4. SITE 101 – BLAKE-BAHAMA OUTER RIDGE (SOUTHERN END)

The Shipboard Scientific Party[1]

INTRODUCTION

The continental rise off eastern North America joins the broad, southeasterly plunging Blake-Bahama Outer Ridge near the latitude of Cape Hatteras (see Figure 1, Chapter 5). This sedimentary ridge, approximately 500 kilometers wide, rises one to three kilometers above the adjacent abyssal plains and is underlain by two to three kilometers of seismically transparent sediment. Site 101 (Figure 1), as well as the subsequent holes described in following sections (102, 103, 104), was chosen to provide information concerning the structure, composition, source, and rate of accumulation of the deposits that form the entire Blake-Bahama Outer Ridge system.

Near the southern end of the western or "inner" Blake-Bahama Outer Ridge a total sediment accumulation of approximately 1000 meters lies on a comparatively smooth Horizon B (Figure 2a, 2b and 2c; also Figure 2a of Chapter 3). A strongly reflecting series of horizons (β) approximately 200 meters from top to bottom, lies above layer B and is in turn overlain by a large buried ridge which consists of at least 500 meters of acoustically transparent material. This ridge is capped by 200 meters of moderately stratified surficial sediment underlain by a prominent reflector (Horizon A?).

The Atlantic Advisory Panel selected the site for Hole 101 near the crest of the "buried" sediment ridge in the hope that deep drilling here would provide information necessary to determine sedimentation processes involved in the construction of large deep-sea sediment accumulations, and would provide another sample of Horizon B.

OPERATIONS

The ship arrived on site around midnight on 24 April 1970. The seismic profiler record was similar to the one recorded earlier by R/V *Conrad*, and a survey was considered unnecessary. Prominent reflectors in the profiler record beginning at about 0.28 and 0.68 seconds were judged to correspond to hard formations difficult to drill, and, unfortunately, the best hard formation bit available was the 3-cone roller bit which had already drilled Hole 98, and was already badly worn.

The hole was started at 1555 hours, 25 April, in 4816 meters of water. A summary of coring operations is given in Figure 4. After two core samples were taken, the brake shoes on the draw-works winch were found to be crystallized and the drill string had to be pulled clear of the ocean bottom while repairs were made. Drilling and coring were resumed approximately 12 hours later in Hole 101A at the same location as 101.

Cores 1A, 2A and 3A were taken at approximately 40-meter intervals in the layer above the first prominent reflector (Figure 2c). They consisted of gray-green hemipelagic mud of Neogene age. The sediments became firmer with depth, and circulating water was required to cut the core at 200 meters. Anticipated resistance to drilling at the depth of the 0.28-second reflector did not materialize, and because of this, the core planned to sample the reflecting zone was not taken. Instead of the expected resistance, the drill encountered softer material at a depth of about 240 meters, and below this depth penetration was easy (Figure 3) down to the 0.68 reflector-Horizon B. The 0.28 second reflector, therefore, appears to correlate with a change from firm to soft sediment. A major unconformity also occurs in this part of the section; the sediment age changes from middle Miocene in Core 3A to middle Cretaceous in Core 4A.

The anticipated increase in drilling resistance took place at the top of Horizon B (0.68 second), where the lithology changed from moderately soft clay to a predominately calcareous section consisting of soft layers (usually not recovered) interbedded with hard limestone. This lithologic change took place between Cores 8A and 9A, probably at about 575 meters as judged from the drilling record.

Penetration of the limestone sequence was moderately slow, but uniform, down to about 680 meters, where the drilling torque increased markedly. This was later found to be the result of the freezing up of two of the bit cones, and probably was not associated with any important lithologic change in the section. The center bit jammed in the drill string after Core 10A had been taken; and, after several unsuccessful attempts had been made to retrieve it, the hole was abandoned. Examination of the bit after retrieval showed that it

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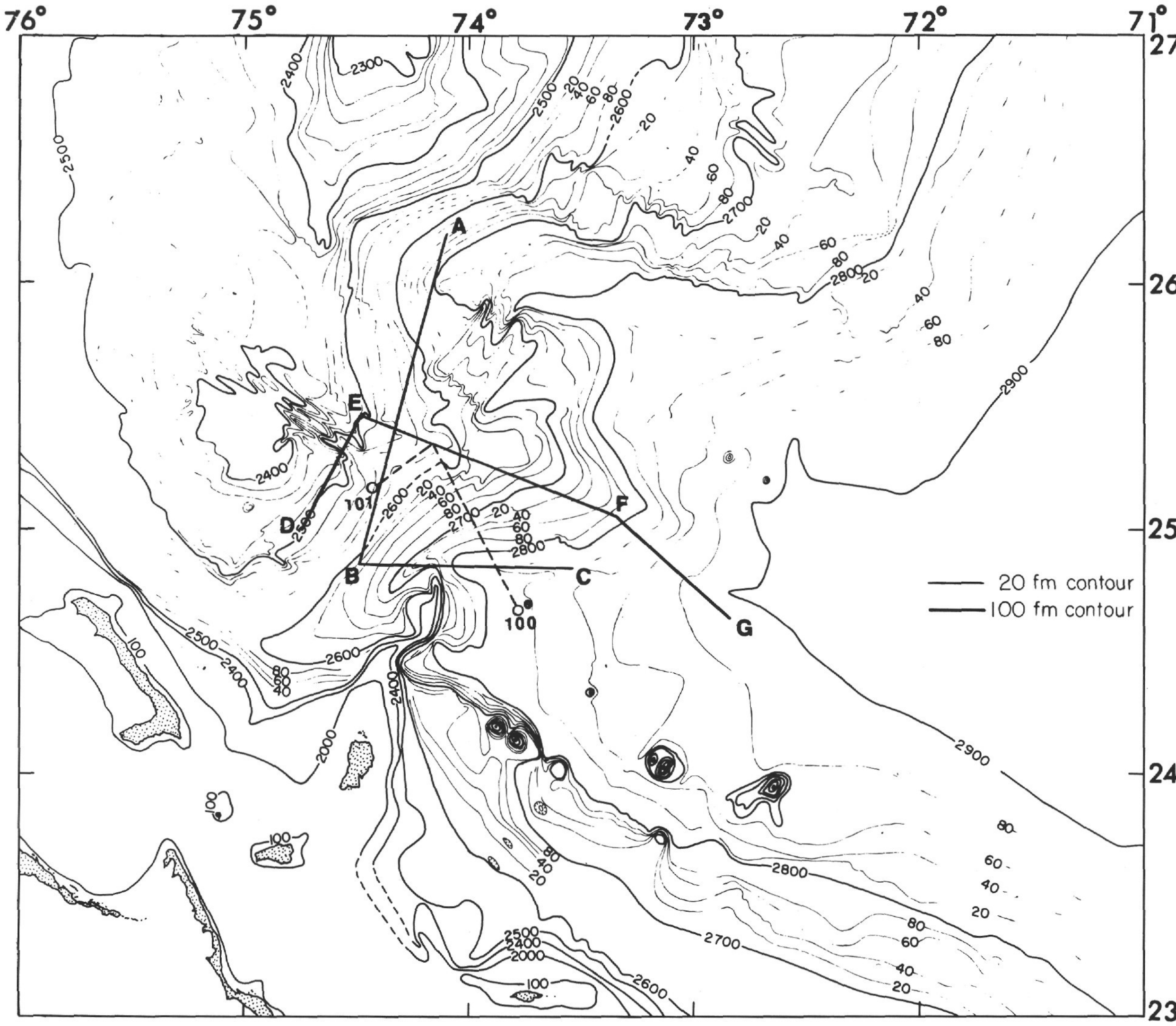

Figure 1. *Topographic map of the Cat Gap area (after Ewing,* et al, *1966) Track ABC corresponds to profiler section in Figure 2a; Track DEFG corresponds to Figure 2b. Dashed line is* GLOMAR CHALLENGER *track between Holes 100 and 101. (See Figure 2a of preceding chapter.)*

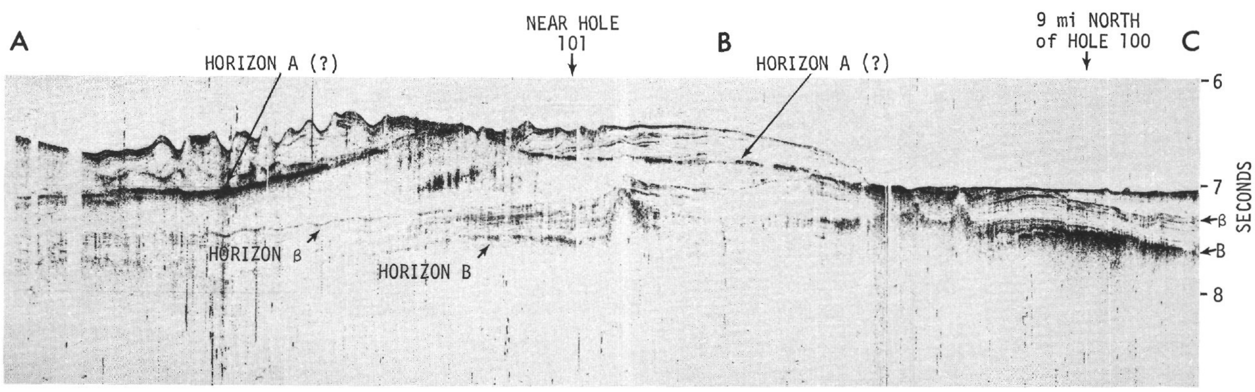

Figure 2a. *Seismic profiler of* CONRAD 10; *the location is shown in Figure 1.*

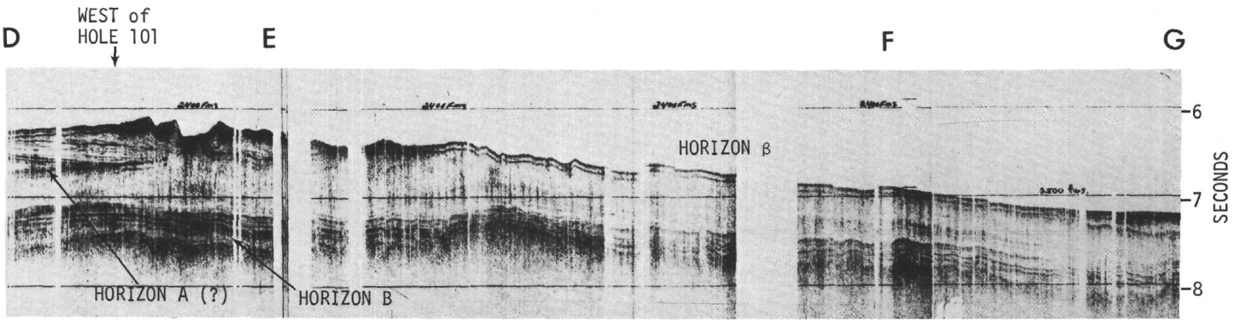

Figure 2b. *Seismic profiler section of* VEMA 21*; the location is shown in Figure 1.*

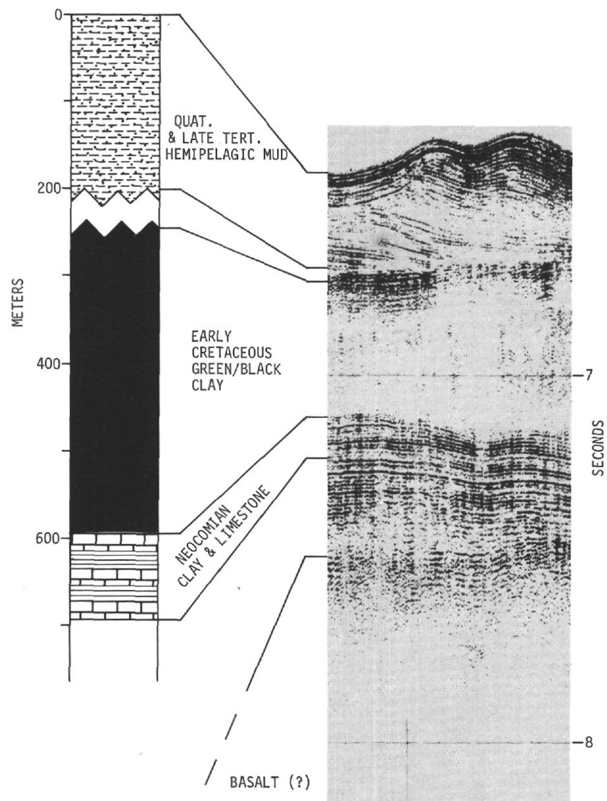

Figure 2c. *Correlations of seismic stratigraphy (*CHALLENGER *record) and lithology at Hole 101.*

was completely worn out, so the hole probably would have been terminated without significantly deeper penetration even if the center bit had not jammed.

STRATIGRAPHY

Biostratigraphy

Foraminifera

Early Pliocene through middle Miocene foraminifers were found at this site. The five core catcher samples which were examined contain relatively few large adult planktonic specimens. The assemblages are primarily composed of small adults, juveniles, and fragments of broken specimens, all of which appear sorted. In addition, three of the samples contain abundant mica flakes, fish remains, pyrite, glauconite and plant fragments. It is concluded that the foraminifers represent a "winnowed" fauna – that they form the finer fraction of deposits that were displaced from their original site of deposition.

Another possible paleoenvironmental parameter is suggested by the fauna in Sample 101A-1, core catcher. This sample contains *Globorotalia miozea* Finlay, a species which is usually more frequent in temperate rather than tropical latitudes (Blow, 1969). The small size of the accompanying fauna, and the few specimens of *G. miozea*, lend only weak support to this interpretation.

The core catcher sample of Core 101A-4 contains a well-preserved Cretaceous planktonic foraminiferal fauna, including *Rotalipora apenninica apenninica* (Renz), *Praeglobotruncana delrioensis* (Plummer), *Hedbergella trocoidea* (Gandolfi), *H. amabilis* Loeblich and Tappan, and *Schackoina cenomana bicornis* Heichel. This assemblage is typical of the "Vraconian" Stage, and is considered to be late Albian. The DSDP Biostratigraphic Panel places this "stage" in the Cenomanian. Benthonic foraminifers occur as well, but are rare. They include the genera *Ammodiscus, Dorothia, Spiroplectammina, Reophax* and *Ammobaculites*, which indicate a deep water environment. Two samples taken from Core 4A contain radiolarians only, which suggests that the depositional site might have been close to the carbonate compensation depth. Fish scales and teeth are frequent in the residues. Two characean oogonia were observed in the core catcher samples and suggest redeposition from a near-shore brackish environment.

The core catcher sample of Core 101A-5 furnished very few specimens of *Hedbergella infracretacea* (Glaessner) and of a species of *Gavelinella* close to *G. barremiana* Bettenstaedt, which is indicative of a probable Aptian age. *Glomospira, Gyroidinoides,* lagenids and primitive agglutinating foraminifers form most of the relatively rich and fairly well-preserved fauna.

Cores 6A, 7A and 8A contain assemblages composed of few poorly preserved, primitive, agglutinating species. No age determination is possible. The fauna indicates a deep water environment. Poorly preserved, in part pyritized, radiolarians are scattered through this interval. Cores 9A and 10A contain a similar fauna, although a few lagenids are also present. This may represent a slight decrease in the depth of deposition or, alternatively, a supply of rapidly buried material from high areas. Core 10A contains *Dorothia praehauteriviana* Dieni and Massari, which is of probable Valanginian age. This species also occurs in Cores 19, 20 and 21 at Site 105. Thin sections from Cores 9A and 10A contain radiolarians, nannoconids, aptychi fragments, and questionable tintinnids. Noteworthy is the occurrence of numerous small serpulids in Core 10A, which were probably living on an indurated substratum.

Calcareous Nannoplankton

The first two cores taken at Site 101 are dated as early Pliocene and late Miocene. The core catcher sample of the first core taken at Hole 101A is assigned to the late Miocene and placed in Zones N16/N17. Cores 2A and 3A are assigned to the late Miocene as well, probably as low as foraminiferal Zone N13. The nannoplankton in these cores are abundant and the preservation is excellent.

Core 4A produced an early Cretaceous (Albian) assemblage. Core 5A is Aptian and contains common, well-preserved, nannoplankton. Cores 6A, 7A and 8A consist of highly carbonaceous sediment, and are essentially barren of nannoplankton. No age assignment is possible. Cores 9A and 10A are composed of hard, dolomitic sediment, and are assigned to the early Cretaceous.

Dinoflagellates

Dinoflagellate fossils were observed in all cores taken at Site 101. The core catcher samples examined from the two cores of Hole 101 and the first three cores of Hole 101A contain a diverse and well-preserved long-ranging flora of Tertiary age. Land-derived pollen grains and spores occur in the five samples as well, and become common in the Miocene cores. Reworked palynomorphs include those of Cretaceous and Carboniferous age, for example, *Densosporites* aff.

The highly carbonaceous clays of the nine samples examined from Cores 4 and 5 contain a rich assemblage of palynomorphs of Cretaceous age. The occurrence of *Palaeohystrichophora infusorioides* Deflandre, *Cleistosphaeridium ancoriferum* (Cookson and Eisenack), *Litospheridium siphoniphorum* (Cookson and Eisenack), *Hystrichosphaeridium arundum* Eisenack and Cookson, and *Hexagonifera chlamydata* Cookson and Eisenack suggests an age of Cenomanian to Albian. The lack of structurally advanced angiosperms in Core 4A suggests that it is no younger than early Cenomanian. Tricolpate dicotyledonous pollen grains are present, however. The core catcher sample of Core 5A contains *H. arundum* and *Apteodinium granulatum* Eisenack, and may be as old as Aptian.

Cores 6A and 7A contain numerous well-preserved cysts, including those assigned to *A. granulatum, Gonyaulacysta helicoides* (Eisenack and Cookson), *G. cassidata* (Eisenack and Cookson), *Carpodinium granulatum* Cookson and Eisenack and *Meiourogonyaulax stoveri* Millioud. These species suggest an age of Aptian to Barremian. The presence of *Rhombodella* ? sp. A (see Chapter 11) in Sample 101A-6-1 (65 to 67 centimeters) suggests a correlation within the interval of Cores 16 to 18 at Hole 105.

Core 8A contains M. *stoveri, Dingodinium cerviculum* Cookson and Eisenack, *Microdinium deflandrei* Millioud, and *Wallodinium krutzschi* (Alberti), which suggests an age of Barremian to Hauterivian. *Coronifera oceanica* Cookson and Eisenack, *Hystrichokolpoma ferox* (Deflandre) and *Odontochitina operculata* (Wetzel) are also present, and support an age designation no older than Hauterivian. The dinoflagellate flora of this core is correlative with the interval of Cores 17 to 19 at Hole 105.

Cores 9A and 10A contain very well-preserved specimens of *M. deflandrei,* including *M. deflandrei* var. A, which suggests that they are Early Cretaceous (Valanginian?). The assemblages in these cores compare closely to those recovered from Cores 20, 21 and 22 at Hole 105 (Association E).

Lithology

Coring at Site 101 started in early Pliocene hemipelagic clays at a depth of 32 meters beneath the sea floor. The two cores recovered from Hole 101 represent the upper part of the sediments of the site; and, coring in Hole 101A began about 40 meters lower than maximum depth reached in the first hole. Therefore, the samples recovered from the two holes show a good continuity and are representative of a single sedimentary record for Site 101.

Three main sedimentary types were recovered: 1) Tertiary hemipelagic muds; 2) early Cretaceous black clays; and 3) Neocomian white and gray limestone.

Sediment composition, compiled from smear slide descriptions (Figure 5), suggests that the upper part of the carbonaceous clays (Cores 4A and 5A) represents an intermediate facies between the black, nannoplankton-poor Neocomian clays and the greenish-gray, nannoplankton-rich, hemipelagic muds of the Tertiary.

Tertiary Hemipelagic Muds (Cores 1, 2, 1A - 3A)

The Tertiary section consists of hemipelagic muds in which clay minerals are largely dominant and associated with quartz, heavy minerals and micas. Pyrite is also common throughout this section, and glauconite is generally present.

The biogenic fraction consists mainly of calcareous nannoplankton and some foraminifera. Siliceous organisms are nearly absent.

Dolomite and siderite occur regularly; some rare calcite grains were observed that could be either detrital or authigenic.

Siderite appears only in a substantial amount in Cores 1A, 2A and 3A, and in lower sections of the hole; while dolomite, which is rather regularly present from Core 1 to Core 3A, is not encountered downhole except in the last core.

Early Cretaceous Black Clays (Cores 4A - 8A)

Cores 4A and 5A appear to be intermediate between the hemipelagic muds and carbonaceous clays. They contain abundant calcareous nannoplankton and rare foraminifera.

The main components of these clays are clay minerals (with some quartz and heavy minerals), organic matter and siderite. Siderite is sometimes concentrated in lenses, hard nodules and layers. Some siderite spherules seem to have a nucleus of organic matter; one dolomite rhomb was found enclosed within a twinned overgrowth of siderite. A thin section made from one nodule shows radiolarian molds filled by drusy siderite in a matrix of fine-grained siderite.

Limonite is an abundant constituent of some thin, yellow layers.

The entire section shows rare, thin laminations and very rare mottling. The lower part is essentially black and the upper part shows alternations of black and dark green layers.

Neocomian White and Gray Limestones (Cores 9A and 10A)

These last two cores yielded a material very different from the upper formations. They consist of rather massive, white to light gray limestone with some intercalations of thinly laminated, dark gray clays.

The light limestone is made up of dominant recrystallized calcite with rare to common calcareous nannoplankton. The clayey, laminated layers contain clay minerals, organic material, some quartz and heavy minerals, and abundant calcareous nannoplankton.

Some layers in the last core contain abundant dolomite, which is probably a diagenetic replacement of the calcite.

The limestone layers show well-preserved primary structures: faint laminations, current bedding, minor slumping, flow structures and abundant small burrows (some filled with pyrite).

The dark zones are very thinly laminated. They consist of numerous alternations of very dark, clayey layers, and thin, carbonate-rich beds in which the calcareous nannofossils are very abundant and better preserved than in the massive limestone beds.

Rate of Sediment Accumulation

During the early Cretaceous in Hole 101, the rate of sediment accumulation was 1.3 cm/1000 yr., an increase of more than 50 percent over the late Jurassic rate in nearby Holes 99 and 100.

DISCUSSION AND CONCLUSIONS

As shown by the profiler record in Figure 2c, there are two distinct reflecting horizons – one at 0.28 second below bottom and one at 0.68 second below bottom. The upper reflector is apparently associated with a slight decrease in drilling resistance and probably corresponds to a major hiatus in the section where sediment age changes from late Miocene to Albian in an interval of 50 meters. The lower reflector, B, corresponds to the interface between the dark clay and the limestone sequence of early Cretaceous age.

If these correlations are correct, the interval velocities are 1.60 km/sec for the Tertiary section and 1.75 km/sec for the Cretaceous clay layer.

The cores retrieved from Holes 101 and 101A represent both a continuous lower Cretaceous section and a Neogene (lower Pliocene-upper Miocene) section separated by a major disconformity, which is on the order of 60 to 80 million years in magnitude.

The early Neocomian carbonate sediments are the only layers which are almost purely pelagic in origin. They consist of light gray to grayish-white nannoplankton ooze, generally well-lithified and in part recrystallized to limestone. Darker and softer layers, finely laminated, are interbedded with the white layers and contain an appreciable amount of clay minerals. The top of the limestone sequence correlates with the seismic Horizon B and appears to be of Hauterivian-Valanginian age.

Above these sediments were found black clays that represent the Cenomanian-Hauterivian Stages.

The Neogene section consists of dark gray to olive gray hemipelagic muds, in part zeolitic, and with abundant siderite.

Bedding planes in the gray-white limestone show minor slump and flow structures, current bedding, and bioturbations. The occurrence of abundant organic matter and dark-colored fine laminations undisturbed by benthonic organisms suggests that anaerobic, tranquil conditions occurred periodically during the early Cretaceous.

The preservation of the extremely abundant organic matter in Cores 6 through 8 indicates that sea floor stagnation at Site 101 became even more prevalent during late Neocomian time. The black Neocomian clays in Core 8 contain bedded siderite with radiolarian molds which may indicate that the black, organic-rich and iron oxide-rich sediments were deposited beneath an open marine environment. The general absence of calcareous nannoplankton and the occurrence of abundant siderite may be due to the solution of calcium carbonate in a low *p*H environment resulting from the accumulation of organic debris under anaerobic conditions.

Site 101 is located approximately 80 miles east of the central portion of the Blake-Bahama Platform, one of the largest carbonate provinces of the world. Yet none of the cores at this site contained clastic carbonate sediments. This contrasts with the situation at Hole 4 (Ewing *et al.*, 1969) where Albian and younger sediments contained substantial quantities of resedimented pelagic and benthic fossils. Thus, it appears that during all of early Cretaceous time, and possibly late Cretaceous time as well, only pelagic sediment and detrital clays reached Site 101, in contrast to the clastics which reached Site 4 via Cat Gap.

The depositional environment at Site 101 was apparently tranquil in early Cretaceous time and at least into the Cenomanian. The hiatus (or extremely shortened section) between early Cenomanian and middle Miocene represents either a long period when bottom currents were strong enough to prevent deposition or a shorter, post-early Cenomanian, period of erosion. Furthermore, the ridge-like shape of the surface of the early Cretaceous accumulation may be a result of early Tertiary - late Cretaceous erosion.

REFERENCES

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Ewing *et al.*, 1969. *Initial Reports of the Deep Sea Drilling Project, Volume I.* Washington (U. S. Government Printing Office).

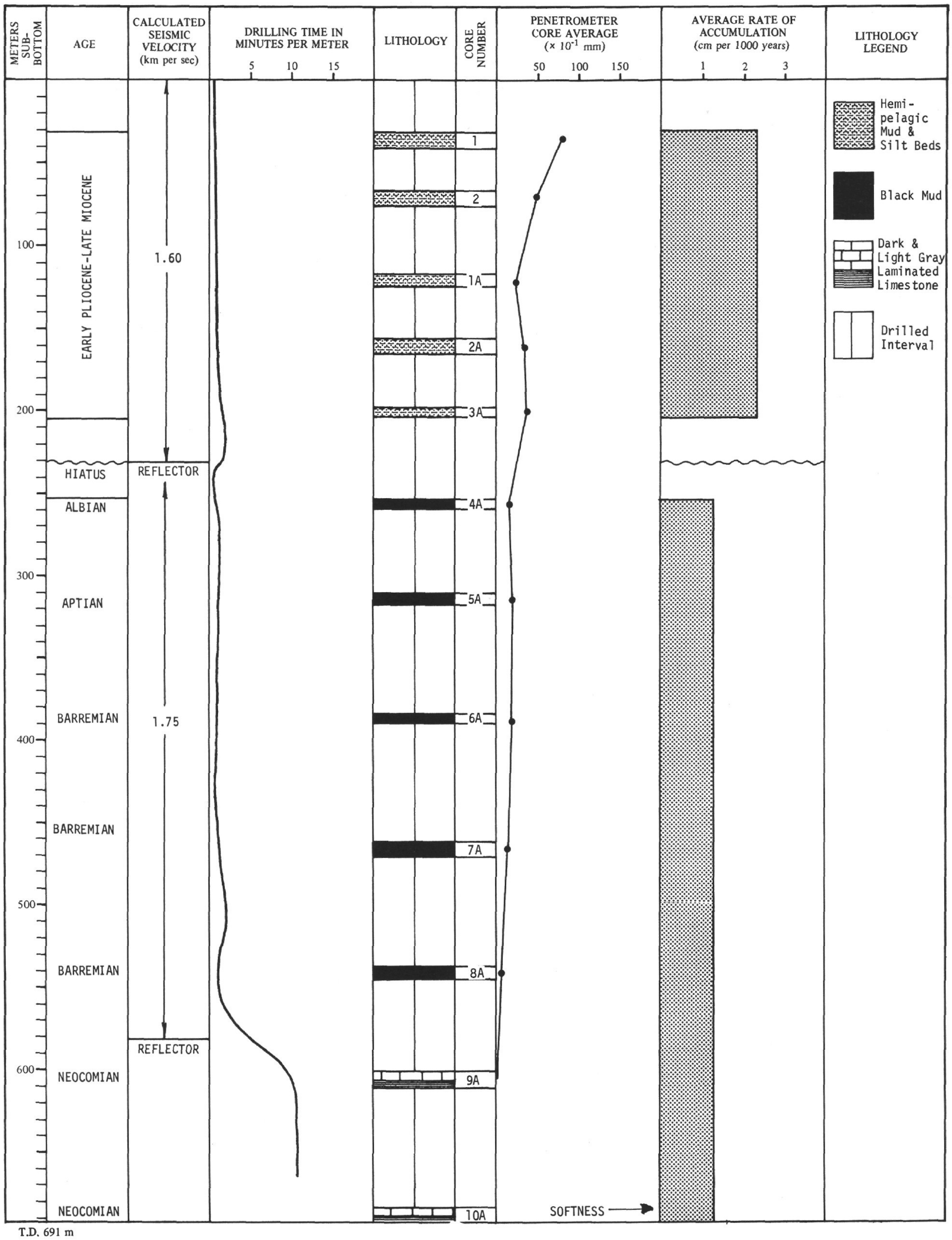


Figure 3. *Site 101 summary chart*

Hole 101

Latitude:	25°11.93′N.
Longitude:	74°26.31′W.
Water depth:	4868 meters (drill pipe); 4773 meters PDR

Core No.	Interval Cored (meters)[a]				Lithology	Age		
	Depth	Amount	Recovery	Subbottom Depth		Foraminifera	Nannoplankton	Dinoflagellates
(Drilled)	(4878-4910)	(32)		(32)				
1	4910-4919	9	9	41	Hemipelagic mud	Early Pliocene		
(Drilled)	4919-4945	(26)		(67)				
2	4945-4954	9	6.8	76	Hemipelagic mud	Late Miocene		

Hole 101A

Latitude:	Same as above
Longitude:	Same as above
Water depth:	Same as above

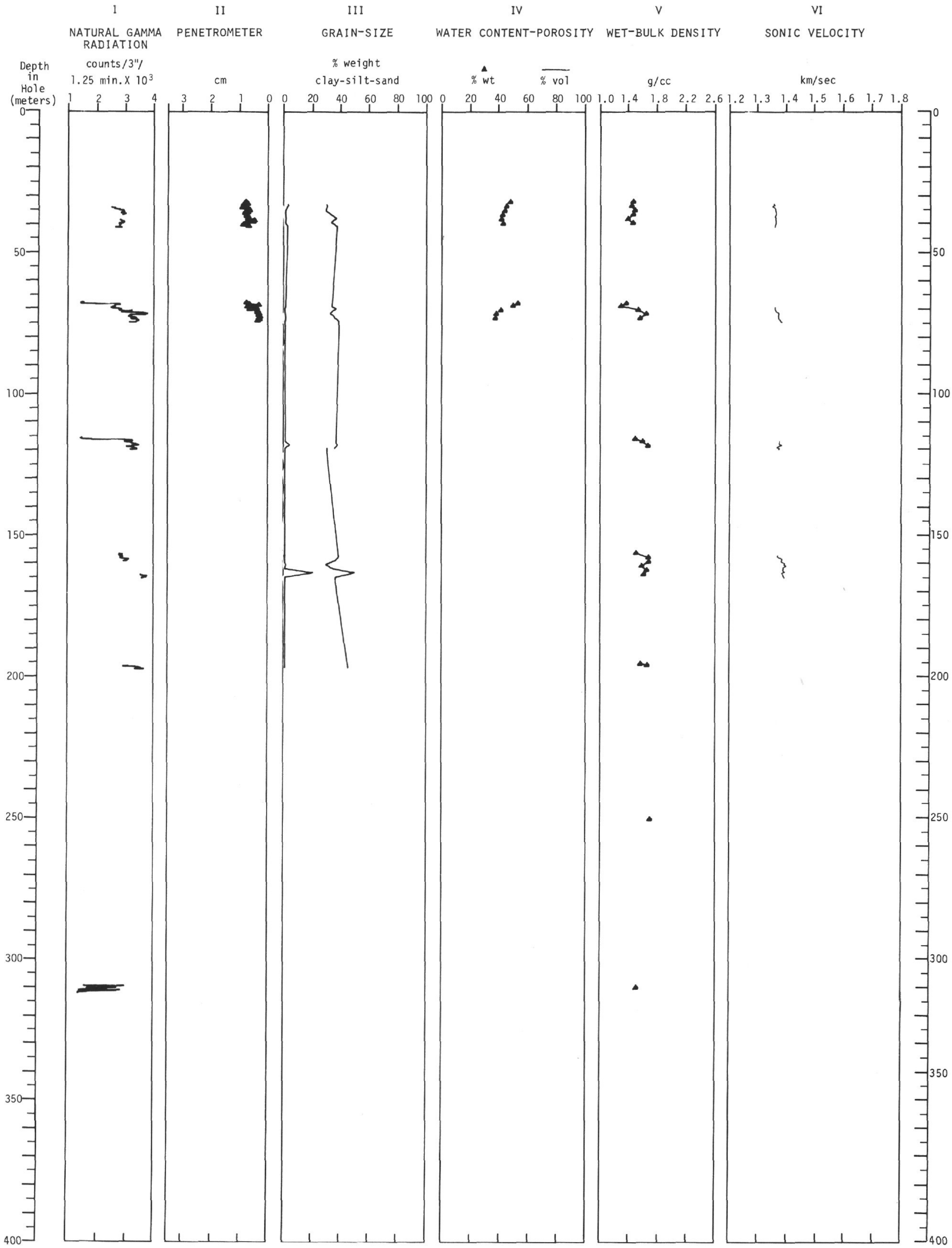
Core No.	Interval Cored (meters)[a]				Lithology	Age		
	Depth	Amount	Recovery	Subbottom Depth		Foraminifera	Nannoplankton	Dinoflagellates
(Drilled)	(4878-4993)	(115)		(115)				
1	4993-5002	9	3.8	124	Hemipelagic mud	Late Miocene		
(Drilled)	(5002-5034)	(32)		(156)				
2	5034-5043	9	9	165	Hemipelagic mud	Late Miocene		
(Drilled)	(5043-5072)	(29)		(194)				
3	5072-5081	9	1.9	203	Hemipelagic mud	Late Miocene		
(Drilled)	(5081-5128)	(47)		(250)				
4	5128-5137	9	0.9	259	Dark Gray clay	Early Cenomanian-Albian	Albian	Early Cenomanian-Albian

Figure 4. *Core Summary table, Site 101.*

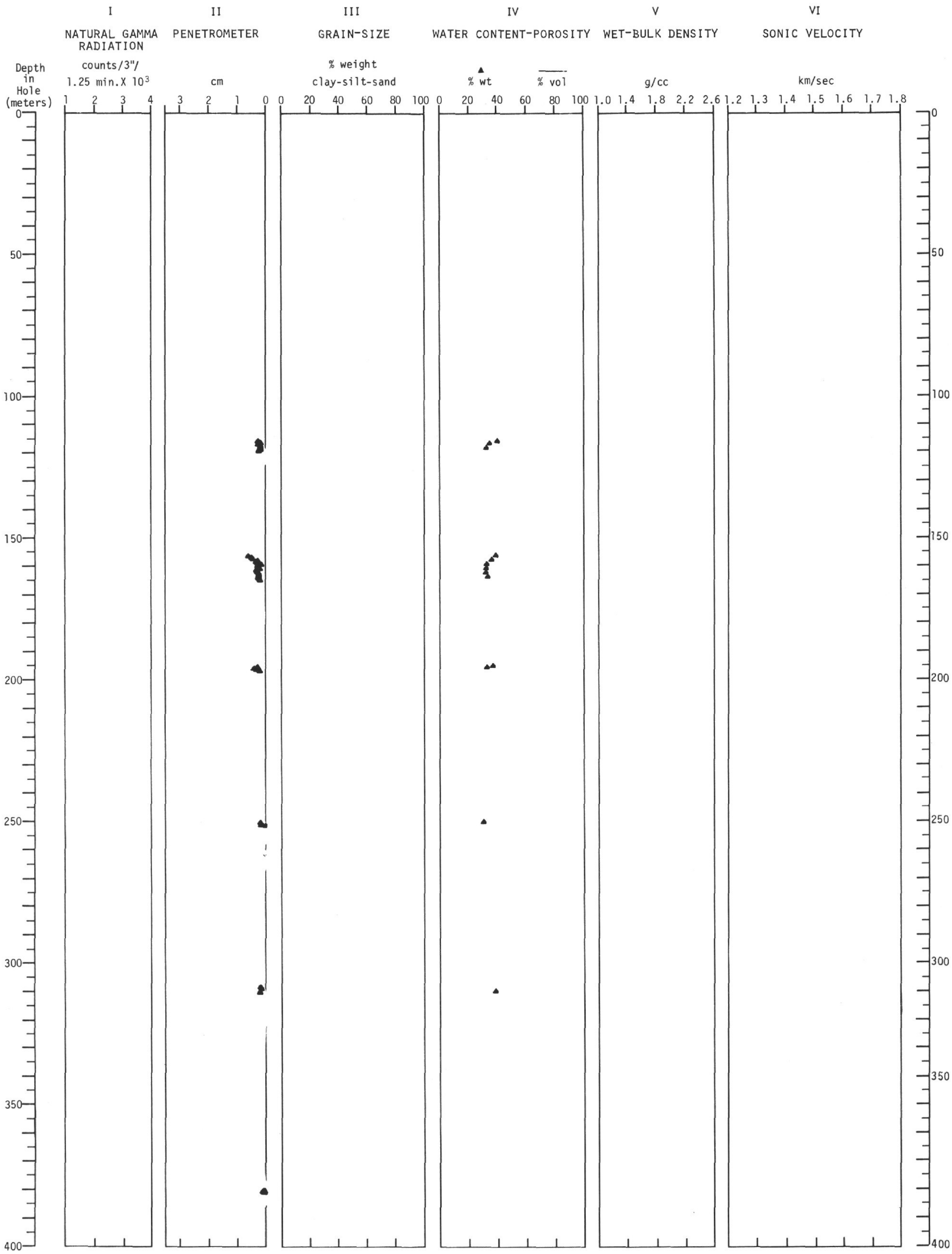
Core No.	Interval Cored (meters)[a]				Lithology	Age		
	Depth	Amount	Recovery	Subbottom Depth		Foraminifera	Nannoplankton	Dinoflagellates
(Drilled)	(5137-5186)	(49)		(308)				
5	5186-5195	9	1.6	317	Black clay	Aptian		Albian-Aptian
(Drilled)	(5195-5258)	(63)		(380)				
6	5258-5267	9	1.0	389	Black and green clay			Aptian-Barremian
(Drilled)	(5267-5338)	(71)		(460)				
7	5338-5347	9	0.8	469	Black and green clay			Aptian-Barremian
(Drilled)	(5347-5412)	(65)		(534)				
8	5412-5421	9	2.6	543	Black clay			Barremian-Hauterivian
(Drilled)	(5421-5477)	(56)		(599)				
9	5477-5488	11	1.1	610	Hard limestone		Early Cretaceous	Valanginian?
(Drilled)	(5488-5563)	(75)		(685)				
10	5563-5569	6	0.8	691	Hard limestone and dolomitic limestone	Valanginian?	Early Cretaceous	Valanginian?

[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 101.* (Cont)



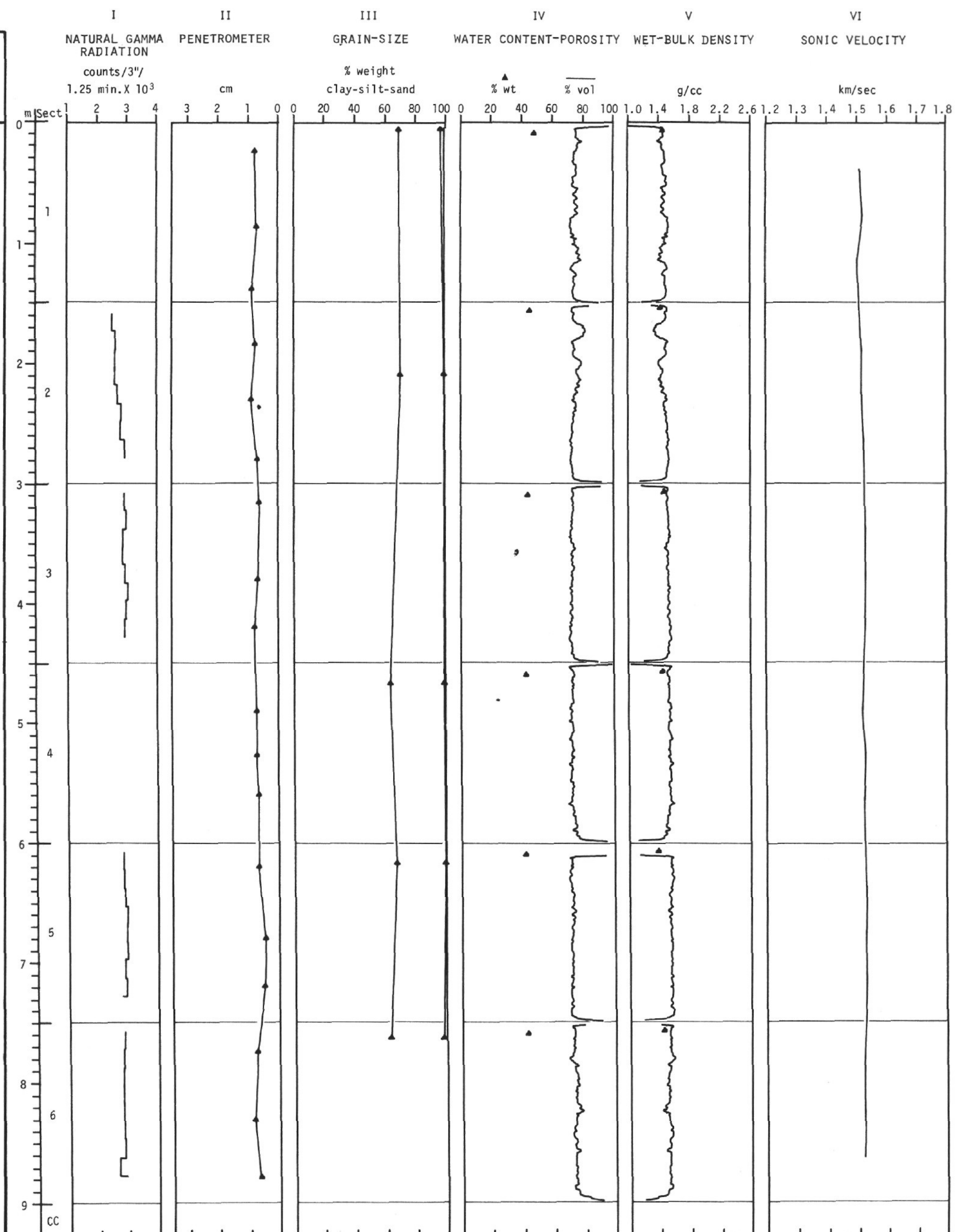
Summary of Physical Properties, Hole 101



Summary of Physical Properties, Hole 101A

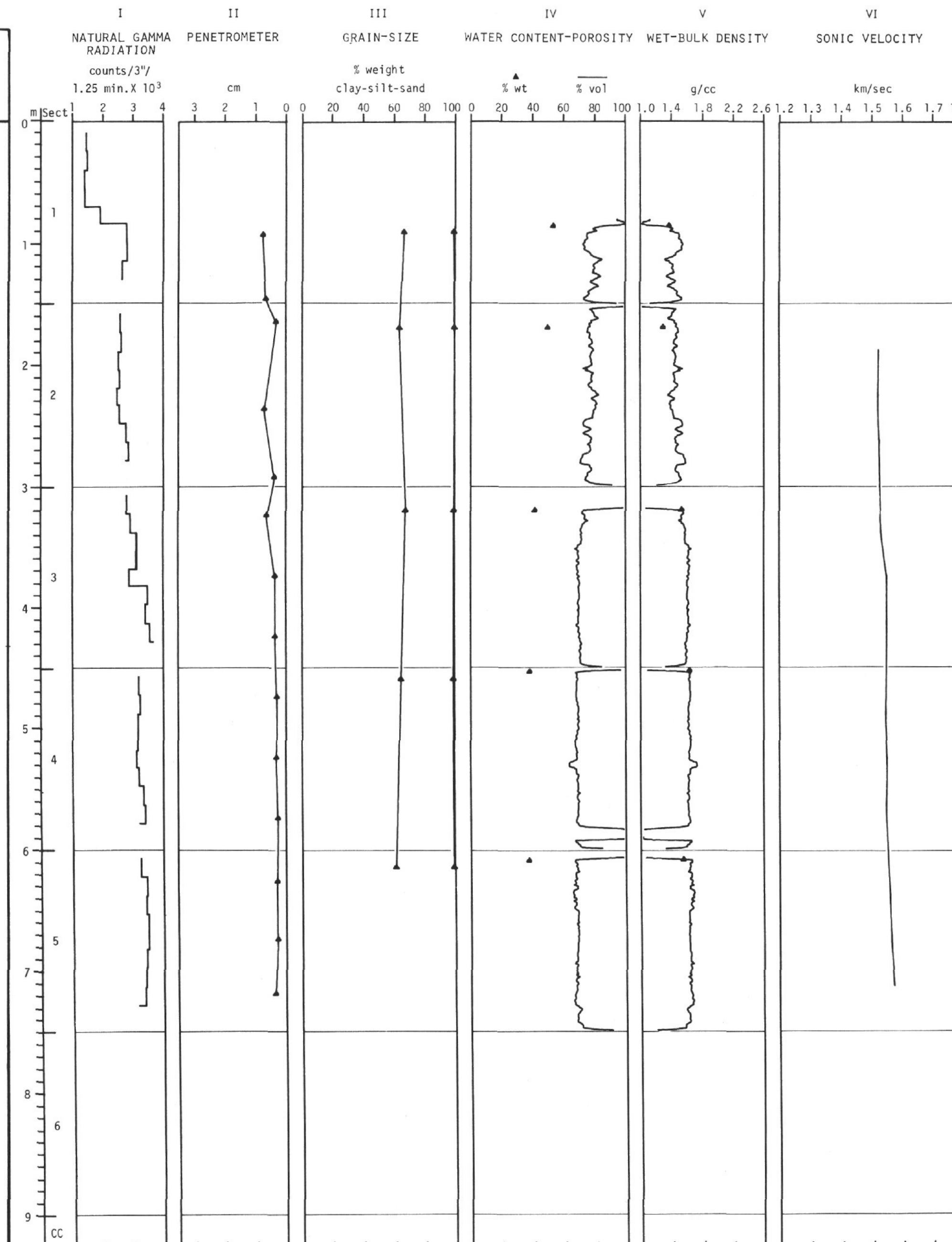
Hole 101, Core 1 (32m to 41m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY PLIOCENE	*Sphaeroidinella dehiscens-Globoquadrina altispira* (N.19) *Reticulofenestra pseudoumbilica*	0–1	1		SS	Hemipelagic mud; soft, plastic, olive gray (5Y4/1) with slight grayish olive (10Y4/2) mottle grading downward into moderate greenish gray (5GY4/1; 6/1) mottle; black (N3) specks of iron sulfide throughout with occasional pyrite nodules becoming more common in lower portion. Quartz, feldspar, mica, rutile, and plant debris common.	
		2	2		SS, CN		CALCAREOUS NANNOPLANKTON: *Reticulofenestra pseudoumbilica, Ellipsoplacolithus lacunosus, Discoaster asymmetricus, D. brouweri, D. pentaradiatus, Ceratolithus rugosus, Cyclococcolithina macintyrei*
		3–4	3		SS	Pyrite nodule.	
		5	4		SS		
		6–7	5		SS	Thin (0.1mm) black (N2) layer.	CORE CATCHER PLANKTONIC FORAMINIFERS: *Globigerina nepenthes, Globigerinoides extremus*
		8	6		SS	Pyrite nodules.	CALCAREOUS NANNOPLANKTON: *Reticulofenestra pseudoumbilica, Ellipsoplacolithus lacunosus, Ceratolithus rugosus, Sphenolithus abies, Discoaster asymmetricus, D. brouweri, D. surculus*
		9	CC		SS PF,CN	Core catcher sample similar to above with one occurrence of very fine grained quartzite noted in smear slide.	



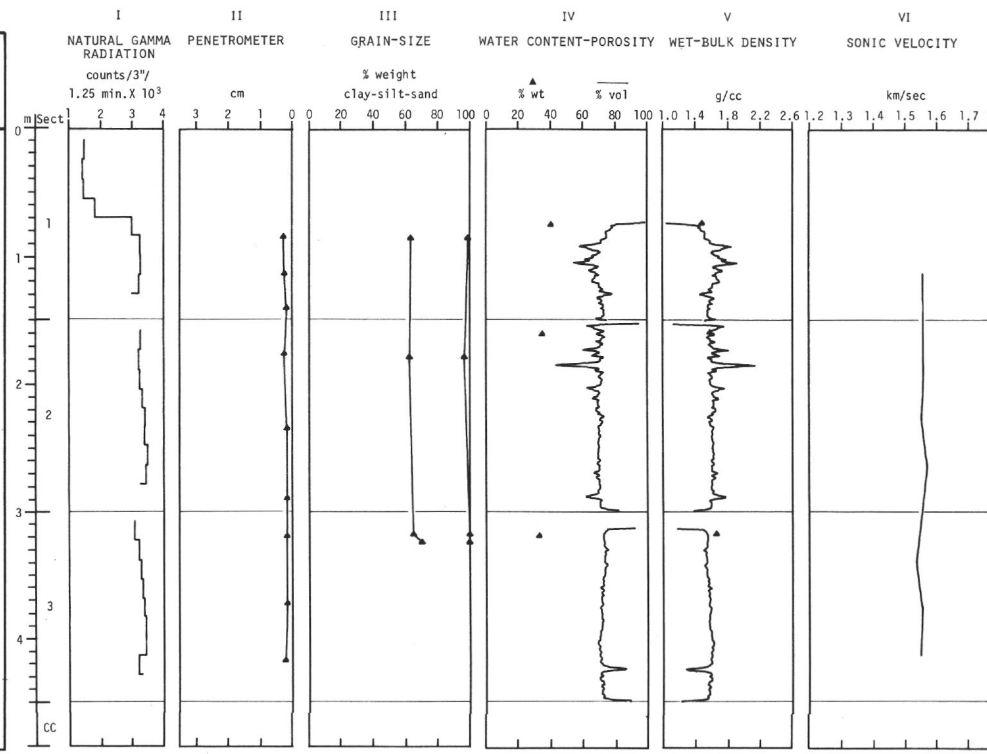
Hole 101, Core 2 (67m to 76m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE MIOCENE	Globorotalia tumida-Sphaeroidinellopsis paenedehiscens (N.18) Discoaster quingeramus	1–7	1		SS	Hemipelagic mud; soft, plastic, dark greenish gray (5GY4/1) becoming grayish olive green (5GY3/2) in last section; slight olive gray (5Y4/1) and greenish gray (5G6/1) mottle; black (N1) specks of iron sulfide; rutile common; quartz, feldspar mica, siderite, and plant debris rare.	
			2		SS		
			3		SS	Pyrite micro-nodules concentrated along faintly developed bedding planes.	
			4		SS	Graded bed at 85-90cm. (See Section 4 summary.)	For flora description, see Section 4, summary page.
			5		SS	Thin diffuse black (N1) layer overlying greenish gray (5G4/1) layer at 36-43cm. Mottle grades into homogeneous greenish gray (5G4/1) layer at 123-125cm.	
			CC		SS PF, CN		*CORE CATCHER* PLANKTONIC FORAMINIFERS: *Globigerina nepenthes, Globigerinoides extremus, Globoquadrina altispira* CALCAREOUS NANNOPLANKTON: *Ceratolithus tricorniculatus, Reticulofenestra pseudoumbilica, Discoaster quinqueramus, D. pentaradiatus, D. surculus, D. variabilis, Helicopontosphaera kamptneri*



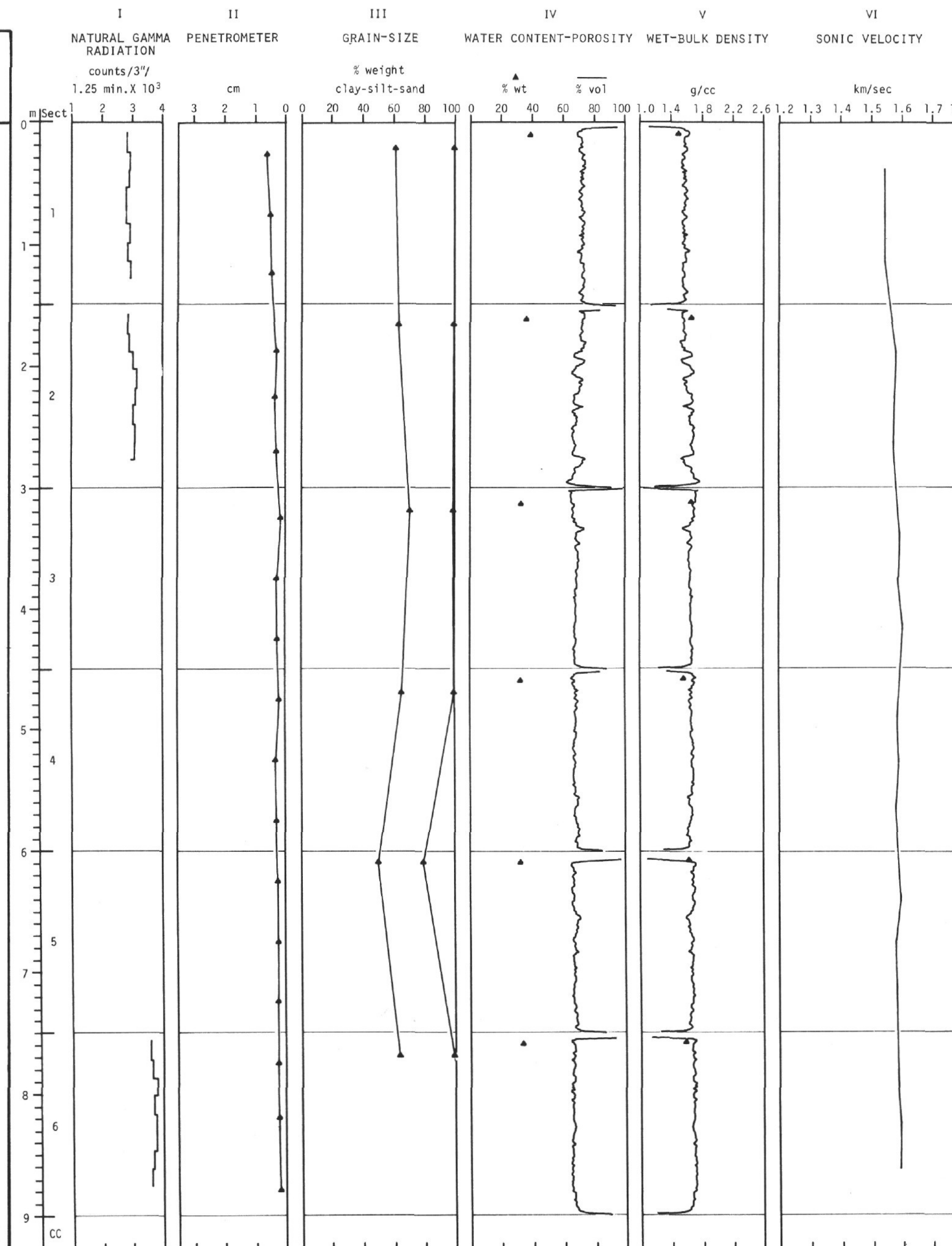
Hole 101A, Core 1 (115m to 124m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE MIOCENE	Turborotalia acostaensis-Globorotalia merotumida (N.16); Discoaster variabilis	1, 2, 3, 4	1, 2, 3, CC		SS, CN, SS, PF, CN, SS	<u>Hemipelagic mud</u>; soft, plastic, dark greenish gray (5G4/1), slight greenish gray (5G6/1) mottle, abundant black (N3) specks of iron sulfide, several large elongate pyrite nodules, abundant micro-nodules of pyrite, quartz, feldspar, rutile, siderite, and plant debris are common.	CALCAREOUS NANNOPLANKTON: *Discoaster quinqueramus, D. surculus, D. pentaradiatus, Reticulofenestra pseudoumbilica, Ceratolithus tricorniculatus, Sphenolithus abies* *CORE CATCHER* PLANKTONIC FORAMINIFERS: *Globorotalia mararitae, Gl. miozea, Gl. cibaoensis, Globigerina nepenthes, Globigerinoides extremus* CALCAREOUS NANNOPLANKTON: *Discoaster quinqueramus, D. surculus, D. exilis, D. challengeri, D. variabilis, Sphenolithus abies, Reticulofenestra pseudoumbilica, Coccolithus pelagicus*



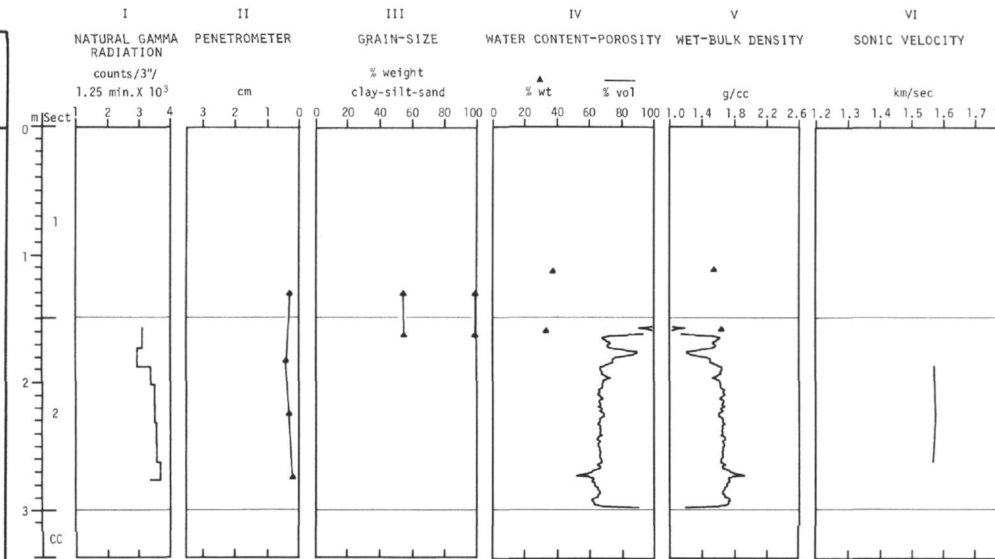
Hole 101A, Core 2 (156m to 165m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE MIOCENE	*Turborotalia acostaensis*-*Globorotalia merotumida* (N.16) *Discoaster variabilis*	0–1	1		SS	<u>Hemipelagic mud</u>; soft to firm, plastic, dark greenish gray (5G4/1), slight greenish gray (5G6/1) and olive gray (5Y4/1) mottle, black (N2) specks of iron sulfide. Quartz, feldspar, mica, rutile, siderite, and plant debris are common. Dolomite rhombs are common in upper half of core.	
		2	2		SS, CN		CALCAREOUS NANNOPLANKTON: *Reticulofenestra pseudoumbilica*, *Sphenolithus abies*, *Discoaster quinqueramus*, *D. variabilis* *D. kugleri*
		3–4	3		SS	Silt layer; calcite dominant, siderite abundant, chert common. Large pyrite nodule.	
		5–6	4		SS	Siderite nodule.	
		7	5		SS		
		8–9	6		SS, PF, CN	Siderite nodules made of very small siderite rhombs (2-3 microns)	*CORE CATCHER* PLANKTONIC FORAMINIFERS: *Globorotalia miozea*, *Globigerinoides extremus* CALCAREOUS NANNOPLANKTON: *Discoaster variabilis*, *D. kugleri*, *D. quinqueramus*, *Reticulofenestra*, *pseudoumbilica*, *Sphenolithus abies*
			CC		SS		



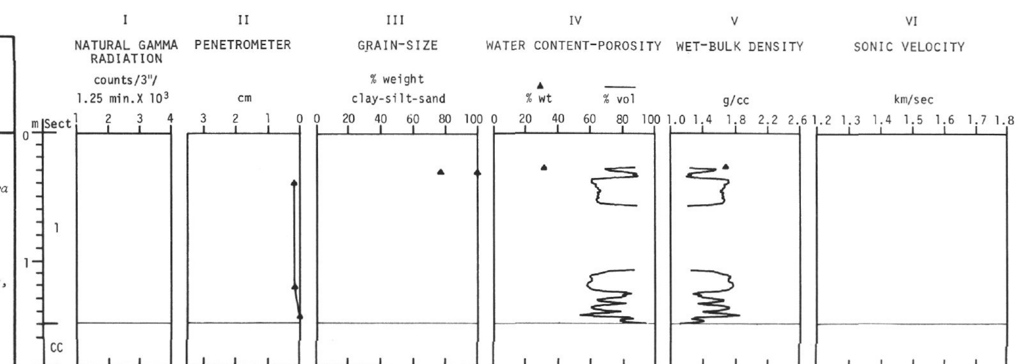
Hole 101A, Core 3 (194m to 203m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE MIOCENE	Globigerina nepenthes-Turborotalia siakensis (N.14) Discoaster exilis	1 2 3	1 2 CC		SS CN SS SSSS SS CF, CN	Hemipelagic mud; soft, plastic, dark greenish gray (5G4/1), moderate greenish gray (5GY4/1) mottle; quartz, rutile, and siderite are common. Black (N2) specks of iron sulfide. Large pyrite nodule with separate inner core.	CALCAREOUS NANNOPLANKTON: *Discoaster variabilis, D. exilis D. challengeri, Reticulofenestra pseudoumbilica, Sphenolithus abies* *CORE CATCHER* PLANKTONIC FORAMINIFERS: *Globigerina nepenthes, Globigerinoides extremus, Turborotalia siakensis, Globoquadrina advena, Gq. venezuelana, Gq. altispira* CALCAREOUS NANNOPLANKTON: *Discoaster variabilis, D. exilis, D. challengeri, Reticulofenestra pseudoumbilica, Sphenolithus abies, Helicopontosphaera kamptneri*



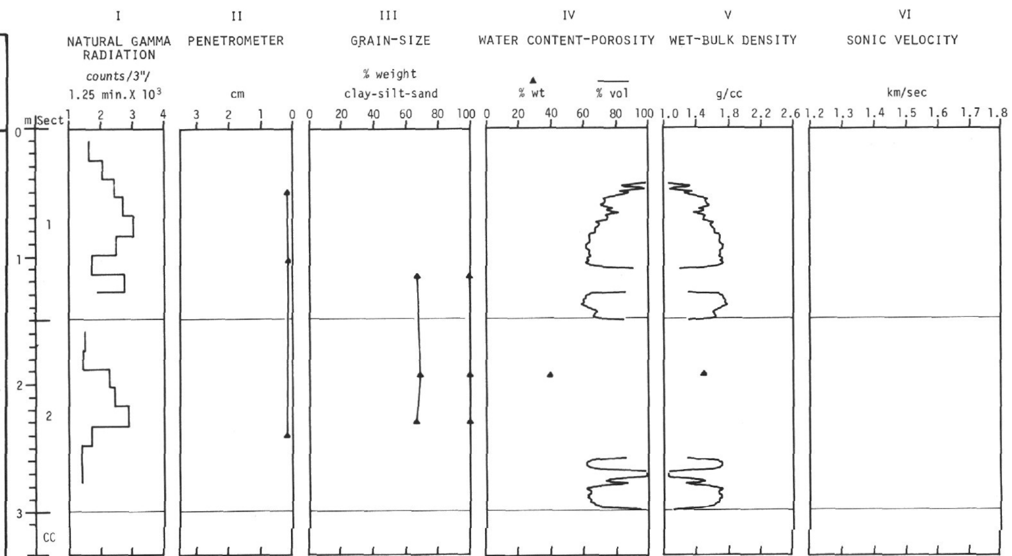
Hole 101A, Core 4 (250m to 259m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
CRETACEOUS (EARLY CENOMANIAN-ALBIAN)		1	1 CC		SS CN F D SS SS CN, D	Hemipelagic mud; soft, plastic, dark greenish gray (5GY4/1) mixed with diffuse layers of dark gray (N3); quartz abundant, rutile and siderite are common. Graded bed at 130-135cm, slightly indurated and laminated, greenish gray (5GY6/1); silt zone at base with siderite dominant, pyrite common; plant debris also common and partially replaced with siderite.	CALCAREOUS NANNOPLANKTON: *Eiffellithus turriseiffeli, Deflandrius intercisus, Apertapetra gronosa, Arkhangelskiella striata, Watznaueria actinosa, Glaukolithus diplogrammus* DINOFLAGELLATES: *Palaeohystrichophora infusorioides, Cyclonephelium vannophorum, Litosphaeridium siphoniphorum, Hexagonifera chlamydata, Cleistosphaeridium ancoriferum, Dinogymnium* sp. A *CORE CATCHER* FORAMINIFERA: *Rotalipora apenninica apenninica, Praeglobotruncana delrioensis, Schackoina cenomana bicornis, Hedbergella amabilis* CALCAREOUS NANNOPLANKTON: *Apertapetra gronosa, Parhabdolithus embergeri, Eiffellithus turriseiffeli, Deflandrius, intercisus, Glaukolithus diplogrammus, Watznaueria actinosa, W. barnesae* DINOFLAGELLATES: *Palaeohystrichophora infusorioides, Cleistosphaeridium ancoriferum, Odontochitina operculata*



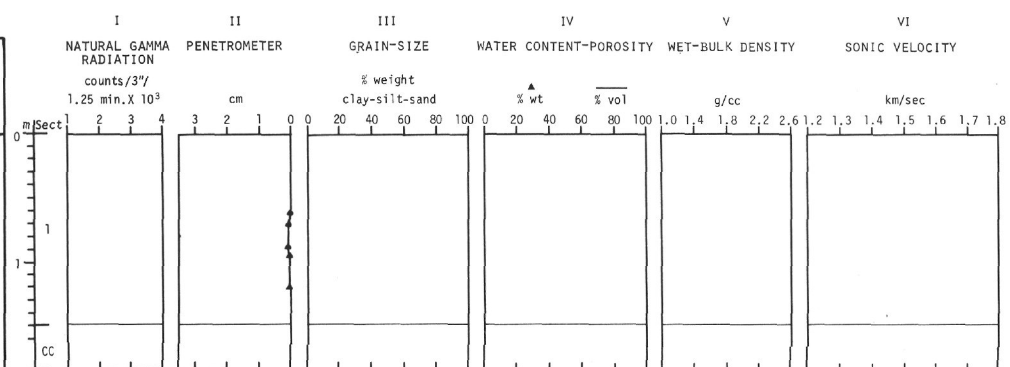
Hole 101A, Core 5 (308m to 317m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY CRETACEOUS (ALBIAN-APTIAN)		1	1		SS, CN, D	Clay; firm, slightly plastic, black (N1) to greenish black (5G2/1), faint discrete dark greenish gray (5GY4/1) laminations, organic matter abundant.	CALCAREOUS NANNOPLANKTON: *Parhabdolithus angustus, Zygolithus ponticulus, Cretarhabous splendens, Stephanolithion crenulatum, Ahmuelleralla asper, Zygodiscus erectus*
						Silt and nodule of siderite.	DINOFLAGELLATES: *Palaeohystrichophora infusorioides, Hystrichosphaeridium arundum, Cleistosphaeridium ancoriferum, Gonyaulacysta exilicristata, Ovoidinium scabrosum*
		2	2		D		DINOFLAGELLATES: *Palaeohystrichophora infusorioides, Hystrichosphaeridium arundum*
							CORE CATCHER
		3	CC		SS, F, CN, D		FORAMINIFERS: *Hedbergella infracretacea, Gavelinella* sp. aff. *G. barremiana*
							CALCAREOUS NANNOPLANKTON: *Cretarhabdus splendens, C. crenulatus, Zygodiscus erectus, Apertapetra gronosa, Ahmuellerella asper, Stephanolithion crenulatum, Watznaueria barnesae, W. actinosa*
							DINOFLAGELLATES: *Apteodinium granulatum, Hystrichosphaeridium arundum*



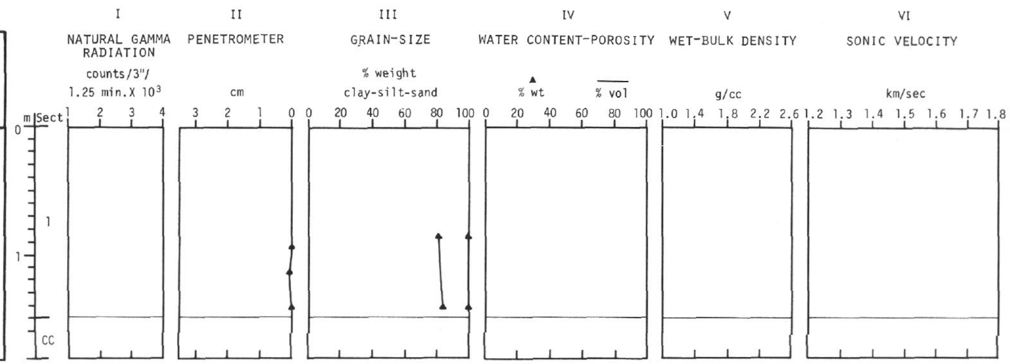
Hole 101A, Core 6 (380m to 389m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY CRETACEOUS (APTIAN-BARREMIAN)		1	1		SS, D, SS, SS, SS, SS, F, SS, SS, SS	Clay; firm, thinly laminated bands of grayish olive green (5GY3/2) and greenish black (5G2/1) to black (N1) interbeds of dark reddish brown (10R3/4) clay and greenish gray (5GY6/1) ironstone (siderite) small siderite nodules in lower part. See Section 1 summary page.	DINOFLAGELLATES: *Apteodinium granulatum, Gonyaulacysta helicoidea, Carpodinium granulatum, Cribroperidinium muderongensis, C. edwardsi, Meiourogonyaulax stoveri, Oligosphaeridium complex, Hystrichokolpoma ferox, Odontochitina operculata, Rhombodella ?* sp. A
			CC		SS, SS, CN, D		*CORE CATCHER*
							CALCAREOUS NANNOPLANKTON: *Watznaueria barnesae*
							DINOFLAGELLATES: *Gonyaulacysta helicoidea, Meiourogonyaulax stoveri, Oligosphaeridium complex, Hystrichodinium voigti, Cyclonephelium distinctum*



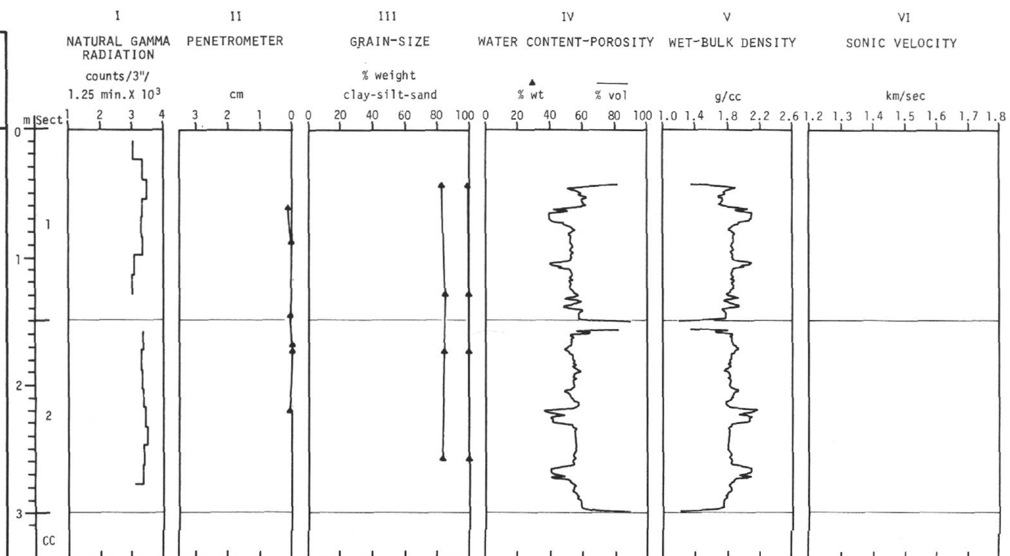
Hole 101A, Core 7 (460m to 469m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY CRETACEOUS (APTIAN-BARREMIAN)		1	1		SS F F D	Clay; firm to hard, interbeds of black (N1) and dark greenish gray (5G4/1) thinly and evenly laminated with greenish black (5G2/1). See Section 1 summary. Micro-nodules of pyrite.	DINOFLAGELLATES: *Gonyaulacysta helicoidea, Cribroperidinium muderongensis, Meiourogonyaulax stoveri, Odontochitina operculata, Deflandrea pirnaensis, Dictyopyxis circulata*
			CC		SS SS D	Nodule of light olive gray (5Y6/1) siderite in core catcher.	*CORE CATCHER* DINOFLAGELLATES: *Gonyaulacysta cassidata Deflandrea pirnaensis*



Hole 101A, Core 8 (534m to 543m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY CRETACEOUS (BARREMIAN-HAUTERIVIAN)		1	1		SS D SS SS	Clay, firm and slightly plastic to hard, black (N1); light olive gray (5Y6/1) siderite silt layer at 58cm; quartz and rutile needles are common, organic matter abundant.	DINOFLAGELLATES: *Microdinium deflandrei, Meiourogonyaulax stoveri, Dingodinium cerviculum, Wallodinium krutzschi, Coronifera oceanica, Oligosphaeridium complex, Deflandrea pirnaensis*
		2, 3	2		SS SS SS SS SS D	Light olive gray (5Y6/1) lenses of siderite silt. Light olive gray (5Y6/1) layer of spherulitic siderite (ironstone) at 121cm; centers of some spherulites appear to contain carbonaceous matter; some spherules show radial growth patterns.	DINOFLAGELLATES: *Microdinium deflandrei, Meiourogonyaulax stoveri, Dingodinium cerviculum, Wallodinium krutzschi, Odontochitina operculata*
			CC		SS CN,D	5 cm of light olive gray (5Y6/1) bedded ironstone containing radiolarians replaced with siderite and radiolarian molds lined with drussy siderite.	*CORE CATCHER* CALCAREOUS NANNOPLANKTON: *Watznaueria barnesae, Zygodiscus erectus* DINOFLAGELLATES: *Meiourogonyaulax stoveri, Oligosphaeridium complex, Odontochitina operculata*



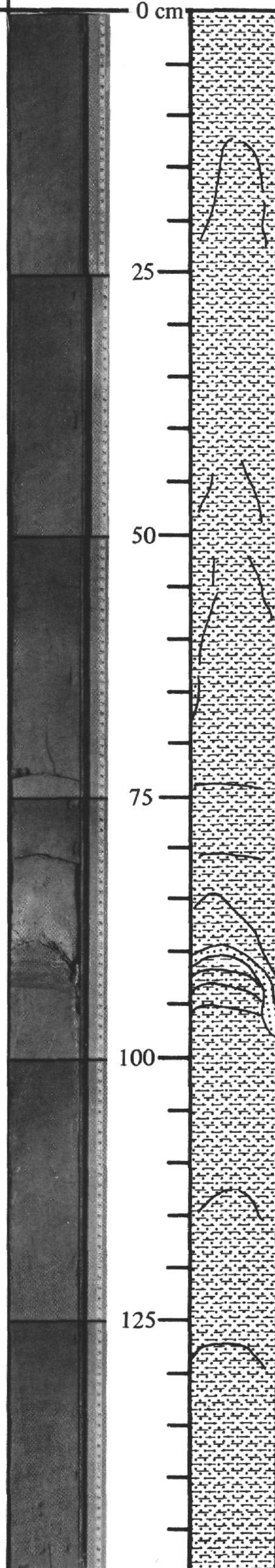
Hole 101A, Core 9 (599m to 610m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY CRETACEOUS (VALANGINIAN?)		1	1		CN SS F SS D SS SS SS	Limestone; hard, light gray (N7), thinly and unevenly bedded and laminated with minor slump structures, burrow fillings, and truncations; darker gray (N5-N3) layers always very finely and evenly laminated with clay minerals abundant or dominant, pyrite abundant in burrow fillings and on bedding planes. See Section summary.	CALCAREOUS NANNOPLANKTON: *Nannoconus steinmanni, Parhabdolithus embergeri, Watznaueria barnesae, Braarudosphaera discula, Lithraphidites carniolensis, Stephanolithion laffittei, Cyclagelosphaera margereli* DINOFLAGELLATES: *Microdinium deflandrei, Meiourogonyaulax bulloidea*
			CC		SS CN		CORE CATCHER CALCAREOUS NANNOPLANKTON: *Nannoconus steinmanni, Lithraphidites carniolensis, Cyclagelosphaera margereli, Diazomatolithus lehmani, Watznaueria barnesae, Braarudosphaera discula*

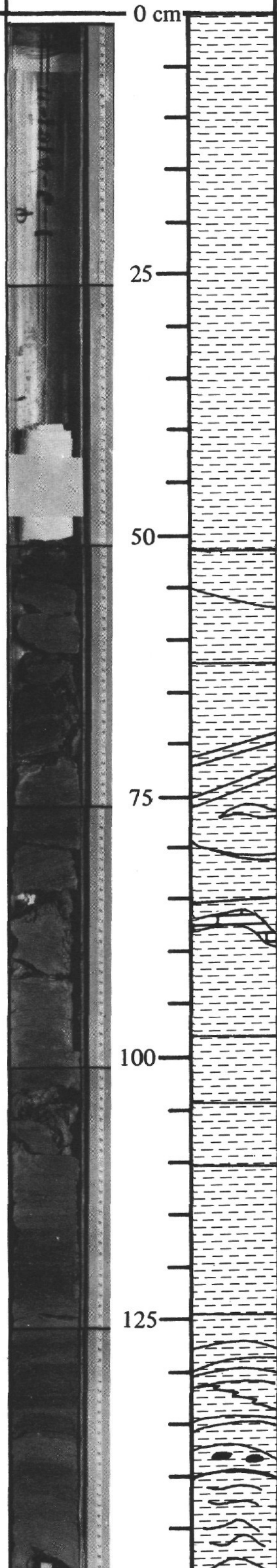
Hole 101A, Core 10 (685m to 691m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY CRETACEOUS (VALANGINIAN?)		1	1		SSCN SS SS SS DF	Limestone dolomitic, hard, light gray (N7), unevenly bedded with minor slump structures, burrow fillings, and truncations; recrystallized nanno calcite dominant; some thin, firm, finely and evenly laminated, dark gray (N3) beds characterized by clay, dolomite, and nannoplankton. See section summary.	FORAMINIFERS: *Dorothia praehauteriviana* CALCAREOUS NANNOPLANKTON: *Nannoconus steinmanni, Lithraphidites carniolensis, Cyclagelosphaera margereli, Parhabdolithus embergeri, Diazomatolithus lehmani, Watznaueria barnesae* DINOFLAGELLATES: *Microdinium deflandrei*
			CC		SS F,CN		CORE CATCHER FORAMINIFERS: *Dorothia praehauteriviana* CALCAREOUS NANNOPLANKTON: *Parhabdolithus embergeri, Cyclagelosphaera margereli, Diazomatolithus lehmani, Nannoconus steinmanni, Lithraphidites carniolensis, Watznaueria barnesae*

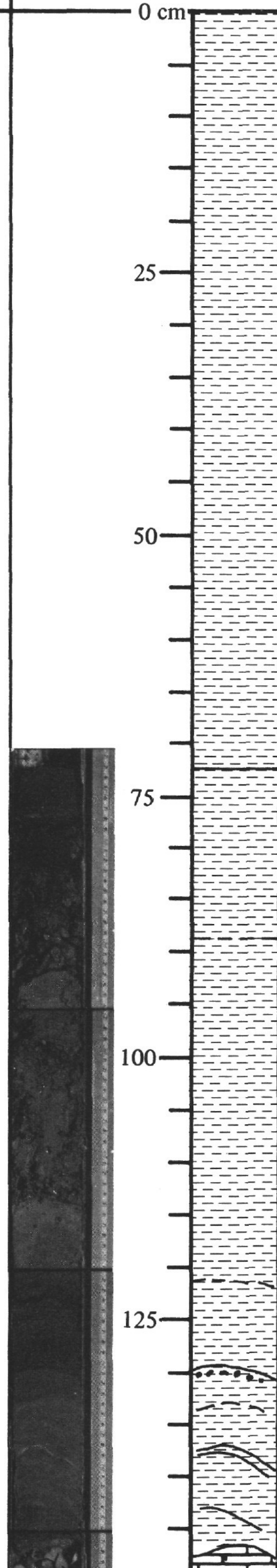
Hole 101, Core 2, Sect. 4

AGE	ZONE	LITHOLOGY	SAMP. INT	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE MIOCENE	*Discoaster quinqueramus*		SS CN	<u>Hemipelagic mud</u>; dark greenish gray (5GY 4/1), slight olive gray (5Y 4/1) and greenish gray mottle appearing as uneven bands in the form of elongated arches caused by friction between soft plastic sediment and core liner. Arching not apparent in photo except in graded bed. Black (N1) specks of iron sulfide. In smear slide clay minerals are dominant; rutile is common; quartz, feldspar, mica, siderite, and plant debris are rare. Nearly horizontal shrinkage cracks. Graded bed of light olive gray (5Y 6/1) hemipelagic mud with a basal layer of calcite silt; forams and quartz are rare in silt layer.	*SAMPLE 107-108 cm* CALCAREOUS NANNOPLANKTON: *Discoaster quinqueramus*, *D. surculus*, *D. variabilis*, *Ceratolithus tricorniculatus*, *Reticulofenestra pseudoumbilica*, *Helicopontosphaera sellii*, *H. kamptneri*

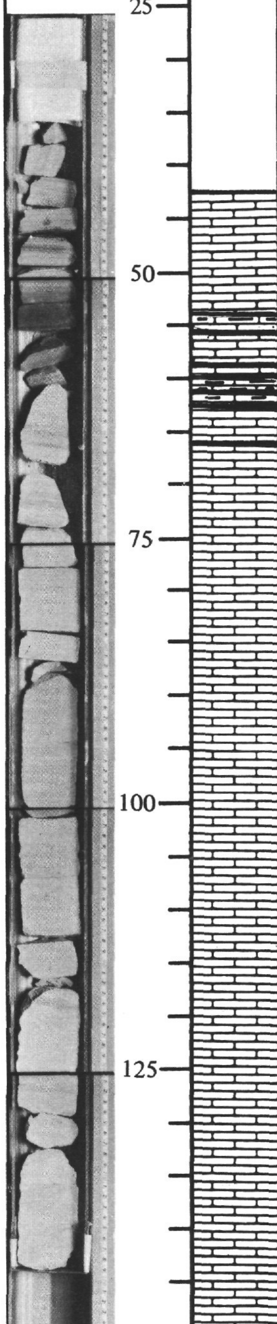
Hole 101A, Core 6, Sect. 1

AGE	ZONE	LITHOLOGY	SAMP. INT	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY CRETACEOUS (APTIAN/BARREMIAN)			SS D SS SS SS F SS F F D SS SS	Clay; firm, laminated and layered as described below. Organic debris and rutile needles are common in green and black beds. Red color due to hematite staining. Yellow layers at 70 and 75cm are limonitic clay. Smear slides at 74 and 84cm are in siderite laminae. Black (N1). Gradational Greenish black (5G 2/1). Reddish brown (10R 3/4); two yellow (5Y 5/6) layers with sharp bedding contacts. Black with reddish brown streak. Grayish olive green (5GY 3/2). Ironstone (siderite); greenish gray (5GY 6/1) Black Reddish brown. Interbedded reddish brown & grayish olive green. Grayish olive green with fine black laminations. - Gradational Interbedded layers of grayish olive green and black. Siderite nodules. Black with zones of reddish brown laminations and thin greenish black layers.	*SAMPLE 65-68 cm* DINOFLAGELLATES: *Hystrichokolpoma ferox* *Apteodinium granulatum* *Cribroperidinium muderongensis* *Oligosphaeridium complex* *Odontochitina operculata* *Cyclonephelium distinctum* *SAMPLE 135-138 cm* DINOFLAGELLATES: Flora the same as above plus: *Cribroperidinium edwardsi*, *Gonyaulacysta helicoidea*, *Carponinium granulatum*, *Meiourogonyaulax stoveri*

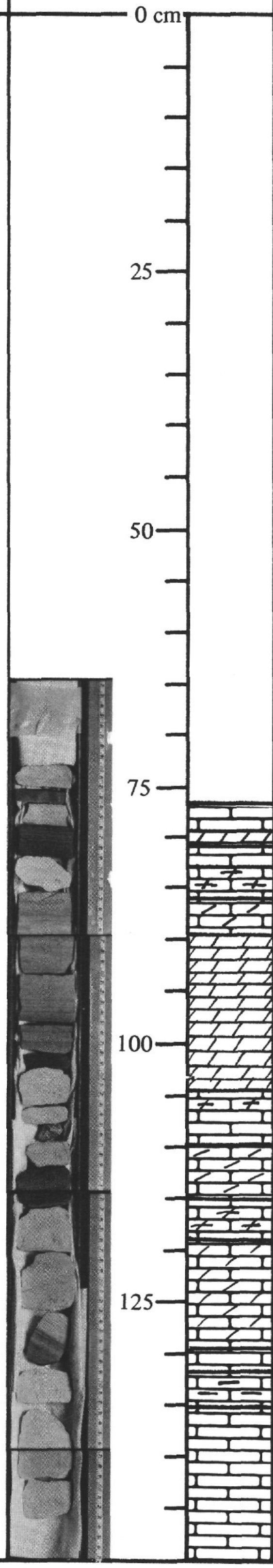
Hole 101A, Core 7, Sect. 1

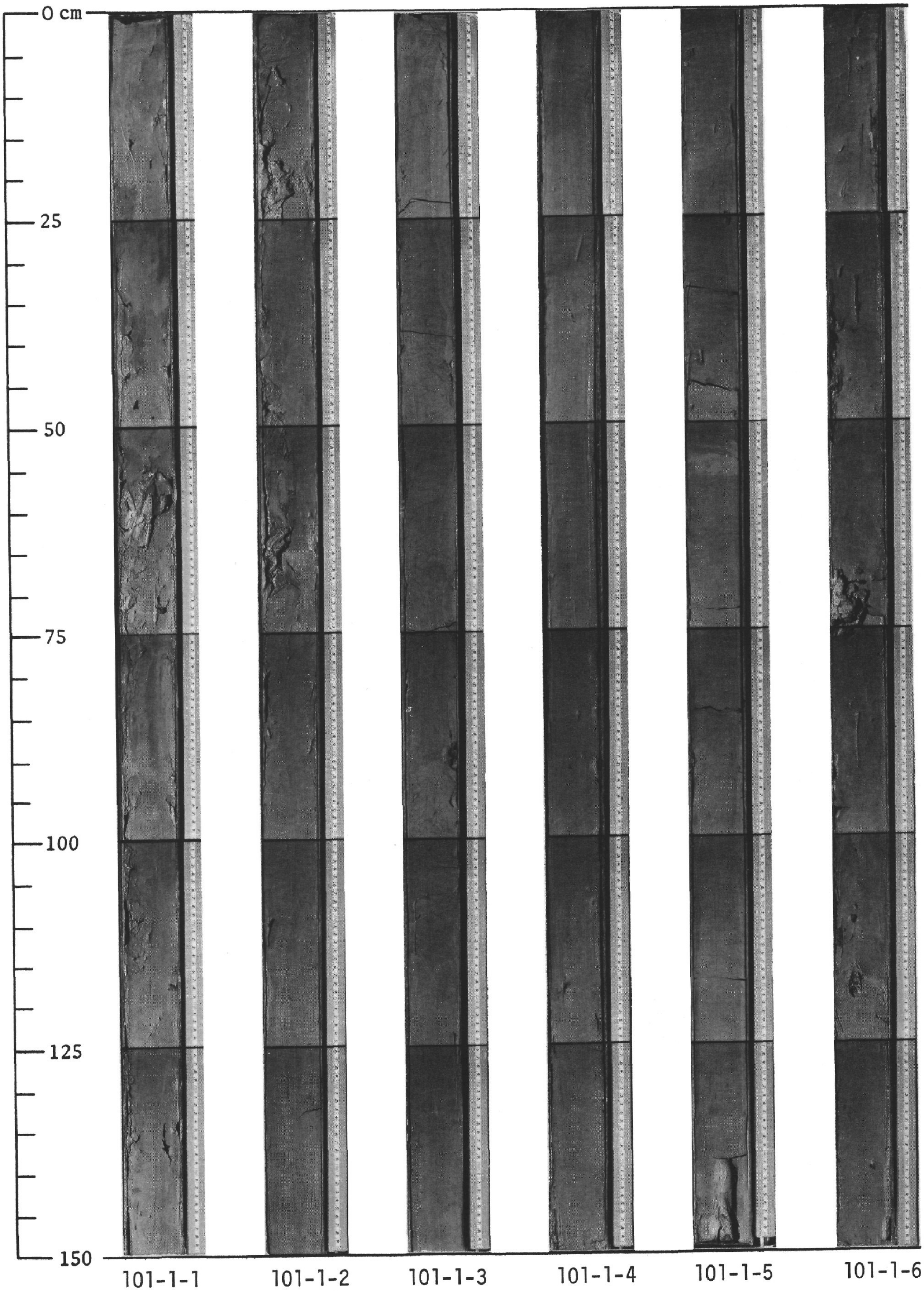
AGE	ZONE	LITHOLOGY	SAMP. INT	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY CRETACEOUS (APTIAN/BARREMIAN)			SS F F D SS	Clay; firm to hard, interbedded black (N1) and dark greenish gray (5G 4/1). Clay minerals dominant in both black and green zones; plant debris abundant in black clay; calcite and siderite present only in green clay. Black (N1), hard, thinly and evenly laminated. Gradational Dark greenish gray (5G 4/1), soft. Gradational Black (N1) with thin beds of greenish black (5G 2/1), hard. Sharp contact with underlying layer of pyrite micro-nodules at 130cm. Deformed laminae of hard green and black clay with one lamina of light olive gray (5Y 6/1) siderite at 137cm. Ironstone (siderite), light olive gray (5Y 6/1)	*SAMPLE 135-138 cm* DINOFLAGELLATES: *Gonyaulacysta helicoidea, Cribroperidinium muderongensis, Meiourogonyaulax stoveri, Odontochitina operculata, Deflandrea pirnaensis, Dictyopyxis circulata*

Hole 101A, Core 9, Sect. 1

AGE	ZONE	LITHOLOGY	SAMP. INT	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY CRETACEOUS (VALANGINIAN?)		 0 cm 25 50 75 100 125	CN (25 cm) SS (55 cm) D (57 cm) F (60 cm) SS (75 cm) SS (80 cm) D (100 cm) SS (105 cm)	<u>Limestone</u>; light gray (N7), thinly bedded and laminated, hard. Some softer, extremely evenly and thinly laminated dark gray (N3) zones. Calcareous nannoplankton dominant; recrystallized nanno-calcite abundant in both light & dark beds. Clay & plant debris abundant in dark beds, rare to absent in light beds. Light gray (N7), hard. Thin medium gray (N5) bed of softer clay-rich calcilutite at 54-56cm. Gradational Dark gray (N3), soft, clayey. Gradational Light gray (N7), thinly bedded, unevenly laminated, extremely fine-grained, very hard. Pyrite is common on laminations & bedding planes & commonly replaces burrow fillings. Some laminae show truncations (bottom current scour & fill?). Small minor slump &/or flow structures. Fecal pellets(?). Light gray zone at 42-52cm is similar to lower light gray beds.	*SAMPLE 27-28 cm* CALCAREOUS NANNOPLANKTON: *Nannoconus steinmanni*, *Parhabdolithus embergeri*, *Watznaueria barnesae*, *Braarudosphaera discula*, *Lithraphidites carniolensis*, *Stephanolithion laffittei*, *Cyclagelosphaera margereli* *SAMPLE 55-58 cm* DINOFLAGELLATES: *Microdinium deflandrei* *SAMPLE 100-102 cm* DINOFLAGELLATES: Same as above.

Hole 101A, Core 10, Sect. 1

AGE	ZONE	LITHOLOGY	SAMP. INT	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY CRETACEOUS (VALANGINIAN?)				Limestone; dolomitic, light gray to white (N7-N9), hard. No bedding or laminations in hard white zones. Dark gray (N3-N5) beds are always softer and extremely evenly and finely laminated. X-ray diffraction analysis of detailed sampling confirms dolomite present throughout section. Clay minerals, plant debris, calcareous nannoplankton abundant in dark beds and rare to absent in white zones. White beds are dominantly recrystallized nanno-calcite. Interrupted bedding in lighter colored zones shows results of burrowing organisms, current action, minor slumping.	
			SS SS CN	White (N8) with two dark (N3) dolomitic beds. Dolomite abundant in smear slide (80cm).	*SAMPLE 85-86 cm* CALCAREOUS NANNOPLANKTON: *Nannoconus steinmanni, Lithraphidites carniolensis, Cyclagelosphaera margereli, Parhabdolithus embergeri, Diazomatolithus lehmani, Watznaueria barnesae*
				White (N9); dolomitic.	
			SS	Light bluish gray (5B 7/1) dolomite. Dolomite dominant in smear slide (97cm).	
				White (N8) with dark (N3) dolomitic bed.	
			SS D	White (N8), dolomitic with one dark (N3) dolomitic bed. Dolomite abundant in smear slide (114cm).	*SAMPLE 115-118 cm* DINOFLAGELLATES: *Microdinium deflandrei*
			F	Light gray (N7) with medium gray (N5) bed.	



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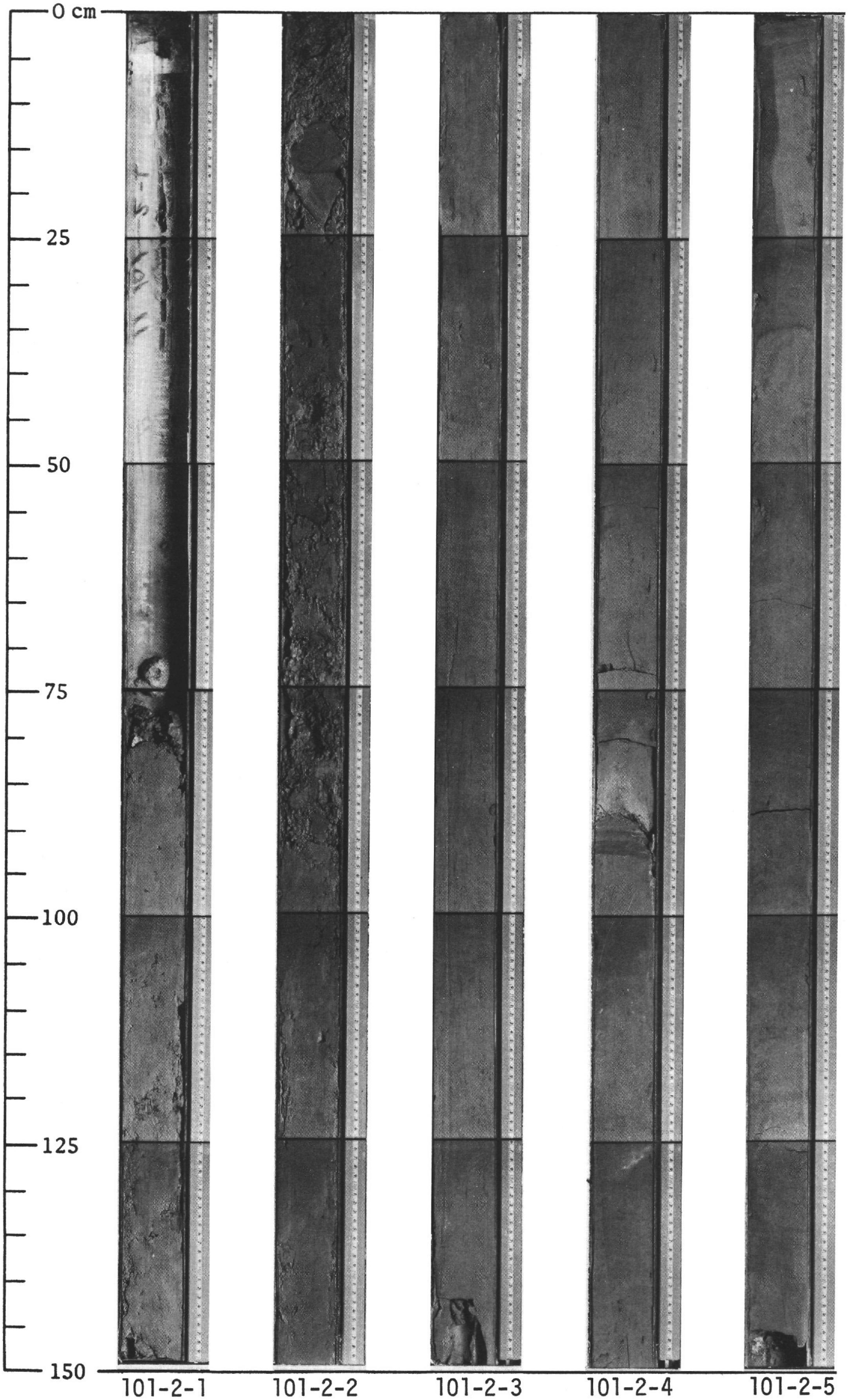
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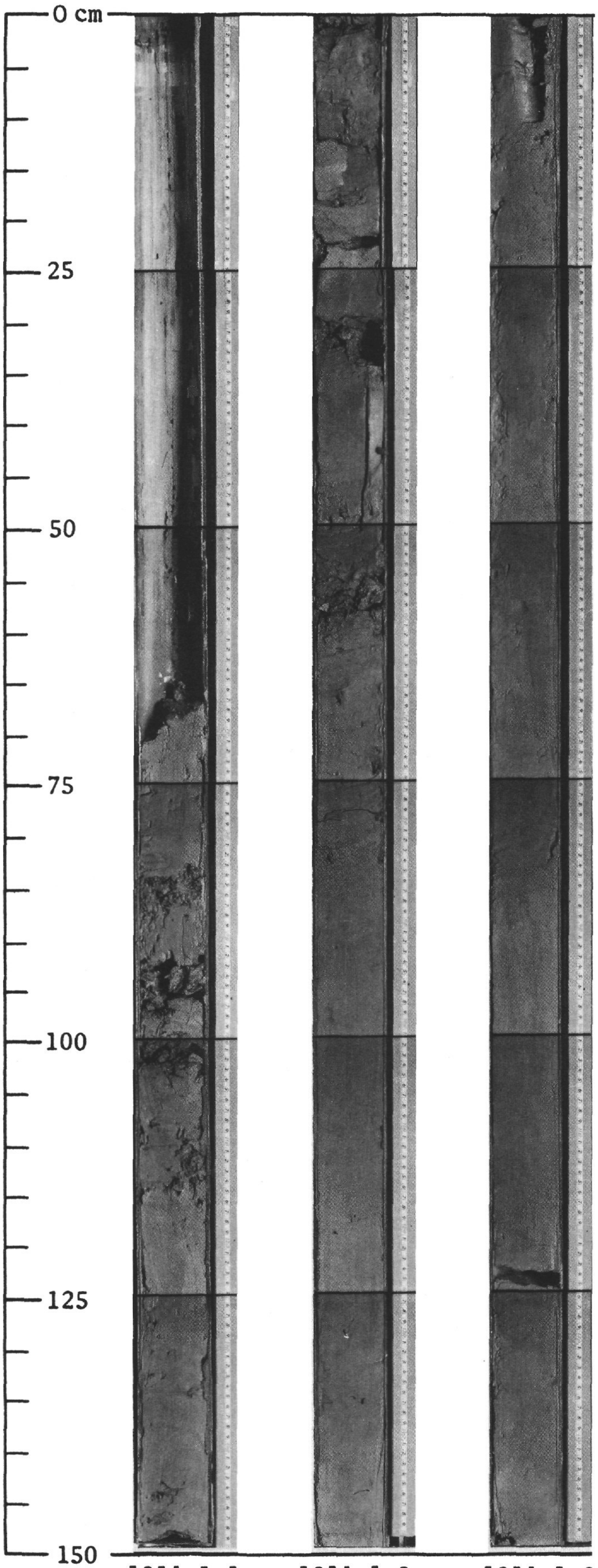
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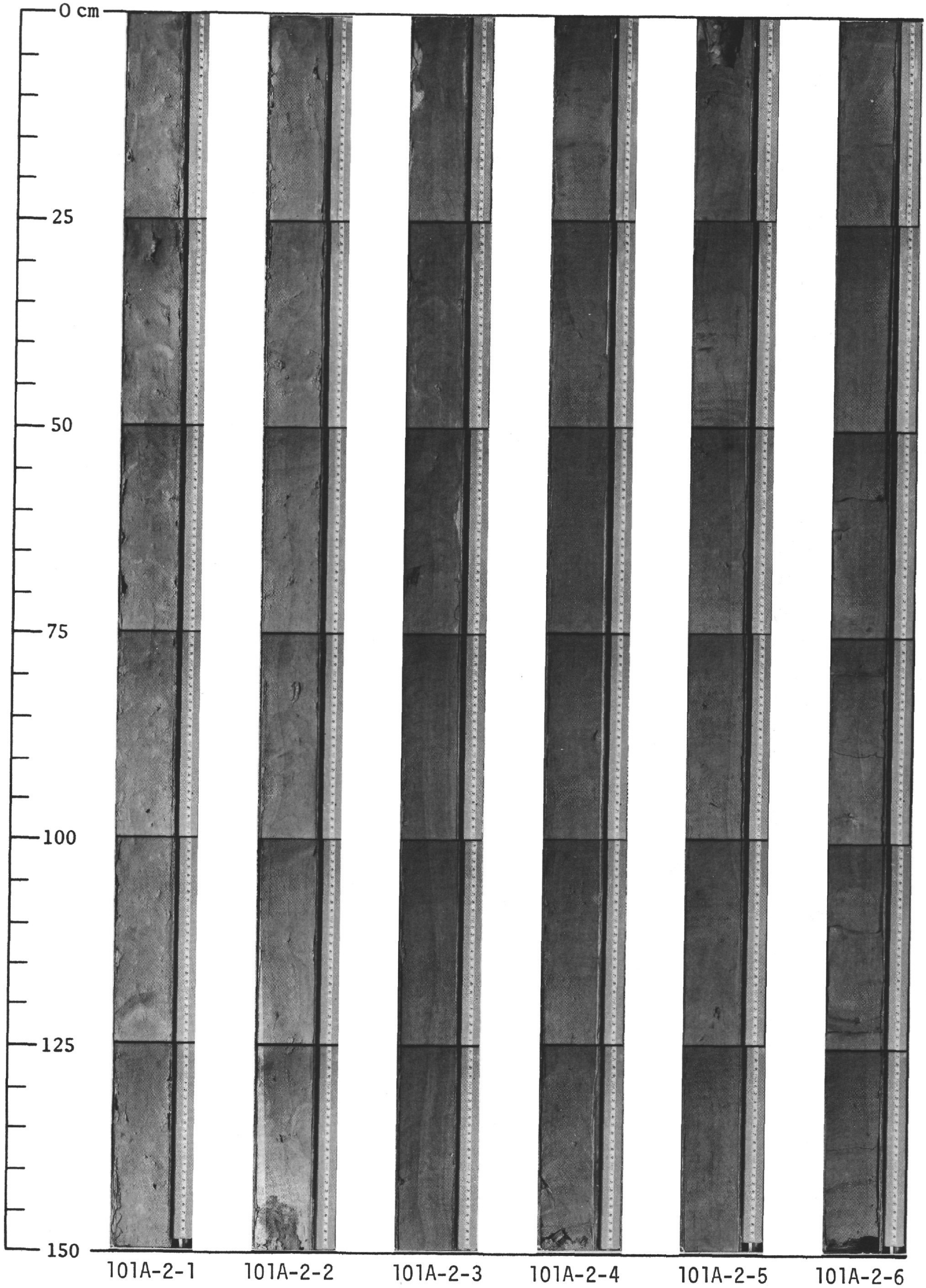
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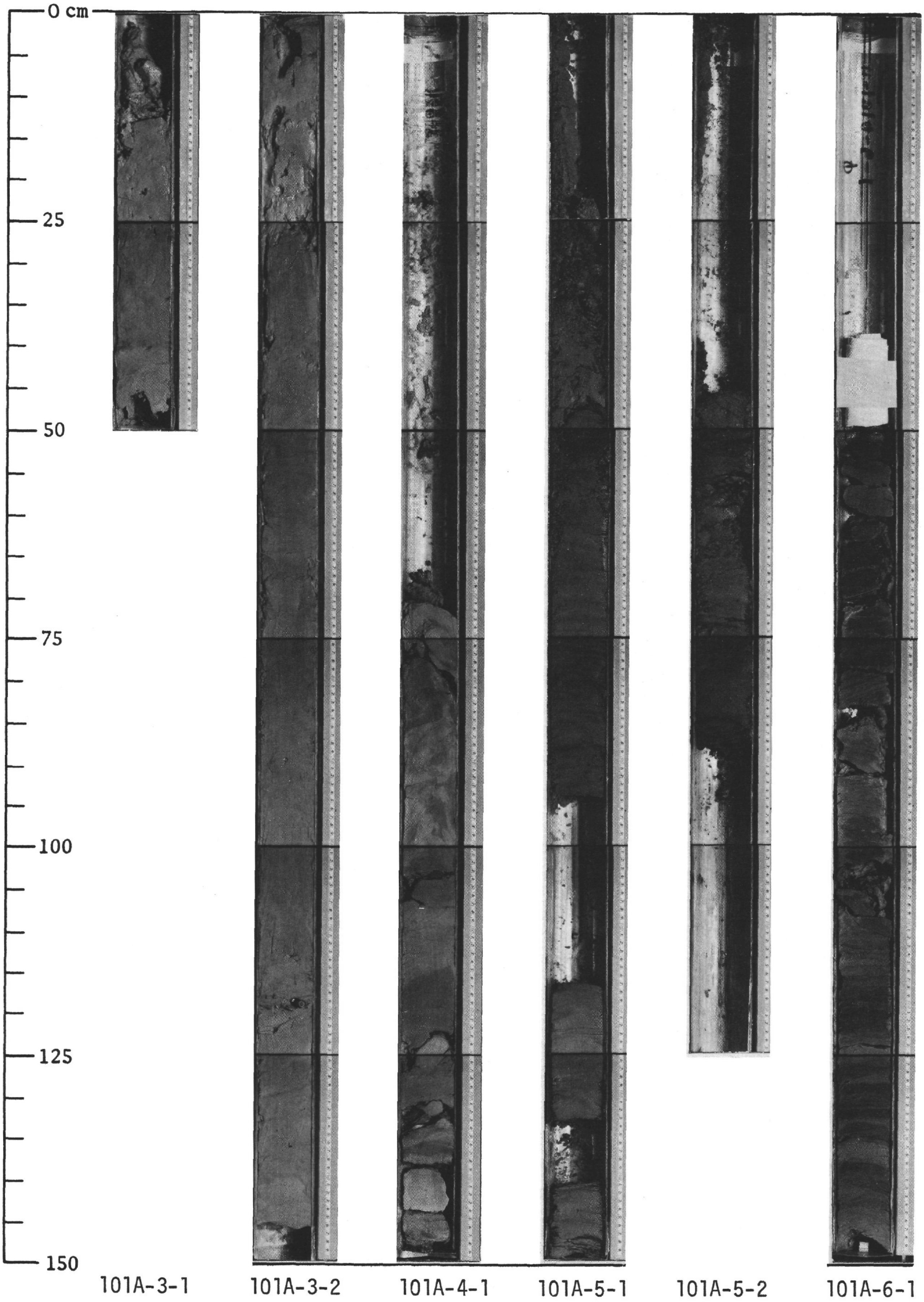
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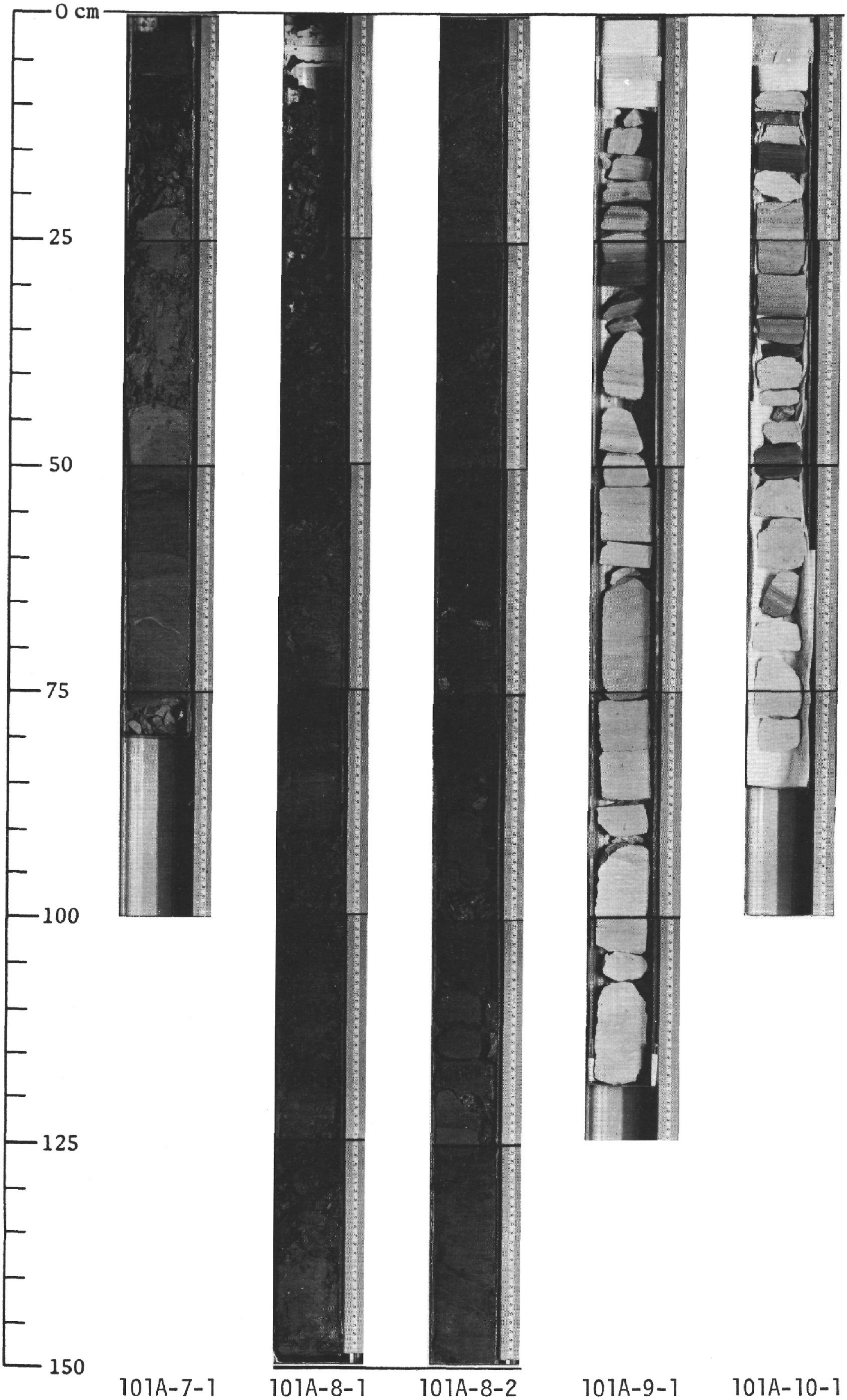
150
101A-3-1
101A-3-2
101A-4-1
101A-5-1
101A-5-2
101A-6-1


0 cm
25
50
75
100
125
150
101A-7-1
101A-8-1
101A-8-2
101A-9-1
101A-10-1