2. SITE 164

The Shipboard Scientific Party[1]

SITE DATA

Position:
Latitude: 13°12.14′N
Longitude: 161°30.98′W.

Geography: North of extension of Clarion Fracture Zone, between Line Island chain and Hawaii.

Water Depth:
PDR, to derrick floor: 5485 meters.
From drill pipe estimate from derrick floor: 5513 meters.
Adopted (see discussion in operations section of text): 5499 meters.

Date Occupied: 6-11 Apr 71.

Time On Location: Four days, 11 hours, 30 minutes.

Depth of Maximum Penetration: 274 meters.

Cores Taken: 28.

Total Length of Cored Section: 260 meters.

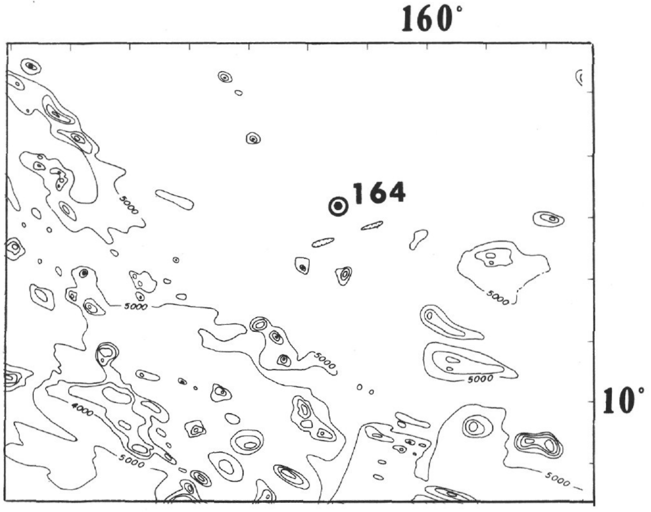
Total Recovery:
Length: 81.1 meters.
Percentage: 31.5.

Percentage of Penetrated Section Cored: 95.

Principal Results: The stratigraphic column begins with an acoustically very transparent layer about 40 meters thick, very soft in its unsampled upper part and grading downward to Oligocene radiolarian zeolitic brown clay. The first cherts occur at 37 meters in the lower Oligocene and continue to the base of the sedimentary section, at 264 meters, in the Lower Cretaceous (Barremian to Albian). Zeolitic brown clay with sparse Radiolaria is interbedded with the chert. Aside from a few coccoliths in cores at 76 meters (Upper Cretaceous) and at 236 meters (Lower Cretaceous), no calcium carbonate was detected. Ten meters of vesicular basalt was cored beneath the sediments. (See Figure 1.)

BACKGROUND AND OBJECTIVES

In keeping with the overall objectives of the leg, we chose this site to provide a crustal age in the Clarion-Molokai block well west of anomaly 32, to obtain as complete a biostratigraphic record as possible, to determine the amount of latitudinal variation this part of the Pacific has undergone during its depositional history, and to identify the ages and composition of the principal seismic layers and reflection horizons.



The estimated age of the deepest sediment at this site is about 115 m.y., based on an extrapolation of the Tertiary spreading rate beyond anomaly 32. There was no contradiction to such an age in the available data from dredging and piston coring, or from drilling in the neighboring Clarion-Clipperton block, but neither was there confirmation. A primary objective therefore was to date the basal sediments.

Several lines of evidence point to a substantial northward component of motion of the Pacific plate. It was hoped that continuous coring at this site would provide a record of accumulation rates of biogenic sediment, which would indicate the time during which this part of the plate was in the equatorial belt of high productivity. Sampling to study possible variations of magnetic inclination with depth (age) might provide supporting or independent evidence of latitudinal variation.

Several seismic profiler traverses were available in the general area of the site, all showing a very thin upper transparent layer and approximately 0.2 sec thickness of opaque layer overlying acoustic basement. Dating and determining the composition of these layers, which are traceable over large portions of the Pacific Ocean, will materially improve our ability to use the seismic control in interpolating geologic data from site to site.

OPERATIONS

The approximate location for the site was chosen from a traverse (showing a local thickening of the upper transparent layer) by R/V *Conrad*, which would facilitate spudding-in. *Glomar Challenger* arrived in the vicinity of the site at 1300 hours, 6 Apr 71, on a course parallel to *Conrad's* and about 5 miles east (Figures 2 and 3). The first

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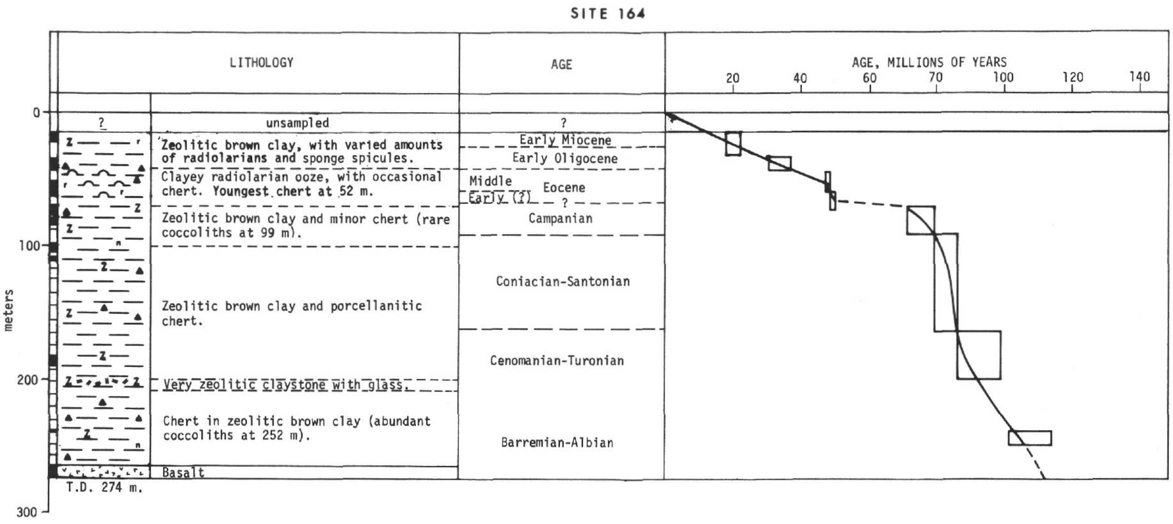

Figure 1. *Graphic log showing lithology, age, and rate of accumulation of sediments at Site 164.*

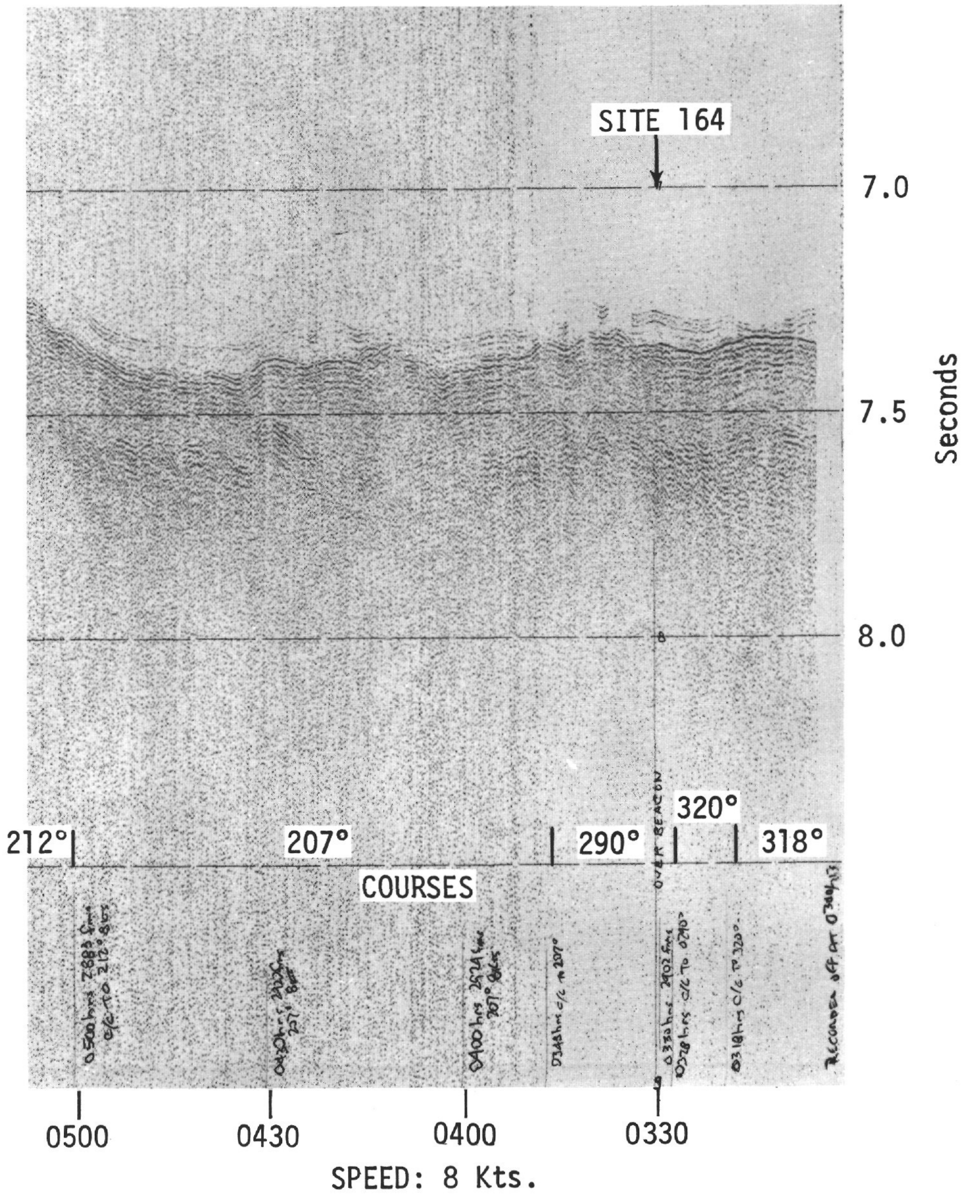

Figure 2. *Seismic profile recorded by* Glomar Challenger *while leaving Site 164.*

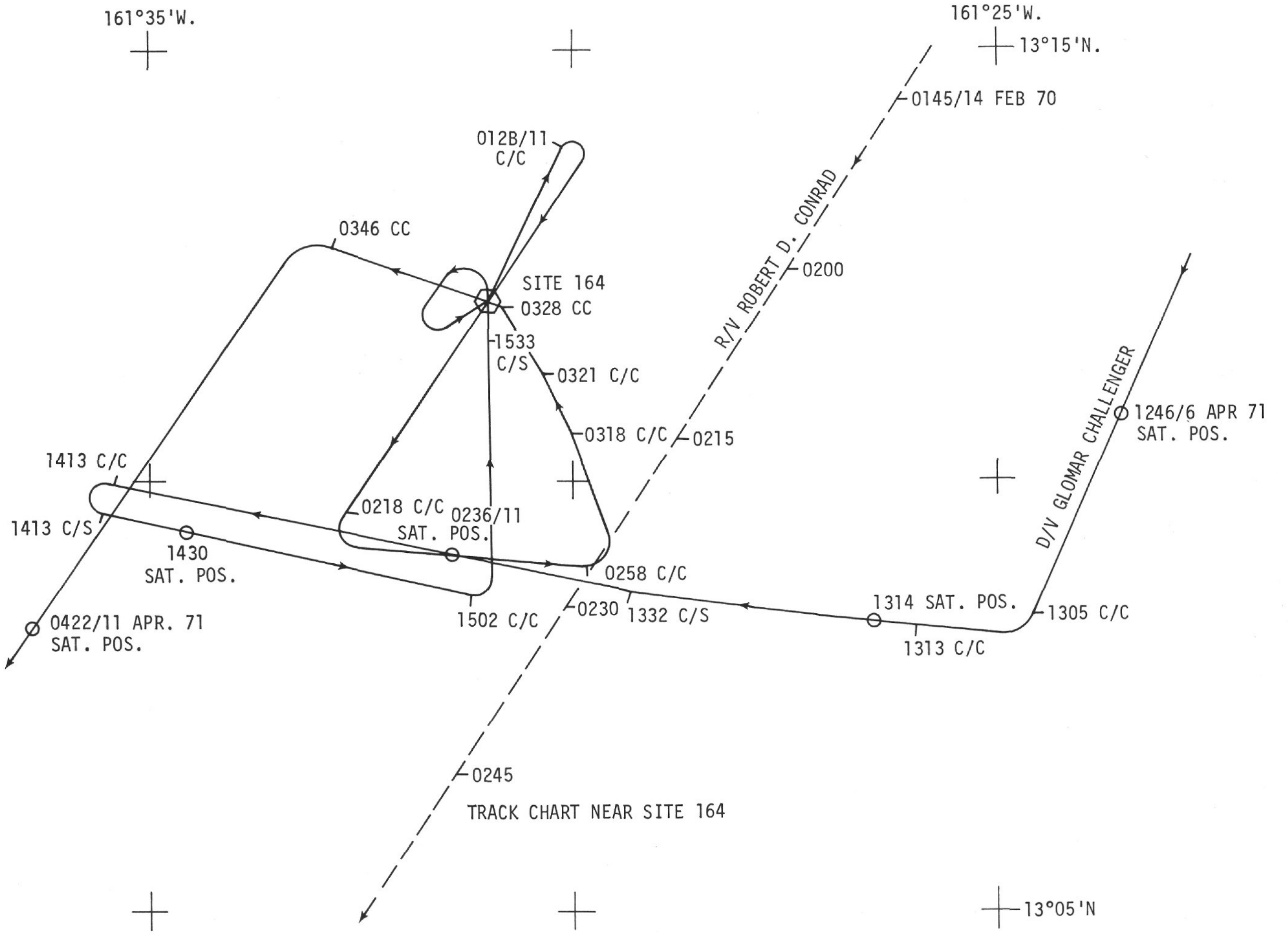

Figure 3. *Tracks of* Glomar Challenger *and* R. D. Conrad *in the vicinity of Site 164.*

pass over the proposed site on course 285° showed the appropriate thickness of transparent layer, but basement was indistinct. It appears that 285° is approximately perpendicular to the grain of basement structure, as its topography has a noticeably shorter period than that observed on the approaching course of about 200°.

The drilling site was finally chosen a short distance northeast of the proposed site. At this point the corrected water depth (according to Matthews' Tables) was 5485 meters from the drill platform, and the profiler showed 0.076 sec of transparent layer thickness and 0.21 sec of opaque layer. Although we are not certain of the true water depth at this site, we have adopted 5499 meters. At later sites we made a major effort to determine water depth as accurately as possible and concluded that in this region, deep echo soundings corrected according to Matthews' Tables are approximately 14 meters shallower than true depth.

The first attempt to core was in the interval 5488 to 5497 meters, and no sediment was recovered. The second attempt at 5497 to 5506 meters also failed to get a sample. In the third attempt, the drill string was lowered three joints (27 m) to 5533 meters and the core barrel was filled—probably more than filled, because the overshot initially would not latch on to the core barrel, apparently because so much sediment had passed through the check valve that the latching mechanisms could not make contact. There was only slight indication on the weight gauge of bottom contact even at 5533 meters, and later analysis indicates that this point was at least 20 meters, and possibly more than 30 meters, below sea floor.

The first hard layer was a silicified interval encountered in Core 3, 37 meters below the accepted depth of the sea floor. Although the driller attempted to use the minimum possible amount of weight on the bit while drilling through it, occasional surges registered 15,000 to 20,000 lbs, and the 6-meter interval of coring required 15 minutes. This layer apparently corresponds to a weakly reflective zone within the transparent seismic layer. The remainder of the section down to basalt consisted of alternating chert layers and layers of zeolitic clay. The cherts appeared to be particularly hard in the region around 85 meters below bottom and again near the bottom of the hole.

In addition to causing slow drilling, the chert beds were responsible for very poor sediment recovery. Large pieces of chert repeatedly wedged in the core catcher and prevented the softer sediment from entering the core barrel. It might have been possible to avoid some of the problem by drilling more slowly through the chert beds without fracturing them, but the sea state was such that it was impossible to maintain a steady weight on the bit. Furthermore, it was not possible to penetrate without the use of the pumps, and this had the usual effect of washing away most of the softer material. Thus, sample recovery was very poor, and, except for the cherts, the material recovered was probably badly disturbed for the most part.

Basalt was reached near the bottom of Core 27. The sample contained a few centimeters of basalt and some chert chips, but no soft or baked sediment. Core 28 required almost 5 hours to cut and recovered 8.5 meters of basalt with no sediment inclusions. The hole was abandoned after this core.

BIOSTRATIGRAPHIC SUMMARY

Sediments at this site were continuously cored from 14 meters below the sea floor to basalt basement. However, the reworked microfossil assemblages of the Tertiary sediments, the diagenetic alteration of lower Tertiary and Cretaceous sediments, poor core recovery, and the caving and mixing of sediments during drilling make the stratigraphy at this site difficult to interpret. This difficulty is heightened by the total absence of foraminifera, the very rare occurrence of calcareous nannofossils, and the poor preservation of the radiolarians.

Based primarily on the radiolarian stratigraphy, the first core sampled lower Miocene (or younger) sediments; the Oligocene-Miocene boundary is located between Cores 1 and 2; and the Eocene-Oligocene boundary is between Cores 3 and 4. Core 6 contains a few radiolarians which are of early Eocene age. The occurrence of a few specimens of Late Cretaceous calcareous nannofossils in Core 8 and of the Cretaceous radiolarian genus *Dictyomitra* in Section 7-4 indicates that the Cretaceous-Tertiary boundary is near the top of Core 7. The Cretaceous radiolarian assemblage found in this section is sparse in Cores 7 through 10 and 19 through 25. However, by comparing the radiolarian assemblage found at this site with those found at subsequent sites, where control by calcareous microfossils is more substantial, the following approximate age assignments can be made. Cores 7 and 8 are from the Campanian; Cores 10 through 16 are Coniacian to Santonian; and Cores 17 through 19 are Cenomanian to Turonian in age. Based on a strongly etched assemblage of calcareous nannoplankton found in sediments overlying the basalt. the basement age is Barremian to Albian. Although the site was continuously cored, no sediments were identified from the upper Oligocene, upper Eocene, Paleocene, or Maestrichtian parts of the section. Such hiatuses may continue into the Cretaceous section where stratigraphic control is poor.

A plot of depth drilled versus age of sediment recovered gives an average rate of sediment accumulation (uncorrected for compaction) of 1.5 m/m.y. for the Tertiary and 5.3 m/m.y. for the Cretaceous.

LITHOLOGIC SUMMARY

The complete sedimentary section has been sampled by continuously coring down to the basement. As a whole the lithology appears very homogeneous throughout and consists primarily of zeolitic brown clay and chert, except near the top of the section where siliceous organisms are abundant. Carbonate components are extremely rare. Most of the cores were badly disturbed and primary structures have rarely been preserved.

Three main lithologic units can be defined:

1) Zeolitic brown clay rich in radiolarians and radiolarian ooze, with some porcellanitic chert at the base of the section (Cores 1 to 6).

2) Zeolitic brown clay and chert (Cores 6 to 27).

3) Basalt (Cores 27 and 28).

Zeolitic, Radiolarian-Rich Clay and Radiolarian Ooze

This first section is characterized by the abundance of siliceous organisms. The upper 30 meters consist of a zeolitic clay containing variable amounts of radiolarians and some sponge spicules. The lower part of this unit is a more or less clayey radiolarian ooze. Porcellanitic chert appears near the middle of the section and is regularly present downward.

The dominant minerals are clay minerals (dominant montmorillonite) and zeolites. The clay minerals show a brown staining, probably owing to the occurrence of iron and/or manganese oxides and hydroxides. Zeolites are mainly phillipsite with characteristic twinning and some clinoptilolite. Palagonite fragments are regularly present, associated with the clay minerals and zeolites. Very rare, angular, small quartz grains occur near the top of the section.

Zeolitic Brown Clay and Porcellanitic Chert

This section appears relatively homogeneous and the only variations in the composition of the sediments are the variable amounts of chert fragments, the occurrence of a zeolite- and glass-rich bed in Core 21, and the minor occurrence of some coccoliths in Cores 8 and 25.

The composition of the clay is comparable to the most clayey portions of the overlying layers. However, X-ray analysis results show distinctive features such as the predominance of mica-illite and palygorskite over montmorillonite in the clay minerals group, the occurrence of substantial amounts of K-feldspars that were absent above, and the absence of phillipsite while clinoptilolite becomes the only zeolite recorded downward in the hole.

Porcellanitic chert fragments become abundant in Core 10 and are especially numerous from Core 22 down to the basaltic basement. Chert is mainly cristobalite with abundant chalcedony-replaced radiolarians.

Rare, very well crystallized calcite fragments were found associated with chert fragments in Core 24. They could be veinlet fillings (no primary structure was preserved). The only other carbonates occurred in Core 25 where coccoliths were relatively abundant, accompanied by occasional dolomite rhombs.

Basalt

Basalt was encountered in the lower part of Core 27. The only sediments recovered near the contact are large chert fragments and it is probable that some of the softer sediments were washed out during the coring. The top few centimeters of the basalt are relatively rich in glass and montmorillonite. They seem to correspond to the top of a flow. The basalt is of rather massive aspect except for the presence of numerous calcite-filled veinlets and a few glassy bands that could be pillow selvages. The rock is slightly porphyritic with phenocrysts of plagioclase and olivine in a groundmass of plagioclase microlites, pyroxene, glass, and opaques. It is highly altered and chlorite and montmorillonite are abundant.

The variations in the texture and composition suggest that the bottom few centimeters cored are either the lower portion of a flow or, more likely, the top part of a preceding flow. If so, it indicates an approximate thickness of 10 meters for the upper flow.

PHYSICAL PROPERTIES

Almost all Site 164 cores are disturbed, making evaluation of wet bulk densities tenuous because of the possibility of water injection. Nevertheless it appears that the commonly observed difference in density between radiolarian ooze and brown clay (due both to the low grain density and the intragrain pore space of Radiolaria) is well marked, the transition occurring at 75 meters. The density (about 1.15) and the gamma count (250) of the radiolarian ooze are typical for equatorial Pacific radiolarian oozes.

Dilution of the brown clays by Radiolaria probably explains the lower gamma counts at 25 to 55 meters and the lowest gamma counts at 55 to 70 meters. However, dilution cannot explain the reduction in gamma below 180 meters. This gamma drop from about 1100 to about 200 within the clays seems to correlate with x-ray evidence of a drop in K-feldspar, montmorillonite, and clinoptilolite; however, it is uncertain whether the few x-ray samples are representative. A similar drop was observed in the younger clays at Site 68 (Tracey, Sutton et al., p. 45-60).

CORRELATION BETWEEN STRATIGRAPHIC SECTION AND SEISMIC REFLECTION PROFILE

There are two distinct subbottom reflectors at this site, and it was expected that there would be no difficulty whatever in determining the lithologic boundaries responsible for them. The upper of these reflectors is at the base of a layer (upper transparent layer[2] of Ewing et al., 1968) whose acoustic impedance must be little different from that of water. In this region, reflections from the top of the layer (sea floor) are so weak that they are difficult to record and will not be clearly visible unless the echo sounding and seismic profiling equipment are operating perfectly. The base of the layer is far more reflective, obviously representing a major change in acoustic impedance, and one might expect a distinct drilling break at that depth. The reflection time to the base of the transparent layer is 0.076 sec, corresponding to a subbottom depth of 57 meters if the speed of sound in the sediment is assumed to be the same as that in the water. A much weaker reflection appears at about 0.05 sec, corresponding to a depth of about 37 meters.

With these observations before us, we were somewhat surprised to strike a hard layer of chert at a drill string depth of 5536 meters, which, according to the estimate of mud line depth based on behavior of the weight gauge and on evidence of the first recovered mud in the core barrel, was only 23 meters below bottom. As mentioned earlier, in the section on operations, we later accumulated data that led us to calculate water depths in the central basin as 14 meters added to the PDR depth corrected by Matthews' Tables. If we use this procedure here, we get a mud line depth of 5499 meters, and the chert layer then begins at 37 meters below bottom, correlating very well with the faint seismic reflection at 0.05 sec.

Below the uppermost chert, drilling resistance was extremely variable, and there appeared to be no specific drilling break to correlate with the seismic reflection at 0.076 sec. There is, however, a change from radiolarian brown clay to zeolitic clay and a significant increase in bulk density and natural gamma radiation in the vicinity of 60 meters below bottom. It is quite possible that there is a hiatus in sediment accumulation at the same depth, but poor core recovery because of the chert raises questions about both the paleontological and sedimentological data. Our inclination is to correlate the 0.076 sec reflection with these changes at about 60 meters depth, but we cannot rule out the possibility that a series of hard chert layers may be responsible.

The acoustic basement is reasonably distinct and correlating it with the basalt gives an interval velocity of 1.89 km/sec for the opaque layer. The 4.45 km/sec velocity for the basalt was measured on a cored specimen with the laboratory velocimeter and is near the lower end of the range of velocities measured for layer 2 by seismic refraction techniques (Shor et al., 1970; Houtz et al., 1970).

We have mentioned earlier that the uppermost cherts are visible in the seismic profile records (40-120 Hz pass band) as a faint, incoherent echo pattern. At this site and at Sites 168 and 169, there are nearby *Conrad* or *Vema* tracks from which both seismic profiles and 3.5 kHz data are available. At both places, the 3.5 kHz device records a strong echo pattern, indicating a very irregular reflective zone, corresponding to the faint reflection in the seismic record, but does not record the deeper, smoother reflection A′ that is a prominent event in the seismic record (see Figure 2, 168 and 169 site reports). We conclude that this echo pattern indicates that the uppermost cherts are nodular and widely dispersed in the sediments but become more closely spaced at increasing depth. The smoothness of reflection A′ in the seismic records suggests that if the cherts cause the reflections, they are at least semi-bedded, certainly not randomly spaced nodules. If, alternately, the reflection is caused by the physical property discontinuity associated with the hiatus, then that surface is relatively smooth for wave lengths of the order of 15 to 20 meters.

CONCLUSIONS

Age of Basement

A linear extrapolation of the 4.5 cm/yr spreading rate inferred from the spacing of magnetic anomalies in the block between the Molokai and Clarion fracture zones (Atwater and Menard, 1970) predicts an age of about 115

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[2] The acoustical "transparency" of this layer is a function of frequency pass band and of amplifier gain settings.

m.y. for the basement at Site 164, while the results of the drilling give an age of at least 100 to 115 m.y. The predicted age assumes that no fracture zone separates Site 164, which is near the south edge of the Molokai-Clarion block, from the line of the magnetic profile, which is in the northern part of the block. Relations near Site 164 are obscured by the effects of the Hawaiian Arch and the Line Islands seamount chain. Even the position and trend of the Clarion Fracture Zone are uncertain in the vicinity of Site 164 (see bathymetric chart, in pocket.) The observed basement age at Site 164 (110-115 m.y.) is probably well within the range of uncertainty from simple extrapolation from the magnetic anomaly patterns farther east, but the actual pattern of sea floor ages may be more complicated.

It should be kept in mind, of course, that no good zonal fossils were recovered from within 20 meters of the base of the sedimentary section, and that the oldest sediments could, therefore, be somewhat older than Barremian (115 m.y.). The uncertainties in slope of the curve for rate of sediment accumulation (Figure 4) are too great to permit a safe extrapolation of paleontological ages to the top of the basement.

In all these calculations it must be remembered just how shaky is our knowledge of how the paleontological zonal scheme should be arranged against a time scale in years, especially in pre-Tertiary strata.

Paleolatitudes

Signs of passage through an equatorial high-productivity zone are hard to read in the sediments at Site 164. Silica occurs throughout the column, both as Radiolaria and as chert, but it is most concentrated in middle and lower Eocene beds. The only calcareous materials cored are the few coccoliths in one core in the upper part of the Upper Cretaceous, and again in another core about 20 meters above the basement, in beds of Albian to Barremian age. Presumably, at all other times, the site was deeper than the compensation depth for calcium carbonate or was beneath a region of extremely low fertility.

It is tempting to associate the upper occurrence of coccoliths with equatorial conditions, and the radiolarian-rich sediments of the Eocene with conditions along the north margin of the equatorial belt. Cherts are abundant beneath the coccolith-bearing beds, but not markedly more so there than farther below.

The lower coccolith-bearing layers may indicate relatively shallow conditions near the rise crest, where the sea floor was above the calcium carbonate compensation depth. It was expected that calcareous beds would be cored close to the base of the section, and it is surprising that we found so little. It may be that the poor core recovery did not provide a fair sampling of the materials present; on the other hand, the want of calcareous strata may be real. It is generally found that water depths near the crest of an oceanic rise are in the range 2000 to 3000 meters, and a calcium carbonate compensation depth as shallow as 3000 meters would require unusual conditions.

At Site 163, about 1300 km southeast of Site 164, highly calcareous sediments were cored in the Senonian, which rests there on basalt (Van Andel et al., 1971). The sea

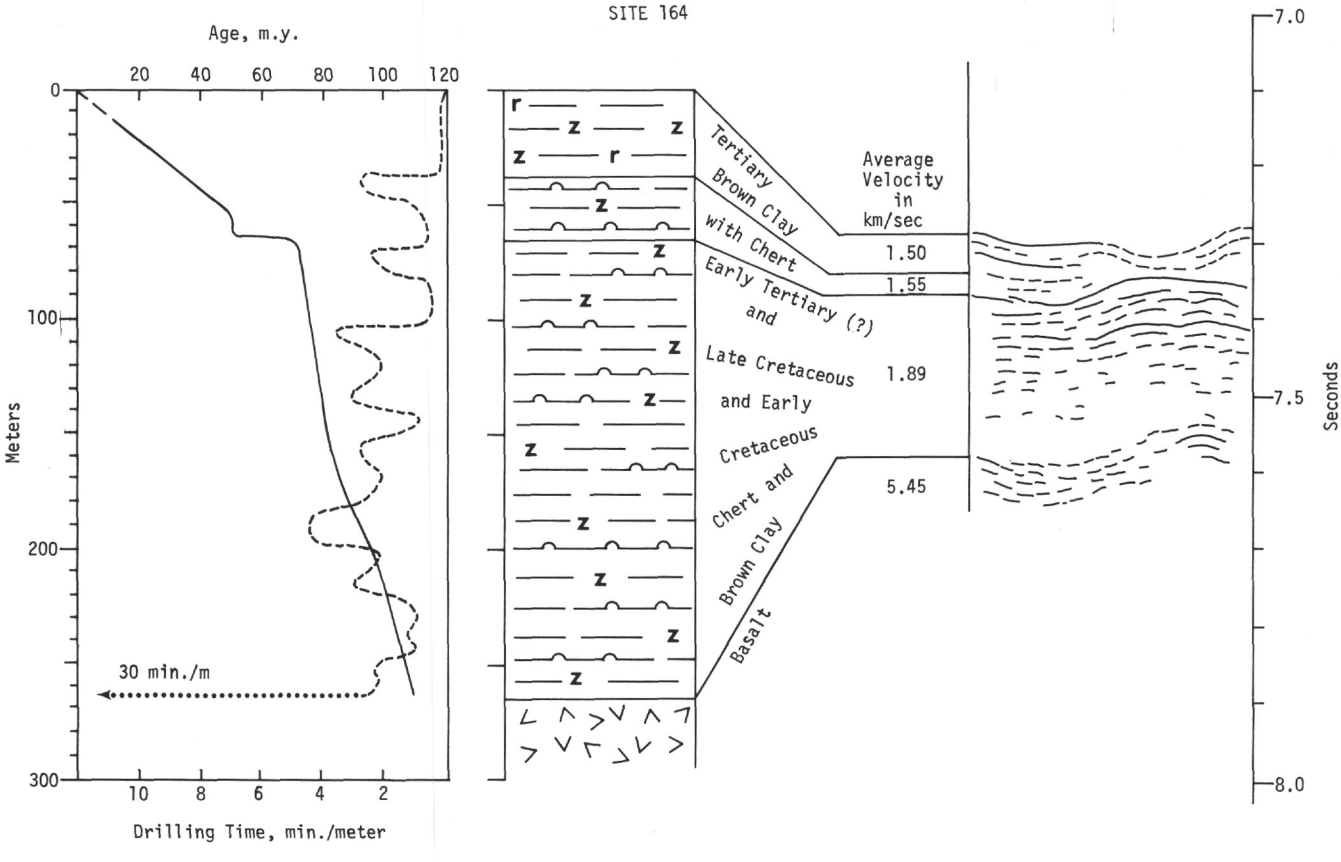

Figure 4. *Correlation of lithology, seismic stratigraphy, drilling rate, and rate of sediment accumulation at Site 164.*

floor at Site 164, being older, may already have been in relatively deep water by Senonian times, but at least we have some evidence from Site 163 that by mid-late Cretaceous time the carbonate compensation depth lay deeper than the local rise crest.

Age of the Cherts

The first chert layers were met in Core 3, within or beneath beds of early Oligocene age, and cherts persisted intermittently all the way to the base of the column.

Rates of Sediment Accumulation

As shown on the diagram (Figure 4), rates of sediment accumulation at Site 164 were slow, especially during the Tertiary. The doubling of the Tertiary rate during the Cretaceous is surprising, since the sediments are predominately zeolitic brown clays, with lesser amounts of interbedded cherts. Perhaps the rate of 3 m/m.y. (neglecting compaction) reflects fairly active regional volcanism.

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APPENDIX A

Core Inventory – Site 164

Core	Depth Below Sea Floor (m)		Total Depth[a] (m)		Cored (m)	Recovered (m)	Lithology	Age
	Top	Bottom	Top	Bottom				
1	14	34	5513	5533	20	9	Zeolitic brown clay	Early Miocene
2	34	37	5333	5536	3	3	Radiolarian-rich zeolitic clay	Early Oligocene
3	37	43	5536	5542	6	9	Radiolarian-rich zeolitic clay and porcellanitic chert	Early Oligocene
4	43	52	5542	5551	9	2	Radiolarian ooze and porcellanitic chert	Middle Eocene
5	52	61	5551	5560	9	9	Clayey radiolarian ooze with rare nannofossils	Middle Eocene
6	61	70	5560	5569	9	1.5	Radiolarian ooze and zeolitic clay with chert	Early Eocene
7	70	79	5569	5578	9	8.5	Zeolitic brown clay and chert	Campanian
8	79	88	5578	5587	9	6	Zeolitic brown clay and chert with some nannofossils	Campanian
9	88	98	5587	5597	10	CC	Zeolitic brown clay with rare nannofossils	?
10	98	108	5597	5607	9	6±	Zeolitic brown clay and chert	?
11	108	117	5607	5616	9	2.5	Zeolitic brown clay and chert	?
12	117	123	5616	5622	6	0.5	Zeolitic brown clay and chert	?
13	123	136	5622	5635	13	1	Zeolitic brown clay and chert	?
14	136	145	5635	5644	9	0.3	Zeolitic brown clay and chert	?
15	145	155	5644	5654	10	0.5	Zeolitic brown clay and chert	?
16	155	164	5654	5663	9	0.3	Zeolitic brown clay	?
17	164	173	5663	5672	9	1	Zeolitic brown clay and chert	Cenomanian to Turonian
18	173	182	5672	5681	9	0.3	Zeolitic brown clay	Cenomanian to Turonian
19	182	192	5681	5691	10	7	Zeolitic brown clay and chert	Cenomanian to Turonian
20	192	201	5691	5700	9	0.5	Zeolitic brown clay	?
21	201	210	5700	5709	9	0.5	Zeolitic brown claystone	?
22	210	220	5709	5719	10	0.1	Cherty mudstone	?
23	220	229	5719	5728	9	0	Chert fragments	?
24	229	238	5728	5737	9	0.5	Chert fragments	?
25	238	247	5737	5746	9	1.5	Chert and calcareous mud	Barremian to Albian
26	247	256	5746	5755	9	CC	Chert and mud with rare nannofossils	?
27	256	265	5755	5764	9	0.5	Chert and Basalt	
28	265	274	5764	5773	9	8.5	Basalt	

[a] Measured from the derrick floor.

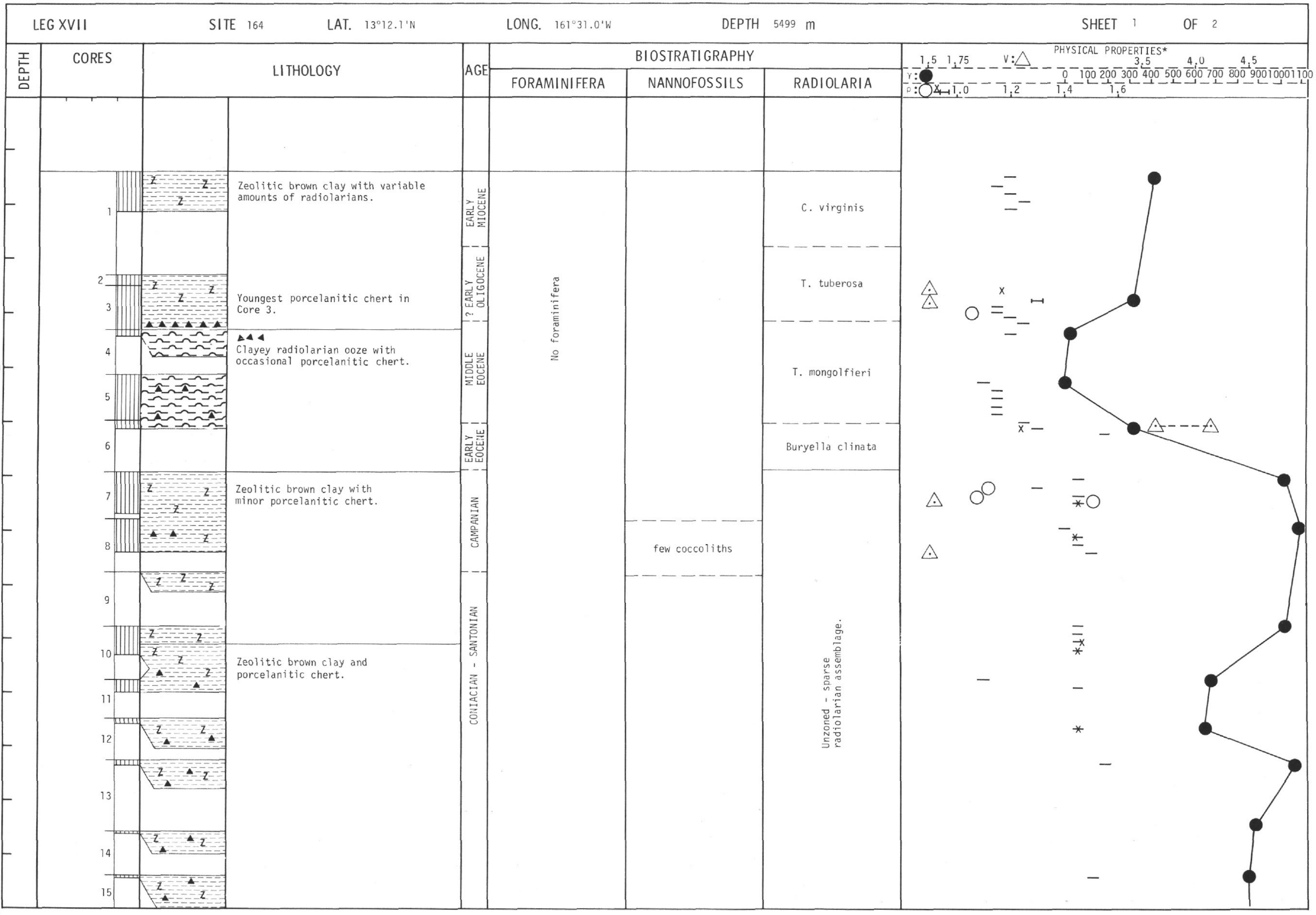
APPENDIX B
Physical Properties – Site 164

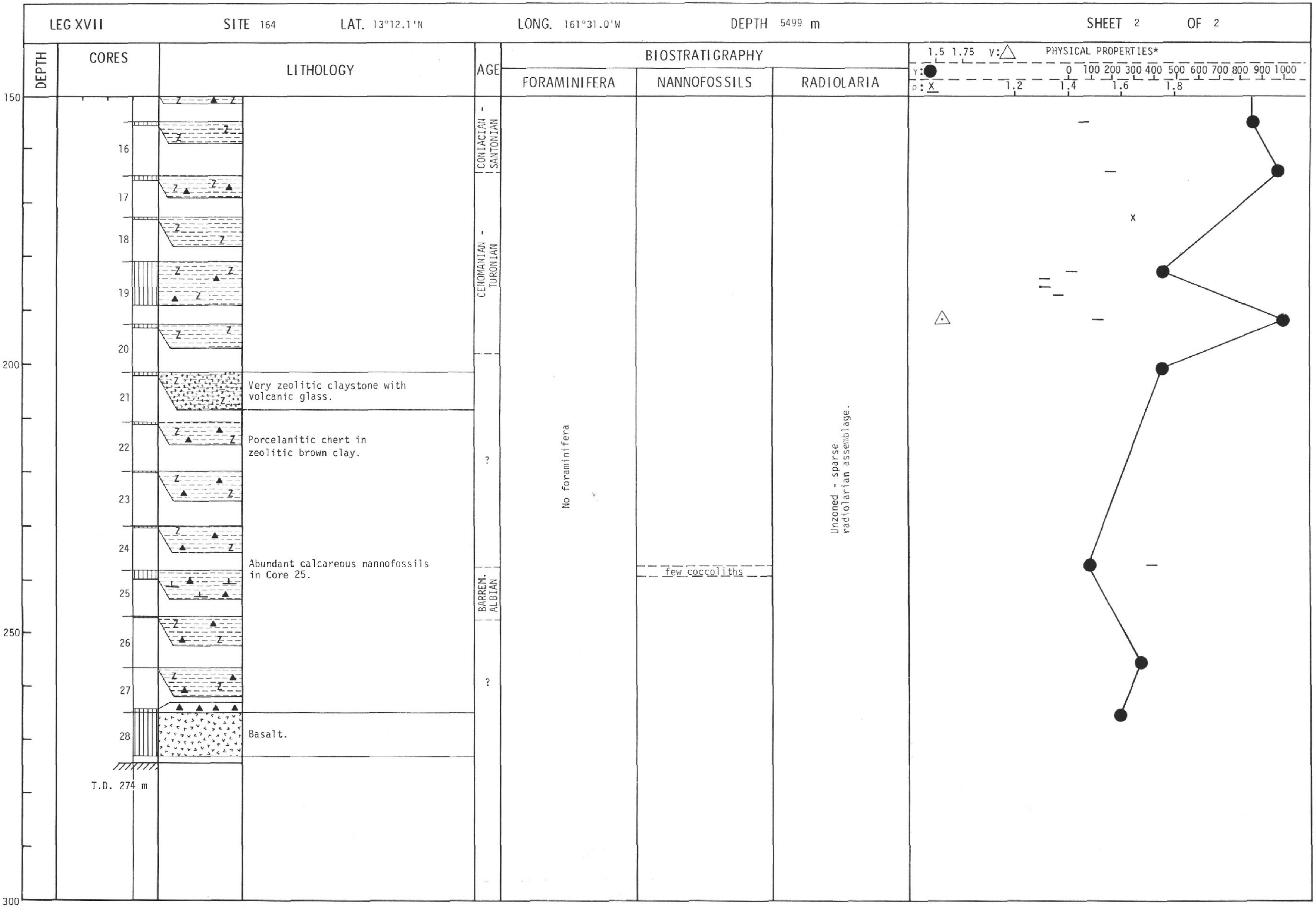
Core-Section	Section Weight Wet Bulk Density (g/cc)	GRAPE					Syringe				Natural Gamma Radiation		Sonic Velocity	
		Wet Bulk Density		Assigned Grain Density (g/cc)	Porosity		Interval Sampled (cm)	Wet Bulk Density (g/cc)	Grain Density (g/cc)	Porosity (%)	Total Count	Net	Interval Sampled (cm)	(km/sec)
		Total Range (g/cc)	Undisturbed (g/cc)		Total Range (%)	Undisturbed (%)								
1-1		1.2		2.75	89.8						1700	425		
1-2		1.15		2.75	92.6									
1-3		1.2		2.75	89.8									
1-4		1.25		2.75	86.9									
1-5		1.2		2.75	89.8									
2-2								1.17	1.91	83			43	1.51
													74	1.52
													105	1.52
3-1		1.3	1.3	2.6	82.4						1600	325	33	1.49
													57	1.51
													95	1.49
													105	1.49
3-2		1.15		2.6	92.0									
3-3	1.06	1.15		2.6	92.0									
3-4		1.2		2.6	88.8									
3-5		1.25		2.6	85.6									
4-1		1.2		2.75	89.8						1300	25		
5-1		1.1		2.3	94.0						1300	0		
5-2		1.15		2.3	90.1									
5-3		1.15		2.3	90.1									
5-4		1.15		2.3	90.1									
5-5		1.15		2.3	90.1									
5-6		1.25		2.3	82.2									
5-CC														3.6-4.1
6-1		1.3		2.6	82.4		63	1.24	1.83	74	1600	325		
6-2		1.55		2.6	66.6									
7-1		1.45	1.45	2.5	71.1	71.1					2300	1025		
7-2	1.12	1.3		2.5	81.3									
7-4	1.08	1.45	1.45	2.5	71.1	71.1								
7-5	1.51	1.45	1.45	2.5	71.1	71.1	60	1.45	2.41	70			23	1.52
													74	1.49
													121	1.60
8-1		1.4	1.4	2.5	74.5						2400	1100		
8-2		1.45	1.45	2.5	71.1	71.1	60	1.44	2.54	72				
8-3		1.45	1.45	2.5	71.1	71.1								
8-4		1.5	1.45	2.5	67.7	71.1							35	1.49
													77	1.50
													127	1.49
10-1		1.45	1.45	2.75	75.3	75.3					2300	1025		
10-2		1.45	1.45	2.75	75.3	75.3								
10-3		1.45		2.75	75.3		70	1.47	2.34	66				
10-4		1.45		2.75	75.3		85	1.45	2.10	61				

APPENDIX B – *Continued*

		GRAPE					Syringe				Natural Gamma Radiation		Sonic Velocity	
		Wet Bulk Density			Porosity									
Core-Section	Section Weight Wet Bulk Density (g/cc)	Total Range (g/cc)	Undisturbed (g/cc)	Assigned Grain Density (g/cc)	Total Range (%)	Undisturbed (%)	Interval Sampled (cm)	Wet Bulk Density (g/cc)	Grain Density (g/cc)	Porosity (%)	Total Count	Net	Interval Sampled (cm)	(km/sec)
11-1		1.1		2.75	95.5						1900	675		
11-2		1.45		2.75	75.3									
12-1		1.4		2.75	78.2		119	1.45	2.25	65	1900	650		
13-1		1.55	1.55	2.75	69.5	69.5					2300	1075		
14-1		1.45		2.75	75.3						2100	875		
15-1		1.50		2.75	72.4						2100	850		
16-1		1.45		2.75	75.3						2100	850		
17-1		1.55	1.55	2.75	69.5	69.5					2200	925		
18-1							57	1.63	2.63	62				
19-1		1.4		2.75	78.2						1700	425		
19-2		1.3		2.75	84.0									
19-3		1.3		2.75	84.0									
19-4		1.35		2.75	81.1									
20-1		1.5	1.5	2.75	72.4	72.4					2300	1000	124	1.55
													132	1.53
20-CC														1.57
21											1700	425		
25-1		1.7		2.75	60.8						1300	75		
27											1500	325		
28-1											1400	225	80	5.25-5.47
28-2													61	5.16-5.50
28-3													82	5.37-5.65

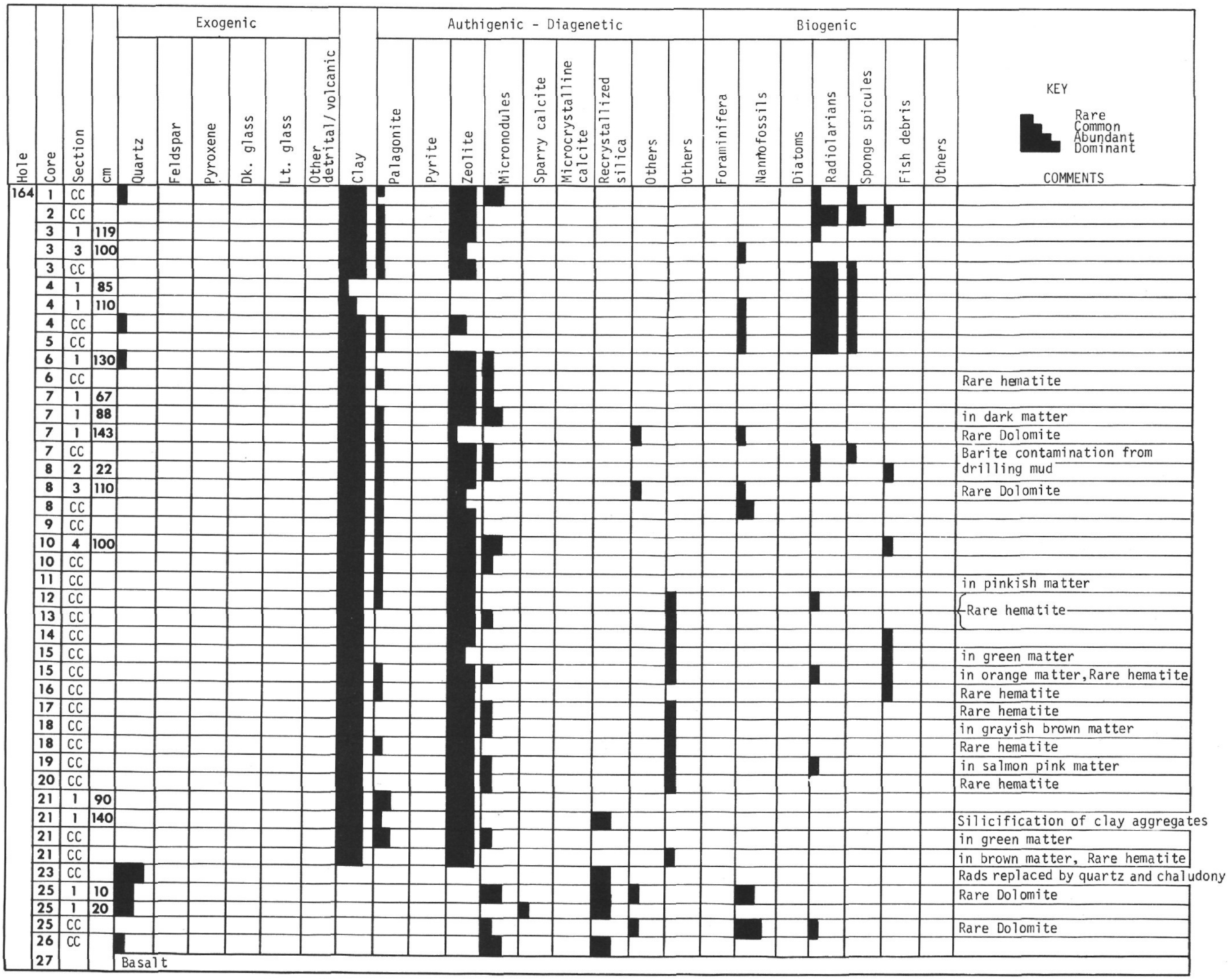
LEG XVII SITE 164 LAT. 13°12.1'N LONG. 161°31.0'W DEPTH 5499 m SHEET 1 OF 2



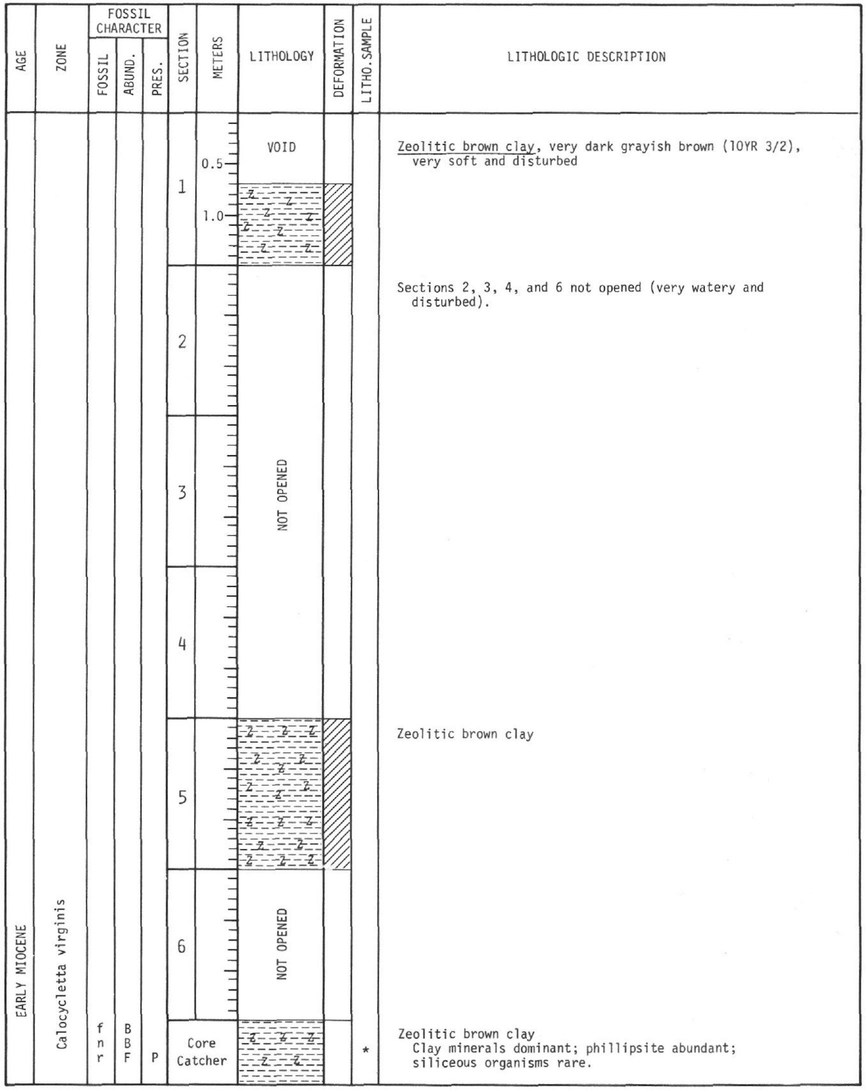

LEG XVII
SITE 164
LAT. 13°12.1'N
LONG. 161°31.0'W
DEPTH 5499 m
SHEET 2 OF 2
DEPTH
CORES
LITHOLOGY
AGE
BIOSTRATIGRAPHY
FORAMINIFERA
NANNOFOSSILS
RADIOLARIA
1.5 1.75 V:△
PHYSICAL PROPERTIES*
Y:●
0 100 200 300 400 500 600 700 800 900 1000
ρ: X
1.2 1.4 1.6 1.8
150
200
250
300
16
17
18
19
20
21
22
23
24
25
26
27
28
T.D. 274 m
Very zeolitic claystone with volcanic glass.
Porcelanitic chert in zeolitic brown clay.
Abundant calcareous nannofossils in Core 25.
Basalt.
CONIACIAN - SANTONIAN
CENOMANIAN - TURONIAN
?
BARREM. ALBIAN
?
No foraminifera
few coccoliths
Unzoned - sparse radiolarian assemblage.
x

SITE 164

SMEAR SLIDE SUMMARY



Site 164 Hole Core 1 Cored Interval: 14 to 34 m



Zeolitic brown clay, very dark grayish brown (10YR 3/2), very soft and disturbed

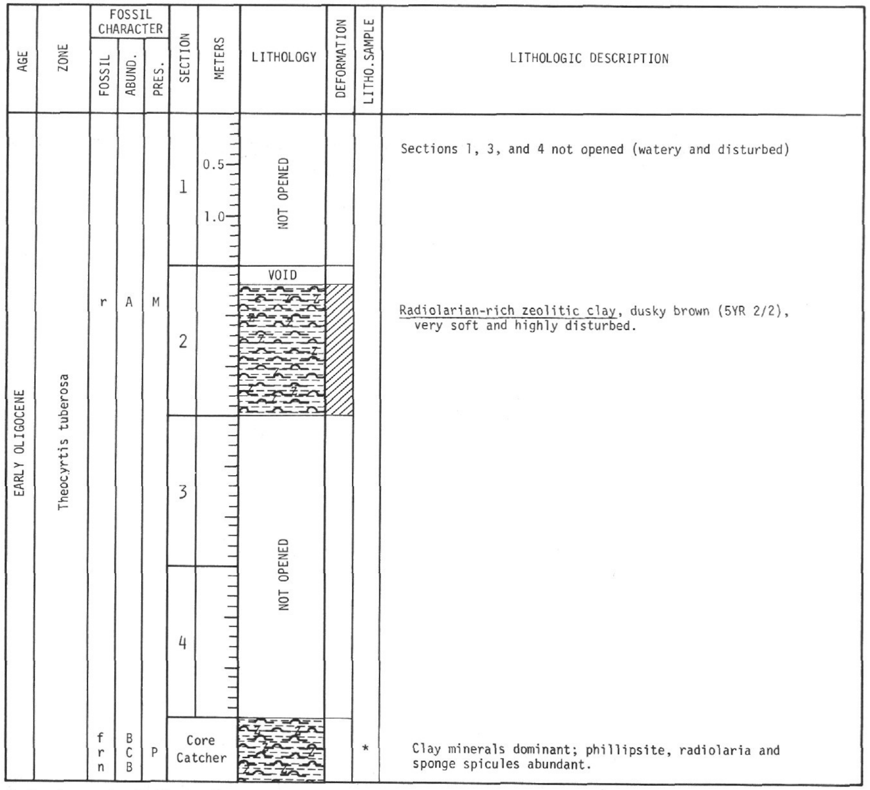
Sections 2, 3, 4, and 6 not opened (very watery and disturbed).

Zeolitic brown clay

Zeolitic brown clay
Clay minerals dominant; phillipsite abundant; siliceous organisms rare.

Explanatory notes in Chapter 1

Site 164 Hole Core 2 Cored Interval: 34 to 37 m?



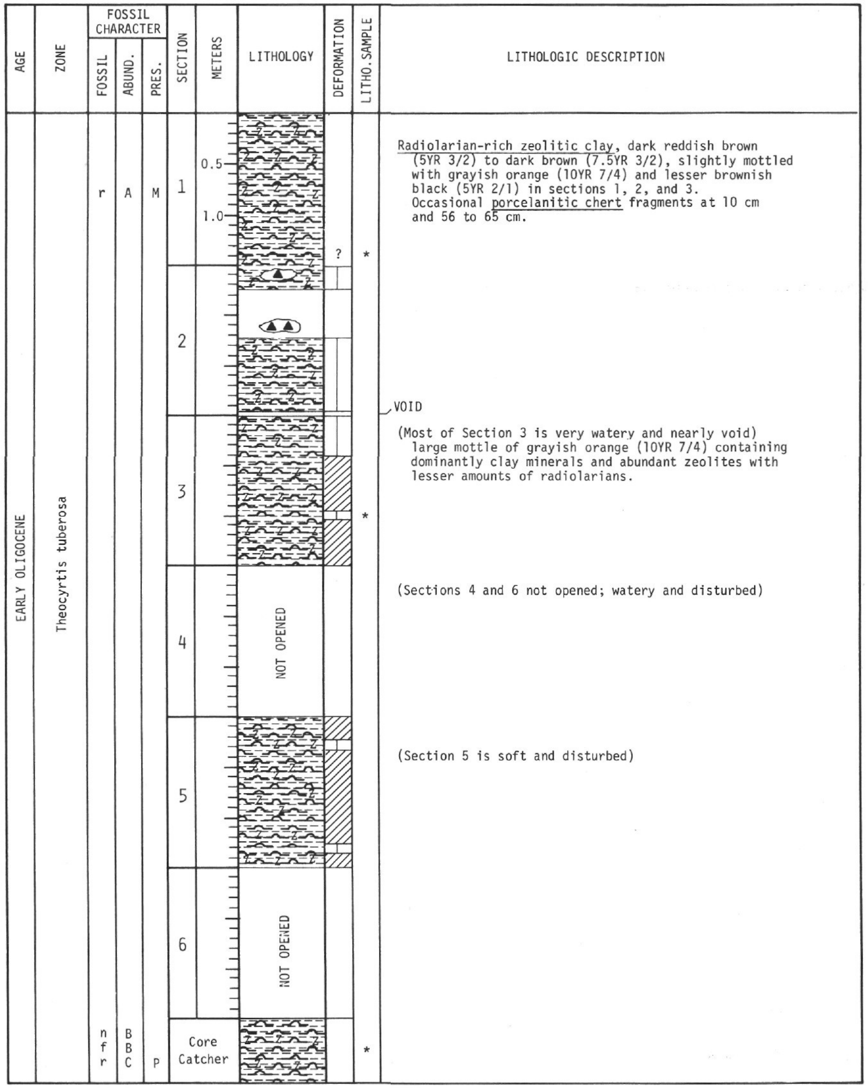
Sections 1, 3, and 4 not opened (watery and disturbed)

Radiolarian-rich zeolitic clay, dusky brown (5YR 2/2), very soft and highly disturbed.

Clay minerals dominant; phillipsite, radiolaria and sponge spicules abundant.

Explanatory notes in Chapter 1

Site 164 Hole Core 3 Cored Interval: 37 to 43 m



Radiolarian-rich zeolitic clay, dark reddish brown (5YR 3/2) to dark brown (7.5YR 3/2), slightly mottled with grayish orange (10YR 7/4) and lesser brownish black (5YR 2/1) in sections 1, 2, and 3. Occasional porcelanitic chert fragments at 10 cm and 56 to 65 cm.

VOID

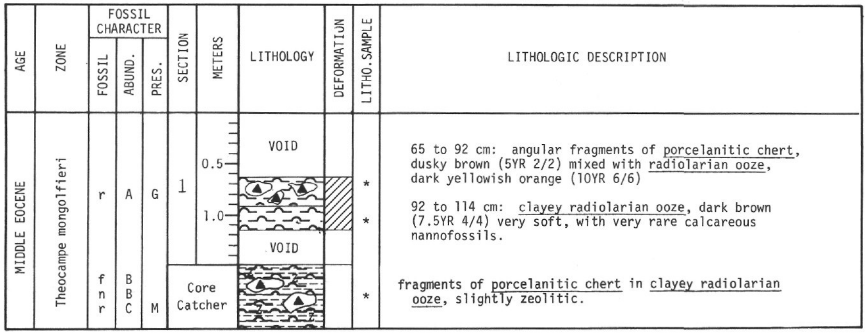
(Most of Section 3 is very watery and nearly void) large mottle of grayish orange (10YR 7/4) containing dominantly clay minerals and abundant zeolites with lesser amounts of radiolarians.

(Sections 4 and 6 not opened; watery and disturbed)

(Section 5 is soft and disturbed)

Explanatory notes in Chapter 1

Site 164 Hole Core 4 Cored Interval: 43 to 52 m



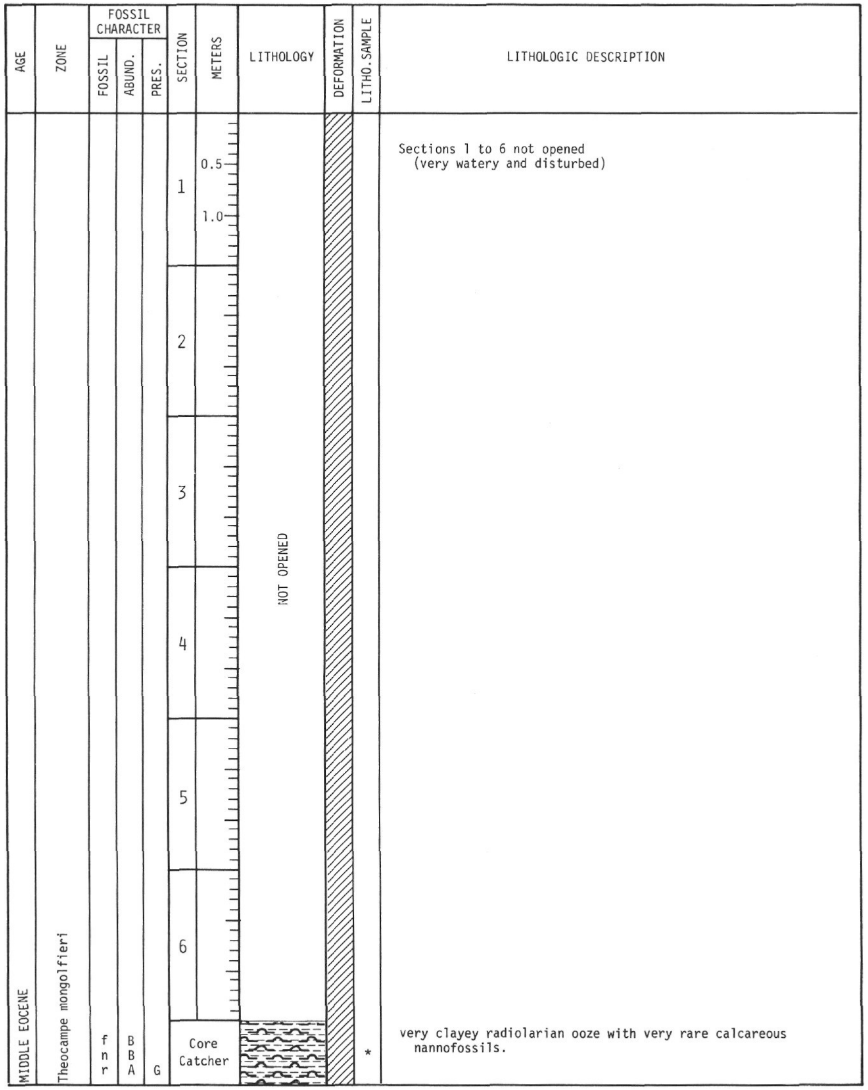
65 to 92 cm: angular fragments of porcelanitic chert, dusky brown (5YR 2/2) mixed with radiolarian ooze, dark yellowish orange (10YR 6/6)

92 to 114 cm: clayey radiolarian ooze, dark brown (7.5YR 4/4) very soft, with very rare calcareous nannofossils.

fragments of porcelanitic chert in clayey radiolarian ooze, slightly zeolitic.

Explanatory notes in Chapter 1

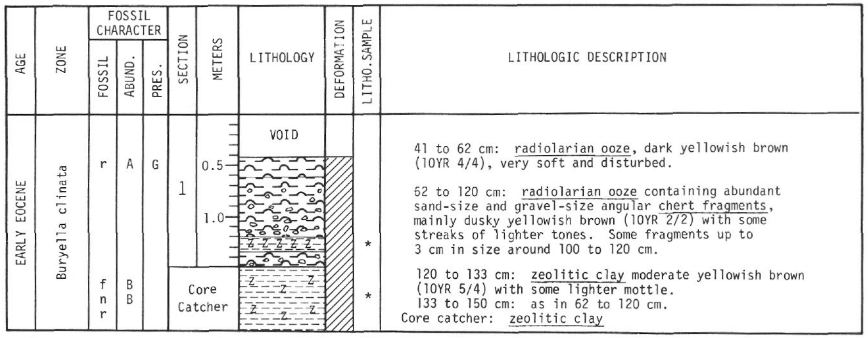
Site 164 Hole Core 5 Cored Interval: 52 to 61 m



AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
MIDDLE EOCENE	Theocampe mongolfieri				1	0.5 1.0	NOT OPENED	▨		Sections 1 to 6 not opened (very watery and disturbed)
					2			▨		
					3			▨		
					4			▨		
					5			▨		
					6			▨		
		f n r	B B A	G	Core Catcher			▨	*	very clayey radiolarian ooze with very rare calcareous nannofossils.

Explanatory notes in Chapter 1

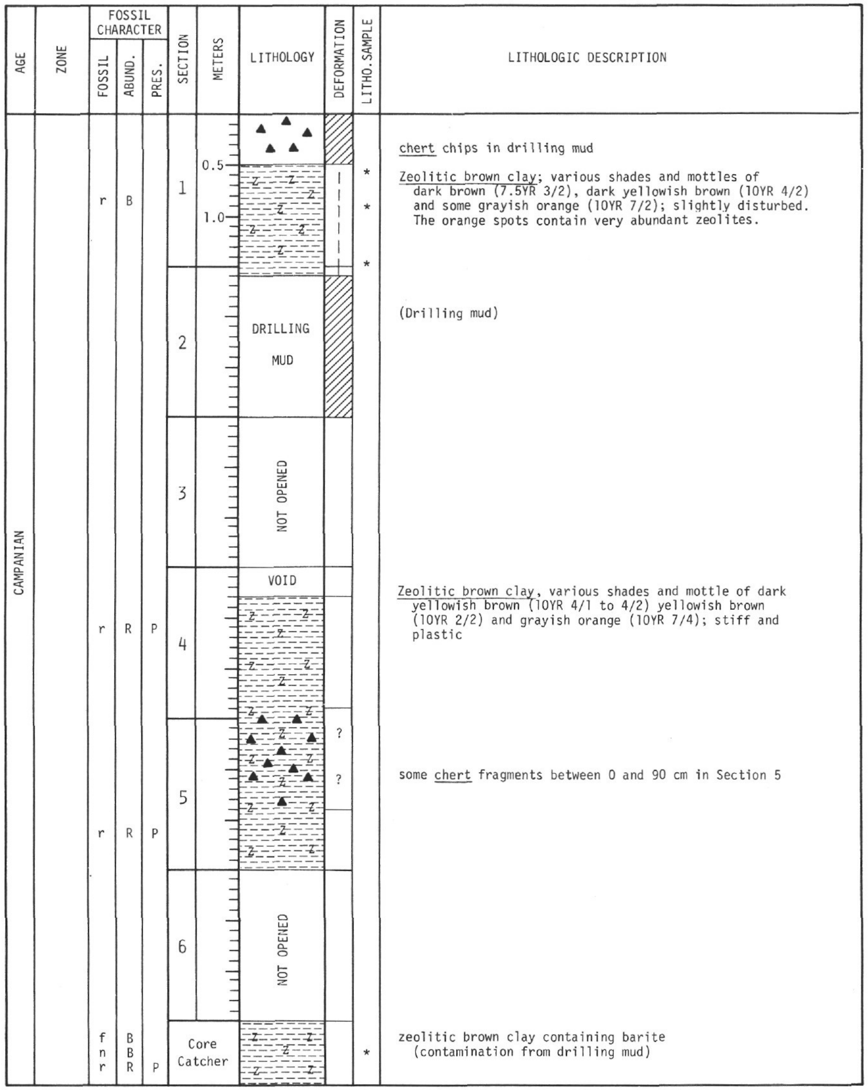
Site 164 Hole Core 6 Cored Interval: 61 to 70 m



AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
EARLY EOCENE	Buryella clinata	r	A	G	1	0.5 1.0	VOID	▨	*	41 to 62 cm: <u>radiolarian ooze</u>, dark yellowish brown (10YR 4/4), very soft and disturbed. 62 to 120 cm: radiolarian ooze containing abundant sand-size and gravel-size angular chert fragments, mainly dusky yellowish brown (10YR 2/2) with some streaks of lighter tones. Some fragments up to 3 cm in size around 100 to 120 cm. 120 to 133 cm: zeolitic clay moderate yellowish brown (10YR 5/4) with some lighter mottle. 133 to 150 cm: as in 62 to 120 cm.
		f n r	B B		Core Catcher			▨	*	Core catcher: zeolitic clay

Explanatory notes in Chapter 1

Site 164 Hole Core 7 Cored Interval: 70 to 79 m



chert chips in drilling mud

Zeolitic brown clay; various shades and mottles of dark brown (7.5YR 3/2), dark yellowish brown (10YR 4/2) and some grayish orange (10YR 7/2); slightly disturbed. The orange spots contain very abundant zeolites.

(Drilling mud)

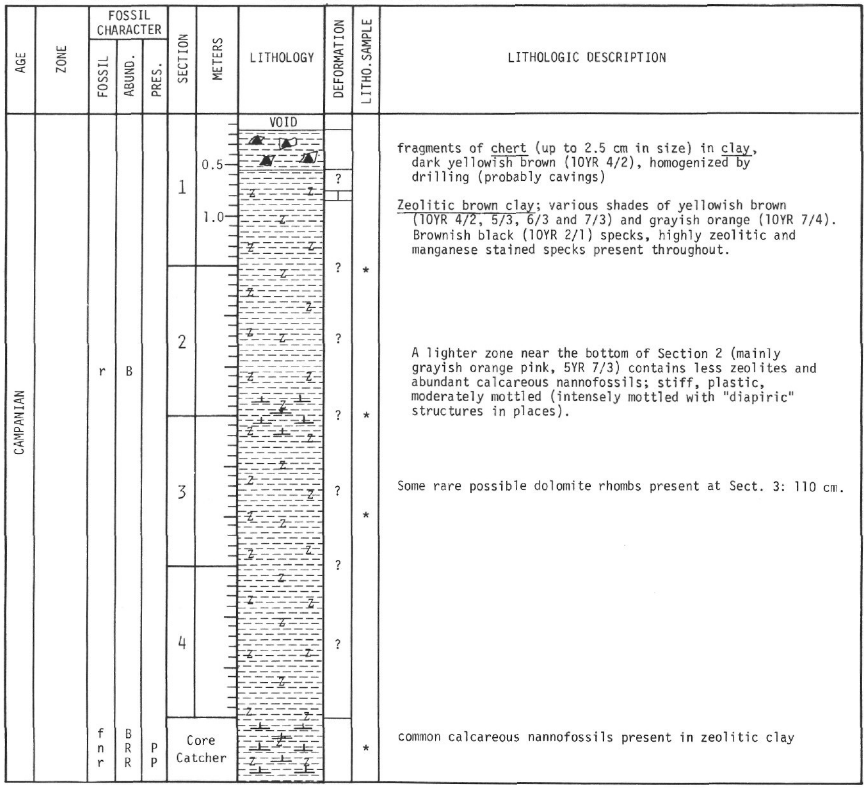
Zeolitic brown clay, various shades and mottle of dark yellowish brown (10YR 4/1 to 4/2) yellowish brown (10YR 2/2) and grayish orange (10YR 7/4); stiff and plastic

some chert fragments between 0 and 90 cm in Section 5

zeolitic brown clay containing barite (contamination from drilling mud)

Explanatory notes in Chapter 1

Site 164 Hole Core 8 Cored Interval: 79 to 88 m



fragments of chert (up to 2.5 cm in size) in clay, dark yellowish brown (10YR 4/2), homogenized by drilling (probably cavings)

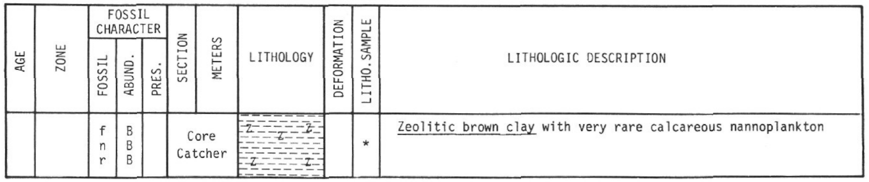
Zeolitic brown clay; various shades of yellowish brown (10YR 4/2, 5/3, 6/3 and 7/3) and grayish orange (10YR 7/4). Brownish black (10YR 2/1) specks, highly zeolitic and manganese stained specks present throughout.

A lighter zone near the bottom of Section 2 (mainly grayish orange pink, 5YR 7/3) contains less zeolites and abundant calcareous nannofossils; stiff, plastic, moderately mottled (intensely mottled with "diapiric" structures in places).

Some rare possible dolomite rhombs present at Sect. 3: 110 cm.

common calcareous nannofossils present in zeolitic clay

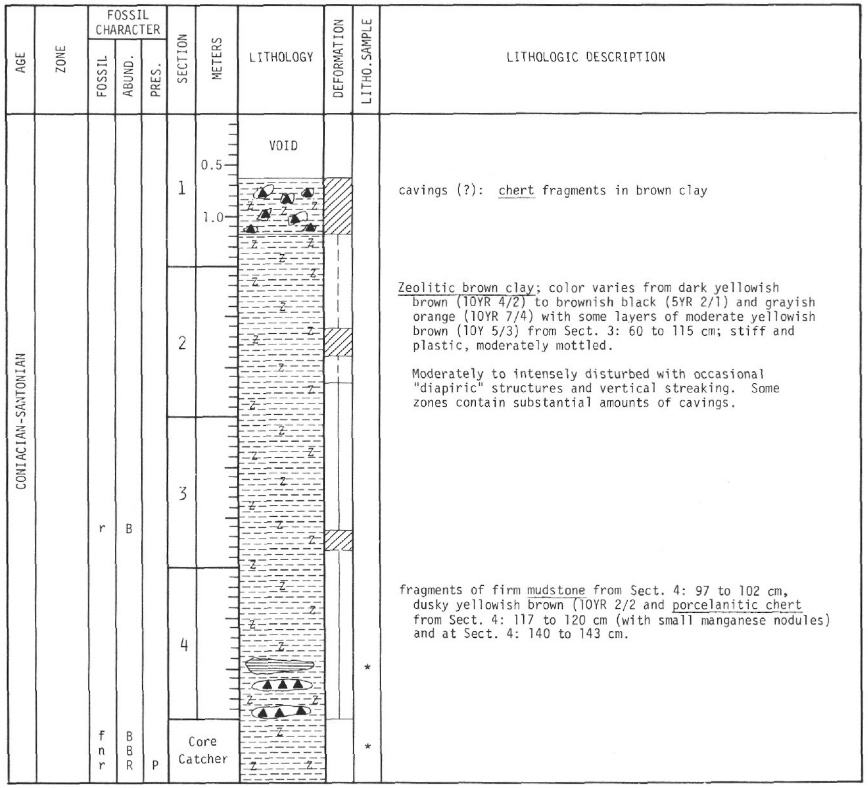
Site 164 Hole Core 9 Cored Interval: 88 to 98 m



Zeolitic brown clay with very rare calcareous nannoplankton

Explanatory notes in Chapter 1

Site 164 Hole Core 10 Cored Interval: 98 to 108 m



cavings (?): chert fragments in brown clay

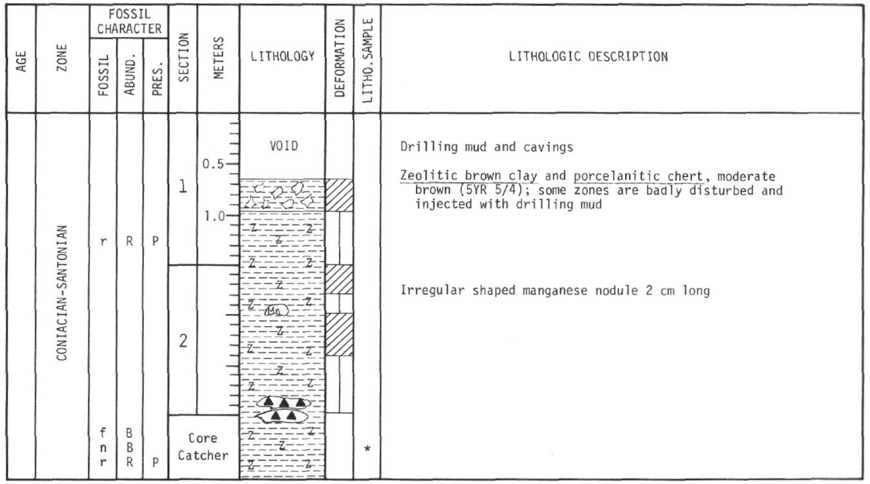
Zeolitic brown clay; color varies from dark yellowish brown (10YR 4/2) to brownish black (5YR 2/1) and grayish orange (10YR 7/4) with some layers of moderate yellowish brown (10Y 5/3) from Sect. 3: 60 to 115 cm; stiff and plastic, moderately mottled.

Moderately to intensely disturbed with occasional "diapiric" structures and vertical streaking. Some zones contain substantial amounts of cavings.

fragments of firm mudstone from Sect. 4: 97 to 102 cm, dusky yellowish brown (10YR 2/2 and porcelanitic chert from Sect. 4: 117 to 120 cm (with small manganese nodules) and at Sect. 4: 140 to 143 cm.

Explanatory notes in Chapter 1

Site 164 Hole Core 11 Cored Interval: 108 to 117 m

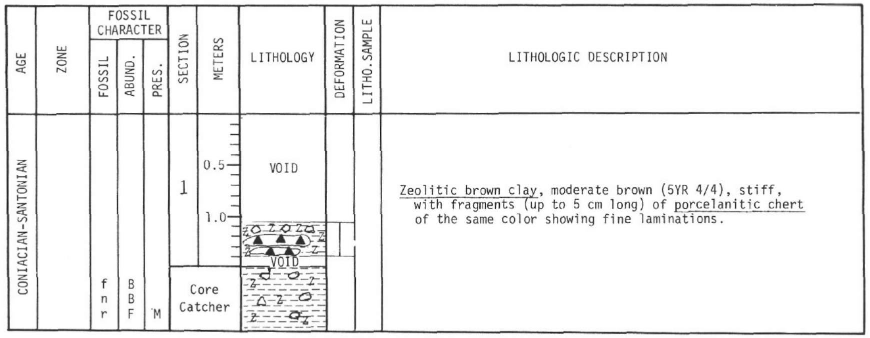


Drilling mud and cavings

Zeolitic brown clay and porcelanitic chert, moderate brown (5YR 5/4); some zones are badly disturbed and injected with drilling mud

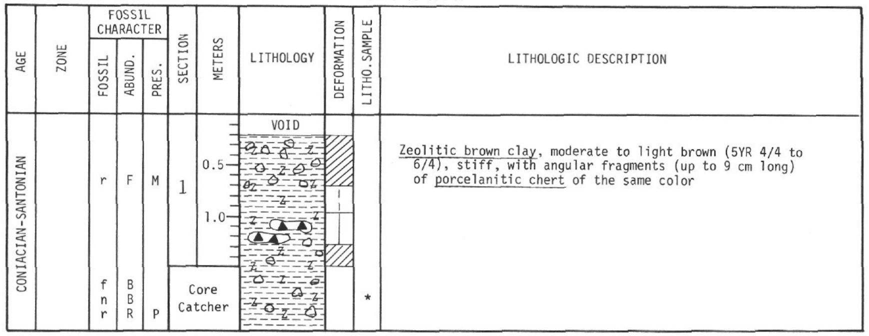
Irregular shaped manganese nodule 2 cm long

Site 164 Hole Core 12 Cored Interval: 117 to 123 m



Zeolitic brown clay, moderate brown (5YR 4/4), stiff, with fragments (up to 5 cm long) of porcelanitic chert of the same color showing fine laminations.

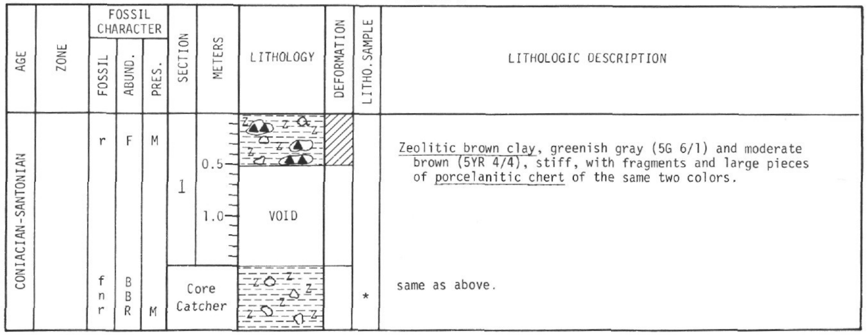
Site 164 Hole Core 13 Cored Interval: 123 to 136 m



Zeolitic brown clay, moderate to light brown (5YR 4/4 to 6/4), stiff, with angular fragments (up to 9 cm long) of porcelanitic chert of the same color

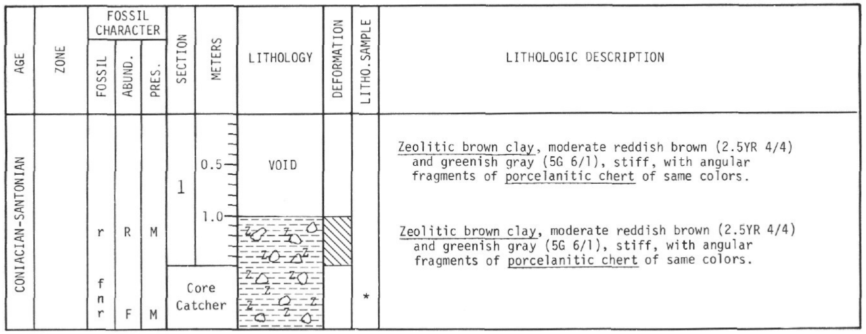
Explanatory notes in Chapter 1

Site 164 Hole Core 14 Cored Interval: 136 to 145 m



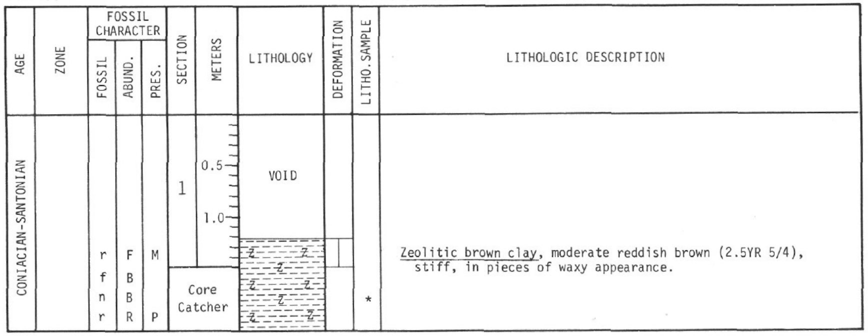
AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
CONIACIAN-SANTONIAN		r	F	M	1	0.5 1.0	VOID			Zeolitic brown clay, greenish gray (5G 6/1) and moderate brown (5YR 4/4), stiff, with fragments and large pieces of porcelanitic chert of the same two colors.
		f n r	B B R	M	Core Catcher				*	same as above.

Site 164 Hole Core 15 Cored Interval: 145 to 155 m



AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
CONIACIAN-SANTONIAN		r	R	M	1	0.5 1.0	VOID			Zeolitic brown clay, moderate reddish brown (2.5YR 4/4) and greenish gray (5G 6/1), stiff, with angular fragments of porcelanitic chert of same colors. Zeolitic brown clay, moderate reddish brown (2.5YR 4/4) and greenish gray (5G 6/1), stiff, with angular fragments of porcelanitic chert of same colors.
		f n r	F	M	Core Catcher				*	

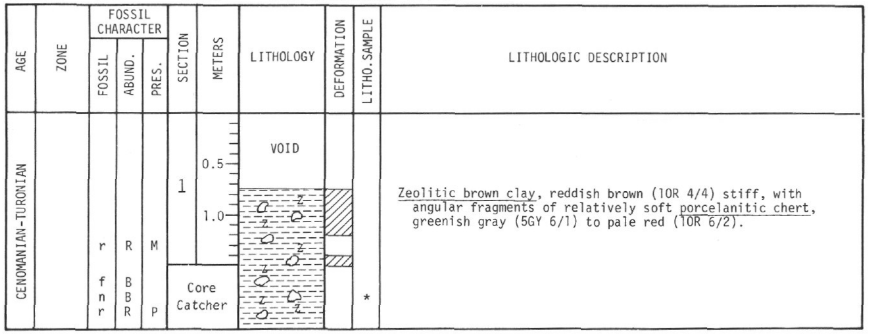
Site 164 Hole Core 16 Cored Interval: 155 to 164 m



AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
CONIACIAN-SANTONIAN		r	F	M	1	0.5 1.0	VOID			Zeolitic brown clay, moderate reddish brown (2.5YR 5/4), stiff, in pieces of waxy appearance.
		f n r	B B R	P	Core Catcher				*	

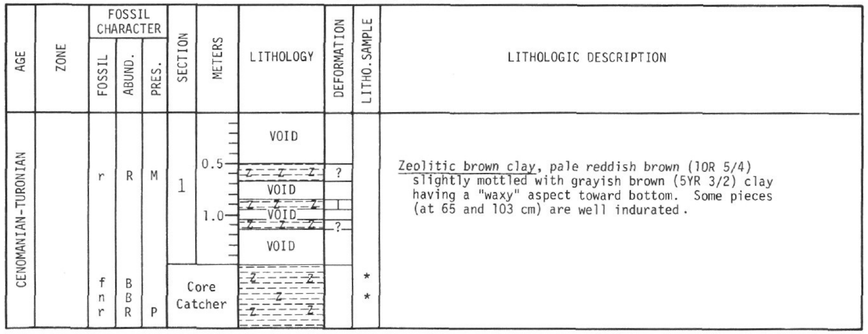
Explanatory notes in Chapter 1

Site 164 Hole Core 17 Cored Interval: 164 to 173 m



AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
CENOMANIAN-TURONIAN		r	R	M	1	0.5 1.0	VOID			Zeolitic brown clay, reddish brown (10R 4/4) stiff, with angular fragments of relatively soft porcelanitic chert, greenish gray (5GY 6/1) to pale red (10R 6/2).
		f n r	B B R	P	Core Catcher				*	

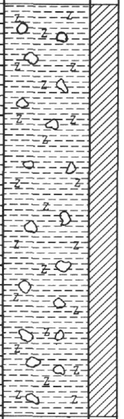
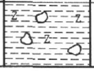
Site 164 Hole Core 18 Cored Interval: 173 to 182 m



AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
CENOMANIAN-TURONIAN		r	R	M	1	0.5 1.0	VOID VOID VOID VOID	? ?		Zeolitic brown clay, pale reddish brown (10R 5/4) slightly mottled with grayish brown (5YR 3/2) clay having a "waxy" aspect toward bottom. Some pieces (at 65 and 103 cm) are well indurated.
		f n r	B B R	P	Core Catcher				* *	

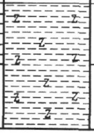
Explanatory notes in Chapter 1

Site 164 Hole Core 19 Cored Interval: 182 to 192 m

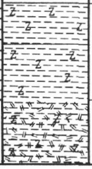
AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
CENOMANIAN-TURONIAN					1	0.5 1.0	VOID 			Zeolitic brown clay and fragments of porcelanitic chert and claystone, all homogenized during coring operation. Color varies from grayish red (10R 4/2) to moderate yellowish brown (5 to 10YR 5/4) and moderate brown (5YR 5/3). The amount of porcelanitic fragments seems to decrease from top to bottom.
		r	R	P	2					
					3					
					4		NOT OPENED			(Sections 4, 5, and 6 not opened, very disturbed)
					5					
					6					
		f n r	B B R	P	Core Catcher				*	

Explanatory notes in Chapter 1

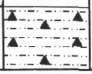
Site 164 Hole Core 20 Cored Interval: 192 to 201 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
?		r	B		1	0.5 1.0	VOID 	?		Zeolitic brown clay, moderate brown (5YR 4/4) to grayish brown (5YR 3/2) stiff and in places well indurated (claystone)
		f n r	B B B		Core Catcher				*	

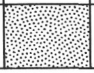
Site 164 Hole Core 21 Cored Interval: 201 to 210 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
?		r r	B R	 P	1	0.5 1.0	VOID 	? ?	* *	55 to 97 cm: Zeolitic brown claystone, well bedded, moderate brown with some grayish to brownish black beds (N2 to 5YR 2/1) probably Mn-rich. Lowest pieces are light brown (5YR 6/6 to 5YR 8/4) 97 cm to core catcher: very zeolitic claystone, mainly pale green (10G 6/2) with abundant thin (1 to 2 mm) laminae and mottles of greenish white (5G 9/1). One piece (107 cm) shows a probable Mn enrichment (brownish black, 5YR 2/1) One piece (140 cm) contains a bed of dusky green (5G 3/2) cherty claystone. Very abundant large zeolite crystals and common light glass. Zeolitic claystone
		f n r	B B R	P	Core Catcher				*	

Site 164 Hole Core 22 Cored Interval: 210 to 220 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
?							VOID			Cherty mudstone, pale brown. Thin section shows abundant radiolarian molds filled with chalcedony in a porcelanitic matrix.
					Core Catcher				TS	

Site 164 Hole Core 23 Cored Interval: 220 to 229 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
?		f n r	B B R	P	Core Catcher				*	Smear of sand size chert fragments showing radiolaria replaced by quartz and chalcedony

Explanatory notes in Chapter 1

Site 164 Hole Core 24 Cored Interval: 229 to 238 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
?		r	R	P	1	0.5 1.0	VOID			Angular fragments of chert, dusky yellowish brown (10YR 2/2). Apparent graded bedding due to coring operation. 3 to 5% of the fragments are light colored silicified mudstone. Rare fragments of very light gray (N8) coarse crystalline carbonate (vein fillings?)
					Core Catcher					

Site 164 Hole Core 25 Cored Interval: 238 to 247 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
BARREMIAN TO ALBIAN		r n	R R	P P	1	0.5 1.0	VOID VOID		* *	Angular fragments of chert, dusky yellowish brown (10YR 2/2) in a slurry of mud of the same color. Abundant quartz grains (radiolarian molds filled with chalcedonitic quartz) and rare well crystallized calcite grains (vein fillings?) The mud contains common calcareous nannoplankton (coccolithic), they are especially abundant in the core-catcher sample
		f n r	B C R	 P P	Core Catcher				*	

Site 164 Hole Core 26 Cored Interval: 247 to 256 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
?		f n r	B B F	 P	Core Catcher				*	Chert fragments with quartz and chalcedony grains (replaced radiolarians) in a mud containing rare calcareous nannoplankton.

Site 164 Hole Core 27 Cored Interval: 256 to 265 m

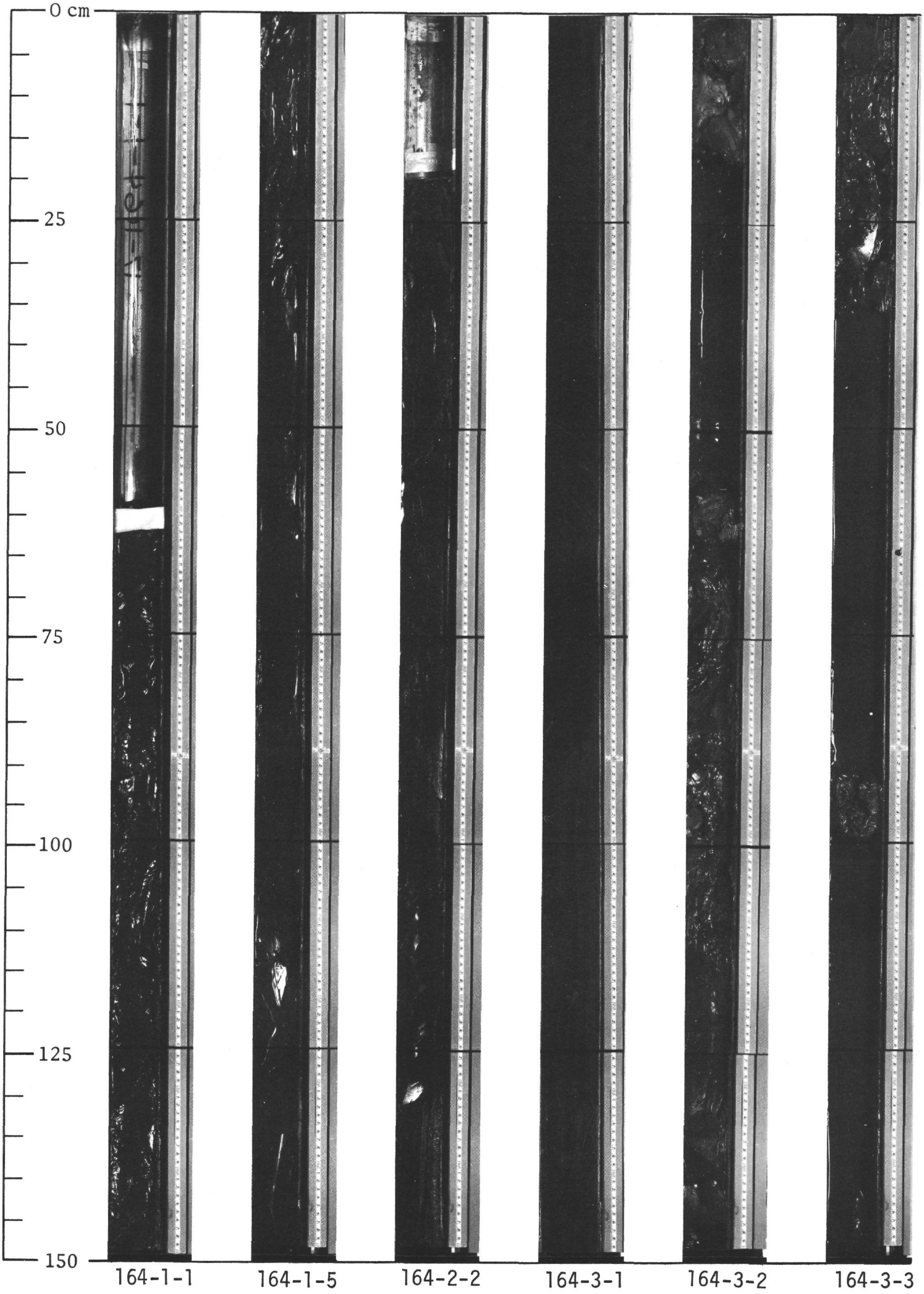
AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
					1	0.5 1.0		?	TS TS	92 to 102 cm: two pieces of chert, dusky yellowish brown (10YR 2/2) with some dark yellowish brown (10R 4/2) spots 102 to core catcher: basalt, light gray (N7) when dry, olive black (5Y 2/1) when wet. common veinlets of white calcite and grayish blue green (5BG 5/2) celadonite (?) Some amygdalus of the same minerals. Top few centimeters bleached to very pale brown (5Y 8/3)
					Core Catcher					

Explanatory notes in Chapter 1

Site 164 Hole Core 28 Cored Interval: 265 to 274 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
					1	0.5 1.0	VOID			Basalt, light gray (N7) on dry cut surfaces, dark gray (N3) to dark greenish gray (5GY 4/1) when wet. White (calcite) and green (chlorite?, chlorophanite?, celadonite?) veinlets. Common phenocrysts of feldspars (<1 mm) and rare amygdales (<2 mm)
					2					
					3					
					4					
					5					
					6					
					Core Catcher					

Explanatory notes in Chapter 1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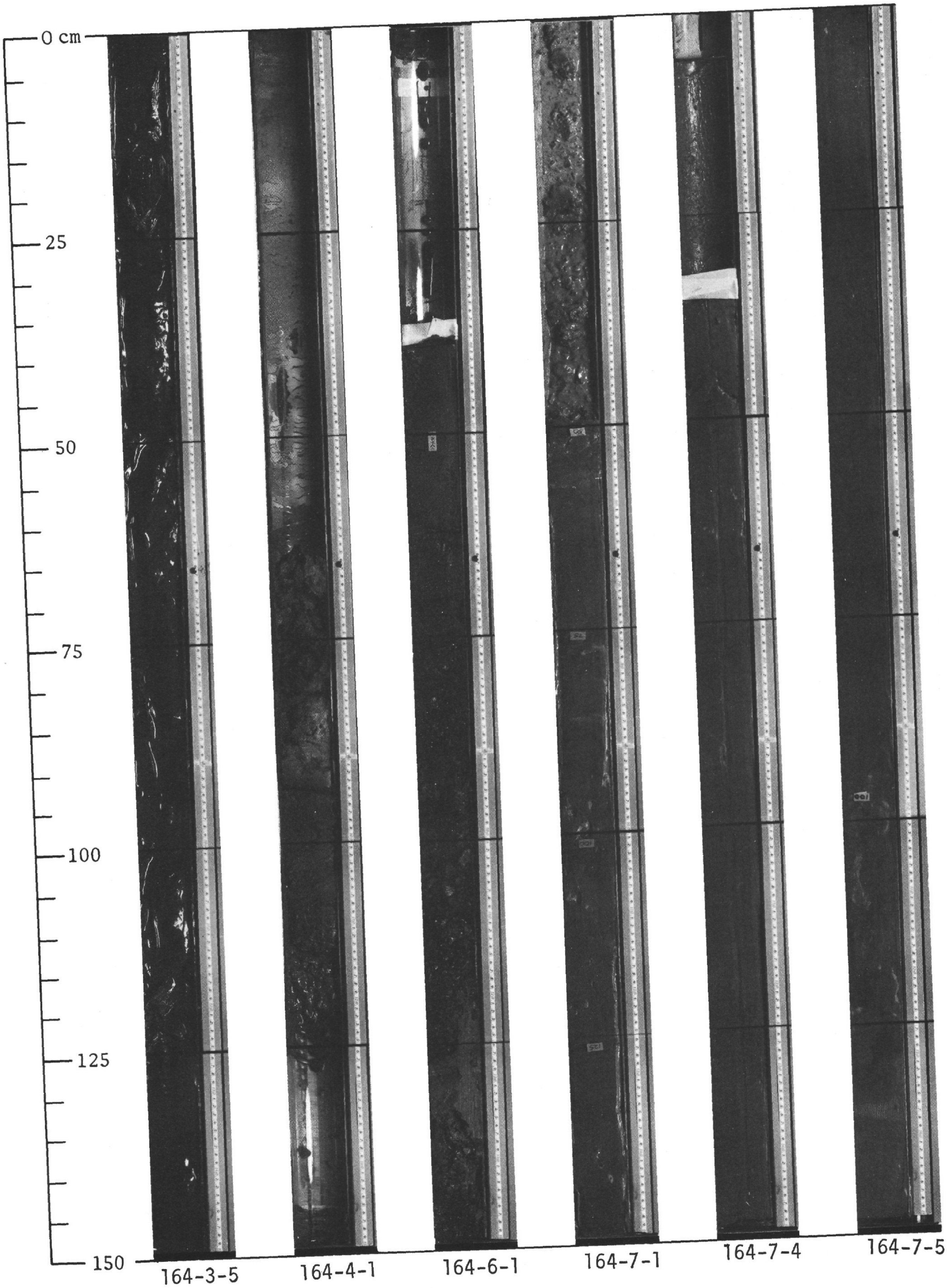
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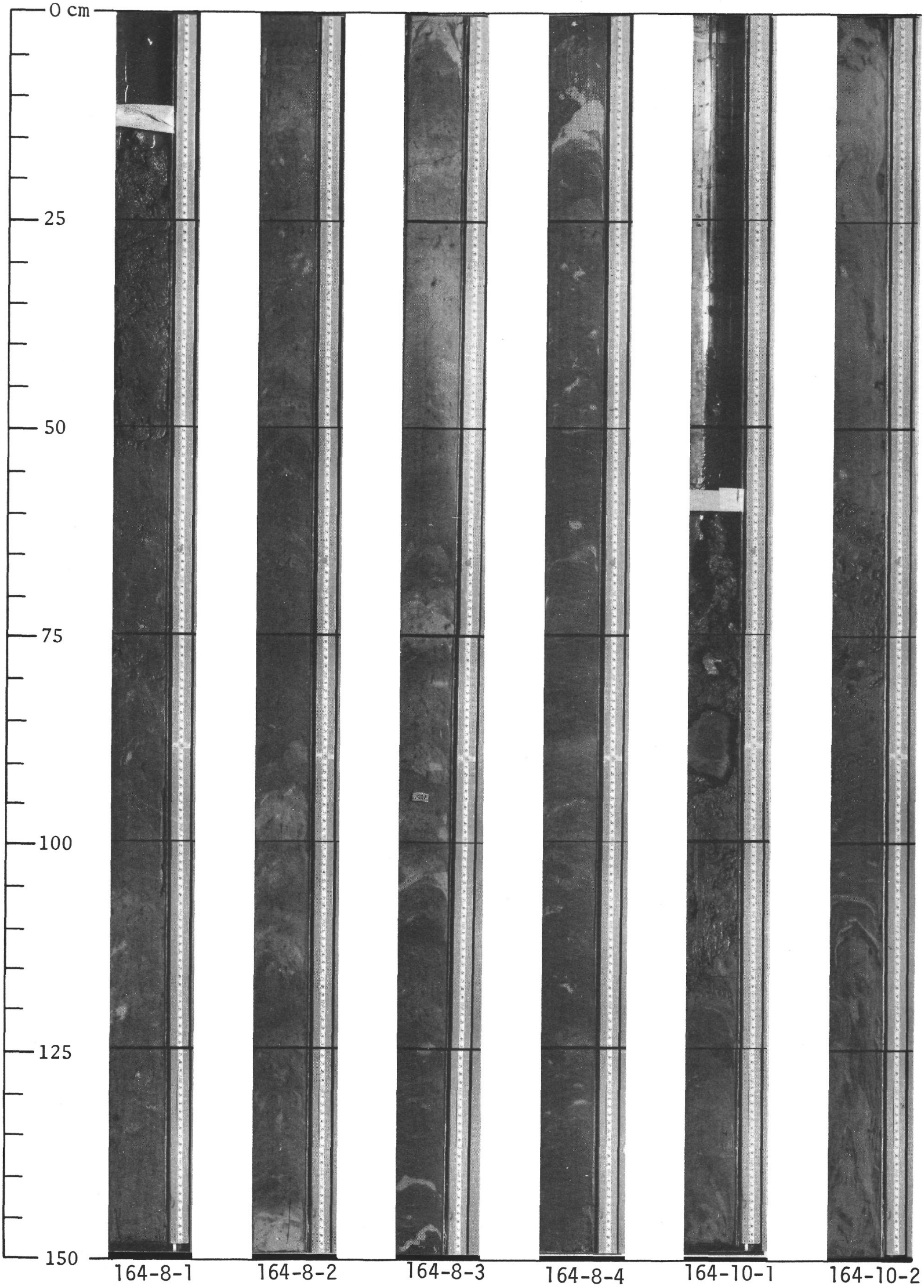
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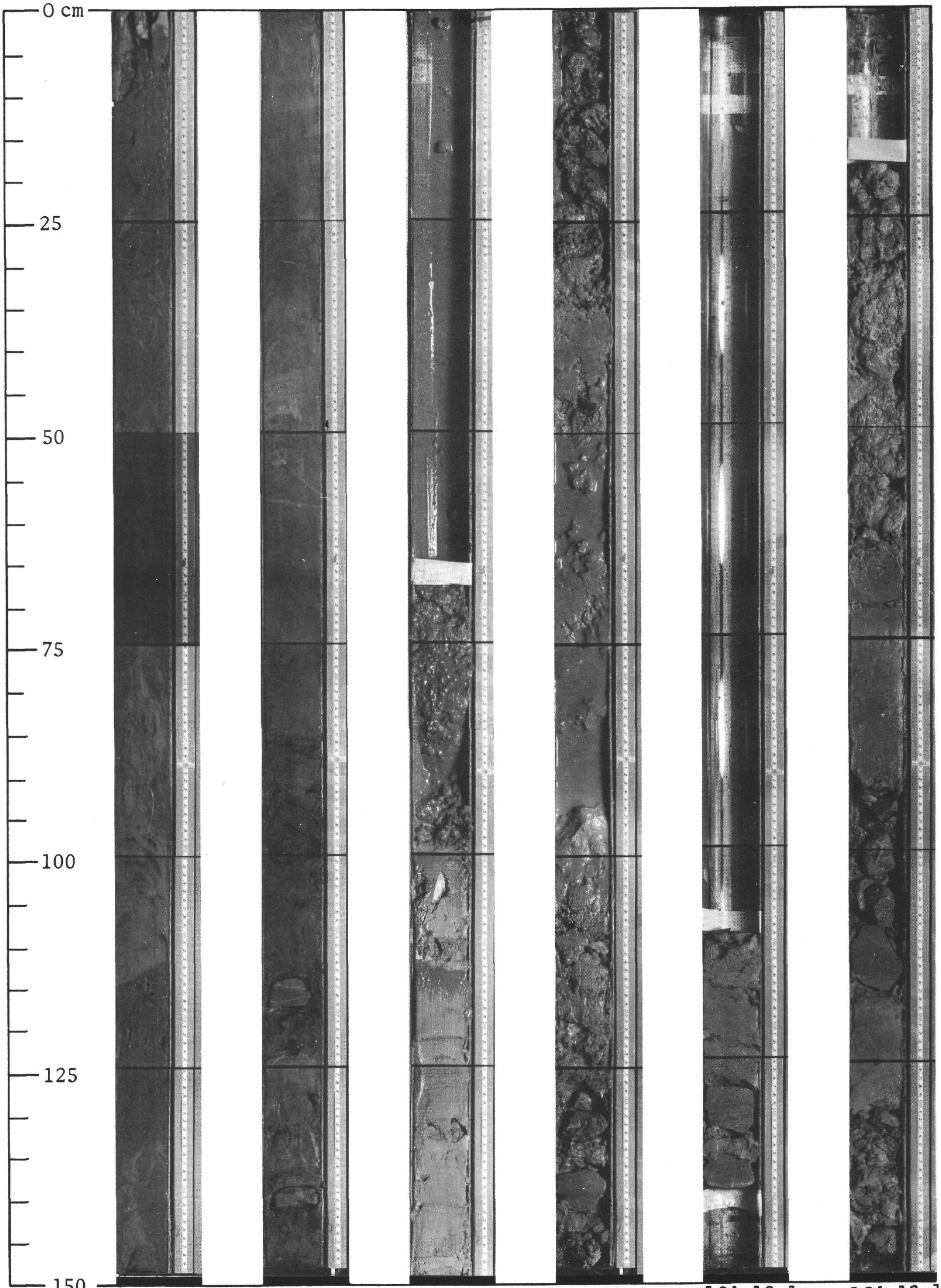

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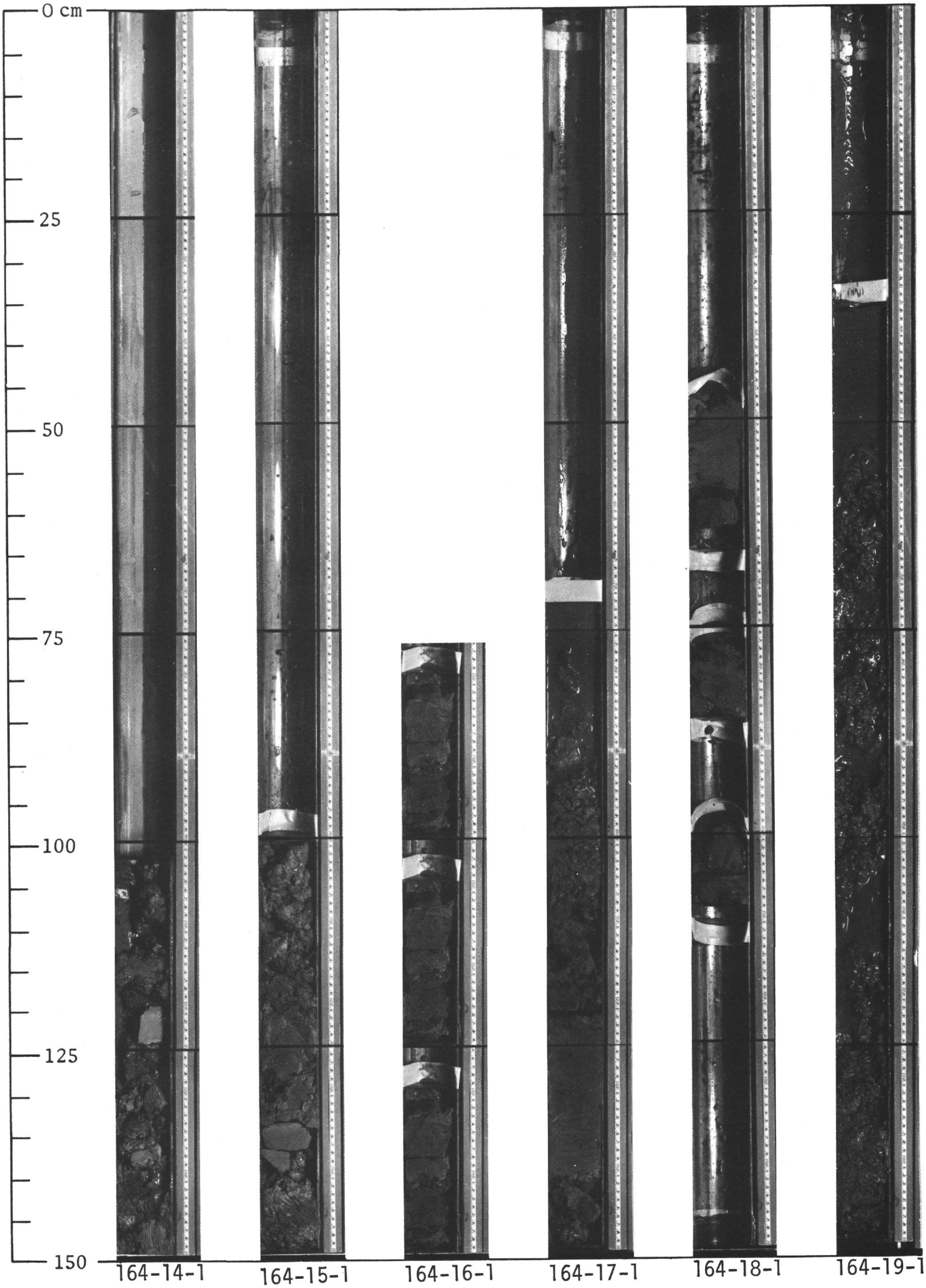
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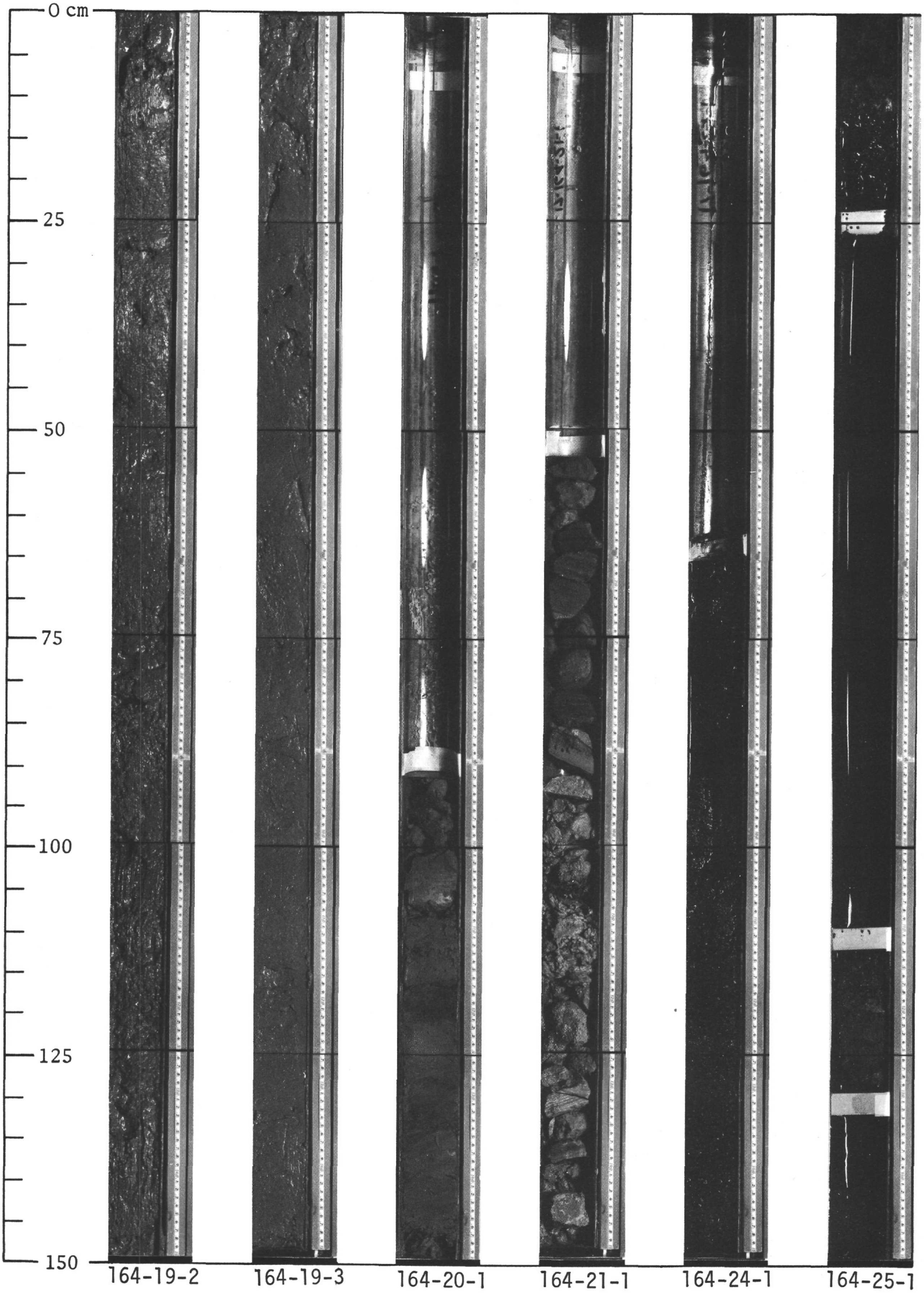
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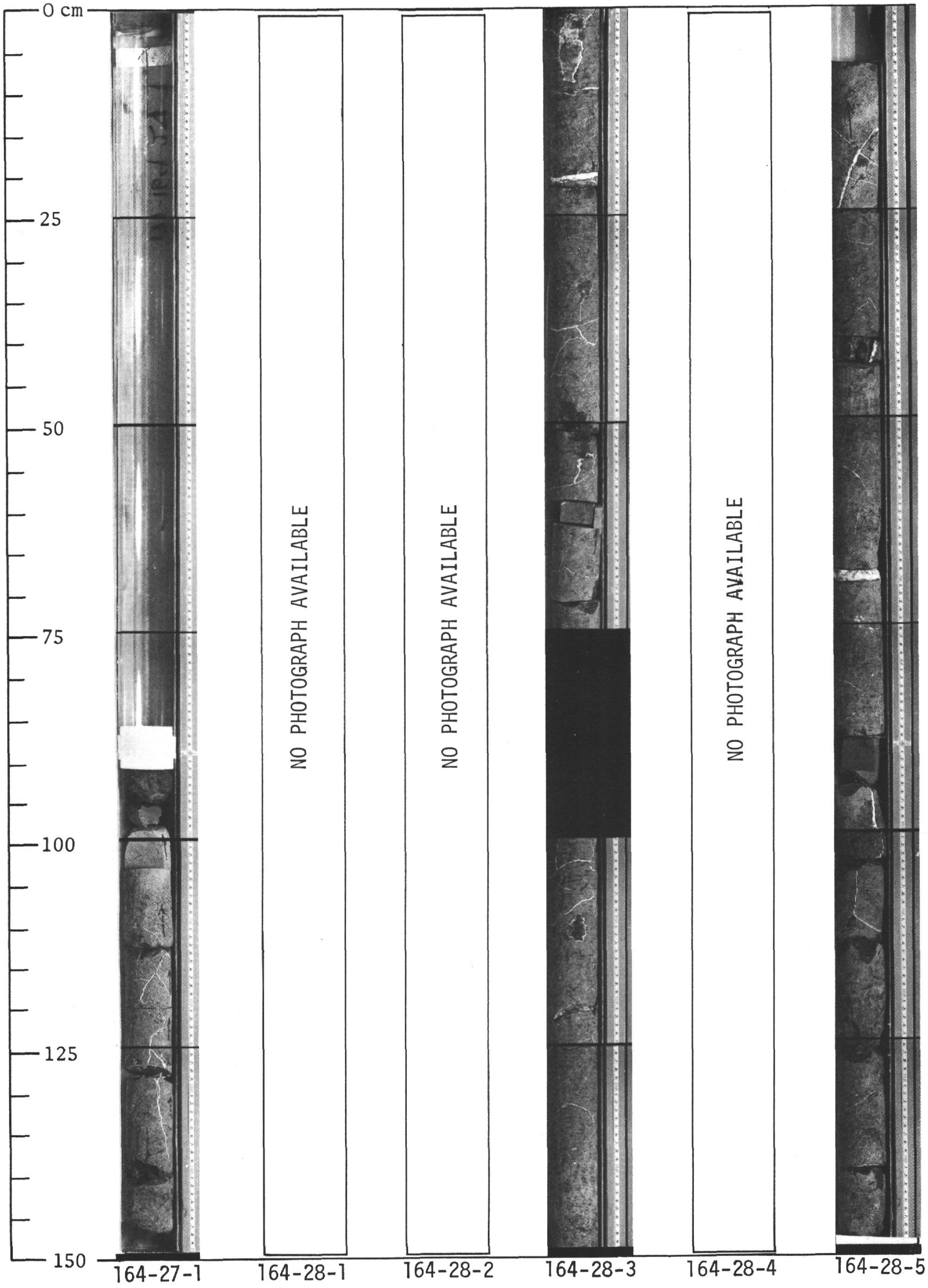
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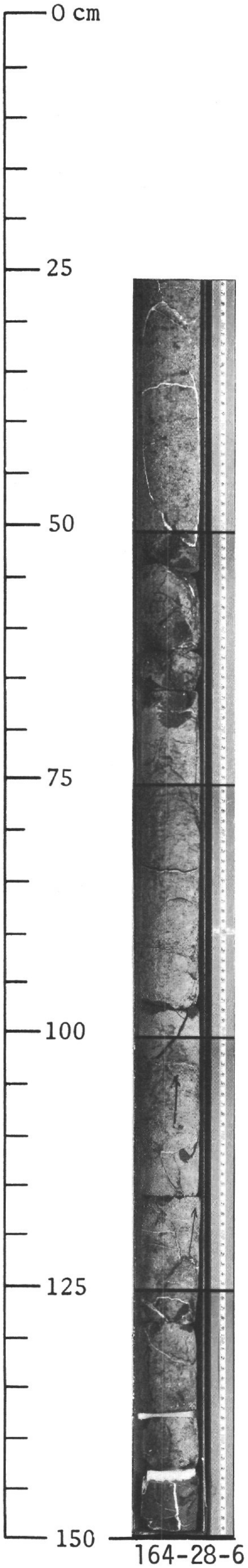

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