7. SITE 90

The Shipboard Scientific Party[1]

SITE DATA

Occupied: March 9-11, 1970.

Position: 23°47.80'N; 94°46.09'W.

Water Depth: 3713 meters.

Total Depth: 768 meters.

Holes Drilled: One.

Cores Taken: Thirteen.

BACKGROUND AND OBJECTIVES

The Sigsbee Basin of the Gulf of Mexico lies between the Sigsbee Scarp to the north (about 200 miles off the Texas-Louisiana coast) the Campeche Scarp to the south (about 150 miles off the Yucatan Peninsula) the West Florida Escarpment to the east, (about 120 miles west of the Florida coast) and the foot of the Mexican continental slope to the west (about 180 miles east of the Mexican coast). The Sigsbee Basin includes the Mississippi Cone, to the east, and the Sigsbee Abyssal Plain to the west and south. The Sigsbee Abyssal Plain is interrupted only by the Sigsbee Knolls, the first three of which were discovered by M. Ewing in 1954 (Ewing, Ericson, and Heezen, 1958)

The study of thirty-three cores in 1953 led Ewing, Worzel, Ericson, and Heezen (1955) to the conclusion that the distribution of sediments in the Gulf of Mexico was profoundly influenced by turbidity currents. In arriving at this conclusion they considered the nature of the sediments cored, the topography of the Mississippi Cone, and the flat floor of the Sigsbee Deep. These authors also concluded, from seismic refraction measurements, that the crust was oceanic in character.

In 1954, a detailed topographic study, supplemented by 124 piston cores taken in the gulf (Ewing, Ericson, and Heezen, 1958), led to the conclusion that silty sediments, supplied in quantity by the Pleistocene Mississippi River and distributed by a turbidity current process, covered the floor of the gulf.

Site 90 was chosen at the foot of the continental rise to the eastern Mexican coast, just above the junction with the Sigsbee Abyssal Plain. This site was chosen principally because the profiler records from the *Kane* showed nearly horizontal beds to a depth of 350 meters underlain by parallel, but easterly dipping beds to 480 meters which, in turn, were underlain by horizontal beds to a depth of at least 820 meters. The profiler record on the *Glomar Challenger,* confirmed by two nearby profiler sections of the *R.D. Conrad,* did not show the sloping beds recorded by the *Kane.* In actuality, there was a zone 150 meters thick from which multiple echoes were recorded. It was underlain by an acoustically transparent zone from 150 to 450 meters which in turn was underlain by a zone of weak multiple echoes from 450 to 500 meters. This was followed by another acoustically quiet zone from 500 to 740 meters where a zone of strong multiple echoes commences and then extends at least to 1300 meters depth. See Figure 1 for the profiler records.

It was decided to drill the hole anyway, and to space the cores strategically so as to sample all the layers indicated by the *Kane* record. This would also provide a good sampling of all the layers indicated by the other profiler sections. The coring schedule was set up to sample a series of multiple echoes near the surface (150 to 450 meters depth), an acoustically transparent zone of weak multiple echoes from 450 to 500 meters and another acoustically quiet zone from 500 to 740 meters. A final zone of strong multiple echoes at 740 meters and extending to at least 1300 meters depth were sampled to the limit of the depth restriction imposed upon us.

The *Glomar Challenger* profiler record between Sites 90 and 91 showed that the former was located near the foot of the continental slope, which continues eastward beneath the horizontal beds of the Sigsbee Abyssal Plain. The Plain appears to overlap onto this continental slope. See Figure 2.

A secondary reason for drilling Site 90 was to provide a geologic section to compare with that to be explored in Hole 91, and to see if the horizons indicated by the profiler records could be correlated across the 80-mile separation.

Thirteen cores were recovered at Site 90 between the seafloor and 768 meters. The site was occupied on March 9-11. A coring summary is given in Table 1.

NATURE OF THE SEDIMENTS

General Description

Site 90, situated on the western edge of the Sigsbee Abyssal Plain, yielded a sedimentary section which demonstrates the transition from continental rise to abyssal plain. The Pleistocene section is represented by an intercalated sequence of pelagites, hemipelagites, hemilaminites, and laminites, reflecting the interaction between pelagic processes of sedimentation and the introduction of terrigenous material to the site via low energy turbidity currents. Source of much of the latter is probably from the nearby continental slope with subsidiary amounts from the north and northeast.

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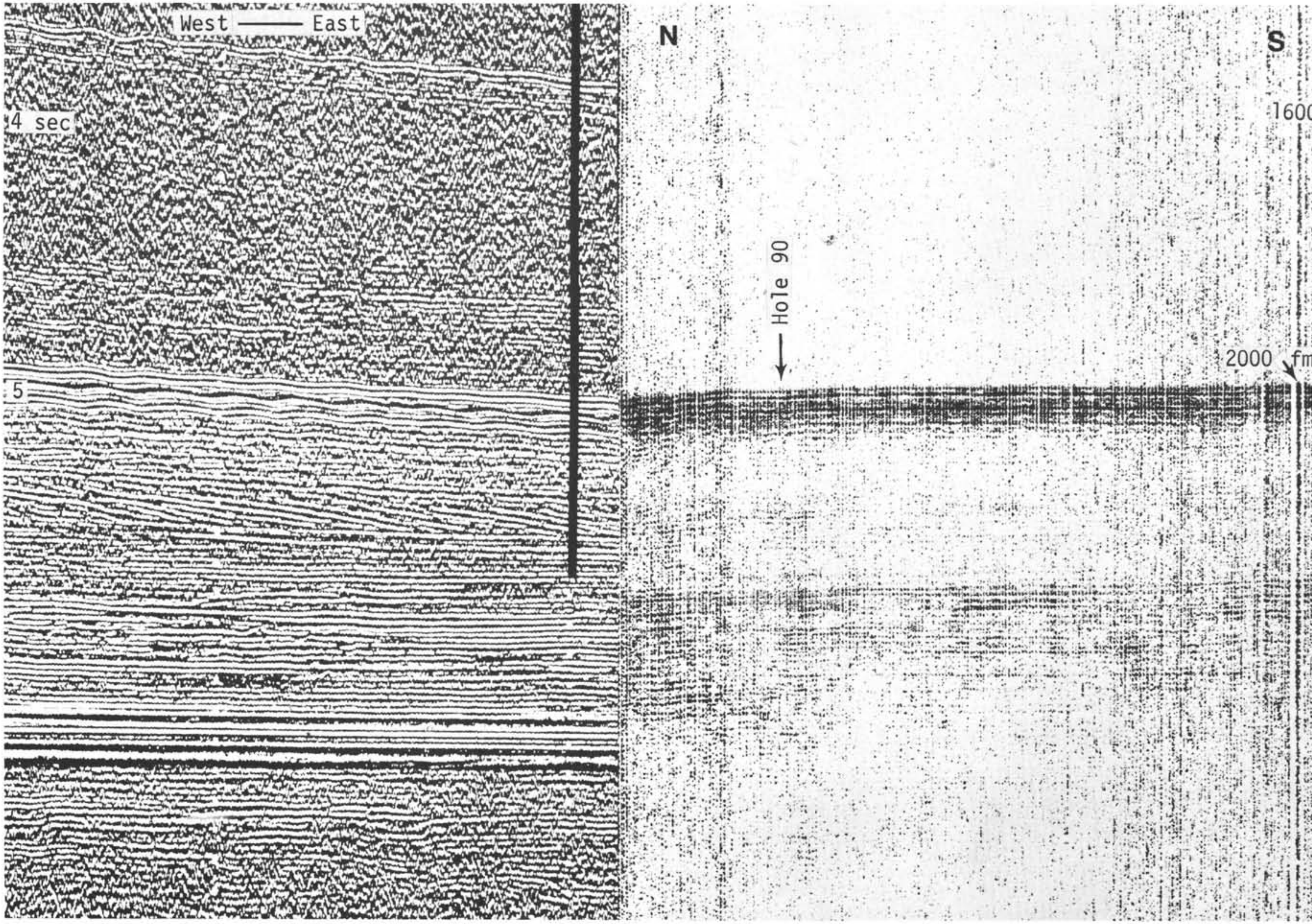


Figure 1. *Profile records showing horizontal beds at Site 90.*

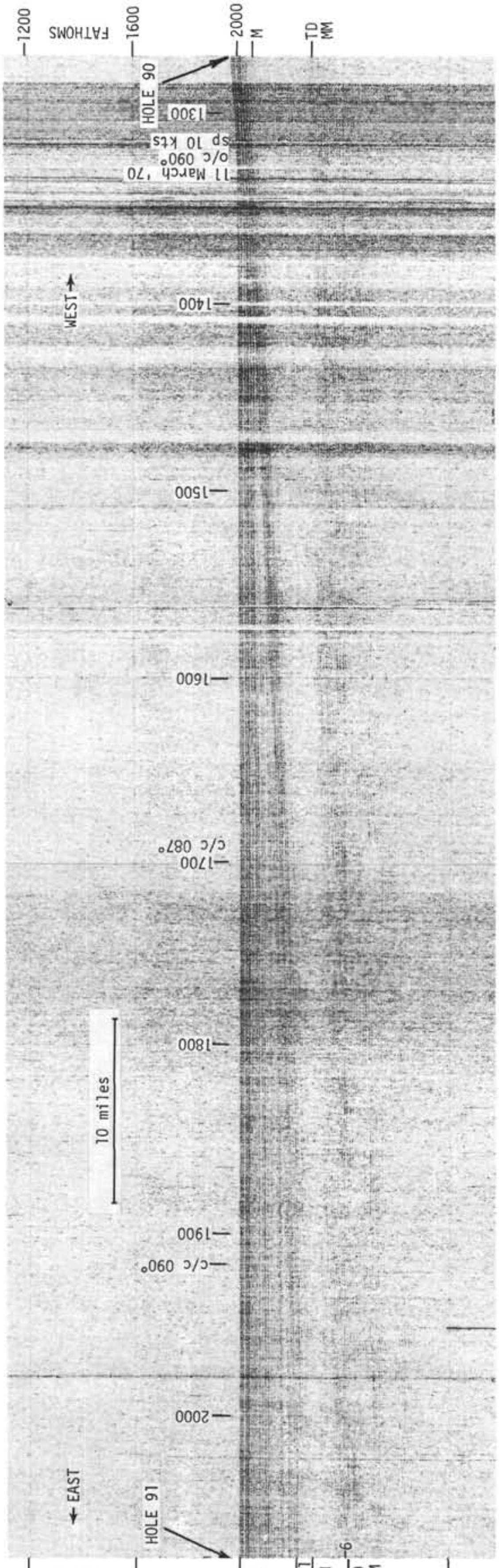


Figure 2. *Profile record between Sites 90 and 91.*

The remainder of the sediments recovered at Site 90 represents the slow transition from dominantly hemilaminites to laminites to coarse sand turbidites at total depth. This sequence is interpreted as representing a transition from low energy, turbidity-current related sedimentation in Late Miocene time to relatively high energy, turbidity current sedimentation of very fine to coarse terrigenous sands in Middle Miocene time. This relationship is somewhat similar to that of the Late Pleistocene in the Mississippi Fan-abyssal plain transition as known from piston cores. Thus, the deeper turbidite sandstones recovered at Site 90 represent somewhat proximal (to the continental slope) abyssal plain sedimentation, whereas the Late Miocene laminite sequence represents coalesced (?) abyssal fans which slowly prograded and aggraded the edge of the abyssal plain. The ramp which these more restricted sediments produced now forms the edge of the western Gulf of Mexico continental rise, covered by a rather thin veneer of Pleistocene rise sediments. The relationship of these sediments to the abyssal plain will be discussed further in the summary of Site 91.

The uppermost core (1) consists of tan, massive to strongly burrowed, clayey, nannofossil-rich, foraminiferal ooze, interbedded with moderately to well laminated, olive gray, sparsely burrowed to massive silty clay with occasional quartz silt laminae. This latter lithology is in turn intercalated with slightly to moderately burrowed, vaguely laminated, slightly foraminiferal, nannofossil-rich clay and nannofossil ooze. The sequence as a whole is described as an interbedded pelagite-laminite assemblage.

Core 2 is somewhat more terrigenous in aspect, consisting of interbedded dark olive gray, sparsely burrowed, vaguely laminated to massive silty clay with occasional laminae/bands/zones of quartzose/carbonate silt and olive gray, strongly burrowed, somewhat foraminiferal, nannofossil-rich clay and sparse to moderately burrowed, slightly foraminiferal, moderately nannofossil-rich clay with some vague laminae. Core 2 is summarized as a laminite-hemilaminite assemblage.

Core 3 is more pelagic in composition, being comprised of interbedded, strongly burrowed, greenish gray, clayey, foraminiferal, nannofossil ooze and olive gray-greenish gray, severely mottled (burrowed), slightly foraminiferal, somewhat nannofossil-rich clay. This lithologic sequence is categorized as hemipelagic.

Cores 4 and 5 are again more terrigenous in nature, consisting of greenish gray to dark greenish gray, moderately to vaguely laminated/banded, sparsely burrowed, locally pyritiferous and zeolitic, sparsely fossiliferous clay. These sediments are typical hemilaminites.

Cores 6 through 9 can be sumarized as laminites, consisting of greenish gray, vaguely to well laminated, generally sparsely burrowed, sparsely fossiliferous, clay and silty clay with common texturally graded quartzose, coarse silts (with sharp basal contacts). Burrow fill of silt is common. Core 6 is locally zeolitic, as is Core 5.

The remaining cores are characterized by thick sections of mechanically disturbed mixtures of sand and mudstone clasts, evidently representing either "cave" or slump from uphole, or disruption during coring. Regardless of stratigraphic position, these sediments appear to represent the

TABLE 1
Core Inventory – Site 90

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	3/9	0930	3713-3722	9.0	9.0	0	9.0	Foram ooze & silty clay	Late Pleistocene
2	4	3/9	1100	3783-3792	9.0	5.5	70.0	79.0	Silty clay	Late Pleistocene
3	3	3/9	1300	3843-3853	10.0	4.0	130.0	140.0	Foram nanno ooze	Early Pleistocene
4	3	3/9	1530	3901-3910	9.0	3.5	188.0	197.0	Clay	Early Pliocene
5	4	3/9	1800	3949-3955	6.0	6.0	236.0	242.0	Clay	Late Miocene
6	2	3/9	2130	4006-4011	5.0	3.0	293.0	298.0	Clay	Late Miocene
7	3	3/10	0000	4054-4061	7.0	4.2	341.0	348.0	Clay	Late Miocene
8	–	3/10	0330	4146-4152	6.0	0.0[b]	433.0	439.0	Clay	Late Miocene
9	1	3/10	0600	4214-4223	9.0	1.5	471.0	480.0	Clay	Late Miocene
10	4	3/10	1030	4308-4310.5	2.5	5.6	595.0	597.5	Silty sand	Middle Miocene
11	6	3/10	1600	4388-4395	7.0	9.0	675.0	682.0	Silty sand	Middle Miocene
12	–	3/10	2200	4474-4476	2.0	0.2	761.0	763.0	Sand	Middle Miocene
13	4	3/11	0200	4476-4481	5.0	6.0	763.0	768.0	Sand	Middle Miocene
Total	40				86.5	57.5		768.0		
% Cored					11.3%					
% Recovered						66.5%				

[a]Drill pipe measurement from derrick floor.
[b]Recovery in core catcher only.

presence of interbedded, greenish gray mudstone and subsidiary greenish gray to dark gray, silty, very fine to fine sand beds. Cores 12 and 13 are especially interesting, in that these cores contain coarser sands than recovered above, and Core 13 contains undisturbed texturally graded, dark gray, dominantly horizontally laminated with occasional overlying crosslamination, quartzose (mineralogically immature), very fine to slightly gravelly, medium sand. These graded sands are very poorly sorted and vary from carbonaceous to slightly carbonaceous.

From a consideration of the proportion of sand and mudstone clasts in Cores 10, 11, and 12, it is suggested that these cores represent a general increase in bed thickness and grain size of sandstone downward, reaching a maximum in Core 13. This depth approximates the position of strong reflections on the profiler record, which have been demonstrated (as at Sites 3 and 11) to indicate relatively high proportions of sand. In summary, Cores 10, 11, and 12 are interpreted as mixtures of turbidite-laminite sequences, whereas Core 13 is categorized as a turbidite assemblage of sediments.

Mineralogically, the coarser sands contain much higher percentages of plagioclase and rock fragments than the overlying finer-grained sediment. Quartz to feldspar ratios for the Miocene segment of Site 90 are considerably lower than for the Pleistocene section, which also apparently holds true for other sites on the abyssal plain. The coarse Miocene sands contain a diverse suite of heavy minerals such as brown and green hornblende, sphene, zircon, chert, glauconite, rutile, and tourmaline. Rock fragments include volcanics, metamorphics (?), and carbonates. The nearest provenance area which contains necessary components to comprise the sands under discussion would appear to be the Rio Grande embayment.

Sedimentological Interpretation

Sedimentation during Middle to Late Miocene time, in the deepwater segment of the Gulf of Mexico, was characterized by a high rate of terrigenous clastic influx, primarily via turbidity currents. The lithological assemblage of turbidites, laminites, and hemilaminites describes a slow decrease in sedimentation rates (at Site 90) from a maximum in (early) Middle Miocene time to a minimum in Pliocene and Early Pleistocene time. This change corresponds to a decrease in abundance of graded sand beds and a probable more local distribution of fine-grained silty clay/clay (as in the hemilaminites). As discussed previously, aggradation and progradation of this latter sediment type evidently produced the ramp which now forms the base of the continental rise along the western Gulf of Mexico slope-abyssal plain transition.

The source of the Miocene clastics is apparently different, at least in part, from that of Pleistocene sediments. Binocular examination suggests an immature mineralogical assemblage of first cycle volcanogenic derivation with a subsidiary metamorphic rock fragment assemblage and a third assemblage of carbonate rock fragments. Proximity of this site to the Rio Grande embayment suggests that area as the most likely immediate source of such detritus. The known thick sequence of Miocene shelf sediments from that region are thought to be comparable in terms of ultimate source, although additional study appears required before final conclusions can be made.

The presence of coarse sand in Miocene sediments is quite interesting, in that such coarse sands are not generally found associated with typical deltaic progradation in the northern Gulf of Mexico shelf sequences. If one postulates initiation of turbidity currents at the shelf-slope transition, then the presence of Miocene coarse sands in the deep-water segment of the Gulf of Mexico appears anomalous. Most Pleistocene sands described from the abyssal plain fall in the very fine to fine grade. The writers prefer an alternative interpretation of eustatic changes in sea level, whereby fluvial processes were able to deliver coarse clastics to the narrow continental margin of the Rio Grande shelf. As in Pleistocene time, progradation was necessarily limited by the resultant steep bottom gradient at the shelf edge, the coastal plain was narrow, and the shelf edge slumped probably more frequently than during high sea level stages. With the resultant higher stream gradient operative during low sea level stages, coastal fluvioldeltaic systems were able to deliver coarser sediments to the shelf edge. The resultant influence on deep-water sediments is thus more clearly related.

Following deposition of Miocene sediments, a lower rate of terrigenous clastic influx to the area of Site 90 was operative. Lower Pleistocene (and Upper Pliocene?) sediments are decidedly more pelagic in composition, suggesting that turbidity currents from the east were not able to reach this area (due to a topographically high position?), and that local sources of terrigenous clastics were equally unimportant. In Late Pleistocene time, a mixed sequence of turbidity-current related sediments were deposited, probably representing contributions from the east, north, and western source areas of the gulf. This aspect of sedimentation will be discussed more fully in the Site 91 summary.

Uppermost Pleistocene and Holocene sediments at Site 90 are characteristically laminites and pelagites, respectively. This agrees well with the transition as known from numerous piston cores throughout the deep-water gulf.

Physical Measurements

Penetrometer measurements describe an orderly increase in consolidation of sediments with depth at this site. At a depth of approximately 500 meters, the sediments can be categorized as "stone" under the consolidation scale being utilized. The sandstone at the base of the hole might be better described as "friable" and, judging from the mechanical disturbance of Cores 10, 11, and 12, is often only semi-consolidated. A thin bed of zeolite-cemented, very fine sand was noted in Core 13.

GRAPE determinations of bulk density also describe increasing consolidation with depth, although the disturbed state of cores in the lower part of the hole make interpretation difficult. Laboratory determinations of bulk density are again higher, by about 0.2 of a gm/cc in general.

Natural gamma measurements reflect the more terrigenous nature of the Miocene sediments, although differences are not particularly marked. The pelagic-related sediments of Cores 1 and 3 yield the lowest count, as is normal. The Miocene sand at the base of the hole is somewhat surprising in that a high count appears characteristic. The disturbed nature of Cores 10 and 11 suggests that the maximum values shown on the summary plot are low. The high count of Core 13 is interpreted to reflect the mineralogically immature composition of the sandstone. Cores 5 and 6 contain local concentrations of zeolites, which yield very high (over 5,000) counts. Counts from these bands are probably much higher, but because the gamma device integrates over such a broad area, the zeolite concentrations show up as broad highs.

Small concentrations of methane and associated natural gas were noted in the upper sediment cores at Site 90. A biogenic origin again seems most plausible in terms of volume and composition distribution with depth.

BIOSTRATIGRAPHY

The biostratigraphy of Site 90 (adjacent to Site 6) is summarized in Figure 3. The interpretation is based on examinations of the foraminifers and calcareous nannofossils. The samples also were examined for radiolarians, but no significant occurrences were noted.

Sample 1 (10-90-1, CC):

Globoratalia truncatulinoides (abundant), *G. menardii* (sinistral, rare), *G. crassiformis, G. scitula, Globigerinoides ruber* (pink), *G. quadrilobata, G. sacculifera, Globigerina inflata* (common to abundant), *G. eggeri, Gephyrocapsa oceanica, G. operta, G.* sp. cf. *G. kamptneri, Pseudoemiliania* sp., *Coccolithus pelagicus,* s.s., *Cyclococcolithus leptoporus leptoporus, Rhabdosphaera claviger,* and *Scapholithus fossilis.*

Age: Late Pleistocene (Wisconsinan): *Globorotalia truncatulinoides* Zone; *Pulleniatina finalis* Subzone.

Environment: Bathyal.

Remarks: Rare reworked Cretaceous calcareous nannofossils were noted.

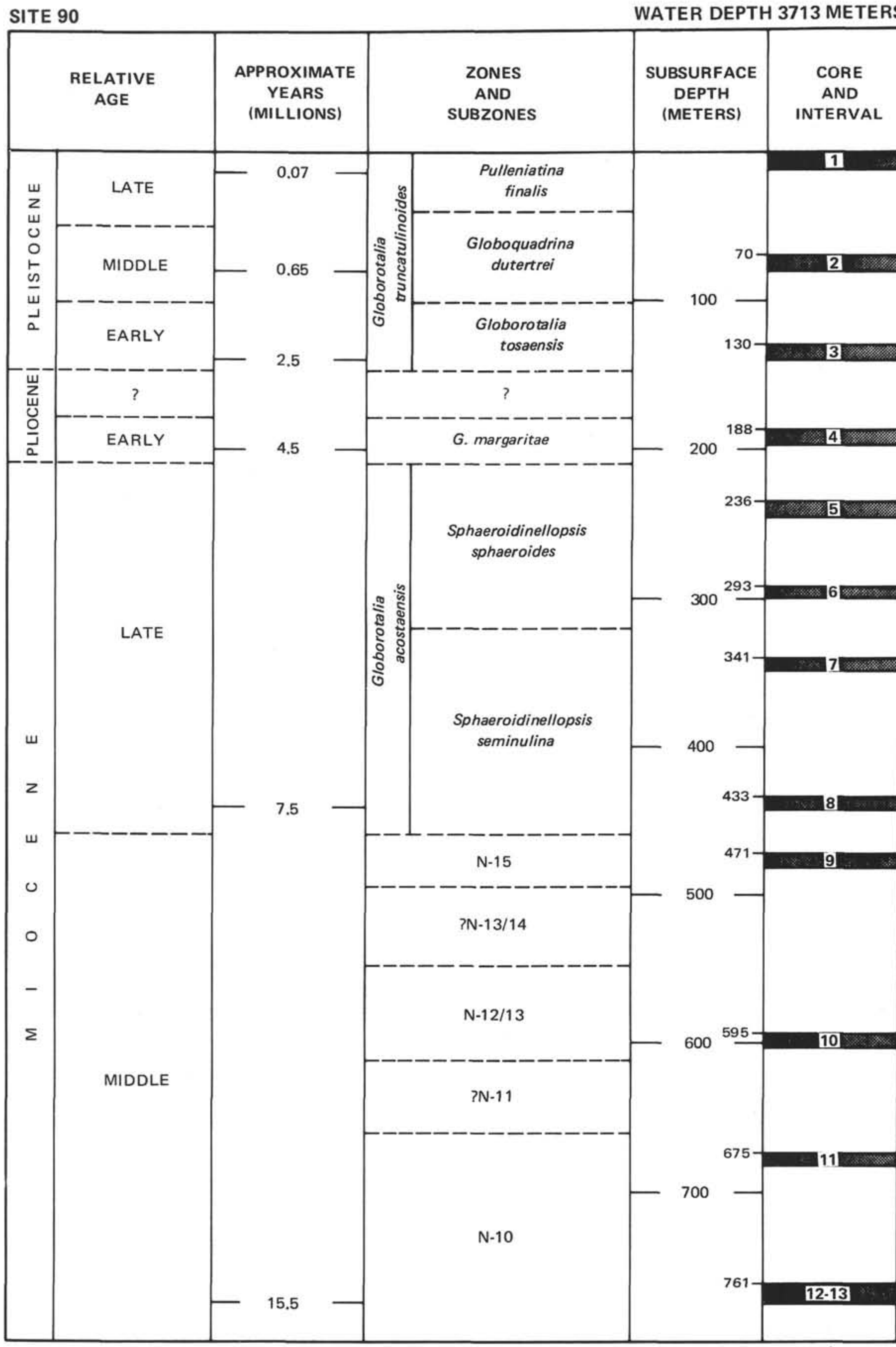


Figure 3. *Biostratigraphic summary of Site 90.*

Sample 2 (10-90-2, CC):

Globorotalia truncatulinoides (abundant), *Globigerina* sp. cf. *G. inflata* (large, abundant), *Sphaeroidinella dehiscens* (abundant), *Pulleniatina obliquiloculata* (common), *Globigerinoides ruber* (white) *Hastigerina aequilateralis, Gephyrocapsa oceanica, G.* sp. cf. *G. caribeanica, Coccolithus pataecus, Pseudoemiliania lacunosa, Cyclococcolithus annulus,* and *Scyphosphaera pulcherrima.*

Age: Late Pleistocene (early Illinoian): *Globorotalia truncatulinoides* Zone; *Globoquadrina dutertrei* Subzone
Environment: Bathyal.
Remarks: A few Cretaceous nannofossils were noted.

Sample 3 (10-90-3, CC):

Globorotalia miocenica, G. pertenuis, G. sp. cf. *G. hirsuta, G. crassiformis, Globigerinoides ruber* (white), *G. conglobatus, G. triloba, Sphaeroidinella dehiscens, Discoaster brouweri, D. surculus, D. pentaradiatus, Cyclococcolithus leptoporus macintyrei, Helicopontosphaera sellii, Coccolithus pataecus, Pseudoemiliania lacunosa, Discolithina millipuncta, and Reticulofenestra pseudoumbilica* (rare).

Age: Early Pleistocene (early Nebraskan): *Globorotalia truncalulinoides* Zone; *Globorotalia tosaensis* Subzone.
Environment: Bathyal.
Remarks: The benthonic foraminiferal assemblage includes *Gyroidina soldanii* and species of *Pullenia* and *Pyrgo.* The discoasters here referred to *D. pentaradiatus* are symmetrical and 5-rayed, but most specimens have rather short nonbifurcating rays.

Sample 4 (10-90-4, CC):

Globigerina nepenthes, Globigerinoides obliqua, Globorotalia miocenica, G. sp. aff. *G. acostaensis, Discoaster brouweri, D. surculus, D. pentaradiatus, D. asymmetricus, D. exilis, D.* sp. cf. *D. quinqueramus, Sphenolithus abies, Ceratolithus tricornulatus, C. rugosus, Pseudoemiliania lacunosa,* and *Reticulofenestra pseudoumbilica.*

Age: Early Pliocene: *Globorotalia margaritae* Zone.
Environment: Bathyal.

Sample 5 (10-90-5, CC):

Discoaster quinqueramus, D. exilis, D. surculus, D. brouweri, D. pentaradiatus (rare), *Sphenolithus abies, S.* sp. cf. *S. heteromorphus, Cyclococcolithus* sp. cf. *C. neogammation, C. leptoporus macintyrei, Sphaeroidinella dehiscens, Globigerinoides obliqua,* and *Globigerina* sp. cf. *G. nepenthes.*

Age: Late Miocene: *Globorotalia acostaensis* Zone; *Sphaeroidinellopsis sphaeroides* Subzone.
Remarks: Both fauna and flora are rare, suggesting a high degree of dilution resulting from high turbidity.

Sample 6 (10-90-6, CC):

Discoaster brouweri, D. surculus, D. exilis, D. challengeri, D. subsurculus, D. bollii, D. quinqueramus, Coccolithus pataecus, Cyclococcolithus sp. cf. *C. neogammation, Craspedolithus nitescens, Globoquadrina altispira,* and *Globigerinoides altiapertura.*

Age: Late Miocene: *Globorotalia acostaensis* Zone.
Environment: Probable Bathyal.
Remarks: Rare reworked Cretaceous and a few reworked Eocene calcareous nannofossils were noted, including *Discoaster lodoensis.* Benthonic foraminifers noted include species of *Bulimina, Ellipsonodosaria, Rotalia, Nonion, Cibicides, Pyrgo, Laticarinina,* and miliolids.

Sample 7 (10-90-7, CC):

Discoaster brouweri, D. exilis, D. challengeri, D. sp. cf. *D. quinqueramus* (rare), *Helicopontosphaera sellii, Cyclococcolithus neogammation, C. leptoporus,* s.l., *Reticulofenestra pseudoumbilica, Scapholithus* sp., *Sphenolithus abies,* Cf. *Catinaster* sp., *Globigerinoides* sp. cf. *G. venezuelana,* and *G. triloba.*

Age: Late Miocene: *Globorotalia acostaensis* Zone.
Environment: Probable Bathyal.

Sample 8 (10-90-8, CC):

Discoaster bollii, D. brouweri, D. exilis, D. challengeri, D. sp. cf. *D. quinqueramus, D.* sp. aff. *D. kugleri, Catinaster calyculus, Reticulofenestra pseudoumbilica,* and *Cyclococcolithus neogammation.*

Age: Late Miocene: *Globorotalia acostaensis* Zone; *Sphaeroidinellopsis seminulina* Subzone.
Environment: Probable bathyal.

Sample 9 (10-90-9, CC):

Catinaster coalitus, Cyclococcolithus neogammation, Discoaster challengeri, Helicopontosphaera sellii, Globorotalia menardii, var., *G.* sp. aff. *G. miocenica, Globigerinoides triloba,* and *G.* sp. cf. *G. altiapertura.*

Age: Middle Miocene (N.15).
Environment: Probable bathyal.

Sample 10 (10-90-10, CC):

Globorotalia fohsi robusta, G. sp. cf. *G. mayeri, Globigerinoides triloba, Discoaster exilis, D. brouweri, D. challengeri, Sphenolithus abies,* and *Cyclococcolithus neogammation.*

Age: Late Middle Miocene (N.12/early N.13).
Environment: Probalbe bathyal.
Remarks: Benthonic foraminifers noted inlcude *Ammonia beccarii.* Rare reworked Cretaceous globotruncanids also were noted. Among the calcareous nannofossils, reworked Oligocene forms include *Helicopontosphaera truncata* and *Coccolithus eopelagicus.*

Sample 11 (10-90-11, CC):

Globorotalia fohsi fohsi, Globigerinoides triloba, Orbulina sp. cf. *O. suturalis, Discoaster brouweri, D. exilis, D.* sp. cf. *D. challengeri, D.* sp. cf. *D. kugleri, D.* sp. aff. *D. bollii,* and *Cyclococcolithus neogammation.*

Age: early Middle Miocene (N. 10), probably *Globorotalia fohsi fohsi* Zone.
Environment: Probable bathyal.
Remarks: Among the calcareous nannofossils were noted Pliocene contamination including *Discoaster asymmetricus* and reworked Eocene including *Marthasterites tribrachiatus.*

Sample 12 (10-90-12, CC):

Globorotalia fohsi fohsi, Globoquadrina venezuelana, Globigerinoides triloba, Discoaster sp. cf. *D. brouweri, D.* sp. cf. *D. challengeri, D.* sp. aff. *D. bollii, D.* sp. aff. *D. kugleri, Helicopontosphaera helicopontosphaera sellii,* and *Cyclococcolithus neogammation.*

Age: early Middle Miocene (N.10) probable early *Globorotalia fohsi fohsi* Zone.

Environment: Probable bathyal.

Sample 13 (10-90-13, CC):

Globorotalia fohsi fohsi, Discoaster sp. cf. *D. brouweri, Helicopontosphaera sellii,* and *Cyclococcolithus neogammation.*

Age: early Middle Miocene (N.10)

Environment: Bathyal.

Remarks: Both the fauna and flora are rare suggesting a high degree of dilution with terrigenous and bioclastic debris. Reworked Oligocene calcareous nannofossils include *Reticulofenestra scissura.* The sample preparations contained abundant biotite.

DISCUSSION AND INTERPRETATION

Thirteen cores were recovered from Site 90. The oldest sediments were Middle Miocene and occurred between 761 and 763 meters, the deepest depth penetrated. The deepest core was a coarse turbidite which correlates with the top of the deeper sequence of echoes on the profiler records (see Figure 4). The upper sequence of reflectors corresponds to the Pleistocene. The Upper Miocene and Pliocene correspond to the zone of little or no reflections.

The sediments recovered from Site 90 represent intercalated sequences of pelagites, hemipelagites, hemilaminites, and laminites, and reflect the interaction between pelagic processes of sedimentation and material transported to the site via low energy turbidity currents during the Pleistocene. Miocene sediments consisted of dominantly hemilaminites to laminites to coarse sand turbidites. The Miocene sequence represents a transition from low energy, turbidity-current activity during the Late Miocene time to relatively high energy turbidity current sedimentation in Middle Miocene time. Aggradation and progradation of the Miocene sediments produced the ramp which now forms the continental rise along the western Gulf of Mexico slope-abyssal plain transition.

The Rio Grande embayment is probably the source of major portions of the Miocene section, while the Upper Pleistocene material represents contributions from not only the west and north, but also from the eastern sections of the basin.

The Upper Pleistocene sediments cored contain interbedded nannofossil ooze and terrigenous mud. Most of these cores contain light-colored highly angular, fine sand and silt-sized shards and silt-and-clay-sized detrital carbonate material. Lower Pleistocene sediments are nannofossil ooze with a trace of quartz, some shards, and a little plant material. All contain foraminifers.

Early Pliocene sediments are nannofossil ooze. Zeolite crystals, dolomite, ferruginous opaques, and plant material are also present, but in very minor amounts.

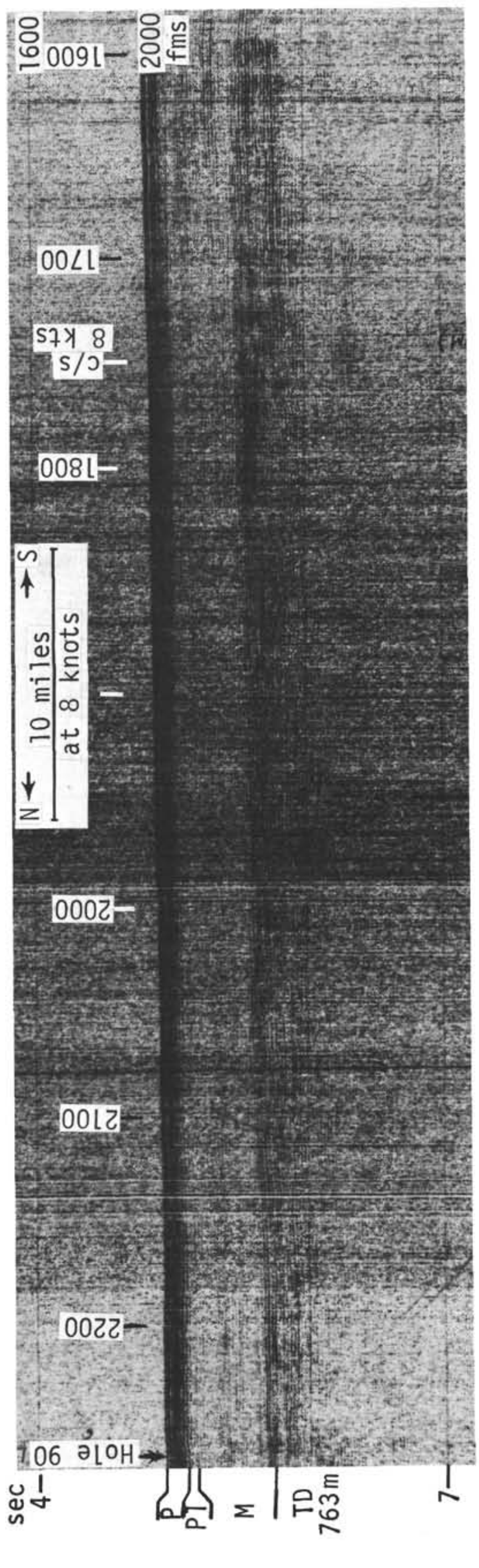


Figure 4. *Profile record, Site 90.*

Late Miocene sediments consist of terrigenous clayey silt or sand. Quartz ranges in quantity from rare to abundant. Detrital carbonate occurrence is common and makes up to 50 per cent or more of the sample in half the sections studied.

Middle Miocene sediments are lithologically similar to the overlying Upper Miocene samples, except that these sediments are more sandy and contain more quartz, dark mica, feldspar, and heavies. Upper Detrital carbonate ranging from 5 to 30 per cent occurs in all samples. Dolomite, pyrite, dark mica, and zeolites occur at spots within the cored section.

In general, the following conclusions can be made:

1) Both oozes and terrigenous sediments were deposited during the Pleistocene.

2) It has been suggested that the source of the bulk of the Pleistocene sediments is from a northerly and westerly source. Further examination of the sediments is necessary before definite source areas can be identified.

3) The Pliocene seems to be a time of ooze deposition not only in Site 90, but also in Sites 86, 88, and 89.

4) Terrigenous clastics predominate in the Miocene for Sites 87, 89 and 90.

5) Zeolites found in Site 90 correlate with the occurrence of volcanic glass and are more conspicuous with depth.

Estimated rates of deposition for Site 90 are as follows:

Late Pleistocene	11 $cm/10^3y$
Early Pleistocene	3 $cm/10^3y$
Pliocene	2 $cm/10^3y$
Late Miocene	2.8 $cm/10^3y$
Middle Miocene	4.1 $cm/10^3y$

The average rate of deposition for Site 90 from the Middle Miocene to the present is 4.9 $cm/10^3y$.

It is interesting to note that the maximum rates of deposition in Site 90 not considering the Pleistocene was during the Middle Miocene. Site 90 lies on the western edge of the Sigsbee Abyssal Plain, but receives only minor amounts of sediments from the main source of sediments comprising the abyssal plain, the Mississippi River. The extremely rugged topography of the continental slope of Mexico, west of Site 90, prevents most nonpelagic sediments of the continental shelf and upper continental slope area from reaching the site. High rates of deposition are usually attributed to the Pleistocene. Two possible factors that make this site one of low deposition in the Pleistocene when compared to other parts of the Sigsbee Abyssal Plain are (1) the distance from the Mississippi River mouth, the source of the bulk of the sediments in the deeper basin in this period, and (2) the rugged topography to the north and west of the site which may have acted as a protective barrier.

During the Miocene, the main contribution must have been from the north and west, mainly the Rio Grande embayment. It is also possible that the western salt barriers were of less relief or nonexistent during the Miocene, which would afford easier access routes for the transportation of material from the shelf and upper slope of Mexico. The large uplift to the west during the Miocene established the Rio Grande embayment as a major depocenter, thus assuring the availability of an abundant supply of sediment that could be transported into the western portion of the basin. Examination of the seismic records indicates that the strong reflectors, which were determined as Miocene from these cores, thin to the east and thereby support the view that there was a westerly source of sediments (Figure 2). In addition, the general nature of the sediments (mostly volcanic) also suggests a western source. In contrast to the above, the Pleistocene section thickens to the east, indicating an easterly source of sediments. The source obviously, being the Mississippi.

The presence of gas was noted in the cores, starting with Core 3 and, in general, ending with Core 13. The following table summarizes the analyses of the gas as determined by gas chromatography. The values are considered to be estimates only.

Sample	Core Depth (m)	Methane (%)	Average Methane Per Core (%)	Ethane
303 top	130	68	68	
4-2-bottom	190	44		
4-2-bottom	192	47	44.7	
4-3-top	194	48		
4-3-top	195	40		
5 top	237	72		
5 middle	230	62		Tr.
5 bottom	241	72	68.5	
5 bottom	241	68		
11 top	675	67		Tr.
11 middle	678	68	69.0	
11 bottom	681	73		Tr.
13 top	764	67		Tr.
13 middle	765	66	65.0	
13 bottom	767	62		Tr.

The volume of gas in the cores was estimated to be the greatest in Cores 5 (236 m) and 11 (675 m). As in 88 and 89, the gas seems to be concentrated at depths of about 300 meters, again suggesting that they have their origins in biogenic activity.

The results of physical measurements on the cores are as follows:

1) Penetrometer measurements describe an orderly increase in degree of consolidation with depth.

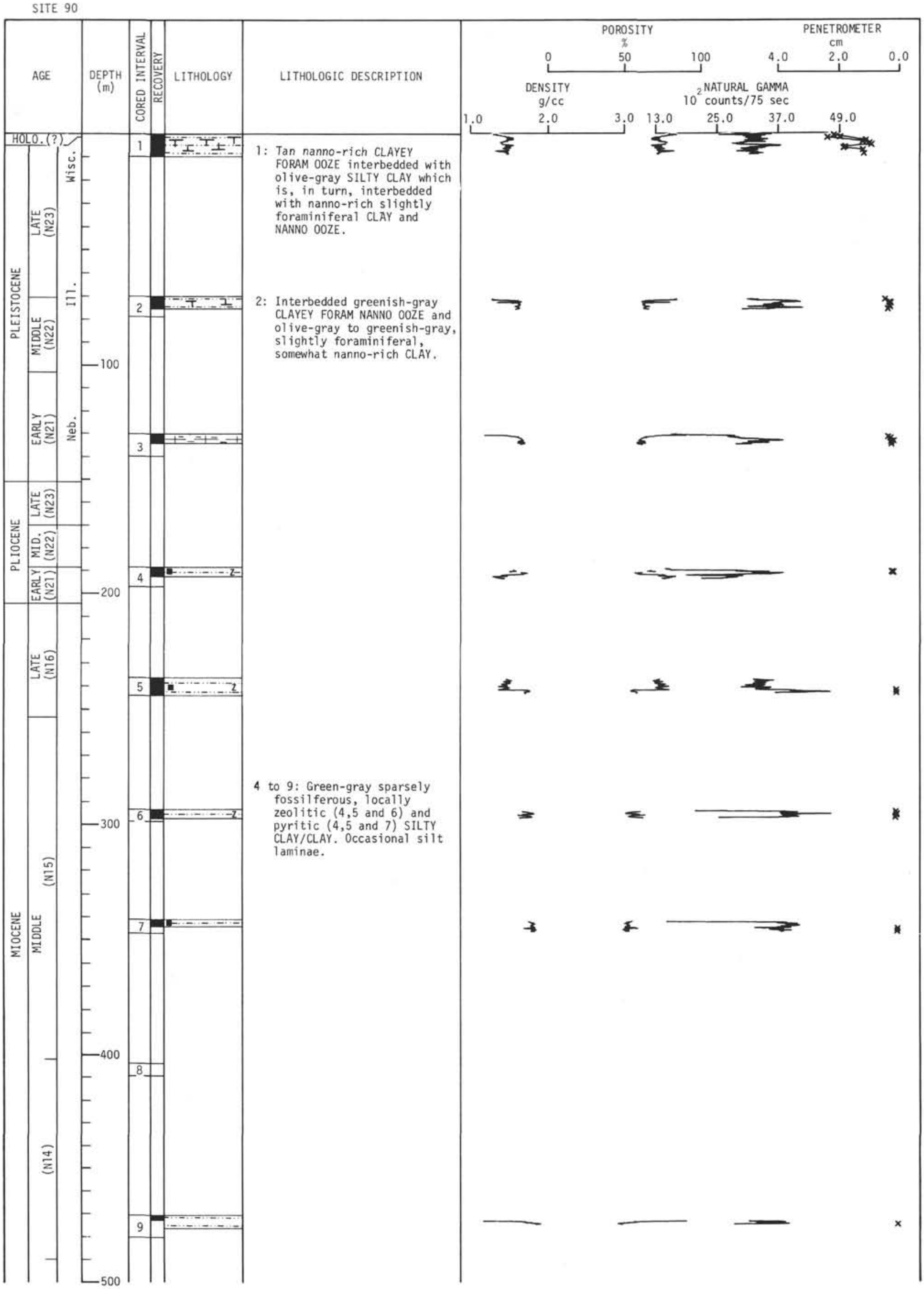
2) At approximately 500 meters depth, the sediments can be categorized as "stone".

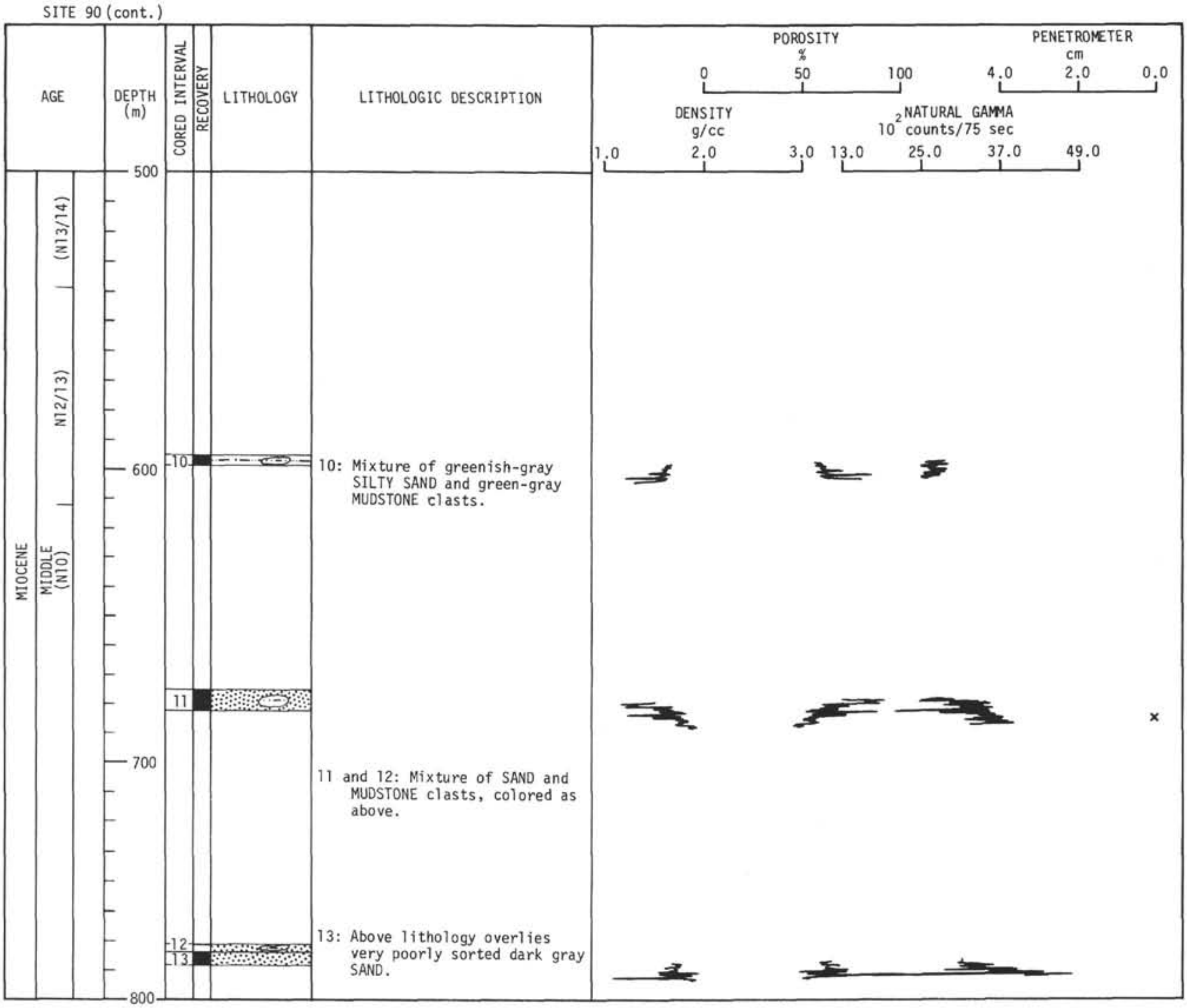
3) GRAPE determinations of bulk density showed increasing densities associated with increasing depth and consolidation characteristics.

REFERENCES

Ewing, M., Ericson, D.B. and Heezen, B.C., 1958. Sediments and Topography of the Gulf of Mexico. *In* Habitat of Oil (L. Weeks Ed.). Am. Assoc. Petrol. Geologists, 995.

Ewing, M., Worzel, J.L., Ericson, D.B. and Heezen, B.C., 1955. Geophysical and Geological Investigations in the Gulf of Mexico, Part I. Geophysics.**20** 1.

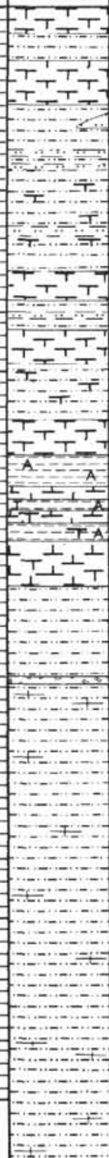

SITE 90
AGE
DEPTH (m)
CORED INTERVAL
RECOVERY
LITHOLOGY
LITHOLOGIC DESCRIPTION
POROSITY %
0 50 100
PENETROMETER cm
4.0 2.0 0.0
DENSITY g/cc
1.0 2.0 3.0
NATURAL GAMMA 10^2 counts/75 sec
13.0 25.0 37.0 49.0
HOLO.(?)
PLEISTOCENE
LATE (N23)
MIDDLE (N22)
EARLY (N21)
Wisc.
Ill.
Neb.
PLIOCENE
LATE (N23)
MID. (N22)
EARLY (N21)
MIOCENE
LATE (N16)
MIDDLE
(N15)
(N14)
100
200
300
400
500
1
2
3
4
5
6
7
8
9
1: Tan nanno-rich CLAYEY FORAM OOZE interbedded with olive-gray SILTY CLAY which is, in turn, interbedded with nanno-rich slightly foraminiferal CLAY and NANNO OOZE.
2: Interbedded greenish-gray CLAYEY FORAM NANNO OOZE and olive-gray to greenish-gray, slightly foraminiferal, somewhat nanno-rich CLAY.
4 to 9: Green-gray sparsely fossiliferous, locally zeolitic (4,5 and 6) and pyritic (4,5 and 7) SILTY CLAY/CLAY. Occasional silt laminae.


SITE 90 (cont.)
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
10^2 NATURAL GAMMA counts/75 sec
13.0
25.0
37.0
49.0
500
600
700
800
MIOCENE
MIDDLE (N10)
N12/13)
(N13/14)
10
11
12
13
10: Mixture of greenish-gray SILTY SAND and green-gray MUDSTONE clasts.
11 and 12: Mixture of SAND and MUDSTONE clasts, colored as above.
13: Above lithology overlies very poorly sorted dark gray SAND.

Site 90 Hole Core 1 Cored Interval: 0-9 m

AGE: LATE PLEISTOCENE (Wisconsin); Mid-Altonian

ZONE: *Globorotalia truncatulinoides (Pulleniatina finalis* Subzone)



SECTION	LITHOLOGIC DESCRIPTION	SAND	SILT	CLAY
1–2	Interbedded CLAYEY FORAM OOZE and SILTY CLAY Former is tan (10YR5/4-6/4 with mottles of 4/2); Massive to burrowed. Latter is olive-gray (5Y4/1); moderately to well laminated; sparsely burrowed to massive with occasional laminations of quartzose silt (ashy?)	0.2	36.5	63.3
3	Interbedded CLAY and CLAYEY FORAM NANNO OOZE Former is slightly foraminiferal and nanno-rich; slightly burrowed and often vaguely laminated. Latter is moderately burrowed. Several ashy zones.	2.0	34.9	63.1
4	SILTY CLAY Olive gray (5Y4/1); quartzose, partially laminated with laminae of quartz silt. Also mixed patches of silt-either burrow-fill or mechanical.	2.1	11.4	86.5
5	As above. Slightly foraminiferal, somewhat nanno-rich. Contains several zones of deformed quartzose silt-probably originally laminae. Also probably moderately to sparsely burrowed.	1.2	21.7	77.1
6		0.9	24.3	74.9
Core Catcher				

Site 90 Hole Core 2 Cored Interval: 70-79 m

AGE: LATE PLEISTOCENE; MIDDLE PLEISTOCENE (Illinoian)

ZONE: *Globorotalia truncatulinoides (Globoquadrina dutertrei* Subzone)

SECTION	LITHOLOGIC DESCRIPTION	SAND	SILT	CLAY
1	CLAYEY FORAM NANNO OOZE/NANNO-RICH SILTY CLAY Light olive-gray (5Y6/1 with minor 5GY6/1); moderately burrowed; faecal specks (N3).			
2–3	SILTY CLAY Dark olive-gray (5Y4/1); sparsely burrowed; vaguely laminated to massive with occasional laminae/bands/zones of quartzose/carbonate silt. Planktonic foraminifera concentrated in coarse laminae.	0.2	29.0	70.8
3–4	NANNO-RICH SILTY CLAY Intercalated beds of olive-gray strongly burrowed, varingly foraminiferal; and sparse to moderately burrowed, slightly foraminiferal, moderately nanno-rich mud. Some vague laminae (Hemi-laminite).	0.8	31.0	68.1
Core Catcher				

Site 90 Hole Core 3 Cored Interval: 130-140 m

AGE	ZONE	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION	GRAIN SIZE WEIGHT % SAND	SILT	CLAY
EARLY PLEISTOCENE (Nebraskan)	*Globorotalia truncatulinoides* (*Globorotalia tosaensis* Subzone)	1	0.5, 1.0	VOID			CLAYEY FORAM NANNO OOZE Greenish-gray (5G7/1 with subsidiary 5Y6/1, 5B5/1 and N3); strongly burrowed.			
		2					Becoming less fossiliferous	1.1	13.5	85.4
							CLAY Olive gray-greenish; severly mottled (burrowed) (5Y6/1,5Y4/1,5GY4/1); slightly foraminiferal; somewhat nanno-rich.			
		3						0.6	13.9	85.5
							Becoming more fossiliferous			
							CLAYEY FORAM NANNO OOZE As above.			
		Core Catcher								

Site 90 Hole Core 4 Cored Interval: 188-197 m

AGE	ZONE	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION	GRAIN SIZE WEIGHT % SAND	SILT	CLAY
EARLY PLIOCENE	*Globorotalia margaritae*	1	0.5, 1.0	VOID			CLAY Greenish-gray (5G6/1); locally pyritiferous and zeolitic; sparsely fossilif. Laminae/ bands (5G7/1,5GY6/1,5G5/1) moderate to vague with a few strongly mottled zones. Speckled throughout with N3 stain.	0.1	11.3	88.7
		2		VOID			Hemi-laminite.			
		3		VOID						
		Core Catcher								

Site 90 Hole Core 5 Cored Interval: 236-242 m

AGE: LATE MIOCENE

ZONE: *Globorotalia acostaensis* (*Sphaeroidinellopsis sphaeroides* Subzone)

SECTION	LITHOLOGIC DESCRIPTION	SAND	SILT	CLAY
1	CLAY Greenish-gray/dark green-gray (5G6/1 with mottles of 5GY6/1, 5Y6/1 and minor 5B5/1); moderately well laminated; sparsely burrowed; sparsely fossilif.			
2		0.6	16.6	82.8
3		0.3	14.4	85.3
4	As above; mixed zone of zeolites and green clay. Local pyrite microconcretions. Alternating 5G6/1 and 5G5/1 with subsidiary 5YR6/1,5Y8/1 and 5Y6/1.	0.3	18.0	81.7
Core Catcher				

Site 90 Hole Core 6 Cored Interval: 293-298 m

AGE: MIDDLE MIOCENE

ZONE: *Globorotalia acostaensis*

SECTION	LITHOLOGIC DESCRIPTION	SAND	SILT	CLAY
1	VOID SILTY CLAY/CLAY Green-gray (5G6/1 with 5G7/1 and 5/1, minor 5GY6/1); sparsely fossilif; sparsely burrowed; vaguely to moderately laminated with common sand/silt laminae of carbonate, quartz, volcanogenic debris. Zeolitic. Silts (5Y6/1 or N3) have sharp bases and appear graded.	0.1	53.1	46.8
2	5G5/1 dominant with subsidiary lamination of 5G4/1,61. Silt is 5Y7/1 or N3.			
Core Catcher				

Site 90 Hole Core 7 Cored Interval: 341-348 m

AGE: MIDDLE MIOCENE

ZONE: *Globorotalia acostaensis*

SECTION	LITHOLOGIC DESCRIPTION	SAND	SILT	CLAY
1	VOID SILTY CLAY/CLAY Green-gray (5G5/1 with subsidiary 5G4/1, 5GY6/1, occasional 5G3/1); sparsely fossilif; moderate to sparsely burrowed. Common graded coarse silts (5Y8/1 with occasional N3) with sharp bases. Speckled with N3 fecal stain.	0.1	27.9	72.0
2	As above. Slightly thicker graded silts toward base. VOID	0.1	28.3	71.6
3	As above. Thicker graded silts. Pyrite burrow-fill. VOID	0.1	36.9	63.1
Core Catcher				

Site 90 Hole Core 8 Cored Interval: 433-439 m

AGE	ZONE	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION	GRAIN SIZE WEIGHT % SAND	SILT	CLAY
MIDDLE MIOCENE	*	Core Catcher					SILTY CLAY/CLAY 5G5/1-4/1; sparsely fossilif. Similar to core 7.			

* *Globorotalia acostaensis (Sphaeroidinellopsis seminulina* Subzone)

Site 90 Hole Core 9 Cored Interval: 471-480 m

AGE	ZONE	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION	GRAIN SIZE WEIGHT % SAND	SILT	CLAY
MIDDLE MIOCENE	N13/14	1	0.5 1.0				5GY5/1 Fine sand - probably "cave" SILTY CLAY/CLAY Green-gray (5G5/1 with subsidiary 5G4/1, 5GY6/1,N3); sparsely fossilif; sparsely burrowed; vaguely laminated to laminated. Occasional graded silts.	1.6	43.5	54.9
		Core Catcher								

Site 90 Hole Core 10 Cored Interval: 595-597.5 m

AGE	ZONE	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION	GRAIN SIZE WEIGHT % SAND	SILT	CLAY
MIDDLE MIOCENE	N12/N13	1	0.5 1.0	UNOPENED			Totally homogenized and disturbed. Reconstruction suggests: SILTY SAND and MUDSTONE clasts. Former is very fine to fine. Latter is green-gray, unfossilif. and exists as subsidiary thin units. Original interbedding is suggested. 5GY5/1 with subsidiary 5G5/1.	13.0	47.8	39.2
		2								
		3								
		4								
		Core Catcher								

Site 90 Hole Core 11 Cored Interval: 675-682 m

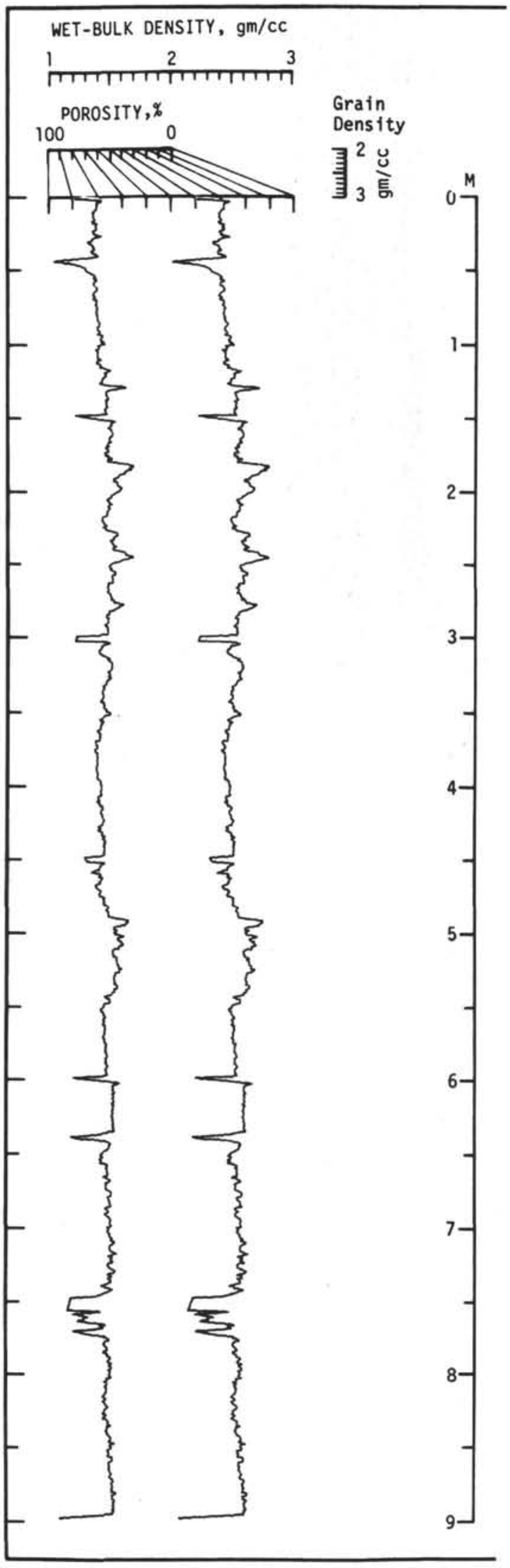
AGE	ZONE	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION	GRAIN SIZE WEIGHT % SAND	SILT	CLAY
MIDDLE MIOCENE	N10	1	0.5 1.0	UNOPENED						
		2					Mixture of MUDSTONE and SAND. Former 5G5/1; latter 5G6/1. Brecciated-mechanically disturbed. Probably originally dominantly mudstone.			
		3								
		4								
		5					As above. Possibly higher percentage of sand.			
		6					As above. ~35% silty sand.			
		Core Catcher								

Site 90 Hole Core 12 Cored Interval: 761-763 m

AGE	ZONE	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION	GRAIN SIZE WEIGHT % SAND	SILT	CLAY
MIDDLE MIOCENE	N10	Core Catcher					Interbedded MUDSTONE and SAND 5G5/1-4/1; former with thin laminae of lighter green (5G6/1) mud/clay stone. Latter very fine to medium/coarse.			

Site 90 Hole Core 13 Cored Interval: 763-768 m

AGE	ZONE	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION	GRAIN SIZE WEIGHT % SAND	SILT	CLAY
MIDDLE MIOCENE	N10	1	0.5 1.0				Mixture of SAND and MUDSTONE clasts. 5GY5/1 dominant with subsidiary 5G6/1, 5GY4/1; former is very fine to coarse and quartzose. Latter is greenish-gray and laminated. Brecciated-mechanically disturbed. Probable interbeds(?).			
		2					As above.			
		3					SAND Dark gray; dominant horizontal laminations, some cross laminations. Tops, graded quartzose very fine to coarse sand. Silty, very poorly sorted, friable. VOID	78.6	14.6	6.8
		4		VOID				79.7	13.5	6.7
		Core Catcher								



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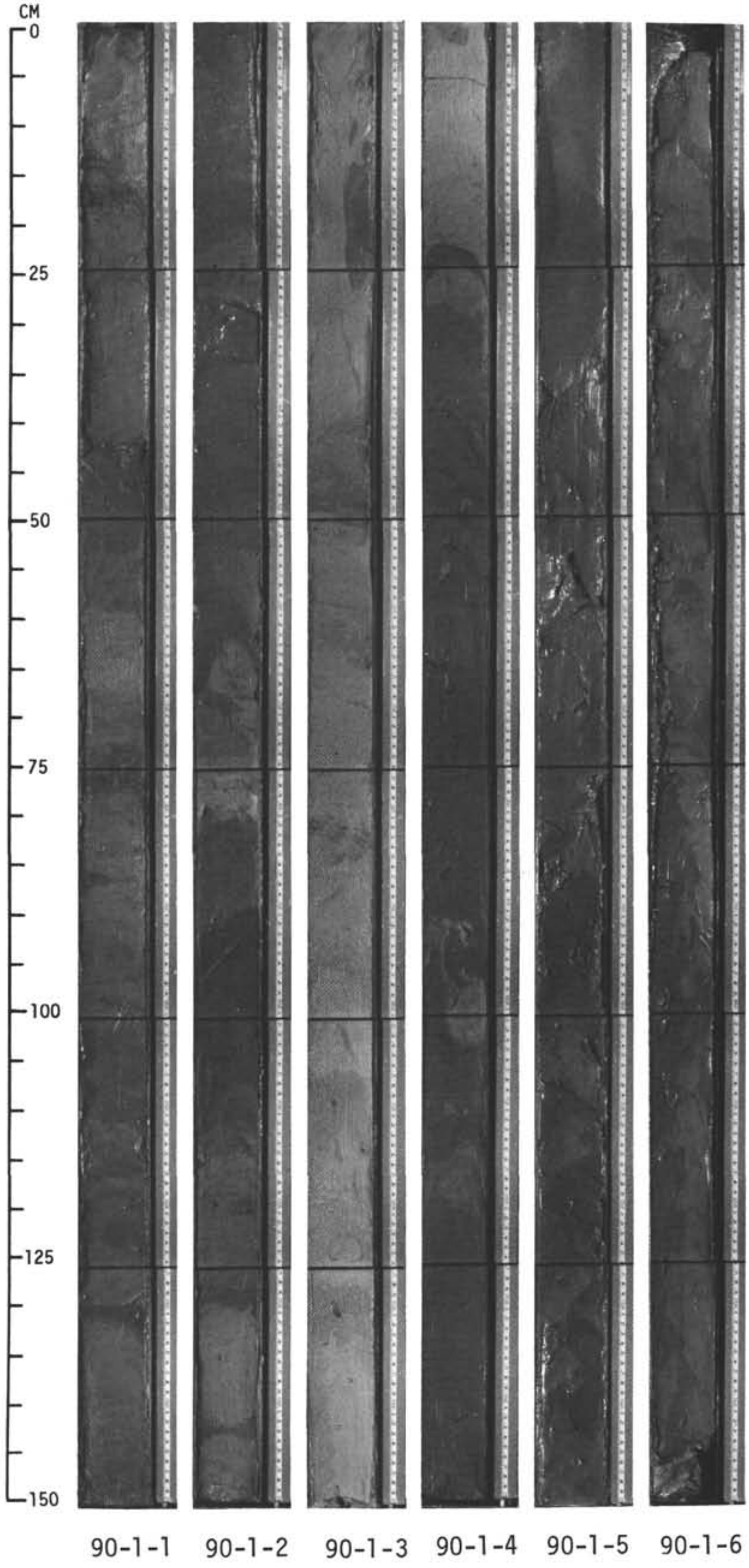

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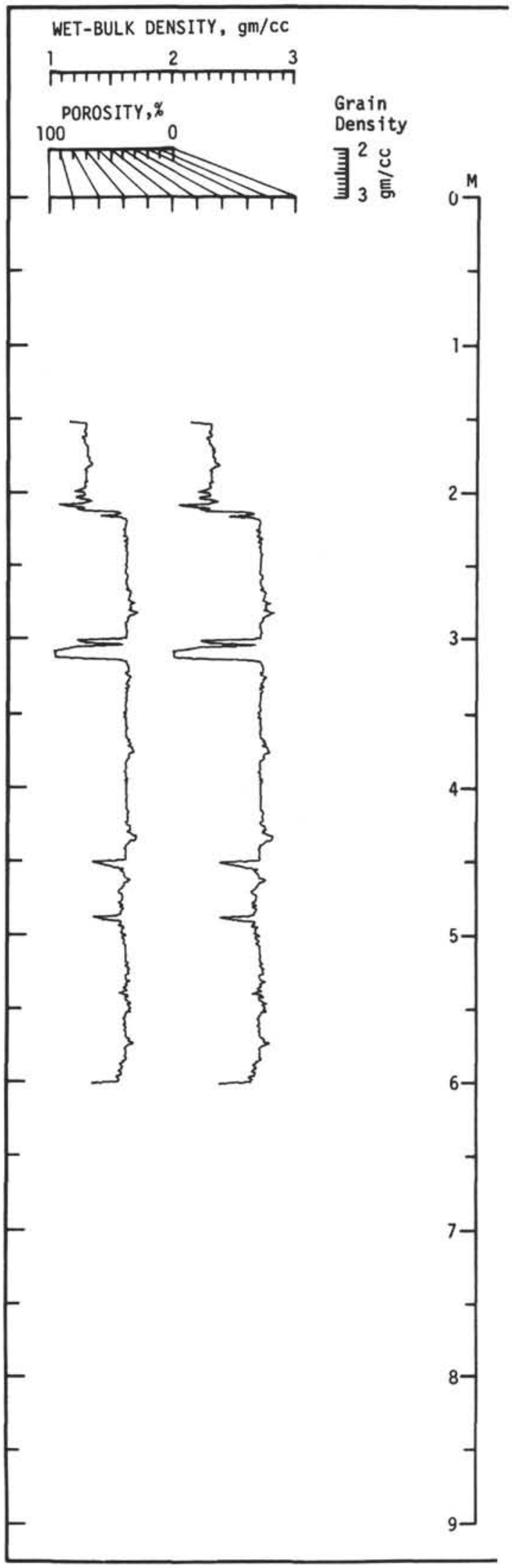

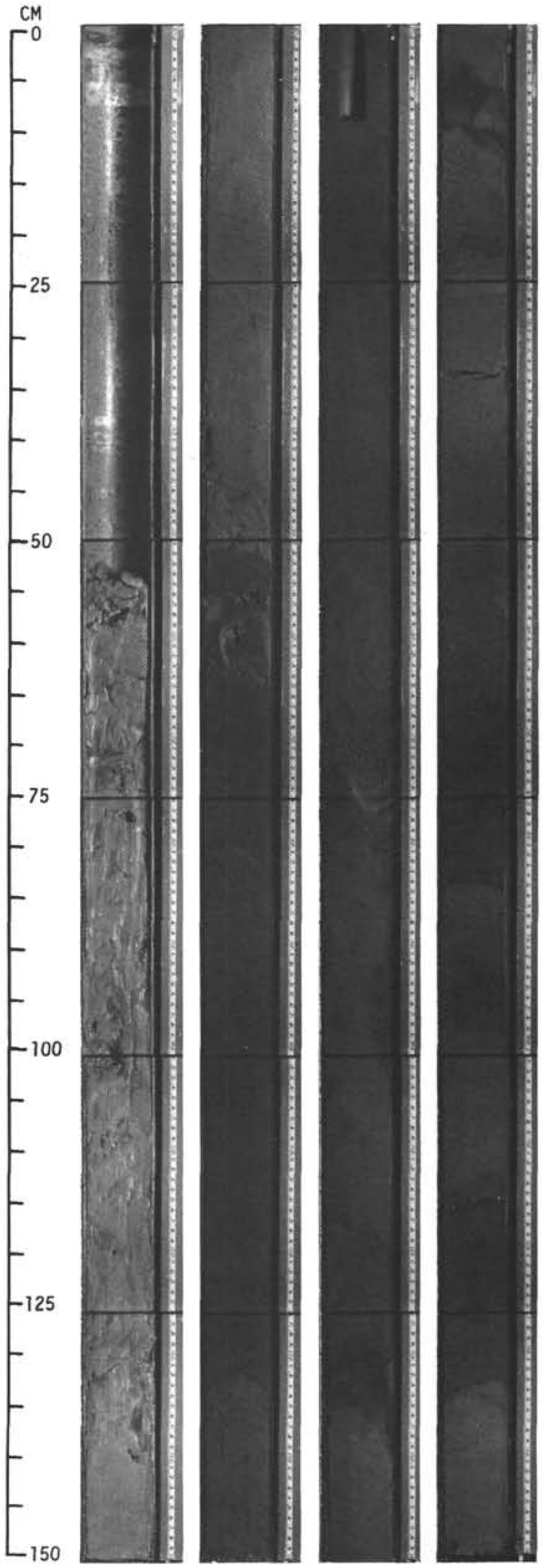

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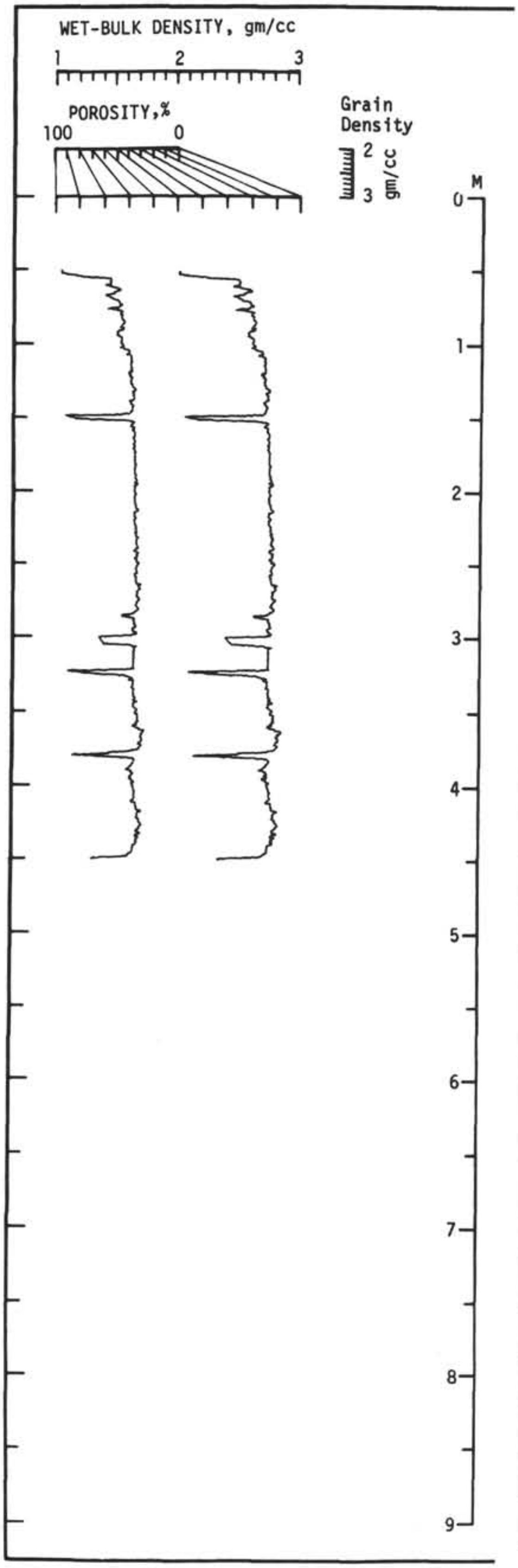

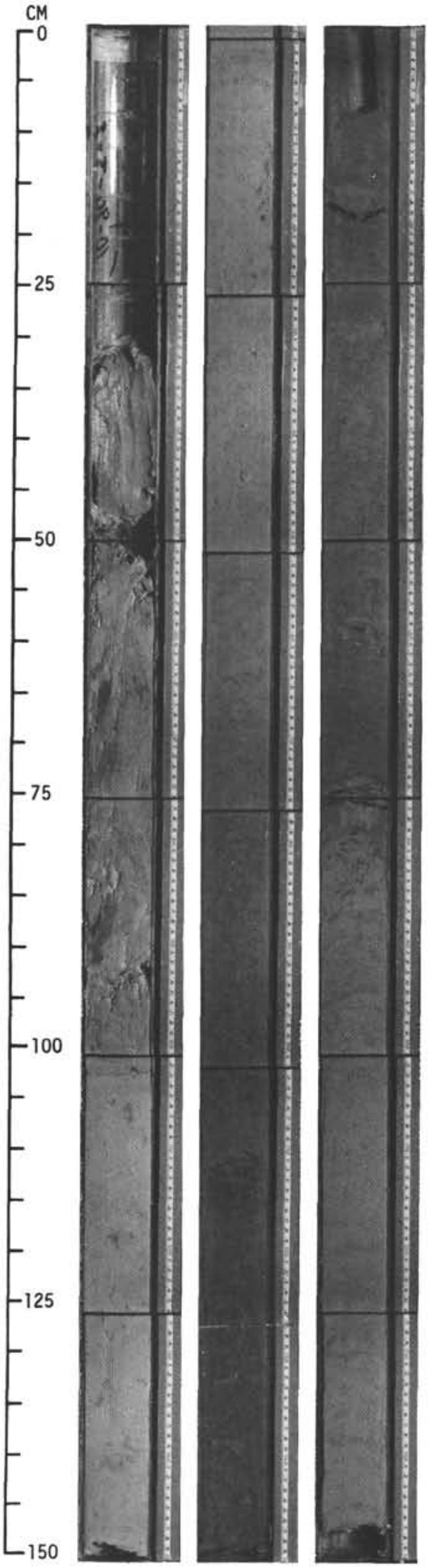

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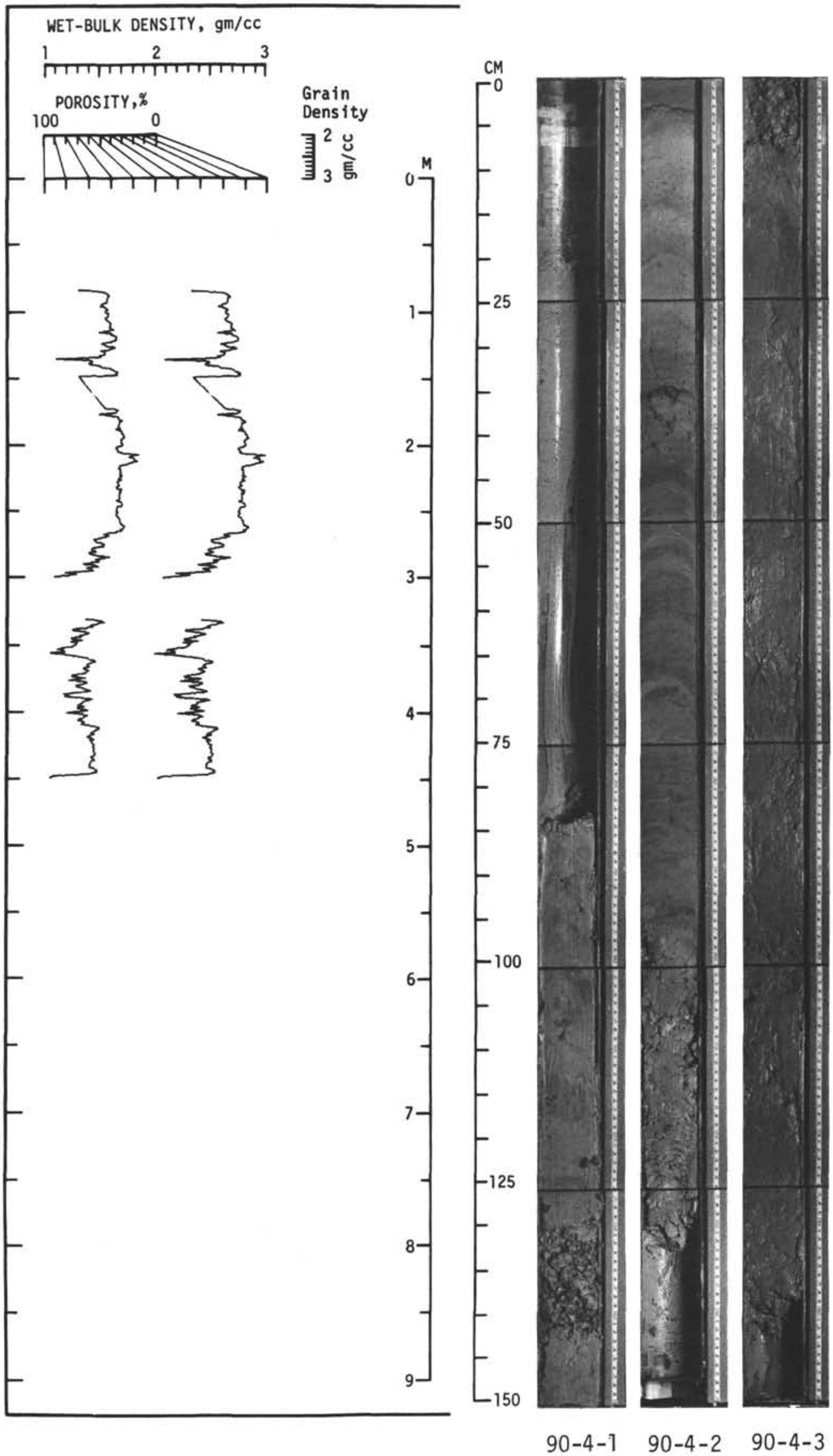
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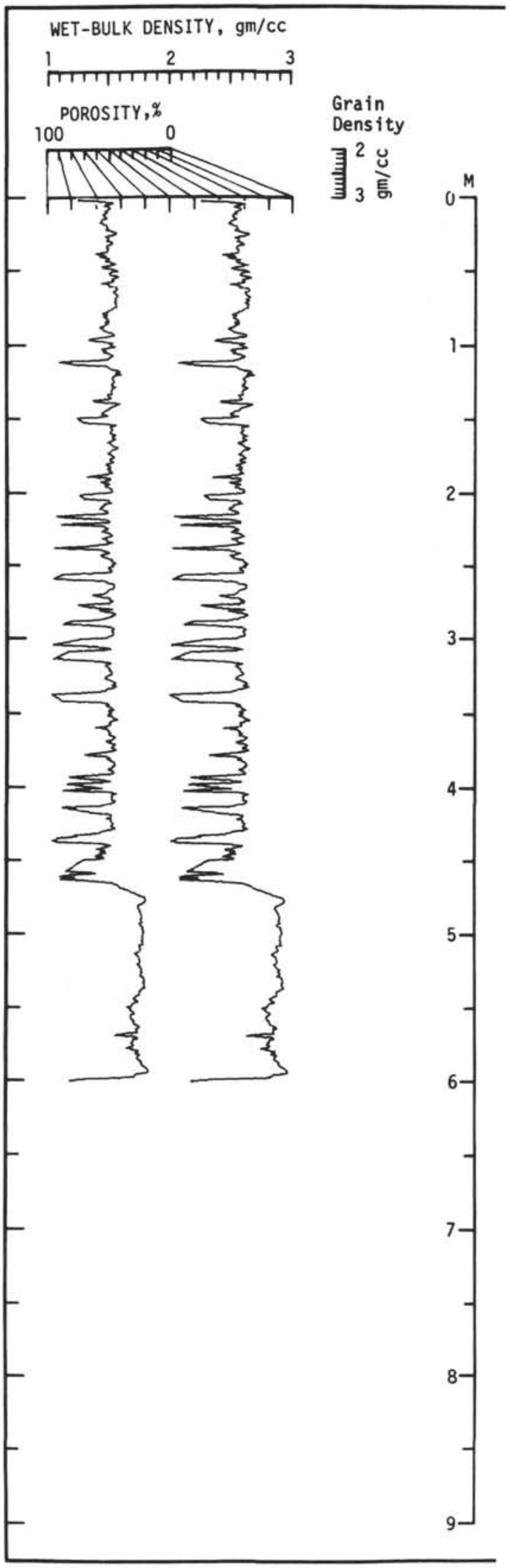

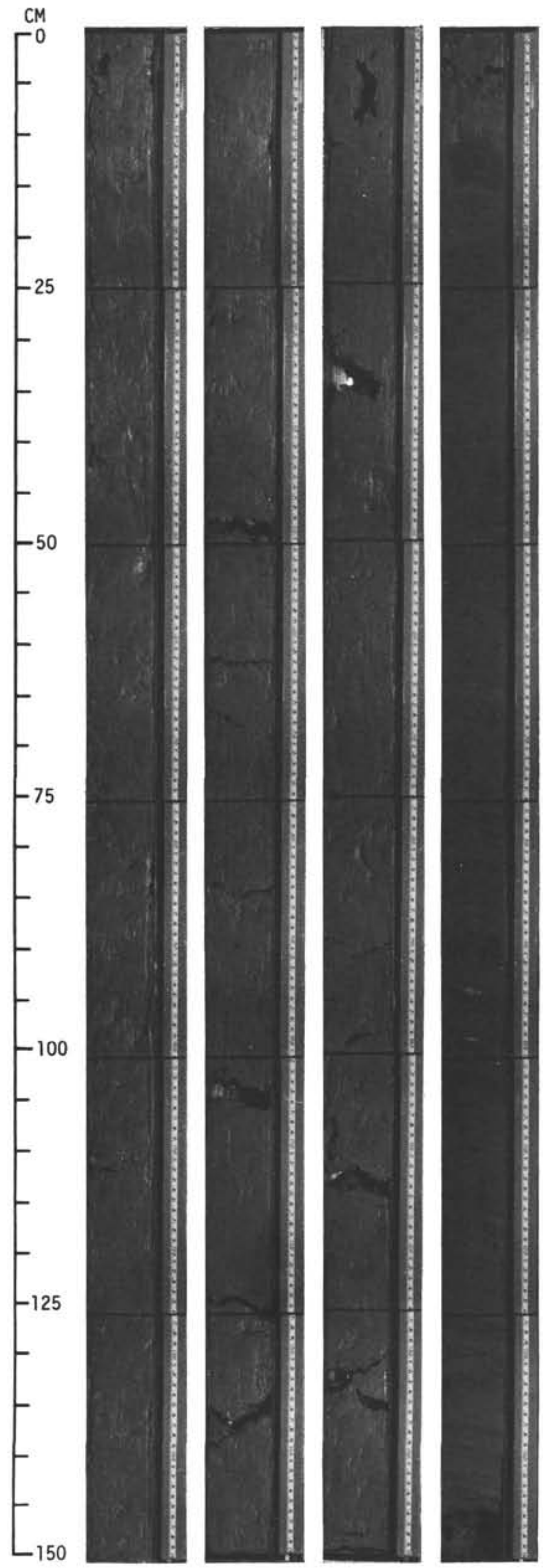

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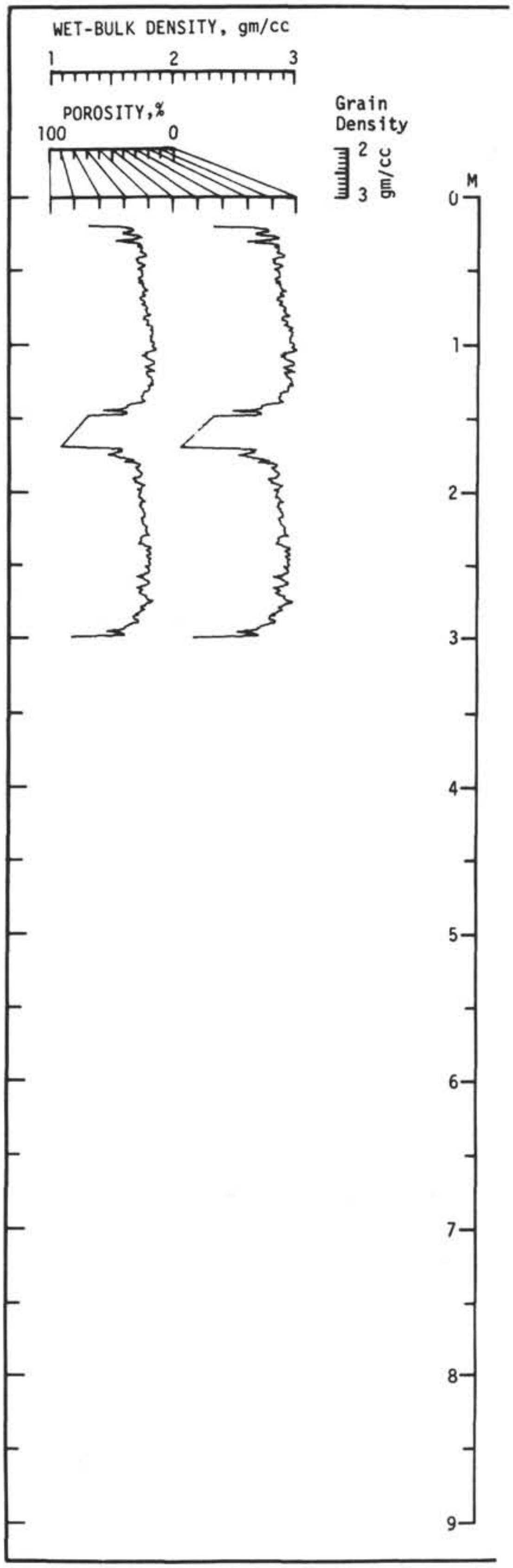
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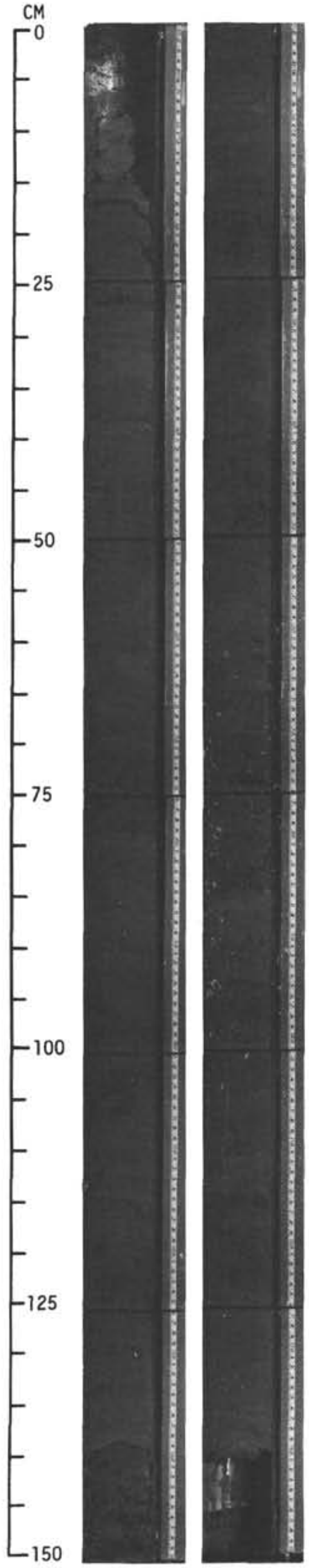
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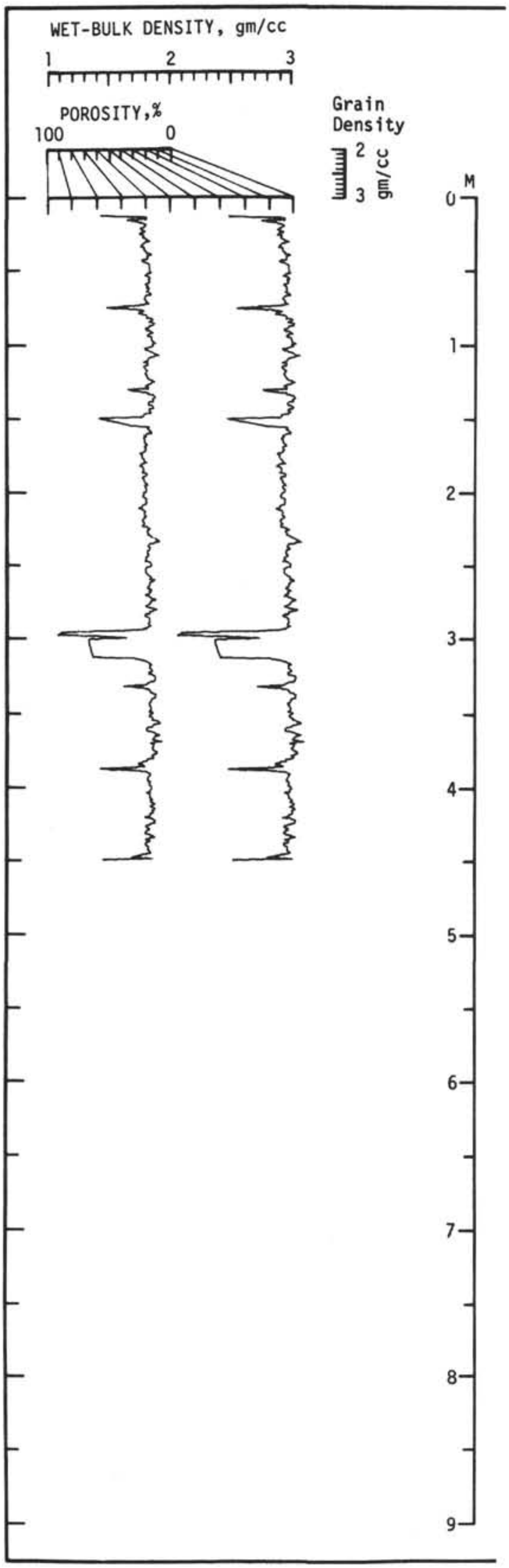

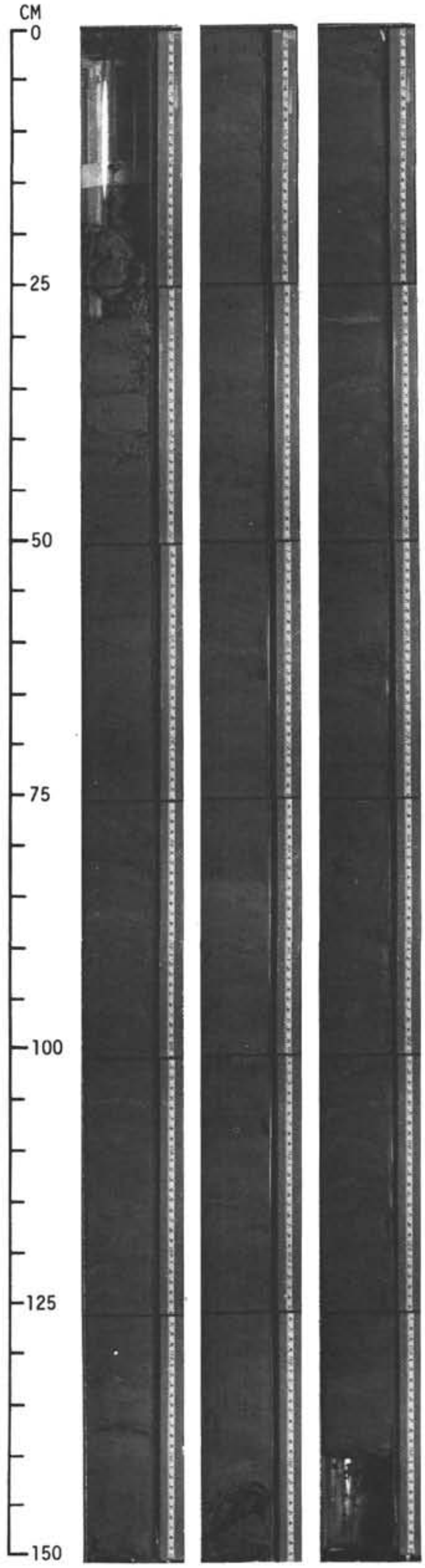

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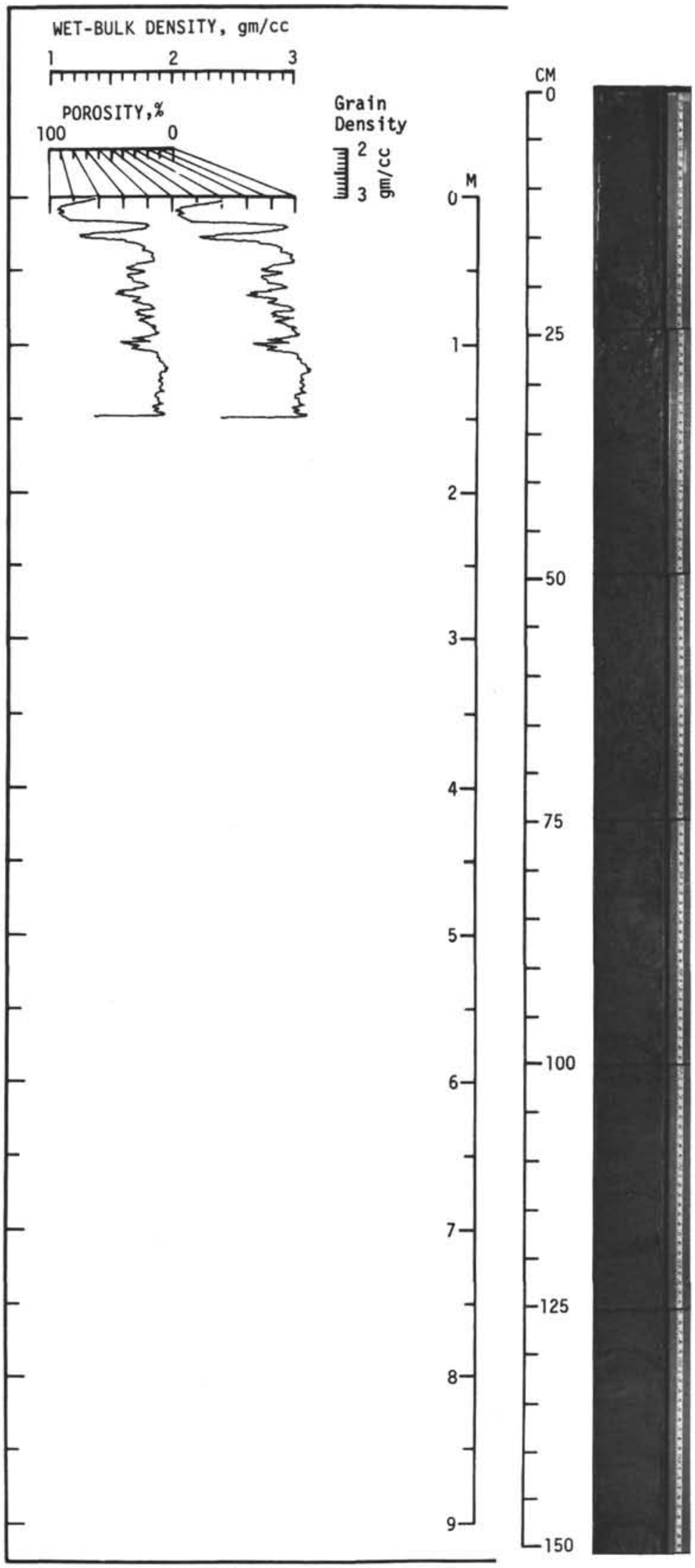
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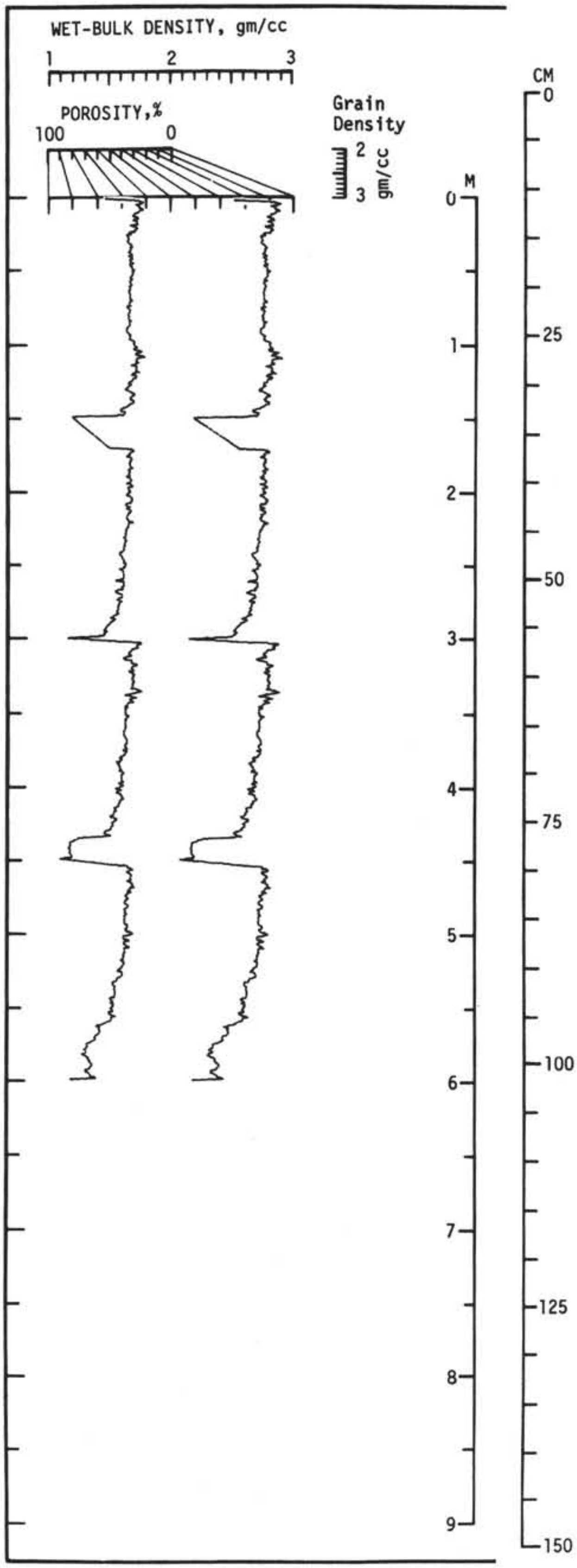
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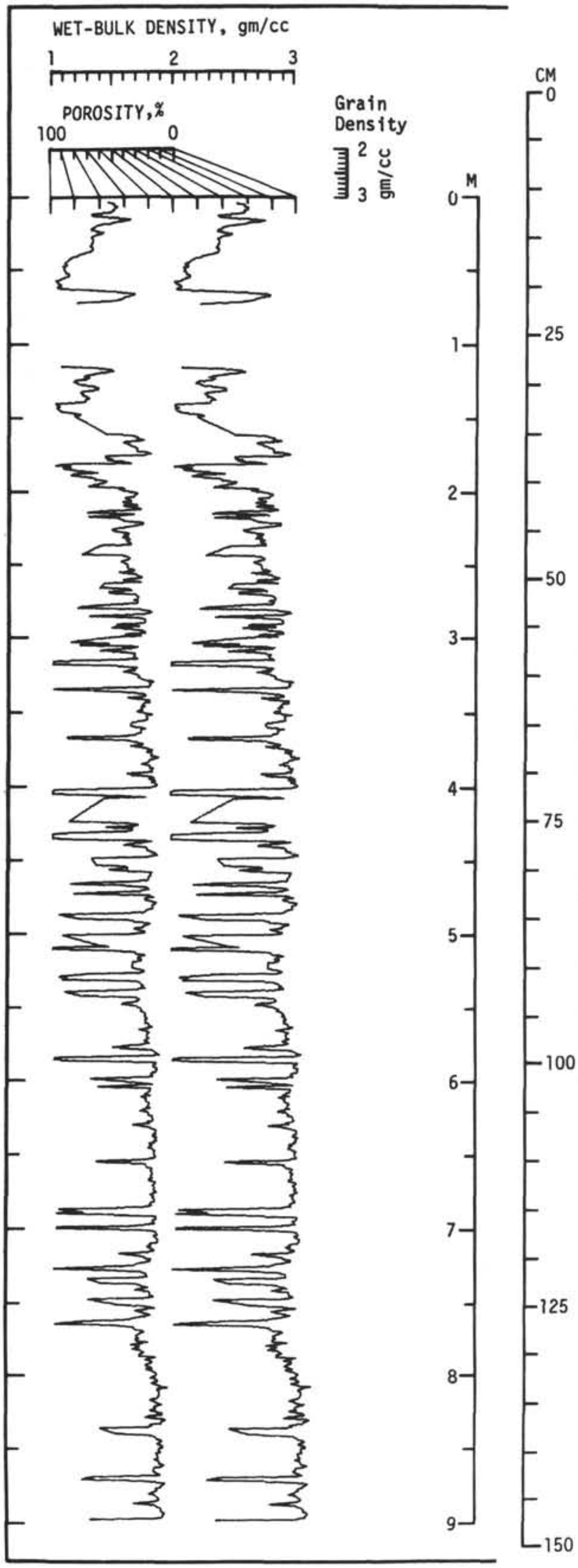

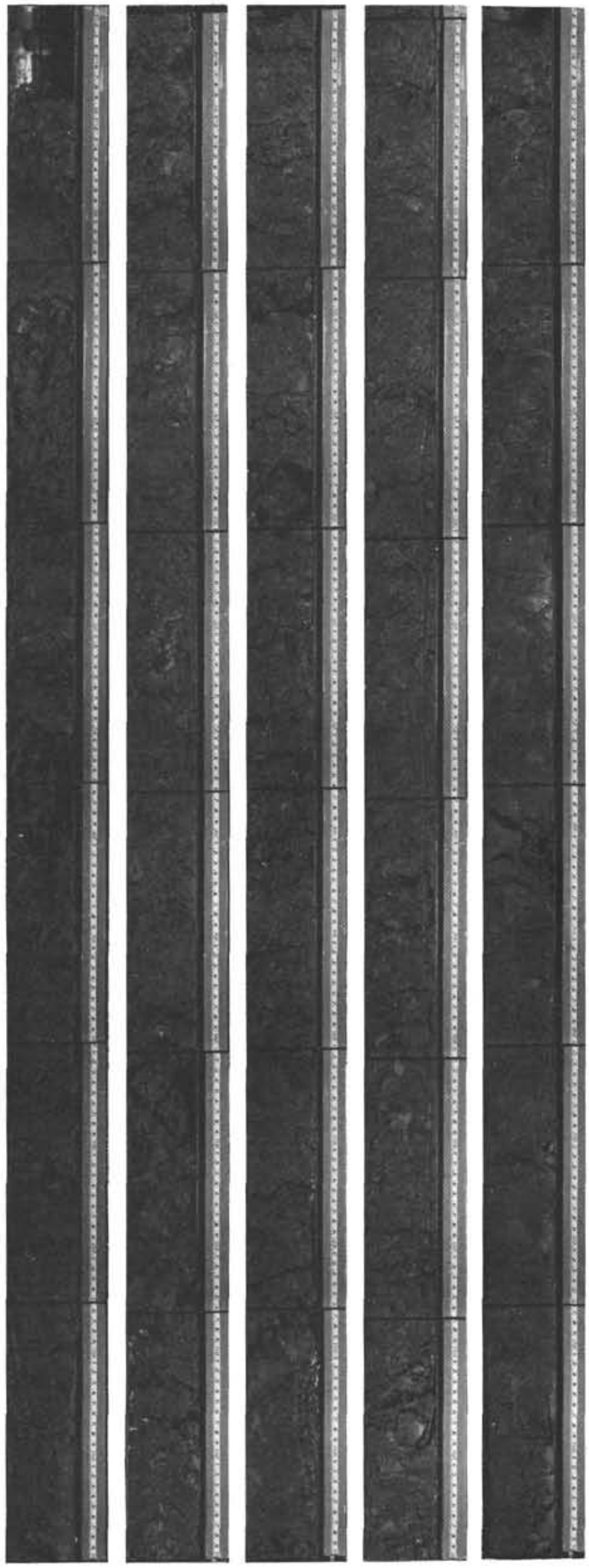

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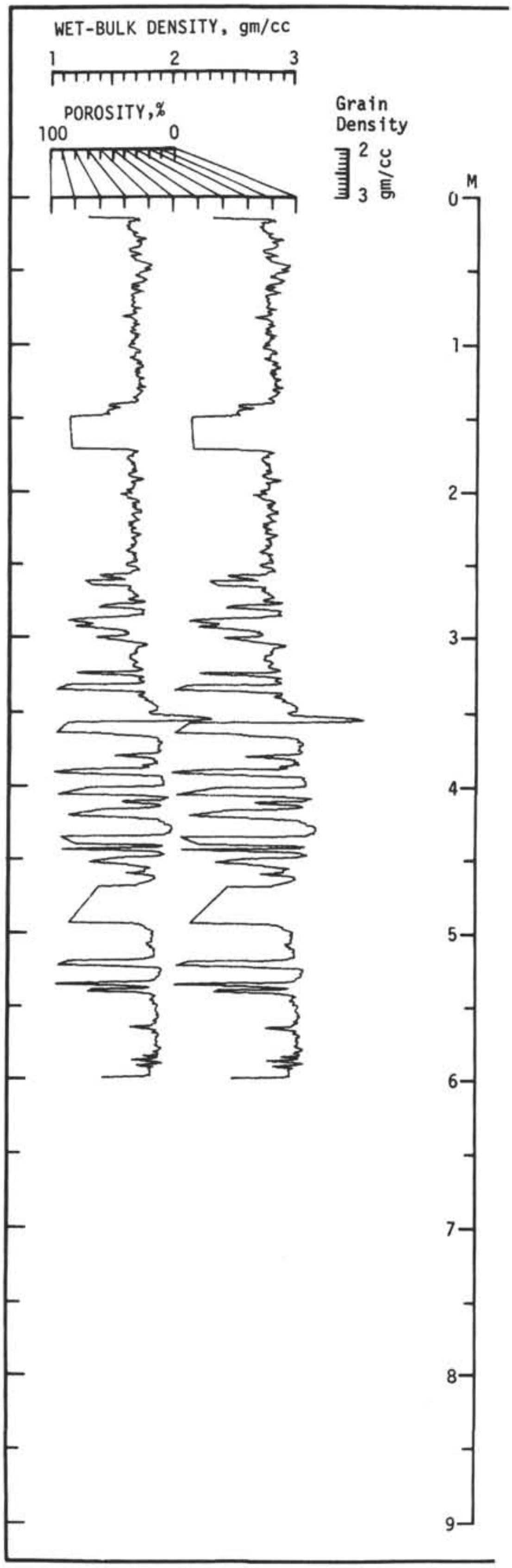

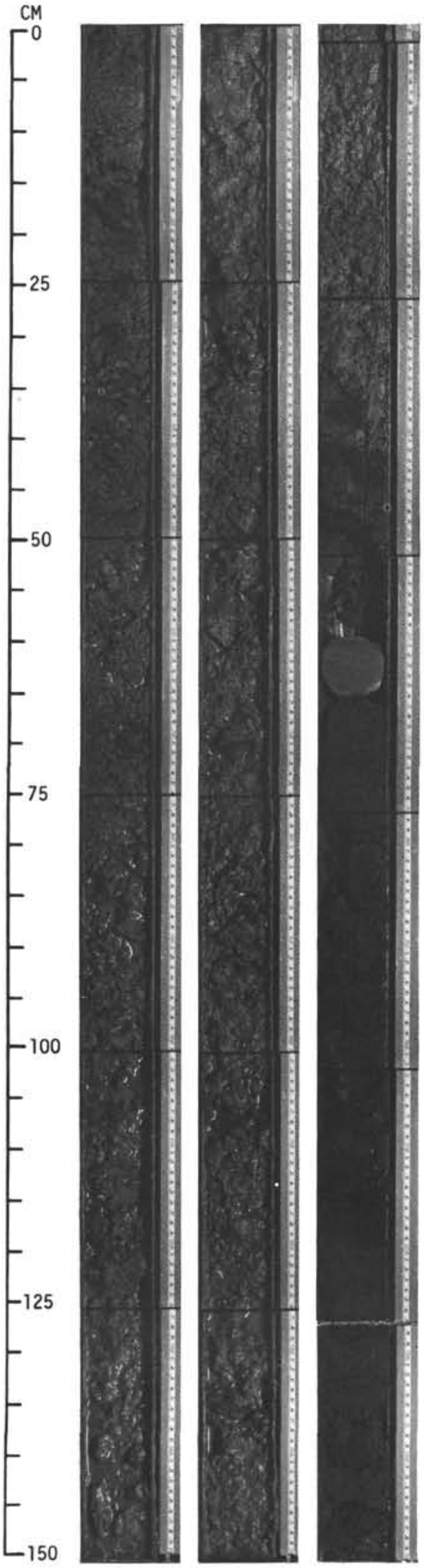

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