6. SITE 222

The Shipboard Scientific Party[1]
With Additional Report From
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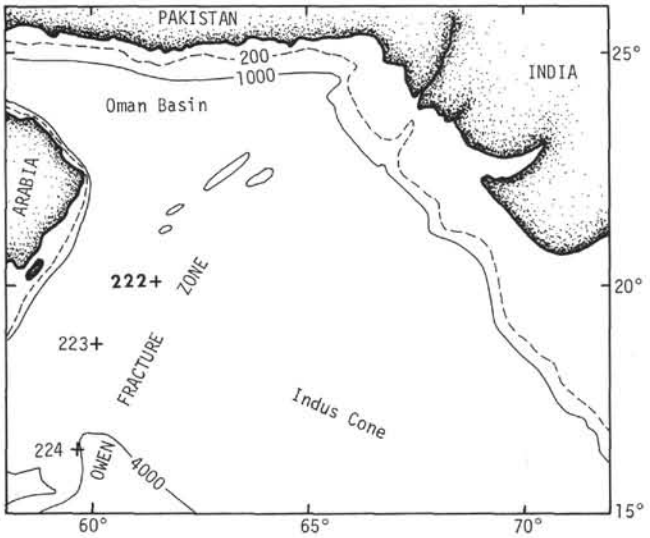
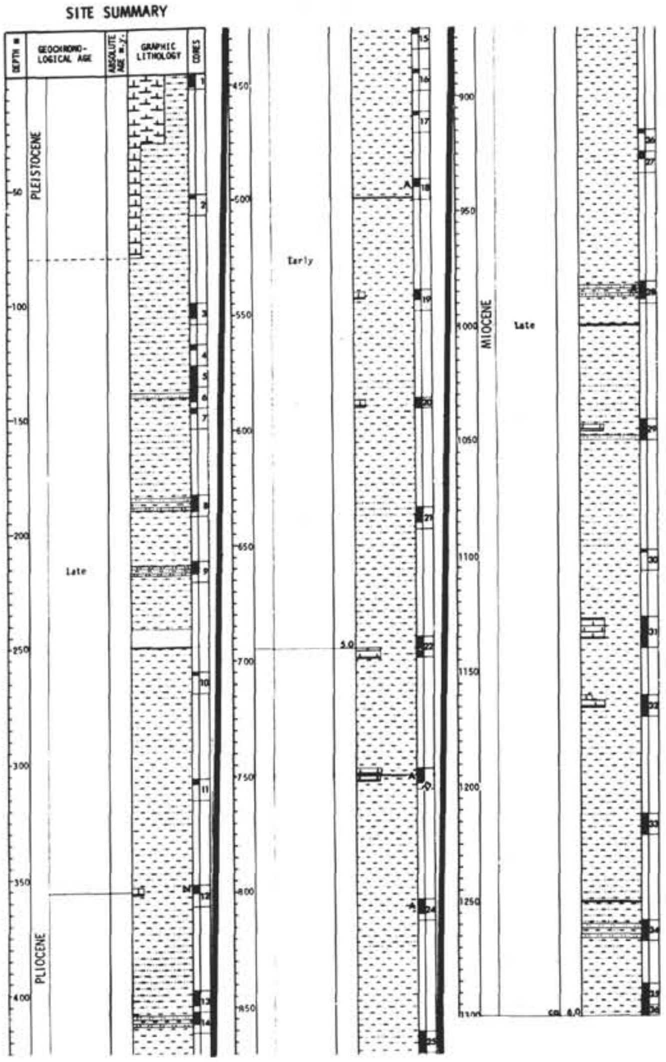


Figure 1. *Position of Site 222 and adjacent Leg 23 sites (shown by +). Contours at 200, 1000, and 4000 meters, from Laughton et al. (1971).*



SITE DATA

Dates: 1350 24 Mar–1805 30 Mar 72

Time: 148 hours

Position (Figure 1): 20°05.49′N, 61°30.56′E

Holes Drilled: 1

Water Depth by Echo-Sounder: 3546 corr. meters

Total Penetration: 1300 meters

Total Core Recovered: 175.6 meters from 36 cores

Age of Oldest Sediment: Late Miocene

Basement: Not reached

ABSTRACT

Deep-water Indus Cone sediments comprise the entire stratigraphic column penetrated here. Variable sedimentation rates characterize the column, which ranges from Late Miocene through Pleistocene time. Gray carbonate-rich detrital silty clay with associated sand and silt beds is the dominant sediment facies. It alternates with a green nanno-rich detrital silty clay facies which apparently reflects periods of slower sedimentation and a relatively greater pelagic contribution. The entire Pleistocene interval is characterized by the latter facies.

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BACKGROUND AND OBJECTIVES

The JOIDES Indian Ocean Advisory Panel had favored the drilling of at least one hole in the northern Arabian Basin. The objectives of drilling such a site would be two-fold. First, the sediments of the Indus Cone could be studied and related to the times of uplift of the Himalayas, and second, the igneous basement, if it was within reach of the drill, could be dated and thus provide a constraint on the sea floor spreading history of the region.

Only one seismic reflection profile was known to have been obtained (by *Conrad*-9) in the north Arabian Basin, and since it would have been unwise to pick a site without the guidance of reflection data, a site had to be sought along this profile.

In a study of magnetic anomalies in the Arabian Sea, McKenzie and Sclater (1971) were able to firmly identify and correlate between tracks, magnetic anomalies 23 to 26 on the Pitman and Heirtzler (1966) scale. These anomalies trend east-west north of the Carlsberg Ridge, but north of 17°N, no further sea floor spreading anamolies can be distinguished although a large positive east-west anomaly was found in an aeromagnetic survey at 20°N between 62° and 65°E (Taylor, 1968). It is in this region north of 17°N, therefore, that a site with the potential of reaching the igneous basement could give information on the age of the crust unobtainable by any other means. However, the approximate results of Neprochnov (1961) on sediment thickness beneath the Indus Cone indicate that along the track of *Conrad*-9 north of 17°N, it may exceed 2.5 seconds of two-way travel time. On the most conservative estimate, this represents 2000 meters of sediment.

The *Conrad*-9 seismic reflection profile across the Indus Cone shows well-stratified sediments for the first few hundred meters below the sea bed. Below this region, the stratification is much weaker and discontinuous and gradually merges into the background noise of the record. No strong acoustic basement is visible anywhere. However, on approaching the Owen Fracture Zone, which is the western boundary of the Indus Cone, a faint subbottom reflector sloping up towards the north-west can be seen. This reflector comes within 0.2 second of the sea bed at the edge of the fracture zone but when first distinguished lies at a depth of 0.7 second. Therefore, whatever the thickness of sediment where the *Conrad* track crosses the edge of the Indus Cone, this site does have the advantage of a near-bottom reflector which is substantially shallower than elsewhere on the seismic profile.

For the above reasons Site 222 was chosen close to the edge of the Indus Cone, where thinner sediments might be expected. The objectives of drilling the site were to:

1) Sample the Indus Cone sediments.

2) Achieve maximum penetration in an attempt to reach basement.

3) Obtain paleomagnetic samples for paleolatitude determinations ashore.

No special restraints were imposed by the JOIDES Advisory Panel on Pollution Prevention and Safety.

OPERATIONS

Site 222 was approached from the southeast on March 24 after 4 days of steaming from Site 221 across the Arabian Basin. At 20°N, 61°45′E, *Glomar Challenger* reduced speed to 8 knots and began a 4-hour site survey (Figure 2). The course to the northwest was continued and took the ship over the track of *Conrad*-9 close to the proposed site. After 9 km a westerly course was steered until four west-facing fault scarps of the Owen Fracture Zone, each less than 60 meters high, had been crossed. Because the relatively complex structure, due to the multiple scarps, made the choice of a site difficult, the strike of the fracture zone was followed to the south until the *Conrad*-9 track was reached, and then the ship turned east. Here, two 90-meter fault scarps were crossed before reaching the edge of the adjacent Indus Cone. Shortly after reaching the Cone, a site with fairly clear and well-stratified reflections was found, and the ship turned on to a reciprocal course at 5 knots at which speed the 16 kHz beacon was dropped when the site was crossed again. When all gear had been retrieved, the ship returned and took up station over the beacon.

With a thick sediment sequence anticipated at this site (more than 1000 m), a program of coring 9 meters and drilling 27 to 45 meters was planned. This program was interrupted by the occurrence of a small amount of ethane and a moderate quantity of methane in Core 3. Because of this gas show, only 9 meters was drilled before Core 4 was cut. This core also contained ethane and methane, and although their quantities had diminished somewhat, it was decided to core continuously in case the ethane content might be building up. This was done for the next 3 cores, but no increase in the ethane level above that of Core 3 was observed. Thus, with no evidence of a gas buildup with depth plus an almost complete absence of potential reservoir rocks in the section, it was decided to return to a program of alternate coring and drilling. The remaining sediment sequence was penetrated in this fashion with 9 meter cores alternating with 9 to 50 meter drilled intervals (Table 1). Shows of methane and ethane on a much diminished level persisted throughout much of the sediment sequence except in the lower half where ethane remained only as a trace and the amount of methane became quite small. Because of the gas shows, when sands were cored, they were spot-checked for hydrocarbon shows under the ultraviolet lamp; however, all tests were negative.

The degree of induration of the section gradually increased with depth except for sporadic thin, hard layers and two thick harder intervals. The thin, hard layers were generally due to either local, indurated streaks of green fossil-rich material or to partly cemented gray sand beds. Both of the thick intervals, 35 and 50 meters thick, which seemingly were not related to differences in lithology, occurred near the bottom of the hole. Naturally, all these aspects of variation in induration were translated into differences in drilling rate. The thin hard layers caused no problems, however, the thicker hard intervals, which slowed the penetration rate to 2 meters/hour, became a problem especially as they occurred at depths below 1100 meters. Finally, after drilling 35 meters of the last hard interval, penetration had practically ceased, and this became a major factor in the decision to abandon the hole. This decision was additionally influenced by the bit usage time, which by now had gone to 53 hours, and by the fact that the last core cut was substantially below gauge.

In penetrating the 1300 meters of section at Site 222, bit weight ranged from 0 to 5000 lb near the surface and up

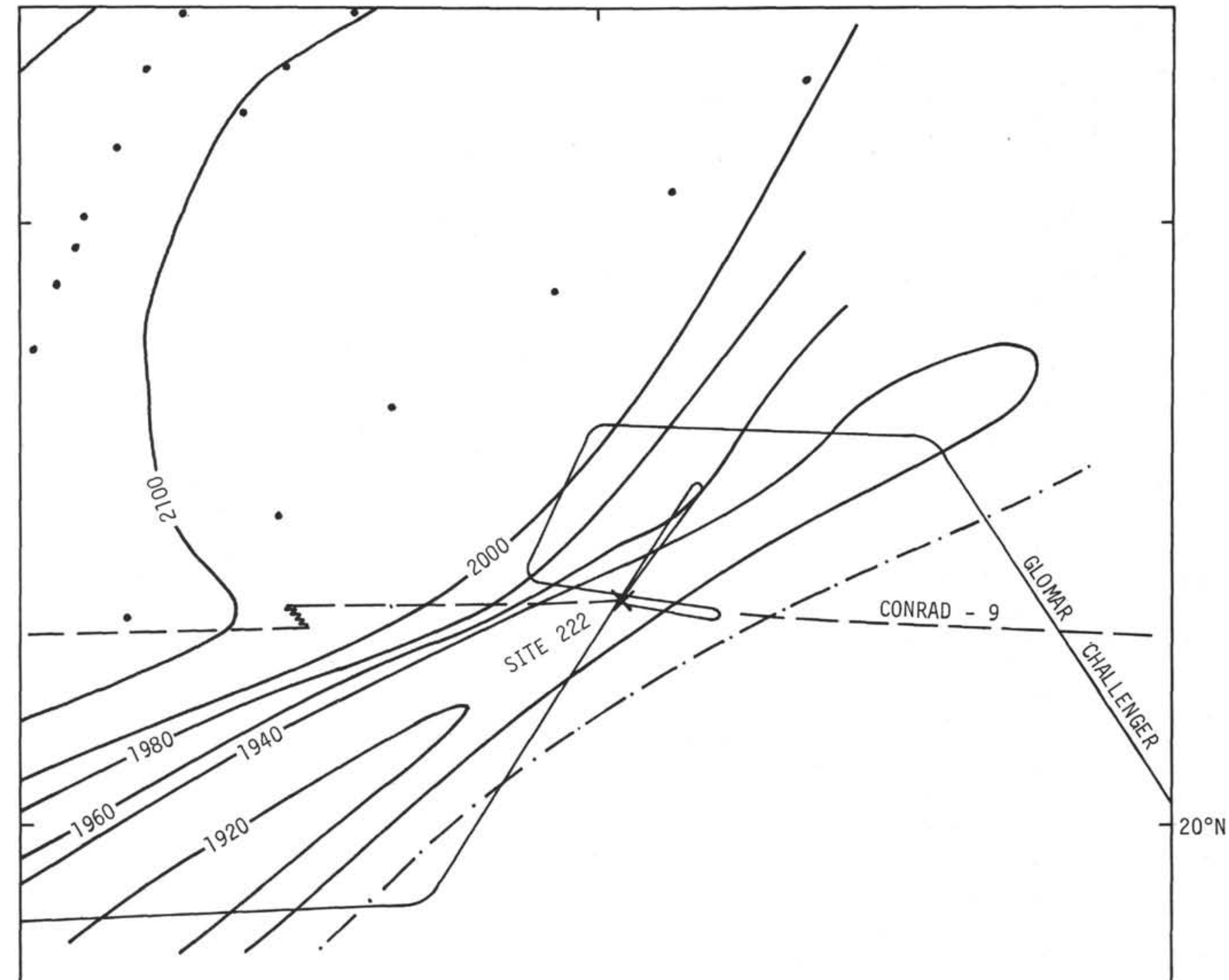

Figure 2. *Bathymetric chart of the area around Site 222 based on soundings of* Glomar Challenger *and* Conrad-*9. Contour interval is 20 fms for depths less than 2000 fathoms but 100 fms at greater depths. Depths are in corrected fathoms; dots represent soundings by other vessels. The dash-dot line represents the edge of the Indus Cone sediments at 1946 fms.* Conrad *data kindly provided by D. E. Hayes, Submarine Topography Department, Lamont-Doherty Geological Observatory.*

to 15,000 to 25,000 lb in the deeper portions of the hole. Circulation was broken several times in the upper 200 meters, and 50 barrels of mud were spotted in several drilled intervals and during the taking of Cores 25 and 35 (see Table 1).

Several times while coring in the deeper, harder portions of the hole, the core was retrieved because penetration had stopped before the interval to be cored was completely penetrated. This was due to the core barrel being full, having collected material within the preceding drilled interval, thereby causing the drill bit to stop cutting as it was spinning on a hard sediment stub at the bottom of the hole. Consequently, deeper cores, although apparently cut between specific depths, may have accreted some material from the preceding drilled interval.

The gas shows throughout much of the hole dictated the precaution of filling the hole with mud after it was abandoned. For this purpose, 475 barrels of 8.6 lb/gal mud was first pumped into the hole followed by another 75 barrels of 11.8 lb/gal mud.

Upon recovery, the 4 roller cone bit was found to have badly worn bearings on two of its cones, but the teeth of all cones were still in excellent condition.

The extreme depth of penetration at this site was due to a combination of several factors:

1) Cruise operations manager and drilling crew both closely monitored drilling conditions. This resulted in good drilling practices, including keeping the hole in good condition with mud and water circulation.

2) Lithologies were favorable. Mostly stiff to indurated terrigenous sediments, without loose running sands, were encountered.

3) Weather, waves, and swell were continuously calm during the 6 days spent at this site. These conditions

TABLE 1
Coring Summary, Site 222

Core	Date/Time Core on Deck (Time Zone-4)	Depth Below Sea Floor (m)	Cored (m)	Recovered (m)
	25 Mar:			
1	0400	0-7	7.0	6.0
2	0555	53-62	9.0	1.1
3[a]	0720	101-110	9.0	5.3
4	0835	119-128	9.0	1.2
5	0945	128-137	9.0	8.4
6	1110	137-146	9.0	4.6
7	1235	146-155	9.0	1.9
8	1430	184-193	9.0	7.0
9	1615	213-222	9.0	4.5
10[b]	1825	261-270	9.0	CC
11	2120	307-316	9.0	1.7
	26 Mar:			
12	0215	353-362	9.0	3.0
13	0600	399-408	9.0	5.9
14	0715	408-417	9.0	4.6
15	0910	427-436	9.0	1.8
16	1100	445-454	9.0	1.5
17	1235	463-472	9.0	0.3
18	1425	492-501	9.0	2.3
19	1655	540-549	9.0	4.0
20[c]	2145	587-591	4.0	5.5
	27 Mar:			
21	0115	634-643	9.0	5.7
22[d]	0530	690-699	9.0	9.4
23	1125	747-756	9.0	5.8
24	1505	804-813	9.0	5.6
25[e]	2325	861-870	9.0	9.4
	28 Mar:			
26	0320	916-925	9.0	CC
27	0525	925-934	9.0	2.5
28[f]	0905	982-991	9.0	7.0
29[g]	1505	1041-1050	9.0	9.4
30	2155	1097-1106	9.0	0.3
	29 Mar:			
31[h]	0340	1126-1135	9.0	9.5
32	1155	1160-1169	9.0	9.5
33[i]	1705	1211-1220	9.0	8.4
34[j]	2210	1258-1267	9.0	9.4
	30 Mar:			
35[k]	0410	1286-1295	9.0	9.5
36[l]	0910	1295-1300	5.0	3.6
Totals			313.0	175.6

[a] Broke circulation from here.

[b] Pumps on from here.

[c] Took 125 min to core; spotted mud 549-587 m.

[d] Spotted mud 643-690 m.

TABLE 1 – *Continued*
Table 1 footnotes continued

[e] Spotted mud while coring.

[f] Spotted mud 934-982 m.

[g] Spotted mud 991-1041 m.

[h] Strong pumping from here.

[i] Spotted mud 1169-1211 m.

[j] Spotted mud 1220-1258 m.

[k] Spotted mud while coring.

[l] Took 3 hours.

allowed relatively constant bit weight to be applied throughout the drilling program even though the ship was being positioned on manual mode throughout the time it was on station.

Glomar Challenger departed from Site 222 at 2045 hours 30 March. A northeasterly course was steered until all the gear had been streamed, and then the ship returned to pass over the beacon at 6 knots. Shortly after passing the beacon, a disposable sonobuoy was launched which transmitted data for some 90 minutes, but the quality of the record did not allow a velocity depth interpretation to be made. The buoy was used in an attempt to measure the total thickness of sediment near the site. A westerly course was then followed at full speed in order to begin the site survey for the next site with a crossing of the north end of the Owen Ridge.

LITHOLOGY

In spite of its record length, Hole 222 penetrated a rather homogeneous sedimentary sequence, which is described in the following table.

TABLE 2
Lithologic Summary, Site 222

	Lithologic Units	Thickness (m)	Subbottom Depth (m)	Cores
I	Green DETRITAL CLAY NANNO OOZE to NANNO-RICH DETRITAL CARBONATE SILTY CLAY	ca. 80	0-80	1,2
II	Gray CARBONATE-RICH DETRITAL SILTY CLAY and minor green bioturbated NANNO-RICH DETRITAL SILTY CLAY	ca. 1220	80-1300	3-36

Methane and ethane were detected in Hole 222. Relatively significant amounts occur between 100 and 200 meters, followed by a decreasing trend down the hole (with some minor reversals). The gas content does not appear to be controlled by the gray and green facies.

Unit I

Unit I consists of a green detrital clay nanno ooze and nanno-rich detrital carbonate silty clay. Few sponge spicules, diatoms, and Radiolaria were noted. Relative to the green intervals of unit II, this unit is much thicker (80 m) and contains 0.3 to 1.9 percent organic carbon, more dolomite (as much as 14.7%), and more sand size particles (as much as 2%). It also has large amounts of palygorskite (28% to 33%) in the $<2\mu$ fraction. In addition, it lacks burrow structures.

Unit II

Eighty-seven percent of the sequence consists of gray silty clay intervals which alternate with green sediments. The alternations do not warrant individual unit status. Consequently, it is considered that this unit displays a major gray detrital silty clay facies and a minor green facies richer in nannofossils.

Gray Silty Clay Facies

Carbonate-rich detrital silty clay represents the dominant lithology. Detrital mineral content (mostly mica, quartz, chlorite, and feldspars) varies between 75 and 85 percent.

Carbonate particles, ubiquitous in the gray facies, represent approximately 15 percent of the total composition. These particles were considered as being clastic components and, therefore, from the rules of sediment classification, termed carbonate.

Few sponge spicules, diatoms, and radiolarians were noted in Cores 3 to 7.

The minor constituents are represented by nannofossils, volcanic glass, and pyrite. A piece of fossilized wood was found in Sample 12, CC.

Color is an important distinguishing feature of this facies. These sediments are differing shades of gray, varying from dark to light, but mostly medium gray.

Bedding characters are highly variable. Sometimes stratification is well defined by numerous intercalations of silty beds (between 1 m and 1 cm but mostly around 10 cm thick) or laminae. They are especially prominent in Cores 9, 14, 28, and 34, occasionally comprising more than 50 percent of the sediments (Table 3 in back pocket). The thickest silty beds (101 cm and 69 cm) appear in Core 9, while Cores 28 and 34 contain the larger number of silty intercalations >1 cm thick (up to 11 per section).

At other times, only a few intercalations are present, leading to a massive aspect. In many cases the silty layers show graded bedding. About 18 percent of the silty intercalations are apparently nongraded. Internal structure is rarely visible, although in a few instances, cross lamination was recorded. Parallel lamination occurs in both graded and nongraded layers as seen in Core 14.

With the exception of the uppermost green interval, the contact between the gray and green facies is sharp. This is reflected by the color, and compositionally by the quantity and character (in situ or reworked), of nannofossils.

Green Facies

These sediments appear throughout unit II. A total of 23 green intervals with an average thickness of 1 meter were found in cores 11, 12, 19, 20, 22, 23, 24, 25, 29, 31, and 35 (Table 3). They range in thickness from 5 cm to 6 meters. Their average composition is 45 (38 to 75) percent of detrital minerals, 40 (15 to 55) percent nannofossils, and 15 (0 to 41) percent carbonate. Small amounts of volcanic glass, pyrite, and foraminifera are frequently observed.

The large size of most carbonate fragments precludes their being broken nannofossils, consequently, a clastic origin is indicated.

This facies is characterized by various values and chroma of green. Greenish gray is the most common, but grayish olive and moderate green are also prevalent.

Bioturbation seems to be an important feature of this facies. The burrows are roughly parallel to bedding. They disappear abruptly at the contact with gray deposits.

Differences and Similarities Between Facies

The following features differentiate the two facies in this unit:

1) Color and lithology: gray carbonate-rich detrital silty clay vs. green carbonate-rich nanno detrital silty clay or green nanno-rich detrital silty clay.

2) Sedimentary structures: laminated, cross-laminated, graded or nongraded coarse-grained intercalations in the gray facies vs. bioturbation in the green facies. However, the first coarse-grained interbeds, in the upper part of the Unit, occur in green deposits (Core 4, Section 1).

3) Nannofossil content: The nannofossils of the green facies are almost entirely indigenous forms, while in the gray facies reworked Cretaceous and indigenous species occur (Table 3 in pocket).

The two facies also have many features in common:

1) The organic carbon content tends toward low values (0.1% to 0.4%; Table 3 in pocket) in both facies.

2) The grain-size distributions of the fine sediments are quite similar. The clay content for both averages about 60 percent (between 45.8% and 76.7%), while their silt content ranges from 23.1 to 54.1 percent. The amount of sand varies from 0 to 0.5 percent.

3) The foraminiferal assemblage, in both the gray and the green sediments, consists of planktonic and deep-water benthonic species together with displaced middle-upper bathyal and neritic forms and reworked Eocene species.

4) The higher nannofossil content of the green sediments is reflected by larger $CaCO_3$ values and lower quartz and mica content. However, sometimes even these values are comparable to those of the gray sediments; especially for those green sediments having a low nannofossil content.

Due to limited space, the tables of grain size, carbon carbonate, X-ray, and *p*H and salinity are presented with the data of other sites in Appendices I, II, III, and IV, respectively, at the end of the volume.

BIOSTRATIGRAPHY

Foraminifera

Planktonic foraminiferal faunas are poorly developed in most horizons from Site 222, primarily due to the high rate of test solution. Most samples containing these species have concentrations of larger, more robust tests, usually accompanied by high fragmentation, or of juveniles probably emplaced by turbidite transport. Deep-water (lower bathyal or abyssal) benthic species are generally equally rare. Pleistocene faunas occur sporadically in Cores 1 and 2, Pliocene faunas in Cores 3 through 22, and probable Miocene faunas below this level. Only in very rare instances were planktonic species sufficiently common and diverse to permit zonal differentiation.

Benthic foraminifera indicative of neritic and upper bathyal depths are present in a number of samples, where they are usually found in association with relatively high quantities of mica and fine sand. Minor occurrences of Eocene planktonic species are present in isolated samples from Cores 8, 9, 32, 33, and 34. Both the reworked Eocene and the transported neritic foraminifera are very largely, but not quite entirely, associated with gray rather than greenish clays and claystones.

Nannofossils

Hole 222 was drilled into sediments ranging in age from Pleistocene to Late Miocene. *Emiliania huxleyi, Gephyrocapsa oceanica, Cyclococcolithus leptoporus,* and *Coccolithus doronicoides* are abundant in the Pleistocene interval found in Core 1. *Pseudoemiliania lacunosa* is rare in Sample 2, CC.

The Late Pliocene interval extends from Core 3 down to Core 12, Section 2. *Discoaster brouweri, Coccolithus doronicoides, Coccolithus pelagicus, Helicopontosphaera kamptneri, Discoaster pentaradiatus,* and *Cyclococcolithus leptoporus* are common throughout certain short intervals of the Late Pliocene. A reworked Cretaceous flora predominates in Cores 8 and 9 and is found through most of the underlying cores. The Early Pliocene interval extends from Core 12 down to Sample 22-4, 79-80 cm and is characterized by the presence of *Reticulofenestra pseudoumbilica, Sphenolithus abies, Discoaster surculus, Discoaster asymmetricus,* and *Discoaster brouweri.* Highly mixed floral assemblages with Cretaceous nannofossils are common in Cores 14, 15, 16, 17, 18, 19, and 21.

Common occurrences of *Discoaster quinqueramus,* and the extinction level of *Discoaster challengeri*, appear in the Late Miocene in Sample 22-4, 79-80 cm. Intervals of reworked Cretaceous flora are present in Cores 24 through 36. Indigenous nannofossils common to the Upper Miocene are found only in thin olive colored beds within the section beginning from Core 24 and extending down to the total depth of 1300 meters in Core 36. Dark gray compacted silty clay sediments within the interval between Core 24 and Core 36 contain common reworked Cretaceous nannofossils and few or no indigenous nannofossils of stratigraphic value. Reworked Cretaceous nannofossils probably originate from massive outcrops of Middle and Upper Cretaceous limestones in W. Pakistan.

Nannofossils present near the bottom of Hole 222, in Core 35, belong to the *Discoaster quinqueramus* Zone of Upper Miocene. Nannofossil and foraminiferal evidence in Core 35 suggest an age of about 6 million years for the oldest sediments penetrated in this hole.

Radiolaria

The first three cores at Site 222 (0 to 110 m below the sea floor) contain a few well-preserved Radiolaria. Species such as *Spongaster tetras tetras, Ommatartus tetrathalamus,* and *Euchitonia furcata* are present and are typical of a low latitude assemblage. The cores also contain numerous diatoms, sponge spicules, and silicoflagellates. Cores 4, 5, and 7 contain rare radiolarians, including Orosphaerid fragments. The remainder of the samples from cores taken at this site are barren of Radiolaria.

Biostratigraphic Summary

Radiolaria are relatively rare in sediments from Cores 1 through 7 (0 to 155 m) at Site 222 and are absent below this level. Planktonic foraminifera are rare and generally nondiagnostic throughout the drilled interval. Benthic foraminifera and reworked Eocene planktonic species, very largely assicated with gray clays and claystones, indicate downslope transport in a number of samples.

Age determinations in Hole 222 are based entirely on nannofossils. Cores 1 and 2 (0 to 54 m) are of Pleistocene age; Lower Pleistocene sediments were recovered only in Sample 2, CC. The Late Pliocene was observed as low as Core 12 (357 m), and the Early Pliocene/Late Miocene boundary was located at the top of the *Discoaster quinqueramus* Zone in Sample 22-4, 79-80 cm (695 m). All sediments below this horizon were referred to this zone.

Reworked Cretaceous nannofossils are common at many horizons in and below Core 8; throughout some intervals (notably Cores 24 through 36), they predominate to the near-complete exclusion of indigenous Miocene species, which are restricted to thin, greenish layers.

Sedimentation Rate

Sedimentation rates are high but variable throughout the Upper Miocene to Pleistocene sequence penetrated at this site (see Figure 3). The highest rate observed was for the Late Miocene interval (690 to 1300 m); it was at least 600 m/m.y. The rate decreased during the Early Pliocene (355 to 650 m) to 135 m/m.y., and increased to at least 350 m/m.y. during the Late Pliocene. A sedimentation rate of 42 to 53 m/m.y. for the Quaternary samples of Cores 1 and 2, while high by deep-sea standards, is the lowest value observed here.

GEOCHEMISTRY

The content of magnesium, titanium, manganese, chromium, copper, nickel, iron, and vanadium in samples from the rather homogeneous beds (consisting of detrital clay and silt with minor intercalations of nanno chalk) which were penetrated at Site 222 are shown in Figure 4).

Among the elements analyzed, titanium, manganese, chromium, iron, copper, nickel, and vanadium show some variations. The detrital minerals constitute a significant portion of the sediments, and, perhaps, in part control the distribution of various trace metals in the sediments of Site 222. Therefore, thorough X-ray, grain-size, and optical mineralogical analyses are needed to explain the geochemical history and distribution pattern of trace metals in these sediments.

On the basis of four samples from the green facies of unit II (see lithology) there appears to be no difference in elemental abundance from the gray facies of this unit.

PHYSICAL PROPERTIES

Measurement of the physical properties of Site 222 sediments was restricted by two factors. First, the presence

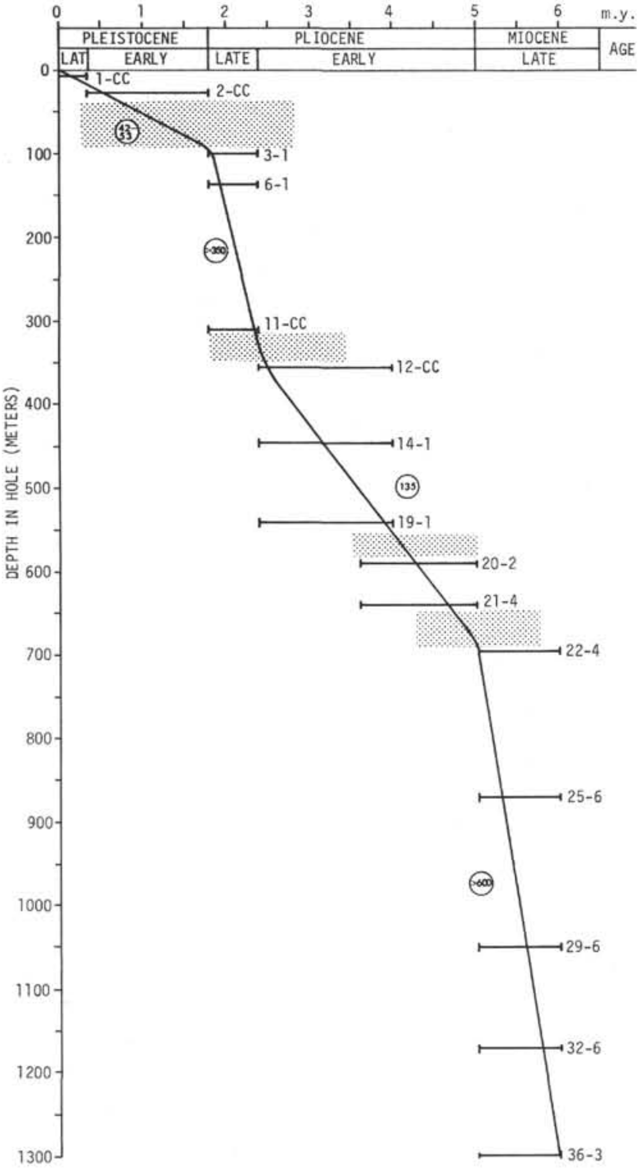

Figure 3. *Sedimentation rate curve, Site 222. Plotted bars are those sufficient to control slopes of lines. Stippled pattern represents some uncored intervals. See Chapter 2, Explanatory Notes, for explanation of age ranges and other symbols.*

of gas in the sediments above about 600 meters caused voids, lowered density values, and made the sediment unsuitable for sonic velocity measurements. Second, the undergauge cores which resulted from the progressive loosening of the drill bit bearings over the remaining 700 meters eventually caused termination of the hole. This resulted in discrepancies between the density measurements made by differing methods as will be outlined below.

Sediment Density, Porosity, and Water Content

The plot of GRAPE density values fluctuates markedly, but an overall gradient can be noted (from 1.6 to 1.9 g/cc with depth) when one considers averages taken over cored intervals. Over most of the sedimentary sequence, the lowest density values can be equated with voids, while the highest values are usually within sandy and silty beds. In graded beds, due to the effects of gas expansion and drilling disturbance, density gradients are not evident as they were at Site 221. Gradients that do occur are usually towards the bases of cores, where the sediments are less disturbed.

The most distinct density peaks occur below 500 meters. The most important of these are equated with lithified calcareous sandstone layers at 990, 1099, and 1215 meters, reaching peaks of between 2.5 and 2.6 g/cc. Other semilithified horizons between 544 and 1169 meters cause peaks of around 2.0 g/cc. For comparison with the GRAPE density measurements, a sample from the lithified calcareous sandstone of Core 28, Section 5 was measured in the shore laboratory and gave a value of 2.538 g/cc. It is apparent that the micrite cement of these sandstones causes their high density values.

No density difference could be noted at the boundaries between the gray and green sediment facies.

The average core density values derived from GRAPE measurements when plotted against those from section weight determinations, show an increasing discrepancy with depth (see Figure 5). The values derived from the two methods differ by only 0.01 to 0.03 g/cc down to 600 meters, but below this depth, there is a progressive increase to 0.23 g/cc at about 1250 meters and a sharp rise to 0.37 g/cc in the lowermost core. A change in core diameter causes a greater percentage change in section weight densities (dependent on the inverse of the square of the radius) than in GRAPE densities (dependent on the inverse of the radius). As an example, for a 6- to 5-cm diameter change, r^2 changes from 9 to 6.25 cm^2; this means a 30.5 percent section weight density error while the change in r causes only a 16.6 percent GRAPE density error. Thus, the graph in Figure 5 is interpreted as representing progressive wear on the drill bit bearings from 600 to 1200 meters, and, hence, a steadily decreasing core diameter, followed by an abrupt deterioration of their bearings at the base of the hole. In less homogeneous sequences, such a plot would be stepped, but at sites where drilling extends beyond 600 meters, this observation could provide a way to monitor the state of the drill bit.

Water content values show a general decrease with depth from 50 to 10 percent downwards. Exceptions occur where the sediment is pasty near voids caused by gas expansion.

Compressional Wave Velocity

The admittedly low number of velocity measurements show a general tendency to remain between 1.55 and 3 km/sec but increase with depth. This is not surprising in this generally homogeneous sedimentary unit. Some minor fluctuation can be noted at the boundaries between green and gray sediment facies, but the major velocity peaks occur in the dense calcareous sandstones reaching values of 4.0 to 4.9 km/sec, e.g., Cores 28 and 30.

Specific Acoustic Impedance

Impedance values again serve to outline the overall homogeneity of the sedimentary sequence together with

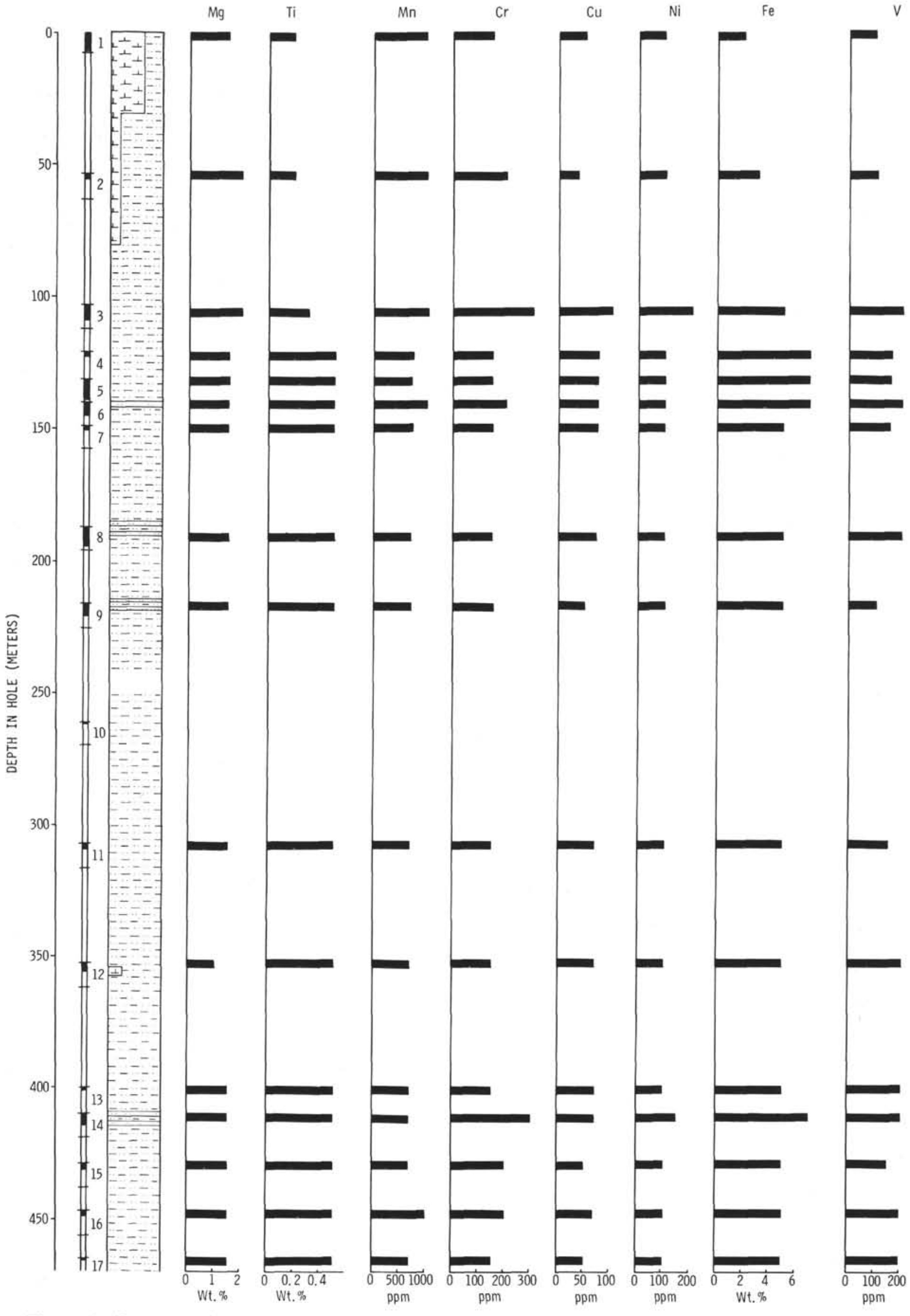

Figure 4. *Chemistry of the sediments from Site 222.*

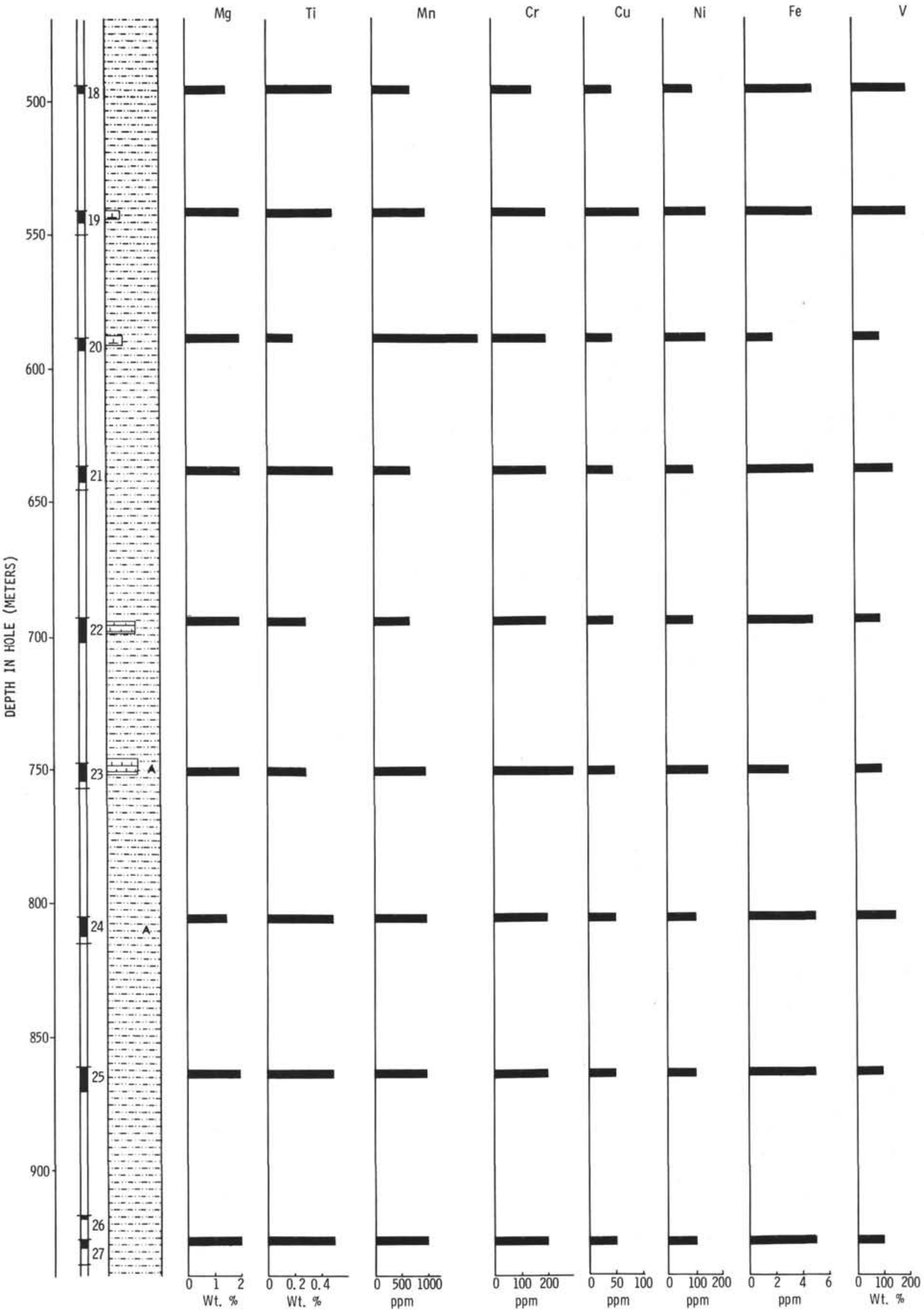

Figure 4. *Continued.*

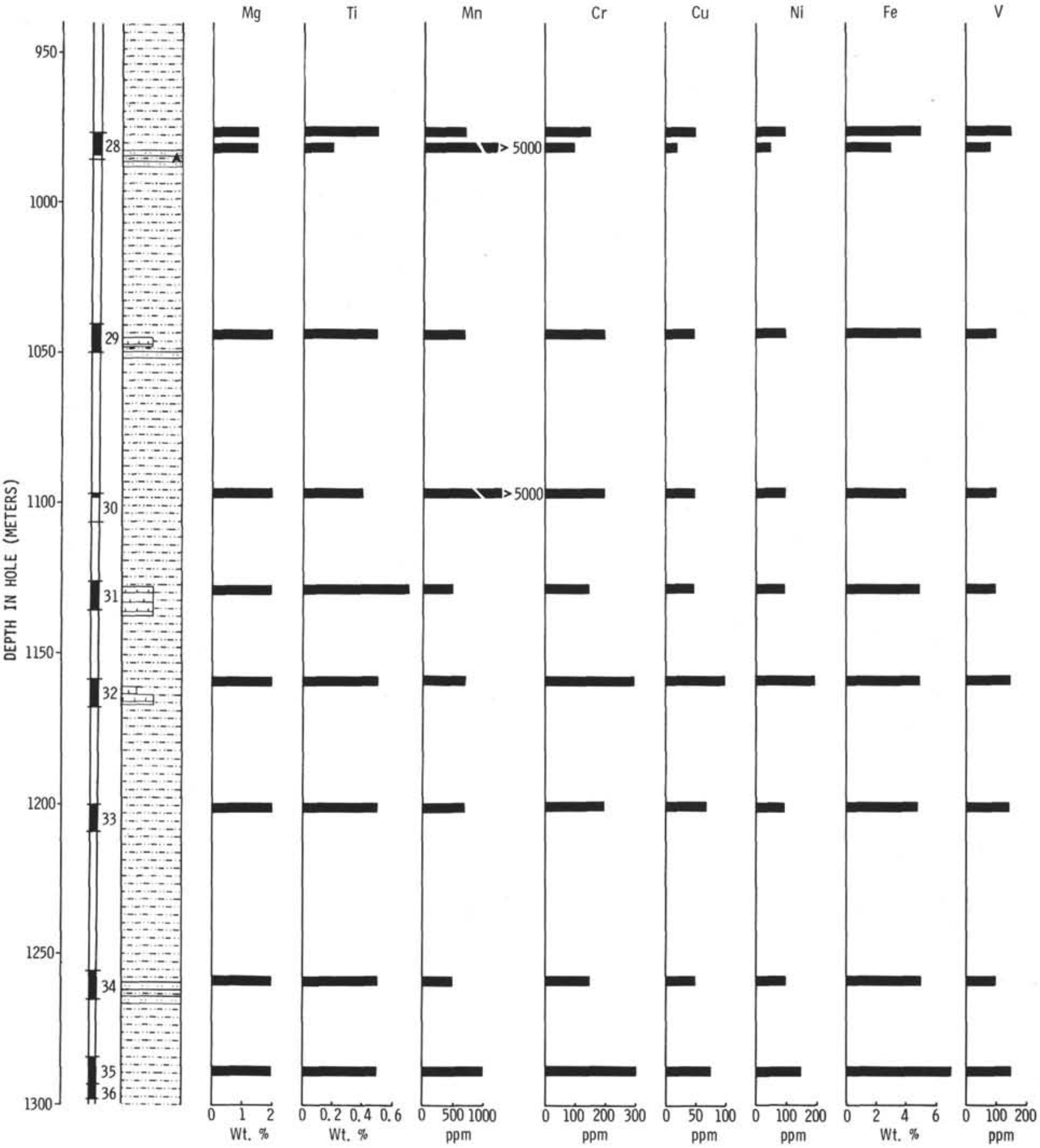

Figure 4. *Continued.*

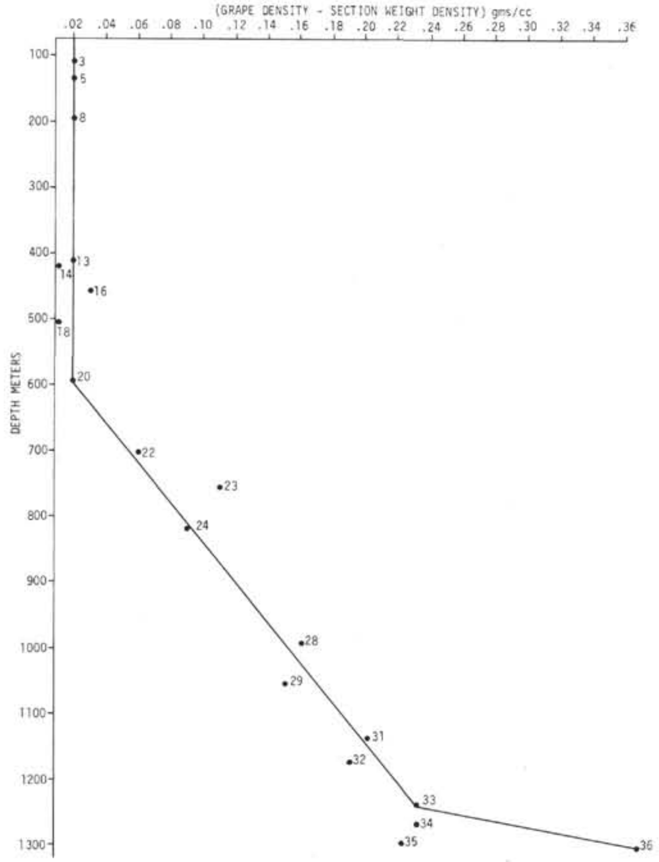

Figure 5. *A plot of differences between density values derived from GRAPE measurements and section weight measurements.*

major excursions from the general trend caused by the high density and velocity values of the lithified calcareous sandstones. These, and the semilithified hard layers, are likely to be the major reflectors in this sequence.

CORRELATION OF REFLECTION PROFILES AND LITHOLOGIES

A record thickness of 1300 meters of sediment was penetrated at this site without reaching basement. Reflections were discernible on the seismic profiles obtained by *Glomar Challenger* as deep as 1.3 seconds below the sea bed, but these reflections probably originate from a higher level than the bottom of the hole. The reflection profile obtained on departure from the site shows an almost continuously stratified record (Figure 6). In detail, however, the stratification is sometimes discontinuous. There is a fairly well marked weakly reflecting to transparent layer from about 0.4 to 0.55 seconds, which is especially well developed beneath the site. A similar shoaler layer at 0.25 seconds was followed for over 100 km on the approach to the site and is the same dipping "reflector" first observed on the *Conrad*-9 record. The patchiness of the reflections suggests the importance of destructive interference of superimposed signals and/or of local subtle changes of lithology. The latter effect is probably more important. Consequently, it is not generally feasible to designate particular bands of stratified reflections as being due to discrete lithological horizons, although this was attempted unsuccessfully while the hole was being drilled. This approach of not picking reflectors from the lithology of the cores is also justified on the basis of the mostly uniform lithology seen in the cores and because of a lack of good physical property measurements due to the gassy nature of the cores.

The only cored lithology which may correspond to a reflector is the nanno silty clay recovered from 2 cores within the interval 695 to 750 meters, which is equated with a reflection at 0.87 seconds. Some hard bands were also noted by the driller during drilling. The observed reflections and the above tentative lithological correlation and hard bands are summarized in Figure 7. The upper two hard bands occur in regions of dense layering on the reflection profile.

PALEOMAGNETIC MEASUREMENTS

A fairly detailed coverage of the cored interval between 588.5 meters below sea floor and the terminal depth of 1300 meters is afforded by the 88 samples used for paleomagnetic study at this site. Stratigraphically, the samples are Late Miocene to Early Pliocene in age. They are fully representative of both the dominant gray silty clay facies and the subordinate green silty clay facies encountered within this part of the hole.

The results of the remanence measurements are presented in Table 4. Intensities of magnetization are in the range of 3.2×10^{-5} G/cm^3 to 1.7×10^{-7} G/cm^3 with a mean value of $1.1 \pm 0.8 \times 10^{-5}$ G/cm^3. The lower NRM intensities are generally characteristic of the green silty clay samples. Three pilot samples, 20-2, 19 cm, 28-3, 129 cm, and 36-3, 72 cm, were progressively alternating field (Af) demagnetized; the latter two samples to a maximum of 450 oersted peak field value. It is clear from the intensity decay curves (Figure 8) that there is a marked similarity in behavior between all three samples. There is no initial rapid decay in intensity at low peak field values. From Table 5 it is apparent that the remanent vector for all three samples shows only slight change in direction during demagnetization. It is reasonable then to infer that the samples have good stability. The same observation appears to hold for a majority of the other samples measured after partial demagnetization at 50 oersted. However, even after partial demagnetization, the directions within individual cores are often widely dispersed. Secular variation may account to some extent for this scatter as sedimentation has been very rapid for the sequence below Core 21. Thus, the effect of the non-dipole component may not have been averaged out in individual samples. But, bioturbation may also be a contributing factor, particularly within the green silty clay intervals.

Negative inclinations predominate in Cores 27, 28, 29, 31, and 32. This is well illustrated by the plot shown in Figure 9 of the variation in mean inclination for individual cores with depth downhole. Thus, to a first approximation, an interval of reversed polarity spans some 300 meters of the sedimentary sequence. Using the inferred sedimentation rate of at least 600 m/m.y., the reversed interval was at least 0.5 m.y. in duration. Tentative correlation with the

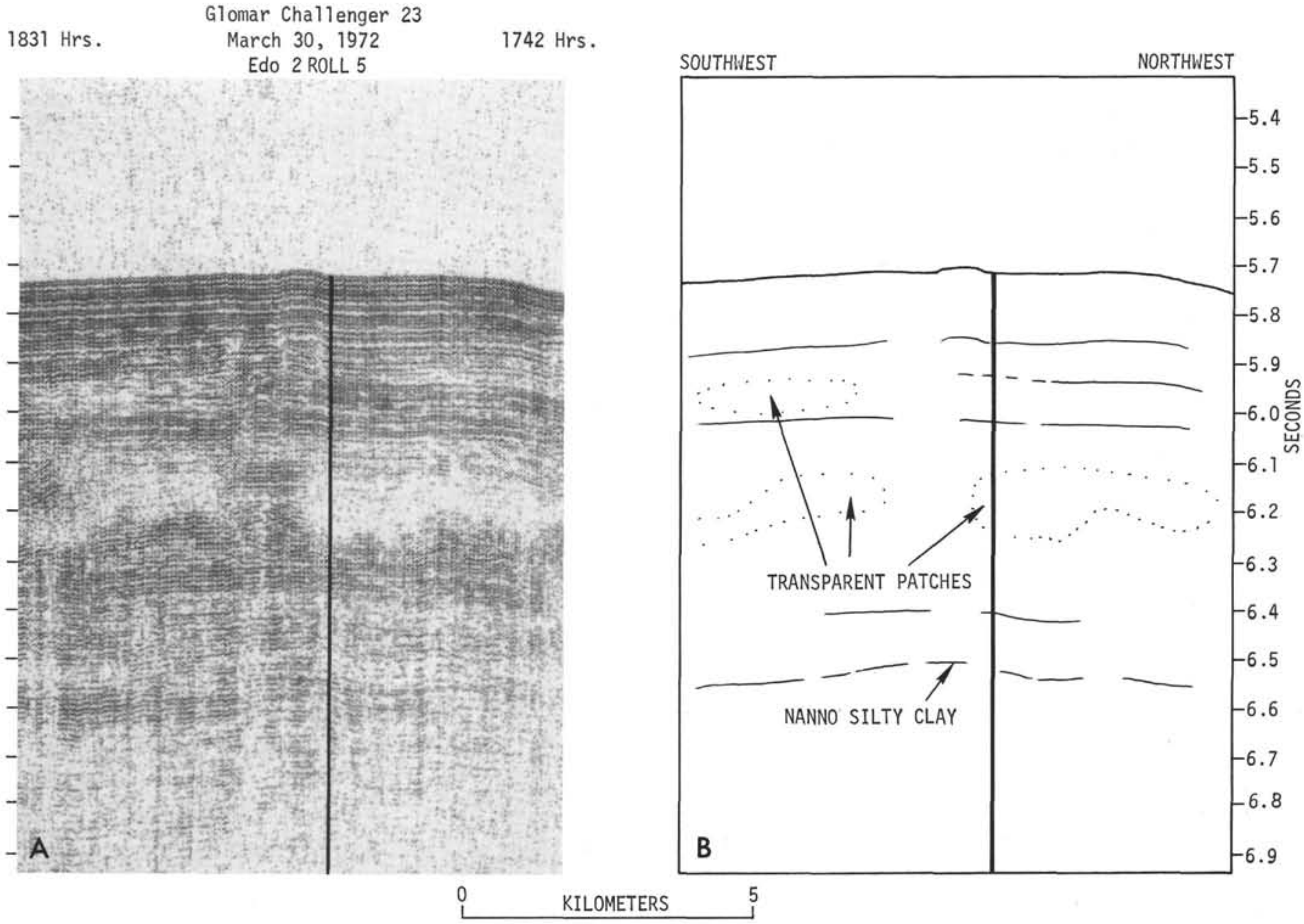

Figure 6. (a). *Seismic reflection profile obtained on departure over the beacon at Site 222. The vertical line represents the penetration of the drill string. Although not shown in the figure, reflections were observed from as deep as 1.3 seconds below the site.* (b). *Tracing of Figure 6*a *showing several reflectors. The two transparent layers are the areas enclosed by dots. The vertical line has tenth second divisions.*

theoretical geomagnetic reversal time scale of Heirtzler et al. (1968) is possible in terms of the reversed polarity interval immediately preceding sea floor spreading anomaly number 3. More recently, Foster and Opdyke (1970) have proposed an extension of the observed polarity sequence into the Middle Upper Miocene. Using their nomenclature, the observed reversal may correlate with the prominent reversed event "A" in epoch 5.

Within the reversed interval identified here, Samples 29-5, 19 cm and 32-6, 49 cm exhibit a positive inclination and show appreciable declination change with respect to adjacent samples. However, it is extremely doubtful that these are representative of true short period excursions of the field to the opposite polarity, particularly in view of the inferred high sedimentation rate. More likely, they should be regarded as anomalous results.

The approximate paleolatitudes of Site 222 during the Early Pliocene and Late Miocene, calculated from the absolute mean inclinations of the paleomagnetic results described here, are given in Table 6.

It is evident that a northward movement of this site, on the order of 10 degrees, has taken place since the Late Miocene.

DISCUSSION AND CONCLUSIONS

Geological Setting

This Site is located along the western margin of the Indus Cone in the Arabian Sea. Situated approximately 250 km east of the Arabian Peninsula, it lies in 3546 meters of water.

Site 222 is 650 km southwest of the apex of the Indus Cone, approximately 3 km east of where the cone sediments terminate against the Owen Fracture Zone. This fracture zone finds sea floor expression in the form of a northeast-southwest trending graben and ridge system. The ridge (named the Owen Ridge by the Leg 23 Shipboard Scientific Party) rises steeply along the western margin of the graben. A complete crossing of the graben in the immediate vicinity of Site 222, as documented on a

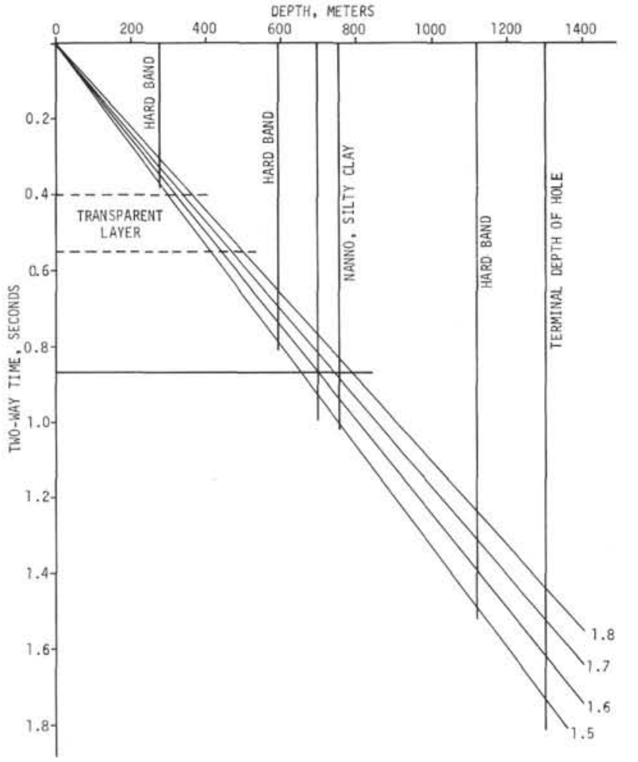

Figure 7. *Plot of reflection times beneath Site 222 against the depth of a significant change in lithology seen in the cores and the depth of hard bands felt by the driller. Lines are drawn with slopes corresponding to mean velocities of 1.5, 1.6, 1.7, and 1.8 km/sec.*

Conrad-9 profiler record, shows a 375 meter deep trough. Its maximum width, as outlined by the 2000 fathom isobath on a map contoured by A. S. Laughton (unpublished), is 17 km.

At Site 222, a series of normal faults with throws of 25 to 150 meters displace the Indus Cone surface into the graben floor. On the eastern lip of the graben, there is a slight rise of the sea floor which interrupts the regional southwesterly dip of the Cone surface. Site 222 was drilled on this rise area.

On the west side of the fault, the Owen Ridge appears to form a barrier to turbidite flows which have constructed the Owen Abyssal Plain.[2] The level of this plain, as seen on the traverse from Site 222 to 223, is at the same elevation as the westernmost margin of the Indus Cone (see map in back pocket of volume). Although the plain is prevented from having direct access to the Indus Cone surface by the Owen Ridge at the latitude of Site 222, it apparently has direct access to this surface north of the site.

Of pertinence is the fact that where Site 222 was drilled, the Owen graben is completely lacking in sediment fill. It is obvious that turbidites from neither the west nor the east have had any effect in filling even the deepest part of the trough. Consequently, one must postulate both a very recent fault movement as well as an absence of turbidite deposition in this area.

The displacement of the Indus Cone surface at Site 222 by faulting is also reflected in the offset of seismic reflectors. Particularly obvious is a reflector at a depth of 0.25 seconds which to the east of the Owen Fracture Zone has an undisturbed eastward sloping surface. This slope when combined with the westerly slope of the fan surface defines an eastward thickening wedge of stratified sediments. These sediments thicken from approximately 100 meters at this drill site to 500 meters, 100 km to the southeast.

During the last 200 km of its approach to Site 222, the *Glomar Challenger* was on a course of 325°. Over this distance, the change in sea floor depth was imperceptible, suggesting that this course parallels the fan contours. Therefore, the fan surface slopes to the southwest (235°).

The Stratigraphic Column

A 1300-meter penetration at this site recorded a continuous stratigraphic sequence extending into the Upper Miocene (however, no Holocene sediments were recovered). Thirty-six cores containing 175 meters of sediment were recovered, which signifies a 13.4 percent representation of the interval penetrated. The cores, separated by 10- to 50-meter drilled intervals, were fairly evenly spaced. This indicates that the recovered sediments should be fairly representative of the stratigraphic column.

Because the site is situated on a submarine cone, it is not surprising that this column consists of a monotonous sequence of terrigenous sediments. Lithologically, it can be divided into only two stratigraphic units. Unit I is an 80-meter-thick green detrital clay nanno ooze and nanno-rich detrital carbonate silty clay. It overlies a 1220-meter unit of mostly fine-grained muds with occasional sand and silt beds. Most of these sediments are various shades of gray. However, interbedded in this gray facies are thin fine-grained green beds. These beds, which are compositionally similar in many aspects to the gray ones, occurs in intervals, 5 to 600 cm thick. By extrapolating the frequency of green layers from the cored to the uncored portion of the hole, one can assume that nearly 100

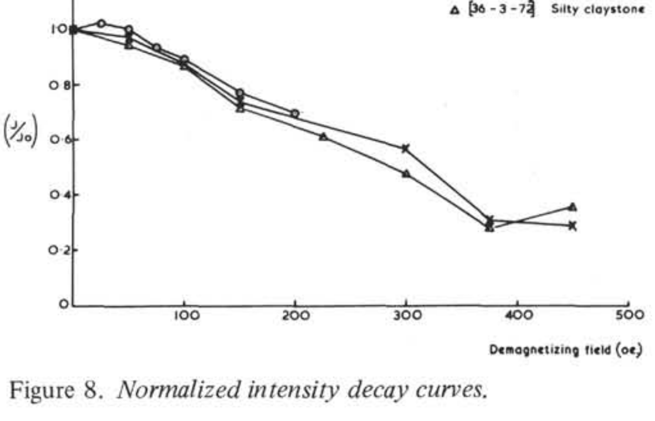

Figure 8. *Normalized intensity decay curves.*

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[2] Owen Abyssal Plain: Defined here as the elongate plain surface bounded by the base of the Arabian continental margin to the northwest and the Owen Ridge to the southeast. Oriented in a northeast-southwest direction, it is 90 to 150 km wide and about 750 km long. To the north, it connects with the Oman Abyssal Plain.

TABLE 4
Summary of Magnetic Data, Site 222

	NRM			Af Demagnetization			
Sample (Interval in cm)	Intensity (G/cm^3)	Relative Declination (degrees)	Inclination (degrees)	Peak Field (oersted)	Intensity (G/cm3)	Relative Declination (degrees)	Inclination (degrees)
20-2, 19	2.4×10^{-5}	92.9	20.3	50	2.5×10^{-5}	86.9	22.0
20-3, 99	6.4×10^{-6}	136.1	28.5	50	5.3×10^{-6}	144.2	27.1
20-4, 29	1.5×10^{-6}	78.5	37.0	50	9.4×10^{-7}	99.2	41.7
20-4, 130	9.5×10^{-7}	168.4	37.5	50	6.9×10^{-7}	166.1	38.4
21-1, 119	1.4×10^{-5}	249.2	3.0	50	1.3×10^{-5}	251.1	4.7
21-2, 19	6.8×10^{-6}	313.6	36.4	50	5.3×10^{-6}	316.3	35.5
21-4, 129	6.5×10^{-6}	215.5	–0.2	50	5.2×10^{-6}	216.4	1.6
22-2, 39	1.2×10^{-5}	102.3	13.2	50	1.0×10^{-5}	99.0	10.4
22-2, 120	1.9×10^{-5}	42.9	6.7	50	1.6×10^{-5}	39.9	5.4
22-4, 17	4.0×10^{-7}	268.2	45.7	50	2.6×10^{-7}	263.1	34.1
22-4, 141	3.3×10^{-7}	87.7	82.5	50	1.6×10^{-7}	91.1	64.7
22-5, 77	4.3×10^{-7}	71.8	–45.4	50	3.3×10^{-7}	41.6	–22.1
23-1, 22	3.4×10^{-6}	174.4	–35.9	50	3.0×10^{-6}	182.5	–37.7
23-1, 141	3.3×10^{-7}	150.8	59.7	50	1.6×10^{-7}	307.6	8.4
23-2, 111	2.4×10^{-7}	321.1	63.1	50	8.6×10^{-8}	267.9	12.5
23-3, 27	1.7×10^{-7}	102.6	–5.6	50	1.4×10^{-7}	182.6	49.2
23-3, 134	4.6×10^{-7}	199.8	63.5	50	1.9×10^{-7}	173.6	55.5
23-4, 89	9.8×10^{-6}	108.7	–6.3	50	1.1×10^{-6}	106.6	–14.6
24-1, 41	2.6×10^{-5}	283.8	9.4	50	2.2×10^{-5}	278.7	18.6
24-1, 91	1.4×10^{-5}	134.8	–8.3	50	1.4×10^{-5}	133.6	–6.3
24-2, 17	7.1×10^{-6}	129.3	–2.2	50	6.0×10^{-6}	128.6	–0.4
24-2, 92	4.9×10^{-6}	151.6	10.5	50	5.1×10^{-6}	148.4	5.0
24-3, 74	1.2×10^{-5}	154.0	15.1	50	9.8×10^{-6}	157.4	12.3
24-4, 142	4.3×10^{-6}	17.3	–13.5	50	4.1×10^{-6}	26.2	–14.6
25-1, 126	1.5×10^{-5}	223.3	14.3	50	1.3×10^{-5}	227.1	10.4
25-2, 34	9.2×10^{-6}	234.5	26.0	50	7.9×10^{-6}	232.2	26.5
25-2, 134	2.2×10^{-5}	29.6	25.2	50	2.0×10^{-6}	33.2	23.4
25-3, 22	1.3×10^{-5}	121.3	29.1	50	1.2×10^{-6}	118.5	25.8
25-3, 143	1.2×10^{-5}	277.9	6.4	50	9.9×10^{-6}	279.2	5.3
25-4, 22	1.7×10^{-5}	39.1	21.6	50	1.5×10^{-5}	39.7	17.9
25-4, 139	1.3×10^{-5}	344.7	20.9	50	1.3×10^{-5}	340.4	19.0
25-6, 22	9.5×10^{-6}	298.6	29.1	50	8.8×10^{-6}	303.7	26.1
25-6, 124	6.1×10^{-6}	261.3	22.2	50	6.3×10^{-6}	261.1	23.8
27-1, 62	1.9×10^{-5}	279.2	–11.3	50	1.8×10^{-5}	279.4	–12.2
27-1, 124	7.7×10^{-6}	42.8	–19.3	50	7.6×10^{-6}	30.9	–24.9
27-2, 47	4.8×10^{-6}	26.4	–2.6	50	5.1×10^{-6}	23.8	–7.2
27-2, 124	6.2×10^{-6}	303.3	0.8	50	7.3×10^{-6}	298.7	–7.3
28-1, 49	1.3×10^{-5}	69.3	1.6	50	1.2×10^{-5}	66.1	–0.3
28-1, 139	1.0×10^{-5}	116.2	–5.8	50	9.9×10^{-6}	118.3	–4.6
28-2, 77	7.2×10^{-6}	154.0	–25.1	50	7.0×10^{-6}	141.6	–15.9
28-3, 36	1.7×10^{-5}	30.8	–2.4	50	1.5×10^{-5}	30.2	–1.1
28-3, 129	1.4×10^{-5}	96.6	–3.9	50	1.3×10^{-5}	98.7	–9.1
28-4, 63	3.8×10^{-6}	167.9	5.5	50	3.6×10^{-6}	181.2	–2.0
28-5, 29	1.2×10^{-5}	122.4	5.3	50	1.0×10^{-5}	128.4	1.7
28-5, 64	1.5×10^{-5}	342.7	–57.6	50	8.2×10^{-6}	326.7	–72.8
28-5-131	4.2×10^{-6}	156.8	4.0	50	3.6×10^{-6}	120.5	–4.1
29-1, 10	3.2×10^{-5}	158.5	–18.3	50	2.8×10^{-5}	158.0	–18.6
29-1, 131	9.8×10^{-6}	41.1	–13.1	50	9.4×10^{-6}	37.4	–15.7
29-2, 67	1.6×10^{-5}	190.1	–6.8	50	1.5×10^{-5}	192.9	–7.7
29-3, 24	2.3×10^{-5}	325.6	–10.7	50	2.2×10^{-5}	325.8	–15.1
29-3, 142	8.6×10^{-6}	310.3	–21.3	50	8.9×10^{-6}	317.9	–17.5
29-4, 75	5.2×10^{-6}	300.6	–54.0	50	5.4×10^{-6}	290.8	–37.2
29-5, 19	8.6×10^{-6}	137.3	9.6	50	8.5×10^{-6}	128.7	17.8
29-5, 141	6.1×10^{-6}	355.4	–23.4	50	5.9×10^{-6}	338.8	–21.3
31-5, 72	2.8×10^{-5}	146.9	–14.8	50	2.4×10^{-5}	140.8	–18.5
31-5, 146	1.7×10^{-5}	262.7	–10.1	50	1.5×10^{-5}	271.7	–9.2
31-6, 62	2.1×10^{-5}	114.3	–9.6	50	1.7×10^{-5}	109.6	–14.3
31-6, 146	2.1×10^{-5}	220.6	–14.5	50	2.0×10^{-5}	227.6	–13.9

TABLE 4 – *Continued*

Sample (Interval in cm)	NRM			Af Demagnetization			
	Intensity (G/cm^3)	Relative Declination (degrees)	Inclination (degrees)	Peak Field (oersted)	Intensity (G/cm^3)	Relative Declination (degrees)	Inclination (degrees)
32-4, 78	6.7×10^{-6}	275.0	–3.8	50	5.5×10^{-6}	278.7	–12.1
32-4, 146	2.3×10^{-5}	350.3	–25.0	50	2.0×10^{-5}	354.4	–26.4
32-5, 58	1.5×10^{-5}	259.3	–8.7	50	1.3×10^{-5}	264.3	–12.0
32-5, 127	1.6×10^{-5}	257.0	–16.2	50	1.4×10^{-5}	253.1	–19.1
32-6, 49	8.1×10^{-6}	49.5	28.9	50	9.1×10^{-6}	28.6	6.5
32-6, 110	1.4×10^{-5}	236.1	–40.4	50	1.0×10^{-5}	282.0	–37.8
33-1-88	4.1×10^{-6}	62.1	27.8	50	3.2×10^{-6}	73.3	6.3
33-2, 30	5.2×10^{-6}	216.2	–22.0	50	4.3×10^{-6}	218.7	–11.5
33-2, 134	3.9×10^{-6}	147.4	–38.9	50	3.6×10^{-6}	151.2	–23.8
33-3, 85	4.2×10^{-6}	149.8	12.2	50	4.1×10^{-6}	145.1	4.8
33-4, 28	6.6×10^{-6}	195.5	16.9	50	6.1×10^{-6}	202.6	12.7
33-4, 88	3.2×10^{-6}	205.2	4.8	50	2.2×10^{-6}	200.0	14.9
33-5, 73	1.7×10^{-6}	258.3	53.5	50	2.5×10^{-6}	59.0	64.7
33-6, 43	3.2×10^{-6}	279.8	16.5	50	2.6×10^{-6}	279.4	0.6
33-6, 127	6.7×10^{-6}	117.5	11.6	50	5.1×10^{-6}	175.3	16.3
34-1, 76	7.6×10^{-6}	34.2	13.1	50	7.8×10^{-6}	23.3	17.5
34-2, 77	1.5×10^{-5}	46.3	5.2	50	1.3×10^{-5}	44.5	8.5
34-3, 82	3.5×10^{-6}	183.0	23.5	50	3.4×10^{-6}	178.6	24.1
34-4, 76	7.6×10^{-6}	347.2	10.1	50	6.4×10^{-6}	354.7	15.5
34-5, 74	1.6×10^{-5}	155.8	38.8	50	1.1×10^{-5}	159.1	25.7
34-6, 69	2.1×10^{-5}	291.4	3.7	50	1.6×10^{-5}	292.7	8.2
35-1, 102	5.4×10^{-6}	355.0	15.7	50	3.5×10^{-6}	347.6	17.0
35-2, 71	2.8×10^{-5}	131.4	19.7	50	1.8×10^{-5}	135.9	23.1
35-3, 77	1.1×10^{-5}	61.2	15.8	50	1.0×10^{-5}	58.0	19.9
35-4, 73	1.9×10^{-5}	326.3	21.3	50	1.6×10^{-5}	327.0	21.7
35-5, 71	2.5×10^{-5}	13.1	29.1	50	2.0×10^{-5}	10.3	24.1
35-6, 74	9.4×10^{-6}	97.9	6.1	50	8.3×10^{-6}	100.8	11.8
36-1, 112	1.1×10^{-5}	44.2	34.4	50	1.0×10^{-5}	42.8	27.7
36-2, 79	3.2×10^{-5}	99.8	55.7	50	2.5×10^{-5}	99.1	51.6
36-3, 72	1.2×10^{-5}	327.7	36.1	50	1.1×10^{-5}	328.2	33.7

TABLE 5
Af Demagnetization, Site 222

Sample	Peak Field (oersted)	Intensity (G/cm^3)	Relative Declination (degrees)	Inclination (degrees)
20-2, 19 cm	NRM	2.4×10^{-5}	92.9	20.3
	25	2.5×10^{-5}	89.3	19.8
	50	2.5×10^{-5}	86.9	22.0
	75	2.3×10^{-5}	84.0	19.6
	100	2.2×10^{-5}	84.2	19.9
	150	1.9×10^{-5}	81.9	20.5
	200	1.7×10^{-5}	78.6	21.0
28-3, 129 cm	NRM	1.4×10^{-5}	96.6	-3.9
	50	1.3×10^{-5}	98.7	-9.1
	100	1.2×10^{-5}	99.4	-6.8
	150	1.0×10^{-5}	99.4	-7.3
	300	7.7×10^{-6}	99.5	-10.5
	375	4.2×10^{-6}	105.6	-13.5
	450	3.9×10^{-6}	110.5	1.3
36-3, 72 cm	NRM	1.2×10^{-5}	327.6	35.9
	50	1.1×10^{-5}	328.2	33.7
	100	1.0×10^{-5}	327.8	31.7
	150	8.6×10^{-6}	326.3	31.3
	225	7.3×10^{-6}	320.8	30.9
	300	5.7×10^{-6}	324.1	31.1
	375	3.3×10^{-6}	328.0	33.5
	450	4.3×10^{-6}	333.3	29.9

green layers occur in unit II. A similar extrapolation indicates that these green beds occupy 14 percent of the stratigraphic column.

Because of the gross compositional similarities between the green and the gray sediment intervals plus the frequency with which they alternate, they did not qualify for unit status.

A comparison of the green and gray facies shows many similarities as well as many differences. Both facies are characterized by a high detrital grain content (including carbonate particles), generally low organic carbon content (0.1% to 0.4%), and similarity of size distribution within the fine-grained sediments.

TABLE 6
Mean Absolute Inclinations and Associated Paleolatitudes

		Mean Inclination[a]	Paleolatitude
Early Pliocene	n = 10	22.1 ± 4.9°	11.5° ± 2.5°N
Late Miocene	n = 78	18.8 ± 1.7°	9.7° ± 0.8°N
Combined data	n = 88	19.2 ± 1.6°	9.9 ± 0.8°N

[a] Mean absolute inclinations after demagnetization.

The differences, besides that of color, include the higher nannofossil content of the green facies. Furthermore, whereas indigenous nannofossils and foraminifera occur in both facies (including some shallow water forms), the gray facies in addition contains reworked Eocene and Cretaceous forms. Also quite evident is the presence of burrow structures only in the green facies and of coarse-grained sand and silt beds only in the gray facies.

The uppermost green interval (unit I) has several peculiarities which serve to distinguish it from the others. Burrow structures are absent, nannofossils are locally the dominant constitutent, its thickness exceeds that of other green intervals, and it appears to have a significant eolian admixture.

Many of the above similarities and differences are shown in Table 3 (see back pocket), where they are plotted on the section level.

Carbonate grains are a constant admixture to both the green and gray facies. These grains are usually in the medium to fine silt-size range. Under the petrographic microscope, they lack biogenic or authigenic characteristics, consequently they were considered to be of clastic derivation. An unusual attribute is the constancy of their proportion in the sediment which seldom deviates from between 12 and 16 percent. In addition to the clastic grains and calcareous fossils, there are trace amounts of volcanic glass and pyrite throughout. Trace amounts of radiolarians, diatoms, sponge spicules, and silicoflagellates occur in Cores 1 to 7.

Induration shows a gradual increase with depth. However, near the bottom of the hole there are local intervals, including sand beds, which are extremely hard. Their induration is due to carbonate cementation (see Matter, Chapter 9). A 5-meter hard interval slowed the penetration rate to the point where it was decided to abandon the hole.

Sedimentation rates at this site, although they are all rapid, nevertheless show significant variations. The slowest rate, 42 to 53 m/m.y., occurs in the Pleistocene strata, which encompass the atypical uppermost green interval. There the presence of only fine-grained sediments, including abundent nannofossils and palygorskite of presumed eolian origin, suggests pelagic processes contributed greatly to this interval. Pre-Pleistocene sedimentation rates vary from 135 m/m.y. in the Early Pliocene to at least 600 m/m.y. in Late Miocene time.

Depositional Agents and Sediment Sources

Deciphering the depositional agents contributing to Site 222 was difficult and not entirely successful. The problems revolve around both the green and the gray fine-grained silty clays and, to a lesser degree, the coarse sediments; in other words, the components of the Indus Fan.

Typically, the coarse beds range from 1 to 8 cm thick, with a maximum thickness of 1 meter. Many have textures and structures which typify turbidites. Others have features suggesting deposition by a different transport agent. Bottom current reworking of turbidite sands for the latter group appears to be the most plausible agent at this time. As the coarse beds only amount to between 7 and 10 percent of the total stratigraphic section, well-defined turbidite deposition constitutes but a small portion of the fan sedimentation at this site.

Quantitatively more important are the green and the gray fine-grained deposits which make up the remaining ~90 percent of the fan material. Of these, as mentioned earlier, only the much more abundant gray facies is associated with the coarse clastics. Typically, a thick interval of gray silty clay grades downward into a much thinner sand or silt bed. Unfortunately, the grading is gradual, and it is difficult to tell whether all or only a small part of the silty clay belongs to a turbidite. The paleontological data indicates the presence of both reworked and indigenous fossils in the fine-grained sediments. However, currents, other than turbidity currents, could have redistributed the small microfossils. Consequently, this is not a diagnostic aspect. Similarly nondiagnostic are X-ray mineralogical examinations of the fine-grained sediments. Suggestions for other transporting mechanisms are discussed by Jipa and Kidd (this volume). For the present, this question, which has posed a similar problem on other *Glomar Challenger* cruises, remains unresolved.

It is recognized that the green silty clays are a product of different processes than those depositing the gray facies. However, what these processes are is unclear. A higher nannofossil content in the green facies indicates that pelagic biogenous productivity is a more important factor. The presence of burrow structures, when taken with the previous statement, indicates a slower rate of deposition for the green intervals (unfortunately, paleontological zonations are not sufficiently refined to verify this hypothesis). The presence of palygorskite in the uppermost green interval points to eolian transport as being important there.

On the basis of heavy mineral studies (see Mallik and also Jipa and Kidd, this volume), the source for the coarse-grained beds appears to have been the Indus River drainage. A similar conclusion is appropriate for the gray

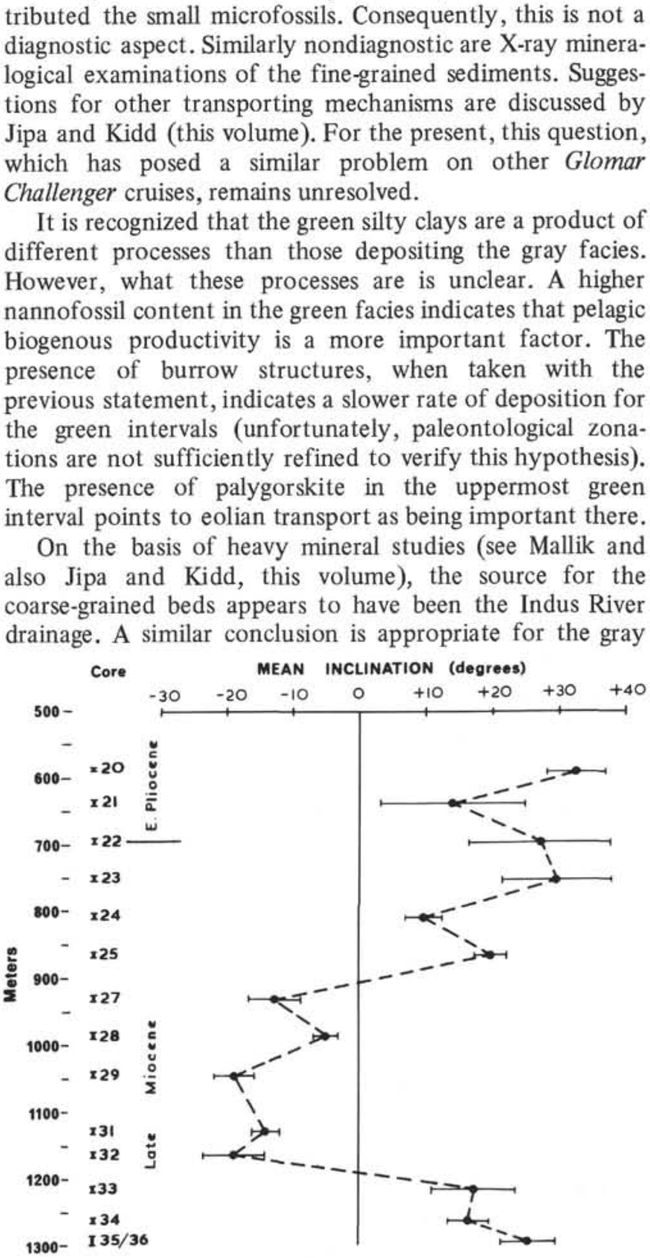

Figure 9. *Change in mean magnetic inclination with depth downhole after Af demagnetization in 50 oersted peak field.*

facies on the basis of X-ray mineralogy studies. However, the question arises as to whether all of these sediments flowed through the Indus Submarine Canyon or whether some came from the Oman Basin. In the latter event, they would have flowed south into the Owen Abyssal Plain and then east toward Site 222 between a gap in the Owen Ridge. Arguing for this viewpoint is the previously mentioned eastward dipping shallow reflector seen at this site and the fact that, at present, the Owen Abyssal Plain and the Indus Cone surface in the vicinity of Site 222 appear to be at grade. Unfortunately, it is not possible to determine whether the buried eastward dipping horizon is a depositional feature or the product of structural deformation along the Owen Fracture Zone.

Depositional History

On the bases of magnetic anomalies recognized in the Arabian Sea and by extrapolating sea floor spreading rates, Site 222 is located in over 70 m.y. old basaltic crust. Consequently, the 6 m.y. time span penetrated at this site represents less than 10 percent of its depositional history. However, on the basis of other Leg 23 drill site data and from an understanding of the normal sequence of sediments deposited on oceanic crust generated at a spreading ridge, it is possible to reconstruct its earlier history. This reconstruction is carried out in Chapter 12. The oldest stratigraphically recognizable interval encompasses the last million years of Late Miocene time. Almost the entire lower half of the 1300 meters of sediment penetrated at Site 222 were deposited during this period. Although consisting largely of gray silty clays plus associated silt and sand beds, there are many intervals of green silty clay as well. These contain burrow structures which, when taken with their higher content of nannofossils, suggests that they represent periods of slower deposition. These periods appear to be too numerous to consider either climatic fluctuation or major periods of tectonic disturbance in the drainage area of the Indus River as causative agents. More likely they represent shifts in the loci of Indus Fan deposition. There is some question as to whether turbidity current deposition was an important factor in the deposition of any except the coarse-grained beds.

This mode of deposition continued into the Pliocene although at a reduced rate. Early and Late Pliocene sediments accumulated at rates of 135 and at least 350 m/m.y., respectively.

A pronounced change in rate and type of deposition took place at about the beginning of Pleistocene time. Coarse turbidites are completely absent and even the finer-grained clastics accumulated at a much slower rate. They, together with a significant admixture of pelagic constituents, were deposited at a rate of 42 to 53 m/m.y. In conclusion, it appears that nonturbiditic processes dominated the depositional regime during Pleistocene time.

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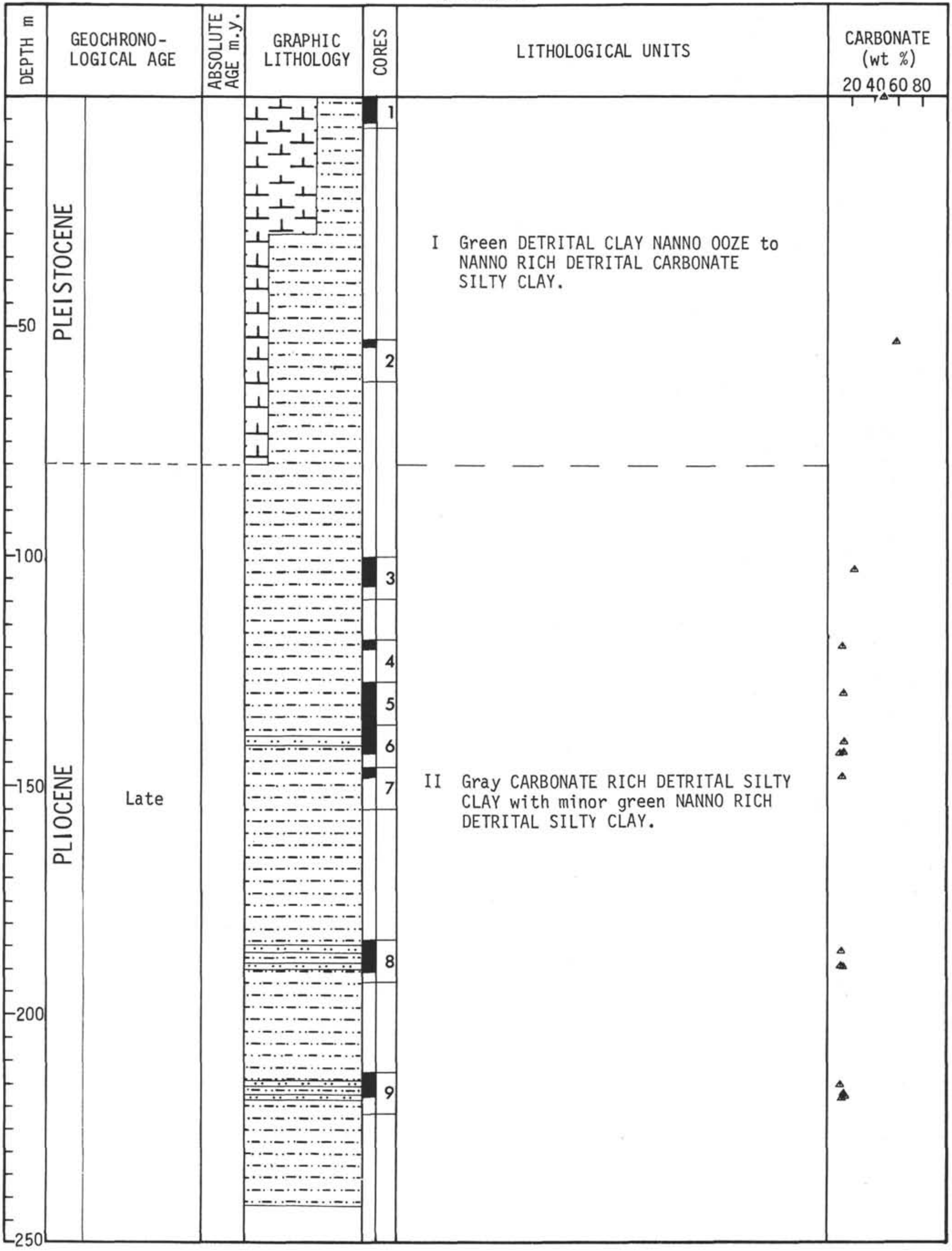
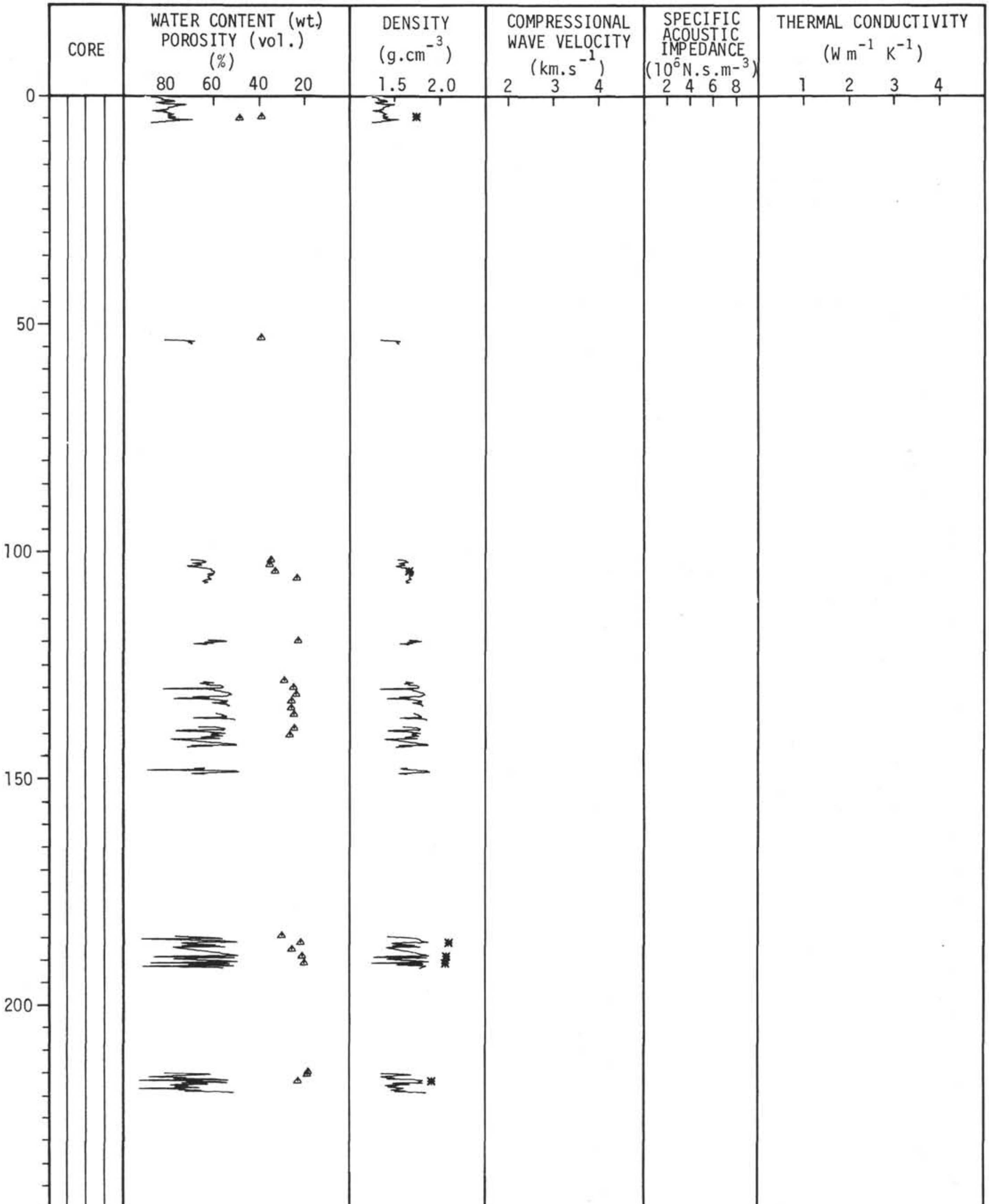
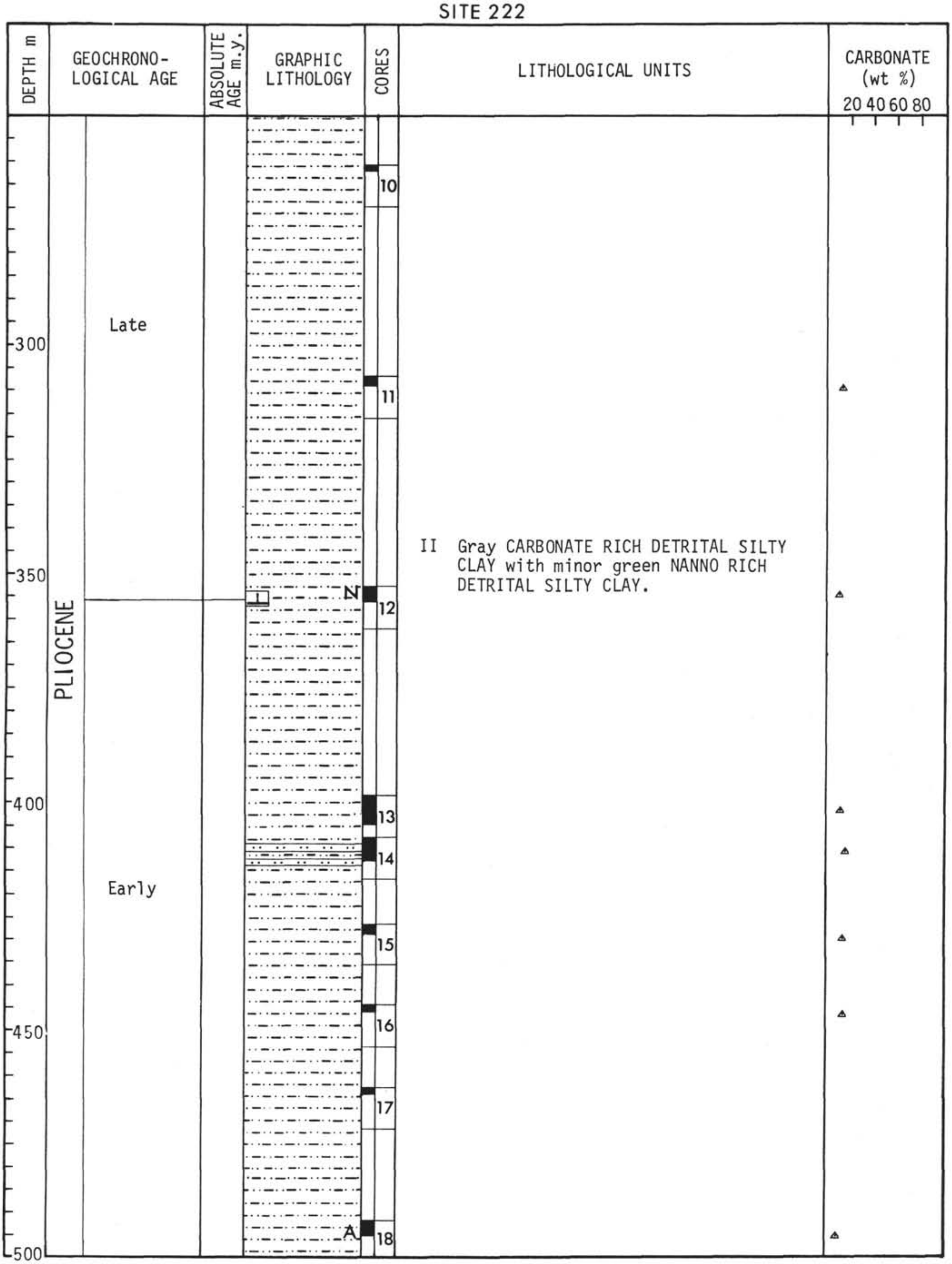
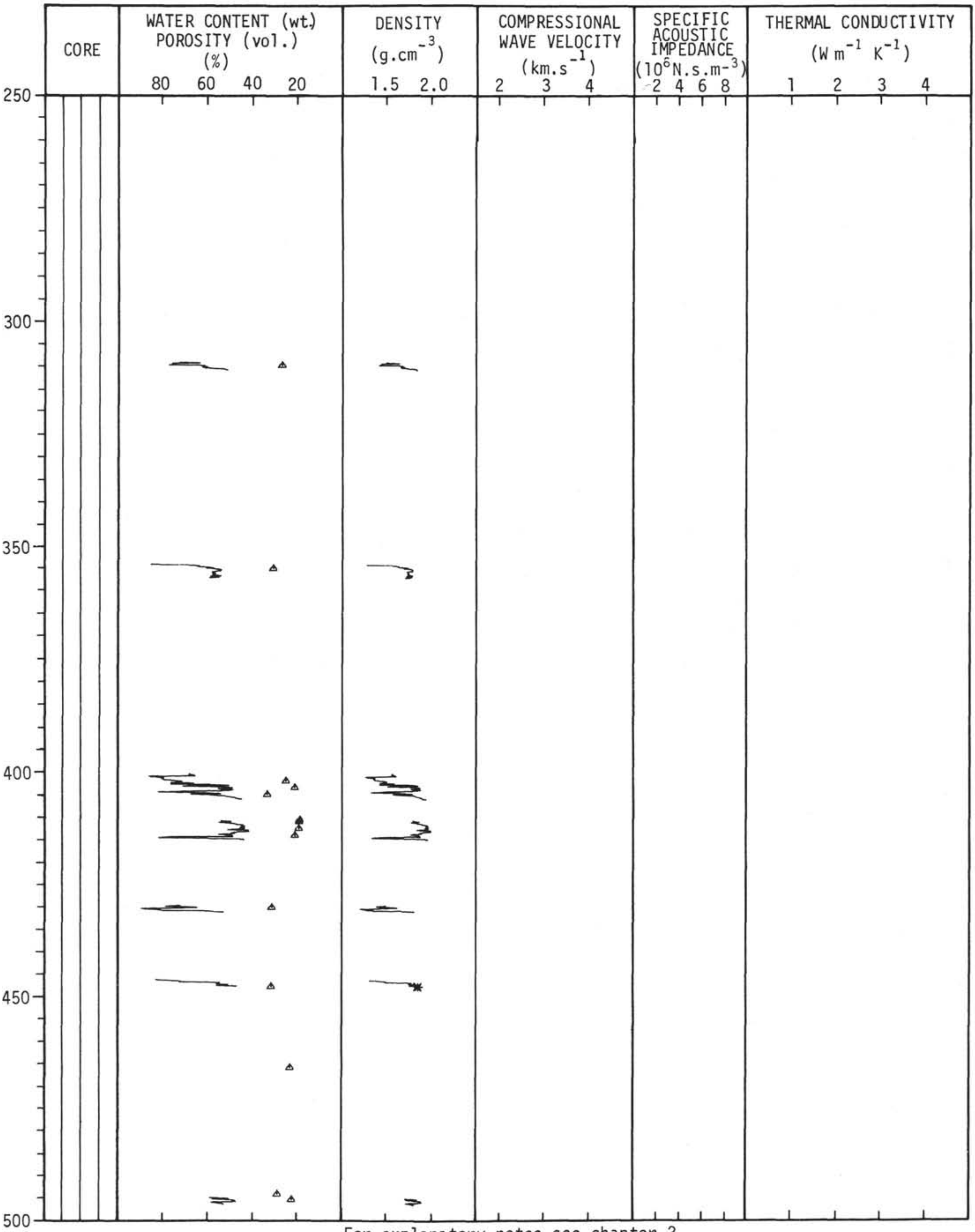
SITE 222


DEPTH m
GEOCHRONO-LOGICAL AGE
ABSOLUTE AGE m.y.
GRAPHIC LITHOLOGY
CORES
LITHOLOGICAL UNITS
CARBONATE (wt %)
20 40 60 80
50
100
150
200
250
PLEISTOCENE
PLIOCENE
Late
1
2
3
4
5
6
7
8
9
I Green DETRITAL CLAY NANNO OOZE to NANNO RICH DETRITAL CARBONATE SILTY CLAY.
II Gray CARBONATE RICH DETRITAL SILTY CLAY with minor green NANNO RICH DETRITAL SILTY CLAY.



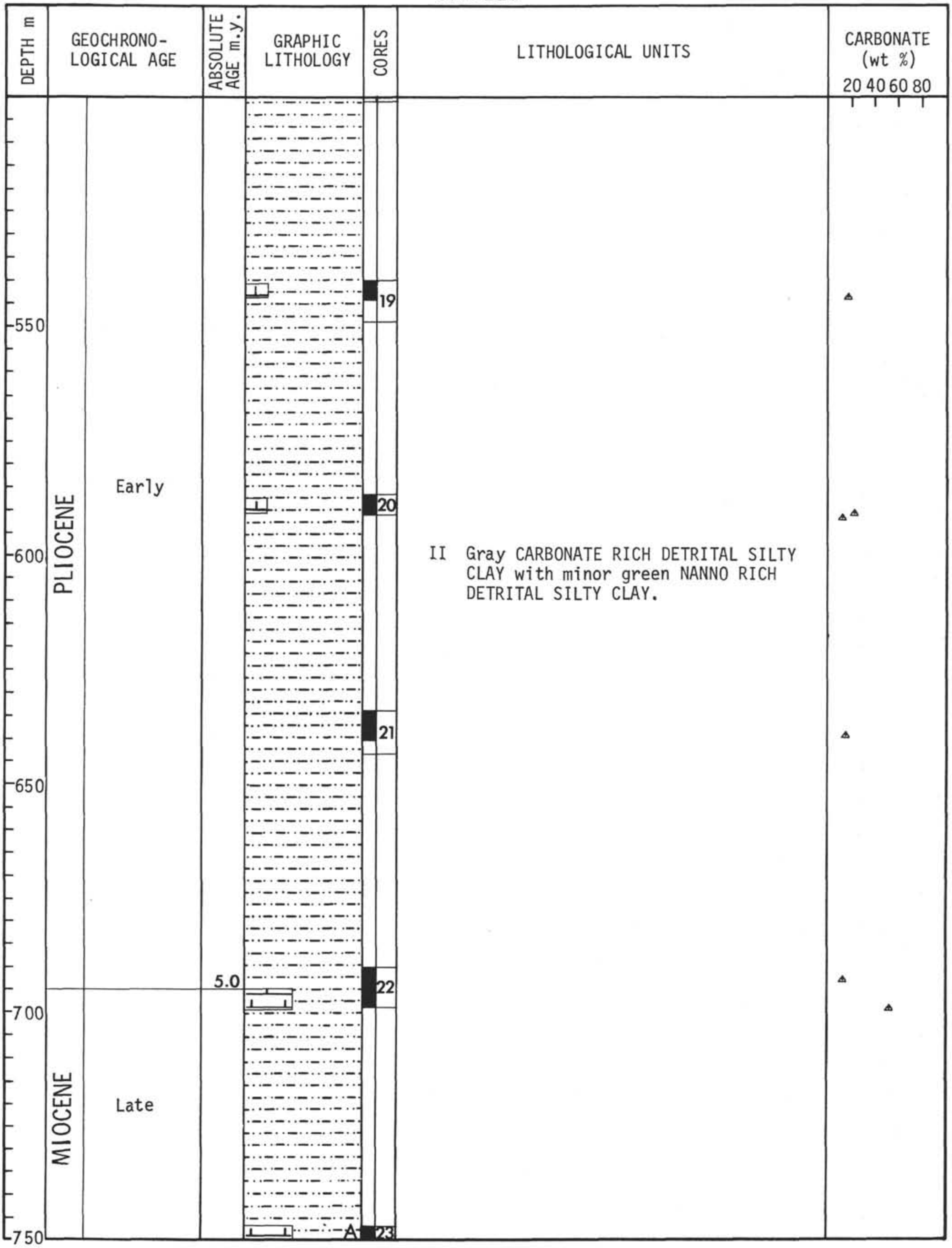
For explanatory notes see chapter 2.


SITE 222
DEPTH m
GEOCHRONO-LOGICAL AGE
ABSOLUTE AGE m.y.
GRAPHIC LITHOLOGY
CORES
LITHOLOGICAL UNITS
CARBONATE (wt %)
20 40 60 80
300
350
400
450
500
PLIOCENE
Late
Early
N
A
10
11
12
13
14
15
16
17
18
II Gray CARBONATE RICH DETRITAL SILTY CLAY with minor green NANNO RICH DETRITAL SILTY CLAY.

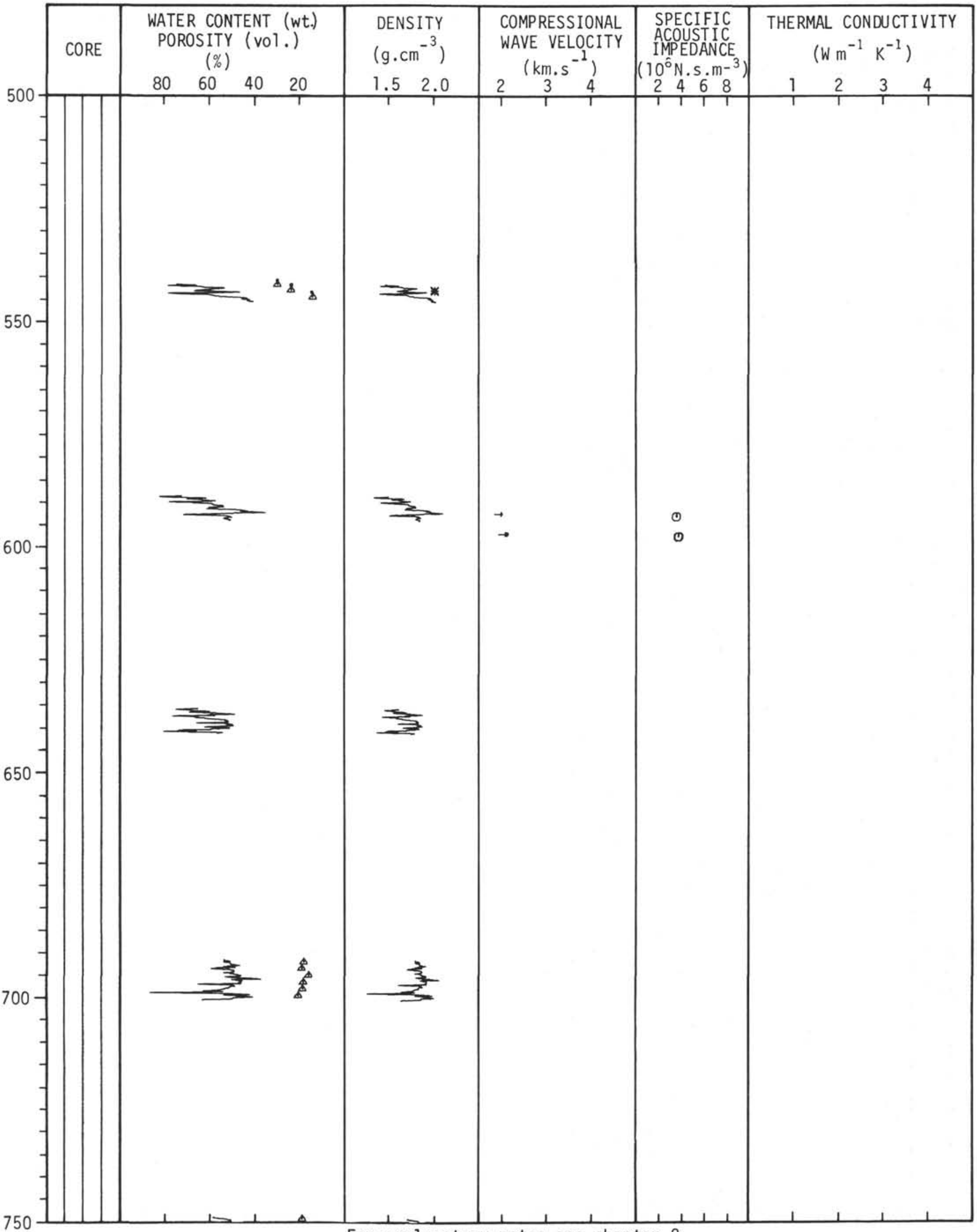


For explanatory notes see chapter 2.

SITE 222

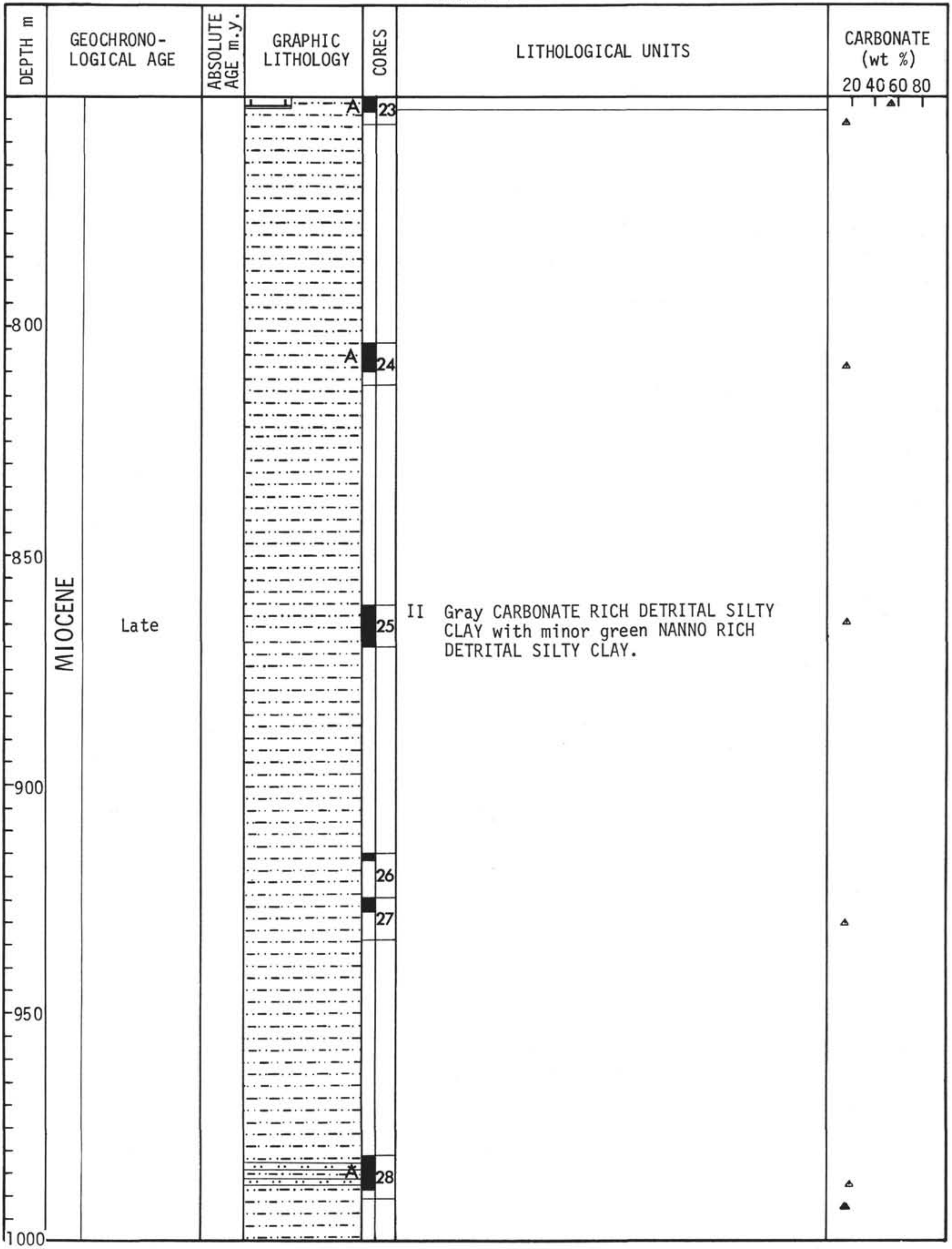


II Gray CARBONATE RICH DETRITAL SILTY CLAY with minor green NANNO RICH DETRITAL SILTY CLAY.

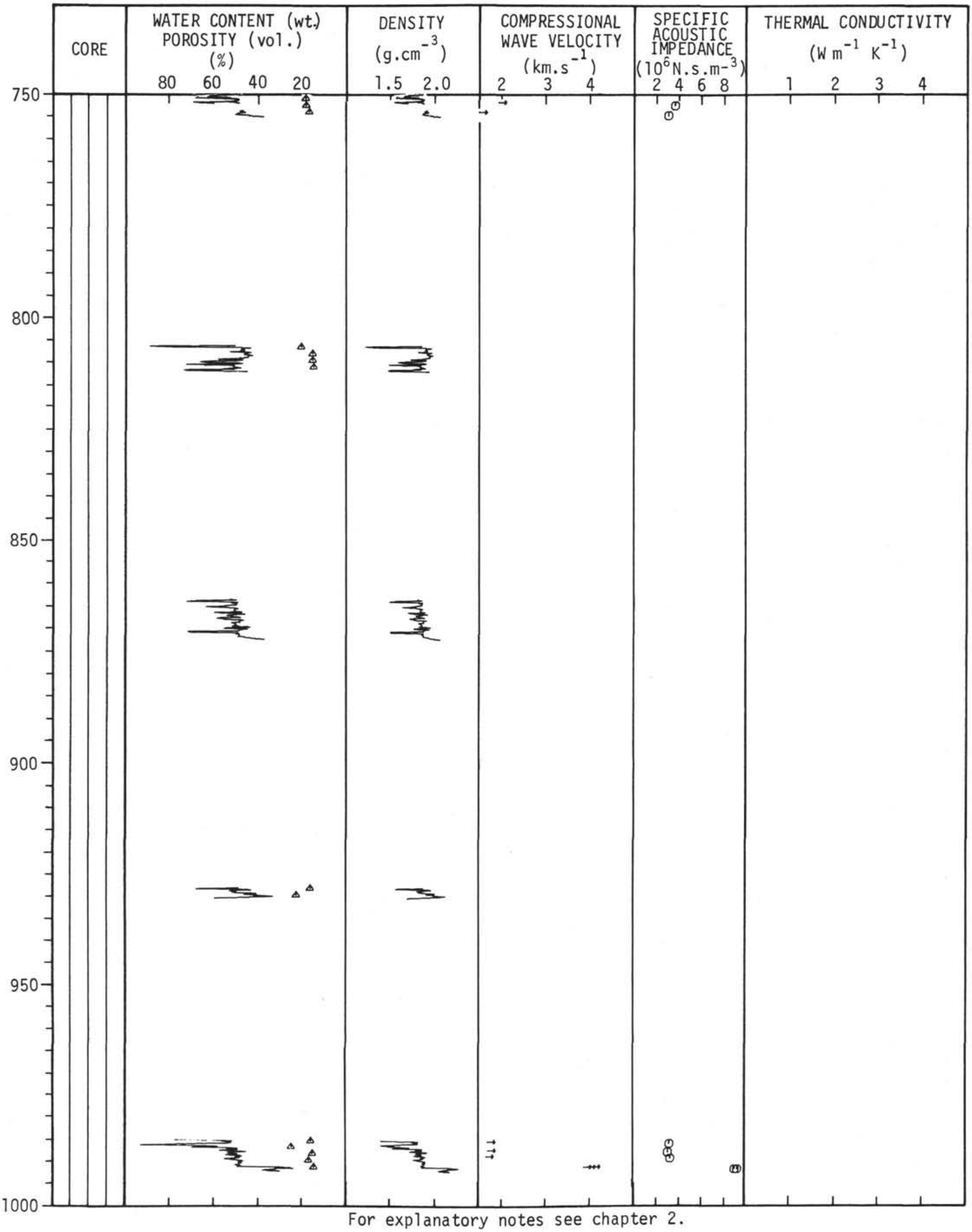


For explanatory notes see chapter 2.

SITE 222

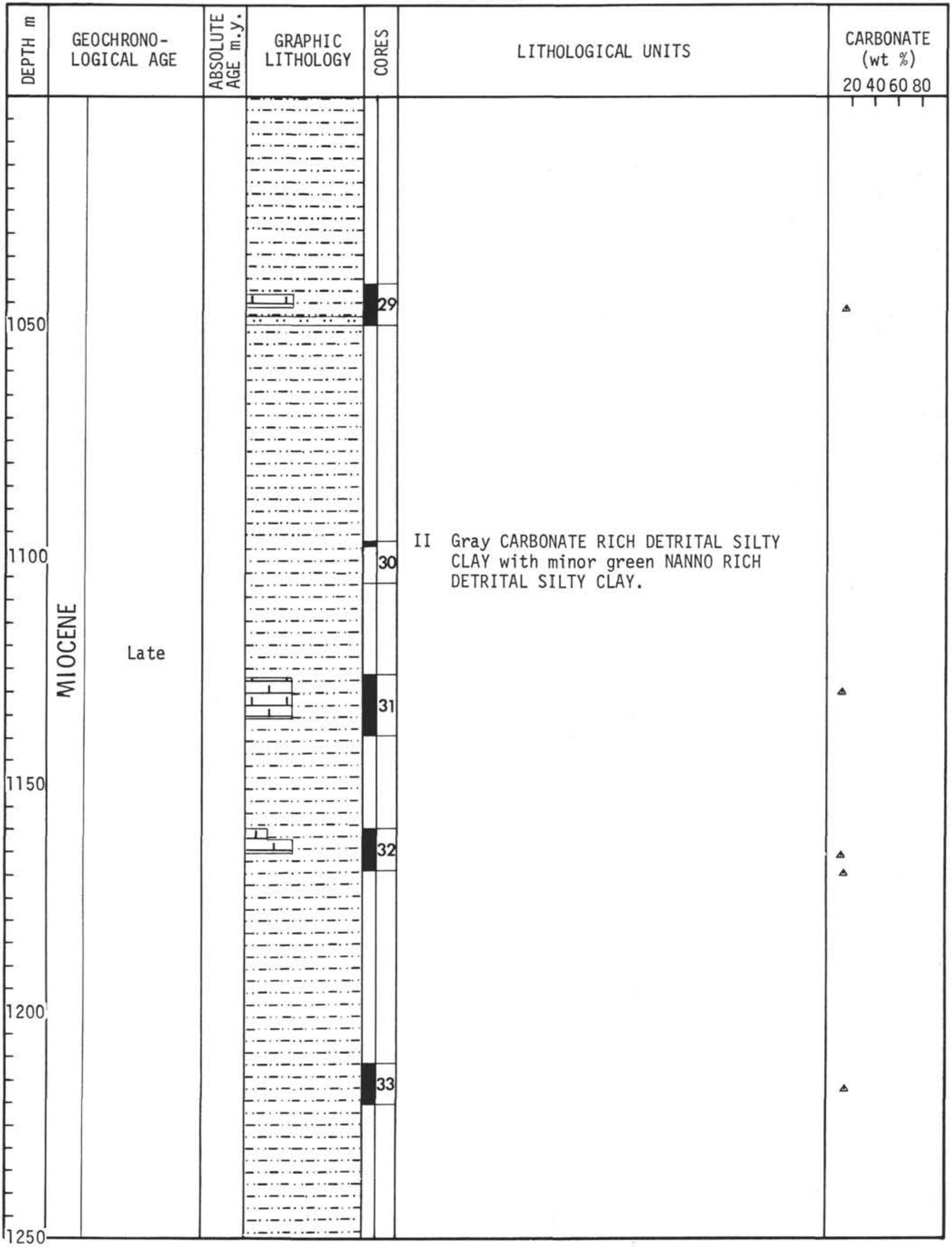


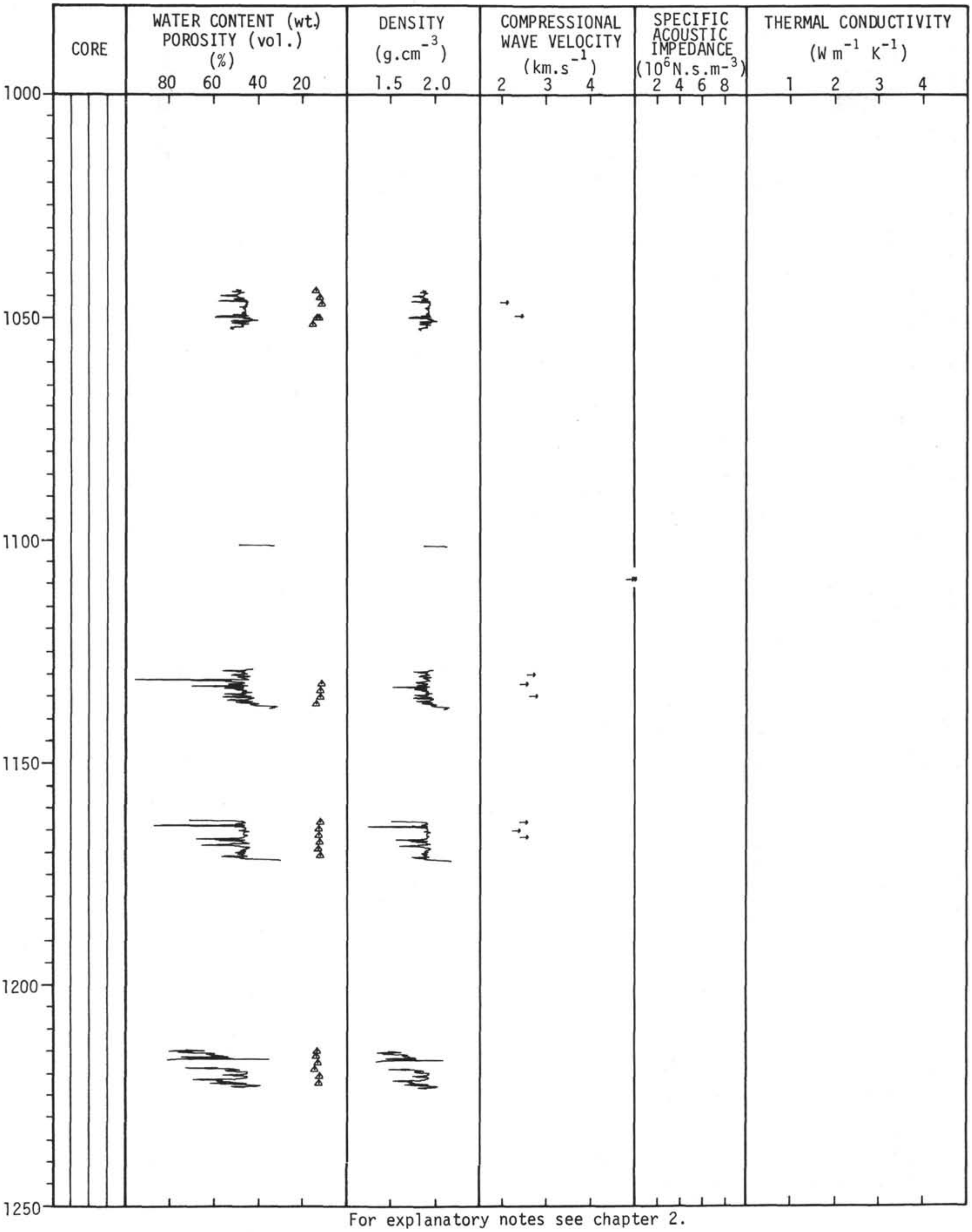
II Gray CARBONATE RICH DETRITAL SILTY CLAY with minor green NANNO RICH DETRITAL SILTY CLAY.



For explanatory notes see chapter 2.

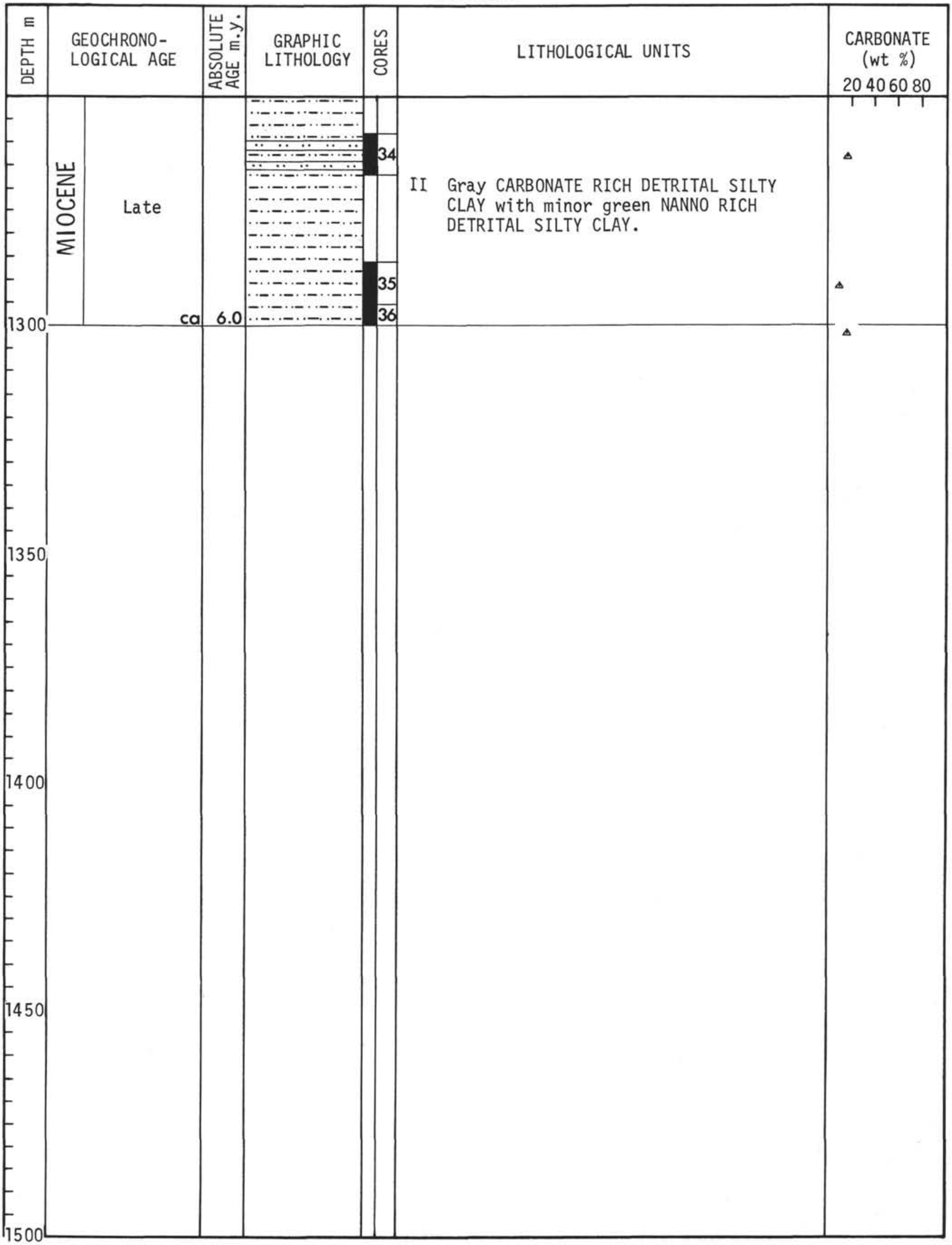
SITE 222

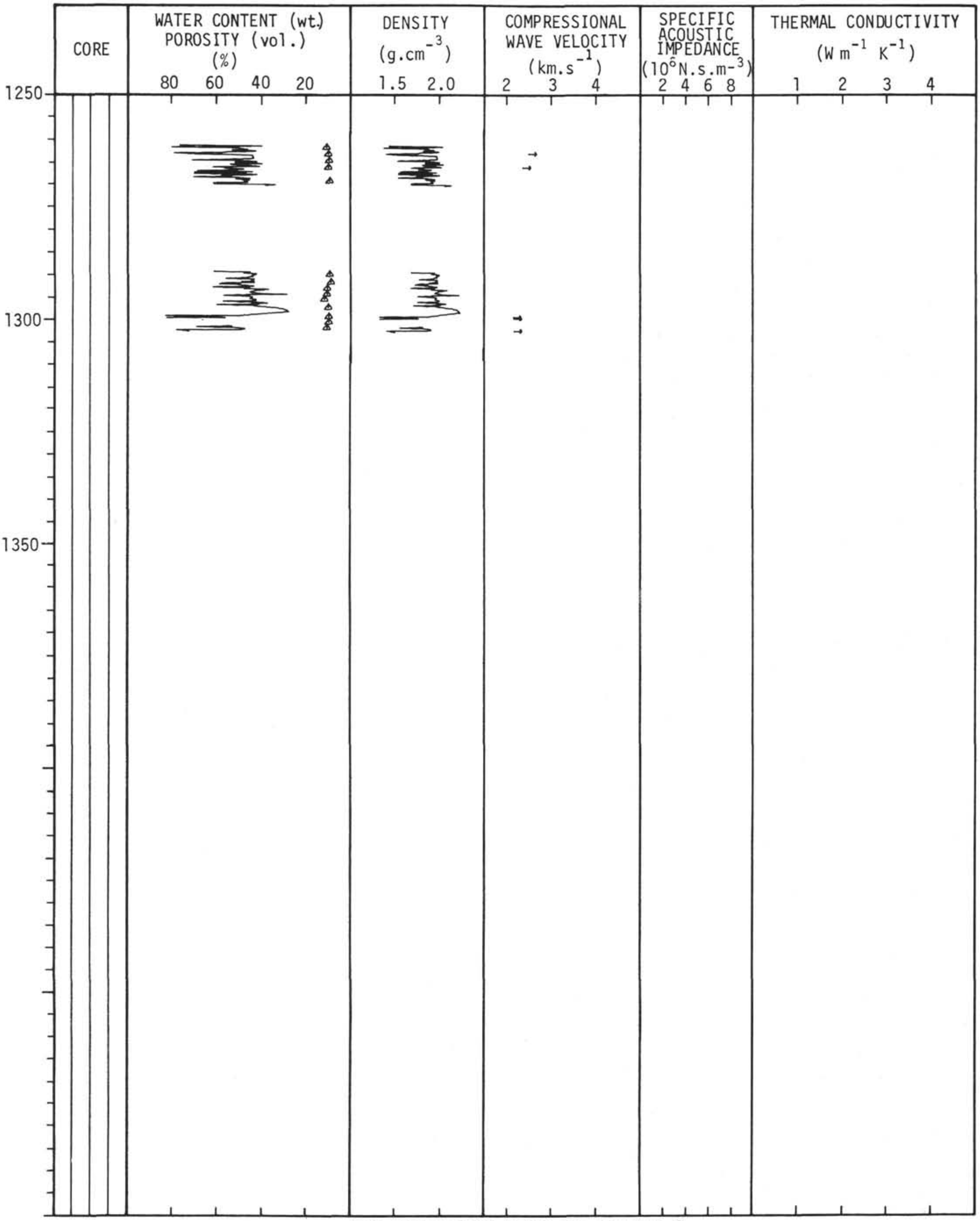

DEPTH m
GEOCHRONO-LOGICAL AGE
ABSOLUTE AGE m.y.
GRAPHIC LITHOLOGY
CORES
LITHOLOGICAL UNITS
CARBONATE (wt %)
20 40 60 80
1050
1100
1150
1200
1250
MIOCENE
Late
29
30
31
32
33
II Gray CARBONATE RICH DETRITAL SILTY CLAY with minor green NANNO RICH DETRITAL SILTY CLAY.



For explanatory notes see chapter 2.

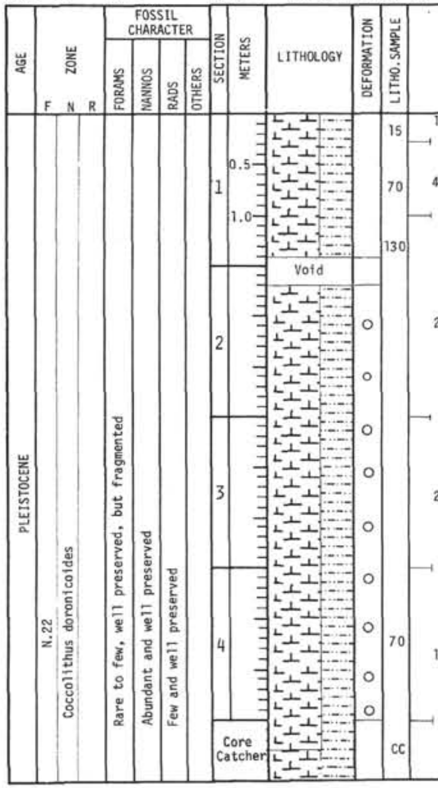
SITE 222


DEPTH m
GEOCHRONO-LOGICAL AGE
ABSOLUTE AGE m.y.
GRAPHIC LITHOLOGY
CORES
LITHOLOGICAL UNITS
CARBONATE (wt %)
20 40 60 80
MIOCENE
Late
ca 6.0
34
35
36
II Gray CARBONATE RICH DETRITAL SILTY CLAY with minor green NANNO RICH DETRITAL SILTY CLAY.
1300
1350
1400
1450
1500



For explanatory notes see chapter 2.

Site 222 Hole Core 1 Cored Interval: 0-7



LITHOLOGIC DESCRIPTION

Gray to olive DETRITAL SILTY CLAY NANNO OOZE

Degree of induration: Soft
Aspects of bedding: Massive
Drilling deformation: Sections 2-4 badly deformed.
Lithology remarks: Streaks of pyrite in the middle part of section 1. Core catcher contains 4% diatoms. Clay material consists largely of detrital carbonate. H_2S smell in section 1.

Dominant lithology SS: Sections 1-15 cm, 70 cm, 130 cm, 4-70 cm, core catcher.
DETRITAL SILTY CLAY NANNO OOZE
Composition:

Nannos	55%
Detrital minerals	45%
Pyrite	Trace
Dolomite rhombs	Trace
Forams	Trace
Sponge spicules	Trace
Diatoms	Trace
Radiolarians	Trace

Color legend:
1 = green gray 5GY 6/1
2 = gray olive 10Y 4/2
3 = pale olive 10Y 6/2
4 = gray yellow green 5GY 7/2

Shore-based laboratory results

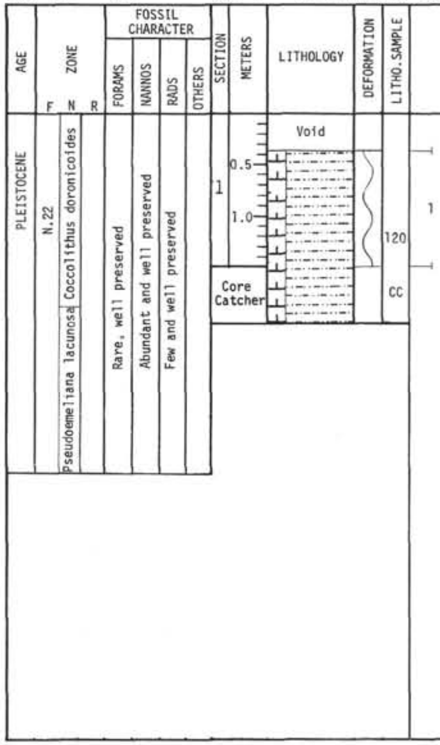
Carbonate
Section 1-40 cm = 47%

Grain size: Section 1-43 cm

Sand	2%
Silt	37%
Clay	61%

Explanatory notes in chapter 2

Site 222 Hole Core 2 Cored Interval: 53-62



LITHOLOGIC DESCRIPTION

Green NANNO RICH DETRITAL CARBONATE SILTY CLAY.

Degree of induration: Stiff
Aspects of bedding: Massive
Drilling deformation: Highly deformed
Lithology remarks: H_2S smell in section 1.

Dominant lithology SS: Section 1-120 cm
NANNO RICH DETRITAL CARBONATE SILTY CLAY
Composition:

Carbonate	41%
Detrital minerals	38%
Nannos	15%
Pyrite	2%
Dolomite rhombs	2%
Forams	2%
Radiolarians	Trace
Sponge spicules	Trace

Color legend:
1 = gray green 10GY 5/2

Shore-based laboratory results

Carbonate
Section 1-49 cm = 58%

Grain size: Section 1-51 cm

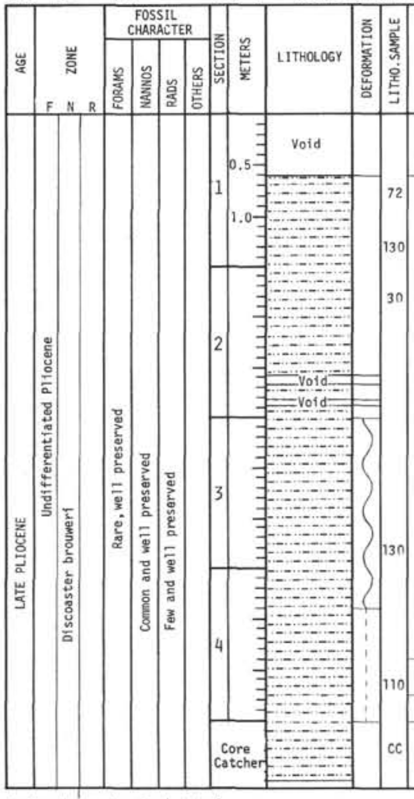
Sand	1%
Silt	40%
Clay	59%

X-ray mineralogy: Section 1-55 cm

Calcite	46%
Dolomite	15%
Quartz	13%
K-feldspar	1%
Plagioclase	7%
Mica	10%
Chlorite	2%
Palygorskite	6%

Explanatory notes in chapter 2

Site 222 Hole Core 3 Cored Interval: 101-110



LITHOLOGIC DESCRIPTION

1 sly. mot.w/2

2

1

Green CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Stiff.
Aspects of bedding: Massive.
Drilling deformation: Section 3 and upper part of 4 badly deformed. Slightly deformed in middle and lower part of section 4.
Lithology remarks: Mollusk fragments in section 2, 5% pyrite in SS 4-110 cm.

Dominant lithology SS: Sections 1-72 cm, 130 cm, 2-30 cm, 3-130 cm.
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	75%
Carbonate	20%
Nannos	5%
Forams	Trace
Sponge spicules	Trace
Diatoms	Trace
Radiolarians	Trace

Color legend:
1 = moderate green 5G 5/6
2 = light olive gray 5Y 5/2

Shore-based laboratory results

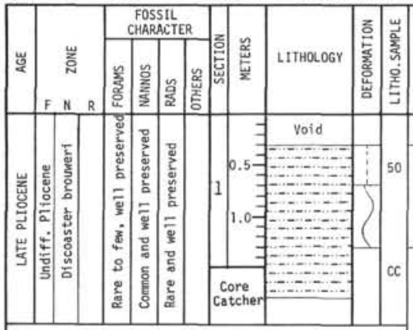
	Carbonate
Section 2-49 cm =	23%

Grain size:	Section 2-41 cm
Sand	1%
Silt	36%
Clay	63%

X-ray mineralogy:	Section 2-47 cm
Calcite	20%
Dolomite	6%
Quartz	21%
Plagioclase	12%
Mica	20%
Chlorite	3%
Montmorillonite	4%
Palygorskite	13%
Amphibole	1%

Explanatory notes in chapter 2

Site 222 Hole Core 4 Cored Interval: 119-128



LITHOLOGIC DESCRIPTION

1 w/ mot. 2

Green CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Stiff.
Aspects of bedding: Massive.
Drilling deformation: Locally slightly to strongly deformed.

Dominant lithology SS: Section 1-50 cm
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	80%
Carbonate	14%
Pyrite	5%
Nannos	1%

Color legend:
1 = gray blue green 5BG 5/2
2 = moderate green 5G 5/6

Shore-based laboratory results

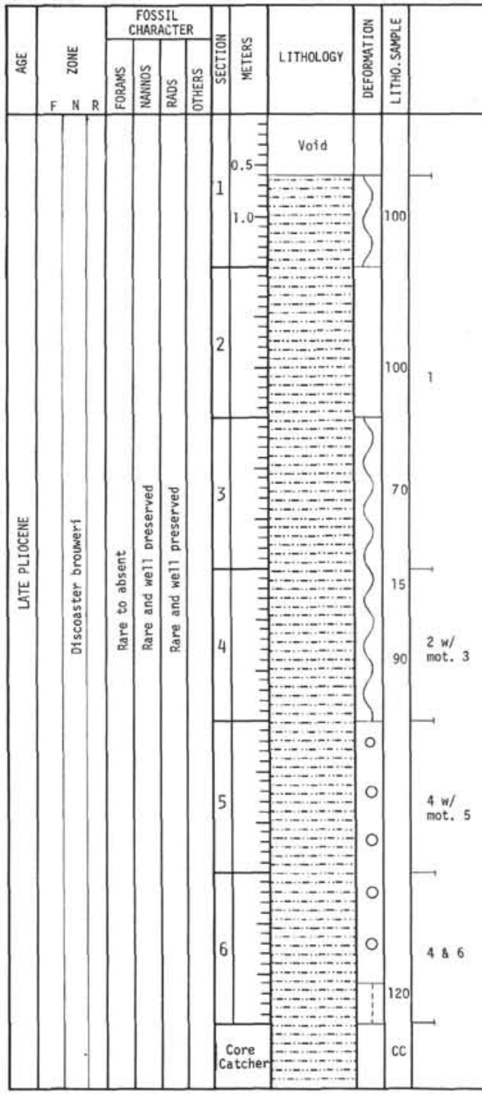
	Carbonate
Section 1-70 cm =	13%

Grain size:	Section 1-71 cm
Silt	32%
Clay	68%

X-ray mineralogy:	Section 1-78 cm
Calcite	12%
Dolomite	1%
Quartz	24%
Plagioclase	6%
Mica	48%
Chlorite	9%

Explanatory notes in chapter 2

Site 222 Hole Core 5 Cored Interval: 128-137



LITHOLOGIC DESCRIPTION

Green to gray CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Stiff.
Aspects of bedding: Massive, where not obscured by drilling distortion. Lamination at the base of section 6.
Drilling deformation: Much of the core is highly disturbed.
Lithology remarks: SS 4-15 cm contains 15% pyrite.

Dominant lithology SS: Sections 3-70 cm, 4-15 cm, 5-90 cm.
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	14%
Nannos	1%
Opaques (pyrite?)	Trace

Color legend:

1 =	gray green	5G 5/2
2 =	moderate green	5G 5/6
3 =	gray blue green	5BG 5/2
4 =	medium gray	N5
5 =	pale blue	5B 6/2
6 =	light brown gray	5YR 6/1

Shore-based laboratory results

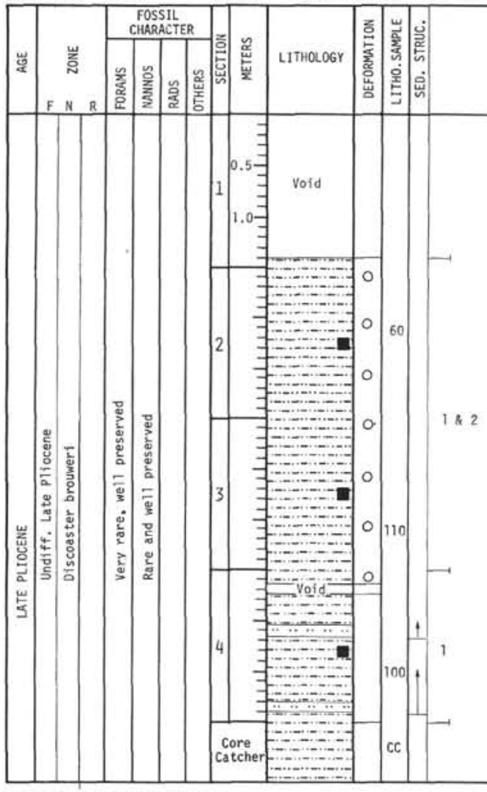
Carbonate
Section 2-40 cm = 14%

Grain size: Section 2-41 cm

Silt	36%
Clay	64%

Explanatory notes in chapter 2

Site 222 Hole Core 6 Cored Interval: 137-146



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Stiff.
Aspects of bedding (visible only in section 4): Silty laminae and at least three intercalations of graded silt layers. These vary in thickness from 25 cm to less than 2 cm. Occasional load casting at the base of the silt beds.

Dominant lithology SS: Sections 2-60 cm, 3-110 cm.
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	80%
Carbonate	14%
Pyrite	5%
Nannos	1%

Color legend:

1 =	medium gray	N5
2 =	medium light gray	N6

Shore-based laboratory results

Carbonate
Section 3-40 cm = 15%

Grain size: Section 3-41 cm

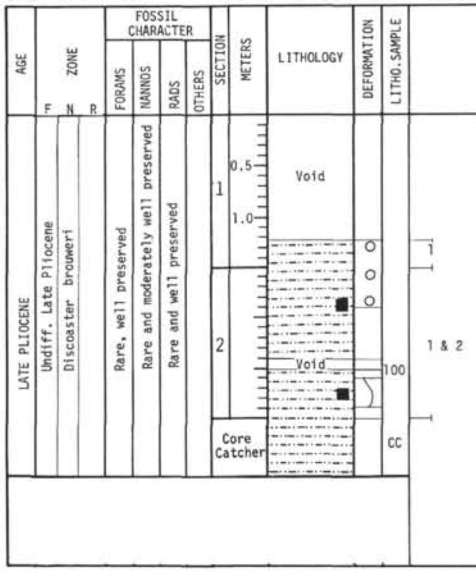
Silt	39%
Clay	61%

X-ray mineralogy: Section 4-113 cm

Calcite	12%
Dolomite	2%
Quartz	27%
Plagioclase	7%
Mica	44%
Chlorite	8%

Explanatory notes in chapter 2

Site 222 Hole Core 7 Cored Interval: 146-155



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Stiff excepting a soft interval in section 2 (110-113 cm).
Aspects of bedding: Massive but mostly obscured by deformation.
Lithology remarks: Lower part of section 2 (135-150 cm) appears coarser grained (silt?).

Dominant lithology SS: Section 2-100 cm
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	80%
Carbonate	14%
Pyrite	5%
Nannos	1%

Color legend:

1 =	medium gray	N5
2 =	light olive gray	5Y 6/1

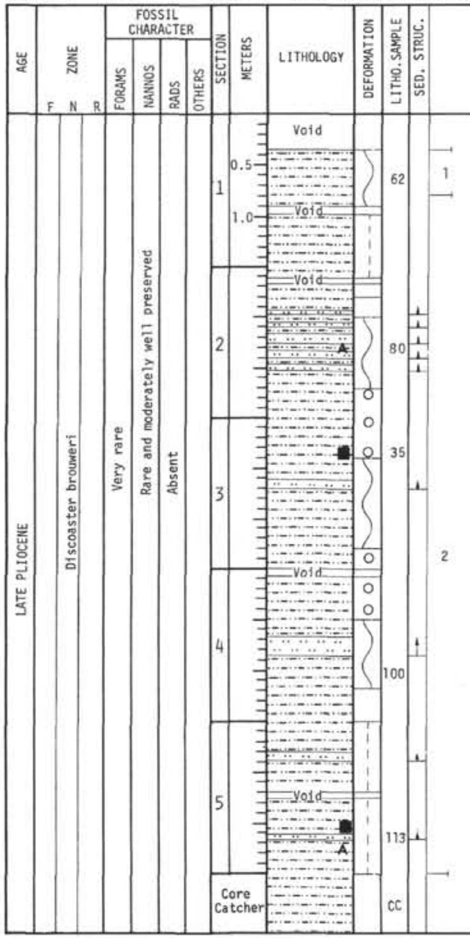
Shore-based laboratory results

Carbonate
Section 2-40 cm = 13%

Grain size:	Section 2-41 cm
Silt	47%
Clay	53%

Explanatory notes in chapter 2

Site 222 Hole Core 8 Cored Interval: 184-193



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Stiff.
Aspects of bedding: Frequent intercalations of silty beds 3-15 cm thick. Graded bedding shown by the intercalated silty beds. The grading is obvious mostly at the transition from silt to clay.

Dominant lithology SS: Sections 1-62 cm, 2-80 cm, 4-100 cm, 5-113 cm.
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	78%
Carbonate	15%
Pyrite	5%
Volcanic glass	2%
Nannos	Trace

Color legend:

1 =	green gray	5GY 6/1
2 =	medium gray	N5

Shore-based laboratory results

Carbonate
Section 2-40 cm = 13%

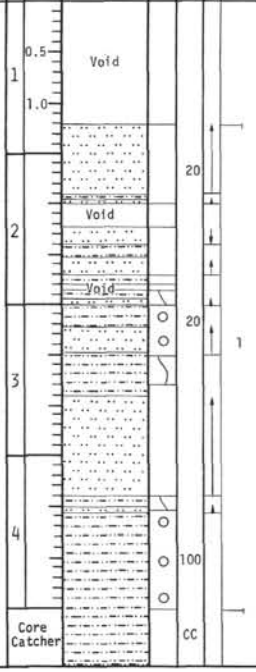
Grain size:	Section 2-41 cm
Silt	33%
Clay	67%

X-ray mineralogy:	Section 4-62 cm
Calcite	9%
Dolomite	1%
Quartz	24%
K-feldspar	2%
Plagioclase	9%
Mica	46%
Chlorite	9%

Explanatory notes in chapter 2

Site 222 Hole Core 9 Cored Interval: 213-222

AGE	ZONE F N R	FOSSIL CHARACTER				SECTION
		FORAMS	NANNOS	RADS	OTHERS	
LATE PLIOCENE	Discoaster brouweri (?)	Rare to absent; minor Eocene reworking	Very rare and moderately well preserved	Absent		1 2 3 4 Core Catcher



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL CLAYEY SILT with intercalations CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Stiff.
Aspects of bedding: Thick clayey silt beds (up to 1 meter) alternating with thinner silty clay beds (40 cm to less than 10 cm thick). Clayey silt beds are graded.
Drilling deformation: Variable, from highly deformed to undeformed.
Lithology remarks: Sediment fragment at the base of section 4 silty sand (sand = 80%, silt = 20%) occurs. Volcanic glass fragment in core catcher.

Dominant lithology SS: Section 2-20 cm
CARBONATE RICH DETRITAL CLAYEY SILT
Composition:

Detrital minerals	88%
Carbonate	12%
Nannos	Trace

Dominant lithology SS: Section 4-100 cm
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace

Color legend:
1 = medium gray N5

Shore-based laboratory results

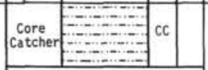
Carbonate
Section 3-81 cm = 15%

X-ray mineralogy: Section 3-84 cm

Calcite	11%
Dolomite	2%
Quartz	24%
K-feldspar	2%
Plagioclase	8%
Mica	44%
Chlorite	9%

Site 222 Hole Core 10 Cored Interval: 261-270

AGE	ZONE F N R	FOSSIL CHARACTER				SECTION
		FORAMS	NANNOS	RADS	OTHERS	
LATE PLIOCENE	Discoaster brouweri (?)	Rare, non-diagnostic	Rare and well preserved	Absent		Core Catcher



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY.

Smear slide: core catcher
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

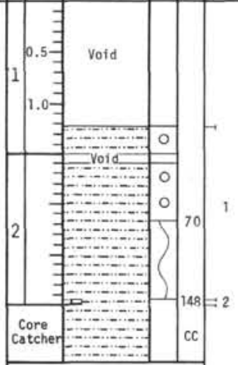
Detrital minerals	85%
Carbonate	15%
Nannos	Trace

Color legend:
1 = medium gray N5

Explanatory notes in chapter 2

Site 222 Hole Core 11 Cored Interval: 307-316

AGE	ZONE F N R	FOSSIL CHARACTER				SECTION
		FORAMS	NANNOS	RADS	OTHERS	
LATE PLIOCENE	Discoaster brouweri (?) Discoaster pentaradiatus	Very rare to absent	Rare and well preserved	Absent		1 2 Core Catcher



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Soft to stiff.
Aspects of bedding: Homogenous

Dominant lithology SS: Section 2-70 cm
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace

Minor lithology SS: Section 2-148 cm and core catcher.
NANNO RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	75%
Nannos	15%
Carbonate	10%

Color legend:
1 = medium light gray N6
2 = light green gray 5G 8/1

Shore-based laboratory results

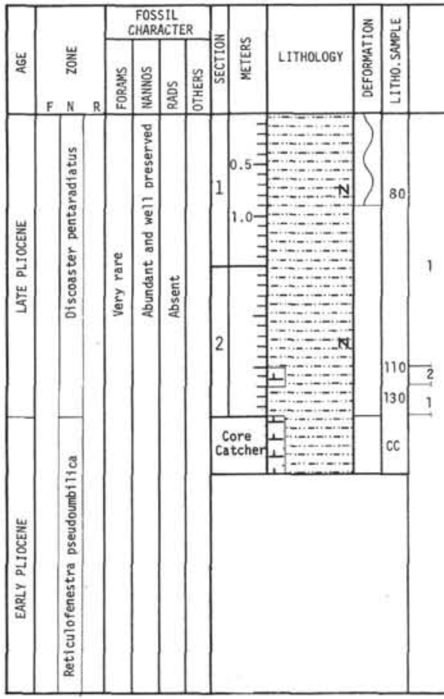
Carbonate
Section 2-40 cm = 15%

Grain size: Section 2-41 cm

Silt	40%
Clay	60%

Explanatory notes in chapter 2

Site 222 Hole Core 12 Cored Interval: 353-362



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Stiff.
Aspects of bedding: Massive.
Drilling deformation: Upper half of section 1 is strongly deformed.

Dominant lithology SS: Sections 1-8 cm, 2-110 cm.
CARBONATE RICH DETRITAL SILTY CLAY.
Composition:

Detrital minerals	85%
Carbonate	12%
Nannos	3%
Pyrite	none to trace

Minor lithology SS: Sections 2-110 cm, 130 cm and core catcher.
NANNO RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	75%
Nannos	15%
Carbonate	10%

Color legend:
1 = medium light gray N6
2 = green gray 5GY 6/1

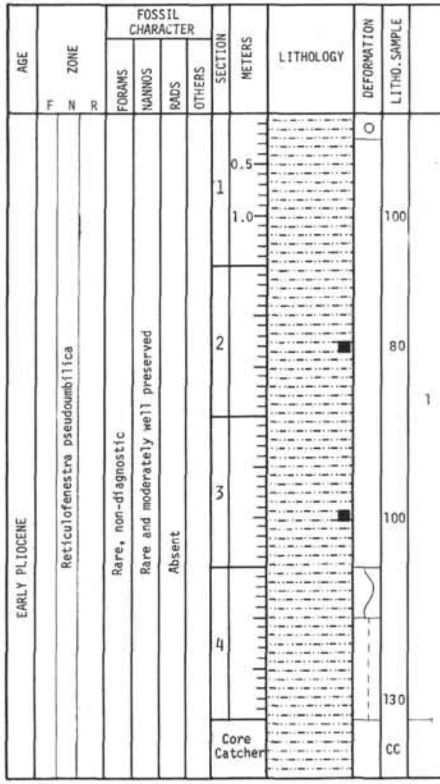
Shore-based laboratory results

	Carbonate
Section 1-90 cm =	12%

Grain size:	Sections 1-95 cm,	2-96 cm
Silt	45%	39%
Clay	55%	61%

Explanatory notes in chapter 2

Site 222 Hole Core 13 Cored Interval: 399-408



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Stiff, soft at the upper part of sections 1 and 2.
Aspects of bedding: Massive.

Dominant lithology SS: Sections 1-100 cm, 2-80 cm, 3-100 cm.
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	83%
Carbonate	15%
Pyrite	2%
Nannos	Trace

Color legend:
1 = medium gray N5

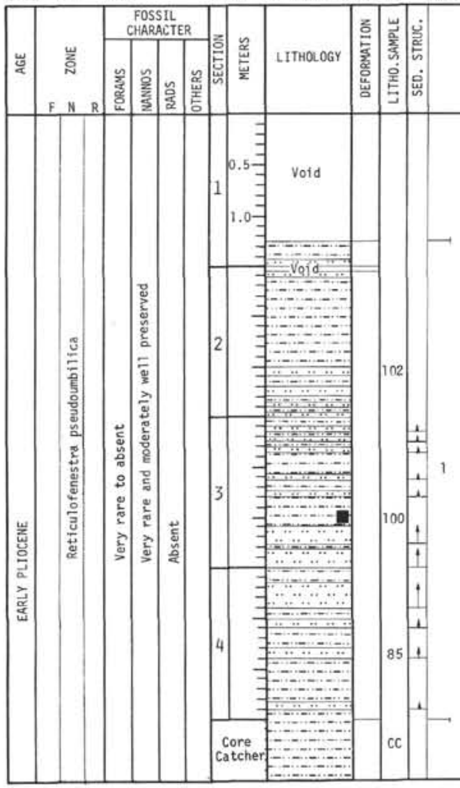
Shore-based laboratory results

	Carbonate
Section 2-40 cm =	13%

Grain size:	Section 2-41 cm
Silt	36%
Clay	64%

Explanatory notes in chapter 2

Site 222 Hole Core 14 Cored Interval: 408-417



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY.

<u>Degree of induration:</u> Stiff.
<u>Aspects of bedding:</u> Frequent intercalations of silty layers (mostly 2-20 centimeters thick). The whole core is laminated and the silty intercalations show grading.
<u>Drilling deformation:</u> Insignificant.

Dominant lithology SS: Sections 2-105 cm, 4-85 cm.
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace

Color legend:
1 = medium gray N5

<u>Shore-based laboratory results</u>

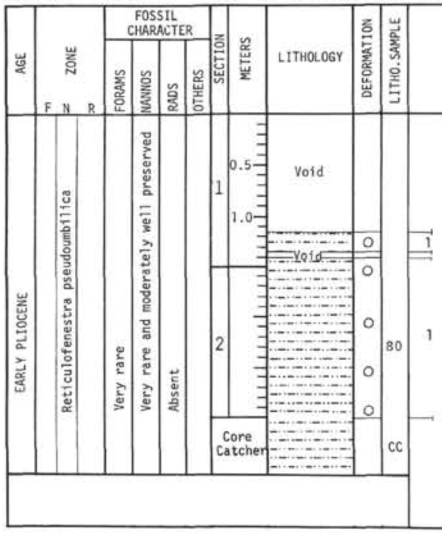
Carbonate
Section 2-40 cm = 17%

Grain size: Section 2-41 cm

Silt	68%
Clay	32%

Explanatory notes in chapter 2

Site 222 Hole Core 15 Cored Interval: 427-436



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY.

<u>Degree of induration:</u> Stiff.
<u>Aspects of bedding:</u> None visible.
<u>Drilling deformation:</u> Entire core badly disturbed.

Dominant lithology SS: Section 2-80 cm
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace

Color legend:
1 = medium gray N5

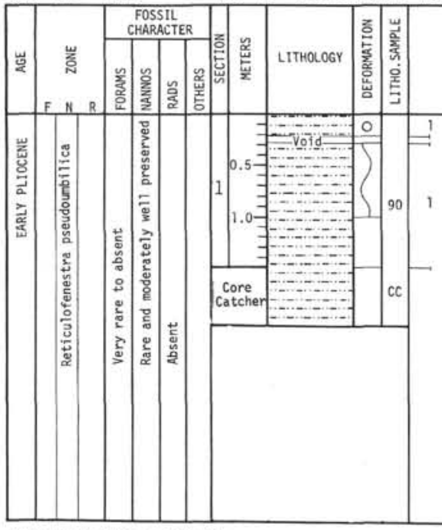
<u>Shore-based laboratory results</u>

Carbonate
Section 2-40 cm = 15%

Grain size: Section 2-42 cm

Silt	45%
Clay	55%

Site 222 Hole Core 16 Cored Interval: 445-454



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY.

<u>Degree of induration:</u> Stiff.
<u>Aspects of bedding:</u> None visible.
<u>Drilling deformation:</u> Upper part of the core - highly disturbed.

Dominant lithology SS: Section1-90 cm
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace

Color legend:
1 = medium gray N5

<u>Shore-based laboratory results</u>

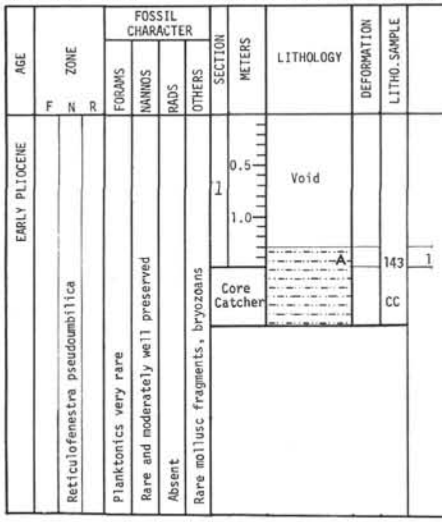
Carbonate
Section 1-40 cm = 16%

Grain size: Section 1-41 cm

Silt	37%
Clay	63%

Explanatory notes in chapter 2

Site 222 Hole Core 17 Cored Interval: 463-472



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY

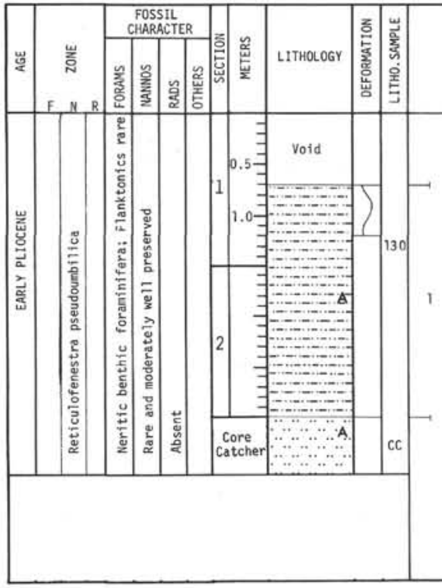
<u>Degree of induration</u>: Stiff.
Aspects of bedding: None visible.

Dominant lithology SS: Section 1-143 cm
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	12%
Volcanic glass	3%
Nannos	Trace

Color legend:
1 = medium gray N5

Site 222 Hole Core 18 Cored Interval: 492-501



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY

Degree of induration: Stiff to semilithified.
Aspects of bedding: Rare thin silty layers (1-2 centimeters thick).
Lithology remarks: Core catcher contains 50% volcanic glass fragments (sand and silt size).

Dominant lithology SS: Section 1-130 cm
CARBONATE RICH DETRITAL CLAY
Composition:

Detrital minerals	85%
Carbonate	11%
Volcanic glass	4%
Nannos	Trace

Color legend:
1 = medium gray N5

Shore-based laboratory results

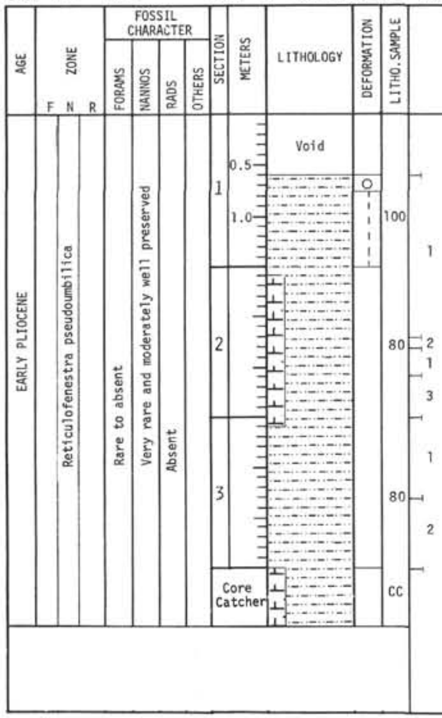
	Carbonate
Section 2-40 cm =	10%

Grain size: Section 2-41 cm

Silt	23%
Clay	77%

Explanatory notes in chapter 2

Site 222 Hole Core 19 Cored Interval: 540-549



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY
locally NANNO RICH DETRITAL SILTY CLAY.

Degree of induration: Mostly stiff to semilithified only rarely lithified.
Aspects of bedding: Clear only in the lithified part exhibiting fine lamination. Two coarser grained intercalations in section 1-100 to 120 cm.

Dominant lithology SS: Sections 1-100 cm, 3-80 cm.
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace

Minor lithology SS: Section 2-80 cm and core catcher.
NANNO RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	75%
Nannos	15%
Carbonate	10%

Color legend:
1 = medium gray N5
2 = dark green gray 5GY 4/1
3 = green gray 5GY 6/1

Shore-based laboratory results

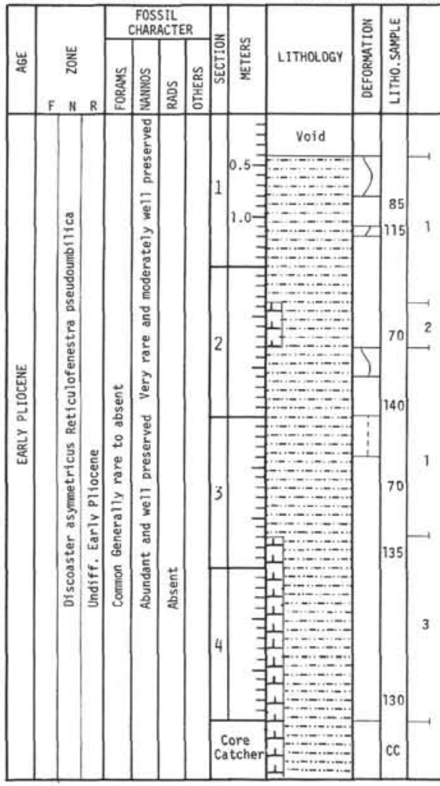
	Carbonate
Section 2-40 cm =	18%

Grain size: Section 2-41 cm

Silt	23%
Clay	77%

Explanatory notes in chapter 2

Site 222 Hole Core 20 Cored Interval: 587-591



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY and green NANNO RICH DETRITAL SILTY CLAY.

Degree of induration: Mostly semilithified but partly soft.
Aspects of bedding: None visible.
Drilling deformation: The soft intervals are badly disturbed.
Lithology remarks: Pyrite streaks in section 2 in the medium light gray sediment.

Dominant lithology SS: Section 2-140 cm
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace

Dominant lithology SS: Section 4-130 cm
NANNO RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	75%
Nannos	20%
Carbonate	5%

Color legend:
1 = medium light gray N6
2 = green gray 5G 6/1
3 = green gray 5GY 6/1

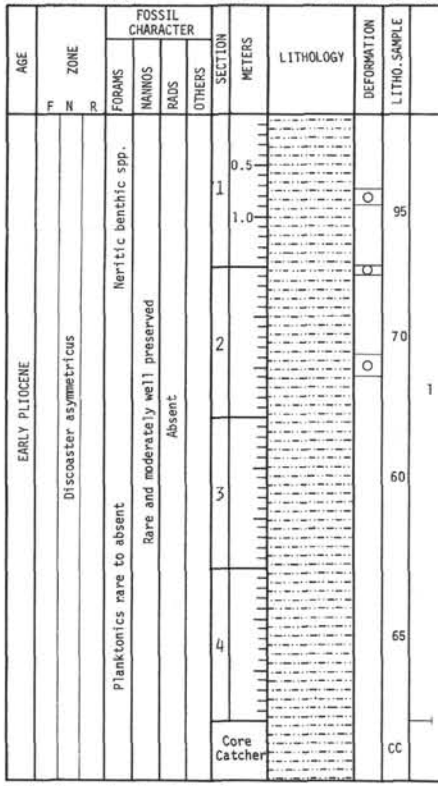
Shore-based laboratory results

Carbonate
Section 2- 50 cm = 24%
Section 2-139 cm = 14%

Grain size:	Sections 2-130 cm,	3-60 cm
Silt	30%	38%
Clay	70%	62%

Explanatory notes in chapter 2

Site 222 Hole Core 21 Cored Interval: 634-643



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Semilithified.
Aspects of bedding: None visible.
Drilling deformation: Insignificant.
Lithology remarks: Pyritization along bedding planes mainly in section 3.

Dominant lithology SS: Sections 1-95 cm, 3-60 cm, 4-65 cm, core catcher.
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace
Pyrite	Trace
Volcanic glass	Trace

Color legend:
1 = medium gray N5

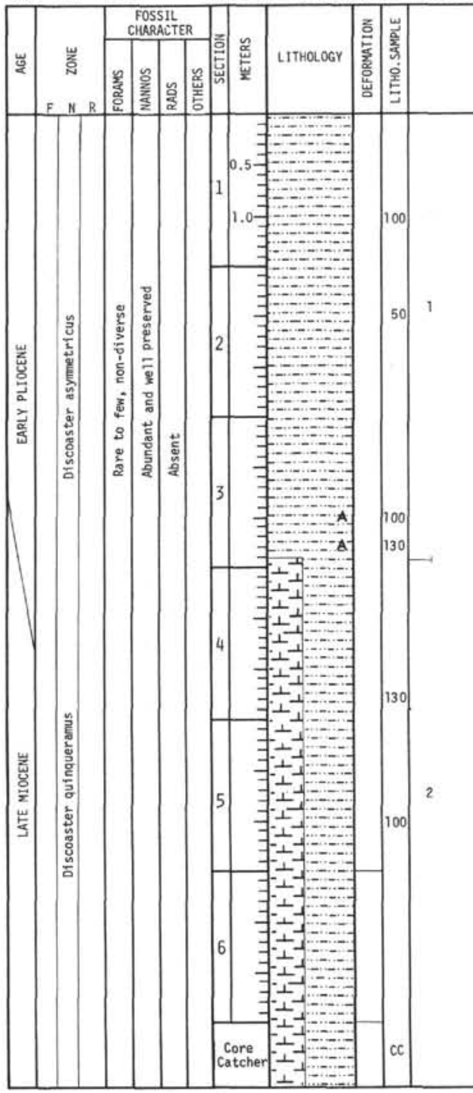
Shore-based laboratory results

Carbonate
Section 3-40 cm = 18%

Grain size:	Section 2-50 cm
Silt	34%
Clay	66%

Explanatory notes in chapter 2

Site 222 Hole Core 22 Cored Interval: 690-699



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY overlying greenish-gray CARBONATE RICH NANNO DETRITAL SILTY CLAY.

Degree of induration: Sediments are stiff in the upper half and lithified in the lower half.
Aspects of bedding: Almost massive in sections 1-3, slightly visible, disturbed by moderate bioturbation, in sections 4-6. The base of section 3 (@ 140 centimeters) represents a lithologic boundary, reflected also in sediment color; this boundary is quite sharp. Bioturbation is a characteristic feature in sections 4-6.
Drilling deformation: Insignficant.

Upr. dominant lithology SS: Sections 2-50 cm, 3-100 cm.
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace
Volcanic glass	Trace

Lwr. dominant lithology SS: Sections 4-130 cm, 5-100 cm, 6-100 cm.
CARBONATE RICH NANNO DETRITAL SILTY CLAY
Composition:

Detrital minerals	45%
Nannos	40%
Carbonate	15%

Color legend:

1 = medium gray N5
2 = green gray 5GY 6/1

Shore-based laboratory results

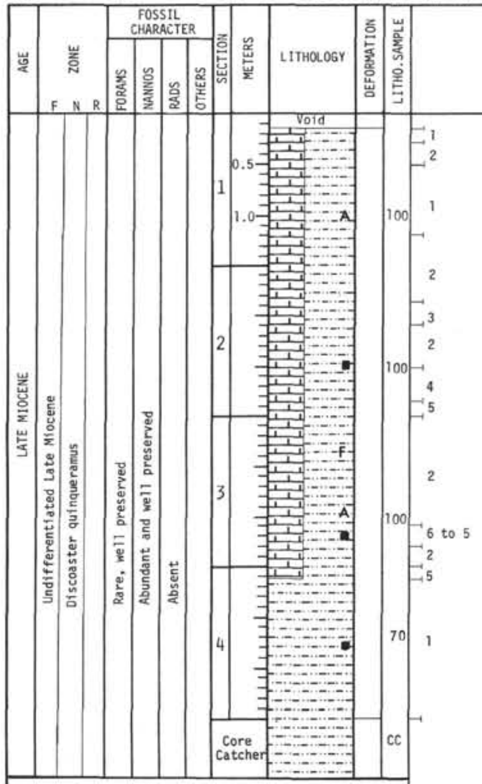
Carbonate
Section 1-74 cm = 16%
Section 5-91 cm = 55%

Grain size: Sections

	1-50 cm,	5-91 cm
Silt	36%	24%
Clay	64%	76%

Explanatory notes in chapter 2

Site 222 Hole Core 23 Cored Interval: 747-756



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH NANNO DETRITAL SILTY CLAY and CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Lithified.
Aspects of bedding: Moderate bioturbation in sections 1-3. Medium gray deposits in section 4 exhibit abundant parallel lamination, cross-lamiantion and 1-2 centimeters thick graded layers. The boundary between the greenish gray bioturbated sediments and the medium gray laminated sediments occurs at section 2-12 cm.

Dominant lithology SS: Sections 1-100 cm, 2-100 cm, 3-100 cm.
CARBONATE RICH NANNO DETRITAL SILTY CLAY
Composition:

Detrital minerals	45%
Nannos	40%
Carbonate	15%
Volcanic glass	Trace
Pyrite	Trace

Minor lithology SS: Section 4-70 cm
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace

Color legend:

1 = medium gray N5
2 = dark green gray 5GY 4/1
3 = green gray 5G 6/1
4 = light green gray 5GY 8/1
5 = green gray 5GY 6/1
6 = light gray N7

Shore-based laboratory results

Carbonate
Section 2- 40 cm = 53%
Section 4-147 cm = 16%

Grain size: Sections

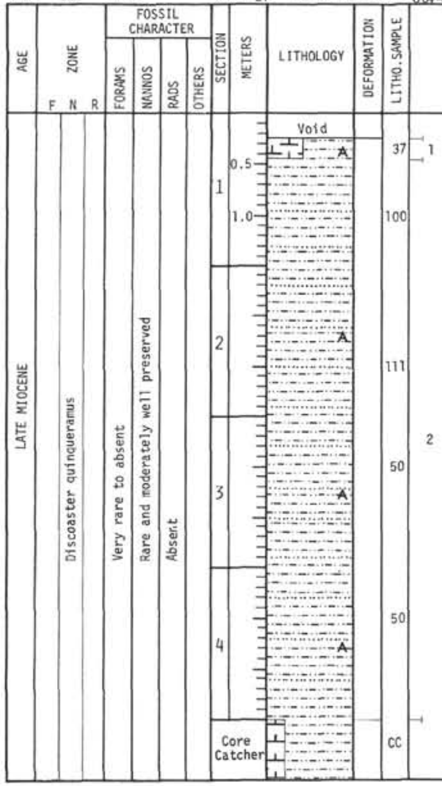
	2-41 cm,	4-124 cm
Silt	29%	49%
Clay	71%	51%

X-ray mineralogy: Section 2-43 cm

Calcite	56%
Dolomite	2%
Quartz	16%
Plagioclase	5%
Mica	17%
Chlorite	3%
Pyrite	1%

Explanatory notes in chapter 2

Site 222 Hole Core 24 Cored Interval: 804-813



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Semilithified.
Aspects of bedding: Marked by numerous laminae or thin beds (<3 cm thick), some of them graded.
Lithology remarks: Dark green gray sediments at the top of section 1 have a large amount of volcanic ash.

Dominant lithology SS: Section 3-50 cm
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace
Volcanic glass	Trace

Color legend:
1 = dark green gray 5GY 4/1
2 = medium gray N5

Shore-based laboratory results

Carbonate
Section 2-40 cm = 16%

Grain size: Section 2-41 cm

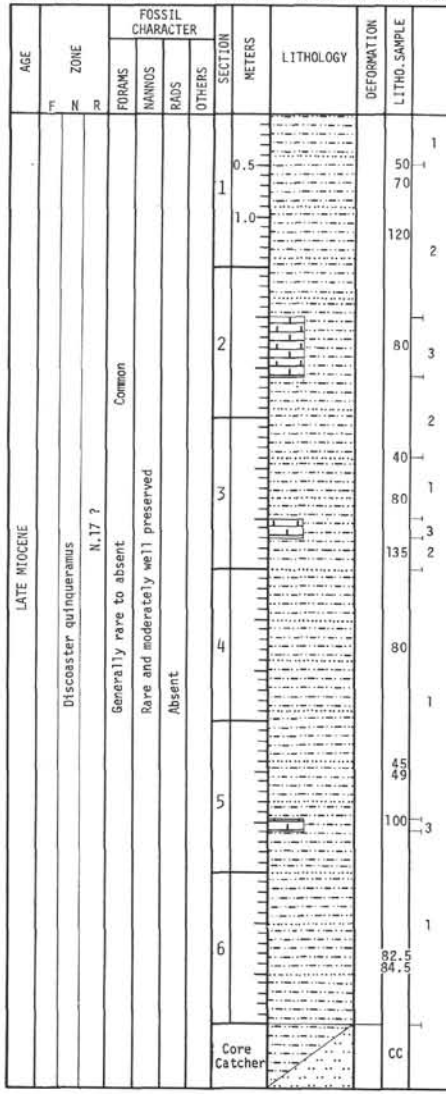
Silt	35%
Clay	65%

X-ray mineralogy: Section 2-45 cm

Calcite	19%
Dolomite	3%
Quartz	31%
Plagioclase	9%
Mica	30%
Chlorite	8%

Explanatory notes in chapter 2

Site 222 Hole Core 25 Cored Interval: 861-870



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Semilithified.
Aspects of bedding: Many silty laminae or very thin layers, sometimes graded.
Drilling deformation: Insignificant.
Lithology remarks: Green gray sediment is bioturbated. Streaks of pyrite parallel to beddings.

Dominant lithology SS: Sections 1-70 cm, 1-120 cm, 3-135 cm, 4-81 cm.
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace

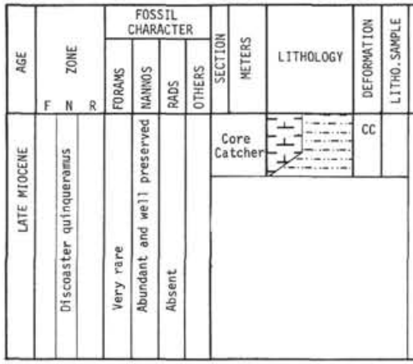
Color legend:
1 = medium dark gray N4
2 = medium gray N5
3 = green gray 5GY 6/1

Shore-based laboratory results

Carbonate
Section 1-45 cm = 16%

Explanatory notes in chapter 2

Site 222 Hole Core 26 Cored Interval: 916-925



LITHOLOGIC DESCRIPTION

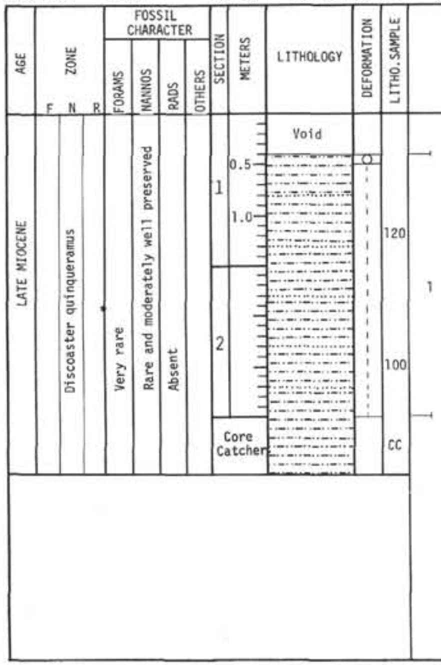
Smear slide: core catcher
Green CARBONATE RICH NANNO DETRITAL SILTY CLAY
Composition:

Detrital minerals	45%
Nannos	40%
Carbonates	15%

Smear slide: core catcher
Gray CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace
Pyrite	Trace

Site 222 Hole Core 27 Cored Interval: 925-934



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAY.

Degree of induration: Semilithified.
Aspects of bedding: Marked by very frequent laminae (usually <0.5 centimeters but sometimes up to 2 centimeters). Most laminae are represented by discontinuous white silty layers.
Drilling deformation: Slight deformation resulting in truncation of some laminae.
Lithology remarks: Frequent pyrite streaks parallel to bedding.

Dominant lithology SS: Sections 1-120 cm, 2-100 cm.
CARBONATE RICH DETRITAL SILTY CLAY
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace
Pyrite	Trace

Color legend:
1 = medium gray N5

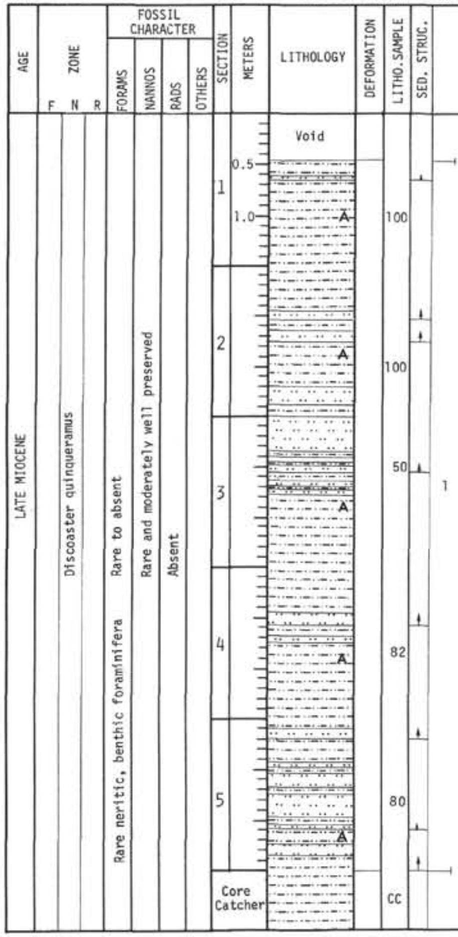
Shore-based laboratory results

Carbonate
Section 2-40 cm = 14%

Grain size: Section 2-41 cm
Silt 26%
Clay 74%

Explanatory notes in chapter 2

Site 222 Hole Core 28 Cored Interval: 982-991



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL CLAYEY SILT

Degree of induration: Semilithified.
Aspects of bedding: Frequent intercalations of silty layers, graded or nongraded. 1 to 20 centimeters thick.
Drilling deformation: Insignificant.

Dominant lithology SS: Sections 1-100 cm, 3-50 cm.
CARBONATE RICH DETRITAL CLAYEY SILT
Composition:

Detrital minerals	82%
Carbonate	15%
Volcanic glass	3%
Nannos	Trace
Pyrite	Trace

Color legend:
1 = medium gray N5

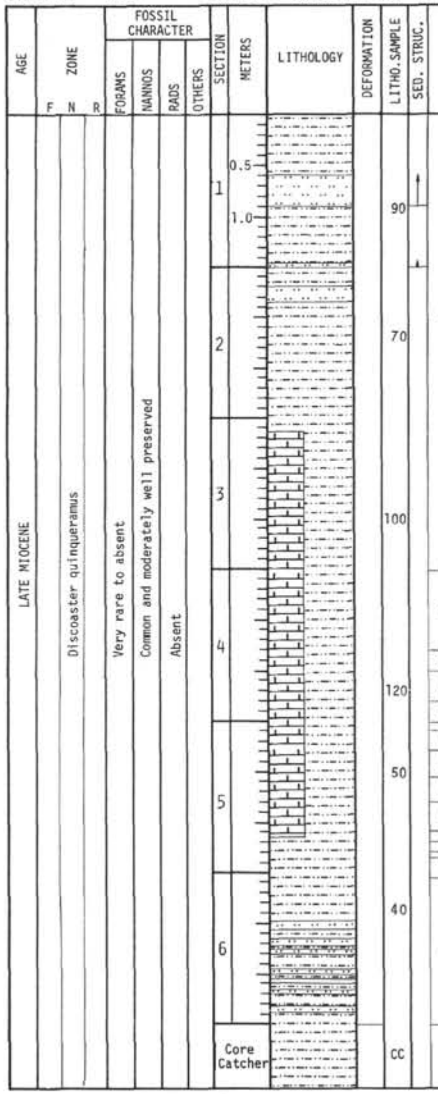
Shore-based laboratory results

Carbonate
Section 2-40 cm = 18%

Grain size: Section 2-41 cm
Silt 54%
Clay 46%

Explanatory notes in chapter 2

Site 222 Hole Core 29 Cored Interval: 1041-1050



LITHOLOGIC DESCRIPTION

1
2
3
4
3
5
6
5
6
5
6
5
6
5
6

Gray CARBONATE RICH DETRITAL SILTY CLAYSTONE and green CARBONATE RICH NANNO DETRITAL SILTY CLAYSTONE.

Degree of induration: Lithified.
Aspects of bedding: Marked by numerous silty intercalations and laminae or burrowing structures (mostly parallel to bedding). Some of the intercalations show graded beddings.
Drilling deformation: Insignificant

Dominant lithology SS: Section 6-40 cm
CARBONATE RICH DETRITAL SILTY CLAYSTONE
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace
Pyrite	Trace
Volcanic glass	Trace

Dominant lithology SS: Sections 3-100 cm, 4-120 cm.
CARBONATE RICH NANNO DETRITAL SILTY CLAYSTONE
Composition:

Detrital minerals	45%
Nannos	40%
Carbonate	15%

Color legend:
1 = medium dark gray N4
2 = gray green 5G 5/2
3 = medium light gray N6
4 = light brown gray 5YR 6/1
5 = gray green 10GY 5/2
6 = medium gray N5

Shore-based laboratory results

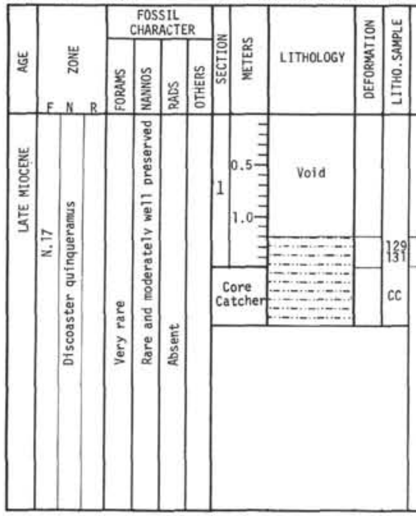
Carbonate
Section 2-40 cm = 16%

Grain size: Section 2-41 cm

Silt	25%
Clay	75%

Explanatory notes in chapter 2

Site 222 Hole Core 30 Cored Interval: 1097-1106



LITHOLOGIC DESCRIPTION

1

Gray CARBONATE RICH DETRITAL SILTY CLAYSTONE

Degree of induration: Lithified.

Dominant lithology SS: Sections 1-129 cm, 1-131 cm.
CARBONATE RICH DETRITAL SILTY CLAYSTONE
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace

Color legend:
1 = medium dark gray N4

Shore-based laboratory results

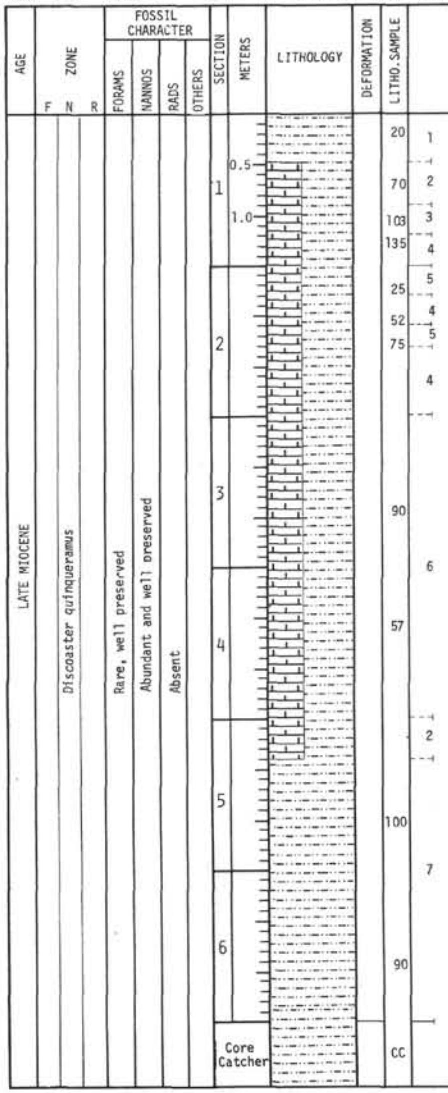
Carbonate
Section 2-36 cm = 16%

Grain size: Section 2-55 cm

Silt	42%
Clay	58%

Explanatory notes in chapter 2

Site 222 Hole Core 31 Cored Interval: 1126-1135



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH NANNO DETRITAL SILTY CLAYSTONE and CARBONATE RICH DETRITAL SILTY CLAYSTONE.

<u>Degree of induration:</u> Semilithified to lithified.
<u>Aspects of bedding:</u> Moderate to strong bioturbation evident in sections 1 to 5-34 cm. Bedding is accentuated by burrows which are oriented parallel to it. Few fine laminae in the medium gray sediments of sections 5 and 6.

Dominant lithology SS: Section 5-100 cm
CARBONATE RICH DETRITAL SILTY CLAYSTONE
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace
Volcanic glass	Trace

Dominant lithology SS: Section 3-90 cm
CARBONATE RICH NANNO DETRITAL SILTY CLAYSTONE
Composition:

Detrital minerals	45%
Nannos	40%
Carbonate	15%

Color legend:
1 = medium dark gray N4
2 = green gray 5G 6/1
3 = dark gray N3
4 = dark green gray 5G 4/1
5 = light blue gray 5B 7/1
6 = dark green gray 5GY 4/1
7 = medium gray N5

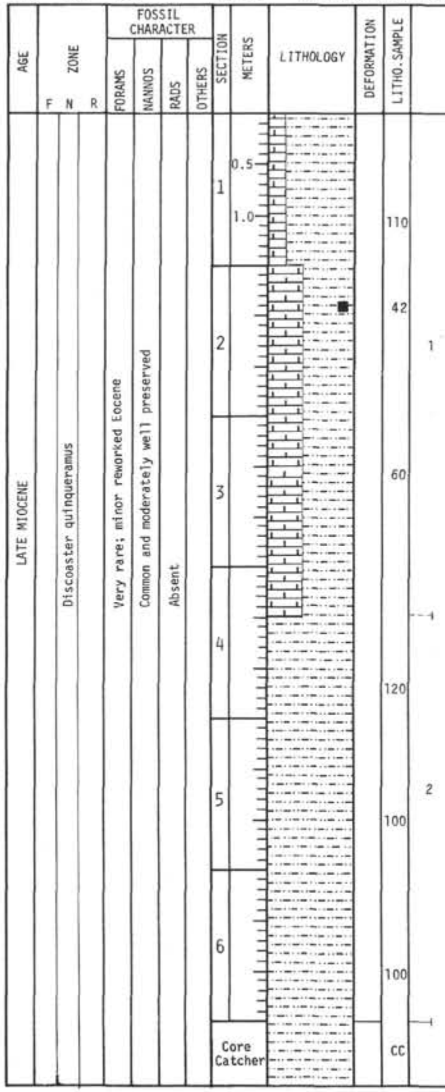
<u>Shore-based laboratory results</u>

Carbonate
Section 1-25 cm = 13%

Grain size:	Section 1-40 cm
Silt	38%
Clay	62%

Explanatory notes in chapter 2

Site 222 Hole Core 32 Cored Interval: 1160-1169



LITHOLOGIC DESCRIPTION

Green CARBONATE RICH NANNO DETRITAL SILTY CLAYSTONE and gray CARBONATE RICH DETRITAL SILTY CLAYSTONE.

<u>Degree of induration:</u> Green gray sediments lithified, medium gray sediments semilithified to lithified.
<u>Aspects of bedding:</u> Green gray sediments are strongly bioturbated. Burrows are mostly parallel to bedding; few are oblique or vertical. Medium gray sediments contain almost no burrows and few silty laminae.
<u>Drilling deformation:</u> Insignificant.

Dominant lithology SS: Section 3-60 cm
CARBONATE RICH NANNO DETRITAL SILTY CLAYSTONE
Composition:

Detrital minerals	45%
Nannos	40%
Carbonate	15%

Dominant lithology SS: Section 4-120 cm
CARBONATE RICH DETRITAL SILTY CLAYSTONE
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace
Volcanic glass	Trace

Color legend:
1 = dark green gray 5GY 4/1
2 = medium gray N5

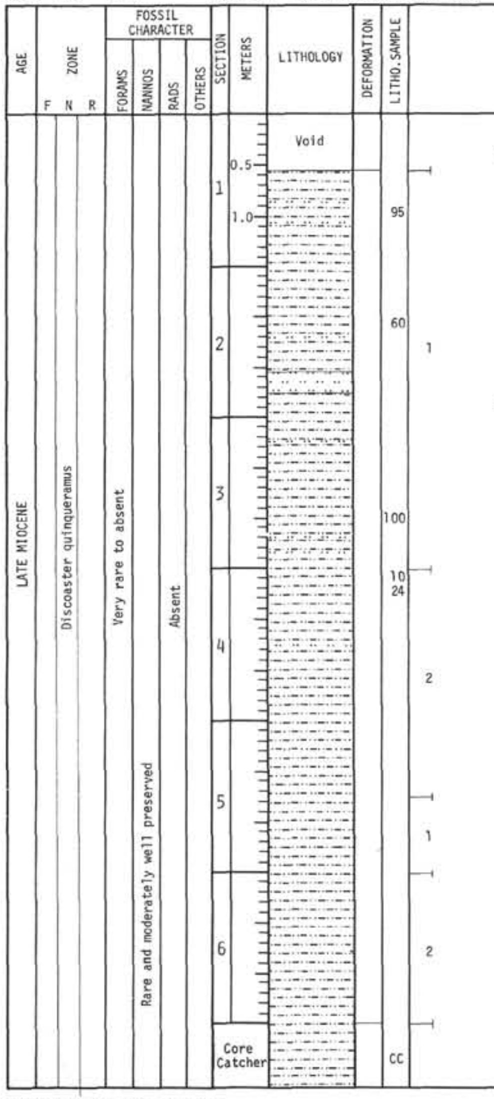
<u>Shore-based laboratory results</u>

Carbonate
Section 2- 40 cm = 12%
Section 4-128 cm = 14%

Grain size: Sections	2-41 cm,	4-128 cm
Silt	38%	37%
Clay	62%	63%

Explanatory notes in chapter 2

Site 222 Hole Core 33 Cored Interval: 1211-1220



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAYSTONE.

Degree of induration: Semilithified to mostly lithified.
Aspects of bedding: Massive with occasional laminae or thin layers of silt.
Drilling deformation: Insignificant.

Dominant lithology SS: Section 4-24 cm
CARBONATE RICH DETRITAL SILTY CLAYSTONE
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace
Pyrite	Trace
Volcanic glass	Trace
Dolomite rhombs	Trace

Color legend:
1 = medium gray N5
2 = medium dark gray N4

Shore-based laboratory results

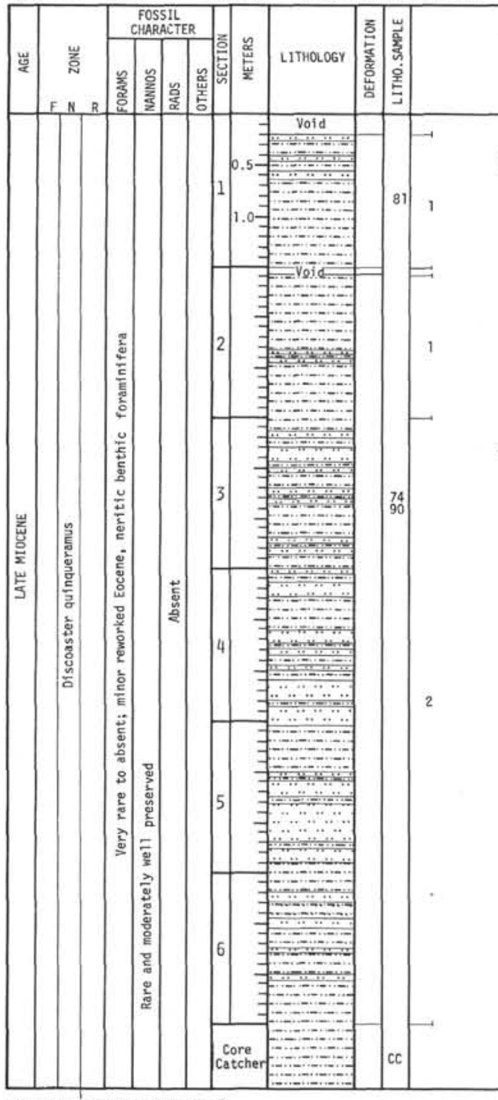
Carbonate
Section 2-38 cm = 14%

Grain size: Section 2-31 cm

Silt	31%
Clay	69%

Explanatory notes in chapter 2

Site 222 Hole Core 34 Cored Interval: 1258-1267



LITHOLOGIC DESCRIPTION

Gray CARBONATE RICH DETRITAL SILTY CLAYSTONE with intercalations of gray SANDY SILTSTONE.

Degree of induration: Semilithified to lithified.
Aspects of bedding: Frequent sandy intercalations 5-60 centimeters or less in thickness. Fine lamination is also present. Sandy beds occasionally show grading and cross-lamination. Sections 4-6 display 2°-4° dips.
Drilling deformation: Insignificant.

Dominant lithology SS: Sections 1-81 cm, 3-90 cm.
CARBONATE RICH DETRITAL SILTY CLAYSTONE
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace
Pyrites	Trace

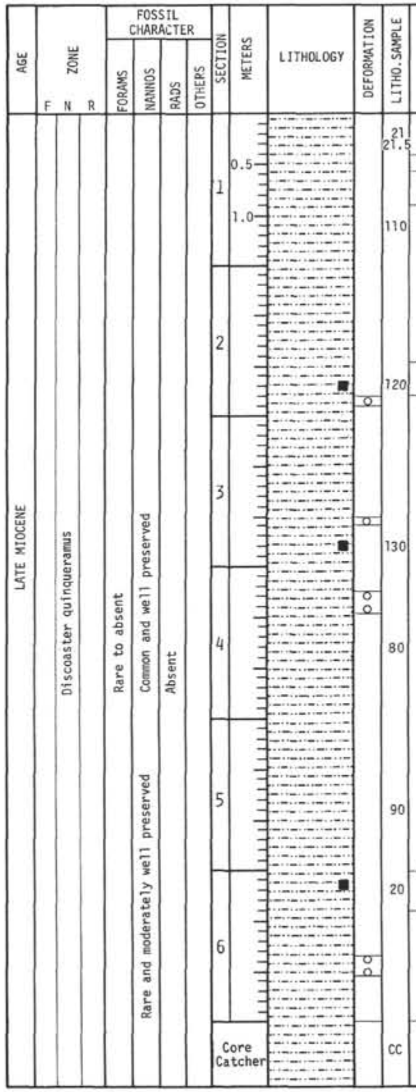
Color legend:
1 = medium gray N5
2 = medium dark gray N4

Shore-based laboratory results

Carbonate
Section 1-40 cm = 16%

Explanatory notes in chapter 2

Site 222 Hole Core 35 Cored Interval: 1286-1295



LITHOLOGIC DESCRIPTION

1 & 2
3
1 & 2
3
1 & 2
3
2
3

Gray CARBONATE RICH DETRITAL SILTY CLAYSTONE

Degree of induration: Lithified.
Aspects of bedding: Almost massive except for alternating color microbands (<0.5 cm) or by scarce lamination in the medium gray intervals. Few burrow structures in the olive gray and dark green gray sediments.
Drilling deformation: Minor amount.

Dominant lithology SS: Sections 3-130 cm, 4-80 cm.
CARBONATE RICH DETRITAL SILTY CLAYSTONE
Composition:

Detrital minerals	82%
Carbonate	15%
Pyrites	3%
Nannos	Trace
Volcanic glass	Trace

Color legend:

1 =	olive gray	5Y 3/2
2 =	dark green gray	5GY 4/1
3 =	medium gray	N5

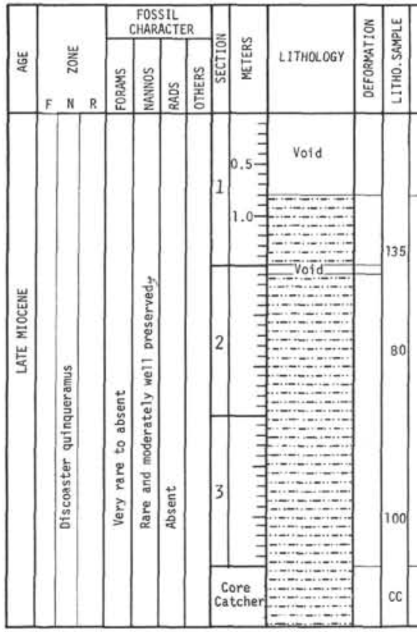
Shore-based laboratory results

	Carbonate
Section 1-49 cm =	9%

Grain size:	Section 1-85 cm
Silt	49%
Clay	51%

Explanatory notes in chapter 2

Site 222 Hole Core 36 Cored Interval: 1295-1300



LITHOLOGIC DESCRIPTION

1

Gray CARBONATE RICH DETRITAL SILTY CLAYSTONE

Degree of induration: Lithified.
Aspects of bedding: Massive, excepting a few laminae. Small burrow structures, concentrated in some zones.
Drilling deformation: Insignificant.

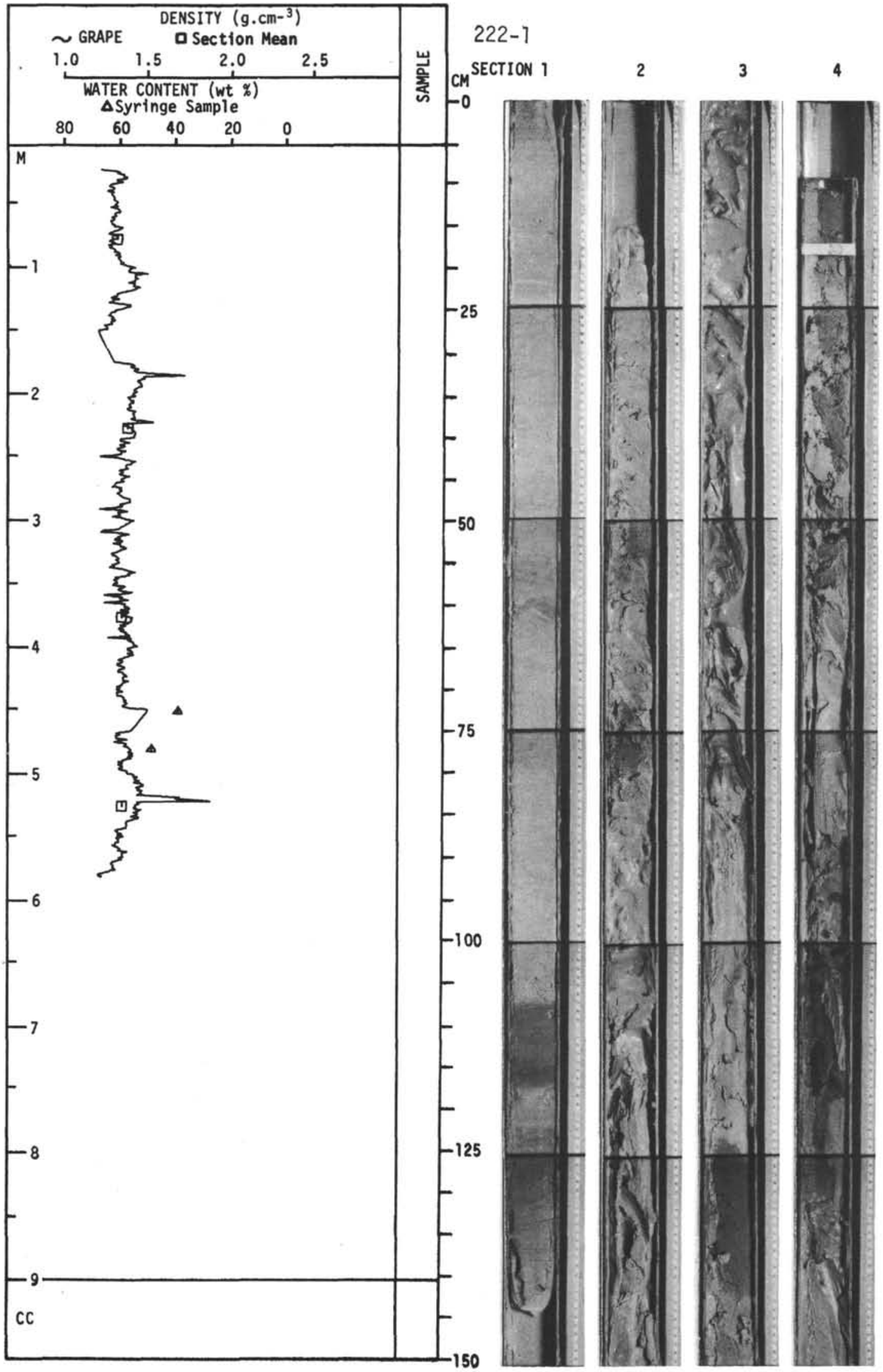
Dominant lithology SS: Sections 1-135 cm, 2-80 cm, 3-100 cm.
CARBONATE RICH DETRITAL SILTY CLAYSTONE
Composition:

Detrital minerals	85%
Carbonate	15%
Nannos	Trace
Forams	Trace
Volcanic glass	Trace
Pyrite	Trace

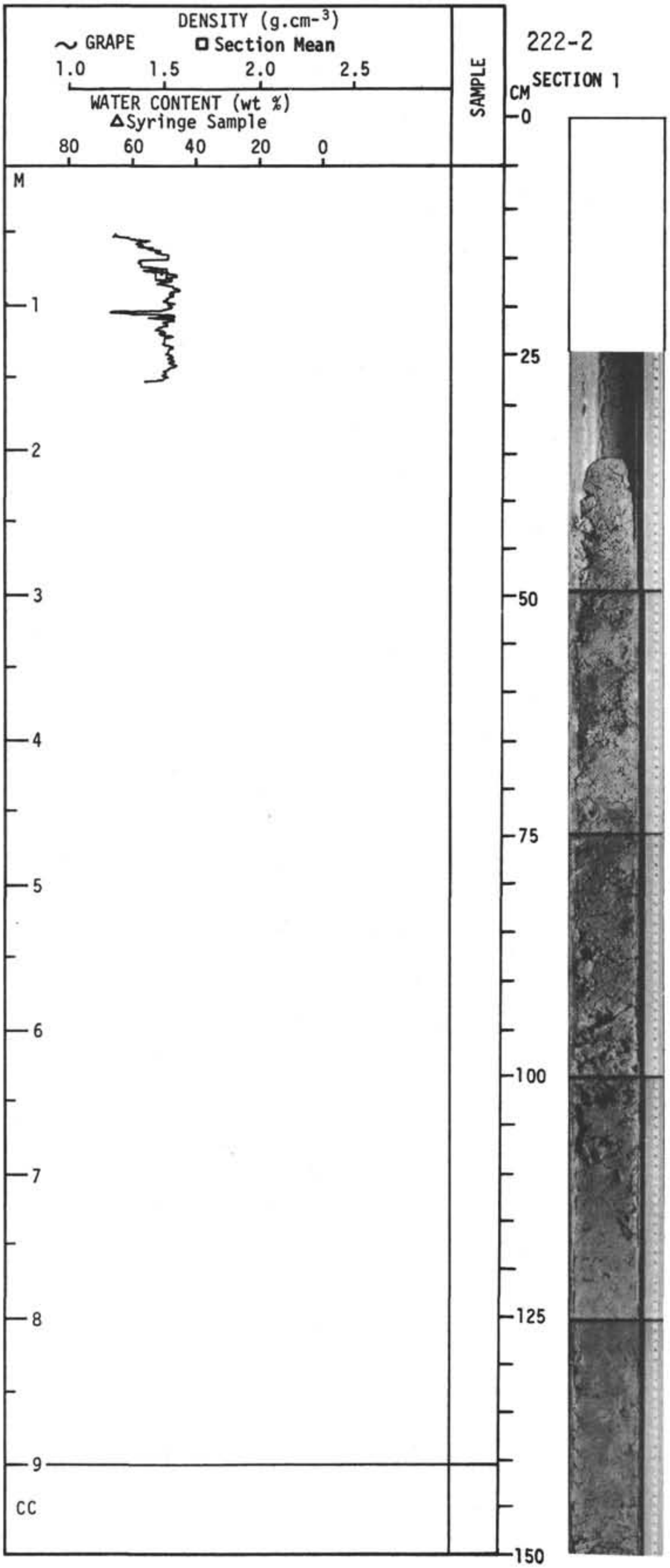
Color legend:

1 =	medium gray	N5

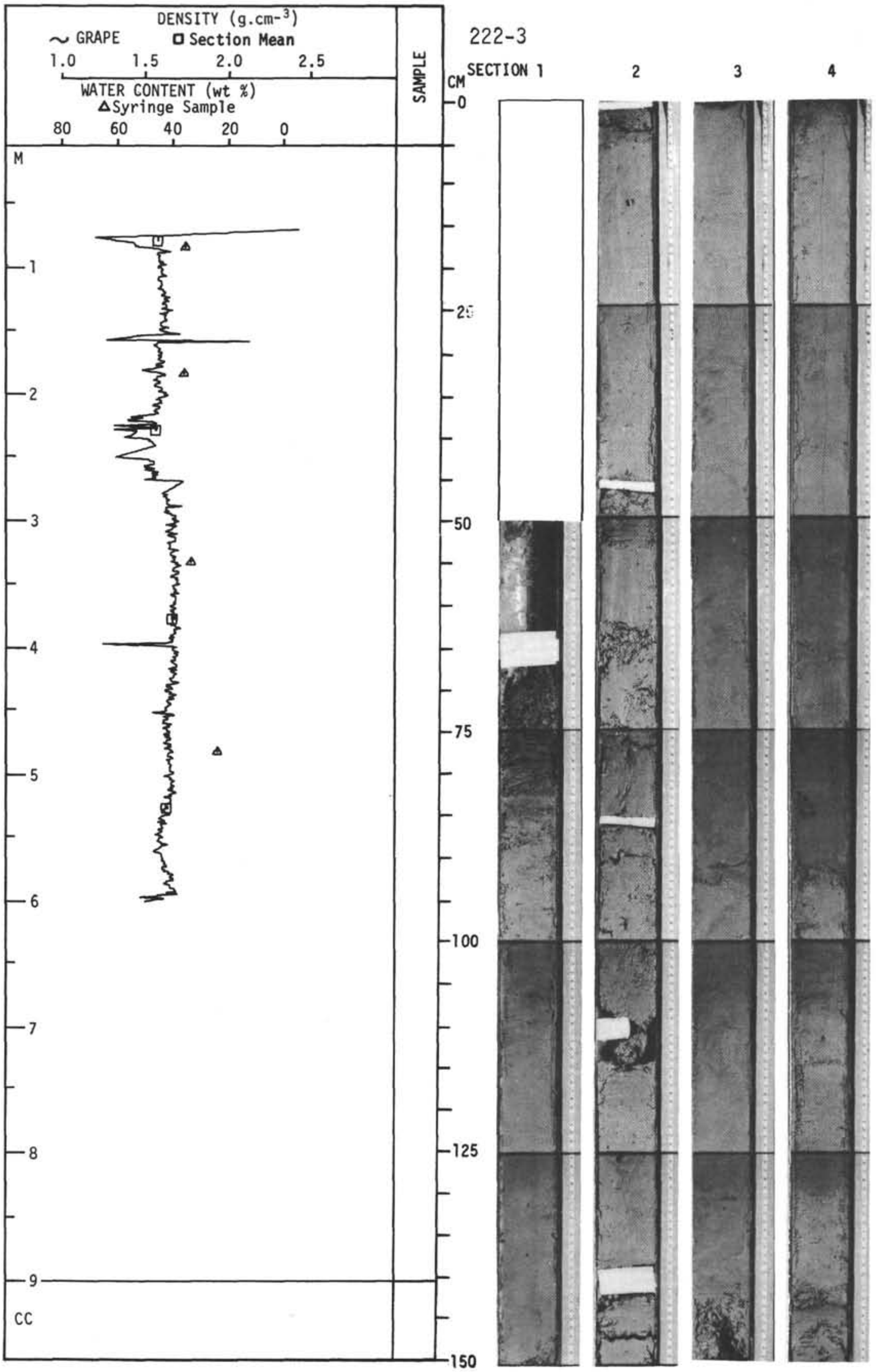
Explanatory notes in chapter 2



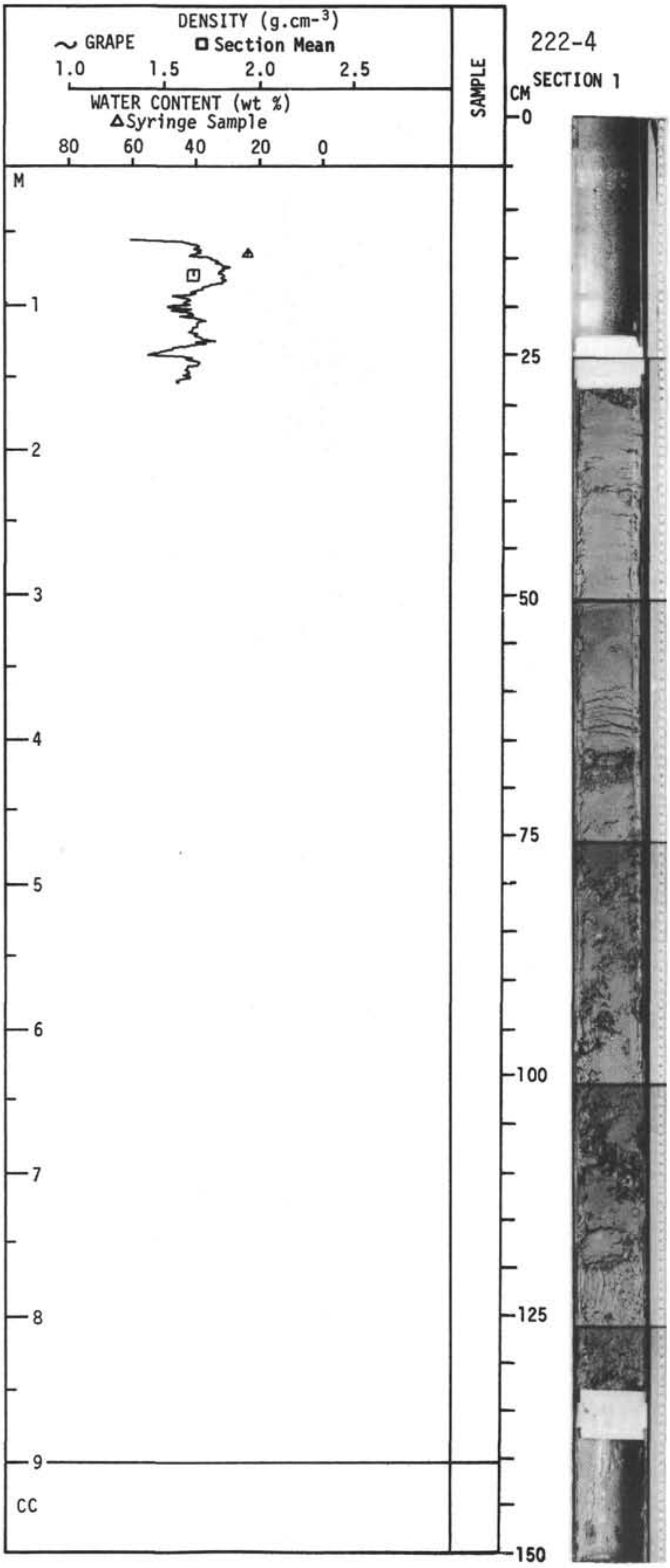
For Explanatory Notes, see Chapter 2



For Explanatory Notes, see Chapter 2



For Explanatory Notes, see Chapter 2



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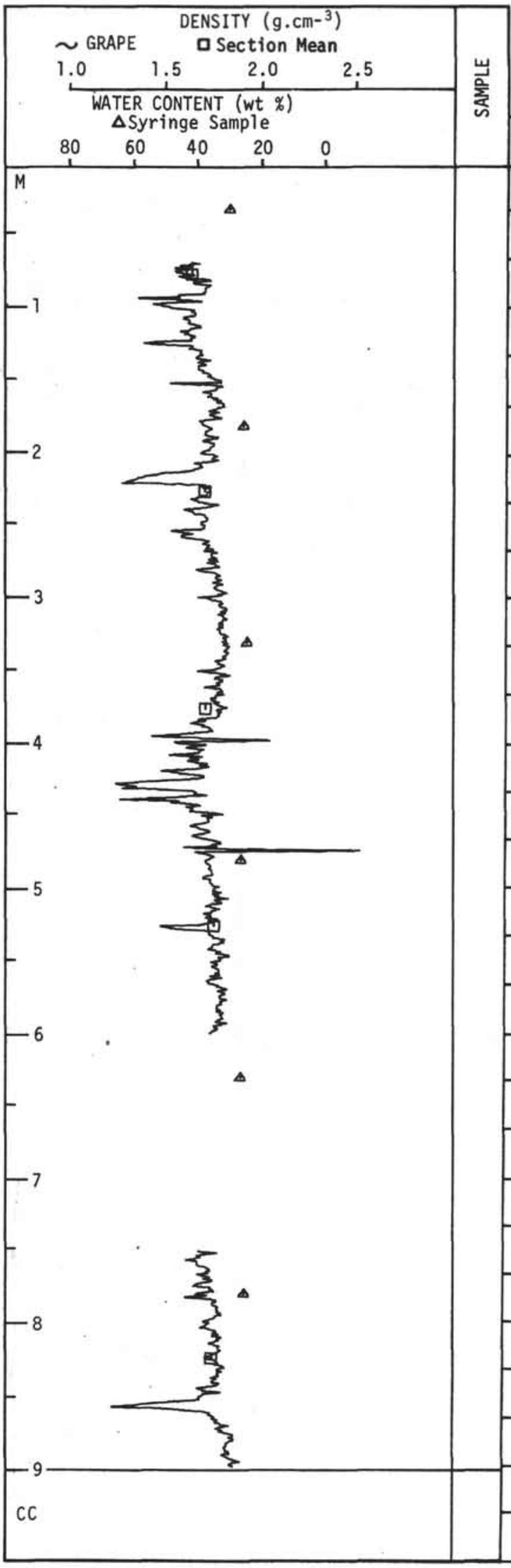
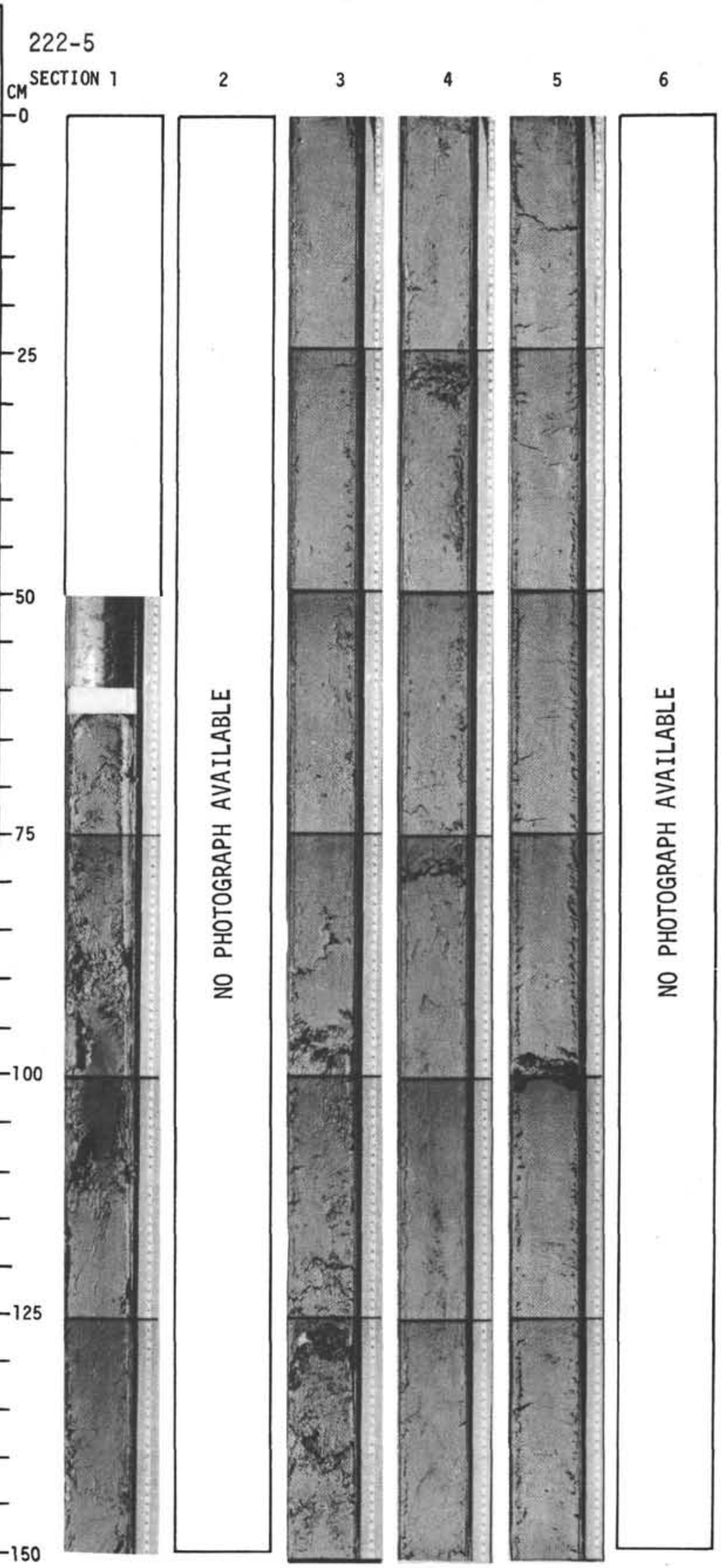
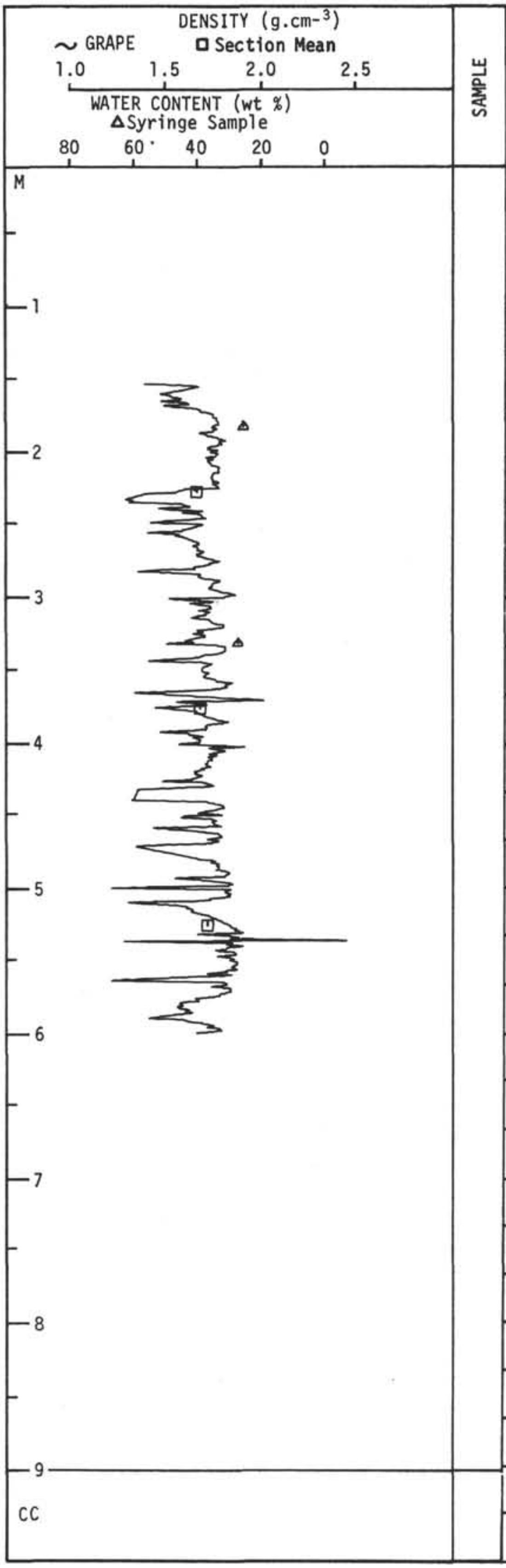
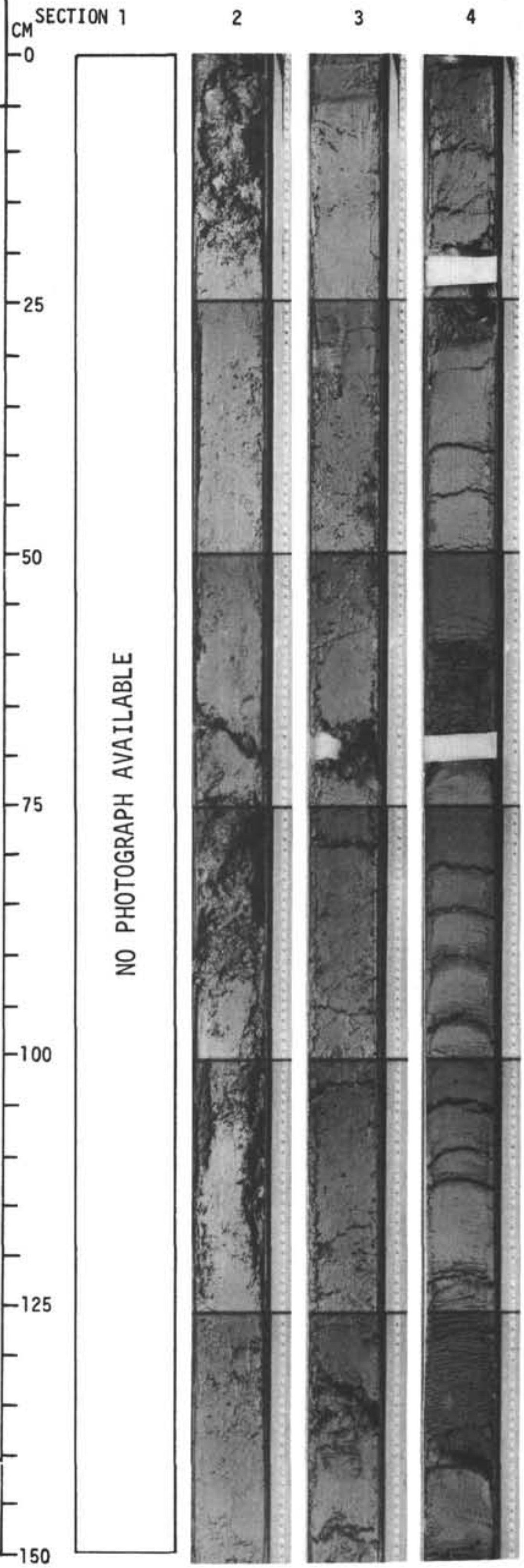




For Explanatory Notes, see Chapter 2



222-6



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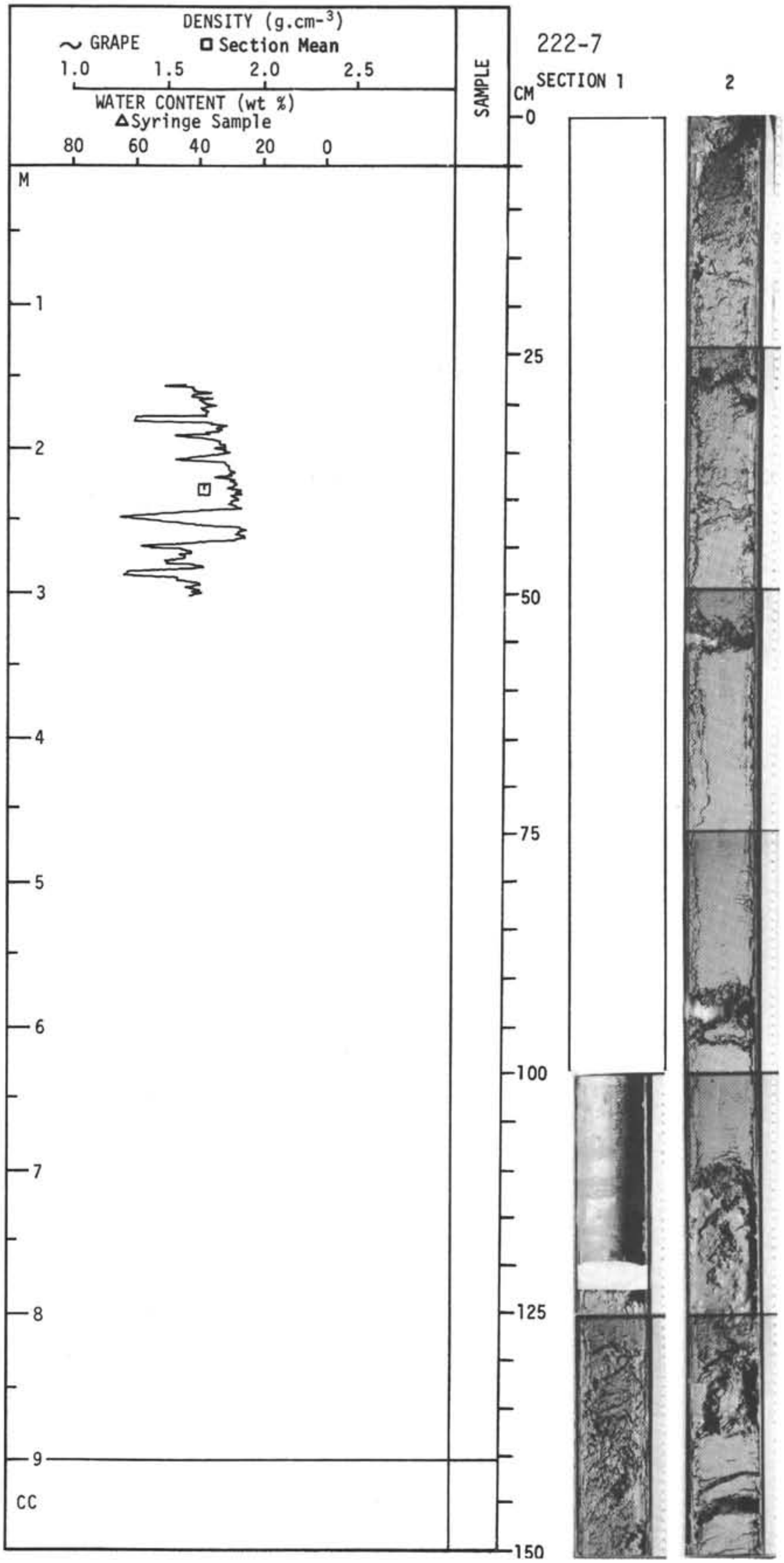

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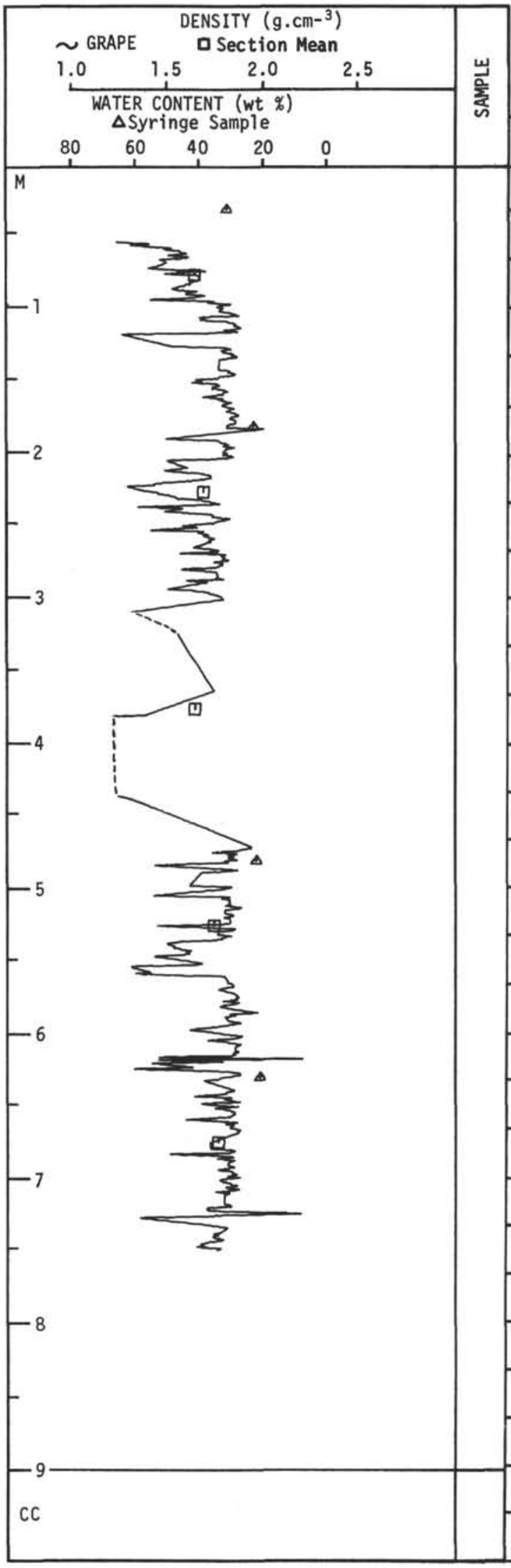

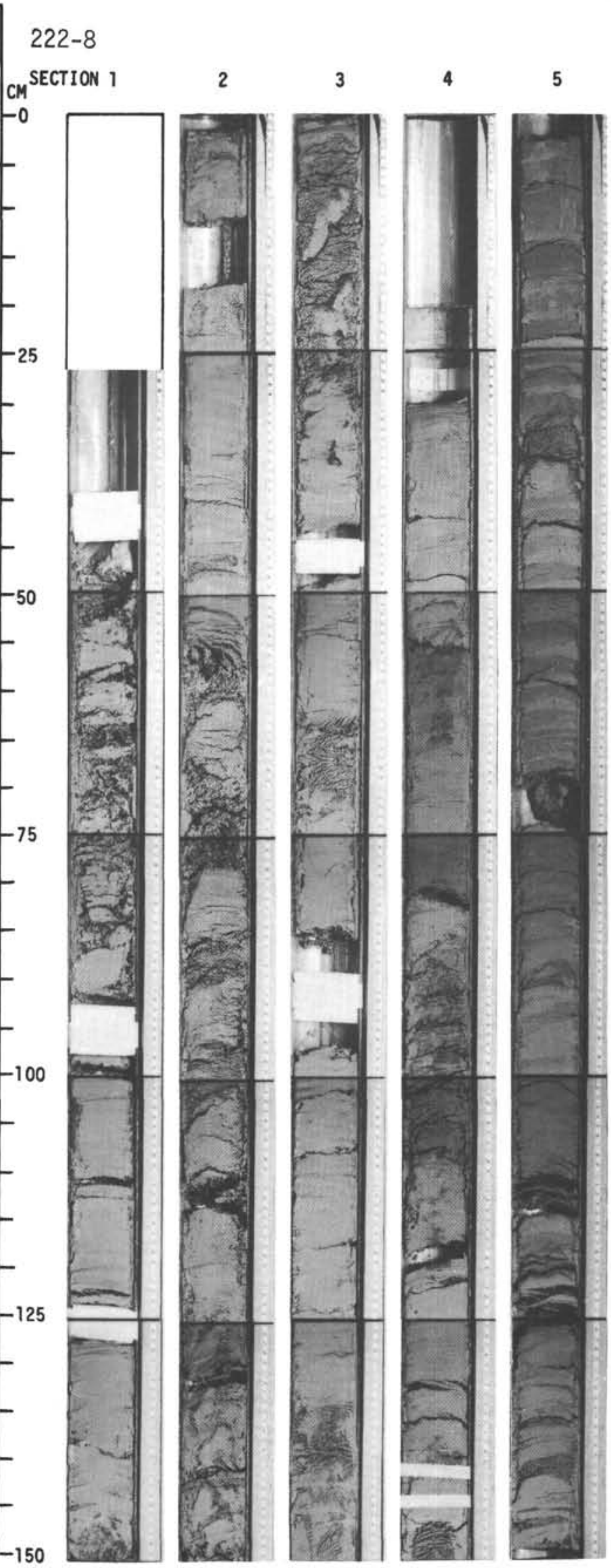

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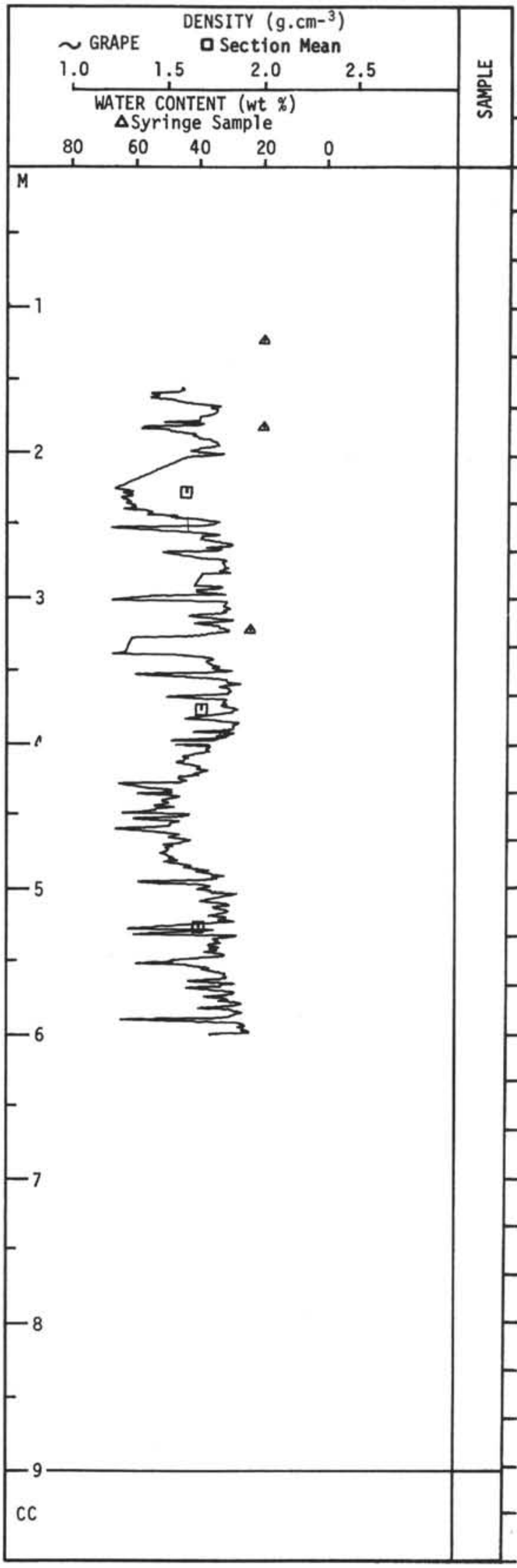

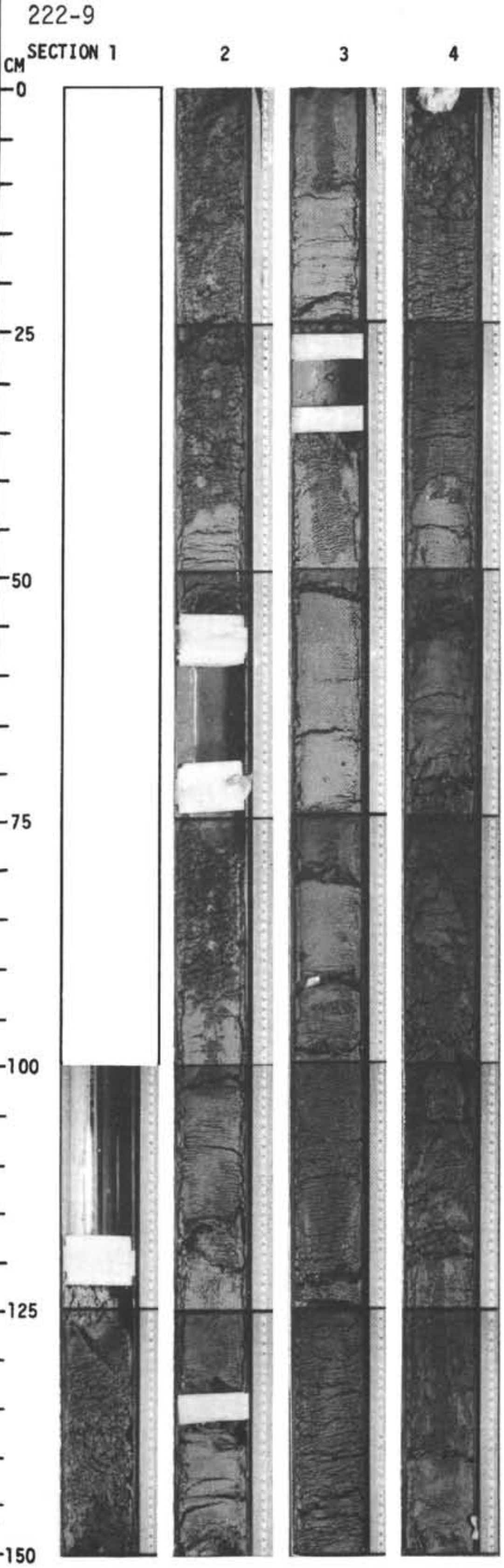

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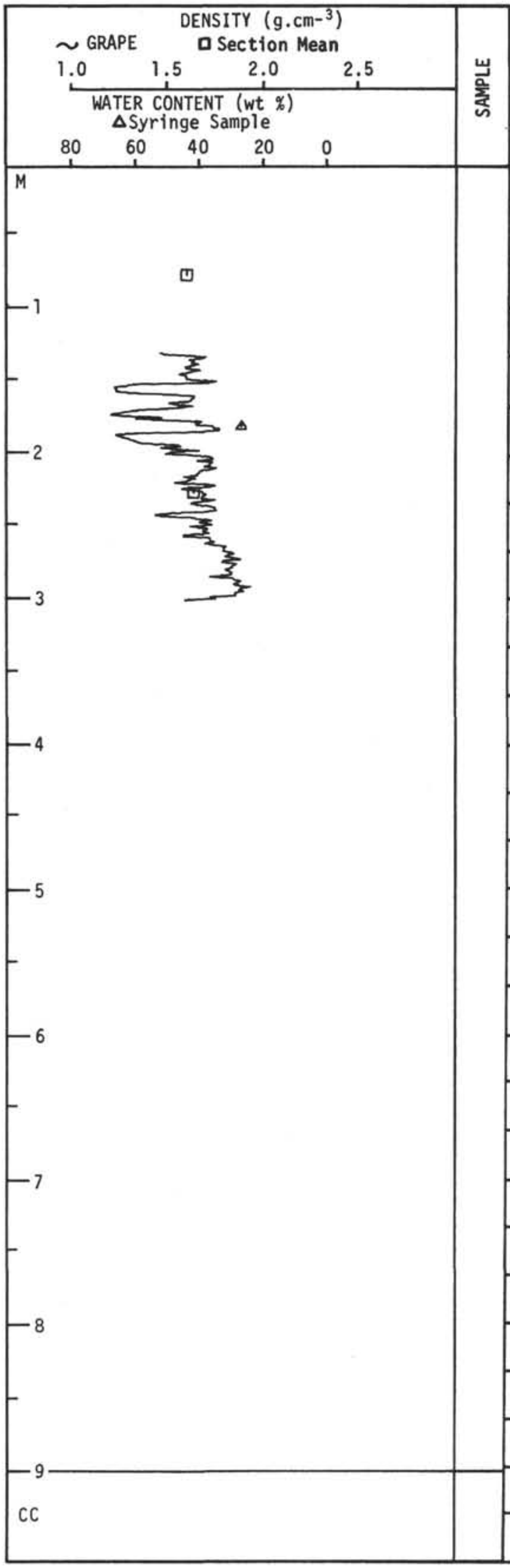

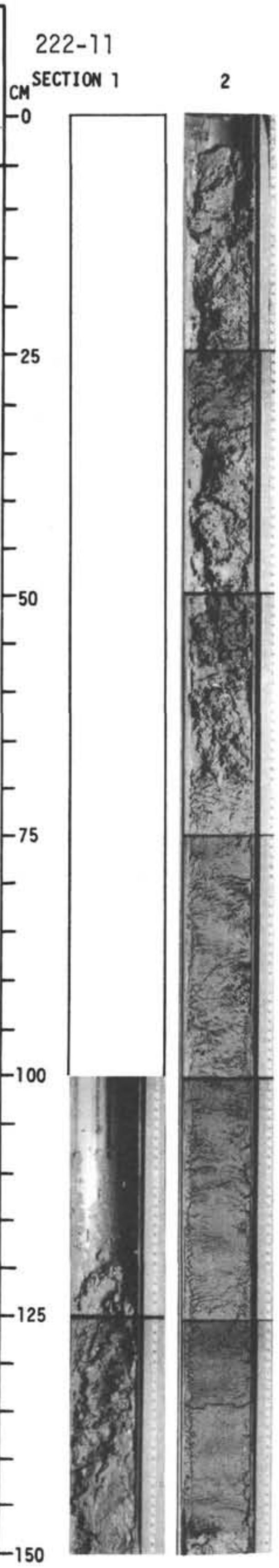

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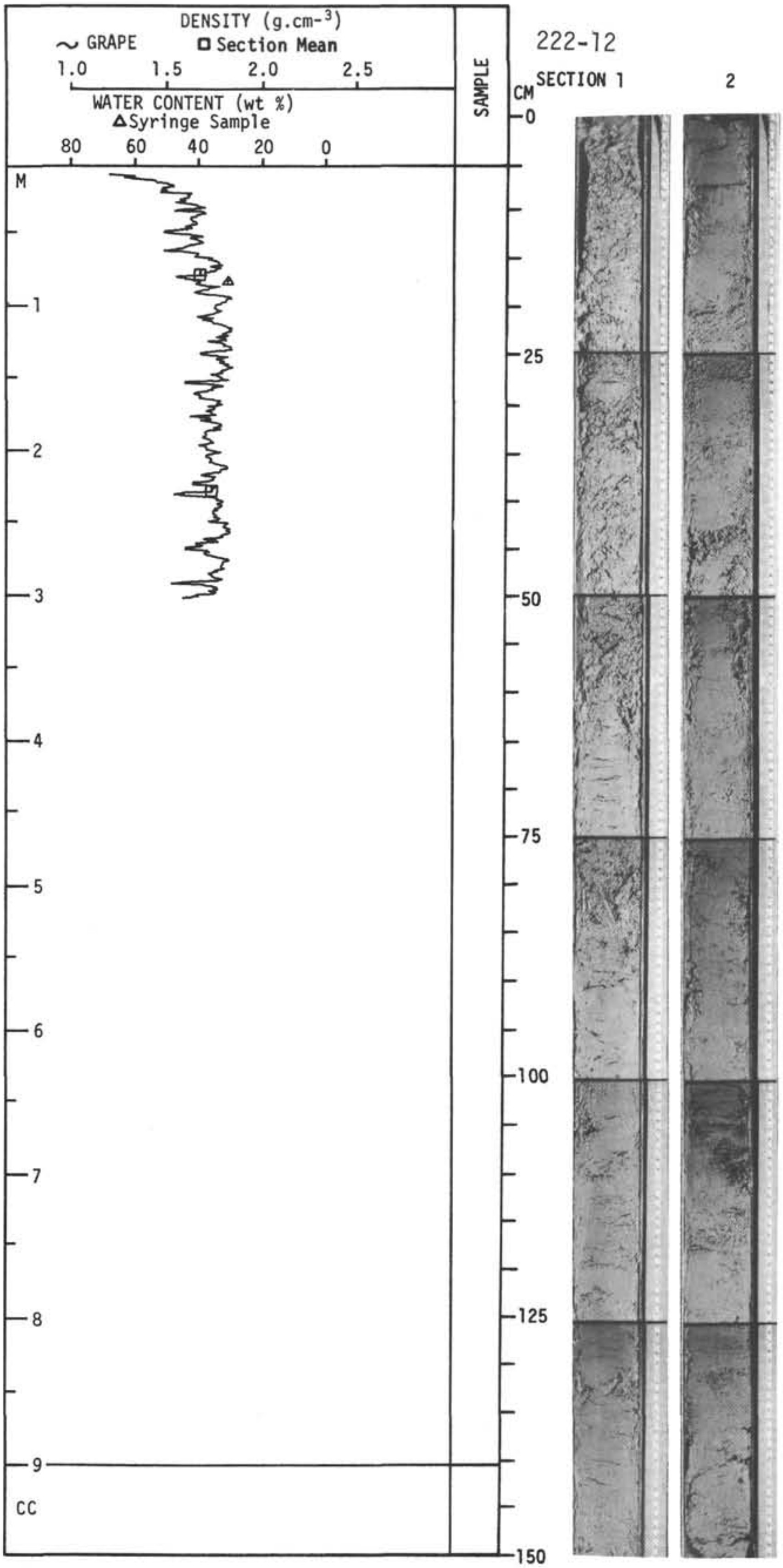

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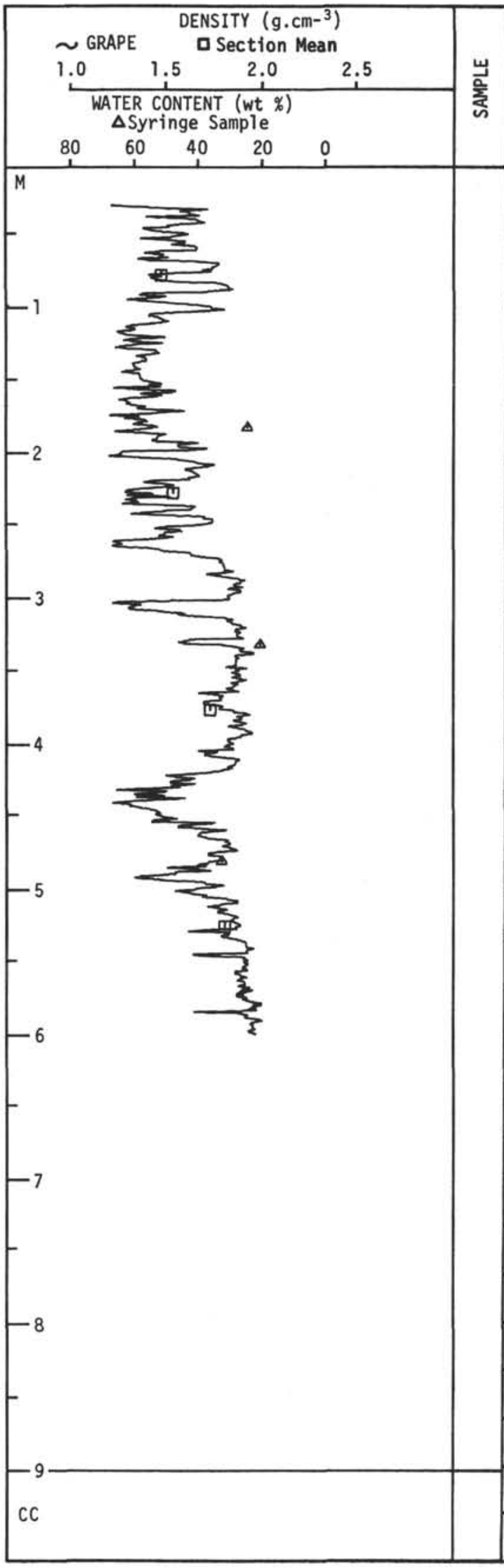

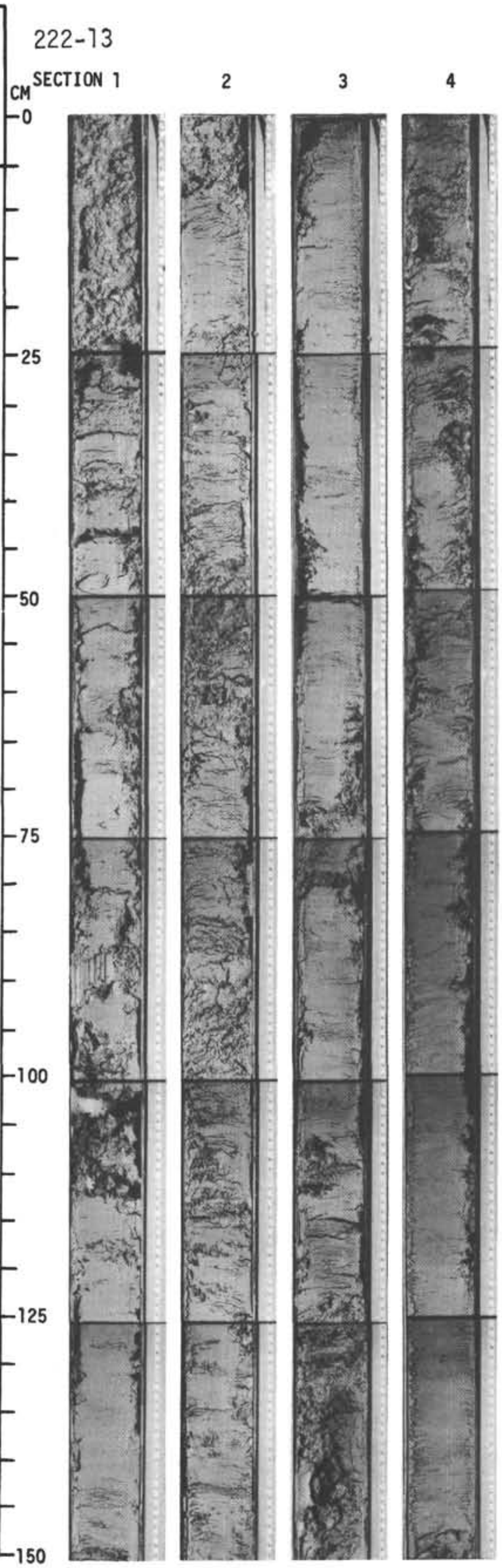

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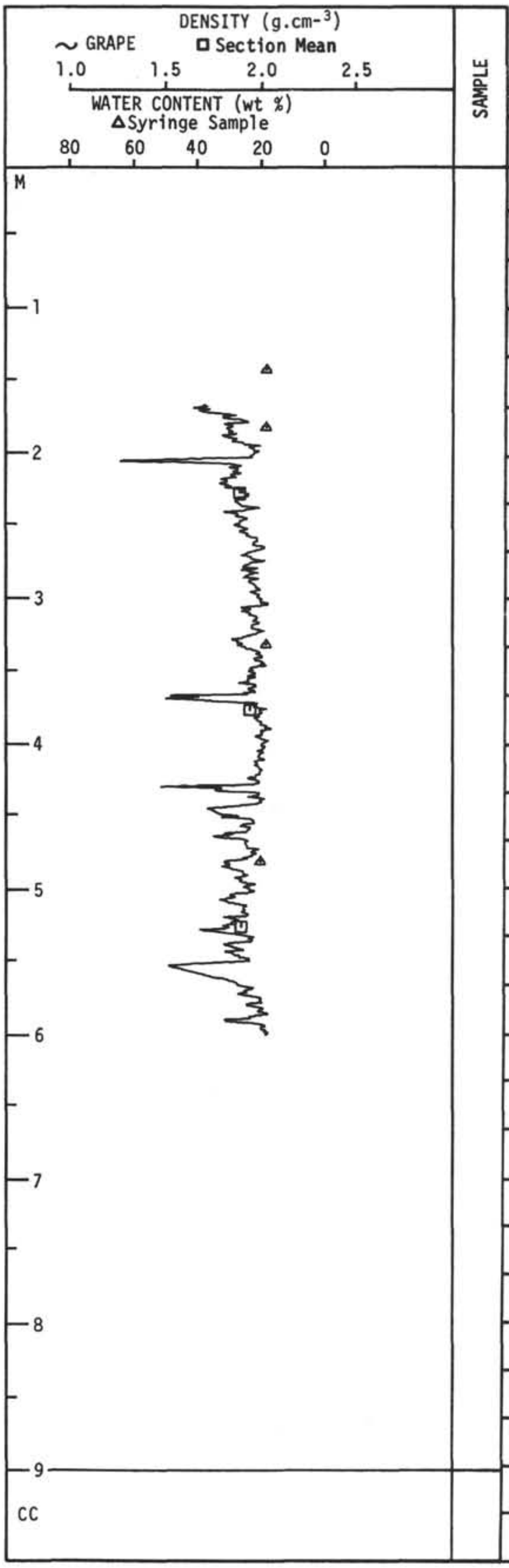

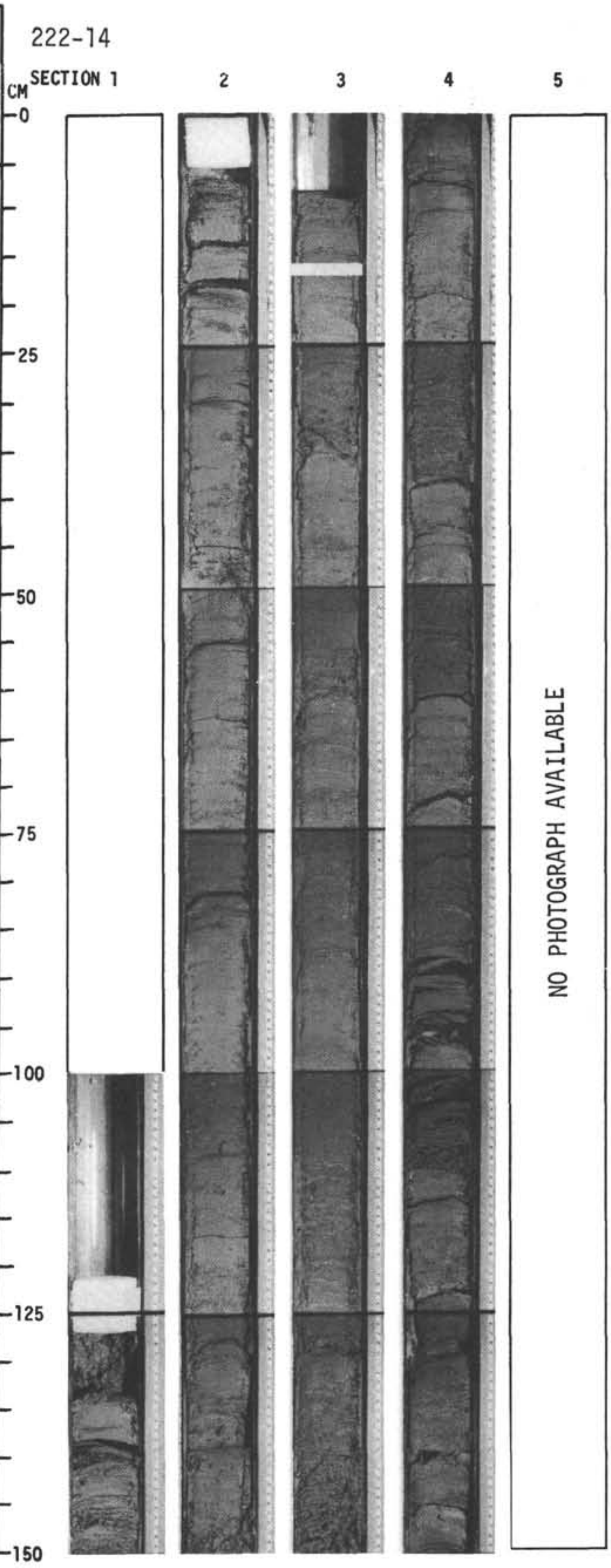

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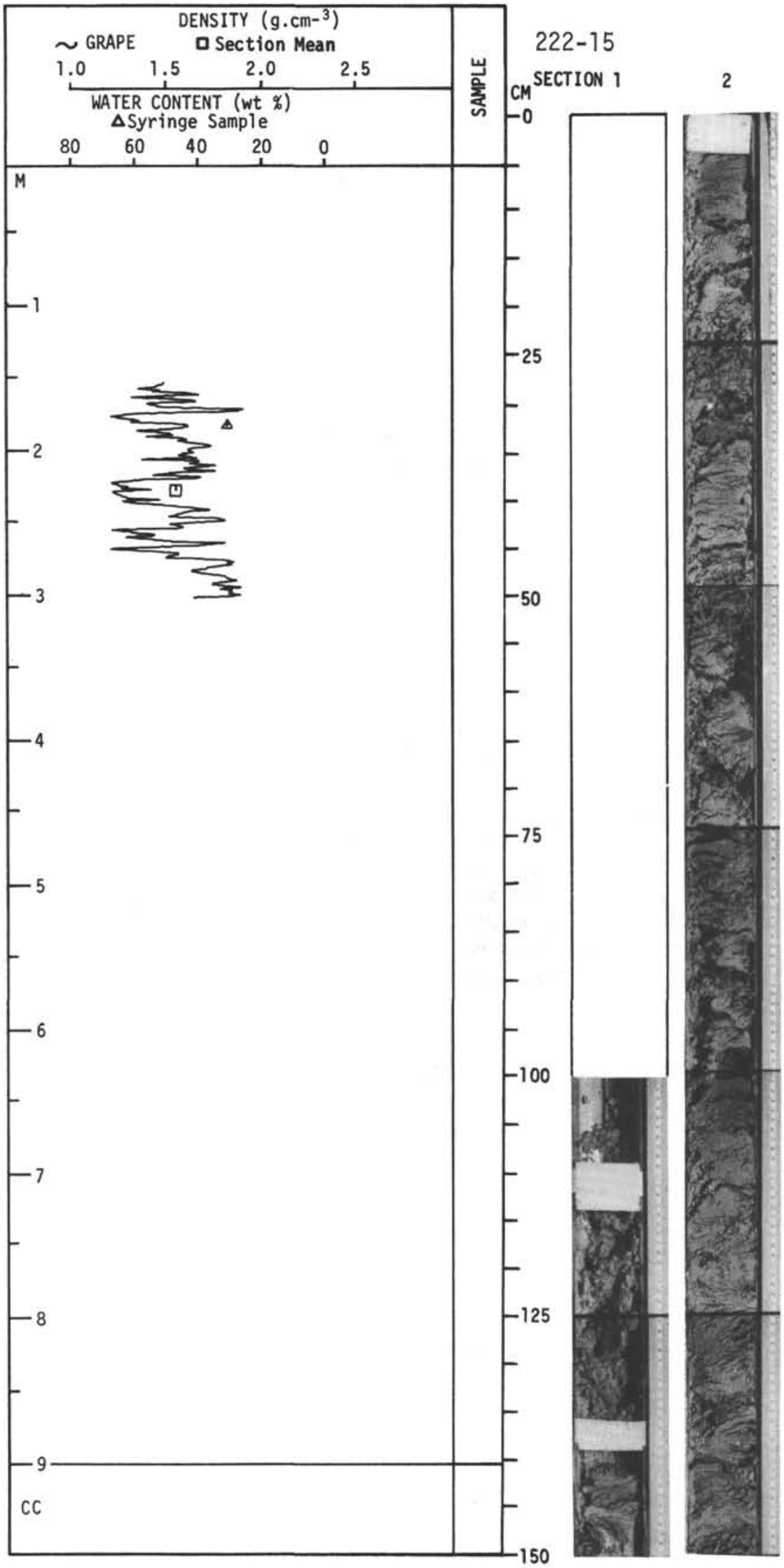

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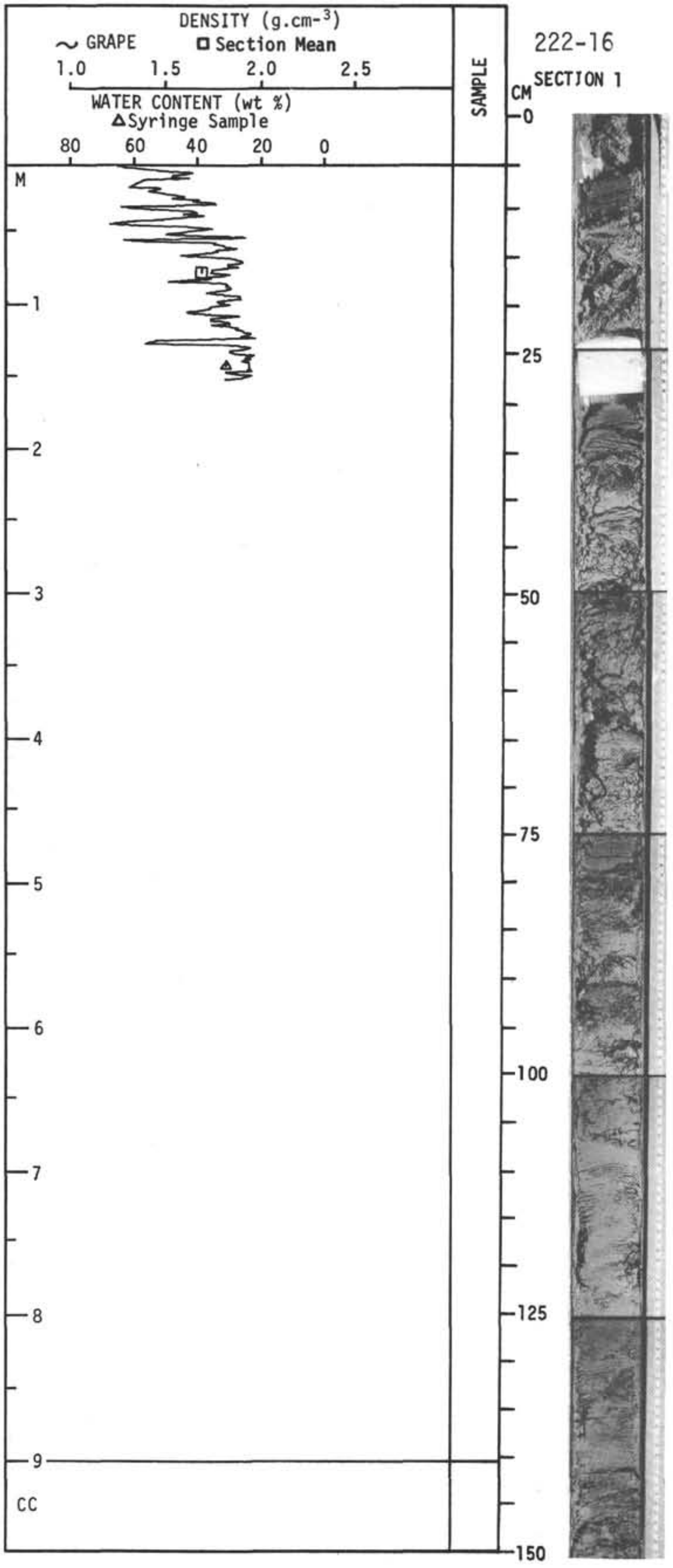

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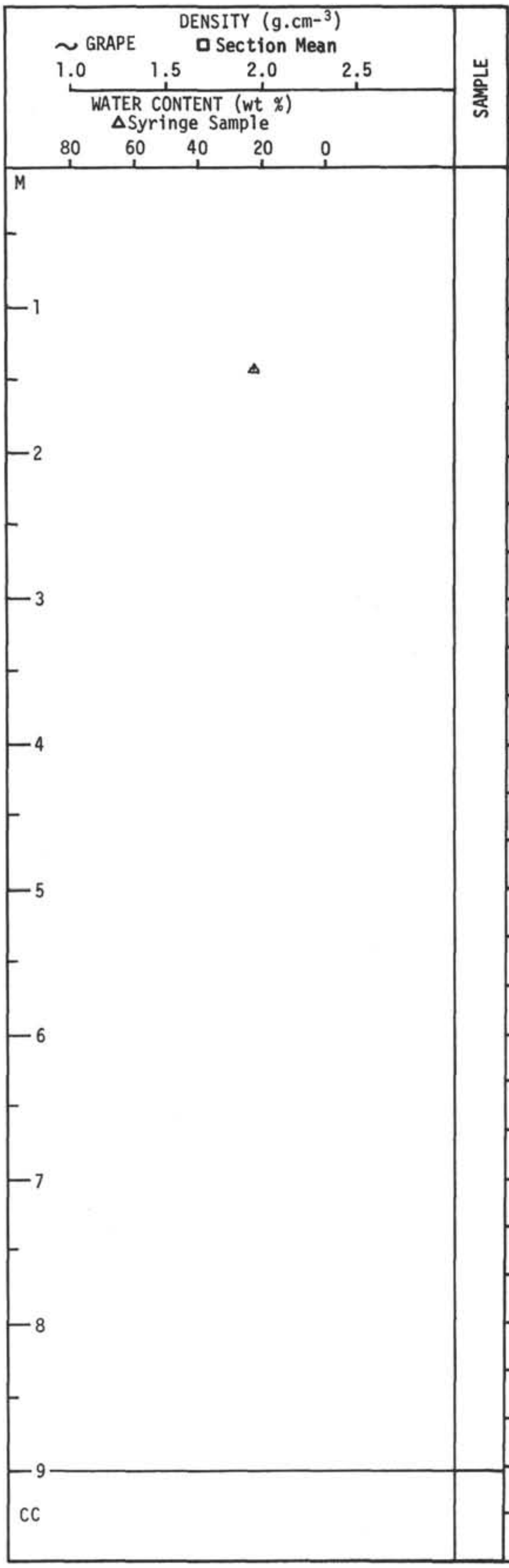

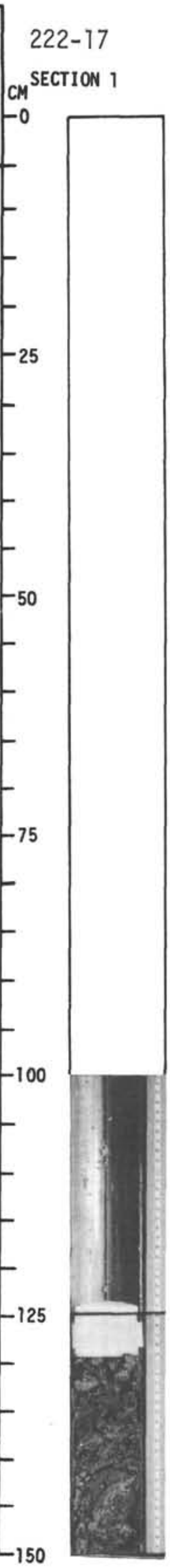

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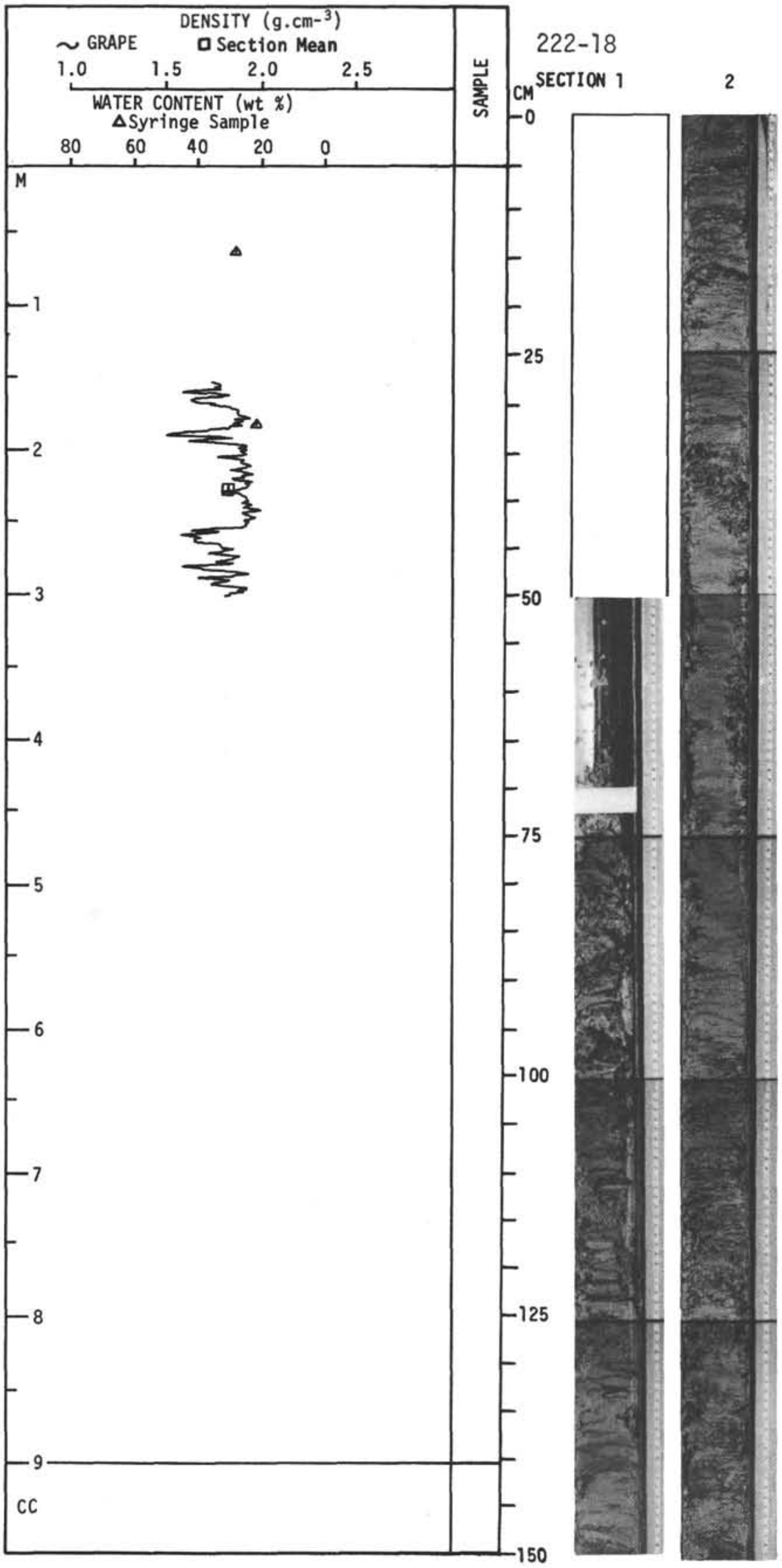

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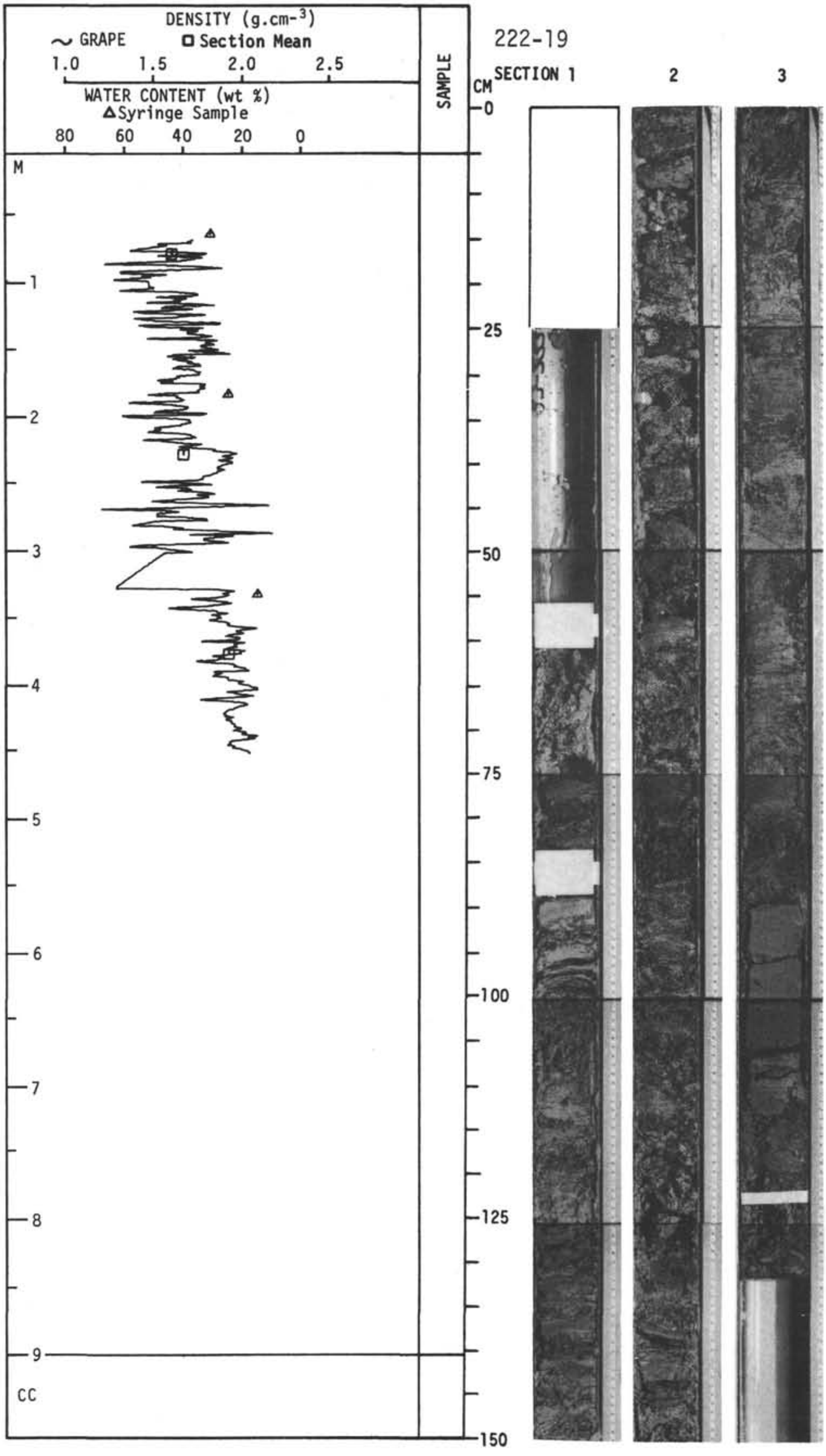

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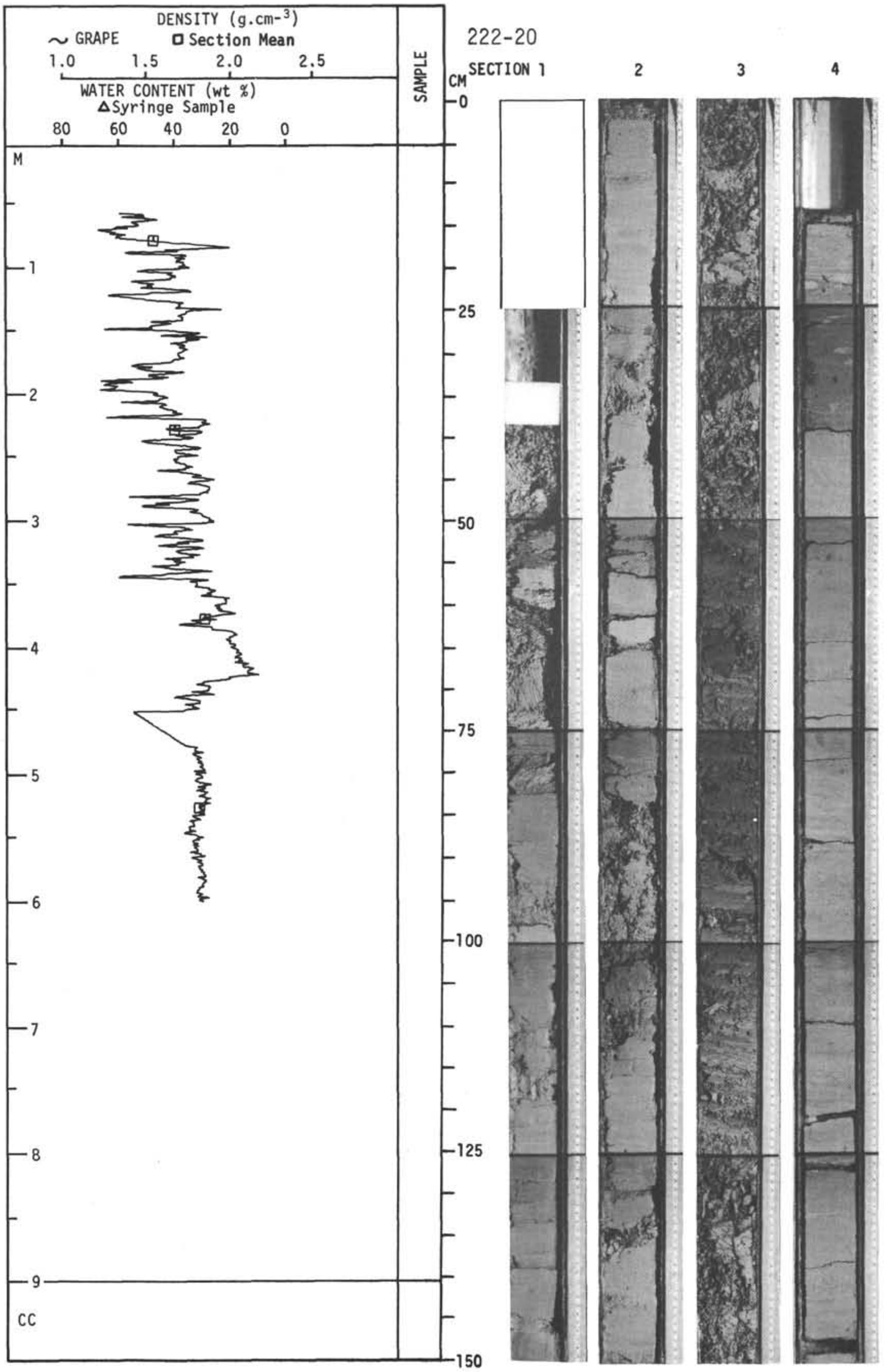

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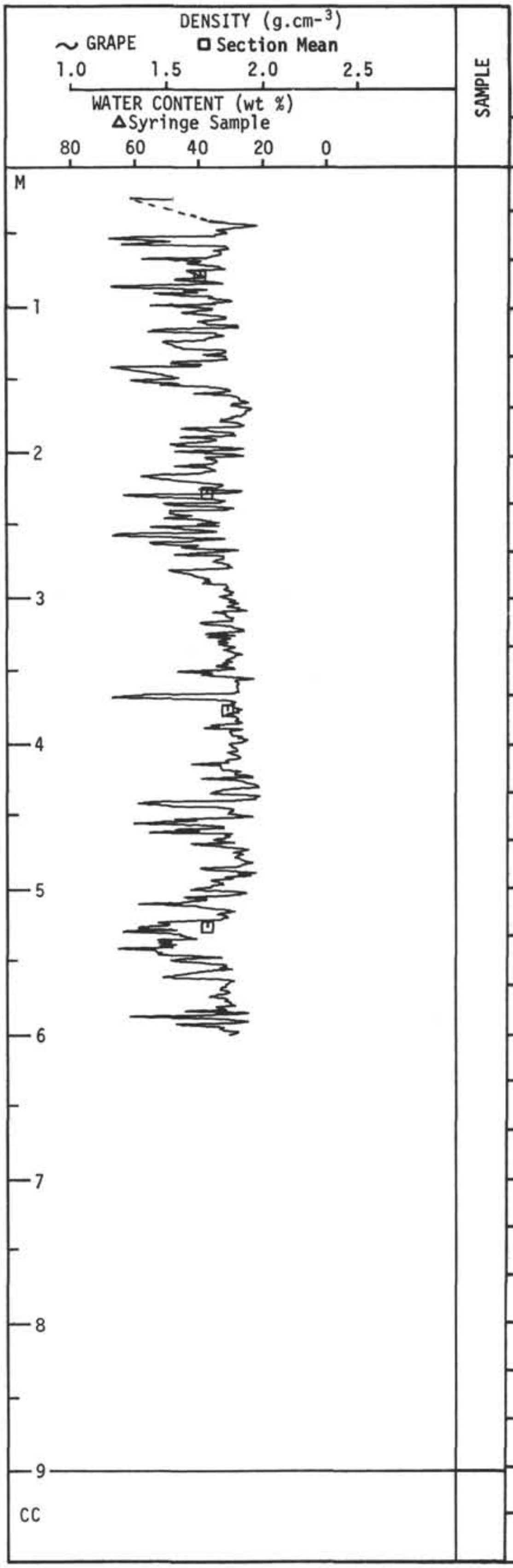

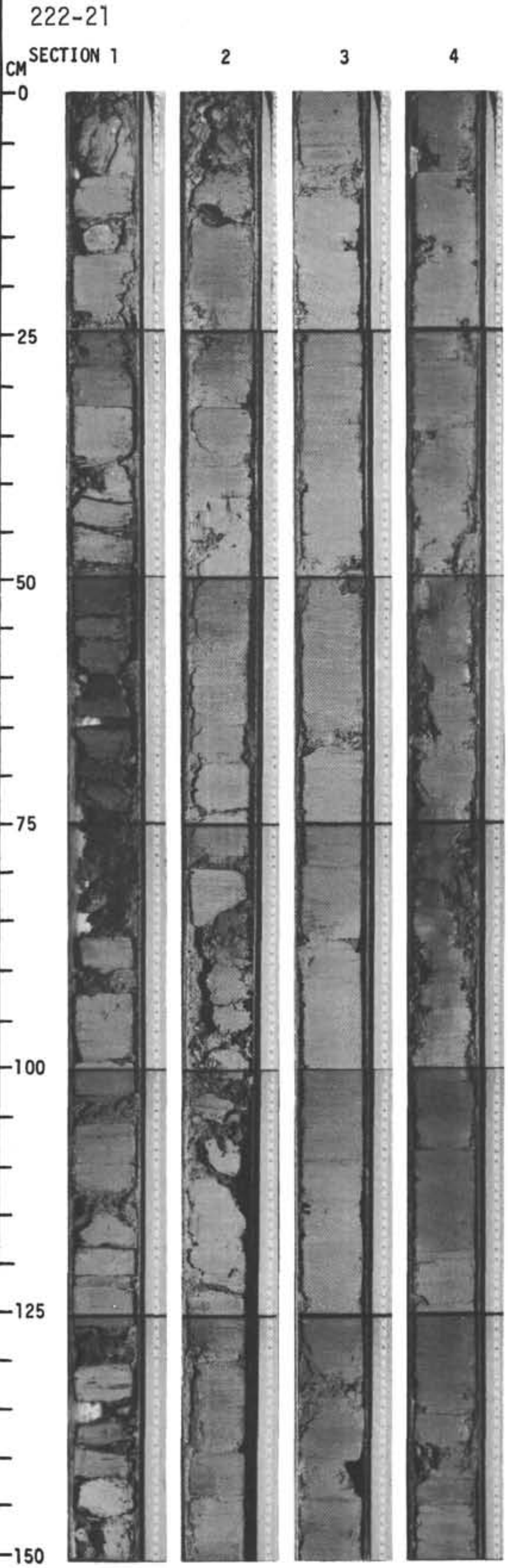

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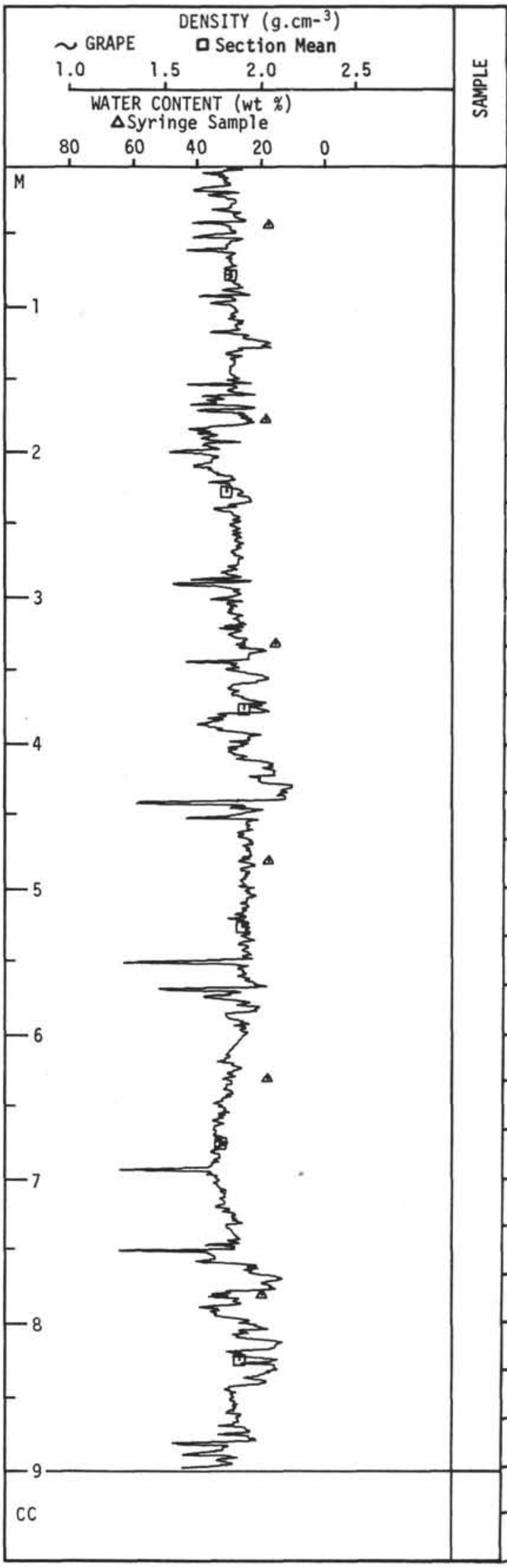

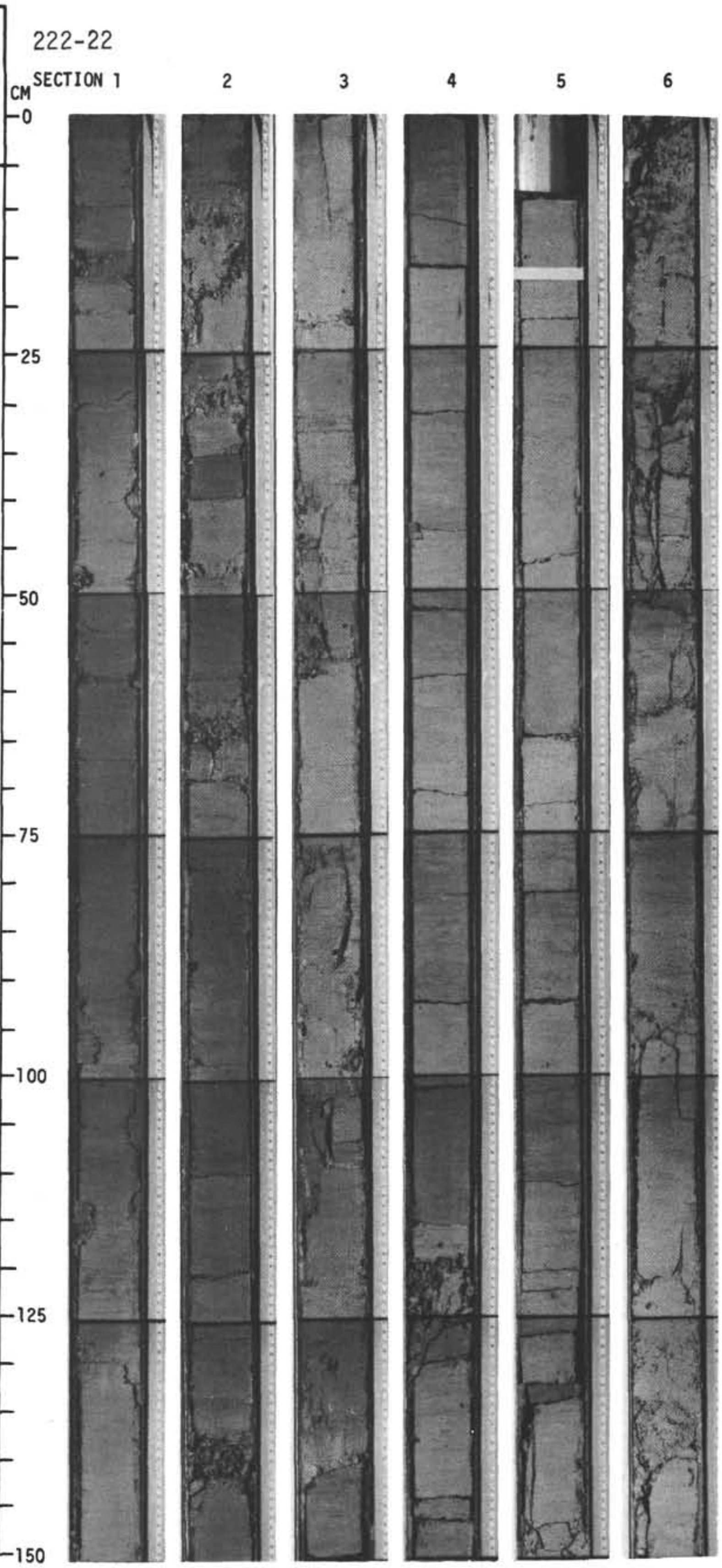

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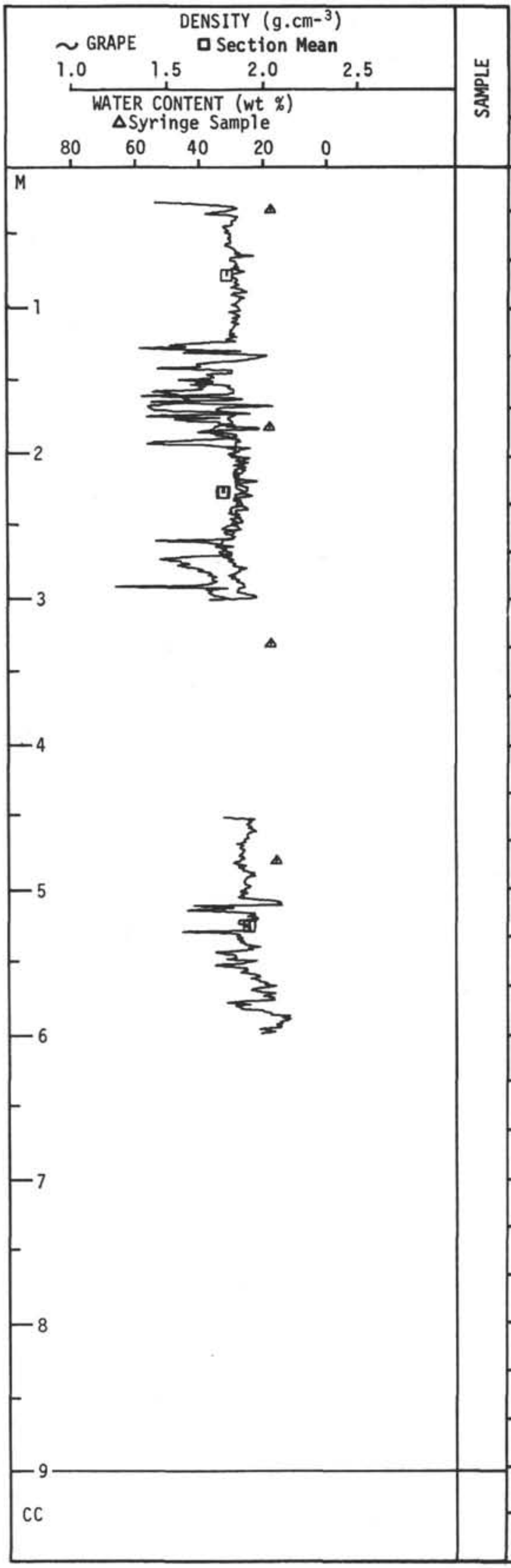
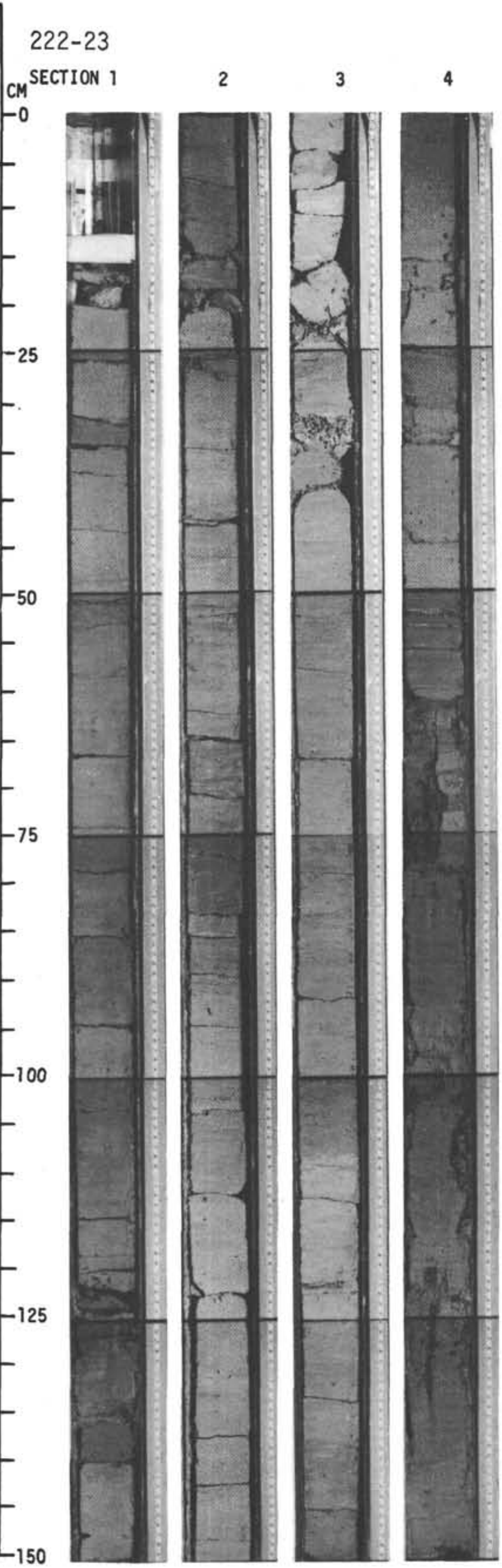
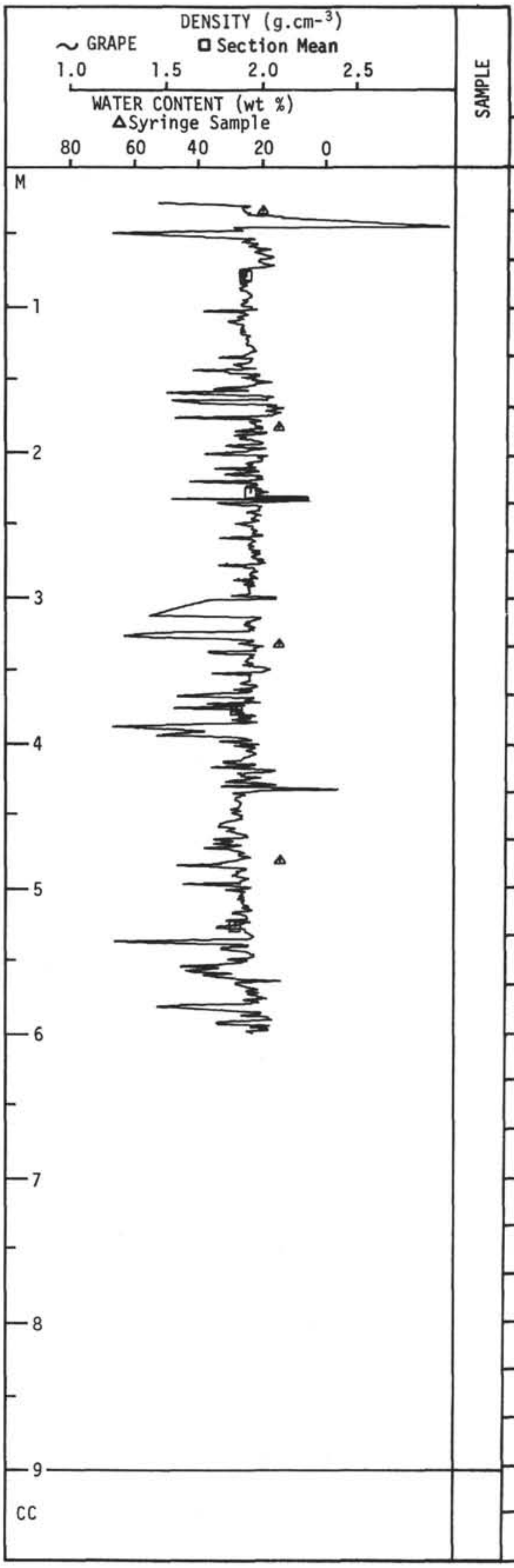
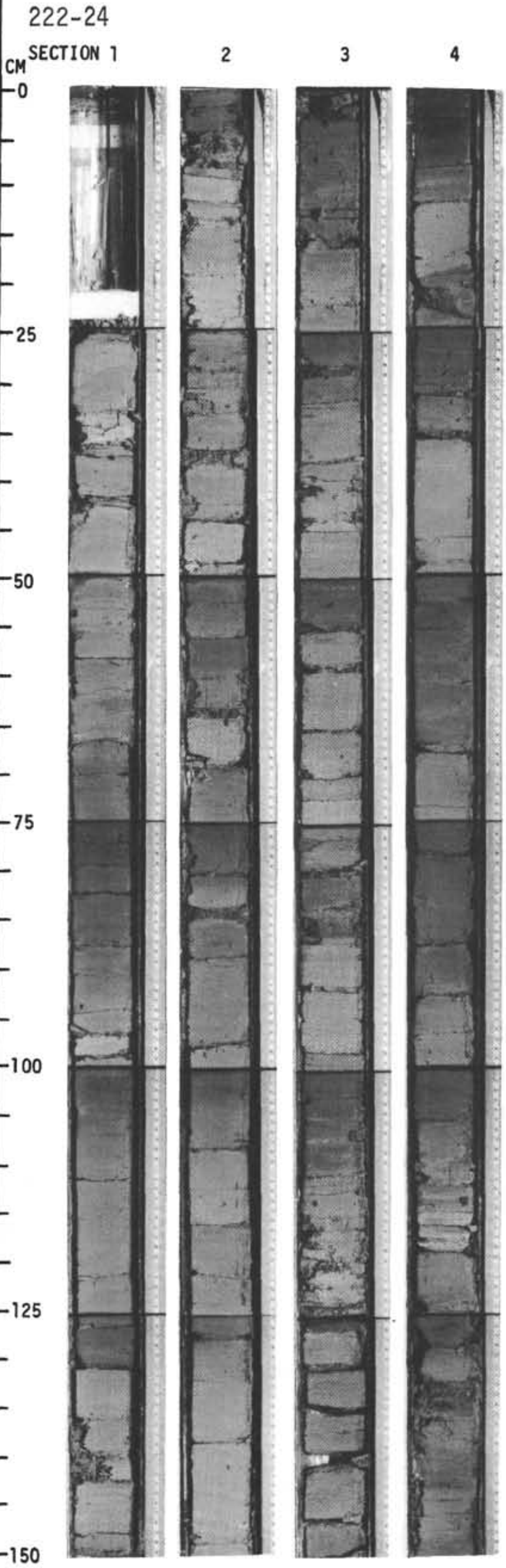




For Explanatory Notes, see Chapter 2





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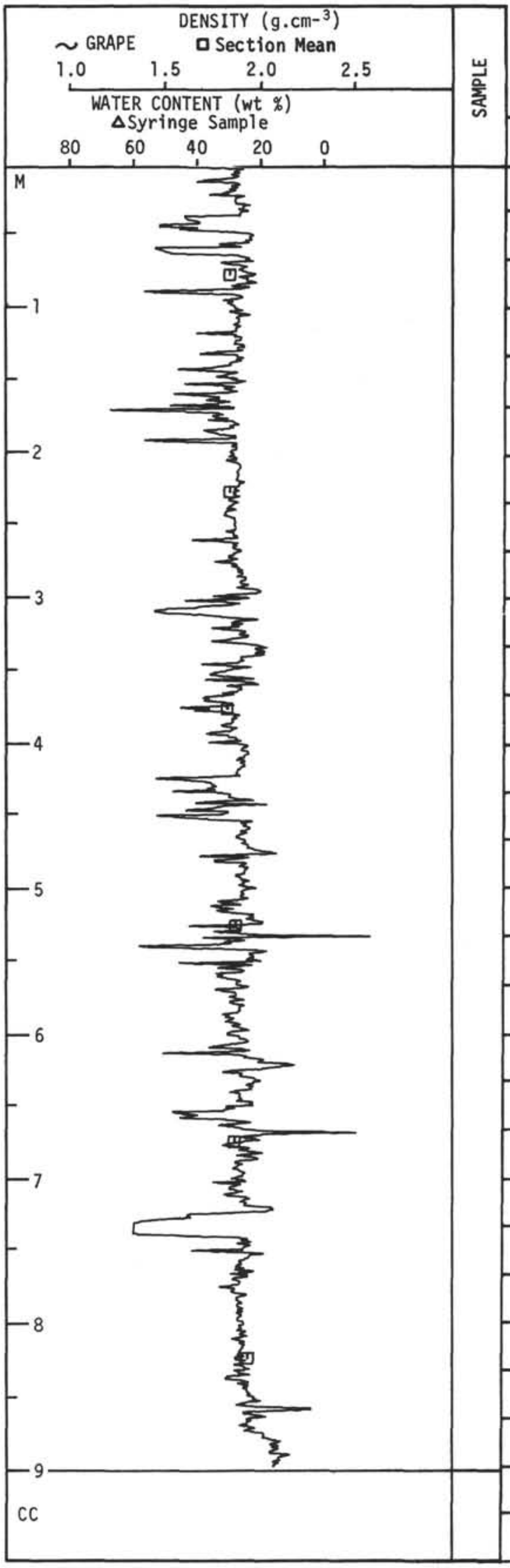

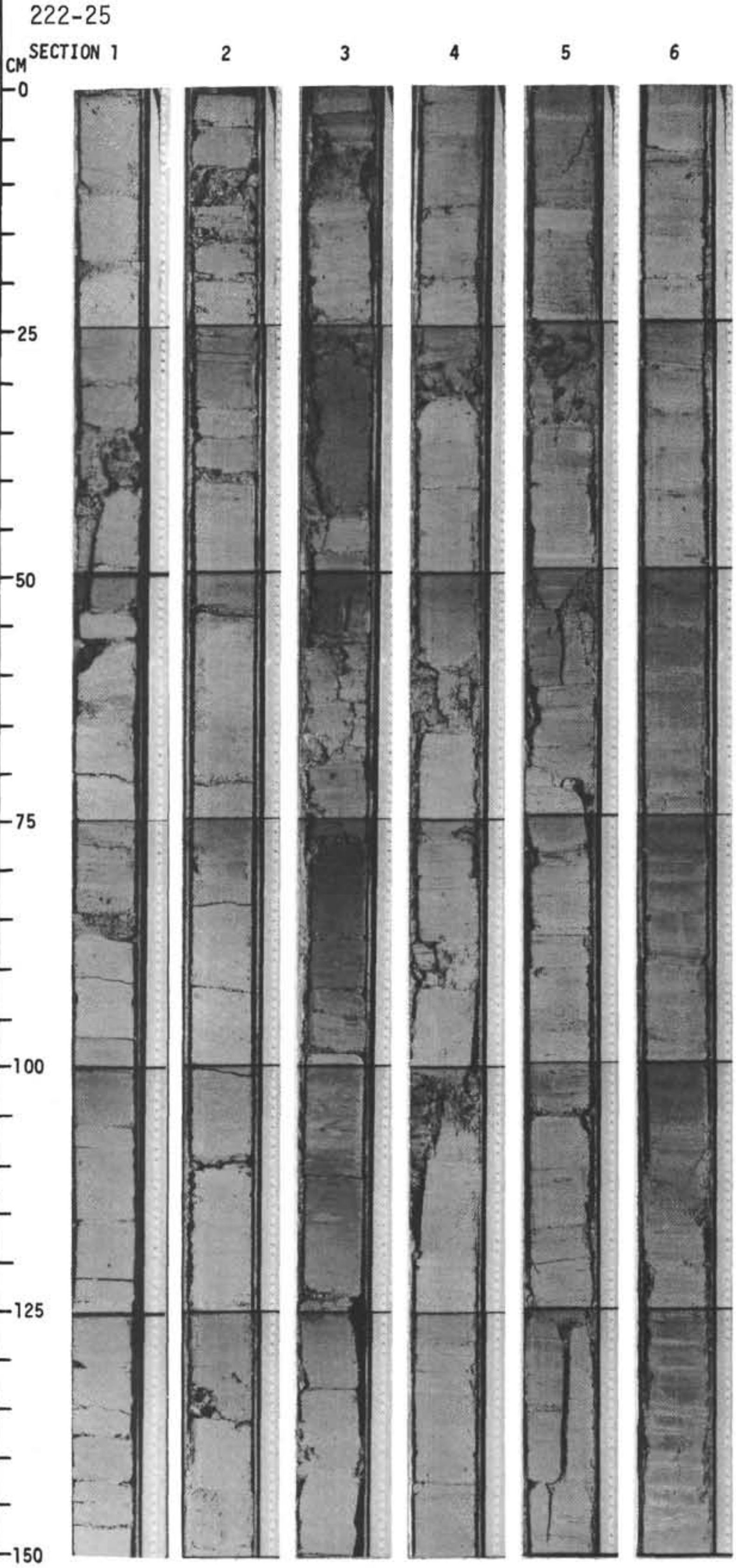

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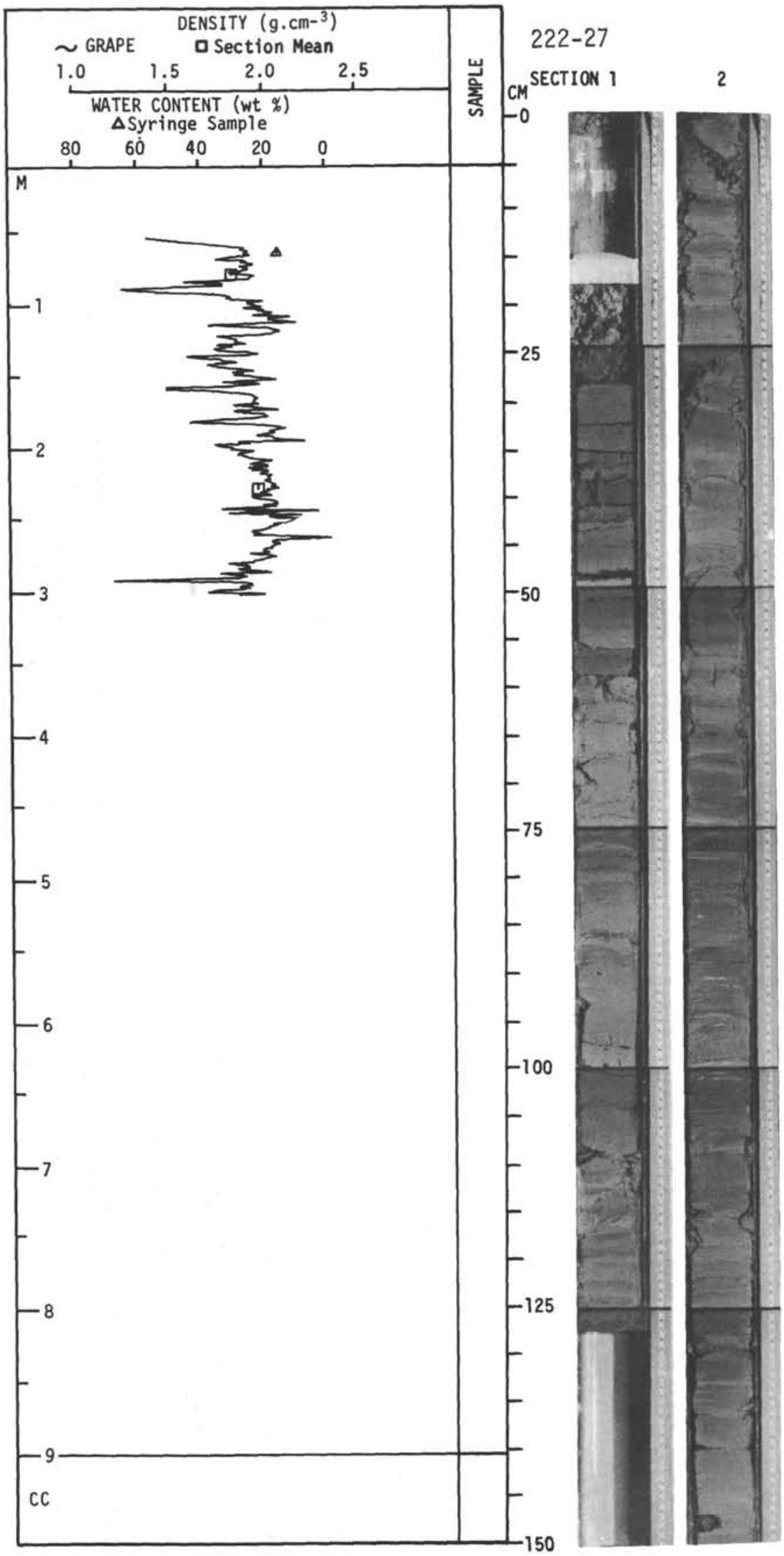

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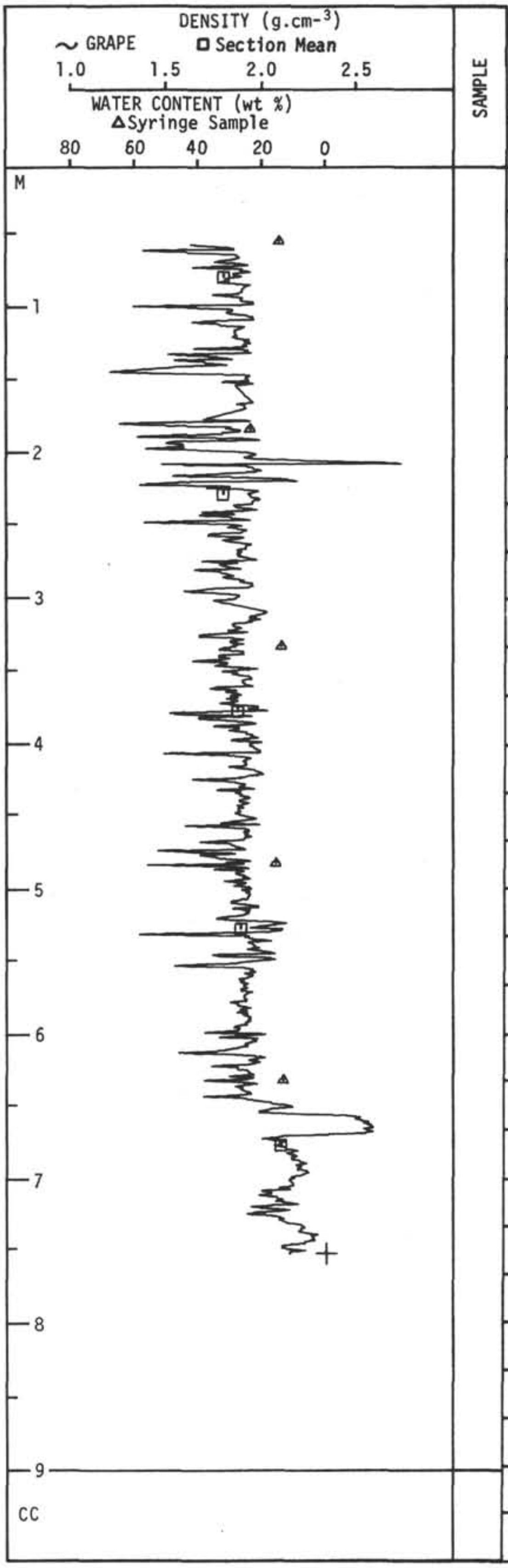

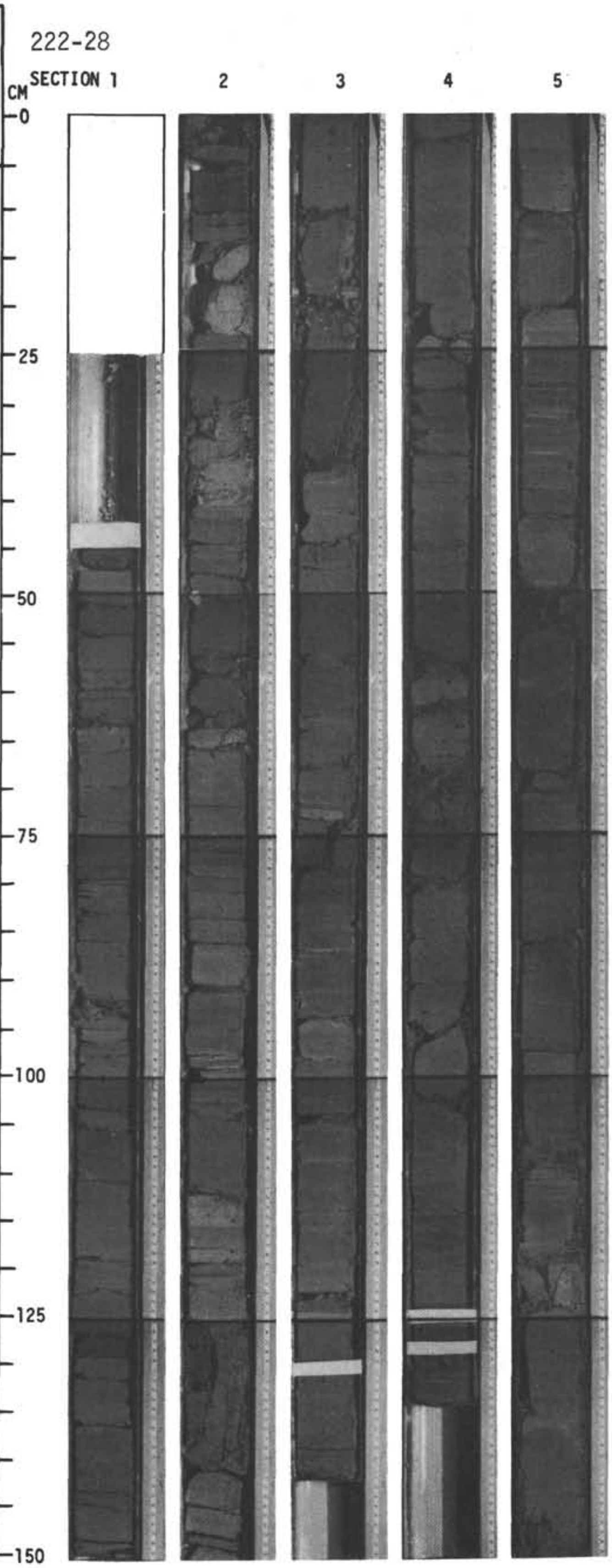

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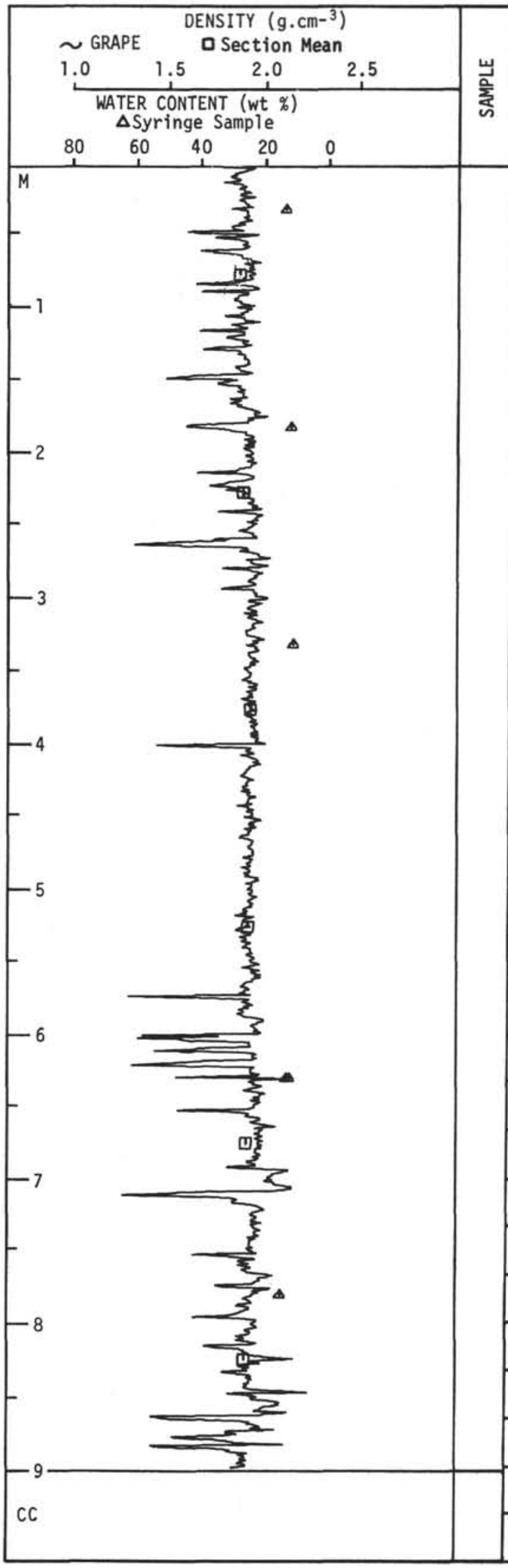
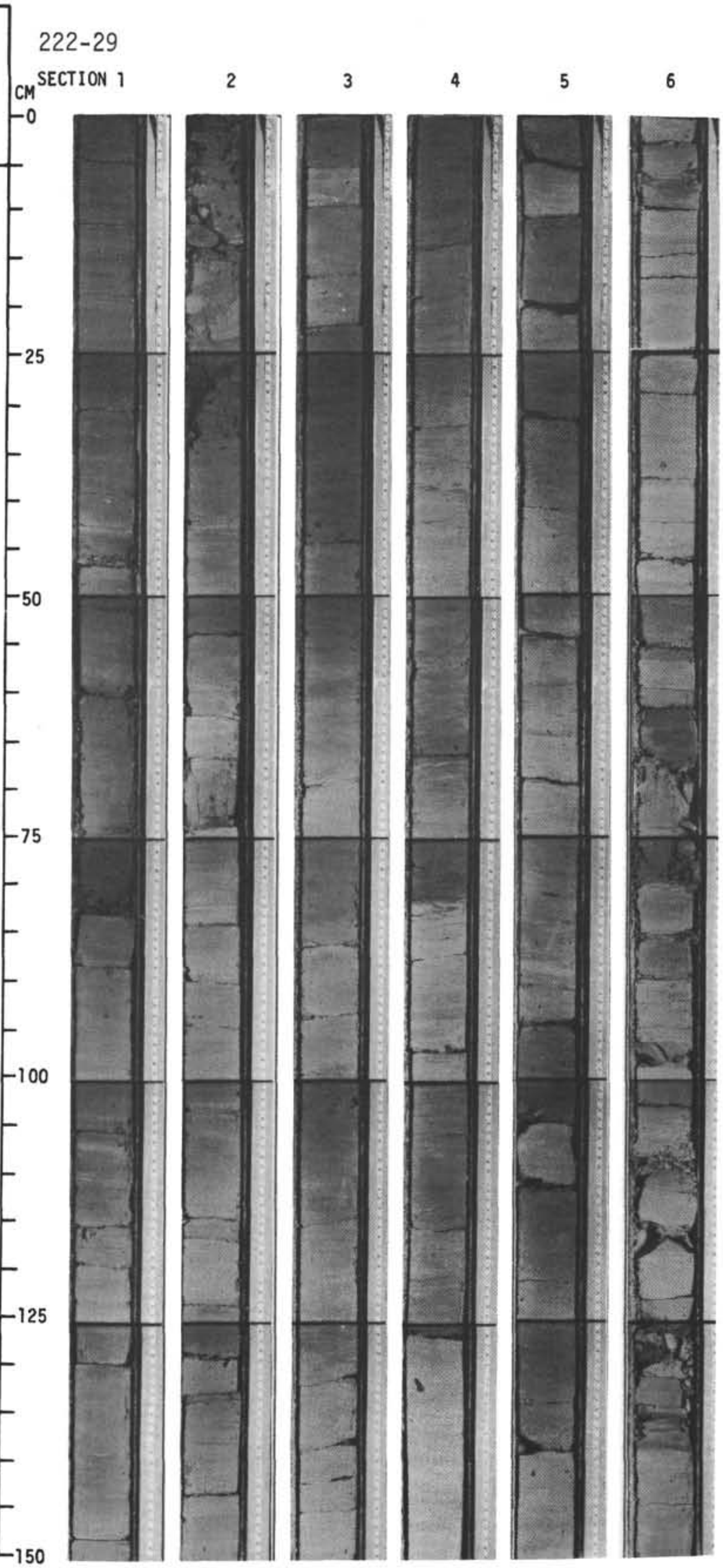
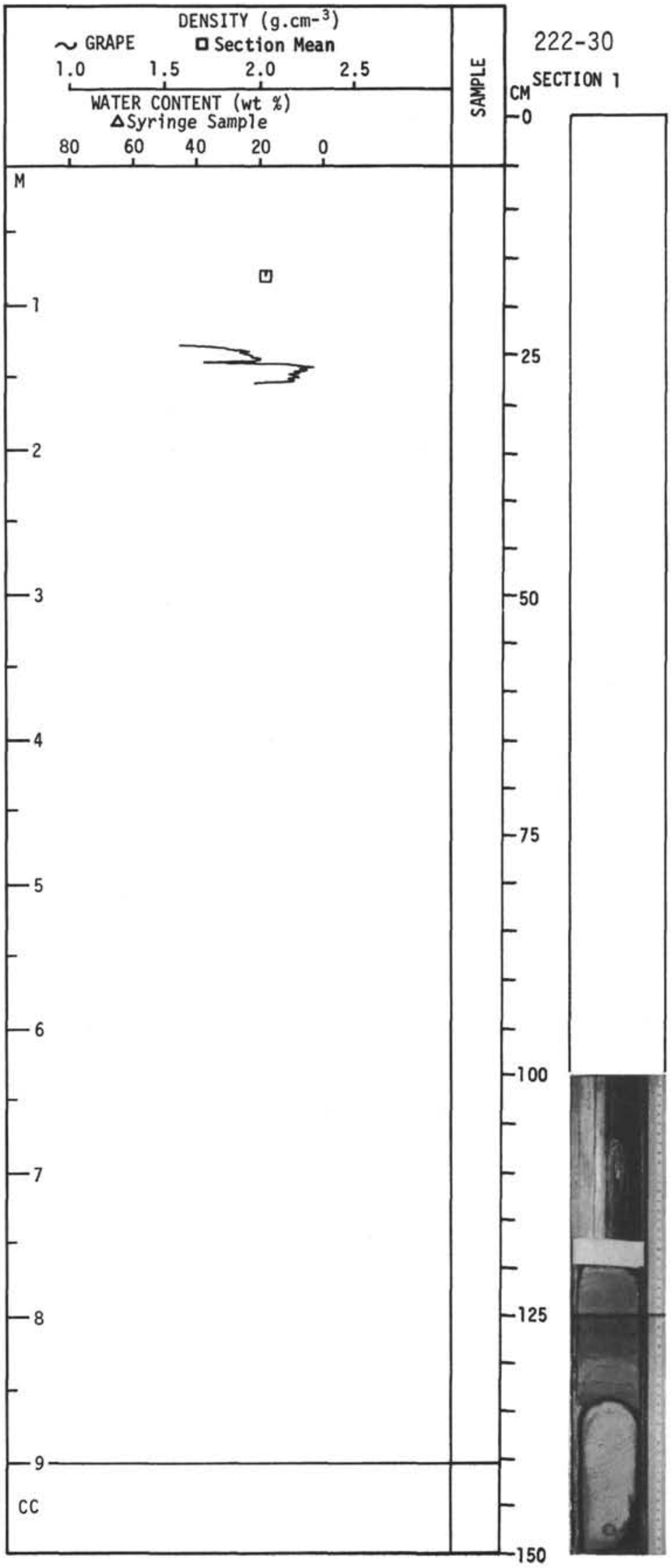




For Explanatory Notes, see Chapter 2



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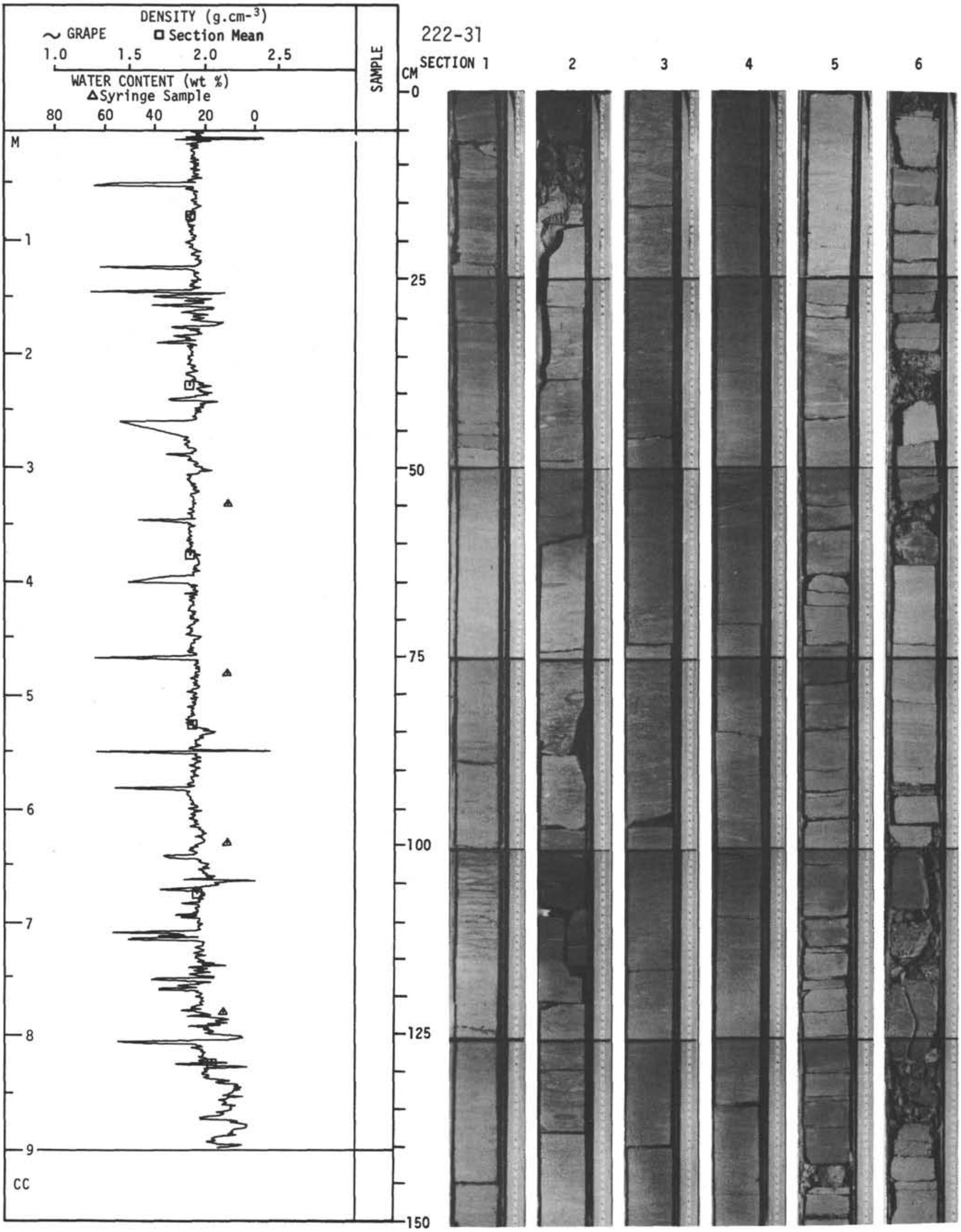
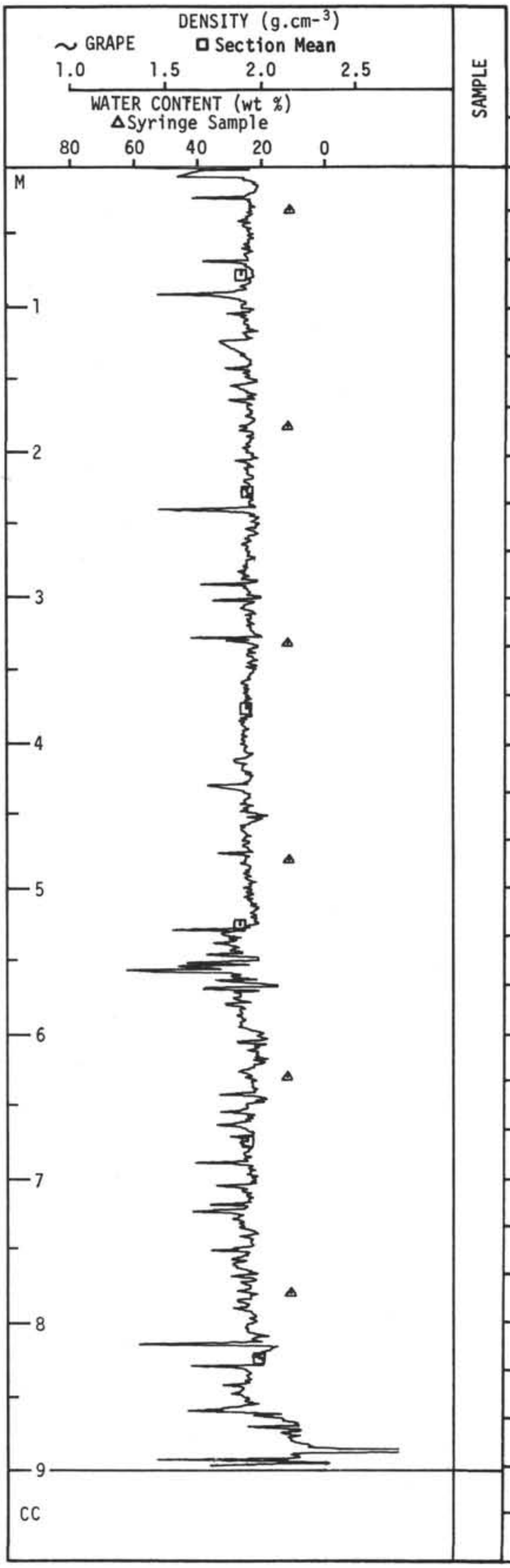
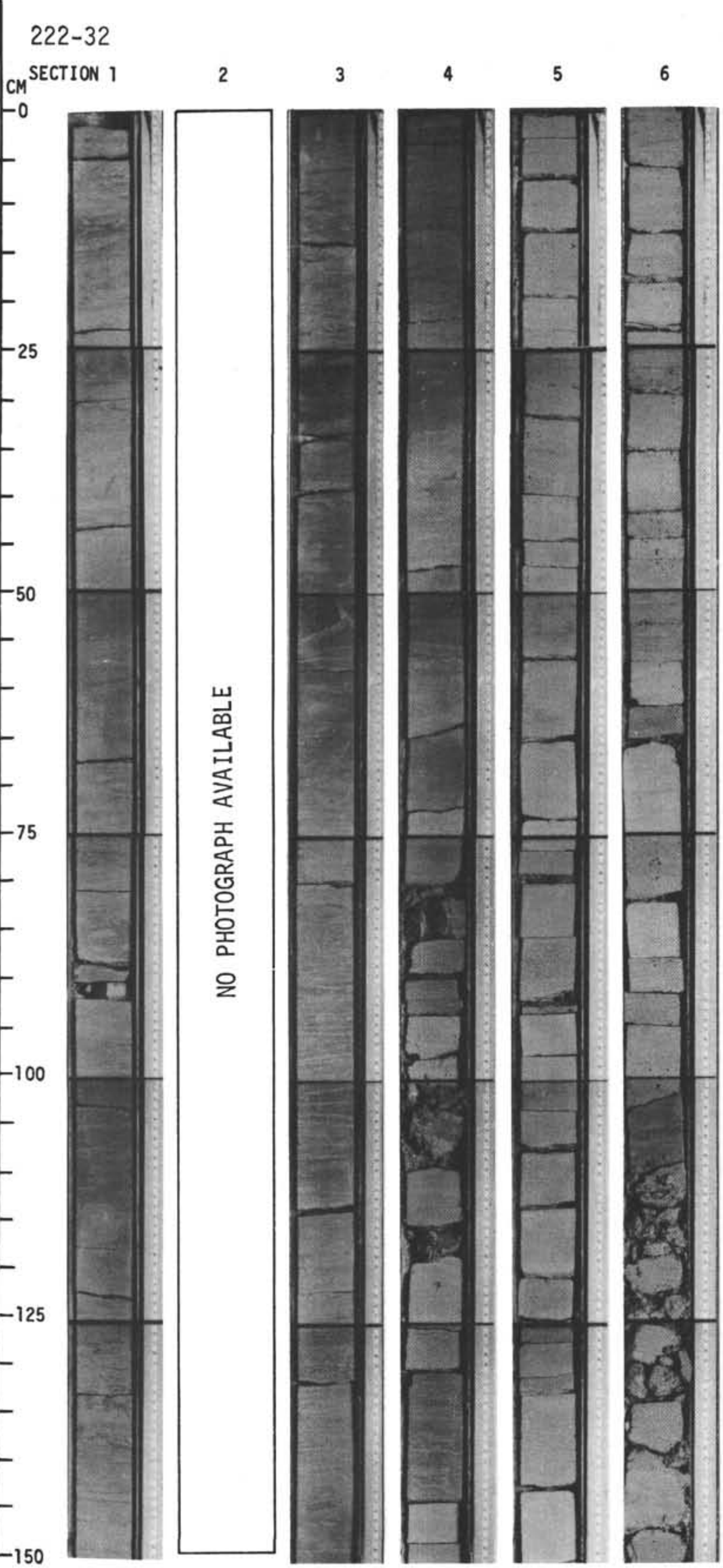


For Explanatory Notes, see Chapter 2





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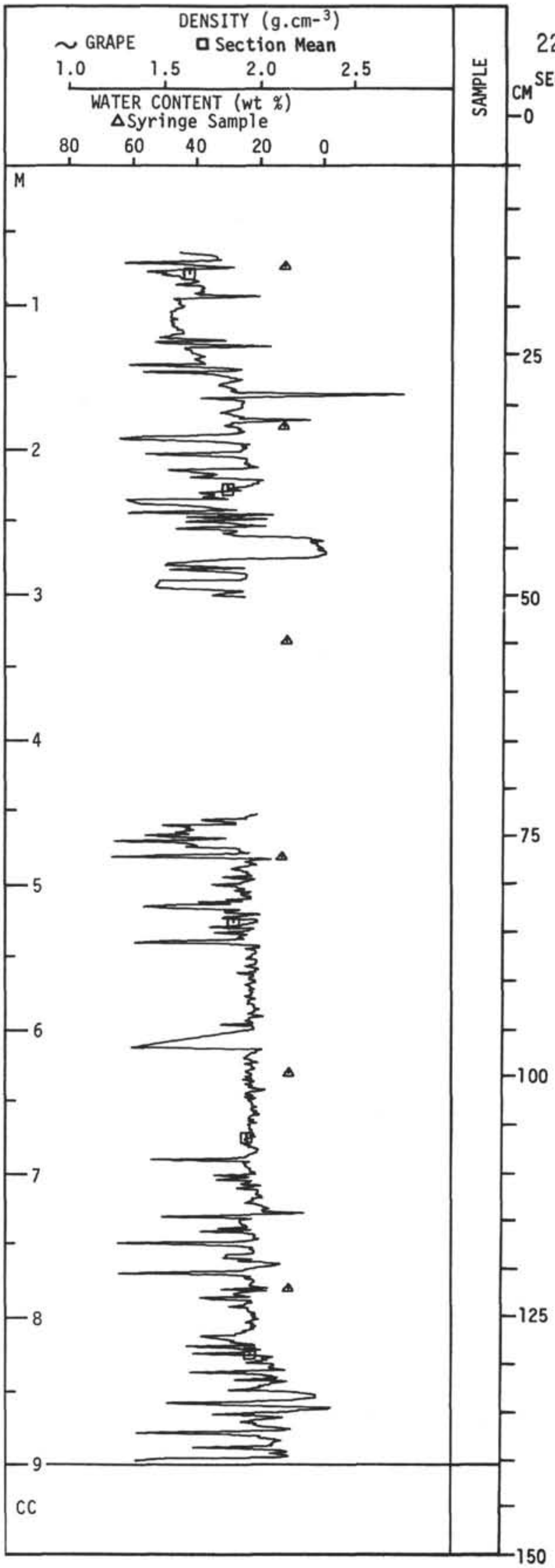

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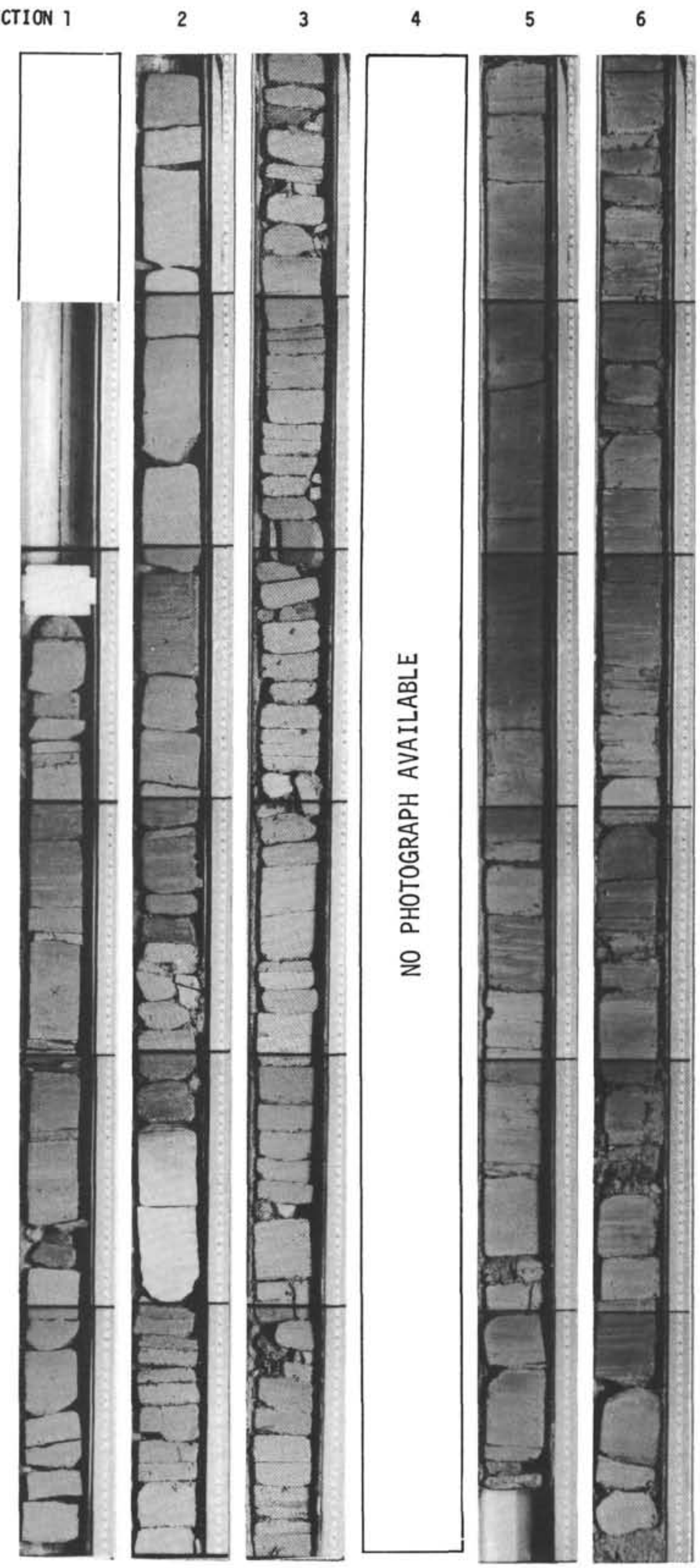
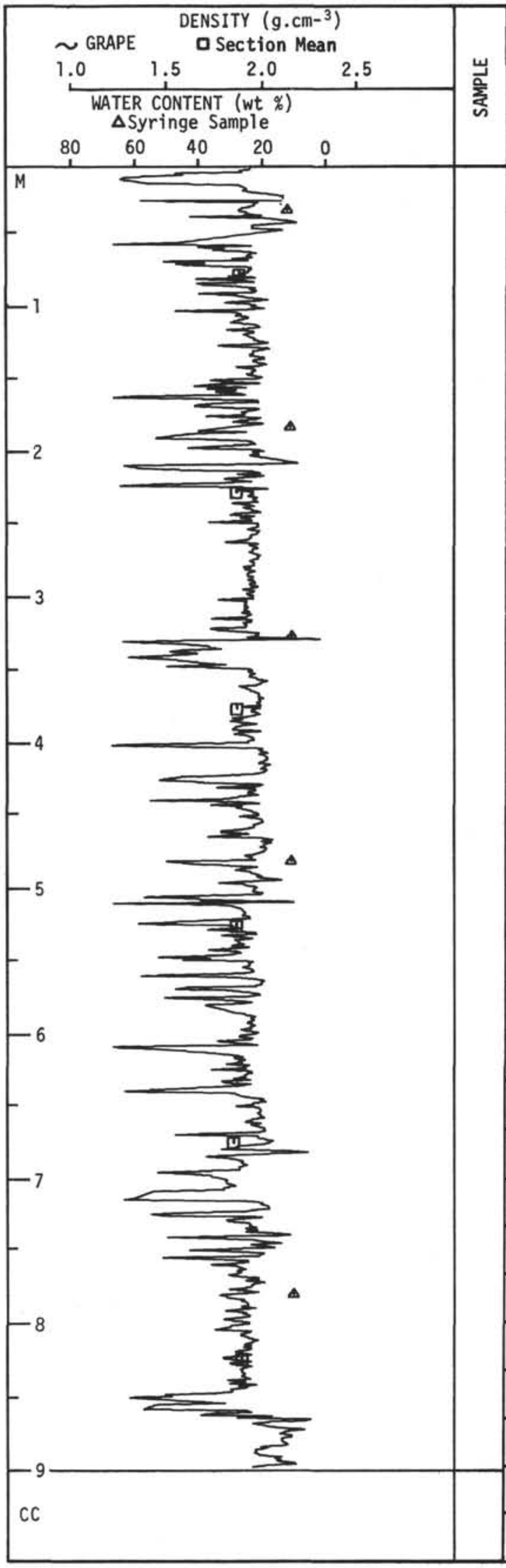
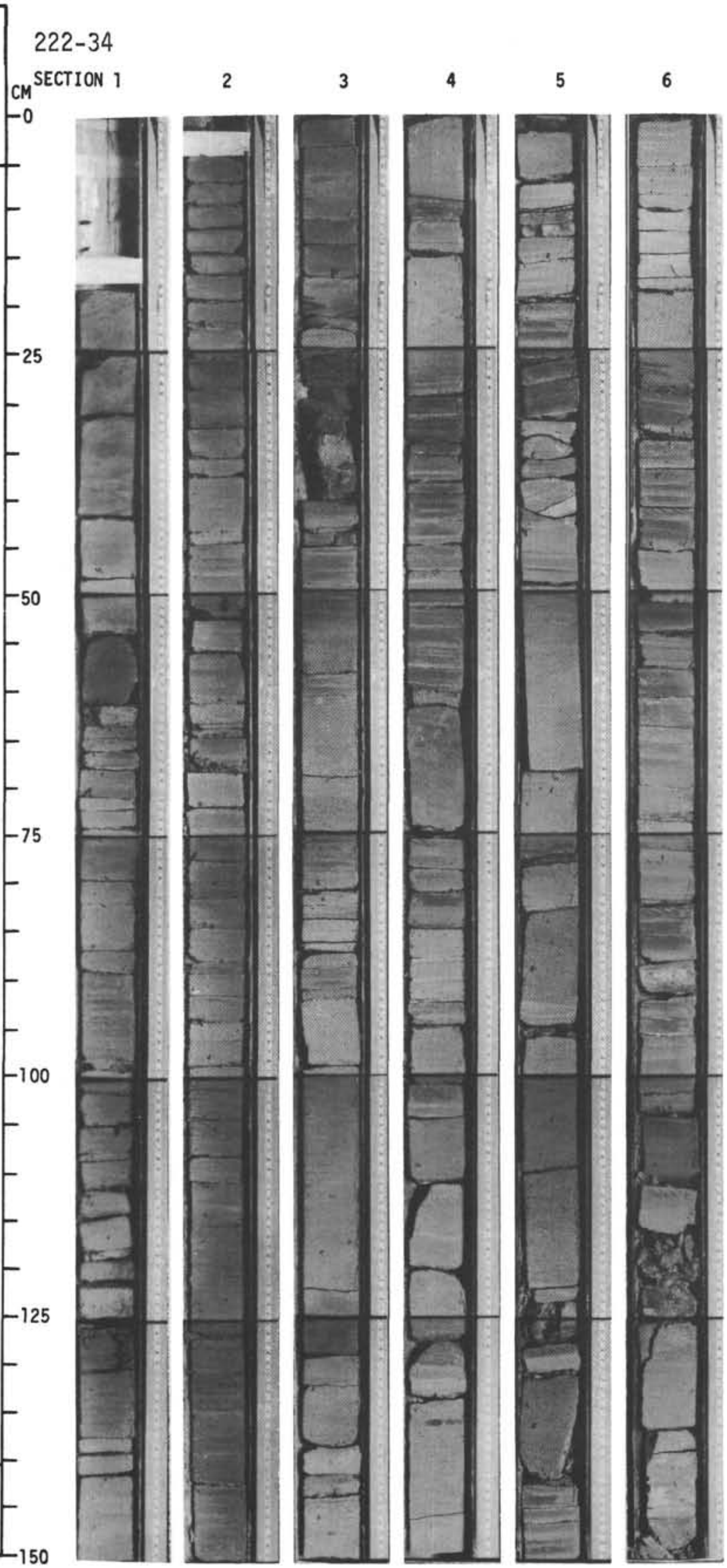


For Explanatory Notes, see Chapter 2





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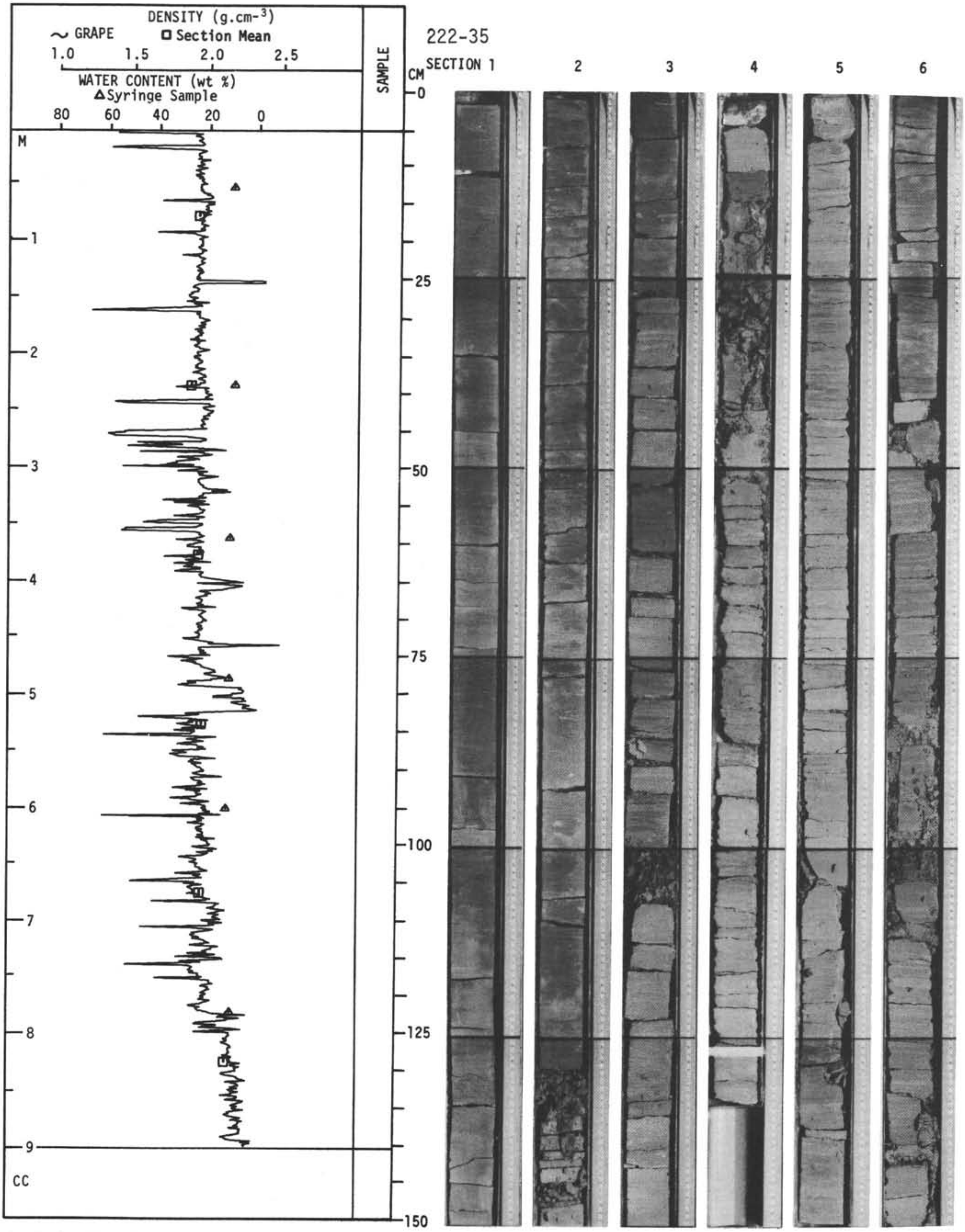

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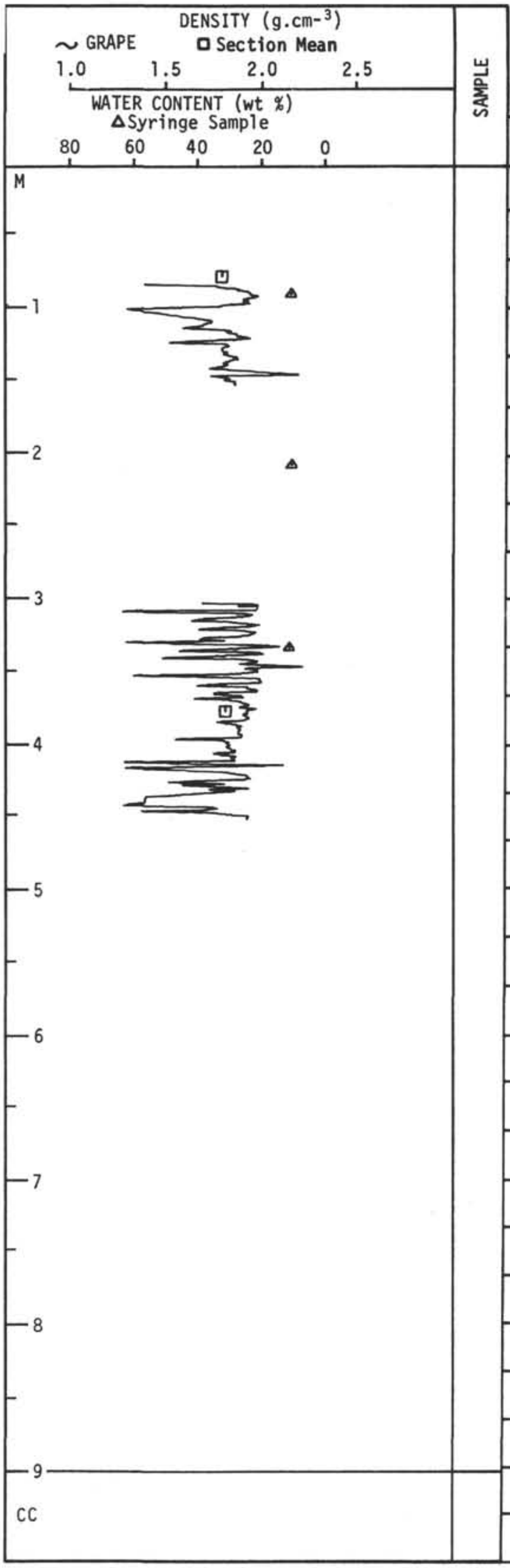

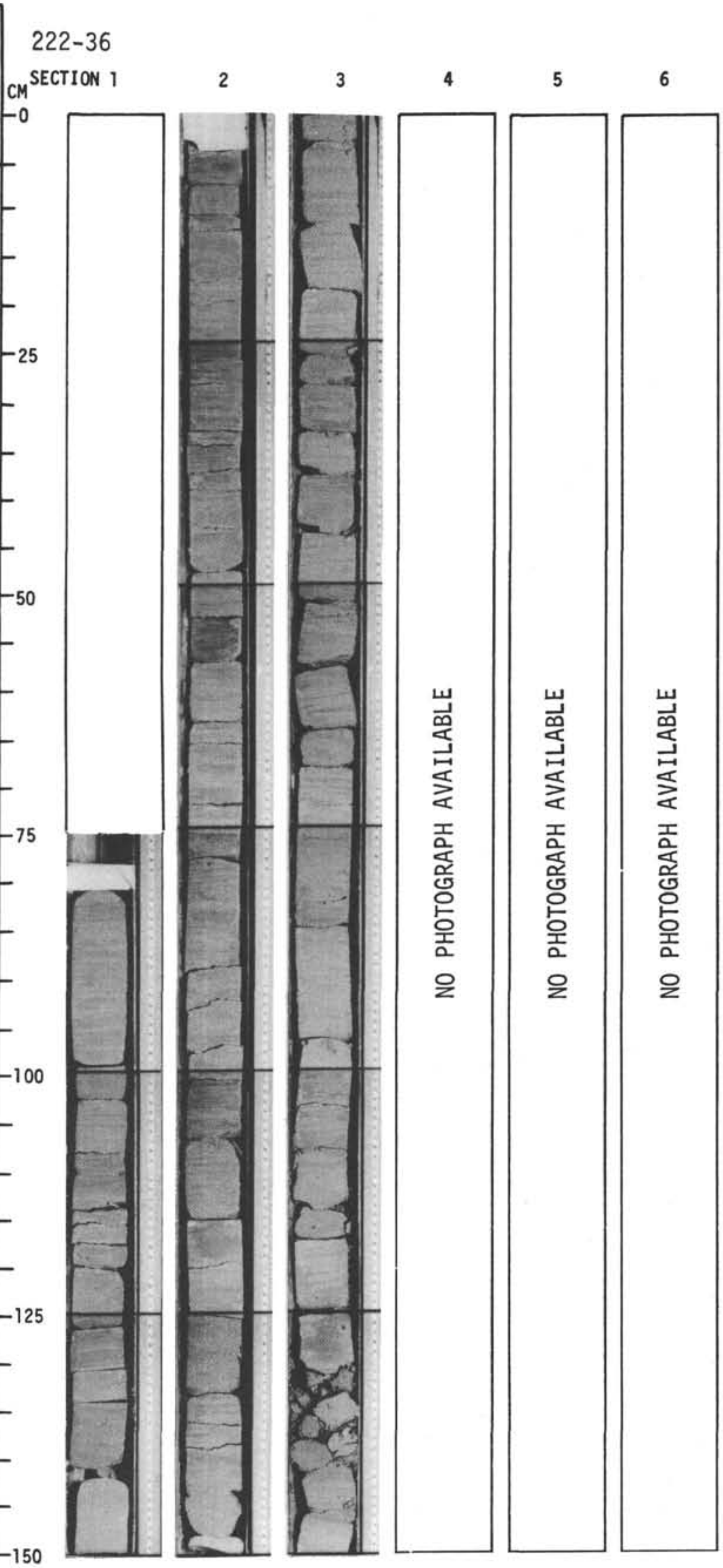

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