-22-4-4, 5 and 6. They consist of 50 to 70 per cent *Braarudosphaera* remains, mixed with other nannofossils. A thin laminated chert has also been recovered.

A 92-meter (302-foot) interval was not represented by cores. If the trend of decreasing foraminifera content, as shown by the last few sections of 3-22-4, persists, then the Lower Oligocene and Upper Eocene sediments are possibly represented, at least in part, by nannofossil oozes largely devoid of foraminifera similar to the Fram Ooze.

The oldest sediments cored from Hole 22 are Middle Eocene nannofossil chalks. These gray to dark gray firm sediments consist mainly of nannofossils, with a few percentages of foraminifera. They had been recrystallized and consolidated to such an extent that they could not be split by a cheese cutter, but had to be sawed in halves. The sediments have been thoroughly burrowed. The burrows appear to have been truncated in places by surfaces of dissolution. At the bottom of the cored intervals is a friable cherty carbonate rock, which prevented further drilling. This hard layer has been identified as the second acoustic reflector at this

TABLE 2
Stratigraphy Site 22

Age	Cored Interval (m)	Formation Name	Probable Interval (m)	Probable Thickness (m)	Description
Upper Quaternary	0-8	Albatross Ooze 3-22-1-1	0-8	8	Very pale brown foraminiferal chalk oozes. 30 to 60 per cent foraminifera, 20 to 30 per cent nannofossil, and 10 to 20 per cent matrix.
Lower Miocene Upper Oligocene	8.0-9.1 47.0-56.1 104.6-113.8 133.3-142.4	Local Unit 3-22-1-6 with 3-22-4-1 Subunit *Braarudosphaera* Chalk	8-?	200	Pink nannofossil chalk oozes with 5 to 20 per cent foraminifera and 0 to 5 per cent radiolarian. The main marker bed of the subunit is a white *Braarudosphaera* Chalk, 80 centimeters thick. *Braarudosphaera* sp. also occurs in the 6 meters of core below the marker, mixed with other nannofossils and associated with chert laminae.
Middle Eocene	234-242	Local Unit 3-22-5-1	?	?	Gray to dark gray hard nannofossil chalk ooze. Burrowed, with solution surfaces truncating burrows. Several irregular stringers of chert carbonate at the bottom of the recovered section.
		Basement not reached			

site (RGR-2, 0.31 second and 242 meters–794 feet–BOB). Correlation of this incompletely cored sequence with sediments elsewhere is not certain, and the authors have designated it the Local Unit 3-22-5-1.

The average sedimentation rates of the penetrated Tertiary section at Site 22 is 240 meters (787 feet) in about 48 million years or about 0.5 cm/t.y. The actual rate, however, is highly variable. The Local Unit 3-22-1-6, some 200 meters (656 feet) thick, was deposited in about 10 million years, or at a rate of 2 cm/t.y. during the Late Oligocene and Early Miocene, only to be followed by a disconformity which spanned a time-interval of some 23 million years. The depositional rate of the Albatross Ooze here is 1 cm/t.y. or less, being slower here than elsewhere. However, this average rate may reflect a fluctuation of the strength of local bottom current. Calcareous planktons were deposited during times of relative quiescence, only to be partly removed by the renewed erosive activities of strong bottom currents.

The Tertiary sediments at Site 22 are similar to those at the adjacent Rio Grande Rise site (Site 21) in several aspects: (1) the common presence of foraminifera, which are especially abundant in the Quaternary, and (2) the absence of marl oozes and red clays. Middle Eocene section has been cored at both sites, and the cherty carbonate rock at Site 22 could be correlated with the dolomitic chalk at Site 21 as the acoustic reflector RGR-2 (Rio Grande Rise, No. 2). Yet, the thick Oligocene-Miocene section at Site 22 is absent at Site 21, where a much thicker Quaternary section is present.

The stratigraphy at Site 22 is summarized by Table 2.

PHYSICAL PROPERTIES

Natural Gamma Radiation

Natural gamma radiation extended from 100 to 750 counts per 1.25 minutes per 7.6-centimeter core segment. The Site 22 norm was about 350 counts. The core averaged radiation counts increased with increasing depth, with counts of about 300 at the surface to an average of 500 counts at a depth of 238 meters (781 feet) (Figures 3A and 4A-9A). Clayey and zeolite minerals were not abundant, but authigenic and possibly some opaque minerals, and compaction may account in part for the radiation increase.

Porosity, Wet-Bulk Density and Water Content

Porosity, wet-bulk density, and water content values at Site 22 ranged from 25 to 85 per cent, 1.24 g/cc to 2.29 g/cc, and 22 per cent to 40 per cent, respectively, with averages of 55 per cent, 1.78 g/cc and 32 per cent (Figures 3A and 4A-9A). Generally, porosity decreased with depth; which is, in part, a result of compaction cementation, grain size, and fossil type.

Sediment Sound Velocity

Sediment sound velocities at Site 22 ranged from 1.51 to 1.67 km/sec with an average of 1.57 km/sec (Figures 3A and 4A-9A). In general, sound velocity irregularly increased with depth with the maximum value (1.67) in the upper part of 3-22-4-2, which is associated with teh *Braarudosphaera* Chalk. The high velocity is probably the result of low porosity and high wet-bulk density caused by a high degree of "sorting" and cementation. The Local Unit, 3-22-1-6, a pink nanno-chalk ooze with calcareous nannoplankton in a crystalline matrix, had moderately high velocities.

Penetrometer

Penetrometer measurements on Site 22 sediments were sparse because of the disturbed condition (soupy) of the cores which deterred splitting. Measurements ranged from complete penetration to 2×10^{-1} millimeters (Figures 3A and 4A-9A). In general, penetration irregularly decreased with depth with a minimum penetration in Core 5, a gray to dark gray hard nanno-chalk (with cherty carbonate at the bottom).

Thermal Conductivity

No thermal conductivity measurements were made at Site 22.

Intersitital Water Salinity

No interstitial salinity samples from Site 22 were processed aboard ship.

REFERENCES

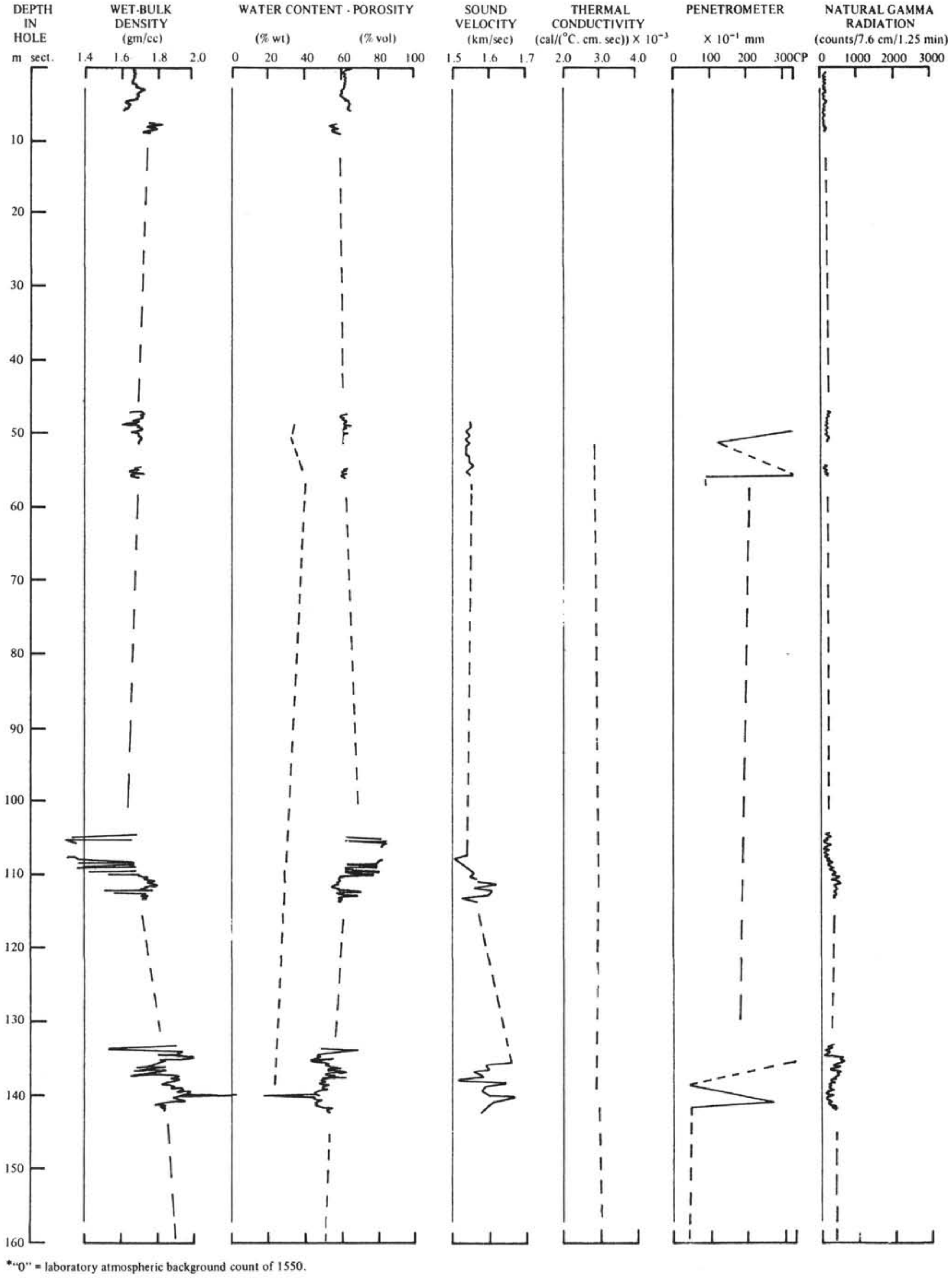
See consolidated list at the end of Chapter 13.

THE CORES RECOVERED FROM SITE 22

The following pages present a graphic summary of the results of drilling and coring at Site 22.

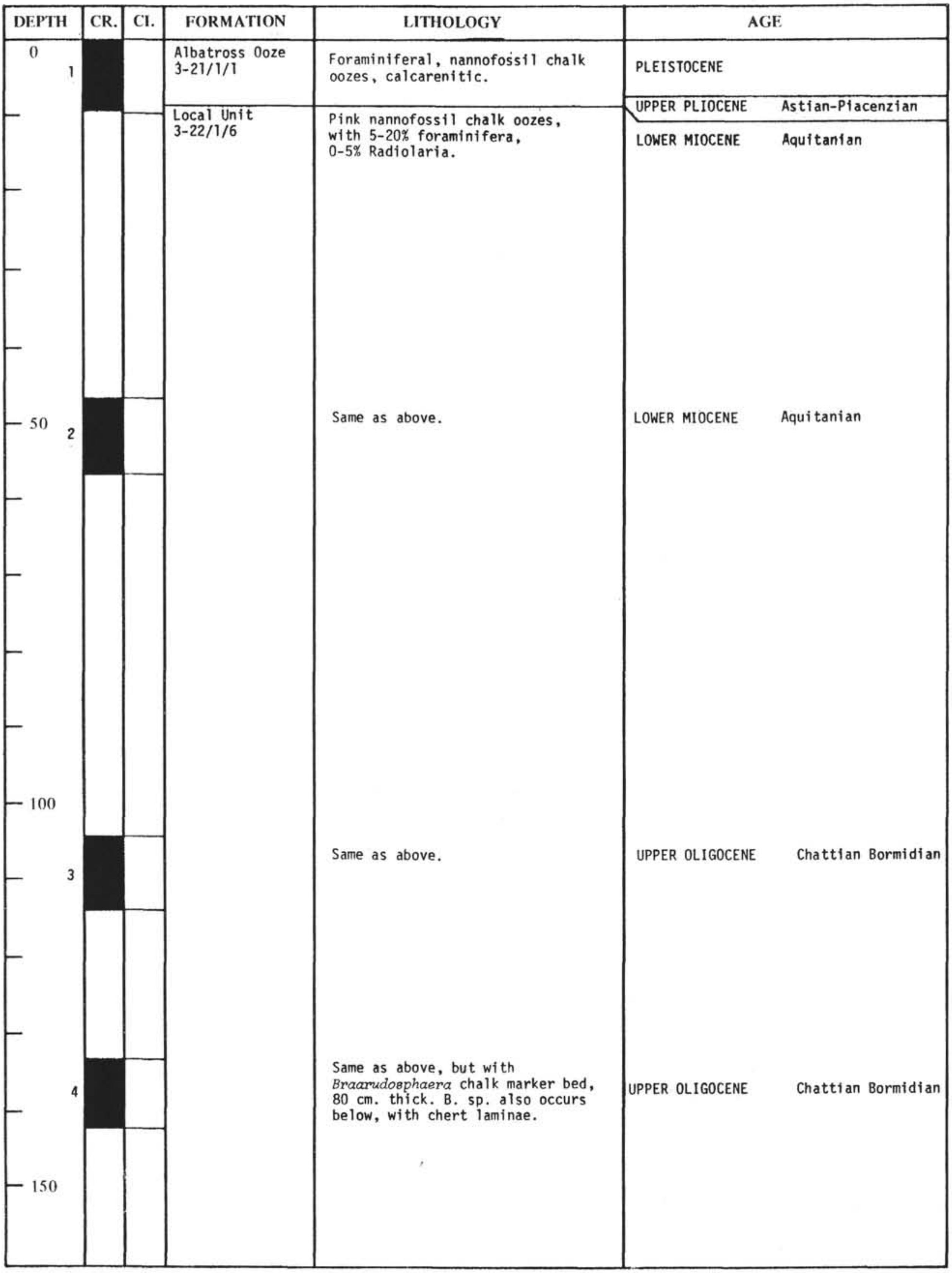
The first illustrations show a summary of the physical properties of the cores, the positions of the cores and cored intervals and some notes on the lithology and ages of the cores recovered from the holes.

Following this summary are more detailed displays of the individual cores recovered from Site 22. 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.



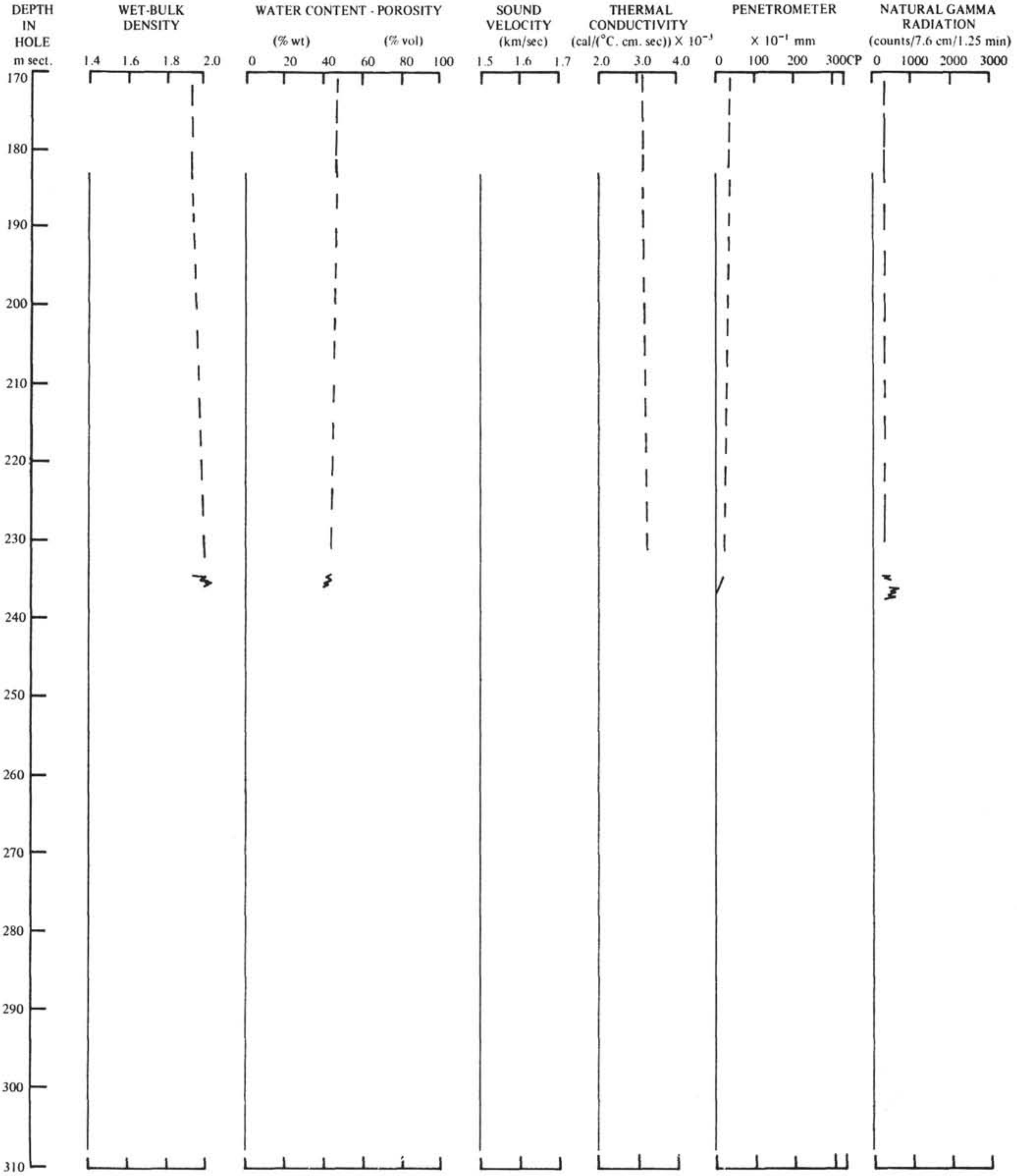
*"0" = laboratory atmospheric background count of 1550.

Figure 3A. *Summary of the Physical Properties of the Cores recovered from Hole 22.*



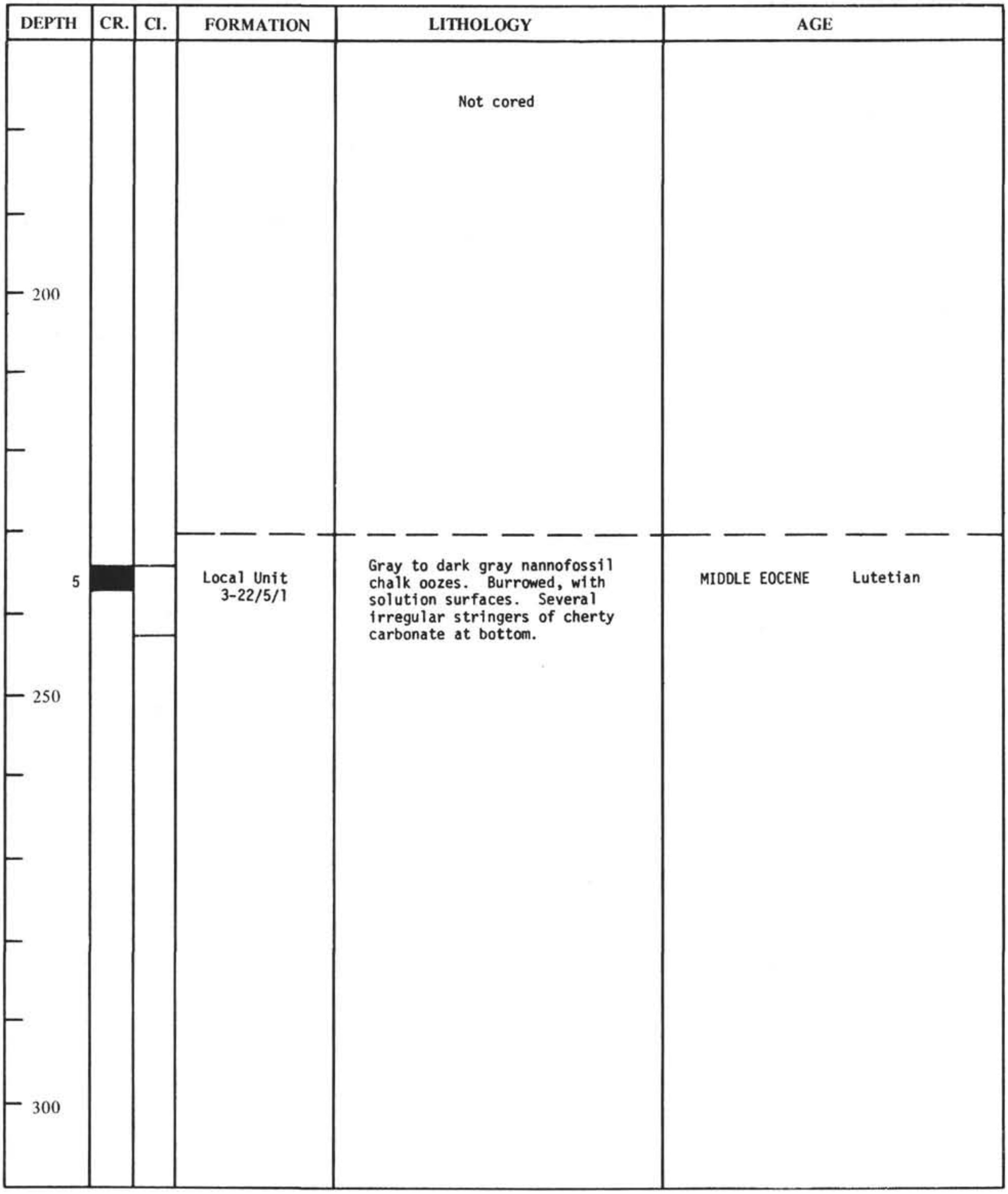
DEPTH	CR.	CI.	FORMATION	LITHOLOGY	AGE
0	1		Albatross Ooze 3-21/1/1	Foraminiferal, nannofossil chalk oozes, calcarenitic.	PLEISTOCENE
			Local Unit 3-22/1/6	Pink nannofossil chalk oozes, with 5-20% foraminifera, 0-5% Radiolaria.	UPPER PLIOCENE Astian-Piacenzian LOWER MIOCENE Aquitanian
50	2			Same as above.	LOWER MIOCENE Aquitanian
100					
	3			Same as above.	UPPER OLIGOCENE Chattian Bormidian
	4			Same as above, but with *Braarudosphaera* chalk marker bed, 80 cm. thick. B. sp. also occurs below, with chert laminae.	UPPER OLIGOCENE Chattian Bormidian
150					

Figure 3B. *Summary of the Cores from Hole 22. (Depth in meters below sea bed; C.R. = core recovered; C.I. = cored interval.)*



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

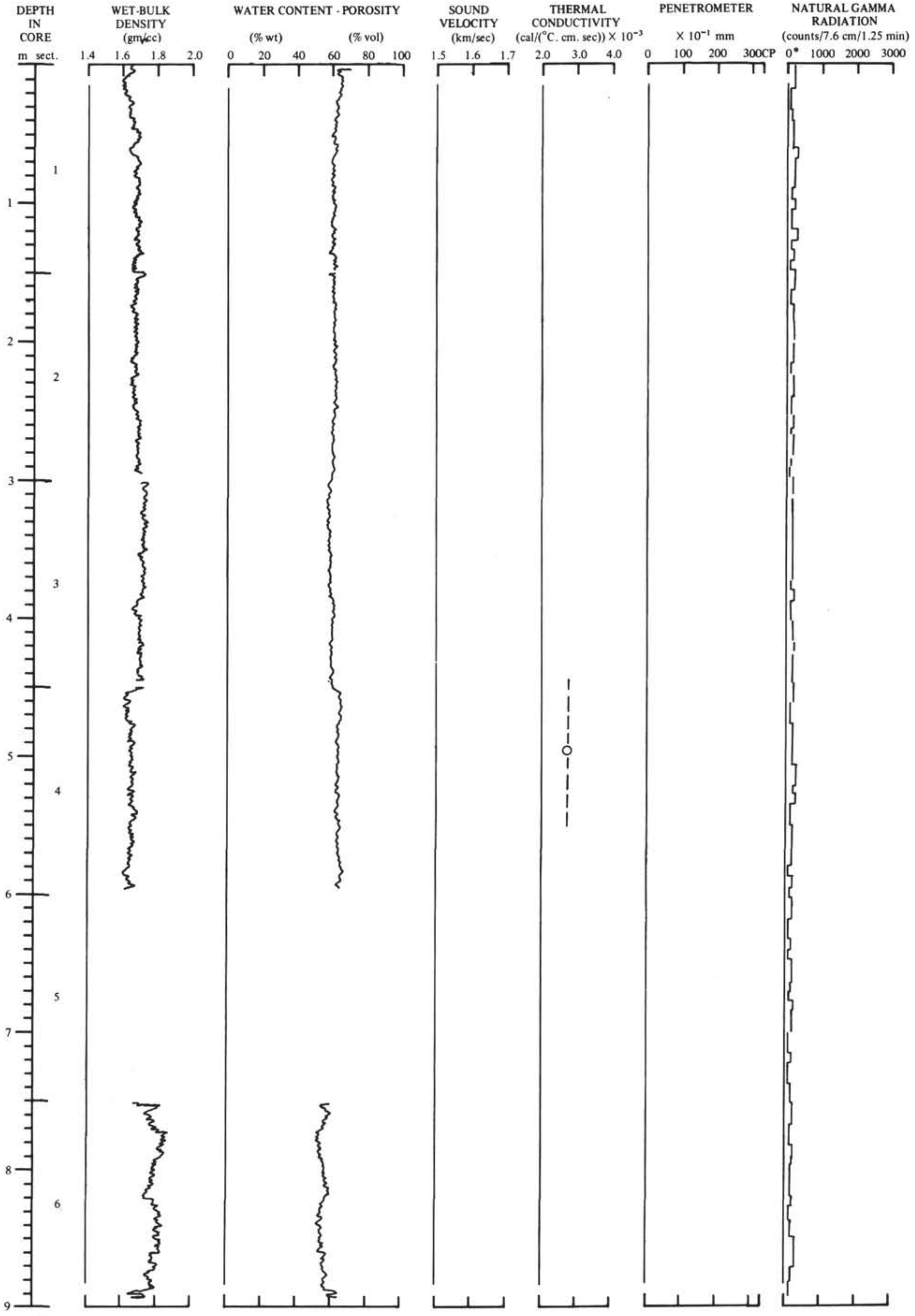
Figure 3A. *(Continued)*



Gray to dark gray nannofossil chalk oozes. Burrowed, with solution surfaces. Several irregular stringers of cherty carbonate at bottom.

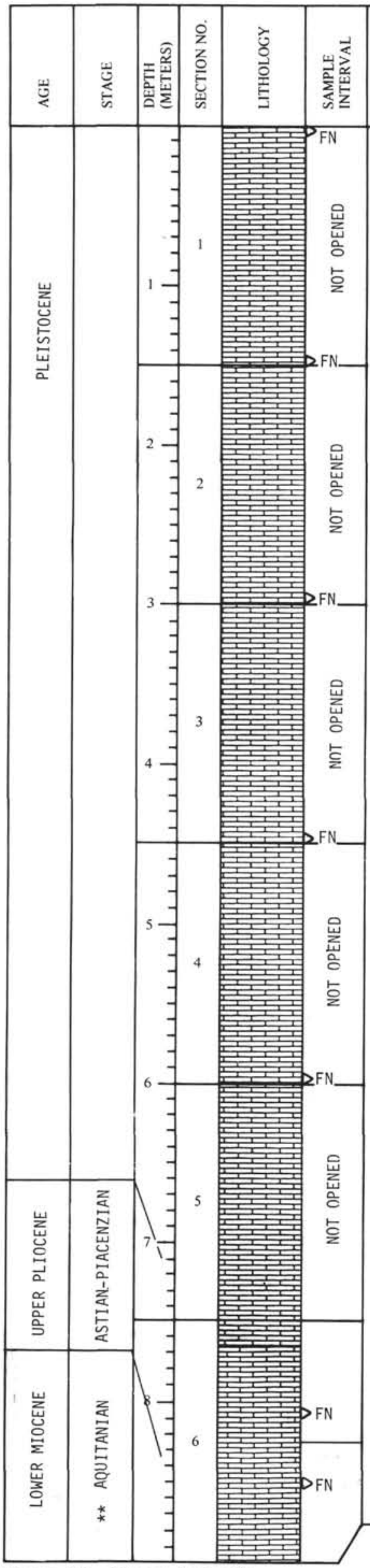
Figure 3B. *(Continued)*

Figure 9A. *Physical properties of Core 5, Hole 22.*



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

Figure 4A. *Physical properties of Core 1, Hole 22.*



LITHOLOGY

Formation 3-22/1/1

Very pale brown (10YR7/3) foram nannofossil ooze.
30-60% foram
20-30% nannofossil
10-30% calc matrix

DIAGNOSTIC FOSSILS

Sample 0-2 cm:
Planktonic foraminifera:
Globorotalia hirsuta, G. menardii (L), *G. truncatulinoides, Pulleniatina finalis, Sphaeroidinella dehiscens.*
Calcareous nannoplankton:
Gephyrocapsa oceanica, Helicopontosphaera kamptneri, Ceratolithus cristatus.
Sample 148-150 cm:
Flora similar to above.
Planktonic foraminifera:
Fauna similar to above with *Pulleniatina finalis* (R), *P.* ***obliquiloculata*** (R), *Globorotalia scitula.*

Flora and fauna similar to above.

Flora and fauna similar to above.

Flora similar to above.

Planktonic foraminifera:
Globorotalia inflata, G. truncatulinoides, G. tosaensis, G. crassaformis, G. tumida, Pulleniatina praecursor, P. ***obliquiloculata*** (L), *Sphaeroidinella dehiscens.*

For flora and fauna descriptions see Section Sheet.

** This interval represents the *Triquetrorhabdulus carinatus* Zone and *Globigerinita dissimilis* Zone.

Figure 4B. *Core 1, Hole 22.*

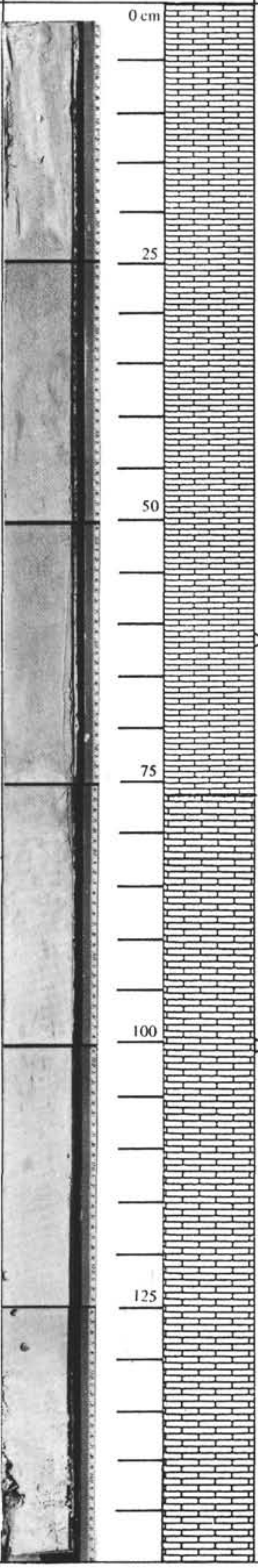
AGE (STAGE)	ZONE	LITHOLOGY	SAMP INT.	LITHOLOGY	DIAGNOSTIC FOSSILS
UPPER PLIOCENE ASTIAN-PIACENZIAN			FN	Unit 3-22/1/1 Nannofossil-foram chalk ooze, very pale brown (10YR7/3) 50% foram 25% nannofossil 25% calc matrix upper 25 cm. disturbed with pale mottling and vertical distortion.	Sample 60-62 cm: Planktonic foraminifera: *Globorotalia menardii* (R), *G. miocenica* (R), *G. inflata* (L), *G. crassaformis* (L), *G. crassula* (L), *G. scitula* (L), *Globigerinoides obliquus*, *Globoquadrina altispira*, *Sphaeroidinella dehiscens*. Calcareous nannoplankton: *Discoaster browweri* (abundant), *Helicopontosphaera kamptneri*, *Ceratolithus cristatus*, *Gephyrocapsa oceanica*, *Cyclococcolithus leptoporus*.
LOWER MIOCENE AQUITANIAN	*Globigerinita dissimilis* Zone *Triquetrorhabdulus carinatus* Zone		FN	Unit 3-22/1/6 Foram-nannofossil chalk ooze pink (7.5YRN8). 5-10% forams 0-5% radiolaria Some very pale brown mottling at 75-110 cm. Radiolaria richer at 140-150 cm.	Sample 100-102 cm: Planktonic foraminifera *Globigerinita dissimilis*, *Globigerina woodi*, *Globoquadrina dehiscens*, *Globorotalia mayeri*, *G. peripheroronda*, *G. birnageae*, *G. praescitula*, *Globigerinoides ruber subquadratus*. Calcareous nannoplankton: *Discoaster deflandrei*, *D. druggi*, *Cyclococcolithus neogammation*, *Sphenolithus belemnos?* Core catcher: Flora similar to above. Planktonic foraminifera: *Globoquadrina dehiscens*, *G. altispira*, *Globigerinita stainforthi*, *G. dissimilis*, *Globorotalia birnagae*, *G. peripheroronda*, *G. praescitula*, *G. siakensis*, *Globigerinoides subquadratus*, *Cassigerinella chipolensis*.

Figure 5. *Summary of Section 6, Core 1, Hole 22.*

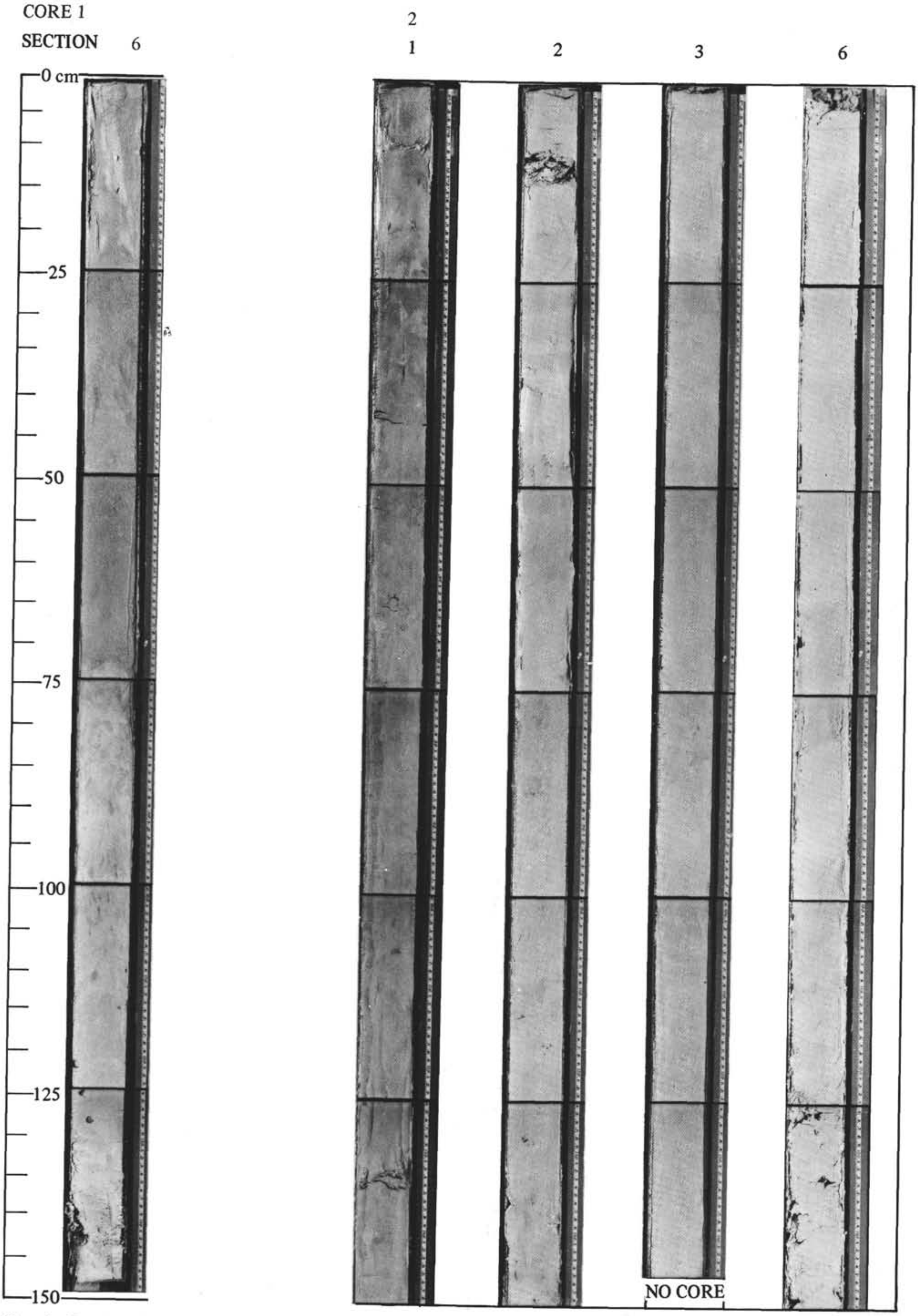
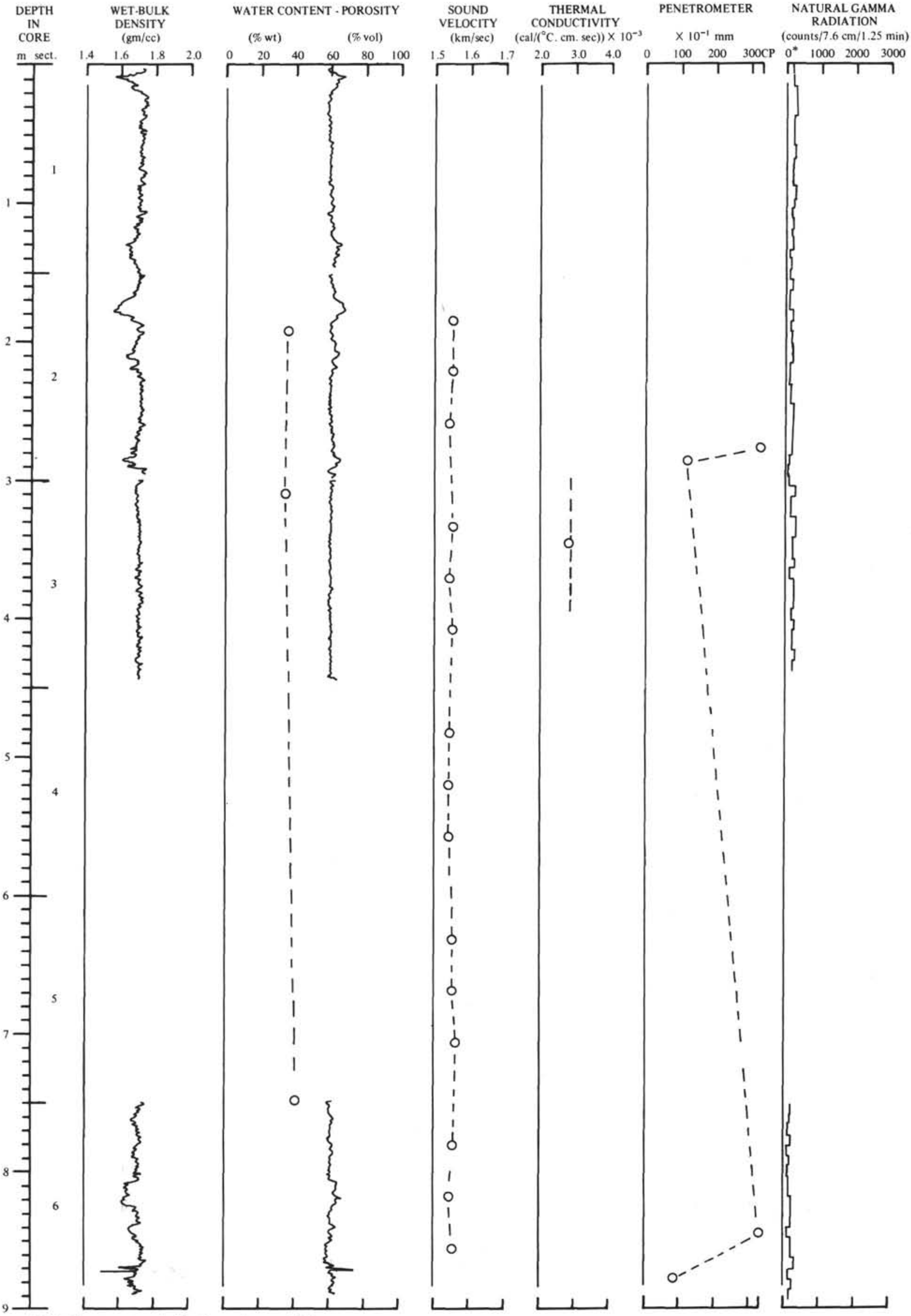
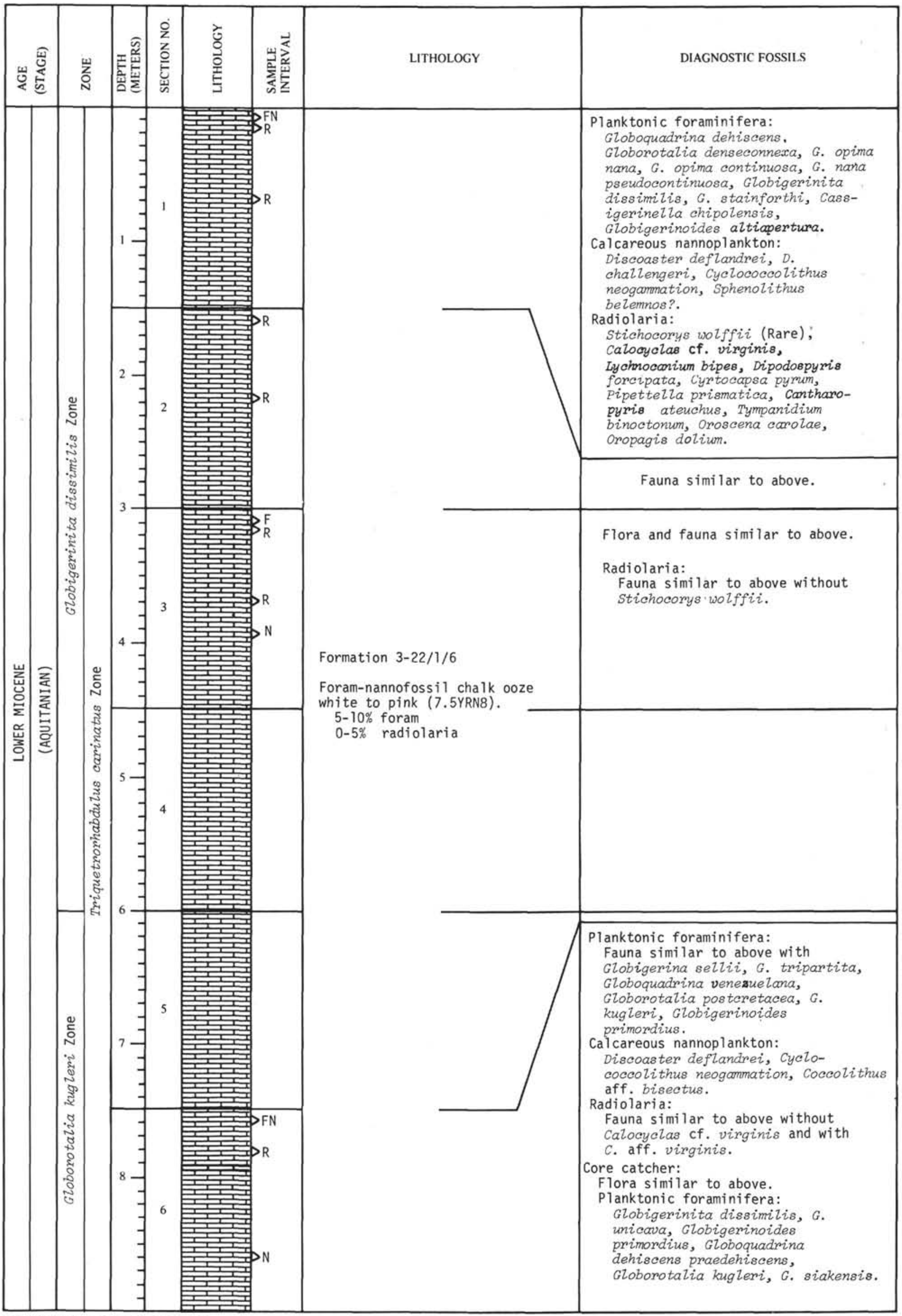


Plate 1. *Sections from Cores 1 and 2, Hole 22.*



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

Figure 6A. *Physical properties of Core 2, Hole 22.*



Formation 3-22/1/6

Foram-nannofossil chalk ooze white to pink (7.5YRN8).
5-10% foram
0-5% radiolaria

Planktonic foraminifera:
Globoquadrina dehiscens, *Globorotalia denseconnexa*, *G. opima nana*, *G. opima continuosa*, *G. nana pseudocontinuosa*, *Globigerinita dissimilis*, *G. stainforthi*, *Cassigerinella chipolensis*, *Globigerinoides* ***altiapertura***.
Calcareous nannoplankton:
Discoaster deflandrei, *D. challengeri*, *Cyclococcolithus neogammation*, *Sphenolithus belemnos?*.
Radiolaria:
Stichocorys wolffii (Rare), ***Calocyclas* cf. *virginis***, ***Lychnocanium bipes***, ***Dipodospyris*** *forcipata*, *Cyrtocapsa pyrum*, *Pipettella prismatica*, ***Cantharopyris*** *ateuchus*, *Tympanidium binoctonum*, *Oroscena carolae*, *Oropagis dolium*.

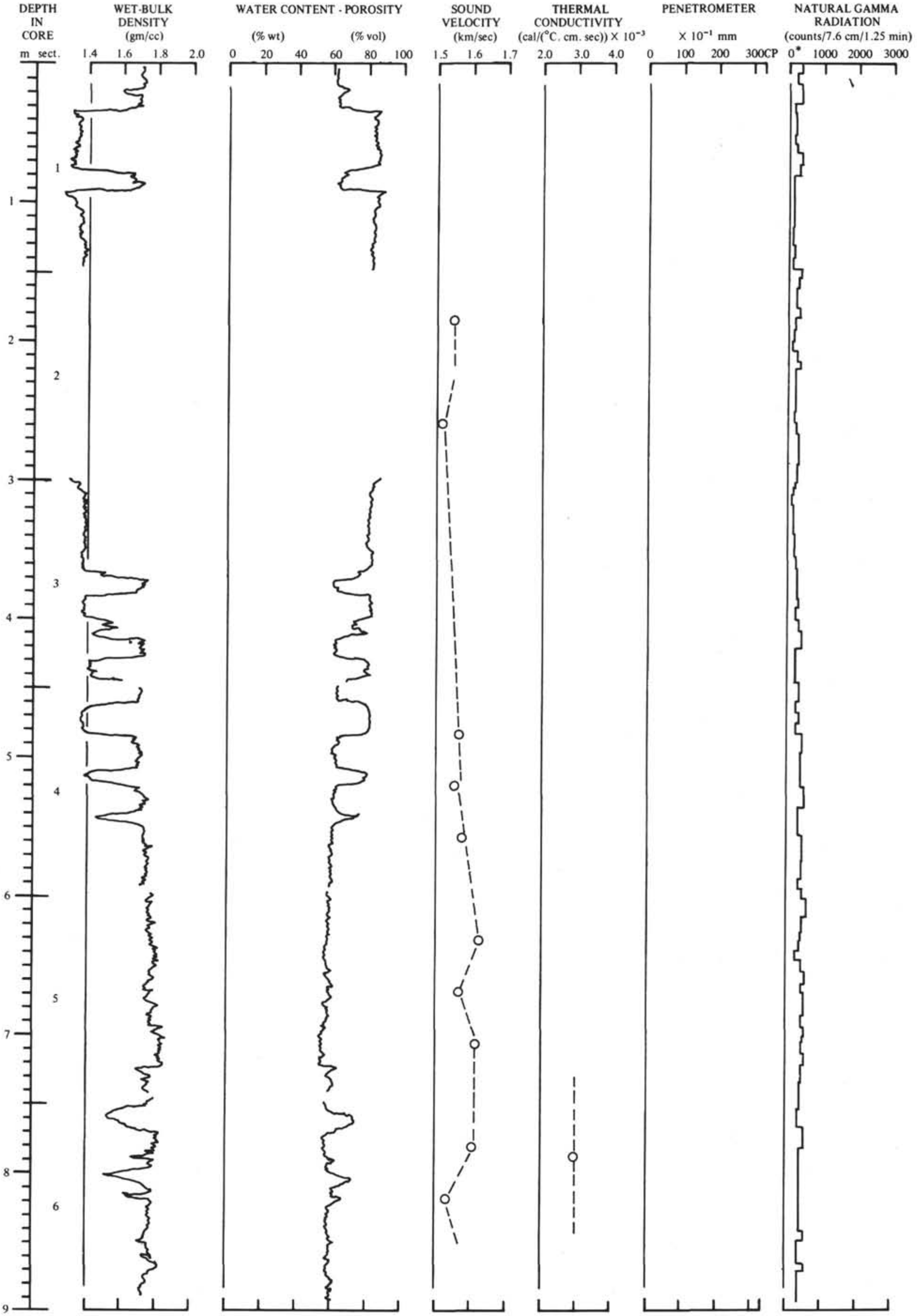
Fauna similar to above.

Flora and fauna similar to above.

Radiolaria:
Fauna similar to above without *Stichocorys wolffii*.

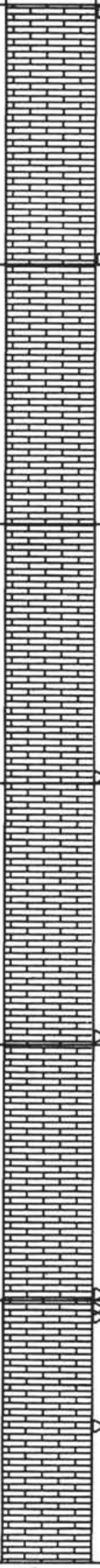
Planktonic foraminifera:
Fauna similar to above with *Globigerina sellii*, *G. tripartita*, *Globoquadrina venezuelana*, *Globorotalia postcretacea*, *G. kugleri*, *Globigerinoides primordius*.
Calcareous nannoplankton:
Discoaster deflandrei, *Cyclococcolithus neogammation*, *Coccolithus* aff. *bisectus*.
Radiolaria:
Fauna similar to above without *Calocyclas* cf. *virginis* and with *C.* aff. *virginis*.
Core catcher:
Flora similar to above.
Planktonic foraminifera:
Globigerinita dissimilis, *G. unicava*, *Globigerinoides primordius*, *Globoquadrina dehiscens praedehiscens*, *Globorotalia kugleri*, *G. siakensis*.

Figure 6B. *Core 2, Hole 22.*



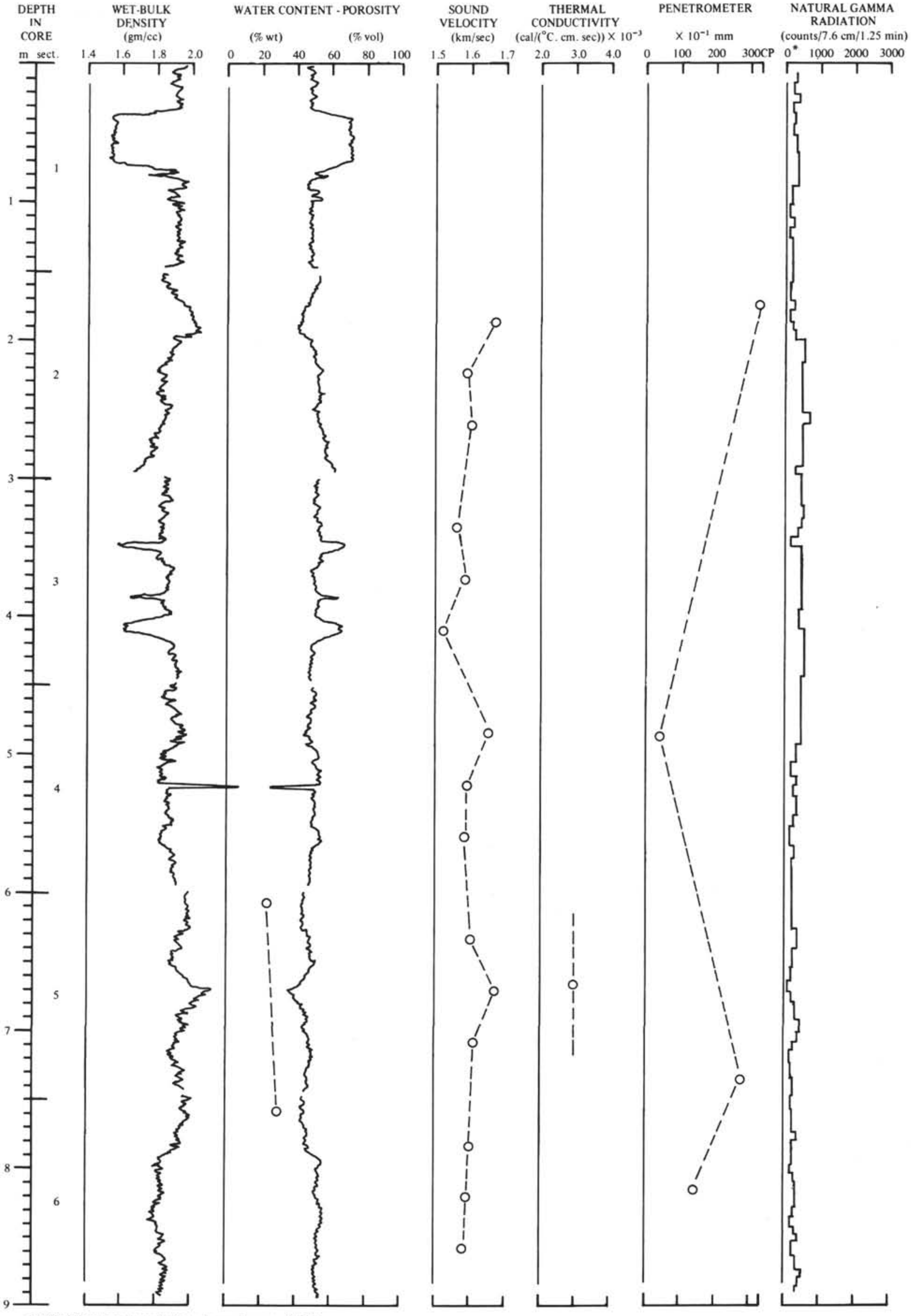
* "0" = laboratory-atmospheric background count of 1550.

Figure 7A. *Physical properties of Core 3, Hole 22.*

AGE (STAGE)	ZONE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
UPPER OLIGOCENE (CHATTIAN-BORMIDIAN)	*Globorotalia opima opima* Zone *Triquetrorhabdulus carinatus* Zone	1	1		FNR* OPENED AT END FNR		Planktonic foraminifera: *Globorotalia opima opima, G. opima continuosa, Globigerina ciperoensis, G. angulisuturalis, Cassigerinella chipolensis.* Calcareous nannoplankton: *Discoaster deflandrei, D. adamanteus, Cyclococcolithus neogammation, Coccolithus* aff. *bisectus.* Radiolaria: *Artophormis gracilis, Tristylospyris* ***triceros,*** *Pipettella prismatica, Trigonactura angusta, Tympanidium binoctonium, Phormocyrtis annosa, Oropagis dolium.*
		2	2		OPENED AT END		
		3 4	3		OPENED AT END FNR	Formation 3-22/1/6 Foram-nannofossil chalk ooze, white - pink (10YR8/1). up to 20% foram 5% rads.	Flora and faunas similar to above.
		5	4		OPENED AT END FNR		Flora similar to above. First appearance of *Coccolithus bisectus.* Faunas similar to above.
	Probably *Sphenolithus ciperoensis* Zone	6 7	5		OPENED AT END NR		Flora and fauna similar to above.
		8	6		R FN R		Flora and faunas similar to above. Core catcher: Flora and faunas similar to above.

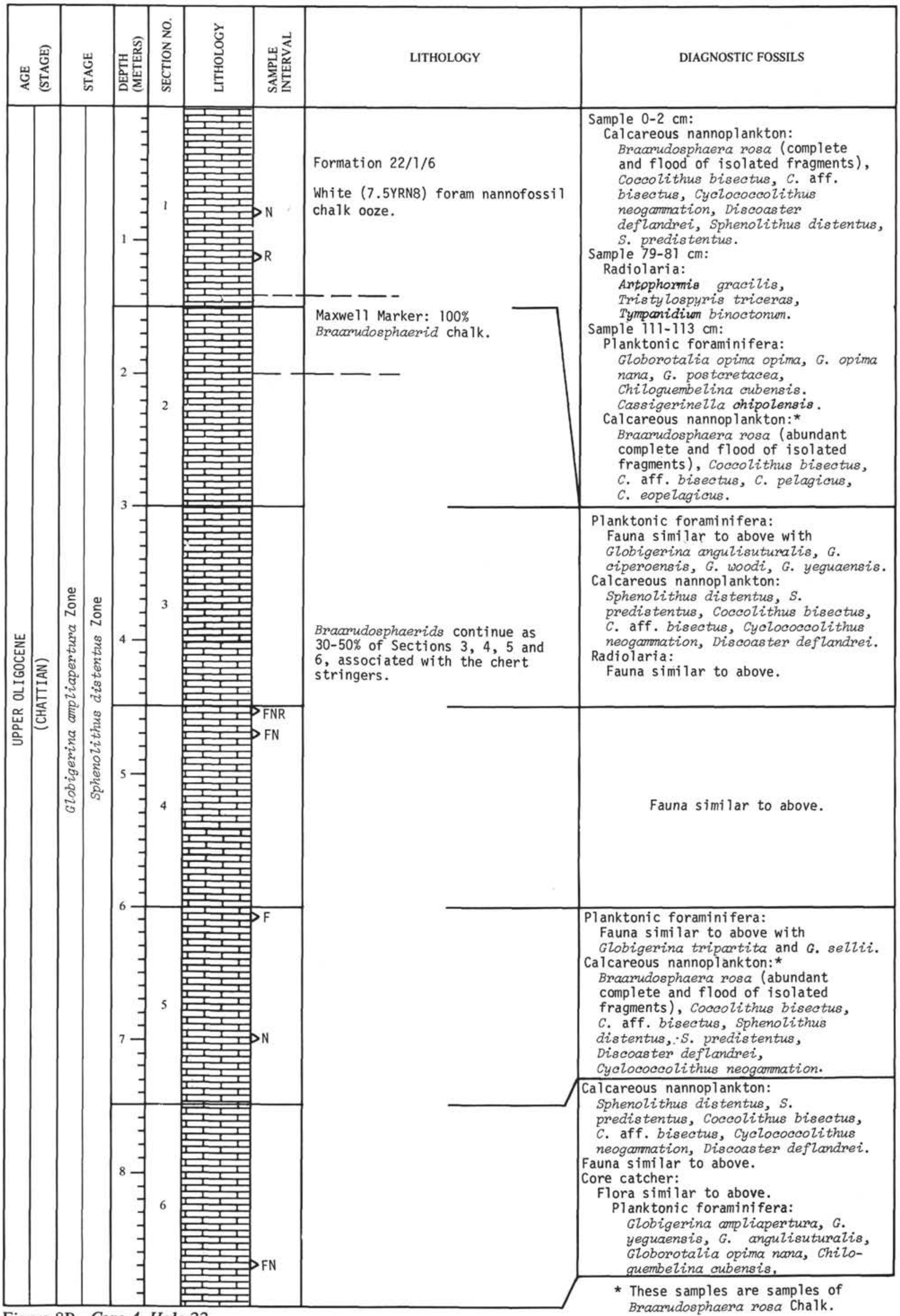
* The top sample is located about 30cm above section 1.

Figure 7B. *Core 3, Hole 22.*



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

Figure 8A. *Physical properties of Core 4, Hole 22.*



Formation 22/1/6

White (7.5YRN8) foram nannofossil chalk ooze.

Maxwell Marker: 100% *Braarudosphaerid* chalk.

Braarudosphaerids continue as 30-50% of Sections 3, 4, 5 and 6, associated with the chert stringers.

Sample 0-2 cm:
Calcareous nannoplankton:
Braarudosphaera rosa (complete and flood of isolated fragments), *Coccolithus bisectus*, *C.* aff. *bisectus*, *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Sphenolithus distentus*, *S. predistentus*.
Sample 79-81 cm:
Radiolaria:
***Artophormis** gracilis*, *Tristylospyris triceras*, ***Tympanidium** binoctonum*.
Sample 111-113 cm:
Planktonic foraminifera:
Globorotalia opima opima, *G. opima nana*, *G. postcretacea*, *Chiloguembelina cubensis*. *Cassigerinella* ***chipolensis***.
Calcareous nannoplankton:*
Braarudosphaera rosa (abundant complete and flood of isolated fragments), *Coccolithus bisectus*, *C.* aff. *bisectus*, *C. pelagicus*, *C. eopelagicus*.

Planktonic foraminifera:
Fauna similar to above with *Globigerina angulisuturalis*, *G. ciperoensis*, *G. woodi*, *G. yeguaensis*.
Calcareous nannoplankton:
Sphenolithus distentus, *S. predistentus*, *Coccolithus bisectus*, *C.* aff. *bisectus*, *Cyclococcolithus neogammation*, *Discoaster deflandrei*.
Radiolaria:
Fauna similar to above.

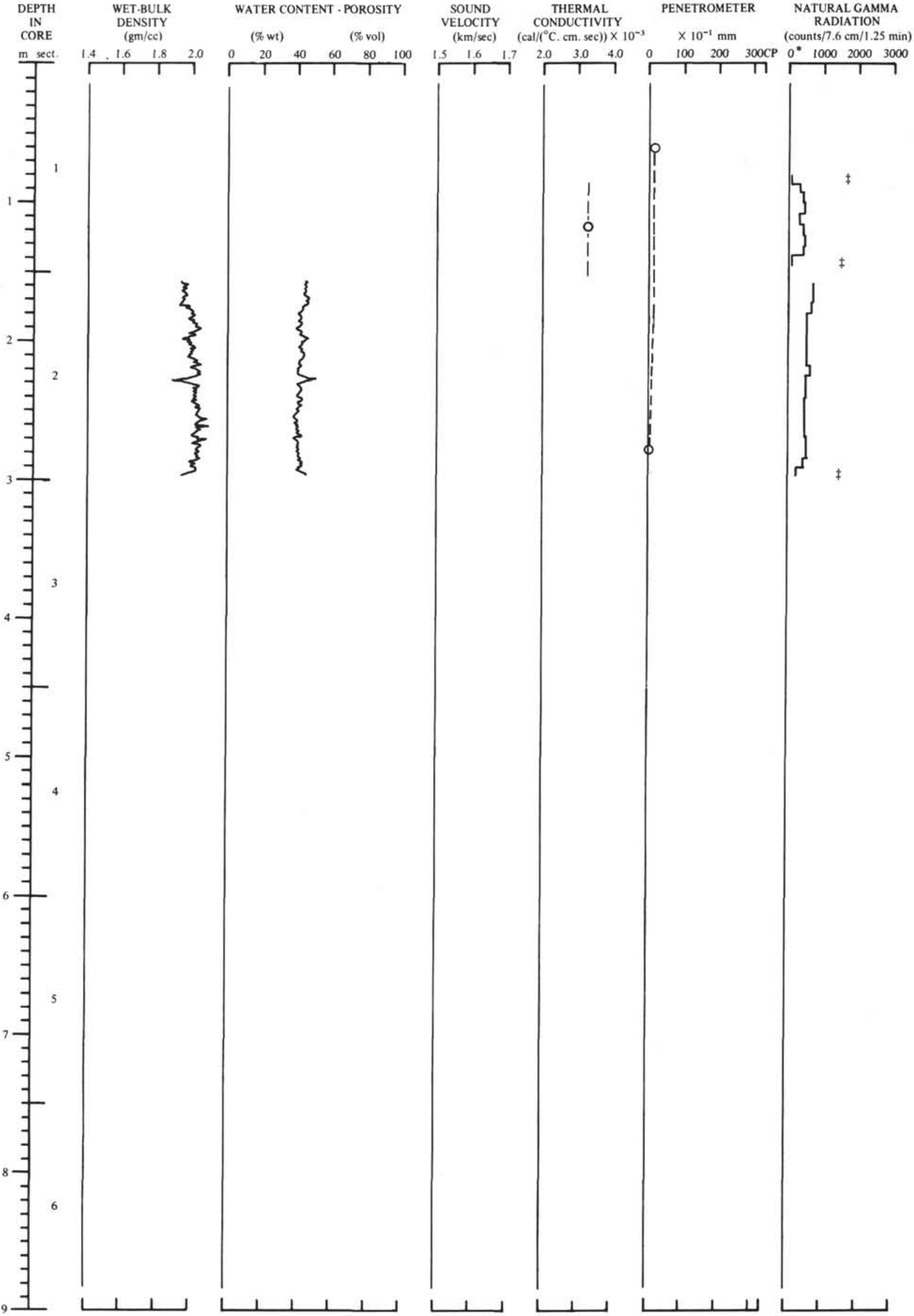
Fauna similar to above.

Planktonic foraminifera:
Fauna similar to above with *Globigerina tripartita* and *G. sellii*.
Calcareous nannoplankton:*
Braarudosphaera rosa (abundant complete and flood of isolated fragments), *Coccolithus bisectus*, *C.* aff. *bisectus*, *Sphenolithus distentus*, *S. predistentus*, *Discoaster deflandrei*, *Cyclococcolithus neogammation*.

Calcareous nannoplankton:
Sphenolithus distentus, *S. predistentus*, *Coccolithus bisectus*, *C.* aff. *bisectus*, *Cyclococcolithus neogammation*, *Discoaster deflandrei*.
Fauna similar to above.
Core catcher:
Flora similar to above.
Planktonic foraminifera:
Globigerina ampliapertura, *G. yeguaensis*, *G. angulisuturalis*, *Globorotalia opima nana*, *Chiloguembelina cubensis*.

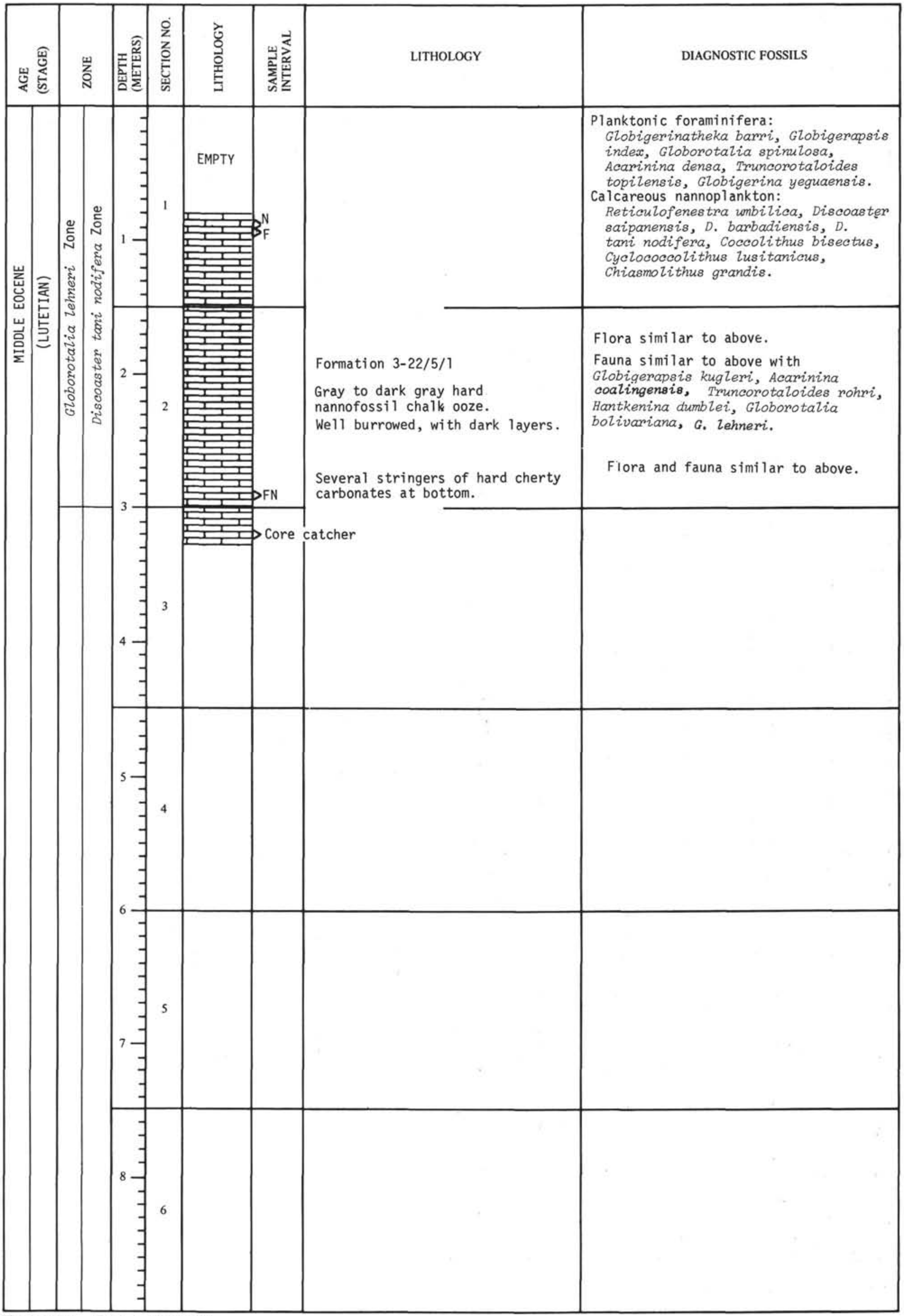
* These samples are samples of *Braarudosphaera rosa* Chalk.

Figure 8B. *Core 4, Hole 22.*



* "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.



AGE (STAGE)	ZONE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
MIDDLE EOCENE (LUTETIAN)	*Globorotalia lehneri* Zone *Discoaster tani nodifera* Zone	0–1	1	EMPTY	N F		Planktonic foraminifera: *Globigerinatheka barri, Globigerapsis index, Globorotalia spinulosa, Acarinina densa, Truncorotaloides topilensis, Globigerina yeguaensis.* Calcareous nannoplankton: *Reticulofenestra umbilica, Discoaster saipanensis, D. barbadiensis, D. tani nodifera, Coccolithus bisectus, Cyclococcolithus lusitanicus, Chiasmolithus grandis.*
		2–3	2		FN	Formation 3-22/5/1 Gray to dark gray hard nannofossil chalk ooze. Well burrowed, with dark layers. Several stringers of hard cherty carbonates at bottom.	Flora similar to above. Fauna similar to above with *Globigerapsis kugleri, Acarinina* **coalingensis,** *Truncorotaloides rohri, Hantkenina dumblei, Globorotalia bolivariana,* ***G. lehneri.*** Flora and fauna similar to above.
		3–4	3		Core catcher		
		5–6	4				
		7	5				
		8	6				

Figure 9B. *Core 5, Hole 22.*

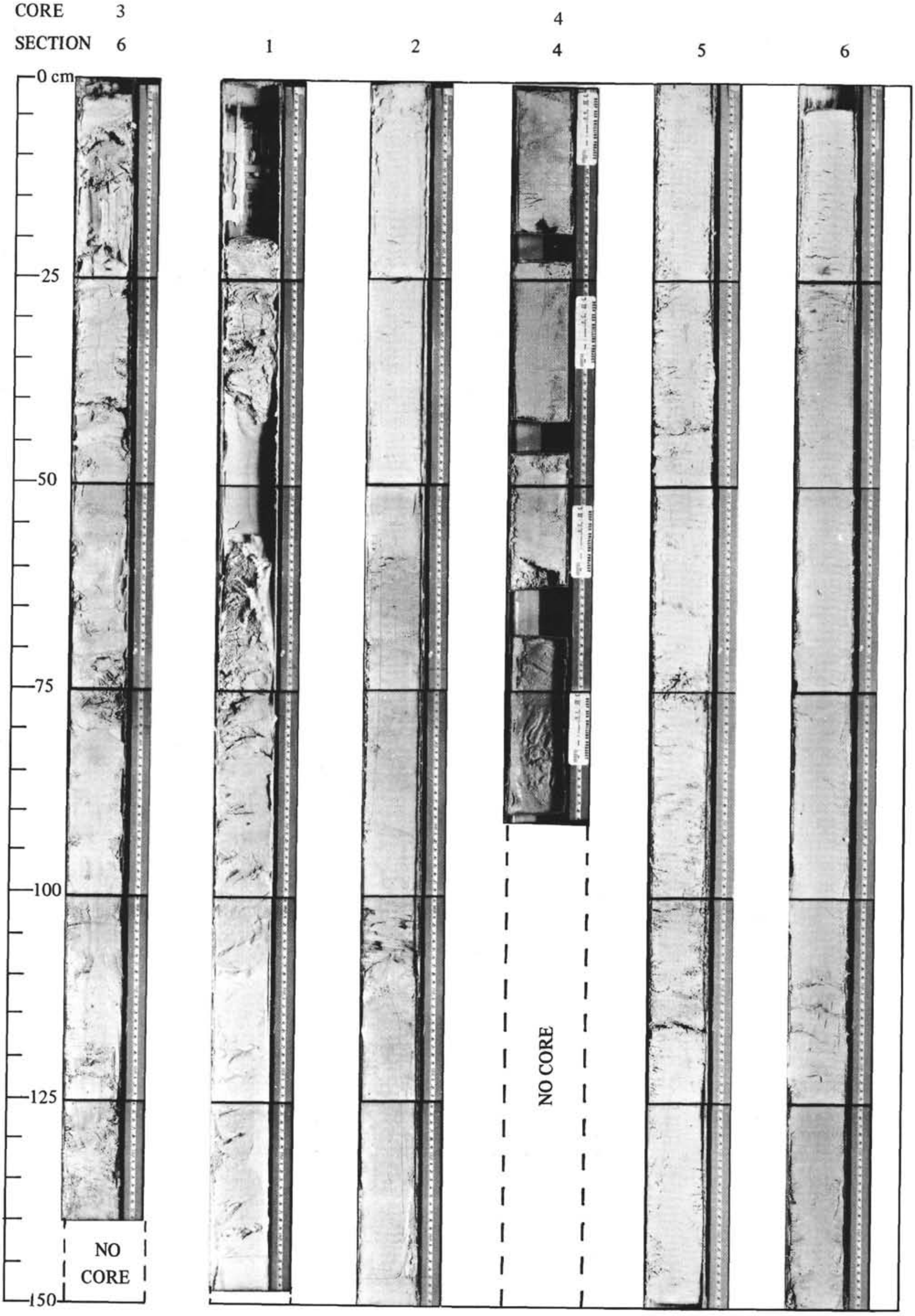


Plate 2. *Sections from Cores 3 and 4, Hole 22.*

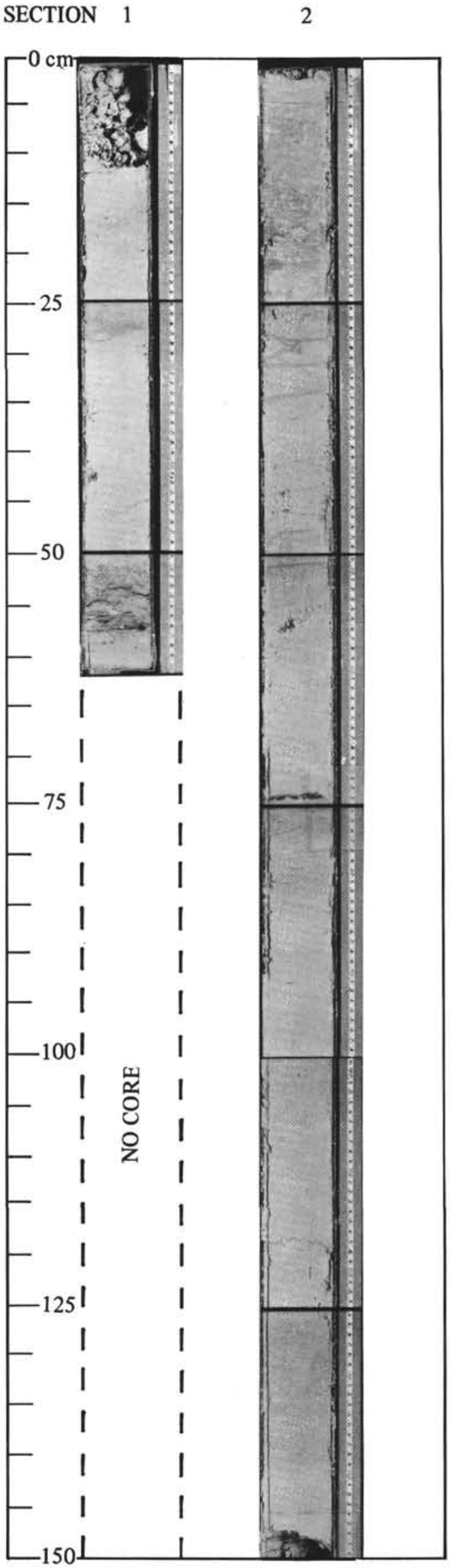


Plate 3. *Sections from Core 5, Hole 22.*