6. SITES 375 AND 376: FLORENCE RISE

Shipboard Scientific Party [1]

SITE DATA: SITE 375

Position: 34°45.74′N, 31°45.58′E

Water Depth (sea level): 1900 corrected meters, echo sounding

Bottom Felt at: 1914 meters, drill pipe

Penetration: 821.5 meters

Number of Holes: 1

Number of Cores: 13

Total Core Recovered: 66.9 meters

Percentage Core Recovery: 91.6%

Oldest Sediment Cored:
Depth subbottom: 821.5 meters
Nature: Marlstone
Age: Early Miocene

Basement: Not reached

SITE DATA: SITE 376

Position: 34°52.32′N, 31°48.45′E

Water Depth (sea level): 2101 corrected meters, echo sounding

Bottom Felt at: 2117 meters, drill pipe

Penetration: 216.5 meters

Number of Holes: 1

Number of Cores: 23

Total Core Recovered: 76.4 meters

Percentage Core Recovery: 39.5%

Oldest Sediment Cored:
Depth subbottom: 2165 meters
Nature: Anhydrite/halite
Age: Late Miocene

Basement: Not reached

Principal Results: Sites 375 and 376 (Figure 1): Sites 375 and 376 were located on the Florence Rise, west of Cyprus. Site 375, near the top of the rise intermittently cored a sediment sequence, Burdigalian to Quaternary in age. Site 376, on the Antalya basin flank of the rise, almost continuously cored a Messinian to Holocene sequence. The sites complement each other and combined, provide a standard section for correlation with sequences described on land in Cyprus.

The Quaternary nannofossil marls contain tephra and sapropelic layers, indicative of volcanic events and periods of basin stagnation, respectively. The Pliocene nannofossil marls, also containing sapropelic layers, have extremely low sedimentation rates, due to numerous hiatuses, and are complicated by sediment slumping.

Nannofossil marlstones and dolomitic marlstones of latest Miocene age overlie a gypsum with marlstone evaporite sequence. Siltstones and sandstones within this upper marl and marlstone unit are interpreted as turbidites. Faunas believed to be autochthonous, contain *Ammonia beccari* and *Cyprideis pannonica* indicative of a brackish euryhaline "Lago Mare" environment. Horizons with marine microfossils show that there was occasional influx of marine waters into this "Lago Mare."

The gypsum with marlstone evaporites, which are interpreted as deposits of a shallow subaqueous environment, are followed downwards by anhydrite and halite at Site 376 and are collectively recognized as the upper part of the Mediterranean Evaporite Formation.

The pre-evaporite sequence of Site 375 comprises 400 meters of flysch-like sediments, including sapropelic layers which overlie more than 200 meters of hemipelagic marlstones with distal turbidites, having at their base intercalated limestones which constitute an acoustic reflector. Analyses of benthic foraminifers suggest that this pre-Messinian sequence was deposited in a basin with water depths throughout in excess of 1000 meters.

BACKGROUND AND OBJECTIVES

Background

From Oman to Cyprus through Zagros and Taurus an important tectonic event of late Cretaceous age has been recognized (Ricou, 1971). It is characterized by large overthrusts associated with sliding bodies and ophiolites. In eastern Turkey these are the Kevan, Besni, Baasit nappes, while in Cyprus they are the Mamonia nappes and also probably the Troodos Massif. This arcuate feature can be followed towards the west. It is marked by the Florence Rise running southeast-northwest as far as the southern Anaximander mountains. Again this unit exists onshore in western Turkey as the Antalya nappes and maybe the periodotite nappes of the Lycian domain in western Taurus.

The Florence Rise on which Site 375 was located (Figure 2) was first named by Biju-Duval et al. (1974). There was considerable shipboard discussion on this name and although both parts of it were considered

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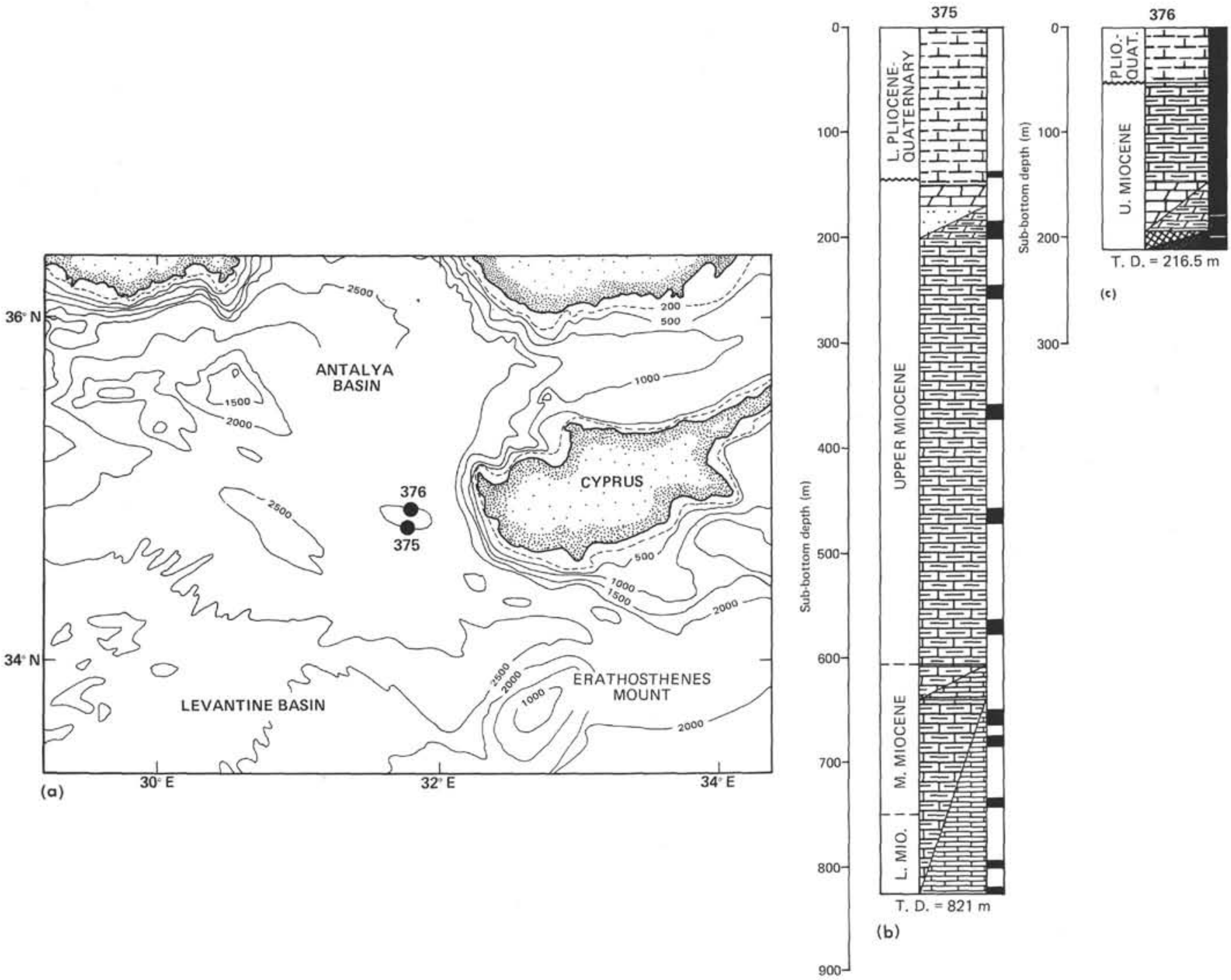

Figure 1. *(a) Site location map (depth contours in meters); (b) generalized hole summary: Site 375; and (c) generalized hole summary: Site 376.*

unfortunate, the prior usage was retained. This is not a continental rise but a ridge which is a part of the Cyprus Arc and separates the Antalya Basin to the north from the Levantine Basin to the south.

The ophiolites associated with this late Cretaceous tectonic unit are well known in Cyprus in the Troodos-Kella Ki massifs. The pillow lavas at the top of the ophiolite suite have been dated as late Cretaceous in age. The Troodos ophiolites are affected by the late Cretaceous event and also by a later Neogene event.

On Cyprus there is a more or less complete sedimentary cover on these ophiolites ranging in age from Maestrichtian to the Quaternary. The sediments are mainly pelagic marls until the Miocene (Robertson and Hudson, 1974), when lower Miocene sandy marl, and upper Miocene evaporites or shallow water carbonates were deposited. The Pliocene-Quaternary sequence consists of sandy marls.

The Florence Rise at the location of Sites 375 and 376 is about 600 meters above the adjacent basins. Seismic profiling shows that it is an asymmetric structure: (1) To the north, the acoustic substratum, at a depth of more than 5 km in the Antalya basin, rises regularly and is only at about 1 km deep under the Florence Rise. (2) In the Antalya basin a very thick sequence (about 2500 m) of Messinian evaporites occurs which pinches out on the Florence Rise. Also on the rise itself, under a thin veneer of Pliocene-Quaternary sediments, the pre-evaporitic layers outcrop successively and can be reached without having to drill through thick evaporites. (3) To the south a series of faults, very probably reverse faults, mark the limit of the Cyprus Arc.

The Cyprus ophiolite complex is generally thought to represent an uplifted fragment of Mesozoic oceanic crust and upper mantle. The provenance of this ophiolite complex is presently a matter of debate. On the one hand, Ricou et al. (1974) suggest large-scale nappe derivation from the Tethyan ophiolite belt of Anatolia while La Pierre and Rocci (1975) envisage an original position south of the Taurus Mountains. In this latter case the eastern Mediterranean could be a relic of a

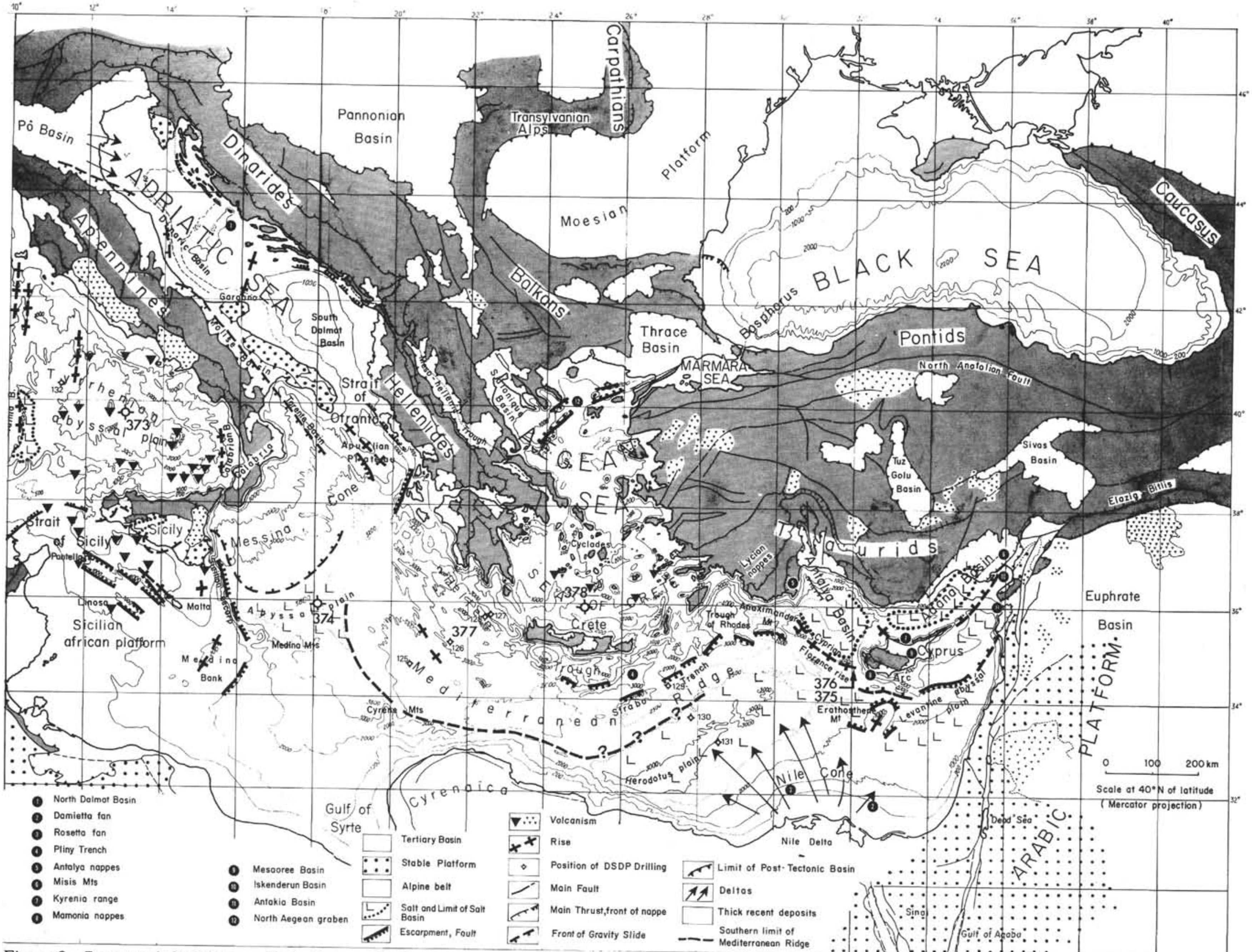

Figure 2. *Structural sketch map of the Eastern Mediterranean from Biju-Duval et al. (1974).*

Mesozoic Tethys (Laubscher and Bernoulli, in press). However there is presently a lively discussion as to whether these rocks represent crust originally produced in an oceanic ridge-type of setting (Moores and Vine, 1971; Ricou et al., 1974), or in a marginal basin associated with an island arc. Whether one or the other hypothesis is correct has a very important bearing on the origin of the eastern Mediterranean basins. A solution of this question can be provided by studies of chemistry of the basalts constituting the top of the ophiolite complex. Subaerial weathering makes such studies of basalt chemistry from samples taken on land inconclusive. It was hoped to recover relatively unaltered material at this drilling site, permitting discrimination between the genetic models proposed for the eastern Mediterranean ophiolites.

Objectives

Our objectives were:

1) to attempt to reach the "acoustic basement," which could be the equivalent of the ophiolitic suite of Cyprus, in order to determine the age of this part of the Mediterranean, and to obtain basement samples for geochemical studies;

2) to establish a stratigraphic and lithologic record of the sedimentary section present below the Messinian evaporites in this part of the Mediterranean; and

3) to obtain information of the paleoenvironments existing in this area prior to the Messinian salinity crisis.

Thus it was proposed to drill two sites without penetrating the thick evaporite section: the first one, on top of the Florence Rise, to reach the deeper layers and maybe even the basement; the second, on the flank to the north, to core the upper part of the pre-evaporitic layers.

OPERATIONS

Site Approach, Site 375

On 7 May, *Glomar Challenger* approached the site from the southwest (see Figure 3). A course change was made to 027° at 1245 LCT to follow the IFP reference profile OD 313. At 1335 LCT a minor adjustment in course was made; the vessel now headed 017° and was steaming supposedly at 5.5 knots speed. It appeared, however, that we were proceeding on a course where the ridge had a higher elevation (or shallower depth) for the given latitude. We began to question the precision of the bathymetric map used and the positioning of the OD 313 profile. The next satellite fix came at 1408 LCT, which showed that we had passed over the site when the fix was being taken. We now realized that we had followed the OD 313 exactly, but that we were steaming at a speed close to 6.5 knots and had thus overshot the target. We also ascertained that the bathymetry on the base map was incorrect. The water depth deduced from the IFP profile for the target was 1000 fathoms. It was decided, therefore, to turn around so as to return to the target position. We hoped to retrace the course of the IFP profile and planned to drop the beacon when the PDR showed 1000 fathoms. The turn was made at 1423 LCT and was completed at 1432 LCT. The vessel now headed 202° The beacon was dropped at 1455 LCT at a depth of 999 fathoms uncorrected. The vessel was positioned over the hole at 1507 LCT 7 May. At 1557 LCT a satellite fix was made while the vessel was hovering over the beacon. The fix indicated a position at approximately the same latitude as the targeted site, but about 1 mile to the west. As the tectonic trend is east-west in the area, we decided to stay on this site and to make no offset in order to avoid any complications in automatic positioning. Eventually the mean position, as calculated from satellite fixes while the vessel was on location, showed that the site was southwest of the proposed target (see Figure 3). It seems that the 1000 fathom contour here is oriented northeast-southwest. As a result the hole was not located at a structural position as favorable as we had expected (see Figure 4). The site location as determined later by satellite fix averages was 34°45.74′N and 31°45.58′E at a water depth of 1900 meters.

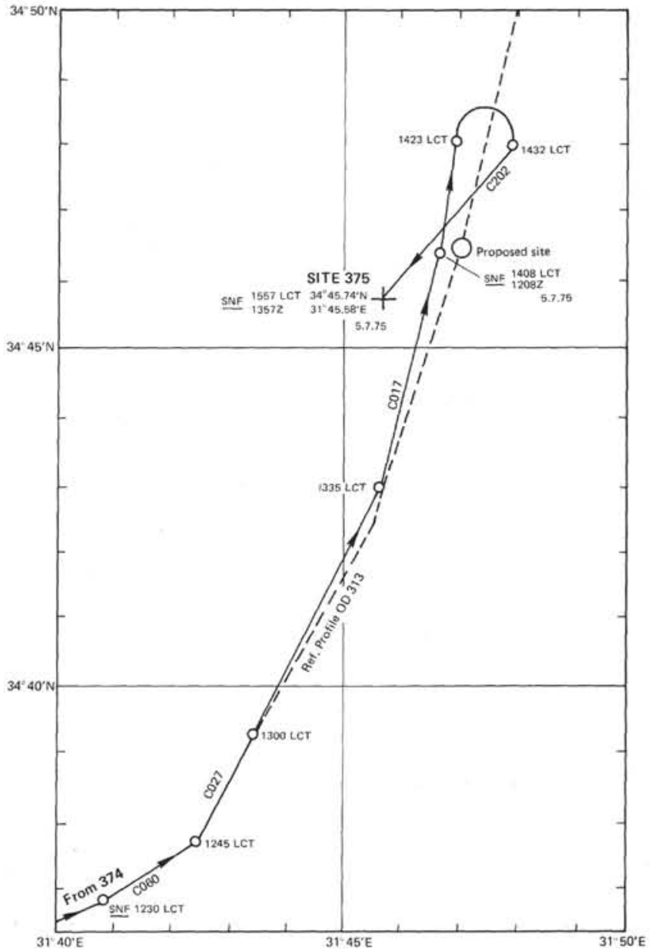

Figure 3. *Site approach; Site 375.*

Drilling Program, Site 375

The vessel was positioned over the hole at 1705 LCT 7 May. The PDR water depth was determined to

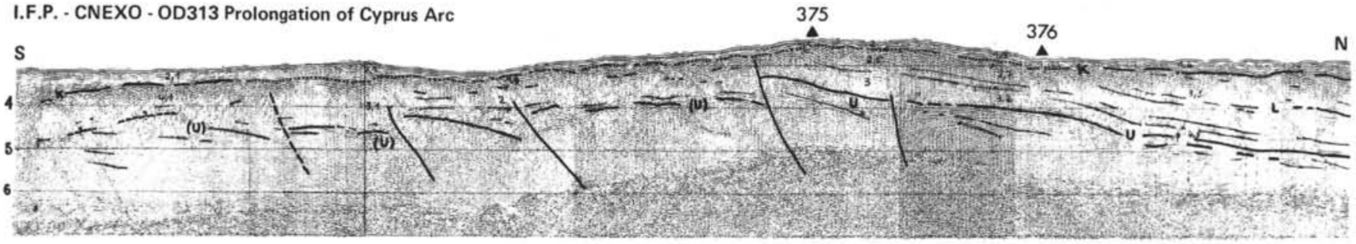

Figure 4. *IFP/CNEXO Profile OD 313 showing the prolongation of Cyprus Arc and locations of Sites 375 and 376.*

be 999 fathoms (uncorrected from the transducer), and 1916 meters (corrected from rig floor). The drill crew started to assemble the drill string, which reached bottom at 2025 LCT in 1914 meters depth. The driller reported firm conditions in the drilled section at some 50 meters subbottom. At 2235 LCT the drill string encountered the first reflector at 137.5 meters subbottom, where the top of the first core was cut. Core 1 was brought up at 2330 LCT. Eventually it was found that its top 15 cm contained both early Pliocene (MPl-2 and MPl-3) and Messinian (with *Cyprideis pannonica* fauna) marls overlying gypsum. It is probable that the Plio-Miocene contact is a drilling artifact, and that the Pliocene marl was pushed into the core barrel as the drill string was washed down to –137.5 meters.

Between 137.5 and 170 meters subbottom, the drilled section must have been mainly gypsum (and or anhydrite). At about 165 meters subbottom on 0240 LCT 8 May, the drill string encountered a very hard interval when 4 to 5 meters were cut in an hour. In view of our subsequent experience at Hole 376, we now believe that this represents a massive nodular anhydrite interval.

At 0334 LCT after 4 meters of newly connected double pipe-segment had been drilled, the drill string apparently penetrated a very soft horizon at 172 meters subbottom. The driller had to feed out some 15 meters of drill string in about 10 mi. However, it was later necessary to retrieve the drill string by about the same amount and it was suspected that the vessel had drifted out of position. The Captain was awakened but after a check of all systems it was ascertained that there had been no drift of the vessel. The driller may have "overfed" the pipe. Its puzzling behavior cannot easily be explained. Subsequently it was found that this disturbance had apparently caused the drill pipe to become slightly bent at the mudline. Our experience with "lost circulation" at Hole 376 leads us now to suspect that the drill string may have drilled into a small cavern at Site 375 also.

The drilling now seemed to be reasonably smooth, and we suspected that we may have penetrated the evaporite section. At 0500 LCT we started to cut a 5-meter core at 189.5 meters subbottom. Since the last hard layer was apparently encountered at about 185 meters subbottom, the core was cut with reduced pump pressure. However, when it was retrieved at 0548 LCT it was found to contain some 5 meters of selenitic gypsum.

The next barrel failed to seat properly, and it was necessary to raise the core barrel and send in an extended core barrel to knock off the piece of rock which prevented the seating. The 2-hour operation was successful; the next barrel was seated properly, and another 3-meter core was cut. During the coring operation, the bit weight was smooth, suggesting that marls were being cut. However, when Core 3 was raised at 0850 LCT, it was found to contain a small piece of nonfossiliferous carbonate breccia. The piece was jammed in the core catcher and had prevented recovery of the marls at this level (194.5-197.5 m subbottom). This carbonate rock probably fell out of the bottom of Core 2, and was one of the rock fragments that had prevented the seating of the previous core barrel. The drilling behavior, meanwhile, left little doubt that we had penetrated well beyond the evaporites. In order to save time and "bit-life," it was decided to postpone our objective of coring the Pliocene/Messinian contact until Hole 376.

The drill string was washed down some 50 meters, and Core 4 was cut from 245.5 to 252 meters subbottom. It was a relief when the sediment in the core catcher was found to be a marl. On the other hand, was a great disappointment to all that on dating the marl, it was shown to be still late Miocene in age. Despite diminishing hopes of our reaching "basement," it was decided to continue with our planned program.

Instructions were given to drill 100 meters before taking the next core. This was done and at 1645 LCT, 8 May, Core 5 was recovered containing Tortonian muds and turbidites. Another 100 meters were drilled: still Tortonian sediments at –470 meters (Core 6). Another 100 meters drilled: still Tortonian at –574.5 meters (Core 7). The mud now became so stiff that we could only drill 50 meters before raising the next core (Core 8: 622 to 631.5 m). We were relieved that these sediments were finally dated as pre-Tortonian in age. (The Tortonian has an impressive thickness of more than 1 km on Cyprus.)

There was always uncertainty concerning the interval from which the core was cut. We could never be sure that the sediment did not get into the core at some level higher than the recorded interval. Meanwhile drilling ahead became increasingly difficult. The core had to be raised at shorter and shorter drilled intervals. Also Cores 5 to 9 all were gaseous. We were permitted to drill ahead as the methane/ethane ratio was 1000 or above (peak height ratios) and was increasing with depth.

At 1420 LCT 9 May, Core 10 was raised. This was found to be Langhian in age, and the core contained no more gas.

However, our relief was short-lived since this co-chief scientist was rewarded with an exciting sight reminiscent of "blow-out." As it transpired this was merely a broken rotary hose which shot water over the rig and rig floor. This caused a loss of 4-1/2 hours of shiptime.

Drilling was resumed at 1940 LCT 9 May, and several hard limestone layers were encountered. However, at 0348 LCT 10 May, and at a depth of 760 meters subbottom, the drilling rate increased dramatically; we had apparently penetrated beyond the Langhian limestones. Yet when Core 12 (registered at 792-793 m) was raised at 0615 LCT 10 May, it was found to contain only one piece of limestone. This rock probably had been rammed into the core catcher (at a higher level, above 760 m subbottom) and had jammed it sufficiently to prevent the coring of the soft marls of this level. Furthermore the sediment core diameter had become abnormally small which is indicative of imminent collapse of the drill bit. Core 13 was cut from 817.5 to 821.5 subbottom, and it contained Burdigalian marls. Meanwhile, the hole diameters became so small that the bottom-hole assembly (BHA) was getting jammed and we were forced to abandon the hole, plugging it at the same time with barite mud. The drill string was pulled out of the hole at 1600 LCT when the vessel prepared to leave for Site 376 (see Table 1).

In conclusion, the following boundaries are recommended for the lithologic units based on drilling characteristics:

0 meters–	Top of marls and muds (including Plio-Quaternary and Upper Miocene).
137.5 meters–	Top of gypsum reflector–gypsum and marls.
165 meters–	Top of a very hard layer–unknown, possibly anhydrite and salt (see Site 376).
185 meters–	Drill break–top of marls and turbidites (Tortonian-Serravallian).
675.5 meters–	Top of limestones and marls (Langhian)
760 meters–	Drill break–top of marls (Burdigalian)
821.5 meters–	Termination depth.

Site Approach, Site 376

The proposed 376 site was located about 12 km to the north of Site 375 on the same IFP reference profile OD 313. It is situated at the foot of the Florence Rise and on the edge of the Antalya basin where the very thick salt layer pinches out. A small break in slope on the sea floor was indicated by the IFP profile. It was thus decided to approach the location using the PDR only (see Figure 5). *Glomar Challenger* departed Site 375 at 1644 LCT crossing the Florence Rise on a 024° heading. At about 1745 LCT we recognized the break in slope, which is a depression about 12 fathoms deep, at the base of the rise. At 1759 LCT the vessel made a Williamson turn and returned to the site. Following PDR indications, the beacon was dropped at 1820 LCT on the side of a small prominence just north of the depression mentioned above. The site location as determined later by satellite fix averages was 34°52.32′N and 31°48.45′E at a water depth of 2101 meters (see Figure 4).

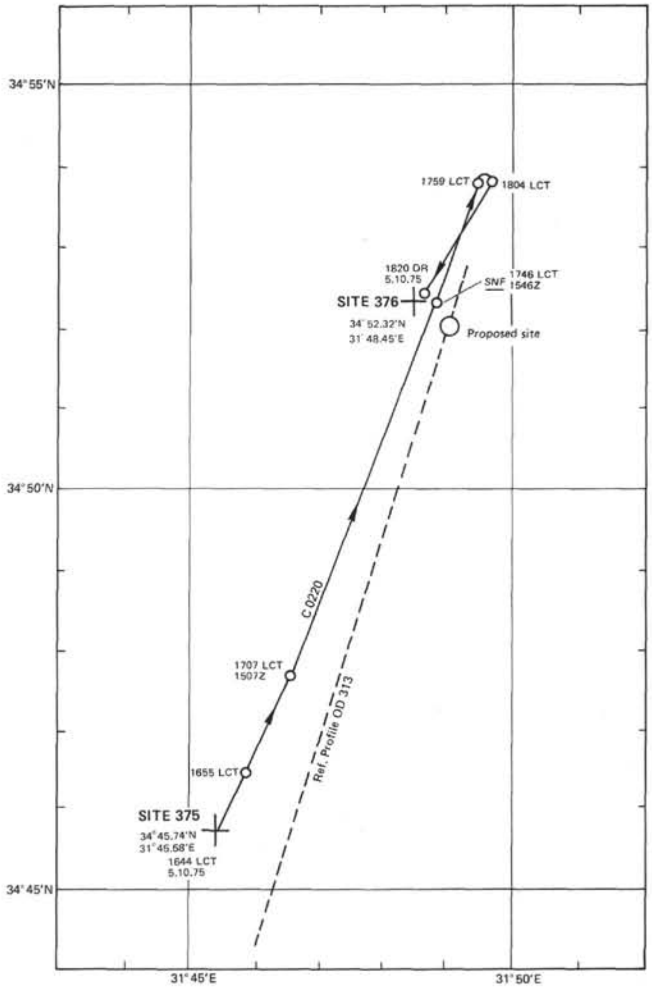

Figure 5. *Site approach: Site 376.*

Drilling Program, Site 376

The vessel arrived on site at 1820 LCT 10 May. The drill crew commenced to assemble the drill string, which encountered the mudline at 0015 LCT 11 May at 2117 meters water depth. A continuous coring schedule was begun. The firm character of the sediments directly below the sea bed permitted us to make heat-flow measurements at 26.5, 55, 74, 102.5, and 131 meters subbottom. There were considerable difficulties drilling and coring in stiff marls before the bottom-hole assembly was buried. Since pumping pressure was needed, 100% recovery was impossible.

The marls were relatively firm from the very top and we expected relatively good down-hole conditions. However, the superposition of the stratigraphic sequence was apparently abnormal in Core 6. This abnormality, expecially the presence of greatly disturbed Pliocene marl under the Miocene in Core 6,

TABLE 1
Coring Summary, Site 375

Core	Date (May 1975)	Time	Depth From Drill Floor (m)	Depth Below Sea Floor (m)	Cored (m)	Recovery (m)	Recovery (%)
1	7	2327	2051.5-2053.5	137.5-139.5	2.0	1.0	50
2	8	0548	2163.5-2108.5	189.5-194.5	5.0	5.0	100
3	8	0850	2108.5-2111.5	194.5-107.5	3.0	0.01	0.3
4	8	1115	2159.5-2166.0	245.5-252.0	6.5	6.5	100
5	8	1645	2274.0-2283.5	360.0-369.5	9.5	9.7	100
6	9	0025	2375.0-2384.0	461.0-470.0	9.0	9.0	100
7	9	0515	2479.0-2488.5	565.0-574.5	9.5	9.6	100
8	9	0835	2536.0-2545.5	622.0-631.5	9.5	9.7	100
9	9	1125	2564.5-2574.0	650.5-660.0	9.5	9.6	100
10	9	1420	2589.5-2593.0	675.5-679.0	3.5	3.5	100
11	10	0020	2657.0-2650.0	733.0-736.0	3.0	2.5	83
12	10	0615	2706.0-2707.0	792.0-793.0	1.0	0.1	10
13	10	1010	2733.5-2735.5	819.5-821.5	2.0	0.7	35
Total					73.0	66.9	91.6

section 4, can be better explained at this level by downslope slumping than by downhole contamination. At 1700 LCT 11 May, the cutting of Core 13 was completed and the bottom-hole assembly had been buried. Two and a half hours later, the drill string hit the gypsum reflector at 134 meters subbottom. Drilling rate slowed down perceptibly in the early morning hours of 12 May and the recovery rate was poor. It appeared that the gypsum layers were interbedded with muds or marls. At 0930 LCT, the drilling superintendent claimed that we had hit the most resistant formation ever encountered during the Deep Sea Drilling Project. This very hard formation was probably selenitic gypsum. At 1130 LCT 12 May, Core 21 came up and was empty.

At 1230 LCT while Core 22 was being cut, the pump pressure dropped sharply almost to zero. There was a discussion on the various possible explanations. At 1300 LCT Core 22 was raised on deck and was found to contain anhydrite and halite. The core also contained black marls which gave off a very strong odor reminiscent of that noted during the Leg 13 drilling of Site 134 in the Messinian salts. The interbedded marls there had yielded mature hydrocarbons (McIver, 1973). While the drilling crew continued operations to check the cause of lost pump pressure, a conference was called and a decision was made to terminate the hole in accordance with an instruction by the JOIDES Safety Panel not to drill through halite. The last core was hauled on deck at 1450 LCT and contained a few pieces of salt. The hole was then plugged with cement and heavy mud. At 1600 LCT the drill crew commenced to pull the string out of the hole. It cleared the mudline at 1625 LCT and was on deck at 2030 LCT 12 May, when the vessel departed for Site 377 (see Table 2).

There was considerable postsite discussion on the cause of "lost pump pressure." This was a very unusual event, never previously encountered during DSDP operations. The analysis by the operation manager (Pennock, 1975, p. 21) is quoted here: "From 192.0 meters BSB (below sea bed) halite was unexpectedly encountered and fortunately recovered. Shortly after this depth, the pump output, 20/25 SPM (strokes per minute), and surface pressure indicated that there was little or no pressure drop in the system. Checks were made to decide whether an extensive wash-out was occurring, but there was no evidence to support this. Other mechanisms accounting for this behavior could have been the very unlikely upward flow of fluid in the annulus originating from bottom; or a loss of fluid into leached halite caverns (considered very likely by the geologists), which were linked allowing lateral movement of fluid at a lower pressure than the annulus back pressure. This effect coupled with a normal head of circulating fluid between the stand pipe and sea level, some 40 psi, probably accounted for the observed reduction in the normal 75/100 psi pumping pressure." (In fairness, it should be pointed out that the possibility of losing fluid into leached caverns was considered likely by some of the shipboard geologists only.)

LITHOLOGY

The two sites drilled on the Florence Rise complement each other and their results have been combined in the following description.

Site 375 was a deep hole (TD 821.5m) with spot coring and recovered mainly the pre-evaporitic succession. Site 376 (TD 216.5m) was offset some 13 km to the north and was cored continuously as far as the Mediterranean evaporite formation. Eleven lithologic units have been distinguished: four units in the Plio-Quaternary pelagic succession, two in the late Miocene evaporitic and post-evaporitic formations, a flysch-type unit in the Tortonian, and four units in the pre-flysch early to middle Miocene.

Table 3 lists the lithologic units encountered in each of the holes. Subbottom depths in the hole summaries and in Table 3 have been corrected according to the recommendations made earlier in the description of drilling characteristics. The names of the equivalent formations on land in Cyprus (Baroz and Bizon, 1974; Weiler, 1964, 1965, 1969, 1970) have been indicated in brackets.

TABLE 2
Coring Summary, Site 376

Core	Date (May 1975)	Time	Depth From Drill Floor (m)	Depth Below Sea Floor (m)	Cored (m)	Recovery (m)	Recovery (%)
1	11	0105	2117.0-2124.5	0.0-7.5	7.5	6.0	80
2	11	0200	2124.5-2134.0	7.5-17.0	9.5	5.3	55
3	11	0300	2134.0-2143.5	17.0-26.5	9.5	6.2	65
4	11	0440	2143.5-2153.0	26.5-36.0	9.5	2.8	29
5	11	0525	2153.0-2162.5	36.0-45.5	9.5	7.0	74
6	11	0615	2162.5-2172.0	45.5-55.0	9.5	5.1	54
7	11	0815	2172.0-2181.5	55.0-64.5	9.5	2.8	29
8	11	0930	2181.5-2191.0	64.5-74.0	9.5	4.1	43
9	11	1155	2191.0-2200.5	74.0-83.5	9.5	5.8	61
10	11	1305	2200.5-2210.0	83.5-93.0	9.5	4.1	43
11	11	1420	2210.0-2219.5	93.0-102.5	9.5	3.3	35
12	11	1615	2219.5-2229.0	102.5-112.0	9.5	7.6	80
13	11	1730	2229.0-2238.5	112.0-121.5	9.5	5.3	55
14	11	1915	2238.5-2248.0	121.5-131.0	9.5	0.2	0.2
15	11	2145	2248.0-2257.5	131.0-140.5	9.5	3.6	38
16	11	2325	2257.5-2267.0	140.5-150.0	9.5	1.6	17
17	12	0150	2267.0-2276.5	150.0-159.5	9.5	0.8	8
18	12	0350	2276.5-2286.0	159.5-169.0	9.5	1.1	11
19	12	0705	2286.0-2295.5	169.0-178.5	9.5	0.5	5
20	12	1000	2302.0-2305.0	185.0-188.0	3.0	1.0	33
21	12	1130	2305.0-2314.5	188.0-197.5	9.5	0.0	0
22	12	1300	2322.5-2324.0	205.0-207.0	2.0	1.0	50
23	12	1450	2324.0-2333.5	207.0-216.5	9.5	0.5	5
Total					202.5	80.0	39.5

Unit I: Nannofossil Marl with Interlayered Sapropel and Tephra

(Site 376: Cores 1 through 4; 5-1; 5-2; 0-75 cm; 6-1; 6-2; 6-3; 0-86 cm; Quaternary).

Unit I, of Quaternary age, consists of very soft nannofossil marls with minor, thin interbeds of sapropelic marl and volcanic ash. It occurs in Cores 1 through 4 of Site 376. Due to drilling disturbances described later, sediments from Unit I also occur as artifacts (downhole contaminants) in Section 1 and the upper part of Section 2 of Core 5 and in Sections 1, 2, and the upper part of Section 3, Core 6.

The nannofossil marls consist chiefly of clay minerals (28%-52%) and nannofossils (25%-55%). Less abundant components include dolomite (up to 5%) and/or unspecified carbonate (5%-10%), foraminiferal tests (rare to 10%), and pyrite (rare to 5%). Smear-slide observations record most of the marls as also containing trace to rare amounts of silt made up of one or more of the following: quartz, altered feldspar, biotite, and amphibole. Bulk X-ray determinations give quartz (6%-12%), plagioclase (2%-6%), and traces of K-feldspar, amphibole, and serpentine. Smectites make up the largest part of the clay minerals (<2 μm, 70%-85%), with small amounts of kaolinite (5%-10%), illite (5%-10%), attapulgite, chlorite (traces to 5%), and traces of mixed-layered minerals. Carbonate content (by carbonate-bomb and carbon-carbonate determinations) ranges between 32% to 45% in the upper part of the unit (Cores 1 and 2) and 35% to 65% in the lower part (Cores 3 and 4).

These marls were intensely disturbed during drilling so that the continuity of bedding was usually destroyed. It appears, however, that these marls occurred as unburrowed interlayers (from perhaps 2 cm to as much as 30 cm thick) of varicolored sediment, ranging in color from shades of gray (e.g., olive-gray, greenish-gray, and light bluish-gray) to shades of brown. The gray colors, which dominate, presumably represent somewhat more reducing conditions and the brown, more oxidized ones.

Interbedded with these marls are two minor lithologies:

(1) *Volcanic ash (tephra) layers:* These consist almost entirely of glass shards, which are usually colorless and perfectly preserved and frequently have elongate vesicles. The ashes also contain trace amounts of biotite and of hematite or pyrite. Their color is yellow-brown or greenish gray. One ash layer in Section 5, Core 1 is 12 cm thick; another in Section 1, Core 3 is 9 cm thick. Thin, disrupted ash layers were also noted in Section 6, Core 1 and Section 4, Core 2, but none were found below Core 3.

(2) *Sapropelic marls:* The more prominent dark sapropel and sapropelic layers noted in Cores 1 through 3 were as follows:

Core	Section	Interval (cm)	Remarks
1	1	52-80	This interval contains 3 distinct sapropel layers which have faint graded bedding (turbidites?)
1	2	40-146	There are at least two sapropels, intensely deformed; thickness of layers unknown
1	3	13-35	This interval has 3 sapropels showing faint graded bedding
1	3	140-150	Possibly 2 sapropels – disturbed

1	4	3-5	These sapropels are intensely deformed and their thicknesses cannot be determined; the intervals given here are in the thickened crests of drilling antiforms
1	4	10-11.5	
1	4	64-71	
1	4	76-77	
1	4	80-88	
2	1	94-96	
2	1	131-150	Intensely deformed; thickness unknown
2	2	1-4	Intensely deformed; thicknesses unknown or uncertain
2	2	4-6	
2	2	10-13	
2	2	20-30	
2	2	120-145	
2	3	1-3	Intensely deformed; thicknesses unknown
2	3	3-20	
2	3	86-124	
2	3	140-148	
2	4	0-40	Consists of 3 layers separated by thin marl interlayers
2	4	70-75	Highly deformed
3	2	30-67	This interval has 3 sapropel layers separated by thin marl interlayers; intensely deformed

The sapropelic intervals in Sections 1 and 3 of Core 1 occur in apparently graded layers averaging about 10 cm thick; they contain common fragments of pteropod shells. Interspersed with the prominent sapropelic layers listed above are other, usually thin (0.1 to 0.75 cm), laminae and layers which are dark gray to black and also appear organic rich.

According to smear-slide descriptions, the prominent sapropels are organic-rich, nannofossil marls. They contain 10%-25% fine-grained organic matter, 20%-30% nannofossils, and 30%-40% clay minerals. Pyrite usually comprises 5% to 10% of the sediment and foraminifers 5% to 15%. Quartz grains are rare, and grains of altered feldspar vary from rare to 15% of the sediments.

Unit I is a hemipelagic sequence deposited in an environment which at times was stagnant and highly reducing (sapropel layers), at other times at least slightly oxidized (light brown layers). The lack of burrowing and the predominant drab gray color of the marlstones suggest that slightly reducing conditions prevailed over most of the time interval represented by this unit.

Site 376, Cores 5 and 6

Cores 5 and 6 contain a complex array of phenomena which are summarized here. For clarity, reference should be made to Figure 6.

TABLE 3
Lithologies at Sites 375 and 376

Unit	Lithology	Cores Site 375	Cores Site 376	Subbottom Depth (m) 375	Subbottom Depth (m) 376	Thickness (m) 375	Thickness (m) 376	Age
I	Gray to brown nannofossil marls with interlayered tephra and sapropels	–	1 to 5-1; 5-2-0-75 cm; 6-1 to 6-3-86 cm.	–	0-38.4		38.4	Quaternary
II	Gray nannofossil marls with a few sapropelic marl interlayers.	–	5-2-75-150 cm; 5-3 to 5-5-43 cm	–	38.4-42.6		4.2	Late Pliocene
III	Brown to orange nannofossil marl with minor sapropelic marl interlayers	1-1-48-58 cm	5-5-43-150; 6-3-86-150 cm; 6-4-0-100 cm; 7-1-28-32 cm.	(137.5) Uncorrected	42.6-48.1		5.5	Early to late Pliocene
IV	Slumped marls of Miocene and early Pliocene age		6-4-100-141 cm.	–	48.1-48.5	137.5	0.4	Early Pliocene
V	Marlstones with interbedded graded sandstones and siltstones subdivided into 4 subunits	1-1-58-60 cm	7-1-32-150 cm;	(137.5) Uncorrected	55-140.5		92.0	Late Miocene Messinian
VI	Evaporites a-Gypsum and green dolomitic marlstone	1-1-60 cm	16 through 20	137.5-185 Corrected	140.5-188	47.5	47.5	Late Miocene, Messinian
	b-Anhydrite and halite	through 4-1	21 through 23		188-216.5 (T. D.)		28.5	
VII	Marlstones with interbedded graded siltstones and sandstones	4 through 7	–	185-600	–	415.0		Late Miocene, Tortonian
VIII	Variegated marlstones to foram nanno limestones	8	–	600-641	–	41.0		Middle Miocene, Serravallian
IX	Dark colored nannofossil marlstones	9	–	641-675	–	34.0		Middle Miocene, Serravallian
X	Reddish-brown nannofossil marlstones with interbedded light gray foraminiferal limestones	10	–	675-760	–	85.0		Middle Miocene, Langhian
XI	Dark green-gray limestones and marlstones	11	–	760-821 (T. D.)	–	61.5		Early Miocene, Burdigalian

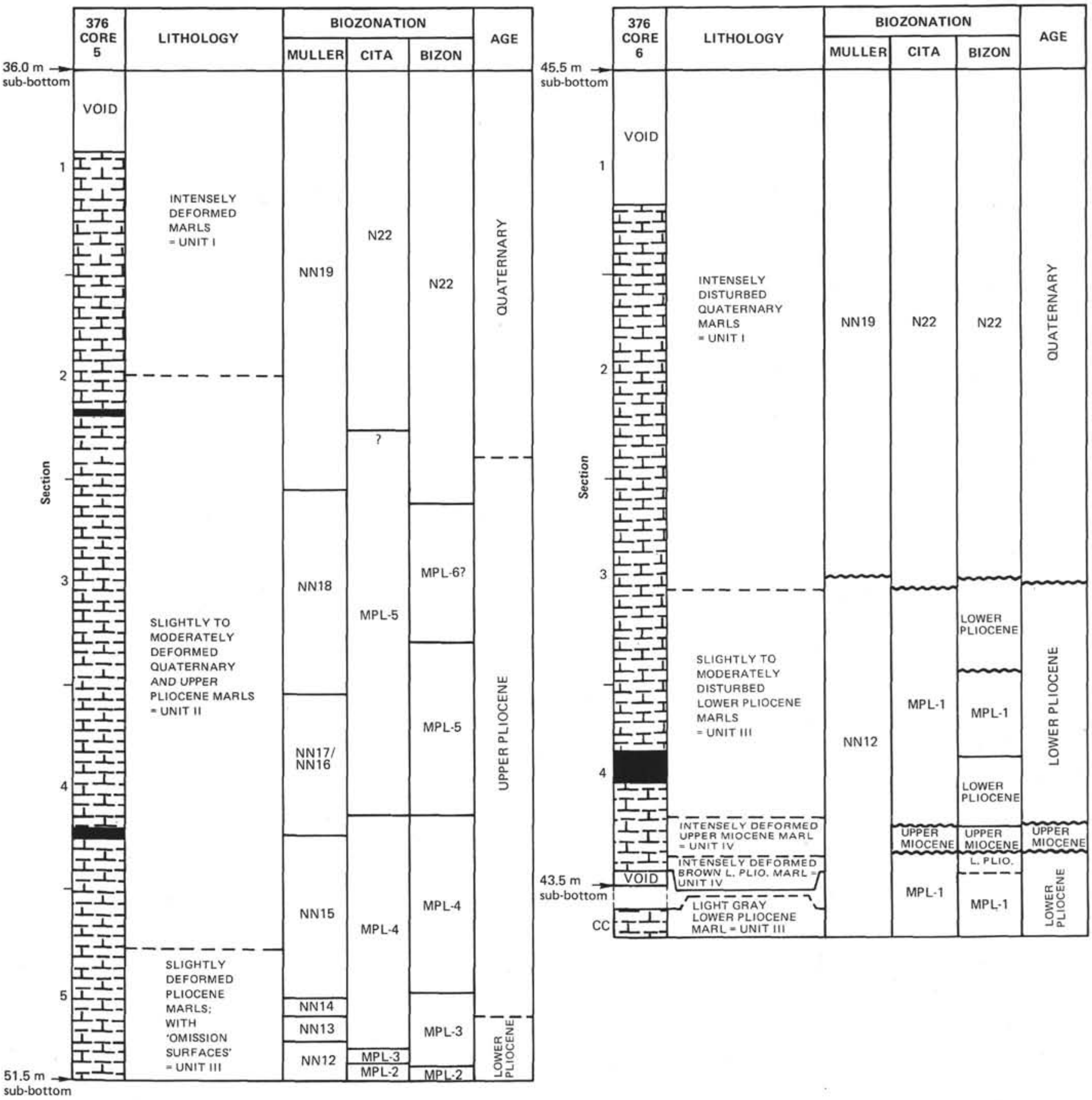

Figure 6. *Detailed lithology and biostratigraphy of Cores 5 and 6. Site 376.*

The upper 2.25 meters of Core 5 is intensely disturbed gray Quaternary nannofossil marl of Unit I. This is underlain by about 3.2 meters of Unit II gray marls of Quaternary and late Pliocene age. The bottom 107 cm of Core 5 is Unit III, composed of brownish nannofossil marls of early Pliocene age with numerous omission surfaces, very minor sedimentiary hiatuses in the sense of Kennedy and Garrison (1975)

In Core 6, the upper 2.86 meters is again Unit I, intensely deformed gray nannofossil marl of Quaternary age. This is a drilling artifact, probably due to downhole slumping. Underlying these Quaternary marls is 1.86 meters of slightly deformed, reddish-brown to white nannofossil marl, assigned to Unit III and of early Pliocene age. This is underlain by 41 cm of intensely deformed marl assigned to Unit IV.

Unit II: Gray Nannofossil Marls

(Core 5-2, 75-100 cm; 5-3; 5-4; 5-5, 0-43 cm; Late Pliocene).

Unit II is composed of nannofossil and foram-nannofossil marls with generally drab colors (light olive-gray, greenish-gray, light blue-gray, dark gray). Lighter colors (moderate brown, light brown) occur in the basal part of Section 3 and as mottles in the top part of Section 5.

The general lithology as deduced by smear-slide analysis is similar to that in Unit IV. The dominant constituents are clay minerals (25%-40%) and nannofossils (> 50%). Unspecified carbonate (at least in part dolomite) is 5%-10%, and foraminifera are present in variable quantities, from trace amounts to 15%.

The main differences from the Unit I Pleistocene marls are the generally smaller amounts of clay minerals, quartz (4%-7% according to bulk X-ray mineralogy), plagioclase (1-3%), and an increase in kaolinite and attapulgite among the clay minerals. K-feldspar, amphibole, serpentine, chlorite, and mixed-layer minerals occur only in traces.

The sediment is soft but firm and generally shows only moderate to slight drilling deformation, in strong contrast to the overlying incompetent Pleistocent nannofossil marls. The colors described above occur in alternating layers each a few centimeters thick. The upper part of the unit contains scattered small pyrite nodules. Burrows appear to be absent except for slight burrowing at the base of the unit (top part of Section 5, Core 5).

Interlayered with the nannofossil marls are dark gray, organic-rich laminae and layers. The thicker, more prominent of these "sapropels" are located as follows:

Core	Section	Interval (cm)
5	2	112-115
5	2	120-121
5	2	138.5-140
5	3	68-70
5	3	145-146
5	4	70-72
5	4	109-111

The composition of these sapropels and sapropelic layers is much like those in Unit 1; they are organic-rich nannofossil marls with 35%-40% clay minerals, 35%-40% nannofossils, and 10%-15% organic matter.

The depositional setting of Unit 2 appears to have been similar to that for Unit 1: generally reducing bottom conditions with periodic and perhaps short-lived intervals of strong stagnation and a few episodes when the bottom was oxidized.

Unit III: Brown to Orange Nannofossil Marls

(Site 376: Core 5-5, 43-150 cm; 6-3, 86-150 cm; 6-4, 0-100 cm; 7-1, 28-32 cm; Site 375: 1-1, 48-58 cm; Early to Late Pliocene).

Unit III is nannofossil marl with bright colors indicative of oxidizing conditions: light brown, pale yellowish-brown, yellowish-gray, moderate brown, very pale orange. It occurs in Cores 5 and 6 where stratigraphic relationships are complicated by downhole slumping and possibly also by sedimentary slumping, as discussed above and in the biostratigraphy section. A small portion of Unit 3 also occurs at the top of Core 7.

Unit III comprises a condensed sedimentary section. The unit is well bedded and contains numerous thin layers which are moderately burrowed and apparently enriched in iron oxides, giving them a darker brown color than the surrounding sediment. Both the burrowing and the iron oxide enrichment may result from non deposition, and these horizons may be omission surfaces representing long pauses in sedimentation.

Sediment in the top 100 cm of Section 4, Core 6, (included in Unit III), is bluish-white and light gray. Prominent sapropelic layers are present in Unit III from 94 to 97 cm, Section 3, Core 6; and from 81-96 cm, Section 4, Core 6. The former is noteworthy because it occurs inter-layered with bright brownish, oxidized sediment, the latter because of its thickness and finely laminated character.

The marls of Unit III appear to be slightly enriched in nannofossils, having 35%-50% clay minerals. Bulk X-ray determinations and clay mineral analysis do not show significant differences between Units II and III with the exception of the upper part of Section 4, Core 6 which appears to be enriched in attapulgite (35%) at the expense of smectites (45%).

A study of the foraminifers of Unit III revealed evidence of strong winnowing of the sediment.

At Site 375, 10 cm of Unit III marls were recovered in Section 1, Core 1. It consists of light brown to moderate brown to yellowish-gray nannofossil marl rich in planktonic foraminifers. The contact with the underlying Unit V marlstones is an artificial drilling contact. The age of the sediment recovered is early Pliocene (MPl-2 and MPl-3) and its lithology matches well with that of coeval sediments at Site 376.

Unit IV: Slumped Marls

(Site 376: Core 6-4, 100-141 cm).

Unit IV comprises two subdivisions, both chaotically deformed:

1) 32 cm of thinly bedded, medium gray nannofossil marl, with small amounts of white and light brown marl mixed in. This interval (100-132 cm of Section 4, Core 6) is a chaotic mixture of small folds and isolated lumps of layered sediment (Figure 7). The contact with the overlying sediment of Unit III is sharp and undeformed. The probable age of this marl is Miocene (see biostratigraphy section).

2) 9 cm of light brown to pale yellowish-brown nannofossil marl, containing small irregular pieces of the overlying gray marls. Lithologically this marl is identical to the brownish, oxidized marls of Unit III above. Its age is early Pliocene.

The possibility that this unit is a drilling artifact was considered and is still believed to be such by one of the shipboard paleontologists. This was rejected by the sedimentologists after long discussions with the Operations Manager.

Unit IV is interpreted here as an early Pliocene sedimentary slump unit consisting of Miocene and early Pliocene sediments. The period of slumping is considered to have been preceded by an early Pliocene

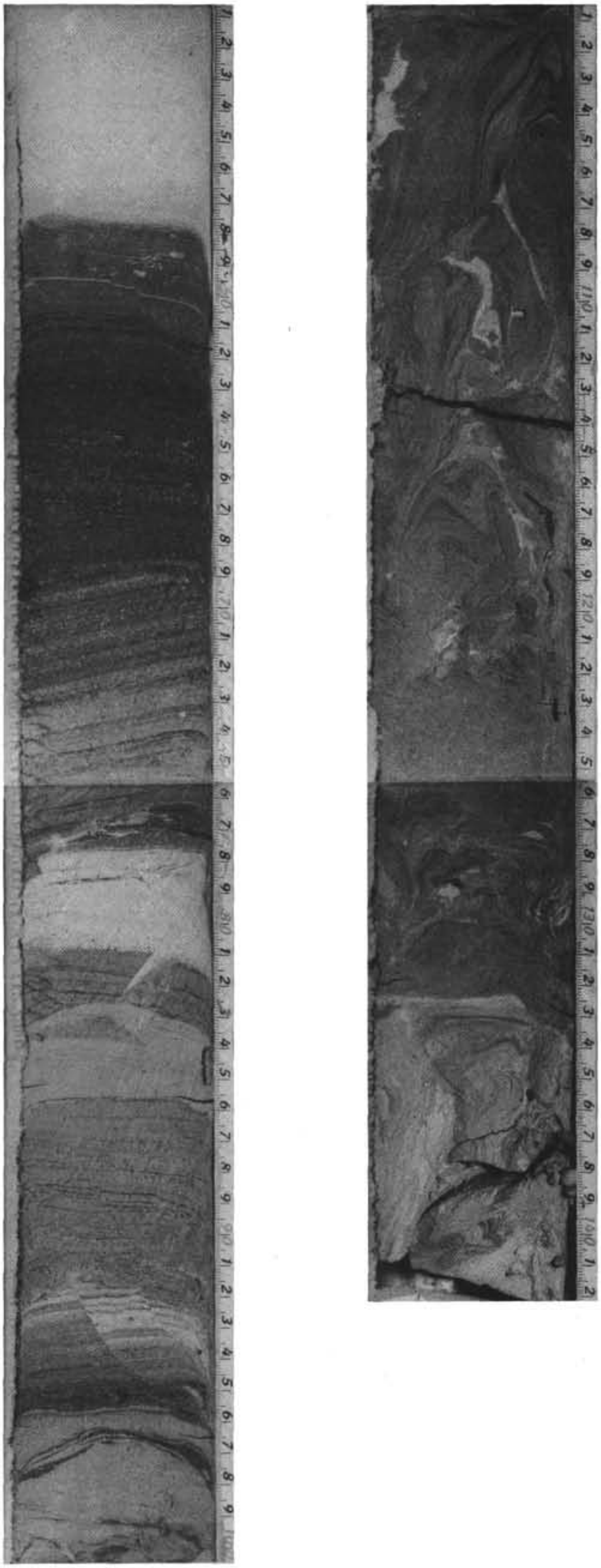

Figure 7. *Chaotically deformed, gray, laminated nannofossil marl with small amounts of white and light brown marl mixed in (Unit IV). This interval is interpreted as a sedimentary slump of late Miocene marls emplaced during sedimentation of the early Pliocene nannofossil marls. This is supported by "lamellar" structure, which is often found in submarine slumping, and associated phacoids (cf. Voigt, 1962) and by the only slightly disturbed stratigraphic contact at the top of the deformed unit. The deformed Unit IV is overlain by finely layered to laminated light gray to olive-gray, organic-rich nannofossil marl and a thick layer of olive-gray to black, laminated, sapropelic nannofossil marl with abundant planktonic foraminifers. Top of the core is bluish-white, mottled nannofossil ooze. (Unit III). Site 142, Units III and IV, lower Pliocene, Sample 6-4, 50-125 cm.*

interval of pelagic deposition of oxidized nannofossil marls. Following the slumping, pelagic deposition was resumed. According to F. Baroz (personal communication), slumping occurs in the coeval Mirtou marls on Cyprus. Additionally, the PDR profiles show that rugged bottom topography is present in the area of the site.

Unit 5: Nannofossil Dolomitic Marlstone With Interbedded Graded Sandstones and Siltstones

(Site 376, 7-1, 32-150 cm; Cores 8 through 15; Site 375, 1-1, 58-60 cm).

Unit V is 85.5 meters thick and is a fining-upward sequence of marlstones and interlayered turbiditic siltstones and sandstones. The latter clastic units become more numerous and coarser grained towards the base of the unit. The marlstones and the turbiditic sandstones and siltstones consistently contain the *Cyprideis pannonica* fauna. They also contain variable amounts of nannofossils, ranging from 5% to 50% and averaging around 20% to 25%. According to C. Muller, the marlstones are distinguished by the occurrence of reworked species from the Cretaceous, Paleogene, and lower/middle Miocene (see later description of nannofossils, Site 376). Some of the turbiditic clastic layers contain reworked upper Cretaceous, Eocene, and upper Miocene foraminifers. Four subunits are recognized based on color differences, mineralogical composition, and on the relative proportions of marlstones and clastic sedimentary rocks. Dolomite is common in Subunits Va and Vb and is practically absent in underlying subunits. Chlorite and Attapulgite are important in Subunits Va and Vb, whereas smectite is almost the only clay mineral within the unit below this level. Subunit Va contains sapropelic layers and less detrital material than subunits below. Subunits Vb and Vc contain thick turbidite intercalations. Subunit Vd differs from the others in containing gypsum often as gypsiferous sandstone layers.

Subunit Va

Subunit Va was recovered in Cores 7 and 8, Site 376, between subbottom depths of 55 and 74 meters. The main lithology is a somewhat silty nannofossil dolomitic marlstone, with minor amounts (about 10%-15%) of interbedded siltstone and sandstone and including sapropelic layers. The marlstones are variegated. The range of colors includes light brown, grayish-orange, pale olive, light bluish-gray, greenish-gray, dark yellowish-orange, dusky yellow, and olive-gray.

This subunit is unburrowed, well bedded, and occasionally finely laminated. The upper part shows cm-scale alternations of marlstones, with differing colors (and with some color mottling unrelated to bedding); within these marlstones are a few thin (0-5 to 2.0 cm) siltstone and very fine grained sandstone layers, which are laminated to cross-laminated. In Section 2 of Core 8 occur three graded turbidite cycles, each 10 to 20 cm thick with fine sandstone, grading upward from an erosional base to marlstone above. One turbidite unit contains a piece of wood 4 cm long.

According to smear-slide descriptions fine-grained carbonate (20%-40%), clay minerals (30%-50%), and nannofossils (5%-30%) are the dominant constituents in the marlstones, and silt size quartz is consistently present in amounts from 5% to 20%. Bulk X-ray analysis of the marlstones records quartz (6%-12%), some plagioclase (3%-5%), traces of K-feldspar (1%-4%), and serpentine (1%-2%). In the clay fraction smectites are the predominant clay minerals (50%-70%), with some attapulgite (10%-30%) and chlorite (10%-20%), and small amounts to traces of illite (trace to 10%) and kaolinite (trace to 5%). The sandstones are composed of quartz (30%-40%), rock fragments (20-30%) (primarily of altered volcanic rocks), about 30% carbonate (partly dolomite, partly unspecified), small amounts of altered feldspar, biotite, amphibole, and volcanic glass. Bulk X-ray determinations of a siltstone record carbonate (mainly dolomite), quartz, plagioclase, K-feldspar, and traces of amphibole and serpentine.

The top part of Section 2, Core 8 has four thin sapropelic layers between 0 and 71 cm. These are dark, organic-rich nannofossil marls; estimates from a smear slide of one layer give 20%-25% fine-grained organic matter, 25%-30% nannofossils, 35% clay minerals, and 5%-10% pyrite.

Subunit Vb

Cores 9 through 11, obtained from subbottom depths of 74 to 102.5 meters, comprise Subunit Vb. It is interbedded silty, nannofossil dolomitic marlstone and sandstone/siltstone; it differs from Subunit Va in having a higher percentage of interbedded clastics (15% to 20%), in having rather uniform drab generally greenish colors (greenish-gray, dark greenish-gray, medium gray), and in containing no sapropelic layers. The clastic layers are mainly olive-gray and grayish-olive. Towards the base of the unit, the predominant color of the marlstones is medium bluish-gray.

Bedding characteristics are similar to those of Subunit Va. Burrows are absent. In Sections 1 and 2 of Core 9, small irregular bodies of sand are intruded into marlstones, apparently as a result of drilling disturbance (see Kidd, this volume). Interlayered sandstone and siltstone layers vary from distinct to thin and indistinct. In Sections 1 and 3 of Core 9 laminated to cross-laminated siltstone and fine-grained sandstone layers show graded bedding; but in contrast to typical turbiditic units, these layers have sharp upper contacts below the overlying marlstones. In Section 2 of Core 11, numerous thin siltstone and fine sandstone beds, 5-15 cm thick, have graded bedding, parallel and sometimes cross-laminations and gradational contacts with the overlying marlstones. Thicker beds, up to 30 cm thick (e.g. Section 3, Core 11) have coarse sand basal portions and partial to complete Bouma cycles (Bouma, 1962) leaving little doubt that they are turbidites. In other parts of the subunit (e.g., Section 2, Core 9, all of Core 10) sandstone or siltstone layers have neither sharp basal contacts nor distinctive internal structures and form rather indistinct layers within the predominant marlstone with only vague fining upwards in grain size. Soft sediment deformation occurs at base of Section 4, Core 9.

Compositionally these rocks resemble those of Subunit Va above. In particular, they are also dolomitic. According to smear-slide observations, the marlstones have three main constituents: clay minerals (20%-55%), nannofossils (20%-50%), and fine-grained carbonate, including dolomite (15%-40%). In addition silt-size quartz, rock fragments, feldspar, mica, pyrite, and opaque minerals are present with varying amounts in most of the marlstones. As in Subunit Va, bulk X-ray analysis indicates the presence of quartz (< 10%), small amounts of plagioclase, and traces of K-feldspar and serpentine, together with a clay mineral assemblage mainly of smectites (55%-90%), followed in abundance by attapulgite (10%-25%) and chlorite (5%-20%) and traces only of illite and kaolinite. Also the clastics (siltstones and fine sandstones) are much like those in Subunit Va; according to smear-slide observations they are composed mainly of quartz (5%-25%), dark rock fragments (5%-40%), and silt-sized calcite and dolomite (30%-40%); most also contain 5%-10% of pyrite and other opaque minerals and up to 10% of altered plagioclase, mica, and amphibole. According to bulk X-ray determinations, traces of K-feldspar and serpentine are also present.

Another distinctive lithology, a white, homogeneous (base) to laminated (top) limestone, forms a layer 18 cm thick in Section 2 of Core 11 (Figure 8). According to M.B. Cita this limestone much resembles the "Colombacci" limestones in the post-evaporitic Messinian of the Apenninic fore-deep (cf. Rabbi and Ricci-Lucchi, 1968; Selli, 1954, 1967). This limestone is very pure (about 80% carbonate) and consists of fine anhedral calcite grains with a few coccoliths. The texture and the juxtaposition with clastic turbidites suggests that this also is of turbiditic origin. The suggestion is supported by its internal structures and its juxtaposition with clastic turbidites. In the Apennines, Rabbi and Ricci-Lucchi (1968) have interpreted such limestones as evaporitic deposits. Possibly this, horizon is a redeposited evaporitic calcareous ooze.

Although some of the clastic layers in Subunit Vb may be turbidites, the origin of others is unclear, mainly because they lack distinctive sedimentary struc-

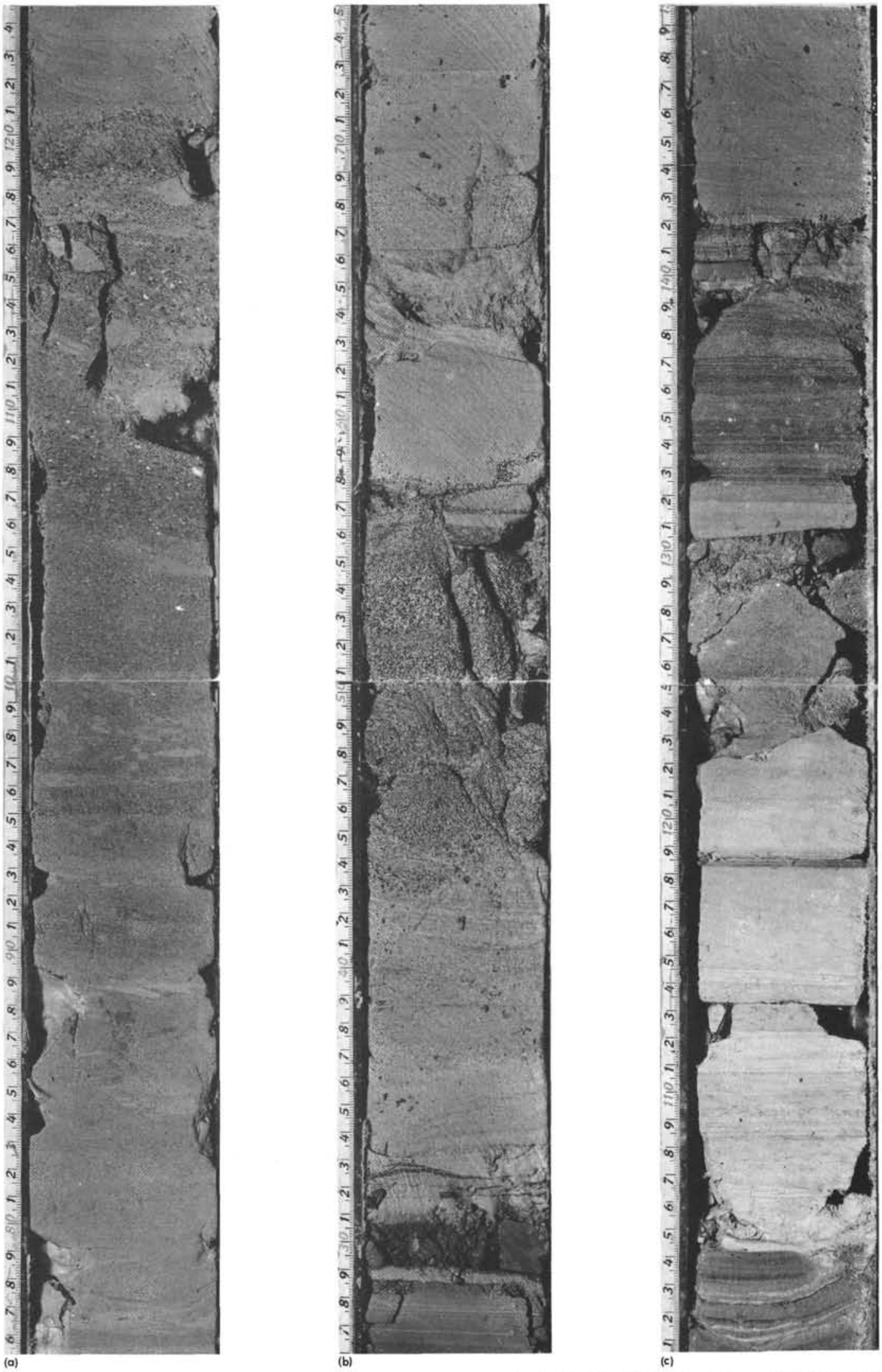

Figure 8. *Limestone and graded sand- to siltstones in Unit V, Site 376, Messinian. (a) Light gray limestone and graded sandstones in Unit V. From top to bottom: (1) Gray dolomitic marlstone with thin layers of white ooze; above 104.5 cm. (2) Light gray micritic limestone, massive at*

terrigenous silt; it is built up of tiny anhedral calcite grains with a small admixture of coccoliths. This limestone is very similar to the Colombacci limestones in the post-evaporitic Messinian of the Apenninic fore-deep in Marche-Romagna (Italy); 104.5-123 cm. (3) Graded and laminated fine sand- to siltstone; 123-130.5 cm. (4) Graded and laminated fine sand- to siltstone; 130.5-139.5 cm. (5) Gray dolomitic marlstone; 139.5-140.5 cm. (6) Finely laminated marlstone with abundant plant fragments; 140.5-142 cm. (7) Gray dolomitic marlstone, below 142 cm; Site 376, Unit Va, Messinian, Sample 11-2, 100-150 cm. (b) Graded and laminated sandstone associated with laminated siltstone and marlstones. The graded sandstone contains mainly detrital carbonate, dark rock fragments, minor amounts of quartz, feldspar, and heavy minerals. In the fine sandstone to siltstone grading is less obvious and is disturbed by drilling. This typically cyclic sequence is interpreted as an alternation of marlstone and turbidites. Note the absence of burrowing in all cores of Unit V. Site 376, Unit Vb, Messinian, Sample 11-3, 26-75 cm. (c) Coarse sandstone grading into silt- and marlstone. Above a basal erosional contact the sandstone shows abundant marlstone fragments, the upper part appears to be finely laminated. The sandstone contains mainly detrital carbonate, dark rock fragments, quartz, feldspar, and heavy minerals, as in Unit Vb, and additionally detrital gypsum. Associated marlstones are finely laminated and lack burrowing. Site 376, Unit Vd, Messinian, Sample 15-3, 75-125 cm.

tures and sequences of structures. These layers may be turbidites which were reworked by sporadic bottom currents, or very distal turbidites.

Subunit Vc

This subunit was recovered in Cores 12, 13, and in the core catcher of Core 14 (subbottom depths between 102.5 and 131). In it the proportions of silty marlstone and sandstone/siltstone are about 70% and 30%, respectively. Most of the colors are rather drab grays and greenish-grays (e.g., medium light gray, dark greenish-gray, grayish-olive-green, dark gray, greenish-gray, brownish-gray).

As in other parts of Unit V, this subunit is well bedded and unburrowed. Thinly bedded interlayered laminated siltstones to marlstones probably are thin turbidites. Thicker graded units with coarse basal portions are present in Sections 3 and 5, Core 12 and Sections 1, 3, and 5, Core 12. In Section 1, Core 12 three cycles up to 80 cm thick are present, which consist of coarse foraminifer-rich, very well sorted, lithic sandstone with numerous plant fragments, grading into silty nannofossil marlstone.

Parts of the unit, however, lack well-defined turbidite layers of the kind described above. Some have ill-defined silty and sandy layers within marlstone, resembling parts of Subunit Vb (e.g., Section 4, Core 2: Section 2, Core 13) and may be very distal or reworked turbidites. Section 2, Core 12 contains a distinctive laminated, organic-rich marlstone with small, yellowish-white flecks. The nature and origin of this rock is unclear and warrants further study. Other prominently laminated, organic-rich marlstones occur in Section 4 of Core 12 and in the upper half of Section 2, Core 13.

The marlstones appear very similar to those in Subunits Va and Vb. In smear slides they contain typically 35%-45% clay minerals, 20%-40% unspecified carbonate, 20%-30% nannofossils, rare to trace amounts of quartz, plagioclase, mica, pyrite, and fine-grained rock fragments. However, X-ray determinations indicate an abrupt change in mineralogical composition between Cores 11 and 12. The carbonate content is very variable (20%-60%), but dolomite is present only in traces. Smectites are virtually the only clay minerals, with traces only of attapulgite, chlorite, illite, and clinoptilolite. Hand lens examination gives the impression that these marlstones have more silt and sand size grains than those above, as well as more small plant fragments.

Plant fragments are also very common in the turbiditic sandstones, whose compositions likewise resemble those in the overlying subunits. Dark rock fragments (primarily altered fine-grained volcanic rock fragments), detrital carbonate, quartz, and some gypsum generally dominate these layers. Biotite, hornblende and other heavy minerals appear as trace constituents. In Cores 12 and 13, the sandstones and siltstones contain frequent radiolarians. Many of the thicker and coarser turbidite layers contain elongate pebbles of marlstone, probably eroded from the underlying sediment during turbidite emplacement.

In summary, Subunit Vc seems to be a mixture of hemipelagic marlstone and of distal and more proximal turbidites.

Subunit Vd

Distinctive greenish sandstones and siltstones containing abundant detrital gypsum characterize this subunit which was recovered in Core 15 (subbottom depth: 131-140.5 m). These clastic layers occur as graded, probably turbiditic units interbedded with green and gray silty nannofossil marlstones containing only minor amounts of dolomite. The proportions of the different lithologies are about 60% marlstone, 40% sandstone/siltstone. Small amounts of coarse-grained secondary gypsum occur in Sections 1 and 2, Core 15. The specific colors are: (1) sandstone and siltstone—pale green, and greenish gray; (2) marlstone—pale green, very light gray, and medium bluish-gray, with mottles of light olive-brown.

Clearly graded sandstone layers are best seen in Section 3, Core 15. These occur in 5 to over 70 cm thick units with sharp, erosional basal contacts. A few appear to have full Bouma sequences, but more are apparently "$T_{b\text{-}e}$ or $T_{c\text{-}e}$" partial sequences (Bouma 1962). As in Subunit 5C, the coarse turbidites contain marlstone pebbles, but plant fragments are rare or absent. The main components of the siltstones and sandstones, based on smear-slide estimates, are quartz (5%-10%), fine-grained dark rock fragments, mainly volcanics (15%-30%), detrital carbonate (15%-40%), and detrital gypsum (trace to over 25%). The latter occurs chiefly as rounded polycrystalline grains of fibrous gypsum.

Coarsely crystalline white gypsum occurs from 18 to 23 cm in Section 2, Core 15. This is either a layer, a nodule, or two redeposited cobbles. Another piece of coarse gypsum occurs within a drilling breccia in Section 1, Core 15. Large gypsum crystals of apparently secondary (diagenetic) origin occur within sandstones and siltstones at the base of Section 1 and the top of Section 2.

Smear-slide estimates suggest the marlstones are compositionally akin to those in Subunits Va to Vc above, except that nannofossils and clays are less abundant, and silt-size detrital carbonate, quartz, and rock fragments are more abundant. Bulk X-ray determinations record quartz (6%-10%), plagioclase (3%-11%), K-feldspar (1%-7%), very variable amounts of calcite (18%-41%) with small amounts of dolomite (3%-5%), and traces of serpentine. The clay mineral assemblage is like that of Subunits Va and Vb, with smectites (65%-85%), attapulgite (10%-25%), chlorite (5%-10%), and traces of illite and kaolinite.

Unit V, Site 375

Two centimeters of Unit 5 lithology were recovered in Section 1 of Core 1. The sediment is gypsum-bearing nannofossil dolomitic marl, light olive-gray to pale blue green. It contains *Cypideis pannonica* which occurs in abundance in Unit V of Site 376. Assignment to a subunit could not be made. The contacts with the overlying Pliocene marls and the underlying evaporites (Subunit VIa) are artificial drilling contacts.

The Unit V sediments here are in part barren of indigenous marine fossils. However numerous episodes of marine influx are indicated by the presence of marine microfossils in individual layers.

The absence of burrow traces from the activity of invertebrate benthos and the restricted character of the unreworked faunas suggests somewhat stressed marine conditions.

Summary of Unit V

Subunit Vd is hemipelagic[2] sediment and proximal turbidites in about equal amounts. Subunit Vc is mainly hemipelagic sediment with proximal and distal turbidites. Subunits Va and Vb are mainly hemipelagic sediment with relatively sparse proximal turbidites. Some thin clastic layers in these units, however, are difficult to interpret. The entire unit might be tentatively interpreted as a deepening sequence from Vd to Va. Peculiar environmental conditions are suggested by Subunit Vc because of its highly individual mineralogic composition: containing virtually smectites alone in the clay mineral fraction and traces only of the otherwise common attapulgite and chlorite.

Unit VI: Mediterranean Evaporite (Lapatza Formation)[3]

Subunit 6A Gypsum and Green Dolomitic Marlstone

(Site 375: Core 1, 60 cm through Core 3, 137-185 m [corrected]; Site 376: Cores 16-20, 140.5-188 m).

This subunit was cored continuously at Site 376; whereas at Site 375 only small parts were recovered by spot coring. For this reason Site 376 is described first. Here the contact with the overlying lithologic Unit V appears greatly disturbed by drilling (top of Core 16) and the boundary has been placed arbitrarily between Cores 15 and 16. It seems, however, that there exists a somewhat gradual downward transition from the detrital sediments containing redeposited gypsum in Subunit 5D to the green sandy dolomitic marlstone in which the gypsum layers are set.

The top of Core 16, Section 1 contains a drilling breccia comprising fragments of coarsely crystalline, banded, recrystallized and very fine grained gypsum with green sandy marlstone. Fragments of coarse sandstone containing coarse gypsum clasts may be basal parts of turbidites as described in Unit V. In the middle of Core 16, Section 1, greenish-gray silty to sandy dolomitic marlstone with thin interlayers of sandstone are present. These rocks contain 10%-15% detrital quartz and up to 15% dark rock fragments besides clay minerals (25%), unspeicified carbonate (40%), rare gypsum, and corroded calcareous nannofissils. The lower part of Core 16 and Cores 17 through 18 consist of a drilling breccia made up of different types of gypsum and rare fragments of soft white nannofossil ooze (Section 376-17-1), all set in a disturbed matrix of greenish-gray to pale green sandy marlstone. The gypsum fragments comprise:

1) Light olive-gray to light gray and very light gray to white, very fine grained and homogeneous gypsum (alabaster).

2) White, crudely layered and recrystallized gypsum with the layering oriented at a high angle to the axis of the core.

3) Evenly layered to crenulated gypsum ("Balatino") which apparently is somewhat recrystallized and in some cases is brecciated and recemented.

4) Coarse selenitic gypsum crystals, elongate, up to 4 cm long.

5) Resedimented gypsum (gypsarenite) with a typically clastic texture; made up of well-sorted, slightly elongated gypsum clasts and rare lithic fragments and clasts of green marlstone. Occasionally there is cross lamination.

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[2] The word "Hemipelagic" here denotes sediment that settled out of suspension in the water column. It does not presuppose a deposit of an open marine environment.

[3] For illustrations and detailed description and analysis of the evaporite sediments of this unit, see Garrison et al, 1977.

6) Coarsely crystalline recrystallized gypsum, with crystals roughly equant, and traces of anhydrite.

7) Coarsely crystalline gypsum with large, elongate selenitic "swallow-tail" gypsum crystals, set in a matrix of gypsiferous greenish-white marlstone.

In Core 19, large pieces of laminated somewhat recrystallized gypsum and of a gypsrudite (gypsum crystal conglomerate) are present. The latter comprise elongate and sangular clasts of gypsum up to 5 cm long, all set in a sparse matrix of pale green sandy marlstone. The clasts comprise fine-grained homogeneous gypsum (alabaster), large, slightly rounded selenitic crystals, coarsely crystalline gypsum with equant crystals, laminated gypsum, and detrital gypsarenite. Additionally clasts of green marlstone are present. Some secondary gypsum crystals have grown in the martrix of the conglomerate and occasionally replacement and recrystallization has affected both matrix and clasts.

The overall lithology of Core 20 comprises gypsum "flat pebble" breccias, parallel and cross-laminated to banded gypsum and detrital gypsarenite. The flat pebble breccias are made up of folded and broken elongate clasts of light-colored, fine-grained, laminated gypsum cemented by vuggy, olive-black, crystalline gypsum sand (cf. fig. 20A in Hardie and Eugster, 1971). The laminated gypsum is slightly wavy, fine-grained and olive-gray to olive-black in color. The banded gypsum is coarse-grained and light gray to olive-black in color with wavy dark laminae and bands. The detrital gypsum is well sorted, faintly laminated, olive-black gypsarenite and gypssiltite. The core emitted a very strong odor of hydrogen sulphide.

Site 375 (Cores 1-1, 60 cm to 4-1, 110 cm; 137.5-186 m)

At Site 375 a very similar sequence of gypsum and greenish-gray sandy dolomitic marlstones, siltstones, and sandstones is present in the upper part of Unit VI. In the lower part laminated gypsum of Balatino-type is predominant.

The marlstones and siltstones occur as a minor lithology and, more important, they typically constitute the sparse matrix in which much of the gypsum occurs (Samples 1-1, 60 cm to 2-3, 34 cm). The marlstones and siltstones chiefly contain clay minerals, nannofossils, unspecified carbonate, and varying amounts of rock fragments, quartz, feldspar, heavy minerals (mainly biotite and amphibole), and rare fragments of volcanic glass. The gypsum crystals are dusky yellow and grayish-yellow-green to very light gray and light bluish-gray. They are equant or elongate (up to 8 cm long) and often oriented at high angles or parallel to bedding. Relatively pure and coarsely crystalline gypsum interbedded with the above lithologies is mottled from grayish-yellow-green and very light gray or faintly laminated with shades ranging from yellowish-gray to light greenish-gray, very light gray, and light bluish-gray.

In Sample 2-3, 34-121 cm, the green marlstones alternate with laminated gypsum which ranges in color: light olive-gray to speckled medium light gray (when dry) to olive-gray and olive-black (when wet). This laminated gypsum occurs in mm-thick alternations of fine and coarse crystalline gypsum with organic- and carbonate-rich laminae. Generally the laminations are parallel, however, in some cases, deformed laminae are present (Sample 3-2, 83-87 m).

In Sample 2-3, 91-97 cm, the green marlstones contain irregularly shaped soft pebbles of white nannofossil ooze as observed at Site 376 (Section 376-17-1). At the base of Core 2, Section 3 and at the top of Section 4, an arenitic to finely ruditic interval, much disturbed by drilling, contains fragments of the marlstone and other lithic fragments.

Core 2, Section 4 and the top of Section 5, 0-5 cm consist exclusively of the laminated gypsum (Balatino-type) with parallel laminae. In one place (Core 2-4, 70-77 cm) an interval of resedimented and recemented elongate gypsum clasts ("flat pebble conglomerate") occurs.

At the base of Section 375-2-5, in Sample 375-3, CC, and at the top of Core 4, a few dolomite fragments occur. The fragments in Core 2 appear to contain, in a finely crystalline dolomite matrix, ghosts of peloids and possible oncoids (Bathurst, 1972) together with biogenic fragments and dolomitized limestone lithoclasts. One of these lithoclasts contains poorly preserved planktonic foraminifers. The carbonate rock in core-catcher 3 and Core 4, Section 1 is a brecciated finely crystalline, slightly calcitic dolomite. We think that these carbonates come from the base of the evaporite formation and might be products of alteration in the vadose zone (cf."Calcare di base" of Schrieber, 1974).

Rock types such as gypsarenites and gypsum crystal conglomerates together with sedimentary structures such as flat-pebble conglomerates, cross-bedding, and possibly algal laminations signify shallow, essentially clastic deposition for the evaporites of Subunit VIa (cf. Hardie and Eugster, 1971). The presence of selenitic and laminated gypsum further indicates shallow subaqueous deposition. Formation of gypsum must have taken place contemporaneously with sedimentation as these gypsum crystals occur as clasts in the conglomerates.

Subunit VIb Anhydrite and Halite

(Site 376, Cores 21-23, 188 to total depth 216.5 m; Messinian).

Recovery in this subunit was very poor: Core 21 at Site 376 made no recovery, but probably belongs in this salt-bearing subunit. Cores 22 and 23 contained only small pieces of anhydrite and halite.

Core 22, Section 1 contained from top to base: (1) numerous small pieces of clear, coarsely crystalline halite with thin (0.5 cm) wavy interlayers of finely crystalline gypsum; (2) larger fragments of white nodular anhydrite with large and small enterolitic folds and occasional chicken-wire structure. These rocks also contain considerable amounts of gypsum. (3) one fragment of banded anhydrite, in which thin dark brown, organic-rich laminae separate up to 1-cm thick bands of nodular anhydrite with occasional chicken-wire structure. Scattered vugs in the anhydrite (Sections 2 and 3) are partly filled with halite. (4) banded halite with 2- to 4-cm thick layers of clear coarsely crystalline halite separated by 0.5-cm thick, brown, fine-grained gypsum layers containing rare anhydrite.

Core 23 contained a rubble of small pieces of clear halite and banded porous anhydrite which may have contained halite.

Recent chicken-wire anhydrites have been described exclusively from sabkha environments. However, some uncertaintly about the environmental interpretation remains as it cannot be excluded that such structures cannot also form by diagenetic growth of anhydrite in other environments.

Both Cores 22 and 23 emitted a very strong odor of hydrogen sulfide.

Subunit 6B was not recovered at Site 375, but the very hard interval encountered by the drill string at 165 meters subbottom may correspond to the anhydrite of this subunit, which also may contain some minor halite at this site.

Unit VII: Marlstones with Interbedded Graded Siltstones and Sandstones (Mia Milea Member of The Kythrea Formation)

(Site 375: Cores 4 through 7, 185-600 m subbottom depth [corrected]; upper Miocene-Tortonian).

Unit VII consists predominantly of dark colored, partly dolomitic marlstones. Intercalated with these marlstones are coarse to fine-grained, lithic to feldspathic and dolomitic, arenites and siltites with thin layers of organic-rich nannofossil marlstones (sapropels) and sapropelic layers. The range of colors in this unit is dark greenish-gray to olive-gray and olive-black.

Typically the sequence shows a distinctly cyclic development, with each cycle consisting of three members. Member A is usually fine terrigenous arenite and siltite with a sharp lower boundary (Figure 9); it grades upwards into member B, composed of homogeneous and structureless marlstones and is overlain in turn by member C, which is marlstone with sparse burrowing. The thickness of the individual cycles may vary from less than 10 cm to more than 1 meter. The cycles may be incomplete and comprise only members A and B (e.g., Cores 6 and 7, Section 1), or B and C, respectively. In Core 5, Section 5 many decimeter thick cycles occur.

The lower boundaries of the arenites and siltites are usually very sharp and obviously represent erosional surfaces above the underlying marlstone. Graded bedding is usually very distinct and parallel lamination very frequent, but small-scale cross-laminations were observed only rarely. The arenites and siltites are poorly sorted. According to smear-slide and thin-section observations, they contain carbonate particles, lithic fragments of metamorphic and altered volcanic rocks, 5%-15% quartz, feldspars and up to 10% biotite and amphibole (Figure 10). Rare fragments of shallow water organisms such as red algae, bryozoa, molluscs,

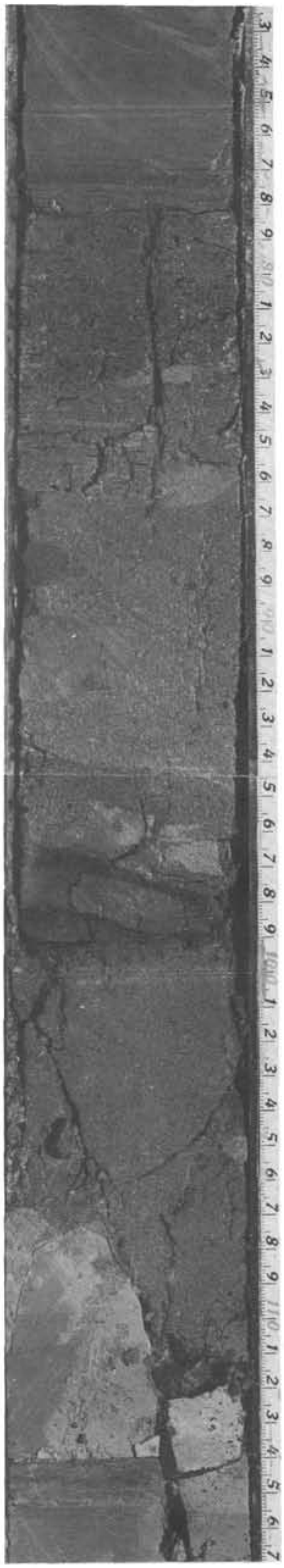

Figure 9. *Terrigenous turbidite. Lower part consists of massive dark sandstone with interca-*

lated organic-rich layers and large rounded marlstone pebbles, higher up plant fragments are abundant. The sandstone is unsorted and contains mainly detrital carbonate, highly altered volcanic fragments, mafic minerals, quartz, and feldspar. This interval grades upward through laminated siltstone into faintly laminated to homogeneous marlstone. At the base of the sandstone an uneven erosional contact, accentuated by drilling disturbance, is present. Site 375, Unit VIII (Kythrea Formation, Mia Milea Member), Tortonian. Sample 6-6, 72-117 cm.

and shelf foraminifers are obviously reworked and/or displaced. Plant fragments are very common, and in the coarse, massive sandstones, marlstone pebbles of centimeter-size occur (e.g., Core 6, Section 2). In the fine matrix, partly reworked calcareous nannofossils are usually present. Traces of unaltered, colorless or brown vescicular glass occur in the arenites and siltites as well as in the marlstones of members B and C. The coarser and thicker arenites occur in Core 4, the upper part of Core 5, and in Core 6.

Member B is composed of structureless, sometimes finely laminated more or less dolomitic nannofossil marlstone (Figure 11) with rare sand- or silt-sized terrigenous constituents, mainly detrital carbonate, and minor amounts of quartz, feldspar, biotite, and volcanic glass. Dolomite and detrital carbonate may occur as tiny rhombohedra. The thickness of these layers may reach 1 meter. Occasionally these mudstones occur as minor intercalations of darker homogeneous mudstones only a few centimeters across in which lighter sediment has been piped down by burrowing organisms (Core 5, Section 6). Colors vary from greenish-gray and dark greenish-gray in the upper part of the unit to more olive and greenish-black shades in the lower part. Burrowing is restricted to the uppermost part of this member.

The marlstones of member C are of essentially the same composition, their main difference from member B being the occurrence of layers rich in planktonic foraminifer and the presence of sparse burrowing, mainly of *Chondrites* type, with a few occurrences of *Planolites* and occasional *Zoophycos*. Colors vary from medium bluish-gray to greenish-gray in the upper part of the formation and olive-gray to greenish-black shades in the lower part.

X-ray analysis confirms the essentially identical composition of the homogeneous and the burrowed marlstones. Clay minerals typically comprise over a third or a half of the bulk mineralogy. Montmorillonite is the predominant clay mineral in the less than 2 μm fraction (40%-80% of the clay minerals). It is associated with appreciable amounts of chlorite (10%-30%) and attapulgite (5%-25%) with minor amounts of illite (5%-10%), and traces of mixed-layer clay minerals and kaolinite. There is a clear upward increase of illite and attapulgite, which coincides with a decrease of smectite and increased regularity of the mixed-layer minerals. In the bulk analysis quartz typically predominates over plagioclase and K-feldspar and serpentine is present only in traces.

The carbonate content in the marlstones is very variable (between 20% and 55%) with somewhat lower values in Core 6 (20%-25%). Dolomite is always present, but only in Core 4 and at the top of Core 5 does it exceed 5%. The content of organic matter is always relatively high (between 0.1% and 0.5%).

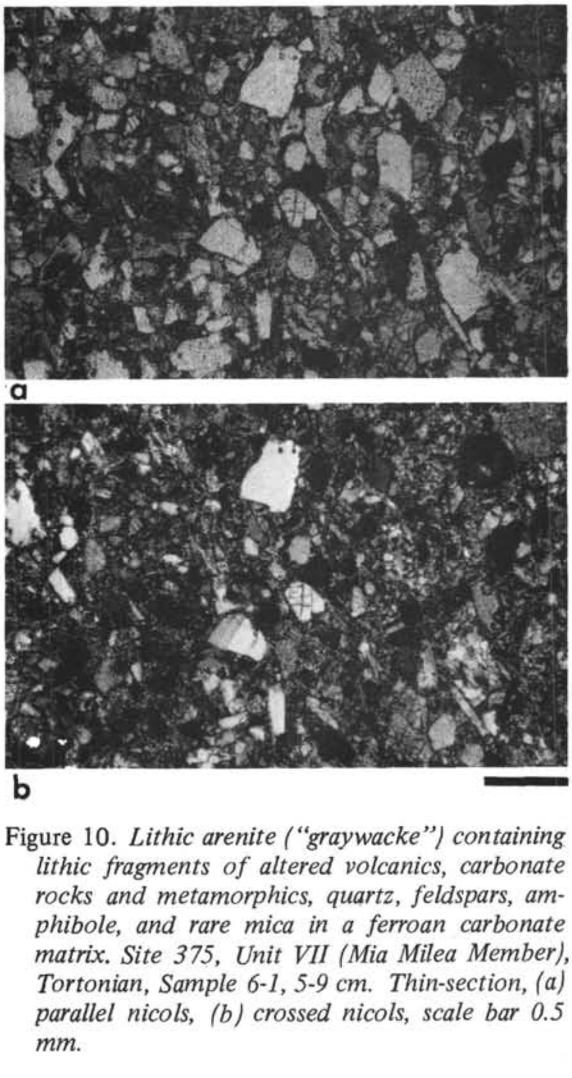

Figure 10. *Lithic arenite ("graywacke") containing lithic fragments of altered volcanics, carbonate rocks and metamorphics, quartz, feldspars, amphibole, and rare mica in a ferroan carbonate matrix. Site 375, Unit VII (Mia Milea Member), Tortonian, Sample 6-1, 5-9 cm. Thin-section, (a) parallel nicols, (b) crossed nicols, scale bar 0.5 mm.*

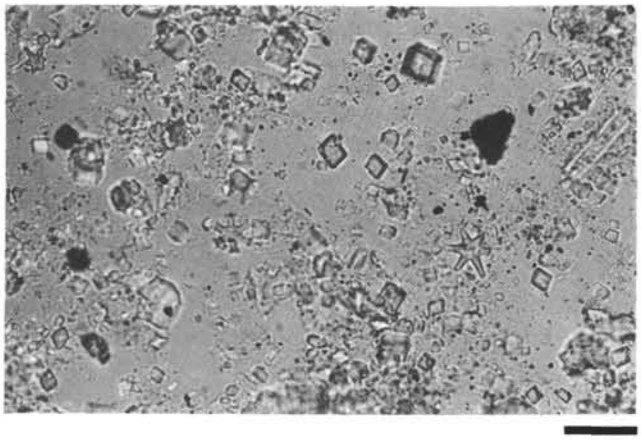

Figure 11. *Dolomitic nannofossil marlstone containing about 50% clay minerals, 40% carbonate including dolomite rhombs and calcareous nannoplankton and traces of quartz, pyrite, etc. Site 375, Unit VII (Mia Milea Formation), Tortonian, Sample 4-2, 81 cm. Smear slide, scale bar 0.025 mm.*

The A-members of the cycles observed in lithologic Unit VII are interpreted as sand and silt deposited by turbidity currents (Ta-Td of Bouma, 1962). The homogeneous, nonburrowed B layers, into which the A layers grade, apparently represent the finest fractions transported by the density currents (Te of Bouma, 1962). Sometimes these layers are not obviously linked to graded beds, but, as they are burrowed only at their top, they must represent events of rapid accumulation and we interpret them as the most distal deposits of turbidity currents (cf., Bernoulli, 1972; Hesse, 1975). The burrowed marlstones of layer C constitute the "normal" hemipelagic sediment. Similar thinly laminated turbiditic "shales," into which lighter hemipelagic sediment has been introduced from above by burrowing, have also been illustrated by Weiler (1965) from the Kythrea Flysch of Cyprus. Concentrations of planktonic foraminifer at the base of such turbiditic mudstones are rare in Unit VII (e.g., Core 4, Section 1), but are frequent in the underlying Units VIII to X.

Organic-rich, black to olive-gray and greenish-black sapropels and sapropelic layers are frequent in Cores 4, 5, and 7. Usually they are distinguished from the dominant nannofossil marlstones only by their high content of organic material (up to 7% in Core 4, Section 4). However, the presence of four distinctly graded cycles in the sapropels of Core 4, Section 4 shows that some of them are redeposited (cf. Nesteroff, 1973).

The composition of the arenites and siltites of Unit VII is essentially the same as that of the "graywackes" of the Mia Milea member of the Kythrea Flysch of Cyprus with which Unit VII can be correlated (see Baroz et al., this volume; Baroz and Bizon, 1974; and Weiler, 1964, 1965, 1969). Deposition apparently took place in the same basin as these equivalent land sections. This was a semireducing and episodically even stagnant basin with oxygen deficiency as is suggested by the abundance of organic matter and pyrite and by the sparse burrowing and the poor benthic assemblages, which at least in part are displaced. The formation contains appreciable amounts of Hydrogen Sulfide and of gaseous hydrocarbons with methane/ethane ratios ranging from 624 to 1024. Intercalations of volcanic tuffs as described from the Kythrea Flysch by Weiler (1964) were not found at Site 375 but volcanic glass occurs frequently as a minor constituent.

Unit VIII: Variegated Nannofossil Marlstones to Foram-Nanno Limestones (Trapeza Marls)

(Site 375, Core 8; 600-641 subbottom; Serravallian).

This unit consists of variegated mudstones to nannofossil marlstones and foram-nanno limestones. Colors vary from light olive-gray, dusky yellow, and yellowish-gray to dusky brown, grayish-brown, and greenish-gray. In Sections 2 and 4, grayish-red and moderate yellow-brown and brown lithologies occur. The overall pattern is a cyclic centimeter to decimeter alternation of dark mudstone and marlstone and light colored foram-nanno limestone. The dark layers are characterized by a sharp lower boundary. They gradually pass upwards into the light colored more calcareous and foraminifer-rich marlstones and limestones. Typically the tops of the dark layers are intensely burrowed from above, with lighter sediments piped down and older burrows burrowed again by younger and usually smaller ones (Figure 12, see also fig 4 in Weiler, 1969). Occasionally there occur burrows in the light colored sediment which are filled by darker sediment. Burrows are of *Chondrites, Planolites,* and *Zoophycos* (sometimes pelleted) type.

The homogeneous marls and mudstones are composed of varying amounts of carbonate (mainly coccoliths) and clay minerals with an admixture of rare quartz and plagioclase. Silty laminae in the claystones contain quartz, plagioclase, and rare mica and amphibole. According to X-ray analysis, quartz predominates over plagioclase, and only traces of K-feldspar, dolomite, and serpentine are present. Smectites are the dominant clay minerals (60%-80% of the decalcified fraction <2 μm) followed by chlorite (5%-25%), attapulgite (5%-10%), illite (5%-10%), and traces of kaolinite and mixed-layer clay minerals.

The lighter calcareous lithologies are generally composed of calcareous nannofossils (40%-90%) and clay minerals with varying amounts of planktonic foraminifers.

Again the argillaceous basal part of the cycles most probably represent distal parts of turbidites. This latter interpretation is supported by the occurrence of an intercalation of light colored graded foraminiferal calcarenite grading into dark marlstone (Sample 8-3, 12-70 cm). The light colored lithologies then could represent slower pelagic carbonate sedimentation in a weakly oxidizing environment.

Unit VIII appears to represent an episode of slower deposition of distal turbidites and hemipelagic marls in a slightly more oxidizing environment between the dark marlstones of Unit IX and the dark greenish turbiditic facies of Unit VIII. Altered plagioclase and

Figure 12. *Characteristic cycle in Unit VIII. Dark mudstone overlain by light colored foraminifera-rich nannofossil marl. The upper part of the dark mudstone is riddled by small burrows of* Chondrites-*type and larger* Planolites *with light sediment infills introduced from above. Smaller* Planolites *burrows show a composite structure with small* Chondrites-*burrows inside. The dark mudstone is interpreted as a distal turbidite overlain by "autochthonous" hemipelagic sediment. Site 375, Unit VIII, Serravallian, Sample 8-1, 80-98.5 cm. Scale bar 2 cm.*

traces of vesiculated glass could point to a volcanic source for part of the noncarbonate fraction.

Unit IX: Dark Colored Nannofossil Marlstones (Trapeza Marls)

(Site 375): Core 9: 641-675 subbottom; Serravallian)

The unit consists of dark colored mudstones and nanno-fossil marlstones interlayered with lighter colored, more calcareous nannofossil marlstones. The main difference between this and the underlying and overlying units is mainly the change of colors, which range from medium dark gray to grayish-brown and dusky brown in the more argillaceous lithologies to light olive-gray in the more calcareous ones. The change to darker colors is accompanied by increased contents in organic matter and pyrite. Thin sapropelic layers are common in all the sections.

The sequence shows a cyclic development, similar to the ones in Units VIII and X, more argillaceous layers grading into the lighter more calcareous lithologies. The darker units show sharp lower boundaries and faint parallel lamination and occasionally graded and cross-laminated layers of fine sand and silt are present at the base (Core 9, Section 2, Figure 13). The gradational contact towards the lighter colored limestone is usually modified by intense burrowing predominantly by various types of *Zoophycos.* Unidentified burrows occur associated with graded and parallel- and cross-laminated siltstone in Core 9, Section 2. As in Unit VIII, the basal argillaceous parts of the cycles are interpreted as distal turbidites.

The light colored lithologies contain only traces of terrigenous silt whereas from smear-slide observations the basal parts of the cycles appear to contain common to rare altered feldspar, rare biotite, amphibole, traces of quartz, and volcanic glass. The fine sediment in the light colored lithologies is mainly made up of coccoliths and clay minerals. In the turbiditic mud and marlstones the carbonate content varies greatly (0%-40%). Bulk X-ray analysis shows small amounts of quartz, plagioclase, and dolomite with traces of K-feldspar and serpentine. In the carbonate-free <2 μm fraction, smectites (55%-70%) predominate again over chlorite (5%-25%), attapulgite (5%-15%), illite (5%-10%), and traces of kaolinite. Again much of the noncarbonate detrital fraction may be derived from a volcanic source and/or older volcanogenic rocks.

Unit X: Reddish-brown and Greenish-gray Nannofossil Marlstones With Interbedded Light Gray Foraminiferal Limestones (Panagra Marls)

(Site 375: Cores 10-11, 675-760 subbottom; Langhian).

Unit X is composed of reddish-brown dolomite-bearing nannofossil marlstones with interbedded grayish-blue green to greenish-gray nannofossil marlstones and hard, well cemented, very light gray to bluish-white foraminiferal limestones. On the ship this unit was informally named "Orbulinico rosso" in analogy to the "Ammonitico rosso" facies. This was because of:

Figure 13. *Characteristic cycle in Unit IX. Light gray foraminiferal marl to marlstone, overlain by sapropelic marlstone and parallel to cross-laminated fine sand- to siltstone which grades upwards into dark gray mudstones. The fine sand to siltstone is mainly composed of small tests of planktonic foraminifera, small volcanic rock fragments and minor amounts of quartz and feldspar. The lower part of the mudstone shows irregular structures, possibly burrows, filled by darker mudstone, the upper part is riddled with* Zoophycos *burrows of varying size. These are filled with light gray pelagic marlstone constituting the normal pelagic sediment overlying the silt to mudstone, which is interpreted as a distal turbidite. Site 375, Unit IX (Kythrea Formation, lower part of Mia Milea Member), Serravallian, Sample 9-2, 25-50 cm. Scale bar 2 cm.*

(1) its richness in *Orbulina*, a planktonic foraminifer, and (2) its great similarity to the Ammonitico rosso, a marly basinal facies of the Tethyan and central Atlantic Jurassic, which is characterized by similar sedimentary features, particularly the occurrence of "pelagic" turbidites (Bernoulli, 1972; Lancelot, Seibold, et al.; 1975).

In Unit X various kinds of cycles can be observed. Cycles similar to the ones described in Units VIII and IX consist of grayish- blue-green to greenish-gray and dark greenish-gray marlstones with sharp lower boundaries and occasional parallel lamination, grading into dark reddish-brown to moderate reddish-brown and moderate brown marlstones, which often show centimeter-banding of foraminifer-rich and poor layers. Burrowing is generally sparse to moderate and of *Chondrites* type with only a few occurrences of *Zoophycos.* Although no coarser laminae at the base of the cycles have been observed, the lower part of the cycles may represent redeposited hemipelagic and pelagic fine-grained sediment.

Another type of cycle is composed of very light gray and bluish-white to pale blue, hard cemented foraminiferal limestones with sharp lower boundaries which grade into gray or red marlstones. In Core 10 these limestones are one or a few centimeters thick and display distinct grading, parallel and ripple drift lamination and occasionally convolute laminae. These beds are composed exclusively of planktonic foraminifers, which are cemented by syntaxial overgrown and blocky, mostly ferroan, calcite cements together with small patches only rich in nannofossils and cemented by calcite overgrowth. The individual grains are sometimes stained black, most probably by pyrite, which gives some of the layers a "salt and pepper" appearance. In some cases these redeposited beds may occur

Figure 14. *Characteristic cycle in Unit X. Reddish-brown marlstone, slightly burrowed with irregular patches and bands rich in planktonic foraminifers. At 34.5 cm a mm thick disrupted limestone layer with planktonic foraminifers occurs. The red marlstone is overlain by hard, light gray foraminiferal limestone with graded bedding and convolute lamination stained by pyrite. The light gray limestone terminates abruptly and is followed by marlstone containing another layer of foraminiferal limestone a few mm thick. Note stylolite seam oblique to bedding in light gray limestone. Site 375, Unit X (Panagra Marls), Langhian, Sample 10-2, 19-36 cm. Scale bar 2 cm.*

as white laminae a few millimeters thick, which are sometimes disrupted (Figure 14). In Core 11, laminated limestones several centimeters thick are present. They are relatively well-sorted foraminiferal lime grainstones (in the sense of Dunham, 1962) obviously formed by the redeposition of sorted, winnowed foraminiferal sand (Figure 15). Thus different types of pelagic and hemipelagic sediments have been redeposited as "pelagic" turbidites.

Some of the cemented limestones in Core 11 have faint, closely spaced solution seams parallel to bedding,

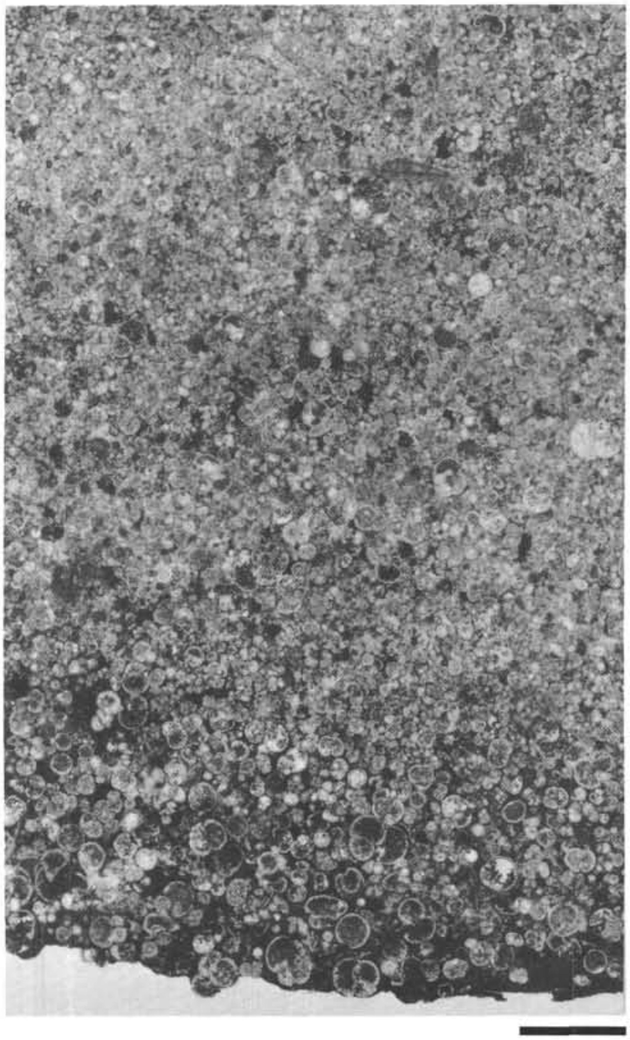

Figure 15. *Graded foraminiferal limestone ("pelagic" turbidite) composed entirely of tightly packed planktonic foraminifers. At the base, some micrite is present between the foraminifers, higher up micrite occurs only as infill in the tests which are cemented by a blocky ferroan calcite cement. Site 375, Unit X (Panagra Marls), Langhian, Sample 11-2, 67-68 cm, thin section. Scale bar 1 mm.*

which may represent the earliest stages of flaser-development. They also have stylolites oblique and perpendicular to bedding.

The fine sediment of the "Orbulinico rosso" shows considerably higher carbonate contents than the overlying units (between 45 and 70%, and more than 90% in the limestones). Terrigenous quartz is rare and plagioclase occurs only in traces. The clay minerals show great variability. They comprise: illite (traces to 10% of the clay fraction), chlorite (0%-25%), traces of mixed-layer clay minerals (illite-chlorite, illite-montmorillonite), montmorillonite (40%-80%), kaolinite (5%-20%), and attapulgite (traces to 25%).

Unit XI: Dark Green-Gray Limestones and Marlstones

(Site 375: Cores 12-13, 760-821.5 ms subbottom; lower Miocene).

Recovery of samples from this unit was very poor and restricted to a few fragments of hard limestone in core-catcher 12 and slim core fragments of green limestone and marl in Core 13.

The limestone found in the core catcher of Core 12 is a hard grayish-olive marly "lime wackestone" (Dunham, 1962) with planktonic foraminifers, filled with a ferroan calcite cement. The fine groundmass consists mainly of calcareous nannofossils, with heavy calcite overgrowth, clay minerals, and some dolomite rhombs. The fragments recovered in Core 13 consist of greenish-gray foram- rich nanno-limestone, which are interbedded with greenish-black marlstones. Some of the fragments reveal a cyclic arrangement of the lithologies similar to the one observed in Units VIII through X with marlstones gradually passing into fine-grained intensely burrowed limestones. The clay mineral association is characterized by montmorillonite (70%), an increased content in kaolinite (25%) with some illite (5%), and only traces of chlorite and mixed-layered minerals.

GEOCHEMICAL MEASUREMENTS

Sites 375 and 376 are separated by a distance of about 12 kilometers. The geophysical profile shows no major faults between them, thus allowing the combination of the geochemical data from each site. Because of poor recovery and lack of squeezable material, in the evaporites, no interstitial water data are available between 140 meters to 350 meters subbottom depth.

Interstitial Water

The salinity and chlorinity trends of Site 376 are shown in Figure 16. The salinity remains nearly constant with a minimum at about 50 meters subbottom, near the top of the dolomitic marls of Unit V, but it increases rapidly with depth at about 150 meters subbottom, near the top of the gypsum and marlstone sequence of Unit VI. The chlorinity shows a slight reverse gradient down to about 120 meters subbottom, and increases rapidly also at about 150 meters. The Ca^{++} concentration shows a steady and significant increase from about 10 to about 40 mM/1 (Figure 17). The magnesium concentration varies little (except for an anomalously high near-surface value). There is a slight reverse gradient down to 120 meters subbottom similar to the chlorinity trend, and the concentration increases slightly at 150 meters subbottom as the top of the evaporite unit is reached. The alkalinity trend (Figure 16) shows a distinct decrease with depth. The *p*H shows a minimum within lithologic Unit V and increases to 8 at a level near the top of the evaporite unit (VI).

The salinity and chlorinity trends of Site 376 are distinctly different from those of Sites 371, 372, and 374. Instead of a steady increase from the surface down to the evaporites, the salinity remains nearly constant and the chlorinity shows a slight reverse trend in the marlstone unit above the evaporites. Such trends are not unexpected if the interstitial waters in some of the sediments were originally brackish, as suggested by the occurrence of *Cyprideis* and *Ammonia* faunas in some cores. The occurrence of the selenitic gypsum near or at the top of the gypsum unit may have served as an effective diffusion barrier, so that the steady increase in the manner of a "classical diffusion gradient" did not begin until the top of the gypsum was penetrated.

The calcium concentration increases with depth from surface down, a trend similar to those at Sites 371 and 372, and at Site 374, before the maximum was reached. The absence of the steep magnesium gradient at Site 376 suggests the presence of an effective diffusion-barrier between the upper gypsum unit and the salt-section where the brines should be very rich in magnesium.

The salinity of interstitial waters from pre-Messinian formations at Site 375 is near normal and remains constant to about 600 meters depth. However, the deepest sample has an abnormally low salinity of 28°/₀₀. The chlorinity seems to show a reverse gradient from normal seawater chlorinity down to 17°/₀₀. The Ca/Mg ratio is much higher than that of normal seawater and approached 1 at greater than 600 meters subbottom depth. The alkalinities are high, and the *p*H is similar to normal seawater.

Organic Geochemistry

The following methane/ethane ratios were measured in Cores 5 to 7 and 9 of Site 375: 375-5-5, 145 cm; M/E = 750; 376-6-2, 52 cm, M/E = 624; 375-7-5, 127 cm; M/E = 1018; 375-9-3, 55 cm; M/E = 996.

Carbonate Content

The carbonate contents of samples from Sites 375 and 376, measured by the "Carbonate Bomb" method onboard ship and by the "Leco" Method at the DSDP shorebase, are plotted alongside the hole summary diagrams.

PHYSICAL PROPERTIES

Site 375

Very little physical property data were obtained at Site 375 primarily because coring did not begin until

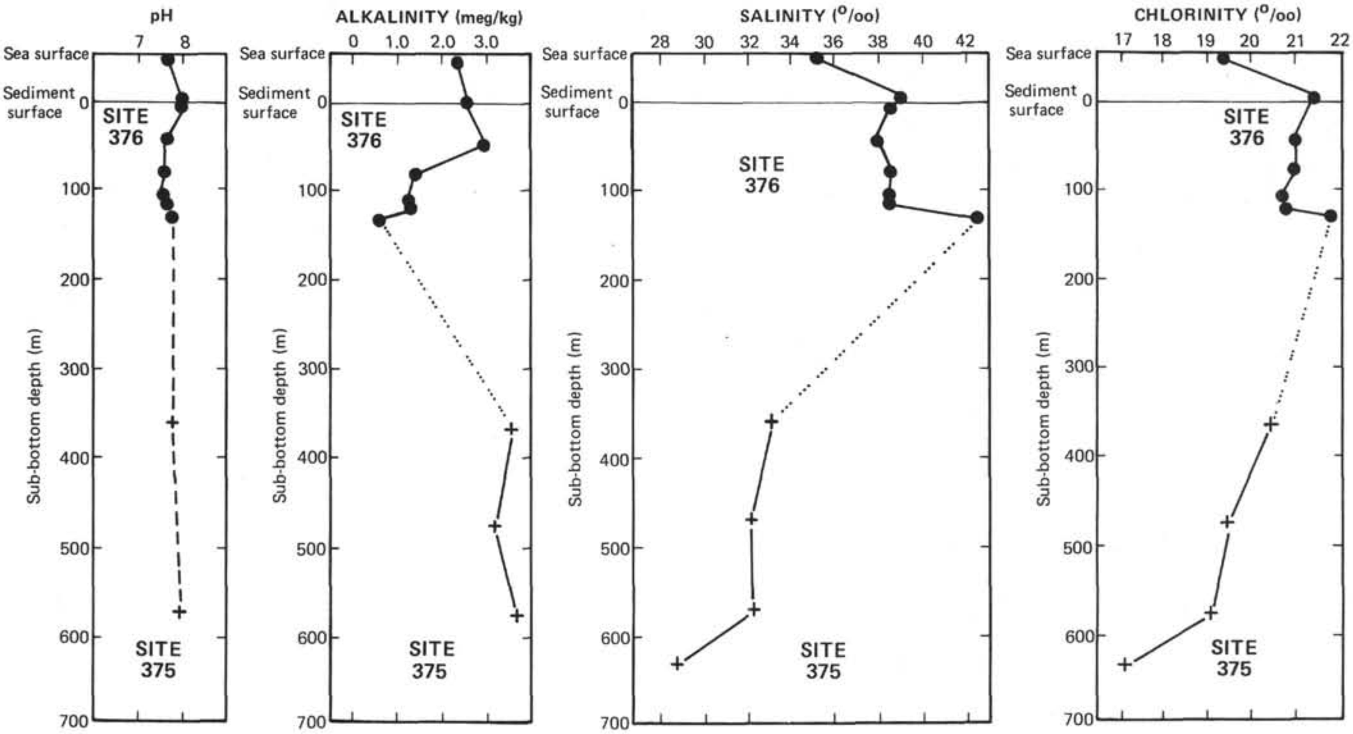

Figure 16. *Geochemical measurements at Sites 375 and 376:* pH, *alkalinity, salinity, and chlorinity.*

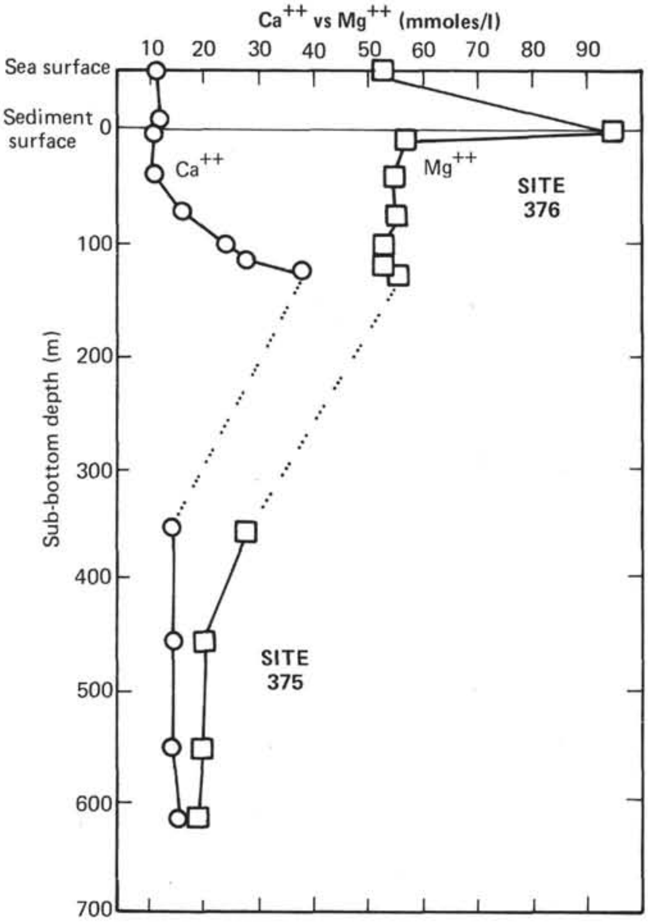

Figure 17. *Geochemical measurements at Sites 375 and 376:* Ca^{++} *and* Mg^{++}.

the drill bit reached the evaporite layer at 137.5 meters. The sediments below the evaporite layer were generally too consolidated or too badly disturbed by drilling to permit thermal conductivity, shear strength, or gravimetric measurements. In addition, the presence of gas in Cores 5 through 9 made even these physical property measurements difficult and/or of questionable validity.

All Site 375 sonic velocity data are summarized in Tables 1 and 2 of Appendix VI and plotted versus depth in Figure 18. High velocities (4.5 to 4.9 km/sec) were measured through pieces of coarsely crystalline gypsum recovered from between 139 and 194 meters subbottom. Slightly higher values (5.5 km/sec) were measured through pieces of thin, hard, laminated limestone layers recovered from 733 to 736 meters subbottom. Some velocities measured in dolomitic marlstones and nannofossil marlstones cored intermittently between 653 to 736 meters subbottom ranged from 2.49 to 2.79 km/sec. Lower velocities (1.98 to 2.02 km/sec) are characteristic of dolomitic nannofossil marlstones recovered near 250 and 570 meters subbottom.

Water content was determined gravimetrically on the four cores recovered between 249 and 678 meters subbottom using the cylinder sampling technique (Table 5 of Appendix VI). Water content values ranging from 9 to 17 weight percent were obtained. Other volumetric bulk properties were not determined on these samples because of the brittle nature of the indurated sediments precluded sampling a known volume using either the syringe or cylinder techniques.

Bulk wet density and porosity measurements were made on five cores between 464 and 736 meters

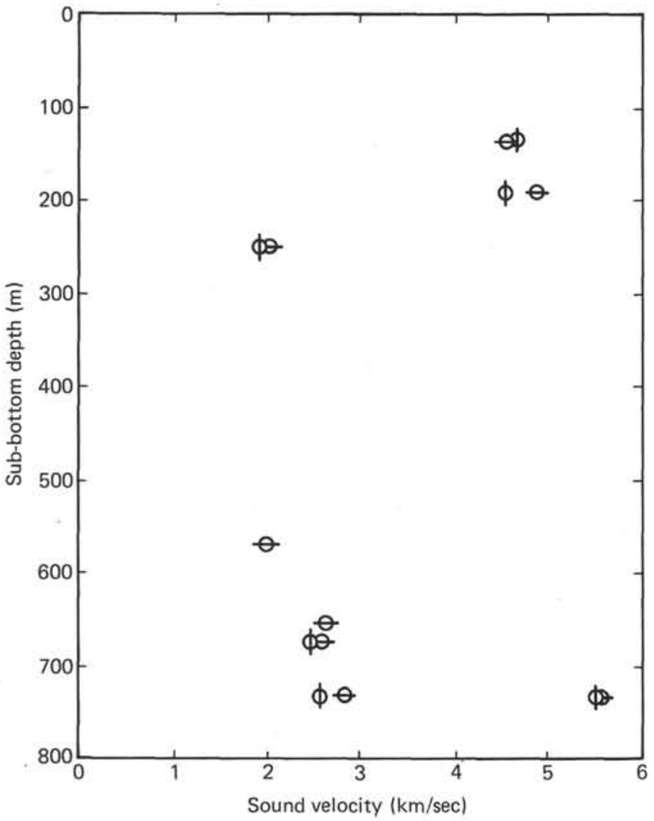

Figure 18. *Sound velocity values measured in the horizontal (⊖) and vertical (⦶) directions on sediments recovered at Site 375.*

subbottom using the gamma ray attenuation techniques (Table 3 of Appendix VI). Density values range from 1.94 to 2.14 g/cc (with a single anomalously high value of 2.33 g/cc) near the top of this interval, and increase downwards to 2.39 g/cc near the bottom. The low water content and high density are typical of well-consolidated sedimentary rocks.

Site 376

Sonic Velocity Data

Measurements of compressional wave velocity were made on unconsolidated sediment within a split core liner, and on hand-trimmed pieces of more consolidated material removed from the liner. These data are listed in Tables 1 and 2 in Appendix VI, and the horizontal velocities are plotted versus subbottom depth in Figure 19.

Immediately apparent in Figure 19 is the very small velocity increase from about 1.5 km/sec at the sea floor to about 1.7 km/sec at 140 meters subbottom. Velocities determined through pieces of gypsum recovered from below 140 meters were high (4.4 to 5.2 km/sec). A single velocity measurement through a piece of siltstone recovered from 186.4 meters gave an intermediate velocity of 3.64 km/sec.

The very low seismic velocity and its constancy with depth above the evaporite layer are unusual features, in view of the rather well-consolidated sediments recovered at this site. The increases noted in bulk wet density are poorly reflected in the velocity profile, and in fact, the significant density decrease observed at 65 meters coincides with a subtle velocity increase. The approximate constancy of the thermal conductivity data with depth is also in general agreement with the velocity data.

Wet Bulk Density, Porosity, and Water Content

Wet bulk density, porosity, and water content were determined using gamma ray attenuation methods (Table 3 in Appendix VI) and, where the consolidation of the sediment made it possible to sample effectively by either the syringe or the cylinder techniques, by gravimetric methods (Tables 4 and 5 in Appendix VI). Where the stiffness of the sediment made sampling a known volume unreliable or impossible, only water content was measured.

The density data shown in Figure 20 increase nearly linearly with depth to about 70 meters, where there is an abrupt density decrease of 0.10 to 0.15 g/cc, followed by another linear increase down to just below the top of the evaporitic layer at 131 meters subbottom. Another density decrease was observed in layers of mud present within the uppermost part of the

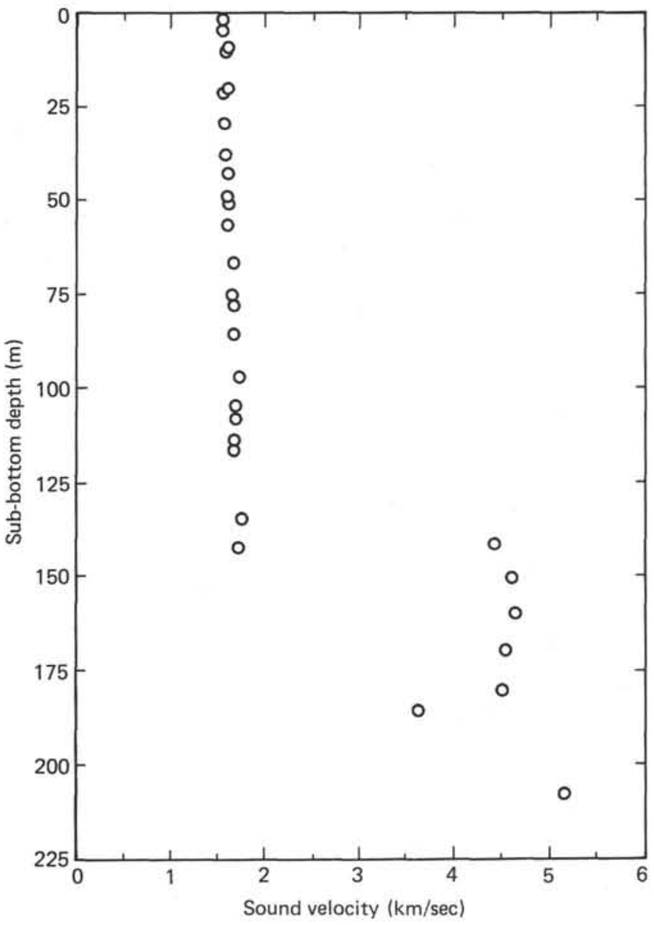

Figure 19. *Sound velocity measured in the horizontal direction through sediments recovered at Site 376, plotted versus subbottom depth.*

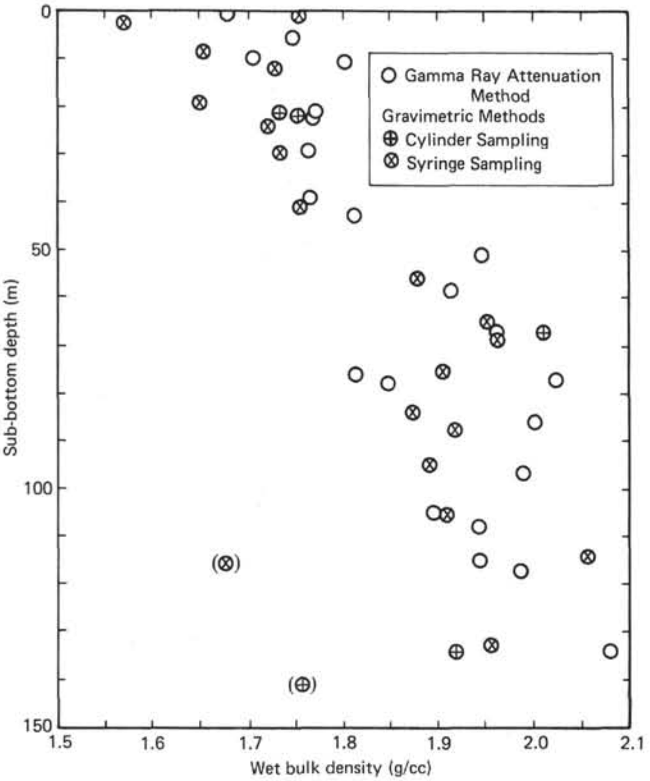

Figure 20. *Wet bulk density data at Site 376, plotted versus subbottom depth.*

evaporite sequence. There is no obvious explanation for the density decrease at 70 meters subbottom, which occurs approximately 15 meters below the top of an 85.5-meter thick layer of nannofossil dolomitic marlstone containing interbedded turbiditic arenites and siltite.

Thermal Conductivity Data

The data show a dramatic increase in conductivity from 2.16 to 2.80 mcal/cm sec°C in the uppermost 20 meters of the sea floor, followed by values which increase only slowly with depth at least as far as 117.5 meters subbottom (Figure 21). The scatter in the data is believed to reflect both the effects of coring and minor variations in lithology. The range of values most commonly observed below 20 meters (2.72 to 3.00 mcal/cm sec°C) is in good agreement with conductivity values measured at somewhat greater depths in the Ionian Basin.

BIOSTRATIGRAPHY

Summary

Sites 375 and 376 overlap stratigraphically only in the lowermost Pliocene. Together, however, they represent a thick deep-sea Neogene succession in the Levantine Basin which allows correlation with land sections on nearby Cyprus (see Baroz et al., this volume).

At Site 375 on the Florence Rise coring was discontinuous and its 13 cores recovered sediments ranging in age from early Pliocene at 137.5 meters subbottom to early Miocene at the terminal depth of 821.5 meters subbottom (Figure 22).

The lower Pliocene was determined in the upper part of Section 1 of Core 1 (137.5-138 m subbottom). The sediments are abundant in well-preserved and diversified microfossil assemblages.

The upper Miocene sequence, recovered in Core 1, Section 1, below 60 cm to Core 7 CC (138.0 to 574.5 m subbottom) is notable mainly for its impoverishment of faunal assemblages. An *Ammonia beccarii* assemblage was recorded in Samples 2-2, 7 cm and Samples 2-2, 30 cm. An increase in the numbers of reworked species and detrital material can be observed below Core 5.

From Core 8 to Sample 11, CC (622.0 to 736.0 m subbottom), the middle Miocene was determined. Well-preserved to slightly overgrown microfossils are abundant in several horizons of this interval. Benthic foraminifers are only rare.

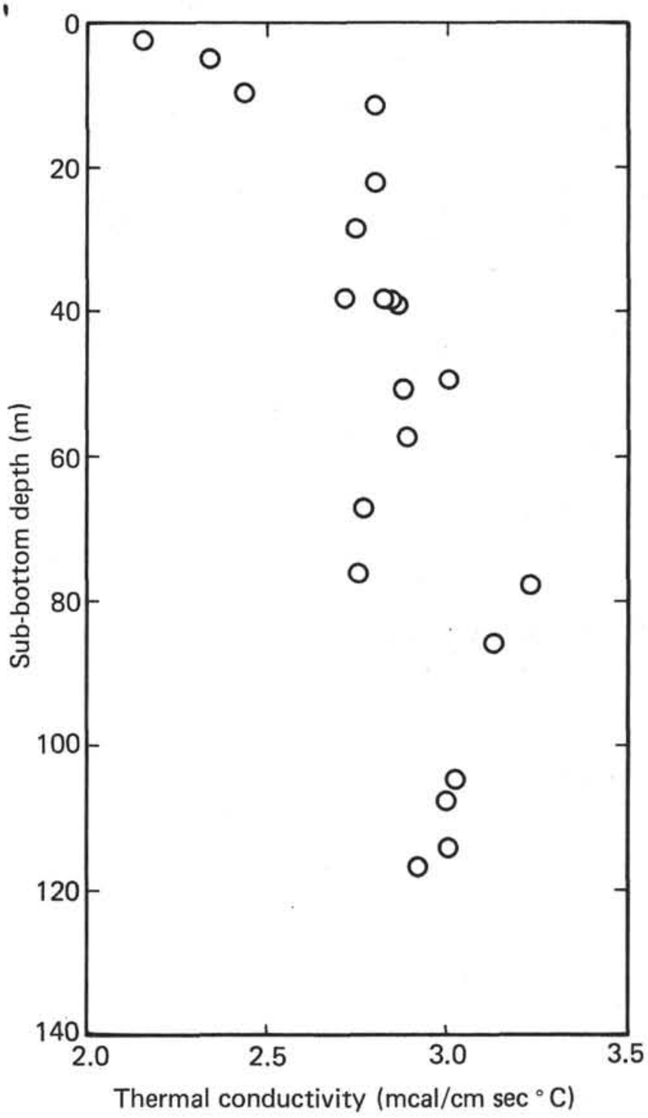

Figure 21. *Thermal conductivity data measured aboard ship on sediments recovered at Site 376, plotted versus subbottom depth.*

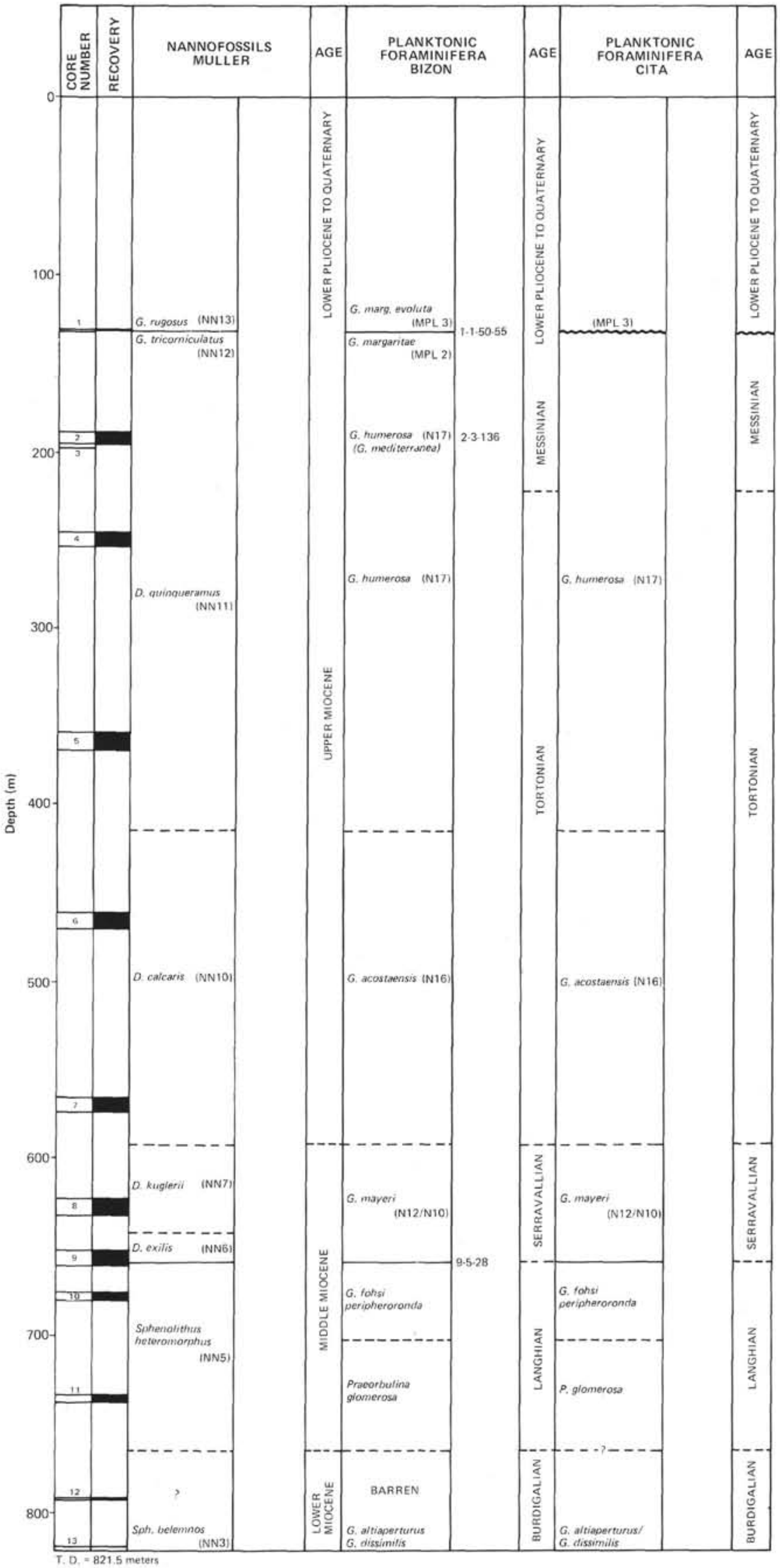

Figure 22. *Relative planktonic microfossil determinations, Site 375.*

No age determination was possible for Core 12. The lower Miocene was determined in Core 13 (819.5 to 821.5 m).

Site 376 is located about 12 km further north at the southern edge of the Antalya Basin and in over 200 meters deeper water. From the sea bottom to a drilling depth of 216.5 meters (Core 1 to Core 23), coring was continuous through sediments ranging from Quaternary to the upper Miocene in age (Figure 23).

Highly condensed sequences were observed in the Quaternary and Pliocene.

Quaternary sediments were recovered in Core 1 to Core 5, Section 2 (0.0 to 39 m) and also in Core 6, Sections 1, 2, and 3. They are richly fossiliferous. The presence of shallow-water benthic foraminifers and reworked nannoplankton from the Cretaceous to Neogene indicates displacement of material from the shelf. This sequence is also notable for its several sapropel layers.

Besides foraminifers and nannofossils, also noted were: Radiolaria, sponge spicules, pteropod fragments, ostracodes, otoliths, echinoid spines, and holothurian sclerites.

There is some evidence that the earliest part of Pleistocene and lowest part of the Pliocene are missing.

The Pliocene sediments are pure highly condensed biogenic oozes and were recovered in Core 5, Section 3 to Sample 5, CC (39 to 45.5 m), and from Core 6, Section 3 to Sample 6, CC (2 m) there occurs a mixed assemblage of lithologies obviously disordered biostratigraphically, due either to sediment slumping or to drilling disturbance.

Foraminifers and nannofossils are well preserved in this interval and show no indication of reworking. Benthic foraminifers are rare (<2%).

The upper miocene was recorded from Core 7 to Core 23 (55 to 216.5 m). The topmost part yields a characteristic *Ammonia beccarii* and ostracode assemblage with a few long-ranging, possibly autochthonous planktonic foraminifers and nannofossils.

The amount of reworked material (Cretaceous to middle Miocene) increases from Core 12 to Core 15 (102.5 to 140.5 m). These marlstones interbedded with graded sandstones are underlain by gypsum, anhydrite, and halite from Core 16 to Core 23 (140.5 to 216.5 m) which contain no microfossils.

Nannofossils

Quaternary (Site 376)

Sediments of Quaternary age were recovered in Cores 1 to 3 and also in Core 6, Sections 1 to 3, at Site 376. The sediments are in general rich in well-preserved nannofossils. The number of reworked species from Cretaceous, Paleogene, and Neogene vary. They are more frequent in late Pleistocene sediments than in the early Pleistocene. This is attributed to the presence of turbidites in the late Pleistocene sequence. The finer upper parts of these turbidites are rich in nannofossils, whereas their bases are poorly endowed. The Quaternary sequence is characterized by sapropels and sapropelic layers which are rich in pyrite and organic material. Their nannofossil assemblages suggest deposition in warm waters (*Umbellosphaera irregularis, Umbellosphaera tenuis, Thoracorsphaera heimi*). Reworked species are less frequent within these layers, however, and are abundant in the sediments directly below. Nannofossil assemblages display low diversity in some of these layers consisting mainly of *Helicosphaera carteri, Discolithina japonica*, and the small variety of *Gephyrocapsa oceanica.*

The *Emiliania huxleyi* Zone (NN21) was determined in Core 1. The assemblage comprises: *Helicosphaera carteri, Syracosphaera pulchra, Cyclococcolithus leptoporus, Emiliania huxleyi, Discolithina japonica*, and the small variety of *Gephyrocpasa oceanica. Coccolithus pelagicus* is absent. *Umbilicosphaera mirabilis, Umbellosphaera tenuis*, and *Colithotus fragilis* are rare.

A Site 376, the interval, Core 2 to Core 3, Section 4, 120-121 cm is assigned to the *Gephyrocapsa oceanica* Zone (NN20).

Core 3, Section 5 to Sample 5-2, 40-41 cm of Site 376 is an interval belonging to the *Pseudoemiliania lacunosa* Zone (NN 19). Reworked species become more frequent in the lowermost part of the *Pseudoemiliania lacunosa* Zone.

Pliocene (Site 375)

In Core 1 (136.0 to 138.0 m subbottom) at Site 375 red and while marls were encountered. The red marls contain the nannofossil assemblage of the *Ceratolithus rugosus* Zone (NN 13). This highly diversitied assemblage consists of: *Syracosphaera pulchra, Helicosphaera carteri, Reticulofenestra pseudoumbilica, Cyclococcolithus leptoporus, Discoaster pentaradiatus, Discoaster surculus, Discoaster brouweri, Cyclococcolithus macintyrei, Scapholithus fossilis, Scyphosphaera pulcherima, Oolithotus fragilis, Ceratolithus tricorniculatus, Cyclococcolithus rotula, Discolithina multipora*, and a few specimens of *Ceratolithus rugosus.* Reworked Cretaceous and Eocene species are present sporadically.

Pliocene (Site 376)

The Pliocene at Site 376 is a considerably reduced sequence. Core 5, Section 3, probably belongs to the *Discoaster brouweri* Zone (NN 18) of the upper Pliocene. *Discoaster brouweri, Discoaster triradiatus*, and *Cyclococcolithus macintyrei* are abundant, while only one specimen each was found of *Discoaster surculus* and *Discoaster pentaradiatus*, and the latter may be reworked. *Scyphospheres* are frequent in the upper Pliocene. The sediments are rich in well-preserved nannoplankton. In some samples discoasters are slightly overgrown; they are enriched and well preserved in the sapropel layers recovered in the Pliocene. Coccoliths, on the other hand, show signs of dissolution in these layers. The *Discoaster surculus* Zone (NN 16) was determined in sampes 376-5-4, 10-11 cm to 376-5-4, 110-11 cm with *Discoaster surculus, Discoaster pentaradiatus, Discoaster brouweri, Discoaster tamalis, Discoaster assymmetricus, Cyclococcolithus macintyrei* and *Pseudoemiliania lacunosa. Ceratolithus rugosus* was found only sporadically.

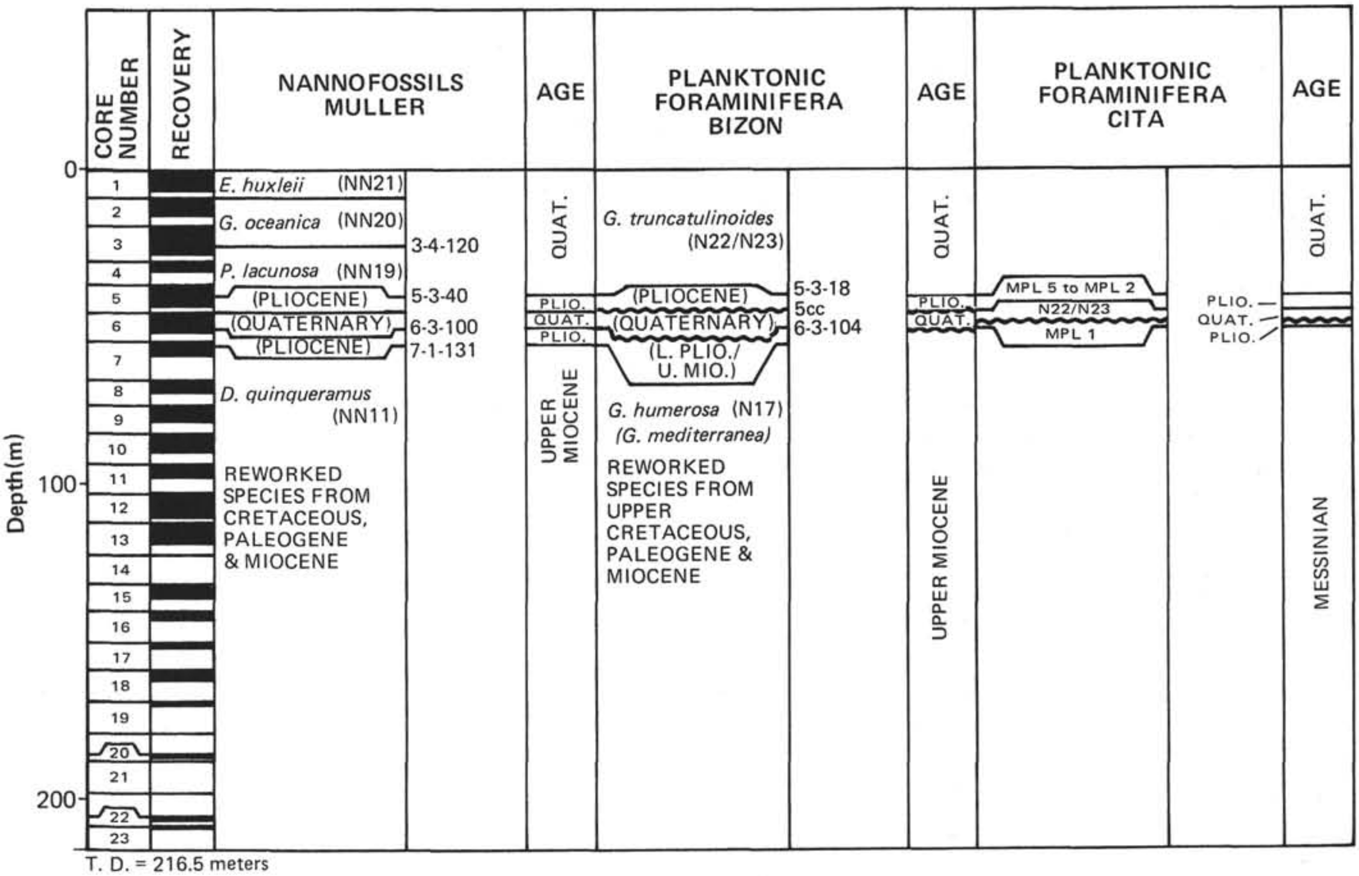

Figure 23. *Relative planktonic microfossil determinations, Site 376.*

The *Reticulofenestra pseudoumbilica* Zone (NN 15) was determined in Samples 376-5-5, 52-54 cm and 5-5, 80-81 cm with *Reticulofenestra pseudoumbilica, Ceratolithus rugosus, Discoaster tamalis*, and *Discoaster asymmetricus.*

The *Discoaster asymmetricus* Zone (NN 14) was determined in Samples 375-5, 88-90 cm and 375-5-5, 91-92 cm, and the *Ceratolithus rugosus* Zone (NN 13) in Samples 375-5, 99-100 cm and 375-5-5, 109-110 cm. The sediments of this sequence are rich in excellently preserved nannofossils. Discoasters and scyphospheres are abundant. Sample 375-5-5, 127-128 cm and 375-5, CC belong to the *Ceratolithus tricorniculatus* Zone (NN 12) of the lowest Pliocene/uppermost Miocene. They are rich in excellently preserved discoasters. *Ceratolithus tricorniculatus* and species of the genus *Scyphosphaera* are frequent. This zone was also determined in the interval 375-6-3, 100-101 cm to 375-7-1, 31-32 cm. However, the sediments at the top of Core 7 are probably not in place. Discoasters are slightly overgrown from Core 6, Section 4 downwards associated with an increase in idiomorphic dolomite crystals and reworked species from the Cretaceous, Paleogene, and Neogene. These sediments represent the transition to the dolomitic marls of Core 7 and the cores below this. The nannofossils are fragile and excellently preserved in the sapropel layer at 375-6-4, 67-68 cm.

Miocene (Site 375)

Nannofossils are rare in the sediments at the base of Core 1 of Site 375 (Sample 375-1-1, 126-127 cm) and in Core 2, Sections 2 and 3. Reworked species from the Cretaceous, Eocene, and lower-middle Miocene are generally rare. Discoasters occur sporadically or are missing in this part of the profile.

A strongly reduced nannofossil assemblage consisting only of *Sphenolithus abies* and a very small species of the genus *Reticulofenestra* was observed in Sample 375-2-3, 93-94 cm. Below this horizon a well-preserved, highly diversified nannoplankton assemblage is present of the *Discoaster quinqueramus* Zone (NN11) with the following species: *Syracosphaera pulchra, Reticulofenestra pseudoumbilica, Helicosphaera carteri, Coccolithus pelagicus, Cyclococcolithus rotula, Helicoshaera pacifica, Scapholithus fossilis, Discoaster brouweri, Discoaster variabilis, Discoaster* cf. *aulakos, Discoaster pentaradiatus, Discoaster surculus, Discoaster icarus, Discoaster quinqueramus, Triquetrorhabdulus rugosus, Cyclococcolithus macintyrei, Lithostromation perdurum, Discolithina multipora, Umbilicospaera jafari*, and *Discolithina japonica.* An impoverishment can be again observed in Section 4 of Core 2. In Core 3 gypsum was encountered.

In Core 4 (245.0-252.0 m subbottom) a highly diversified assemblage is present containing the same species described from Sample 2-3, 137-138 cm plus *Discoaster calcaris.* This core is assigned to the lower part of the *Discoaster quinqueramus* Zone (NN 11), which can be correlated with the upper part of the Tortonian. Reworked species are only rare. Coccoliths are less abundant (dissolved) in the sapropel layer at 375-4-4, 41-42 cm while discoasters are relatively enriched. From 375-4-4, 113-114 cm to 375-5-1, 10-11 cm, the sediments are rich in well-preserved nannofossils; idiomorphic dolomite crystals are rare and detrital material is increased. In some samples reworked species become more frequent. Samples 375-5-1, 146-147 cm and 375-5-5, 110-111 cm are rich in pyrite and coccoliths are rare; discoasters are enriched due to dissolution of the less-resistant forms.

Sections 2 to 5 of Core 5 (360.0-369.0 m subbottom) contain less nannofossils due to dilution by the large amounts of detrital material. Discoasters are less frequent and numbers of reworked species increase slightly. This part of the core still belongs to the *Discoaster quinqueramus* Zone (NN 11)).

Samples 5-6, 14-15 cm and 5, CC of Site 375 are again rich in nannofossils with discoasters slightly overgrown. Reworked species are rare. This part of Core 5 and the interval down to Core 7, CC is assigned to the *Discoaster calcaris* Zone (NN 10).

The sediments of Core 6 and Core 7, Sections 1 and 2, are poor in nannofossils, again due to dilution by detrital material. Amounts of reworked Cretaceous to lower-middle Miocene species are slightly higher than in Core 5. The lower part of Core 7 contains more nannofossils and discoasters are slightly overgrown. Reworked species and detrital material are all but absent. Sample 375-8, 1-20-21 cm is barren of nannofossils. Other samples of this core, however, contain rich assemblages belonging to the *Discoaster kugleri* Zone (NN 7). Discoasters are slightly overgrown and reworked species are present only sporadically.

The *Sphenolithus heteromorphus* Zone (NN 5) was determined in Cores 10 and 11 (675.0-736.0 m subbottom) with *Sphenolithus heteromorphus, Coccolithus pelagicus, Coccolithus abisectus, Reticulofenestra pseudoumbilica, Cyclococcolithus macintyrei, Helicosphaera carteri,* and *Discoaster deflandrei.* The nannofossil content in general is low, with the exception of Samples 375-10-3, 7-8 cm, 11-1,111-112 cm, and 11-2, 145-146 cm. Those recorded are well preserved to slightly overgrown.

No age determination based on nannofossils is possible for Sample 12, CC. In Sample 375-13-1, 135-136 cm (828.0-832.0 m subbottom), the *Sphenolithus belemnos* Zone (NN 3) was determined. The sediments are abundant in nannofossils with discoasters slightly overgrown. The following species were recorded: *Reticulofenestra* c.f. *pseudoumbilica, Helicosphaera carteri, Coccolithus pelagicus, Coccolithus abisectus, Helicosphaera ampliaperta, Sphenolithus belemnos,* and few specimens of *Sphenolithus heteromorphus.*

Miocene (Site 376)

The sequence of dolomitic marls recovered in Cores 7 to 16, overlying the evaporites at Site 376 are assigned to the upper Miocene. Few specimens of *Discoaster quinqueramus* were found in Samples 7-1, 75-76 cm and 7, CC only. The nannofossil assemblages of the interval (Cores 8 to 16) contain only a few autochthonous long-ranging species, such as *Reticulofenestra pseudoumbilica, Sphenolithus abies, Helicosphaera carteri, Cyclococcolithus macintyrei, Cyclococcolithus rotula,* and *Discolithina multipora.* Reworked species from the Cretaceous, Paleogene, and lower-middle Miocene are more or less frequent in all samples. They are more frequent in Cores 11 to 16. The amount of reworked species decreases towards the top of this interval associated with an increase in idiomorphic dolomite crystals and a dcrease in detrital material. (Dolomite crystals were observed down to Core 10. Below this level they are missing or are rare. They are rare or absent in those samples rich in reworked species from Cores 7 to 10.) Reworked species from the Cretaceous and Palogene are most frequent in the upper part of the sequence, while others from the Oligocene to lower-middle Miocene are most frequent in the lower part of the profile (Cores 13-16).

In the evaporitic breccia of Core 17, Section 1, a pebble of white nannofossil ooze was found. It contained a very small species of the genus *Reticulofenestra* and also *Sphenolithus abies.* This reduced nannoplankton assemblage seems to be typical of horizons deposited in a restricted environment.

Planktonic Foraminifers (Cita)

The combined biostratigraphy of Sites 375 and 376 is treated here in stratigraphic order. The stratigraphic overlap of the two drill sites is limited to Core 1 Site 375, where early Pliocene oozes were recorded in contact with Messinian sediments. The composite record of the two Levantine Basin drill sites encompasses most of the Neogene.

The Plio-Pleistocene sedimentary succession continuously cored at Site 376, at the edge of the Antalya Basin, displays several peculiar features, some highly puzzling such as: (1) the dilute sapropels and tephra layers in Cores 1 and 2, whose correlation with the deep-sea record known from piston cores and from the continuously cored DSDP Site 125 is highly problematic; (2) the greatly condensed Pliocene section recorded in Section 5, Core 5; (3) the surprising occurrence of Pleistocene sediments in Sections 1 to 3 of Core 6, stratigraphically underlying condensed early Pliocene oozes of MPl-2 zonal age and overlying foraminiferal oozes with a prominent, 20-cm thick black layer ("Mystery Sapropel") of MPl-1 zonal age; and (4) a further succession, which does not follow Steno's law of stratigraphic superposition, recorded in the lowermost part of Section 4 of Core 6 and including the core catcher. Here Caspi-brackish faunal assemblages characteristic of the latest Messinian were found in highly disturbed olive-gray marls above early Pliocene oozes of MPl-1 zonal age.

Consequently the section recovered is interesting, but sufficiently complicated that it may not improve greatly our knowledge of the fossil record of the eastern Mediterranean. Furthermore, spot coring in the pre-Messinian succession penetrated at Site 375, along with the semi-indurated nature of the sediments and the extensive occurrence of turbidites (clastic in the late Miocene, mostly pelagic in the middle Miocene), make tbis sedimentary succession far from ideally suited for detailed biostratigraphic investigations. Nevertheless a fairly precise age determination was possible at most levels.

Range charts for the Plio/Pleistocene section continuously cored at Site 376 and for the Serravallian/Burdigalian section penetrated at Site 375 appear in Bizon et al. (this volume). Also in Cita et al. (this volume) a range chart is provided for the Tortonian section penetrated at Site 375 (Cores 4 to 7 included).

Pleistocene (Site 376)

Forty-two samples were investigated from the interval attributed to the Pleistocene (Site 376, Core 1 to Sample 5-2, 128 cm). In particular, most of its dark layers (sapropels and sapropelic layers) were investigated paleontologically. The biogenic component is diluted in these hemipelagic sediments by a substantial volcanogenic component, recorded both as discrete tephra layers and as shards of volcanic glass dispersed in the sediment. The watery character of the sediments at these levels together with disturbance by drilling combine to make counting of the numbers of sapropels in Cores 1 and 2 difficult. Nine of the sapropels sampled are from Core 1, nine from Core 2, and one from Core 3. None were recorded in Core 4.

A characteristic foraminiferal assemblage dominated by *Globigerina eggeri-dutertrei* and by *Globigerina bulloides* (see Parker, 1958; Ryan, 1972; Cita et al., 1973) was observed in the following sapropels at Site 376: Samples 2-1, 147 cm; 2-2, 5 cm; 2-2, 26 cm; 2-3, 1 cm; 2-3, 143 cm; 2-4, 30 cm. This assemblage was recorded in sapropels S-6, S-9, S-11, and S-12 of the late Pleistocene (Brunhes Epoch) by McCoy, 1974, and is indicative of strongly diluted superficial waters as shown by studies on stable isotopes (Cita et al., in press). Similar faunal assemblages have also been recorded in the "Brunhes/Matuyama sapropels" (see Cita and Ryan, 1973) recovered in Core 1 at DSDP Site 125, located on the crest area of the Mediterranean Ridge in the Ionian Basin.

Further detail on the sapropel stratigraphy is to be found in Kidd et al. (this volume). It suffices here to say that we have no record in the Antalya Basin of the thick, prominent, organic-rich, black "Matuyama pre-Jaramillo sapropels" as recorded in Core 3 of DSDP Site 125. The physiographic setting of Site 125 on the crest of a ridge should make it less likely to record faithfully all the stagnant cycles than a basinal setting such as that of Site 376. The foraminiferal assemblages of the "Matuyama pre-Jaramillo sapropels" do not yield the *Globigerina eggeri-dutertrei/G. bulloides* assemblage, so they should not be correlated with the sapropels recovered in our Core 2. Does this mean that the Pleistocene record is incomplete in its lower part in the Antalya Basin? It seems so, as is also shown by the nannofossil stratigraphy (see above). It appears that the latest Pleistocene is missing. This is confirmed by the fact that the somewhat confused succession of sapropels and tephra layers at Site 376, also does not appear to correlate with the well-known late Pleistocene record of the Levantine Basin established from piston cores (Ryan, 1972; McCoy, 1974).

Pliocene/Pleistocene Boundary

The Pliocene/Pleistocene boundary is tentatively located between Samples 5-2, 128 cm and 5-3, 115 cm based on the following criteria: The presence of *Globorotalia puncticulata, G. puncticulata padana*, and *Globigerina apertura* which usually do not extend beyond the Pliocene. They have their highest record in Sample 5-3, 115 cm. The lowest record of taxa which are used to subdivide the latest Pliocene and Pleistocene is as follows: *Globorotalia inflata* in Sample 5-2, 115 cm; *Globorotalia truncatulinoides* in Sample 5-1, 130 cm; *Globigerina pachyderma* (s.str.) in Sample 5-1, 130 cm.

Late Pliocene (Sites 375 and 376)

Sediments of late Pliocene age were recorded from Section 3 of Core 5 to the topmost part of Section 5, Core 5 (upwards from 62 cm) i.e., over a thickness of some 3 meters.

The youngest biozone (MPl-6 of Cita, 1975b) could not be identified. This observation concurs with the previous one suggesting a sedimentary gap at the base of the Pleistocene. Whether this supposed gap can be supported by seismic evidence is unclear.

MPl-5 Zone at Site 376

This biozone was recorded with typical assemblages at Site 376 in Section 4 of Core 5. It includes two sapropel layers at 64 and 105 cm, respectively. The white sediments interbedded between the sapropels and overlying them show obvious evidence of winnowing and sorting by size. Sorting appears to be bimodal, both the smallest and the largest foraminiferal tests being extremely abundant. A range chart showing the distribution of the main species is included in Bizon et al., 1977 (this volume). Among the species recorded in this interval are *Globigerinoides obliquus extremus, Globorotalia emiliana, G. puncticulata*, and *G. bononiensis.* Benthic foraminifers are well diversified and large in a level investigated from above the uppermost black sapropel of Section 4, Core 5. The P/B ratio is always extremely high indicative of water depths in excess of 1000 meters. Nine sapropels were recovered from this same interval (MPL-5 Zone) at Site 374, although coring was not continuous. This observation suggests that oceanographic conditions leading to stagnation were more pronounced in the deepest part of the Ionian Basin (now at 4100 m subbottom) than in the Antalya Basin (now at 2100 m subbottom).

MPl-4 to MPl-2 Zones at Site 376

Section 5 of Core 5 is paleontologically very interesting. It contains a strongly condensed succession which spans a time interval of approximately 2 m.y.

and corresponds to most of the Zanclean stage (Cita, 1975a; Cita and Gartner, 1973). Extremely low sedimentation rates are recorded for this time interval (see below). Values of around 1 m/m.y. for the lower Pliocene are minimum estimates since they are calculated assuming that no gaps exist in the sedimentary succession. The recorded occurrence of all the biozones in the deep-sea Mediterranean sediments (Cita, 1973, 1975b), including the zonal markers and accompanying species, indicate that, if gaps do exist, they are of short duration, at least shorter than the biozones themselves.

Ten samples were investigated from the 150-cm length of Core 5, Section 5 which is extremely condensed (see Figure 24). Seven were taken from the pale brown to light pink, structureless, moderately burrowed sediment in the lower part of the section. The sand-size fraction of this sediment is made up of foraminifers, 99% of which are planktonic. The benthic foraminifers from this interval indicate middle bathyal conditions (see below). The pink color, the large size of the foraminiferal tests, and the pronounced sorting by size all indicate a well-ventilated environment; eutrophic conditions with winnowing.

Three samples investigated from the upper part of this section at 5-6 cm; 36-37 cm; and 62-63 cm belong to the *Sphaeroidinellopsis subdehiscens* Interval Zone (MPl-4).

Two samples (108 cm and 110-111 cm) from the multi-layered lower-middle part of the section, where several omission surfaces are recorded, belong to the *Globorotalia margaritae/G. puncticulata* Concurrent-Range-Zone (MPl-3).

Five samples examined from the lowermost part of the section, below 110 cm, consistently yield foraminiferal faunas of MPl-2 zonal age. The distributions of the individual taxa are recorded on the range charts in Bizon et al., this volume.

Since Zones MPl-2 and MPl-3 have durations of approximately 0.7 and 0.9 m.y., respectively (see Ryan, 1972; Ryan et al., 1974), the lower part of the section appears biochronologically more condensed than the upper part. This is consistent with the occurrence of several omission surfaces in the lower part of Section 5, Core 5. Sediment samples investigated from the dark layers (at 108 cm and at 119 cm) which are interpreted as omission surfaces, and from a concentration of burrows below a well-defined bedding plane at 123 cm revealed that the faunas are quite normal: all specimens are well developed and well preserved and no reworking from older sediments was noted. Also no encrusted tests, which would suggest reduced sedimentation are present and the benthic faunas do not indicate unusual conditions: The benthic foraminifers are again rare and little diversified with no peculiarities. Some (rare) quartz grains, plant debris, and fragments of organic matter were recorded from the dark layer at 119 cm.

MPl-3 at Site 375

The pink ooze recovered in the topmost part of Core 1 yielded an abundant and well diversified assemblage of planktonic foraminifers indicating an MPl-3 zonal age with *Globorotalia margaritae margaritae, G. margaritae evoluta, G. puncticulata*, etc. Benthic foraminifers, although rare, are more abundant and diverse than those recorded from the same biozone at Site 374 in the Messina abyssal plain. The facies is strikingly similar to that recorded from the same interval at Site 376 (see above).

MPl-1 at Site 376

Sediments referable to the *Sphaeroidinellopsis* Acme-Zone (of Cita, 1973, 1975b) were recorded at Site 376 in the lower part of Section 3 and in most of Section 4 of Core 6. Thirteen samples were investigated from 95 cm in Section 3 to the bottom of Section 4. Since the stratigraphic succession is abnormal, a detailed description follows (see also Figure 6).

A thin, dense, black sapropel, almost barren of foraminifers is present at the top of the interval, in Section 6-3. It underlies the Pleistocene sediments which are intercalated in the early Pliocene section. We refer this sapropel to the early Pliocene, but remain unsure of its biostratigraphic position because of its practically barren nature.

Samples examined from the pink oozes at 110, 130, and 140 cm in Section 3 consistently yield foraminiferal populations characteristic of the *Sphaeroidinellopsis* Acme Zone, as do the sediments analyzed from 36 cm in Section 4, overlying the "Mystery Sapropel."

A thick, dilute sapropel (dubbed the "Mystery Sapropel" onboard ship) which is finely laminated in its lower part, is present from 55 to 75 cm in Section 4. It is very rich in planktonic foraminifers including abundant, giant-size Orbulinas (Figure 25). All the species recorded from this sapropel have an epipelagic habitat. Mesopelagic taxa were not recorded. Many broken tests were noted.

Representatives of the genus *Sphaeroidinellopsis* were recorded from the whitish calcareous marls underlying the "Mystery Sapropel" (Samples 6-4; 80 cm and 6-4; 90 cm), but were absent in the gray marls at Sample 6-4; 101 cm. This last sample, along with that investigated from Sample 6-4;117 cm are discussed below.

Typical assemblages of the *Sphaeroidinellopsis* Acme Zone were again recorded in the white to pinkish oozes at Sample 6-4; 135 cm and in the core catcher.

Miocene/Pliocene Boundary at Sites 375 and 376

At Site 375 the Miocene/Pliocene boundary coincides with the sharp sedimentary break recorded at Sample 375-1-1, 60 cm where a white ooze some 2 cm thick is in contact with an olive-gray marl a few cm thick overlying gypsum. Both sediments are fossiliferous: the white ooze is a biogenic sediment extremely rich in planktonic foraminifers and calcareous nannofossils which are characteristic of an early Pliocene age (see above). The olive-gray marl contains *Cyprideis "pannonica"* associated with spores, gypsum, fragments, and angular and frosted quartz grains.

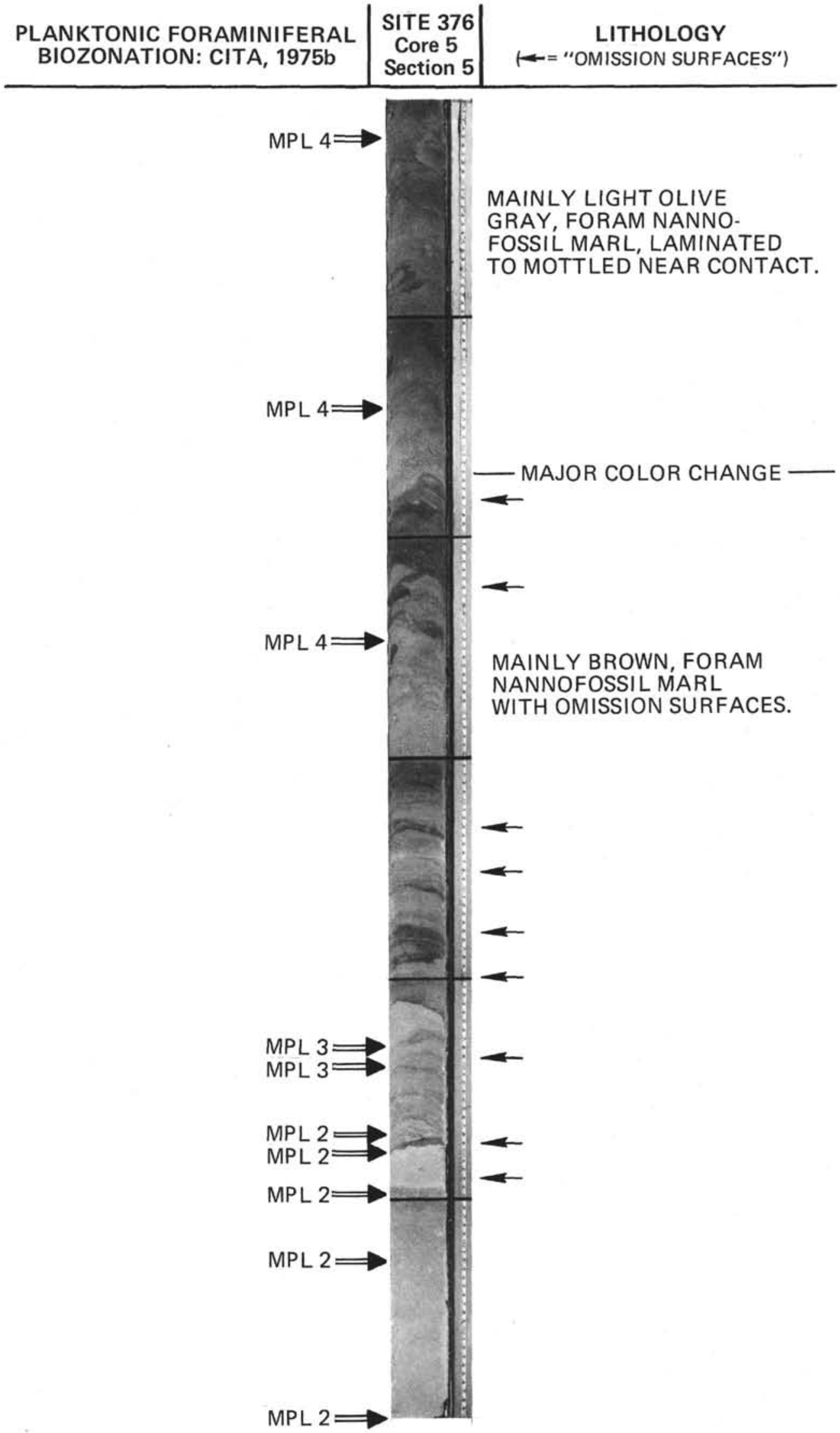

Figure 24. *Biozonation by M. B. Cita of the extremely condensed Pliocene, Section 5 of Core 5, Site 376.*

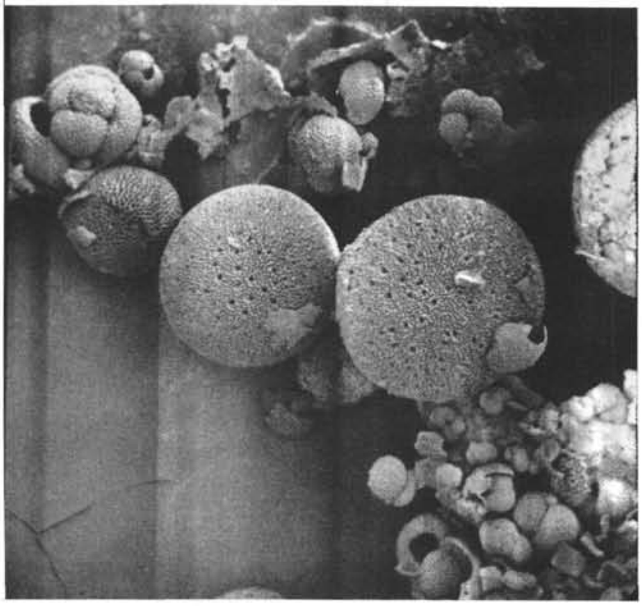

Figure 25. *Giant* Orbulinas *from the "Mystery Sapropel" layer, 376-6-4.*

The paleoenvironments suggested by the two adjacent lithologies are markedly different: a deep-sea, open marine, well-oxygenated environment of the early Pliocene overlies an oligohaline alkali lake environment of the latest Miocene.

With reference to the time scale of Ryan et al. (1974) the hiatus at the base of the Pliocene has an estimated duration of approximately 1 m.y.

At Site 376 we have two Miocene/Pliocene boundaries: one at 100 cm in Core 6, Section 4 and a second at the top of Core 7. This apparent paradox is explained as a drilling artifact.

A sample (6-4, 101 cm) taken at the top of an olive-gray fine-grained, structureless mud which overlies a similar but disturbed lithology and underlies a coarse-grained pale gray sediment grading into the Mystery Sapropel, recorded a faunal assemblage with: *Orbulina universa, O. bilobata, Globigerina bulloides, G. bulbosa, G. nepenthes, Globigerinoides obliquus obliquus, G. obliquus extremus, G. quadrilobatus, G. sacculifer*, plus one valve *of Cyprideis "pannonica."*

A sample from the disturbed gray interval referred to above and taken at 117 cm yielded an assemblage of planktonic foraminifers similar to that recorded from 101 cm but including also *Sphaeroidinellopsis seminulina* plus an admixture of (a) fine detrital quartz, (b) mica flakes, (c) gypsum crystals, (d) spores, (e) *Cyprideis "pannonica,"* and (f) *Ammonia beccarii tepida.*

The *Cyprideis* faunal assemblage is a typical Caspi-brackish, continental association characteristic of the "Lago-mare" environment (see Cita et al., this volume). The assemblage is never recorded together with abundant and well-diversified planktonic foraminiferal assemblages since the ecological niches of these faunas are very different.

Messinian at Sites 375 and 376

The Messinian succession recovered by continuous coring at Site 376 on the edge of the Antalya Basin consists of two distinct lithologic units which also differ markedly in their fossil content.

Forty samples were investigated from lithologic Unit V (Cores 7 to 15 inclusive) which consists of grayish marlstones, siltstones, and sandstones, with occasional gypsum beds. None was useful for biostratigraphy. As a consequence, detailed range charts have not been prepared for this interval. The fossil content is extremely variable in both quantity and quality. Several samples are barren, such as 7-1, 110-112 cm; 7-2, 60-62 cm; 7, CC (containing an extremely small sand-size fraction); 8-1, 80-82 cm (with fine sand); 8-3, 50-52 cm; 10-1, 112-114 cm; 10-3, 74 cm (yielding a large, unsorted, coarse sand-size fraction: turbidite); 11-2, 105-106 cm; 12-2, 70-72 cm; 12-3, 30-32 cm; 12-4, 75-77 cm; 13-4, 130-132 cm; 13, CC (with an extremely small sand-size fraction; and 15-2, 70-72 cm: Other samples yielded abundant reworked faunas indicating various ages and habitats. For example, Samples 11-3, 100-102 cm and 11, CC yielded very abundant, partially abraded tests and fragments of large foraminifers such as *Lepidocyclina*; 12, CC yielded interalias *Globotruncana fornicata*; and other species reworked from the Upper Cretaceous; 13-3, 47-49 cm contained an extremely abundant fauna of planktonic foraminifers indicating a Serravallian age, with *Globoquadrina dehiscens advena, G. altispira, Globorotalia mayeri*, etc., and 15, CC yielded Eocene *Globorotalias* and upper Cretaceous *Globotruncanas.*

Sparse, small planktonic foraminifers with a wide stratigraphic range in the Neogene, including the latest Miocene, were recovered at several intervals, including 7-1, 44-46 cm; 7-1, 54-56 cm, 7, CC; 9, CC; 10, CC; 12-3, 97-99, 12-3 CC; and 15-3, 50-52 cm. The taxa recorded include *Globigerina quinqueloba, Globigerinita glutinata*, and occasionally *Orbulina universa.*

The most characteristic fossil of this unit, however, is *Cyprideis "pannonica,"* a typical constituent of the Caspi-brackish faunal assemblage (see Ruggieri, 1967; Benson, 1973; Cita et al., this volume). The highest record of this taxon at Site 376 is in Section 4 of Core 6, at 101 cm (one valve). It is consistently recorded from Cores 7 to 15, with the exception of the barren intervals (see above). It was recorded in Samples 7-1, 54-56 cm; 8, CC; 9-1, 64-66 cm; 9-2, 120-122 cm; 9-3, 40-42 cm; 9-3, 134-136 cm; 9-3, 136-138 cm; 9-3, 138-140 cm; 9, CC; 11-3, 100-102 cm; 11, CC; 12-5, 60-62 cm; 12, CC; 13-2, 96-97 cm; 13-3, 47-49 cm; 14, CC, and 15-1, 80-82 cm. It often co-occurs with *Ammonia beccarii tepida.*

Lithologic Unit VI, the evaporite formation, represents an abiotic environment. In the core catcher of Core 16 the sand-size fraction of the sediment is made up of gypsum, with small amounts of small-sized detrital quartz. Occasional foraminifers were recorded, including *Globorotalia mayeri* and *Cibicides* sp. They are reworked whereas the fairly abundant fauna of

Ammonia beccarii tepida, a species which is tolerant of high salinity, might be autochthonous.

At Site 375, Messinian sediments were recovered from Core 1 (below 60 cm in Section 1) to Core 3 inclusive. Of the eight samples examined from this interval, only four were found to be fossiliferous. They were: (1) 1-1, 60 cm from above the gypsum, as discussed under the heading Miocene/Pliocene boundary; (2) 2-2, -30-32 cm which yielded abundant fragments of gypsum, rounded quartz, green rock fragments, and abundant reworked forms with *Amphisteqina,* fragments of *Lepidocyclina* and several shelf species. Also planktonic foraminifers are recorded, with *Globoquadrina dehiscens* as most prominent species; (3) 2-3, 127-128 cm: here the sediment fraction greater than 63μ was almost entirely gypsum fragments. A few plant debris were noted, as well as two speciments of *Globigerina* (contaminants?); (4) 2-4-7-8 cm: as well as quartz, gypsum, and glauconite, several foraminifer were recorded in this sample: *Bolivinoides miocenicus, Ammonia beccarii tepida,* and several planktonic species including *Globigerinoides trilobus, Globorotalia miozea, G.* cf. *acostaensis, Orbulina universa, Globigerina bulloides, G. bulbosa,* and *Globigerinita glutinata.* The preservation of the tests is very poor and reworking is considered probable.

Tortonian at Site 375

Cores 4 to 7 of Site 375 can be referred to the Tortonian stage, which extends biostratigraphically from Zone 15 (pars) to Zone 17 (pars) on the standard scale (see Cita and Blow, 1969; Ryan et al, 1974). Detailed range charts appear in Cita et al., this volume.

Following Blow's zonation, Core 4, Sections 1 and 2 can be referred to Zone N17 and the remaining sections to Zone N16. By the recently proposed zonation by d'Onofrio et al, (in press), the four cores under discussion are referable to the *Globorotalia acostaensis* Zone, *Globigerinoides obliquus extremus* Subzone (Cores 4 and 5) and *Globorotalia opima continuosa* Subzone (Cores 6 and 7). With reference to the Mediterranean zonation of Bizon and Bizon (1972), Cores 4 and 5 can be referred to the *Globorotalia dutertrei-humerosa* Zone and Cores 6 and 7 to the *Globorotalia acostaensis* Zone.

Cores 4 and 5 yielded rich and diversified fossil assemblages in most samples. *Globigerinoides obliquus extremus* was consistently recorded along with *Globorotalia acostaensis* and *G. humerosa. Globortalia* cf. *plesiotumida* was recorded only in Core 4 along with numerous keeled Globorotalias including *G.merotumida* and the *G.menardii* plexus. These taxa are illustrated in the plates of Cita et al., this volume. *Globigerina nepenthes* was abundant and was represented by very typical, well-developed specimens.

Generally Cores 6 and 7 are less fossiliferous than Cores 4 and 5, and they display more turbiditic layers. Foraminifers are rare to abundant depending on the nature of the sediment. The content of sand-size pyrite decreases downhole suggesting a gradual improvement in ventilation. An organic-rich sapropel was recorded at Sample 5-3, 21-23 cm. Bryozoa and fragments of thick-shelled pelecypods were recorded in Sample 6-1, 145 cm which also yielded the inner shelf foraminifer *Discorbis.* A heterogeneous, well-sorted sand was recorded in the same core at 134 cm in Section 2. Fragments of pelecypods were recorded along with abraded *Spiroloculina, Spiroplectammina carinate,* and plant debris. This turbiditic layer with its richness in organic matter suggests sediment transport by turbidity currents within a stagnant basin. A turbiditic layer from Section 4 of Core 6 (71 cm) yielded abundant quartz fragments, both angular and rounded. Shell fragments, otoliths, ostracodes, and abraded *Elphidium, Quinqueloculina,* and *Ammonia beccarii* are recorded along with rare planktonic foraminifera.

Reworked foraminifers are recorded in Samples 6-3, 30-22 cm and 6-3, 58-60 cm. Other samples investigated are barren (6-5, 40-42 cm, 7-4, 76-78 cm, and 7-5, 48-50 cm).

No typical specimens of *Globigerinoides obliquus extremus* were found in either Core 6 or Core 7, however specimens of *G. obliquus obliquus* transitional to *extremus* occurred in Core 6, which indicates that these sediments are not far from the biostratigraphic horizon marked by the first occurrence of that taxon.

Serravallian at Site 375

Cores 8 and 9 can be referred to the Serravallian stage, which includes Zones 10 to 15 (pars) of Blow's standard scale. Fifteen samples were studied from these two cores, which contain several pelagic turbidites. The pink, semi-indurated sediments of Core 8 yielded moderately to poorly preserved foraminiferal assemblages. The fossil record is complicated by extensive displacement of foraminiferal tests by turbidity currents. For example, samples from 140-142 cm in Section 1 are extremely rich in planktonic foraminifers, but these are sorted by size, with an unusual abundance of giant-size, subspherical forms. These belong to the species *Globoquadrina dehiscens advena* and in part to *Globoquadrina altispira.* The biostratigraphic assignment is to Zone N 13. The N 13/N 14 zonal boundary is defined by the first evolutionary occurrence of *Globigerina nepenthes,* evolving from *G. druryi.* Phylogenetically advanced specimens of *G. druryi* are consistently recorded from this core, however no true *G. nepenthes* has been found. The assignment to the latest part of Zone N 13 is supported by the occurrence—in 8, CC—of *Globigerinoides subquadratus,* a species which becomes extinct in the latter part of Zone N 13.

More pelagic turbidites were found in Core 9. The sediment fraction greater than 63 μm at 20-22 cm in Section 3 is entirely biogenic, and is at least 10 times more abundant than the sand-size fraction of normal biogenic sediments. The organic productivity of the planktonic foraminifers is such as to represent approximately 10% to 15% of this sediment whereas in Recent or late Pleistocene sediments from the eastern Mediterranean it is less than 5%. Such an enormous quantity of foraminifers can be explained only by post-depositional transport. Sorting by size is obvious: the most prominent (not necessarily the most abundant) forms are giant-size *Globoquadrinas* with subsphaerical shape, mostly *G.dehiscens advena.*

Similar pelagic turbidites extremely rich in planktonic foraminifers are recorded at Samples 4-4, 6 cm and 4-1, 119-121 cm and at 4-1, 94-96 cm is a sandy turbidite. As well as *Globoquadrinas,* which are sorted by size, other significant species include *Globorotalia siakensis, Globigerinoides subquadratus, Globigerina druryi, Orbulina universa, O. suturalis,* and *Globorotalia peripheroronda* (highest occurrence in Sample 9-6, 114-116 cm).

The biostratigraphic assignment is to Zones N 11/N 12 of Blow's zonal scheme.

Langhian at Site 375

The sedimentary expression of the Langhian stage is found in Cores 10 and 11 at Site 375. The semi-undurated nature of the sediments means that the tests are poorly to moderately preserved and the recurrent presence of pelagic turbidites obscures somewhat the fossil record. Nevertheless the evolution of the *Praeorbulina-Orbulina* bioseries can be followed through this interval. Core 10 consistently yielded abundant *Praeorbulina* with highly evolved forms (*P.glomerosa circularis*) along with *Orbulina suturalis.* The latter taxon is recorded in Sections 2 and 3, but was not found in the core-catcher sample. The N 8/N 9 zonal boundary is consequently located in the lower part of Core 10. Noteworthy is the occurrence of fragments of pelecypods (small, thin-shelled ostreds) in 10, CC, quite similar in shape and size to those recorded from the Langhian at Site 372 (Sample 30-2, 110-112 cm).

Core 11 is pre-*Orbulina* datum in age; it is extremely rich in *Praeorbulinas,* and also yielded *Globoquadrina dehiscens advena, Hastigerina praesiphonifera, Globigerinoides subquadratus,* and *Globorotalia mayeri.*

The size-sorted layers of pelagic turbidites are packed with *Praeorbulina glomerosa* in both Cores 10 and 11: The average diameter of the larger specimens is 500 to 600μm.

Burdigalian

Early Miocene pre-Langhian sediments containing few poorly preserved foraminifer were recovered from Cores 12 and 13.

The (tentative) biostratigraphic assignment is to Zones N 6/N 7.

Planktonic Foraminifers (Bizon)

The detailed foraminiferal biostratigraphy of Sites 375 and 376 by this author is discussed in Baroz et al. (this volume) as well as correlation with land sections in Cyprus. A summary of the zonal assignments appears here.

Pliocene at Site 375

Sample 1-1, 50 cm belongs to the *Globorotalia margaritae evoluta* Zone of the lower Pliocene. In this pink colored nannofossil marl, the planktonic foraminiferal assemblages are dominated by *Globorotalia margaritae* and *Globorotalia puncticulata.* In the white colored nannofossil marl recovered somewhat below, at Sample 1-1, 55 cm, the *Globorotalia margaritae* Zone was identified.

Quaternary and Pliocene at Site 376

The interval from Core 1 to Sample 5-3, 7 cm at Site 376 is Quaternary in age. The boundary between the Quaternary and upper Pliocene can be drawn between Samples 375-5, 3-7 cm and 376-5, 3-18 cm. The first *Globorotalia truncatulinoides* associated with *Globorotalia tosaensis* occurs in Sample 5-3, 7 cm, while the last *Globigerinoides obliquus* occurs at Sample 5-3, 44 cm.

From Samples 5-3, 18 cm to 5, CC, a highly condensed section was recovered involving at least four and possibly five planktonic foraminiferal zones over a space of only 5 meters of nannofossil marl. Between Samples 5-3, 18 cm and 5-3, 110 cm (the last occurrence of abundant *Globorotalia crassaformis*), the foraminiferal assemblages are dominated by epipelagic species. *Globorotalia inflata* appears to be missing, but it is not excluded that this interval could be the equivalent of the *Globorotalia inflata* Zone. The interval from 5-3, 139 cm to 5-4, 95 cm is assigned to the *Globigerinoides obliquus extremus* Zone. The first occurrence of *Globorotalia aemiliana* was at Sample 5-4, 95 cm while the last occurrence of *Sphaeroidinellopsis* was at Sample 5-4, 134 cm. Between 5-4, 134 cm and 5-5, 77 cm is the *Sphaeroidinellopsis subdehiscens* Zone whereas between Samples 5-5, 84 cm and 5-5, 109 cm occurs the *Globorotalia margaritae evoluta* Zone. The interval from Samples 5-5, 127 cm to 5, CC belongs in the *Globorotalia margaritae* Zone.

Surprisingly, samples from Sections 6-1 and 6-3, down to 100 cm, are Quaternary in age.

In the interval from Samples 6-3, 104 cm to 6-3, 133 cm, assemblages are dominated by epipelagic species (*Globigerina* and *Globigerinoides*) predominant with *Globorotalia acostaensis* (right coiling) also present.

The *Sphaeroidinellopsis* acme occurs between Samples 6-3, 149 cm and 6-4, 56 cm (lowermost Pliocene).

Miocene at Site 375

Ammonia beccarii assemblages were recorded in Core 2 (7 to 30 cm). A limited number of samples were taken in the marlstones of lithologic Unit 6. A heterogeneous microfauna was found with reworked planktonic foraminifers from Maestrichtian to middle Miocene, associated with some species from the uppermost Miocene (*Globorotalia mediterranea, Globorotalia humerosa*). These samples cannot be older than the *Globorotalia mediterranea* Subzone of the Mediterranean area.

Two fragments of limestone breccia found in 3, CC and at 4-1, 101 cm contained highly recrystallized and generally undeterminable planktonic foraminifers with *Orbulina* sp.

From Samples 4-1, 136 cm to 5-5, 134 cm, only a few samples were fossiliferous. The others were very poor in microfossils and contained pyrite, cysts of algae, and some *Orbulina, Globigerina,* , and *Globigerinoides obliquus.* Two samples with *Globorotalia humer-*

osa (left coiling), *Hastigerina siphonifera involuta, Globorotalia psuedomiocenica* belong to the *Globorotalia humerosa* Zone, upper Miocene (Samples 5-5, 134 cm and 5-2, 100 cm). The interval from 5-6, 77 cm to Sample 7, CC is assigned to the *Globorotalia acostaensis* Zone.

The upper part of Core 8 may belong to the *Globorotalia menardii* Zone since the last occurrence of *Globorotalia mayeri* was recorded in Sample 8-3, 70 cm. The upper part of the core was very poorly fossiliferous but warrants further investigation.

Samples 6-4, 66 cm to 6-4, 125 cm record a gradual passage from an open marine to a restricted marine environment. The lowermost part of Core 6 (6-4, 140 cm to 6, CC) is a decollement surface associated with a sedimentary slump.

Samples 6-4, 66 cm to 6-4, 89 cm contain epipelagic assemblages with *Globorotalia acostaensis* (right coiling). Oligotypic assemblages were found in Samples 6-4, 108 cm and 6-4, 125 cm, with epipelagic species such as small *Bolivinas* and also *Rosalina* sp. This shallow water facies belongs probably to the upper Miocene.

The *Sphaeroidinellopsis* Acme Zone (lowest Pliocene) occurs for a second time from between 6-4, 140 cm (red marls) and 6, CC (white marls).

In Core 7-1, 39 cm, the oligotypic assemblage is again present with *Rosalina, Bolivina* and epipelagic planktonic foraminifers (upper Miocene?).

Samples taken in Cores 8 and 9 are dominated by associations of *Ammonia beccarii* and ostracodes, with some planktonic epipelagic foraminiferal species.

From Core 10 to Sample 15, CC, *Turborotalita* aff. *clarkei* was more or less recorded continuously, sometimes in considerable abundance. In the turbiditic layers, a few *Globorotalia mediterranea* associated with *Globorotalia acostaensis* (left coiling) and reworked species, from Maestrichtian to upper Miocene in age, were recorded. We can only say that this interval cannot be older than upper Miocene (*Globorotalia mediterranea* Subzone).

The interval, 8-3, 70 cm to Core 9-5, 28 cm belongs to the *Globorotalia mayeri* zone of the Mediterranean area.

The last occurrence of *Globorotalia fohsi peripheroronda* was determined in Core 9, Section 6 at 98 cm. Consequently, the interval 9-6, 98 cm to 10-3, 148 cm is assigned to the *Globorotalia fohsi peripheroronda* zone of the Mediterrranean area.

Core 11 belongs in the *Praeorbulina glomerosa* zone while Core 12CC was barren. Core 13CC is assigned to the *Globigerinoides altiaperturus-Globigerinita dissimilis* zone of the early Miocene Burdigalian stage.

Benthic Foraminifers

Site 375

The Lower Pliocene section of Site 375 contains some samples with a rich well-preserved upper mesobathyal (>1000 m) benthic foraminiferal fauna including *Astrononion umbilicatulum*, whereas other samples are barren of benthic foraminifers.

The upper part of the upper Miocene (?), Core 2, Section 2 (30 cm) contains many reworked and worn shelf (*Ammonia beccarii* and *Amphistegina lessonii*) and bathyal taxa (*Eponides umbonatus, Gyroidina,* and *Osangularia*) mixed together. Except for their worn character they are reminiscent of the mixed assemblages of Core 9 of Site 372. The remainder of the Messinian section is barren.

The Tortonian benthic foraminifers are small and the fauna is very restricted in abundance and diversity. The presence of *Epistominella rugosa convexa* indicates a depth at least in the low epibathyal zone (>500-700 m). There are numerous barren and turbiditic intervals in this sequence.

The middle Miocene benthic foraminiferal fauna is also very poor in quantity and preservation although the planktonic foraminiferal fauna seems rather well developed. Bottom conditions may have been semistagnant at the same time that layers higher in the water column were well oxygenated. Although few species were identified which give good paleobathymetric control, that fauna which is present suggests water depths in excess of 400-600 meters.

The lower Miocene samples contain a few poorly preserved *Epistominella, Eponides umbonatus,* and *Gyroidina* which indicate a lower epibathyal depth or greater. The fauna is very poor.

Site 376

The benthic foraminiferal fauna in the Pleistocene interval of this site is fairly well preserved and diverse, although not represented by many specimens. Specimens of the upper mesobathyal (>1000-1300 m) species including *Articulina tubolsa, Bulimina inflata, Gyroidina lamarchiana,* and *Uvigerina peregrina dirupta* occur. There are a variety of displaced shelf species and numerous glass shards in the upper part of the sequence. Sponge spicules (siliceous triaxons), Radiolaria, and echnoid spines are rare components of the samples.

The upper Pliocene section contains the upper mesobathyal species *Astrononion umbilicatulum, Bulimina exilis, Cibicides kullenbergi,* and *C. wuellerstorfi*. The specimens are well preserved but not particularly abundant. Benthic foraminiferal tests comprise about 2% of the tests, a proportion typical of water depths in excess of 1000-1200 meters.

The sapropelic sediments of the lower Pliocene contain a very poor benthic foraminiferal fauna in the sequences just above and below the sapropels whereas the planktonic fauna in these samples is rich. Apparently, semistagnant conditions on the bottom hindered benthic life at the same time that well oxygenated upper water layers were producing abundant pelagic sediments. When benthic foraminifers are present in the sequence, they are represented by upper mesobathyal taxa such as *Eponides polius*.

The upper part of the Messinian (upper Miocene) sequence consists of a mixed shelf (*Ammonia beccarii*), upper epibathyal (*Trifarina bradyi, Uvigerina mediterranea*) and lower epibathyal (*Epistominella rugosa convexa, Eponides umbonatus*) fauna. All of these specimens are poorly preserved and appear to be reworked. Lower in the section (Core 9) the fauna is dominated by a restricted shallow water inner shelf fauna consisting of *Ammonia beccarii* and the cytheracean ostracod *Cyprideis* sp. The well-preserved specimens of these two species are abundant. All growth stages are represented and consequently the specimens appear to be in situ. The association of these two species indicates a euryhaline environment although *Cyprideis* tends to dominate in water of lower salinity (2%-5% up to 20%-25%; Sandberg, 1964). The remainder of the Messinian sequence consists of poorly preserved species from inner shelf marine and euryhaline environments.

SEDIMENTATION RATES

Sedimentation rates were calculated for the Neogene succession penetrated at Sites 375 and 376 from the paleontologists' depth assignments of their zonal boundaries (Figures 22 and 23) and by reference to the time scale of Ryan et al. (1974). The implications of changes in sedimentation rate at these two sites are discussed in Cita et al. (this volume).

Site 375

No calculations of instantaneous sedimentation rates can be made for the Plio-Pleistocene section at Site 375 since: (1) it was not cored; (2) it is probably incomplete, as is suggested by the seismic profiles, and (3) it is separated from the underlying Messinian sediments by a significant time gap, estimated to span about 1 m.y. If this is taken into account, giving a time range of 4.2 m.y., the average sedimentation rate for the Plio-Quaternary would be 3.4 cm/10^3 yr.

More meaningful, although still average, sedimentation rates can be calculated for the pre-evaporitic succession, lithologic Units VII to XI.

Most of the plots shown in Figure 26 represent boundaries agreed on by the paleontologists and placed between cores. The plot of the Messinian/Tortonian boundary which was placed by convention between Cores 3 and 4 lays about 39 meters below the plot at –190 meters of the drill break which is thought to be the Messinian/Tortonian boundary. A line from the former to the 592-meter plot of the Tortonian/Serravallian boundary placed between Cores 7 and 8 gives a mean late Miocene (Tortonian) sedimentation rate of 7.0 cm/10^3 yr. This relatively high rate would appear consistent with the Lithologies encountered in these cores, which are hemipelagic sediments with turbidites.

A line drawn from the 592-meter point to that for the Serravallian/Langham boundary, placed by the paleontologists at the base of Core 9 at 660 meters illustrates a sharp lowering in sedimentation rate over this interval. The resulting sedimentation rate for the Serravallian, is 1.7 cm/10^3 yr. The remaining plot for the middle/lower Miocene boundary placed between Cores 11 and 12 allows calculation of an average sedimentation rate for the Langhian of 10.0 cm/10^3 yr. This is consistent with the drilled lithologies which in the Serravallian sediments are hemipelagic and pelagic types without significant terrigenous input.

Similar sedimentation rate changes have been observed in the middle and late Miocene of Cyprus by Baroz and Bizon (1974).

Site 376

Because of the condensed sequences and slumped units observed within the Pliocene succession of Site 376, it is difficult to present a graphical interpretation of the sedimentation rates. Figure 27 plots only the Quaternary/Pliocene boundary placed by all the paleontologists at –39 meters subbottom and that for the Pliocene/Miocene boundary placed on foraminiferal evidence at –55 meters subbottom. These determinations give an average sedimentation rate (2.2 cm/10^3 yr) for the Quaternary only. Very low values are likely in the lower Pliocene (averaging less than 0.1 cm/10^3 yr) where the condensed sequences are prominent.

Cores 7 to 23 contained Messinian sediments with obviously high sedimentation rates. If the sediments at the 216.5-meter terminal depth had been lowermost Messinian, the rates would be at least 115 m/m.y. They are certainly much higher than this when it is remembered that only part of the upper evaporite member was penetrated.

CORRELATION OF SEISMIC REFLECTION PROFILES WITH DRILLING RESULTS AT SITES 375 AND 376

Sites 375 and 376 were located on the Florence Rise, a marked feature in the bathymetry, running from Cyprus to the Anaximander Mountains and separating the Antalya Basin from the Levantine Basin. The IFP/CNEXO seismic profile OD 313 shows that this rise corresponds to a late Tertiary uplift bounded to the south by reversed faults (Figure 28). On both sides of this structure, the thick Messinian salt layer pinches out. This brings pre-evaporitic layers close to the sea bottom below a relatively thin cover of Pliocene and Quaternary sediment.

Site 376 was located near the top of the structure where a strong reflector (U) appears to come close to the sediment surface. In this area the Plio-Quaternary is about 100 msec thick (two-way travel time) and is separated from the pre-evaporitic layer by a strongly diffracting surface, which was interpreted as an erosional feature. The deep reflector U is about 480 msec (two-way travel time) below this diffracting horizon.

Interval velocities calculated from the seismic reflection profiling have a relatively low precision due to the dip of the reflectors and to their unequal coherence. They suggest velocities of about 2 km/sec for the Plio-Quaternary and 2.5 km/sec to 3 km/sec for the next interval as far as reflector U.

Drilling at Site 376 showed the Pliocene and Quaternary to be 138.5 meters thick, which is in general agreement with the calculation from the seismic profile of about 160 meters. Below the Pliocene about 55 meters of gypsum sediment were drilled. This layer had not been detected on the seismic profile because of

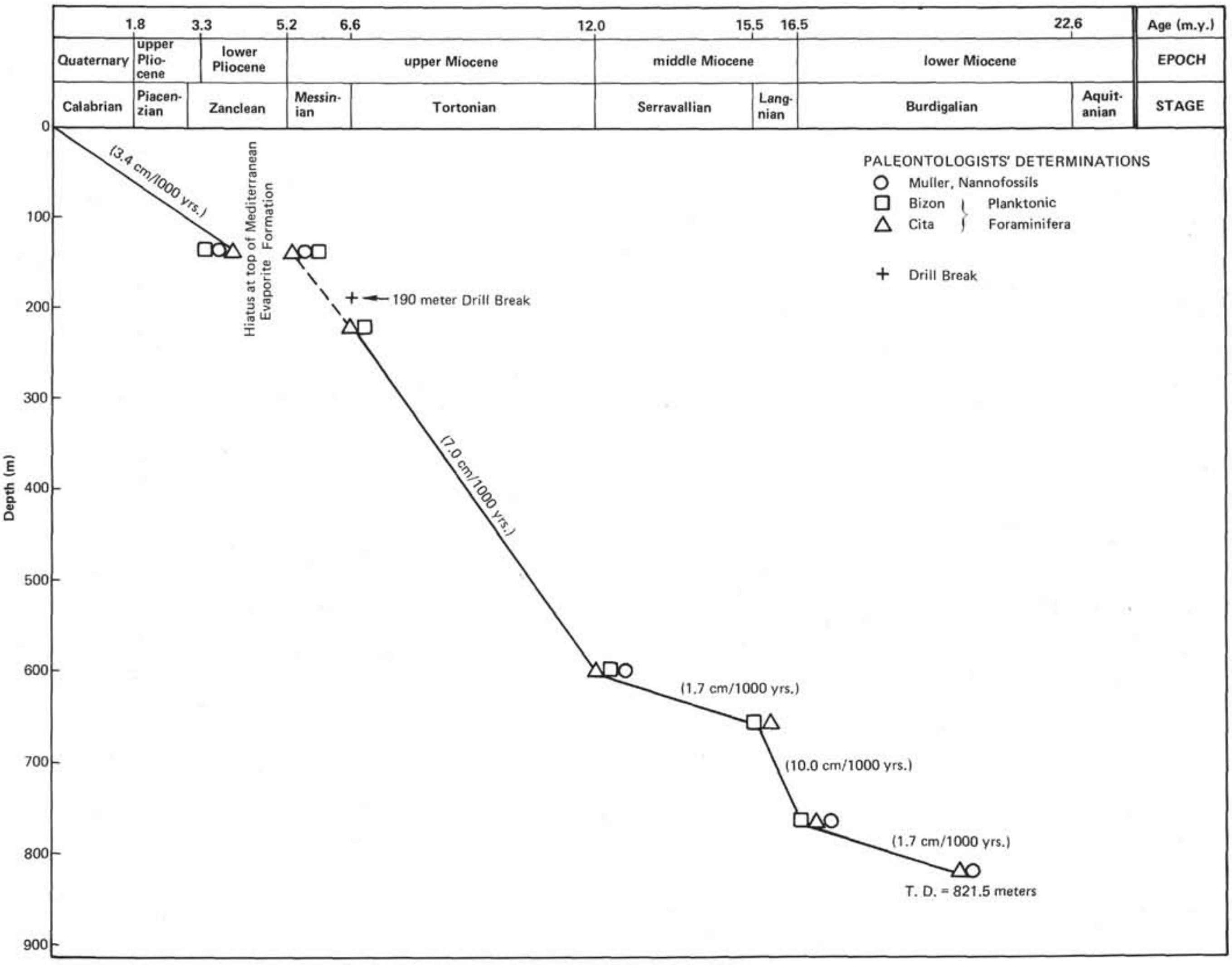

Figure 26. *Sedimentation rates at Site 375.*

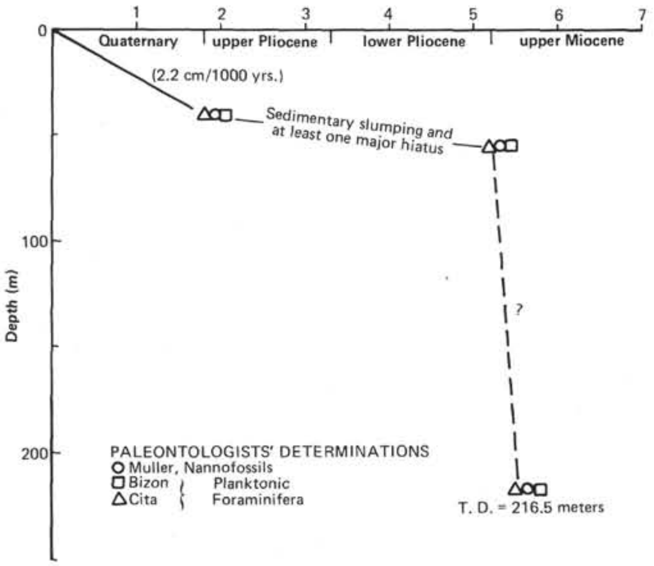

Figure 27. *Sedimentation rates at Site 376.*

its thinness (about 20 msec with a velocity of about 4 km/sec) which meant that it could not be distinguished as a separate layer from the rest of the section due to the length of the seismic impulse. Under the evaporites 485 meters of Tortonian and Serravallian marls and turbidites were drilled. Drilling was continued as far as sediments of Langhian and Burdigalian age. The sediments of Langhian age are characterized by the presence of hard limestone layers which caused marked changes in drilling behavior. The Langhian is about 57 meters thick and overlies marls and limestones of Burdigalian age. As inferred from the seismic data, the depth of reflector U is about 650 meters below Plio-Quaternary with a mean velocity of 2.7 km/sec for 680 msec (two-way travel time). If a calculation is made taking into account the evaporites (65 m thick with a 4 km/sec velocity giving about 20 msec (two-way travel time) and only 460 msec (two-way travel time) of Tortonian-Serravallian, we obtain a thickness of about 620 meters for the Tortonian-Serravallian.

This value seems in fairly good agreement with drilling results (see Table 4) at Site 375. Thus it is

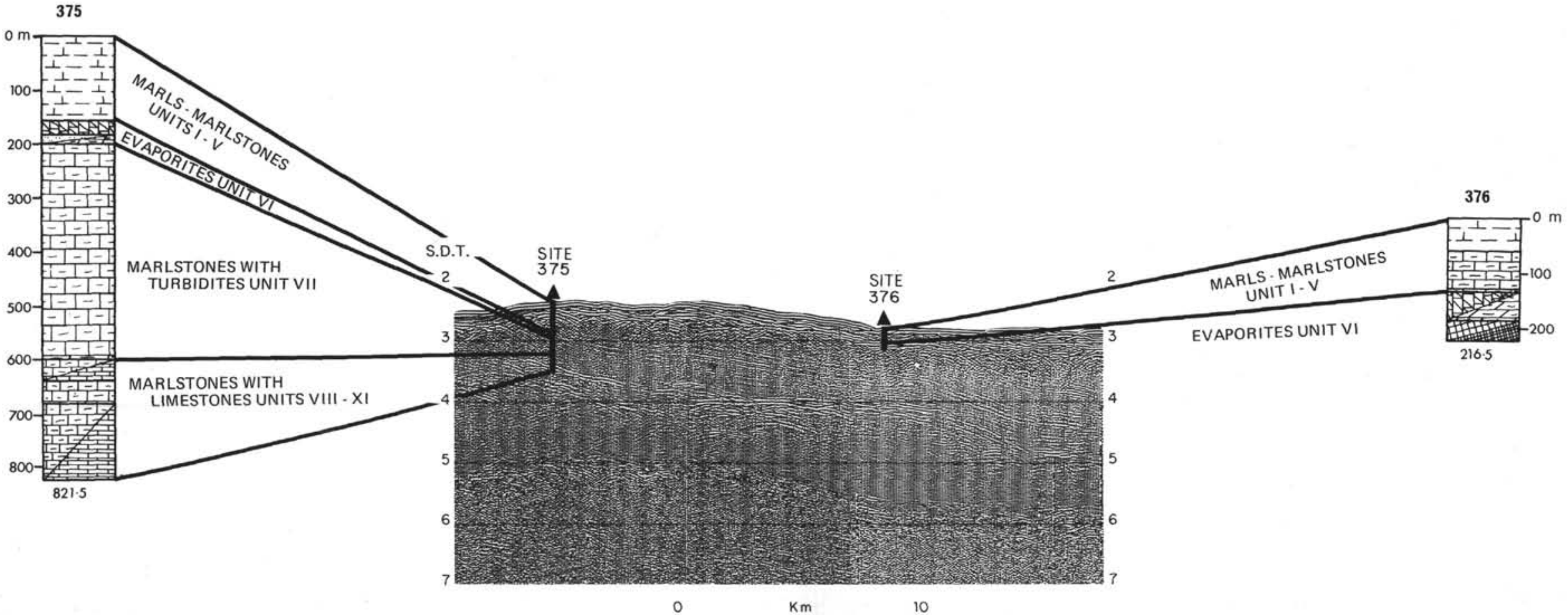

Figure 28. *Interpretation of IFP/CNEXO Profile OD 313 from drilling results at Sites 375 and 376.*

TABLE 4
Drilling Results

	Two-Way Travel Time (msec)	Thickness from Seismic Profile (m)	Thickness of Sediment in Hole 375 (m)
Pliocene and Quaternary	Bottom sea 0	160	138.5
	Top evaporites = 160		
Evaporites			55.0
	Base evaporites	650 (or 620)	
Tortonian Serravallian			485.0
	Top limestones = 810		
Langhian			57.0
Burdigalian			60.0

reasonable to conclude that the reflector U corresponds to the top of the limestone intercalations of Langhian age, and that a very thick sedimentary section still exists below.

SUMMARY AND CONCLUSIONS

Sites 375 and 376 were located on the Florence Rise, the submarine prolongation of the Cyprus Arc, which is a young tectonic feature partially separating the Antalya Basin to the north from the Levantine Basin to the south. The main objectives of these two drill sites were: (1) to reach the acoustic basement and determine its age and nature; (2) to obtain a stratigraphic and lithologic record of the pre-Messinian sediments; and (3) to reconstruct the environmental history of the eastern Mediterranean prior to and after the Messinian salinity crisis.

The drill sites were chosen from an IFP seismic profile oriented north-south across the rise. To the north of the rise, the acoustic basement of the Antalya Basin rises from a depth of more than 5 km subbottom to only about 1 km beneath the Florence Rise. Along this northern slope, the thick upper Miocene salt layer of the Antalya Basin pinches out towards the rise and successively older layers of pre-evaporitic sediment seem to subcrop beneath a veneer of Plio-Quaternary sediments. To the south the rise appears overthrust along a series of northward-dipping reverse faults.

Site 375 was drilled on the southern flank of the Rise near the crest with the intention of sampling the pre-evaporitic horizons and if possible, to reach the "basement." The site was located at 34°45.74′N and 31°45.58′E in 1900 meters of water. After spot coring in the pre-evaporitic formations, the hole was terminated at 821.5 meters subbottom in marls and limestones of early Miocene age due to collapse of the drill bit. Consequently our first objective of reaching acoustic basement was unrealized.

Site 376 was located some 12 km to the north, at the southern margin of the Antalya Basin and near the pinch-out of the salt layer. Its coordinates were 34°52.32′N and 31°48.45′E and its water depth 2101 meters of water. The hole was cored almost continuously to 216.5 meters subbottom, at which depth it also had to be abandoned, this time in the Messinian evaporite formation, in accordance with the instructions of the JOIDES Safety Panel. The two holes complement each other with only a small duplication of cored section within the evaporite formation. Thus the description of the post-evaporitic and evaporitic units is mainly based on Site 376.

Eleven lithologic units have been distinguished: four in the Pliocene-Quaternary, two in the upper Miocene evaporite sequence, and five in the lower to middle Miocene.

Unit I consists of Quaternary nannofossil marls with minor intercalations of sapropelic marls and volcanic ash (tephra). The unit is about 37 meters thick. Its sediments are hemipelagic and were deposited in an environment which at times was stagnant and highly reducing, while at other times it was slightly oxidizing. The lack of burrowing and the predominantly drab gray colors suggest that slightly reducing conditions prevailed on the sea bottom over most of the interval. Water depths in excess of 1800 meters are indicated by fairly well preserved and diversified benthic foraminifers.

Units II, III, and IV are composed of nannofossil marls and nannoforam marls of Pliocene age with a probable slumped bed (Unit IV) consisting of intercalated Quaternary, Pliocene, and probable upper Miocene sediments near the base of the Pliocene section. The thickness of Units II through IV is only 16 meters and a stratigraphic hiatus is present between the upper Pliocene and the lower Pleistocene, as indicated by the absence of the uppermost biozone of the Pliocene (MPl-6). The uppermost Pliocene (Unit II, biozone MPl-5) is similar in color and composition to Unit I and also contains interlayers of sapropels. The middle Pliocene (upper part of Unit III) contains a very condensed sequence with thin, brown, moderately burrowed layers enriched in iron oxides. All foraminiferal zones from biozone MPl-2 through 4 are present, but the average sedimentation rate is only about 0.1 $cm/10^3$ yr. There might be minor hiatuses, as suggested by the presence of iron-enriched horizons ("omission surfaces"), and by shipboard investigations of nannofossils. The lower part of lithologic Unit III (biozone MPl-1) consists of bluish-white and light gray nannofossil marls with two prominent sapropel layers. At the base, but clearly within Unit III, a complex of chaotically deformed slumped marls (Unit IV) occurs, comprising gray nannofossils of probable Miocene age and minor light brown to pale yellowish-brown marls of the lowermost Pliocene (MPl-1). These deformed sediments are interpreted as an early Pliocene sedimentary slump.

Unit V consists of nannofossil dolomitic marlstones, with intercalations of siltstones and sandstones. The marls are dark gray to dark greenish-gray. They are composed of dolomite, clay minerals, and varying amounts of biogenic material. The darker beds are mainly turbidites with graded bedding. The detrital component of these turbidites is made up of clasts of carbonate rocks, altered volcanics, quartz, and heavy minerals. Some of these materials were considered as derived from an ophiolite terrain. Detrital gypsum also occurs in some of the turbidites.

The dolomitic marls commonly contain a significant assemblage of *Ammonia beccarii* and *Cyprideis pannonica*, a peculiar benthic fauna that has been recognized in the upper Messinian formations of the Periadriatic, in Sicily, in Leg 13, Hole 129, under the Mediterranean Ridge (Ryan, Hsu, et al., 1973) and also in other regions on land (Cita et al., Messinian Paleoenvironments this volume), and in Paratethyan basins of eastern Europe (Jiricek, 1975). Biometric analyses (Cita et al., this volume) suggest that the fauna is autochthonous or displaced for short distances only. These marls were for the most part deposited in a euryhaline environment. An important supply of fresh or brackish waters from continental sources is also indicated by isotopic data (see Pierre and Fontes, this volume; McKenzie and Ricchiuto, this volume; Ricchiuto and McKenzie, this volume).

Marine microfossils, such as oligotypic planktonic foraminifers and cysts of marine planktonic algae have been identified in several horizons. Their presence suggests the occasional influx of marine waters into this predominantly brackish "Lago Mare" environment.

Parts of Unit V have also been recognized at Site 375; however, its thickness there is unknown. Seismic data show that Unit V increases markedly in thickness towards the Antalya Basin.

Unit VI comprises part of the upper Mediterranean evaporite formation. At Site 376, two subunits have been distinguished: Subunit VIa consisting of gypsum and green dolomitic marlstone, and Subunit VIIb, anhydrite and halite. The thickness of the evaporites is less than 50 meters at Site 375, but more than 76 meters at Site 376. Gypsum crystals of various types, but mainly selenitic (Subunit VIa), appear to have grown in the sandy dolomitic marls. Laminated, fine-grained balatino-type gypsum is also present. Both the selenitic and the laminated gypsum are indicative of deposition in shallow subaqueous environments. Gypsum crystals also occur as clasts in a green marly matrix, forming gypsrudite and gypsarenite. Recovered lithologies in Subunit VIb comprise pieces of clear, coarsely crystalline halite as well as anhydrite with chicken-wire structure and enterolithic folds. The halite has a very low bromine content of about 2-30 ppm (Kuëhn and Hsü, this volume).

Unit VII consists of dark colored nannofossil marlstones which are dolomitic in the upper part of the unit, with interbedded turbiditic arenites and siltites. The unit is late Miocene in age. These rocks show a typical flysch-like cyclic development with graded turbiditic arenites and siltites, gradually fining upwards into homogeneous and nonburrowed marlstones. These are usually overlain by hemipelagic basinal sediments, which are only sparsely burrowed. Organic-rich sapropelic layers occur as "normal" basinal deposits as well as graded turbiditic sediments.

The sedimentation rate of these flysch-like sediments is relatively high (about 7 cm/10^3 yr). The redeposited material is made up of lithic fragments, carbonate, some quartz, plagioclase, plant fragments, biotite, hornblende, and occasionally volcanic glass. Deposition of this material apparently took place in a semireducing and episodically stagnant basin.

Units VIII through XI are hemipelagic deposits of middle Miocene (Units VIII through X) and early Miocene (Unit XI) age. The overall pattern of these hemipelagic deposits is a centimeter-to decimeter scale alternation of dark marlstones grading into lighter colored more calcareous and burrowed lithologies rich in planktonic foraminifers. The basal marly parts of the cycles are interpreted as the distal parts of turbidites.

The various units in the lower part of the hole have been distinguished mainly on the basis of color variation. The dark and olive-gray Units IX and XI were deposited in somewhat reducing conditions, whereas the variegated Unit VIII and the red Unit X were under more oxidized conditions. Unit X ("Orbulinico rosso") includes several layers of resedimented pelagic materials ("pelagic turbidites"). Some of these sediments are cemented to hard foraminiferal limestones, which constitute the prominent reflector U on the IFP profile (Figure 24).

Units VIII, IX, X, and XI were deposited in a bathyal (> 1000 m) basin at a rate of at least 2.5 cm/10^3 yr, which is comparable to that of open-ocean pelagic sediments.

Comparison of the Drill Sites with Land Sections

The pre-evaporitic sequence recovered at Site 375 correlates very well with sequences described on land in Cyprus. There, in the northern part of Mesaoria and along the Kyrenia Range, a sedimentary sequence has been described by Baroz and Bizon (1974) that is in part identical to the pre-evaporitic Neogene at Site 375. A tentative correlation chart is shown in Table 5.

There is considerable evidence that the Troodos massif was thrust and uplifted before the Neogene, more specifically during Maestrichtian (Biju-Duval et al., 1974). Further Miocene uplift is indicated by the unconformity of Miocene deposits on top of the oceanic sediments and pillow-lavas of the Troodos. At Site 375, the Neogene sequence evidently reflects Tortonian orogenic movements in this part of the Mediterranean, as does the Kytrea flysch on Cyprus. Post-Tortonian

TABLE 5
Stratigraphic Correlation Between the Neogene Sequences of Northern Cyprus and Sites 375, 376

	Leg 42A	Northern Cyprus (Baroz and Bizon, 1974)	
		Pentadaktylos Range Ovgos Potamos	Mesaoria
(Early Pliocene	Units 3 – 4	Myrtou Marls	Myrtou Marls)
Messinian	Unit 5		
	Unit 6	Lapatza Formation	Lapatza Formation
Tortonian	Unit 7	Davlos Sandstone	Mia Milea Member
Serrayallian	Unit 8		
	Unit 9	Trapeza Marls	
Langhian	Unit 10	Panagra Marls	Panagra Marls
Burdigalian	Unit 11	Flamoudi Sandstone	Lefkara Formation

movements are indicated by the pinch-out of the salt-layer towards the Florence Rise. The youngest deformations are Pliocene to possibly even Recent in age, since the Messinian evaporites on Cyprus have been deformed and uplifted accompanying thrusting movement in the Kyrenia Range and other parts of the Cyprus Arc.

Origin of the Evaporites

Seismic data show that only the upper evaporite member is present at Site 375 and that Site 376 only penetrated the top of this. As at Site 374, we noted a systematic upward change in depositional environment during the late Messinian from salt precipitation to alternate formation of gypsum and dolomite, ending finally in subaqueous deposition of dolomitic marls.

The salt at Site 376 is interlaminated with gypsum. Magnesium or potash salts were not present in our cored section. The salt has a low bromine content (24 to 30 ppm), less than half that of the first halite from modern Mediterranean saltpans. Either the salt brines here were diluted by continental waters (low in bromine), or the salt has been recycled, and thus is similar in origin to members C and D of the salts mined in Sicily (Decima, 1975). The Sr-content of the gypsum is low compared to that in gypsum coprecipitated with halite (Kuehn and Hsü, this volume); a fact that also argues against salt-precipitation from a brine of purely marine origin. The brine pool was probably not deep, and Site 376 was subaerially exposed when the nodular anhydrite (capping the salt) was deposited. The gypsiferous sediments were deposited mainly in a shallow subaqueous environment. Evidence of subaerial exposure is scarce. The erosion of penecontemporaneously deposited gypsum and the sedimentation of the eroded debris as gypsrudite and gypsarenite suggests a shallow subaqueous environment similar to the intertidal flats fringing the sabkhas of Persian Gulf. A sudden change in the O^{18} value in gypsum may indicate a hiatus in sedimentation, when Site 376 might have been subaerially exposed (see Pierre and Fontes, this volume; McKenzie and Ricchiuto, this volume; Ricchiuto and McKenzie, this volume). However, no well-defined cycles of periodic flooding and exposure, such as those exhibited by the Site 374 cores, can be recognized at Site 376.

The last stage of the Messinian salinity crisis is represented at Site 376 (as in Site 374) by deposits of a "Lago Mare" environment. Marls were deposited in a euryhaline (and probably hyposaline) subaqueous body and interbedded with sandy turbidites. At times the water-chemistry favored the precipitation of calcite which constitutes a limestone comparable to the "Colombacci" of Italy. At other times, especially near the end of the salinity crisis when Units 5A and 5B were deposited, conditions permitted the formation of dolomite. The large influx of water from continental sources may have kept pace with evaporation and outflow so that this lake remained fresh or brackish. Yet there might have been repeated influx of marine waters which brought in marine microfossils to live in a more saline "Lago Mare" environment. The water level of the lake was probably seldom, if ever the same as the worldwide sea level, and it must have been considerably lower when Site 376 was covered by a shallow subaqueous body since the basin had been deep since pre-Messinian times.

The salinity crisis ended abruptly here as elsewhere in the Mediterranean. The dolomitic marls bearing a euryhaline *Cyprideis* fauna are overlain by a deep marine sediment of earliest Pliocene age (MPl-1). The basin very quickly attained a depth in excess of 1300 meters and has remained deep since then.

Heat Flow

Five downhole temperature measurements were made at Site 376. The upper three measurements, between 26.5 and 74.0 meters subbottom, were used to calculate a heat flow of 0.94 ±0.35 μcal/cm^2 sec. The lower two measurements at 102.5 and 131.0 meters subbottom, gave temperatures significantly lower than expected from downward extrapolation of the thermal gradient determined from the upper three measurements. These last measurements are believed to have been affected by unusual hydrologic conditions in the borehole and/or by the presence of slumped material in the hole during the temperature measurement, and thus have not been used in determining the heat flow at this site.

The poorly determined heat flow value of 0.94 μcal/cm^{2}sec is consistent both with the mean (0.74 ±0.30 μcal/cm^{2}sec) of 33 conventional heat-flow values in the eastern Mediterranean reported by Erickson (1970), and with the heat flow of 0.80 μcal/cm^{2}sec determined at Site 374 in the Messina Abyssal Plain. The generally low heat-flow values characteristic of the eastern Mediterranean suggest that this area as a whole has had a fundamentally different origin and geologic history than the western Mediterranean, where the heat-flow average is approximately three times higher than in the eastern Mediterranean. The regionally low heat flow suggests that the eastern Mediterranean is very old, and may also be indicative of depression of the isotherms as the sea floor is subducted beneath the Aegean and Tyrrhenian seas. For additional detail and analysis of heat-flow operations at this site, see Erickson and von Herzen, this volume.

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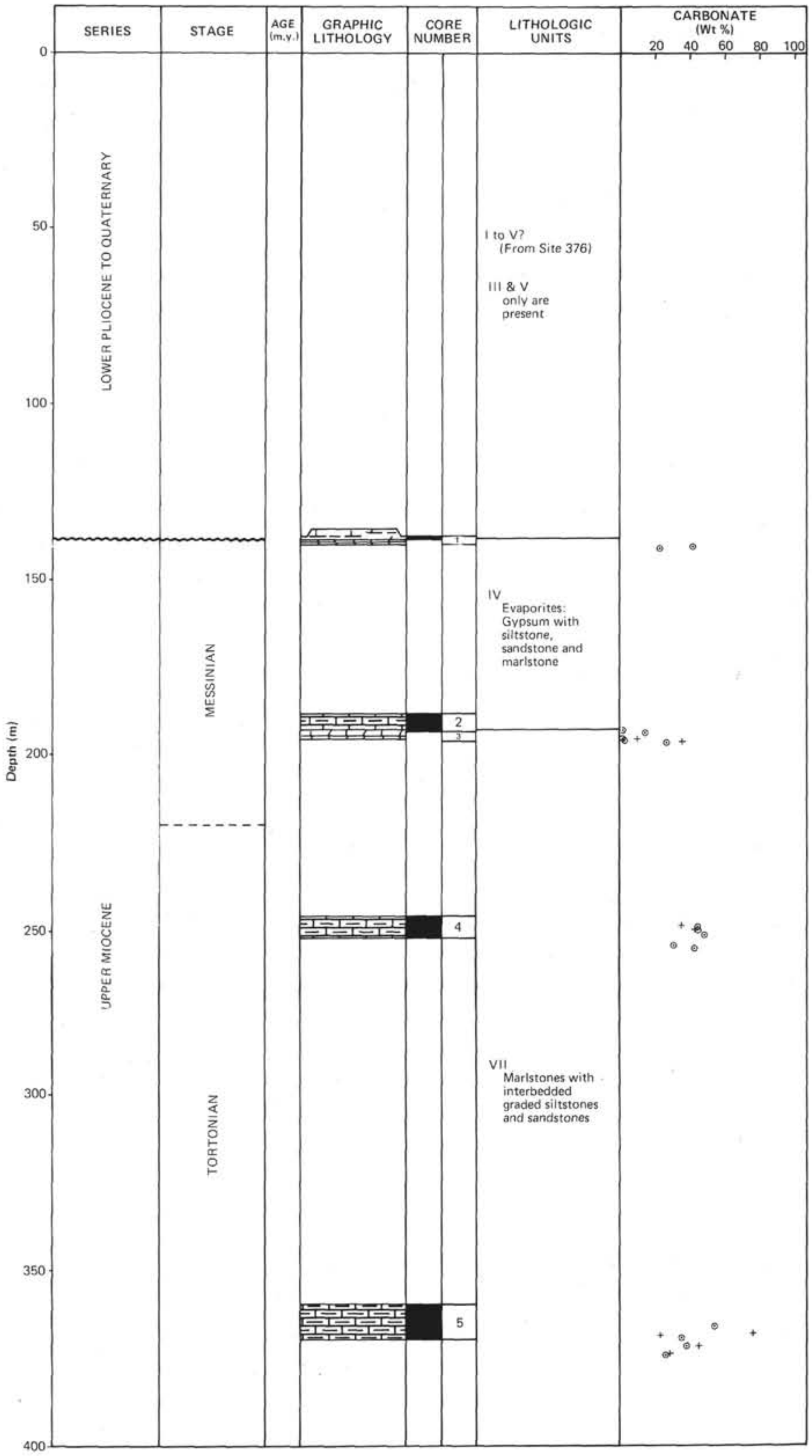
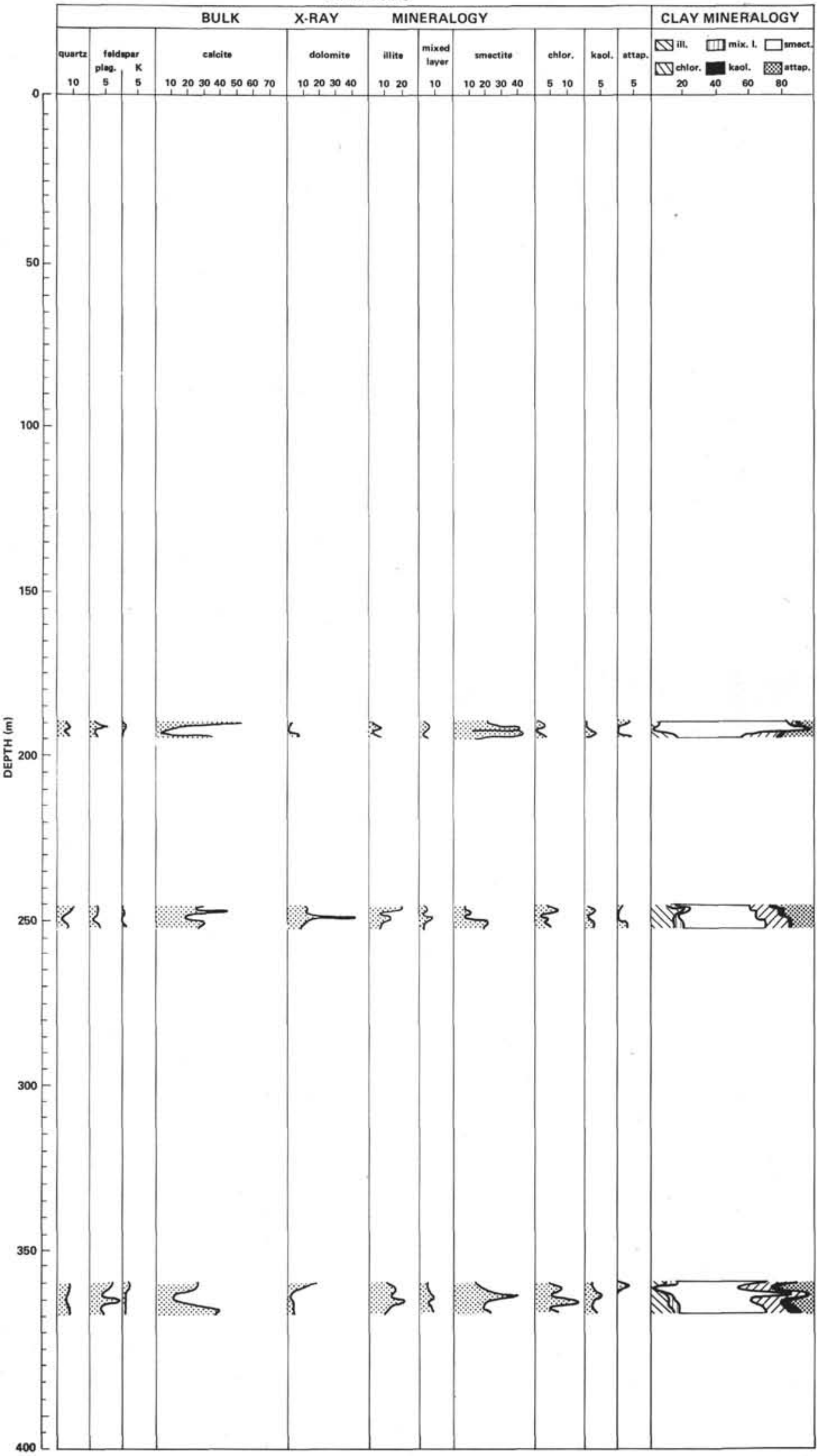
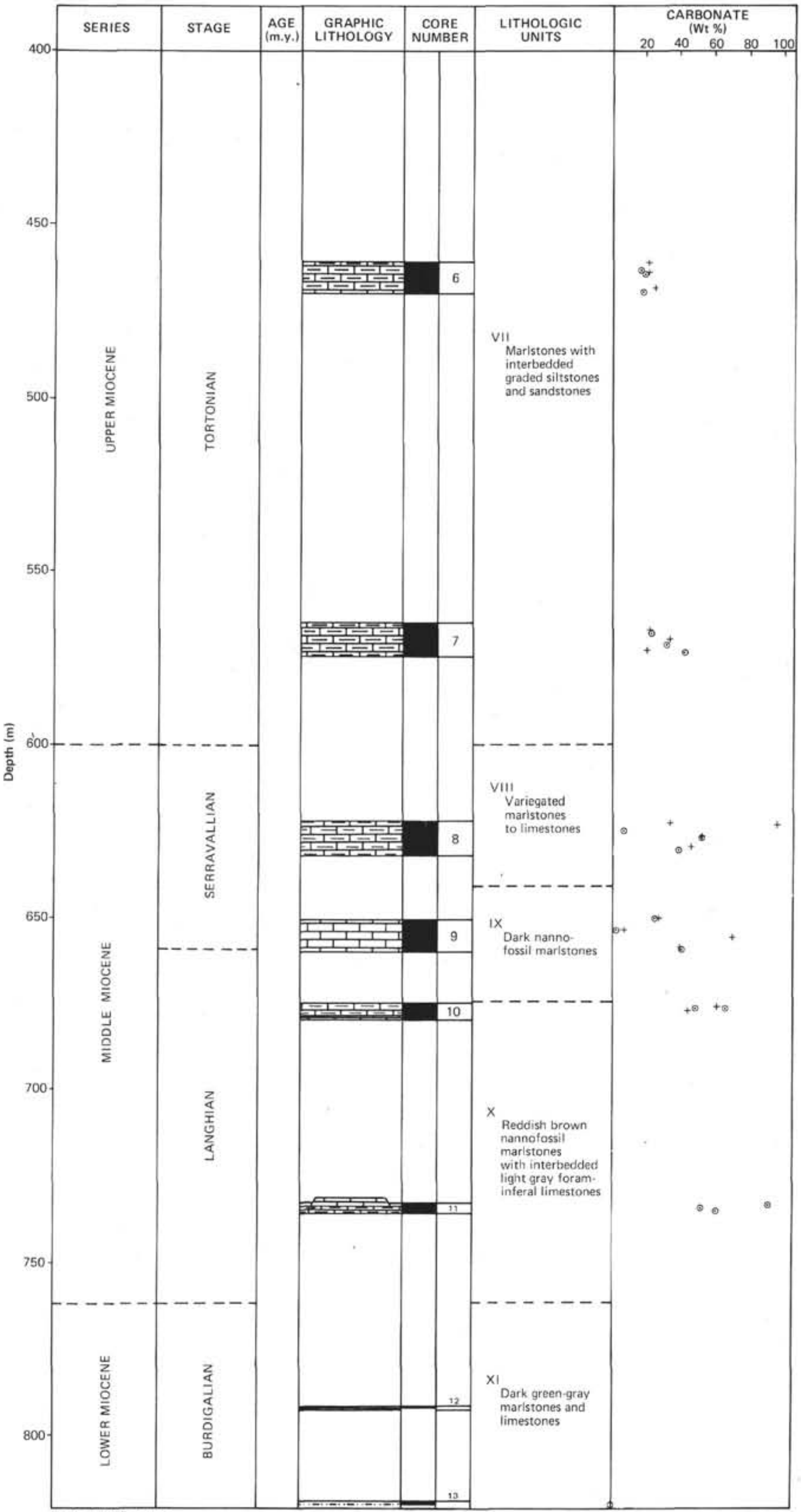

SERIES
STAGE
AGE (m.y.)
GRAPHIC LITHOLOGY
CORE NUMBER
LITHOLOGIC UNITS
CARBONATE (Wt %)
20 40 60 80 100
Depth (m)
0
50
100
150
200
250
300
350
400
LOWER PLIOCENE TO QUATERNARY
UPPER MIOCENE
MESSINIAN
TORTONIAN
1
2
3
4
5
I to V? (From Site 376)
III & V only are present
IV Evaporites: Gypsum with siltstone, sandstone and marlstone
VII Marlstones with interbedded graded siltstones and sandstones

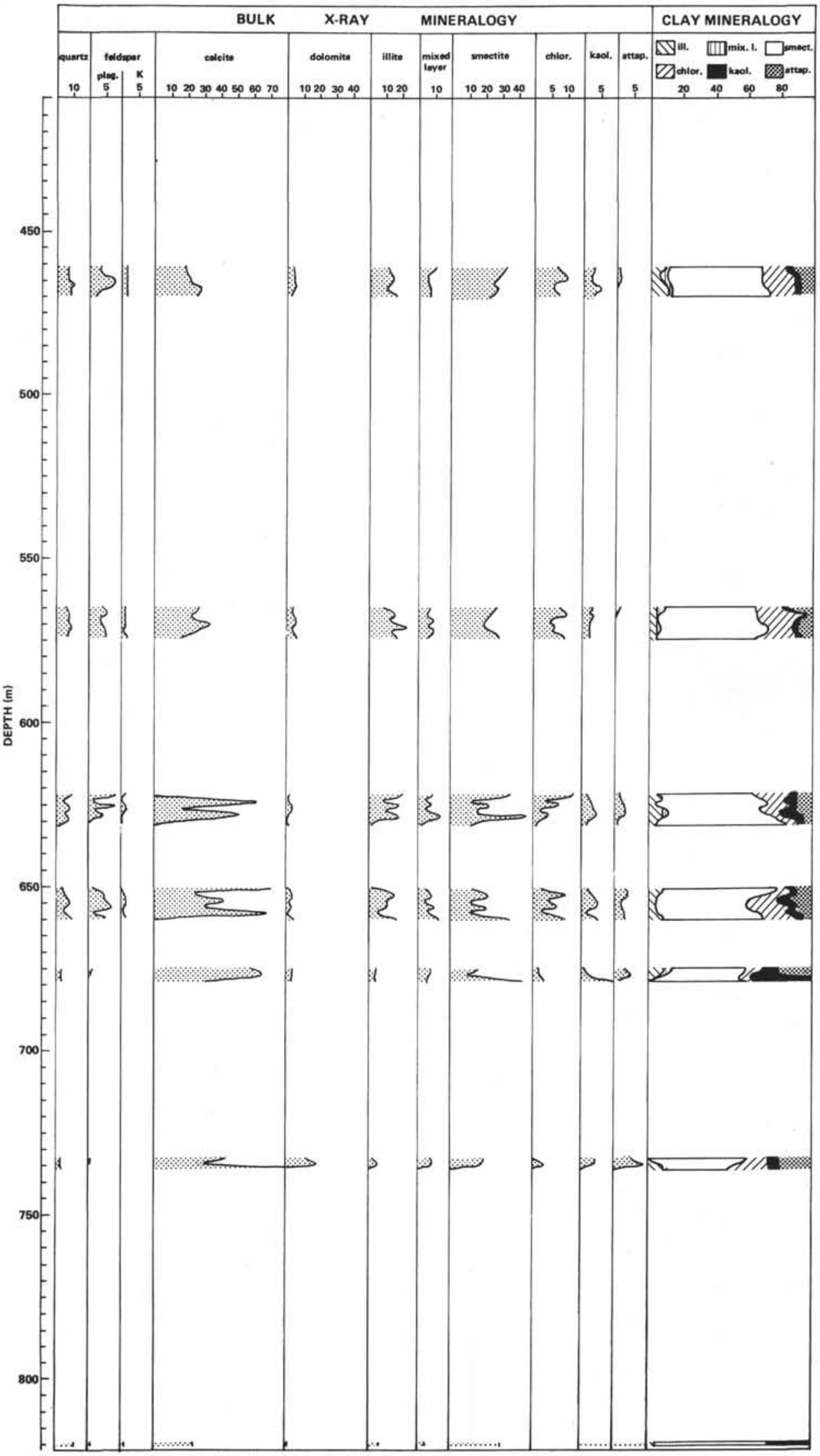
SITE 375

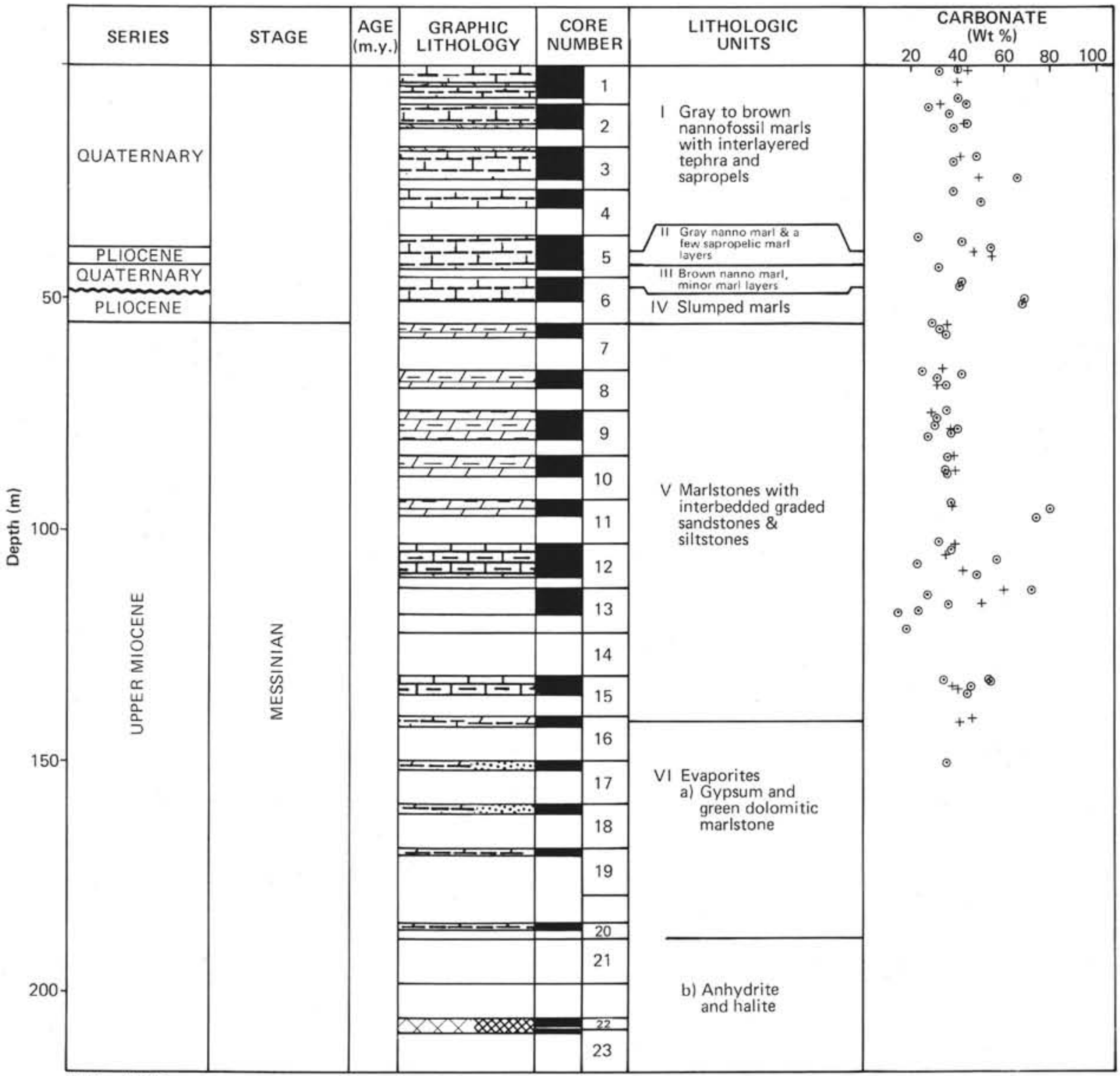

BULK X-RAY MINERALOGY
CLAY MINERALOGY
quartz
feldspar
plag.
K
calcite
dolomite
illite
mixed layer
smectite
chlor.
kaol.
attap.
ill.
mix. l.
smect.
chlor.
kaol.
attap.
10
5
5
10 20 30 40 50 60 70
10 20 30 40
10 20
10
10 20 30 40
5 10
5
5
20 40 60 80
DEPTH (m)
0
50
100
150
200
250
300
350
400



T. D. = 821.5 meters

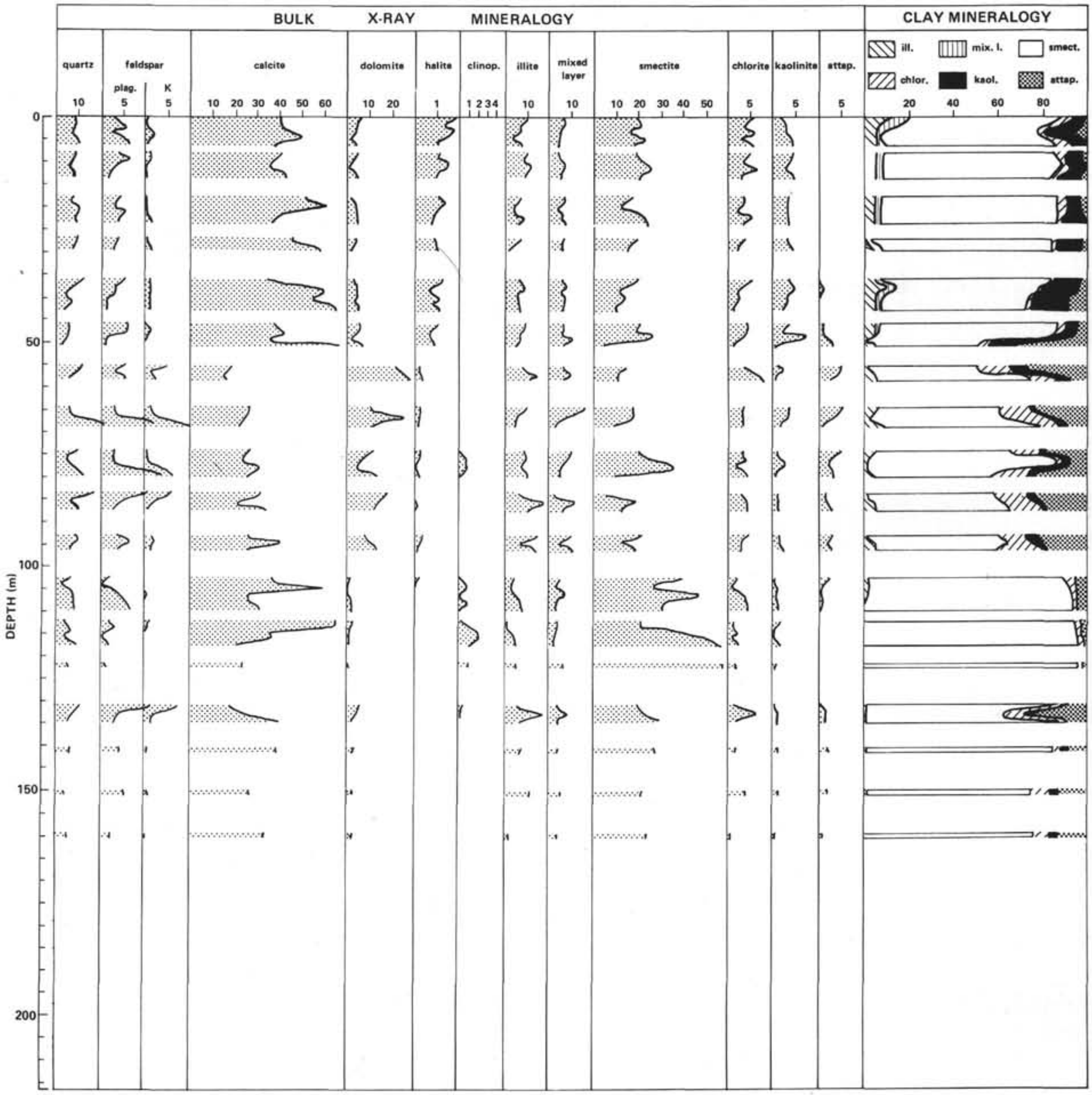
SITE 375


BULK X-RAY MINERALOGY
CLAY MINERALOGY
quartz
feldspar
plag.
K
calcite
dolomite
illite
mixed layer
smectite
chlor.
kaol.
attap.
ill.
mix. l.
smect.
chlor.
kaol.
attap.
10
5
5
10 20 30 40 50 60 70
10 20 30 40
10 20
10
10 20 30 40
5 10
5
5
20 40 60 80
DEPTH (m)
450
500
550
600
650
700
750
800

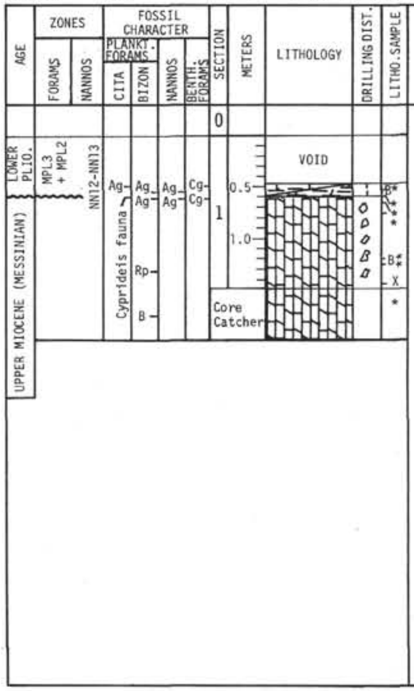


T. D. = 216.5 meters

SITE 376


BULK X-RAY MINERALOGY
CLAY MINERALOGY
quartz
feldspar
plag.
K
calcite
dolomite
halite
clinop.
illite
mixed layer
smectite
chlorite
kaolinite
attap.
ill.
mix. l.
smect.
chlor.
kaol.
attap.
10
5
5
10 20 30 40 50 60
10 20
1
1 2 3 4
10
10
10 20 30 40 50
5
5
5
20
40
60
80
DEPTH (m)
0
50
100
150
200

Site 375 Hole Core 1 Cored Interval: 137.5-139.5 m



LITHOLOGIC DESCRIPTION

GYPSUM OVERLAIN BY NANNOFOSSIL AND DOLOMITIC MARLS

1-48 to 57 cm: Brown (5YR 6/4 to 5YR 4/4) and gray (laminated) nannofossil marl 57 to 60 cm olive gray (5Y 5/2) and pale blue green dolomitic marl.

1-60 cm to base: Gypsum. Broken pieces, dusky yellow green (5GY 5/2) to grayish yellow green (5GY 7/2) to very light gray (N8).

1-60 to 125 cm: Large elongate gypsum crystals in matrix of green dolomitic marl and dolomitic marl.

1-125 to 150 cm. Relatively pure and coarsely crystalline.

MINOR LITHOLOGIES

NANNOFOSSIL MARL
SS 1-54

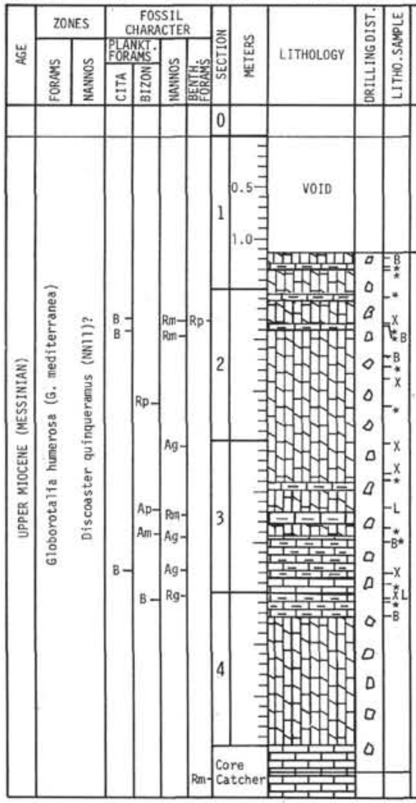
Nannos	A	Forams	R
Clay	A	Quartz	T
Carb. unspec.	R	Mica	T
Pyrite	R		

DOLOMITIC MARL
SS 1-60

Dolomite	A	Nannos	C
Clay	A	Pyrite	R
Gypsum	C		

BOMB:
1-50 to 51 cm = 42% $CaCO_3$
1-123 to 124 cm = 23% $CaCO_3$

Site 375 Hole Core 2 Cored Interval: 189.5-194.5 m



LITHOLOGIC DESCRIPTION

GYPSUM WITH INTERBEDDED DOLOMITIC AND NANNOFOSSIL MARLSTONES

Coarse crystalline gypsum, light gray (N8) to yellowish gray (5Y 7/2). Crystals usually elongate, parallel or perpendicular to bedding, often zoned. Gypsum evenly laminated below 3-80 cm, gray with dark thin laminae of marlstone. Marlstones often sandy, greenish gray (5G 6/1), mottled. Interbeds 2-5 cm thick. Varying percentages of nannofossil carbonate.

MAJOR LITHOLOGIES

MARLSTONE
SS 4-7

Clay	A	Nannos	C
Carb. unspec.	A	Pyrite	R

NANNOFOSSIL MARLSTONE
SS 4-3

Smectite	15%	Calcite	36%
Mixed layer	7%	Dolomite	8%
Illite	9%	Quartz	8%
Attapulgite	4%	Plag. felds.	3%
Chlorite	4%	Gypsum	3%
Kaolinite	2%	Halite	1%

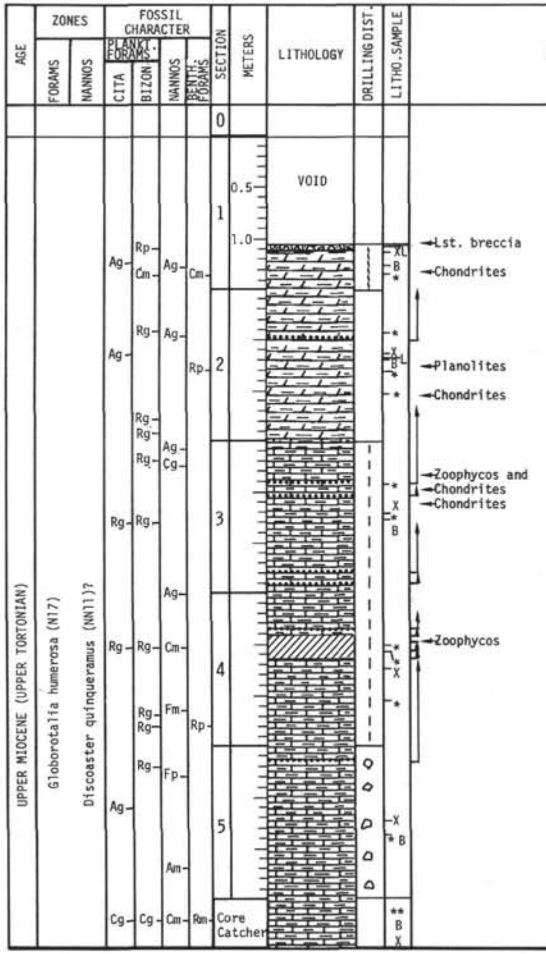
Indurated. Broken pieces but succession appears stratigraphically correct.

Section 5 exuded H_2S odor on splitting.

BOMB:
1-119 to 120 cm = 2% $CaCO_3$
2-39 to 40 cm = 15% $CaCO_3$
3-65 to 66 cm = 1% $CaCO_3$
3-96 to 100 cm = 3.5% $CaCO_3$
4-23 to 24 cm = 27% $CaCO_3$

Site 375, Core 3, 194.5-197.5 m: NO RECOVERY

Site 375 Hole Core 4 Cored Interval: 245.5-252.0 m



LITHOLOGIC DESCRIPTION

DOLOMITIC NANNOFOSSIL MARLSTONE WITH GRADED UNITS AND A SAPROPEL

Slightly to moderately deformed or brecciated, greenish gray (5GY 6/1 and 5G 6/1) to medium bluish gray (5B 5/1) and black (5GY 2/1) dolomitic nannofossil marlstone, variously pyrite bearing or nannofossil rich, "less dolomitic towards base of core." Burrows include Chondrites, Planolites, Zoophycos. Repeated graded units cyclically developed. Silty or sandy basal members displaying sharp, often erosional contacts. These fine upwards through laminated sequences into homogeneous and finely burrowed intervals. Limestone breccia at 104 to 110 cm (Drilling artifact?). Sapropel interval at 4-40 to 62 cm including 4 minor graded units.

MAJOR LITHOLOGY

NANNOFOSSIL MARLSTONE
SS 1-134

Clay	A	Quartz	C
Nannos	A	Pyrite	C
Dolomite	C		

MINOR LITHOLOGIES

DOLOMITIC SILT
SS 3-41

Dolomite	A	Pyrite	C
Clay	C	Gypsum	C
Mica and heavy mins.	C	Nannos	R
		Forams	R

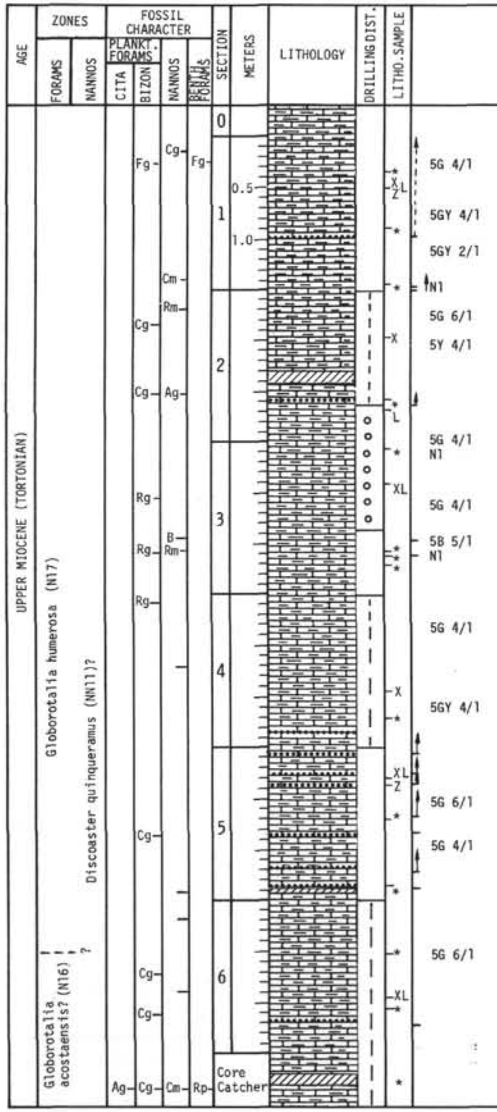
SAPROPEL
SS 4-57

Organic matter	A	Pyrite	R
Clay	C	Forams	R
Nannos	C	Mica	T
Dolomite	C		

H_2S odor on splitting.

BOMB:
1-126 to 127 cm = 45% $CaCO_3$
2-70 to 71 cm = 45% $CaCO_3$
3-79 to 80 cm = 49% $CaCO_3$
5-88 to 89 cm = 31% $CaCO_3$
CC = 43% $CaCO_3$

Site 375 Hole Core 5 Cored Interval: 360.0-369.5 m



LITHOLOGIC DESCRIPTION

DOLOMITIC NANNOFOSSIL MARLSTONE WITH GRADED UNITS AND SAPROPELS

Firm, indurated. Slightly disturbed to brecciated, greenish gray (5GY 4/1, 5G 6/1, 5G 4/1) nannofossil marlstone with graded units. Units typically are dark colored at their bases and are lighter at their tops or where light sediments are introduced downwards by burrowing. Basal contacts generally sharp and often with Chondrites burrow traces below. Sometimes coarser base has a lamina of pyrite. Parallel lamination within units and rare cross lamination. Elsewhere homogeneous or mottled, sometimes with pyrite nodules. Sapropels at 2-82 to 88 cm and 5-139 to 141 cm. Sapropelic(?) beds and laminae, black (N1), at 1-146 to 147, 2-4 to 6, 3-21 to 23, and 3-109 to 111 cm and in core catcher.

MAJOR LITHOLOGY

NANNOFOSSIL MARLSTONE
SS 3-121

Clay	A	Dolomite	C
Nannos	A	Pyrite	R

MINOR LITHOLOGIES

DOLOMITIC MUD (SANDY SILT)
SS 2-105

Clay	A	Nannos	C
Dolomite	A	Pyrite	R
Forams	C		

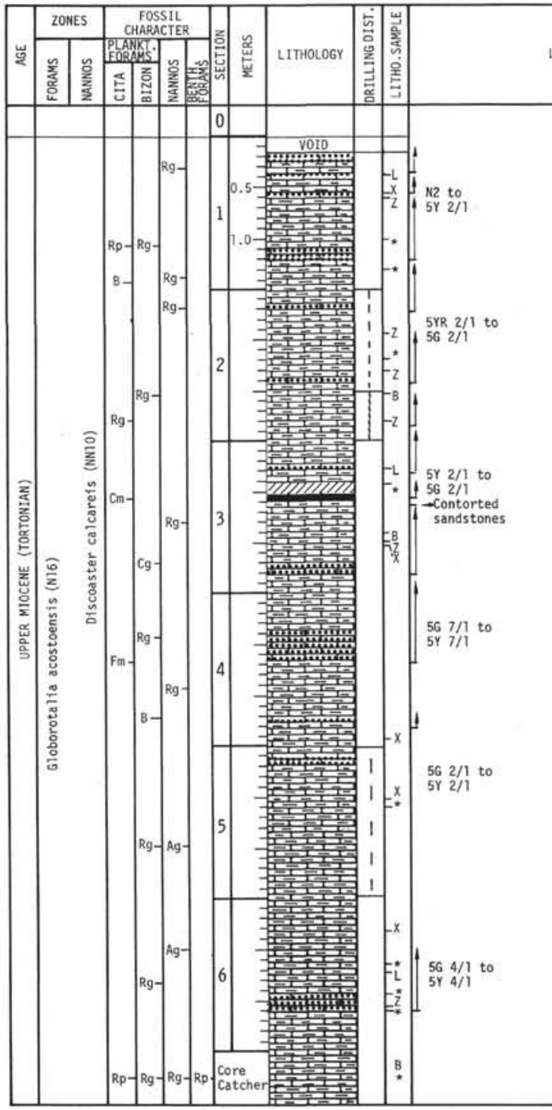
SAPROPELIC MARLSTONE
SS 3-111

Organic matter	A	Carb. unspec.	C
Clay	A	Nannos	R
Pyrite	C		

BOMB:
1-74 to 75 cm = 55% $CaCO_3$
3-96 to 97 cm = 36% $CaCO_3$
5-47 to 48 cm = 39% $CaCO_3$
CC = 27% $CaCO_3$

54 cm Zero Section - split

Site 375 Hole Core 6 Cored Interval: 461.0-470.0 m



LITHOLOGIC DESCRIPTION

GRADED SAND AND SILT UNITS SET IN NANNOFOSSIL MARLSTONE

Slightly disturbed to undisturbed, moderately indurated. Generally grayish black (N2) to greenish black (5GY 2/1). Graded sand and silt units with plant and rock fragments, sharp basal contacts. Parallel lamination and rare cross lamination overlain by homogeneous structureless marlstone. Sometimes massive basal members with clay pebbles. Nannofossil marlstone homogeneous or faintly laminated. Thin sandstone interbeds. Also, not obviously graded. Sapropels at 3-45 to 48 cm and 3-53 to 55 cm. Sapropelic layers at 5-48 to 50 cm and in core catcher.

MAJOR LITHOLOGIES

SILT
SS 1-100

Clay	A	Quartz	C
Forams	C	Feldspar	C
Mica	C	Pyrite	R
Heavy mins.	C		

(POLYGENIC) SAND
SS 3-43

Clay	A	Heavy mins.	C
Carb. unspec.	C	Pyrite	C
Quartz	C	Feldspar	C
Mica	C		

NANNOFOSSIL MARLSTONE
SS 1-130

Clay	A	Dolomite	C
Nannos	A	Forams	R
Quartz	C	Mica	T

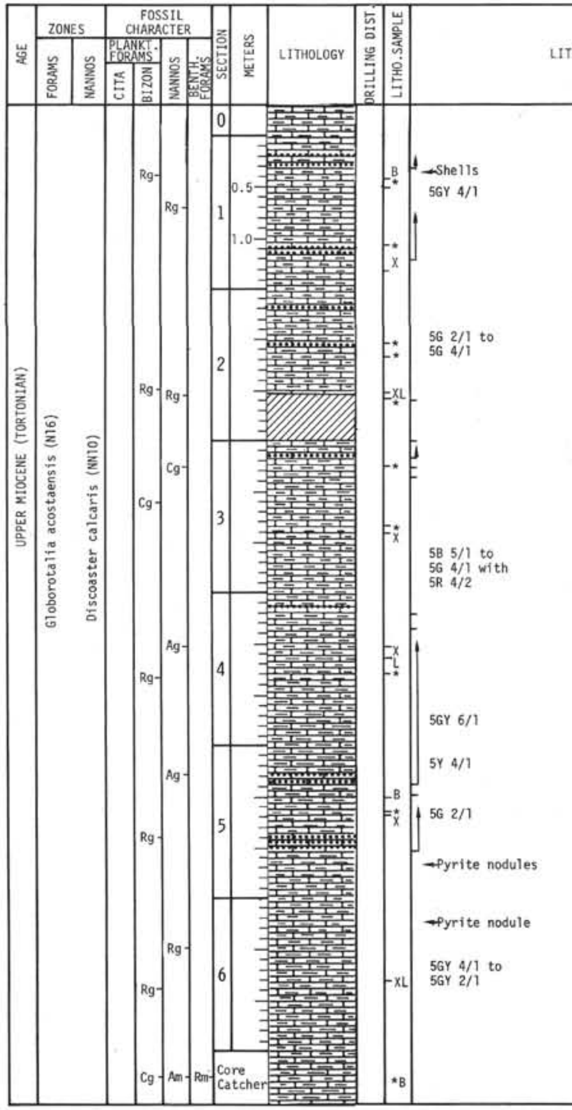
X-ray:
5-52

Smectite	28%	Quartz	8%
Illite	9%	Dolomite	5%
Mixed layer	7%	Plag. felds.	3%
Chlorite	5%	K-feldspar	1%
Kaolinite	5%	Serpentinite	1%
Calcite	28%		

Gaseous - bubbles in liner.

BOMB:
2-105 to 106 cm = 17% $CaCO_3$
3-91 to 92 cm = 19% $CaCO_3$
CC = 18% $CaCO_3$

Site 375 Hole Core 7 Cored Interval: 565.0-574.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARLSTONE WITH GRADED SANDSTONE AND SILTSTONE UNITS INTERBEDDED

Indurated, undisturbed. Generally dark greenish gray (5GY 4/1) to greenish black (5G 2/1), medium bluish gray (5B 5/1) or grayish red (5R 4/2). Reddish hues occur at tops of graded units. Nannofossil marlstone is in places mottled or faintly laminated but is mostly homogeneous. Graded sandstones and siltstone with sharp basal contacts often with macrofossils. Internally are generally parallel laminated but may be massive or cross-laminated. Sets of thin sapropel layers at 2-105 to 150 cm, sapropelic layers in intervals 4-21 to 34 cm and 5-51 to 52 cm.

MAJOR LITHOLOGIES

NANNOFOSSIL MARLSTONE
SS 2-66

Clay	A	Pyrite	R
Nannos	C	Feldspar	R
Dolomite	C	Mica	T
Quartz	C		

X-ray:
3-90

Smectite	20%	Quartz	8%
Illite	13%	Dolomite	5%
Mixed layer	9%	Plag. felds.	3%
Chlorite	5%	K-feldspar	1%
Kaolinite	3%	Serpentinite	1%
Calcite	32%	Aragonite	T

(POLYGENIC) SILT
SS 1-108

Clay	A	Mica	R
Carb. unspèc.	A	Feldspar	R
Quartz	A	Heavy mins.	R

MINOR LITHOLOGY

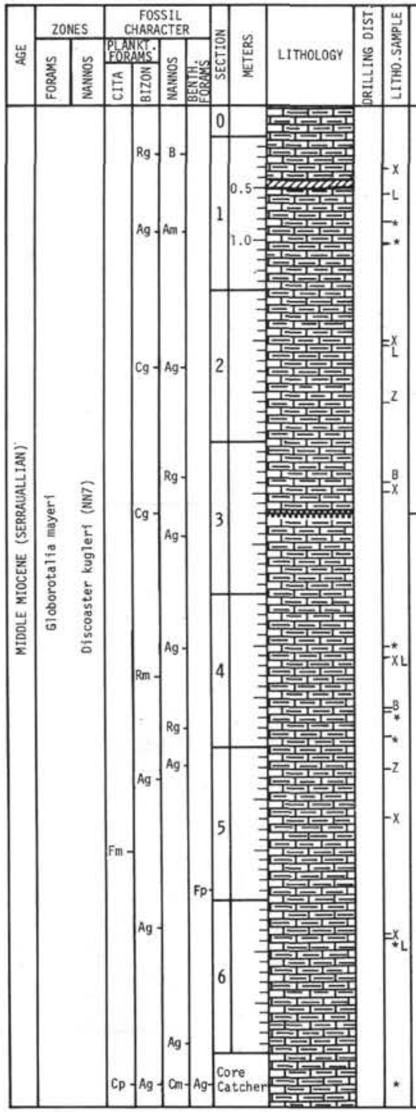
SAPROPELIC MARLSTONE
SS 2-106

Clay	A	Quartz	R
Organic matter	A	Nannos	R
Pyrite	C	Mica	T
Dolomite	C		

BOMB:
3-46 to 47 cm = 23% $CaCO_3$
5-51 to 52 cm = 32% $CaCO_3$
CC = 42% $CaCO_3$

47 cm Zero Section - split

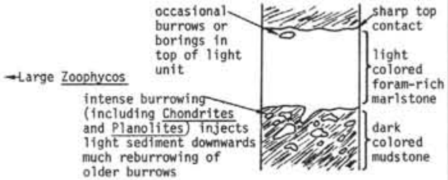
Site 375 Hole Core 8 Cored Interval: 622.0-631.5 m



LITHOLOGIC DESCRIPTION

FORAM NANNOFOSSIL MARLSTONE

Indurated, variegated foram nannofossil marlstones. Colors range: light olive gray (5Y 6/1), greenish gray (5GY 6/1), dusky yellow (5Y 6/4), grayish brown (5YR 3/2) and in parts of Sections 2 and 4, grayish red (5R 4/2) overall pattern of sedimentation is cyclic - an alternation of light and dark colored marlstones in cycles ranging in thickness 2 to 40 cm. Generalized unit is:



One graded foram-rich bed at 3-66 to 70 cm. Sapropel at 1-41 to 44 cm.

MAJOR LITHOLOGY

FORAM NANNO MARLSTONE
SS 4-50

Clay	A	Volc. glass	T
Nannos	A	Quartz	C
Forams	C	Dolomite	R

X-ray:
4-62

Smectite	14%	Calcite	53%
Illite	10%	Quartz	6%
Mixed layer	5%	Plag. felds.	1%
Attapulgite	3%	K-feldspar	T
Kaolinite	3%	Dolomite	2%
Chlorite	2%	Serpentinite	1%

Grain size:
5-21

Sand	3.3%
Silt	39.2%
Clay	57.5%

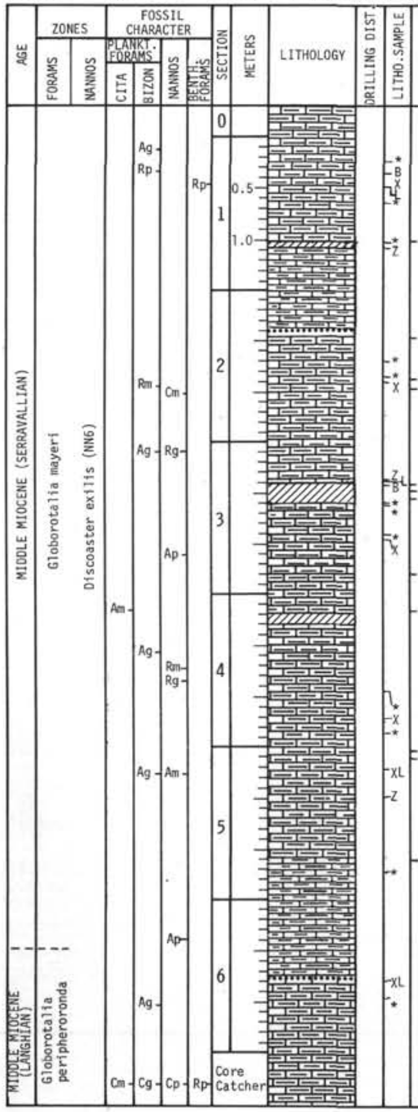
LECO: 4-64 cm

Total Carb.	6.4%
Organic Carb.	0.1%
$CaCO_3$	53%

BOMB:
3-39 to 40 cm = 7% $CaCO_3$
4-109-110 cm = 52% $CaCO_3$
CC = 39% $CaCO_3$

43 cm Zero Section - split

Site 375 Hole Core 9 Cored Interval: 650.5-660.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARLSTONE AND MUDSTONE

Cyclic sedimentation units continued as in Core 8 - colors: medium dark gray (N4) to grayish brown (5YR 3/2) and dusky brown (5YR 2/2) in mudstones to light olive gray (5Y 6/1 to 5Y 5/2) in marlstones. Graded and cross-laminated fine sand and silt in Section 2. Zoophycos burrow traces are well-developed in Sections 2 to 6. Sapropels at 1-100 to 101 cm, 3-39 to 56 cm, and 4-16 to 18 cm. Sapropelic laminae and beds (up to 2 cm thick) occur at 2-48, 2-88 to 98, 3-133, 5-7, 5-13, 5-113.

MAJOR LITHOLOGIES

NANNOFOSSIL MARLSTONE
SS 3-90

Clay	A	Forams	C
Nannos	A	Quartz	C
Carb. unspec.	C		

X-ray:
3-94

Smectite	13%	Calcite	43%
Illite	11%	Quartz	8%
Mixed layer	5%	Plag. felds.	5%
Chlorite	5%	K-feldspar	1%
Kaolinite	4%	Dolomite	3%
Attapulgite	2%	Serpentinite	T

NANNOFOSSIL MUDSTONE
X-ray:
6-80

Smectite	36%	Quartz	9%
Illite	16%	Plag. felds.	5%
Mixed layer	11%	K-feldspar	1%
Chlorite	10%	DOlomite	5%
Kaolinite	4%	Serpentinite	T
Attapulgite	3%		

MINOR LITHOLOGY

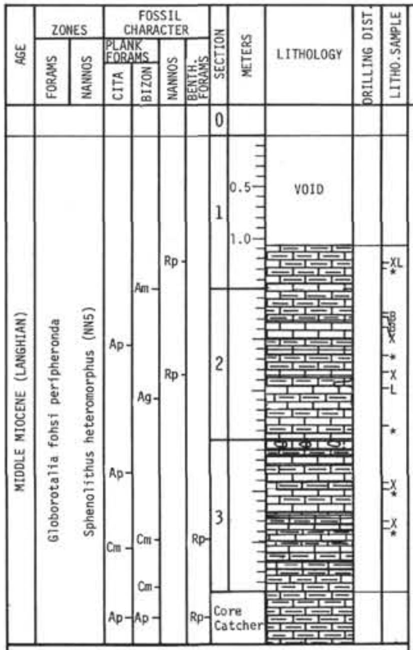
SAPROPELIC MARLSTONE
1-100

Organic matter	A	Clay	C
Pyrite	C	Carb. unspec.	R

BOMB:
1-36 to 37 cm = 25% $CaCO_3$
3-41 to 43 cm = 2% $CaCO_3$
CC = 41% $CaCO_3$

44 cm Zero Section - split

Site 375 Hole Core 10 Cored Interval: 675.5-679.0 m

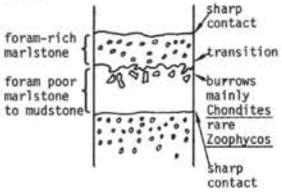


LITHOLOGIC DESCRIPTION

DOLOMITIC (FORAM) NANNOFOSSIL MARLSTONE WITH LIMESTONE LAYERS

Dark reddish brown (10R 3/4) and moderate brown (5YR 4/4) to dark greenish gray (5GY 4/1) dolomitic nannofossil marlstone with varying foraminiferal content.

Basic sedimentation pattern is an alternation of foram-rich and foram poor cycles with selective burrowing as in:



superimposed on this are occasional thin layers of limestone-hard, light gray, foram-rich, often graded, laminated to rippled; at intervals varying from 5-35 cm thick.

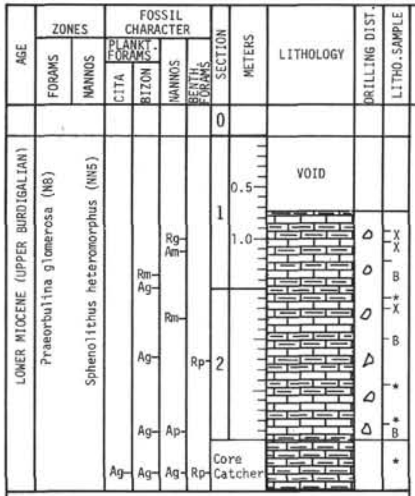
MAJOR LITHOLOGY

DOLOMITIC NANNOFOSSIL MARLSTONE
SS 2-64

Clay	A	Forams	R
Nannos	C	Quartz	R
Dolomite	C	Pyrite	T

BOMB:
2-22 to 24 cm = 49% $CaCO_3$
2-24 to 25 cm = 66% $CaCO_3$

Site 375 Hole Core 11 Cored Interval: 733.0-736.0 m



LITHOLOGIC DESCRIPTION

INTERBEDDED MARLSTONES AND LIMESTONES

Indurated, broken into pieces but succession appears correct. Chondrites burrow traces throughout.

Three MAJOR LITHOLOGIES

Grayish blue green (5BG 5/2) to greenish gray (5G 6/1) MARLSTONE, generally foram-poor and homogeneous to slightly burrowed contains scattered pyrite nodules and laminae of pyritized foram shells.

Dark reddish brown (10R 3/4) to moderate reddish brown (10R 4/6) MARLSTONE, foram-rich to foram-poor.

Bluish white (5B 9/1) to pale blue (5PB 7/2) hard laminated LIMESTONE of well sorted densely packed planktonic forams with stylolites.

Two MINOR LITHOLOGIES

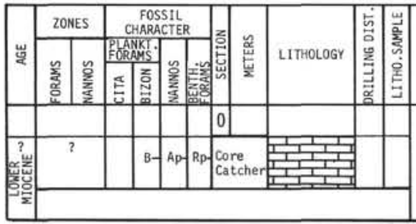
White foram-rich LIMESTONE in thin 0.25 to 0.5 cm laminated layers.

Thin greenish black (5G 2/1) laminae within blue green MARLSTONES.

Thicknesses of major lithology layers range 2 cm to 10 cm but limestone intervals may be thicker - up to 20 cm.

BOMB:
1-132 to 134 cm = 91% $CaCO_3$
2-51 to 55 cm = 52% $CaCO_3$
2-157 to 158 cm = 61% $CaCO_3$

Site 375 Hole Core 12 Cored Interval: 792.0-793.0 m



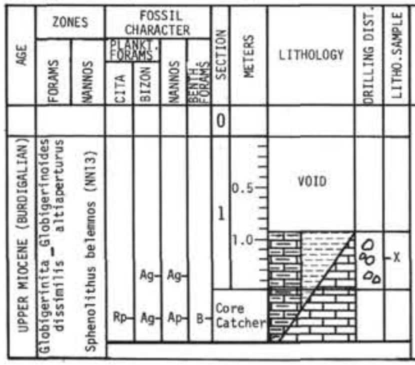
LITHOLOGIC DESCRIPTION

Core Catcher only - LIMESTONE.

Marly nannofossil limestone.

BOMB:
CC = 65% $CaCO_3$

Site 375 Hole Core 13 Cored Interval: 819.5-821.5 m

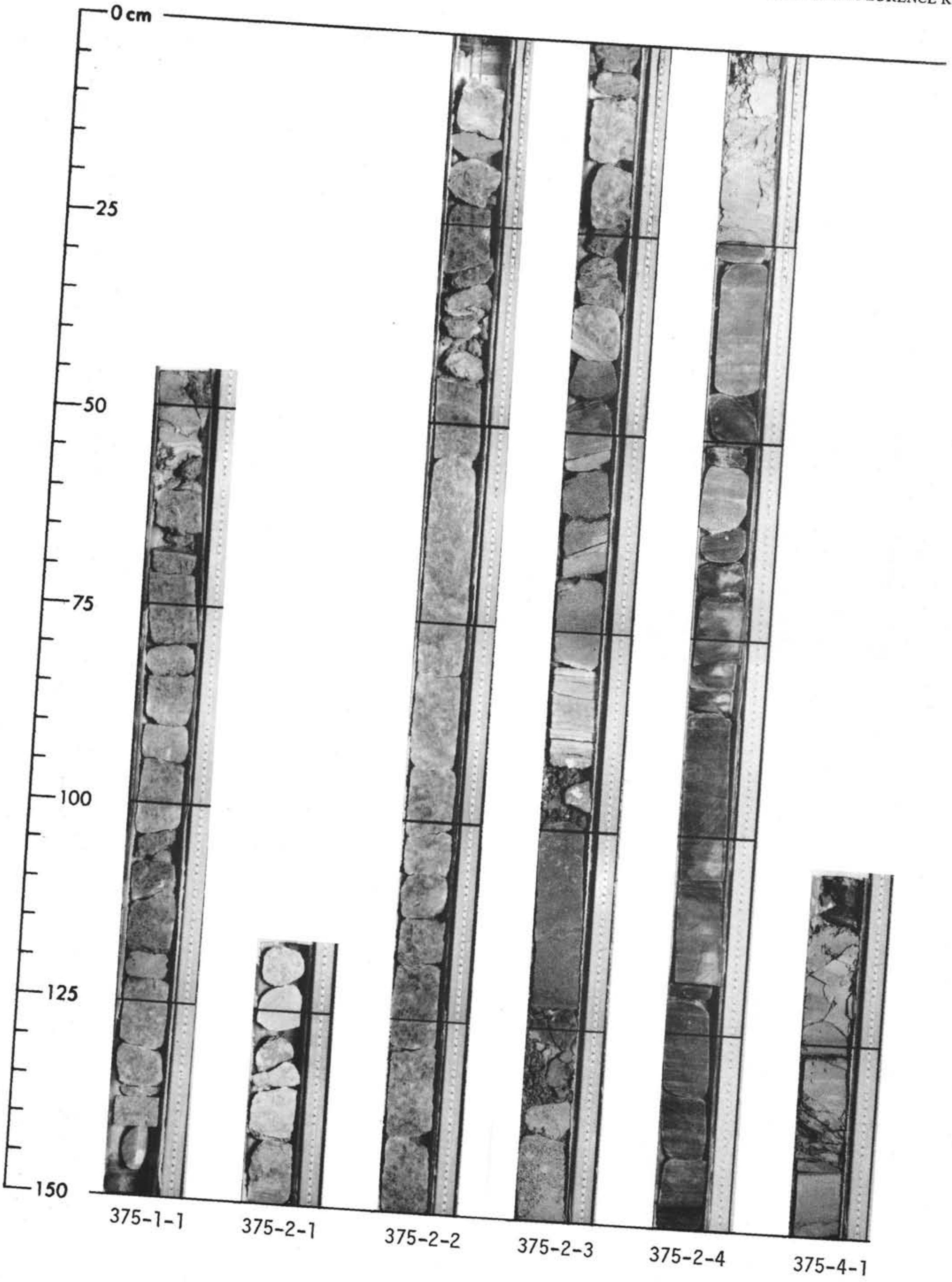


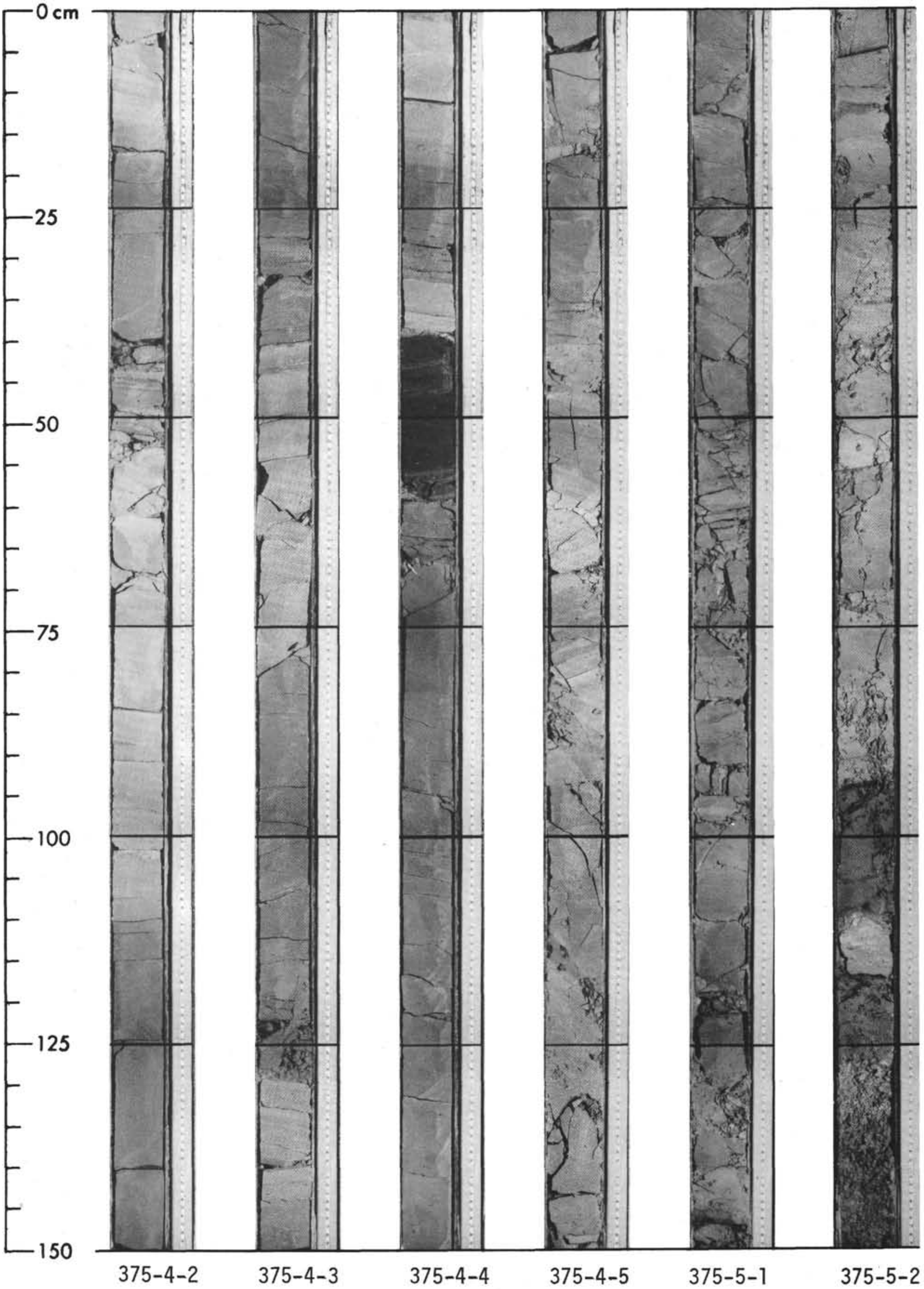
LITHOLOGIC DESCRIPTION

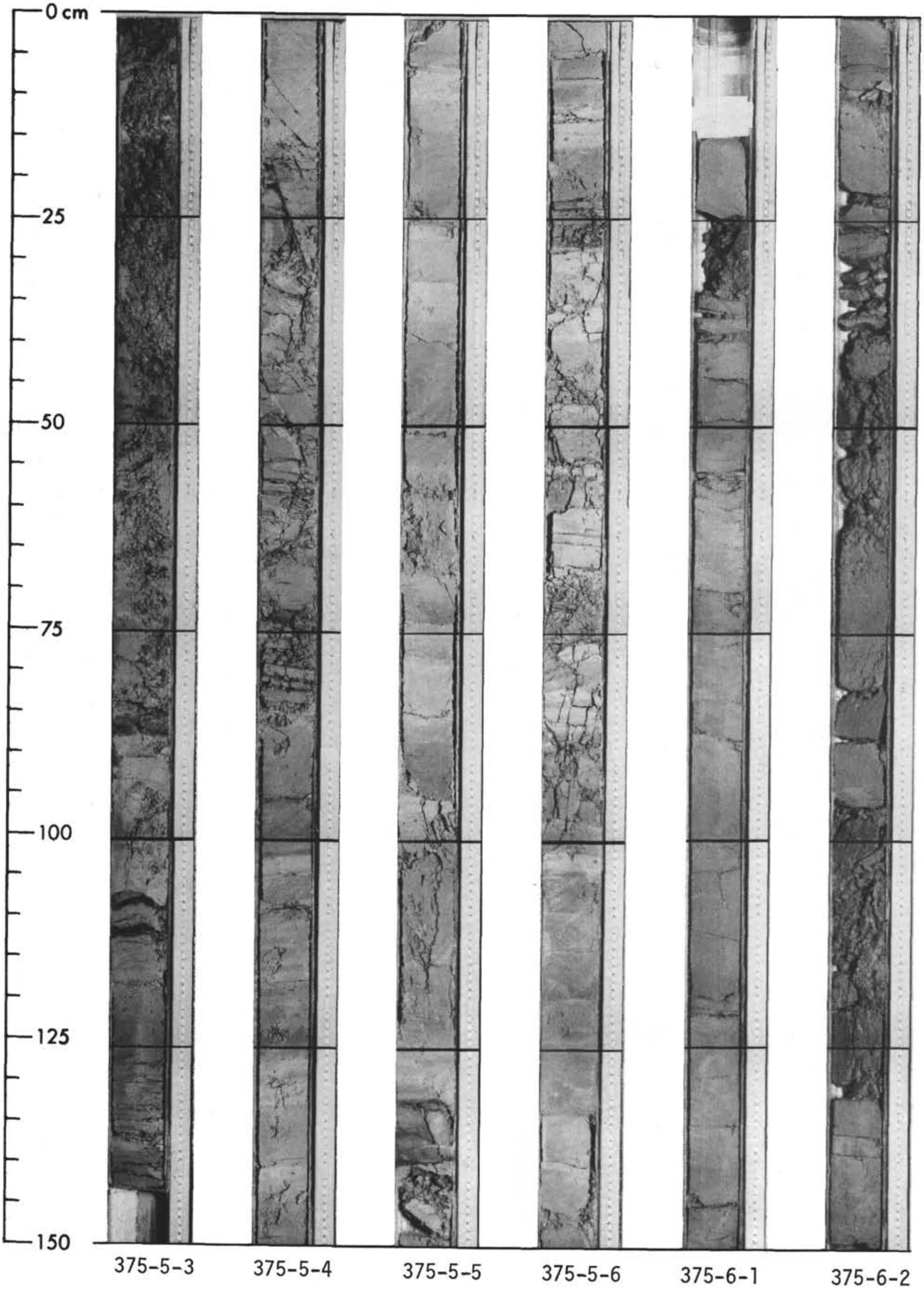
DRILLING BRECCIA plus Core Catcher pieces only - MUDSTONE, MARLSTONE AND LIMESTONE

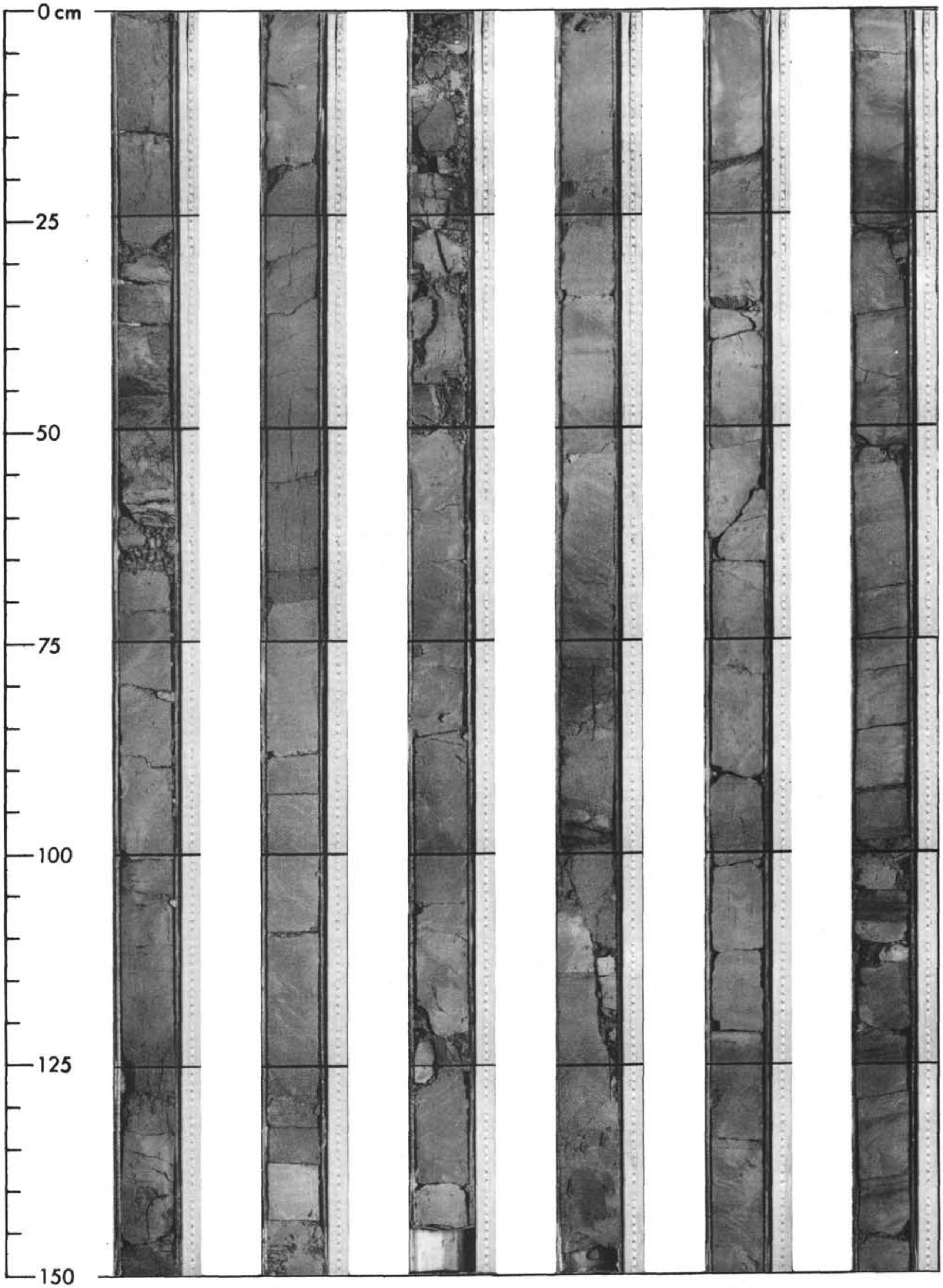
Greenish black (5GY 2/1) to greenish gray (5GY 6/1) nannofossil mudstone to marlstone with dark greenish gray (5GY 4/1) foram-rich nannofossil limestone. These are apparently interbedded since one piece has a burrowed contact between marlstone and limestone which looks part of a cycle as described further uphole.

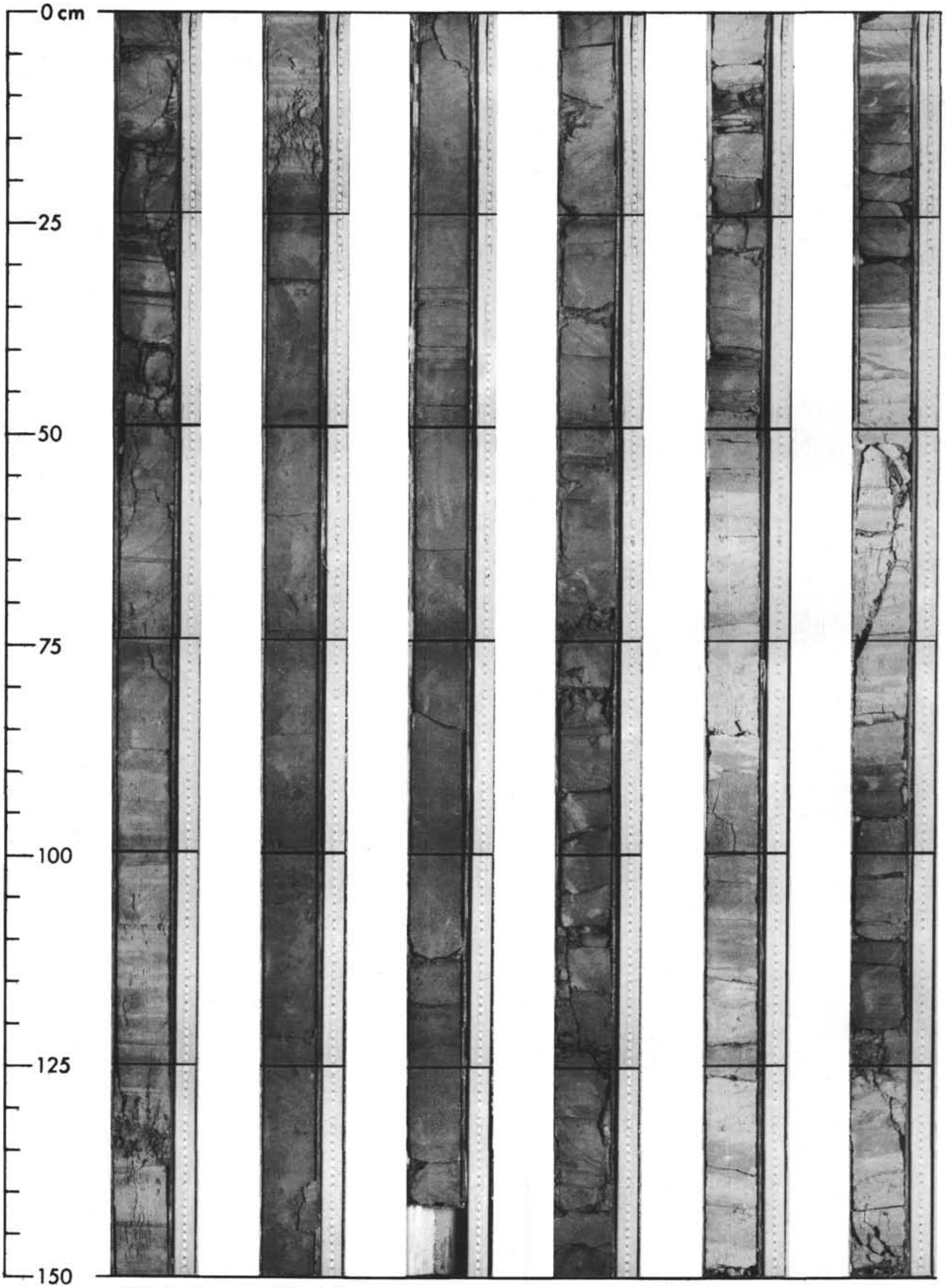
BOMB:
CC = 0% $CaCO_3$

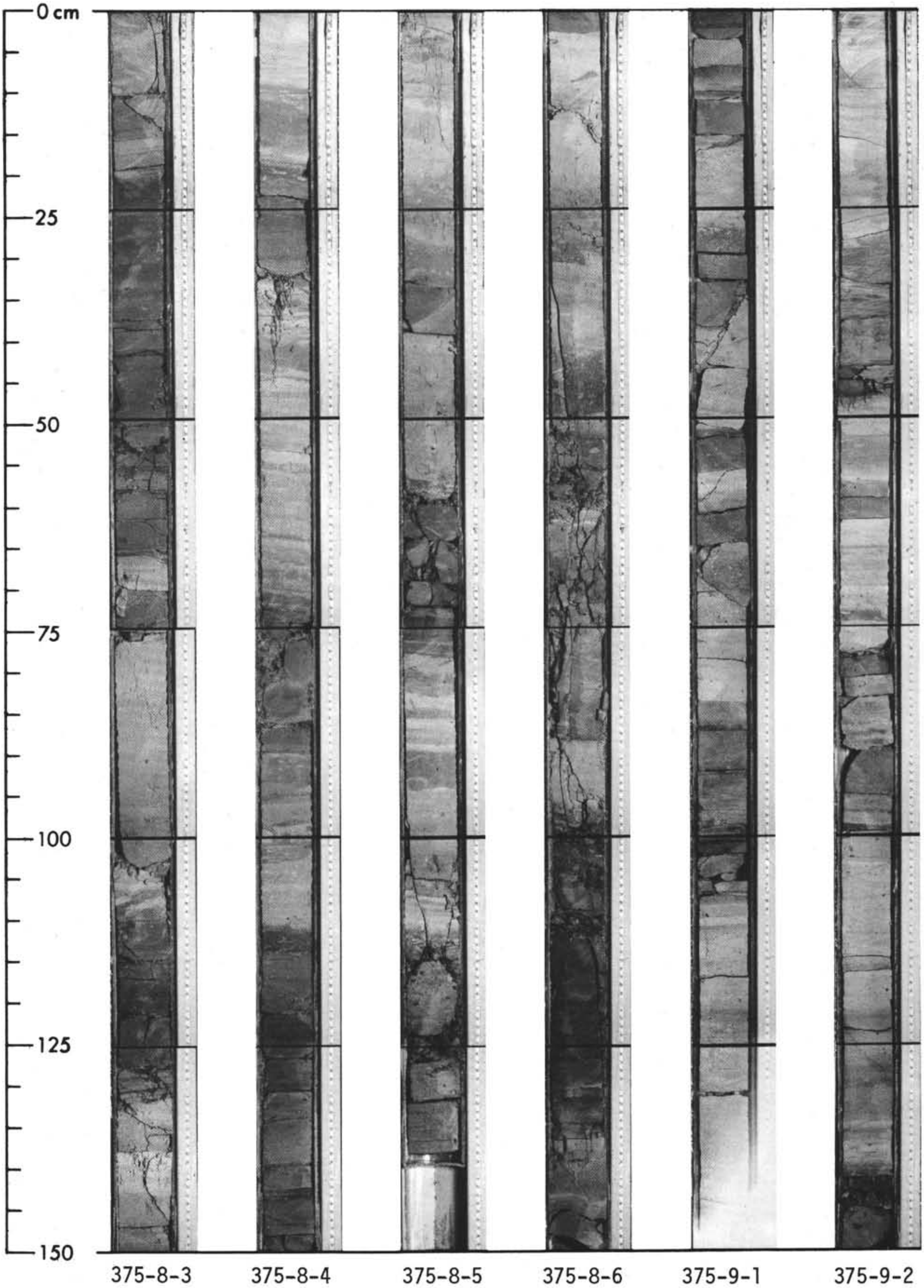

0 cm
25
50
75
100
125
150
375-1-1
375-2-1
375-2-2
375-2-3
375-2-4
375-4-1

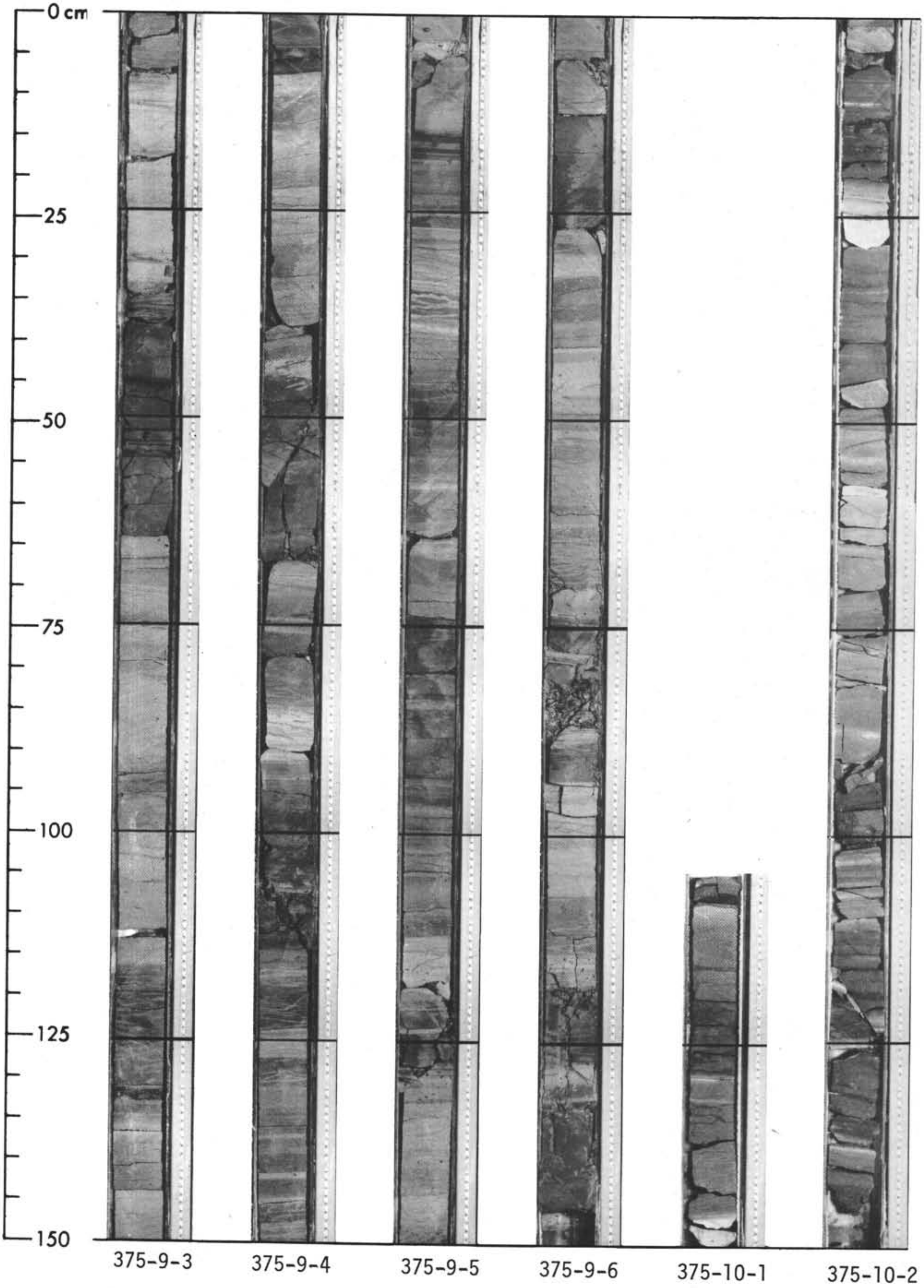

0 cm
25
50
75
100
125
150
375-4-2
375-4-3
375-4-4
375-4-5
375-5-1
375-5-2

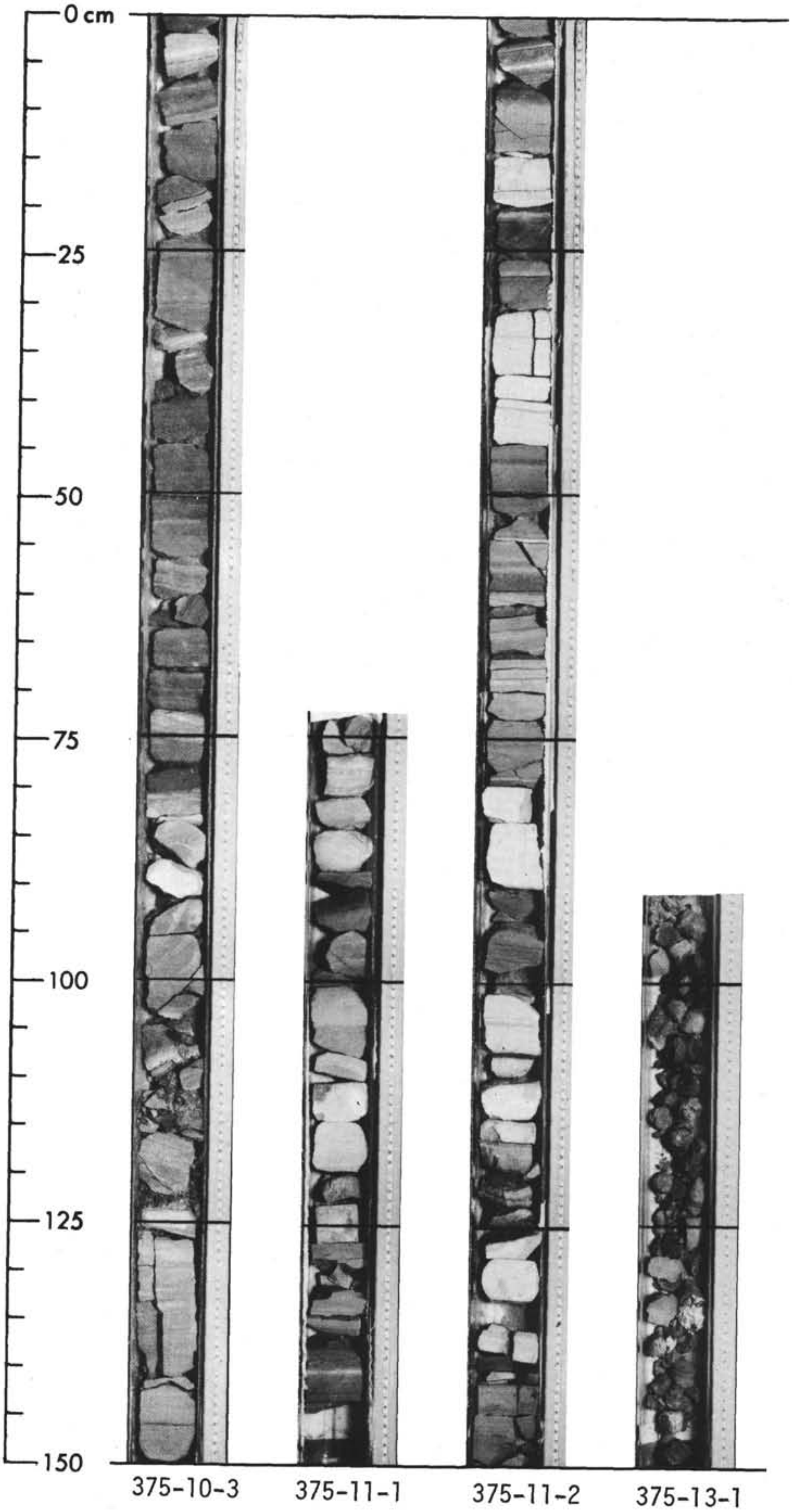

0 cm
25
50
75
100
125
150
375-5-3
375-5-4
375-5-5
375-5-6
375-6-1
375-6-2


0 cm
25
50
75
100
125
150
375-6-3
375-6-4
375-6-5
375-6-6
375-7-1
375-7-2

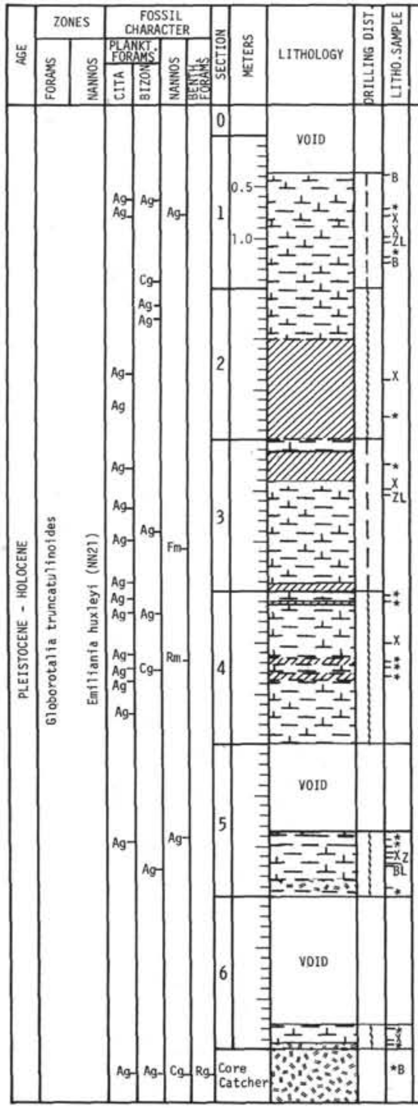

0 cm
25
50
75
100
125
150
375-7-3
375-7-4
375-7-5
375-7-6
375-8-1
375-8-2


0 cm
25
50
75
100
125
150
375-8-3
375-8-4
375-8-5
375-8-6
375-9-1
375-9-2


0 cm
25
50
75
100
125
150
375-9-3
375-9-4
375-9-5
375-9-6
375-10-1
375-10-2


0 cm
25
50
75
100
125
150
375-10-3
375-11-1
375-11-2
375-13-1

Site 376 Hole Core 1 Cored Interval: 0.0-7.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARL WITH SAPROPELS AND VOLCANIC ASH LAYERS

Soft, watery, intensely to moderately deformed. Bedding contacts extended up to 1 meter upwards in core (most thicknesses uncertain, so dashed contacts in column opposite). Gray (5Y 3/2, 5Y 7/2, 5B 7/1, 5Y 5/2, 5GY 6/1) to brown (10YR 5/4, 5Y 5/6, 5YR 5/6) nannofossil marls with volcanic ash layers in Sections 5 and 6. Interbedded sapropel layers, olive black (5Y 2/1) in Sections 1 and 4 (maximum thicknesses displayed), some are multiples of 2-3 layers up to 1 cm thick. Closely spaced; in some a suggestion of grading. Similar less organic sapropelic intervals at 1-52 to 80 cm, 3-130 to 150 cm, 4-3 to 5 cm, 4-10 to 12 cm, 4-76 to 77 cm.

MAJOR LITHOLOGY

NANNOFOSSIL MARL
SS 5-100

Clay	A	Pyrite	R
Nannos	A	Quartz	R
Carb. unspec.	C	Feldspar	R
Forams	R	Mica	T

X-ray:
5-106

Smectite	20%	Quartz	8%
Illite	10%	Plag. felds.	6%
Chlorite	6%	Dolomite	3%
Mixed layer	5%	Halite	1%
Kaolinite	4%	Serpentinite	1%
Calcite	36%	Hornblende	1%

Grain size: 5-110

Sand	3.0%
Silt	40.1%
Clay	56.9%

LECO: 5-112 cm

Total Carb.	4.9%
Organic Carb.	0.1%
$CaCO_3$	40%

MINOR LITHOLOGIES

SAPROPEL
SS 2-129

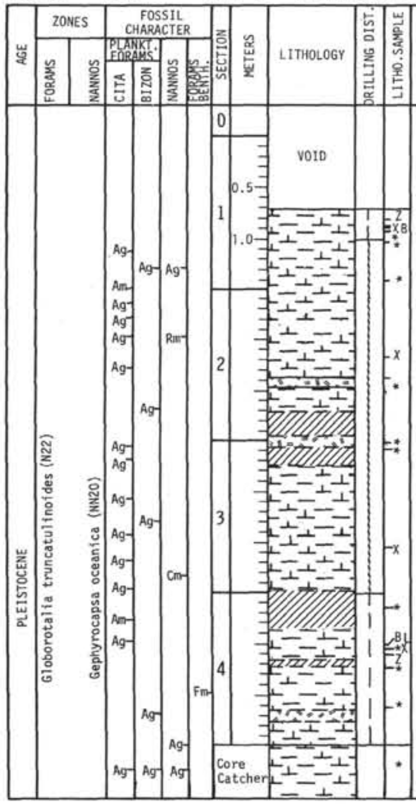
Organic matter	A	Pyrite	C
Clay	A	Forams	C
Nannos	C	Quartz	R

VOLCANIC ASH (TEPHRA)
5-140

Volc. glass	D	Pyrite	R
Hematite	R		

BOMB:
1-38 to 39 cm = 40% $CaCO_3$
1-124 to 125 cm = 32% $CaCO_3$
5-119 to 120 cm = 40% $CaCO_3$
CC = 27% $CaCO_3$

Site 376 Hole Core 2 Cored Interval: 7.5-17.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARL WITH SAPROPELITIC AND VOLCANIC ASH LAYERS

Soft, watery, intensely to moderately deformed, bedding contacts extended upcore, contacts and thicknesses uncertain (dashed). Gray (5Y 6/1, 5G 6/1, 5B 7/1, 5Y 3/2, 5GY 6/1) to brown (5YR 5/6, 10YR 4/2) nannofossil marls with tephra layers in Sections 2 and 4, and olive brown (5Y 4/4). Sapropel intervals at 2-120 to 145 cm, 3-3 to 30 cm, and 4-0 to 40 cm; sapropelic layers at 1-94 to 96 cm, 1-131 to 150 cm, 2-1 to 30 cm, 3-1 to 3 cm, 3-86 to 124 cm, 3-140 to 148 cm, 4-70 to 75 cm; often in multiples of individual laminae.

MAJOR LITHOLOGY

NANNOFOSSIL MARL
SS 4-57

Clay	A	Pyrite	R
Nannos	A	Quartz	R
Carb. unspec.	C	Forams	T

X-ray:
4-57

Smectite	21%	Quartz	7%
Illite	10%	Dolomite	3%
Mixed layer	6%	Plag. felds.	2%
Kaolinite	4%	Serpentinite	1%
Chlorite	3%	Halite	1%
Calcite			

MINOR LITHOLOGIES

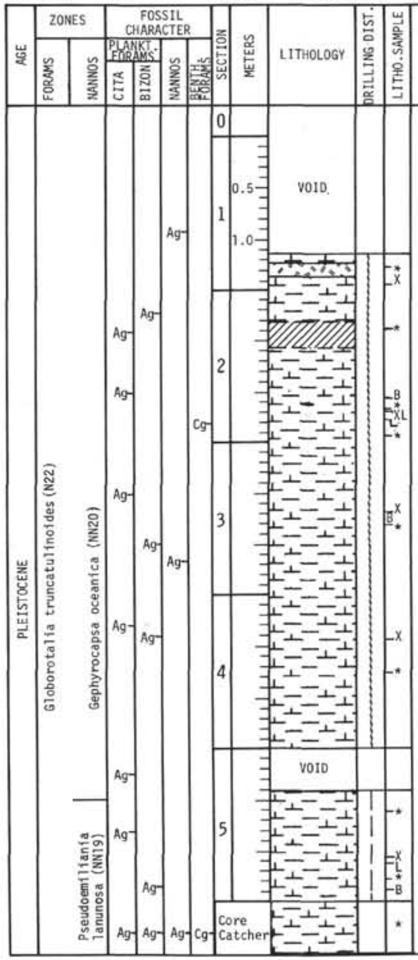
SAPROPEL
SS 3-2

As in Core 1

VOLCANIC ASH (TEPHRA)
SS 2-90

BOMB:
1-87 to 88 cm = 43% $CaCO_3$
3-0 to 1 cm = 36% $CaCO_3$
4-54 to 55 cm = 44% $CaCO_3$
CC = 38% $CaCO_3$

Site 376 Hole Core 3 Cored Interval: 17.0-26.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARL WITH A VOLCANIC ASH AND SAPROPELIC LAYERS

Soft, intensely to moderately deformed bedding contacts extended upcore so thicknesses uncertain. Gray (5Y 6/1, 5GY 6/1, 5G 6/1, 5Y 7/2, 5Y 3/2, 5Y 4/1) to brown (5YR 6/4) nannofossil marls. Tephra horizon, up to 9 cm thick, in Section 1. Sapropel layers, <1 cm up to 18 cm thick in Section 2, 30 to 67 cm, olive gray (5Y 3/2) to black (N1).

MAJOR LITHOLOGY

NANNOFOSSIL MARL
SS 2-119

Nannos	A	Quartz	R
Clay	A	Pyrite	R
Carb. unspec.	C		

X-ray:

Smectite	12%	Quartz	6%
Illite	4%	Plag. felds.	3%
Mixed layer	3%	Dolomite	3%
Chlorite	3%	Serpentinite	1%
Kaolinite	3%	Hornblende	1%
Calcite	60%	Halite	1%

MINOR LITHOLOGIES

SAPROPELIC NANNOFOSSIL MARL
SS 2-37

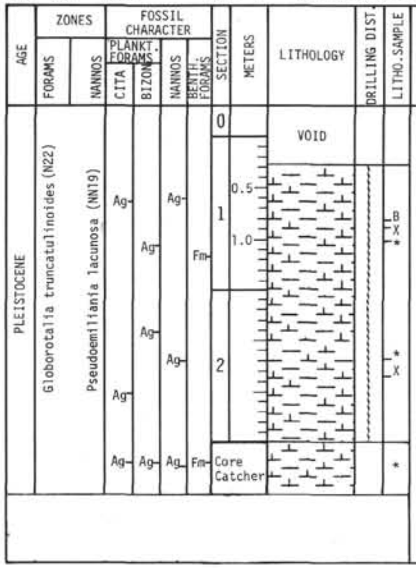
Clay	A	Pyrite	C
Nannos	A	Carb. unspec.	R
Organic matter	C	Forams	R

VOLCANIC ASH (TEPHRA)
SS 1-128

Volc. glass	A
Mica	T

BOMB:
2-115 to 116 cm = 48% $CaCO_3$
3-78 to 80 cm = 38% $CaCO_3$
5-137 to 138 cm = 66% $CaCO_3$

Site 376 Hole Core 4 Cored Interval: 26.5-36.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARL

Soft, intensely deformed, yellowish gray (5Y 7/2) bluish gray (5B 7/1) and light olive gray (5Y 5/2) to light olive brown (5Y 5/6) nannofossil marl, forams common, pteropods rare on sediment surface. Thin interlayers of dark organic-rich marls.

MAJOR LITHOLOGY

NANNOFOSSIL MARL
SS 2-70

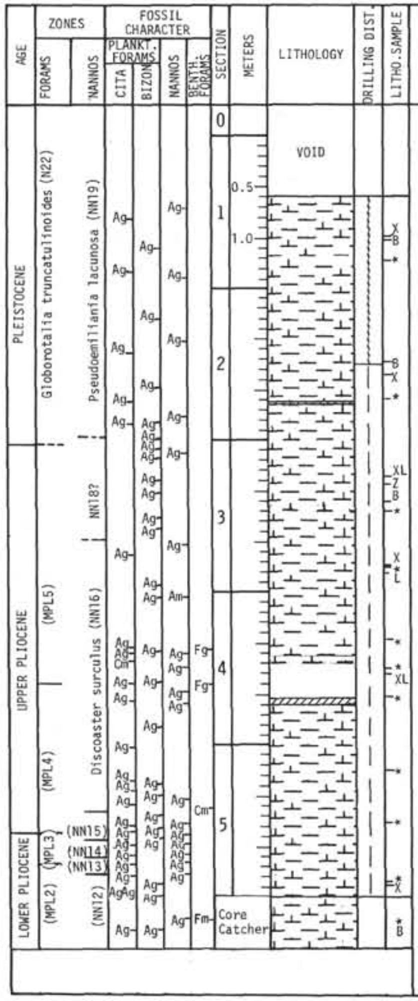
Nannos	A	Forams	C
Clay	A	Quartz	T
Carb. unspec.	C	Pyrite	T

X-ray:
2-85

Smectite	15%	Quartz	8%
Mixed layer	6%	Plag. felds.	3%
Kaolinite	4%	K-feldspar	1%
Chlorite	2%	Dolomite	2%
Illite	1%	Halite	1%
Calcite	56%		

BOMB:
1-80 to 81 cm = 38% $CaCO_3$
CC = 50% $CaCO_3$

Site 376 Hole Core 5 Cored Interval: 36.0-45.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARL WITH SAPROPELIC LAYERS

Soft intensely deformed to firm slightly deformed gray (5Y 6/1, 5G 6/1, 5Y 72/, 5B 7/1, N3, 5GY 6/1) to brown (5YR 6/4, 5YR 4/4, 5YR 5/6) variegated nannofossil marl considerably condensed sequence paleontologically, see Figure 6. Below 5-40 cm becomes dominatly brown, displays possible sedimentation breaks (see below). Interbedded black sapropelic layers in Sections 2 to 4, <1 to 6 cm thick. Sapropels at 2-112 to 115 cm and 4-105 to 111 cm.

MAJOR LITHOLOGY

NANNOFOSSIL MARL
SS 3-126

Clay	A	Carb. unspec.	C
Nannos	A	Quartz	R
Forams	C	Pyrite	T

X-ray:
3-125

Smectite	10%	Dolomite	4%
Mixed layer	6%	Quartz	4%
Illite	4%	Plag. felds.	1%
Chlorite	3%	K-feldspar	1%
Kaolinite	2%	Halite	1%
Calcite	63%	Serpentinite	1%

MINOR LITHOLOGY

SAPROPELIC MARL
SS 4-72

Organic matter	A	Pyrite	R
Clay	A	Quartz	T
Nannos	C	Mica	T
Forams	C	Sponge spicules	T

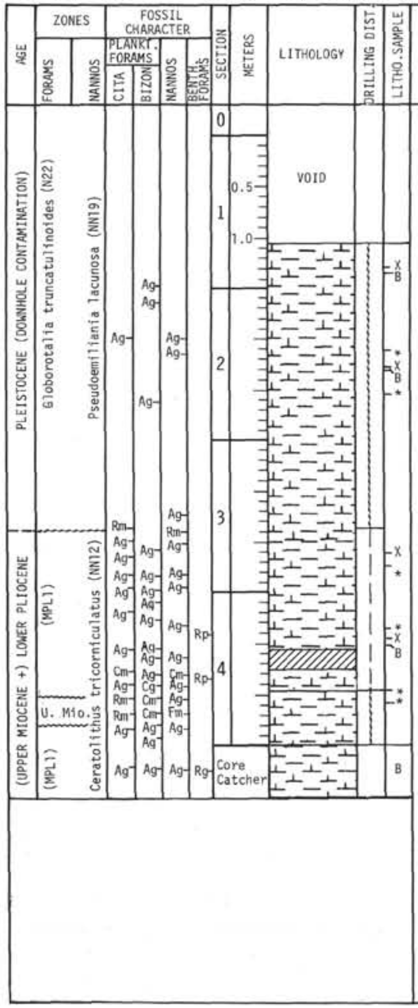
40 cm - color change from mainly gray above to brown below

←47
←67
←84
←90
←96
←100
←120
←125

Arrows indicate thin layers of moderate brown (5YR 3/4) marl - bedding planes with burrowing below ('Omission Surface')

BOMB:
1-103 to 104 cm = 23% $CaCO_3$
2-72 to 73 cm = 42% $CaCO_3$
3-60 to 61 cm = 54% $CaCO_3$
CC = 32% $CaCO_3$

Site 376 Hole Core 6 Cored Interval: 45.5-55.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARL WITH SAPROPELIC LAYERS

1-104 to 3-86 soft intensely deformed variegated gray to brown (5YR 5/6, 5G 6/1, 5Y 7/2, 5GY 6/1, 5B 7/1, 5G 7/2, 5B 5/1) nannofossil marl with dark streaks of sapropelic marl - drilling artifact.

3-86 to 4-55 slightly deformed nannofossil marl, light brown (5YR 5/6, 5YR 4/4) to very pale orange (10YR 8/2) and yellowish gray (5Y 5/2). Some brown layers are burrowed. The lower part of Section 3, 90 to 150 cm is very similar to Core 5, Section 5. In Section 4: 0-58 cm bluish white (5B 9/1) mottled and burrowed nanno marl. Sapropel at 4-55 to 75. Sapropelic layers at 3-94 to 97 cm and 4-95 to 98 cm.

Base of Section 4-108 to 125 cm intensely deformed upper Miocene nannofossil marl medium gray (N5) and light brown (10YR 6/2) - sedimentary slump

MAJOR LITHOLOGY

NANNOFOSSIL MARL
SS 2-103

Clay	A	Quartz	R
Nannos	A	Organic matter	T
Carb. unspec.	C		

X-ray:
2-80

Smectite	19%	Quartz	6%
Illite	7%	Plag. felds.	6%
Mixed layer	5%	K-feldspar	1%
Chlorite	4%	Dolomite	5%
Kaolinite	2%	Hornblende	1%
Attapulgite	1%	Halite	1%
Calcite	42%		

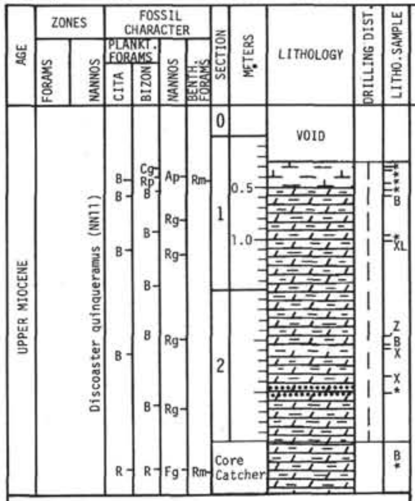
MINOR LITHOLOGY

SAPROPELIC NANNOFOSSIL MARL
SS 4-95

Clay	A	Pyrite	R
Nannos	A	Quartz	R
Organic matter	C	Mica	T
Dolomite	C		

BOMB:
1-133 to 134 cm = 42% $CaCO_3$
2-83 to 84 cm = 41% $CaCO_3$
4-50 to 51 cm = 69% $CaCO_3$
CC = 68% $CaCO_3$

Site 376 Hole Core 7 Cored Interval: 55.0-64.5 m



LITHOLOGIC DESCRIPTION

DOLOMITIC MARLSTONE OVERLAIN BY NANNOFOSSIL MARLS (22 cm)

Soft to firm, indurated, gray (5G 6/1, 5GY 6/1, 5B 7/1, N6) to brown (5YR 5/6) nannofossil dolomitic marlstone with thin (<1 cm to 2 cm) silty sandstone layers in places with well-defined cross lamination. No burrows. Overlain by nannofossil marls: 28 to 32 cm light brown (5YR 5/6) to yellowish gray (5Y 7/2), soft very deformed 32 to 50 cm - thinly bedded and interlayered light to medium bluish gray (5B 7/1 to 5B 5/1) with patches of greenish gray (5G 6/1) soft intensely deformed.

MAJOR LITHOLOGIES

DOLOMITIC MARLSTONE
SS 1-95

Clay	A	Glauconite	R
Dolomite	A	Pyrite	R
Quartz	C	Mica	R
Nannos	C	Forams	T

X-ray:
1-100

Smectite	14%	Calcite	17%
Illite	8%	Quartz	12%
Mixed layer	7%	Plag. felds.	5%
Attapulgite	5%	K-feldspar	4%
Chlorite	3%	Serpentinite	1%
Kaolinite	1%	Halite	T
Dolomite	23%		

NANNOFOSSIL MARL
SS 1-28

Clay	A	Quartz	R
Nannos	A	Pyrite	R
Forams	R	Organic matter	T
Carb. unspec.	R		

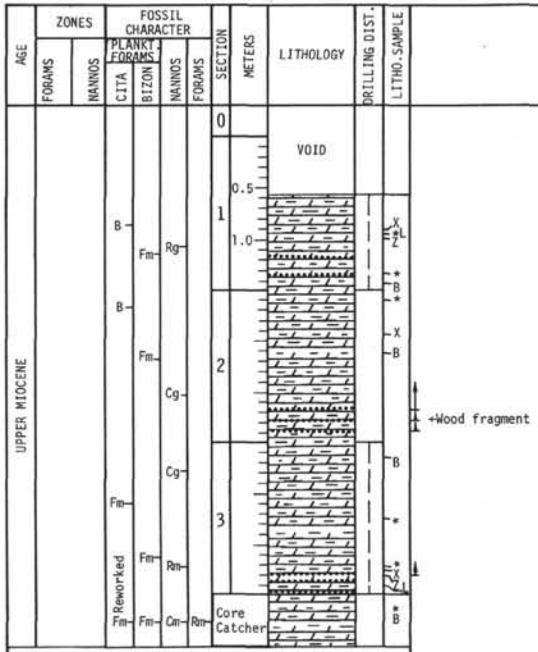
MINOR LITHOLOGY

DOLOMITIC SILTSTONE
SS 2-100

Dolomite	A	Nannos	R
Quartz	A	Mica	T
Carb. unspec.	C	Forams	T
Clay	C		

BOMB:
1-59 to 60 cm = 29% $CaCO_3$
2-51 to 52 cm = 32% $CaCO_3$
CC = 35% $CaCO_3$

Site 376 Hole Core 8 Cored Interval: 64.5-74.0 m



LITHOLOGIC DESCRIPTION

DOLOMITIC MARLSTONE WITH SANDY AND SAPROPELIC LAYERS

Firm, slightly disturbed to undisturbed, medium bluish gray (5B 5/1) to greenish gray (5G 6/1) dolomitic marlstone with thin sandy layers, <1 cm to 10 cm thick, most normally graded in sandstone or siltstone to marlstone cycles, sharp basal contacts. Marlstone laminated, unburrowed, siltstone layers laminated to cross laminated. Interbedded sapropelic layers most <1 cm but up to 2 cm thick in interval 2-0 to 71 cm.

MAJOR LITHOLOGY

DOLOMITIC MARLSTONE
SS CC

Clay	A	Pyrite	R
Dolomite	A	Quartz	R
Nannos	C	Forams	R

X-ray:
2-46

Smectite	17%	Calcite	24%
Mixed layer	9%	Quartz	6%
Illite	6%	Plag. felds.	3%
Attapulgite	4%	K-feldspar	1%
Chlorite	3%	Serpentinite	1%
Kaolinite	3%	Halite	T
Dolomite	24%		

MINOR LITHOLOGIES

POLYGENIC SANDY SILT
SS 1-132

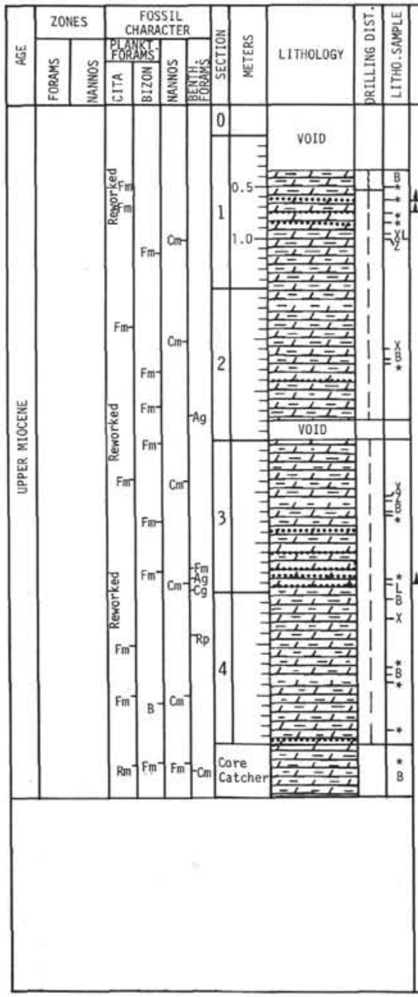
Quartz	A	Mica	R
Rock fragments	C	Amphibole	R
Dolomite	C	Volc. glass	T
Carb. unspec.	C	Forams	T
Feldspar	C		

SAPROPELITIC NANNOFOSSIL MARL
SS 2-10

Clay	A	Dolomite	R
Nannos	A	Volc. glass	R
Organic matter	A	Mica	T
Pyrite	C		

BOMB:
1-140 to 141 cm = 25% $CaCO_3$
2-62 to 70 cm = 42% $CaCO_3$
3-17 to 18 cm = 31% $CaCO_3$
CC = 35% $CaCO_3$

Site 376 Hole Core 9 Cored Interval: 74.0-83.5 m



LITHOLOGIC DESCRIPTION

DOLOMITIC MARLSTONE, WITH SANDY INTERBEDS

Firm, slightly to intensely deformed greenish gray (5G 6/1) to dark greenish gray (5G 4/1), subordinately light olive gray (5Y 6/1) dolomitic marlstone with varying nannofossil abundance and interbedded siltstones and sandstones. Coarse interbeds and laminae, massive to cross-laminated with sharp basal contacts and often top contacts. Also, many with marlstone pebbles. Not all are graded. Where normal grading occurs only the sand size fraction is involved. Marlstone silty, homogeneous or finely laminated. No burrow traces. Interbeds at base of Section 4 display flame structure and soft sediment deformation unconnected with drilling disturbance.

MAJOR LITHOLOGY

DOLOMITIC MARLSTONE
SS 1-50

Clay	A	Quartz	C
Carb. unspec. (partly dolomite)	A	Nannos	R
Volcanogenic material	C	Mica	R
		Heavy mins.	T

X-ray:
1-97

Smectite	22%	Dolomite	11%
Mixed layer	10%	Quartz	9%
Illite	9%	Plag. felds.	3%
Attapulgite	5%	Serpentinite	1%
Chlorite	3%	Halite	T
Kaolinite	1%		
Calcite	26%		

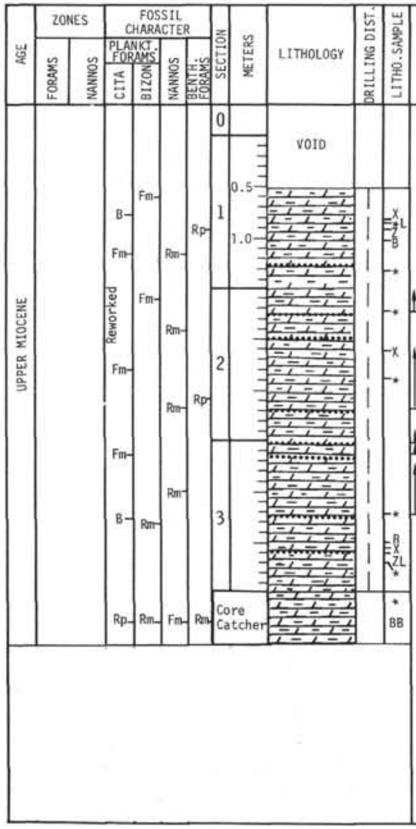
MINOR LITHOLOGY

SILTY DOLOMITIC SANDSTONE
SS 1-85

Carb. Unspec. (partly dolomite)	A	Pyrite	C
		Feldspar	R
Volcanogenic material	A	Heavy mins.	R
		Mica	R
Quartz	C	Forams	R

BOMB:
1-50 to 51 cm = 35% $CaCO_3$
2-70 to 71 cm = 31% $CaCO_3$
3-70 to 71 cm = 30% $CaCO_3$
4-4 to 5 cm = 40% $CaCO_3$
4-80 to 81 cm = 37% $CaCO_3$
CC = 27% $CaCO_3$

Site 376 Hole Core 10 Cored Interval: 83.5-93.0 m



LITHOLOGIC DESCRIPTION

DOLOMITIC MARLSTONE, WITH SANDY LAYERS

Firm, slightly disturbed, light olive gray (5Y 6/1) to dark greenish gray (5G 4/1) and medium bluish gray (5B 5/1) with intervals of light brown (5YR 5/6) mottling. Dolomitic marlstone, silty, varying nannofossil content. Homogeneous but in places faintly laminated oxidized pyrite nodule layer at 3-47 cm. Sandy layers with no sharp basal contacts and only vague fining upward. Grain size distribution.

MAJOR LITHOLOGY

DOLOMITIC MARLSTONE
SS 3-120

Clay	A	Quartz	C
Nannos	A	Mica	R
Dolomite	C		

X-ray:
3-108

Smectite	14%	Calcite	35%
Illite	10%	Dolomite	12%
Mixed layer	7%	Quartz	9%
Chlorite	4%	Plag. felds.	3%
Attapulgite	3%	K-feldspar	1%
Kaolinite	1%	Serpentinite	1%

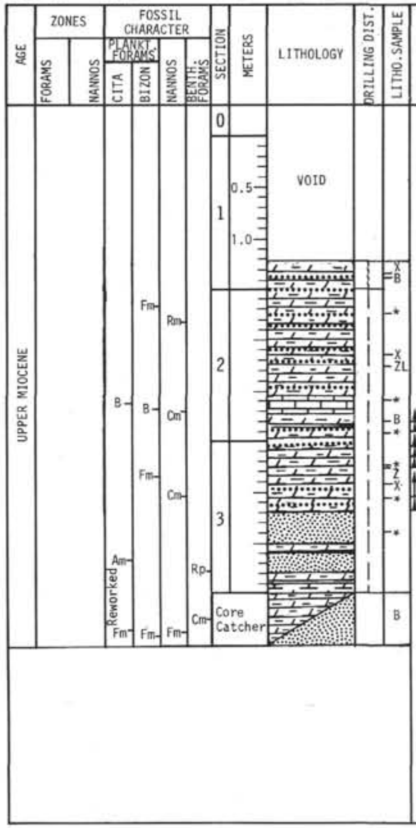
MINOR LITHOLOGY

SILTY DOLOMITIC SANDSTONE
SS 3-74

Dolomite	A	Pyrite	R
Clay	C	Mica	R
Quartz	C	Nannos	R
Calcite	C	Heavy mins.	T
Volcanogenic rock frags.	C		

BOMB:
1-101 to 102 cm = 36% $CaCO_3$
3-100 to 101 cm = 34% $CaCO_3$
CC = 35% $CaCO_3$

Site 376 Hole Core 11 Cored Interval: 93.0-102.5 m



LITHOLOGIC DESCRIPTION

DOLOMITIC MARLSTONE, LIMESTONE AND SANDSTONE

Firm, slightly disturbed to broken (intensely disturbed at top).

1-123 to 2-104 cm: Dolomitic marlstone, medium bluish gray (5B 5/1) to medium light gray (N6) with graded silty interbeds, faintly cross-laminated to massive and sandy.

2-104 to 2-123 cm: Soft micritic limestone, very light gray (N8) to light gray (N7). Massive to finely laminated. Grades downwards to:

2-123 to 2-130.5 cm: Fine sandstone to siltstone.

2-130.5 to 3-70 cm: Dolomitic marlstone with interbedded graded marlstone units, cross-laminated to laminated, containing abundant gypsum, plant and dark rock fragments.

3-70 cm to base: Sandstone with dolomitic marlstones.

MAJOR LITHOLOGIES

DOLOMITIC MARLSTONE
SS 2-141

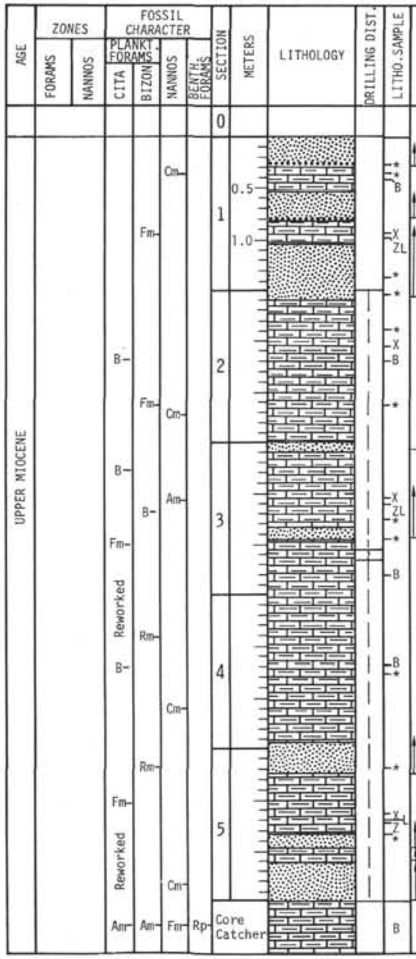
Carb. unspec. (mostly dolomite)	A
Clay	A

CALCAREOUS DOLOMITIC SILTSTONE
SS 2-24

Rock fragments	A	Pyrite	C
Dolomite (+ calcite)	A	Mica	R
		Feldspar	R
Quartz	C	Heavy mins.	T

BOMB:
1-139 to 140 cm = 37% $CaCO_3$
2-130 to 131 cm = 80% $CaCO_3$
CC = 74% $CaCO_3$

Site 376 Hole Core 12 Cored Interval: 102.5-112.0 m



LITHOLOGIC DESCRIPTION

MARLSTONE WITH SANDSTONE INTERBEDS

Firm, slightly disturbed, dark greenish gray (5G 4/1) marlstone with graded sandstone interbeds, greenish black (5G 2/1) and often with organic rich layers near sharp basal contacts. Sandstones. Massive to cross-laminated and rich in plant debris and lithic fragments. Sections 2 and 4 with interlayered grayish yellow green (5GY 7/2) marlstone and organic-rich grayish olive green (5GY 3/2) silty marlstone. No burrow traces.

MAJOR LITHOLOGIES

MARLSTONE
SS 2-39

Carb. unspec.	A	Pyrite	C
Rock frags.	A	Quartz	R
Forams	C	Glauconite	T

X-ray:
2-54

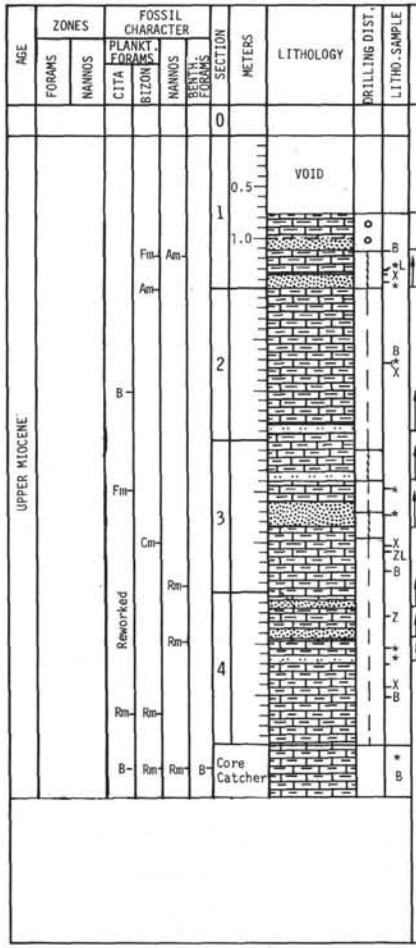
Smectite	26%	Calcite	60%
Mixed layer	3%	Quartz	3%
Illite	3%	Plag. felds.	1%
Attapulgite	1%	Dolomite	1%
Chlorite	1%	Clinoptilolite	1%
Kaolinite	1%		

POLYGENIC SANDSTONE
SS 1-26

Rock frags. (volc.)	A	Quartz	C
		Plant debris	C
Forams	A	Nannos	T
Dolomite	C	Glauconite	T
Pyrite	C		

BOMB:
1-40 to 42 cm = 32% $CaCO_3$
2-70 to 71 cm = 37% $CaCO_3$
3-130 to 131 cm = 57% $CaCO_3$
4-70 to 71 cm = 22% $CaCO_3$
CC = 48% $CaCO_3$

Site 376 Hole Core 13 Cored Interval: 112.0-121.5 m



LITHOLOGIC DESCRIPTION

MARLSTONE WITH SANDSTONE AND SILTSTONE INTERBEDS

Firm, slightly disturbed to intensely disturbed to broken, light gray (N6, N8) to greenish gray (5GY 6/1, 5GY 4/1) marlstone with interbedded olive gray (5Y 4/1) to light olive gray (5Y 6/1) sandstones to siltstones. Beds graded, laminated to cross laminated with sharp basal contacts and abundant plant and rock fragments, often massive. Marlstones homogeneous to finely laminated. No burrow traces.

MAJOR LITHOLOGIES

MARLSTONE
SS 3-76

Clay	A	Quartz	R
Dolomite	A	Pyrite	R
Nannos	C	Mica	T

X-ray:
3-106

Smectite	51%	Calcite	36%
Illite	5%	Quartz	3%
Mixed layer	3%	Plag. felds.	T
Chlorite	1%	Dolomite	T
Kaolinite	T	Clinoptilolite	2%

SILTSTONE
SS 1-145

Dolomite + calcite	A	Quartz	R
Forams	A	Radiolaria	R
Rock frags. (volc.?)	C	Mica	T
Pyrite + opaques	C	Heavy mins.	T
		Hematite	T

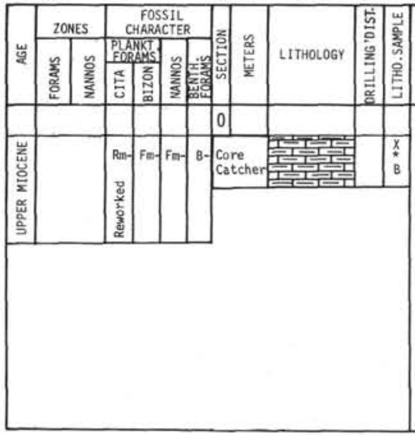
SANDSTONE

Grain size:
4-7

Sand	39.1%
Silt	38.6%
Clay	22.3%

BOMB:
1-114 to 115 cm = 72% $CaCO_3$
2-71 to 72 cm = 27% $CaCO_3$
3-130 to 131 cm = 36% $CaCO_3$
5-102 to 103 cm = 23% $CaCO_3$
CC = 14% $CaCO_3$

Site 376 Hole Core 14 Cored Interval: 121.5-131.0 m



LITHOLOGIC DESCRIPTION

MARLSTONE

Core Catcher only

MAJOR LITHOLOGY

MARLSTONE
SS CC

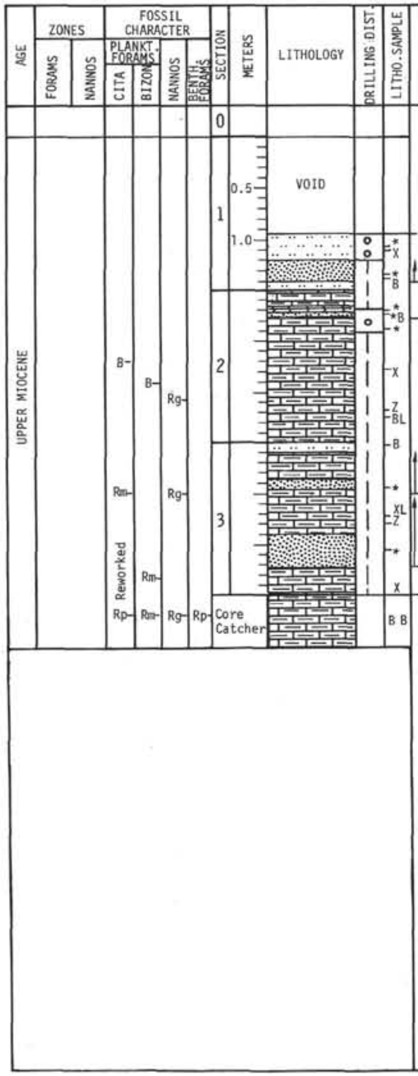
Clay	A	Pyrite	R
Nannos	A	Quartz	R

X-ray:
CC

Smectite	57%	Calcite	23%
Mixed layer	6%	Quartz	5%
Illite	5%	Plag. felds.	1%
Chlorite	2%	Clinoptilolite	1%
Kaolinite	T	Serpentinite	1%

BOMB:
CC = 18% $CaCO_3$

Site 376 Hole Core 15 Cored Interval: 131.0-140.5 m



LITHOLOGIC DESCRIPTION

MARLSTONE WITH GYPSIFEROUS SANDSTONES AND SILTSTONES

Indurated, slightly disturbed to broken silty, green and gray (10G 6/2, 5B 5/1, N8) mottled with light olive brown (5Y 5/6), nannofossil marlstone with interbedded graded gypsiferous sandstone and siltstone layers. Beds have sharp erosional basal contacts, best displayed in Section 3. Contain marlstone pebbles and dark rock fragments coarsely crystalline white gypsum at 2-18 to 23 cm.

MAJOR LITHOLOGIES

MARLSTONE
SS 2-39

Clay	A	Quartz	C
Carb. unspec.	A	Feldspar	R
Nannos	C		

X-ray:
2-38

Smectite	22%	Calcite	26%
Illite	17%	Quartz	8%
Mixed layer	8%	Plag. felds.	4%
Chlorite	6%	K-feldspar	1%
Attapulgite	2%	Dolomite	4%
Kaolinite	1%	Serpentinite	1%

GYPSIFEROUS SANDSTONE
SS 2-21

Gypsum	A
Rock frags. (volc.?)	C
Nannos	C

SILTSTONE
SS 1-105

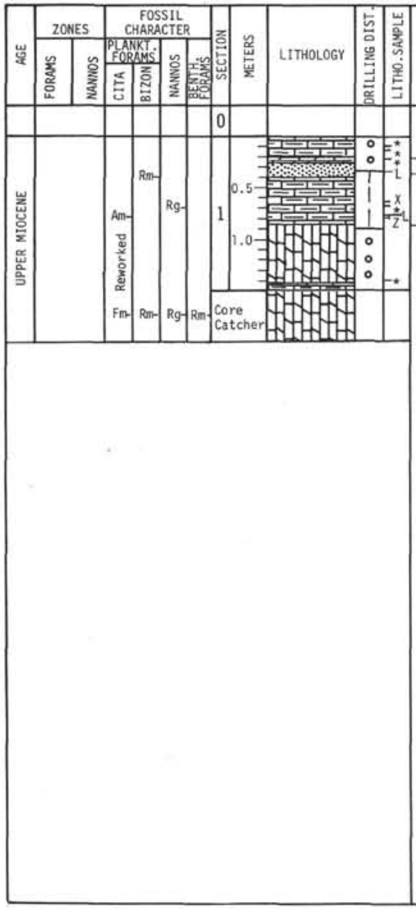
Clay	A	Quartz	C
Nannos	C	Dolomite	R
Rock frags.	C	Mica	R
Gypsum	C	Pyrite	R
Feldspar	C		

X-ray:
1-108

Smectite	20%	Plag. felds.	11%
Illite	6%	K-feldspar	7%
Mixed layer	4%	Quartz	10%
Attapulgite	1%	Gypsum	14%
Chlorite	1%	Hornblende	1%
Kaolinite	T	Serpentinite	1%
Calcite	18%	Clinoptilolite	T
Dolomite	5%		

BOMB:
1-137 to 138 cm = 53% $CaCO_3$
2-35 to 36 cm = 54% $CaCO_3$
2-125 to 126 cm = 33% $CaCO_3$
3-2 to 3 cm = 46% $CaCO_3$
CC = 44% $CaCO_3$
CC = 35% $CaCO_3$ Rim of gypsum

Site 376 Hole Core 16 Cored Interval: 140.5-150.0 m



LITHOLOGIC DESCRIPTION

MARLSTONE WITH GYPSIFEROUS SANDSTONE AND SILTSTONE, AND COARSELY CRYSTALLINE GYPSUM

Drilling breccias top and bottom of section with slightly disturbed interval between.

Strongly disturbed transition between Cores 15 and 17.

0-20 cm: Coarsely crystalline, banded, recrystallized gypsum (selenite).

20-25 cm: Sandy green marlstone with very fine-grained gypsum.

25-36 cm: Coarse sandstone with gypsum fragments.

36-87 cm: Greenish gray (5G 6/1) silty to silty marlstone with thin sandstone layers containing dark rock fragments and detrital gypsum.

SILTY MARLSTONE
X-ray:
1-68

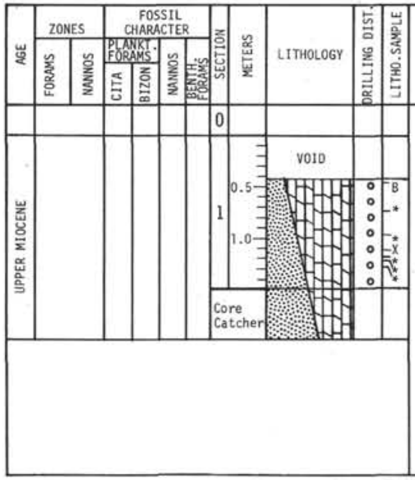
Smectite	27%	Dolomite	2%
Illite	7%	Gypsum	6%
Mixed layer	4%	Quartz	6%
Attapulgite	2%	Plag. felds.	4%
Chlorite	2%	Hornblende	1%
Kaolinite	1%	Serpentinite	1%
Calcite	38%		

Grain size:
1-72

Sand	3.2%
Silt	47.9%
Clay	49.0%

87-50 cm: Gypsum, 4 types:
1) Fine-grained, homogeneous, light olive gray (5Y 6/1) to white;
2) crystalline, crudely layered, white;
3) layered, crenulated;
4) coarse selenite.
Set in matrix of greenish gray silty marlstone.

Site 376 Hole Core 17 Cored Interval: 150.0-159.5 m



LITHOLOGIC DESCRIPTION

GYPSUM, IN SANDSTONE MATRIX

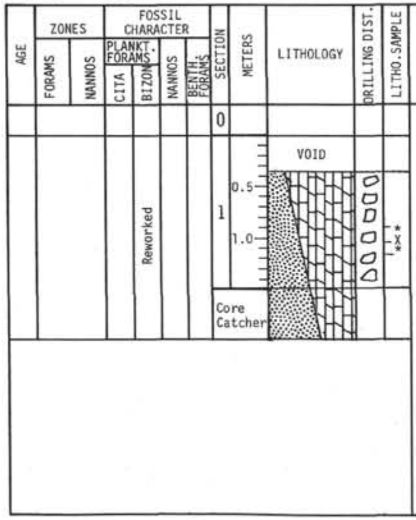
Drilling breccia of pieces of different forms of gypsum in a pale green (5G 7/2) matrix of marly sandstone.

1) Homogeneous light gray (N8 and N7) fine grained gypsum.
2) Gypsiferous sandstone, in places cross-laminated.
3) Banded to laminated gypsum, in some places brecciated and re-cemented e.g. 1-96 cm. Laminae sometimes crenulated.
4) Coarsely crystalline recrystallized gypsum.
5) Large "swallow-tail" crystals of selenitic gypsum ($\leq$4 cm).

White nannofossil ooze fragments at 1-122 cm.

BOMB:
1-45 to 47 cm = 35% $CaCO_3$

Site 376 Hole Core 18 Cored Interval: 159.5-169.0 m



LITHOLOGIC DESCRIPTION

GYPSUM, IN SANDSTONE MATRIX

Drilling breccia of pieces of different forms of gypsum in a pale green (5G 7/2) marly sandstone matrix. Gypsum varieties: 1, 2, 3, 4 and 5, as in Core 17.

MAJOR LITHOLOGIES

GYPSUM
SS 1-91

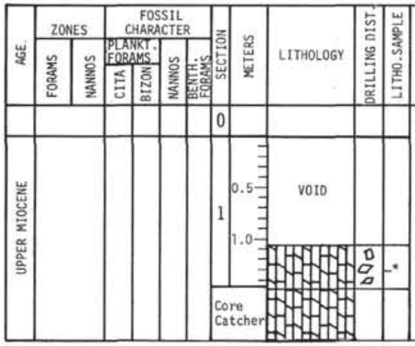
GYPSIFEROUS SANDSTONE
SS 1-117

Carb. unspec.	A	Nannos	R
Gypsum	A	Quartz	R
Rock frags. (volc.?)	C		

X-ray:
1-106

Smectite	24%	Calcite	32%
Mixed layer	4%	Dolomite	2%
Illite	2%	Gypsum	26%
Attapulgite	1%	Quartz	5%
Chlorite	1%	Plag. felds.	2%
Kaolinite	T	Serpentinite	1%

Site 376 Hole Core 19 Cored Interval: 169.0-178.5 m

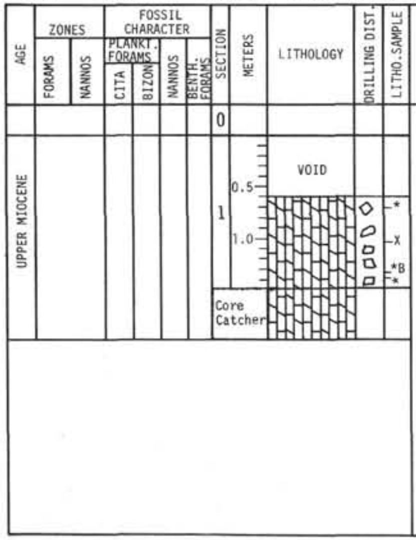


LITHOLOGIC DESCRIPTION

GYPSUM BRECCIA

Three large pieces, and several small ones, of a sedimentary conglomerate composed of elongate, subangular gypsum fragments in a sparse pale green (5G 7/2) marlstone matrix. Gypsum clasts, up to 5cm diameter of types 1 to 5 as in Core 17. Two pieces of somewhat recrystallized, laminated gypsum.

Site 376 Hole Core 20 Cored Interval: 185.0-188.0 m



LITHOLOGIC DESCRIPTION

GYPSUM

Broken pieces.

60-72 cm: Breccia of laminated, elongated white gypsum clasts in vuggy olive black (5Y 2/1) matrix of gypsum and dolomite.

72-96 cm: laminated (slightly wavy), fine grained gypsum, olive gray (5Y 4/1) to olive black (5Y 2/1).

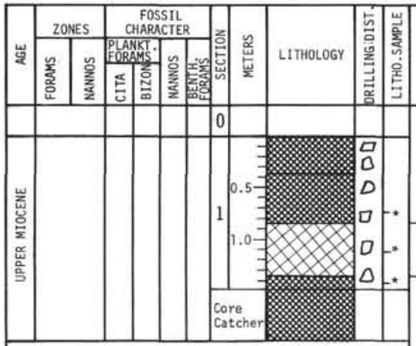
90-112 cm: banded to laminated coarse grained gypsum, light gray to olive black (5Y 2/1).

112-120 cm: dark gray (N3), faintly laminated very fine grained gypsum.

120-150 cm: Gypsum sandstone and siltstone (resedimented).
Core exuded H_2S odor on splitting.
BOMB:
1-135 t0 137 cm = 0% $CaCO_3$

Site 376, Core 21, Interval 188-197.5 m: NO RECOVERY.

Site 376 Hole Core 22 Cored Interval: 205.0-207.0 m



LITHOLOGIC DESCRIPTION

0-85 cm: HALITE, coarsely crystalline, numerous small pieces, with thin interlayers of finely crystalline gypsum.

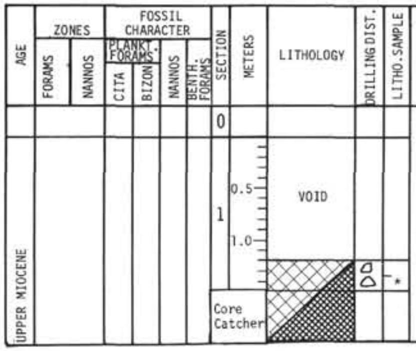
85-130 cm: Nodular ANHYDRITE, large pieces, with large and small enterolithic folds, one shows "chicken-wire" structure, scattered vugs filled with halite; associated gypsum.

130-136 cm: Banded ANHYDRITE, one piece, with thin dividing dark brown laminae, small scale "chicken-wire" structure.

136-150 cm: Banded HALITE, coarsely crystalline in 2-4 cm thick bands separated by 0.5 cm thick brown, fine-grained gypsum/anhydrite layers.

Core exuded strong H_2S odor on splitting.

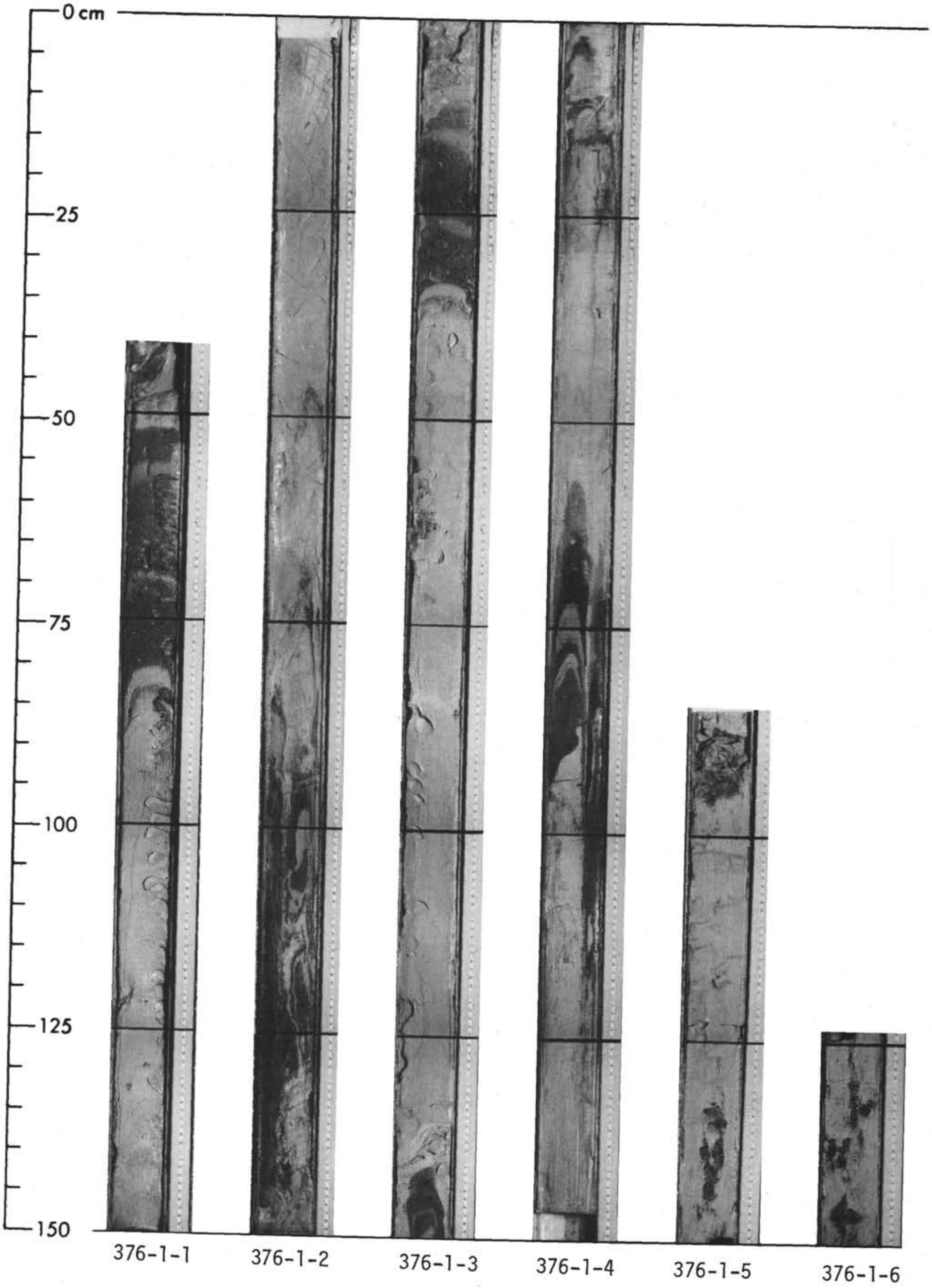
Site 376 Hole Core 23 Cored Interval: 207.0-216.5 m

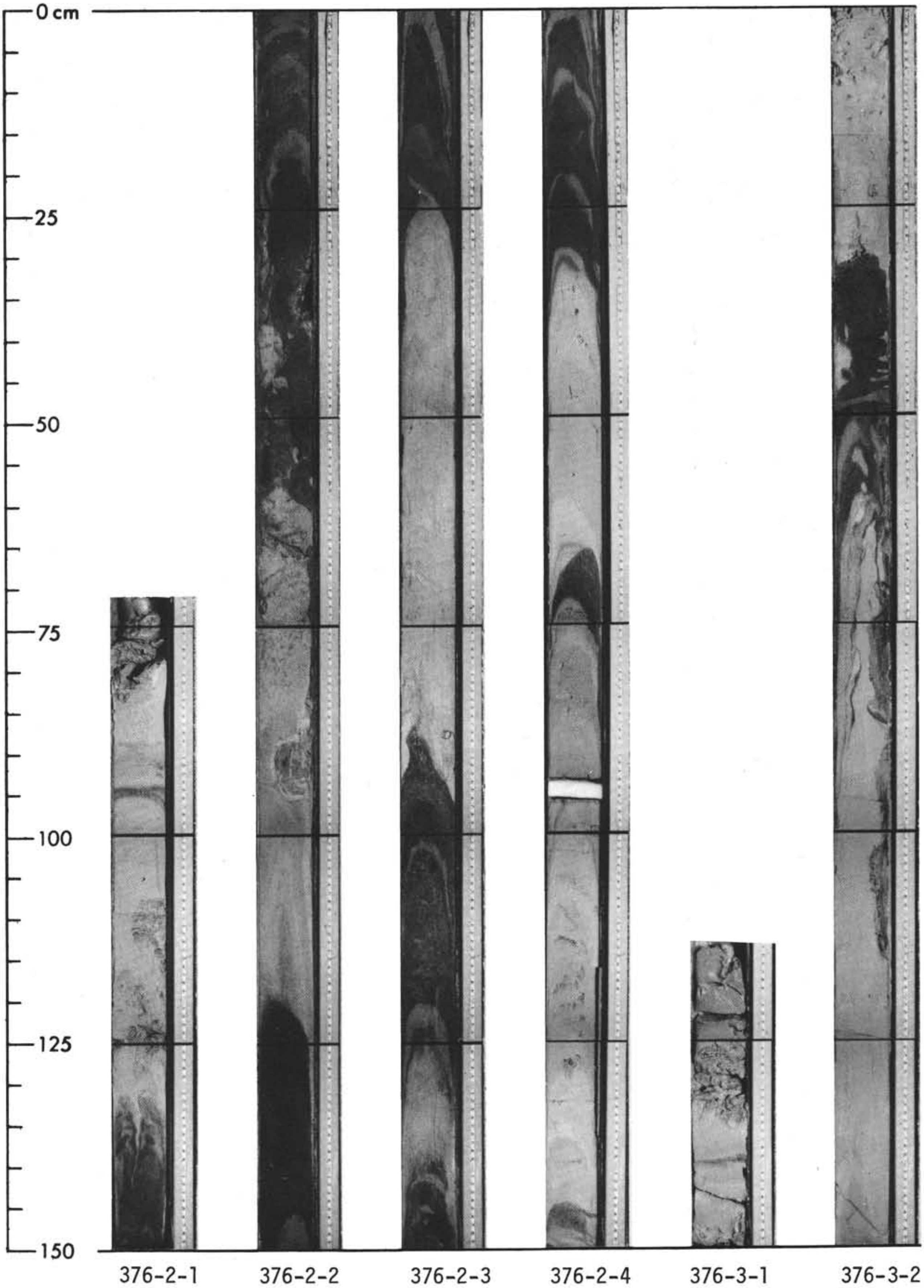


LITHOLOGIC DESCRIPTION

ANHYDRITE AND HALITE

Rubble of small pieces of banded *vuggy anhydrite and clear halite.* (Anhydrite has dark bands and appears porous, may have had vugs filled with halite, now lost in solution during drilling.)


0 cm
25
50
75
100
125
150
376-1-1
376-1-2
376-1-3
376-1-4
376-1-5
376-1-6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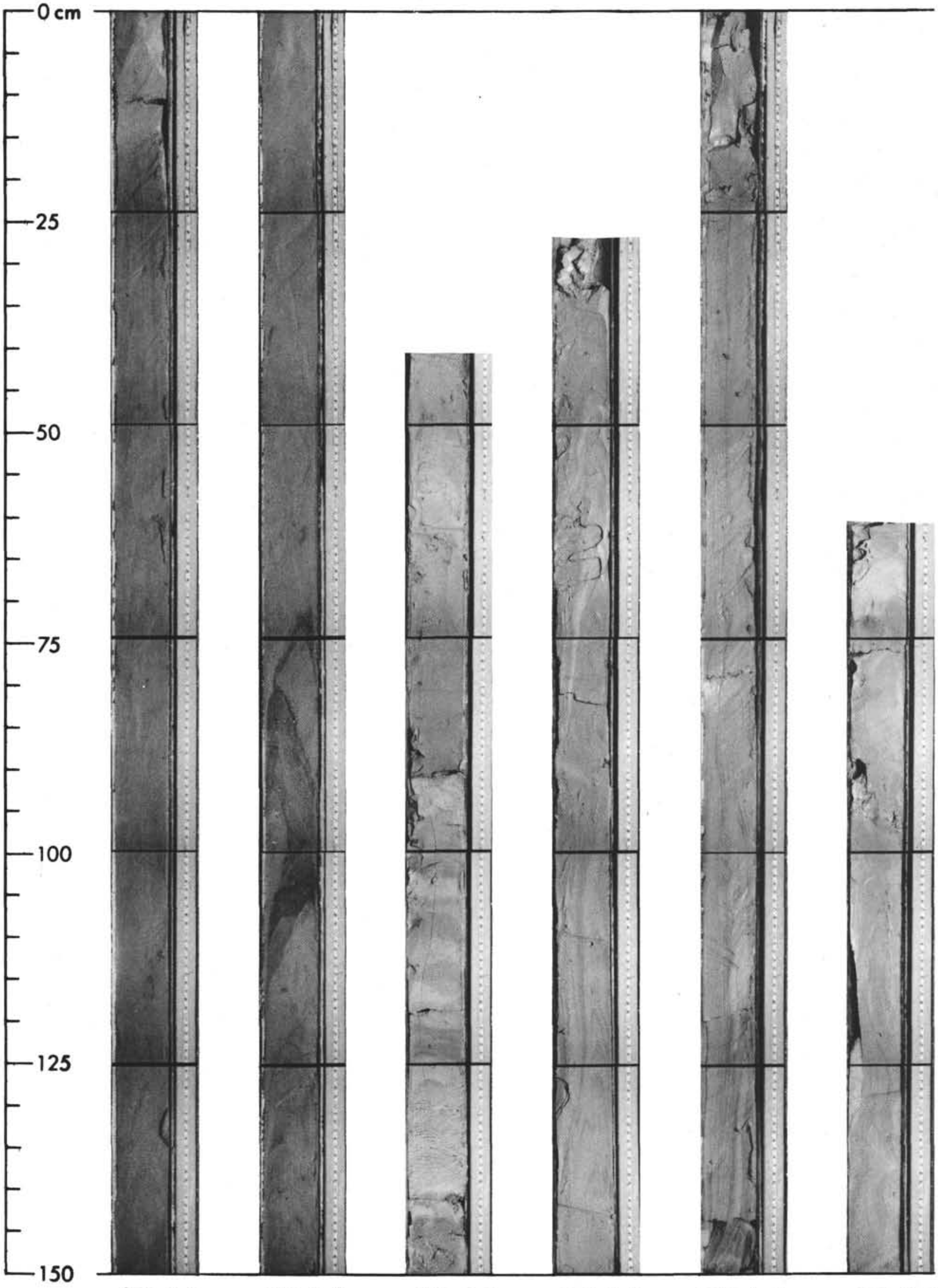
376-3-2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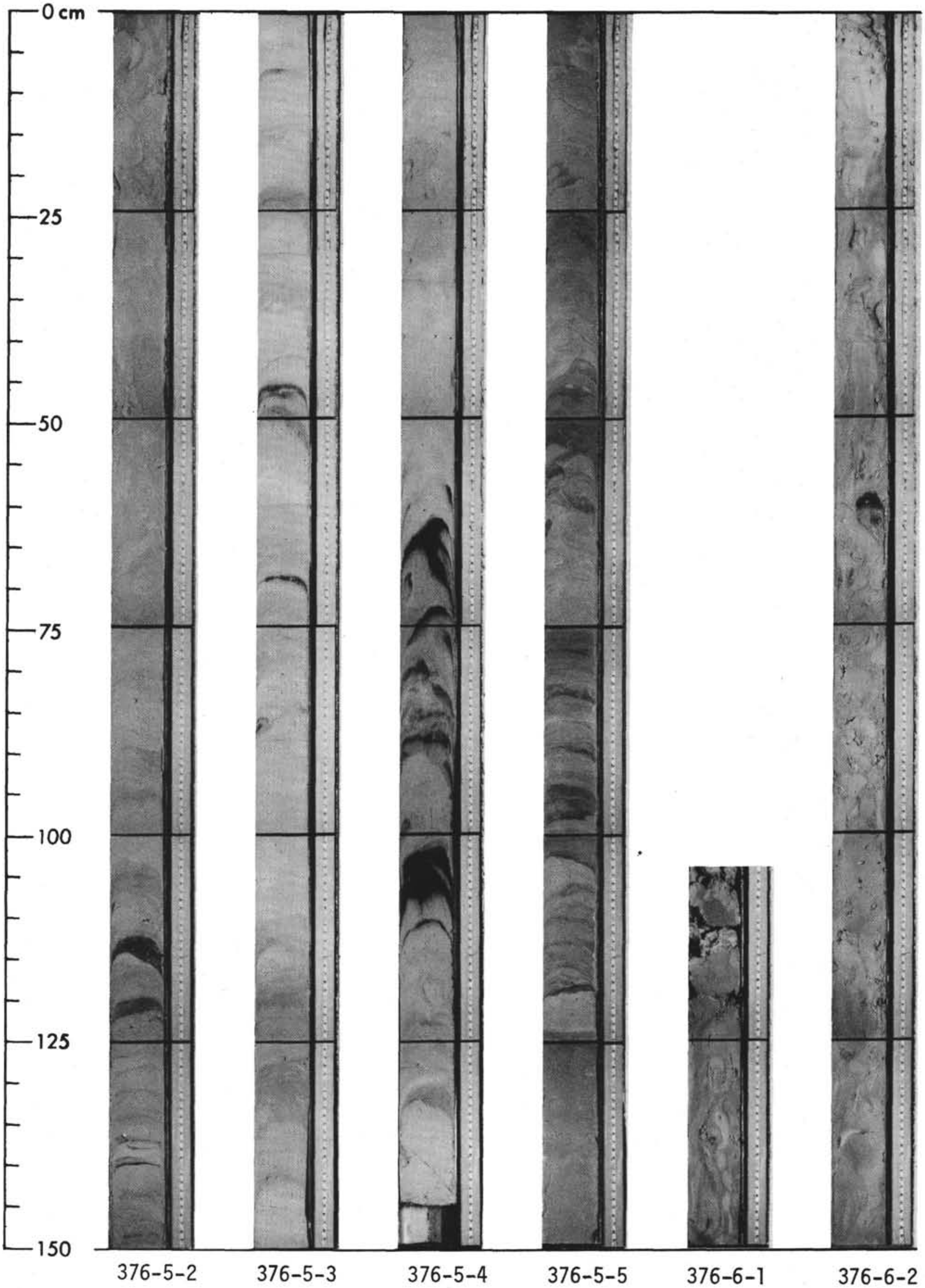
376-5-1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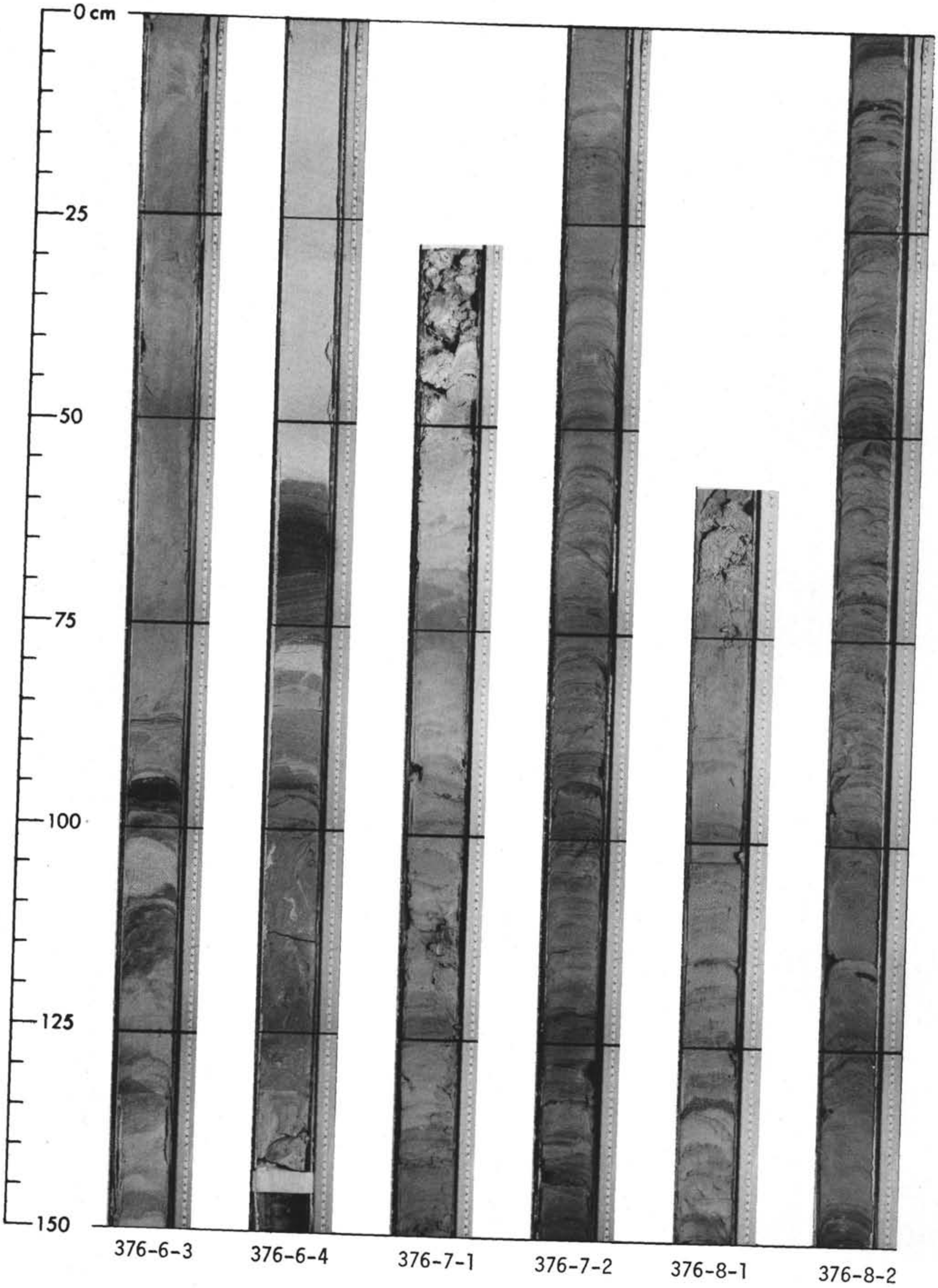
376-6-2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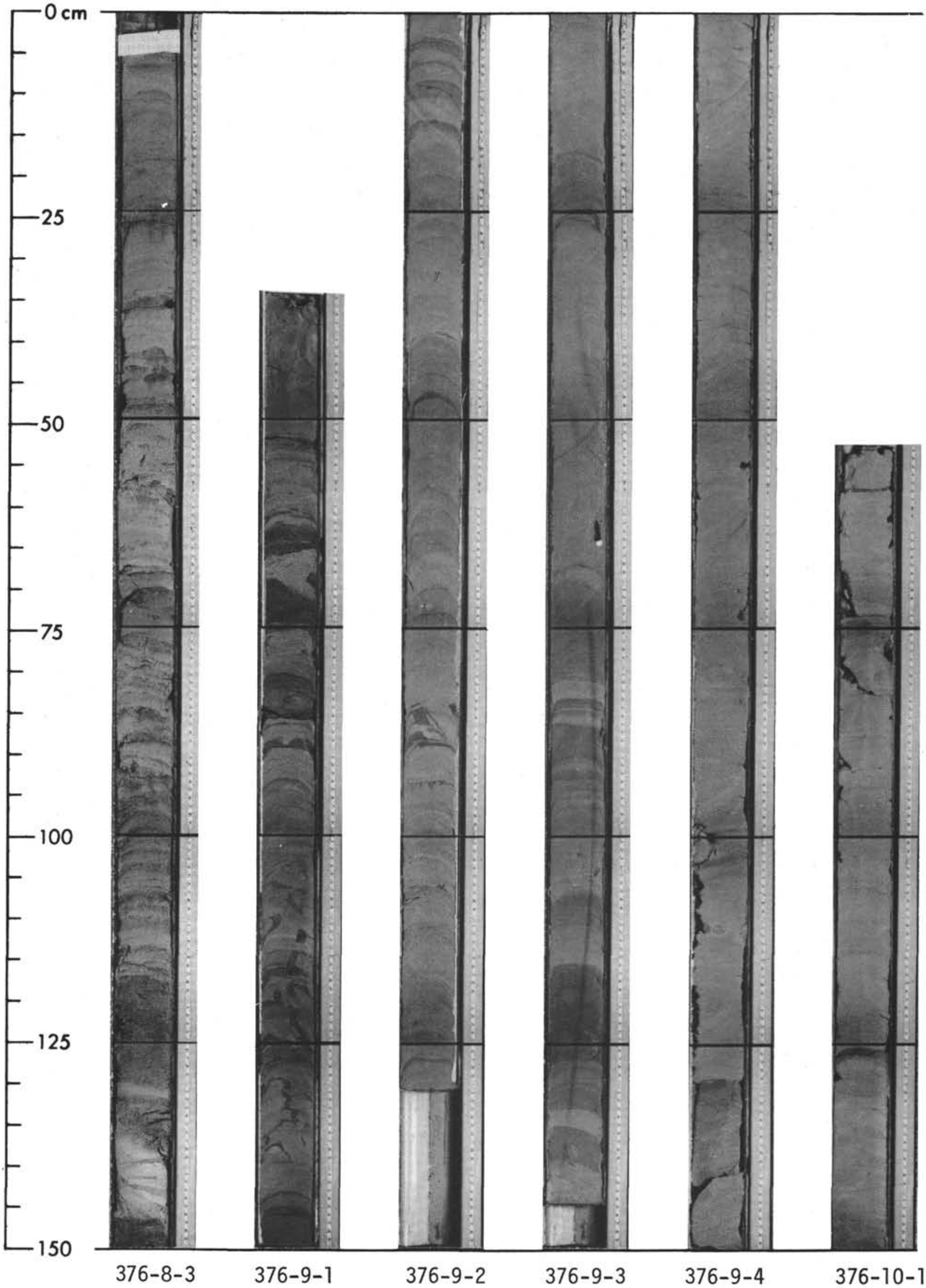
376-8-1
376-8-2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75
100
125
150
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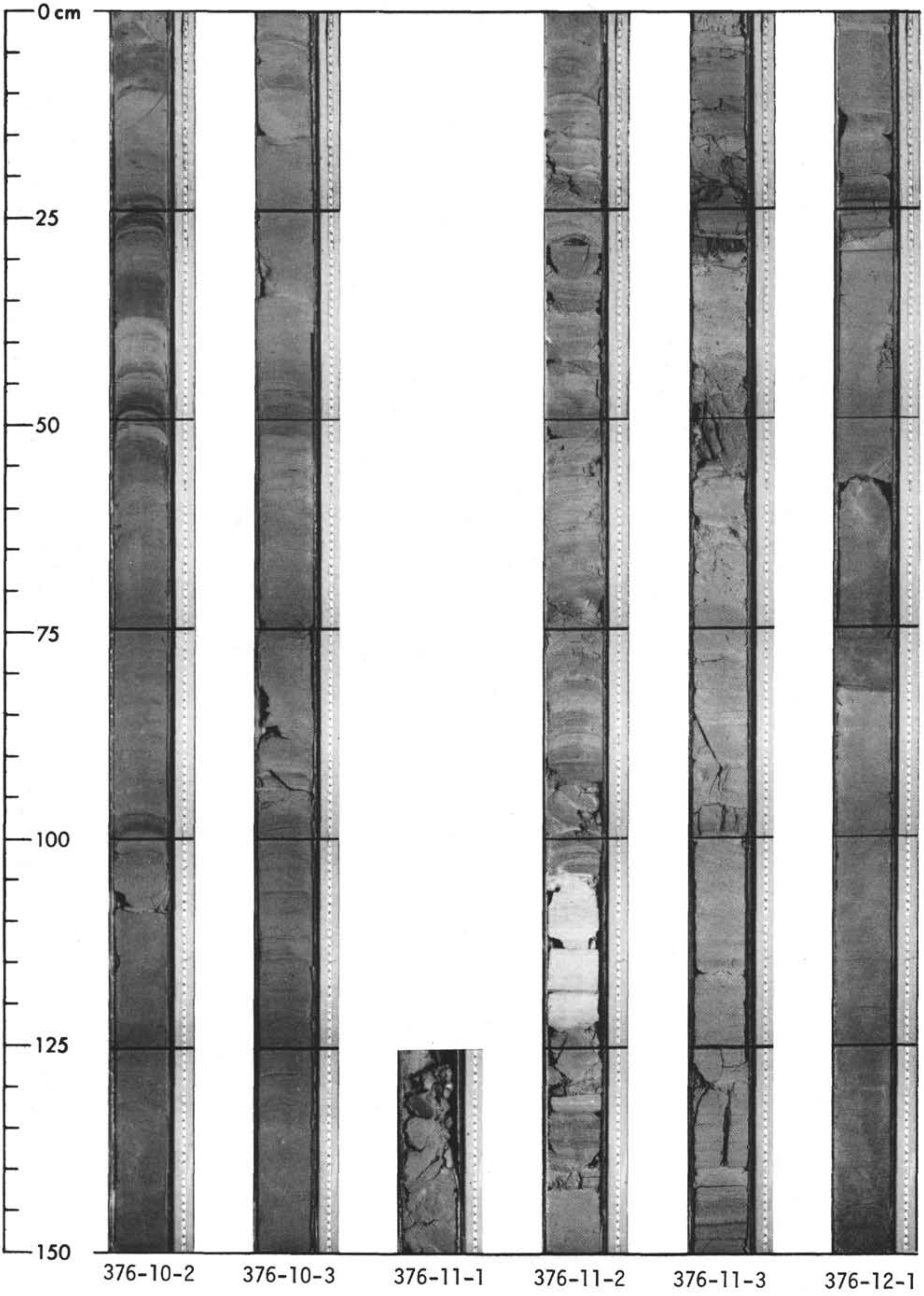
376-9-1
376-9-2
376-9-3
376-9-4
376-10-1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75
100
125
150
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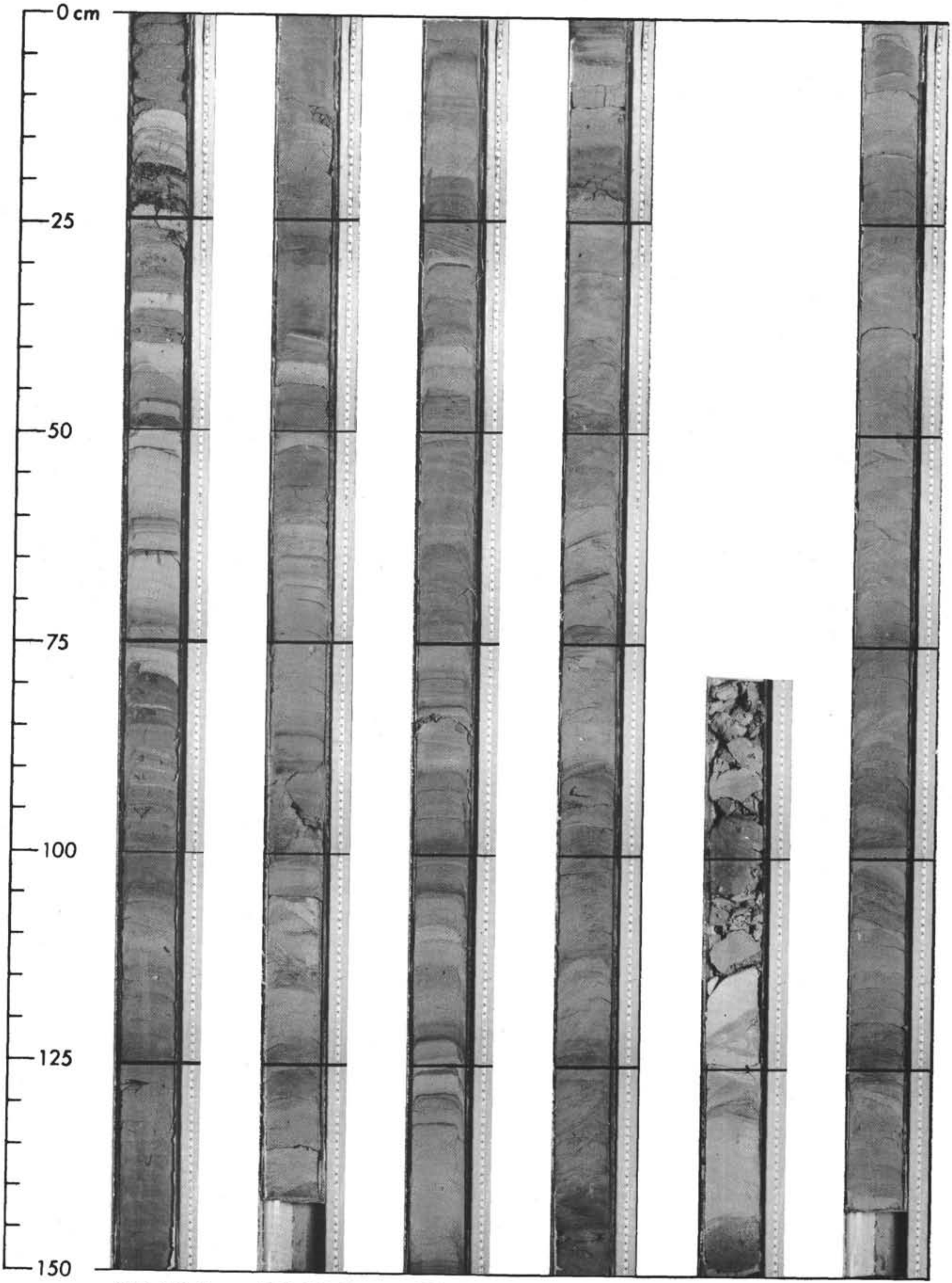
376-10-3
376-11-1
376-11-2
376-11-3
376-12-1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125
150
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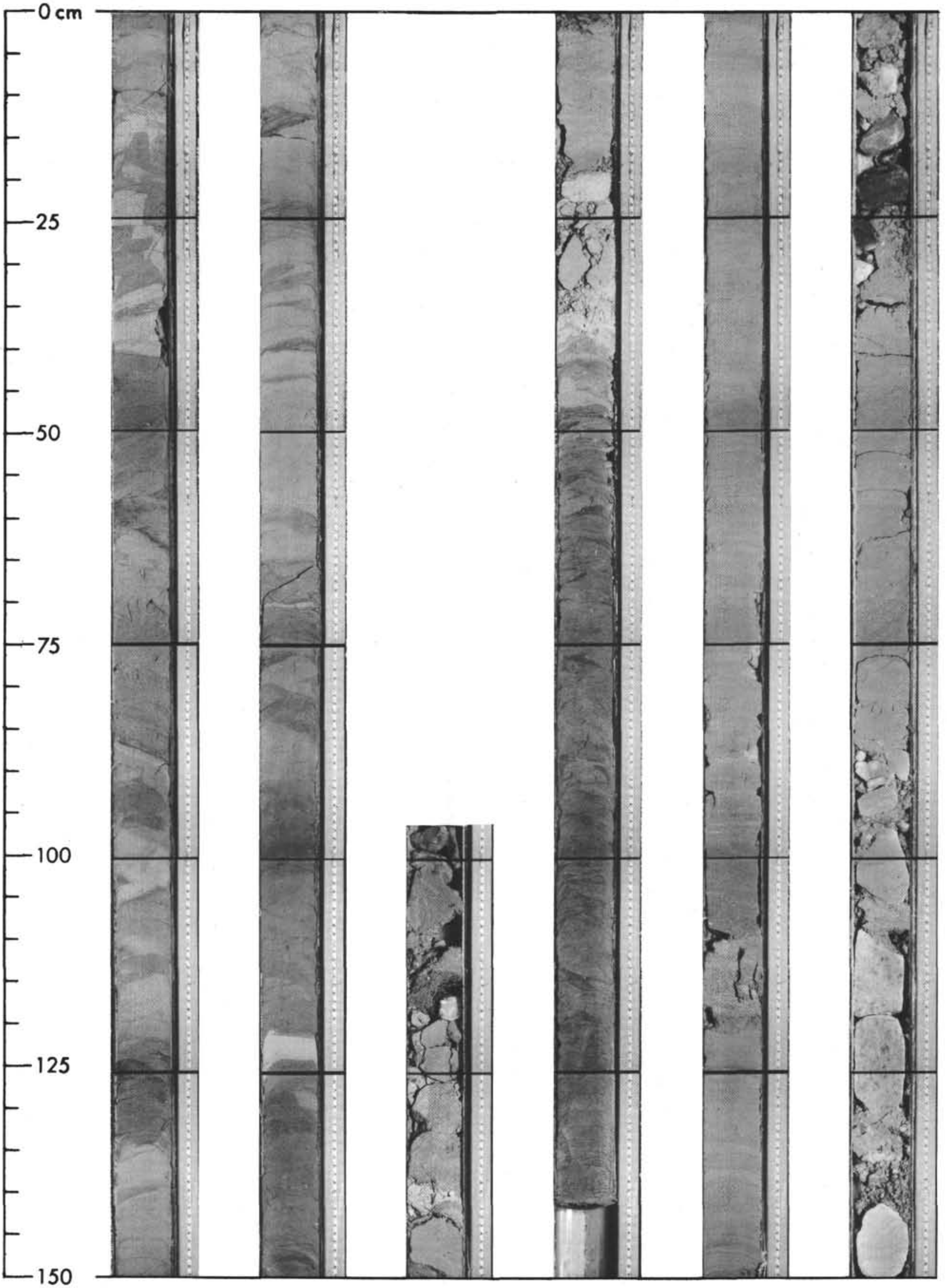
376-12-5
376-13-1
376-13-2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125
150
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376-13-4
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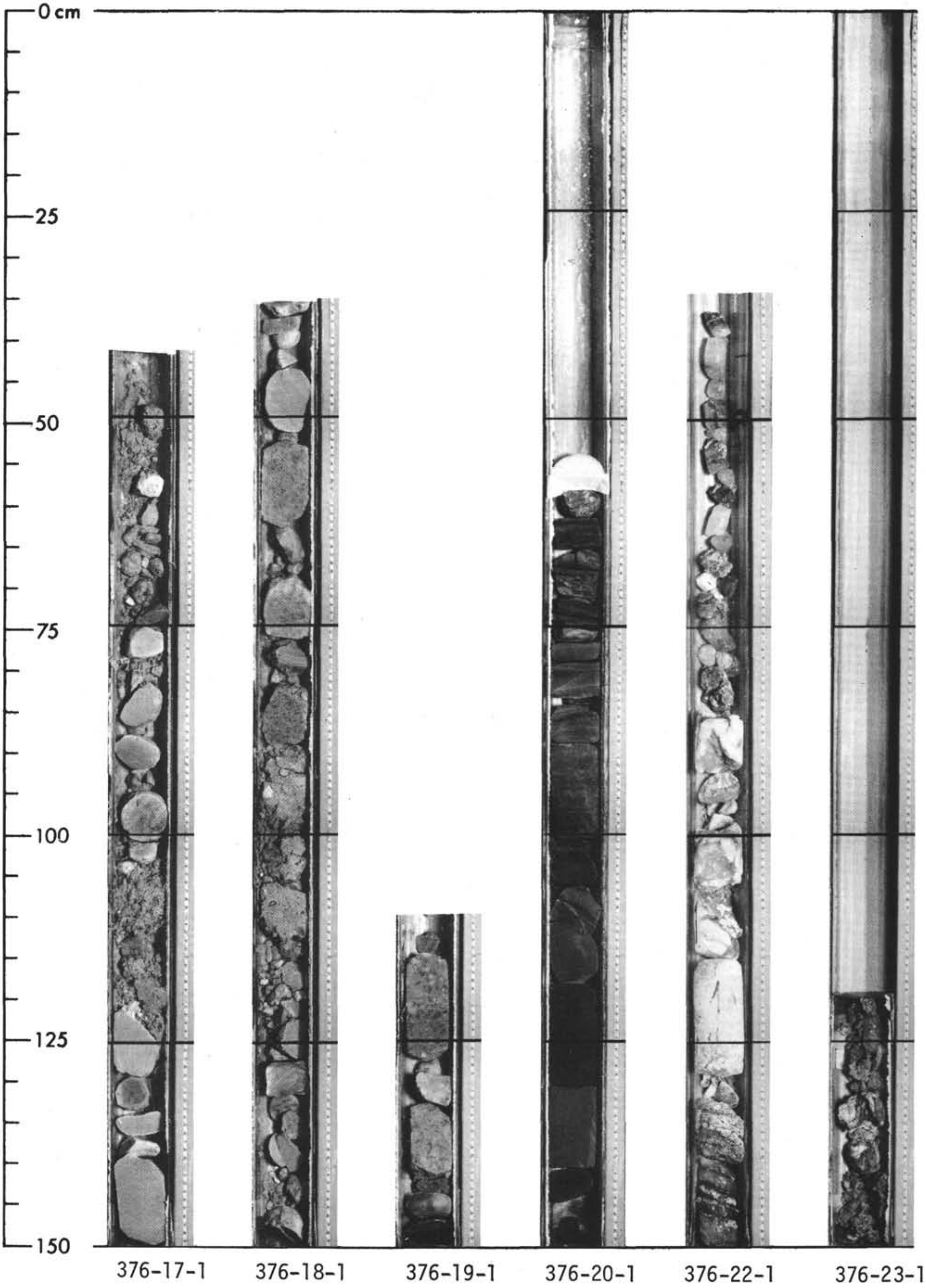
376-15-2
376-15-3
376-16-1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376-18-1
376-19-1
376-20-1
376-22-1
376-23-1