8. SITES 116 AND 117

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SITE 116

Location: East side of Hatton-Rockall Basin.

Position: 57° 29.76′N, 15° 55.46′W; Satellite Navigation.

Depth of water: 1151 meters (corrected).

Total penetration: 854 meters.

SITE 117

Location: Boundary between Hatton-Rockall Basin and Rockall Bank (37 km ESE of 116).

Position: 57° 20.17′N, 15° 23.97′W.

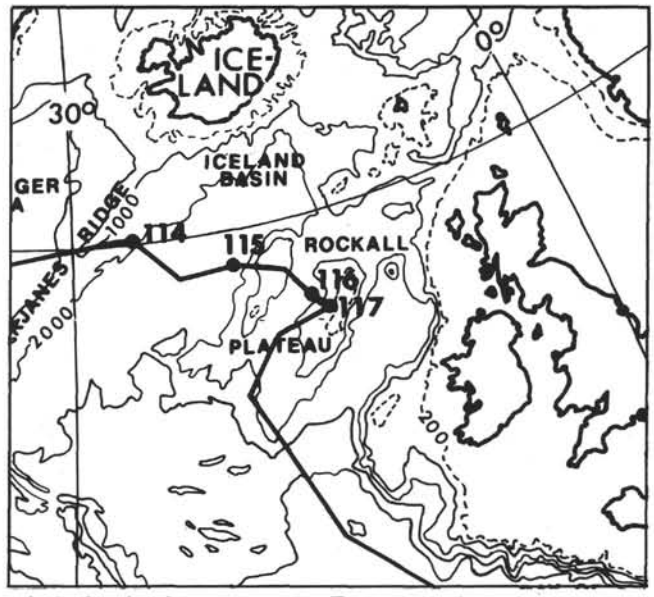
Depth of water: 1038 meters (corrected).

Total penetration: 313 meters.

SITE BACKGROUND AND OBJECTIVES

Although Sites 116 and 117 are nearly 40 kilometers apart, the second site was chosen as a direct consequence of the results obtained at the first, and is in essence a stratigraphic continuation of the first hole. For this reason both sites will be described and discussed in the same chapter.

Rockall Plateau (Figure 1) is a shoal area of about 1000 meters depth, some 450 by 600 kilometers in extent, lying between the Reykjanes Ridge and Northwestern Europe, and separated from them by basins or troughs of over 2500 meters depth. To the southwest, the plateau is flanked by steep scarps, but to the northeast, it is connected by



relatively shoal water to the Faroe Islands and the nearby banks and shoals.

The main topographic trends of the plateau are NE–SW. A central depression, the Hatton-Rockall Basin, is flanked to the northwest by Hatton Bank with a minimum depth of 485 meters, and to the southeast by Rockall Bank much of which is less than 200 meters in depth, but which at its northeast end appears above the sea as the small rock island of Rockall. Rockall Island is made of an aegirine granite of Lower Eocene age (Sabine, 1965) and is part of a planated Tertiary volcanic center (Roberts, 1969).

Geological and geophysical data on Rockall Plateau has been reviewed by Roberts (1971) and by Scrutton and Roberts (1971). Isotope studies of the aegirine granite of Rockall Island by Moorbath and Welke (1969) suggest that it has been intruded through a continental crust. Magnetic data show that the linear magnetic anomaly pattern, characteristic of a spreading ocean floor to the west and south, is not present on the plateau (Avery, Vogt and Higgs, 1969). The change in magnetic character at the plateau margins suggests structural differences from the surrounding areas. Free air gravity profiles across the plateau (Roberts, 1971) show that it is on the whole in isostatic equilibrium (except for Rockall Bank where there is a +70 mgal broad anomaly), implying that the crust beneath the plateau is nearer to a typical continental thickness rather

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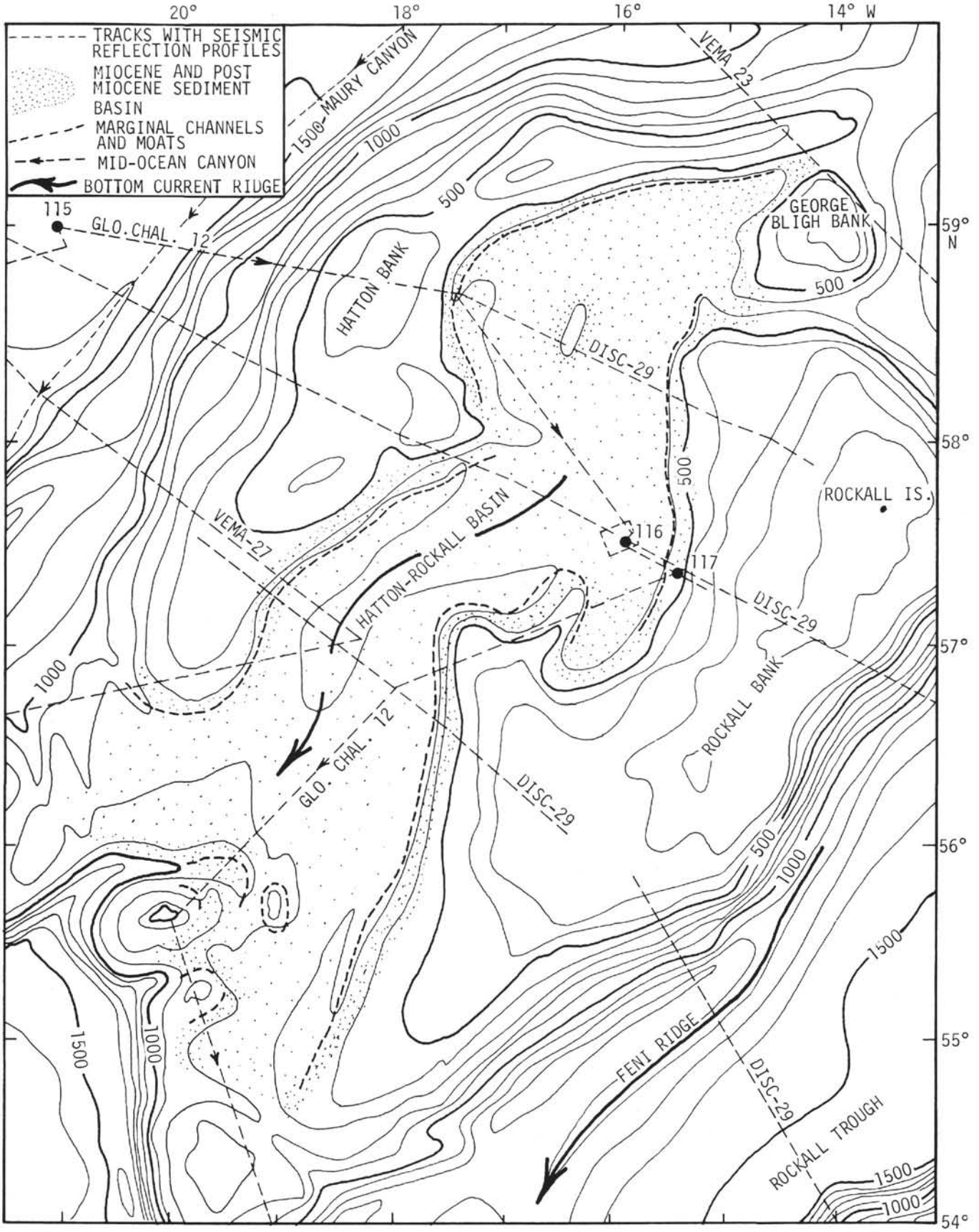

Figure 1. *Bathymetric chart of Rockall Plateau showing location of tracks with seismic reflection profiles, and the limits of the Miocene sediments in Hatton-Rockall Basin. Contours in corrected fathoms at 100 fathom interval. Area outlined around Site 116 is shown in more detail in Figure 4.*

than an oceanic one. Subsequent seismic refraction experiments have confirmed that the crust below Rockall Bank (Scrutton, 1970) and below Hatton-Rockall Basin (Scrutton, personal communication) is continental both in crustal velocities and in the depth to Moho. A continental nature of Hatton and Rockall Banks was suggested by Bullard, Everett and Smith (1965) on a purely geometrical basis in order to fill a gap in the reconstruction of the continental margins of the North Atlantic prior to continental drift.

An analysis of the magnetic anomaly pattern between Rockall Plateau and Greenland (Avery, Vogt and Higgs, 1969; Vogt, Ostenso and Johnson, 1970), that is, across the Reykjanes Ridge and Iceland Basin, shows that the western margin of the plateau lies adjacent to Anomaly 24 (60 million years isochron), and that the plateau became separated from Greenland at about this time. The age of the Rockall Island granite is also 60 ±10 million years (Miller and Mohr, 1965), suggesting that it was intruded at the time of the initial break from Greenland.

It has also been suggested (Vine, 1966) that Rockall Trough has resulted from an older, and now extinct, movement of Rockall Plateau away from northwestern Europe. However the evidence for this is circumstantial. The magnetic field in the trough is very smooth and unlike the magnetic field found in most parts of the ocean basins, the sediments are very thick and the interpretation of seismic refraction data is ambiguous (Scrutton and Roberts, 1971). It is clear, however, that there are two major structural discontinuities separating the trough from the plateau and from the continental margin of northwestern Europe.

Three seismic reflection profiles across Rockall Plateau revealed the existence of a large sedimentary basin (Figure 3) between Hatton and Rockall Banks (Roberts, Bishop, Laughton, Ziolkowski, Scrutton and Matthews, 1970). Another profile by *Glomar Challenger*-12 further defined the basin (Figure 2). The sediments of Hatton-Rockall Basin attain a thickness in places of at least 2 second two-way travel time (1700 meters at a mean velocity of 1.7 km/sec), with an average thickness of about 1400 meters. Two major reflecting horizons (4 and 5) were recognized on the three profiles. A series of essentially horizontally layered sediments overlie and pinch out against Horizon 4, below which there is a relatively transparent sedimentary layer. This horizon consists of a number of hyperbolic echoes suggesting structural disturbance or diapiric intrusion. Reflector 5 is considerably more irregular than reflector 4 and comprises a large number of overlapping hyperbolic echoes. It is not possible to determine from the seismic reflection results whether reflector 5 is the crystalline basement, or merely the fractured top of an even older sedimentary basin. Refraction data favors the latter explanation. This question will be discussed further when the results of the drilling at Sites 116 and 117 are interpreted.

In contrast to the Hatton-Rockall Basin, there is little penetration on Hatton and Rockall Banks. These appear to have a crystalline basement near to the sea bed. The sedimentary layer between reflectors 4 and 5 drapes the flanks of the Banks but wedges out near the top.

If Rockall Plateau is indeed a continental fragment as is suggested by the above evidence, its geological history should be preserved in the sedimentary strata of the Hatton-Rockall Basin. It was for this reason, principally, that a site was chosen to drill through these sediments on Leg 12. The elevated location of the Basin compared with Iceland Basin west of the Plateau and with Rockall Trough was believed, at the time of drilling, to afford some protection from the influence of contour current mechanisms and, hence, it was hoped that an undisturbed record of Tertiary pelagic sediments might be preserved here. In any event, the biostratigraphy should reflect Tertiary vertical movements of Rockall Plateau and their relation to changes in sea floor spreading regimes and perhaps also give information on the climatological and circulation changes resulting from the opening of the North Atlantic during the Tertiary.

Ideally, a hole in the center of Hatton-Rockall Basin penetrating to reflector 5 would have been chosen. However this was beyond the reach of the drilling capability. Therefore, the first site was chosen somewhat east of the center where some of the lower layers above reflector 4 had already pinched out so that we could be assured at least of penetrating into the transparent zone beneath the reflector 4. Some concern was felt at the possibility of encountering hydrocarbons in the sediments, since they were believed to be of continental origin, so structural traps were avoided in the selection of the site.

The decision to drill a second hole (117) was not taken until we had penetrated through reflector 4 at Hole 116, and it was realized that we were unlikely to be able to penetrate far into the transparent layer. The *Discovery*-29 profile (Roberts *et al.*, 1970) showed that the sediments above reflector 4 wedged out some 40 kilometers east of Site 116 and that a basement reflector was accessible for drilling below the transparent layer. A new major objective therefore was to sample and identify the basement reflector.

In summary the objectives were:

(a) To obtain details of the biostratigraphy and lithology of the sediments of Hatton-Rockall Basin to determine the environmental and tectonic history of Rockall Plateau.

(b) To delineate Cenozoic high latitute paleobiogeography.

(c) To determine the nature of reflector 4 and the associated depositional unconformity.

(d) To compare the transparent sediments below reflector 4 with the stratified sediments above.

(e) To obtain samples either of reflector 5, or of the basement further east to test the continental nature of the Plateau.

SURVEY DATA (116)

Pre-Leg 12 Survey Data

Prior to Leg 12, the site had been chosen on the basis of a seismic reflection profile obtained by *Discovery*-29. This seismic system was tuned by careful adjustment of airgun depth, hydrophone array depth and bubble pulse interval, to a frequency of 30 Hz. While the system gave good

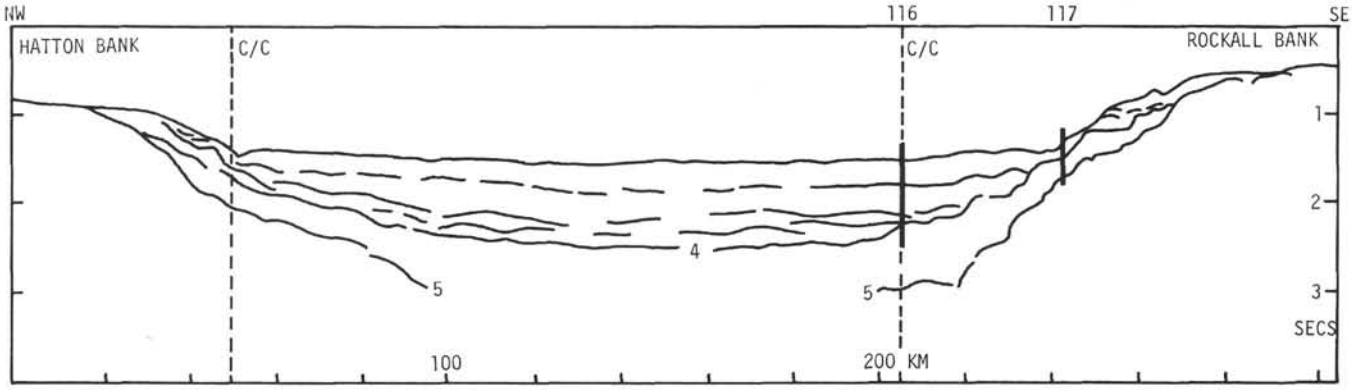

Figure 2. *Line drawing of seismic reflection profile across Hatton-Rockall Basin by* Glomar Challenger-*12.*

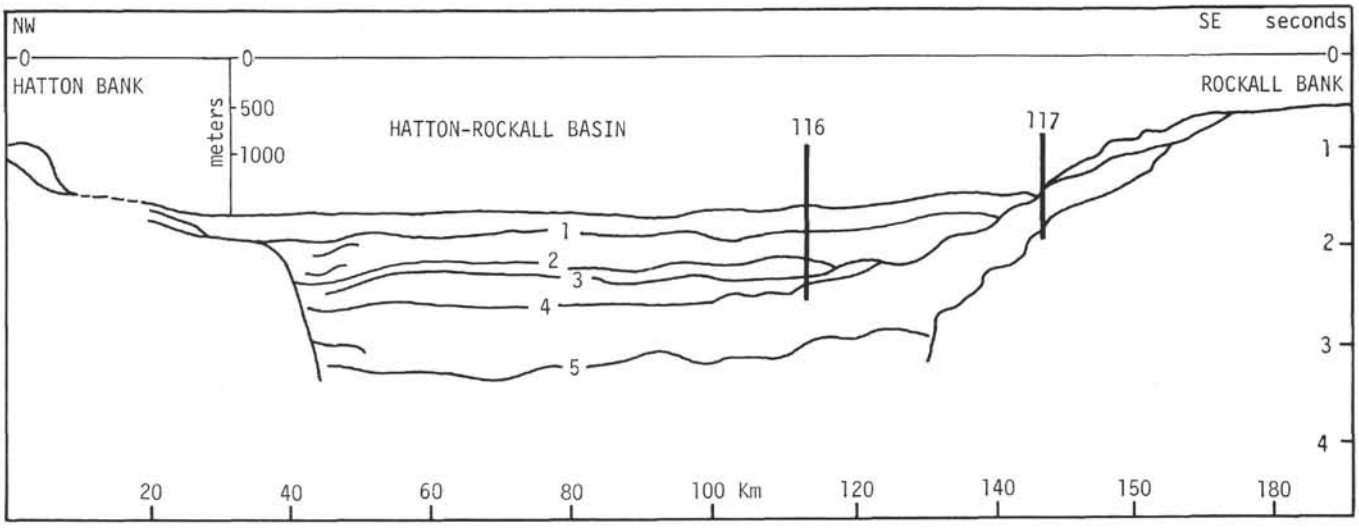

Figure 3. *Line drawing of central seismic reflection profile across Hatton-Rockall Basin by* Discovery-*29 (after Roberts* et al., *1970).*

penetration and showed reflector 5 clearly, the ringing pulse shape obscured some of the finer structure nearer to the surface.

A site survey was made, therefore, by *Discovery*-33 in April 1970 to provide a detailed picture of the subbottom structure. Details of this survey are given in Appendix II. In summary, a box survey of 7 legs in a six mile square was made relative to an anchored buoy (Figure 4). Navigation was by radar, and the buoy position determined by satellite. Air gun profiles (30 to 300 Hz) enabled the reflectors to be mapped, and an isopachyte map (Figure 5) of the sediments above reflector 4 was plotted, as well as an accurate bathymetric map. Within the box all layers above reflector 4 were approximately horizontal. Reflector 4 itself varied in depth below surface from 0.60 to 0.95 second. A site was chosen for drilling where Horizon 4 was well developed and at 0.85 second (720 meters at 1.7 km/sec). It turned out that this position could not be occupied accurately because of a breakdown of the satellite navigator.

Survey by *Glomar Challenger*

The track from Site 115 to 116 was chosen to give a profile (Figure 2) across Hatton Bank north of the long *Discovery*-29 profile from northwestern Ireland to the Reykjanes Ridge, and to link with the more northerly *Discovery*-29 profile which did not completely cross Hatton-Rockall Basin.

In places on the west slope of Hatton Bank, up to 0.4 second of acoustically transparent sediment lie on what may be faulted basement blocks. An alternative explanation of these sediments is that they may have been deposited by contour currents traveling northward. On the east slope, the sediments of Hatton-Rockall Basin have a similar relationship to basement as they do on Rockall Bank. An acoustically transparent layer covers basement conformably, thinning toward the crest (Figure 6). It is overlain unconformably by a series of nearly horizontally bedded sediments, the unconformity being reflector 4 of Roberts *et al.* (1970) (Figure 3). Near Hatton Bank this sequence, which contains many reflectors, is distorted, possibly by slumping, and a channel is found characteristic of the margin of the Hatton-Rockall Basin sediments.

The draping of the transparent layer onto Hatton Bank in this section is in contrast to the section further south taken by *Discovery*-29, where reflector 4 abuts the basement of Hatton Bank (Figure 3), and therefore establishes the continuity of the layer over both Hatton and

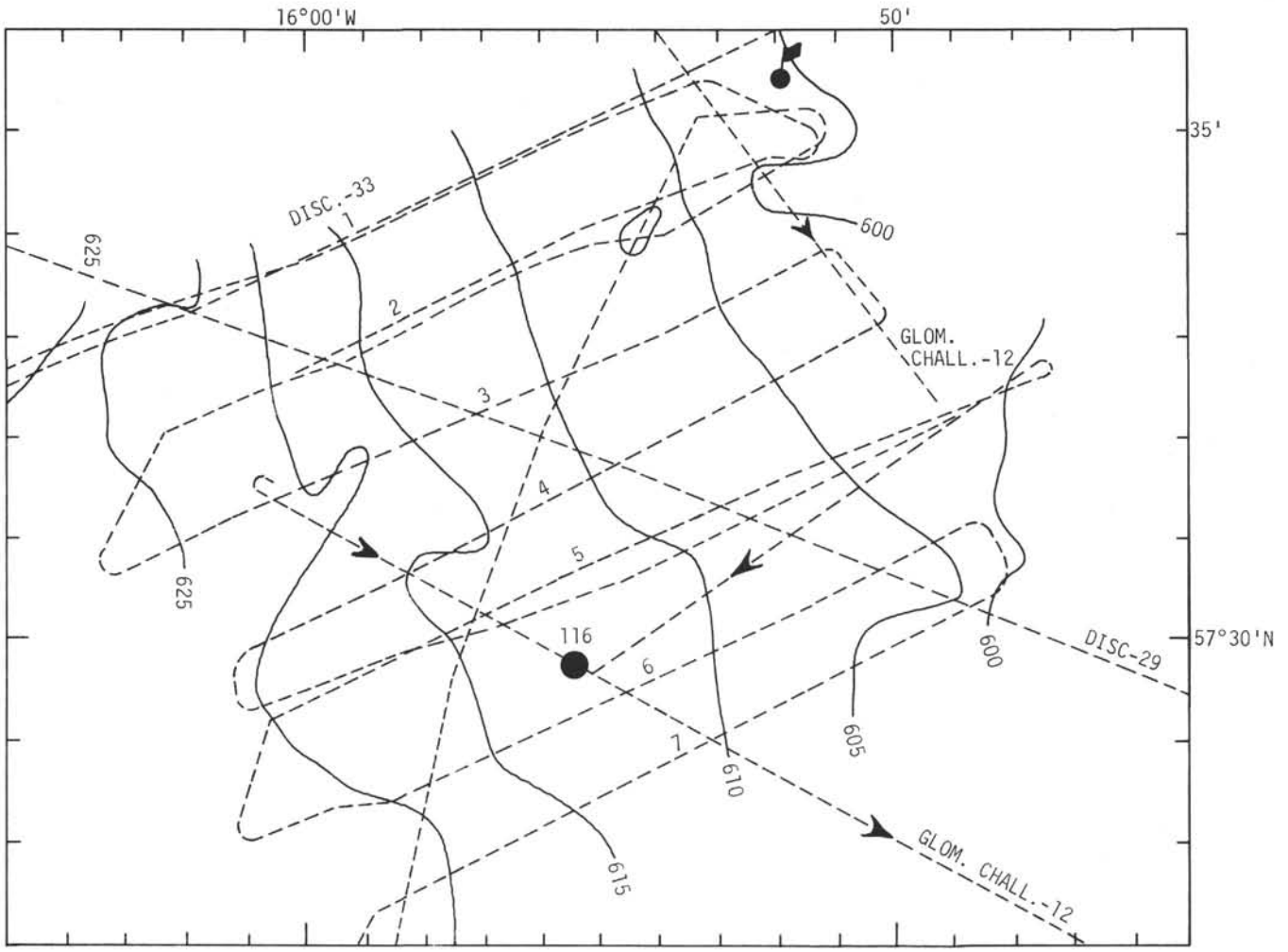

Figure 4. *Track chart and bathymetry of site survey around Site 116 by* Discovery-*33, with* Discovery-*29 and* Glomar Challenger-*12 tracks. Depths in uncorrected fathoms (at 800 fm/sec): Contour interval 5 fathoms.*

Rockall Banks. Furthermore, the *Glomar Challenger* section suggests the continuity of basement from Hatton Bank to reflector 5 (Roberts *et al.*, 1970). Such continuity could not be established by *Discovery* on the Rockall side of the basin. Unfortunately basement could not be followed continuously under the basin on the *Glomar Challenger* record, but the *Discovery*-29 north profile does show indications of it as deep as 2 seconds.

From the junction with the *Discovery*-29 north profile, the track crossed the basin to Site 116 on the *Discovery*-29 central profile. The basin was continuous on this track, and not divided as suggested by Roberts *et al.*, 1970, Figure 1. The sediment surface was characterized by numerous small indentations which appear to reflect structures in the deeper sediment horizons. They may be related to the wavy topography characteristic of contour current produced ridges. A 90 degree turn near Site 116 altered the spacing of these, suggesting that they are part of a linear pattern.

The approach to Site 116 was controlled only by poor Loran A fixes. A comparison of soundings and subbottom structure with *Discovery*-33 site survey showed us to be northeast of the site, so the course was altered to the southwest and the speed reduced to 4 knots (Figure 4). This new track crossed a slightly shallower region of reflector 4 shown by the isopachyte map of the site survey (Figure 5). The gear was recovered and the beacon dropped within a mile of the site chosen on the basis of the site survey.

The position of Site 116 was only established accurately after several days of observations of sun and stars and after the cruise, by calculation from satellite passes. Working a dead reckoning track back from the site and using the site survey data as control, the Loran A fixes were found to be consistently 2 miles too far west (due to sky wave interference).

On site, reflecting horizons were chosen from three available records working with different systems and at different frequencies: *Discovery* (30 to 300 Hz, Figure 7), *Glomar Challenger* (80 to 160 Hz, Figure 8 and 160 to 320 Hz, Figure 10). It was difficult to correlate reflectors on all three records. The best defined were obtained on the 160 to 320 Hz record and were labeled 1, 2, 3 and 4 to conform to the *Discovery* labels (Roberts *et al.*, 1970). Of the upper reflectors, 1 and 3 are the strongest. Reflector 4 was somewhat diffuse and more variable in depth near the site than the higher ones, and lay about 0.80 to 0.90 second depth.

While drilling, no correlations were made between lithological changes and reflectors 1 to 3. This was partly a result of the widely spaced cores. Reflector 1 which shows

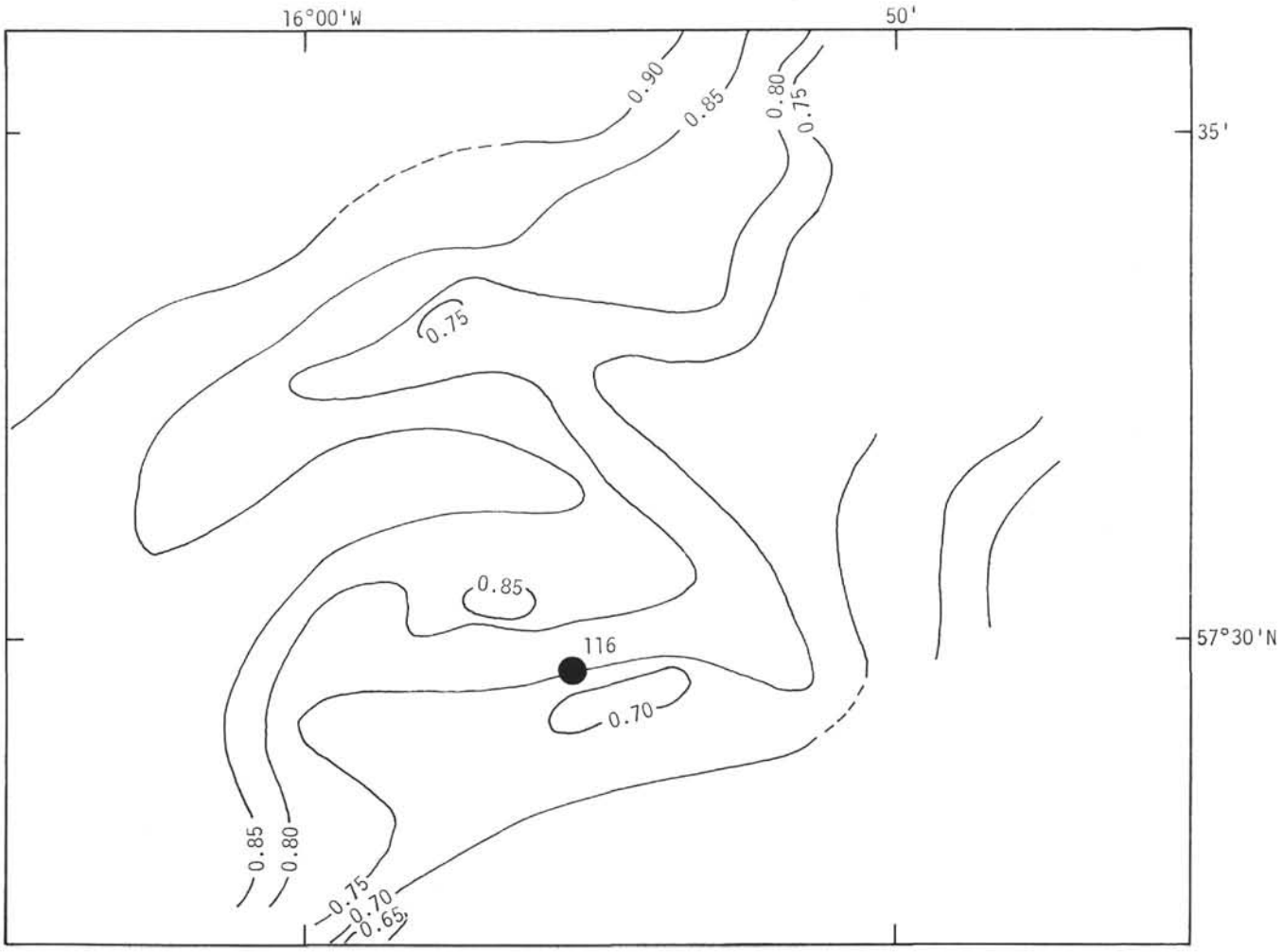

Figure 5. *Isopachyte map (in seconds of two-way travel time) to Reflector 4.*

strongly on the 160 to 320 Hz record and which would be expected at about 270 meters (0.31 second at 1.75 km/sec) failed to show as a drilling break. However reflectors 2 and 3 (520 and 615 meters) do relate in general to an increase in drilling hardness below 480 meters.

Reflector 4, expected at 700 meters, assuming a velocity of 1.75 km/sec, corresponded to a general increase in drilling hardness associated with hard chalks and cherts. It is discussed in greater detail in the discussion section at the end of this chapter. No seismic reflector could be correlated with the massive hard chalk sampled below 823 meters.

On leaving the site, gear was streamed while steaming WNW away from the site for 3 miles and a crossing was made over the beacon at 4 knots going ESE (Figure 4). The records were not good owing to 60 Hz interference, and contributed little new data on this site. The track followed the *Discovery*-29 track towards Rockall Bank to select a site for Hole 117, to continue the section below reflector 4 to the basement. The geophysical data pertinent to this area will be discussed under Site 117, although the story is essentially continuous with Site 116.

DRILLING OPERATIONS (116)

The beacon was dropped at 0830 hours on July 17th in 1151 meters of water. After 25 minutes the signal became intermittent and then failed. Another beacon was dropped as soon as possible. The bottom assembly on the drill string consisted of a Smith 3-cone tungsten carbide insert bit, 10 drill collars and 3 bumper-subs, totaling 40,000 pounds.

The first core was cut at 50 meters depth, but on trying to recover the core barrel, the overshot became locked onto the barrel which was jammed. Repeated jerks of the sand line sheared a release pin. To recover the core barrel, the whole string had to be brought to the surface. It was found that a loose pin on the core barrel locking mechanism had prevented it from reaching the bottom so no core was retained.

The second entry into the bottom was not given an "A" number since no samples were obtained from the first, although some mud was obtained from the bit containing Lower Pleistocene material. The first core for the new hole was therefore taken at 70 meters. Thereafter until 650 meters, cores were cut every 50 meters. Full core barrels were obtained from these, but the degree of disturbance was very high and the sediment was very fluid. Often sections of the core contained little other than a slurry of white coccolith ooze. This may have been due to the increasing heave of the ship due to the weather, to the disturbing action of a 3-cone bit in sampling soft sediments, or to the need to use occasional bursts of circulation to clear the bit.

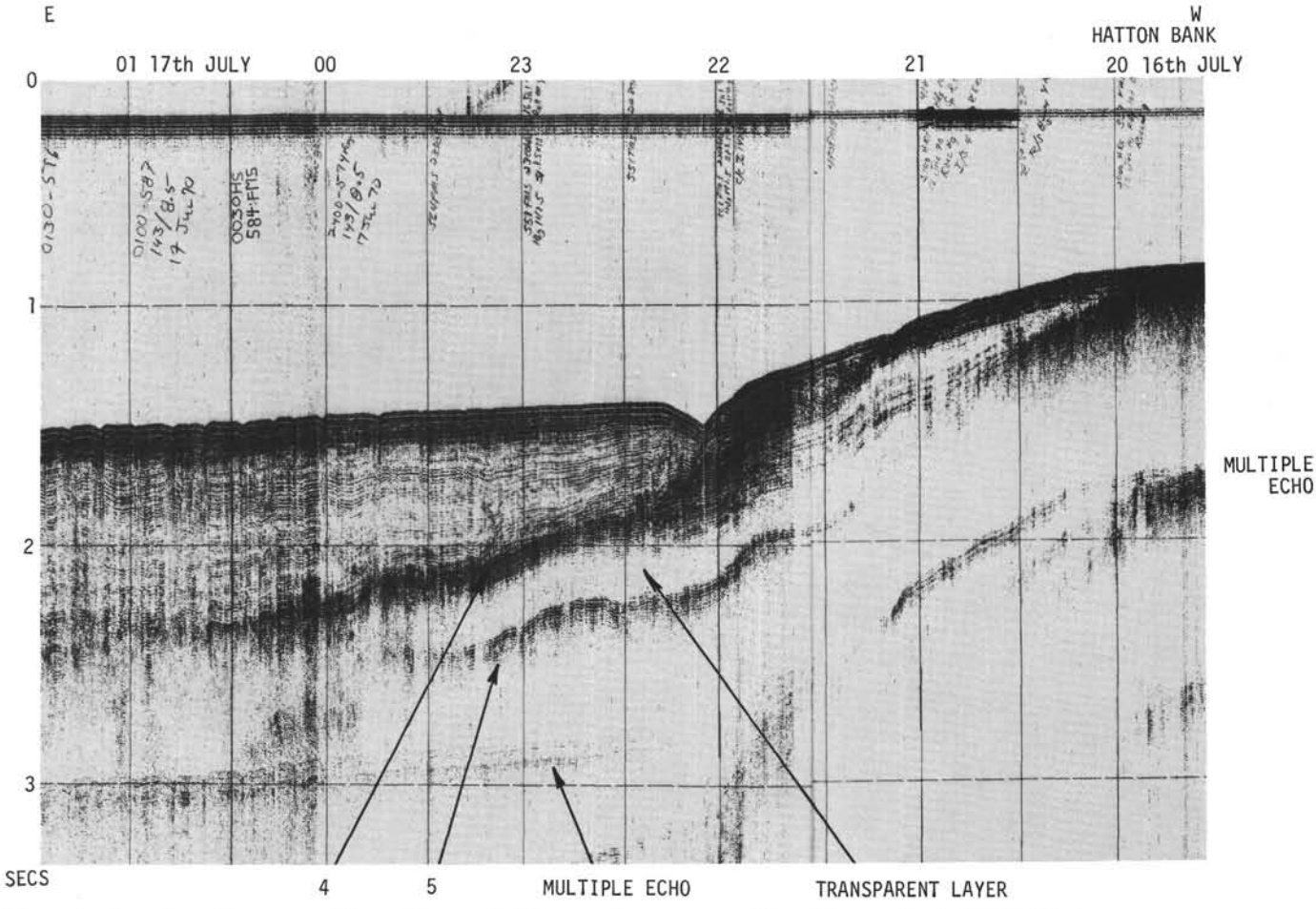

Figure 6. *Seismic reflection profile by* Glomar Challenger-*12 across east side of Hatton Bank (80-160 Hz).*

From Core 13 (649 meters) downward, continuous cores were cut in order to locate and identify reflector 4, the predicted depth of which is dependent on the velocity chosen for the sediments above. The first core was cut using a different technique to avoid obtaining cores filled with water during breaks of circulation. Core 13 was cut with higher bit weight of 5 to 20 klb, to avoid the bit lifting off the bottom of the hole, but had to be stopped after 4 m because the bit became plugged. Core 14 used continuous circulation at 7 s.p.m. However both cores gave only short pieces of hard chalk in the core catcher and no soft sediment. Cores 15 to 22 were cut with no circulation except short breaks. In Core 19, drilling became harder and the core was withdrawn after 3 meters were cut before continuous circulation was necessary. In Cores 20 to 22 (701 to 728 meters), thin hard bands of chert were recovered interbedded with softer sediments.

The failure to find the unconformity expected at reflector 4 at a depth of about 700 meters led to an opening up of the core spacing. An interval of 22 meters was drilled before Core 23 was obtained which was below the Upper Oligocene/Lower Oligocene unconformity although the lithology appeared similar to that above. The bottom 3 meters were hard to cut, and more chert was found in the core. Alternating layers of hard and softer sediment were encountered down to 823 meters. Mud was spotted down the hole in order to try to remove the chert chippings which were accumulating in the hole bottom and sucked back while cutting a core, or while retrieving the core barrel.

While drilling down from Core 25 (806 to 810 meters), continuously hard material was encountered at 823 meters, which drilled more smoothly than the chert beds which snatched at the drill string. This was cored in 26 and 27 (825 to 840 meters) and gave a clean cut column of crystalline cherty chalk. Circulation of 15 s.p.m. was used to cut these, so any soft sediment was washed away. However 9 meters of rock were recovered from 15 meters cored. The last 2 meters of Core 27 were soft, so Core 28 was cut without circulation. However, a hard layer was again encountered and the core barrel was withdrawn after 1 meter had been cut. Hard chalk, ooze and some gray clay were recovered of Upper Eocene age.

It was intended at this stage to drill onward into the transparent layer below reflector 4. From 841 to 854 meters, drilling alternated between hard and soft layers and proceeded only at about 8 meters an hour. In view of the time available and the considerable depth to reflector 5, we decided that it was more profitable to withdraw from the hole at this site and to drill another hole at a site further east where the transparent layer is thinner and where basement is accessible. At 2300 hours on July 20th, we withdrew pipe up to the mud line.

LEG 6

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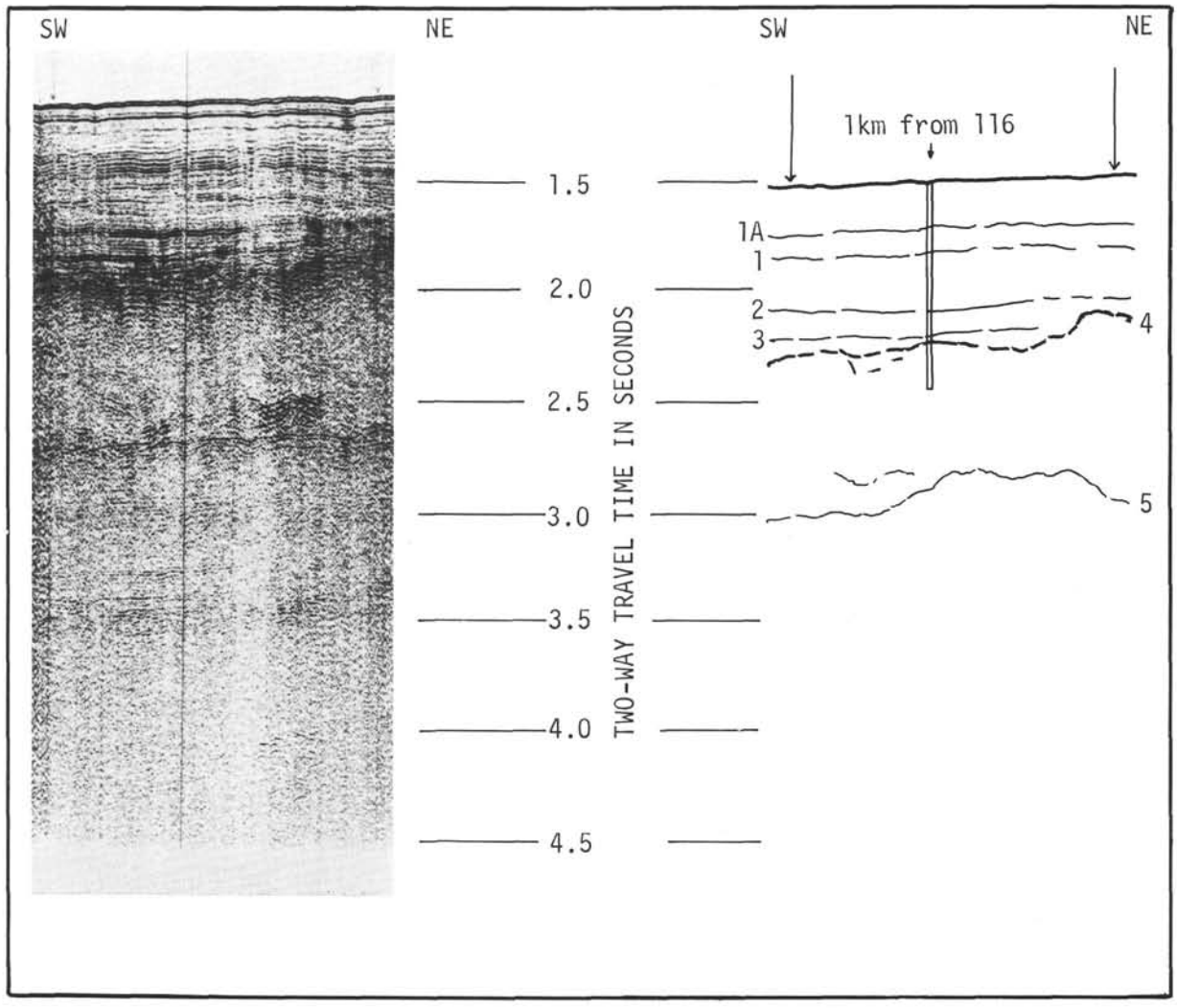

Figure 7. *Seismic reflection profile of Leg 6 of site survey at 116 by* Discovery-*33 (30-300 Hz).*

The upper layers of sediment at this site were expected to contain a good record of Pliocene-Pleistocene glaciation. A series of continuous cores was taken, therefore, from surface to 99 meters in Hole 116A by re-entering the bottom without moving ship. A considerable overlap was necessary below Core 1 of Hole 116, since there appeared to be an inconsistency of age between 116-1 and 116A-9 at equivalent depths. However the cores were all highly disturbed and the inconsistency may be more apparent than real.

All the gear was aboard and secured by 1845 hours July 21st. Thirty-nine cores had been cut, a total of 325 meters of which 284 meters were recovered. The weather during the 4.5 days on site had again been kind with winds less than 20 knots from the west and north, and sea and swell less than 8 feet.

SURVEY DATA (117)

The track from Site 116 southeast onto Rockall Bank (Figure 9) was located along the track of the *Discovery*-29 profile in order to find a suitable site on the flanks of Rockall Bank where the transparent layer below reflector 4 was near to the sea floor, where basement was within drilling reach and where there was enough sediment cover to stabilize the drill before hitting a hard layer.

The profile (Figure 10) was run to a point where it was thought there might be a pond of sediments. However, this site looked unpromising when we got there, and a site was chosen further down the slope where the upper sediments of the Hatton-Rockall Basin met the slope. The ship slowed from 8 to 4 knots while crossing the chosen site going down the slope, the profiling gear was recovered and the position reoccupied.

The profiles confirmed the draping of the transparent layer onto the rising basement of Rockall Bank and further indicated that reflector 4 consisted of a complex series of reflectors. Some of these appeared to outcrop on the slope and give rise to the cliffs and benches found there, suggesting tectonic disturbances.

When drilling was finished, the ship ran 3 miles at 069 degrees while streaming gear, then reversed course to cross

TABLE 1
Cores Cut at Site 116

Hole	Core	Cored Interval (m, subbottom)	Core recovered (m)
116	1	70-79	9.00
116	2	109-118	9.10
116	3	159-168	9.20
116	4	209-218	8.80
116	5	259-268	9.10
116	6	309-318	5.90
116	7	359-368	9.28
116	8	409-418	3.15
116	9	459-468	4.50
116	10	509-518	9.20
116	11	559-568	9.25
116	12	599-608	9.28
116	13	649-653	0.15
116	14	653-662	0.10
116	15	662-671	9.28
116	16	671-680	9.28
116	17	680-689	9.28
116	18	689-698	9.28
116	19	698-701	6.90
116	20	701-710	7.50
116	21	710-719	9.28
116	22	719-728	9.28
116	23	750-759	9.27
116	24	759-768	0.80
116	25	806-810	7.65
116	26	825-831	5.09
116	27	831-840	3.85
116	28	840-841	2.60
116A	1	0-9	2.24
116A	2	9-18	6.40
116A	3	18-27	8.60
116A	4	27-36	8.07
116A	5	36-45	5.46
116A	6	45-54	8.97
116A	7	54-63	7.73
116A	8	63-72	7.70
116A	9	72-81	9.00
116A	10	81-90	8.15
116A	11	90-99	9.28

the beacon at 6 knots. This profile (Figure 11) crossed the slope at an angle of 50 degrees to the approach track. Basement could be easily followed for 7 kilometers from the site but thereafter suddenly dropped away. Faint echoes from reflector 5 were seen shortly afterwards but no continuity of basement with reflector 5 could be established.

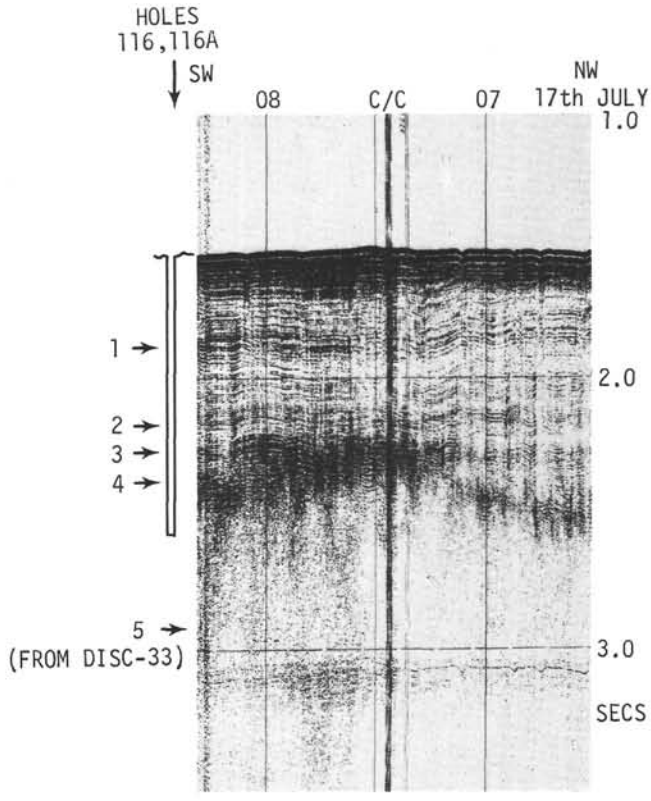

Figure 8. *Seismic profile during approach to Site 116 by* Glomar Challenger-*12 (80-160 Hz).*

The passage towards the next site was chosen to explore the southern extension of the Hatton-Rockall Basin. Apart from crossing a spur of Rockall Bank, the thick Miocene sediments of the basin were followed for a distance of 300 kilometers SSW right to the steep southern scarp of the Rockall Plateau (Figure 1). The Hatton-Rockall Basin therefore covers an area of approximately 400 by 100 kilometers (40,000 square km).

At Site 117, reflections were seen in the range of 0.04 to 0.16 second and these were all ascribed to reflector 4. It was expected, therefore, that in this zone indurated oozes, chalk and chert layers would be found similar to those drilled in Site 116 between 700 and 840 meters. These were in fact found in the depth range of 15 to 150 meters and correspond in age with sediments below the unconformity at Site 116. A mean velocity of 1.75 km/sec for this sequence would give rise to reflections between 0.02 and 0.17 second, in good agreement with the seismic observations.

The basement reflection, from the seismic section after completion of drilling, occurs at 0.32 secs. A closer study, however, shows this to consist of three reflectors between 0.32 and 0.355 second which can be correlated with the hard clay, sandstone and basalt sampled at 280, 303 and 311 meters. These are discussed in relation to acoustic impedance changes in the section on physical properties.

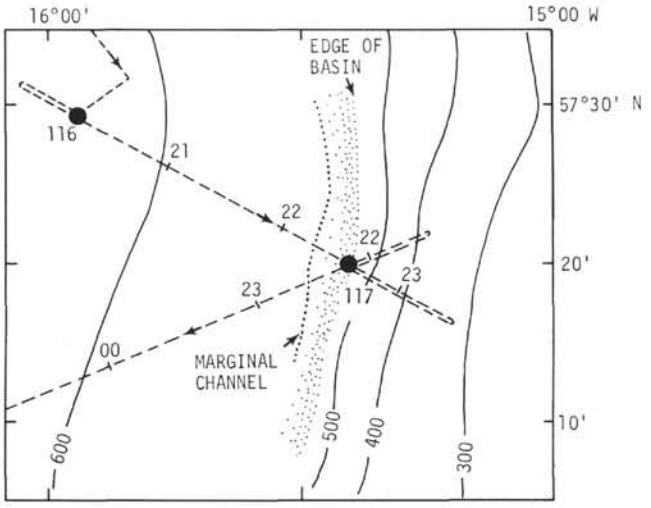

Figure 9. *Tracks around Sites 116 and 117. (Depths in corrected fathoms).*

DRILLING OPERATIONS (117)

The beacon was lowered at 0124 hours on July 22nd in 1038 meters of water. The bottom hole assembly consisted of a Smith 4-cone tungsten carbide insert bit below 10 drill collars and 3 bumper-subs, a total weight of 40,000 pounds.

The sea floor was soft and only felt by the pump pressure change. However after washing in down to 16 meters, a moderately hard layer was encountered, the first of several in the top 100 meters. A small amount of weight on the bit was necessary and considerable circulation. Some gentle rotation was needed to cut through these layers, which turned out in Core 1 at 50 meters to be thin chert.

Core 1 was cut without circulation in order to preserve soft sediment and progressed very slowly. After 2 meters, the bit became plugged up and the core barrel was withdrawn. Considerable quantities of chert cuttings were recovered.

Between Core 1 and 2 at 100 meters, two pumps were used for circulation and drilling alternated between slow on hard layers and fast in between. Before cutting Core 2, mud was spotted through the circulation to remove chert chippings. Core 2 started hard, and a 10 s.p.m. pump was used. However it became softer and the pump was stopped for the last meter.

Twenty-two meters of soft drilling followed, before some more hard layers were met. Core 3 at 147 meters was cut initially with minimum circulation. However after 3 meters, the bit plugged up and considerable pumping, and raising and lowering of the drill string was necessary to restore circulation. Again chert cuttings were recovered in the core.

Throughout the period of drilling of Hole 117, the weather conditions got progressively more difficult. A fresh wind from the west required considerable engine power to maintain position head to wind; at the same time a long swell of 5 meters amplitude came from a storm in the north. This resulted in heavy rolling (up to 17° either side) which made work difficult and dangerous on the drill floor. Moreover the heave of the drill platform (measured by the echo sounder to be between 3 and 6 meters) made it impossible to keep the bit on the bottom or to take good cores. The drilling superintendent decided that it was necessary to withdraw from the hole until the weather moderated. Core 3 was still in the core barrel at the bottom while withdrawing to the mud line. A sample of gray clay found in the core catcher was attributed, therefore, to a layer sampled near the top of the hole. On the basis of Hole 117A, it was later thought to have been sampled at the bottom of the hole.

At 0200 hours on July 23rd, the entire drill string was on board and inspected. It was found that two bumper-subs were seized up and the bit badly worn by the pounding of the heaving ship. A new bottom assembly started down into Hole 117A at 0530 hours, and bottom reached at 0930 hours. The wind had by now dropped to light and the swell had gradually decreased during the night. It was possible to maintain the ship head to swell and keep her steady.

We drilled, using a center bit and 60 s.p.m. on two pumps, down to 150 meters to take the first core. The same hard layers of chert were encountered resulting in considerable torque variations.

Before coring, 60 barrels of drilling mud were shot to clear the chips. In Core 1, however, a considerable quantity of chips was recovered as well as the chalk and gray clay found in 117-3. The clay was found to be Lower Eocene indicating an unconformity below the Oligocene coccolith ooze, chalk and chert.

The next core was taken, therefore, at 174 meters and showed us to be still in the gray clay/silt sequence. Drilling now became very easy and fast, but great care had to be exercised to avoid the chert cuttings flushing back into the hole and core barrel while coring. Mud was spotted and the hole flushed before coring. To recover the soft sediment, minimum circulation was used during coring and some short bursts used for flushing. Core 4 was pulled prematurely because the bit became plugged. One hundred barrels of mud were used before Core 5, but the bit became plugged once again after 3 meters were cut. To prevent back flow due to cuttings when opening the pipe to extract the core barrel, more mud was spotted during barrel recovery. This resulted in considerable bentonite contamination in the core.

The hole was continuously cored from Core 4 (270 meters) downward. Cores 6, 7 and 8 required continuous low circulation and gave improved recovery. The sediment became progressively harder and coarser. The chert chippings problem improved.

Core 9 at 303 meters hit hard material thought to be basement and was withdrawn after 1 meter, yielding a highly fossiliferous gray sandstone. However this was not believed to be basement, and Core 10 penetrated to a softer layer again. Again gray sandstone was recovered.

At 311 meters, Core 11 was cut into an extremely hard layer. With 30,000 pounds on the bit no noticeable progress was made in over two hours. However on withdrawal, it was found that 1.85 meters of basalt had been cut. The hole was therefore finished at 1345 hours on July 24th and the drill string was on board by 2030 hours.

In fourteen cores, 86 meters had been cut and 42 meters recovered (49 per cent).

The weather improved steadily throughout the second hole, the fresh westerly winds dying to nothing and the northerly swell fading away.

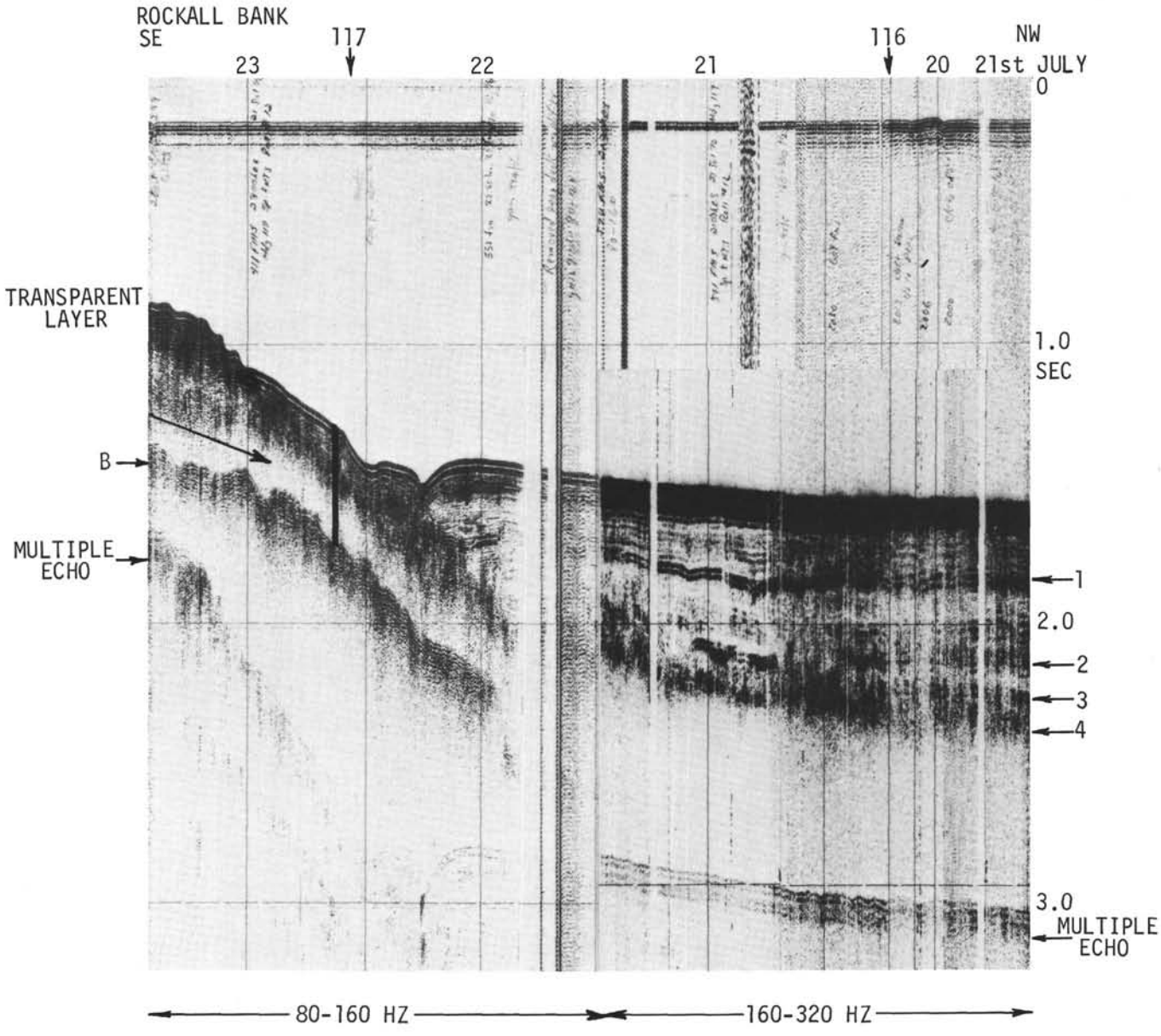

Figure 10. *Seismic reflection profile across Sites 116 and 117 onto west side of Rockall Bank (at 160-320 Hz to 2145, then at 80-160 Hz).*

LITHOLOGY

Sites 116 and 117 are situated only 37 kilometer apart. Because of this and the possibility of stratigraphic continuity between the two sites, according to reflection records, the lithologies recovered from Holes 116, 116A, 117 and 117A are described together.

The following general sequence was found:

Site 116 Depth (m)		Site 117 Depth (m)
0		
	4. Foraminiferal nannofossil ooze, foraminiferal sand and silty clay.	
71		0
	3. Limestone, chalk and ooze.	
-> 854		145
	2. Clay and basal clastic sediments.	
?		311
	1. Basalt with sedimentary infill in cracks.	

Only units 3 and 4 were sampled at Site 116 and units 1 to 3 at Site 117. The various lithologies are discussed below starting with the basalt.

Summary grain size diagrams for each site are presented in Figures 12 and 13. At Site 116 sand contents in excess of 10 per cent were only found in glacial sediments (4. in the above sequence). The single high sand content at Site 117 was in a sample of glauconitic ooze; the remaining grain size samples were Lower Eocene clay.

Basalt and Sedimentary Infill of Cracks (117A, Core 11)

This is a weathered and fractured olivine basalt in which the cracks are partly filled with micritic or zeolitic calcisparite containing *Lithothamnium* fragments, thick mollusc shell fragments (mostly lamellibranchs, some gastropods, all with borings), bryozoans, foraminifera (for example, *Operculina*), and a few basalt pebbles. Fossils

TABLE 2
Cores Cut at Site 117

Hole	Core	Cored Interval (m, subbottom)	Core Recovered (m)
117	1	50-52	1.00
117	2	100-109	6.00
117	3	147-156	1.50
117A	1	146-155	1.50
117A	2	174-183	cc only
117A	3	222-227	7.25
117A	4	270-272	8.58
117A	5	272-276	1.40
117A	6	276-285	4.50
117A	7	285-294	5.60
117A	8	294-303	2.88
117A	9	303-304	0.40
117A	10	304-311	0.36
117A	11	311-313	1.85

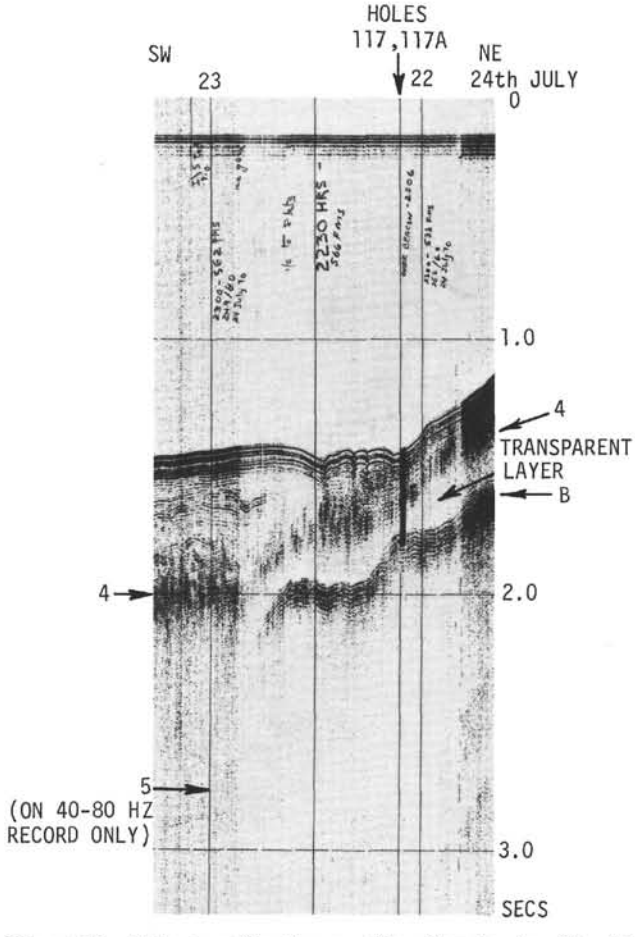

Figure 11. *Seismic reflection profile after leaving Site 117 (80-160 Hz).*

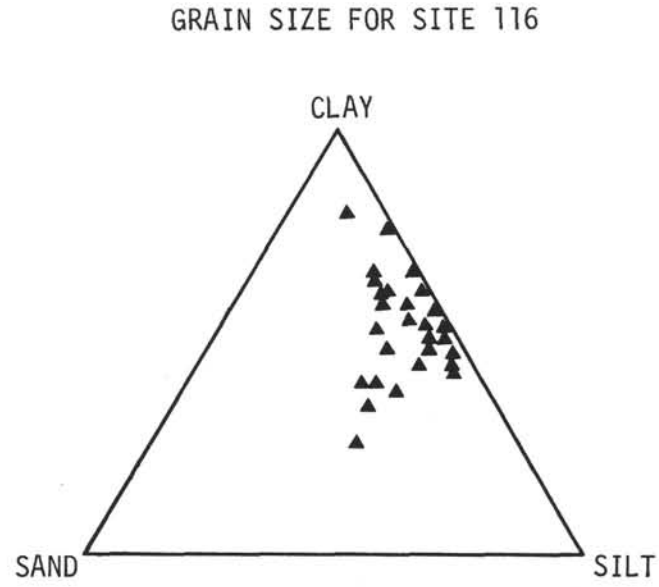

Figure 12. *Grain size triangular diagram for Site 116.*

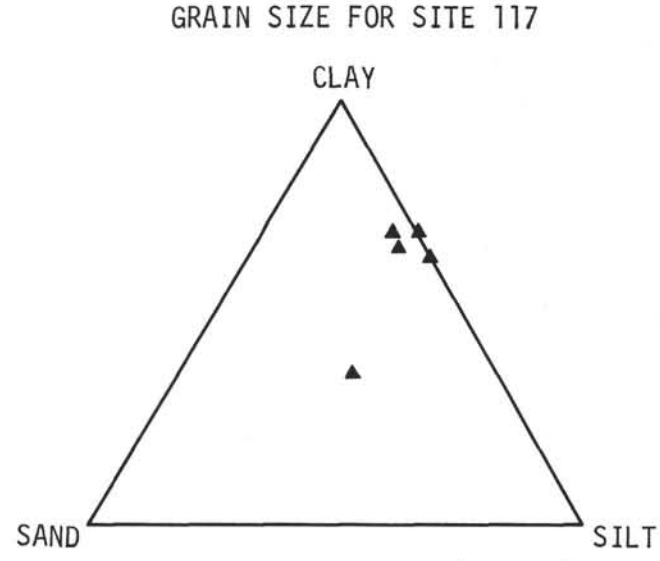

Figure 13. *Grain size triangular diagram for Site 117.*

found in the basalt fissures are indicative of shallow water conditions and are similar to fauna found in the overlying sediment.

Petrological descriptions of the basalts by Aumento, Clarke and Cann, a section on opaque mineralogy by Ryall and a separate report by Sabine, follow below. A comparison of the strontium and lead isotope ratios of the basalt with those of Rockall Island (Moorbath and Welke, 1969) was not considered to be possible owing to the weathered nature of the samples, and therefore isotope measurements were not attempted.

Preliminary Petrography of the Basalt

F. Aumento and B. C. Clarke, Dalhousie University, Halifax, Nova Scotia, and
J. R. Cann, University of East Anglia, Norwich, U. K.

117A-11-1, 1-6 cm:

This is a specimen of calcareous sediment attached to weathered basalt. The sediment is rich in foraminiferal tests, bryozoans and rounded basalt fragments, some of which are highly altered. All of the components appear to be reworked, and in some cases, for example where bryozoans and basalt form part of the same clast, it can be demonstrated that their history prior to deposition must have been complex. The specimen is cut by a vein of iron-manganese oxide.

117A-11-2, 13-20 cm, 26-32 cm, 44-47 cm, 47-52 cm and 107-114 cm:

All of the samples are of porphyritic, medium-grained basalt. Abundant phenocrysts of olivine, replaced by iddingsite and carbonate, and rare ones of plagioclase, are present. The groundmass consists of plagioclase laths (An_{65}), 1 × 0.2 millimeters in size, showing a rough flow texture, granular olivine altered to iddingsite and carbonate, and granular clinopyroxene and iron ore. Interstitial areas are filled with dark green chlorite. Plagioclase shows some replacement by saussurite. Thick veins cut the rock, and are filled with carbonate, chlorite (often radiating), analcite and radiating bunches of natrolite.

117A-11-2, 66-68 cm:

A calcareous sediment in contact with a highly weathered, medium-grained basalt. The sediment contains highly recrystallized debris of planktonic foraminifera.

The basalt of these specimens is a slowly cooled olivine basalt. The presence of olivine in the smallest crystal sizes suggests alkaline affinities. In several ways that are hard to define, this basalt is unlike ocean floor basalts. The abundance of olivine phenocrysts coupled with a paucity of plagioclase phenocrysts is unusual, as is the coarse grain size. The ground mass texture, with its rectangular blocky plagioclase crystals, is atypical, and so too are the areas filled with bright green chlorite. Analcite and natrolite are rare as vein fillings in ocean floor basalts. All in all, there is a suggestion here that this basalt is not of the ocean floor basalt type, and may have been formed by some other volcanic process than those operating at mid-ocean ridge crests. Geochemical information will be necessary before this suspicion can be substantiated, and this will require the availability of larger samples.

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

Ti	Rb	Sr	Y	Zr	Nb
11400	10.5	520	18	150	12

These results lie outside the range of composition of ocean floor basalts, and the sample appears to be an alkali basalt accumulated in olivine, such as is found on ocean islands and on continents.

Opaque Mineralogy of Basalt

Patrick J. C. Ryall, Dalhousie University, Halifax, Canada

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: homogenous titanomagnetite
Class 2 and 3: magnetite with increasing amounts of ilmenite lamellae
Class 4: oxidation of ilmenite lamellae to ferri-rutile and titanohematite
Class 5: appearance of black spinel spicules in remaining magnetite
Class 6: complete replacement of titanomagnetite by titanohematite, pseudobrookite and/or ferri-rutile

117A-11-1, 1-6 cm:

Relatively few magnetite grains. Those seen being uniformly gray brown (probably maghemitized) Class 1 with one probable Class 4. Fine hematite is widely disseminated throughout the specimen giving a red-orange background silicate color.

117A-11-2, 26-32 cm:

Large skeletal pale grey brown Class 1 magnetites.

117A-11-2, 107-114 cm:

Several very large (100 micron) grains of gray white (probably maghemitized) Class 1 magnetite.

The large grain size of the titanomagnetite (up to 100 microns) is more typical of subaerial than of submarine basalts, consistent with the observation of very shallow water sediments lying immediately above.

Preliminary Report on the Basalt

P. A. Sabine, Institute of Geological Sciences, London, U.K.

Introduction

The specimens examined (Plate 1) are of core recovered immediately beneath the Paleocene conglomerate in Hole 117A of Leg 12, 57° 20.17′N, 15° 23.97′W. The specimen is from 117A-11-2, 311 to 313 meters below sea bed, that is, 1350 meters below sea level.

The upper specimen (117A-11-2, 0 to 10 centimeters) consists of olivine-basalt with one large vesicle about 35 × 15 × 10 millimeters, with a sparry mineral lining, 1 millimeter thick, and there are mineral veins, approximately horizontal in the core and many small amygdales filled with microcrystalline material. A second specimen (117A-11-2, 140 to 150 centimeters) is about 1.3 meters lower down. Material for analysis was removed and thin sections were cut from each portion of core before the remainder was removed for examination to determine whether analysis of strontium and lead isotopic ratios (at Oxford University) was possible.

Petrography

Both specimens are altered olivine-basalts. The higher is the more altered. Density, porosity and color values

were obtained by R. W. Sanderson for two specimens, as follows:

Specimen	Saturated Density ρs gm/cc	Dry Density ρd gm/cc	Grain Density ρg gm/cc	Effective Porosity %
117A-11-2, 0-10 cm	2.62	2.55	2.73	6
117A-11-2, 140-150 cm	2.55	2.45	2.70	9

The specimens, when dry, have color values close to 5GY 6/1 and to a lesser extent 5G 6/1 (Munsell, 1969). The densities and effective porosities of the rocks were obtained by a method similar to that of Parasnis (1952). Owing to the presence of natrolite in the veins cutting the rocks, the specimens were dried at a temperature of 43°C or slightly less instead of the usual 110°C. Because of this low temperature drying some water may have been retained within the rock. Therefore of the above values ρd may be slightly high and ρg slightly low.

The rock is seen in thin section (F7159[2], Plate 2, Figure 1) to be composed of laths of feldspar commonly 0.25 millimeter or less in length, pseudomorphs after olivine, plentiful fine-grained pyroxene, plentiful titanomagnetite, mainly in equidimensional crystals, and partly in skeletal form, possibly orthopyroxene, and abundant chloritic, or serpentinous mineral, the margins of individual areas of which are bright green. The rock displays some foliation. The pseudomorphs after olivine microphenocrysts are commonly 0.7 millimeter or less in length but form glomeroporphyritic aggregates. They are composed of carbonate and colorless chloritic matter, with deep brown or red limonitic rims, perhaps in part iddingsite.

The feldspar laths are considerably altered to very fine-grained material, much of it pale-green. Its grain size is too fine to allow readily a determination of the birefringence, but it appears to be very low and the mineral is probably chlorite. The plagioclase that remains is labradorite zoned to oligoclase andesine. In crush, the most basic feldspar found was about An_{67}, but the most acid only An_{45}.

The interstitial chloritic matter is partly colorless and very fine-grained but is commonly margined by bright bluish-green, moderately birefringent, vermicular crusts (Plate 2, Figure 2) of 'viridite' which is probably a smectite. Rims of orange-brown iron ore or iddingsite are also present. Bowlingite occurs in some pseudomorphs.

The opaque ore is strongly magnetic (to a small hand magnet). Examination by R. I. Lawson using a 'Geoscan' electron-probe X-ray microanalyzer suggests that it is titanomagnetite, containing about 17 per cent titanium and 2 per cent manganese. The skeletal crystals have about the same composition as the equidimensional ones. In the bright-green bordered viriditic areas, manganese was not a significant constituent of a central brown portion (which was rich in iron) and there was only a little manganese in the green rims.

[2]Thin section in the Petrographical collection of the Institute of Geological Sciences, London.

The rock is traversed by veins of coarse calcite about 9.5 to 2 millimeters thick among which there are spheroidal growths of orange-brown ore mineral, about 9.15 millimeters across, aggregates of very fine-grained carbonate possibly of higher refringence, and a little low birefringent mineral, presumed analcime. There is a very small amount of more strongly birefringent fibroradiate mineral, probably uniaxial positive, probably chalcedony, situated in the center of a vein and moulded on the carbonate.

In the vesicle, a dense velvety mat of short prisms which display many rosette growths (Plate 3) is composed of natrolite. Scattered clear colorless lustrous equidimensional crystals, some interpenetrant, and growing on the natrolite, are of calcite. Natrolite and calcite were noted by Matthews (1962) in cavities in lava from the Western Seamounts; and chalcedony was recorded as an alteration product. The absence of records of carbonate replacement in spilites from oceanic environments was noted by Cann (1969) as one of the features distinguishing them from continental spilites. Natrolite was also recorded by Melson *et al.* (1968) from rare vesicles in lavas from the Mid-Atlantic ridge.

The lower specimen also displays approximately horizontal 1 to 2 millimeter white veins near which the rock is more altered. A thin section (F7160'; Plate 2, Figure 3) shows abundant pseudomorphs, some after olivine, in an aggregate of plagioclase laths commonly 0.4 millimeter or less in length, prisms and granules of brown pyroxene, plentiful equidimensional (and some skeletal) opaque ore, mainly magnetite, but some leucoxene, and plentiful interstitial chloritic material in compact areas, some with deeper green margins. This magnetite is presumably also a titaniferous variety.

The plagioclase laths contain little chlorite but are mainly fairly fresh bytownite (An_{72}) zoned to andesine (An_{47}). Plagioclase that occurs in better shaped laths has the higher refringence with the sharper twinning; that with lower refringence is more equidimensional and untwinned, as is common in basaltic rocks.

The calcite, analcime and natrolite were confirmed by X-ray methods (films X5873-6L; 5885) by B. R. Young, who also found in the rock powders smectite which yielded lines at 14-15Å and lines at 18.0Å after glycerol treatment. After heat treatment at 500°C for 3 hours (film X5932) the material yielded a line at 9.5Å. It was not possible to measure the 14 to 15Å peak accurately owing to the presence of chlorite. In thin section, R. W. Elliot detected that some of the carbonate in the veins is biaxial negative, with moderate 2V, but aragonite was not confirmed.

Examination by R. Dearnley using a Quantimet analyzer (F7160) yielded:

Plagioclase	36.50%
Magnetite	1.05%
Remainder	62.45%

The mean grain size length of the plagioclase laths is 0.28 millimeters. The alteration prevented further discrimination of the minerals and it was not possible to obtain any measurements on the more altered thin section, F7159.

The small amygdales (Plate 1) are nearly spherical, the largest being about 5 millimeters in diameter. On a very small cut face of about 1000 sq.mm there were 8 amygdales of approximate diameters, 5, 3, 2 and 1 millimeters,

occupying about 4 per cent of the rock. The infilling is of very fine-grained spherulitic growths, partly chlorite but partly more strongly birefringent material. Plagioclase laths in the rock around the amygdale are tangential to it.

Chemical Analyses, and Norms

In Table 3, the chemical analyses of the two chips are shown. Both are very basic, although the alteration prevents too thorough discussion. If calcium carbonate (12 per cent) is removed from the analysis, Column II, and the analysis recalculated, SiO_2 and $A1_2O_3$ percentages become very close to those of Column I, although there are some significant differences in the other elements. Column I thus probably better represents fairly closely the original composition of the rock, if due allowance is made for removal of CO_2 and corresponding CaO.

The relatively low chlorine figure shows that there is no gross contamination with sea-water. The $FeO:Fe_2O_3$ ratio confirms that the alteration is not solely a weathering phenomenon.

The 'norms' are shown in Table 4, although the alteration inhibits their use. In Column IIa, a 'norm' has been calculated to allow for removal of carbon dioxide. The marked disparity between Columns I and II, and IIa, with the appearance of 10.64 per cent nepheline suggests that the calcite has been introduced in that form and has not been produced at the expense of the calcium-bearing minerals. The normative ferromagnesian minerals occur modally in pyroxene and olivine, and much less modal magnetite and ilmenite are present.

Within Yoder and Tilley's five-fold division of the basalts (1962), the rock—having normative hypersthene and olivine—may be classed as olivine-tholeiite. Although it is not a true spilite, it has affinities with this group, and comparable rocks associated with spilite have been recorded by Cann (1969) from the Carlsberg Ridge.

Origin of the Basalt

It is of some interest that both rocks fall in the field in which both normative nepheline and quartz are lacking, a characteristic that Chayes (for example, 1970) has pointed out is typical of the basalts of deep ocean ridges.

There are no borehole specimens from Rockall Bank itself. Two of the dredged basaltic pebbles from Rockall Bank in the collections of the British Museum (Natural History) have been sliced and are *not* similar to the DSDP specimens. It is possible that these specimens are not typical of the bank and have been derived from erratics, ballast, etc. One of the British Museum specimens (1955,279 (2n)), which the writer saw by courtesy of J. D. H. Wiseman, could be matched very closely among Northern Ireland Tertiary basalts, and these are presumably younger than the altered basalts now described.

The amygdaloidal and vesicular nature of the specimens might suggest that they were extruded subaerially, or only under shallow water conditions. The writer is indebted to G. P. L. Walker for suggesting (personal communication) that the water depth might not be more than 1 kilometer. Some vesicular basalts have been described from under considerable depths of water, for example from Swallow Bank, eastern North Atlantic, where the depth of water is

TABLE 3
Chemical Analyses of Basalts[c]

	I[a]	II[b]
SiO_2	43.33	38.14
Al_2O_3	14.73	12.81
Fe_2O_3	4.13	7.43
FeO	6.54	4.29
MgO	8.54	6.63
CaO	9.24	11.75
Ha_2O	2.37	2.40
K_2O	0.81	1.75
$H_2O>105°C$	3.50	4.36
$H_2O<105°C$	2.85	2.60
TiO_2	1.88	1.62
P_2O_5	0.30	0.25
MnO	0.31	0.25
CO_2	0.96	5.26
Allow for minor constituents	0.29	0.29
	99.78	99.83
	ppm	ppm
Ba(s)	190	240
Co(s)	51	76
Cr(s)	390	330
Cu(s)	66	22
Ca(s)	15	10
Li	29	36
Ni(s)	190	180
Sr(s)	530	440
V(s)	120	87
Zr(s)	140	140
B	19	33
F	380	450
S	100	110
Cl	450	500
(s) = spectrochemical determination		

Notes:
[a] Column I Olivine-basalt, chloritized, 311 to 313 meters below sea floor in Hole 117A of Leg 12 of Deep Sea Drilling Project. Eight centimeters from bottom of Section 2 of Core 11. F7160. Lab no. 2197.
[b] Column II Olivine-basalt, chloritized and carbonated. As I. Top of Section 2 of Core 11. F7159. Lab. no. 2196.
[c] Analysts: J. M. Murphy and G. A. Sergeant. Spectographic work by D. R. Powis.

TABLE 4
C.I.P.W. Norms of Olivine-Basalt

	I	II	IIa
Z	0.02	0.02	0.02
or	4.78	10.29	11.67
ab	20.11	20.45	3.93
an	27.05	19.09	21.95
no	-	-	10.64
di	8.62	3.26	33.24
hy	12.21	9.57	-
ol	7.81	3.80	2.38
mt	6.10	9.99	11.36
hm	-	0.51	0.64
il	3.56	3.05	3.50
ap	0.71	0.65	0.67
cc	2.18	11.98	-

Notes:
Localities as Table 3.

Column I Olivine-basalt, chloritized.
Symbol: III. 5. "4. 4". *Auvergnose.*
Column II Olivine-basalt, chloritized and carbonated.
Symbol (II) III. 5.3."4. *Camptonose.*
Column IIa Analysis II recalculated to remove CO_2 and H_2O, and total 100%.

4960 meters. In describing these rocks, Matthews (1962) called attention to the occasionally expressed view that submarine lavas would not have been vesicular if extruded at depths greater than about 2.5 kilometers (under a hydrostatic pressure greater than the critical pressure of water). A factor which influences these observations is however the considerable increase in knowledge in recent years about movement of ocean floor rocks subsequent to their emplacement.

Macdonald (1963) has suggested that the depth at which vesicles start to form in Hawaiian magma is uncertain, varying "with the gas content and the degree of vesiculation (and resulting density) of the overlying magma column", but that from deep exposures of dikes, it is generally or always less than 2000 feet below the contemporaneous surface. Distinction must be drawn between the sparry-lined vesicles, which are probably part of the veining system, formed at a late stage in the history of the rock, and the nearly spherical amygdales. Their occurrence together complicates determination of the likely depth of emplacement of the lava in terms of Moore's study (1965) of Hawaiian basalt, taken into account in Jones's comparison of Icelandic and Welsh pillow lavas (1969); but more measurements of larger rock surfaces on the cores are required.

The alteration is not a weathering effect but probably deuteric or due to the lowest grade regional metamorphism. The single large gas cavity is only partly filled by mineral matter (as now preserved), which might suggest a relatively young age; but if the writer were seeking a match among British rocks, he would think that on purely petrographical grounds the Paleozoic or older rocks might provide examples. Some of the chloritic alteration products might represent devitrified glass, but is difficult to ascertain to what extent.

A very speculative suggestion is therefore that this is a shallow water extrusion.

Extent of This Note

Chemical analyses and petrographic examinations included in this report are preliminary, time and circumstances precluding further studies.

Clay and Basal Clastic Sediments (117, Core 3; 117A, Cores 2 to 10)

The upper Paleocene and lowermost Eocene sediments of Site 117 can be considered a terrigenous, transgressive, suite of sediments. There occurs in stratigraphic sequence, sandy conglomerate, sandstone, silty clay, mudstone and clay.

The sandy conglomerate is composed predominantly of poorly reworked volcanic material resulting from erosion of a basalt similar to the basement. Although the conglomerate is poorly sorted, the constituent grains are altered and rounded. The overlying sandstone is better sorted than the material below, contains mollusc shells, annelid tubes (*Ditrupa*, Plate 4) and is highly burrowed (Plate 5), the burrows having been infilled by carbonate-rich material.

This is overlain by sandy silt and silty clay which grades into a mudstone, in turn overlain by clay containing 14 to 18 per cent carbonate. These sediments are all dark in color. Bryozoan fragments are found from 270 meters (Core 117A-4) downward, reworked basalt fragments and mollusc shell fragments (in particular, one specimen of an articulated *Ostrea* sp.) below 289 meters (Core 117A-7), and there are also occurrences of larger foraminifera. The clay, like the sandstone, is also highly burrowed but shows signs of graded bedding. A 3-centimeter diameter phosphorite nodule in Section 117A-3-1 (223 meters) has inclusions of fish debris and ophiurids. Phosphorite has been found associated predominantly with marine sediments with a water depth ranging from 30 to 300 meters (Bromley, 1967).

Limestone, Chalk and Ooze (116, Cores 1 to 18: 116A, Cores 9 to 11; 117, Cores 1 and 2; 117A Core 1)

Although this section contains sediments of different degrees of lithification all these rocks are described together because they are basically organic rocks of high carbonate content and because the limestones, chalks and oozes do not occur as discrete thick beds but are interbedded.

The oldest sediments in this group are light gray to white Upper Eocene limestones and ooze from the bottom of Hole 116 (Cores 26 to 28). Some of the limestones are burrowed. Chloritic slickensides, small faults in the form of offset burrows, as well as laminations dipping at 30 degrees, indicate post-depositional movement (Plate 6). The limestone is very fine grained, comminuted and contains

numerous foraminifera tests, predominantly heterohelids. The tests are recrystallized and are filled with sparry calcite.

The Oligocene and younger cores of Site 116 pass upward from predominantly hard chalk to foraminiferal-nannofossil ooze. The chalk and ooze (80 to 98 percent carbonate) consist mainly of calcareous nannoplankton with occurrences of foraminifera ranging from common to abundant. Zoophycoid burrows (Plate 7) were identified below 760 meters and indicate a bathyal facies (F. Seilacher, personal communication). Many small faults of varying dip slip (syndepositional) were also identified below 760 meters. Cherty layers in the chalk or chert fragments are also found between 810 and 662 meters but microscopic examination of the Radiolaria samples revealed the occurrence of chert as high as 560 meters (Core 116-11). Other siliceous material seen under the microscope included diatoms, Radiolaria and sponge spicules. A detailed study by R. N. Benson of diagenetic mobilization of biogenous silica is presented below. Secondary pyrite is a small but consistent factor in almost all the oozes when viewed under the microscope. Specks and patches of pyrite in the cores, first seen at 759 meters, persist to 710 meters. Other signs of pyrite are found at 360 meters (Core 116-7), and hydrogen-sulfide gas around 215 meters (Core 116-4). Authigenic carbonate resulting from recrystallization of calcite was also present in all cores. Except for occasional clay minerals, and one occurrence of a recognizable felspar twin, terrigenous material is not observed in this sediment.

Besides the autochthonous chert fragments, a variety of clearly allochthonous pebbles was found at several depths between 662 and 699 meters. These pebbles, which include two dreikanter at 695 meters, presumably were transported by floating vegetation. The dreikanter are presumably reworked. In Scotland wind-faceted, or specifically dreikanter, pebbles have been found in sediments of Torridonian (Phemister, 1960), Upper Old Red Sandstone (MacGregor and MacGregor, 1948) and Permian (Read, 1948; Pringle, 1948) age. These rocks outcrop today along the northwest coast of Scotland, around the Firth of Clyde and Wigtownshire, Isle of Arran and West Kintyre, respectively. All these places lie about 300 miles from Site 116. A large shale pebble (?ice-rafted) was also found at 74 meters (Core 116A-9). No pebbles were recovered from the intervening 588 meters of sediment (represented by 112 meters of core).

The upper two cores of Hole 117 contained Oligocene cherty limestone and glauconitic ooze (79 per cent carbonate). In the ooze, glauconitic aggregates and foraminifera replaced by glauconite are common. Cores 117-3 and 117A-1, which overlap, contain fragments of chert or cherty limestone with some ooze, sandstone and clay.

It is interesting to compare the lithologies obtained at Sites 116 and 117 where they overlap in age. The Eocene sediments are strikingly different in that Lower Eocene clays were recovered at Site 117 while Upper Eocene hard chalky limestones and ooze were found at Site 116. Although chert was found at the base of Core 117A-1 and was the dominant constituent of Core 117-3–both of which cores had coccoliths as old as Early Eocene–there is some doubt as to whether the chert is of this age. The presence of younger coccoliths in samples of Late Oligocene, Early Eocene and Late Paleocene age at this site suggests that material was falling down the hole. It is noticeable also that no siliceous material is involved in the lithification of the Site 116 Eocene limestone.

However comparison of the Oligocene cores shows that at this time similar lithologies were being deposited at Sites 116 and 117. Microscopic examination of the insoluble residue at 810 meters (Core 25) shows the advent of chert which persists for the next 100 meters and which is expressed as siliceous bands in ooze on a macroscopic scale. The size of the cherty limestone fragments recovered in Core 117-2 and their inclusion within a sequence of ooze strongly suggests that these siliceous rocks are *in situ*. A comparison of Cores 116-25 and 117-2, which lie about 15 and 40 meters, respectively, above the base of the Oligocene sediments, further emphasizes the similarity of the lithologies (Plate 8).

From about 650 meters up to 70 meters in Hole 116, the sediments were remarkably uniform, highly calcareous nannofossil (ranging from Early Miocene to Late Pliocene in age) ooze deposited at a mean rate of over 3 cm/1000 yrs. The sedimentation mechanism for this unit is discussed later.

Foraminiferal Nannofossil Ooze, Foraminiferal Sand and Silty Clay (116A, Cores 1 to 8)

The Upper Pliocene and Pleistocene muds and clays of Hole 116A are not unlike the oozes they overlie, in that they, too, contain large quantities of calcareous microfossils and authigenic carbonate. They differ however in containing variable quantities of detrital minerals (Figure 15) with a consequent decrease in carbonate content (33 to 92 per cent, average of eleven samples is 68 per cent). There also seems to be an inverse relation between the contents of sand and carbonate (Figure 14). Carbonate content always exceeds that of sand which lies between 8 and 33 per cent. Since the sand content is relatively insensitive to changes in carbonate content the latter must contain few sand size particles and/or the variations in carbonate are due to changing proportions of silt and clay.

Typical for this part of the sediment pile is an alternation of gray, unclean, clayey ooze and clean, chalky, nannofossil ooze. The quantity of glass is notably greater here than deeper in the section and palagonite, glauconite, and zeolites appear widespread throughout the material. Small quantities of clay minerals and a few presumably ice-rafted gneiss pebbles are also present.

Diagnenetic Mobilization of Biogenous Silica

One of the characteristics of the calcareous sediments cored at Site 116 in the Hatton-Rockall Basin is the fairly high percentage of biogenous silica in the HC1-insoluble residues. In many of the cores much of the silica shows varying degrees of diagenetic mobilization all the way to a dense chert. An attempt was made to distinguish the different siliceous components in order to understand better the chert forming process.

In a semiquantitative manner the volume of HC1-insoluble residue of particulate matter greater than 63 microns in diameter was determined for each core catcher sample of 116 (Figure 16). The nannoplankton ooze of

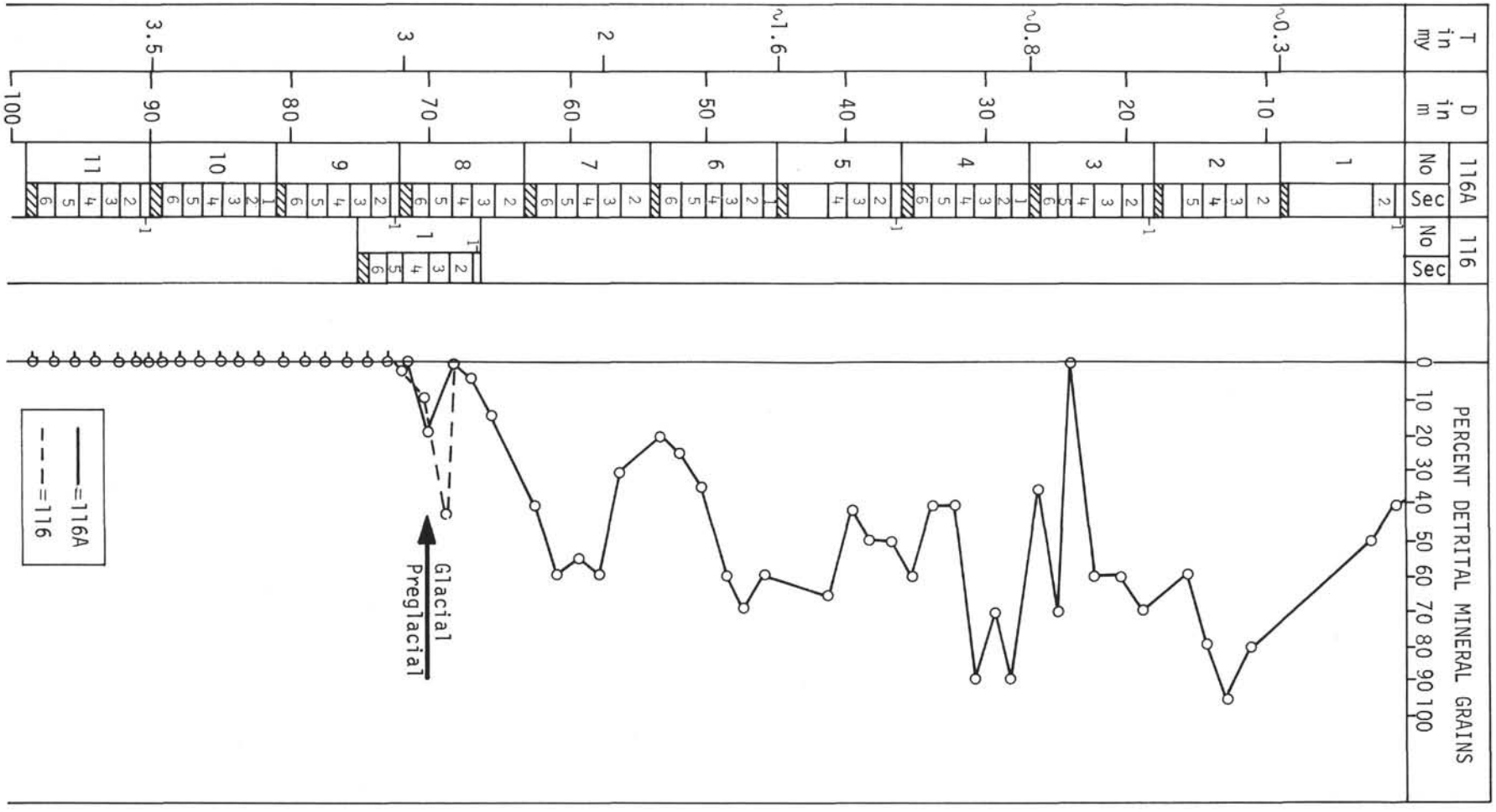

Figure 14. *Percentage of detrital minerals estimated by microscopic examination of the HCl insoluble clay-free residues of samples from Holes 116 and 116A. The influx at 71.5 meters is believed to represent the onset of glaciation.*

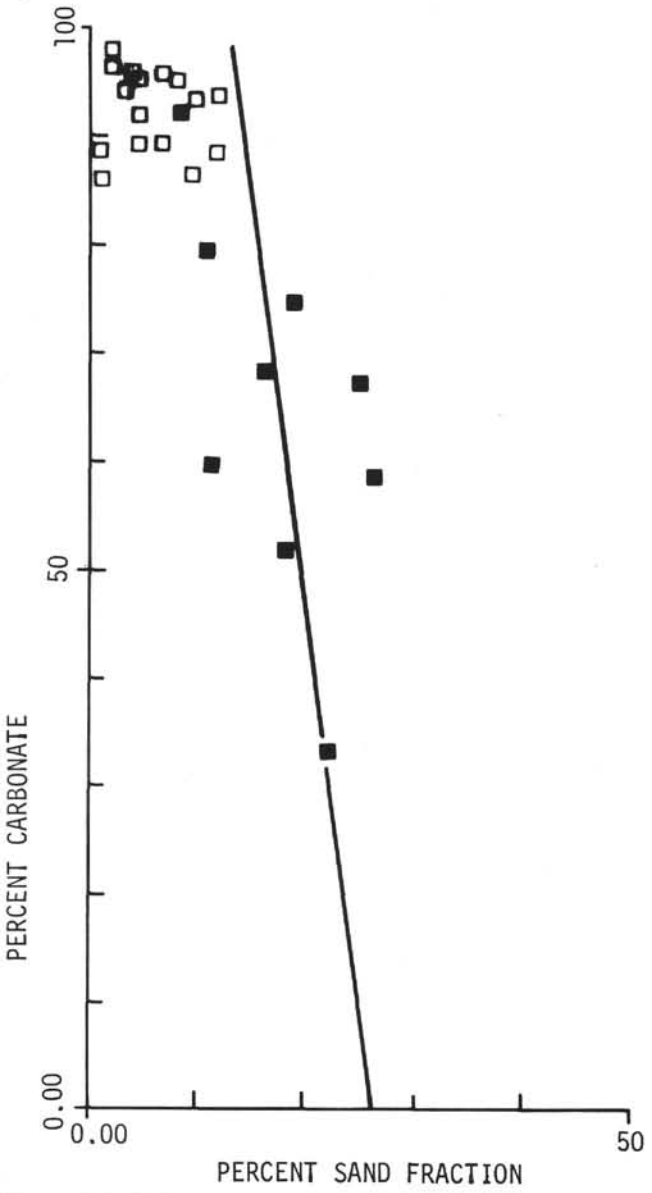

Figure 15. *Carbonate content plotted against the sand content of samples obtained within 10 centimeters of the carbonate sample. The glacial samples follow the trend line indicated; the sand content of pre-glacial samples appears to independent of carbonate content.*

Hole 116 consists of about 85 to 95 per cent calcium carbonate; therefore, residue volumes tend to be small. Since the amount of original sediment treated was quite large (enough to half fill a large evaporating dish), in nearly all samples (except Core 13) the volumes of residues from each core are comparable. Except for Cores 26 and 28, 90 to 100 per cent of each residue consists of silica, either predominantly biogenic or diagenetic.

Nine siliceous components were recognized in the residues (Figure 16). The source of nearly all the silica in the sediment, whether diagenetically mobilized or not, appears to be biogenic. Sponge spicules account for most of this, but in addition there are radiolarians, siliceous cysts (parts of sponges ?; see radiolarian report of Site 113), larger diatoms (smaller diatoms less than 63 microns in diameter probably make a significant contribution to the siliceous sediment), and flake-like fragments of the large diatom *Ethmodiscus rex*. The last are characterized by a grid pattern of closely and equally spaced minute pores (4 to 6 pores per 10 microns), and some show clear margins, either fringed or smooth (Plate 9, Figures 1-2). In Cores 3 through 8, the flake-like fragments lack pores, but in all other respects they resemble the perforated ones deeper in the hole. In Figure 16 clear "flakes" are included under fragments of *Ethmodiscus rex* even though their origin is in doubt. They could be of volcanic origin, but their flatness and thinness suggest some other source, possibly biologic.

The four major components included under diagenetic silica are: (1) amorphous cloudy masses of silica (brownish color, matted appearance); (2) clumps of biogenous silica (identifiable biogenous, siliceous structures plus clay (?) cemented by silica into a dense but translucent mass); (3) internal casts of foraminiferal chambers (generally composed of cloudy amorphous silica but sometimes of clear chalcedonic silica); and (4) chert fragments (dense, opaque except for chalcedonic foraminiferal walls).

The chert appears to be comprised mainly of silicified foraminiferal casts cemented by cloudy amorphous silica (Plate 9, Figure 3). If indeed the diagnetic events leading to chert formation at Site 116 are sequential, their order appears to be as follows: 1) partial solution of biogenous silica to form clumps, 2) further mobilization to form cloudy masses of amorphous silica, this probably concomitant with infilling of foraminiferal chambers, 3) cementation by amorphous silica of the infilled foraminiferans still with their calcite walls intact (otherwise chamber walls would be present around the internal casts in the HCL-insoluble residues), and 4) replacement of the calcitic walls by clear chalcedonic silica.

With the possible exception of Core 11, the formation of diagenetic silica does not seem to be dependent on outside sources of silica. There may have been introduction of additional silica in Core 11 as shown by the three-fold increase in residue volume, however a similar increase without any evidence of silica mobilization occurs in Cores 16 and 17, in this case due mainly to a large influx of fragments of *Ethmodiscus rex*. In Cores 20 through 28 in which diagenetic silica is about 80 to 95 per cent of the residue, the residue volumes are relatively low, being of about the same order of magnitude as in Cores 1 through 9 with nearly 100 per cent biogenous silica.

Finally, worthy of mention is the nearly complete mobilization of silica in Core 11 with very little if any mobilization above and below this level in Cores 10 and 12, respectively (Plate 10). Very few radiolarians and sponge spicules are recognizable in the residues from Core 11; therefore, the lack of siliceous fossils in chert beds does not necessarily imply that the source of the silica was nonbiogenic. In order for chert formation to occur it may be necessary for the siliceous fossils to be concentrated in layers or pods rather than distributed uniformly throughout the sediment. This would allow for greater ease in clumping of the siliceous elements as a first stage in diagenesis.

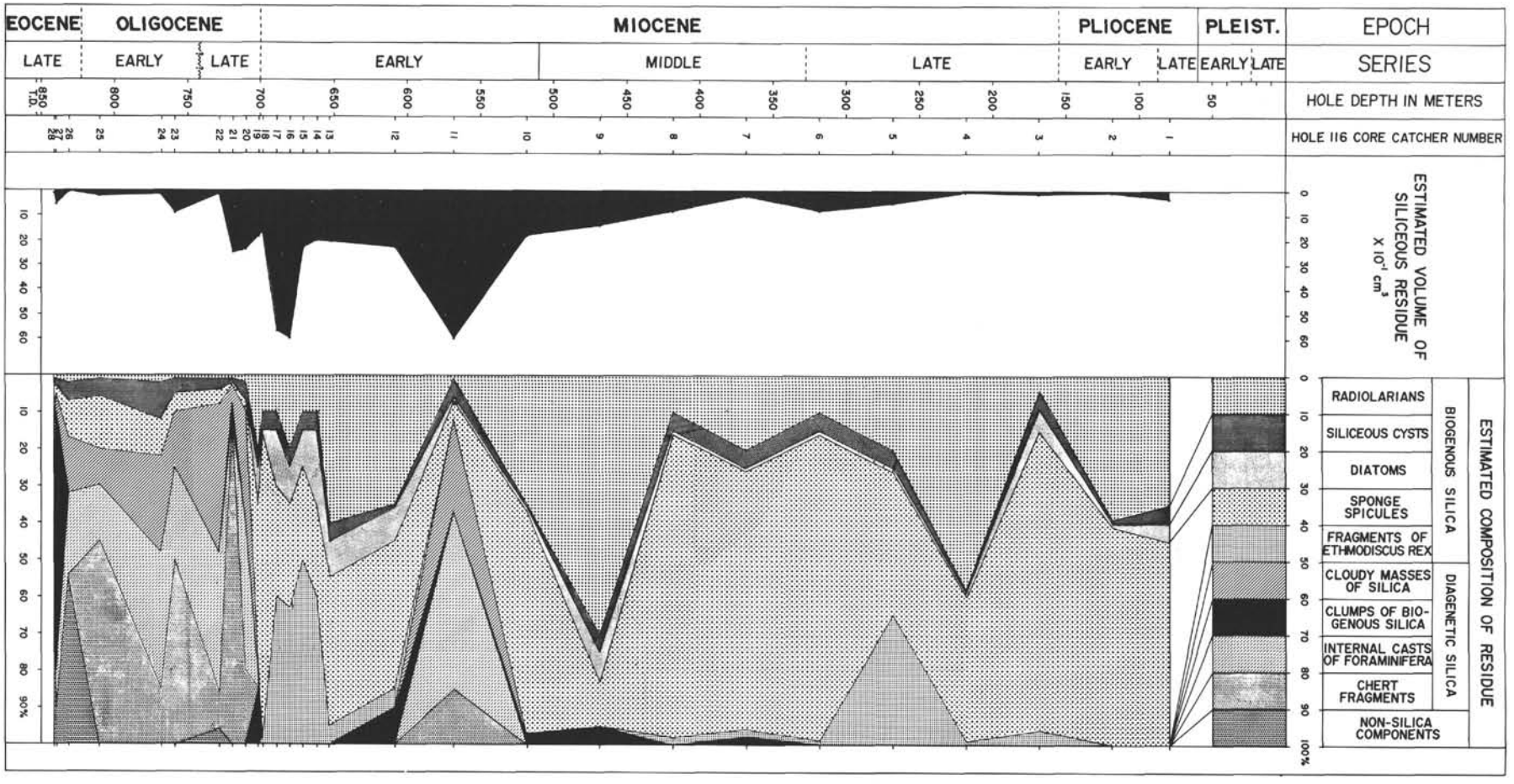

Figure 16. *Particulate silica greater than 63 microns in Hole 116.*

PHYSICAL PROPERTIES (116)

At Site 116 the cores are often watery and commonly have suffered considerable deformation during coring. It is not possible to list all the affected sections here (the reader should examine the disturbance logs on the core summaries and the core photos for detailed information) but the cores most affected are 116-5, 116-10, 116-11, 116-12, 116-23 and 116-25. Many sections were not split as a result of their watery appearance, and consequently the aberrant low GRAPE densities measured over such sections are probably, but not certainly, attributable to watery patches in these cores. The watery nature of many sections has been allowed for in drawing trend lines on the density, impedance, porosity and natural gamma plots.

Density increases fairly rapidly with depth in the first 70 to 80 meters (1.45 to 1.7 gm/cc) which is a sequence of ooze with foraminiferal sand and silty clay. Below this depth density only increases by a further 0.1 gm/cc in the next 650 meters. This increase is associated with the gradual change from soft foraminiferal-nannofossil ooze to ooze with chalk. The increasing firmness is also indicated by the penetrometer and by the velocity which increases from 1.5 to 1.7 km/sec between the sea bed and 730 meters.

Below about 700 meters both density and velocity increase more rapidly as chalk becomes predominant over ooze. The rapid velocity increase in this region, in spite of the increase in density, indicates that the lithification associated with the formation of chalk causes the bulk modulus and rigidity of the sediment to increase even more rapidly than density. The deepest core contained a hard chalky limestone with density 2.05 gm/cc and velocity 2.7 km/sec.

In detail the GRAPE density plots have few interesting features. Many plots show up lumps of hard chalk in a fluid ooze. Alternations of lower density foraminiferal ooze and higher density clay are apparent in Core 116A-2, and a single pebble is detected in Section 116A-9-2. Two series of small density peaks at 5 and 7 meters in 116-4 are of unknown origin but may be associated with bubbles of hydrogen sulfide which were detected when cutting Sections 4, 5 and 6 of this core.

Gamma radiation in the topmost 70 meters is on average considerably greater than at all deeper horizons sampled in the hole. The number of counts also shows appreciable fluctuations over short distances. Low counts of 550 and 350 in Cores 116A-2 and 116A-3, respectively, are associated with layers of foraminiferal ooze, and, high counts appear to be associated with detrital mineral grains in the glacial Pliocene-Pleistocene sediments. A fairly abrupt increase in radiation which occurs just above 71 meters (116A-8-5) is in the same section as the first influx of detrital grains and lies very close to the rather approximate paleontologically determined onset of glaciation. Only one carbonate sample obtained above this depth exceeds 85 per cent, while the majority of samples from below 71 meters exceed 90 per cent. It is clear, therefore, that the fluctuating gamma count may reflect the proportion of detrital mineral grains and the carbonate content of the sediment, and this in turn seems to be related to the glaciation. The subject is treated further in Chapter 13.

Below 71 meters, the natural gamma radiation is uniformly low, averaging about 200 counts, and with one exception the larger variations are associated with alternations of firm and watery core. The exception is the whole of Core 11 which has above average activity overall reaching up to 1500 counts. Unfortunately, only two sections of this core were split on board ship; these sections were composed of pale olive gray or yellowish-gray moderately mottled foraminiferal-nannofossil ooze. The carbonate content of these sections is not known, but a relatively low value of 60 per cent would probably be sufficient to give a gamma count of 1500. It may also be significant that this core (unlike Cores 10 and 12) exhibits complete remobilization of biogenous silica.

Depth of Reflectors

Roberts *et al.* (1970) detected five reflectors below the Hatton-Rockall Basin. It was one of the objectives of Site 116 to determine the nature of the lowest two reflectors. Presumably due to the rather widespread cores from the middle section of Site 116 it is not possible to recognize any of the upper reflectors by studying the physical property measurements. Reflector 4, however, does seem to be associated with the relatively rapid increase in lithification which occurs in the chalk below about 700 meters. The diffuse character of the reflector on the 160 to 320 Hz records is possibly due to it being caused by an increase in impedance which is gradual rather than sudden when "viewed" at a 5 to 10 meter wavelength. An explanation for the "transparent" layer below reflector 4 may be that since the chalk has reached a lithified state at this depth only gradual increases in impedance (due to increasing lithification) will occur below this depth, and these are insufficient to give rise to reflected energy. A corollary is that a deeper reflector will only occur if there is a sudden change in lithology below reflector 4. The reflector data are summarized in Figure 17.

PHYSICAL PROPERTIES (117)

The lithologies cored at this site were such as to produce cores of chippings (117-3, 117A-1) or cores fragmented by many transverse breaks (117A-6-5 onwards). Consequently, because of the loosely packed state or gaps between segments of these cores, the GRAPE data often seem to indicate low densities. Also, all sections of Core 117-2 and Sections 117A-4-1, 117A-4-3, 117A-6-1 and 117A-6-2 contained watery sediment. In drawing trend lines on the density, impedance, porosity and natural gamma plots, allowance has been made for aberrant data caused by the above effects.

The sediments cored in the top 150 meters of Site 117 are of the same age (Oligocene) and of similar lithology as those obtained just below 700 meters at Site 116. Even so, it is surprising that the density and velocity of the sediments recovered from 50 to 150 meters at Site 117 (1.7 gm/cc, 1.60 km/sec) have similar values to those of the sediments recovered from at least 550 meters deeper at Site 116 (for example, 1.7-1.8 gm/cc, 1.59 km/sec in Core 116-17). This suggests that the oozes concerned became sufficiently lithified shortly after deposition to be unaffected by the subsequent addition of up to 700 meters

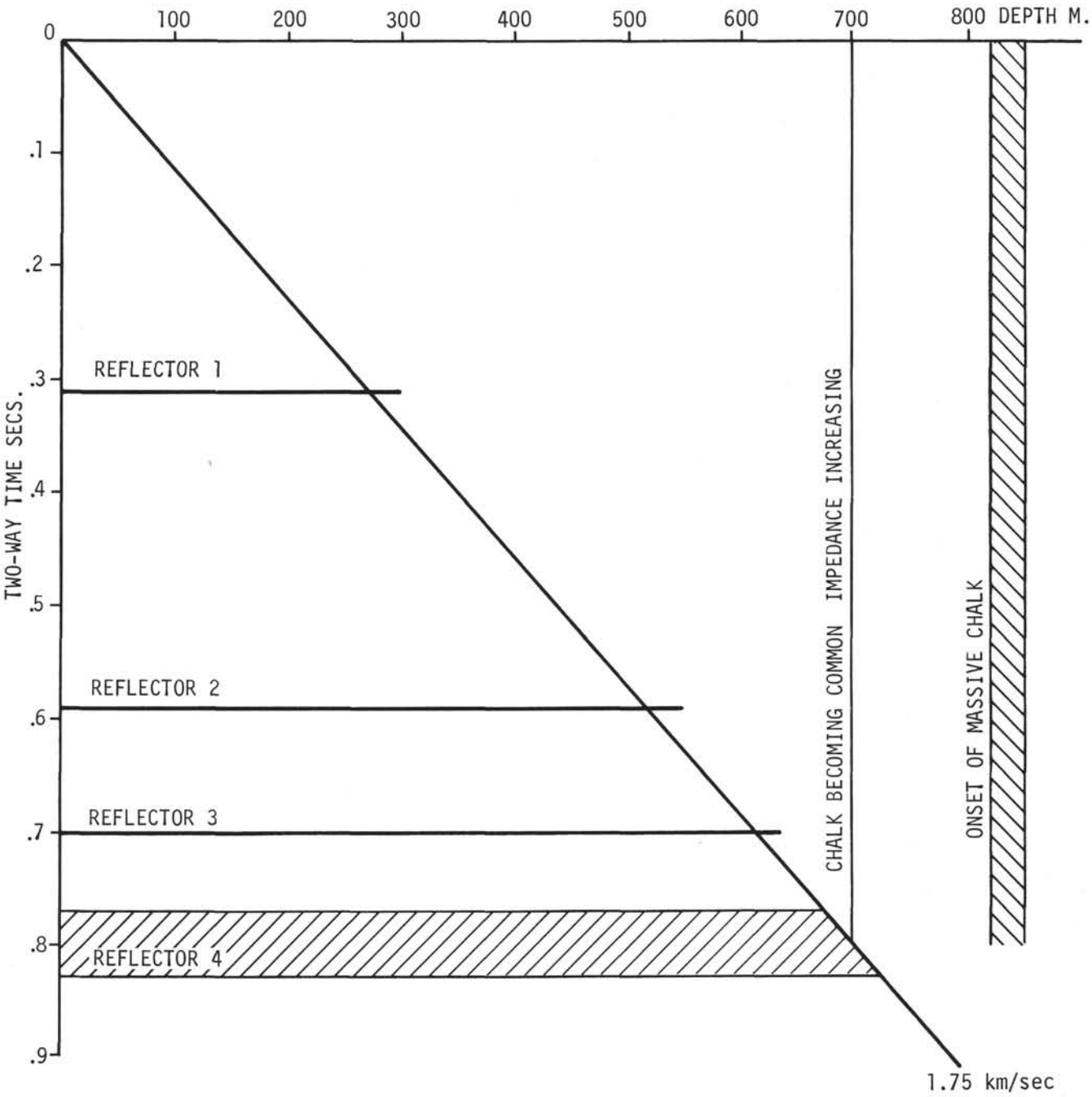

Figure 17. *Two-way travel times below the sea-bed of observed reflections plotted against the downhole depths of horizons believed to have given rise to these reflections. The mean velocity to the deepest reflection associated with a definite depth is given close to the line representing this velocity. (Site 116).*

of overburden (effectively about 40 kg/cm^2 overburden pressure). It is possible, according to the micropaleontology, for the Oligocene sedimentation rate at Site 117 to have been a fraction of that at Site 116. The slower rate of sedimentation could have led to an initially more lithified higher density ooze and *vice versa*. The probably shallower depth of deposition at Site 117 may also be pertinent to the formation of the lithified oozes. It should be noted, however, that the gamma activity of the Oligocene rocks differs between the two sites, averaging about 200 counts at Site 116 and 400 at Site 117. From the sparse data available, this seems to be entirely due to a lower carbonate content at Site 117.

Section 117A-1-1 clearly indicates the dependence of gamma activity on lithology, since relatively low counts were obtained from the foraminiferal sand and ooze, intermediate counts from the cherty limestone and high counts from the clay.

The cores below 150 meters show more variable physical properties. Core 117A-3 generally has a

density of 1.55 gm/cc, but at its base this becomes as high as 1.65 gm/cc corresponding to a change from firm clay to dense, burrowed clay. At the same time the gamma activity also increases from 600 to just under 1200 counts as the sediment color changes from greenish-black to gray to black. The gray clay contains only 14 per cent carbonate, and therefore the 100 per cent increase in gamma activity in the black clay is not explicable solely on the basis of decreased carbonate and probably indicates enrichment in uranium and thorium.

Continuous coring was maintained between 270 meters and the bottom of the hole. The clay persists down to 285 meters and has densities between 1.45 and 1.75 gm/cc. The gamma activity is variable, but two highs of 1200 and 1300 counts occur in 117A-6-5 and 117A-6-6 in association with dark bands in these sections. In the former section, 700 counts were obtained over sediment containing 21 per cent carbonate and therefore the high of 1200 is not explicable on the basis of absence of carbonate and suggests enrichment in uranium and thorium.

Core 117A-7 contains a mudstone of density 1.7 to 1.95 gm/cc (1.77-1.80 km/sec) in its upper 5.5 meters and a dense conglomerate (1.95 gm/cc, 1.93 km/sec) near its base. The mudstone has a gamma activity of 700 to 800 counts except for a peak of 920 counts in the top 60 centimeters of 117A-7-4 associated with a blue-green color. Core 117A-8 contains silty clay and sandy silt with densities up to 1.7 gm/cc and gamma activity around 1000 counts.

Core 11 was composed entirely of basalt and gave a gamma count of 250. The (weight/volume) density and porosity and the velocity are 2.56 gm/cc, 6 per cent and 4.8 km/sec, respectively.

Paleomagnetic measurements were made on four oriented specimens of basalt from Core 11 by J. Ade-Hall. All the specimens had a strong horizontal component relative to the vertical component of magnetization so that no definite determinations of the polarity of the paleofield were possible. The results are summarized in Table 5.

TABLE 5

Specimen	Polarity	Remarks
117A-11-1, 1 to 6 cms.	Indeterminate	Two oriented fragments have weak vertical components in opposite senses
117A-11-2, 26 to 32 cms.	R?	
117A-11-2, 44 to 47 cms.	N?	
117A-11-2, 107 to 114 cms.	None?	No measurable vertical component

Depth of Reflectors

Two strong reflectors, referred to as reflector 4 and "basement," were detected below Site 117. The upper reflector is spread out between 0.04 and 0.16 second and does not clearly relate to a measured increase in impedance in the cores above 150 meters. However chert chippings were recovered from cores above this depth and reflector 4 is undoubtedly due to stringers of extra hard limestone spread over some tens of meters as is suggested by the drilling data.

The "basement" reflection, from the seismic section after completion of drilling, occurs at 0.32 second. A close inspection of the record suggests, however, that the energy in this reflection derives from two reflectors, the lower one being at 0.35 second. Measurement of the acoustic impedance of recovered core material shows that there is an impedance change at 280 meters, corresponding to the very hard clay in 117A-6-5 and another larger one at 303 meters is related to the hard sandstones sampled in 117A-9-1. Again at 311 meters the impedance increases on entering basaltic basement. A velocity of 1.75 km/sec would give reflection times to these impedance changes of 0.32, 0.345 and 0.355 seconds, respectively. It is therefore likely that the start of the "basement" reflection is in fact due to the thin layer of overlying clays and sandstones and not to the basaltic basement. These data are summarized in Figure 18.

PALEONTOLOGY AND BIOSTRATIGRAPHY (116)

General

Sedimentation appears to have been continuous from Late Oligocene time to the present at this location. The extremely low estimated rates of sedimentation during the Oligocene indicate the presence of one or more unconformities in the Oligocene section. Chert horizons were encountered at about 700 meters; these become more common and persistent with increasing depth.

The material obtained from these two holes will be useful in delineating the Neogene development of planktonic and benthonic microfossils in temperate latitudes. It would appear that the present day deep-water benthonic

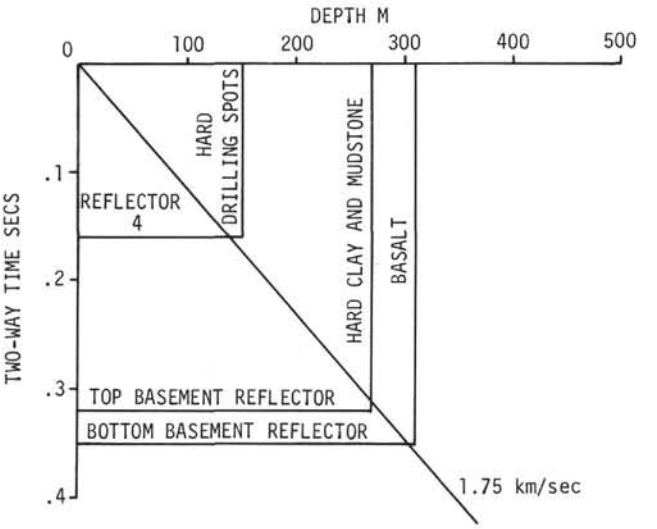

Figure 18. *Two-way travel times below the sea-bed of observed reflections plotted against the downhole depths of horizons believed to have given rise to these reflections. The mean velocity to the deepest reflection associated with a definite depth is given close to the line representing this velocity. (Site 117).*

foraminiferal fauna became established in this region about 15 million years ago (near the *Orbulina* Datum, which was identified in Hole 116, Core 10, 509 to 518 meters). Late Neogene planktonic foraminiferal faunas are essentially similar to those encountered at the previous sites on Leg 12. Upper Oligocene and Lower Miocene sediments, approximately the interval between Core 10 (509 to 518 meters) and 22 (719 to 728 meters) are characterized by various species of the genus *Globoquadrina*. Species of the *Globorotalia miozea* group characterize Middle and Upper Miocene and Lower Pliocene sediments. As at other sites on Leg 12, *Globigerian atlantica* is the dominant element in Pliocene cores and is replaced in Late Pliocene-Pleistocene time by *Globigerina pachyderma* The Pleistocene is characterized by populations of *Globigerina bulloides*, *G. pachyderma* and *Globorotalia inflata*. It may be possible to delineate broad patterns of climatic fluctuations in the Pliocene–Pleistocene in Hole 116A, but this study is not yet completed.

Other microplankton groups are abundant at this location. Calcareous nannoplankton are common, but Miocene discoasters are calcified and difficult to identify. Site 116 contains the most complete record of Cenozoic radiolarians. Late Eocene-Oligocene forms exhibit evidence of corrosion and silicification. Diatoms are scattered throughout the stratigraphic succession. Siliceous sponge spicules occur at many levels, particularly in the Middle-Late Miocene.

In the following sections a summary is given of the major faunal components in terms of their stratigraphic development beginning with the Pleistocene.

Discussion

Foraminifera

Pleistocene

The Pliocene-Pleistocene boundary is drawn at about 60 meters (within Core 7, Hole 116A). The lower part of the Pleistocene sequence is characterized by *Globigerina bulloides* and *Globorotalia inflata*. The upper part of the Pleistocene is characterized by an abundance of *Globigerina pachyderma* and *Globigerina bulloides*. Commonly occurring accessory species include *Globorotalia scitula, G. crassula, G. crassaformis, G. truncatulinoides, Orbulina universa* and *Globigerinita glutinata*. The benthonic foraminiferal fauna is quite rich and diversified and includes among other forms *Sigmoilopsis schlumbergeri, Pyrgo lucernula, Pyrgo murrhyna, Gyroidina neosoldanii, Uvigerina hollicki, Cibicidoides pseudoungeriana, Melonis pompilioides, Melonis barleeanum Bulimina marginata, Eponides tener* and *Karreriella bradyi*. These forms and numerous others, characteristic of Recent sediments in the Atlantic Ocean, occur relatively commonly in sediments at this site as old as Middle Miocene.

Pliocene

The Miocene-Pliocene boundary is placed approximately at 155 meters (that is slightly above Core 3, in Hole 116A). The Pliocene, then, in this area is approximately 100 meters thick. The dominant planktonic foraminiferal element in the Pliocene is *Globigerina atlantica*. Relatively high frequencies of *Globorotalia puncticulata* and *G. crassaformis* serve as useful criteria in the biostratigraphic subdivision of the Pliocene at this site. Indeed, it would appear that the presence of *Globorotalia puncticulata* and the absence of other distinctive Pliocene forms may serve as a criteria for distinguishing Pliocene from Miocene.

Miocene

The Oligocene-Miocene boundary is tentatively drawn (on relatively weak biostratigraphic data) at about 700 meters between Cores 18 and 19 in Hole 116. The Miocene is thus about 550 meters thick at Site 116 (all data below refer to Hole 116). Cores 3 through 6 are of Late Miocene age; Cores 7 through 10 (part) are of Middle Miocene age; Core 10 (part) through 18 are of Early Miocene age.

Upper Miocene sediments are characterized by large robust specimens of *Globigerina bulloides* and forms apparently belonging to the *Globorotalia acostaenis-humerosa* complex. *Globigerina atlantica* occurs sporadically throughout this interval and is predominantly dextrally coiled. The faunas, in general, show a marked resemblance to those recorded from the type Tortonian of Italy.

The Middle Miocene is characterized by relatively large globigerinids assigned to *Globigerina praebulloides, Globoquadrina dehiscens, Globorotalia siakensis* and sphaeroidinellids. *Globorotalia miozea* is a characteristic form in Cores 6, 7 and 8, and *Globorotalia praemenardii* is a relatively common form in Core 9. *Globigerina nepenthes* occurs in Core 7. The evolutionary development from *Praeorbulina* to *Orbulina* occurs from Core 10 to Core 9 and allows relatively precise stratigraphic dating of this part of the section. A gradual but pronounced change in the benthonic foraminiferal fauna is noticed within the lower part of the Miocene at this site. Several forms characteristic of the older sediments at this site have their upper ranges within the Lower Miocene, whereas most of the forms common in the Pliocene and Pleistocene have their lowest occurrences within this same interval.

The Lower Miocene (Cores 10 through 18) is characterized by a relatively monotonous assemblage of globoquadrinids (*Globoquadrina dehiscens, G. baroemoenensis* and *G. praedehiscens*). *Spaeroidinellopsis seminulina* is particularly common in Core 11. *Globigerinita dissimilis*, the dominant form in Oligocene samples below, has its highest occurrence in Core 13. *Globorotalia birnageae* occurs in Core 12. The dominant benthonic foraminiferal element throughout the Lower Miocene and Oligocene is a siphoninid here assigned to *Siphonina tenuicarinata*. Other characteristic Lower Miocene benthonic foraminifera include *Planulina renzi, Oridorsalis ecuadorensis, Anaomalina alazanensis, Gyroidina complanata* and *Cibicidoides trincherasensis.*

Oligocene

The Eocene-Oligocene boundary occurs between the base of Core 25 and the base of Core 26 in Hole 116. It is arbitrarily drawn here at the top of Core 26 at about 825

meters. The Oligocene, thus, is about 125 meters thick. Extremely low rates of sedimentation calculated for the Oligocene (see section on sedimentation rates) suggest the presence of one or more unconformities within the Oligocene at this site. Cores 19 through 25 are assigned an Oligocene age. The Oligocene is characterized by a planktonic foraminiferal fauna of low diversity, including *Globigerinita dissimilis* and *G. unicava*. Chiloguembelinids occur as high as Core 23 and *Globigerina ampliapertura* as high as Core 24, which suggest that Cores 20 through 22 are of Late Oligocene age and Cores 23 through 25 are of Early Oligocene age. Characteristic benthonic foraminiferal elements in the Oligocene include *Siphonina tenuicarinata, Heterolepa mexicana, C. trincherasensis, Planulina renzi, Anomalina pompilioides, A. alazanensis, Oridorsalis ecuadorensis* and *Uvigerina havanensis*. Small individuals of compressed unkeeled globorotaliids are found in Cores 24 and 25 and are assigned here to the species *Globorotalia postcretacea, Globorotalia denseconnexa,* and *G. inaequiconica*. The latter two species were described from the Oligocene-Lower Miocene sediments of the Polyanitskaya group of the Carpathian Mountains.

Eocene

The Eocene is represented by Cores 26 through 28. The planktonic foraminiferal fauna consists of an assemblage of globigerinids dominated by *Globigerian galavisi*. Also present are *G. linaperta* and *Globigerapsis index*. Chiloguembelinids occur commonly but *Pseudohastigerina micra* has not been found. This may support the suggestion, made elsewhere by this writer, that *Pseudohastigerina* became extinct at high latitudes within Late Eocene time, whereas it ranges well into the Oligocene in lower latitudes. Characteristic benthonic foraminiferal elements include *Osangularia mexicana,* and *Oridorsalis ecuadorensis*.

A planktonic foraminiferal biostratigraphic subdivision of Site 116 is presented in Figures 19, 20 and 21, and some of the characteristic benthonic foraminiferal elements at Sites 116 and 117 are shown in Figure 22.

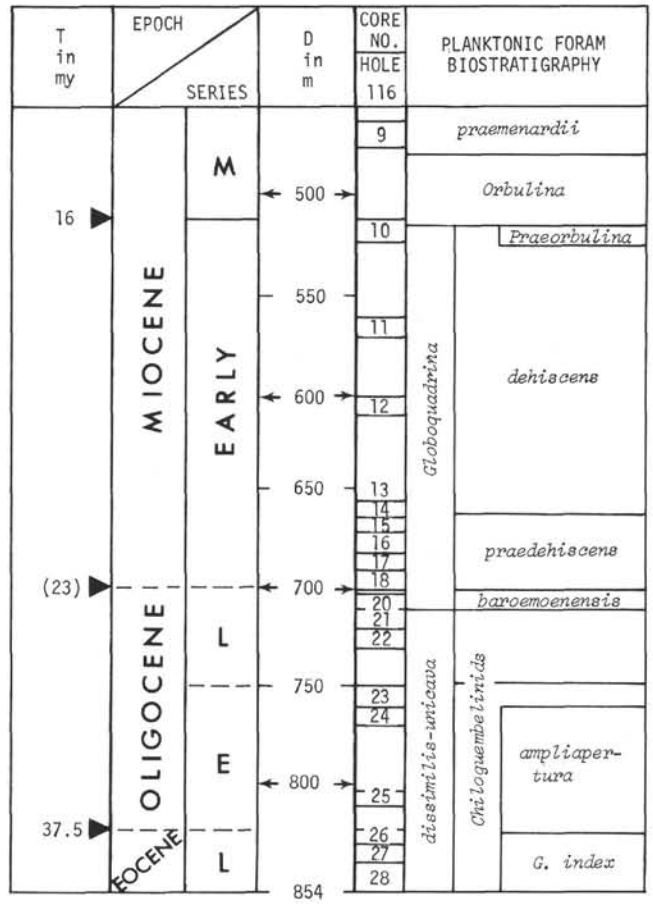

Figure 19. *Late Eocene – Early Miocene planktonic foraminiferal biostratigraphy of Site 116.*

Calcareous Nannoplankton

At Site 116, a complete sequence of Neogene and some Paleogene was cored and yielded a good insight into high latitude coccolith assemblages.

Pleistocene and Pliocene

Hole 116A was cored continuously to give information about the development of the fauna and flora in high latitude Pleistocene, the Pliocene/Pleistocene boundary and the age of the beginning of the glaciation in this region.

All Pleistocene zones could be recognized in Cores 1 to 7 (116A). It was hoped that this sequence would furnish an ideal profile to check temperature oscillations during the Pliocene and Pleistocene. However, the soupy calcareous oozes and slightly clay-richer oozes were mixed by drilling disturbance. It is therefore questionable how much a fine analysis of the material will yield.

In Figure 23 the results of the preliminary study of the smear slides prepared on board the ship are presented. *Coccolithus pelagicus* was found to vary considerably in quantity, from abundant to extremely rare or absent. Several species of *Scyphosphaera* are present, especially in the lower part of the sequence. A relation between the presence of detrital minerals and reworked, mostly Late Cretaceous, coccoliths can be observed. Both were not observed lower than 116A-7-1, in the lower most Pleistocene. They might reflect glacial influence. Where do the Late Cretaceous coccoliths come from? The source could be subaqueous or Ireland.

Generally, the Pleistocene and Pliocene assemblages are not much richer than those from the more northern sites. Discoasters are again extremely rare and their scarcity makes it difficult to define the Pliocene/Pleistocene boundary that has been set here above the highest

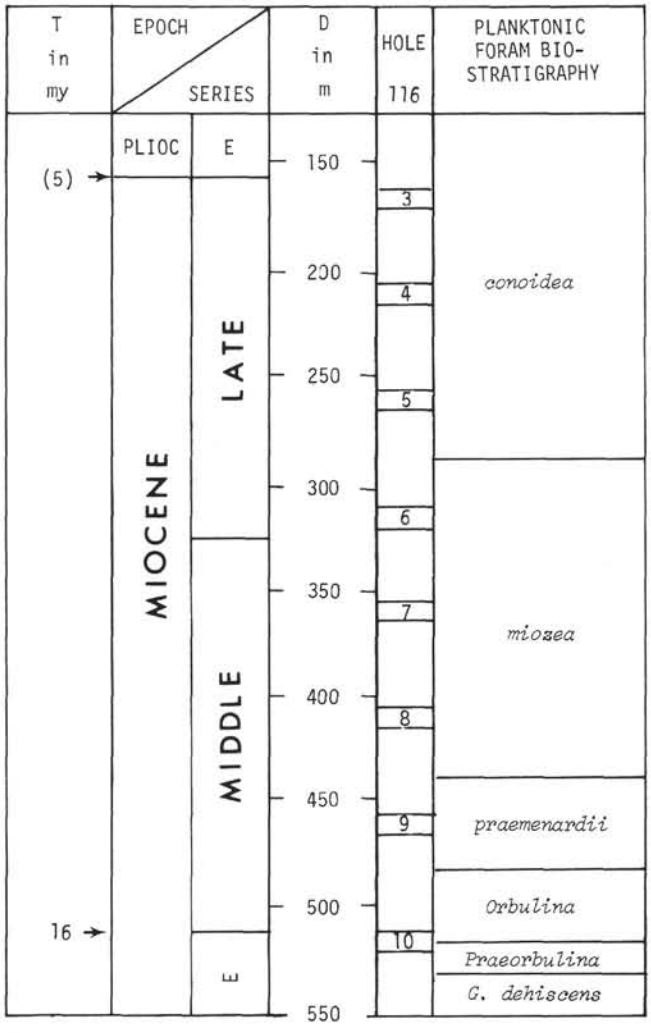

Figure 20. *Middle-Late Miocene planktonic foraminiferal biostratigraphy of Site 116.*

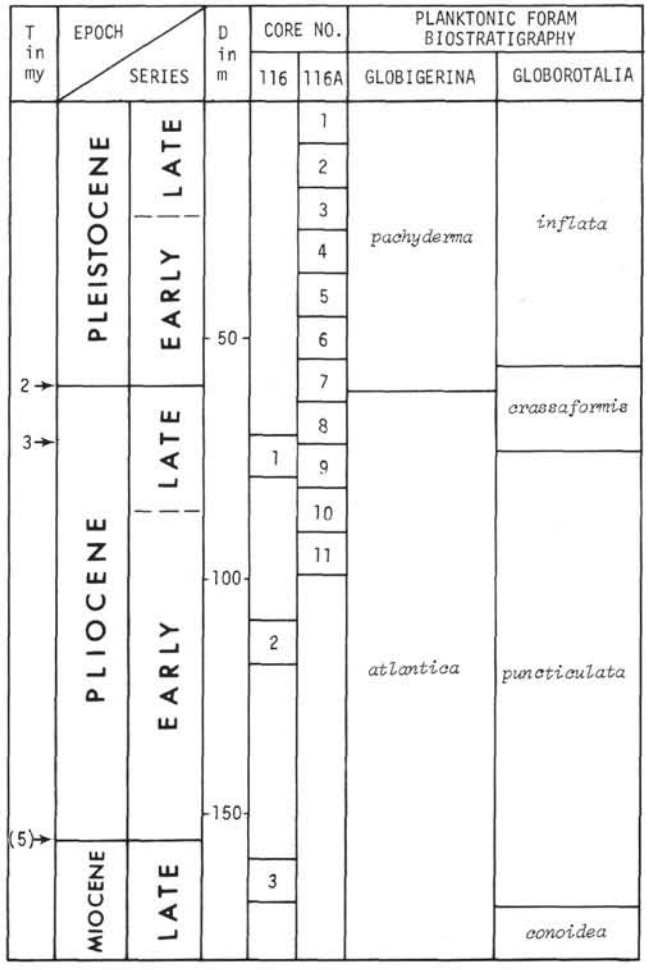

Figure 21. *Pliocene-Pleistocene planktonic foraminiferal biostratigraphy of Site 116.*

occurrence of a discoaster. *Cyclococcolithus macintyrei* occurs as high up as in the *C. jaramillensis* zone. *Coccolithus pelagicus* is present in several variations including a small central opening, an opening spanned by a crossbar or a cross and a form with a wide central opening spanned by a crossbar or a cross. Electron microscope examination of the coccolith with a crossbar has shown that it differs from *Cruciplacolithus neohelis* in the construction of the distal shield and the wall. A further variety shows an elevated wall covering most of the central area. It occurs together with "normal" *Coccolithus pelagicus* on the same *coccosphaeres. Syracosphaera histrica, Syracosphaera* sp. and different *Pontosphaera* are present and more or less frequent in most samples. *Helicopontosphaera kamptneri* and *H. sellii* are also present throughout the sequence. *Ellipsodiscoaster lidzi* (?) was found in Cores 116A-10 and 11. In Sections 116A-9-2 to 4, four-rayed *Discoaster brouweri* were found. *Rhabdolithus* sp. is more frequent in the Pliocene than in the Pleistocene. *Sphenolithus neoabies* (?) was only found in the core catcher of 116A-7; *S. abies*—otherwise found below the onset of glaciation—seems to be absent here, a fact surprising, considering the otherwise somewhat richer assemblage. Besides the coccoliths mentioned, the coccoliths defining the zones are present and an almost constant background of innumerable very small coccoliths and/or broken coccoliths. It is those coccoliths, sometimes together with *Coccolithus pelagicus,* that are the main ingredients of the fine fraction of the ooze. Ceratoliths were only found as two specimens in Section 116A-10-2 in the Late Pliocene.

The lowermost core assigned to the Pliocene, Core 116-2, contains only long-ranging species, so that an exact age cannot be given for it.

Miocene

The discoasters present in the samples assigned to the Miocene—116-3 to 18?—are calcified and their determination difficult. Cores 4 and 5 are assigned to the *Discoaster quinqueramus* Zone on basis of the presence of a discoaster similar to *D. quinqueramus* and the absence of *D. hamatus. Chiasmolithus* sp. occurs in Core 5—a high occurrence for this genus. For Cores 6 to 9, only their Miocene age could be established. The presence of *Helicopontosphaera parallela* and *Coronocyclus nitescens* in Core 9 suggests the presence of the *Discoaster exilis* Zone or older. Only in Core 10, a better age assignment is again possible. Together

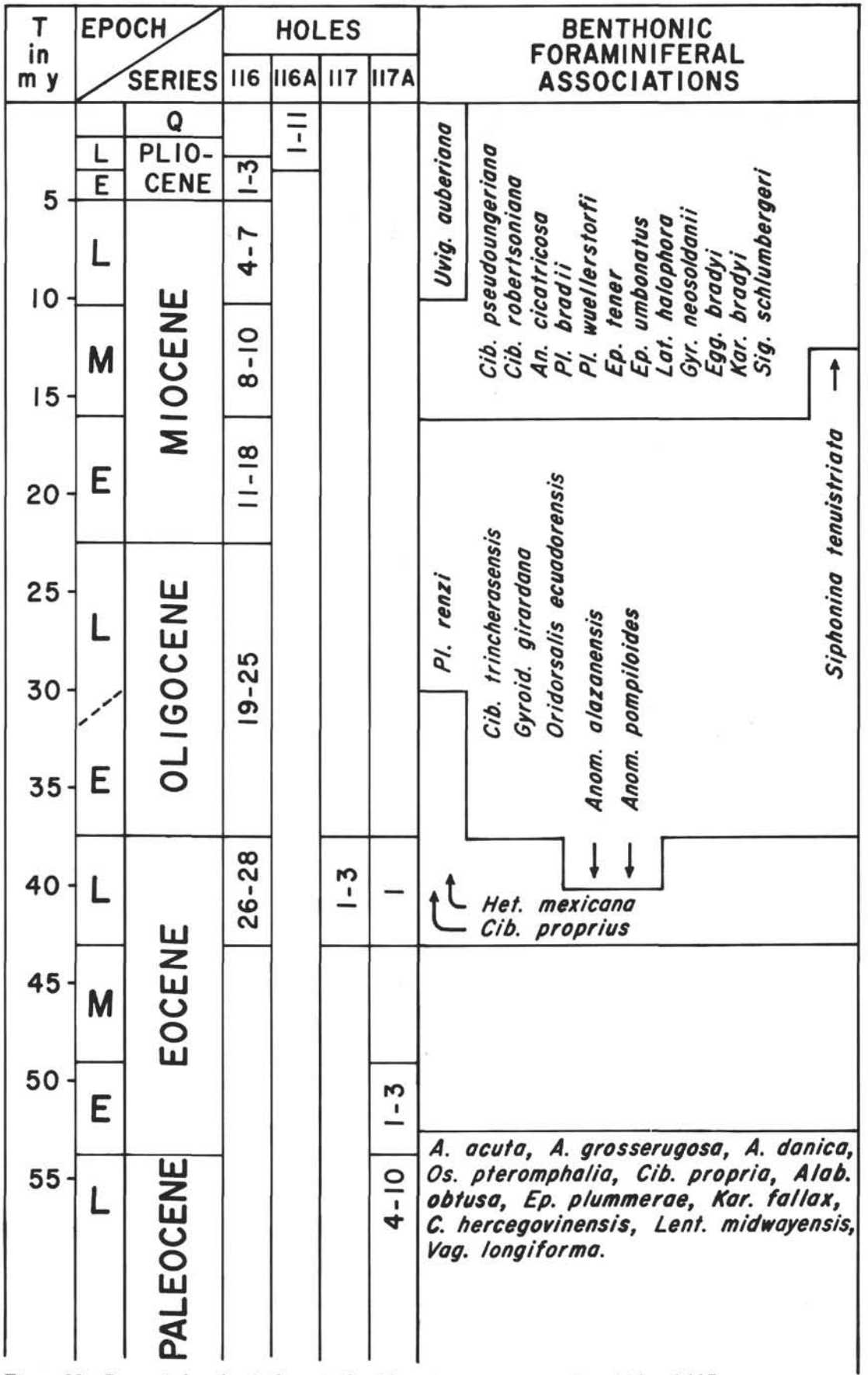

Figure 22. *Cenozoic benthonic foraminiferal faunal associations at Sites 116 and 117.*

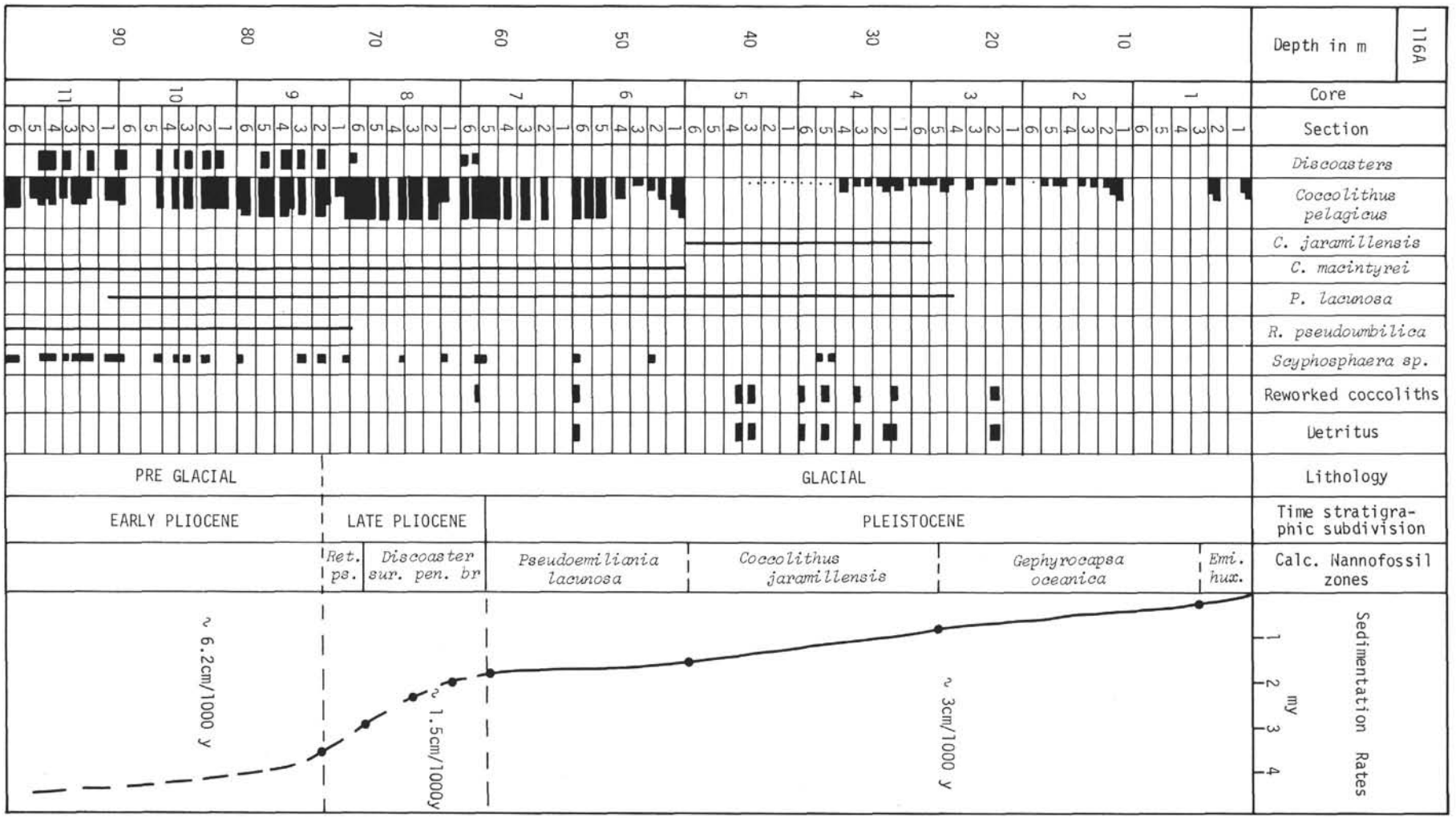

Figure 23. *Stratigraphic distribution of calcareous nannoplankton in the upper Pliocene and Pleistocene and estimated average rates of sedimentation at Site 116.*

with Core 11, it represents the *Sphenolithus heteromorphus* Zone, with this species and *Coronocyclus nitescens* and *Cyclococcolithus leptoporus* only present in Core 10. In the tropics, the range of *C. leptoporus* and *Helicopontosphaera parallela* overlaps in the *H. ampliaperta* Zone (Bramlette and Wilcoxon, 1967). They overlap here, too, in Core 10, indicating that the *H. ampliaperta* Zone might be represented by Core 10 and 11. An undescribed species of *Discolithina* occurs occasionally in the Early Miocene and Late Oligocene. Cores 12 through 14 are tentatively assigned to the *Sphenolithus belemnos* Zone due to the presence of *S. belemnos* or similar sphenoliths and the missing or extreme scarcity of *Triquetrorhabdulus carinatus*. Normally, sphenoliths are not abundant in these cores. Best represented is generally an undescribed form and *S. moriformis,* a long-ranging species without much value for age determination. Many samples have a background of coccolith debris. *Triquetrorhabdulus carinatus* is present in various amounts in Cores 15 to 22, which allows assignment of these cores to the Late Oligocene/early Miocene interval, the exact boundary being difficult to set, as *Sphenolithus ciperoensis* which is characteristic of this interval - seems to be absent. From Core 12 downwards, a form similar to *Zygrhablithus bijugatus* occurs in ascending frequency and reaches about 30 per cent of the larger coccoliths in Core 18, and below. The content in this form, however, varies from sample to sample and might well have had an influence on the characteristics of the sediment.

Oligocene

As mentioned above, the boundary between the Miocene and the Oligocene cannot be exactly defined by coccoliths at this site. Generally the Oligocene assemblages contain the same long-ranging coccoliths as the Early Miocene. Core 19 to 22 are thus assigned to the Late Oligocene. In Core 20, *Triquetrorhabdulus* is still present. Because *Sphenolithus distentus* and *S. predistentus* that mark the next lower zone are not present here (but in other high latitude Oligocene), the cores are assigned to the *S. ciperoensis* Zone (*S. ciperoensis* is also absent, but was found in other high latitude samples). Also the Oligocene shows a considerable amount of *Zygrhablithus* cf. *Z. bijugatus,* and occasionally *Chiasmolithus* sp. is also present.

The Early Oligocene is represented by Cores 23 to 25 that all contain *Isthmolithus recurvus* (rare) but no disc-shaped discoasters, indicative of the *Ericsonia obruta* Zone. Thus, the Mid-Oligocene seems to be missing, although this is only seen by negative evidence (lack of Mid-Oligocene species in Cores 20, 21 and 22). The Early Oligocene flora is somewhat richer than the Late Oligocene and Miocene flora at this site and resembles the Early Oligocene from northern Europe. However, with the difference that here *Zygrhablithus* cf. *Z. bijugatus* plays a sometimes prominent part in the assemblage. *Braarudosphaera bigelowi* also occurs. *B. bigelowi* is known, in recent seas, to live in basins and gulfs rather than in the open sea (indication of restriction of the sea before nondeposition after the Early Oligocene?). The presence below and above the nondeposition period of *Z.* cf. *Z. bijugatus* in high quantities could indicate that the conditions did not change drastically in the Oligocene or that similar conditions were maintained nearby while there was nondeposition at this site—or, that sedimentation, after all, was only reduced but continuous.

Eocene

Cores 26 to 28 are believed to belong to the Late Eocene. Due to lithification, the coccoliths in these cores show a bad preservation. *Isthomlithus recurvus* was found in all three cores, as well as *Discoaster saipanensis* or *D. barbadiensis.* Also, the Late Eocene assemblage is comparable to the assemblages of the same age found in Northern Europe. Again, *Z.* cf. *Z. bijugatus* is present in variable amounts.

Miscellaneous

Preservation

Except for the fairly well-preserved Pliocene and Pleistocene flora, most coccoliths and discoasters are badly preserved, broken or calcified. The assemblages are generally poor, but it is difficult to say whether this is due to a primarily poor assemblage living here or to selective solution.

Reworking

Well-preserved coccoliths of Late Campanian or Early Maestrichtian age were found in several samples in the Pleistocene. Late Eocene to Early Oligocene forms occur occasionally in the Miocene (*Chiasmolithus grandis, C. expansus*). From seismic records it can be assumed, that during Miocene and later, Eocene-Oligocene sediments outcropped at the border of the basin and were eroded and transported by currents to be mixed and redeposited with the actual nannoplankton of the time. The same may be the case for the Late Cretaceous forms that occur in the Pleistocene.

Radiolaria

Of all the sites drilled during Leg 12, Site 116 has the most complete record of Cenozoic radiolarians. With the exception of Core 11 where most of the biogenous silica has been mobilized to form chert and other siliceous masses, all Hole 116 cores down to about 700 meters (Pleistocene through Oligocene-Miocene; 116-1 to 19) contain rare to common and occasionally abundant, well-preserved radiolarians. Most of the assemblages include enough representatives of low latitude Cenozoic faunas that several of the standard radiolarian zones (Moore, in press; Riedel and Sanfilippo, 1970, and in press) can be recognized (Chapter 17, Table 1). In the Oligocene-Eocene section (116, Cores 20 to 28), radiolarians are very rare to absent, and all are corroded or silicified. Residues of samples from all of these cores contain ample evidence of diagenetic mobilization of silica in the presence of chert fragments, silicified internal casts of foraminifers, and cloudy siliceous masses or clumps. The absence or near absence of radiolarians in this interval is more than likely the result of silica mobilization (see discussion in Lithology section).

Hole 116A

Radiolarians are present in most of the sample residues from Hole 116A, but they are seldom common or abundant (Figure 24). Abundances increase slightly and assemblages are more diverse below the glacial-preglacial boundary (just above 116A-8-6), which is placed at a position below which detrital mineral grains are absent in the HCl-insoluble, clay-free residues. Presumably, the presence of detrital grains, although representing a very low percentage of the total sediment, is indicative of times of glaciation and is either the result of ice-rafting or the movement of sand into deep water during the low stands of sea level. The Pliocene-Pleistocene boundary shown in Figure 24 is based on the nannofossil evidence. The complete absence of detrital mineral grains and the common occurrence of a fairly diverse radiolarian assemblage in 116A-3-4 suggest an interglacial interval. Based on the nannofossil evidence, the extrapolated age of this sample is about 0.72 million years which would place it in about the middle of the Yarmouth Interglacial of the North American Pleistocene (= Mindel-Riss Interglacial in Europe). Of all the interglacials recognized the Yarmouth was of the longest duration, beginning a little over one million and ending about 400,000 years before present (Ericson *et al.*, 1964). The presence of a fairly diverse radiolarian assemblage and the absence of detrital mineral grains in 116A-3-4 either represent a sampling accident or may reflect an interglacial climatic maximum.

As at Site 114, the radiolarian assemblages in Hole 116A are dominated by the same species of spheroidal and discoidal spumellarians. Species which persist throughout all eleven cores include: *Actinomma antarcticum* (Haeckel), *A.* spp., *Thecosphaera* spp., *Hexacontium* spp., *Ommatodiscus* spp., *Spongodiscus* spp., *Euchitonia* spp., *Lithelius minor* Joergensen, *L.* spp., and orosphaerid fragments and spines. Species which occur very rarely and irregularly include: *Actinomma medianum* Nigrini, *Heliodiscus asteriscus* Haeckel, *Spongocore puella* Haeckel, *Lamprocyclas maritalis maritalis* Haeckel, *L. maritalis polypora* Nigrini, *Androcyclas gamphonycha* Joergensen, *Theocalyptra davisiana* (Ehrenberg), *Pterocanium trilobum* (Haeckel), and *Cornutella profunda* Ehrenberg. Species present in all eleven cores but more persistent and abundant below the Pliocene-Pleistocene boundary include: *Stylodictya validispina* Joergensen, *Spongopyle osculosa* Dreyer, *Spongotrochus* sp. cf. *S. glacialis* Popofsky, *Amphisphaera cronos* (Haeckel), *Phorticium pylonium* (Haeckel?) Cleve, *Druppatractus acquilonius* Hays, *D. irregularis* Popofsky, *Lithomelissa thoracites* Haeckel, *Helotholus histricosa* Joergensen, *Eucyrtidium calvertense* Martin, and *Artostrobium auritum* (Ehrenberg). No species worth noting are confined to the Pleistocene. *Lamprocyclas heterporos* Hays is present in the Pliocene but just above and below the glacial-preglacial boundary. Species which are present only below this boundary (116A-8-6 and below) include: *Spongaster* sp. cf. *S. tetras* Ehrenberg (see radiolarian report for Site 114), *Theocorythium trachelium* (Ehrenberg), *Anthocyrtidium cineraria* Haeckel, *Coracalyptra cervus* (Ehrenberg), *Lithomitra lineata* (Ehrenberg), and *Carpocanistrum* spp.

Hole 116

PLIOCENE TO OLIGOCENE-MIOCENE

The distribution of biostratigraphically significant radiolarian species and the standard radiolarian zones recognized in Cores 116-1 to 22 (Pliocene - Oligocene-Miocene) are given in Chapter 17, Table 1. All radiolarians are well preserved except in Cores 116-11 and 20 to 22 where they are corroded or absent because of their dissolution. Of the stratigraphically significant fossils the following are characteristic in that they are present in most samples from Cores 5 through 19: *Calocyclas margatensis* Campbell and Clark, *Stichocorys delmontensis* (Campbell and Clark), *Cyrtocapsella cornuta* Haeckel, and *C. tetrapera* Haeckel.

Core 1 corresponds in depth below sea bed with portions of Cores 8 and 9 of Hole 116A. As discussed under 116A above, the glacial-preglacial boundary occurs above Section 116A-8-6. This boundary, determined in the same way, occurs in Hole 116 just below 116A-1-3 (Figure 25). Other evidence of correspondence between the two holes is the presence of *Spongaster* sp. cf. *S. tetras* Ehrenberg in Section 116A-8-6 of 116A and in all samples from 116-1. As noted in the radiolarian report of Site 114, the stratigraphically restricted occurrence of this species in this part of the North Atlantic may represent a migration event which occurred during the preglacial to glacial transition in the late Pliocene.

All of Core 1 plus Sections 1 and 2 of Core 2 lack stratigraphically significant fossils; therefore, no radiolarian zone is recognized for this interval. The presence of *Stichocorys peregrina* (Riedel) and the absence of any other significant fossils in the lower portion of Core 2 support the assignment of this interval to the *Spongaster pentas* Zone of Pliocene age.

Except for two very rare occurrences of *Stichocorys delmontensis* (Campbell and Clark), all of Core 3 and Section 1 of Core 4 lack significant fossils; therefore, no zonal determination could be made for this interval.

The interval form 116-4-2 through 116-5-CC probably represents either or both the *Stichocorys peregrina* and *Ommatartus penultimus* Zones of late Miocene age. The highest occurrence in Hole 116 of *Cyrtocapsella tetrapera* is in Section 116-4-2. Riedel and Sanfilippo (1970, Figure 3) indicate a questionable range of this species as high as the *S. peregrina* Zone, and for this reason 116-4-2, 97 to 98 centimeters, through 116-4-6, 89 to 90 centimeters, may represent as young a zone as this one. More convincing evidence of zonal assignment is the concurrence of *Stichocorys peregrina* and *S. delmontensis* from 116-4-CC through 116-5-CC. Riedel and Sanfilippo (in press, Figure 2) indicate the lower and upper evolutionary (but not morphological) limits of the former and latter, respectively, at the boundary between the *O. penultimus* and overlying *S. peregrina* Zones. The presence of *Ommatartus antepenultimus* Riedel and Sanfilippo in the same interval in Hole 116 argues for a more probable assignment to the *O. penultimus* Zone (Moore, in press, range chart).

All of Core 6 is unzoned because of the lack of significant fossils, other than the relatively long-ranging *Stichocorys delmontensis* and *Cyrtocapsella tetrapera.*

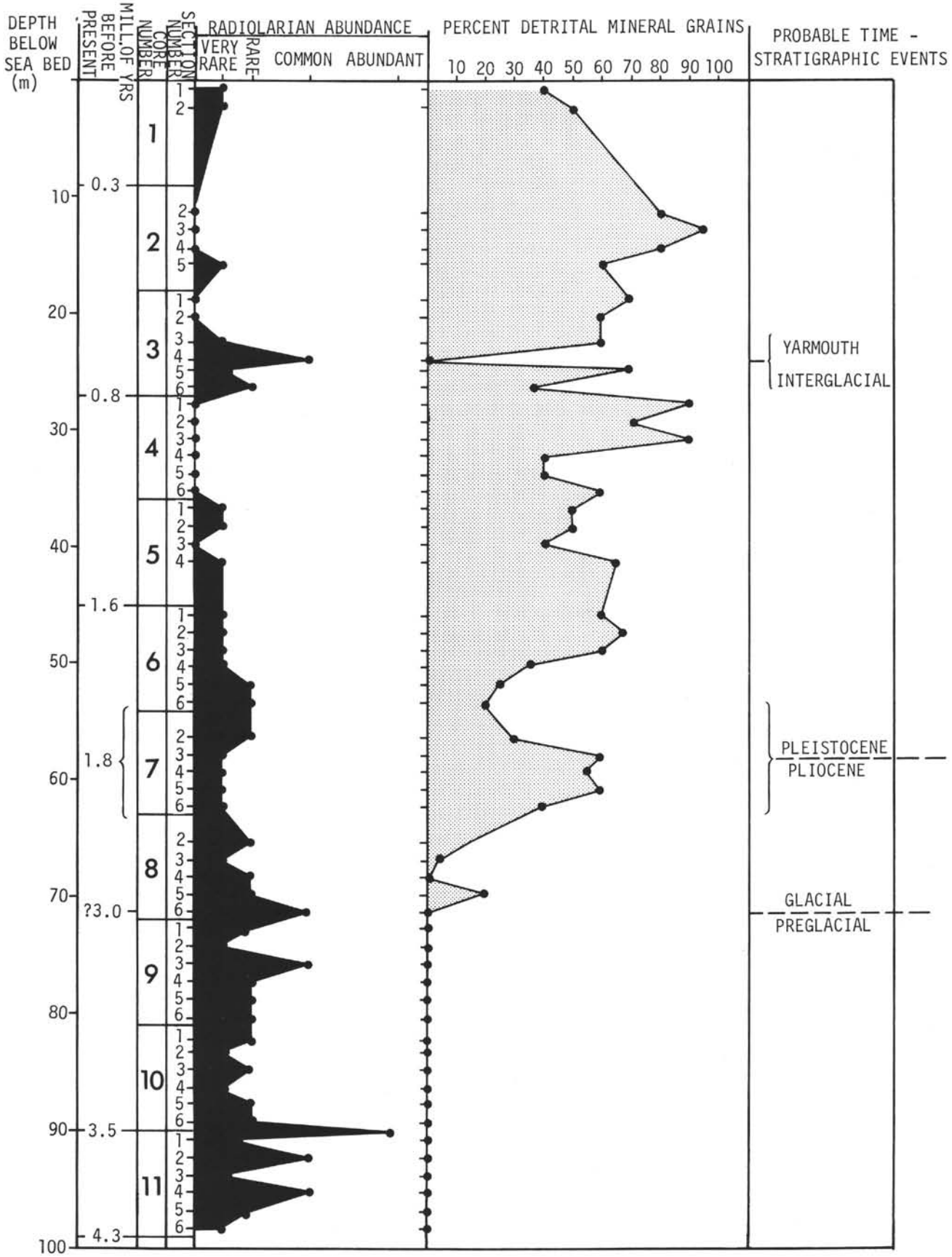

Figure 24. *Results of visual examination of HCL-insoluble, clay-free residues from Hole 116A.*

The persistent and occasionally common to abundant occurrences of *Cyrtocapsella japonica* (Nakaseko) and the absence of *Lithopera renzae* Sanfilippo and Riedel and *L. neotera* Sanfilippo and Riedel in Cores 7 and 8 place this interval questionably in the *Cannartus* (?) *petterssoni* Zone of middle Miocene age (compare Riedel and Sanfilippo, 1970, Figure 3, with Riedel and Sanfilippo, in press, Figure 2). Also indicative of a middle Miocene age is the concurrence of digitately branched with curved, flat *Oroscena* spines (Friend and Riedel, 1967).

The persistent occurrence of *Lithopera renzae* along with the irregular occurrences of *L. neotera* place Cores 9 and 10 within the *Dorcadospyris alata* Zone of early middle Miocene age (Riedel and Sanfilippo, in press, Figure 2). Because of the mobilization of biogenous silica in Core 11, no significant radiolarian species are present; therefore, zonal assignment is impossible for this core.

Several species which occur in the *Calocycletta virginis* Zone (Riedel and Sanfilippo, in press, Figure 2) are present in Cores 12 through 19 which are assigned to this zone of early Miocene (to Oligocene (?) in lowest part) age. These include *Lychnocanium bipes* Riedel, *Cyclampterium (?) pegetrum* Sanfilippo and Riedel, *Dorcadospyris simplex* (Riedel), *D. ateuchus* (Ehrenberg), *Cyclampterium*(?) sp. cf. *C.* (?) *milowi* Riedel and Sanfilippo (see radiolarian report of Site 112), *Cannartus prismaticus* (Haeckel), *Theocorys spongoconum* Kling, *Theocyrtis annosa* (Riedel), and *Carpocanopsis cingulatum* Riedel and Sanfilippo.

The absence or near absence of *Cyrtocapsella tetrapera* and *C. cornuta* and the very rare presence of *Lychnocanium bipes* and *Dorcadospyris ateuchus* place Core 20 within the *L. bipes* Zone of Oligocene age. The corroded radiolarians of Cores 21 and 22 are nondiagnostic; therefore, no age could be assigned to these cores.

EOCENE–LOWER OLIGOCENE

In the Lower Oligocene interval (116 – 23 to 25) the only Oligocene radiolarian present is *Cyclampterium* (?) *milowi* Riedel and Sanfilippo from 116 - 25 - CC. Late Eocene species identified from Cores 26 to 28 (Hole 116) include very rare specimens of *Tristylospyris triceros* (Ehrenberg), *Calocyclas semipolita semipolita* Clark and Campbell, *Spongasteriscus cruciferus* Clark and Campbell, *Spongurus bilobatus* Clark and Campbell, (?) *Sethochytris babylonis* (Clark and Campbell) group, *Heliodiscus heliastericus* Clark and Campbell, and *Lophoconus titanothericeraos* Clark and Campbell.

PALEONTOLOGY AND BIOSTRATIGRAPHY (117)

General

The sedimentary sequence cored at Site 117 represents Oligocene, Lower Eocene and Upper Paleocene. The Oligocene is a coccolith chalk with abundant bryozoan fragments. This chalk lies (? disconformably; 117-3-CC; 117A-1-1) on Lower Eocene shales in which foraminifera and radiolarians have been replaced by zeolites. The Upper Paleocene at Site 117 is represented by shales and silts, the latter composed of volcanic mineral grains and contains a neritic benthonic foraminiferal fauna (Figure 22), elements of which are found in the Paleocene of Europe and North America. Worm tubes, bryozoans and molluscan shells occur in varying abundance in these silts.

Separate reports dealing with the ostracods and bryozoans at Site 117 are presented at the end of this section.

Discussion

Foraminifera

Oligocene sediments at this location are characterized by a relatively low diversity planktonic foraminiferal fauna. Among the forms present are *Globigerina galavisi, G. angiporoides, G. prasaepis, Globigerinita unicava, G. dissimilis, G. pera, G. africana,* and *Globorotalia opima* s.s. and *G. opima nana.* Benthonic foraminiferal elements include *Heterolepa mexicana, Cibicidoides perlucida, Anomalinoides pompilioides, Vulvulina jarvisi.* The Lower Eocene sediments are characterized by a small planktonic foraminifera consisting of *Globigerina patagonica* and small indistinct acarininids. Characteristic benthonic foraminifera include *Anomalinoides grosserugosa, Osangularia pteromphalia* (the dominant form), *Anomalina acuta, Lenticulina decorata, Cibicidoides sulzensis, Cibicidoides propria* and *C. hercegovinensis.* The Upper Paleocene fauna is essentially similar to that recorded above but includes also *Anomalinoides danica, Allomorphina halli, Lenticulina midwayensis, Alabamina obtusa, Karreria fallax*, and *Vaginulina longiforma*. These faunas exhibit strong similarity to Paleocene/Lower Eocene faunas from the Gulf and Atlantic coastal plain of North America and from northwestern Europe.

Bryozoans and ostracods are abundant in the Upper Paleocene-Lower Eocene and Oligocene sediments at Site 117. These have been studied independently and the results are included as separate reports at the conclusion of this section. Other microfossils (oysters, gastropods and worm tubes) are common in Core 9 and attest to the relatively shallow water depths of the sediments immediately above the basaltic basement at this site. Specimens of a "larger foraminifera", *Operculina heberti,* occur in Core 117A-9; this is the northernmost reported occurrence of the genus and is a further indication of the relatively warm and shallow waters present in this area during Late Paleocene time.

Calcareous Nannoplankton

Miocene-Oligocene

The preservation of the coccoliths in most samples at this site is poor. In the Miocene-Oligocene part of the sequence, discoasters are scarce and calcified. Cores 1 to 3 (Hole 117) can be assigned to Early Miocene to Late Oligocene. They have all long-ranging species as *Cyclococcolithus neogammation, C. bisectus, Sphenolithus moriformis* in common, while I could not find enough age-diagnostic forms to decide on an age. As at Site 116, *Zygrhablithus* cf. *Z. bijugatus* is present and can attain a rockbuilding percentage. In some samples (117-2), *Chiasmolithus* sp. is abundant.

The core catcher of 117-3, the lowermost core of this hole, contains coccoliths of Early Eocene age, including *Discoaster kuepperi* and *D. lodoensis.* It is, however, mixed with coccoliths of Oligocene and ?Miocene age (*Discoaster*

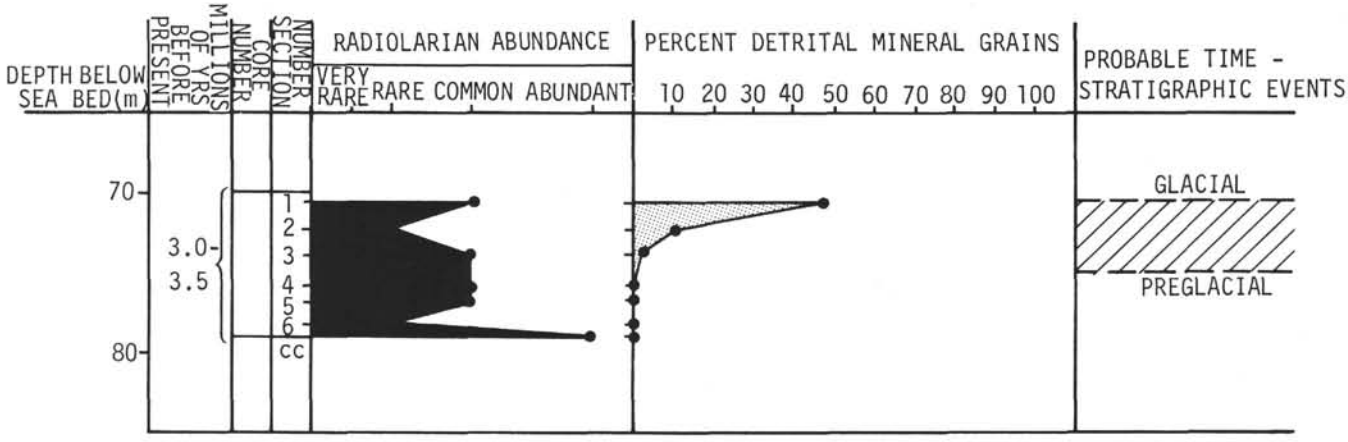

Figure 25. *Results visual examination of HCl insoluble-free residues from Core 1, Hole 116.*

exilis). In the top of this core a Late Oligocene assemblage including *Sphenolithus predistentus* was found. The same interval, with a nondeposition from Early Eocene to Late Oligocene, was cored in 117A-1.

Early Eocene – Late Paleocene

Cores 117A-2 to 10 contain a lower Eocene to upper Paleocene sequence including the zones of *Marthasterites tribrachiatus, M. contortus* and *Discoaster multiradiatus*. The assemblage from the *M. tribrachiatus* Zone can be compared with the Lower Eocene from Denmark. But here, as in the Oligocene, *Zygrhablithus* cf. *Z. bijugatus* is present. It does not reach the high percentages it reaches later. Also present and more frequent than in Denmark, are different species of the genus *Micrantholithus* and *Braarudosphaera,* indicating a restricted sea in the Late Paleocene - Early Eocene.

The oldest coccoliths found still indicate the presence of the *Discoaster multiradiatus* Zone. Thus, about 10 meters above the basalt core in Core 11, the sediment can be dated to be about 56 million years old.

Miscellaneous

In several samples of Late Oligocene, Early Eocene and Late Paleocene age, younger coccoliths were found (from the Miocene?). The mixing is probably due to the fact that chert fragments with adhering chalk kept falling down the hole from higher Oligocene-Miocene strata. No reworked Cretaceous coccoliths were found at this site.

Radiolaria

The only identifiable radiolarians *in situ* at Site 117 occur in Core 1 of Hole 117 and include *Cyrtocapsella tetrapera* Haeckel and *Anthocyrtium ehrenbergi ehrenbergi* (Stöhr) of Miocene age. One orosphaerid (*Oropelex* (?) sp., Oligocene-Lower Miocene) was recovered from the core water of 117-3.

In Hole 117A the only significant radiolarian occurrence is Core 2 of Eocene age. Here the unidentifiable, very abundant radiolarians, as well as sponge spicules, are completely replaced by zeolite. A similar but rare assemblage occurs in Core 4. Most of the remaining cores show some evidence of mobilization of biogenous silica. Dinoflagellate cysts are present in Cores 1, 3, 4 and 5. Cores 6, 7 and 8 are characterized by high percentages of organic matter in the HCl-insoluble residues.

The absence of radiolarians in the late Paleocene - early Eocene sediments of the 117A probably reflects the shallow water paleoenvironment at this time, and the abundant but zeolitized radiolarians of Core 2 may indicate the first signficiant deepening due to subsidence of Rockall Plateau.

Preliminary Report on the Ostracods of Holes 117 and 117A

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Abstract

Six samples obtained from upper Paleocene and Oligocene strata penetrated by adjacent DSDP Holes 117 and 117A on the Rockall Bank (57° 20.17′N; 15° 23.97′W; 1038 meters) have yielded over 300 ostracod specimens representing fourteen genera. Of these taxa nine are now living in the deep-sea, and the remainder are frequently found in "deep-water" fossil deposits. From consideration of the living distribution of the extant genera, the development of blindness with increasing depth, the absence of a typical shelf assemblage, and from an estimate and comparison of relative values of diversity, it is postulated that the Paleocene bottom was shallower than at present (from 100 to 600 meters depth), and that the Oligocene assemblage was formed under bathymetric conditions similar to those at present (1000 meters or more).

Introduction

Samples of Paleocene and Oligocene age from Holes 117 and 117A obtained from Rockall Bank have yielded specimens representing fourteen ostracod genera. Although the systematics and distribution of fossil deep-sea Ostracoda is far from well-known, the genera of these samples are familiar to me and their probable ecological limitations could be estimated. Some of these genera still have extant species in the modern oceans, and others are known from fossil "deep-water" assemblages. Characteristic morphological traits distinguish them from their contemporaries

inhabiting the sublittoral zone. These data can be used to infer the bathymetric ranges of the fossil ostracods of Rockall Bank during the Paleocene and Oligocene.

The Paleogene fossil record of the deep-sea (psychrospheric) ostracods is sparse. Specimens have been described from only a few core and dredge samples from the ocean floor. The assemblages from several surface outcrops in southern Europe and the Caribbean are known. Therefore the 300 well-preserved ostracod specimens from the samples of Holes 117 and 117A are particularly interesting. The Oligocene assemblage is remarkably similar to modern ones living at depths near 1000 meters. The Paleocene assemblage has a number of extinct genera that have been previously found in so-called "deep-water" deposits.

The status of knowledge of ostracods of the Atlantic Ocean floor has been given elsewhere (Benson, 1966, 1969). Information is accumulating rapidly (two generic names are given as *nomina nuda* here). Whereas a few years ago there were less than a hundred stations collected for ostracods from the world ocean floor, in making the present study I have referred to a data array with over 300 samples from the deep-sea (with 60 or more from the Atlantic shelf of North America). The base for the present comparison is considerable, and although the lower ends of the stratigraphic ranges of most taxa are incompletely known, some confidence can be placed in the statements of their broader environmental tolerances.

The purposes of the analyses were threefold: (1) to examine the modern depth distribution of taxa found in the cores; (2) estimation of the difference in relative species diversity between Recent shallow and deep assemblages, for comparison with that of the core samples; and (3) to determine the presence and absence of eye tubercules, representing the onset of blindness associated with increasing depth. From these analyses it was hoped that some estimate of the *in situ* depth of the samples could be made.

Material Studied

Hole 117: Cores 2, 3
Hole 117A: Cores 4, 7, 8
} 330 ostracod specimens

Data on the samples studied are listed in Table 6, which also includes the ages of the cores, the genera identified, and the counts of specimens belonging to each. The specimens were silicified in part, some were deformed by compaction, but most were very well preserved. More complete discussions of other aspects of the core samples are given elsewhere in this volume.

General Faunal Aspect

Of the fourteen genera identified from the Paleocene (nine) and Oligocene (eleven), nine contain still extant species. Although some of these genera are found in shallow deposits (*Echinocythereis* with eye tubercules, *Cytherella, Bairdia, Bythocypris*, and *"Hermanites"*), none is especially typical of shallow shelf environments. Forms restricted to shallow shelf deposits of the Paleocene of either Europe or North America are notably absent. However, some "deep-water" forms described from the Eocene portion of the Possagno section of northeastern Italy (Ascoli, 1969) of the London Clay (Bowen, 1953; also see Hazel, 1965) or from the Paleogene sections of Trinidad (Bold, 1957, 1960) are present. Specimens of *Trachyleberidea*, similar in the degree of fineness of their surface morphology to the ones of the present study, have been reported from a middle Eocene sample from a submarine canyon (*Gosnold* 2621C; Gibson, Hazel and Mello, 1968) in the Atlantic shelf of North America. This form is also known from the London Clay (Bowen, 1953). Specimens of *Agrenocythere hazelae*, which may be conspecific with those of the present study, have been described as *"Bradleya" hazelae* and *"Cythereis" hazelae* from northern Italy and Trinidad.

As shown in Table 6, there is a change in assemblage composition from the Paleocene samples (117A-7 and 8) to the Oligocene samples (117-2 and 3). The number of extant genera increases, and three extinct genera (*Phacorhabdotus*, *"Hermanites"*, and *Trachyleberidea*) disappear. The one form called *"Hermanites"* is related to several species known from North America (*"H." midwayensis* (Alexander), *"H." gibsoni* Hazel, and *"H." dohmi* (Howe and Chambers) according to Hazel (personal communication). It became extinct in the Atlantic by the Oligocene, but may have survived in the eastern Pacific (*"Cythereis" kewi* LeRoy; a "cold-water", upper-slope or outer-shelf inhabitant).

The number of blind members of the Oligocene assemblage increases to the exclusion of those with eye tubercules that are found in the Paleocene. Because as deep-sea (psychrospheric) ostracod taxa are both blind and have considerable longevity, this change in faunal aspect is interpreted as an increase in depth during Oligocene time.

The form called *Agrenocythere* (which is being described in manuscripts being prepared for publication) is of particular interest (Plate 11, Figure 5) as it occurs in many fossil localities of comparable age to the samples of Hole 117A. When it is found in abundance in modern oceans, the depths are usually more than 1000 meters and less than 2000 meters. At these depths it is blind, as are the specimens in the Oligocene samples of Hole 117.

It may be significant that forms such as *Abyssocythere* (Benson, 1971) and the antecedents to *"Cythere" acanthoderma*, two groups of species which are typically associated with very modern ostracod assemblages, are absent. This fact suggests some consistency in the depth ranges of deep-sea ostracods throughout the Tertiary.

The functional architecture of the ostracod carapace responds to the many factors involved with an increase in depth. Among these is the decrease in light and the corresponding loss of sight. Many of the species of the Paleocene samples had clear, functional eye tubercules, whereas those of the Oligocene samples were blind. More will be said about this subject in a later section. Also noteworthy is the usual increase in fragility (thinner walls and more intricate surface sculpture) of ostracod carapace with depth (corresponding to decreasing mechanical energy levels). Both Paleocene and Oligocene ostracod assemblages can be considered as having fragile carapaces, at least they are certainly not typical of inner shelf, high energy level environments.

In summary, the general aspect of the Oligocene ostracod assemblage suggests a deep-sea habitat (probably between 1000 and 1500 meters), and that of the Paleocene

TABLE 6
Specimen Counts

	Sample Level					
	Oligocene		Paleocene			
Hole	117			117A		
Core	2	3	4	4	7	8
Section	6	1	1	6	1	1
Interval (cm)	Bottom	30-35	42-67	101-105	95-100	130-134
Penetration (m)	110	150	250	250+	280	300
Depth below sea level (m)	1148	1188	1288	1288+	1318	1338
OSTRACODS						
Henryhowella	35					
Pterygocythere?	8					
**Poseidonamicus*	8					
Macrocypris	1					
Echinocythereis	1	2				
**Agrenocythere*	18				13	6
Krithe	15	2			2	1
Cytherella	9	1	1	12	7	8
Bairdia	16	3		2	13	16
Bythocypris	13	6		2	16	4
Hazelina	1 (?)	1			1	9
Trachyleberidea			1	5	14	20
"Hermanites"				1	14	20
Phacorhabdotus					1	1
Totals	125	15	2	22	81	85

*Proposed names of new genera now in manuscript.

assemblage (containing sighted individuals) to be shallower (deeper than 200 meters but shallower than 600 meters). The absence of typical shelf taxa, well known from the nearby continent, represents negative evidence against the likelihood that the sediments of Site 117 were very close to sea level during the Paleogene.

Modern Depth Distribution

From the presence of extant genera, such as *Agrenocythere, Echinocythereis, Henryhowella* and *Poseidonamicus*, in the Oligocene samples, and the absence of several common deeper dwelling forms, one can reconstruct the likelihood of past depth ranges; that is, assuming these have not changed substantially over the last 40 million years. I have selected these four genera because of their ease of identification and because distributions are reasonably well known. All four genera occur in Core 2 (see Table 6). These include *Henryhowella*, which is common to depths ranging from outer shelf to over 5000 meters, but blind forms occur only in the deeper part of the range; *Agrenocythere* (*nomen nudum*, concept includes forms related to "*Cythereis*" *hazelae* Bold, 1946, and "*Cythere*" *radula* Brady, 1880), most common to depths between 1000 and 1500 meters; *Poseidonamicus* (*nomen nudum*, concept includes forms related to "*Cythere*" *viminea* Brady, 1880), most common to depths over 2500 meters and never found in waters shallower than 1000 meters; and *Echinocythereis* (the species group associated with *E. echinata* Sars), which has a wide depth range but becomes blind below 600 meters. The summation of these frequency distributions is given in Figure 26 and is based on 222 recordings. Minimum depth records for the Recent distribution of each of the four genera are 300, 400, 1190 and 600 meters, respectively. It is interesting to note that the present Oligocene discovery represents the shallowest of some 85 such records for *Poseidonamicus*.

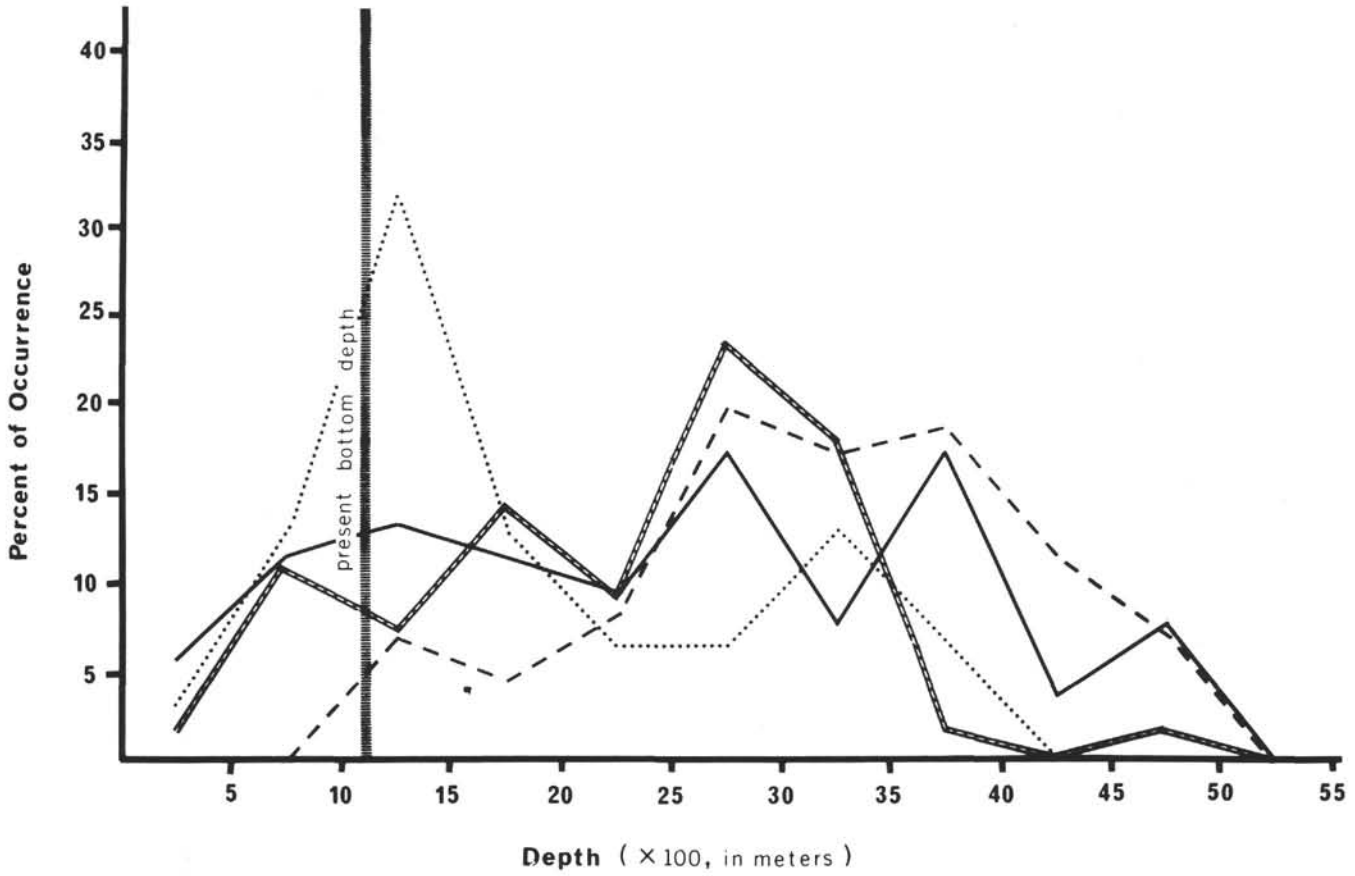

Figure 26. *The relative depth distribution, expressed in percentage of the likelihood of occurrence of each of four genera,* Agrenocythere *(dotted line),* Poseidonamicus *(dashed line),* Echinocythereis *(solid line) and* Henryhowella *(laddered line), at a given depth interval (500 meters) extending from sea level to 5500 meters depth. The present bottom depth of Site 117 (1038 meters) is also indicated.*

The frequency distributions given in Figure 26 represent the relative likelihood of finding any one of the above genera living within a particular depth interval of 500 meters over a range of depth from sea level to 5500 meters. The chance of finding any of the forms in waters shallower than 500 meters is nil to less than six per cent. Most of the genera are found typically in waters greater in depth than the present bottom at Site 117. However, *Agrenocythere* is most typical of waters of from 1000 to 1500 meters in depth. One might judge from this distribution, combined with the limits of range of the others, that their combined occurrence indicates bottom depths at least as great as 1000 meters.

Relative Species Diversity

Several methods for determining relative species diversity are available. The one used in the present study is the number of species (S) minus the number of species with only one specimen (S-s) found in each sample plotted as the ordinate, and the number of specimens of a given sample plotted as the abcissa. The result is a bivariant plot (Figure 27) of the likelihood of finding a particular number of species (those with more than one specimen) in a sample with a specified number of individual specimens, from either the psychrosphere (depth greater than 1000 meters) or the thermosphere (depths less than 500 meters). The plot shows a good separation between the tendency for Recent shallow ostracod assemblages to contain more species than deep ocean assemblages (more than twice as many in an abundant sample). With samples of fewer than 150 specimens the two curves of the plot begin to converge, however some tendency for the shallow samples to contain more species is still indicated.

These data are taken from the deep sea from all over the world and from the shelf of eastern North America. I believe that they are representative of the size range of samples and number of included species usually encountered. The plot of four of the more abundant core samples (solid triangles) on this distribution suggests that they tend toward the species diversity of deeper water assemblages. With the material at hand, however, this analysis is not conclusive. Larger samples are required.

Blindness

Although some shallow-water ostracods are blind, most have eyes. In many, this is observable through the presence of an optically clear eye tubercule. However, no psychrospheric ostracod assemblage has yet been found containing a species with eyes. With increasing depth, the eye tubercules atrophy and disappear. Because few genera transcend the boundary of the outer shelf and upper slope, examples of gradual atrophy are difficult to find. Eyes and

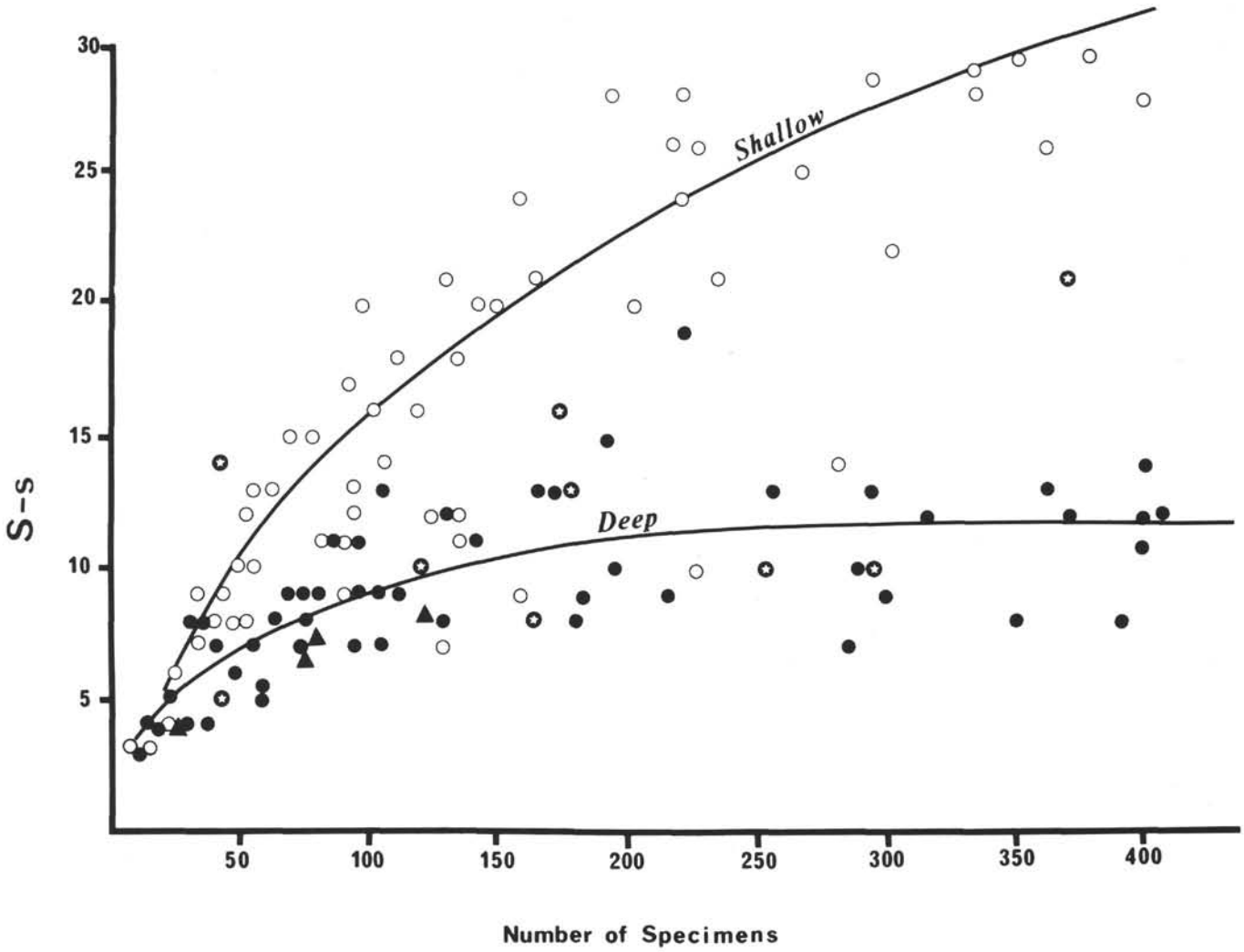

Figure 27. *The relative species diversity (see text for explanation) of ostracod assemblages from approximately 60 shelf samples (open circles) and 50 deep-sea (solid, > 1000 meters; and starred dots, 500 to 1000 meters). Four of the more abundant assemblages of the core samples of Hole 117A are plotted (solid triangles) for comparison.*

eye tubercules can be seen to disappear with depth in *Echinocythereis* sp. aff. *E. echinata* on the northern slope of the Gulf of Mexico. Blindness in this form occurs between 600 and 800 meters.

It seems reasonable to assume that a fossil assemblage of all blind species would indicate considerable depth, and one with all or many species with eye tubercules would indicate a shelf environment. From comparison of many possible species in living faunas (a somewhat hurried search through my collection), assemblages having species with eye tubercules would seem to live in waters shallower than 600 meters. Conversely, assemblages having all blind members lived at depths greater than 800 meters. The difference between the two levels represents a zone of change where the ocular structures disappear.

As shown in Plates 11 and 12 and in Figure 28, the preponderance of ornate ostracods (those in which eye tubercules would most likely be seen) of Paleocene age (Cores 7 and 8) found in 117A were sighted, and all of those of Oligocene age (Cores 2 and 3) were blind. This change in state of visual ability can actually be seen to occur in three of the genera (*Agrenocythere, Trachyleberidea* and *Hazelina*). These data suggest an increase in depth from Paleocene to Oligocene.

Conclusions

The relative species diversity, the Recent distribution of the genera present, and the increase in blindness of ostracods found in the Paleocene and Oligocene samples of Holes 117 and 117A, all indicate that Site 117 was probably shallower during the Paleocene than it is today, but that it was nearly as deep during the Oligocene as now. The absence of sublittoral ostracods typical of the shelf deposits of both Europe and North America during this time interval suggests that the depths were always greater than 100 meters. Ostracods with eye tubercules in the Paleocene assemblage indicate that depths at this time were less than 600 meters. The genera (all blind) found in the Oligocene samples are all known from the psychrosphere of the Recent Atlantic. They live in depths nearly as great as

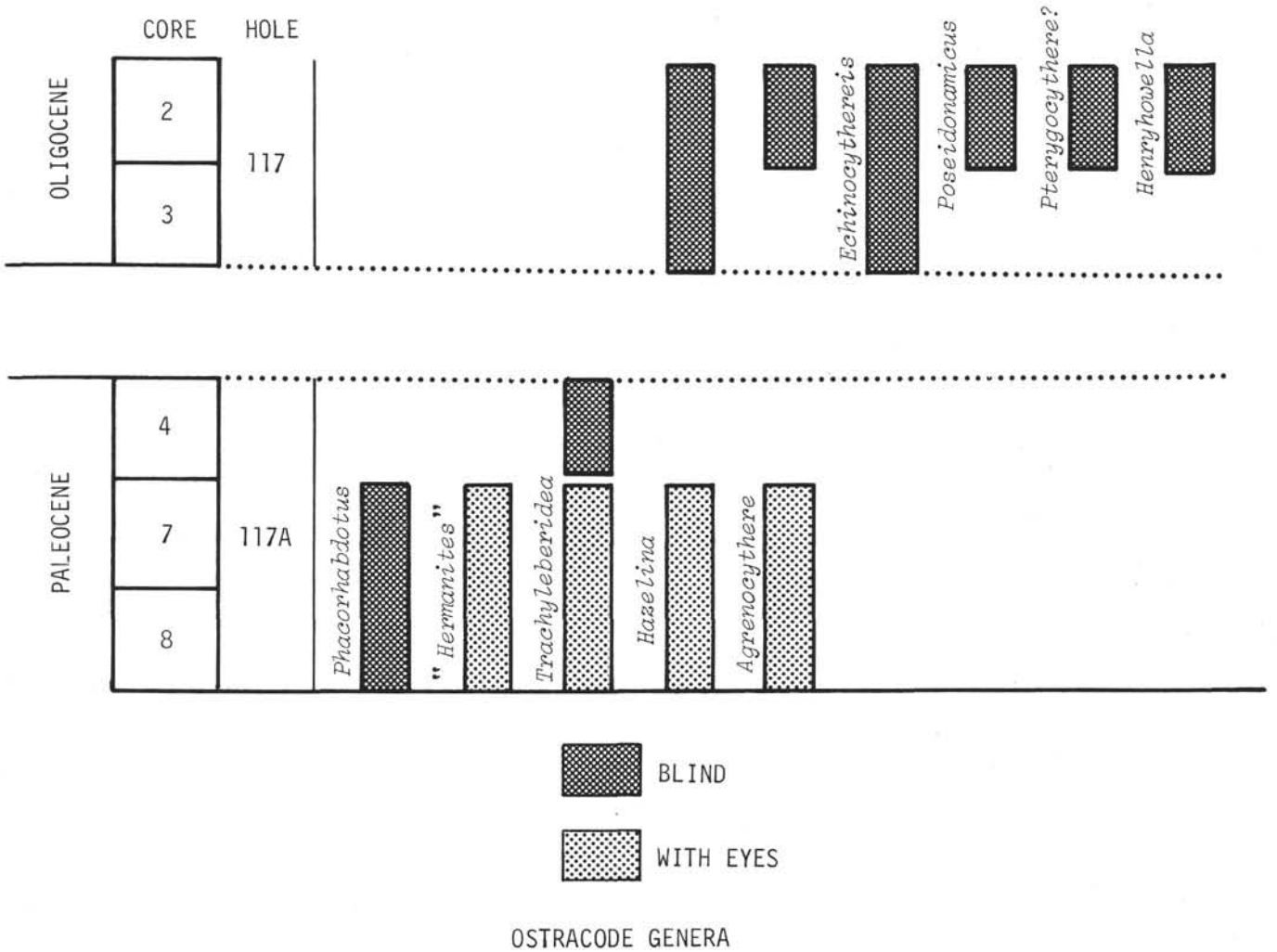

Figure 28. *The distribution of the more ornate ostracod genera within the sections represented by the cores of Holes 117 and 117A, showing their local stratigraphic ranges and also the presence or absence of eyes (eye tubercules) to indicate a change in depth of water sometime after the Paleocene and before the Oligocene.*

or greater than the present site of Hole 117A. This evidence indicates that downward tectonic displacement did occur as suggested by Laughton *et al.* (1970), but it was not in the order of magnitude suggested, and probably at an earlier time. The greatest sinking was probably during Eocene rather than during the Miocene.

ACKNOWLEDGMENTS

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Preliminary Report on Bryozoa (Site 117)

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Abstract

Seven samples from upper Paleocene and Oligocene sediments cored in two holes at Site 117 on the Rockall Plateau (lat 57° 20.17′N; long 15° 23.97′W; 1038 meters) yielded more than 10,000 bryozoans referable to the orders Cheilostomata and Cyclostomata. Preliminary study of the cheilostome specimens indicates that at least 94 species belonging to 68 genera are represented. Close biogeographic connections with both Europe and North America are suggested for the Paleocene assemblages, and closer

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connections with Europe than North America for the Oligocene ones. Few of the genera in the Paleocene assemblages and several in the Oligocene ones survive in modern oceans, and their Recent bathymetric distributions, together with the distribution of colony growth forms and species diversities, indicate probable restriction of these assemblages to sublittoral and upper bathyal depths. Changes in the assemblages are consistent with a progressive isolation of the Rockall Plateau and subsidence of the sea floor at Site 117 from slightly less than 60 meters to slightly more than 200 meters below sea level from late Paleocene to Oligocene time.

Introduction

Clays, sandy silts, and cherty limestones of late Paleocene and Oligocene age cored in Holes 117 and 117A on the Rockall Plateau yielded abundant, generally well-preserved bryozoans. More than 3500 specimens referable to the order Cheilostomata and nearly 7000 referable to the order Cyclostomata were recovered from seven samples of about 50 cc each.

The Paleogene record of Bryozoa, especially of cheilostomes, has been extensively documented from continental areas bordering the North Atlantic. Major taxonomic discordances, expressed at generic and familial as well as specific levels, are obvious in stratigraphic and biogeographic distributions as presently understood. Stratigraphically, one of the most profound changes is between Paleocene and Eocene assemblages in both Europe and North America (Larwood *et al.*, 1967); those from the Paleocene have a Cretaceous aspect markedly contrasting with the distinctly more modern aspect of those from the Eocene and Oligocene. For the most part, however, the most diversified of these assemblages occur well above or below the Paleocene-Eocene boundary, and the discovery of diversified faunas intermediate in position between the two would be important to interpretation of the evolutionary significance of this discordance. A similar discordance is also apparent in the biogeography of Paleogene cheilostomes, especially those in the Eocene and Oligocene, which show a pronounced separation of Old World and New World taxa. Many genera widespread in the Old World Paleogene, such as *Schizostomella* and *Orbitulipora*, have not hitherto been known to occur with New World Paleogene genera, such as *Leiosella*. Again, faunas intermediate in position between the continental margins of the Atlantic are potentially significant to understanding the evolution of cheilostomes. The Paleocene and Oligocene assemblages from Holes 117 and 117A partly fill these gaps and thus reveal some new relationships in cheilostome history.

This preliminary study of the cheilostomes in seven samples from Holes 117 and 117A indicates that more than 94 species belonging to 68 genera are represented. The abundance and species diversity of these assemblages are in general comparable to those of well-known Paleogene faunules from similar sediments in Europe and North America that have been inferred to have accumulated in sublittoral environments (Braga, 1963; Canu and Bassler, 1933, p. 24; Cheetham, 1963; 1966; Labracherie and Prud'homme, 1966; 1967).

Most of the cheilostomes from Holes 117 and 117A belong to undescribed species, and a few represent new genera. Even this preliminary taxonomic study, however, suggests biogeographic affinities with both western Europe and eastern North America and also indicates changes in the closeness of these relationships during the late Paleocene-late Oligocene interval represented. Some of the genera and one of the species represented survive in modern oceans, and their Recent bathymetric distributions indicate restriction of these assemblages to depths several hundred meters shallower than the present sea floor at Site 117. Changes in the paleoenvironments of these assemblages can be inferred from differences in taxonomic composition, species diversity, and relative abundances of colony growth forms.

Oligocene Bryozoa from Hole 117

Nearly 4000 bryozoan specimens representing 48 species of cheilostomes and an undetermined number of species of cyclostomes were obtained from 117-2 and 3 (Table 7 and Plates 13 through 20). More than half the specimens are cheilostomes. A few specimens are silicified and all are fragmentary, but preservation for the most part is excellent. An exception is the badly abraded and partially leached single specimen of *Lunulites* sp. (Table 7; Plate 13, Figure 3), which may have been reworked, possibly from Eocene sediments no longer present at Site 117. Cores 2 and 3 have been assigned, on foraminiferal and nannofossil evidence discussed elsewhere in this volume, to the upper Oligocene, ?*Sphenolithus ciperoensis* and ?*S. distensus* Zones.

The abundance and species diversity of the faunule in the older of the two upper Oligocene samples are comparable to those of many well-known late Paleogene assemblages, such as those in the Castle Hayne Formation of North Carolina, Ocala Group of Florida, Marianna Limestone of Alabama, Upper Bracklesham Beds of Sussex, St. Estéphe Limestone of the Aquitaine, and Priabona Marl of northern Italy. The younger sample has only about half of the abundance and diversity of the older one, but shares all but two of 18 species with it. There are no apparent differences in the known stratigraphic ranges of species which occur in one sample but not the other.

The late Oligocene assemblages from Hole 117 combine Old World and North American elements. Sixteen species have Old World affinities, especially with western Europe; five have North American affinities; and three are known from both Europe and North America. Most of the species, however, are not directly comparable with previously described cheilostomes. Compared to late Paleogene assemblages in Europe and North America, these faunules conspicuously lack genera having modern representatives restricted to tropical and subtropical zones. On the other hand, some of the species have numerical dominance in both samples belong to genera, such as *Adeonellopsis* and *Floridina*, that are at present most common in tropical to warm-temperate regions. Possible representatives of cool-water genera, such as *Microporina* and *Escharella*, are much less common in these assemblages.

The Recent bathymetric distributions of seven genera and one species characteristic of the late Oligocene assemblages suggest with high probability that this association of taxa represents sublittoral depths (Figure 29). Abundance

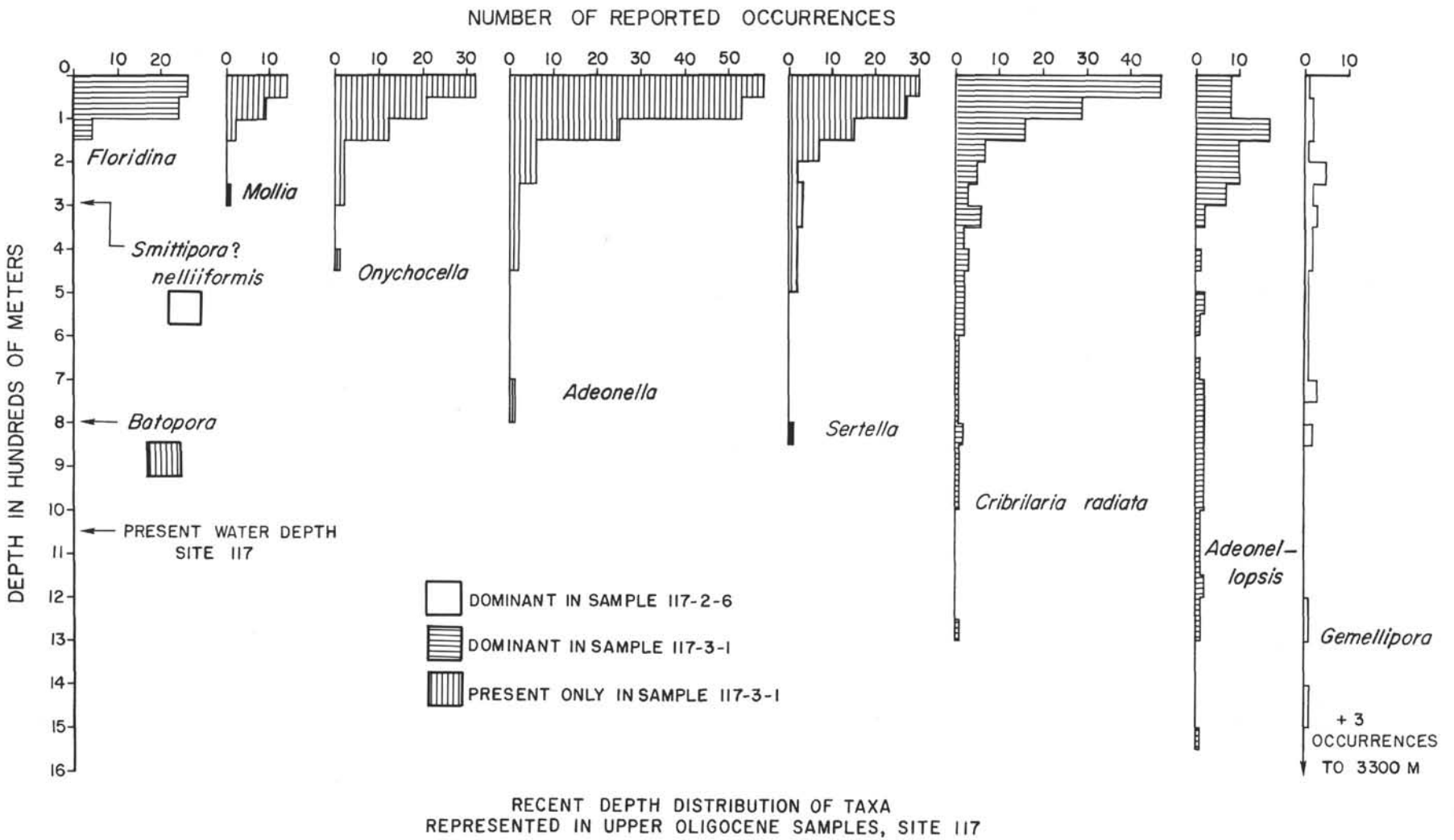

Figure 29. *Recent depth distribution of taxa represented in Oligocene samples, Site 117.*

of *Floridina* in both upper Oligocene samples might be evidence that water depths were less than 150 meters for both, except that many more species of this genus lived in Paleogene time than do now and hence its total depth range may have been significantly greater than that of Recent species alone. The peak occurrences of *Adeonellopsis* (100 to 150 meters) and *Gemellipora* (200 tp 250 meters) make an outer sublittoral depth of 150 to 200 meters more likely to have included this association of taxa. Moreover, the single known occurrence of *Smittipora? nelliiformis*, with which the species abundant in the younger sample compares closely in both zooecial and zoarial morphology, is at 289 meters in an area that has been extensively sampled through a great range of depths (Harmer, 1926). It seems unlikely that the late Oligocene assemblages lived at depths as great as suggested by the single known Recent occurrence of *Batopora* (804 meters; Cook, 1966); Paleogene species of *Batopora* occur with genera, such as *Poricellaria*, that are restricted in modern seas to depths less than 100 meters.

The species diversity of the older of the two late Oligocene assemblages from Hole 117 also suggests outer sublittoral depths. At Recent stations below 200 meters, the total number of bryozoan species is generally less than 40 per station (Schopf, 1969), whereas the cheilostomes alone total 46 species in Sample 117-3-1. The younger of the late Oligocene assemblages probably represents a depth exceeding 200 meters, as indicated by its considerably lower diversity, by the greater abundance in it of *Gemellipora* and *Smittipora*? aff. *S.*? *nelliiformis*, and by the absence from it of *Mollia, Onychocella*, and *Adeonella*. Its diversity is not, however, low enough to suggest depths in excess of 600 meters.

Both upper Oligocene samples contain high proportions of delicately erect, rigid colonies (adeoniform and vinculariiform, Table 8), commensurate with growth in little-agitated water. The most conspicuous differences between the two samples are the much lower percentage of membraniporiform specimens and the much higher proportion of cellariiform specimens in the younger sample. The rarity, relative to the older sample, of membraniporiform colonies reflects a decrease in grain size of the sediment available for encrustation, as would be expected with increasing depth. Increase in percentage of cellariiform (jointed) colonies commonly occurs with decreasing depth, but it is also associated with increasing proportions of loose, fine-grained sediment (Lagaaij and Gautier, 1965).

The abundance in both late Oligocene assemblages of taxa having overlapping bathymetric ranges makes it improbable that either assemblage represents a depositional mixture of shallow- and deep-water cheilostome species, such as appear to occur in upper Eocene strata in Tonga (Cheetham, in press).

Late Paleocene Bryozoa from Hole 117A

Nearly 7000 specimens representing 47 species of cheilostomes and an undetermined number of species of cyclostomes were obtained from Hole 117A, Cores 4, 7 and 8 (Table 7 and Plates 21 through 28). One species only, *Cribrilaria radiata*, appears also to be present in the upper Oligocene samples from Hole 117 (a single fragment in Sample 117A-4-1 at 127 to 132 centimeters of *Craspedozoum*? sp., characteristic of the late Oligocene assemblages, is probable a contaminant). In contrast to their dominance in the late Oligocene bryozoan assemblages, cheilostomes comprise less than one-quarter of the bryozoan specimens in the late Paleocene faunas. The abundance, species diversity, and general aspect of the assemblages are similar to those of the upper Paleocene Vincentown Formation of New Jersey, but only a few of the species are closely related to Vincentown forms. The most consistently occurring species in the assemblages from Hole 117A, *Coscinopleura* sp., "*Beisselina*" sp., and *Smittipora*? sp. 3, are probably more closely related to European than to North American species of these genera.

In abundance, diversity, taxonomic composition, preservation, and colony forms the five assemblages fall in three groups that can conveniently be discussed separately (Table 7): (1) an upper group comprising the two younger samples from Core 4; (2) a middle sample, the oldest one from Core 4; and (3) a lower group comprising the samples from Cores 7 and 8. The age of all these assemblages has been determined, from foraminiferal and nannofossil evidence discussed elsewhere in this volume, as late Paleocene, *Globigerina triloculinoides-Discoaster multiradiatus* Zone.

The cheilostomes in the upper group of samples include at least 25 species. Abundance is markedly lower than in the lower group, but preservation is the best of any of the late Paleocene assemblages, and morphologic detail is comparable to that in the late Oligocene cheilostomes. Although the species compositions of the two samples assigned to this assemblage differ, both include the same abundant species. Of the 10 species having recognizable affinities, six have a Cretaceous-Paleocene aspect, and four an Eocene or younger aspect. Biogeographic affinities are about evenly divided between Europe and North America, with a high proportion (seven of 25) of species probably having affinities with both sides of the Atlantic. The high proportion of extinct genera in this assemblage makes its paleoenvironment difficult to interpret. Four taxa, *Floridina, Mollia, Cribrilaria radiata* and *Poricellaria*, have Recent representatives, all of which are common at sublittoral depths (see Figure 29 for depth distributions of the first three). The presence of *Poricellaria* is especially significant, for its modern representatives are tropical, reef-associated forms not found at depths exceeding 60 meters (Harmer, 1926). In colony forms, this assemblage is similar to the older of the two late Oligocene assemblages, except for lacking reteporiform colonies.

The middle sample of the upper Paleocene sequence yielded not only the smallest number of specimens but also the fewest species (five). None of the species is distinctive of the assemblage; four occur in the upper group, four in the lower group, and three in both. No species having an Eocene or younger aspect is present. Preservation is the poorest of all the samples, many of the specimens being conspicuously abraded. This and the dominance of stout colonies (exchariform; see Table 8) suggests that many of the specimens could have been reworked.

The lower late Paleocene assemblage includes the largest number of species, 32; of these, eleven also occur in the higher samples. Abundance is higher than in the other

TABLE 7
Specimen Counts of Bryozoa from Leg 12, Site 117

	Oligocene Sample Level								
	Oligocene		Upper Paleocene						
Hole	117		117A						
Core	2	3	4	4	4	7	8		
Section	6	1	1	1	6	1	1		
Interval Sampled	Bottom	30-35cm	62-67cm	127-132cm	101-105cm	95-100cm	130-134cm	Inferred Colony Form[a]	Previously Known Distribution of Species or Related Species
Penetration	110m	156m	270m	270m	271m	286m	295m		
CHEILOSTOMATA									
Smittoidea sp. 2	3	–	–	–	–	–	–	V	
Dittosaria prima (Reuss)	8	–	–	–	–	–	–	C	Upper Eocene, North America; Oligocene, Europe
Membraniporidra aff. *M. similis* Canu & Bassler	2	82	–	–	–	–	–	M	Upper Eocene-Oligocene, North America
Antropora? oculifera (Canu & Bassler)	3	40	–	–	–	–	–	M	Middle Europe, Europe
Smittipora? aff. *S.? nelliiformis* (Harmer)	142	21	–	–	–	–	–	C	Recent, Indo-Pacific
Floridina sp. 1	45	190	–	–	–	–	–	M	
F. sp. 3	3	43	–	–	–	–	–	M	
Setosella fragilis Canu	1	8	–	–	–	–	–	C	Middle-Upper Eocene, Europe
Cellaria sp.	73	114	–	–	–	–	–	C	
Craspedozoum? sp.	55	96	–	1[b]	–	–	–	E	
Scrupocellaria elliptica (Waters) Waters, *not* Reuss	7	7	–	–	–	–	–	C	Upper Eocene, North America; Upper Eocene-Oligocene, Europe
Adeonellopsis subteres (Roemer)	78	329	–	–	–	–	–	A	Upper Eocene-Oligocene, Europe
Schizostomella aff. *S. lontensis* (Waters)	26	120	–	–	–	–	–	A	Upper Eocene-Oligocene, Europe
Sertella marginata (Reuss)	29	70	–	–	–	–	–	R	Upper Eocene-Oligocene, Europe
Sparsiporina elegans (Reuss)	40	20	–	–	–	–	–	R	Upper Eocene-Oligocene, Europe
Gemellipora sp.	18	7	–	–	–	–	–	C	
pasytheid, new genus	75	25	–	–	–	–	–	C	
Membraniporidra aff. *M. porrecta* Canu & Bassler	–	2	–	–	–	–	–	E	Upper Eocene, North America
Lunulites sp. 1	–	1[c]	–	–	–	–	–	L	
Onychocella aff. *O. laciniosa* Canu & Bassler	–	13	–	–	–	–	–	M	Upper Eocene, North America

Smittipora? sp. 2	–	48	–	–	–	–	–	V	–
Floridina sp. 3	–	2	–	–	–	–	–	M	–
Mollia sp. 1	–	4	–	–	–	–	–	M	–
Rosseliana? sp.	–	7	–	–	–	–	–	M	–
Microporina? aff. *M.? polysticha* (Reuss)	–	29	–	–	–	–	–	C	Upper Eocene-Miocene, Europe
Stoganoporella sp.	–	2	–	–	–	–	–	V	
Gephyrotes? aff. *G.? convexa* Canu & Bassler	–	3	–	–	–	–	–	M	Upper Eocene, North America
Corbulipora? sp.	–	10	–	–	–	–	–	M	–
Hippopleurifera sp.	–	1	–	–	–	–	–	M	–
Escharoides sp. 1	–	2	–	–	–	–	–	M	–
E. sp. 2	–	1	–	–	–	–	–	M	–
Perina sp.	–	23	–	–	–	–	–	V	–
Tubucella cf. *T. papillosa* (Reuss)	–	13	–	–	–	–	–	A	Upper Eocene-Miocene, Europe
Adeonella ornatissima (Stoliczka)	–	121	–	–	–	–	–	A	Oligocene, Europe
Schizostomella aff. *S. curryi* Cheetham	–	51	–	–	–	–	–	E	Upper Eocene, Europe
Cleidochasma sp.	–	2	–	–	–	–	–	M	–
Dakaria? sp.	–	3	–	–	–	–	–	V	–
Schizomavella aff. *S. trigonostoma* Cheetham	–	6	–	–	–	–	–	V	Upper Eocene, Europe
Escharella aff. *E. selseyensis* Cheetham	–	2	–	–	–	–	–	V	Middle-Upper Eocene, Europe
E. sp. 2	–	3	–	–	–	–	–	M	–
Smittoidea variabilis (Canu)	–	30	–	–	–	–	–	E	Middle-Upper Eocene, Europe
Bactridium? sp.	–	1	–	–	–	–	–	E	–
Leiosella aff. *L. rostrifera* Canu & Bassler	–	11	–	–	–	–	–	V	Oligocene, North America
Hemiphylactella? sp.	–	5	–	–	–	–	–	V	–
Orbitulipora sp.	–	1	–	–	–	–	–	O	Upper Eocene-Oligocene, Europe
Batopora sp.	–	2	–	–	–	–	–	O	Upper Eocene-Oligocene, Europe Recent, Indo-Pacific
ascophoran, genus A indeterminant	–	4	–	–	–	–	–	E	–
Cribrilaria radiata (Moll)	1	10	2	–	–	10	–	M	Upper Eocene-Recent, North America-Europe
Periporosella? sp. 1	–	–	1	1	5	–	–	M	Paleocene, North America
Stamenocella sp.	–	–	1	4	–	–	–	C	–

[a] A = adeoniform; C = cellariiform; E = eschariform; L = lunulitiform; M = membraniporiform; O = orbituliporiform; R = reteporiform; V = vinculariiform.
[b] Caved? not counted in total.
[c] Reworked? not counted in total.

TABLE 7 – *Continued*

	Oligocene Sample Level								
	Eocene		Upper Paleocene						
Hole	117		117A						
Core	2	3	4	4	4	7	8		
Section	6	1	1	1	5	1	1		
Interval Sampled	Bottom	30-35cm	62-67cm	127-132cm	101-105cm	95-100cm	130-134cm	Inferred Colony Form[a]	Previously Known Distribution of Species or Related Species
Penetration	110m	156m	270m	270m	271m	286m	295m		
Smittipora? sp. 4	–	–	3	–	–	–	–	V	–
S.? sp. 5	–	–	10	11	–	–	–	V	–
Floridina sp. 6	–	–	16	9	–	–	–	V	–
F. sp. 7	–	–	–	2	–	–	–	M	–
onychocellid, genus B indeterminate	–	–	1	–	–	–	–	V	–
microporid, genus indeterminate	–	–	2	–	–	–	–	V	–
Semieschariella? sp. 2	–	–	–	1	–	–	–	C	Cretaceous-Paleocene, Europe;
	–	–	–	1	–	–	–	C	Paleocene, North America
Pericellaria sp.	–	–	–	1	–	–	–	C	Cretaceous-Miocene, North America; Paleocene, Recent Old World
Pachythecella? sp.	–	–	4	3	–	–	–	V	–
Schizostomella? sp. 1	–	–	–	2	–	–	–	V?	Middle Eocene-Pliocene, Europe Europe (?)
S.? sp. 2	–	–	–	1	–	–	–	V?	Middle Eocene-Pliocene, Europe (?)
vittaticellid, new genus	–	–	2	1	–	–	–	C	Middle Eocene-Recent (?)
ascophoran, genus B indeterminate	–	–	–	1	–	–	–	M?	–
Membraniporidra? sp.	–	–	5	5	–	–	44	M	–
Smittipora? sp. 3	–	–	12	9	2	8	17	C	–
S.? sp. 7	–	–	12	28	–	12	–	V	–
Floridina sp. 4	–	–	1	–	–	1	6	M	–
Mollia sp.2	–	–	5	7	–	–	46	M	–
Semieschariella? sp. 1	–	–	1	2	–	1	5	C	Cretaceous-Paleocene, Europe,
	–	–			–				Paleocene, North America
Coscinopleura sp.	–	–	11	18	64	33	1(?)	E	Cretaceous-Paleocene, Europe (<Paleocene, North America)[d]
Pliophloea sp.	–	–	5	5	–	3	7	M	Cretaceous-Paleocene, Europe; Paleocene, North America

"Beisselina" sp.	–	–	28	53	19	183	20	A	Cretaceous-Paleocene, Europe (<Paleocene, North America)[d]
Ellisina? sp	–	–	–	–	2	22	2	M	–
calloporid, genus indeterminate	–	–	–	–	–	19	101	M	–
Periporosella? sp. 2	–	–	–	–	–	23	8	M	Paleocene, North America
Pithodella sp.	–	–	–	–	–	1	–	E	Cretaceous-Paleocene, Europe
Stamenocella cf. *S. "oculata* Ulrich & Bassler"	–	–	–	–	–	5	13	C	Paleocene, North America
Lunulites sp. 2	–	–	–	–	–	–	1	L	Cretaceous-Paleocene, Europe
L. sp. 3	–	–	–	–	–	–	2	L	Cretaceous-Paleocene, Europe
L. sp. 4	–	–	–	–	–	1	–	L	Cretaceous-Paleocene, Europe
L. sp. 5	–	–	–	–	–	27	–	L	Eocene, North America
Smittipora? sp. 6	–	–	–	–	–	4	–	V	–
Floridina sp. 5	–	–	–	–	–	70	8	M	–
cnychocellid, genus A indeterminate	–	–	–	–	–	27	–	M	–
Pliophloea? sp.	–	–	–	–	–	–	2	M	–
Kelostoma aff. *K. elongatum* Marsson	–	–	–	–	–	–	3	M	Cretaceous, Europe
K.? aff. *K.? simplex* Canu & Bassler	–	–	–	–	–	–	2	M	Paleocene, North America
Tricephalopora? sp.	–	–	–	–	–	–	2	M	
Castanopora? sp.	–	–	–	–	–	1	–	–	Cretaceous-Paleocene, Europe, North America
Balantiostoma cf. *B. septentrionalis* (Canu & Bassler)	–	–	–	–	–	–	7	M	Cretaceous-Paleocene, Europe, North America
Pachythecella sp.	–	–	–	–	–	5	25	V	Cretaceous-Paleocene, Europe
Smittoidea? sp.	–	–	–	–	–	–	2	V?	Eocene-Recent (?)
smittinid?, genus indeterminate	–	–	–	–	–	–	2	E?	Eocene-Recent (?)
Fissuricella sp.	–	–	–	–	–	–	3	M	Cretaceous-Paleocene, Europe
indeterminate membranimorphs	–	–	–	1	–	–	111	M	–
Indeterminate *Floridina*-like forms	–	–	8	–	–	–	3	M	–
indeterminate coilostegans	–	–	–	–	1	–	1	–	–
indeterminate acanthostegans	–	–	4	1	–	2	1	M	–
indeterminate ascophorans	–	–	–	–	2	1	1	–	–
indeterminate cheilostomes	–	–	32	10	2	11	7	–	–
CYCLOSTOMATA	556	1084	1212	1208	732	775	1379	–	–
TOTAL BRYOZOA	1165	2669	1378	1385	829	1245	1832	–	–

[a] A = adeoniform; C = cellariiform; E = eschariform; L = lunulitiform; M = membraniporiform; O = orbituliporiform; R = reteporiform; V = vinulariiform.
[d] Less indicative of Paleocene in North America.

TABLE 8
Percentages of Cheilostome Specimens of Inferred Colony Forms, Leg 12, Site 117

	Sample Level						
	Oligocene		Upper Paleocene				
Hole	117		117A				
Core	2	3	4	4	4	7	8
Section	6	1	1	1	6	1	1
Interval Sampled	Bottom	30-35cm	62-67cm	127-132cm	101-105cm	95-100cm	130-134cm
COLONY FORMS							
Membraniporiform	8.86	26.07	23.13	13.85	7.60	38.86	83.56
Lunulitiform	0.00	*	0.00	0.00	0.00	6.11	0.46
Orbituliporiform	0.00	0.18	0.00	0.00	0.00	0.00	0.00
Cellariiform	41.05	5.61	11.94	10.84	2.17	3.05	8.45
Retoporiform	11.33	5.68	0.00	0.00	0.00	0.00	0.00
Eschariform	9.03	11.61	8.20	10.84	69.56	7.42	0.70
Adeoniform	17.07	36.81	20.89	31.92	20.65	39.65	0.46
Vinculariiform	12.65	14.02	35.82	32.53	0.00	4.58	6.33

*1 specimen (reworked?)

upper Paleocene samples and nearly as high as in one of the upper Oligocene ones. Preservation is variable, both samples containing some well-preserved specimens, some that are crushed, and some that are coated with sparry calcite. The species compositions of these two samples differ more than do those of the two samples making up the upper group. Sixteen species have recognizable Cretaceous-Paleocene affinities. *Cribrilaria radiata,* one species of *Lunulites*, and possibly *Smittoidea*? sp. and the indeterminate smittinid are the only ones having an Eocene and younger aspect. The biogeographic affinities are slightly more toward Europe than North America, but with ten of the 32 species having close relationships with both sides of the Atlantic. Depth-diagnostic taxa are virtually absent; the presence of *Mollia* and *Cribrilaria radiata* is consistent with a depth no greater than the maximum of 60 meters inferred for the upper group of samples, but there is no positive taxonomic evidence that the lower assemblage did not live at greater depths. The high percentage of membraniporiform and lunulitiform specimens and the low percentage of vincularii-form ones suggest, however, that this was probably the shallowest cheilostome assemblage at Site 117.

The taxonomic differences between the upper and lower assemblages appear to be related more to age than to environment, the upper one including a significantly larger number of species having an Eocene and younger aspect than the lower one does. The presence of *Poricellaria* in the upper group indicates that the depth at which the late Paleocene assemblages lived was not deeper than 60 meters, but nothing in the fauna indicates that the depth was much less than that.

Conclusions

The changing taxonomic compositions and proportions of colony forms of late Paleocene and late Oligocene assemblages of cheilostome Bryozoa from Holes 117 and 117A are generally consistent with a history of subsidence for the Rockall Plateau.

Progressive isolation of this area from the eastern and western margins of the North Atlantic is reflected in the decreasing proportions of species with recognizable European and North American affinities during the portion of Paleogene time represented by bryozoan-bearing sediments at Site 117. The decline in relationships with North America is more pronounced; species with North American or amphi-Atlantic affinities comprise 41 per cent of the late Paleocene assemblages and 17 per cent of the late Oligocene ones. The decrease in faunal similarities with Europe is less severe; European-related and amphi-Atlantic forms comprise 44 per cent of the late Paleocene assemblages and 40 per cent of the late Oligocene ones. This difference in rates of faunal isolation is in keeping with the present geographic position of the Rockall Plateau. The high rate of change of amphi-Atlantic species alone, from 31 per cent in the late Paleocene assemblages to 6 per cent in the late Oligocene ones, suggests that isolation of this area may have been directly involved in reducing transatlantic faunal interchange.

Progressive subsidence of the Rockall Plateau from inner sublittoral to upper bathyal depths is indicated by the depth distributions of Recent representatives of taxa included in the late Paleocene and late Oligocene assemblages and by changes in their proportions of colony forms.

The youngest Paleocene assemblage probably accumulated in not more (but not much less) than 60 meters of water, to judge by the few extant shallow-water taxa and the prevalence of rigidly erect colonies in it. The absence of depth-diagnostic extant taxa from the oldest late Paleocene assemblage makes its interpretation more unsure, but its more abundant encrusting colonies, significant number of lunulitiform ones, and rare delicately erect ones all perhaps suggest a slightly shallower depth. Both late Oligocene assemblage contain a number of extant taxa that suggest depths of about 200 meters; the high diversity and greater abundance of shelf-characteristic taxa in the older assemblage indicate a depth of 150 to 200 meters, whereas the low diversity and greater abundance of upper-bathyal characteristic taxa in the younger assemblage indicate a depth greater than 200 meters but probably considerably less than 600 meters. Thus, water depth at Site 117 appears to have increased from slightly less than 60 meters to slightly more than 200 meters during the late Paleocene-late Oligocene time interval represented by the seven samples studied.

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Preliminary Results of a Quantitative Micropaleontological Analysis (116, 117)[4]

Introductions

A quantitative micropaleontological analysis is being made of 96 samples from Sites 116 and 117 (52 of Hole 116, 22 of Hole 116A, 4 of Hole 117, and 16 of Hole 117A). The washed residue (coarser than 105 microns) of each sample was split over a sample-splitter until a representative cut was obtained which was small enough to have its complete microfaunal contents counted without running into numbers too high. Some samples yielded few fossils, so that the entire sample could be counted and no split was needed. Most samples had to be split several times before a workable size was obtained.

Procedure

Until now, three parameters have been determined on this material (see Figures 30, 31 and Table 9):

1. The percentage of planktonic foraminifers in the total foraminiferal fauna (plankton/benthos relation). N_1 in Table 9 gives the total number of specimens used in determining the percentage; this is the complete "end split".

2. The percentage of ostracods in the number of ostracods plus benthonic foraminifers (ostracod/foraminifer relation). N_2 in Table 9 gives the number of specimens used to compute this percentage. Because planktonic foraminifers dominate most samples the last split had only few benthonics, and ostracods and additional material had to be included in the count. In most cases it was sufficient to use the second half of the last split. For these reasons N_2 does not compare with N_1.

3. The percentage of siliceous plankton in the total planktonic fauna and flora larger than 105 microns. N_3 of Table 9 is the number of specimens on which this percentage is based.

The results of the calculations are graphically presented in Figures 30 and 31. Work is in progress to determine also the diversity and dominance of the benthonic foraminiferal fauna. An interpretation of the present results (and also of the additional future results), still can only be speculative. It is not possible yet to distinguish which of the physical (hydrostatic pressure, temperature, turbidity), chemical (salinity, *p*H, nutrients) or biological (nutrients, predators) properties of seawater influence a particular value of the calculated parameters, and to which amount. For instance, a high percentage of planktonic foraminifers can be indicative for normal deep water or for nutrient-rich (phytoplankton blooming) shallower water (Bandy *et al.*, div. publ.). In other words, the changes we see in coming up section in Figures 30 and 31 do not necessarily reflect changes in water depth but could also be the results of changes in ocean current pattern, climate etc. Even assuming that we can draw conclusions on the depth of deposition, studies of the Recent are too scarce to allow for a detailed interpretation.

The conclusions below are mainly based on data published by Grimsdale and van Morkhoven (1955) for the Gulf Coast and the North Atlantic, who relate the above percentages to the depth of water overlying the seabed at the time of deposition. Their findings were basically confirmed in several subsequent investigations, but the depth limits may vary for different areas. For instance, higher plankton percentages were found in material from the Snellius Expedition (West Pacific and Indian Ocean): samples from water deeper than 1000 meters have more than 95 per cent of planktonics, 99 to 90 per cent planktonics are present in samples from 1000 to 500 meters, 95 to 70 per cent in samples from 500 to 350 meters, 70 to 40 per cent in samples from 500 to 100 meters, and 40 per cent in water shallower than 100 meters (73 samples, van Hinte, 1959). The values found by Bandy *et al.* (div. publ.) on the other hand are lower than those given by Grimsdale and van Morkhoven.

Depth of Deposition

It is beyond doubt that the lowest sedimentary rock at 117 was deposited at near-shoreline depth. The percentage of planktonic foraminifers in Core 11 is zero, and the fauna-flora which is present is known to have lived in the shallowest Tertiary waters. From Figure 31 it is apparent that the plateau went down during the Late Paleocene-Early Eocene. The 50 per cent–plankton line is crossed between Cores 3 and 4 of Hole 117A, suggesting that the section below originated in waters shallower than about 200 meters, the section above in water deeper than 200 meters. It is most unfortunate that no sample from Hole 117A, Core 2 was available. The Lower Eocene of Hole 117A, Core 1, immediately underneath the unconformity,

[4] The shipboard scientific party were assisted by E. M. Gannon of Imperial Oil Enterprises, Ltd., Calgary, Canada.

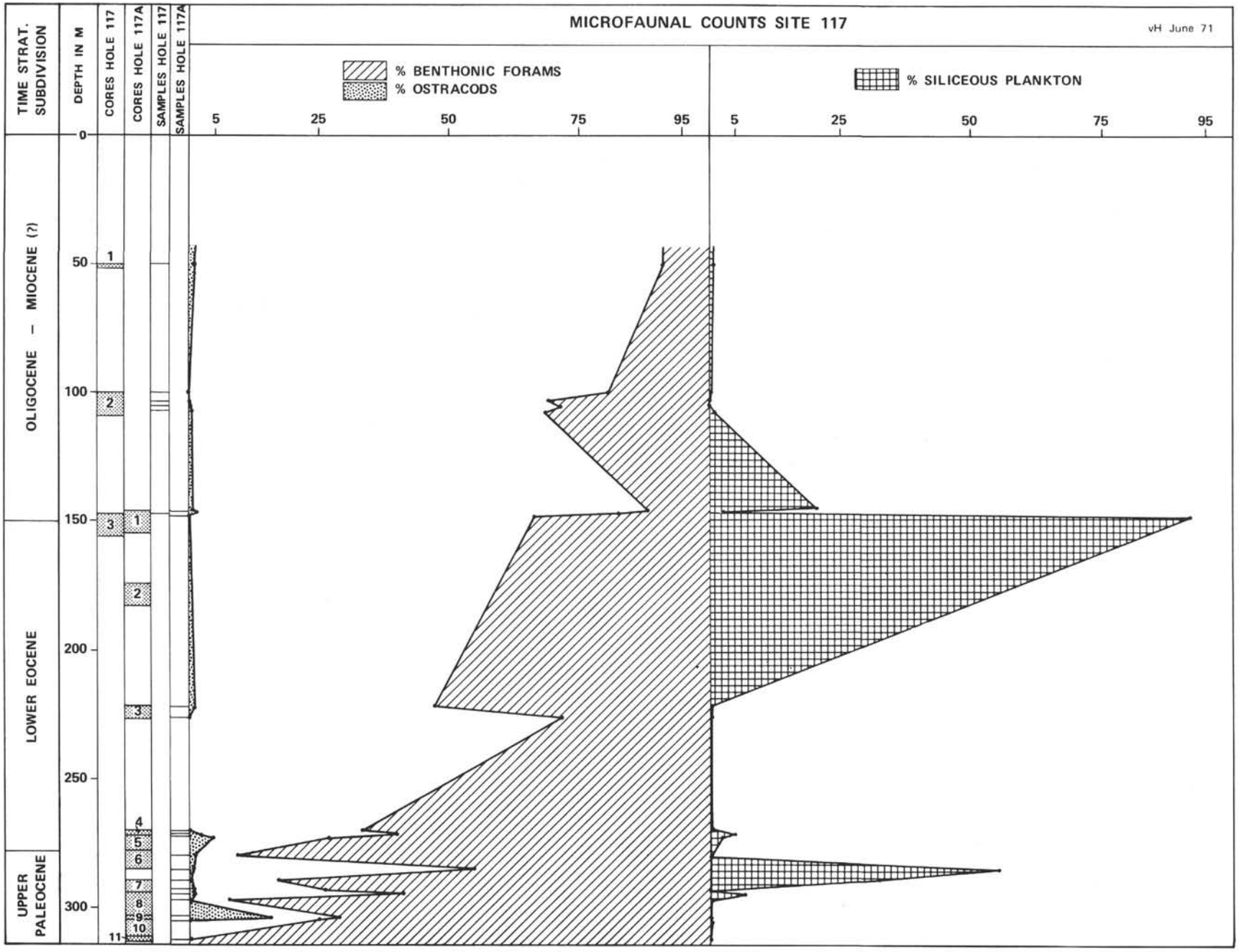

Figure 30. *Microfaunal counts at Site 117.*

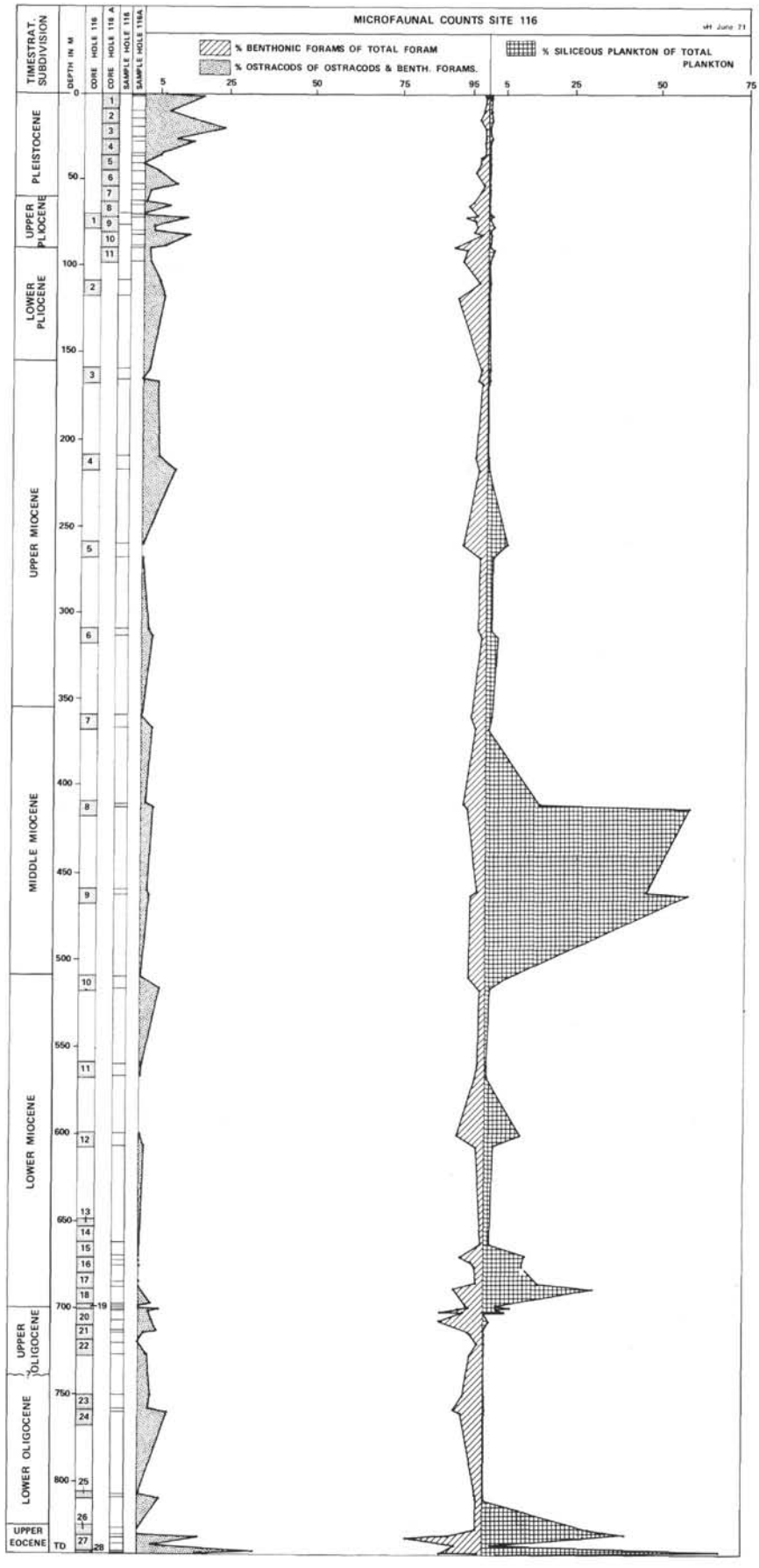

Figure 31. *Microfaunal counts at Site 116.*

TABLE 9

Hole	Core	Section	Interval (cm)	N_1	N_2	N_3
116	1	1	10-13	1135	66	1106
116	1	6	5.5-8.0	2198	143	2156
116	2	1	2-5	3514	203	3430
116	2	6	Base	3844	359	3509
116	3	1	38-41	2951	129	2902
116	3	5	Base	1482	42	1450
116	3	6	10-13	4096	184	4042
116	4	1	21-24	2136	163	2060
116	4	6	16-19	2572	117	2512
116	5	0	Base	1755	125	1732
116	5	6	Base	2895	211	2902
116	6	1	30.5-33.0	1526	107	1506
116	6	4	9-12	1845	102	1884
116	7	1	22-25	2580	110	2505
116	7	6	4-7	1667	223	1823
116	8	2	19-22	1444	95	1599
116	8	3	10-13	804	137	1840
116	9	1	11-14	646	25	1177
116	9	3	15-18	960	83	2184
116	10	0	Base	4611	238	4857
116	10	6	30-33	1817	110	1813
116	11	0	Base	1875	227	1838
116	11	6	4-7	1213	138	1182
116	12	1	11-14	1564	124	1602
116	12	6	24-27	1740	135	1744
116	15	1	8-11	3147	81	3165
116	15	6	5-8	1258	208	1191
116	16	2	17-20	1014	146	1103
116	16	4	29-33	3371	91	3700
116	17	4	21-25	1246	120	1445
116	17	6	37-40	830	123	1112
116	18	4	6-9	705	144	702
116	19	1	82-85	813	100	842
116	19	2	6-7	2347	177	2246
116	19	4	12-15	56	16	52
116	20	1	12-15	149	34	141
116	20	5	17-23	194	50	172
116	21	3	24-27	4065	184	3890
116	21	4	9-12	1725	287	1663
116	22	1	Base	2641	74	2601
116	22	6	21-24	1843	121	1770

TABLE 9 – *Continued*

Hole	Core	Section	Interval (cm)	N_1	N_2	N_3
116	23	0	Base	5826	357	5482
116	23	6	129-132	1588	138	1459
116	24	1	37-39	665	86	625
116	25	3	Base	422	11	413
116	25	5	5-7	667	30	654
116	26	2	0-2	300	63	379
116	26	4	22-24	99	18	151
116	27	1	Top	63	23	70
116	27	3	50-53	172	26	161
116	28	1	90-93	9	3	25
116	28	2	9-12	142	6	146
116A	1	1	60-63	4401	169	4356
116A	1	2	4-7	2042	113	2026
116A	2	1	106-109	2454	186	2418
116A	2	5	6-9	1631	134	1591
116A	3	1	27-31	1308	156	1298
116A	3	6	407	1620	172	1616
116A	4	1	100-103	4179	151	4125
116A	4	6	7-9	1559	117	1543
116A	5	1	54-57	2481	102	2429
116A	5	4	4-7	3294	160	3216
116A	6	1	17-22	2857	188	2755
116A	6	6	10-13	3788	128	3752
116A	7	2	2-5	3458	155	3388
116A	7	6	132-135	1030	153	985
116A	8	2	7-10	1359	280	1287
116A	8	6	13-16	1575	106	1485
116A	9	1	8-11	2154	343	2061
116A	9	6	2-5	1856	95	1771
116A	10	1	92-95	1421	115	1403
116A	10	6	8-11	950	99	857
116A	11	0	Base	2209	312	2102
116A	11	6	2-5	1759	146	1623
117	1	1	40-43	2380	391	2107
117	2	1	Top	2528	500	2085
117	2	3	42-45	2378	746	1633
117	2	4	2-5	1991	562	1431
117	2	6	3-6	504	173	333
117	3	1	0-3	485	154	402

TABLE 9 – *Continued*

Hole	Core	Section	Interval (cm)	N_1	N_2	N_3
117A	1	1	6-9	1904	226	2107
117A	1	1	70-73	59	277	496
117A	3	1	83-85	211	113	99
117A	3	6	149-150	14	4	10
117A	4	0	Base	298	200	98
117A	4	6	110-113	165	102	72
117A	5	1	6-8	218	167	59
117A	6	1	132-135	110	101	10
117A	6	6	110-112	593	271	735
117A	7	1	3-4	207	172	52
117A	7	4	127-130	500	372	130
117A	8	1	24-26	213	127	93
117A	8	2	141-144	190	176	14
117A	9	1	22-28	7	6	2
117A	10	1	5-6	4	3	1
	(11, thin sections)					

has 66.2 per cent planktonic foraminifers suggesting a water depth of 500 to 800 meters. The Oligocene above the unconformity yielded 88.2 and 82.5 per cent of planktonics, indicating a depth of deposition of more than 900 meters. Cores 1 and 2 of Hole 117 are hard to interpret because the cores are mixed; Core 2 probably has 70 to 80 per cent, Core 1 more than 90 per cent plankton.

The Upper Eocene basal part of Hole 116 with its 75 to 90 per cent of planktonics possibly originated at a water depth between 700 and 1000 meters. From 830 meters (Core 26, Upper Eocene) to 700 meters downhole the foraminiferal fauna consists of more than 85 per cent of planktonics. This strongly suggests that the water depth was 1000 meters or deeper; from 700 meters up all samples have more than 90 per cent planktonics, indicating that for that part of the section depositional depth was more than 1200 meters. Finally, above 665 meters, practically all samples yielded more than 95 per cent of planktonics, which suggests that the water was 1500 meters deep or deeper.

Toward the later part of the Early Pliocene the percentage of planktonics gradually seems to decrease. This could be the natural effect of shallowing, because of sediment accumulation, and approaching the present depth of 1151 meters. One would expect this trend to continue until the Recent, but it doesn't. A renewed increase of planktonic foraminifers is apparent during the Late Pliocene and Pleistocene. This time, however, the increase is accompanied by a marked increase of ostracods and probably is not the result of increased water depth but of nutrient enrichment by upwelling water. The present-day circulation pattern over Rockall Bank (Seaton, 1967; Steele *et al.*, 1971) thus might have established itself during the Pliocene.

ESTIMATED RATES OF SEDIMENTATION (SITE 116)

It would appear that average rates of sedimentation have remained relatively constant–about 3 cm/1000 yrs in this area over the past 25 million years, approximately. The estimated rates over specific intervals of time are enumerated below.

The Pliocene–Pleistocene boundary (2 million years) is placed on paleontologic data at about 60 meters (within Core 7, Hole 116A). This yields an average rate of sedimentation of about 3cm/1000 yrs during the Pleistocene (Figure 32). Between this level and the late Miocene-Middle Miocene boundary there is one problem. Depth relationships suggests direct correlation of 116-1 with the lower part of Core 8 and most of Core 9, Hole 116A, whereas, calcareous nannoplankton biostratigraphy suggests that part of Core 8 is within the *D. brouweri* Zone, 116-1, which overlaps 116A-8 and 9, contains the *R. pseudoumbilica* and *D. surculus* Zones. If one draws the boundary between these two zones (3 million years) within 116-1, at about 75 meters, then one obtains an estimated sedimentation of about 1.5 cm/1000 yrs for the interval 75 to 60 meters (=late Pliocene).

Calcareous nannofossil data suggest that 116-5 is within the *Discoaster quinqueramus* Zone and this level (268 meters) is assigned an age of 6 million years. This yields an estimated average sedimentation rate of 6.2 cm/1000 yrs for the interval between 268 and 75 meters (Figure 33).

The Early/Middle Miocene boundary (=*Orbulina* Datum = 16 million years) occurs at about 510 meters in Core 10, Hole 116. This yields an estimated average sedimentation rate of 2.4 cm/1000 yrs for the Middle Miocene.

The Oligocene-Miocene boundary (23 million years) is tentatively drawn (on relatively weak biostratigraphic data) at about 700 meters, between Cores 18 and 19 in Hole 116. This yields an estimated rate of sedimentation of 3 cm/1000 yrs for the Early Miocene. These figures are shown in parentheses in Figure 34 to indicate the uncertainty involved in these estimates.

The Eocene-Oligocene boundary (37.5 million years) occurs between the base of Core 25 and the base of Core 26 in Hole 116. It is arbitrarily drawn here at the top of Core 26, at about 825 meters. Cores 23 (750 to 759 meters) and 24 (806 to 810 meters) are placed in the *Ericsonia obruta* Zone. On the assumption that Core 23 is in the upper part of the zone, an estimate of 35.5 is made for that level. An estimated sedimentation rate of about 3.7 cm/1000 yrs is made for the interval between 740 to 825 meters. If we extrapolate the rate of 3 cm/1000 yrs estimated for the Early Miocene above, down below 700 meters, a level at 740 meters (intermediate between Cores 23 and 24 at 730 to 750 meters) would be about 25 million years. This suggests the presence of an unconformity at about 740 meters representing about a 10 million year hiatus (Figures 34 and 35).

Sedimentation rates may be corrected for natural consolidation using the steady density gradient of 0.00023 gm/cc/m in the upper 700 meters of the hole. The uncorrected and corrected rates appear in Table 10.

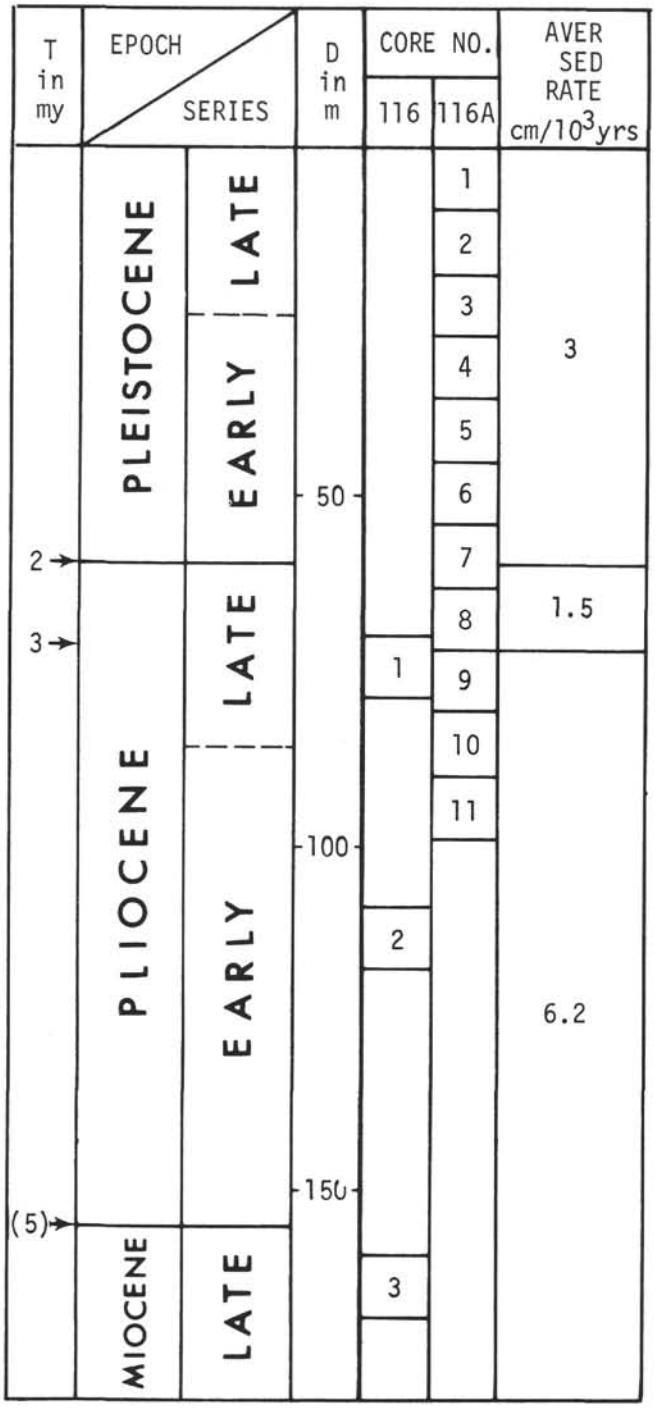

Figure 32. *Estimated Late Miocene – Pleistocene average sedimentation rates at Site 116.*

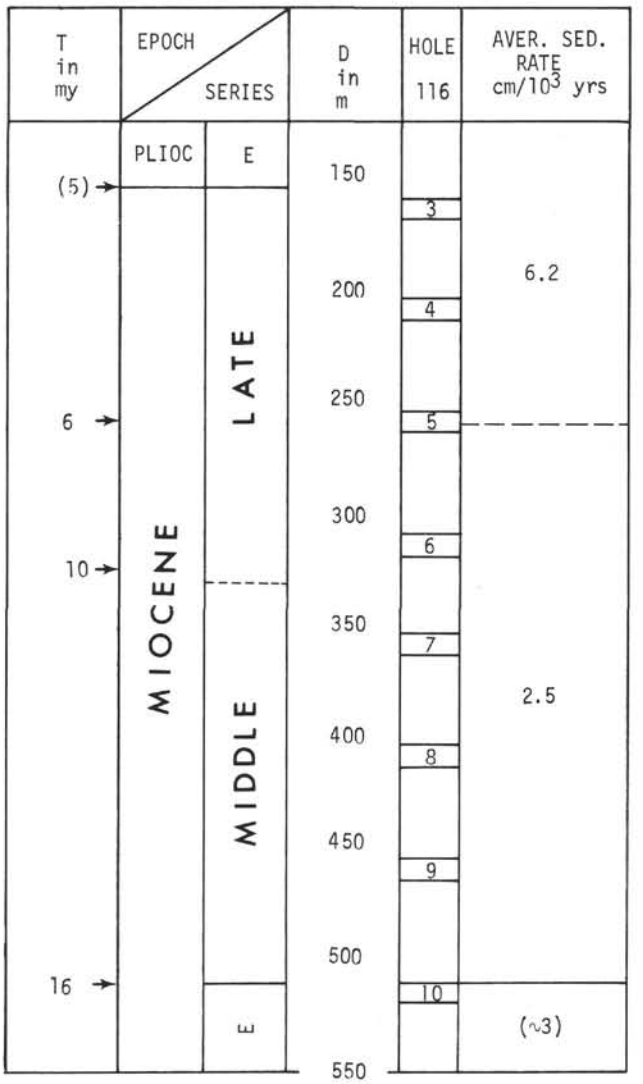

Figure 33. *Estimated Middle-Late Miocene average sedimentation rates at Site 116.*

ESTIMATED RATES OF SEDIMENTATION (SITE 117)

An estimated average rate of sedimentation during the late Oligocene of about 1 cm/1000 yrs is suggested by calcareous nannoplankton data from Cores 117-1 to 3. An unconformity separates upper Oligocene from lower Eocene at about 147 meters. Calcareous nannofossil data suggest an average sedimentation rate of about 3.1 cm/1000 yrs during the late Paleocene at Site 117.

TABLE 10

Time Span	Uncorrected Rate	Corrected Rate
m.y.	cm/1000 yrs	
0-25	3.0	4
35.0-37.5	3.7	5

The rate of deposition of the Oligocene sediments is not defined precisely enough for it to be worthwhile applying a correction for natural consolidation. Similarly, the spacing of density measurements below 150 meters does not allow one to confidently assign a density gradient to this region and so the 3.1 cm/1000 yrs average rate between 150 and 311 meters remains uncorrected.

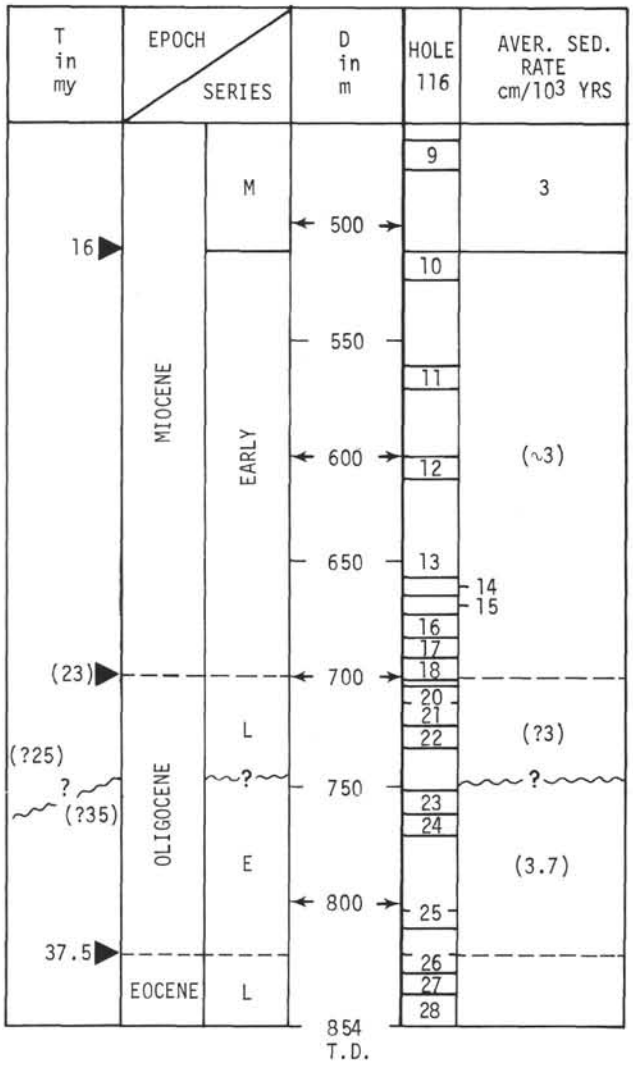

Figure 34. *Estimated Late Eocene–Early Miocene average sedimentation rates at Site 116.*

DISCUSSION (116 and 117)

Introduction

Two sites were drilled in the Hatton-Rockall Basin. The hole at the first site (116) terminated at 854 meters in cherty limestones of Late Eocene age. In order to reach lower stratigraphic levels drilling was continued at a new site to the east on the lower flanks of the Rockall Bank where seismic profiling showed that the subsurface strata was considerably more shallow. The expected continuity in stratigraphic section was found at Site 117, and the hole bottomed at 313 meters in a weathered olivine basalt which was overlain by shallow water conglomerates, silty clays and mudstones of Late Paleocene age. Pertinent data regarding Sites 116 and 117 are shown below. (Table 11)

A relatively complete sequence of Cenozoic sediments is present in the Hatton-Rockall Basin. The gradual sinking of this basin to its present depth during the Cenozoic is reflected in the nature of the sediments: predominantly detrital in the lower part, with a gradually increasing proportion of pelagic material in the younger horizons. Two unconformities were recorded: at Site 116 between the Upper Oligocene/Lower Oligocene–representing a time-interval of about 10 million years; at Site 117 between the Oligocene/Lower Eocene–representing about 20 million years.

TABLE 11

	Total Cored (m)	Core Recovered (m)	Total Penetration (m)
Hole 116	226	195.3	854
Hole 116A	99	89.1	99
Hole 117	20	85.0	156
Hole 117A	66	34.3	313

Cenozoic Biogeography

One of the objectives in drilling Sites 116 and 117 was to delineate Cenozoic high latitude paleobiogeography. Sediments representative of each of the Cenozoic epochs were recovered in the course of drilling these two sites. The sequential sinking of Hatton-Rockall Bank is reflected in the microfaunas so that one obtains a picture of the gradual development of deeper water benthonic faunas in addition to the climatically induced changes in planktonic foraminiferal faunas.

In the Late Paleocene and Early Eocene benthonic foraminiferal and bryozoan faunas exhibit a marked similarity with contemporaneous faunas recorded from Europe and North America. In the Oligocene, closer connections with Europe are seen in the bryozoan faunas. Middle Cenozoic (Oligocene-Early Miocene) benthonic foraminiferal faunas exhibit a marked similarity with contemporaneous faunas recorded in both the Caribbean and Mediterranean regions. The present day North Atlantic benthonic foraminiferal fauna appear to have developed in the Middle Miocene, about 15 million years ago.

A gradual provincialization of the planktonic foraminiferal fauna during the Cenozoic is seen in the sedimentary sequence at these two sites. The presence of keeled globorotaliids in the Middle and Late Miocene and the fact that the Late Pliocene-Pleistocene interval consists primarily of nannofossil oozes with relatively minor amounts of glacially derived clastic sediments suggests that the Gulf Stream may have flowed in the vicinity of Hatton-Rockall Bank throughout the Late Cenozoic.

The Nature of Reflector 4

The seismic profiles across Hatton-Rockall Basin (Figures 2 and 3) show reflector 4 to be a major boundary between the essentially horizontally bedded sediments above and the transparent sediments below. A principal objective of Hole 116 was to penetrate this reflector and to determine its cause.

At Site 116, reflector 4 is a complex and rather diffuse reflector at 0.80 ±.03 second (Figure 7). Assuming a mean velocity from the sea bed to the reflector of 1.75 km/sec,

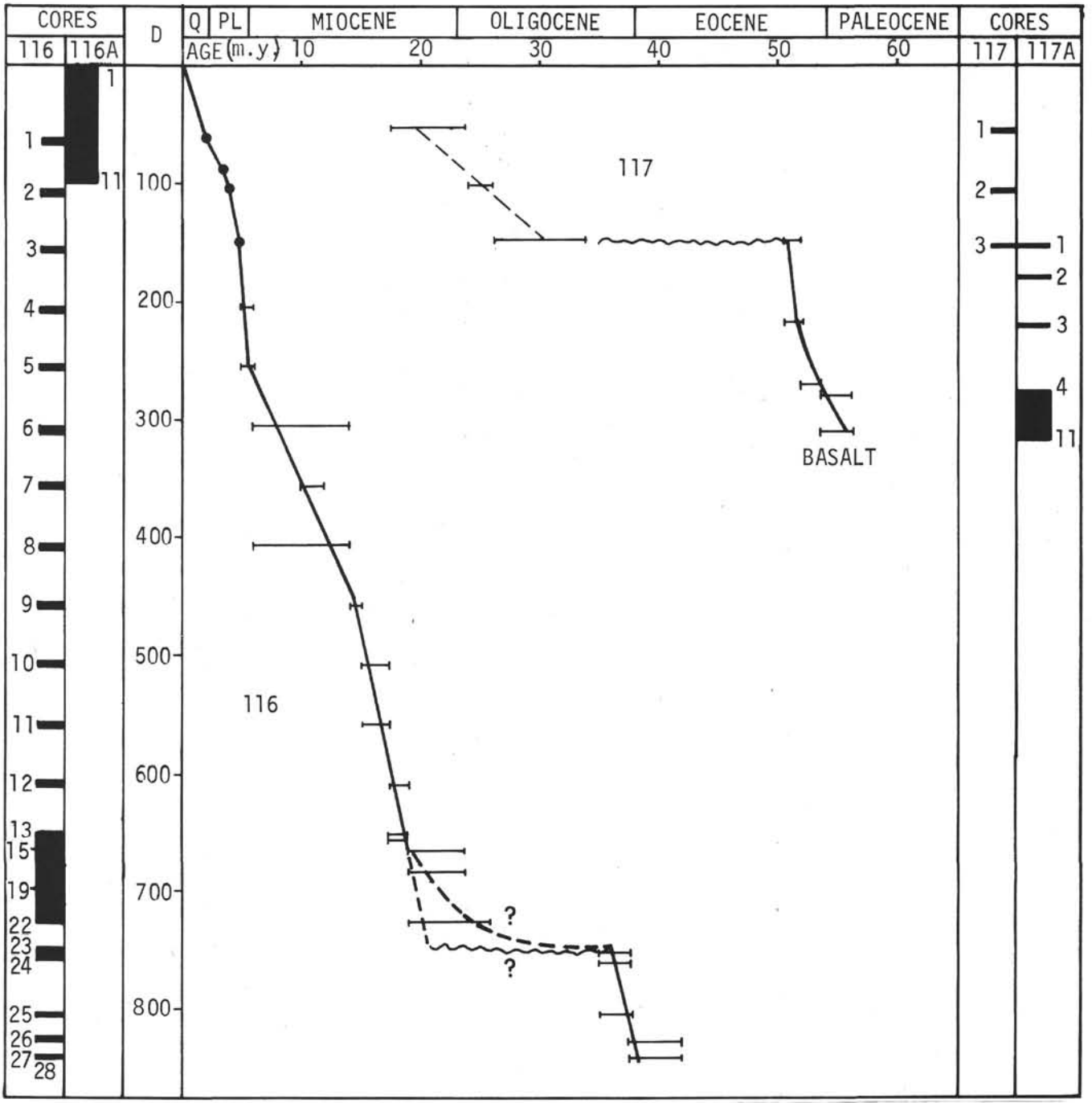

Figure 35. *Age vs. depth relationship at Sites 116 and 117 based upon calcareous nannoplankton.*

its expected depth would be 700 ±25 meters. The first cherty layers were cored at 670 meters; drilling became considerably harder at 700 meters with the advent of layers of hard chalk and chert (116-20-5); and, the unconformity between the Upper and Lower Oligocene came between 730 and 750 meters. The resolution of the seismic data and the lack of knowledge of the interval velocity does not enable reflector 4 to be correlated positively with any one of these depths. The measurement of the acoustic impedance of recovered core material (see Physical Properties) suggests that it arises from the increased lithification of the chalk below 700 meters. To associate it with the unconformity at 740 meters would require a mean velocity to the reflector of 1.85 km/sec, which is higher than one would expect for the rather rapidly deposited nannofossil oozes above. At Site 117, reflector 4 lies in the top 150 meters and is associated with the Oligocene cherty limestones which lie above the unconformity with the Lower Eocene clays. The paucity of cores and the broken nature of the recovered material here made it difficult to study quantitatively the physical properties of the reflector 4 region.

Although at both sites the reflector seems to be associated with hard cherty layers, there is little doubt that

on the basin-wide scale, reflector 4 is associated with an angular unconformity since the layers above it can be seen to pinch out as the reflector approaches the surface at the margins of the basin. There appears to be a correlation of the age and lithology of the top 150 meters at Site 117 with the sediments at 700 meters at Site 116 (Figure 36).

The maximum depth below sea bed of reflector 4 in the two sections of the Hatton-Rockall Basin to the west and northwest of Site 116 is 1.0 second (or 875 meters at 1.75 km/sec). An extrapolation to this depth of the sedimentation rate of 3.0 cm/1000 yrs found for the sediments above the unconformity at Site 116 gives an age of 29 million years, in contrast to the age of 36 million years found below the unconformity. In other words, a depositional unconformity probably exists over the entire basin, of some of some 7 million years in the center and increasing to 15 million years at Site 116 and about 20 million years or more at Site 117.

A short section of the *Discovery*-29 seismic reflection profile has been digitized and processed by deconvolution with the propagated pulse and with time varied filtering. Reflector 4 is revealed in greater detail and is shown to be a complex mixture of topographic highs giving low energy hyperbolic echoes, with the intervening depressions filled with multiple strong reflectors covering a time range of about 0.1 second. The rough topography of the low energy reflector may well correlate with the unconformity between the Lower and Upper Oligocene at 740 meters in Site 116. Its roughness may be due to minor tectonic disturbances during the Middle Oligocene which have given rise to the faulting and the tilted bedding of the chalks and limestones of the lower cores of Hole 116. The fractured appearance of reflector 4 near Site 117 is suggested by the cliffs and benches seen on the seismic reflection profile. Matthews and Smith (1971) have searched for evidence of major normal faulting on reflector 4 from the *Discovery*-29 profiles and conclude that in no case does the throw of such faults, as might be postulated, exceed 0.2 second. They suggest that an alternative cause of the hyperbolic echoes in reflector 4 might be mud diapirs. The faulting observed in the cores may be associated with this diapirism. However the absence of such faulting immediately above the unconformity suggests that any such movements ceased after the Middle Oligocene.

The first sedimentation above the unconformity appears to have occurred in the depressions in the horizon. On the whole, these are flat-bedded and not draped, suggesting that gravity controlled currents transported the sediments there. The sediments are relatively rich in silica, and in Hole 116 up to 660 meters, are partly lithified and cherty.

It is concluded, therefore, that reflector 4 arises from lithified sediments accummulated in depressions of an unconformity, that may have suffered minor tectonic disturbances in the Middle Oligocene.

The Sediments Above Reflector 4

At Site 116, the top 700 meters are Miocene and Pliocene-Pleistocene nannofossil calcareous ooze mostly in the size range of clay and silt, and sedimented at a rate of between 3 and 4 cm/1000 yrs without interruption. Pyrite was common, indicating an oxygen poor environment.

The seismic profiles across the Hatton-Rockall Basin show that this body of sediment is extensive. It is confined to the east by the basement high of Rockall Bank and to the west by that of Hatton Bank (Figure 1). To the northeast it is very restricted by George Bligh Bank, but to the southwest it divides around a volcanic seamount at 55.5°N, 20°W. The passage of *Glomar Challenger* away from Site 117 demonstrated the southerly extent of the sediments of Hatton-Rockall Basin (Figure 37). The basin is approximately 100 kilometers wide, 400 kilometers long and the sediments above reflector 4 average a thickness of about 600 meters. The sediments are characterized by:

(a) Approximately horizontal stratification independent of the underlying topography of reflector 4.

(b) A sharp boundary against basement highs, which have little or no sediment cover.

(c) A marginal channel on both sides of the basin and moats around the three basement highs at the southwestern end. (Figure 1). Older buried marginal channels can be seen in the seismic profiles.

(d) A domed upper surface, the axis of which lies in the center of the southwestern part of the basin.

(e) An upper surface indented by small regularly spaced valleys (?) believed to be oriented NE-SW (Figure 6). The internal structure also shows a wavy pattern. (cf. discussion on site survey, Appendix II). These features are believed to be related to the wavy surface found on such sediment ridges as the Feni and Gardar Ridges.

These features are similar to those found on sediment ridges which have been formed by the fallout of sediment from ocean bottom currents, which are discussed at greater length in Chapter 11. In Rockall Trough just east of Rockall Plateau, the Feni Ridge has been attributed to the flow of Norwegian Sea water down the western side of the trough (Johnson and Schneider, 1969; Jones, Ewing, Ewing and Eittreim, 1970). A similar mechanism built the Gardar Ridge and the Site 114 ridge in the Iceland Basin between Rockall Plateau and the Reykjanes Ridge. It is plausible to postulate, therefore, that the Miocene sediments of Hatton-Rockall Basin have been deposited from a bottom current flowing between the two Banks.

However, whereas the Feni, Gardar and Site 114 ridges clearly result from an ocean current banked up by Coriolis force against the western side of a basin, the sediments and channels in the Hatton-Rockall Basin do not show this asymmetry. If the axis of highest velocity lies above the marginal channel and Coriolis force is dominant, then the pattern of channels indicate that the bottom current travels northwards along the eastern side and southwards along the western side of the basin. If, however, the basin is too narrow or too shallow to allow appreciable banking up of the current or if the flow fills the entire cross section of the basin, then marginal channels could form simultaneously on both sides due to local acceleration by restriction. A uniform flow to the southwest is the simpler hypothesis and explains the moats around the seamounts at the southwest end of the basin. The source of this bottom current must then be in the vicinity of George Bligh Bank. Northeast of this it may derive from the upper part of Norwegian Sea water overflowing between Faroe Island and

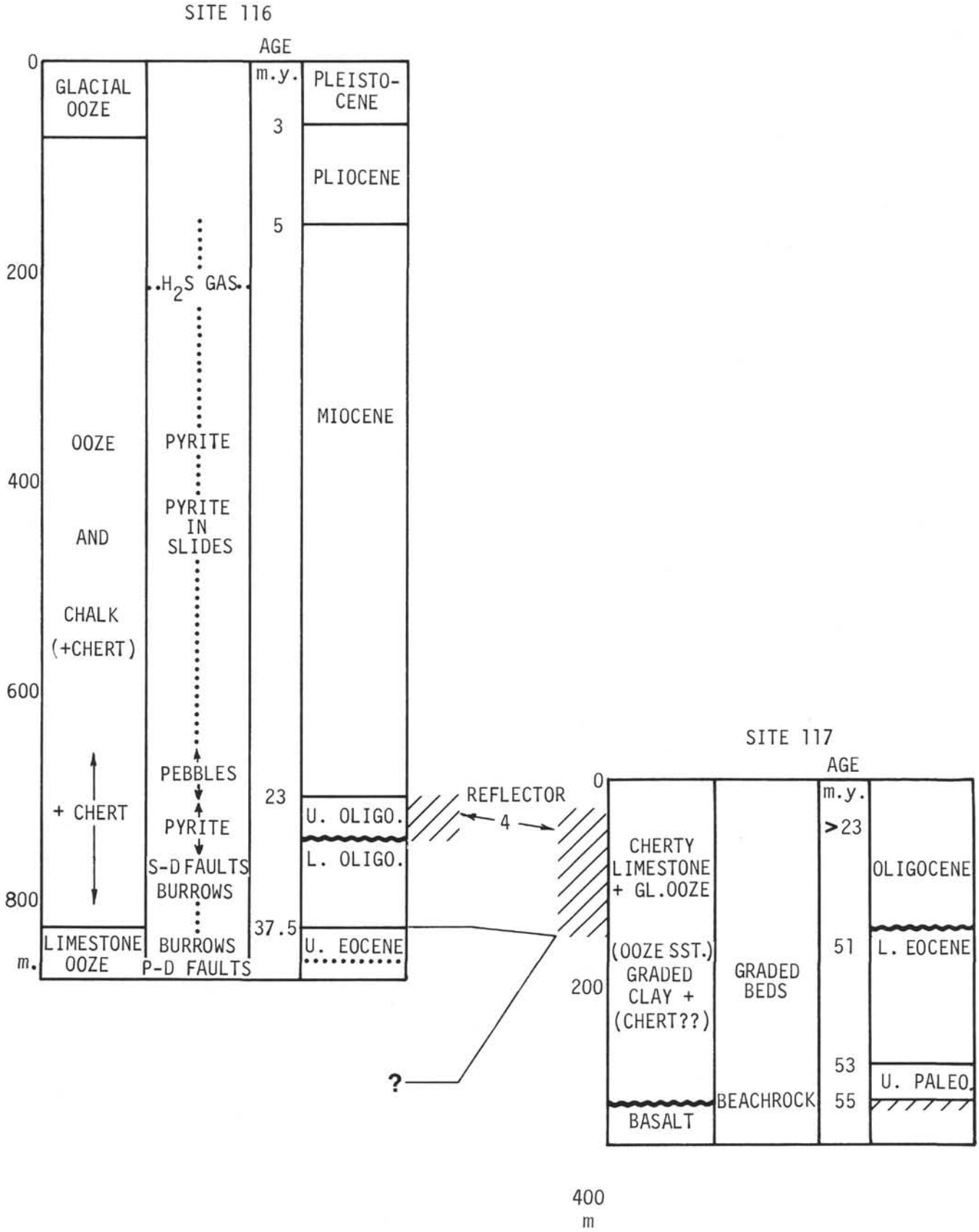

Figure 36. *Comparison of lithology and stratigraphy of Holes 116 and 117. P-D is post-depositional and S-D is syn-depositional.*

Scotland, the lower part traveling along the eastern ridge of Rockall Bank and forming the Feni Ridge. If this is so, there may be some similarity between the sediments of Feni Ridge and those of Hatton-Rockall Basin.

The oldest sediments of this sequence that were sampled at Site 116 were Upper Oligocene (25 million years), although further west the sequence may have started about 30 million years ago. The comparatively constant sedimentation rate and the uniform stratification of the sediments indicates that the sedimentation mechanism here has been constant during this time, and therefore that a southwest-going bottom current has been flowing for at least 30 million years.

The Sediments Below Reflector 4

The seismic profiles show reflector 4 to be underlain by a relatively transparent layer bounded below by reflector 5 in the center of the basin and by the basement rocks of Rockall and Hatton Banks at the margins. In contrast to the Miocene bottom current sediments above reflector 4, this layer is draped onto the flanks of the banks. In many places it is 0.7-second thick (700 meters at 2.0 km/sec). The processed section the of *Discovery*-29 profile shows some sub-horizontal reflectors near to the base of the layer filling depressions in the more rugged reflector 5. In places there are suggestions of overlapping hyperbolae in the layer indicating discrete reflectors.

Hole 116 penetrated reflector 4 and terminated in the top of the transparent layer, in Upper Eocene chalky limestone. In the discussion on the physical properties, it was suggested that the lack of reflections in the transparent layer was related to the absence of rapid physical (and therefore lithological) changes below the limestone and that this therefore constituted the transparent layer. On the other hand, the transparent layer below reflector 4 at Site 117 (150 to 300 meters) was shown to consist of a rather uniform dense gray clay of Lower Eocene and Upper Paleocene age with high terrigenous content and containing shallow water ostracods and bryozoa. By age comparison, this represents the lower part of the transparent layer below 116 (equivalent to a depth of 2400 meters below sea level if the sedimentation rate in the Upper Eocene of Hole 116 is extrapolated downwards.)

These two conflicting data on the nature of the transparent layer need to be resolved. The continuity of the transparent layer between 117 and 116 is quite certain. Two interpretations are possible to explain the data: (a) There is a gradual facies change from clay to limestone from 117 to 116 corresponding to a progressively changing environment of deposition away from Rockall Bank, or (b) that there is clay at the base of the transparent layer below 116 as well as below 117, but that there is a gradual facies change at Site 116 from clay near the bottom to limestone higher up, corresponding, perhaps, to a progressively deeper environment as the basement below Hatton-Rockall Basin sank. Some evidence of a shallower water environment for the deposition of the Upper Eocene and Lower Oligocene limestones of Hole 116 comes from the species diversity of the foraminifera, and from the presence of *Braarudosphaera bigelowi* which is known at present to live in restricted seas. These data support the sinking hypothesis.

The Nature of Reflector 5

Reflector 5 was seen below the transparent layer on the *Discovery*-29 and 33 seismic profiles across the whole basin, but only near the margins on the *Glomar Challenger* profiles. In the central section of the *Discovery*-29 profile (Figure 3), continuity could not be established with any certainty between reflector 5 and the basement of Hatton or Rockall Banks. In the southern basin, reflector 5 could be seen on the *Glomar Challenger* record (Figure 37) on the low frequency recorder, rising from about 1.5 seconds below the seabed to merge with the base of the magnetic (and therefore probably volcanic) seamount at the southwest end of the basin. Seismic refraction data in the basin by Scrutton (personal communication) suggest that reflector 5 is not the top of the crystalline basement, but may represent another sediment horizon. The processed seismic reflection record in the southern basin shows the reflector to be extremely irregular and probably faulted, with additional reflecting horizons lying within the depressions.

It must be concluded, therefore, that although Hole 117 sampled a basaltic basement below the transparent layer, there is inadequate data to correlate reflector 5 below the Hatton-Rockall Basin with this, and that the nature of the reflector will only be determined by further drilling.

Environmental Conditions During Sedimentation

A variety of data from studies of the flora and fauna, and of the lithology, enable some estimates to be made of the depth of the sea during the periods of sedimentation represented in Holes 116 and 117.

(a) Quantitative micropaleontological analysis. Shipboard estimates of the ratios of benthic to planktonic foraminifera led to a depth of deposition/age relationship which was the basis of the subsidence curve published in Laughton *et al.* (1970). Subsequent laboratory studies, presented in detail above, have altered these conclusions. At Site 117, the sea bed subsided from sea level to 200 meters in the Late Paleocene to early Early Eocene (53 million years), and to 500-800 meters by late Early Eocene (51 million years). At Site 116, the Upper Eocene (38 million years) basal section probably originated at a water depth of 700 to 1000 meters, the Lower and Upper Oligocene (25 to 37 million years) at over 1000 meters, the early Lower Miocene (19 to 23 million years) at over 1200 meters and the later sediments at over 1500 meters, until sediment accumulation reduced the depth to the present 1151 meters. It is realized that these calculations are such rough approximations that one could argue that they are meaningless. Still, it is believed that they have relative value, suggesting a trend and indicating an order of magnitude.

(b) Ostracod studies (see R. H. Benson above). In Hole 117A, late Paleocene ostracods are predominantly sighted suggesting a depth of 100 to 600 meters. Oligocene ostracods in Hole 117 are blind and belong to an environment similar in depth to that in which they were recovered.

(c) Bryozoa studies (see Cheetham and Håkansson above). Oldest Paleocene (56 million years) samples above basement at Hole 117A are thought to have come from

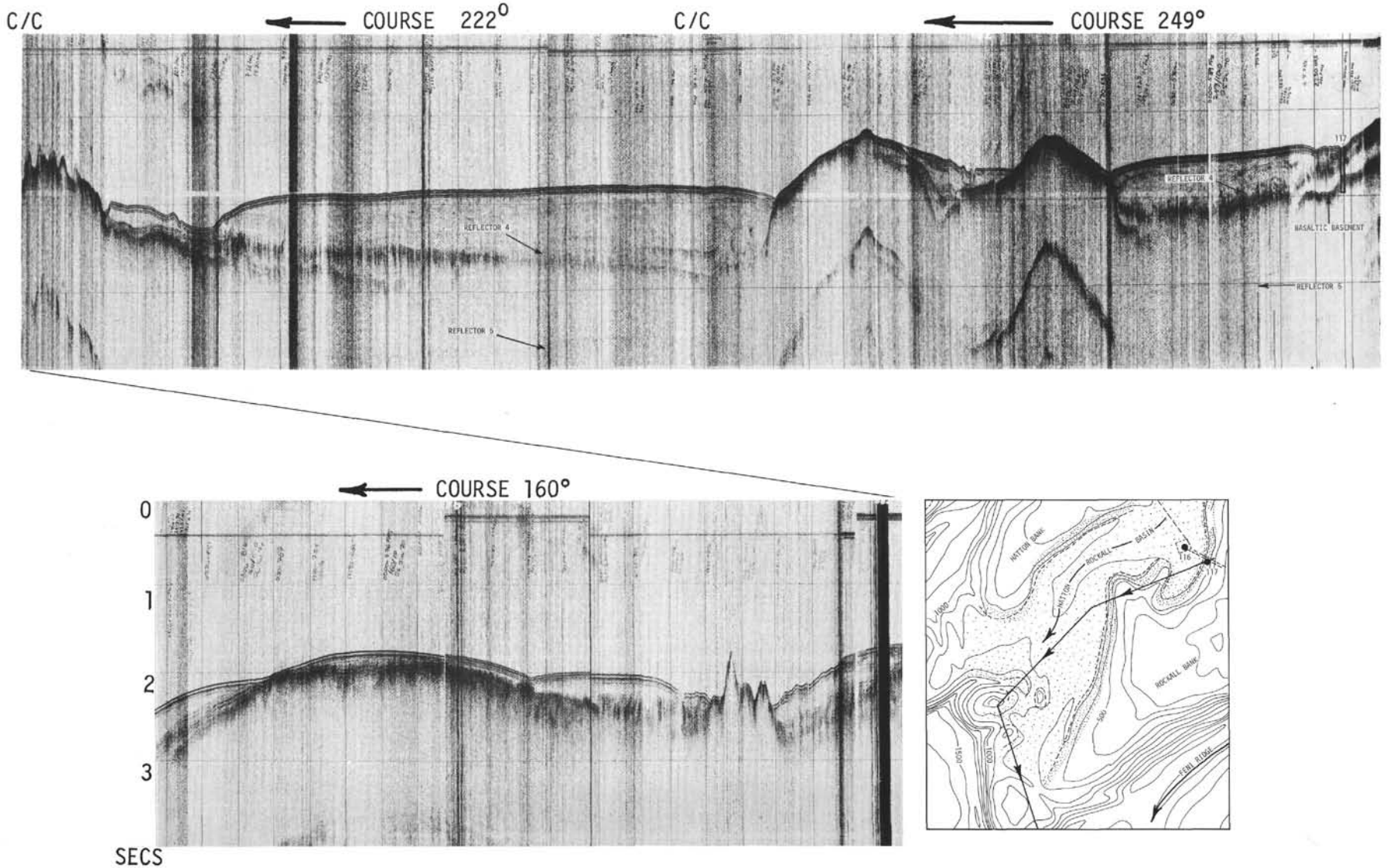

Figure 37. *Seismic reflection profile by* Glomar Challenger *along the Hatton-Rockall Basin southwest from Site 117 showing the marginal channels against the basement highs and the moats associated with the seamounts at the southwestern end of the basin.*

about 30 to 60 meters depth, and the youngest Paleocene (54 million years) from about 60 meters. The older Late Oligocene (30 million years) bryozoa of Hole 117 indicate a water depth of 150 to 200 meters, whereas, the younger (25 million years) bryozoa give 200 to 600 meters.

(d) Radiolaria. The absence of Radiolaria in the Late Paleocene of Site 117 suggests a shallow water environment, in contrast to their presence in the Oligocene.

(e) Other fossil evidence. Molluscs, gastropods and annelid tubes were found in the Paleocene basal sandstone of Hole 117A, indicating a shallow water environment.

(f) Phosphorite. A nodule was found in Lower Eocene (52 million years) sediments of Hole 117A indicating a depth range of 30 to 300 meters.

(g) Sediment facies. The basal conglomerates in Hole 117A are poorly sorted, altered and rounded suggesting a nearshore environment.

(h) Basalts. The vesicular nature of the basalts suggests a shallow water origin.

(i) Nannoplankton. In Hole 116, the early Oligocene nannoplankton suggest a restricted environment such as a basin or gulf.

(j) Burrowing. Burrows of a zoophycos type were found in Hole 116 in the Early Oligocene sediments indicating bathyal depths.

In Figures 38 and 39, the above data is plotted against geological age in order to deduce a subsidence history of the two sites. Sedimentation rates are also plotted such that the area beneath the curve up to a given age indicates the sediment accumulation to that time.

At Site 117, the evidence for the Late Paleocene is mutually consistent and indicates a shallow or nearshore environment for the basal sediments (56 million years) and progressive deepening to about 600 meters in the Early Eocene (51 million years). There is no data for Middle Eocene to Middle Oligocene since there are no sediments.

In the late Oligocene, there is a substantial disagreement between the bryozoa data, and the ostracod and planktonic data which remains unresolved. If one accepts the upper bathyal depths of the bryozoa, two major episodes of subsidence are implied. For the purposes of the subsequent discussion, the simpler hypothesis of one episode of subsidence is followed, the discrepancy being noted for future investigation.

At Site 116, the data provide a consistent story of progressive subsidence from middle bathyal depths in Early Oligocene to the present depth in Middle Miocene.

It must be emphasized that the criteria on which these environmental data are founded are in many cases very tentative, and that the depth ranges deduced are subject to revision as more is known of the determining environmental factors.

Tectonic History of Rockall Plateau

At Site 117 (Figure 39), subsidence started very soon after the nearshore sediments were laid down 56 million years ago, and by Early Eocene (51 million years) basement had dropped to 600-700 meters depth, at a mean rate of 14 cm/1000 yrs. If this mean rate is continued to the present basement depth of 1350 meters, the subsidence would have ceased in Middle Eocene (47 million years). It is possible, however, that it slowed down or stopped in Early Eocene and renewed tectonic activity in Early Oligocene brought it to its present depth, (assuming the ostracod data is accepted in preference to the bryozoa data). There is some suggestion from the quantitative micropaleontological analysis that some sinking took place during the Early Miocene, as it did at Site 116, although the data is poor. Tectonic activity after the Paleocene is indicated in the Upper Paleocene cores by the presence of slickensides and faulted sediment layers. The step-like bottom and sub-bottom topography of the west flank of Rockall Bank (Figure 10) suggests that the faulting was widespread in the region. Several episodes of tectonic activity are therefore likely at Site 117.

The oldest data available from Site 116 (Figure 39) are Late Eocene. The increase in planktonics and the decrease in ostracods suggest that at that time the sea was still deepening over the site. Slickensides, microfaulting and dipping laminations testify to Late Eocene tectonic activity. During the Oligocene, on the other hand, no subsidence seems to have taken place. A gradual decrease in planktonics even suggests some shallowing which can be explained by sediment accumulation. The beginning of the Early Miocene possibly was a period of renewed subsidence for Site 116. One could interpret the depth of deposition of Core 19 (23 million years old, 700 meters deep) as 1200 meters, and of Core 14 (19 million years old, 660 meters deep) as 1500 meters. Consequently, Site 116 went down 340 meters during 4 million years, that is 8.5 cm/1000 yrs. The data suggest, therefore, a total subsidence of 900 meters at this rate between Late Oligocene (25 million years) and Early Miocene (18 million years), followed by a gradual shoaling of the sea bed as the late Tertiary sediments accumulated.

A simpler subsidence curve (shown by dashed lines in Figure 39) ignores the possible lack of subsidence during the Oligocene, and gives a subsidence of 1200 meters between the start of the Oligocene (38 million years) and the Middle Miocene (13 million years) equivalent to a mean rate of 4.8 cm/1000 yrs.

Data from both sites together suggest that Rockall Plateau subsided in two periods: during the Paleocene–Eocene, and during the Early Miocene. During the Oligocene and after the Early Miocene, the plateau seems to have been stable. If there was no differential sinking or tilting between Site 117 and the bulk of Rockall Bank, the top of the bank would have had an elevation of 1400 meters above sea level during the Paleocene. However, the western flank of Rockall Bank appears to be substantially faulted so that the top of the bank was probably considerably lower than this.

The evidence available suggests that there was substantial relative vertical movement between Sites 117 and 116. The inferred depths of the Oligocene at 116 and 117 are similar, so that the Early Miocene subsidence at 116 gave rise to differential movement. If the pre-Oligocene subsidence at 117 also affected Site 116, then reflector 5 would have been near sea-level during the Paleocene. If it is a sedimentary horizon, then the sediments would consist of shelf or continental facies.

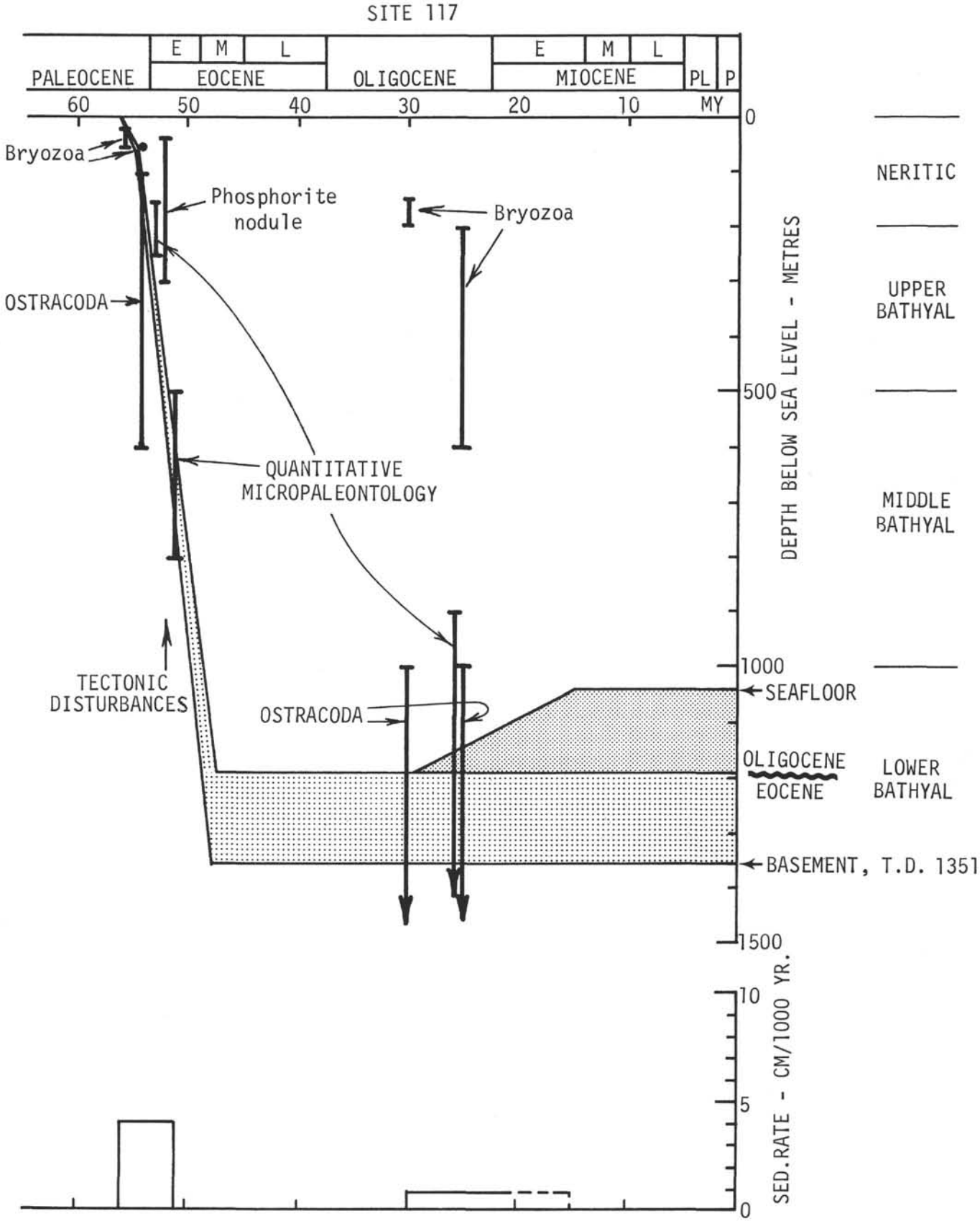

Figure 38. *Crustal subsidence and sediment accumulation at Site 117 based on estimates of environmental conditions from the core material. The area beneath the curve up to a given age indicates the sediment accumulation to that time. The denser shading indicates sediment above the Oligocene-Eocene disconformity.*

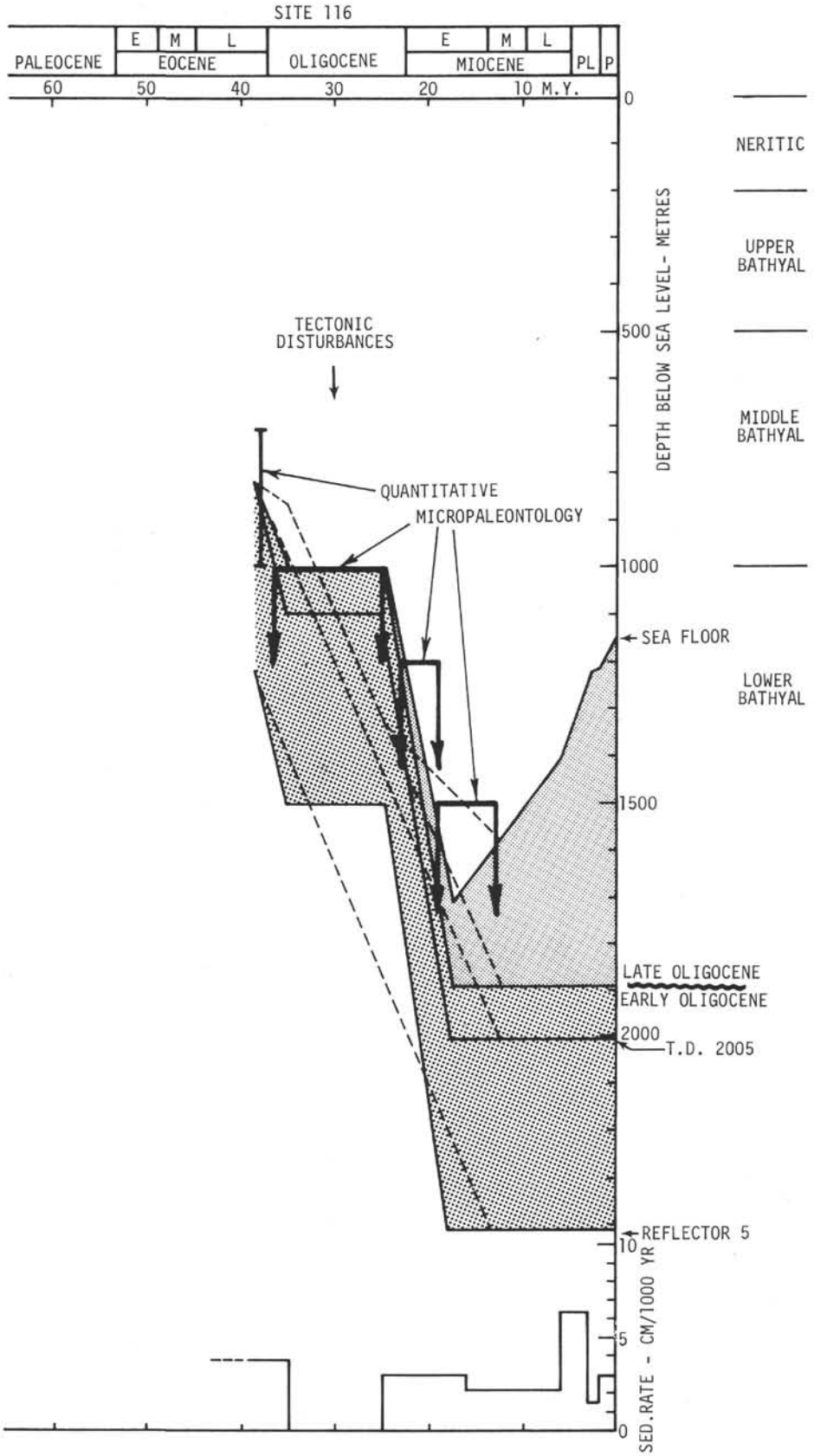

Figure 39. *Crustal subsidence and sediment accumulation at Site 116 based on estimates of environmental conditions from the core material. The area beneath the curve up to a given age indicates the sediment accumulation to that time. The denser shading indicates sediment above the Oligocene-Eocene disconformity.*

In conclusion, the evidence from Sites 116 and 117 strongly support the hypothesis that Rockall Plateau is a continental fragment detached from Greenland some 60 million years ago and subsequently subsided by at least 1400 meters, and probably in the center by 2500 meters.

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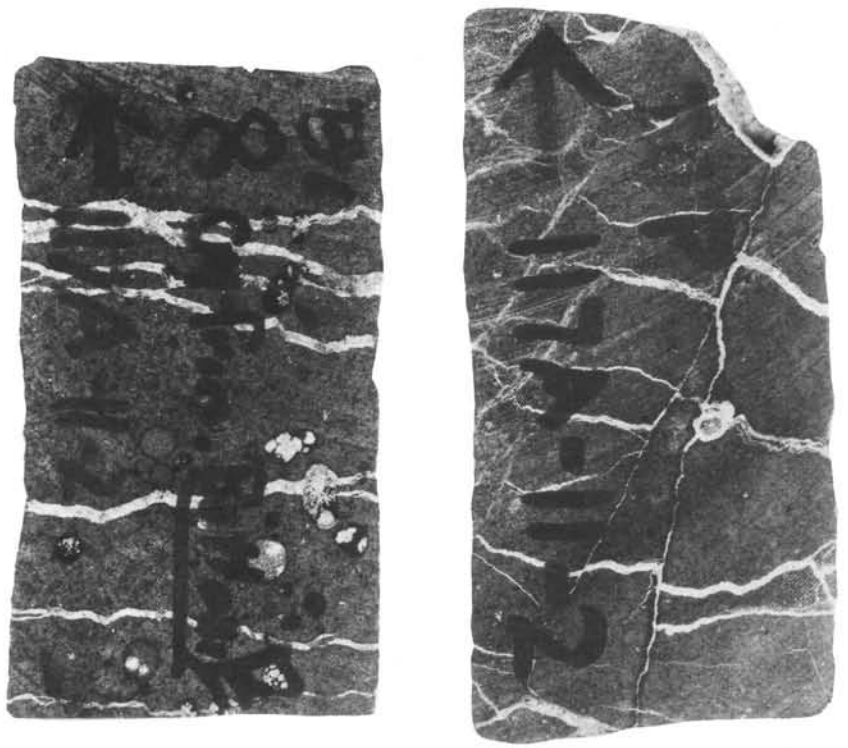
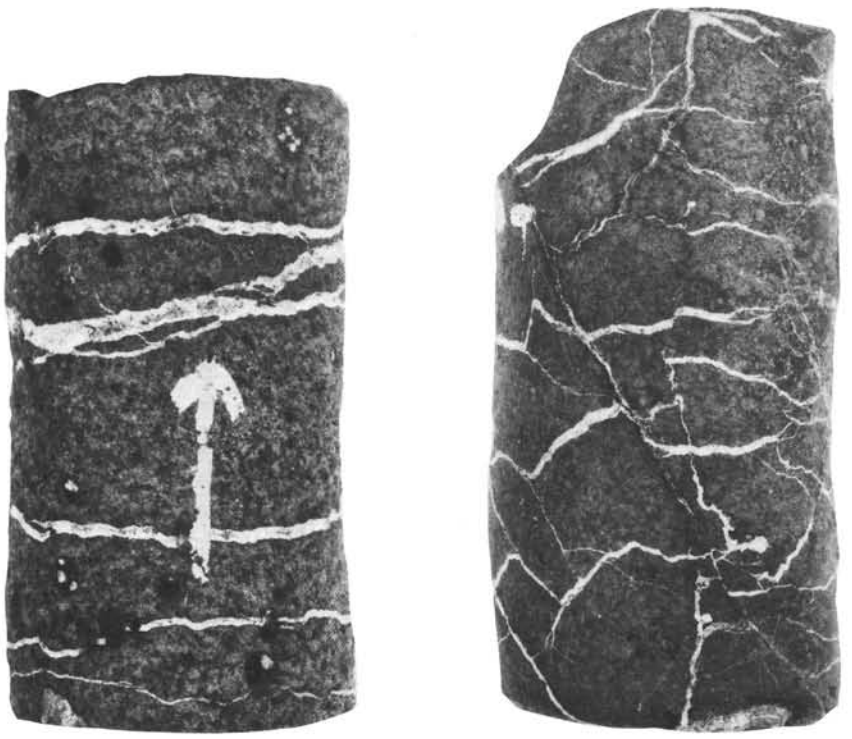
PLATES

Plate 1	Basalt Core (117A-11).
Plate 2	Photomicrographs of basalt (117A-11).
Plate 3	Vesicle in basalt (117A-11).
Plate 4	Annelid tubes of Ditrupa. (Photo J. v. Hinte, courtesy Imperial Oil Enterprises Ltd).
Plate 5	Burrowed sandstone from Site 117. (Photo J. v. Hinte, courtesy Imperial Oil Enterprises Ltd).
Plate 6	Slickensides, small faults and tilted bedding. (Photo J. v. Hinte, courtesy Imperial Oil Enterprises Ltd).
Plate 7	Zoophycoid burrows seen at Site 116. (Photo J. v. Hinte, courtesy Imperial Oil Enterprises Ltd).
Plate 8	Comparison of photographs of Cores 116-25 and 117-25 to illustrate the similarity of the lithology of these two cores.

PLATE 1

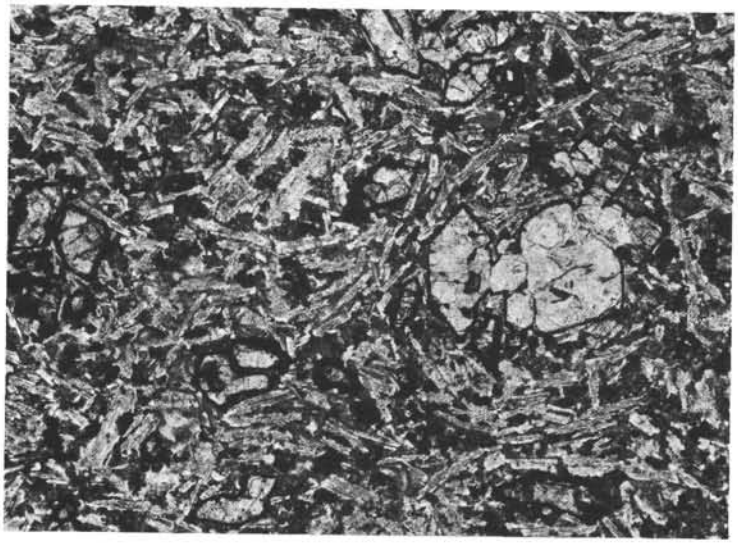


Specimen F7159 (right, showing vesicle), F7160 (left). Cut face.
Approximately true scale. MN 24296.

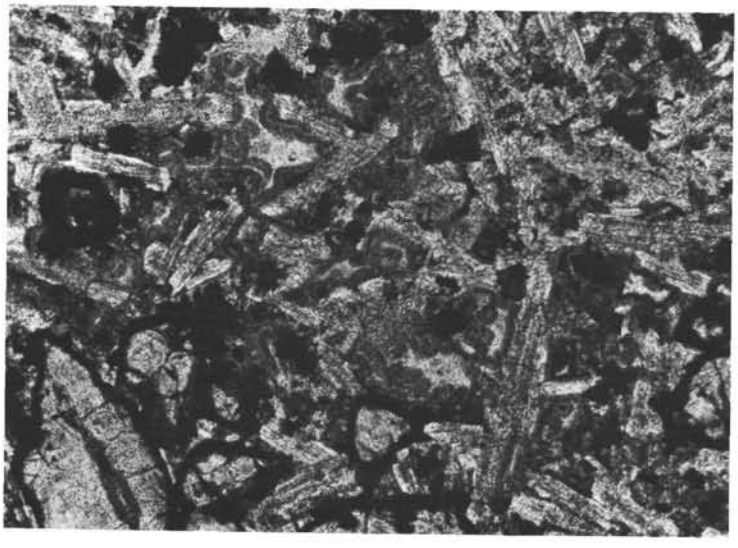


Specimens as above. Outside surface of core segments. MN 24295

PLATE 2



1. Pseudomorphs after olivine in groundmass showing some flow texture. F7159 X25. Plane polarised light.



2. Groundmass of olivine-basalt. Altered plagioclase and interstitial chlorite. F7159 X70. Plane polarised light.

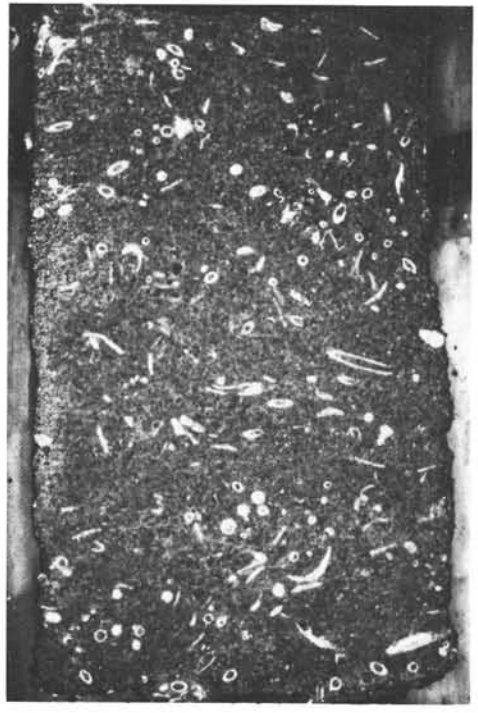
3. Chloritised olivine-basalt. F7160. X25 Plane polarised light.

PLATE 3

Calcite euhedra on natrolite. Magnification X18

PLATE 4.

CORE No. 9, 303-304 m. PALEOCENE.
Section I. *Ditrupa* sandstone.



0 - 10 cm.

top view at 15 cm
Ditrupa and
pelecypods

22 - 28 cm. X3
with *Operculinoides*

PLATE 5

CORE No. 7, 289-294 m. UPPER PALEOCENE. Section 1, 21-40 cm. Cherned, argillaceous volcanic detritus with fossils.

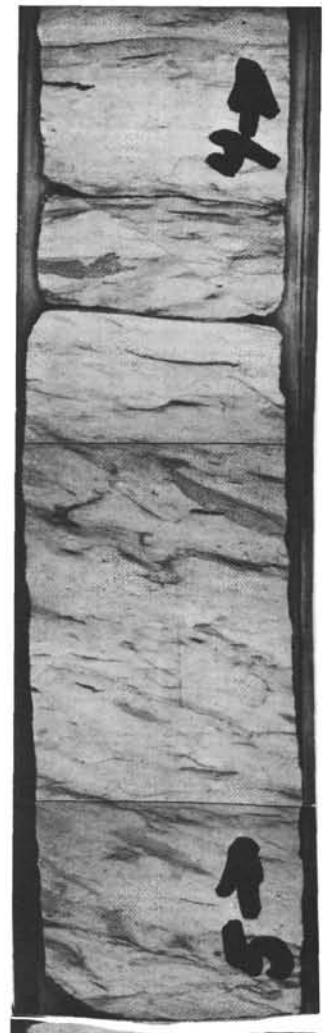
CORE No. 7, 289-294 m. PALEOCENE. Section 2, 140-150 cm. Burrowed clay and volcanic detritus with fossils.

CORE No. 8, 294-303 m. PALEOCENE. Section No. 1, 114-121 cm. Clay with fossils and basaltic fragments.

PLATE 6

CORE No. 27, 831-890 m. OLIGOCENE.

Section 2, 82-92 cm.
Fault with slicken sides; Zoophycos.



CORE No. 27, 831-840 m. LOWER OLIGOCENE.

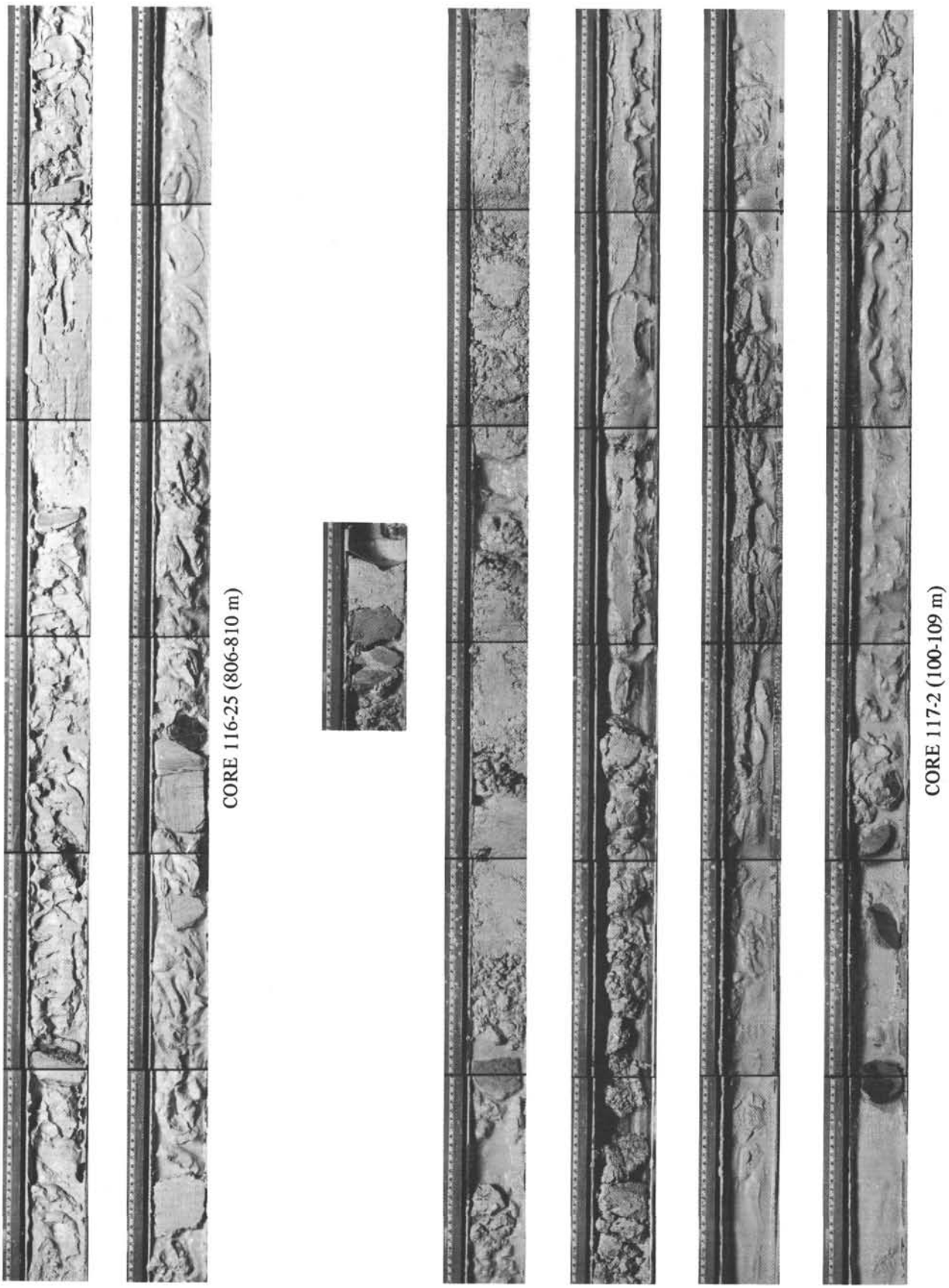
Section 1, base of section. Lowest part brecciated, above it smear and top undistorted. TECTONIC. Fauna of core catcher is squashed.

PLATE 7

CORE No. 26,
825-831 m. OLIGOCENE.

Section 3, 112-134 cm. Burrowed chalk with Zoophycos.

PLATE 8



116-25-4 116-25-5 CORE 116-25 (806-810 m) 117-2-1 117-2-3 117-2-4 117-2-5 117-2-6 CORE 117-2 (100-109 m)

PLATE 9

Diagenetic mobilization of biogenous silica, Site 116

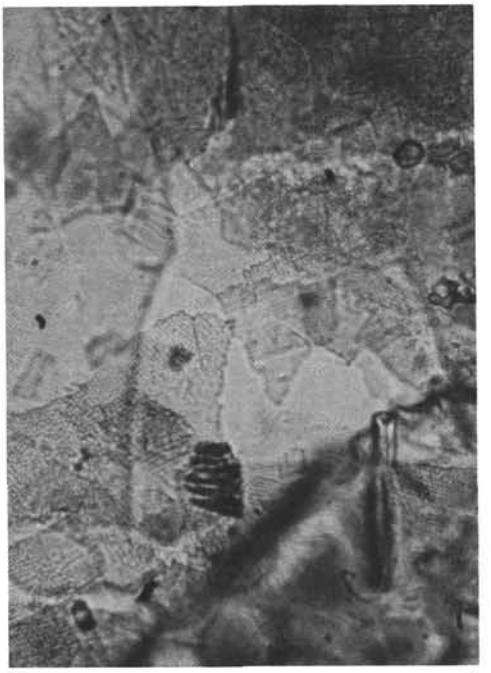
Figure 1 Fragments of *Ethmodiscus rex* (Rattray). ×420. 12-116-14-CC; BN-2.

Figure 2 Fragment of *Ethmodiscus* sp. cf. *E. rex* (Rattray) illustrating poreless fringed margin. ×420. 12-116-15-CC; BN-2; Y11/3.

Figure 3 Typical chert fragment with foraminiferal walls replaced by clear chalcedonic silica; matrix of cloudy amorphous silica. ×273. 12-116-20-CC.

Figure 4 Corroded orosphaerid radiolarian spine. ×68. 12-116-20-CC; BN-1; T4/4.

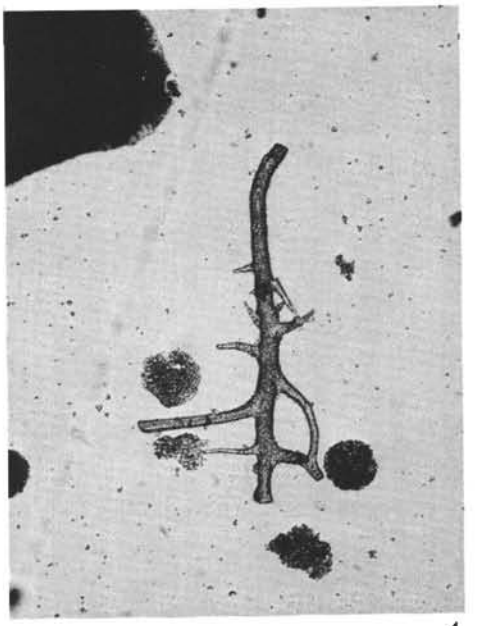
PLATE 9



1

2

3



4

PLATE 10

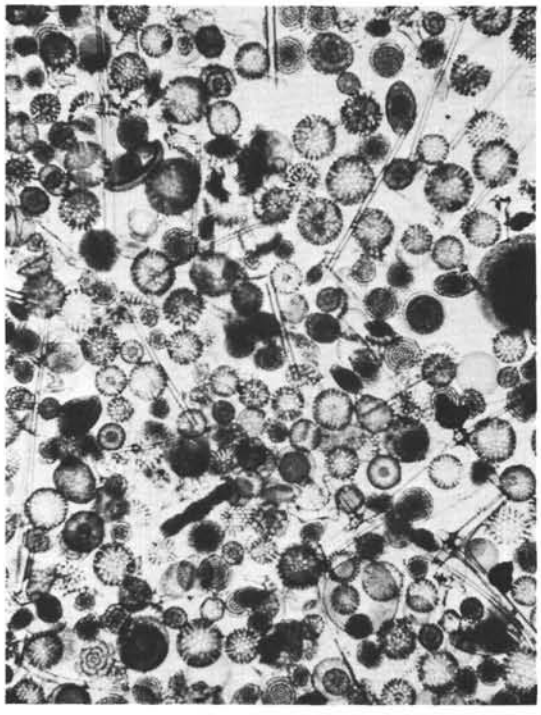
Diagenetic mobilization of biogenous silica, Site 116

Figures 1, 2 — Well-preserved biogenous silica. X42. 1: 12-116-9-CC; BN-2.2: 12-116-10-CC; BN-1.

Figure 3 — Mobolized biogenous silica typical of Core 11. Masses of cloudy amorphous silica, internal casts of foraminifera, angular chert fragments, corroded sponge spicules. X42. 12-116-11-CC; BN-1.

Figure 4 — Little or no silica alteration in Core 12. X42. 12-116-12-CC; BN-1.

PLATE 10



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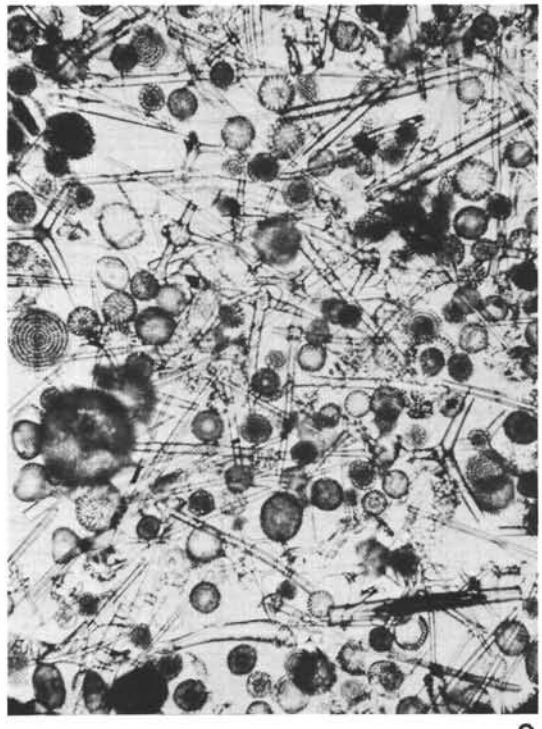

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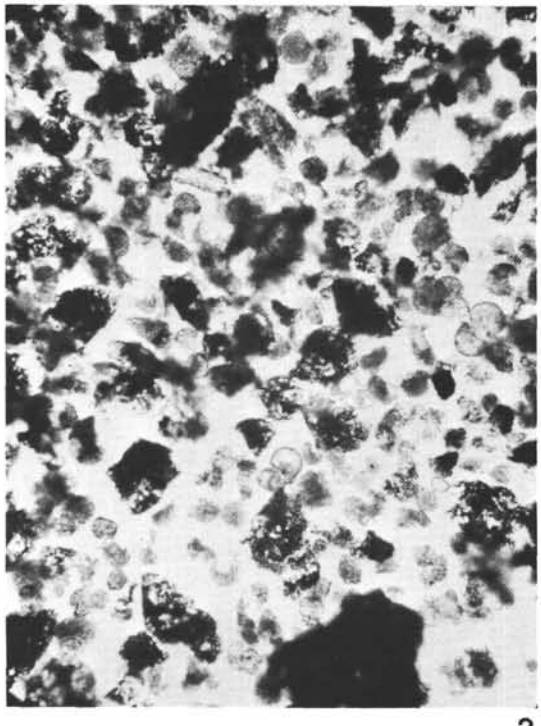

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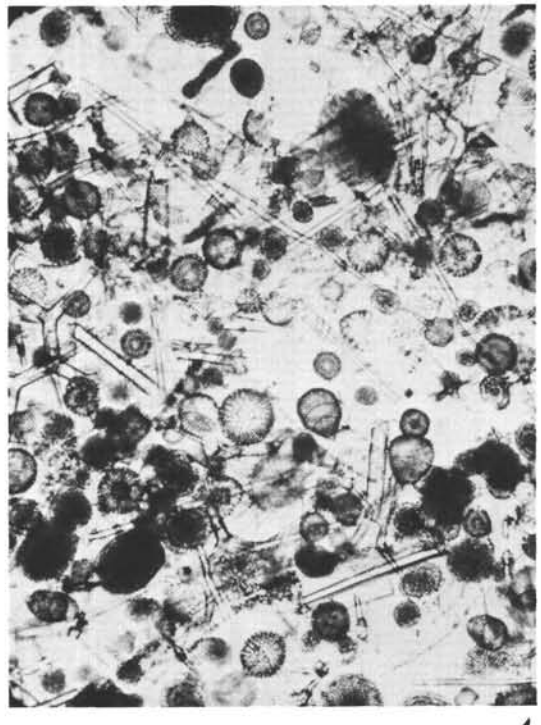


4

PLATE 11
(All illustrations ×60)

Figures 1, 2 — *"Hermanites"*
1. Left valve, side stereo view; USNM 170742.
117A-8-1, 130-134 cm. *Discoaster multiradiatus* Zone, Paleocene.
2. Left valve, side stereo view; USNM 170743.
117A-8-1, *Discoaster multiradiatus* Zone, Paleocene.

Figure 3 — *Poseidonamicus*
Left valve, side stereo view; USNM 170744.
117-2-6, *Sphenolithus ciperoensis* Zone (calcareous nannoplankton), Zone P21-P22 (planktonic foraminifera), Late Oligocene.

Figure 4 — *Henryhowella*
Left valve, side stereo view; USNM 170745.
117-2-6, Bottom. *Sphenolithus ciperoensis* Zone (Calcareous nannoplankton), Zone P21-P22 (planktonic foraminifera), Late Oligocene.

Figure 5 — *Agrenocythere*
Left valve, side stereo view; USNM 170746.
117A-7-1, 95-100 cm. *Discoaster multiradiatus* Zone, Paleocene.

Figure 6 — *Bythocypris*
Right valve, side stereo view; USNM 170747.
117-2-6, Bottom. *Spehnolithus ciperoensis* Zone (calcareous nannoplankton), Zone P21-P22 (planktonic foraminifera), Late Oligocene.

PLATE 11

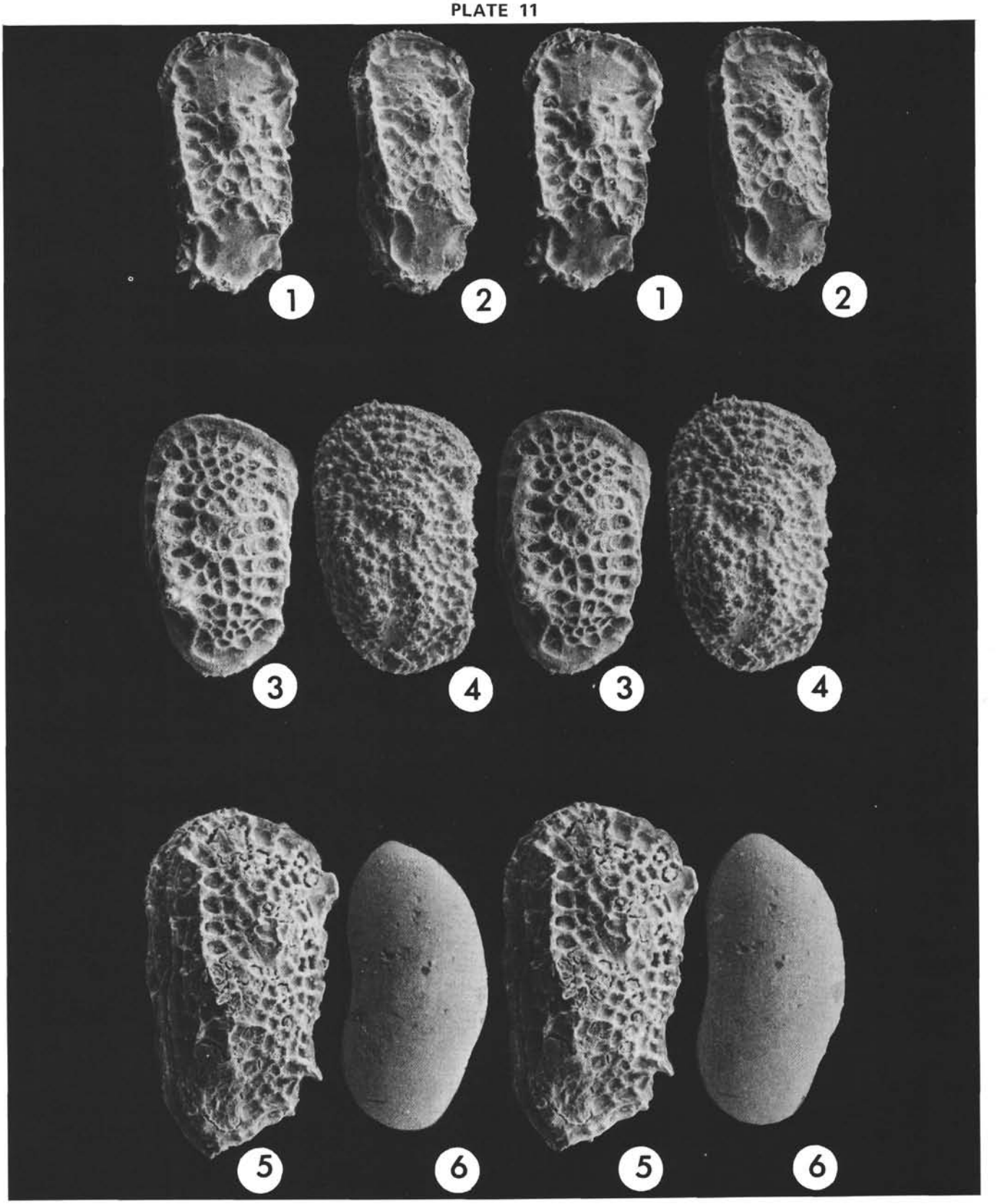


PLATE 12
(Illustrations 1-3, ×40; 4-6, ×60)

Figure 1 *Bairdia*
Left valve, side stereo view; USNM 170748.
117-2-6, Bottom. *Sphenolithus ciperoensis* Zone (calcareous nannoplankton), Zone P21-P22 (planktonic foraminifera), Late Oligocene.

Figure 2 *Krithe*
Left valve, side stereo view; USNM 170749.
117-2-6, Bottom. *Sphenolithus ciperoensis* Zone (calcareous nannoplankton), Zone P21-P22 (planktonic foraminifera), Late Oligocene.

Figure 3 *Echinocythereis*
Left valve, side stereo view; USNM 170750.
117-2-6, Bottom. *Sphenolithus ciperoensis* Zone (calcareous nannoplankton), Zone P21-P22 (planktonic foraminifera), Late Oligocene.

Figure 4 *Phacorhabdotus*
Left valve, side stereo view; USNM 170751.
117A-8-1, 130-134 cm. *Globigerina triloculinoides* Zone, Paleocene.

Figure 5. *Trachyleberidea*
Left valve, side stereo view; USNM 170752.
117A-8-1, 130-134 cm. *Globigerina triloculinoides* Zone, Paleocene.

Figure 6 *Hazelina*
Left valve, side stereo view; USNM 170753.
117A-8-1, 130-134 cm. *Globigerina triloculinoides* Zone, Paleocene.

PLATE 12

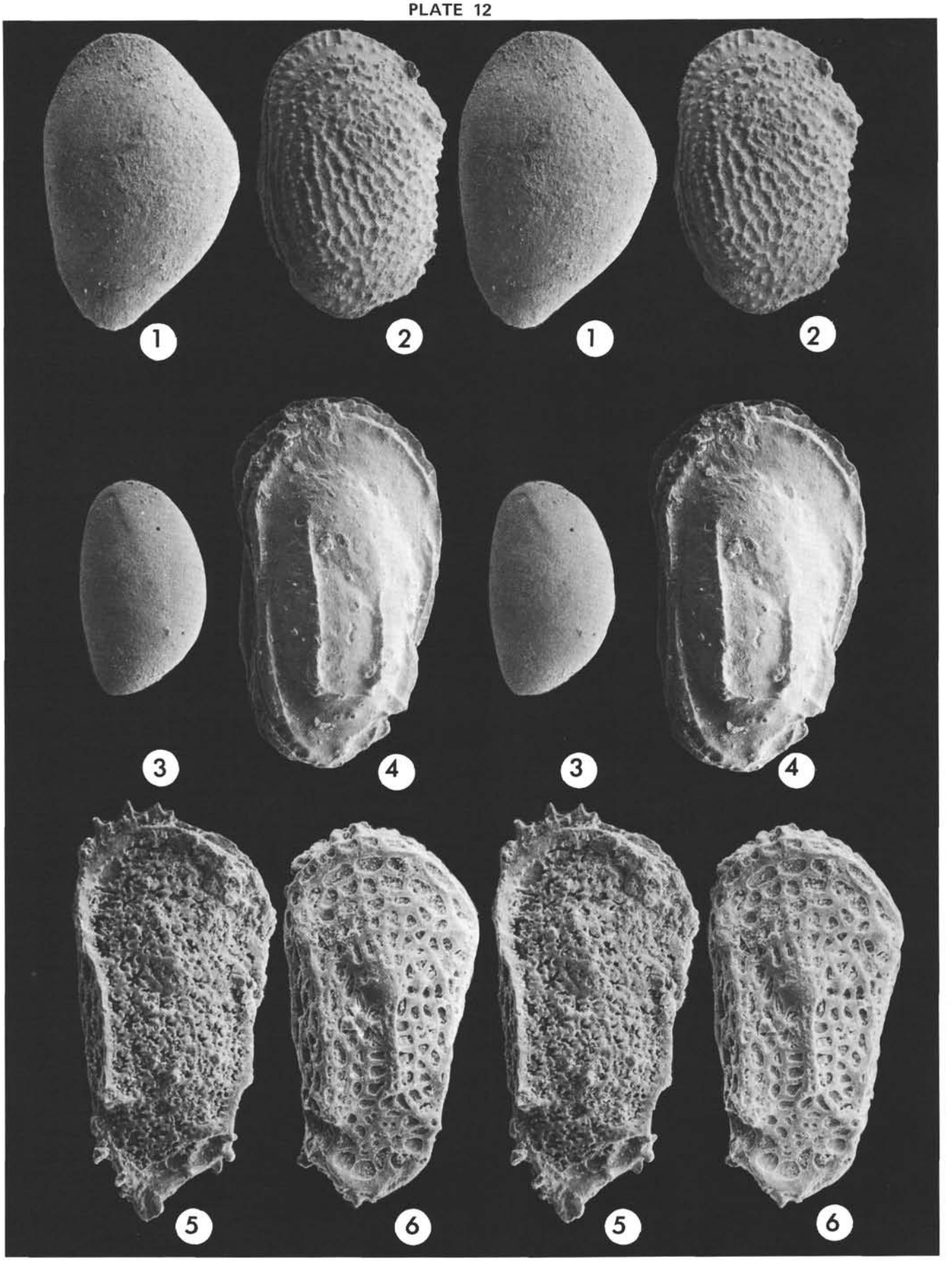


PLATE 13
Late Oligocene Bryozoa, Site 117)
(All specimens X 50; from ?*Sphenolithus distensus* Zone)

Figures 1, 2, 4 — *membraniporidra* aff. *M. similis* Canu & Bassler
1. Basal view, USNM 171624. 2. Zooecia, USNM 171622. 4. Avicularim, USNM 171623. 117-3-1, 30-35 cm.

Figure 3 — *Lunulites* spl 1
3a. Frontal view; 3b. basal view; USNM 171627. 117-3-1, 30-35 cm.

Figure 5 — *Membraniporidra* aff. m. *porrecta* Canu & Bassler
Bilaminate fragment, USNM 171621. 117-3-1, 30-35 cm.

Figures 6, 7 — *Antropora*? *oculifera* Canu & Bassler
6. Tubular fragment with narrow zooecia, USNM 171626.
7. Flat fragment with wide zooecia, USNM 171625. 117-3-1, 30-35.

PLATE 13

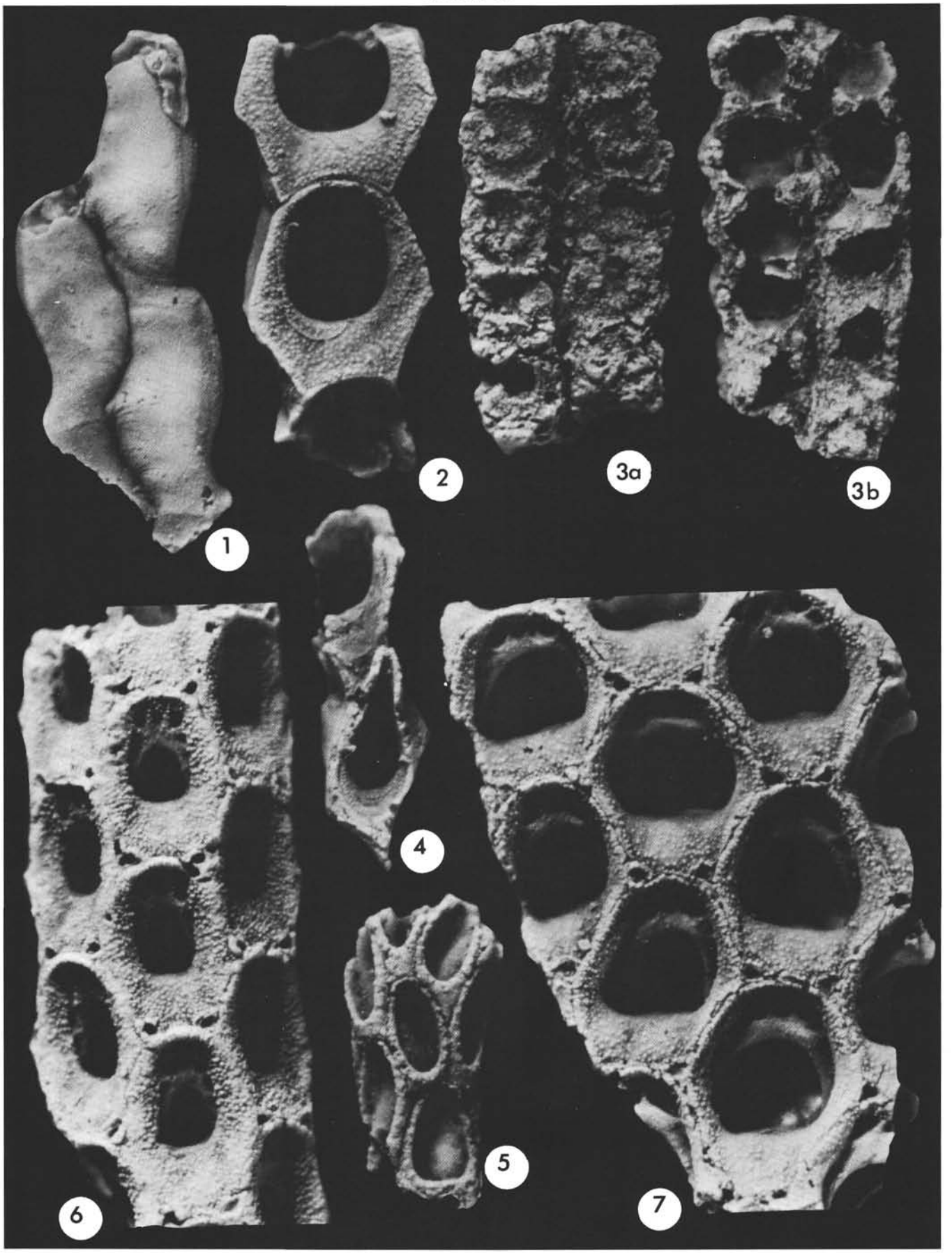


PLATE 14
Late Oligocene Bryozoa, Site 117
(All specimens X 50)

Figure 1 — *Floridina* sp 2
Tubular fragment, USNM 171635. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figures 2, 3 — *Floridina* sp 3
2. Zooecia, proximal one with ovicell, USNM 171636.
3. Zooecia, and onychocellarium, USNM 171637. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figures 4-6 — *Smittipora?* aff. *S. ? nelliiformis* (Harmer)
4. Broken internode, USNM 171630.
5. Proximal end of internode, USNM 171631.
6. Distal end of internode with paired bases rami, USNM 171629. 117-2-6, Bottom. *?Sphenolithus ciperoensis* Zone.

Figure 7 — *Smittipora?* sp 2
Ovicelled and nonovicelled zooecia, USNM 171632. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figures 8, 10 — *Floridina* sp 1
8. Ovicelled and nonovicelled zooecia, USNM 171633.
10. Nonovicelled zooecia, USNM 171634. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figure 9 — *Onychocella* aff. *O. laciniosa* Canu & Bassler
Zooecia and onychocellaria, USNM 171628. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

PLATE 14

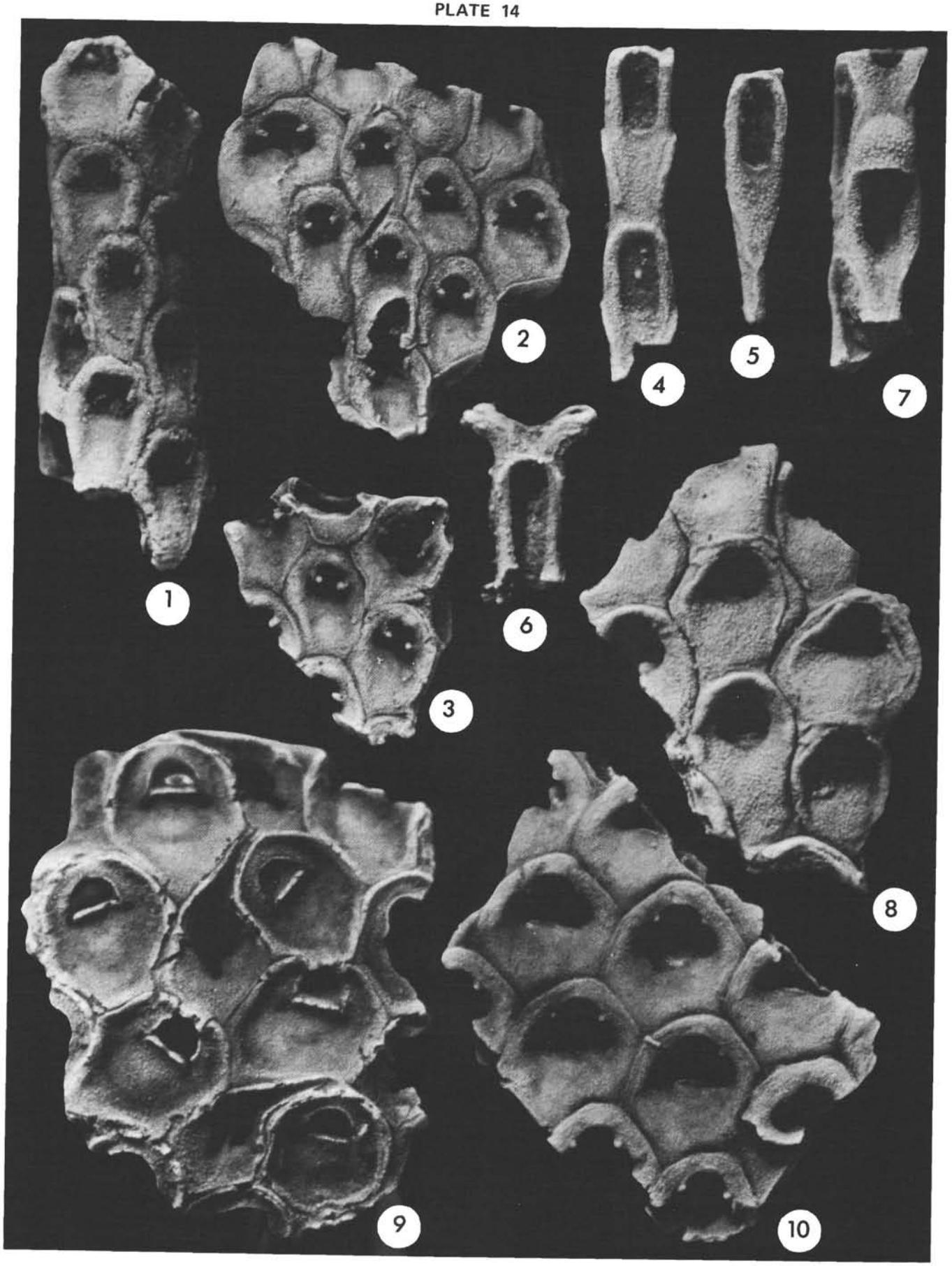


PLATE 15
Late Oligocene Bryozoa, Site 117
(All specimens X50; from *?Sphenolithus distensus* Zone)

Figures 1-3 — *Cellaria* sp.
1. Doubly tapering fragment with ovicelled and nonovicelled zooecia, avicularia, USNM 171646. 2. Bifurcation with nonovicelled zooecia, USNM 117647. 3. Distally tapering fragment with ovicelled and nonovicelled zooecia, avicularia, USNM 171648. 117-3-1, 30-35 cm.

Figure 4 — *Rosseliana?* sp.
Fragment of zoarium encrusting cyclostome, USNM 171639, 117-3-1, 30-35 cm.

Figure 5 — *Mollia* sp. 1
Fragment of zoarium with small interzooecial fenestrae, USNM 171638. 117-3-1, 30-35 cm.

Figure 6-8 — *Microporina?* aff. M. ? *polysticha* (Reuss)
6. Part of internode with bipartite, lateral basis rami, USNM 171641. 7. Zooecia, USNM 171640. 8. Distal end of internode, USNM 171642. 117-3-1, 30-35 cm.

Figures 9, 10 — *Craspedozoem?* sp.
9. Frontal view, USNM 171649. 10. Basal view USNM 171650. 117-3-1, 30-35 cm.

Figures 11, 12 — *Setosella fragilis* Canu
11. Edge view of quadriserial fragment, USNM 171644. 12. Frontal view of parts of two zooecia; cryptocyst with slitlike opesiules in distal hollows; USNM 171643. 117-3-1, 30-35 cm.

Figures 13-15 — *Scrupocellaria elliptica* (Waters):
13. Basal view of internode fragment with paired vibracula in axil, USNM 171653. 117-3-1, 30-35 cm. 14. Nonovicelled zooecia with well-preserved scute bases, USNM 171651. 117-2-6, Bottom. 15. Ovicelled zooecia, USNM 171652. 117-3-1, 30-35 cm.

Figure 16 — *Steganoporella* sp.
Parts of zooecia with steeply descending cryptocyst, wide distal shelf, USNM 171645. 117-3-1, 30-35 cm.

PLATE 15

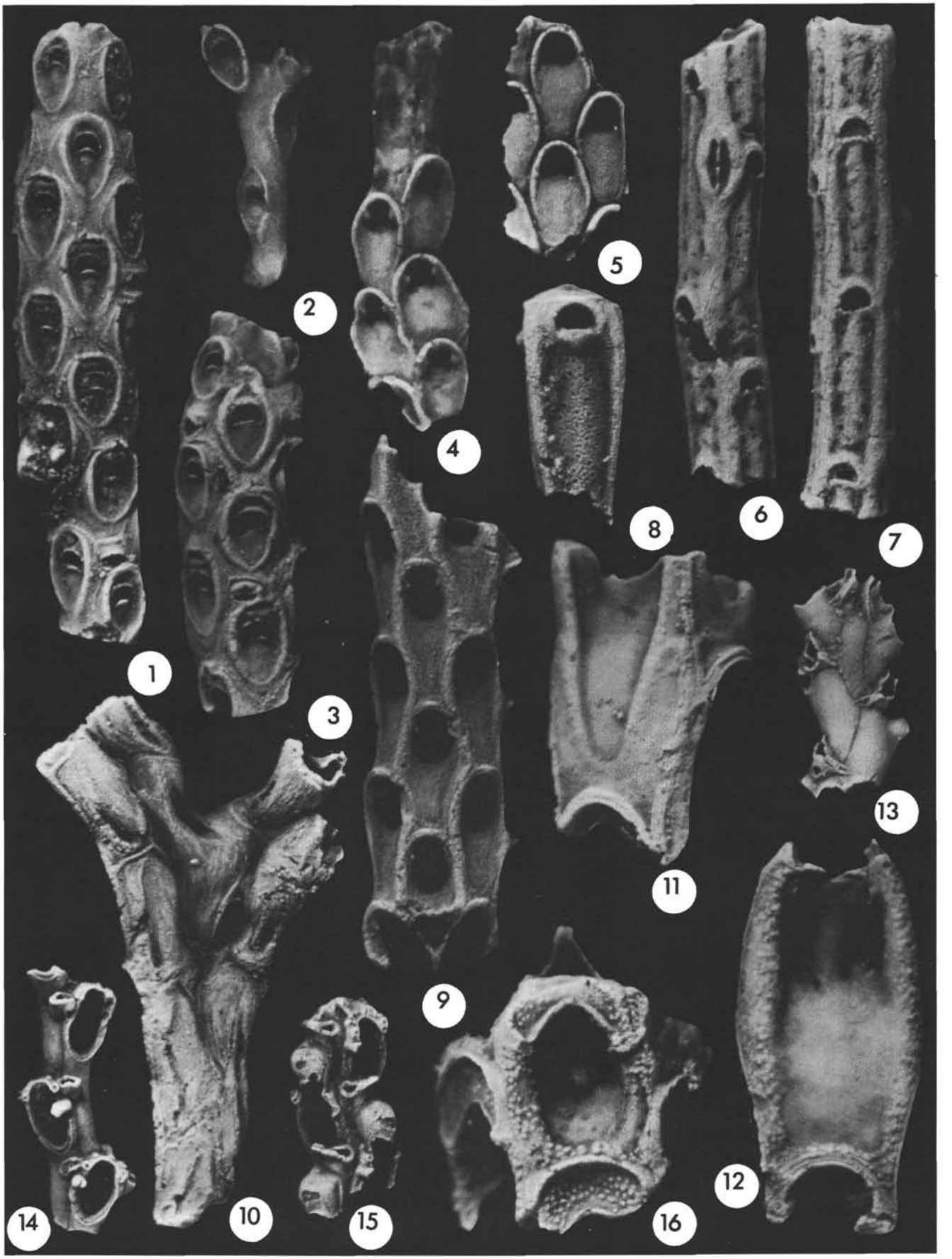


PLATE 16
Late Oligocene Bryozoa, Site 117)
(All specimens X 50; from *?Sphenolithus distensus* Zone)

Figures 1, 2 — *Cribrilaria radiata* (Moll)
1. Ovicelled and nonovicelled zooecia, USNM 171654. 2. Zooecia and avicularia, USNM 171655. 117-3-1, 30-35 cm.

Figures 3, 4 — *Gephyrotes?* aff. *G. ? convexa* Canu & Bassler
3. Nonovicelled zooecia, USNM 171657. 4. Nonovicelled and ovicelled zooecia, USNM 171656. 117-3-1, 30-35 cm.

Figure 5 — *Escharoides* sp 2
Encrusting fragment, USNM 171662. 117-3-1, 30-35 cm.

Figure 6 — *Escharoides* sp. 1
Encrusting fragment, USNM 171661, 117-3-1, 30-35 cm.

Figure 7 — *Hippopleurifera* sp.
Parts of three zooecia, USNM 171660. 117-3-1, 30-35 cm.

Figure 8, 9 — *Corbulipora?* sp.
8. Basal view, showing remnants of *Beania*-like connecting tubes, USNM 117659. 9. Frontal view, showing coastal shield, oral spine bases, USNM 171658. 117-3-1, 30-35 cm.

Figures 10, 11 — *Porina* sp.
10. Zooecia with small, circumperistomial avicularia, USNM 171663. 11. Heavily calcified zooecia, one with a large proximal-oral avicularium, USNM 171664. 117-3-1, 30-35.

Figure 12 — *Tubucella* cf. *T. papillosa* (Reuss)
Zooecia, USNM 171665. 117-3-1, 30-35 cm.

PLATE 16

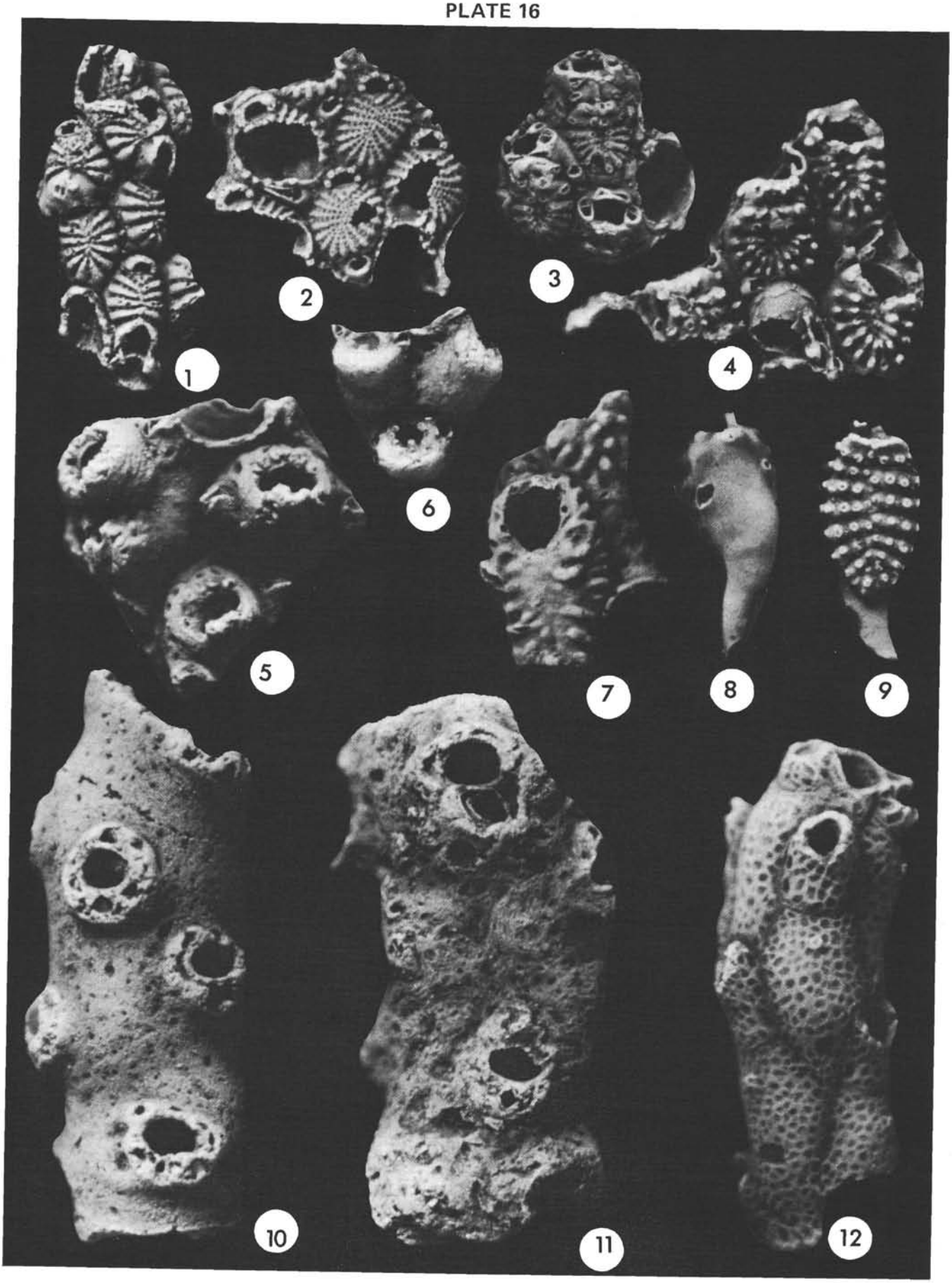


PLATE 17

Late Oligocene Bryozoa, Site 117

(All specimens X50; from *?Sphenolithus distensus* Zone)

Figures 1-4 — *Adeonellopsis subteres* (Roemer)
1. Small, encrusting zooecia, zone of astogenetic change, USNM 171666. 2. Thick-walled zooecia from proximal fragment of large colony, USNM 171668. 3. Large zooecia (gonoecia?), USNM 171669. 4. Thin-walled zooecia on fragment near growing margin, USNM 171667. 117-3-1, 30-35 cm.

Figures 5, 6 — *Adeonella ornatissima* (Stoliczka)
5. Thick-walled zooecia and marginal gonoecia with large avicularia, USNM 171671. 6. Thin-walled zooecia and marginal gonoecia with small avicularia, USNM 171670. 117-3-1, 30-35 cm.

Figure 7 — *Schizostomella* aff. *S. lontensis* (Waters)
Subcylindrical fragment with thin-walled zooecia, USNM 171672. 117-3-1, 30-35 cm.

PLATE 17

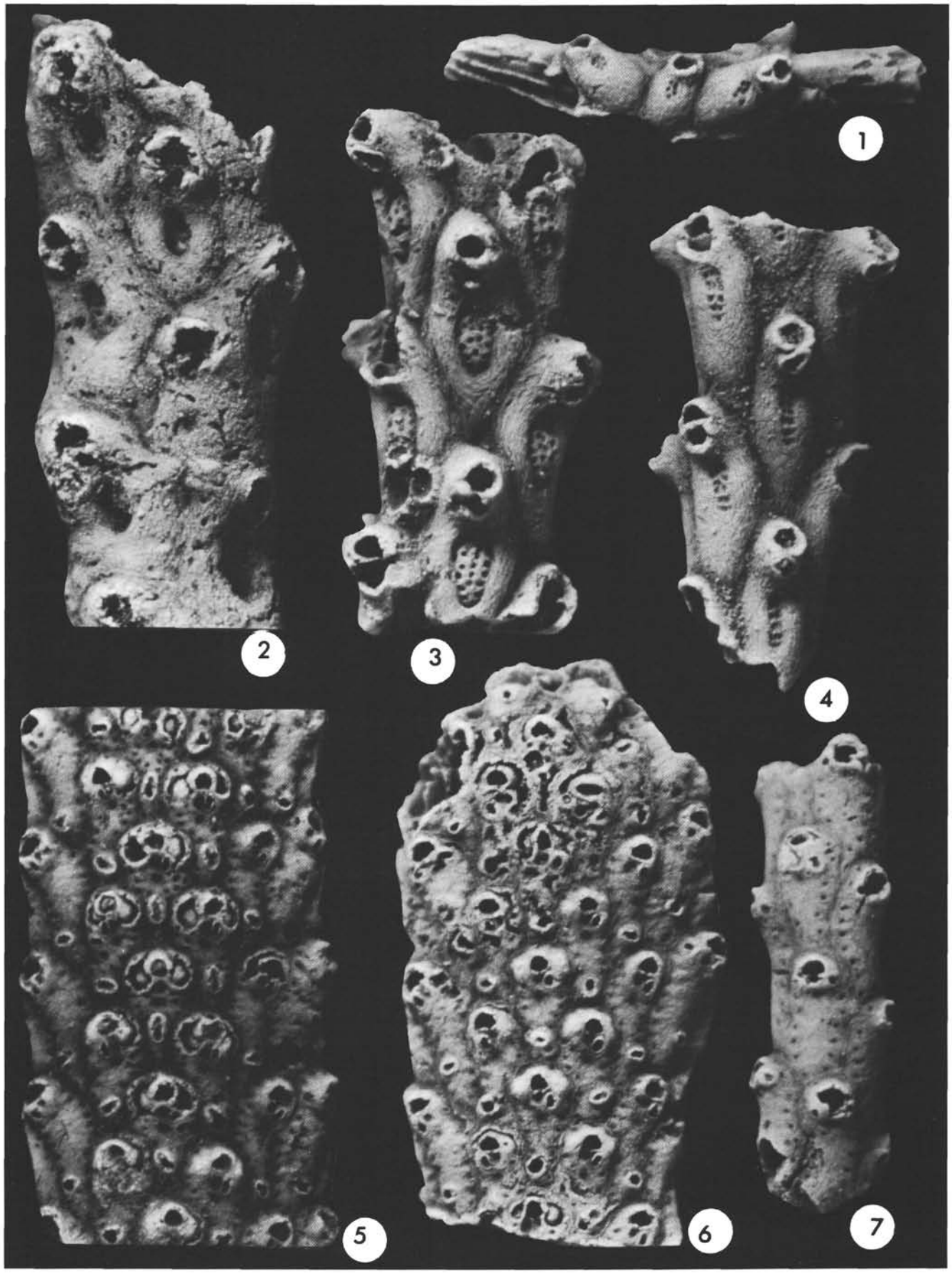


PLATE 18
Late Oligocene Bryozoa, Site 117
(All specimens X50)

Figure 1 — *Escharella* sp. 2
Encrusting zoarium, USNM 171679. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figure 2 — *Smittoidea variabilis* (Canu)
Ovicelled and nonovicelled zooecia, encrusting fragment, USNM 171680. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figure 3, 4 — *Schizostomella* aff. *S. curryi* Cheetham
3. Thin-walled zooecia, USNM 171674. 4. Thick-walled zooecia and broken gonoecium, USNM 171675. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figure 5 — *Smittoidea* sp. 2
Parts of four zooecia, USNM 171682. 117-2-6, Bottom. *?Sphenolithus ciperoensis* Zone.

Figure 6 — *Schizomavella* aff. *S. trigonostoma* Cheetham
Fragment, USNM 171677. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figure 7 — *Escharella* aff. *E. selseyensis* Cheetham
Quadriserial fragment, USNM 171678. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figure 8 — *Schizostomella* aff. *S. lontensis* (Waters)
Bilaminate fragment with thick-walled zooecia, USNM 171673. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figure 9 — *Dakaria?* sp.
Quadriserial fragment, USNM 171676. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

PLATE 18

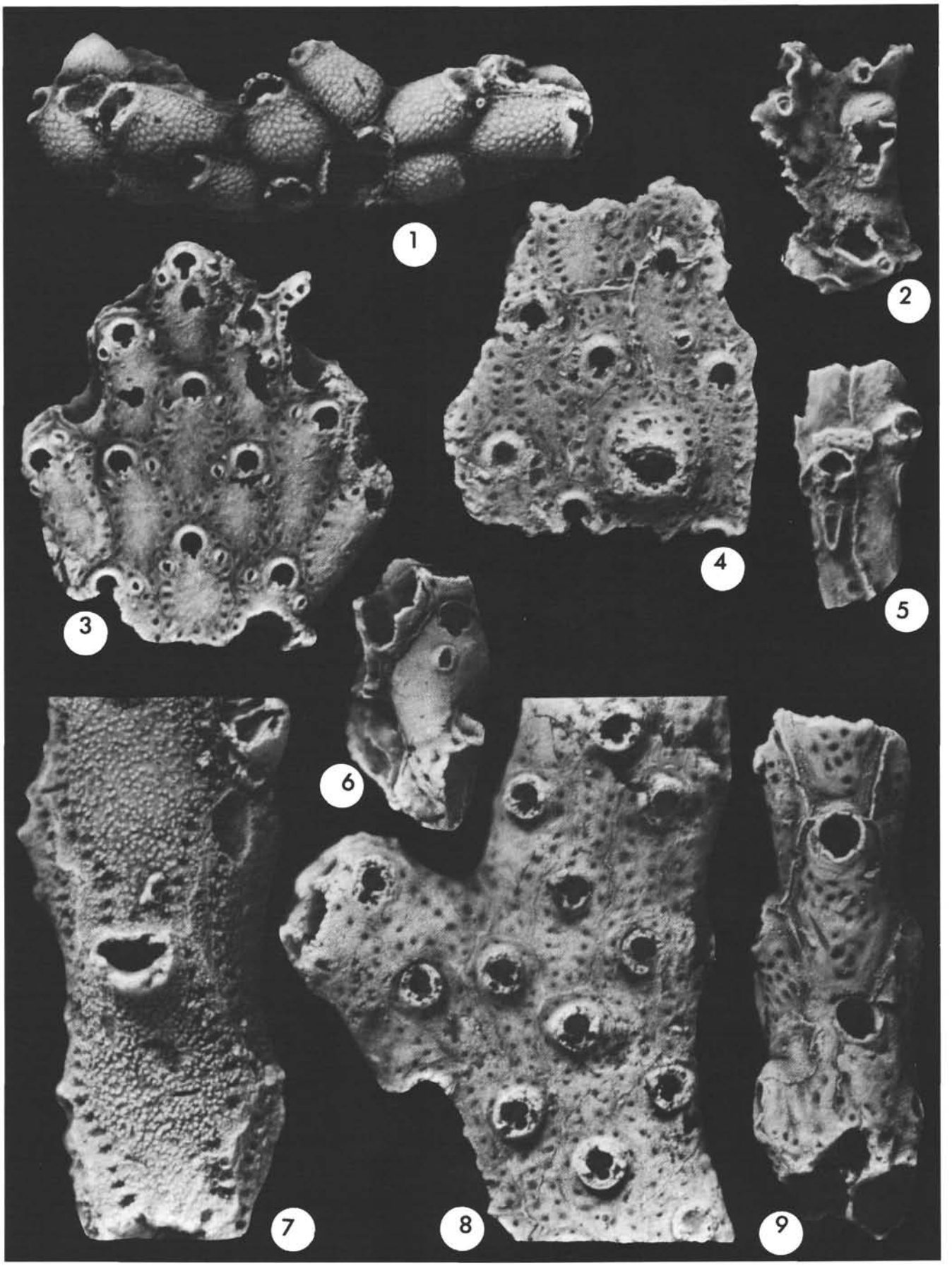


PLATE 19
Late Oligocene Bryozoa, Site 117
(All specimens X50)

Figures 1-3 *Sertella marginata* (Reuss)
1. Reverse view of anastomosis with small, round avicularia. USNM 171685. 2. Reverse view of bifurcation with larger spatulate avicularia, USNM 171684. 3. Ovicelled zooecium with large frontal avicularium and small oral avicularium; nonovicelled zooecia with oral avicularia only; USNM 171683. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figure 4 *Hemiphylactella?* sp.
Zooecia with high peristomes surrounding orfice with condyles, USNM 171692. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figure 5 *Smittoidea variabilis* (Canu)
Bilaminate fragment with thick-walled zooecia, USNM 171681. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figures 6-8 *Sparsiporina elegans* (Reuss)
6. Reverse view showing lateral rows of zooecia, USNM 171688. 7. Medial and lateral rows of zooecia, USNM 171687. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone. 8. Ovicelled and nonovicelled zooecia, USNM 171686. 117-3-1, 30-35 cm. *?Sphenolithus ciperoensis* Zone.

Figure 9 *Bactridium?* sp.
Biserial fragment, USNM 171689. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

PLATE 19

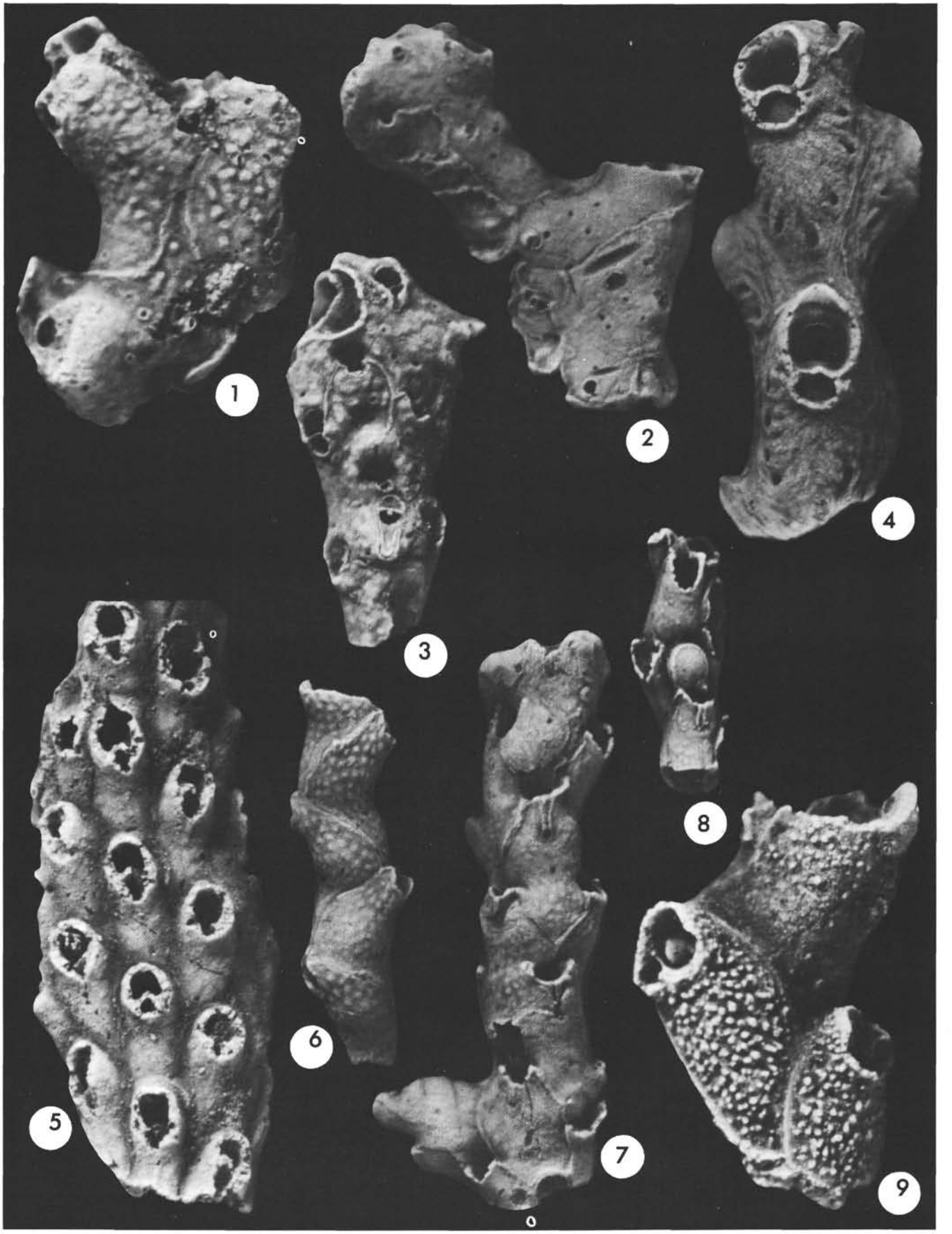


PLATE 20
Late Oligocene Bryozoa, Site 117
(All specimens X50)

Figure 1 — Ascophoran, gen. A indet.
Parts of zooecia, two ovicelled, USNM 171704. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figures 2, 3 — *Dittosaria prima* (Reuss)
2. Frontal view, USNM 171693. 3. Lateral view, USNM 171694. 117-2-6, Bottom. *?Sphenolithus ciperoensis* Zone.

Figures 4-7 — Pasytheid, n. gen.
4. Proximal end of internode, beginning with single zooecium, USNM 171698. 5. Broken internode with quadriserially arranged zooecia, USNM 171699. 6. Distal end of internode with distal and lateral bases rami, USNM 171697. 7. Zooecia with sinuate orifices and well-developed distolateral avicularia, USNM 171700. 117-2-6, Bottom. *?Sphenolithus ciperoensis* Zone.

Figures 8, 9 — *Gemellipora* sp.
8. Lateral view, showing orifices of alternate zooecia, USNM 171695. 9. Frontal view showing twisted orifice, USNM 171696. 117-2-6, Bottom. *?Sphenolithus ciperoensis* Zone.

Figure 10 — *Orbitulipora* sp.
Nearly complete, discoidal zoarium, USNM 171701. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figures 11, 12 — *Batopora* sp.
11. Basal view of four-zooecium zoarium, USNM 171703. 12. Frontal view of larger, hemispherical zoarium, USNM 171702. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

Figures 13, 14 — *Leiosella* aff. *L. rostrifera* Canu & Bassler
13. Zooecia with small oral avicularium and larger frontal avicularium; zooecium just above center ovicelled; USNM 171691. 14. Zooecium at lower left ovicelled, USNM 171690. 117-3-1, 30-35 cm. *?Sphenolithus distensus* Zone.

PLATE 20

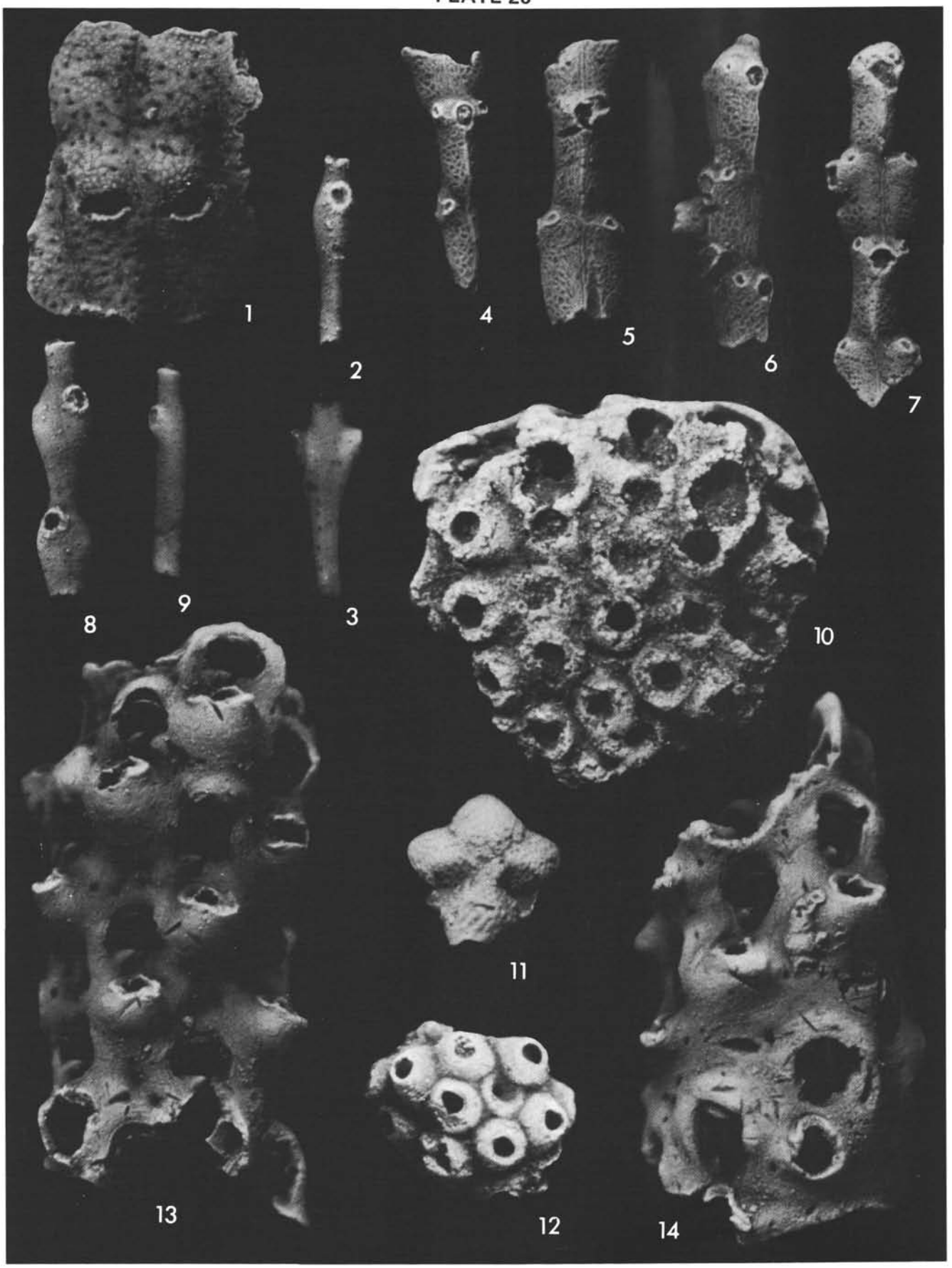


PLATE 21
Late Paleocene Bryozoa, Site 117
(All specimens X 50; from *Globigerina triloculinoides - Discoaster multiradiatus* Zone)

Figures 1, 4, 5 Calloprid, gen. indet.
1. Basal view, USNM 172386. 4. Ovicelled zooecia, USNM 172385. 5. Zooecia and avicularia, USNM 172384. 117A-8-1, 130-134 cm.

Figures 2, 3 *Membraniporidra*? sp.
2. Zooecia and avicularia, USNM 172382. 3. Ovicelled and non-ovicelled zooecia, USNM 17283. 117A-8-1, 130-134 cm.

Figure 6 *Ellisina?* sp.
Zooecia and avicularia, USNM 172381. 117A-7-1, 95-100 cm.

PLATE 21

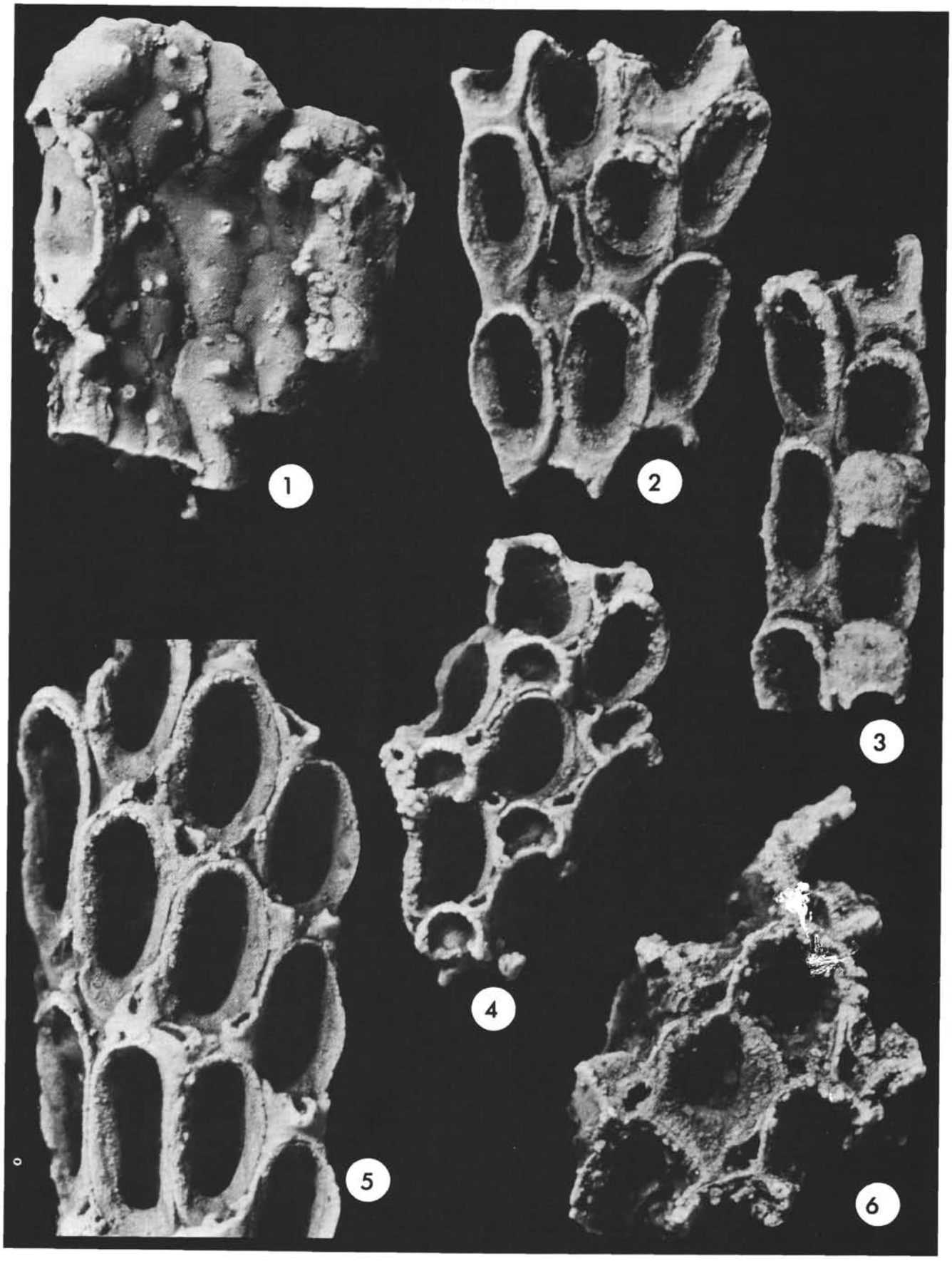


PLATE 22
Late Paleocene Bryozoa, Site 117
(All specimens X50; from *Globigerina triloculinoides - Discoaster multiradiatus* Zone)

Figure 1 — *Periporosella* ? sp. 1
Zooecia and avicularia (encrusting *Coscinopleura* sp.), USNM 172387. 117A-4-1, 62-67 cm.

Figure 2 — *Periporosella* ? sp. 2
Zooecia, USNM 172388. 117A-8-1, 130-134 cm.

Figure 3 — *Stamenocella* cf. *S "oculata* Ulrich & Bassler
Proximal part of internode, showing partly occluded zooecia and avicularia, USNM 172390. 117A-8-1, 130-134 cm.

Figure 4 — *Pithodella* sp.
Distal tip of branch, showing zooecia and avicularia, USNM 172389. 117A-7-1, 95-100 cm

Figure 5 — *Lunulites* sp. 4
5a. Frontal view; 5b. Basal view; USNM 172395. 117A-7-1, 95-100 cm.

Figure 6 — *Stamenocella* sp.
Partly occluded zooecia and avicularia, USNM 172391. 117A-4-1, 127-132 cm.

Figures 7, 8 — *Lunulites* sp. 5
7. Basal view, USNM 172397. 8. Frontal view, USNM 172396. 117A-7-1, 95-100 cm.

PLATE 22

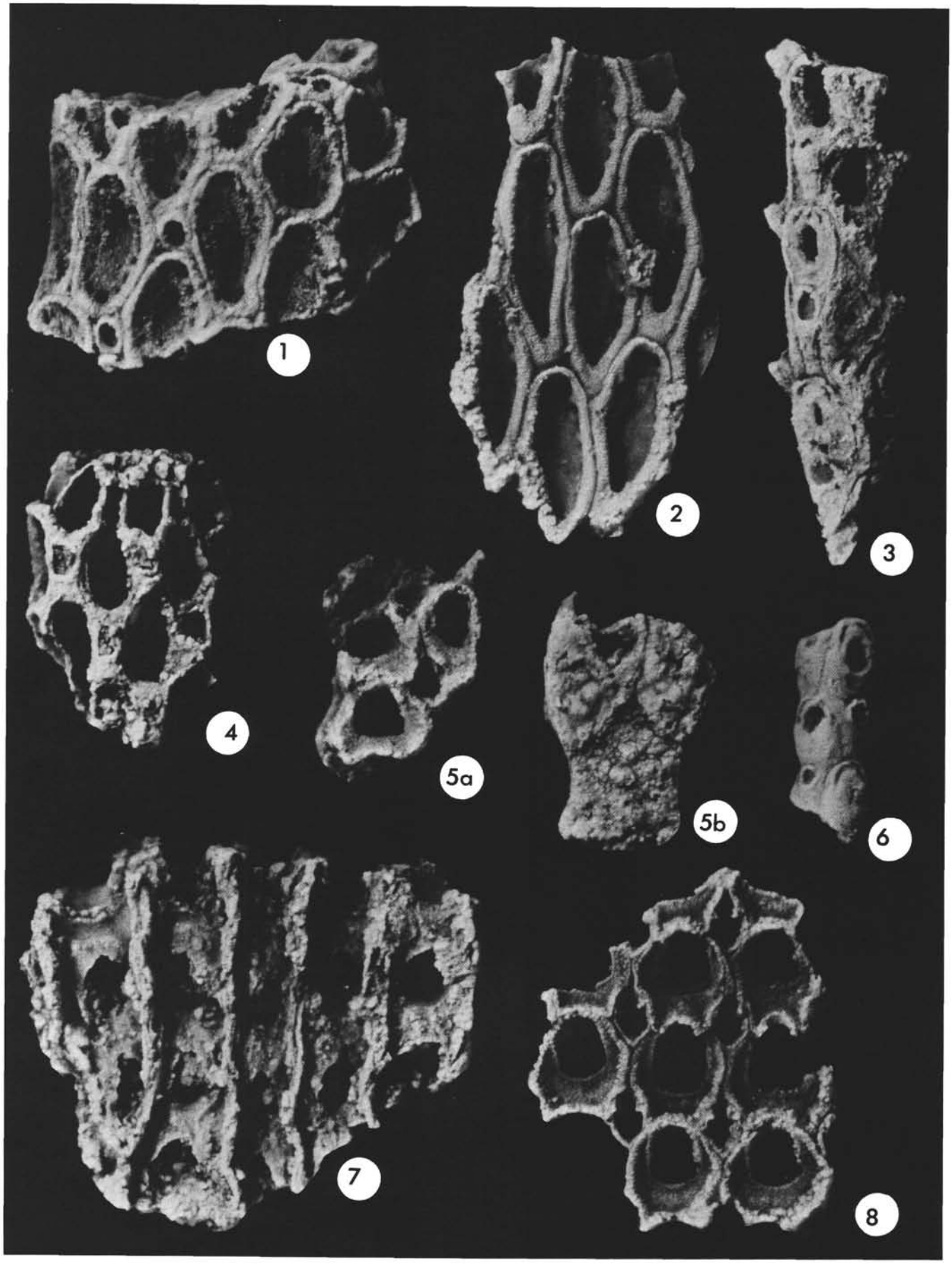


PLATE 23
Late Paleocene Bryozoa, Site 117
(All specimens X50; from *Globigerina triloculinoides - Discoaster multiradiatus* Zone)

Figure 1 — *Lunulites* sp. 2
1a. Frontal view; lb. Basal view; USNM 172392. 117A-8-1, 130-134 cm.

Figure 2 — *Smittipora* ? sp. 6
Zooecia, USNM 172404. 117A-7-1, 95-100 cm.

Figures 3-5 — *Smittipora* ? sp. 3
3. Zooecia, USNM 172398. 4. Distal tip of internode, USNM 172400. 5. Proximal tip of internode, USNM 172399. 117A-8-1, 130-134 cm.

Figure 6 — *Smittipora* ? sp. 7
Zooecia and ovicells (?), USNM 172405. 117A-7-1, 95-100 cm.

Figure 7 — *Smittipora* ? sp. 4
Zooecia, USNM 172401. 117A-4-1, 62-67 cm.

Figures 8, 9 — *Smittipora* ? sp. 5
8. Zooecia, USNM 172402. 9. Occluded zooecia and ovicell, USNM 172403. 117A-4-1, 62-67 cm.

Figures 10, 11 — *Lunulites* sp. 3
10. Zooecia and vibracula near the ancestrula, USNM 172394. 11. Part of large zoarium; a, frontal view; b, basal view; USNM 172393. 117A-8-1, 130-134 cm.

PLATE 23

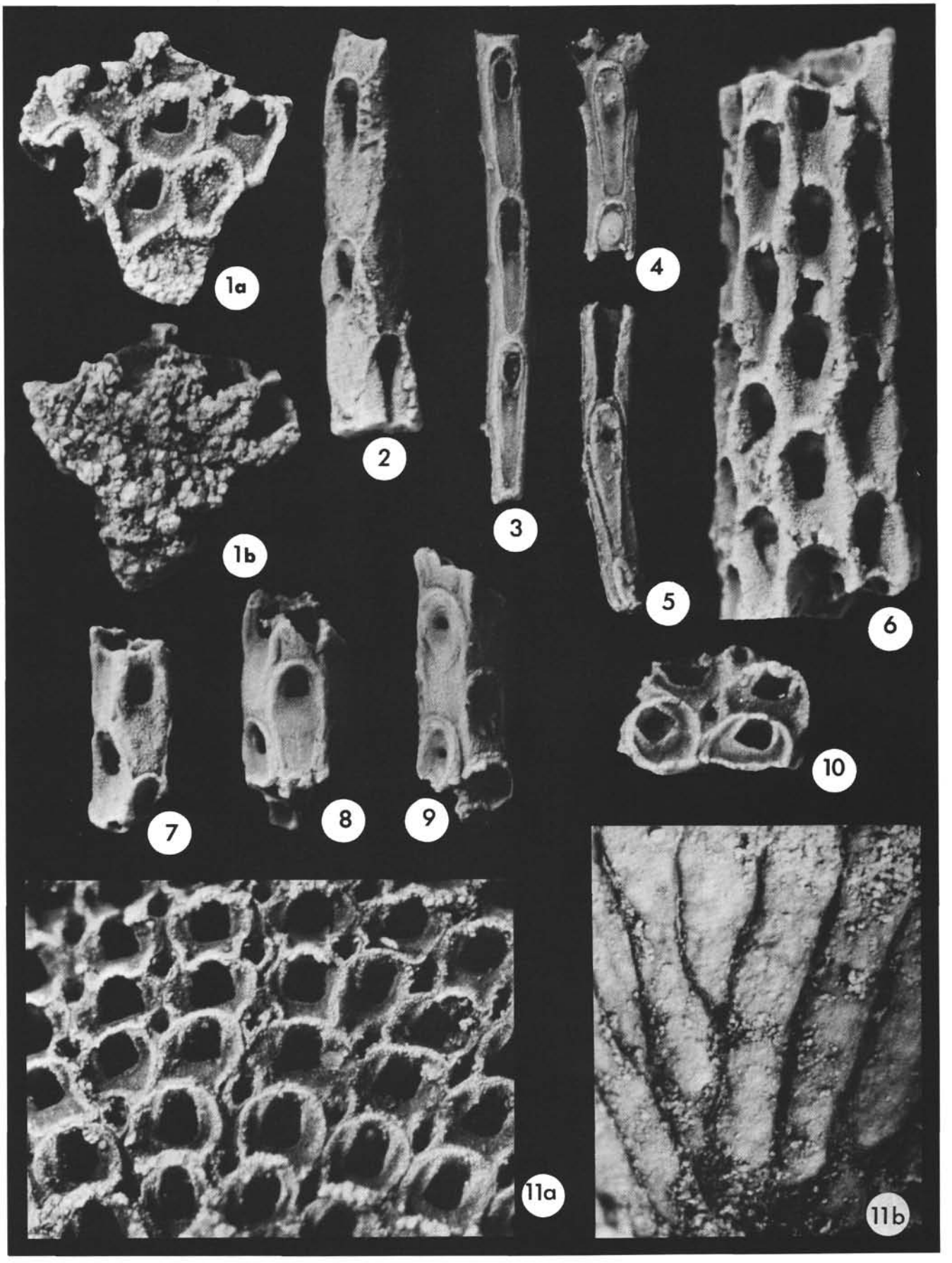


PLATE 24
Late Paleocene Bryozoa, Site 117
(All specimens ×50; from *Globigerina triloculinoides - Discoaster multiradiatus* Zone)

Figures 1, 3, 4 — *Mollia* sp. 2
1. Marginal kenozooecia and ovicelled (?) zooecium, USNM 172412. 3. Totally regenerated zooecia, USNM 172413. 4. Normal and occluded zooecia, USNM 172411. 117A-8-1, 130-134 cm.

Figure 2 — *Floridina* sp. 6
Subcylindrical fragment (small axial hollow not shown), USNM 172409. 117A-4-1, 62-67 cm.

Figure 5 — *Floridina* sp. 7
Zooecia and part of onychocellarium, USNM 172410. 117A, 4-1, 127-132 cm.

Figures 6, 7, 10 — Onychocellid, gen. A indet.
6. Fragment of biserial branch, USNM 172414. 7. Tip of branch with occluded zooecia, USNM 172416. 10. Ovicelled and occluded zooecia, USNM 172415. 117A-7-1, 95-100 cm.

Figures 8, 11 — *Floridina* sp. 5
8. Zooecia and onychocellarium, USNM 172407. 117A-7-1, 95-100 cm. 11. Ovicelled and nonovicelled zooecia, some occluded, USNM 172408. 117A-8-1, 130-134 cm.

Figure 9 — *Floridina* sp. 4
Widely-spaced zooecia, some occluded, USNM 172406. 117A-7-1, 95-100 cm.

PLATE 24

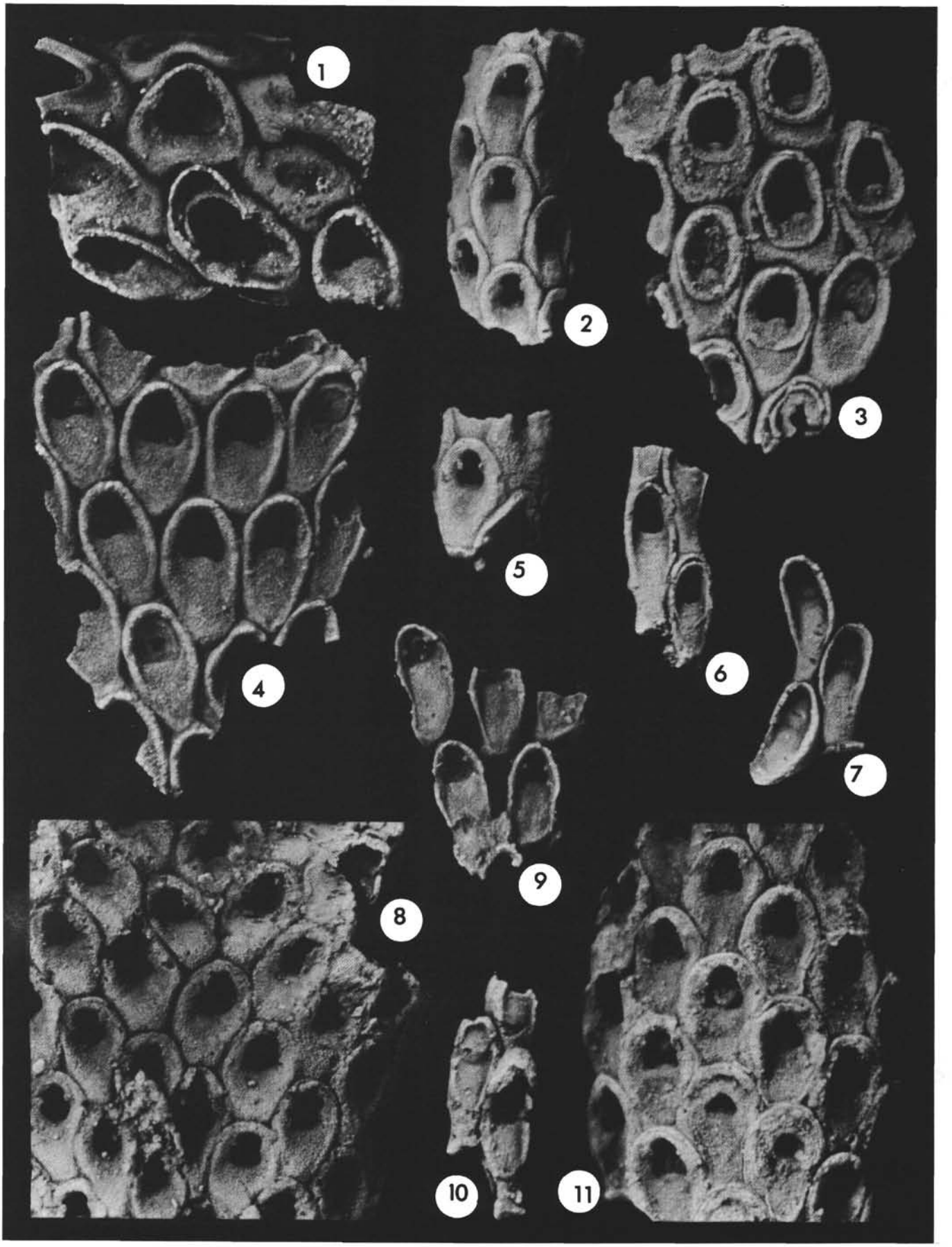


PLATE 25
Late Paleocene Bryozoa, Site 117
(All specimens X50; from *Globigerina triloculinoides - Discoaster multiradiatus* Zone)

Figure 1 — *Poricellaria* sp.
Zooecia and avicularia, proximal part of internode, USNM 172421. 117A-4-1, 127-132 cm.

Figures 2, 5-7 — *Cosdinopleura* sp.
2. Ovicelled zooecia, USNM 172425. 117A-4-1, 127-132 cm. 5. Thick-walled zooecia from proximal part of large zoarium, USNM 172422. 6. Less thick-walled zooecia from median part of large zoarium, USNM 172423. 117A-7-1, 95-100 cm.

7. Thin-walled zooecia from distal part of zoarium, USNM 172424. 117A-4-1, 62-67 cm.

Figure 3 — nychocellid, gen. B indet.
Zooecia, USNM 172417. 117A-4-1, 62-67 cm.

Figure 4 — *Semieschariella*? sp. 2
Zooecia and avicularia from proximal part of internode, USNM 172420. 117A-4-1, 127-132 cm.

PLATE 25

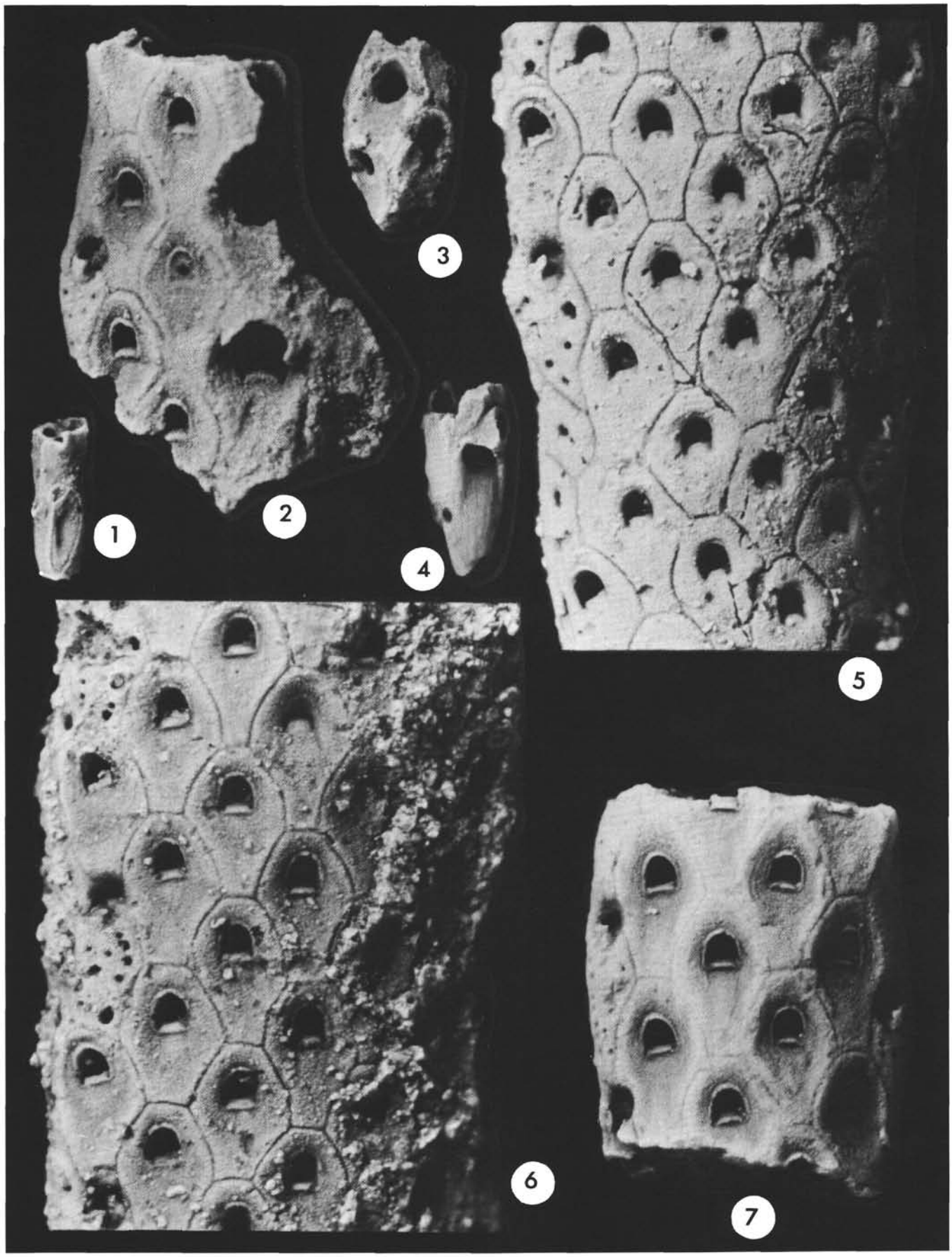


PLATE 26
Late Paleocene Bryozoa, Site 117
(All specimens X50; from *Globigerina triloculinoides - Discoaster multiradiatus* Zone)

Figure 1 — *Balantiostoma* cf. *septentrionalis* (Canu & Bassler)
Ovicelled and non-ovicelled zooecia, USNM 172435. 117A-8-1, 130-134 cm.

Figure 2 — Microporid, gen. indet.
Zooecia, USNM 172418. 117A-4-1, 62-67 cm.

Figure 3 — *Semiescharinella* ? sp. 1
Zooecia and avicularia, USNM 172419. 117A-8-1, 130-134 cm.

Figures 4, 5 — *Cribrilaria radiata* (Moll)
4. Ovicelled and non-ovicelled zooecia, and an avicularium, USNM 172426. 117A-4-1, 62-67 cm. 5. Zooecia, USNM 172427. 117A, 7-1, 95-100 cm.

Figure 6 — *Pliophloea* ? sp.
Ovicelled zooecia and avicularia, USNM 172430. 117A-8-1, 130-134 cm.

Figure 7 — *Tricephalopora* ? sp.
Ovicelled zooecia and avicularia, USNM 172433. 117A-8-1, 130-134 cm.

PLATE 26

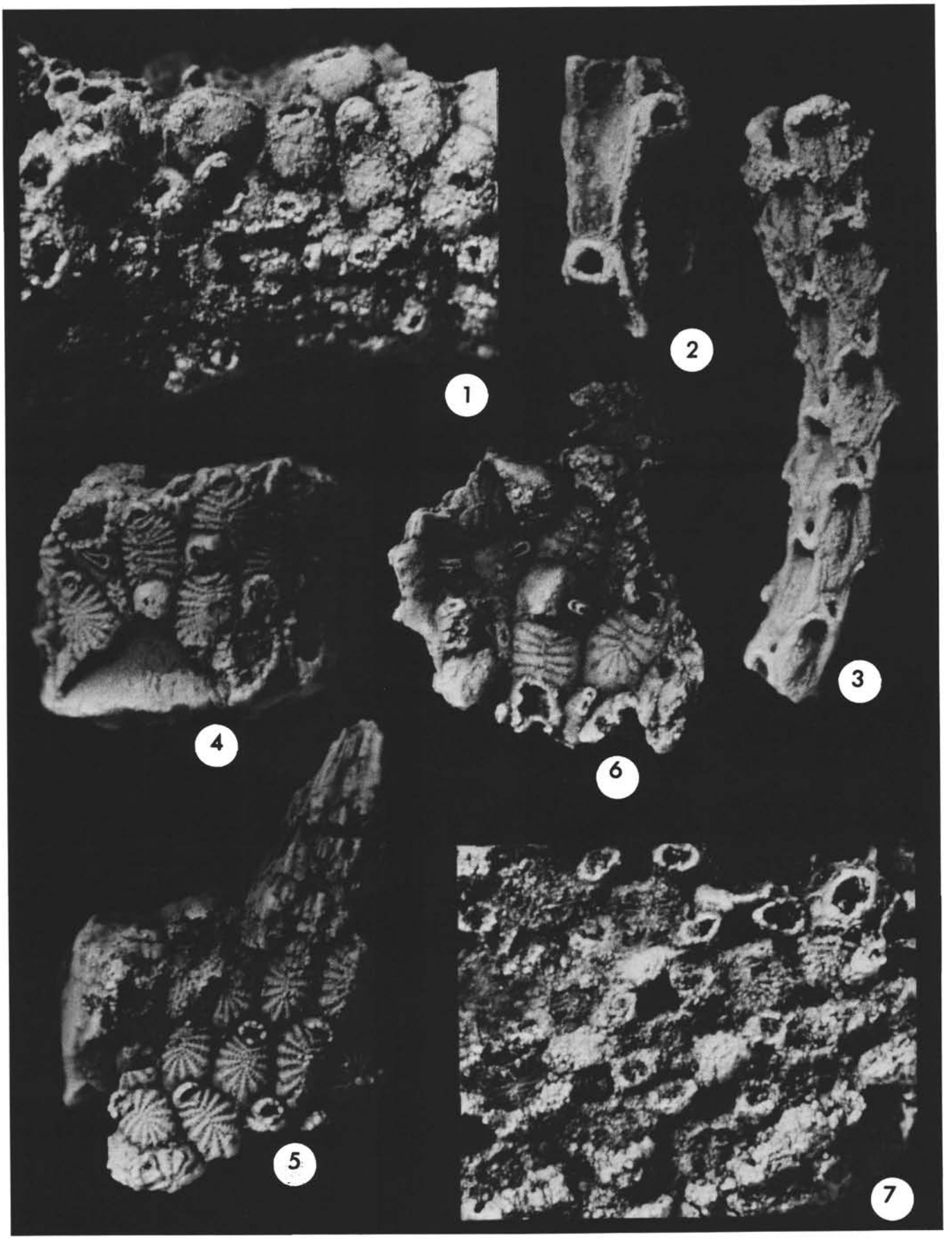


PLATE 27
Late Paleocene Bryozoa, Site 117
(All specimens X50; from *Globigerina triloculinoides - Discoaster multiradiatus* Zone)

Figure 1 — *Kelestoma* aff. *K. elongatum* Marsson Zooecia and avicularium, USNM 172431. 117A, 8-1, 130-134 cm.

Figure 2 — *Kelestoma*? aff. *K.* ? *simplex* Canu & Bassler Zooecium and avicularia, USNM 172432. 117A-8-1, 130-134 cm.

Figures 3, 4 — *Pliophloea* sp.
3. Zooecia with broad gymnocysts, USNM 172429. 117A-4-1, 62-67 cm. 4. Ovicelled and non-ovicelled zooecia with narrow gymnocysts, and avicularia, USNM 172428. 117A-4-1, 127-132 cm.

Figures 5, 7 — *"Beisselina"* sp.
5. Distal part of branch with thin-walled zooecia, USNM 172436. 117A-7-1, 95-100 cm. 7. Thick-walled zooecia from proximal part of large zoarium, USNM 172437. 117A-8-1, 130-134 cm.

Figure 6 — *Castanopora* ? sp.
Portions of broken zooecia and an avicularium, USNM 172434. 117A-7-1, 95-100 cm.

PLATE 27

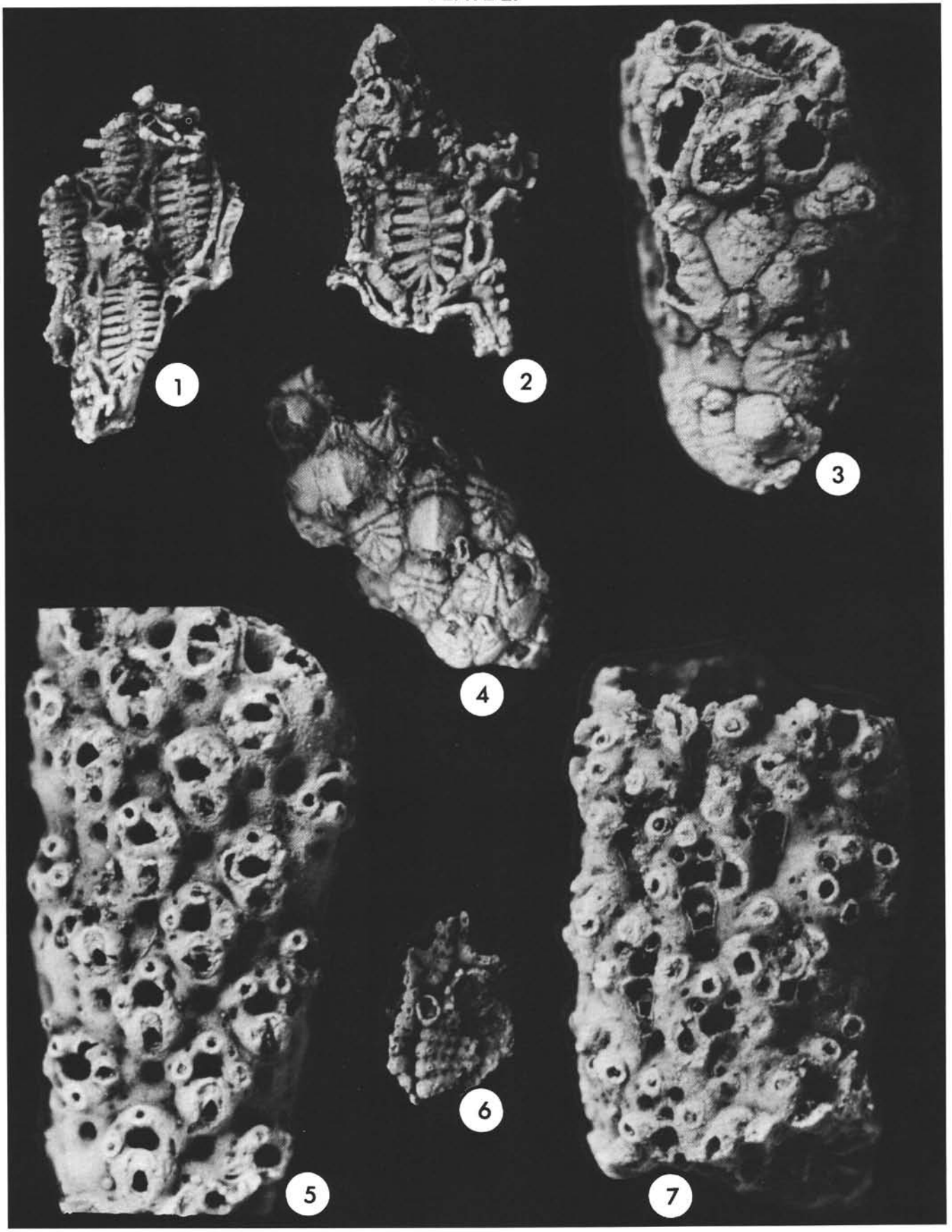


PLATE 28
Late Paleocene Bryozoa, Site 117
(All specimens ×50; from *Globigerina triloculinoides - Discoaster multiradiatus* Zone)

Figure 1 — *Pachythecella?* sp.
Zooecia and avicularia (?) from basal part of zoarium, USNM 172439. 117A-4-1, 127-132 cm.

Figure 2 — Smittinid ?, gen. indet.
Ovicelled and non-ovicelled zooecia, and avicularia, USNM 172441. 117A-8-1, 130-134 cm.

Figures 3-5 — *Fissuricella* sp.
3. Relatively short, open zooecium, USNM 172447. 4. Closed zooecium, USNM 172448. 5. Long, open zooecium, USNM 172449. 117A-8-1, 130-134 cm.

Figures 6, 7 — Vitaticellid, n. gen.
6. Basal view of internode fragment, USNM 172445. 117A-4-1, 127-132 cm. 7. Zooecia and avicularia, USNM, 172444. 117A-4-1, 62-67 cm.

Figure 8 — *Schizostomella?* sp. 1
Zooecium with frontal avicularium from distal tip of branch, USNM 172442. 117A-4-1, 127-132 cm.

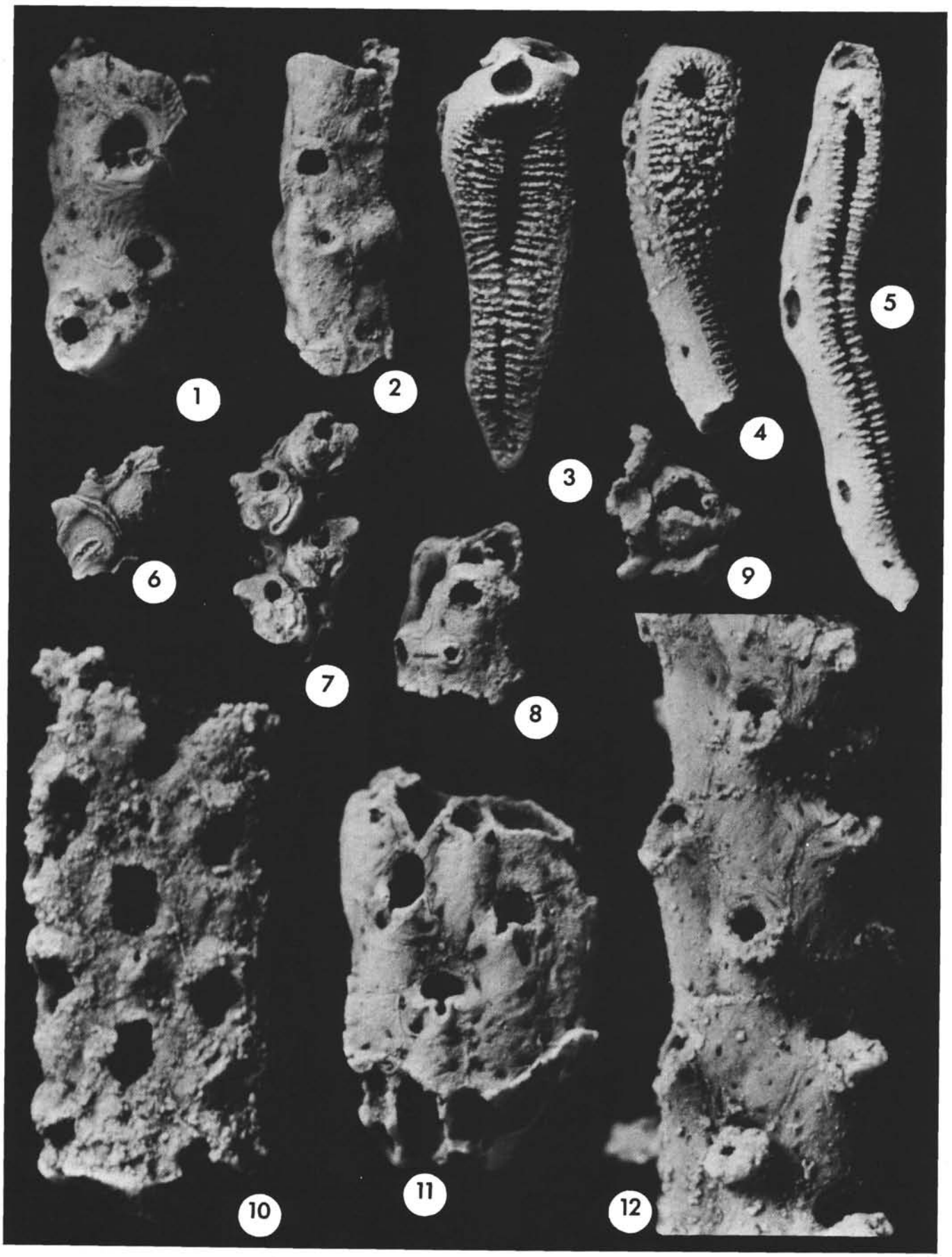
Figure 9 — Ascophoran, gen. B. indet.
Slightly broken zooecium, USNM 172446. 117A-4-1, 127-132 cm.

Figure 10 — *Smittoidea* ? sp.
Ovicelled and non-ovicelled, worn zooecia with frontal avicularia, USNM 172440. 117A-8-1, 130-134 cm.

Figure 11 — *Schizostomella* ? sp. 2
Zooecia from distal tip of branch, USNM 172443. 117A-4-1, 127-132 cm.

Figure 12 — *Pachytecella* sp.
Zooecia with partly broken oral avicularia, USNM 172438. 117A-8-1, 130-134 cm.

PLATE 28



APPENDIX A. SHIPBOARD SMEAR SLIDE OBSERVATIONS

	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
116	CB																		R							90	C	D	R		C			Nannofossil-foraminiferal ooze.
116	1	CC																C	R					X		85	A	D	R		C			Other minerals-limonite (R).
116	1	CC												R	R									X						C	A			Other minerals-?dolomite (C).
116	1	1	66											R					R							85	A	A	C		C			Foraminiferal nannofossil ooze.
116	1	1	68						R					R				R	C							85	C	A	C		C			Foraminiferal-nanno ooze.
116	1	3	75						R					R				R								85	C	D	C		C			Foraminiferal nannofossil ooze.
116	1	5	75											R					C							85	C	A	C	R	C			Foraminiferal nannofossil ooze; some foraminiferal shells recrystallized.
116	1	4	100											C		R			R							90	C	D	C	R	C			Foraminiferal-coccolith ooze; other minerals-tintinnid (R).
116	1	5	126											C				R	R							85	C	C	C	C	A			Foraminiferal-nannofossil ooze.
116	1	6	75											R					R							95	C	D			C			Coccolith ooze.
116	2	CC						R						C															C	C	A			
116	2	CC												R					R								C	R	R	R	R			Coccolith ooze.
116	2	1	70											R				C	R							80	C	A	C	C	A			Foraminiferal nannofossil ooze; other minerals-tintinnid S(C).
116	2	1	75											C					R							90	C	D	C	R	C			Coccolith ooze.
116	2	2	75											C	R												C	A	C		R			Foraminiferal nannofossil ooze.
116	3	CC												R				R	R								C	D	C		C			Nannoplankton-foraminiferal ooze.
116	3	1	24											R					R								C	D	R		R			Coccolith ooze.
116	3	CC												D	C														C		A			Non-carbonate material almost entirely glass and sponge spicules.
116	3	2	59											R				R	R								A	D		R	C			
116	3	2	75											R					R							95	R	D	C	R	R			Coccolith ooze.
116	3	3	75																C								C	D	R		C			Coccolith ooze.
116	3	4	75																R							98	A	D	R		C			Coccolith foraminiferal ooze.
116	3	6	75											R					R								A	D	R		A			Foraminiferal-nannofossil ooze.
116	4	CC												R				R	R								R	D			C			Coccolith ooze.
116	4	CC												R	R														C	C	A			
116	4	1	75											R	R											95	C	D	R		C			Nannofossil foraminiferal ooze.
116	4	3	75											C													C	D			C			Coccolith ooze.

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

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
116	4	5	75											R												95	C	D			R			Foraminiferal coccolith ooze.
116	5	1	50											R				R	R							90	C	D	R		C			Foraminiferal nanno ooze.
116	5	3	105															R	C							95	R	D			C			Nannofossil ooze; some foraminiferal recrystallized.
116	5	4	75											R					C							95	R	D			C			Nannofossil ooze (coccolith ooze).
116	5	5	75											R				R	R								C	D	R		C			Foraminiferal-coccolith ooze.
116	6	1	75												R				R								A	A	R		C			Foraminiferal-nannofossil ooze.
116	6	1	90											C				R	R					X		60	A	A	R	R	C			Foraminiferal-nannofossil-rich marl; other minerals-clay mins (C), limonite (R).
116	6	2	75											R				R	R								C	A			R			Foraminiferal coccolith ooze.
116	6	3	75											V					V								V	F	T		V			Foraminiferal nannofossil ooze.
116	7	1	62											R				R	R							90	C	D			C			Coccolith ooze.
116	7	1	140											R				A								70	C	A	R		C			Pyrite-rich foraminiferal nannofossil ooze.
116	7	3	62											R					R							90	C	D	R	R	C			Foraminiferal coccolith ooze.
116	7	6	55											R				R	R							85	C	A	R		C			Foraminiferal nannofossil ooze.
116	8	1	145																								C				C			
116	8	2	75															R	R								C	D	R	R	C			
116	8	3	23											R					C								A	A	R		C			
116	8	3	75											R				R									C	D	C		C			
116	9	CC												R												95	C	D	C		C			Coccolith foraminiferal ooze.
116	9	2	75											R				R									C	D	R		C			Coccolith ooze.
116	10	1	80											R					C								C	D	R		C			Coccolith ooze.
116	11	CC												R	R				R					X			C	A	R					Nannofossil-foraminiferal ooze; other minerals-limonite (R).
116	11	2	75													R		R									A	D	R					Foraminiferal nannofossil ooze.
116	11	6	60											C	C			R	C							85	A	A	C					Foraminiferal nannofossil ooze.
116	12	CC																									R	D			R			Coccolith ooze.
116	12	1	83															R	R								C	D	R		C			Nannofossil-foraminiferal ooze.
116	12	1	93															R	R								R	D	R		C			Nannofossil ooze.
116	15	1	75											R				R									C	D	R		C			Nannofossil-foraminiferal ooze.

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
116	15	3	75										R	R				R	C								C	D	R		A			Nannofossil-foraminiferal ooze.
116	15	5	75																R								R	D	R		A			Nannofossil ooze.
116	16	2	80											R	R												C	D	C	R	C			Foraminiferal-nannofossil ooze.
116	16	4	134											R											95	A	A	R		A			Foraminiferal-nannofossil ooze.
116	17	CC												R												A	A	C		A			Foraminiferal-nannofossil ooze.
116	17	4	75											R										X		C	D			A			Coccolith ooze; other minerals-limonite (R).
116	18	4	75										R	R		R		R	R						90	A	D	R		A			Nannofossil-foraminiferal ooze.
116	19	2	45											C				R							80	R	D						Coccolith ooze.
116	20	CC												R												A	A			R			Foraminiferal-nannoplankton ooze.
116	20	1	40											R					R							A	D			R			Foraminiferal-coccolith ooze.
116	20	5	73										R	R	R				R						90	R	A	R		R			Nannofossil-foraminiferal ooze.
116	20	5	100											R					R						90	A	D	R		R			Nannofossil-foraminiferal ooze.
116	21	CC												R				C	R							C	D	R			R		Foraminiferal-nannofossil ooze.
116	21	3	71											C	R			R	R						85	A	D	C					Nannofossil-foraminiferal ooze.
116	21	4	75															C							80	R	D	R					Coccolith ooze.
116	21	3	144											R	R			D	R						30	R	A	R					Pyrite rich nannofossil-foraminiferal ooze.
116	23	CC												R				R						X	95	A	D	C					Foraminiferal-nannofossil ooze; other minerals-limonite (R).
116	24	CC												R				R							90	C	D						Foraminiferal-nannofossil ooze.
116	24	1	105											R				R	R								C	D	R					Foraminiferal-nannofossil ooze.
116	26	CC												R				R	R						90	C	D						
116	27	2	35											C					A					X		R	A	R					Foraminiferal coccolith ooze; other minerals-clay minerals (C).
116	27	2	118															C	A														
116A	1	CC		C	C	R								C	R	R		R	C			R			65	C	C	R		R			Silty sandy marl.
116A	1	1	95	A	A									C	R			R				R			50	A	C	C		C			Foraminiferal-rich sandy silt.
116A	1	2	13	C	A	C								A	R			R	C						35	C	C	R		C			Sandy clayey silt; much recrystallization, nannofossils very small.
116A	1	2	20	C	C									A	R			R	C					X		C	C	R					Sandy silt; other minerals-limonite (R).
116A	2	CC		A	C	R								C	R			R	R			R			40	A	C	C		R			Sandy silty marl.
116A	2	1	120											R	R			R	R						90	D	C	R		C			Foraminiferal ooze.

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
116A	2	3	60	A	C	R									R			C	R							60	A	C	C		C			Sandy silty marl.
116A	2	4	40	C	A	R								C	R				C							60	C	A	R		R			Sandy silty marl; many fossils recrystallized.
116A	2	5	80	A	C	R								C	R	R		R	R			R				65	A	C	R					Sandy silty marl.
116A	3	CC												R				R	R							90	D	A	R		C			Foraminiferal-nannofossil ooze.
116A	3	1	102	C	A	R								C	R			R	C			R		X		15	R	C						Sandy silt; other minerals-clay minerals (C).
116A	3	2	75	C	C	R								A	C			R	C			C				20	C	C	R		R			Sandy silt.
116A	3	2	120	C	D	R								C				R	C							60	C	D	C		R			Foraminiferal-nannofossil ooze.
116A	3	5	75									R	R			R	C									75	A	A	C		A			Foraminiferal-nannofossil ooze; many fossils recrystallized, coccoliths very small.
116A	3	6	75											C				R	C							75	A	A	C		A			Foraminiferal nannofossil ooze; many fossils recrystallized.
116A	3	6	140											C	R			R	C							70	A	A	C	R	R			Foraminiferal-nannofossil ooze.
116A	4	1	120											R	R			R	C					X		70	A	A						Foraminiferal-nannofossil ooze; other minerals-limonite (R).
116A	4	3	60											C				R	R					X		80	A	A	C		C			Foraminiferal-nannofossil ooze; other minerals-calcedony (R).
116A	4	4	35											C					C							85	C	A	C	R	C			Foraminiferal-nannofossil ooze.
116A	4	4	115											R	R				A	R				X		90	R	A	R		R			Nannofossil ooze; other minerals-limonite (R).
116A	4	5	100											C	R			R	C					X		85	A	A	C		C			Foraminiferal-nannofossil ooze; other minerals-limonite (R).
116A	4	6	75											C	R				R					X		90	A	A	C		C			Foraminiferal-nannofossil ooze; other minerals-limonite (R).
116A	5	2	78											A	R				R							80	A	A	C		A			Foraminiferal-nannofossil ooze.
116A	5	3	75											C	R			R	C							80	D	D	C		C			Foraminiferal-nannofossil ooze.
116A	6	3	75											C				R	C							85	C	A	C		C			Foraminiferal-nannofossil ooze.
116A	6	5	75											C	R				C							85	A	A	C		C			Foraminiferal-nannofossil ooze.
116A	6	6	80											C	C			R	C					X		80	C		R		C			Foraminiferal nannofossil ooze; much recrystallization; other minerals-limonite (R).
116A	6	6	85											C	R			R	C							85	A	A			C			Foraminiferal-nannofossil ooze; much recrystallization.
116A	6	6	135											R				R	R					X		90	C	D			R			Foraminiferal-nannofossil ooze; much recrystallization; other minerals-limonite (R).
116A	7	1	108											C	C				C							80	A	A	R		R			Foraminiferal-nannofossil ooze; much recrystallization.
116A	7	6	102											C	R			R	C							85	C		R		R			Foraminiferal-nannofossil ooze; much recrystallization.

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
116A	7	6	105											C												80	C	A	C	R	C			Foraminiferal-nannofossil ooze.
116A	8	6	75											R				R	R							90	A	A	C	R	C			Foraminiferal-nannofossil ooze.
116A	9	CC												C					R							80	C	D	R		R			Nannofossil-foraminiferal ooze.
116A	9	6	75											R	R			R	R							90	A	A	C		C			Foraminiferal-nannofossil ooze.
116A	10	1	107											C				C	C								R	D	R		C			Nannofossil-foraminiferal ooze.
116A	10	1	120											R					R							90	R	D	R		R			Nannofossil-foraminiferal ooze.
116A	11	2	75											R	R			R	R		C					80	C	A	R		C			Foraminiferal-nannofossil ooze.
116A	11	3	75											R					R								C	D	R		R			Nannofossil-foraminiferal ooze.
116A	11	4	75											C	R				R		R					70	C	A	C		C			Foraminiferal-nannofossil ooze.
116A	11	5	75	C	A	R								C	R			R	R		R					60	C	A	C		C			Foraminiferal-nannofossil ooze.
116A	11	6	75	A	A	R								C	R			R	R		C					60	A	A	C		C			Foraminiferal-nannofossil ooze.
117	2	3	40										R		R			R	R					X		70	C	A			R			Foraminiferal-nannofossil ooze; other minerals-chalcedony (C).
117	2	4	16											R	C				R					X		60	C	A						Foraminiferal-nannofossil ooze; other minerals-chalcedony (C).
117	2	4		R	C	R								C		D			C					X				R						Glauconite-rich silt; other minerals-limonite (R).
117	2	5	75											R		R			A								C	C					R	Sandy nannofossil marl; foraminifera are planktonic and benthonic; bryozoa (R).
117A	2	CC		R	A	R								C		R		C	R			C				15		C						Sandy clayey silt.
117A	3	CC		C	A	R								R	R	C			R					X				C						Sandy silt; other minerals-clay mineral aggregates (A).
117A	3	5	75		C	D		R		R				A				C	R		R			X				A						Silty nannofossil clay; other minerals-limonite.
117A	4	CC			C	D		R		R				A	R	R		C	C							10		R						Silty clay; coccoliths are mostly fragmented.
117A	4	1	85	C	C	R								C				R	C							20	C	C						Sandy silt.
117A	4	5	82	R	C	R								C		R			C					X		25	R	C						Sandy silt; other minerals-clay minerals (C).
117A					C	D	R	R	R	R				C	A	R		R	C		R						R	C	R		R			Silty clay.
117A	6	1	140	R	C	R								C	R			C	C					X			R	C						Sandy clayey silt; other minerals-clay lumps (C).
117A	6	3	142	R	A	D	R	R	R					A	C	R		C			D						C	D						Silty clay.
117A	6	3	142		A	D					R			A		R		R	C		R					30		C						Silty marly clay.
117A	6	4	130			D		R						A	R	R		C	R							10	R	C						Silty clay.
117A	6	5	75		C	D								A	C			C	C					X		5		C						Silty clay; other minerals-limonite (R).
117A	8	2	70		A	D	R	R						A	C				A		R							C						Silty clay.

APPENDIX B. GRAIN SIZE DETERMINATIONS ON SAMPLES FROM SITES 116 AND 117[1]

Site	Core	Section	Interval	Per Cent Sand	Per Cent Silt	Per Cent Clay	Classification
116	1	1	25.0	6.5	35.0	58.5	Silty clay
116	1	2	25.0	9.1	30.2	60.7	Silty clay
116	1	3	25.0	11.4	30.0	58.6	Silty clay
116	2	2	24.0	6.4	44.2	49.5	Silty clay
116	3	1	34.0	3.1	36.5	60.3	Silty clay
116	3	3	25.0	1.6	36.5	61.9	Silty clay
116	3	6	25.0	4.1	37.5	58.4	Silty clay
116	4	2	54.0	1.0	40.3	58.7	Silty clay
116	4	3	30.0	3.7	43.4	52.9	Silty clay
116	4	5	24.0	1.9	38.5	59.6	Silty clay
116	5	1	44.0	2.7	49.9	47.4	Clayey silt
116	5	4	85.0	5.0	51.9	43.1	Clayey silt
116	6	1	24.0	7.5	37.6	54.9	Silty clay
116	6	3	28.0	4.6	41.4	54.0	Silty clay
116	7	1	37.0	5.4	52.7	41.9	Clayey silt
116	7	3	10.0	3.9	43.2	52.9	Silty clay
116	8	2	25.0	3.0	45.6	51.4	Silty clay
116	9	1	25.0	1.7	38.6	59.7	Silty clay
116	9	3	24.0	2.8	40.9	56.3	Silty clay
116	10	6	95.0	4.1	40.4	55.6	Silty clay
116	11	2	102.0	4.9	45.3	49.8	Silty clay
116	11	6	112.0	10.8	57.5	31.7	Clayey silt
116	12	1	64.0	1.1	22.0	76.8	Clay
116	15	1	70.0	8.7	45.0	46.4	Silty clay
116	15	5	40.0	0.7	32.0	67.2	Silty clay
116	16	3	23.0	2.0	37.2	60.8	Silty clay
116	17	4	90.0	1.0	46.0	53.0	Silty clay
116	17	6	99.0	2.4	44.9	52.8	Silty clay
116	20	1	75.0	2.9	43.7	53.3	Silty clay
116	20	5	52.0	4.4	28.4	67.2	Silty clay
116	21	3	20.0	9.1	43.6	47.3	Silty clay
116	21	4	35.0	0.9	41.0	58.1	Silty clay
116	22	6	137.0	1.0	40.6	58.4	Silty clay
116A	1	1	109.0	15.6	32.0	52.4	Silty clay
116A	2	2	24.0	10.4	26.1	63.5	Silty clay
116A	3	6	24.0	8.2	12.1	79.7	Clay
116A	4	2	24.0	22.0	38.2	39.8	Sand-silt-clay
116A	5	2	24.0	18.1	26.7	55.1	Silty clay
116A	5	3	25.0	26.0	39.3	34.6	Sand-silt-clay
116A	6	2	25.0	16.1	36.3	47.7	Silty clay
116A	7	2	25.0	24.6	35.5	39.9	Sand-silt-clay
116A	7	4	25.0	18.6	43.2	38.2	Clayey silt
116A	7	6	30.0	32.7	41.7	25.6	Sand-silt clay
116A	8	2	24.0	11.1	28.3	60.6	Silty clay
116A	9	1	24.0	9.2	25.2	65.6	Silty clay

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

APPENDIX B – *Continued*

Site	Core	Section	Interval	Per Cent Sand	Per Cent Silt	Per Cent Clay	Classification
116A	10	2	25.0	4.4	51.0	44.6	Clayey silt
116A	10	6	25.0	11.5	44.4	44.1	Clayey silt
116A	11	1	25.0	3.4	36.0	60.6	Silty clay
116A	11	3	25.0	4.3	45.7	50.0	Silty clay
116A	11	4	25.0	3.9	42.5	53.6	Silty clay
117	2	3	54.0	29.4	34.8	35.9	Sand-silt-clay
117A	3	3	60.0	0.1	31.2	68.7	Silty clay
117A	3	6	25.0	0.2	36.3	63.5	Silty clay
117A	4	5	142.0	5.7	26.4	67.9	Silty clay
117A	6	5	58.0	5.1	29.5	65.4	Silty clay
117A	7	2	4.0	15.9	41.5	42.6	Silty clay
117A	8	1	8.0	5.6	36.6	57.9	Silty clay

APPENDIX C. CARBON-CARBONATE DETERMINATIONS ON SAMPLES FROM SITES 116 AND 117[1]

Site	Core	Section	Top Interval	Hole Depth	Total Carbon	Organic Carbon	$CaCO_3$
116	1	1	15.0	70.2	10.8	0.1	89
116	1	3	15.0	71.7	10.4	0.1	86
116	1	5	15.0	76.2	10.7	0.1	88
116	2	2	14.0	109.1	11.6	0.1	96
116	3	1	30.0	159.3	11.4	0.1	95
116	3	2	30.0	160.8	11.3	0.1	93
116	3	3	15.0	162.1	11.8	0.1	98
116	3	6	15.0	166.6	11.5	0.1	95
116	4	2	40.0	210.9	11.4	0.1	95
116	4	3	20.0	212.2	11.4	0.1	94
116	4	5	14.0	215.1	11.4	0.1	95
116	5	1	7.0	259.1	11.2	0.1	93
116	5	4	47.0	264.0	10.9	0.1	90
116	6	1	19.0	309.2	11.5	0.0	95
116	6	3	15.0	312.1	11.0	0.1	91
116	7	1	20.0	359.2	11.4	0.1	94
116	7	3	15.0	362.1	11.5	0.1	95
116	8	2	15.0	410.6	11.6	0.1	96
116	9	1	17.0	459.2	11.7	0.1	97
116	9	3	14.0	462.1	11.0	0.1	91
116	10	6	52.0	517.0	11.3	0.1	94
116	12	1	31.0	599.3	11.3	0.1	93
116	15	1	57.0	662.6	9.7	0.2	80
116	15	5	30.0	668.3	10.8	0.1	89
116	16	3	59.0	673.1	10.0	0.1	82
116	17	4	7.0	684.6	9.8	0.1	81
116	17	6	71.0	688.2	10.7	0.1	88
116	20	1	28.0	701.3	10.9	0.0	91
116	20	5	18.0	707.2	10.6	0.1	88
116	21	4	16.0	714.7	10.9	0.1	90
116	22	6	111.0	727.6	10.3	0.0	86
116A	1	1	70.0	0.7	10.4	0.3	85
116A	2	2	15.0	10.6	9.8	0.2	80
116A	3	5	14.0	24.1	11.1	0.1	92
116A	4	2	15.0	28.6	4.2	0.2	33
116A	5	2	14.0	37.6	6.4	0.1	52
116A	5	3	15.0	39.2	7.2	0.2	59
116A	6	2	15.0	46.7	8.3	0.1	68
116A	7	2	15.0	55.7	8.2	0.1	67
116A	7	4	15.0	58.7	9.1	0.1	75
116A	7	6	15.0	61.7	9.5	0.1	79
116A	8	2	14.0	64.6	7.4	0.2	60
116A	9	1	14.0	72.1	11.3	0.1	94
116A	10	2	15.0	82.7	10.8	0.1	89
116A	10	6	15.0	88.7	11.3	0.0	94
116A	11	1	15.0	90.2	11.6	0.1	96
116A	11	3	15.0	93.2	11.2	0.2	92
116A	11	4	15.0	94.7	11.4	0.1	94

APPENDIX C – *Continued*

Site	Core	Section	Top Interval	Hole Depth	Total Carbon	Organic Carbon	$CaCO_3$
117	2	3	50.0	103.5	9.6	0.1	79
117A	3	3	50.0	225.5	2.9	0.1	23
117A	3	6	15.0	229.6	1.9	0.2	14
117A	4	5	30.0	276.3	3.6	0.1	29
117A	6	5	92.0	282.9	2.7	0.2	21

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

APPENDIX D, PART 1 LISTS OF SELECTED PLANKTONIC AND BENTHONIC FORAMINIFERA AND AGE DETERMINATIONS (116)

W. A. Berggren

Hole 116

Sample 12-116-1-1, 143-146 cm:
PF: *Globigerina atlantica* (abundant, dominant, sinistral), *G. bulloides, Globigerinita glutinata.*
BF: *Planulina bradii, Anomalinoides cicatricosa, Sigmoilopsis schlumbergeri* - all common; *Cassidulina subglobosa, Sphaeroidina bulloides, Hoeglundina elegans, Eponides umbonatus, Cibicidoides pseudoungeriana, Gyroidina neosoldanii, Laticarinina halophora, Dentalina advena, Pleurostomella* sp., *Nodosarella* sp.
Also Present: Sponge spicules.
Age: Pliocene (Middle).

Sample 12-116-1-2, 146-149 cm:
PF: *Globigerina atlantica* (abundant, common), *G. bulloides, Globigerinita glutinata, Globorotalia crassaformis, G. scitula.*
BF: Essentially the same as the preceding sample above, plus *Karreriella bradyi.*
Also present: Sponge spicules.
Age: Pliocene (Middle).

Sample 12-116-1-3, 143-146 cm:
PF: Same as preceding samples above.
BF: As above plus *Stilostomella antillea'.*
Also present: Sponge spicules; solution effects visible on foraminiferal tests.
Age: Pliocene (Middle).

Sample 12-116-1-4, 141-144 cm:
PF: Same as preceding sample.
BF: As above plus *Uvigerina* sp.
Also present: Sponge spicules.
Age: Pliocene (Middle).

Sample 12-116-1-5, 144-146 cm:
All data as above.
Age: Pliocene (Middle).

Sample 12-116-1-6, 143-145:
All data essentially the same as above, plus *Gyroidina neosoldanii.*

Sample 12-116-1, Core Catcher:
PF: *Globigerina atlantica (dominant, abundant, sinistral), G. bulloides, Globigerinita glutinata, Globorotalia crassaformis, G. inflata, G. scitula, Orbulina universa.*
BF: *Cibicidoides pseudoungeriana, C. kullenbergi, C. robertsoniana, C. subhaidingeri, Anomalina* sp. cf. *A. globulosa, Laticarinina halophora, Cassidulina subglobosa, Gyroidina neosoldanii, Uvigerina peregrina, U.* sp. cf. *U. schwageri, Eponides umbonatus, Planulina bradii, P. wuellerstorfi, Stilostomella antillea, Sigmoilopsis schlumbergeri, Sphaeroidina bulloides.*
Also present: Sponge spicules, ostracods (common).
Age: Pliocene (Middle).
Remarks: 5-6 chambered forms of *G. atlantica* exhibit marked similarities to *G. dutertrei.*

Sample 12-116-2-0, 16-18 cm:
PF: *Globigerina atlantica* (abundant, dominant), *G. bulloides, Globorotalia crassaformis, G. scitula, Orbulina universa* (common).
BF: Essentially same fauna as Sample 12-116-1, Core Catcher with following modification: *Uvigerina auberiana* present; *Uvigerina peregrina* not observed.
Also present: Echinoid spines, sponge spicules.
Age: Pliocene (Early).

Sample 12-116-2-1, 145-147 cm:
PF: *Globigerina atlantica* (dominant, abundant, sinistral), *G. bulloides, Orbulina universa, Globorotalia cibaoensis, G. crassula, G. miozea conoidea, G. puncticulata, G. crassaformis.*
BF: Essentially as above, plus *Uvigerina schwageri.*
Also present: Ostracods.
Age: Early Pliocene.

Sample 12-116-2-2, 139-142 cm:
PF: *Globigerina bulloides* (dominant, abundant), *Orbulina universa, Globorotalia puncticulata.*
BF: Sparse, fauna made up of various elements listed above; also present: *Martinottiella nodulosa.*
Also present: Ostracods.
Age: Early Pliocene.
Note: Marked change in planktonic foraminiferal fauna between this sample and the one above (abundant *G. atlantica* and *G. bulloides* above.

Sample 12-116-2-3, 150 cm:
PF: *Globigerian bulloides* (dominant, abundant), *Globigerina atlantica, Orbulina universa, Globorotalia puncticulata.*
BF: Relatively diverse, as above.
Also present: Ostracods.
Age: Early Pliocene.

Sample 12-116-2-4, 150 cm:
Data same as above.

Sample 12-116-2-6, Core Catcher:
PF: *Globigerina bulloides* (dominant, abundant), *G. atlantica, Orbulina universa, Globorotalia puncticulata, G. acostaensis, G. humerosa.*
BF: *Cibicidoides pseudoungeriana, C. kullenbergi, Eponides umbonatus, Cassidulina subglobosa, Uvigerina auberiana, Gyroidina soldanii, Planulina wuellerstorfi, Laticarinina halophora, Karreriella bradyi, Sigmoilopsis schlumbergeri,* nodosariids, dentalinids.
Also present: Sponge spicules, echinoid spines, ostracods (common)
Age: Early Pliocene.
Note: *Uvigerina auberiana* occurs commonly throughout Core 2; it is replaced by *U. peregrina* in Core 1 above.

Sample 12-116-3-0, 19-22 cm:
PF: *Globigerina atlantica, G. bulloides, Orbulina universa, Globorotalia puncticulata.*
BF: Varied including *Cibicidoides pseudoungeriana, C. kullenbergi, Eponides umbonatus, Uvigerina auberiana, U. peregrina, Gyroidina soldanii, Planulina bradii, P. weullerstorfi, Laticarinina halophora, Sigmoilopsis schlumbergeri,* nodosariids, dentalinids stilostomellids.
Also present: Echinoid spines, sponge spicules, ostracods (rare).
Age: Late Miocene.

Sample 12-116-3-1, 144-147 cm:
Data same as for preceding sample above.

Sample 12-116-3-2, 140-143 cm:
PF: *Globigerina atlantica, Globigerina bulloides, Globorotalia margaritae, Orbulina universa.*
BF: As above.
Age: Late Miocene.

Sample 12-116-3-3, 142-145 cm:
PF: As above.
BF: As above, plus *Eggerella propinqua.*
Age: Late Miocene.

Sample 12-116-3-4, 140-143 cm:
PF: *Globigerina atlantica, Globigerina bulloides, Orbulina universa, Globorotalia humerosa, Globorotalia margaritae.*
BF: Essentially as above, Planulina bradii common.
Age: Late Miocene.

Sample 12-116-3-5, 150 cm:
Data essentially same as for preceding sample.

Sample 12-116-3-6, 140-143 cm:
Data essentially same as above.

Sample 12-116-3, Core Catcher:
PF: *Globigerina atlantica, Globigerina bulloides, Globorotalia acostaensis, G. humerosa, G. scitula, Orbulina universa.*
BF: *Cibicidoides pseudoungeriana, C. kullenbergi, C. robertsoniana, Planulina wuellerstorfi, P. bradii, Laticarinina halophora, Eponides umbonatus, E. tenera, Gyroidina neosoldanii, Uvigerina auberiana, U. schwageri, U. gaudryinoides, Karreriella bradyi, Eggerella bradyi, Martinottiella bradyana, Sigmoilopsis schlumbergeri, Stilostomella* sp., dentalinids, nodosariids.
Also present: Sponge spicules, echinoid spines, ostracods.
Age: Late Miocene.

Sample 12-116-4-1, 143-146 cm:
PF: Coarse fraction, sieve no. 100 (149 mm opening): only *Globigerina bulloides;* fine fraction 149 mm opening, *Globorotalia acostaensis, Globorotalia* sp. cf. *G. scitula.*
BF: Fauna as in Core 3, Core Catcher plus *Cibicidoides cicatricosa, Sphaeroidina bulloides, Cassidulina subglobosa.*
Age: Late Miocene.

Sample 12-116-4-2, 142-145 cm:
PF: As above, *Orbulina universa* (dominant, abundant); few *G. acostaensis - humerosa.*
BF: As above, uvigerinids not observed.
Also present: Sponge spicules, volcanic glass shards.
Age: Late Miocene.

Sample 12-116-4-3, 138-141 cm:
Data essentially the same as preceding sample above.

Sample 12-116-4-4, 135-138 cm:
PF: *Globigerina bulloides, Globorotalia acostaensis, G. scitula, Orbulina universa.*
BF: Rich, diverse, as Sample 12-116-3 Core Catcher (above).
Age: Late Miocene

Sample 12-116-4-5, 141-144 cm:
Data essentially same as above.

Sample 12-116-4-6, 142-144 cm:
Data essentially same as above.

Sample 12-116-4, Core Catcher:
PF: *Globorotalia acostaensis, G. humerosa, G. scitula, Globigerina bulloides, G. atlantica, Orbulina universa.*
BF: Same fauna as Sample 12-116-3, Core Catcher; *Uvigerina auberiana* common.
Age: Late Miocene.
Remarks: Typical *G. atlantica* occurs in Core Catcher sample of Core 4; *G. humerosa-acostaensis* forms occur also.

Sample 12-116-5-0, Bottom:
PF: *Globigerina praebulloides* (dominant, abundant) *G. bulloides, G. decoraperta, Globorotalia miozea conoidea, G.* sp. cf. *G. subscitula, G. acostaensis.*
BF: Rich diverse, including *Cibicidoides pseudoungeriana, C. kullenbergi, Anomalinoides globulosa, A. cicatricosa, Gyroidina neosoldanii, Melonis barleeanum, Sigmoilopsis schlumbergeri, Laticarinina halophora, Uvigerina auberiana, Pullenia* sp., *Planulina bradii, Cassidulina subglobosa, Martinottiella bradyana, Eponides umbonatus.*
Also present: Sponge spicules, Radiolaria common.
Age: Late Miocene (probably Zone N16).

Sample 12-116-5-1, 53-56 cm:
Planktonic and benthonic fauna essentially same as in preceding sample above; *G. decoraperta* not observed.
Also present: Abundant spicules and radiolaria, ostracods present.
Age: Late Miocene (probably Zone N16).

Sample 12-116-5-2, 138-141 cm:
PF: Essentially same as above; inflated, sinuous or cap-like bulla(e) develop on some high-spired globigerinid forms giving a superficial resemblance to *Globoquadrina altispira* or *Globigerina gortanii.*
BF: Essentially as above plus *Cibicidoides robertsoniana, Planulina wuellerstorfi.*
Also present: Abundant spicules and Radiolaria; ostracods present.
Age: Late Miocene (probably Zone N16).

Sample 12-116-5-3, 119-122 cm:
Data essentially similar to above; *Globigerina zealandica* Hornibrook (hispid surface, umbilical "teeth").

Sample 12-116-5-4, 130-133 cm:
PF: As above plus *Globigerina zealandica, Orbulina universa.*
BF: As above, rich, diverse.
Age: Late Miocene.

Sample 12-116-5-5, 140-143 cm:
Data essentially same as above; *G. atlantica.*
Age: Late Miocene.

Sample 12-116-5-6, Bottom:
Data essentially same as above.
Age: Late Miocene.

Sample 12-116-5, Core Catcher:
PF: *Globigerina praebulloides, G. bulloides, G. apertura, G. foliata, Globorotalia acostaensis, G. continuosa, Globorotalia miozea*
BF: As above, rich diverse; see faunal list given for Sample 12-116-5-0, Bottom, and remarks under individual samples above, plus *Karreriella bradyi,* stilostomellids, pleurostomellids, nodosariids, dentalinids.
Also present: Abundant sponge spicules, Radiolaria; ostracods common.
Age: Late Miocene (probably low N16).
Remarks: Core 5, Hole 116 is characterized by a rich and diversified benthonic fauna and a rich, though relatively monotonous, planktonic foraminiferal fauna. The characteristic elements here include a group of globigerinids referred to *Globigerina bulloides, G. praebulloides* and *G. apertura. G. praebulloides* is the dominant form. These forms exhibit the morphologic characters and variation mentioned by Lipps (1964, p. 117) to occur in the group to which he referred *G. bulloides, G. dubia* and *G. quadrilatera.* Most of the forms in Core 5 agree well with *G. quadrilatera* as figured by Lipps *(op. cit.),* but comparison with the holotype specimen of *G. quadrilatera* has shown that Lipps' specimen is not referable to *quadrilatera.* We refer these forms to *praebulloides.* In Core 4 and above the forms are more typical of *G. bulloides. Globorotalia miozea conoidea* occurs in the upper portion of this core (Sections 0, 1-3) but was not observed in the lower portion (Sections 4-6and the Core Catcher sample). The association of these forms together suggests that Core 5 is of Tortonian age and equivalent to the middle of Zone N16.

Sample 12-116-6-1, 141-143 cm:
PF: *Globigerina praebulloides, Globorotalia acostaensis, Globigerina obesa, Sphaeroidinellopsis seminulina, S. subdehiscens, Globorotalia menardii, Globoquadrina dehiscens, Orbulina universa.*
BF: Rich, diverse (essentially same as in Core 5; see list above).
Also present: Sponge spicules, radiolarians.
Age: Tortonian (Late Miocene).

Sample 12-116-6-2, 143-145 cm:
PF: *Globigerina praebulloides, Globorotalia acostaensis-humerosa* group, *Globorotalia miozea, Globigerina* spp. indet., *Globoquadrina dehiscens.*
BF: Diverse, abundant, as above and in Core 5, *Planulina bradii* common.
Age: Middle-Late Miocene.

Sample 12-116-6-3, 143-146 cm:
PF: *Globigerina praebulloides* (abundant, dominant, *about 90 per cent of planktonic fauna), Globigerina* sp., *Globorotalia miozea, G. menardii.*
BF: Rich, diverse, as above; plus *Saracenaria italica, Planulina bradii* common.
Age: Middle-Late Miocene.

Sample 12-116-6-4, 138-141 cm:
PF and BF fauna as above; keeled globorotaliids not observed.
Age: Middle Miocene.

Sample 12-116-6, Core Catcher:
PF: *Globigerina praebulloides* (dominant, abundant), *G. foliata, G.* sp. cf. *G. druryi, Globoquadrina acostaensis, G. dehiscens, Orbulina universa, Globorotalia miozea, Sphaeroidinellopsis seminulina, S. subdehiscens.*
BF: *Eponides umbonatus, Planulina bradii* (common), *Karreriella bradyi, Laticarinina halophora, Gyroidina neosoldanii.*
Also present: Abundant sponge spicules; Radiolaria and ostracods.
Age: Middle-Late Miocene (probably lower Zone N16).
Remarks The presence of *Globorotalia menardii* indicates that the bottom of Core 6 is not older than Zone N14. The presence of *Globigerina apertura* and of forms assigned here to *G. acostaensis* suggest that Core 6 is within Zone N16.

Sample 12-116-7-0, Bottom:
PF: Very rich (high P:B ratio) including, *i, al., Globigerina praebulloides* (dominant, abundant), *G. apertura, G. nepenthes, Orbulina universa, Globorotalia cultrata* (circular outline, thick keel), *G. menardii* (elongate-oval outline), *Globorotalia* sp. cf. *G. scitula* (Blow, 1969, pl. 39, Fig. 4, 10) *Globigerinoides triloba, Globigerinoides* sp. (high, broad primary aperture; diminutive supplementary aperture), *Sphaeroidinellopsis subdehiscens, Globoquadrina dehiscens.*
BF: Relatively rich, containing, *i. al., Eponides umbonatus, Planulina bradii, P. wuellerstorfi, Stilostomella* sp., *Dorothia* sp. *Laticarinina halophora, Uvigerina auberiana, Cibicidoides pseudoungeriana, C. kullenbergi, Anomalinoides cicatricosa, Gyroidina neosoldanii, Cassidulina subglobosa.*
Also present: Sponge spicules, Radiolaria, ostracods.
Age: Middle-Late Miocene (? N16).

Sample 12-116-7-1, 138-141 cm:
PF: *Orbulina universa* (dominant, common) *Globigerina* sp., *Globorotalia* aff. *acostaensis, G. continuosa, G. miozea, Globigerina nepenthes* (common), *Globigerinoides triloba, Globoquadrina dehiscens.*
BF: As above.
Also present: Abundant volcanic scoria and glass.
Age: Middle Miocene (probably Zone N14-N15).

Sample 12-116-7-2, 140-143 cm:
PF: *Globigerina praebulloides, G. druryi, Globorotalia* aff. *acostaensis, G. continuosa, Globorotalia* sp. (low-conical, keeled), *Globoquadrina dehiscens, Orbulina universa, Globigerinoides obliqua, Globigerinoides* sp. *(Globigerina nepenthes* not observed).
BF: In general, as above, but not as diverse nor as rich (higher P:F ratio).
Age: Middle Miocene (probably Zone N14-N15).

Sample 12-116-7-3, 146-149 cm:
Data essentially same as preceding sample above; *G. nepenthes* not observed.
Age: Middle Miocene (probably Zone N14-N15).

Sample 12-116-7-4, Bottom:
PF: Essentially same as samples above; plus *Globigerina nepenthes, Globorotalia siakensis* (one specimen), *G. miozea.*
BF: As above.
Also present: Volcanic scoria and glass.
Age: Middle Miocene (probably Zone N14-N15).

Sample 12-116-7-5, Bottom:
PF: *Globigerina praebulloides, Globorotalia continuosa* (abundant), *G.* sp. aff. *acostaensis, G. miozea, Sphaeroidinellopsis subdehiscens* (common).
BF: Rich, diverse, as above.
Age: Middle Miocene (Zone N14-N15).

Sample 12-116-7-6, 133-136 cm:
PF: *Globorotalia continuosa G.* aff. *acostaensis, Globigerina* sp. cf. *G. atlantica* (dextral), *Globigerina praebulloides, G. foliata.*
BF: Essentially as above.
Also present: Sponge spicules, ostracods.
Age: Middle-Late Miocene (Zone N15-N16).

Sample 12-116-7, Core Catcher:
PF: *Globorotalia* aff. *acostaensis* (dextral), *Globorotalia* sp. cf. *G. scitula* (Blow, 1969, pl. 39, figs. 4, 10), *Globigerina praebulloides* (rare), *G. bulbosa, Globigerinoides triloba, Globoquadrina dehiscens, Orbulina universa, Sphaeroidinellopsis subdehiscens.*
BF: *Cibicidoides pseudounderiana, C. kullenbergi, Cassidulina subglobosa, Pullenia bulloides, P. subcarinata, Gyroidina neosoldanii, G. complanata, Cibicides* sp., *Lenticulina* sp., dentalinids, nodosariids, *Eponides tener, E. umbonatus, Laticarinina halophora, Uvigerina auberiana* (common), *Anomalinoides cicatricosa, Planulina bradii.*
Also present: Sponge spicules, ostracods.
Age: Middle-Late Miocene (N15-N16).
Remarks: Core 7 is characterized by 4-5 chambered forms here assigned to *Globorotalia* aff. *acostaensis.* The occurrence of *Globigerina nepenthes* (Sections 0,1,3,4)(Range Zone N14-N19) and *Sphaeroidinelopsis subdehiscens* (Range N13-N20) indicate that this core is no older than Zone N14 (Serravallian; Middle Miocene). The occurrence of forms assigned to *G.* aff *acostaensis* and of several specimens of a compressed globorotaliid identified as *Globorotalia* sp. cf. *G. scitula* (which Blow, 1969, p. 356, indicates occurring only in the lower to middle parts of Zone N16) would support an age determination of Zone N16 or Tortonian, Late Miocene. Since the changes observed in the faunas here are gradual and subtle, it may be that the exact relationships of ranges of several taxa are not yet completely understood; alternatively the writer's taxonomy may be at fault. For the present an age assignment of Middle Miocene (pre-Tortonian, approximately equivalent to Zone N14-N15) is made for all of Core 7.

Sample 12-116-8-2, 142-145 cm:
PF: *Globigerina praebulloides, Globorotalia continuosa, G.* sp. aff. *acostaensis, G. miozea* (common).
BF: *Eponides tener, E. umbonatus, Planulina bradii* (common), *Unigerina rutila, Cibicidoides kullengergi, Melonis barleeanum, Gyroidina* sp., *Lenticulina* sp., nodosariids.
Also present: Radiolarians.
Age: Lower-Middle Miocene.
Note: This sample is characterized by the uncommonly high frequency of specimens of *Globorotalia miozea.*

Sample 12-116-8-3, 143-146 cm:
PF: Essentially same as above with *G. praebulloides, G. acostaensis, G. miozea* present; also *Globorotalia* sp. cf. *G. cultrata.*
BF: Essentially as above, plus *Gyroidina neosoldanii, Laticarinina halophora.*
Age: Early-Middle Miocene.

Sample 12-116-8, Core Catcher:
PF: *Globigerina praebulloides, G. praebulloides pseudociperoensis, Globigerina parabulloides, Globigerina* sp. (bullate), *G. zealandica, Globorotalia siakensis* (top), *G. continuosa, G. miozea, Globorotaloides variabilis, Orbulina universa.*
BF: *Laticarinina halophora, Eponides umbonatus, Cibicidoides kullenbergi, Planulina wuellerstorfi, P. bradii, P.* sp.
Also present: Sponge spicules, Radiolaria.
Age: Middle Miocene.

Remarks: Core 8 is characterized by a variety of globigerinids and non-keeled globorotaliids which are difficult to distinguish taxonomically. The forms identified as *Globigerina pseudociperoensis* are similar to specimens identified as *Globigerina dubia* by Lipps (1964, pl. 1, figs. 5a-c) from the Luisian Stage of California. The presence of *Globorotalia siakensis* (ranges to Zone N14), *Orbulina universa* (appears at base Zone N9) and absence of *Globigerina nepenthes* (appears at base Zone N14) suggests that Core 8 is older than Zone N14; from evidence in Cores 9 and 10 (see below) we know it is younger than Zone N9. Tentative correlation with Zone N12-N13 is made here. *Globorotalia miozea* is quite common at some levels in Core 8.

Sample 12-116-9-1, 139-142 cm:
PF: *Praeorbulina glomerosa circularis* (common), *Orbulina suturalis, Globigerina praebulloides, G.* sp., *Globorotalia peripheroacuta, G. praemenardii* (exhibiting similarities to *G. archeomenardii*), *G. siakensis, Globoquadrina baroemoenensis* (=?*G. langhiana*), *Globigerinoides triloba.*
BF: *Planulina wuellerstorfi* (common), *Siphonina tenuicarinata* (top), *Bulimina* sp., *Eggerella bradyi, Lenticulina* sp., *Eponides tener, Sphaeroidina bulloides, Gyroidina neosoldanii.*
Also present: Abundant Radiolaria; ostracods, echinoid spines.
Age: Middle Miocene (Zone N9/10).
Note: This sample contains the highest occurrence of *Globototalia peripheroacuta* appears base Zone N10) and *Praeorbulina glomerosa circularis* (ranges to upper part of Zone N9). Actually, *G. peripheroacuta* may range upward in the stratigraphic section between Cores 9 and 8; it was not observed elsewhere in Core 9. This may be a basal occurrence rather than an upper occurrence. Sample is dated Middle Miocene, approximately Zone N9/N10 boundary. This sample also contains the highest occurrence of *Siphonina tenuicarinata*, a distinctive and dominant component of Lower Miocene assemblages at this site (see below).

Sample 12-116-9-2, 142-144 cm:
PF: Essentially as above; *G. praemenardii* common; plus *Globoquadrina altispira.*
BF: Essentially as above, plus *Gyroidina complanata.*
Age: Middle Miocene (Zone N9-N10).

Sample 12-116-9-3, 137-140 cm:
PF: Essentially as above; *Globorotalia praemenardii* common; some forms show relationship to *G. miozea; Globoquadrina dehiscens* also present.
BF: As above; *Planulina wuellerstorfi* common to abundant.
Also present: Abundant sponge spicules, Radiolaria, ostracods.
Age: Middle Miocene (Zone N10).

Sample 12-116-9, Core Catcher:
PF: *Orbulina suturalis, Praeorbulina glomerosa curva, Globorotalia praemenardii, G.* aff. *miozea, Globigerina* spp., *Globoquadrina dehiscens.*
BF: *Gyroidina neosoldanii, G. complanata, Planulina wuellerstorfi, Siphonina tenuicarinata, Eponides umbonatus.*
Also present: Abundant radiolarians, spicules.
Age: Middle Miocene (Zone N9-N10).
Remarks: Core 9 is characterized by the common occurrence of *Globorotalia praemenardii* (range: Zone N10-within Zone N12) and *Praeorbulina glomerosa circularis* (range latest part Zone N8 to upper part Zone N9). The age of Core 9 is interpreted here as Middle Miocene (equivalent to the latest part of Zone N9-earliest part Zone N10). *Siphonina tenuicarinata*, a common element in the Lower Miocene sediments at this site, has its highest occurrence within this core (Section 1).

Sample 12-116-10-0, Top:
PF: *Orbulina suturalis, Praeorbulina glomerosa circularis, Globoquadrina dehiscens, G. baroemoenensis, Globorotalia praescitula, Globorotalia* spp., *Globigerina parabulloides, Globigerina* spp., *Globigerinoides triloba, G. sicana.*
BF: *Siphonina tenuicarinata* (dominant, common), *Planulina renzi* (top occurrence), *Planulina* sp. (robust, biconvex), *Cibicidoides* sp. aff. *pseudoungeriana, Anomalinoides cicatricosa, Oridorsalis ecuadorensis, Pleurostomella* sp.
Also present: Abundant Radiolaria, sponge spicules; ostracods common.
Age: Middle Miocene (Zone N9).

Sample 12-116-10-0, Bottom:
PF and BF: Essentially same as preceding sample above, plus *Gyroidina jarvisi* (top occurrence).
Age: Middle Miocene (Zone N9).

Sample 12-116-10-1, 87-91 cm:
PF and BF: Essentially same as above; plus *Sphaeroidinellopsis seminulina* and *Planulina subtenuissima.*
Age: Middle Miocene (Zone N9).

Sample 12-116-10-1, 140-144 cm:
Data essentially same as above.
Age: Middle Miocene (Zone N9).

Sample 12-116-10-2, 43-49 cm:
PF: *Orbulina suturalis, Praeorbulina glomerosa circularis, P. transitoria, Globigerinoides triloba, G. sicana, Globigerina praebulloides, G.* spp., *Globoquadrina altispira, G. dehiscens, G. baroemoenensis, Globorotalia praescitula.*
BF: As above.
Age: Middle Miocene (Zone N9).

Sample 12-116-10-2, 135-138 cm:
PF: As above, plus *Praeorbulina glomerosa glomerosa* (top occurrence).
BF: As above.
Age: Middle Miocene (Zone N9).

Sample 12-116-10-3, 62-65 cm:
PF: As above, plus *Praeorbulina glomerosa curva* (top occurrence), *P. transitoria, O. suturalis* (first occurrence).
BF: As above; *Siphonina tenuicarinata* and *Cibicidoides pseudoungeriana* common; *Planulina renzi* also a distinctive element.
Age: Middle Miocene (basal Zone N9).

Sample 12-116-10-3, 143-146 cm:
All data essentially same as above; *P. glomerosa circularis* (first occurrence).
Age: Latest Early Miocene (top Zone N8).

Sample 12-116-10-4, 31-34 cm:
Data essentially same as above.
Age: Late Early Miocene (top Zone N8).

Sample 12-116-10-4, 140-143 cm:
Data essentially same as above.
Age: Late Early Miocene (top Zone N8).

Sample 12-116-10-5, 60-63 cm:
Data essentially same as above.
Age: Late Early Miocene (Zone N8).

Sample 12-116-10-5, 137-140 cm:
Data essentially same as above; plus *Anomalina pompilioides* (top occurrence); *Praeorbulina glomerosa glomerosa* (first occurrence).
Age: Late Early Miocene (Zone N8).

Sample 12-116-10-6, 62-65 cm:
Data essentially same as above.
Age: Late Early Miocene (Zone N8).

Sample 12-116-10-6, 141-144 cm:
Data essentially same as above.
Age: Late Early Miocene (Zone N8).

Sample 12-116-10-6, Core Catcher:
PF: *Praeorbulina glomerosa curva, Globigerinoides triloba, G. sicana, Globigerina praebulloides, Globigerina* sp., *Globoquadrina dehiscens, G. altispira, G. baroemoenensis, Sphaeroidinellopsis seminulina.*

BF: *Siphonina tenuicarinata* (dominant, common), *Cibicidoides pseudoungeriana, C. atratiensis* (top), *Planulina renzi, Planulina* sp. aff. *wuellerstorfi, Planulina subtenuissima, Gyroidina complanata, G. girardana, Anomalina pompilioides, A. alazanensis, Oridorsalis ecuadorensis, Sphaeroidina bulloides, Lenticulina* sp. aff. *plummerae, L.* sp.
Age: Late Early Miocene (Zone N8).
Remarks: Core 10 is unique and extremely interesting. Almost the complete evolutionary sequence leading from *Globigerinoides sicana* to *Orbulina suturalis* occurs within the 9-meter interval of this core. The more significant aspects of this core are listed below:

1. The first evolutionary appearance of *Orbulina* (*O. suturalis*) occurs within Section 3; the boundary between Zones N8 and N9 is drawn here.
2. In the lower part of the core (Section 6 and Core Catcher) *Globigerinoides triloba* and *G. sicana* are common: there is a marked upward decrease in both these taxa as the praeorbulinids develop.
3. In Section 6 and the Core Catcher only *Praeorbulina glomerosa curva* and some forms transitional between *Globigerinoides sicana* and *P. glomerosa curva* occur.
4. Sections 2 through 5 are characterized by abundant specimens of *Praeorbulina glomerosa glomerosa* and *P. glomerosa circularis; P. glomerosa circularis* (which appears in Section 3) ranges to the top of Core 9 so that its approximate upward stratigraphic range can be estimated.
5. A rich and diversified benthonic foraminiferal fauna occurs in this core. The last (youngest) occurrence of several long-ranging and stratigraphically important species occurs within this core; *Planulina renzi, P. subtenuissima, Gyroidina jarvisi, Anomalina pompilioides, Cibicidoides atratiensis.*
6. A significant shift in faunal elements can be seen in this core from those with Oligocene-early Miocene affinities (below) to late Neogene types (above).
7. Radiolarians and siliceous sponge spicules are common to abundant throughout this core.

Sample 12-116-11-0, Top:
PF: *Globoquadrina dehiscens, G. baroemoenensis, Sphaeroidinellopsis seminulina, Globigerina praebulloides, G. obesa.*
BF: *Siphonina tenuicarinata* (dominant, common), *Pyrulina* sp., *Uvigerina rustica* (top occurrence), *Melonis barleeanum, Gyroidina girardana, Sphaeroidina bulloides, Cibicidoides* sp. aff. *pseudoungeriana.*
Also present: Organogenic fragments composed of bryozoans, foraminifera.
Age: Early Miocene (Late Burdigalian).
Note: Presence of *S. seminulina* (first appearance in Zone N6) and absence of *Praeorbulina* (appears near base Zone N8) suggests that this level is equivalent to Zones N6 or N7. From other evidence (see below) this level (and core) is correlated with Zone N7.

Sample 12-116-11-0, Bottom:
PF: *Sphaeroidinellopsis seminulina* (dominant, abundant), globoquadrinids and globigerinids (see above) subordinate.
BF: As above, plus *Planulina renzi, Anomalina* sp.
Age: Early Miocene (Late Burdigalian).

Sample 12-116-11-1, Bottom:
Data essentially same as above; *S. seminulina* abundant.
Age: Early Miocene (Burdigalian).

Sample 12-116-11-2, 142-145 cm:
PF: As in preceding sample, few *Globorotalia siakensis.*
BF: As above, plus *Anomalinoides cicatricosa; Melonis pompilioides, Siphonina tenuicarinata* not observed.
Age: Early Miocene (Burdigalian).

Sample 12-116-11-3, Bottom:
PF and BF: As in preceding sample above: benthonics, including *Siphonina tenuicarinata*, generally reduced in size. Recrystallized, indurated pieces of organogenic limestone common.
Age: Early Miocene (Burdigalian)

Sample 12-116-11-4, Bottom:
PF and BF: As in preceding sample above.
Age: Early Miocene (Burdigalian).

Sample 12-116-11-5, Bottom:
PF and BF: As above. Organogenic limestone, moderately indurated.
Age: Early Miocene (Burdigalian).

Sample 12-116-11-6, 140-143 cm:
PF and BF: Essentially same as above; preservable elements rarer than above as larger amounts organogenic limestone fragments and recrystallized limestone present.
Age: Early Miocene (Burdigalian).

Sample 12-116-11, Core Catcher:
PF: Rare in 125-micron fraction, common in 63-micron fraction; preservation fair to poor. *Sphaeroidinella seminulina, Globoquadrina dehiscens, G. baroemoenensis, Globigerina praebulloides, Globigerina* spp.
BF: Small, specifically indeterminate; cibicidids, anomalinids, bolivinids, siphoninids.
Also present: Organogenic detritus, recrystallized limestone and scattered glauconite and (?) phosphatic grains; foraminifera replaced by glauconite in some instances.
Age: Early Miocene (Burdigalian).
Remarks: This core shows a marked gradation upward from partially indurated organogenic limestone (with recrystallized fragments) to a relatively pure foraminiferal-nannofossil ooze. The lithologic sequence represents a foraminiferal-nannofossil ooze exhibiting decreasing degree of lithification upwards. In the upper part (Sections 1 and 2) *Sphaeroidinellopsis seminulina* is abundant and the globoquadrinids form a minor component of the planktonic foraminiferal assemblage. The presence of *S. seminulina* and absence of *Praeorbulina* suggest that Core 11 is within the interval of Zones N6-N7. The core is assigned a late Early Miocene age (Zone N7 equivalent) on the basis of the last (youngest) occurrence of *Globigerinita dissimilis* (which is within Zone N6) in Core 13 (see below).

Sample 12-116-12-1, 144-147 cm:
PF: *Globoquadrina dehiscens* (dominant, common), *G. baroemoenensis, Sphaeroidinellopsis seminulina, Globorotaloides suteri, Globorotalia birnageae, G. semivera.*
BF: *Siphonina tenuicarinata* (dominant, common), *Gyroidina girardana, Lenticulina* sp., *Siphogenerina multicostata, Anomalina alazanensis, Cibicides* sp.
Age: Early Miocene (Burdigalian).

Sample 12-116-12-2, 143-146 cm:
PF: Abundant planktonic foraminifers (but low species diversity) including *Globorotaloides suteri, Globoquadrina dehiscens, Globorotalia siakensis,* (abundant, dominant), *Globigerina* spp.
BF: As above; also *Gyroidina jarvisi, Uvigerina basicordata.*
Age: Early Miocene (Burdigalian).

Sample 12-116-12-3, 135-138 cm:
Data essentially same as above.
Age: Early Miocene (Burdigalian).

Sample 12-116-12-4, 124-127 cm:
PF: Essentially same as above, including *Globorotalia birnageae,* and *G. semivera.*
BF: Essentially as above.
Age: Early Miocene (Burdigalian).

Sample 12-116-12-5, Bottom:
PF: *Globoquadrina dehiscens, G. baroemoenensis, Globorotalia siakensis, G. semivera, G. birnageae, Globorotaloides suteri, Globigerina* sp.
BF: Rich, diverse fauna including, *i. al., Siphonina tenuicarinata,* (dominant, abundant), *Gyroidina girardana, G. jarvisi, Lenticulina* sp., *Anomalina alazanensis, Planulina renzi, Uvigerina basicordata, Stilostomella curvatura.*
Age: Early Miocene (Burdigalian).

Sample 12-116-12-6, 143-146 cm:
PF: As above.
BF: As above, plus *Siphogenerina multicostata.*
Age: Early Miocene (Burdigalian).

Sample 12-116-12, Core Catcher:
PF: *Globoquadrina dehiscens, G. baroemoenensis, Globorotalia birnageae, Globorotaloides suteri, Globigerina* sp.
BF: *Siphonina tenuicarinata* (dominant, common), *Gyroidina girardana, G. jarvisi, Planulina renzi, Anomalina alazanensis, Cassidulina* sp.
Also present: Abundant sponge spicules and pyrite.
Age: Early Miocene (Burdigalian).
Remarks: Core 12 is characterized by the occurrence of abundant globoquadrinids throughout. The common occurrence of *Globorotalia birnageae* and *Globorotaloides suteri* suggest that Core 12 is of Early Miocene (Burdigalian) age, approximately equivalent to Zone N7 of Blow. *Sphaeroidinellopsis seminulina* was not observed in Core 12. Samples within this core contain a rich planktonic and benthonic fauna which are well preserved; *Siphonina tenuicarinata* is the dominant benthonic form throughout the core.

Sample 12-116-13, Core Catcher:
PF: *Globoquadrina* sp. cf. *G. dehiscens, Globigerinita dissimilis, Globorotaloides suteri, Globigerina* sp.
BF: Sparse, including *Planulina renzi, Vulvulina* sp., cibicidids, *Oridorsalis ecuadorensis, Gyroidina jarvisi.*
Also present: Radiolaria, spicules.
Age: Early Miocene (Aquitanian-Burdigalian).
Remarks: Only the Core Catcher was recovered from Core 13. The sample is chalky, specimens few and mostly broken, preservation generally poor to fair. Presence of single specimen of *Globigerinita dissimilis* suggests Core 13 is at or near Zone N6/N7 boundary (*i.e.*, extinction of *G. dissimilis*).

Sample 12-116-14, Core Catcher:
PF: Sparse, small globoquadrinids and globigerinids.
BF: Sparse, *Siphonina tenuicarinata.*
Also present: Abundant Radiolaria, sponge spicules.
Age: Early Miocene (Aquitanian) (See above, Core 13).
Remarks: Only the Core Catcher and 1.10 centimeter of sediment in section were recovered from Core 14. The sediments are siliceous (Radiolaria) and nannoplankton ooze; foraminifera are scarce and generally small.

Sample 12-116-15-1, 141-143 cm:
PF: *Globoquadrina baroemoenensis, G. dehiscens, Globigerinita dissimilis.*
BF: *Siphonina tenuicarinata, Gyroidina complanata, Planulina renzi, Anomalina alazanensis, Oridorsalis ecuadorensis.*
Also present: Abundant Radiolaria and sponge spicules.
Age: Early Miocene (Aquitanian); Zone N6.

Sample 12-116-15-3, 144-147 cm:
Data essentially same as for preceding sample above; sample is a nannofossil-radiolarian ooze.
Age: Early Miocene (Aquitanian); Zone N6.

Sample 12-116-15-5, 146-149 cm:
Data as above; nannofossil-radiolarian ooze; *Globoquadrina baroemoenensis* present to the exclusion of *G. dehiscens; G. dissimilis* present.
Age: Early Miocene (Aquitanian); Zone N6.

Sample 12-116-15-6, 142-145 cm:
Data essentially same as above plus *Globoquadrina praedehiscens* (highest occurrence observed). *Anomalinoides pompilioides* present.
Age: Early Miocene (Aquitanian); Zone N6.

Sample 12-116-15, Core Catcher:
PF: *Globoquadrina baroemoenensis, G. praedehiscens, Globigerinita dissimilis.*
BF: *Siphonina tenuicarinata, Gyroidina complanata, G. girardana, Planulina renzi, Oridorsalis ecuadorensis,* cibicidids.
Age: Early Miocene (Aquitanian); Zone N6.

Remarks: Core 15 is a radiolarian-nanno fossil ooze. Planktonic foraminifera play a subordinate role in this core. Characteristic forms include *Globoquadrina baroemoenensis* and *Globigerinita dissimilis*. The youngest occurrence of *G. praedehiscens* in this hole was observed in Section 6, suggesting that this core is equivalent to Zone N6. The benthonic foraminiferal fauna is essentially the same as in Cores 11 through 14 above.

Sample 12-116-16-2, 131-134 cm:
PF: *Globoquadrina baroemoenensis, G. praedehiscens, G. venezuelana, Globigerinita dissimilis.*
BF: *Siphonina tenuicarinata, Gyroidina girardana, Lenticulina* sp., *Anomalina alazanensis,* polymorphinids.
Also present: Abundant radiolarians and sponge spicules.
Age: Early Miocene (Aquitanian).

Sample 12-116-16-4, 136-139 cm:
PF: *Globoquadrina praedehiscens* (common, dominant), *G. baroemoenensis, G. venezuelana, Globigerinita unicava, G. dissimilis.*
BF: As above.
Age: Early Miocene (Aquitanian)

Sample 12-116-16, Core Catcher:
PF: *Globoquadrina praedehiscens, G. baroemoenensis, G. venezuelana, Globigerinita dissimilis.*
BF: *Siphonina tenuicarinata, Planulina renzi, Gyroidina girardana.*
Age: Early Miocene (Aquitanian).
Remarks: Core 16 is a radiolarian-nannofossil ooze and is characterized by the common occurrence of forms here referred to *Globoquadrina praedehiscens* and *G. venezuelana.* This association is of Early Miocene (Aquitanian) age and is probably equivalent to Zone N6.

Sample 12-116-17-4, 141-144 cm:
PF: *Globoquadrina praedehiscens, G. venezuelana, G. baroemoenensis, G. dehiscens, Globigerina praebulloides.*
BF: *Siphonina tenuicarinata* (dominant, common), *Gyroidina girardana, Anomalina alazanensis, Oridorsalis ecuadorana,* cibicidids, polymorphinids.
Age: Early Miocene (Aquitanian)

Sample 12-116-17-6, 141-144 cm:
Data essentially same as for preceding sample above.

Sample 12-116-17, Core Catcher:
PF: *Globoquadrina praedehiscens, G. dehiscens, Globigerina praebulloides.*
BF: *Siphonina tenuicarinata, Oridorsalis ecuadorensis, Planulina renzi, Gyroidina girardana,* stilostomellids, lagenids, cibicidids, polymorphinids.
Age: Early Miocene (Aquitanian).
Remarks: Core 17 is a nannofossil-radiolarian ooze (see remarks above under Cores 13 through 16). *Globoquadrina praedehiscens* occurs commonly throughout the interval examined (Sections 4, 6, Core Catcher; Sections 1-3 and 5 were not split). The benthonic forms *Siphonina tenuicarinata* and *Oridorsalis ecuadorensis* occur commonly. Core 17 is of Early Miocene (Aquitanian-Burdigalian) age equivalent to Zone N6 or N5.

Sample 12-116-18-4, 143-146 cm:
PF: *G. baroemoenesis, Globorotaloides suteri, Globigerina woodi,* small globigerinids.
BF: *Planulina renzi,* Lenticulina sp.
Also present: Radiolaria and sponge spicules.
Age: Early Miocene.

Sample 12-116-18, Core Catcher:
PF: *Globoquadrina baroemoenesis* (common, dominant), *G. praedehiscens, Globigerinita dissimilis.*
BF: *Cibicidoides trincherasensis, Cibicidoides* sp., *Anomalina pompilioides, Siphonina tenuicarinata, Pullenia* sp., *Planulina renzi.*
Age: Early Miocene.

Remarks: Six sections were recovered from Core 18, but only section 4 was opened due to the soft, soupy nature of the material. *Globoquadrina baroemoenensis* is the dominant planktonic foraminifer. Age diagnostic forms are, in general absent. Core 18 is probably of Early Miocene (Aquitanian-Burdigalian) age, equivalent to Zones N5 or N6.

Sample 12-116-19-1, 142-146 cm:
Sample is chalky and there are few disaggregated foraminifera. Globoquadrinids, cibicidids and *Siphonina tenuicarinata* occur.
Age: Oligocene-Miocene.

Sample 12-116-19-2, 69-72 cm:
PF: *Globoquadrina baroemoenensis, Globorotaloides suteri,* globigerinids.
BF: *Siphonina tenuicarinata, Oridorsalis ecuadorensis, Uvigerina* sp., cibicidids.
Also present: Sponge spicules, Radiolaria.
Age: Oligocene-Miocene.

Sample 12-116-19-5, 133-136 cm:
PF: As above.
BF: As above; *Siphonina tenuicarinata* common.
Age: Oligocene-Miocene.

Sample 12-116-19, Core Catcher:
PF: *Globoquadrina baroemoenensis, G. praedehiscens, Globorotaloides suteri, Globigerina* spp.
BF: *Siphonina tenuicarinata, Cibicidoides trincherasensis, Gyroidina girardana.*
Age: Oligocene-Miocene
Remarks: Only Sections 1, 2, and 5 were opened in Core 19. Disaggregated foraminifera are not abundant due to the relatively chalky matrix. A relatively homogeneous planktonic fauna occurs in the core and renders precise age determination difficult. The core is of Oligocene-Miocene age (radiolarians).

Sample 12-116-20-1, 116-119 cm:
Sample is a relatively well-cemented chalk with few disaggregated foraminifera. Globigerinids and globoquadrinids and *Siphonina tenuicarinata* present.
Age: Late Oligocene (see below).

Sample 12-116-20-5, 125-128 cm:
As above, plus indurated (? chert) fragments.
Age: Late Oligocene.

Sample 12-116-20, Core Catcher:
PF: *Globoquadrina baroemoenensis, Globigerinita dissimilis.*
BF: *Siphonina tenuicarinata, Uvigerina* sp.
Age: Late Oligocene.
Remarks: Only Sections 1 and 5 were opened in Core 20. Lack of diagnostic fauna and generally poor fauna renders age determination difficult. Core is Late Oligocene according to radiolarian evidence.

Sample 12-116-21-3, 130-133 cm:
PF: *Globoquadrina baroemoenensis, Globigerina venezuelana, Globigerina* spp., *Globigerinita dissimilis, Globorotalia siakensis.*
BF: *Siphonina tenuicarinata, Cibicidoides trincherasensis, Oridorsalis ecuadorensis, Vaginulina* sp., *Gyroidina* sp.
Age: Late Oligocene.

Sample 12-116-21-4, 135-137 cm:
PF: *Globigerina* sp., *Globigerinita dissimilis, G. unicava, Globorotaloides suteri.*
BF: Sparse, *Siphonina tenuicarinata.*
Age: Late Oligocene.

Sample 12-116-21, Core Catcher:
PF: *Globigerina venezuelana, Globigerina* sp., *Globorotaloides suteri, Globorotalia siakensis, Globigerinita dissimilis, G. unicava.*
BF: Sparse, *Siphonina tenuicarinata, Gyroidina girardana.*
Age: Late Oligocene.
Remarks: Only Sections 3 and 4 in Core 21 were split. Chert fragments occur commonly with the chalk. Diagnostic foraminifera are generally absent. Typical globoquadrinids, common above, are rare or absent in Core 21.

Sample 12-116-22-1, Bottom:
Sample appears to be contaminated (*Orbulina*).

Sample 12-116-22-2, Bottom:
PF: Small globigerinids, including *Globigerina praebulloides, G.* spp., *Globigerinita dissimilis.*
BF: *Siphonina tenuicarinata.*
Age: Late Oligocene.

Sample 12-116-22-3, Bottom:
PF: As above.
BF: As above, plus *Cibicidoides mexicana* (common, highest occurrence) *Oridorsalis ecuadorensis.*
Age: ?Late Oligocene.

Sample 12-116-22-4, Bottom:
Data as above.
Age: ?Late Oligocene.

Sample 12-116-22-5, Bottom:
Data same as above.

Sample 12-116-22-6, 144-147 cm:
Data same as above.
PF: *Globigerinita unicava, G. dissimilis, Globoquadrina praedehiscens,* small globigerinids.
BF: *Cibicidoides mexicana, Siphonina tenuicarinata* (common), *Oridorsalis ecuadorensis, C. trincherasensis, Planulina renzi, Anomalina pompilioides, Lenticulina* spp., *Vaginulina* sp., *Gyroidina girardana.*
Age: ?Late Oligocene.
Remarks: Core 22 was not split with the exception of Section 6. Samples were taken at the bottom of each section, however, and are from within Section 6. These contain a rather uniform, low diversity planktonic foraminiferal fauna composed of globigerinids and globigerinitids indicating a ?Late Oligocene age. The highest occurrence of the distinct and relatively long-ranging benthonic form *Cibicidoides mexicana* was noted in this core (Bottom, Section 3). Chert fragments occur in all the samples studied from this core.

Sample 12-116-23-0, Bottom:
PF: *Globigerinita dissimilis* (dominant, abundant), *G. unicava, G. pera, Globorotalia opima nana.*
BF: *Siphonina tenuicarinata, Cibicidoides mexicana, Uvigerina mexicana, U. havanensis, Anomalina pompilioides, Planulina renzi, Gyroidina* sp., *Pullenia* sp., *Lenticulina* sp.
Age: Early Oligocene.

Sample 12-116-23-1, Bottom:
Data essentially same as for sample above.
Age: Early Oligocene.

Sample 116-23-2, 124-127 cm:
Data essentially same as above, plus *Globigerina tripartita.*
Age: Early Oligocene.
The following samples yield the same data as above:
Sample 12-116-23-4, Bottom
Sample 12-116,23-5, Bottom
Sample 12-116-23-6, 135-137 cm

Sample 12-116-23, Core Catcher:
PF: *Globigerina angiporoides, Globigerinita dissimilis, G. unicava, G. pera, Globorotalia opima nana, Chiloguembelina* sp.
BF: *Cibicidoides mexicana, Siphonina tenuicarinata, Anomalina pompilioides, Lenticulina* sp., *Oridorsalis ecuadorensis.*
Age: Early Oligocene.
Remarks: Core 23 is characterized by an abundance of globigerinitids, in particular *Globigerinita dissimilis.* In the upper part of this core, well-preserved specimens of this species were particularly common. The distinctive *Uvigerina mexicana* occurs commonly in the upper part of this core, together with *Cibicidoides mexicana, Siphonina tenuicarinata* and *Planulina renzi. U. mexicana* is essentially restricted to the Oligocene, ranging up into the Lower Miocene in North Africa. Chert fragments are present in all samples examined.

Sample 12-116-24-1, 142-145 cm:
Cohesive chalk, few disaggregated (free) specimens of foraminifera. No age determination possible.

Sample 12-116A-2-4, 67-70 cm:
Essentially as above.
Age: Pleistocene.

Sample 12-116A-2, Core Catcher:
PF: *Globigerina bulloides* (dominant, abundant), *G. pachyderma* (dextral, quantitatively minor), *Globorotalia inflata* (abundant), *G. truncatulinoides, G. hirsuta, G. crassaformis, G. scitula, Hastigerina siphonifera, Hastigerinella digitata, Orbulina universa.*
BF: *Pyrgo lucernula, Rupertia stabilis, Uvigerina hollicki, Sigmoilopsis schlumbergeri, Gyroidina neosoldanii, Cibicidoides pseudoungeriana, Bulimina aculeata, Pyrgo murrhyna.*
Also present: Pelecypod fragments common, ostracods common (*Echinocythereis, Krithe, Cytherella*), glacially-rafted quartz and rock fragments.
Age: Pleistocene.
Remarks: Core 2 consists of foraminiferal lutites made up of abundant planktonic foraminifera. The dominant forms include *Globigerina bulloides, G. pachyderma,* and *Globorotalia inflata.* The varying frequencies of *Globigerina pachyderma* are an indication of fluctuating climatic conditions, but no quantitative study of its frequency has been made in this preliminary report.

Sample 12-116A-3-1, 143-146 cm:
Rich planktonic and benthonic fauna and abundant volcanic fragments and glacially-rafted quartz.
PF: *Globigerina pachyderma* (sinistral, abundant, approximately 90 per cent of total planktonic foraminiferal fauna), *Globigerina bulloides.*
BF: *Sigmoilopsis schlumbergeri, Lenticulina* sp., *Pyrgo lucernula, Bulimina marginata, Cibicides* spp.
Age: Pleistocene (glacial).

Sample 12-116A-3-2, 65-68 cm:
PF: *Globigerina pachyderma* (sinistral), *G. bulloides, Globorotalia inflata, G. scitula* (*G. quinqueloba* in fine fraction).
BF: As above.
Also present: Glacially-rafted quartz abundant in fine fraction.
Age: Pleistocene.

Sample 12-116A-3-2, 141-145 cm:
PF: *Globorotalia inflata* (abundant), *Globigerina bulloides, Globigerina pachyderma, Globorotalia crassaformis, G. scitula, Orbulina universa.*
BF: *Cibicidoides pseudoungeriana, Cibicides* sp., *Melonis barleeanum.*
Age: Pleistocene.

Sample 12-116A-3-3, Bottom:
Lithology and fauna essentially the same as preceding sample above.
Age: Pleistocene.

Sample 12-116A-3-4, Bottom:
PF: *Globigerina bulloides, G. pachyderma* (random coiling), *Globorotalia inflata, G. scitula, Globigerinita glutinata, Orbulina universa* (*Globigerina quinqueloba* in smaller fractions).
BF: *Pyrgo lucernula, Melonis barleeanum, Karreriella* sp.
Age: Pleistocene.

Sample 12-116A-3-5, 140-143 cm:
Fauna essentially the same as above, including *Globorotalia truncatulinoides* and *G. hirsuta*. Relative percentages of the species, however, are changed. *Globigerina bulloides* is dominant and abundant in this sample.
Age: Pleistocene.

Sample 12-116A-3-5, 145-148 cm:
Brown silty marl with abundant green (epidote) mineral grains, scattered planktonic (globigerinids) and benthonic (nodosariids, lagenids, buliminids, uvigerinids) foraminifera.
Age: Pleistocene.

Sample 12-116A-3-5, 141-144 cm:
PF: *Globigerina bulloides* (dominant and abundant), *G. pachyderma* (predominantly sinistral), *Globorotalia inflata, G. scitula, Globigerinita glutinata* (*Globigerina quinqueloba* in finer fractions).
BF: *Bulimina* sp., *Melonis barleeanum, Pullenia* sp., *Karreriella* sp.
Age: Pleistocene.

Sample 12-116A-3, Core Catcher:
PF: *Globigerina bulloides* and *Globorotalia inflata* (dominant and abundant), *Globigerina pachyderma* (common, sinistral), *Orbulina universa, Globorotalia hirsuta, G. crassaformis, G. scitula, Hastigerinella digitata.*
BF: Rich diversified, including *Karreriella* sp., *Pyrgo murrhyna, Cibicidoides* sp., *Sigmoilopsis schlumbergeri, Bulimina marginata, Planulina* sp., *Sphaeroidina* sp., *Uvigerina* sp., lagenids.
Also present: Sponge spicules (common), ostracods common (*Echinocythereis, Krithe, Cytherella*), pelecypod fragments, echinoid spines, minor amounts of quartz.
Age: Pleistocene.
Remarks: Core 3 is predominantly a foraminiferal lutite containing an abundant planktonic foraminiferal fauna. Dominant elements throughout most of the core are *Globigerina bulloides* and *Globorotalia inflata,* although in the upper part (Section 1) one sample contains fauna dominated almost wholly by sinistrally coiled *Globigerina pachyderma.*

Sample 12-116A-4-2, 61-64 cm:
PF: *Globigerina pachyderma* (dominant, abundant, sinistral), *G. bulloides, Globorotalia inflata, Globigerinita glutinata,* (*Globigerina quinqueloba* in finer fractions).
BF: Essentially as in samples above.
Also present: Ice-rafted quartz and mineral and rock fragment debris and pelecypod fragments, sponge spicules, echinoid spines and ostracods.
Age: Pleistocene.

Sample 12-116A-4-2, 143-146 cm:
Lithology and fauna essentially the same as preceding sample above.
Age: Pleistocene.

Sample 12-116A-4-3, 53-56 cm:
PF: *Globigerina bulloides* (dominant, abundant), *Globorotalia inflata* (common), *Globigerina pachyderma* (random coiling), *Orbulina universa.*
BF: *Cibicidoides pseudoungeriana, Melonis* sp., *Planulina* sp., *Cibicides* sp., *Sigmoilopsis schlumbergeri.*
Age: Pleistocene.

Sample 12-116A-4-4, 58-61 cm:
Faunal composition essentially the same as above including *Globorotalia scitula, Globigerinita glutinata* and *G. quinqueloba.* Relative percentages changed. *Globigerina pachyderma* (sinistral) dominant in this sample.
Age: Pleistocene

Sample 12-116A-4-4, 145-148 cm:
Fauna essentially the same as preceding sample above.
Age: Pleistocene.

Sample 12-116A-4-5, 24-26 cm:
PF: *Globigerina pachyderma* (sinistral), *G. bulloides, Globorotalia inflata, G. scitula, Globigerinita glutinata, Orbulina universa, Hastigerina siphonifera.*
BF: Essentially as in samples above.
Age: Pleistocene.

Sample 12-116A-4-6, 35-37 cm:
Lithology and fauna essentially the same as in preceding sample above.
Age: Pleistocene.

Sample 12-116A-4-6, 143-145 cm:
Lithology and fauna as in preceding sample above.
Age: Pleistocene.

Sample 12-116A-4, Core Catcher:
PF: *Globorotalia inflata* and *Globigerina bulloides* (dominant and abundant), *Globigerina pachyderma* (sinistral), *Globorotalia scitula, G. crassula, G. crassaformis, G. truncatulinoides, Orbulina universa, Hastigerina siphonifera.*

Sample 12-116-24, Core Catcher:
PF: *Globigerina ampliapertura* (top), *Globigerinita dissimilis, G. pera, Globorotalia postcretacea, Globorotalia denseconnexa, G. inaeguiconica, G. opima nana, Chiloguembelina* sp.
BF: *Cibicidoides mexicana, Gyroidina* sp., *Oridorsalis ecuadorensis, Planulina* sp., *Uvigerina havanensis.*
Age: Early Oligocene.
Remarks: The highest occurrence of *Globigerina ampliapertura* occurs in Core 24. Chiloguembelinids are common in the Core Catcher sample. The Late Eocene-Mid Oligocene *Uvigerina havanensis* is also a diagnostic component of the fauna in this core.

Sample 12-116-25-3, 139-142 cm:
PF: *Globigerinita dissimilis* (dominant, common), *G. unicava, G. pera, Globorotalia opima nana, Chiloguembelina* sp.
BF: *Siphonina tenuicarinata, Uvigerina mexicana, Pullenia* sp., *Lenticulina* sp., *Vaginulina* sp., *Anomalina alazanensis.*
Age: Early Oligocene.

Sample 12-116-25-3, Bottom:
Essentially same as above; chalk is more coherent and there are fewer disaggregated (free) specimens of foraminifera.
Age: Early Oligocene.
The same conditions are true for the following samples:
Sample 12-116-25-4, 140-144 cm
Sample 12-116-25-5, 145-147 cm

Sample 12-116-25, Core Catcher:
PF: *Globigerinita dissimilis, Globigerinita* sp., *Globigerina* sp. cf., *G. prasaepis, Globorotalia inaequiconica, Chiloguembelina* (common).
BF: *Cibicidoides trincherasensis, Amonalina alazanensis,* cibicidids, polymorphinids, *Gyroidina* sp. (acute periphery).
Age: Early Oligocene.

Sample 12-116-26, Core Catcher:
PF: *Globigerinita dissimilis, G. pera, Globigerapsis index, Chiloguembelina* sp.
BF: *Lenticulina* spp., *Cibicidoides* sp. cf. *C. perlucida,* siphonodosariids.
Age: Late Eocene (Bartonian).
Remarks: Only the Core Catcher sample was studied in Core 26. A single specimen of *Globigerapsis index* was found which would suggest that this sample is of Late Eocene age; the Eocene/Oligocene boundary is drawn, accordingly, between Cores 25 and 26.

Sample 12-116-27-2, 62-63 cm:
Indurated chalk with few disaggregated (free) specimens of foraminifera. Globigerinids, globigerinitids, and chiloguembelinids present; preservation poor (recrystallized and some specimens deformed).
Age: Probably Late Eocene.

Sample 12-116-27-3, 0-7 cm:
Data same as for sample above.

Sample 12-116-27, Core Catcher:
Lithified chalk, few free specimens, material recrystallized and distorted.
PF: *Globigerapsis index,* globigerinids, globigerinitids, chiloguembelinids.
BF: *Osangularia mexicana,* cibicidids.
Age: Late Eocene (Bartonian).

Sample 12-116-28-1, 93-96 cm:
Lithified chalk, poor preservation, specimens distorted, Globigerinids, chiloguembelinids present.
Age: Probably Late Eocene.

Sample 12-116-28-2, 145-148 cm:
PF: *Globigerapsis index, Globigerina galavisi, G. linaperta, G.* sp., *Chiloguembelina* sp.
BF: *Osangularia mexicana, Oridorsalis ecuadorensis.*
Age: Late Eocene (Bartonian).

Sample 12-116-28, Core Catcher:
PF: *Globigerapsis index, Globigerina galavisi, G. linaperta, Chiloguembelina* sp.
BF: *Osangularia mexicana, Oridorsalis ecuadorensis,* cibicidids, anomalinids, *Gyroidina* sp. (acute periphery).
Age: Late Eocene (Bartonian).
Remarks: Core 28 is the only core with a relatively well-preserved upper Eocene fauna. *Osangularia mexicana* forms the dominant component of the benthonic fauna.

Hole 116A

Sample 12-116A-1-2, 45-47 cm:
PF: *Globigerina pachyderma, G. bulloides, Globorotalia hirsuta, G. inflata, G. truncatulinoides, Globigerinita glutinata, Orbulina universa.*
BF: *Sigmoilopsis schlumbergeri, Lenticulina* sp., *Planulina* sp., *Uvigerina* sp.
Also present: Molluscan fragments, sponge spicules, otoliths, relatively minor amounts of ice-rafted quartz and mineral fragments.
Age: Pleistocene.

Sample 12-116A-1-2, 136-139 cm:
Fauna essentially same as above plus *Globorotalia scitula.*
Age: Pleistocene.

Sample 12-116A-1-2, 145-148 cm:
PF: *Globigerina pachyderma* (sinistral), *G. bulloides, Globorotalia inflata, G. hirsuta, G. scitula, Orbulina universa.*
BF: Sparse, essentially as above.
Also present: Ice-rafted quartz and mineral fragments.
Age: Pleistocene.

Sample 12-116A-1, Core Catcher:
PF: *Globigerina bulloides* (dominant, abundant), *Globigerina pachyderma* (sinistral), *Globorotalia inflata, G. hirsuta, G. scitula, Orbulina universa.*
BF: *Karreriella* sp., *Pyrgo murrhyna, Pyrgo lucernula, Sigmoilopsis schlumbergeri, Gaudryina atlantica, Melonis pompilioides, Cibicidoides pseudoungeriana, Quinqueloculina* sp., *Rupertia stabilis.*
Also present: Pelecypod fragments, otoliths, ostracods (*Echinocythereis, Krithe*), sponge spicules, volcanic rock fragments, volcanic glass and glacially-rafted quartz.
Age: Pleistocene.
Remarks: Core 1 is characterized by a rich cold-temperate planktonic foraminiferal fauna dominated by *Globigerina bulloides* and sinistrally coiled *G. pachyderma.* Evidence of glaciation is afforded by the scattered to moderate amounts of detrital quartz and various rock and mineral fragments.

Sample 12-116A-2-2, 0-3 cm:
PF: *Globigerina bulloides, G. pachyderma, Globorotalia inflata, G. scitula, G. truncatulinoides, Orbulina universa,* (*Globigerina quinqueloba* present in finer fractions).
BF: *Sigmoilopsis schlumbergeri, Uvigerina peregrina, Uvigerina auberiana, Melonis pompilioides.*
Age: Pleistocene.

Sample 12-116A-2-3, 91-94 cm:
PF: *Globigerina bulloides* (dominant, abundant), *G. pachyderma, Globorotalia hirsuta, G. inflata, G. scitula, Globigerinita glutinata, Orbulina universa.*
BF: Essentially as above.
Age: Pleistocene.

Sample 12-116A-2-3, 146-149 cm:
PF: *Globigerina pachyderma* (sinistral, abundant), *G. bulloides, Globorotalia inflata, Globigerinita glutinata.*
BF: As above.
Also present: Moderate amounts of glacially-rafted quartz in fine fraction.
Age: Pleistocene.

BF: *Pyrgo murrhyna, Pyrgo lucernula, Cibicidoides pseudoungeriana, Bulimina marginata, Sigmoilopsis schlumbergeri, Eponides tener, Spiroloculina rotunda, Gyroidina* sp., *Karreriella bradyi,* various nodosariids.
Also present: Molluscan shell fragments, echinoid spines and sponge spicules and glacially-rafted quartz debris.
Age: Pleistocene.
Remarks: Core 4 is a foraminiferal lutite containing a rich planktonic foraminiferal fauna. The dominant elements are *Globigerina bulloides, G. pachyderma* and *Globorotalia inflata;* the percentages of each varying at different levels. *Globorotalia scitula* occurs commonly at several levels. *Globorotalia truncatulinoides* occurs sporadically. Glacially-rafted quartz and rock and fragments occur in varying frequencies throughout the core.

Sample 12-116A-5-1, 143-145 cm:
PF: *Globigerina bulloides* (dominant and abundant), *G. pachyderma* (sinistral), *Globorotalia inflata, G. crassaformis, Globigerinita glutinata, Orbulina universa.*
BF: *Cibicidoides pseudoungeriana, Sigmoilopsis schlumbergeri, Melonis barleeanum, Bulimina marginata.*
Also present: Molluscan fragments, echinoid spines, sponge spicules, glacially-rafted quartz and rock fragments.
Age: Pleistocene.

Sample 12-116A-5-2, 145-147 cm:
PF: *Globigerina bulloides, G. pachyderma, Globorotalia inflata, G. scitula, G. truncatulinoides, G. crassaformia, Hastigerina siphonifera, Globigerinita glutinata, Orbulina universa.*
BF: Essentially as above.
Age: Pleistocene.

Sample 12-116A-5-3, 51-54 cm:
Lithology and fauna essentially the same as above.
Age: Pleistocene.

Sample 12-116A-5-3, 145-148 cm:
Fauna essentially the same as preceding samples above.
Age: Pleistocene.

Sample 12-116A-5-4 46-49 cm:
Fauna essentially the same as preceding samples above:
Age: Pleistocene.

Sample 12-116A-5-4, 143-146 cm:
Planktonic foraminiferal fauna essentially same as above. Benthonic foraminiferal fauna diverse, consisting of *Bulimina marginata, Uvigerina peregrina, Cibicidoides pseudoungeriana,* various cibicidids and lagenids and nodosariids.
Age: Pleistocene.

Sample 12-116A-5, Core Catcher:
PF: *Globigerina pachyderma* (dominant, abundant, sinistral), *G. bulloides* (abundant), *Globorotalia inflata* (common) and *Globorotalia crassaformis, G. hirsuta, G. scitula, Hastigerina siphonifera.*
BF: *Melonis barleeanum,* various polymorphinids, *Bulimina marginata, Uvigerina peregrina, Karreriella bradyi, Cibicidoides pseudoungeriana, Eponides tener, Sigmoilopsis schlumbergeri, Pyrgo murrhyna, Planulina* sp. , *Lenticulina* sp., nodosariids.
Also present: Echinoid fragments, pelecypod fragments, ostracods (*Echinocythereis, Krithe, Cytherella*), minor amounts of quartz and rock fragments.
Age: Pleistocene.
Remarks: Core 5 is a foraminiferal lutite containing abundant planktonic foraminifera. The dominant elements are *Globigerina bulloides,G. pachyderma* and *Globorotalia inflata,* the percentages of which fluctuate in the various samples.

Sample 12-116A-6-1, 50-53 cm:
PF: *Globigerina bulloides, G. pachyderma* (sinistral), *Globorotalia inflata, G. crassaformis, G. scitula, Orbulina universa. Globigerinita glutinata.*
BF: Essentially as above.
Also present: Minor amounts of quartz and rock fragments.
Age: Pleistocene.

Sample 12-116A-6-1, 146-149 cm:
Fauna essentially the same as preceding samples above; *Globigerina pachyderma* predominantly dextrally coiled.

Sample 12-116A-6-2, 30-33 cm:
PF: *Globigerina bulloides, Globorotalia inflata* (dominant and abundant), *Globigerina pachyderma* (less common, dextral), *Globorotalia crassaformis.*
BF: *Uvigerina peregrina, Gyroidina* sp., *Cibicidoides* sp., *Bulimina marginata.*
Also present: Echinoid spines, sponge spicules, ostracods (*Echinocythereis*), minor amounts of quartz.
Age: Pleistocene.

Sample 12-116A-6-2, 145-148 cm:
Fauna essentially the same as preceding sample above.

Sample 12-116A-6-3, 59-62 cm:
Planktonic foraminiferal fauna essentially the same as above. Dominant elements are *Globigerina bulloides* and *Globorotalia inflata.*
Age: Pleistocene.

Sample 12-116A-6-3, 142-145 cm:
As above. *Globigerina pachyderma* predominantly sinistrally coiled.
Age: Pleistocene.

Sample 12-116A-6-4, 37-40 cm:
Fauna essentially the same as above, including *Hastigerina siphonifera* and *Globorotalia crassaformis.*
Age: Pleistocene.

Sample 12-116A-6-4, 145-148 cm:
Fauna essentially the same as above.
Age: Pleistocene.

Sample 12-116A-6-5, 54-57 cm:
Planktonic fauna essentially the same as above. Relative increase in *Globorotalia crassaformis.*
Age: Pleistocene.

Sample 12-116A-6-5, 145-148 cm:
Fauna essentially the same as above.
Age: Pleistocene.

Sample 12-116A-6-6, 57-59 cm:
PF: *Globigerina bulloides, Globorotalis inflata* (dominant, abundant), *Orbulina universa, Globorotalia crassaformis, Globigerinita glutinata, Globorotalia scitula, Globigerina pachyderma.*
BF: *Cibicidoides* sp., *Sigmoilopsis schlumbergeri, Angulogerina* sp.
Also present: Only minor amounts of quartz in fine fraction.
Age: Pleistocene.

Sample 12-116A-6-6, 130-133 cm:
Fauna essentially the same as sample above. *Globigerina bulloides* abundant; *Globorotalia inflata* relatively less common.
Age: Pleistocene.

Sample 12-116A-6, Core Catcher:
PF: *Globigerina bulloides* (abundant), *Globorotalia crassaformis* and *G. hirsuta* (common), *G. pachyderma* (rare).
BF: *Sigmoilopsis schlumbergeri, Karreriella bradyi, Cibicidoides pseudoungeriana, Sphaeroidina bulloides, Gyroidina neosoldanii, Pyrgo murrhyna.*
Also present: Sponge spicules, echinoid spines, ostracods (*Echinoicythereis, Krithe*), minor amount of quartz grains in fine fraction.
Age: Pleistocene.
Remarks: Core 6 is characterized by a change in the planktonic foraminiferal fauna from one in the lower parts of Core 6 in which the dominant elements are *Globigerina bulloides* and *Globorotalia crassaformis* to a fauna in the upper part of the core in which the dominant elements are *Globigerina bulloides* and *Globorotalia inflata.* A change in the relative frequency of the dominant faunal elements appears to be at the expense of *Globigerina pachyderma,* which is less common in Core 6 than in cores above.

Sample 12-116A-7-2, 50-53 cm:
PF: *Globigerina bulloides* (dominant, abundant), *Globorotalia crassaformis, G. inflata, G. hirsuta, Globigerina pachyderma* (predominantly dextral), *Globigerinita glutinata, Orbulina universa.*
BF: *Cibicidoides pseudoungeriana, Sigmoilopsis schlumbergeri, Gyroidina neosoldanii.*
Also present: Echinoid spines, sponge spicules, ostracods (*Echinocythereis*).
Age: Pleistocene.

Sample 12-116A-7-2, 143-146 cm:
PF: *Globigerina bulloides* (dominant, abundant), *Globorotalia inflata, G. scitula, Hastigerina siphonifera, Orbulina universa, Globigerinita glutinata, Globigerina pachyderma* (dextral).
BF: As above.
Age: Pleistocene.

Sample 12-116A-7-3, 45-48 cm:
Fauna essentially the same as preceding sample above, including *Globorotalia hirsuta.*
Age: Pleistocene.

Sample 12-116A-7-3, 145-148 cm:
PF: *Globigerina bulloides* (common), *G. pachyderma* (rare, dextral), *Globorotalia inflata, G. scitula, G. hirsuta, Orbulina universa, Globigerinita glutinata.*
BF: *Sigmoilopsis schlumbergeri, Karreriella bradyi.*
Age: Pleistocene.

Sample 12-116A-7-4, 45-48 cm:
Lithology and fauna essentially the same as the preceding sample above, including *Hastigerina siphonifera.*
Age: Pleistocene.

Sample 12-116A-7-4, 141-147 cm:
Lithology and fauna essentially the same as sample above.
Age: Pleistocene.

Sample 12-116A-7-5, 59-62 cm:
PF: *Globigerina bulloides, G. pachyderma* (rare, dextral), *Globorotalia crassaformis, G. scitula, Globigerinita glutinata, Orbulina universa.*
BF: *Pyrgo lucernula, Sigmoilopsis schlumbergeri, Cibicidoides pseudoungeriana,* various cibicidids.
Age: Pleistocene.

Sample 12-116A-7-5, 146-149 cm:
Fauna essentially the same as the preceding samples above.
Age: Pleistocene.

Sample 12-116A-7-6, 140-143 cm:
PF: *Globigerina atlantica* (dominant, abundant, sinistral; wide morphologic variation including four and five chambered evolute forms, as well as high-spired involute forms with final cap-like chamber obscuring umbilical region), *Globigerina bulloides, Globorotalia scitual.*
BF: *Sigmoilopsis schlumbergeri,* various cibicidids, *Gaudryina* sp.
Age: Late Pliocene.
Remarks: There is a significant lithologic and faunal change between Sample 7-5, 146-149 cm and Sample 7-6, 140-143 cm. The former is primarily a coccolith planktonic foraminiferal lutite, containing abundant planktonic foraminifera, sponge spicules, echinoid spines, and volcanic glass shards. Very little detrital material is present in the fine fraction. The latter sample, however, contains a significant amount of glacially-rafted quartz and rock fragment detritus. Whereas the sample from Section 5 contains a relatively diverse planktonic foraminiferal fauna in which the dominant elements are robust, large individuals of *Globigerina bulloides* and *Orbulina universa,* the sample from Section 6 contains a rich planktonic foraminiferal fauna of which 95 per cent consists of the single species *Globigerina atlantica,* which has been recorded at other sites in the North Atlantic as the dominant element in Pliocene faunas. The Pliocene-Pleistocene boundary is accordingly drawn between Section 5 and Section 6 in Hole 116A.

Sample 12-116A-7, Core Catcher:
PF: *Globigerina atlantica* (dominant, abundant; over 95 per cent of the fauna, sinistral), *G. bulloides, Globorotalia hirsuta.*
BF: *Melonis barleeanum, polymorphinids, Lenticulina* spp., Planulina sp., *Cibicides lobatulus, Gyroidina* sp., *Sigmoilopsis schlumbergeri.*
Also present: Sponge spicules, abundant, rounded and angular, glacially-rafted quartz and rock fragments and volcanic glass shards as well as broken pelecypod fragments.
Age: Late Pliocene.
Remarks: Sections 1 through 5 of Core 7 consist of foraminiferal lutite with rich planktonic faunas dominated by robust, large individuals of *Globigerina bulloides* and *Orbulina universa. Globorotalia crassaformis* occurs in relatively large numbers in some samples. As noted above, a marked lithologic and faunal change occurs between Sections 5 and 6 and the Pliocene-Pleistocene boundary has been drawn between Sections 5 and 6 based on the abundant presence of *Globigerina atlantica* in Section 6 and in the Core Catcher sample.

Sample 12-116A-8-1, 122-125 cm:
PF: *Globigerina atlantica* (dominant, abundant, sinistral), *G. bulloides, Globorotalia crassaformis, Orbulina universa.*
BF: *Gyroidina* sp., *Cibicidoides* sp., *Sigmoilopsis schlumbergeri.*
Age: Late Pliocene.

Sample 12-116A-8-1, 138-141 cm:
PF: *Globigerina atlantica* (dominant, abundant, sinistral), *G. bulloides, G. pachyderma* (small, rare, essentially sinistral), *Globorotalia hirsuta, G. inflata.*
BF: *Vulvulina pennatula* (relatively common), *Sigmoilopsis schlumbergeri, Pyrgo* sp., *Cibicidoides pseudoungeriana.*
Age: Late Pliocene.

Sample 12-116A-8-2, 41-44 cm:
Lithology and fauna essentially the same as in preceding sample above.
Age: Late Pliocene.

Sample 12-116A-8-2, 143-146 cm:
Fauna essentially the same as in preceding samples above. *Globigerina atlantica* and *Orbulina universa* are the dominant faunal elements. *Globorotalia inflata* occurs as a relatively minor element of the fauna.
Age: Late Pliocene.

Sample 12-116A-8-3, 65-68 cm:
Foraminiferal fauna essentially the same as that recorded above. *Globigerina praedigitata* also observed in planktonic foraminiferal fauna; *Cibicidoides robertsoniana* present in benthonic fauna.
Age: Late Pliocene.

Sample 12-116A-8-3, 143-146 cm:
Faunal composition as in preceding samples above.
Age: Late Pliocene.

Sample 12-116A-8-4, 143-146 cm:
Fauna essentially the same as in samples above. *Globorotalia puncticulata* also observed as a rare element.
Age: Late Pliocene.

Sample 12-116A-8-5, 49-52 cm:
PF: *Globigerina atlantica* (dominant, abundant, sinistral). *G. bulloides, Globigerinita glutinata, Globorotalia crassaformis, G. scitula, Orbulina universa.*
BF: *Cibicidoides pseudoungeriana, Sigmoilopsis schlumbergeri, Lenticulina* sp., *Cibicidoides robertsoniana.*
Age: Late Pliocene.

Sample 12-116A-8-5, 132-136 cm:
Fauna essentially the same as in preceding sample above.
Age: Late Pliocene.

Sample 12-116A-8-6, 67-70 cm:
PF: *Globigerina atlantica* (dominant, abundant, sinistral), *G. bulloides, Globorotalia scitula, G. puncticulata, G. crassaformis, Globigerina* sp., cf. *G. pachyderma* (dextral) *Orbulina universa.*
BF: Relatively rich and diverse, containing among others *Gyroidina* sp., *Eponides* sp., *Cibicidoides pseudoungeriana, Sigmoilopsis schlumbergeri.*
Also present: Abundant sponge spicules, some Radiolaria and relatively numerous ostracods.
Age: Late Pliocene.

Sample 12-116A-8-6, 144-147 cm:
Fauna essentially the same as in samples above.
Age: Late Pliocene.

Sample 12-116A-8, Core Catcher:
PF: Rich planktonic foraminifera dominated almost wholly by *Globigerina atlantica*; also present *Globigerina bulloides,* Orbulina universa. No globorotaliids observed.
BF: Rich and diverse, including among others, *Laticarinina halophora, Planulina bradii, Pullenia* sp., *Martinotiella sp., Cibicidoides pseudoungeriana, Anomalinoides cicatricosa, Karreriella bradyi, Pyrgo* sp.
Also present: Abundant sponge spicules. Ostracods relatively common.
Age: Late Pliocene.
Remarks: Core 8 is a coccolith-foraminiferal ooze containing a rich planktonic-foraminiferal fauna dominated by sinistrally coiled *Globigerina atlantica.* Specimens referable to *Globigerina pachyderma* occur sporadically at some levels in this core. Quartz and other detrital fragments are almost wholly absent from most of the samples but occur sporadically in others in relatively minor amounts.

Sample 12-116A-9-1, 42-45 cm:
PF: *Globigerina atlantica* (dominant, abundant, sinistral), *G. bulloides, Globigerinita glutinata, Globorotalia scitula, G. inflata, Orbulina universa, Globigerinoides* sp., *Globigerina pachyderma* (predominately dextral, rare).
BF: Diverse, relatively abundant, including among others *Sigmoilopsis schlumbergeri, Cibicidoides pseudoungeriana,* various lagenids, lenticulinids, cibicidids, *Gyroidina* sp.
Also present: Sponge spicules, glacially-rafted quartz and rock fragment detritus.
Age: Late Pliocene.

Sample 12-116A-9-1, 147-150 cm:
PF: *Globigerina atlantica, G. bulloides, G. pachyderma* (rare), *Globigerinita glutinata, Globorotalia scitula, G. crassaformis, G. puncticulata, G. inflata, Orbulina universa.*
BF: Essentially as above.
Age: Late Pliocene.
The following samples were examined and found to contain essentially the same fauna as that listed above:
Sample 12-116A-9-2, 67-70 cm
Sample 12-116A-9-2, 146-149 cm
At this point a change in fauna is noted between Section 2 and Section 3. Samples above contain a fauna dominated by *Globigerina atlantica* with subordinate amounts of *Globigerina bulloides* and *Orbulina universa.* In the samples listed below the dominant element is *Globigerina bulloides,* which, together with *Orbulina universa* makes up over 90 per cent of the total fauna. *Globigerina atlantica* occurs but sporadically in these samples. *Globorotalia puncticulata, G. crassaformis* and *G. scitula* occur consistently throughout the interval below. These samples include:
Sample 12-116A-9-3, 69-72 cm
Sample 12-116A-9-3, 144-147 cm
Sample 12-116A-9-4, 65-68 cm
Sample 12-116A-9-4, 145-148 cm
Sample 12-116A-9-5, 50-53 cm
Sample 12-116A-9-5, 145-148 cm (G. puncticulata particularly well developed in this sample)
Sample 12-116A-9-6, 60-63 cm
Sample 12-116A-9-6, 145-148 cm

Sample 12-116A-9, Core Catcher:
PF: *Globigerina atlantica* (abundant, sinistral), *G. bulloides, Orbulina universa, Globigerinita glutinata, Globorotalia scitula.*
BF: *Sigmoilopsis schlumbergeri, Anomalinoides globulosa, Planulina wuellerstorfi, P. bradii, Pyrgo murrhyna, Cibicidoides pseudoungeriana, Eggerella bradyi, Laticarinina halophora, Sphaeroidina bulloides, Stilostomella* sp., nodosariids.
Age: Late Pliocene.
Remarks: Core 9 contains a rich planktonic foraminiferal fauna The dominant element in Sections 1 and 2 is *Globigerina atlantica,* in Sections 3 to 5 *Globigerina bulloides,* and again in Section 6 and the Core Catcher sample *Globigerina atlantica.Orbulina universa* is a common accessory form throughout this core. *Globorotalia puncticulata* occurs consistently in moderate amounts in Core 9.

Sample 12-116A-10-1, 100-103 cm:
PF: *Globigerina atlantica* (dominant, abundant), *G. bulloides, Orbulina universa.*
BF: *Cassidulina subglobosa, Cibicidoides* sp., *Sigmoilopsis schlumbergeri,* various cibicidids and rotaliids.
Age: Late Pliocene.

Sample 12-116A-10-1, 146-149 cm:
PF: *Globigerina atlantica* (dominant, abundant), *G. bulloides, Orbulina universa, Globorotalia scitula, G. crassaformis*
BF: *Cassidulina subglobosa, Anomalinoides globosa, Laticarinina halophora, Cibicidoides pseudoungeriana, Uvigerina* sp.
Age: Late Pliocene
The following samples were examined and found to contain essentially the same fauna:
Sample 12-116A-10-2, 47-50 cm
Sample 12-116A-10-2, 143-146 cm
Sample 12-116A-10-3, 68-71 cm
Sample 12-116A-10-3, 144-147 cm (*G. puncticulata* observed as a rare element in this sample; benthonic fauna relatively abundant and diverse)
Sample 12-116A-10-4, 3-6 cm
Sample 12-116A-10-4, 67-70 cm (fauna generally as above but including specimens referable to *Globorotalia crassaformis* and *G. scitula*)
Sample 12-116A-10-5, 65-68 cm
Sample 12-116A-10-5, 144-147 cm
Sample 12-116A-10-6, 65-68 cm (*G. puncticulata* occurs rarely in this sample)
Sample 12-116A-10-6, 143-146 cm

Sample 12-116A-10, Core Catcher:
PF: *Globigerina atlantica* (dominant, abundant), *G. bulloides, Globorotalia scitula, G. puncticulata, Orbulina universa.*
BF: Rich diverse fauna including *Pyrgo murrhyna, Planulina wuellerstorfi, Gyroidina neosoldanii, Gyroidina* sp., *Uvigerina hollicki, Melonis barleeanum, Fissurina cucullata, Parafrondicularia* sp. cf. *P. advena, Sigmoilopsis schlumbergeri, Cassidulina subglobosa, Cibicidoides pseudoungeriana, Anomalinoides globosa, Laticarinina halophora, Martinotiella nodulosa, Stilostomella abyssorum.*
Age: Late Pliocene.
Remarks: Core 10 is characterized throughout by rich planktonic and relatively rich and diverse benthonic foraminiferal fauna. The planktonic fauna is dominated by *Globigerina atlantica* and *Orbulina universa.* Specimens referable to *Globorotalia puncticulata* occur sporadically throughout Core 10. Typical *Globorotalia puncticulata* has not been recorded in pre-Pliocene sediments. *Globorotalia inflata* was not found in Core 10.

Sample 12-116A-11-0, Bottom:
PF: *Globigerina atlantica* (common), *G. bulloides, Globorotalia puncticulata, Orbulina universa.*
BF: Relatively rich and diverse, *Cibicidoides pseudoungeriana Sigmoilopsis schlumbergeri, Gyroidinoides neosoldanii, Melonis barleeanum, Pullenia* sp., *Sphaeroidina bulloides, Pleurostomella* sp., *Laticarinina halophora, Uvigerina* sp.
Age: Early-Late Pliocene.
The following samples have been examined and found to contain an essentially similar planktonic and benthonic foraminiferal fauna:
Sample 12-116A-11-1, 35-38 cm (*Globorotalia scitula* occurs relatively commonly in this sample)
Sample 12-116A-11-1, 143-146 cm
Sample 12-116A-11-2, 55-58 cm
Sample 12-116A-11-2, 144-147 cm
Sample 12-116A-11-3, 64-67 cm
Sample 12-116A-11-3, 145-148 cm
Sample 12-116A-11-4, 64-67 cm
Sample 12-116A-11-4, 144-147 cm
Sample 12-116A-11-5, 32-35 cm
Sample 12-116A-11-5, 144-147 cm
Sample 12-116A-11-6, 60-63 cm
Sample 12-116A-11-6, 143-146 cm

Sample 12-116A-11, Core Catcher:
PF: *Globigerina atlantica* (dominant, abundant, sinistral) *G. bulloides, Orbulina universa, Globorotalia puncticulata, G. scitula.*
BF: Rich, diverse; *Cibicidoides pseudoungeriana, Uvigerina asperula Eggerella bradyi, Sigmoilopsis schlumbergeri, Textularia* sp. *Sphaeroidina bulloides, Laticarinina halophora, Cassidulina subglobosa, Melonis pompilioides, Gyroidina neosoldanii, Planulina wuellerstorfi, Planulina bradii.*
Also present: Echinoid spines.
Age: Early-Late Pliocene.
Remarks: Core 11 is characterized by a rich planktonic and benthonic foraminiferal fauna throughout. The planktonic foraminiferal fauna is dominated by *Globigerina atlantica.* A significant feature of Core 11 is the relatively high percentage of *Globorotalia puncticulata.* The relatively high percentage of *G. puncticulata* appears to be at the expense of *Globigerina bulloides,* which occurs in significantly lower frequencies than in the cores above. *Globorotalia scitula* occurs consistently throughout this core.

APPENDIX D, PART 2. LISTS OF SELECTED PLANKTONIC AND BENTHONIC FORAMINIFERA AND AGE DETERMINATIONS (117)

W. A. Berggren

Sample 12-117-1, Core Catcher:
Bryozoan limestone and chert gravel (caused by drilling).
PF: *Globigerinita unicava, Globorotaloides suteri, Globoquadrina* sp., small globigerinids, globigerinitids.
BF: Rich, diverse, includes *Heterolepa mexicana, Planulina renzi, Vulvulina jarvisi, Siphonina tenuicarinata, large, robust lenticulinids, dentalinids, Eponides* sp., *Gyroidina* sp.
Also present: Pleistocene contaminants, particularly planktonic foraminifera: *Globigerina pachyderma, G. bulloides, Globorotalia inflata, G. crassaformis.*
Age: Late Oligocene - Early Miocene.
Remarks: Only the core catcher was obtained from Core 1. A mixed fauna occurs in a bryozoan limestone and chert gravel mixture.
The association of *Globigerinita unicava, Globorotaloides suteri* and *Globoquadrina* sp. support a Late Oligocene-Early Miocene determination based on calcareous nannoplankton.

Sample 12-117-2, Top:
Cherty limestone with mixed fauna.
PF: *Globigerina galavisi, Globigerinita unicava, G. pera, G.* sp. cf. *G. praestainforthi, Globorotalia opima.*
BF: *Heterolepa mexicana, Cibicidoides* sp. cf. *C. perlucida, Gyroidina soldanii, Pullenia* sp., *Anomalinoides pompilioides, Eponides repandus, Vulvulina jarvisi,* large nodosariids, dentalinids, lagenids, *Siphonina tenuistriata, Uvigerina* sp., *Pullenia* sp., *Bulimina* sp.
Age: Late Oligocene (Zone P21-P22).

Sample 12-117-2-3, 145-148 cm:
Glauconitic chalk ooze with rich foraminiferal and bryozoan fauna
PF: Rich, relatively diverse, including *i.al., Globigerinita unicava, Globorotaloides suteri* (common), *Globigerina prasaepis* (common), *G. praebulloides* ss., *G. praebulloides occlusa, Globorotalia opima nana.*
BF: Rich, diverse and essentially same as above.
Age: Late Oligocene (? P22).

Sample 12-117-2-4, 146-149 cm:
Glauconitic chalk with rich foraminiferal and bryozoan fauna (as above).
PF: *Globigerinita dissimilis, G. unicava, G. pera, Globigerina praebulloides* s.s., *G. prasaepis, G. galavisi, G. tripartita, Globorotaloides suteri, Globorotalia opima nana.*
BF: Rich, diverse, essentially as above.
Age: Early-Late Oligocene (P21-P22).

Sample 12-117-2-6, 143-146 cm:
Data essentially same as above.

Sample 12-117-2, Core Catcher:
PF: *Globigerina galavisi, G. tripartita, G. praebulloides* s.s., *G. prasaepis, Globigerinita unicava, G. dissimilis, Globorotalia opima nana, Globorotaloides suteri.*
BF: *Heterolepa mexicana, Cibicidoides* sp. cf. *C. perlucida, Siphonina tenuicarinata, Anomalina alazanensis, Vulvulina jarvisi, Uvigerina* sp., *Anomalinoides pompilioides, Gyroidina* spp.
Age: Oligocene.
Remarks: Core 2 is essentially a foraminiferal-nannofossil ooze with abundant bryozoa-echinoid fragments, in places silicified. A rich benthonic and planktonic foraminiferal fauna occurs throughout the core. The association of globigerinitids and *G. suteri* and *G. prasaepis* indicate that Core 2 is of Oligocene age. The presence of *G. opima opima* indicates that this core may be close to the P21/P22 boundary; this determination is supported by the questionable assignment of Core 2 to the *Sphenolithus ciperoensis* Zone.

Sample 12-117-3-1, 0-3 cm:
Silicified limestone, chalk-ooze and rock chips resulting from drilling. Foraminiferal fauna essentially as above (see Core 2) but with abundant Pleistocene contaminants *(Globigerina pachyderma, G. bulloides, Globorotalia scitula, G. inflata).* Oligocene planktonic foraminifera as in Core 2.
Age: Oligocene.

Sample 12-117-3, Core Catcher:
PF: *Globigerina galavisi, G. angiporoides, Globigerinita unicava, G. dissimilis, G. pera, Globigerapsis* sp.
BF: *Heterolepa mexicana, Cibicidoides* sp. cf. *C. perlucida (=?C pippeni), C. trincherasensis, Anomalinoides pompilioides, Anomalina alazanensis, Eponides rapandus, Cassidulina subglobosa, Gyroidina soldanii, Lenticulina* sp.
Also present: Abundant bryozoan fragments.
Age: Eocene.
Remarks: Only Section 1 and Core Catcher retrieved from Core 3. Rich and diverse benthonic foraminiferal fauna, mostly indigenous probably, but some contaminants from above may be present. The presence of a large globigerapsid in the Core Catcher suggests that this level is of middle or late Eocene age; it is questionably referred to the Early Eocene *Marthasterites tribrachiatus* Zone (calcareous nannoplankton).

Hole 117A

Sample 12-117A-1-1, 40-42 cm:
PF: *Globigerina angiporoides* (dominant, abundant), *Globigerinita unicava, Globigerina praebulloides occlusa.*

BF: *Heterolepa mexicana* (dominant, abundant), *Stilostomella verneuili, Stilostomella* spp., *Lenticulina* spp., *Anomalinoides pompilioides, Bolivina* sp., *Angulogerina* sp., *Gyroidina* sp (acute periphery).
Age: Oligocene.

Sample 12-117A-1-1, 78-80 cm:
This sample contains Oligocene planktonic and benthonic foraminiferal contaminants. Indigenous elements consist of benthonic foraminifera, Radiolaria and echinoid spines which have been replaced by zeolites and other indeterminate minerals.
Age: Early Eocene (on basis of nannofossils).

Sample 12-117A-1, Core Catcher:
Same remarks as for sample above.
Remarks: Core 1 contains an unconformity separating Oligocene and Lower Eocene sediments. The Lower Eocene sediments consist of sands and silty clays in which foraminifera and Radiolaria have been replaced by zeolites.

Sample 12-117A-2, Core Catcher:
This sample, the only one recovered from Core 2, consists of sand and silty clay with Radiolaria replaced by zeolites and some glauconitic fecal pellets. No foraminifera present.
Age: Early Eocene (nannofossils).

Sample 12-117A-3-1, 145-147 cm:
Silty clay with glauconite.
PF: *Globigerina patagonica*, acarininids.
BF: Cibicidids, anomalinids (*A. grosserugosa*), buliminids, cassidulinids, gyroidinids, pulleniids.
Age: Early Eocene (Ypresian).

Sample 12-117A-3-2, 124-128 cm:
PF: *Globigerina patagonica*, acarininids.
BF: *Anomalinoides grosserugosa*, cibicidids, buliminids, *Osangularia pteromphalia*, lenticulinids.
Age: Early Eocene (Ypresian).

Sample 12-117A-3-3, 143-145 cm:
PF: *Globigerina patagonica*, acarininids.
BF: *Anomalinoides grosserugosa, Anomalina acuta, Lenticulina alatolimbata, Lenticulina decorata, Cibicidoides sulzensis, Osangularia pteromphalia, Gyroidina* sp., nodosariids, *Verneuilina* sp., *Angulogerina* sp., *Eponides* sp.
Age: Early Eocene (Ypresian).

Sample 12-117A-3-6, 145-148 cm:
Similar to above; only fine fraction left after preparation.

Sample 12-117A-3, Core Catcher:
PF: *Globigerina patagonica*, acarininids (pan fraction).
BF: *Bathysiphon* sp., *Anomalina acuta.*
Age: Early Eocene (Ypresian).
Remarks: Core 3 consists primarily of tan, brown and gray silty clays with varying amounts of glauconite. Planktonic foraminifera occur sporadically; 4-5 chambered acarininids (?*A. pentacamerata*) are common at some levels. Benthonic foraminifera characteristic of the Paleocene-Lower Eocene of Europe include *Anomalinoides grosserugosa, Anomalina acuta, Lenticulina decorata, Cibicidoides sulzensis* and *Osangularia pteromphalia.*

Sample 12-117A-4-0, 5 cm:
Olive-gray silty clay with abundant bryozoan fragments. Planktonic foraminifera not observed.
BF: *Cibicidoides proprias, C. hercegovinensis*, cibicidids, *Stomatorbina* sp., *Textularia* sp., *Lenticulina* sp., polymorphinids, nodosariids.
Age: Late Paleocene-Early Eocene.

Sample 12-117A-4-1, 140-143 cm:
Lithology and fauna as above. Globigerinids in pan fraction.
BF: *Vulvulina* sp., *Verneuilina* sp., *Lenticulina* sp., *Eponides* sp., *Stomatorbina* sp., *Planulina* sp., *Osangularia pteromphalia, Cibicidoides proprias, C. hercegovinensis*, nodosariids.
Age: Late Paleocene-Early Eocene.

Sample 12-117A-4-2, Bottom:
Lithology and fauna as above.

Sample 12-117A-4-4, Bottom:
Lithology and fauna as above; *Cibicidoides hercegovenensis* common, robust and large. Globigerinids present in pan fraction.

Sample 12-117A-4-6, 143-146 cm:
Lithology and fauna as above.

Sample 12-117A-4, Core Catcher:
PF: *Globigerina triangularis, G. velascoensis*, acarininids (pan fraction).
BF: *Osangularia pteromphalia* (dominant, common), *Cibicidoides hercegovinensis, C. proprias, Pullenia corryelli, Anomalinoides* sp., cf. *A. danica, Lenticulina* spp., nodosariids, *Eponides plummerae, Alabamina obtusa, Vulvulina* sp., *Polymorphina* sp.
Also present: Ostracods (*Bairdia, Cytherella).*
Age: Late Paleocene
Remarks: Cibicidids which lived attached to a substrate (algae, etc.) are present and indicate that the bryozoan-bearing clays and mudstones were probably formed in inner-middle neritic environments (less than 100 meters water depth).

Sample 12-117A-5-1, 127-130 cm:
Brown silty clay; fauna essentially same as for sample above (Core 4, Core Catcher).

Sample 12-117A-5-1, 142-145 cm:
Lithology and fauna essentially similar to above; *Allomorphina halli* also present.

Sample 12-117A-5, Bottom:
PF: *Globigerina triangularis.*
BF: *Cibicidoides proprias, C. hercegovinensis, Osangularia pteromphalia, Anomalinoides* sp., *Lenticulina* spp., nodosariids.
Age: Late Paleocene.

Sample 12-117A-6-1, 147-150 cm:
Brown silty clay with bryozoans.
PF: *Globigerina triangularis*, acarininids.
BF: *Osangularia pteromphalia, Cibicidoides proprias, C. hercegovinensis*, cibicidids, *Lenticulina* spp.
Age: Late Paleocene.

Sample 12-117A-6-4, 146-149 cm:
Undiagnostic.

Sample 12-117A-6-5, 133-135 cm:
PF: *Globigerina triangularis*, acarininids
BF: Essentially as in samples above, plus *Lenticulina midwayensis*
Age: Late Paleocene.

Sample 12-117A-6, Core Catcher:
Bryozoan bearing silty clay.
PF: *Globigerina triangularis.*
BF: *Osangularia pteromphalia, Anomalinoides danica*, nodosariids, *Allomorphina halli, Lenticulina midwayensis, Alabamina obtusa, Vulvulina.*
Also present: Pelecypods, fecal pellets, echinoid spines, ostracods (*Bairdia, Cytherella*).
Age: Late Paleocene.
Remarks: Core 6 is composed of brown and gray silty clay containing variable amounts of bryozoans and molluscan fragments. Planktonic foraminifera are rare; a single globigerinid species, *G. triangularis*, and small acarininids (probably one or two species) occur sporadically. Distinctive benthonic elements include *Cibicidoides proprius, C. hercegovinensis, Osangularia pteromphalia* and *Anomalinoides danica.*

Sample 12-117A-7-3, 142-145 cm:
Bryozoan mudstone.
PF: *Globigerina triangularis, G. velascoensis.*
BF: *Anomalinoides danica, Cibicidoides hercegovinensis*, cibicidids, lenticulinids, nodosariids.
Also present: Ostracods, molluscs (pectenids, gastropods).
Age: Late Paleocene.

Sample 12-117A-7-4, 139-142 cm:
PF: *Globigerina triangularis, G. velasconensis.*
BF: Essentially same as above plus *Lenticulina midwayensis, Karreria fallax, Anomalinoides acuta.*
Age: Late Paleocene.

Sample 12-117A-7, Core Catcher:
Bryozoan mudstone with rich and diverse benthonic foraminiferal fauna.
PF: *Globigerina triangularis, G. velascoensis.*
BF: *Anomalinoides danica, A. acuta, Gavelinella neelyi, Cibicides* sp., *Osangularia pteromphalia, Lenticulina midwayensis, Dentalina plummerae,* nodosariids, *Pullenia* sp., *Vulvulina* sp., *Karreria fallax, Ammodiscus* sp.
Age: Late Paleocene.
Remarks: Core 7 is a bryozoan-rich mudstone with a diverse benthonic foraminiferal fauna of inner-middle neritic affinities.

Sample 12-117A-8-1, 4-6 cm:
Bryozoan mudstone with relatively diverse benthonic foraminiferal fauna.
PF: *Globigerina triangularis, G. velascoensis.*
BF: *Anomalinoides danica, A. acuta, Gavelinella neelyi, Cibicidoides proprias, Osangularia pteromphalia, Lenticulina midwayensis, Vaginulina longiforma,* polymorphinids (*Guttulina* sp.), *Gyroidina* sp., *Vulvulina* sp.
Age: Late Paleocene.

Sample 12-117A-8-2, 86-89 cm:
Lithology and fauna essentially same as above.

Sample 12-117A-8, Core Catcher:
PF: Rare, small globigerinids in pan fraction.
BF: *Cibicidoides proprias,* cibicidids, *Lenticulina midwayensis, Marginulina* sp., nodosariids, *Osangularia pteromphalia, Gyroidina* sp., *Eponides* sp., *Verneuilina* sp.
Age: Late Paleocene.
Remarks: Core 8 is a bryozoan mudstone with abundant molluscan fragments, fecal pellets and reworked basaltic minerals. Distinctive inner-middle neritic amphi-Atlantic species of benthonic foraminifera occur in this core, as above. Many of the individuals exhibit evidence of abrasion. A relatively large ostreid was found at the bottom of Section 2.

Sample 12-117A-9, Core Catcher:
Basaltic (reworked) sandstone with shell fragments (molluscs, oysters, worm tubes, echinoid spines) and few foraminifera.
PF: Rare, small globigerinids (in pan fraction).
BF: *Marginulina* sp., polymorphinids, *Alabamina* sp., *Gyroidina* sp., *Eponides plummerae* (these may be contaminants from above). Indigenous fauna consists of a larger foraminifera, *Operculina heberti.*
Age: Late Paleocene.
Remarks: Core 9 recovered only the Core Catcher sample and a small amount of material in Section 1. It consists of a basaltic (reworked) sandstone with shell fragments of various molluscs and a larger foraminifera: *Operculina heberti.*

Sample 12-117A-11-1, 25-30 cm:
Thin sections of limestone filling in basalt with calcareous algae, bryozoans, rounded basalt fragments, echinoderms, miliolids, rotaliids and *Gypsina.*

APPENDIX E. COCCOLITH SPECIES AND STRATIGRAPHIC ASSIGNMENT OF SITES 116 AND 117

David Burky

Hole 116

Upper Pliocene
(*Discoaster brouweri* Zone)

12-116-1-6, 140-141 cm; depth 79 m:
Coccolithus doronicoides, C. pelagicus [abundant], *Coccolithus* sp. [tiny], *Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri, D. variabilis variabilis, Helicopontosphaera sellii* [common], *Scyphosphaera apsteinii* Lohmann, *Syracosphaera pulchra* Lohmann.

Middle Miocene
(*Sphenolithus heteromorphus* Zone)

12-116-10-6, 139-140 cm; depth 518 m:
Coccolithus eopelagicus, Cyclococcolithina neogammation, Discoaster sp. cf. *D. deflandrei, D.* sp. cf. *D. exilis, Discolithina segmenta* Bukry and Percival, *Helicopontosphaera granulata* Bukry and Percival, *H.* sp. cf. *H. kamptneri, Sphenolithus heteromorphus* Deflandre.

Lower Miocene
(*Triquetrorhabdulus carinatus* Zone)

12-116-18-4, 140-141 cm; depth 695 m:
Coccolithus pelagicus [abundant], *Cyclococcolithina neogammation, Dictyococcites abisectus, D. scrippsae, Discoaster deflandrei, Discolithina* sp., *Helicopontosphaera parallela* (Bramlette and Wilcoxon), *Sphenolithus moriformis, Triquetrorhabdulus* sp. cf. *T. carinatus* Martini, *Zygrhablithus bijugatus* [abundant].

Upper Oligocene
(*Sphenolithus ciperoensis* Zone)

12-116-21-4, 140-141 cm; depth 716 m:
Chiasmolithus altus, Coccolithus fenestratus, C. pelagicus, Cyclococcolithina neogammation, Dictyococcites abisectus, D. bisectus, D. scrippsae, Discoaster deflandrei, Discolithina segmenta, Reticulofenestra gartneri, Sphenolithus moriformis, Zygrhablithus bijugatus [abundant].

Lower Oligocene
(*Helicopontosphaera reticulata* Zone)

12-116-25-5, 141-142 cm; depth 812 m:
Chiasmolithus oamaruensis, Coccolithus fenestratus, C. pelagicus, Cyclococcolithina formosa, Dictyococcites bisectus, D. scrippsae, Discoaster tani nodifer, Isthmolithus recurvus, Pontosphaera vadosa, Reticulofenestra hillae, R. umbilica, Zygrhablithus bijugatus.

Upper Eocene
(*Discoaster barbadiensis* Zone)

12-116-26-1, 66-67 cm; depth 826 m:
Coccolithus eopelagicus, Cyclococcolithina formosa, C. neogammation, C. sp. cf. *C. reticulata, Dictyococcites bisectus, D. scrippsae, Discoaster* sp. cf. *D. tani nodifer, D. saipanensis, Isthmolithus recurvus, Lanternithus minutus* Stradner, *Pontosphaera vadosa, Reticulofenestra hillae, R. umbilica, Zygrhablithus bijugatus.*

12-116-28-1, 90-91 cm; depth 840 m:
Chiasmolithus sp. cf. *C. expansus, C. oamaruensis, Coccolithus pelagicus, Cyclococcolithina formosa, C.* sp. cf. *C. reticulata* [small], *Dictyococcites bisectus, D. scrippsae, Discoaster saipanensis, Reticulofenestra umbilica, Zygrhablithus bijugatus.*

Hole 116A

Upper Pleistocene or Holocene

12-116A-1A-2, 133-134 cm; depth 2 m:
Coccolithus pelagicus, Cyclococcolithina leptopora, ?Emiliania huxleyi Kamptner, *?Gephyrocapsa ericsonii* McIntyre and Be, *Helicopontosphaera kamptneri, Syracosphaera* sp. cf. *S. histrica.*

Lower Pleistocene
(*Coccolithus doronicoides* Zone)

12-116A-4A-6, 140-141 cm; depth 35 m:
Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discolithina japonica, D. multipora s.l., Emiliania annula, Gephyrocapsa caribbeanica, Helicopontosphaera kamptneri, Scyphosphaera sp., *Syracosphaera histrica.*

12-116A-7A-2, 140-141 cm; depth 56 m:
Coccolithus neohelis, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Helicopontosphaera sellii, Rhabdosphaera clavigera, Syracosphaera sp.

12-116A-8A-3, 141-142 cm; depth 66 m:
Acanthoica sp. aff. *A. acanthos* Schiller, *Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Helicopontosphaera sellii, Rhabdosphaera* sp. cf. *R. stylifera* Lohmann, *Syracosphaera* sp.

Upper Pliocene?

12-116A-8A-4, 147-148 cm; depth 68 m:
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster sp. cf. *D. brouweri* [rare], *Discolithina japonica, Emiliania annula, Helicopontosphaera kamptneri* [rare].

Hole 117

Upper Oligocene
(*Sphenolithus ciperoensis* Zone)

12-117-2-3, 146-148 cm; depth 102 m:
Braarudosphaera discula Bramlette and Riedel [rare], *Chiasmolithus altus* [fantastically abundant], *Coccolithus eopelagicus, Cyclococcolithina neogammation, Dictyococcites abisectus, D. bisectus, D. scrippsae, Discoaster deflandrei, Sphenolithus moriformis, Zygrhablithus bijugatus* [abundant].

12-117-2-4, 144-145 cm; depth 103 m:
Chiasmolithus altus, Coccolithus eopelagicus, Cyclococcolithina neogammation, Dictyococcites abisectus, D. bisectus, D. scrippsae, Discoaster deflandrei, Discolithina sp., *Reticulofenestra gartneri, Sphenolithus ciperoensis, S. moriformis, Zygrhablithus bijugatus.*

Hole 117A

Upper Oligocene
(*Sphenolithus ciperoensis* Zone)

12-117A-1A-1, 54-55 cm; depth 147 m:
Chiasmolithus altus, Coccolithus eopelagicus, Cyclococcolithina neogammation, Dictyococcites bisectus, D. scrippsae, Helicopontosphaera truncata (Bramlette and Wilcoxon), *Zygrhablithus bijugatus.*

12-117A-1A-1, 70-71 cm; depth 147 m:
Chiasmolithus altus, Cyclococcolithina neogammation, Reticulofenestra gartneri. Reworked Lower Eocene taxa: *Discoaster lodoensis, D.* sp. aff. *D. obscurus* Martini, *Discoasteroides kuepperi, Tribrachiatus orthostylus.*

Lower Eocene
(*Tribrachiatus orthostylus* Zone)

12-117A-3A-1, 131-132 cm; depth 222 m:
Chiasmolithus grandis, Coccolithus crassus, Cyclococcolithina luminis, Discoaster binodosus, Markalius inversus, Micrantholithus sp., *Syracosphaera fimbriata, Transversopontis pulcheroides, Tribrachiatus orthostylus, Zygolithus dubius, Zygrhablithus bijugatus.*

12-117A-3A-4, 137-138 cm; depth 226 m:
Chiphragmalithus calathus Bramlette and Sullivan, *Discoaster obscurus, D.* sp. aff. *D. obscurus, Discoasteroides kuepperi, Lophodolithus nascens, Syracosphaera fimbriata, Tribrachiatus orthostylus, Zygolithus dubius, Zygrhablithus bijugatus.*

12-117A-3A-6, 140-141 cm; depth 229 m:
Discolithina ocellata (Bramlette and Sullivan), *Micrantholithus* sp., *Syracosphaera fimbriata, Transversopontis pulcher, T. pulcheroides, Zygolithus dubius, Z. protenus* (Bramlette and Sullivan).

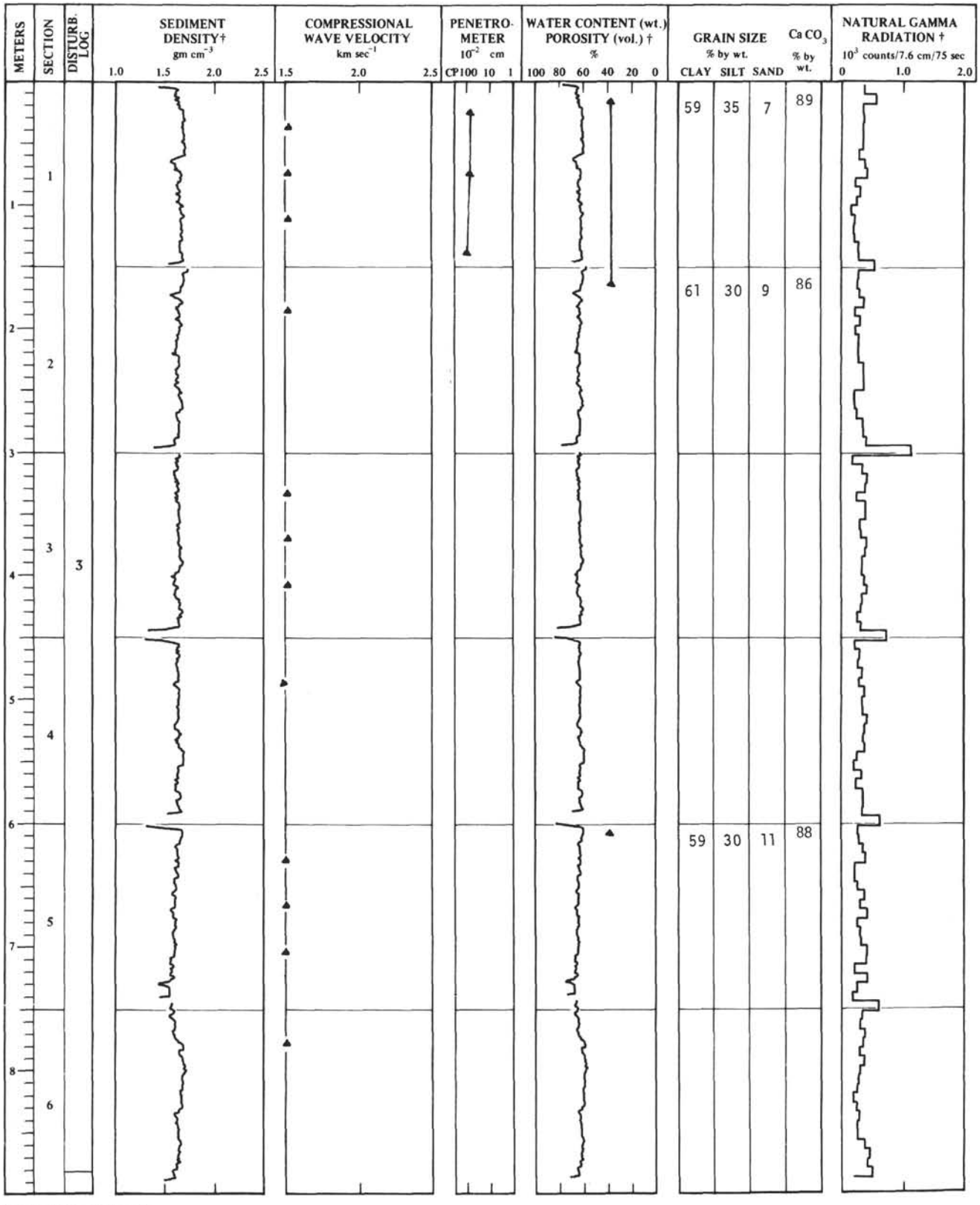
Upper Paleocene or Lower Eocene

12-117A-4A-1, 136-137 cm; depth 271 m:
Braarudosphaera bigelowi, Chiasmolithus bidens (Bramlette and Sullivan), *Discoaster multiradiatus* Bramlette and Riedel, *D. ornatus* Stradner, *Ellipsolithus distichus* (Bramlette and Sullivan), *Zygolithus chiastus* Bramlette and Sullivan, *Z. dubius, Z. junctus* Bramlette and Sullivan.

12-117A-6A-1, 144-145 cm; depth 276 m:
Braarudosphaera bigelowi, Chiasmolithus bidens, Discoaster sp. cf. *D. diastypus* Bramlette and Sullivan, *Discolithina ocellata, Ellipsolithus macellus* Bramlette and Sullivan, *Markalius inversus, Transversopontis pulcheroides, Tribrachiatus contortus* (Stradner), [basionym: *Discoaster contortus* Stradner, 1958, Erdoel-Z. 74: p. 187, figs. 35-36], *Tribrachiatus orthostylus, Zygrhablitus bijugatus.*

HOLE 116

CORE 1



†Adjusted data, see Chapter 2

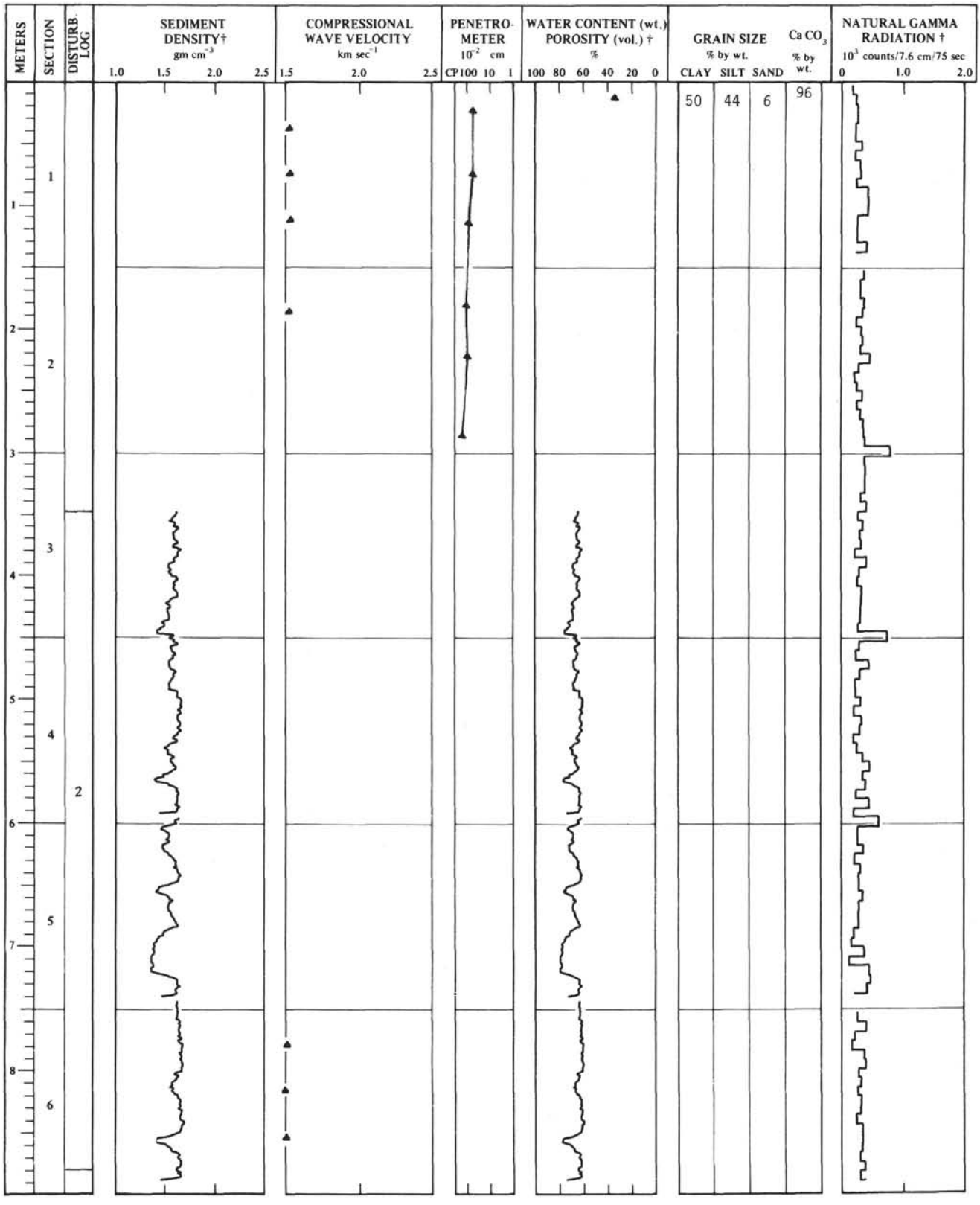
HOLE 116 70 TO 79 m

CORE 1

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		XM R N XM F	White to light gray foram-nannofossil ooze, moderately mottled pale red purple, pale green and medium dark gray. Dark areas contain a higher pyrite concentration with occasional pyritized burrows. Ostracods occur rarely, the main coarse fraction component (<63μ) is foraminifera. The entire core is disturbed X-ray Mineralogy (bulk) Calc. 99.5 Qtz. .5 Amorph. 30.8	Radiolarians common. *Spongaster* sp. cf. *S. tetras, Druppatractus irregularis, discoidal and spheroidal spumellarians. Coccolithus pelagicus, Cyclococcolithus leptoporus, C. macintyrei, Pseudoemiliania lacunosa, Helicopontosphaera kamptneri, H. sellii, Pontosphaera discopora, P. scutellum, Syracosphaera* sp., *Scyphosphaera apsteini, Sphenolithus* cf. *S. neoabies, Discoaster* sp. *D. brouweri, D. surculus, D. pentaradiatus. Globigerina atlantica, G. bulloides, Globigerinita glutinata*		
2	2		N R,XM		Flora similar to above Radiolarians rare. *Spongaster* sp. cf. *S. tetras.* Assemblage similar to above	*Discoaster surculus*	
3			F		*G. atlantica, G. bulloides, G. glutinata, Globorotalia crassaformis, G. scitula*		
4	3		R N	N9 N8	Radiolarians common. *Spongaster* sp. cf. *S. tetras.* Assemblage similar to above. Flora similar to above		
			F		Fauna similar to above		PLIOCENE
5	4		N R		Flora similar to above Radiolarians common. *Spongaster* sp. cf. *S. tetras, Lamprocyclas heteropores.* Assemblage similar to above.		
6			F		Fauna similar to above		
	5		N		Flora similar to above *Reticulofenestra pseudoumbilica*	*Reticulofenestra pseudoumbilica*	
7			N R XM		Flora similar to above Radiolarians common. *Spongaster* sp. cf. *S. tetras*. Assemblage similar to above.		
			N		Flora similar to above		
			F		Fauna similar to above		
8	6		N R		Flora similar to above Radiolarians rare. *Spongaster* sp. cf. *S. tetras*. Assemblage similar to above.		
			F		Fauna similar to above		
	CC		R N F		Radiolarians abundant, *Spongaster* sp. cf. *S. tetras, Pterocanium praetextium,* spheroidal and discoidal spumellarians. Flora & fauna similar to above.		

HOLE 116

CORE 2



†Adjusted data, see Chapter 2

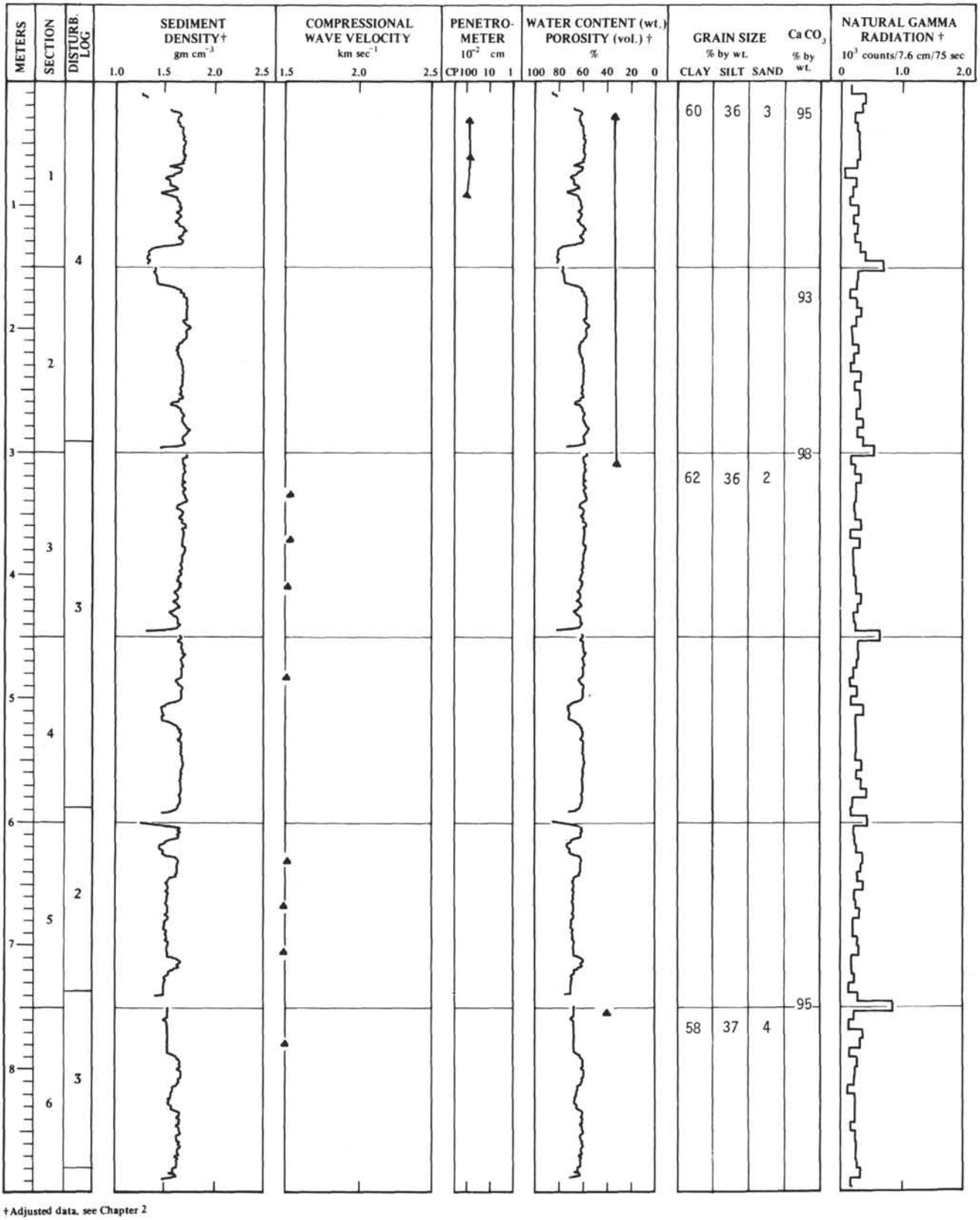
HOLE 116 109 TO 118 m

CORE 2

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		XM,F	Light gray and pale greenish yellow foram-nannofossil ooze moderately mottled black, yellow and pale olive. Dark areas contain high pyrite concentrations. Glass & glauconite are rare. Sandier layers with very high foram concentration occur in section 1. "Zero" section (10 cm) also present. X-ray mineralogy Calc. 100 Amorph. 27	*G. atlantica, G. Bulloides, G. crassaformis, G. Scitula, G. universa Coccolithus pelagicus, Cyclococcolithus leptoporus, C. macintyrei, Helicopontosphaera sellii, H. kamptneri, Pontosphaera scutellum, P. discopora, Reticulofenestra pseudoumbilica, Scyphosphaera* sp., *Thoracosphaera* sp., *Syracosphaera pulchra, Sphenolithus abies, Discoaster pentaradiatus* Radiolarians very rare. Spheroidal and discoidal spumellarians.		PLIOCENE
			N R				
			XM				
2			F				
	2		N R		*G. atlantica, G. bulloides, O. universa, G. crassula, G. crassaformis, G. miozea conoidea, G. cibaoensis, G. puncticulata* Flora similar to above Radiolarians very rare.		
3			F		*G. bulloides, o. universa, G. puncticulata*		
	3						
4							
			N,F,R	N8 10Y 8/2	Flora similar to above. Fauna similar to above. Radiolarians rare. Similar to above *Stichocorys peregrina.*		
5	4	NOT SPLIT					
6			N,F R		Flora similar to above. Fauna similar to above. Radiolarians rare. Same as above.		
7	5					*Spongaster pentas.*	
			N,R		Flora similar to above. Radiolarians common. Same as above. *Stichocorys peregrina*		
8	6				Core Catcher: Radiolarians rare. Flora similar to above Radiolarians abundant. Similar assemblage. *Stichocorys peregrina, Artostrobium doliolum.*		
			N,R				
	CC		R N F		Flora similar to above *G. bulloides, G. atlantica, O. universa, G. puncticulata, G. acostaensis, G. humerosa*		

HOLE 116

CORE 3



†Adjusted data, see Chapter 2

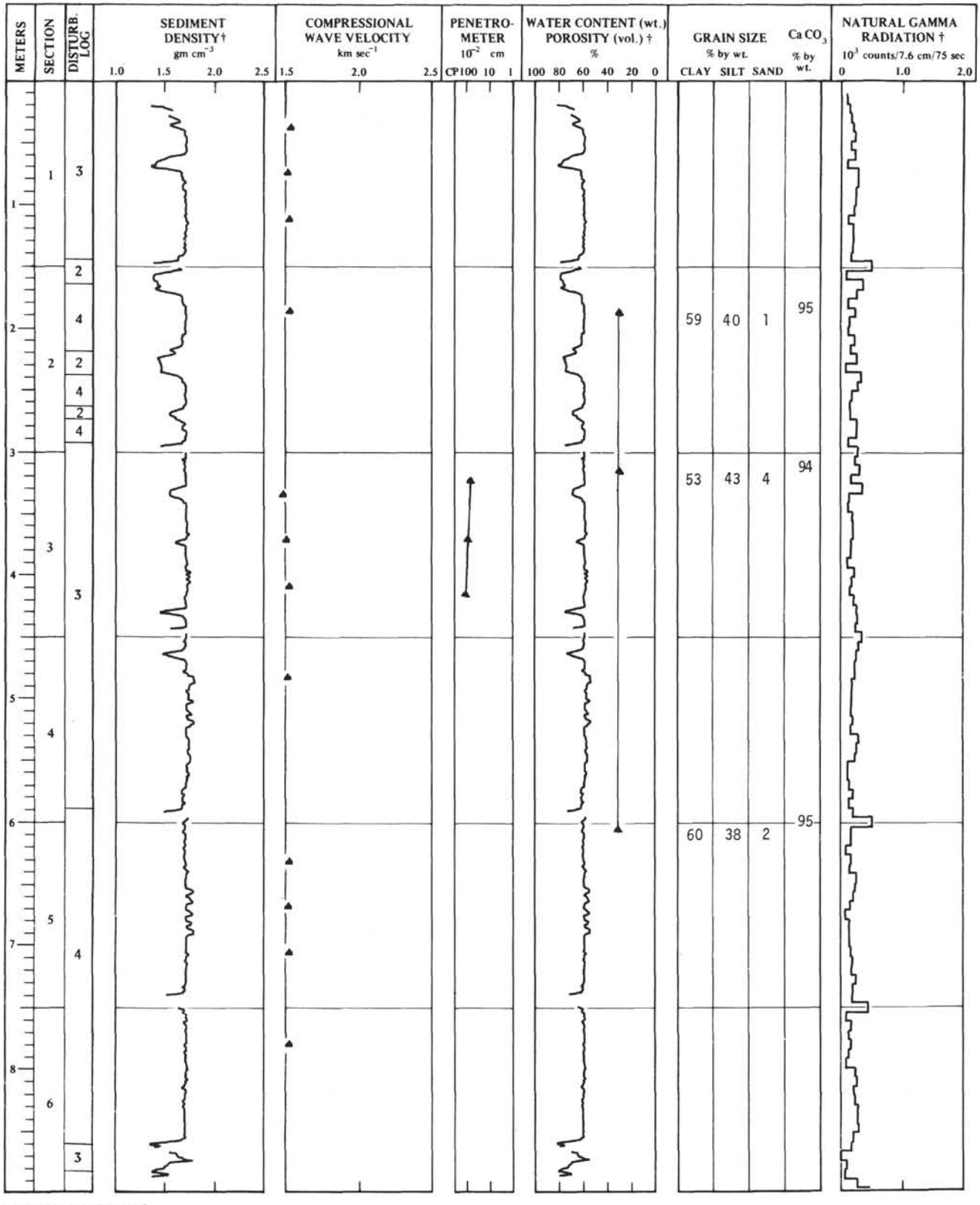
HOLE 116 159 TO 168 m

CORE 3

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NOT SPLIT	F XM N R XM	Light gray, pale yellowish white, and bluish white foram-nannofossil ooze, irregularly mottled light olive. Foraminifera dominant coarse fraction component. Strong H_2S odor emitted from section 2. Entire core is disturbed. "Zero" section (20 cm) of same lithology also present. X-ray Mineralogy (bulk) Calc. 100 Amorph. 27	*Coccolithus pelagicus, Cyclococcolithus leptoporus, C. macintyrei, Reticulofenestra pseudoumbilica, Thoracosphaera* sp., *Scyphosphaera* sp., *Sphenolithus abies, Helicopontosphaera sellii, H. kamptneri, Pontosphaera scutellum, P. discopora, Discoaster* sp. *G. atlantica, G. bulloides, O. universa, G. puncticulata* Radiolarians very rare. Spheroidal and discoidal spumellarians. Fauna similar to above		MIOCENE? PLIOCENE?
2	2		F N		Flora similar to above, + *Discoaster pentaradiatus* Fauna similar to above		
3	3		F N R				
4			XM		Flora similar to above Radiolarians very rare		
5	4		XF N R	N8 5Y 9/1 5B 9/1 10Y 5/4	*G. atlantica, G. bulloides, O. universa, G. humerosa, G. margaritae* Flora similar to above Radiolarians very rare		
6	5		N,F,R		Flora similar to above		
7					Fauna similar to above Radiolarians rare. *Stichocorys delmontensis*		
8	6		N R	A few volcanic glass shards	Flora similar to above, + D. pentaradiatus Radiolarians very rare		
			F		Fauna similar to above		
	CC		F N R		Flora & fauna similar to above, + *D. pentaradiatus* Radiolarians rare. *Stichocorys delmontensis*		

HOLE 116

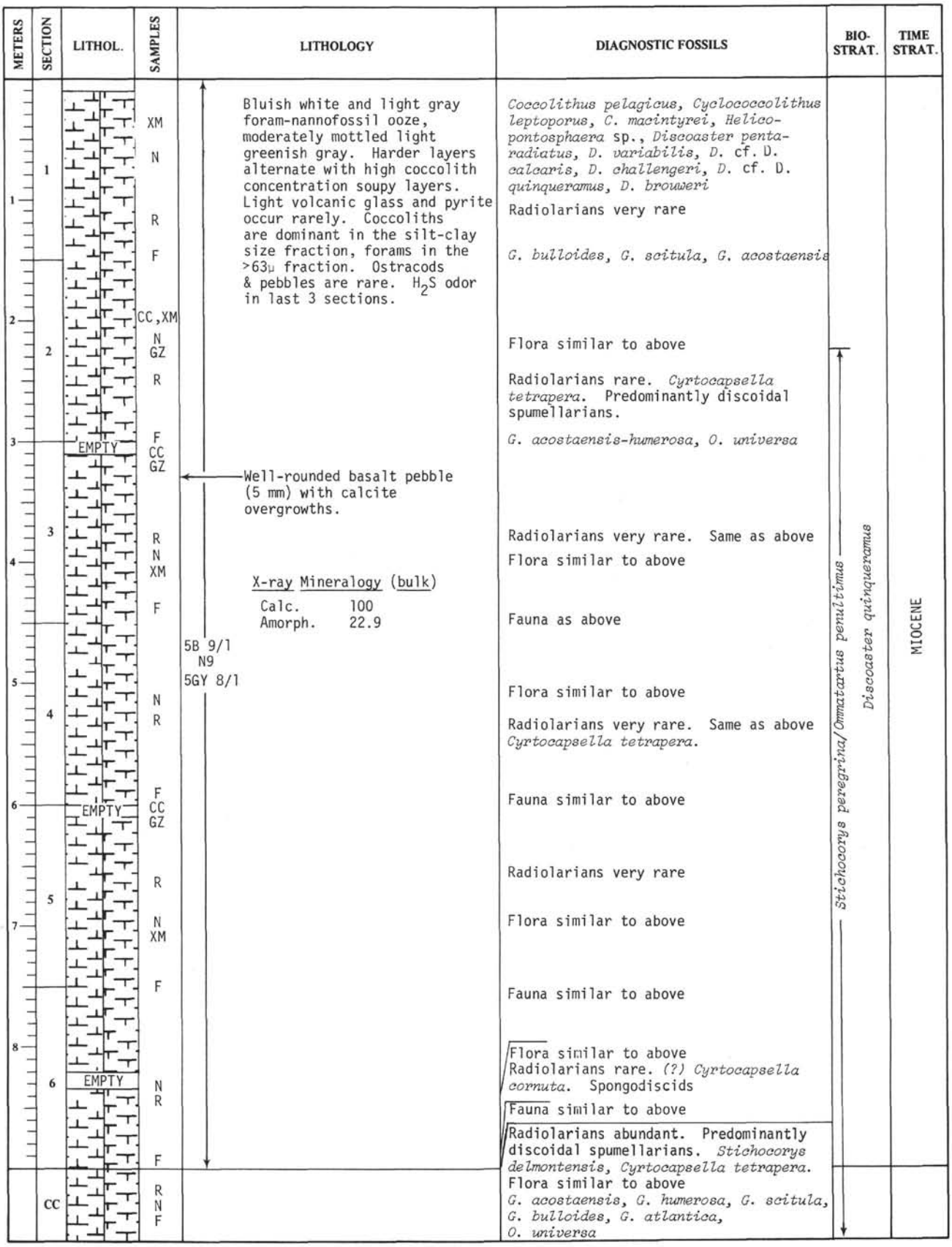
CORE 4



†Adjusted data, see Chapter 2

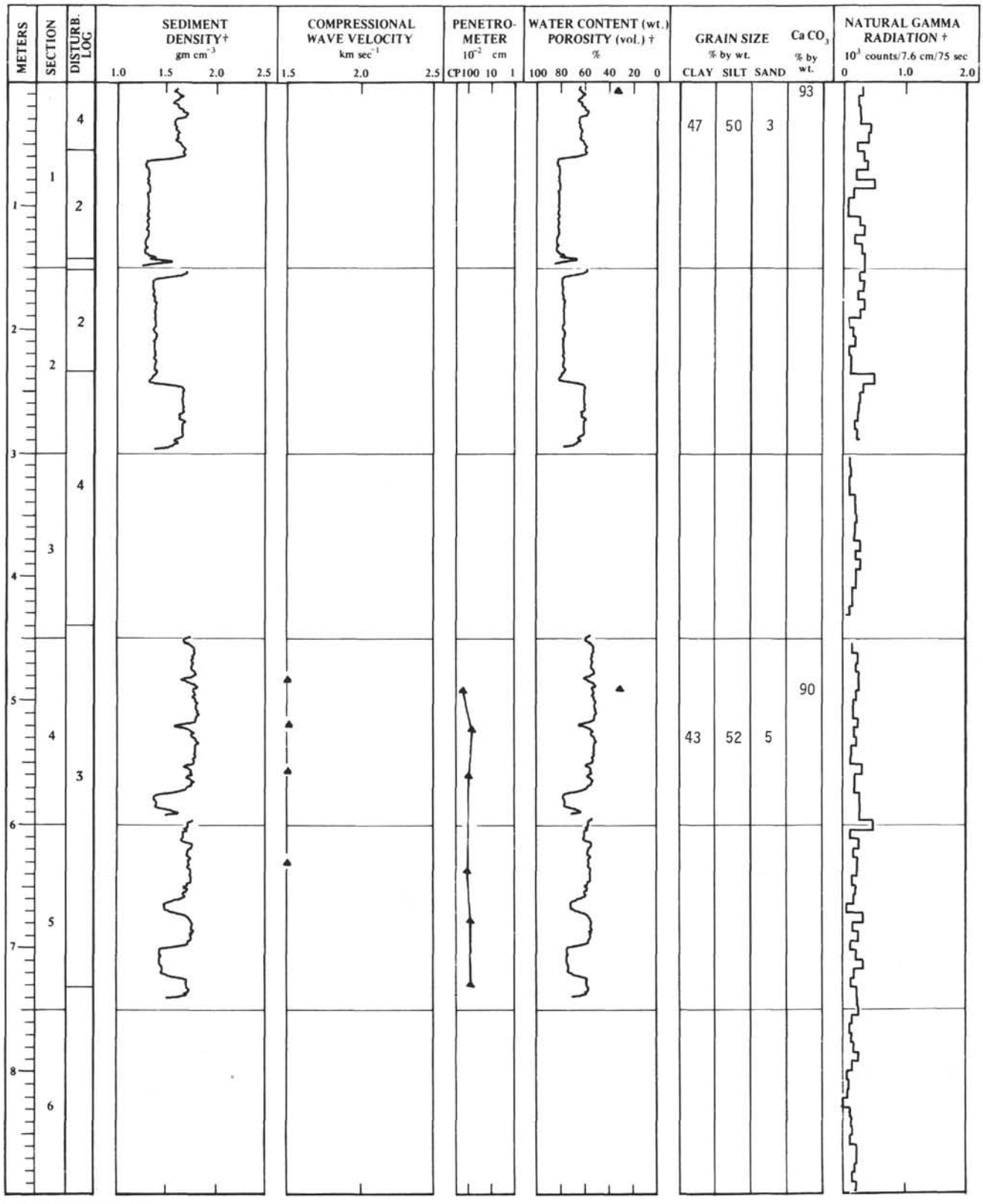
HOLE 116 209 TO 218 m

CORE 4



HOLE 116

CORE 5



†Adjusted data, see Chapter 2

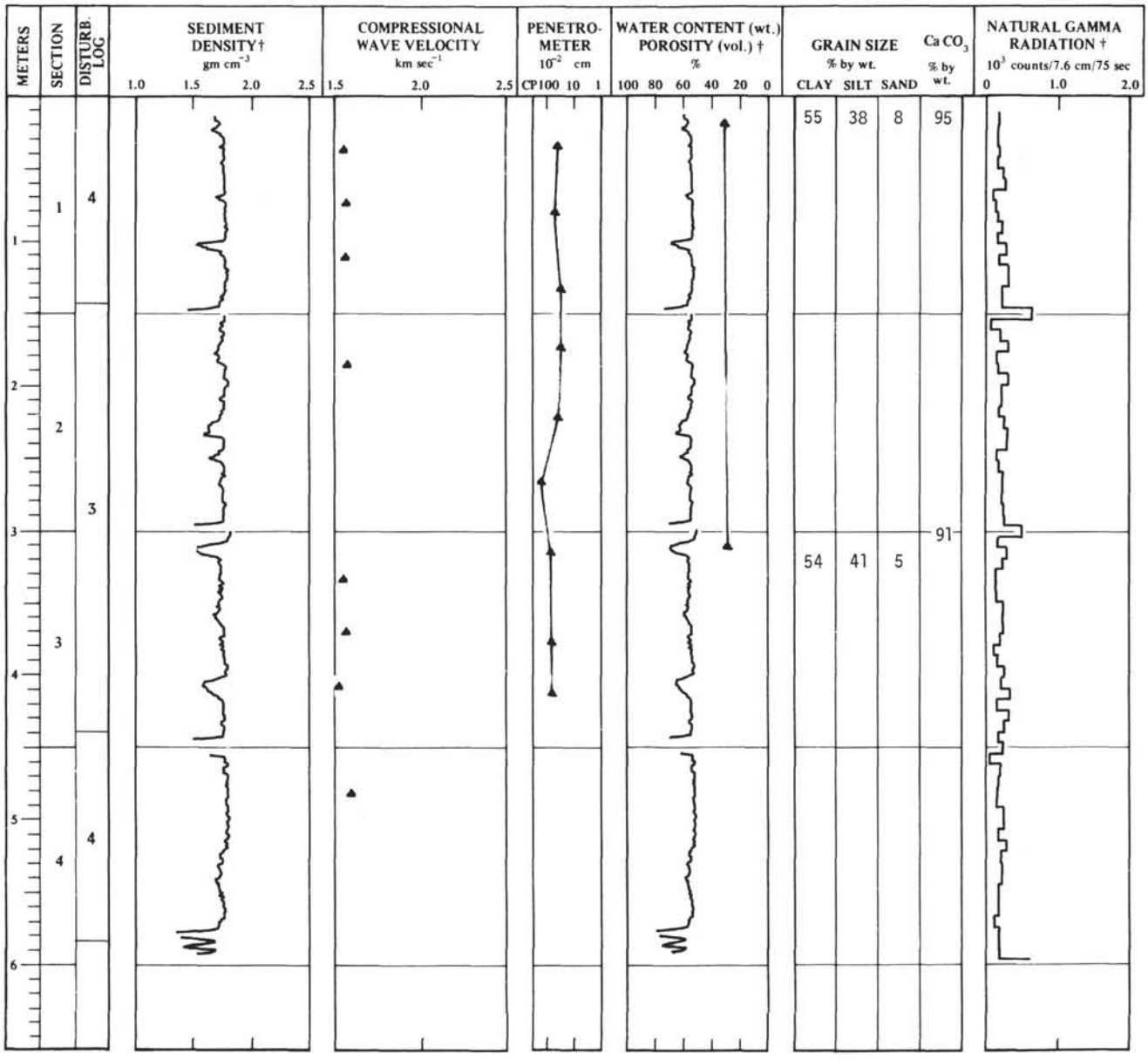
HOLE 116 259 TO 268 m

CORE 5

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N,F XM,R R,CC XM F GZ N	Light gray, white, and medium gray soft and watery foram-nannofossil ooze, slightly mottled light olive gray, and olive gray. Dominant components are coccoliths & forams. "Zero" section (28 cm) of same lithology also present. X-ray Mineralogy (bulk) Calc. 100 Amorph. 27.9	*Coccolithus pelagicus, Cyclococcolithus leptoporus, C. macintyrei, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Discoaster browseri, D. pentaradiatus, D. challengeri, D. variabilis, D. quinqueramus, Sphenolithus moriformis, Sphenolithus* sp. Radiolarians common. *Ommatartus antepenultimus, Stichocorys delmontensis, S. peregrina, Cyrtocapsella cornuta, Calocyclas margatensis G. praebulloides, G. bulloides, G. decoraperta G. miozea canoidea, G.* cf. *subscitula, G. acostaensis*	*Stichocorys peregrina/Ommatartus penultimus* *Discoaster quinqueramus?*	MIOCENE
2	2		N R F	Flora similar to above Radiolarians rare, similar to above *Cyrtocapsella tetrapera* Fauna similar to above			
3	3		N8 N N9 R N5 F	Flora similar to above Radiolarians common, similar to above Fauna similar to above plus *Globigerina zealandica*			
4	4	NO CORE	CC N R,GZ XM F	Flora similar to above Radiolarians rare, similar to above Fauna similar to above, plus *Globigerina zealandica*			
5	5	NO CORE	N R F	Flora similar to above Radiolarians same Fauna similar to above, plus *G. atlantica*			
6	6	NOT SPLIT	R,N,F	Radiolarians common, similar to above *Cyrtocapsella japonica* Fauna similar to above Flora similar to above			
	CC		R N F		Radiolarians common, similar to above. Flora similar to above. *G. bulloides, G. praebulloides, G. apertura, G. foliata, G. acostaensis, G. continuosa, G. miozea*		

HOLE 116

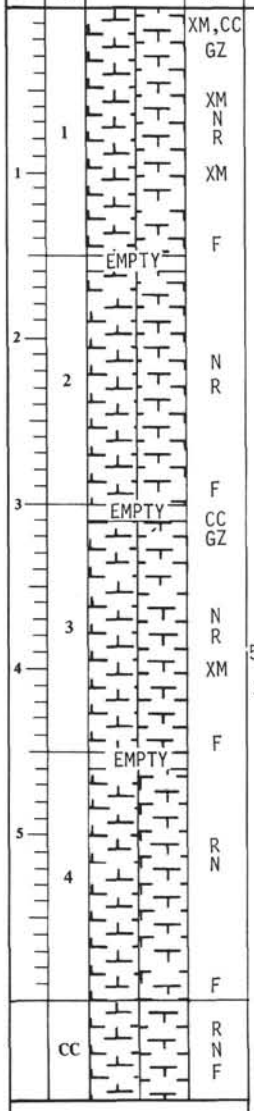
CORE 6



†Adjusted data, see Chapter 2

HOLE 116 309 TO 318 m

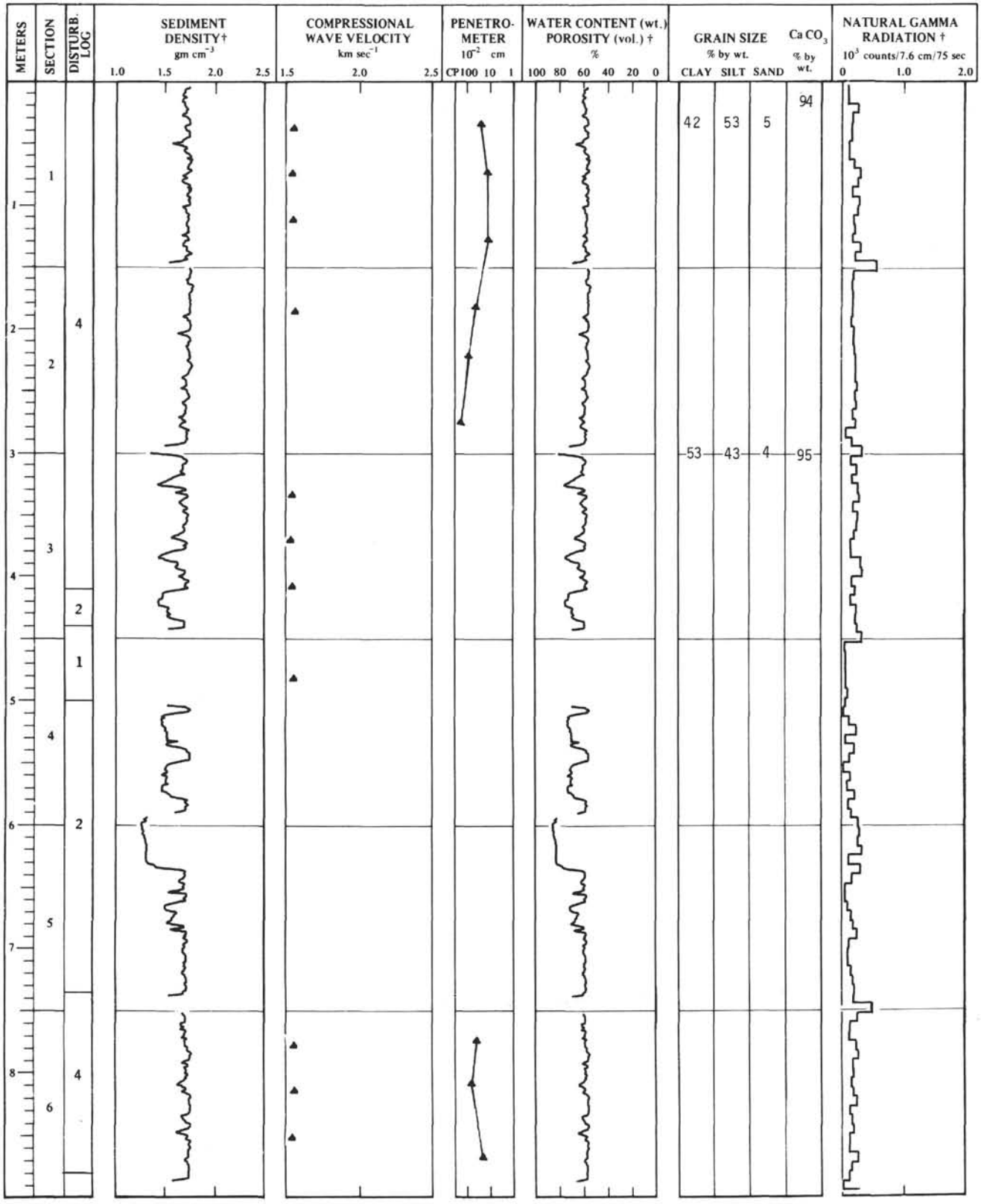
CORE 6



LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
Light greenish gray and bluish white soupy and firm ooze, mottled white, light gray, and greenish gray. Sponge spicules, fish debris, ostracods, pyrite, clay minerals all rare; forams and calcareous nannoplankton abundant. X-ray Mineralogy (bulk) Calc. 99.6 Qtz. .4 Amorph. 27.8 5GY 9/1 5B 9/1	*Coccolithus pelagicus, Cyclococcolithus leptoporus, C. macintyrei, Reticulofenestra pseudoumbilica, Sphenolithus* sp. *Helicopontosphaera kamptneri, Discoaster* cf. *hamatus, D. brouweri, D.* cf. *variabilis, D.* cf. *aulakos* Radiolarians very rare *G. praebulloides, G. acostaensis, G. obesa, Sph. seminulina, S. subdehiscens, G. menardii, G. dehiscens, O. universa* Flora similar to above Radiolarians very rare. *Stichocorys delmontensis* Fauna similar to above, plus *G. miozea* Flora similar to above Same as above Fauna similar to above Radiolarians very rare. *Cyrtocapsella tetrapera* Flora similar to above Fauna similar to above; no keeled globorotaliids Core Catcher: Radiolarians rare. (?) *Ommatartus antepenultimus, Stichocorys delmontensis, Cyrtocapsella tetrapera* Flora & fauna similar to above	*Discoaster hamatus?*	LATE MIOCENE

HOLE 116

CORE 7



† Adjusted data, see Chapter 2

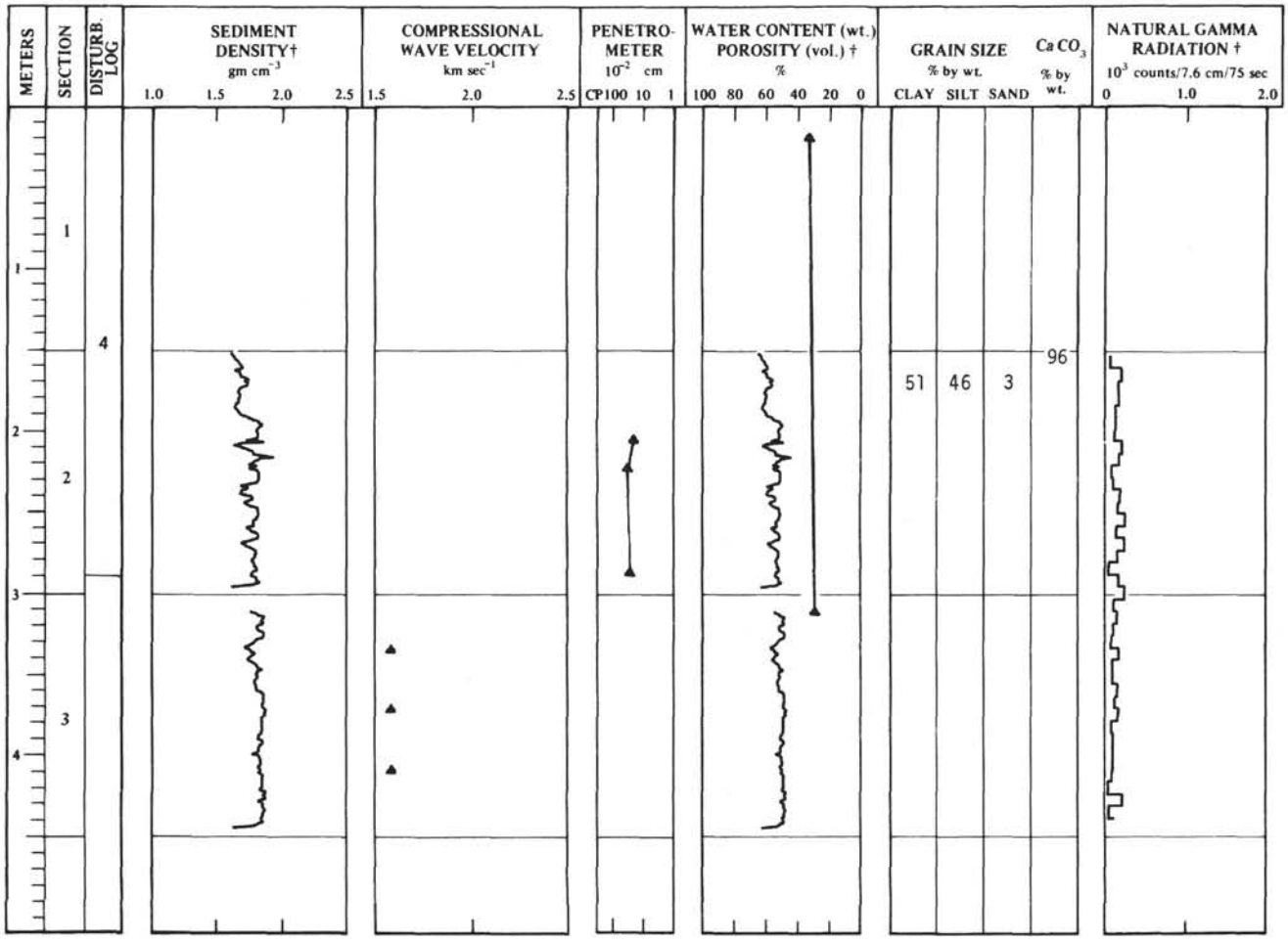
HOLE 116 359 TO 368 m

CORE 7

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N,F XM,CC GZ N R XM F	Bluish-white soft foram-nannofossil chalk ooze, slightly mottled pale red purple and yellowish gray. Siliceous microfossils, fish debris, ostracods, rock fragments, glass & pyrite rare; coccoliths and forams dominant. "Zero" section (29 cm) of same lithology also present. X-ray Mineralogy (bulk) Calc. 100 Amorph. 24.9	*Coccolithus pelagicus, Cyclococcolithus leptoporus, C. macintyrei, Helicopontosphaera kamptneri, Sphenolithus moriformis, Reticulofenestra pseudoumbilica, Discoaster* sp. + ? reworked Oligocene coccoliths? *G. praebulloides, G. opertura, G. nepenthes, O. universa, G. cultrata, G.* cf. *scitula* (of Blow), *Gl. triloba, Sph. subdehiscens, G. dehiscens*		
2	2		N R		Radiolarians very rare. *Stichocorys delmontensis, Cyrtocapsella japonica, C. cornuta,* digitately branched *Oroscena* spine Flora similar to above Same radiolarians		
3			F GZ CC		Fauna similar to above; no *G. nepenthes*		
	3		N R		Flora similar to above Similar radiolarians. Curved, flat *Oroscena* spines.	*? Camartus (?) pettersoni* N14 - N15	MIDDLE MIOCENE
4			F	5B 9/1 5RP 6/2 5Y 7/2	Fauna similar to above		
	4						
5		NOT SPLIT					
6			N,F,R		Flora similar to above Fauna similar to above, plus *G. nepenthes, G. miozea, G. siakensis*		
	5				Radiolarians rare. *Cyrtocapsella japonica* and curved, flat *Oroscena* spines common. Plus similar assemblage.		
7					Flora similar to above Fauna similar to above Radiolarians same as above.		
			N,F,R		Flora similar to above Radiolarians very rare. Similar assemblage.		
8					Fauna similar to above, plus. *G.* cf. *G. atlantica, G. acostaensis*		
	6		N R		Radiolarians abundant. *Cyrtocapsella japonica* abundant assemblage, similar to above. *Siphocampe corbula, Pharmostichoartus corona*		
			F		Flora similar to above		
	CC		R N F		*G.* aff. *acostaensis, G.* cf. *scitula* (Blow), *G. praebulloides, G. bulbosa, G. triloba, G. dehiscens, Sph. subdeniscens*		

HOLE 116

CORE 8



†Adjusted data, see Chapter 2

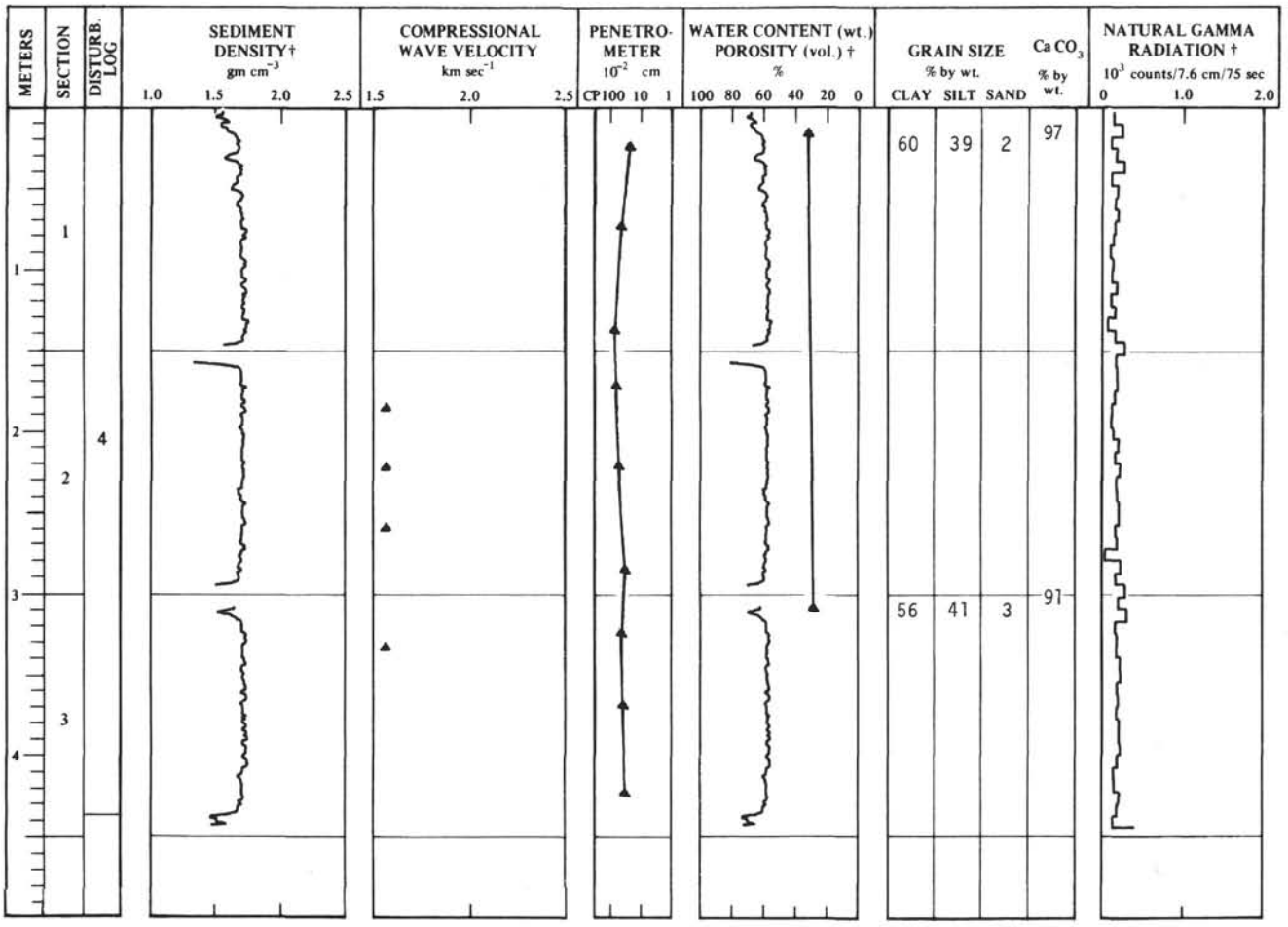
HOLE 116 409 TO 418 m

CORE 8

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	EMPTY					
2	2	EMPTY	CC GZ XM N XM,R	5B 9/1 N3 Bluish white foram-nannofossil chalk ooze, very slightly mottled dark gray. Chalk is limited to discreet layers and is extremely friable. Siliceous microfossils, ostracods, pyrite, and glass occur rarely; coccoliths and foraminifera are dominant. X-ray Mineralogy (Bulk) Calc. 100 Amorph. 25.4	*Coccolithus pelagicus, C. eopelagicus Cyclococcolithus leptoporus, C. macintyrei, Helicopontosphaera kamptneri, H.* cf. *sellii, Sphenolithus moriformia, S.* sp. Radiolarians very rare. *Cyrtocapsella japonica, Stichocorys delmontensis,* digitately branched, *Oroscena* spikes		
3	3	EMPTY	F N R		*G. praebulloides, G. continuosa, G.* aff. *acostaensis. G. miozea* Flora similar to above Radiolarians common. *C. japonica, C. cornuta, C. tetrapera, S. delmontensis,* digitately branched *Oroscena* spines, *Calocyclas margatensis*	*? Cannartus (?) pettersoni*	MIDDLE MIOCENE
4	CC		F R N F		Fauna similar to above, plus *G.* cf. *G. cultrata* Core Catcher: Radiolarians common, as above. Flora similar to above. *G. praebulloides, G. parabulloides, G. zealandica, G. siakensis, G. continuosa, G. miozea, G. variabilis, O. universa*		

HOLE 116

CORE 9



†Adjusted data, see Chapter 2

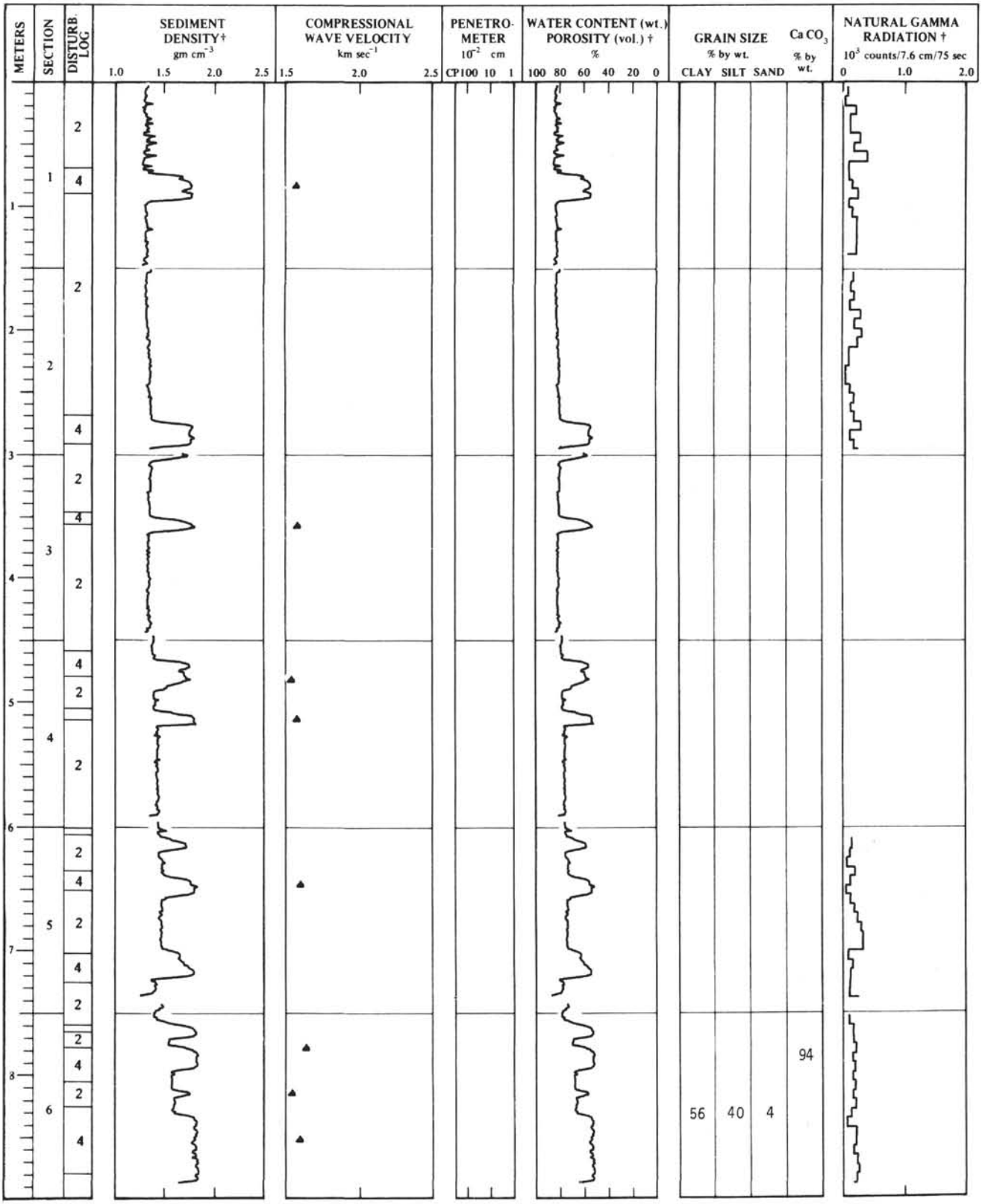
HOLE 116 459 TO 468 m

CORE 9

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		XM CC GZ N R F	Bluish-white foram-nannofossil chalk ooze slightly mottled white, medium light gray and yellowish gray. Ostracods, fish debris, glass, and pyrite are rare. X-ray Mineralogy (bulk) Calc. 100 Amorph. 24.2	*Coccolithus pelagicus, C. eopelagicus, Cyclococcolithus leptoporus? Helicopontosphaera kamptneri, H.* cf. *H. parallela, Sphenolithus moriformis, Reticulofenestra pseudoumbilica, Disocaster* sp., *Coronocyclus nitescens.*	*Doradospyris alata* *Discoaster exilis?* N.10	MIDDLE MIOCENE
2	2		R N F	5B 9/1	Radiolarians common. *Lithopera renzae, Cyrtocapsella japonica, C. cornuta, C. tetrapera, Stichocorys delmontensis,* digitately branched *Oroscena* spines. *Praeorb. glomerosa circularis, O. suturalis, G. praebulloides, G. peripheroacuta, G. praemenardii, G. siakensis, Globoquadrina baroemoenensis, G. triloba* Radiolarians rare. As above. Flora similar to above		
3	3		CC GZ N N XM R N F		Fauna similar to above. Flora similar to above Flora similar to above Radiolarians abundant. *C. tetrapera* abundant; flat, curved *Oroscena* spines; plus above. Flora similar to above Flora similar to above; *G. praemenardii* common		
4	CC		R N F		Core Catcher: Radiolarians abundant. *Lithopera neotera, L. renzae, (?) Cannartus laticonus,* plus assemblage as above. Flora similar to above . *Pr. glomerosa curva, G. praemenardii, G.* aff. *miozea, G. dehiscens*		

HOLE 116

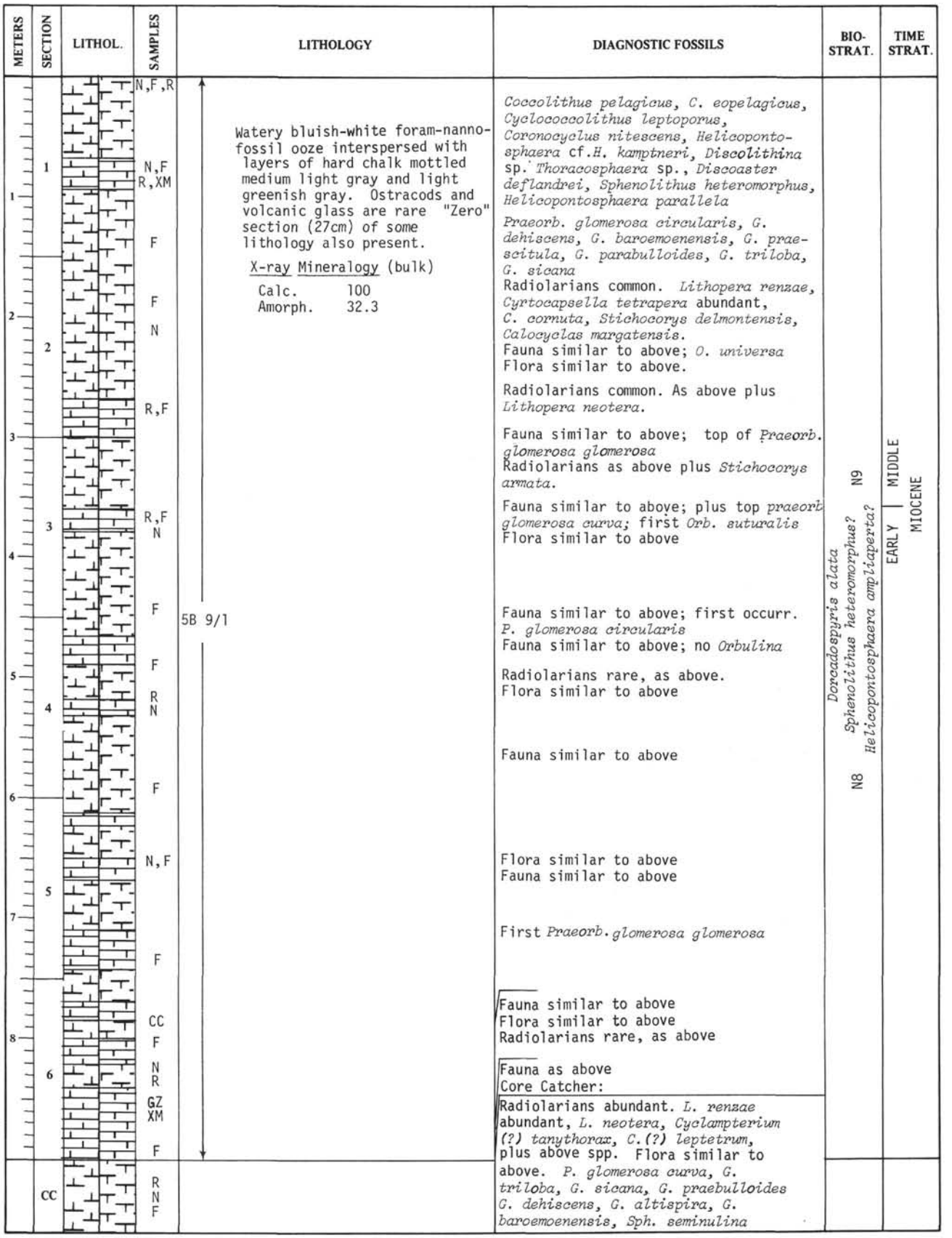
CORE 10



†Adjusted data, see Chapter 2

HOLE 116 509 TO 518 m

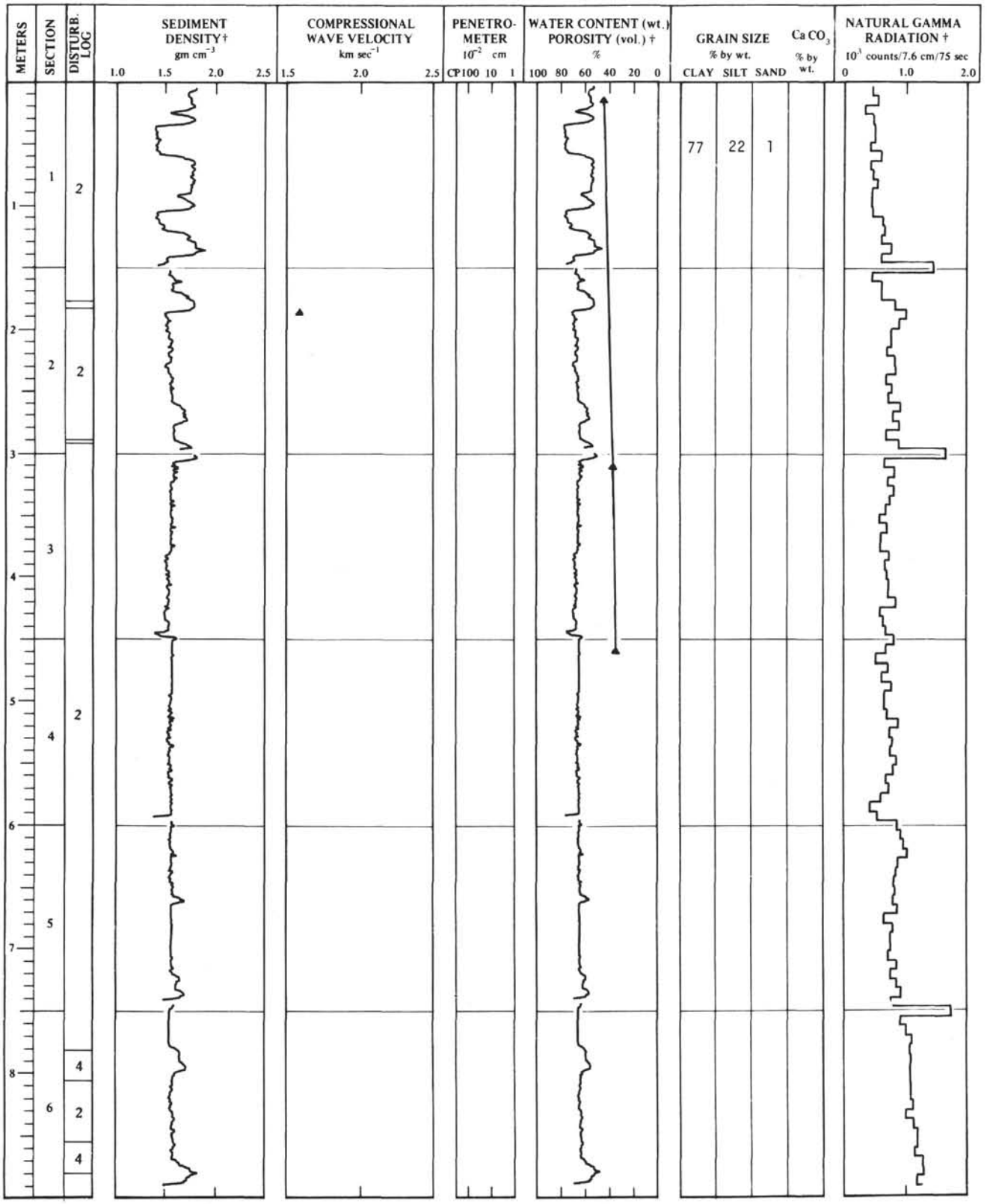
CORE 10



METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N,F,R N,F R,XM F	Watery bluish-white foram-nannofossil ooze interspersed with layers of hard chalk mottled medium light gray and light greenish gray. Ostracods and volcanic glass are rare "Zero" section (27cm) of some lithology also present. X-ray Mineralogy (bulk) Calc. 100 Amorph. 32.3	*Coccolithus pelagicus, C. eopelagicus, Cyclococcolithus leptoporus, Coronocyclus nitescens, Helicopontosphaera* cf.*H. kamptneri, Discolithina* sp. *Thoracosphaera* sp., *Discoaster deflandrei, Sphenolithus heteromorphus, Helicopontosphaera parallela*		
2	2		F N R,F		*Praeorb. glomerosa circularis, G. dehiscens, G. baroemoenensis, G. praescitula, G. parabulloides, G. triloba, G. sicana* Radiolarians common. *Lithopera renzae, Cyrtocapsella tetrapera* abundant, *C. cornuta, Stichocorys delmontensis, Calocyclas margatensis.* Fauna similar to above; *O. universa* Flora similar to above. Radiolarians common. As above plus *Lithopera neotera.*		
3	3		R,F N		Fauna similar to above; top of *Praeorb. glomerosa glomerosa* Radiolarians as above plus *Stichocorys armata.*		
4	3		F	5B 9/1	Fauna similar to above; plus top *praeorb glomerosa curva;* first *Orb. suturalis* Flora similar to above	N9	
5	4		F R N		Fauna similar to above; first occurr. *P. glomerosa circularis* Fauna similar to above; no *Orbulina* Radiolarians rare, as above. Flora similar to above	*Dorcadospyris alata* *Sphenolithus heteromorphus?*	EARLY MIDDLE MIOCENE
6	4		F		Fauna similar to above	*Helicopontosphaera ampliaperta?*	
7	5		N,F F		Flora similar to above Fauna similar to above First *Praeorb. glomerosa glomerosa*	N8	
8	6		CC F N R GZ XM F		Fauna similar to above Flora similar to above Radiolarians rare, as above Fauna as above Core Catcher: Radiolarians abundant. *L. renzae* abundant, *L. neotera, Cyclampterium (?) tanythorax, C.(?) leptetrum,* plus above spp. Flora similar to above. *P. glomerosa curva, G. triloba, G. sicana, G. praebulloides G. dehiscens, G. altispira, G. baroemoenensis, Sph. seminulina*		
	CC		R N F				

HOLE 116

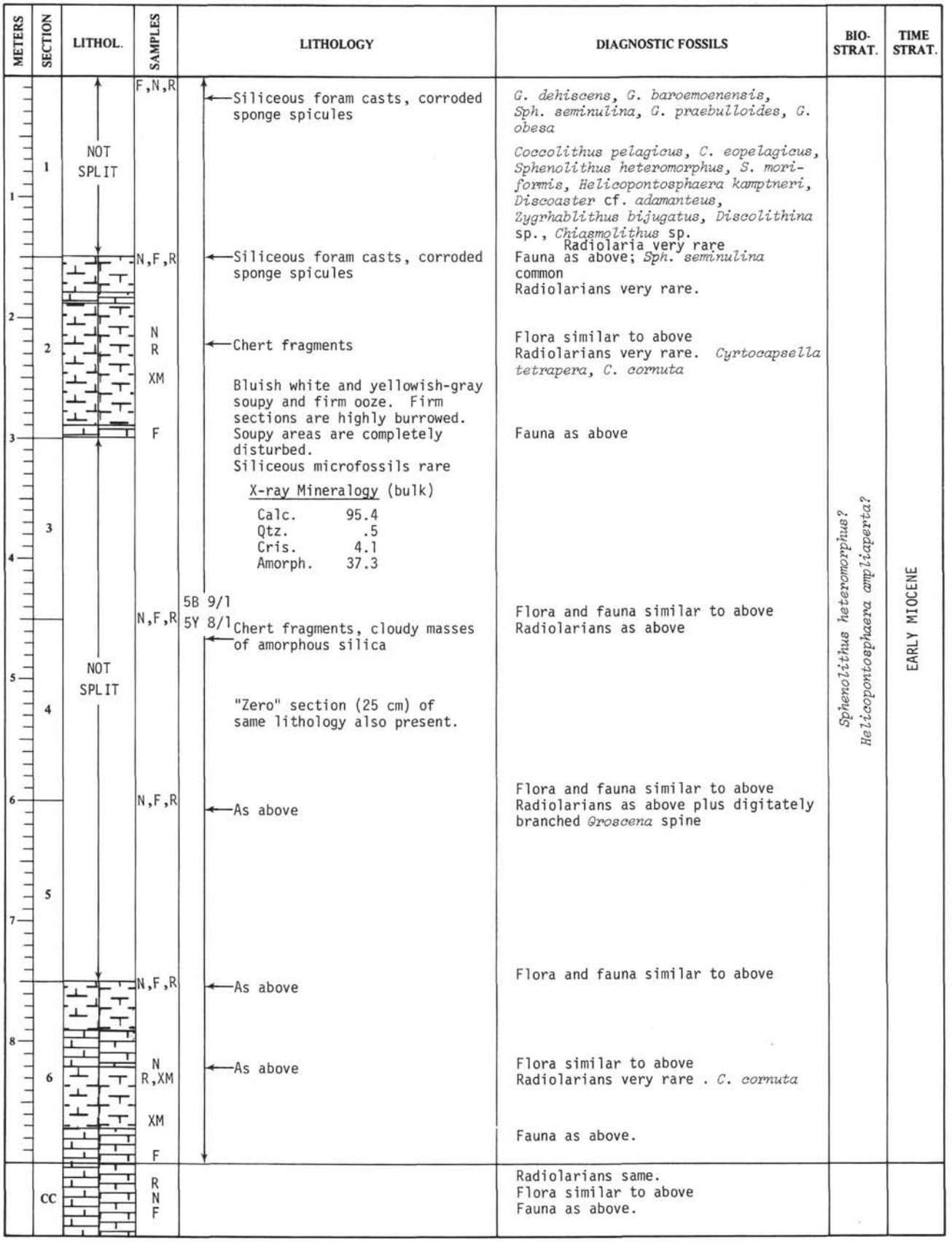
CORE 11



†Adjusted data, see Chapter 2

HOLE 116 559 TO 568 m

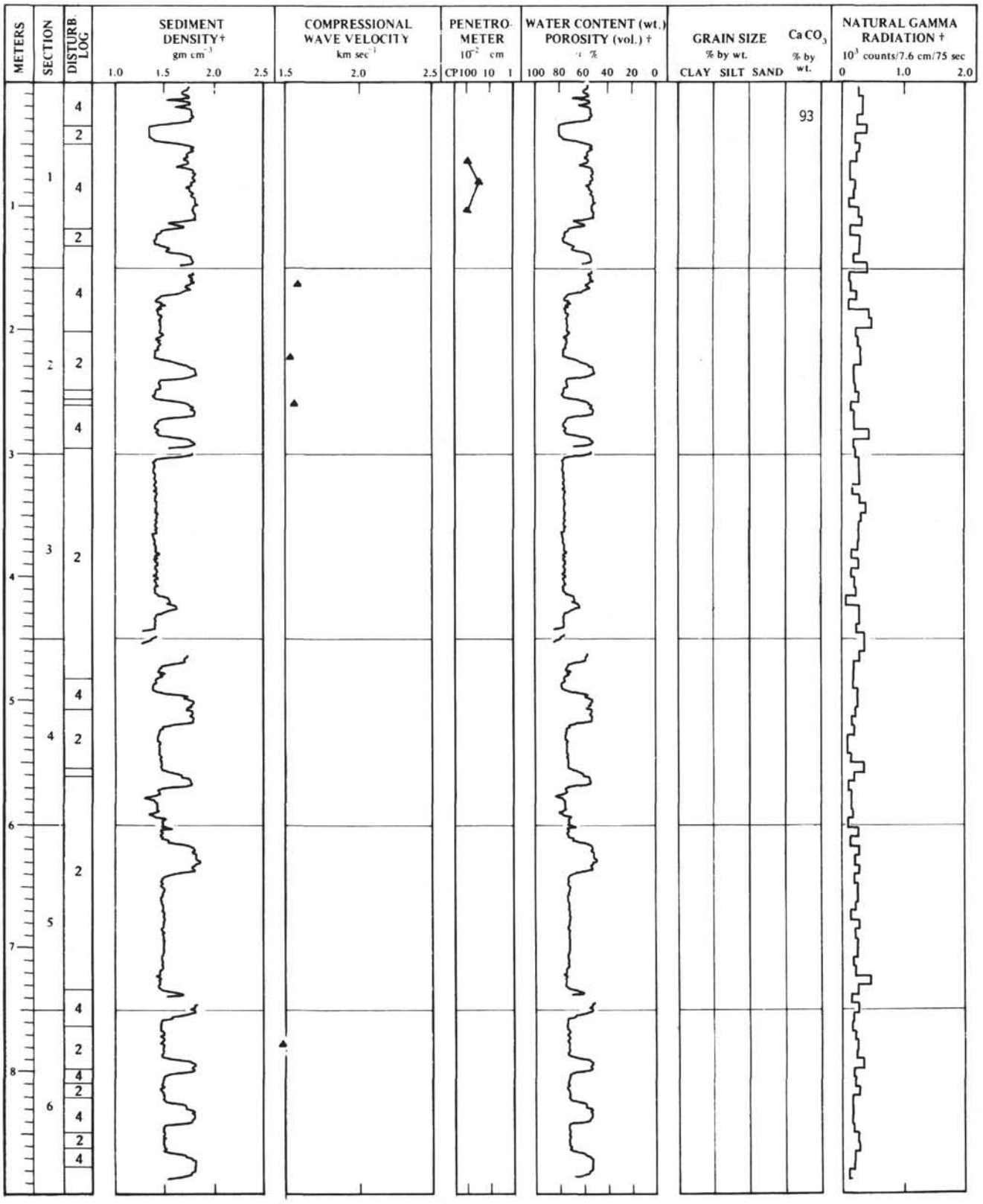
CORE 11



METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NOT SPLIT	F,N,R	←Siliceous foram casts, corroded sponge spicules	*G. dehiscens, G. baroemoenensis, Sph. seminulina, G. praebulloides, G. obesa*	*Sphenolithus heteromorphus?* *Helicopontosphaera ampliaperta?*	EARLY MIOCENE
					Coccolithus pelagicus, C. eopelagicus, Sphenolithus heteromorphus, S. moriformis, Helicopontosphaera kamptneri, Discoaster cf. *adamanteus, Zygrhablithus bijugatus, Discolithina* sp., *Chiasmolithus* sp. Radiolaria very rare		
2			N,F,R	←Siliceous foram casts, corroded sponge spicules	Fauna as above; *Sph. seminulina* common Radiolarians very rare.		
	2		N R	←Chert fragments	Flora similar to above Radiolarians very rare. *Cyrtocapsella tetrapera, C. cornuta*		
3			XM	Bluish white and yellowish-gray soupy and firm ooze. Firm sections are highly burrowed.			
			F	Soupy areas are completely disturbed. Siliceous microfossils rare	Fauna as above		
4	3			X-ray Mineralogy (bulk) Calc. 95.4 Qtz. .5 Cris. 4.1 Amorph. 37.3			
			5B 9/1 N,F,R 5Y 8/1	Chert fragments, cloudy masses of amorphous silica	Flora and fauna similar to above Radiolarians as above		
5	4	NOT SPLIT		"Zero" section (25 cm) of same lithology also present.			
6			N,F,R	←As above	Flora and fauna similar to above Radiolarians as above plus digitately branched *Groscena* spine		
7	5						
			N,F,R	←As above	Flora and fauna similar to above		
8	6		N R,XM	←As above	Flora similar to above Radiolarians very rare . *C. cornuta*		
			XM				
			F		Fauna as above.		
	CC		R N F		Radiolarians same. Flora similar to above Fauna as above.		

HOLE 116

CORE 12



†Adjusted data, see Chapter 2

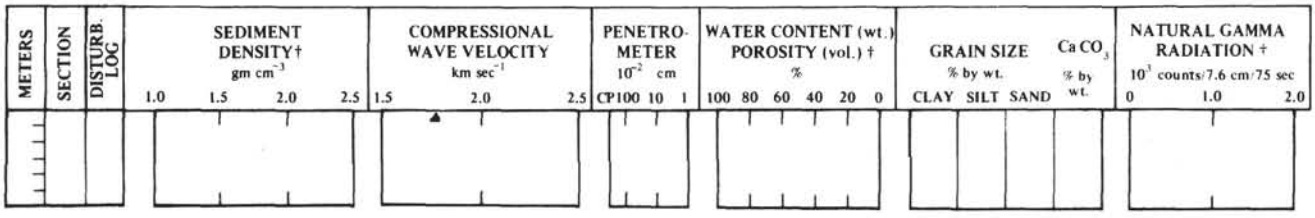
HOLE 116 599 TO 608 m

CORE 12

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	EMPTY	XM CC R N GZ N XM F	Alternating layers of firm and soupy bluish white foram-nannofossil ooze, slightly mottled medium light gray and light olive gray. Pyrite occurs as rare, isolated blebs. "Zero" section (28 cm) of same lithology also present. X-ray Mineralogy (bulk) Calc. 98.9 Mont. 1.1 Amorph. 29.7	Radiolarians rare. *Cyrtocapsella tetrapera, C. cornuta, C. japonica, Stichocorys delmontensis, Calocyclas margatensis. Coccolithus pelagicus, C. eopelagicus, Cyclococcolithus neogammation, Reticulofenestra* sp. *Sphenolithus moriformis, S.* cf. *S. heteromorphus Helicopontosphaera* cf. *H. parallela, Discoaster* sp., *Sphenolithus* cf. *S.* belemnos, *Coronocyclus nitescens G. dehiscens, G. baroemoenensis, Sph. seminulina, G. suteri, Gl. birnageae, G. semivera*	*Calocycletta virginis* *Sphenolithus belemnos?* N7	MIOCENE
2	2	EMPTY	R		Radiolarians common, as above.		
3			F		Fauna as above		
4	3		N R		Flora similar to above Radiolarians rare, as above plus *Carpocanopsis bramlettei*		
			F	5B 9/1 N6 5Y 6/1	Fauna as above		
5	4		N R		Flora similar to above Radiolarians same as above.		
6			F		Fauna as above, including *G. birnageae, G. semivera*		
7	5	NOT SPLIT					
			N,F,R		Flora and fauna similar to above Radiolarians common, as above		
8	6		N R F		Flora similar to above Radiolarians rare, as above Fauna as above Flora and fauna similar to above. Radiolarians abundant. *Lychnocanium bipes, Cyclampterium (?) pegetrum, Cyrtocapsella tetrapera* abundant, *C. cornuta* common, *C. japonica, Cyclampterium (?) leptetrum,* plus fossils as above.		
	CC		R N F				

HOLE 116

CORE 13



†Adjusted data, see Chapter 2

HOLE 116 649 TO 653 m

CORE 13

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
	CC		F N R	5B 9/1 Core catcher (11 cm) only of slightly burrowed, firm white chalk.	Core Catcher: *Globoquadrina* cf. *dehiscens, G-ita. dissimilis, G. suteri* *Coccolithus pelagicus, C. eopelagicus Cyclococcolithus neogammation, Discoaster* sp. *Sphenolithus moriformis, Thoracosphaera* sp., *Helicopontosphaera* cf. *H. parallela* Radiolarians abundant. *Dorcadospyris simplex, Stichocorys delmontensis, Cyrtocapsella cornuta, C. tetrapera, Calocyclas margatensis, Cyclampterium (?)* sp. cf. *C. (?) milowi*	*Calocycletta virginis*	EARLY MIOCENE

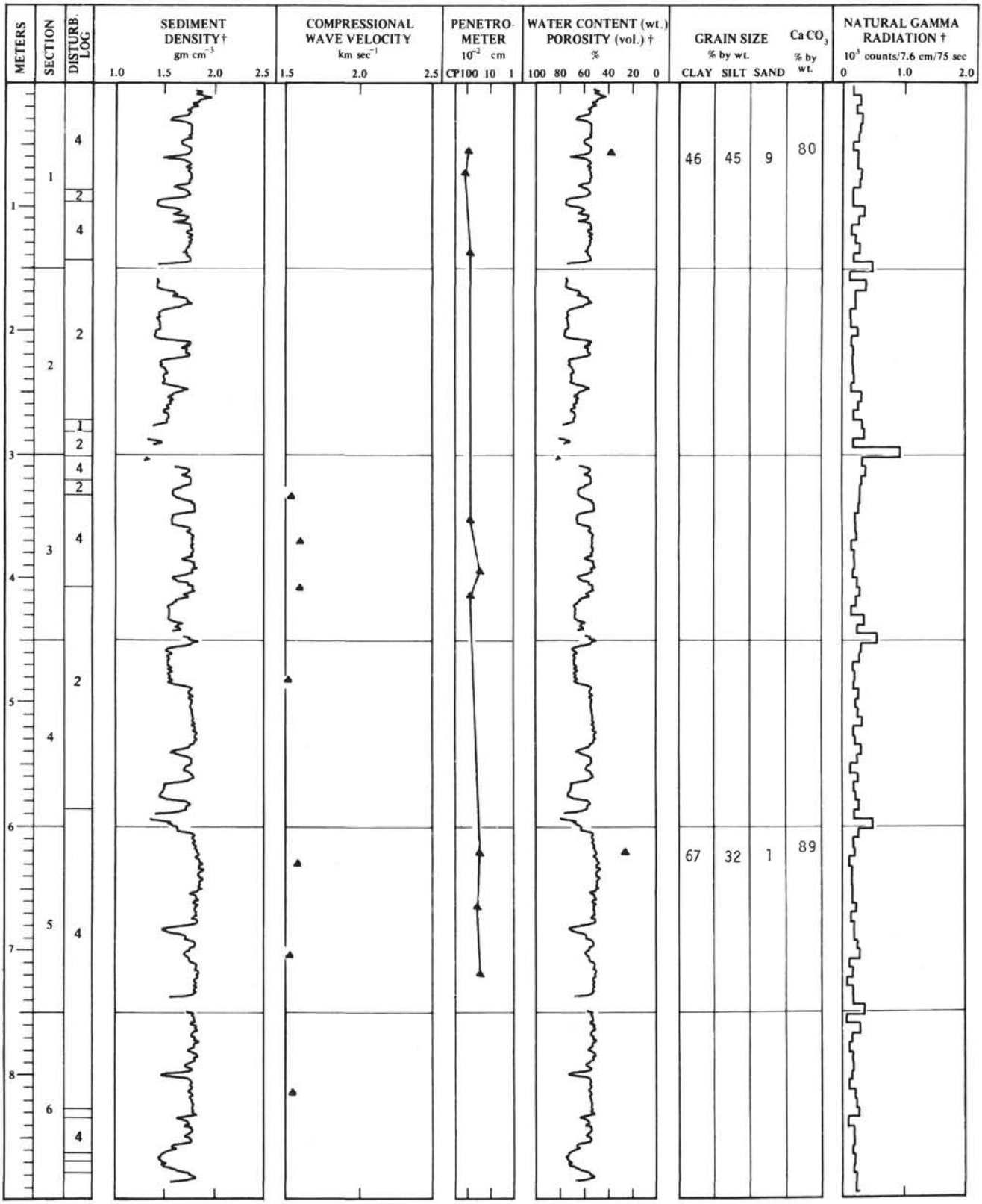
HOLE 116 653 TO 662 m

CORE 14

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
	CC		F, XM N R	5B 9/1 Core catcher (11 cm) only of white foram-nannofossil ooze	Small globigerinids and globoquadrinids *Coccolithus pelagicus, Cyclococcolithus neogammation, Discoaster* sp. *Sphenolithus sp. Zygrhablithus* cf. *bijugatus* Radiolarians common. *Dorcadospyris ateuchus, D. simplex, Cannartus prismaticus, Cyrtocapsella tetrapera, C. cornuta, Stichocorys delmontensis, Calocyclas margatensis, Cyclampterium (?)* sp. cf. *C. (?) milowi*	*Calocycletta virginis*	EARLY MIOCENE

HOLE 116

CORE 15



† Adjusted data, see Chapter 2

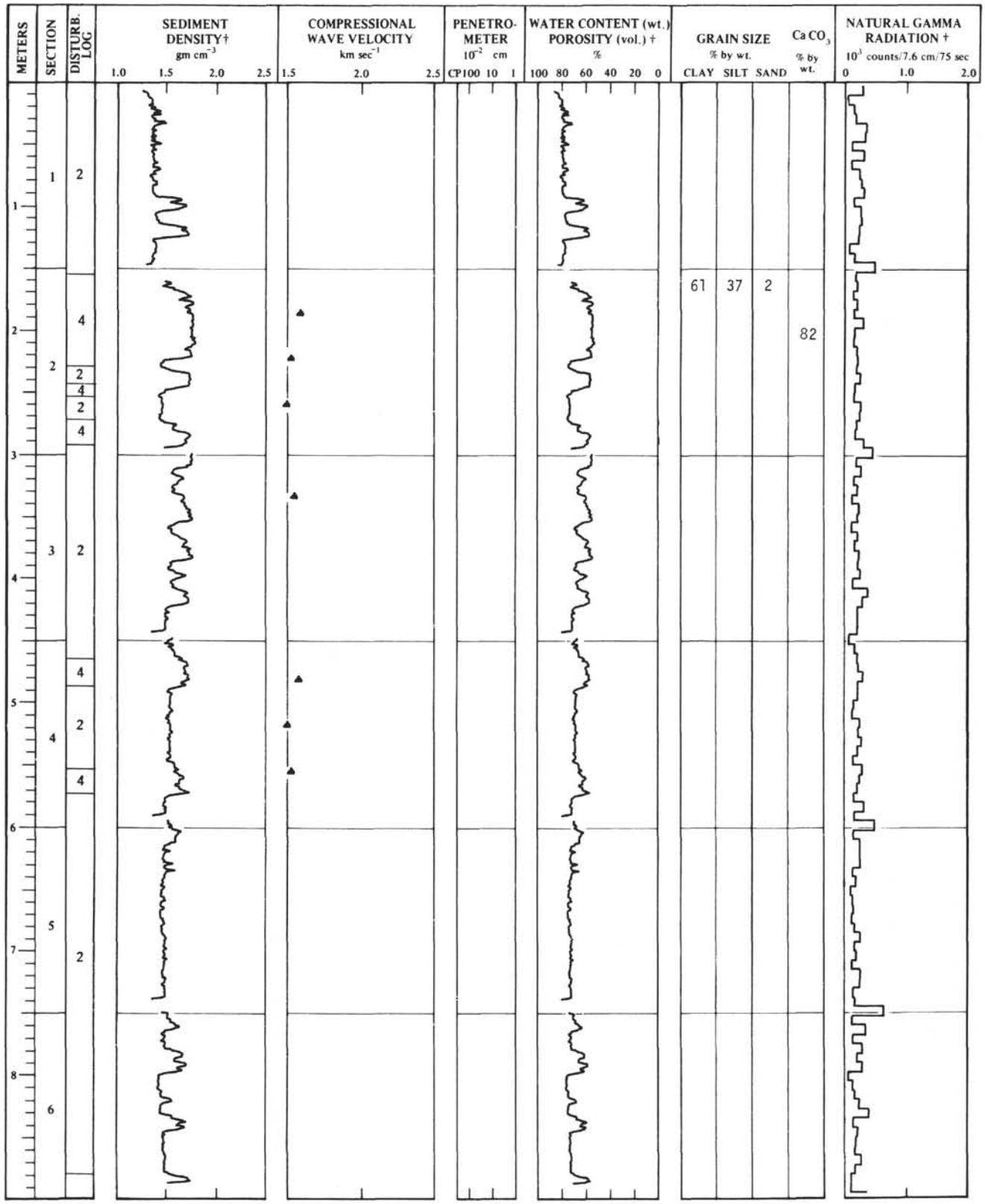
HOLE 116 662 TO 671 m

CORE 15

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N,R CC XM N R GZ,XM F	Bluish white firm and soft ooze with rock fragments (basalt, chert, quartzite) scattered throughout first three sections. Section 5 is slightly mottled light gray. All soupy areas completely disturbed. X-ray Mineralogy (bulk) Calc. 98.7 Qtz. .1 Mica 1.2 Amorph. 30.7 "Zero" section (28 cm) of some lithology also present.	*Coccolithus pelagicus, Cyclococcolithus neogammation, Sphenolithus* sp., *Zygrhablithus* cf. *bijugatus, Helicopontosphaera* cf. *parallela, Discoaster adamanteus, D.* sp., *Chiasmolithus sp., Triquetrorhabdulus* cf. carinatus Radiolarians rare to common. *Lychnocanium bipes, Cyrtocapsella tetrapera, C. cornuta, C. japonica, Stichocorys delmontensis, S. armata, Calocyclas margatensis.* *Globoquadrina dehiscens, G. baroemoenensis, G. dissimilis*	*Calocycletta virginis* *Triquetrorhabdulus carinatus ?* N6	EARLY MIOCENE
2	2	NOT SPLIT					
3	3		XM N R F	5B 9/1	Flora similar to above Radiolarians common. As above plus *Dorcadospyris simplex, Stichocorys diploconus, Theocorys spongoconum.* Fauna as above		
4							
5	4	NOT SPLIT					
6	5		CC GZ N R XM F	5B 9/1 N7	Flora similar to above Radiolarians rare. *Lychnocanium bipes, Dorcadospyris simplex, Stichocorys delmontensis, Cyrtocapsella tetrapera, C. cornuta.* *G. baroemonenensis, G. dissimilis*		
7							
8	6		N R F	5B 9/1	Flora similar to above Radiolarians as above. Fauna as above plus *G. praedehiscens* (top)		
	CC		R,XM N F		Radiolarians common, as above. *Cyclampterium (?)* sp. cf. *C. (?) milowi* Flora similar to above Fauna as above		

HOLE 116

CORE 16



†Adjusted data, see Chapter 2

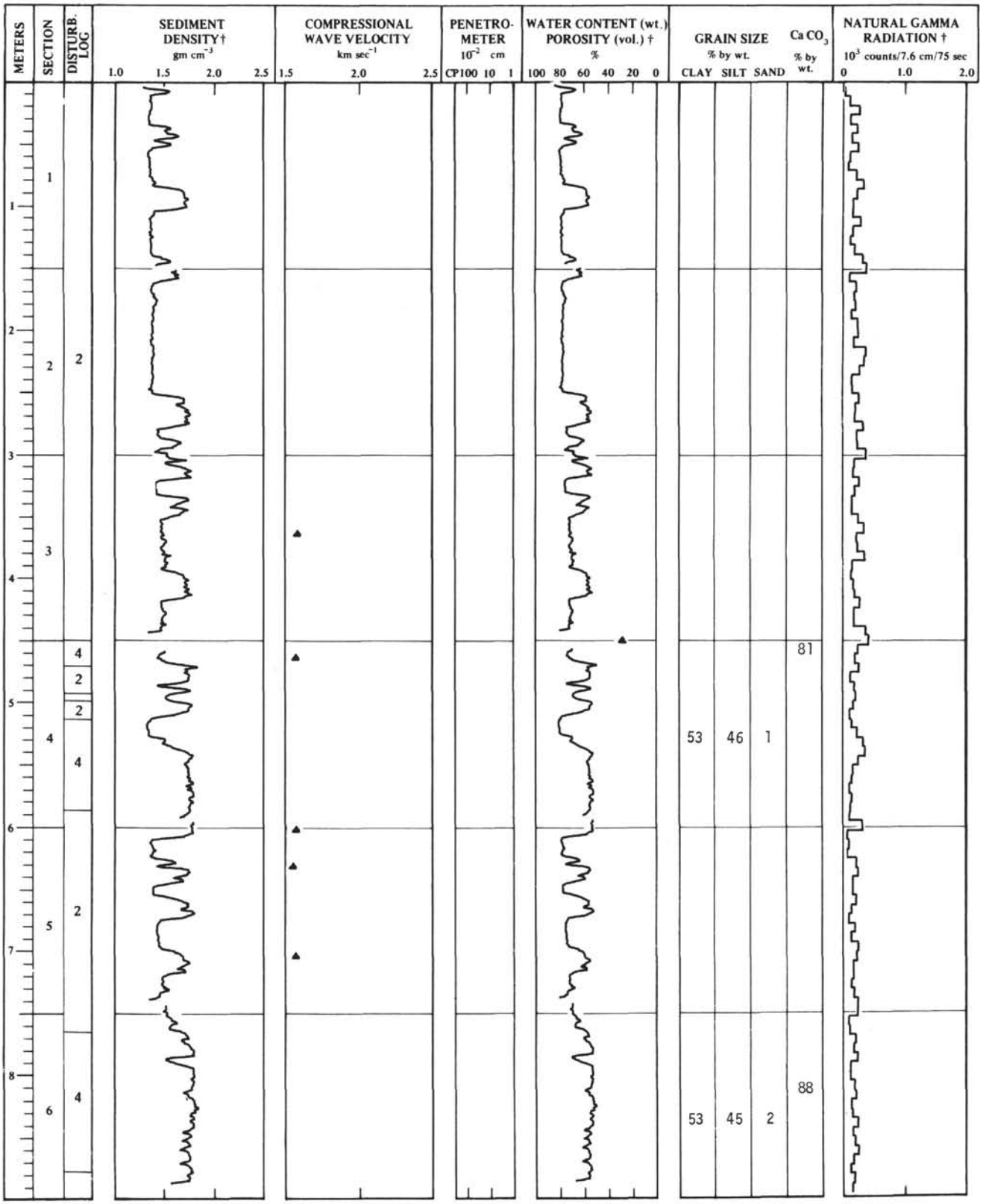
HOLE 116 671 TO 680 m

CORE 16

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NOT SPLIT			*Coccolithus pelagicus, Cyclococcolithus neogammation, Thoracosphaera* sp., *Discoaster* sp., *Sphenolithus* sp. *Chiasmolithus* sp. *Zygrhablithus* cf. *bijugatus, Triquetrorhabdulus* cf. *carinatus* Radiolarians rare. *Dorcadospyris simplex, Stichocorys diploconus, Cyrtocapsella tetrapera, C. cornuta*	*Calocycletta virginis* *Triquetrorhabdulus carinatus*? N6	EARLY MIOCENE
2		EMPTY					
	2		XM N XM,R F	Soupy gray and greenish gray foram-nannofossil ooze. Core is completely disturbed and contains several hard chalky lumps. Rock fragments, pyrite aggregates & pyritized worm burrows also occur. "Zero" section (29 cm) of same lithology also present. X-ray Mineralogy (bulk) Calc. 100 Amorph. 36.5	Flora similar to above Radiolarians as above plus *Theocyrtis annosa, Calocyclas margatensis* *G. baroemoenensis, G. praedehiscens, G. venezuelana, G. dissimilis*		
3	3	NOT SPLIT					
4			5GY 8/1 N8 5G 9/1				
	4		N,R N,R F		Flora similar to above Radiolarians abundant. *Cyrtocapsella cornuta, C. tetrapera, Lychnocanium bipes, Stichocorys delmontensis, S. armata, Calocyclas margatensis* Flora similar to above Radiolarians rare. *C. tetrapera, C. cornuta, L. bipes, Cyclampterium (?)* sp. cf. *C. (?) milowi* Fauna as above; *G. praedehiscens* common		
5	5	NOT SPLIT					
6	6						
7							
8	CC		F N R		*G. praedehiscens, G. baroemoenensis, G. venezuelana, G. dissimilis* Flora similar to above. Radiolarians abundant. *Cannartus prismaticus* plus assemblage similar to above.		

HOLE 116

CORE 17



†Adjusted data, see Chapter 2

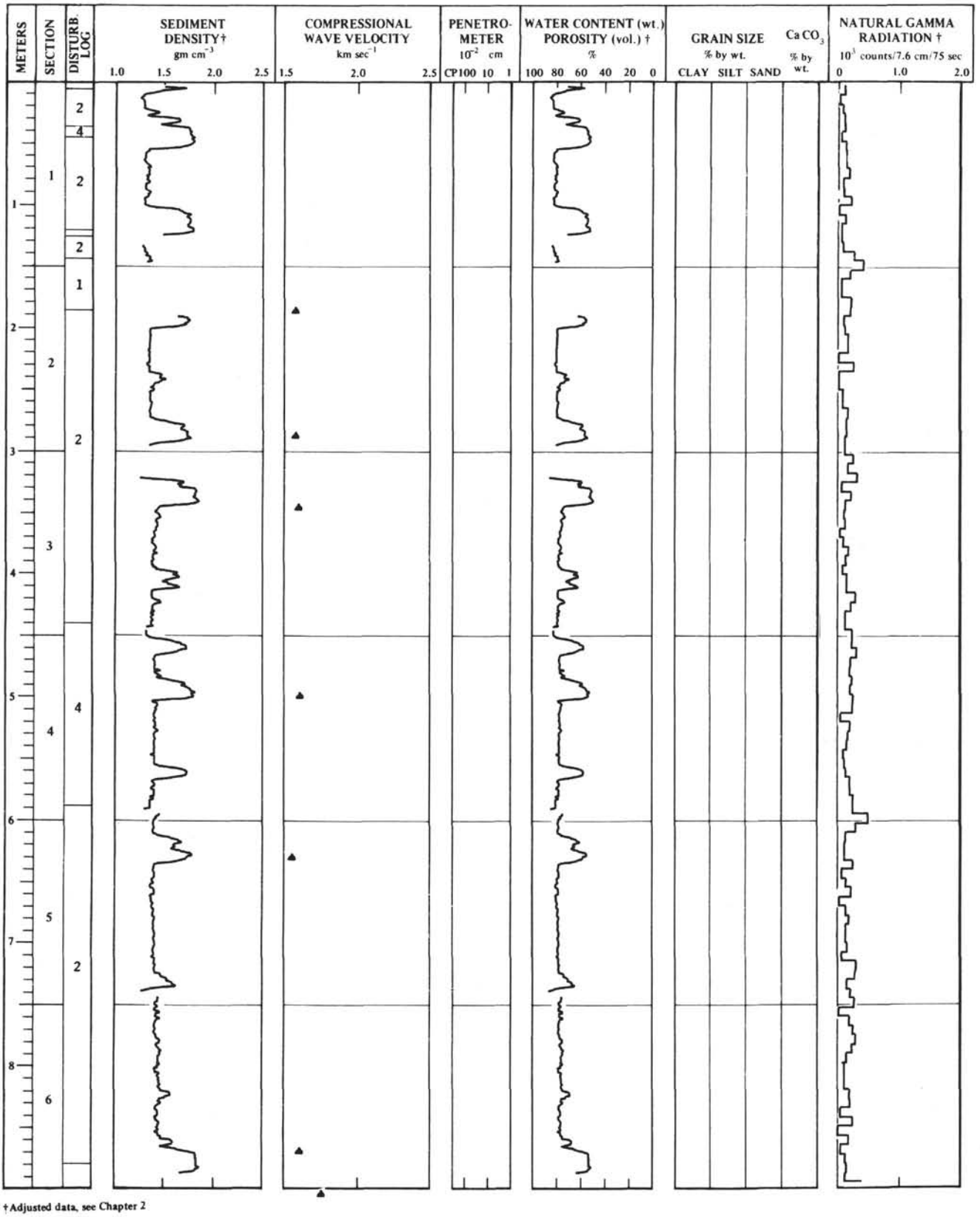
HOLE 116 680 TO 689 m

CORE 17

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N,R		*Coccolithus pelagicus, C. eopelagicus, Reticulofenestra* sp., *Zygrhablithus* cf. *bijugatus, Triquetrorhabdulus* cf. *carinatus, Sphenolithus* sp., *Helicopontosphaera parallela, Chiasmolithus* sp. Radiolarians abundant. *Lychnocanium bipes, Cyrtocapsella cornuta, C. tetrapera, Calocyclas margatensis*	*Calocycletta virginis* / *Triquetrorhabdulus carinatus?* N5 - N6	EARLY MIOCENE
2	2	NOT SPLIT					
3	3						
4				5B 9/1			
5	4		N,R XM N R XM	Bluish white soupy foram-nannofossil ooze. Ostracods, fish debris, and volcanic glass occur rarely. Entire core is disturbed. Zero section (27 cm) of same lithology also present. X-ray Mineralogy (bulk) Calc. 100 Amorph. 31.3	Flora similar to above Radiolarians rare. *Cannartus prismaticus, Cyrtocapsella tetrapera, C. cornuta, Calocyclas margatensis* Flora similar to above Radiolarians common. *Lychnocanium bipes, Cyrtocapsella tetrapera, C. cornuta, Cyclampterium (?)* sp. cf. *C. (?) milowi* *G. praedehiscens, G. venezuelana, G. baroemoenensis, G. dehiscens, G. praebulloides*		
6			F				
7	5	NOT SPLIT					
8	6		N R XM F		Flora similar to above Radiolarians rare. Assemblage similar to above. Fauna as above Flora & fauna similar to above Radiolarians common. *Dorcadospyris simplex, (?) D. ateuchus, Lychnocanium bipes, Cyclampterium (?) pegetrum, Cyrtocapsella tetrapera, C. cornuta, Theocorys spongoconum.*		
	CC		N F R				

HOLE 116

CORE 18



†Adjusted data, see Chapter 2

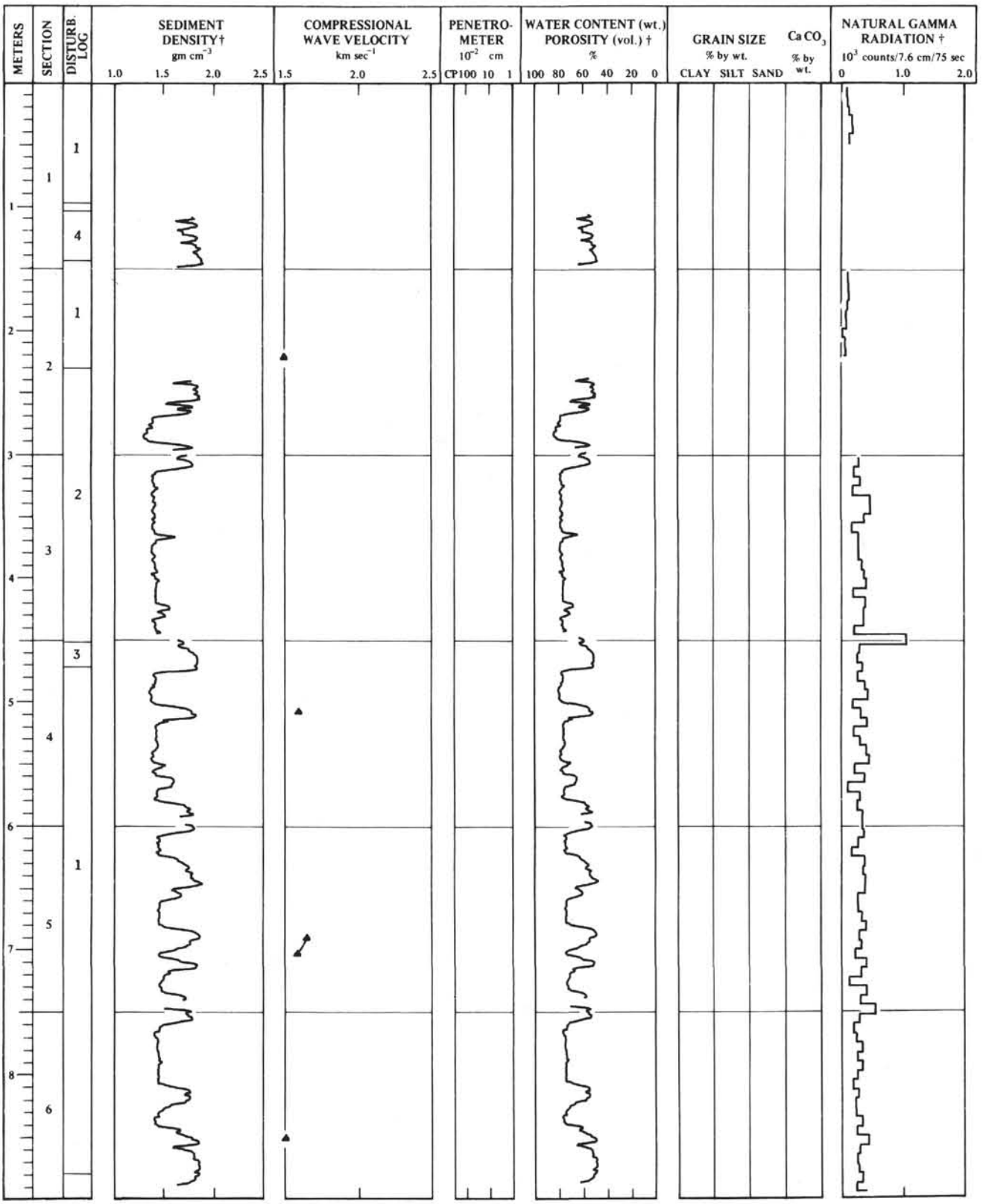
HOLE 116 689 TO 698 m

CORE 18

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N,R		*Coccolithus pelagicus, Cyclococcolithus neogammation, Discolithina* sp., *Helicopontosphaera parallela, Chiasmolithus* sp., *Triquetrorhabdulus* cf. *carinatus, Zygrhablithus* cf. *bijugatus, Reticulofenestra* sp., Radiolarians common. *Dorcadospyris simplex, Cannartus prismaticus, Cyrtocapsella cornuta, C. tetrapera, Cyclampterium (?)* sp. cf., *C. (?) milowi, Calocyclas margatensis*	*Calocycletta virginis* *Triquetrorhabdulus carinatus?* N5-N6	EARLY MIOCENE
2	2	NOT SPLIT					
3	3			5B 9/1			
4			N,R	Very soupy, bluish-white, foram-nannofossil ooze with minor quantities of volcanic glass, glauconite, and pyrite. Two large driekanter pebbles also present. Core is disturbed. "Zero" section (28 cm) of same lithology also present.	Flora similar to above Radiolarians rare. *Lychnocanium bipes, Cyrtocapsella cornuta, C. tetrapera, Calocyclas margatensis, Stichocorys delmontensis*		
5	4		R		Radiolarians rare.		
6			N,F		Flora similar to above *G. baroemoenensis, G. suteri, G. woodi*		
7	5	NOT SPLIT					
8	6				Radiolarians common. *Dorcadospyris ateuchus, D. simplex, Lychnocanium bipes, Calocyclas margatensis, Cyrtocapsella cornuta, C. tetrapera, Stichocorys delmontensis, Cyclampterium (?) leptetrum, C.* (?) sp. cf. *C. (?) milowi* Flora similar to above *G. praedehiscens, G. baroemoenensis, G. dissimilis*		
	CC		R N F				

HOLE 116

CORE 19



†Adjusted data, see Chapter 2

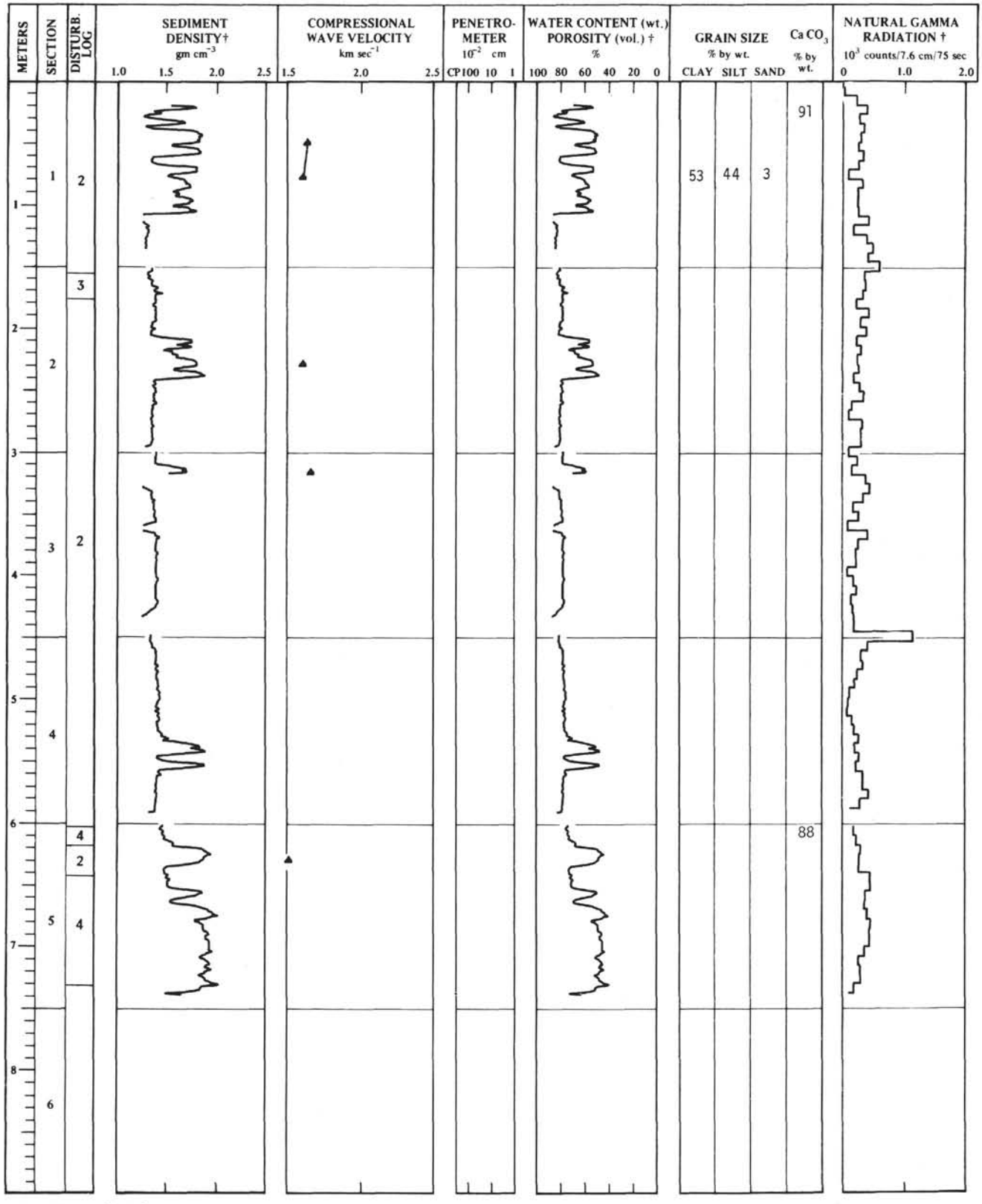
HOLE 116 698 TO 701 m

CORE 19

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NO CORE	R N	Alternating layers of soupy and firm bluish white foram-nannofossil chalk ooze with basalt pebble at bottom of section 1. Entire core is disturbed.	Radiolarians common. *Dorcadospyris ateuchus, D. simplex, Lychnocanium bipes, Cyrtocapsella cornuta, C. tetrapera, Calocyclas margatensis, Cyclampterium (?)* sp. cf. *C (?) milowi, Stichocorys delmontensis, (?) S. armata.* *Coccolithus pelagicus, C. eopelagicus, Cyclococcolithus neogammation, Helicopontosphaera parallela, Zygrhablithus* cf. *Z. bijugatus, Discolithina* sp., *Sphenolithus* sp., *Discoaster* sp., *Reticulofenestra* sp. *Triquetrorhabdulus* sp. Globoquadrinids, Cibicidids	*Calocycletta virginis*	LATE OLIGOCENE?
2	2		F XM N,R F	Basalt pebble	Flora similar to above Radiolarians rare. *G. baroemoenensis, G. suteri*		
3	3	NOT SPLIT					
4			N,R	5B 9/1	Flora similar to above, + *Coccolithus bisectus, Chiasmolithus* sp. Radiolarians very rare, as above.		
5	4		N,R		Flora similar to above Radiolarians very rare. *Carpocanopsis cingulatum* plus assemblage as above		
7	5	NOT SPLIT	F		Fauna as above		
8	6				Radiolarians abundant. (?) *Artophormis gracilis, Dorcadospyris ateuchus, D. simplex, Cannartus prismaticus, Cyclampterium* (?) *pegetrum, C.* (?) sp. cf. *C.* (?) *milowi, Carpocanopsis cingulatum, L. bipes, Crytocapsella cornuta, C. tetrapera* Flora similar to above *G. baroemoenensis, G. praedehiscens, G. suteri*		
	CC		R N F				

HOLE 116

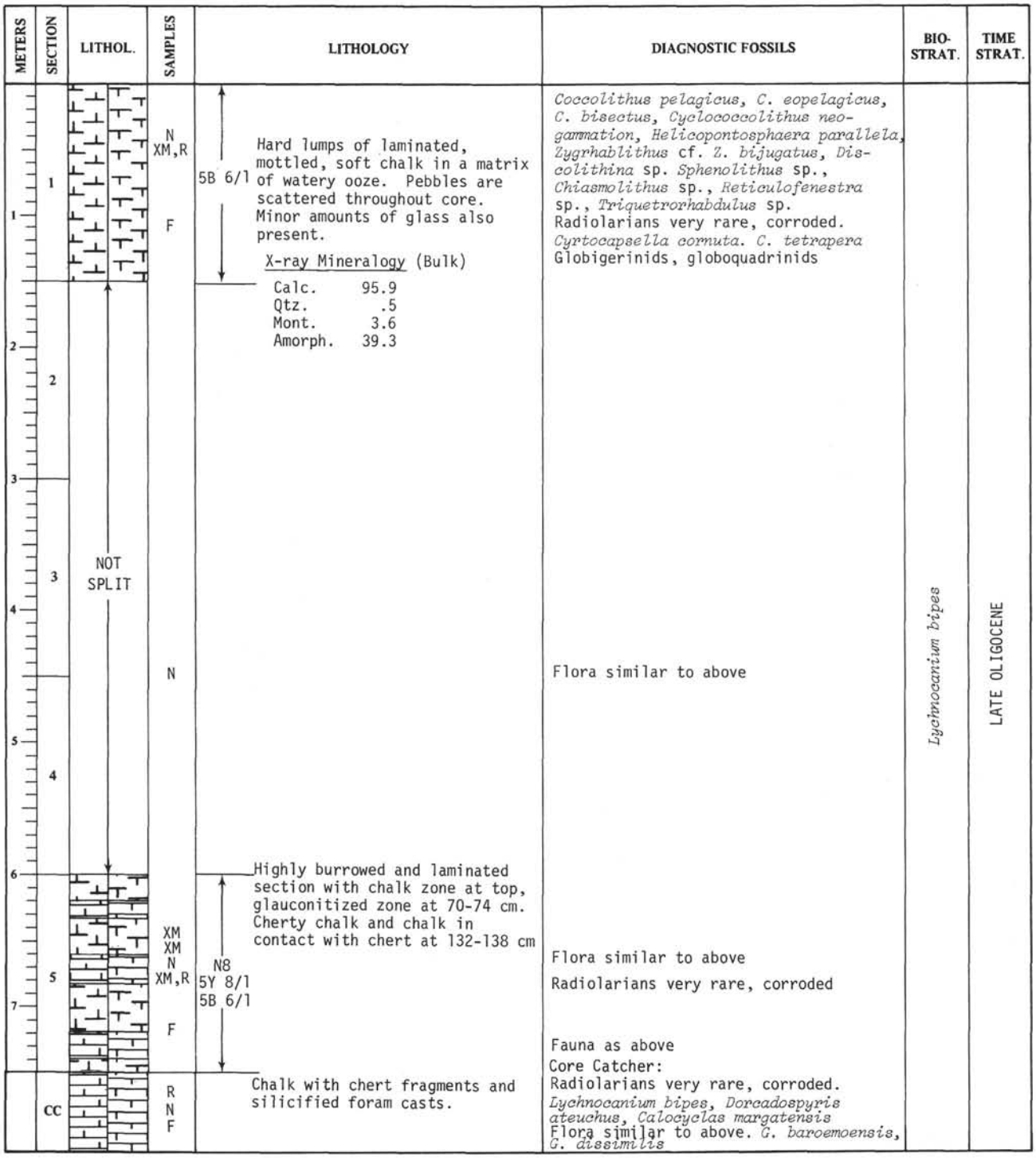
CORE 20



†Adjusted data, see Chapter 2

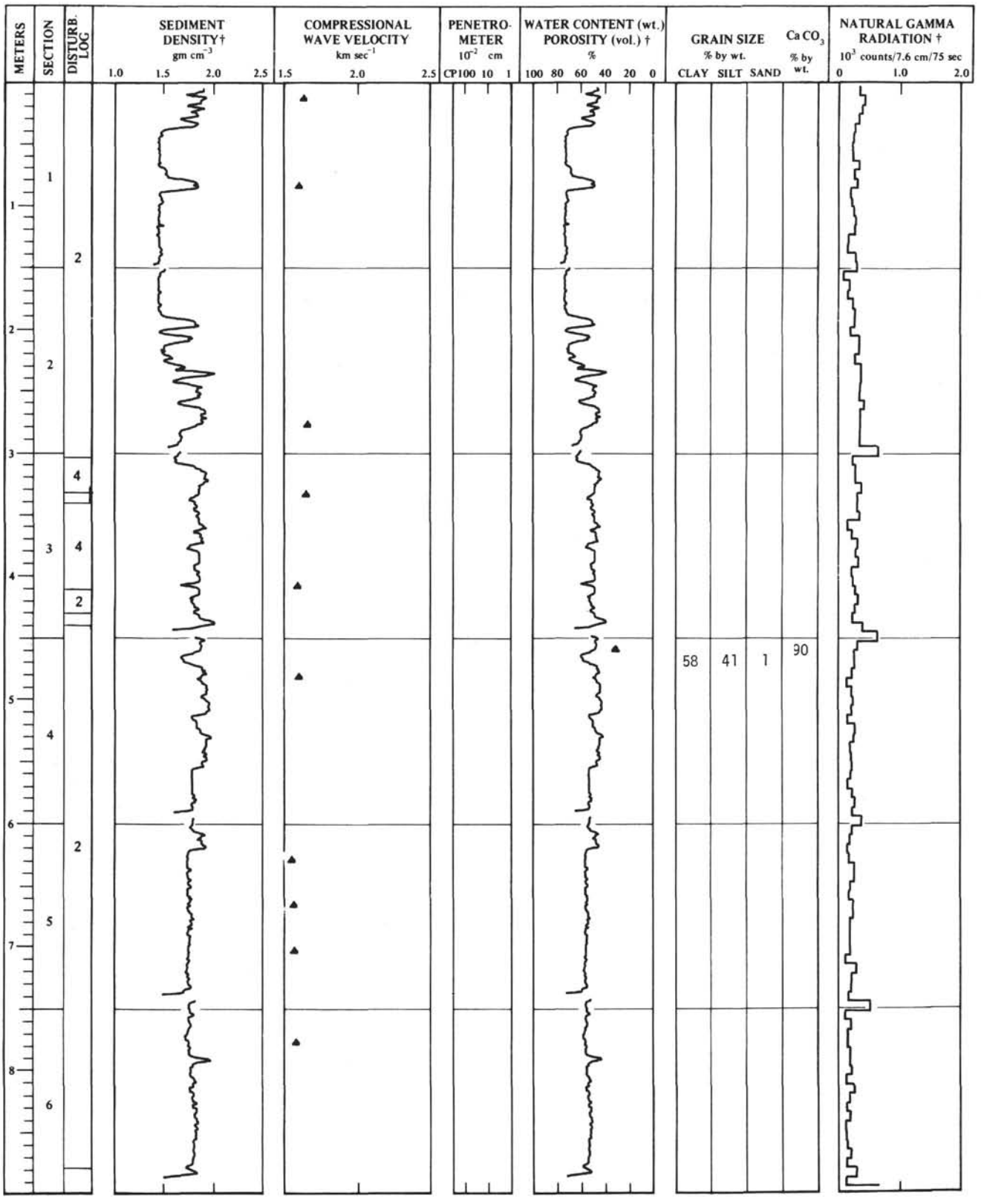
HOLE 116 701 TO 710 m

CORE 20



HOLE 116

CORE 21



†Adjusted data, see Chapter 2

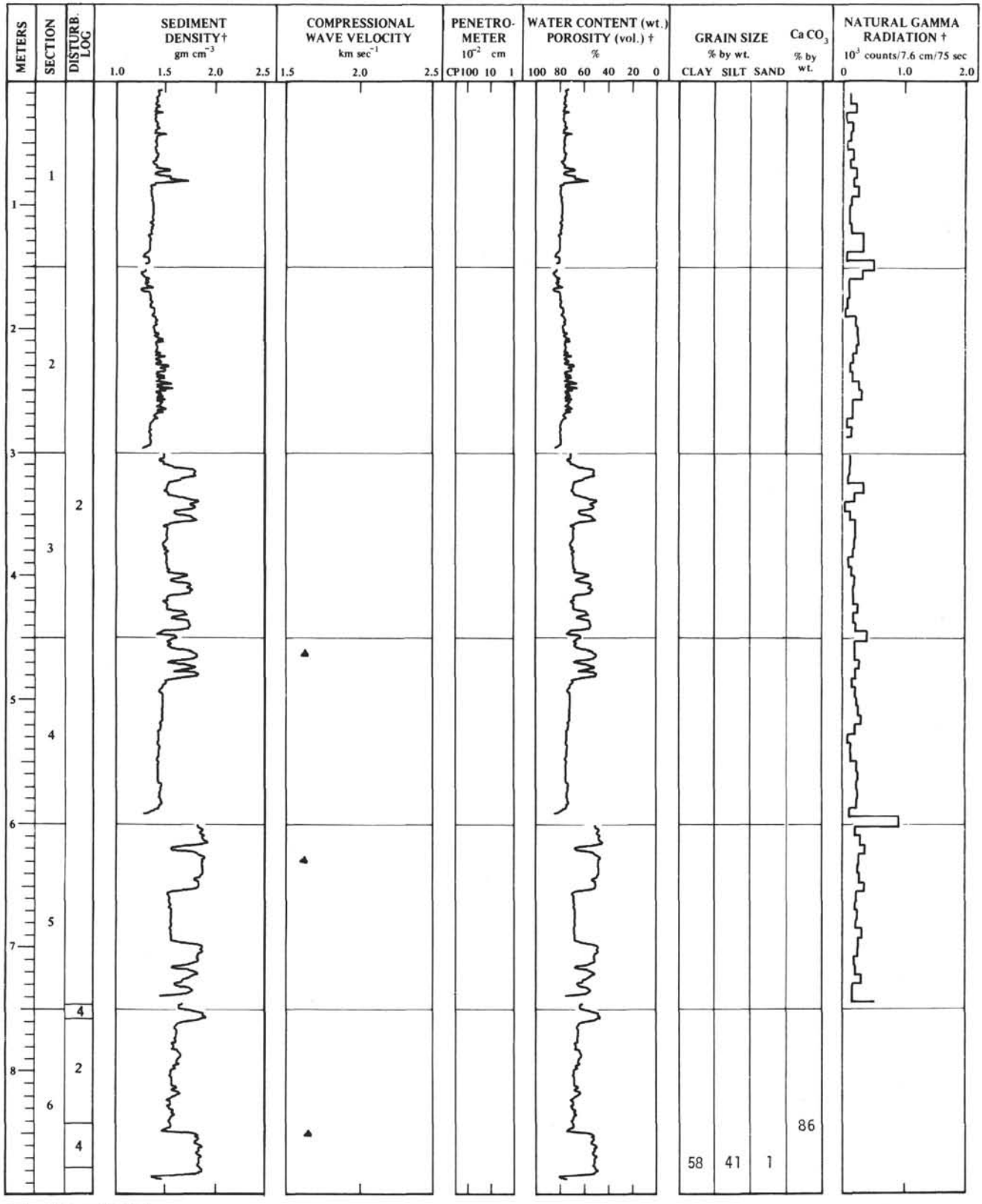
HOLE 116 710 TO 719 m

CORE 21

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NOT SPLIT	N, R		*Coccolithus pelagicus, C. eopelagicus, C. bisectus, Cyclococcolithus neogammation, Helicopontosphaera parallela, H.* cf. *truncata, Zygrhablithus* cf. *bijugatus, Discolithina* sp. *Sphenolithus* sp., *Chiasmolithus* sp. *Reticulofenestra* sp., *Discoaster* sp. *Thoracosphaera* sp. Radiolarians very rare, corroded		
2	2						
3	3		XM	Bluish-white foram-nanno-fossil ooze with hard chalk fragments. Lenticular anastomising lamination (flaser structure), pyrite laminae, and load casts are present in section 3			
4			N		Flora similar to above		
			N	X-ray mineralogy (bulk)	Flora similar to above		
			F	Calc. 70.1 Cris. 9.9 Amorph. 36.0	*G. baroemoenensis, G. venezuelana G. dissimilis, G. siakensis*		LATE OLIGOCENE?
5	4		R	"Zero" section (28 cm) of same lithology also present	One corroded radiolarian.		
			N, XM	5B 9/1	Flora similar to above		
6			F		Fauna as above		
7	5	NOT SPLIT					
8	6						
	CC		R N F	Chalk with chert fragments and silicified foram casts.	Two corroded radiolarians Flora similar to above Fauna as above		

HOLE 116

CORE 22



†Adjusted data, see Chapter 2

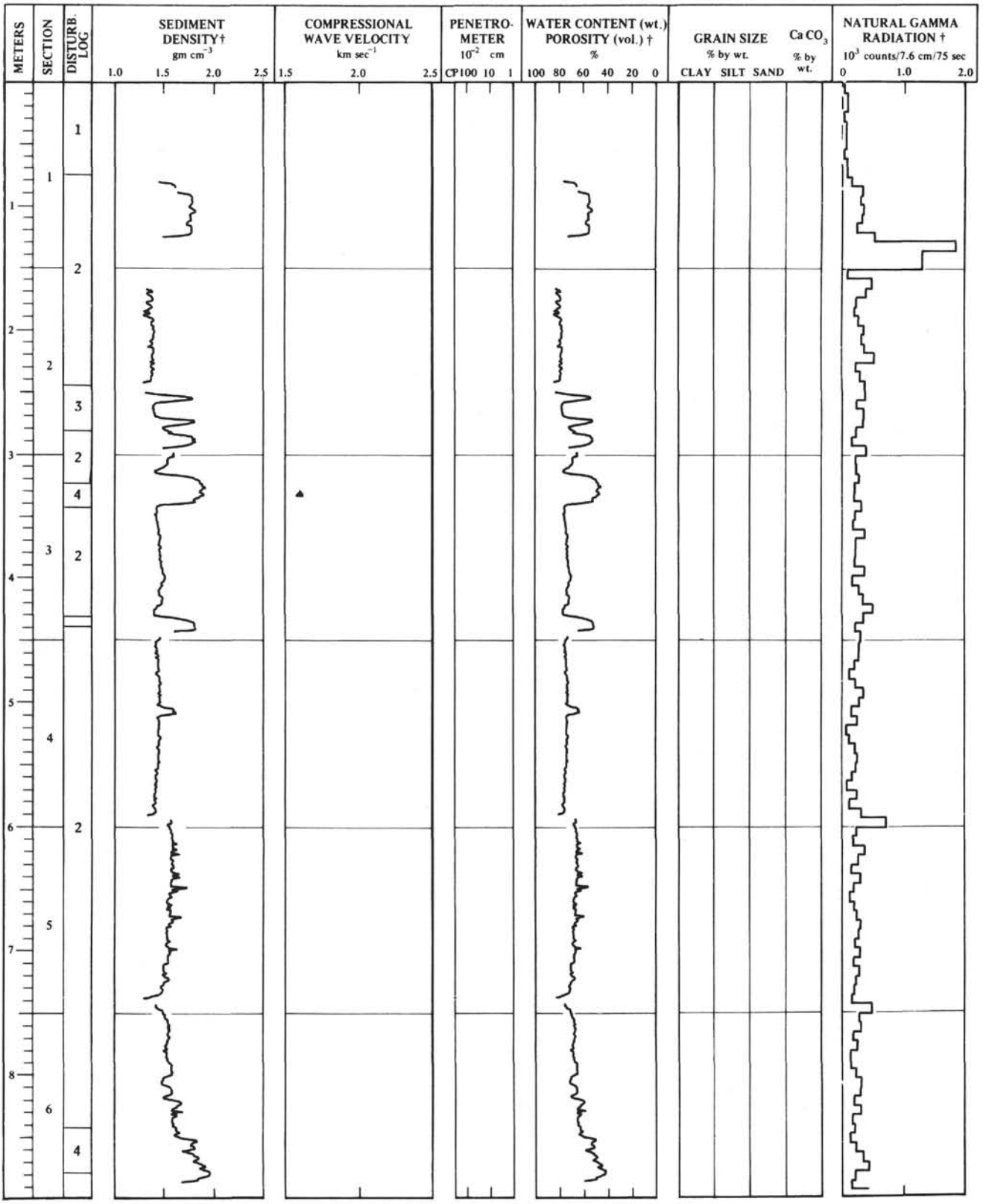
HOLE 116 719 TO 728 m

CORE 22

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NOT SPLIT	R		A few corroded radiolarians.		LATE OLIGOCENE
					Coccolithus pelagicus, C. eopelagicus, C. bisectus, Helicopontosphaera parallela, Zygrhablithus cf. *bijugatus, Cyclococcolithus neogammation, Discolithina* sp., *Chiasmolithus* sp., *Reticulofenestra* sp., *Thoracosphaera* sp.		
			N,F,R		A few corroded radiolarians.		
2	2			Unsplit sections examined at ends. Material consists of bluish white ooze with chert fragments scattered throughout.			
3			N,F,R	"Zero" section (28 cm) of same lithology also present. Entire core is disturbed.	Flora similar to above *G. praebulloides, G. dissimilis* No radiolarians.		
4	3						
			N,F,R	5BY 9/1	Flora and fauna similar to above No radiolarians.		
5	4						
6			N,F,R		Flora and fauna similar to above No radiolarians		
7	5						
			N,F, XM,R	Chalk and ooze. Chalk is mottled and contains a large pyrite patch.	Flora and fauna similar to above A few corroded radiolarians		
8	6			X-ray Mineralogy (bulk) Calc. 95.4 Qtz. .5 Cris. 3.0			
			N,XM		Flora similar to above *G. unicava, G. dissimilis, G. praedehiscens*		
			F				
	CC		R N	Same lithology as sec. 6.	A few corroded radiolarians. Flora similar to above.		

HOLE 116

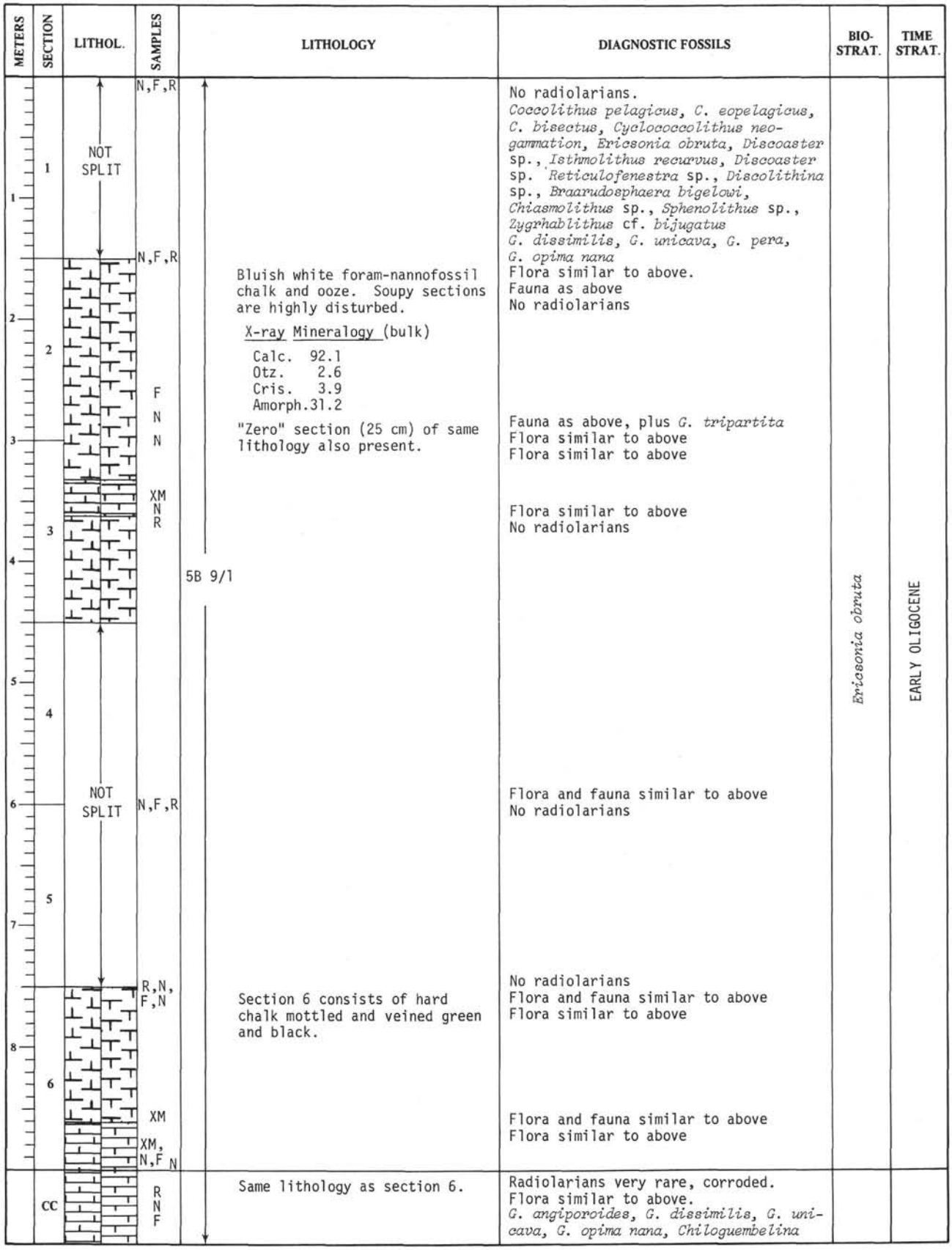
CORE 23



†Adjusted data, see Chapter 2

HOLE 116 750 TO 759 m

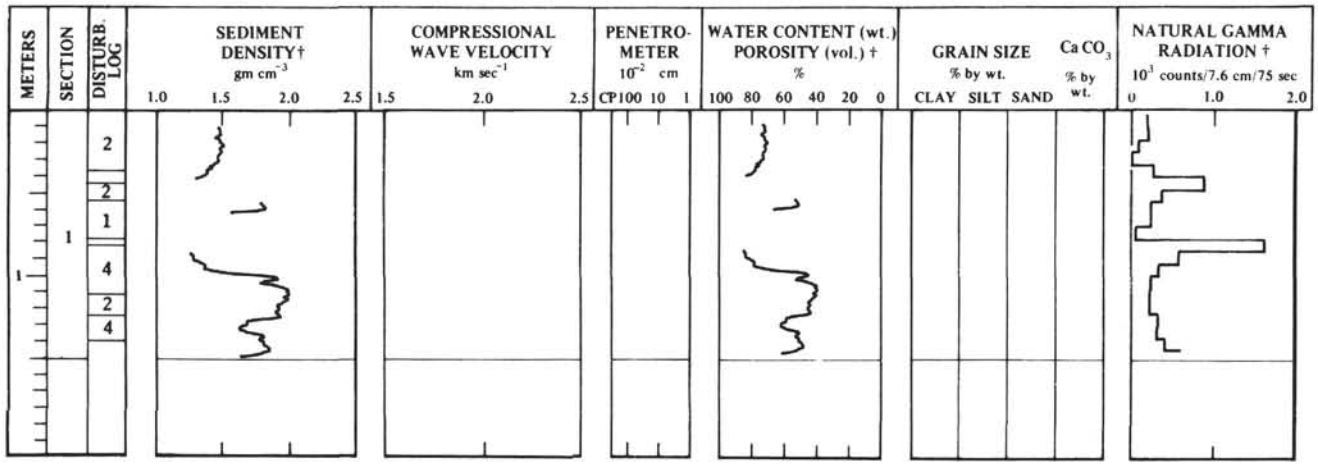
CORE 23



LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
	No radiolarians. *Coccolithus pelagicus, C. eopelagicus, C. bisectus, Cyclococcolithus neogammation, Ericsonia obruta, Discoaster* sp., *Isthmolithus recurvus, Discoaster* sp. *Reticulofenestra* sp., *Discolithina* sp., *Braarudosphaera bigelowi, Chiasmolithus* sp., *Sphenolithus* sp., *Zygrhablithus* cf. *bijugatus* *G. dissimilis, G. unicava, G. pera, G. opima nana*	*Ericsonia obruta*	EARLY OLIGOCENE
Bluish white foram-nannofossil chalk and ooze. Soupy sections are highly disturbed. X-ray Mineralogy (bulk) Calc. 92.1 Otz. 2.6 Cris. 3.9 Amorph.31.2	Flora similar to above. Fauna as above No radiolarians		
"Zero" section (25 cm) of same lithology also present.	Fauna as above, plus *G. tripartita* Flora similar to above Flora similar to above		
	Flora similar to above No radiolarians		
	Flora and fauna similar to above No radiolarians		
Section 6 consists of hard chalk mottled and veined green and black.	No radiolarians Flora and fauna similar to above Flora similar to above		
	Flora and fauna similar to above Flora similar to above		
Same lithology as section 6.	Radiolarians very rare, corroded. Flora similar to above. *G. angiporoides, G. dissimilis, G. unicava, G. opima nana, Chiloguembelina*		

HOLE 116

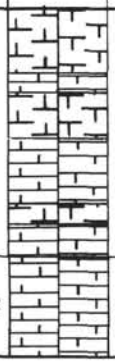
CORE 24



†Adjusted data, see Chapter 2

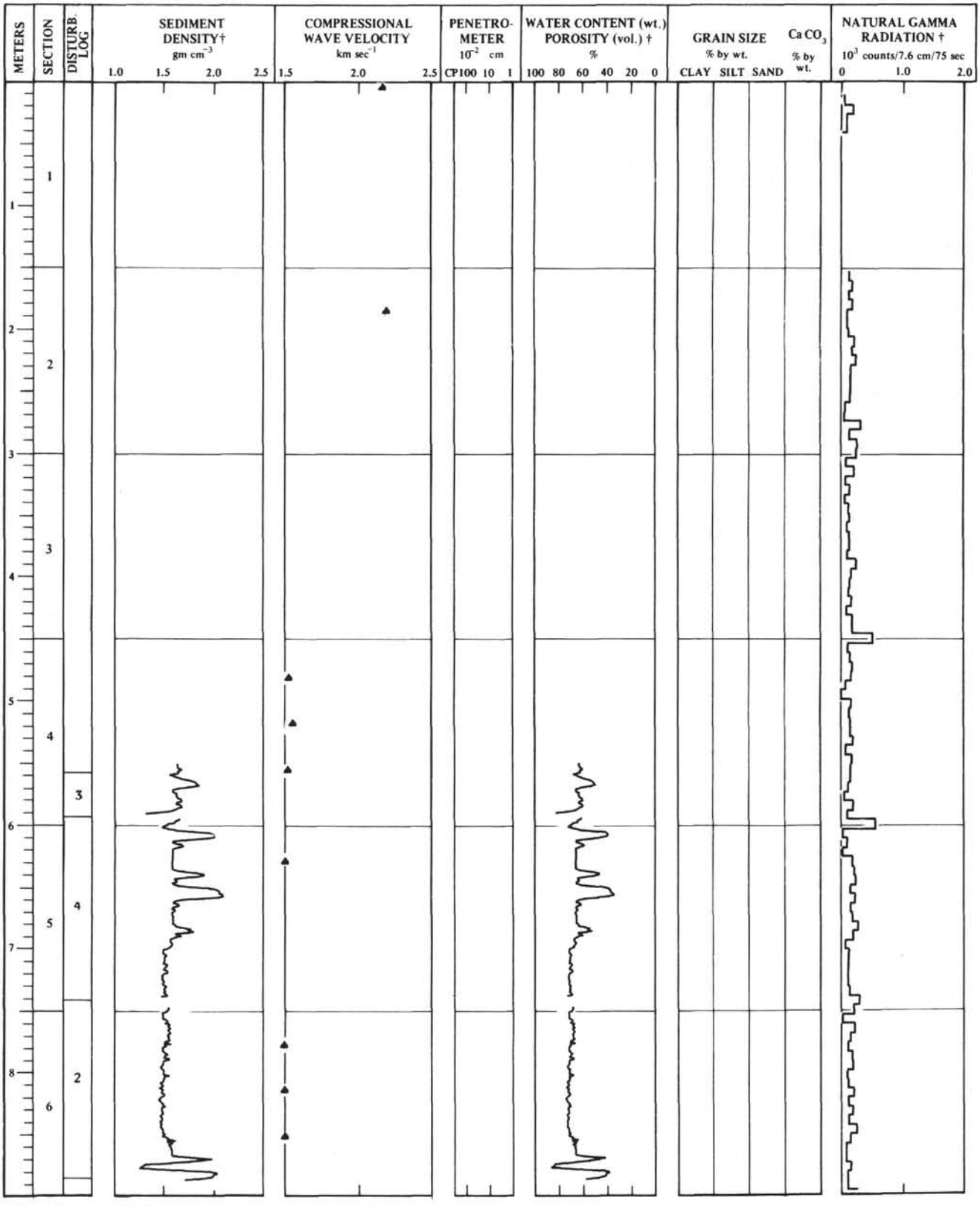
HOLE 116 759 **TO** 768 **m**

CORE 24

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		XM N,R F 5Y6/1 - 5Y6/1	Foram-nannofossil chalk and soupy ooze. The chalk is hard and heavily mottled. Many worm burrows are cut by small faults. Bottom of section appears brecciated and has a marbelized appearance.	*Coccolithus pelagicus, C. eopelagicus, C. bisectus, Cyclococcolithus neogammation, Ericsonia obruta, Discoaster* sp. *Isthmolithus recurvus, Discoaster* sp. *Reticulofenestra* sp. *Discolithina* sp. *Braarudosphaera bigelowi, Zygrhablithus* cf. *bijugatus, Chiasmolithus* sp. *C. oamaruensis, Sphenolithus* sp., *Zygolithus* sp. Radiolarians very rare, corroded. Few disaggregated (free) foraminifera	*Ericsonia obruta*	EARLY OLIGOCENE
	CC		N F	Foram-nannofossil chalk	Core Catcher: Radiolarians very rare, corroded. (?) *Cyclampterium (?) milowi.* Flora similar to above. *G. ampliapetura* (top), *G. dissimilis, G. pera, G. postcretacea, G. denseconnexa, G. inaeoviconica, G. opima nana, Chiloquembelina*		

HOLE 116

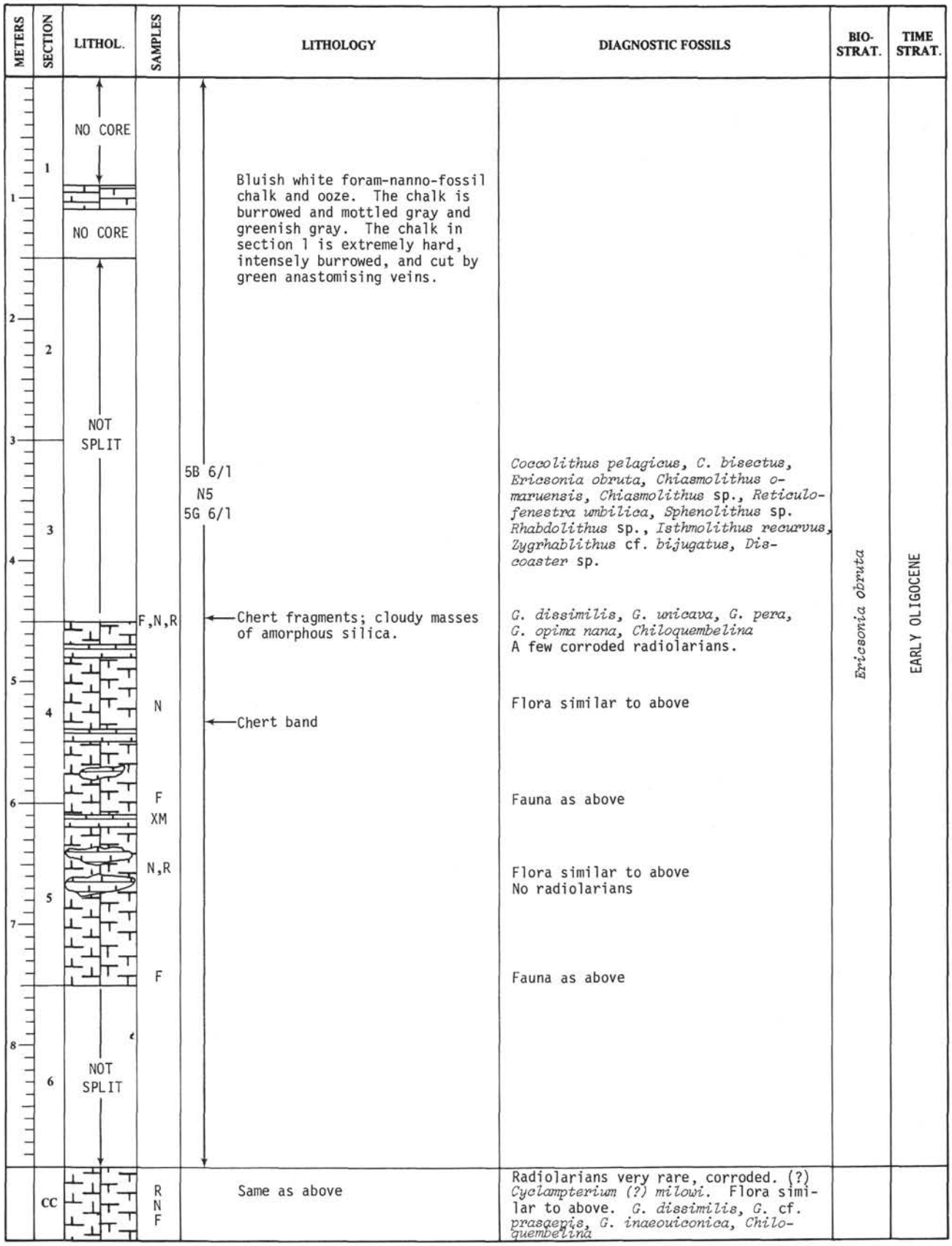
CORE 25



†Adjusted data, see Chapter 2

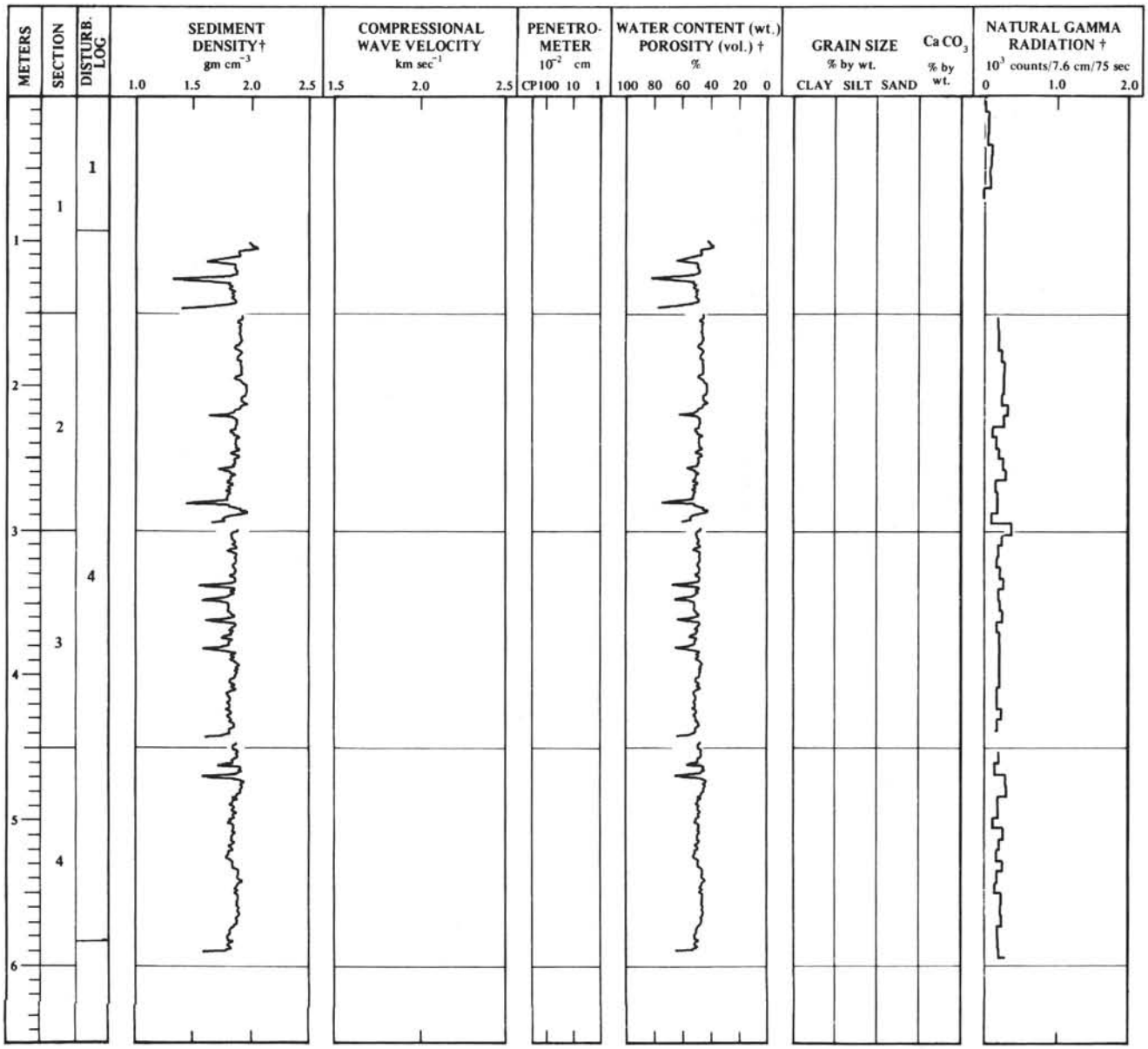
HOLE 116 806 TO 810 m

CORE 25



HOLE 116

CORE 26



†Adjusted data, see Chapter 2

HOLE 116 825 TO 831 m

CORE 26

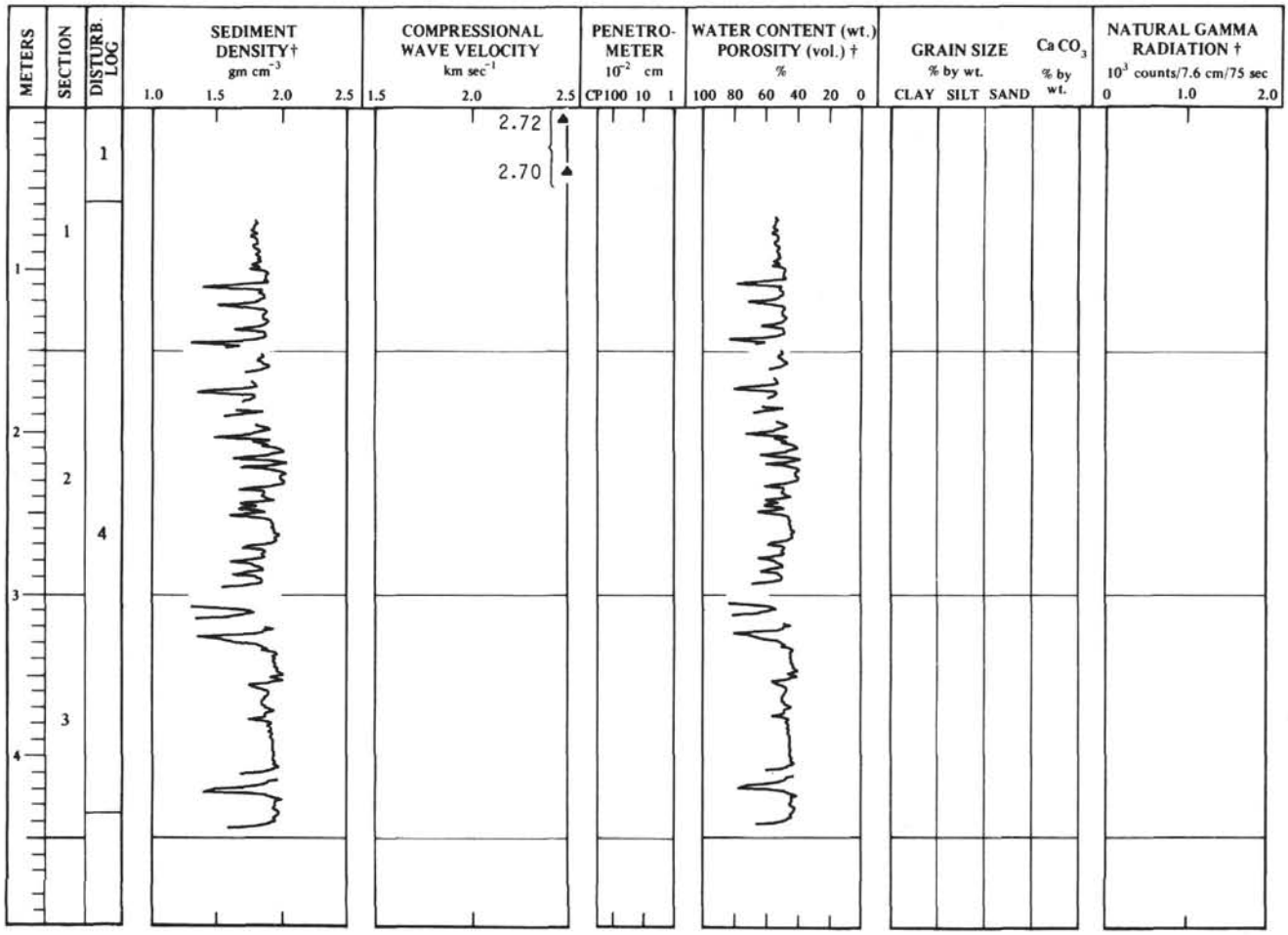
METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NO CORE	N	Very hard, intensely burrowed, very light gray fragmented foram-nannofossil chalk. Flow structures and faults are also present. Burrows are predominantly gray in color and are occasionally accompanied by pale green chlorite halos. Chloritic clay layers are found at the base of almost every piece of chalk.	*Ericsonia ovalis, E. obruta, Coccolithus eopelagicus, Chiasmolithus oamaruensis, Reticulofenestra umbilica, Discoaster saipanensis, Sphenolithus* sp., *Markalius inversus, Helicopontosphaera* cf. *lophota, Zygrhablithus* cf. *jugatus, Isthmolithus recurvus*	*Isthmolithus recurvus* s.l.	LATE EOCENE
2	2		N		Flora similar to above		
3	3		XM				
			N	5Y 6/1 N8 5G 7/2	Flora similar to above		
4	4		N		Flora similar to above		
5			XM				
	CC		R N F	As above	Core Catcher: Radiolarians very rare, corroded to slightly silicified, zeolitized. *Tristylospyris triceros, Calocyclas semipolita semipolita, Spongasteriscus cruciferus, Spongurus bilobatus, Sethochytris* sp. aff. *S. babylonis* group. Flora similar to above *G. dissimilis, G. pera, Globigerapsis index, Chiloguembelina*		

X-ray Mineralogy (bulk)

Calc.	95.1
Qtz.	.5
Mont.	1.8
Clin.	2.6
Amorph.	35.9

HOLE 116

CORE 27



†Adjusted data, see Chapter 2

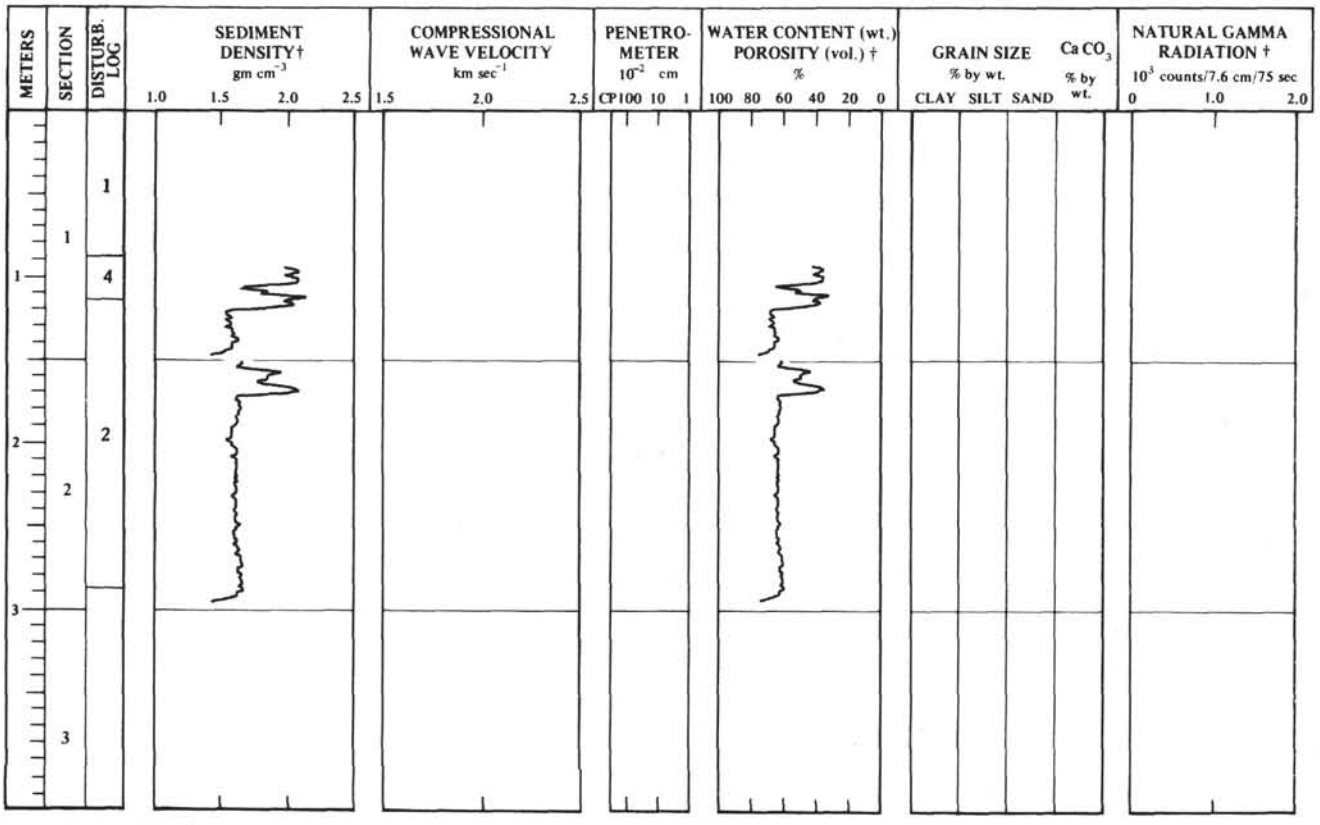
HOLE 116 831 TO 840 m

CORE 27

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NO CORE					
2	2		XM N R,F	Very light gray foram-nannofossil chalk with medium light gray and light olive gray blebs and laminations. Laminations dip at an angle of approximately 33° and occur in concentrated areas throughout the core. Chloritic slickensides appear in section 2. Intense lamination in section 3 gives a marbelized appearance to the sediment. N6 N8 5Y 6/1	*Ericsonia ovalis, Reticulofenestra umbilica, Cribrocentrum reticulatum, Coccolithus eopelagicus, C. bisectus, Discoaster tani, D. barbadiensis, Chiasmolithus oamaruensis, C. expansus, Isthmolithus recurvus, Sphenolithus* sp. *Braarudosphaera bigelowi, Zygrhablithus* cf. *bijugatus* Three silicified radiolarians. Indet. globigerinids, chiloguembelinids	*Isthmolithus recurvus* s.l.	LATE EOCENE
3	3		N,F XM	X-ray Mineralogy (bulk) Calc. 89.6 Cris. 10.4 Amorph. 38.0	Flora similar to above Fauna as above		
4			N		Flora similar to above		
	CC		R N F	As above.	Core Catcher: Radiolarians very rare, silicified to corroded. *Calocyclas semipolita semipolita.* Flora similar to above. *G. index,* globigerinids, chiloguembelinids		

HOLE 116

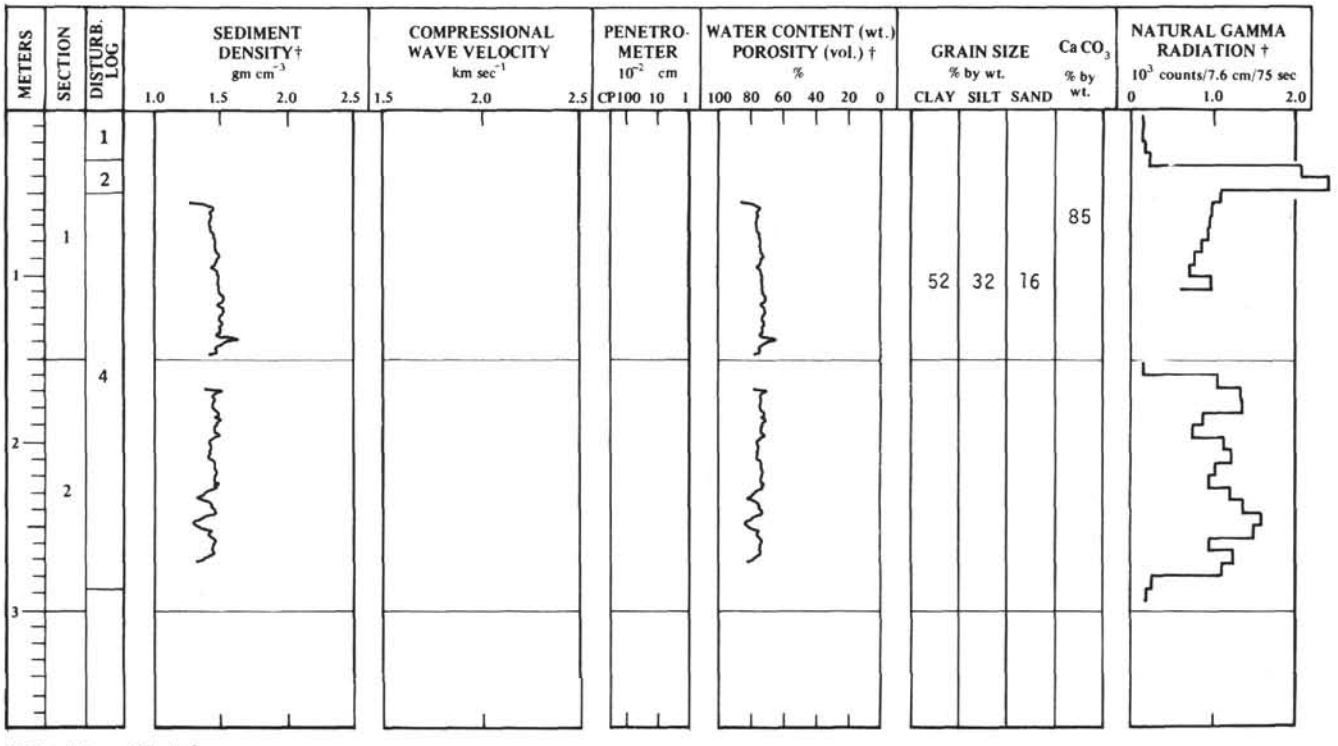
CORE 28



†Adjusted data, see Chapter 2

HOLE 116A

CORE 1



†Adjusted data, see Chapter 2

HOLE 116 840 **TO** 841 **m**

CORE 28

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NO CORE		Hard white foram-nannofossil chalk in a matrix of fluid ooze.	*Reticulofenestra umbilica, Cribrocentrum reticulatum, Sphenolithus* sp. *Ericsonia ovalis, Zygrhablithus* cf. *bijugatus, Coccolithus bisectus, Chiasmolithus oamaruensis, Chiasmolithus* sp., *Isthmolithus recurvus,* Globigerinids, Chiloguembelinids No radiolarians	*Isthmolithus recurvus* s.l.	LATE EOCENE
		EMPTY	N,F,R				
			XM				
2	2		N		Flora similar to above. No radiolarians		
			R				
			F		*G. index, G. galavisi, G. linaperta, Chiloguembelina*		
	CC		F N R	As above.	Core Catcher: Flora and fauna similar to above Radiolarians very rare. *Heliodiscus heliastericus,* (?) *Calocyclas semipolita semipolita,* (?) *Lophoconus titanothericeraos*		

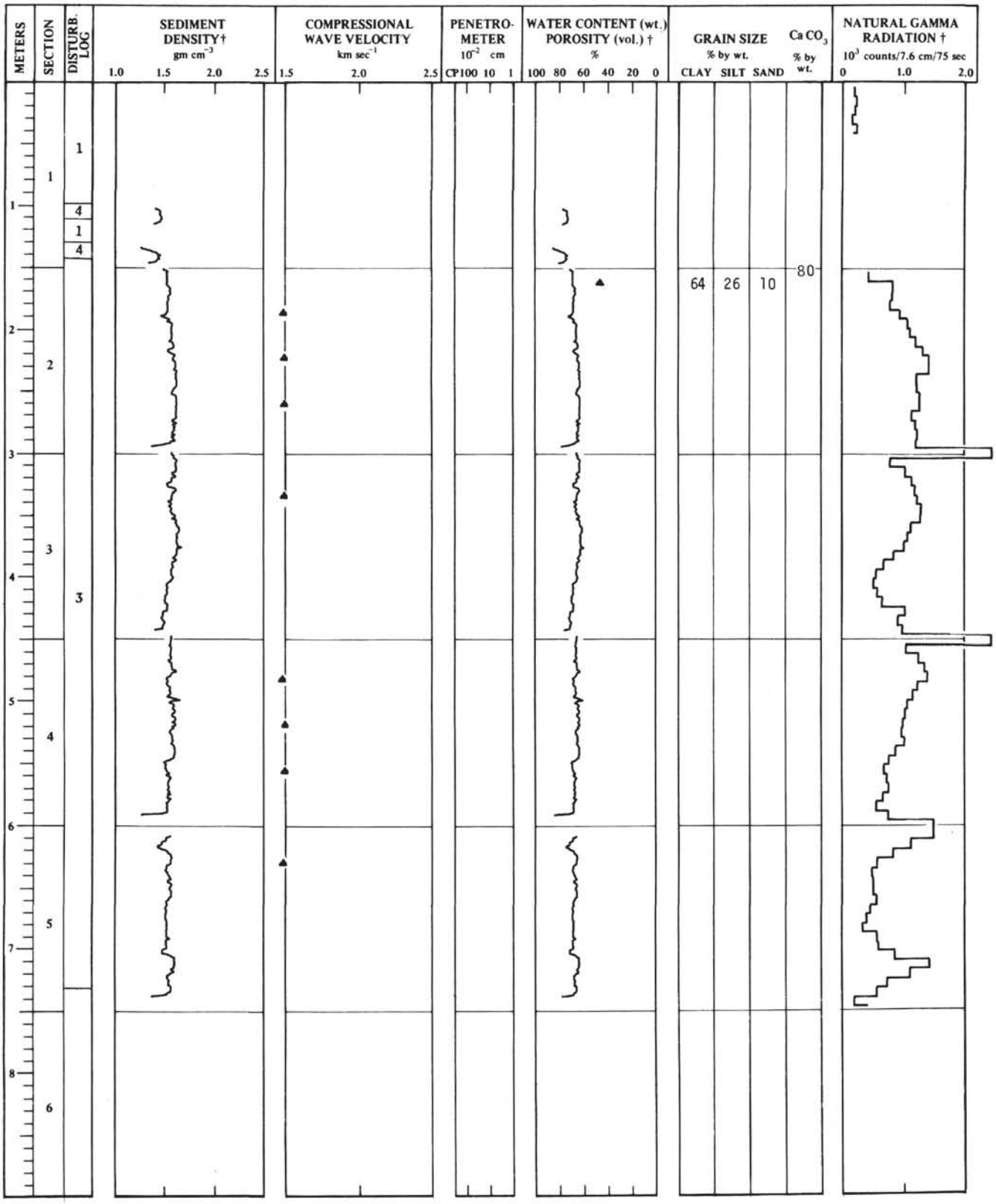
HOLE 116A 0 **TO** 9 **m**

CORE 1

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NO CORE	N	Gray foram-nannofossil marl chalk. Flow structures indicate coring disturbance.	*Coccolithus pelagicus, Cyclococcolithus leptoporus, Syracosphaera* sp. *Emiliania huxleyi, Gephyrocapsa oceanica, G. aperta, Helicopontosphaera kamptneri, H. sellii, Rhabdolithus* sp. Flora similar to above Radiolarians very rare. *Actinomma antarcticum, Lamprocyclas maritalis*	*Emiliania huxleyi*	PLEISTOCENE
			XM				
			N	N7			
			R	N8			
2	2	NO CORE	XM	Yellowish gray foram nannofossil marl mud mottled grayish brown and dark grayish mud mottled yellowish gray. Siliceous fossils are rare as well as quartz, ostracods, and fish debris. X-ray Mineralogy (bulk) Calc. 93. Qtz. 2.8 Plag. 2.3 Mica 1.9 Amorph. 39.7	*G. pachyderma, G. bulloides, G. hirsuta, G. inflata, G. truncatulinoides O. universa* Flora similar to above Radiolarians very rare		
			F	2.5Y 5/2			
			N	2.5Y 4/2			
			R	5Y 8/1			
			F		Fauna as above		
			F		Fauna as above		
	CC		F N		Core Catcher: Fauna as above. Flora similar to above, less *E. huxleyi?*, + rew. Late Cretaceous coccoliths		

HOLE 116A

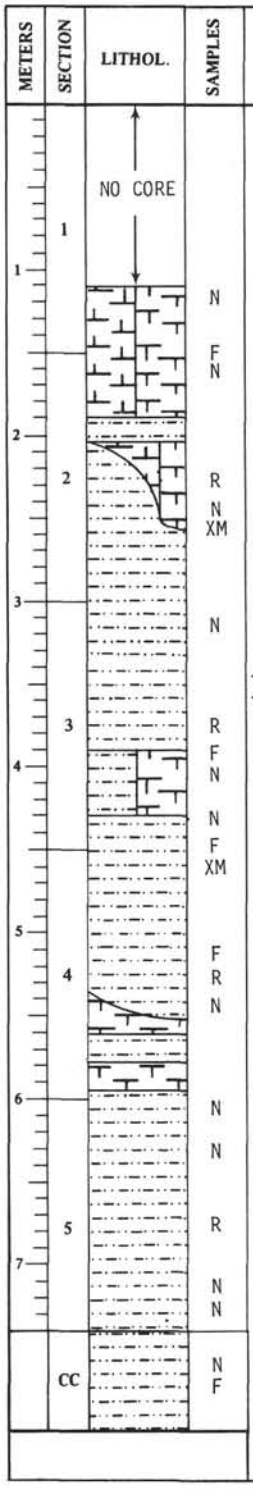
CORE 2



†Adjusted data, see Chapter 2

HOLE 116 A 9 TO 18 m

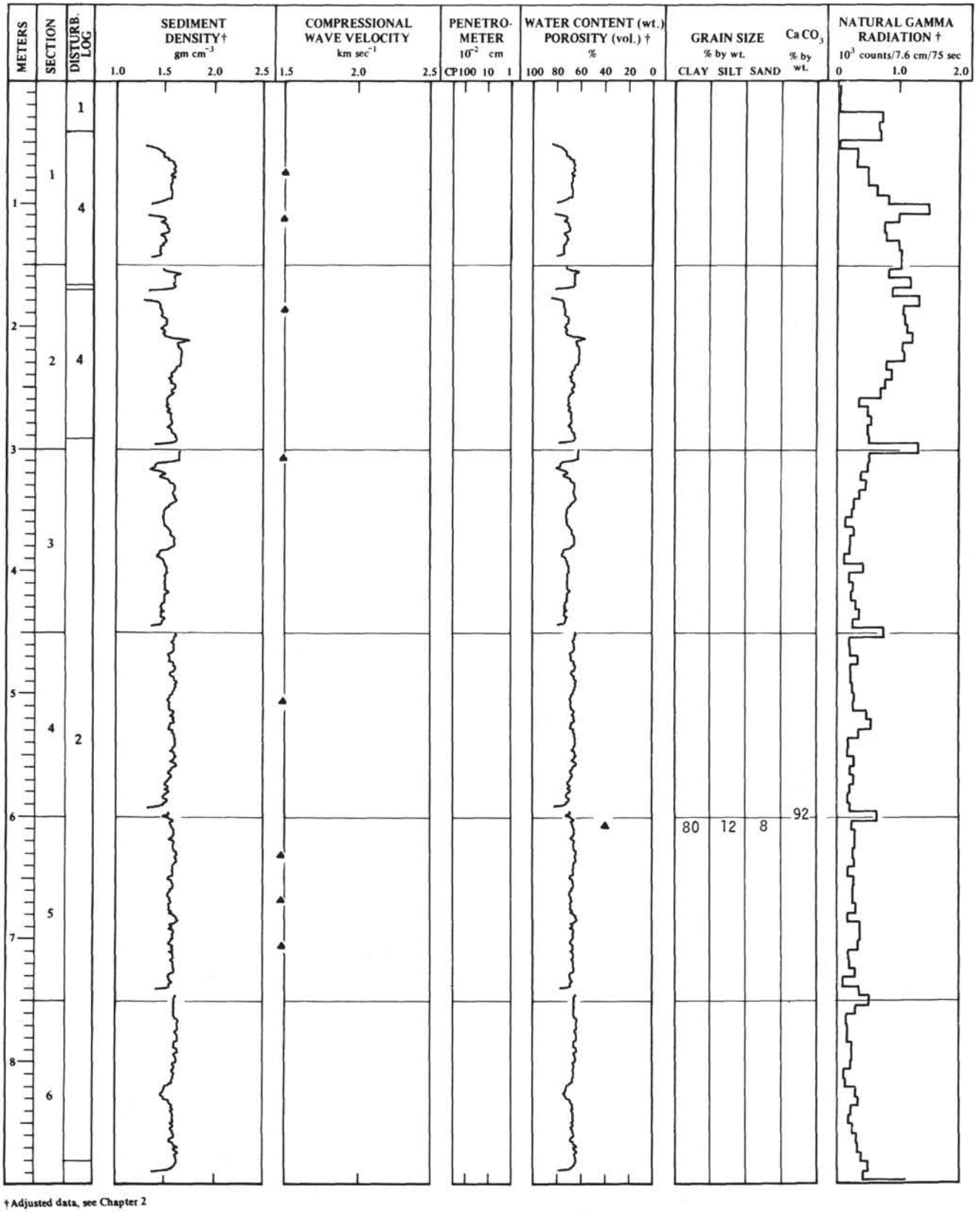
CORE 2



LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
	Coccolithus pelagicus, Cyclococcolithus leptoporus, Syracosphaera pulchra, Gephyrocapsa oceanica, G. aperta, Helicopontosphaera kamptneri, H.sellii, Rhabdosphaera clavigera, Thoracosphaera sp.		
	G. bulloides, G. pachyderma, G. inflata, G. truncatulinoides, O. universa Flora similar to above		
Gray and brown structurless foram-nannofossil ooze & foram rich silty clay. Contains small quantities of volcanic glass and pyrite. This is interbedded with calcareous mud. Occasional gneiss pebbles occur in the mud	No radiolarians Flora similar to above		
	Flora similar to above		
N8 10YR 7/4 10YR 5/2			
X-ray Mineralogy (bulk) Calc. 45.8 Dolo. 6.0 Qtz. 21.1 Plag. 13.1 Kaol. 1.3 Mica 11.3 Chlorite 1.4 Amorph. 56.0	No radiolarians Fauna as above Flora similar to above Flora similar to above Fauna as above	*Gephyrocapsa oceanica* N22	PLEISTOCENE
	Forams as above No radiolarians Flora similar to above		
	Flora similar to above Flora similar to above		
	Radiolarians very rare		
	Flora similar to above Flora similar to above		
	Core Catcher: Flora similar to above *G. inflata, G. truncatulinoides, G. hirsuta, G. crassaformis, G. bulloides, G. pachyderma*		

HOLE 116A

CORE 3



† Adjusted data, see Chapter 2

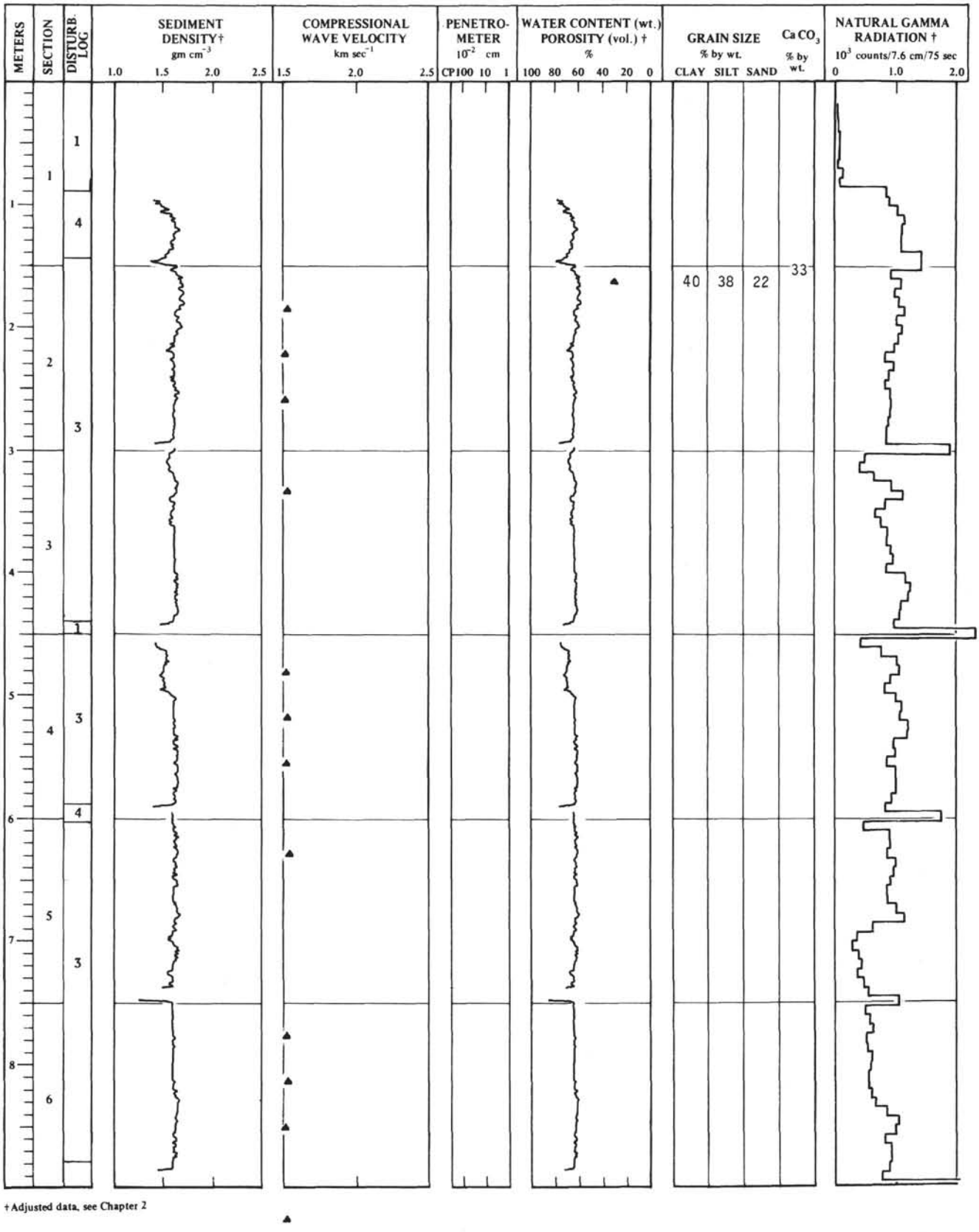
HOLE 116 A 18 TO 27 m

CORE 3

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NO CORE	XM				
		NO CORE			*Coccolithus pelagicus* (rare), *Cyclococcolithus leptoporus, Syracosphaera pulchra, Rhabdosphaera clavigera, Pontosphaera scutellum, P. discopora, Gephyrocapsa oceanica, G. aperta, Helicopontosphaera sellii, H. kamptneri*		
			N	White foram-nannofossil ooze grading into a dark brown, olive gray, and gray silty mud. The mud is rich in volcanic glass and clay minerals. The calcareous ooze contains small amounts of volcanic glass, palagonite, and pyrite. The core is completely disturbed.	No radiolarians		
			R				
			F	5B 9/1	*G. pachyderma, G. bulloides*		
		NO CORE					
		NO CORE					
2				X-ray Mineralogy (bulk) (Calcareous ooze) Calc. 99.5 Qtz. .5 Amorph. 29.0			
	2		N,F		Forams as above + *G. inflata, G. scitula*		
			R		Flora similar to above, + reworked Cretaceous coccoliths		
					No radiolarians		
			N		Flora similar to above		
3			F		Foram fauna as above.		
	3						
4		NOT SPLIT	F,N,R		Forams as above + *G. truncatulinoides* Flora similar to above Radiolarians very rare. *Actinomma antarcticum, Ommatodiscus* spp.	*Gephyrocapsa oceanica* N22	PLEISTOCENE
	4						
5							
6			N,R		Radiolarians common. *Actinomma antarcticum, Ommatodiscus* spp., *Stylodictya validispina, Androcyclas gamphonycha, Lamprocyclas maritalis, Eucyrtidium calvertense, Theocalyptra davisiana*		
			N		Flora similar to above		
	5				Flora similar to above		
			R		Radiolarians very rare. Similar to above but reduced diversity.		
7			XM				
			N		Flora similar to above, + *Pseudoemiliania lacunosa*		
			F	5B 9/1			
					Forams as above		
			N		Flora similar to sect. 5-126		
8	6						
			R		Radiolarians rare. Similar to above		
					Forams as above Flora similar to sect. 5-126		
			F N				
	CC		N F		Flora and fauna similar to above, + *"Coccolithus jaramillensis", + Pseudoemiliania lacunosa,* less *G. oceanica*	*"Coccolithus jaramillensis"*	

HOLE 116A

CORE 4



†Adjusted data, see Chapter 2

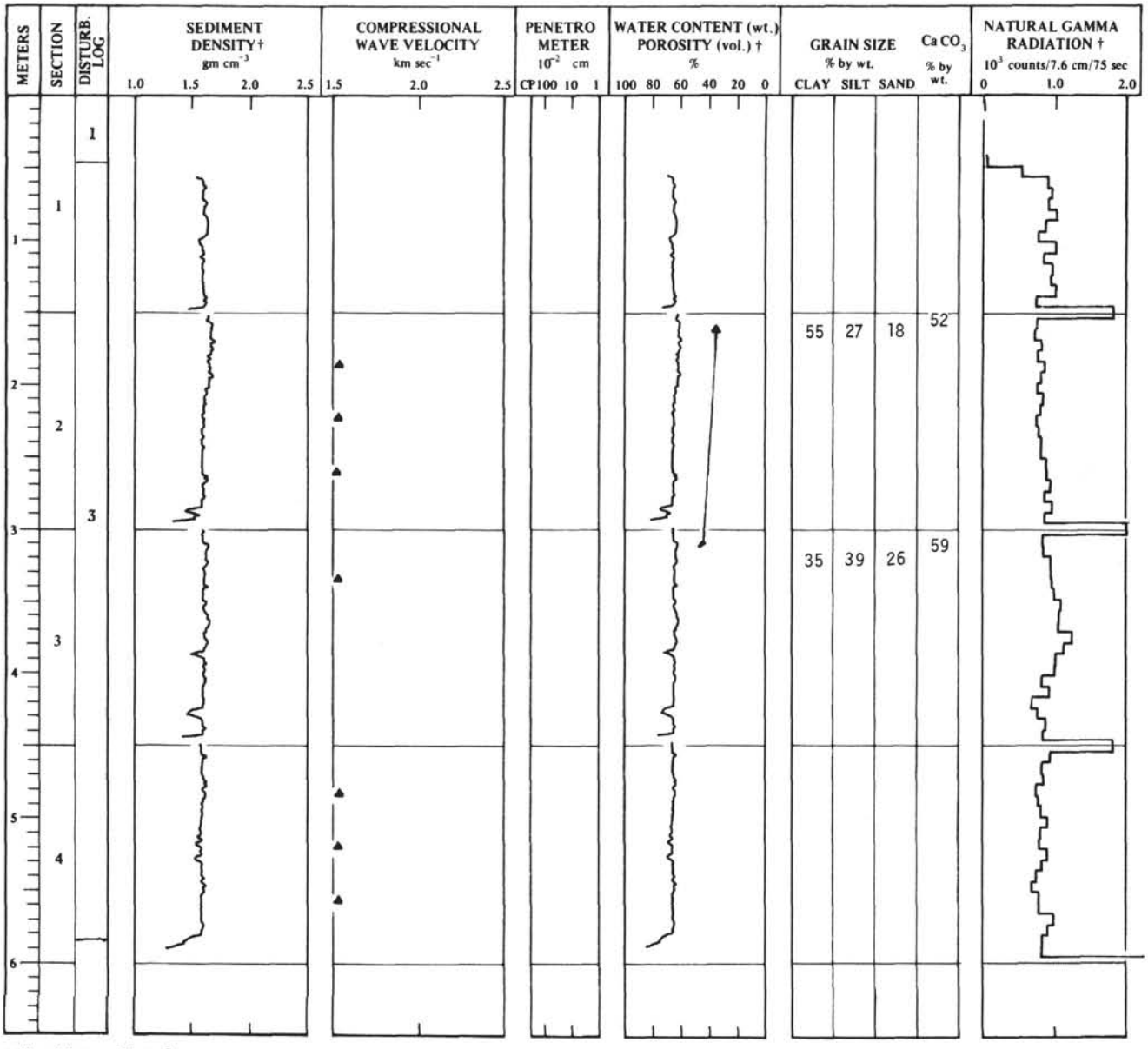
HOLE 116 A 27 TO 36 m

CORE 4

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
	1	NO CORE			*Coccolithus pelagicus, Cyclococcolithus, Syracosphaera pulchra, Helicopontosphaera kamptneri, H. sellii, Pontosphaera scutellum, P. discopora, Pseudoemiliania lacunosa, "Coccolithus jaramillensis"*		
1			N	White foram-nannofossil chalk ooze interbedded with brown and olive gray silty clay. The ooze is composed predominantly of calcareous microfossils with minor amounts of glass and pyrite. The silty clay is composed of calcareous tests, clay minerals, quartz grains (some with hematite coating), and both sedimentary and igneous rock fragments. The entire core is disturbed by drilling.	Flora similar to above, + reworked Cretaceous coccoliths		
			N		No radiolarians		
			R				
			XM				
2	2		N		Flora similar to above		
			F		*G. pachyderma, G. bulloides, G. inflata, G. glutinata*		
			R		No radiolarians		
			N		Flora similar to above		
			XM				
			F	X-ray Mineralogy (bulk) (clay)	Forams as above		
3			N	Calc. 76.2	Flora similar to above		
				Qtz. 10.5			
			F	Plag. 3.7			
	3			Mica 8.5	Forams as above		
			R	Chlorite 1.1	No radiolarians		
4				Amorph. 49.5			
			N	N8	Flora similar to above, + reworked Cretaceous coccoliths		
		GAP		5Y 6/1			
				5GY 6/1			
5			N,F		Flora and fauna similar to above		
	4		R		No radiolarians		
			N		Flora and fauna similar to above, less *C. pelagicus?*	*"Coccolithus jaramillensis"* N22	PLEISTOCENE
6			F				
			N,F		Flora similar to above, few *C. pelagicus*, + *Scyphosphaera* sp.		
					No radiolarians		
	5		R				
			N		Flora similar to above, + reworked Cretaceous coccoliths, few *C. pelagicus*		
7			N		Flora similar to above, less *C. pelagicus?*, + *Scyphosphaera* sp.		
			N		Flora similar to above, less *C. pelagicus?* Forams as above.		
8			F				
	6		R		No radiolarians		
			N		Flora similar to above, + reworked Cretaceous coccoliths		
			F		Forams as above		
	CC		N		Flora similar to above, few *C. pelagicus*, + *Scyphosphaera* sp.		
			F		Forams as above incl. *G. truncatulinoides*		

HOLE 116A

CORE 5



†Adjusted data, see Chapter 2

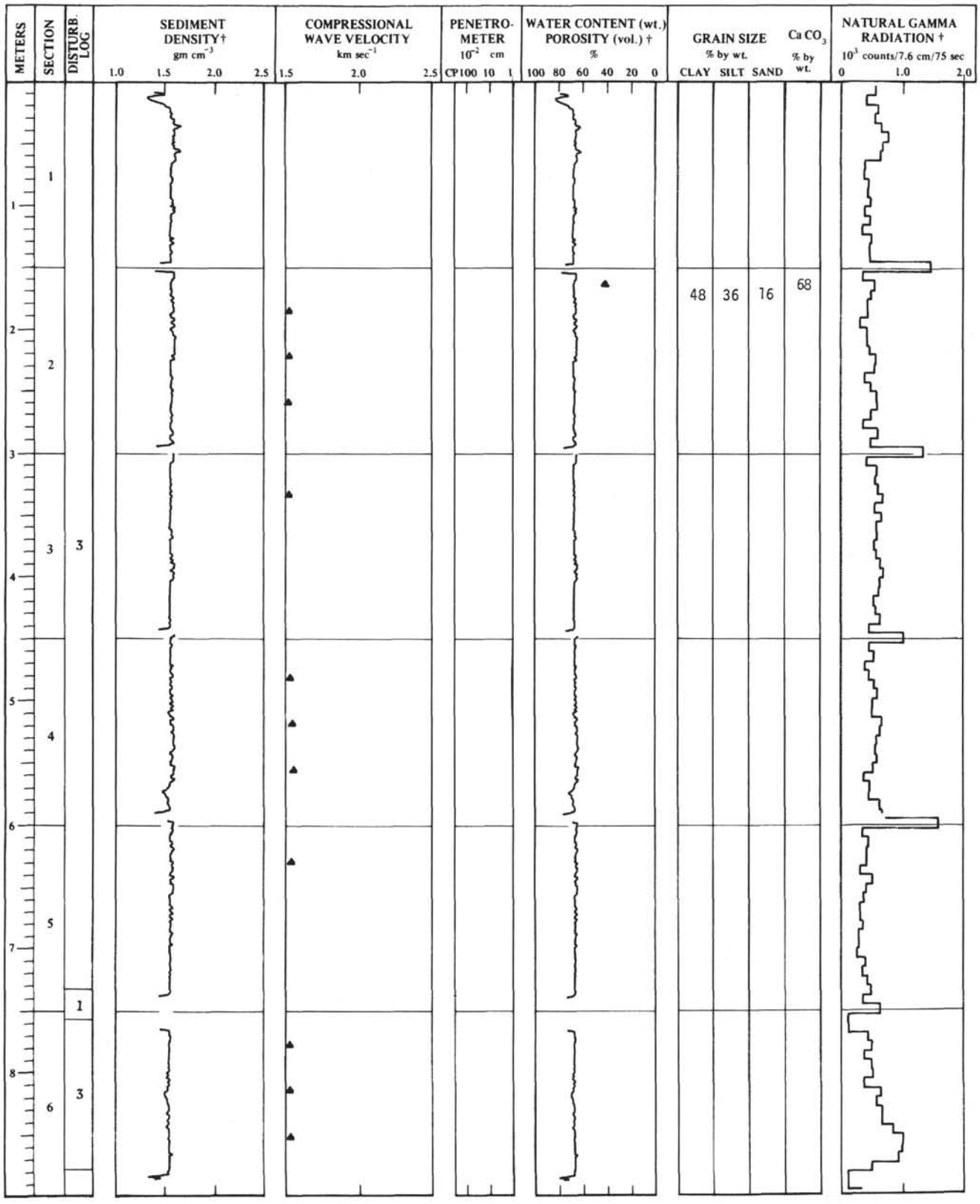
HOLE 116 A 36 TO 45 m

CORE 5

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
		NO CORE					
1	1		N R F	Gray and light olive gray foram nannofossil ooze. Contains volcanic glass and minor amounts of pyrite. Sediment is completely disturbed by coring. X-ray Mineralogy (bulk) Calc. 82.1 Qtz. 7.5 K-feld. 1.8 Plag. 3.6 Mica 5.0 Amorph. 48.7	*Coccolithus pelagicus* (few), *Cyclococcolithus leptoporus*, *C.* cf. *macintyrei*, *Syracosphaera pulchra*, *Helicopontosphaera kamptneri*, *H. sellii*, *Pontosphaera scutellum*, *P. discopora*, *Pseudoemiliania lacunosa* Radiolarians very rare		
2	2		N R XM		*G. bulloides*, *G. pachyderma*, *G. inflata*, *G. crassaformis*, *O. universa* Flora similar to above Radiolarians very rare.		
3			N F,XM		Flora similar to above, less *C. pelagicus*? *Forams as above* + *G. truncatulinoides*		
4	3		N,F R XM N	N8 N7 N5 5Y 6/1 5Y 4/1	Flora similar to above, + reworked Cretaceous coccoliths, less *C. pelagicus*? No radiolarians - Forams as above Flora similar to above, less *C. pelagicus*? Forams as above	*"Coccolithus jaramillensis"* N22	PLEISTOCENE
5	4		F N F R N		Flora similar to above, + reworked Cretaceous coccoliths, less *C. pelagicus*? Forams as above Radiolarians very rare. Flora similar to above, less *C. pelagicus*?		
			F		Forams as above		
	CC		N F		Core Catcher: Flora similar to above Fauna as above		

HOLE 116A

CORE 6



† Adjusted data, see Chapter 2

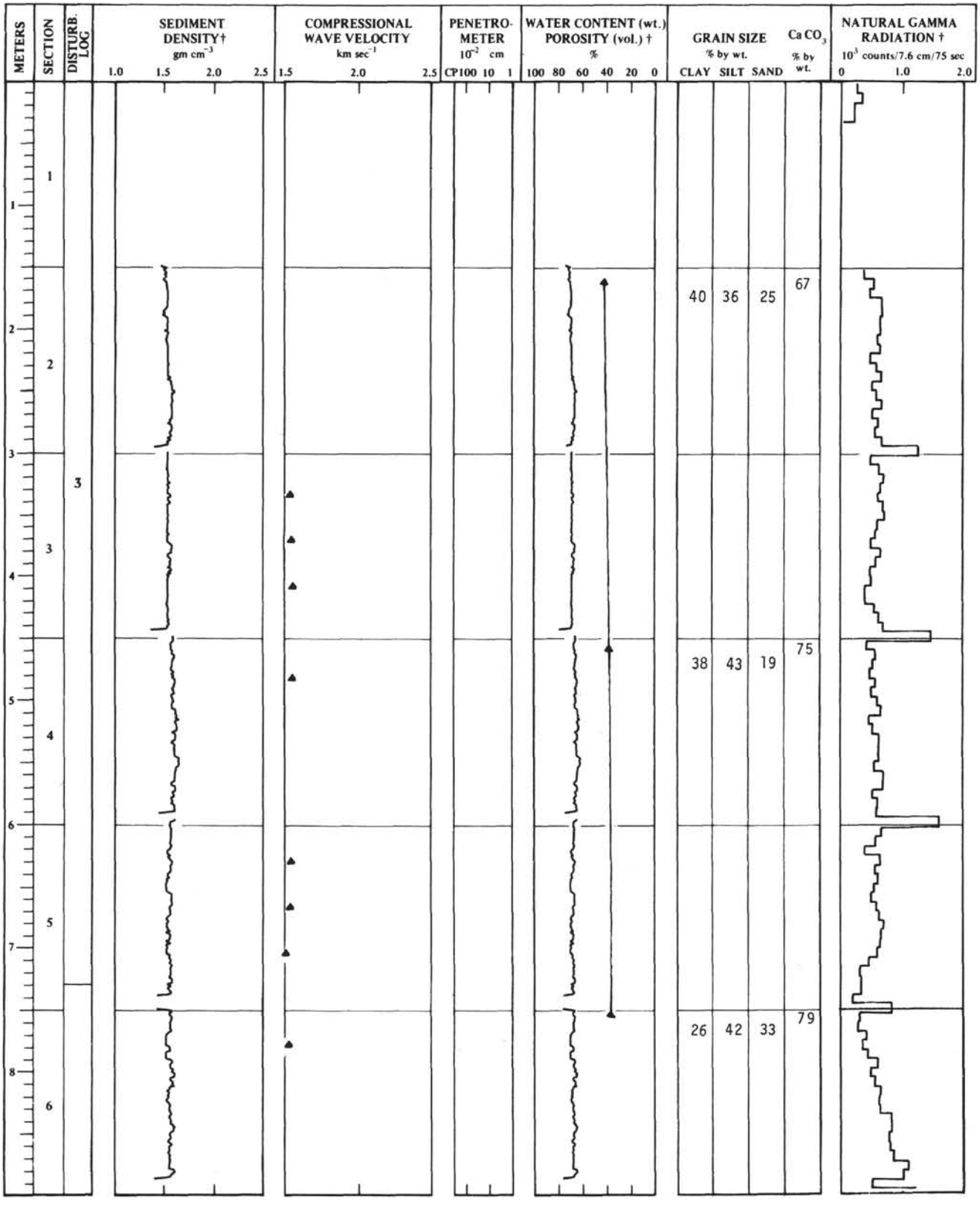
HOLE 116 A 45 TO 54 m

CORE 6

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N F N R	Vertically streaked gray, olive, and white foram-nannofossil ooze with occasional black blebs. Glass occurrence is common. Minor amounts of pyrite and palagonite are also present.	*Coccolithus pelagicus*, *C.* cf. *neohelis*, *Cyclococcolithus leptoporus*, *C. macintyrei*, *Pseudoemiliania lacunosa*, *Syracosphaera pulchra*, *Pontosphaera* sp., *Helicopontosphaera sellii*, *H. kamptneri*	*Pseudoemiliania lacunosa*	PLEISTOCENE
			F		Radiolarians very rare. *Ommatodiscus* spp., *spongodiscids*, *liosphaerids*. *G. bulloides*, *G. pachyderma*, *G. inflata*, *G. crassaformis*, *G. scitula* Forams as above		
2	2		N,F	X-ray Mineralogy (bulk) Calc. 92.3 Qtz. 2.8 K-Feld. 1.4 Plag. 1.2 Mica 2.3 Amorph. 37.1	Flora similar to above Fauna as above		
			R		Radiolarians very rare.		
			N		Flora similar to above, + *Scyphosphaera* sp.		
3			F XM		Forams as above		
	3		N		Flora similar to above Radiolarians very rare		
4			R				
			F	5B 9/1	Forams as above		
5	4		R N		Radiolarians very rare Flora similar to above		
6			F		Forams as above		
7	5		N F R		Flora similar to above Forams as above Radiolarians rare. *Druppatractus irregularis*, *D. acquilonius*, *spongodiscids*		
			F		Forams as above		
8	6		N		Flora similar to above		
			F R		Forams as above Rare discoidal and spheroidal radiolarians		
		GAP	N F		Forams as above Flora similar to above, + reworked Cretaceous coccoliths, + *Scyphosphaera* sp.		
	CC		N F		light ooze) Flora similar to above dark ooze) *G. bulloides*, *G. crassaformis*, *G. hirsuta*, *G. pachyderma*		

HOLE 116A

CORE 7



†Adjusted data, see Chapter 2

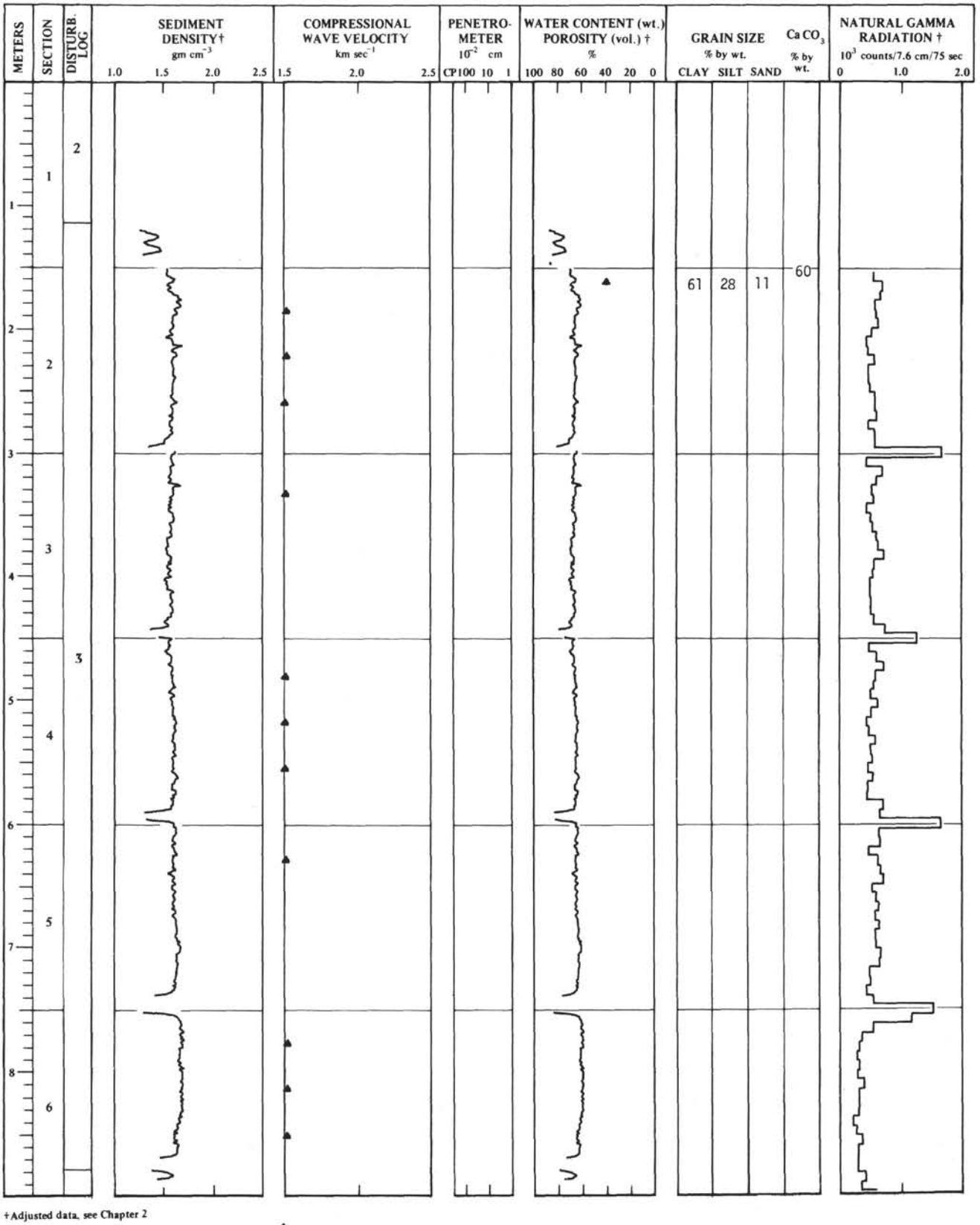
HOLE 116 A 54 TO 63 m

CORE 7

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NO CORE					
2	2		XM F N R XM	Gray and white foram-nannofossil ooze. Light olive gray clay "pebbles" are found at top of core. Flow structures as a result of drilling disturbance are evident throughout the core. Volcanic glass, palagonite, and pyrite occur in small quantities. Rock fragments are also sparsely distributed in the sediment.	*Coccolithus pelagicus, Cyclococcolithus leptoporus, C. macintyrei, Pseudoemiliania lacunosa, Syracophaera pulchra, Pontosphaera scutellum, P. discorpora, Helicopontosphaera kamptneri, H. sellii* Radiolarians rare. Assemblage similar to above. G. bulloides, G. crassaformis, G. inflata, G. hirsuta, G. pachyderma		
3			F	X-ray Mineralogy (CLAY) Calc. 35.3 Qtz. 31.3 Plag. 10.8 Kaol. 2.0 Mica 14.0 Chlo. 2.4 Mont. 4.2 Amorph. 61.4	Forams as above		
4	3		N R		Flora similar to above, Radiolarians very rare		
5			F	X-ray Mineralogy (OOZE) Calc. 80.9 Qtz 7.4 K-Feld. 1.7 Plag. 3.5 Mica 5.2 Mont. 1.3 Amorph. 44.5	Forams as above		
6	4		N R XM F	N8 5Y 8/1 5Y 6/1 5GY 6/1	Flora similar to above Radiolarians very rare. *Actinomma antarcticum, A. medianum, spongodiscids* Forams as above	*Pseudoemiliania lacunosa*	PLEISTOCENE
7	5		N F N R N F		Flora similar to above Forams as above Flora similar to above Radiolarians very rare. Similar to above. Flora similar to above, +*Scyphosphaera* sp. Forams as above		
8	6		N R N XM F		Flora similar to above, + *Discoaster browseri* Radiolarians similar to above Flora similar to above, + *D. browseri Globigerina atlantica* (top), *G. bulloides, G. scitula*	*Discoaster browseri*	PLIOCENE
	CC		N F N		Flora similar to above, + *D. browseri G. atlantica, G. bulloides, G. hirsuta*		

HOLE 116A

CORE 8



†Adjusted data, see Chapter 2

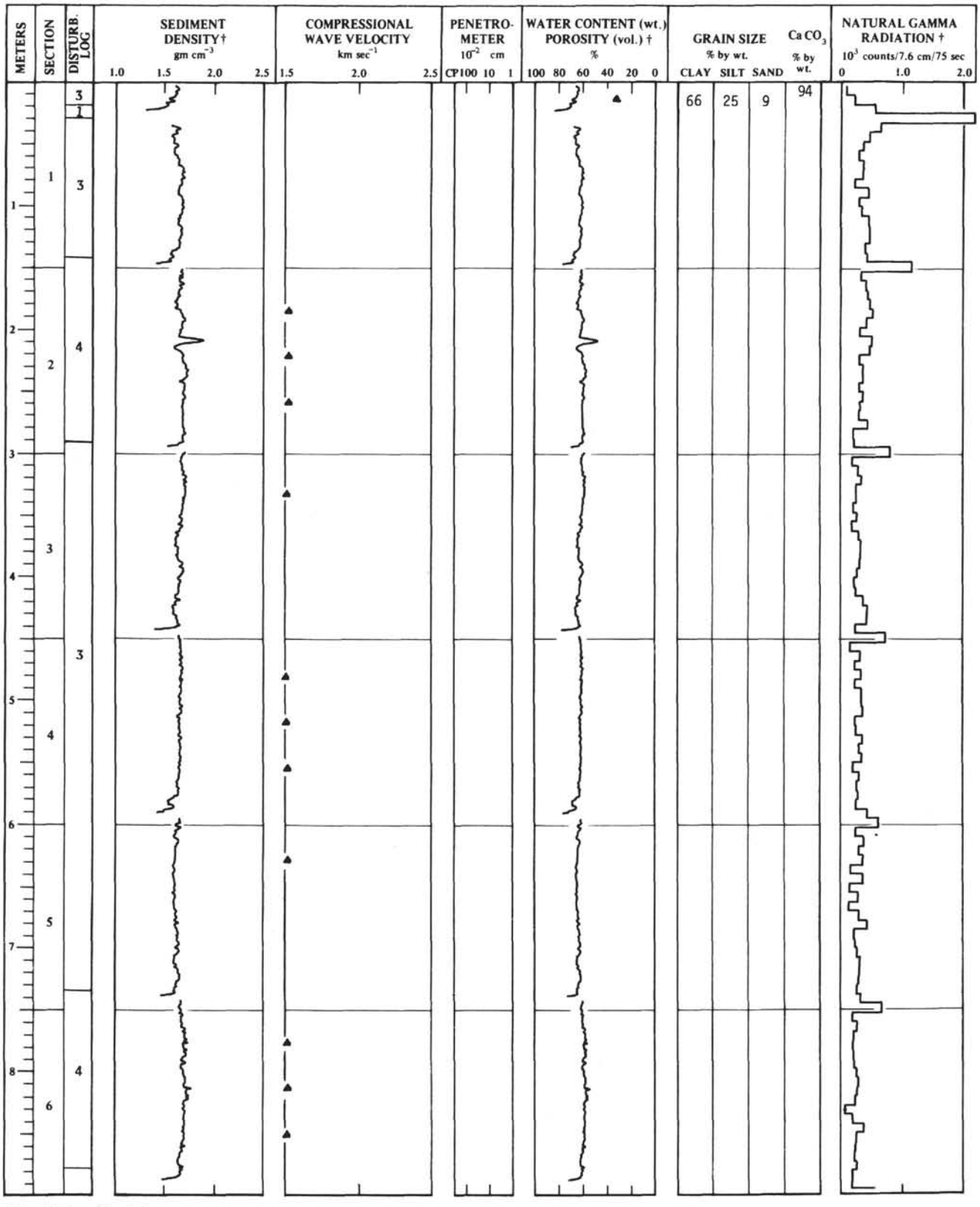
HOLE 116 A 63 TO 72 m

CORE 8

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NO CORE					
			F		*Coccolithus pelagicus, Cyclococcolithus leptoporus, C. macintyrei, Coccolithus* cf. *neohelis, Discoaster* sp. *helicopontosphaera sellii, H. kamptneri, Pontosphaera discopora, P. scutellum*		
			F		Flora similar to above		
			N		*G. atlantica, G. bulloides, G. crassaformis*		
			F	Foram nannofossil chalk ooze interspersed with patches of greenish gray clay and olive gray silty clay. Core is disturbed.	Flora similar to above		
2			N		Fauna as above		
	2		R	X-ray Mineralogy (bulk)	Flora similar to above		
			XM	Calc. 96.1			
				Qtz. .9	Radiolarians rare. Predominantly spheroidal and discoidal spumellarians. *Theocalyptra davisiana, Actinomma antarcticum, Druppatractus acquilonius, D. irregularis, Androcyclas gamphonycha, (?) Lamprocyclas heteroporos.*		
			F	Plag. 3.0	Forams as above		
3			N	Amorph. 33.9	Flora similar to above		
			F		Forams as above		
	3		N		Flora similar to above		
			R		Radiolarians very rare		
4			F	5GY 5/1 5Y 4/1	Forams as above		
			N		Flora similar to above		
5			N		Flora similar to above, + *Scyphosphaera* sp.		
	4		R		Radiolarians rare. Assemblage similar to above. *Lamprocyclas heteroporos*		
6			F		Forams as above + *G. puncticulata*	*Discoaster surculus - D. pentaradiatus- D. brouweri*	PLIOCENE
			N		Flora similar to above		
			F		*G. atlantica, G. bulloides, G. crassaformis, G. scitula*		
	5		R		Radiolarians rare, same as above		
7			N		Flora similar to above		
			F		Forams as above		
			N		Flora similar to above		
			XM				
8			F		Forams as above		
	6		N		Flora similar to above, + *Reticulofenestra pseudoumbilica.*	*Reticulofenestra pseudoumbilica*	
			R		Radiolarians common. *Spongaster* sp. cf. *S. tetras, Eucyrtidium calvertense, Lamprocyclas heteroporos, Androcyclas gamphonycha*		
	CC		F		Foram fauna as above		
			N		Flora similar to above, + *Reticulofenestra pseudoumbilica*		

HOLE 116A

CORE 9



†Adjusted data, see Chapter 2

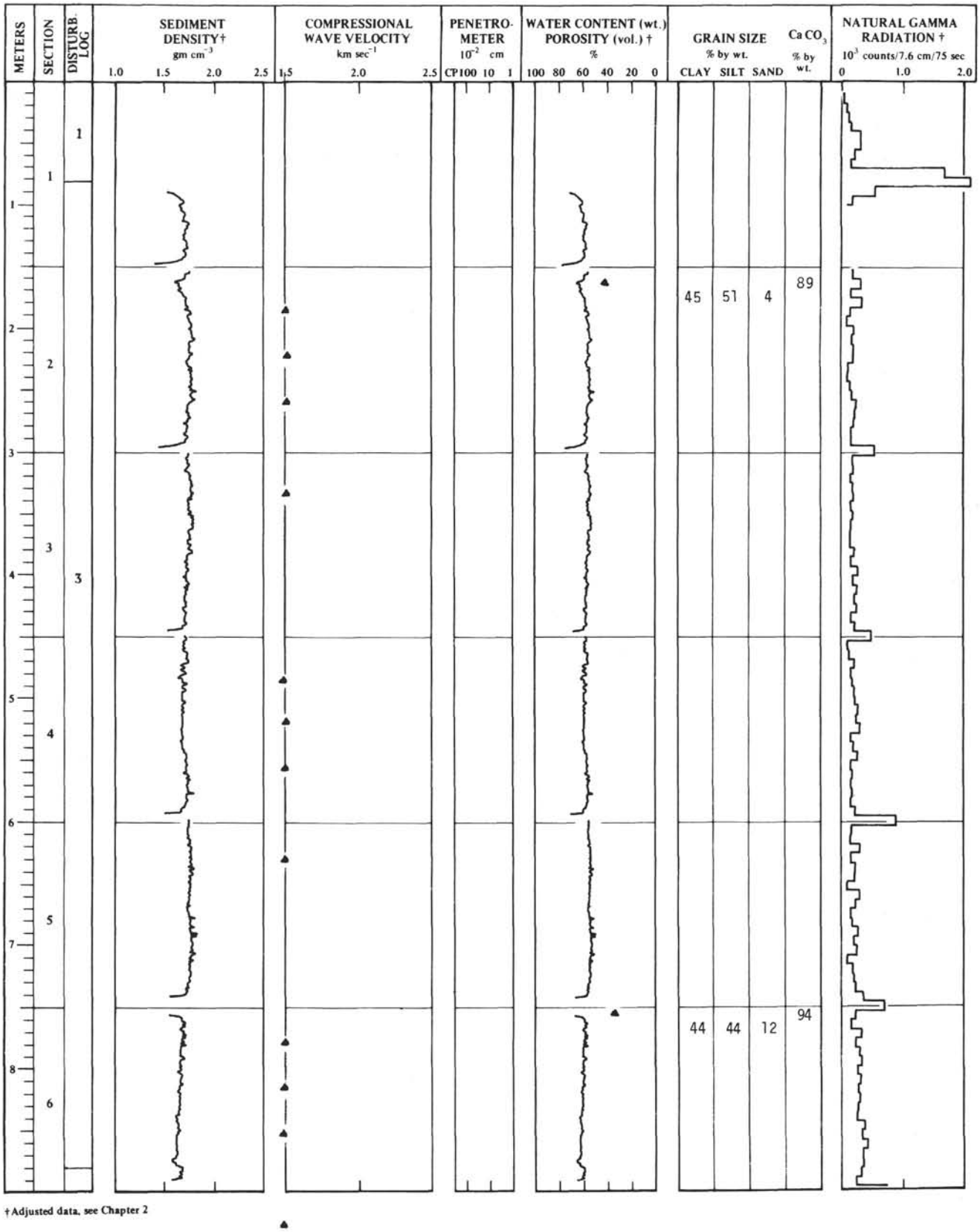
HOLE 116 A 72 TO 81 m

CORE 9

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N N N,F R XM XM	Pale greenish gray foram nannofossil ooze with patches of olive gray silty clay grading into a bluish white and then yellow white ooze. A large shale pebble was found at 60-67 cm in section 2. Core completely disturbed X-ray Mineralogy (bulk) Calc. 99.5 Qtz. .5 Amorph. 34.7	*Coccolithus pelagicus*, *Cyclococcolithus leptoporus*, *C. macintyrei*, *Reticulofenestra pseudoumbilica*, *Pseudoemiliania lacunosa*, *Helicopontosphaera sellii*, *H. kamptneri*, *Pontosphaera discopora*, *P. scutellum*, *Syracosphaera pulchra*, *Scyphosphaera* sp. *Discoaster* sp. Radiolarians rare. Predominantly spheroidal and discoidal spumellarians. *G. atlantica*, *G. bulloides*, *G. pachyderma*, *G. glutinata*, *G. scitula*	*Reticulofenestra pseudoumbilica?*	PLIOCENE
2			F,XM N F		Flora similar to above Forams as above		
	2		R N		Radiolarians very rare. Similar to above. Flora similar to above, + *Discoaster brouweri*, 4 rays		
3			F		Forams as above + *G. puncticulata*		
	3		N F R		Flora similar to sect. 2, 90 cm. Forams as above Radiolarians common. Similar to above. *Phorticium pylonium* and *Druppatractus irregularis* common. *Lithomitra lineata*, *Carpocanistrum* spp.		
4			F	5GY 8/1 5Y 4/1 5B 9/1 5Y 9/1	Forams as above		
5	4		N N F R		Flora similar to sect. 2, 90 cm. Flora similar to sect. 2, 90 cm. Forams as above Radiolarians rare. Reduced assemblage similar to above		
6			N N		Flora similar to above, no discoasters Flora similar to above, + *Discoaster brouweri*		
	5		F R		Forams as above Radiolarians same as above		
7			F		Forams as above + *G. puncticulata* (common)		
8	6		N,F N,R		Flora and fauna similar to above, no discoasters Flora similar to above, no discoasters Radiolarians same as above		
			F		Forams as above		
	CC		F N		*G. atlantica* (abundant), *G. bulloides*, *G. glutinata*, *G. scitula* Flora similar to above, no discoasters, + *Discosphaera tubifera*		

HOLE 116A

CORE 10



†Adjusted data, see Chapter 2

HOLE 116 A 81 TO 90 m

CORE 10

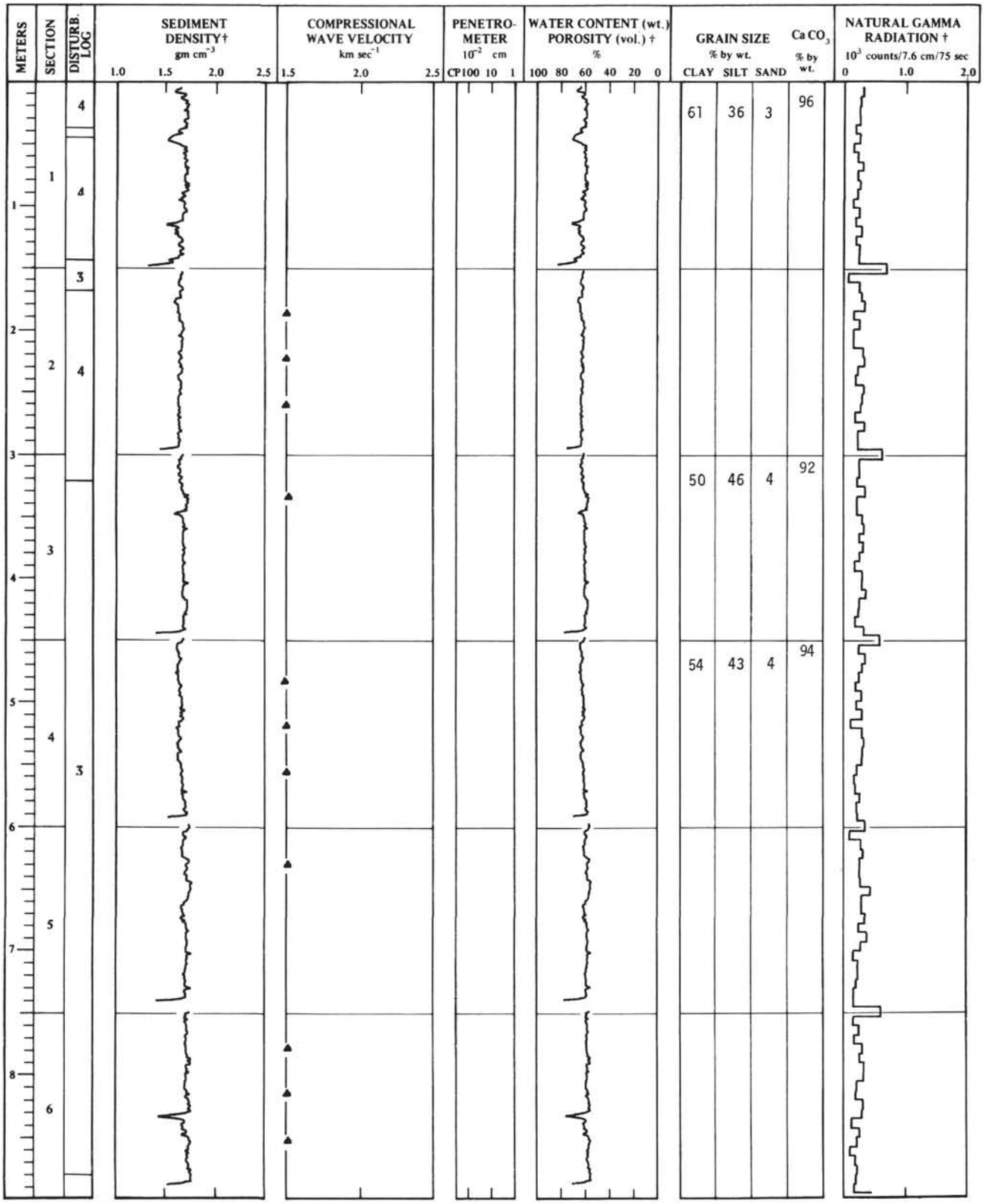
METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
	1	NO CORE					
1			N	Light gray and white foram nannofossil ooze mottled dark gray, pale red purple and medium gray. Flow-in disturbance present throughout core. Volcanic glass and pyrite are dispersed throughout. Pyrite micro nodules are also found.	*G. atlantica* (abund.), *G. bulloides*, *O. universa* *Coccolithus pelagicus*, *Cyclococcolithus leptoporus*, *C. macintyrei*, *Reticulofenestra pseudoumbilica*, *Pseudoemiliania lacunosa*, *Helicopontosphaera sellii*, *H. kamptneri*, *Pontosphaera scutellum*, *Thoracosphaera* sp. *Scyphosphaera* sp.		
			F		Radiolarians rare - Similar to above.		
			R		Flora similar to above, + *Discoaster* sp., *D.* cf. *surculus*		
			N				
			F		Flora similar to above, + *Ceratolithus rugosus*		
2	2		N		Forams as above		
			R		Flora similar to above, + *D.*cf. *surculus*		
					Radiolarians very rare		
			F		Forams as above		
3			XM				
			F		Forams as above		
	3		N		Flora similar to above, + *Discoaster browseri*		
			R		Radiolarians rare		
4				N9 N3 SRP 6/2 N6			
			F		Forams as above + *G. puncticulata* (rare)		
			F		Flora similar to above, + *D. browseri*, *D. surculus*		
			N		Forams as above + *G. crassaformis*		
5	4		F		Radiolarians very rare		
			R				
6							
			N		Flora similar to above		
			F		Forams as above		
	5		R		Radiolarians rare		
7							
			F		Forams as above		
8							
	6		F		Forams as above + *G. puncticulata*		
			R		Radiolarians rare. Increase in discoidal spumellarians		
			N		Flora and fauna similar to above, no discoasters		
			F				
	CC		N		Flora similar to above		
			F		*G. bulloides*, *G. atlantica* (abund.), *G. scitula*, *G. puncticulata*		

Reticulofenestra pseudoumbilica?

PLIOCENE

HOLE 116A

CORE 11



†Adjusted data, see Chapter 2

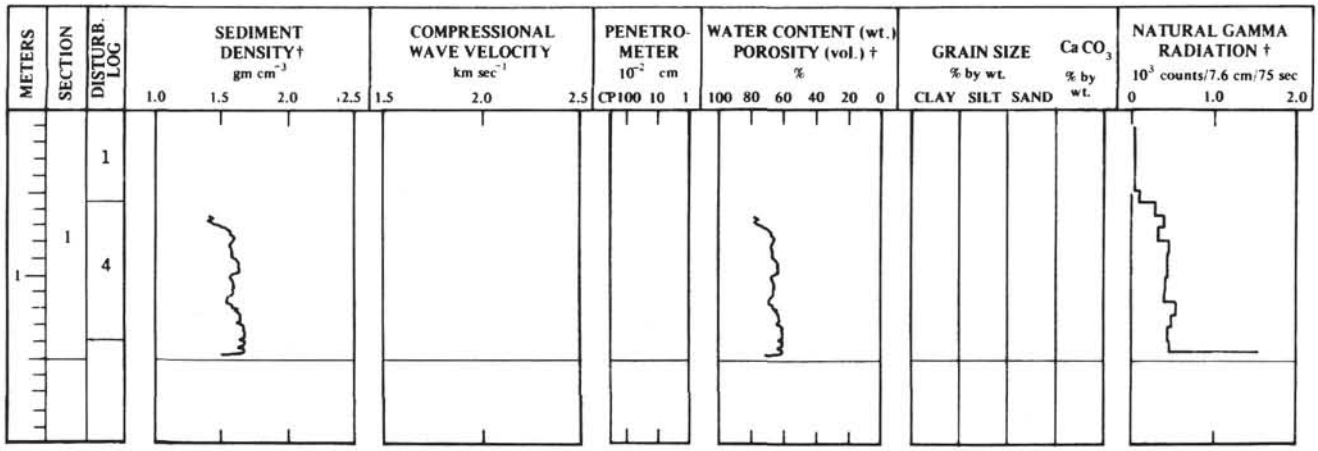
HOLE 116 A 90TO 99 m

CORE 11

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		F,N,R XM N F N R XM F	Very light gray, white, light olive gray, and yellowish gray soft and soupy ooze. The core is slightly mottled pale red purple (5RP 6/2) and green (5G 6/1). Volcanic glass as well as small quantities of palagonite and pyrite occur in the sediment. "Zero" section (28 cm) of same lithology also present. X-ray Mineralogy (bulk) Calc. 100 Amorph. 27.7	Radiolarians abundant, diverse. Predominantly Discoides *Coccolithus pelagicus, Cyclococcolithus leptoporus, C. macintyrei, Scyphosphaera* sp., *Syracosphaera pulchra, Helicopontosphaera sellii, H. kamptneri, Pontosphaera scutellum, Reticulofenestra pseudoumbilica, Rhabdolithus* sp., *Thoracosphaera* sp. *Discoaster* sp. Radiolarians very rare. Reduced assemblage. Forams (here and above): *G. atlantica* (abund.), *G. bulloides, G. puncticulata, O. universa* Flora and fauna similar to above., + *Discoaster variabilis* Radiolarians common. Spongodiscids, *Ommatodiscus* spp., *Enchitonia* spp.		
2	2		N,F R N F		Flora similar to above, no discoasters Forams as above		
3	3		N F R		Flora similar to above, no discoasters Forams as above Radiolarians very rare		
4	4		N F	N8 N9 5Y 6/1 5Y 8/1	Flora similar to above, + *Discoaster pentaradiatus* Forams as above	*Discoaster asymmetricus?*	PLIOCENE
5	4		F R N		Forams as above Radiolarians common. Similar to 11-2. Flora similar to above, + *Discoaster* cf. *asymmetricus, D. pentaradiatus*		
6	5		N,F N,F R N		Flora and fauna, similar to above, + *D. browseri* Flora and fauna similar to above, + *Discoaster surculus* Radiolarians rare. Discoidal & spheroidal spumellarians		
7	5		F		Flora similar to above, no discoasters Forams as above		
8	6		F R N N F		Forams as above Radiolarians very rare. Discoidal spumellarians. Flora similar to above, no discoasters Flora and fauna similar to above, no discoasters		
	CC		F N		*G. atlantica* (abund.), *G. bulloides, G. puncticulata* Flora similar to above, no discoasters		

HOLE 117

CORE 1



†Adjusted data, see Chapter 2

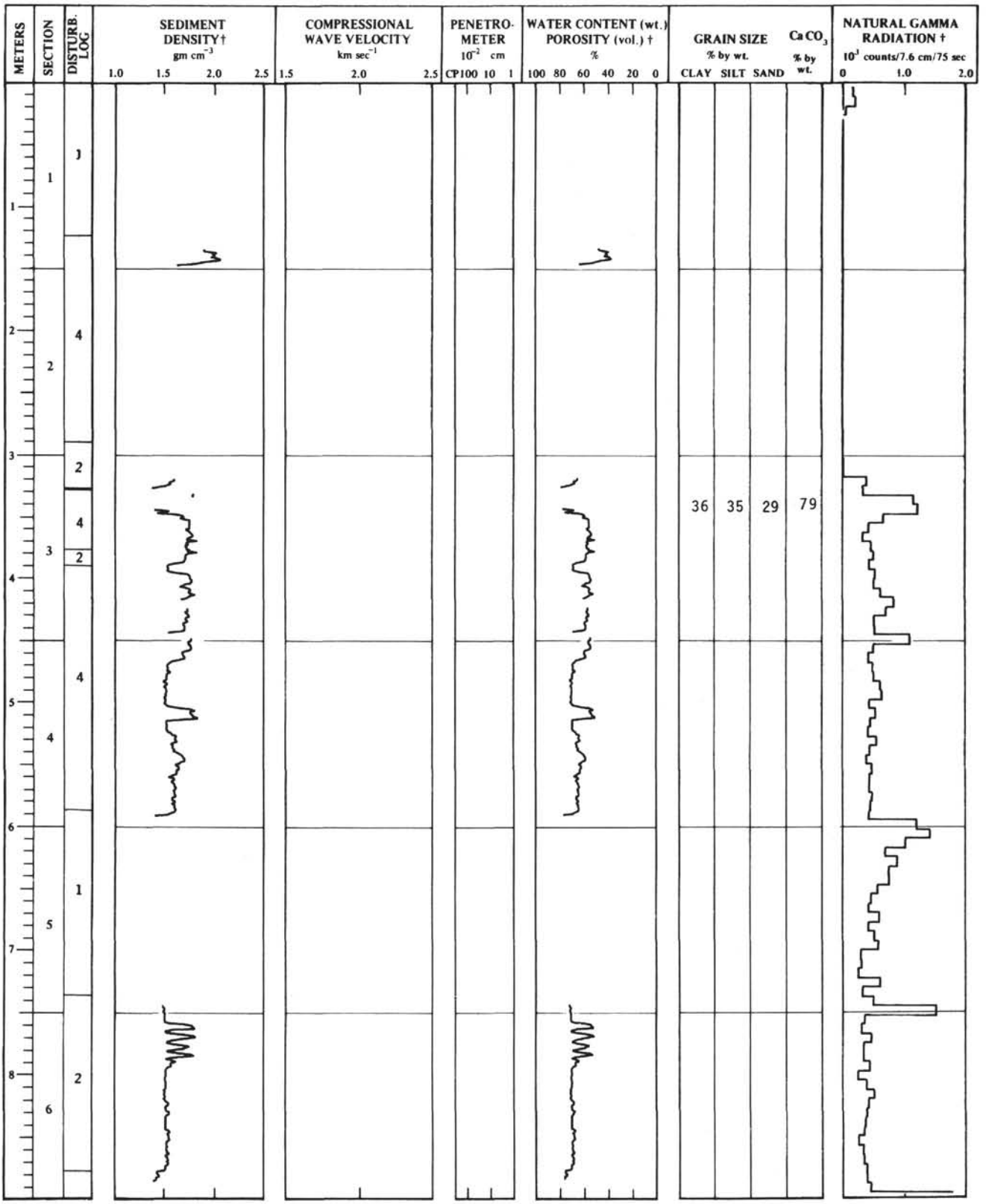
HOLE 117 50 TO 52 m

CORE 1

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NO CORE	N N XM	White, very light gray, and yellowish gray limestone and chert gravel. The gravel is graded, but this phenomenon is probably a result of drilling disturbance.	*Coccolithus pelagicus*, *C. bisectus*, *Chiasmolithus* sp., *Cyclococcolithus neogammation*, *Discolithina* sp., *Rhabdolithus* sp., *Sphenolithus* sp. *Zygrhablithus* cf. *bijugatus* Flora similar to above Core Catcher: Radiolarians very rare. *Cyrtocapsella tetrapera* Flora similar to above		OLIGO-MIOCENE?
	CC		R N				

HOLE 117

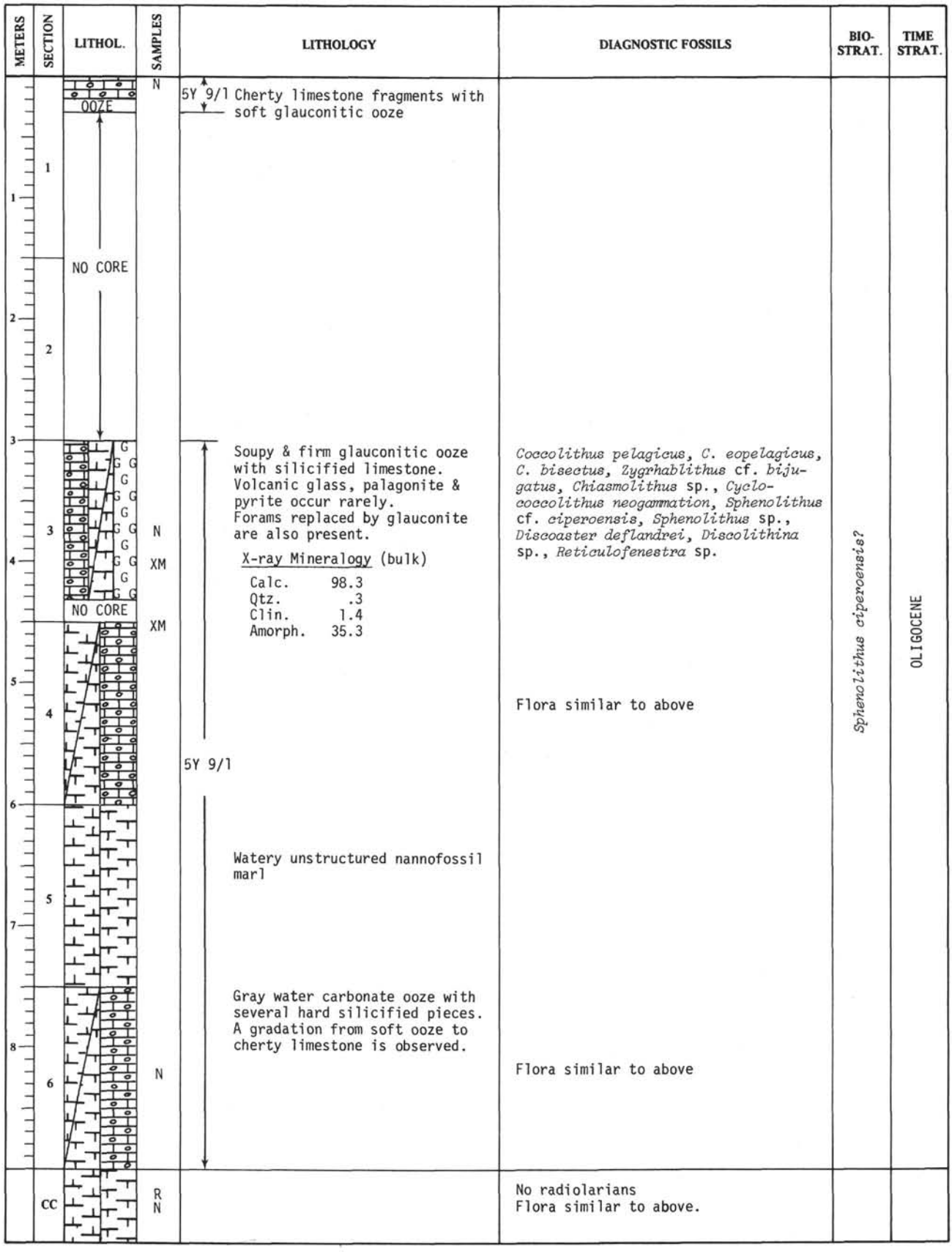
CORE 2



†Adjusted data, see Chapter 2

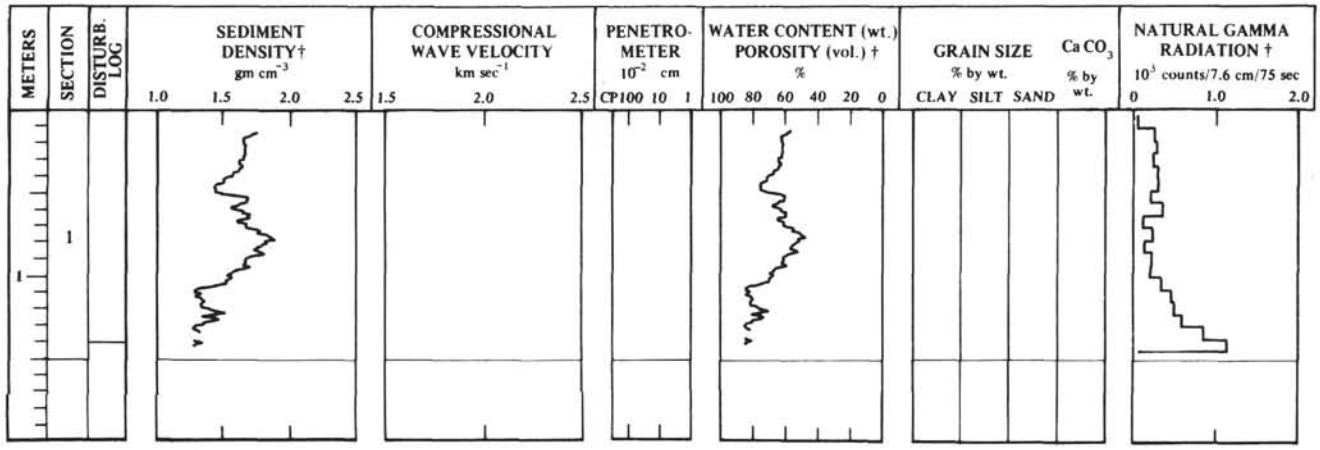
HOLE 117 100 TO 109 m

CORE 2



HOLE 117

CORE 3



†Adjusted data, see Chapter 2

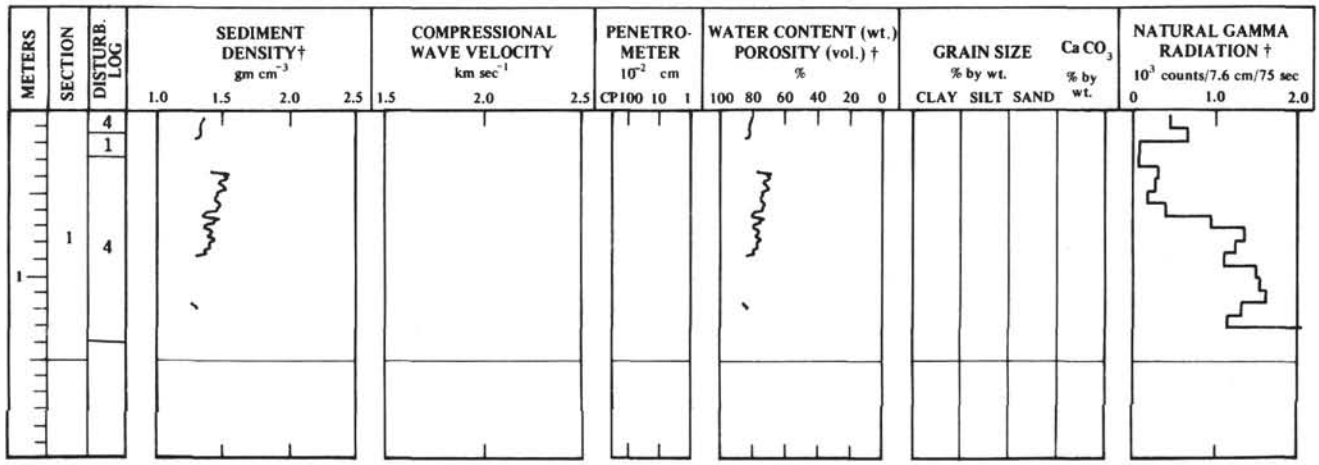
HOLE 117 147 TO 156 m

CORE 3

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N,XM	Rock fragments with size ranging from sand to gravel. The chips are predominantly chert with some sandstone and quartzite fragments. Some lumps of white foram-nanno ooze are also present. Fragments are probably the result of drilling disturbance.	*Coccolithus pelagicus, C. eopelagicus, C. bisectus, Sphenolithus predistentus, Chiasmolithus* sp., *Cyclococcolithus neogammation, Braarudosphaera bigelowi, Zygrhablithus* cf. *bijugatus, Helicopontosphaera truncata**	*Sphenolithus predistentus? S. distentus?*	OLIGOCENE
	CC		N		Core Catcher: Dark: *Discoaster lodoensis, D. binodosus Discolithina exilis,* Light: *Coccolithus bisectus*: mixed few small coccoliths * + reworked Late Paleocene (*Fasciculithus* sp., *Neococcolithus junctus*) and contamination by *Gephyrocapsa oceanica* (Pleistocene)! Core water: one orosphaerid radiolarian ((?) *Oropelex* sp.)	Core Catcher: *M. tribrachiatus*	EOCENE

HOLE 117A

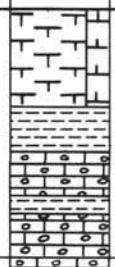
CORE 1



†Adjusted data, see Chapter 2

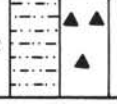
HOLE 117 A 146 TO 155 m

CORE 1

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N,F XM XM N,F	5Y 6/1 N9 5G 4/1 Gray foram sand, white ooze, dark greenish gray clay, and cherty limestone gravel with graded bedding. The contact between the gravel & clay is very sharp. Whole core is disturbed. X-ray Mineralogy (bulk) Calc. 13.4 Qtz. 2.3 Plag. 19.7 Mont. 40.0 Clin. 19.9 Augite 4.7 Amorph. 73.3	*Coccolithus pelagicus, C. eopelagicus, C. bisectus, Sphenolithus predistentus, Sphenolithus* sp., *S. moriformis, Helicopontosphaera truncata, Cyclococcolithus neogammation, Discolithina* sp., *Zygrhablithus* cf. *bijugatus, Braarudosphaera bigelowi Coccolithus bisectus, Chiasmolithus pelagicus, Isthmolithus recurvus, Markalius inversus, Marthasterites obscurus, Discoaster kuepperi, D. elegans, M. tribrachiatus Transversopontis pulcher, Fasciculithus?* sp.: Mixed assemblage Early Eocene to Early Oligocene 1-1, 40-42: *G. angiporoides, G. unicava* Core Catcher: Zeolitized forams *Discoaster lodoensis, D. kuepperi, D. binodosus, Marthasterites tribrachiasus, Markalius inversus, Braarudosphaera bigelowi, Discolithina* sp. *Chiphragmalithus armatus Helicopontosphaera seminulum, Chiasmolithus,* contaminated by Oligo-Miocene forms Core water: one *Cyrtocapsella tetrapera*	*Sphenolithus distentus-predistentus?* *Marthasterites tribrachiatus* Core Catcher: *Marthasterites tribrachiatus*	OLIGOCENE EOCENE EARLY EOCENE
	CC		F N R				

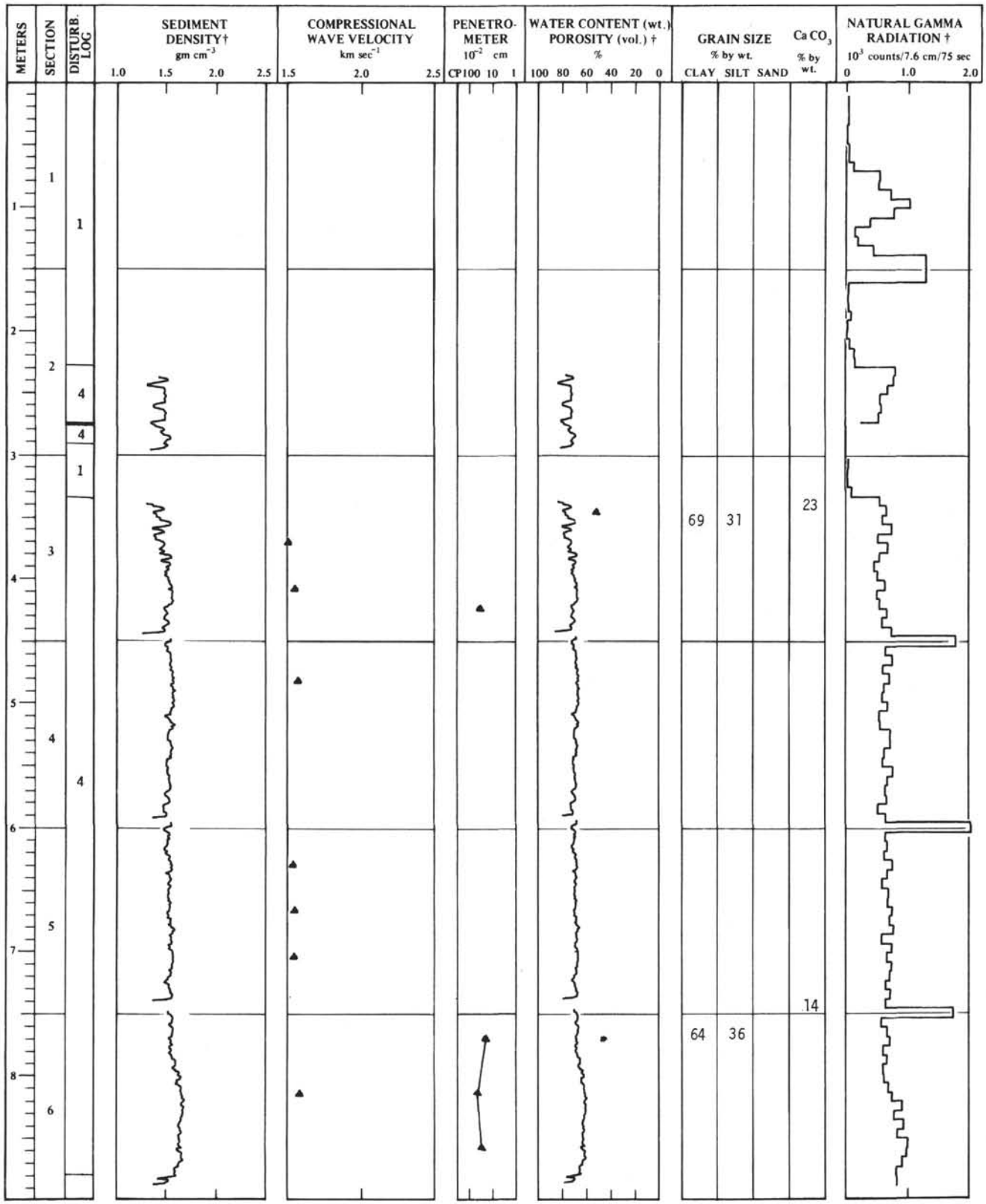
HOLE 117 A 174 TO 183 m

CORE 2

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
	CC		F N,XM R	Core Catcher only, consisting of chert cuttings and gray silty clay. Volcanic glass and pyrite occur commonly with a small amount of glauconite.	No Foraminifera *Marthasterites tribrachiatus, M. obscurus, Discoaster kuepperi, D. binodosus, Chiasmolithus eograndis, C. bidens, Neococcolithus protenus, Chiphragmalithus armatus, Transversopontis pulcher, Toweius occultatus, Ericsonia ovalis, Discolithina panarium, D. plana.* Assemblage contaminated by Oligocene coccoliths: *Coccolithus bisectus, Sphenolithus* sp. Very abundant zeolitized radiolarians.	*Marthasterites tribrachiatus*	EARLY EOCENE

HOLE 117A

CORE 3



† Adjusted data, see Chapter 2

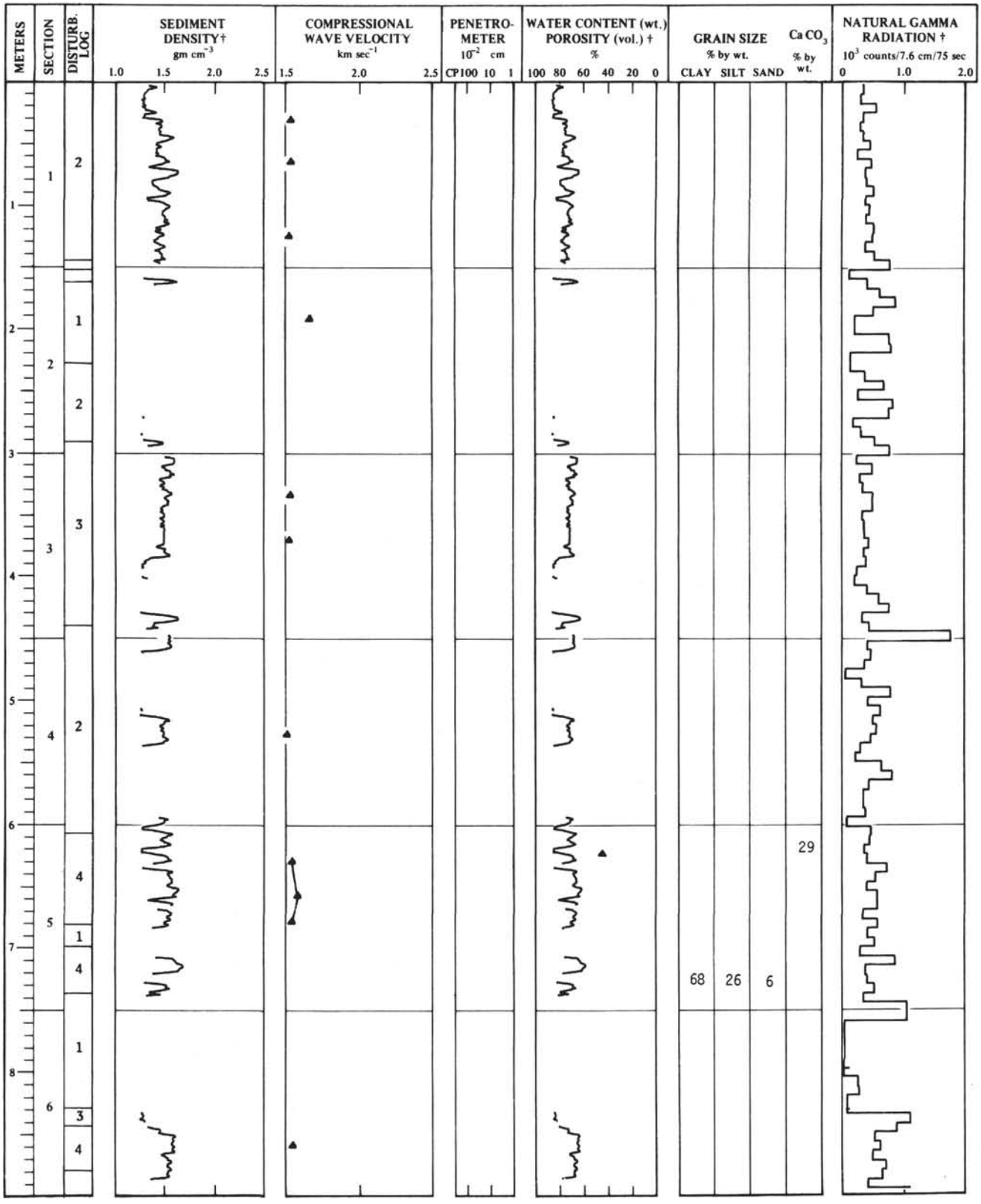
HOLE 117 A 222 TO 227 m

CORE 3

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NO CORE	XM	Alternating layers of soupy & firm olive gray clay with phosphorite nodule at 122-125.5 cm. Nodule contains randomly distributed fish debris and ophiurids. Volcanic glass is abundant. Clay becomes denser & darker toward bottom of core and is intensely burrowed. Sections 1-3 are disturbed.	*Ericsonia ovalis, Marthasterites tribrachiatus, M. obscurus, Micrantholithus flos, Rhabdolithus* sp. *Discolithina fimbriata, Neococcolithes protenus, N.* cf. *dubius, Braarudosphaera bigelowi, Sphenolithus anarrhopus, Sphenolithus* sp. *Zygrhablithus bijugatus, Toweius craticulus, Discoaster kuepperi, Thoracosphaera* sp., *Chiasmolithus* sp. *Globigerina patagonica,* acarininids	*Marthasterites tribrachiatus?*	EARLY EOCENE
		NO CORE	N				
			F				
		NO CORE					
2	2		N	X-ray Mineralogy (bulk) Calc. 30.9 Qtz. 1.0 K-Fe 10.0 Plag. 2.4 Kaol. 2.7 Mont. 53.0 Amorph. 77.2	Flora similar to above, + *Discoaster gemmeus, Discolithina plana, D. exilis*		
			F	5Y 4/1	Foram fauna as above; *Anomalinoides grosserugosa, Osangularia pteromphalia*		
3	3						
4			N		Flora similar to above		
			F		Foram fauna as above + *Lenticulina alatolimbata, L. decorata, Cibicidoides sulzensis, Os. pteromphalia*		
5	4		N		Flora similar to above, + *Discoaster lodoensis* (rare)		
6	5		N	5Y 2/1	Flora similar to above, + *Lophodolithus nascens*		
7			N		Flora similar to above, + *L. nascens*		
8	6		N		Flora similar to above		
			XM				
			F		Foram fauna as above		
	CC		R N F		No radiolarians Flora similar to above Foram fauna as above + *An. acuta*		

HOLE 117A

CORE 4



†Adjusted data, see Chapter 2

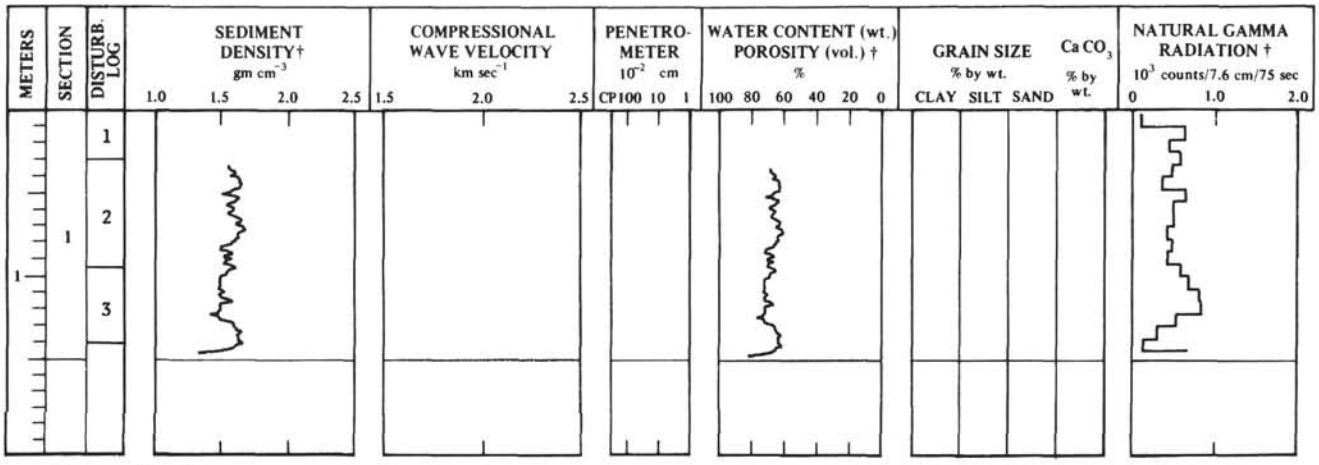
HOLE 117 A 270 TO 272 m

CORE 4

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N,F N F	Very watery and disturbed olive gray clay 5Y 4/2	*Discoaster multiradiatus, D. salisburgensis, D.* cf. *gemmeus, Zygodiscus adama, Chiasmolithus bidens, Toweius craticulus, Ellipsolithus distichus, E. macellus, Markalius inversus, Fasciculithus* sp., *Braarudosphaera bigelowi, Micrantholithus vesper, Thoracosphaera* sp. *Neococcolithes protenus, N.* cf. *dubius, Marthasterites* cf. *contortus* No planktonic forams; BF: *Cib. proprius, C. hercegovinensis*	*Discoaster multiradiatus - Marthasterites contortus*	LATE PALEOCENE - EARLY EOCENE
2	2	NOT SPLIT					
3	3		N,F N	X-ray Mineralogy (bulk) Calc. 37.2 Qtz. 1.0 K-Feld. 2.2 Plag. 1.3 Mont. 45.8 Clin. 12.5 5Y 4/2	Flora and fauna similar to above Flora similar to above		
4	4	NOT SPLIT					
5	5	GAP	N,F XM N	Dense olive gray clay with small patches of pale yellow calcitic/zeolitic silt and bryozoa fragments. Volcanic glass occurrence increases toward bottom of core. Core is disturbed. Zero section (26.5) of olive gray clay (5Y 4/1) also present. 5Y 4/2 2.5Y 7/4	Flora and fauna similar to above Flora similar to above		
7		GAP					
8	6		XM N,F		Flora and fauna similar to above		
	CC		R N F		Rare zeolitized radiolarians Flora similar to above *Globigerina triangularis, Globig. velascoensis,* acarininids		

HOLE 117A

CORE 5



†Adjusted data, see Chapter 2

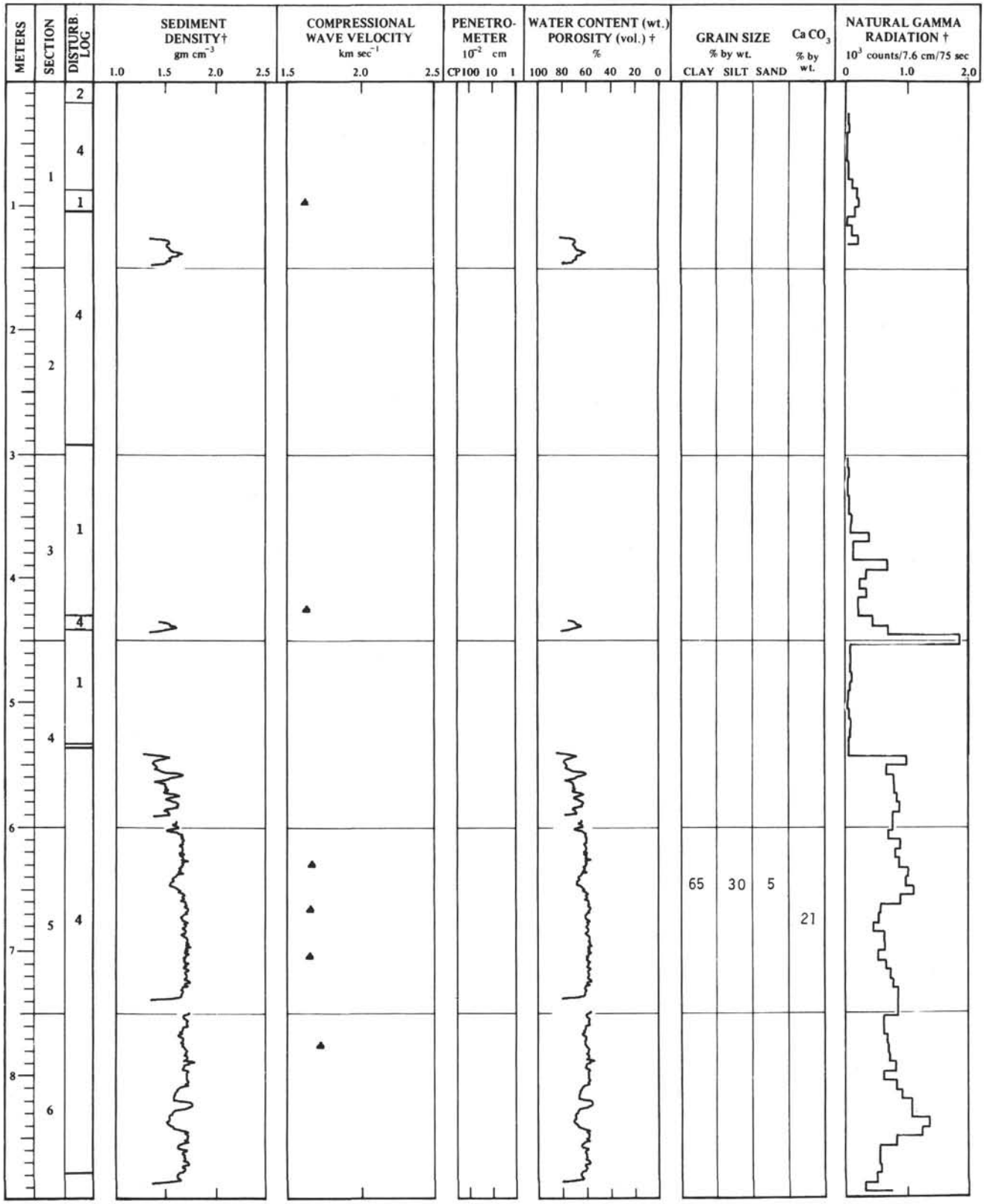
HOLE 117 A 272 **TO** 276 **m**

CORE 5

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N XM N,F F	5Y 4/1 5GY 4/1 Very firm, dense, olive gray clay grading into a dark greenish gray clay. Core is very slightly burrowed and mottled.	*Chiasmolithus bidens, Ellipsolithus distichus, Discoaster multiradiatus, Discoaster* sp., *Toweius* sp., *Thoracosphaera* sp., *Fasciculithus* sp., *Sphenolithus anarrhopus, Markalius inversus, Marthasterites* cf. *contortus, Neococcolithes protenus, N. concinnus* Flora similar to above *Globigerina triangularis, Globig. velascoensis*, acarininids; *Eponides plummerae, Alabamina obtus, Cib. hercegovinensis, Cib. proprius* Core Catcher: No radiolarians Flora similar to above Fauna as above	*Discoaster multiradiatus - Marthasterites contortus*	LATE PALEOCENE – EARLY EOCENE
	CC		R N F				

HOLE 117A

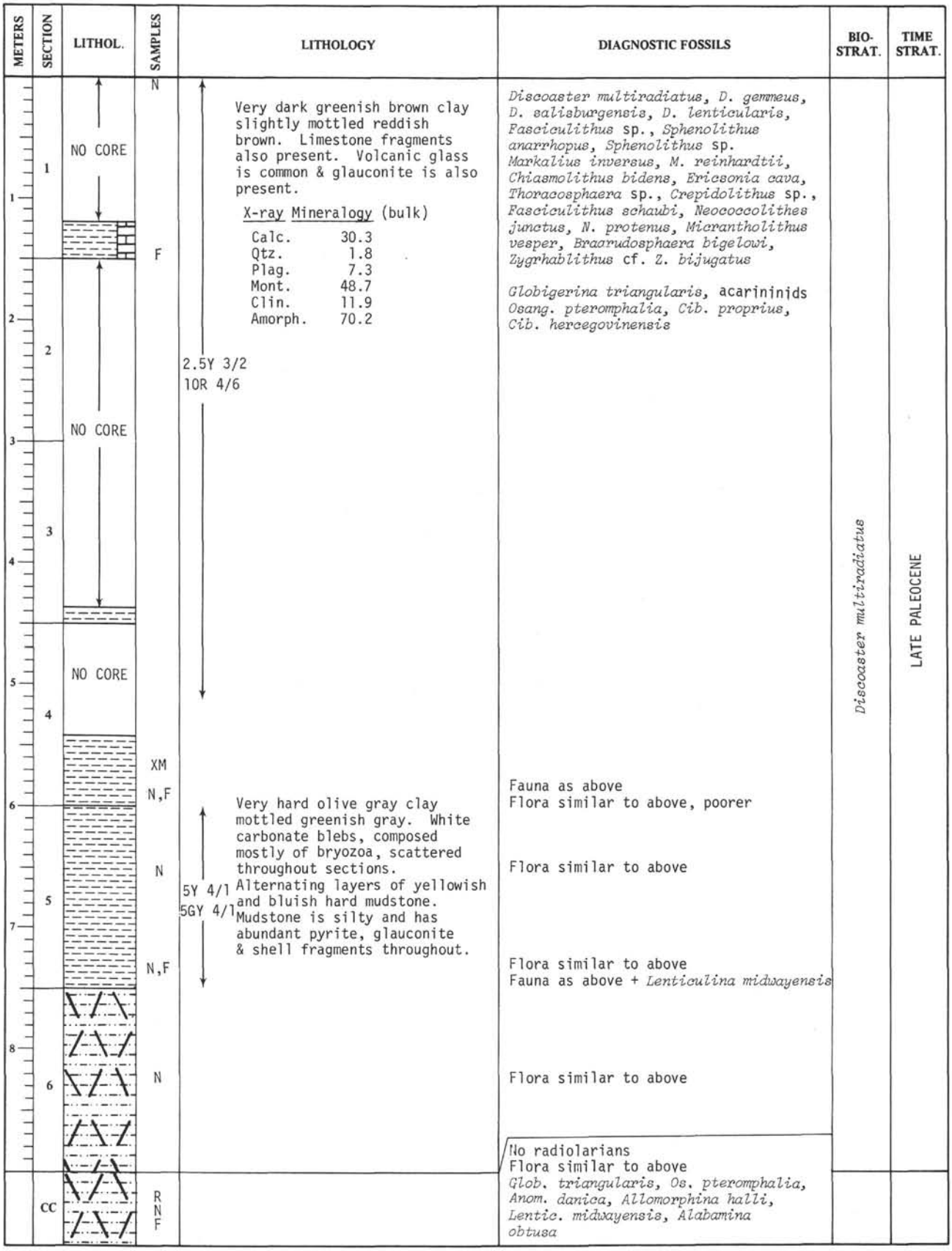
CORE 6



† Adjusted data, see Chapter 2

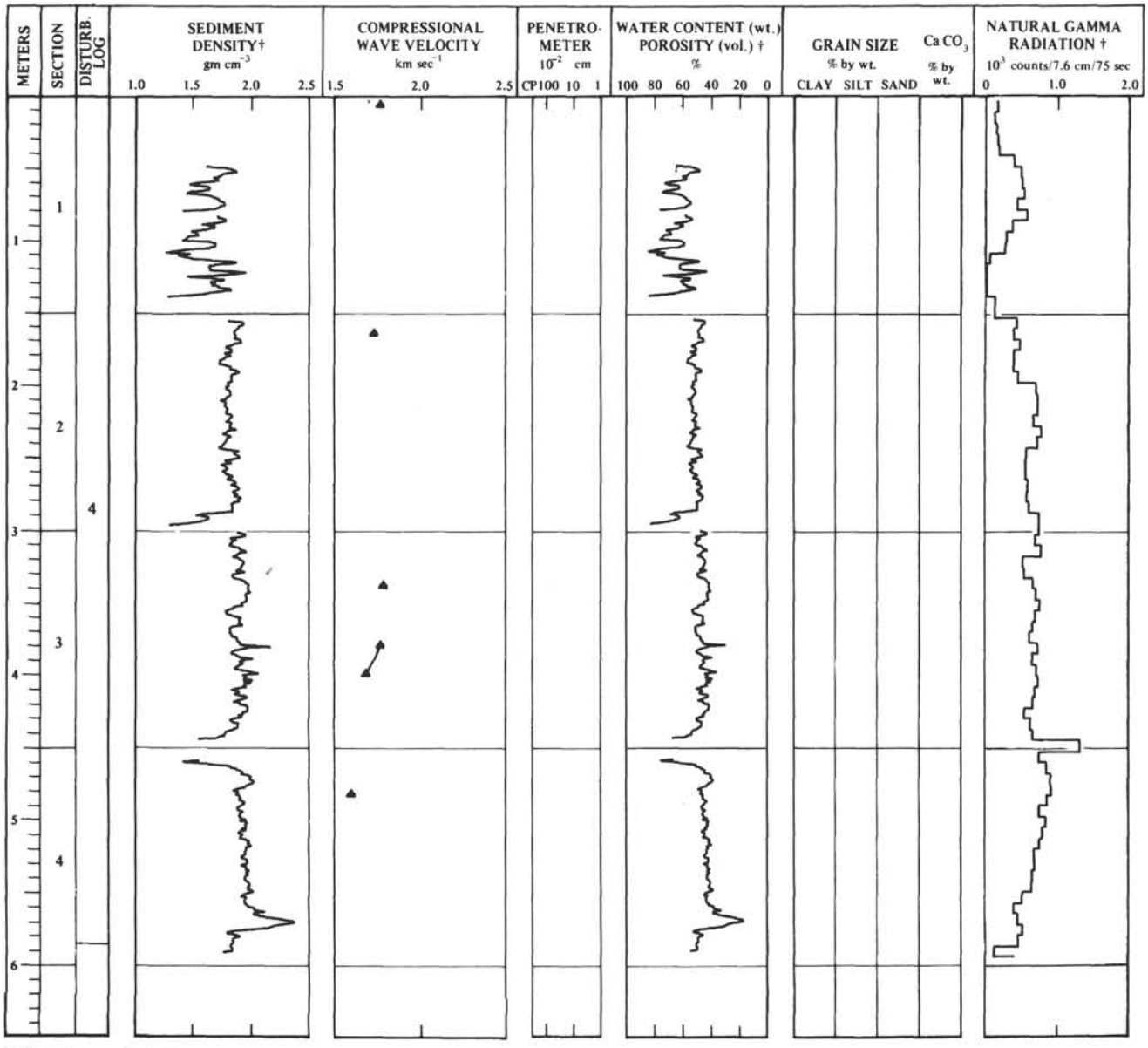
HOLE 117 A 276 TO 285 m

CORE 6



HOLE 117A

CORE 7



†Adjusted data, see Chapter 2

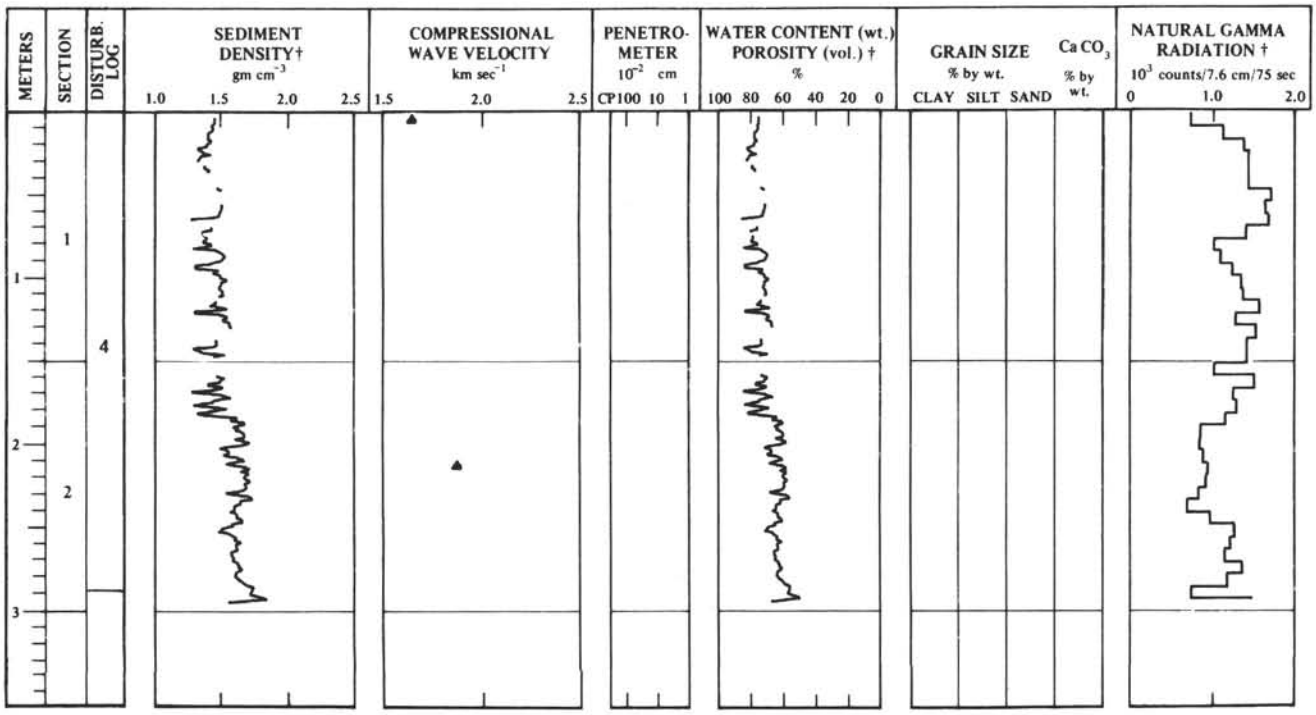
HOLE 117 A 285 TO 294 m

CORE 7

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N	5Y 4/1 Dark gray & greenish olive gray fragmented mudstone with 5Y 5/2 inclusions of reworked volcanic material, bryozoa & molluses.	*Discoaster multiradiatus, Chiasmolithus* cf. *consuetus, Ericsonia cava, Thoracosphaera operculata, Markalius inversus, M. reinhardtii, Ellipsolithus distichus, E. macellus, Toweius craticulus, Fasciculithus* sp. *Braarudosphaera bigelowi, Discolithina plana, Sphenolithus* sp.	*Discoaster multiradiatus*	LATE PALEOCENE
		NO CORE					
2	2		XM				
			N		Flora similar to above		
3			N		Flora similar to above		
4	3		N	Purple, green, & yellow mudstone with a layer of very hard conglomerate composed of purple & green mudstone fragments in a carbonate cement. The conglomerate is underlain by a smooth light olive gray (5Y 5/2) clay.	Flora similar to above		
			F		*Globigerina triangularis, Globig. velascoensis, Karreria fallax, Anom. acuta, Lentic. midwayensis*		
5	4		N		Flora similar to above		
			N		Flora similar to above		
	CC		R N F		No radiolarians Flora similar to above Foram fauna as above		

HOLE 117A

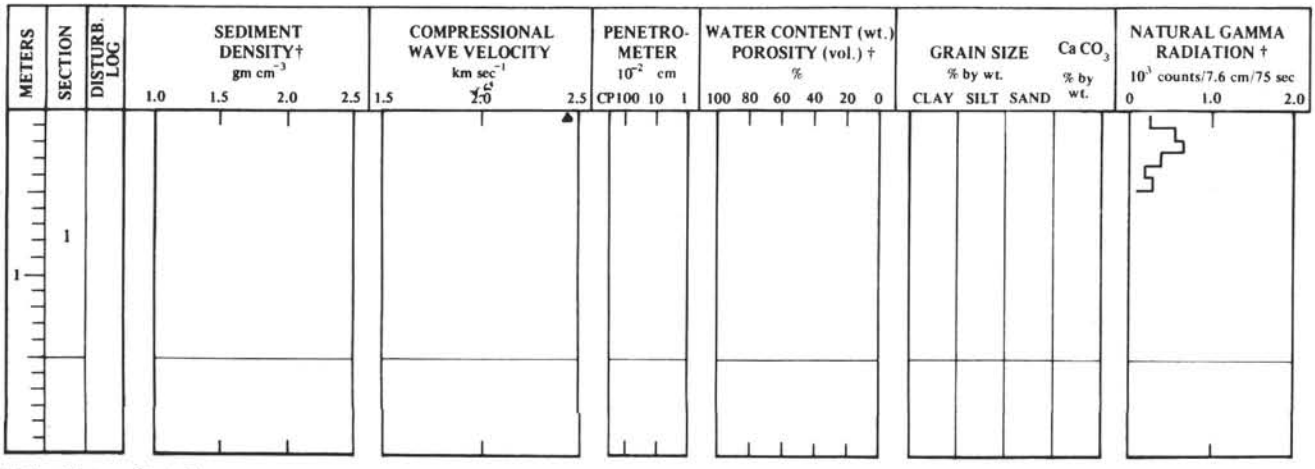
CORE 8



†Adjusted data, see Chapter 2

HOLE 117A

CORE 9



†Adjusted data, see Chapter 2

HOLE 117 A 294 TO 303 m

CORE 8

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1		N XM,F	10YR 4/2 Dark yellowish brown silty clay with mollusc shells. Slickensides dipping at an angle of 60° appear on a clay pebble at 30-37 cm.	*Discoaster* cf. *gemmeus*, *Micrantolithus bramlettei*, *Braarudosphaera bigelowi*, *Transversopontis* sp. *Crepidolithus* sp., *Fasciculithus* sp. *Neococcolithes* cf. *dubius*, *N. protenus* *Thoracosphaera* sp., *Toweius craticulus*, *Crepidolithus* sp., *Chiasmolithus consuetus*	*Discoaster multiradiatus*	LATE PALEOCENE
			N	5Y 2/1 Olive black sandy silt composed of rock fragments (mainly poorly reworked volcanic material). Large articulated Ostrea shell at bottom of section 1.	Flora similar to above, + *Discoaster multiradiatus* *Globig. triensularis*, *G. velascoensis*, *Anom. danica*, *A. acuta*, *Os. pteromphalia*		
2	2		N		Flora similar to above		
			N,F	10YR 4/2 5Y 2/1 Dark yellowish brown and olive black reworked volcanic material. Volcanic glass & palagonite are common; Phillipsite occurs rarely. Many Bryozoa are present in the sediment.	Flora similar to above Foram fauna as above		
	CC		F N R		Foram fauna as above Flora similar to above, + *Cruciplacolithus tenuis* No radiolarians		

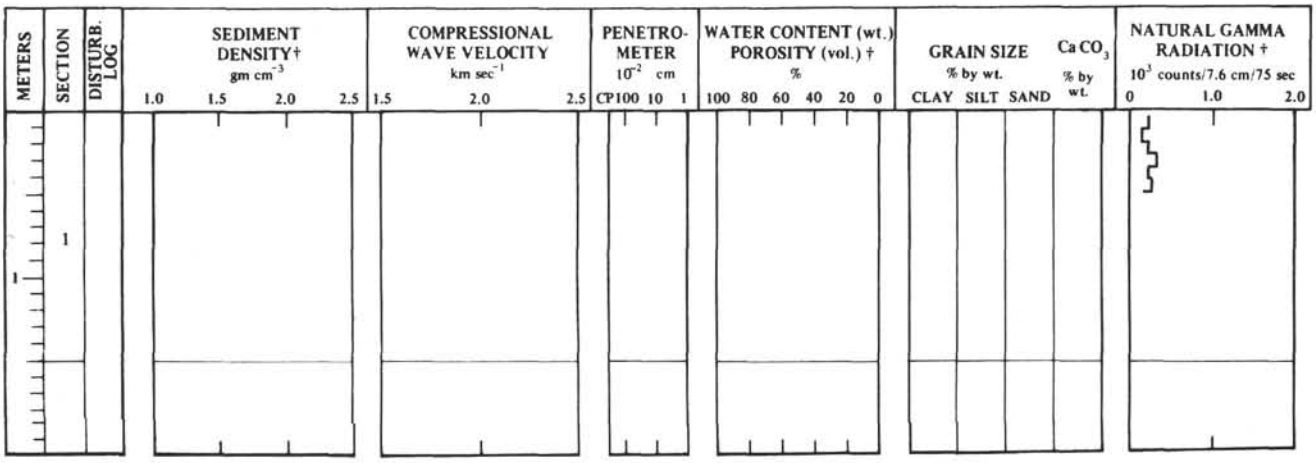
HOLE 117 A 303 TO 304 m

CORE 9

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NO CORE NO CORE	N	Sandstone with fossil fragments consisting of mollusc shells and carbonate annelid worm burrows	*Fasciculithus* sp., *Ericsonia cava*, *Discoaster multiradiatus*, *Micrantholithus* cf. *attenuatus*, *Chiasmolithus consuetus*, *Toweius craticulus*, *Thoracosphaera* sp.	*Discoaster multiradiatus*	LATE PALEOCENE
	CC		N F		*Thoracosphaera* sp., *Ericsonia cava*, small coccoliths. Small Globigerinids, *Marginulina*, Polymorphinids, *Eponides plummerae*, *Operculina heberti*		

HOLE 117A

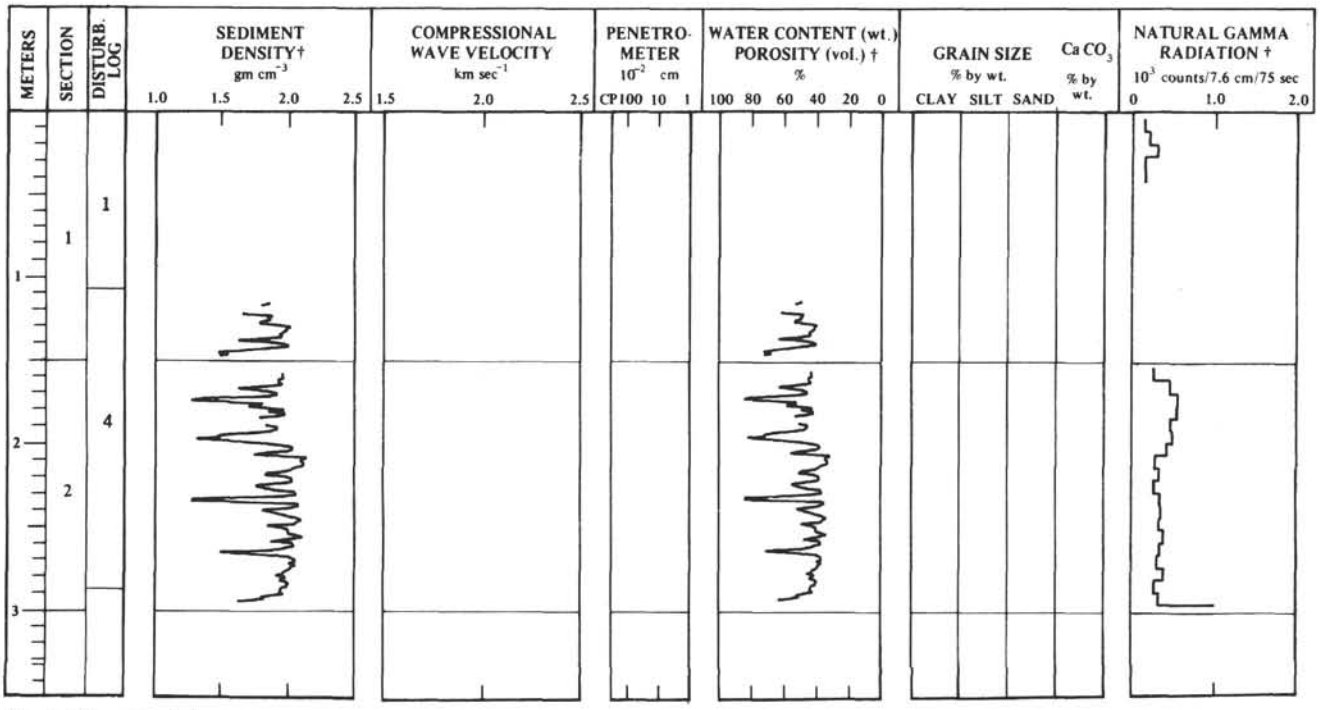
CORE 10



†Adjusted data, see Chapter 2

HOLE 117A

CORE 11



†Adjusted data, see Chapter 2

HOLE 117 A 304 TO 311 m

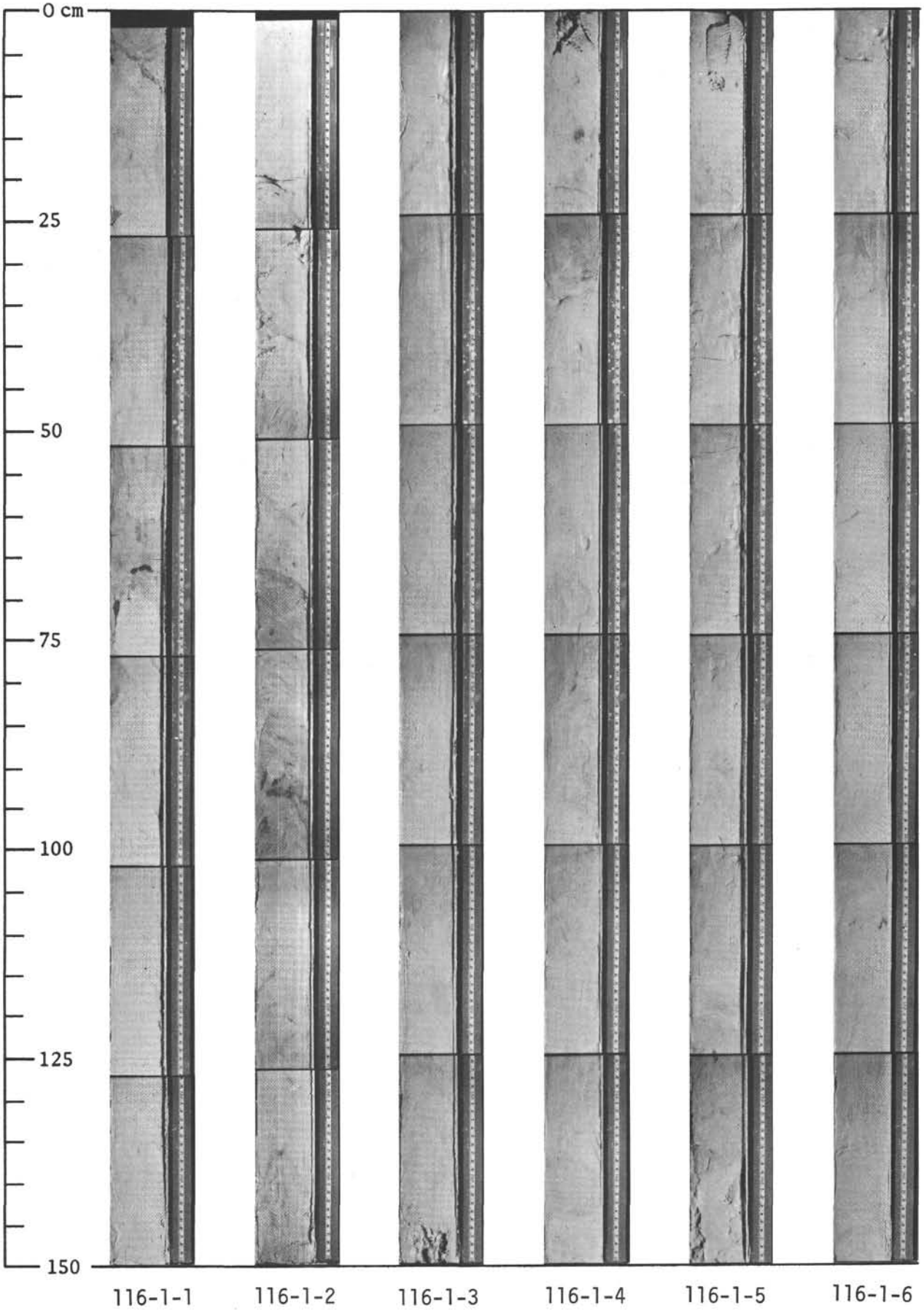
CORE 10

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	NO CORE		Dark greenish gray sandy conglomerate of poorly reworked volcanic material (5GY 4/1)	*Braarudosphaera bigelowi, Chiasmolithus consuetus, Fasciculithus* sp. *Zygrhablithus* cf. *exilis, Neococcolithus* sp. *Ellipsolithus macellus, E. distichus, Micrantholithus* sp. *Sphenolithus* sp., *Discoaster multiradiatus*	*Discoaster multiradiatus*	LATE PALEOCENE
	CC		N				

HOLE 117 A 311 TO 313 m

CORE 11

METERS	SECTION	LITHOL.	SAMPLES	LITHOLOGY	DIAGNOSTIC FOSSILS	BIO-STRAT.	TIME STRAT.
1	1	EMPTY		Dark blue-green basalt, fragmented, contains veins with shell fragment and sandstone inclusions			
2	2	NOT SPLIT					
	CC	NO CORE					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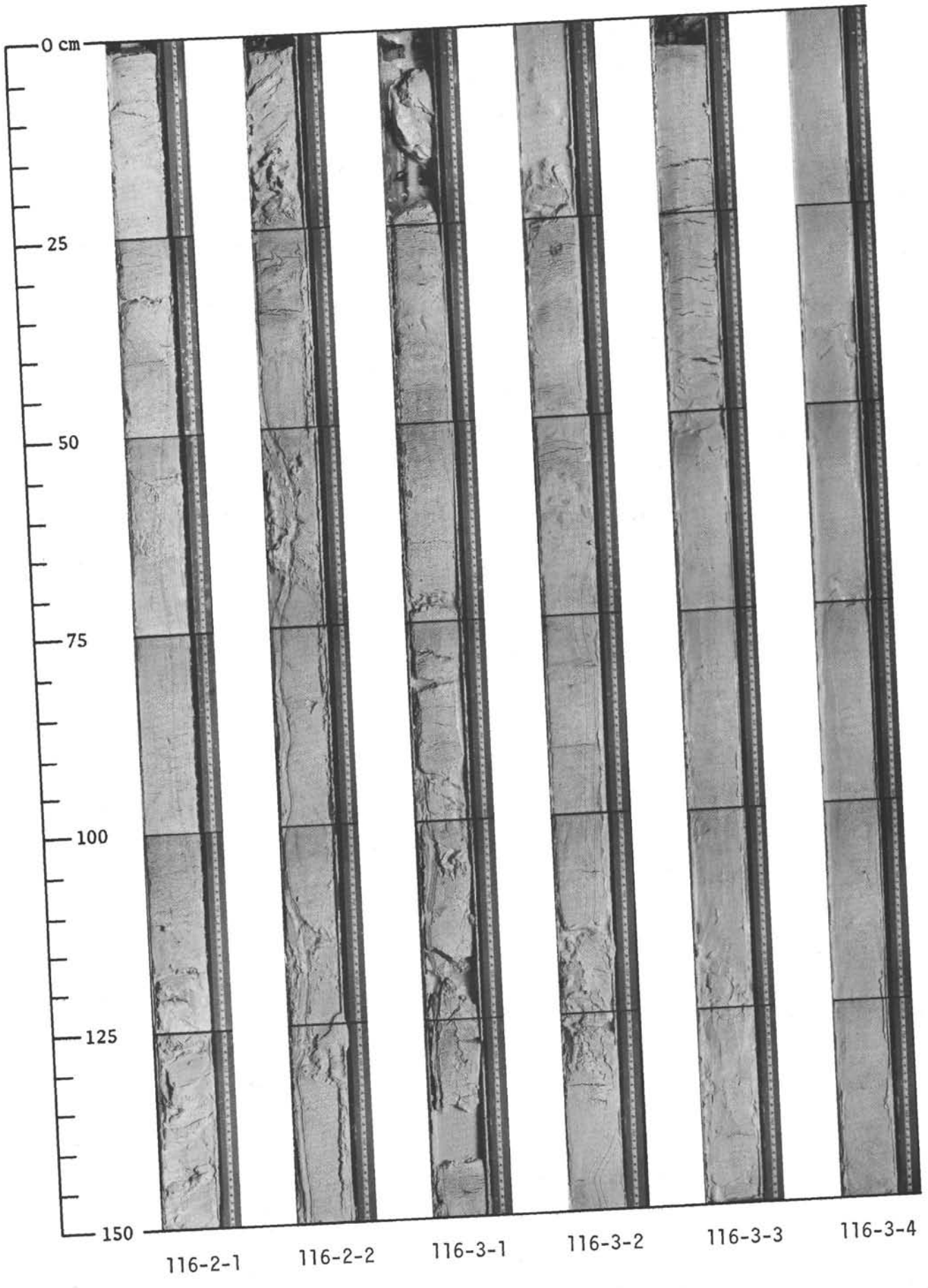
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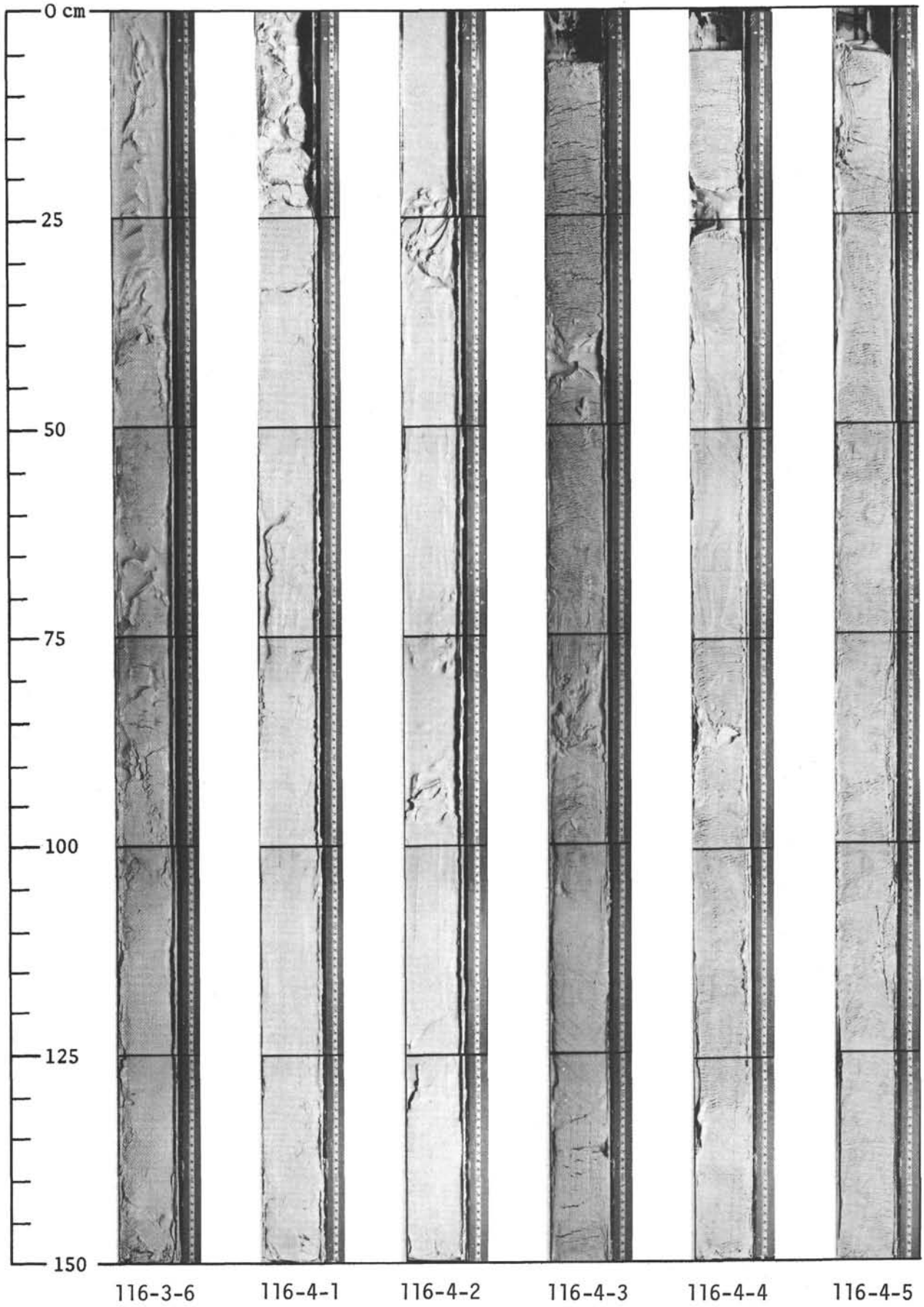
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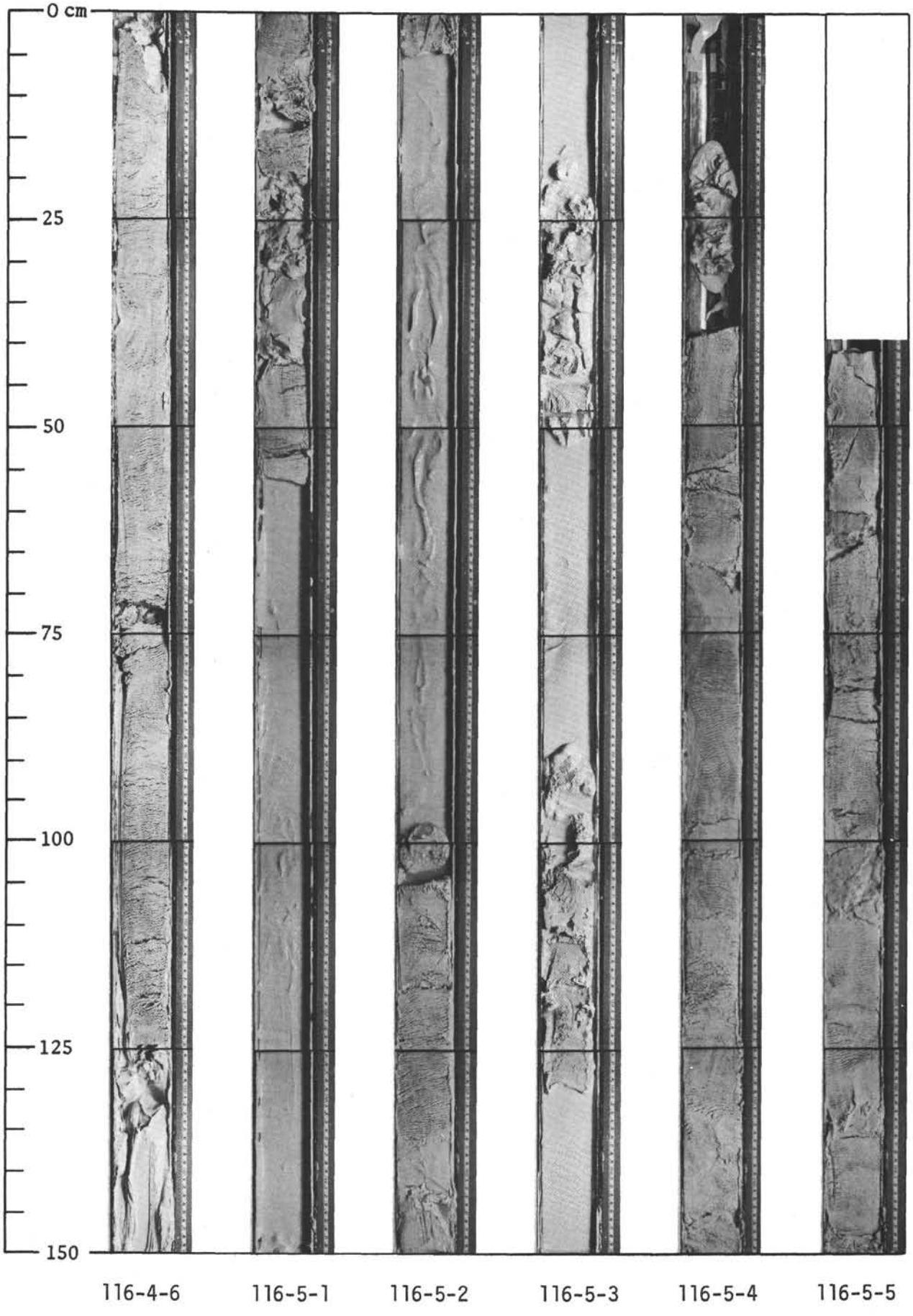
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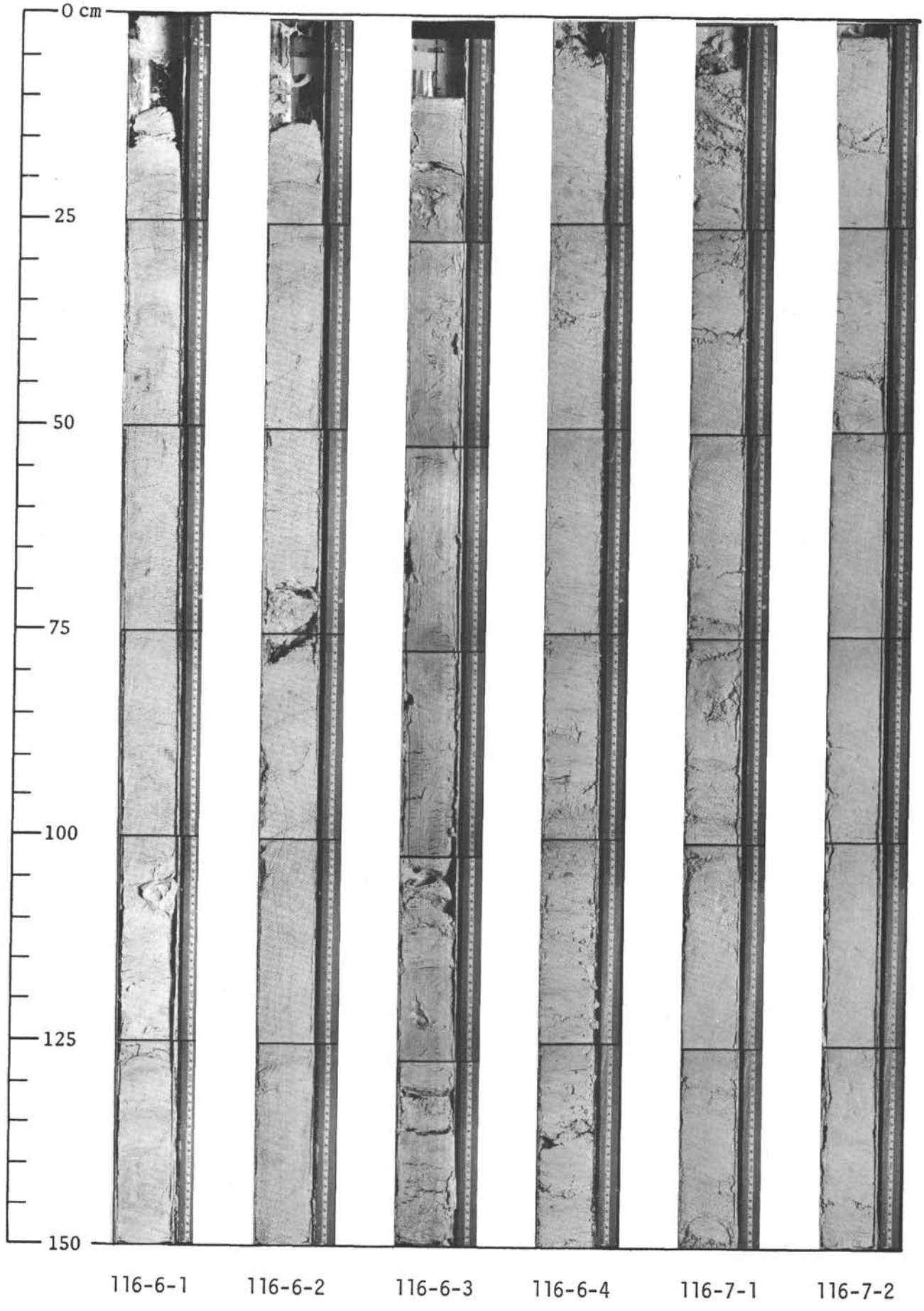
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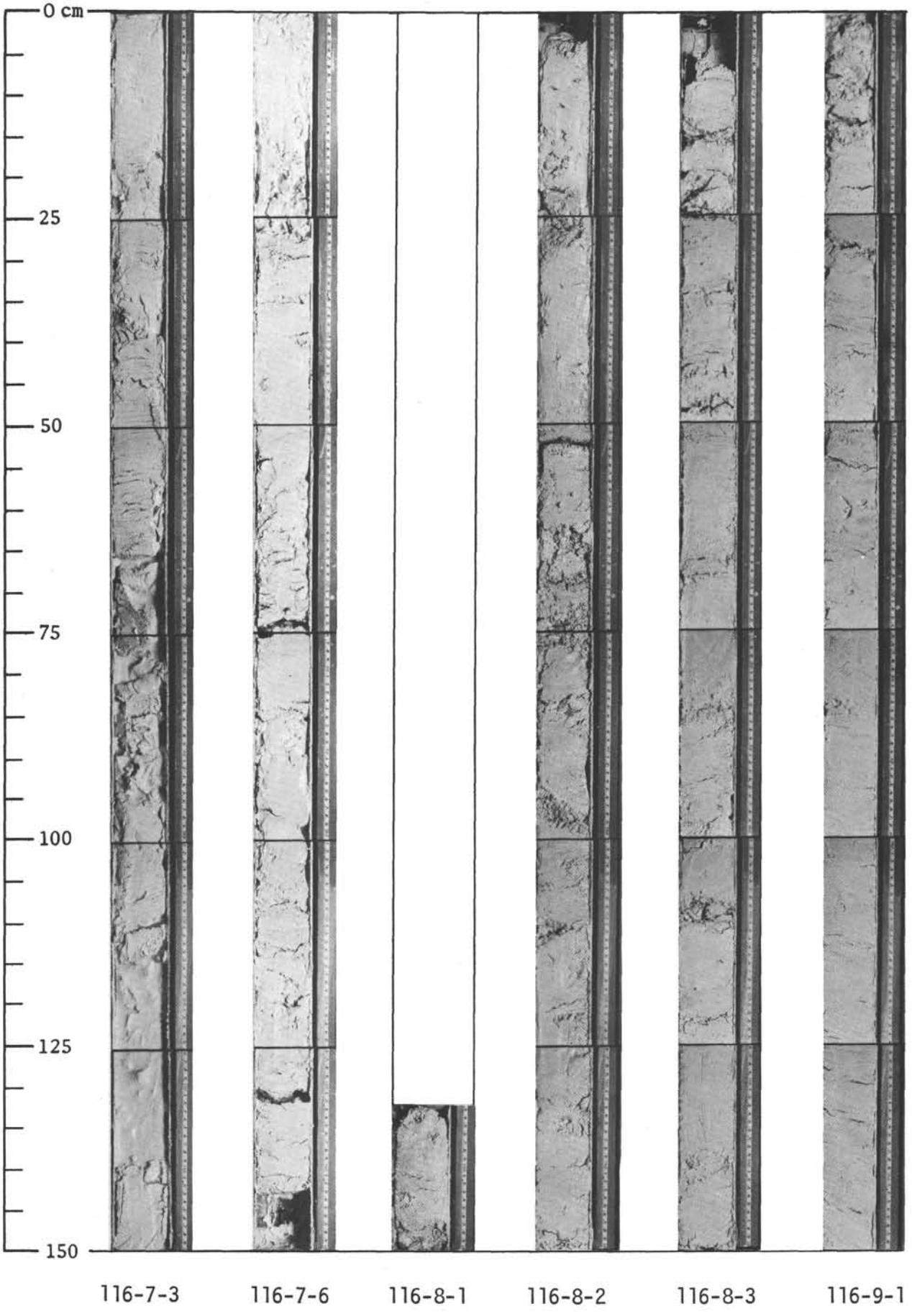
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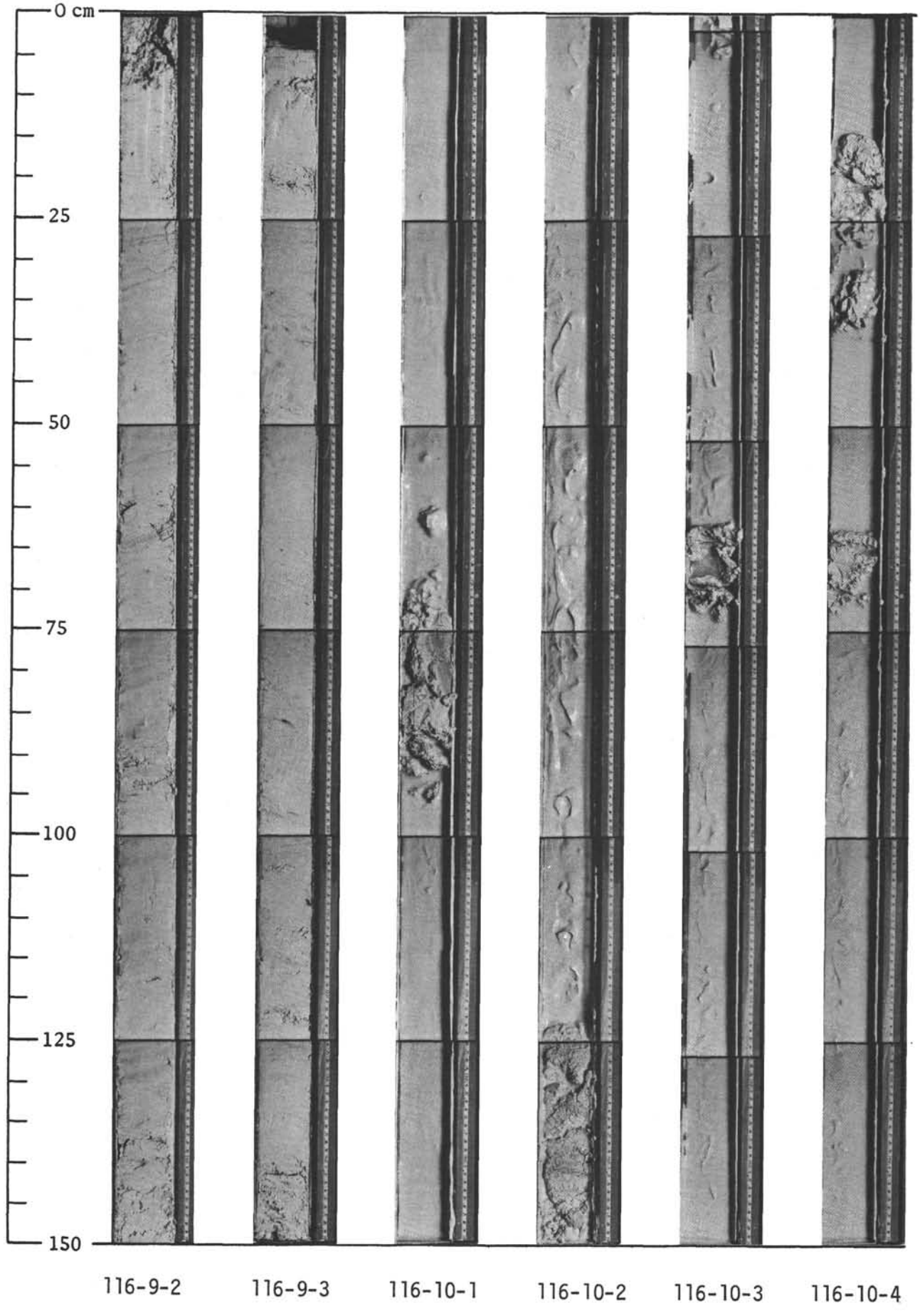
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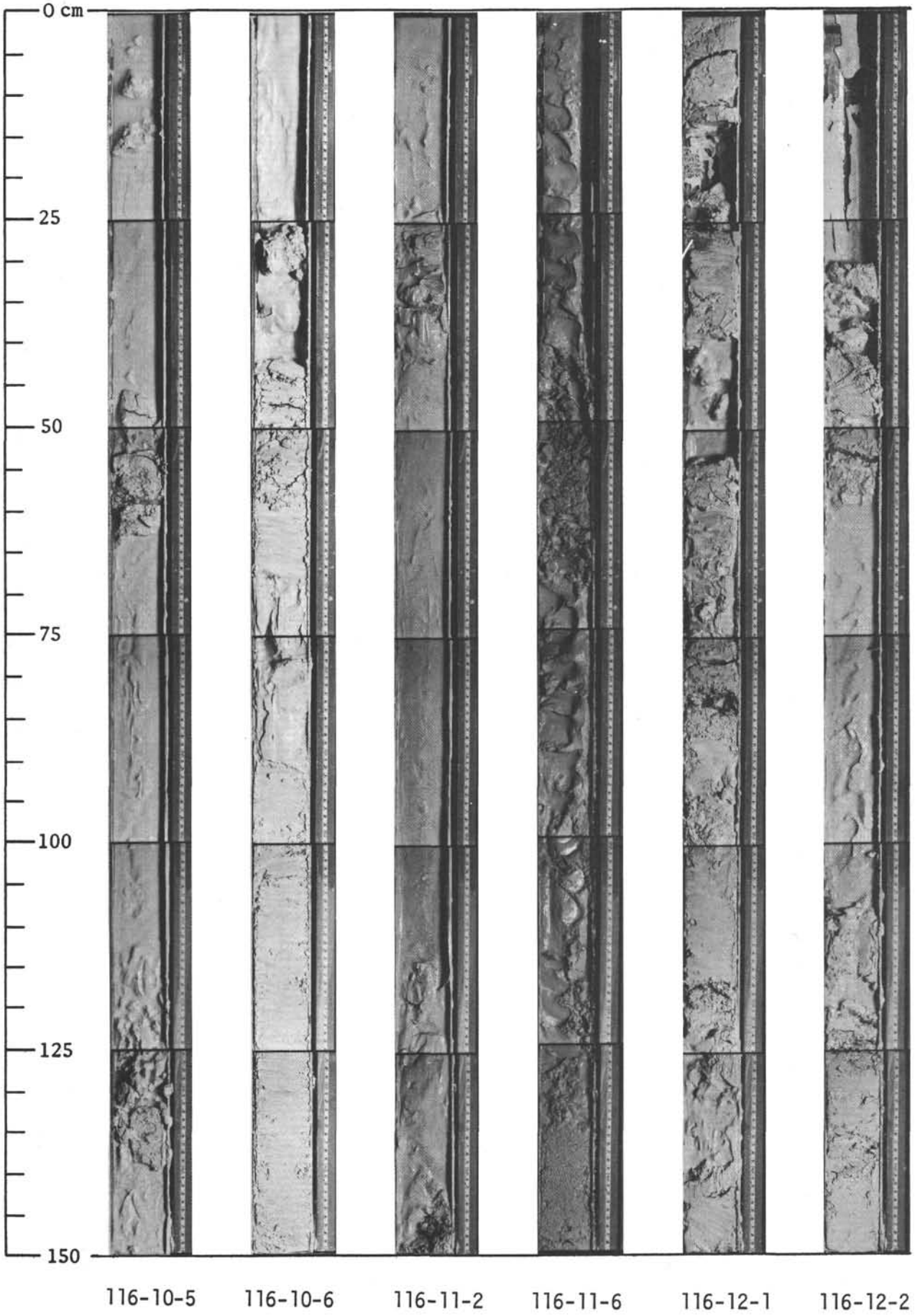
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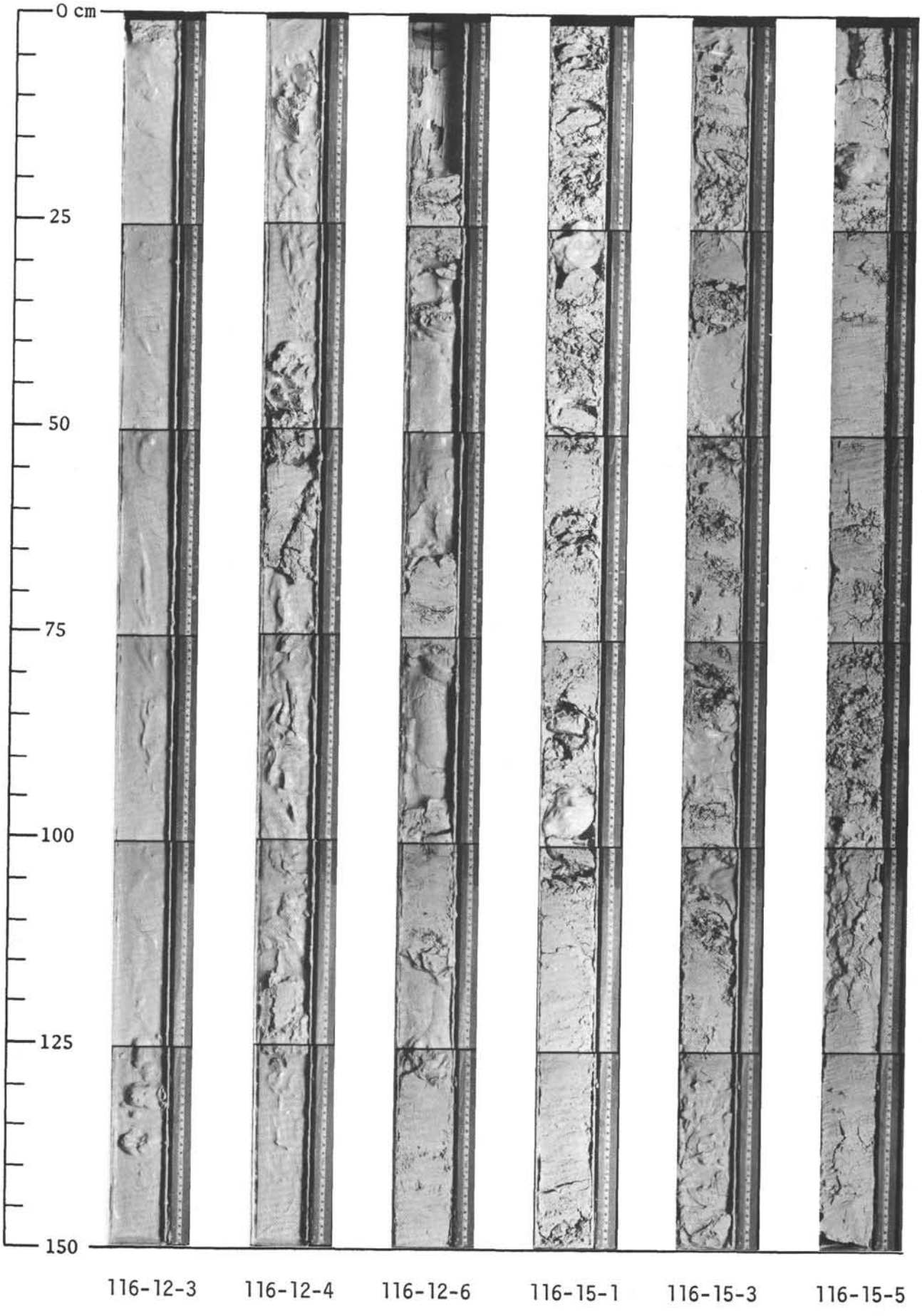
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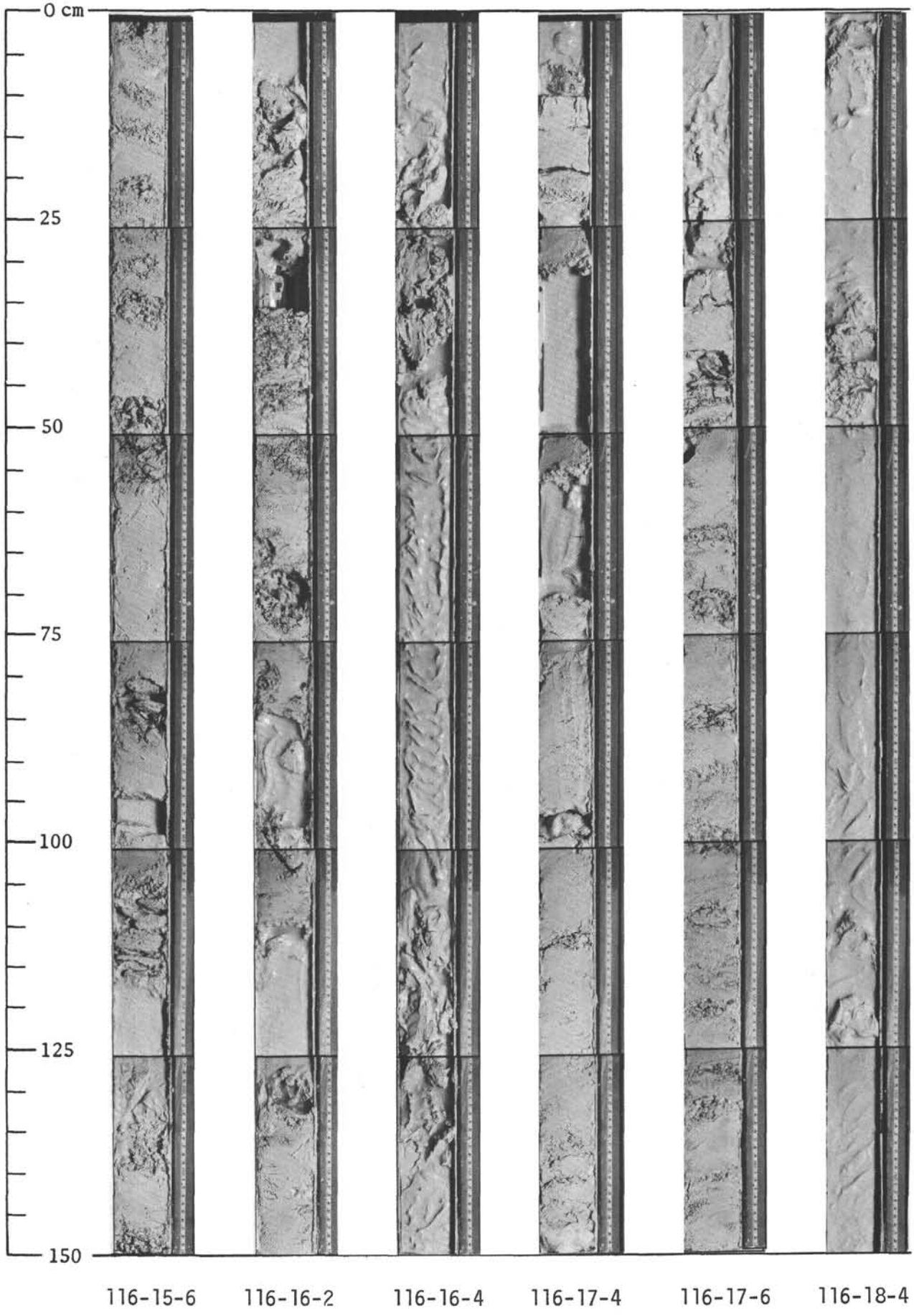
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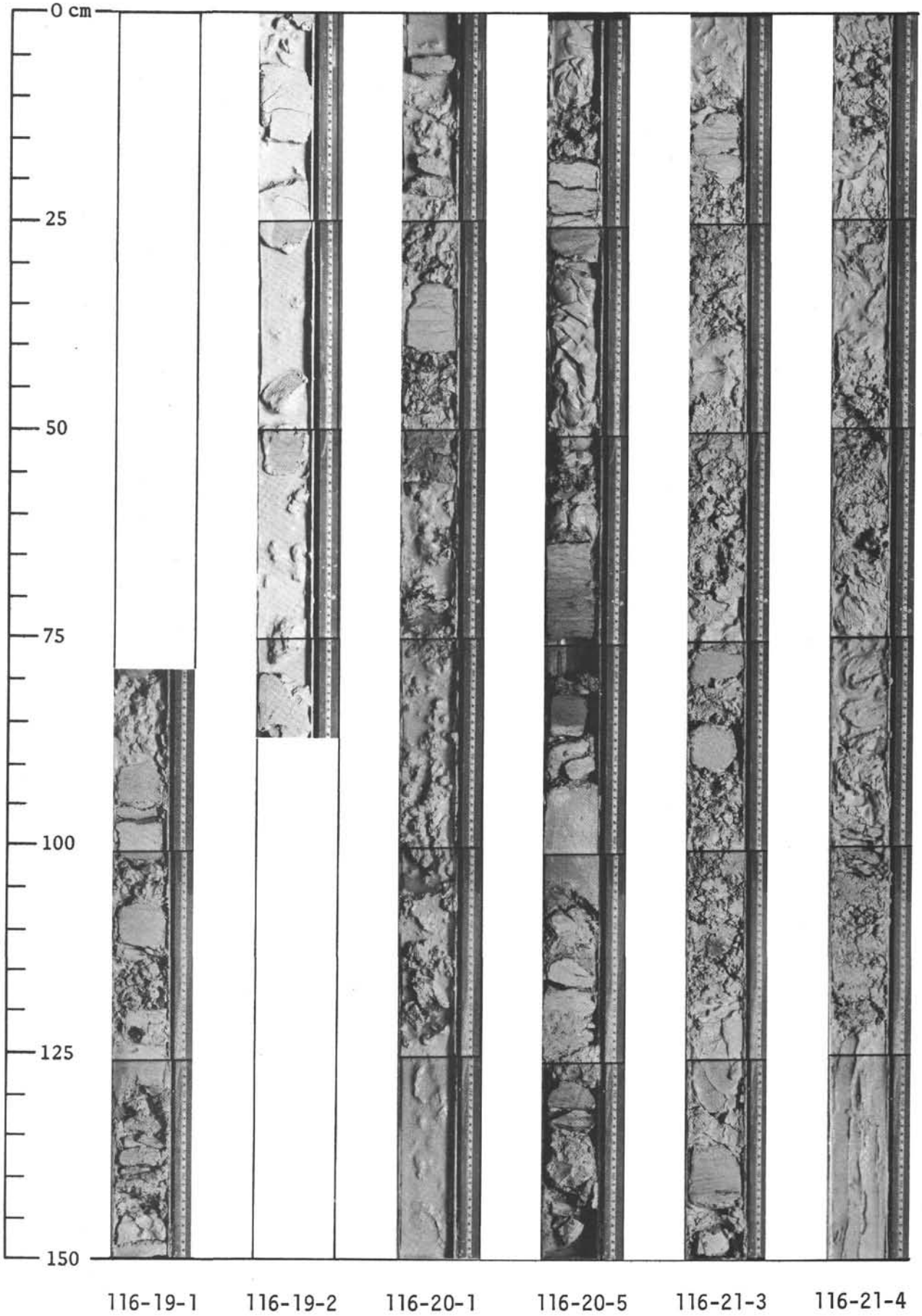
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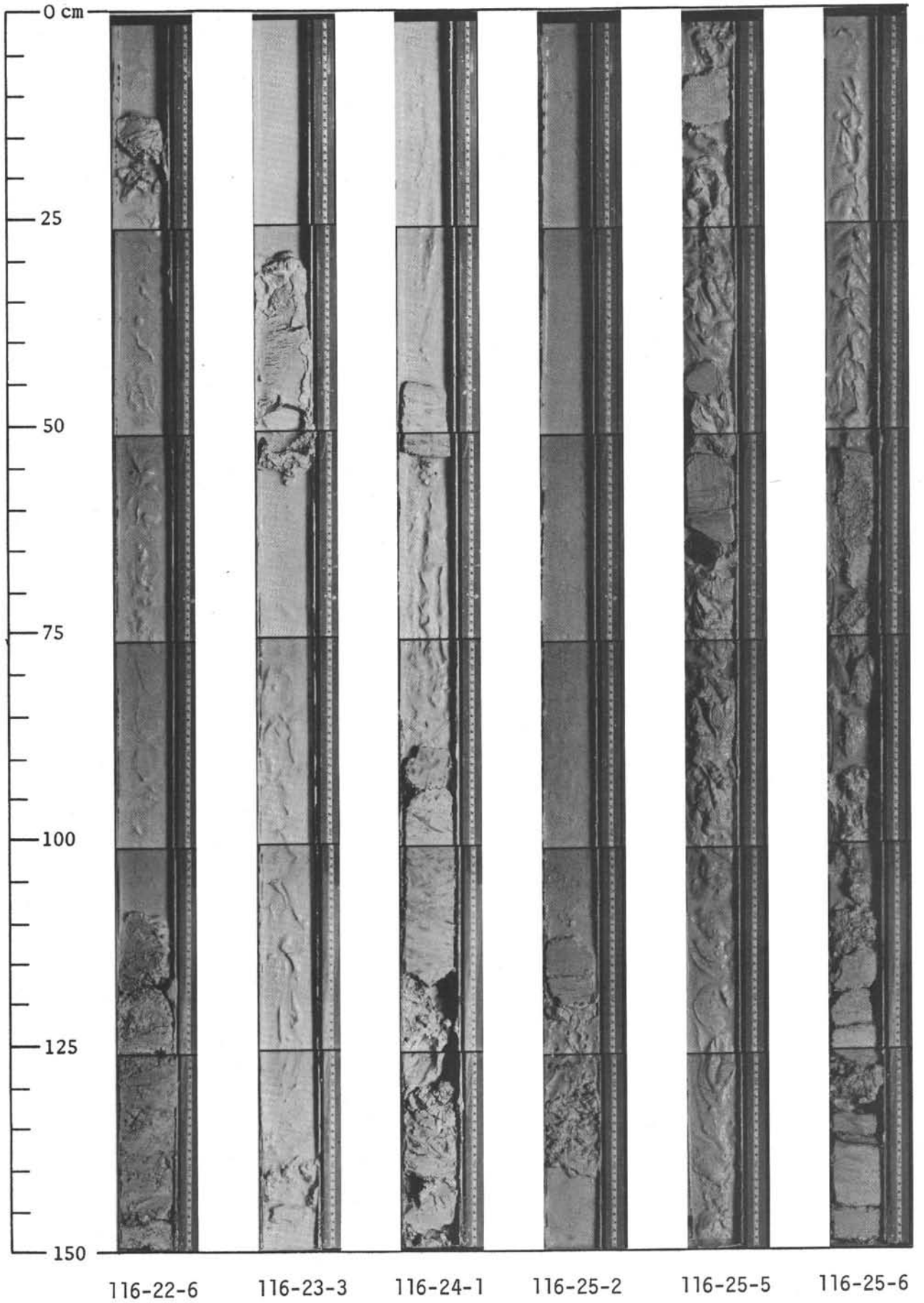
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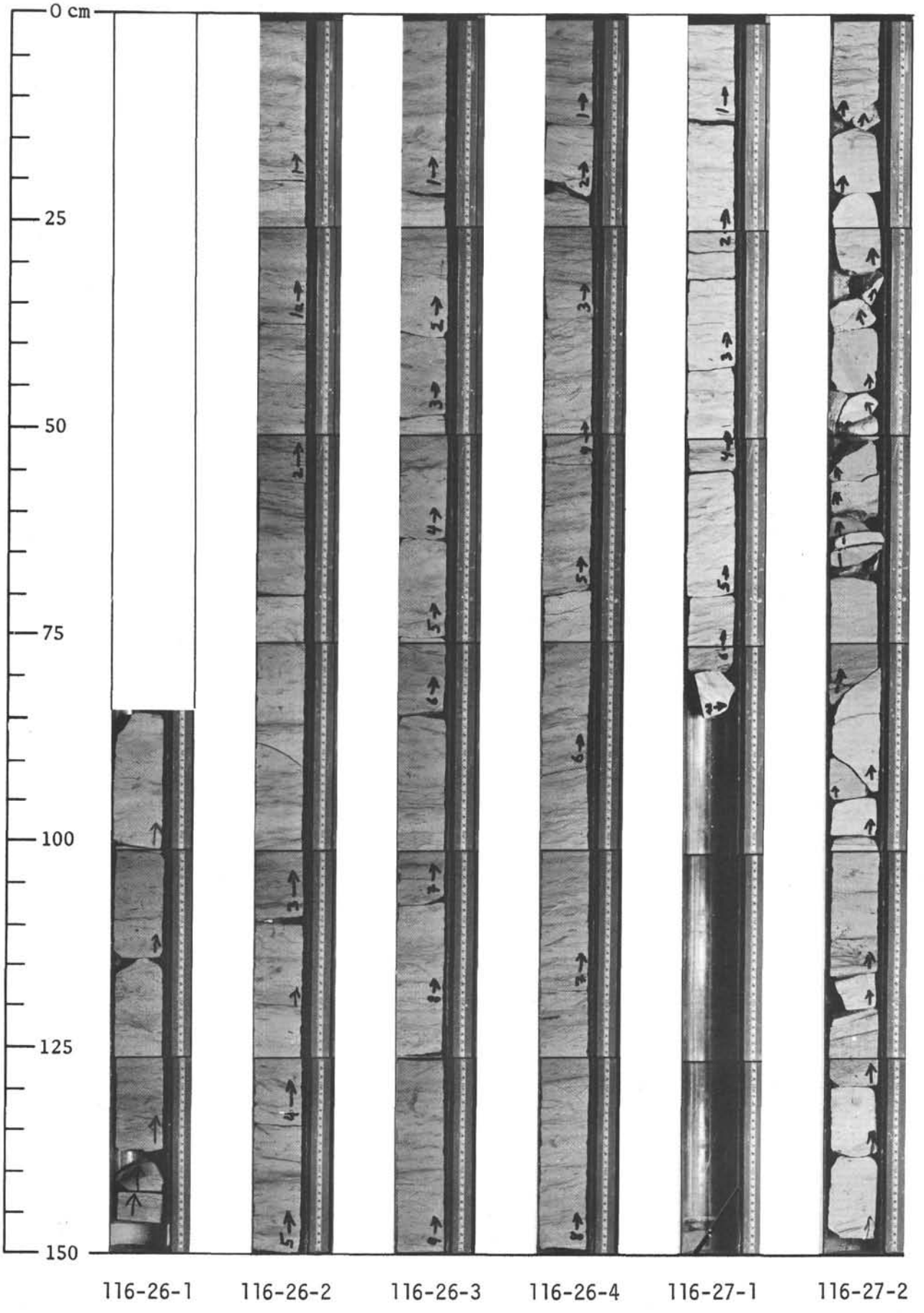
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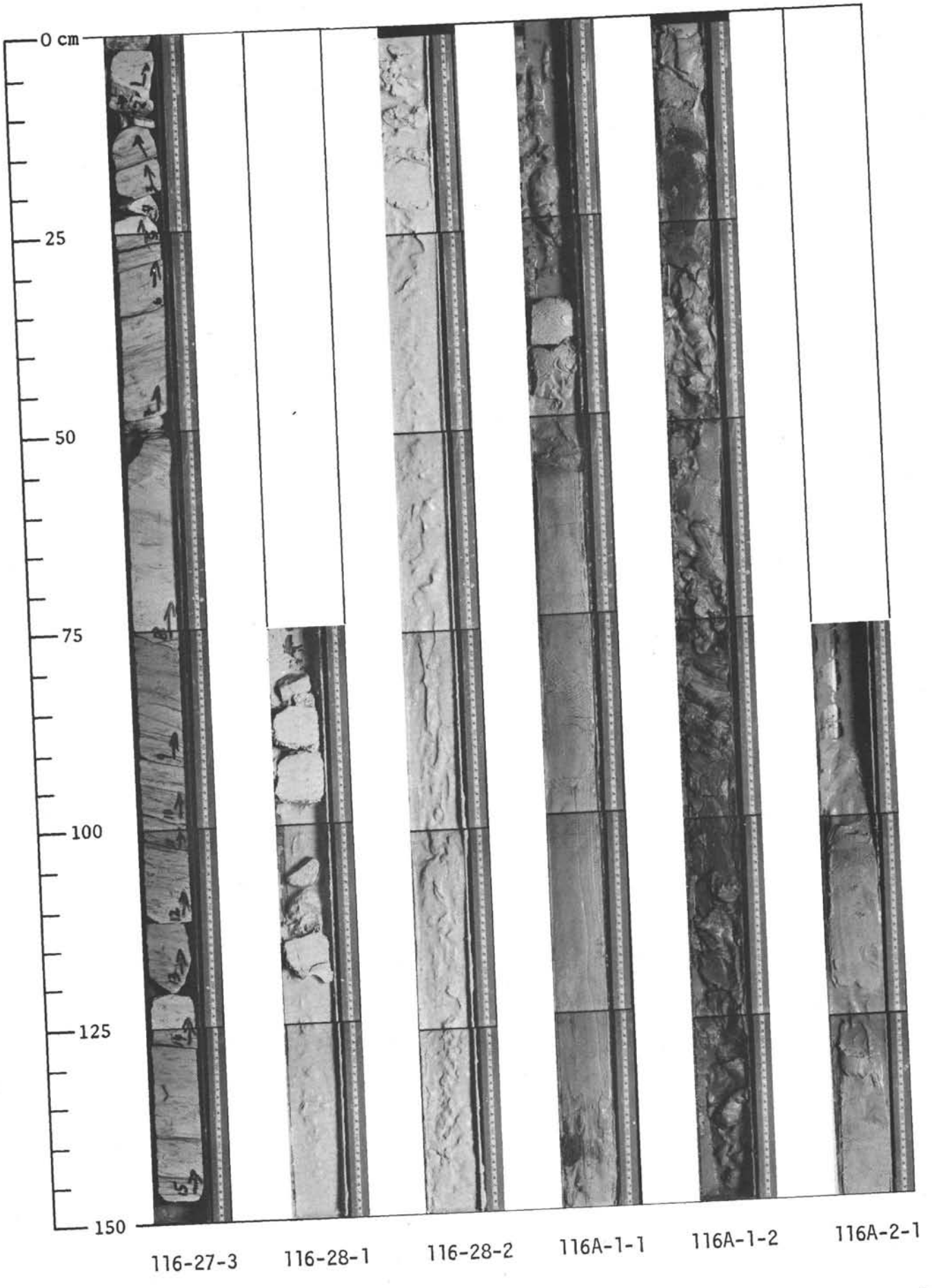
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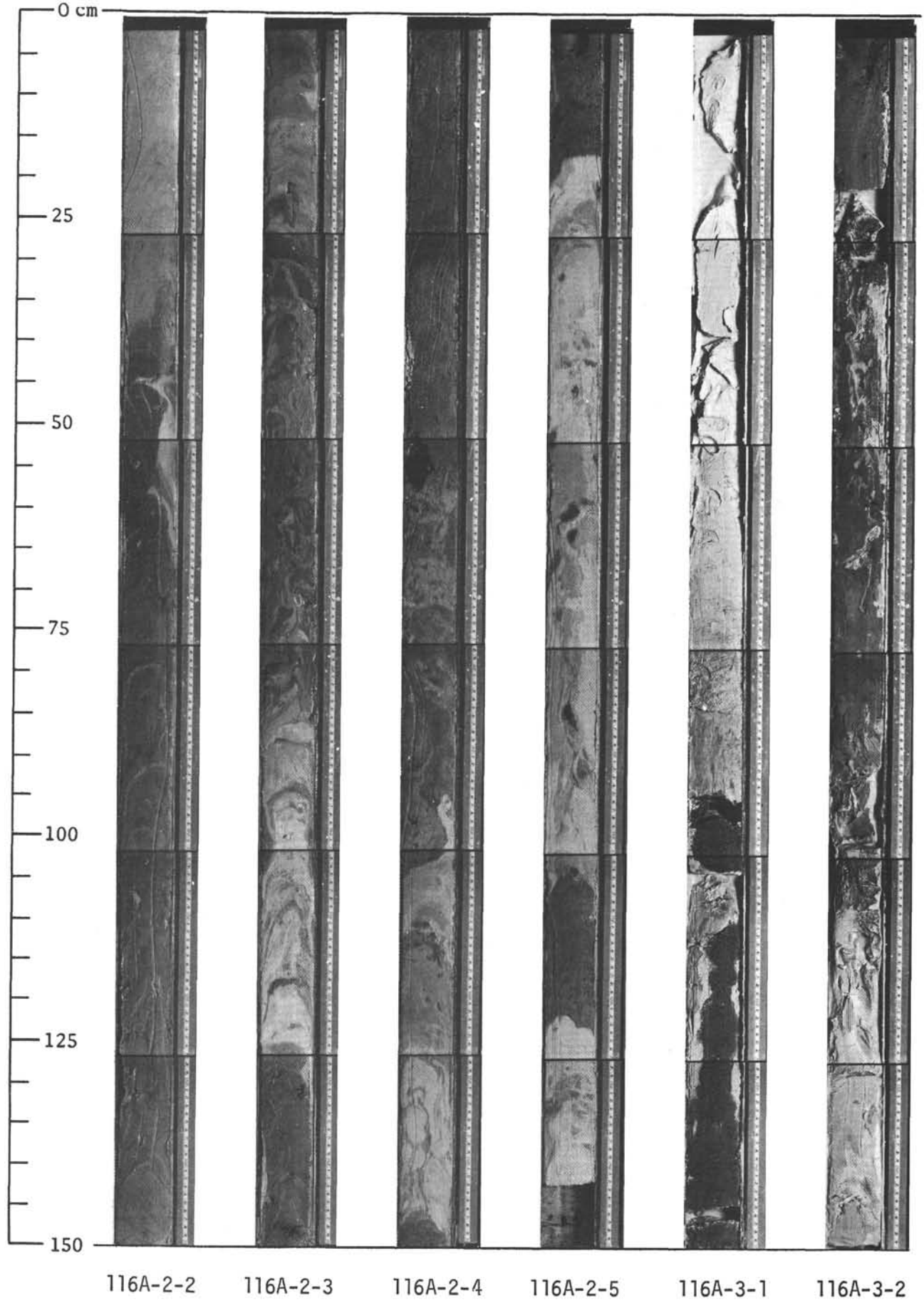
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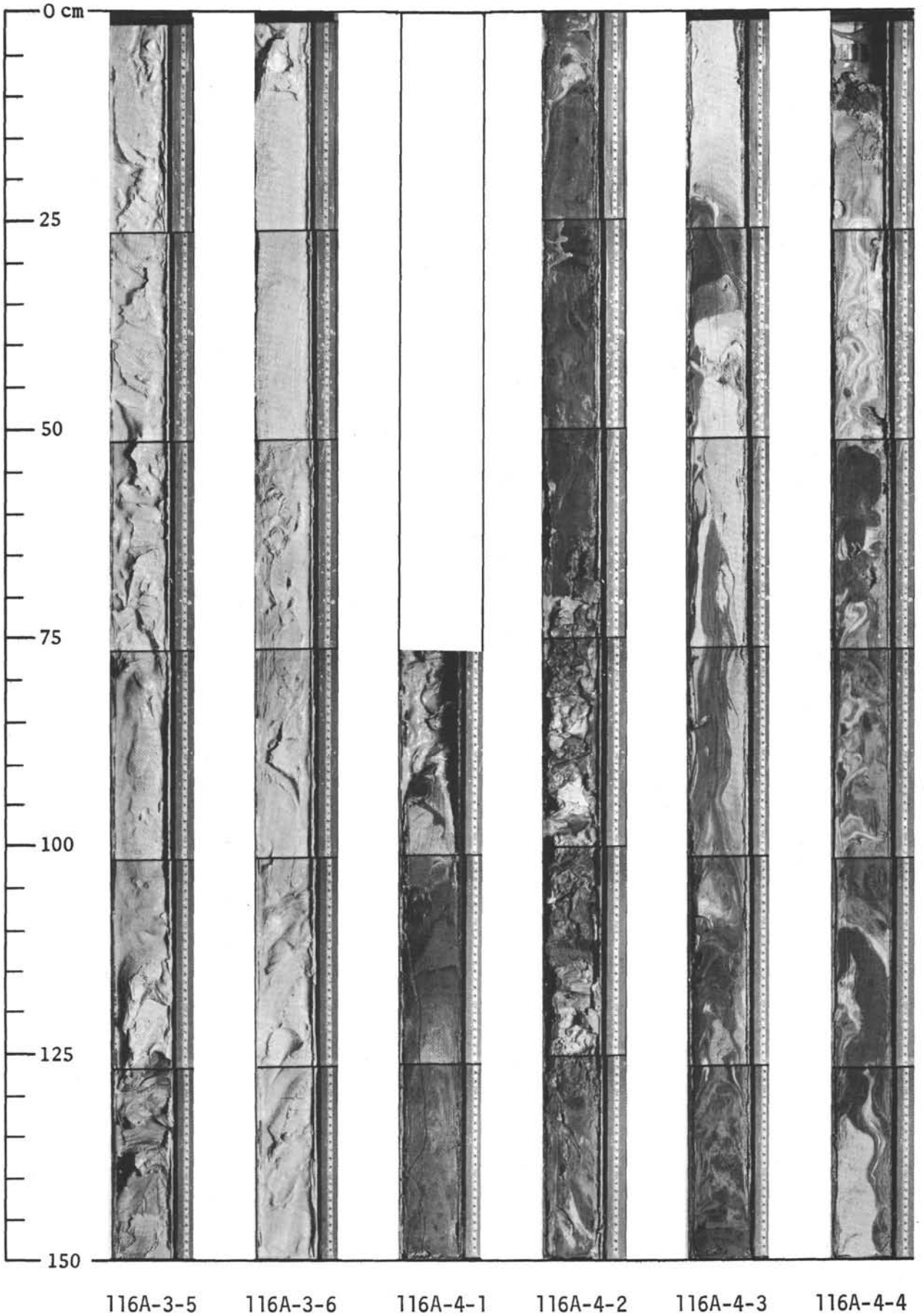
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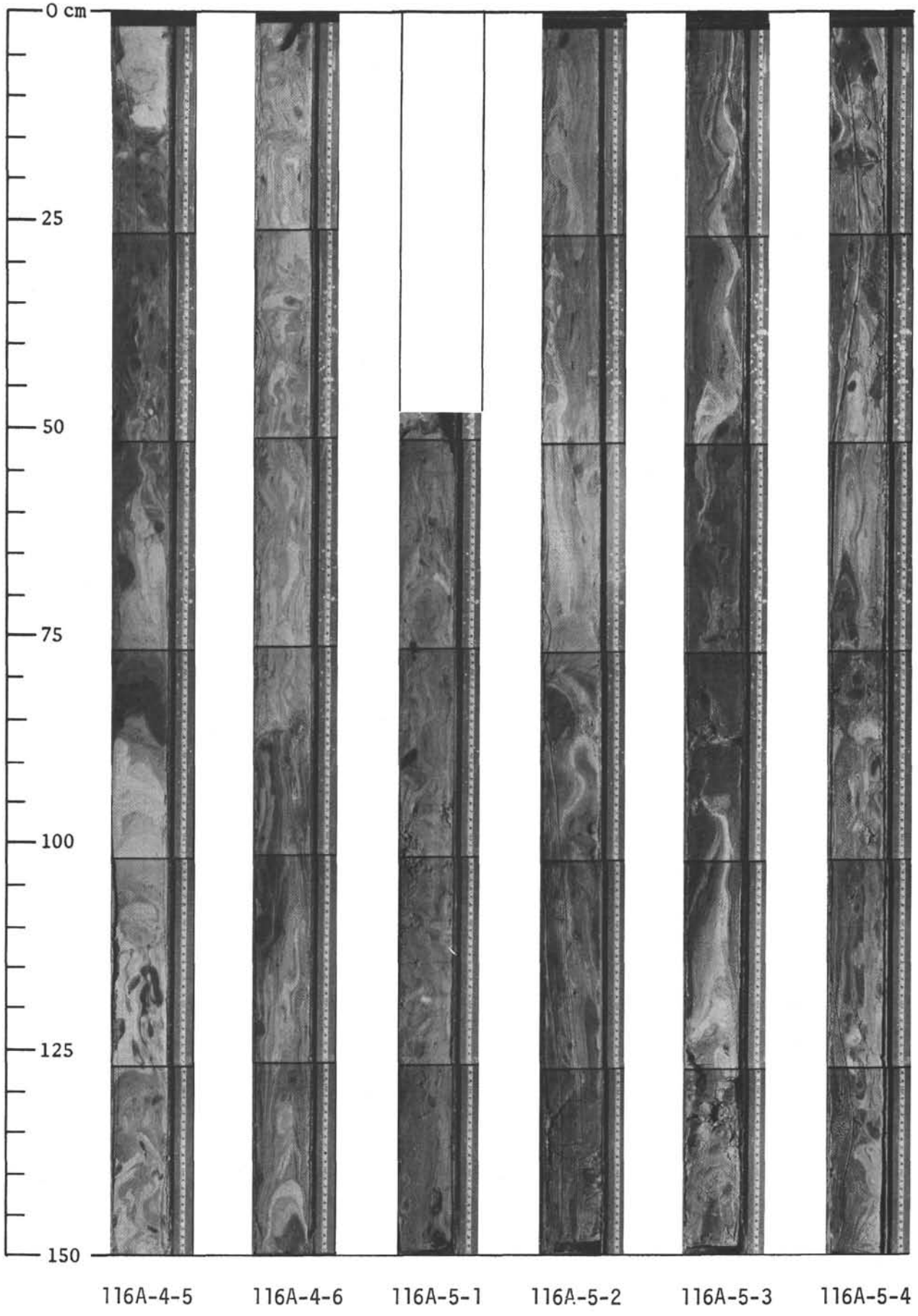
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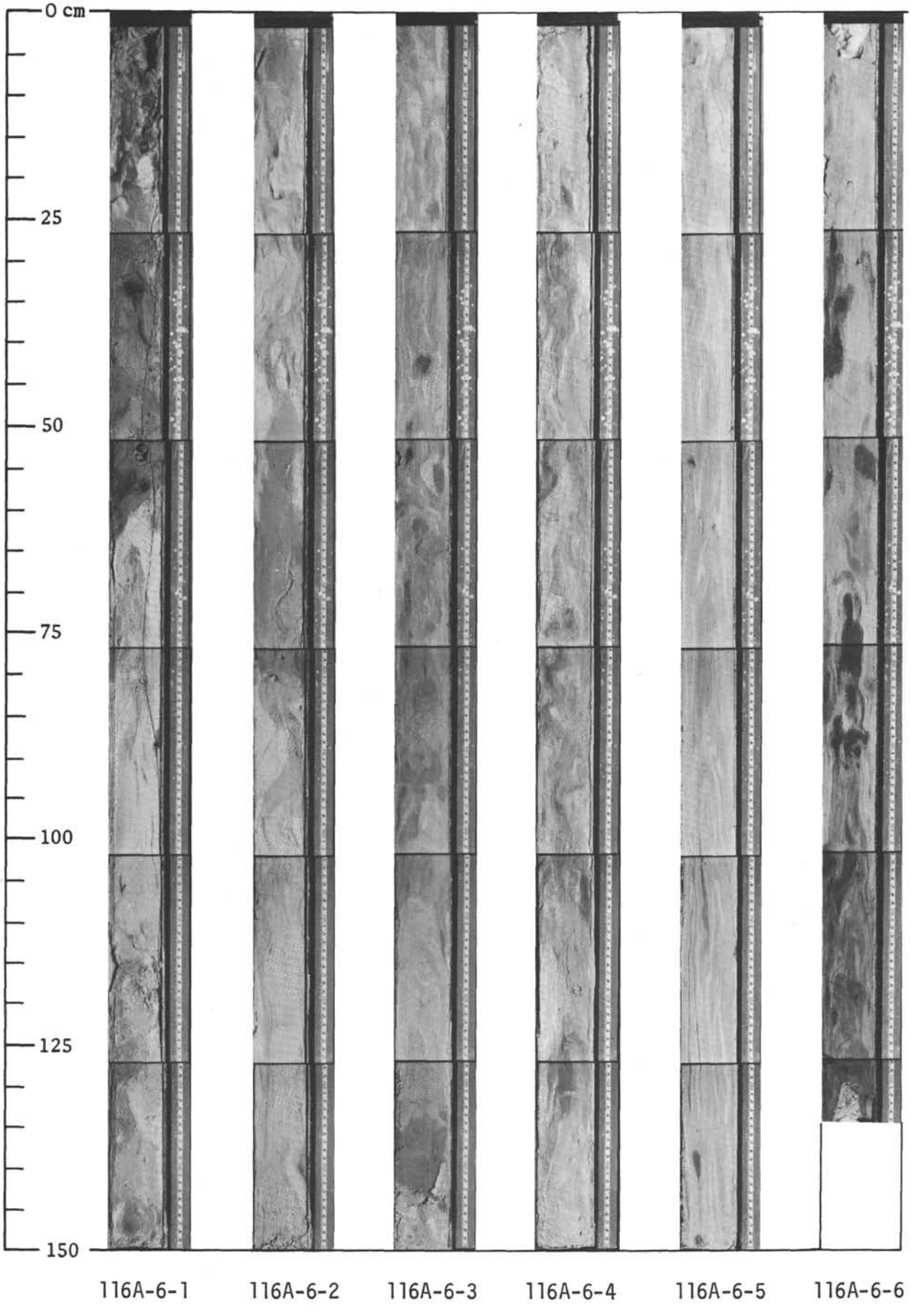
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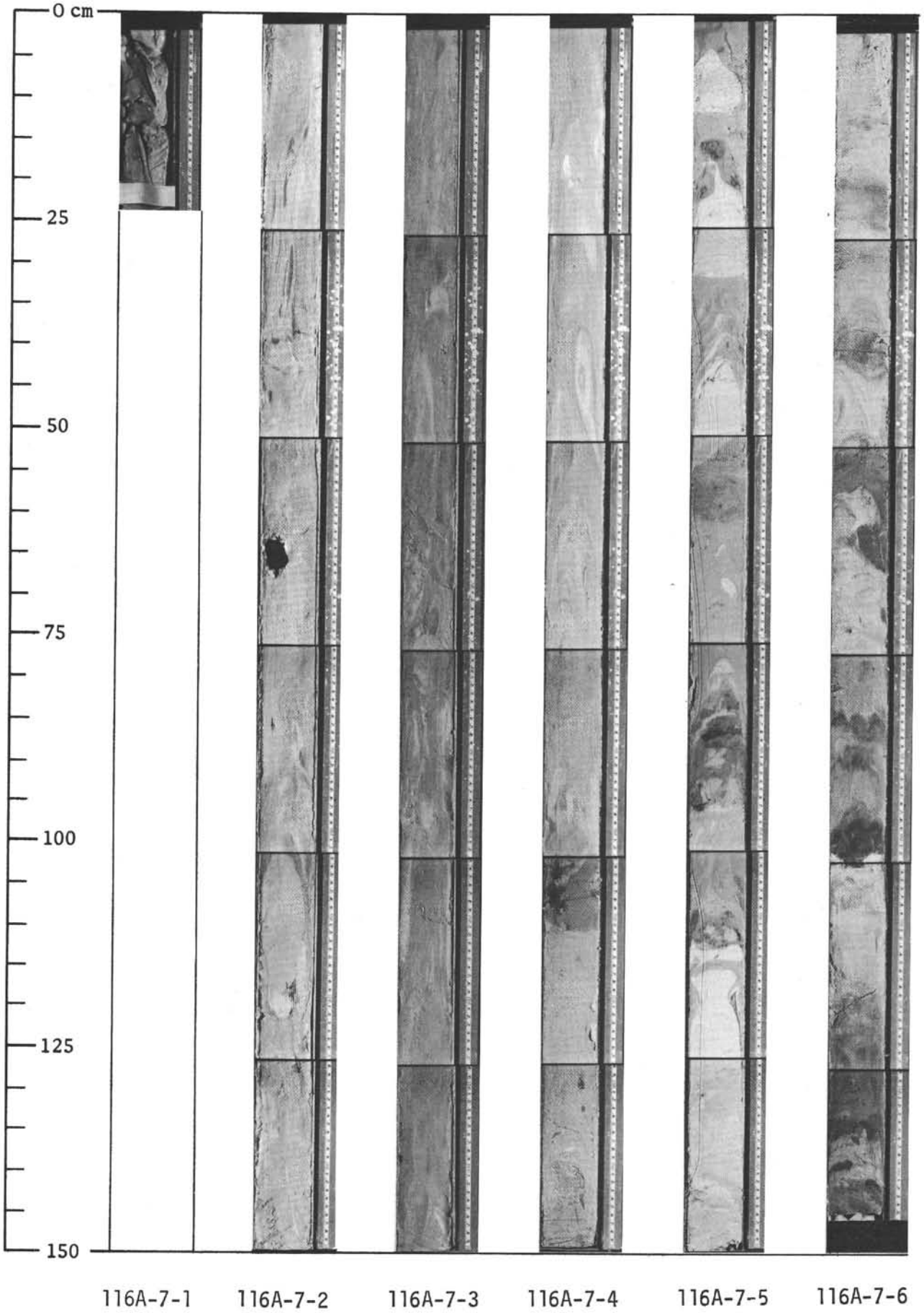
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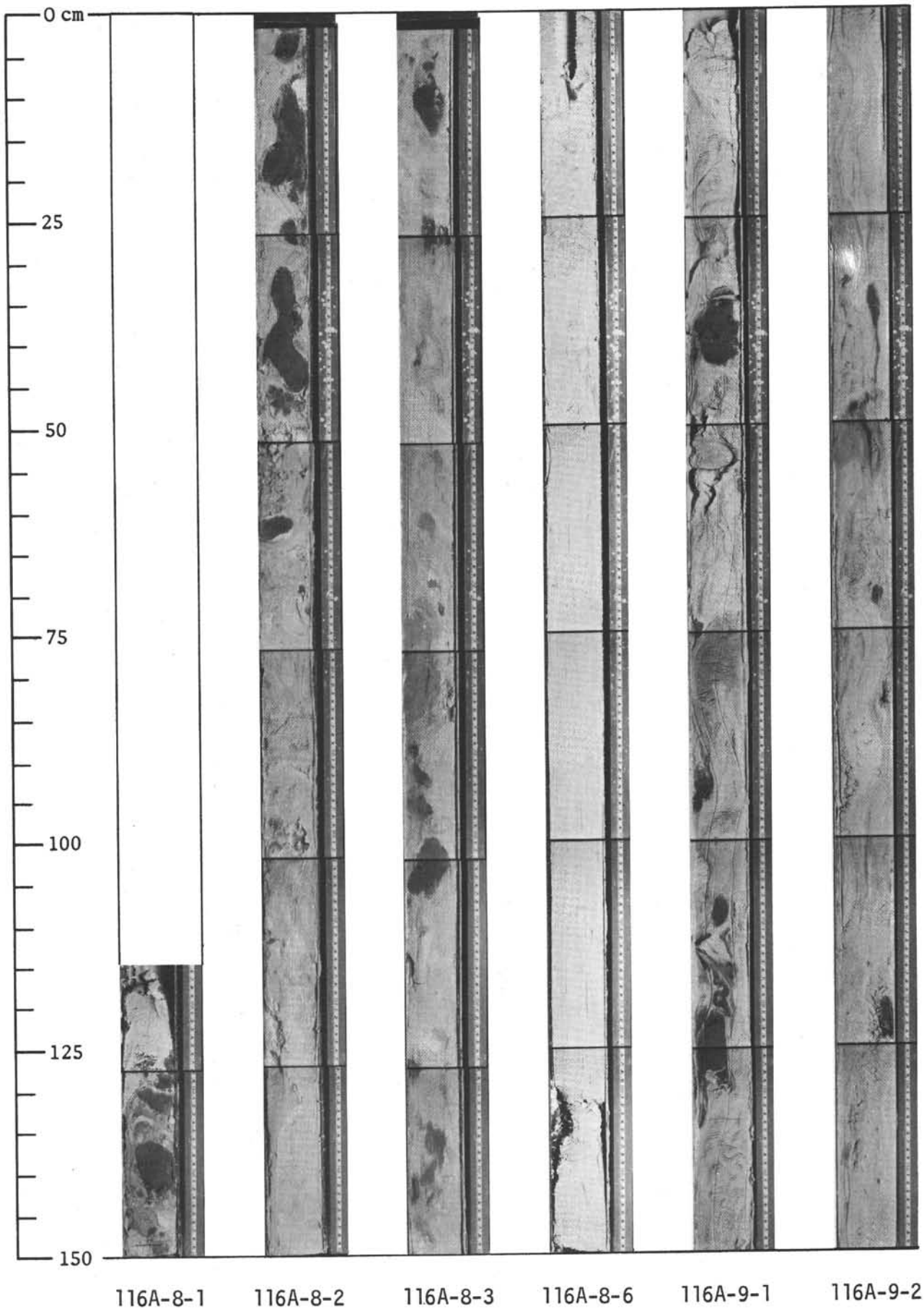
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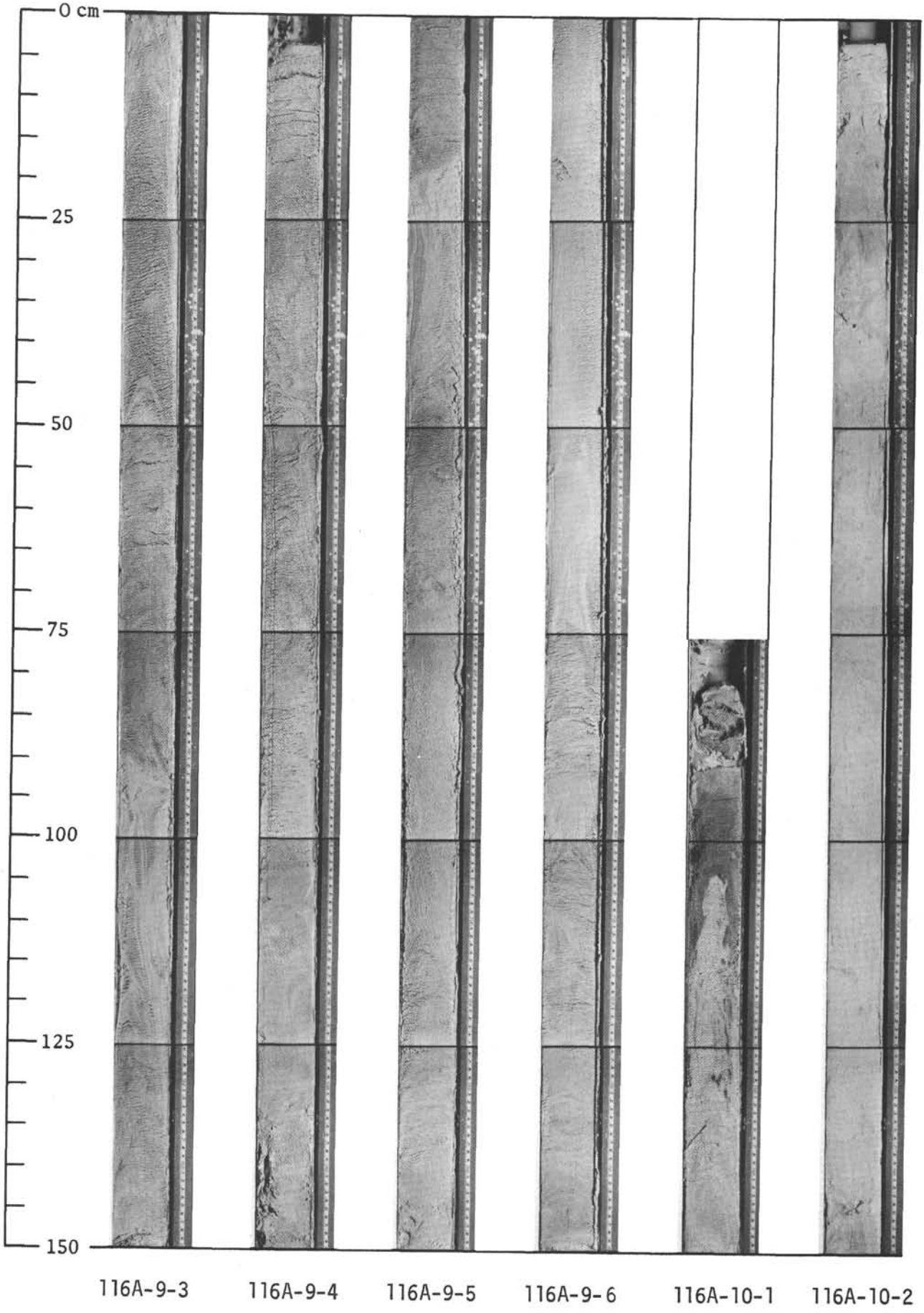
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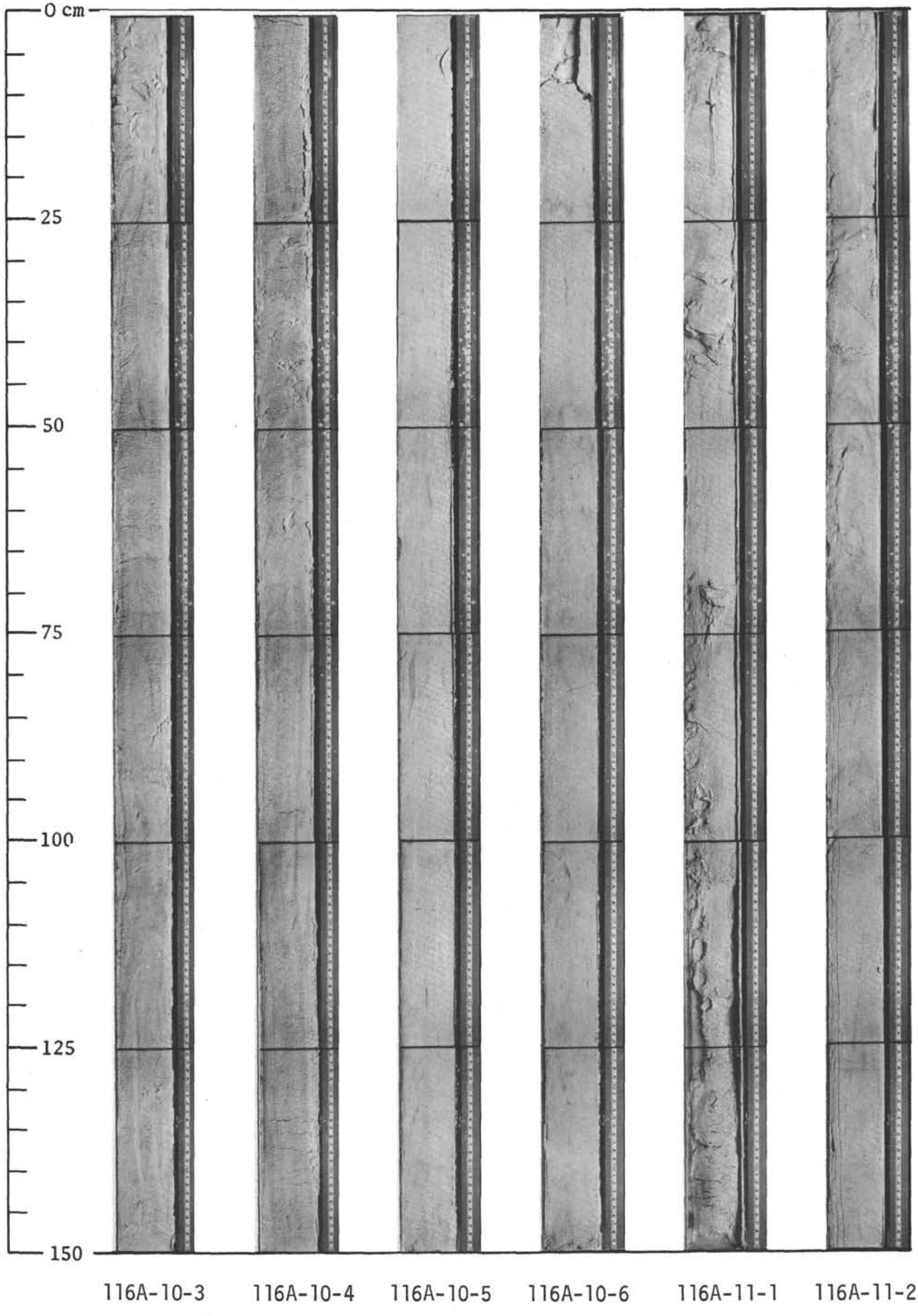
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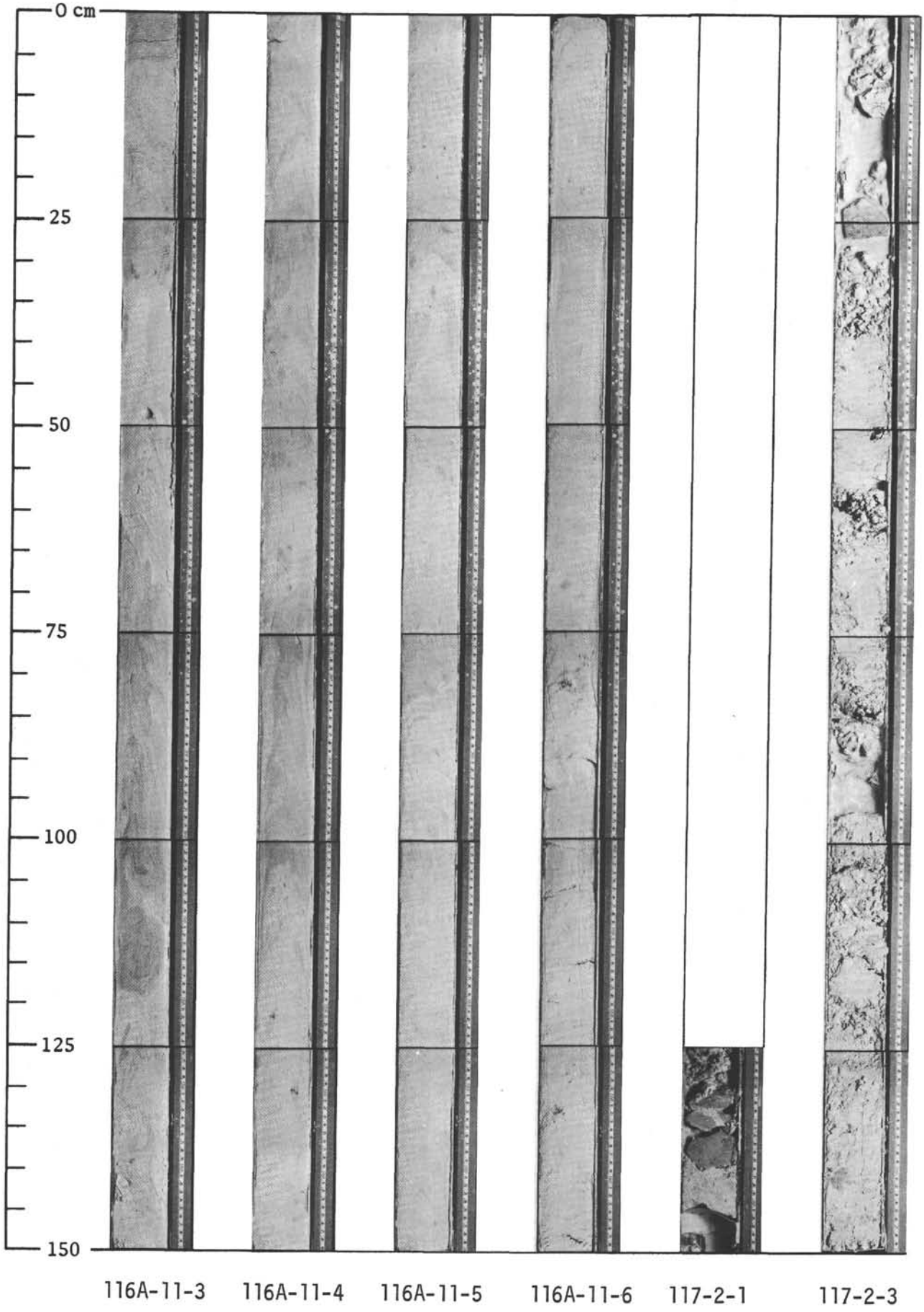
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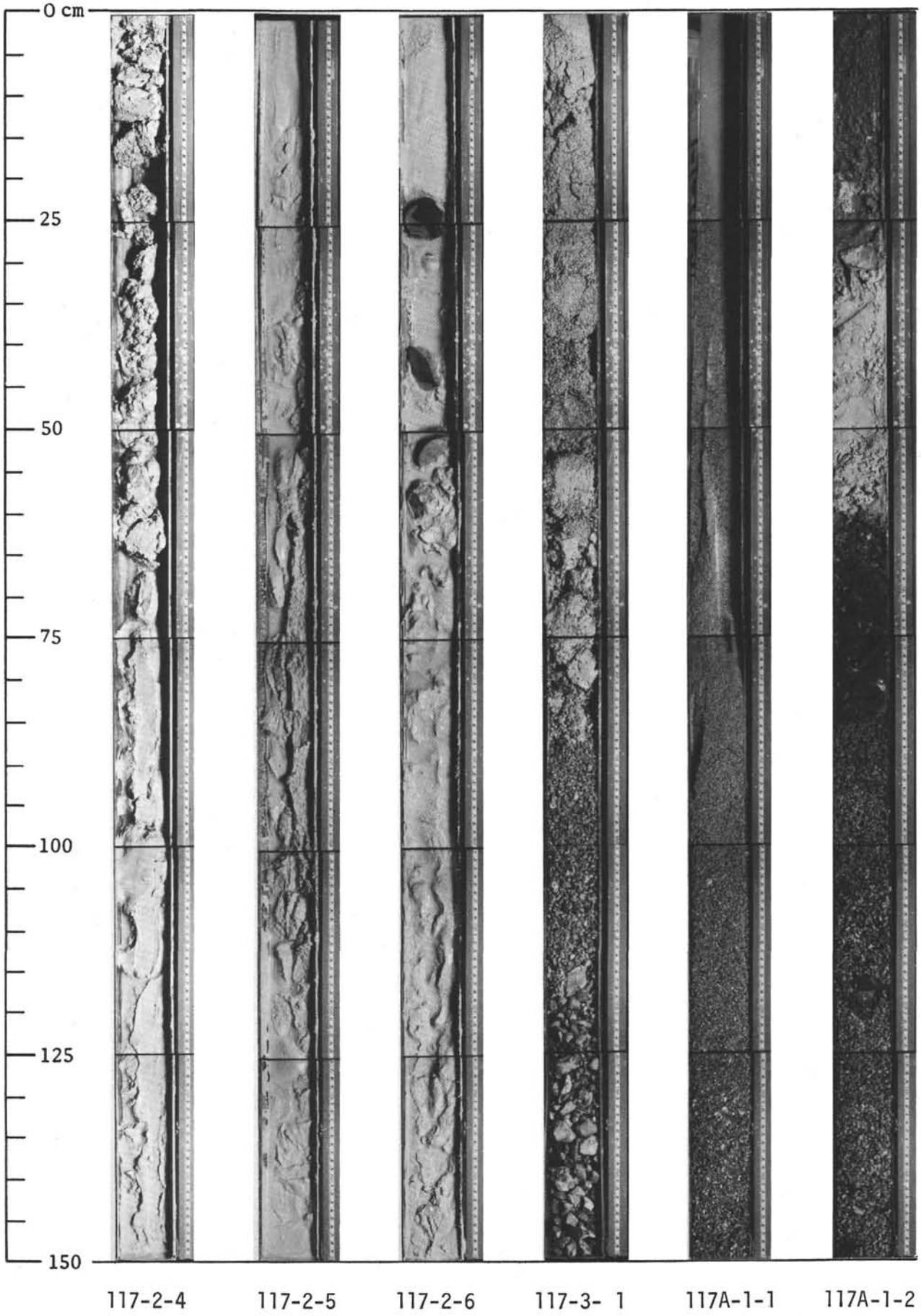
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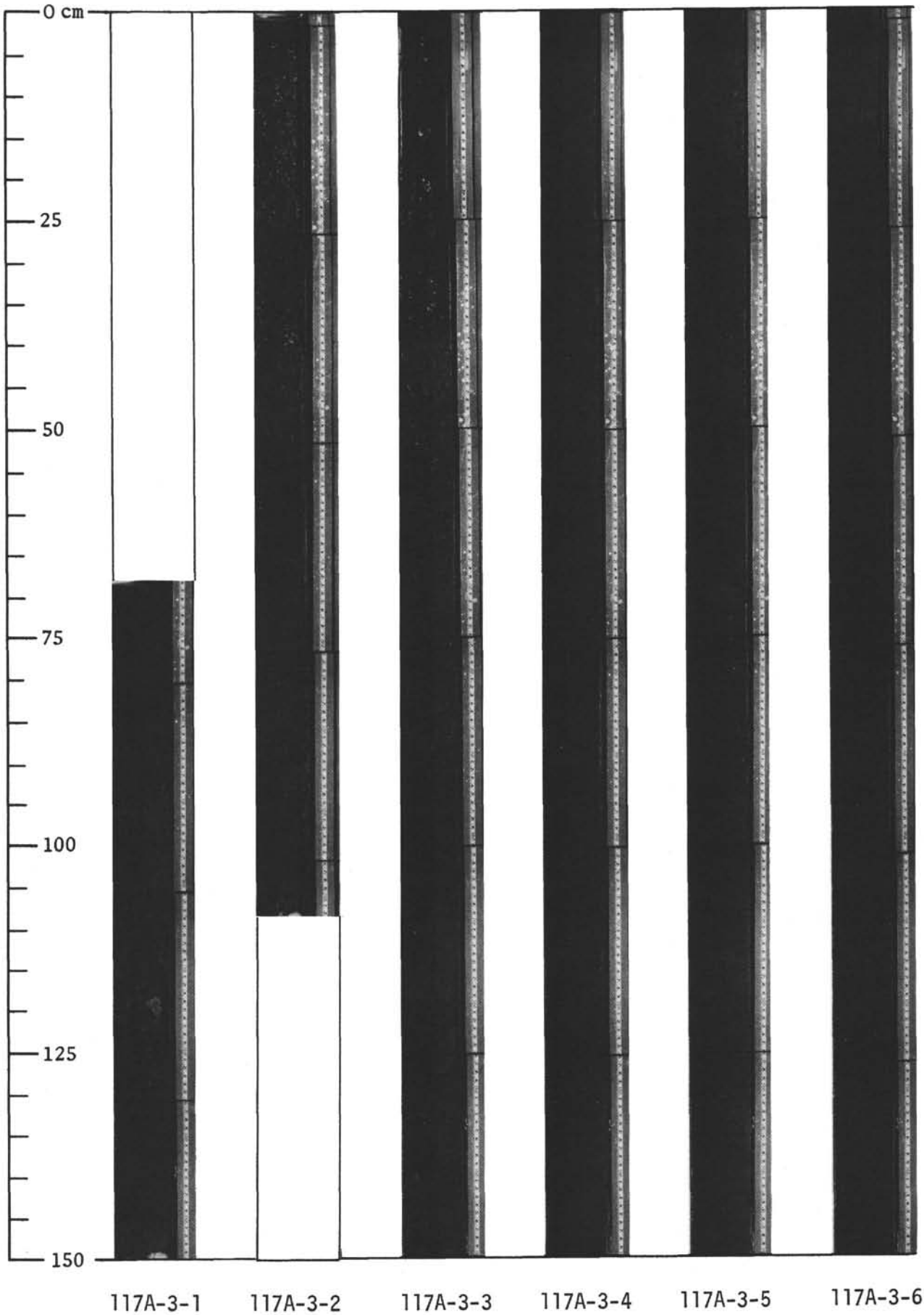
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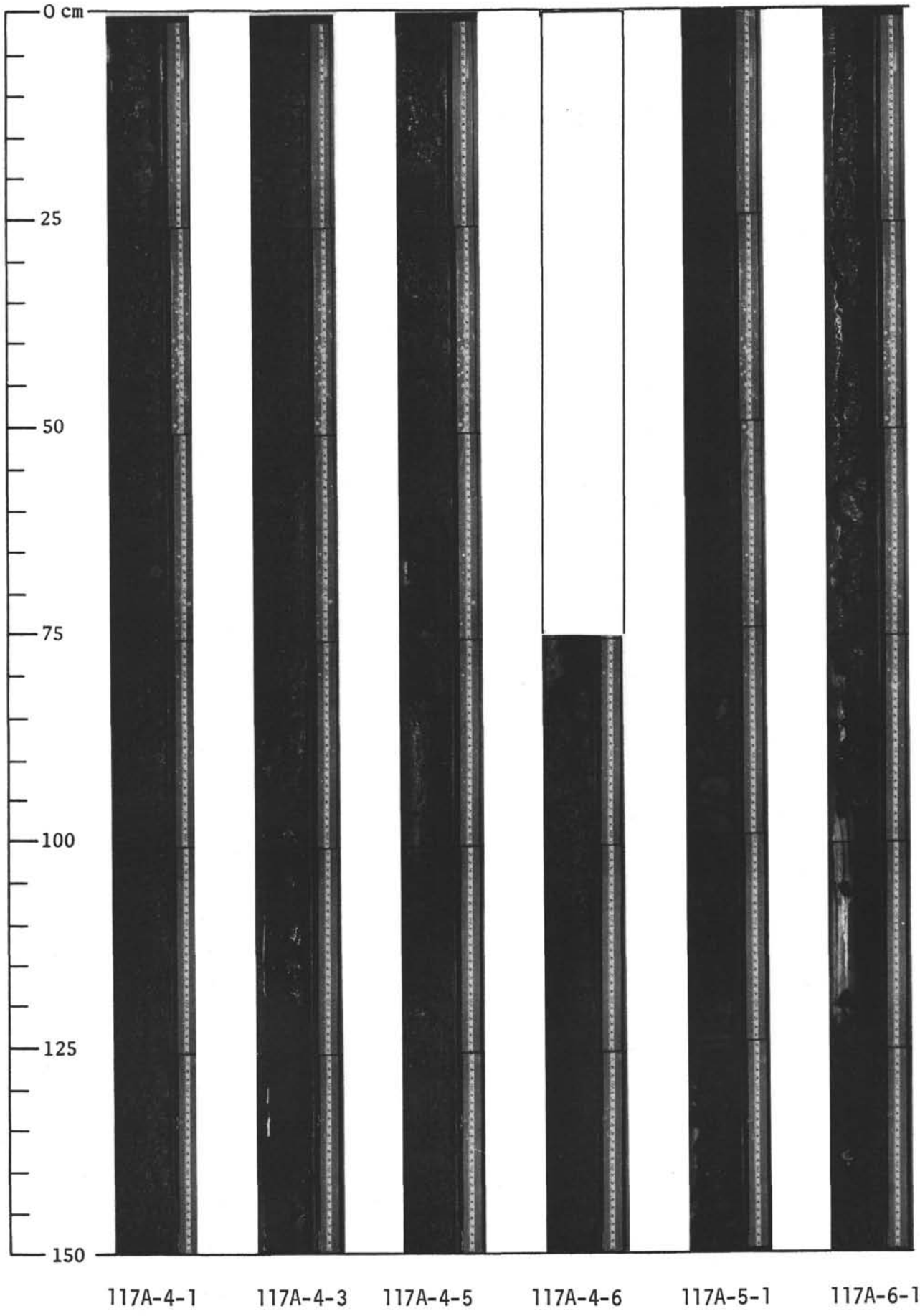
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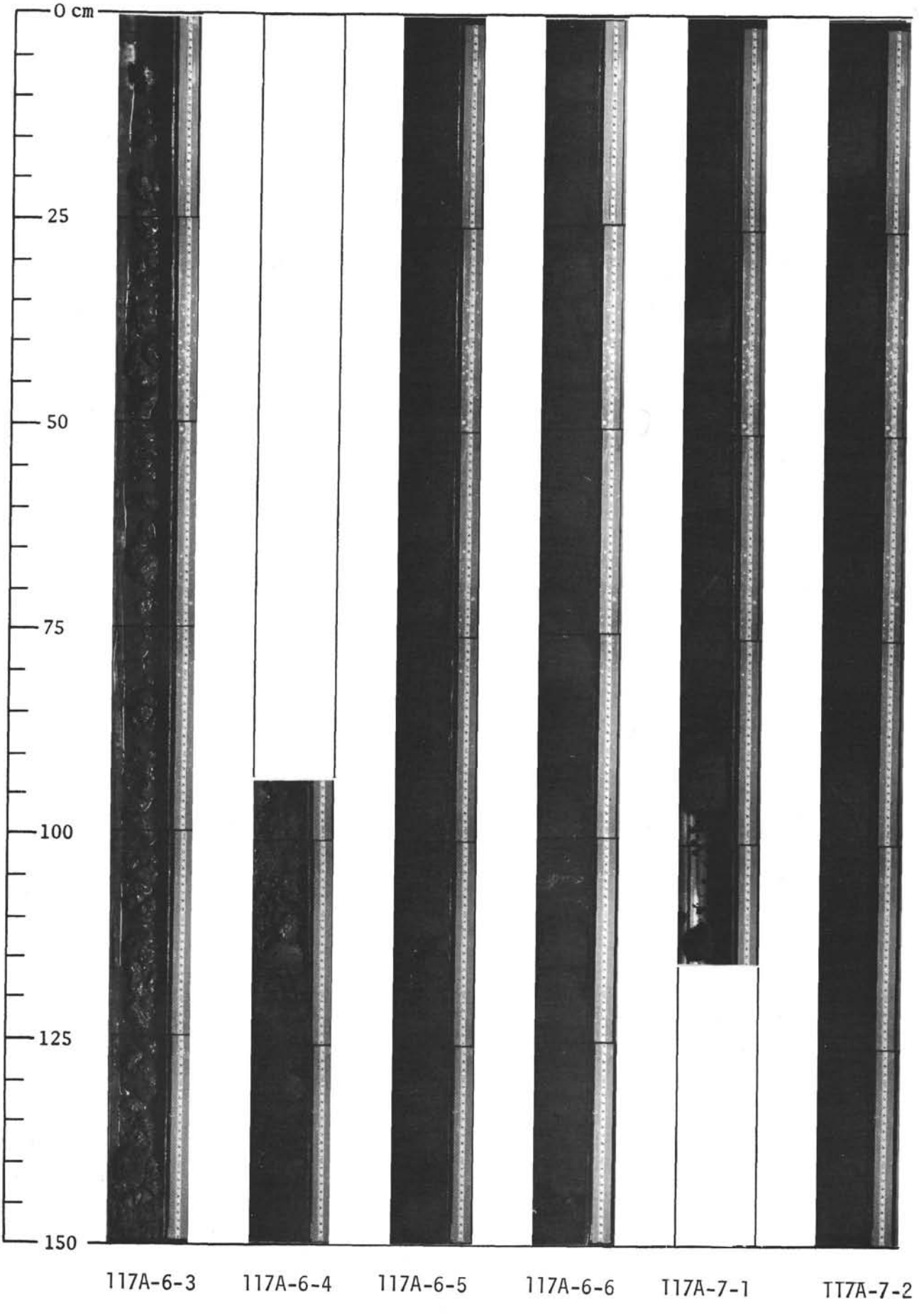
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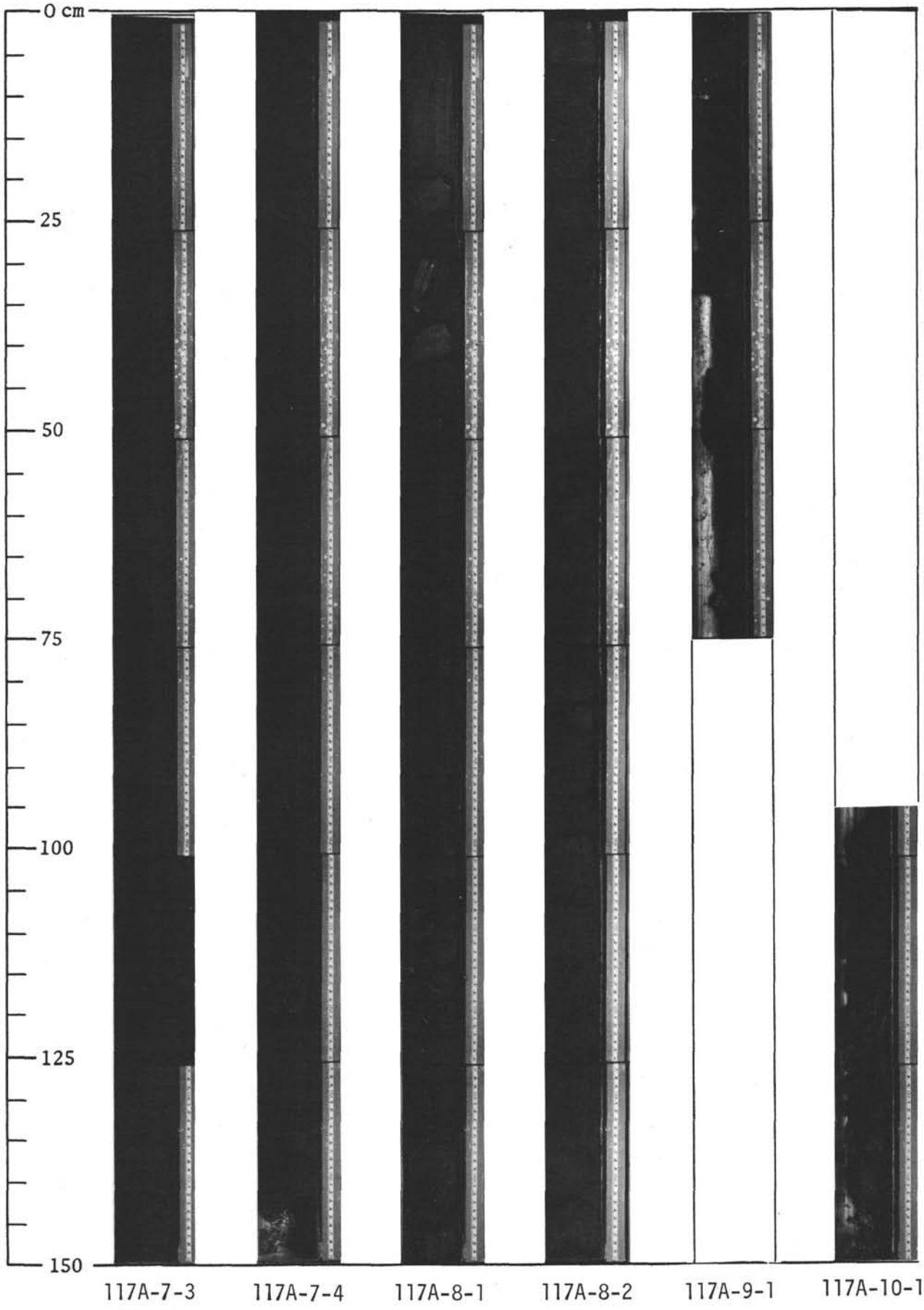
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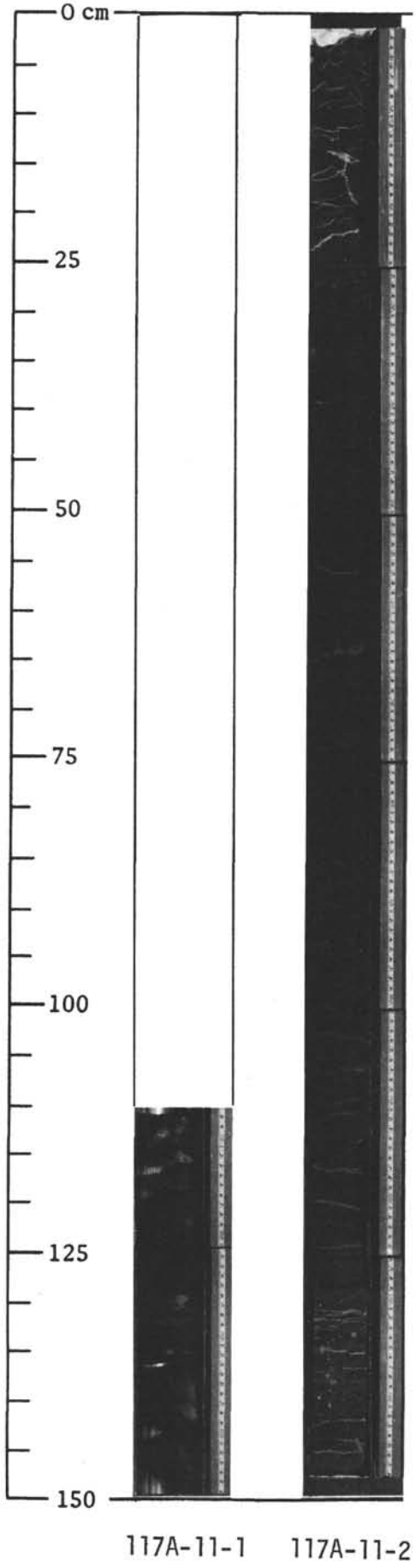
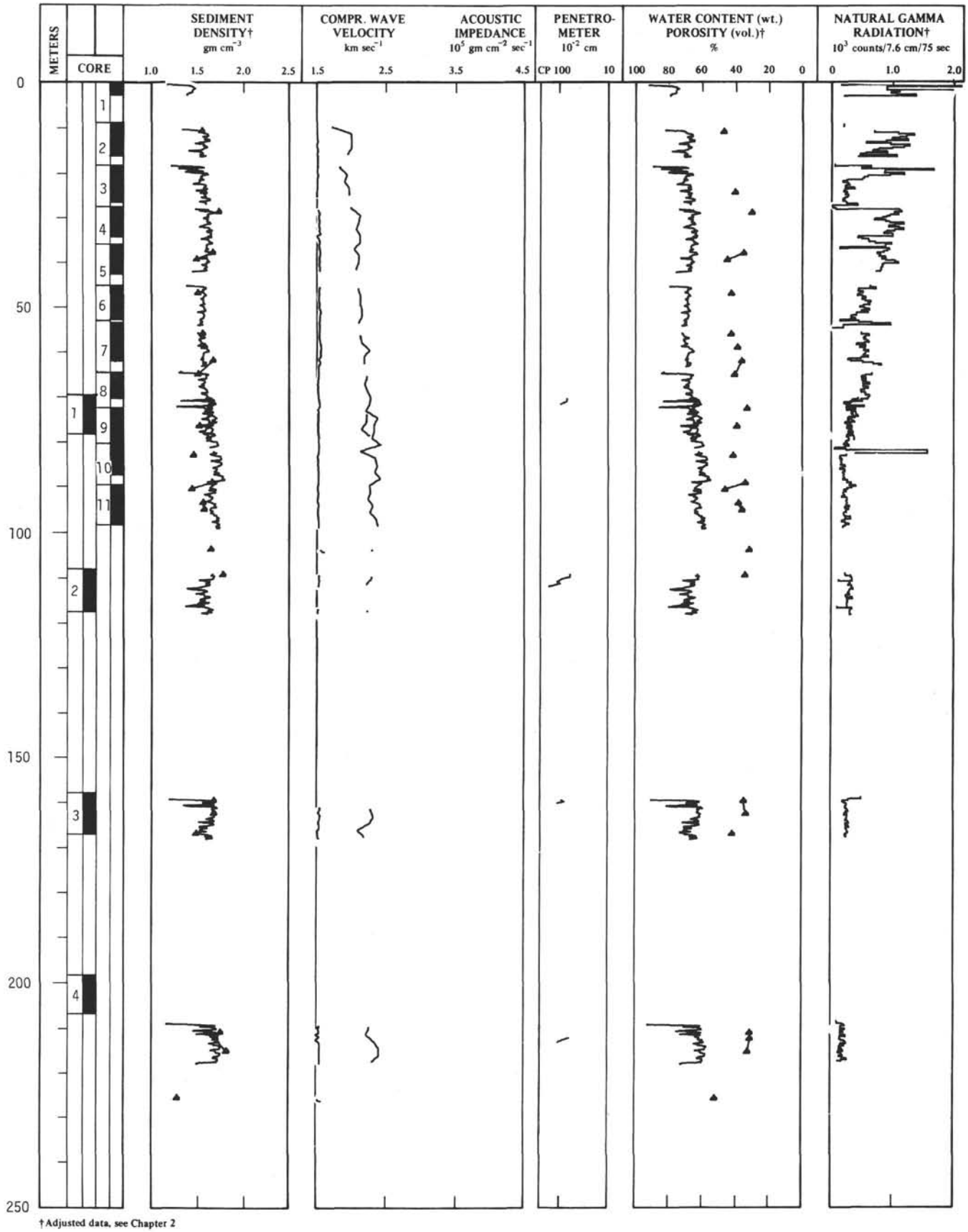
117A-7-3
117A-7-4
117A-8-1
117A-8-2
117A-9-1
117A-10-1

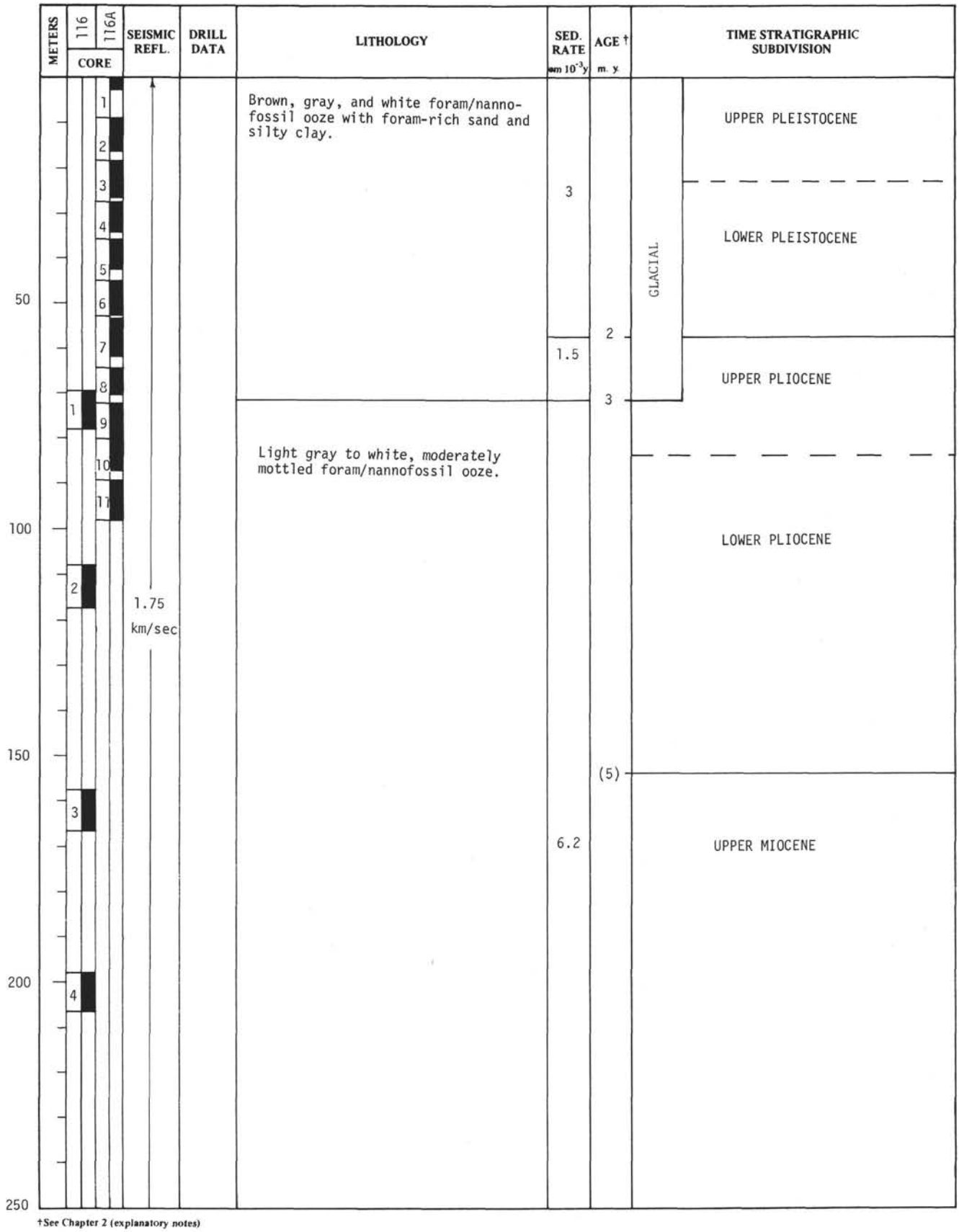

0 cm
25
50
75
100
125
150
117A-11-1
117A-11-2

SITE 116 0m TO 250m



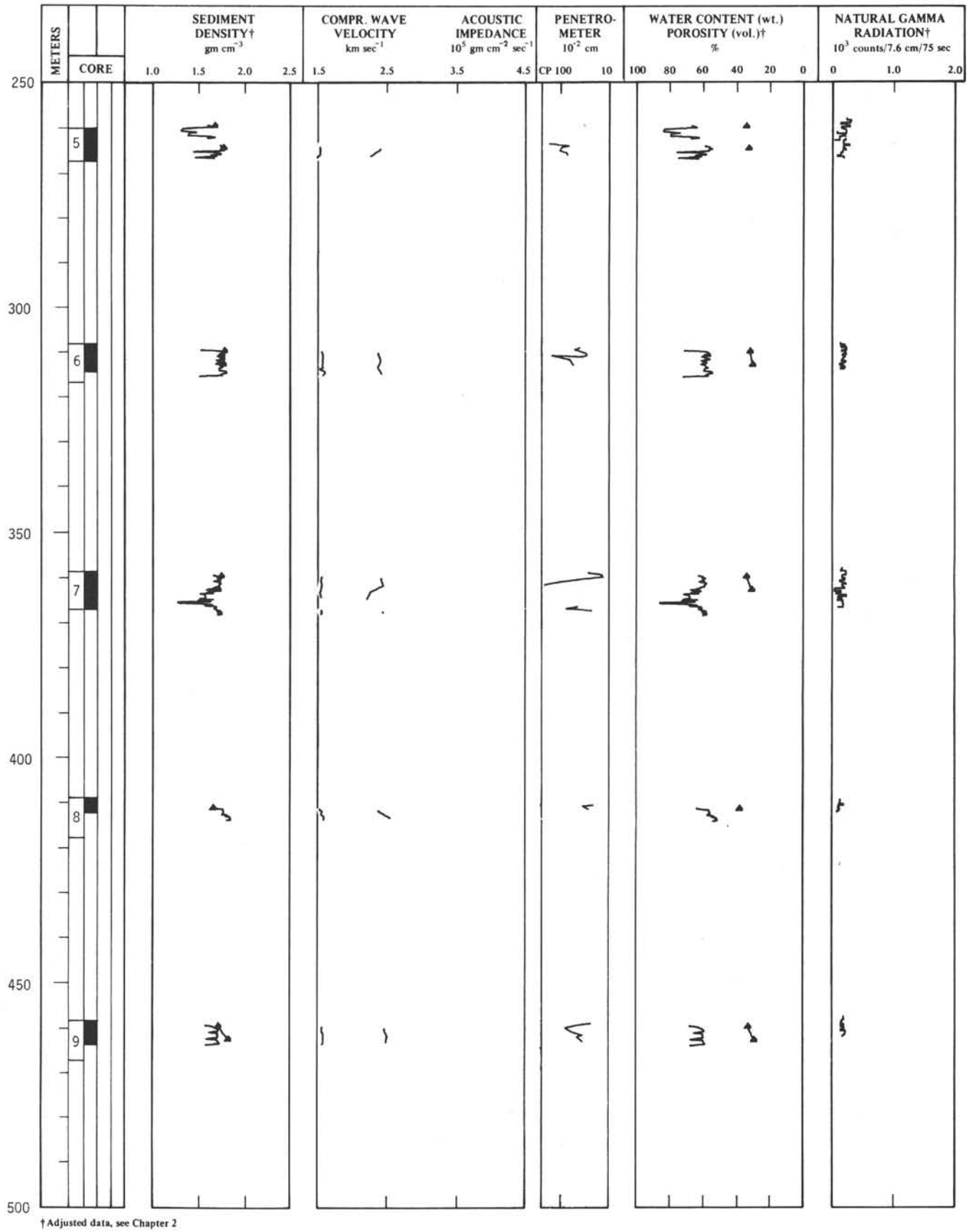
†Adjusted data, see Chapter 2

SITE 116 0 TO 250 m



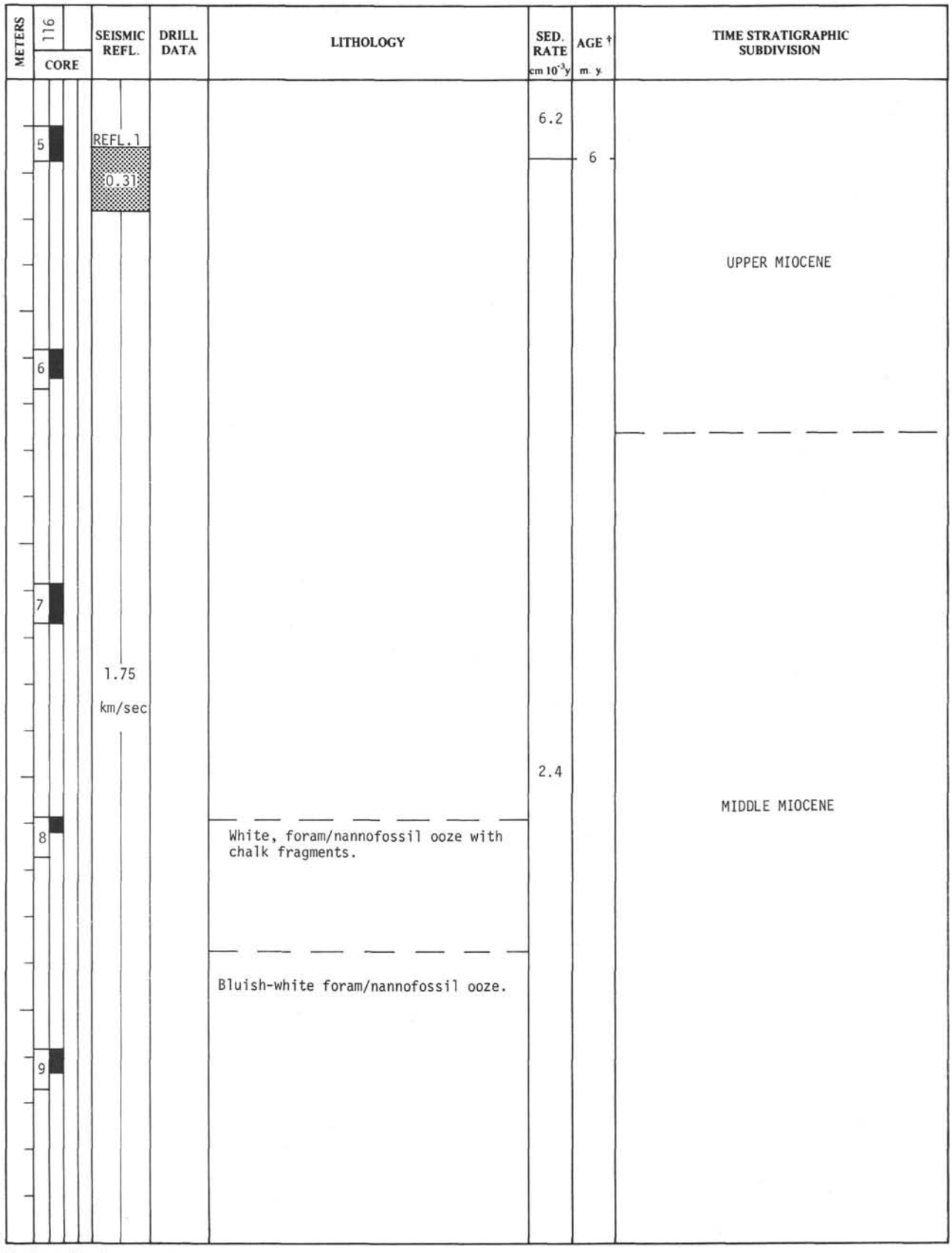
†See Chapter 2 (explanatory notes)

SITE 116 250m TO 500m



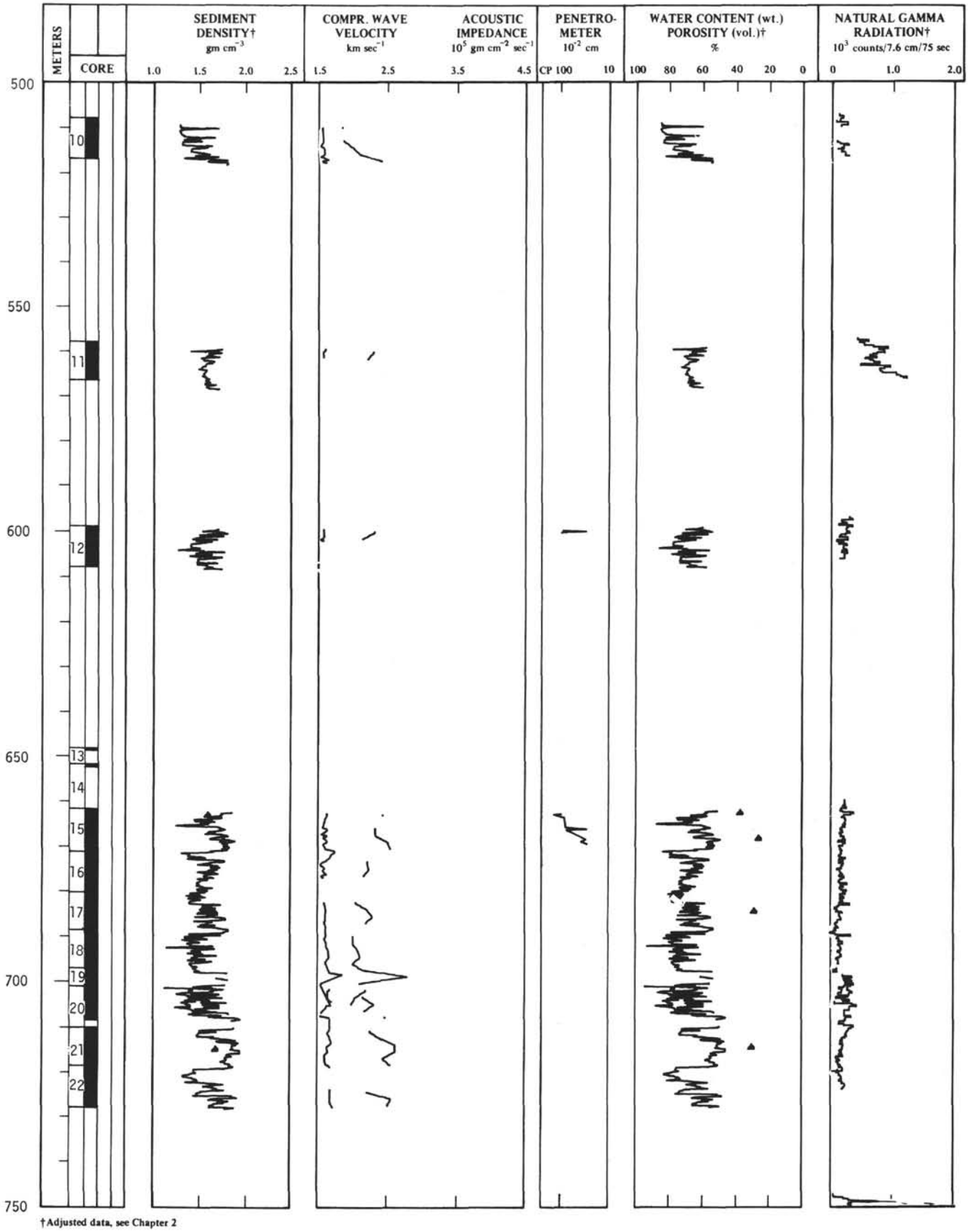
† Adjusted data, see Chapter 2

SITE 116 250 TO 500 m



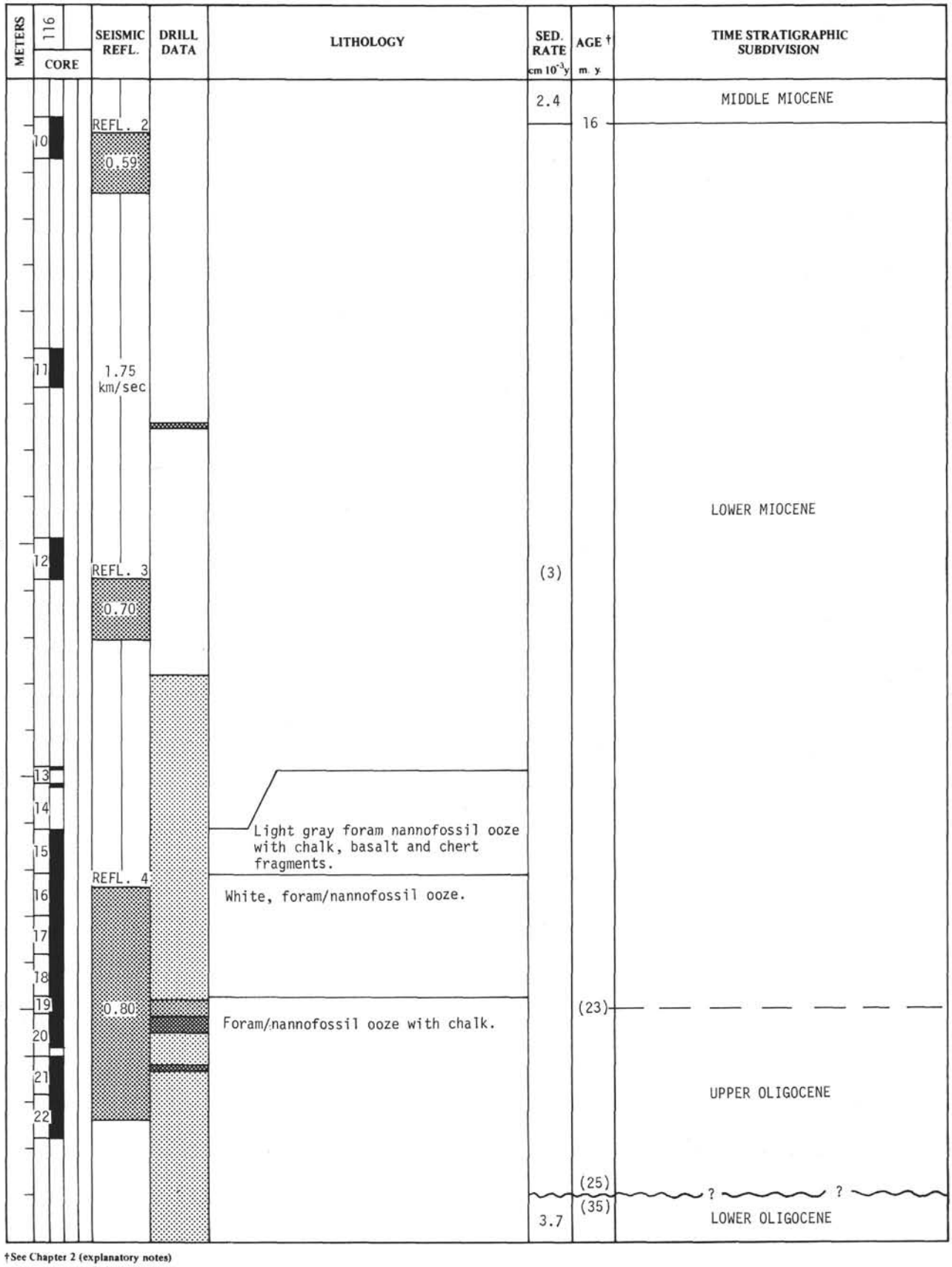
†See Chapter 2 (explanatory notes)

SITE 116 500m TO 750m



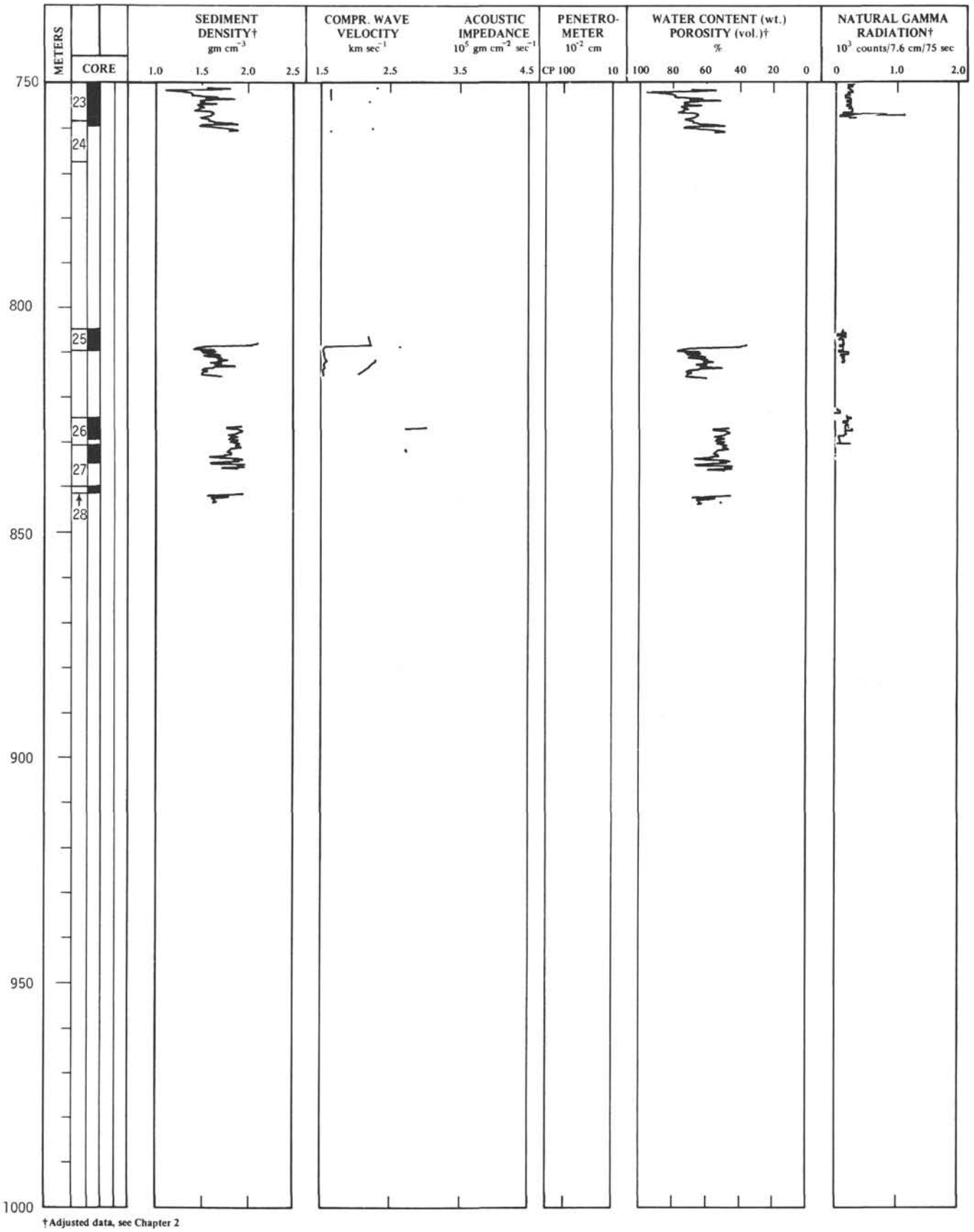
†Adjusted data, see Chapter 2

SITE 116 500 TO 750 m



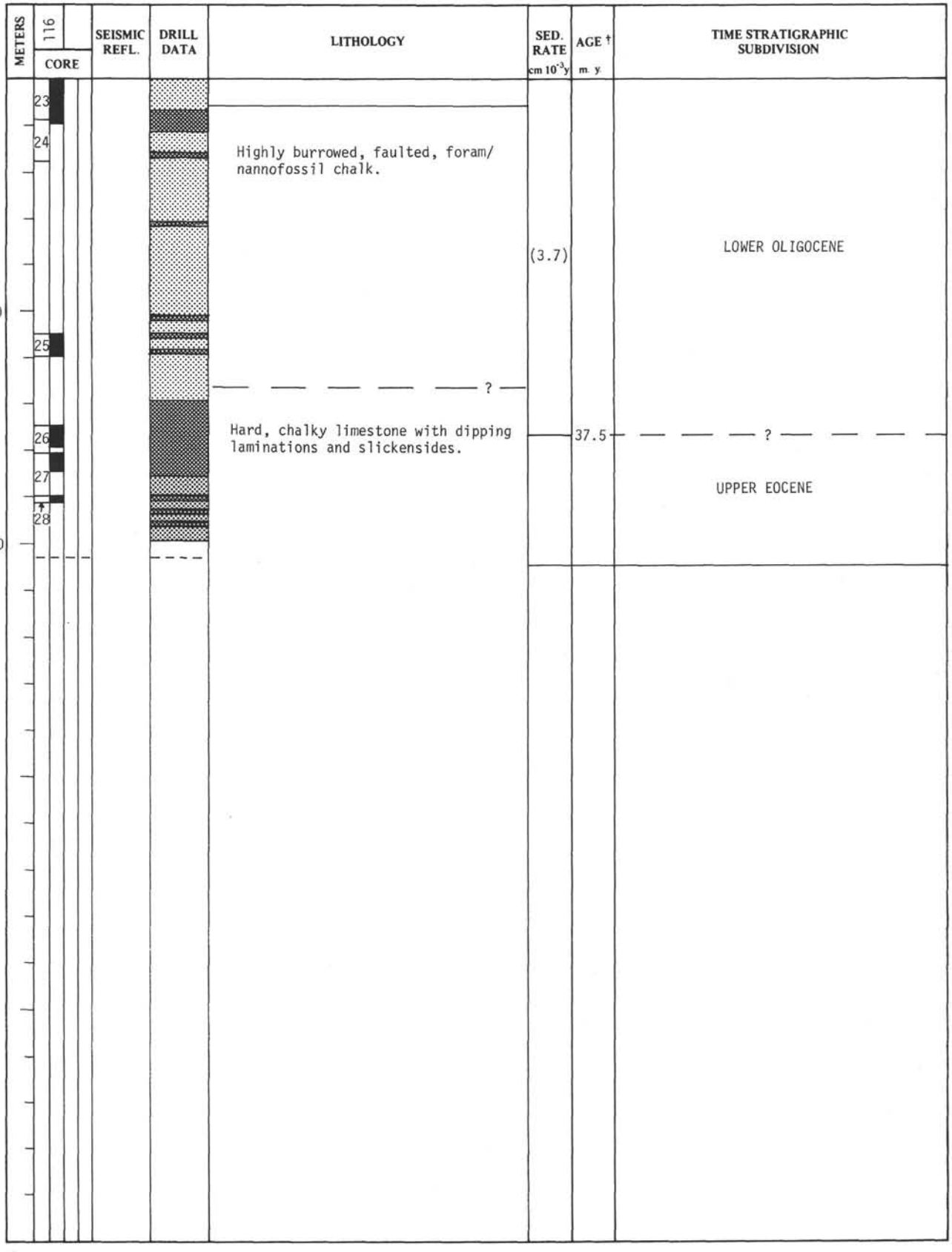
†See Chapter 2 (explanatory notes)

SITE 116 750m TO 1000m



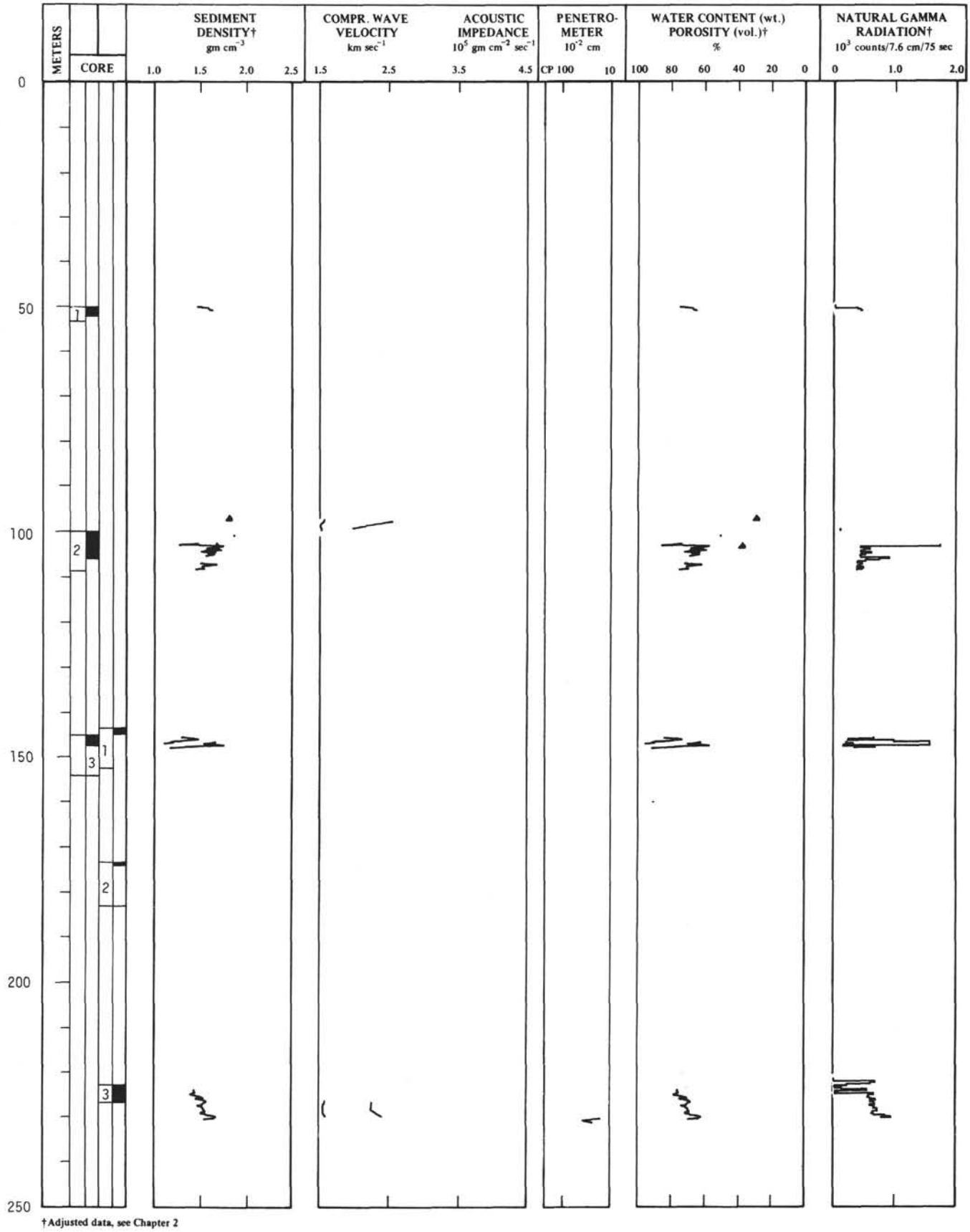
†Adjusted data, see Chapter 2

SITE 116 750 TO ---- m



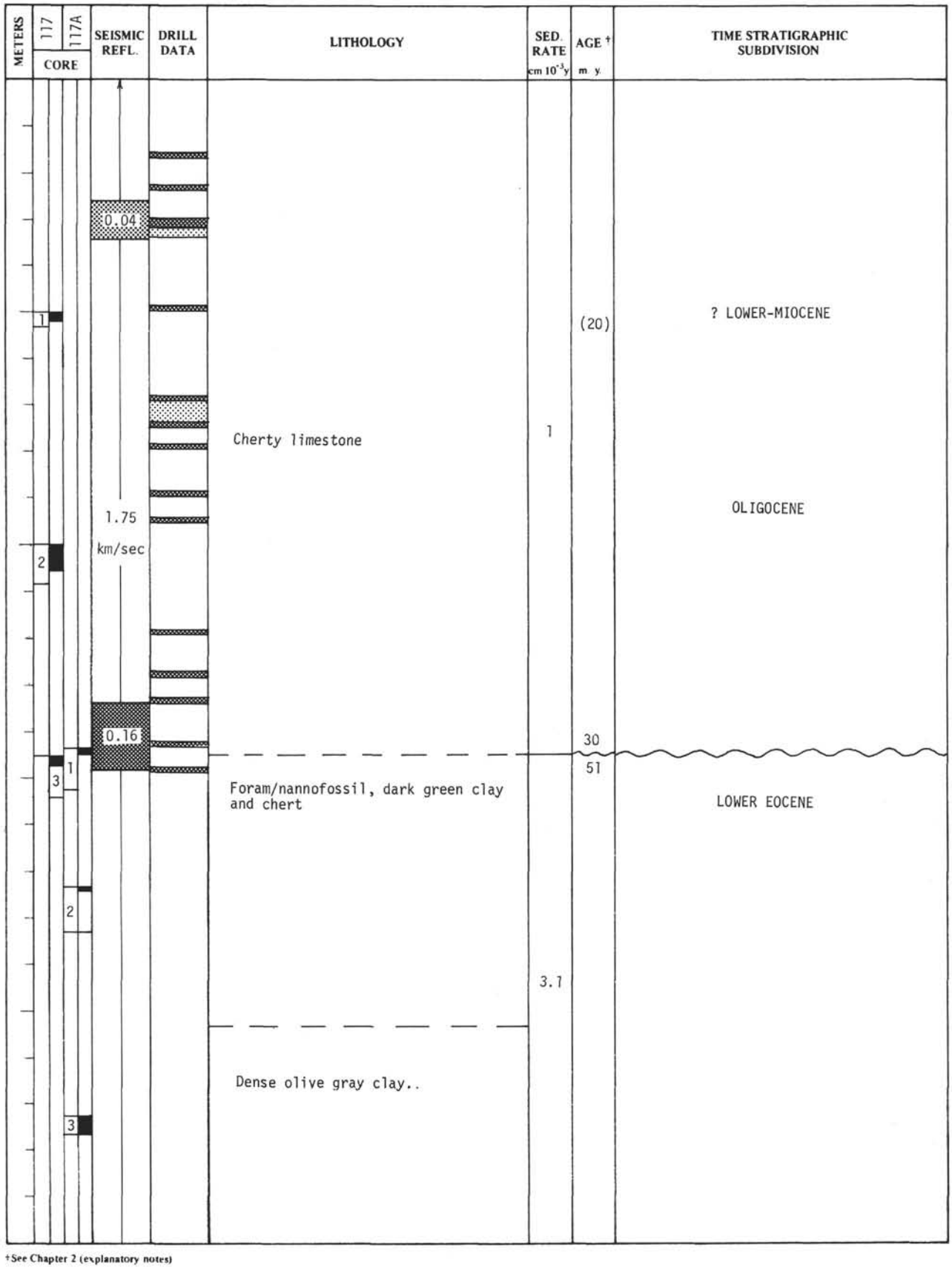
†See Chapter 2 (explanatory notes)

SITE 117 0m TO 250m



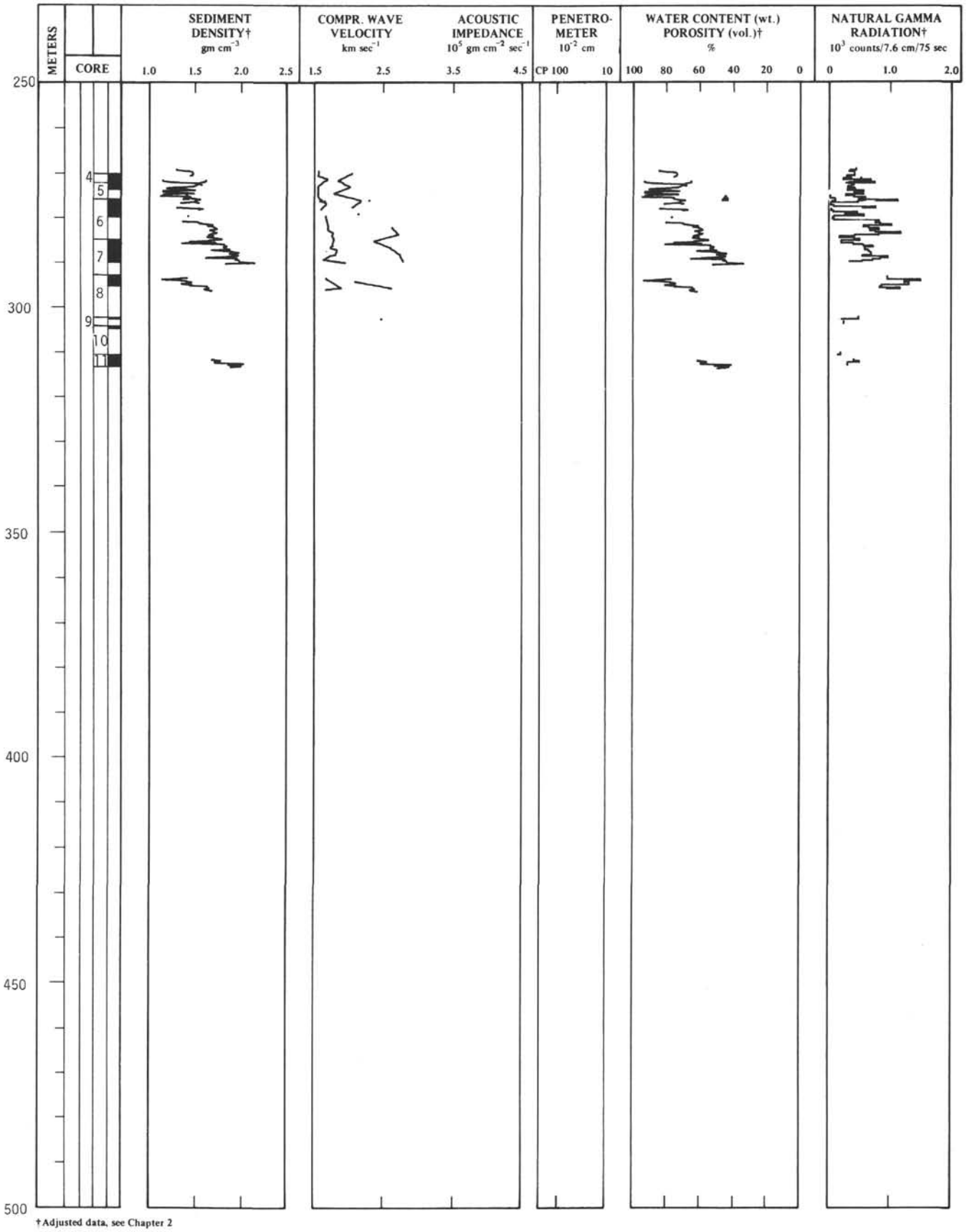
†Adjusted data, see Chapter 2

SITE 117 0 TO 250 m



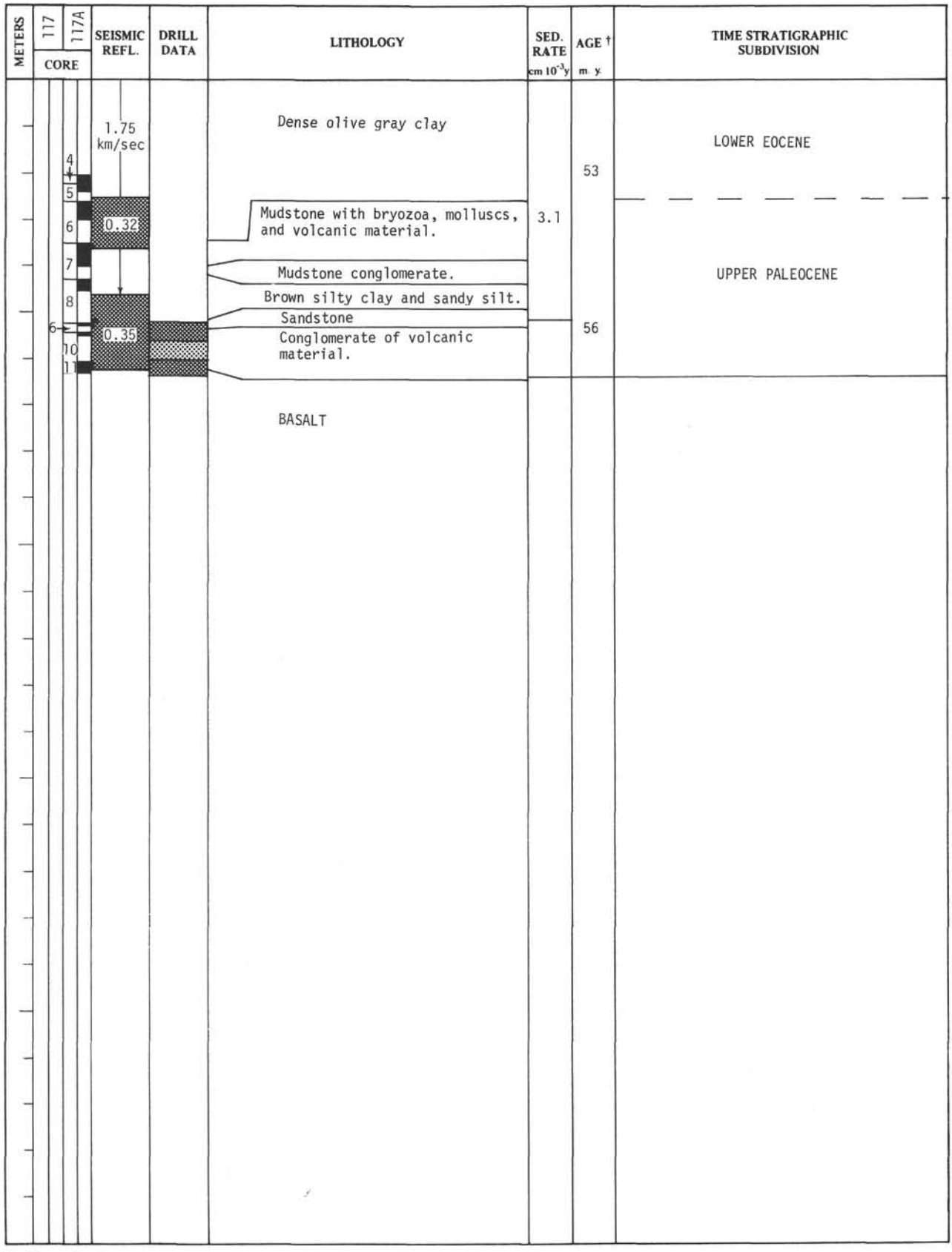
†See Chapter 2 (explanatory notes)

SITE 117 250m TO 500m



†Adjusted data, see Chapter 2

SITE 117 250 TO 500 m



†See Chapter 2 (explanatory notes)