2. SITE 99 – CAT GAP

The Shipboard Scientific Party[1]

INTRODUCTION

The principal objective at this site was the recovery of Mesozoic sediment and a sample of Horizon B (or basement). The location chosen for drilling is about 40 nautical miles southeast of San Salvador (Figures 1a and 1b) in 4914 meters of water. Seismic profiler records indicate that erosion or nondeposition over a region of elevated basement has resulted in an anomalously thin sediment cover. A piston core taken by R/V *Vema* in the vicinity of this site recovered 4 meters of calcareous lutite, sand, and gravel of Miocene age (L. Burckle and T. Saito, personal communication); and traverses connecting this site to the Horizon A outcrop area toward the north indicate that most of the sediment cover at Site 99 is pre-Tertiary. Its thickness varies between 250 and 400 meters (assuming 2.0 km/sec for speed of sound) in the vicinity of the site (Figures 2a and 2d).

The sediment section is moderately to highly stratified and, judging from the results at Hole 4, Leg 1, was not expected to be easy to penetrate (Ewing *et al*, 1969). However, the location of the site in the oldest part of the Atlantic, according to the sea-floor spreading hypothesis and the relatively thin cover of sediment, caused it to receive a high priority in the Leg 11 program. Aside from the possibility of recovering the oldest Atlantic sediment, drilling at this site could be expected to produce interesting samples for comparison stratigraphically and lithologically with those of Holes 4 and 5 of Leg 1.

OPERATIONS

The ship arrived in the vicinity of the site at 0430 hours, 13 April, 1970. A seismic profiler survey was conducted while a new wire line was installed on the coring winch. The ship was stopped on site at 1434 hours; the beacon was released at 1450 hours. Because of a set of about 2 knots, the eventual position of the beacon was somewhat to the north and east of the spot selected, but still well within the area of relatively thin sediment cover. The on-site reflection record is complicated by multiples and is difficult to relate to a specific point along the underway record. Two prominent reflectors occur: one about 0.2, and one about 0.3 seconds reflection time.

The bottom assembly of the drill string touched bottom at 0425 hours on 14 April. The bit (4-cone chert bit) washed in for 19 meters without requiring rotation. From that depth downward, rotation and circulation were used continually. A moderately firm layer containing two or three thin, hard beds was penetrated between 19 and 70 meters. Below that depth alternating layers of soft, medium, and hard sediment were encountered to total depth.

In view of the principal goal of reaching the deepest sediment, the initial plan called for drilling well into the bottom at this site before attempting to core. A later decision was made to core when the bit reached 84 meters below bottom. Drilling had proceeded at an average rate of 10 m/hr to this point (Figure 3). Slower drilling below about 80 meters had raised a question about the condition of the center bit, and the decision was made to pull it and core. While cleaning the hole in preparation for coring, the bit became stuck; and, in the process of freeing it, the string parted at the top of the second-from-bottom bumper sub.

The only sample recovered from Hole 99 consisted of several pieces of mud and cuttings smeared on the drill collar just above the break. These samples were found to contain fossils ranging in age from Pliocene to Senonian.

A second attempt (Hole 99A) was made after a modification to the bottom hole assembly. Three, instead of six, drill collars were used between the upper and the lower bumper subs, and a 3-cone chert bit was used. The second touch-down was made late in the evening on 15 April. Drilling was slow from about 80 meters to well below 100 meters, mainly because of chert (Figure 5), and was moderately slow down to 186 meters, where a thick section of chalk was reached. The chalk was easy to drill but difficult to sample. Extremely difficult drilling was encountered at 232 meters in a sequence of limestone interbedded with red and green layers of firm, muddy limestone. The rate of drilling in this part of the section was as slow as 1 m/hr, but an occasional thin, soft layer was penetrated. The hole terminated in this unit when the core barrel jammed in the drill string and prevented further drilling.

Except for Cores 1 and 2, which were punch cores, recovery was very low. Only chips or smears were brought to the surface in Cores 3, 4, 6, 7, 12 and 13, and recovery was less than 1 meter in several others (Figure 4). None of the major units could be drilled

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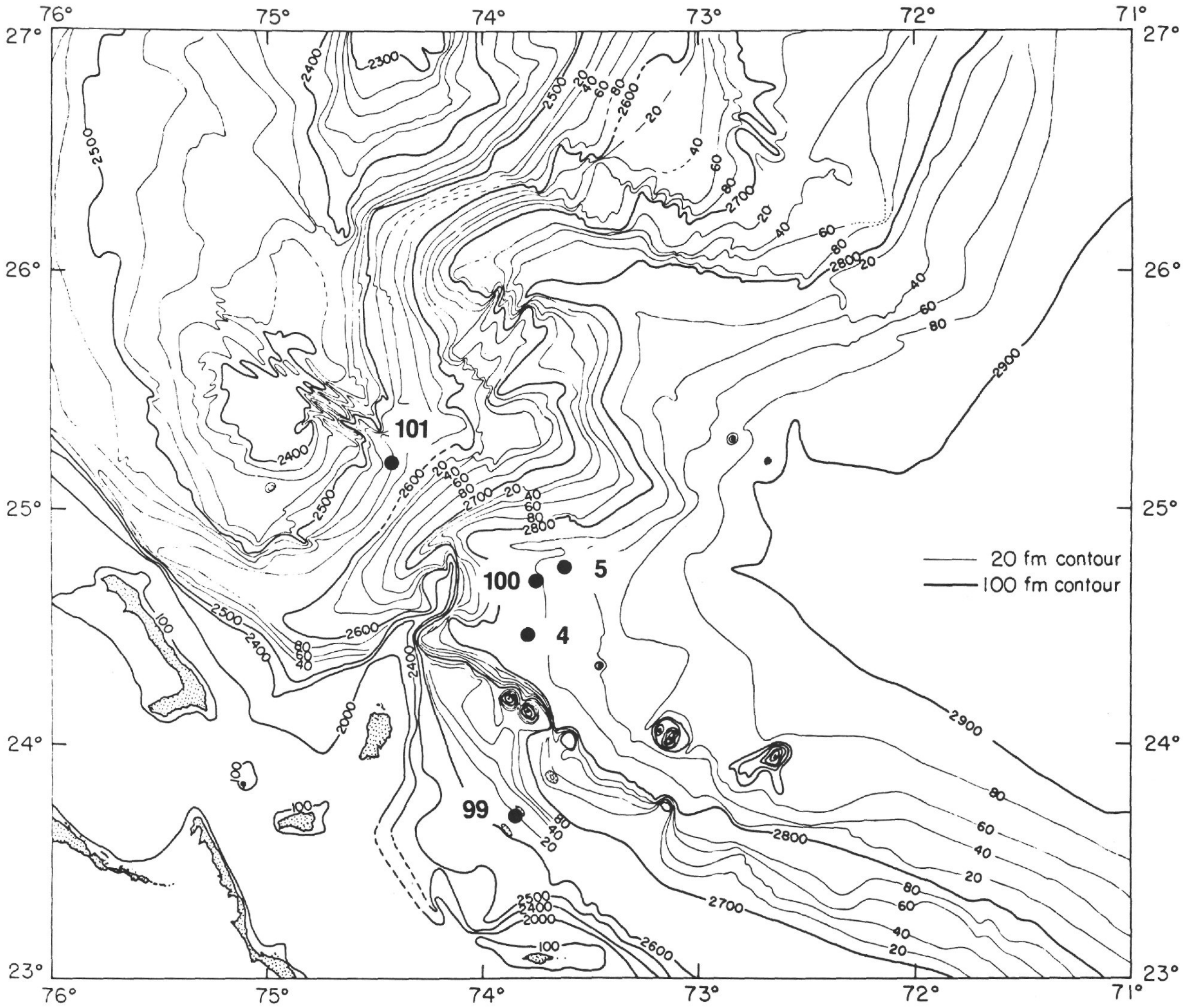

Figure 1a. *Bathymetry of the Cat Gap region (after Ewing,* et al, *1966) with locations of Sites 4, 5, 99, 100 and 101.*

without occasional or continual circulation, which usually washed away most or all of the material except for the hardest.

STRATIGRAPHY

Biostratigraphy

Neogene Foraminifera (Hole 99)

The single sample from this hole contains a mixture of Pliocene to middle Eocene foraminifers, including *Sphaeroidinella dehiscens, Globigerina nepenthes, Lepidocyclina* spp. and *Dictyoconus* sp. The Pliocene specimens show effects of dissolution. The assemblage of larger foraminifers is similar to that reported from near this site by Sachs (1969, *Initial Reports of the Deep Sea Drilling Project, Volume I*, Sites 4 and 5).

Neogene Foraminifera (Hole 99A)

A thin veneer of late Cenozoic sediment is separated from the early Cretaceous by a hiatus. The first sample examined, at 9 meters below the sea bottom (Core 1), contains an early Pleistocene assemblage of planktonic foraminifers characterized by *Globorotalia truncatulinoides, G. tosaensis* and pink *Globigerinoides ruber*. This indicates a level within lower Zone N. 22. Many of the specimens are partially dissolved. Reworked specimens of Eocene *Hantkenina* and Oligocene-Miocene *Lepidocyclina* are also included in the sample (Sachs, 1969).

The core-catcher sample from Core 2 contains the oldest Cenozoic foraminiferal assemblage examined. Here, *Globigerinoides extremus, Globigerina nepenthes, G. praecalida* and *Globoquadrina altispira* place the assemblage in Zone N. 19 of the early Pliocene. As in the

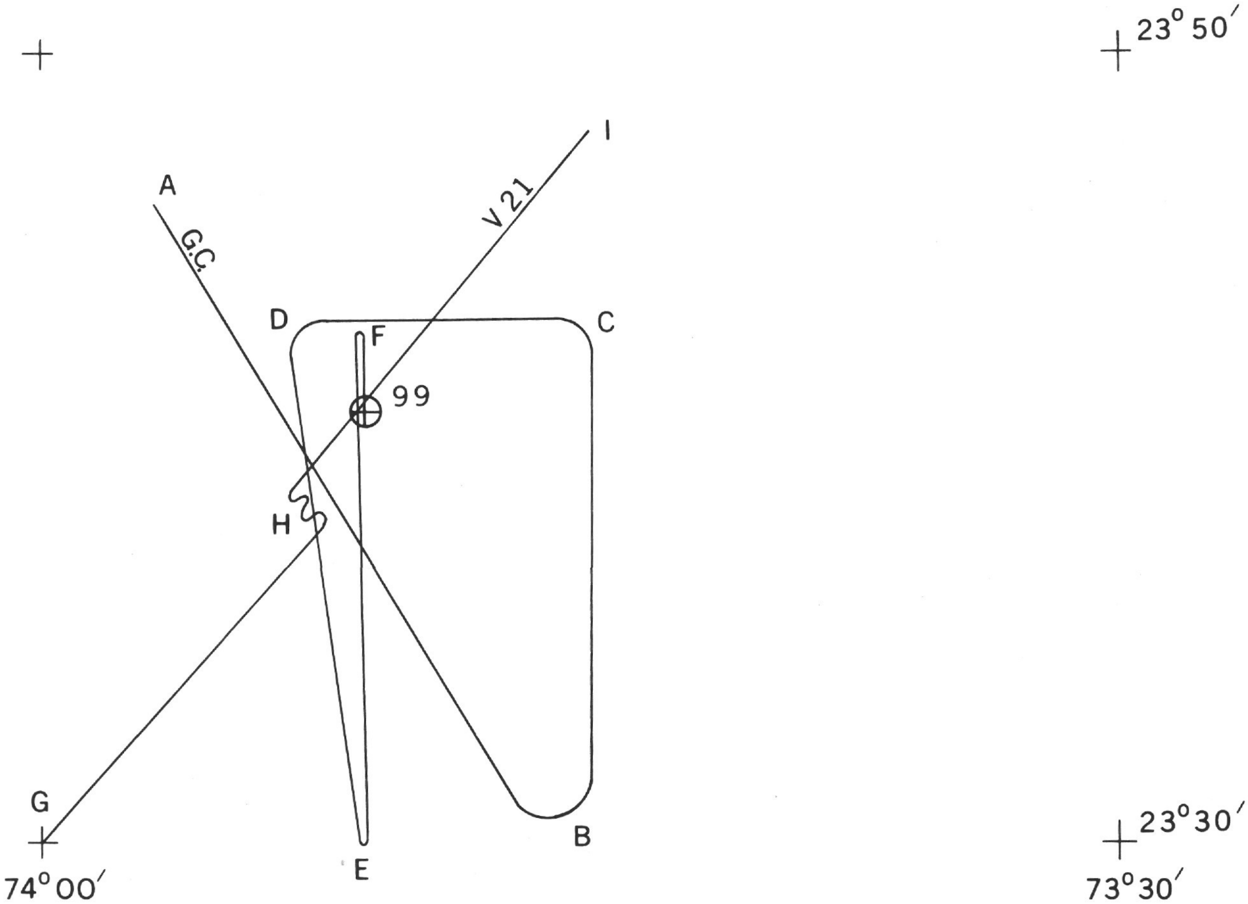

Figure 1b. Glomar Challenger *and R/V* Vema *Survey tracks near Site 99.*

first sample, the specimens show effects of dissolution. Reworked older forms are again present, including *Rotalipora* (Cretaceous), and *Lepidocyclina* and *Miogypsina* (late Eocene - mid-Miocene). Pleistocene and Pliocene species are present as contamination in most of the older samples examined at this site.

Mesozoic (Washed Residues)

Recovery at Hole 99A was very poor. The chips and smears recovered were generally too small to be processed for foraminifera. In addition, most samples were badly contaminated by down-hole cavings originating mainly from the detrital layer which contains Paleocene to early Miocene plankton and larger foraminifera.

The few samples processed are either devoid of foraminifera or contain only rare age-undiagnostic forms. Age determinations are therefore based on other groups of fossils.

Core 14 contains a sparse and poorly preserved foraminiferal faunule with *Spirillina* spp., *Haplophragmoides* sp. and *Bathysiphon* (?) sp., together with a few sponge spicules and holothurian skeletal elements. Indeterminate fragments of aptychi are relatively frequent in Cores 13 and 14. The presence of fragments of *Saccocoma* sp. cf. *S. quenstedti* Sieverts-Doreck (a pelagic crinoid; see chapter by H. Hess in this volume) in the core-catcher of Core 14 allows a tentative correlation with Cores 100-4, 105-37 and 105-38.

The faunal associations in Core 99A-14 indicate a deep-water depositional environment.

Calcareous Nannoplankton

The only sample recovered from Hole 99 contained a mixture of Quaternary, Pliocene, Eocene and Cretaceous nannoplankton; thus, a valid age assignment is not possible.

In Hole 99A, the upper 21 meters (Core 1 and 2) contain a normal sequence of Pleistocene to early Pliocene nannoplankton assemblages. The next two cores (3 and 4) contain, along with scattered occurrences of nannoconids, an early Cretaceous assemblage indicative of the Hauterivian Stage. A small amount of hard limestone, representing all that was recovered in Core 5, is barren of nannoplankton. There is a change in species

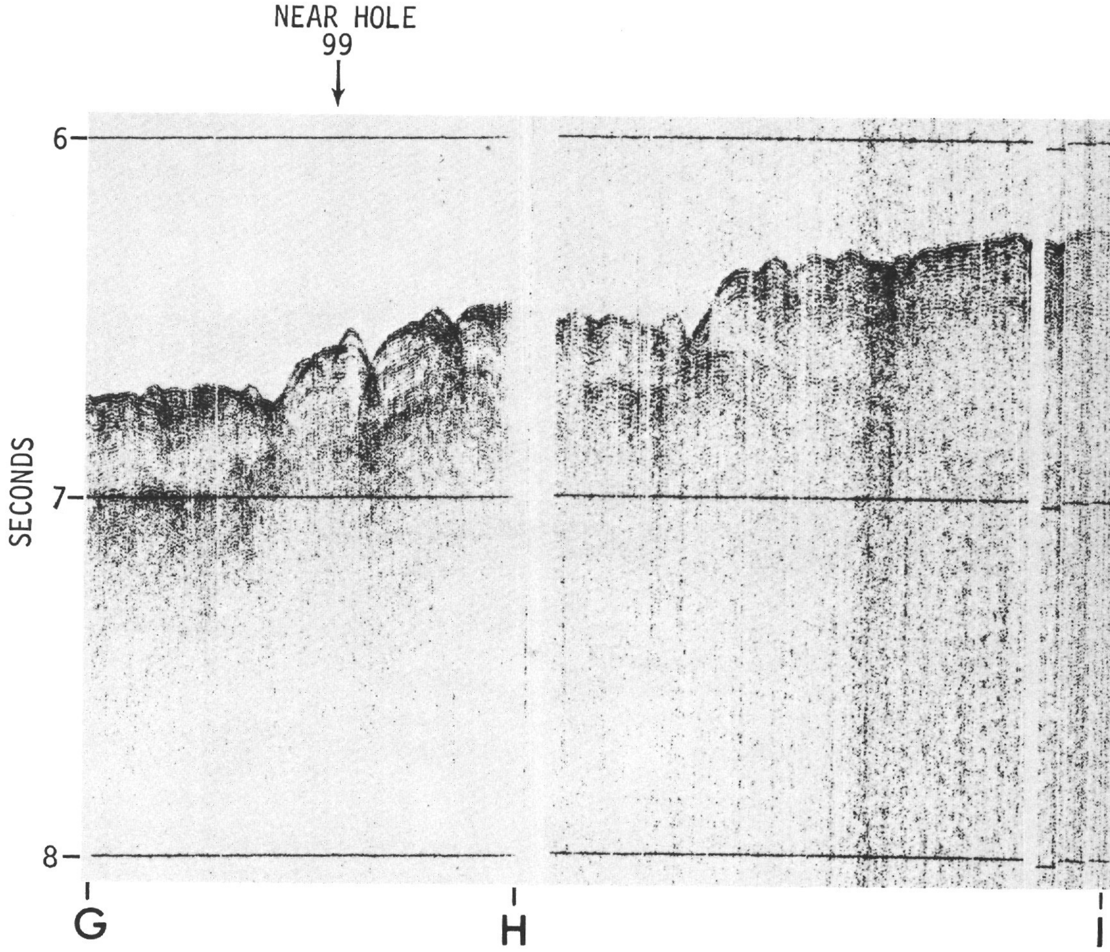

Figure 2a. *Vema 21 Seismic record near Hole 99. See Fig. 1b for track location.*

composition in Cores 6 and 7; rare Tithonian forms occur together with early Cretaceous forms. An early Cretaceous age was assigned to these cores, but a stage definition was not attempted. Cores 8 through 12, which represent approximately 138 meters of section, were assigned to the late Jurassic Tithonian. This age assignment is based on the presence of several reliable indices for that stage including, in Core 9, common tintinnids. Cores 13 and 14 were assigned to the Oxfordian Stage on the basis of the presence of *Cyclagelosphaera margereli* Noel, *Stephanolithion bigoti* Deflandre, *Zygodiscus salillum* (Noel), *Watznaueria britannica* (Stradner) and the absence of nannoconids and *Parhabdolithus embergi* (Noel), which are indicative of a Tithonian or younger age.

Dinoflagellates

Dinoflagellate cysts were examined from Cores 3, 8, 9, 10, 11, 13 and 14 at Hole 99A. Where samples were available, the recovery of these fossils was generally good. Only a few samples were found to be largely barren of cysts. Preservation at this site is good to excellent, especially in nannoplankton ooze lithology where a good proportion of relatively uncompressed cysts was observed.

The core catcher sample of Core 3 contains a diverse assemblage of early Cretaceous species, including *Oligosphaeridium complex* (White), *Hystrichokolpoma ferox* (Deflandre), *Microdinium deflandrei* Millioud, and *Dingodinium cerviculum* Cookson and Eisenack. These species, particularly the latter two, allow a correlation of this assemblage with the dinoflagellate Association D at Site 105 which is Barremian/ Hauterivian age.

Six samples were macerated from Core 8, 9 and 10, and each contains an assemblage which correlates with dinoflagellate Association E at Site 105. Diagnostic species include *Microdinium deflandrei* Millioud var. A, *Scriniodinium (Endoscrinium) campanula* Gocht and *Wallodinium krutzschi* (Alberti) n. comb; these suggest an early Cretaceous age.

The core catcher sample of Core 11 yielded a sparse residue, from which were recovered *Biorbifera*

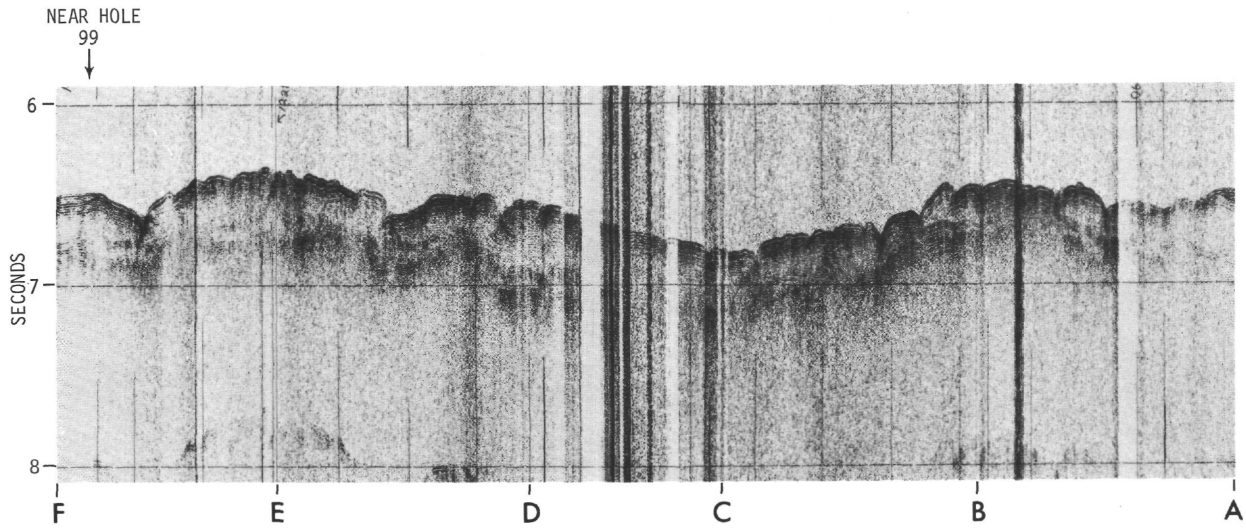

Figure 2b. *Seismic profiler survey in the vicinity of Hole 99. Track is shown in Fig. 1b.*

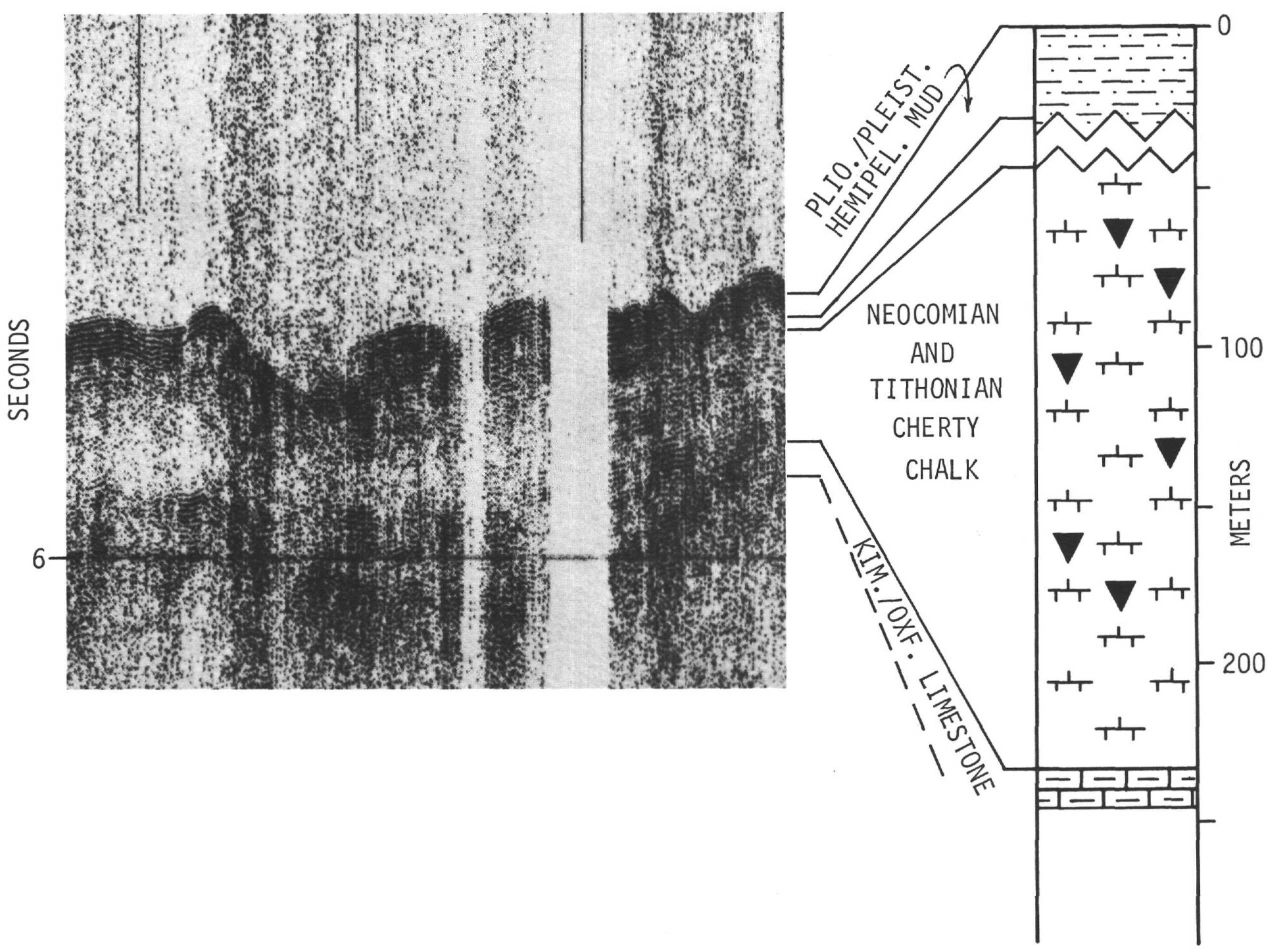

Figure 2c. *Seismic stratigraphy and lithology at Site 99.*

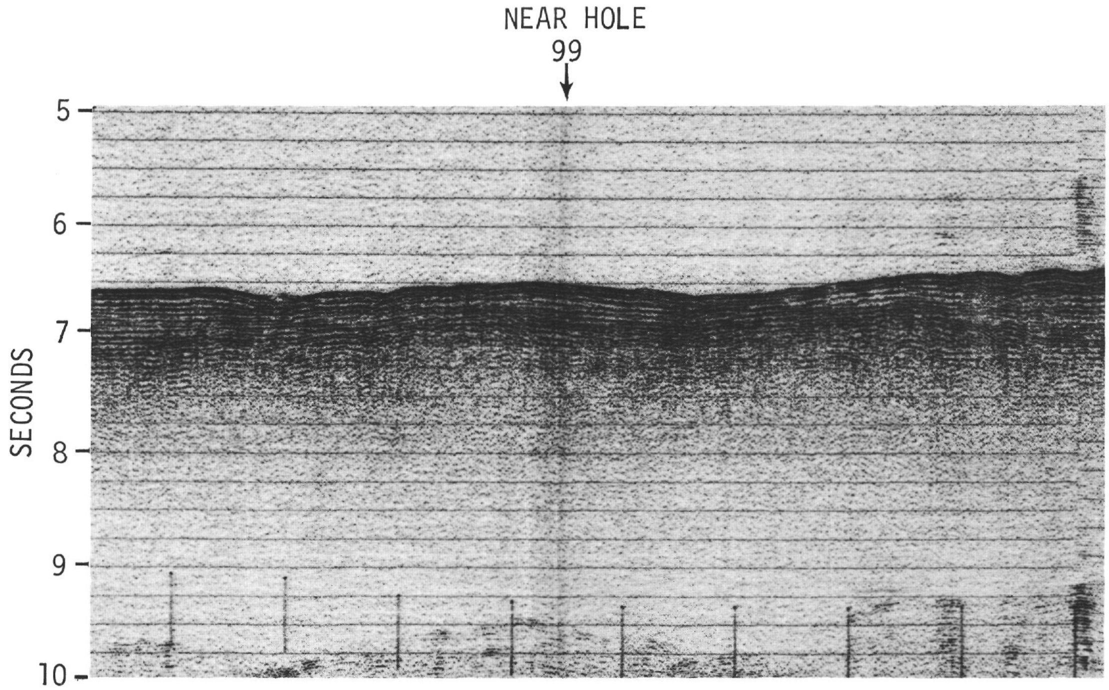

Figure 2d. *R/V* CHAIN *seismic record near Site 99. Track is approximately EF in Fig. 1b.*

johnewingi new genus, new species (one specimen), *Diacanthum hollisteri* new genus, new species, *Scriniodinium (Endoscrinium) dictyotum* Cookson and Eisenback, and *Cometodinium* sp. A. The assemblage is similar to that forming Association F at Site 105, and is probably early Cretaceous or late Jurassic in age.

Samples 99A-13, core catcher and 99A-14-1 (130 to 133 centimeters) are largely devoid of dinoflagellates.

The assemblages observed in Samples 99A-14-2 (24 to 26 centimeters), 99A-14-2 (112 to 114 centimeters), and 99A, core catcher contain a number of age-diagnostic species, including *Gonyaulacysta nuciformis* (Deflandre), *G. scarburghensis* Sarjeant, *Cyclonephelium densebarbatum* Cookson and Eisenack, *Pareodinia ceratophora* Deflandre, *Chlamydophorella wallala* Cookson and Eisenack, *Chytroeisphaeridia pococki* Sarjeant and *Tenua verrucosa* Sarjeant. These species suggest an Oxfordian or Kimmeridgian age, and correspond to Association H at Site 105.

Rate of Sediment Accumulation

The accuracy of the calculated Mesozoic sediment accumulation rate at this site is severely limited by imprecise dates for the included stages. Cenozoic accumulation rates were not calculated owing to sparsity of data. The 45×10^6 years of Jurassic time were equally divided among the late, middle and early series. Based on this assumption, the gross accumulation rate for the early Cretaceous–late Jurassic (Hauterivian-Oxfordian) is 0.6 cm/1000 yr.

Lithology

Most of the sediments recovered from Hole 99A are calcareous nannoplankton oozes and chalks with interbedded chert layers (Figure 5). Upper layers (Pleistocene and Pliocene) contains terrigenous material—mainly clay minerals, quartz and mica—and benthonic as well as planktonic foraminifera.

Quaternary-Neogene Hemi-Pelagic Ooze

The Pleistocene (Cores 1 and 2) brown, clayey ooze consists of nannoplankton, primarily coccolithid forms, and common to abundant clay minerals. Planktonic foraminifera are very abundant and large (sand-sized); benthonic species were observed to be common in the coarse fraction.

Aragonite needles, dolomite rhombs, sponge spicules and radiolarians are regularly present, and sand and silt-sized quartz is common throughout.

The very top of Core 1 contains abundant clay minerals, quartz, micas, and feldspars. Nannoplankton and foraminifera increase in abundance rapidly with depth; they are abundant to dominant below 40 centimeters.

Terrigenous constituents are important in Section 3 of Core 1, where clay minerals and quartz abound.

The coarse fraction consists of planktonic foraminifera, calcareous rock fragments, large benthonic foraminifera, sponge spicules and iron-manganese micronodules.

All large fragments are well rounded. The coarse fraction of the core-catcher sample contains sparry calcite and aggregates of large (sand-sized) dolomite rhombs.

No sharp distinction between Pleistocene and Pliocene sediments can be made through smear-slide examination. However, a slight change in lithology occurs in Core 2, Section 5. Foraminifera which were abundant in the upper part of the core become very rare, while nannoplankton – mainly coccolithid forms – become dominant. Discoasters are common. Other components remain the same. Clay minerals are common; quartz, sparry calcite and aragonite needles are rare.

Neocomian-Tithonian Carbonate Ooze

Thin section and smear slide examinations were performed on corecatcher samples only. The core catcher of Core 3 contains chert and calcilutite. The chert consists of quartz which appears to be a replacement of the nannoplankton. Few radiolarians were observed although one very well-preserved form, completely replaced by iron oxide, was seen. Calcilutite appears to be exclusively composed of recrystallized nanno-calcite.

A slide made from fluid mud recovered from the core catcher of Core 4 contains very few nannoplankton and numerous silt-sized grains of barite—the latter being contamination from drilling mud.

The core catcher of Core 5 contains fragments of calcilutite (recrystallized nanno-calcite).

The core catcher of Core 6 (early Cretaceous) provided a small chert fragment and some mud containing uphole material, including large foraminifera, quartz, micas and clay minerals. In addition, barite grains from drilling mud were seen. Nannoplankton (including coccolithid forms) recrystallized nanno-calcite and pieces of limestone dominate the carbonate material. Pyrite is also abundant. The core catcher samples of Cores 6 and 7 consist mainly of downhole contamination, including dolomite, quartz and clay minerals. Coccolithid forms are common.

Cores 8, 9, 10 and 11 are dominated by recrystallized nanno-calcite with rare glauconite (top of Core 8), quartz, sparry calcite, chert fragments, and grains of pyrite. Pyrite and clay minerals are abundant near the bottom of Core 8. Coccolithid forms are usually common; however, they are rare in soft layers of Core 9, Section 1, and abundant in clay-rich layers toward the bottom of this section.

At the bottom of Core 9 a fragment of hard calcilutite – consisting of recrystallized nanno-calcite, with sand-sized fragments of nannoplankton chalk, and rare microscopic fragments of calcilutite – was seen. Insoluble residues consist of spherules of disordered cristobalite. The core catcher sample of Core 9 provided fragments of chert and nannoplankton chalk with recrystallized nanno-calcite and clay minerals. The sample contains grains of pyrite and radiolarian fragments replaced by pyrite. A few small spherical particles composed of isotropic silica were seen. A thin section of a large chert fragment revealed nannoplankton chalk grading to isotropic silica and quartzose chert, with some cloudy areas of abundant spherules of isotropic silica (diameter approximately 5 microns).

Samples from Cores 10 and 11 contain sand and silt-sized fragments of chalk and quartzose chert, and some spherical chert pieces. Dark laminae from the core catcher sample of Core 11 contain commonly occurring pyrite grains.

Red Clayey Oxfordian; Kimmeridgian Limestone

The core catcher sample of Core 12 contains a calcilutite that is red-colored at the top and green and white toward the bottom. The red layer contains abundant clay minerals, sand, silt and clay-sized sparry particles, coccolithid forms, rare oolites, and hematite grains. The white and green bands contain silt-sized calcite fragments, some sparry calcite, and abundant nannoplankton. Pyrite is common and clay minerals are rare.

The core catcher sample of Core 13 consists of red and white limestone. The layers consist of small calcite grains, large (60 microns) sparry calcite grains, a few clay minerals, hematite, and coccolithid forms. The white layers, on the other hand, lack clay minerals and hematite.

In Core 14, quartz and clay minerals, as well as nannoplankton (primarily coccolithid forms), are abundant throughout. The green layers are rich in carbonaceous material. Some plant debris was observed. The red layers contain iron oxide. Toward the bottom of the core, nannoplankton and silt-sized quartz dominate. Micas are rare to common throughout. The core catcher sample consists of recrystallized nanno-calcite. Silt-sized calcite grains, sometimes aggregated (sand-sized), are abundant.

Sample from Drill Bit (Depth about 5189 meters – bottom of hole)

This sample of firm, red, clayey ooze consists of clay minerals and quartz; coccolithid forms and recrystallized nanno-calcite are abundant, and hematite and iron oxide, as well as sparry calcite, are common.

Lithologic Summary

The oldest sediments at Hole 99A range from white, pale red and greenish-gray, indurated or partially indurated limestone and stiff red clayey oozes of late

Jurassic (Kimmeridgian-Oxfordian) age through white or light gray (Tithonian) chalks, nannoplankton oozes and chert. One Tithonian sample contains abundant dolomite rhombs and clay minerals, and is stained with limonite. Poor recovery of material from cores taken in the sediments of Cretaceous age precludes an accurate description of these materials. A loose gravel of drill cuttings, which contains chips of chert, small pieces of hard chalk, sparry calcite, and large and small pieces of calcareous fossils, suggests that thin chert zones, loosely cemented calcarenites and calcirudites, and nannoplankton chalks constitute much of the section. The interval between sediments of early Cretaceous and Pliocene ages was not cored. Pliocene sediments recovered are light yellowish-brown, slightly clayey, foraminiferal-nannoplankton oozes. Silica in brown chert fragments at the base of this section is composed entirely of quartz. Clay minerals and lesser amounts of other detrital minerals increase in abundance upward in Quaternary sediments to a maximum of about 60 percent in the topmost sediments of the hole. Two nodules of limonite with a black surface coating (manganese oxide ?) were found near the top of the highest core.

Coccolithid forms are the principal component of the sediments throughout the section. They are often recrystallized to irregularly shaped calcite grains in many partially indurated chalks and replaced by silica in chert. Radiolarians are rare in the sediments from this hole. One sample of chalk contains numerous spherical molds of radiolarians; many of the molds are empty, but some are lined with pyrite. One thin section of chert contains a radiolarian that has been completely replaced by iron oxide. Thus, radiolarians may have been more abundant in the original sediment, but they have been dissolved, and the silica has migrated to replace calcareous material elsewhere to form chert or partially silicified chalk. No volcanic ash or zeolites were observed.

DISCUSSION AND CONCLUSIONS

Late Jurassic sediment which contains plant fragments, clay minerals, hematite, and quartz in brick-red laminated muddy limestone was cored at Site 99. The relative abundance of terrigenous components suggests a source other than the Bahama platform, which is relatively close. They might have been transported into the area from the north. There is evidence of bottom water stagnation in the Oxfordian sediments. Near the bottom of the hole horizontal layers of finely laminated, dark gray material are present. Benthic foraminifera are absent in these laminae but are present in the sediments immediately above and below.

The early Cretaceous sediments at Site 99 are principally cherty oozes, chalk, and shallow, warm-water carbonate debris, suggesting "normal" pelagic deposition above the carbonate compensation depth, with periodic inflowing of fore-reef material from the nearby Bahama platform.

Massive erosion, or nondeposition, occurred during the time between early Cretaceous and late Tertiary. Middle Pliocene sediment was recovered 21 meters below bottom, followed by the recovery of early Cretaceous sediments in the next core at only 53 meters below bottom. The hiatus indicated in Figure 3 cannot be definitely established because of the unsampled interval between these two cores. Some pre-Pliocene Tertiary material must be present, as evidenced by the recovery of Miocene sediment in a *Vema* piston core.

During the Pleistocene, terrigenous material was again deposited in the area and probably transported not more than 200 to 300 miles from the source area. After the last influx of terrigenous material, sediment deposition has been "normal" pelagic and hemipelagic to the present. The pre-Recent deposits are characterized by a thick layer with abundant larger foraminifera.

The site was chosen on the basis of the V-21 record shown in Figure 2a. However, satellite navigation was not available for that cruise, so we cannot be certain about the position of the site in relation to the seismic data. The arrow indicates the position on the V-21 track that coincides with the *Glomar Challenger* satellite fix at the site. The water depth at this point on the V-21 track is the same as that measured at the drilling site.

Figure 2b shows the record made by *Glomar Challenger* before Hole 99 was drilled. Figure 2c shows the record made after the drilling as the ship passed over the beacon, and also indicates our interpretation of the lithologic and seismic data. The deepest reflector apparently rises to approximately 6.80 seconds total reflection time (0.30 seconds below bottom) at the site. There is a shallower reflector that apparently rises in the vicinity of the site to about 0.24 seconds subbottom.

The third set of data was recorded by R/V *Chain* during a passage through the area after the drilling. The record over the site, supplied through the courtesy of E. Uchupi of the Woods Hole Oceanographic Institution, is shown in Figure 2d. Satellite navigation was used and indicates that the ship passed very near the site on a course of 180°, approximately along track EF of *Glomar Challenger* (Figure 1b). At the indicated location of the drilling site, two subbottom reflecting interfaces can be identified with reasonable certainty, one at about 0.24 seconds and another at about 0.30 seconds below the sea floor.

The drilling rate graph shows appreciable variation, due in large part to chert layers; but, there is a principal change at about 235 meters that correlates well with a major lithologic change from marl and chalk to a hard limestone. We judge this drilling break and change in lithology to correspond to the reflector that is observed about 0.1 second above the deepest one. If this interpretation is correct, it seems likely that the deeper reflector (basement ?) would have been reached with a few more tens of meters drilling. Unfortunately, the core barrel stuck in the drill string about half way to bottom after Core 14, and the hole had to be abandoned.

If the correlation of seismic and drilling data shown in Figure 2c is correct, the average speed of sound in the upper 235 meters is 1.96 km/sec. However, the interpretation of the seismic data is not very certain, and the average velocity of this interval could be as high as 2.15 km/sec.

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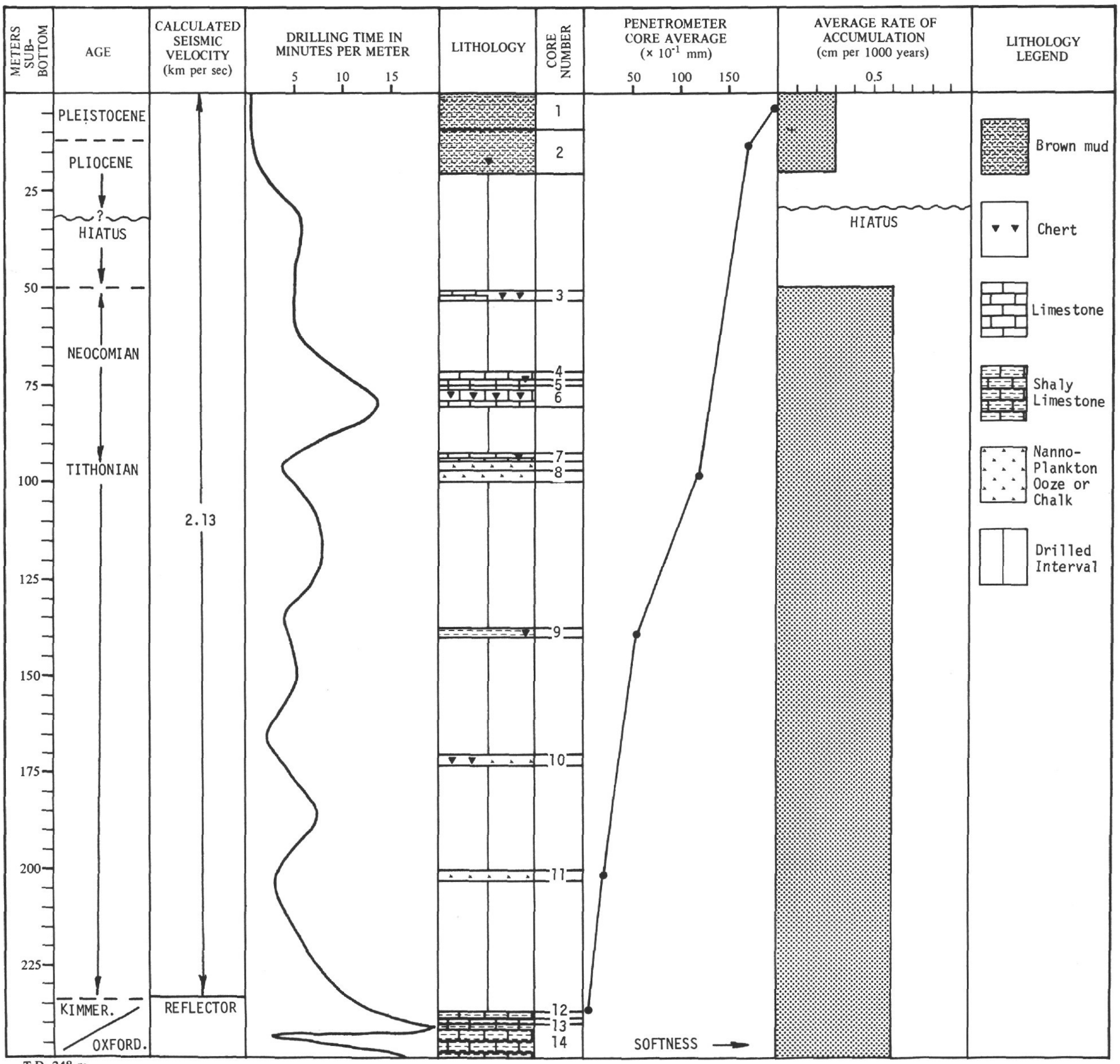


Figure 3. *Site 99 summary chart*

Hole 99A
Latitude: 23°41.14′N
Longitude: 73°50.99W
Water depth: 4914 meters (drill pipe); 4922 (PDR)

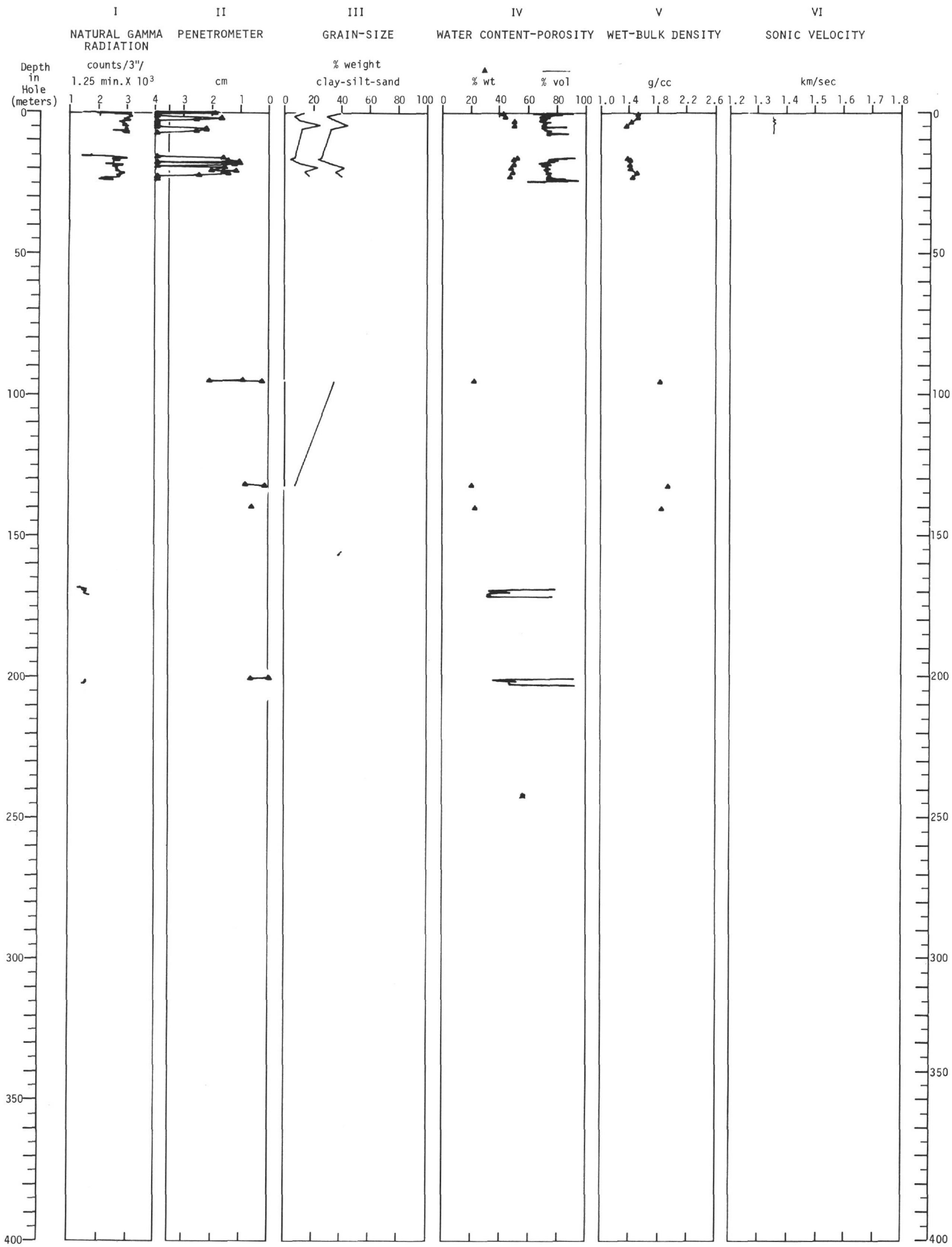
Core No.	Interval Cored (meters)[a]				Lithology	Age		
	Depth	Amount	Recovery	Subbottom Depth		Foraminifera	Nannoplankton	Dinoflagellates
1	4924-4933	9	7.5	9	Brown clay and foram-nannoplankton ooze	← Quaternary →		
(Drilled)	4933-4939	(6)		(15)				
2	4939-4945	6	9	21	Foram-nannoplankton ooze	Early Pliocene	Middle Pliocene	
(Drilled)	(4945-4968)	(23)		(44)				
3	4968-4977	9	0.08	53	Chert and limestone		← Early Cretaceous →	
(Drilled)	(4977-4996)	(19)		(72)				
4	4996-4998	2	0.01	74	Chert		Early Cretaceous	
5	4998-4999	1	1	75	Chert and limestone (drill cuttings)			
6	4999-5005	6	<0.01	81	Chert (drill cuttings)		Early Cretaceous	
(Drilled)	(5005-5009)	(4)		(85)				
7	5009-5018	9	<0.01	94			Early Cretaceous	

Figure 4. *Core Summary table, Site 99*

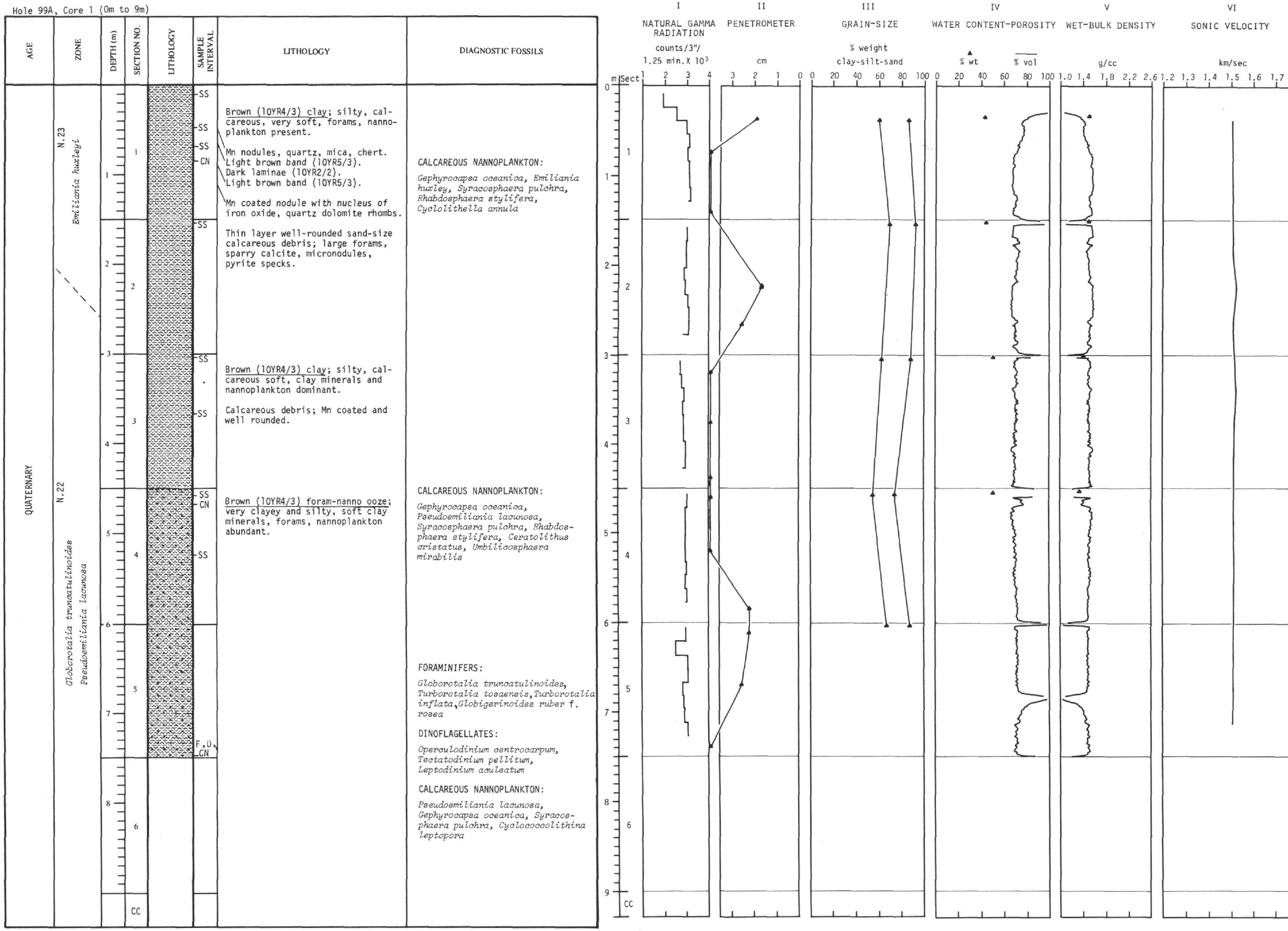
Core No.	Interval Cored (meters)[a]				Lithology	Age		
		Amount	Recovery	Subbottom Depth		Foraminifera	Nannoplankton	Dinoflagellates
8	5018-5024	6	3	100	Nannoplankton ooze		Late Jurassic	Early Cretaceous
(Drilled)	(5024-5055)	(31)		(131)				
9	5055-5064	9	1	140	Nannoplankton ooze and Carbonaceous clay		Late Jurassic	Early Cretaceous
(Drilled)	5064-5092	(28)		(168)				
10	5092-5097	5	2.6	173	Cherty and limestone (drill cuttings)		Late Jurassic	Early Cretaceous
(Drilled)	5097-5122	(25)		(198)				
11	5122-5126	4	2	202	Hard chalk		Late Jurassic	Early Cretaceous
(Drilled)	5126-5159	(33)		(235)	(Very hard layer at 5156 meters)			
12	5159-5162	3	0.1	238	Clayey red limestone		Late Jurassic	
13	5162-5163	1	0.16	239	Clayey red limestone	← Late Jurassic →		
14	5163-5172	9	1.8	248	Clayey red limestone	← Late Jurassic →		

[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 99* (Cont)

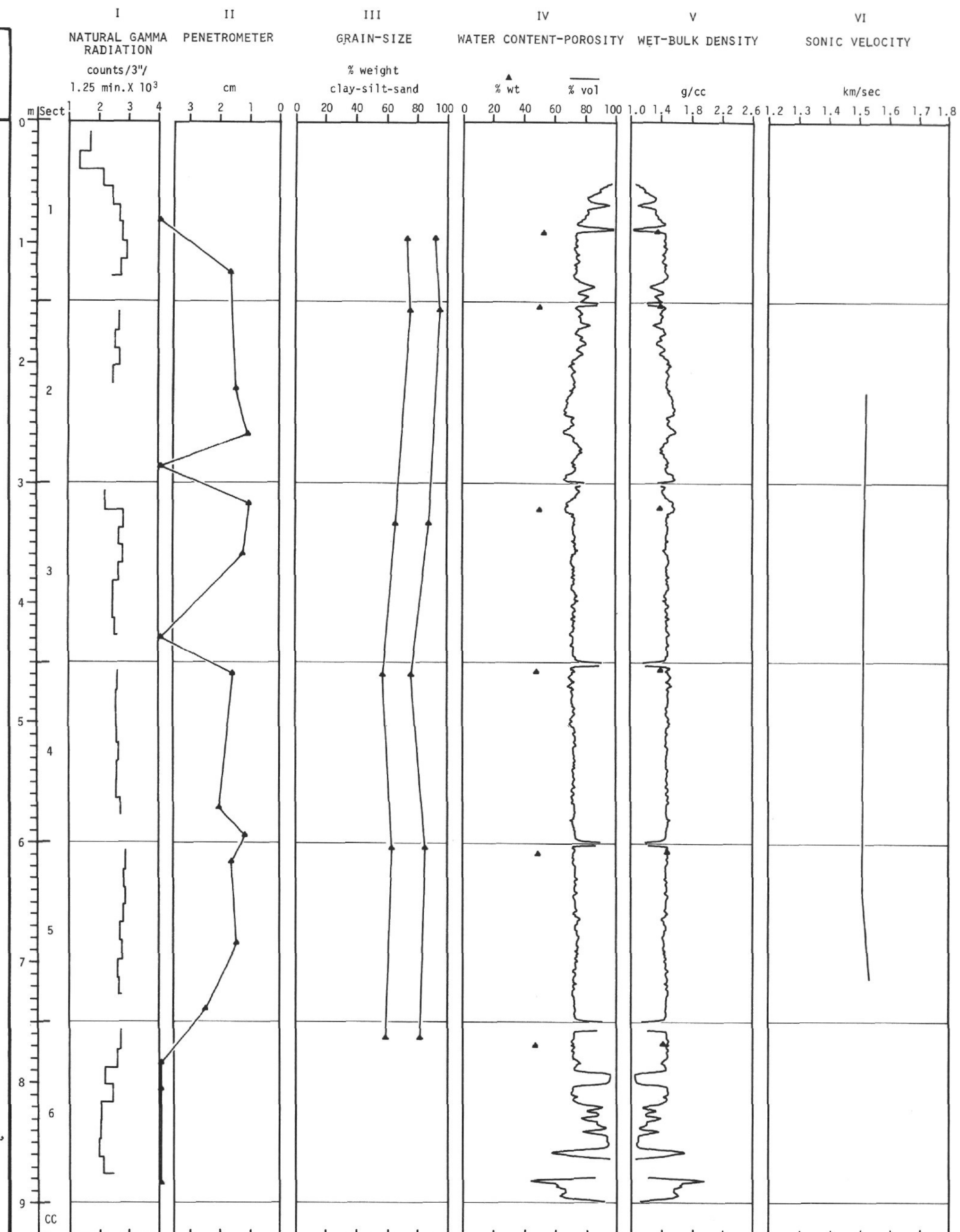


Summary of Physical Properties, Hole 99A


Hole 99A, Core 1 (0m to 9m)
AGE
ZONE
DEPTH (m)
SECTION NO.
LITHOLOGY
SAMPLE INTERVAL
LITHOLOGY
DIAGNOSTIC FOSSILS
QUATERNARY
N.23
Emiliania huxleyi
N.22
Globorotalia truncatulinoides
Pseudoemiliania lacunosa
CC
SS
CN
F, D, CN
Brown (10YR4/3) clay; silty, calcareous, very soft, forams, nannoplankton present.
Mn nodules, quartz, mica, chert.
Light brown band (10YR5/3).
Dark laminae (10YR2/2).
Light brown band (10YR5/3).
Mn coated nodule with nucleus of iron oxide, quartz dolomite rhombs.
Thin layer well-rounded sand-size calcareous debris; large forams, sparry calcite, micronodules, pyrite specks.
Brown (10YR4/3) clay; silty, calcareous soft, clay minerals and nannoplankton dominant.
Calcareous debris; Mn coated and well rounded.
Brown (10YR4/3) foram-nanno ooze; very clayey and silty, soft clay minerals, forams, nannoplankton abundant.
CALCAREOUS NANNOPLANKTON:
Gephyrocapsa oceanica, Emiliania huxley, Syracosphaera pulchra, Rhabdosphaera stylifera, Cyclolithella annula
CALCAREOUS NANNOPLANKTON:
Gephyrocapsa oceanica, Pseudoemiliania lacunosa, Syracosphaera pulchra, Rhabdosphaera stylifera, Ceratolithus cristatus, Umbilicosphaera mirabilis
FORAMINIFERS:
Globorotalia truncatulinoides, Turborotalia tosaensis, Turborotalia inflata, Globigerinoides ruber f. rosea
DINOFLAGELLATES:
Operculodinium centrocarpum, Tectatodinium pellitum, Leptodinium aculeatum
CALCAREOUS NANNOPLANKTON:
Pseudoemiliania lacunosa, Gephyrocapsa oceanica, Syracosphaera pulchra, Cyclococcolithina leptopora
m
Sect
I
NATURAL GAMMA RADIATION
counts/3"/ 1.25 min. X 10³
II
PENETROMETER
cm
III
GRAIN-SIZE
% weight
clay-silt-sand
IV
WATER CONTENT-POROSITY
% wt
% vol
V
WET-BULK DENSITY
g/cc
VI
SONIC VELOCITY
km/sec

Hole 99A, Core 2 (15m to 21m)

AGE	ZONE	DEPTH (m)	SECTION NO.	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
PLIOCENE	N.19 *Sphaeroidinella dehiscens/ Globoquadrina altispira* *Reticulofenestra pseudoumbilica*	0–1.5	1	SS	Foram-nanno ooze; clayey, soft, yellowish brown (10YR5/4), some darker mottling, nannoplankton dominant.	
		1.5–3	2	SS, CN	Pale brown (10YR6/3) with dark brown (10YR3/1) streaks.	CALCAREOUS NANNOPLANKTON: *Discoaster browweri, D. asymmetricus, D. surculus, Cyclococcolithina macintyrei, Pseudoemiliania lacunosa, Ceratolithus rugosus, Reticulofenestra pseudoumbilica*
					Coarse calcareous particles, large forams.	
				SS	Cream white (10YR2/2) layer.	
					White (10YR8/1) patches.	
		3–4.5	3	SS	White (10YR8/2) layer.	
					Yellowish brown (10YR5/4) layer. Thin foram layer. Brown (10YR4/3).	
					Top of silty zone.	
					Large forams.	
		4.5–6	4	SS	Foram-nanno ooze; clayey, soft, light yellowish brown (10YR6/4) with lighter streaks, clay minerals stained with iron oxide, nannoplankton and forams abundant.	
		6–7.5	5	SS		
				SS, SS	Dark gray (N3) layer, nannoplankton dominant.	*CORE CATCHER*
		7.5–9	6		Brown (10YR3/2) chert, quartzose.	FORAMINIFERS: *Globoquadrina altispira, Globigerina nepenthes, Sphaeroidinellopsis subdehiscens, S. seminulina, Globigerinoides extremus*
					Brown (10YR3/2) chert, quartzose.	CALCAREOUS NANNOPLANKTON: *Discoaster asymmetricus, D. browweri, Reticulofenestra pseudoumbilica, Sphenolithus abies, Ceratolithus rugosus*
		9–	CC	F, CN, D		DINOFLAGELLATES: *Achomosphaera ramulifera*



Hole 99A, Core 3 (44m to 53m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY CRETACEOUS (BARREMIAN-HAUTERIVIAN)			CC	▲	SS SS SS CN,D	Core catcher sample only: Chips of quartzose chert and hard limestone. Thin section of chert: quartz replacement of nannoplankton ooze; few radiolarians, one of which is well preserved by replacement with iron oxide. Thin section of hard limestone: dominantly recrystallized nannoplankton, no forams or whole nannoplankton.	DINOFLAGELLATES: *Dingodinium cerviculum, Microdinium deflandrei, Oligosphaeridium complex, Hystrichokolpoma ferox* CALCAREOUS NANNOPLANKTON: *Apertapetra gronosa, Braarudosphaera discula, Lithastrinus septentrionalis, Micrantholithus obtusus, Nannoconus colomi, N. bucheri, N. steinmanni*

Hole 99A, Core 4 (72m to 74m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY CRETACEOUS (HAUTERIVIAN)			CC	▲ ▲ ▲	SS CN	Core catcher sample only: Chips of quartzose chert in mud, silt size barite contamination from drilling mud, observed in smear slide.	CALCAREOUS NANNOPLANKTON: *Parhabdolithus embergeri, Watznaueria barnesae, Braarudosphaera discula, Nannoconus* cf. *N. bucheri*

Hole 99A, Core 5 (74m to 75m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
		1	1			Drill cuttings: Chert, limestone, chalk, and large forams. Section 2 not opened, but appears similar to Section 1.	
		2	2	Drill cuttings			
			CC		SS	Core Catcher: Limestone, hard, recrystallized, nanno-calcite dominant.	

Hole 99A, Core 6 (75m to 81m)

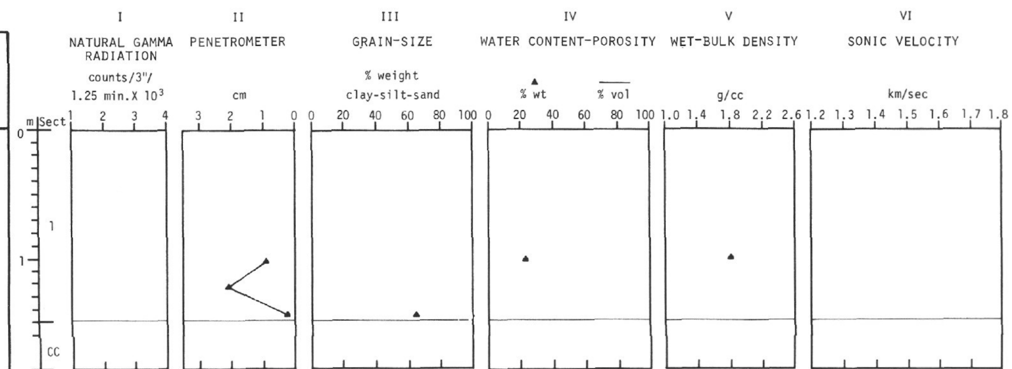
AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY CRETACEOUS			CC	▲ ▲ ▲	SS CN	Core catcher sample only: One small chip of chert and mud, much barite contamination from drilling mud and much up-hole debris.	CALCAREOUS NANNOPLANKTON: *Stephanolithion laffitei, Nannoconus steinmanni, N. globus, Parhabdolithus embergeri, Ahmuellerella asper, Watznaueria barnesae*

Hole 99A, Core 7 (85m to 94m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
EARLY CRETACEOUS			CC		SS CN	Core catcher sample only: Chips of dolomite, much contamination from up-hole, forams, dolomite, and clay abundant.	CALCAREOUS NANNOPLANKTON: *Stephanolithion laffitei, Braarudosphaera discula, N. atznaueria barnesae, Nannoconus steinmanni, N. dolomiticus*

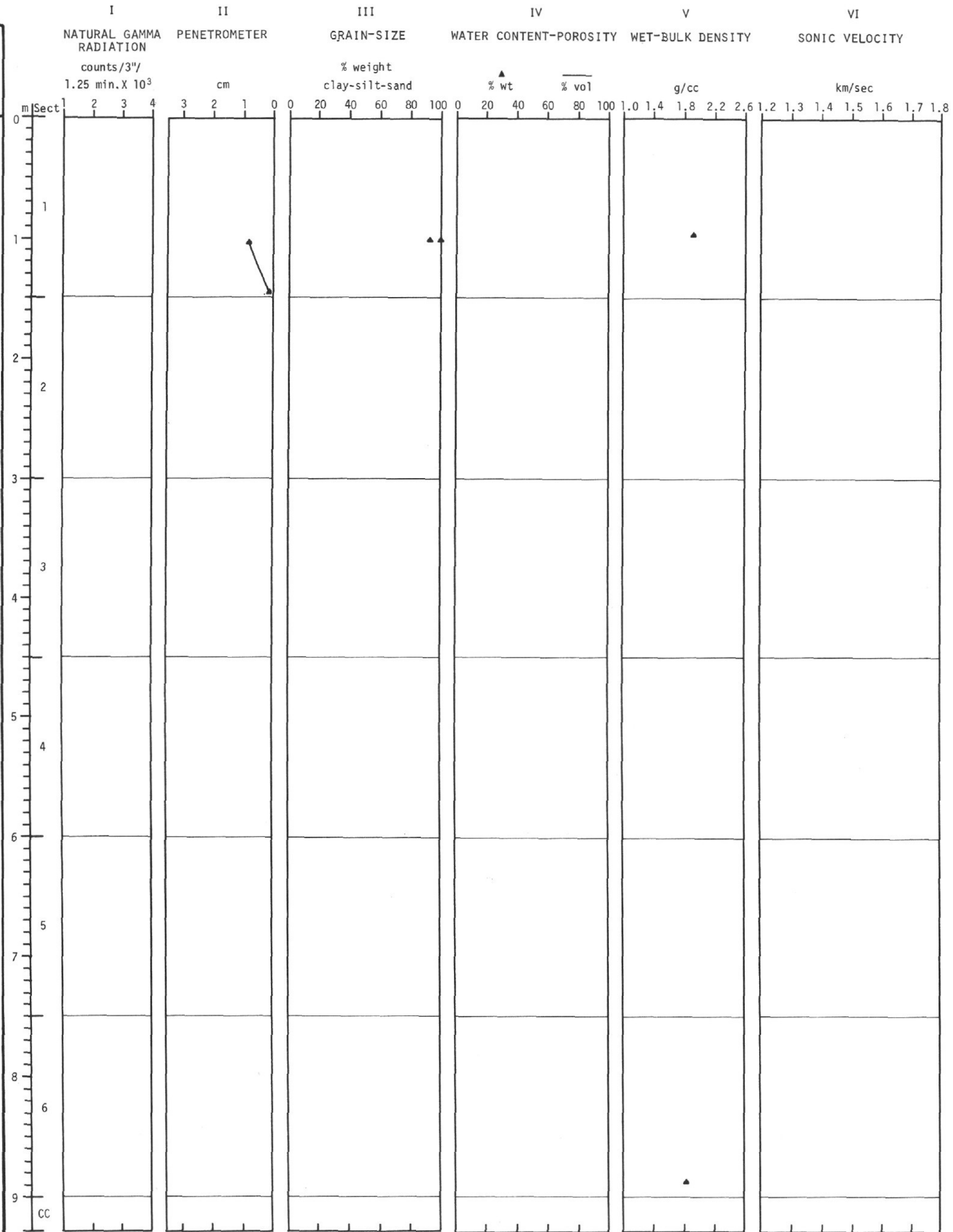
Hole 99A, Core 8 (94m to 100m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE JURASSIC (TITHONIAN) (Dinoflagellates) EARLY CRETACEOUS		1, 2, 3	1, CC, 2, 3		CN,D; SS; SS; SS; SS; SS; CN,D	Nannoplankton ooze; soft to firm, light gray (N8) to greenish gray, clayey at bottom.	CALCAREOUS NANNOPLANKTON: *Lithraphidites carniolensis, Parhabdolithus embergeri, Watznaueria barnesae, Braarudosphaera discula, Diazomatolithus lehmani, Nannoconus steinmanni* DINOFLAGELLATES: *Microdinium deflandrei, Wallodinium krutzschi, Dingodinium jurassicum* *CORE CATCHER* DINOFLAGELLATES: *Microdinium deflandrei* CALCAREOUS NANNOPLANKTON: *Diazomatolithus lehmani, Cyclagelosphaera margereli, Watznaueria britannica, Stephanolithion laffitei, Nannoconus steinmanni*



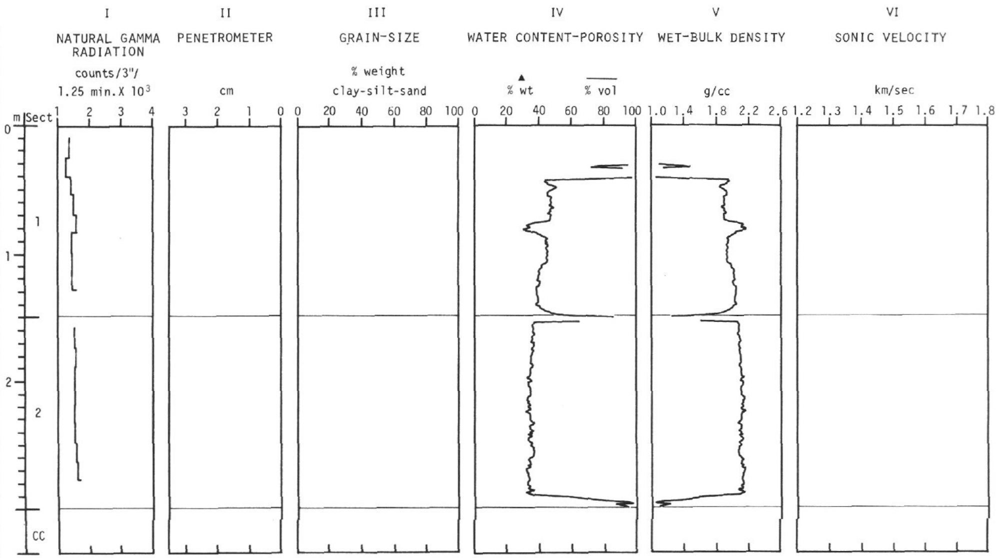
Hole 99A, Core 9 (131m to 140m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE JURASSIC (TITHONIAN) EARLY CRETACEOUS	(Dinoflagellates)	0–1.5	1		SS, SS, SS D	<u>Nannoplankton ooze</u>; soft, plastic, light gray (N8), recrystallized fragment of ooze set in matrix of soft ooze, nannoplankton abundant in dark gray (N4) clay-rich bands at bottom.	DINOFLAGELLATES: *Microdinium deflandrei*
		1.5–3	2				
		3–4.5	3				
		4.5–6	4				
		6–7.5	5			Drill cuttings (hard limestone and contamination from up-hole): <u>Limestone</u> hard, light gray (N7), abundant empty radiolarian molds, some with coating of pyrite, some with fillings of silica; pyrite specks common; insoluble residue contains clumps of spherules of disordered cristobalite	
		7.5–9	6	Drill cuttings	SS, SS, CN,D	Thin section of <u>chert</u> fragment from core catcher shows nannoplankton chalk grading to isotropic silica (disordered cristobalite) and quartzose chert; cloudy areas contain many spherules of isotropic silica of 5 um size.	CALCAREOUS NANNOPLANKTON: *Diazomatolithus lehmani*, *Parhabdolithus embergeri*, *Watznaueria britannica*, *Cyclagelosphaera margereli*, *Calpionella elliptica* DINOFLAGELLATES: *Microdinium deflandrei*
			CC	▲ ▲ ▲	SS		



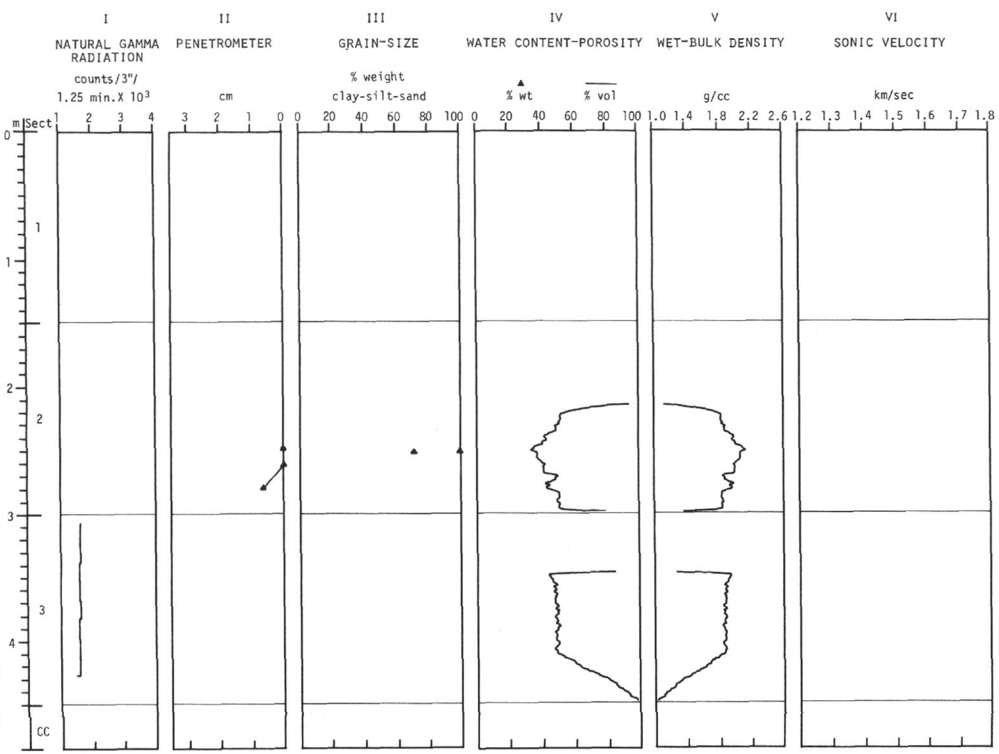
Hole 99A, Core 10 (168m to 173m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE JURASSIC (TITHONIAN) (Dinoflagellates) EARLY CRETACEOUS		1	1			Section 1 not opened but appeared identical to Section 2.	
		2	2	Drill cuttings	CN,D	Drill cuttings: Chert (mostly black), limestone, chalk, abundant up-hole contamination including large foraminifera, abundant metal shavings from outside surface of drill collars. Chert fragments, large vitreous, quartzose.	*CORE CATCHER* CALCAREOUS NANNOPLANKTON: *Watznaueria britannica, W. barnesae, Diazomatolithus lehmani, Parhabdolithus embergeri, Stephanolithion laffittei, Nannoconus steinmanni*
			CC		SS CN,D		DINOFLAGELLATES *Microdinium deflandrei*



Hole 99A, Core 11 (198m to 202m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE JURASSIC (TITHONIAN)		1	1	Drill cuttings		Section 1 not opened, contained only a smear of fines from drill cuttings along entire interior of plastic liner.	
		2	2	Drill cuttings	SS SS	Drill cuttings. Nannoplankton chalk; firm and brittle to hard, very soft pieces at both ends of chalk zone, recrystallized nannoplankton.	
		3, 4	3	Drill cuttings	CN,D	Drill cuttings of chert, chalk, and limestone; probably much contamination from up-hole. Core catcher sample: Limestone; hard, white (N9), with numerous dark irregular laminae, one set of laminations appears to truncate the other set, surface is chalky, complete pelecypod valve on top of fragment, chert spheres and fragments of sand and silt sizes are abundant.	*CORE CATCHER* CALCAREOUS NANNOPLANKTON: *Watznaueria britannica, W. barnesae, Parhabdolithus embergeri, Diazomatolithus lehmani, Nannoconus steinmanni*
			CC		SS SS SS CN,D		DINOFLAGELLATES: *Diacanthum hollisteri*



Hole 99A, Core 12 (235m to 238m)

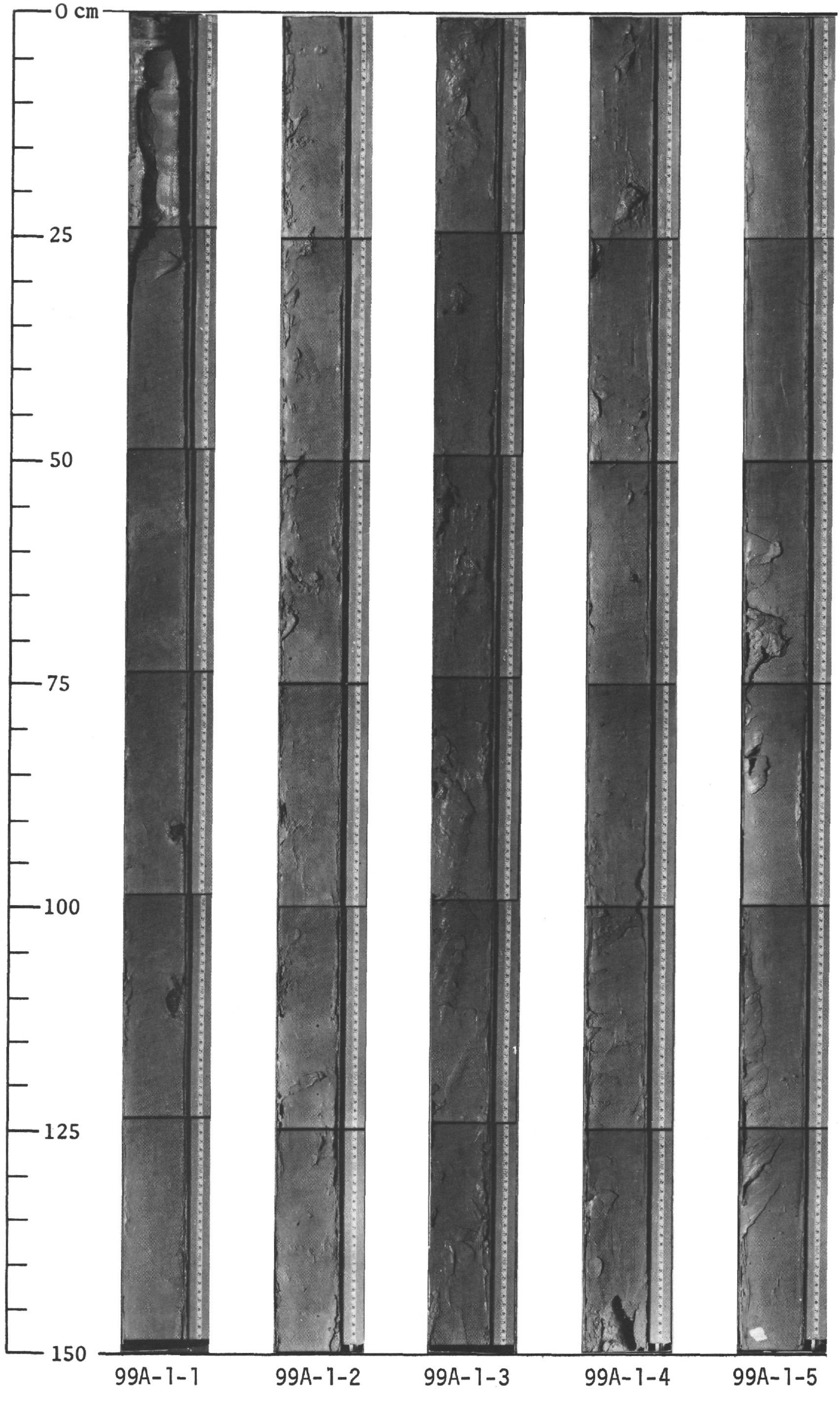
AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE JURASSIC (TITHONIAN)			CC		SS SS SS CN	Core catcher sample only: <u>Limestone</u>; hard, top half pale red (10R6/2) to reddish brown (10R5/4), and fissile, bottom half is mainly white (N9) with very irregular thin lenses and layers of greenish gray (5G6/1); red/white contact is sharp but irregular; thin, very irregular red layer in white zone with sharp contacts. Red zone: clay about 20%, iron oxide staining and nannoplankton common, recrystallized nanno-calcite common, sparry calcite common in sand, silt and clay sizes. White and green zone: silt size calcite dominant, nannoplankton common, clay and black pyrite (?) specks rare.	CALCAREOUS NANNOPLANKTON: *Cyclagelosphaera margereli, Watznaueria britannica, W. barnesae, Podorhabdus* sp., *Parhabdolithus embergeri*

Hole 99A, Core 13 (238m to 239m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE JURASSIC (KIMMERIDGIAN - OXFORDIAN)			CC		SS SS SS CN	Core catcher sample only: <u>Limestone</u>; hard, pale red (10R6/2) in upper piece, white (N9) in lower; red homogenous lens in laminated red zone; 0.5 cm irregular bed of red limestone in white zone with very sharp contacts. Red lens: small (5μm) calcite grains abundant, large (60μm) calcite grains rare, clay rare, hematite rare, nannoplankton rare. Red laminated zone: small (5μm) calcite grains abundant, large (60μm) calcite grains common, clay, quartz, hematite, oolites, and dolomite rare. White zone: small calcite grains dominant, clay and quartz rare.	CALCAREOUS NANNOPLANKTON: *Watznaueria britannica, W. barnesae, Diazomatolithus lehmani, Cyclagelosphaera margereli, Zygodiscus salillum, Z. bussoni*

Hole 99A, Core 14 (239m to 248m)

AGE	ZONE	DEPTH (m)	SECTION NO.	LITHOLOGY	SAMPLE INTERVAL	LITHOLOGY	DIAGNOSTIC FOSSILS
LATE JURASSIC (KIMMERIDGIAN - OXFORDIAN)		1 2 3	1 2 CC		SS CN D D PC, D,CN	<u>Limestone</u>; hard, interbedded bands of various shades of reddish brown (10R3/4) and greenish gray (5GY7/1); some clayey zones, finely laminated with red and white (N9) laminae which show truncation, differential compaction around clasts (?) and indurated lenses, and effects of burrowing organisms and bottom currents.	CALCAREOUS NANNOPLANKTON: *Cyclagelosphaera margereli, Watznaueria britannica, W. barnesae, Zygodiscus erectus, A. salillum, Diazomatolithus lehmani* DINOFLAGELLATES: *Tenua verrucosa, Chytroeisphaeridia pococki* DINOFLAGELLATES: *Gonyaulacysta nuciformis, G. scarburghensis, Chytroeisphaeridia pococki, Polygonifera evitti* *CORE CATCHER* PELAGIC CRINOIDS: *Saccocoma* sp. cf. *S. quenstedti* DINOFLAGELLATES: *Pareodinia ceratophora, Polygonifera evitti* CALCAREOUS NANNOPLANKTON: *Stephanolithion bigoti, Watznaueria britannica, W. barnesae, Cyclagelosphaera margereli, Zygodiscus erectus, Z. salillum, Diazomatolithus lehmani*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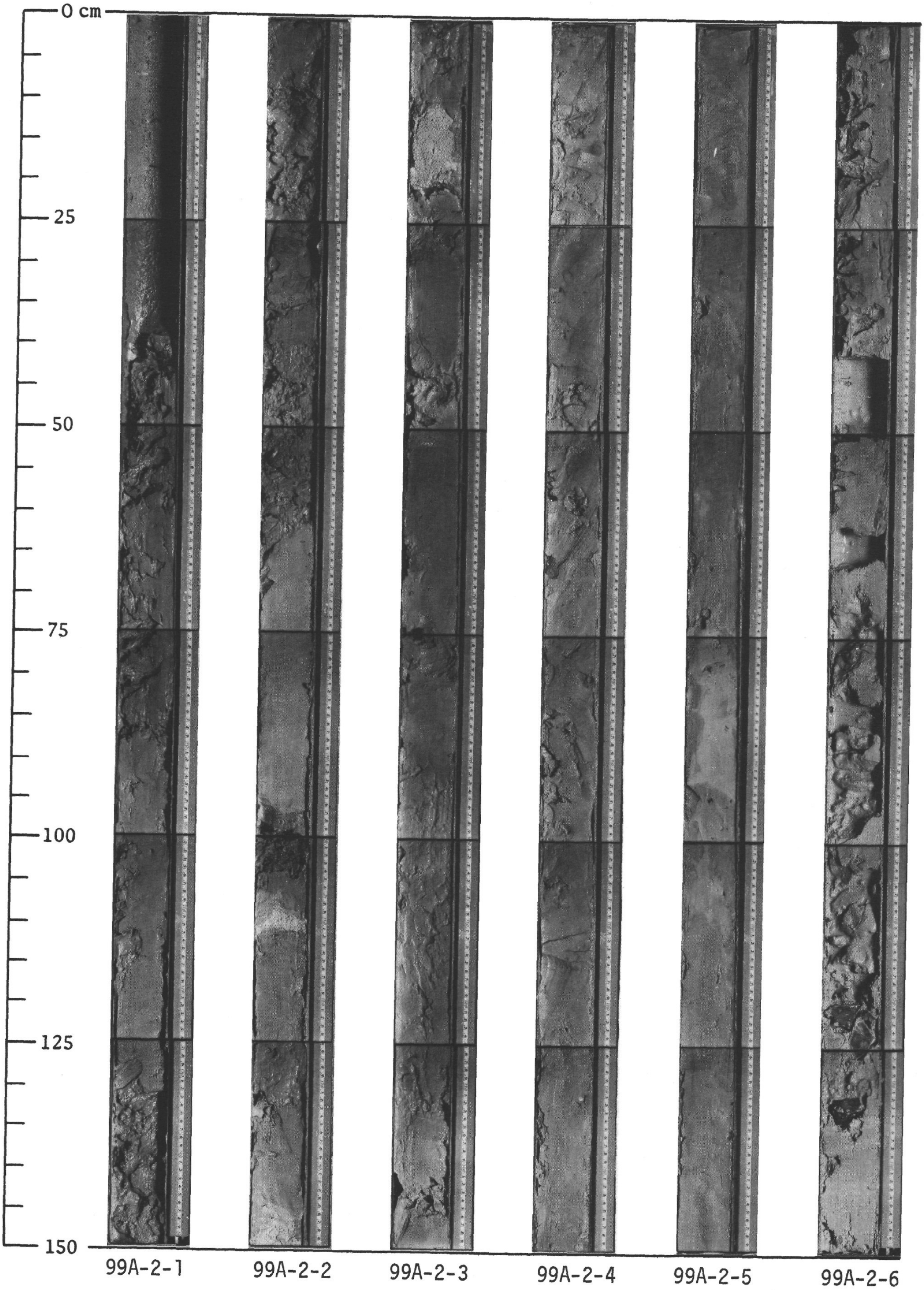
99A-1-4
99A-1-5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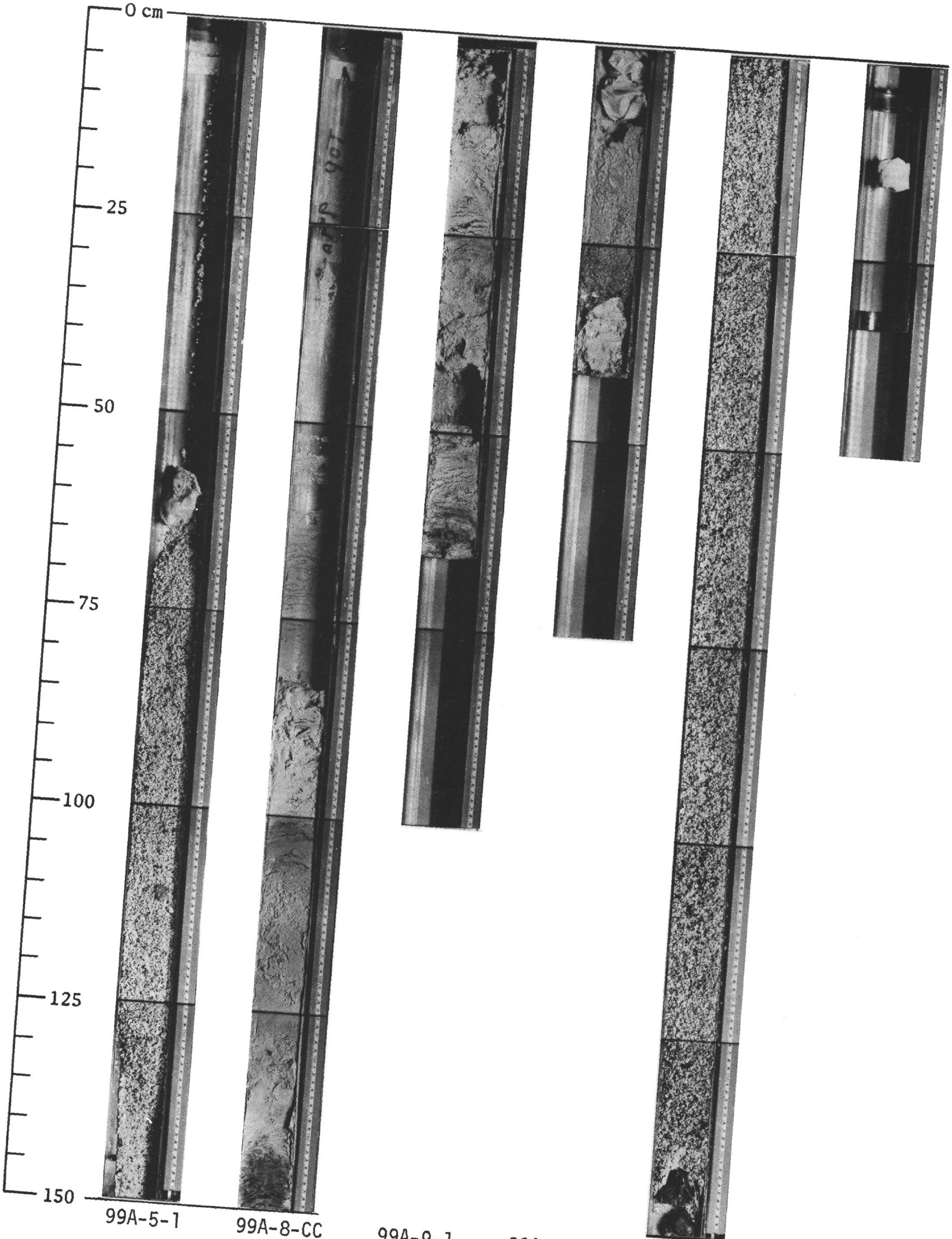
99A-2-6



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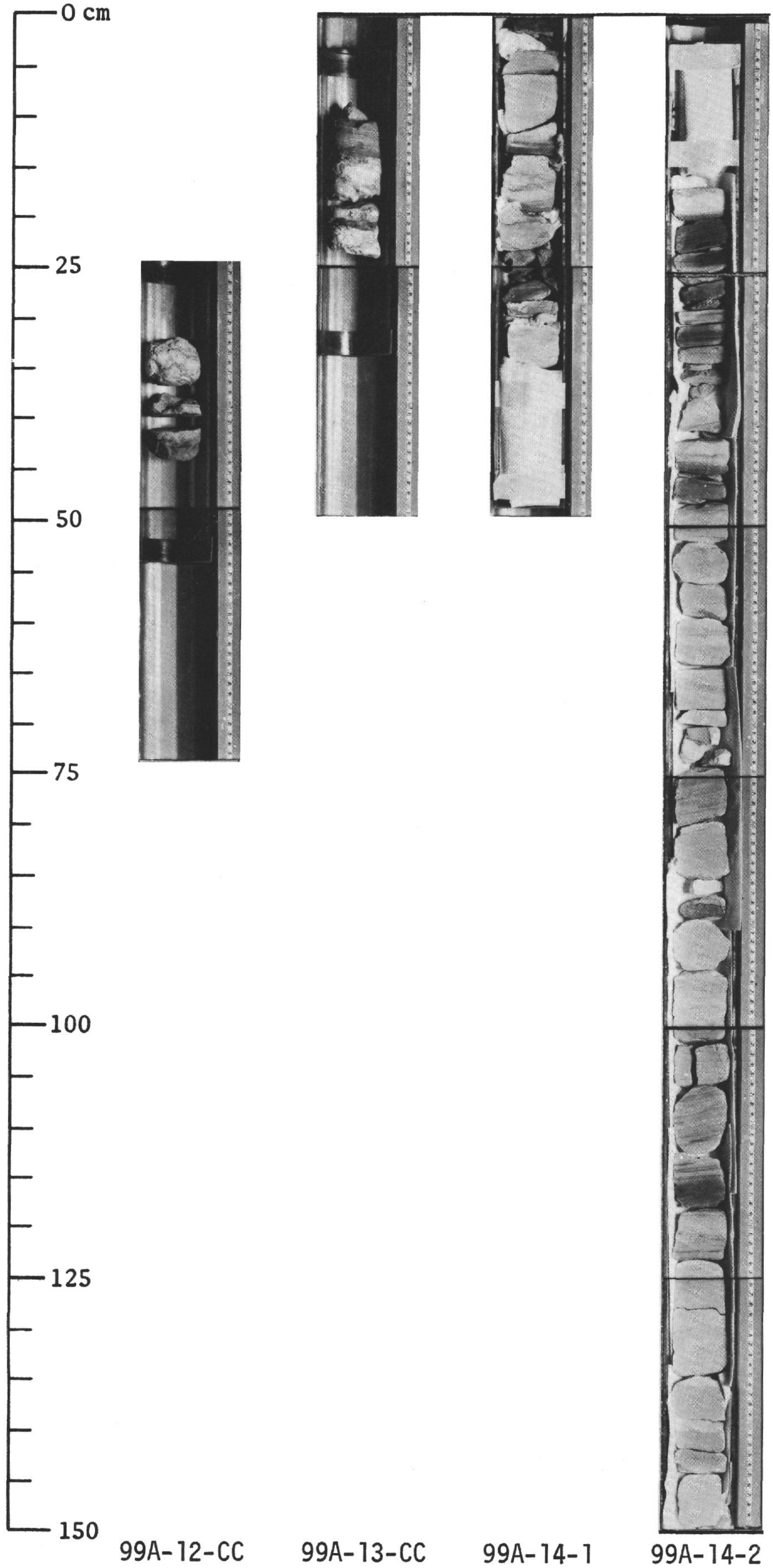

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99A-13-CC
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99A-14-2