9. SITE 118

The Shipboard Scientific Party[1]
With Additional Reports From
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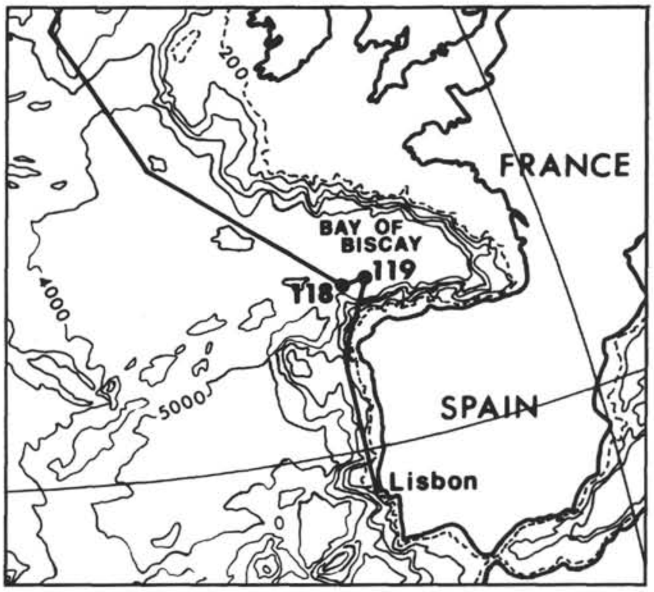
Location: Western Biscay Abyssal Plain.

Position: 45° 02.65'N 9°00.63'W; (satellite navigation).

Depth of water: 4901 meters (corrected).

Total penetration: 761 meters.



SITE BACKGROUND AND OBJECTIVES

The Bay of Biscay (Golfe de Gascogne) is bounded on the northeast side by the rather broad continental shelf off France and the even broader shelf southwest of the British Isles across which sediments have been transported from the Irish Sea, and from the North Sea through the English Channel. On the southern side of the bay off Spain, the continental shelf is narrow and the continental slope is extremely steep.

The floor of the Bay of Biscay slopes gently to the south and west, the result of a supply of terrigenous material from the northeast through numerous submarine canyons and especially from the Cap Breton Canyon in the eastern corner. The continental rise is well developed at the foot of the French slope and merges gradually into the Biscay abyssal plain at a depth of between 4500 and 4800 meters. The abyssal plain dominates the topography of the bay. It abuts the foot of the Spanish continental slope, and grades southwestward to the interplain channel in Theta Gap (Laughton 1960, 1968) through which the sediments pour into the Iberian abyssal plain. The upper sediments of the Biscay abyssal plain are therefore the result of passing turbidity currents partly erosional, partly depositional depending on their speed.

At the western end of the Bay of Biscay, there is a group of seamounts, the Biscay Seamounts, rising 1000 meters above the abyssal plain and elongated approximately E-W. They are linked to the northwestern end of a broad swell stretching across the ocean from near the Azores (The Azores-Biscay Rise). Three other small seamounts emerge above the abyssal plain: (a) Cantabria Seamount elongated ENE-WSW, surveyed by *Discovery*-11 and *Charcot* (Vanney 1967); (b) Gascony Seamount elongated ESE-WNW, surveyed by *Discovery*-11; and, (c) "3270 m" Seamount at the foot of the Asturian slope further east.

Seismic reflection studies in Biscay have been made by the National Institute of Oceanography and Cambridge University in the United Kingdom, the Lamont-Doherty Geological Observatory in the U.S.A., the Vening Meinesz Laboratory in Holland, and by CNEXO and the Institute Francais du Pétrole in France. The later profiles by CNEXO and IFP have been used a Flexotir seismic system which has far greater penetration than the earlier sparker and airgun systems. On these profiles, some of which cross the whole

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Bay of Biscay and also cross both Cantabria and Gascony Seamounts, reflections can often be seen to 4 seconds (2 way) below the seabed.

Deeper crustal studies of Biscay have been made by Bacon, Gray and Matthews (1969), using gravity and seismic refraction techniques. They demonstrate that the bay has an oceanic crust (of velocity 6.6 km/sec and thickness 7 kilometers) and show the existence of deep sedimentary basins at the foot of the continental slopes to the north and the south. They conclude that the evidence supports the theory of formation of Biscay by the rotation of Spain away from France as proposed by Bullard, Everett and Smith (1965) rather than by vertical movements as proposed by Cholet *et al.* (1968).

Further evidence for the rotation of Spain theory comes from the magnetic lineations in Biscay (Matthews and Williams, 1968; Le Pichon, 1969; Le Borgne and Le Mouël, 1970), which radiate from the southeastern corner. The trend of these anomalies is perpendicular to those of the mid-Atlantic Ridge lineation which are found just west of the bay (Williams and McKenzie 1971). The central positive anomaly is believed to have been the latest to have been produced before the rotation of Spain stopped. There is some evidence of transform faults crossing this magnetic pattern.

Evidence for the rotation of Spain comes also from paleomagnetic data. Girdler (1965) suggested 38 degrees anticlockwise since the Permian, Van der Voo (1969) gives 35 degrees between Late Triassic and Late Cretaceous, whereas, Watkins and Richardson (1968) require 20 degrees since the Eocene. However the latter data is contested by Van der Voo (1968) and Van der Voo and Zijerveld (1971). Jones and Ewing (1969) combine the data from the few samples of Mesozoic and Tertiary sediments that have been obtained, with seismic reflection data and conclude that a large part of Biscay was in existence in Late Cretaceous times and that the Tertiary opening is limited to a maximum of 12 degrees.

However, more recent French studies (Montadert *et al.*, 1971), which take into account the extensive exploration of the Aquitaine basin and its offshore extension, the Armorican continental margin of France and the Asturian margin of Spain, as well the IFP and CNEXO profiles in the bay, question the simple model of angular opening and favor an origin of the bay by vertical sinking of a continental crust. Montadert *et al* conclude however that more data and analysis are necessary to unravel its complex history and to resolve these fundamentally different interpretations. A full account of the existing data is presented by Debysen, Le Pichon, and Montadert (1971).

It is against this background of rapidly increasing data about Biscay and an uncertainty about its interpretation that sites were chosen to drill two holes during Leg 12. The thick sediments over the whole bay, especially at the margins, limited the choice of drill sites. A preliminary analysis of the French profiles indicated the following sedimentary sequences in the abyssal plain areas (Montadert *et al.*, 1971).

(A more recent analysis of the seismic reflection data in Biscay has been made by Sibuet, Pautot and Le Pichon 1971) of CNEXO, in which the sedimentary layers have been labeled A, B, C and D. In the following analysis these labels have been indicated in parentheses after those of Montadert *et al.* (1971). See also Figure 5.)

(a) Upper horizontally stratified sediments (R) (Sibuet *et al.* A and Upper B). These are unstructured, and vary in thickness up to 2000 meters. They are believed to be turbidites of Miocene to Recent age. In the southeast they can be divided by a continuous strong reflector (here called the "mid-R" reflector) into an upper zone (800 to 1000 meters thick) (Sibuet *et al.* A) and a lower zone (900 to 1000 meters thick) (Sibuet *et al.*, Upper B). The "upper turbidites", "homogeneous zone" and "lower turbidites" of Jones and Ewing (1969) are found in the upper 500 meters of formation R. The formation pinches out against the seamounts rising out of the plain.

(b) Formations 2 and 3 (Sibuet *et al.* Lower B and C). These lie below R sometimes conformably and sometimes unconformably. They are relatively unstructured but are sometimes tilted, and they vary in thickness from 0 to 3000 meters. The deposition of formations 2 and 3 appears to have been influenced by an E-W rise in formation 4 extending the length of the bay. Their age is suggested to be Upper Cretaceous or Lower Tertiary to Miocene.

(c) Formation 4 (Sibuet *et al.* d). This is separated from formations 2 and 3 by a major unconformity. It is extremely irregular comprising multiple diffraction hyperbolae, suggesting considerable tectonic disturbance. It has been tentatively ascribed by Montadert *et al.* to Lower Cretaceous or older sediments. However it is not clear that layer 4 is not in fact part of an extremely irregular igneous basement structure, at least at the western end of the bay. No obvious igneous basement can be seen below formation 4 in spite of the high penetrating power of the system.

The principle objective at Site 118 was to sample formation 4 in a region where it was within reach of the drill. Initially, two sites had been chosen for this purpose, both based on single profiles obtained by *Charcot*-9 with a Flexotir system. At both sites formation 4 shoaled to less than 1 second below the seabed, formations 2 and 3 had almost pinched out, whereas formation R remained approximately constant in thickness. The southernmost site was chosen since the thickness of turbidites above formation 4 was less, and some difficulty was anticipated in drilling through the incoherent sands that were expected to be encountered there. It was hoped at this site to penetrate through formation 4 to basement, and also to determine the age of the prominent horizons associated with formation R.

In summary, the objectives were:

(a) To sample and date formation 4.

(b) To sample basement.

(c) To date prominent reflecting horizons (mid-R reflector) in the turbidite sequence.

SURVEY DATA

The approach to the site, chosen on the basis of the *Charcot*-9 profile, was made along the same profile from the west insofar as our celestial navigation would allow (Figures 1 and 2). After reaching the *Charcot* track, we turned east for 15 miles and identified on our records the same features as on the *Charcot* record, excepting that the

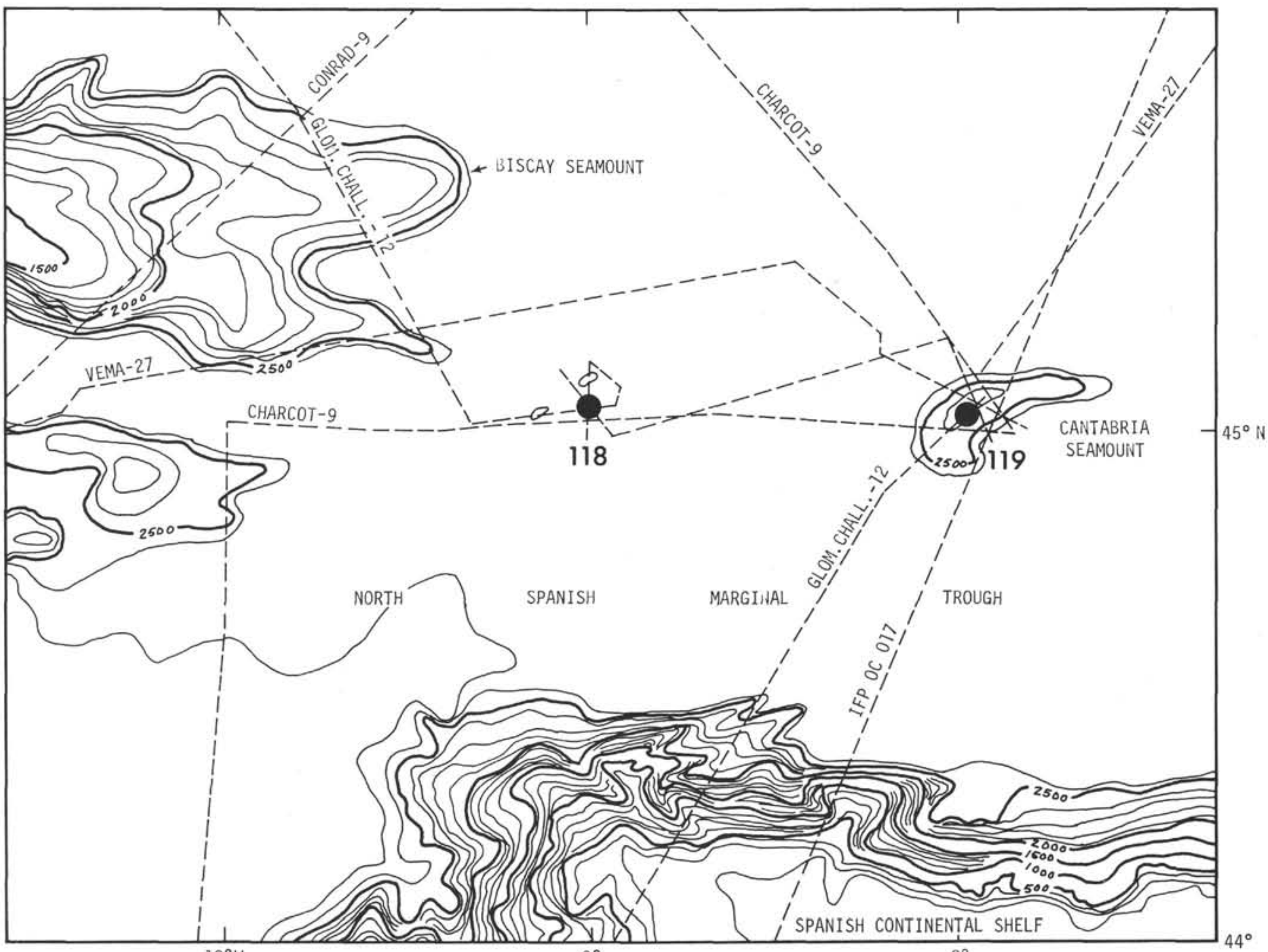

Figure 1. *Bathymetry of southwestern end of Biscay abyssal plain with tracks of seismic reflection profiles. Depths in corrected fathoms, (Matthews, 1939) contour interval 100 fathoms.*

subbottom high on our record broke surface of the abyssal plain to form a small hill (compare Figures 3(a) and 3(c)).

After crossing the ridge, we were forced by other ship traffic to make a complete loop, before heading north and northwest to make another N-S traverse of the site which showed a substantial hill 150 meters high (Figure 3(b)) which was evidently part of a ridge running ENE-WSW. The site chosen for Hole 118 was on the south side of this ridge and we doubled back to it, retrieved the gear and laid the beacon.

After completion of the hole, another crossing was made of the ridge from the northwest and over the beacon, carrying on for 4 miles before heading for the next site.

The three sets of tracks showed that there was a substantial buried ridge with strike ENE-WSW, the top of which came above the level of the surrounding abyssal plain in two places. The third crossing between, however, showed very much more subdued relief. Both north and south of the ridge, a strong reflector at 0.5 second was identified in the turbidite sequence (formation R) which corresponds to the mid-R reflector of the *Charcot* profile. The contact between mid-R reflector and the buried ridge is shown in Figure 2.

The boundary between formation R and formations 2 and 3 was not uniquely identified on the *Glomar Challenger* records. Accepting the identification on the *Charcot* record, and following horizons at the equivalent depth on the *Challenger* records, the edge of formations 2 and 3 pinching out against the buried ridge is plotted in Figure 2. It will be seen that in Hole 118 the seismic evidence suggested that formations 2 and 3 were not encountered.

At this site, numerous reflectors can be seen in the top 0.3 second, then a relatively transparent layer to about 0.5 second, followed by the strong mid-R reflector which lies above another series of reflectors. A weak reflector at 0.48 second and a stronger one at 0.51 second can be correlated with patches of hard drilling at 400 and 430 meters, giving a mean velocity between seabed and reflectors of 1.67 km/sec. These reflectors arise, apparently, from the top of coarse turbidite layers from which a sample of sandstone was recovered at 450 meters.

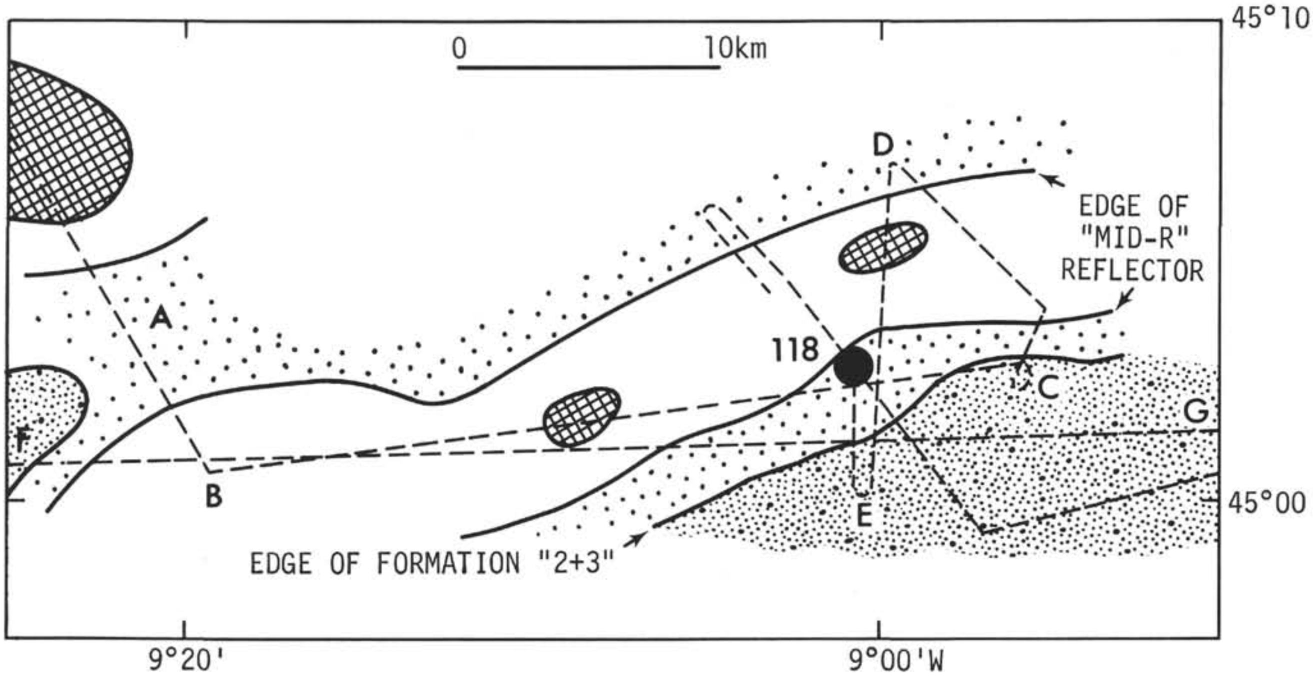

Figure 2. *Subbottom structures near Site 118. Cross-hachured areas stand above abyssal plain. Heavy stipple shows limits of formation 2 and 3, and light stipple shows the limit of sediments below mid–R reflector. Sections ABC, DE, and FG are shown in Figures 3a, 3b, and 4.*

Below this the reflections are very patchy near the site. The up-bowing of the mid-R reflectors, and the absence of deeper reflectors, suggest that a buried high lies beneath. It is not possible to define specifically a reflection from the high nor to define basement. The concept of a formation 4 mantling the basement with a thickness of 0.4 second from an annotated *Charcot* record cannot be sustained on the basis of the *Glomar Challenger* record. The *Charcot* record crosses the ridge at a very oblique angle and thus many side echoes are therefore possible from the ridge which could give the appearance of distorted layer mantling basement. The stratigraphic unconformity found from drilling at about 680 meters cannot be seen on the records. However it is possible that the boundary between formation R and formations 2 and 3 penetrates valleys in the buried ridge but cannot be detected on the seismic records. The depth of the unconformity at 680 meters would correspond to 0.82 second (2 way) at 1.67 km/sec., which is consistent with the depth of this boundary close to Site 118 on the basis of the *Charcot* record (Figure 4). The considerable steepness of the N-S section of the ridge makes any exact correlation of reflections from "basement" with the sampled depth of 760 meters impossible. With reasonable velocities, it should be shallower than 0.9 second on the reflection record.

DRILLING OPERATIONS

The beacon was dropped at 0430 hours on July 29th in 4901 meters of water. A Smith 3-cone tungsten carbide insert bit was used beneath 9 drill collars and 3 bumper-subs, the bottom hole assembly weighting 40,000 pounds.

The bottom was reached at 1800 hours, with the drill string within 2 meters of the depth given by the echo sounder. We drilled down to 100 meters for the first core of gray coccolith ooze with turbidite silts. Cores 1, 2 and 3 at 100-meter intervals, and 4 at 350 meters depth were cut without circulation. Drilling was easy and fast, although core recovery in 3 and 4 was only 30 per cent.

Just before Core 5 at 399 meters, drilling became slightly harder, eased during the top half of 5 and hardened up during the bottom half. At 425 meters, a hard layer of about 12 meters was encountered. This is probably a cemented sandstone, similar to ones sampled in Core 6, and may be responsible for the major reflector seen on the seismic profile at about 0.50 second.

A number of such hard layers were encountered during the next 200 meters, and the cores at 50-meter intervals showed them to be very hard cemented calcareous sandstones. These cores had to be cut with pump circulation of 10 to 20 s.p.m., thereby washing out much of the soft material. Recovery was about 1 meter out of 9 meters cut. The coccolith clays were also hard and tended to plug the core barrel without circulation.

Below 630 meters, drilling became generally easier and sandstones were no longer sampled in the cores. Core 11 at 650 meters gave a gray clay.

The time interval between Cores 10 and 11, 50 meters apart had risen to 6.5 hours. To reduce this, instead of running the center bit between cutting cores, the core barrel was dropped and the pump circulation kept high while drilling. Progress became much faster this way, the cutting rate being higher and time being saved on the dropping and recovery of the center bit. However, any hard layers drilled and not washed out would accumulate at the top of the core barrel and there would be some doubt about where these came from. To initiate "a core", the pump circulation was reduced from 60 s.p.m. on 2 pumps and to 10 s.p.m. on one pump.

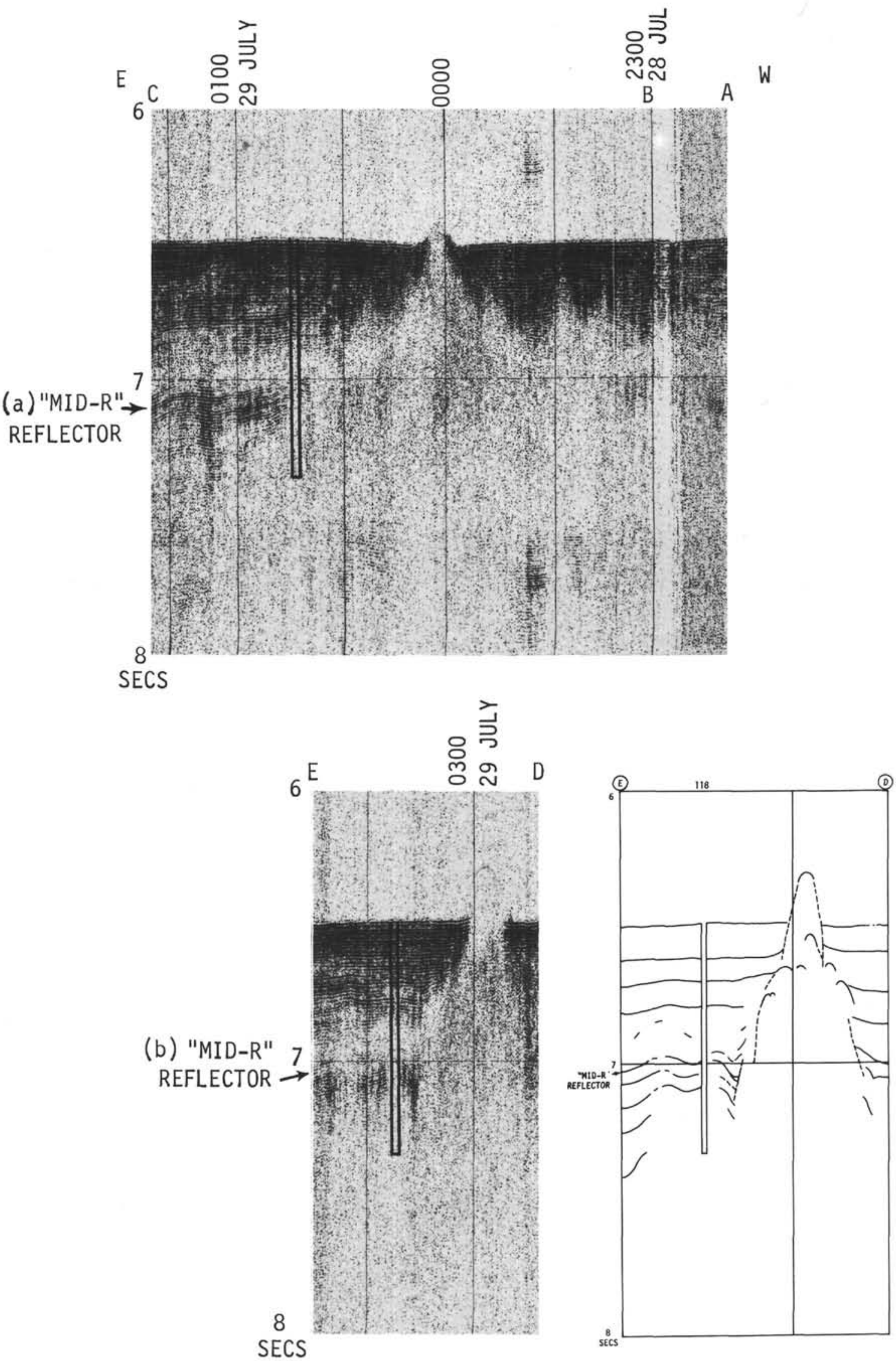

Figure 3. *(a) E-W seismic reflection profile by* Glomar Challenger *at 80-160 Hz, on approach run. (b) N-S seismic reflection profile by* Glomar Challenger *across site and line drawing interpretation.*

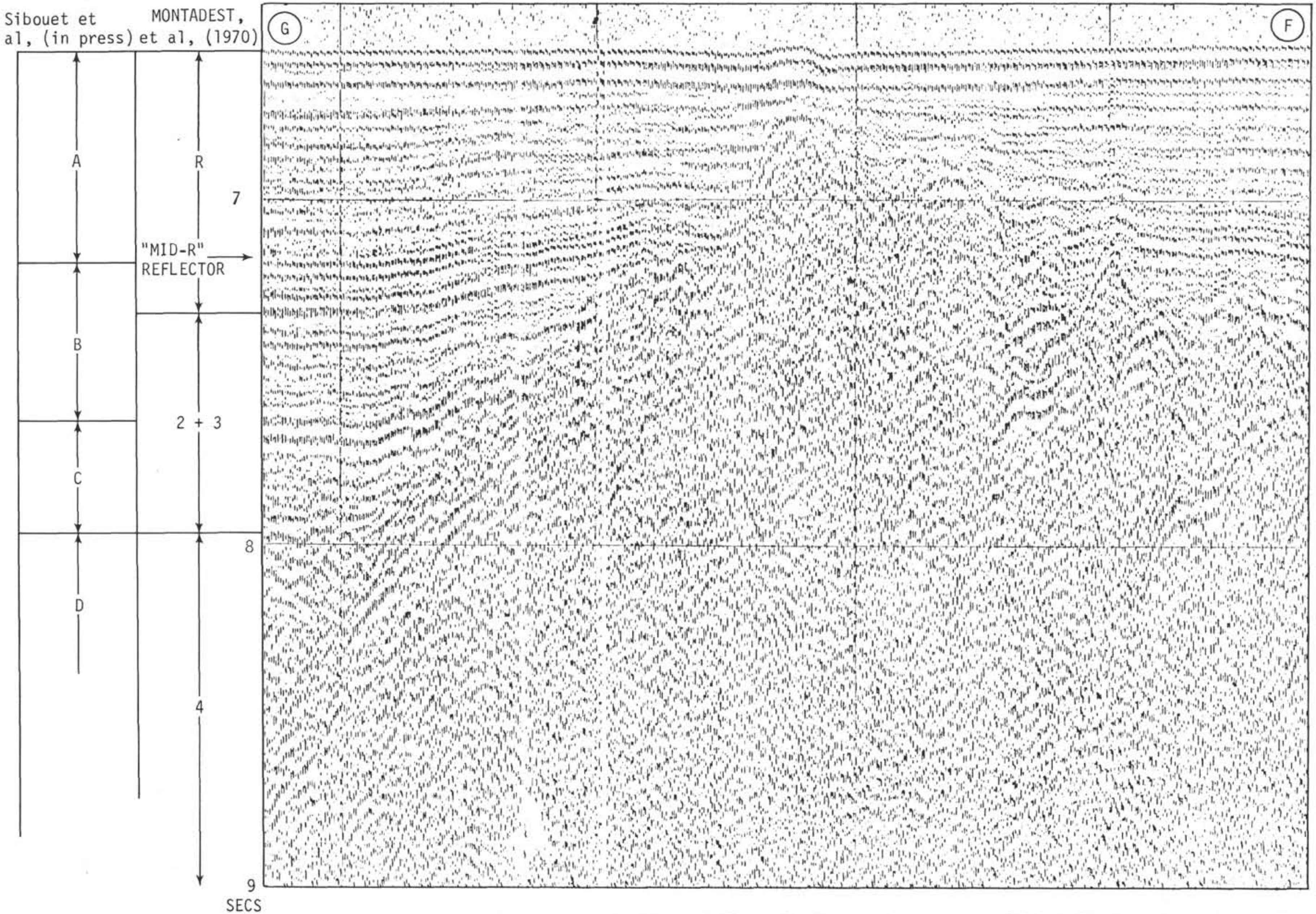

Figure 4. *Seismic reflection profile by Flexotir technique by* Charcot-*9 south of Site 118 (Figure 2). The equivalent position of Hole 118 is shown by projection along strike of basement ridge. Nomenclature of layers by Montadert* et al. *(1971) and Sibuet* et al. *(1971) is shown on the left. (Record by courtesy of Centre National de l'Exploitation des Oceans, France.)*

With this technique, drilling proceeded from 658 to 687 meters, with a hard layer at 678 to 680 meters. Core 12 was cut with reduced circulation from about 689 to 693 meters, but this yielded 5.3 meters of core which included the unconformity between the Lower Miocene hard gray clay and the Eocene hard brown clay. Owing to the uncertainty of precise levels with this technique, it is considered possible, and even likely, that the hard gray clay came from 678 to 680 meters and that the contact was not actually sampled. At the end of the core, the drill sat on a hard formation making no progress.

Core 13 was cut very slowly from 693 to 695 meters. For two hours, the drill sat on this hard layer with 25,000 pounds on the bit, drilling steadily without torquing up. No appreciable movement could be seen although the bumper-subs allowed some progress. This was thought to be basaltic basement, but the core produced 3 meters of very hard Eocene coccolith clay. The slow drilling must be attributed to a clay ball forming in the bit and skidding around in the hole.

The next core (14) was cut with low circulation to start with (695 to 698 meters), but circulation was increased to 80 s.p.m. and this finally broke through the hard clay layer. Penetration stopped again at 708 meters, due to suspected balling up. The core of 3 meters was thought, therefore, to come from the interval of 695 to 698 meters, rather than the nominal cored interval of 698 to 708 meters.

We drilled on from 708 to 714 meters with high circulation (80 s.p.m.), then cut back to 50 s.p.m. to cut Core 15 (714 to 723 meters), the last three meters with 20 s.p.m. to obtain better core recovery. Only one meter was recovered which is attributed to the interval 720 to 723 meters. Cores 16, 17 and 18 were cut consecutively with 5 to 10 s.p.m. Sometimes hard layers were met, but these may have been plugging up in the bit. They all yielded about one meter of hard red clay, sometimes mixed with gray clay pebbles. Initially, Core 19 drilled more easily, but became very hard at the end. Basalt was found below hard red clay.

In order to get more basalt another core was cut, sitting with 25,000 pounds on the bit for almost an hour. Since all the teeth of the core catcher were sheared, the basalt sample recovered was only held in the core barrel by a tilted piece of baked red clay that was certainly below the basalt stratigraphically. More basalt below this may, however, have dropped out. To investigate any further sediment that might be below this sill, another core was cut, yielding 1.4 meters of basalt. The hole was therefore finished at 761 meters at 2130 hours on August 1st.

A total of 147 meters were cored yielding 51.6 meters of sample (35.3 per cent) in 21 cores. Throughout the hole, the wind remained in the north and northeast, light to moderate. For a period, there was some low swell from the northwest which gave some slight rolling.

LITHOLOGY

The sediments cored at Site 118 can be divided into two major sections, Eocene and Paleocene red clays overlain by Miocene to Pleistocene turbidites and pelagic sediments. The hole bottomed in at a highly altered olivine basalt.

The sedimentary succession can be further subdivided as follows:

		Approximately subbottom depth (m)
Turbidites and Oozes	Silty clays and graded sand layers	
		250
	Clays, oozes and silty clays	
		420
	Clays, silts and carbonate sandstones	
		570
	Mottled clays and clay breccias	
		685
Red Clays	Chemically altered nannofossil red clays	
		710
	Altered and recrystallized red clays	
		750
Basalt	Altered basalt sills	

TABLE 1
Cores Cut at Site 118

Hole	Core	Cored Interval (m, subbottom)	Core Recovered
118	1	96-105	7.94
118	2	200-209	9.00
118	3	300-309	2.7
118	4	350-359	3.57
118	5	399-408	3.12
118	6	448-457	2.94
118	7	396-501	0.88
118	8	505-512	1.13
118	9	553-559	1.62
118	10	604-613	1.17
118	11	650-658	0.27
118	12	687-693	5.26
118	13	693-695	3.0
118	14	695-708[a]	3.0
118	15	714-723	1.0
118	16	723-732	0.53
118	17	732-741	0.55
118	18	741-750	1.80
118	19	750-756	0.30
118	20	756-759	0.64
118	21	759-761	1.40

[a]Core 14 could have come from anywhere in the interval 695-708, see text.

These subdivisions can be clearly recognized on visual examination and obvious compositional variations can be seen in the smear slides. These are summarized in Figure 5, where the gross composition of each core has been qualitatively indicated. Appendix A shows in more detail the results of an examination of the smear slides.

	CORE NO.	QUARTZ	FELDSPAR	HORNBLENDE	CHLORITE	BIOTITE	STAUROLITE	KYANITE	ANDALUSITE	ZIRCON	TOURMALINE	GARNET	RUTILE	DARK GLASS	LIGHT GLASS	PALAGONITE	PYRITE	LIMONITE	GLAUCONITE	AUTH. CARBONATE	DETRITAL CARBONATE	ZEOLITES & INDET. CLAYS	FORAMS	NANNOPLANKTON	SILICEOUS FOSSILS
PLEISTOCENE TURBIDITES	1	●	●	●	●	●	●								●		●			•		●	●	●	
	2	●	●	●	●	●	●	●		●	●			•	●		●			●		●	●	●	
MIO-PLIOCENE SILTY CLAYS	3	●	●		●	●	●						●	•			●			●		●	●	●	
	4	●	●	●	●	●			●		●			•	•		●		●	●		●	●	●	
	5	●	●			●	●	●	●		●	●			•		●		●	●	●	●	●	●	
MIOCENE SANDSTONES	6	●	●		●	●	●				●						●		●	●	●	●	●	●	●
	7																			●	●			●	●
	8	•									•				•		•			●	●			●	●
	9	●	●			●				●	●						●		●	●		●	●	●	●
MIOCENE SILTY CLAYS	10														•		●			●	●	●	●	●	●
	11														●	●	●					●			
	12	●	●			•				●					●	●	●		●			●			●
PARTIALLY ALTERED EOCENE CLAYS	12	•																•		●		●			
	13	•									●							•	●			●		●	
	14														●			●		●		●		●	
ALTERED EOCENE CLAYS	15														●			●				●			
	16														●			●				●		•	
	17																	●				●			
	18																	●				●		•	
	19																	●				●			

● Readily observed • Few, scattered occurrences

Figure 5. *Approximate composition of sediments cored at Site 118.*

The Basalt

Cores 19, 20 and 21 which recovered samples of basalt sills and short sections of the associated altered clays are summarized diagramatically in Figure 6. Thin sections of the basalts and were examined by Aumento, Clarke and Cann and are described below.

The hard red "claystone" at the bottom of Core 20 is probably the result of incorporation of red clay into the fluid basalt flow. Depending on viewpoint the rock can be considered either as a highly altered red clay or as a highly altered basalt. Thin sections show that it consists entirely of sparry calcite and indeterminate silicates, mixed with hematite. The rock from the contact zone above the basalt in Core 19 is composed of the same materials. The altered red clay above this contact zone, however, seems to be devoid of calcite, consisting almost entirely of recrystallized, indeterminate clay minerals and hematite. The boundary between the red clay above and the hard rock of the contact zone has slickensides indicating movement and confirming that the basalts are indeed sills rather than lava flows.

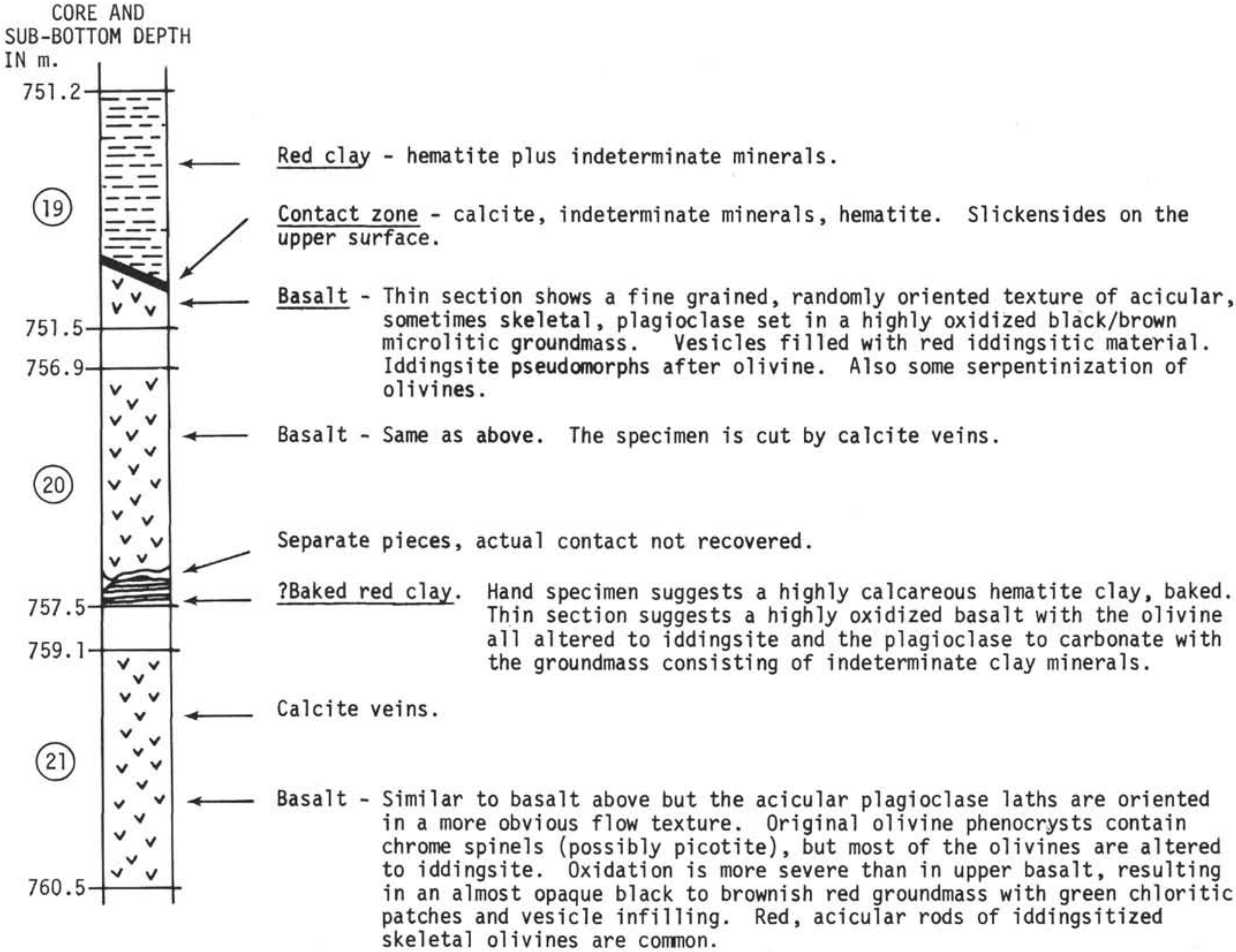

Figure 6. *Details of hard rock Cores 19, 20 and 21, Site 118.*

Preliminary Petrography of the Basalts

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and
J. R. Cann, University of East Anglia, England,
with additional comments by W. B. Bryan,
Woods Hole Oceanographic Institution, Massachussetts

118-19-1, 31-33 cm

This is a specimen of fine-grained, oxidized, variolitic basalt. Rare phenocrysts of olivine have been replaced by serpentine and iddingsite. The groundmass consists of a network of acicular plagioclase crystals, the cores of which have been replaced by a zeolite, set in a matrix of granular clinopyroxene, smaller plagioclase needles and iron ore, which is often skeletal. Vesicles are filled with brown chloritic material.

118-20-1, 20-21 cm

This highly oxidized fine-grained basalt contains olivine phenocrysts now altered to serpentine and iddingsite. The groundmass is composed of randomly oriented acicular to skeletal plagioclase crystals set in an oxidized matrix in which grains of clinopyroxene and iron ore may be seen. Vesicles are filled with brown to green chloritic material. Veins of calcite, and clacite, chlorite and iron-manganese oxide cut the rock.

118-20-1, 63-63.5 cm

This sample is composed of ovoid patches of red-brown clay mineral up to 1 centimeter across, set in a matrix in which elongate, rounded carbonate crystals (about 0.1 x 0.01 millimeter), making up 80 per cent of the rock, are surrounded by similar red clay mineral material. It might be interpreted (F. A. and B. D. C.) as a highly altered and oxidized basalt in which plagioclase laths have been replaced by carbonate, or (J. R. C.) as a metamorphosed sediment with carbonate porphyroblasts.

Trace element analyses have yielded the following results (in ppm):

Ti	Rb	Sr	Y	Zr	Nb
7100	6.0	172	23	85	4.0

118-20-1, 67-71, 123-126 and 126-135 cm

These samples are all of oxidized variolitic basalt. Phenocrysts of olivine are almost all altered to serpentine and iddingsite, though some fresh patches remain, which show inclusions of chrome spinal. Plagioclase phenocrysts are less abundant, and are replaced by zeolite to varying degrees. The groundmass consists of acicular to skeletal plagioclase crystals, showing varying degrees of replacement by zeolite, set in a fine-grained oxidized matrix in which granular clinopyroxene and iron can be seen, as well as thin rods representing olivine replaced by iddingsite. Much of the matrix is indeterminate, being composed of patches of green to brown chloritic material. Vesicles are filled with red-brown chloritic material. Veins filled with calcite cut the rock.

118-21-1

118-21-1 was described by W. B. Bryan (personal communication) and appears to have been originally very similar to a second sample (118-19), also described by Bryan. It differs mainly in containing a large vug filled with calcite, and in the greater alteration of the groundmass. Feldspar laths show good albite twinning, with extinction angles up to 40 degrees indicating compositions in the range of calcic labradorite or sodic bytownite. Interstitial quench pyroxene is largely replaced by chlorophaeite and vuggy areas of zeolite, chalcedony and clay.

Comments

The basalt from this hole is very similar to that from Hole 112 in the Labrador Sea, except that it is more oxidized, and thus presumably older, and lacks the clinopyroxene phenocrysts of the basalt from Hole 112. Again the basalts are very similar to weathered and oxidized basalt collected from the flanks of the mid-ocean ridges, and demonstrable geochemically as belonging to the group of ocean floor basalts. They can thus be interpreted as samples of oceanic basement, generated some tens of millions of years ago in the Bay of Biscay by ocean floor spreading, and subsequently altered profoundly by prolonged contact with sea water or with oxidizing interstitial solutions. Geochemical investigation, when larger samples are available, should test this hypothesis. Unfortunately, all of the samples examined are unsuitable for potassium-argon or fission track dating. The degree of weathering allows only an approximate estimate of their age.

Opaque Mineralogy

J.C. Ryall, Dalhouseie University,
Halifax, Nova Scotia

Examination of polished sections has been carried out using a Reichert Zeto Pan microscope. Total magnification was X1350. In the descriptions given below, titanomagnetite deuteric (high temperature) oxidation is quoted on a 1 to 6 scale, where:

Class 1: homogeneous titanomagnetite

Class 2 and 3: magnetite with increasing amounts of ilmenite lamellae

Class 4: oxidation of ilmenite lamellae to feri-rutile and titanohematile

Class 5: appearance of black spinel spicules in remaining magnetite

Class 6: complete replacement of titanomagnetite by titanohematite, pseudobrookite and/or ferri-rutile

118-20-1, 20-21

Uniform distribution of small skeletal Class 1 magnetites. These are everywhere completely whitened and the silicate background is generally reddened by widespread disseminated hematite. While it is difficult to be sure of the intrinsic properties of such small grains, the lack of anisotropy suggests that the grains are titanomaghemite rather than titanohematite replaced.

Weak natural remanent magnetization in the material from this site, located within the magnetic smooth zone, is associated with uniformally altered titanomagnetite. The nature of the alteration suggests that maghemite may have replaced the magnetite, but the small size of the grains prevents certain identification of the alteration product.

The fact that widespread alteration of the titanomagnetite, in material which was probably originally similar to typical oceanic basalt, is associated with weak remanent magnetization may be significant in explaining the origin of the magnetic smooth zones of the North Atlantic.

Altered Red Clays

Immediately overlying the basalt is a section of about 40 meters of altered red clays, represented by Cores 15 to 19. These are smooth, hard, red and brown clays. They are burrowed throughout with chondrite-type burrows. In composition they consist mostly of indeterminate "zeolites" and clay minerals with, in the upper part, what appears to be partially crystallized volcanic glass. The red and yellow coloring is due to limonite and hematite. The hematite, along with some ?tridymite, is much more common in the lower part of the section, especially Core 19. (Compare with the upper part of the section, Cores 1 to 12, where pyrite is the predominant iron mineral.) In some places the clays are very rich in poorly preserved Radiolaria. There is little or no trace of calcareous fossils, other than a few recrystallized nannofossils. This could be due to deposition below the carbonate compensation depth, but the general aspect of the sediments suggests recrystallization and alteration due to the intrusion of the basalt below and this could account for the absence of calcareous fossils. The iron-rich nature of the sediments could be due to the intrusion of the basalt, see Boström and Peterson (1969).

Above the altered red clays just described are some 25 meters of brown and gray clays (Cores 12 to 14) with quite common nannofossils. These clays are extensively burrowed with chondrite-type burrows. When cut, the cleaned surface of the cores has a marbled appearance and several "crushed zones" are seen suggesting deformation. White patches indicative of chemical alteration (bleaching) are common. In the smear slides, besides common nannofossils, "zeolites" and clay minerals, a few detrital grains, mainly of quartz and tourmaline can be seen. It seems that these clays are essentially the same as the red clays beneath but, being more removed from the basalt, while still being altered and deformed, they have been less extensively changed than the clays below.

Turbidites and Oozes

The top 685 meters cored (Cores 1 to 12) consist of a long succession of typical abyssal plain sediments, turbidites interbedded with normal pelagic sediments. Although the lowermost samples of this sequence and the uppermost samples of the underlying red clay both occur within Core 12, the actual contact between the two lithologies was not recovered. However, there is clearly a considerable change in depositional environment and the paleontological studies indicate a considerable stratigraphic gap, the red clays being Eocene in age and the turbidites Miocene. These facts imply a period of nondeposition, or perhaps even uplift and erosion, occurring between deposition of the red clays and deposition of the turbidites. The seismic reflection profiles show Site 118 to be on the side of a basement high which could explain, at least in part, the hiatus in deposition at the site, since the turbidites would accumulate initially in the depressions in the pre-existing topography.

The turbidite succession consists predominantly of dark olive gray silty clays, with quite a varied mineralogy, interbedded with pale gray coccolith-rich clays. Although they are basically pelagic sediments, the coccolith clays have a significant terrigenous contribution so they should, perhaps, not be described as oozes. The silty nature of the turbidite beds is well displayed in Figure 7 and in Appendix B, which present the results of grain size analyses of samples from the basal parts of turbidite layers. For comparative purposes, the results of an analysis of the underlying pelagic clay, from the bottom of Core 12, are also shown.

Quite coarse, graded, sandy layers are encountered in Cores 1, 2, 7 and 8. To demonstrate the grading, a series of samples from a single sandy layer in Section 6 of Core 2 was analyzed. The results are shown in Appendix B and Figures 8 and 9. Although grading of deep sea sands is a widely recognized and well-documented phenomenon (for example, Kuenen, 1964, Beall and Fischer, 1969, Van Andel and Komar, 1969), one aspect of the grading observed here, merits further comment. Visual examination of the core itself suggests clearly that the texture at about 107 centimeters is finer grained than that above and below. In other words, the sand layer appears to be doubly graded. This also shows very clearly in the grain size analyses.

Work carried out earlier (Davies, 1967, unpublished) on a sand layer in Core D5600, collected by RRS *Discovery* from the Iberian Abyssal Plain, showed a similar phenomenon (Figure 10). Semiquantitative analysis of the composition of the different size fractions of that sand layer showed marked variations in the vertical distribution of the different components (Figure 11). This strongly suggested that the apparent anomalies in the grading, revealed by simple size analysis were, in fact, not significant and that had the correct hydrodynamic parameter (settling velocity) been determined, rather than simply the grain-size distribution, then a more uniform and simpler pattern of grading would have emerged. A quick, qualitative examination of the size fractions indicates that a similar segregation of components has taken place in the samples from Core 2, Site 118. Below 107 centimeters the sand fractions consist dominantly of mineral material, mostly quartz and feldspar. In the upper part of this lower segment mica flakes become the dominant mineral and above 105 centimeters the coarse fraction consists almost entirely of foraminifera and foraminiferal fragments with only occasional mica flakes as the mineral component.

The composition of the turbidites is interesting (Figure 12). The coarse sandy layers in Cores 7 and 8 are composed almost entirely of carbonate material. A thin section taken from one of the sandstone beds in Core 8 showed a chaotic mixture of shell fragments, foraminifera and foraminiferal fragments, with just a few grains of quartz and feldspar. Digestion of the sediment in dilute acid also revealed the presence of some glauconite and siliceous fossil remains, mostly sponge spicules. Above Core 6 however the dominating carbonate component is greatly reduced and a more varied mineralogy is seen in the silty clays and sandy layers. Samples from Core 2 especially contain excellent examples of grains of quartz, feldspar, hornblende, ?augite, biotite, staurolite, kyanite, zircon and tourmaline. Some shallow water foraminifera are seen also. The general aspect of these sediments suggests clearly that they are largely composed of material derived from an area of regional metamorphism, probably Brittany.

The predominance of silty clays and clayey silts in the nonpelagic sediments of Cores 1 through 12 suggests that the "normal" turbidite deposit at this location is a fairly fine-grained deposit and leads to the suggestion that the sandy layers reflect times when there was an especially large supply of coarse sediment available for transport to the deep ocean. The carbonate sands in Cores 7 and 8 then represent a time immediately following the early Mid-Tertiary earth movements in the region of the Pyrenees and the Aquitaine, when the Gulf of Aquitaine shoaled and diminished in size (Bonnard *et al.*, 1958), thus making large quantities of recently deposited and loosely consolidated shallow water carbonate sediment subject to erosion. Similarly, the sand layers in Cores 1 and 2 reflect the increased turbidity current action during the Pleistocene when the continental shelves were exposed to strenuous erosion.

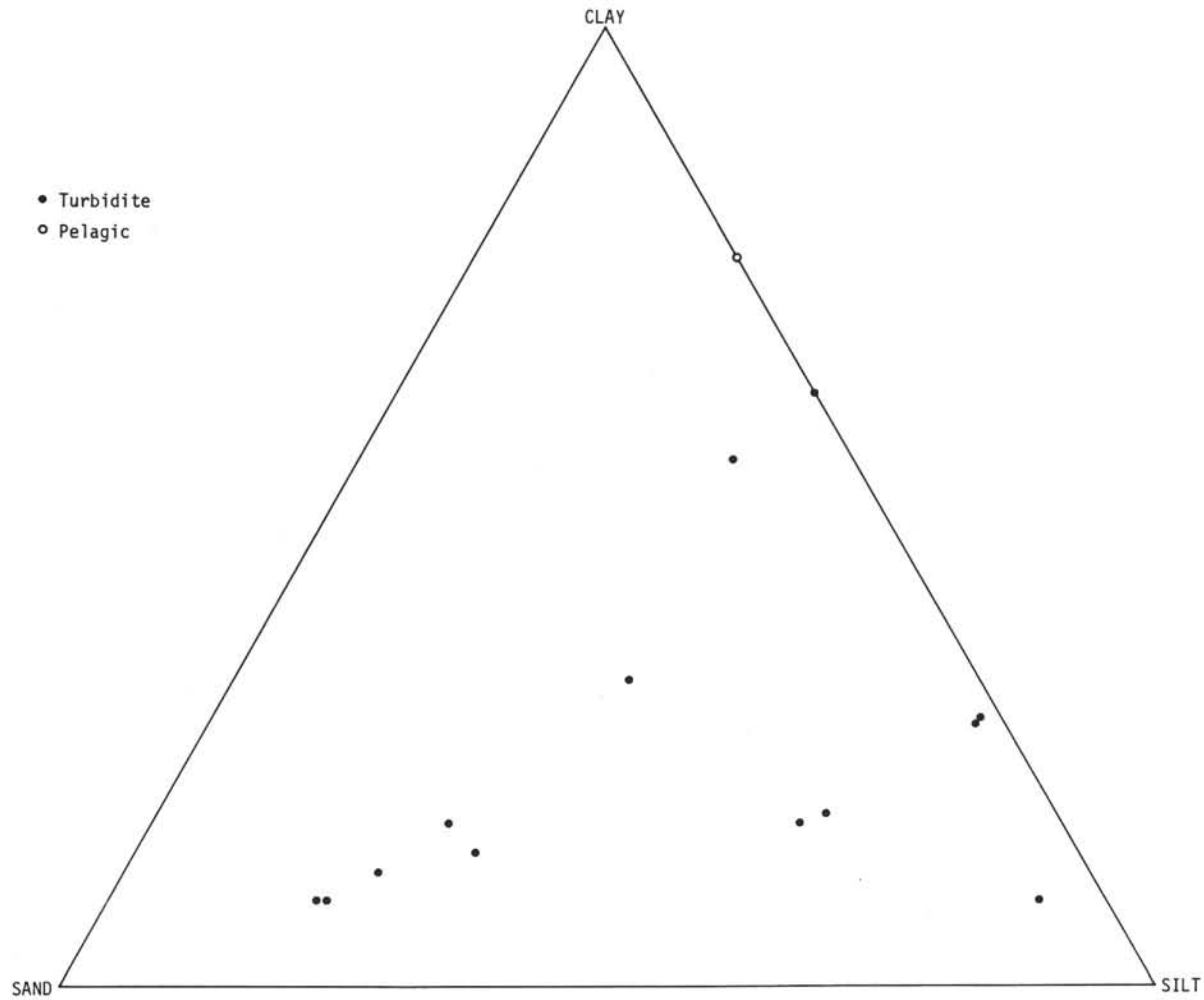

Figure 7. *Texture of samples from Cores 1 through 12, Site 118.*

PHYSICAL PROPERTIES

Core 7 and later cores are generally considerably fragmented and, in detail, this causes spurious fluctuations in the GRAPE data. In particular, three cores have aberrant low densities due either to fragmentation of the core (118-11, 118-15) or to a high degree of disturbance and wateryness (118-18).

Density appears to increase steadily in the first 300 meters having maximum values on the Site Summary plots of 1.85, 1.9 and 1.95 gm/cc in cores recovered from 100, 200 and 300 meters, respectively. Within these cores however considerable density fluctuations are observed (for example: 1.5-2.1 gm/cc in 118-1; 1.7-2.0 gm/cc in 118-2; 1.7-2.05 gm/cc in 118-3) apparently due to the graded nature (turbidites) of these cores. The greater densities correspond to sands and the lesser densities to clays. Nevertheless, the maximum density of 1.85 gm/cc attained at 100 meters seems to be unusually high for a Pleistocene sediment at this depth and would appear to reflect the importance of dense detrital minerals, such as hornblende (3-3.5 gm/cc), staurolite (3.7 gm/cc) and pyrites (4.8-5.1 gm/cc) which are observed at the base of the turbidite layers. Natural gamma activity in these cores shows considerable fluctuations within the range 1000 to 2500 counts. The fluctuations within cores are related to the varying carbonate fraction and can be correlated with alternations of ooze and clay in 118-1-6. Three spot carbonate samples gave values in the range 23 to 77 per cent. Nevertheless, the average gamma level is quite high for turbidity current material and suggests that the source area of the detrital minerals has a relatively high level of radioactivity. In detail, however, the higher activity is exhibited by the clays rather than the sands (see 118-2-5 and 118-2-6) and this could be due to the long exposure of the clays on the seabed, with the consequent absorption of uranium and thorium, in contrast to the almost instantaneous deposition of the turbidite sands in which calcareous foraminifera are also abundant or common.

From 300 to 680 meters there seems to be no appreciable increase in density and an average of 1.9 gm/cc is maintained. The sediments (clay, silt, sandstone) become firmer however as indicated by the velocity and penetrometer plots. In particular, bands of yellow-gray sandstone were met in Cores 7 and 8 which gave velocities

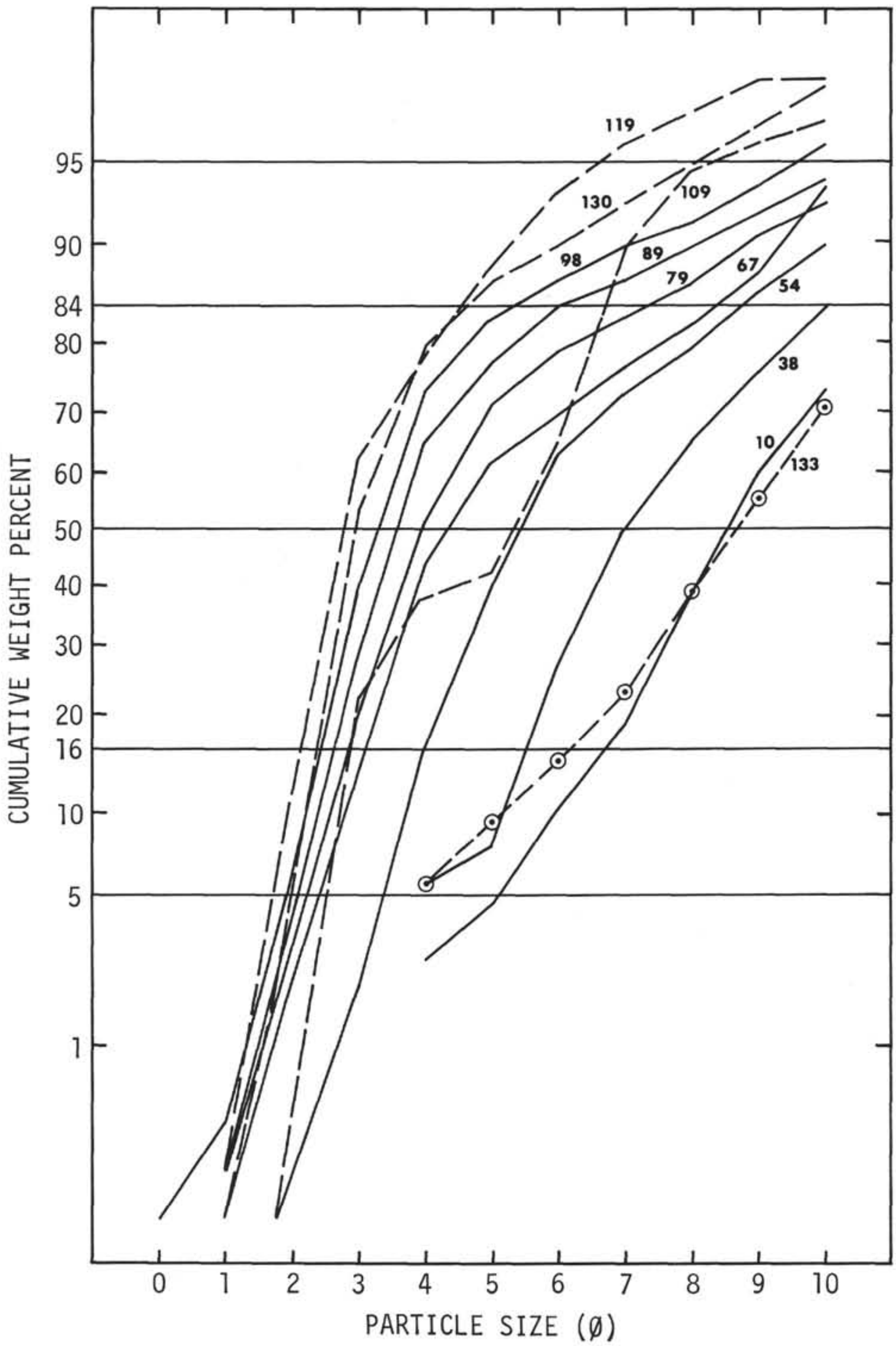

Figure 8. *Grain-size distribution of samples from a single graded bed (118-2-6). Dashed lines refer to the lower part of the bed, solid lines to the upper part (see Figure 9).*

between 3.20 and 3.78 km/sec. Natural gamma activity is variable over this range but still maintains a high level between 1200 and 3000 counts. The fluctuating activity seems to be due to the varying carbonate content (for example, the contrast of ooze and clay in 118-5-2) which five spot samples indicate to be in the range of 42 to 71 per cent. The particularly low activity of Cores 7 and 8 (clay and sandstone) may be due to a preponderance of carbonate (a sandstone in 118-8-1 has 68 per cent carbonate), but it is probably also significant that these cores are almost completely lacking in detrital minerals, especially biotite.

The oldest Miocene clays at this site, which were recovered in Core 12, have a density of 1.75 gm/cc which is somewhat less than that of the clays 130 meters higher up in Core 9. The gamma activity of the former however

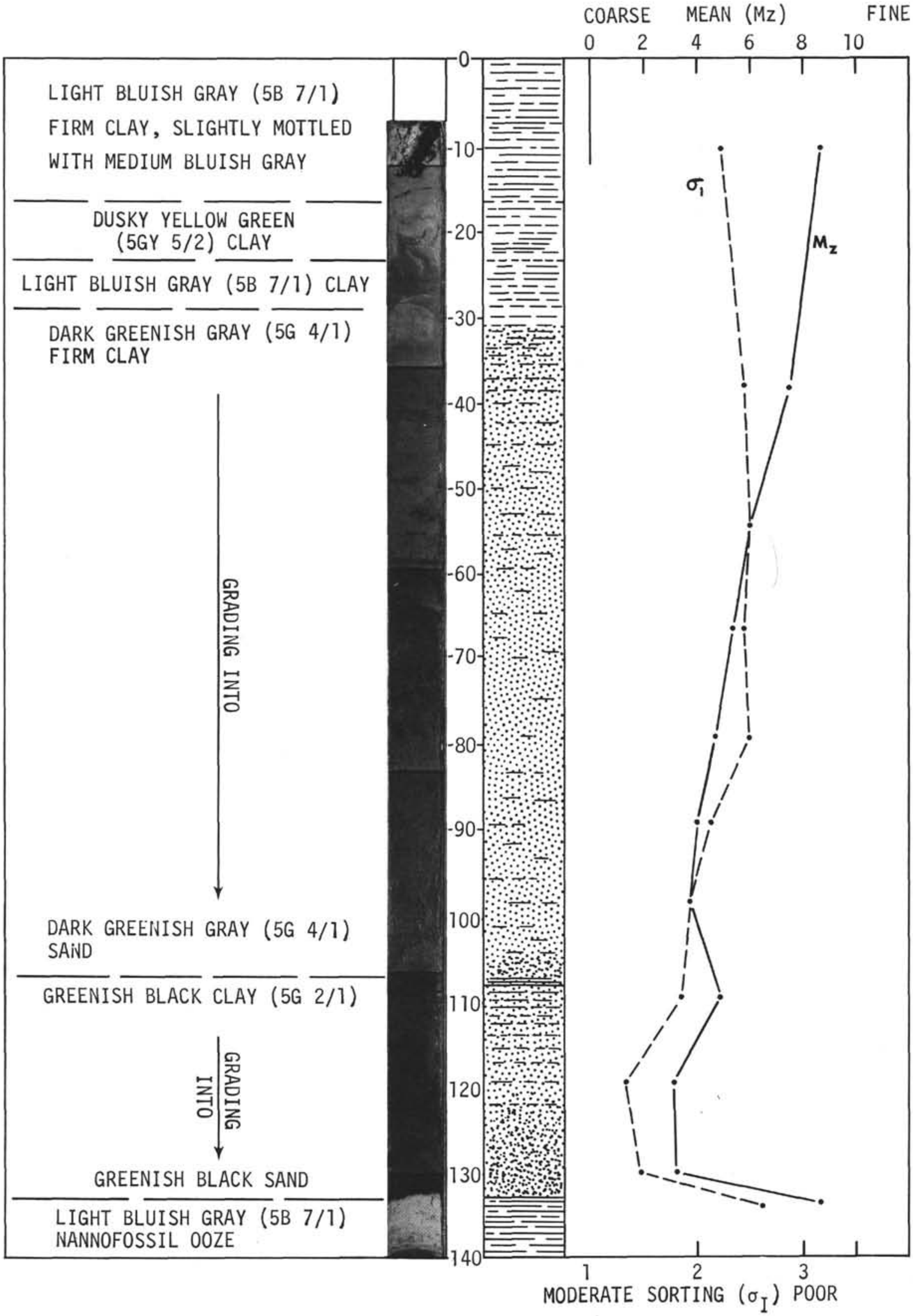

Figure 9. *Textural changes through a single graded bed (Section 6, Core 2, Hole 118).*

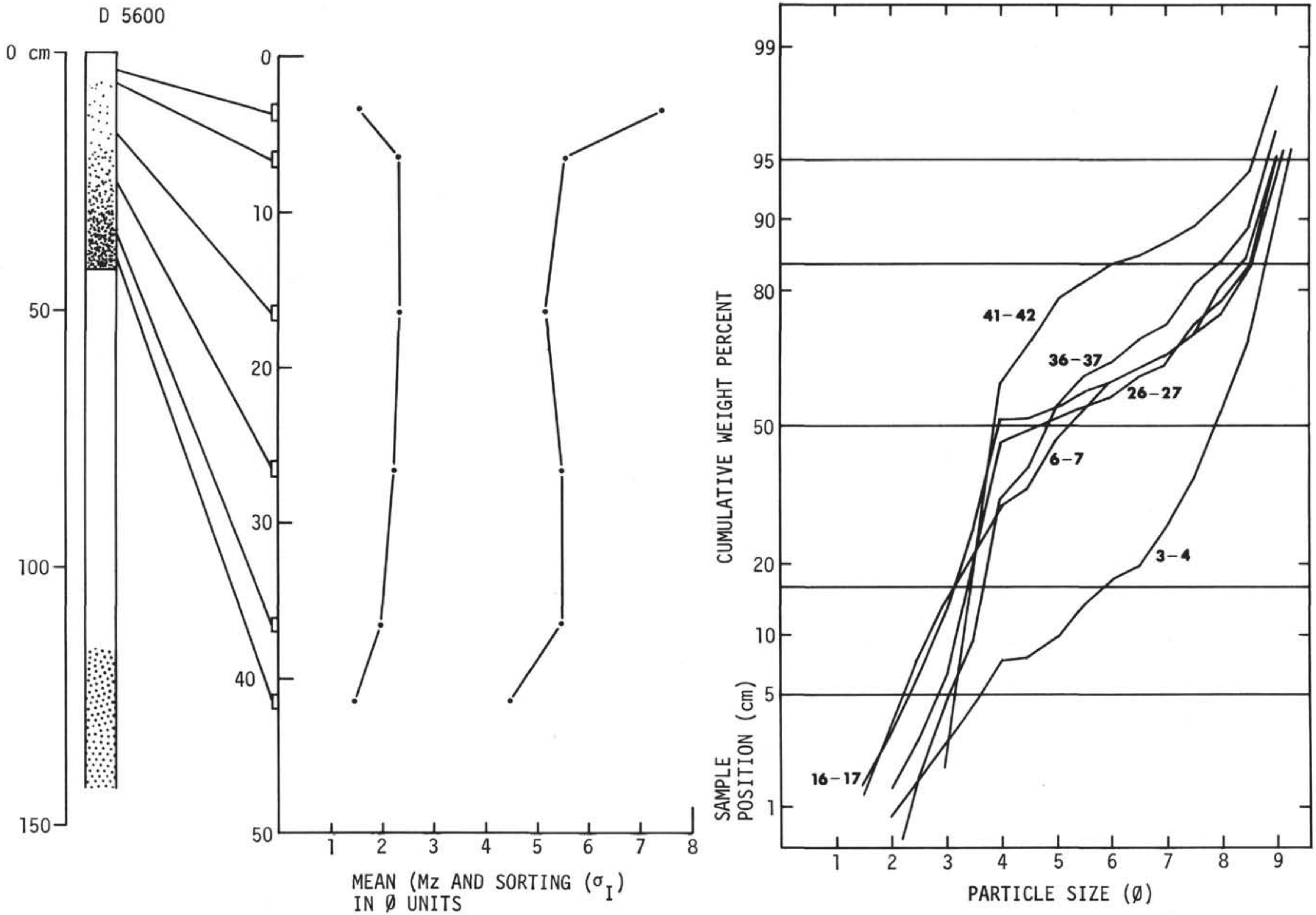

Figure 10. *Textural changes through a single graded bed, with grain-size distributions of samples, from Core D5600 (Iberian Abyssal Plain).*

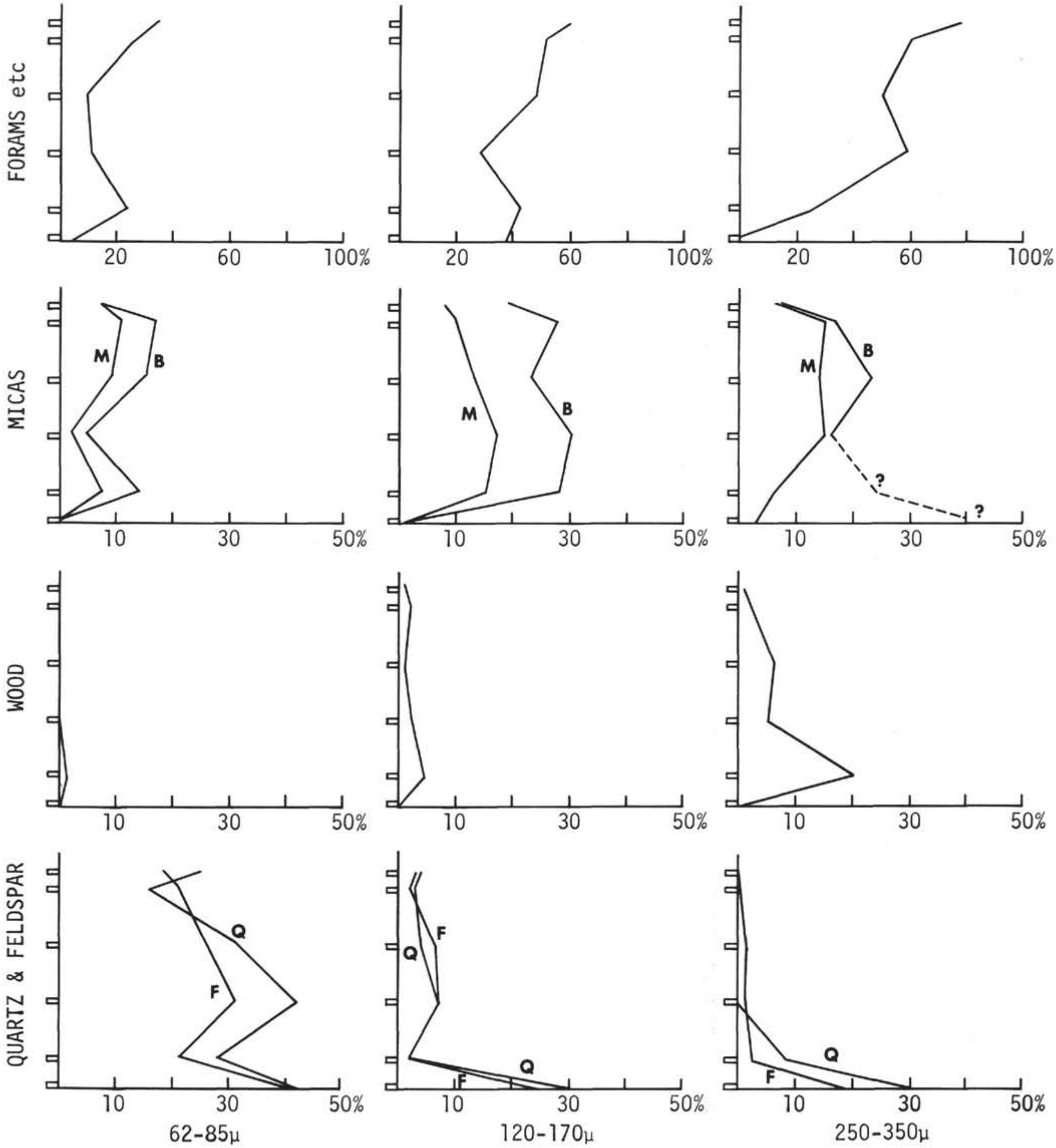

Figure 11. *Graphs to show the variation in relative abundance with position in the graded bed for various components and size fractions for samples from D5600.*

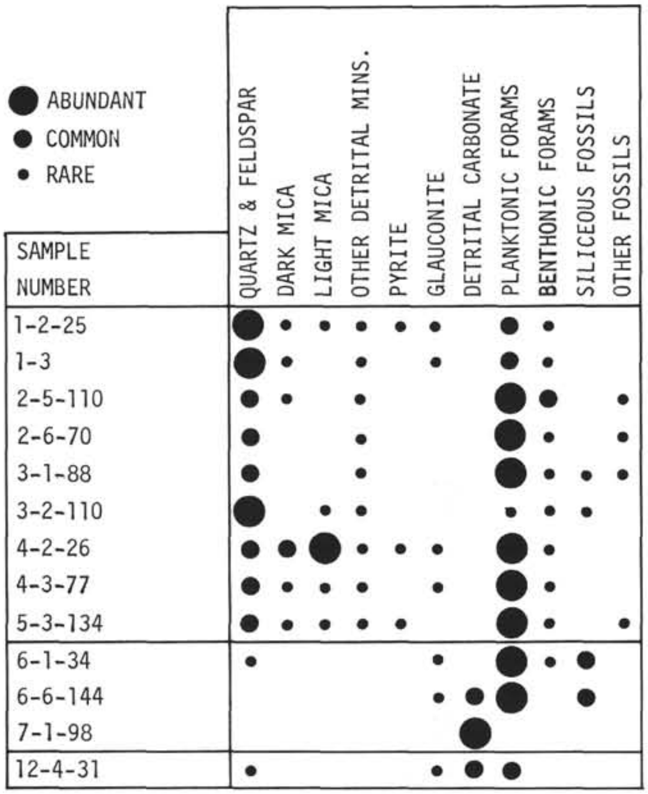

Figure 12. *Composition of the coarse fraction of the turbidites, Cores 1 through 12, Site 118.*

reaches 3700 counts in 118-12-2. The section is composed of a gray clay moderately mottled with light bluish gray and with coral and shell fragments scattered throughout. This occurrence of high gamma activity differs from the typical association with black or yellow clays found in Leg 12 cores. The explanation could lie in the presence of zircon, glauconite and zeolite (phillipsite?) among the detrital minerals and also of coral fragments which may contain up to 3 p.p.m. of uranium.

Gamma activity decreases abruptly between the base of 118-12-2 (3700 counts) and the top of 118-12-3 (1380 counts) and simultaneously density increases up to 1.9 gm/cc. This spectacular change represents a stratigraphic break of at least 32 million years and a lithological change from mottled clay to altered hard clay. Velocity also increases slightly across the unconformity.

The cores of Eocene clay from below 700 meters are considerably disrupted and the density and velocity measurements on these cores are probably too low. The gamma activity of Cores 17 and 18 has increased to around 5000 counts. The reason for this is suggested by an X-ray measurement in Core 17 which indicates 54 per cent mica and 10 per cent potash feldspar.

Basalt was cored below 751 meters and has a (weight/volume) density and porosity and velocity of 2.66 gm/cc, 1 per cent, and 4.71 to 5.45 km/sec, respectively. The gamma activity lies between 260 and 350 counts.

A variety of features can be seen in the GRAPE barrel plots. Pebbles (118-1-2) and shell fragments (118-12-1) show up as sharp density peaks. Graded layers are detectable in 118-2-6, 118-6-1 and 118-9-2, while the effects of combinations of beds of clay, silt, sand and ooze are clearly seen in 118-1-5 and 118-1-6, 118-2-6 and throughout 118-4.

Paleomagnetic measurements were made on two specimens of basalt by J. Ade-Hall. Only one (normally magnetized) specimen (118-20-1, 20 to 21 centimeters) gave a certain indication of the polarity of the paleofield. The other specimen (118-21-1, 74 to 75 centimeters) was weakly magnetized and had no detectable vertical component of magnetization.

Depth of Reflectors

Beneath the site several reflectors were identified in the range zero to 0.3 seconds overlying a transparent zone with another two-part reflector beneath it, called the mid-R reflector, which was observed at 0.48 and 0.51 second. The upper group of reflectors would seem to be associated with the dense turbidites sampled in the upper 300 meters which have a wide range of densities (see above). The transparent zone would then correspond to the clays of uniform density below 300 meters. The mid-R reflector is explained by the presence of beds of high velocity sandstone sampled in Cores 7 and 8 but first seen in Core 6. The drill first encountered hard layers at 400 meters. Neither the unconformity at 680 meters nor the basalt at 750 meters were detectable as reflectors at the site. Because of the density and velocity increase at these horizons, both levels should be adequate to give reflections and these may yet be detected if further work is carried out in this area. The reflection data are summarized in Figure 13.

PALEONTOLOGY AND BIOSTRATIGRAPHY

General

Pleistocene, Pliocene, Miocene, Eocene (the lower part of the Middle and a part of the Lower), and Upper Paleocene sediments were recovered. An unconformity at about 700 meters separates Lower Miocene and early Middle Eocene sediments.

The Miocene through Pleistocene sequence appears to consist primarily of turbidity current deposits and it is unlikely that this sequence is continuous. The strongly fluctuating estimated average rates of sedimentation calculated from a few control points tend to bear this out. The Paleocene through Eocene sediments are of pelagic origin but exhibit evidence of slumping and micro-faulting. The planktonic foraminiferal fauna exhibits some similarities to those encountered in the more northerly holes of Leg 12, such as the development of *Globorotalia miozea* and *Globorotalia conoidea* in the Middle and Late Miocene and the development of *Globigerina atlantica* as the dominant form in the Pliocene fauna. The benthonic foraminiferal fauna is of a deep-water bathyal nature throughout and indicates that this area was already at bathyal depths in the Paleogene.

Discussion

Foraminifera

The Pleistocene is represented in Cores 1 (96 to 105 meters) and 2 (200 to 209 meters). Distinctive faunal

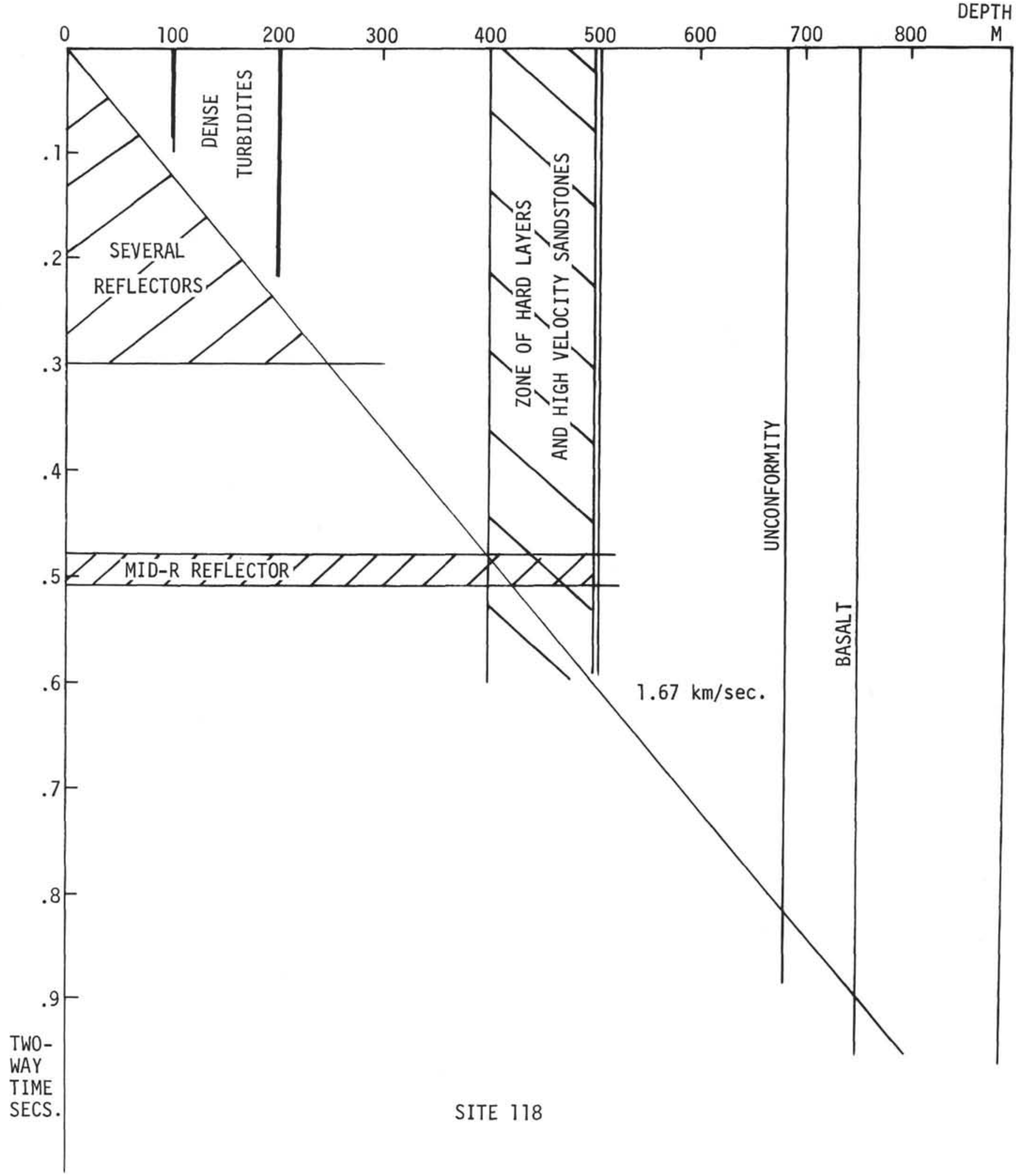

Figure 13. *Two-way travel times below the seabed of observed reflections plotted against the downhole depths of horizons believed to have given rise to these reflections. The mean velocity to the deepest reflection associated with a definite depth is given close to the line representing this velocity.*

elements include *Globigerina pachyderma*, *Globorotalia truncatulinoides* and *Globorotalia inflata*. A varied benthonic fauna includes *Pyrgo murrhyna*, *Melonis barleeanum*, *M. pompilioides*, *Epistominella exigua*, *Eponides umbonatus*, *Gyroidina soldanii* and *Cassidulina carinata* among other forms. The presence of various shallow-water forms belonging to *Quinqueloculina*, *Elphidium*, and *Cibicides* indicate displacement from shallow-water depths by turbidity currents. The Pliocene is represented by Cores 3 (300 to 309 meters) and 4 (450 to 459 meters). Both cores contain turbidite-rich sands and a rich suite of heavy minerals. Planktonic foraminifera are less common in Core 3 than in Cores 1 and 2; in Core 4 they are very rare. *Globigerina atlantica* occurs in Cores 3 and 6, indicating its stratigraphic distribution in sediments of Late Miocene to Pliocene age, which is similar to observation at other sites in the North Altantic. The presence of *Sphaeroidinellopsis subdehiscens* and *Globigerinoides obliqua* in Core 4 supports the questionable age determination of Early Pliocene (*Ceratolithus rugosus* Zone). The Miocene-Pliocene boundary is placed approximately at 400 meters at the top of Core 5 based on the questionable assignment of Core 5 to the *Ceratolithus tricorniculatus* Zone. This zone lies at or near the Miocene-Pliocene boundary. Core 5 (399 to 408 meters) contains a very poor faunal assemblage, consisting primarily of broken foraminiferal tests derived from turbidity currents. Size sorting appears to have occurred in the turbidites, as only the smaller size specimens are present. This has been observed in several other cores at this site as well. Core 6 (448 to 457 meters) contains a modest planktonic foraminiferal fauna, which contains among other forms, *Globorotalia miozea*, *Globorotalia conoidea*, and *Globigerina apertura*.. The presence of these forms together suggests that Core 6 is of Late Miocene (Tortonian) age, and this agrees with the assignment of Core 6 to the *Discoaster neohamatus* Zone.

The presence of *Globorotalia fohsi* and *Globorotalia miozea* together with specimens identified here as *Globigerina* sp. cf. *G. druryi* indicates that Core 8 is assignable to Zone N12 (Middle Miocene). This is corroborated by its assignment to *Discoaster exilis* Zone. *Globorotalia miozea* occurs commonly together with *Orbulina universa* and *Praeorbulina glomerosa circularis*, and *Globoquadrina dehiscens* and suggests that Core 10 may be assigned to Zone N9. This agrees with the questionable assignment of Core 10 to the *Sphenolithus heteromorphus* Zone. A residue of fine quartz sand, mica, and a green (? epidote) mineral characterizes all these Upper and Middle Miocene cores.

The Middle Miocene is represented by Cores 11 and 12 (part). An unconformity occurs within Section 2 of Core 12 (687 to 693 meters). Planktonic foraminifera are virtually absent above this unconformity but the radiolarian fauna suggests an Early Miocene age. The sediments immediately below the unconformity contain planktonic foraminifera such as *Acarinina densa*, *Acarinina collactea*, *A. coalingensis*, *Globorotalia pseudoscituala*, and *Globigerapsis index*. and such benthonic foraminifera as *Nuttallides truempyi*, *Oridorsalis ecuadorensis*, and *Gaudryina* sp. cf. *G. hiltermanni* and *Anomalinoides grosserugosa* which indicates an early Middle Eocene age. Core 13 (693 to 695 meters) is of the same age.

A striking difference is seen in Core 14 (695 to 708 meters). (This core was recovered by drilling and washing with the core barrel in the hole part of the total distance, after which actual coring was done. It is not possible to determine from which depth the total nine meters recovered actually came.) The microfauna contains, among other forms, *Globorotalia subbotina marginodentata*, *G. formosa*, *G. formosa gracilis*, *G. aragonensis*, *Acarinina soldadoensis*, *A. soldadoensis angulosa*, *A. coalingensis*, *A. pentacamerata*, *Globigerina patagonica*, and *Chiloguembelina wilcoxensis*. The presence of these conical globorotaliids and the absence of *Globorotalia velascoensis* and/or *G. acuta* suggest that this level is of Early Eocene age. *Pseudohastigerina*, the first evolutionary appearance of which is used to determine the Paleocene-Eocene boundary, has not been found in this, or indeed any of the other Eocene cores at Site 118. Cores 16 (723 to 732 meters) and 17 (732 to 741 meters) are also of Early Eocene age on the basis of a similar although diminished fauna. At some levels in these cores the clay has been decalcified and only radiolarians (zeolitized) and manganese grains and rods are found.

The Paleocene-Eocene boundary is tentatively placed between Cores 17 (732 to 741 meters) and 18 (741 to 750 meters). The presence of *Globorotalia acuta*, *G. aequa*, and a varied acarininid fauna in Core 18 and of *Globorotalia marginodentata* and *G. acuta* in Core 19 (750 to 756 meters) suggest that these cores are in Zone P6a or youngest Paleocene.

Cores 20 (750 to 759 meters) and 21 (759 to 761 meters) contain fractured basalt. At the base of Core 20 several centimeters of unfossiliferous baked red clay were found which indicated that the basalt was injected in the form of a sill at this level. The hole was terminated at 761 meters.

The planktonic foraminiferal biostratigraphy at Site 118 is summarized in Figure 14.

Calcareous Nannoplankton

The coccoliths on this site are, in general, poorly preserved due to sedimentation on an abyssal plain that sometimes was about at calcium carbonate compensation depth. The coccoliths deposited by turbidity currents seem better preserved than those in the pelagic sediments.

Pleistocene

Pleistocene coccolith assemblages were recovered in Cores 1 (up to 90 per cent of the assemblage) and 2, Core 1 being assigned to the *Gephyrocapsa oceanica* Zone, Core 2 to the *Pseudoemiliania lacunosa*, or perhaps the *Coccolithus jaramillensis* Zone. These Pleistocene assemblages both contain reworked Cretaceous and Eocene coccoliths. They do not contain significantly more species than the Pleistocene assemblages in the higher latitudes, but there is less dominance of *Coccolithus pelagicus* and small coccoliths here. *Scapholithus fossilis* was found here and on Site 111 and seems to be missing in higher latitudes.

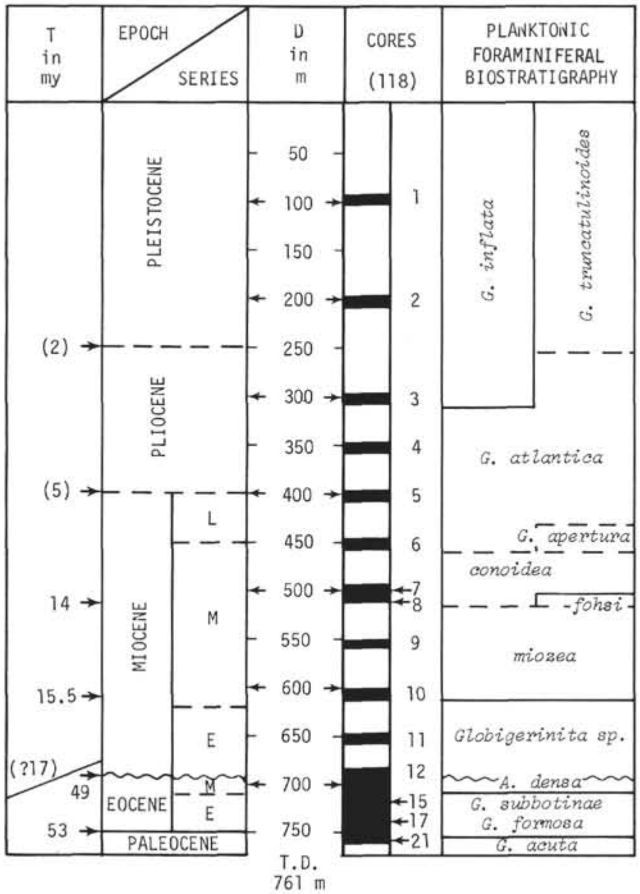

Figure 14. *Planktonic foraminiferal biostratigraphy at Site 118.*

Pliocene

No attempt was made on this site to locate exactly the Pliocene-Pleistocene boundary or the onset and influence of glaciation. The Pliocene-Pleistocene boundary is arbitrarily set at 250 meters, midway between Cores 2 and 3. The Pliocene is represented by Cores 3 to 5. As both the discoasters and ceratoliths are rare in Cores 3 and 4, their assignment to the *D. surculus* and *C. rugosus* Zones is uncertain. More, but poorly preserved, discoasters are present in Core 5. Here, in samples from the varicolored clays, mostly discoasters are preserved; in the nannofossil ooze in Section 5-2, coccoliths are also abundant. In Core 4, birefringent and nonbirefringent ceratoliths occur, while in Core 5 only nonbirefringent ceratoliths were found. Core 5, therefore, might be of Miocene age.

Miocene

Cores 6 to 11 are assigned to the Miocene. Core 6 contains only long-ranging species, with the exception of *Triquetrorhabdulus rugosus* that is known from the Late Miocene mainly. In Core 7, discoasters similar to *D. hamatus* are present; however, their recognition is difficult, due to calcification. Calcite rhombohedrons are present, indicating formation of calcite in the sediment. Coccoliths are often broken into small pieces. *Discoaster exilis* is present in the core catcher of Core 8. While the light sediment in it contains a flora of mainly coccoliths, the darker marl includes more discoasters. Core 9 may be assigned to the *D. exilis* Zone, together with Core 8. Core 10 contains *Sphenolithus heteromorphus* and is assigned to the zone of this name, while for Core 11, only its probably Early Miocene age can be given. Here, the samples in the core are barren or contain only *Coccolithus pelagicus* and a few small coccoliths. Only the core catcher yielded a richer assemblage, including discoasters and coccoliths of Miocene age. Generally the Miocene assemblages were poor and badly preserved.

Core 12 contains Middle Eocene coccoliths and discoasters in Section 3, while six samples in the two higher sections contain no calcareous nannofossils. They were, however, dated by radiolarians to be of Early Miocene age.

Eocene-Paleocene

The Middle Eocene assemblage in 118-12-3 and 4 are similar to those found in northern Europe and in France. The discoasters are also calcified and difficult to determine. Furthermore, the sediments in this and the following cores are disturbed, partly by drilling, partly probably by slumping and faulting. Calcite rhombohedrons are also present. Core 13 also seems to belong within the *Nannotetrina fulgens* Zone. In Core 14, *Nannotetrina* sp. is found; but, the uppermost sample, also containing *Discoaster sublodoensis*, is thought to belong to the *D. sublodoensis* Zone. The rest of Section 1 is assigned to the *Discoaster lodoenis* Zone. In Section 2, *Discoaster multiradiatus* is present, together with *Marthasterites tribrachiatus, Fasciculithus* sp. and *Marthasterites contortus*, and assemblages similar to the one found in Core 15 and assigned to the Late Paleocene or Early Eocene. Thus, the sedimentation was slow during the early to middle Eocene, when it ceased until it started again the Miocene.

In Core 16, only *Ericsonia cava* was found; in Core 17 there were no coccoliths. In Core 18, the assemblage includes *Nannotetrina pappi* and *N. fulgens*, as well as *Discoaster multiradiatus* and *Discoaster brouweri;* a completely mixed-up sediment; whether the mixing of the flora is due to drilling or tectonics is impossible to say.

Basalt was cored in Cores 19 to 21, some baked clay being present between the sills or lavaflows. In Core 19, Late Plaeocene is indicated by *Discoaster gemmeus*. Miocene forms, however, are present, too. The same mixture was found in the water of Core 20 and in red clay inside the sleeve of Core 21: *Discoaster multiradiatus , Fasciculithus involutus, D. gemmeus, Chiasmolithus bidens* and *Zygodiscus sigmoides* constitute a reasonable Late Paleocene assemblage.

Radiolaria

Cenozoic radiolarians are either absent or when present very rare in Hole 118. In Cores 15 through 21, however, zeolitized radiolarians are common to abundant, but the few identifiable forms are of late Cretaceous age.

Miocene–Pleistocene

Diagnostic radiolarian species occur only in 118-6, and 118-8 to 118-12-1 of the Miocene–Pleistocene turbiditic interval.

In Core 6, a late Miocene age is indicated by the concurrence of *Stichocorys peregrina* (Riedel) and *Ommatartus antepenultimus* Riedel and Sanfilippo. According to Moore's range chart (in press) the overlapping of the ranges of these two species occurs within the lowermost part of the *Stichocorys peregrina* Zone. A somewhat older age for this core is indicated by the presence of *Cyrtocapsella japonica* (Nakaseko), *C. cornuta* Haeckel, and *C. tetrapera* Haeckel. These species may have been reworked from Lower Miocene sediments because the Lower Miocene species *Lychnocanium bipes* Riedel (present in Core 6) can only be there as a result of reworking.

In Cores 8 through 11 the concurrence of digitately branched, with curved flat *Oroscena* spines, along with *Stichocorys delmontensis* (Campbell and Clark), *S. wolffii* Haeckel, *Cyrtocapsella tetrapera, C. cornuta,* and *C. japonica* suggests a middle Miocene age, although an early Miocene age is not out of the question.

The only zonal assignment which can be made unequivocally is from Core 12, Section 1, Bottom. Although the radiolarians here are silicified, species identifications are possible and include *Dorcadospyris simplex* (Riedel), *Lychnocanium bipes* Riedel, *Stichocorys wolffii, S. delmontensis, Cyrtocapsella cornuta, C. tetrapera, C. japonica, C. elongata* (Nakaseko), and *Calocycletta virginis* Haeckel. The concurrence of these species defines the *Calocycletta virginis* Zone of Early Miocene age.

Paleocene–Eocene

Radiolarians from 118-12-CC through 118-14-CC are very rare, silicified and unidentifiable.

No identifiable radiolarian species of Paleocene-Eocene age are present in core catcher samples from Cores 15 through 21. However, reworked zeolitized Upper Cretaceous radiolarians, surprisingly, are abundant in the sample residues from most of these cores. Because of their poor preservation, identification is impossible although four-armed discoidal forms (hagiastrins) and multiple-jointed theoperids (*Amphipyndax* (?) spp., *Dictyomitra* (?) spp., *Stichomitra* (?) spp.) are recognizable. A few forms are illustrated in Plate 3 of Chapter 16. A sample of 118-16-CC was sent to Helen Foreman who reports as follows (personal communication):

> They are Upper Cretaceous, below Late Campanian but aside from that there is little more I can tell you. One form with a very distinctive shape may be referrable to *Stylospongia* sp. A Pessagno, 1963, p. 199, pl. 3, fig. 7-9 (lower Campanian, Parguera limestone, Cuba, rare, found in only one sample). It has not been noted from any other locality and its range is not known. The only other recognizable form is possibly referrable to *Crucella cachensis* Pessagno (1971) described from the middle Turonian of California, Pessagno loc. 697.
>
> An age of Upper Cretaceous, or to be a little more specific middle-early Upper Cretaceous, is the most you can hope to say about this assemblage.

The source of the Upper Cretaceous radiolarians could be as far removed as the French or Spanish continental shelf and/or slope, or as near as the small hills adjacent to Site 118 (Figure 2). It is surprising that there are no reworked Cretaceous foraminifers in Cores 15 through 21, but there are a few upper Cretaceous nannofossils present. Their absence would be explained if the source sediments which supplied the reworked radiolarians either accumulated below the carbonate compensation depth for that time and locale or were subjected to diagenetic leaching of carbonate after burial.

ESTIMATED RATES OF SEDIMENTATION

There are few reliable time control points based on biostratigraphic data in Hole 118. The calculations based on the few control points which have been used strongly suggest fluctuating rates of sedimentation at this site. In view of the nature of the sedimentary processes responsible for the deposition of sediments at this location it is quite likely that the Miocene through Pleistocene section is incomplete. In particular, there would seem to be relatively large hiatuses within Middle and Late Miocene time.

The Pliocene-Pleistocene boundary (2 million years) is drawn at approximately 250 meters, midway between Core 2 (of Pleistocene age) and Core 3 (of Pliocene age). This yields an estimated average sedimentation rate of 12.5 cm/1000 yrs for the Pleistocene (Figure 15). The Miocene-Pliocene boundary (5 million years) is drawn approximately at 400 meters (at the top of Core 5). This yields an estimated average sedimentation rate for the Pliocene of 5 cm/1000 yrs. The fact that both the Miocene-Pliocene boundary and the Pliocene-Pleistocene boundary are drawn either between cores or are based on relatively weak biostratigraphic data is indicated by placing these dates within parentheses in the column to the left in Figure 15.

Core 8 is assigned to Zone N12, for which an age of 14 million years is estimated. This yields an estimated average sedimentation rate of 1.2 cm/1000 yrs for the interval between Cores 8 and 5 (500 to 400 meters). In view of the fact that these sediments are primarily of turbidite origin it is unlikely that the section between these cores is complete and we would suggest the presence of one or more erosional hiatuses within this interval. The estimate of 1.2 cm/1000 yrs is placed, therefore, within parentheses and with a question mark before it in Figure 15.

Core 10 is correlated with Zone N9, for which an estimated age of 15.5 million years is made. This yields an estimated average sedimentation rate of 6.6 cm/1000 yrs for the interval between Cores 10 and 8 (600 to 500 meters).

There is an unconformity separating Lower Miocene from lower Middle Eocene within Core 12 at about 690 meters. There is no firm biostratigraphic evidence in Cores 11 or 12 to indicate precisely the age of these sediments

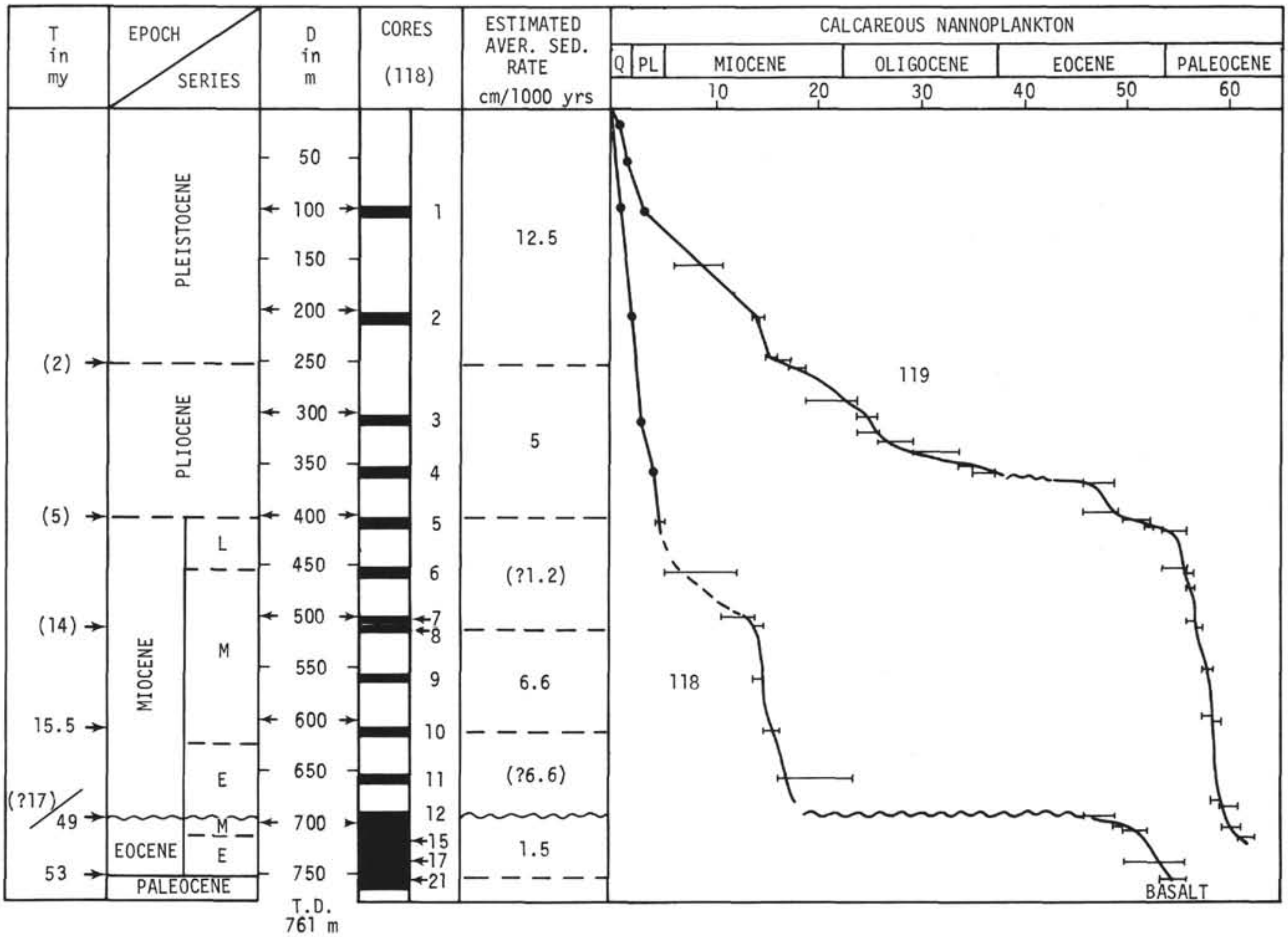

Figure 15. *Estimated average sedimentation rate at Site 118.*

other than that they are of Early Miocene age. If we extrapolate down the sedimentation rate calculated for the Lower Miocene above (6.6 cm/1000 yrs) then the sediments immediately above the unconformity within Core 12 are approximately 17 to 18 million years old. This is shown in Figure 15 in the column to the left within parentheses and with a question mark. Sediments immediately below the unconformity are approximately 49 million years old, and therefore the unconformity would represent approximately somewhat over 30 million years of time.

The Paleocene–Eocene boundary is tentatively drawn between Cores 17 and 18 and this yields an estimated average sedimentation rate of 1.5 cm/1000 yrs for the Early Eocene at Site 118.

It only appears necessary to correct for natural consolidation in the upper 250 meters of this site where density increases steadily at an average rate of about 0.001 gm/cc/m. Below this depth the average density seems to be constant. On correction, the sedimentation rate increases from 12.5 to 16.3 cm/1000 yrs.

DISCUSSION

Twenty-one cores were taken at Site 118. About 52 meters were recovered of a total 147 meters cut. The hole bottomed at 761 meters in basalt above which lay altered red clays of Late Paleocene age. Sediments of Pleistocene, Pliocene, Miocene (Upper, Middle and part of the Lower), Eocene (lower part of the Middle and a part of the Lower) and Upper Paleocene age were recovered.

The Miocene-Pleistocene sediments are primarily turbidity current deposits; the Paleocene-Eocene sediments are of pelagic origin but exhibit evidence of slumping and micro-faulting. The upper turbidites are related to late Cenozoic glaciation and increased run off; the lower turbidities are probably related to various phases of the Alpine Orogeny.

An unconformity at about 685 meters separated Lower Miocene/Middle Eocene strata, representing a time interval of about 32 million years.

Basement

Hole 118 bottomed in weathered and oxidized basalt similar to that found on the flanks of mid-ocean ridges and belonging to the group of ocean floor basalts. A few meters above the basalt of Core 21, a sill of similar basalt about half a meter thick was penetrated, and the intervening sediments were baked red clay, thought to have been incorporated into the basalt sill while still fluid. The presence of one sill suggests that the lower basalt might also be a sill and that older sediments may be found below. However the seismic reflection record (Figure 3) suggests that igneous basement might be expected near the bottom of the hole, although there are no strong basement reflections.

Formation 4 (or D)

Formation 4 has been described by Montadert *et al.* (1971) as a contorted and fractured layer overlying the igneous basement over a large part of the Bay of Biscay and overlain by the essentially flat-bedded sediments of formation 1, 2 and 3. They believe it to be Cretaceous. Sibuet, Pautot and Le Pichon (1971) also identify this formation and label it D, pointing out that it drapes the igneous basement relief. Based on the preliminary results of Leg 12 (Laughton *et al.*, 1970), they attribute a Middle Eocene age to formation D.

In the discussion of the survey data earlier in this chapter, it was pointed out that in the vicinity of Site 118 there was no clear indication of formation 4 from *Glomar Challenger* records. The *Charcot*-9 record, published and annotated in Sibuet *et al.* (1971), suggests that formation 4 laps onto the basement high west of Site 118 and that Hole 118 might have penetrated it. However due regard was not paid to the nearly E-W elongation of the basement high and to the fact that Hole 118 lay north of the *Charcot* track (Figure 2). We believe that the *Charcot* record shows a zone of diffraction hyperbolae from the nearby basement which here gives the impression of formation 4. (Figure 4). We do not know, therefore, whether formation 4–as typical of the Bay of Biscay as a whole–was in fact sampled in Hole 118.

The oldest sediments above the basalt were Paleocene red clays, grading upwards to Middle Eocene brown and gray clays 80 meters above. If the basalts sampled at the bottom of the hold were both sills above igneous basement, older sediments may lie below. The Paleocene to Middle Eocene sediments are believed to be deep sea pelagic sediments deposited at 1.5 cm/1000 yrs, and deposited perhaps below the carbonate compensation depth. The marbled appearance and crushed zones indicate subsequent tectonic activity which might have lifted the basement and sediments to form the basement ridge. The 32 million year unconformity above the Middle Eocene clays does not permit the age of this tectonic activity to be accurately assessed. However, assuming no erosion after uplift, it probably took place in the Middle Eocene after which sediments accumulated only in the deeper basins around the ridge until they covered the site in the Lower Miocene.

In conclusion, therefore, if the sediments below the unconformity represent formation 4 (or D), the formation is tectonized Paleocene to Middle Eocene (55 to 47 million years) red clay.

The Turbidites and Oozes

Above the unconformity of 32 million years at 680 meters, there is a long succession of turbidites interbedded with normal pelagic sediments. The sedimentation rate is much higher than below the unconformity, varying widely from 1 to 12 cm/1000 yrs. During the Middle to Late Miocene there was a period of slower sedimentation, or even a period of erosion. The strong mid-R reflector at 400 meters correlates with the top of a zone of sandstones. However these sandstones extend down to 600 meters (into the region of high sedimentation rate in the Middle Miocene) and therefore contribute to the long reverberations of the mid-R reflections. These carbonate sands may have been supplied during a time following earth movements in the Pyrenees and the Aquitaine which made available for erosion large quantities of loosely consolidated shallow water carbonate sediments.

The high sedimentation rate (5 cm/1000 yrs) in the Pliocene brought finer sediments to the site. The absence of coarse sediment layers gave rise to a relatively transparent layer. In the Pleistocene, coarser turbidites were deposited at an even higher rate (12.5 cm/1000 yrs) than during the Middle Miocene, due possibly to the lower sea level during the glacial period and the consequent intense erosion of the continental shelves. These sand layers give rise to the strong reflections observed in the top 0.3 second. Not all the sediments coming into the Bay of Biscay by turbidity currents from the continental shelves are deposited on the abyssal plain. The plain has now exceeded the sill depth at its southwestern end and turbidity currents have cut a deep channel linking the Biscay abyssal plain with the Iberian abyssal plain (Laughton, 1960). Recent erosion in the channel has been observed photographically (Laughton, 1968). If the sill depth had not been exceeded, the recent sedimentation rate would have been even higher than the 12.5 cm/1000 yrs observed for the last 5 million years.

The Tectonics of the Bay of Biscay

Hole 118 has indicated that a deep ocean basin existed there at least as early as the Paleocene, and that a major tectonic event occurred to uplift the local ridge during the Middle Eocene or later (prior to Lower Miocene). A discussion of the significance of this in relation to the history of the development of the Bay of Biscay and to movements of Spain and Europe will be deferred until the end of the following chapter when the two Biscay holes will be discussed together.

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Site Hole	Core	Section	Interval (cm)	Sand	Silt	Clay	Quartz	Feldspar	Pyroxene	Chlorite	Dark Mica	Light Mica	Dark Glass	Light Glass	Palagonite	Glauconite	Phosphorous	Pyrite	Authigenic Carbonates	Barite	Phillipsite	Other Zeolites	Micronodules	Other Minerals	Abundance	Estimated Carbonates	Foraminifera	Calcareous Nannofossils	Diatoms	Radiolaria	Sponge Spicules	Plant Debris	Fish Debris	Lithology and Comments
118	1	1	130	R	A	A	C			R			R	R				C				R				20		A						Silty clay; some detrital minerals and limonite(?), few foraminiferal frags.
118	1	2	21		A	A	A	C						R				C			R					20		A						Fine silty clay; lots of indeterminate clays and phillipsite.
118	1	2	26	A	A	C	A	A		C	C			C				C						X		10		C						Fine sandy silt; hornblende.
118	1	3		A	A	C	C	C		R	C			C				C						X		15	R	C						Sandy silt; some glass has long acicular inclusions; some staurolite, hornblende, calcite.
118	1	5	130		C	A	A	A		C	C							C								10		C						Silty clay; staurolite, hornblende.
118	1	5	148		C	A	R	R			R							C	R							75		A						Silty clay; dominantly nannoplankton clay.
118	1	6	70		A	D	R	R																			C	D						Silty clay; nannofossil-foraminiferal clay.
118	1	6	80	R	A	A	A	A		C	C			C				C						X		15		C						Silty clay; hornblende, organic fibers, includes some discoasters and lot of clay.
118	2	2	147		A	A	C	C			C			C				C				C				15		C						Silty clay; long needles-natrolite(?).
118	2	2	140		A	A	R	R		C												C				15		C						Fine silty clay; abundant clay minerals and zeolites.
118	2	3	140	R	A	A	C	C			C		R					C						X										Silty clay; kyanite, staurolite.
118	2	4	90	C	A	A	C	C			C							C								25	C							Slightly sandy silt; some detrital minerals.
118	2	5	100	C	A	C	A	A			R							R	R							25	C	C						Fine sandy silt; tourmaline, hornblende, zircon.
118	2	5	130		A	D	R															A				75		A						Silty clay.
118	2	6	100	A	A	C	A	C		C								C	R								C	C						Fine sand; dolomite, zircon.
118	2	6	134	A	C	C	A	C			C							C	X			X				15	C	R						Med-fine sand; dolomite, staurolite, natrolite, hornblende.
118	3	1	89	C	A	C	C	C										C				C				25	C	C						Sandy silt; natrolite, staurolite, epidote.
118	3	2	111	A	A	A	A	C		R	R		R					C	X			R				20	C	C						Silty sand; dolomite, staurolite, natrolite, rutile.
118	4	2	20	R	A	D	C				R								R			R		X		35	C	A						Silty clay; tourmaline.
118	4	2	120	C	A	C	C	R			R					C		C	C			R		X	R	30	C	A						Sandy silt; tourmaline and andalusite.
118	4	3	40	A	A	C	C	C		R						C		C	C					X		50	C	C						Sandy silt; hornblende, tourmaline.
118	4	3	92		R	A	R				R			R				R	R			R				85		D						Clay.
118	4	3	125		C	A	R						R			R		R				R				75		D						Slightly silty clay.
118	5	2	139	C	A	C	C	R			R					R		A						X		10	R	C						Sandy silt; tourmaline.
118	5	2	50		R	A													C							85	R	D						Clay.
118	5	2	63		C	A	R				R			C				C				C				75		A						Slightly silty clay.
118	5	3	136	C	A	A	C	C			R					R		C	C					X	R	40	C	A						Sandy silt; andalusite, staurolite, kyanite, garnet; much more carbonate than layers above.
118	6	1	37	A	A	A	C									C		X	A			R				70	A	C			A			Fine silty sand.

D = Dominant, 65+%; A = Abundant, 41%–65%; C = Common, 16%–40%; R = Rare, 0%–15%.

APPENDIX A – *Continued*

Site Hole	Core	Section	Interval (cm)	Sand	Silt	Clay	Quartz	Feldspar	Pyroxene	Chlorite	Dark Mica	Light Mica	Dark Glass	Light Glass	Palagonite	Glauconite	Phosphorous	Pyrite	Authigenic Carbonates	Barite	Phillipsite	Other Zeolites	Micronodules	Other Minerals	Abundance	Estimated Carbonates	Foraminifera	Calcareous Nannofossils	Diatoms	Radiolaria	Sponge Spicules	Plant Debris	Fish Debris	Lithology and Comments
118	6	3	20	A	A	C	C	C								R		C						X	R	50	C	C			A			Fine silty sand; tourmaline, staurolite.
118	6	6	64	A	A	A	C	C		R	R					R		C	C							80		C			A			Sandy silt
118	6	6	90		C	A												C	C									A			A			Silty clay.
118	6	6	140	C	A	A	R									R		C	C							35	C	C			A			Sandy silt.
118	7	1	100																															Silty sand; all recrystallized carbonate and sponge spicules, lot of authigenic calcite.
118	9	2	47	A	A	C	C	C			R					R		R	C			R		X	R	60	C	C			C			Sandy silt; zircon, tourmaline.
118	10	1	53		C	A								R				R	C							75	R	A			C			Slightly silty clay.
118	10	1	85		C	D								R					A			C				80		D			C			Slightly silty clay.
118	11	1	20		C	A	R							C	R			R				A				5								Slightly silty clay.
118	12	1	43		A	A	R							A	A			R				A				5					C			Silty clay.
118	12	2	75	R	A	A	C	R			R			C	C	R		C				C		X		5					A			Slightly sandy silt; zircon.
118	12	3																																Limonitic clay.
118	13	2	70		C	D	R															C		X	R	30		C						Slightly silty clay; very rare tourmaline, mostly clay minerals and nannofossils.
118	16	1	40											D																				All glass shards.
118	17	1	130																															All clay minerals.

APPENDIX B
TABLE 1
Deep Sea Drilling Project Grain Size Determinations for Site 118[a]
(All samples, except 12/4/31, are from the coarse part of turbidites.)

Site	Core	Section	Interval	Per Cent Sand	Per Cent Silt	Per Cent Clay	Classification
118	1	2	25.0	2.2	69.6	28.2	Clayey silt
118	1	3	0.0	11.4	34.2	54.4	Silty clay
118	2	5	110.0	71.3	19.7	9.0	Silty sand
118	2	6	70.0	54.8	31.1	14.1	Silty sand
118	3	1	49.0	0.0	37.4	62.6	Silty clay } Top/middle/bottom of single graded bed
118	3	1	88.0	6.4	84.9	8.9	Silt } Top/middle/bottom of single graded bed
118	3	2	110.0	24.2	59.4	16.4	Sandy silt } Top/middle/bottom of single graded bed
118	4	2	26.0	2.5	70.0	27.4	Clayey silt
118	4	3	77.0	21.2	61.1	17.7	Sandy silt
118	5	3	134.0	55.6	27.3	16.9	Silty sand
118	6	1	34.0	65.5	22.8	11.7	Silty sand
118	6	6	144.0	32.0	36.4	31.6	Sand-silt-clay
118	7	1	98.0	71.9	19.3	8.7	Silty sand
118	12	4	31.0	0.1	24.4	75.5	Clay

[a]Analyses carried out under the supervision of G. W. Bode and R. E. Boyce, Scripps Institution of Oceanography.

APPENDIX B
TABLE 2
Grain Size Analysis of Samples from a Single Turbidite (118 - 2-6)[a]

Sample Position	Grain Size Distribution (%; Size classes in Phi units) <0	0-1.0	1-1.75	1.75-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10	Percentiles (Phi units) P_5	P_{16}	P_{50}	P_{84}	P_{95}	M_z[b]	σ_I[c]
10.0			2.6			2.0	5.6	8.8	19.2	21.7	13.7	26.4	5.1	6.7	8.5	(11.0)	(12.7)	8.7	2.22
					2.6	4.6	10.2	19.0	38.2	59.9	73.6	100							
38.0			5.6			2.1	19.3	23.3	14.8	10.6	8.0	16.2	(3.6)	5.5	7.0	10.0	(12.4)	7.5	2.45
					5.6	7.7	27.0	50.3	65.1	75.7	83.7	99.9							
54.0		0.1		1.9	14.0	23.9	23.3	9.3	6.7	6.4	4.2	10.1	3.4	4.0	5.4	8.8	(11.8)	6.0	2.48
			0.1	2.0	16.0	39.9	63.2	72.5	79.2	85.6	89.8	99.9							
67.0		0.1	1.0	12.5	29.9	17.7	8.4	6.5	5.6	5.5	6.3	8.5	2.4	3.1	4.4	8.4	(10.3)	5.3	2.41
		0.1	1.1	13.6	43.5	61.2	69.6	76.1	81.7	87.2	93.5	102							
79.0		0.2	1.3	18.4	31.9	18.9	7.7	4.4	3.6	4.0	2.4	7.0	2.2	2.8	4.0	7.3	(11.3)	4.7	2.50
		0.2	1.5	19.9	51.8	70.7	78.4	82.8	86.4	90.4	92.8	99.8							
89.0		0.2	1.7	26.1	36.6	12.2	7.1	2.9	2.8	2.5	1.9	6.0	2.1	2.6	3.6	6.0	(10.5)	4.0	2.13
		0.2	1.9	28.0	64.6	76.8	83.9	86.8	89.6	92.1	94.0	100							
98.0	0.1	0.3	2.7	36.6	33.2	9.5	4.2	2.8	1.9	2.4	1.9	4.3	1.9	2.4	3.3	5.4	9.6	3.7	1.92
	0.1	0.4	3.1	39.7	72.9	82.4	86.6	89.4	91.3	93.7	95.6	99.9							
109.0			0.1	22.4	15.4	4.5	22.8	24.2	5.0	1.4	0.8	3.4	2.5	2.8	5.3	6.7	8.3	4.9	1.85
			0.1	22.5	37.9	42.4	65.2	89.4	94.4	95.8	96.6	100							
119.0		0.2	5.5	56.7	15.9	9.8	5.3	2.3	1.2	0.9	–	2.0	1.7	2.1	2.7	4.5	6.6	3.1	1.34
		0.2	5.7	62.4	78.3	88.1	93.4	95.7	96.9	97.8	97.8	99.8							
130.0		0.1	1.8	50.5	26.6	7.6	3.2	2.9	2.2	1.5	1.2	2.5	2.0	2.3	2.9	4.6	8.0	3.2	1.48
		0.1	1.9	52.4	79.0	86.6	89.8	92.7	94.9	96.4	97.6	100							
133.0			5.5			3.8	5.6	8.0	16.4	18.6	12.6	29.4	(3.8)	6.1	8.7	(11.1)	(12.7)	8.6	2.60
					5.5	9.3	14.9	22.9	39.3	57.9	70.5	99.9							

[a]Analyses by J.W. Bode; Methods: $\phi < 4.0$ dry sieve
$\phi > 4.0$ Pipette.

[b]Graphic mean $(M_z) = (P_{16} + P_{50} + P_{84})/3$.

[c]Inclusive graphic standard devision $(\sigma_I) = \frac{(P_{84} - P_{16})}{4} + \frac{(P_{95} - P_5)}{6.6}$.

[d]First line per entry – % within size class.
Second line per entry – cumulative % to size class.

APPENDIX C. CARBON-CARBONATE CONTENT OF SAMPLES FROM SITE 118[1]

Site	Core	Section	Top Interval	Hole Depth	Total Carbon	Organic Carbon	$CaCO_3$
118	1	2	14.0	97.6	3.7	1.0	23
118	1	6	30.0	103.8	9.5	0.2	77
118	2	6	15.0	207.6	5.9	0.7	43
118	4	2	15.0	351.6	5.6	0.5	42
118	5	2	47.0	401.0	8.6	0.1	71
118	8	1	115.0	506.1	8.2	0.1	68
118	10	1	28.0	604.3	7.0	0.6	54
118	11	1	15.0	650.2	6.4	0.2	51
118	15	1	0.0	714.0	7.7	0.1	64

[1]Analyses carried out under the supervision of G. W. Bode and R.E. Boyce, Scripps Institute of Oceanography.

APPENDIX D. LISTS OF SELECTED PLANKTONIC AND BENTHONIC FORAMINIFERA AND AGE DETERMINATIONS

W. A. Berggren

Site 118

Sample 12-118-1-1, 146-149 cm:
PF: *Globigerina bulloides, G. pachyderma* (predominantly dextral), *Globorotalia inflata, G. truncatulinoides, G. hirsuta, Globoquadrina dutertrei, Globigerinoides conglobata, Orbulina universa, Globigerinita glutinata.*
BF: *Bulimina marginata, Cibicides* sp. cf. *C. lobatula.*
Also present: Echinoid spines, mica flakes, and green (?epidote) mineral grains.
Age: Pleistocene.
A similar fauna to the above is found in the following samples:
Sample 12-118-1-2, 144-147 cm
Sample 12-118-1-3, 146-149 cm
Sample 12-118-1-5, 147-150 cm

Sample 12-118-1-6, 133-136 cm:
PF: *Globigerina bulloides, G. pachyderma* (predominantly dextral), *Globorotalia inflata, G. truncatulinoides, Globoquadrina dutertrei, Orbulina universa, Globigerinita glutinata.*
BF: Rich, diverse, containing *i. al. Cassidulina crassa, Pullenia sphaeroides, Eponides frigidus*?, *Cibicides lobatulus, Eponides umbonatus, Melonis* sp., *Melonis barleeanum, M. pompilioides, Gyroidina soldanii, Fissurina annectens, Fissurina* sp. (*marginata* group), *Oolina globosa, Cassidulina carinata, Pyrgo denticulata, Pyrgo* sp., *Angulogerina angulosa, Quinqueloculina* sp. cf. *Q. seminulum, Virgulina* sp. cf. *V. schreibersiana.*
Age: Pleistocene.

Sample 12-118-1, Core Catcher:
PF: *Globigerina bulloides, G. pachyderma* (predominantly dextral), *Globorotalia inflata, G. truncatulinoides, Hastigerina siphonifera, Globigerinoides conglobata, Orbulina universa.*
BF: Varied common, including *Globobulimina* sp., *Pyrgo murrhyna, Quinqueloculina* sp., *Nonion barleeanum, N. pompilioides, Epistominella exigua, Eggerella bradyi, Textularia agglutinans, Eponides* sp., Cibicides sp. cf. *C. lobatulus, Anomalina* sp. cf. *A. globulosa.*
Age: Pleistocene.
Remarks: Samples from Core 1 contain, in general, a varied planktonic and benthonic foraminiferal fauna of Pleistocene age. Quartz grains (both angular and clear and rounded and frosted) occur commonly in these samples and particularly in Sample 12-118-1-3, 146 to 149 centimeters. In this sample there are abundant broken discolored fragments of thick-shelled mollusca. Although some of the detrital fragments in this core may have been transported by ice-rafting the major mode of transportation appears to have been by turbidity currents.

Sample 12-118-2-1, 145-148 cm:
Gray-blue clay with abundant mica, quartz and silt-sized grains and badly worn fragments of mollusca, bryozoa and foraminifera, indicating transportation by turbidity currents.
PF: *Globigerina bulloides, G. pachyderma, Globorotalia truncatulinoides, G. inflata, Orbulina universa, Globigerinita glutinata*
BF: Cibicidids, *Angulogerina*, miliolids, *Elphidium* and other shallow-water foraminifera.
Age: Pleistocene.
Essentially similar faunas (as above sample) are found in the following samples from this section:
Sample 12-118-2-2, 145-148 cm
Sample 12-118-2-3, 145-148 cm
Sample 12-118-2-4, 145-148 cm
Sample 12-118-2-5, 104-107 cm
Sample 12-118-2-5, 124-127 cm
Sample 12-118-2-5, 143-146 cm
Sample 12-118-2-6, 143-146 cm
In Sample 12-118-2-5, 104 to 107 centimeters angulogerinids and discorbids are particularly prominent.

Sample 12-118-2, Core Catcher:
Lithology as above.
PF: *Globigerina pachyderma* (predominantly dextral), *G. bulloides, Globorotalia truncatulinoides, G. inflata, Hastigerina siphonifera, Orbulina universa, Globigerinoides rubra*
BF: *Uvigerina* sp., *Cibicides* sp., *Nonion pompilioides, Pullenia* sp., *Eponides* sp., *Elphidium* sp.
Age: Pleistocene.
Remarks: The mixed benthonic foraminiferal fauna in Core 2 contains both abyssal faunal elements and faunal elements which have been displaced from shallow waters by turbidity currents. The presence of *Globorotalia truncatulinoides* corroborates the Pleistocene age determination based upon calcareous nannofossils.

Sample 12-118-3-1, 146-149 cm:
Only fine residue remained after processing and consists predominately of minute globigerinids and bolivinids.
Age: Late Pliocene (based upon calcareous nannoplankton).

Sample 12-118-3-2, 146-149 cm:
PF: *Globigerina bulloides, Globorotalia crassaformis, Orbulina universa, Globigerinita glutinata.*
BF: Benthonics sparse, relatively small. *Melonis* sp., various rotaliids.
Age: Late Pliocene.

Sample 12-118-3, Core Catcher:
PF: *Globigerina atlantica* (sinistrally coiled), *Globorotalia inflata, G. puncticulata, G. crassaformia, G. hirsuta.*
BF: *Cassidulina subglobosa, Pyrgo* sp., *Quinqueloculina* sp., *Eggerella bradyi, Eponides* sp., *Karreriella bradyi, Nonion barleeanum, Textularia agglutinans, Planulina* sp., *Lenticulina* sp., *Dentalina* sp., *Fischerina exsculpta.*
Age: Late Pliocene.
Remarks: Core 3 contains the youngest occurrence of *Globigerina atlantica.* Its apparent termination here in sediments of Late Pliocene age is similar to that observed in cores from the North Atlantic. Sediments of Core 3 were deposited primarily as turbidite sands.

Sample 12-118-4-1, 147-150 cm:
Only fine sand residue remained after processing. Fauna consists of minute globigerinids, bolivinids, and rotaliids. No age determination (Core 4 is dated as Early Pliocene based on calcareous nannoplankton).

Sample 12-118-4-2, 141-144 cm:
Essentially the same as sample above. Faunal residue consists of abundant minute globigerinids, bolivinids, rotaliids, lagenids among others. The sediment is apparently of turbidite origin.
Age: Early Pliocene (calcareous nannoplankton).

Sample 12-118-4-3, 146-149 cm:
Residue of quartz sand, mica, epidote, and small foraminifera including gyroidinids, uvigerinids, Eponides, and rotaliids.
Also present: Reworked planktonic foraminifera, including *Globorotalia subbotinae* of Early Eocene age.
Age: Early Pliocene (see above).

Sample 12-118-4, Core Catcher:
PF: *Sphaeroidinellopsis subdehiscens, Globigerinoides obliqua.*
BF: *Eponides* sp., *Laticarinina halophora, Cibicides* spp., *Cassidulina subglobosa, Lenticulina* sp., *Gyroidina* sp., *Pyrgo* sp.
Age: Early Pliocene (based on calcareous nannoplankton).
Remarks: Core 4, in general, contains a very meager assemblage of planktonic foraminifera. Age determination of this core is based entirely upon calcareous nannoplankton. The sediments of Core 4 are primarily turbidites.

Sample 12-118-5-2, 141-144 cm:
Turbidite sands with very fine-grained residue of quartz and minute benthonic and planktonic foraminifera. No age determination (See below under remarks).

Sample 12-118-5-3, 140-143 cm:
Same as sample above. Various cibicidids and rotaliids present.

Sample 12-118-5, Core Catcher:
Turbidite sand with abundant mica and small foraminiferal fauna. *Melonis* sp., *Gyroidina* sp., cibicidids and rotaliids.
Remarks: The sediments of Core 5 consist of turbidite-derived sands and clays with abundant mica. Foraminifera, in general, are preserved only in the small fraction; very few foraminifera were found in the larger fractions. This suggests that coarser material has been winnowed out during transportation. No age determination based upon planktonic foraminiferal fauna has been possible. Core 5 is questionably assigned to the *C. tricorniculatus* Zone. This zone is approximately equivalent to Zone N18, and is at or slightly above the Miocene-Pliocene boundary.

Sample 12-118-6, Top:
Rich planktonic foraminiferal fauna, with cemented biogenic and quartz-mineral grain matrix.
PF: *Orbulina universa, Globigerina bulloides, G.* sp. cf. *G. atlantica, Globorotalia miozea, G. conoidea, Globigerinoides* spp.
BF: Various rotaliids, cibicidids.
Age: Late Miocene.

Sample 12-118-6-1, 147-149 cm:
Essentially the same as the sample above.

Sample 12-118-6-6, 138-140 cm:
Turbidite sand with abundant strongly corroded and worn thick-shelled molluscan fragments. Benthonic and planktonic foraminifera as above. *Globigerina apertura* also observed.

Sample 12-118-6, Core Catcher
Turbidite sand with abundant shell fragments as above.
PF: *Globigerina bulloides, G.* sp., *Orbulina universa, Globigerinoides* sp. cf. *G. triloba, Globorotalia miozea, G. conoidea.*
BF. *Cibicides refulgens, Elphidium* sp., *Discorbis* sp., *Uvigerina* sp., *Sphaeroidina bulloides, Globobulimina, Melonis pompilioides.*
Remarks: Sediments of Core 6 consist of turbidite-derived sands with abundant badly worn shell fragments. Sponge spicules and echinoid fragments are common. Foraminifera are commonly broken and cemented together. The presence of *Globorotalia miozea* and *G. conoides* together suggest that Core 6 is of Late Miocene age (Tortonian). Correlation with Zone N16 is suggested, and this is in agreement with the assignation of this core to the *Discoaster neohamatus* Zone.

Sample 12-118-7-1, 54-56 cm:
Residue of quartz and foraminiferal sand and broken shell fragments and abundant sponge spicules.
PF: Small indeterminate globigerinids.
BF: Various cibicidids, rotaliids, bolivinids, angulogerinids, etc.
Age: No age determination possible (see below).

Sample 12-118-7, Core Catcher:
Lithology as above.
PF: Planktonic foraminifera sparse and poorly preserved. *Orbulina universa, Globoquadrina dehiscens, Globigerinoides* sp.
BF: *Lenticulina* sp., *Cibicides* sp., *Gyroidina* sp., *Melonis* sp., *Planulina* sp., lagenids.
Age: Early Miocene (based on calcareous nannoplankton).
Remarks: Sediments in Core 7 are primarily of turbidite origin. The biogenic components are badly corroded and broken. Age determination based on planktonic foraminifera has not been found possible. Core 7 is placed in the *Discoaster hamatus* Zone by K.P-N. This would place it in the Middle Miocene, approximately equivalent to the upper part of Zone N14 or the lower part of Zone N15.

Sample 12-118-8-1, 97-99 cm:
Residue of quartz and shell fragments and foraminifera.
PF: Planktonic foraminiferal fauna sparse and poorly preserved. *Globigerina* sp., *Globoquadrina dehiscens, Globigerinoides* sp., *Sphaeroidinellopsis seminulina, Globigerina* sp. cf. *G. druryi, Globorotalia miozea.*
BF: Rotaliids and cibicidids.
Age: Middle Miocene.

Sample 12-118-8, Core Catcher
Gray-blue silty marl with moderate foraminiferal fauna.
PF: *Globorotalia fohsi* s.s., *Globigerinoides triloba, Globoquadrina dehiscens, Orbulina universa, Globigerina woodi.*
BF: *Gyroidina* sp., *Planulina* sp., *Melonis barleeanum, Eggerella bradyi, Laticarinina halophora, Fischerina, Siphonodosaria* sp., *Oolina* sp.
Also present: Shark teeth and pelecypod fragments.
Age: Middle Miocene.
Remarks: The presence of relatively well-preserved specimens of *Globorotalia fohsi* s.s. indicates that Core 8 is assignable to Zone N12. This is corroborated by its assignation to the *Discoaster exilis* Zone by K.P-N.

Sample 12-118-9-1, 145-147 cm:
Residue of quartz sand and cemented biogenic debris (mollusca and foraminiferal shell fragments).
PF: Sparse, generally poorly preserved. *Orbulina universa, Globoquadrina dehiscens, Globigerinoides* sp., *Globorotalia* sp. (keeled).
BF: Sparse. *Eggerella* sp., rotaliids.
Age: Middle Miocene.

Sample 12-118-9-2, 144-146 cm:
Lithology essentially the same as above. Predominantly benthonic foraminifera, quartz sand, echinoid and sponge spicules. Planktonic fauna virtually absent. Benthonic fauna consisting of abundant rotaliids, cibicidids, *Eggerella* sp., *Melonis* sp., *Planulina* sp.
Age: Middle Miocene.

Sample 12-118-9, Core Catcher
Gray-blue clay with sparse fauna.
PF: *Sphaeroidinellopsis seminulina, Globoquadrina dehiscens.*
BF: *Stilostomella* sp., *Cibicides* sp., *Laticarinina* sp., *Melonis pompilioides.*
Age: Middle Miocene.
Remarks: Core 9 consists of turbidite-derived quartz sand and foraminiferal and shell fragments. Stratigraphically distinct forms

are absent but an age determination of Middle Miocene is possible based on age determinations of Core 8 above and Core 10 below.

Sample 12-118-10-1, 116-119 cm:
Fine residue of quartz sand and benthonic foraminifera, sponge spicules and Radiolaria. No age determination (Middle Miocene, see below).

Sample 12-118-10, Core Catcher:
PF: *Globorotalia miozea* (common), *Orbulina universa, Globoquadrina dehiscens, Globigerina* sp. (small, four-chambered, with distinct high-arched aperture opening over the first chamber of the last whorl. This species bears a strong resemblance to *Globigerina druryi*. However, the arched aperture in that form is centrally located), *Praeorbulina glomerosa circularis*.
BF: *Planulina ariminensis, Melonis pompilioides, Cassidulina subglobosa, Gyroidina* sp.
Age: Middle Miocene (probably Zone N9). This agrees with the questionable assignment of Core 10 to the *S. heteromorphus* Zone.

Sample 12-118-11-1, 20-23 cm:
Residue of fine quartz sand, mica and green (? epidote) mineral grains. Barren.

Sample 12-118-11, Core Catcher:
Sparse fauna, preservation poor.
PF: *Globigerinita* sp. cf. *G. dissimilis, Globigerinoides triloba*.
BF rotaliids, cibicidids, *Melonis, Gyroidina, Eponides*.
Remarks: The poor faunal data in Core 11 does not allow a definite determination of its age. The presence of a globigerinitid similar to *Globigerinita dissimilis* and the absence of *Orbulina* suggests that Core 11 is of Early Miocene age.

Sample 12-118-12-1, 0-5 cm:
Residue of fine quartz sand, spicules and abundant Radiolaria. Foraminifera rare, including Pleistocene contaminants.
Age: Early Miocene (based on Radiolaria, see report by R. B.). Fine quartz sand with abundant sponge spicules, Radiolaria and rich planktonic foraminiferal fauna.
PF: *Globorotalia subbotinae, G. marginodentata, G. aequa, Acarinina coalingensis* (= *A. primitiva* = *A. triplex*), *A. soldadoensis angulosa, Globigerina patagonica*.
Age: Probably Early Miocene; planktonic foraminiferal fauna is of Early Eocene age (Zone P6)
Remarks: This sample probably represents turbidite deposition in the Early Miocene, in which an Early Eocene planktonic foraminiferal assemblage has been incorporated. No evidence of mixing from other horizons is indicated. An unconformity occurs within Section 2 at about 145 centimeters between Miocene clays above and Middle Eocene clays below. Because of the way this core was drilled, this is probably not a true contact but represents a gap of several meters. Therefore, this sample which is within Section 1 is considered to be of Early Miocene age.

Sample 12-118-12, Base Section 1:
Buff, tan colored clays with abundant quartz and Radiolaria. No foraminifera.
Age: Early Miocene (Radiolaria).

Sample 12-118-12-2, 71-74 cm:
Essentially data is the same as for preceding sample.

Sample 12-118-12-2, 136-137 cm:
Quartz sand and abundant Radiolaria and fragments of indeterminate agglutinated foraminifera.
Age: Early Miocene (Radiolaria).

Sample 12-118-12-2, 146-149 cm:
Quartz sand and Radiolaria.
Age: Indeterminate, probably Early Miocene.

Sample 12-118-12-3, 129-131 cm:
Diverse benthonic foraminifera. Sparse planktonic foraminiferal fauna.
PF: *Acarinina densa, Globorotalia pseudoscitula* (= *G. renzi*), *Acarinina collactea, Globigerapsis index*.
BF: *Nuttallides truempyi, Gaudryina* sp. cf. *G. hiltermanni*, bolivinids, rotaliids.
Age: Middle Eocene (Zone P10).

Sample 12-118-12-3, 139-141 cm:
Fauna essentially the same as preceding sample above.

Sample 12-118-12-4, 143-146 cm:
Fauna same as above.

Sample 12-118-12, Core Catcher:
PF: *Acarinina densa, A. coalingensis, Globigerina senni.*
BF: Abundant, diverse: *Karreriella chapapotensis, K.* sp. cf. *K. bradyi, K. chilostoma, Cibicidoides havanensis, C. trinidadensis, C. martinezensis, Pleurostomella naranjoensis, P. beirigi, Oridorsalis ecuadorensis, Alabamina dissonata, Cibicides cushmani, Gaudryina jacksonensis, Nodosarella mappa, Stilostomella verneuilli, S. paucistriata*?, *Buliminella grata, Cassidulina subglobosa, Rhabdammina* sp. ?, *Glomospira charoides, Nuttallides truempyi, Gyroidinoides planulatus, G. altiformis, Melonis havanese*?.
Age: Middle Eocene (Zone P10).
Remarks: An unconformity was observed on shipboard at 145 centimeters in Section 2. This unconformity separates Miocene clays above from Eocene clays below. The Miocene clays are characterized by a high quartz sand residue with abundant Radiolaria and sponge spicules and are primarily of turbidite origin. The Eocene clays, on the other hand, are composed primarily of rich benthonic and planktonic foraminiferal assemblages and are of pelagic origin. Within Section 1 (83 to 84 centimeters) a planktonic foraminiferal fauna of Early Eocene age (similar to those recorded in Core 14, see below) was found in a turbidite sand.

Sample 12-118-12-1, 140-141 cm:
Buff colored, planktonic foraminiferal marl.
PF: *Acarinina densa, A. soldadoensis angulosa, Acarinina* sp.
BF: *Nuttallides truempyi, Oridorsalis ecuadorensis, Anomalinoides grosserugosa, Gaudryina* sp. cf. *G. hiltermanni*, diverse cibicidids.
Age: Middle Eocene (Zone P10).

Sample 12-118-13-2, 148-150 cm:
Data essentially the same as preceding sample above.

Sample 12-118-13, Core Catcher:
PF: *Acarinina densa, A. coalingensis, Globorotalia aragonensis, Globigerina* sp.
BF: *Nuttallides truempyi, Oridorsalis ecuadorensis, Gyroidina nitidula, Gaudryina* cf. *hiltermanni*, diverse cibicidids.
Age: Middle Eocene (Zone P10).

Sample 12-118-14-1, Top:
PF: *Globorotalia subbotinae, G. marginodentata, G. formosa, G. lensiformis, Globigerina patagonica, Acarinina soldadoensis, Acarinina coalingensis*.
BF: *Nuttallides truempyi, Oridorsalis ecuadorensis, Gaudryina* cf. *hiltermanni Gyroidina* sp., diverse cibicidids and rotaliids.
Age: Early Eocene, probably *G. formosa* Zone (P7).

Sample 12-118-14-1, 4-6 cm:
Planktonic foraminiferal marl. Fauna essentially the same as sample above. Acarininids dominant, globorotaliids subordinant.
Age: Early Eocene.

Sample 12-118-14-1, 66-68 cm:
Pelagic fauna essentially as above. *Globorotalia aragonensis* also present.
Age: Early Eocene.

Sample 12-118-14-1, 142-143 cm:
Pelagic marl.
PF: *Acarinina broedermanni, Acarinina soldadoensis, Globigerina patagonica, G.* sp., *Globorotalia subbotinae, G. aragonensis*.

BF: *Nuttallides truempyi, Oridorsalis ecuadorensis, Gaudryina* cf. *hiltermanni*, diverse rotaliids and cibicidids.
Age: Early Eocene.

Sample 12-118-14-2, 132-134 cm:
Rich planktonic faunal assemblage.
PF: *Globorotalia subbotinae, G. marginodentata, G. formosa, G. formosa gracilis, Acarinina soldadoensis, A. soldadoensis angulosa, Globigerina patagonica.*
BF: *Nuttallides truempyi, Oridorsalis ecuadorensis, Gaudryina* cf. *hiltermanni*, diverse rotallids and cibicidids.
Age: Early Eocene (probably Zone P7).

Sample 12-118-14, Core Catcher:
Buff colored planktonic foraminiferal marl. Benthos relatively rare. Abundant keeled globorotaliids.
PF: *Globorotalia subbotinae, G. formosa gracilis, G. marginodentata, Acarinina wilcoxensis, A. coalingensis, A. soldadoensis, A. pentacamerata, Globigerina patagonica, Chiloguembelina* sp. cf. *wilcoxensis.*
Age: Early Eocene (probably Zone P6).
Remarks: Core 14 consists of tan to buff colored marls composed almost entirely of planktonic foraminifera and calcareous nannoplankton. In some samples the keeled globorotaliids and acarininids occur in comparable quantities; in other samples one or the other group dominate.

Sample 12-118-15, Top:
Coccolith-foraminiferal ooze.
PF: *Globorotalia subbotinae, G. marginodentata, G. formosa gracilis, G. aequa, Globigerina patagonica, Acarinina coalingensis, A. soldadoensis, Chiloguembelina wilcoxensis.*
BF: Sparse, *Nuttallides truempyi*, rotaliids.
Age: Early Eocene (Zone P6).

Sample 12-118-15-1, 99-101 cm:
Lithology and fauna same as preceding sample above. Preservation of planktonic foraminifera extremely good.
Age: Early Eocene (Zone P6).

Sample 12-118-15, Core Catcher:
Lithology and fauna essentially the same as above.
PF: *Globorotalia subbotinae, G. marginodentata, G. aequa, Globigerina patagonica, Chiloguembelina wilcoxensis, Acarinina coalingensis, A. soldadoensis.*
BF: *Nuttallides truempyi*, diverse rotaliids.
Age: Early Eocene (Zone P6).
Remarks: Core 15 is characterized by a rich and diverse and well-preserved Early Eocene planktonic foraminiferal fauna. The presence of *Globorotalia subbotinae* and *G. marginodentata* and the absence of distinct Paleocene forms, such as *Globorotalia velascoensis* and *G. acuta*, and of younger forms, such as *Globorotalia formosa* (found in Core 14 above) suggests that this core is within the upper part of Zone P6, *i.e.*, Zone P6b.

Sample 12-118-16, Top:
Radiolaria-diatom ooze. No planktonic foraminifera or other calcareous organisms present.
Age: No age determination possible from foraminifera; Early Eocene (see below).

Sample 12-118-16-1, 51-53 cm:
Lithology and fauna as above.
Age: Early Eocene.

Sample 12-118-16, Core Catcher:
Reddish clay. Only Radiolaria and diatoms.
Age: Early Eocene.

Remarks: Core 16 is composed of reddish clays containing only a radiolarian-diatom fauna, calcareous organisms having been dissolved out. Core 16 is assigned an Early Eocene age because of its stratigraphic position.

Sample 12-118-17-1, 146-149 cm:
Reddish clay with some altered Radiolaria and abundant manganese nodules. A few planktonic foraminifera (acarininids, globigerinids).
Age: probably Early Eocene.

Sample 12-118-17-1, Base:
Lithology and fauna same as sample above.

Sample 12-118-17, Core Catcher:
Reddish clay as above but with large amount of quartz and calcareous benthonic and planktonic foraminifera of Mid-Cenozoic age. Probably contaminants from drilling operations.
Age: probably Early Eocene.
Remarks: Core 17 consists of reddish clays with abundant manganese and varying amounts of Radiolaria and diatoms and few calcareous foraminifera. It is placed in the Early Eocene, based on its stratigraphic position.

Sample 12-118-18-1, 144-147 cm:
Brownish clay. Residue contains large amount of quartz and cemented fragments of quartz and spicules and the broken cemented tests of agglutinated foraminifera, found in Miocene samples higher up in this hole. Also present are the green (?epidote) grains common at higher levels in this hole. This mixed lithology is probably the result of drilling contamination. Planktonic foraminifera consists of acarininids (*A. coalingensis* and *A. soladoensis*) globorotaliids (*G. subbotinae* and *G. marginodentata*), and globigerinids (*G. patagonica*) Also present are abundant Radiolaria and diatoms.
Age: Late Paleocene or Early Eocene.

Sample 12-118-18-2, 95-98 cm:
Lithology same as sample above (indicating drilling contamination).. Fauna same as above including *Chiloguembelina wilcoxensis.*

Sample 12-118-18, Core Catcher:
Gray-bluish and brownish clay with moderate planktonic foraminiferal fauna.
PF: *Globigerina patagonica, Globorotalia acuta, Globorotalia aequa, Acarinina soldadoensis, A soldadoensis angulosa, A. coalingensis.*
Also present: Diatoms and Radiolaria.
Age: Probably Latest Paleocene (Zone P6a)
Remarks: The planktonic foraminiferal fauna is essentially similar to those found in cores above, though the fauna is not very rich. Good specimens referable to *Globorotalia marginodentata* or *G. subbotinae were not found in the Core Catcher of Core 18. On the contrary, several specimens referable to Globorotalia acuta* were found suggesting that this level may be within the latest part of Zone P6a. The Paleocene-Eocene boundary is drawn here between Cores 17 and 18.

Sample 12-118-19, Core Catcher:
This sample, the only one recovered from Core 19, consists of reddish clay with a moderate planktonic foraminiferal fauna and some Radiolaria.
PF: *Globorotalia aequa, G. marginodentata, G. acuta, Acarinina coalingensis, A. soldadoensis, Globigerina patagonica, G. velascoensis.*
Also present: Manganese nodules.
Age: Probably Latest Paleocene (Zone P6a).
Remarks: Only the Core Catcher sample was obtained from Core 19. This is the lowest core from which fossiliferous samples were recovered. The fauna is sparse thus suggests a latest Paleocene age. Cores 20 and 21 are basalt, with many veins of calcite. Water samples obtained from these two cores contain a mixed assemblage of foraminifera and do not aid meterially in determination of the oldest stratigraphic level of this hole.

APPENDIX E. COCCOLITH SPECIES AND STRATIGRAPHIC ASSIGNMENT OF SITE 118

David Bukry

Hole 118

Lower Pleistocene
(*Coccolithus doronicoides* **Zone**)

12-118-2-6, 147-148 cm: depth 209 m:
Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discolithina japonica, D. multipora s.l., *Gephyrocapsa caribbeanica, Helicopontosphaera kamptneri, H. sellii, Rhabdosphaera clavigera, Scapholithus* sp.

Upper Pliocene
(*Discoaster brouweri* Zone)

12-118-3-2, 149-150 cm; depth 303 m:
Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri s.l. [rare].

Upper Miocene
(*Ceratolithus tricorniculatus* Zone)

12-118-4-3, 147-148 cm; depth 354 m:
Ceratolithus tricorniculatus, Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri s.l., D. pentaradiatus, D. sp. cf. *D. variabilis variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica.*

Middle Miocene
(*Discoaster exilis* Zone)

12-118-6-1, 144-145 cm; depth 449 m:
Coccolithus eopelagicus, Cyclococcolithina leptopora, C. macintyrei, C. leptopora, Discoaster sp. cf. *D. aulakos* Gartner, *D. braarudii, D. challengeri, D. deflandre, D. exilis, D. variabilis variabilis, Helicopontosphaera kamptneri, Lithostromation perdurum* Deflandre, *Reticulofenestra pseudoumbilica, Triquetrorhabdulus rugosus.* Reworked Eocene taxon: *Discoaster saipanensis.*

12-118-8-1, 92-93 cm; depth 506 m:
Coccolithus eopelagicus, Cyclococcolithina macintyrei, Discoaster braarudii, D. challengeri, D. sp cf. *D. dilatus* Hay, *D.* sp. cf. *D. exilis, D. variabilis variabilis, Discolithina multipora s.l., Regiculofenestra pseudoumbilica.* Reworked Miocene taxon: *Sphenolithus heteromorphus.*

12-118-10-1, 111-112 cm; depth 605 m:
Coccolithus eopelagicus, Cyclococcolithina leptopora, Discoaster braarudii, D. deflandrei, D. exilis, Reticulofenestra pseudoumbilica, Sphenolithus neoabies, Triquetrorhabdulus rugosus.

Series Unknown

12-118-11-1, 28-29 cm; depth 650 m:
Barren.

12-118-12-1, 0-5 cm, depth 687 m:
Barren.

12-118-12-2, 71-74 cm, depth 688 m:
Barren.

Middle Eocene
(*Chiphragmalithus quadratus* Zone)

12-118-12-4, 141-142 cm; depth 692 m:
Campylosphaera dela, Chiasmolithus expansus, C. gigas (Bramlette and Sullivan), *C. grandis, C. solitus* [small], *Chiphragmalithus cristatus* (Martini, *C. quadratus* Bramlette and Sullivan, *Coccolithus pseudogammation, C. staurion* Bramlette and Sullivan, *Cyclococcolithina formosa, Discoaster barbadiensis, D. gemmeus* Stradner, *D. saipanensis, D. wemmelensis.*

Middle Eocene
(*Discoaster sublodoensis* Zone)

12-118-13-2, 148-150 cm; depth 696 m:
Chiasmolithus sp. cf. *C. expansus, C. solitus, Chiphragmalithus cristatus, Coccolithus pseudogammation, C. staurion, Cyclococcolithina formosa, Discoaster barbadiensis, D.* sp. cf. *D. lodoensis, D.* sp. cf. *D. sublodoensis, Triquetrorhabdulus inversus* Bukry and Bramlette.

Lower Eocene
(*Discoaster lodoensis* Zone)

12-118-14-1, 140-141 cm; depth 696 to 708 m:
Chiasmolithus grandis, Coccolithus crassus, Cyclococcolithina formosa, Discoaster barbadiensis, D. lodoensis [large, abundant], *D. stradneri* Noël, *Discoasteroides kuepperi* [rare], *Tribrachiatus orthostylus* [rare].

Mixed Upper Paleocene and Lower Eocene

12-118-14-2, 132-134 cm; depth 696 to 708 m:
Eocene taxa: *Chiasmolithus grandis, Coccolithus crassus, Discoaster barbadiensis, D. diastypus, Tribrachiatus orthostylus.* Paleocene taxa: *Campylosphaera eodela* Bukry and Percival, *Discoaster multiradiatus, D. ornatus.* Eocene and Paleocene taxa: *Chiasmolithus consuetus, Ellipsolithus macellus.*

12-118-15-1, 99-100 cm; depth 714 m:
Paleocene taxa: *Campylosphaera eodela, Chiasmolithus bidens, Discoaster lenticularis* Bramlette and Sullivan, *D. multiradiatus, D. ornatus, Rhomboaster cuspis* Bramlette and Sullivan, *Toweius eminens* Bramlette and Sullivan. Eocene or Paleocene taxa: *Chiasmolithus consuetus, ?Tribrachiatus contortus.*

Series unknown

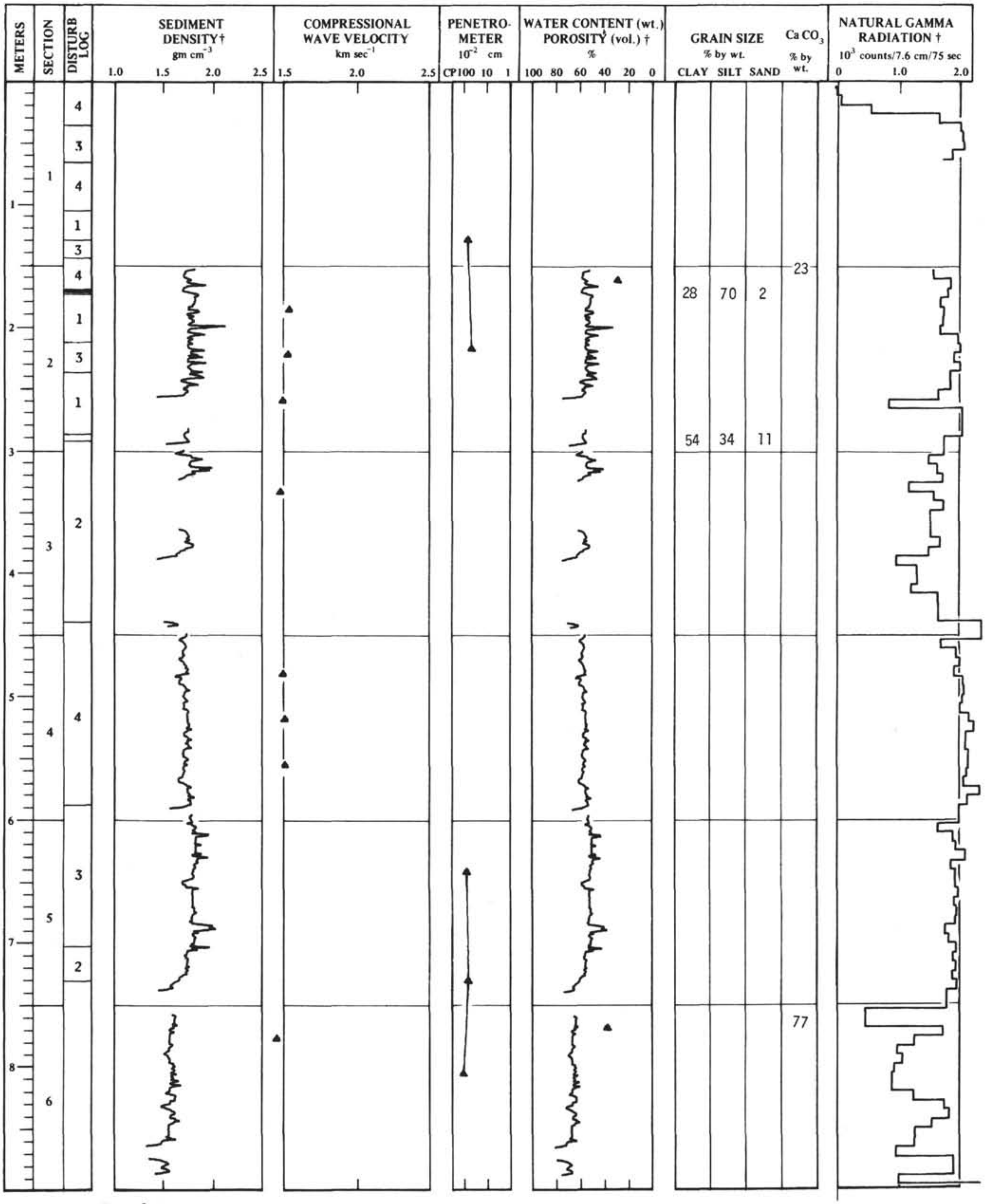
12-118-16-1, 52-53 cm; depth 723 m:
Barren.

12-118-17-1, 143-144 cm; depth 732 m:
Barren.

12-118-19-1, 8-9 cm; depth 750 m:
Barren.

HOLE 118

CORE 1



†Adjusted data, see Chapter 2

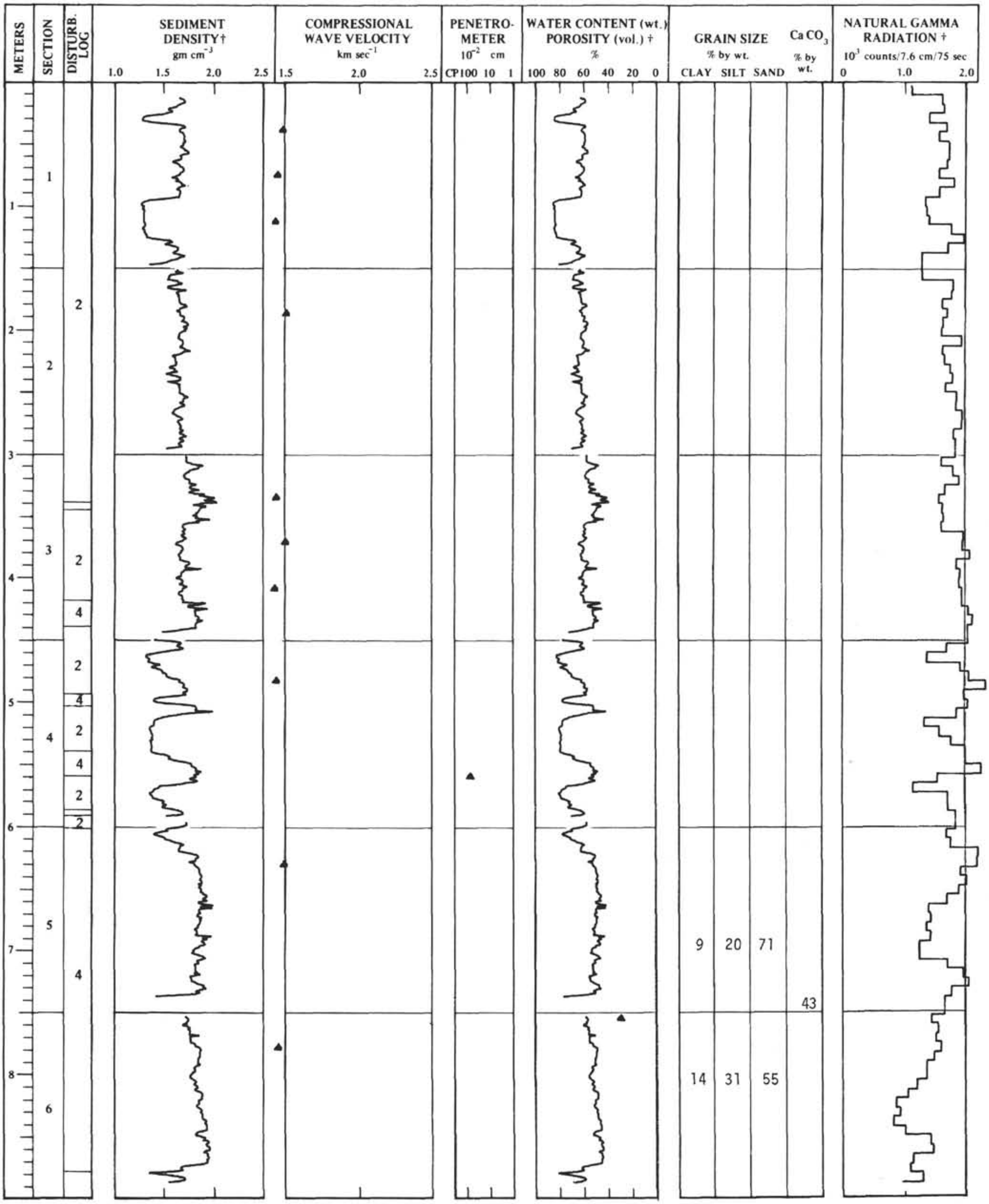
HOLE 118 96 **TO** 105 **m**

CORE 1

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
0–1.5	1	EMPTY			Flora: *Coccolithus pelagicus, Cyclococcolithus leptoporus, Gephyrocapsa oceanica, G. aperta* plus reworked Late Maestrichtian and Eocene (*Nephrolithus frequens, Zygrahablithus bijugatus*) 90% reworked.	*Gephyrocapsa oceanica* N22	PLEISTOCENE
1.5–3	2	EMPTY	N F N F	Silt grading up into silty clay. Coarse fraction mostly mineral particles, but some forams. 5Y5/1	Flora: *Coccolithus pelagicus, Gephyrocapsa* sp. Late Cretaceous, reworked, ca. 90%. FORAM FAUNA: *Glob. bulloides, G. pachyderma, G. inflata, G. truncatulinoides, G. hirsuta, G. dutertrei, G. conglobata.*		
3–4.5	3	EMPTY EMPTY	N F	Silty clays. Coarse fraction mostly mineral grains and forams. X-ray mineralogy (bulk) Calcite 52.3 Qtz. 21.4 Plag. 5.6 Kaol. 5.4 Mica 10.9 Chlorite 4.3 Amorph. 56.6	Flora: *Coccolithus pelagicus, Gephyrocapsa oceanica, G. aperta* plus ca. 50% reworked Cretaceous. Foram Fauna as above.		
4.5–6	4	SECTION NOT OPENED					
6–7.5	5		N,F	5Y4/1	Flora: *Coccolithus pelagicus, Cyclococcolithus leptoporus, Gephyrocapsa oceanica, G. aperta, Helicopontosphaera kamptneri, Pontosphaera* cf. *discopora.* Foram Fauna as above.		
7.5–9	6	EMPTY	N F	5B9/1 5Y3/2 5B9/1 Highly deformed gray clay and white nannofossil ooze. X-ray mineralogy (bulk) Calcite 76 Quartz 5.4 Mica 18.6 Amorph. 41.7	Flora similar to Sect. 5, plus *Rhabdosphaera clavigera.* Forams as above.		
	CC		R N F		No radiolarians. Flora similar to Sect. 6. Foram fauna as above.		

HOLE 118

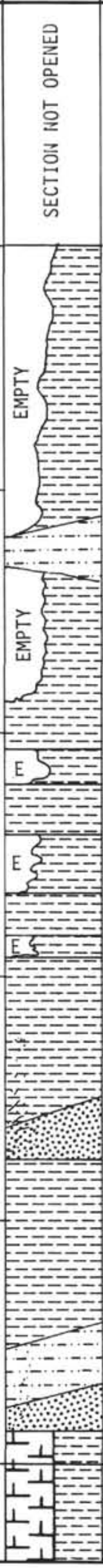
CORE 2



†Adjusted data, see Chapter 2

HOLE 118 200 **TO** 209 **m**

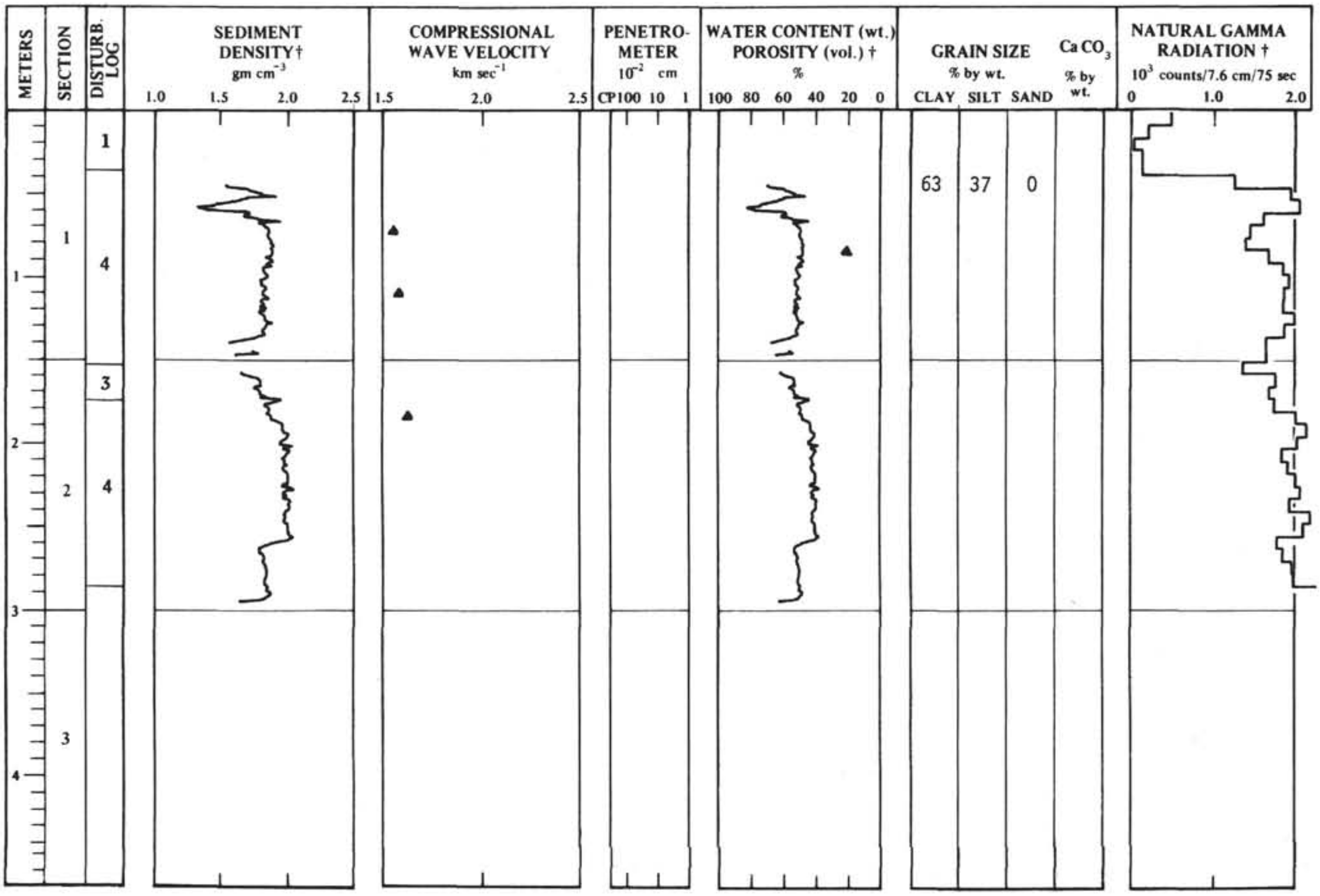
CORE 2



METERS	SECTION	SAMPLES	COLOR	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
0–1.5	1	N,F		Very sloppy, watery gray clay. X-ray mineralogy (bulk) Calcite 15.5 Qtz. 23.1 Plag. 1.5 Kaol. 2.7 Mica 54.5 Chlorite 2.5 Amorph. 54.6	Flora: *Coccolithus pelagicus, Cyclococcolithus leptoporus, Helicopontasphaera kamptneri, Pontosphaera scutellum, P. discopora, P.* sp., *Pseudoemiliania lacunosa, "Coccolithus jaramillensis"*, plus ca. 10% reworked Late Cretaceous and Tertiary. Foram Fauna: *Glob. bulloides, G. pachyderma, G. truncatulinoides, G. inflata, O. universa.*	*Pseudoemiliania lacunosa* / N22	PLEISTOCENE
1.5–3	2	N F	5Y5/2	Completely disturbed olive gray clay.	Flora similar to above. Foram fauna as above.		
3–4.5	3	N F	5Y5/1 10YR5/2	Olive gray silty clay. Disrupted gray clay. Yellow brown clay.	Flora similar to above, only ca. 1% reworked coccoliths. Foram fauna as above.		
4.5–6	4	N F	10Y4/2	Gray clay with disrupted watery patches. Greenish gray clay grading down into	Flora similar to above, less than 1% reworked coccoliths, plus *Cyclococcolithus macintyrei, Helicopontosphaera sellii, Scapholithus fossilis.* Foram fauna as above.		
6–7.5	5	F N F F	5G4/1 5Y6/1	sand.	Foram fauna as above. Flora: *Coccolithus pelagicus, Gephyrocapsa* sp.		
7.5–9	6	F	5B7/1 5G4/1 5G2/1 5B7/1	Light bluish gray mottled clay, passing into firm greenish clay passing into silty clay, grading into sand. Sharp boundary. Nannofossil clay.	Foram fauna as above. Foram fauna as above.		
	CC	F N R			Foram fauna as above. Flora similar to above, only few reworked coccoliths from the Tertiary and Cretaceous. No radiolarians		

HOLE 118

CORE 3



†Adjusted data, see Chapter 2

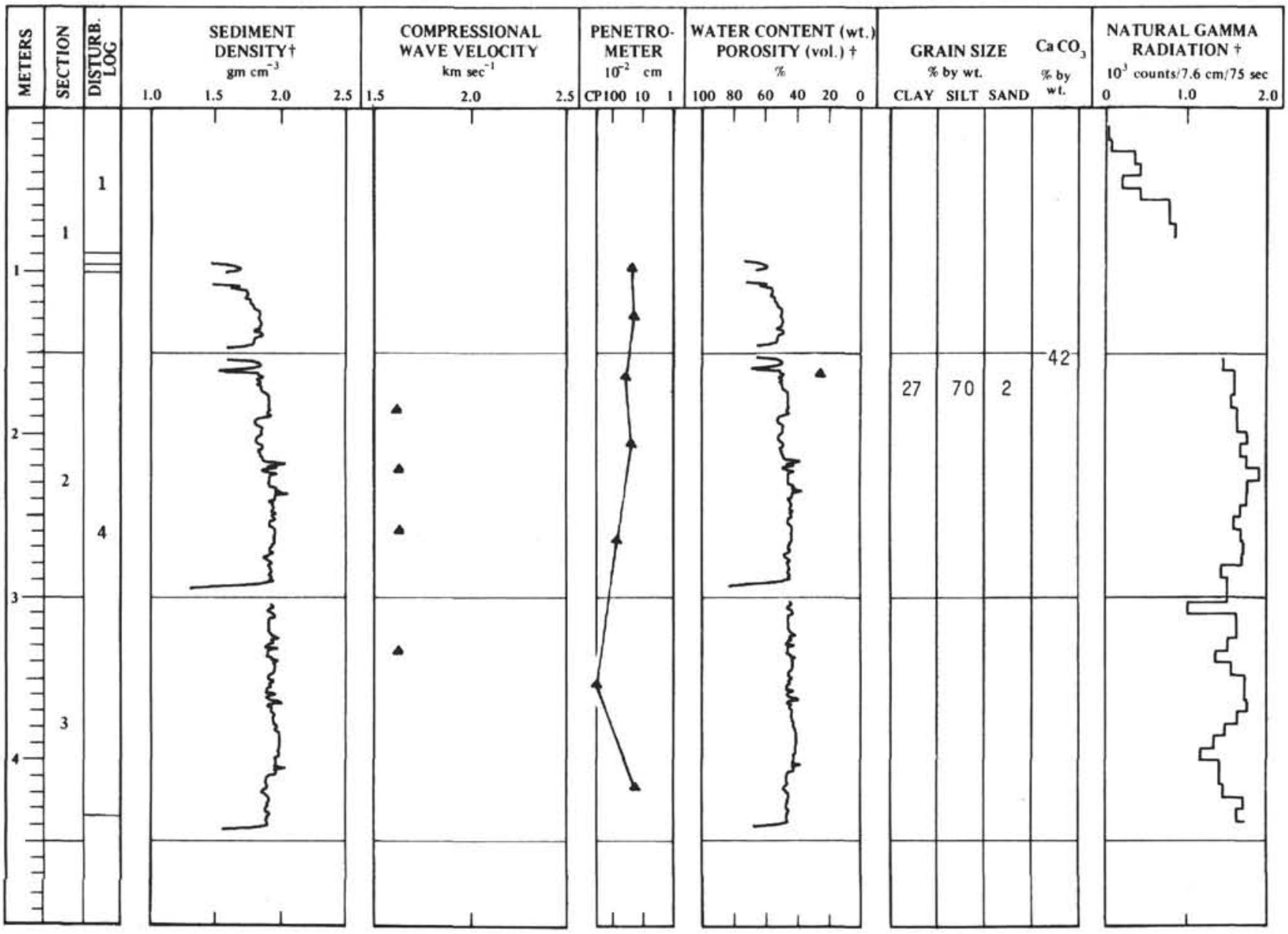
HOLE 118   300 **TO** 309 **m**

CORE 3

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
0–1	1	EMPTY	N F	5Y4/1 Alternating layers of firm olive gray silts and light gray or white silty clays. Light clays are burrowed and olive gray clays appear to have sharp bases and sharp, or well-defined gradational tops.	Flora: *Coccolithus pelagicus*, *Cyclococcolithus leptoporus*, *C. macintyrei*, *Helicopontosphaera kamptneri*, *H. sellii*, *Syracosphaera* sp., *Discoaster brouweri*, *D. pentaradiatus*, *D. surculus*, *Pseudoemiliania lacunosa*, *Sphenolithus neoabies*, *Pontosphaera* sp. Foram Fauna: *Globigerinids and bolivinids.*	*Discoaster surculus*	PLIOCENE
2–3	2		N F	5Y5/2 X-ray mineralogy Calcite 25.0 Siderite 1.3 Qtz. 24.2 Plag. 1.1 Kaol. 8.2 Mica 39.5	Flora similar to above. Foram Fauna: *G. bulloides*, *G. crassaformis*, *G. glutinata*, *O. universa*		
	CC		F N R		Core Catcher: Foram Fauna: *Glob. atlantica*, *G. inflata*, *G. puncticulata*, *G. crassaformis*, *G. hirsuta*. Flora similar to above, plus few reworked coccoliths from the Tertiary and Cretaceous. No radiolarians.		

HOLE 118

CORE 4



†Adjusted data, see Chapter 2

HOLE 118 350 **TO** 359 **m**

CORE 4

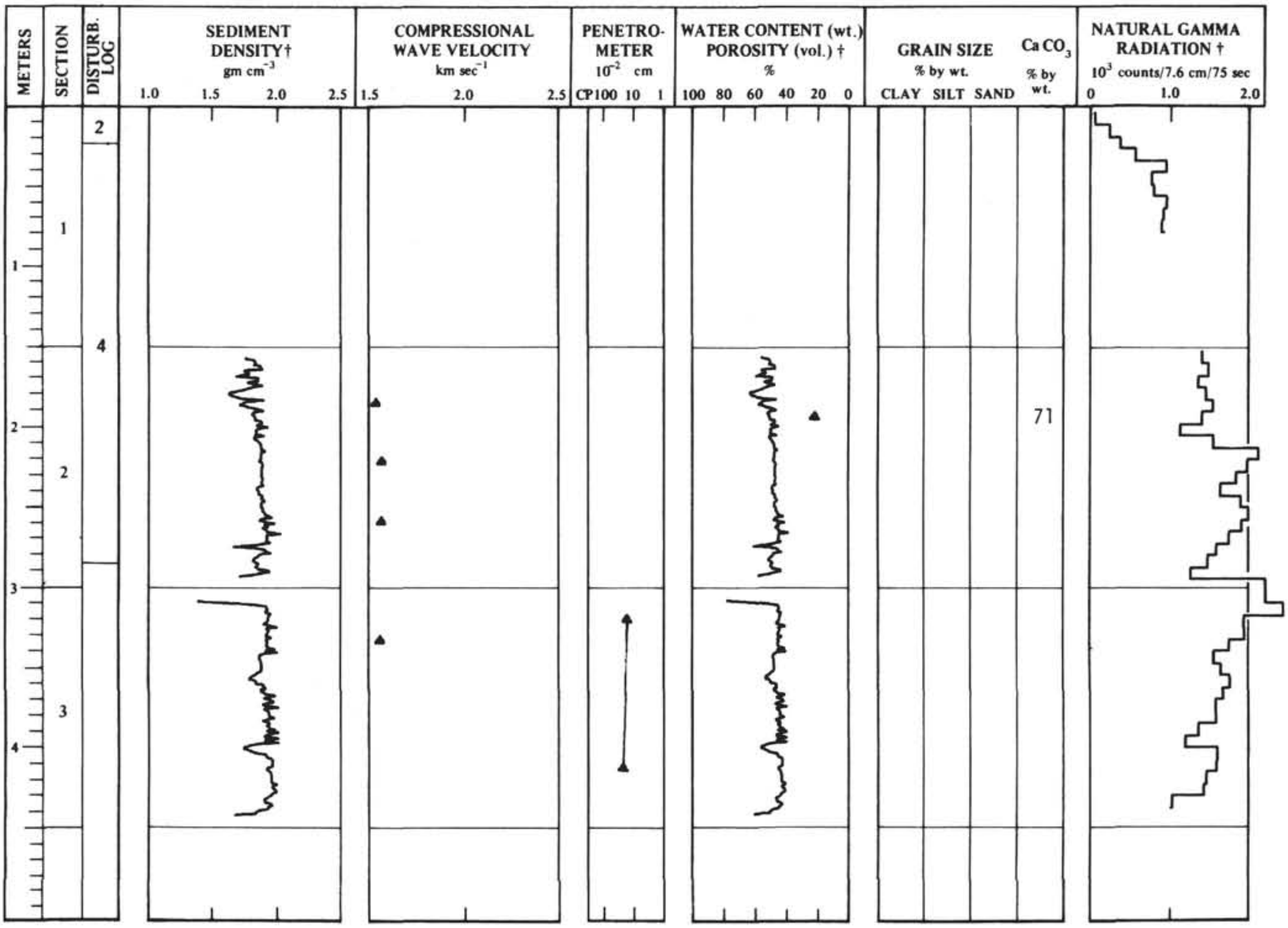
METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
0–1	1	EMPTY			Flora: *Coccolithus pelagicus, C. eopelagicus, Cyclococcolithus leptoporus, C. macintyrei, Pontosphaera* sp. *Discoaster brouweri, D. pentaradiatus, D.* cf. *variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica* plus reworked Tertiary coccoliths and discoasters.	*Ceratolithus rugosus*	PLIOCENE
1	1		N, N, F	5GY6/1 — Firm bluish and greenish gray clay.			
2	2		N	5Y4/1 — Dk. greenish gray silt.	Flora similar to above, plus *Discoaster challengeri, Ceratolithus* sp.		
2	2		N	5GY 5/1 — Uniform olive gray clay.	Flora similar to above, more reworked coccoliths (ca. 10%). Fauna: minute globigerinids, bolivinids.		
3	2–3		F	5GY4/1 — Dark greenish gray silt.	Flora similar to above, plus *Ceratolithus* sp. Fauna as above.		
4	3		N, F	N7 — Light gray and light greenish gray firm clay, mottled with olive and bluish gray.	Flora similar to above, plus *Ceratolithus rugosus.* Foram fauna as above.		
	CC		F, N, R		Core Catcher: Foram fauna: *Sph. subdehiscens, Gl. obliqua.* Flora similar to above, plus *Ceratolithus rugosus.* No radiolarians.		

X-ray mineralogy (bulk)

Mineral	%
Calcite	23.7
Qtz.	36.6
K-feld.	2.3
Plag.	7.3
Mica	27.8
Chlorite	1.0
Mont.	1.0
Amorph.	46.8

HOLE 118

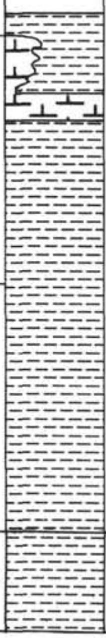
CORE 5



†Adjusted data, see Chapter 2

HOLE 118 399 **TO** 408 **m**

CORE 5

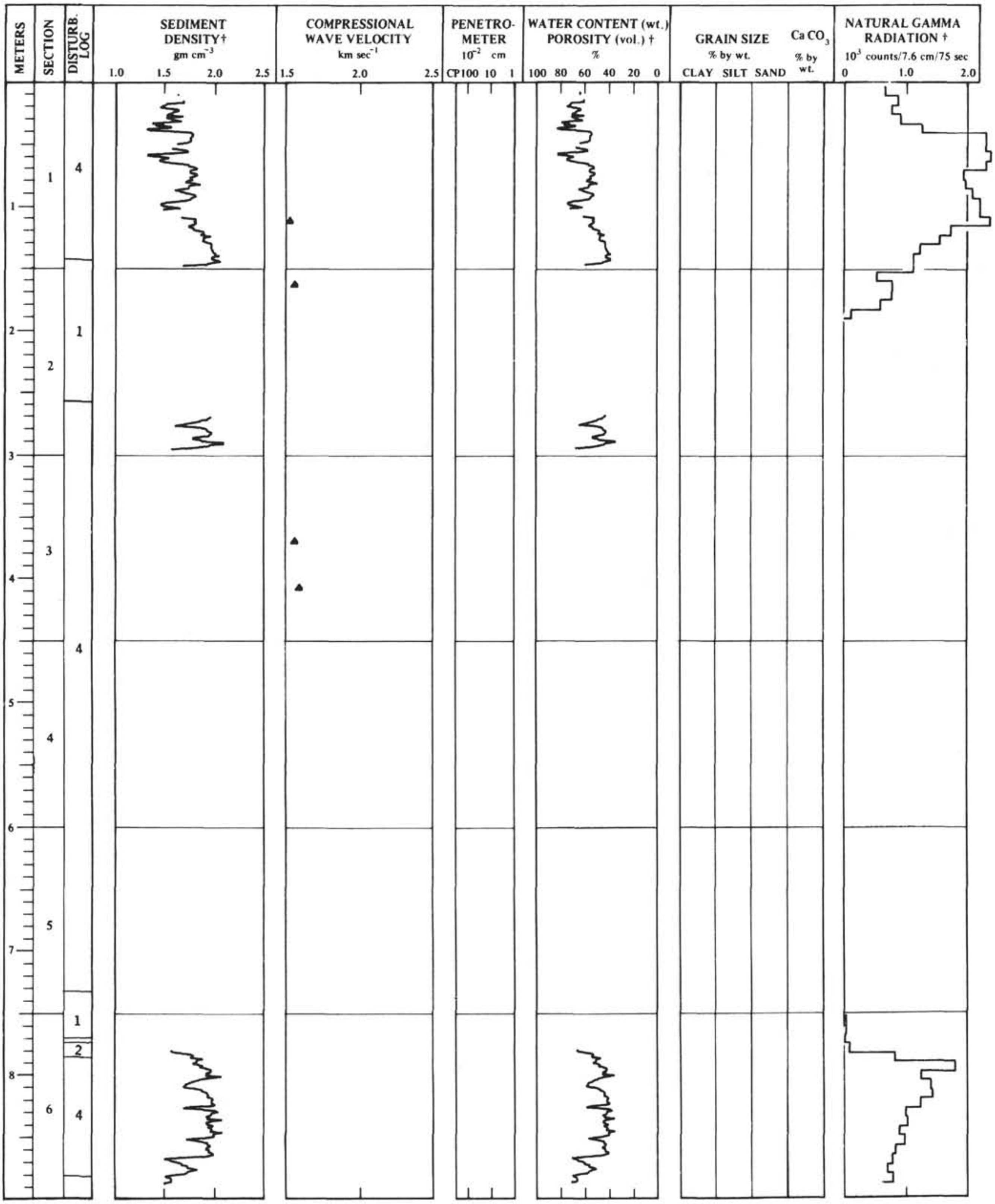
METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
0–1	1	EMPTY					
2	2		N, N, F N	N9 5Y6/2; 5Y5/2 — Nannofossil ooze. Laminated firm clay of many colors, mostly grays, greenish grays, olive grays and purplish.	Flora: *Coccolithus pelagicus, Cyclococcolithus leptoporus, Reticulofenestra pseudoumbilica, Helicopontosphaera kamptneri, Discoaster* cf. *variabilis, Coronocyclus* sp. *Discoaster* cf. *quinqueramus*. Flora enriched in discoasters, similar to above plus *Discoaster variabilis, D. pentaradiatus, D. brouweri, D.* cf. *exilis*. Flora similar to sect. 2-107, poorer, plus *Ceratolithus tricorniculatus*	*Ceratolithus tricorniculatus?*	LATE MIOCENE-EARLY PLIOCENE
3–4	3		N, N, F	5B7/1 — Mottling at boundary. Light bluish gray clay.	Flora similar to sect. 2-50, plus *Ceratolithus tricorniculatus*.		
	CC		R N F		Foram Fauna: Minute planktonic and benthonic forams. Core Catcher: No radiolarians. Poor assemblage of *Coccolithus pelagicus, Reticulofenestra pseudoumbilica, Discoaster variabilis* FORAM FAUNA: Cibicidids, rotaliids.		

X-ray mineralogy

Mineral	%
Calcite	25.7
Qtz.	10.7
Plag.	1.4
Kaol.	5.0
Mica	56.1
Chlorite	1.0
Amorph.	58.3

HOLE 118

CORE 6



†Adjusted data, see Chapter 2

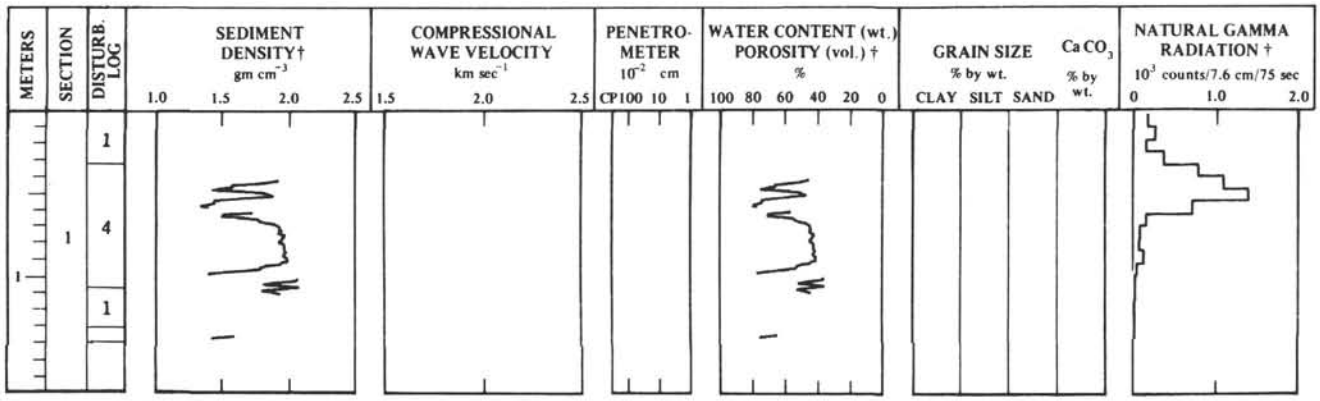
HOLE 118 — 448 **TO** 457 **m**

CORE 6

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
0–1.5	1		F	5Y7/2 → Light gray sandstone.	Foram Fauna: *G. bulloides, G.* cf. *atlantica, G. miozea, G. conoidea.*		LATE MIOCENE
			N	5B5/1 → Very firm clay, light bluish gray passing down into olive gray, silty at base	No coccoliths.		
1.5–3	2		N	5Y5/2, 5Y5/1, 5B7/1 Very firm clay. Light bluish gray layers alternating with olive gray layers. X-ray mineralogy (bulk) Calcite 43.1 Aragonite 12.4 Qtz. 11.5 Kaol. 1.8 Mica 28.5 Chlorite 1.0 Mont. 1.9 Amorph. 59.8	Flora: *Coccolithus pelagicus, C. eopelagicus, Cyclococcolithus leptoporus, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Discoaster brouweri, Discoaster* sp., *Discolithina* cf. *multipora, Discoaster variabilis, D. deflandrei, Sphenolithus moriformis, Pontosphaera discopora, Discoaster* cf. *surculus* (mixed assemblage?)		
3–4.5	3	EMPTY					
4.5–6	4	EMPTY					
6–7.5	5	EMPTY					
7.5–9	6		N	5G4/1 Dark green-gray clay. 5B5/1 Light gray clay 5GY6/1 Greenish gray clay grading down into silt.	Flora similar to above, less discoasters, plus *Triquetrorhabdulus rugosus.* Foram Fauna: corroded benthonics and planktonics *G. apertura.*		
			F				
	CC		N F R		Flora poorer than sect. 6, + reworked coccoliths from the Eocene and Cretaceous. Fauna: *G. bulloides, G. miozea, G. conoidea.* Radiolarians very rare. *Stichocorys peregrina, Ommatartus antepenultimus,* plus reworked Lower Miocene species.		

HOLE 118

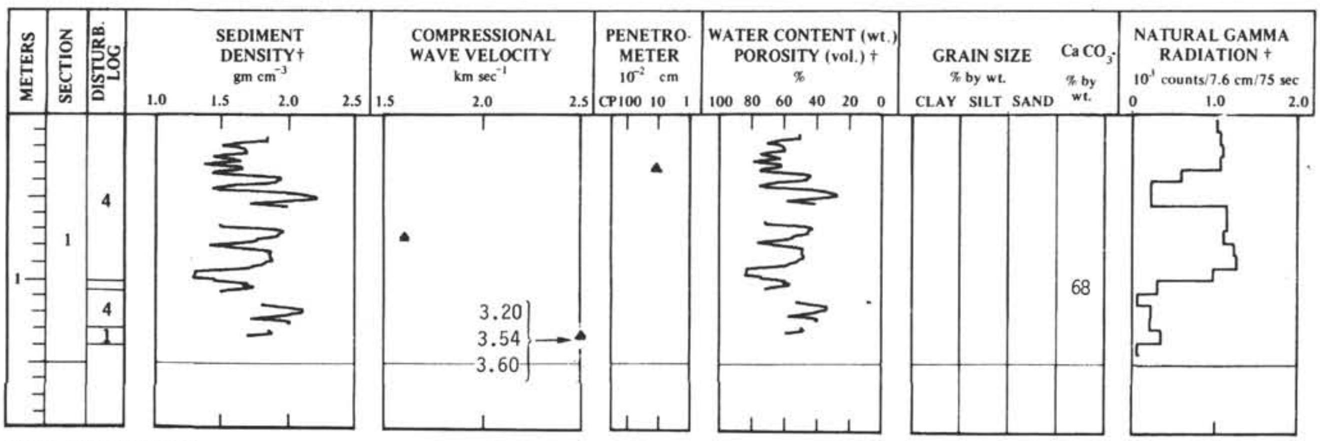
CORE 7



†Adjusted data, see Chapter 2

HOLE 118

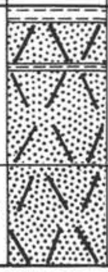
CORE 8



†Adjusted data, see Chapter 2

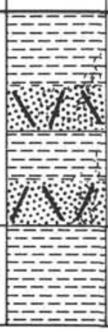
HOLE 118 396 **TO** 501 **m**

CORE 7

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
	1		N F	5Y6/1 5Y8/1 0-8 cm dense gray clay. 5GY4/1 8-25 yellow gray sandstone. 5GY6/1 25-26 laminated greenish gray clay. 26-94 yellow gray sandstone. 5Y8/1 X-ray mineralogy (bulk) Calcite 86.8 Dolomite 4.3 Aragonite 1.7 Qtz. 7.2 Amorph. 40.1	Flora: *Coccolithus pelagicus, Cyclococcolithus leptoporus, Reticulofenestra pseudoumbilica, Sphenolithus* sp., *Coccolithus eopelagicus, Helicopontosphaera kamptneri, Coccolithus* cf. *bisectus.* Foram Fauna: Small globigerinids, bolivinids, cibicidids, rotalilds. Core Catcher: Foram fauna: *Gl. dehiscens, O. universa.* Flora similar to above, plus reworked Cretaceous coccoliths. Radiolarians very rare.		MIOCENE
	CC		F N R				

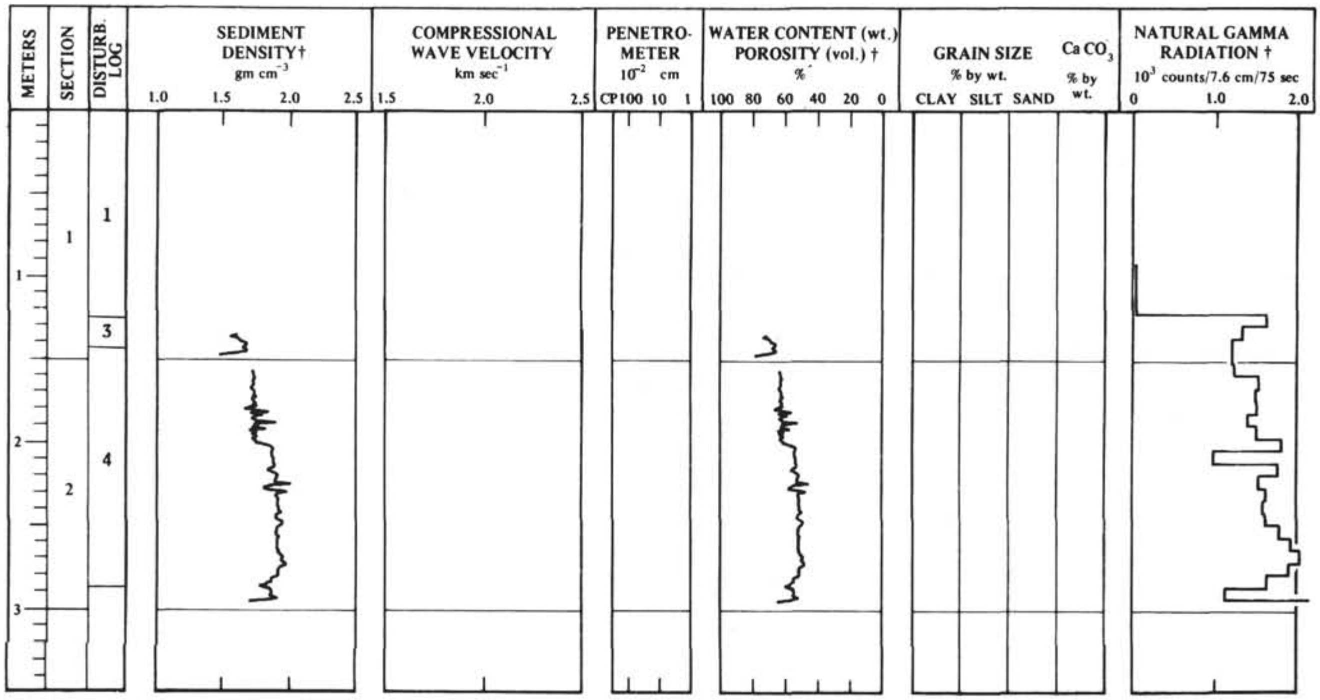
HOLE 118 505 **TO** 512 **m**

CORE 8

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N R F	N8 Dense, light gray clay grading down into olive gray 5Y6/1 clay and yellow gray sandstone. 5Y8/1 5B7/1 Light bluish gray clay (mottled) grading down into gray 5Y5/1 clay and yellow gray sandstone. 5Y7/1 X-ray mineralogy (bulk) Calcite 94.4 Dolomite 2.2 Qtz. 1.9 Mont. 1.5 Amorph. 38.5	Flora: *Coccolithus pelagicus, C. eopelagicus, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Discolithina multipora, Discoaster* sp. No radiolarians. Foram Fauna: *Gl. dehiscens, Sph. seminulina, Gl.* cf. *druryi, G. miozea.* Core Catcher: *Gl. fohsi* s.s., *Gl. triloba, G. dehiscens, Gl. woodi.* dark: Discoaster brouweri, D. aulakos, D. variabilis, D. challengeri, D. exilis. light: Flora similar to sect. 1. Radiolarians very rare. *Stichocorys delmontensis, Cyrtocapsella tetrapera,* digitately branched and curved, flat *Oroscena* spines.	*Discoaster exilis?*	MIDDLE MIOCENE
	CC		F N R				

HOLE 118

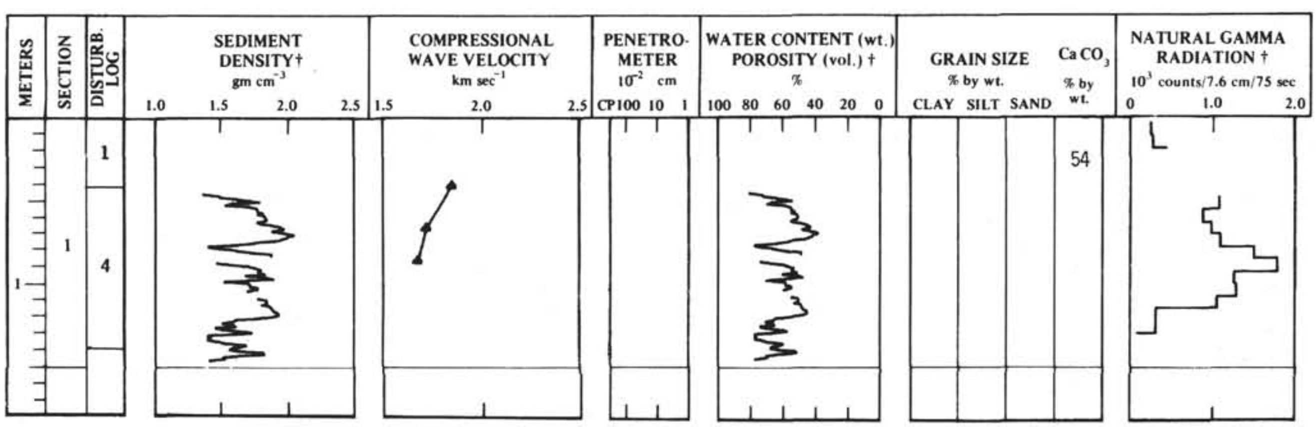
CORE 9



†Adjusted data, see Chapter 2

HOLE 118

CORE 10



†Adjusted data, see Chapter 2

HOLE 118 553 TO 559 m

CORE 9

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	EMPTY			Flora: *Coccolithus pelagicus*, *C. eopelagicus*, *Cyclococcolithus leptoporus*, *Sphenolithus* sp., *S. neoabies*, *Rhabdolithus* sp., *Reticulofenestra pseudoumbilica*, *Discoaster exilis*, *D. aulakos*, *Discoaster* sp. *Discolithina multipora*, *Pontosphaera discopora*, *Scyphosphaera* sp.	*Discoaster exilis?*	MIDDLE MIOCENE
2	2		N,F N F	N6 Disturbed gray clay. Clay breccia, probably not the result of drilling; very hard, greenish and yellowish clay in a light gray clay matrix. 46-70cm graded bed of clay fragments in clay matrix. 70-150 intermixed gray and light and dark greenish gray clays.	Fauna: *Gl. dehiscens*, *Orbulina universa*. Flora: *Coccolithus pelagicus*, *Reticulofenestra pseudoumbilica*, *Discoaster* sp. Foram fauna rare.		
	CC		R N F	X-ray mineralogy (bulk) Calcite 36.3 Qtz. 14.3 Plag. 2.2 Kaol. 3.6 Mica. 34.9 Mont. 8.6 Amorph. 61.9	Core Catcher: Radiolarians very rare. Digitately branched and curved, flat *Oroscena* spines. Flora similar to sect. 1, more discoasters. Foram Fauna: *Sph. seminulina*, *Gl. dehiscens*.		

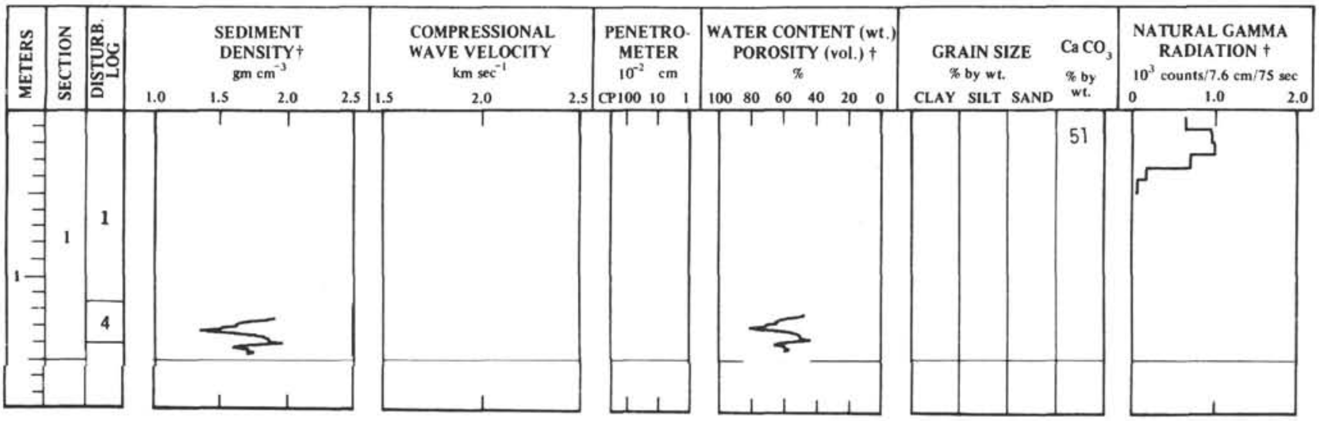
HOLE 118 604 TO 613 m

CORE 10

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	EMPTY	N F	Very hard clays, mostly gray and olive gray, interbedded with light gray or white mottled clays. Colors include 5GY6/1, 5Y5/1, N4, 5B9/1, N9.	Flora: *Coccolithus pelagicus*, *C. eopelagicus*, *Cyclococcolithus leptoporus*, *Helicopontosphaera kamptneri*, *Reticulofenestra pseudoumbilica*, *Sphenolithus* cf. *neoabies*, *Discolithina multipora*, *Discoaster* sp. Indeterminate foram fauna.	N9 *Sphenolithus heteromorphus?*	MIDDLE MIOCENE
	CC		R N F	X-ray mineralogy (bulk) Calcite 30.8 Dolomite 1.1 Qtz. 24.4 Plag. 2.0 Kaol. 3.2 Mica 35.5 Mont. 2.9 Amorph. 54.4	Core Catcher: Radiolarians rare. *Stichocorys delmontensis*, *S. wolffii*, *Cyrtocapsella japonica*, *C. tetrapera*, *Calocyclas margatensis*, digitately branched *Oroscena* spines. Flora similar to above, plus *Sphenolithus heteromorphus*. Foram Fauna: *Gl. miozea* (common), *Gl. dehiscens*, *Praeorbulina glomerosa circularis*.		

HOLE 118

CORE 11



†Adjusted data, see Chapter 2

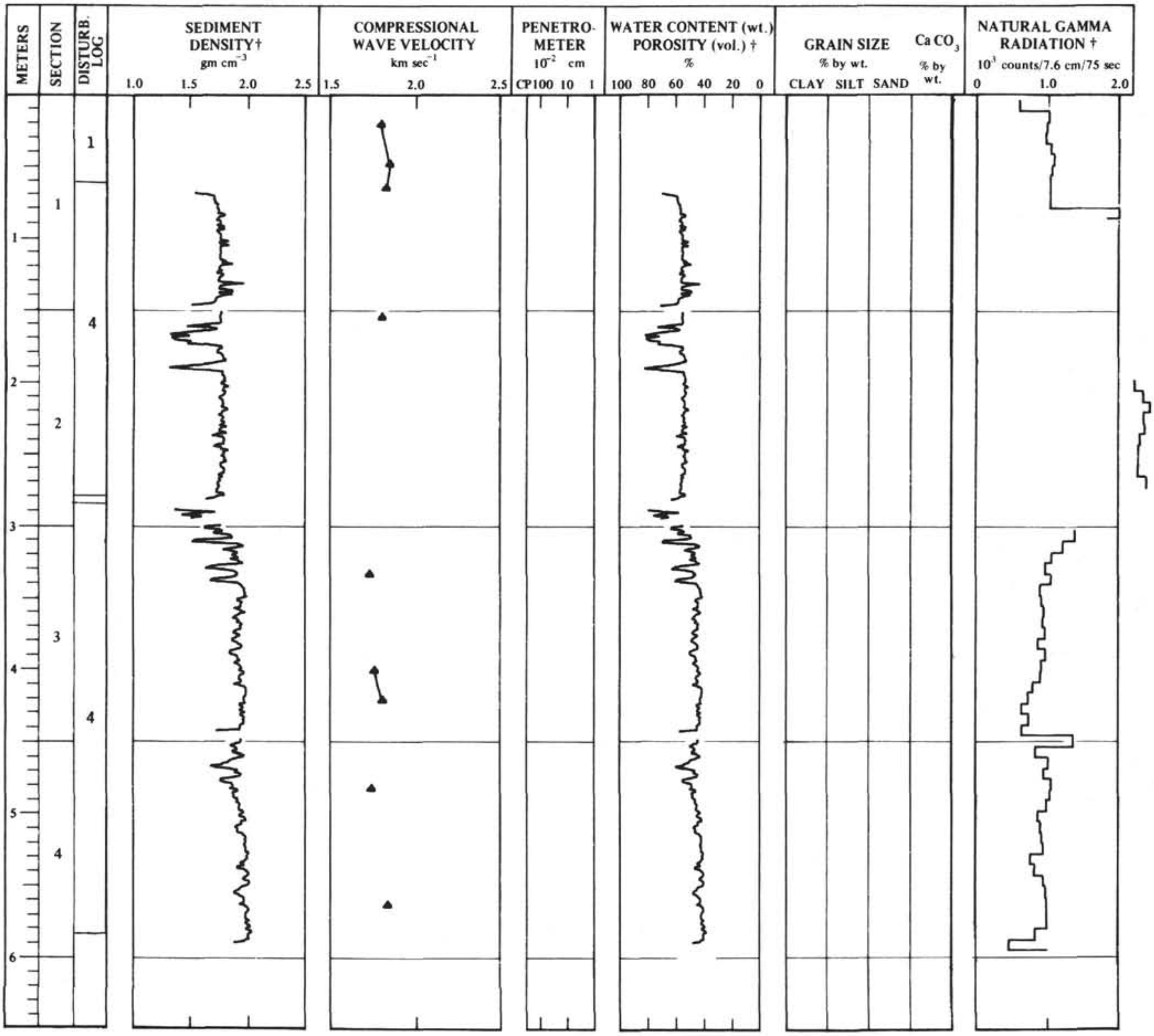
HOLE 118 650 **TO** 658 **m**

CORE 11

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
	CC		N N F N R	5GY5/1 5Y6/2 Hard, greenish gray clay with white flecks overlying firm, moderately mottled, light olive gray clay. X-ray mineralogy (bulk) Qtz. 19.2 Plag. 2.6 Kaol. 4.7 Mica 71.1 Mont. 2.4 Amorph. 59.2	No coccoliths. Flora: *Coccolithus pelagicus*, few small coccoliths. Core Catcher: Foram Fauna: *Globigerinita* cf. *dissimilis*, *Gl. triloba*. Flora: *Coccolithus pelagicus*, *C. eopelagicus*, *Reticulofenestra pseudoumbilica*, *Discoaster druggii*, *D. aulakos*, *Sphenolithus* sp., *Helicosphaera kamptneri*, *Discolithina multipora*. Radiolarians very rare. *Cyrtocapsella japonica*, *C. elongata*, *C. tetrapera*, *C. cornuta*, digitately branched and curved, flat *Oroscena* spines.		EARLY MIOCENE

HOLE 118

CORE 12



†Adjusted data, see Chapter 2

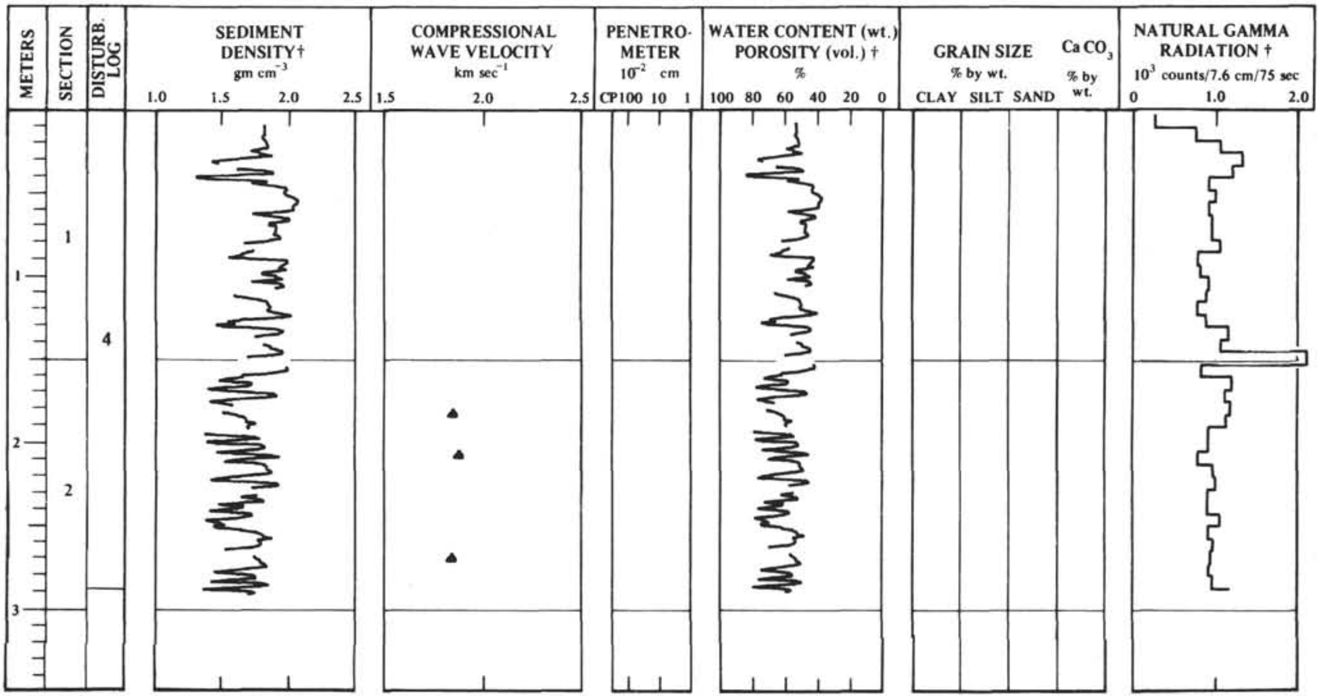
HOLE 118 687 **TO** 693 **m**

CORE 12

METERS	SECTION	LITHOL.	SAMPLES		LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
0–1	1		N F	2.5Y5/2	Very hard grayish-brown clay, moderately mottled with light bluish gray. Contains shell fragments scattered throughout.	No coccoliths. Fauna: *Gl. subbotinae, G. marginodentata, G. aequa, Acarinina coalingensis, A. soldadoensis angulosa, Gl. patagonica* (all reworked).	*Calocycletta virginis*	EARLY MIOCENE
			N			No coccoliths.		
1–2		EMPTY	R F			Radiolarians common, silicified. *Dorcadospyris simplex, Lychnocanium bipes, Stichocorys wolffii, S. delmontensis, Cyrtocapsella japonica, C. cornuta, C. tetrapera, C. elongata, Calocycletta virginis.* No foraminifera.		
2	2		N,F			No coccoliths. No foraminifera.		
			N.F N		145cm in Section 2 is the Miocene/Eocene boundary. Because of the way the core was cut this is probably not a true contact but probably represents a gap of several meters.	No coccoliths; fragments of agglutinated forams.		
3	3		N,F	10YR7/6		No coccoliths. No coccoliths.	*Nannotetrina fulgens* P10	MIDDLE EOCENE
			N	2.5Y6/4 and 2.5Y7/4		Flora: *Coccolithus eopelagicus, Chiasmolithus grandis, C. expansus, C. gigas, Reticulofenestra* cf. *umbilica, Nannotetrina fulgens, N. pappi, Discoaster barbadiensis, D. wemmelensis, Sphenolithus moriformis, Cyclococcolithus* sp.		
4			N,F F			Flora similar to above.		
5	4		N		Very dense, hard, yellowish brown and pale yellow clay. Burrow mottling is present. White patches which are the result of chemical alteration are common. Several crushed zones, possibly indicating faulting are present.	Foraminifera: *Acarinina densa, Gl. pseudoscitula, Ac. collactea, Gl. index, Nuttallides truempyi.* Flora similar to above.		
			F			Foram fauna as above.		
	CC		R N F			Core Catcher: Radiolarians rare, silicified. Flora similar to above. Forams: *Ac. densa, Ac. coalingensis, Gl. senni, Cib. havanensis, Cib. trinidadensis, Oridorsalis ecuadorensis, Alabamina dissonata, Nuttallides truempyi.*		

HOLE 118

CORE 13



†Adjusted data, see Chapter 2

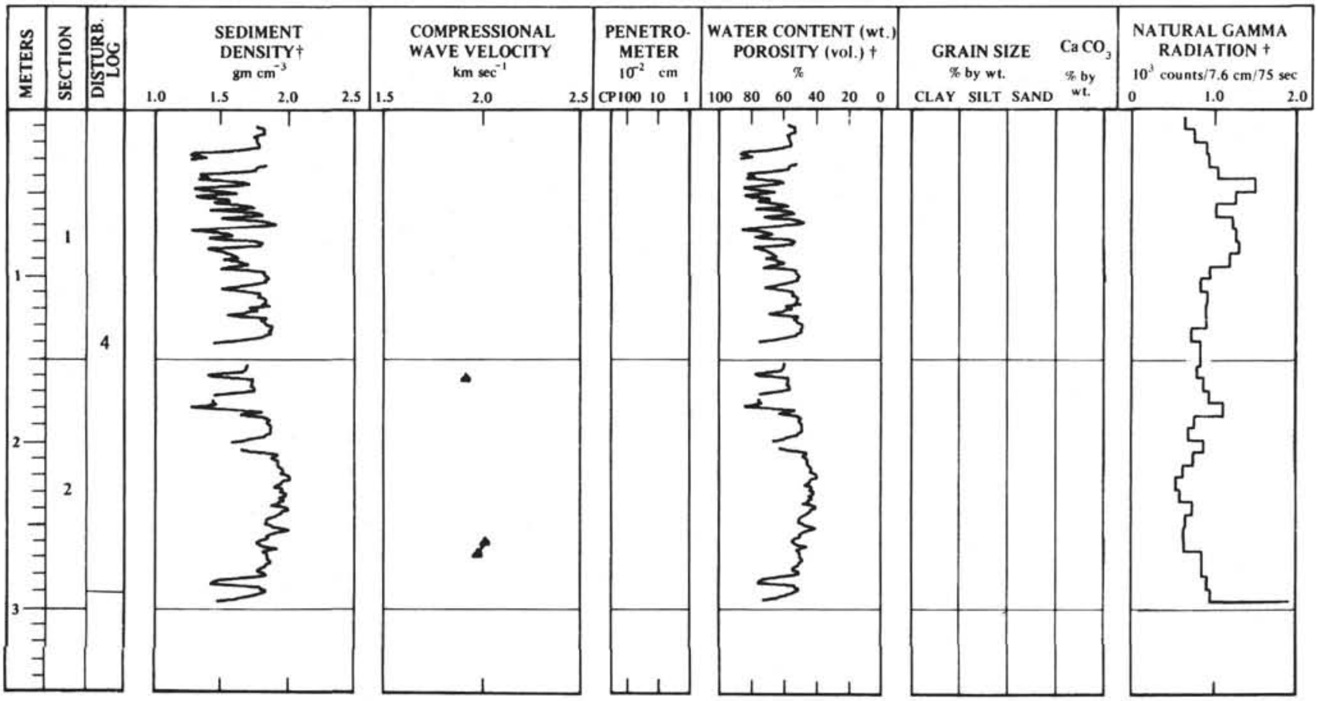
HOLE 118 693 TO 695 m

CORE 13

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
0–3	1		N, F	2.5Y7/4 and 2.5Y6/4. Light yellowish brown and pale yellow very dense, hard clay. Intensely burrow mottled throughout with grayish brown. White patches resulting from chemical alteration are common and several of these are cut by faults.	Flora: *Nannotetrina pappi*, *Discoaster barbadiensis*, *D. wemmelensis*, *Coccolithus* sp. *Chiasmolithus solitus*, *Sphenolithus moriformis*, *Ericsonia cava* plus few reworked Cretaceous coccoliths. Forams: *Ac. densa*, *A. soldadoensis angulosa*; *Nuttallides truempyi*, *Oridorsalis ecuadorensis*.	P10 / *Nannotetrina fulgens*	MIDDLE EOCENE
	2		N, F	X-ray mineralogy (bulk): Calcite 73.1; Qtz. 4.1; Kaol. 1.8; Mica 17.3; Mont. 3.4; Amorph. 51.1	Flora similar to above, plus *Ericsonia alternans*, *Coccolithus eopelagicus*. Foram fauna as above.		
	CC		R, N, F		Core Catcher: Radiolarians very rare, silicified. Flora similar to above. Forams: *Ac. densa*, *A. coalingensis*, *Gl. aragonensis*.		

HOLE 118

CORE 14



†Adjusted data, see Chapter 2

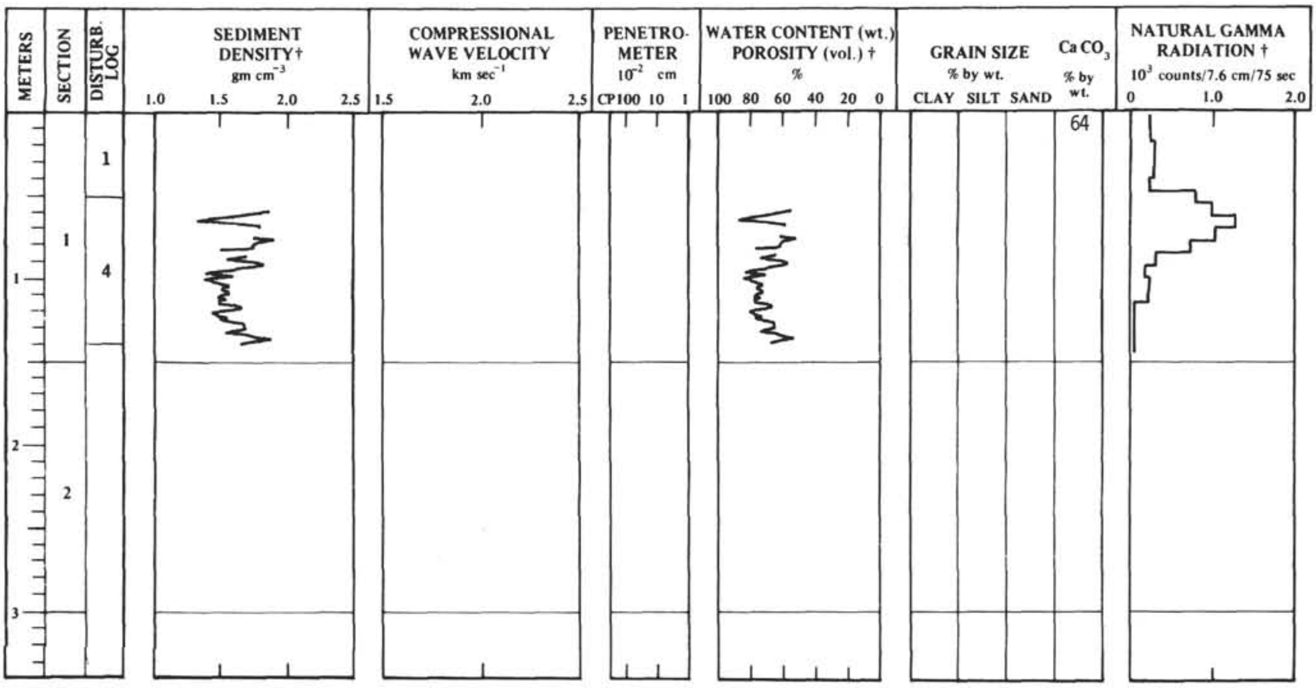
HOLE 118 695 **TO** 708 **m**

CORE 14

METERS	SECTION	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
0	1	F, N, N,F	Grayish brown and olive gray dense, hard clay. Intensely burrowed in white throughout, with many pale brown patches resulting from chemical alteration. The sediment is intensely deformed and crushed zones are present suggesting post depositional movement.	Flora: *Discoaster sublodoensis*, *D. barbadiensis*, *D.* cf. *lodoensis*, *Nannotetrina* sp., *Ericsonia ovalis*, *Chiasmolithus* cf. *eograndis*, *Sphenolithus* sp.	*D. sublodoensis* / *Nannotetrina*	MID EOCENE
1		N		Flora similar to above, less *Nannotetrina* sp. and *D. sublodoensis*.	*Discoaster lodoensis*	
		N, N, F		Flora similar to Sect. 1-66.		
	2			Flora similar to above, Sect. 1-66.		
				Flora similar to above, Sect. 1-66.		
2		N		Forams: *G. subbotinae*, *G. marginodentata*, *G. formosa*, *G. lensiformis*, *G. aragonensis*, *Ac. soldadoensis*, *G. patagonica*.	*Marthasterites contortus*-*Discoaster binodosus* / P6	EARLY EOCENE
		F		Flora: *Discoaster multiradiatus*, *D. barbadiensis*, *Marthasterites tribrachiatus*, *Markalius inversus*, *Sphenolithus anarrhopus*, *Sphenolithus* sp. *Fasciculithus* sp. *Toweius craticulus*, *Ericsonia ovalis*, *Chiasmolithus eograndis*, *Ellipsolithus macellus*.		
				Foram Fauna as above.		
	CC	F, N, R		Core Catcher: Foram fauna as above. Flora similar to above. Radiolarians very rare, silicified.		

HOLE 118

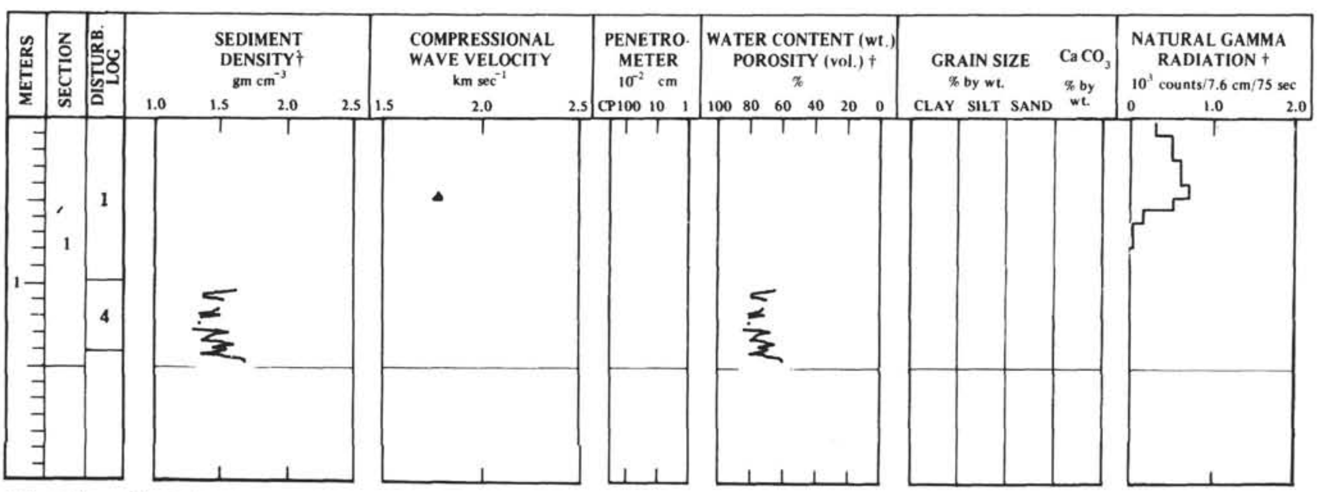
CORE 15



†Adjusted data, see Chapter 2

HOLE 118

CORE 16



†Adjusted data, see Chapter 2

HOLE 118 714 **TO** 723 **m**

CORE 15

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
	1		N,F N F	2.5Y 5/2 10YR 6/4 Very dense, intensely mottled grayish brown clay. Mottles are dark gray and pale yellow. Light yellow-brown band at ca.50 cm. X-ray mineralogy (bulk) Calcite 75.2 Qtz. 3.1 Kaol. 2.0 Mica 19.5 Amorph. 47.8	Flora: *Discoaster multiradiatus, Marthasterites contortus, Chiasmolithus bidens, Toweius craticulus, T. eminens, Ellipsolithus macellus, Fasciculithus* sp. *Ericsonia cava, Sphenolithus primus, Zygodiscus adamas, Neococcolithes junctus Cruciplacolithus* cf. *tenuis*. Flora similar to above, plus *Coccolithus eopelagicus* (contamination?) Forams: *G. subbotinae, G. marginodentata, G. formosa gracilis, G. aequa, G. patagonica, Ac. coalingensis, A. soldadoensis, Chiloguembelina wilcoxensis*.	P6 \ *Marthasterites contortus*	PALEOCENE - EOCENE
	CC		N R F		Core Catcher: Flora similar to above. Abundant reworked Upper Cretaceous Zeolitized radiolarians. Foram fauna as above.		

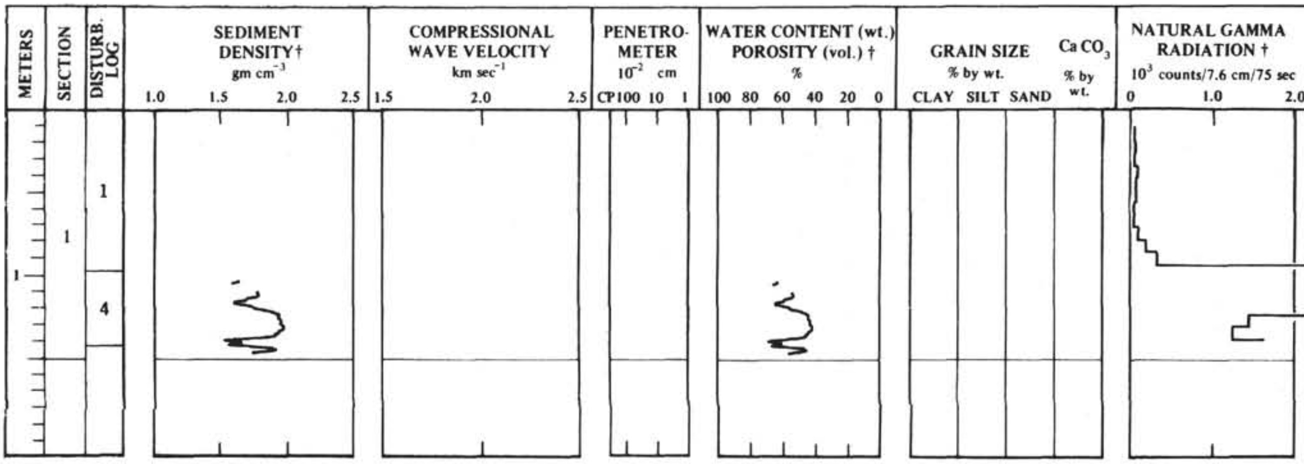
HOLE 118 723 **TO** 732 **m**

CORE 16

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
			F N F	7.5YR5/8 and 5G6/1 Dense, hard orange brown clay, moderately mottled greenish gray. X-ray mineralogy (bulk) Qtz. 12.5 Plag. 3.4 Kaol. 7.8 Mica 57.1 Mont. 5.4 Clin. 13.7 Amorph. 73.9	No foraminifera. No coccoliths.		(PALEOCENE?)
	CC		R N F		Core Catcher: Abundant reworked Upper Cretaceous zeolitized radiolarians. Flora: *Ericsonia cava*. No forams.		

HOLE 118

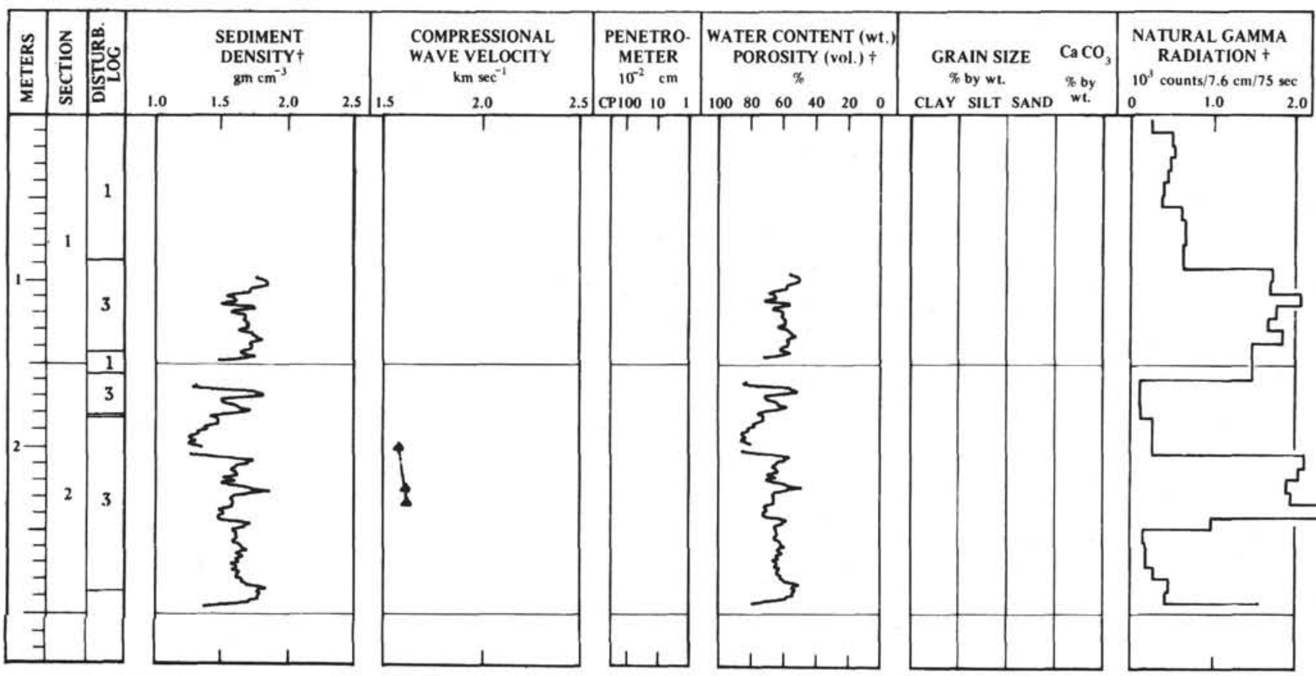
CORE 17



†Adjusted data, see Chapter 2

HOLE 118

CORE 18



†Adjusted data, see Chapter 2

HOLE 118 732 TO 741 m
CORE 17

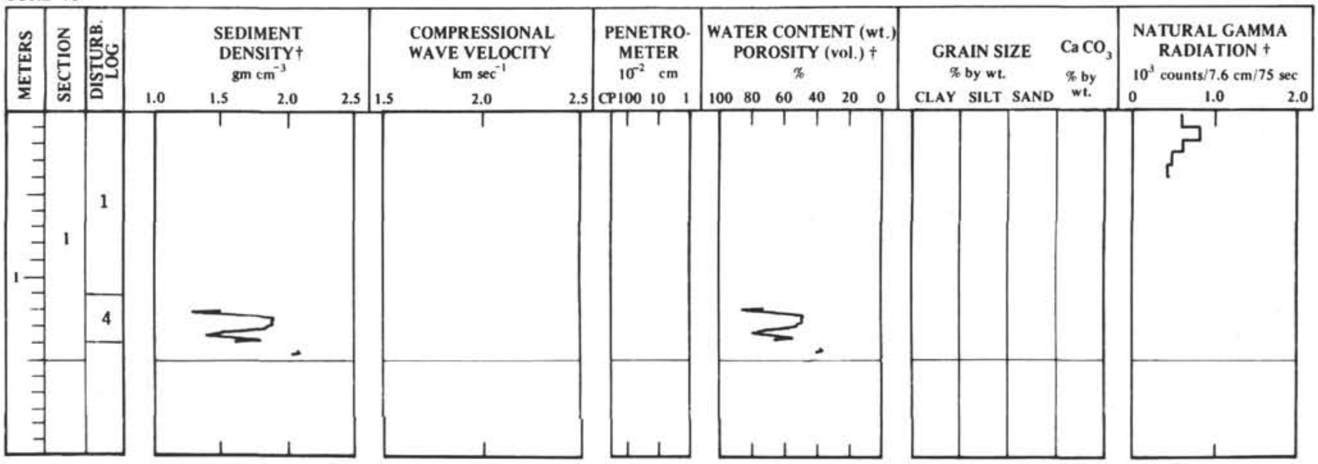
METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	EMPTY	N, F	5YR6/6 Reddish yellow, mottled hard clay. X-ray mineralogy (bulk) Qtz. 24.1 K-feld. 9.9 Plag. 3.3 Kaol. 8.6 Mica 54.0 Amorph. 83.1	No coccoliths Forams: Small acarininids, globigerinids.		(PALEOCENE?)
	CC		F		Core Catcher: Mid-Cenozoic foram contaminants.		

HOLE 118 741 TO 750 m
CORE 18

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N, F	7.5YR6/6 Disturbed brown clay with patches of reddish-yellow clay and gray mottles.	Flora: *Chiasmolithus bidens, Sphenolithus anarrhopus, Nannotetrina pappi, Discoaster multiradiatus, Ericsonia ovalis* (=mixed Paleocene and Eocene assemblage) Forams: *Ac. coalingensis, A. soldadoensis, G. subbotinae, G. marginodentata, G. patagonica.*		? (Mixed MIOCENE, EOCENE, PALEOCENE)
2	2	EMPTY	N, F	7.5YR4/4	Flora: *Discoaster barbadiensis, D. wemmelensis, Nannotetrina pappi, N. fulgens, Chiasmolithus californicus, Coccolithus eopelagicus, Discoaster lodoensis.* Foram fauna as above.	P6a	
	CC		F, N, R		Core Catcher: Forams: *Gl. patagonica, G. acuta, G. aequa, Ac. soldadoensis, A. coalingensis.* Flora: (red clay): *Discoaster barbadiensis, Chiasmolithus californicus, Cruciplacolithus mutatus, Chiasmolithus bidens.* (Gray clay): *Discoaster challengeri, Coccolithus eopelagicus, C. neogammation, Discoaster brouweri, D. pentaradiatus.* Abundant reworked Upper Cretaceous zeolitized radiolarians.		

HOLE 118

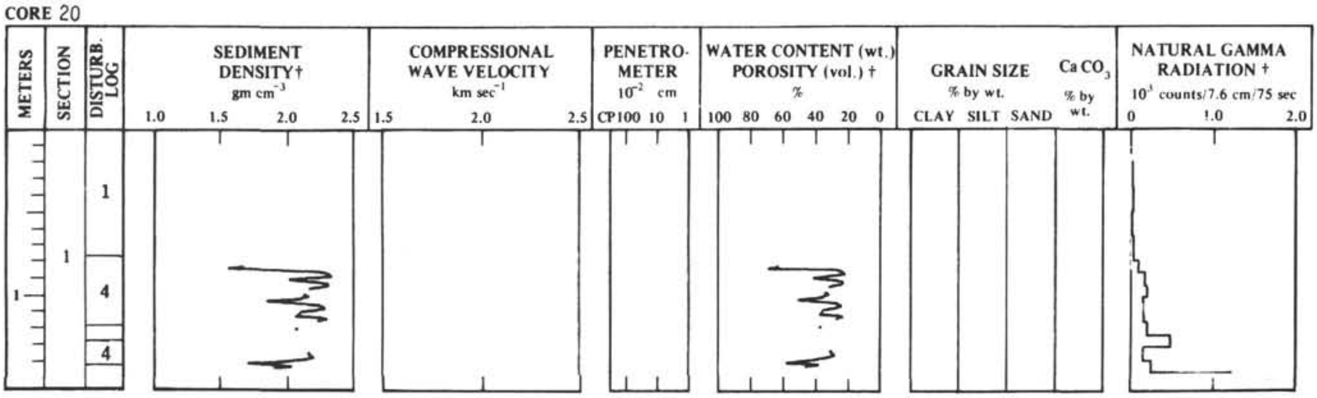
CORE 19



†Adjusted data, see Chapter 2

HOLE 118

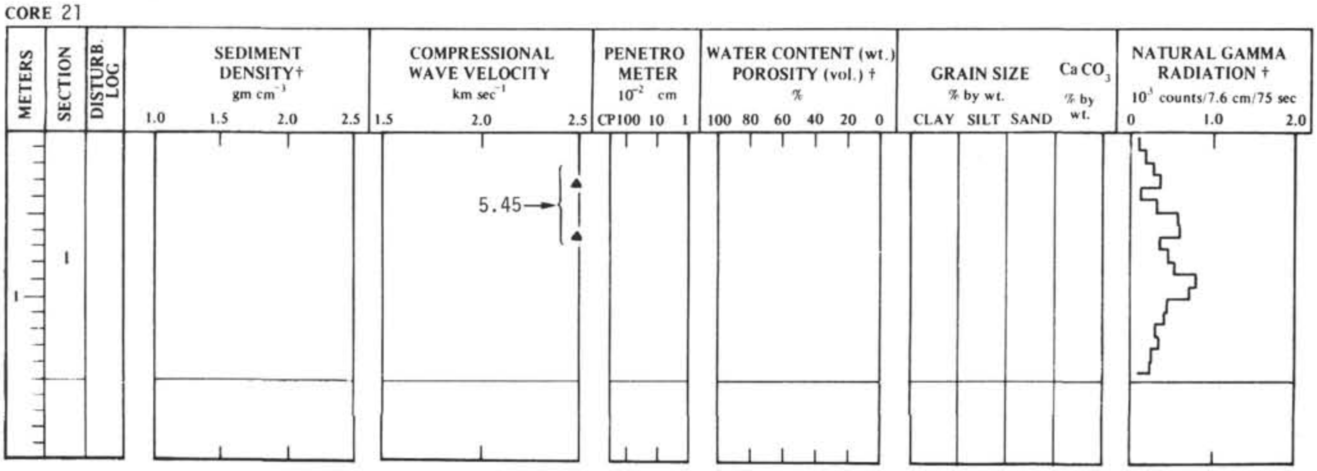
CORE 20



†Adjusted data, see Chapter 2

HOLE 118

CORE 21



†Adjusted data, see Chapter 2

HOLE 118 — 750 TO 756 m

CORE 19

METERS	SECTION	LITHOL.	SAMPLES		LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
				7.5YR6/6	Reddish-yellow clay in contact with basalt. There is a thin yellow-gray baked zone above the basalt and a crushed zone in the clay at 18-22cm.	Core Catcher:	P6a	(PALEOCENE)
	CC		F N R		X-ray mineralogy (bulk) Qtz. 54.6 Plag. 3.5 Kaol. 17.1 Mica 21.2 Mont. 3.5 Amorph. 71.8	Forams: *G. aequa, G. acuta, G. marginodentata, Ac. coalingensis, A. soldadoensis, G. patagonica.* Flora: *Chiasmolithus bidens, Discoaster gemgeus, Ericsonia cava, Reticulofenestra* sp. Rare reworked Upper Cretaceous zeolitized radiolarians.		LATE PALEOCENE

HOLE 118 — 756 TO 759 m

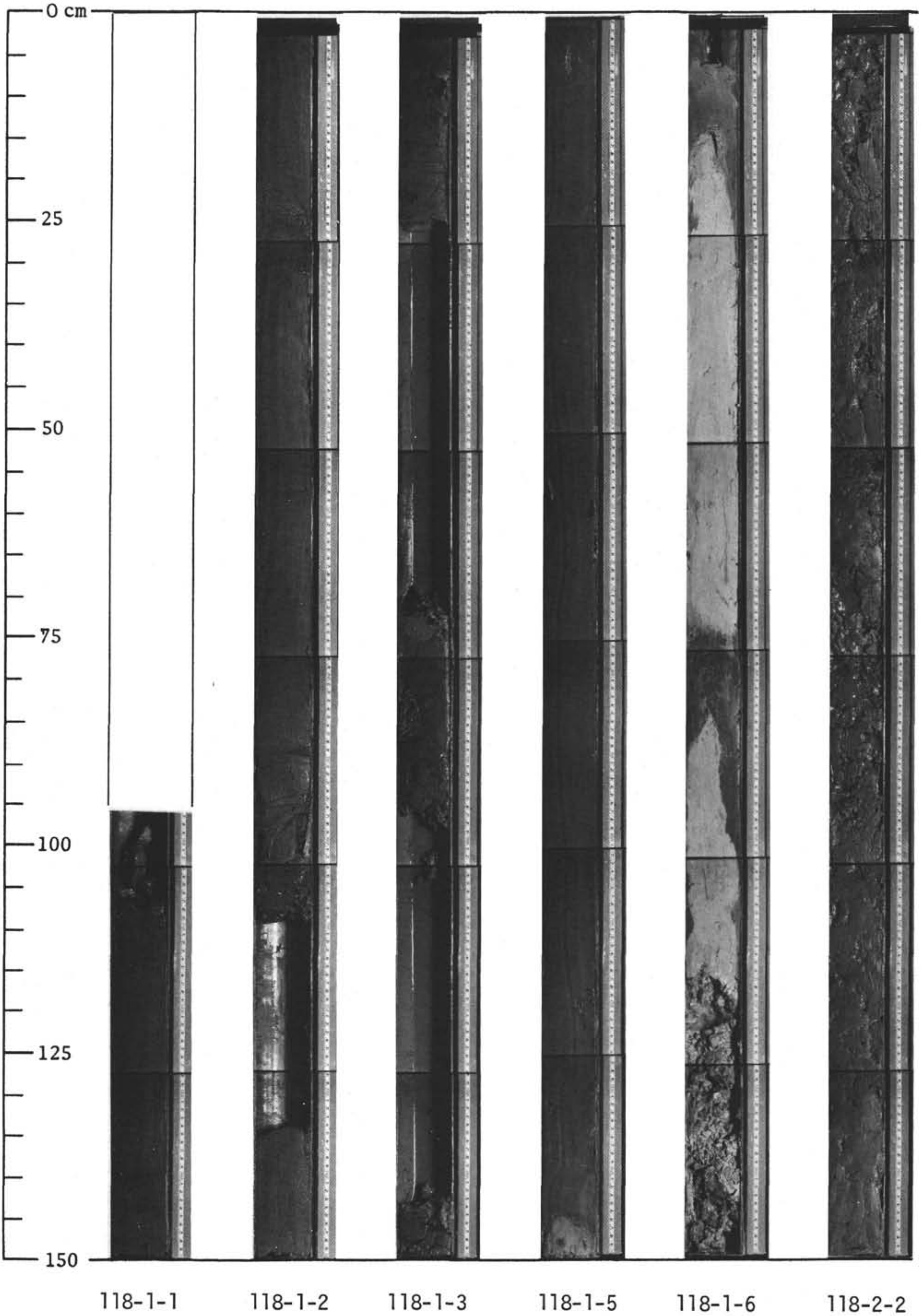
CORE 20

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
			N R	Basalt, with many veins of calcite. Alteration halos are visible around veins. Calcite probably deposited in fractures after alteration, as weathering occurred. Bottom 7cm baked red clay.	Core water; mixed assemblage of Late Paleocene to Miocene coccoliths, rare reworked Upper Cretaceous zeolitized radiolarians.		(PALEOCENE)
	CC						

HOLE 118 — 759 TO 761 m

CORE 21

METERS	SECTION	LITHOL.	SAMPLES		LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1			N4	Basalt with numerous calcite veins. Alteration halos visible around veins.	*Inside liner: Discoaster multiradiatus, D. gemmeus, Fasciculithus involutus, Ericsonia cava, Chiasmolithus bidens, Zygodiscus sigmoides, Toweius* sp. *Sphenolithus* sp. plus abundant reworked Upper Cretaceous zeolitized radiolarians.	*Discoaster multiradiatus*	LATE PALEOCENE
	CC		N R					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75
100
125
150
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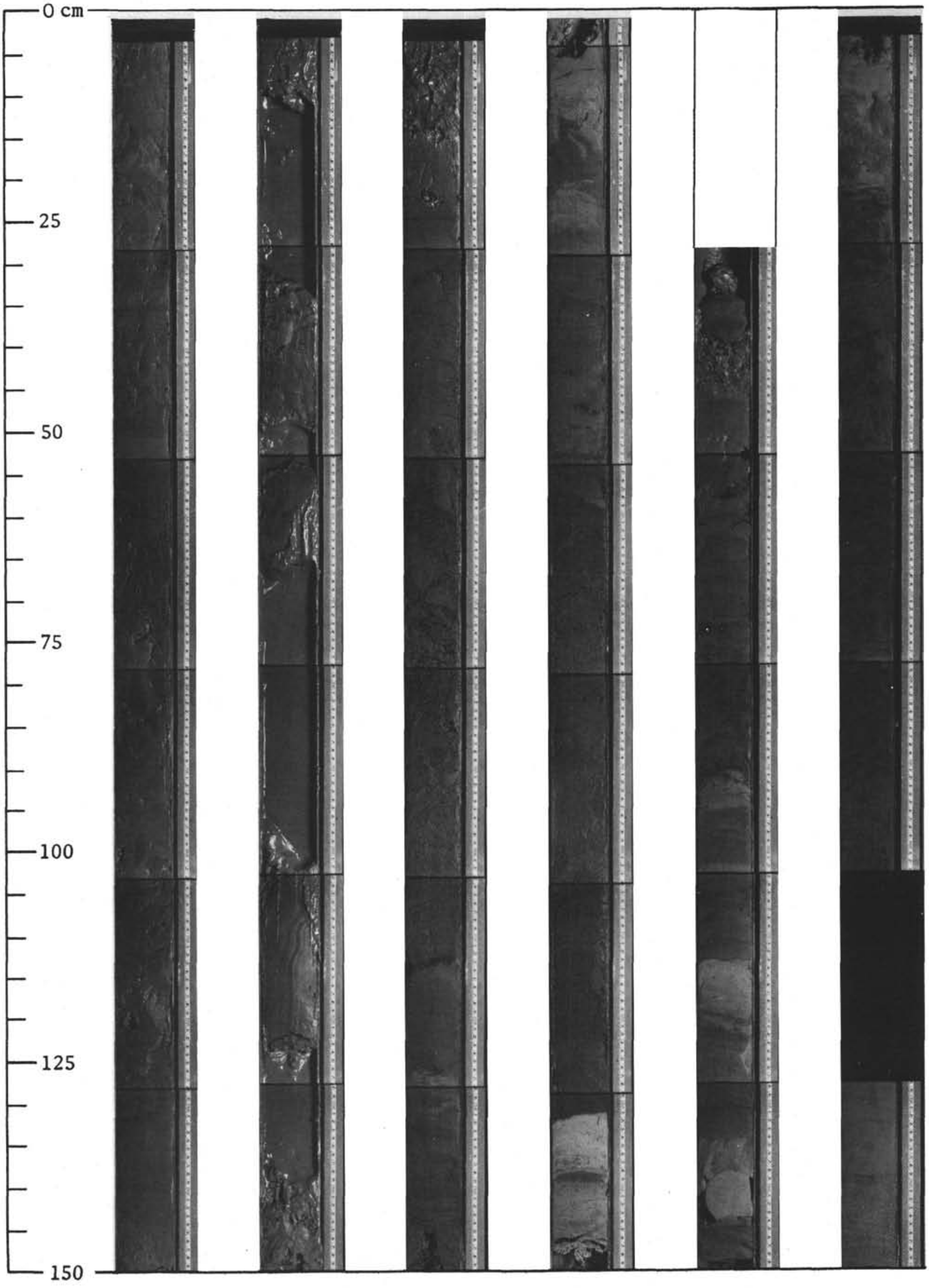
118-1-2
118-1-3
118-1-5
118-1-6
118-2-2


0 cm
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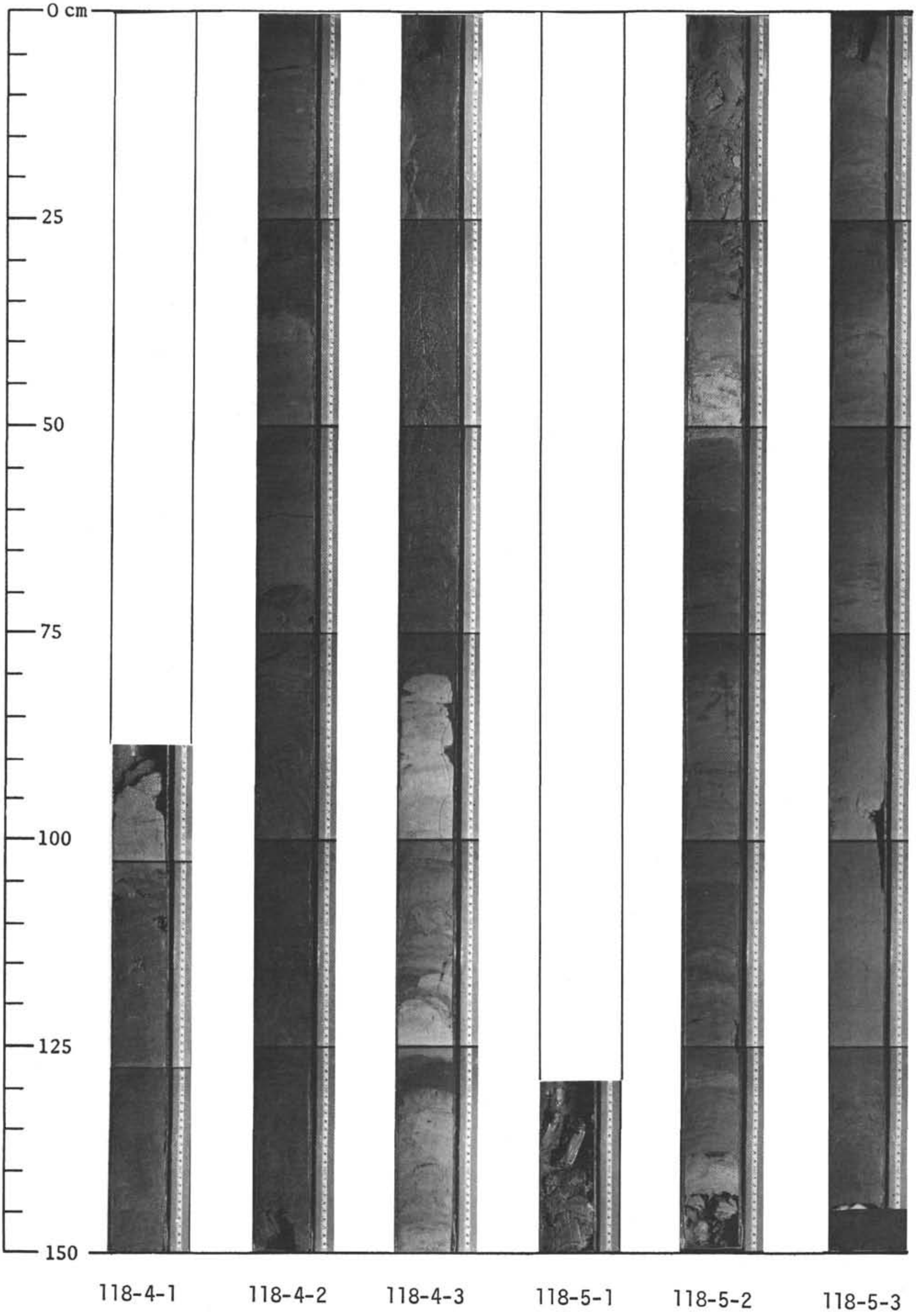
50
75
100
125
150
118-2-3
118-2-4
118-2-5
118-2-6
118-3-1
118-3-2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150
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118-4-3
118-5-1
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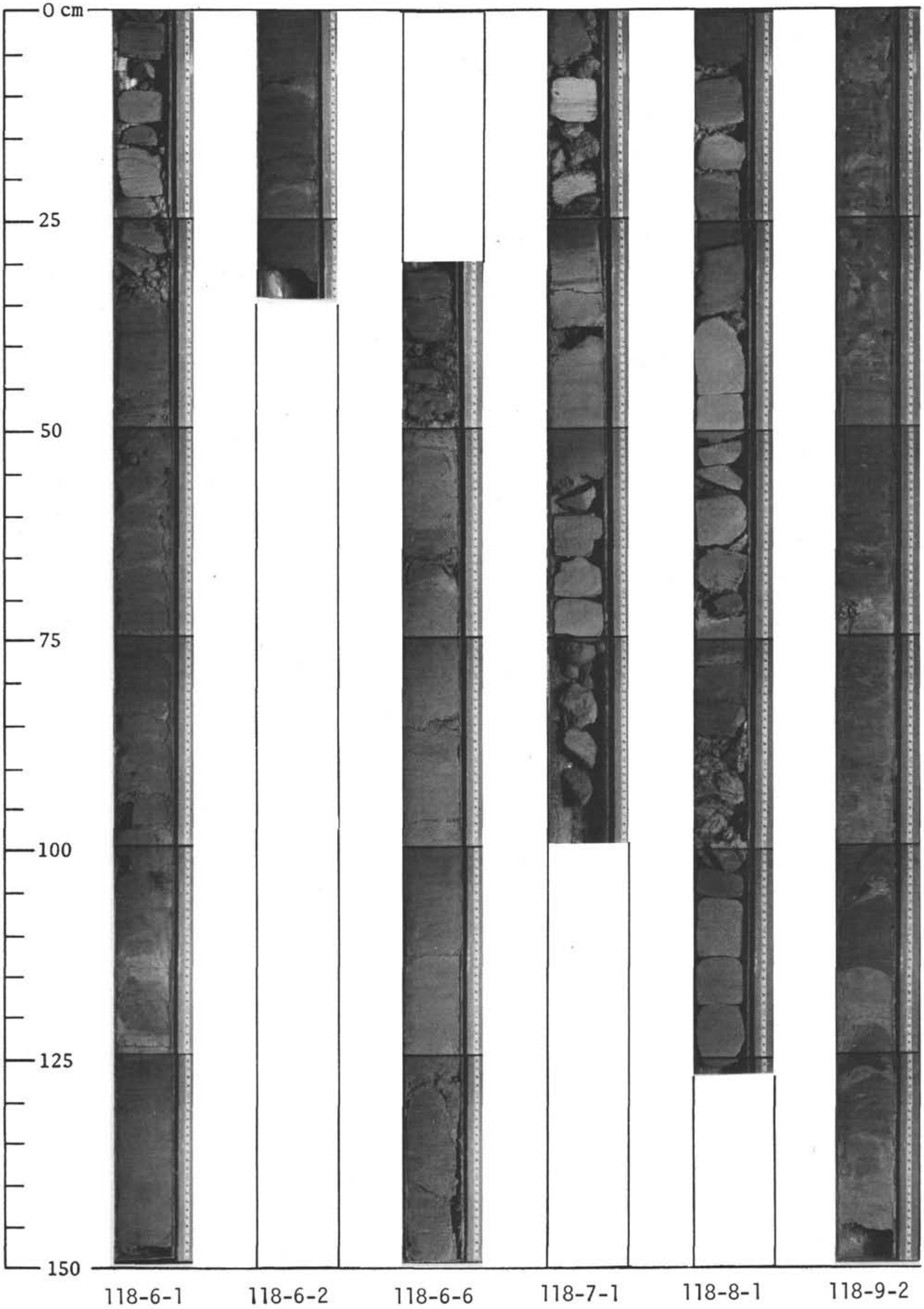
118-5-3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118-6-1
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118-6-6
118-7-1
118-8-1
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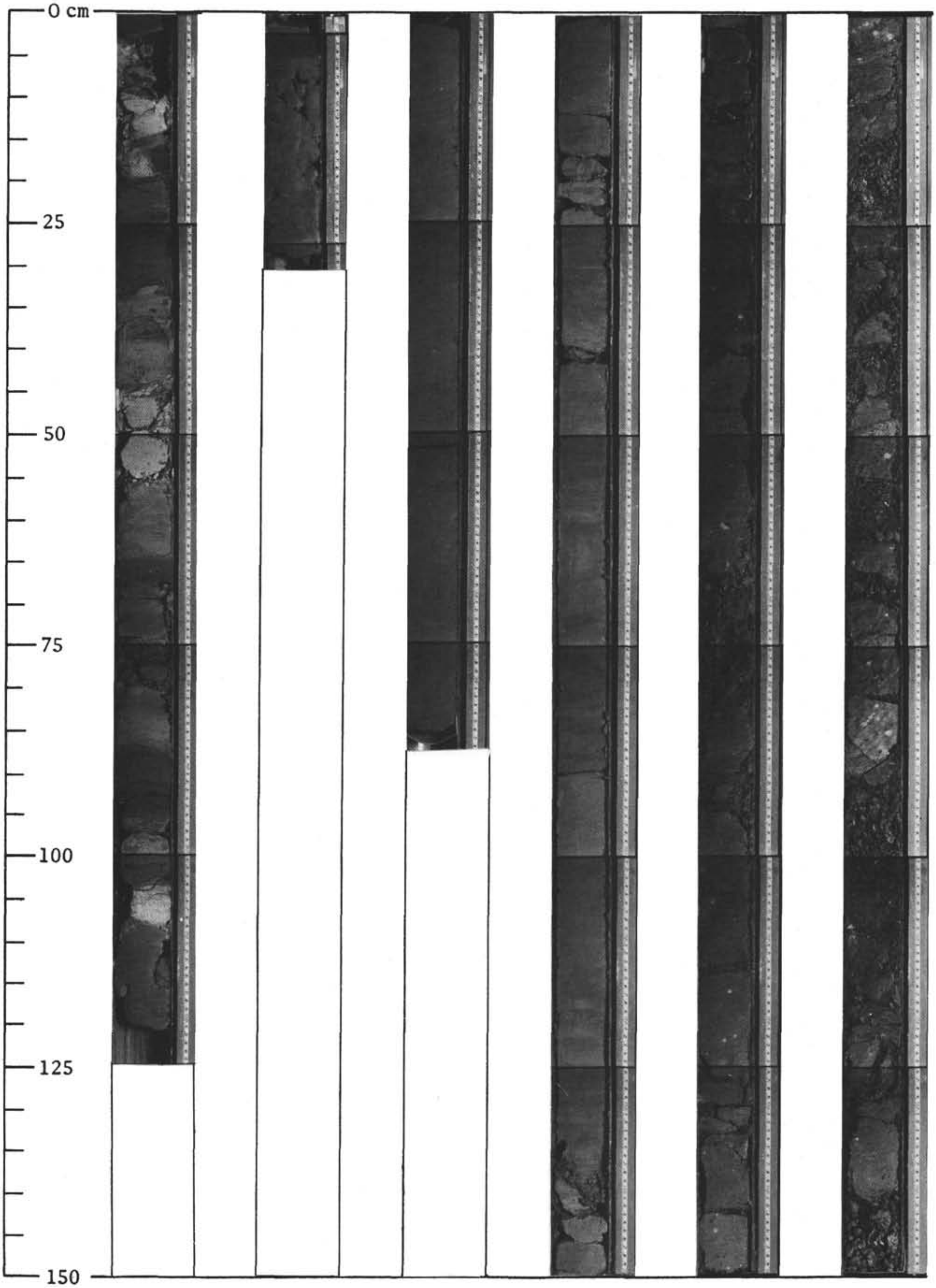
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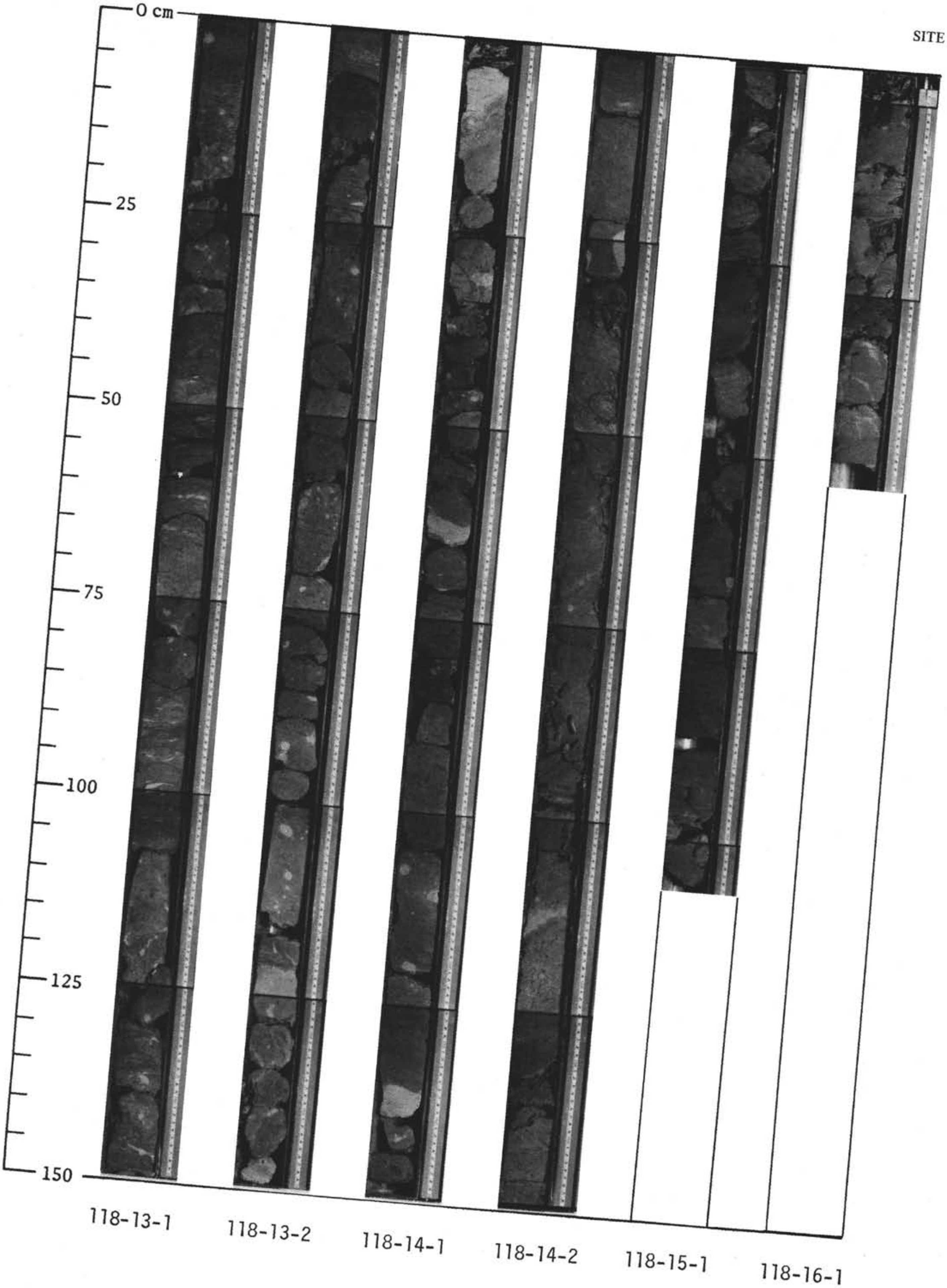
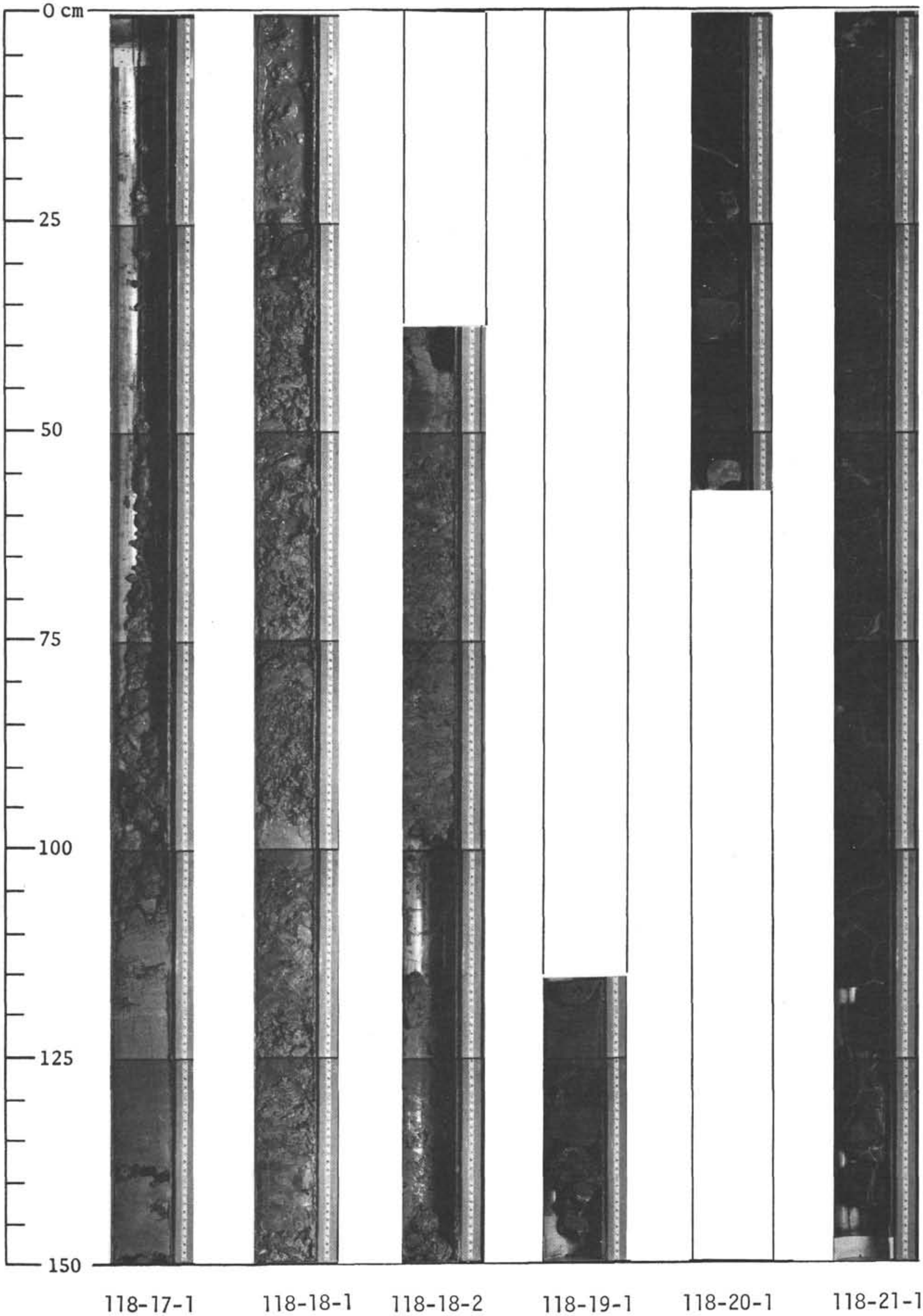
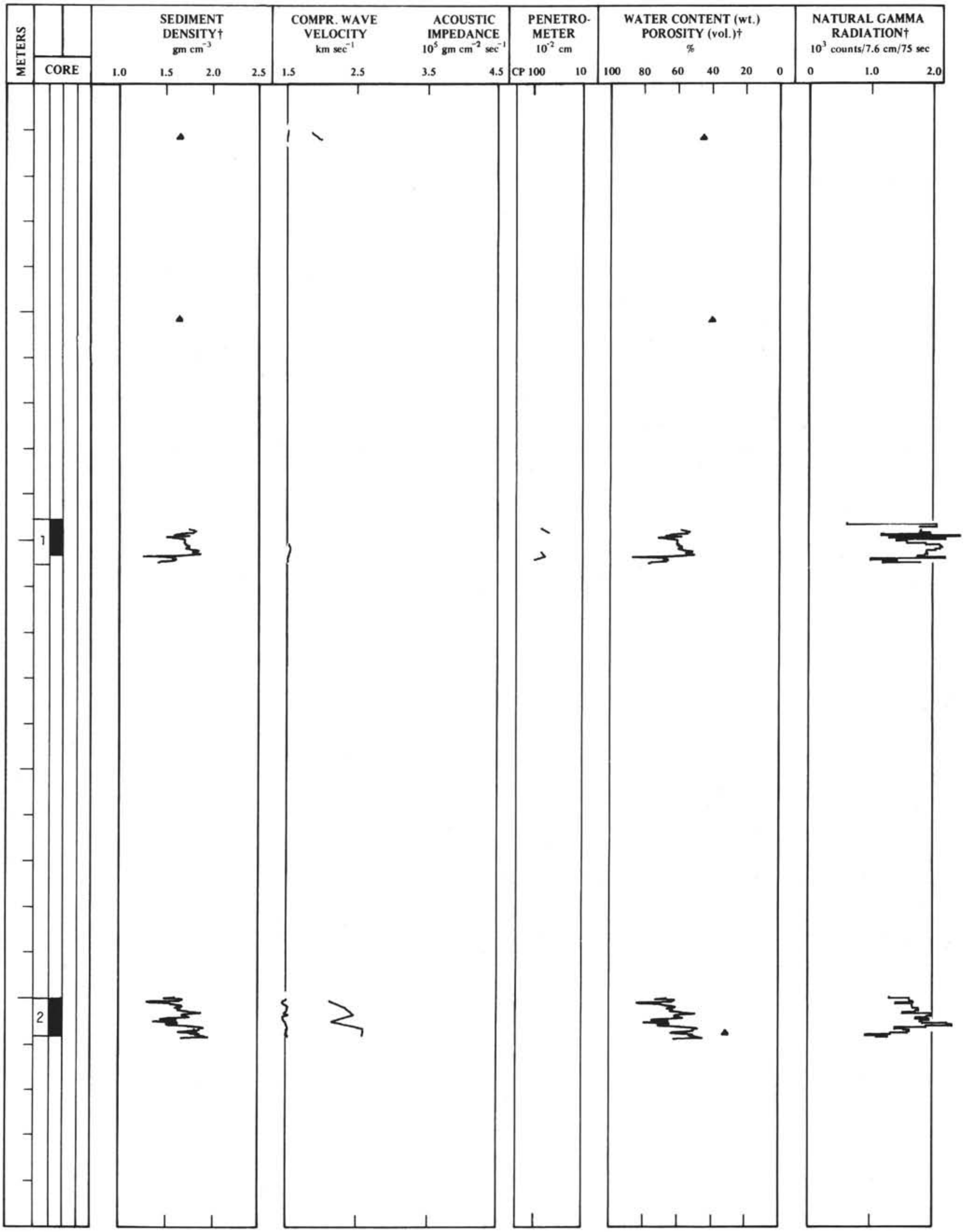
150
118-10-1
118-11-1
118-12-1
118-12-2
118-12-3
118-12-4


0 cm
25
50
75
100
125
150
118-13-1
118-13-2
118-14-1
118-14-2
118-15-1
118-16-1



0 cm
25
50
75
100
125
150
118-17-1
118-18-1
118-18-2
118-19-1
118-20-1
118-21-1

SITE 118 0m TO 250m



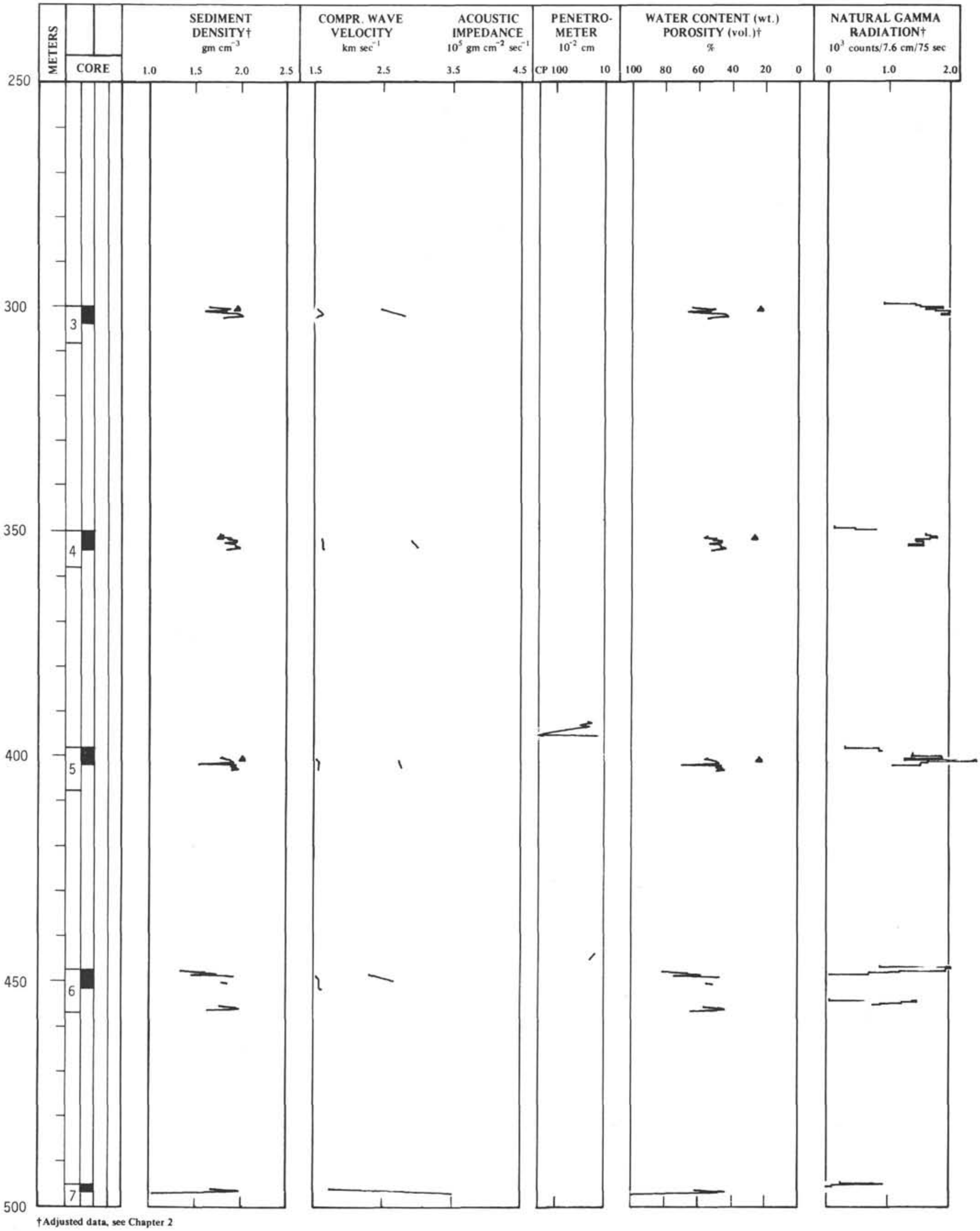
†Adjusted data, see Chapter 2

SITE 118 0 TO 250 m

METERS	CORE (118)	SEISMIC REFL.	DRILL DATA	LITHOLOGY	SED. RATE cm 10^{-3}y	AGE † m. y.	TIME STRATIGRAPHIC SUBDIVISION
50 100 150 200 250	1 2	1.67 km/sec MANY REFLECTORS BETWEEN 0.0 and 0.3 SECS.		Gray silty clays with graded sand layers.	12.5	2	PLEISTOCENE

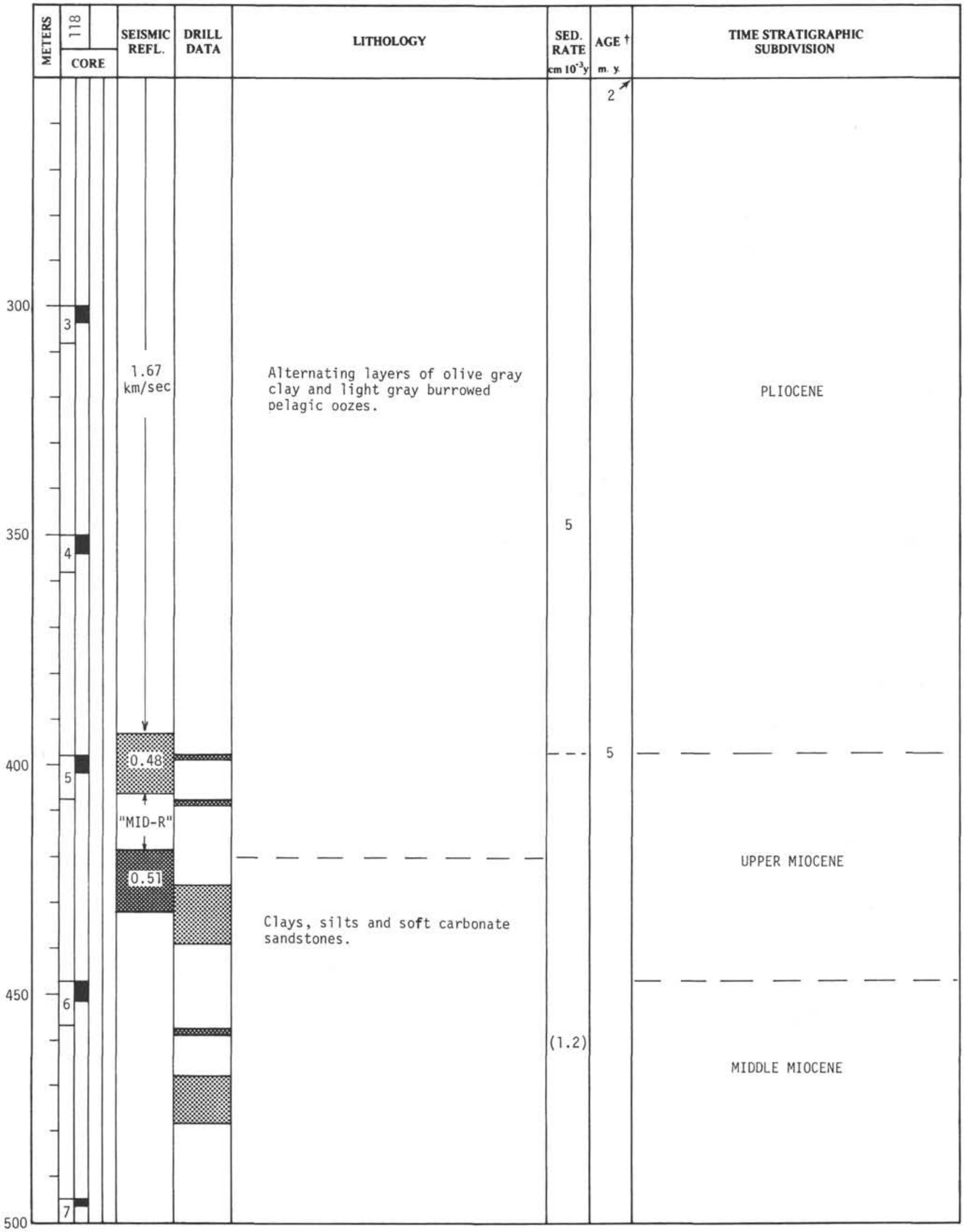
†See Chapter 2 (explanatory notes)

SITE 118 250m TO 500m



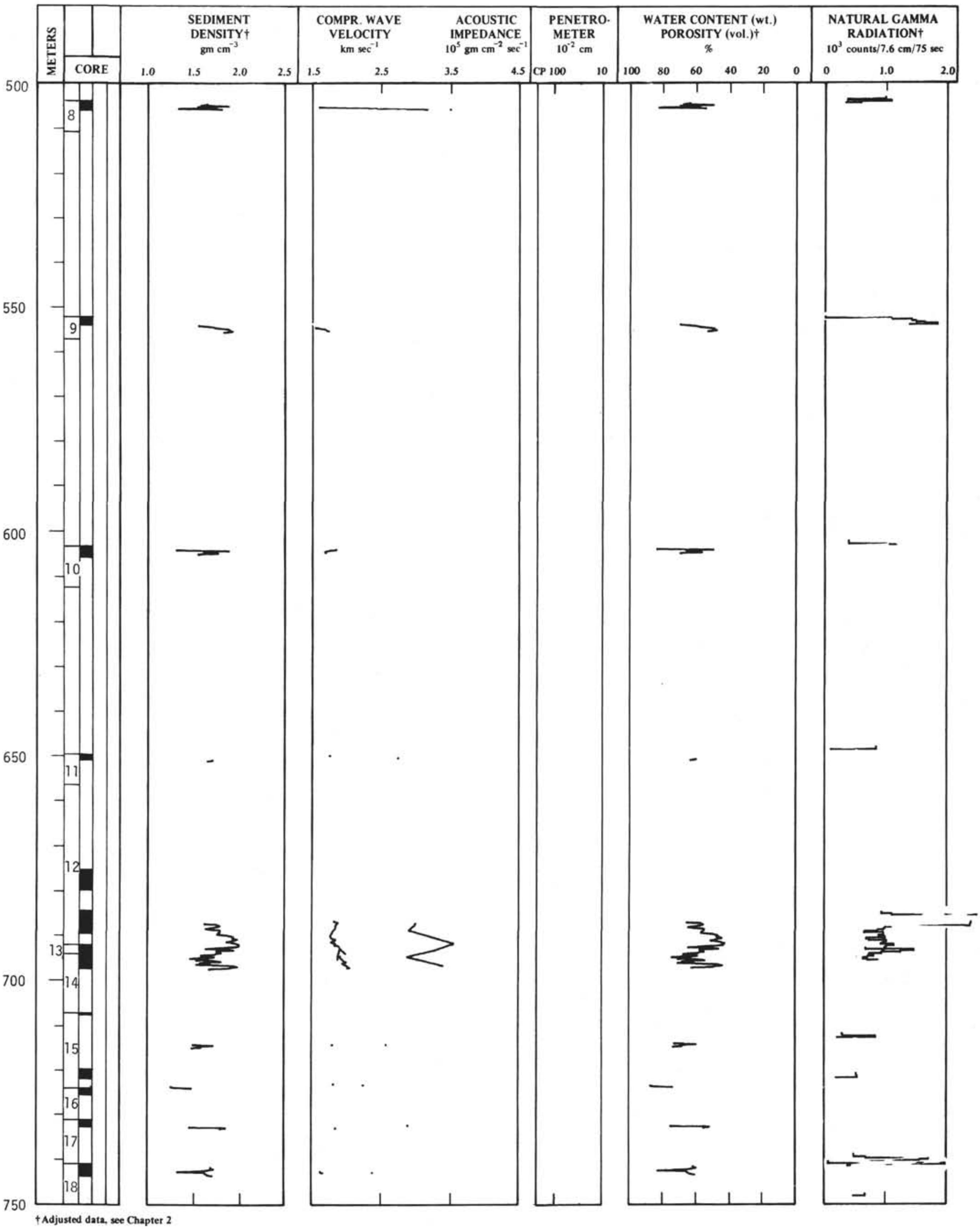
†Adjusted data, see Chapter 2

SITE 118 250 **TO** 500 **m**



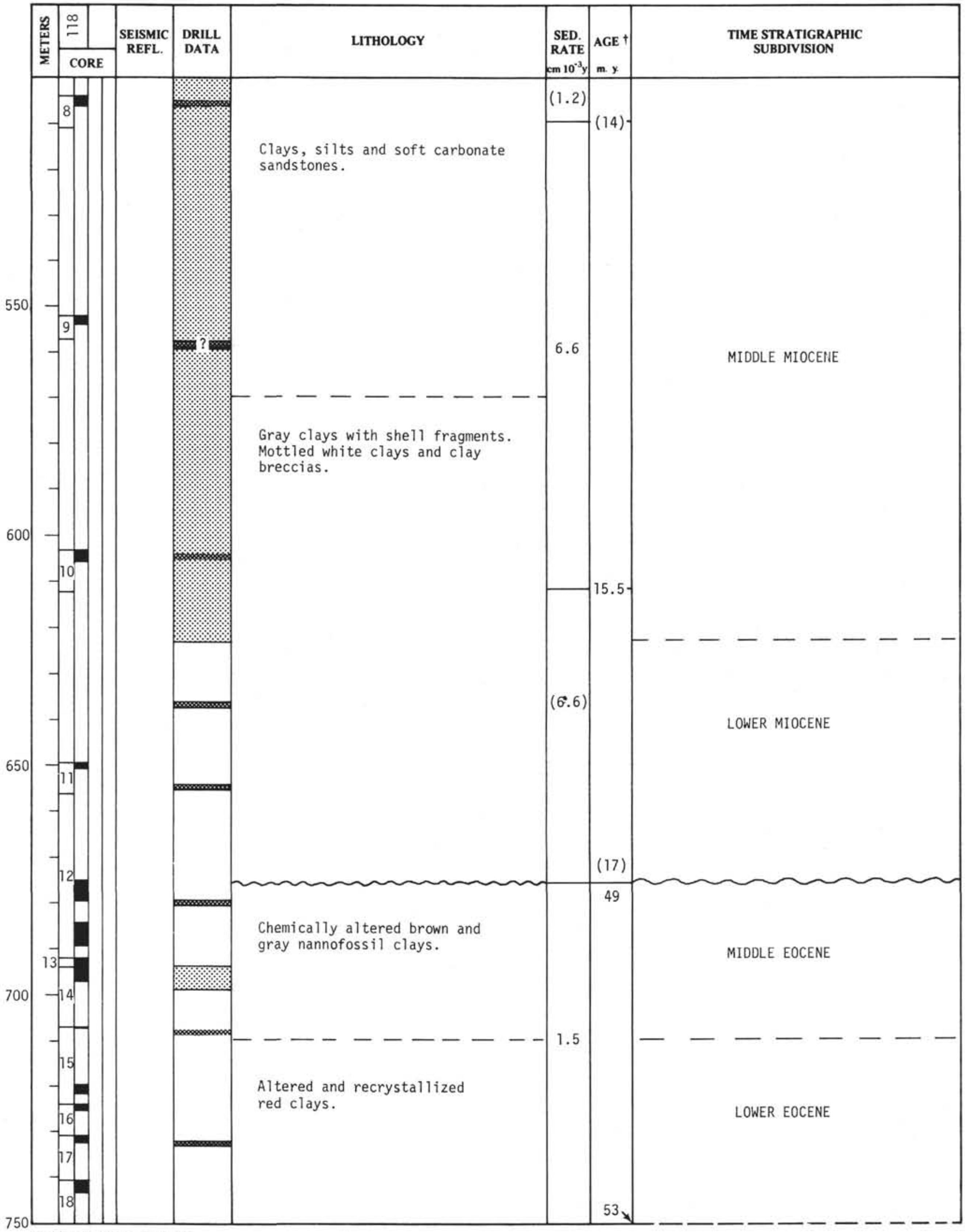
†See Chapter 2 (explanatory notes)

SITE 118 500m TO 750m



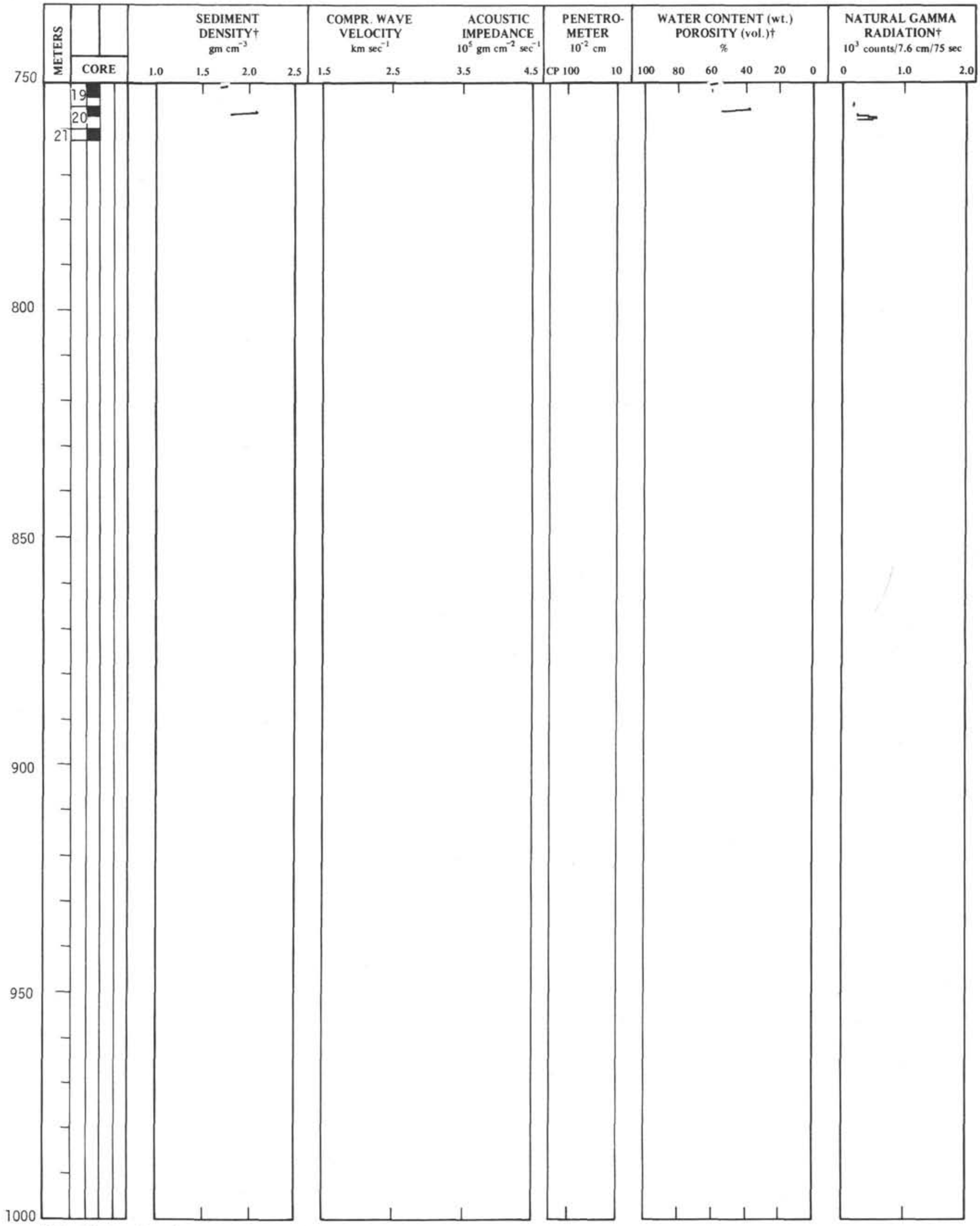
†Adjusted data, see Chapter 2

SITE 118 500 TO 750 m



†See Chapter 2 (explanatory notes)

SITE 118 750m TO 1000m



†Adjusted data, see Chapter 2

SITE 118 750 **TO** 761 **m**

METERS	118 CORE	SEISMIC REFL.	DRILL DATA	LITHOLOGY	SED. RATE cm 10^{-3}y	AGE † m. y.	TIME STRATIGRAPHIC SUBDIVISION
	19					53	PALEOCENE
	20			Altered basalt sills.			
	21						
800							

†See Chapter 2 (explanatory notes)