4. SITE 4[1]

The Shipboard Scientific Party[2]

SITE REPORT

Setting and Purpose

Drill holes 4 and 4A were drilled at Site 4, which is located between the Hatteras Abyssal Plain and the Bahama Platform. It is just seaward of Cat Gap, a valley which breaks the continuity between the Blake outer ridges and the ridge extending to the north-northeast of San Salvador Island.

The Bahama Platform is a platform of calcareous rocks which is dissected by deep channels, each of which deepens toward the ocean. This platform was first described by Field (1931) and Hess (1933) who interpreted the deep channels as a drainage pattern. Worzel and Shurbet (1955) proposed that this calcareous platform was laid down on a formerly oceanic crust. In that case the calcareous sediments would be of the order of 28.5 kilometers in thickness, and, assuming isostatic compensation, the last 5 kilometers of sediments (approximately the depth of the well drilled on Andros Island; Eardley, 1951) would have been laid down in water depths of less than 700 meters. Talwani, Worzel, and Ewing (1960) discussed the gravity measurements observed in the water-covered parts of the Bahama Platform. Seismic measurements in the similar, deep channel of the Straits of Florida, showed 2 to 4 kilometers of low density sediments within the deep channel. Assuming that similar low density layers are present in the deep channels of the Bahama Platform, and allowing for the water present, one can account for the observed anomalies. This, then, would argue for a tectonic origin for the deep channels.

Katz and Ewing (1956) reported seismic refraction measurements made in the ocean basin nearby as showing a typical oceanic crustal section. Houtz, Ewing, and LePichon (1968) published sonobuoy data for the nearby region which enable one to interpret the reflection profiler records in terms of layer depths.

Seismic profiling in the ocean basin has shown that three reflecting horizons, called Horizon A, β, and B are generally present in the western Atlantic Ocean. This work has been described by Ewing, Worzel, Ewing and Windisch (1966), who also indicated an area to the north and east of San Salvador, where the section has been uplifted and Layer A outcrops. Much piston coring and profiling has since been concentrated in this area. Later work (Windisch, Leyden, Worzel, Saito and Ewing, 1968) reported a smaller region within the Layer A outcrop area where a deeper layer, believed to be Layer β outcrops, and an even smaller area where still deeper layers appear to outcrop. Figure 1 shows these latter areas. Piston cores within the area recovered sediments containing fossils indicating ages from Hauterivian to Maestrichtian. Although profiling had not indicated any cover above β in the area, a number of piston cores with Tertiary, Pleistocene and Recent fossils were also recovered. This indicates at least a partial cover, so thin that profiling could not delineate it, but so thick that piston coring could not penetrate it.

In the northern section of the area, piston cores had recovered carbonaceous layers containing abundant pollen (Habib, 1968) which were identified as middle Cretaceous assemblages, and believed to indicate a much shallower water environment than presently exhibited.

Layer B could possibly be basement, but its smoothness could also indicate that it is a sedimentary filling of depressions in the rougher basement topography beneath it, since several pinnacles protruded through to the sea floor in several places. Profiler records failed to indicate any penetration below Layer B.

In the southern part of the area, Layer B lies about 700 meters subbottom and the layers above are present in somewhat greater thicknesses than to the north. Therefore, Holes 4 and 4A were located in this region in order to detail the layers above B (Figure 2), and to penetrate Layer B in an attempt to determine whether it was basement rock or another sedimentary cover above basement. These holes were drilled at 24°28.68′ N, 73°47.52′W, where the water depth (corrected for sound velocity in sea water and the depth of the transducer) was 5319.5 meters (17,452 feet). The roller bit used on Hole 4 was destroyed by cherts after a penetration of 258.8 meters (849 feet). Since penetration to Layer B had not been possible, a drag bit was

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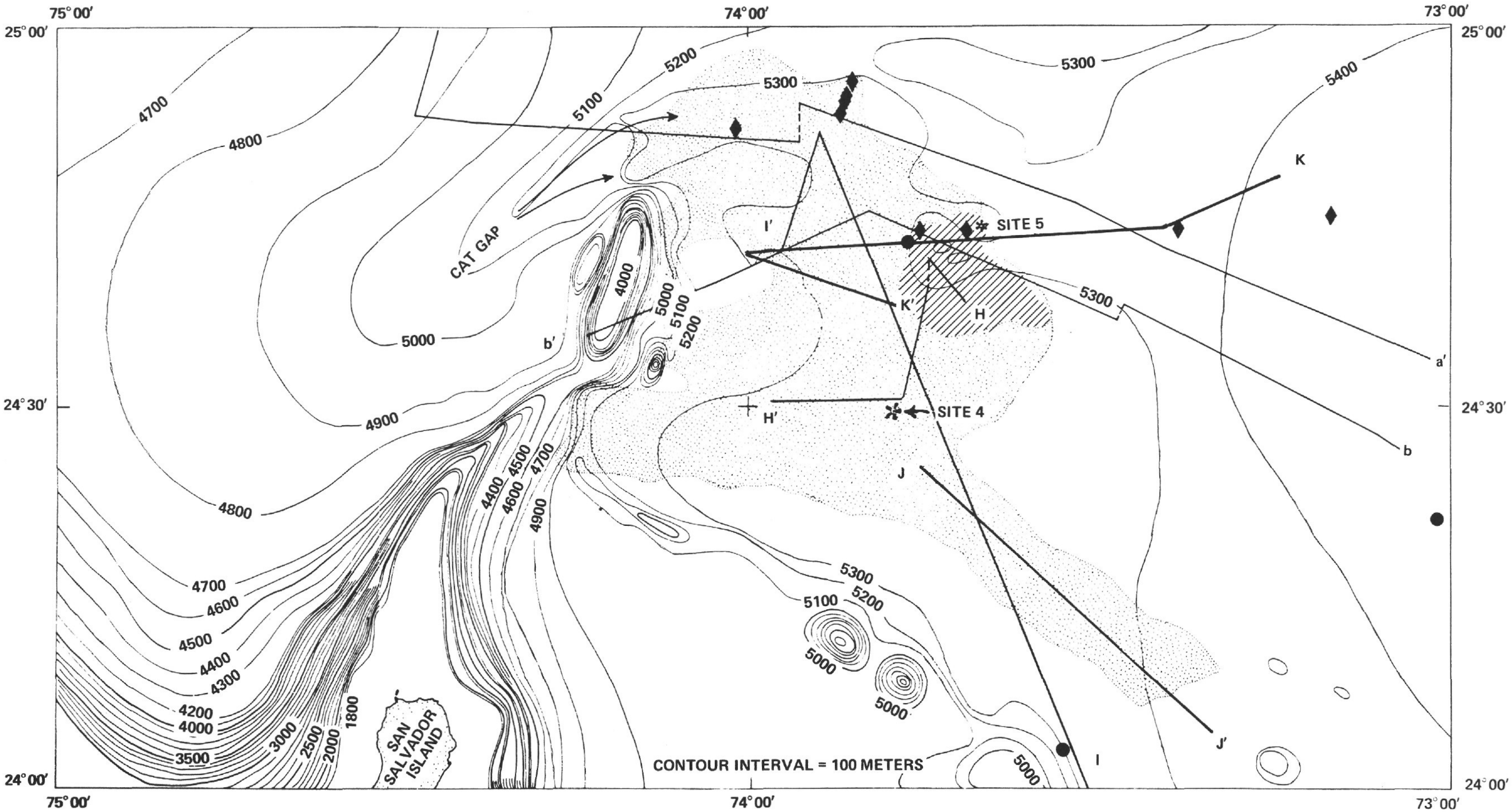


Figure 1. *Bathymetric chart of the seismic horizon β outcrop area showing Sites 4 and 5 and the results obtained by piston coring. Outcrop of β is stippled, and the oldest outcropped sediments are indicated by hachures. Solid diamonds indicate Cretaceous cores (after Windisch* et al. *1968).*

put on the drill string and a second attempt was made at the same position. This bit was destroyed after a penetration of 207.2 meters subbottom and the site was abandoned because it was necessary to return an injured man to shore.

As the profiler on *Glomar Challenger* was inoperative and coverage by previous Lamont-Doherty surveys is incomplete near Site 4, the detailed geologic setting of this site cannot be given until the site survey reports of *Vema*, Cruise 26, from April, 1969, become available.

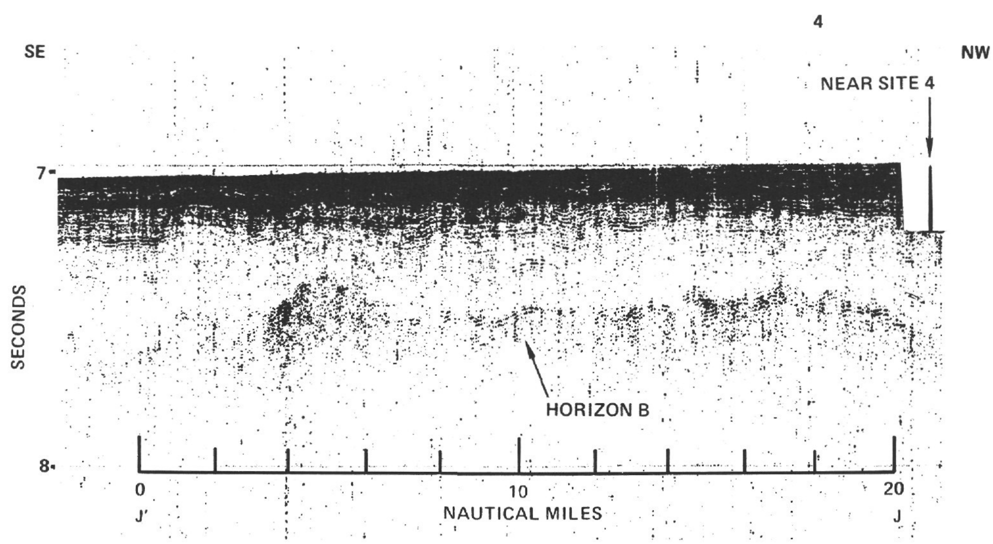


Figure 2. *Profiler record near Site 4. Depth of* Glomar Challenger *drilling penetration is shown. Location of section is indicated in Figure 1.*

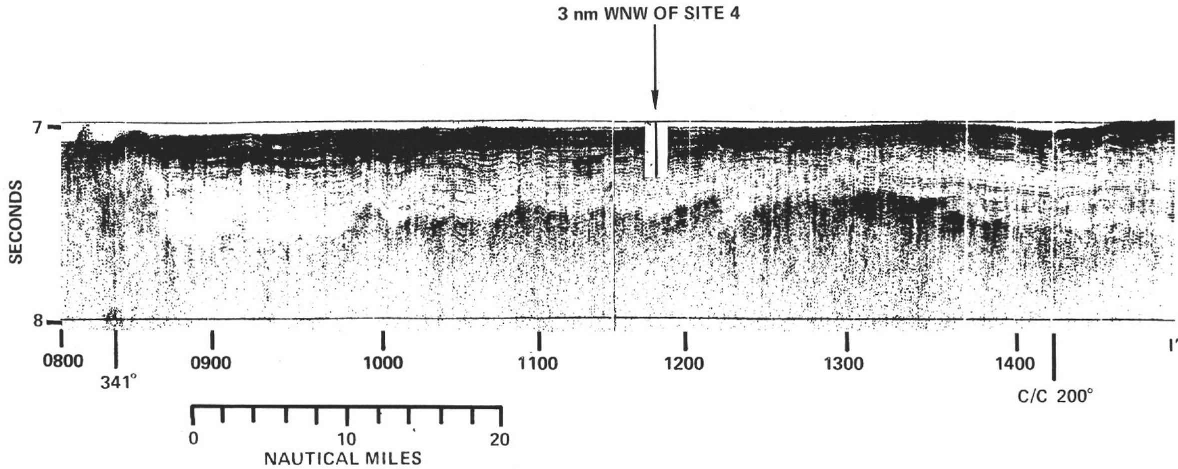


*Figure 3. Profiler record near Site 4. Location is shown in Figure 1 (*Vema*-24, 26 January 1967, 0800-1430).*

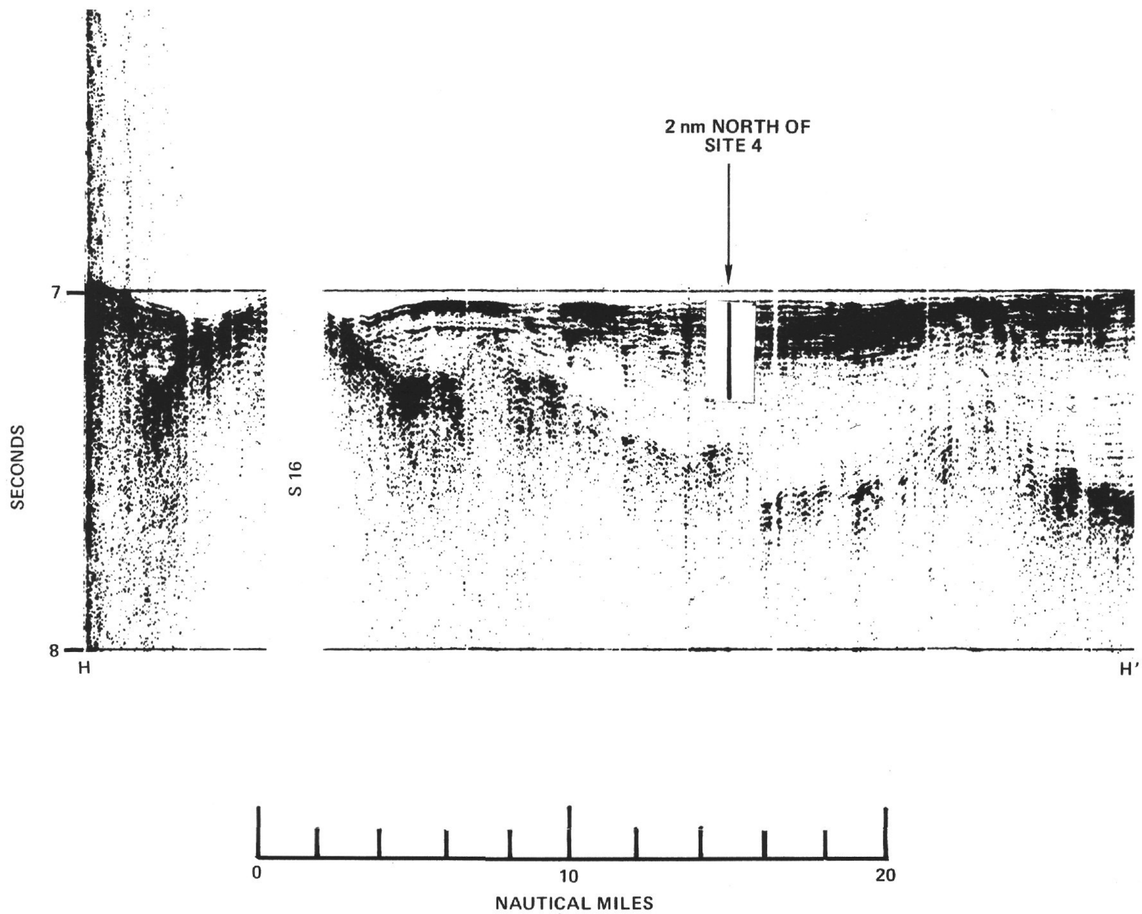


Figure 4. *Profiler record near Site 4. Location is shown in Figure 1 (*Vema*-24, 28 January 1967, 1230-1800).*

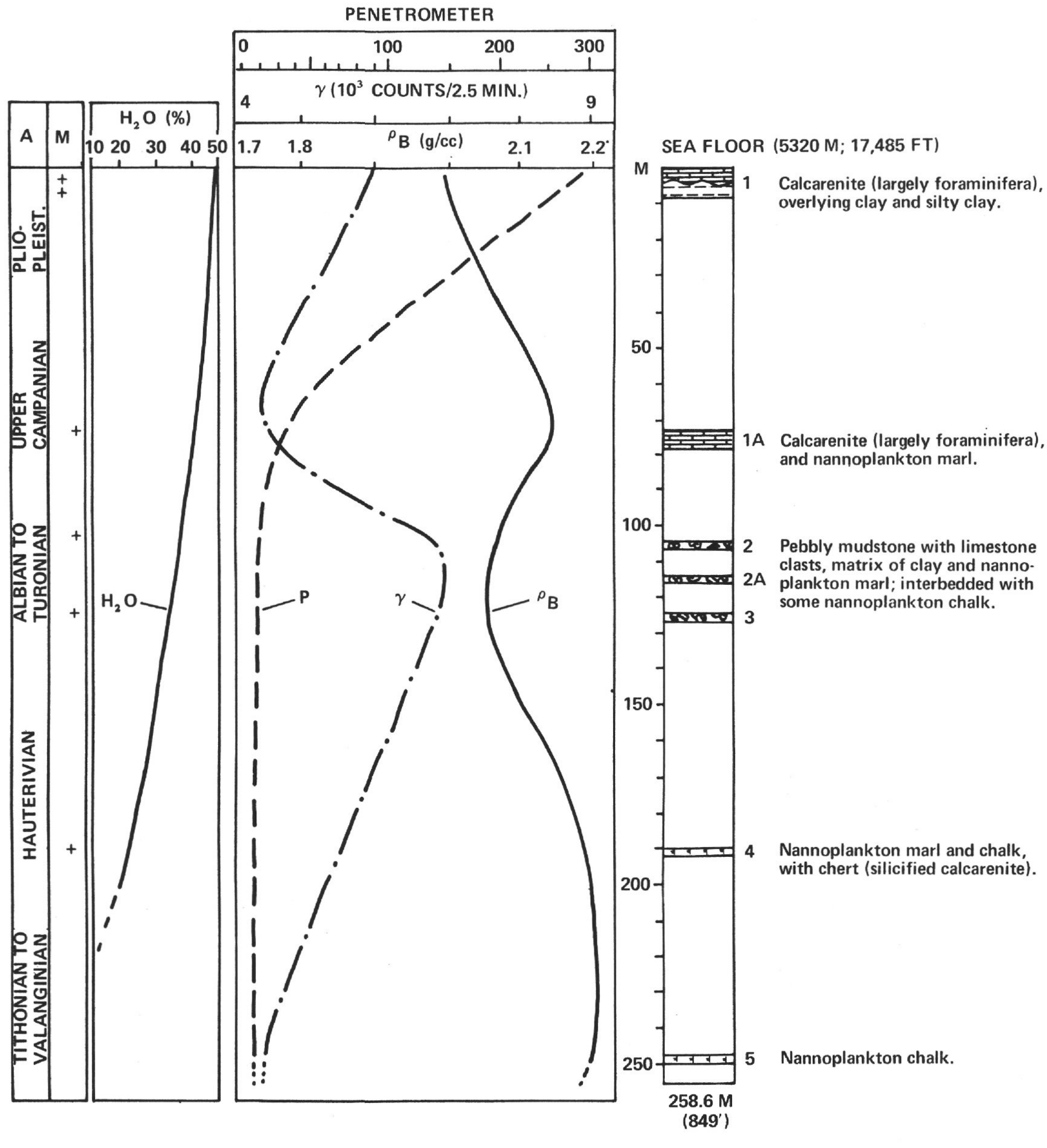


Figure 5. *Summary of drilling and coring at Site 4.*

The Cores Recovered from Site 4

Figures 6 through 12 are the graphic summaries of the cores recovered at Site 4.

These figures show, for each core:

(1) The stratigraphic age.
(2) The paleomagnetic results–normal (+) or reversed (-).
(3) The natural gamma radiation (full line).
(4) The bulk density as determined by the GRAPE (Gamma Ray Attenuation Porosity Evaluator) equipment (broken line).
(5) The length of the core in meters measured from the top of the core and the subbottom depth of the top of the cored interval.
(6) The lithology (see key with Site 1 Report).
(7) The positions of the tops of each core section.
(8) Some notes on the lithology.

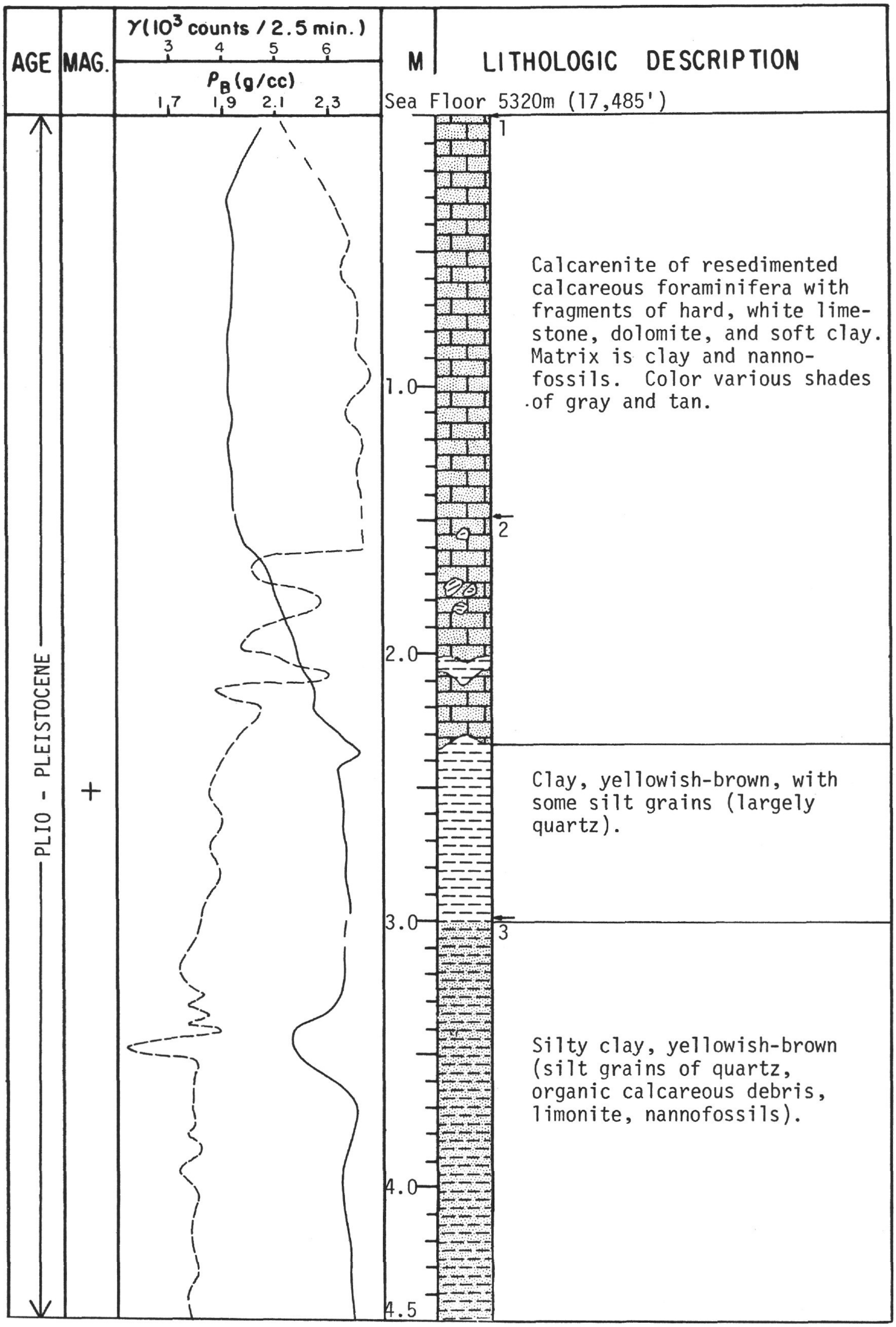


Figure 6. *Hole 4, Core 1.*

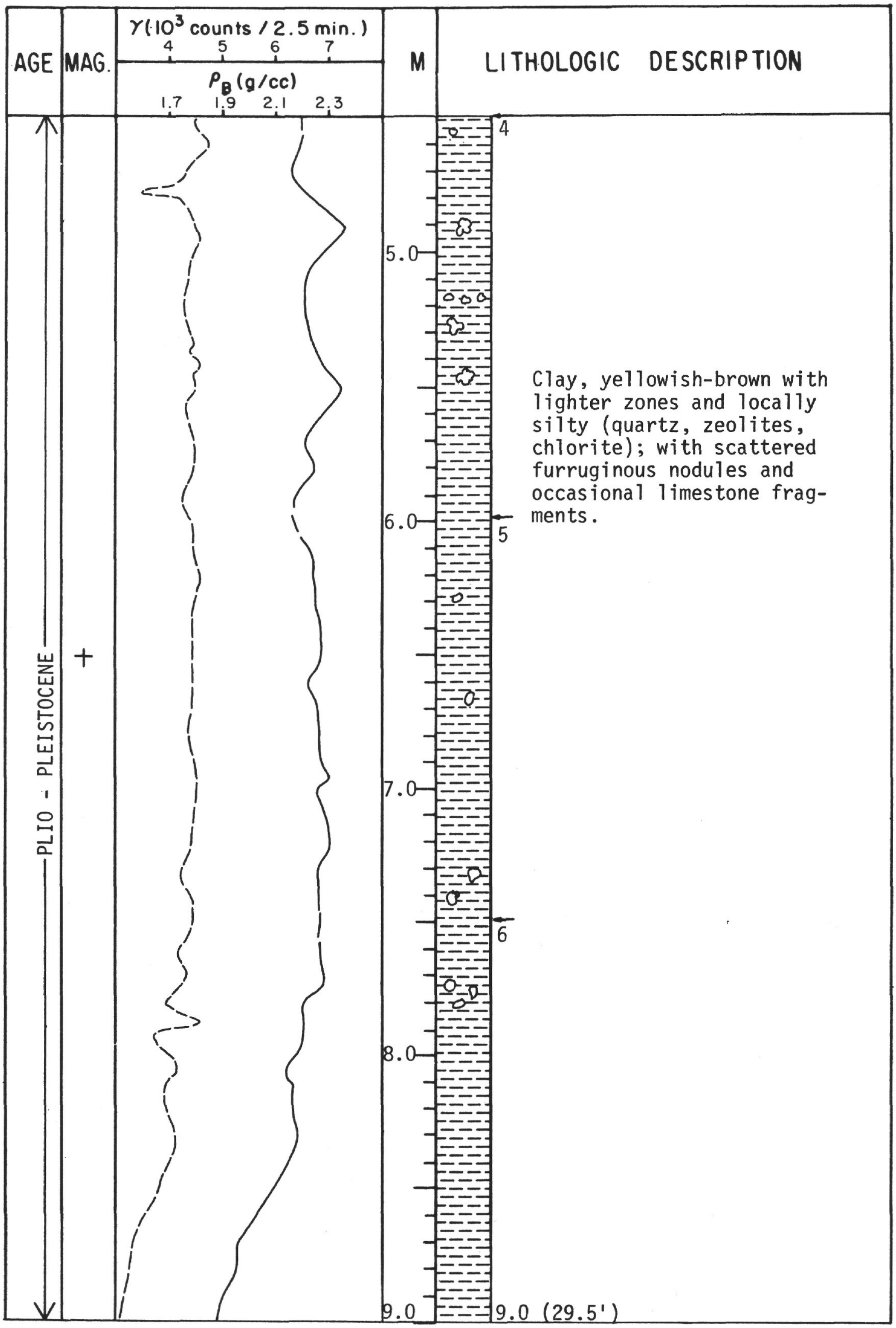


Figure 6. *Continued.*

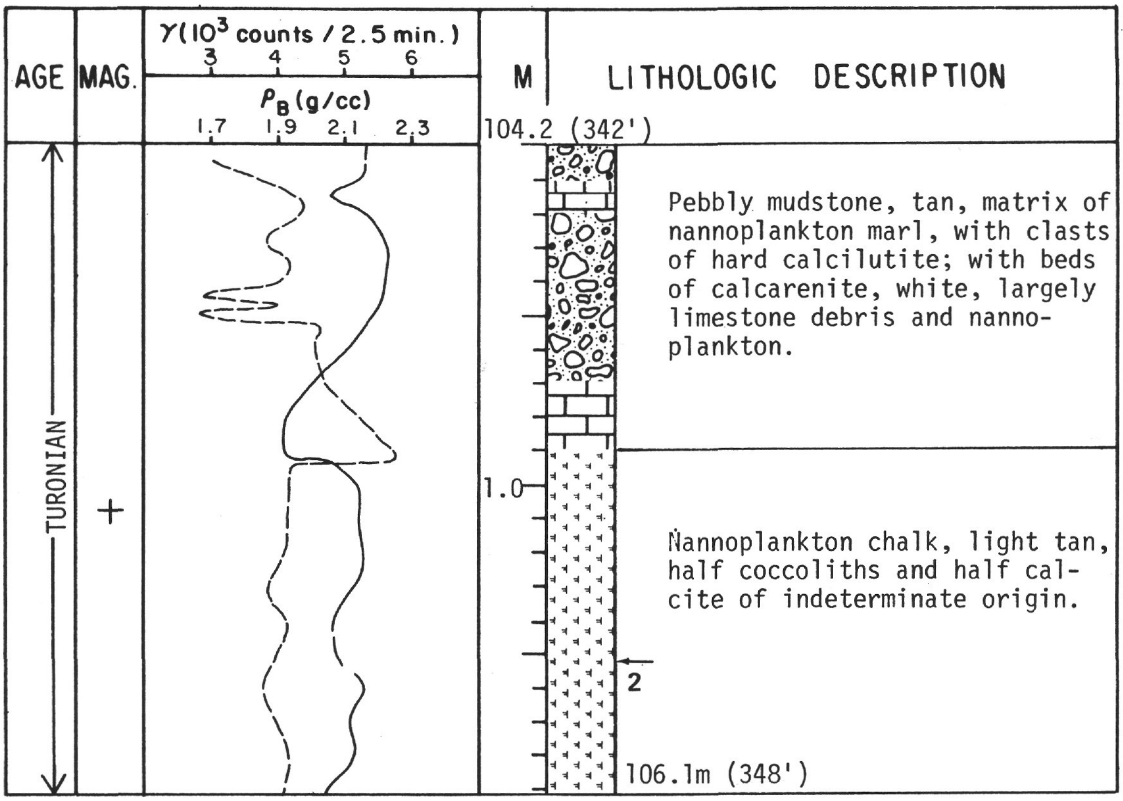


Figure 7. *Hole 4, Core 2.*

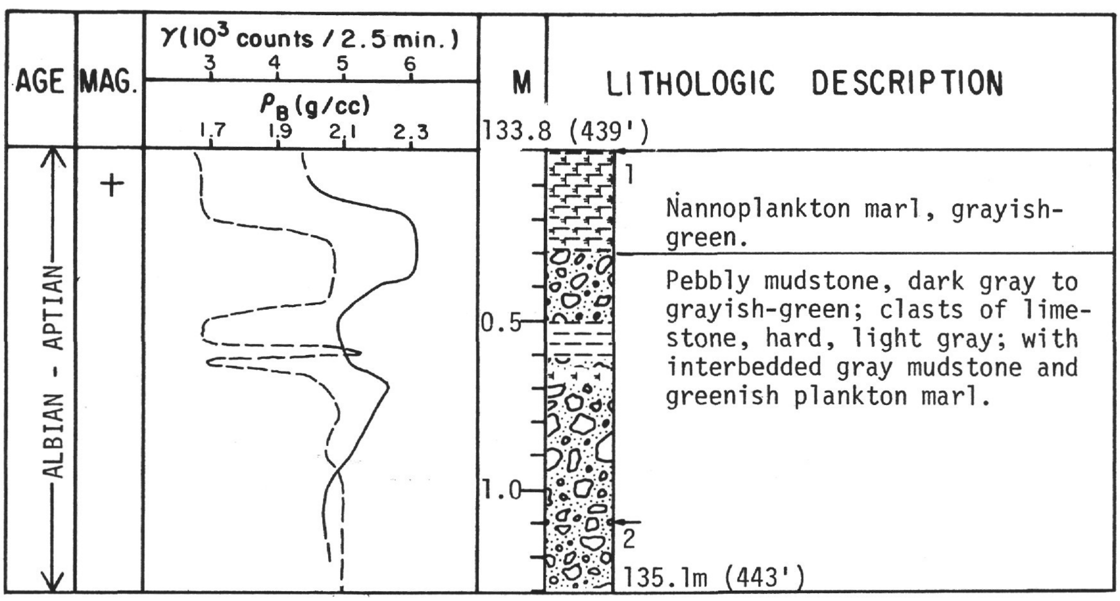


Figure 8. *Hole 4, Core 3.*

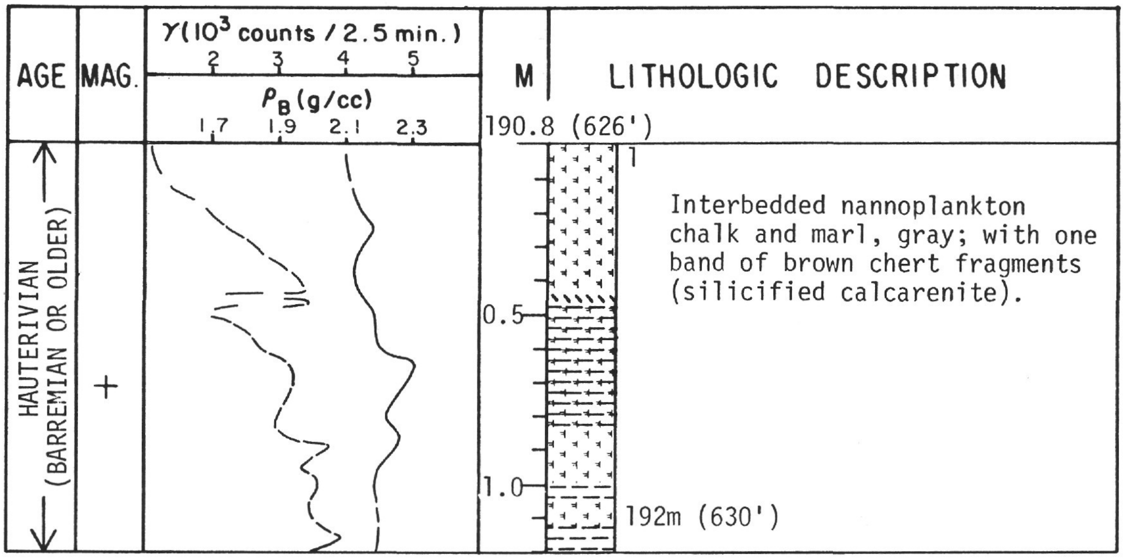


Figure 9. *Hole 4, Core 4.*

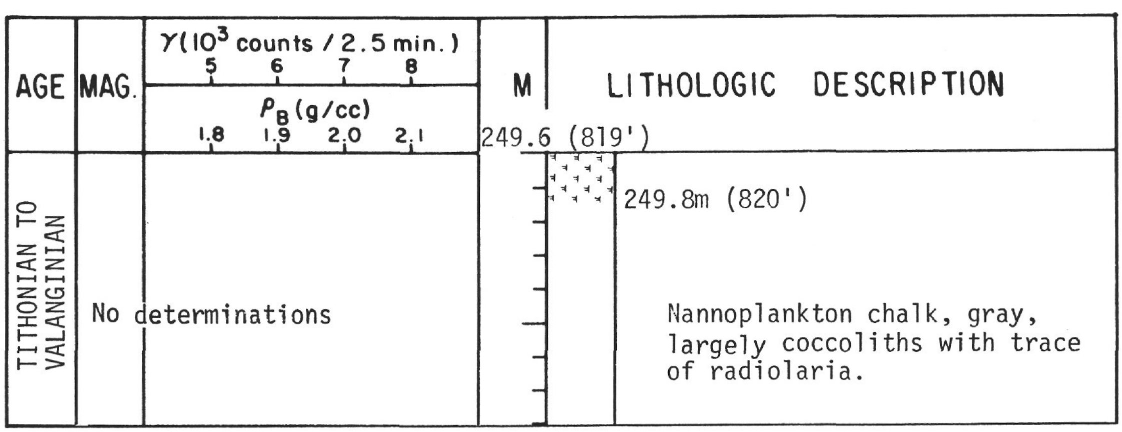


Figure 10. *Hole 4, Core 5.*

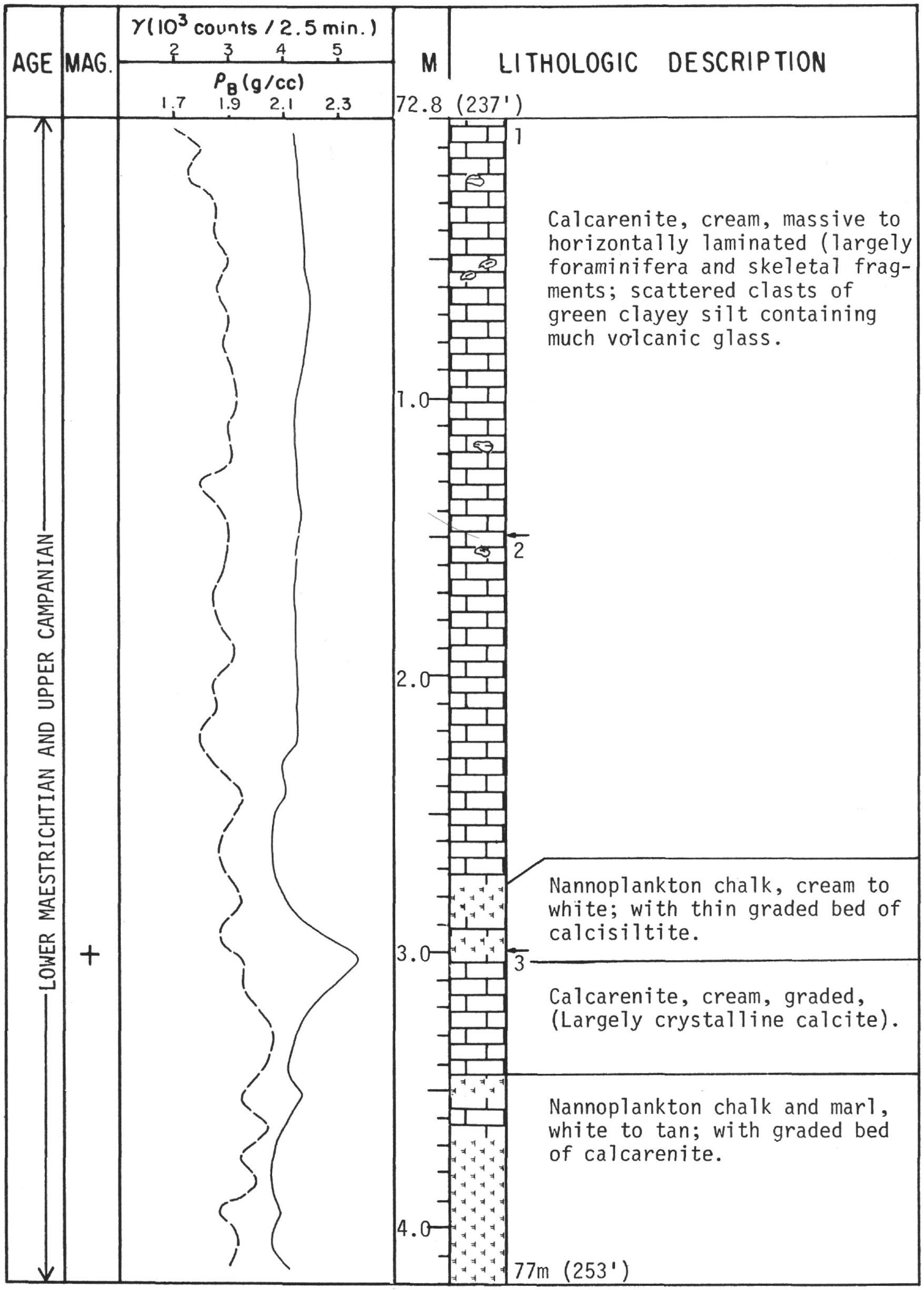


Figure 11. *Hole 4A, Core 1.*

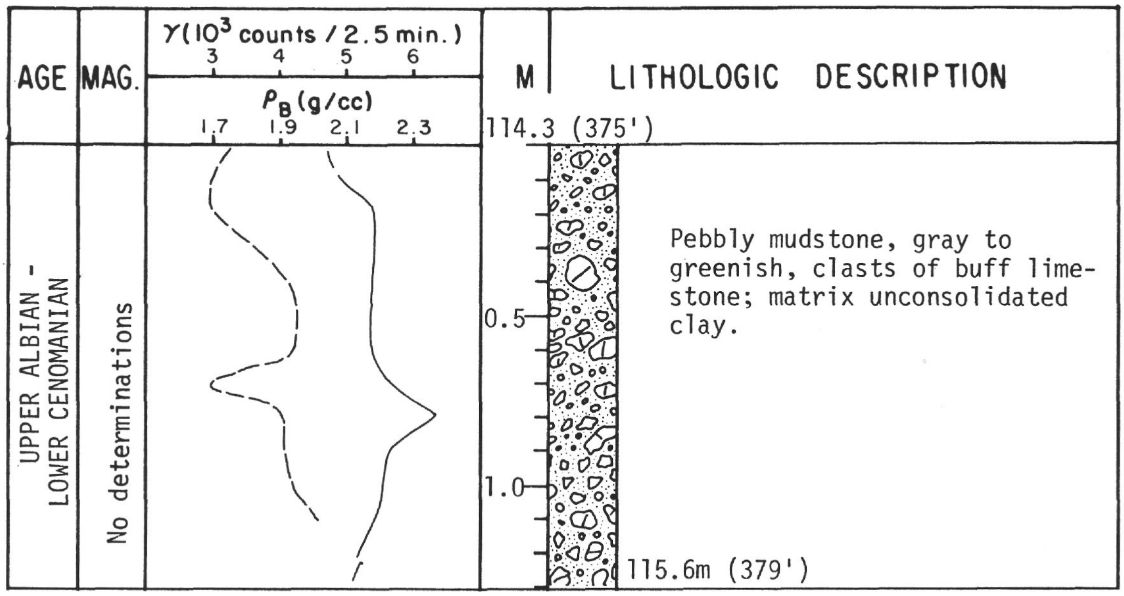
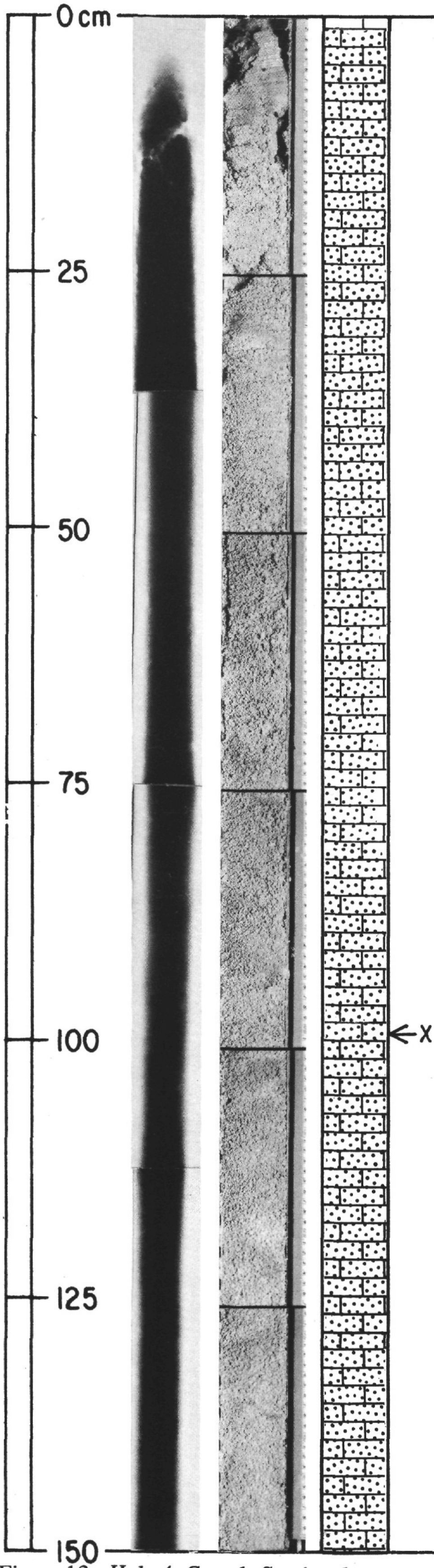


Figure 12. *Hole 4A, Core 2.*

Figures 13 through 28 show details of the individual core sections of the cores from Site 4.

Each figure shows:

(1) A scale of centimeters from the top of each section.
(2) An X radiograph of the core section.
(3) A photograph of the core section.
(4) The lithology (see key with Site 1 Report).
(5) The positions of smear slides (x).
(6) Notes on the lithology, carbon content, expressed as a percentage of total sediment (see Chapter 11), the water content (see Chapter 10) and the grain size (see Chapter 9). Colors are given with reference to the GSA Rock Color Chart.



Calcarenite of resedimented Eocene-Oligocene foraminifera, (10YR 5/4), fragments of hard white limestone and buff sugary dolomite, pinkish chert; also clasts of brown clay; matrix clay and nannofossils.
Color mainly pale tannish-gray (10YR 7/2), with yellowish-brown bands (10YR 5/4 - 7/6) as noted. Section may have been severely disturbed in coring.
(10YR 5/4).

Total C 10.9; Org. C 5.0; $CaCO_3$ 49.1.
Water content 16.8.
Sand 84.0; silt 8.6; clay 7.4.

(10YR 5/4).

Mottled with lighter shade (10Y 7/1).

Figure 13. *Hole 4, Core 1, Section 1.*

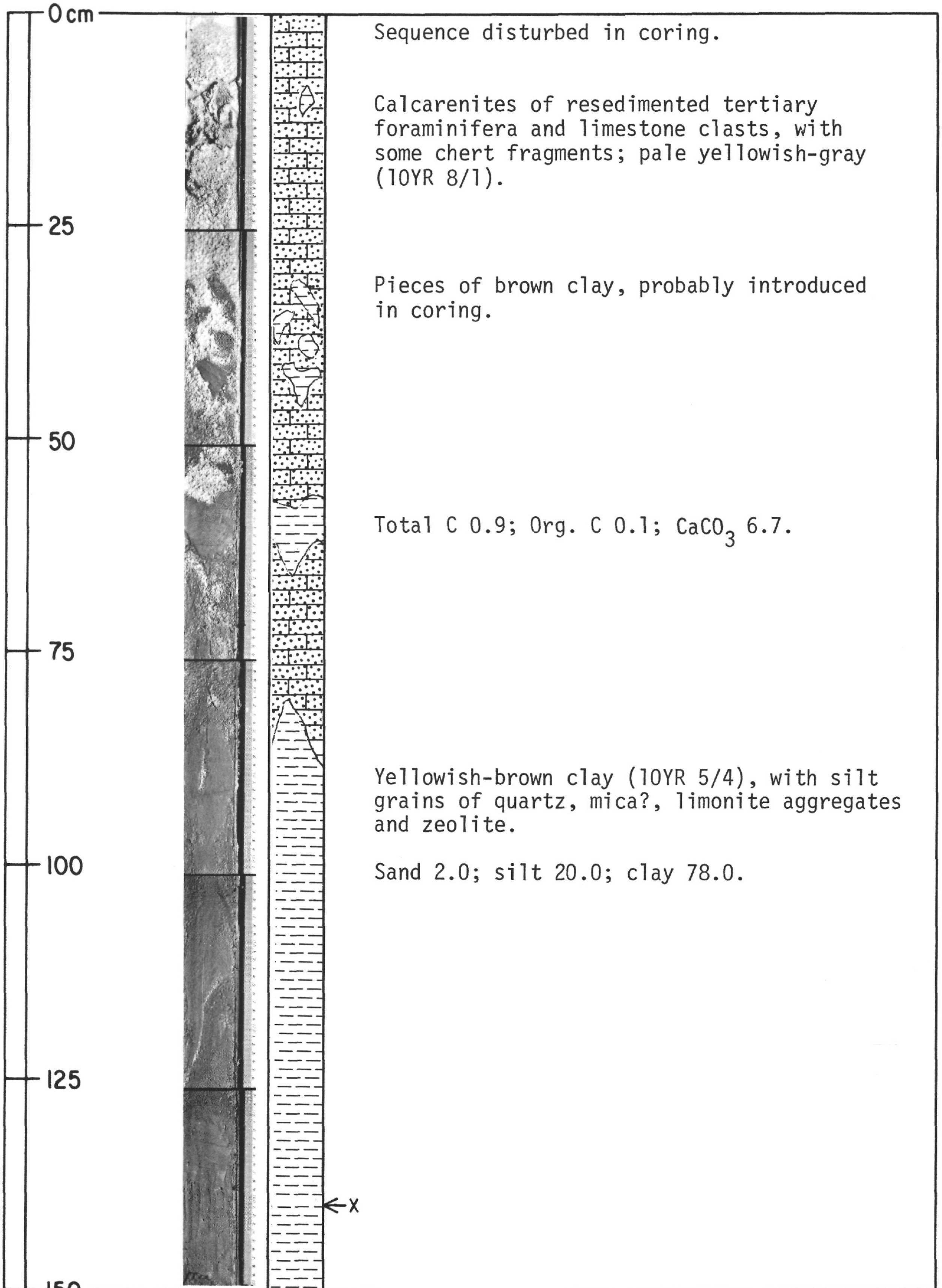
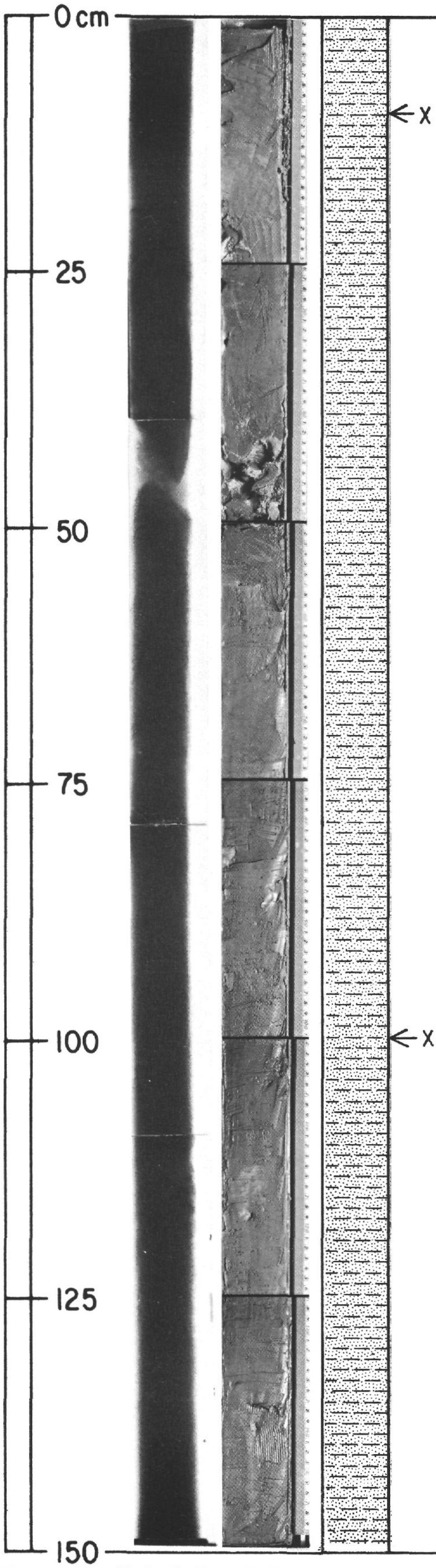


Figure 14. *Hole 4, Core 1, Section 2.*

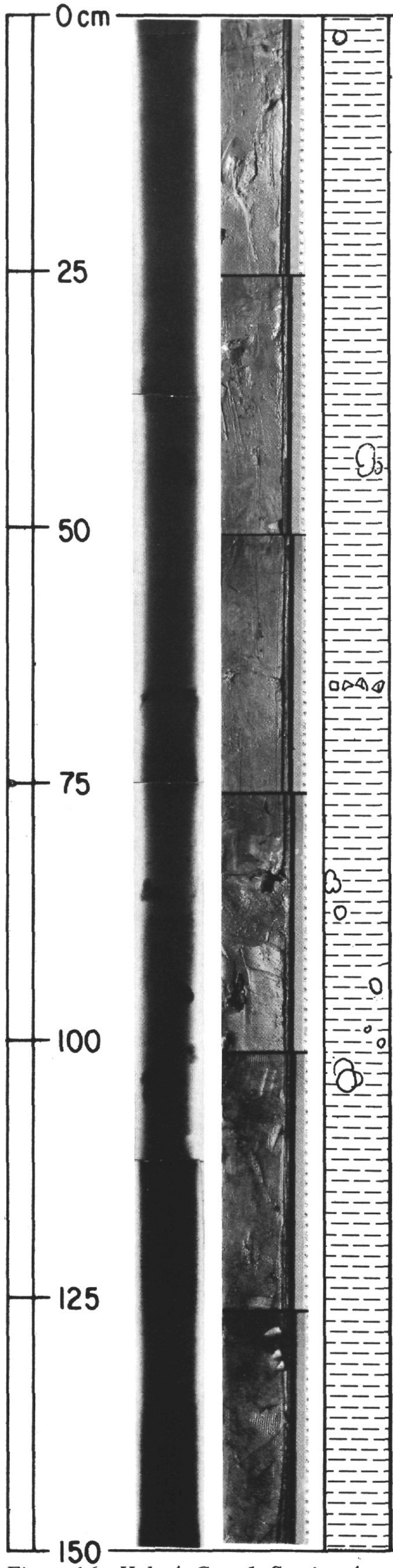


Total C 4.0; Org. C 0.1; $CaCO_3$ 33.6.
Water content 40.6.
Sand 12.8; silt 17.1; clay 70.1.

Clay, silty (quartz, carbonate skeletal fragments, limonite aggregates, nannofossils). Yellowish-brown (10YR 6/4) with darker (10YR 5/4) streaks.

Uniform and probably mechanically disturbed in coring. At 23 - 26 cm a bleb of calcarenite like that in Section 2.

Figure 15. *Hole 4, Core 1, Section 3.*



Total C 1.1; Org. C 0.1; $CaCO_3$ 8.9.
Water content 46.0.

Sand 13.6; silt 16.3; clay 70.1.

Clay, yellowish-brown (10YR 5/3) with lighter (10YR 6/3) zones. Some parts are silty-sandy, with quartz, limonite aggregates, zeolites, chlorite.

Nodules of limonitic appearance, with vesicular structure, appear to be altered pieces of vesicular basalt or pumice (see X-radiograph).

Zone of detrital limestone clasts, 5 - 10 mm (note X-radiograph).

Figure 16. *Hole 4, Core 1, Section 4.*

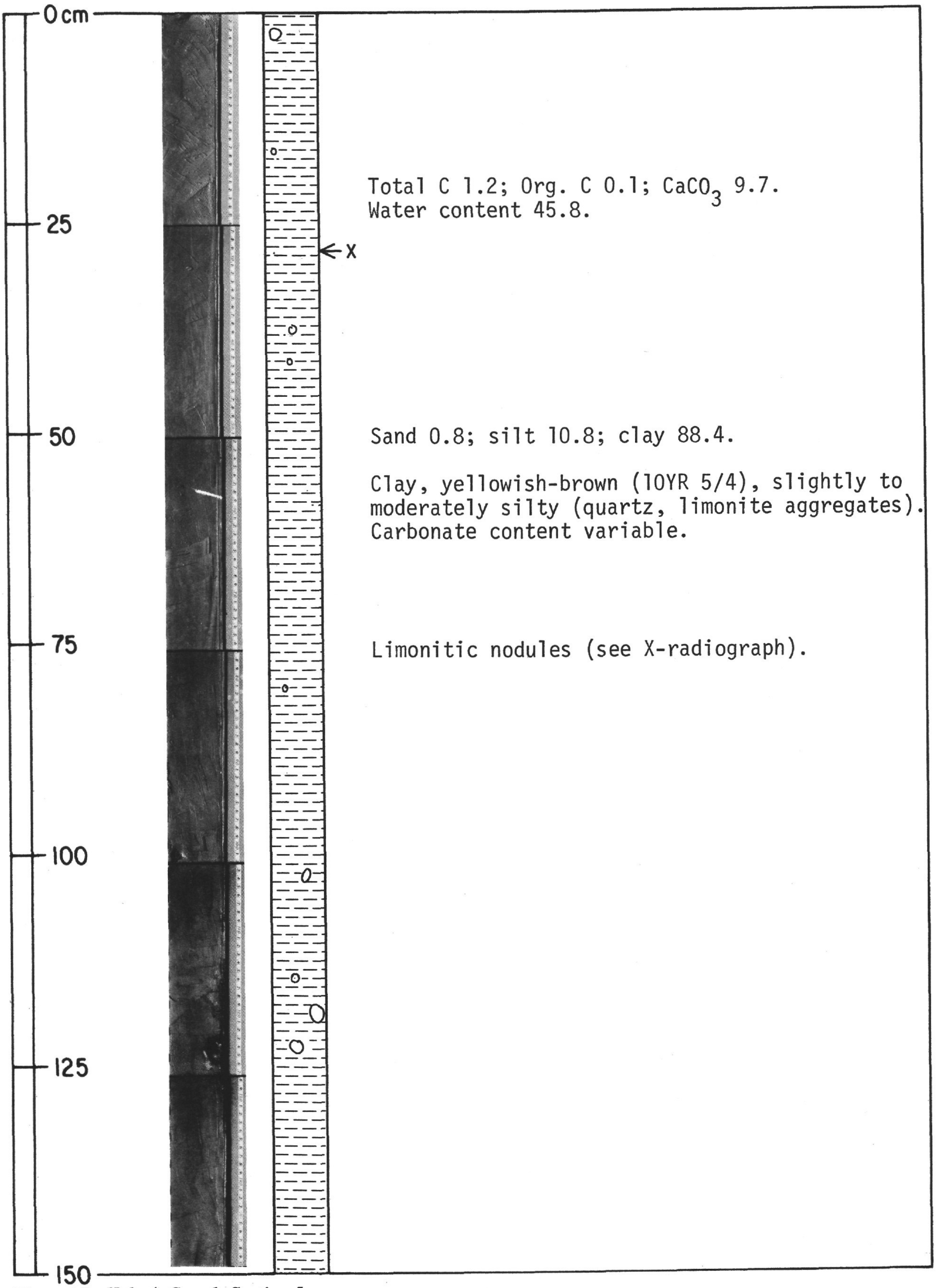
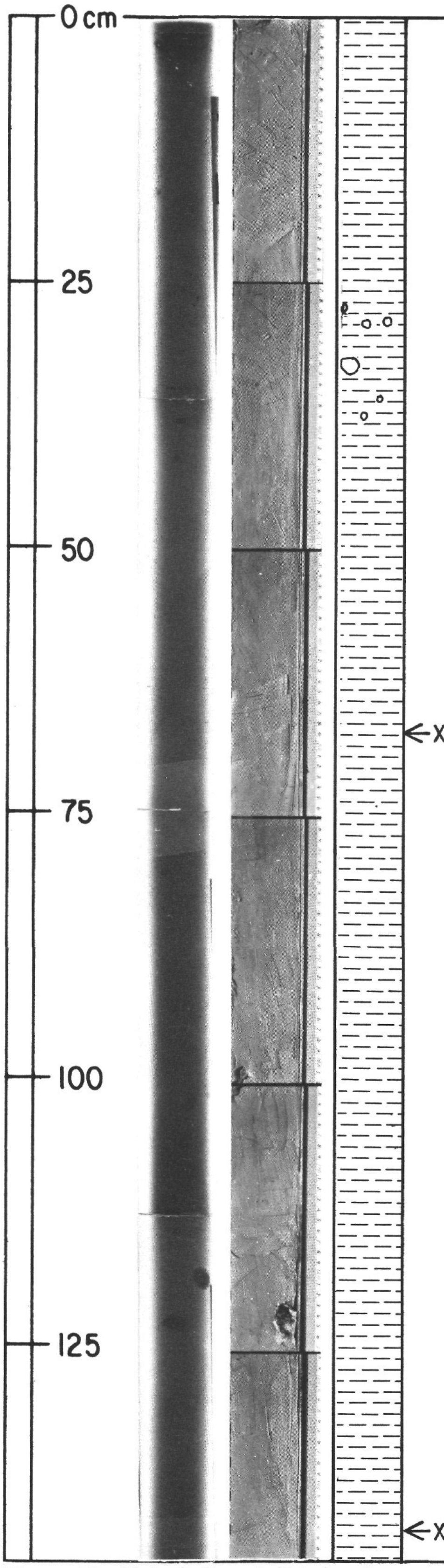


Figure 17. *Hole 4, Core 1, Section 5.*



Total C 0.1; Org. C 0.1; $CaCO_3$ 0.0.
Water content 46.1.
Sand 2.2; silt 19.4; clay 78.4.

Clay, yellowish-brown (10YR 5/4) to (10YR 5/3); silty fraction consists of quartz, limonitic aggregates, possibly some shards.

Small (1 - 2 mm) limonitic nodules are disseminated throughout; larger ones (see X-radiograph) as plotted.

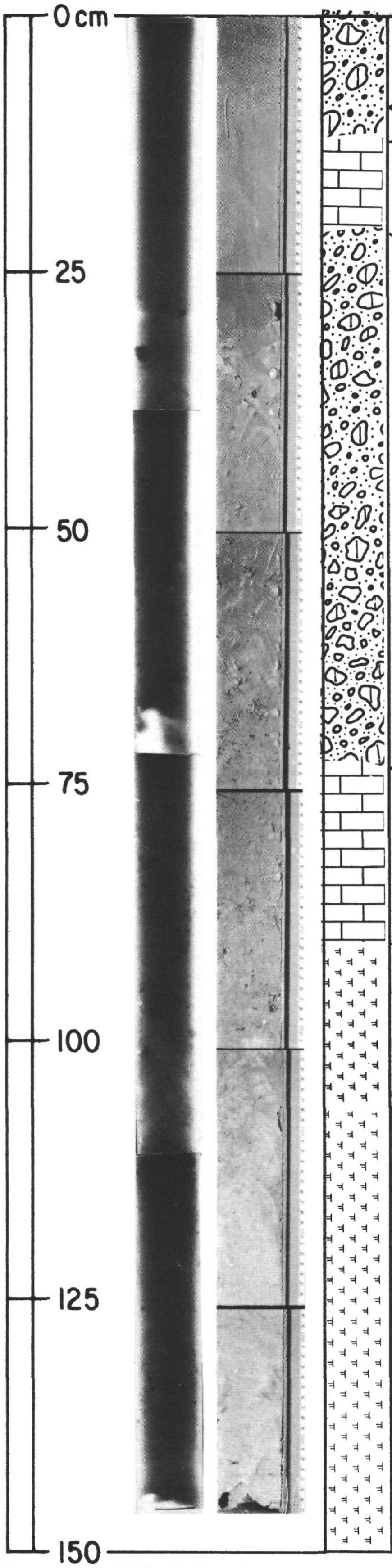
Entire section appears intensely disturbed; how much of this is natural, how much due to coring process is uncertain.

Clay as above, but yellow (2.5Y 8/6) and brown (10YR 6/3).

Same, (2.5Y 8/6).

Same, pale yellowish-gray (2.5Y 8/2) speckled yellow (2.5Y 5/2).

Figure 18. *Hole 4, Core 1, Section 6.*



Pebbly mudstone, tan (10YR 7/4); matrix nannoplankton marl, with clast (up to 100 mm) of white, fine, hard calcilutite and of mudstone (rock fragments).

X Total C 6.2: Org. C 0.7; $CaCO_3$ 45.9.

Calcarenite, whitish (10YR 8/1), clasts mainly hard white calcilutite (rock fragments), 2% quartz; some nannoplankton in matrix.

Pebbly mudstone as above.

Calcarenite as above, finely laminated.

Nannoplankton chalk (half coccoliths, half indeterminate silt-grade calcite).

X Sand 0.0; silt 35.2; clay 64.8.

Figure 19. *Hole 4, Core 2, Section 1.*

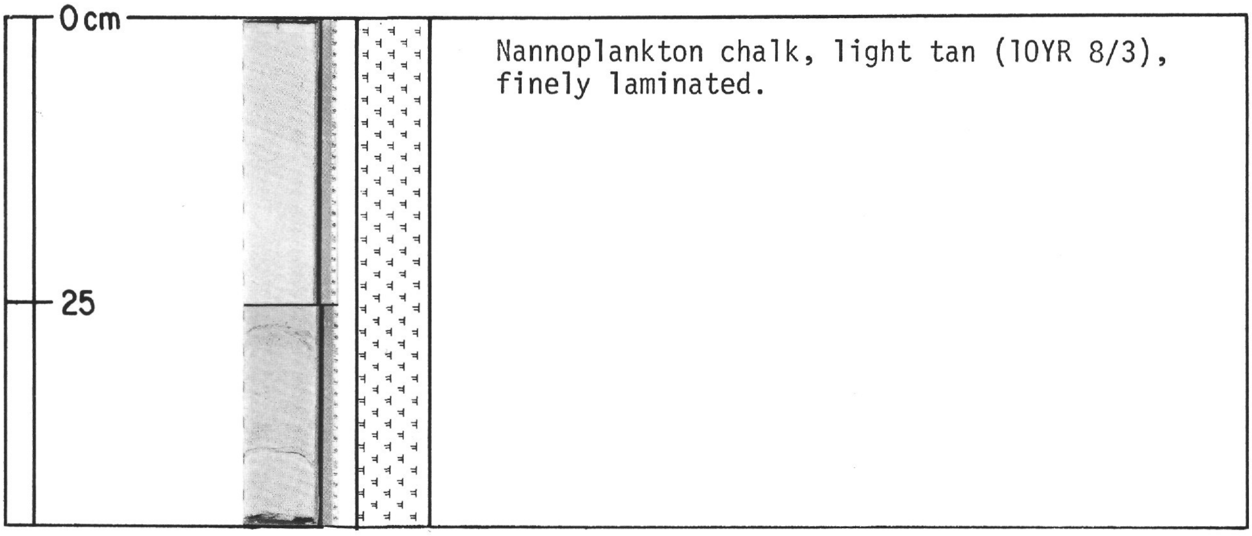


Figure 20. *Hole 4, Core 2, Section 2.*

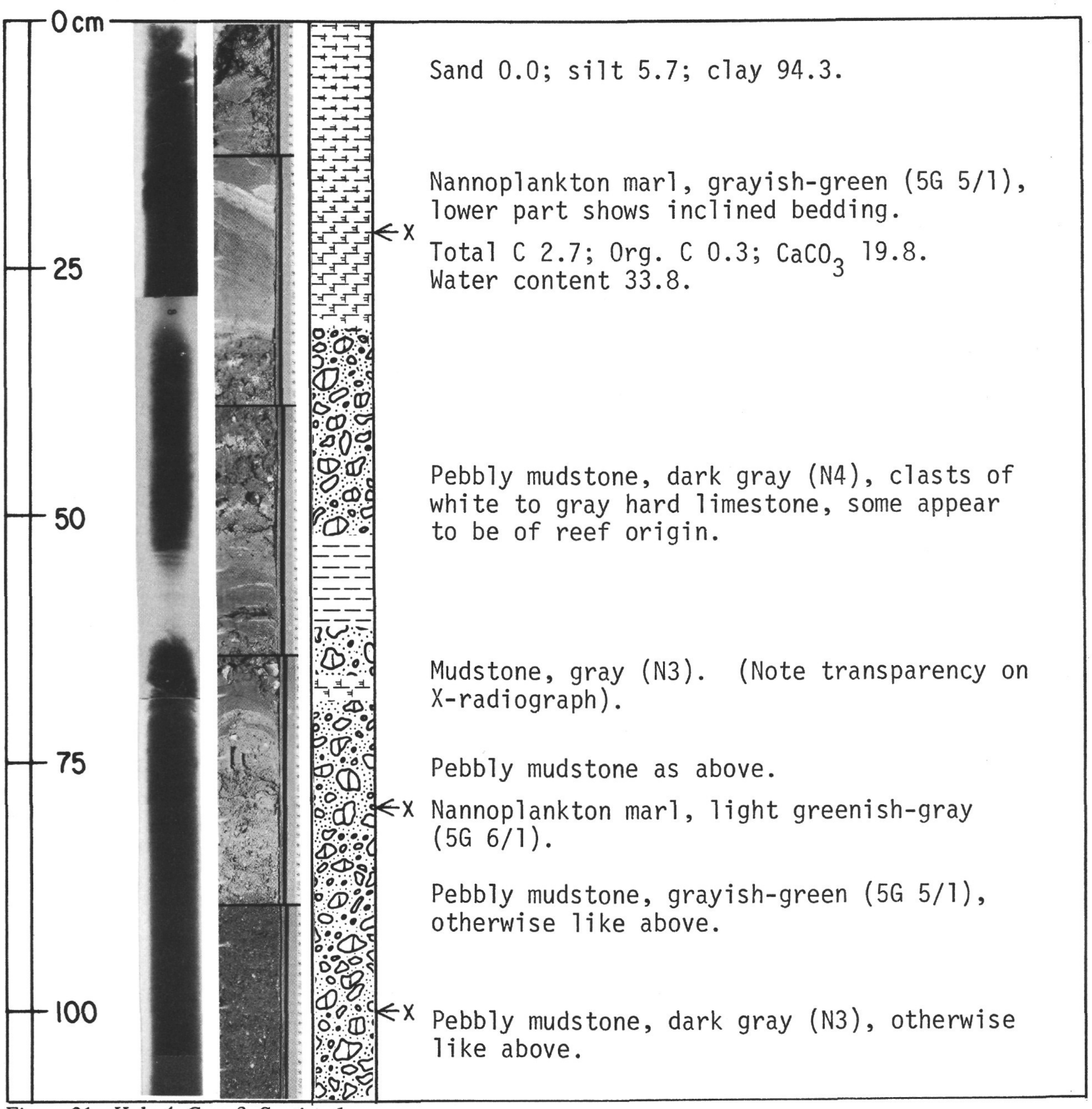


Figure 21. *Hole 4, Core 3, Section 1.*

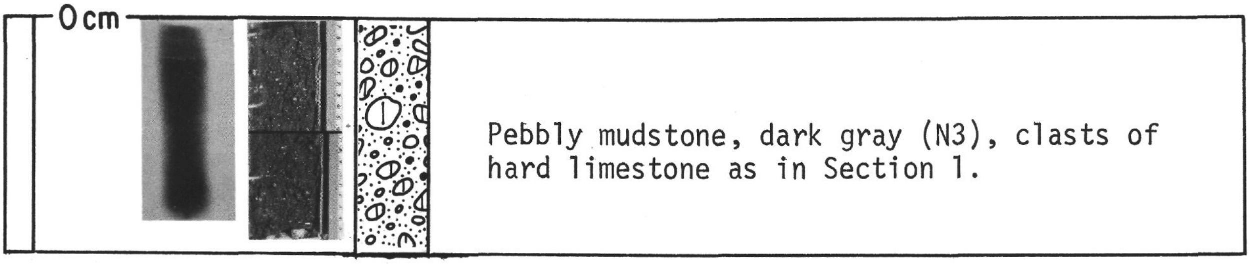


Figure 22. *Hole 4, Core 3, Section 2.*

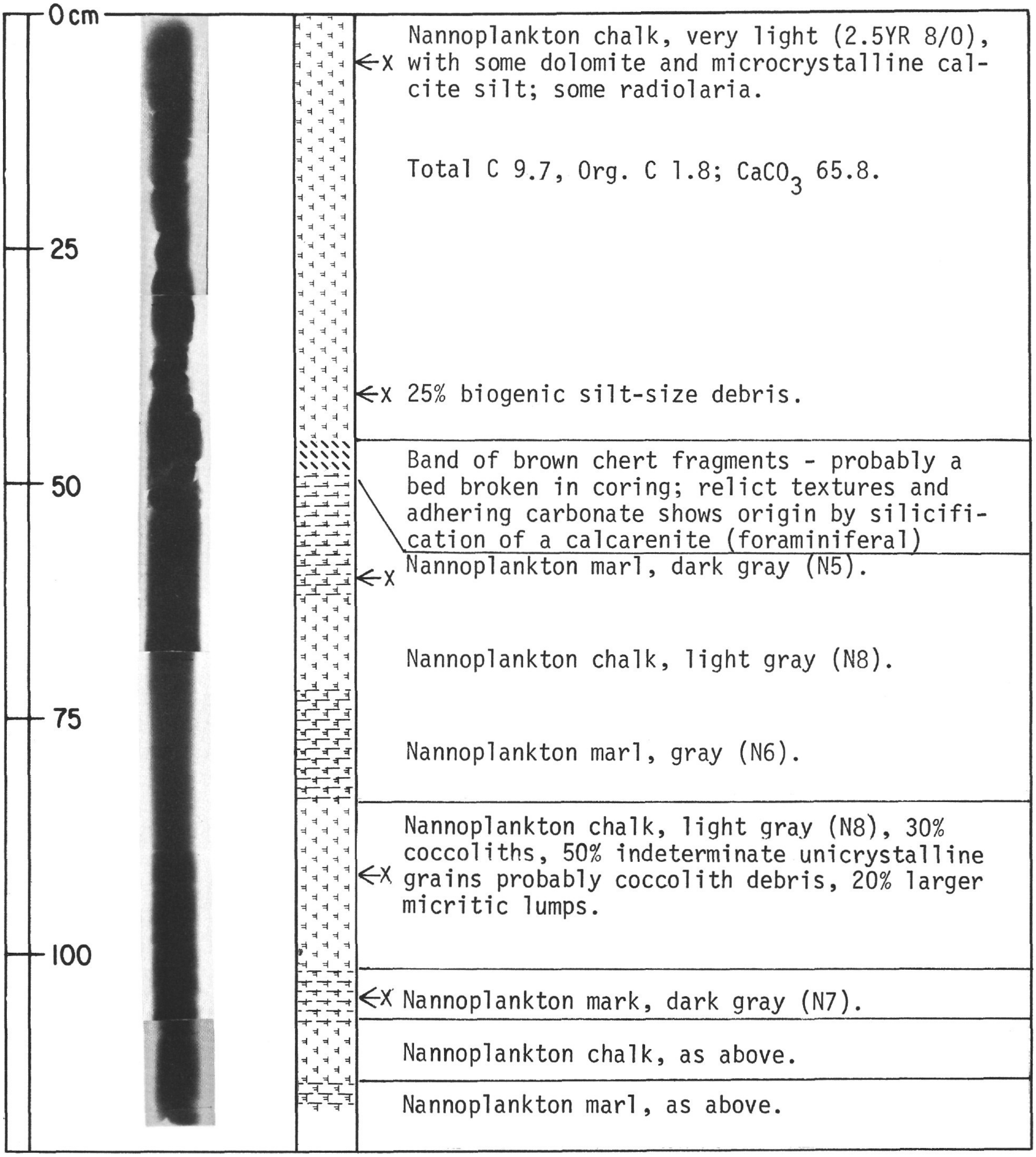


Figure 23. *Hole 4, Core 4, Section 1.*

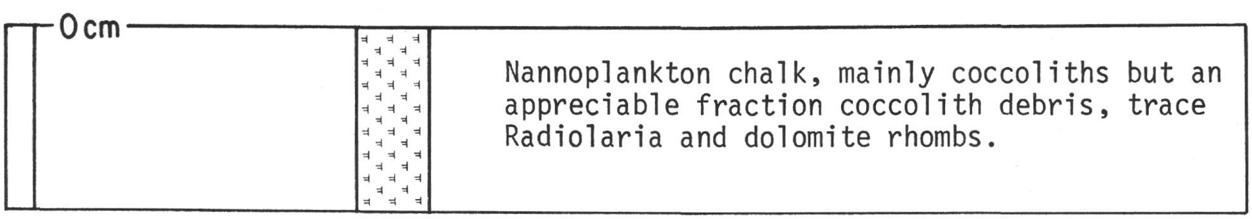
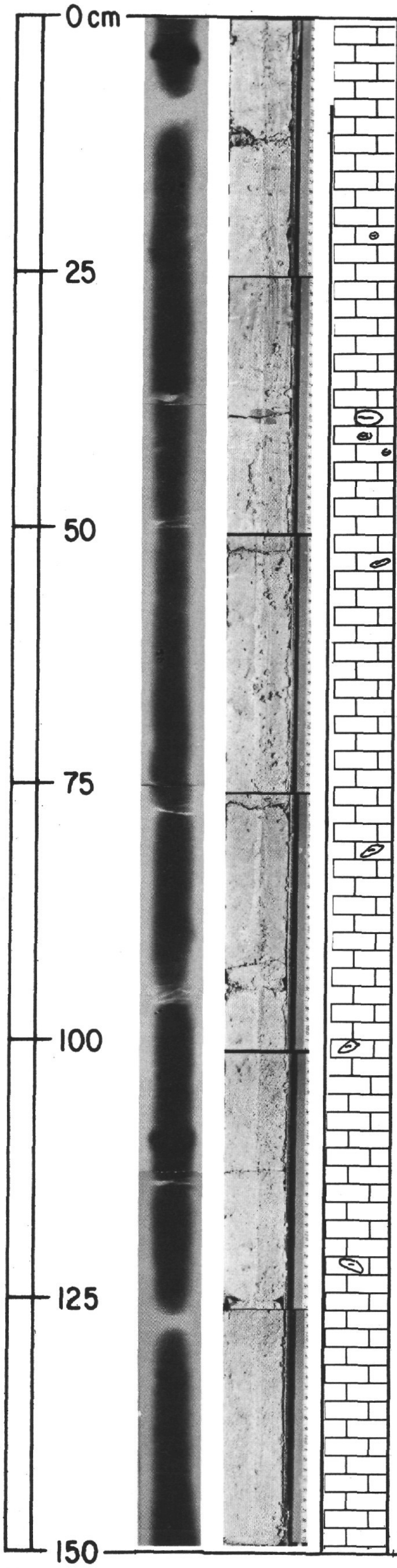


Figure 24. *Hole 4, Core 5, Section 1.*



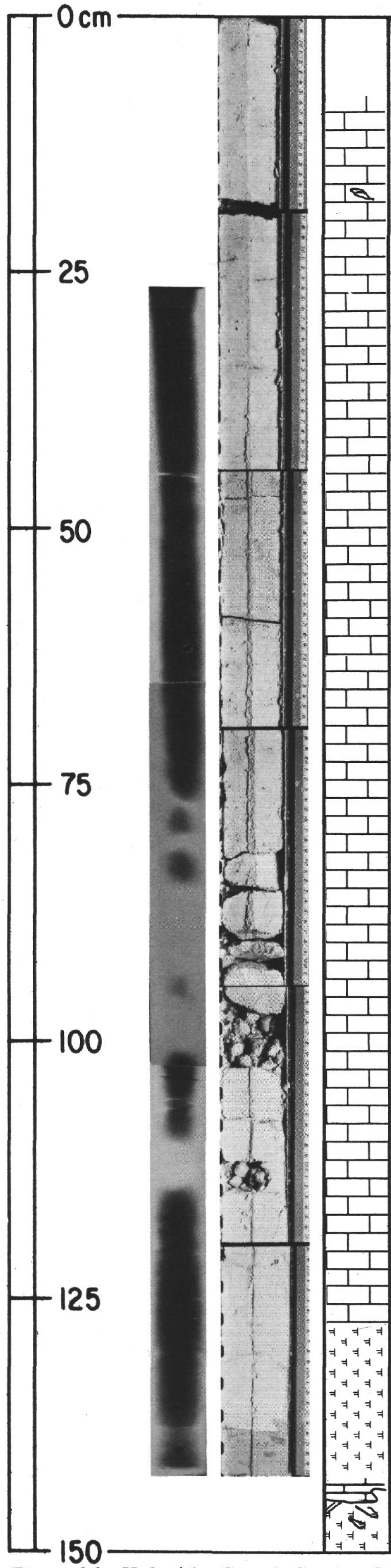
Total C 9.5; Org. C 2.2; $CaCO_3$ 77.1.
Water content 20.6.
Sand 51.9; silt 24.4; clay 23.7.

Calcarenite, cream (2.5Y 8/2), massive to horizontally laminated, consisting of micritized foraminifera and skeletal fragments and indeterminate micrite including some nannofossils; cemented with calcite scalenohedra and some dolomite rhombs.

Contains scattered clasts of green clayey silt containing much volcanic glass.

Sample contains abundant black opaque grains.

Figure 25. *Hole 4A, Core 1, Section 1.*



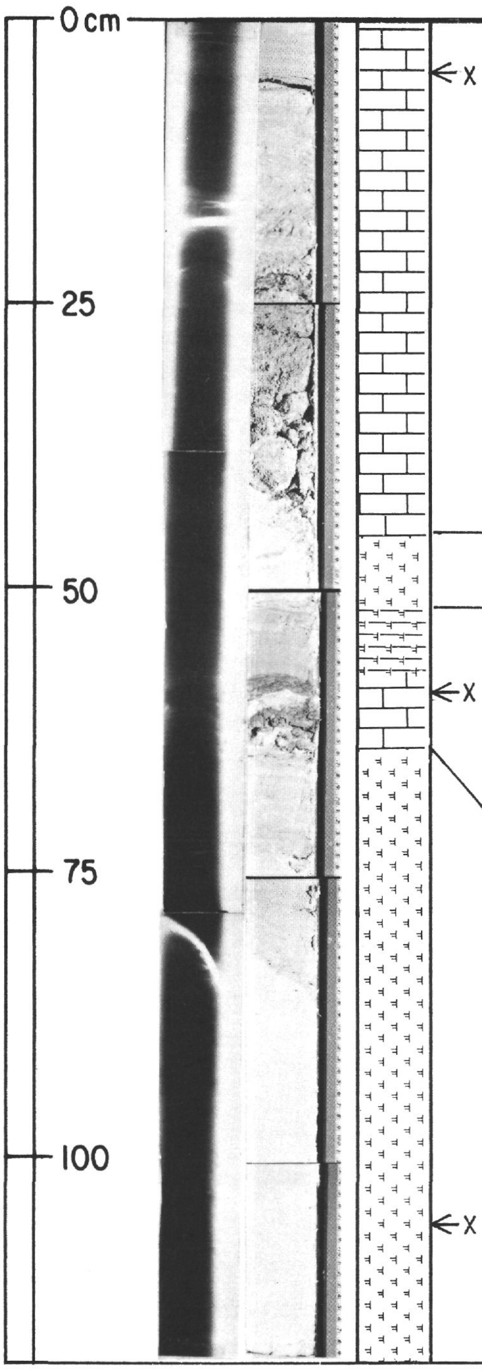
Calcarenite, cream (2.5Y 8/2), massive to horizontally laminated, appears multiply graded; consists of skeletal fragments and micritized foraminifera; abundant authigenic calcite cement.

Total C 11.8; Org. C 1.9; $CaCO_3$ 81.9.
Water content 23.6.

Nannoplankton chalk, white; some scalenohedral authigenic calcite.

Graded calcisiltite.
Nannoplankton chalk, cream (2.5Y 8/2), burrowed.

Figure 26. *Hole 4A, Core 1, Section 2.*



Sand 12.9; silt 31.2; clay 55.9.

Total C 9.9; Org. C 0.1; $CaCO_3$ 78.2.
Water content 15.9.

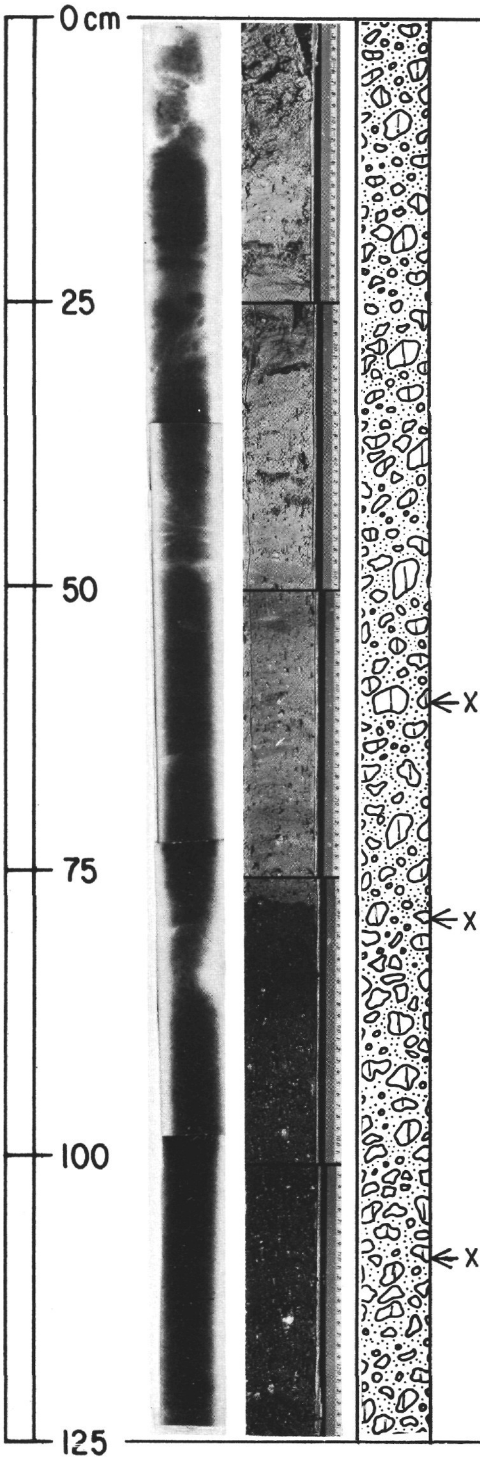
Calcarenite, tan-cream (2.5Y 7/2 - 8/2), graded, mainly of unicrystalline grains of indeterminate origin (at 3 cm); also multi-crystalline aggregates, probably recrystallized skeletal fragments, some nannofossils; trace dolomite rhombs. Cemented with authigenic calcite.

Nannoplankton chalk; white (N9).

Couplet of calcarenites, grayish to cream (N9 - 2.5Y 7/0), composed of micritized skeletal fragments and peloids; authigenic scalenohedral calcite, some dolomite rhombs.

Nannoplankton chalk, majority of grains indeterminate; white (N9).

Figure 27. *Hole 4A, Core 1, Section 3.*



Pebbly mudstone. Clasts < 20 mm white to buff limestone (including dense miliolid-bearing calcilutite, and radist-bearing reef rock (?)) - matrix containing clay, some nannofossils, and silt-grade authigenic calcite.

Sand 43.5; silt 19.0; clay 37.5.

Olive-green (5Y 6/3).

Yellow-green (10YR 7/4).

Clayey, dark gray (10Y 5/2).

Figure 28. *Hole 4A, Core 2, Section 1.*

Nature of the Sediments

For a discussion of the nature of the sediments at Site 4, see Chapter 5 where a discussion of sedimentation in the general region of Sites 4 and 5 is presented.

Physical Properties of the Sediments

For a discussion of the physical properties of the sediments cored at Site 4, see Chapter 5 where a discussion of the properties of the sediments in the general region of Sites 4 and 5 is presented.

Biostratigraphy

Foraminifera and Radiolaria

The biostratigraphy of Site 4, as deduced from the planktonic foraminifera and Radiolaria, is shown in Figure 29. The faunas of the samples listed in Figure 29 are discussed below. As with previous sites, the faunal lists are not necessarily complete or representative, but show only the most common or significant species. In Samples 3 through 13: A represents abundant (6 or more specimens); C represents common (3 to 5 specimens), and R represents rare (1 or 2 specimens).

Sample 1 (1-4-1-1, top):
Globorotalia truncatulinoides, Globigerinoides conglobata, G. rubra, G. sacculifera, Globoquadrina dutertrei, Orbulina universa.
Age determination: Tertiary-Recent.

Sample 2 (1-4-1-6, core catcher):
Turborotalita sp. cf. *T. humilis* (one specimen).

Discussion:
The sediments in this core are essentially of turbidity current origin. Larger foraminifera ranging from Middle Eocene-Miocene in age occur in several samples which were examined (see special report on Larger Foraminifera by Dr. K. N. Sachs, Chapter 18). A sample at 100 centimeters from Section 1 has yielded such stratigraphically diverse forms as *Globigerina nepenthes, G. angulisuturalis, G. obesa* and *Acarinina* sp. The samples from the core catcher consist of very fine, comminuted and agglutinated carbonate particles with pyrite and manganese specks attached. The absence of fossils suggests deep water deposition. The age is probably not older than Late Miocene.

Sample 3 (1-4A-1-1, top):
Globotruncana rosetta (Carsey) A, *Globotruncana plummerae* Gandolfi A, *Globotruncana fornicata* Plummer A, *Globotruncana nothi* (Bronnimann and Brown) A, *Planoglobulina multicamerata* de Klasz A, *Globotruncana linneiana* (d'Orbigny) A, *Globotruncana elevata* (Brotzen) A, *Globotruncana stuartiformis* Dalbiez A, *Pseudotextularia elegans* (Rzehak) A, *Globotruncana lapparenti* s.s. Brotzen A, *Pseudoguembelina costulata* (Cushman) A, *Rugoglobigerina rugosa* (Plummer) R, *Heteroheliz punctulatus* (Cushman) C, *Globotruncana arca* (Cushman) A, *Rugotruncana subcircumnodifer* (Gandolfi) C, *Globotruncana hilli* Pessagno A, *Globotruncanella havanensis* (Voorwijk), *Heterohelix striata* (Ehrenberg) C.
Age determination: Earliest Maestrichtian. *G. fornicata-stuartiformis* Assemblage Zone, *R. subcircumnodifer* Subzone (*G. lapparenti* s.s. Zonule).

Sample 4 (1-4A-1-1, 9-10 cm):
Globotruncana calcarata Cushman R (two specimens), *Globotruncana ventricosa* White R, *Globotruncana elevata* (Brotzen) A, *Globotruncana stuartiformis, Globotruncana fornicata* Plummer A, *Globotruncana linneiana* (d'Orbigny) A, *Globotruncana arca* (Cushman) A, *Globotruncana stephensoni* Pessagno A, *Globotruncana rosetta* (Carsey) A, *Rugotruncana subcircumnodifer* (Gandolfi) A, *Globotruncana lapparenti* s.s. Brotzen A, *Planoglobulina multicamerata* de Klasz A, *Pseudotextularia elegans* (Rzehak) R, abundant larger foraminifera (see report from K. N. Sachs, Chapter 18).
Age determination: Latest Campanian. *G. fornicata-stuartiformis* Assemblage Zone, *G. elevata* Subzone (*G. calcarata* Zonule).

Remarks: Larger foraminifera reworked penecontemporaneously are abundant. These were probably derived from shallow neritic depths and carried to abyssal depths by turbidity currents.

Sample 5 (1-4A-1-3, core catcher):
Globotruncana elevata (Brotzen) R, *Globotruncana plummerae* Gandolfi R, *Pseudoguembelina costulata* (Cushman) A, sparse Radiolaria.
Age determination: Late Campanian largely via superposition. *G. fornicata-stuartiformis* Assemblage Zone, *G. elevata* Subzone (undifferentiated).

Sample 6 (1-4-2-1, 10 cm):
Planktonic foraminifera: *Marginotruncana canaliculata* (Reuss) R, *Clavihedbergella simplex* (Morrow) R, *Hedbergella amabilis* Loeblich and Tappan R, *Globigerinelloides asperus* (Ehrenberg) R, *Heterohelix reussi* (Cushman) A, *Hedbergella modesta* (Bolli) R. Radiolaria: *Pseudoaulophacus gallowayi* (White) A, *Pseudoaulophacus pargueraensis* Pessagno R, *Dictyomitra multicostata* Zittel A, *Pseudoaulophacus lenticulatus* (White) R, *Pseudoaulophacus* n. sp. aff. *P. floresensis* Pessagno C, *Melitosphaera* n. sp. (likewise, known from the Upper Cretaceous of California), *Stylospongia* (?) *verteroensis* Pessagno C.
Age determination: Late Turonian to early Santonian (Coniacian?). *M. helvetica* Assemblage Zone, *W. archaeocretacea* Subzone, *W. archaeocretacea* Subzone to *G. bulloides* Assemblage Zone, *M. concavata* Subzone.

Remarks: The presence of *Clavihedgergella simplex* (Morrow), *Hedbergella ambilis* Loeblich and Tappan, and *Hedbergella modesta* (Bolli) in this sample suggests

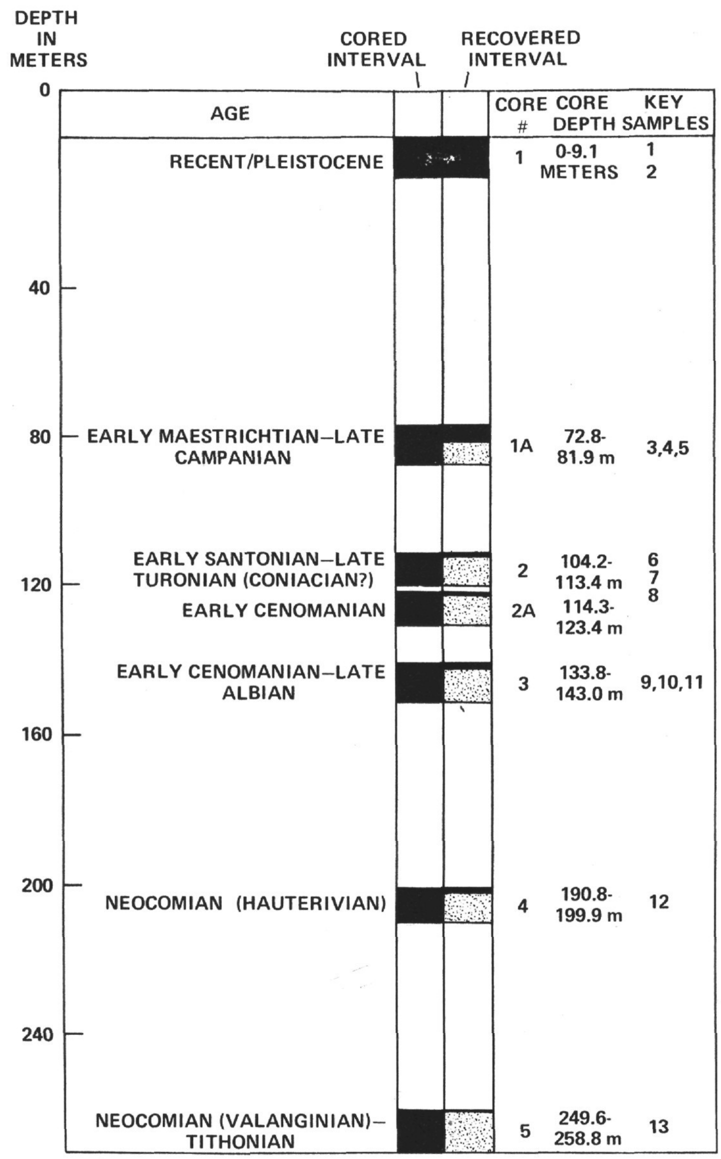


Figure 29. *Biostratigraphy of Site 4 as deduced from the foraminifera and Radiolaria.*

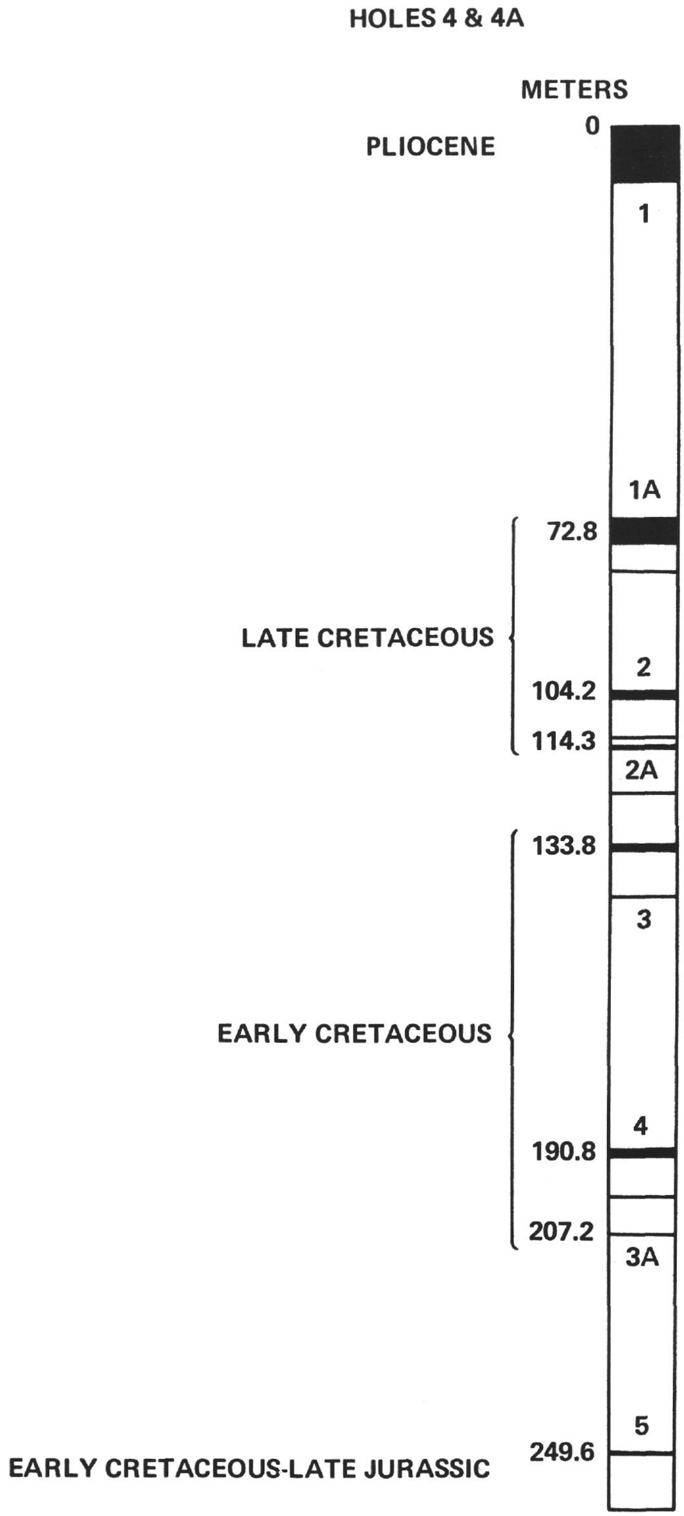


Figure 30. *Biostratigraphy of Site 4 as deduced from the calcareous nannoplankton.*

reworking of Cenomanian material. Most of the species of *Pseudoaulophacus* cited above do not occur below the middle Turonian. *M. canaliculata* (Reuss) is the most diagnostic of the planktonic foraminifera present. In the Western Hemisphere, this species has a range of late Turonian to early Santonian.

Sample 7 (1-4-2-1, core catcher):
Pseudoaulophacus gallowayi (White) C, *Heterohelix* sp. (finely costate) R.
Age determination: Via superposition (Sample 6) it can be established that this sample is no younger than late Turonian-early Santonian (Coniacian?). Furthermore, work by the investigator in California and elsewhere indicates that the range zone of *P. gallowayi* does not extend below the Turonian (*M. helvetica* Assemblage Zone).

Sample 8 (1-4A-2-1, 109-111 cm):
Rotalipora evoluta Sigal; some forms transitional to *R. appenninica* A, *Rotalipora appenninica* (O. Renz) A, *Rotalipora greenhornensis* (Morrow) R, *Praeglobotruncana stephani* (Gandolfi) A, *Praeglobotruncana stephani turbinata* Reichel R, *Hedbergella delrioensis* (Carsey) R, *Hedbergella amabilis* Loeblich and Tappan C, *Hedbergella planispira* Tappan R, *Globigerinelloides caseyi* Bolli, Loeblich, and Tappan R, *Globigerinelloides bentonensis* (Morrow) R, Ostrocods (rare), smaller benthonic foraminifera (common).
Age determination: Early Cenomanian, *Rotalipora* s.s. Assemblage Zone, *R. evoluta* Subzone. The presence of *R. appenninica* s.s. (O. Renz) and *R. greenhornensis* (Morrow) indicates the upper part of the *R. evoluta* Subzone.

Sample 9 (1-4-3-1, 0-5 cm):
Rotalipora evoluta (Sigal) C, *Praeglobotruncana stephani* (Gandolfi) A, *Praeglobotruncana delrioensis* (Plummer) A, *Hedbergella delrioensis* (Carsey) A.
Age determination: Early Cenomanian. *Rotalipora* s.s. Assemblage Zone, *R. evoluta* Subzone (lower part).

Sample 10 (1-4-3-1, 55-57 cm):
Rotalipora evoluta Sigal A, *Rotalipora montsalvensis* Mornod A, *Rotalipora balernaensis* Gandolfi C, *Planomalina buxtorfi* (Gandolfi) R, *Globigerinelloides caseyi* Bolli, Loeblich, and Tappan A, *Globigerinelloides bentonensis* (Moreman) C, *Praeglobotruncana delrioensis* (Plummer) A, *Hedbergella delrioensis* (Carsey) C, *Hedbergella planispira* (Tappan) R, with two new species of *Hedbergella.* Benthonic smaller foraminifera (generally common) include: *Quinqueloculina* sp., *Robulus* sp., *Gyroidina* sp., and *Dentalina* sp.
Age determination: Early Cenomanian. *Rotalipora* s.s. Assemblage Zone, *R. evoluta* Subzone (lower part).

Remarks: Penecontemporaneous reworking of smaller benthonic foraminifera seems to have occurred. The presence of a miliolid (*Quinqueloculina*) suggests possible reworking from shallow to middle neritic depths via turbidity currents.

Sample 11 (1-4-3-1, 100-102 cm):
Praeglobotruncana delrioensis (Plummer) C, *Hedbergella planispira* (Tappan) C, *Globigerinelloides caseyi* Bolli, Loeblich, and Tappan C, with two new species of *Hedbergella.*
Age determination: Late Albian? Probably *H. washitensis* Assemblage Zone. Absence of *Rotalipora evoluta* Sigal suggests Albian.

Sample 12 (1-4-4-1, 5-8 cm):
Radiolaria: *"Melitosphaera"* sp. aff. *"M." sphaeroconus* Rust A (see Chapter 25, Plate 4D). Foraminifera: *Marginulina* sp. R.
Age determination: See data presented by Bukry and Bramlette, Chapter 15.

Sample 13 (1-4-5-1, core catcher):
First examples of *Pseudoaulophacidae* Riedel.
Age determination: See data presented by Bukry and Bramlette, Chapter 15.

Calcareous Nannoplankton

The biostratigraphy of Site 4, as deduced from the calcareous nannoplankton, is summarized in Figure 30. For a detailed discussion of the faunas see the report by Bukry and Bramlette, Chapter 15.

SUMMARY: HISTORICAL AND REGIONAL ASPECTS

Continuous seismic reflection profiles begun by Lamont-Doherty Geological Observatory in 1961 had revealed a very extensive acoustic reflector beneath much of the Atlantic Ocean (Ewing and Ewing, 1962) which was referred to as "Horizon A" and interpreted to be the result of a widespread flood of turbidites (Ewing, 1963). Other surveys during 1961 indicated that a small area east of the Bahama Islands might yield very old sediments with conventional piston coring techniques; Horizon A appeared to crop out here, whereas, elsewhere it was buried beneath 300 to 500 meters of sediment or even more in some areas. Paleontological studies of subsequent piston cores showed rich uppermost Cretaceous fossil collections (Windisch *et al.,* 1968).

Another zone of reflectors was mapped beneath Horizon A, and referred to as "Horizon β" (Ewing *et al.,* 1966). Five piston cores from this same vicinity east of the Bahama Platform contained lower Cretaceous fossils (Windisch *et al.,* 1968). The deeper acoustic basement is locally smooth in its deepest parts, but highly irregular in general. The smooth, deepest reflector has been referred to as "Horizon B" (Ewing *et al.,* 1966).

Sites 4 and 5 were located in the area of these exposures between the Hatteras Abyssal Plain and the Bahama Platform, as shown in Figure 31.

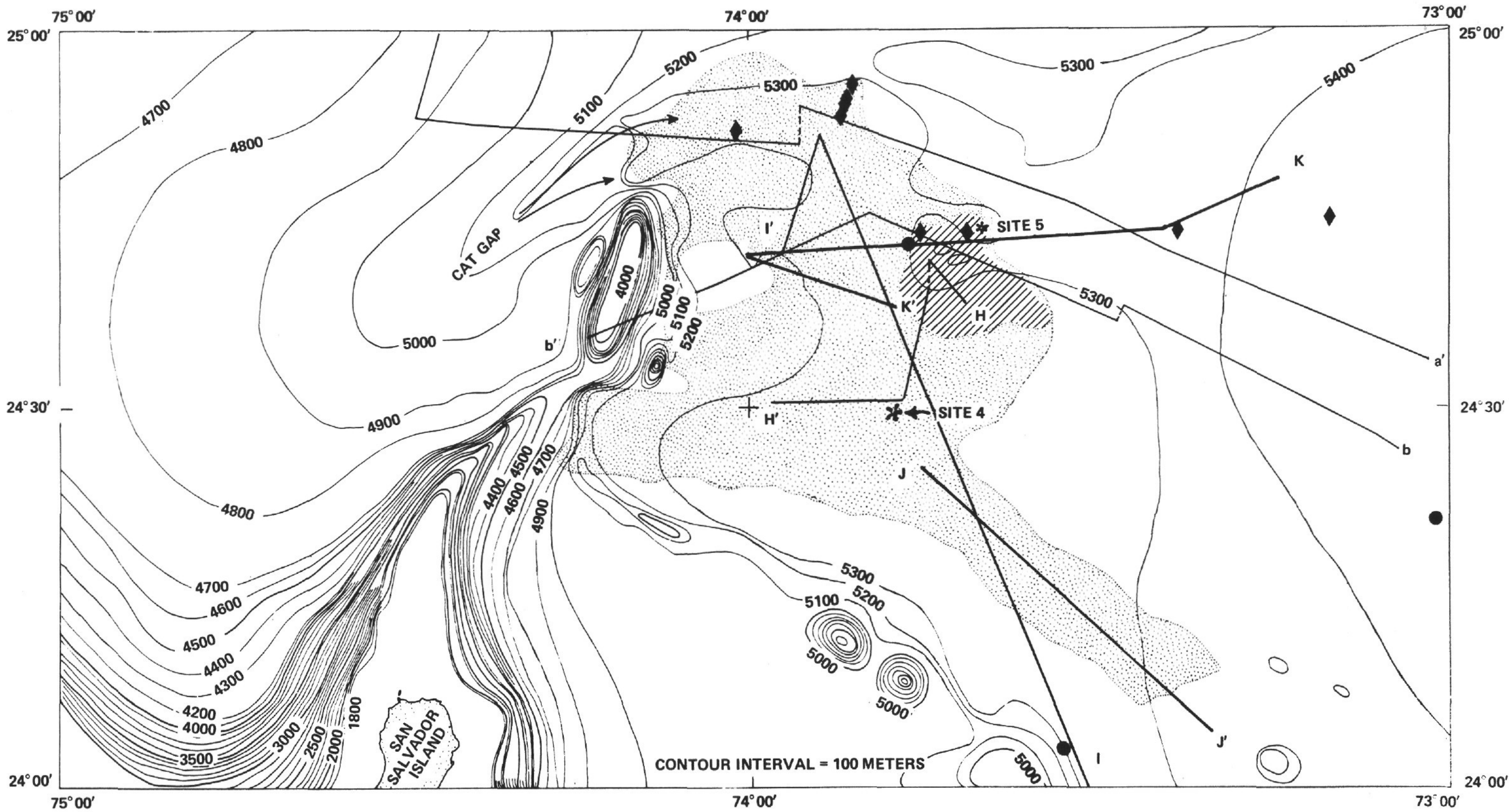


Figure 31. *Bathymetric chart of the seismic Horizon β outcrop area showing Sites 4 and 5 and the results obtained by piston coring. Outcrop of β is stippled and the oldest outcropped sediments are indicated by hachures. Solid diamonds indicate Cretaceous cores (after Windisch* et al., *1968).*

The objectives were to examine the Cretaceous and Tertiary sequence, and to recover the oldest sediments possible. Site 4 was situated about 45 nautical miles northeast of the island of San Salvador in 5319 meters (17,452 feet) of water. Two holes were drilled and the maximum penetration below the sea floor was 259 meters (849 feet).

The sequence sampled at Sites 4 and 5 represents nearly all of the Cretaceous and Tertiary ages. At Site 4, the Plio-Pleistocene was cored, Oligocene-Miocene fragments were recovered on the bit, Eocene-Oligocene cavings were found on top of one core, Maestrichtian, Campanian, Turonian, Cenomanian, Albian, Hauterivian, and older Neocomian were also cored. The relations of these cores are shown in Figure 32.

Approximately 250 meters of sediment thus appears to represent about 125 x 10^6 years of time, an overall sedimentation rate of only 2 mm/10^3 years. This is an order of magnitude lower than the apparent rate for organic pelagic deposits, and a rate certainly not supported by the turbidites present. Rather than indicating an exceptionally low rate of sedimentation, the very thin section at Site 4 appears to result from a great many small gaps in the sequence. Throughout the Cretaceous and Tertiary this area was one which was largely bypassed, where most of the sediment was swept away, and where only intermittently some was preserved—a situation which appears to have persisted to the present.

The Plio-Pleistocene is represented by a calcarenite turbidite (largely benthonic foraminifera) overlying calcareous clays. The Upper Cretaceous contains similar calcarenites and nannoplankton marls. The Middle Cretaceous is rich in pebbly mudstones with limestone clasts and nannoplankton chalk. The Lower Cretaceous consists of similar chalk and thin beds of chert (silicified

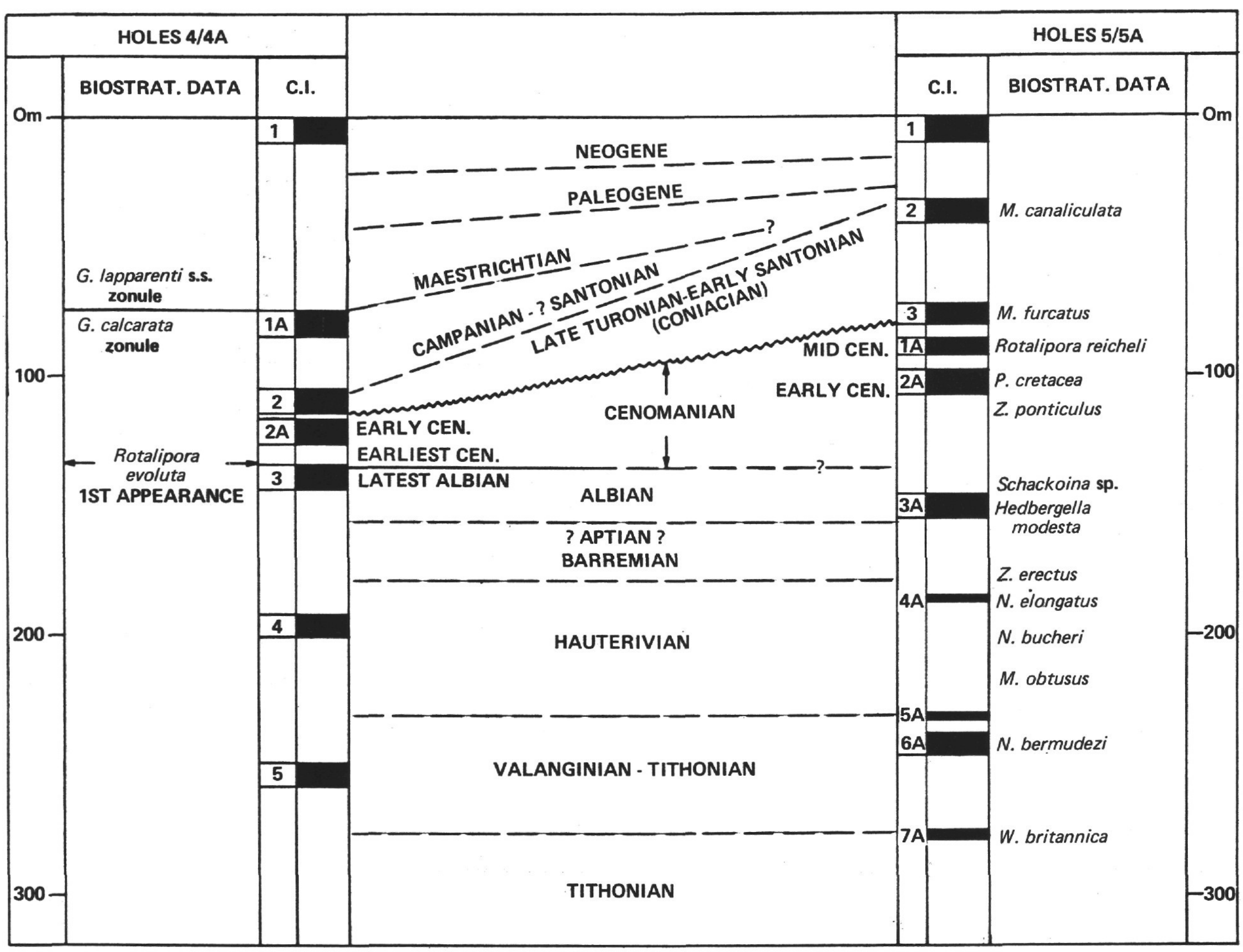


Figure 32. *Stratigraphic correlation of Sites 4 and 5.*

calcarenite). The overall Cretaceous and Tertiary sequence at Site 4 is thus largely calcareous turbidites, probably transported from the Blake Plateau-Bahama Platform area. All of the Cretaceous cores contain coccoliths and scalenohedral calcite (of uncertain origin) in graded beds. Certainly much of this material is resedimented pelagic oozes which may have been preserved below the depth of carbonate compensation due to a sudden influx of such sediment.

The Plio-Pleistocene core contains at least one clast of ocherous clay which resembles soil and which contains in turn weathered chert chips, suggesting direct transport from a more mainland or distant source. The Plio-Pleistocene nannofossils also were dominated by reworked Miocene forms. It is of interest to note the lithified and unconsolidated sediments so intimately interbedded; in general, it appears that the allochthonous material is unstable and most susceptible to diagenetic lithification.

The presence of early Neocomian coccolith oozes suggests that the conditions of deep-water sedimentation at that time were not notably different from those of today. On the basis of the data from Site 4, there is no apparent reason for considering this area at the close of the Jurassic to be anything except a deep-ocean floor.

Horizon B, the acoustic basement, was not reached (Figure 33). The abundant reflectors of Horizon β were not positively recognized, but they appear to represent the mid-Cretaceous sequence. Seismic reflection data from Lamont's *Conrad-10* cruise show abundant reflectors to a depth of about 190 meters in the near vicinity of Site 4. Below these reflectors there is a relatively transparent section. The total thickness of the sedimentary sequence in this area is at least as thick as the interval drilled, suggesting the presence of sediments well back into the Jurassic.

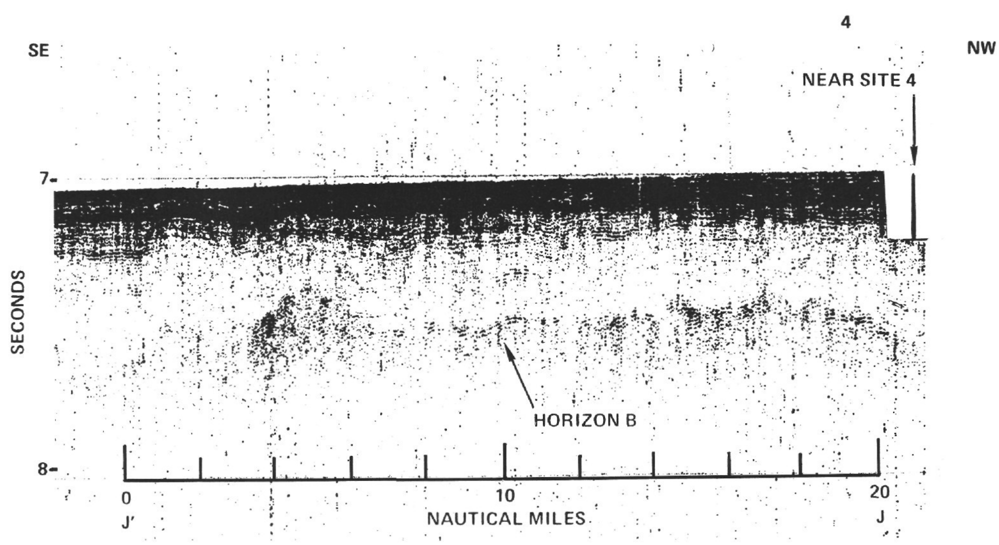


Figure 33. *Profiler section near Site 4. Location shown in Figure 31.*

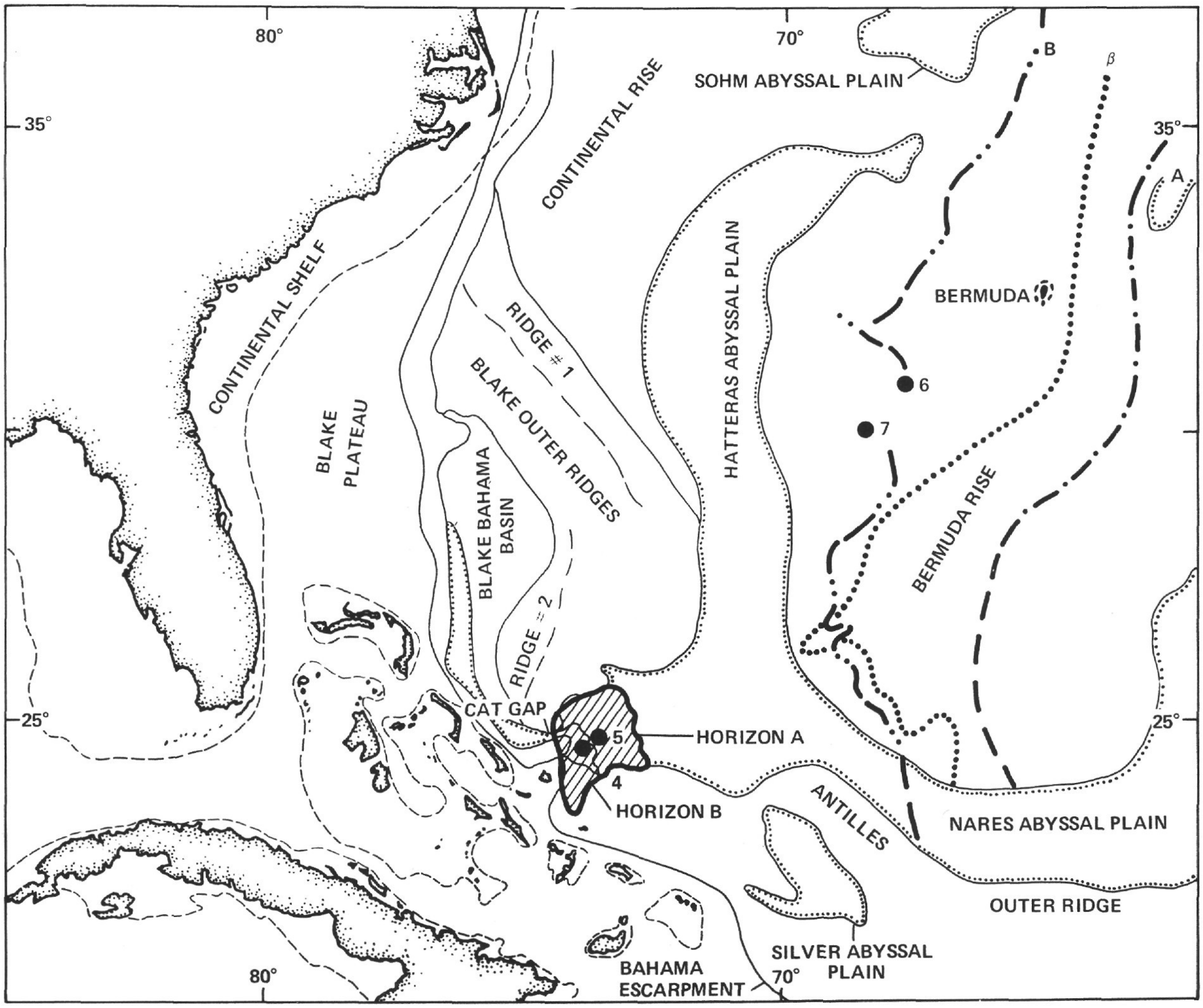


Figure 34. *Physiographic diagram showing Sites 4, 5, 6, and 7.*

REFERENCES

Eardley, A. J., 1951. *Structural Geology of North America.* New York (Harper & Brothers).

Ewing, J. and Ewing, M., 1962. Reflection profiling in and around the Puerto Rico Trench. *J. Geophys. Res.* **67**, 4729.

Ewing, J., Worzel, J. L., Ewing, M. and Windisch, C., 1966. Ages of Horizon A and the oldest Atlantic sediments. *Science.* **154** (3753), 1125.

Ewing, M., 1963. Sediments of ocean basins. **In** *Man, Science, Learning, and Education.* S. W. Higginbotham (Ed.). Houston (Wm. Marsh Rice University) 41.

Field, R. M., 1931. Geology of the Bahamas. *Bull. Geol. Soc. Am.* **42**, 759.

Habib, D., 1968. Spores, pollen, and microplankton from the Horizon Beta outcrop. *Science.* **162**, 1480.

Hess, H. H., 1933. Interpretation of geological and geophysical observations in Navy-Princeton Gravity Expedition to the West Indies in 1932. U. S. Hydrog. Office. 26.

Houtz, R., Ewing, J. and LePichon, X., 1968. Deep-sea sediment velocity determination made while reflection profiling. *J. Geophys. Res.* **73** (8), 2597.

Katz, S. and Ewing, M., 1956. Seismic-refraction measurements in the Atlantic Ocean, part VII: Atlantic Ocean Basin, west of Bermuda. *Bull. Geol. Soc. Am.* **67**, 475.

Talwani, M., Worzel, J. L. and Ewing, M., 1960. Gravity anomalies and structure of the Bahamas. *Trans. Second Caribbean Geol. Confr.*, Univ. Puerto Rico, Mayaguez, p. 156-161.

Windisch, C. C., Leyden, R. J., Worzel, J. L., Saito, T. and Ewing, J., 1968. Investigation of Horizon Beta. *Science.* **162**, 1473.

Worzel, J. L. and Shurbet, G. L., 1955. Gravity interpretations from standard oceanic and continental crustal sections. *Geol. Soc. Am. Spec. Papers.* **62**, 87.