7. SITE 106 – LOWER CONTINENTAL RISE

The Shipboard Scientific Party[1]

INTRODUCTION

The principal objective of drilling at this site was to determine the nature of the sediments that constitute the lower continental rise. Some investigators had suggested that most of the sediments would be turbidite sands (Dietz 1960, 1965). Others thought that only clays and silts would be present (Heezen, Hollister, and Ruddiman 1966).

Seismic reflector configurations had been interpreted (Ballard, 1966; Emery *et al.*, 1970) as indicating slumping and sliding of sediment from the continental slope to the lower continental rise. Others had emphasized the role of contour currents in bringing material from region up-current (Heezen, Hollister, Ruddiman 1966). Through deep drilling we hoped to establish the composition and structure of the sediment and the processes responsible for building this thick sedimentary accumulation.

Seismic reflection profiles in the vicinity of Site 106 (Figure 1) show distinct features from top to bottom:

1. A stratified zone about 0.40 second thick, with numerous highly reflective horizontal layers, which appears to consist of sediments ponded between the lower continental rise hills and the shallower part of the rise (Figures 2a and 2b). This sediment pond creates a broad terrace-like step in the continental rise at a depth of about 4500 meters and extends from the vicinity of the Hudson Canyon to the vicinity of the Hatteras Canyon.

2. An acoustically transparent interval about 0.7 second thick, with no strong reflectors, that seems to be part of the main body that constitutes the continental rise and lower continental rise hills.

3. An indistinct reflector, lying at about 7 seconds reflection time (1.1 second under the sea floor), that appears to be a westward continuation of Horizon A.

Objectives of the drilling operations were to sample the above three units in order to (a) verify the presence of coarse sediments ponded in the upper section; (b) obtain information on the nature of the transparent interval; (c) determine whether the deep reflector corresponds to the hiatus that possibly exists in Hole 105.

OPERATIONS

Positioning

The ship arrived on site during the morning of May 20, 1970, and the bit was on bottom at 1715 hours. Unfavorable weather made holding position rather difficult because of the combination of current, strong winds, and a quite erratic beacon; and, after having taken six cores between the sea floor and 350 meters below bottom, conditions were such that the drill string had to be pulled clear of the ocean floor to await better weather before launching a new beacon.

Operations were resumed early on May 22 at Hole 106A after dropping a new beacon about 1.5 miles from the previous hole. When it was determined that the bottom hole assembly had been lost, a new hole was drilled (106B) at the same site (Figure 3).

Drilling

Spudding-in was performed at Hole 106 in sand and silt, and 44 meters of penetration was accomplished before rotation was required. Six cores were recovered from an interval of 350 meters under the sea floor, and operations had to be ended due to unfavorable conditions. The material recovered was primarily clay with a substantial amount of fine sand and silt (Figure 5).

Drilling resumed in Hole 106B at 1000 hours on May 23. The hole was drilled to 366 meters below bottom, and alternately drilled and cored below that depth (Figure 4). In order to conserve time, cores were spaced widely in the interval between the base of the surficial stratified zone and Core 5B at 944 meters. The remainder of the cores was taken at closer intervals in order to increase the chance of detecting any major lithologic or stratigraphic boundary.

The Pliocene-Miocene clay was very firm and dry. It remained loose in the plastic liners, thus obviating the value of shipboard sonic velocity measurements.

Drilling became extremely difficult shortly before taking Core 5B. For the first time at this site, the clay

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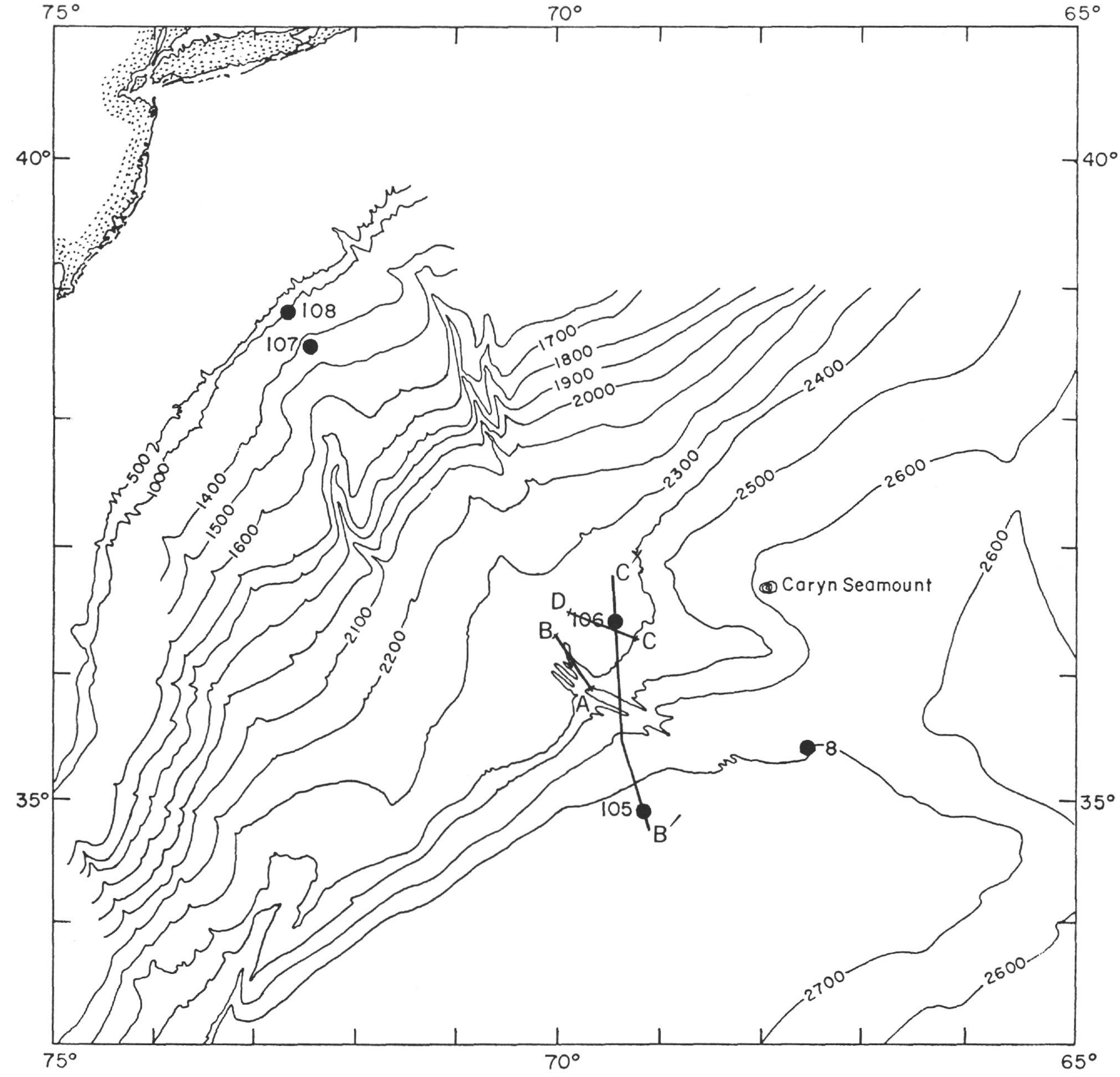

Figure 1. *Bathymetry of the continental slope and rise southeast of New York. Track AB corresponds to Figure 2b; track CD to Figure 2c.*

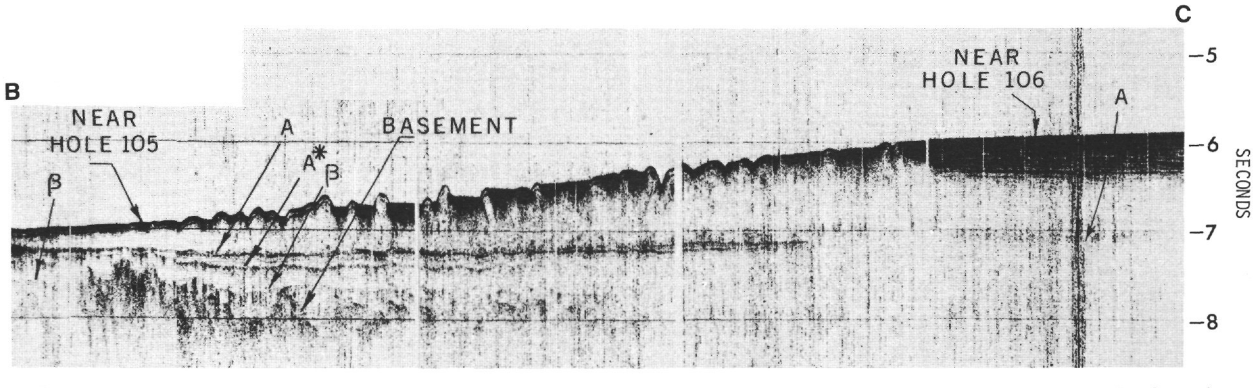

Figure 2a. Vema 23 *seismic profiler record BC between Holes 105 and 106. See Figure 1, Chapter 6 for location.*

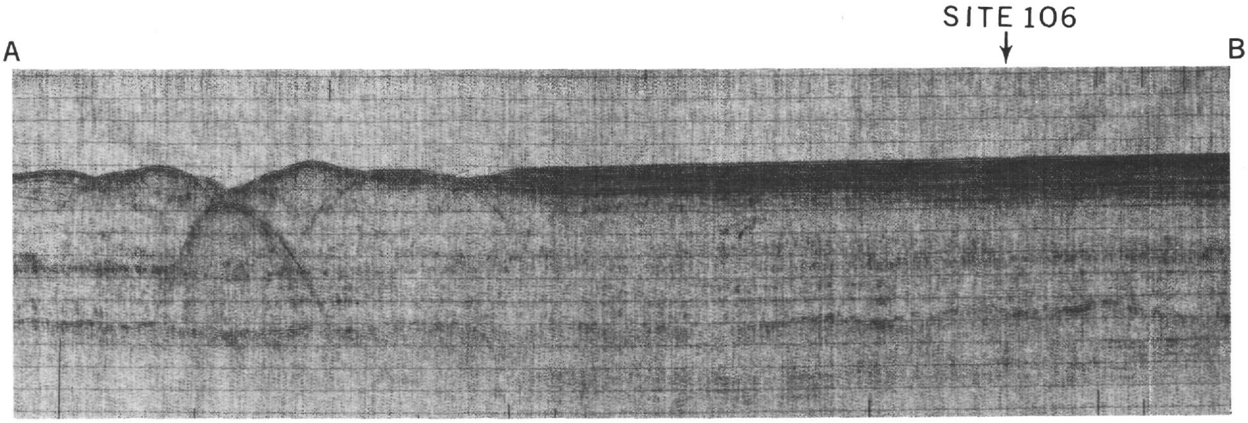

Figure 2b. *R/V* Chain *seismic profiler record near Site 106. See Figure 1 for location.*

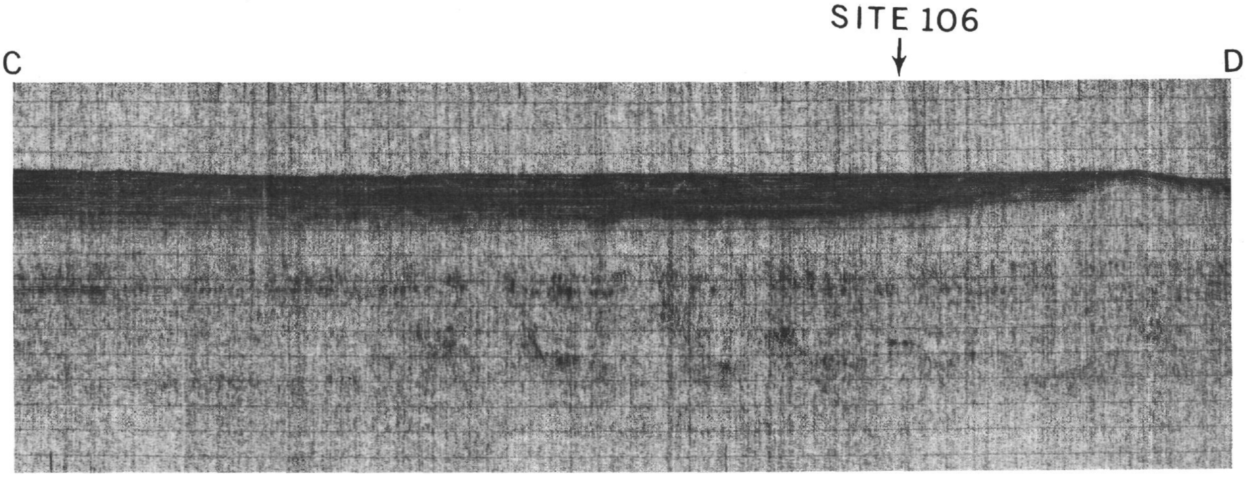

Figure 2c. *R/V* Chain *seismic profiler record near Site 106. See Figure 1 for location.*

recovered had to be cut with the diamond saw. Core 6B was essentially the same consistency as Core 5B.

Shortly before recovering Core 7B, drilling became even more difficult and drilling torque was occasionally high enough to stall the power sub. The center bit, which had been intact after drilling to Core 6B, was found to be badly worn. Several diamonds were missing and pieces of steel had been torn from the cutting faces. The samples from Cores 7B and 8B were even harder than those in Cores 5B and 6B and contained chips of silicified claystone and siderite. Further drilling was considered impossible.

The hole bottomed in the moderately distinct reflector at about 7.1 seconds (Figure 2a), which is probably caused by a concentration of siderite and silica. The fainter reflecting zone beginning at about 6.9 seconds could correspond to the gradually hardening material above the silica-siderite zone. Correlation between this hole and Hole 105 indicates that the drill probably penetrated into, but did not go through Horizon A. Therefore, we were not successful in determining whether or not the late Cretaceous/early Tertiary disconformity (or severely shortened section) of Site 105 extends to Site 106.

This hole was drilled with a Williams controlled-bite diamond drag bit that allowed penetration of 1015 meters (3330 feet) at an average rate of 35 m/hr.

STRATIGRAPHY

Biostratigraphy

Foraminifera

Planktonic foraminifers are present in abundance in sediments of Holocene to middle Miocene age. Biostratigraphic Zones N. 23, 22 (Hole 106), 21, 19, 17, 14 and 13 (Hol ,106B) were recognized. For the first time on Leg 11, an abundance of the cool-water species

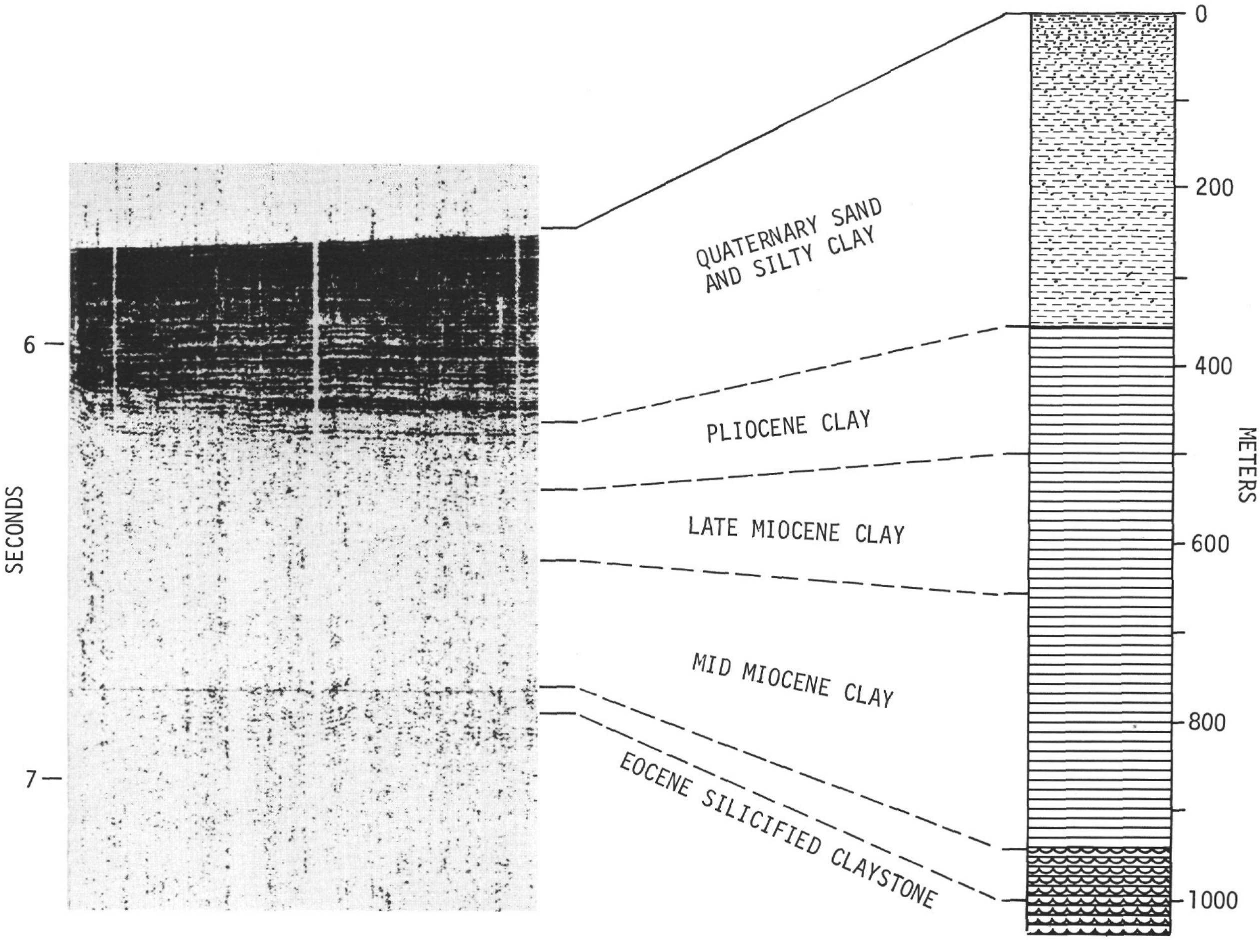

Figure 2d. *Correlations of lithology and seismic stratigraphy at Site 106.*

Globigerina bulloides and persistent *G. pachyderma* are present in the Holocene and Pleistocene sediments. This is a consequence of temperate water at this mid-latitude location. Displaced inner sublittoral foraminifers are also common throughout the Holocene and Pleistocene samples.

In Hole 106B, the sediments of Core 1 contain late Pliocene planktonic foraminifers of Zone N. 21. Core 2, approximately 85 meters deeper, is of early Pliocene (N. 19) age; Core 3 belongs in N. 17. The planktonic foraminiferal faunas are poor in Cores 4 and 5, but sufficient diagnostic forms are present to allow assignment to Zones N. 14 and N. 13, respectively (middle Miocene). Indigenous planktonic foraminifers are absent in deep cores. A prominent assemblage of agglutinated benthonic foraminifers is present in Cores 4 through 7 (Hole 106B). (Refer to the chapter on "Neogene Foraminiferal Biostratigraphy" by Poag for more detailed analysis and discussion of the foraminiferal assemblages from this hole.)

Calcareous Nannoplankton

The six cores recovered from the initial hole at this site were assigned a Quaternary Age. The first two cores contain assemblages typical of the *Gephyrocapsa oceanica* Zone, followed by cores containing assemblages typical of the *"Pseudoemiliania lacunosa"* Zone. These zones are equivalent to the planktonic foraminiferal Zones N. 23 and N. 22 of Blow.

Drilling in Hole 106B penetrated a thick sequence of upper Tertiary sediments, including approximately 460 meters of Quaternary ? and Pliocene, and 500 meters of Miocene sediments, and terminated within Oligocene-Miocene sediments at a total depth of 1015 meters. Cores 1 and 2 are assigned to the late Pliocene and early Pliocene, respectively, based on the presence of well defined *Discoaster brouweri* and *Reticulofenestra pseudoumbilica* Zones. These nannoplankton zones correlate with the planktonic foraminiferal Zones N. 21 and N. 19. Core 3 contains a well-developed assemblage indicative of the *Discoaster* *quinqueramus* Zone of the late Miocene Zone N. 17. Core 4 contains only a sparse assemblage, but the presence of *Sphenolithus heteromorphus* and *Cyclococcolithus neogammation* suggests an early middle Miocene age (Zones N. 9/10 of Blow, as well as assigment to the *Sphenolithus heteromorphus* nannoplankton zone). Core 5 was likewise referred to the early middle Miocene (Zones N. 9/10) based on the representative taxa present. Cores 6, 7 and 8 contain very spare assemblages, but the species present are indicative of an early Miocene or late Oligocene age; several Eocene species are present.

Dinoflagellates

The dinoflagellate species found in the Pleistocene cores at Site 106 are the same as those reported for the Pleistocene at Site 102. *Operculodinium centrocarpum* and *Tectatodinium pellitum* are more frequent in those samples containing appreciable numbers of spruce pollen, and fern spores. Reworked palynomorphs are relatively common, and include specimens of Cretaceous and Carboniferous age.

Achomosphaera ramulifera occurs in the Pliocene and older Tertiary cores.

Hystrichosphaeropsis obscurum was observed in Cores 3B and 4B and, on the basis of its distribution at Sites 103, 104 and 105, suggests a Miocene age for these cores. As in the Miocene cores at these sites, oak and alder pollen occur in increased frequencies. Core 5B contains *Pentadinium taeniagerum* and *Chiropteridium* sp. A, which suggest that it correlates with Core 10 at Site 104.

Radiolaria

Large assemblages of radiolarians are present in Hole 106B, Cores 5, 6 and 7. Owing to the sparsity of planktonic foraminifers in this interval, tentative shipboard identifications were made of several radiolarian species. Core 5 contains a middle Miocene assemblage characterized by *Cannartus laticonus? Eucyrtidium delmontense,* and *Crytocapsa pyrum*. Core 6 is middle to early Miocene in age based on the presence of *Crytocapsa pyrum, Calocyclas virginis, Cannartus laticonus* and *Panarium antepenultimum* (?). Core 7 contains two distinctly different radiolarian associations. Predominant is a varied group of species which has been altered by a compression and silification. This group of poorly-preserved specimens contains what appear to be Eocene elements, such as, *Calocyclas turris* and *Sethamphora mongolfieri*. The other group consists of a few well-preserved whole specimens of early Miocene and late Oligocene age including *Cantharospyris ateuchus* and *Theocyrtis tuberosa*. Further study at the shore-based laboratory (W. R. Riedel, personal communication) has confirmed the presence of an Eocene radiolarian assemblage in the lowest samples of Site 106.

Lithology

The six cores recovered from Hole 106 represent the upper part of the sediments of the site; and, coring in Hole 106B began about 21 meters below the maximum depth reached in the first hole. The samples recovered from the two holes show good continuity and are thus representative of a single sedimentary record for Site 106.

Two different facies, which correlate well with the units appearing on the seismic record (see Figure 5) can be identified:

1. Pleistocene turbidites that correspond to the highly stratified zone in the upper part of the sediment section; and,

2. Tertiary, gray homogeneous, hemipelagic muds that correspond to the transparent interval.

Sands and Clays from the Pleistocene (Cores 1-6)

The terrigenous fraction is very important; clay minerals, quartz, micas, and heavy minerals are the main components. Sand layers show a great abundance of quartz, feldspars and heavy minerals; mud layers often contain some iron oxides. Glauconite was observed in most of the slides. Silt-sized and rare sand-sized calcite fragments are found in nearly all the samples, and are probably detrital.

Both calcareous and siliceous microfossils are present in the clay layers, and in minor proportion in the silty and sandy layers.

Most of the clays contain siderite, dolomite and organic matter.

Though it is probable that most of the coarse-grained material was emplaced by turbidity currents, no primary structures could be observed, since all the cores retrieved in this section are badly disturbed.

Pliocene to Eocene Hemipelagic Gray Silty Muds (Cores 1B-8B)

The composition of the terrigenous fraction (clay minerals, some quartz, rare heavy minerals) is almost constant throughout, but there is noteworthy variation in the composition of the biogenic fraction, as well as the distribution of authigenic carbonates (calcite, dolomite and siderite). Pyrite is present throughout the section.

Cores 1B to 4B contain abundant calcareous nannoplankton, rare foraminifera, and very rare radiolarians. Cores 5B and 6B are very rich in siliceous microfossils (radiolarians, sponge spicules and some diatoms), and are almost barren of calcareous microfossils.

Calcite fragments, which may be either detrital or recrystallized, and dolomite tend to disappear with depth, while the siderite content increases regularly,

The negative correlation between the amounts of siderite and calcareous microfossils strongly suggests that the latter were the source for this carbonate.

A similar observation can be made for the silica content of Cores 7B and 8B. Reprecipitation of the silica in the form of disordered cristobalite, which is largely responsible for the high degree of induration of the clay, could have occurred after dissolution of opal from the siliceous microfossils.

Most of the cores from this interval showed a high gas content (CO_2, H_2S, CH_4) which could be responsible for some of the burrow-like structures observed in several sections. Upward migration of gas could also have been the origin of numerous vertical, very thin veinlets, which are often filled with siderite. Some of these veinlets produce a vertical fracturing that cuts through other primary structures.

Rate of Sediment Accumulation

Except for Site 102 on the crest of the Blake-Bahama Outer Ridge, the average rate of accumulation at Site 106 was more rapid than at any previous site drilled during Leg 11. The Pleistocene value, however, exceeds even that of Site 102.

During the Eocene-early Miocene, sediment accumulated at a rate of 0.2 cm/1000 yr. and then the rate increased twenty-fold during the middle Miocene-Pliocene interval, reaching 4.3 cm/1000 yr.

The rate again increased nearly five-fold during the Pleistocene to a maximum of 20 cm/1000 yr. This exceeds all rates previously determined for Pleistocene accumulation in a major ocean basin.

CONCLUSIONS

The main features that had been recognized on the seismic profiles in this area have been identified as follows:

1. The highly stratified upper section consists of terrigenous sands, and sandy and silty clays that were emplaced during Pleistocene time by turbidity currents, probably from the Brandywine and Hudson canyons, and which accumulated in a large depression on the continental rise.

2. The underlying transparent interval corresponds to a thick accumulation of well-indurated and faintly bedded, Tertiary hemipelagic mud that can be traced to the nearby lower continental rise. The upper section of this interval (late middle Miocene and late Miocene) is rich in carbonates, while the lower part (middle Miocene) is more siliceous. A good correlation can be established between Sites 102, 103, 104 and this site, based on composition as well as paleontological correlation. Turbidites appear to be absent.

3. The last two cores obtained from this site sampled a hard silicified zone, probably Eocene in age, which lies very close to the horizontal reflector situated at 1.1-second reflection time under the sea floor, and which shows continuity with Horizon A. However, the presence of the hiatus observed at Sites 99, 101, and 105 could not be established at this site, as drilling stopped before the layer beneath Horizon A could be sampled.

Figure 2a shows the V23 seismic profile between Holes 105 and 106. Horizon A*, β and basement cease to be visible about half way along the traverse, although reflections at the approximate depth to correspond to both β and basement are observed in a sonobouy record very close to Hole 106. Horizon A also disappears, or nearly so, in a region near the southern edge of the pond of stratified sediment in which Hole 106 was drilled but apparently reappears in the vicinity of the site at a total depth slightly in excess of 7 seconds reflection time.

A portion of a record made by R/V Chain in the general vicinity is shown in Figure 2b. This record, kindly made available by K. O. Emery of Woods Hole Oceanographic Institution, shows without question that Horizon A is continuous, although of variable reflectivity, in the questionable region of the V23 record; so there is little doubt that the reflector at 7.1 seconds at the drilling site is, in fact, Horizon A.

The most likely correlations of drilling breaks with lithology and acoustic data are to associate the drilling break at 340 meters with the base of the stratified zone, which is about 0.40-second thick, and the major break at 1020 meters with the upper part of Horizon A. The drag bit used at this site suffered little wear (judging by the condition of the center bit) until very near the bottom of the hole and was destroyed quickly there. The sediments at the bottom are silicified; one fragment in the last core was a silicified siderite of a hardness comparable to chert.

An exact date cannot be assigned to the deepest sample, but W. R. Riedel (personal communication) places it in the Eocene on the basis of a few poorly preserved radiolarians. Hence, from the definite continuity of Horizon A as a seismic reflector across Sites 8, 105 and 106, and from the available dating at the three sites, we conclude that the reflecting horizon is in the Eocene and is unlikely to be seriously time-transgressive between these sites. Similar assumptions and reasoning applied to the seismic data suggest that the multicolored layers, the black clays, and the limestone sequence all continue well underneath the continental rise without appreciable change in depth.

The seismic, lithologic, and drilling correlations that seem most reasonable indicate an interval velocity of 1.73 km/sec for the stratified pond of sandy, silty clay and a velocity of 1.94 km/sec for the acoustically homogeneous layer underneath. This deeper layer consists of hemipelagic mud, and its higher velocity probably results from a rather high degree of compaction and possibly from the presence of some gas hydrate which may cause sonic velocities to be anomalously high (Stoll *et al.*, 1971).

A sonobouy-station record near the drilling site (V23-60) gave values of 1.73 km/sec for the sea floor – 6.29 second interval – and 1.99 km/sec for the interval 6.29 to 7.10 seconds, in good agreement with the values mentioned above.

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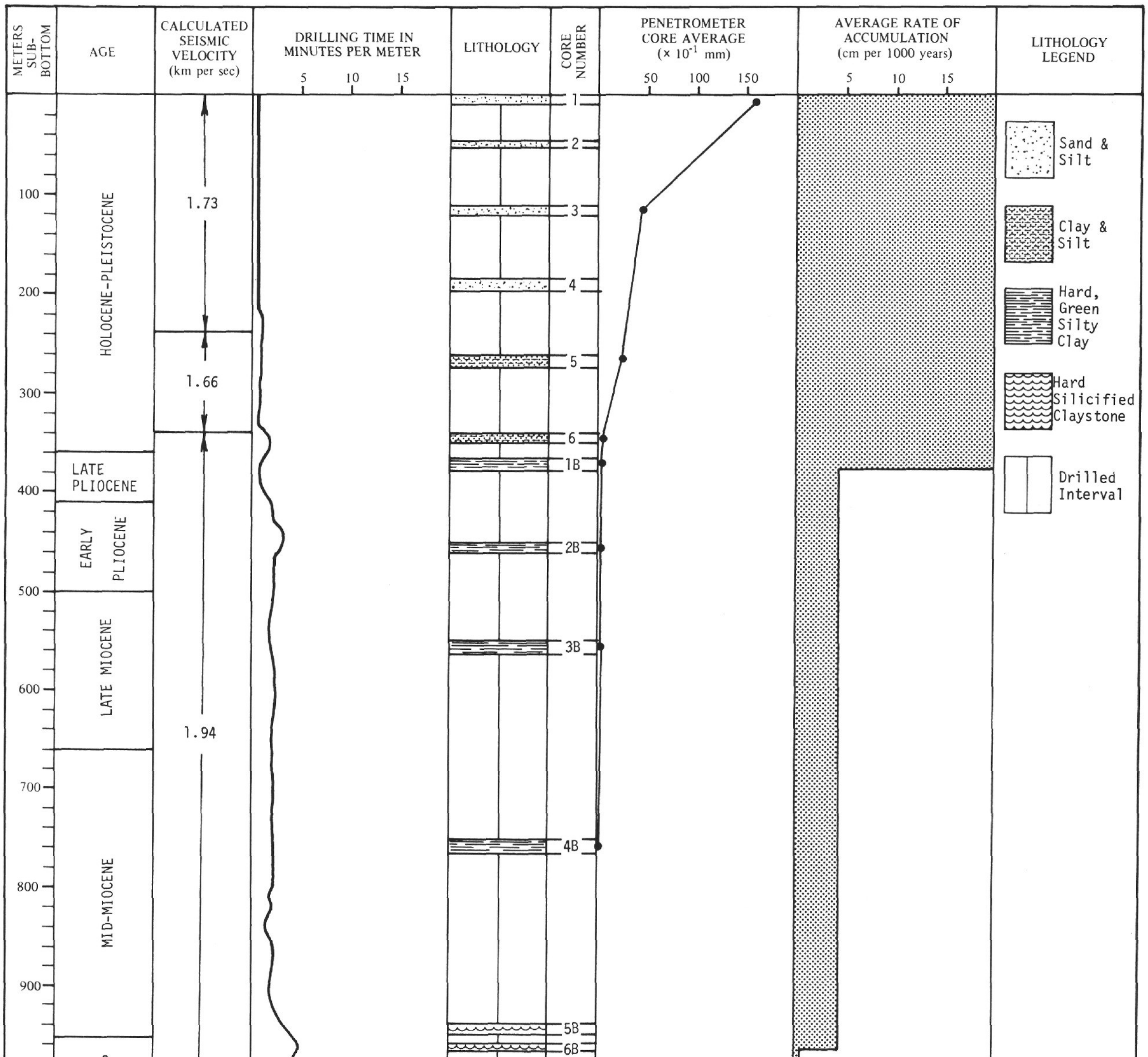


Figure 3. *Site 106 summary chart*

Hole 106

Latitude: 36°26.01′N

Longitude: 69°27.69′W

Water depth: 4500 meters (drill pipe); 4492 meters (PDR)

Core No.	Interval Cored (meters)[a]				Lithology	Age		
	Depth	Amount	Recovery	Subbottom Depth		Foraminifera	Nannoplankton	Dinoflagellates
1	4510-4517	7	6	7	Sand and silt	Holocene	Pleistocene	
(Drilled)	(4517-4555)	(38)		(45)				
2	4555-4560	5	5	50	Sand, silt and clay	Late Pleistocene	Early Quaternary	
(Drilled)	(4560-4620)	(60)		(110)				
3	4620-4629	9	7	119	Sand, silt and clay	Late Pleistocene	Early Quaternary	
(Drilled)	(4629-4697)	(68)		(187)				
4	4697-4706	9	<0.1	196	Silt and clay	← Early Pleistocene →		
(Drilled)	(4706-4773)	(67)		(263)				
5	4773-4782	9	3.7	272	Silt and clay	← Early Pleistocene →		
(Drilled)	(4782-4850)	(68)		(340)				
6	4850-4859	9	4.3	349	Sand, silt and clay	← Early Pleistocene →		

Figure 4. *Core Summary table, Site 106.*

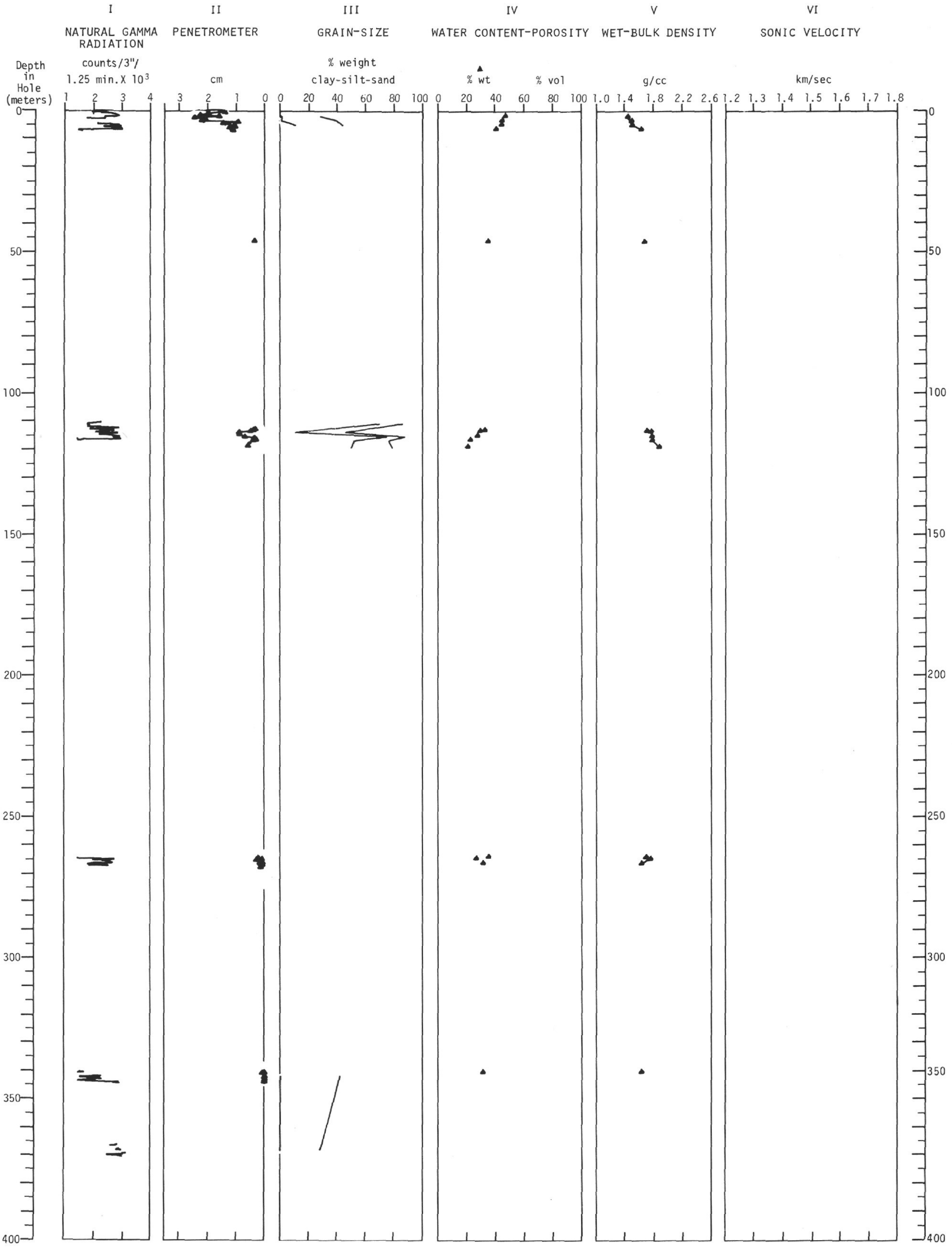
Hole 106B

Latitude: 36°25.28′N
Longitude: 69°25.81′W
Water depth: 4504 meters (drill pipe); 4488 meters (PDR)

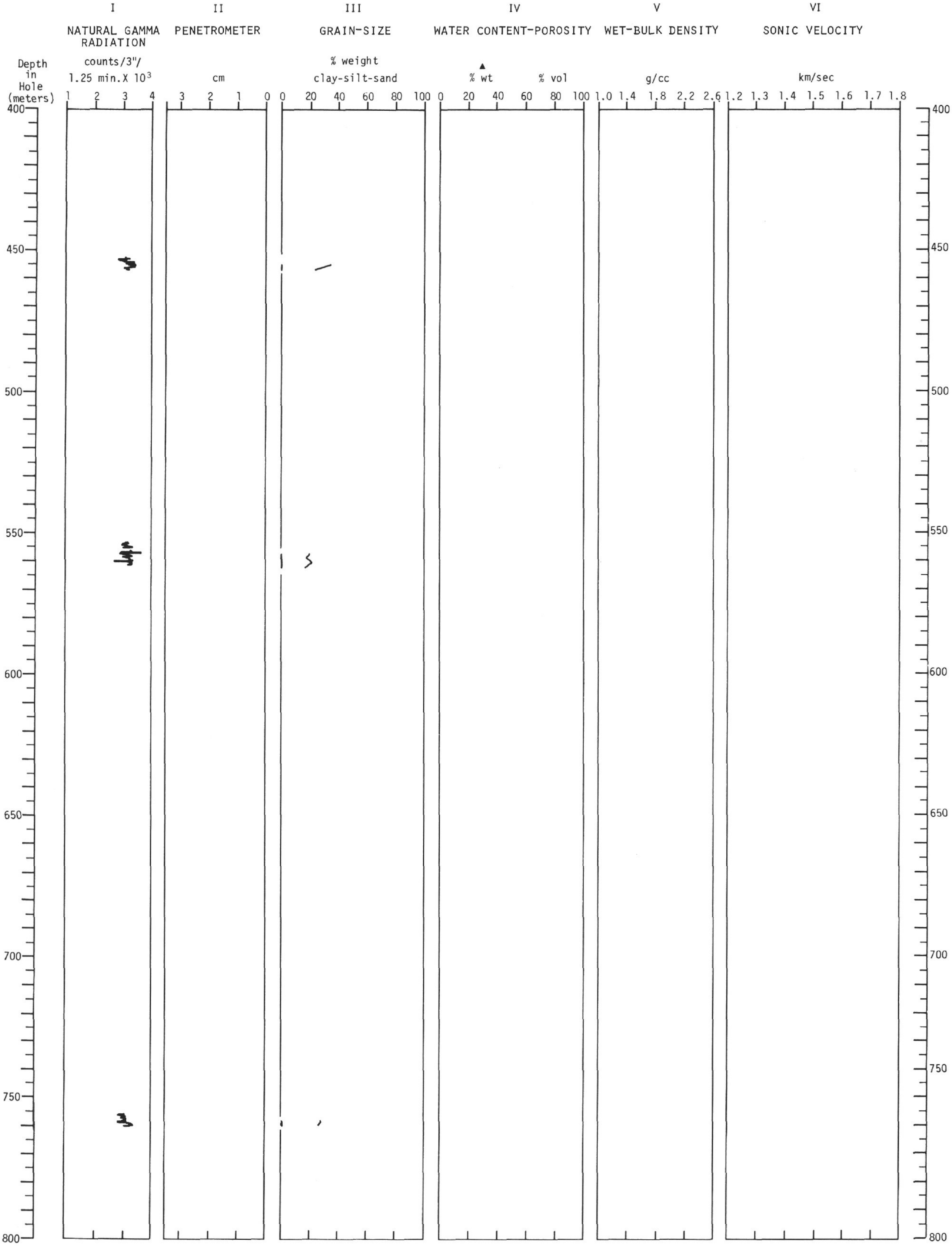
Core No.	Interval Cored (meters)^a				Lithology	Age		
	Depth	Amount	Recovery	Subbottom Depth		Foraminifera	Nannoplankton	Dinoflagellates
(Drilled)	(4514-4880)	(366)		(366)				
1	4880-4889	9	4.2	375	Hard hemipelagic mud	← Late Pliocene →		Pliocene
(Drilled)	(4889-4965)	(76)		(451)				
2	4965-4974	9	5.2	460	Hard hemipelagic mud	← Early Pliocene →		Pliocene
(Drilled)	(4974-5067)	(93)		(553)				
3	5067-5076	9	9.2	562	Hard hemipelagic mud	← Late Miocene →		Miocene
(Drilled)	(5076-5268)	(192)		(754)				
4	5268-5277	9	5	763	Hard hemipelagic mud	Late-Middle Miocene	Middle Miocene	Miocene
(Drilled)	(5277-5449)	(172)		(935)				
5	5449-5458	9	9	944	Very hard hemipelagic mud	← Middle Miocene →		
(Drilled)	(5458-5468)	(10)		(954)				
6	5468-5475	7	4.4	961	Very hard silicified hemipelagic mud		Middle or Early Miocene	
(Drilled)	(5475-5526)	(51)		1012				
7	5526-5529	3	1.3	1015	Very hard silicified mudstone		Oligocene-Miocene?	
8	5529-5529.5	0.5	0.3	1015.5	Very hard silicified mudstone		Oligocene-Miocene?	

[a] All intervals are measured by drill pipe from the derrick floor which is 10 meters above water surface.

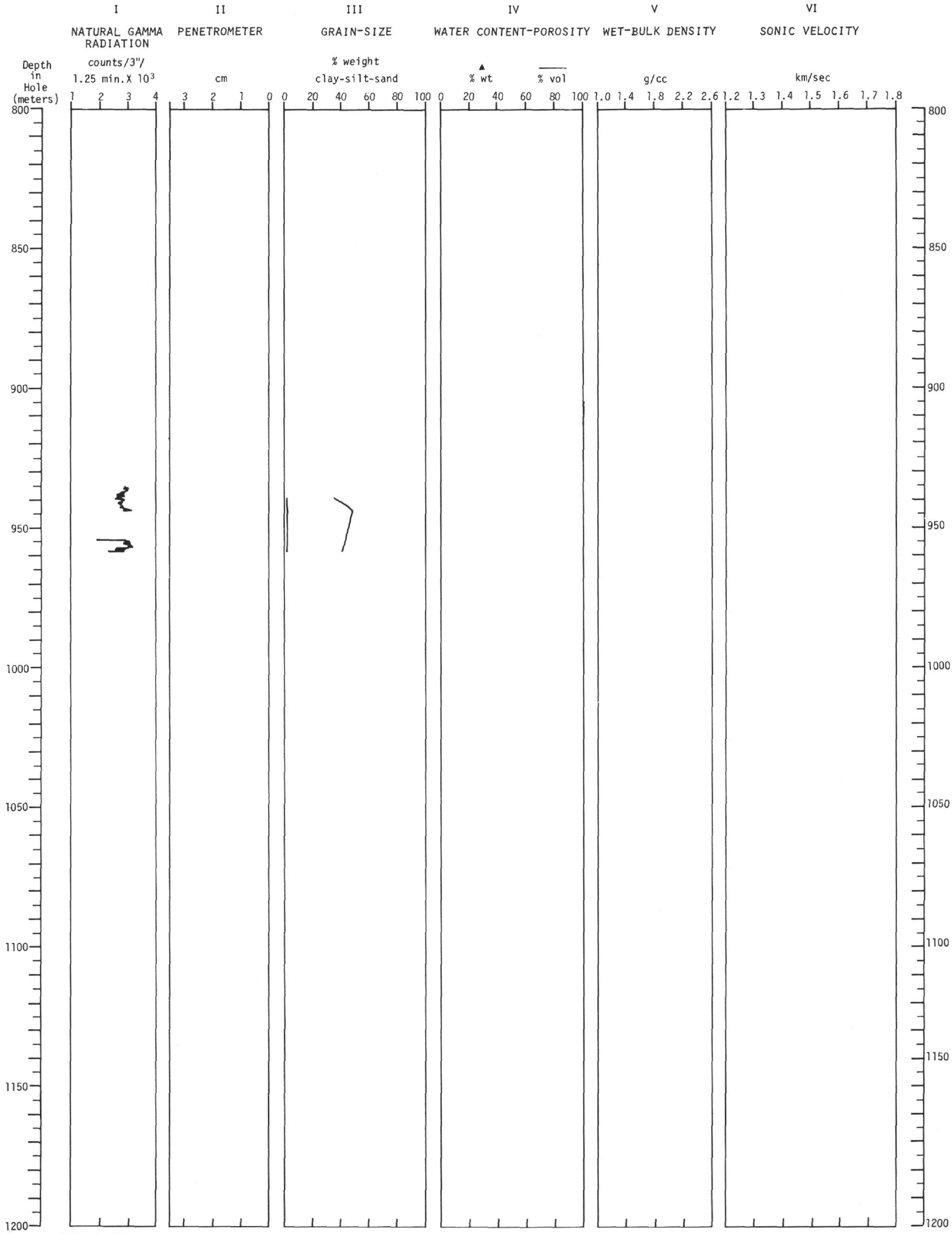
Figure 4. *Core Summary table, Site 106.* (Cont)



Summary of Physical Properties, Hole 106



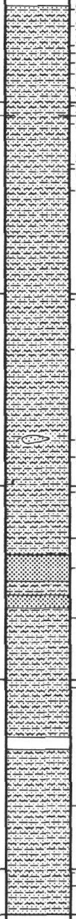
Summary of Physical Properties, Hole 106 (Cont'd)

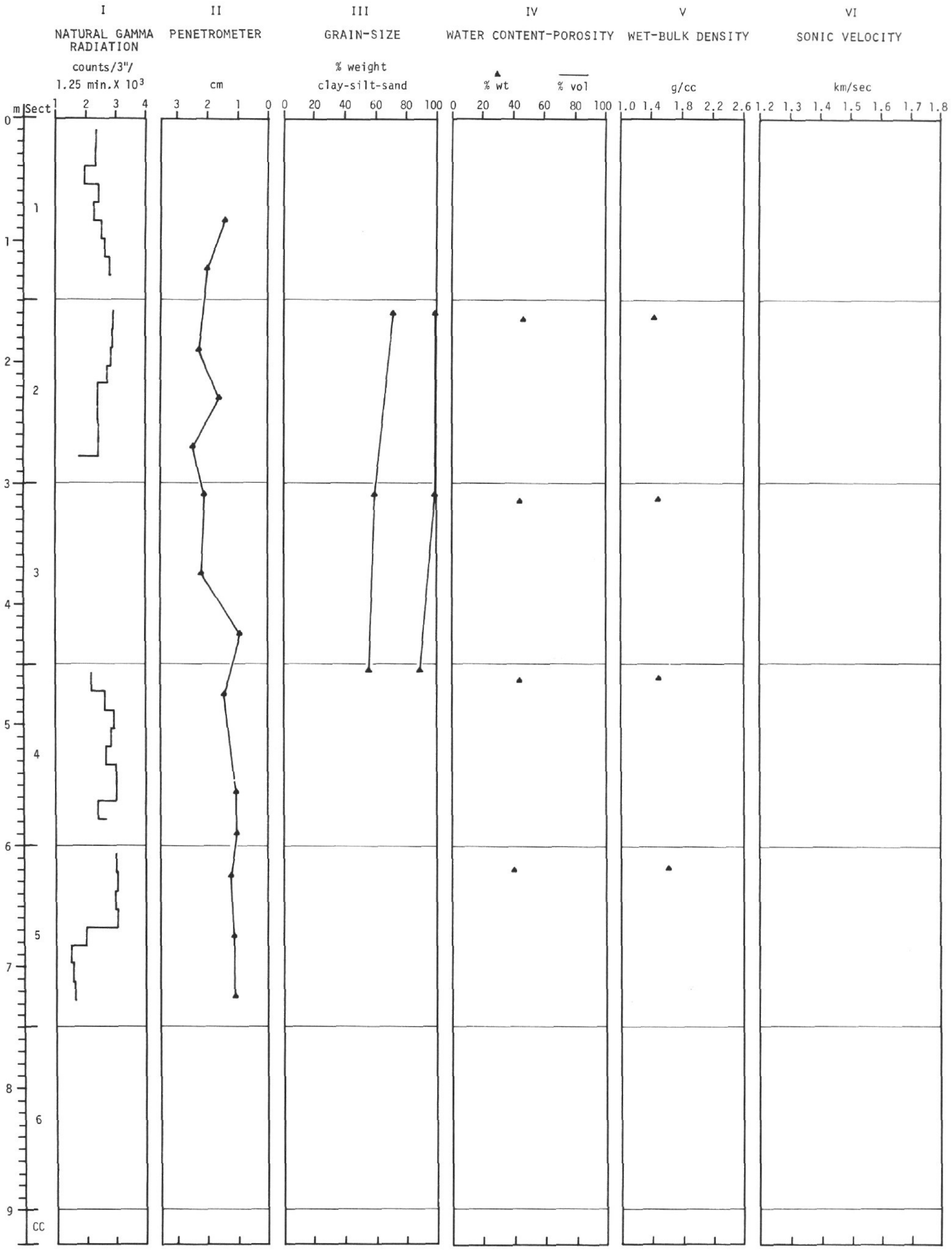


Summary of Physical Properties, Hole 106 (Cont'd)

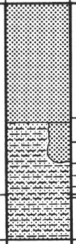
See Physical Property Core Summaries for Hole 106B

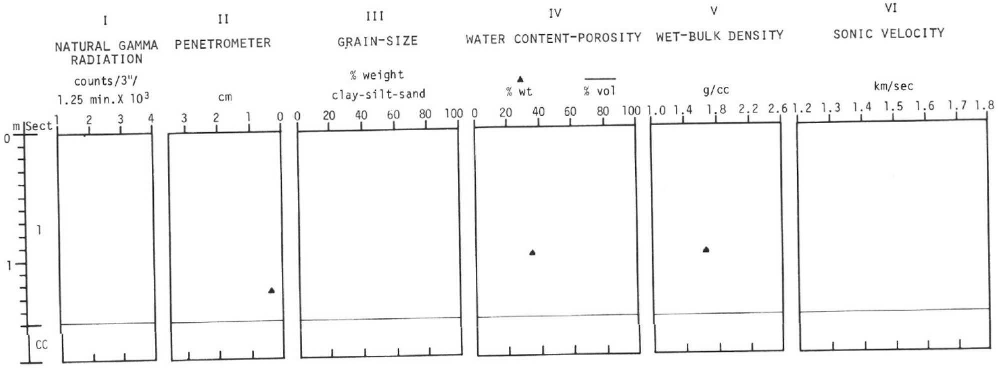
Hole 106, Core 1 (0m to 7m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
HOLOCENE LATE PLEISTOCENE	Globigerina calida/Sphaeroidinella excavata N.23 Gephyrocapsa oceanica	1 2 3 4 5 6 7	1 2 3 4 5 CC		SS SS SS F SS SS SS SS SS SS F CN SS SS SS SS SS SS SS SS SS SS D,CN SS	Hemipelagic mud, soft and plastic, dominantly olive gray (5Y 4/1 and 5Y 5/1) with occasional thin layers of yellowish and light brown (10YR 4/2, 10YR 6/2, 5YR 5/2) in the upper part; reddish brown (10YR 5/4) admixed and interlayered with olive gray in upper part of Section 2; thin layers of light gray (N6, N7), bluish gray (5B 7/1) and brownish gray (5YR 6/1) in upper part of Section 4; tinge of grayish red (10YR 4/2) in lower part of the core. Whole core disturbed and no Primary structures were preserved. Clay minerals abundant. Nannoplankton and foraminifers common to abundant in upper part, rare to absent in middle part, common to abundant again in lower part. Siliceous organisms (radiolarians sponge spicules and occasional diatoms) regularly present (rare to common) throughout the upper part, rare to absent in lower part. Calcite fragments (detrital or recrystallized?) common throughout the core. Inclusion of terrigenous sand (quartz dominant; feldspar, micas heavy minerals, glauconite, common to rare.) Foram-rich terrigenous sand. Hemipelagic mud as above. Highly disturbed sand layer. Hemipelagic mud as above.	PLANKTONIC FORAMINIFERS: *Globigerina bulloides,* *Globigerina calida,* *G. rubescens,* *Globigerinoides ruber* f. *rosea,* *Globorotalia cultrata,* *Gl. truncatulinoides,* *Turborotalia inflata* CALCAREOUS NANNOPLANKTON: *Gephyrocapsa oceanica,* *Ceratolithus cristatus,* *Syracosphaera pulchra,* *Discolithina japonica,* *Rhabdosphaera stylifera* PLANKTONIC FORAMINIFERS: *Globigerina bulloides,* *Globorotalia truncatulinoides,* *Turborotalia inflata* *CORE CATCHER* DINOFLAGELLATES: *Operculodinium centrocarpum,* *Tectatodinium pellitum,* *Leptodinium aculeatum* CALCAREOUS NANNOPLANKTON: *Gephyrocapsa oceanica,* *Ceratolithus cristatus,* *Syracosphaera pulchra,* *Cyclococculithina leptopora*



Hole 106, Core 2 (45m to 50m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE PLEISTOCENE	Globigerina calida/Sphaeroidinella excavata N.23 Pseudoemiliania lacunosa	1	1 CC		SS SS SS CN F,SS D,CN	Thick smear of <u>terrigenous sand</u> (quartz dominant), gray (N3, N4) on inside wall of the liner. Inclusion of <u>terrigenous sand</u>. <u>Hemipelagic mud</u>, soft and plastic, greenish gray (5G 5/1). Core disturbed - no structures preserved. Clay minerals abundant. Nannoplankton common to rare. Calcite fragments (detrital or recrystal?) common.	CALCAREOUS NANNOPLANKTON: *Pseudoemiliania lacunosa, Gephyrucapsa oceanica, Ceratolithus cristatus, Syracosphaera pulchra, Coccolithus pelagicus* PLANKTONIC FORAMINIFERS: *Globorotalia truncatulinoides, Turborotalia inflata, Globigerina bulloides, G. pachyderma* *CORE CATCHER* DINOFLAGELLATES: *Similar to 106-1-cc.* CALCAREOUS NANNOPLANKTON: *Pseudoemiliania lacunosa, Gephyrocapsa oceanica, Ceratolithus cristatus, Syracosphaera pulchra.*



Hole 106, Core 3 (110m to 119m)

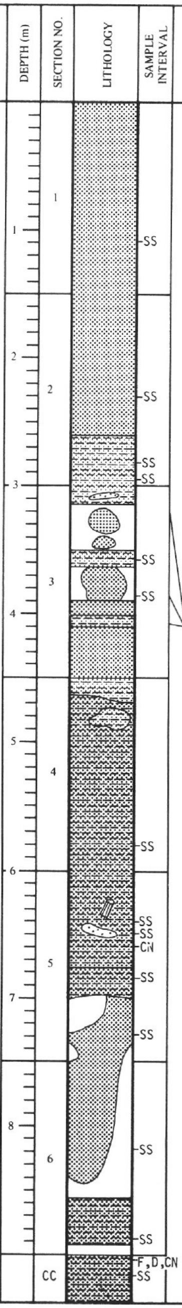
AGE

LATE PLEISTOCENE

ZONE

Globigerina calida/Sphaeroidinella excavata N.23

Pseudoemiliania lacunosa



LITHOLOGY

Terrigenous sand, unconsolidated, gray (N4), highly disturbed (no primary structures preserved).

Quartz, abundant to dominant.

Clay min., feldspar, micas, heavy min., common.

Glauconite, pyrite, rare to common.

Nannoplankton and foraminifers present.

Whole core highly disturbed.

Hemipelagic mud, soft and plastic, brownish gray (5YR 5/1).

Clay minerals, abundant.

Quartz, common.

Nannoplankton rare.

Calcite fragments (detrital or recryst.?), common.

Patches of loose terrigenous sand, sandy clay, hemipelagic mud and drill cuttings.

Hemipelagic mud, soft and plastic, light brownish gray (5YR 6/1).

Mixture of terrigenous sand, dark greenish gray (5G 4/1), watery clay and hemipelagic mud, light brownish gray (5YR 6/1) and dark greenish gray (5G 4/1).

Abundant wood, plant debris and mica flakes.

(See section summary for Section 5)

Large carbonized wood fragment.

Hemipelagic mud, soft and plastic, grayish red (10R 3/2) mixed with brownish gray (5YR 4/1) clay.

Terrigenous sand, unconsolidated, greenish gray (5G 5/1) to olive gray (5Y 4/1).

Mixture of terrigenous sand, olive gray (5Y 5/1) and brownish gray (5YR 6/1) clay and mud.

DIAGNOSTIC FOSSILS

CORE CATCHER

PLANKTONIC FORAMINIFERS:

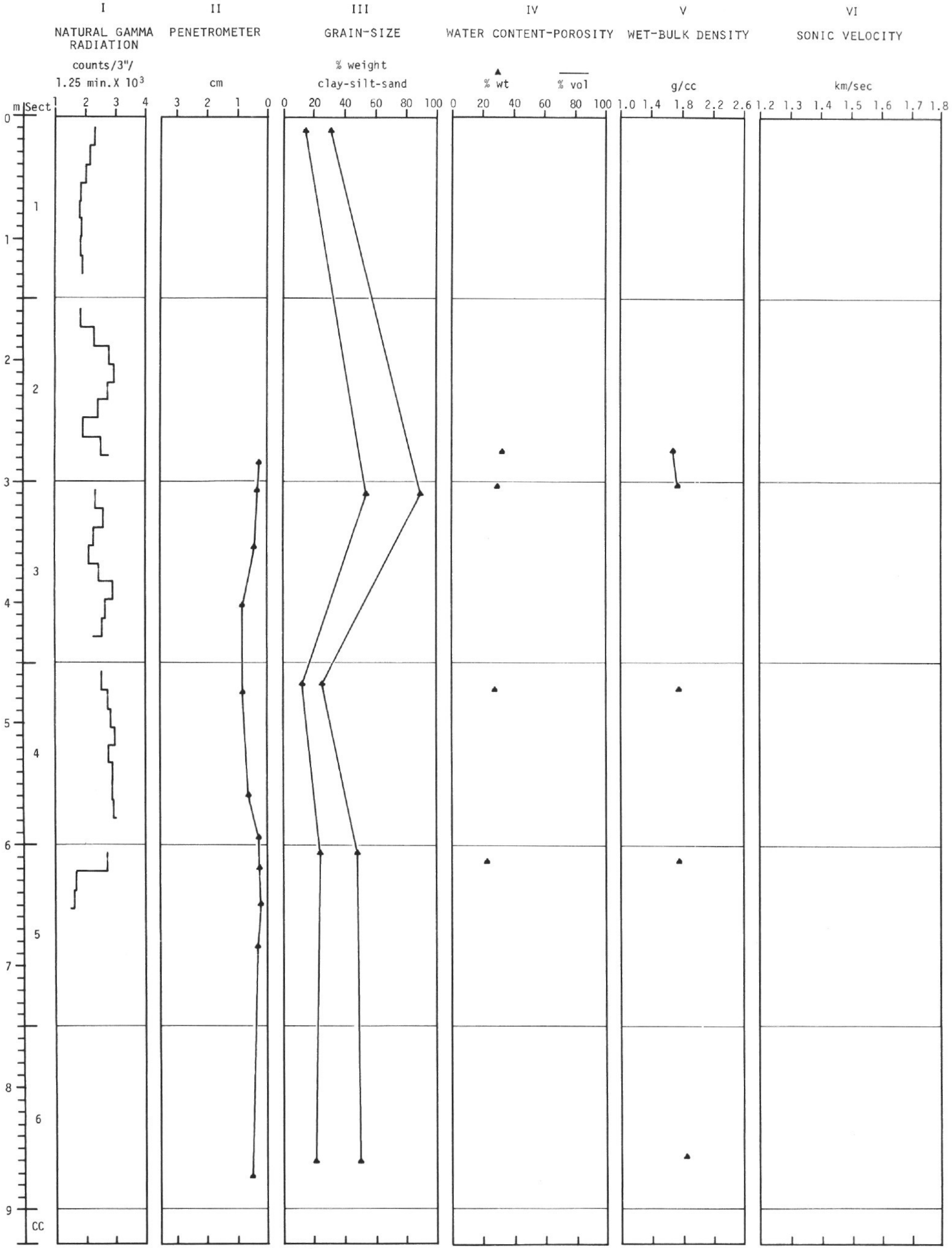
Turborotalia inflata,
Globigerina bulloides,
Globigerina pachyderma

CALCAREOUS NANNOPLANKTON:

Pseudoemiliania lacunosa,
Gephyrocapsa oceanica,
Rhabdosphaera stylifera

DINOFLAGELLATES:

Operculodinium centrocarpum,
Tectatodinium pellitum

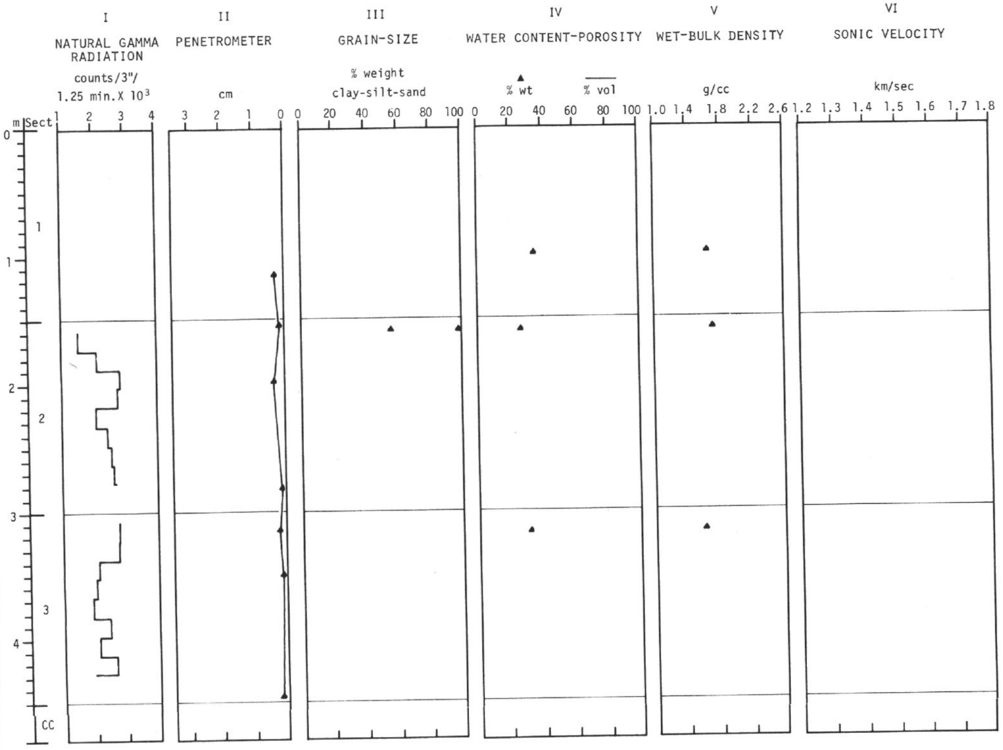


Hole 106, Core 4 (187m to 196m)

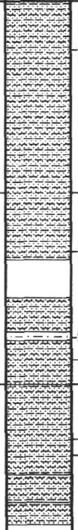
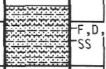
AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY PLEISTOCENE	Globorotalia truncatulinoides N.22 Pseudoemiliania lacunosa		CC		F,D, SS CN	Hemipelagic mud, soft and plastic, greenish gray (5G 5/1), containing abundant calcite fragments.	*CORE CATCHER* PLANKTONIC FORAMINIFERS: *Turborotalia tosaensis*, *T. inflata*, *Globorotalia truncatulinoides*, *Globigerina bulloides*, *Globigerina pachyderma* DINOFLAGELLATES: *Flora similar to 106-3-cc.* CALCAREOUS NANNOPLANKTON: *Pseudoemiliania lacunosa*, *Gephyrocapsa oceanica*, *Ceratolithus cristatus*, *Syracosphaera pulchra*

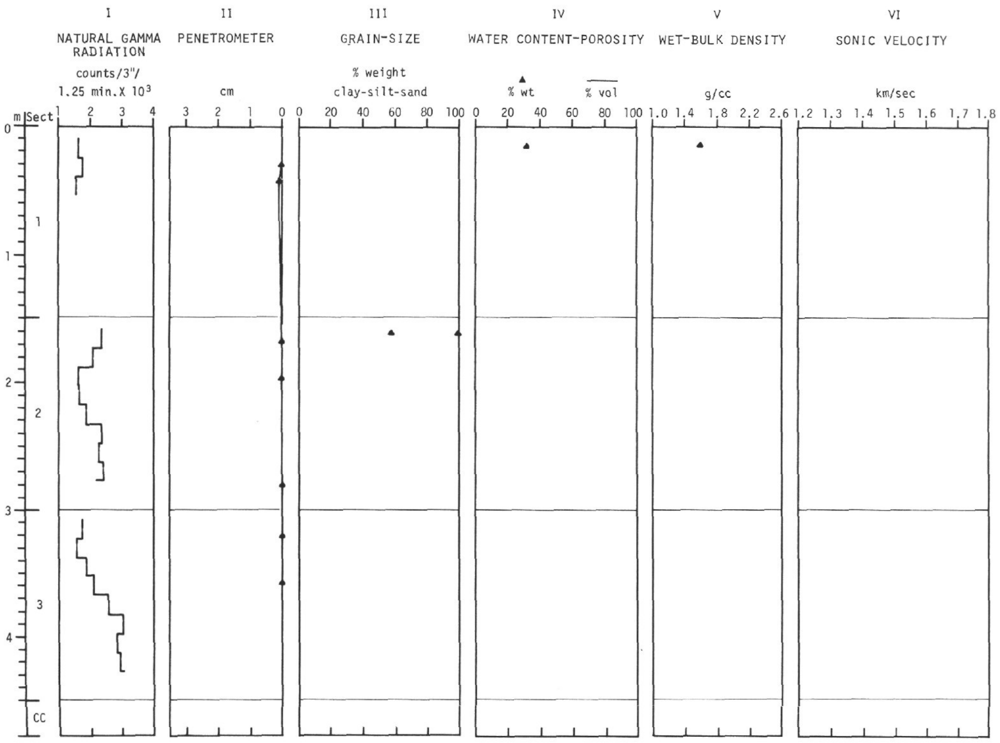
Hole 106, Core 5 (263m to 272m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY PLEISTOCENE	Globorotalia truncatulinoides N.22 Pseudoemiliania lacunosa	1 2 3 4	1 2 3 CC		SS SS CN SS SS SS F,CN	Hemipelagic mud, soft and plastic, slightly indurated in lower part, dark greenish gray (5G 4/1). Whole core disturbed and no structures observed (appears homogeneous). Clay min., abundant (other terrigenous components are rare). Nannoplankton abundant. Calcite fragments (detrital or recryst.?) common. Siliceous organisms (radiolaria, diatoms, spicules), rare. Foraminifers, rare. Abundant siliceous organisms (mainly diatoms) in lower part of Section 2.	CALCAREOUS NANNOPLANKTON: *Pseudoemiliania lacunosa*, *Ceratolithus cristatus*, *Discolithina japonica*, *Syracosphaera pulchra* *CORE CATCHER* PLANKTONIC FORAMINIFERS: *Globorotalia truncatulinoides*, *Turborotalia inflata*, *Globigerina bulloides*, *Globigerina pachyderma* CALCAREOUS NANNOPLANKTON: *Pseudoemiliania lacunosa*, *Umbilicosphaera mirabilis*, *Ceratolithus cristatus*, *Syracosphaera pulchra*



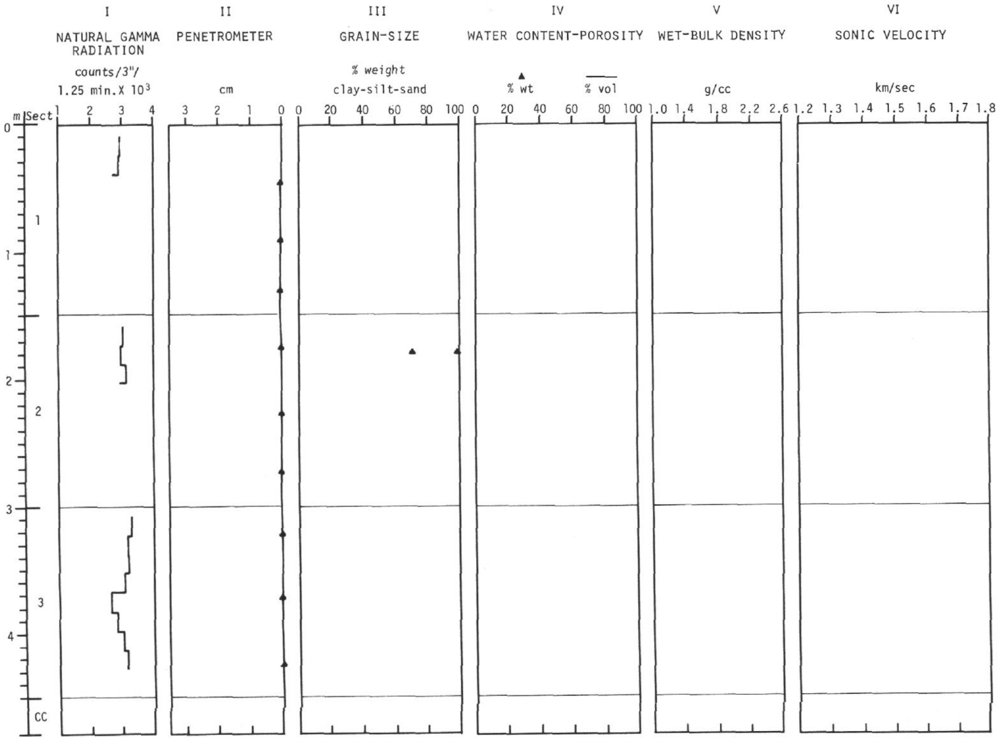
Hole 106, Core 6 (340m to 349m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY PLEISTOCENE	Globorotalia truncatulinoides N.22 Pseudoemiliania lacunosa	1 2 3 4	1 2 3		SS SS SS SS SS CN	Hemipelagic mud, firm, semi-plastic, dark greenish gray (5GY 4/1). Whole core disturbed and no apparent primary structures (some artificial bedding due to coring operations in rough weather). Upper part (Section 1 and upper part of Section 2): Clay min., common (other terrigenous components, rare). Nannoplankton, abundant. Siliceous organisms (radiolaria, diatoms, spicules), abundant. Lower part: Clay min., common to abundant. Nannoplankton, abundant. Siliceous organisms, absent to rare. Sandy zone (with abundant diatoms) in a highly disturbed zone. Highly disturbed zone.	PLANKTONIC FORAMINIFERS: *Turborotalia inflata,* *Globigerina bulloides,* *Globigerina pachyderma* CALCAREOUS NANNOPLANKTON: *Pseudoemiliania lacunosa,* *Gephyrocapsa oceanica,* *Ceratolithus cristatus,* *Syracosphaera pulchra,* *Discolithina japonica* *CORE CATCHER*
			CC		F,D,CN SS		FORAMINIFERA: *Globigerina inflata,* *G. bulloides,* *G. pachyderma* DINOFLAGELLATES: *Operculodinium centrocarpum,* *Tectatodinium pellitum* CALCAREOUS NANNOPLANKTON: *Pseudoemiliania lacunosa,* *Gephyrocapsa oceanica,* *Ceratolithus cristatus,* *Syracosphaera pulchra*



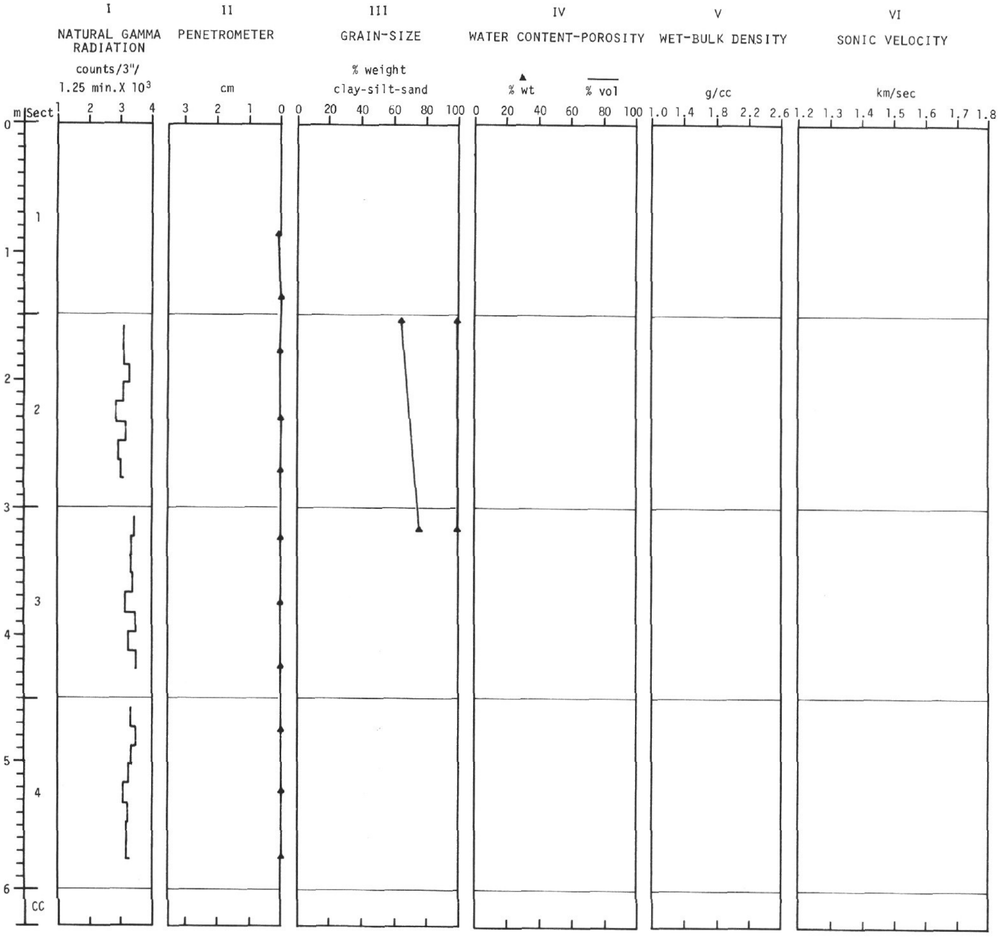
Hole 106B, Core 1 (366m to 375m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE PLIOCENE	Turborotalia tenuitheca N.21 Discoaster brouweri	1 2 3 4	1 2 3 CC		F SS SS F SS SS F CN SS D,CN SS	Hemipelagic mud, indurated, very firm, dark greenish gray (5GY 3/1). Some poorly developed bedding and abundant lenses of slightly lighter shade; occasional even laminations. Small pyrite-filled burrows, occasional small thin plates of pyrite (well crystallized) and numerous accumulations of coarse crystalline pyrite (noteworthy in Section 3). Clay minerals, abundant. Calcareous nannoplankton, common to abundant. Carbonaceous matter, rare to common. Calcite fragments, rare. Lighter lenses appear to contain more calcareous nannoplankton than the darker material. (See section summary for Section 3.)	PLANKTONIC FORAMINIFERS: *Globigerinoides extremus*, *Globorotalia miocenica* (See section summary for Section 3.) *CORE CATCHER* DINOFLAGELLATES: *Operculodinium centrocarpum* CALCAREOUS NANNOPLANKTON: *Discoaster brouweri*, *D. pentaradiatus*, *Pseudoemiliania lacunosa*, *Ceratolithus rugosus*, *Cyclococcolithina macintyrei*



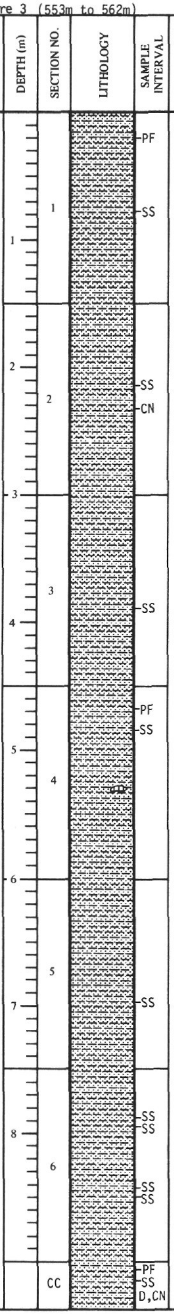
Hole 106B, Core 2 (451m to 460m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY PLIOCENE	Sphaeroidinella dehiscens/Globoquadrina altispira N.19 Reticulofenestra pseudoumbilica	1 2 3 4 5 6	1 2 3 4 CC		PF SS SS SS SS SS CN SS PF D,CN SS	<u>Hemipelagic mud</u>, indurated, very firm, slightly fissile; dark greenish gray (5GY 3/1). Poorly developed bedding with artificial bedding planes due to coring operation. Abundant lenses of slightly lighter shade. Occasional small pyrite filled burrows. Clay minerals, abundant. Other terrigenous components, rare. Pyrite, rare to common (+ nodules). Foraminifers, rare. Calc. nannoplankton, abundant. Radiolarians, rare. Organic matter, rare. Siderite, common. Calcite fragments, common. Foraminifers and nannoplankton appear more abundant in the lighter zones than in the dark material. Pyrite crystals in a burrow-fill. Pyrite nodule.	CALCAREOUS NANNOPLANKTON: *Reticulofenestra pseudoumbilica,* *Ceratolithus rugosus,* *Discoaster asymmertricus,* *D. brouweri,* *D. surculus,* *Sphenolithus abies* PLANKTONIC FORAMINIFERS: *Globigerinoides extremus,* *Globoquadrina altispira,* *Globorotalia margaritae,* *Gl. multicamerata,* *Globigerina nepenthes,* *Pulleniatina primalis,* *Sphaeroidinellopsis subdehiscens,* *Ss. seminulina* *CORE CATCHER* DINOFLAGELLATES: *Achomosphaera ramulifera* CALCAREOUS NANNOPLANKTON: *Reticulofenestra pseudoumbilica,* *Sphenolithus abies,* *Ceratolithus rugosus,* *Discoaster asymmetricus,* *D. brouweri,* *D. surculus*



Hole 106B, Core 3 (553m to 562m)

AGE	ZONE	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE MIOCENE	Globorotalia plesiotumida N.17 Discoaster quinqueramus		



LITHOLOGY

Hemipelagic mud, indurated, very firm, slightly fissile; dark greenish gray (5GY 3/1), with lenses and layers of slightly lighter shade.

Poorly developed bedding, with artificial bedding planes due to coring operations.

Abundant small white burrow-like structures.

Clay minerals, abundant

Calc. nannoplankton, abundant.

Radiolarians (pyritized), rare.

Siderite common.

Rare foraminifers and abundant calc. nannoplankton in lighter zones and lenses.

Thin siderite lens.

DIAGNOSTIC FOSSILS

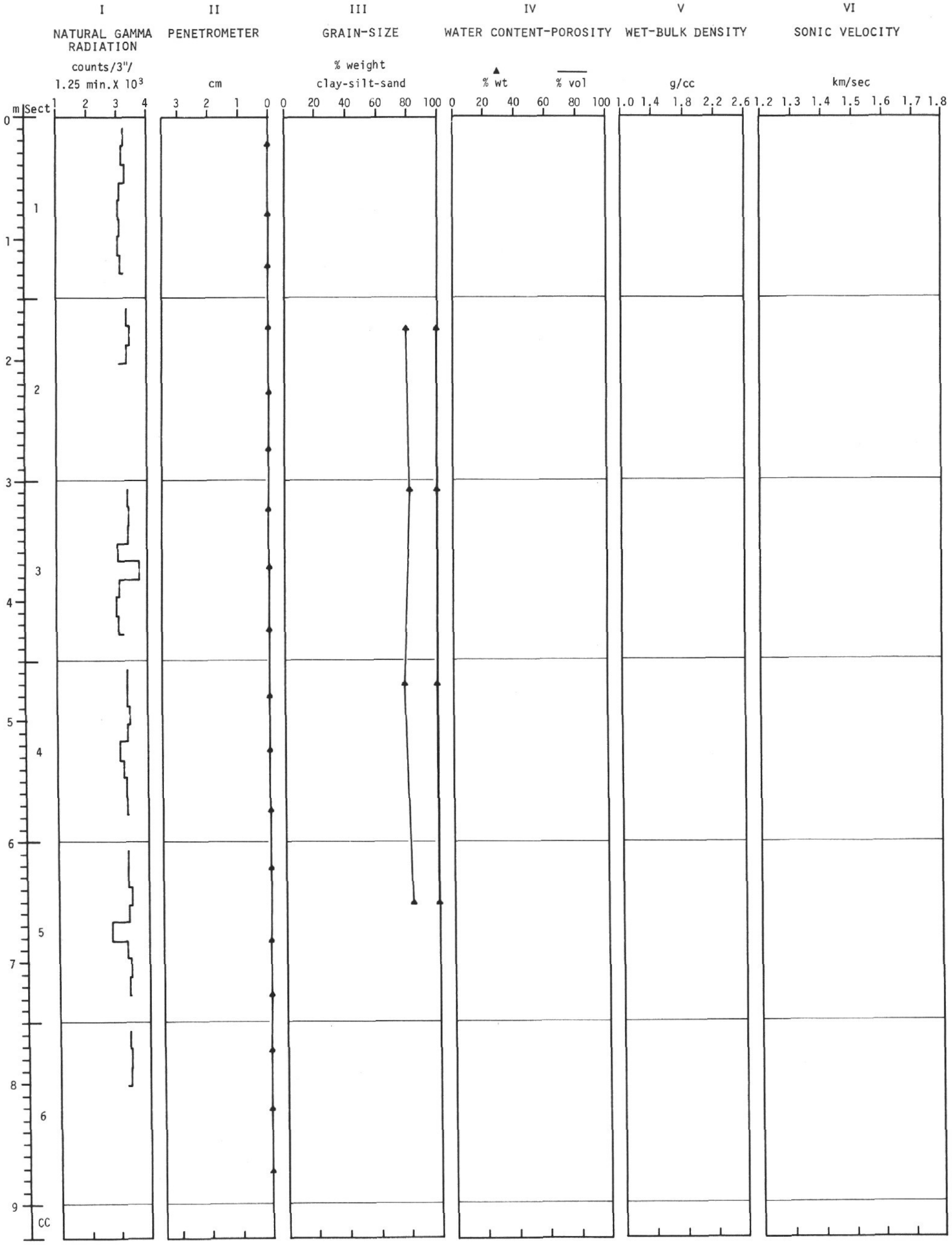
CALCAREOUS NANNOPLANKTON:
Discoaster quinqueramus,
D. exilis,
D. surculus,
D. variabilis,
Ceratolithus tricorniculatus,
Reticulofenestra pseudoumbilica,
Sphenolithus abies.

PLANKTONIC FORAMINIFERS:
Globorotalia plesiotumida,
Gl. cibaoensis,
Globoquadrina altispira,
Globigerina nepenthes,
Sphaeroidinellopsis kochi,
Ss. paenedehiscens

CORE CATCHER

DINOFLAGELLATES:
Hystrichosphaeropsis obscurum,
Achomosphaera cf. *A. triangulata*

CALCAREOUS NANNOPLANKTON
Discoaster quinqueramus,
D. exilis,
D. surculus,
D. variabilis,
Reticulofenestra pseudoumbilica,
Ceratolithus tricorniculatus,
Sphenolithus abies



Hole 106B, Core 4 (754m to 763m)

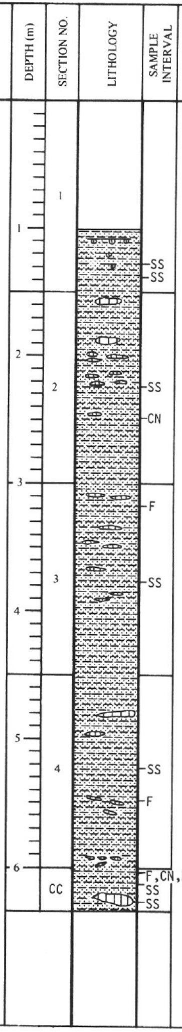
AGE

MIDDLE MIOCENE

ZONE

Globigerina nepenthes/turborotalia siakensis N.14

Sphenolithus heteromorphus



LITHOLOGY

Hemipelagic mud, indurated, very firm, greenish black (5G 2/1).

Some irregular bedding planes, occasional lenses of slightly lighter shade, abundant siderite filled burrows and lenses (sometimes concentrated along bedding planes), light olive gray (5Y 6/1).

Clay min., abundant (other terrigenous components, rare).

Calc. nannoplankton, rare.

Siderite, common to abundant, (scattered throughout + nodules and lenses).

Siderite nodule.

DIAGNOSTIC FOSSILS

CALCAREOUS NANNOPLANKTON:

Sphenolithus heteromorphus, Cyclococcolithina neogammation, Discoaster bollii, D. variabilis, Sphenolithus abies, Reticulofenestra pseudoumbilica

PLANKTONIC FORAMINIFERS:

Globigerina nepenthes, Turborotalia continuosa, Globorotalia limbata, Globoquadrina dehiscens, Gq. adrena

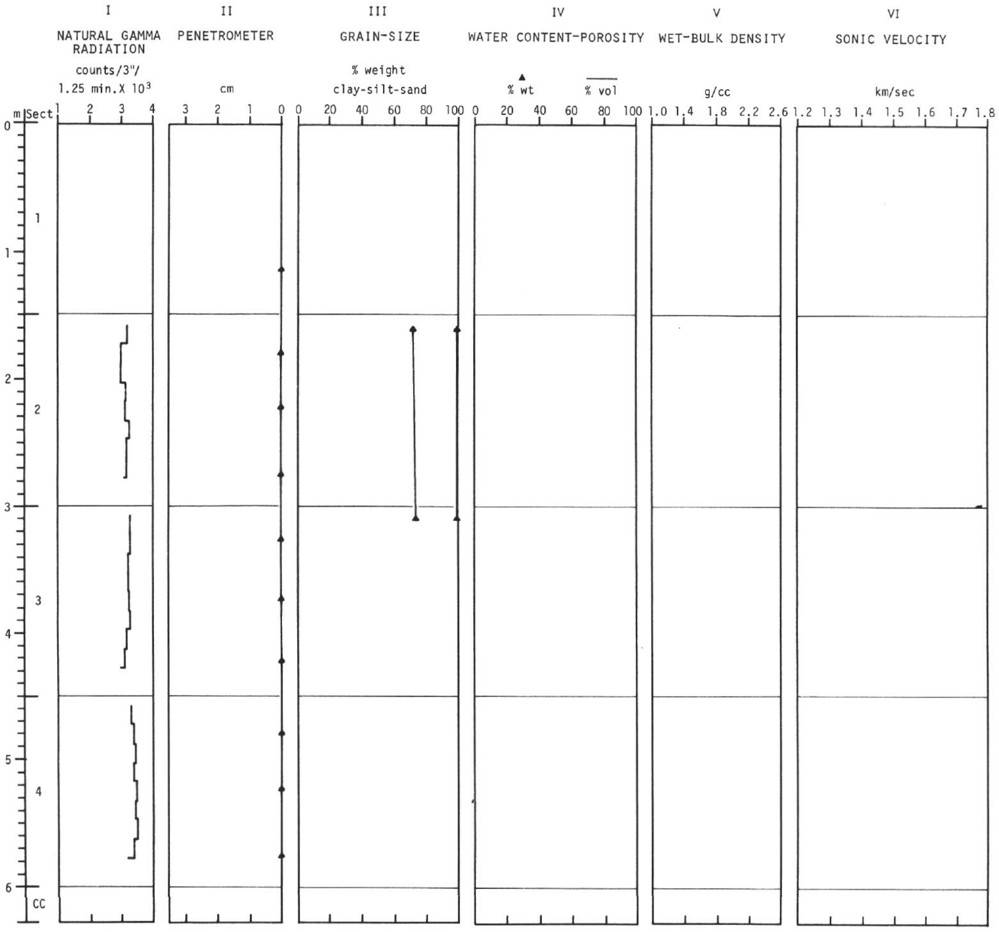
CORE CATCHER

DINOFLAGELLATES:

Hystrichosphaeropsis obscurum, Achomosphaera ramulifera

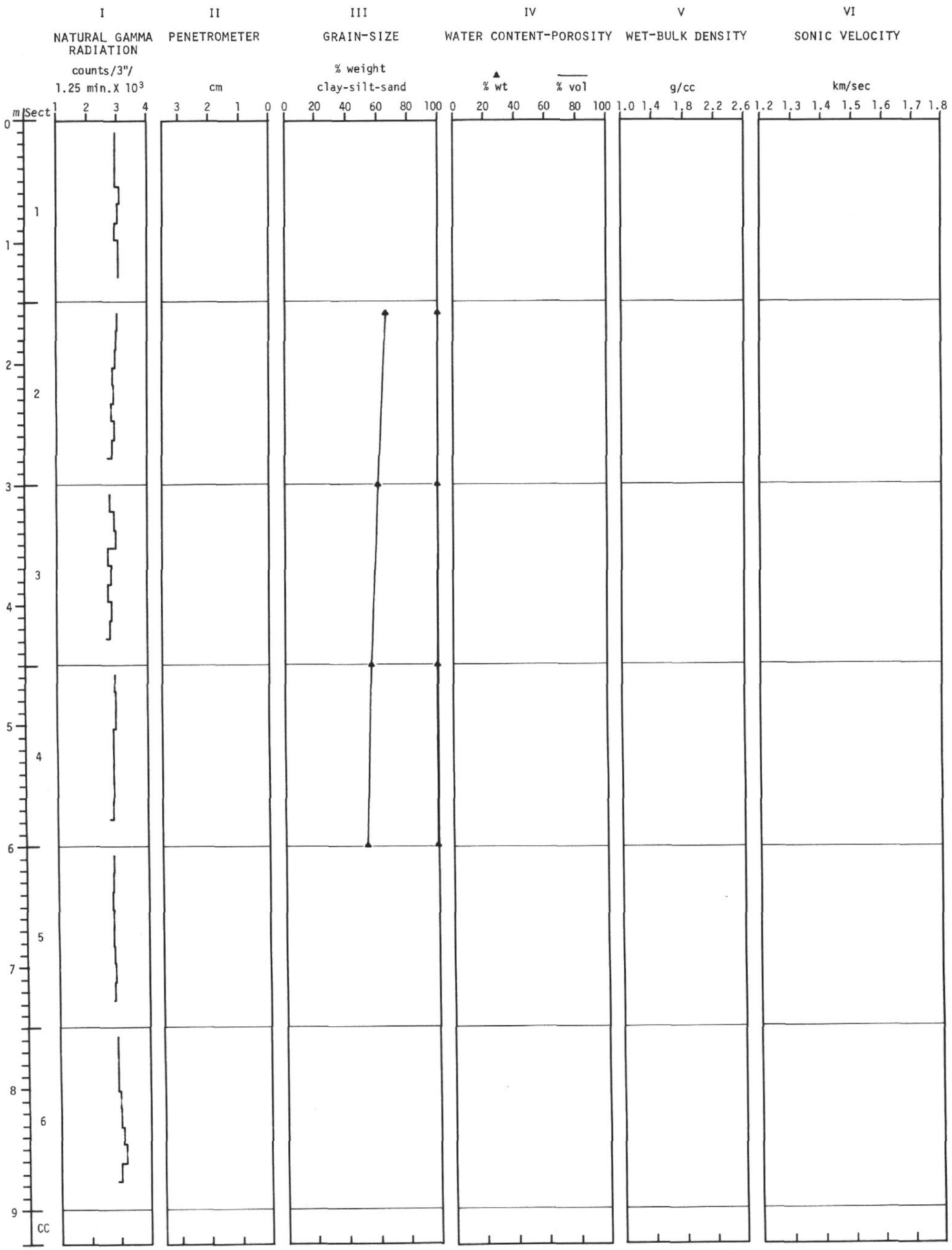
CALCAREOUS NANNOPLANKTON:

Sphenolithus heteromorphus, Cyclococcolithina neogammation, Reticulofenestra pseudoumbilica



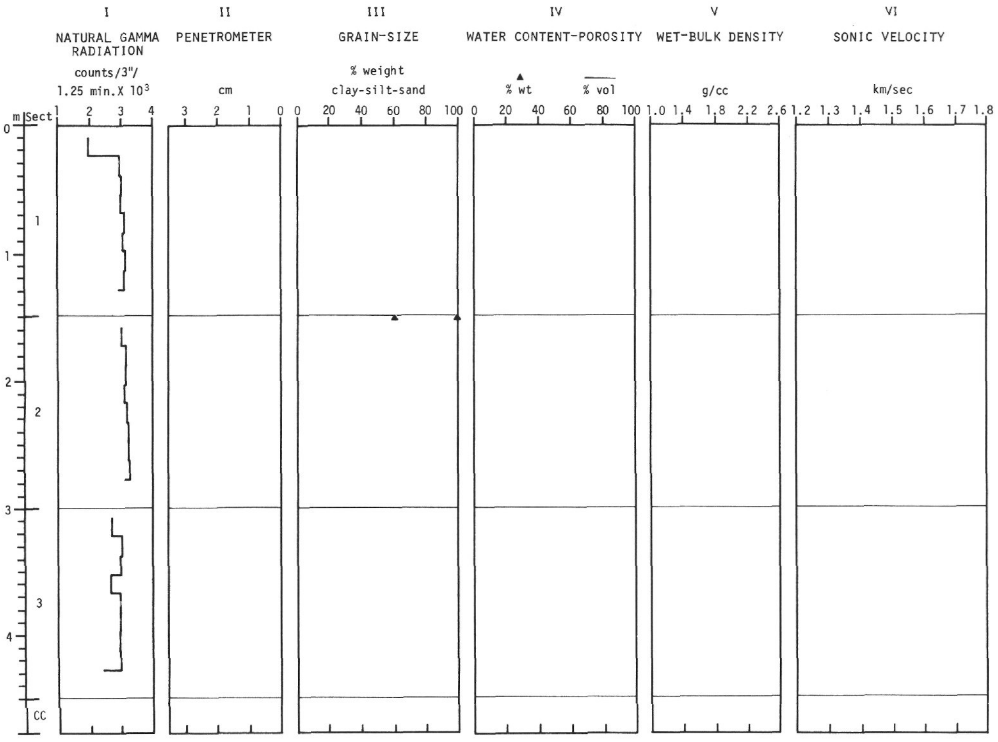
Hole 106B, Core 5 (935m to 944m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
MIDDLE MIOCENE	Sphaeroidinellopsis subdehiscens/Globigerina druryi N.13	1	1		SS SS	Hemipelagic mudstone, hard, dark greenish gray (5GY 4/1). Accumulation of very abundant ±lenticular structures of different faint colorations, very irregular bedding. Lenticular and horizontal structures may be due in part to burrowing and possibly to the presence of gas in the sediments (especially in lower part). Vertical fractures (might be related to gas structures?). Clay minerals, common to abundant. Siliceous organisms very abundant, (radiolarians and spicules with few diatoms). Siderite, rare (but regularly present). Calc. nannoplankton almost absent. Some of the radiolarians are pyritized.	
		2	2		SS CN		CALCAREOUS NANNOPLANKTON: *Cyclococcolithina neogammation,* *Reticulofenestra pseudoumbilica,* *Discoaster bollii,* *D. exilis,* *Sphenolithus abies*
		3 4	3		SS		
		5	4		SS		
		6 7	5		SS		PLANKTONIC FORAMINIFERS: *Turborotalia siakensis,* *T. peripheroacuta,* *Globorotalia praemenardii,* *Gl. miozea,* *Globoquadrina altispira,* *Sphaeroidinellopsis subdehiscens,* *Ss. seminulina* DINOFLAGELLATES: *Hystrichosphaeropsis obscurum,* *Achomosphaera ramulifera,* *Spiniferites* sp. A, *Pentadinium taeniagerum,* *Chiropteridium* sp. A,
		8	6		SS		CALCAREOUS NANNOPLANKTON: *Cyclococcolithina neogammation,* *Reticulofenestra pseudoumbilica,* *Sphenolithus abies,* *Discoaster kugleri,* *D. bollii,* *D. exilis*
					F,D,CN SS		



Hole 106B, Core 6 (952m to 961m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY MIOCENE		1 2 3 4	1 2 3 CC		CN D,CN SS	Hemipelagic mudstone, hard, ±silicified, dark greenish gray (5GY 4/1). Accumulation of very abundant ±lenticular structures of different faint colorations, very irregular bedding. Lenticles and other structures may be due in part to burrowing and possibly to the presence of gas in the sediments. Clay minerals, abundant Siliceous organisms (radiolarians, diatoms, spicules) common to abundant. Organic matter, rare to common. Siderite, rare (but regularly present). Calc. nannoplankton absent. Pyrite, common. Some of the radiolarians are pyritized.	CALCAREOUS NANNOPLANKTON: Barren *CORE CATCHER* DINOFLAGELLATES: *Achomosphaera ramulifera*, *Spiniferites* sp. A CALCAREOUS NANNOPLANKTON: *Cyclococcolithus neogammation*



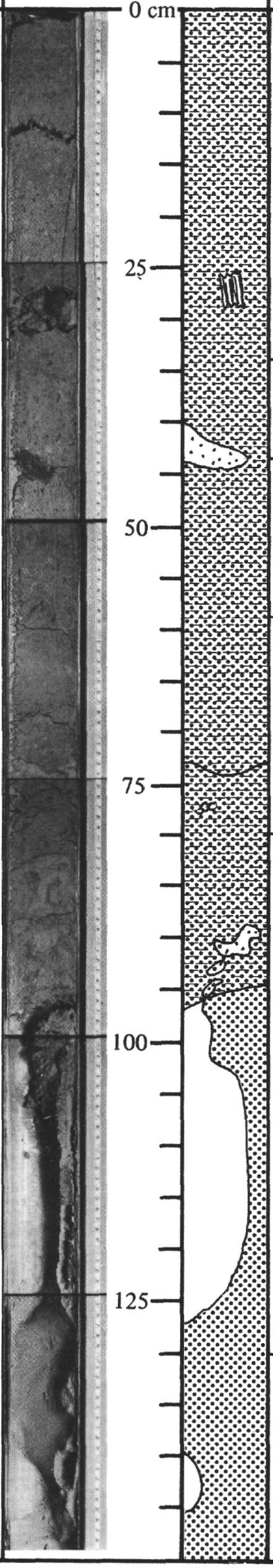
Hole 106B, Core 7 (1012m to 1015m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
OLIGOCENE - MIOCENE?		1	1 CC		SS SS CN SS SS,F CN	Hemipelagic mudstone, silicified, very hard, dominantly grayish green (10G 4/2) with some darker lenses and streaks (black N2, N3) and a dusky yellowish green zone in middle part. Burrow-like structures (due to gas?) are abundant throughout. Clay minerals dominant. Pyrite, rare (+ rare pyritized radiolarians). Siderite rare (+ lenses and nodules). (See section summary.)	CALCAREOUS NANNOPLANKTON: Barren *CORE CATCHER* FORAMINIFERA: *Turborotalia* cf. *T. opima*, *Globigerinita* cf. *G. unicava* CALCAREOUS NANNOPLANKTON: *Cyclococcolithina neogammation*

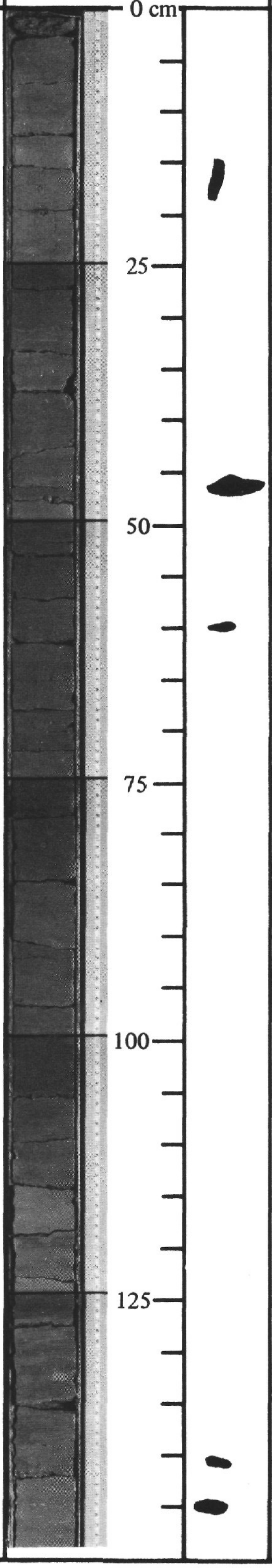
Hole 106B, Core 8 (1015m to 1015.5m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EOCENE?		1	1			<u>Hemipelagic mudstone</u>, silicified, very hard; grayish green (10G 4/2) with intergradational zones of dusky yellowish green (10GY 3/2). Numerous black streaks (N2, N3) and scattered fine white laminations (due to gas?). Siderite filled burrow-like flat structures. Clay minerals largely dominant and no microfauna present (except for rare pyritized radiolarians), recrystallized silica is responsible for the induration of the sediment.	No age diagnostic dinoflagellate flora. *CORE CATCHER* CALCAREOUS NANNOPLANKTON: *Cyclococcolithina neogammation*, *Discoaster bollii*, *D. variabilis*
			CC	▨	SS, CN		

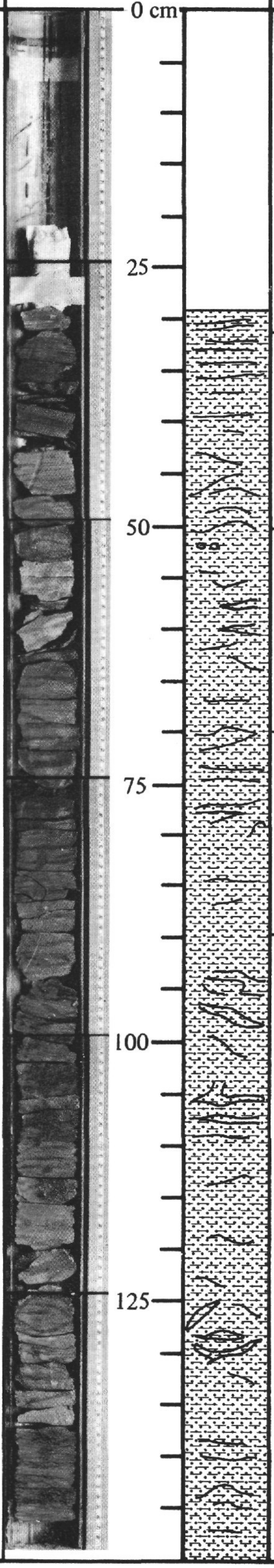
Hole 106, Core 3, Section 5

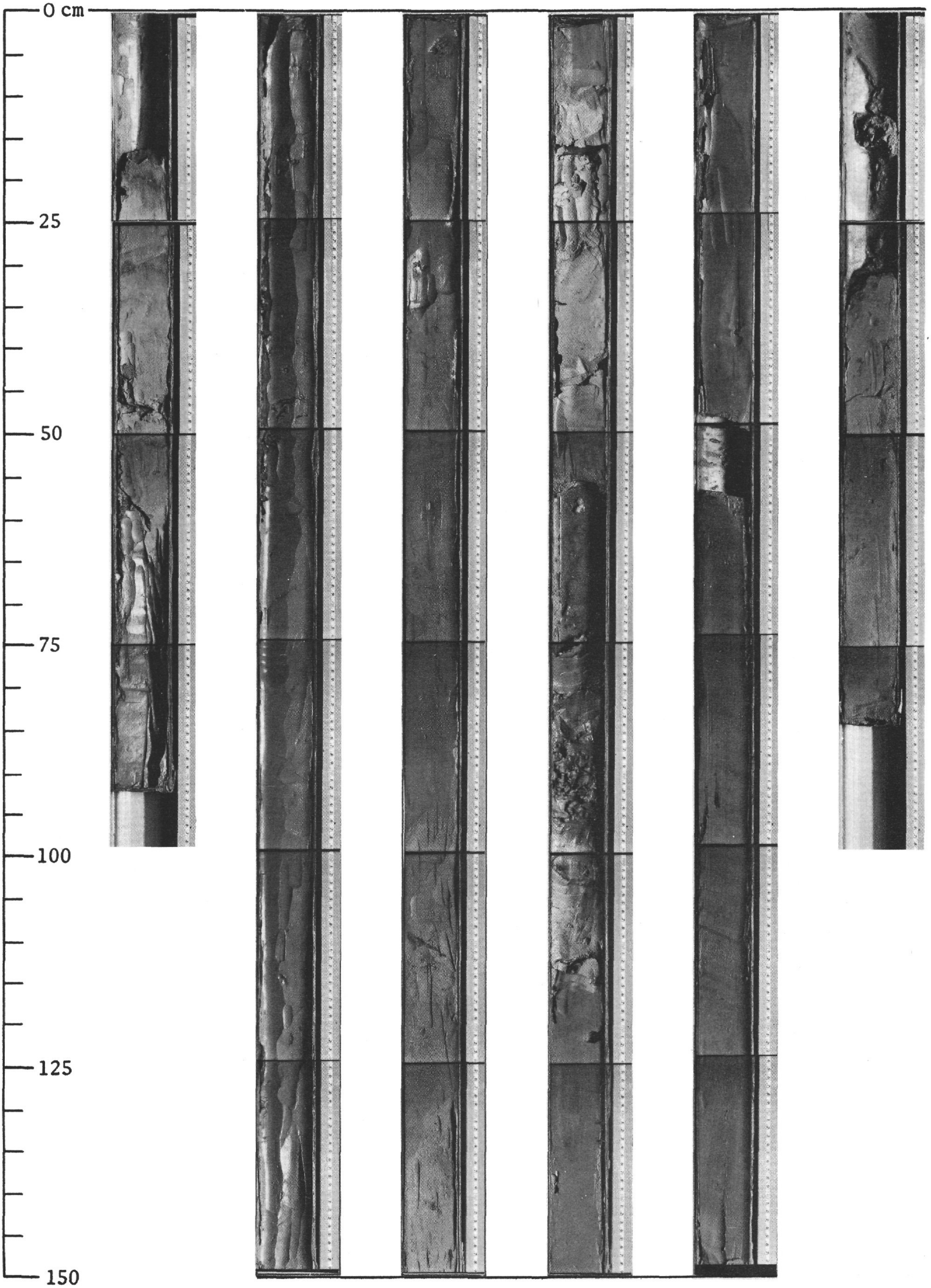
AGE	ZONE	LITHOLOGY	SAMP. INT	LITHOLOGY	DIAGNOSTIC FOSSILS
QUATERNARY (N.22)	*Pseudoemiliania lacunosa*		SS SS CN SS SS	Tightly packed mixture of terrigenous sand and hemipelagic mud; dark greenish gray (5G 4/1). (Core disturbed, no structures preserved.) Large carbonized wood fragment. Clay min. and nannoplankton abundant; quartz, heavy mins., mica, plant debris and calcite fragments, common; foraminifers rare. Inclusion of terrigenous sand. Hemipelagic mud, soft, plastic, grayish red (10R 3/2) and brownish gray (5YR 4/1) admixed with darker zones (5Y 4/1) of terrigenous sand. Terrigenous sand, highly disturbed, olive gray (5Y 4/1). Quartz abundant; feldspars and heavy mins. common; nannoplankton and calcite fragments rare	CALCAREOUS NANNOPLANKTON: *Pseudoemiliania lacunosa, Gephyrocapsa oceania, Syracosphaera pulchra, Rhabdosphaera stylifera*

Hole 106B, Core 1, Section 3

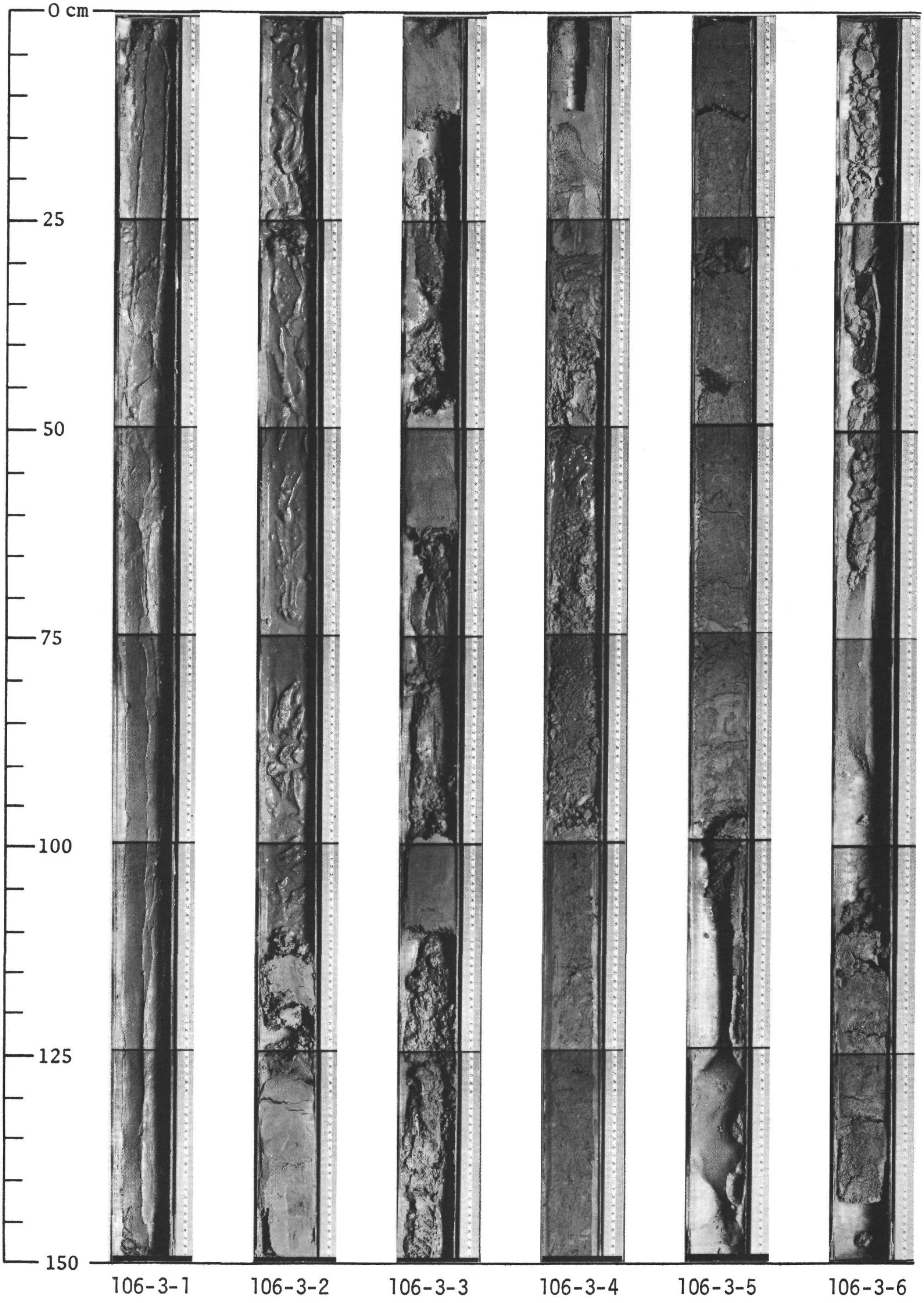
AGE	ZONE	LITHOLOGY	SAMP. INT	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE PLIOCENE	*Turborotalia tenuitheca* N. 21 *Discoaster brouweri*		SS F, CN	Hemipelagic mud, indurated, very firm, slightly fissile, dark greenish gray (5GY 3/1) Discrete bedding and faint laminations, (apparent laminations on the photograph are artificial). Accumulations of well-crystallized pyrite; some have a lenticular shape, others are small burrow fillings. White specks (forams?) present throughout. Clay mins. abundant; heavy mins; nannoplankton and organic matter common; pyrite (+nodules), dolomite siderite, quartz and mica, rare.	PLANKTONIC FORAMINIFERS: *Turborotalia inflata* *Globigerina bulloides*, *Globigerinoides extremus*, *Globorotalia miocenica* CALCAREOUS NANNOPLANKTON *Discoaster brouweri*, *D. pentaradiatus* *Pseudoemiliana lacunosa* *Cyclococcolithina macintyrei*, *Ceratolithus rugosus*

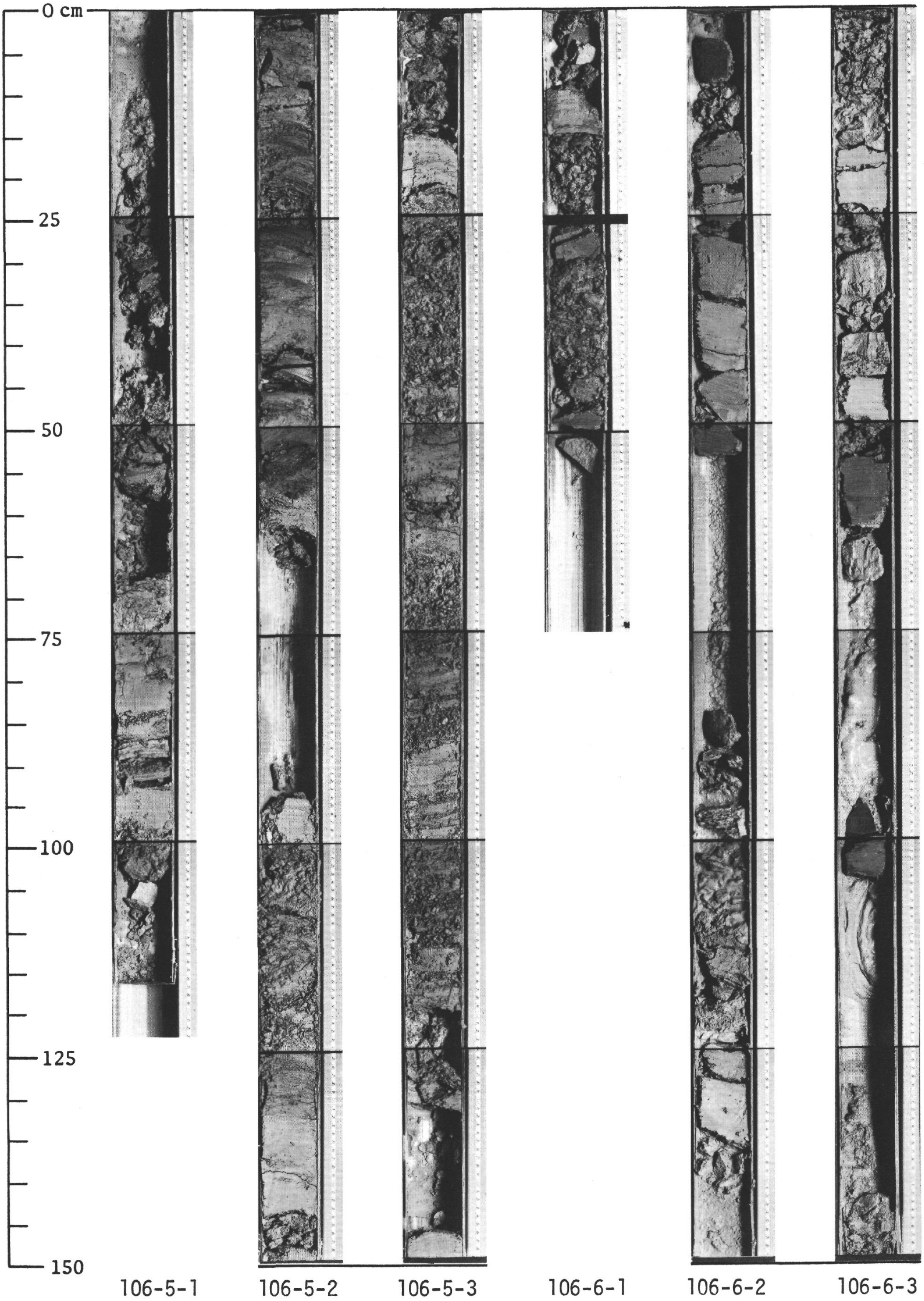
Hole 106B, Core 7, Section 1

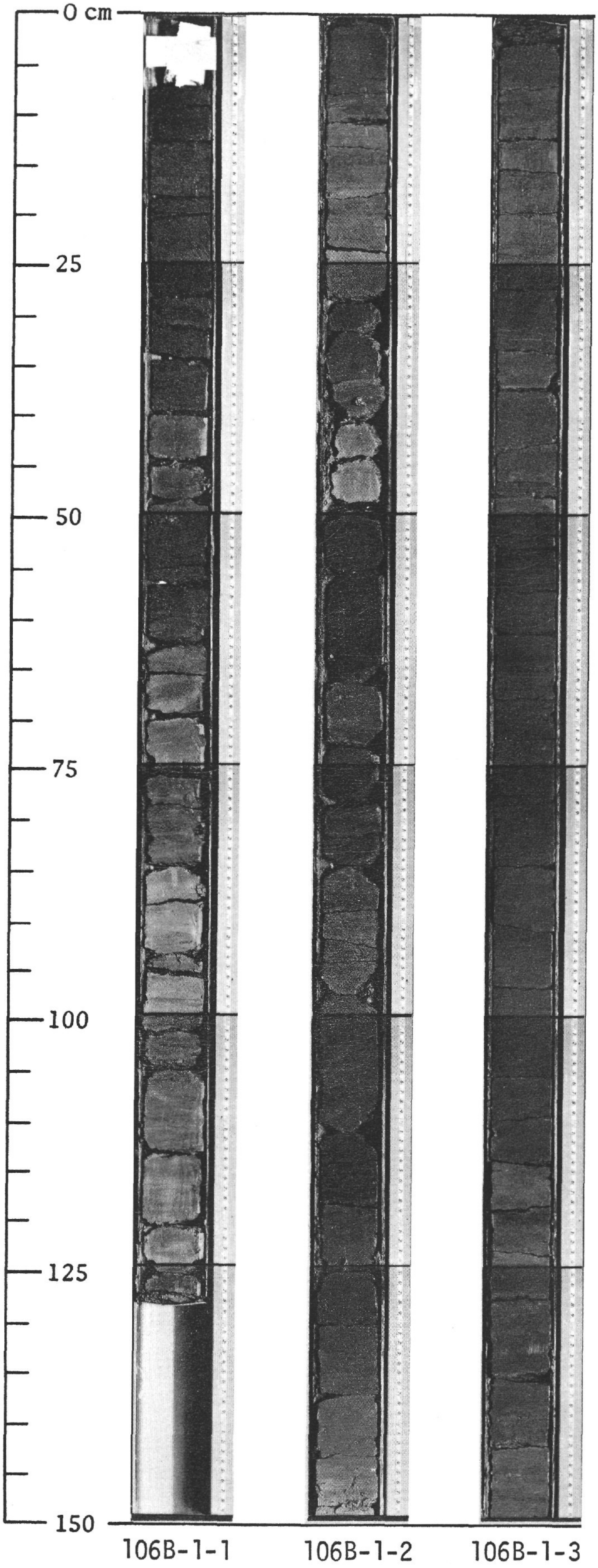
AGE	ZONE	LITHOLOGY	SAMP. INT	LITHOLOGY	DIAGNOSTIC FOSSILS
OLIGOCENE - MIOCENE ?			SS SS CN SS	Hemipelagic mudstone, very hard, silicified; dominantly grayish green (10G 4/2) with abundant dark (N2, N3) zones and streaks; dusky yellowish zone from 85 to 92 cm. Numerous siderite filled burrow-like structures Siderite flat nodules at 52 cm. Most of the dark streaks and zones could be the result of gas concentration and circulation in the sediment. Clay mins. dominant; siderite in nodules and lenses, rare in the matrix; pyrite rare (+ some pyritized radiolarians near top of the section); recrystallized silica present throughout.	CALCAREOUS NANNOPLANKTON: -- BARREN -- FORAMINIFERS: No diagnostic foraminifers.

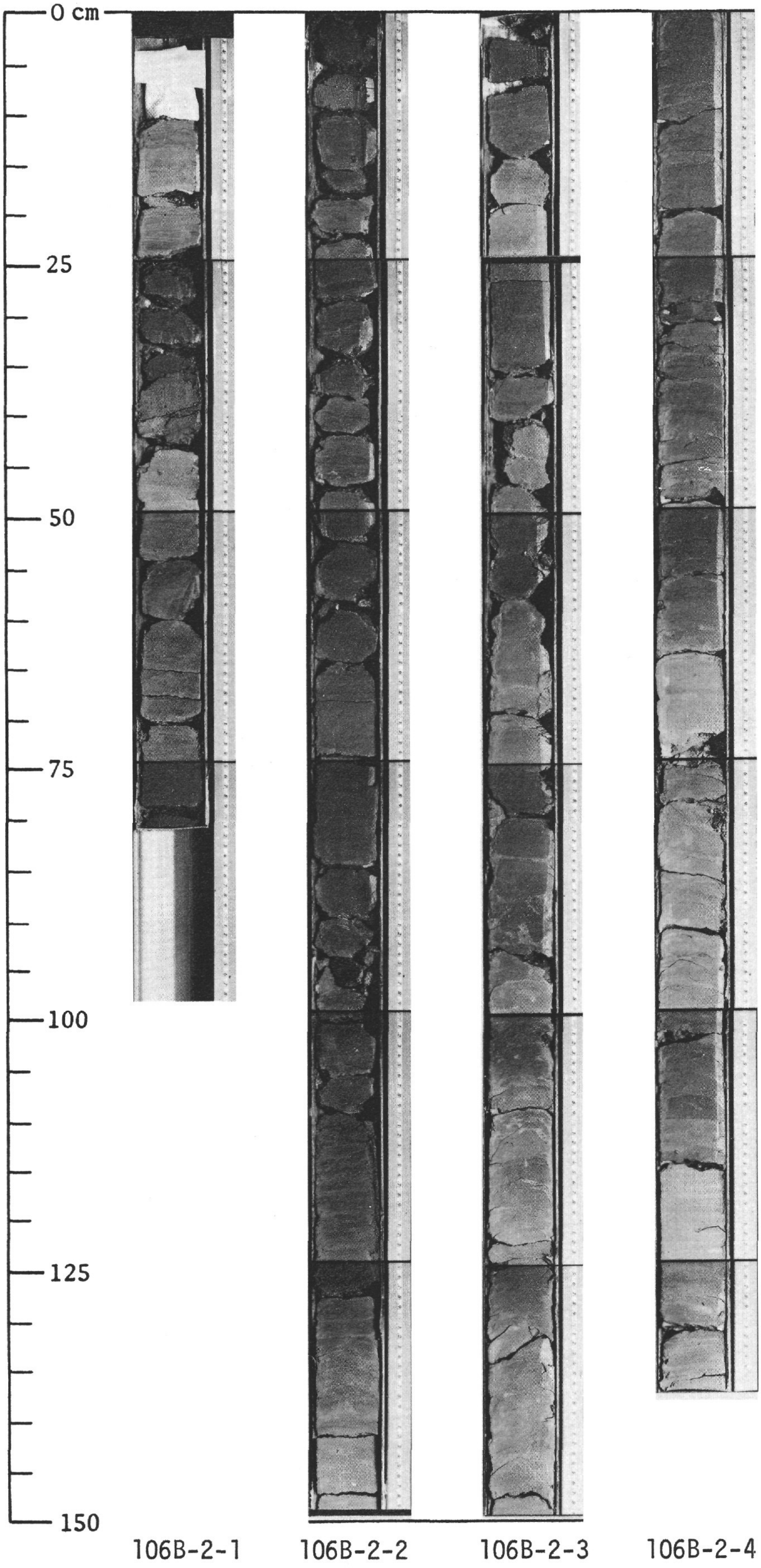


106-1-1 106-1-2 106-1-3 106-1-4 106-1-5 106-2-1


0 cm
25
50
75
100
125
150
106-3-1
106-3-2
106-3-3
106-3-4
106-3-5
106-3-6


0 cm
25
50
75
100
125
150
106-5-1
106-5-2
106-5-3
106-6-1
106-6-2
106-6-3


0 cm
25
50
75
100
125
150
106B-1-1
106B-1-2
106B-1-3


0 cm
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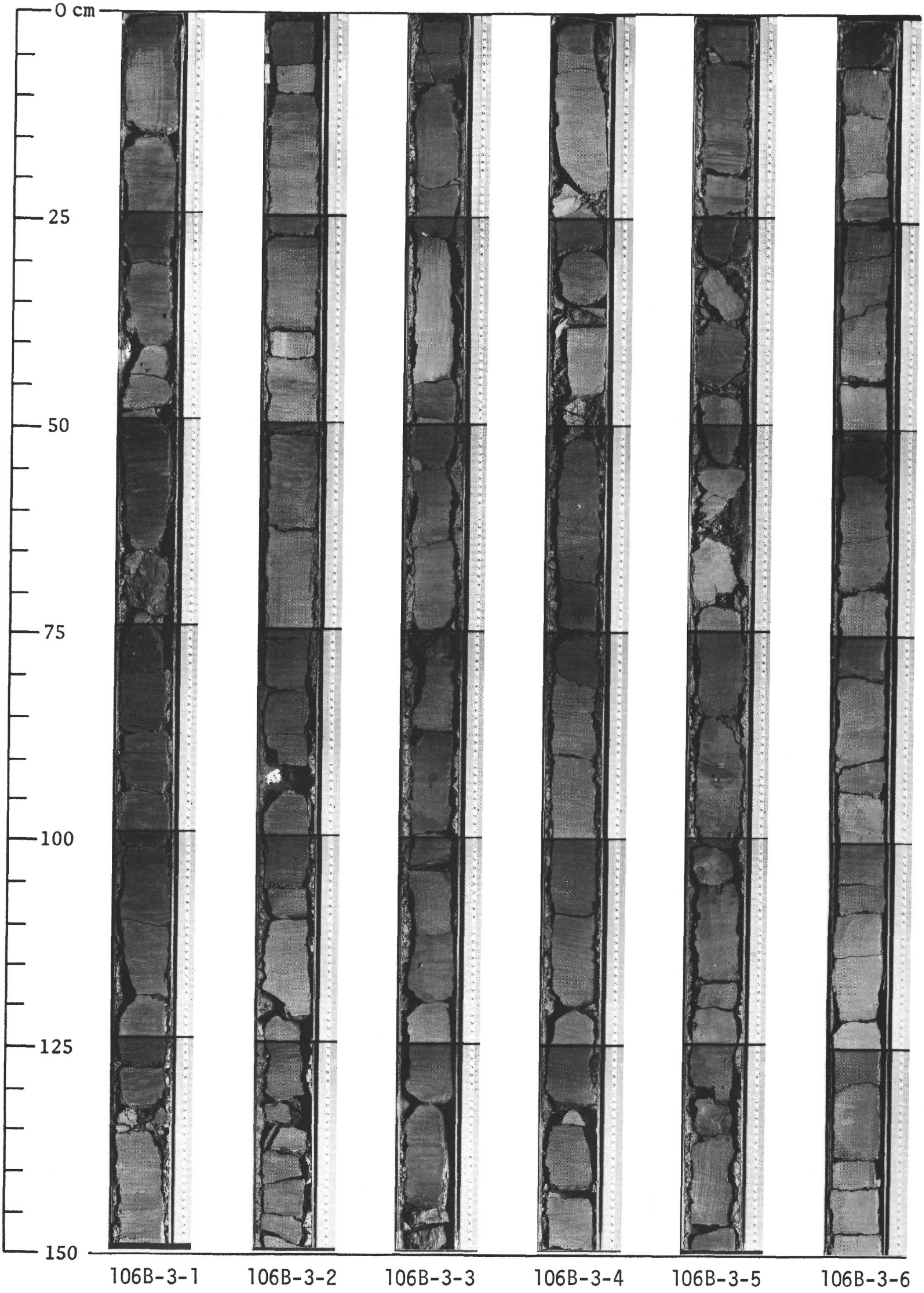
75
100
125
150
106B-2-1
106B-2-2
106B-2-3
106B-2-4


0 cm
25
50
75
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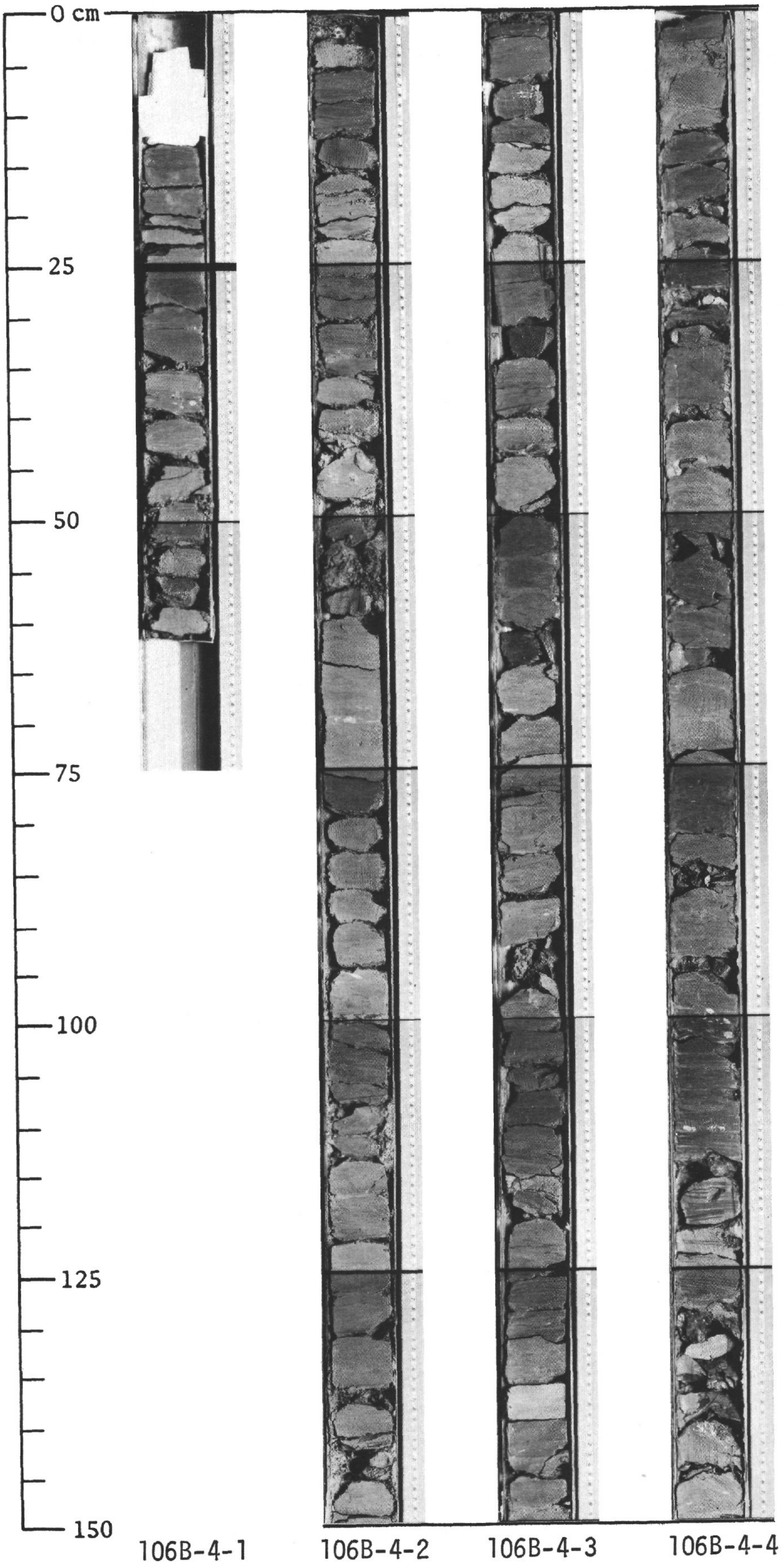
125
150
106B-3-1
106B-3-2
106B-3-3
106B-3-4
106B-3-5
106B-3-6


0 cm
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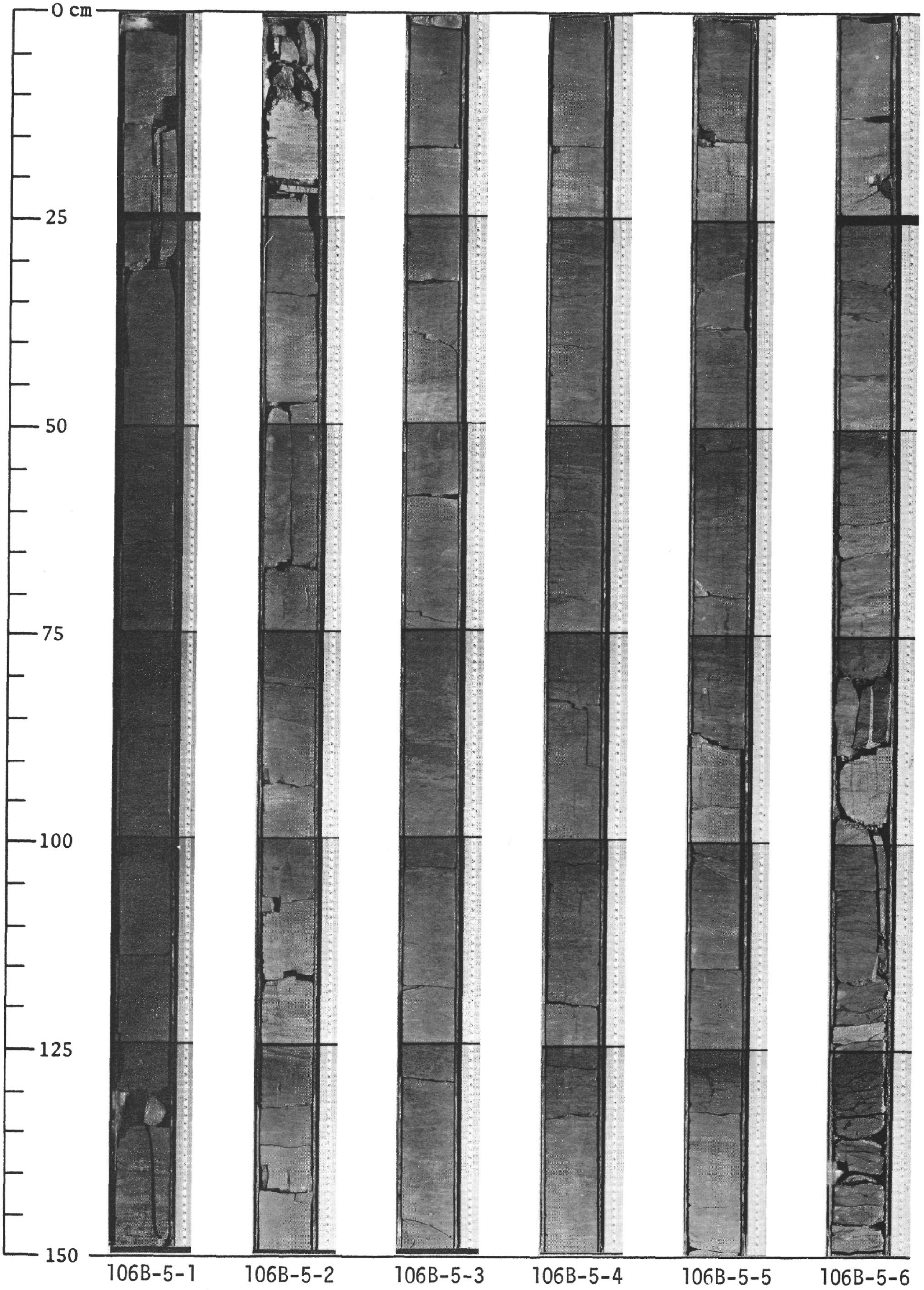
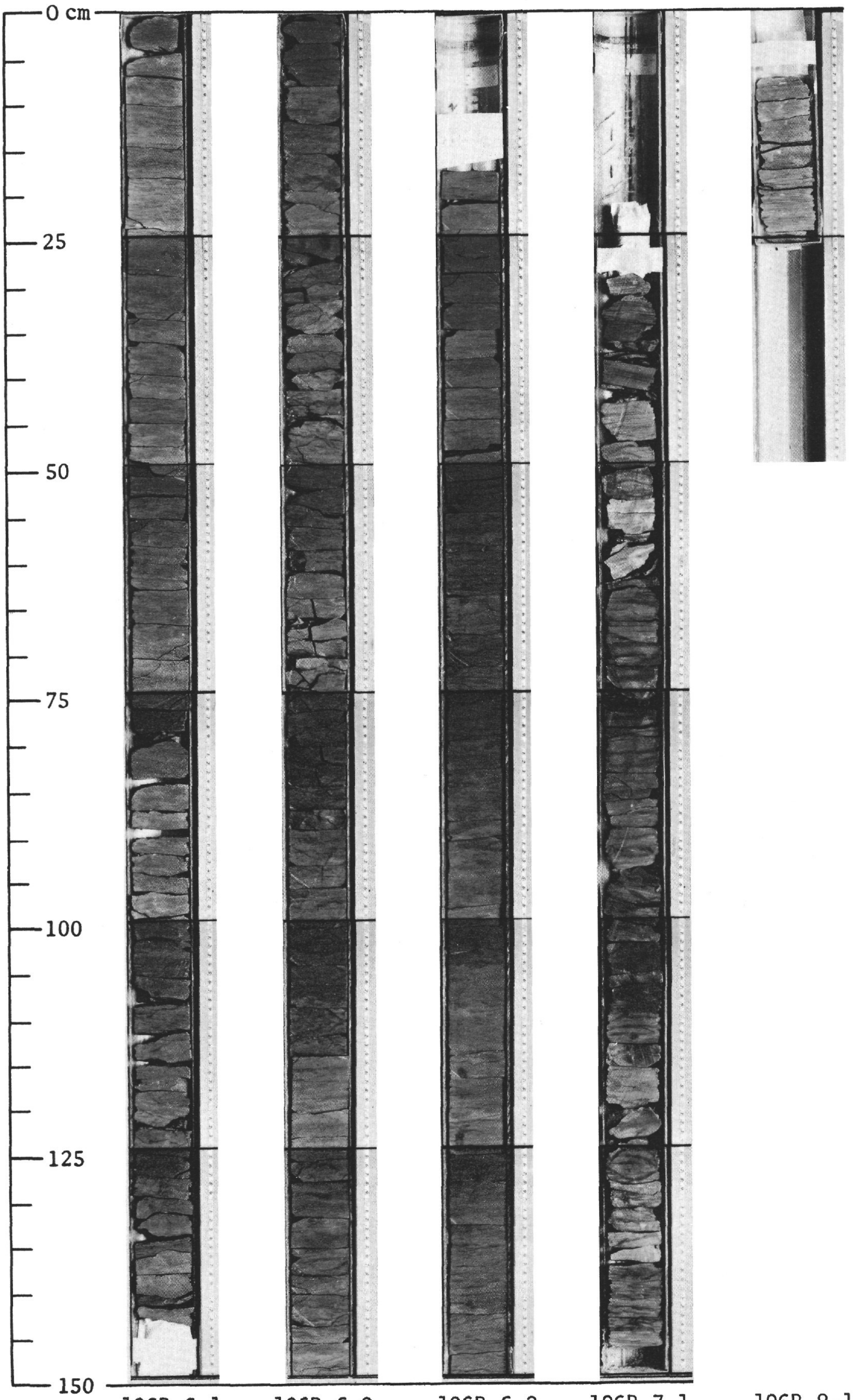
75
100
125
150
106B-4-1
106B-4-2
106B-4-3
106B-4-4


0 cm
25
50
75
100
125
150
106B-5-1
106B-5-2
106B-5-3
106B-5-4
106B-5-5
106B-5-6


0 cm
25
50
75
100
125
150
106B-6-1
106B-6-2
106B-6-3
106B-7-1
106B-8-1