2. SITE 23

The Shipboard Scientific Party[1]

SETTING AND PURPOSE

The location of Sites 23 and 24[2] was chosen by the Atlantic Advisory Panel in order to sample the stratigraphic section near the continental margin where the sediment overlying the basement is relatively thin. Seismic reflection profiles in this area, obtained by Lamont-Doherty Geological Observatory (*Vema*-22, 1966; *Conrad*-8, 1963) showed an irregular basement at 0.5 second below the ocean floor and a strong smooth intermediate reflecting horizon at 0.2 second having characteristics similar to Horizon "A" in the North American Basin (Ewing, Worzel, Ewing and Windisch, 1966). The main objectives were to sample the basement and the intermediate reflector and determine the age and nature of each.

The physiographic setting of Sites 23 and 24 corresponds to the lower continental rise province described by Heezen *et al.* (1959), and mapped for this area of the South Atlantic by Heezen and Tharp (1961). The sedimentary province of the South American continental rise region of the Brazil and Argentine Basins is characterized by substantial thickening of sediments shoreward of the abyssal plain boundary due to an increased percentage of turbidites (Ewing, LePichon and Ewing, 1966). The anomalously thin cover at this location made it an attractive drilling site. Using sediment velocities of 1.7 to 1.9 km/sec (Ewing, Ludwig and Ewing, 1964; Leyden, Sheridan and Ewing, 1967), determined for similar regions to the south in the Argentine Basin, it was estimated that the total sediment thickness would be about 450 meters (1476 feet). Reflecting Horizon "A", present in this area at the characteristic depth of 0.2 second, has been traced over a broad region of the South Atlantic from the Rio Grande Rise to the southern Argentine Basin (Ewing *et al.*, 1964). Its similarities with Horizon A in the North American Basin (Ewing, Worzel, Ewing and Windisch, 1966) have been noted with the exception that in the North Atlantic the reflector is level regardless of sea floor topography, whereas in the Argentine Basin it is generally conformable to the topography. The nature of Horizon "A" in the northwestern Brazil Basin has been discussed by Leyden, Sheridan and Ewing (1967) with respect to a transect of seismic refraction measurements from Recife, Brazil to Freetown, Sierra Leone. These authors find that the reflecting horizon is present in this area, but is difficult to trace at the base of the Brazil Slope due to the presence of numerous seamounts. Unlike its counterpart in the eastern Atlantic, Horizon "A" in the western Atlantic Basin is not a refractor.

SITE SURVEY

The *R/V Vema* of Lamont-Doherty Geological Observatory, with Dennis Hayes as chief scientist, arrived in the Site 23-24 area on 4 February, 1969, and carried out survey operations until 6 February. These site survey measurements included continuous underway echo sounder (PDR), gravity, magnetics, and seismic reflection observations along the ship's track with satellite navigation control (Talwani, Dorman, Worzel and Bryan, 1966). Piston cores and bottom photographs were obtained at specific sites. Figure 1 illustrates the generalized topography of the site, contoured from the *Vema* echo sounder data.

A gentle slope of approximately 1:3 downward toward the southeast is observed in this area of the lower continental rise. Greater relief is observed in the central and eastern portions of the area, where two small seamounts rise 300 and 100 fathoms (549 and 183 meters), respectively, above the surrounding sea floor. The highest seamount, located about ten miles (16 kilometers) to the east of Site 23, was crossed by *Glomar Challenger* while coming on site, and a magnetometer measurement taken at that time showed an anomaly of about 35 gammas below the average value for the surrounding area, indicating a typical volcanic seamount. At its base, both the ocean bottom and the subbottom reflectors appear to warp downward, suggesting subsidence of volcanic feature. That this subsidence is relatively recent is shown by the absence of sediment fill in the surrounding 20- to 40-fathom (37- to 73-meter) deep depression.

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[2]Sites 23 and 24 are discussed together because of their close proximity. The initial plan called for one drilling site in this area, but technical difficulties with the drilling and positioning equipment caused abandoment of Site 23 before the drilling objectives could be achieved. A position 10 miles (16 kilometers) southeast of Site 23, believed to be more favorable, was chosen for Site 24.

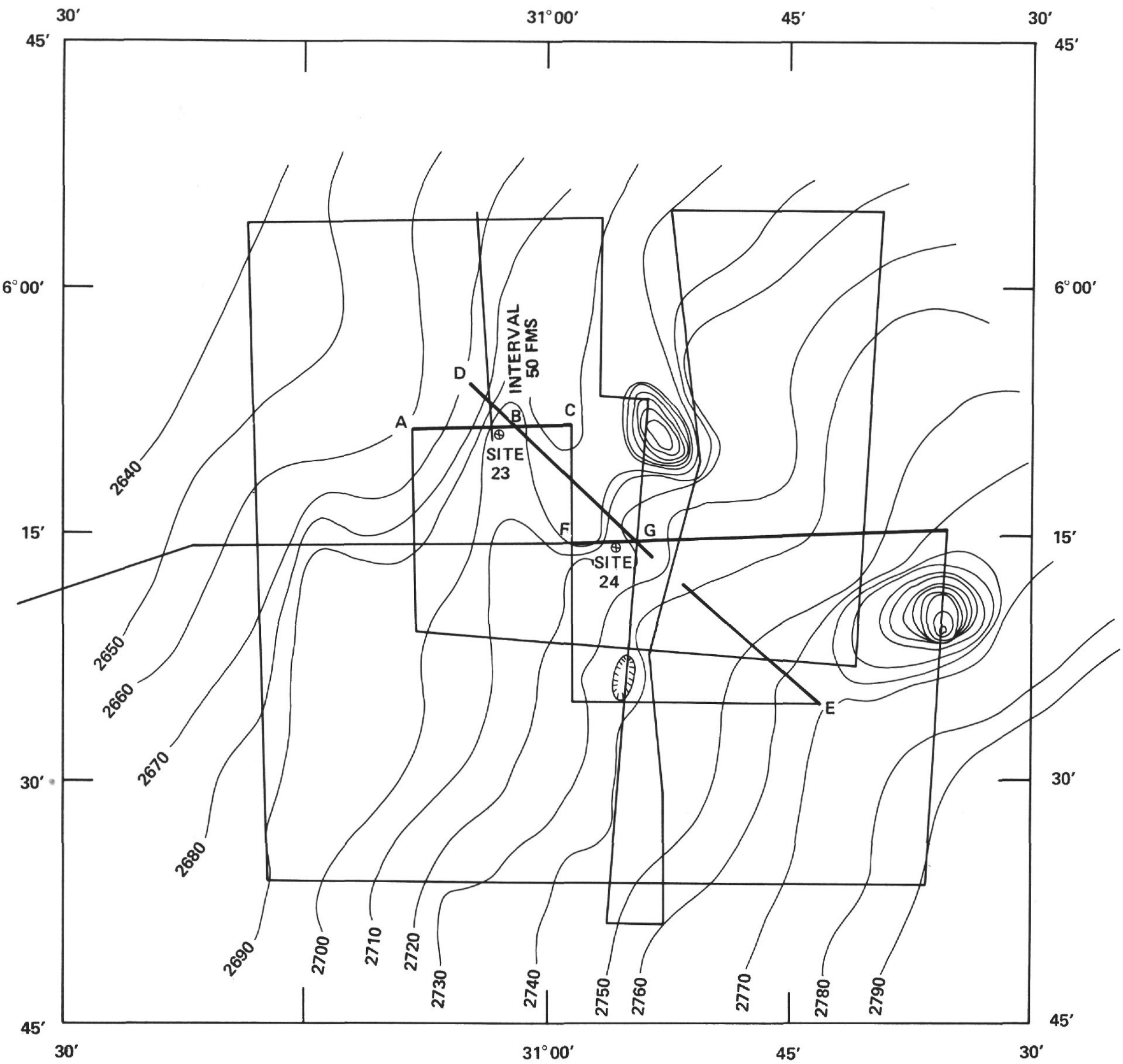

Figure 1. *Topography at Sites 23 and 24; contour interval 10 fathoms. Light lines indicate track of* R/V Vema *made in carrying out site survey. Dark lines indicate locations of reflection profiler transects shown in Figure 2.*

Continuous reflection profiler records were obtained during the *Vema* Survey along the track indicated in Figure 1. Profiler section A-B-C (Figure 2-A) illustrates the nature of subsurface reflecting layers at Site 23. Several poorly defined reflectors are observed between 0.03 and 0.25 second (two-way travel time), Our sampling of an estimated 1.5-meter (5-foot)–thick layer of basalt at 184 meters (605 feet)–Core 23-7–would correspond to that portion of the profiler record at approximately 0.21 second subbottom, assuming an average of 1.75 km/sec sound velocity in the overlying sediments. It is noted that assumed interval velocities of 1.7 to 1.8 km/sec were reported for unconsolidated sediments on Leg 3 sites (Leg 3 Shipboard Summary Reports) in the South Atlantic, based on comparison of profiler records and drilling results. Ewing *et al.* (1964) report velocities of 1.7 to 2.0 km/sec for the upper unconsolidated and semi-consolidated sediments in the Argentine Basin, based upon seismic refraction measurements. Similar values are reported by Leyden *et al.*

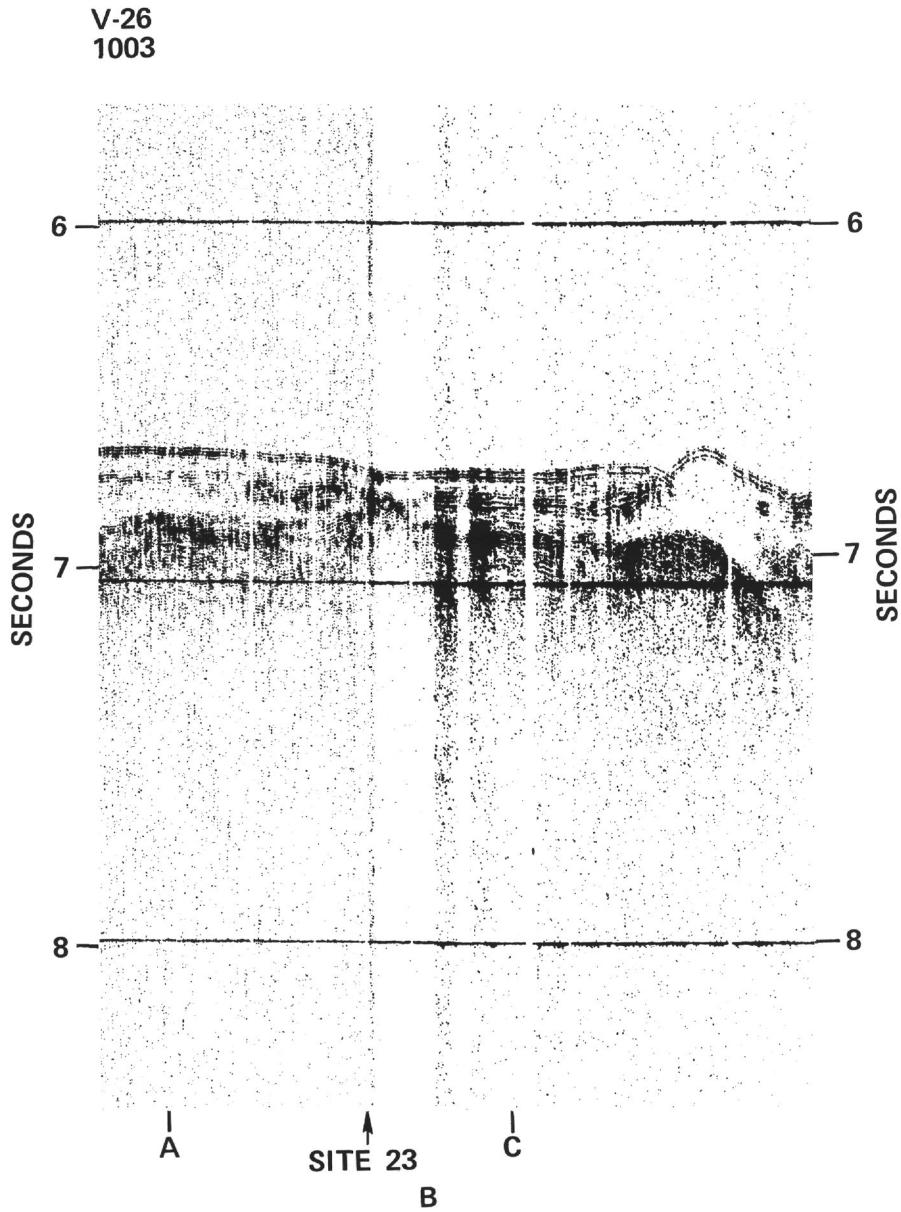

Figure 2A. *Reflection profiler sections A-B-C, across Sites 23 and 24 from the* R/V Vema *survey.*

(1967) for the sediments of the northern Brazil Basin. Discontinuous intermediate reflectors between 0.07 and 0.12 second on this record may correspond to turbidite beds (e.g., Cores 23-4, 5 and 6) sampled at this site between 112 and 131 meters (367.5 and 430 feet).

Profiler sections D-B-G-E and F-G-H (Figure 2B and 2C) record the subbottom reflectors on E-W and NW-SE transects across the drilling sites and show that the basement increases greatly in depth toward the south and east and appears to have fewer intermediate reflectors than on the northwest, perhaps because the basement feature acted as a barrier for turbidite transport from the continental side during earlier periods of deposition. Figure 3 is a tracing of the principle subbottom reflectors across Sites 23 and 24 taken from the reflection profiler records discussed above.

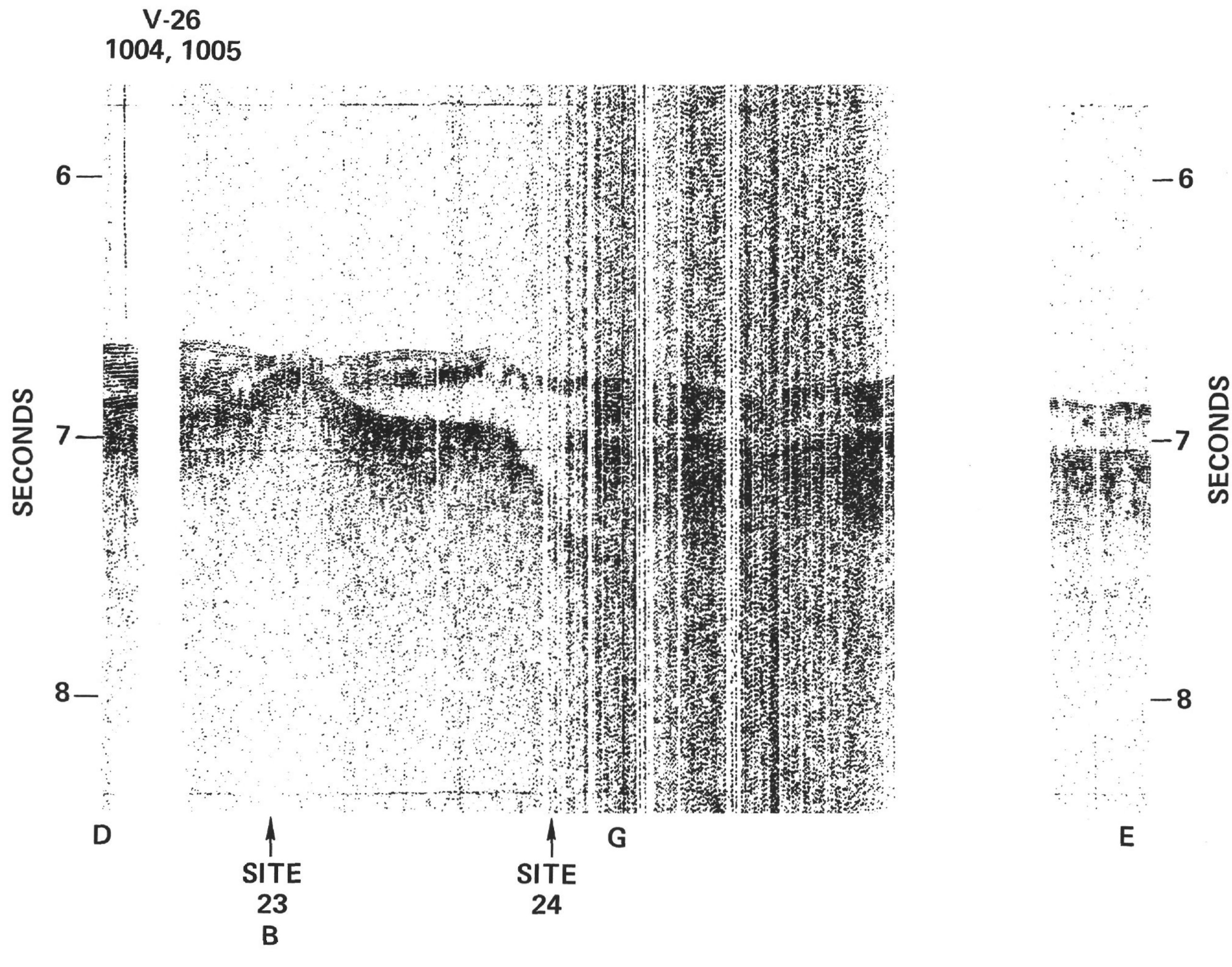

Figure 2B. *Reflection profiler sections D-B-G-E, across Sites 23 and 24 from the* R/V Vema *survey.*

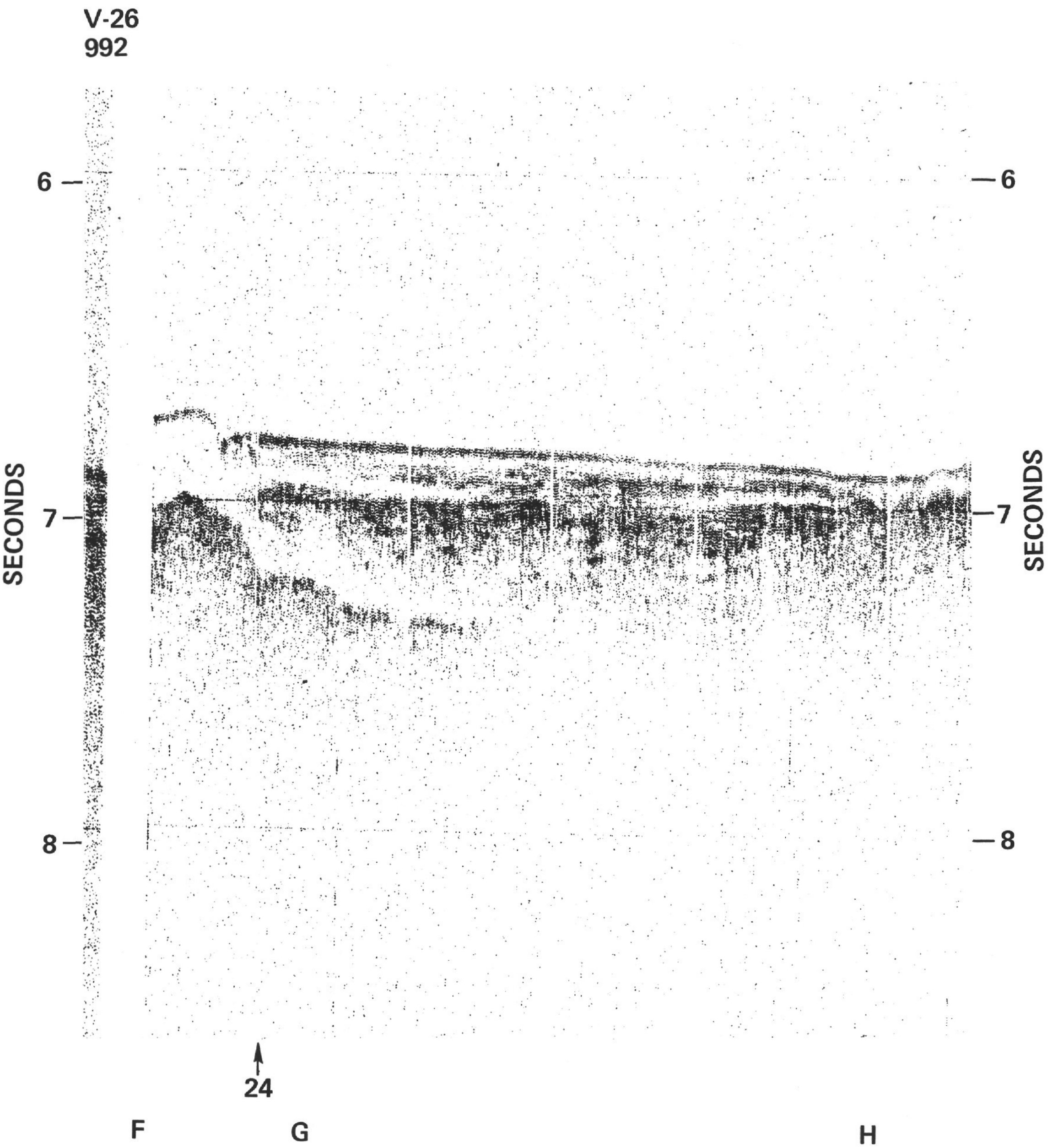

Figure 2C. *Reflection profiler sections F-G-H, across Sites 23 and 24 from the* R/V Vema *survey.*

DRILLING AND CORING OPERATIONS

The approach to Site 23 was made by the *Glomar Challenger* beginning at 1404 hours on February 1, 1969 on course 270, using the GDR (echo sounder) and the reflection profiler in order to approximate a previous crossing and profiler transect made by the *R/V Vema* (Cruise 22, Sheet 186-A, 187-A, taken on 14-15 February, 1966). These records, which were used as a guide, showed the rough basement reflector rising to a minimum of about 0.3 second subbottom and the intermediate "A" Horizon at about 0.15 second. Since there was no site survey vessel to help determine the drilling site (the *R/V Vema* did not arrive in the area until February 4, 1969), it was necessary to choose the location based upon the original proposed coordinates, modified by data obtained from the profiler and echo

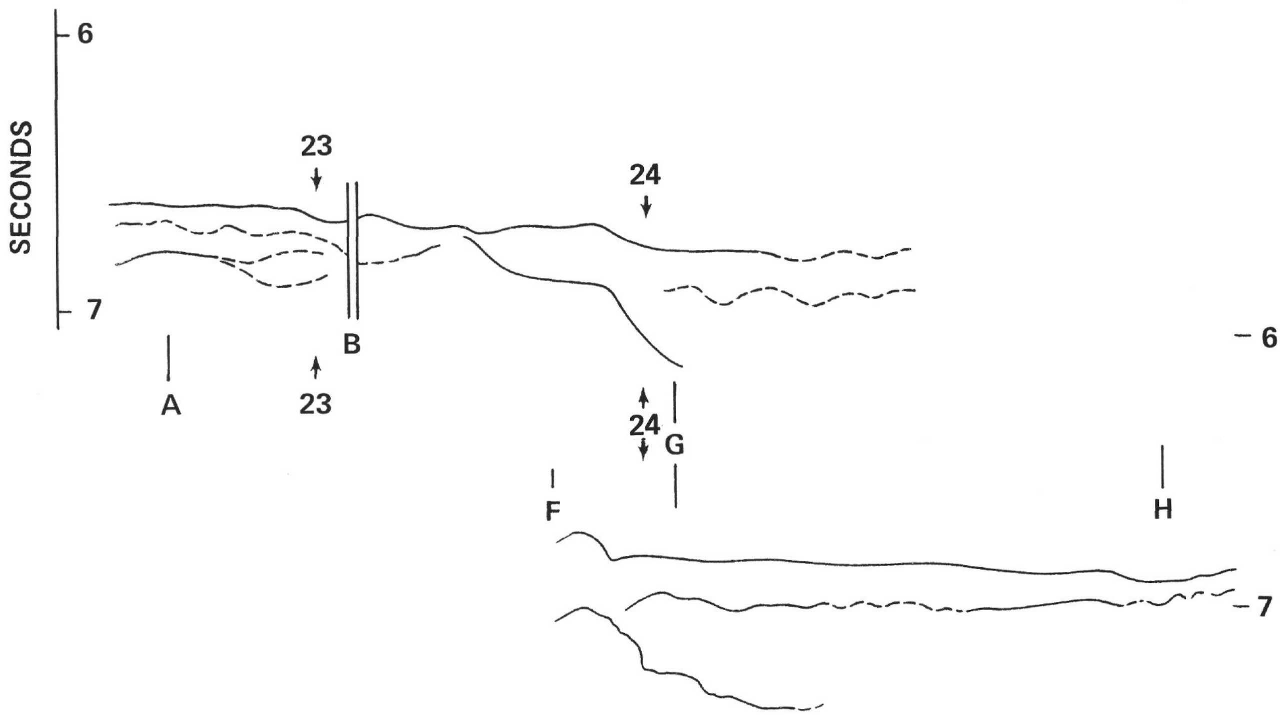

Figure 3. *Tracing of principle subbottom reflectors across Sites 23 and 24 shown on Figure 2.*

sounder aboard the *Glomar Challenger.* The profiler record obtained along the site approach was, unfortunately, of poor quality due to low acoustic output of the sound source (air gun) and the low signal-to-noise ratio in the receiving and recording system. The record obtained showed apparent reflectors at the anticipated depths; and, this information, together with the correspondence of geographic position and topography, was considered sufficient to identify the intended site.

Accordingly, a PPM (Pulse Position Method) beacon was dropped at 1600 hours at a position later determined by satellite navigation fixes at latitude 06° 08.75′ South, longitude 31° 02.06′ West. The drill tools were lowered at 1900 hours, and the drill string was spudded in at 0730 hours on February 2 in 1789 fathoms (5085 meters) depth. Sonic ocean depths given for this site and subsequent sites in this report are corrected for speed of sound in sea water according to Matthews (1939) and the depth of the hull-mounted transducer below the sea surface (3 fathoms; 5.5 meters).

A massive diamond bit was used in anticipation of reaching a chert layer at the depth of the intermediate reflector. The drilling summary (Table 1) lists the intervals drilled and cored. Drilling in the sediment layers was rapid, 1 to 15 minutes per 9.1-meter (30-foot) core, and recovery ranged from 0 to 80 per cent, with best results in soft upper clays, and poorest results in the turbidites and basalt. Total core recovery was low; out of nine cores, representing 725 meters (238 feet) of attempted coring, only 22.8 meters (74.5 feet) or 31.3 per cent of core were recovered. The formations drilled and cored consisted of unconsolidated material with one exception: a basaltic rock layer, estimated to be 1.5-meters (5-feet) thick, was penetrated between 184 and 190 meters (605 and 623 feet) below ocean bottom. Although the recovered core representing this layer was only 0.46 meter (1.5 feet), a 1.5-meter (5-foot) thickness is inferred on the basis of the drilling record. Coring rates in the unconsolidated sediment ranged from 1 to 30 minutes for a 9.1-meter (30-foot) penetration; in the case of the basalt layer, it took 90 minutes to penetrate 5.5 meters (18 feet).

On February 3 at 1300 hours, after coring the interval 199 to 208 meters (653 to 683 feet) below bottom the beacon failed and it was necessary to come out of the hole before pulling the core barrel (Core 9). The beacon, which had shown signs of weakening since the previous evening, continued to pulse, but its signal envelope shape was no longer acceptable to the computer, and it was necessary to maintain the ship on position with manual control while the drill string was being tripped out of the hole.

TABLE 1
Cores Recovered from Hole 23
(Using a Diamond Bit)

Core	Drill String (m)	Penetration (m)	Core Recovered (m)
1	5098-5108	0-9	7.6
2	5152-5161	53-62	1.2
3	5161-5170	62-72	3.4
4	5211-5220	112-122	9.1
5	5220-5229	122-131	0.6
6	5229-5238	131-140	0.0
7	5283-5288	184-190	0.5
8	5288-5297	190-199	0.0
9	5297-5307	199-208	0.3
		Total	22.7

When the bit was clear of the mud line at 1430 hours, the overshot was sent down to recover Core 9, which had been taken earlier. Only the "spearpoint" at the top of the core barrel assembly was brought up. The bearing shaft had failed, and the core barrel remained locked in the outer barrel. It was, therefore, necessary to trip the entire drill string back to the surface, ending further work at this site. The tools were laid down on deck at 0200 hours on February 4, and shortly thereafter the ship was under way for Site 24, about ten miles (16 kilometers) to the southeast.

LITHOLOGIC SUMMARY

For detailed lithology and paleontology see Hole Summaries. (See pages 29-35).

Although coring was at fairly widely spaced intervals, and recovery generally poor, the different sediments recovered at Site 23 indicate that a variety of depositional environments have existed at this site.

The Pleistocene sediments must constitute a thin veneer, because Core 1, which recovered surficial deposits to a depth of 24 feet (7.3 meters) contains mixed assemblages of Pleistocene and Pliocene planktonic foraminifera and calcareous nannoplankton. The sediments are mostly greenish-gray, slightly silty and sandy clay, with detrital feldspar, quartz and mica making up less than 10 per cent of the sediment. There is a planktonic foraminiferal sand, which was originally probably a few inches thick, present at a depth of about 10 feet (3.1 meters). Except for this unique layer, the planktonic foraminifera and calcareous nannofossils are generally sparse and corroded.

Cores 2 and 3, taken between 175 and 235 feet (53.3 and 71.6 meters) below the sea floor recovered more typical deep sea "red clay". The clay is actually yellowish-brown, and contains zeolites, but is almost completely devoid of calcareous fossils. Fortunately, a small sample taken from the center bit prior to drilling Core 2 contained an adequate nannoplankton sample to permit dating of the material as *Discoaster hamatus* Zone (late Middle Miocene).

Cores 4, 5 and 6 were taken between 369 and 459 feet (112.5 and 139.9 meters) below the sea floor, starting just above the predicted depth of Horizon A. These recovered sandy turbidites with quartz and calcareous fossils, including some larger shallower water foraminifera, interbedded with greenish-gray silty clays virtually devoid of calcareous fossils. Planktonic foraminifera and calcareous nannofossils are abundant but sometimes poorly preserved in the sandy turbidite layers, and indicate an age of early Early Miocene.

Cores 7, 8 and 9 were drilled between 605 and 623 feet (184.4 and 189.9 meters) below the sea floor, but only the uppermost of these recovered a sample. About 1.5 feet (0.5 meters) of basalt were retrieved; the basalt contains coarse plagioclase crystals and finer laths of plagioclase as well as altered pyroxene (Titan-augite). Saponite (?) is an abundant secondary mineral. The basalt is heavily altered, and much of the texture has been destroyed. The texture appears to be diabasic or porphyritic. Several of the larger basalt fragments exhibit steeply dipping banding. (This description of the basalt is based on preliminary shipboard examination by W. E. Benson; a more definitive description by W. G. Melson is presented in a latter section.)

PHYSICAL AND CHEMICAL PROPERTIES

A very rough correlation between gamma-radiation and clay content can be seen in Figure 4. The predominately clay sediment is characterized by relatively high radiation levels (1600 to 2200 counts per 1.25 min.). Sandy sediment, both biogenic and non-biogenic, has a relatively low radiation level (on the order of 500 counts/1.25 min.) as found in Section 23-4-5. The contact between the clay sequence and the sandy turbidite sequence at approximately 122 meters readily shows up in a decrease in gamma-ray intensity. Each section (a mean value) has been plotted for the depth interval 122 to 140 meters to emphasize the nonhomogeneity of the interbedded clays and turbidites and the effect of clay-sand sequences upon gamma-radiation levels.

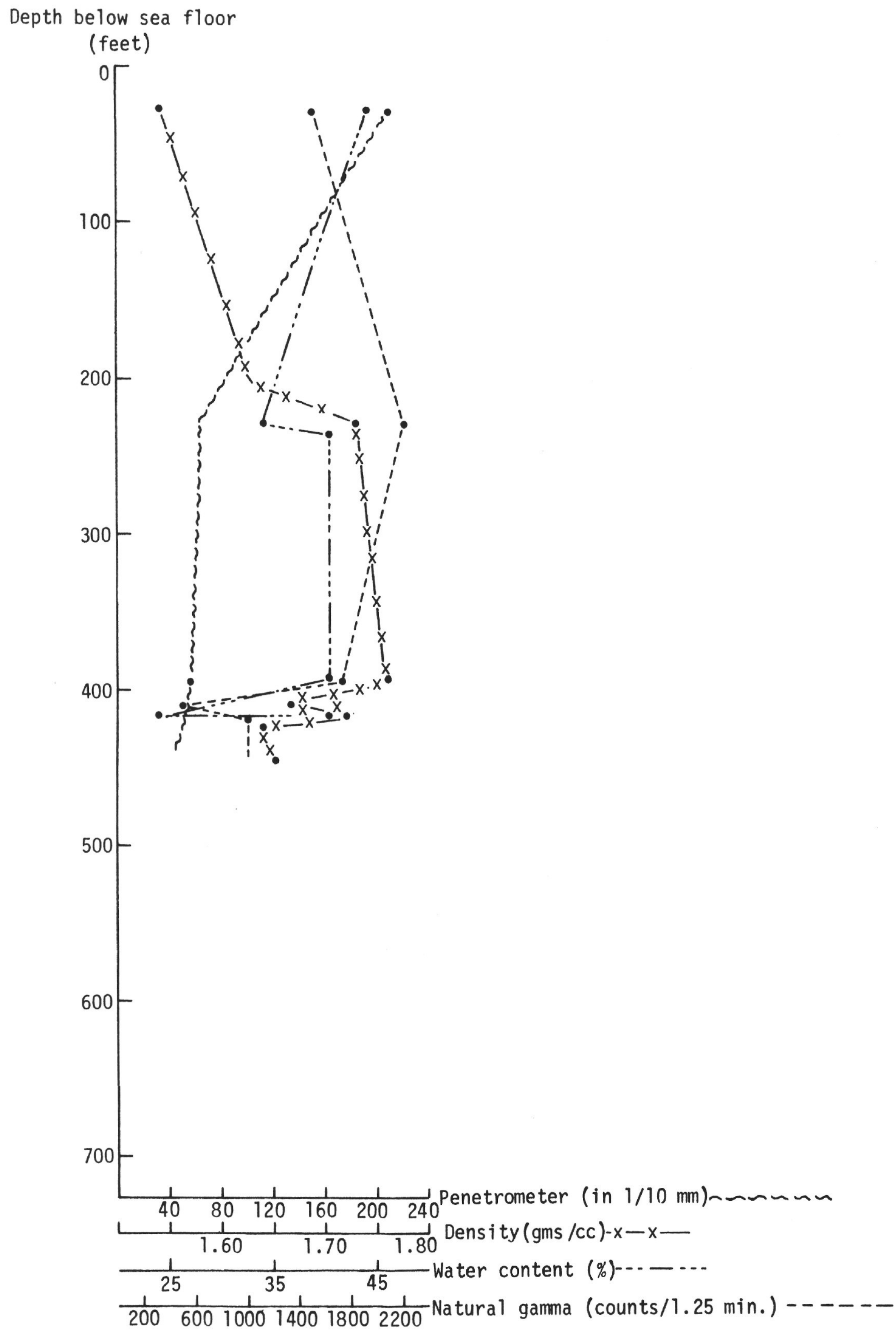

Figure 4. *Summary of physical properties, Site 23.*

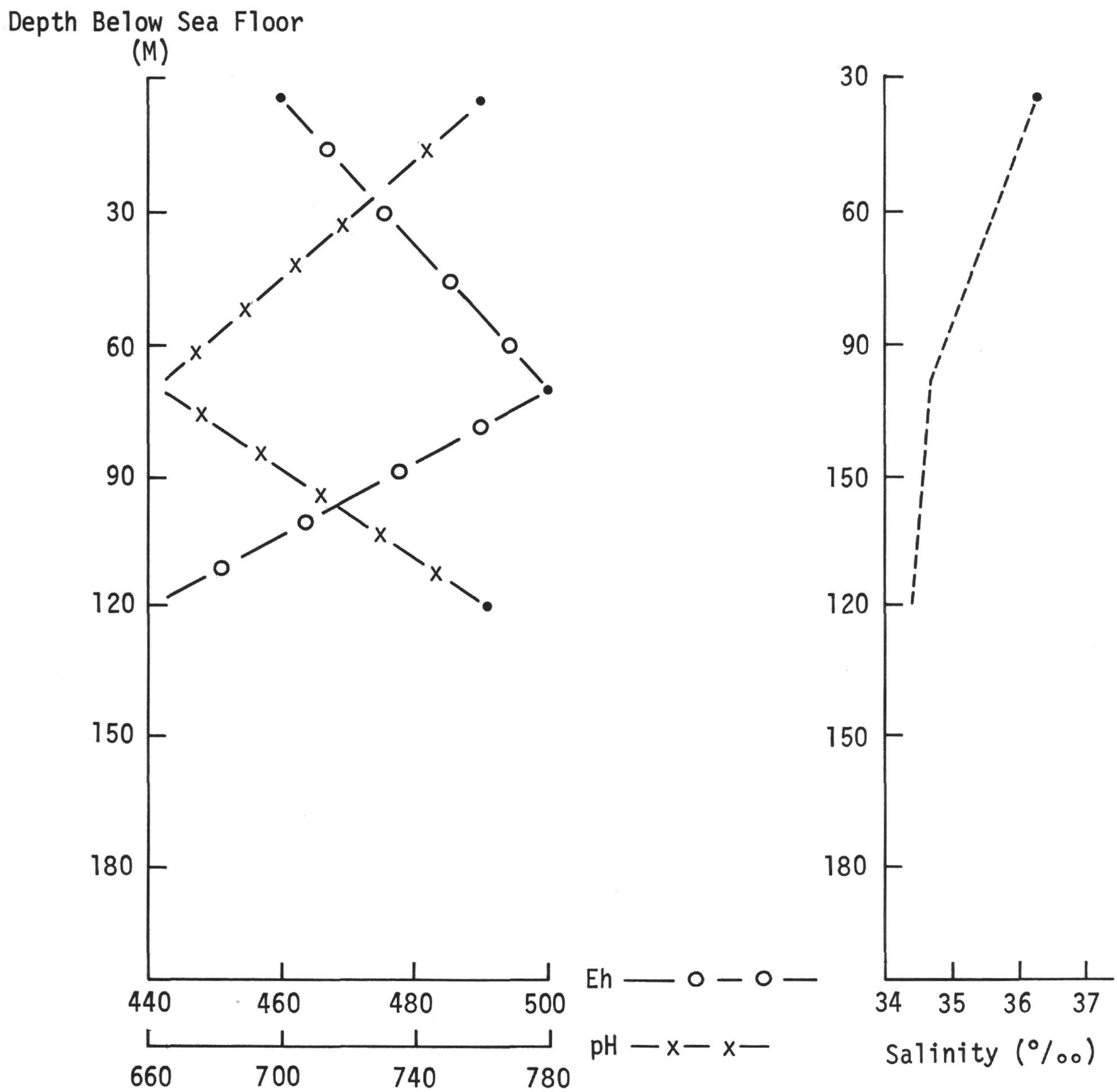

Figure 5. *Summary of chemical properties, Site 23.*

The clay-turbidite contact shows up clearly in the water content and density data presented as a function of depth. There is a marked density decrease in passing from the clay to the turbidite sequence. The sands invariably have low water content (20 to 25 per cent); the clays are similar to those in the overlying sequence (40 per cent). Despite the lower water content the density of the sandy interbeds is lower than that of the overlying clay sequence. The clays in the turbidite sequence have still lower densities. Density, water content and natural gamma values for each section have been plotted in the interval 122 to 140 meters because presenting mean values for two distinct types of sediment would be meaningless.

The penetrometer measurements show a relatively smooth decrease with depth. There is no indication of the lithology change at 122 meters in these data. It is probable that no penetrometer measurements were made in the sandy portion of the turbidite sequence. These data indicate a steady increase in consolidation with depth.

The change in penetrometer readings below 76 meters is slight and is consistent with the lack of change in water content (the data are very sparse) of the clays. The consistency and constancy of the penetrometer and water content data (for the clays) make the density decrease observed in Cores 4 and 5 difficult to interpret. It cannot be attributed to greater disturbance of the cores, as there is no evidence of increased water content or disruption. The change is also greater than the expectable maximum error. There is no evidence of a composition change such as an increase in organic content which might account for the decrease. Most probably it is a combination of error and undetected disturbance compounded by poor sample coverage.

The carbonate content of Cores 1 through 4 (clays) averages 3.4 per cent. Core 5 contains a sandy layer with abundant foraminifera and nannofossils. The water depth at this site is 5079 meters, and thus it is presumed that the carbonate is of turbidite origin. The organic carbon content is nil to 0.1 per cent except for the sample for Core 5 in which it is 0.3 per cent.

There are few chemical data available for Site 23; only three interstitial water samples were collected due to poor recovery and to the highly disturbed nature of many of the cores. Eh values indicate oxidizing conditions in all of the samples (Eh = + 440 to 500 millivolts). The *p*H values are all significantly more acid than standard sea water under the pressures calculated for the depths of the samples (*p*H = 7.62, 6.63, 7.61). One sample has a total salinity of 36.3 per mil. The other two are slightly below sea water (34.7, 34.4; see Figure 5). There is some question as to the validity of the high salinity measurement.

A single shipboard thermal conductivity measurement was obtained from Core 4, Section 4, in silty clay. The value obtained, 2.41×10^{-3} cal/°C/cm/sec, falls about mid-range within the values measured for deep sea cores obtained on this leg.

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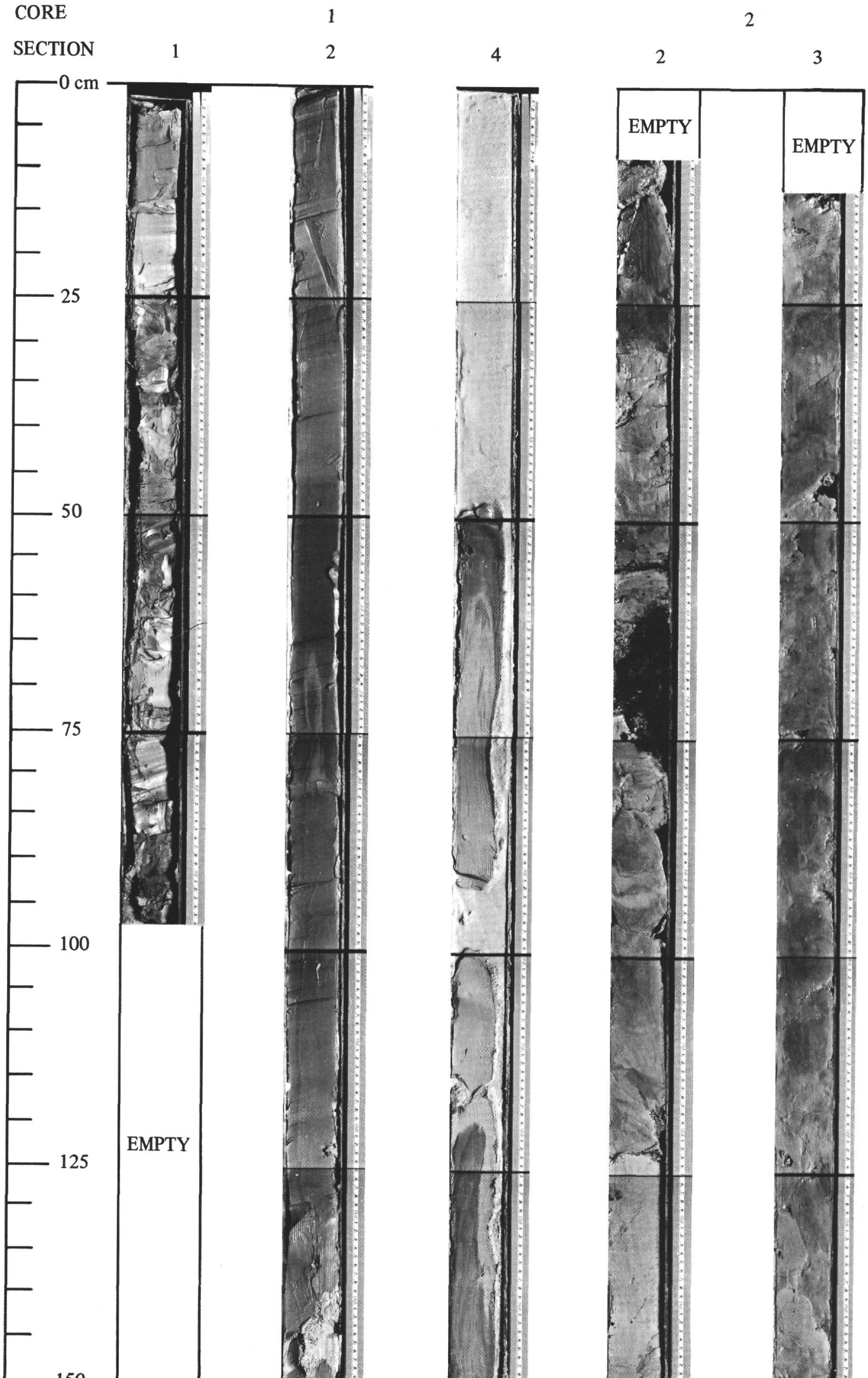


Plate 1. *Cores 1 and 2, Hole 23*

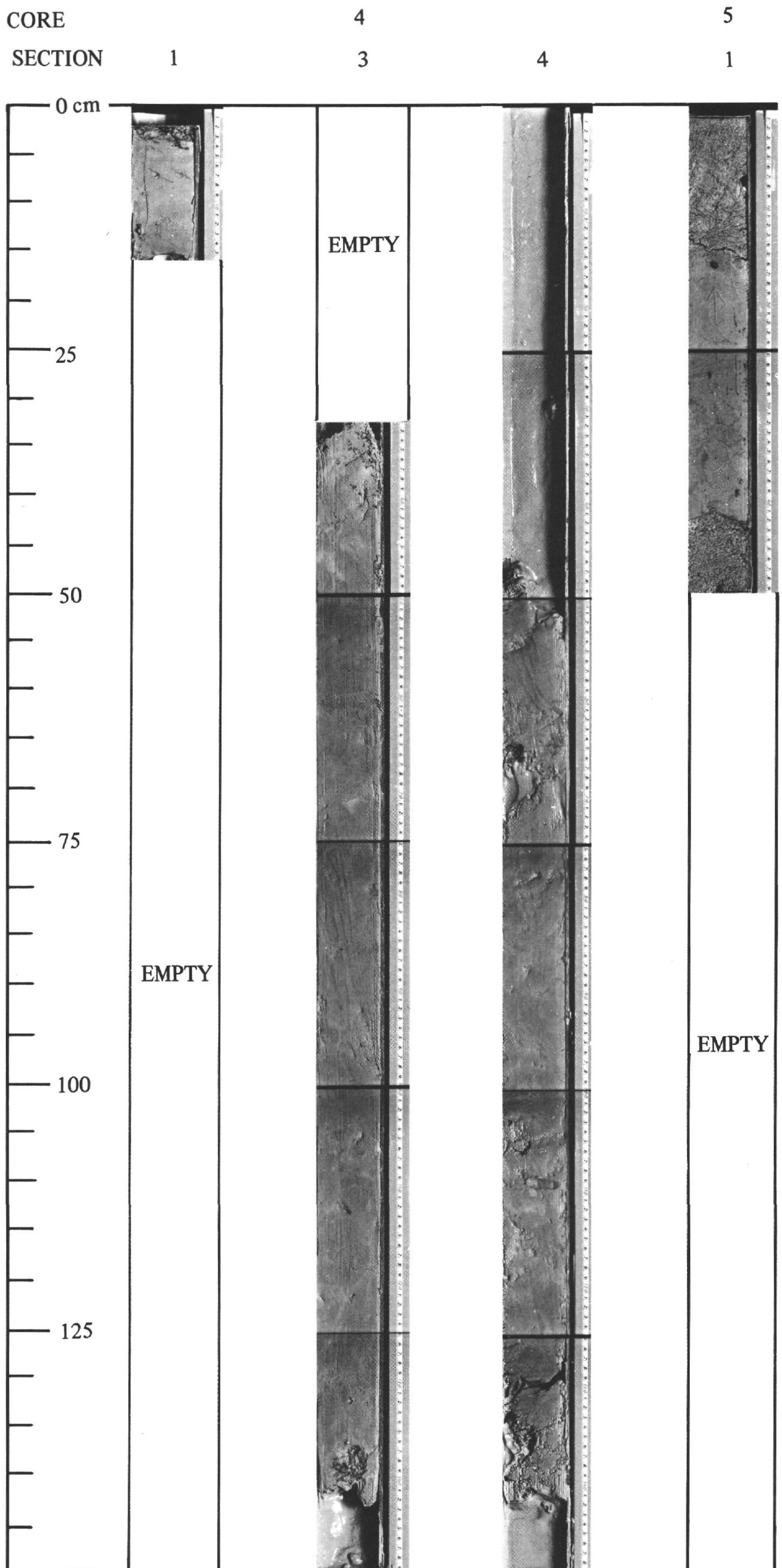


Plate 2. *Cores 4 and 5, Hole 23*

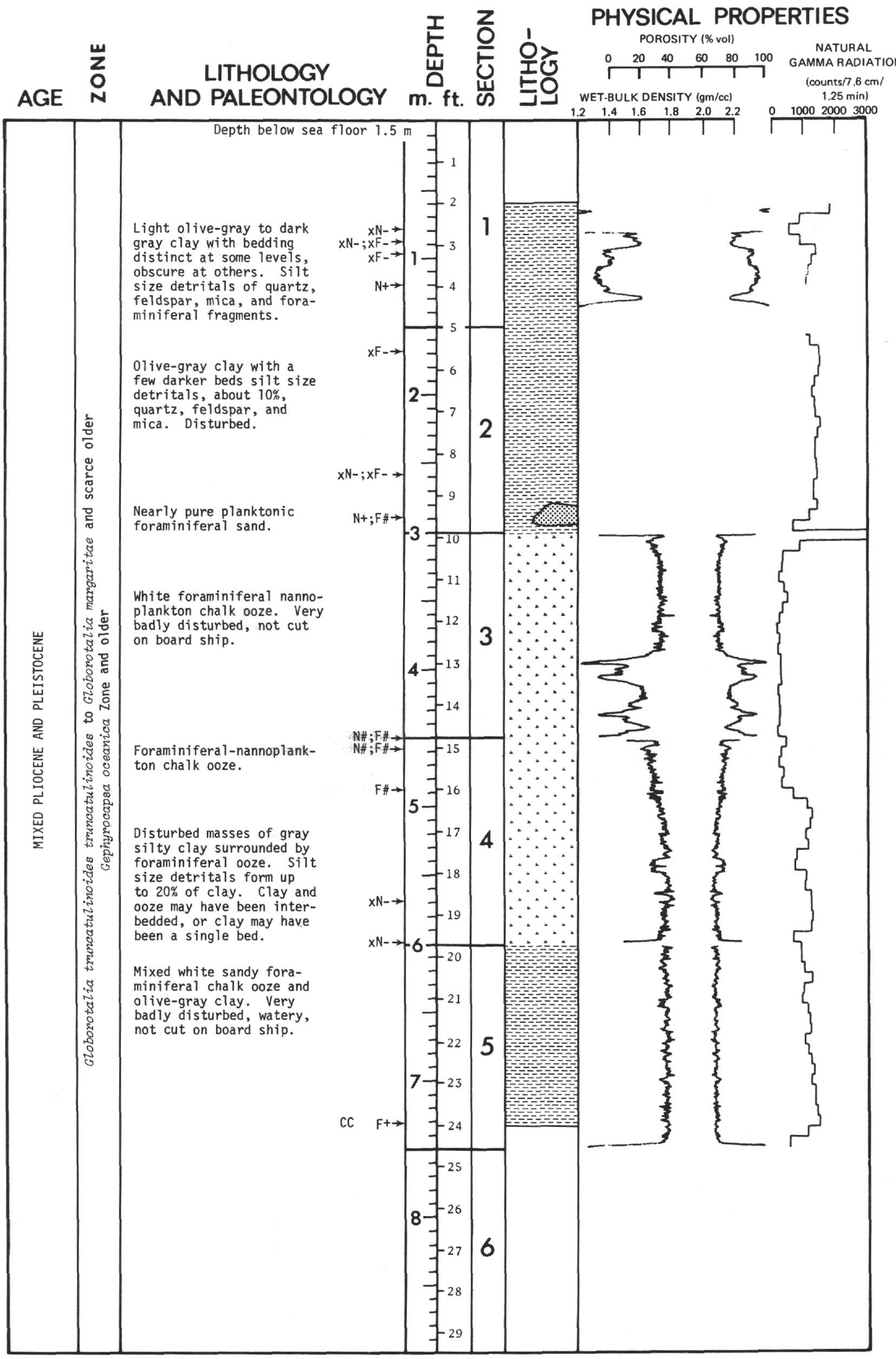


Figure 6. *Core 1. Hole 23,*

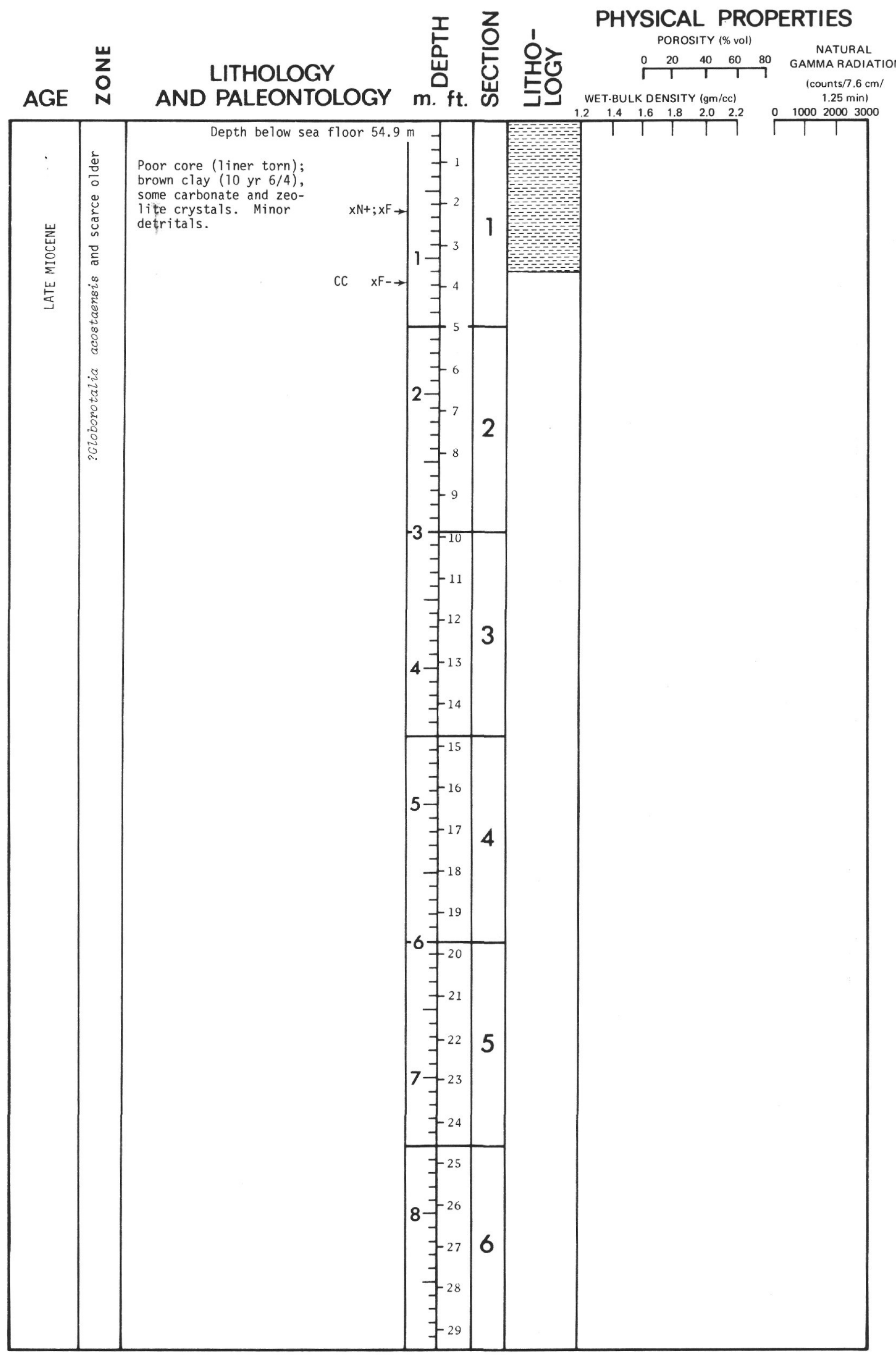


Figure 7. *Core 2. Hole 23,*

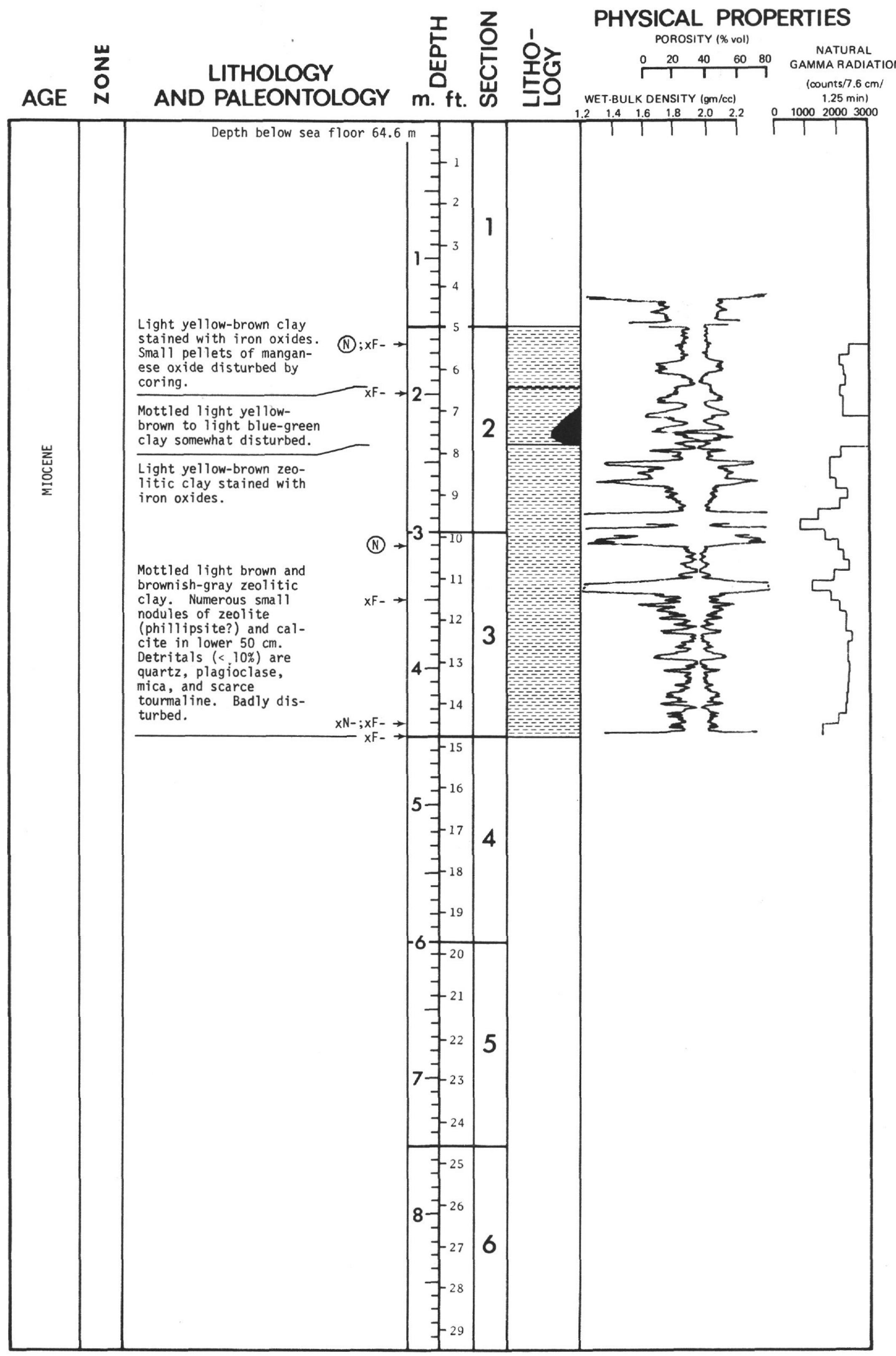


Figure 8. *Core 3. Hole 23,*

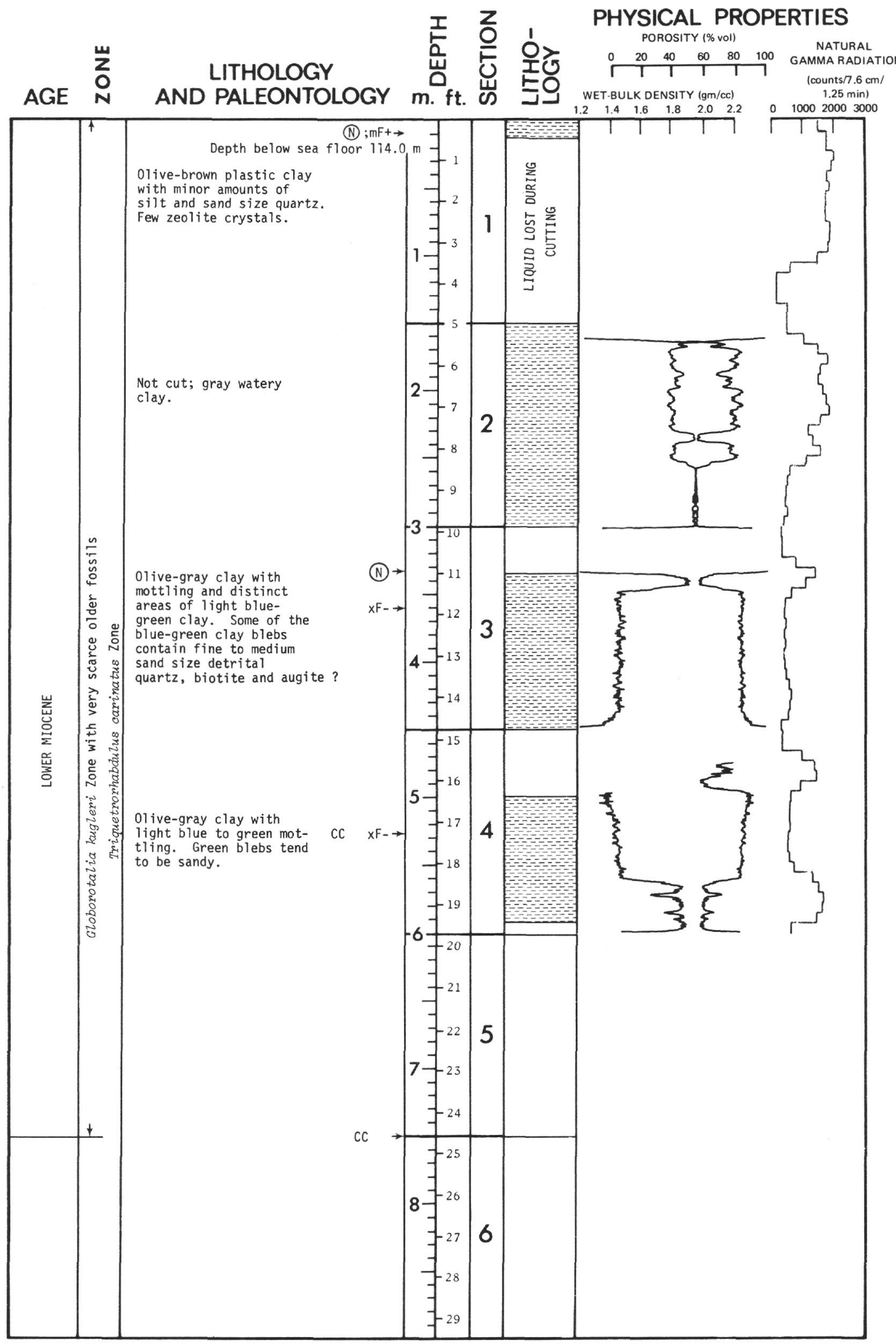
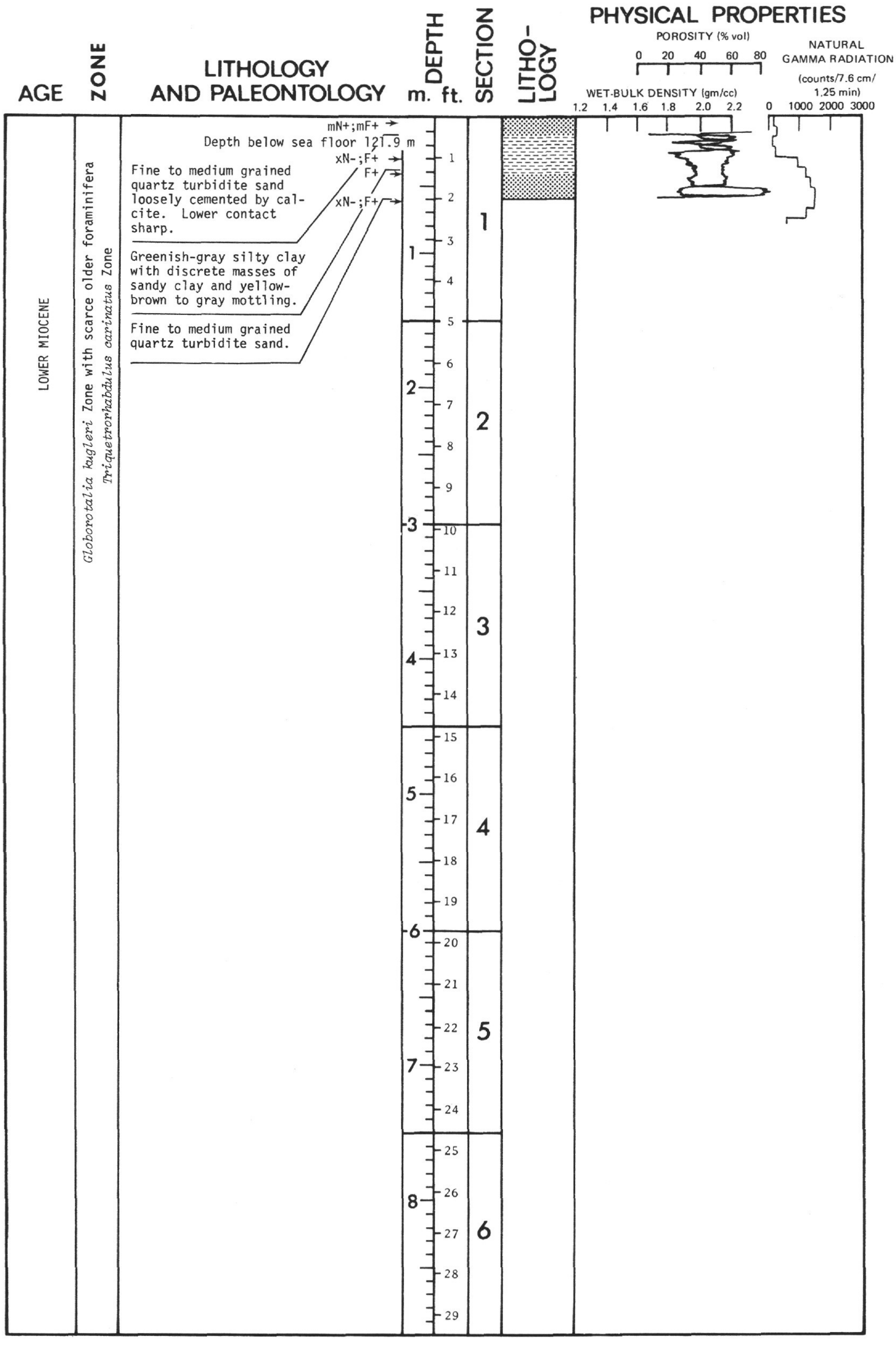


Figure 9. *Core 4. Hole 23,*



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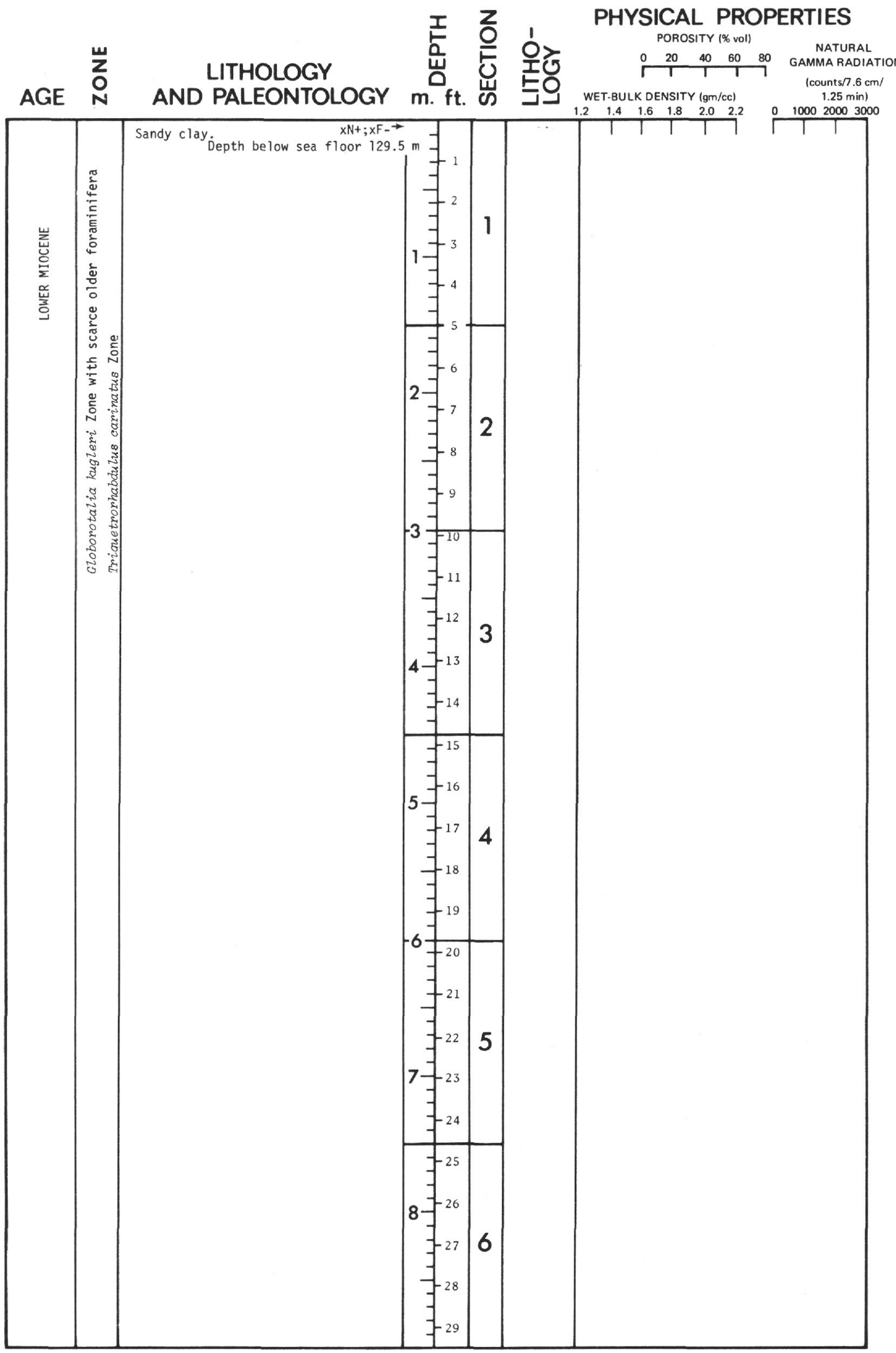

Figure 11. *Core 6. Hole 23,*

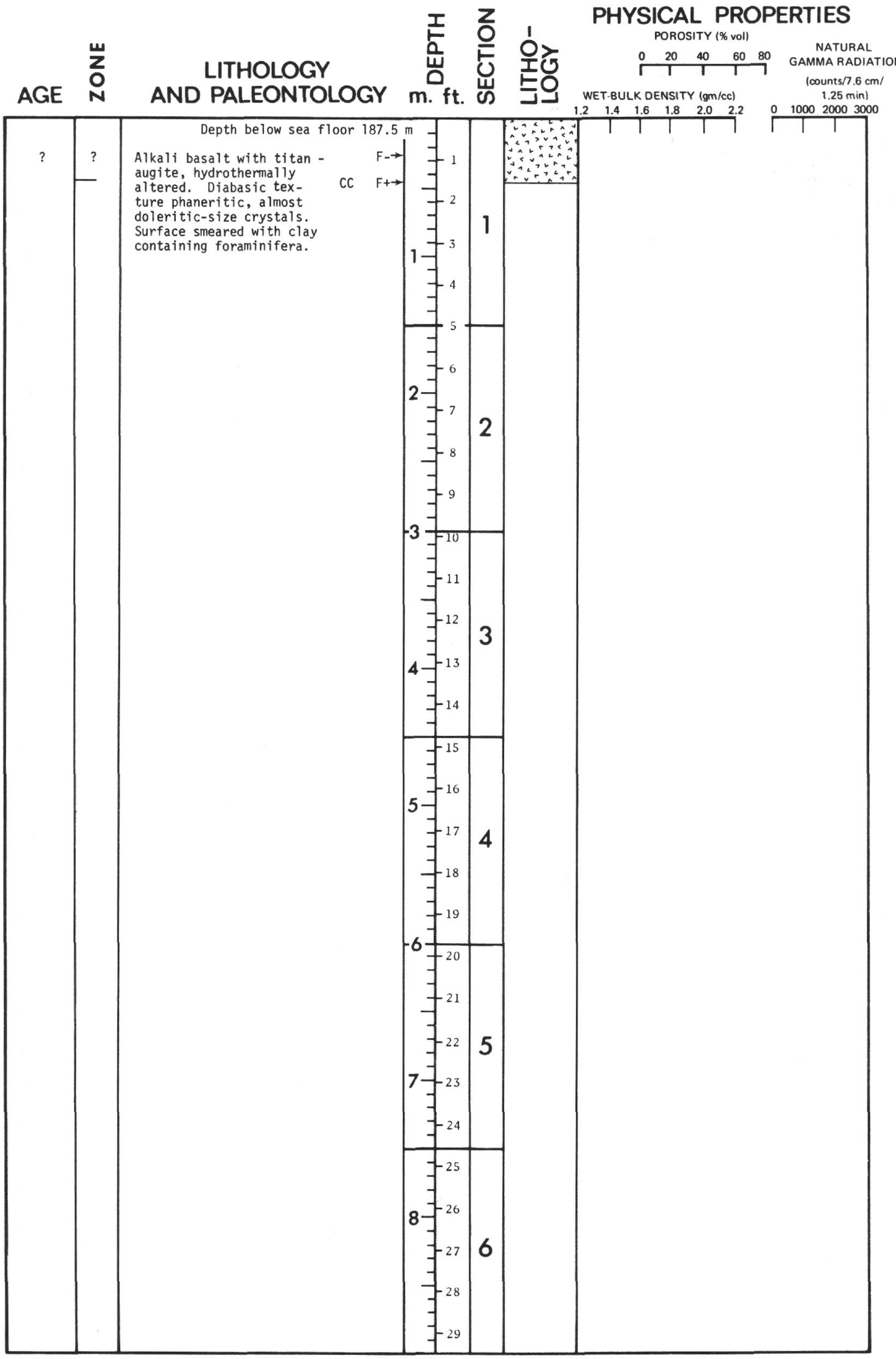

Figure 12. *Core 7. Hole 23,*