3. SITE 13

The Shipboard Scientific Party[1]

SURVEY DATA AND SITE BACKGROUND

The preliminary planning and approach to this site were taken from the JOIDES Atlantic Advisory Panel Report and from a recent detailed survey of the site by *R/V Vema* of the Lamont Geological Observatory. The *Vema* data included bathymetric and seismic profiling (CSP) data, compiled as contour maps of depth and isopachs of thickness to the major reflecting horizons, out to horizontal distances of 20 to 60 kilometers surrounding the site. Position control was by satellite navigation. The position of the drilling site, as determined by satellite navigation aboard *Glomar Challenger,* is 6° 02.4′N, 18° 13.71′W.

Several CSP profiles crossing the selected site in various directions show an uplifted portion of the sea floor roughly circular in shape of about 10 kilometers in diameter. On the north side, the slope of the bottom down towards the abyssal plain is relatively steep (20 m/km), and that of the subbottom reflectors even steeper (Figure 1). The two major subbottom reflecting horizons also appear elevated beneath the site to an even greater degree than the bottom, as deduced from the decreased travel time to these horizons (Figures 1 and 2). The apparently decreased depth and thickness to the major reflecting horizons was a major consideration in site selection.

In contrast to the smooth bottom of the surrounding abyssal plain, the topography of the small rise selected for the site has a small-scale roughness of amplitude of 40 to 80 meters. On the other hand, the first major subbottom reflector (probably comparable to layer "A" at some sites in the western Atlantic) is quite smooth on both the small rise and the abyssal plain. The second reflector, here designated as basement, is moderately rough (40 to 100 meters) everywhere. At the site, the bottom depth was measured as 4588 meters (15,048 feet) corrected (2433 fathoms uncorrected). Acoustic travel times (round trip) from the bottom to the first and second reflecting horizons were measured as 0.22 and 0.54 second, respectively. For acoustic velocities of 1.86 km/sec between the bottom and the first reflector, and 2.0 km/sec between the first and second reflectors, the depth to basement was estimated at about 520 meters (1705 feet). The actual drilling depth to the supposed "basement" reflector was somewhat less (about 460 meters) (1508 feet), which is consistent with the measured sonic velocities on the cores being smaller than the interval velocities assumed above.

The magnetometer record shows the site to be located over a local high of about 100 gammas in the magnetic field. Magnetic anomalies at and around this site have not been related to proposed models of the spreading sea floor.

OPERATIONS

Positioning

At 0530 hours on 3 December, 1968, the marker beacon was put over the side. Since it was necessary to remake part of the drill string and reposition the pipe in the racks, more time than ordinary was required before the drill string could be assembled and lowered into the water. It was not until 1030 hours on 4 December that the string reached bottom in 4585 meters (15,038 feet) of water. Drilling, coring and logging continued until 1400 hours on 11 December and during this entire period the ship maintained position above the hole to within 60 meters (197 feet), and most of the time within 15 meters (49 feet). Ideal weather conditions and no major equipment malfunctions were primary factors in this successful positioning.

Drilling

An analysis of the drilling records provides some insight into the lithological character of the sediments. Table 1 summarizes the major drilling breaks noted at Site 13. These are referenced in both time and depth in order that they might be correlated with the coring summary.

The most significant of these breaks were at depths of 125, 177 and 432 meters (410, 580 and 1417 feet). At 125 meters (410 feet) there was a noticeable

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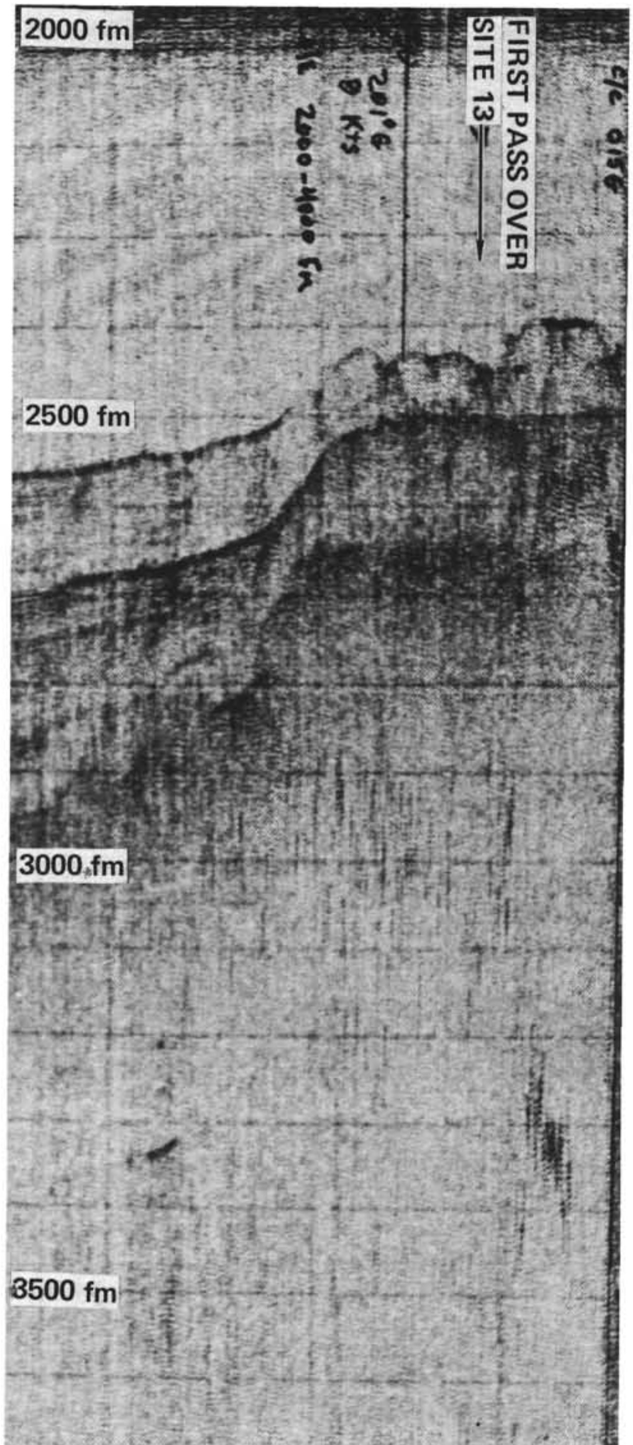


Figure 1. *Continuous seismic profiler record in the vicinity of Site 13.*

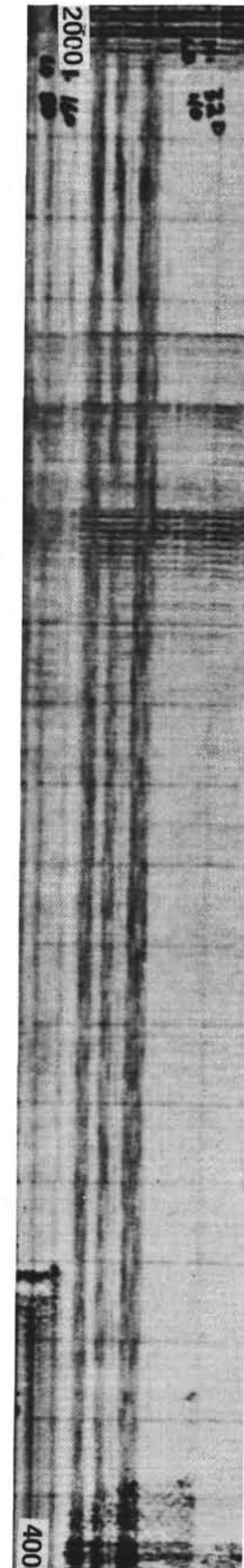


Figure 2. *Continuous seismic profiler record on Site 13.*

TABLE 1
Summary of Drilling Breaks at Site 13

Date/Time	Depth (m)	Average Drilling Rate Prior Hour (m/hr)	Average Drilling Rate Subsequent Hour (m/hr)	Minimum Drill Rate (m/hr)	Remarks
12-6-68					
0100	125	52.0	107.0	–	Break between relatively firm over softer sediments.
0610	177	90.0	1.5	0.5	Top of chert layer estimated to be 5 meters thick, possibly other stringers.
1335	196	2.4	46.0	–	At 226 meters 15 min. required to drill 0.3 meter.
1730	244	46.0	6.0	–	Encountered firm layer while coring.
12-7-68					
1720	350	9(?)	1.5	–	9 meters prior to removing worn center bit.
12-8-68					
0800	362	1.5	3.0	–	Increased rotation from 40 to 80 rpm. during coring.
1800	380	3.0	1.5	–	
12-9-68					
0330	–	1.5-3.0	9.0	–	After replacing gasket in Bowen unit.
1430	432	12.0	4.6	1	Minimum rate coincides with large increase in torque, indicating very hard layer.
12-10-68					
0600	463	1.0	nil	nil	Broke drill bit.

TABLE 2
Summary of Coring at Site 13

Date	Time	Core No.	Interval Cored (m below sea floor)	Core Retrieved (m)		Remarks
12-4-68	1630	13-1	0-9	9.0		Three unsuccessful attempts to retrieve core barrel.
	1915	13-2	21-30	9.0		
12-5-68	0210	13-3	136-145	8.5		Left core catcher in hole necessitating abandonment of hole.
12-6-68	1030	13A-1	177-179	1.0		Encountered chert layer.
	1930	13A-2	242-251	1.0		
12-7-68	1130	13A-3	307-316	5.3		
12-8-68	0730	13A-3a	355	trace		Recovered from center bit.
	2130	13A-4	380-382	1.5		
12-9-68	1130	13A-5	411-415	1.5		
	2215	13A-6	443-449	0.2		Weight on bit increased from 20k to 40k lbs.
12-10-68	0915	13A-7	461-463	0.8		Parts of drill bit recovered in core.
Totals			60.4	37.8	63%	

increase in the drilling rate from 52 to 107 m/hr, indicating a change from a relatively firm to a softer sediment. At 177 meters (580 feet) the first hard chert layer was encountered; this reduced the drilling rate from 90 to 1.5 m/hr. and at one point to a minimum of only 0.5 m/hr. Again, at 432 meters (1417 feet) there was a marked reduction in drilling because of chert. At this point the drilling rate dropped from 12 to 4.6 m/hr. From this point to the bottom of the hole at 463 meters (1518 feet), the drilling fluctuated between 4.6 and 1.5 m/hr as stringers of chert were drilled. At 463 meters (1518 feet), penetration was reduced to near zero while coring. At this point, the hole was abandoned.

Coring

A list of the cores collected, times of arrival on deck, interval cored and length is shown in Table 2.

While retrieving the initial core, difficulty was encountered in latching onto the barrel. Three unsuccessful lowerings of the overshot were made with the sand line. After vigorous circulation to clean out the pipe, a fourth attempt proved to be successful and a 9-meter core (13-1) was recovered. The pipe was then washed to a depth of 21 meters (69 feet) and another 9-meter core (13-2) was recovered with no difficulties. On the third core (13-3), made at a depth of 136 meters (446 feet) below ocean bottom, it was discovered that the core catcher had come unscrewed and two dog catchers and a basket catcher had been left in the hole. This necessitated abandoning the hole and pulling in the drill string.

An inspection showed the drill bit and bearing seat for the core barrel to be in satisfactory condition. Nonetheless, the bearing was replaced to be on the safe side, and set screws were installed on the core catcher. The set screws appeared to solve the problem as no further casualties of this nature occurred at Site 13. It is noted that similar difficulties were experienced on Leg 2.

At a depth of 355 meters (1164 feet) a resistant layer was encountered, and the center bit was retrieved yielding a sample adequate to be identified as Upper Cretaceous. No core was collected from this depth. It is noted, however, that the diamond center bit was worn smooth and it was replaced with a tungsten-carbide bit. Cores 13A-1 through 13A-7 were only partial recoveries. Each of these cores contained very stiff sediments–some of it chert–which may account for the poor recovery.

Core 13A-7, cut at a depth below bottom of 461 meters (1512 feet), contained 0.8 meter of red shale and clay mixed with pieces of flint-like chert. In addition, three pieces of the diamond drilling bit were found in the core. It was obvious that the chert had destroyed the main bit, and Hole 13A had to be abandoned.

Logging

Because of the broken bit, it was necessary to log the hole from inside the pipe. A gamma-neutron log was lowered to the bottom of the drill string to commence logging operations; however, as the probe was being retrieved, a portion of the rigging failed parting the logging cable. Logging operations were aborted at this point and the cable end and probe were pulled out of the drill stem.

PALEONTOLOGY

Upper Pliocene, Lower Pliocene and Middle Eocene sediments were cored in Hole 13; and Middle Eocene, Campanian and undifferentiated Senonian were cored in Hole 13A. No stratigraphic boundaries were cored and the coring was discontinuous through the hole. In the upper part of the Campanian of Hole 13A, a few small blocks of lower Maestrichtian sediments were found. In addition, small samples recovered from the center bit, when it was retrieved from the hole, indicated the presence of uncored sediments of Early Miocene age in Hole 13, and of late Maestrichtian age in Hole 13A.

The purpose of drilling this hole was to gain stratigraphic knowledge of the sediments constituting the Sierra Leone Rise. The stratigraphic results are shown in the Hole Summary Sheets (Figures 3A and 3B) and are given below.

In Hole 13, the sediments of Core 1 and the upper half of Core 2 consist predominantly of calcareous nannoplankton and planktonic foraminifera. Those of the lower half of Core 2 are brown zeolite clays with micronodules of manganese and are barren of microfossils. In Core 3, the lithology is composed of a non-calcareous radiolarian ooze with numerous diatoms. In Hole 13A, the sediments in Core 1 consist of radiolarian silts and clays with a hard chert layer. In Cores 2 through 5, they are mainly nannofossil chalk oozes. The lithology in Core 6 is varied and consists of cherts, dolomitic cherts, radiolarian oozes and dolomites. In Core 7, grayish-red purple shales are present. Variations from lithologic unit to lithologic unit are discussed in the section on Stratigraphy.

In Core 1, from 0 to 9 meters (0 to 29 feet), of Hole 13, the sediments are Late Pliocene (Astian-Piacenzian) in age based on the calcareous nannoplankton and planktonic foraminifera. The flora contains: *Discoaster brouweri* Tan Sin Hok, *D. challengeri* Bramlette and Riedel, *D. surculus* Martini and Bramlette and *D. pentaradiatus* Tan Sin Hok; and the fauna includes: *Globorotalia* *menardii miocenica* Palmer, *G. multicamerata* Cushman and Jarvis, *G. tosaensis* Takayanagi and Saito and *G. fistulosus* (Schubert). Most of the samples studied are contaminated by Pleistocene planktonic foraminifera. This contamination probably resulted from mixing within the core barrel by drilling.

Lower Pliocene (Zanclian) sediments are found in the upper 4.5 meters (15 feet) of Core 2, from 21 to 30 meters (69 to 98 feet), in Hole 13 based on the planktonic foraminifera. The lower 4.5 meters (15 feet) of this core are barren of planktonic microfossils and only sporadic occurrences of fish teeth were noted. The fauna consists of *Globorotalia margaritae* Bolli and Bermudez, a diagnostic Lower Pliocene species associated with *Globoquadrina altispira* (Cushman and Jarvis), *Globorotalia tosaensis* and *Sphaeroidinellopsis seminulina* (Schwager). Most of these samples are contaminated by Pleistocene planktonic foraminifera from the drilling, as mentioned previously. The calcareous nannoplankton from this portion suggest that the boundary between the Lower and Upper Pliocene occurs in Section 2 between samples from a depth of 15 to 17 centimeters and 99 to 101 centimeters. This boundary is based on the first downward occurrence of *Reticulofenestra pseudoumbilica* (Gartner) (Bukry and Bramlette, personal communication, 1969) in the lower sample with a flora similar to the one mentioned above. Several pieces of a firm radiolarian silt were collected from the center bit when the drill string was pulled from a depth of 145 meters (476 feet) in Hole 13. The pieces are rounded apparently by drilling action, and are of three main color groups plus a mottled group. These are: (1) a dusky yellow-green, (2) a grayish yellow-green, (3) a very pale green, and (4) a grayish yellow-green mottled with the dusky yellow-green group. After careful cleaning, representative pieces of each color were processed for microfossils and found to contain abundant Middle Eocene Radiolaria similar to the assemblage collected from Core 3. In addition, diagnostic Lower Miocene Radiolaria and calcareous nannoplankton are also present in these firm sediments. Except for the presence of *Cycladophora goetheana* Haeckel, an examination of disaggregated material failed to show distinctive late Upper Eocene forms, such as, *Artophormis barbadiensis* (Ehrenberg) and *Calocyclas turris* Ehrenberg–or short-ranging Oligocene index forms, such as, *Artophormis gracilis* Riedel, *Trigonactura angusta* Riedel–and other characteristic species generally found in sediments of this time interval.

Radiolaria found in these samples are: *Pipettella prismatica* Haeckel, *Lychnocanium bipes* Riedel, *Phormocyrtis annosa* Riedel, *Dipodospyris forcipata* Haeckel, *Tympanidium binoctonum* Haeckel, *Calocyclas* aff. *virginis* Haeckel, *Oroscena carolae* Friend and Riedel, *Orodapis spongiosa* Friend and Riedel, *Oropagis dolium* Friend and Riedel, plus abundant re-worked Middle Eocene Radiolaria. The assemblage is Early Miocene (Aquitanian) in age.

Calcareous nannoplankton are found only in the very pale-green center bit sample and include *Cyclococcolithus neogammation* Bramlette and Wilcoxon, *Discoaster druggi* Bramlette and Wilcoxon, *D. challengeri*, *D. deflandrei* Bramlette and Riedel, and *D. adamanteus* Bramlette and Wilcoxon. This flora is Lower Miocene (Aquitanian) in age and probably represents the upper part of the *Triquetrorhabdulus carinatus* Zone of Bramlette and Wilcoxon (1967).

These results show that this firm sediment retrieved from the bottom of Hole 13 represents uncored material from above a depth of 136 meters (446 feet). The microfossil assemblage and the lithology suggest it represents Lower Miocene sediments unconformably overlying the Middle Eocene radiolarian ooze.

The actual position of this firm material in the hole may correspond to a drilling break or change recognized at 125 meters (410 feet) in depth. This position in the hole also has been taken as the level of lithologic change from the zeolitic clays above and the radiolarian silts below. This would indicate that these zeolitic clays are no older than Early Miocene in age.

Middle Eocene (Lutetian) sediments occur in Core 3 of Hole 13 from 136 to 145 meters (446 to 476 feet). They consist of a radiolarian ooze with numerous diatoms, mostly *Coscinodiscus* spp., but are barren of calcareous microfossils. The Radiolaria present are: *Podocyrtis triacantha* Ehrenberg, *Eusyringium fistuligerum* (Ehrenberg), *Lithocyclia ocellus* Ehrenberg, *Dictyophimus babylonis* Clark and Campbell, *Anthocyrtium hisidum* (Ehrenberg), *Podocyrtis papalis* Ehrenberg and *Phormocyrtis embolum* (Ehrenberg). These forms occur throughout the core, though the upper part of this core contains several undescribed radiolarian species thought to represent the upper portion of the Middle Eocene as represented on Barbados, W.I.

In Core 1 of Hole 13A from 177 to 179 meters (581 to 587 feet) the sediments consist of radiolarian silts and clays with a hard chert layer. The top of the upper reflector (Horizon A) at Site 13 is interpreted to be this chert layer. The top of the highest level of chert layers in this core is essentially equivalent with the first evolutionary appearance of *Podocyrtis triacantha* Ehrenberg. This species can be observed to evolve at this point from its ancestor, as yet an unnamed species. Forms intermediate between *Eusyringium fistuligerum* (Ehrenberg) and its apparent precursor *Sethocapsa lagena* (Ehrenberg) make their first appearance at about this same horizon. This distinctive level can readily be placed in the Middle Eocene radiolarian biostratigraphy. Calcareous nannoplankton are also present in these sediments and are characteristic of the lower portion of the Middle Eocene. The diagnostic species in the sample from 140 to 142 centimeters are: *Chiphragmalithus quadratus* Bramlette and Sullivan, *Campylosphaera dela* (Bramlette and Sullivan), *Discoaster barbadiensis* Tan Sin Hok, *D. sublodoensis* Bramlette and Sullivan, and *Cyclococcolithus lusitanicus* (Black) which indicate the *Discoaster sublodoensis* Zone of Hay (Hay *et al.,* 1967). The sample examined from 64 to 66 centimeters is characterized by the absence of *Discoaster sublodoensis* which suggests the *Chiphragmalithus quadratus* Zone of Hay (Hay *et al.,* 1967).

Well-rounded pebbles of five distinct lithologies were recovered from the center bit when the drill was pulled from a depth of 463.6 meters (1519 feet). These are: (1) light gray nannoplankton-rich marl, (2) grayish-green nannoplankton-rich chalk ooze, (3) pale yellowish-green nannoplankton chalk, (4) light greenish-gray chert, and (5) grayish-red purple shale. A representative chip from each of the nannoplankton-rich sediments was examined for planktonic foraminifera and nannoplankton. The only lithology which was new is the light gray nannoplankton-rich marl which contains abundant nannoplankton and planktonic foraminifera. The planktonic foraminifera are of late Maestrichtian age and consist of *Rugoglobigerina pustulata* Brönnimann, *R. reicheli* Bronnimann, *R. rugosa* (Plummer), *Pseudoguembelina excolata* (Cushman), *P. costulata* (Cushman), *Globotruncanella citae* (Bolli) and *Globigerinelloides subcarinatus* (Bronnimann). The nannoplankton also indicate a late Maestrichtian age and consist of *Arkhangelskiella cymbiformis* Vekshina, *Tetralithus murus* Martini, *Micula decussata* Vekshina, and *Microrhabdulus stradneri* Bramlette and Martini. This sample belongs to an uncored interval between 179 and 242 meters (587 and 794 feet). Its position being questionably placed at 200 meters (656 feet), where a drilling break was noted.

The four other lithologies, on the basis of microfossils and lithologic similarities, can be identified with the cored section; namely, the pale yellowish-green nannoplankton-rich chalk which is lower Maestrichtian based on planktonic foraminifera and nannoplankton, and the grayish-green nannoplankton-rich chalk ooze which is Campanian based on nannoplankton. A similar grayish-red purple shale was found in Core 7 and similar cherts were found in Cores 6 and 7.

Core 2 from 242 to 251 meters (794 to 823 feet), Core 3 from 307 to 316 meters (1007 to 1036 feet), Core 4 from 380 to 382 meters (1246 to 1253 feet) and Core 5 from 411 to 415 meters (1348 to 1361 feet) of Hole 13A are Upper Cretaceous (Campanian) in age based mainly on the characteristic calcareous nannoplankton assemblages. These assemblages are similar to the ones reported by Stradner (1963) from Europe and Gartner (1968) from the Gulf Coast. Planktonic foraminifera occur only sporadically; arenaceous benthonic foraminifera are common but not diagnostic for age determination at the stage level. *Dictyomitra multicostata* Zittel, a radiolarian, occurs in Cores 2 through 5 and lowers the age limit for this part of the drilled sections to Senonian, based on the reported range of this species (Foreman, 1968). Included in this taxon are forms with from six or seven to ten or more conical segments increasing in width before constriction of the lower part begins. Variability in other characters were noted; but, for the present, all of these costate forms are tentatively grouped together. Though the Cretaceous radiolarian fauna become quite rich and diversified in the lower cores of Hole 13A, their state of preservation deteriorates with depth. From their tests, most of the Radiolaria show an obvious alteration below Core 3.

In Cores 2 and 3 the diagnostic calcareous nannoplankton are *Tetralithus nitidus* Martini, *T. nitidus trifidus* (Stradner), and *Zygodiscus lacunatus* Gartner. During the study of the microfossils of Core 2, the sample from 68 to 70 centimeters was found to contain a lower Maestrichtian planktonic foraminiferal fauna and calcareous nannoplankton flora. The diagnostic planktonic foraminifera are: *Heterohelix pulchra* (Brotzen), *Globotruncana rosetta* (Carsey), *G. gagnebini* Tilev, *Globotruncanella havanensis* (Voorwijk) and *G. petaloidea* (Gandolfi). The diagnostic calcareous nannoplankton include *Arkhangelskiella cymbiformis* (abundant), *Microrhabdulus stradneri* and *M. decoratus* Deflandre. Since this sample is apparently surrounded by Campanian sediments, the core photographs, descriptions and X-ray photographs were examined. This examination revealed small blocks of the Maestrichtian sediment intermixed with the typical Campanian age sediments. These blocks may be interpreted as either blocks which collapsed into the hole after washing down to core or blocks which became mixed with the Campanian sediments after intervening softer sediments had been washed out during the coring process. Either interpretation suggests that the phenomenon is the result of drilling and not of geologic processes.

In Cores 4 and 5, the characteristic calcareous nannoplankton species are *Broinsonia parca* (Stradner) (abundant), *Zygodiscus lacunatus* and *Cyclolithus gronosus* Stover. A typical Campanian planktonic foraminifera fauna is found in the sample from 6 to 7 centimeters in Core 4. The diagnostic species are *Globigerinelloides asperus* (Ehrenberg), *G. volutus* (White), *Heterohelix reussi* (Cushman), *H. striata* (Ehrenberg), and *Rugoglobigerina tradinghausensis* Pessagno.

A Senonian age is assigned to Core 6 from 443 to 449 meters (1453 to 1473 feet) in Hole 13A based on the calcareous nannoplankton and Radiolaria. The Radiolaria *Dictyomitra multicostata* Zittel is present and, as previously mentioned, indicates a Senonian age. The calcareous nannoplankton are rare and consist of *Micula decussata* and *Watznaueria barnesae.* The extreme rarity of these forms and their extreme abundance uphole strongly suggest that these are probably contaminants.

In Hole 13A, Core 7, from 461 to 463 meters (1512 to 1518 feet), is assigned a questionable Senonian age based on benthonic foraminifera and calcareous nannoplankton. The benthonic foraminifera are: *Ammodiscus cretaceus* (Reuss), *Cyclammina* sp., *Dorothia* sp., *Glomospira gordialis* (Jones and Parker), *Haplophragmoides* spp., *Pelosina complanata* Franke, *Rzehakina epigona* (Rzehak) and *Trochammina* sp. The calcareous nannoplankton are rare in the silt and consist of *Watznaueria barnesae* (rare), *Broinsonia parca* (very rare) and *Micula decussata* (very rare). As mentioned above these may also represent contamination from uphole.

STRATIGRAPHY

Six lithologic units were cored in Holes 13 and 13A. They are, in order of increasing age:

3-13-1-1	Foraminiferal nannofossil oozes
3-13-2-3	Brown zeolitic clays
3-13-3-1	Radiolarian oozes with chert member 3-13A-1-1
3-13A-2-1	Nannofossil marl oozes and clays, with intercalated dolomitic claystones
3-13A-6-1	Cherts, limestones, and soft interbeds
3-13A-7-1	Grayish-red purple shales with cherts.

The Pliocene 3-13-1-1 unit consists of interbedded nannofossil chalk oozes, marl oozes and brown zeolitic clays. The cores have been badly disturbed; the low calcium carbonate content is low for a chalk ooze, but this may have resulted in part from a mixing of the chalk oozes with the clays during the coring. The zeolitic interbeds are more frequent in the lower part of the unit (3-13-2-1, 24 to 54 centimeters, and 78 to 85 centimeters); and, the lower boundary of the unit was placed at 3-13-2-3, 93 centimeters, at a sharp contact between a very pale brown nannofossil marl ooze and a yellowish-brown, mottled dark grayish-brown zeolitic clay.

The unit 3-13-2-3 is a brown zeolitic clay, very low in calcium carbonate content (< 3 per cent) and barren of identifiable fossils. Dark gray dust-like specks of manganese compounds are scattered throughout. Foraminifera molds and carbonate rhombs are present. The insoluble residue includes labradorite, probably derived from submarine volcanics. The base of the unit was not cored. The authors believe that the drill break at 125 meters (410 feet) BOB (below ocean bottom) may represent the contact with the underlying radiolarian ooze. The drill bit samples recovered after the drill string was pulled from a depth of 145 meters (476 feet) in Hole 13 showed chips of light brown clay containing Lower Miocene nannofossils and Radiolaria. These were interpreted as the base of Unit 3-13-2-3. If this is so, that unit would be mainly a part of a Miocene formation, which lies disconformably above the Middle Eocene radiolarian silt.

The Unit 3-13-3-1 consists of light greenish-gray to grayish-yellow green deposits of siliceous planktons. The oozes are very homogeneous, very poorly consolidated and very porous. Intercalated are stringers of hard chert. The uppermost chert interval (3-13A-1-1) as the drilling rate suggests, may be 19 meters (62 feet) thick, that is from 177 to 196 meters (580 to 643 feet). The thickest chert layer is some 5 meters (16 feet) thick, which most likely represents the acoustic reflector Horizon A, at this site. A second chert interval may be present at 226 meters (741 feet) where a hard bed some 0.3 meter (1 foot) thick was encountered by drill. The chert includes a few Radiolaria in a cryptocrystalline matrix. In contrast, the siliceous oozes consist of well preserved Radiolaria and diatoms, showing no evidence of recrystallization. No transition between these two types of lithology was found.

The top of Core 1 from Hole 13A is a 16-centimeter thick "sand" layer, consisting of Radiolaria and radiolarian clay chips, resting with a sharp contact above a radiolarian clay. The genesis of this sand was a puzzle until experience eventually led the authors to believe that this thin layer is a drilling debris residue, deposited from the circulating drilling fluid (see Chapter 2).

Unit 3-13A-2-1 consists of very pale green to green gray, firm nannofossil oozes and clays. The top of the unit could either be placed at the drill break 196 meters (643 feet), or at 226 meters (741 feet) BOB. The top of the core (Hole 13A-2) also contains a drilling debris layer, some 33 centimeters thick. Lower Maestrichtian sediments were found mixed with a Campanian nannofossil marl ooze. The rest of the unit consists of nannofossil clay. Intercalated hard layers, silicified and dolomitized in part, are irregularly laminated. "Breccias" were observed at several cored intervals (for example: 3-13A-3-4, 100 to 138 centimeters; 3-13A-4-1, 30 to 80 centimeters, and 3-13A-5-1, 10 to 62 centimeters). The fragments of such breccias are lithologically identical to the intercalated hard layers, and they are scattered in a matrix identical to the nannofossil clay. The authors believe, therefore, that these breccias are mechanical mixtures caused by drilling disturbances (see Chapter 2).

The nature of the two lowest formations was interpreted on fragmentary evidence: the core 3-13A-6-1 is represented by twenty-five small rock chips in a gray mud matrix. Except for the one small red shale chip mentioned below, the chips are evenly divided

TABLE 3
Stratigraphy Site 13
Holes 13 & 13A

Age	Cored Interval (m)	Lithologic Unit	Probably Interval (m)	Probable Thickness (m)	Description
Pliocene	0-9.2 21-25	3-13-1-1 Foraminiferal nannofossil oozes	0-25	25	Very pale brown, unconsolidated, marl oozes of foraminifera and nannofossils, with zones of gray dark brown zeolite clays and nannofossil chalk ooze.
Upper or Mid-Tertiary	25-30	3-13-2-3 Brown clay	25-125	100	Yellow brown to brown zeolite clay, with manganese dust, foraminifera molds, and dolomite rhombs.
Eocene	136-145 178-179	3-13-3-1 Radiolarian ooze with 3-13A-1-1 chert member	125-196 226?	46-76	Light greenish gray to gray yellow green unconsolidated radiolarian oozes, with abundant diatoms. 1.5 meters of hard chert at 178 meters, and a few thinner stringers of chert interbedded with radiolarian oozes.
Campanian	242-251 307-316 355 380-382 411-415	3-13A-2-1 Nannofossil clay	196/226-432	200-230	Very pale green to green-gray, firm, nannofossil oozes and clays, with intercalations of green-gray partly silicified, partly dolomitic claystones.
Senonian	443-450	3-13A-6-1 Chert with interbeds	432-450?	18?	Vitreous cherts, gray to dark gray laminated dolomitic cherts and limestone, and gray radiolarian sediments.
Senonian?	462-463	3-13A-7-1 Red shales with cherts	450?-463+	13+	Grayish-red purple shales and hard vitreous cherts and siliceous shales - white to light purplish-gray.

between cherts and cherty carbonate rocks. The gray mud consists of numerous Radiolaria specimens (sand- and silt-sized) with chips of cherts, and a few dolomite rhombs. Drilling records show that hard layers occurred at six horizons, each 0.3 to 0.6 meter (1 to 2 feet) thick, within the 432 to 450 meter (1417 to 1476 foot) interval. The dominant lithology of this formation must, therefore, be a soft sediment which could be disintegrated easily and washed away during the coring operations. It is not likely that the soft interbeds are cherty carbonate rocks, and the color argues against red shale. The alternative chosen was that the soft intervals were mainly radiolarian oozes and clays. The hard layers are chert and carbonate rocks. The top of this unit is most probably the major drill break at 432 meters (1417 feet).

The formation 3-13A-7-1 consists of red shale with five or six hard chert layers, each 0.3 to 0.6 meter (1 to 2 feet) thick, the last of which may have prevented further penetration in the hole. The few Campanian nannoplankton mudstone fragments (less than 5 millimeters long) mixed in this core are believed to represent contaminations. The top of this unit is placed tentatively at 450 meters (1476 feet) because a very small chip of red shale was found in the gray ooze of Core 13A-6 near the bottom, suggesting that this core had reached the red horizon.

Age, lithology, and probable interval of the units are summarized in Table 3.

PHYSICAL PROPERTIES

Natural Gamma Radiation

Natural gamma radiation of 200 to 2200 counts/(1.25 minutes)/7.6-centimeter core segment or advance was recorded at Site 13 (Figures 3A and 4A-12A). The highest radiation counts were emitted from sediments rich in clay minerals, zeolites, and possibly dolomite and manganese particles. Intermediate counts were obtained from biogenic calcareous sediments, and the lowest counts were from radiolarian oozes. Formation 3-13-2-3 consisted of zeolitic sediments, and gave counts greater than 1000. Other formations which also had high gamma counts were the shaly and zeolitic portions of 3-13A-2-1, and 3-13A-7-1. Formation 3-13A-7-1, which is comprised in part of red shales, also showed high gamma counts, but these, in part, may be brought about by the low porosity of the formation allowing more geologic material to be scanned in a given core interval. Intermediate counts of 900 to 950 were recorded from Formation 3-13-1-1, which is mainly biogenic calcareous microfossils. Distinctly lower counts of 200 to 250 were obtained from the radiolarian oozes of Formation 3-13-3-1. These low counts may have been accentuated by the high porosity of these sediments.

In summary, if porosities were constant, the counts over 1000 may suggest the presence of clays and zeolitic minerals; intermediate counts of 500 to 1000 may suggest that calcareous biogenic microfossils are present, and low counts of 200 to 500 may be characteristic of radiolarian oozes. More data and detailed statistical analyses are necessary within this sedimentary province to place any certainty on these crude subdivisions. Gamma radiation data appear to fluctuate irregularly with depth with a very crude similarity to wet-bulk density (Figure 3A). One important problem at all sites is that these sediments are disturbed and do not necessarily represent *in situ* conditions in respect to porosity, sediment structure, and, to a much lesser extent, the mineralogy and interstitial water.

Porosity, Wet-Bulk Density, and Water Content

Porosities of unconsolidated sediments from all formations at Site 13 were within 38 to 90 (?) per cent, with wet-bulk densities ranging from about 1.15 (?) to 1.93 g/cc, and water content spanning 30 to 75 per cent (Figures 3A and 4A-12A). The highest porosities and lowest densities occurred in the radiolarian oozes. These high porosities and low densities are probably the consequence of the thin porous structures of the low density opaline radiolarians. Consolidated shale and rock fragments of Formation 3-13A-7-1 had an apparent overall porosity of about 10-25 per cent and a density of 2.2-2.4 g/cc. Chert fragments in Formation 3-13A-1-1 had a maximum wet-bulk density of 1.85 g/cc and a minimum porosity of 18 per cent. Dolomitic chalk siltstone from Formation 3-13A-4-1 had a minimum porosity of 50 per cent and a maximum wet-bulk density of 1.88 g/cc. Since these chert and chalk units were not clean-cut core sections, but were surrounded in part by unconsolidated sediment, then their true porosity is less, and their true wet-bulk density is somewhat greater than those measured values.

Sediment porosities appear to irregularly decrease with depth in Holes 13 and 13A. The wet-bulk density, when plotted relative to the depth of the recovered sample, reflects changes in porosity and mineralogy, such as, the low density of opaline radiolarian oozes. The number of measurements, however, is not large enough to create a good statistical population and not all grain sizes and textures are represented. Secondly, these values are probably not completely representative of *in situ* conditions, as these cores are obviously mechanically and hydraulically disturbed.

Sediment Sound Velocity

Sediment sound velocities at Site 13 measured 1.47 to 1.69 km/sec at ambient room temperatures and one atmospheric pressure (Figures 3A and 4A-12A). Sound velocity of sea water at these same conditions is about 1.50 km/sec. These sediment sound velocities (uncorrected for temperature and pressure) appear to increase with depth, which is a rough direct correlation to the apparent sediment wet-bulk densities, and an inverse correlation to apparent sediment porosities.

Sound velocities were lowest in the upper Formations 3-13-1-1 and 3-13-2-3, which are a calcareous foraminiferal-nannoplankton ooze and a red zeolite clay, respectively. Intermediate sound velocities were measured in Formation 3-13-3-1, a radiolarian ooze, which had intermediate porosities and was also very stiff. The highest velocities were through Formations 3-13A-2-1, 3-13A-6-1 and 3-13A-7-1. These high velocities may have had part of their derivation from sediment compaction and lithification. These formations essentially consist of shales, cherts, dolomites and shaly sediments. However, because of the disturbed condition of the cores, these data probably do not accurately represent *in situ* sound velocities, even after temperature-pressure corrections.

Penetrometer

Penetrometer values are in units of 1×10^{-1} millimeters that a standard needle (1 millimeter OD) will penetrate under a fixed load of 50 grams. Penetration limits at Site 13 were from complete penetration to the core liner, to zero penetration of some cherts (Figure 3A and 4A-12A). Penetration was completely through to the liner in Formation 3-13-1-1; it averaged 180×10^{-1} millimeters in Formation 3-13-2-3; and 250×10^{-1} millimeters in Formation 3-13-3. In formations of Site 13A the penetration was usually 20 with excursions up to 111×10^{-1} millimeters. Penetrometer values, in general, decreased with depth; and, they appear to have a rough direct relation to porosity, varying inversely to density, and have a distinct inverse relationship to gamma radiation. This gamma radiation relationship may be secondary with the primary relationship being the plasticity of the clay and zeolite minerals, grain size distribution, or a combination of all of these factors.

Thermal Conductivity

Thermal conductivity values of sediments from Site 13 ranged from about 2.0 to 4.3×10^{-3} cal/°C cm sec, with the bulk of the values being in the lowest 1/3 of this range (Figures 3A and 4A-12A). In general, conductivity increased with depth in the holes, showed an inverse correlation with porosity and a direct correlation with density, although the variability of the data precluded deducing any numerical relationship.

Interstitial Water Salinity

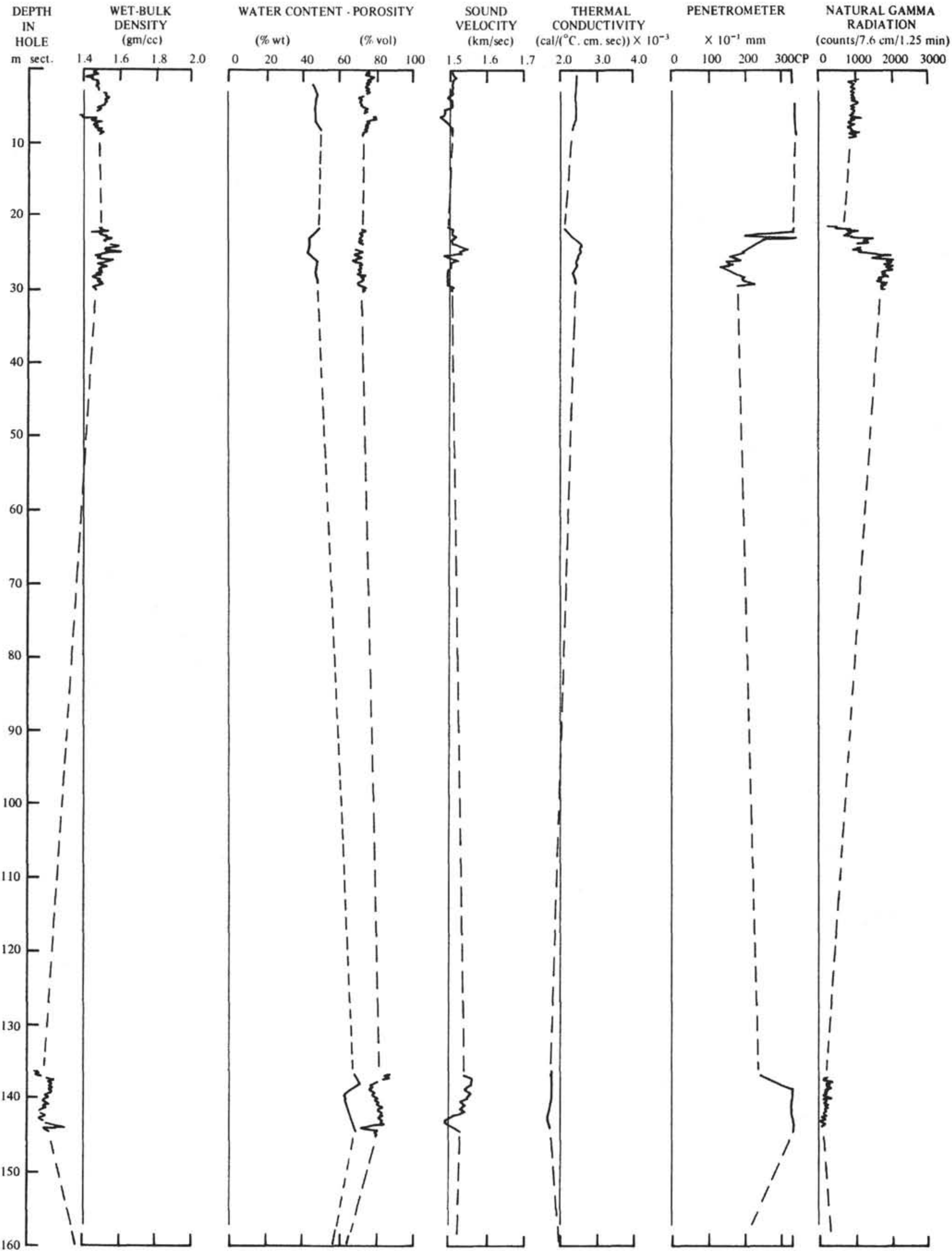
At Hole 13A, two interstitial salinity samples were measured aboard ship from cores which were retrieved from 27 meters (89 feet) and 140 meters (459 feet) within the hole. These sediments were Pliocene-Eocene and had salinities of 35.2 and 35.8 ppt, respectively, which appear to be normal salinities.

THE CORES RECOVERED FROM SITE 13

The following pages present a graphic summary of the results of drilling and coring at Site 13.

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 13. 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.

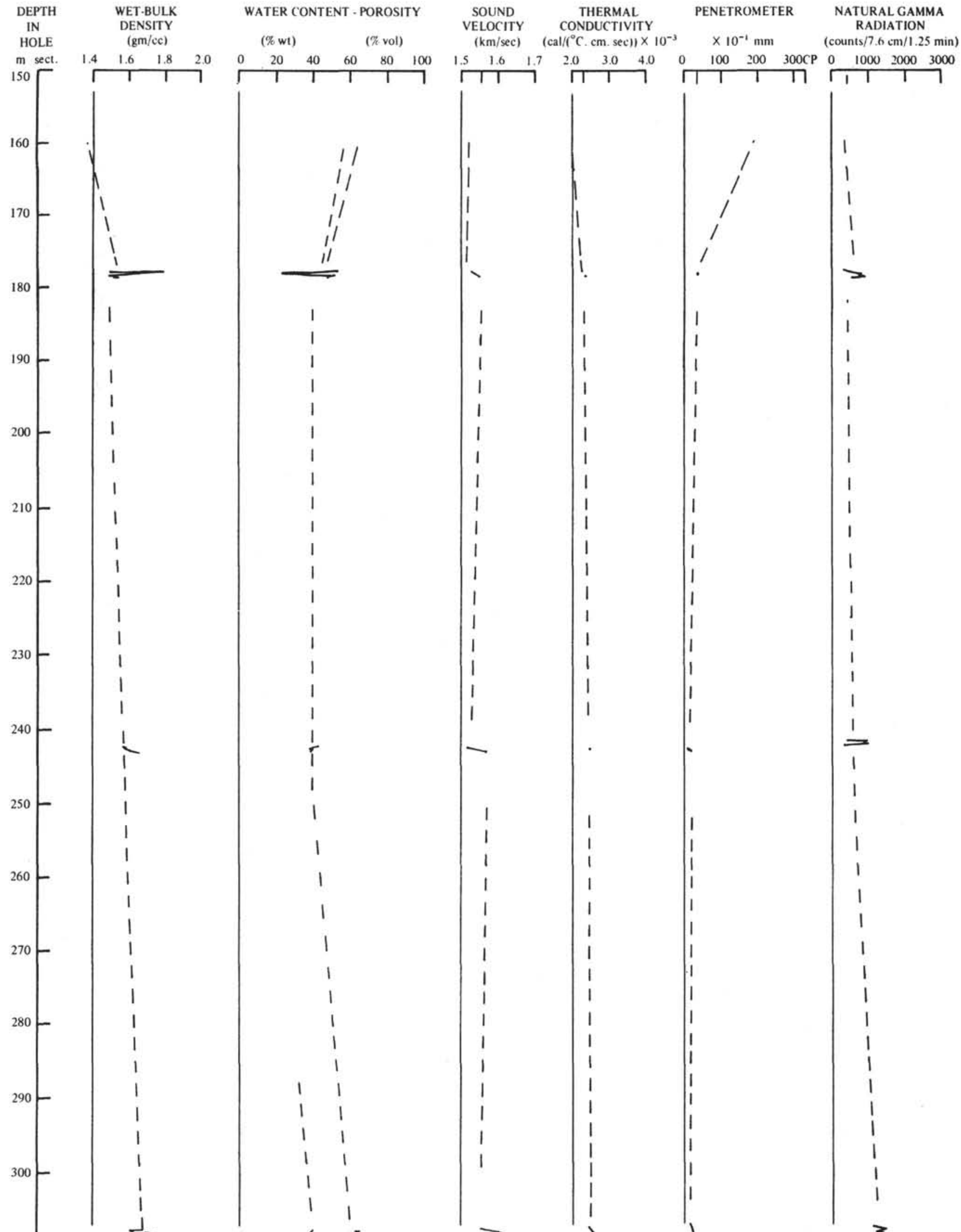


*"0" = laboratory atmospheric background count of 1550.

Figure 3A. *Summary of physical properties of the cores recovered from Holes 13 and 13A.*

DEPTH	CR.	CI.	FORMATION	LITHOLOGY	AGE
0	1		3-13/1/1 Marl Ooze	Very pale brown marl oozes of foraminifera and nannofossils, with zones of gray brown zeolitic clays and chalk oozes.	UPPER PLIOCENE Astian Piacenzian LOWER PLIOCENE Zanclian
	2		3-13/2/3 Red Clay	Yellow brown to brown zeolitic clays, with Mn dust, foraminifera molds, and dolomite rhombs.	AGE INDETERMINATE
50 100				Light brown clays with Radiolaria and nannofossils. (based on drill bit samples from 0-145 m.; actual depth unknown)	LOWER MIOCENE Aquitanian (based on center bit samples from 0-145 m.; actual depth unknown)
150	3		3-13/3/1 Radiolarian Ooze	Light greenish gray to yellowish green radiolarian oozes, with abundant diatoms and	MIDDLE EOCENE Lutetian

Figure 3B. *Summary of the cores from Holes 13 and 13A (Depth in meters below sea bed; C.R. = core removed; C.I. = cored interval.)*

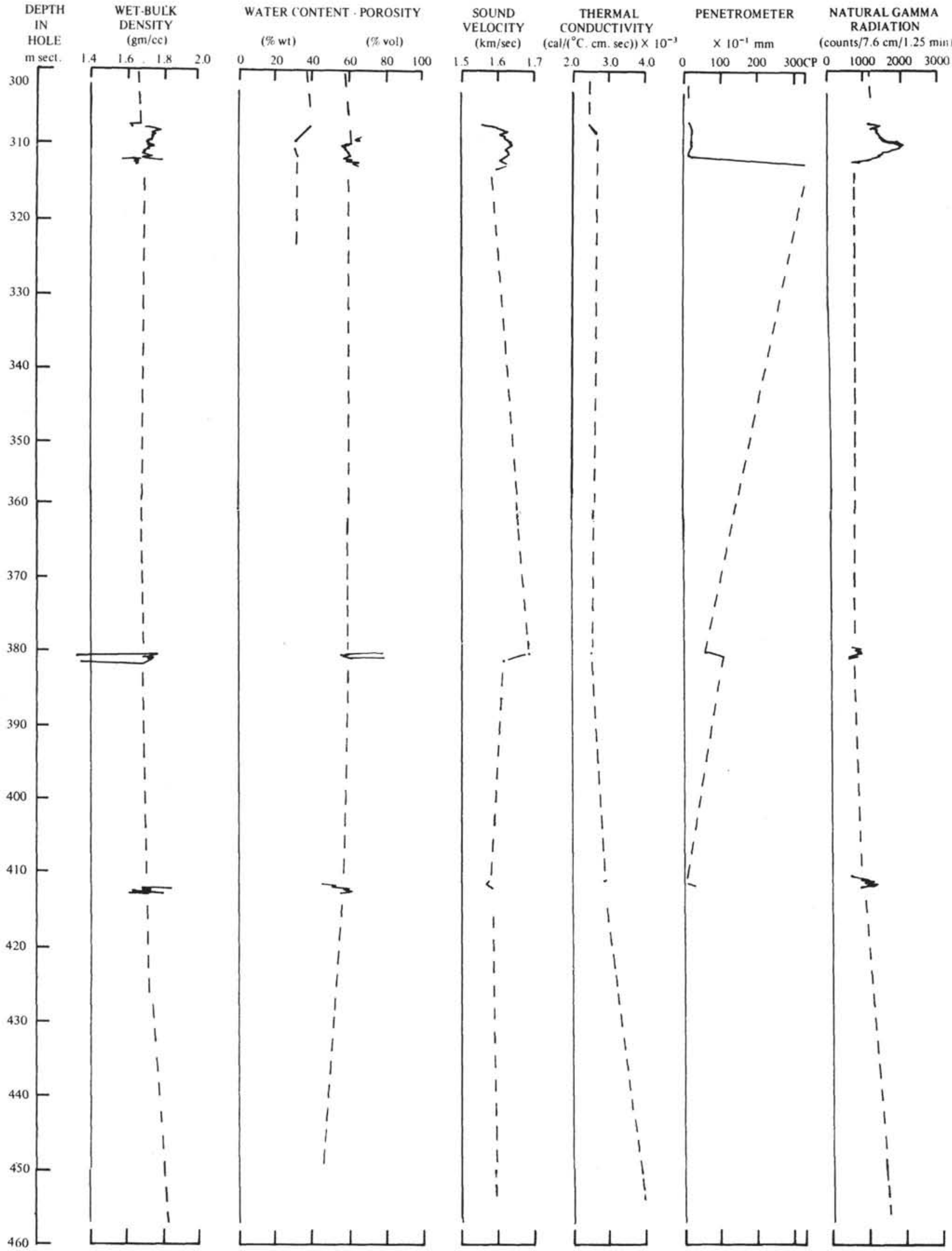


*"0" = laboratory atmospheric background count of 1550.

Figure 3A. *(Continued)*

DEPTH		Cl.	FORMATION	LITHOLOGY	AGE
1			3-13A/1/1 chert subunit	Hard chert layers, one 1.5m. thick, other thinner, intercalated in soft radiolarian oozes. Calcareous nannofossils are present.	MIDDLE EOCENE Lutetian
200				Very pale green nannofossil chalk oozes. (based on drill bit sample from 0-463.6 meters; actual depth unknown)	UPPER CRETACEOUS Maestrichtian (based on center bit sample from 0-463.6 meters; actual depth unknown)
2			3-13A/2/1 Nannofossil Clay	Very pale green to green gray, firm, nannofossil marl oozes and clays, with intercalations of green gray, partly silicified, slightly dolomitic claystones.	UPPER CRETACEOUS Campanian
250					
300					
3					

Figure 3B. *(Continued)*

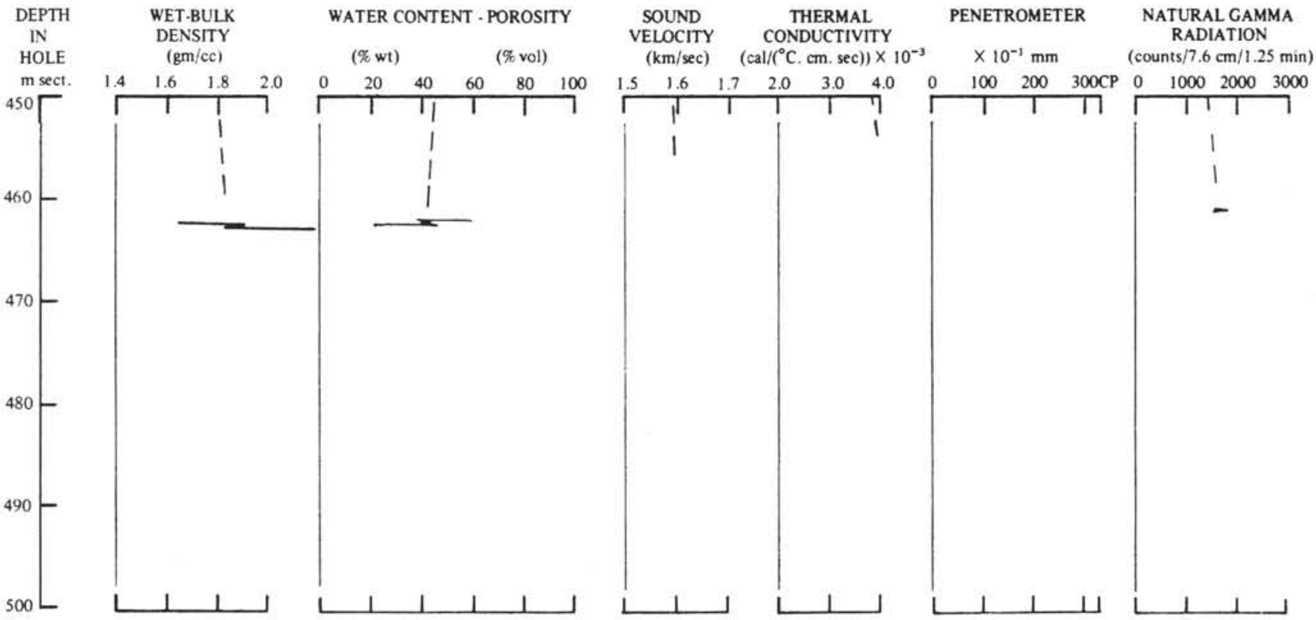


*"0" = laboratory atmospheric background count of 1550.

Figure 3A. *(Continued)*

DEPTH	CR.	CI.	FORMATION	LITHOLOGY	AGE
	3		3-13A/2/1 Nannofossil Clay	Same as above.	UPPER CRETACEOUS Campanian
350					
	4			Same as above.	UPPER CRETACEOUS Campanian
400					
	5			Same as above.	UPPER CRETACEOUS Campanian
	6		3-13A/6/1 Cherty Carbonate	Vitreous cherts, gray to dark gray laminated dolomitic cherts and limestones, and gray radiolarian oozes.	UPPER CRETACEOUS Senonian
450					

Figure 3B. *(Continued)*

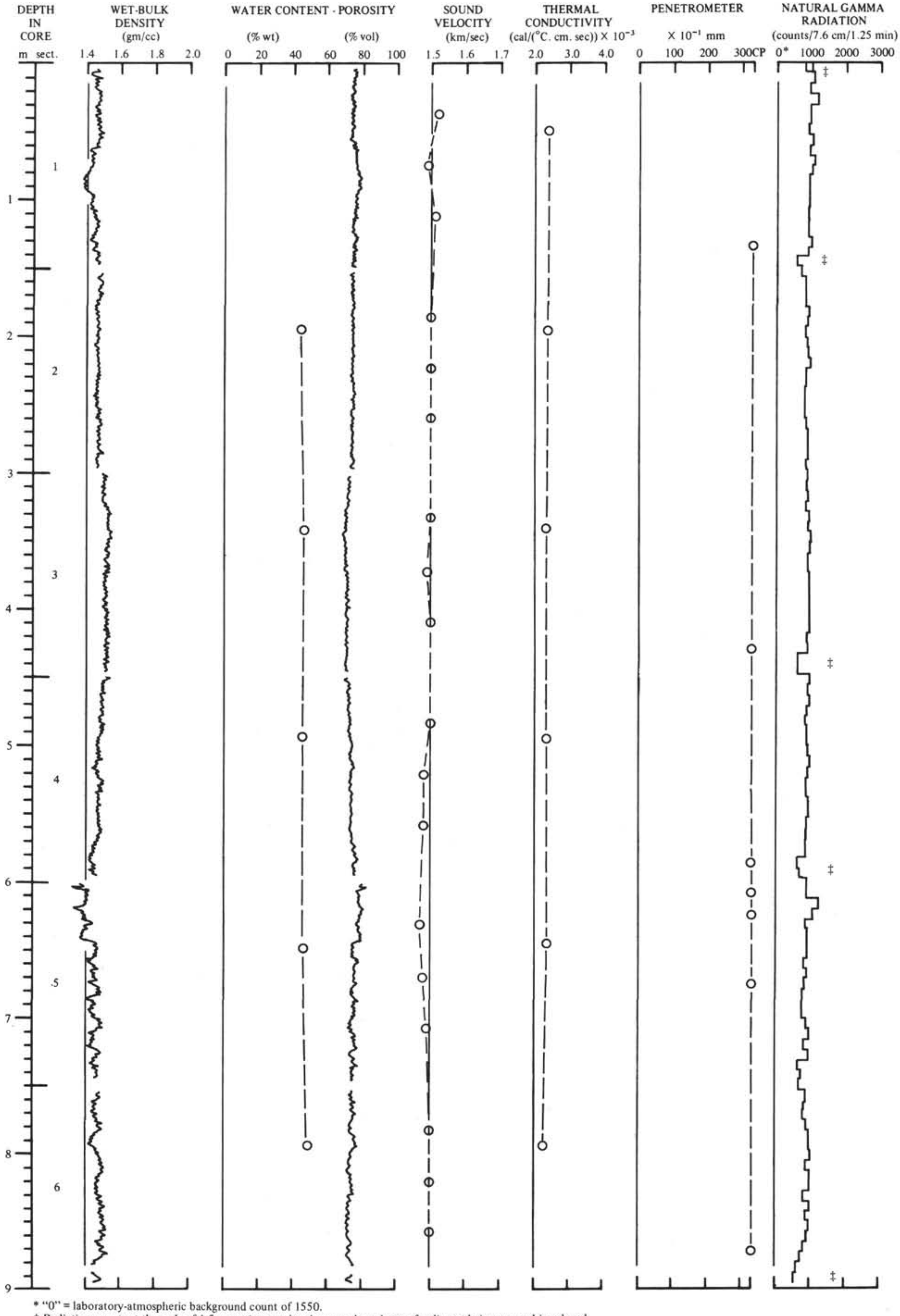


*"0" = laboratory atmospheric background count of 1550.

Figure 3A. *(Continued)*

DEPTH	CR.	CI.	FORMATION	LITHOLOGY	AGE	
450						
7			3-13A/7/1	Grayish red purple shales and hard vitreous cherts and siliceous shales - white to light purplish gray.	UPPER CRETACEOUS	Senonian?
500						

Figure 3B. *(Continued)*



* "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 1, Hole 13.*

AGE	STAGE	SECTION NO.	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
UPPER PLIOCENE	ASTIAN - PIACENZIAN	1	FN	(Core disturbed)	Planktonic foraminifera: *Globorotalia exilis, G. menardii, G. menardii miocenica, G. multicamerata, G. tosaensis, G. truncatulinoides, Pulleniatina finalis, P. obliquiloculata, Globigerina praedigitata, Globigerinoides fistulosus.* Calcareous nannoplankton: *Discoaster brouweri, D. surculus, D. pentaradiatus, Cyclococcolithus leptoporus, Ceratolithus cristatus, C. rugosus, Helicopontosphaera kamptneri.*
		2	FN	Formation 3-13/1/1	Flora and fauna similar to above.
		3	FN	Very pale brown (10YR7/4) foram-nannofossil chalk ooze with 10-20% foram. Some lighter, foraminifera rich sandy zones containing 70% forams.	Flora and fauna similar to above.
		4	FN		Flora similar to above. Fauna similar to above.* First appearance of *Pulleniatina praecursor, Globorotalia crassula* and *G. humerosa.*
		5	FN	Zeolite silty clay, olive gray (5Y5/2) and dark brown (7.5YR4/4)	Flora similar to above. Fauna similar to above. First appearance of *Globorotalia pseudopima.*
		6	FN	Very pale brown foram-nannofossil chalk ooze with streaks of gray (10YR4/1) to grayish brown (10YR4/2) and dark brown (75YR4/4) foram-nannofossil ooze.	Flora and fauna similar to above. Core catcher: Flora and fauna similar to above.

DEPTH (METERS): 1, 2, 3, 4, 5, 6, 7, 8

* These samples contain Pleistocene. planktonic foraminifera contaminants from uphole.

Figure 4B. *Core 1, Hole 13.*

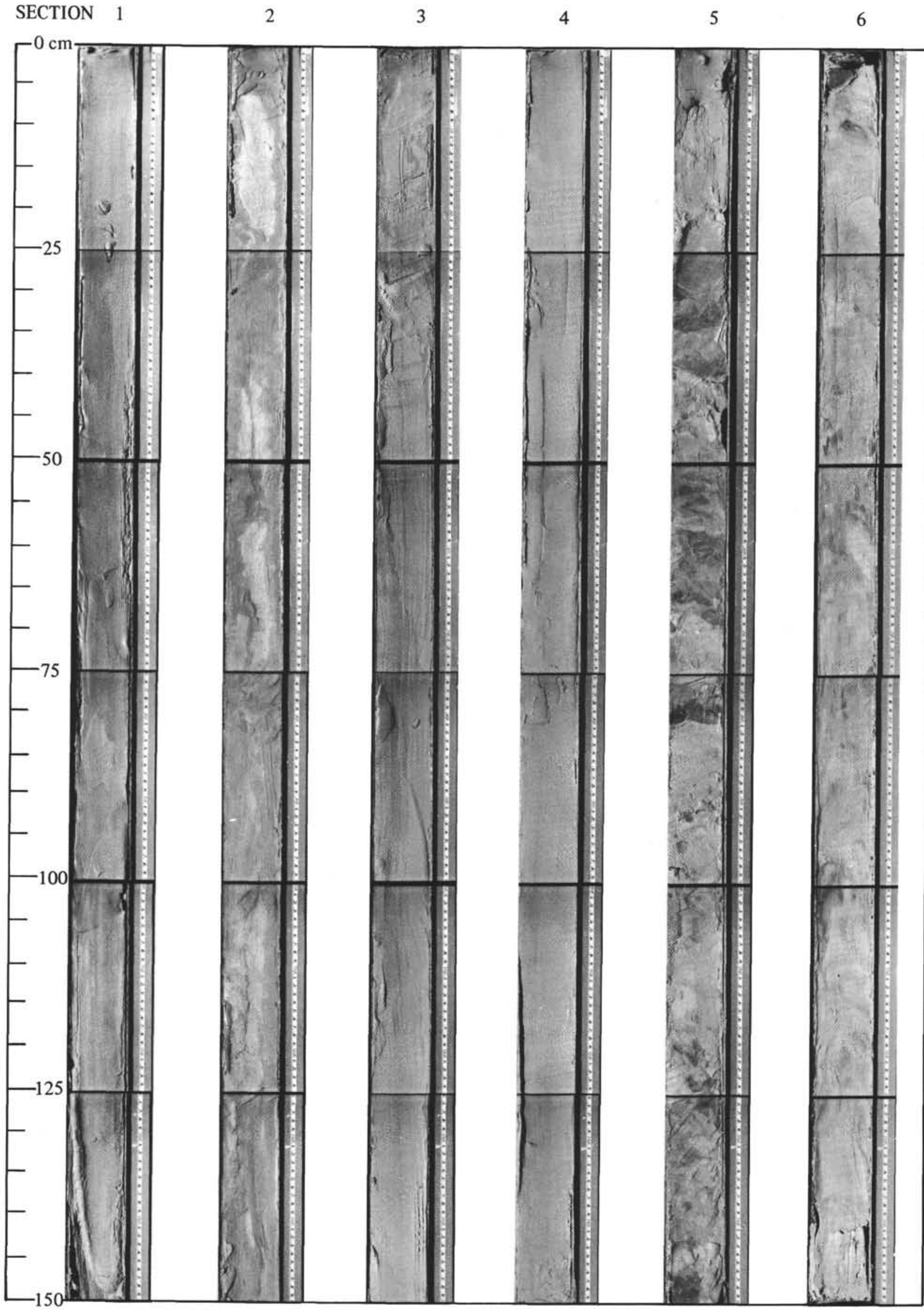


Plate 1. *Core 1, Hole 13.*

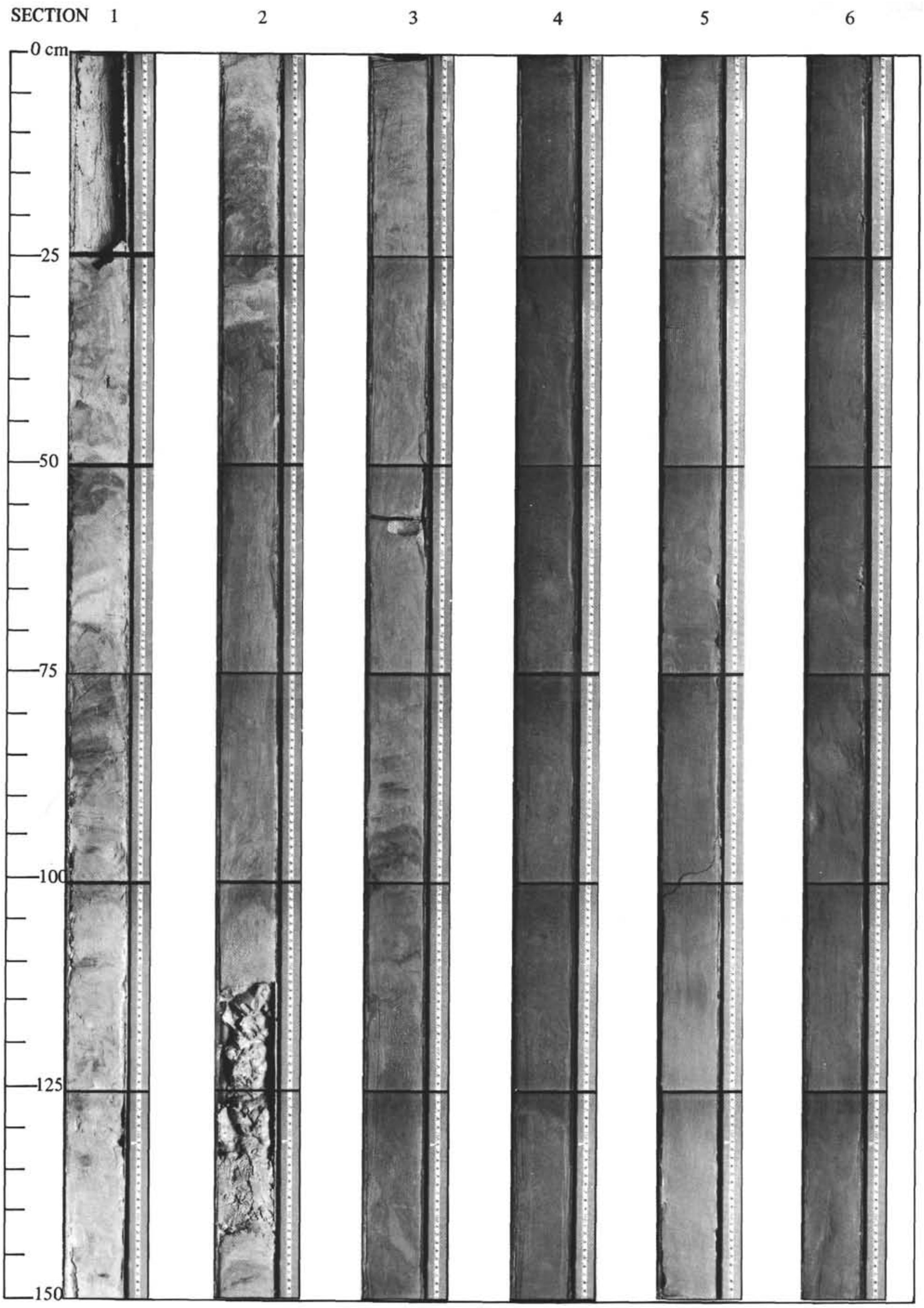
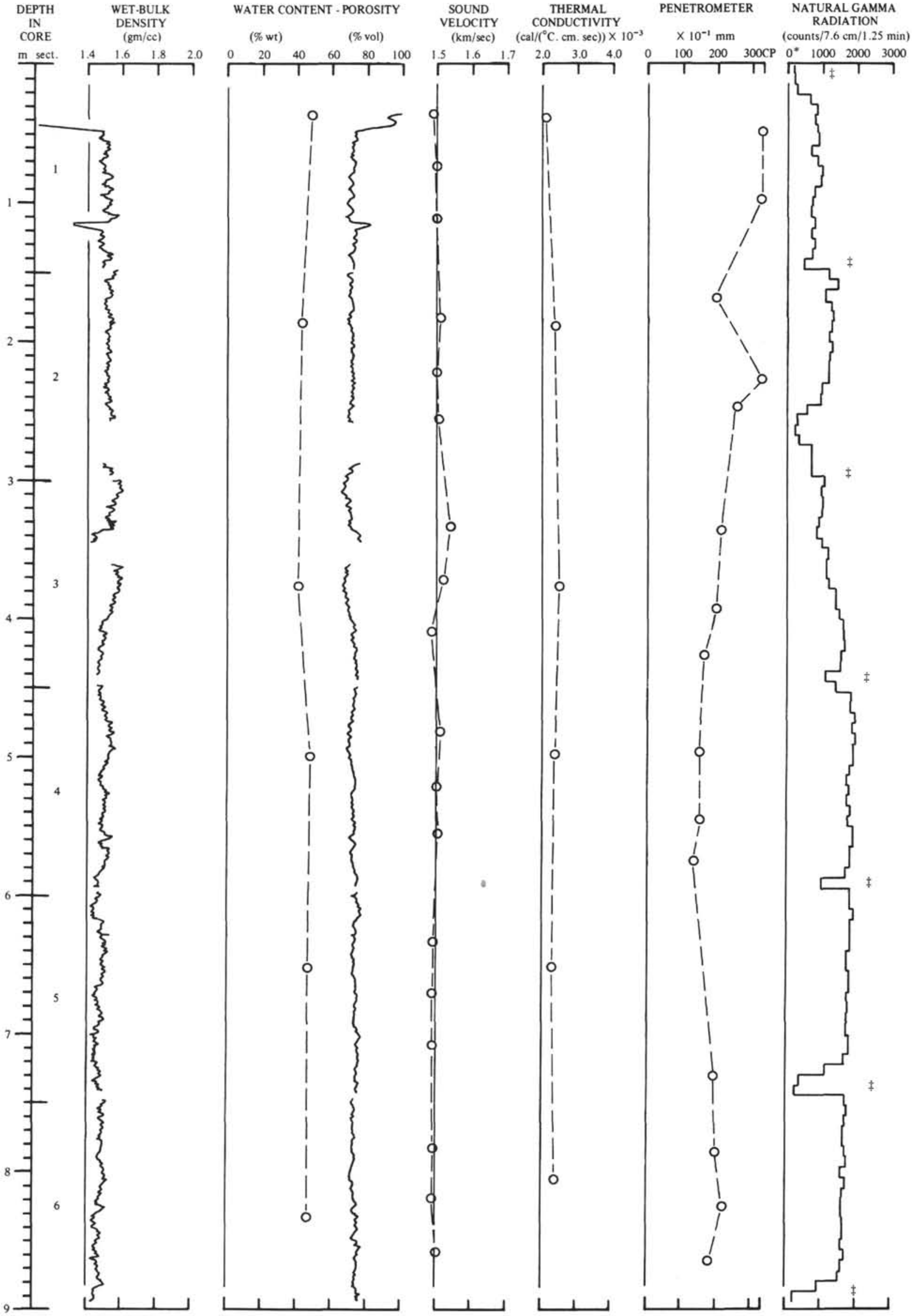


Plate 2. *Core 2, Hole 13.*



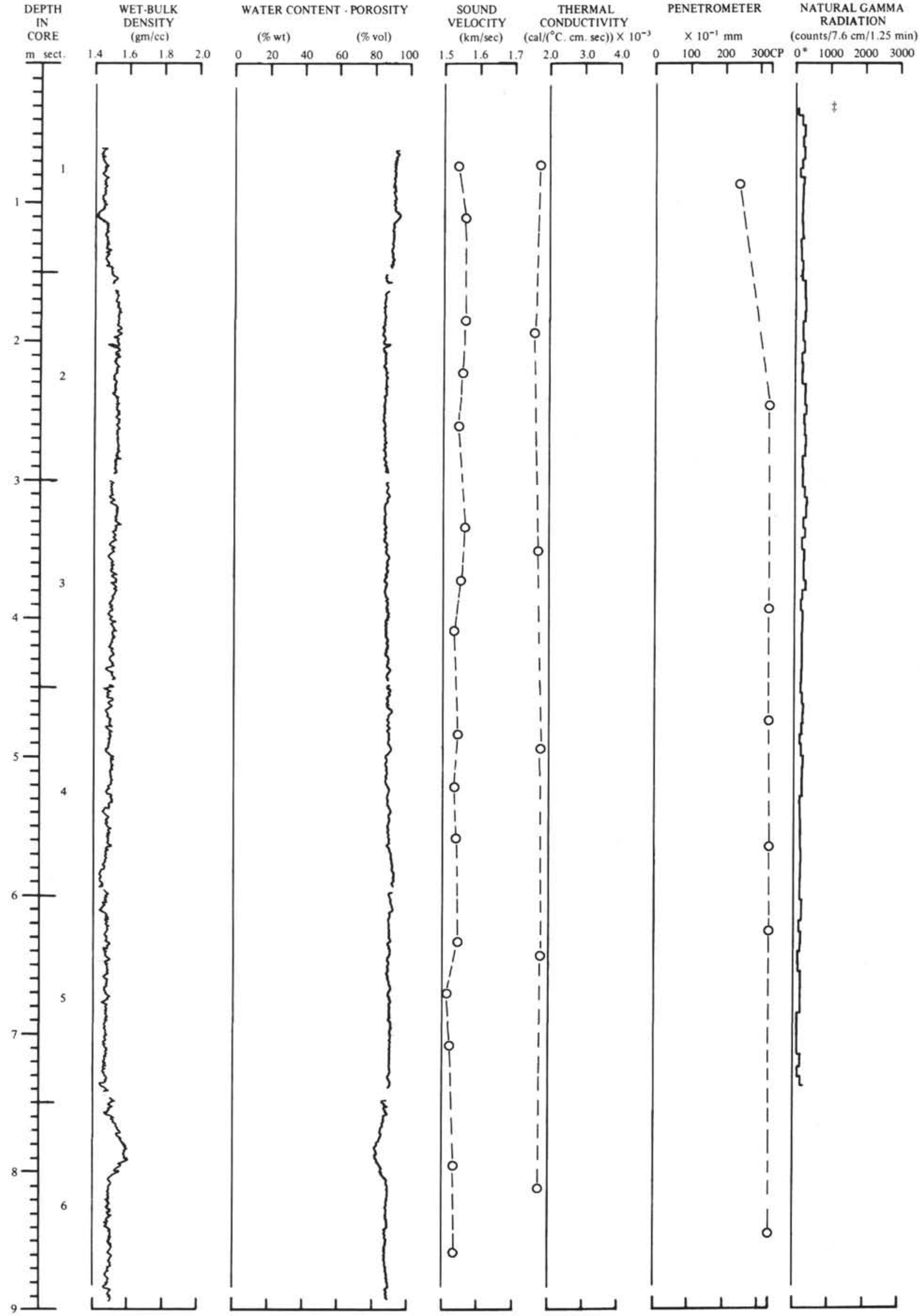
* "0" = laboratory-atmospheric background count of 1550.
‡ Radiation counts at the ends of 1.5 m sections are low because the volume of sediment being scanned is reduced.

Figure 5A. *Physical properties of Core 2, Hole 13.*

AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LOWER PLIOCENE	ZANCLIAN	1	1	EMPTY	FN	Core disturbed	Planktonic foraminifera: *Globorotalia acostaensis, G. humerosa, G. margaritae, G. multicamerata, G. tosaensis, G. exilis, Globoquadrina altispira, Sphaeroidinellopsis seminulina, Globigerinoides obliquus.* Calcareous nannoplankton: *Discoaster brouweri, D. challengeri, D. pentaradiatus, D. surculus, Cyclococcolithus leptoporus, Helicopontosphaera kamptneri, Ceratolithus rugosus.*
		2	2		FN, FN	Formation 3-13/1/1 Very pale brown (10YR7/4) to dark yellow brown (10YR7/4) foram-nannofossil ooze, to dark yellow brown (10YR4/4), 5-10% forams, with intercalcations of foram rich ooze, very pale brown (10YR8/4), of pure nannofossil ooze, and of zealite silty clays, all artifically disturbed.	Flora similar to above. Fauna similar to above with *Globigerinoides fistulosus, Globorotalia ciboaensis** Sample 99-101 cm: Flora similar to above. First appearance *Reticulofenestra pseudoumbilica.*
		3, 4	3		FN	Formation 3-13/2/3 Yellow brown to brown (10YR5.5/4 to 7.5YR5/4) zeolite silty clay with foram molds, Mn dust, and dolomite rhombs.	Flora and fauna similar to above. Planktonic foraminifera: *Globorotalia tumida* (R)
AGE INDETERMINATE		5, 6	4		FN, FN		Barren of planktonic microfossils
		7	5		FN, FN		Barren of planktonic microfossils
		8	6		FN, FN		Barren of planktonic microfossils Sample 10-12: Fish teeth Core catcher: Barren of planktonic microfossils.

* These samples contain Pleistocene planktonic foraminifera contaminants from uphole.

Figure 5B. *Core 2, Hole 13.*



* "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 6A. *Physical properties of Core 3, Hole 13.*

AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
MIDDLE EOCENE	LUTETIAN	1	1	EMPTY	R R R		Sample 0-2 cm: Radiolaria: Mixed fauna Sample 63-65 cm: Radiolaria: *Podocyrtis triacantha, Eusyringium fistuligerum, Sethamphora mongolfieri, Lithocyclia ocellus, Dictyophimus babylonis, Anthocyrtium hispidum, Podocyrtis papalis, Phormocyrtis embolum*
		2	2		R		Fauna similar to above.*
		3, 4	3		R R	Formation 3-13/3/1 Light greenish gray (5GY7/1) to grayish green (5GY75/2) radiolarian ooze with abundant diatoms.	Fauna similar to above.*
		5	4		R		Fauna similar to above.*
		6, 7	5		R R		Fauna similar to above.*
		8	6		R R		Fauna similar to above.* Core catcher: Fauna similar to above.*

* No calcareous microfossils.

Figure 6B. *Core 3, Hole 13.*

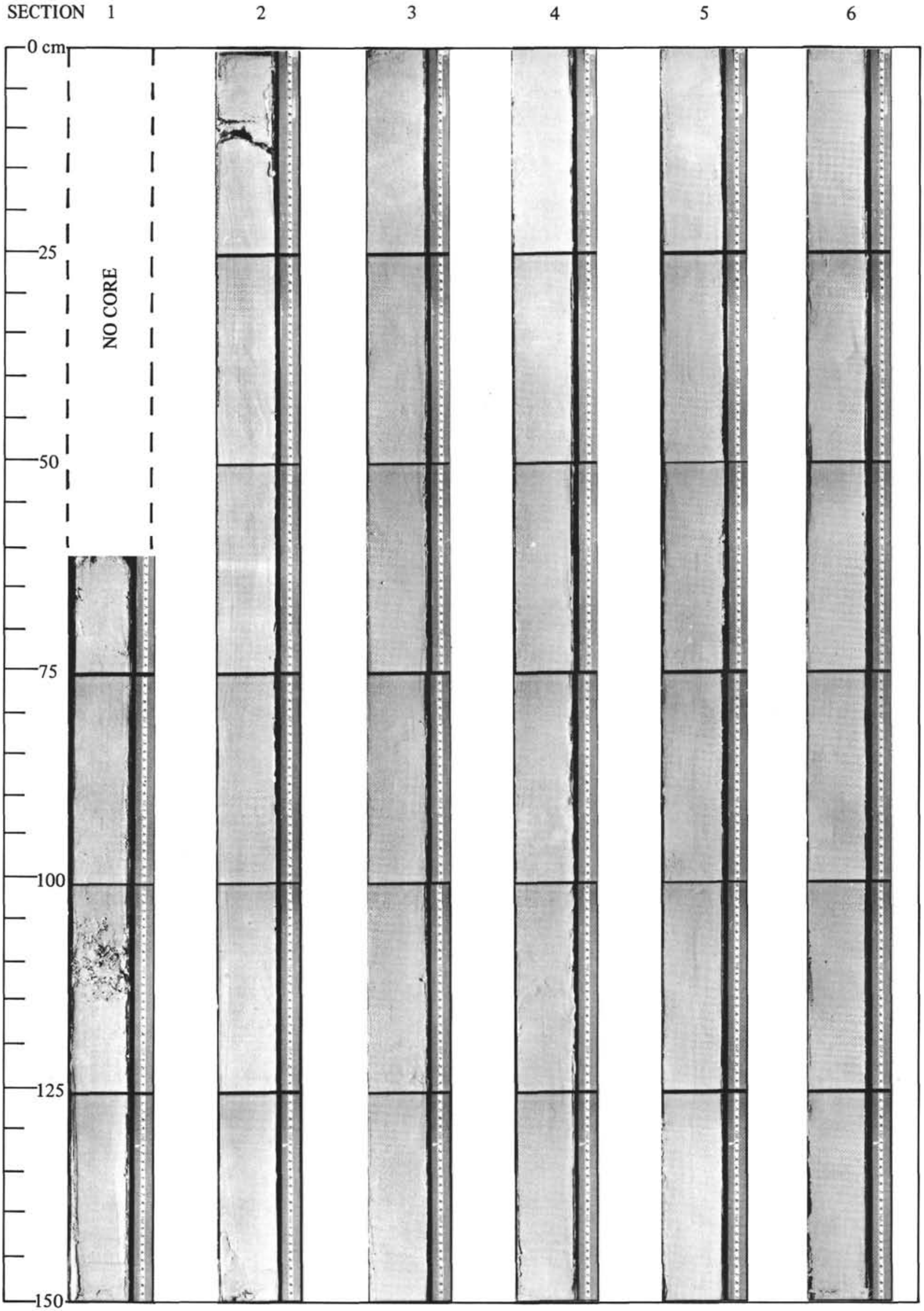


Plate 3. *Core 3, Hole 13.*

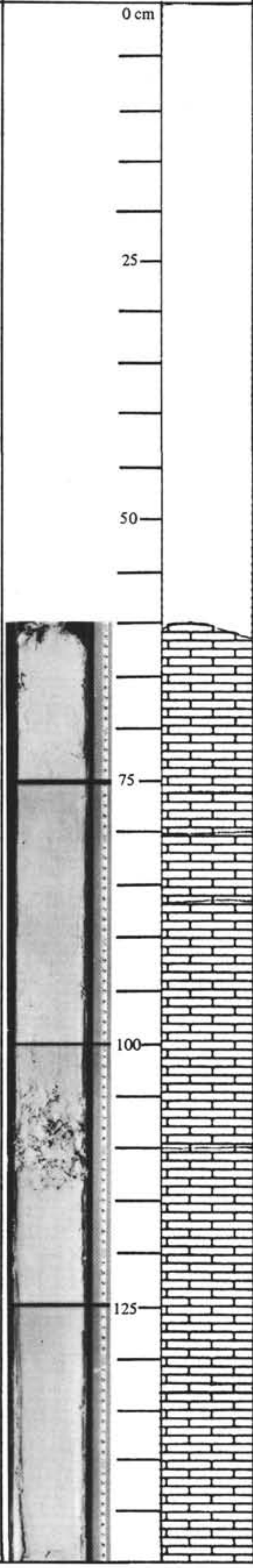
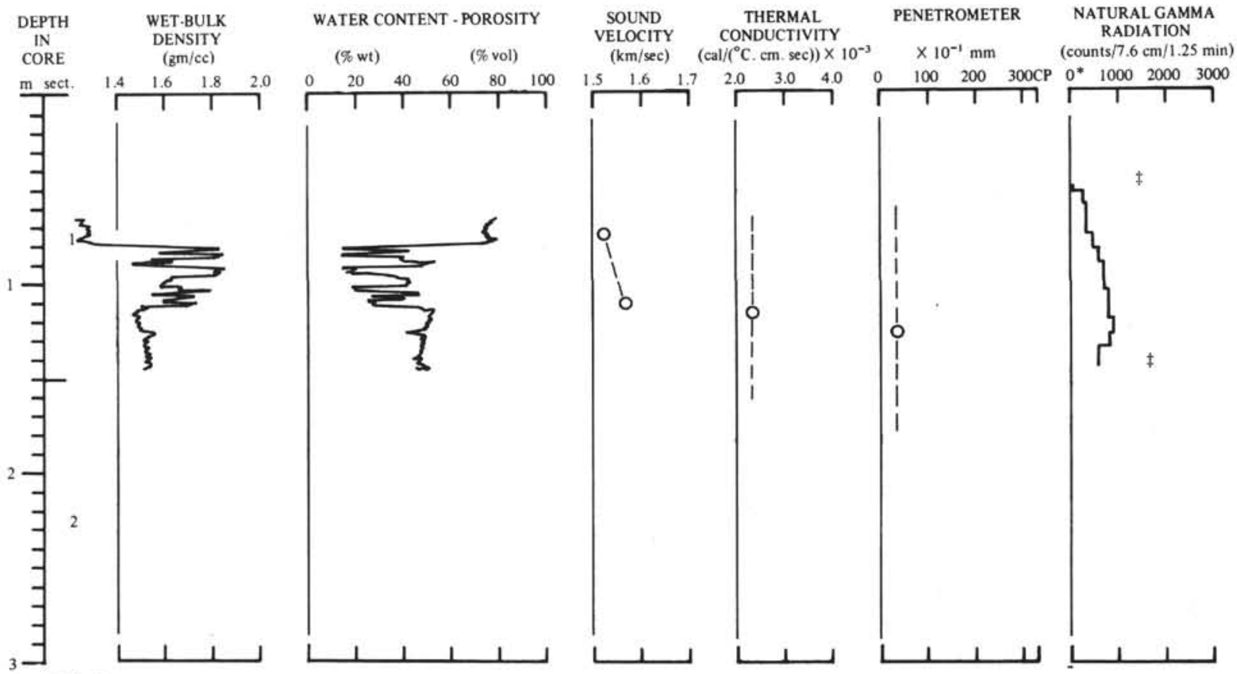
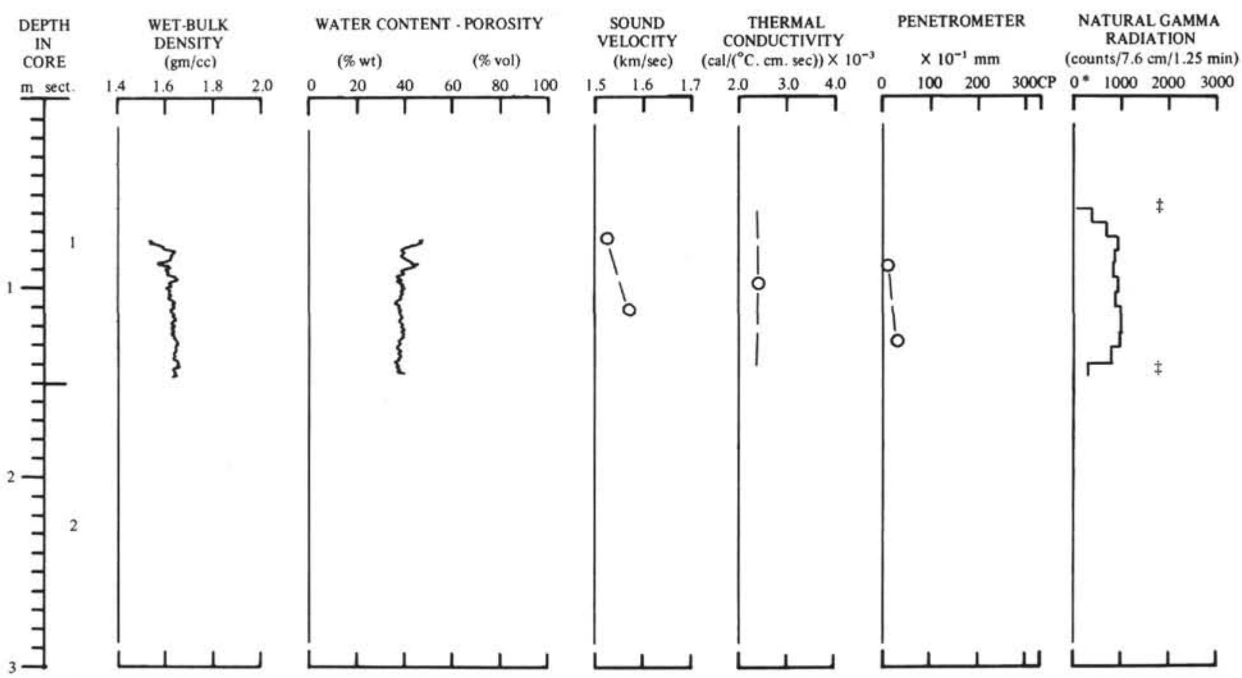
AGE (STAGE)	ZONE	LITHOLOGY		LITHOLOGY	DIAGNOSTIC FOSSILS
MIDDLE EOCENE	LUTETIAN			Unit-3-13/3/1 0-60 cm. empty 60-76 Greenish yellow gray (5GY5/2) silty sand with radiolaria and radiolarian clay chips. 76-80 Sharp contact. Radiolarian silty clay. Greenish gray and bluish white (5GY7/1-N8). 80-87 Yellow gray (5GY5/2) Radiolarian sandy silt and chert fragments. 87-110 Greenish gray Radiolarian (5GY7/1) sandy silt with chert. 110-150 Greenish gray (5GY7/1) Radiolarian silty clay with chert fragments.	Sample 60-62 cm: Radiolaria: Mixed fauna Sample 123-125 cm: Radiolaria: *Podocyrtis triacantha,* *Eusyringium fistuligerum,* *Sethamphora mongolfieri,* *Lithocyclia ocellus,* *Dictyophimus babylonis,* *Anthocyrtium hispidum,* *Podocyrtis papalis,* *Phormocyrtis embolum.*

Figure 7. *Summary of Section 1, Core 3, Hole 13.*



* "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 properties of Core 1, Hole 13A.*



* "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.

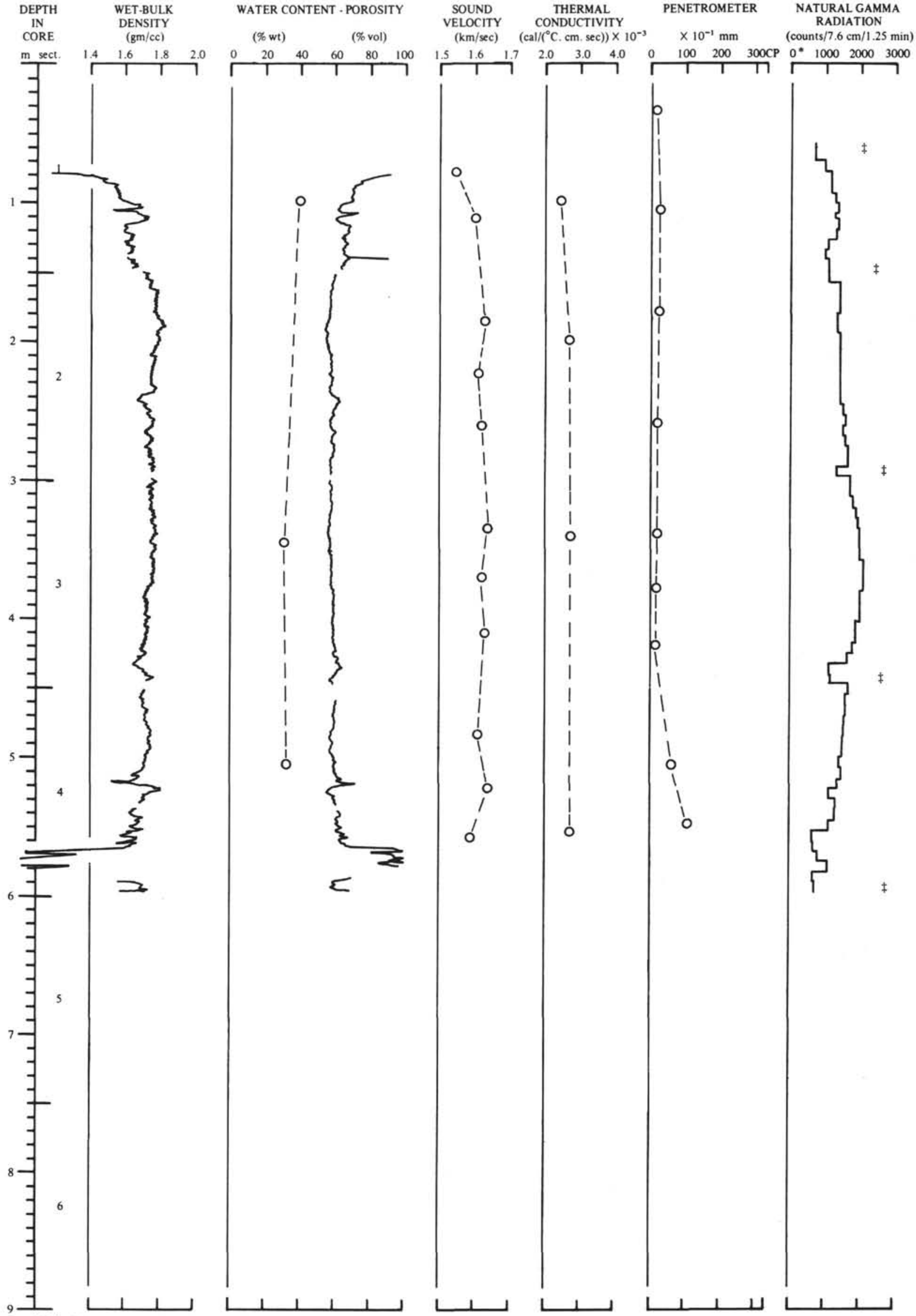
Figure 9A. *Physical properties of Core 2, Hole 13A.*

AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
See Section Summary		1	1	EMPTY		Formation 3-13/3/1 Light greenish gray (5GY7/1) to grayish yellow green (5GY5/2) radiolarian ooze with abundant diatons. Chert fragments. 80-110 cm chert fragments intermixed.	See Section Summary
		2 3	2				

Figure 8B. *Core 1, Hole 13A.*

AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
See Section Summary		1	1	EMPTY		Formation 3-13A/2/1 Very pale green (5G7/2) to pale yellow green (10GY7/2) nannofossil clay with fragments of green, gray, partially lithifild nannofossil clays, partly dolomitic, partly silicified.	See Section Summary
		2 3	2				

Figure 9B. *Core 2, Hole 13A.*



* "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 3, Hole 13A.*

AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
UPPER CRETACEOUS	CAMPANIAN	0–1	1	EMPTY	FN, R, R		Benthonic foraminifera: *Haplophragmoides* spp, *Ammodiscus cretaceous*, *Glomospira coronatus*, *Pulvinulinella florealis*, *Pullenia minuta*. Calcareous nannoplankton: *Tetralithus nitidus nitidus*, *T. nitidus trifidus*, *Micula decussata*, *Zygodiscus lacunatus*, *Cyclolithus gronosus*, *Lithastrinus floralis*. Radiolaria: *Dictyomitra multicostata* and vars., *Amphipyndax* spp., *Pseudoaulophacus* spp.
		2	2		R, FN, R	Formation 3-13A/2/1 Gray green (10GY5/2) nannofossil clay. Pale grayish green (5G6/2).	Flora and faunas similar to above.
		3–4	3		FN, R, R		Flora and faunas similar to above.
		5–6	4		R, FN, R	Mudstone chips, gray green.	Flora and faunas similar to above. Core catcher: Flora and faunas similar to above.
		7	5	EMPTY			
		8	6				

Figure 10B. *Core 3, Hole 13A.*

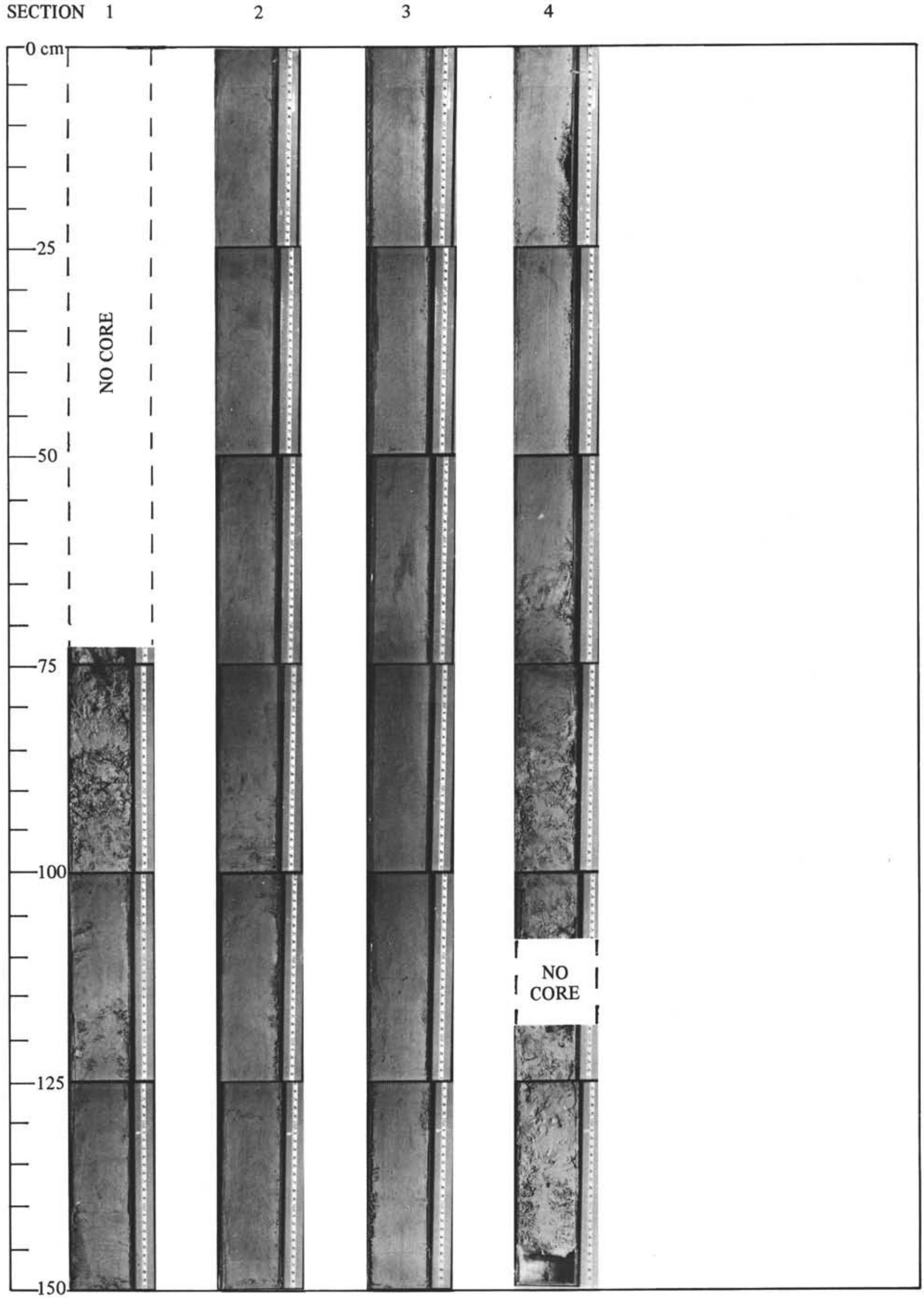
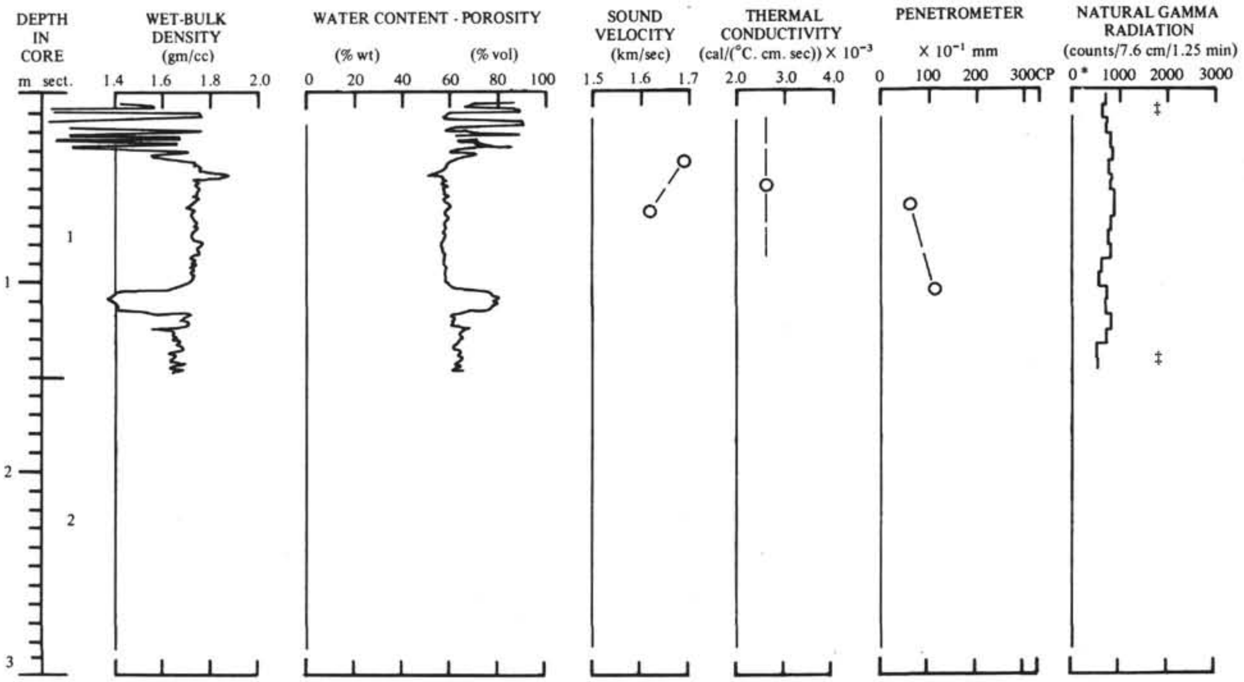
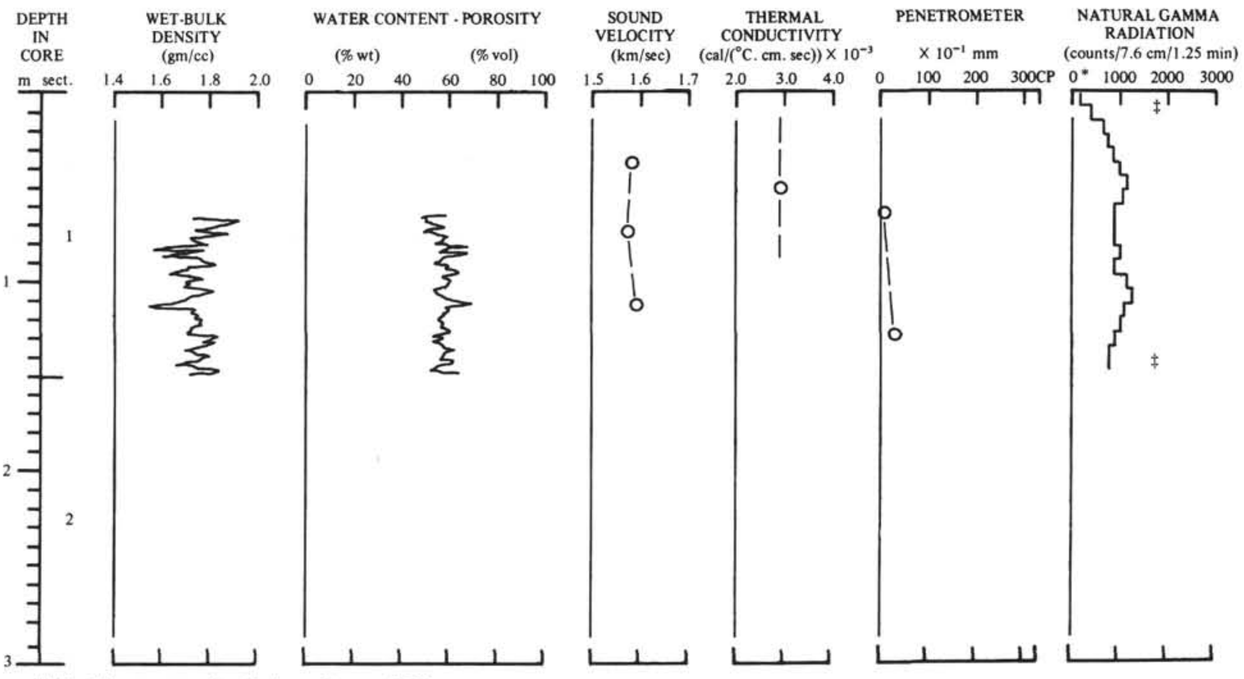


Plate 4. *Core 3, Hole 13A.*



* "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 11A. *Physical Properties of Core 4, Hole 13A.*



* "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 5, Hole 13A.*

AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
		1	1			Formation 3-13A/2/1 0-32 cm dolomitic nannofossil clay gray green (10GY5/2) hard, lithified, with dark gray streaks. 32-150 cm: Fragments of lithified, Dolomitic nannofossil clay, in soft ooze, (fragments 0.1-4 cm).	
		2 3	2				

Figure 11B. *Core 4, Hole 13A.*

AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
		1	1			Formation 3-13A/2/1 See Section Summary Fragments Dark greenish gray (5G 3/1) to grayish green (10GY5/2) Fragments dolomitic lithified nannofossil clay with fragments of ooze of same lithology.	
		2 3	2				

Figure 12B. *Core 5, Hole 13A.*

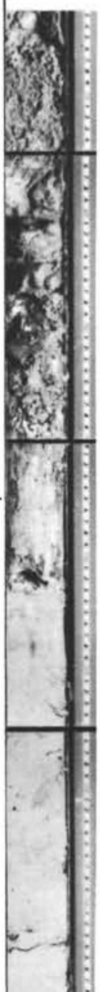
AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
		1	1			Formation 13A/6/1 Very light gray (N8) to dark gray (N3) chert (vitreous) and dolomitic chert and dolomite (predominates); only c.c. sample.	
		2					

Figure 13. *Core 7, Hole 13A.*

AGE	STAGE	DEPTH (METERS)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
		1	1	EMPTY		Formation 3-13A/7/1 Grayish red purple (5RP4/2) shale and shale fragments with white to light purplish gray chert and mudstone chips.	See Section Summary
		2					

Figure 14. *Core 7, Hole 13A.*

AGE (STAGE)	ZONE	LITHOLOGY	SAMP. INT.	LITHOLOGY	DIAGNOSTIC FOSSILS
MIDDLE EOCENE LUTETIAN	*Chiphragmalithus quadratus*; *Discoaster sublodoensis*	0 cm, 25, 50, 75, 100, 125	>RN, >R, >R, >R, >R, >N	Formation 3-13/3/1	



Formation 3-13/3/1

Light greenish gray to grayish yellow green (5GY7/1 to 5GY5/2) radiolarian ooze with abundant diatoms.

Chert fragments.

DIAGNOSTIC FOSSILS

Sample 64-66 cm:*

Calcareous nannoplankton:
Discoaster barbadiensis, D. saipanensis, Campylosphaera dela, Coccolithus eopelagicus, Cyclococcolithus lusitanicus.

Radiolaria:
Mixed fauna.

Sample 77-79 cm:

Radiolaria:
Podocyrtis triacantha, Eusyringium cf. *fistuligerum.*

Sample 90-92 cm:
Fauna similar to above.

Sample 109-111.

Radiolaria:
Podocrytis papalis, Phormocrytis embolum, Sethamphora mongolfieri, Dictyophimus babylonis, Sethocapsa lagena, Lithocyclia ocellus, Spongatractus pachystylus (Rare).

Sample 126-128 cm:
Fauna similar to above.

Sample 140-142 cm:*

Calcareous nannoplankton:
Discoaster barbadiensis, D. saipanensis, D. sublodoensis, Camplyosphaera dela, Coccolithus eopelagicus, Cyclococcolithus lusitanicus, Chiphragmalithus quadratus.

Core catcher:*
Flora and fauna similar to above.

* These samples are barren of planktonic foraminifera.

Figure 15. *Summary of section 1, Core 1, Hole 13A.*

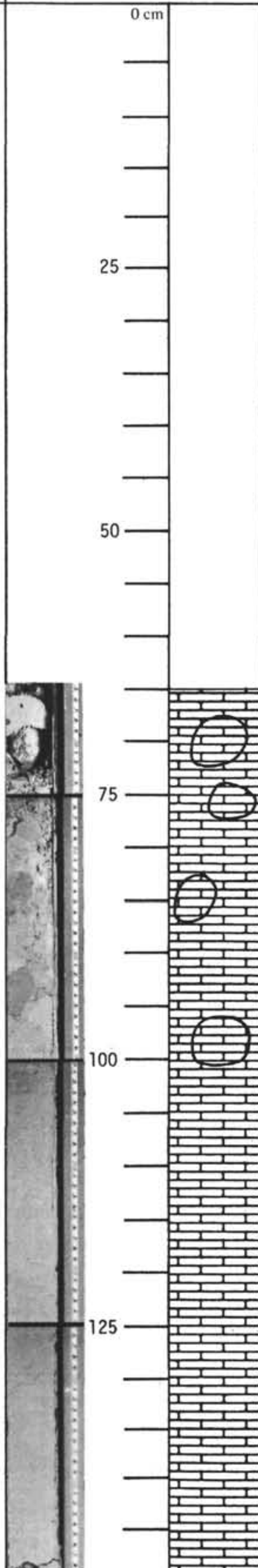
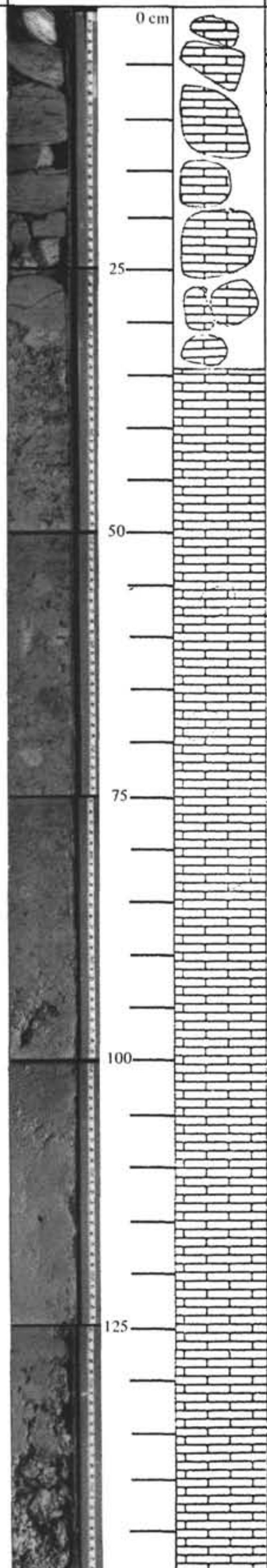
AGE	STAGE	LITHOLOGY	SAMP. INT.	LITHOLOGY	DIAGNOSTIC FOSSILS
UPPER CRETACEOUS	CAMPANIAN		N FN R N RN FN	Unit 3-13A2/1 Very pale green to pale yellow green (5G7/2-10GY7/2), nannofossil ooze with fragments of green gray partially lithified nannofossil clays, partly dolomitic, partly silicified (mainly 65-100cm.)	Sample 65-66 cm: Calcareous nannoplankton: *Tetralithus nitidus nitidus, T. nitidus trifidus, Zygodiseus lacunatus, Miculodecussata, Lithraphidites carneolensis, Cribrosphaerella ehrenbergi.* Sample 68-70 cm: Planktonic foraminifera:* *Rugotruncana subcircumnodifer, R. subpennyi, Praeglobotruncana havanensis, P. petaloidea, Globotruncana rosetta, G. gagnebini, Heterohilix pulchra.* Calcareous nannoplankton: *Arkhangelskiella cymbiformis Microrhabdolus stradneri, M. decoratus, Micula decussala, Lithraphadites carneolensis.* Sample 83-85 cm: Radiolaria: *Distyomitra multicostata* and vars., *D.* cf. *andersoni, Amphipyndax* spp. Sample 94-96 cm: Calcareous nannoplankton: *Tetralithus nitidus, T. nitidus trifidus, Zygodiscus lacunatus, Micula decussata, Lithraphidites carneolensis.* Sample 116-118 cm: Flora and fauna similar to above. Sample 129-1313cm: Planktonic foraminifera: *Schackoina multispinata, Praeglobotruncana petaloides.* Core catcher: Flora similar to above. Radiolaria: Fauna similar to above. * Lower Maestrichtian fauna and flora. For interpretation see Chapter 3, Paleontology section.

Figure 16. *Summary of Section 1, Core 2, Hole 13A.*

AGE	STAGE	LITHOLOGY	SAMP. INT.	LITHOLOGY	DIAGNOSTIC FOSSILS
UPPER CRETACEOUS	CAMPANIAN				

Unit 3-13A2/1

0-32 cm.
Gray green (10GY5/2) lithified, dolomitic, nannofossil clay, with dark gray streaks.

32-150 cm.
Fragments lithified dolomitic nannofossil clay in soft nannofossil ooze.

Sample 4-5 cm:
Calcareous nannoplankton:
Micula decussata,
Cyclolithus gronosus,
Zygodiscus lacunata
Broinsonia parca,
Eiffellithus turriseiffeli.

Sample 6-7 cm:
Planktonic foraminifera:
Globigerinelloides asperus,
G. volutus,
Heterohelix reussi, *G. striatus*,
Rugoglobigerina tradinghausensis.

Sample 58-60 cm:
Radiolaria:
Dictyomitra multicostata,
Amphipyndax spp.

Sample 74-76 cm:
Fauna similar to above.

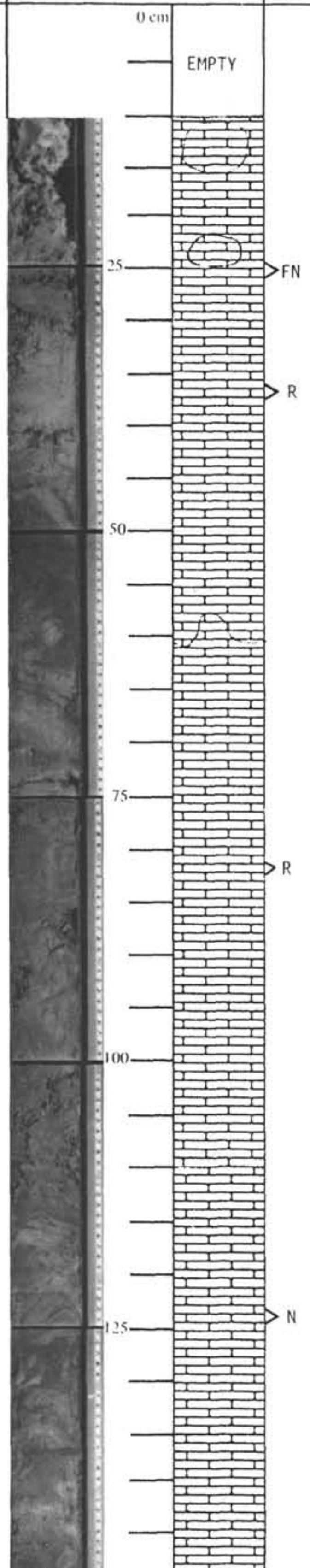
Sample 100-101 cm:
Flora similar to above.

Sample 148-150 cm:
Flora similar to above.
Planktonic foraminifera:
Globigerinelloides asperus. *G. subcolinatus*, *Heterohilix pulchra*.

Core catcher:
Radiolaria
Fauna similar to above.

Figure 17. *Summary of Section 1, Core 4, Hole 13A.*

AGE	STAGE	LITHOLOGY	SAMP. INT.	LITHOLOGY	DIAGNOSTIC FOSSILS
UPPER CRETACEOUS	CAMPANIAN				



Unit 13A/2/1

10-47 cm (10GY5/2)
Grayish green nannofossil chalk ooze with chalk fragments.

47-62 cm.
Dark greenish gray (5G3/1), dolomitic, nannofossil chalk ooze.

62-111 cm.
Gray green (10GY5/2), nannofossil chalk ooze with dark dolomitic mottling.

111-150 cm.
Dark greenish gray (5G3/1) dolomitic nannofossil chalk ooze with gray green (10GY5/2), disturbed laminations.

Sample 25-27 cm:
Benthonic foraminifera:
Eponides haidingerii, E. spinea, Globorotalites micheliniana, Homosina sp., *Rzehakina* sp.
Calcareous nannoplankton:
Micula decussata, Cyclolithus gronosus, Zygodiscus lacunatus, Eiffellithus turriseiffeli.

Sample 36-38 cm:
Radiolaria:
Dictyomitra multicosta and vars., *Amphipyndax* spp.

Sample 81-83 cm:
Fauna similar to above.

Sample 122-124 cm:
Flora similar to above.

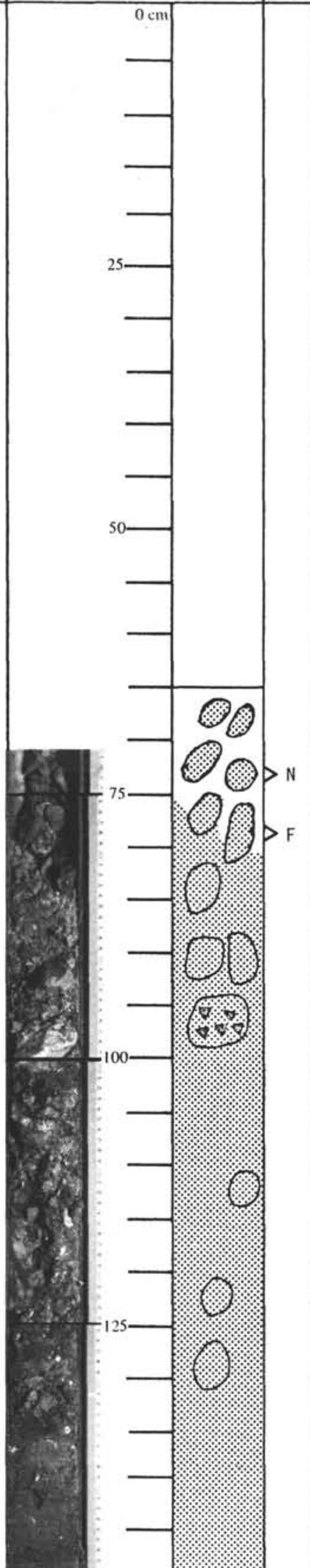
Core catcher:
Flora similar to above.
Benthonic foraminifera:
Fauna similar to above with *Ramulina aculeata, Neoflabellina aculeata.*

Figure 18. *Summary of Section 1, Core 5, Hole 13A.*

AGE	STAGE	LITHOLOGY	SAMP. INT.	LITHOLOGY	DIAGNOSTIC FOSSILS
UPPER CRETACEOUS	SENONIAN	0 cm  25 50 75 100 125		Light gray to dark gray (N8-N3) chert, dolomitic chert, and dolomitic chalk in gray ooze matrix.	Core catcher: Benthonic foraminifera: *Bathysiphon* sp., *Haplophragmoides* spp., *Rhabdammina* sp., *Rzehakina* sp., *Trochammina globigeriniformis*. Calcareous nannoplankton: *Micula decussata* (very rare), *Watznaueria barnesae*. Radiolaria: *Dictyomitra multicostata* and vars., *Amphipyndax*.

Figure 19. *Summary of Section 1, Core 6, Hole 13A.*

AGE	STAGE	LITHOLOGY	SAMP. INT.	LITHOLOGY	DIAGNOSTIC FOSSILS
UPPER CRETACEOUS	SENONIAN?				



0-72 cm. empty

Unit 3-13A/7/1

Broken fragments of (5RP4/2) grayish red shale (5RP4/2), in a matrix of shelly purple clay with fragments of white-light purplish chert and mudstone, tan flints, gray dolomitic shale fragments and gray green nannofossil chalks. Probably a drilling breccia since bit was found to be broken on retrieval.

Sample 72-73 cm:
  Calcareous nannoplankton:*
    Watznaueria barnesae (rare).
Sample 78-82 cm:
  Benthonic foraminifera:
    Ammodiscus cretaceus, Cyclammina sp., *Dorothia* sp., *Glomospira gordialis, Haplophragmoides* spp., *Pelosina complanata, Rzehakina epigona, Trochammina* sp.

Core catcher:
  Benthonic foraminifera:
    Fauna similar to above.

  Calcareous nannoplankton:*
    Watznaueria barnesae (rare), *Broinsonia parca* (very rare), *Micula decussata* (very rare), *Eiffellithus turriseiffeli* (very rare).
  Radiolaria:
    Amphipyndax spp.

* Probably contamination from uphole.

Figure 20. *Summary of Section 1, Core 7, Hole 13A.*