9. SITE 51

Shipboard Scientific Party[1]

SITE DATA

Occupied: July 4-5, 1969.

Position: Abyssal floor of Pacific:
Latitude 33° 28.5′N
Longitude 153° 24.3′E

Water Depth: 5981 meters (record depth to date).

Hole 51.0: Three cores, total depth 132 meters in Cretaceous chert and carbonate.

Hole 51.1: Three cores, total depth 128 meters in brown clay (or chert) and carbonate.

MAIN RESULTS

Deep sea brown clays with a considerable admixture of volcanic ash, lie on cherty chalk oozes of Upper Cretaceous (Cenomanian-Santonian) age. These cherty beds form here the top of the upper opaque acoustic unit.

BACKGROUND

Site 51 shows the seismic section typical of the Northwest Pacific ocean floor—an upper transparent layer, upper opaque layer, lower transparent layer, and B′. It was located at a place where the upper transparent layer reached abnormal thickness.

In view of our lack of success in penetrating the abyssal sequence farther to the east, where covering soft sediments are too thin for safe spudding, it seemed imperative to make another attempt at penetration here. Furthermore, for a limited objective, it seemed important to test the age and nature of the upper transparent layer, and to date the top of "A′," the upper opaque sequence, so as to discover whether this acoustostratigraphic unit is essentially a time-unit, or is notably time-transgressive.

A bathymetric contour map of the area around Site 51 is given as Figure 1, the *Challenger* bathymetric and magnetic profile as Figure 2, and bottom soundings as Figure 3.

OPERATIONS

Site 51 was drilled with a diamond bit, in expectation of hard drilling in the upper opaque layer, and in hopes of penetrating this and the underlying lower transparent section to sample the underlying material.

The beacon was dropped at 2000 hours July 4 and Hole 51.0 was spudded on the 5th at 0800 hours. The hole was quickly drilled to 114 meters to bury the bottom-hole assembly. A core at this depth recovered brown clay, but at 124 meters hard drilling was encountered. An 8-meter core recovered only a catcher sample of chert with a calcareous interbed, for a total depth of 132 meters. A third core found the hole obstructed by clay, chert and white foraminiferal sediments, and only penetrated to 126 meters.

With progress thus halted by chert, the authors considered the possibility of retrieving the drill string and attempting to penetrate the section with one of the Mohole button roller bits, but the depth of soft cover was deemed insufficient to support the long assembly of drill collars needed to weight such a bit.

Therefore, tools were withdrawn to the mudline only, and Hole 51.1 was spudded in order to obtain more samples from the mud section. Three such cores were taken, but the lower one suffered a collapsed liner. The site was abandoned at 2300 hours July 6.

NATURE OF THE SEDIMENTS

Hole 51.0

Of three cores attempted in this hole between 114 and 126 meters subbottom depth, only the first recovered sediments in significant amounts.

Core 1 contains 9.0 meters of sediment. Sections 1 through 3 and most of Section 4 consist of a "drilling breccia", highly disturbed by coring and composed of platy fragments of coherent dark brown zeolitic clay and occasional mottles of yellowish-brown silty diatomaceous ooze with up to 20 per cent of grains of volcanic glass. The platy fragments of this "breccia"

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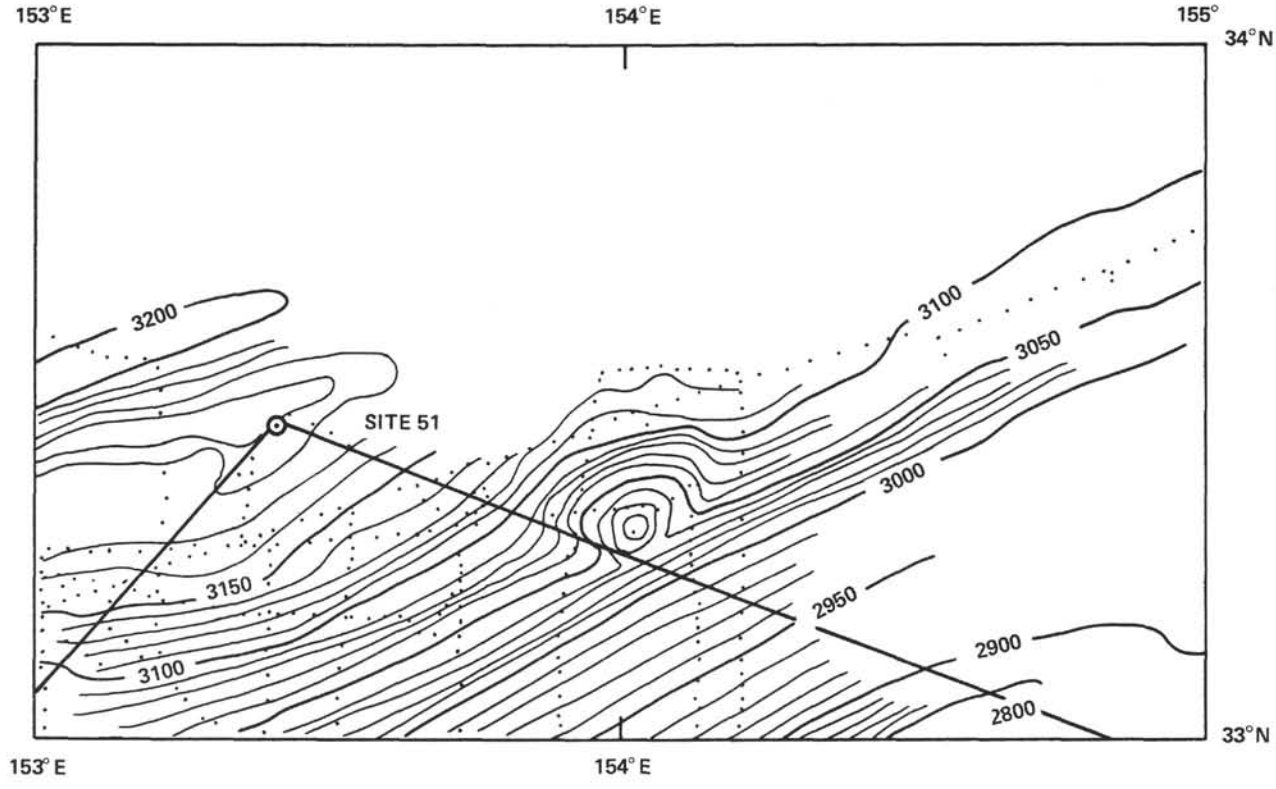

Figure 1. *Bathymetric contour map of Site 51.*

are 3 to 4 centimeters long and 1 to 2 centimeters thick. They are embedded in a matrix of watery zeolitic clay that, compositionally, appears identical to the platy fragments. The basal part of Section 4 is mostly a layer of firm, consolidated brown zeolitic clay. Another "drilling breccia" of zeolitic clay extends from the lowermost part of Section 4 to the basal part of Section 5. The remainder of the core is largely non-zeolitic brown clay that is very firm and compact and contains, in addition to abundant clay minerals and limonitic grains, small amounts of volcanic glass and rarely coccoliths. Within this brown clay near the bottom of Section 6 is a thin interlayer of sand composed of volcanic glass, coarse zeolites, chert grains, silicified foraminiferal and radiolarian tests altered to secondary quartz; this layer appears to have been redeposited from a source area of volcanic and cherty material. The core catcher for Core 1 contained brown clay; the washed coarse fraction from this clay consists of abundant fish debris, opaque grains, volcanic glass and grains of palagonite.

Recovery from Core 2 consists of a small amount of brown clay, with abundant limonitic grains and rare zeolites and volcanic glass, and several large (up to 8 centimeters) angular pieces of reddish-purple chert. The chert is very dense and glassy, fractures conchoidally and contains occasional poorly preserved radiolarian tests and partially to completely silicified foraminifera. The chert also has thin white to light brown laminae and bands up to 5 centimeters thick that appear to be incompletely silicified limestone (Chapter 38).

The only recovery from Core 3 was a core catcher sample that consists of a small amount of brown clay and a few blebs of white foraminiferal-nannoplankton chalk ooze.

TABLE 1
Summary of Coring at Site 51

Core No.	Interval Cored (Below Mudline) (ft)	(m)	Recovery (ft)	(m)
51.0-1	374-404	114.0-123.1	30	9.1
51.0-2	406-433	123.7-132.0	1	0.3
51.0-3	411	125.3	0	0.0
51.1-1	75-105	22.9-32.0	30	9.1
51.1-2	396-416	120.7-126.8	6	1.8

Water depth: 5980.5 meters (19,621 feet).

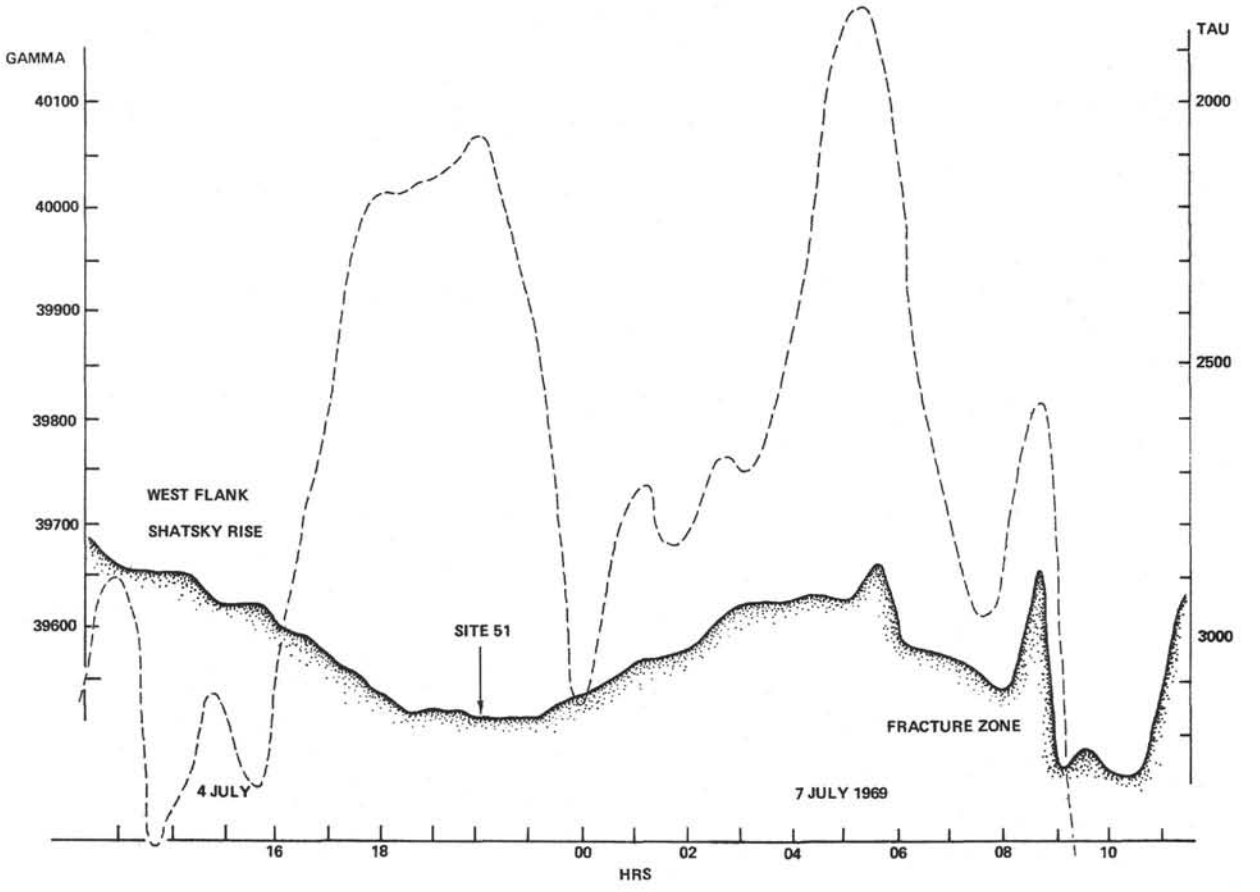

Figure 2. Challenger *bathymetric and magnetic profile at Site 51.*

Hole 51.1

Two cores were recovered from this hole and a third was recovered inadvertently.

Core 1, drilled between 18 and 27 meters below mudline, has 9 meters of interlayered radiolarian- and diatom-rich volcanic ash and sand to silty clays with abundant volcanic glass and variable amounts of quartz and plagioclase. The most characteristic features of this sediment are the high percentages of volcanic glass and the excellent preservation of the siliceous microfossils throughout the core. Volcanic glass in the upper part of the core is mostly clear, unaltered and often vesicular; palagonite and altered palagonite become somewhat more abundant in the lower part. The upper 175 centimeters of Core 1 (Sections 1, 2) are light brown, gray, clayey volcanic ash with abundant volcanic glass and silt size feldspar, and common diatoms, and Radiolaria. Between 175 and 412 centimeters (Sections 2, 3) are alternating layers of light gray-brown, poorly sorted diatom-radiolarian ooze and gray to yellow-brown silty volcanic ash with abundant clay minerals and glass, common plagioclase, and rare diatoms, Radiolaria and zeolites. Between 412 and 750 centimeters (Sections 3 through 5) are highly disturbed layers of light brown, light gray and gray-brown, sandy to silty clay with abundant volcanic glass and common diatoms and Radiolaria. A layer of uniform gray-brown, sandy clay, with abundant glass and altered glass, lies between 750 and 840 centimeters (Section 6), and the remainder of Section 6 (840 to 900 centimeters) is sandy clay with abundant diatoms and Radiolaria.

Core 2 was drilled between 121 and 128 meters below mudline and recovered about 2.2 meters of dark brown clay that has abundant limonitic grains and common to rare, lath-shaped zeolites. Also present are a few mottles of light brown zeolitic mud. The upper 70 centimeters of this core is a "drilling breccia" like that in Core 1, Hole 51.0. Samples in this core also contain, according to X-ray studies by Rex, quartz and potash feldspar but little plagioclase; the latter is in contrast to Core 1 which has plagioclase but no potash feldspar.

A third core was inadvertently recovered somewhere between 91 and 111 meters below mudline. It consists of about 150 centimeters of coherent dark brown zeolitic clay like that in Core 2.

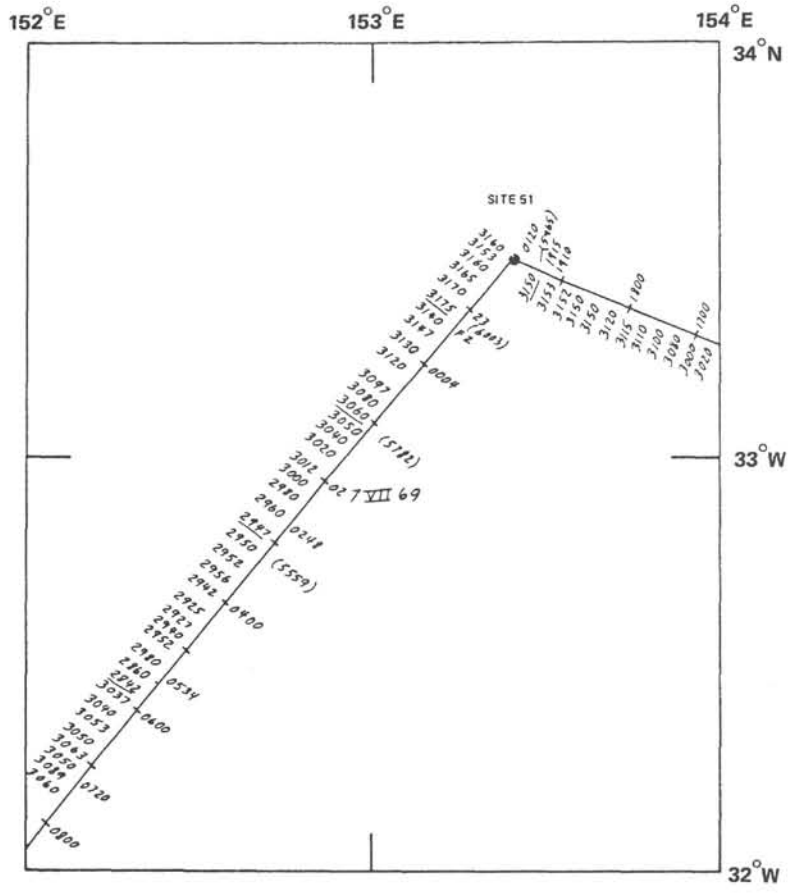

Figure 3. *Bottom soundings in area of Site 51.*

PHYSICAL PROPERTIES

Coring disturbance prevented these physical property measurements from being representative of *in situ* conditions.

Natural Gamma Radiation

Hole 51.0

Natural gamma radiation of Core 1 (114 to 123 meters below mudline) from Hole 51.0 ranged from 600 to 2200 counts/7.6 cm core segment/1.25 minutes. The average for the top five sections was 1200 counts, the sediment being a "drilling breccia" comprising compact fragments of Miocene zeolitic and diatomaceous ash-rich clay in a soupy matrix of zeolitic clay. Towards the bottom of Section 5 and throughout Section 6, the gamma ray counts were increased, averaging 1500 and 1900, respectively, which appears to be of decreasing porosity, thus, increasing the amount of sediment scanned per 7.6-centimeter core interval. The sediment in this lower part is a compact Miocene brown clay.

Hole 51.1

Natural gamma radiation of Pleistocene and Cretaceous (?) volcanic ash with clay, siliceous ooze, and brown clay from Hole 51.1 averaged 1200 counts/7.6 cm core segment/1.25 minutes (see core and hole plots). A range from 700 to 1900 counts/7.6 cm core segment/1.25 minutes was emitted from interbedded Pleistocene diatom and radiolarian volcanic (abundant glass) silt and sand (23 to 33 meters below mudline) in Hole 51.1. The lower 4.5 meters of the core consisted mainly of clay with ash having an average of 1100 counts.

Section 1 of Core 2 was recovered at 120 to 122 meters in Hole 51.1. It comprises brown zeolitic clay with gamma ray counts ranging from 900 to 1800 with an average of 1300 counts/7.6-cm core segment/1.25 minutes.

Porosity, Wet-Bulk Density, and Water Content

Hole 51.0

The porosity of sediments cored in Hole 51.0 between 114 and 128.1 meters below the mudline ranged from 63 to 85 per cent (1.22 to 1.53 g/cc) with a mode of 80 per cent (1.30 g/cc). The sediment is an "artificial drilling breccia" comprising compact Miocene clay clasts in a soft watery matrix. The water content ranged from 51 to 62 per cent with an average of 57 per cent. The compact brown clay in Section 6, which may have

been relatively undisturbed, had an average wet-bulk density of 1.41 g/cc and a porosity of 70 per cent.

Hole 51.1

Pleistocene-Pliocene diatom-radiolarian silty volcanic muds and sands from Hole 51.1 were recovered between 23 meters and 33 meters below the mudline. Their porosity ranged from 65 to 90 per cent(?) (1.15 to 1.60 g/cc), with an average of about 77 per cent (1.30 g/cc). The water content ranged from 51 to 57 per cent with an average of 55 per cent (see hole and core plots).

One and one-half meters of brown zeolitic clay (Cretaceous?) was also recovered between 120 meters and 122 meters below the mudline. Porosity, wet-bulk density, and water content measured on the sediment samples gave values of 70 per cent, 1.35 g/cc, and 52 per cent, respectively, while the GRAPE data obtained a 72 to 84 per cent porosity and a 1.35 to 1.43 g/cc wet-bulk density.

Sound Velocity

Hole 51.0

One core of Miocene zeolitic clays was recovered at Hole 51.0 from 114 to 123 meters below the mudline. Sound velocities averaged 1.51 km/sec, with a range from 1.48 to 1.55 km/sec. Part of the sediment is an "artificial drilling breccia" comprising compact fragments of clay in a very soft sloppy matrix. The lowermost section is a homogenous compact clay. There was not a distinct change in velocity at the breccia clay boundary as the porosity only varied about 10 per cent across it.

Hole 51.1

One core of clay with varying amounts of volcanic ash was recovered from 23 to 33 meters below the mudline in Hole 51.1. Sound velocities average 1.50 km/sec, with a range from 1.47 to 1.61 km/sec. The highest sound velocity of 1.61 km/sec is related to lower porosity and low penetrability.

Thermal Conductivity

Hole 51.0

One thermal conductivity measurement was made on Core 51.0-1, Section 4 in the "artificial drilling breccia" consisting of Miocene zeolite and diatom with ash-rich clays. The heat conductivity was 2.12×10^{-3} cal-°C^{-1} cm^{-1} sec^{-1}.

Hole 51.1

One thermal conductivity value of 2.07×10^{-3} cal-°C^{-1}cm^{-1}sec^{-1} was obtained in the Pleistocene ashey clay from Core 1, Section 4. It was recovered from a depth of 27 meters below the sediment surface.

Penetrometer

Hole 51.0

Penetrometer readings were taken on the "drilling breccia" between 114 and 120 meters below mudline. The hard compact Miocene clay clasts in the breccia had penetrometer values ranging from 32 to 85×10^{-1} millimeters, while the soft matrix ranged from 195 to 240×10^{-1} millimeters.

Hole 51.1

Sediment between 23 meters and 33 meters below mudline in Hole 51.1 was Pleistocene ashey clay with fossils. Penetrometer readings are usually quite low, but range from 43 to complete penetration. A few places gave high readings of about 220×10^{-1} millimeters although the sediment did not appear to have a different composition from the more compact material. Penetration irregularly decreased toward the bottom of the core.

Core 2, recovered between 121 and 123 meters below mudline, contained compact (Cretaceous?) dark brown zeolitic clay. Penetrometer readings ranged from 30 to 68×10^{-1} millimeters.

CONCLUSIONS

The Neogene brown clay sequence here is unusually thick, a local condition related to topography. The cores suggest that all or nearly all of this thick sequence is Neogene, with the Pleistocene extending at least to a depth of 32 meters and the Miocene to a depth of 124 meters. Such depositional rates seem much too high for abyssal brown clays. Furthermore, the apparent absence or near-absence of the Paleogene in this deep-water setting appears anomalous, and the clays recovered were exceedingly brecciated and disturbed. The authors are not wholly convinced that these are the depths at which these sediments actually occur and suspect that they may represent slumps from higher in the hole.

The Cretaceous is represented by cherts and by foraminiferal ooze of Santonian and Cenomanian ages. These sediments represent the top of the upper opaque acoustic unit in this area. Thus, the top of the upper opaque unit here is roughly as old as its base at Site 45.

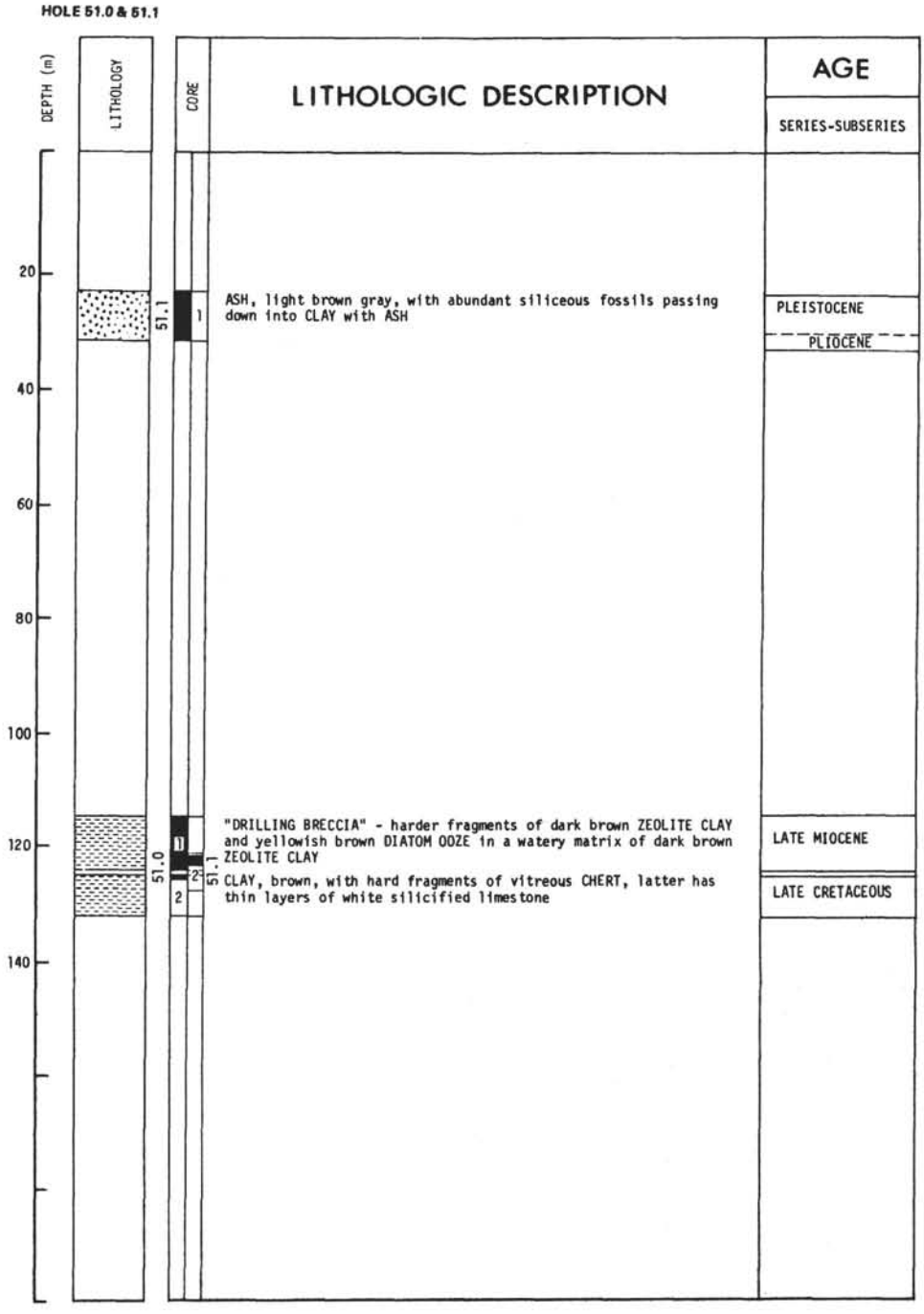

Figure 4. *Summary of lithology in Hole 51.0 and 51.1.*

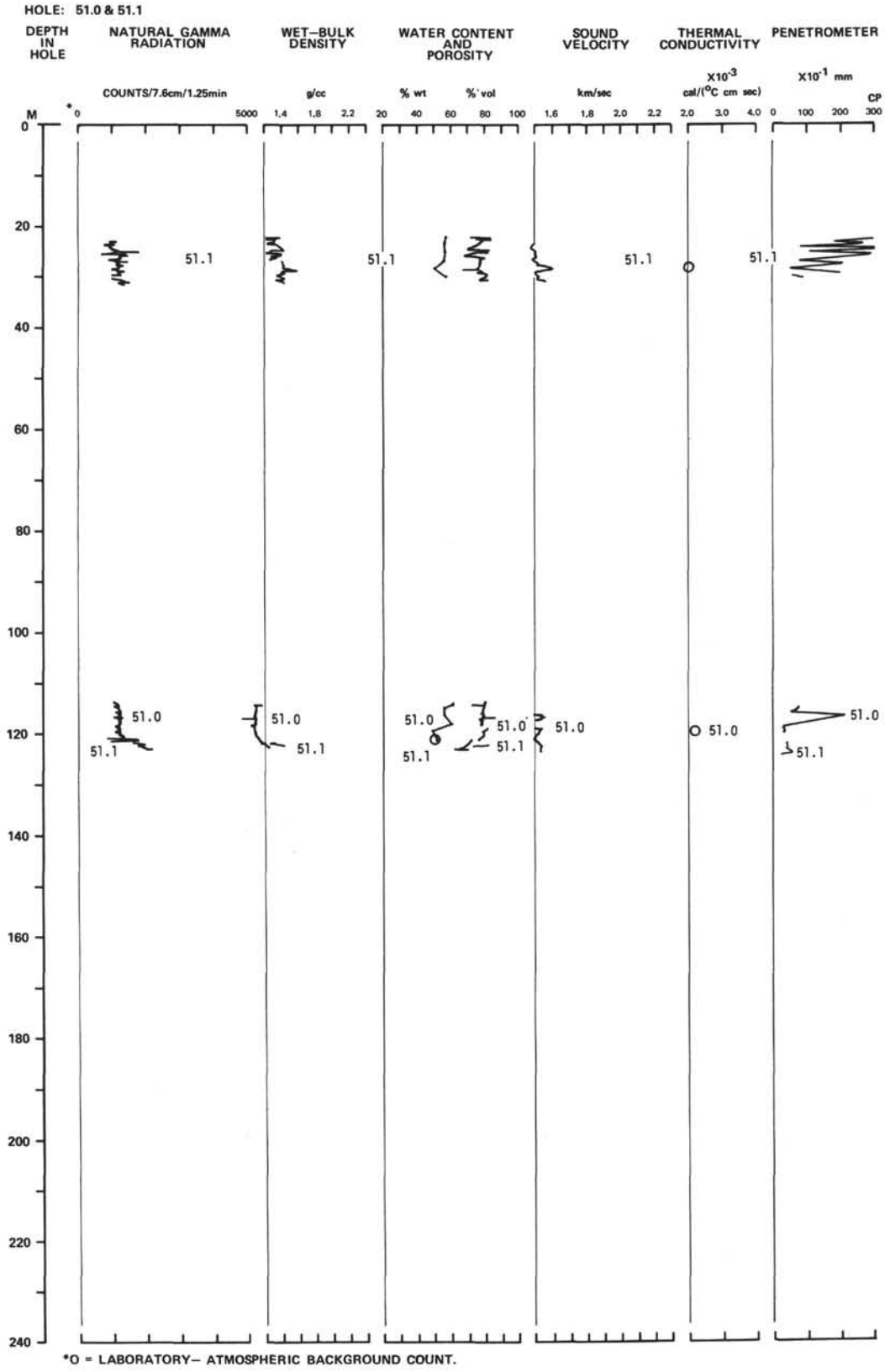

Figure 5. *Summary of physical properties in Hole 51.0 and 51.1.*

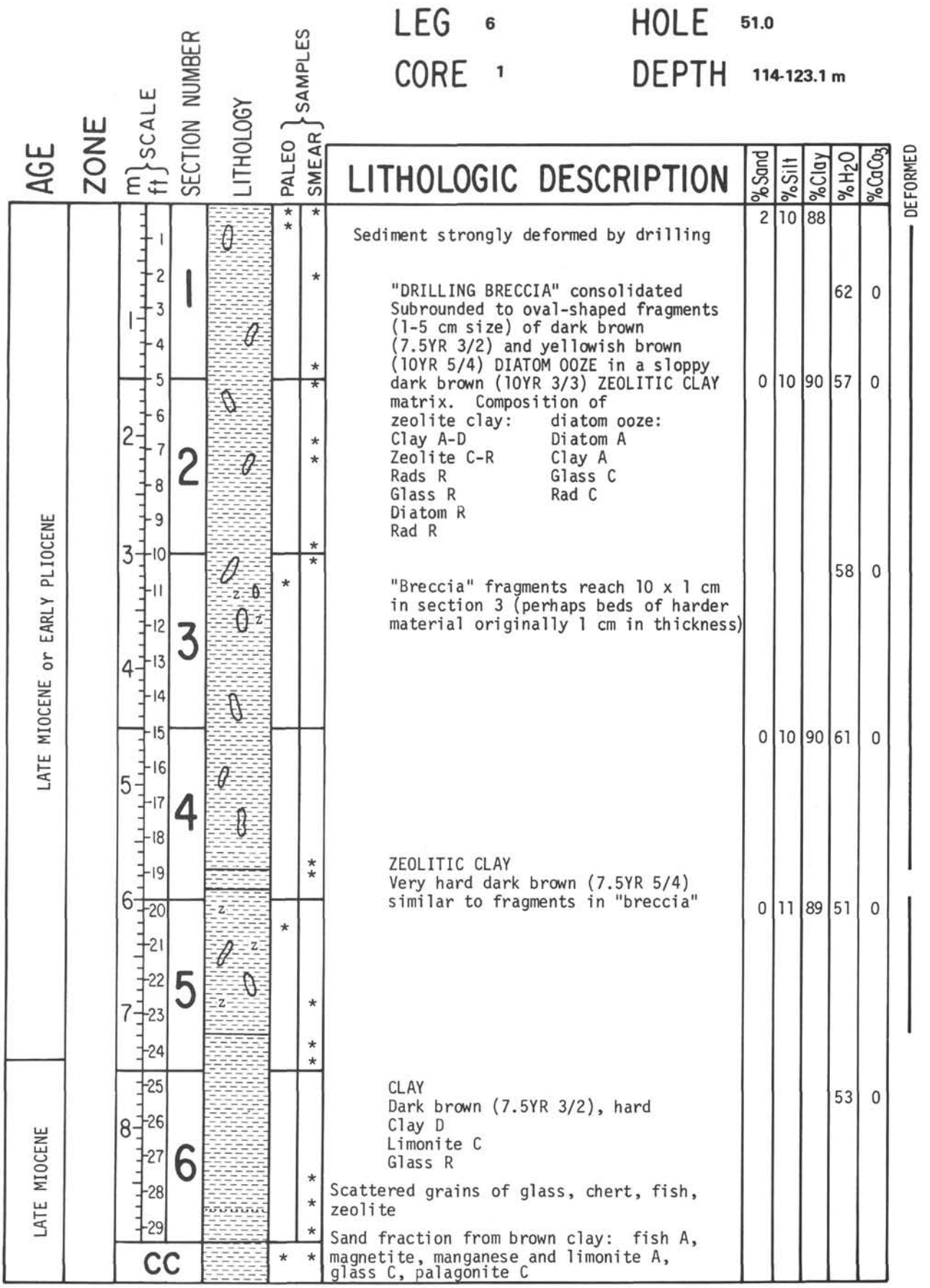

Figure 6. *Summary of lithology in Hole 51.0 Core 1.*

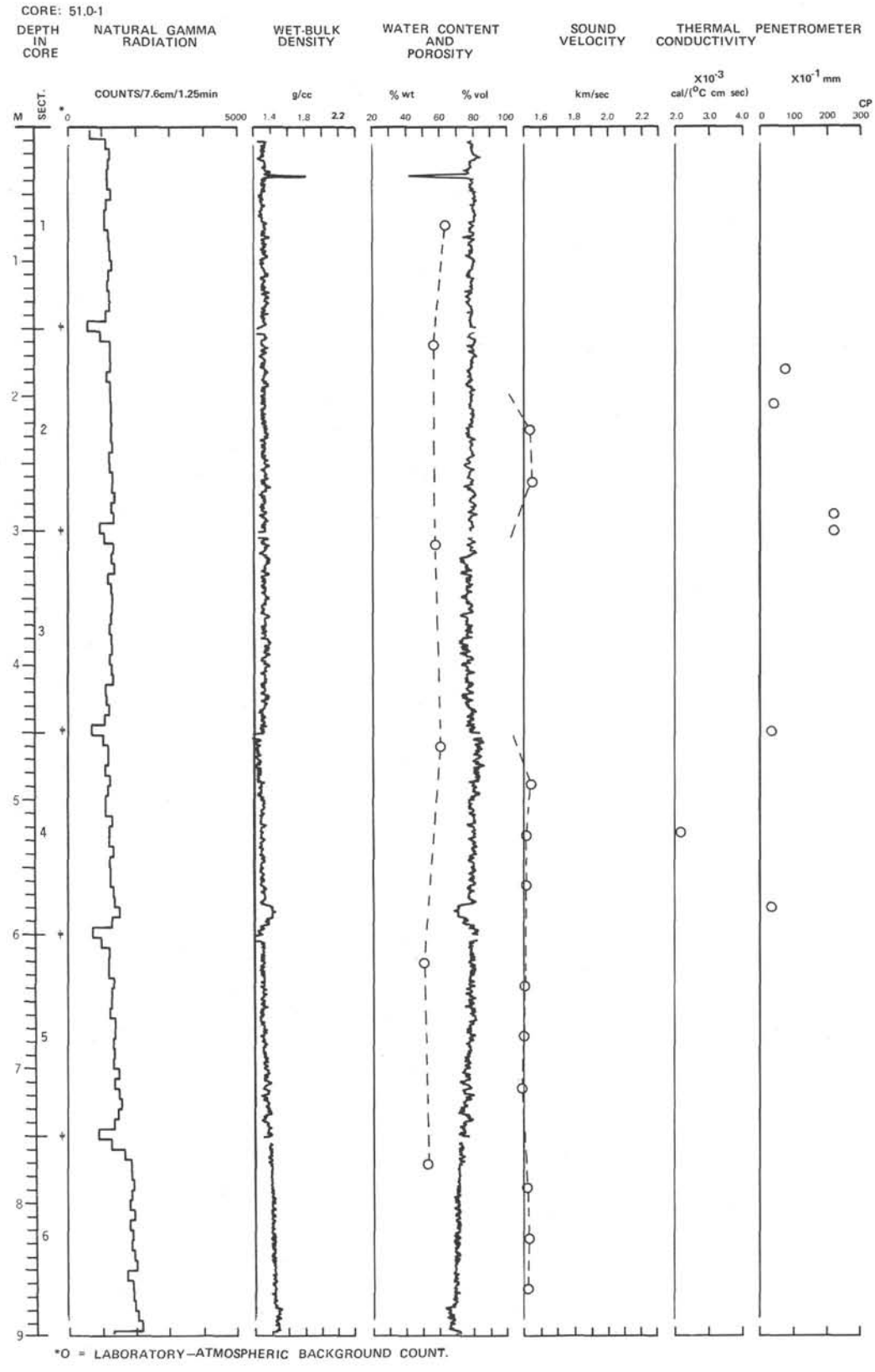

Figure 7. *Summary of physical properties in Hole 51.0 Core 1.*

LEG 6 HOLE 51.0

CORE 1 DEPTH 114-123.1 m

FORAMINIFERA	NANNOPLANKTON	RADIOLARIA
None.	None.	Radiolaria are rare to absent in this core. Most of the core contains species in the ranges of the *Spongaster pentas* (lower Pliocene) and *Stichocorys peregrina* (upper Miocene) Zones. The core catcher sample contains *Stichocorys delmontense* indicating an older age probably equivalent to the middle upper Miocene *Ommatartus penultimus* Zone. Also in the core catcher are poorly preserved Cretaceous species. TOP: *Stichocorys peregrina*, *Eucyrtidium calvertense*, *Druppatractus acquilonius*, *Stylatractus universus*, and *Lithopera bacca*. BOTTOM: *Eucyrtidium delmontense* and *Druppatractus acquilonius*. Spiny-ringed saturnalids.

Figure 8. *Summary of biostratigraphy in Hole 51.0 Core 1.*

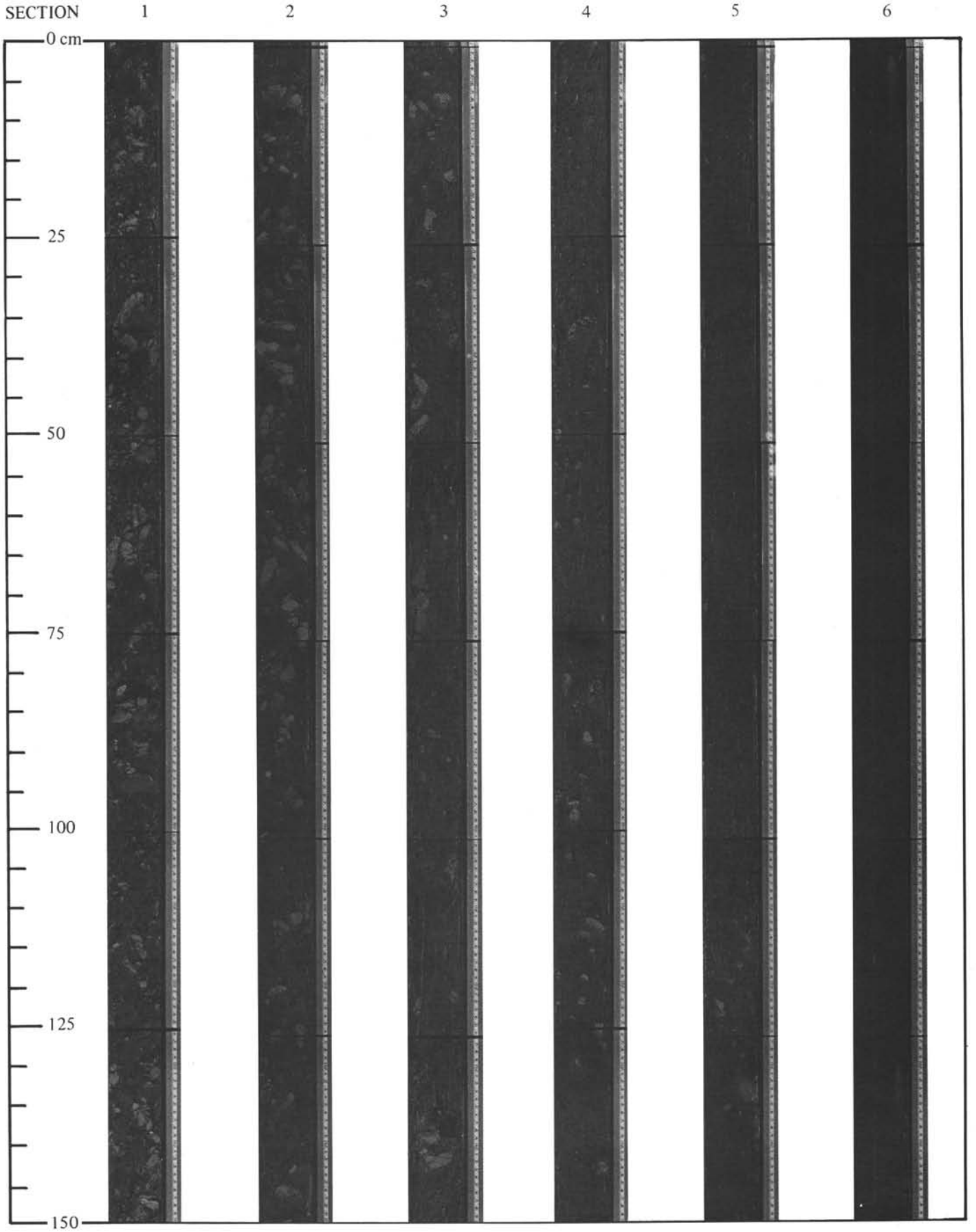

Plate 1. *Photographs of Hole 51.0 Core 1.*

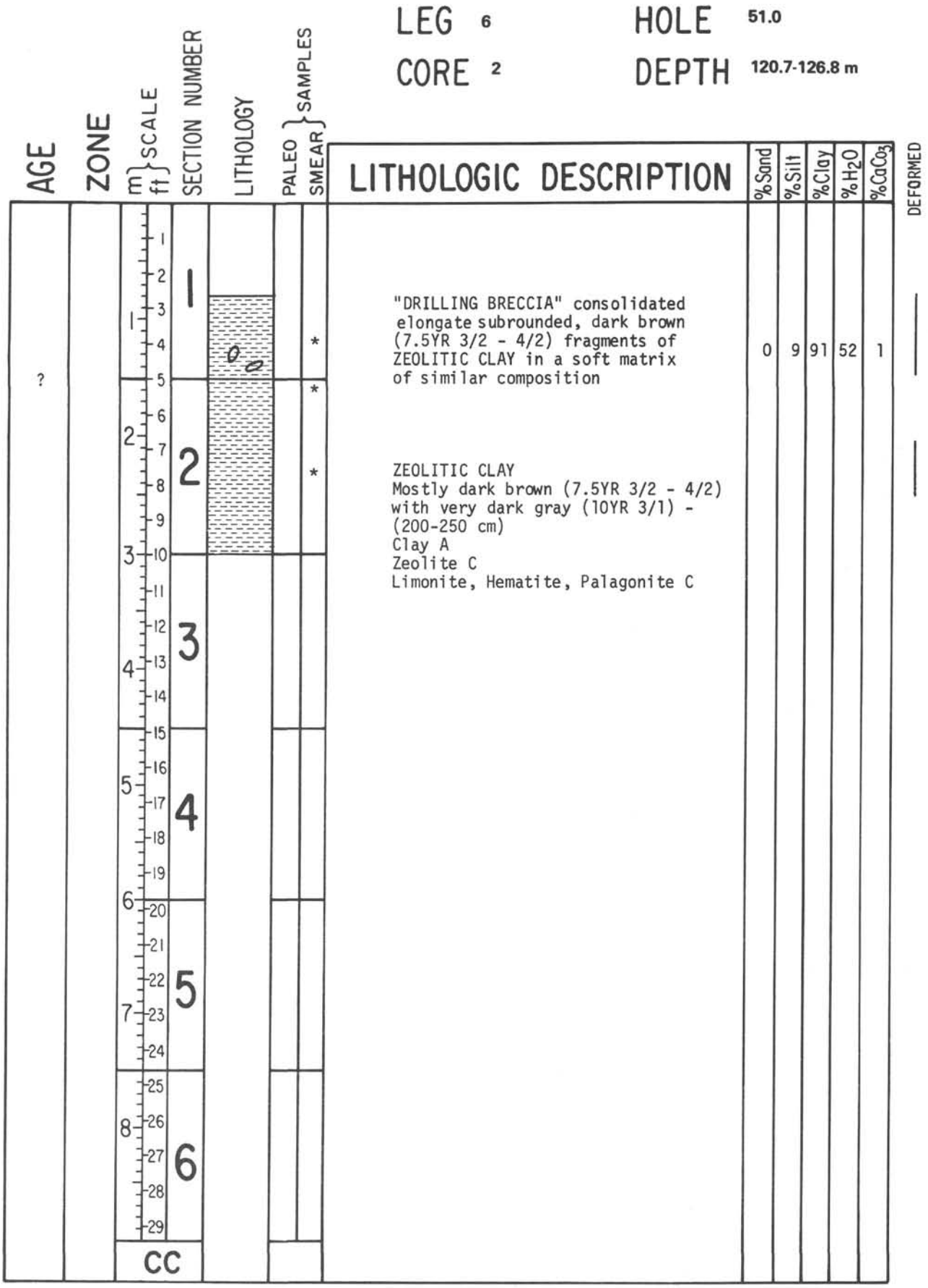

Figure 9. *Summary of lithology in Hole 51.0 Core 2.*

LEG 6 HOLE 51.0

CORE 2 DEPTH 123.7-132.0 m

FORAMINIFERA	NANNOPLANKTON	RADIOLARIA
None.	None.	The core catcher sample contains poorly preserved (quartz infilled) radiolarians of probable Cretaceous age with rare Tertiary species. The Cretaceous species are also present in chert chips. CORE CATCHER: *"Dictyomitra"* spp., *Dictyomitra sagitifera (?)*, and *Pseudoaulophacus (?) sp.*

Figure 10. *Summary of biostratigraphy in Hole 51.0 Core 2.*

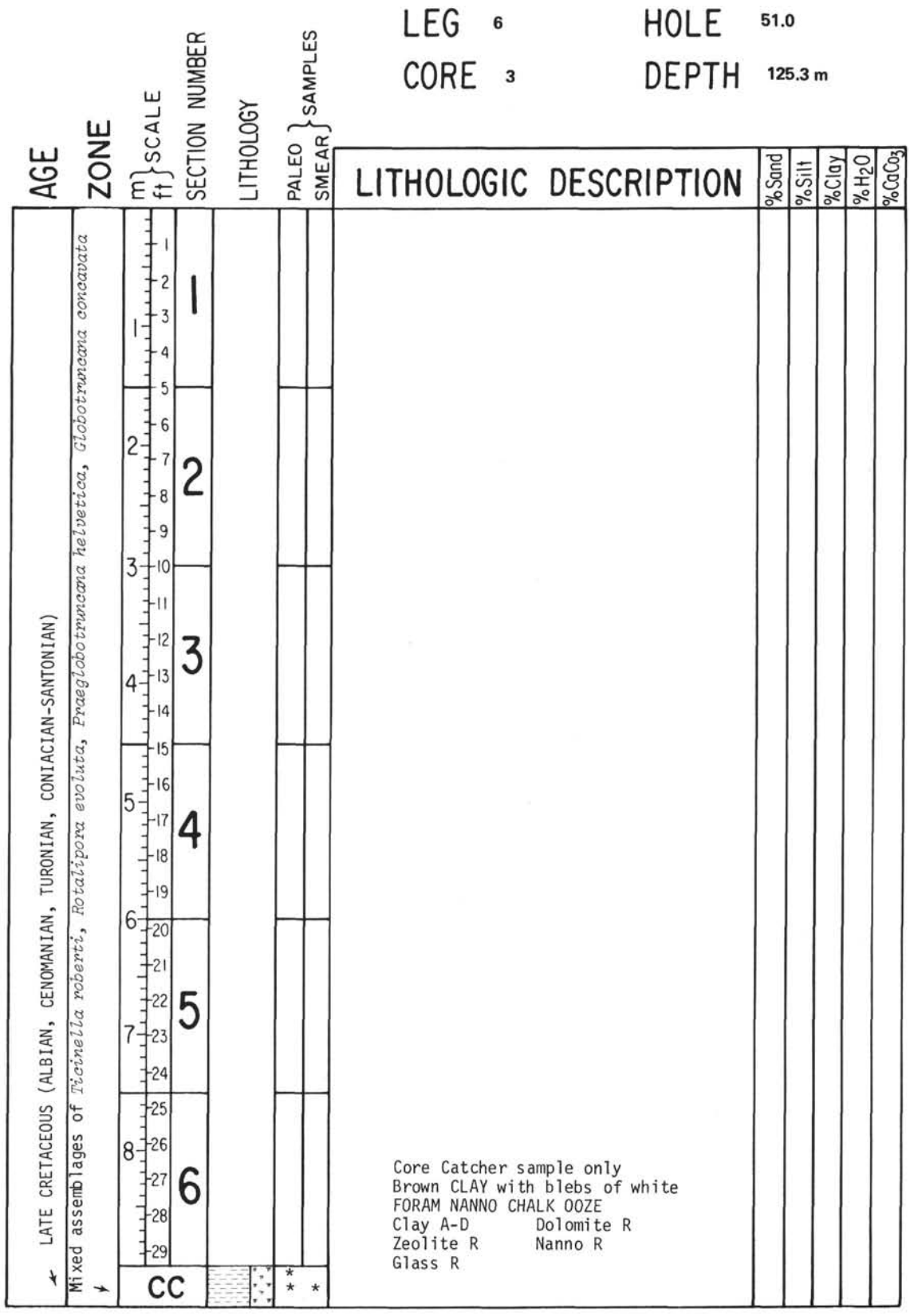

Figure 11. *Summary of lithology in Hole 51.0 Core 3.*

LEG 6 HOLE 51.0

CORE 3 DEPTH 125.3 m

FORAMINIFERA	NANNOPLANKTON	RADIOLARIA
A very small amount of sediment containing a mixed assemblage of Upper Albian, Cenomanian, Turonian and Coniacian-lower Santonian species was scraped from an otherwise empty core-liner. Most of the planktonic foraminifera (>75%) are part of the *Globotruncana concavata* Zone; also represented are parts of the *Tricinella roberti*, *Rotalipora evoluta* and *Praeglobotruncana helvetica* Zones. Albina: *Ticinella roberti*, *T. primula*, *Biticinella breggiensis*. Cenomanian: *Rotalipora evoluta*, *Hedbergella trochoidea*, *H. portsdownensis*, *H. amabilis*, *Clavihedbergella moremani*, *C. simplex*. Turonian: *Praeglobotruncana helvetica*, *Globotruncana sigali*. Coniacian-lower Santonian: *Globotruncana concavata*, *G. fornicata*, *G. renzi*, *G. pseudolinneiana*, *G. coronata*, *Archaeoglobigerina* sp. *Heterohelix reussi*, *Hastigerinoides alexanderi*, *Gublerina decoratissima*.	The core-catcher sample contains an assemblage of Upper Cretaceous nannoplankton. Species present include *Apertapetra gronosa*, *Chiastozygus disgregatus*, *Cretarhabdus crenulatus*, *Cribrosphaera ehrenbergi*, *Cylindralithus* sp., *Eiffellithus augustus*, *E. eximius*, *E. turriseiffeli*, *Gartnerago concavum*, *Microrhabdulus decoratus*, *Micula* sp. cf. *M. decussata*, *Prediscosphaera cretacea*, *Rucinolithus hayi*, *Vagalapilla octoradiata*, *Watznaueria actinosa*, *W. barnesae*, *W. coronata*, and *Zygodiscus phacelosus*. This assemblage is considered upper Turonian to lower Santonian.	No Radiolaria.

Figure 12. *Summary of biostratigraphy in Hole 51.0 Core 3.*

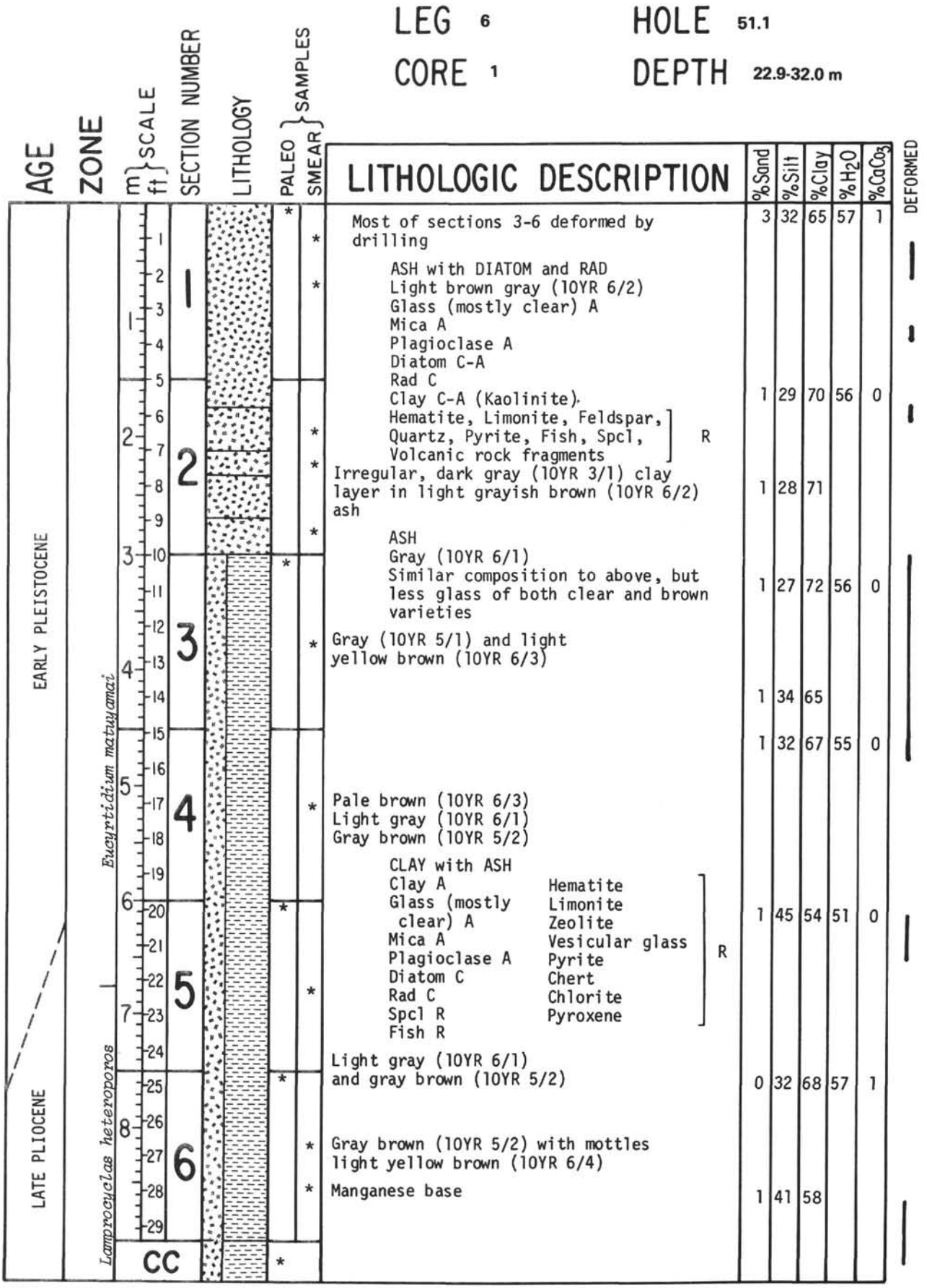

Figure 13. *Summary of lithology in Hole 51.1 Core 1.*

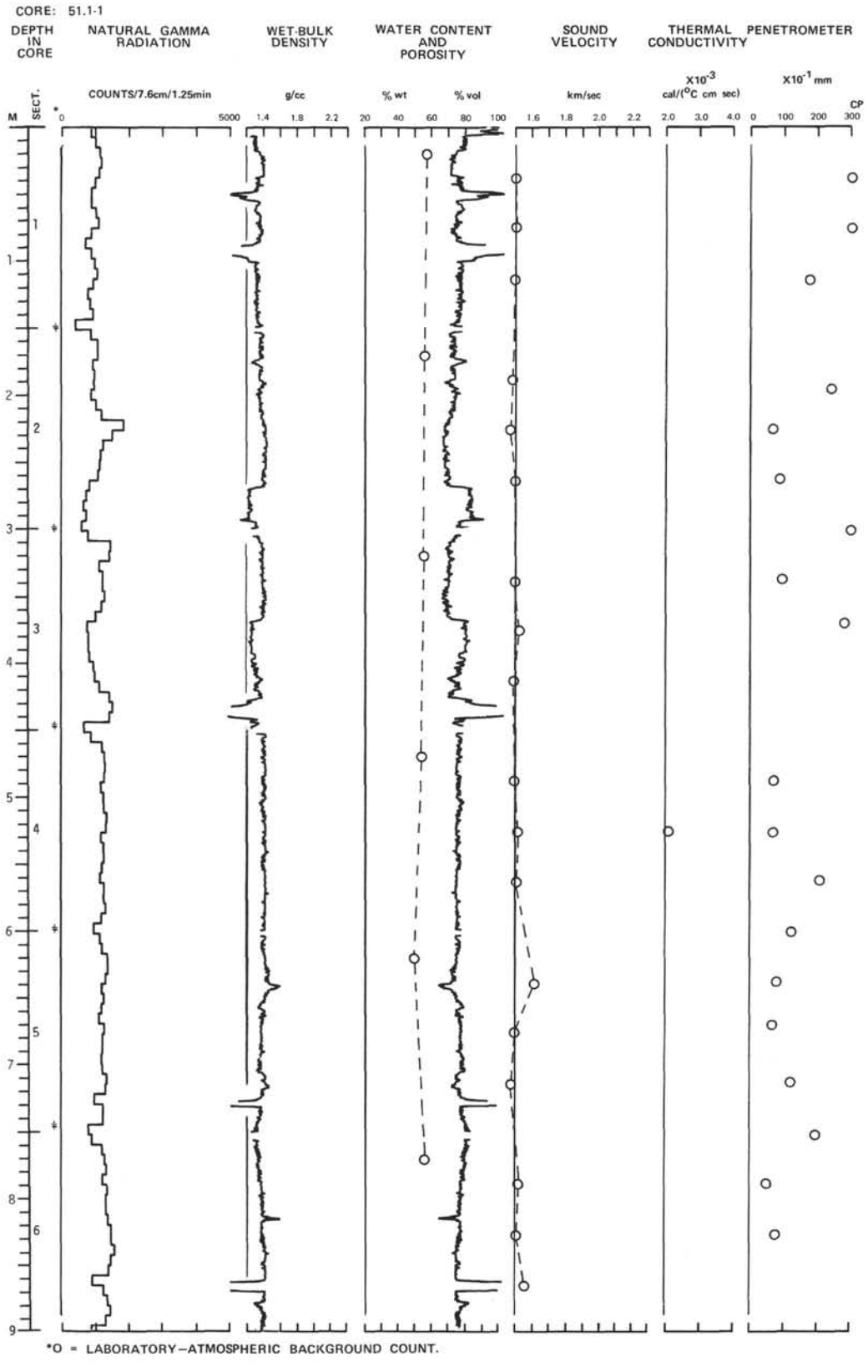

Figure 14. *Summary of physical properties in Hole 51.1 Core 1.*

LEG 6 HOLE 51.1

CORE 1 DEPTH 22.9-32.0 m

FORAMINIFERA	NANNOPLANKTON	RADIOLARIA
None.	None.	The upper part of this core contains species belonging to the lower Pleistocene *Eucyrtidium matuyamai* Zone. The lower part is in the upper Pliocene *Lamprocyclas heteroporos* Zone. TOP: *Eucyrtidium matuyamai*, *E. tumidulum*, *E. calvertense*, *Druppatractus acquilonius*, and *Stylatractus universus*. BOTTOM: *Eucyrtidium calvertense*, *E. tumidulum*, *Lamprocyclas heteroporos*, *Druppatractus acquilonius*, and *Stylatractus universus*.

Figure 15. *Summary of biostratigraphy in Hole 51.1 Core 1.*

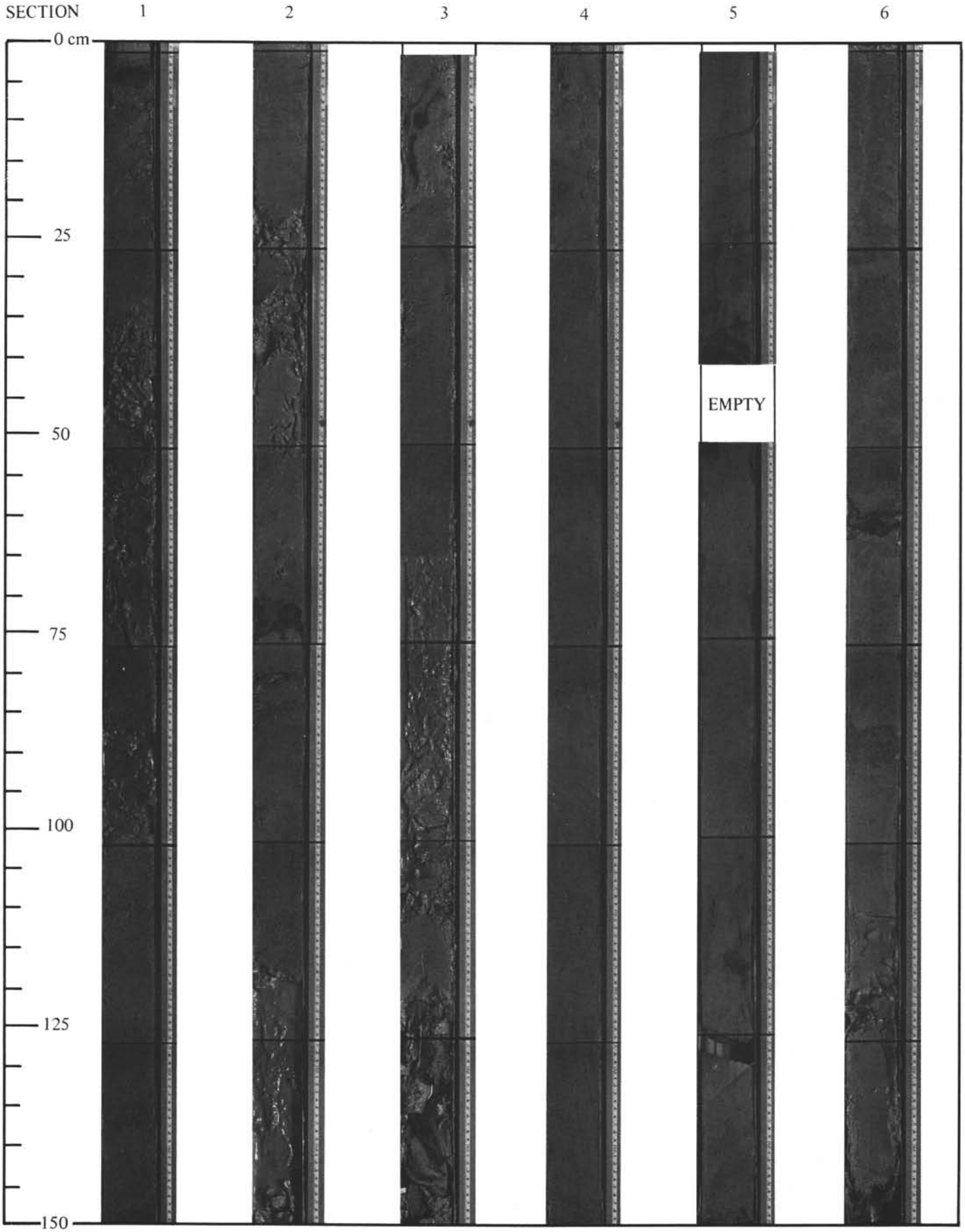

Plate 2. *Photographs of Hole 51.1 Core 1.*

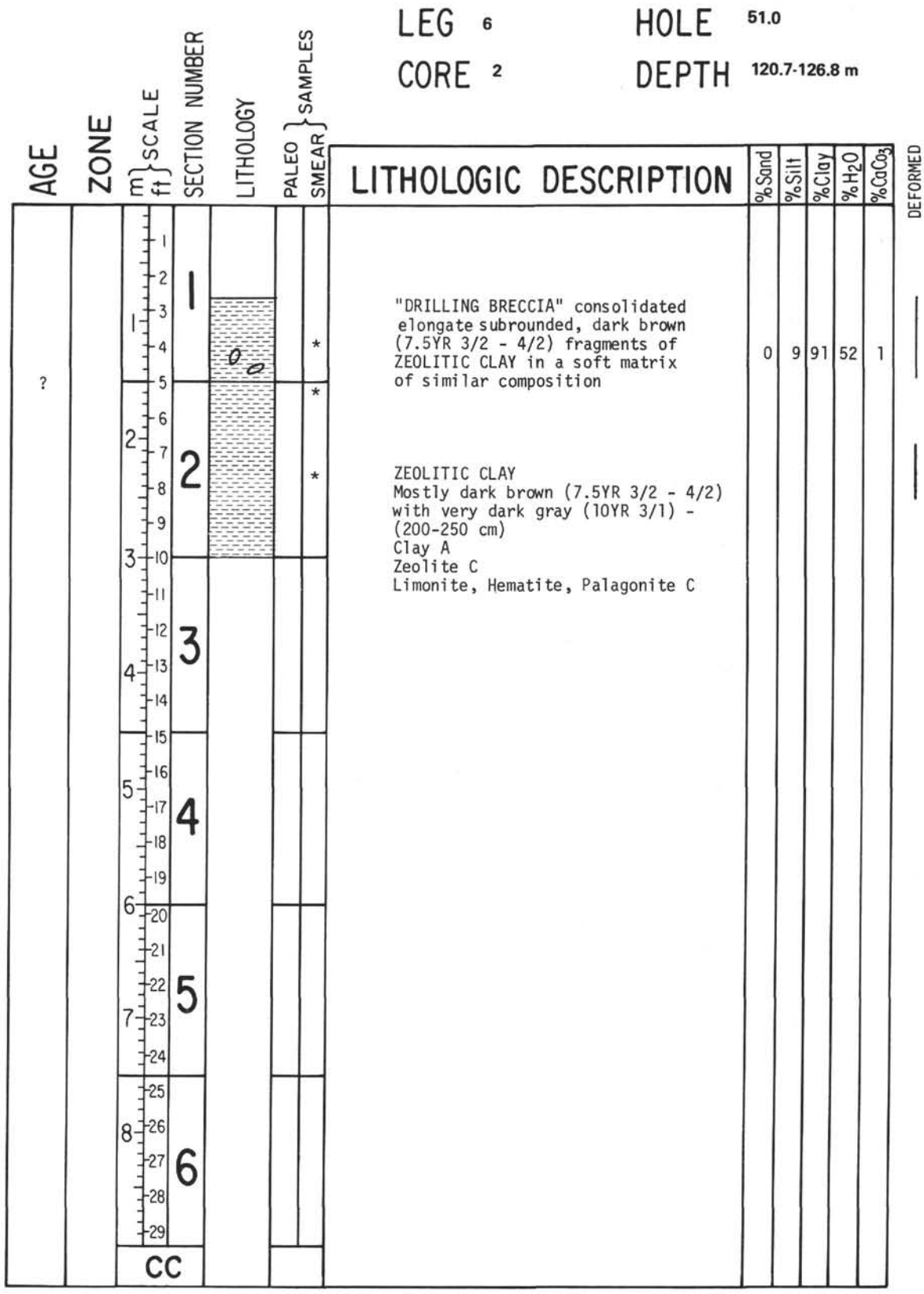

Figure 16. *Summary of lithology in Hole 51.0 Core 2.*

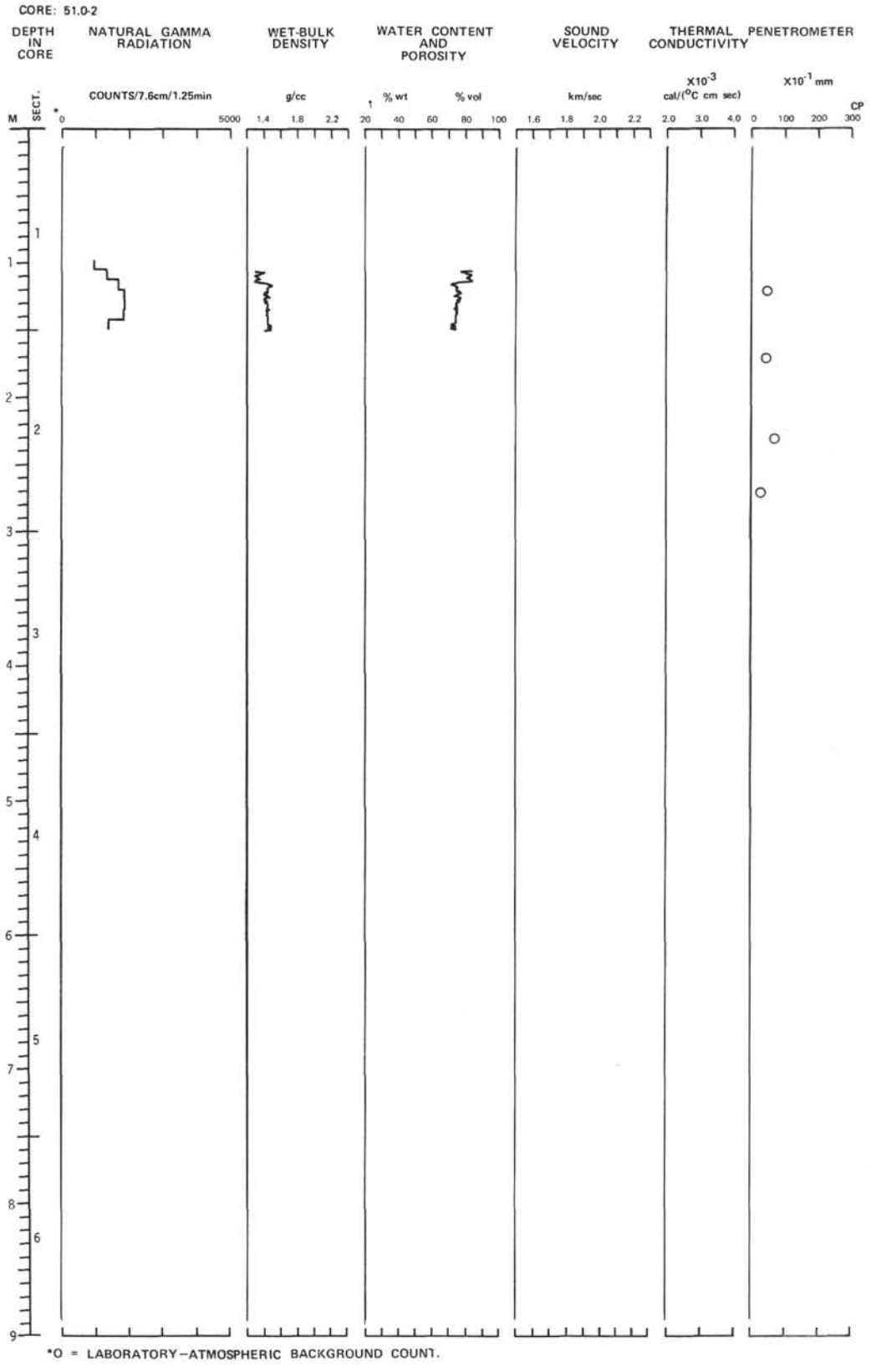

Figure 17. *Summary of physical properties in Hole 51.1 Core 2.*

LEG 6 HOLE 51.1

CORE 2 DEPTH 120.7-126.8 m

FORAMINIFERA	NANNOPLANKTON	RADIOLARIA
None.	None.	No Radiolaria.

Figure 18. *Summary of biostratigraphy in Hole 51.1 Core 2.*

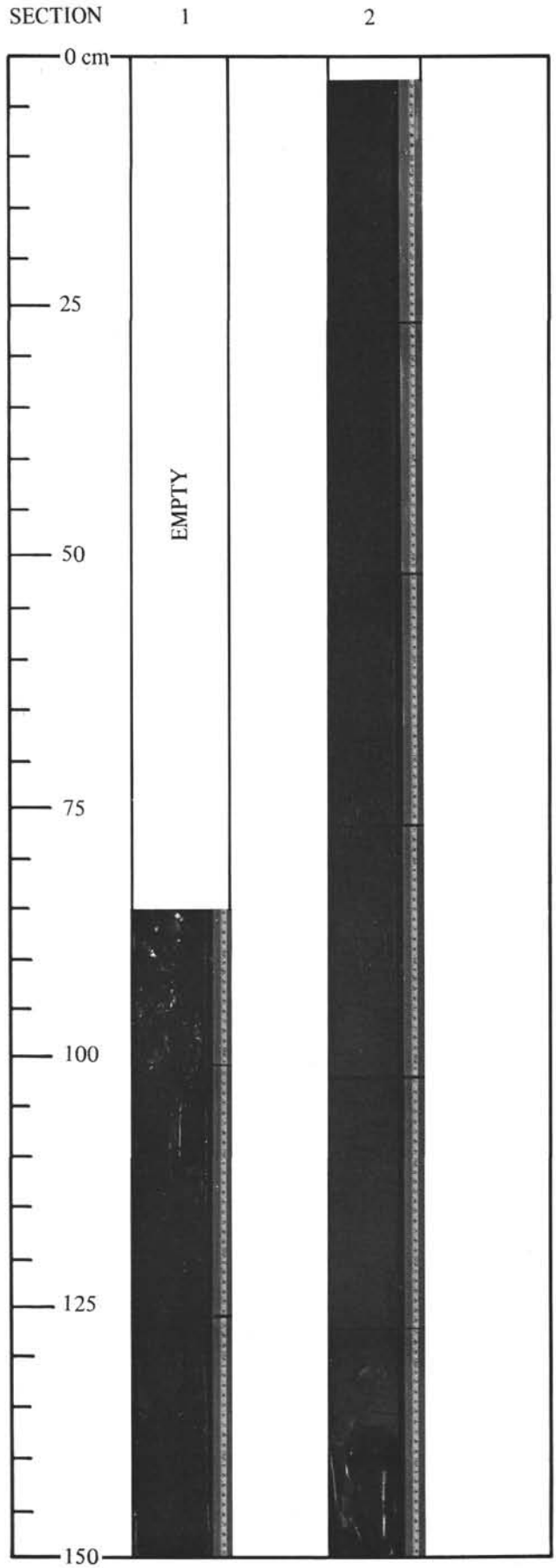

Plate 3. *Photographs of Hole 51.1 Core 2.*