13. SITE 96

The Shipboard Scientific Party[1]

SITE DATA

Occupied: March 30-31, 1970.

Position: 23°44.56′N; 85°45.80′W.

Water Depth: 3439 meters.

Total Depth: 332 meters.

Holes Drilled: One.

Cores Taken: Five.

BACKGROUND AND OBJECTIVES

Three topographic highs in the western end of the Straits of Florida and southeastern Gulf of Mexico have been surveyed by Pyle et al. (1969) and Bryant et al. (1969). Each of these three structures, called Jordan Knoll, Pinar del Rio Knoll, and Catoche Knoll, have a positive magnetic anomaly associated with it. All other features of similar structural outline in the Gulf basin have been associated with salt tectonics; however, the knolls of the southeastern Gulf of Mexico, due to the presence of the positive magnetic anomalies, are suspected of being mainly results of igneous intrusions.

A positive total intensity magnetic anomaly of approximately 200 gammas is associated with Jordan Knoll, while positive magnetic anomalies of from 100 to 200 gammas have been associated with the other two knolls. (Pyle et al., 1969).

A knoll located at the mouth of Catoche Tongue, with small surface relief (10 fathoms) was reported by the U.S.S. *Kane* during a geophysical cruise in 1969. The knoll, selected from Site 96, lies within the "belt of volcanic-type anomalies" as reported by Gough (1967).

It had been suggested by Pyle et al. (1969) and Bryant et al. (1969) that Jordan Knoll, Pinar del Rio Knoll, and Catoche Knoll are igneous instrusions, because of the following:

1) Pinar del Rio and Jordan knolls lie along a line of extension of an axial valley anomaly and parallel the outcrop of ultramafic rocks of Cuba.

2) A positive magnetic anomaly is associated with such features.

3) Catoche Knoll is located within Gough's belt of volcanic-type anomalies.

4) No salt structures are known to occur within the Gulf Basin east of a line from Campeche Canyon to De Soto Canyon. A definite origin for the diapiric structures in the southeastern Gulf cannot be forthcoming until such structures are drilled and sampled to their core. The question of their origin is obviously important in considerations of salt distribution and the history of the Gulf of Mexico.

It was decided that drilling one of these diapiric structures would best be accomplished if the structure was outside the main flow of the Gulf Stream, had sufficient sediment cover to bury the bottom assembly before encountering hard material, and had been surveyed with the aid of satellite navigation. Thus, the knoll in the Catoche Tongue area, surveyed by the U.S.S. *Kane,* was chosen as Site 96.

The main objective at Site 96 was to drill to the core of the knoll, a depth of approximately 350 meters, and obtain samples of material which would aid in determining the origin of the structure. A coring inventory is given in Table 1.

NATURE OF SEDIMENTS

General Description

Based on somewhat widely spaced sampling, Site 96 appears to be in a rather thick sequence of Upper Pleistocene, terrigenous laminite clays and associated quartzose turbidites overlying a thick sequence of lower Tertiary nannofossil ooze and chalk, locally chert bearing. In conjunction with an interpretation of the profiler record (see Objectives), the structure on which Site 96 was drilled is interpreted as a basement knoll (possibly Early Cretaceous in age?) on which was deposited considerable lower Tertiary (and possibly Upper Cretaceous?) pelagic ooze.

Through pelagic nondeposition, erosion, or subsidence, the knoll was more or less buried in Late Pleistocene time by "typical" abyssal plain clay, mud, and associated turbidity current deposits. Normal consolidation around the flanks of the structure has apparently preserved minor relief on the sea floor. Alternatively, the relief of the sea floor suggests the possibility that Core 1 could have been deposited up to 16 meters or more above the surrounding abyssal plain. It could then be argued that turbidity currents carry very fine sand in suspensions at least 16 meters thick.

Core 1 recovered olive gray to dark olive gray, massive to occasionally laminated, terrigenous clay, with occasional graded muddy silt laminae and rare quartzose, sandy, coarse silt, graded beds. This sequence is interpreted as a laminite-turbidite facies assemblage. The underlying sediments of Cores 2, 3, 4, and 5 are very light greenish white to very light yellow white (at the base),

[1]J. Lamar Worzel, Marine Biomedical Institute, University of Texas, Galveston; William Bryant, Texas A&M University (co-chief scientists); Arthur O. Beall, Jr., Continental Oil Company (lead sedimentologist); Kendell Dickinson, United States Geological Survey; Robert Laury, Southern Methodist University; Lee Anderson Smith, ESSO Production Research (lead paleontologist); Blake McNeely, Shell Oil Company; Helen P. Foreman, Oberlin College; Roy Capo, Lamont-Doherty Geological Observatory.

TABLE 1
Core Inventory – Site 96

Core	No. Sections	Date	Time	Cored[a] Interval (m)	Cored (m)	Recovered (m)	Subbottom Penetration (m) Top	Subbottom Penetration (m) Bottom	Lithology	Age
1	6	3/30	1900	3540-3549	9.0	7.7	101.0	110.0	Clay	Early Pleistocene
2	6	3/30	2215	3638-3647	9.0	9.3	199.0	208.0	Foram Nanno ooze	Early Oligocene
3	6	3/31	0130	3740-3749	9.0	9.3	301.0	310.0	Foram Nanno chalk	Early Eocene
4	–	3/31	0430	3760-3768	8.0	0.6[b]	321.0	329.0	Foram Nanno chalk	Late Paleocene
5	1	3/31	–	3768-3771	3.0	1.0	329.0	332.0	Foram Nanno chalk	Late Paleocene
Total	19				38.0	27.3		332.9		
% Cored					11.4%					
% Recovered						71.8%				

[a]Drill Pipe measurement from derrick floor.

[b]Core catcher recovery only.

strongly burrowed, foraminiferal, nannofossil ooze and soft chalk. Cores 2 and 4 contain greenish gray, calcareous chert. Core 2 also contains a few zones of burrow-mixed volcanic ash. The first appearance of soft chalk was noted in Core 3, although Core 2 is quite mechanically disturbed and could be of an intermediate state of consolidation (tending toward chalk).

Sedimentological Interpretation

The presence of lower Tertiary pelagic oozes at Site 96 suggests considerable relief on the surrounding sea floor such that normal abyssal plain sediments could not be deposited on bathymetric highs. As terrigenous abyssal plain sedimentation continued to the north, it might be postulated that subsidence of the area under discussion eventually brought the crest of the knoll within reach of turbidity current sedimentation. The rather thick abyssal fan to the north and interpreted stratigraphic relationships within the fan suggest that accelerated burial subsidence probably took place during Pleistocene time. Alternatively, the relationships described above could be interpreted as an indication of eventual "filling" of the southeastern "end" of the abyssal plain, some knolls being buried during earlier stages of sedimentation. Other knolls of greater relief still stand well above the level of the abyssal plain and are thus without a Pleistocene abyssal plain cover. The latter interpretation would be enhanced if it could be shown that a thin sequence of Pliocene pelagite occurs beneath the upper Pleistocene abyssal plain sediments in Site 96.

Although Core 1 is interpreted as representative of Mississippi abyssal plain sedimentation, it should be pointed out that considerable calcareous detritus is present, apparently concentrated in the fine fraction. Paleontological data suggests a preponderance of Upper Cretaceous carbonate, indicating that considerable amounts of slumping from the Yucatan and/or Florida continental slope were probably occurring during Late Pleistocene sedimentation. On the other hand, most of the thin silts and silty, very fine sands of Core 1 appear to be highly quartzose, which suggest a terrigenous source (Mississippi Fan). Low feldspar and high montmorillonite contents also support a Mississippi Fan source.

Core 2 (Early Oligocene) contains the youngest stratigraphic occurrence of chert yet noted from the various holes drilled on Leg 10. This tends to support the interpretation of a "silica gradient" towards the southeast as postulated on the basis of results at Sites 86, 94, and 95. The presence of ash and siliceous organisms in Core 2 is also somewhat noteworthy since abundant ash in Oligocene sediments has not been noted previously from other holes. The lower cores (3, 4, and 5) appear quite similar but slightly less clayey or more calcite-rich as compared to correlative sediments in Sites 86, 94, and 95.

Physical Measurements

Natural gamma-ray measurements of Site 96 cores show a marked contrast between Core 1 (high terrigenous clay content–high gamma count) and the remaining cores (low clay content). Core 2 has several zones yielding higher than normal counts which correspond to ash-rich intervals. The lower Tertiary cores are quite comparable, in terms of gamma-ray count, to stratigraphically equivalent cores of Site 95. No gamma-ray data were obtained for Cores 4 and 5.

GRAPE bulk density is approximately the same for Cores 1 and 2. Core 3 is too disturbed to yield meaningful bulk density data and was omitted from the summary chart. Penetrometer data again reflected consolidation of the sediments with depth. Penetrometer measurements on

Cores 3 and 5 are based on fragments of chalk thought to represent undisturbed sediment at those depths. In drawing the various curves on the summary chart, the interpretations previously discussed were used as a guide and, as a result, are highly interpretive.

BIOSTRATIGRAPHY

As interpreted from the fossil plankton (foraminifers and calcareous nannofossils), the biostratigraphy of Site 96 is summarized in Figure 1. The section penetrated is compressed (Late Paleocene to Holocene in less than 320 meters), but it is not known whether it is condensed or shortened by a number of disconformities (probably the latter). The Pleistocene core (10-96-1) apparently is as diluted (with terrigenous clastic debris and residuum) as are glacial sections in the northwestern Gulf of Mexico. The allochthonous materials, however, seem generally much finer at Site 96 than in areas more directly affected by the Mississippi River. Almost all of the reworked calcareous nannofossils recovered from Core 1 are of Late Cretaceous (probable Campanian) age, although there is a small component furnished from deep marine Miocene sediments.

Sample 1 (10-96-1, top of core):

The assemblage from this sample is essentially the same as that listed for Sample 2.

Age: Pleistocene (glacial), probably Nebraskan.
Environment: Bathyal.
Remarks: The dominant flora is a reworked Late Cretaceous (probable Late Campanian) assemblage, essentially as listed for Sample 2 (10-96-1, CC).

Sample 2 (10-96-1, CC):

Globorotalia truncatulinoides, Globigerinoides ruber (white), *G. triloba, Globigerina* sp. cf. *G. inflata, G. eggeri,* and *G. bulloides.*

Age: Early Pleistocene (glacial), probable Nebraskan.
Environment: Bathyal.
Remarks: The sample contains very common reworked Late Cretaceous (probable late Campanian) calcareous nannofossil assemblage, including: *Discoaster*? *hayi, Arkhangelskiella cymbiformis, Vagalapilla octoradiata, Zygodiscus deflandrei, Micula staurophora, Prediscosphaera cretacea, Eiffelithus angustus, E. turriseiffeli, Watznaueria barnesae, Cretarhabdus conicus,* and *Microrhabdulus belgicus.*

Sample 3 (10-96-2, CC):

Globorotalia opima opima, G. nana, G. sp. cf. *G. pseudokugleri, Globigerina angulisuturalis, G. ciperoensis, Globoquadrina venezuelana, Catapsydrax dissimilis, Cyclococcolithus neogammation, Reticulofenestra scissura, R. umbilica, Sphenolithus ciperoensis, S. pseudoradians, Helicopontosphaera parallela, H. seminulum* ssp., *H. truncata, Discoaster adamanteus, D. deflandrei, D. trinidadensis,* and radiolarians of the *Dorcadospyris ateuchus* zone.

Age: Early Oligocene (P. 21), the *Globorotalia opima opima* Zone.
Environment: Bathyal.

Sample 4 (10-96-3, CC):

Globorotalia rex, G. aequa, G. gracilis, G. wilcoxensis, G. sp. cf. *G. quetra, Globigerina* sp. cf. *G. soldadoensis, Chiasmolithus grandis, C. consuetus, C. Californicus, Cruciplacolithus tenuis, Heliorthus distentus, Fasciculithus involutus, Discoaster lenticularis,* and radiolarians of the *Bekoma bidarfensis* zone.

Age: earliest Eocene (P. 6), the *Globorotalia rex* Zone.
Environment: Bathyal

Sample 5 (10-96-4, CC):

Globorotalia velascoensis, G. aequa, G. occlusa, G. acuta, Globigerina sp. cf. *G. soldadoensis, Heliorthus distentus, Zygodiscus sigmoides, Cruciplacolithus tenuis, Fasciculithus typaniformis, F. involutus, Ericsonia alternans, Toweius* sp., *Marthasterites* sp. aff. *M. contortus, Chiasmolithus bidens, Ellipsolithus* sp., and radiolarians *Buryella tetradica* n. sp., *Hamptonium pennatum* n. sp., *Phormocyrtis striata exquisita* and *Phormocyrtis turgida.*

Age: Late Paleocene (P. 5), the *Globorotalia velascoensis* Zone.
Environment: Bathyal.
Remarks: Several inches of chert were cored in the lower part of this barrel.

Sample 6 (10-96-5, CC):

Globorotalia velascoensis, G. pseudomenardii, G. acuta, G. laevigata, G. aequa, Globigerina velascoensis, G. linaperta, G. primitiva, G. triangularis, Chiasmolithus consuetus, Cruciplacolithus tenuis, Toweius eminens, Fasciculithus typaniformis, F. involutus, F. mitreus, F. sp., *Coccolithus marisomontium, Ericsonia* sp., *Discoaster lenticularis, D.* sp. cf. *D. gemmeus,* and radiolarians *Buryella tetradica, B. pentadica* n. sp., and *Phormocyrtis striata exquisita.*

Age: Late Paleocene (P. 4), *Globorotalia pseudomenardii* Zone.
Environment: Bathyal.
Remarks: Most of the foraminifers contained in the sample examined were Pliocene to Holocene contaminants.

DISCUSSION AND INTERPRETATION

Originally, the knoll at the mouth of Catoche Tongue (Site 96) was thought to be an igneous intrusion. This idea resulted from examinations of other such features in the area and the magnetic anomalies associated with them. However, a very brief survey of the site indicated that no magnetic anomaly existed for the knoll in question. A uniform magnetic field apparently exists in the area. This was a surprise and now casts doubts as to the assumed origin of the structure.

While *Glomar Challenger* was on Site 96 (Figure 2), March 30-31, 1970, five cores were recovered between the sea floor and a subbottom depth of 332 meters (Table 1). Upper Paleocene sediments were the oldest recovered. No Pliocene or Miocene sediments were recovered, nor did we realize the objective set for Site 96. No indication of the nature the core of the diapiric structure drilled was obtained due to premature site abandonment resulting from beacon failure.

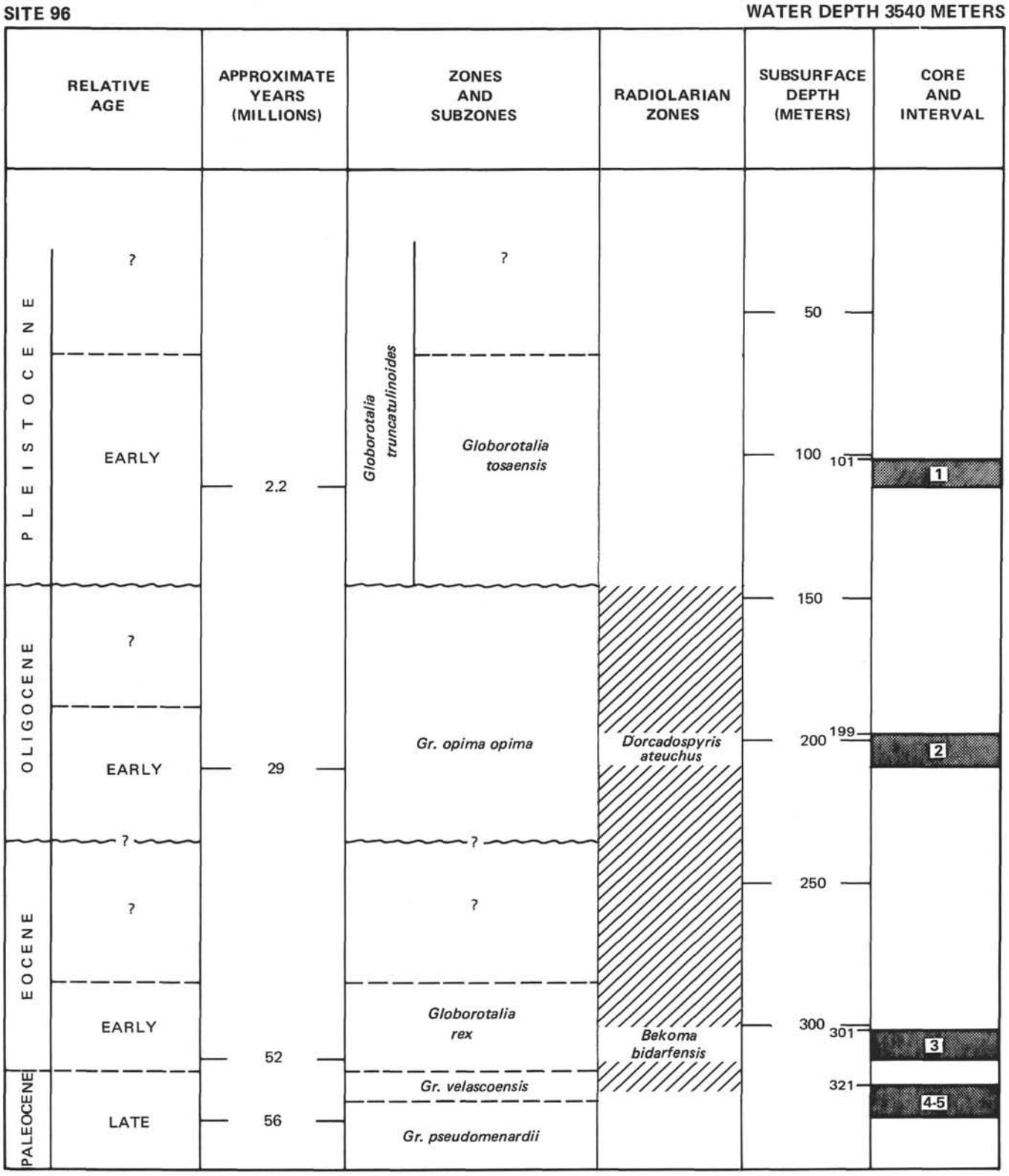


Figure 1. *Biostratigraphic summary of Site 96.*

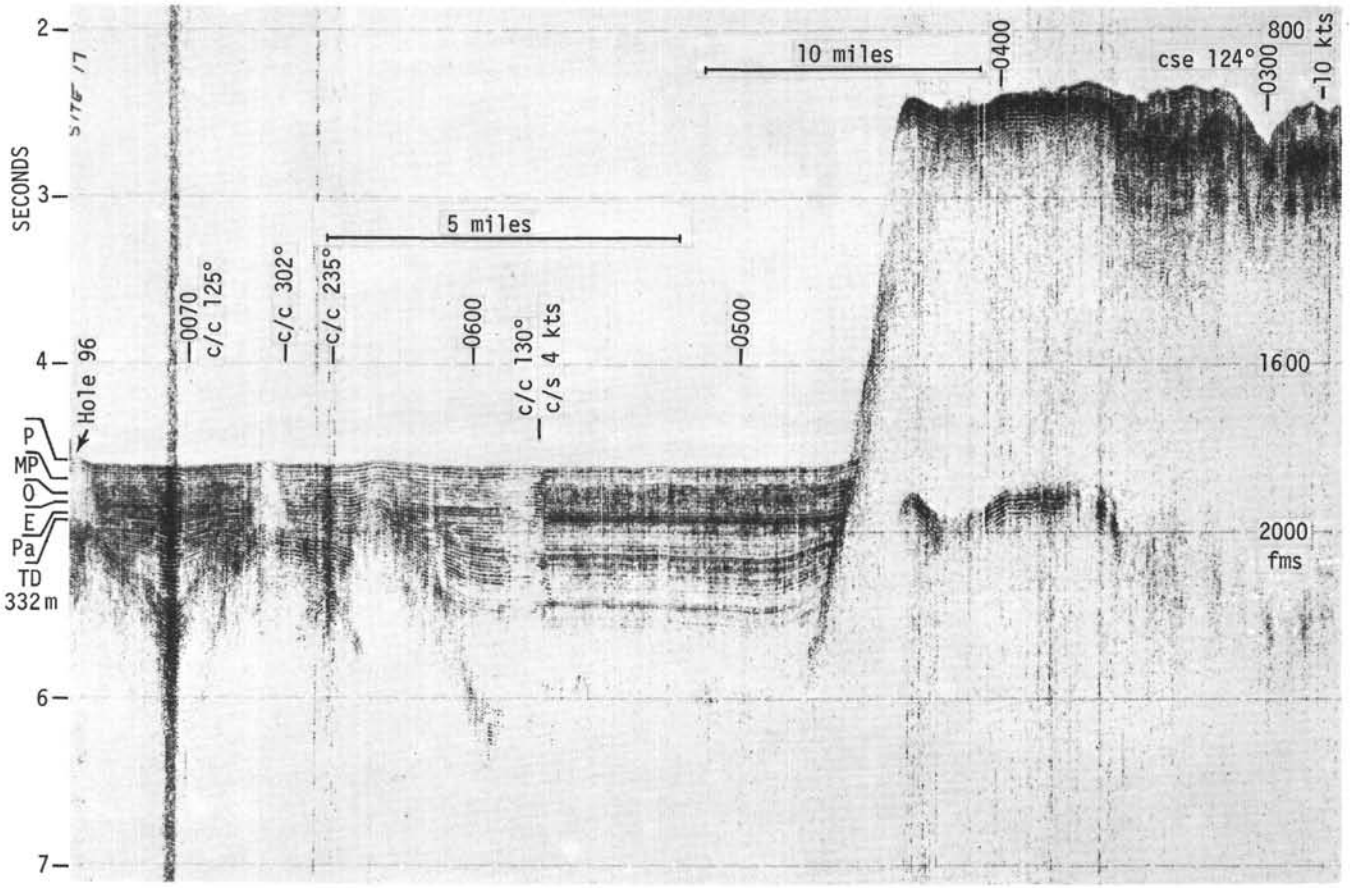


Figure 2. *Profile record, Site 96.*

Core 1 is comprised of a rather thick sequence of Pleistocene laminite terrigenous silts/clays and associated quartzose turbidites overlying a thick sequence of lower Tertiary coccolith ooze and chalk which include an occasional chert layer. Plant debris is common to abundant. Most of the sections contain traces to rare amounts of abraided dolomite rhombs. The carbonate content averages about 35 per cent; detrital carbonate is the main constituent. The carbonate content reflects the rather slow rates of deposition as compared to the Mississippi Fan and the Sigsbee Abyssal Plain sediments. Since much of the carbonate debris present consists of Upper Cretaceous carbonates, the Campeche Bank was the probable source and slumping the probable transporting mechanism of a good portion of the sediments recovered. Other constituents found are siliceous skeletal material and volcanic glass.

The occurrence of very fine sand turbidites on top of the knoll suggests that either turbidity currents can carry fine sand-sized sediments in suspensions 16 or more meters above the sea floor or that the relief of the knoll was less than at present.

Core 2 (199-208 meters), of Late Oligocene age, is a calcareous foraminiferal nannofossil pelagic ooze with average carbonate content of about 85 per cent Radiolarians, siliceous sponge spicules, quartz, and amphibole-bearing heavy minerals are present.

The sediments of Core 3 (301-310 meters), of Early Eocene age, are silica-rich organic oozes. Radiolarians are abundant and siliceous sponge spicules common to abundant. The carbonate content averages about 50 per cent and is in the form of calcareous nannofossils and foraminifers. Dolomite rhombs are also present. The first appearance of soft chalk occurs in Core 3. Calcareous chert of greenish gray color in Core 3 represents the youngest stratigraphic occurrence of chert yet noted in the Gulf.

Core 4 sediments are Upper Paleocene nannofossil oozes containing mainly calcareous nannofossils, dolomite, chert, traces of foraminifers, radiolarians, and volcanic glass.

The presence of lower Tertiary pelagic oozes in Site 96 suggests that the knoll formerly was elevated above the sea floor. Subsequent subsidence of the knoll or upbuilding of the surrounding sediments could have brought the crest of the knoll within the reach of turbidity currents during the Late Pleistocene. Alternatively, the level of the surrounding abyssal plain may have risen to bury the knoll to such a depth that turbidites could reach the upper parts of the knoll.

The average rates of deposition at Site 96 were determined to the the following:

Late Pleistocene	5.6 cm/10^3y
Late Oligocene to Early Pleistocene	0.33 cm/10^3y
Eocene	0.42 cm/10^3y
Late Paleocene to present	0.6 cm/10^3y.

As one can see, the rates of deposition are rather low; the section penetrated is compressed, being either condensed or shortened by a number of disconformities. However, the average rate of deposition for the site is similar to that found at Sites 86, 94, and 95, all located on topographic highs.

In general, the main objective of the hole was not realized due to failure of the beacon and the shortage of time. It is unfortunate that the hole was not drilled to completion, particularly since no magnetic anomaly exists over the knoll. Data of the U.S.S. *Kane,* Lamont-Doherty, and Texas A & M will be reexamined to determine the magnetic nature of the structure and, thus, the most likely explanation for its origin.

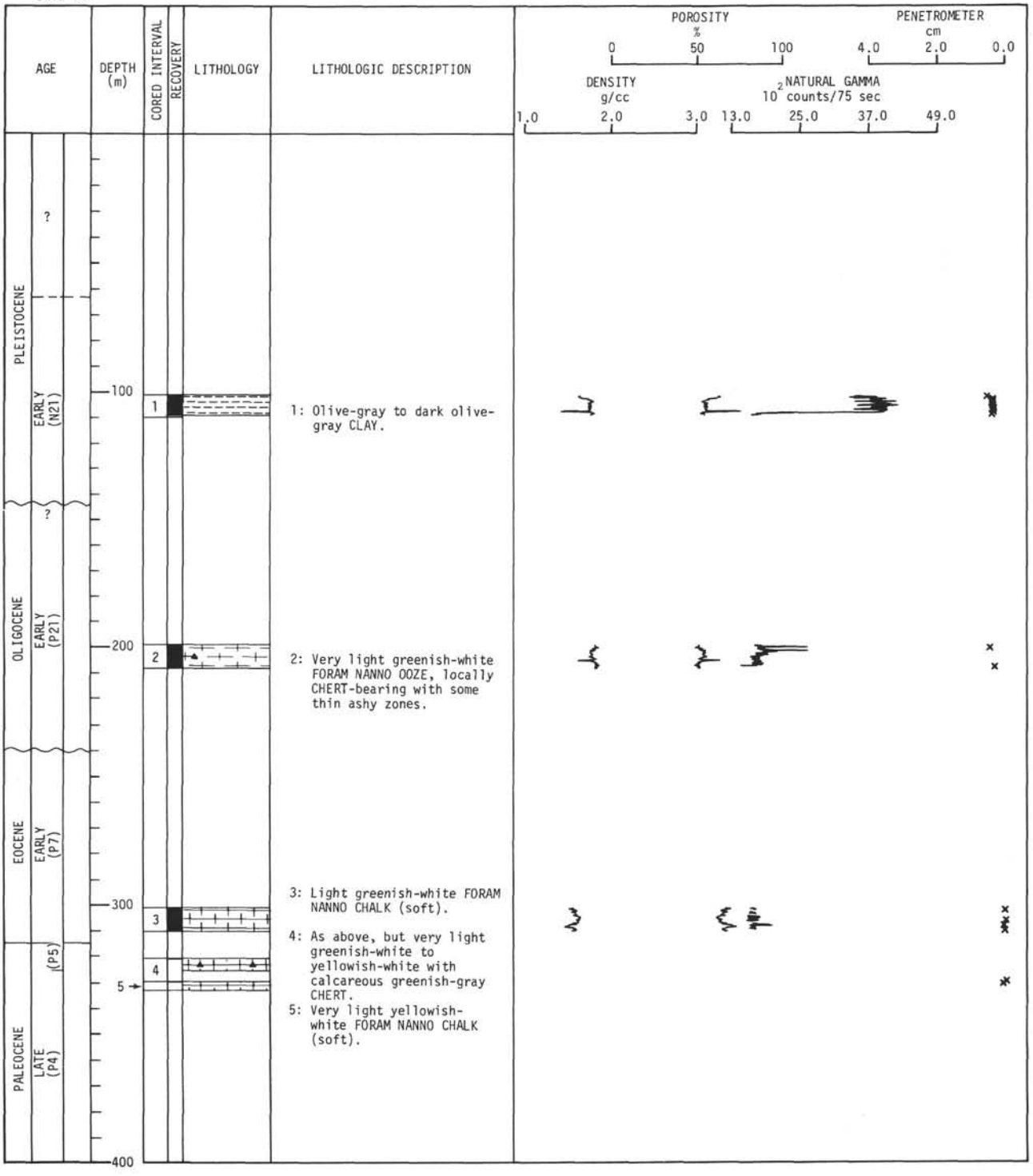
REFERENCES

Bryant, W.R., Meyerhoff, A.A., Brown, N.K., Furrer, M.A., Pyle, T.E. and Antoine, J.W., 1969. Escarpments, reef trends, and diapiric structures, eastern Gulf of Mexico. Bull. Am. Assoc. Petrol Geologists. **53** (12), 2506.

Gough, D.I., 1967. Magnetic anomalies and crustal structure in eastern Gulf of Mexico. Bull. Am. Assoc. Petrol. Geologists. **51,** 200.

Pyle, T.E., Antoine, J.W., Fahlquist, D.A. and Bryant, W.R., 1969. Magnetic anomalies in Straits of Florida. Bull. Am. Assoc. Petrol. Geologists. **53** (12), 2501.

SITE 96


AGE
DEPTH (m)
CORED INTERVAL
RECOVERY
LITHOLOGY
LITHOLOGIC DESCRIPTION
POROSITY
%
0
50
100
PENETROMETER
cm
4.0
2.0
0.0
DENSITY
g/cc
1.0
2.0
3.0
NATURAL GAMMA
10² counts/75 sec
13.0
25.0
37.0
49.0
PLEISTOCENE
EARLY (N21)
?
OLIGOCENE
EARLY (P21)
EOCENE
EARLY (P7)
(P5)
PALEOCENE
LATE (P4)
100
200
300
400
5
1
2
3
4
1: Olive-gray to dark olive-gray CLAY.
2: Very light greenish-white FORAM NANNO OOZE, locally CHERT-bearing with some thin ashy zones.
3: Light greenish-white FORAM NANNO CHALK (soft).
4: As above, but very light greenish-white to yellowish-white with calcareous greenish-gray CHERT.
5: Very light yellowish-white FORAM NANNO CHALK (soft).

Site 96 Hole Core 1 Cored Interval: 101-110 m

AGE	ZONE	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION	GRAIN SIZE WEIGHT % SAND	SILT	CLAY
EARLY PLEISTOCENE (Nebraskan)	N21	1	0.5	VOID						
			1.0				Brecciated-mechanically disturbed.			
		2					5Y3/1 to mixed 5Y3/1 and 5Y4/1.			
							5Y3/1			
		3					5Y4/1 dominant with coarser zones of 5Y3/1.	0.0	18.3	81.7
		4					CLAY Olive gray to dark olive gray; massive to rarely to occasionally laminated; occasional graded clayey silt laminae and rare graded beds of very fine sand (quartzose).	0.1	15.8	84.2
		5						0.0	12.4	87.6
		6						0.0	14.3	85.7
							Graded sandy silt.			
		Core Catcher					VOID			

Site 96 Hole Core 2 Cored Interval: 199-208 m

AGE	ZONE	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION	GRAIN SIZE WEIGHT % SAND	SILT	CLAY
EARLY OLIGOCENE	P21	1	0.5				Mechanically disturbed throughout.	6.3	50.1	43.6
			1.0				FORAM NANNO OOZE Very light greenish-white (N9-5G9/1 stained with N6); vague laminae/burrow fill, probably strongly (?) burrowed; chert-bearing and ashy locally-based on gamma count and smear slides.	5.2	48.2	46.6
		2								
		3					As above. Strongly streaked with N7 and N3 fecal stain.	10.1	53.7	36.2
		4					As above with: CHERT Greenish-gray (5G6/1, mottled with 5G8/1-9/1); calcareous.			
		5					Scattered chert fragments.	4.2	50.1	45.6
		6					As above. Less disturbed.	4.6	50.8	44.6
		Core Catcher								

Site 96 Hole Core 3 Cored Interval: 301-310 m

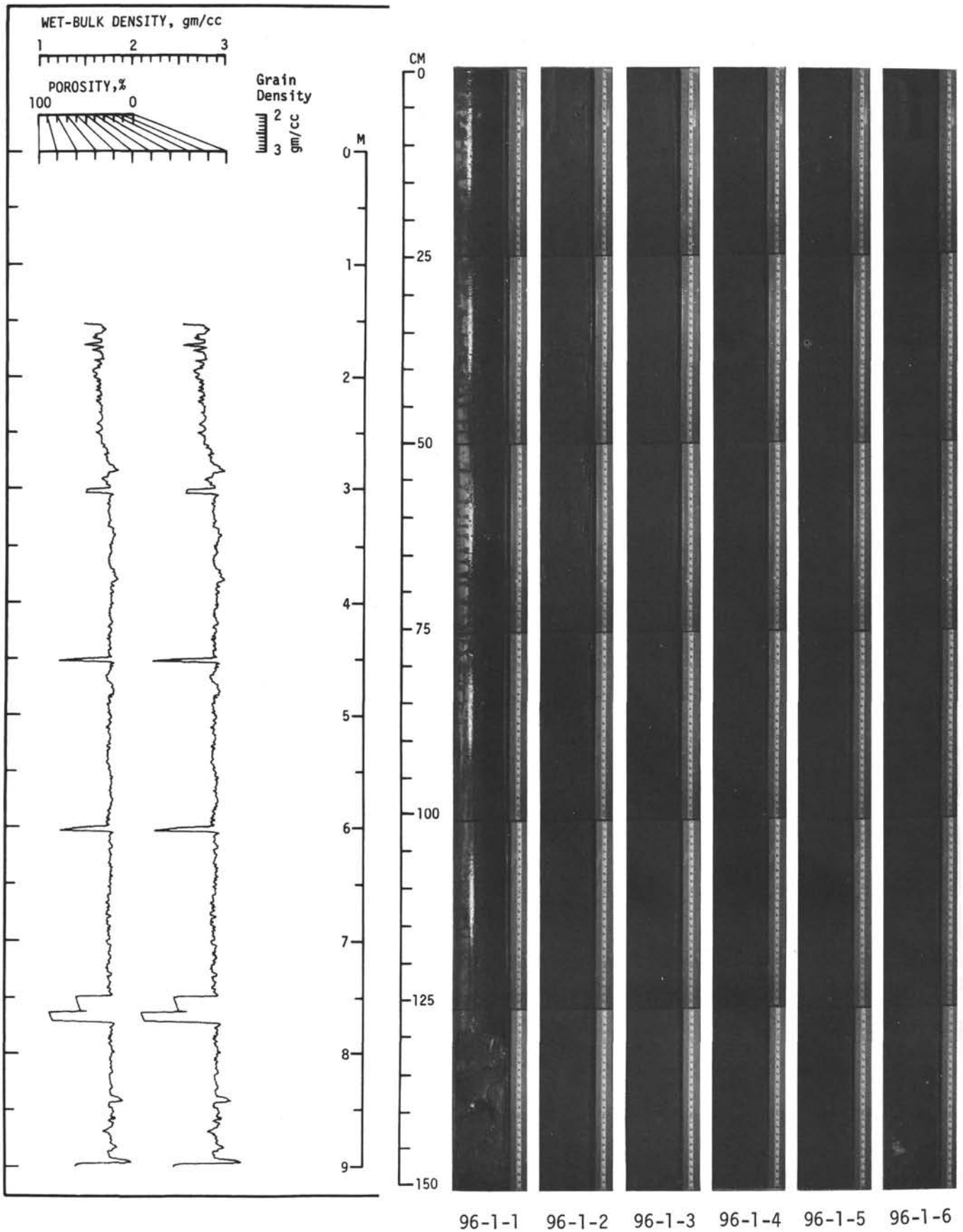
AGE	ZONE	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION	GRAIN SIZE WEIGHT % SAND	SILT	CLAY
EARLY EOCENE	P21	1	0.5				Mechanically disturbed throughout.			
			1.0				FORAM NANNO CHALK (soft) Light greenish-white (5G9/1 mottled with N7); strongly burrowed. Scattered pieces of soft chalk throughout.	5.7	48.1	46.1
		2								
		3						4.9	45.9	49.2
		4						5.9	44.9	49.2
		5					As above. Very rare vague laminae.	5.2	39.3	55.5
		6						4.4	45.2	50.3
		Core Catcher								

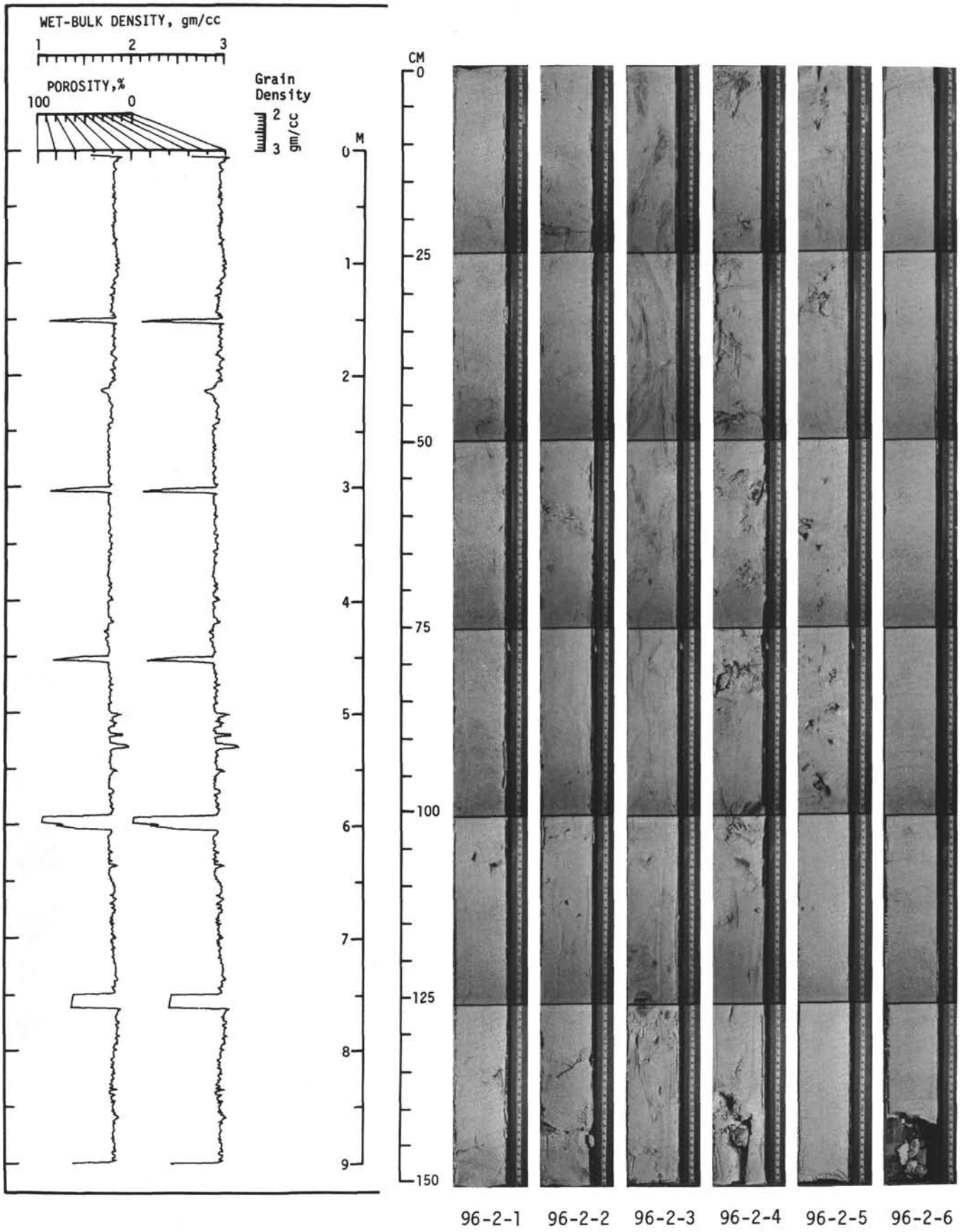
Site 96 Hole Core 4 Cored Interval: 321-329 m

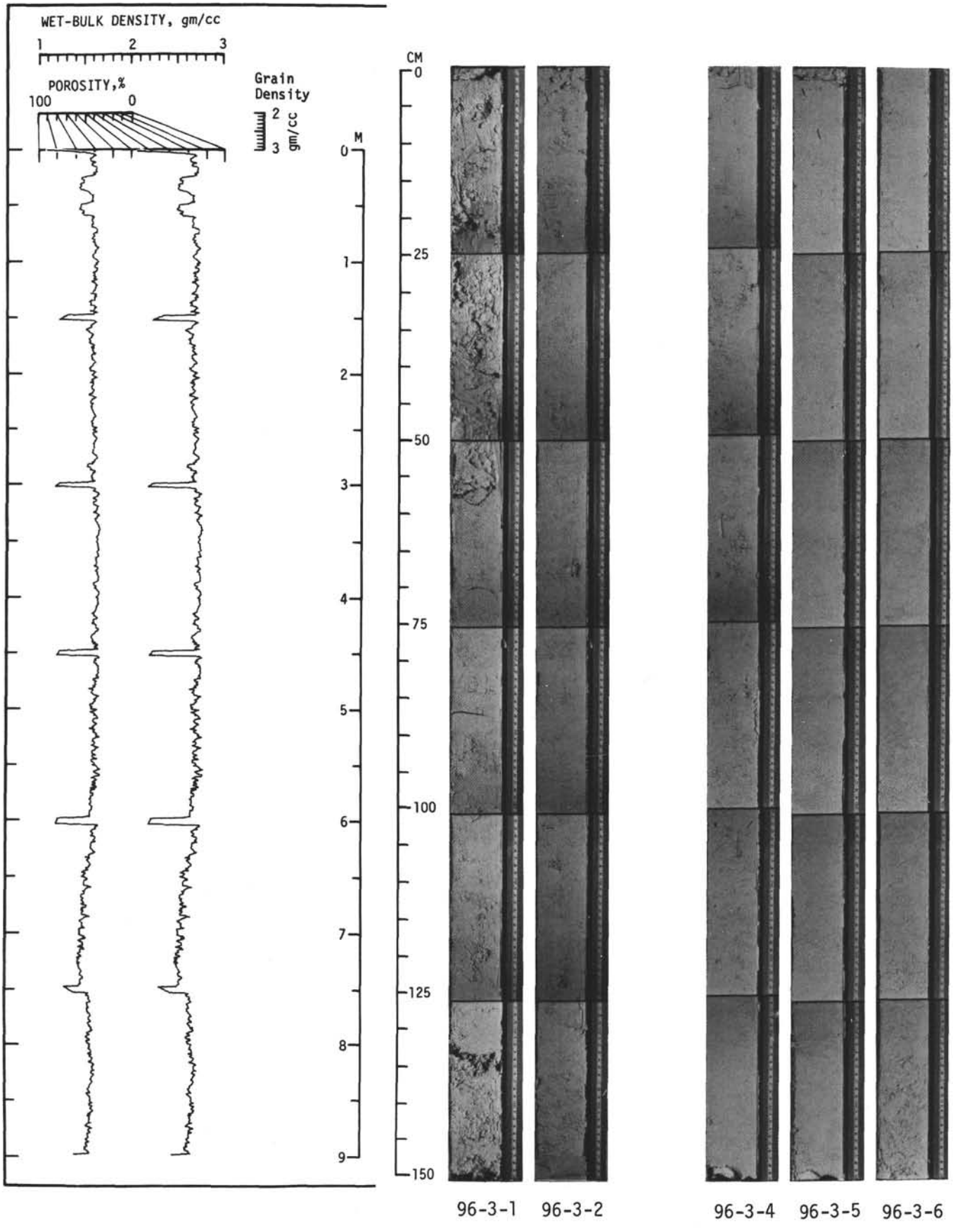
AGE	ZONE	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION	GRAIN SIZE WEIGHT % SAND	SILT	CLAY
LATE PALEOCENE	P6	Core Catcher					Core catcher: FORAM NANNO CHALK (soft) Very light greenish-white to light yellowish white and CHERT Greenish-gray 5GY5/1. Calcareous (impure).			

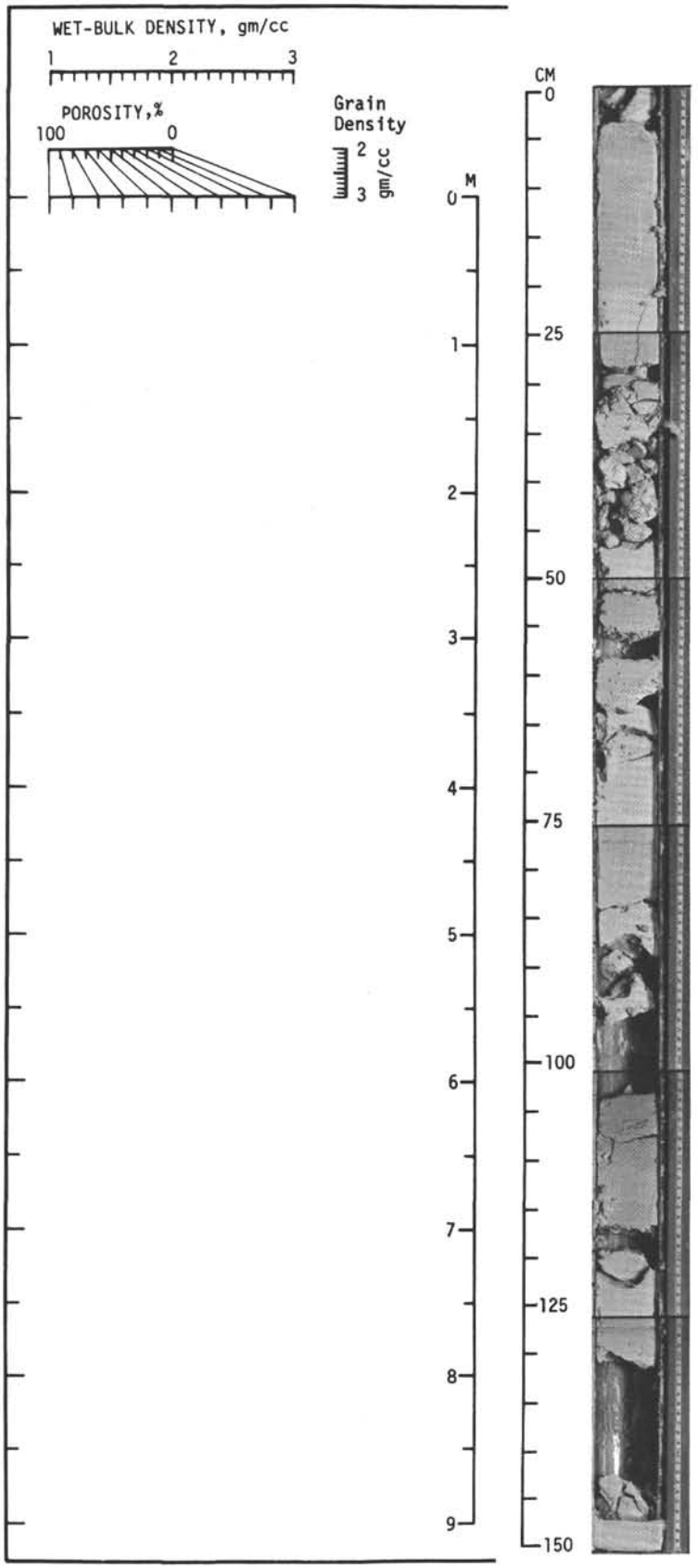
Site 96 Hole Core 5 Cored Interval: 329-332 m

AGE	ZONE	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION	GRAIN SIZE WEIGHT % SAND	SILT	CLAY
LATE PALEOCENE	P5	1	0.5	VOID			Mechanically disturbed in part. FORAM NANNO CHALK (soft) Very light yellowish/white (5Y9/1-N9); strongly burrow-mottled.			
			1.0							
		Core Catcher								


WET-BULK DENSITY, gm/cc
1
2
3
POROSITY,%
100
0
Grain Density
2
3
gm/cc
M
0
1
2
3
4
5
6
7
8
9
CM
0
25
50
75
100
125
150
96-1-1
96-1-2
96-1-3
96-1-4
96-1-5
96-1-6


WET-BULK DENSITY, gm/cc
1
2
3
POROSITY,%
100
0
Grain Density
2
3
gm/cc
M
0
1
2
3
4
5
6
7
8
9
CM
0
25
50
75
100
125
150
96-2-1
96-2-2
96-2-3
96-2-4
96-2-5
96-2-6


WET-BULK DENSITY, gm/cc
1
2
3
POROSITY,%
100
0
Grain Density
2
3
gm/cc
M
0
1
2
3
4
5
6
7
8
9
CM
0
25
50
75
100
125
150
96-3-1
96-3-2
96-3-4
96-3-5
96-3-6


WET-BULK DENSITY, gm/cc
1
2
3
POROSITY,%
100
0
Grain
Density
2
3
gm/cc
M
0
1
2
3
4
5
6
7
8
9
CM
0
25
50
75
100
125
150

96-5-1