9. SITE 67

Shipboard Scientific Party[1]

Occupied: September 28 - October 1, 1969.

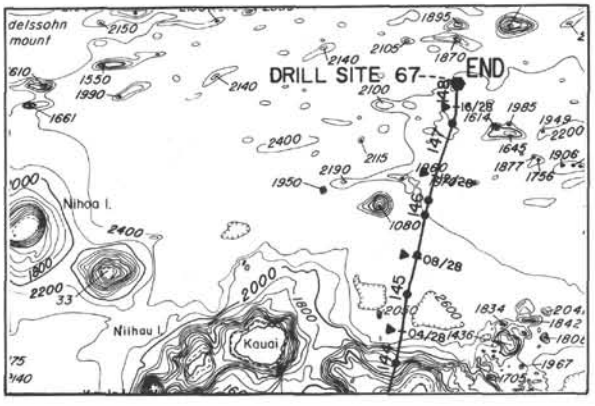
Position: 24° 22.52′N., 157° 39.05′W.

Water Depth: 4473 meters.

Total Depth: 60 meters, in porcelanite, of early Eocene or late Paleocene age.

Holes Drilled: 2.

Cores Taken: 3.



Main Results: Well consolidated and bedded volcanic sandstone and mudstone, and claystone extends from the sea floor to a depth of 60 meters, where a layer of hard brown porcelanite stopped the bit. Displaced radiolarians in mud from a core at 60 meters indicate sediments of early Eocene or late Paleocene age are present somewhere above that depth. Only about half of the total stratigraphic column, as inferred from seismic reflection profiles, was penetrated.

BACKGROUND AND OBJECTIVES

Site 67 is on the Hawaiian Arch (see Plate 1), in the general region selected for one of the Mohole Project sites. Therefore, intensive geophysical surveys have been made in the area. The region lies a few hundred kilometers west of Magnetic Anomaly 32 (Pitman *et al.*, 1968, Figure 10) in the region devoid of any strong linear magnetic pattern, and is thus in a region where the age of the basement beneath the sedimentary cover is of special interest. The estimated age of the crust at Anomaly 32 (Heirtzler *et al.*, 1968) is about 75 million years (Late Cretaceous).

A deep-tow survey around the site, seen in Figures 1 and 2 (Spiess *et al.*, 1969), shows a patchy distribution of sediments in an area of complex topography. About 0.17 second of sediment is shown on reflection profiles (Figure 3) at the site chosen for drilling. Clues to the nature of the sediment come from reflection profiles, which show several highly reflective layers within the sediments, and from cores taken in the general site region (Spiess *et al.*, 1969), which usually retrieve only brown lutite with volcanic ash bands. Hard layers at or near the sea floor are poor recovery in cores and by bent coring devices.

Our objectives were to penetrate the entire sedimentary sequence to basement in order to learn the petrology and ages of the sediments and of the seismic reflectors, and to obtain samples of the underlying basement rocks.

OPERATIONS

Site Survey and Approach

Site 67, on the Hawaiian Arch, about 180 kilometers (100 miles) north of Oahu, was approached from the South (Plate 1). The proposed site is located just to the north of the ridge on the sea floor in an area intensely surveyed by Scripps Institution of Oceanography (Figure 1).

A questionable subbottom reflector may be present in the profile south of the ridge (Reflection Record 147, See Chapter 26), but is very faint and almost impossible to trace with any confidence. North of the ridge in the vicinity of Site 67 (Figure 4) reflectors were observed at 0.04, 0.07, and 0.14 seconds on the records.

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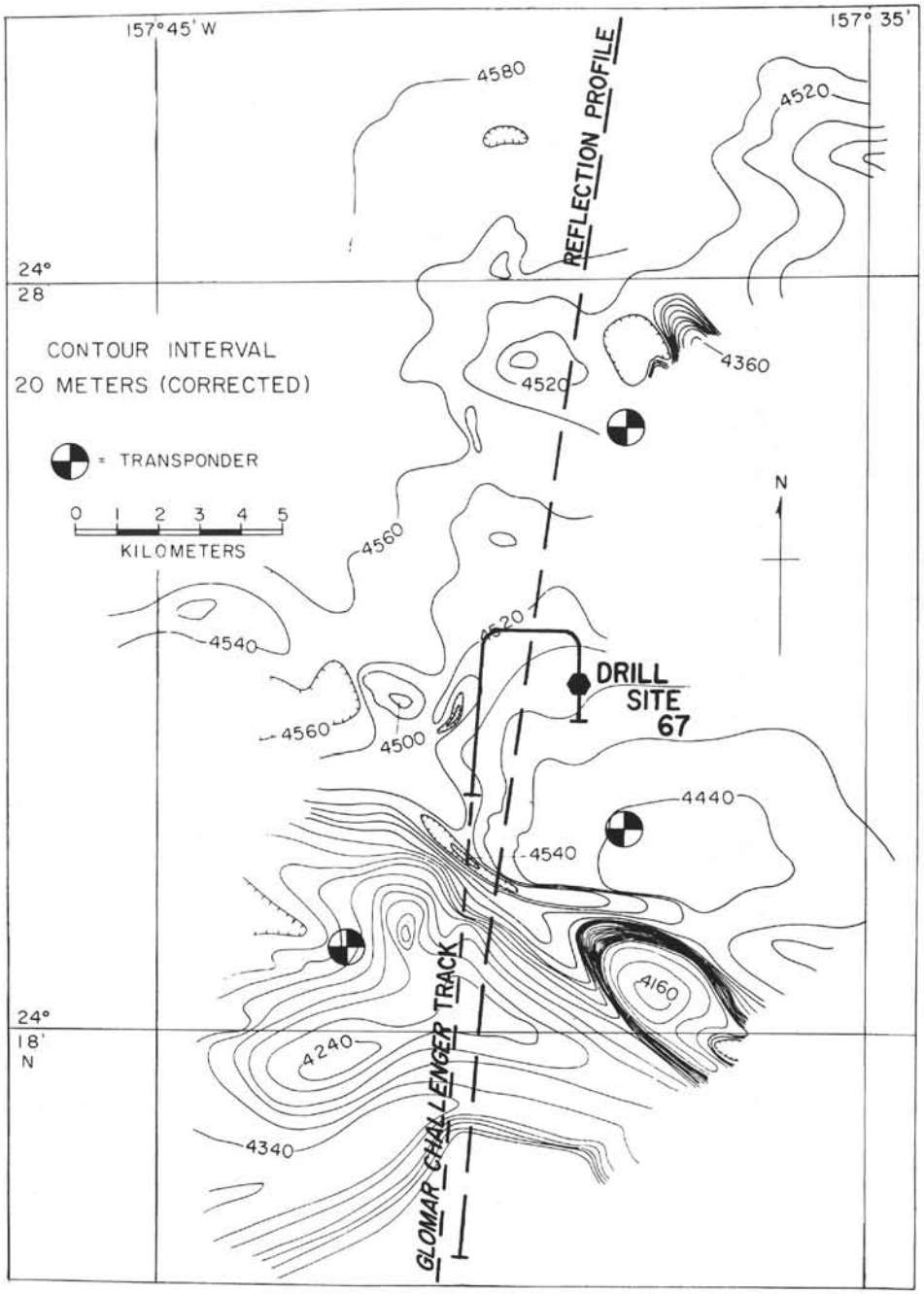


Figure 1. *Bathymetry of area near Site 67, from deep-tow survey of Spiess* et al. *(1969, Figure 5), showing the location of Site 67, the track of D/V* Glomar Challenger *and the locations of the profiles shown in Figures 3 and 4.*

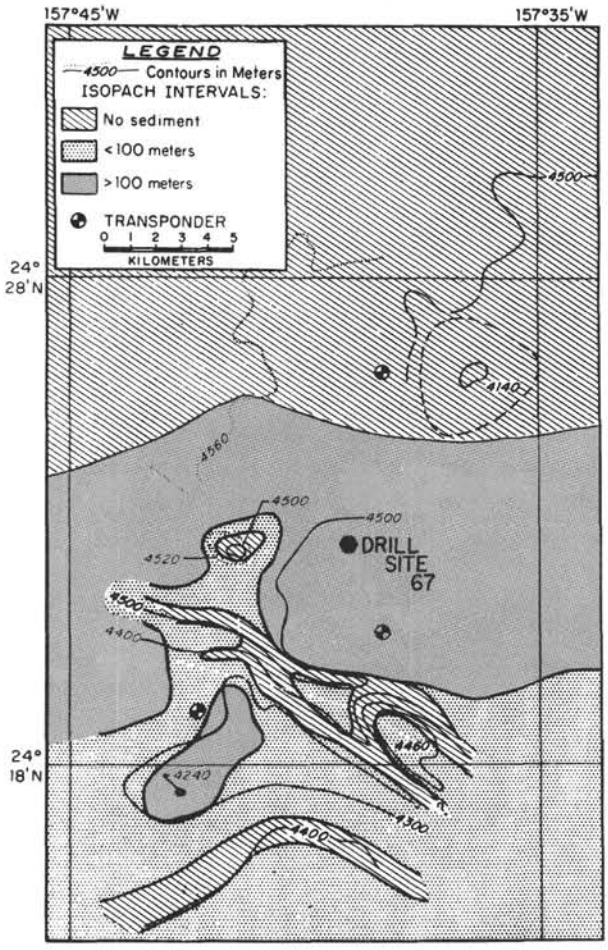


Figure 2. *Sediment isopachs near Site 67, from Spiess* et al. *(1969, Figure 14).*

Drilling Operations

After a brief survey during approach to the site (Figure 1), the beacon was dropped at 1835 hours on September 28. A light-set diamond bit led the drill string, which reached the sea floor at about dawn on the 29th. In cutting the very first core at the sea floor, very firm material was struck at the outset, and only 15 feet (4.6 meters were cut for fear that the water ports in the bit might become clogged with sediment. On the attempt to retrieve the core barrel, a part of the overshot unscrewed itself from the wire line; and, after an unsuccessful try at fishing, the entire drill string was pulled back to the derrick floor. Inspection of the bit showed that of the 10 ports, seven were clogged with rock and mud. The core barrel contained about 5 feet of broken pieces of firm sandstone and mudstone plus a 4-inch strip of rubber packing that had worked out of the lower bumper sub.

The string was lowered again and hole 67.1 spudded. Using a center bit and strong pump pressures, we drilled down to 23 meters, where a 30-foot core was cut. Again, the recovery was only about 5 feet of broken pieces of sandstone and mudstone. In the interval drilled from 32 to 60 meters, several hard layers were met, and at 60 meters a very hard layer slowed the drilling rate to almost nil. The core barrel was dropped and six inches of core were cut in about an hour.

Drilling conditions, which had been poor up to this time, now became very much worse. The ship was pitching very strongly; this caused the bit to bounce up and down on the bottom, and made it impossible to maintain a steady weight on the tool. The drill string vibrated markedly during the cutting of the core at 60 meters. The dangers to the string were increased because only about one-half the drill collars and only one bumper sub were below the sea floor; the rest of the bottom-hole assembly remained unsupported. When the core was brought on deck, the hard layer was seen to be cherty. Under these conditions we decided to abandon the site. The drill string was retrieved and the ship headed for Honolulu, departing from the site at 0918 hours on October 1.

SITE SUMMARY

Lithology

At Site 67, samples were recovered at only three depths. The recovery was small, and all of that recovery was of fragments of sediment broken by the bit, not of cores cut by the bit. The types of rocks recovered, along with the drilling record and inferences from some of the lithologic associations in the samples, suggest a section of hard volcanic sandstones and soft volcanic mudstones, with intervals of softer beds–probably including some radiolarian-bearing oozes near the base–underlain by a very hard cherty bed at about 60 meters. That is only about one-third of the section deduced from reflection seismic records; the deeper layers remain unsampled.

The sandstone fragments that are the most characteristic rock-types recovered in Hole 67.0, Core 1 are well-indurated and colored various shades of brown. They are of volcanic origin. The even, parallel lamination of many pieces–along with the subordinate amount of glass grains altered to clay or palagonite–compared to the amount of well-sorted pyroxene, feldspar and basalt grains suggest that the sandstones are epiclastic rather than pyroclastic, and almost certainly are not hyaloclastic. Lighter brown phillipsitic mudstones found with the sandstones are also tentatively assigned a volcanic origin. Contacts between the two lithologies are sharp, but not parallel to the distinct lamination of the sandstones. The contacts, which are often wavy or grooved, cut across sandstone laminae and indicate the existence of strong bottom currents immediately prior to the deposition of the mudstone.

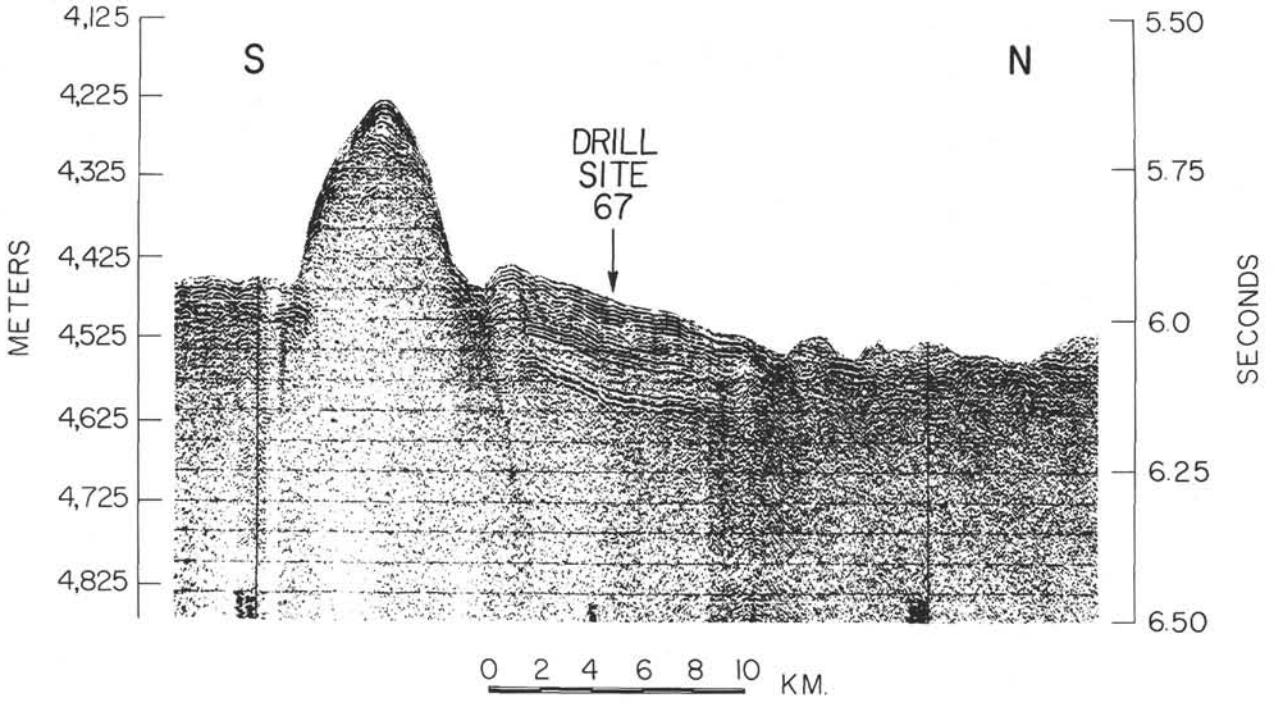


Figure 3. *Seismic reflection record near Site 67 (see Figure 1 for location) from Spiess* et al. *(1969, Figure 13).*

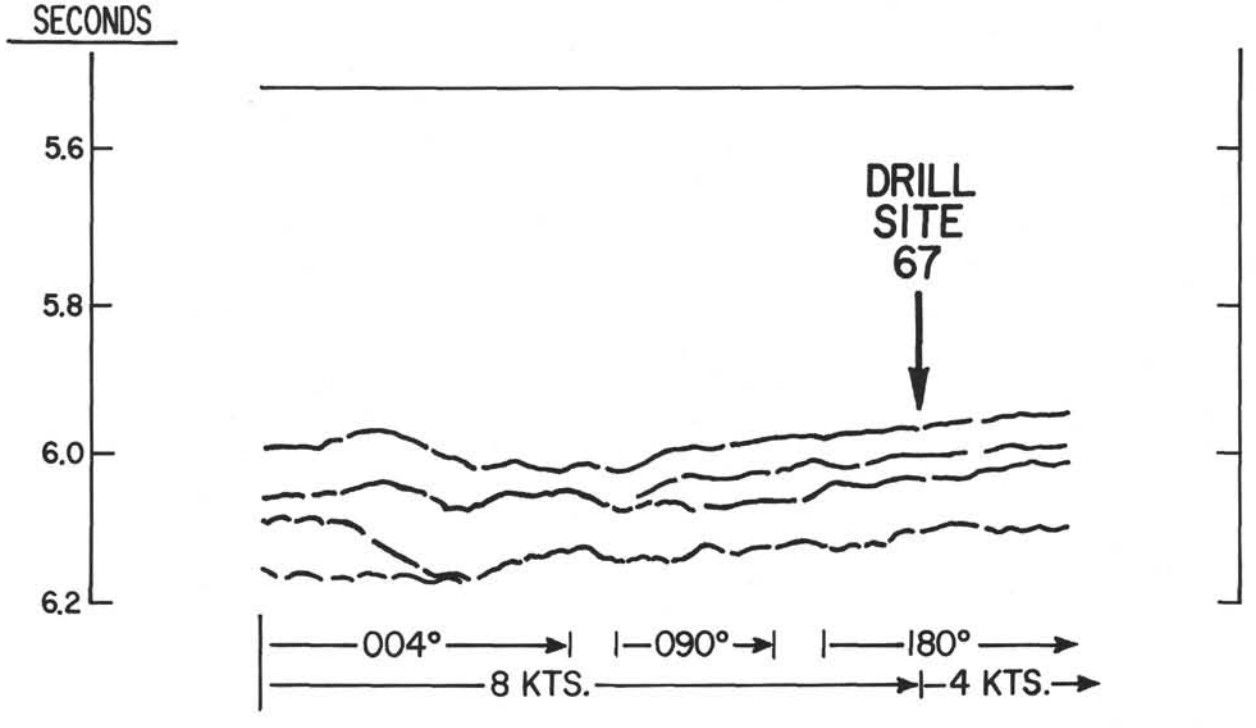


Figure 4. *Line drawing of selected reflectors on Reflection Record 148 (Reflection Seismology Chapter) in the vicinity of Site 67.*

TABLE 1
Drilling Summary, Site 67

Hole	Interval (ft)	Interval (m)	Cores Drilled	Core Cut (ft)	Core Cut (m)	Core Cut %	Core Recovered (ft)	Core Recovered (m)	Core Recovered %
67.0	0-15	0-5	Core 1	15.0	4.6		5.0	1.5	
Totals	15		1	15.0	4.6	100	5.0	1.5	33
67.1	0-74		Drilled						
	74-104	23-32	Core 1	30.0	9.1		5.0	1.5	
	104-197		Drilled						
	197-197.5	60-60.15	Core 2	0.5	0.1		0.5	0.1	
Totals	197.5		2	30.5	9.2	15	5.5	1.6	18
Site Totals	212.5		3	45.5	13.8	21	10.5	3.1	23

The other principal rock type encountered at the site was porcelanite at about 60 meters depth in Hole 67.1, Core 2. This hard rock blocked any deeper penetration of the bit at this site. The brown porcelanite resembles that of the equatorial Central Basin at Sites 65 and 66, except that no obvious remains of radiolarians are seen other than vague circular outlines and scattered opaline spines. Cristobalite pervades the rock in a three-dimensional, anastomosing web of 2 to 4 microns-diameter filaments. Similar cristobalitic masses are present in some of the zeolitic mudstone pieces of Cores 1 and 2 of Hole 67.1. Sand-sized quartz grains and chalcedony are also common in the chert. The paler pieces of cherty rocks are composed only of silica, and it is reasonable to propose an origin from a radiolarian ooze. The darker ones, with strong iron-oxide colorings, may have been impure radiolarian oozes or pelagic clays.

Lower Eocene or upper Paleocene radiolarians from the muddy water and small amounts of pelagic clay recovered along with the nonfossiliferous zeolitic mudstone and porcelanite of Hole 67.1, Core 2 very likely fell down into the hole from some unknown distance above the porcelanite. Some of the softer beds between 25 and 60 meters depth are almost certainly radiolarian-rich oozes or muds.

At Site 67, the rate of deposition was low. If the episodic, rapid deposition of the coarser volcanic beds is taken into account, the rate of purely pelagic deposition alone becomes very low indeed. Remoteness from terrigenous sources of sediment, low productivity in the overlying water mass, depth of the sea floor, and scouring action of bottom currents were probably responsible for the slow rate of sediment accumulation.

Physical and Chemical Properties

The physical and chemical properties of cores obtained at Site 67 are summarized in Table 2 and are displayed as a function of depth in the Site Summary at the end of this chapter. The significance of these data is discussed in separate contributions elsewhere in this volume.

Paleontologic-Biostratigraphic Summary

Radiolaria

The only radiolarian found in the surface core (67.0-1) was a single specimen, apparently reworked, of the Lower to Middle Eocene form *Thyrsocyrtis hirsuta hirsuta.* Core 67.1-1, from about 23 meters, contains no radiolarians, but the sample from about 59 meters (67.1-2-CC) contains sufficient specimens to suggest an age very near the Eocene/Paleocene boundary.

In addition to the diverse, rather well-preserved Paleogene assemblage, the radiolarian preparations from 67.1-2-CC contain many well-formed, twinned zeolites and ferromanganese micronodules, and much fish skeletal debris. This association suggests an artificial admixture of a nonradiolarian zeolitic clay with a radiolarian ooze, which could be caused by caving from the sides of the drill-hole. A few well-preserved Quaternary radiolarians occur together with the Paleogene forms, but there appears to be no admixture of forms of intermediate age. Thus the radiolarian assemblage in this sample may be used as an indication of the

TABLE 2
Physical Properties of Cores Recovered From Site 67

Identification	Lithology	Physical Properties									
		Saturated Bulk Density (Sect. Wt.)[a] gm/cm^3	Saturated Bulk Density (GRAPE)[b] gm/cm^3	Mean Grain Density[c] gm/cm^3	Porosity (Calculated)[d] Per Cent	Porosity (Drying, Ship)[e]		Penetrometer[f] cm	Sonic Velocity[g] m/sec.	Natural Gamma Radiation[h]	
						Interval cm	Per Cent				
Hole 67.0											
Core 1-1	Volcanic Sandstone and Mudstone		1.307		77.8						
Hole 67.1											
Core 1-1	Volcanic Sandstone and Mudstone										
1-2											

[a]Saturated bulk density derived by dividing net section weight by volume.

[b]Saturated bulk density derived from gamma ray attenuation data (see text). Value given is average of all valid data points per section.

[c]Mean grain density is assigned, considering selected grain density measurements made and reported elsewhere in this volume, and gross mineralogy of the section.

[d]Porosity is calculated: $\phi = \frac{\rho_g - \rho_B}{\rho_g - \rho_f}$; ρ_B is from GRAPE, average per section ρ_g is from column 5; $\rho_f = 1.024$; units in per cent of total volume.

Early Eocene-Paleocene age of a level somewhere between Core 67.1-1 and 67.1-2-CC.

DISCUSSION

The fact that radiolarian sediments of possible early Eocene or late Paleocene age occur at this site at a depth of less than 60 meters suggests that the chances of finding Mesozoic sediments here are good. Judging from the reflection profile at the site, a thickness of at least 60 meters of layered rocks lies beneath the chert at the bottom of the hole.

Our samples include no calcareous sediments, and the porcelanite strongly resembles that at Sites 61, 65 and 66 where the associated beds were radiolarian oozes.

Nothing resembling the volcanic sandstone and mudstone cored in the upper portion of the section at this site was cored at any other site on this leg, and until more is known of its age and petrology few conclusions can be drawn about its origin. The complex sea-floor topography in this area, including features interpreted as lava flows (Speiss *et al.*, 1969), suggests that local vulcanism was chiefly responsible for these deposits.

Rates of Accumulation

If the sediments at 60 meters are assumed to be early Eocene or late Paleocene in age, and if no unconformities interrupt the section, an average rate of accumulation of only about 1 m/m.y. results (Figure 5). On the other hand, the coarse texture and sharp irregular contacts within the volcanic sandstone and mudstone section sampled in the upper part of the sequence suggest rapid deposition, and the occurrence of very firm sediments essentially at the sea floor suggests either an erosional surface or a surface on which virtually no deposition has taken place for a long time. Thus neither assumption, that is, a uniform accumulate rate and an uninterrupted Eocene to Recent sequence, is probably valid.

Velocity Profile

The reflector at 0.07 seconds is correlated with the chert drilled at 60 meters. This gives a velocity of approximately 1.7 km/sec for the upper part of the column and suggests that basement lies at least another 60 meters below the chert.

In general, the area north of the Hawaiian Ridge is characterized by extremely high reflectivity. The encounter of the well-indurated volcanic sandstones at

TABLE 2 – *Continued*

	Grainsize[i]					Carbon/Calcium Carbonate			Interstitial Water				
	Interval cm	Sand Per Cent	Silt Per Cent	Clay Per Cent	Classification	Interval cm	Calcium Carbonate Per Cent	Organic Carbon Per Cent	Interval cm	pH	Eh (mu)	Temp °C	Salinity %
	27.0	5.8	61.2	33.0	Clayey Silt	34.0	0.0	0.2					
	61.0	0.2	55.2	44.5	Clayey Silt	76.0	0.3	0.3					

[e]Porosity is by drying (shipboard measurements) and is corrected for salt.

[f]Only the minimum penetrometer measurement per section is given.

[g]Sonic velocity measurements were made aboard ship and are corrected to 23°C. Maximum of three measurements per section is shown.

[h]Natural gamma radiation: Average of middle 16 of 20 counts/3 inch/1.25 minutes minus 1350 background.

[i]Grainsize: Sand per cent of total weight greater than .062 millimeter; clay per cent of total weight less than .0039 millimeter; silt remainder of total weight.

or near the sea floor at Site 67 may suggest a plausible explanation for the observed high reflectivity.

REFERENCES

Heirtzler, J. R., Dickson, G. D., Herron, E. M., Pitman, W. C., III and Le Pichon, X., 1968. Marine magnetic anomalies, geomagnetic field reversals, and motions of the ocean floor and continents. *J. Geophys. Res.* **73** (6), 2119.

Pitman, W. L., III, Herron, E. M. and Heirtzler, J. R., 1968. Magnetic anomalies in the Pacific and sea floor spreading. *J. Geophys. Res.* **73** (6), 2069.

Spiess, F. N., Luyendyk, B. P., Larson, R. L., Normark, W. R. and Mudie, J. D., 1969. Detailed geophysical studies on the northern Hawaiian Arch using a deeply towed instrument package. *Marine Geol.* **7**, 501.

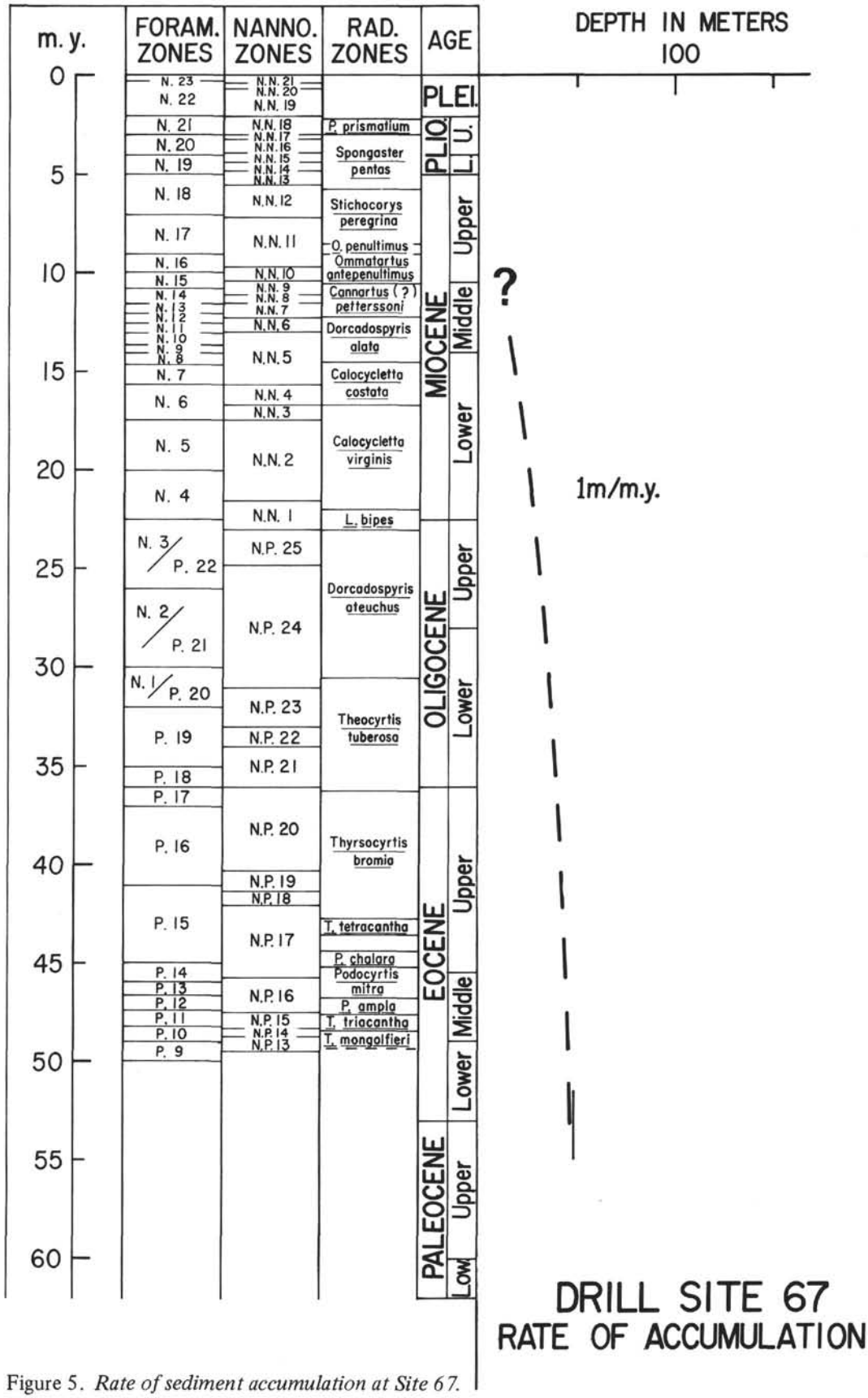
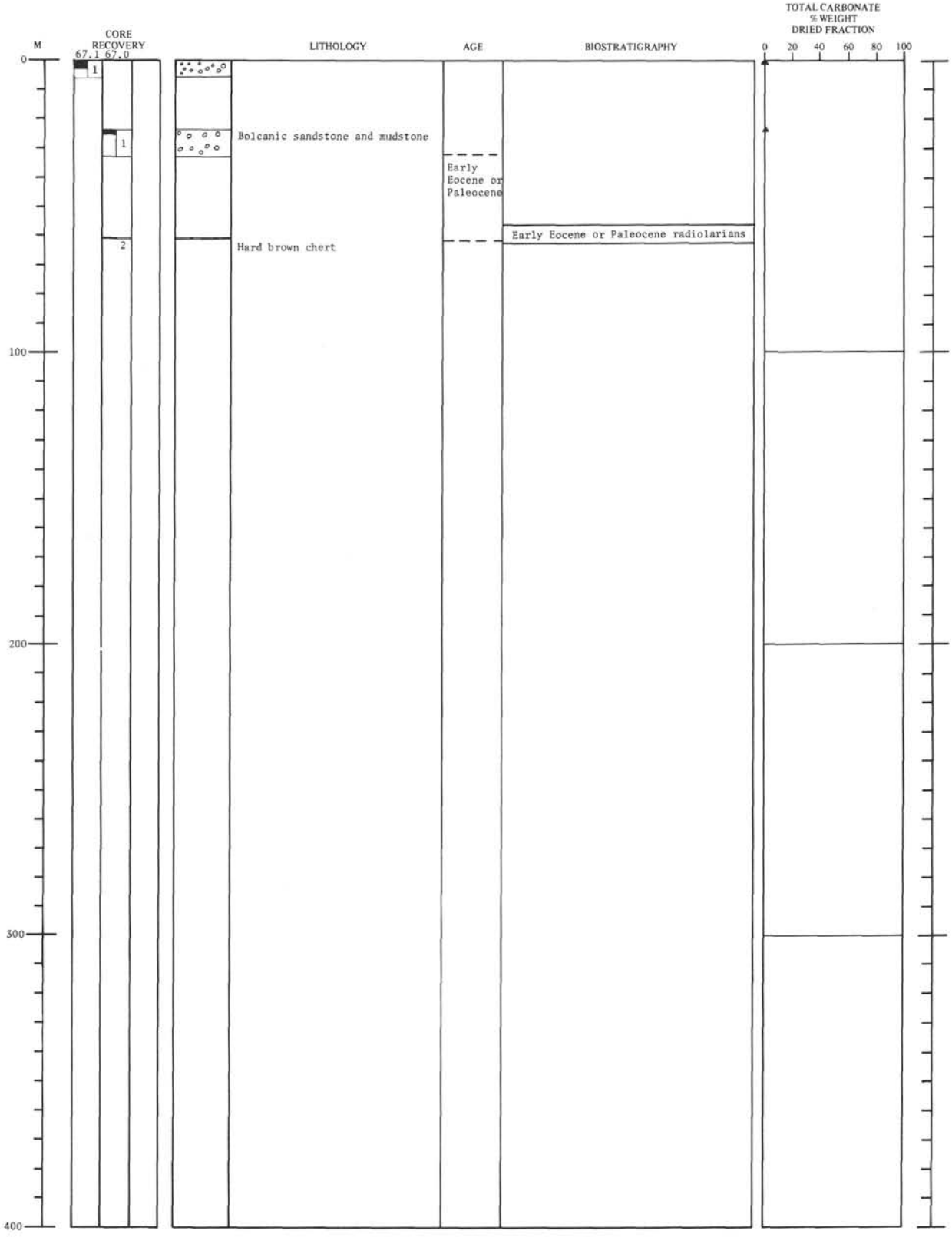
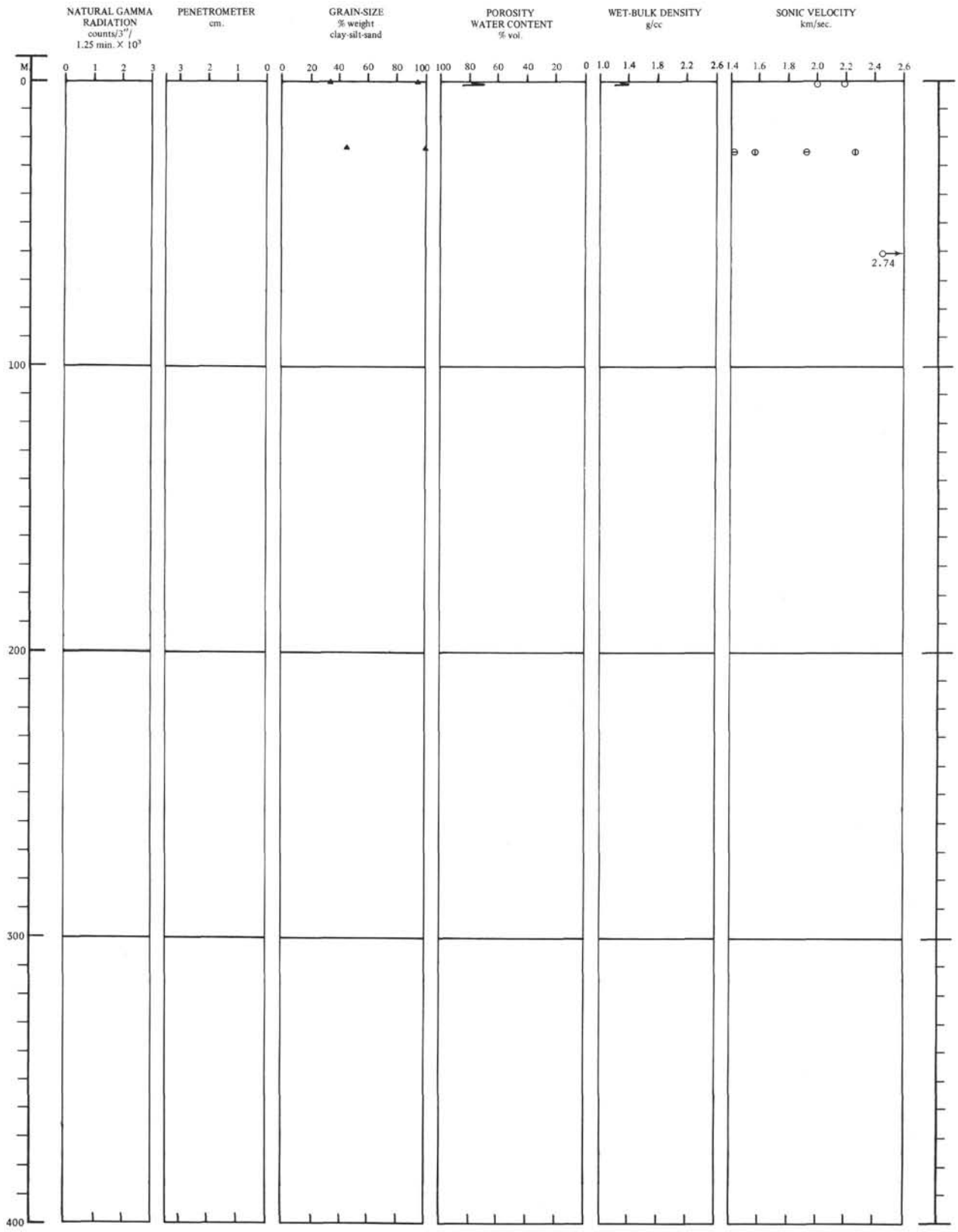


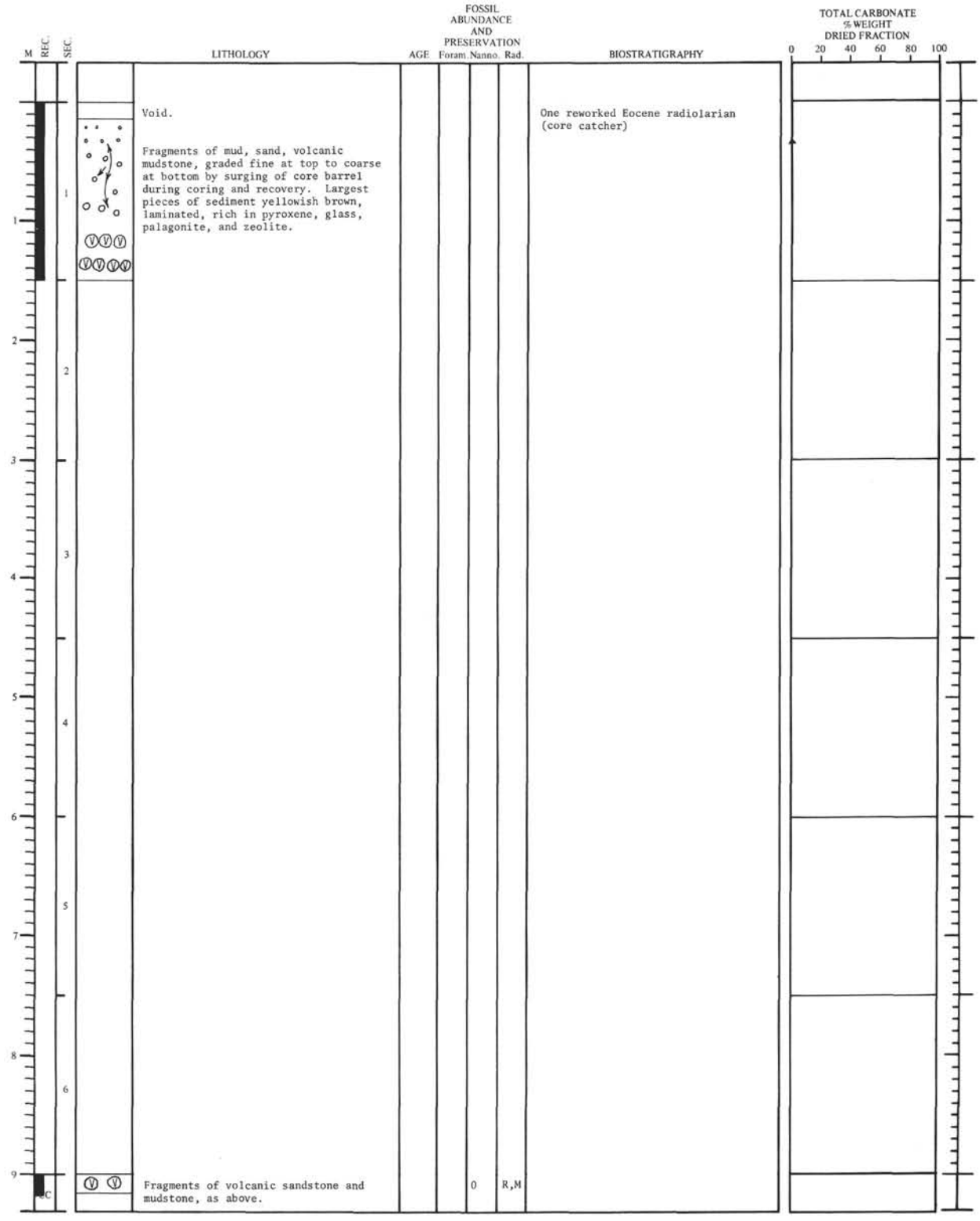
Figure 5. *Rate of sediment accumulation at Site 67.*



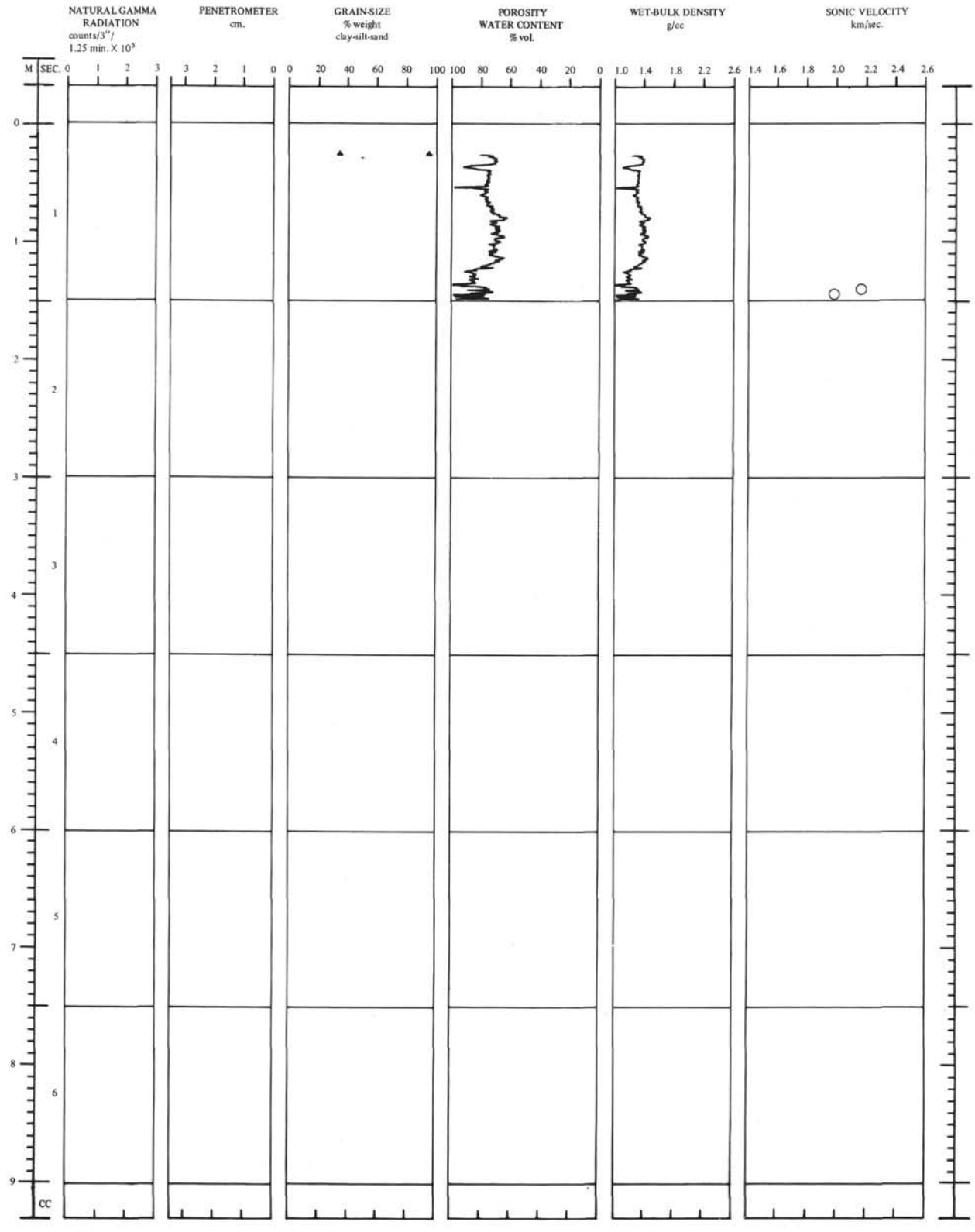
Lithology and biostratigraphy of Site 67.



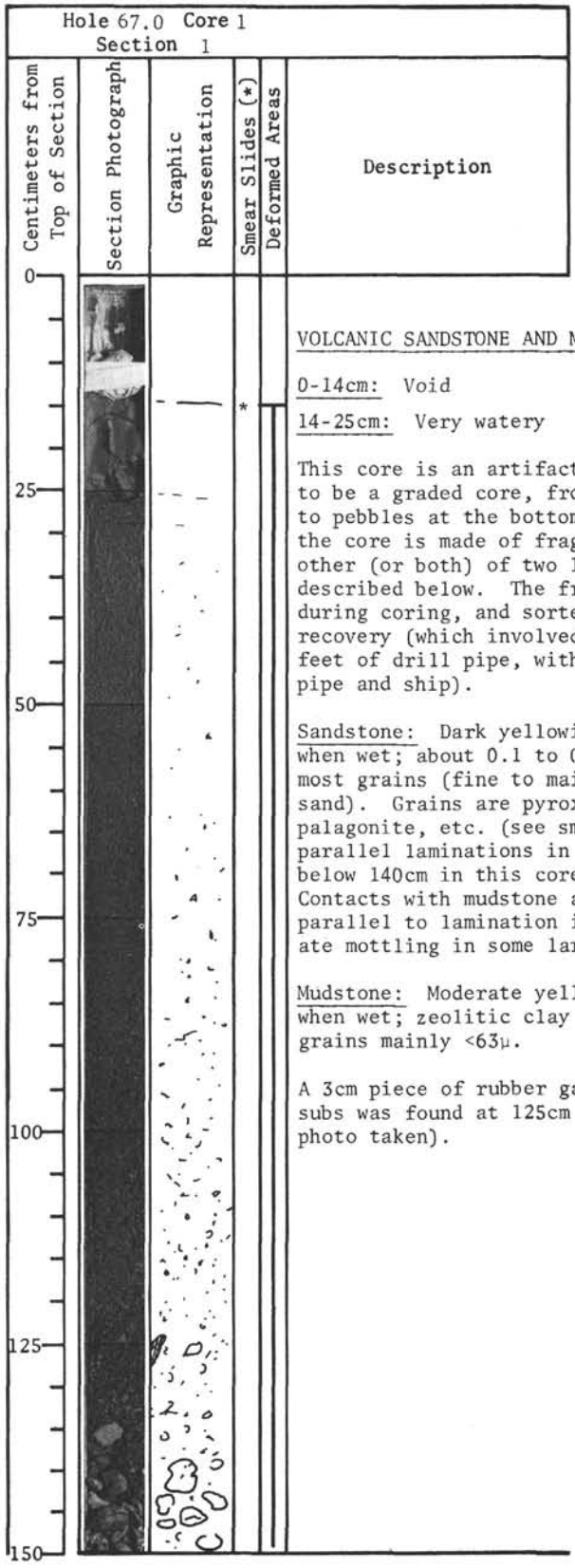
Physical properties of Site 67.



Lithology and biostratigraphy of Core 1, Hole 67.0.



Physical properties of Core 1, Hole 67.0.



VOLCANIC SANDSTONE AND MUDSTONE

0-14cm: Void

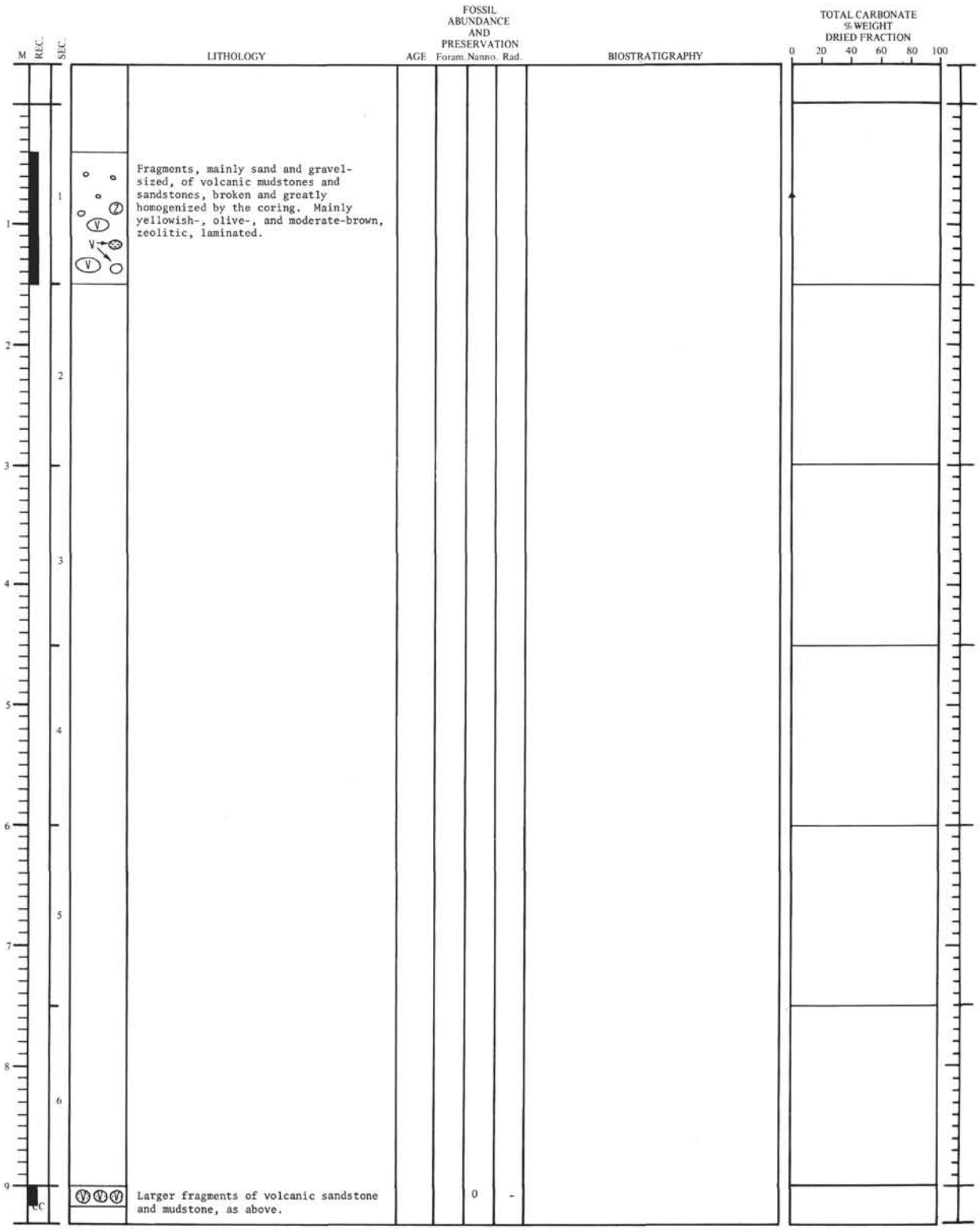
14-25cm: Very watery

This core is an artifact in that it appears to be a graded core, from silt at the top to pebbles at the bottom. However, all of the core is made of fragments of one or the other (or both) of two lithologies, to be described below. The fragments were made during coring, and sorted to size during recovery (which involved raising the 1400 feet of drill pipe, with surging of the pipe and ship).

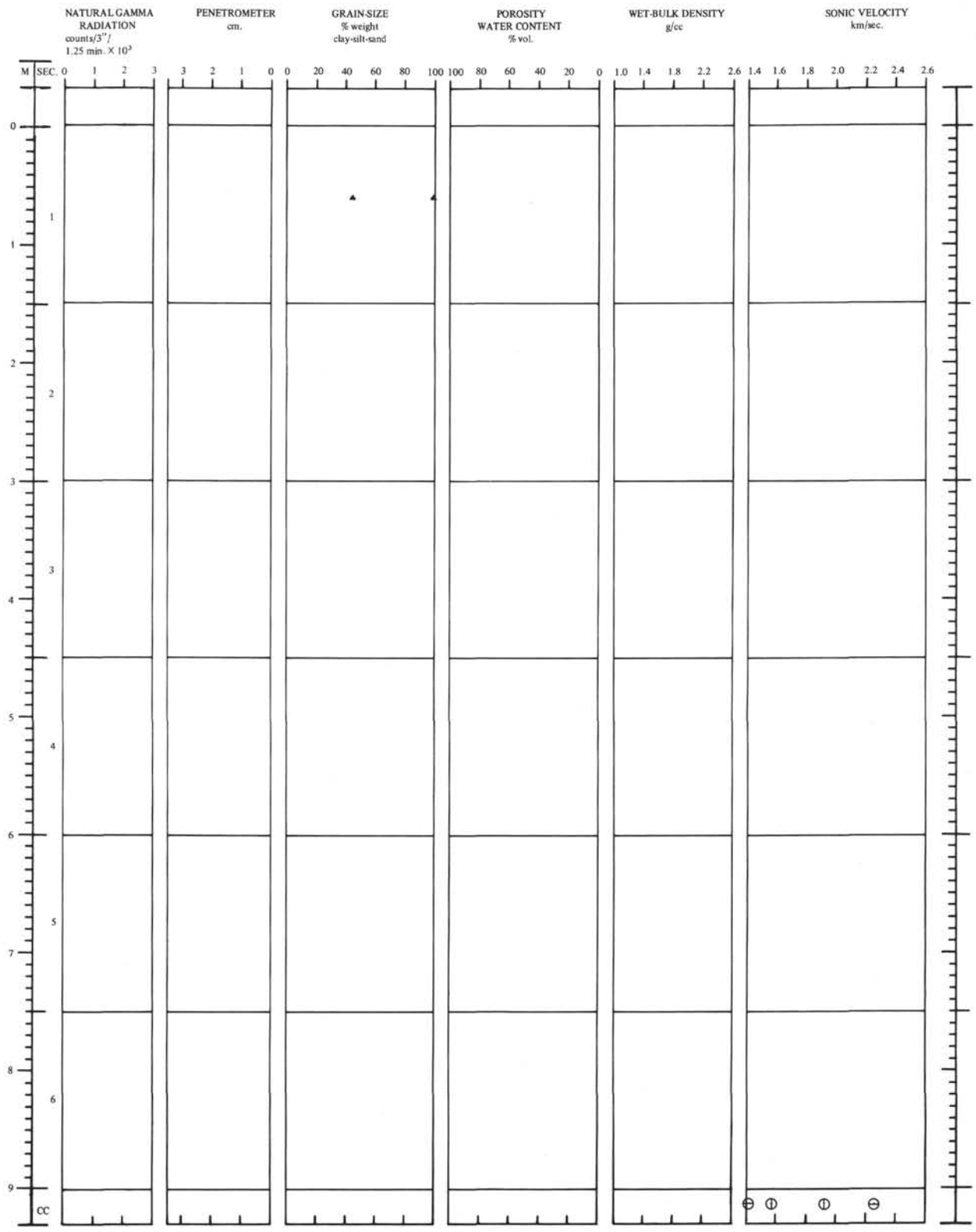
Sandstone: Dark yellowish brown (10YR3/2) when wet; about 0.1 to 0.2mm diameter for most grains (fine to mainly medium grained sand). Grains are pyroxene, olivine, glass, palagonite, etc. (see smear slides). Faint parallel laminations in some large pieces, below 140cm in this core and in core catcher. Contacts with mudstone are sharp, though not parallel to lamination in sandstone. Moderate mottling in some large pieces.

Mudstone: Moderate yellowish brown (10YR5/4) when wet; zeolitic clay lumps, but mineral grains mainly <63μ.

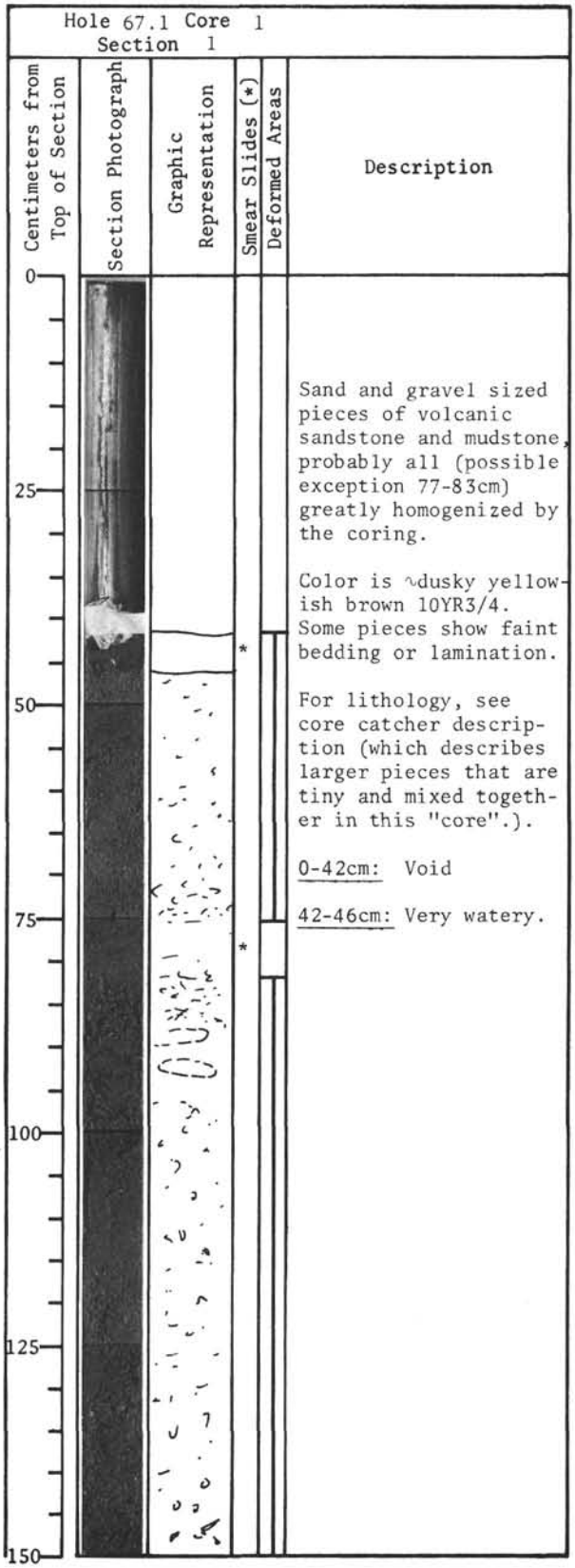
A 3cm piece of rubber gasket from the bumper subs was found at 125cm (removed before photo taken).

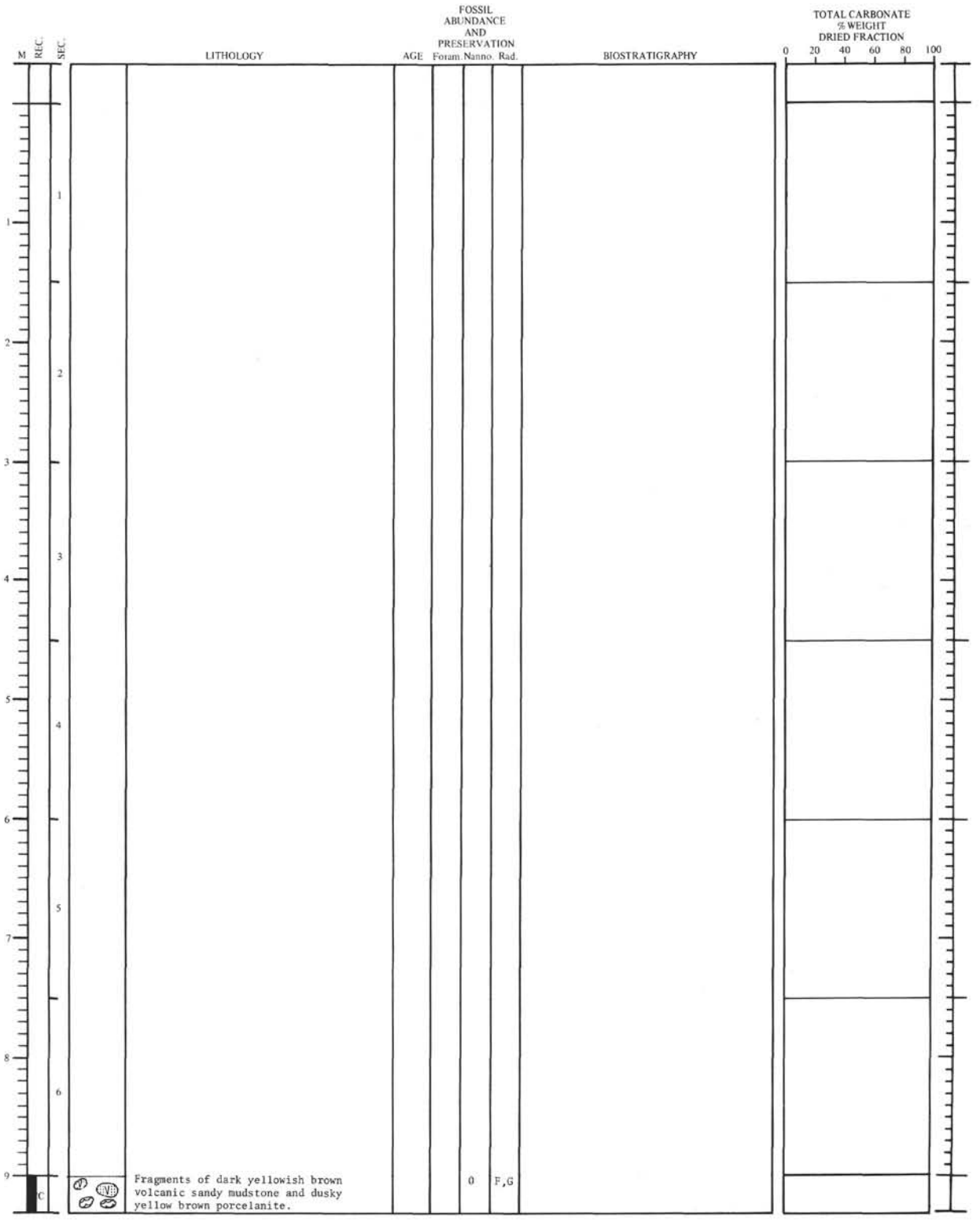


Lithology and biostratigraphy of Core 1, Hole 67.1.

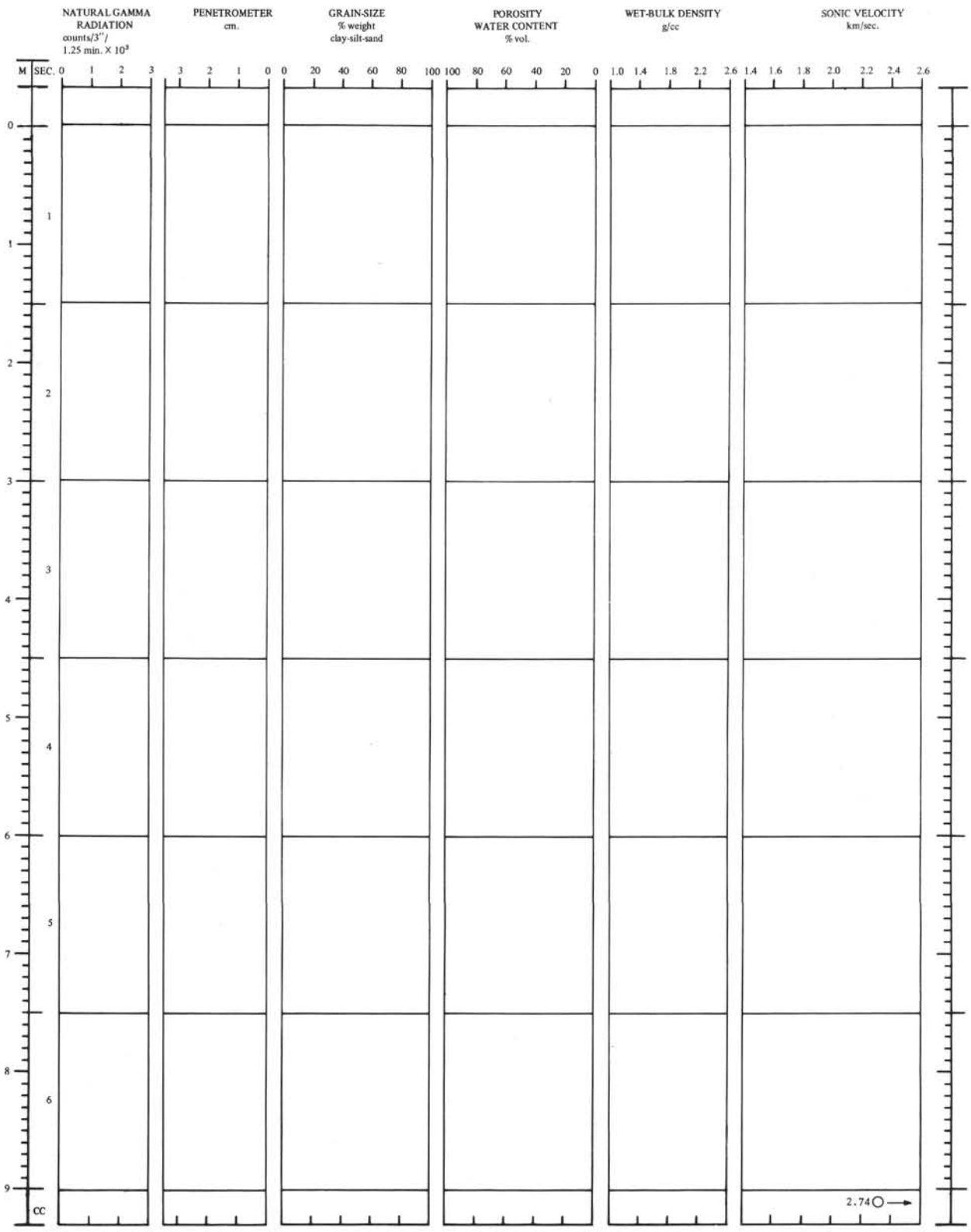


Physical properties of Core 1, Hole 67.1.


Hole 67.1 Core 1
Section 1
Centimeters from Top of Section
Section Photograph
Graphic Representation
Smear Slides (*)
Deformed Areas
Description
0
25
50
75
100
125
150
*
*
Sand and gravel sized pieces of volcanic sandstone and mudstone, probably all (possible exception 77-83cm) greatly homogenized by the coring.
Color is ∿dusky yellowish brown 10YR3/4. Some pieces show faint bedding or lamination.
For lithology, see core catcher description (which describes larger pieces that are tiny and mixed together in this "core".).
0-42cm: Void
42-46cm: Very watery.



Lithology and biostratigraphy of Core 2, Hole 67.1.



Physical properties of Core 2, Hole 67.1.