2. SITE 76

The Shipboard Scientific Party[1]

MAIN RESULTS

Two holes at this site continuously cored 27 meters of lower Pliocene to Recent phillipsitic clay and calcareous nannofossil ooze interbedded with calcareous turbidites. The fossils (calcareous nannofossils and foraminifera) contained in these turbidites range in age from Eocene to Pleistocene. The drill bit was stopped by a silicified calcareous turbidite of Early Pliocene age. The average accumulation rate at this site was between 6 and 7 m/m.y. Since no biogenic silica is present in the sediments recovered, this site deserves further study as a possible example of non-biogenic chert formations.

INTRODUCTION

Background and Objectives

Site 76 (Figure 1) was selected by the Chief Scientist of Leg 9 after discussions with the scientific staffs of Legs 8 and 9. The objectives of this site were to core a thick sequence of sediments north of the Tuamotu ridge that had been crossed by *Glomar Challenger* just prior to the termination of Leg 8 in Tahiti. This sedimentary sequence is acoustically highly stratified and it was assumed that the stratification is caused by interbedding of turbidites from the Tuamotus with pelagites. Coring such a sequence, it was thought, might accomplish the following: 1) Allow a comparison between the shallow water benthonic species found in the turbidites and the planktonic species found in the pelagites. This would be important because it would permit accurate correlations between the highly refined planktonic stratigraphy and the less well dated benthonic stratigraphy used on the islands. 2) The frequency of turbidites or lack of them might give some clue to their history of island uplift and eventual emergence. 3) Since the site is downwind (NW) from a number of atolls the lower part of the sequence might contain ash layers which would allow us to date the time when these islands were active volcanoes. Since this was an unscheduled site there was no survey conducted prior to the arrival of *Glomar Challenger.*

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OPERATIONS

Site Survey

After leaving Tahiti, the *Challenger* traveled over rough topography with thin sediment cover until the small atolls of Ake and Manihi in the Tuamotu group were passed. Here the ocean floor became smooth and was underlain by a thick sedimentary sequence which consisted of an upper highly stratified sequence about 0.2 second thick, a middle transparent layer also about 0.2 second thick and a lower stratified layer of indeterminate, but at least 0.1 second, thickness. A prominent reflector that might be interpreted as basement could not be located on the records. Since the sedimentary sequence seemed quite uniform over several miles of steaming, a drilling site was selected arbitrarily. However, to assure that the spot we would drill was representative of the sequence we had been traveling over, a survey was made with the *Challenger* which amounted to a one square mile area. During the survey the water depth did not vary more than 5 fathoms from the 2440 fathoms (uncorrected) PDR depth. The sequence of sediment layers varied only slightly in the relative thickness of the various acoustical units and it was decided to drill at the northern corner of our survey (the point farthest from the Tuamotus). After leaving Site 76, we steamed due north for several miles and encountered the same kind of topography and sediment acoustic characteristics that we had noted at our drill site.

Coring

On arrival at Site 76 at 0027 hours, December 8, 1969, a Burnett beacon was dropped and the drill string run to the sea floor. Coring was started at the sea floor by punching the bit into the sediment without rotating. To our surprise, before the first core was completed it was necessary to rotate the bit and break circulation. After recovery of our first core our general plan was to drill 50 meters and core again, continuing the practice until we reached basement. The bit was stopped by a hard layer at 25 meters below the sea floor. Since the lower drilling assembly was not buried in the sediments, no more than 10,000 pounds of weight was applied to the bit. Rotation on the hard layer continued for about an hour. The bit was brought above the mud line and respudded (Hole 76A), coring

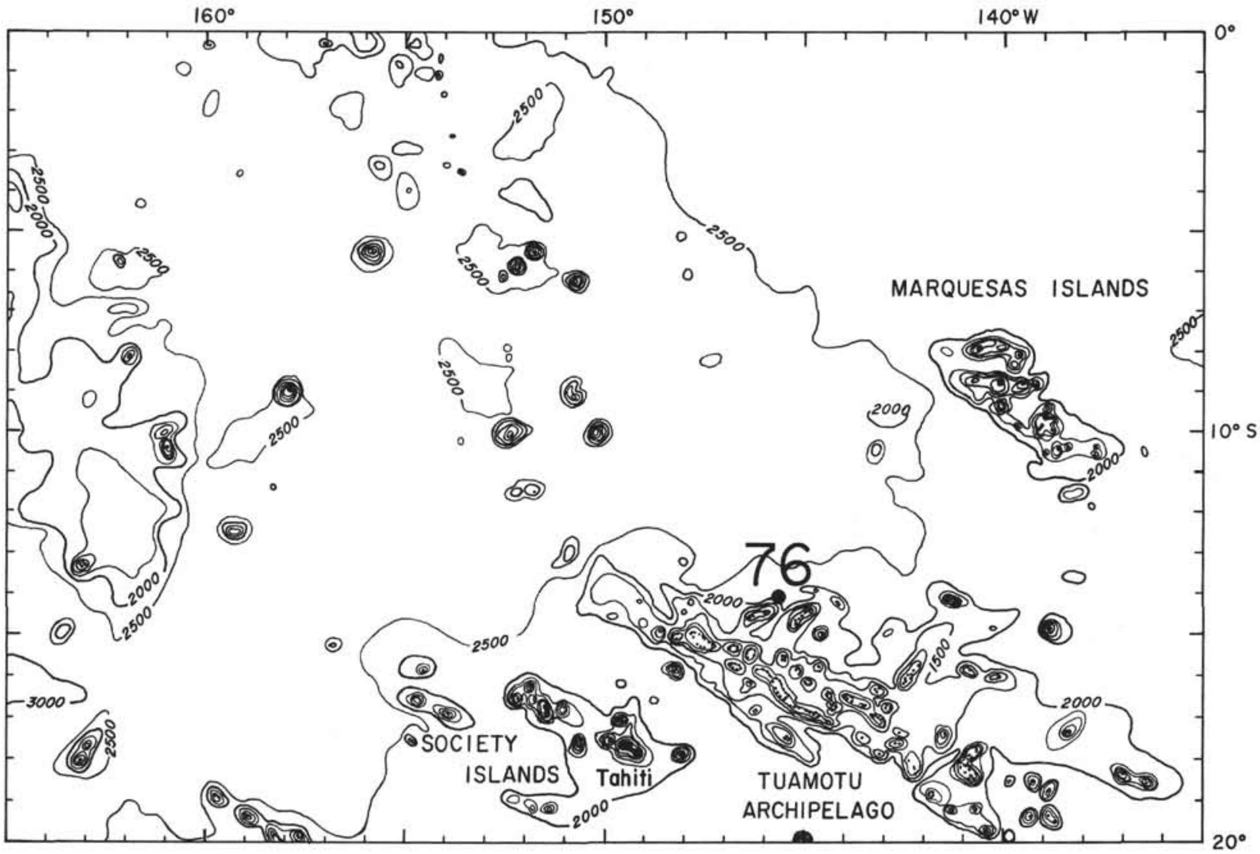


Figure 1. *Location of Site 76.*

from 9 to 18 meters and from 18 to 25.5 meters. At 25 meters the bit again encountered the firm layer. Apparently just before the drill string was drawn up, the ship surged applying additional weight to the bit which was sufficient to snap off two drill collars causing their loss, along with the bit, core barrel, and inner barrel assembly.

LITHOLOGY

The sediments at Site 76 are divided into five informal units (Figures 7, 9, 11 and 13). Because this was the only site drilled in the Tuamotu Archipelago the areal extent of these units is unknown. However, they may be fairly extensive because many of the sediments consist of allochthonous carbonate sands, which are believed to have been derived from the Tuamotu volcanic-carbonate islands, about 100 kilometers southwest of Site 76.

The five units are differentiated on the basis of color, percentage of calcium carbonate, microfossil types, zeolite distribution, and percentage of clay. Allochthonous carbonate beds are common throughout the section and comprise about 15 to 25 per cent of the total thickness. The beds of carbonate debris range from 2 to 90 centimeters in thickness and contain clasts up to 5 centimeters in maximum dimension.

The dusky brown material in these units which is referred to as "red clay" consists, at least in part, of amorphous iron oxides and crystallized iron oxide in the form of goethite (Cook and Zemmels, 1971). The zeolites phillipsite and clinoptilolite are present in these sediments with phillipsite being the most abundant (Cook and Zemmels, 1971).

Fossils of various ages occur within these sediments. Displaced fossils range in age from late Eocene to Pleistocene; therefore, it is possible that the entire sequence was deposited in Pleistocene time.

Unit 1 (0 to 9.1 meters)

Unit 1 consists of dusky brown (5YR2/2) phillipsite-clay mud and interbedded allodapic[2] carbonate debris beds. About 15 to 20 per cent of this unit consists of allochthonous carbonate sands that occur in beds

[2]Meischner (1964) proposed this term for shoal-water organic or inorganic carbonate sands which were transported (allochthonous) to a contemporaneous deeper water environment before lithification.

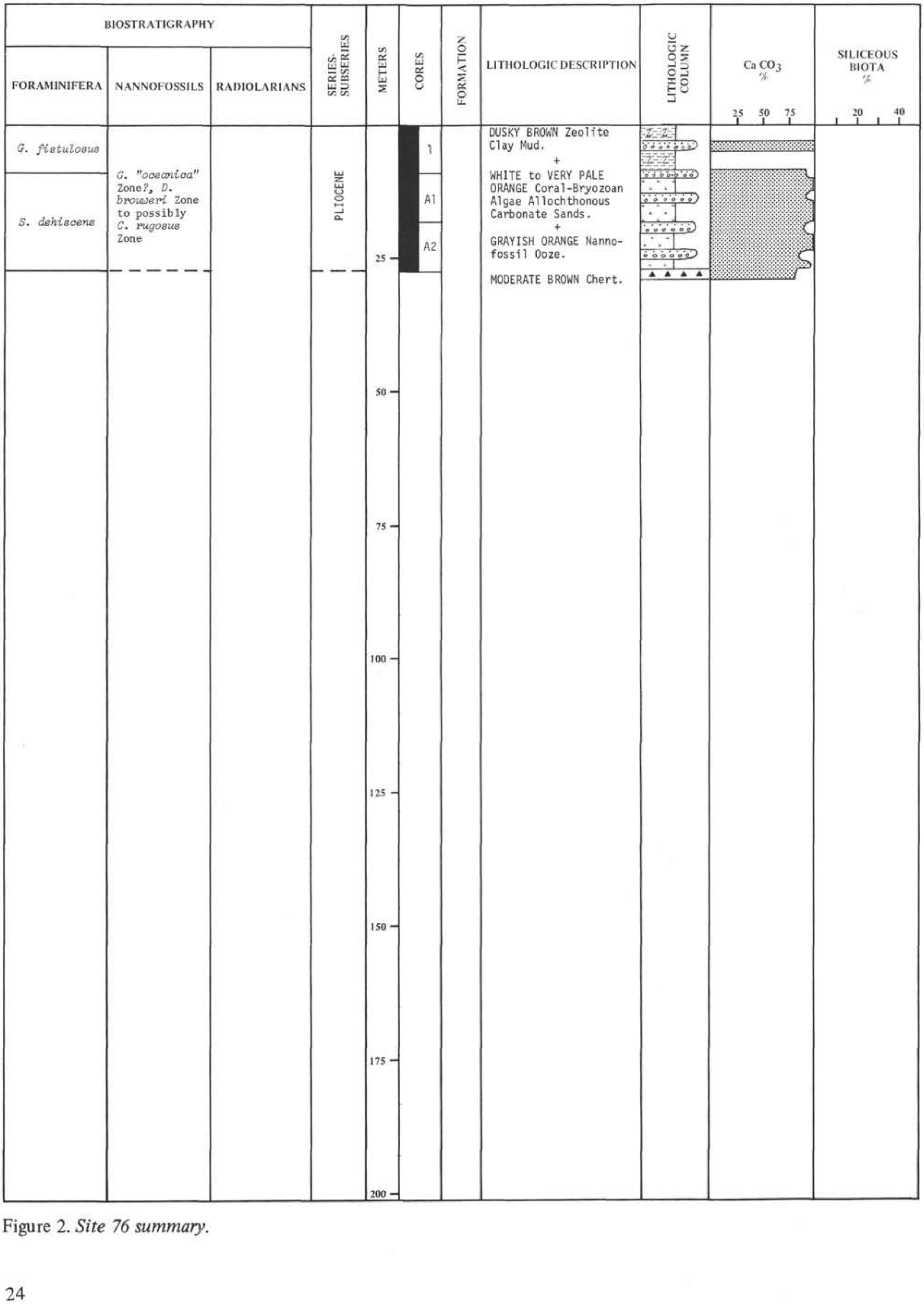


Figure 2. *Site 76 summary.*

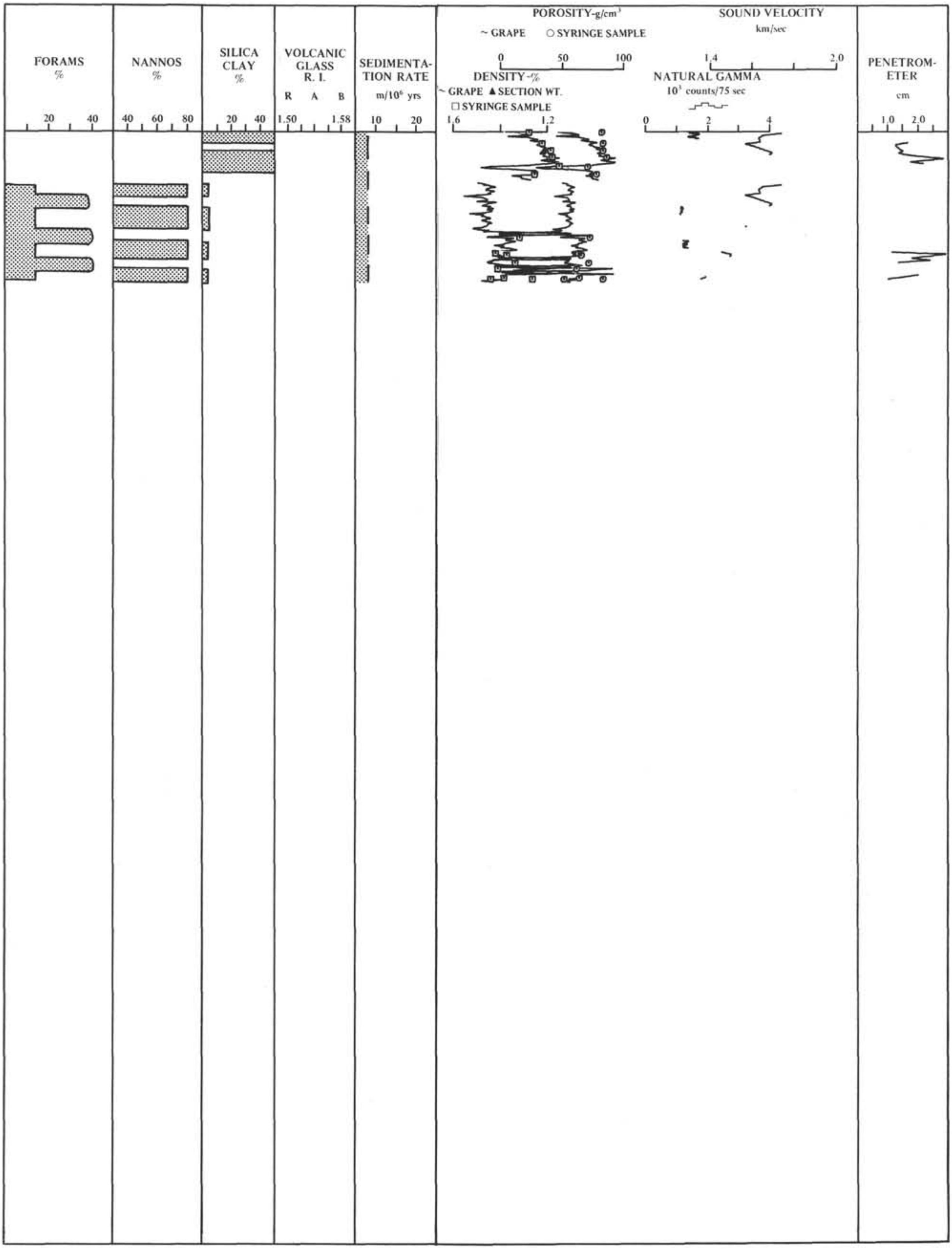


Figure 3. *Site 76 summary.*

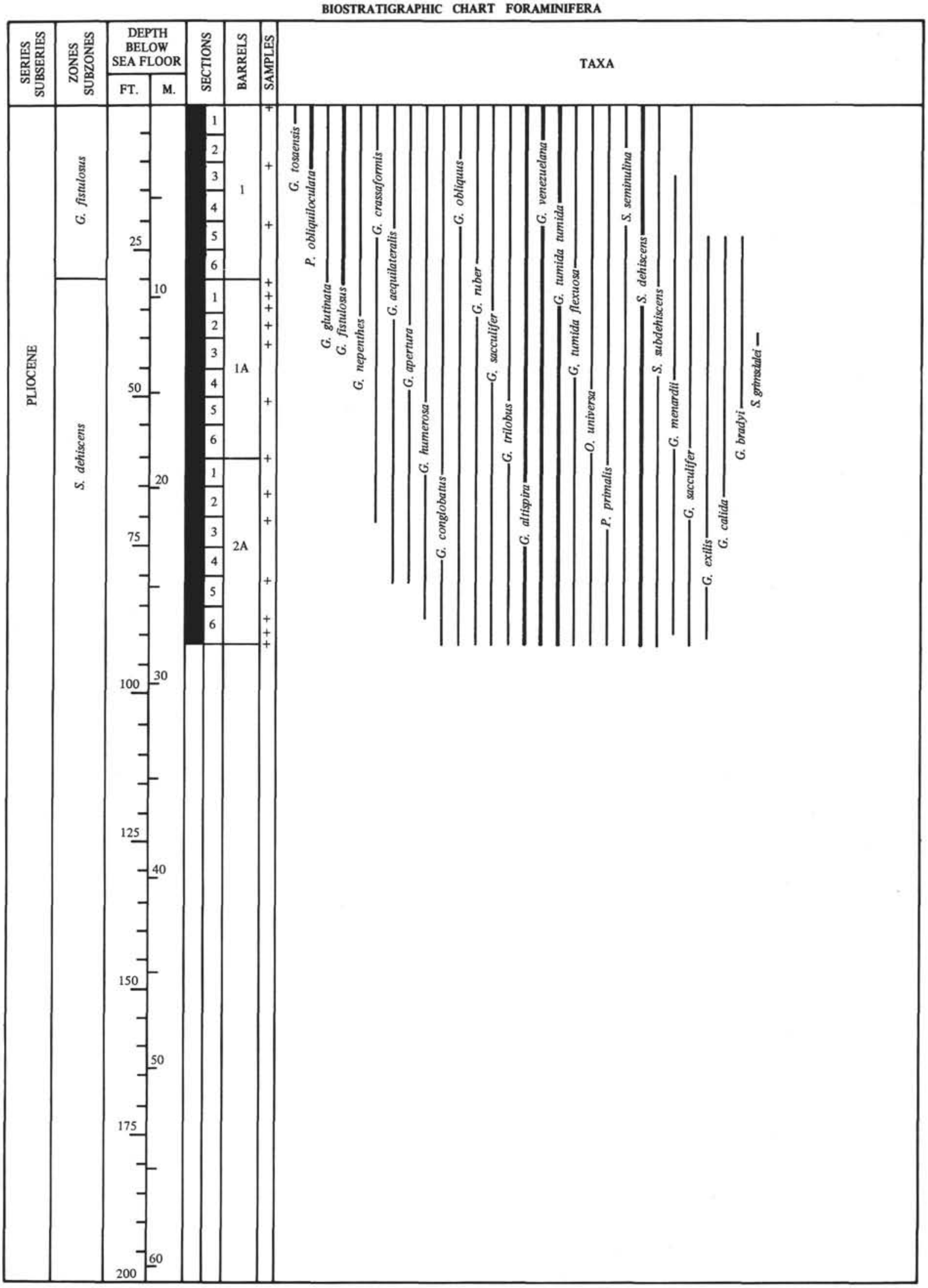
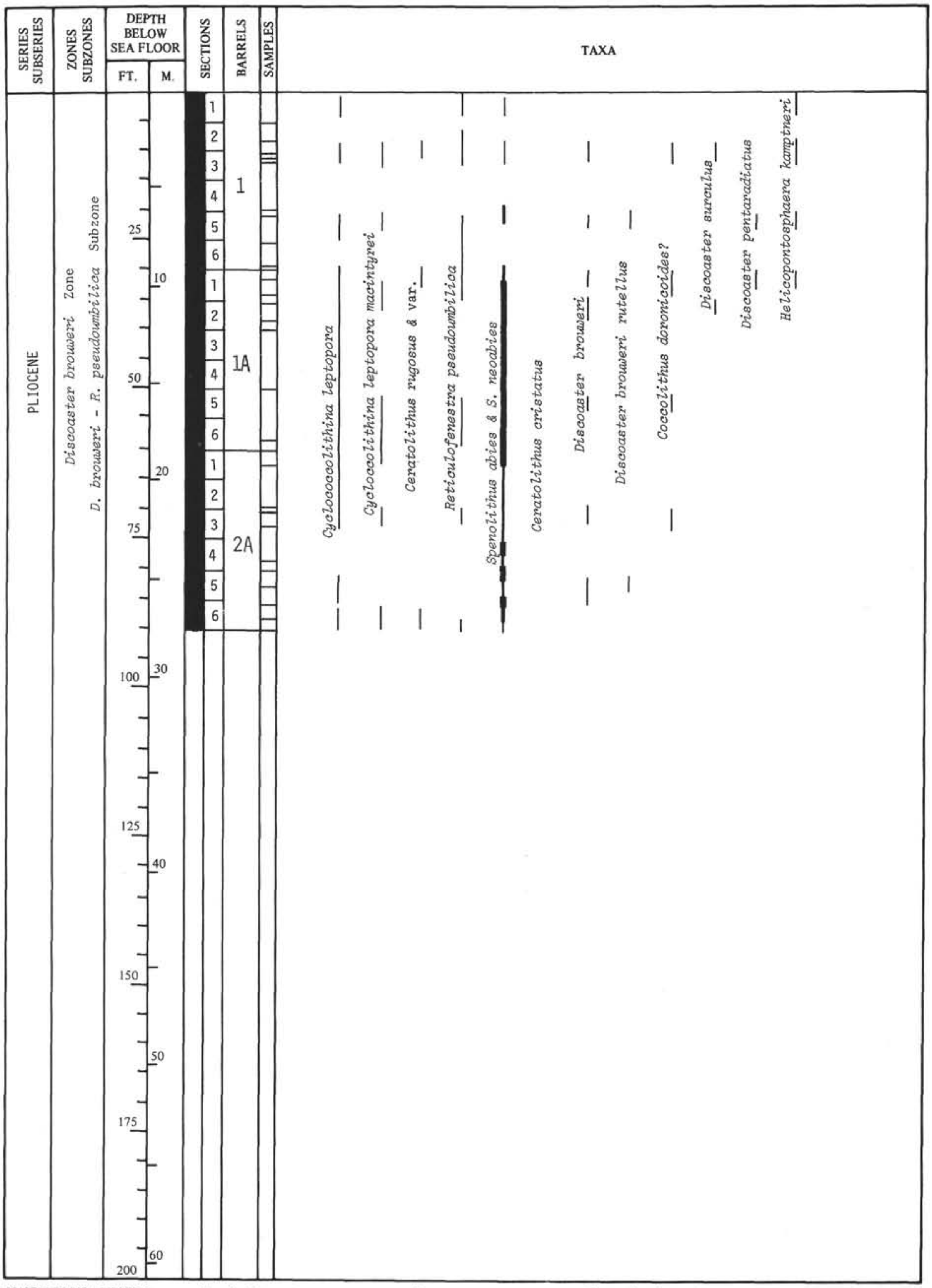


Figure 4. *Site 76 Biostratigraphic Chart Foraminifera.*

BIOSTRATIGRAPHIC CHART NANNOFOSSILS



NANNOFOSSIL LEGEND: —— Rare to infrequent occurrence. —— Frequent occurrence. ▬▬ Greater than frequent occurrence.

Figure 5. *Site 76 Biostratigraphic Chart Nannofossils.*

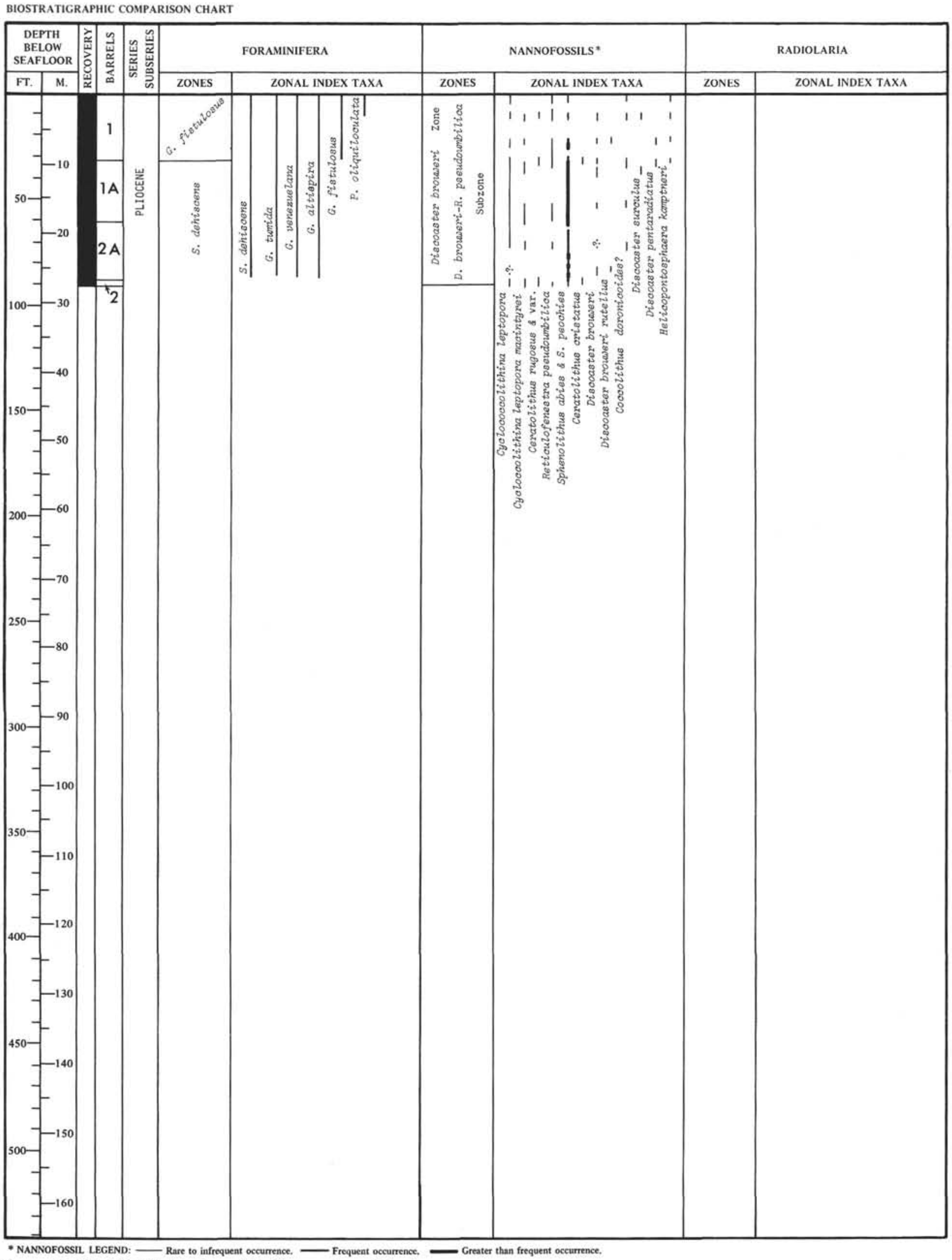
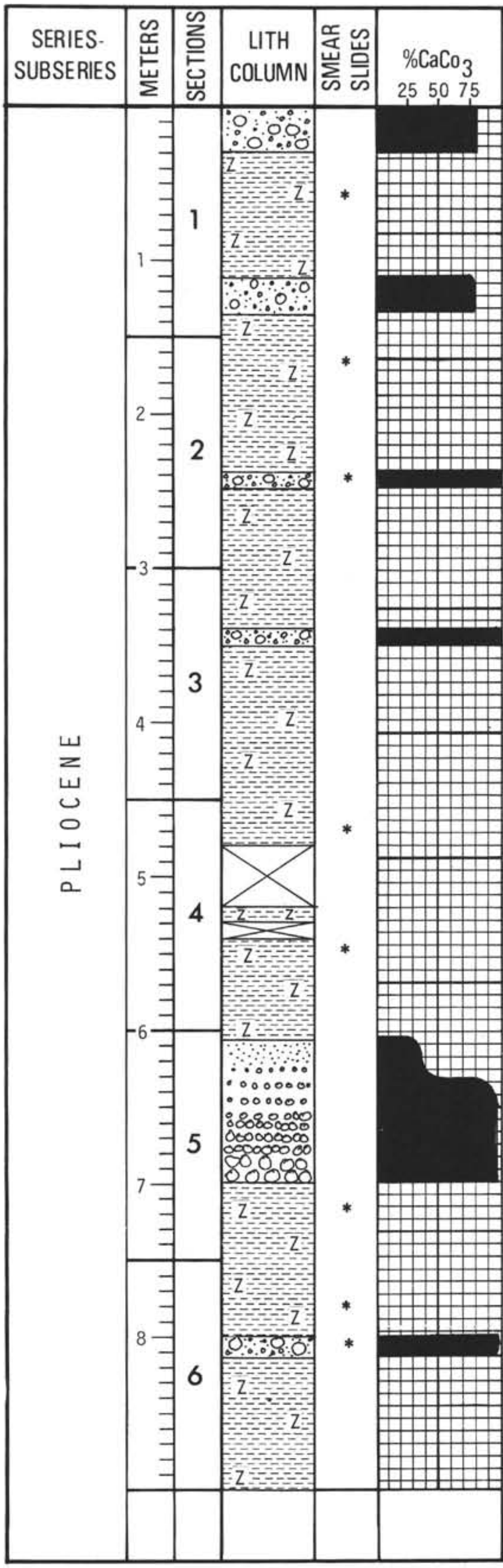


Figure 6. *Site 76 Biostratigraphic Comparison Chart.*



LITHOLOGIC DESCRIPTION

UNIT 1

DUSKY BROWN (5YR2/2), zeolitic (25%-40%) - clay (60%-75%) mud.

VERY PALE ORANGE (10YR8/2), foraminiferal (15%-25%) - calcareous nannofossil (75%-85%) ooze.

WHITE (N9) to VERY PALE ORANGE (10YR8/2), coralline - bryozoan - algal (?) allodapic packstone to grainstone turbidite. Graded from sand and pebble sizes at base to silt and mud sizes at top. Contains micro manganese (?) nodules 2-5 mm in diameter.

Figure 7. *Hole 76, Core 1 (0 to 9.1m).*

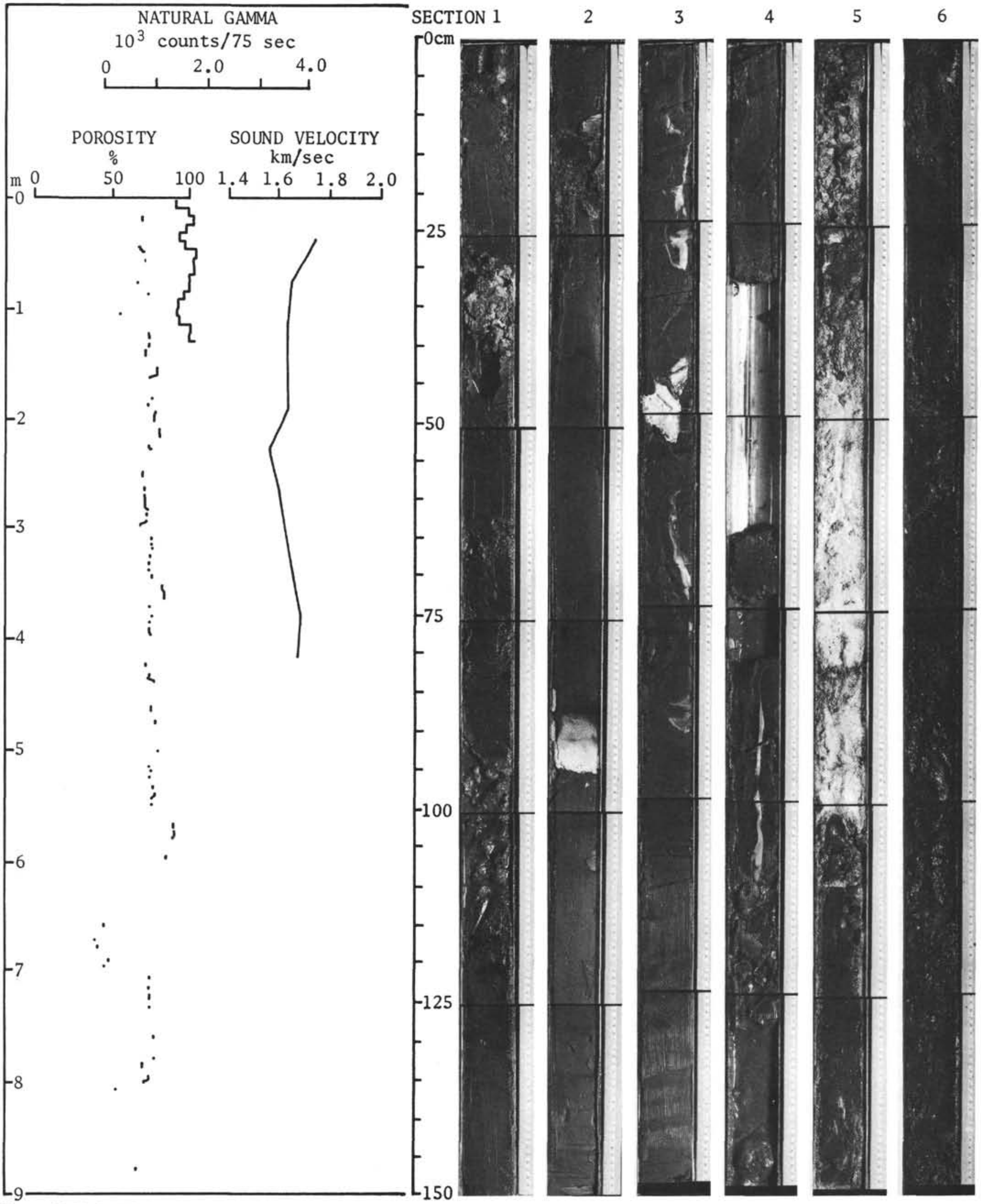


Figure 8. *Hole 76, Core 1, Sections 1-6, Physical Properties.*

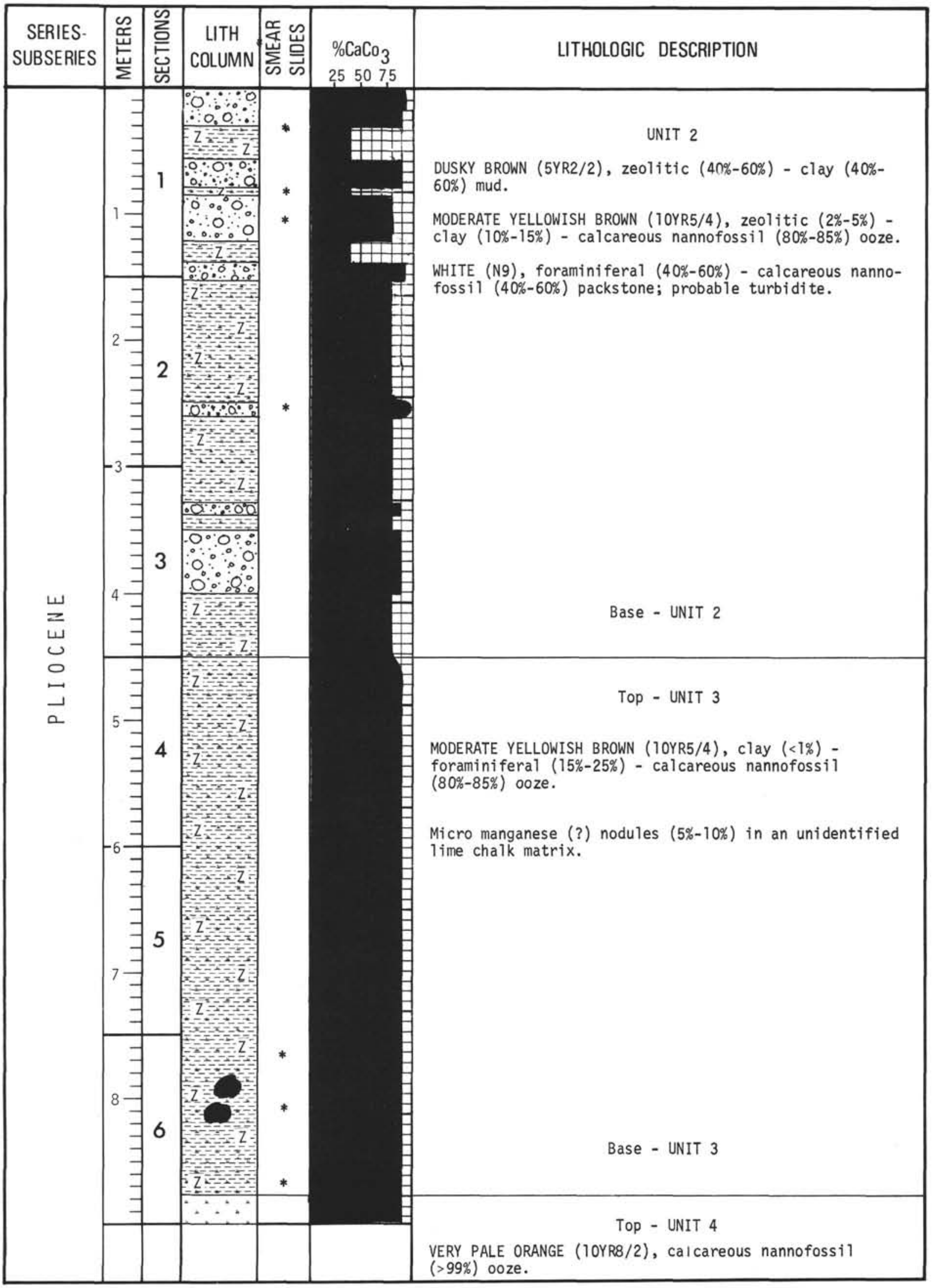


Figure 9. *Hole 76A, Core 1 (9.1 to 18.2m).*

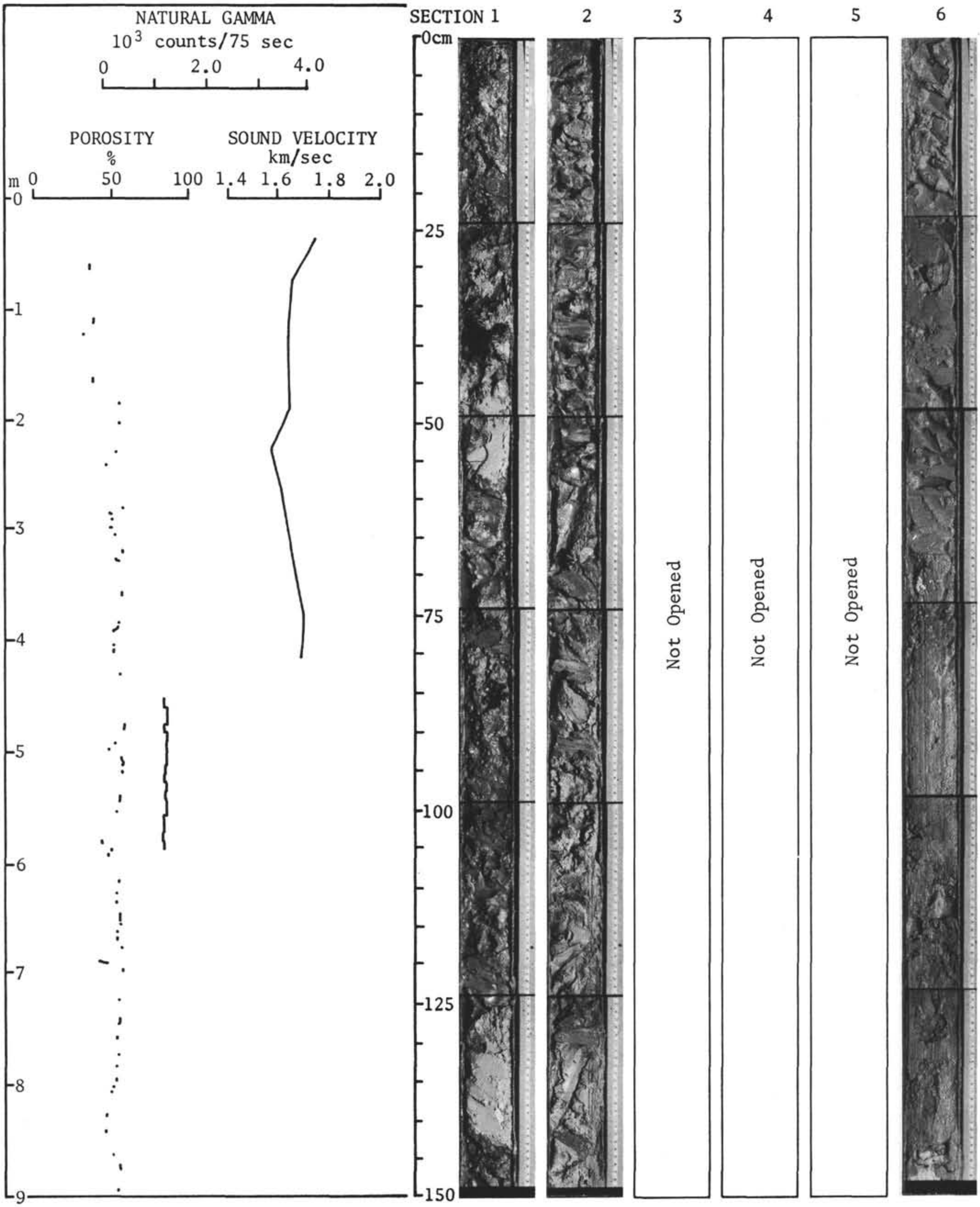


Figure 10. *Hole 76A, Core 1, Sections 1-6, Physical Properties.*

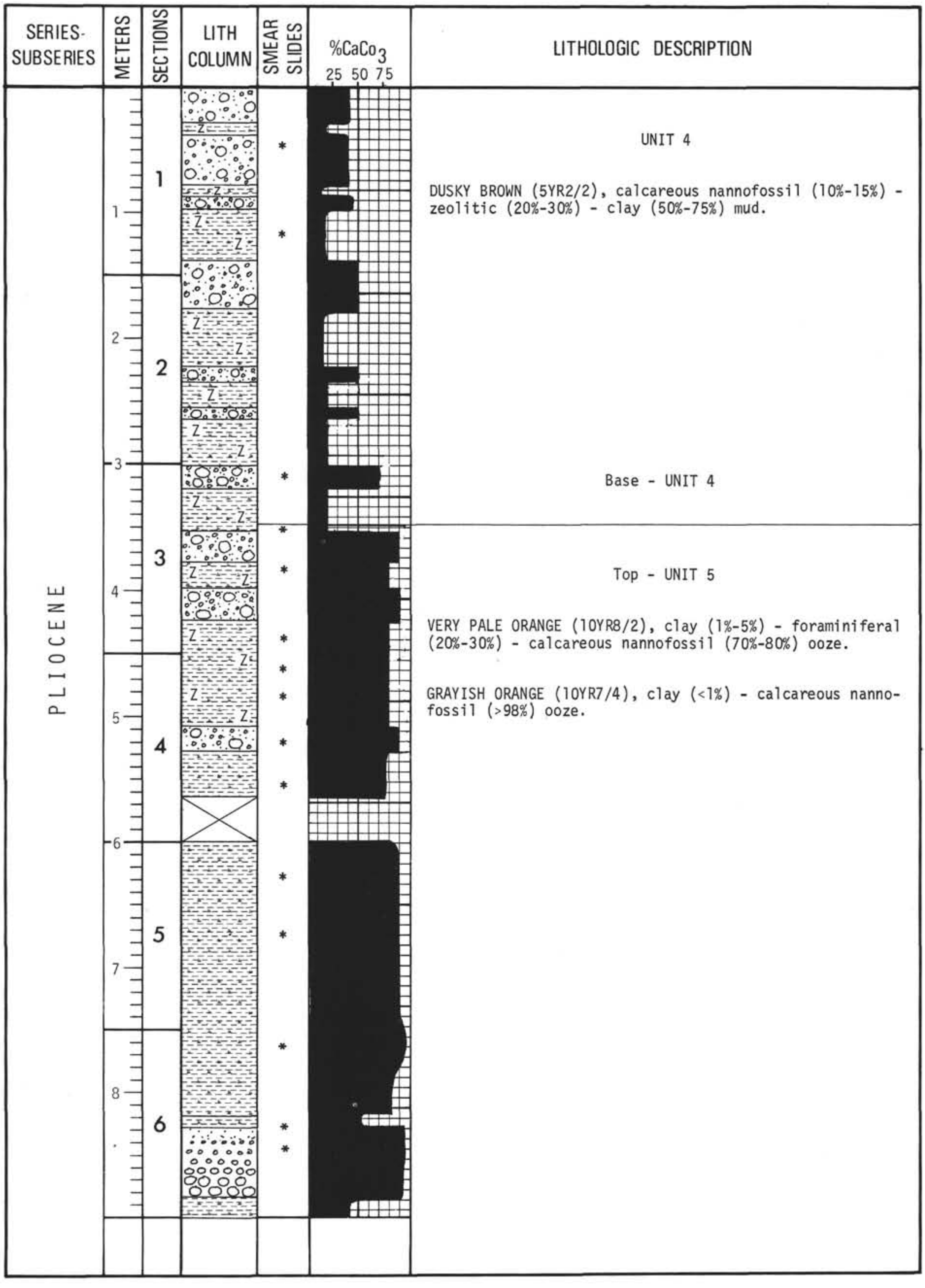


Figure 11. *Hole 76A, Core 2 (18.2 to 27.3m).*

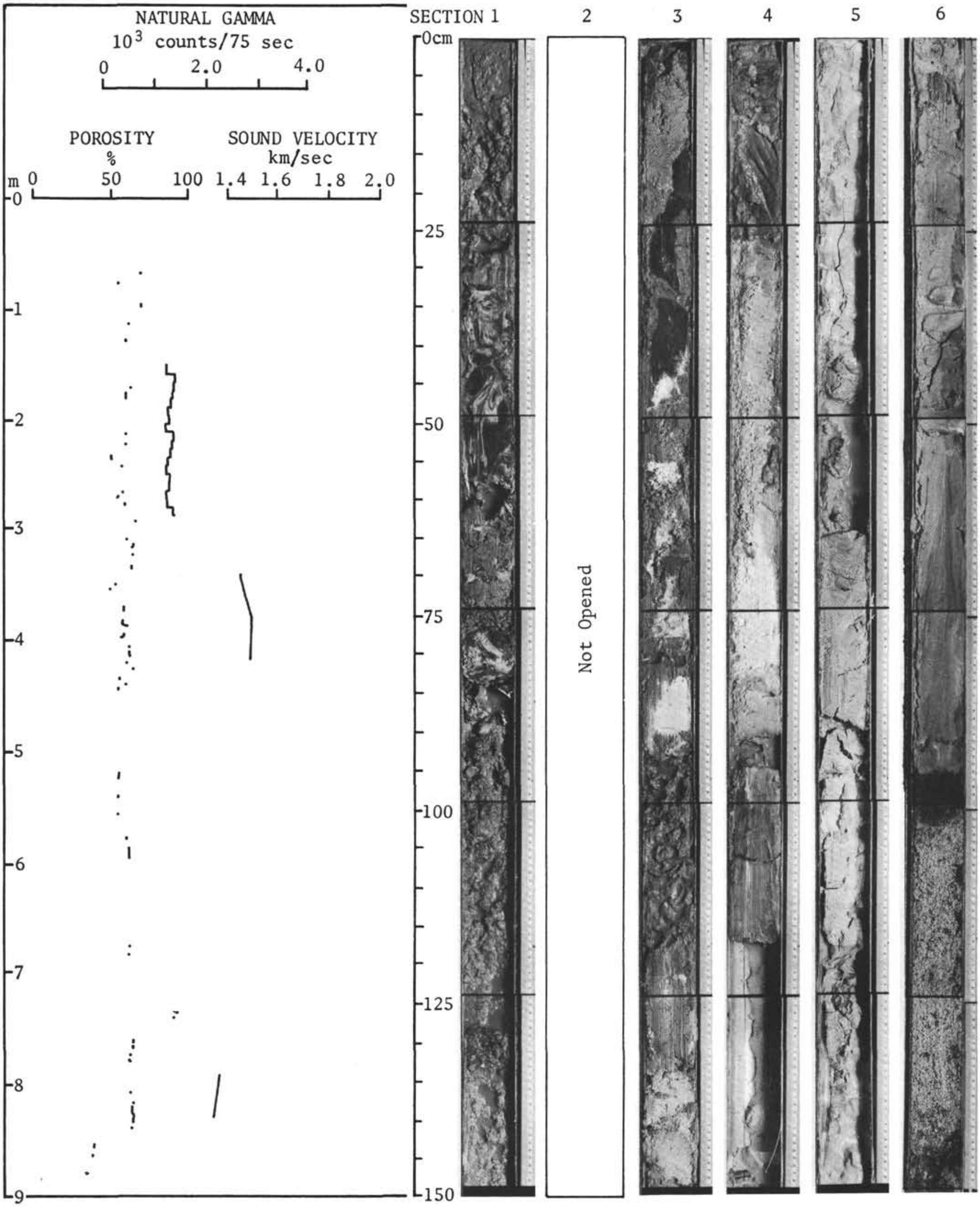


Figure 12. *Hole 76A, Core 2, Sections 1-6, Physical Properties.*

SERIES-SUBSERIES	METERS	SECTIONS	LITH COLUMN	SMEAR SLIDES	%CaCo3 25 50 75	LITHOLOGIC DESCRIPTION
PLIOCENE	1 2 3 4 5 6 7 8	1 2 3 4 5 6	NOT CORED	*	•	UNIT 5 DARK YELLOWISH ORANGE (10YR6/6) and MODERATE YELLOWISH BROWN (10YR5/4), partly silicified foraminiferal (?) (15%-25%) - calcareous nannofossil (75%-85%) packstone to grainstone.

Figure 13. *Hole 76, Core Catcher (27.3 to 27.6m).*

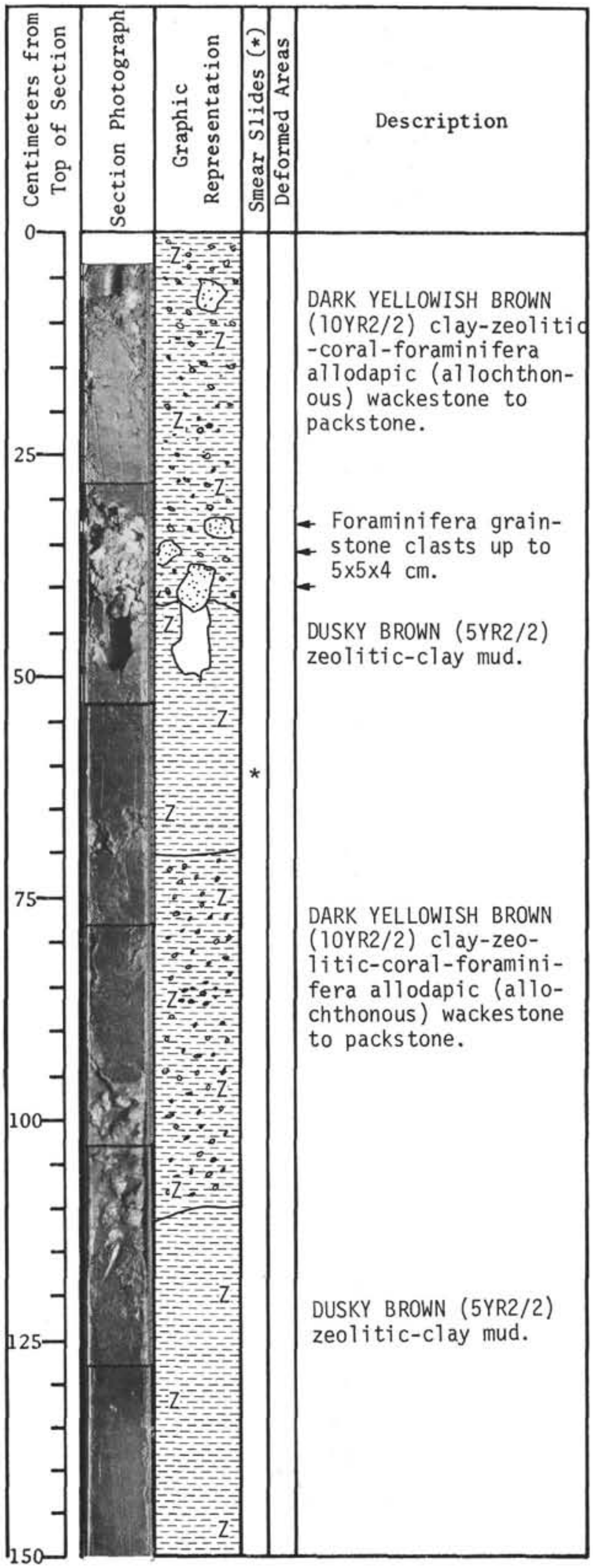


Figure 14. *Hole 76, Core 1, Section 1.*

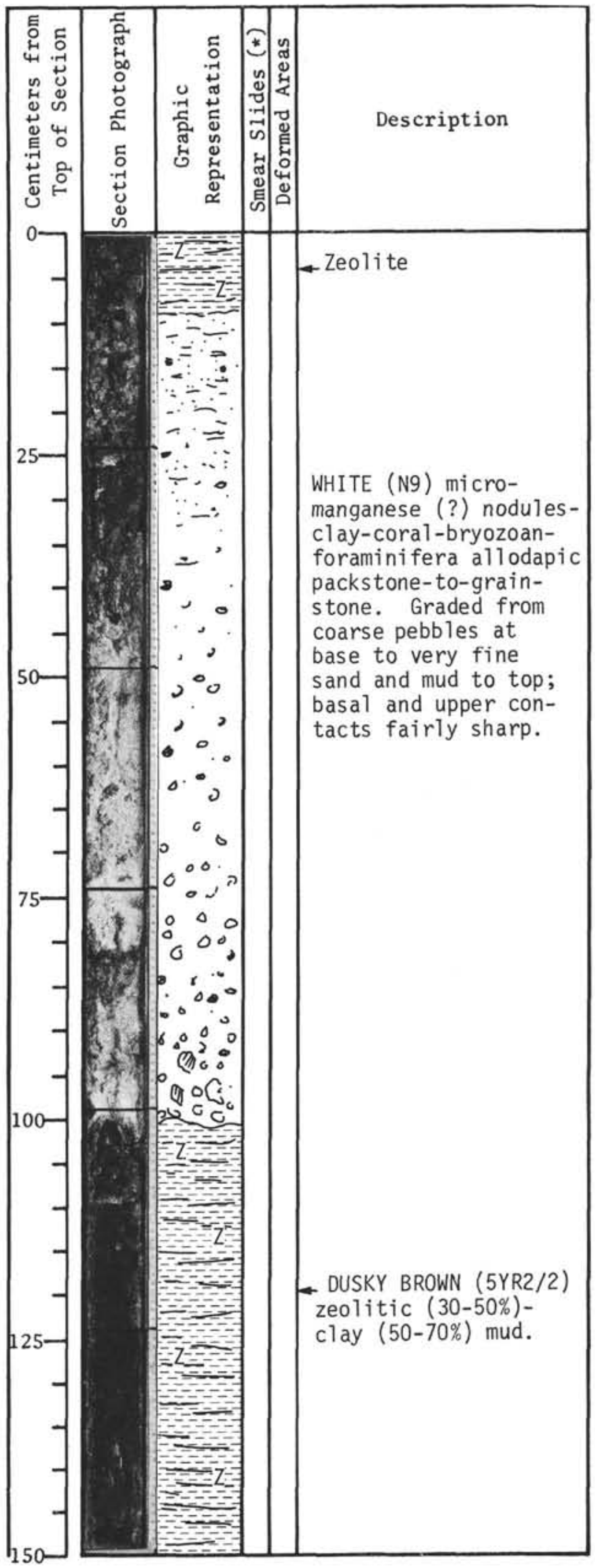


Figure 15. *Hole 76, Core 1, Section 5.*

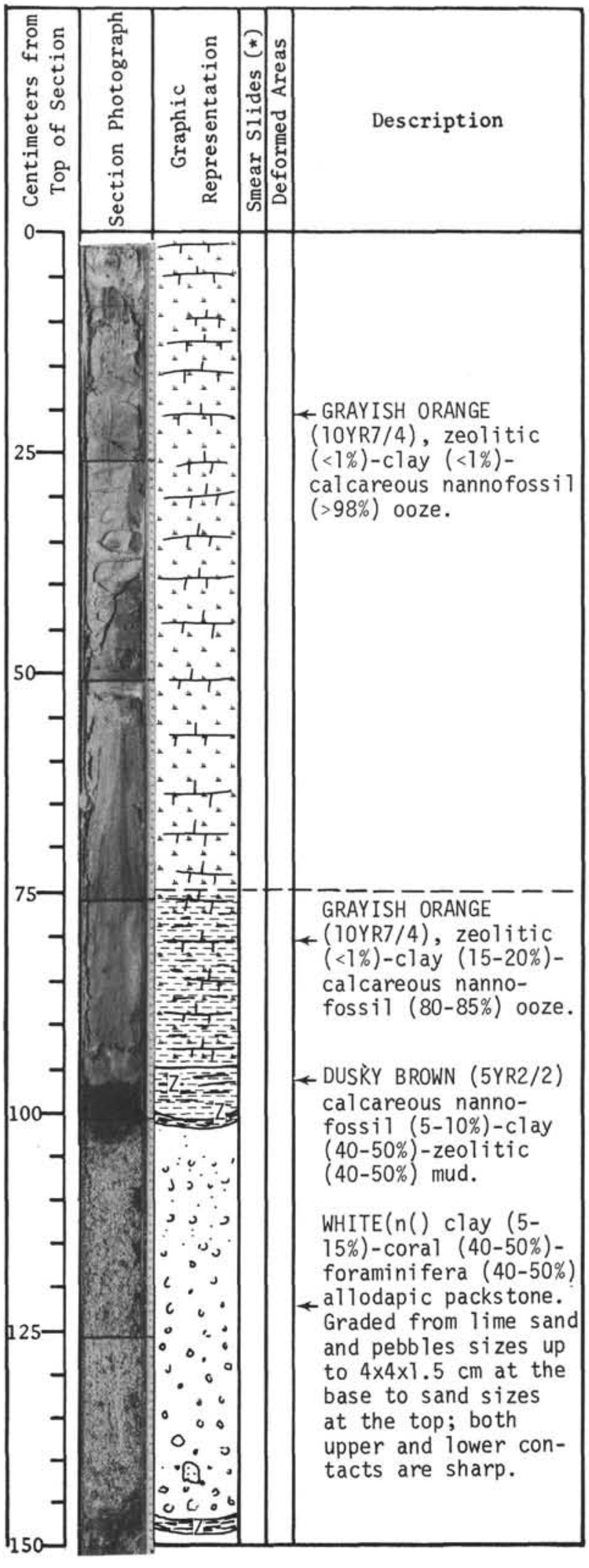


Figure 16. *Hole 76A, Core 2, Section 6.*

which range from 5 to 90 centimeters in thickness. These beds generally are very low in their mud content and vary from white to very pale orange in general coloration. Carbonate rock fragments and sands comprise the allochthonous constituents–these consist of foraminiferal grainstone clasts up to 5 centimeters in maximum diameter and individual fragments of coral, bryozoa, red algae (?), foraminifera, and manganese micronodules (Figure 14). Mixed age assemblages of calcareous nannofossils also occur. One of these beds, 90 centimeters thick, is graded from sand and pebble sizes at the base to silt sizes at the top with sharp lower and upper contacts (Figure 15).

About 75 to 85 per cent of unit 1 is a dusky brown clay mud, very rich in phillipsite. Phillipsite occurs in percentages ranging from 25 to 50 per cent, and "red clay" ranges between 30 and 60 per cent. These phillipsitic "red clay" muds are massive with no visible laminations.

Unit 2 (9.1 to 13.6 meters)

Unit 2 is a dark yellowish-brown (10YR2/2) clay–phillipsite–calcareous nannofossil ooze and interbedded allodapic carbonates. Allochthonous carbonate debris beds in this unit range from 35 to 50 centimeters in thickness and comprise about 15 to 25 per cent of the total thickness of the unit. In contrast to most of the debris beds in unit 1, debris beds in unit 2 have a higher percentage of mud in their matrix. This mud is probably a primary depositional feature, and is not due to mixing during drilling as suggested by their relatively undisturbed basal and upper contacts.

The coarse-grained fraction of the debris is similar to that in unit 1; however, light colored foraminiferal grainstone fragments are more numerous and larger in unit 2. The mud matrix in these allochthonous deposits is a dark yellowish-brown (10YR2/2) clay (5 to 10 per cent)–foraminiferal (10 to 20 per cent)–calcareous nannofossil (70 to 80 per cent) ooze.

Unit 3 (13.6 to 17.9 meters)

Moderate yellowish-brown (10YR5/4) foraminiferal-calcareous nannofossil ooze constitutes unit 3. It appears to have been very badly disturbed during coring, and no laminations are apparent. Much of the ooze is probably allochthonous, based on the mixed ages of the microfossils in these sediments, but the original textures and the thickness of the beds are not known.

Unit 4 (17.9 to 21.4 meters)

This unit consists of grayish-orange (10YR7/4) calcareous nannofossil ooze and allodapic carbonate debris beds. Allodapic carbonate beds in this unit range from 5 to 35 centimeters in thickness, have a high mud content, no visible grading, and a high percentage of pebble-sized fragments; thus, they are very similar to the debris beds in unit 2. The interbedded pelagic muds are dusky brown (5YR2/2) calcareous nannofossil (10 to 25 per cent)–phillipsitic (20 to 30 per cent)–clay (50 to 75 per cent) muds that have well defined, relatively undisturbed, horizontal beds 2 to 5 centimeters in thickness.

Unit 5 (21.4 to 27.3 meters)

Grayish-orange (10YR7/4) calcareous nannofossil ooze and allodapic debris beds comprise unit 5. In this unit carbonate debris beds are of two basic types: mud-rich allodapics and mud-poor allodapics. Mud-poor types are least disturbed and exhibit excellent, sharp basal and upper contacts with the enclosing zeolitic-clays. One mud-poor debris bed is 45 centimeters thick and shows excellent grading from sand- and pebble-sized debris at the base to sand sizes at the top (Figure 16).

About 75 per cent of this unit consists of grayish-orange (10YR7/4) calcareous nannofossil ooze with some of the ooze containing up to 5 per cent clay. The calcareous nannofossil oozes with the highest percentage of clay seem to be more indurated than the mudfree oozes.

The top one-third of unit 5 contains minor amounts of moderate yellowish-brown (10YR5/4) phillipsitic (10 to 15 per cent)–foraminiferal (10 to 20 per cent)–calcareous nannofossil (65 to 80 per cent) ooze and micromanganese nodules in a white chalk.

This hole was terminated in a dark yellowish-orange (10YR6/6) partially silicified limestone. Silica occurs as a replacement and an interparticle, void-filling chalcedony. The original rock was composed dominantly of sand-sized spheroidal grains whose depositional texture was that of a packstone to grainstone. It is most likely that these grains were either foraminifera, oolites, radiolarians, or a combination of these constituents which have been completely replaced by chalcedony. No obvious indication of the original grain type(s) remains. However, immediately above this chert is an allodapic mud-poor debris bed that contains abundant foraminifera and clasts of foraminiferal grainstones. This chert may represent a partially silicified portion of an allochthonous foraminifera debris bed.

PHYSICAL PROPERTIES

Natural Gamma

At Site 76 the natural gamma radiation readings range from 1087 to 1756 counts/75 sec. Pale orange and dark brown sediments at Site 76 could be differentiated on the basis of natural gamma radiation emission.

In Hole 76, Core 1, Section 1, the natural gamma readings range from 1349 to 1756 counts. The dusky brown sediments gave off higher levels (1600 to 1756 counts) of gamma radiation than the interbedded light orange and white sediments (Figure 14). The higher counts in the dark brown sediments are probably due to the high content of the potassic zeolites phillipsite and clinoptilolite, and montmorillonite and mica. The interbedded pale orange to white foraminiferal-calcareous nannofossil oozes and foraminiferal grainstone turbidites record lower natural gamma readings (1349 to 1700 counts). The smaller clay and zeolite content of the light colored sediments is the probable cause of the lower readings.

In Hole 76A, Core 1, Section 4 the moderate yellow foraminiferal-calcareous nannofossil oozes, as seen through the core liner and in the core catcher, record lower natural gamma radiation readings than the dark phillipsitic clay mud in other sections. These lower readings are probably the result of less clay and zeolite content in the lighter sediments.

In Hole 76A, Core 2, Section 2 the readings range from 1178 to 1368 counts. This section was not opened but the sediments, as seen through the core liner and in the core catcher, appeared to be dusky brown phillipsitic clay interbedded with orange calcareous nannofossil ooze and turbidite material.

The remaining cores were not tested for natural gamma radiation emission because of recorder malfunction.

Porosity

Porosity at Site 76 ranges from 52 to 86 per cent. There is no correlation between porosity and depth at this site. This is a shallow 27.6-meter hole and apparently was not deep enough to show evidence of compaction. The lowest porosity was in a moderate yellow brown foraminiferal-calcareous nannofossil ooze. The highest porosity was in a dusky brown phillipsitic clay mud. However, there is no consistent variation between lithology and porosity.

Sonic Velocity

The sound velocity readings range from 1565 m/sec to 1736 m/sec. Velocity values are higher in the cores containing much phillipsitic mud and lower in cores containing mostly foraminiferal-calcareous nannofossil ooze or where the core is significantly disturbed.

Bulk Density

Only one reading of 1.245 g/cc was taken at this site.

Penetrometer

Although this site was only about 30 meters deep there is a marked contrast between the penetrometer readings at this site and other Leg 9 sites for this stratigraphic interval. Readings at Site 76 were very low and ranged from only 0.1 to 0.3 centimeters. In the rest of the sites, sediments with this degree of induration came from depths of 100 meters or more. The possible influence of the very high percentage of "red clay" at this site on the physical properties is discussed in the Synthesis section.

One anomalously high reading was taken at about 20 meters in a zone of core disturbance.

BIOSTRATIGRAPHY

Foraminifera

Although Site 76 was the shallowest hole drilled on the entire leg, the foraminiferal faunas recovered from the three cores yielded considerable information on the environment and Cenozoic history of the Tuamotu archipelago.

A Pliocene history of successive turbidity flows from shallow to deep water is reflected at this site by lithology and the substantial reworking of foraminiferal and other invertebrate faunas.

The cored interval penetrated what appears to be a continuous section including the *Globigerinoides fistulosus* Zone and the *Sphaeroidinella dehiscens* Zone of the upper and lower Pliocene.

The indigenous planktonic foraminifera are abundant and well preserved except in occasional samples from the uppermost core in which some secondary solution of the foraminiferal tests was evident.

Reworked foraminiferal material includes in most cases either shallow water *Amphistegina* sp. or much older upper-middle Miocene (such as, *Globorotalia fohsi*); lowermost Miocene (such as, *Globorotalia kugleri*); upper Eocene (such as, *Hantkenina alabamensis*) and lower Eocene (such as, *Globorotalia aequa*). (See distribution chart, Figure 4.)

This was the only hole that terminated in chert. Although foraminiferal samples from the chert itself (recorded at 30 meters) were too hard to process or make an age assignment on, the lowermost sample (Hole 76A, Core 2, core catcher) is from the *Sphaeroidinella dehiscens* Zone and contains chert-infilled foraminifera.

Radiolaria

At Site 76, Radiolaria were not observed in smear slides by the geologists or in the calcareous microfossil samples. Consequently, radiolarian samples were not taken.

DISCUSSION AND INTERPRETATION

Although the bit failed to penetrate a resistant layer at a depth of only 30 meters below the sea floor, the sediments recovered at this site provide some information on a number of interesting problems that will be discussed below.

Seismic Reflectors

The chert layer which stopped our drilling probably occupies the top of a thick series of interbedded cherts. These chert beds serve as strong reflectors which are recognizable as the upper stratified layer on the seismic-reflection profiles at this site. Because the top of the strong reflectors lies at a depth of 0.05 second on the profiles, sound velocities in the soft sediment above the chert must be approximately 1.5 km/sec rather than the usually accepted value of 2.0 km/sec. This is borne out by the direct acoustical measurements on the cores. The prominent seismic reflectors within the upper stratified layer were followed for miles during the pre-site survey and after we left Site 76.

Pelagic and Turbidite Sediments

All three cores from this site contained coarse-grained sand beds, many with sharp upper and lower contacts, alternating with either dark chocolate brown phillipsitic clay (Hole 76, Core 1) or brown clay intermixed with nannofossil ooze (Hole 76A, Cores 1 and 2). Because of the water depth (4590 meters) and the nature of the upper 10 meters of sediment, we have assumed that the pelagic sediments at this site are phillipsitic clays. Consequently, the fine- and coarse-grained calcareous debris has been swept to this location from the nearby Tuamotu Islands (60 miles to the south) by turbidity and bottom currents. This model is not difficult to defend, because the coarse-grained layers contain genera of shallow water benthonic foraminifera, such as, *Amphistegina* and *Calcarina*, as well as calcareous algae, coral sclerites, mollusc fragments and abraded reefal debris. These constituents clearly indicate that the source for some or all of the coarse layers was in very shallow water near the surf line. Planktonic foraminifera are present also in the coarse layers, and they are probably derived from deeper water. They range in age from late Paleocene to Pliocene. Because the planktonic foraminifera are not indigenous to the abyssal phillipsitic clays, we can safely assume that they have been carried down slope from shallower regions on the flanks of the Tuamotu island chain. If the Tuamotu atolls were built on the top of extinct volcanoes, then the volcanoes must have been in existence during early Eocene time (see below). The coarse turbidites also contain manganese micronodules in greater abundance than in the phillipsitic clays, suggesting that these were entrained in the turbidity current before it reached the depth of our site.

The majority of the coccoliths and diseoasters intermixed with the clays of Cores 1 and 2 of Hole 76A have stratigraphic ranges from early Eocene to early Miocene. The overlap of the oldest planktonic foraminifera and oldest calcareous nannofossils suggests that the oldest material entrained by the turbidity currents is of early Eocene age. The turbidite occurring at base of Core 2, Hole 76A (25.5 meters) contains a suite of early Pliocene and older planktonic foraminifera. For this reason, we place the age of the bottom of the hole as no older than early Pliocene but possibly younger. This provides additional evidence that not only are the coarse layers reworked but so are the fine nannofossils found so abundantly between the coarse layers of Cores 1 and 2 from Hole 76A. It is interesting to note that the age of the most common reworked nannofossils is early Miocene.

The small piece of chert that was present in the core catcher of Core 2, Hole 76A, appears to be a coarse grain-supported silicified sediment. It immediately underlies a turbidite, and we conclude that the chert is the lower silicified portion of the turbidite. If this is true, then the chert is early Pliocene or younger in age and is the youngest deep-sea chert on record. Chert was not observed in the pelagic sediment between the turbidites, and we conclude from this that the turbidite is important in the formation of chert.

Many of the graded turbidites cored at this site contain very little mud, and their sharp upper contacts suggest that bottom currents moving over this area have winnowed out the fine material. Another explanation of these features is that they are channel deposits. The latter explanation is supported by the presence on our profiler records of strong vertically-arrayed reflectors that have short horizontal extent. These reflectors could represent discrete channel fillings. The lack of fine-grained material results in high permeability for the turbidites, which may facilitate flow of silica mineralizing solutions resulting in the deposition of chalcedony.

The origin of chert remains problematic. Previous DSDP legs have encountered Eocene cherts interbedded with sediments containing large concentrations of biogenous opal. Yet, the sediments overlying the chert at this site are devoid of this material. Because opaline sediments of late Miocene-early Pliocene age are not common in this region, the sediments underlying the cherts are also probably barren of opaline silica. An alternative explanation must be sought. Even in late Tertiary time, the Tuamotu Ridge may have been a source of hydrothermal emanations which were channeled by the permeable coarse-grained layers. However, our preferred interpretation as the source of the silica is the clay minerals. The presence of large amounts of phillipsite implies that the clays have undergone alteration to this authigenic mineral. The index of refraction of this phillipsite indicates that the silica content is relatively low (approximately 45 per cent).

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