5. SITE 374; MESSINA ABYSSAL PLAIN

Shipboard Scientific Party[1]

SITE DATA

Position: 35°50.87′N, 18°11.78′E

Water Depth (sea level): 4078 corrected meters, echo sounding

Bottom Felt at: 4088 meters, drill pipe.

Penetration: 457 meters

Number of Holes: 1

Number of Cores: 24

Total Core Recovered: 77.2 meters

Percentage Core Recovery: 50.3%

Oldest Sediment Cored:
Depth subbottom: 457 meters
Nature: Halite
Age: Late Miocene

Basement: Not reached.

Principal Results: Site 374 in the central Messina Abyssal Plain (Figure 1) penetrated over 80 meters into the upper part of the Mediterranean Evaporite formation and revealed cycles of evaporite deposition within this section. The Plio-Quaternary sequence, which overlies the late Miocene (Messinian) evaporites, is of hemipelagic nannofossil muds, marls, and oozes interspersed with sapropels and sapropelic marls, which were deposited when the basin was stagnant. An upward increase in the frequency of sand and silt layers, a decrease in carbonate content and an increase in sedimentation rate, together show a trend towards more terrigenous influx to the basin in the late Quaternary. The site has remained at mesobathyal depths since the early Pliocene. Repopulation of benthic faunas after the Messinian salinity crisis probably took place gradually. This suggests the existence of a shallow sill between the eastern and western Mediterranean in the earliest Pliocene. The late Miocene evaporites drilled, by reference to seismic profiles, must belong to the "upper Evaporite" member of the Mediterranean Evaporite formation. Dolomitic mudstones overlie a sequence of mudstone-gypsum cycles and these in turn overlie anhydrite and halite. The dolomitic mudstones are generally barren of fossils but rare occurrences of Radiolaria and sponge spicules are evidence of marine incursions. These sediments are interpreted as deposits of an alkali lake/sea ("Lago Mare") which covered the area in the latest Messinian. An idealized cycle in the mudstone-gypsum sequence below is, in descending order: (a) Dolomitic mudstone, organic-rich, with secondary gypsum nodules and crystals; in places diatomaceous, in places laminated (stromatolitic); (b) Evenly laminated gypsum, (c) Wavy bedded to nodular gypsum. Nodular anhydrite occurs below this sequence of cycles and the hole eventually penetrated halite. More highly soluble potash and magnesium salts are suspected as having been washed by the drilling from the interval between the anhydrite and the halite. The occurrence of the salts and mudstone gypsum cycles shows that this area, during their deposition, was at times covered by shallow water bodies and at other times subjected to subaerial exposure.

BACKGROUND AND OBJECTIVES

Background

Site 374 on the Messina Abyssal Plain in the Ionian Basin was planned in order to sample the uppermost sequence of late Miocene restricted sediments with evaporites, together with their overlying basal Pliocene transgressive series, in an eastern Mediterranean province (Figure 2).

The Leg 13 drilling in the eastern Mediterranean failed to penetrate more than a few meters into Messinian sediments. At Site 125, a gypsiferous dolomitic marl was cored just before the Messinian contact. At Site 129, ostracode-bearing marls, characterized by the typically Para-Tethyan *Cyprideis* fauna, were found in the "melange" zone of the Strabo Trench wall. This meager evidence, interpreted within the geological framework of the Messinian evaporites as known from Sicily and the Ionian Islands, led Hsü et al. (1972) to formulate an alkali-lake model for the uppermost Messinian sedimentation of the eastern Mediterranean basins. Later, drilling during Leg 23B unearthed indications of alkali-lake sedimentation during the latest Messinian in the Red Sea. The Messina Abyssal Plain Site is located so that its Messinian record could serve as a connecting link between the western Mediterranean and the Red Sea over this period and, at the same time, provide a means for more direct comparison with the Sicilian and Ionian Islands sections. Furthermore, by choosing a site in the deepest part of the Ionian depression, we were likely to drill a section of mostly continuous Plio-Miocene sedimentation where few of the hiatuses or disconformities that are common on basin margins, like the Menorca and Florence rises, should be present. The latter were

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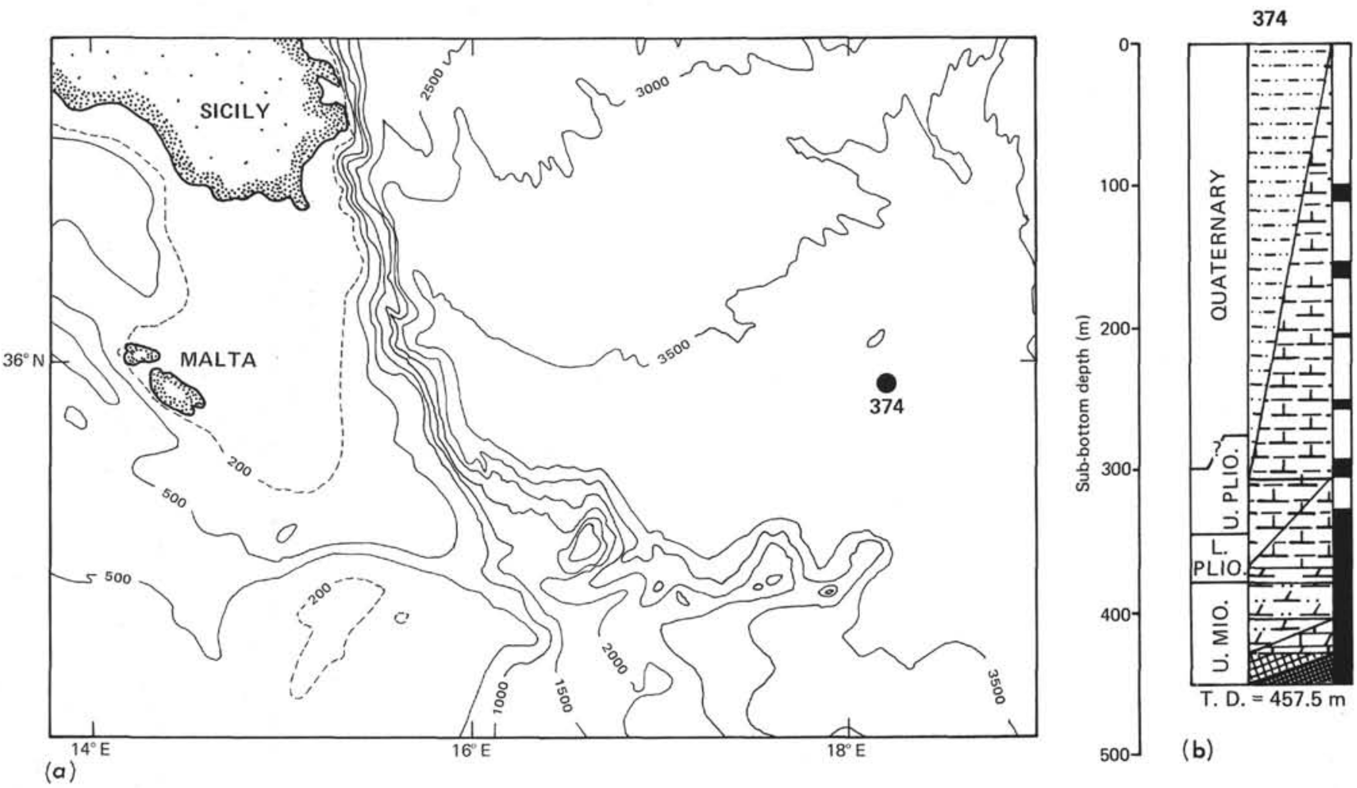

Figure 1. *(a) Site location map (depth contours in meters); and (b) generalized hole summary.*

caused presumably by regression due to late Miocene desiccations or by winnowing by early Pliocene bottom currents. In sampling the section at this site, we hoped to study the terminal phase of the Messinian.

Specifically, as formulated by the proposal of the Mediterranean Advisory Panel, our brief was to examine arguments which had been put forward against the deep basin desiccation model of evaporite genesis. These arguments had developed from seismic profiling evidence that everywhere in the Mediterranean the evaporite bodies in the deep basins show a succession of three sequences:

1) An upper evaporitic sequence, with numerous reflectors, which can be several hundred meters thick and which is probably an alternation of dolomitic marls, dolomite, gypsum, anhydrite, and possibly even halite.

2) A salt sequence, seismically homogeneous, which can be more than 1000 meters thick.

3) A lower evaporitic sequence with several reflectors more or less evident depending on the area.

Such a sequence implies: (1) sufficient influx of seawater to permit these thick accumulations, and (2) a process which would allow the accumulation of a thick layer of a single mineral (salt) of the sequence of minerals normally deposited by simple evaporation of a body of seawater. Many scientists consider that these requirements could best be satisfied by a barred basin model (King, 1947) with eventually evaporite deposition in relatively deep water in the central part of the basin. The proponents of the deep desiccated basin model (Hsü et al., 1972) on the other hand, postulate intermittent episodes of extensive flooding and mineral zonation to explain these same facts.

Objectives

Drilling into the evaporite deposits in the eastern Mediterranean was important to test the different models of evaporite deposition, even if it was to be restricted to a part of the upper evaporitic sequence. In particular we expected:

1) to learn if there had been flooding cycles, and if those cycles are correlative on the two sides of the sill represented by the Straits of Sicily;

2) to determine if the distal central basin deposits reflect a more soluble or less soluble evaporitic facies;

3) to further examine the subaqueous facies by comparing equivalent deposits in the Ionian Basin (now at –4.5 km water depth) with that at Site 134 (now at –3.3 km water depth), Site 124 (–3.1 km), and Site 132 (–3.0 km);

4) to determine if communication of brines occurred across (over) the sill, or through it by subterranean means; and

5) to possibly determine if there was occasional westward transport of water from the Para-Tethys to the western Mediterranean.

Furthermore, we planned to drill the early Pliocene here to look for clues to the sill depth separating the eastern and western Mediterranean basins. At that time proponents of the deep desiccated basin model consider that the sill separating the western Mediterranean from the Atlantic was deep since a deep bathyal lower Pliocene benthic fauna was found at the Tyrrhenian

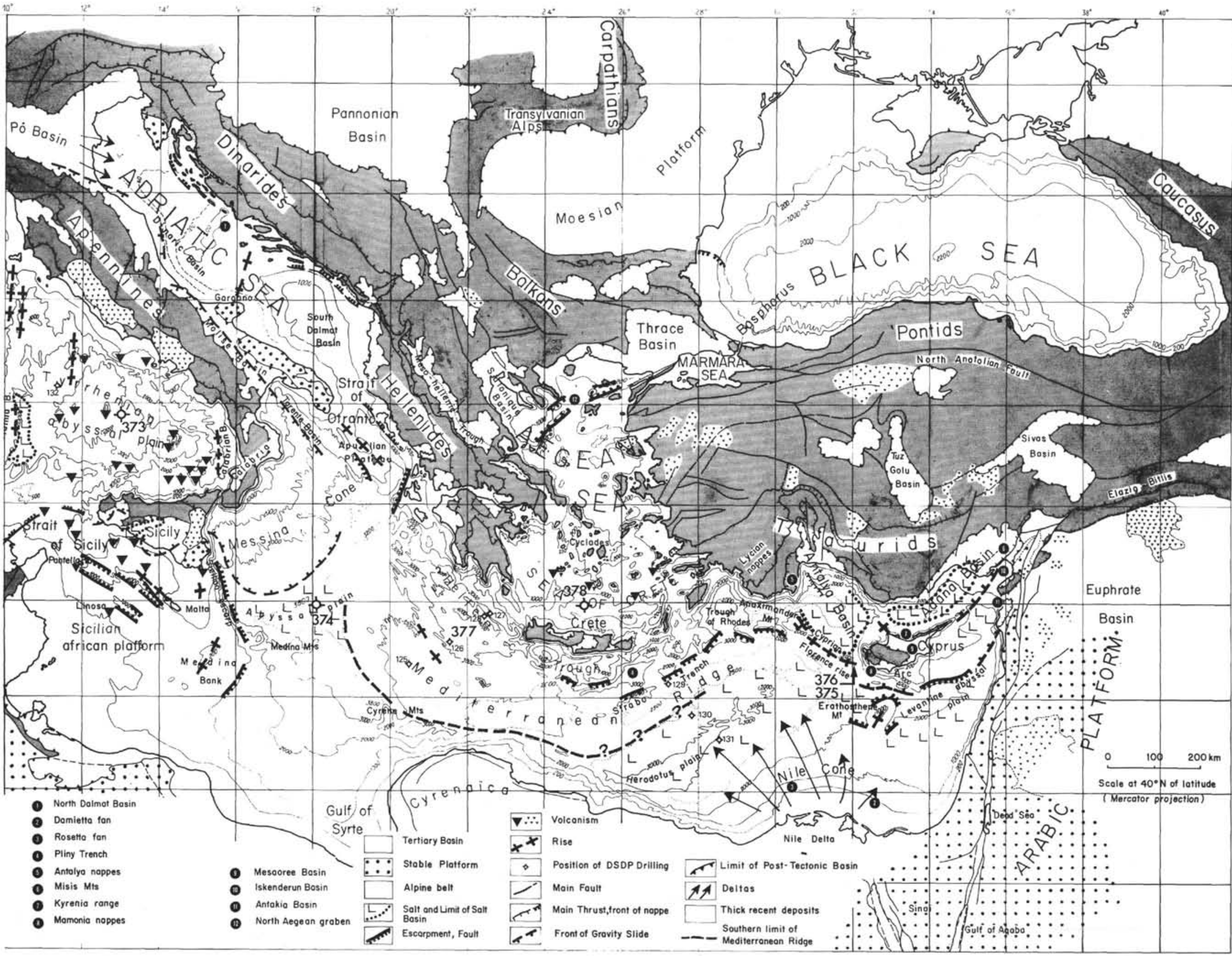

Figure 2. *Structural sketch map of the eastern Mediterranean from Biju-Duval et al. (1974).*

Site 132. We hoped to obtain at Site 374 data for the earliest Pliocene of the eastern Mediterranean which is not provided by any of the Leg 13 sites.

Site surveys by IFP over the Ionian Abyssal Plain indicated that the Messinia evaporites are made up of a sequence as described above with an aggregate thickness up to 1 km or more. Site 374 was thus chosen on the CEPM-CNEXO profile OD-22 at shot point 870, in a location where the Pliocene seemed thickest and most complete (about 350 msec two-way time).

We planned:

1) to continuously core the section from about 40 meters above the evaporites to 50 meters below their upper surface;

2) to use a drill bit that would optimize core recovery;

3) to core with as little circulation as technically feasible to enhance recovery of the expected soft dolomitic laminites.

OPERATIONS

Site Approach

The *Glomar Challenger* approached the site from the northwest (Figure 3). At 0300 LCT the vessel was on a 123° course at 9.04 knots. The course was changed at 0336 LCT to 155.9° to follow the CEPM-CNEXO profile OD-22. A minor adjustment in course was made at 0404 LCT to 147.5° and at the same time the speed was dropped to 6 knots to give enough time for two satellite fixes to be made before reaching the station. A course change to 140° was made at 0440 LCT after the second satellite fix was made. The vessel passed over the site at 0444 LCT, when the beacon was dropped. After the seismic gear was retrieved, the vessel made a Williamson turn. She arrived on station and engaged automatic positioning at 0600 LCT. The PDR depth was 2118 fathoms from the transducer (uncorrected) and 4088 meters from the rig floor (corrected). The M-reflector was estimated to be at about 400 meters subbottom. The site location, as determined later by satellite fix averages, was 35°50.87′N and 18°11.78′E (Figure 4).

Drilling Program

The drill crew began to assemble the drill string at 0600 LCT, 1 May. It touched bottom at 1325 LCT at 4090 meters depth from the rig floor. The first part of the drilling program was devoted to heat-flow measurements. Penetration was by washing ahead, with the core barrel in place, down to 100.5 meters where the cutting of Core 1 was begun. This barrel was raised to deck level at 1522 LCT.

Between 1530 LCT, 1 May and 0600 LCT, 2 May, five heat-flow measurements were made at about 50-meter intervals. There was some difficulty encountered in seating the probe properly, during the first measurement, because of downhole slumping of sand. The following four heat-flow operations were very successfully carried out. Five sediment cores were obtained after each drilled interval. These cores provided material with which to estimate the sedimentation rate and to measure conductivity. The heat-flow program ended at 0600 LCT, 2 May, the last measurement being taken at 304 meters subbottom. Detail of its operation and results appears in Erickson and von Herzen (this volume).

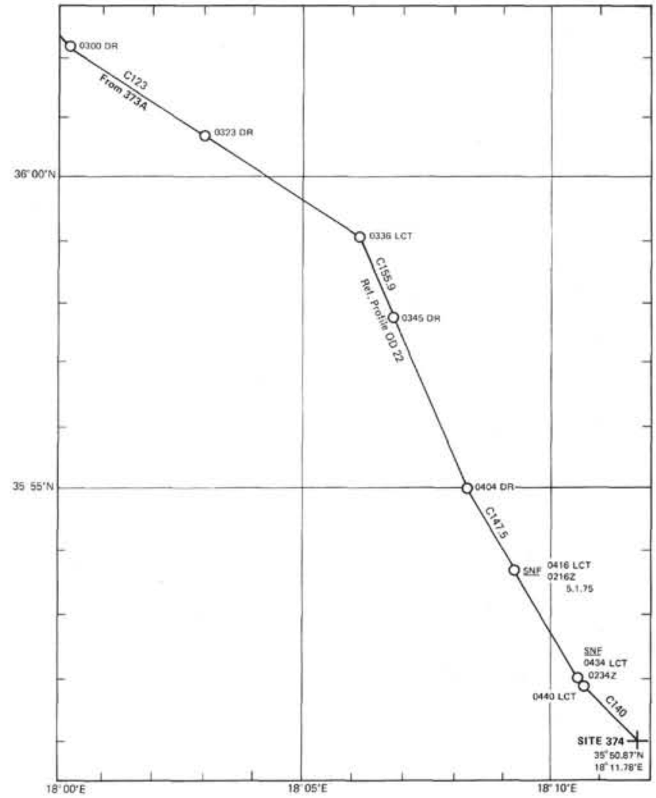

Figure 3. *Site approach, Site 374.*

At 0600 LCT, 2 May, the paleontologists were consulted as to the level at which continuous coring should begin. When it was confirmed that penetration was only as far as the upper Pliocene, we agreed that we should drill some 20 meters deeper before cutting the next core.

At 0648 LCT, 2 May continuous coring was begun. Core 6 was cut at 330.5 meters subbottom and was raised on deck at 0745 LCT. The next three cores were retrieved at 1-3/4-hr intervals with good recovery and each contained Pliocene marls and sapropels.

Because the 16-kHz beacon seemed to be causing positioning problems, it was decided at 0940 LCT 2 May to drop a second beacon with a 13.5-kHz signal.

Core 10 was cut between 1330 and 1400 hr and when raised on deck was found to contain only 0.7 meter of sediment, mainly of Pliocene age. The Pliocene marls appeared to be underlain by softer dark muds. The softer mud had failed to dislodge the overlying stiff marl from the core catcher, and most of the section below had been washed away.

Cores 11 and 15 were taken between 1440 LCT and 2340 LCT, 2 May. The section consists mainly of dark

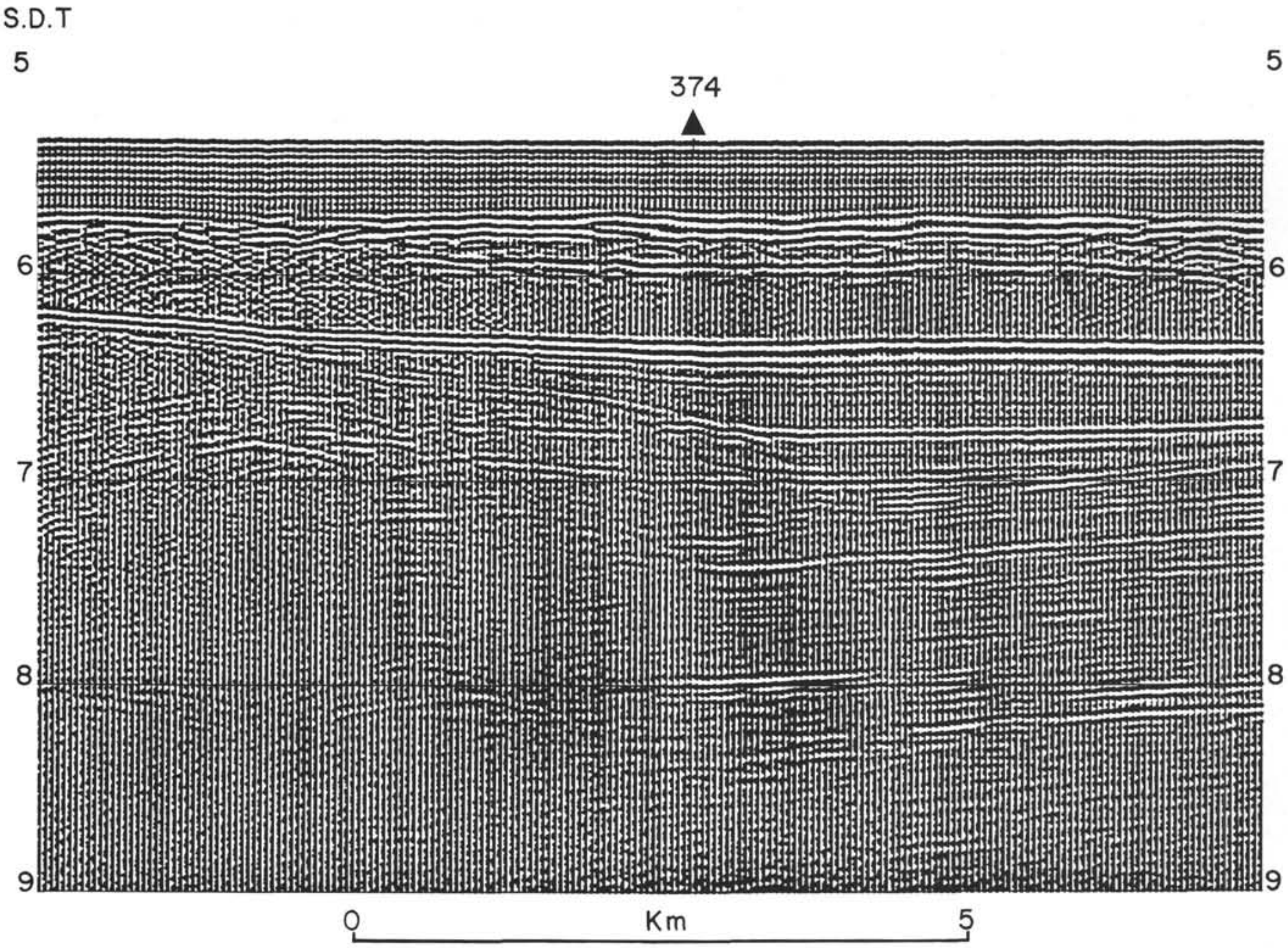

Figure 4. *Position of Site 374 on IFP-CNEXO multi-channel profile OD-22. (See Figure 15 for interpretation.)*

dolomitic marl with intercalated gypsum layers. The mud gave off a very strong odor, but no hydrocarbons were detected by the fluoroscope.

The drill crew started to cut Core 16 at 0005 LCT, 3 May. There was some difficulty with the ship's positioning at this time. After 5 meters were cut, the coring rate became very slow. Fearing that the catcher might have been jammed, the barrel was raised and was found to contain a good core of laminated gypsum. Slow penetration was thus related to lithology and not to mechanical difficulties.

In the early hours of 3 May, Core 18 was being cut. A full 9.5-meter barrel was cored very rapidly, but the barrel was almost empty (0.5 m recovery) when it was pulled on deck. After considerable discussion, the poor recovery was attributed to problems with the automatic positioning. Apparently only about 2 meters were cored; the other 7-meter length had been extended to compensate for the drift of the vessel. A correction of the coring depth was made accordingly for Core 18.

At this time considerable attention was given to the problem of the ship's positioning. At 0925 LCT 3 May, this was changed from a vertical reference gyro and was returned to a 16-kHz beacon-to-monitor system. Although all bridge and computer room equipment showed maximum excursions not in excess of 100 ft, the drill string continued to touch bottom at depths less than those that were recorded when we began to retrieve core. This would indicate that the vessel had drifted from the hole when core was being cut and returned as the core was retrieved. Similar indications of "apparent drift" were encountered at Sites 375 and 376 when the drill string penetrated halite-bearing sections.

Coring operations continued. At 1705 LCT Core 22 was retrieved. It was found to contain halite. However, two further attempts to recover (Cores 23 and 24) salt failed entirely. We suspected that more soluble salts than halite might have been encountered. Since penetration was now more than 40 meters beneath the strong gypsum reflector at 406.5 meters subbottom, it was decided to terminate the site in accordance with the recommendations of the Safety Panel.

The drill string was raised to 375 meters subbottom, where Core 25, the first sidewall core, was taken. The core was brought on deck at 2230 LCT and contained a full recovery. Meanwhile 100 barrels of mud were pumped down the hole. In view of our success with this sidewall coring, a second attempt was made at 370.5 meters subbottom. But the retrieval by wire line failed.

The crew then continued operations to bring the drill pipe on deck. The drill string cleared the mud line at 0100 LCT, 4 May.

The second sidewall core (Core 26) was retrieved when its associated drill collar was raised on deck. A full recovery had again been obtained. The last of the drill string was raised and secured at 0900 LCT, 4 May when the vessel departed for Site 375 west of Cyprus (Table 1).

LITHOLOGY

At Site 374, the upper 330 meters were cored discontinuously (Cores 1 to 5). Below this the section was continuously cored to the terminal depth of 457 meters subbottom. However, core recovery was frequently poor over this lower part, so here also information on which to establish the lithologic sequence is fragmentary.

Three main lithologic units are recognized (Table 2): a hemipelagic sequence of nannofossil marls, muds, and oozes spanning the upper 373 meters of the hole (Unit I); a sequence of evaporitic sediments over its lowermost 75 meters (Unit III); these linked by a dolomitized interval of mud and limestone (Unit II).

Unit I

The sediments of this unit are obviously those of an open-marine environment. They differ from the Unit II sediments in that they show no evidence of extensive dolomitization.

Unit I is split into three subunits because of varying amounts of detrital material through its thickness. Most sedimentologic characteristics show a general trend throughout the entire unit and these divisions can be regarded as part of an overall tendency from base to top in which the unit becomes progressively less pelagic in aspect. Consequently no distinct boundaries are expected between the subunits. Subunit Ic contains nannofossil marls but also somewhat purer oozes; Subunit Ib contains only marls and muds with two minor graded units (turbidites) while Subunit Ia, which is known from one core only, is made up almost entirely of distal turbidite units and contains no pelagic sediment at all. As would be expected, an overall upward decrease in $CaCO_3$ content parallels this trend. Boundaries between the units are, of necessity, placed arbitrarily in uncored intervals.

Unit I is characterized by a wide spectrum of colors from dark brownish-red to various light pale colors to bluish, or olive shades of gray, to dark gray. In general, in Cores 2 to 4, gray hues predominate, while in the Cores 5-10 reddish and brownish hues are more important. In some cores (4 to 6) variegated colors are prevalent. Most cores contain some dark layers (see below), which because of their unusually high content in organic matter and plant debris (visible in smear slides), are recognized as sapropels or sapropelic layers.

The average content of biological carbonate (foraminifers plus nannoplankton as determined in smear

TABLE 1
Coring Summary, Site 374

Core	Date (May 1975)	Time	Depth from Drill Floor (m)	Depth Below Sea Floor (m)	Cored (m)	Recovered (m)	Recovery (%)
1	1	1525	4190.5-4200.0	100.5-110.0	9.5	2.6	27
2	1	1852	4247.0-4251.5	157.0-161.5	4.5	4.5	100
3	1	2210	4298.0-4299.0	208.0-209.0	1.0	1.0	100
4	2	0140	4341.5-4346.5	251.5-256.5	5.0	4.8	96
5	2	0445	4387.0-4354.0	297.0-304.0	7.0	6.8	97
6	2	0745	4430.0-4430.0	330.5-340.0	9.5	9.6	100
7	2	0930	4430.0-4439.5	340.0-349.5	9.5	9.7	100
8	2	1110	4439.5-4449.0	349.5-359.0	9.5	5.5	57
9	2	1245	4449.0-4458.5	359.0-368.5	9.5	6.1	64
10	2	1440	4458.5-4468.0	368.5-378.0	9.5	0.7	7.
11	2	1605	4468.0-4471.5	378.0-381.5	3.5	2.5	70
12	2	1800	4471.5-4477.5	381.5-387.5	6.0	2.5	40
13	2	2010	4477.0-4482.5	387.5-392.5	5.0	4.1	80
14	2	2135	4482.5-4487.0	392.5-397.0	4.5	3.3	73
15	2	2340	4487.0-4496.5	397.0-406.5	9.5	3.1	32
16	3	0250	4496.5-4501.0	406.5-411.0	4.5	1.0	22
17	3	0515	4501.0-4506.0	411.0-416.0	5.0	1.2	25
18	3	0748	4506.0-4508.0	416.0-418.0	2.0	0.5	25
19	3	0950	4508.0-4510.0	418.0-420.0	2.0	1.3	60
20	3	1245	4510.0-4515.5	420.0-425.5	5.5	1.4	25
21	3	1425	4515.5-4525.0	425.5-435.0	9.5	0.5	5
22	3	1705	4525.0-4534.5	435.0-444.5	9.5	4.5	47
23	3	1920	4534.5-4543.5	444.5-454.0	9.5	0	0
24	3	2045	4543.5-4547.0	454.0-457.0	3.0	0	0
25[a]	3	2230	4465.0-4465.5	375.0-375.5	0.5	0.5	100
26[a]	4	0830	4460.5-4461.0	370.5-371.0	0.5	0.5	100
Total					154.5	78.2	50.

[a]Sidewall cores.

TABLE 2
Lithologies at Site 374

Unit	Lithology	Core	Subbottom Depth (m)	Thickness (m)	Age
I	a) Nannofossil marl with graded unit of foraminiferal quartzose sand to silt	1	100.5 to 110.0	110 ?	Pleistocene and Pliocene
	b) Nannofossil marl and mud	2 to 5	110 to ~ 315	205	
	c) Nannofossil marl and ooze	6 to 10 and side wall core 26	315 to 373	58	
II	Dolomite	11 and side wall core 25	373 to 381.5	8.5	Lowermost Pliocene (?)
III	a) Dolomitic mudstone with minor gypsum layers	12 to 15	381.5 to 406.5	25	Late Miocene (Messinian)
	b) Gypsum/dolomitic mudstone cycles	16 to 20	406.5 to 436	29.5	
	c) Anhydrite and salts	21 to 22	436 to 457	21	

slides) shows an increasing trend from Core 2 downwards. The maximum value (56%) occurs in Core 8. From there on down to Core 10, Section 1, the values decrease slightly. This parallels the average $CaCO_3$ curve drawn from "carbonate bomb" and "LECO" data. As noted above, the amounts of terrigenous material recorded in smear slides show an opposing trend. The highest average $CaCO_3$ values are in Core 1 (Subunit Ia) while in Subunit Ic the average does not exceed 5%. Most terrigenous material is in the form of detrital clay. Shore-based X-ray mineralogical studies show that illite and mixed layer clay minerals are dominant throughout the unit with chlorite and kaolinite consistently recorded in minor amounts. Smectite is one of the main clay minerals down to Core 5, but below this appears in low percentages. Below Core 4 attapulgite appears in trace amounts.

Core 1 (100.5-110 m) is made up of pale olive soupy sediment in which the coarse fraction (sand to coarse silt) increases towards the bottom of Section 2, while nannofossil marl predominates in the upper sediments of Section 1. The sediments are characterized by a number of features which indicate transport from a shelf area by a density current ("turbidity current"), namely: their high content of terrigenous minerals (quartz, feldspar, mica, heavy minerals, etc.) together with rock fragments, coated grains, pellets, and shallow water fauna (benthic foraminifers, echinoderm fragments, spicules of holothuria, tunicate, sponge and bryozoan debris, and juvenile brachiopods) which is associated with reworked nannofossils from the Cretaceous and Tertiary. It is highly probable that turbidites also appear in the higher uncored strata (Hieke et al., 1974). Consequently, a boundary between subunits separating the predominantly hemipelagic sequence from one dominated by turbiditic sedimentation is placed just below Core 1.

In Subunits Ib and Ic there are only two occurrences of graded silt layers: in Sample 6-5, 63-73 cm, containing plant debris at its base; and in Sample 4-5, 77-80 cm, containing abraded skeletal fragments and limestone fragments. Together with the rising amount of terrigenous material, these two thin "turbidites" testify to the increase in terrigenous input to this area towards the Quaternary. In addition, about 48 silt layers without obvious grading could be observed in Cores 2 through 11 and a general trend of downward decreasing thickness of silty layers, per 1.5 meter section, is noted.

Burrowing (bioturbation) of the sediment varies remarkably. In general, it appears that in lower parts of Unit I (Subunit Ic) burrowing is more frequent than in higher parts.

In several cores, at this site especially those from Unit I, microfaulting was observed: for example, sections 5-3, 5-4, 6-5, 8-3, and 9-3. In some cores this was clearly caused by drilling deformation (e.g., 6-2, 6-3, 6-5, 8-3, 9-4, and 15-1); in others such an interpretation was questionable (e.g., 9-2 and 11-1) and primary tectonic features may indeed exist. Apart from these tectonic and "pseudotectonic" structures, quite often it was observed that drilling in stiff sediment appeared to produce a "stratification" with an intriguing equidistant spacing (e.g., 9-4). This core-discing could easily be confused with cyclic sedimentary bedding (see Kidd, this volume).

Dark, mostly olive-black horizons, identified by their organic carbon content as sapropels (2.0% org. C) or sapropelic layers (0.5%-2.0% org. C), occur in all cores of Unit I except Cores 1 and 7. A total of 38 occurrences of these organic-rich hemipelagic nannofossil sediments were counted in the Unit I sequence, 17 of which are sapropels. Individual layers vary in thickness from just less than 1 cm up to a maximum of 7 cm. At four levels they occur in groups or "multiples" of two to three beds. Some occurrences are obviously only pieces of layers that have been disturbed by the drilling or occur only partially in the core catchers. Many are laminated and a few are burrowed. Organic carbon measurements show that at least 15 of these laminated layers are true sapropels, containing greater than 2.0% organic carbon. In one layer in Sample 5-3, 49-52 cm (late Pliocene) a value of 16.7% org. C was measured which to date is by far the most organic-rich sapropel recorded from the Mediterranean. Other measurements, on the other hand, show that some layers, even with quite dark coloration are sapropelic rather than true sapropels. Aside from their richness in organic matter, the dark layers contain planktonic foraminifers, pyrite, and rare detrital grains set in a matrix of nannofossil marl. Benthic foraminifers are absent. These layers are an important record of periods in the history of the Ionian Basin, when its sea floor suffered stagnation.

Comparing the Plio-Pleistocene "dark layers" from Site 374 with Quaternary stagnation layers of the Ionian Sea from piston cores (Olausson, 1960, 1961, 1965; Nesteroff, 1973; Hieke et al., 1973) the "dark layers" of Site 374 are generally thinner. This in part, may be due to their more advanced stage of compaction, but could also imply a shorter duration of the individual stagnation periods. The existence of sapropelic layers as deep as Core 11, that is as far back in time as the early Pliocene, is of major importance in our understanding the development of the Ionian Basin.

Gypsum appears intermittently in the lower part of Unit I (Cores 7-10). It is interpreted as of secondary origin because of its coarse crystalline to fibrous habit (fragments of veins?) or nodular appearance.

Unit II

This unit is a dolomitized pelagic marl (Bernoulli and Mélières, this volume) and is considered a distinct unit because of its diagenetic character. The unit is represented only by sidewall Core 25, mainly greenish-gray dolomite containing sapropelic material, and by Core 11, light yellowish-gray to medium bluish-gray limestone with a number of sapropel layers and a 4-cm-layer of broken coarsely crystalline gypsum pieces. Core 11 appears to become progressively more diagenetically altered (dolomitized) downcore. Section 1 still contains nannofossils but highly altered. Section 2 has a carbonate content, equally as high as in Subunit Ic but no nannofossils could be detected. It seems likely that the high carbonate content originates from skeletal material, primarily from nannofossils and foraminifers which have been dolomitized (dolomite values reach 55% and 73% of the bulk mineralogy at the base of Section 1 and in Section 2, respectively, while calcite values are only 14% and 0%). This is especially significant since the alteration masks somewhat the record of major repopulation of the basin by marine life after the evaporation period. The gypsum horizon in Section 2 represents a veinlet of secondary origin. The sapropelic layers are the earliest evidence of stagnation periods, while the basin was part of a marine environment. On the other hand, moderate to intense mottling and *Zoophycos* and *Chondrites* traces document the activity of burrowing organisms unheeded by restricted conditions.

Unit III

The boundary between Units II and III was drawn at a major change in lithology. Unit III is characterized by an abundance of evaporitic minerals and lack of calcareous material. It is divided into three subunits which are described only generally here. (For detailed description and interpretation, see Garrison et al., this volume.)

Subunit IIIa is dolomitic mud and mudstone spanning Cores 12 through 15 (subbottom depth 381.5-406.5 m). This dark greenish-gray sediment is homogeneous (unburrowed) and contains numerous white spheres with diameters ranging up to 4 mm. The spheres, when broken, have no apparent internal structure. Shore-based studies revealed that they are composed of a rare Mg-phosphate-borate mineral known as lüneburgite (see Müller and Fabricius, this volume). The dolomitic marl is barren of calcareous fossils. No calcite is recorded in bulk X-ray mineralogical analyses, while dolomite content ranges from 11% to 26%. Some sponge spicules and a few Radiolaria were found in the core catcher of Core 15. Clay mineral assemblages continue to be illite and mixed layer dominated with minor chlorite and kaolinite as in Units I and II, but smectite ranks with the first two (ranging 6%-18%) having appeared low in Subunit Ic.

Subunit IIIb spans cores 16 through 20 cm and is a sequence of gypsum/dolomitic mudstone cycles. The crystalline and/or laminated gypsum is white and dark gray to light olive-gray, or yellowish-brown in color. It is interbedded with gypsiferous-dolomitic mudstones or diatomaceous mudstones, which are light olive-gray to black, or with anhydrite, which may be crystalline and white, or laminated and brown. The mudstones are rich in organic carbon and, if placed in a marine sequence, could have qualified as sapropels (organic carbon values range 0.9% to 5.3% in Cores 16-21).

Although there are gaps caused by poor core recovery, several cycles (about 5) can be recognized. Figure 5 displays these diagramatically and includes detailed structural description. An idealized complete cycle is suggested in Figure 6. The cycles are interpreted as a record of changing water and salinity levels, from the subaqueous (A member) to the subaqueous hypersaline (B member) to the subaerial (C member). Detailed description and analysis of these evaporite cycles appears in Garrison et al. (this volume).

Subunit IIIc spans the interval of Cores 21 and 22. Core 21 and Core 22 down to 1-104 cm contains nodular and layered anhydrite. At the base of Core 22, trunslucent, colorless to gray crystalline halite was recovered with thin light greenish-gray muddy polyhalite interbeds. Other salts identified by shore-based studies include kainite, sulfoborite, sylvite, and bischovite (Kuehn and Hsü, this volume). The halite surface in Core 22, Sections 2 and 3 was etched by solution making the polyhalite interbeds stand out at irregular spacings of less than 1 cm to about 10 cm. Cores 23 and 24 were empty, but the drilling rates suggest these intervals also represented penetration through salts, but through varieties which were more soluble and unrecoverable.

GEOCHEMICAL MEASUREMENTS

Interstitial Water

Salinity, chlorinity, calcium and magnesium content, alkalinity, and *p*H were determined from Cores 2 through 9 and from Cores 13 through 15. In one core

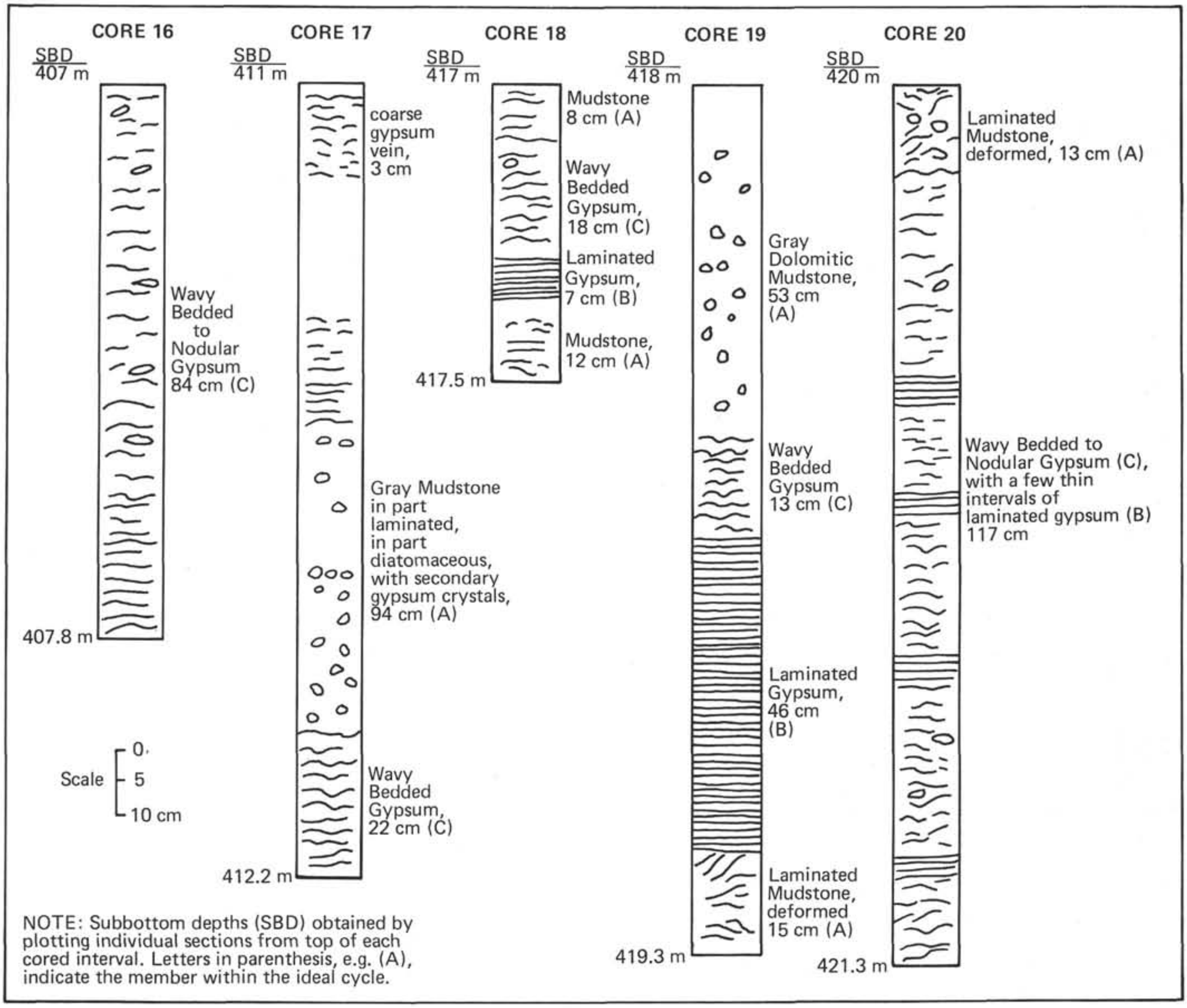

Figure 5. *Evaporite cycles at Site 374.*

(7), special sampling at one sample per section was undertaken for shipboard and shore-based analysis. These values are displayed in Figures 7 and 8.

Salinity and chlorinity (Figure 7): Both characteristics show a trend towards increased values downhole. They exceed halite saturation in Core 7 and below. The data suggest the presence of potassium and magnesium salts with solubilities up to 55%, which may explain our failure to recover any material in Cores 23 and 24.

Calcium and magnesium content: Both values show an increase with depth as far as the base of Lithologic Unit I (Figure 8). In this section, Mg/Ca decreases from about 5.5 in Core 1 (approximating that of seawater) to around 3 in Cores 6 to 11. The calcium concentration also shows a steady and dramatic increase, reaching a broad maximum value of 450-525 mM/l at about –350 to –375 meters (Cores 8-9, lower Pliocene), before decreasing suddenly to almost nil in the dolomitic marls (Cores 12-15). An abnormally high calcium concentration of 168 mM/l was also found in brines of Site 227 in the Red Sea, and the anomaly there was explained by assuming the dissolution of tachyhydrite ($Ca_{0.6}\ Mg_{2.4} \cdot Cl_6 \cdot 12H_2O$) in the section (Manheim et al., 1974). The still higher concentration at Site 374 could hardly be explained unless we assumed an occurrence of this high soluble mineral near the top of the evaporite unit. In the dolomitic mudstone, the Mg concentration becomes still higher, whereas the pore waters are almost devoid of Ca. The very steep reverse Ca^{++} gradient below the maximum suggests the presence of an effective barrier to ionic diffusion (possibly the gypsum layer at the base of Core 10,?).

The interstitial brines of the dolomitic mudstone unit (Cores 12-15) have very high alkalinity, reaching a value of 5 in Core 15 (Figure 7). These highly alkaline brines have a low *p*H of 5 to 6. The unusual water

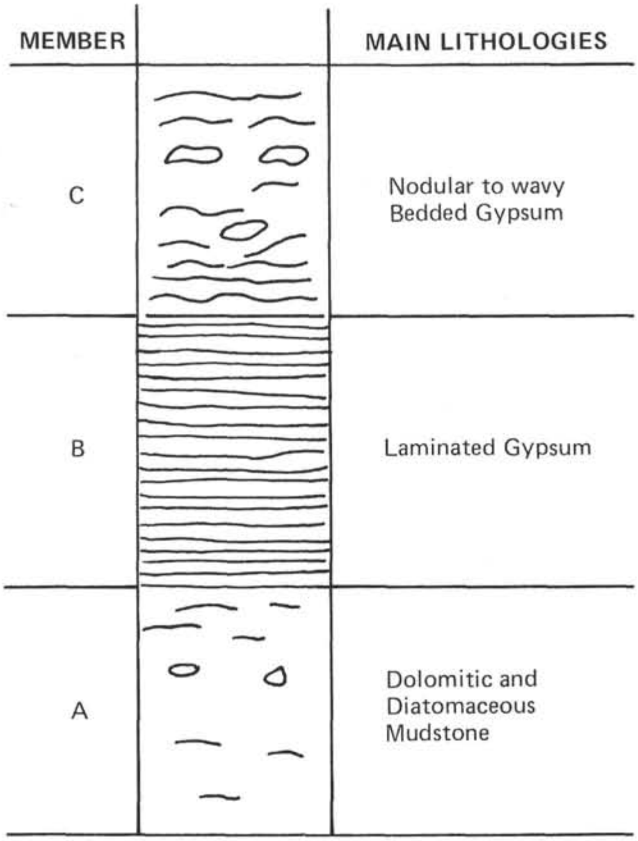

Figure 6. *Idealized evaporite cycle, Site 374.*

chemistry is probably related to the unusual mineralogy of the cores.

Carbonate Content

The carbonate contents measured by the "carbonate bomb" and "LECO" methods determine the different lithologic units (see plot with hole summary).

The Quaternary and Pliocene sediments show a general decrease in terrigenous sand and silt and a steady increase in $CaCO_3$ with depth. Core 11 yielded apparent "bomb" measurements of up to 80% total carbonate. A drastic drop in carbonate content occurs between Cores 11 and 12. In the dark gray mudstones (Cores 12-15) no calcite remains and dolomite values are lower than in Core 11. The interstitial waters are characterized by extremely low Ca/Mg ratios (Figure 8). In core-catcher 15, higher carbonate values coincide with traces of open-marine biota (radiolarians and sponge spicules).

The underlying units (Cores 16-23) contain mainly sulfates or chlorides. The intercalations of dark mudstones have been investigated (four measurements). Three measurements yielded no carbonate, whereas the fourth (Core 19, Section 1) is dolomite bearing.

PHYSICAL PROPERTIES

Sonic Velocity

The velocity data show a gradual increase in velocity from 1.85 km/sec at a depth of 158 meters subbottom to 2.00 km/sec at 396 meters (Figure 9). Beginning at 398 meters subbottom there is a dramatic increase in velocity from 2.6 km/sec in gypsiferous dolomitic mudstone up to about 5 km/sec in coarsely crystalline gypsum, laminated gypsum and anhydrite, recovered from 407 to 435 meters subbottom (Tables 1 and 2 of Appendix VI).

Velocities measured out of the liner on chunks of the evaporites tend to be slightly higher in the horizontal direction (4.87 ±0.14 km/sec, n = 25) than in the vertical direction (4.75 ±0.17 km/sec, n = 21), but the difference may not be significant considering the varying lithologies of the sediments which were measured. The most striking anisotropy was observed in a piece of thinly laminated gypsum, where the means of five velocity measurements in the horizontal and vertical directions were 5.09 ±0.42 and 4.67 ±0.08 km/sec, respectively. Other, more homogeneous-looking rocks showed no significant velocity differences in the two directions.

Wet Bulk Density, Porosity, and Water Content

Bulk wet density, porosity, and water content were determined using gamma ray attenuation techniques (GRAPE) (Table 3 of Appendix VI). Where the sediments were soft enough to sample using either the syringe or cylinder sampling techniques, these properties were also measured gravimetrically (Tables 4 and 5 of Appendix VI). Each of the three types of data shows a large amount of variation, especially below about 300 meters, with the syringe and GRAPE data having the largest and smallest variability, respectively (Figure 10). Despite the variability of the data, a general density increase with depth is still evident in the nannofossil marls and dolomite above 382 meters subbottom. An abrupt increase to values between 2.02 to 2.08 g/cc occurs in the dolomitic mudstone containing minor gypsum layers, and markedly higher densities of 2.25 to 2.35 g/cc are characteristic of the anhydrite and gypsiferous and/or dolomitic mudstone recovered between 406 and 436 meters subbottom.

Thermal Conductivity Data

Nineteen thermal conductivity measurements were made on sediment recovered from between 104 and 353 meters subbottom. The data are highly variable, ranging from 2.51 up to 3.41 mcal/cm sec°C. With the exception of two relatively low values (2.51 and 2.60 mcal/cm sec°C) at 337 and 339 meters subbottom, respectively, the data show an overall small downward increase in thermal conductivity (Figure 11). The mean thermal conductivity is 3.07 ±0.28 mcal/cm sec °C.

The large variations in conductivity are understandable in terms of the significant variations in porosity (Tables 4 and 5 of Appendix VI) measured at this site. The extent to which the measured variations in both conductivity and porosity reflect the in situ sediment properties rather than the effects of coring and/or sampling disturbances is difficult to estimate.

BIOSTRATIGRAPHY

Site 374, drilled in the central part of the Ionian Abyssal Plain at a water depth of 4078 meters, pene-

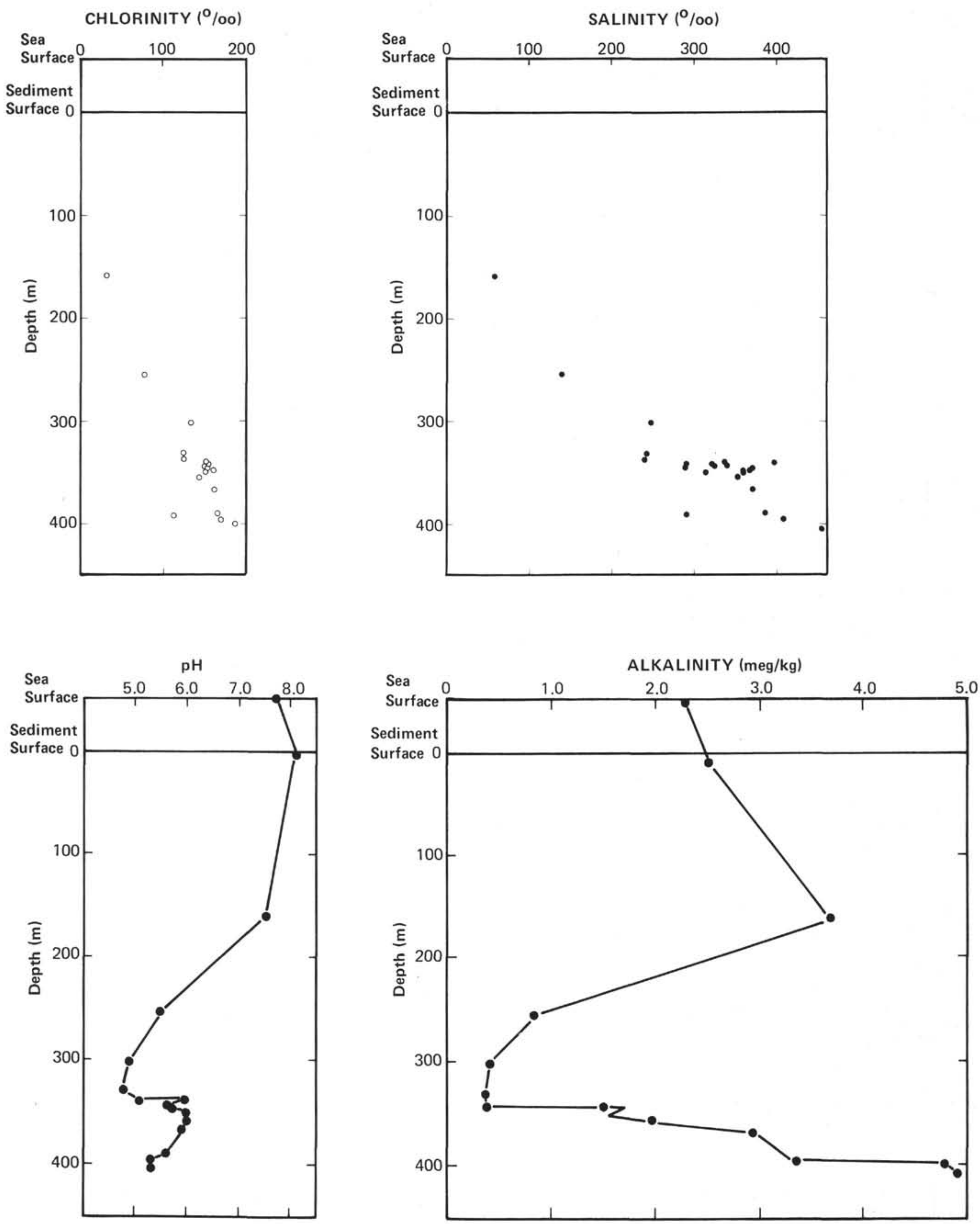

Figure 7. *Geochemical measurements at Site 374:* pH, *alkalinity, chlorinity, and salinity.*

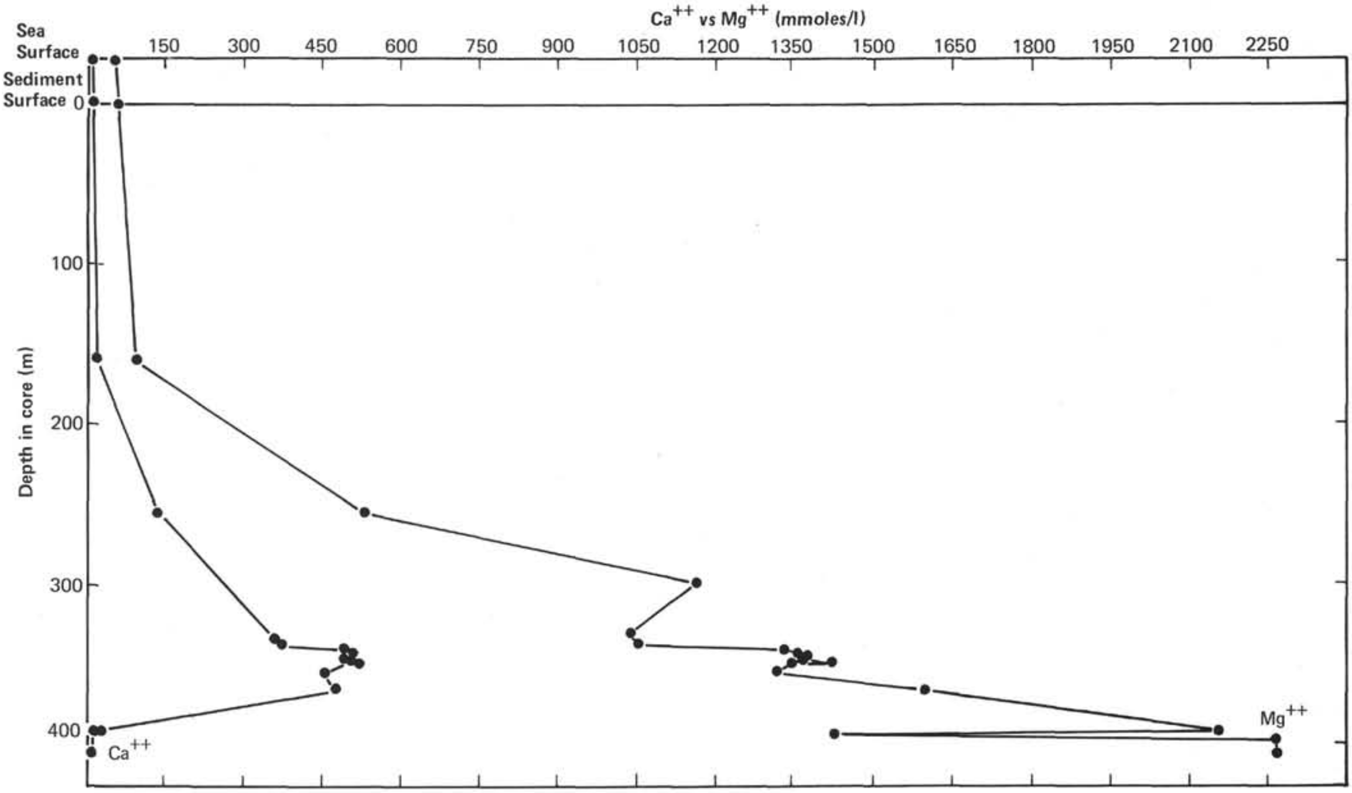

Figure 8. *Geochemical measurements at Site 374: Ca^{++} and Mg^{++}.*

trated 457 meters of sediments which, below the Quaternary and late Pliocene, were continuously cored (see Figure 12).

The sediments yielded rich and diversified fossil assemblages from Cores 1 to 10 (Quaternary to early Pliocene).

Quaternary ages were assigned to sediments in Cores 1 to 5 (Section 1 and part of Section 2). These hemipelagic sediments are rich in well-preserved microfossils. Reworked species from the Miocene and Pliocene are frequent. The presence of tunicate spicules and benthic foraminifers from the shelf indicate displacement of material possibly by turbidites.

The Plio-Pleistocene boundary might be an unconformity in Core 5 from the nannofossil evidence, but this may also be a drilling artifact.

The late Pliocene was determined from Core 5, upper part of Section 2 to Core 7, Section 6, and the early Pliocene from Sample 7, CC to Core 10 (possibly also Core 11, Section 1). The Pliocene sediments are rich in well-preserved microfossils; benthic foraminifers are less common than in the Quaternary sequence and reworked fossils are rare or absent.

The Pliocene-Pleistocene sequence is characterized by the presence of numerous sapropels and sapropelic layers. The content of microfossils in these layers is highly variable.

In Core 11, Section 2, some highly recrystallized foraminiferal tests are present. Precise age assignment of this core is problematical. The sediments below are barren of calcareous microfossils.

Generally the dolomitic mudstones in Core 12 to Sample 15, CC yielded intermittently, rare algal cysts, diatoms, Radiolaria, and sponge spicules. Diatoms are more frequent in the finely laminated sediments of Cores 17 and 18.

Nannofossils

Quaternary

Core 1 (100.5-105.0 m) is assigned to the *Emiliania huxleyi* zone (NN21) of the Quaternary with the following species: *Emiliania huxleyi, Syracosphaera pulchra, Helicosphaera carteri, Discolithina japonica, Holodiscolithus macroporus, Thoracosphaera heimi, Rhabdosphaera clavigera, Scapholithus fossilis, Gephyrocapsa oceanica,* and *Coccolithus pelagicus. Oolithotus fragilis, Discosphaera tubifera, Umbellosphaera tenuis,* and *Pontosphaera syracusana* are only rare. The sediments of this zone are rich in well-preserved nannofossils, and reworked Mio/Pliocene species are frequent. The presence of tunicate spicules indicates that some of the material was redeposited from shelf areas.

The *Gephyrocapsa oceanica* Zone (NN20) was determined from Samples 2-1, 75-76 cm to 4, CC (157.0-256.0 m). This sequence is characterized by sapropelic layers. They are generally rich in well-preserved to slightly etched nannofossils. Reworked species are less abundant in these layers, while they are abundant in the background sediments. *Helicosphaera carteri, Rhabdosphaera clavigera,* and *Gephyrocapsa oceanica* are the most important species in these layers. The sediments directly below the sapropel layers are rich in reworked species of the Mio/Pliocene.

The interval from 5-1, 147-148 cm to 5-2, 42-43 cm belongs to the *Pseudoemiliania lacunosa* Zone (NN

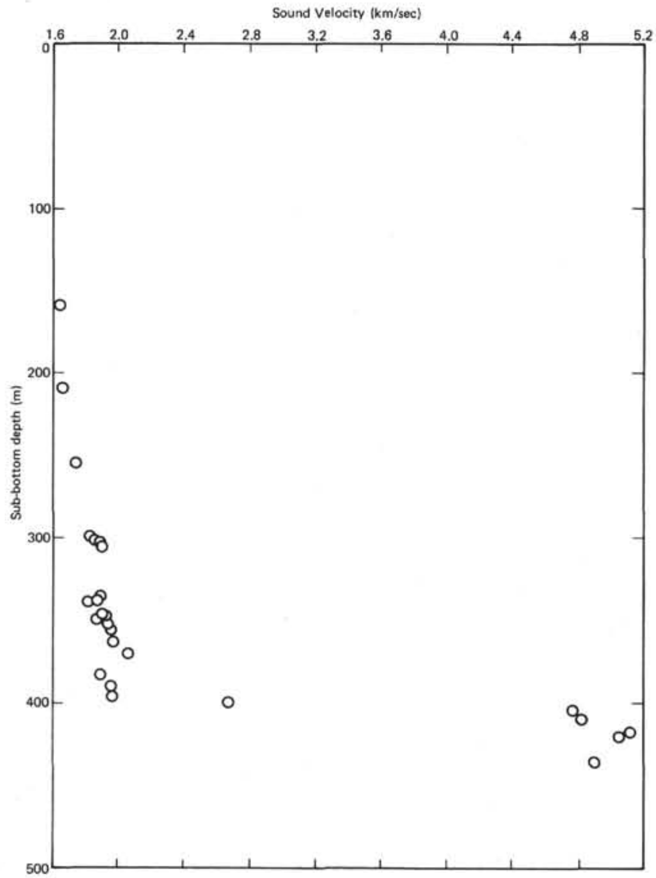

Figure 9. *Sound velocity measurements in the horizontal direction made on sediments recovered from Site 374, plotted versus subbottom depth.*

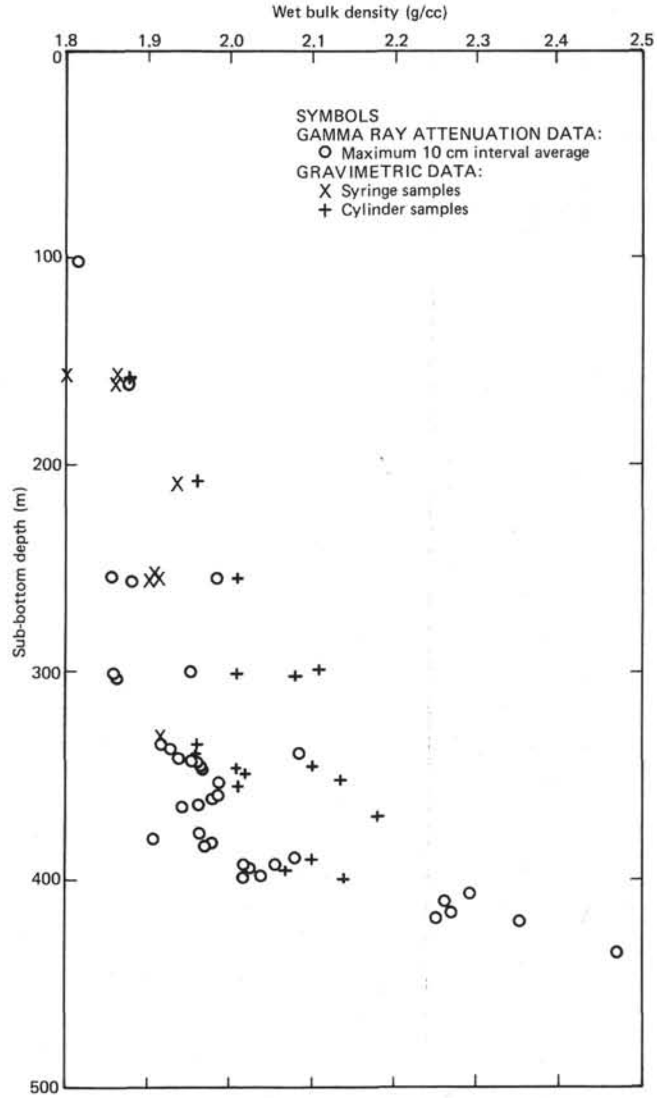

Figure 10. *Wet bulk density determined gravimetrically and by gamma ray attenuation at Site 374, plotted versus subbottom depth.*

19). The sapropel layer represented by Sample 5-2, 33-34 cm contains only a few etched nannofossils. Sediments of the NN19 Zone are abundant in nannofossils and reworked Neogene species.

Pliocene

The *Discoaster brouweri* Zone (NN 18) of the upper Pliocene was determined in Samples 5-2, 52-53 cm, 5-2, 72-73 cm, and 5-2, 18-149 cm which were rich in *Discoaster brouweri* and *Discoaster triradiatus*, typical of the uppermost Pliocene (*Discoaster brouweri* Zone [NN 18]) and contained a few specimens of *Ceratolithus rugosus. Discoaster surculus* and *Discoaster pentaradiatus* were found only sporadically in some samples of this interval together with other Neogene discoasters. It is supposed that these species are reworked.

The abundance of *Discoaster brouweri* and *Discoaster triradiatus* in these samples argues against the assumption that there is a hiatus including all of the uppermost Pliocene (see results of the foraminiferal studies). However, it is possible that a part of it is missing. The *Discoaster surculus* Zone (NN 16) includes the sequence from 5-3, 11-12 cm to 6-4, 140-141 cm. *Discoaster pentaradiatus* and *Discoaster surculus* are common only in the lower part of this zone. The sediments are rich in well-preserved nannoplankton. Coccoliths in the sapropel layers are etched, while the discoasters are enriched due to selective dissolution of the more fragile coccoliths. Reworked species are generally missing in this section. Species of the genus *Scyphosphaera* are abundant in some layers. They are absent in the sapropel layers, either due to climatic factors or to dissolution. Also ceratoliths are rare.

Samples 6-5, 38-39 cm to 7, CC belong to the *Reticulofenestra pseudoumbilica* Zone (NN 15). Its sediments are abundant in well-preserved nannofossils, and reworked species are missing. *Discoaster tamalis* becomes frequent in some layers, which is typical of this zone. The *Discoaster asymmetricus* Zone (NN 14) based on nannofossils was not recognized; it is possible that this zone is represented by the void at the top of Core 8.

The interval from 8-1, 108-109 cm to 9-1, 130-131 cm is assigned to the *Ceratolithus rugosus* Zone (NN 13) with *Ceratolithus rugosus* and *Ceratolithus tricor-*

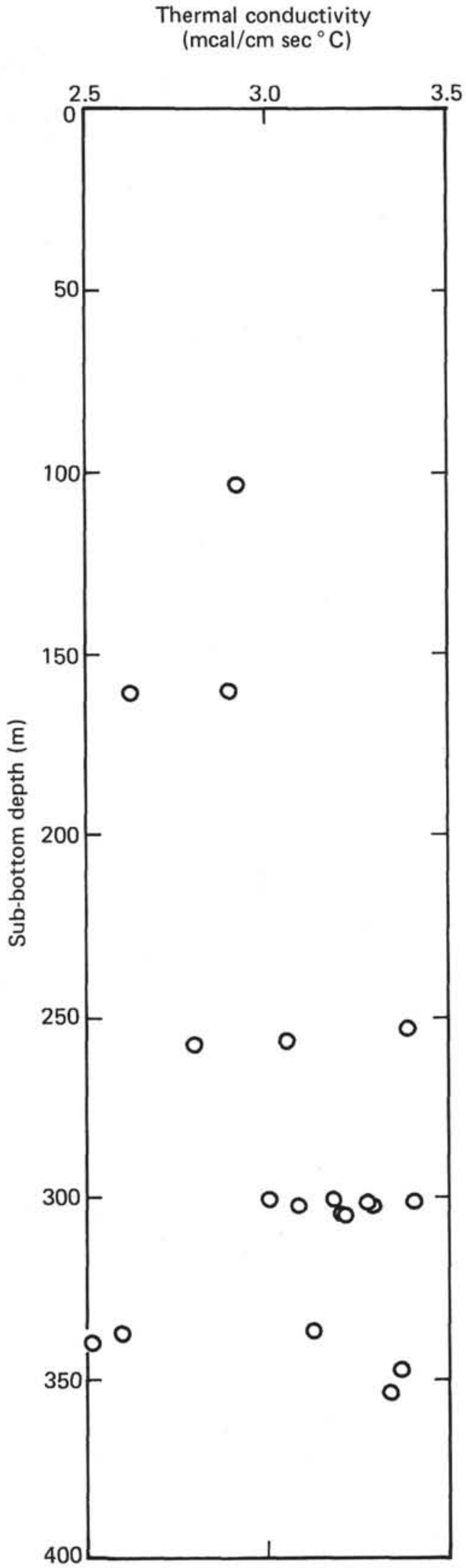

Figure 11. *Thermal conductivity values measured aboard ship on sediment recovered from Site 374, plotted versus sub-bottom depth.*

niculatus, but without *Discoaster asymmetricus*. The sediments are rich in nannofossils which are slightly overgrown. In some layers discoasters are only rare. The nannofossils in the sapropel layer at 8-3, 39-40 cm are well preserved.

The sequence from 9-2-1-2 cm to 11-1, 108-109 cm belongs to the *Ceratolithus tricorniculatus* Zone (NN 12) of the lowermost Pliocene/uppermost Miocene. Well-preserved nannofossils are abundant but are broken in the sapropelic sediments at Samples 9-1, 1-2 cm, 9-3, 13-14 cm, 10, CC, and 11-1, 108-109 cm. Discoasters *(Discoaster decorus)* and *Ceratolithus tricorniculatus* are frequent. In some samples the variety of *Ceratolithus tricorniculatus* with a horn becomes frequent. Below Core 11, Section 1 the sediments are barren of nannofossils due to recrystallization.

Sidewall Core 25 was barren of nannofossils. On the other hand, the assemblage of sidewall Core 26 indicates an early Pliocene age (*Ceratolithus tricorniculatus* Zone, NN12), since here the sediments are abundant in slightly to strongly overgrown nannofossils.

Planktonic Foraminifers (Cita)

The late Neogene section penetrated at Site 374, in the central part of the deepest abyssal plain of the Mediterranean, yielded rich and diversified foraminiferal assemblages from Cores 1 to 10 (Pleistocene to early Pliocene). The sediments are hemipelagic with a significant terrigenous input in the upper part of the section and hemipelagic to truly pelagic in its lower part. Core 11 consists of a lithified fine-grained sediment entirely recrystallized. It contains remains of an important biomass which records the repopulation of the basin by marine organisms after the salinity crisis. The strong diagenesis undergone by the sediment, however, prevents precise age determinations (see below).

Twenty-nine occurrences of organic-rich dark layers (sapropels or sapropelic layers) were recorded, which are considered the sedimentary expression of deep-water stagnation.

Eighty-six samples were studied in detail from the Plio/Pleistocene interval. A range chart containing information on planktonic foraminifers, as well as on other fossil remains and characteristic minerals is found in Bizon et al. (this volume). The chart includes samples from 19 sapropels recorded above Core 11. In contrast to the Plio-Pleistocene section, the pre-Pliocene section is essentially unfossiliferous. The evaporites themselves (Cores 16-22) are barren and indicate deposition in an abiotic environment. The associated nonevaporitic sediments yielded siliceous microfossils (diatoms, Radiolaria, siliceous sponge spicules) in generally small amounts. An exception are the common to abundant occurrences of diatoms in laminated sediments, which underlie the finely laminated ("balatino" facies) gypsum layers of Cores 17 and 18. Other microfossils present within the evaporite formation include spores and plant debris, which are obviously allochthonous to the environment in which they are recorded.

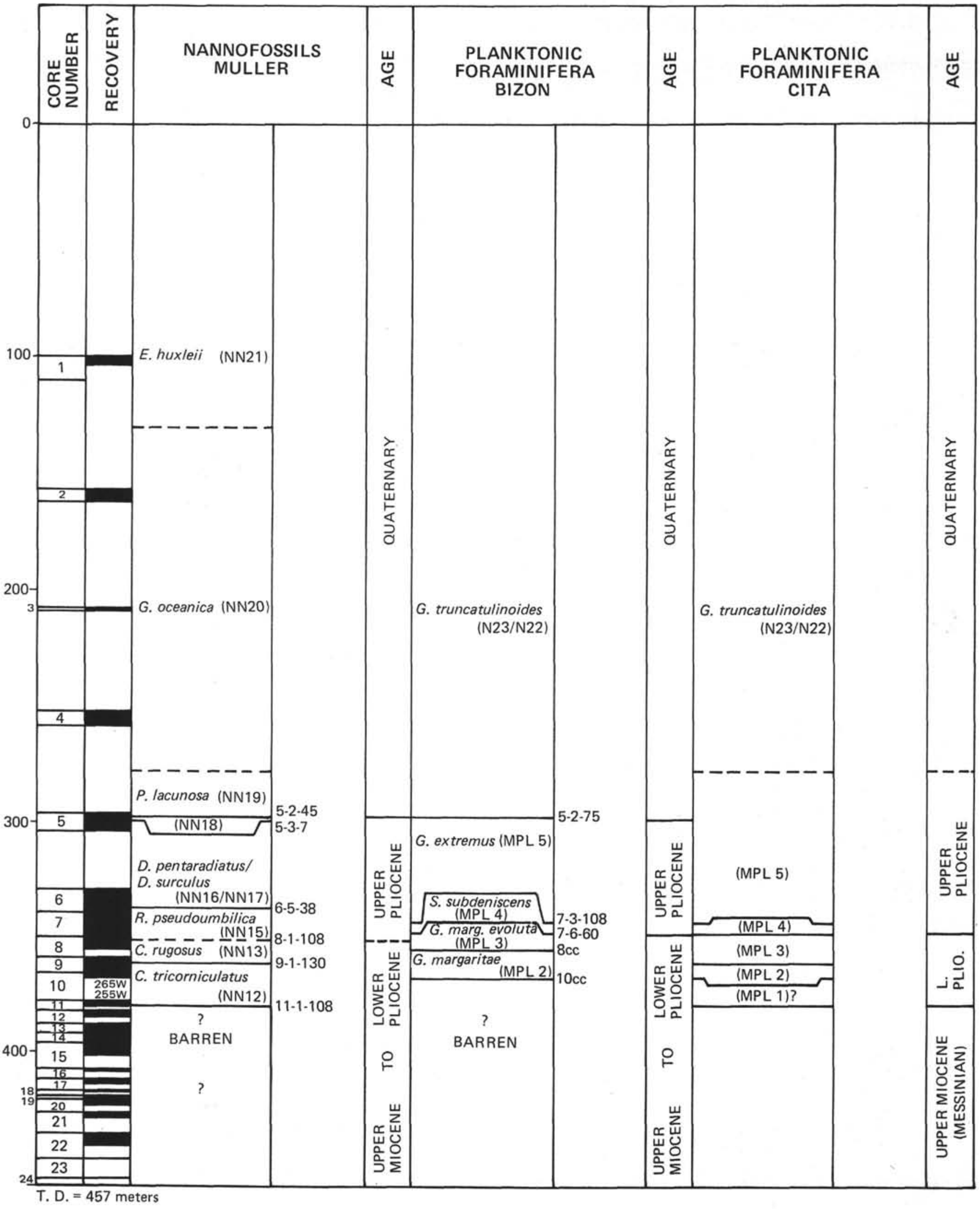

Figure 12. *Relative planktonic microfossil determinations, Site 374.*

Pleistocene

Planktonic foraminifers are rare to abundant in Cores 1 to 4 of the Pleistocene, as a result of their mechanism of deposition. In this interval hemipelagic sediments in which the biogenic component is dominant are associated with fine-grained turbidites in which sorting by size is obvious and only the smallest species, or juvenile specimens of large taxa, are recorded. Displacement of benthic foraminifers from shallower environments and reworking of calcareous nannofossils from older sediments are consistently recorded. The rate of sedimentation is very high in the Pleistocene: some 140 m/m.y. This high rate must be attributed to terrigenous influx, since organic productivity is known to be low in the Mediterranean at present, and also was low during the Pleistocene. Shards of volcanic glass in the sand fractions of Sample 3-1, 103-104 cm suggests that volcanogenic material also may have played some role in the sediment accumulation on the floor of the Messina Abyssal Plain during the Pleistocene.

For description, identification and stratigraphy of the more prominent sapropels and sapropelic layers of Cores 2 to 4, see Kidd et al. (this volume).

Pliocene/Pleistocene Boundary

The topmost part of Core 5 (Section 2, down to 64 cm) yields planktonic foraminifers indicative of a Pleistocene age, including the marker fossil *Globorotalia truncatulinoides.* As in other drill sites previously discussed where coring was discontinuous, the drilling technique used was such that the occurrence of Pleistocene sediments in the upper part of the core can be accounted for by partial filling of the core before it reached the actual depth of cutting (–297 m subbottom). Therefore, for calculating sedimentation rates, it is considered safer to locate the Pliocene/Pleistocene boundary arbitrarily in the 40-meter thick interval between Cores 4 and 5.

Pliocene

Fossiliferous Pliocene sediments were recovered from Cores 5 to 11, and from sidewall Cores 25 and 26. Of the six biozones distinguished in the Pliocene deep-sea record, only four could be identified at Site 374.

MPl-6, the youngest biozone of the late Pliocene, is not recorded in Core 5, whose main part is referable to MPl-5, while its top yields Pleistocene faunas (see above). Also, the oldest biozone of the Pliocene (M Pl-1) could not be identified because of lithification undergone by the sediments overlying the evaporite formation. However, the biozone is probably represented by Core 11 (see later discussion).

MPl-5, Cores 5 (from Section 2, 79 cm), 6, and the topmost part of Core 7 (to 1-40 cm) belong to this biozone. They consist of hemipelagic sediments and include 11 sapropelic layers and sapropels (see Kidd et al., this volume). The faunal assemblages are rich and diversified. They include up to 20 species of planktonic foraminifers, with *Globigerinoides obliquus extremus* consistently recorded in every sample processed, along with *Globigerina bulloides, G. apertura, G. quinqueloba, G. falconensis, G. bulbosa, Orbulina universa, Globigerinita glutinata,* and *Globorotalia scitula.* The occurrence and/or abundance of epipelagic taxa sensitive to climatic changes (warm-water indicators) such as *O. universa, Hastigerina siphonifera, Globigerinoides ruber, G. conglobatus,*, and *G. sacculifer* differ widely from sample to sample, indicating climatic fluctuations. The occurrence of representatives of the genus *Globorotalia* seems controlled, not only by their stratigraphic range, but also by changes in the structure of the permanent thermocline. This holds true in particular for the taxa *Globorotalia crassaformis* and *G. aemiliana,* whose record is scattered. Climatic changes are also inferred from the varying abundances of discoasters recorded in the late Pliocene (see section on calcareous nannofossils). The climatic fluctuations discussed above correspond to, and can be correlated with, the "green" and "yellow" climatic episodes of Ciaranfi and Cita (1973), as recorded in the *Globigerinoides obliquus extremus* Interval-Zone (MPl-5) and *Discoaster surculus* Nannofossil Zone (NN 16) of both the Ionian and Tyrrhenian basins.

The M Pl-4 biozone is recorded in Core 7. More precisely, foraminiferal faunas indicating an M Pl-4 zonal age have been recorded from Section 1 of Core 7, beginning at 100 cm, to the sample immediately above the core catcher. The sediments are pink, more or less mottled, marls and oozes, with no sapropels. The foraminiferal assemblages are rich and well diversified, indicating eutrophic conditions. The P/B ratio is consistently very high (more than 98%). The genus *Sphaeroidinellopsis* is well represented, and specimens referable to *Sphaeroidinella ionica ionica* are also recorded. This interval, where warm-water indicators are either rare or absent, corresponds to the "brown" episode of Ciaranfi and Cita (1973), a long and cool episode which spans the interval from approximately 3.0 to 3.3 m.y. (*Reticulofenestra pseudoumbilica* Nannofossil Zone) and which was recorded both in the Ionian and in the Tyrrhenian basins. This is the time of the onset of Arctic glaciation. A cooling and erosional phase ("Aquatraversan erosional phase" of Ambrosetti et al., 1971) is recorded in the central Mediterranean at that time. The rate of sedimentation calculated for this interval at Site 374 is 27 m/m.y. Well-ventilated conditions at the bottom of a previously semistagnant basin and an upward increasing sedimentation rate are considered the response to this major cooling phase, which reactivated the deep geostrophic thermohaline circulation in the eastern Mediterranean.

The M Pl-3 biozone has been recorded from Core 7 to Sample 9-2, 2 cm. The sediments are white to pale gray, and include two sapropelic layers. The P/B ratio is always very high (more than 98%). Evidence of dissolution at depth in the form of many broken tests and thinned and partially corroded foraminiferal tests was recorded at 33-35 cm in Section 1 of Core 9, as well as at 95-97 cm in the same section. The sedimentation rate is extremely low: about 13 m/m.y.

All these observational data concur in delineating a paleoenvironment characterized by a biogenic, particle-by-particle deposition in a deep-water basin with very weak thermohaline circulation at depth which resulted in periodic stagnations.

The M Pl-2 biozone has been recorded from Core 9, Section 2 (beginning at 92 cm) to Sample 10, CC, and also from sidewall Core 26. A sapropel layer was found in Section 3, at 14 cm. Evidence of dissolution at depth has been recorded consistently within this biozone (at Samples 9-3, 30-32 cm, 9-3, 90-92 cm, 9-4, 50-52 cm, 9, CC, and 10, CC). Sample 9-2, 22 cm is practically devoid of foraminiferal tests. It comes from a very fine grained, white, structureless sediment underlying a sapropelic layer. The same comments on paleoenvironmental conditions, as formulated for M Pl-3, can be also extended to this biozone.

M Pl-1 (?): The *Sphaeroidinellopsis* Acme Zone of the basal Pliocene could not be identified at Site 374, although its presence is considered very probable. The seismic profiles over the site indicate a continuous set of conformable strata in the lower part of the section overlying the Mediterranean Evaporite, and its basinal setting suggests that the oldest Pliocene strata should be present. Unfortunately, the strong diagenesis undergone by the highly calcareous sediments which overlay the dark, unfossiliferous mudstones of the terminal Miocene has practically destroyed the fossil tests. Figure 13 shows the presence of abundant planktonic foraminifers, including *Orbulina* and *Sphaeroidinellopsis* (?) preserved as casts and as internal molds. The test itself has always been destroyed. Under these circumstances it is impossible to make any precise age determination. In Sample 11-2, 85-87 cm within an *unconsolidated* interval, the sand-size fraction of the sediment greater than 63 μm consisted of agglomerates of crystals of calcite (?) and/or dolomite (?) most as internal molds of planktonic foraminifers. From their general shape, the following taxa could be tentatively identified: *Orbulina universa, O. bilobata*, and *Sphaeroidinellopsis seminulina.*

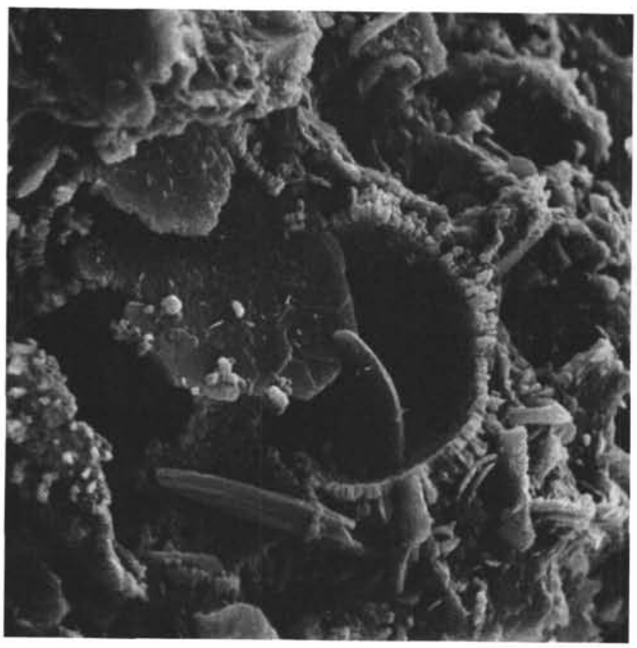

Figure 13. *Scanning electron micrograph of diagenetically altered fossils from Core 11, Site 374 (374-11-1, 107.5 cm) X 1400.*

The lithostratigraphic correlation of the presumably oldest Pliocene sediments recovered at Site 374 (which have several sapropel layers, Sections 1 and 2 of Core 11) with the demonstrably oldest Pliocene sediments recovered at Site 376 (which also yield a prominent sapropel) strongly support the assumption that M Pl-1 was recovered.

More specifically Core 11 and sidewall Core 25 are placed in the M Pl-1 biozone based on: (a) their high carbonate content, presumably of a biogenic nature; (b) the presence of a biomass of planktonic foraminifers, unclearly visible because of strong diagenesis and lithification; (c) the continuity of the seismic record, which suggests that the oldest Pliocene strata should be present; and (d) the lithostratigraphic correlation with Site 376, where the earliest Pliocene (M Pl-1) is also sapropelic.

Miocene/Pliocene Boundary

The Miocene/Pliocene boundary at Site 374 consequently is obscured somewhat by the diagenetic processes undergone by the earliest Pliocene horizons. The occurrence of thin stringers of gypsum higher in the section than the evaporite formation caused the location of this boundary to be placed too high in the section in the shipboard report. This gypsum is now considered diagenetic, and included in sediments of Pliocene age.

Since pre-Pliocene sediments at Site 374 are consistently devoid of calcareous micro- and nannofossils, the boundary itself is weakly defined. It corresponds to a drastic change in environment, as is clearly shown by the change in carbonate content. Since the carbonates are biogenic (calcareous nannofossils and foraminifers) and essentially planktonic, the drastic drop indicates a change which is certainly not gradational.

Planktonic Foraminifers (Bizon)

Quaternary

The Quaternary was recorded from Core 1 to Sample 5-2-75 cm. In Samples 5-2-75 cm and 5-2-64 cm, *Globorotalia truncatulinoides* was found with *Globorotalia tosaensis*, and *Sphaeroidinella dehiscens. Globigerinoides* cf. *fistulosus* becomes extinct at Sample 5-2, 64 cm and *Globigerinoides obliquus extremus* at Sample 5-2, 80 cm.

Pliocene

From Sample 5-2, 80 cm to 7-3, 30 cm, planktonic foraminiferal assemblages seem to be referable to the *Globigerinoides elongatus* Zone. *Globorotalia inflata* or *Globorotalia pachyderma* could not be found in the upper part of this interval. The *Globorotalia inflata* Zone appears to be missing.

Epipelagic species are predominant in Core 5, Sections 3, 4, and 5. From Core 6, Section 1 to Section 3, *Globorotalia crassaformis* is abundant and is associated in Section 4 with *Globorotalia emiliana.*

The *Sphaeroidinellopsis subdehiscens-Globigerinoides elongatus* zonal boundary occurs in Core 7. In Section 1 of Core 7, there is an overlap between the first occurrence of *Globorotalia crassaformis* and *Globorotalia emiliana,* and the last occurrence of *Globoquadrina altispira.* Some *Sphaeroidinellopsis* were found without a vitreous external cortex. In Core 7, Section 2, *Globorotalia puncticulata* is abundant. In Sample 7-3, 108 cm, typical *Sphaeroidinellopsis subdehiscens* and *S. seminulina* are present. It is probable that the boundary can be drawn in Core 7, between Sections 2 and 3. At this site, the extinction of taxa follows fairly well the succession observed by Berggren in the Atlantic Ocean (*Sphaeroidinellopsis subdehiscens, Globoquadrina altispira*).

The boundary between the *Sphaeroidinellopsis subdehiscens* and the *Globorotalia margaritae evoluta* Zone can be drawn between Samples 7-6, 60 cm and 7, CC. *Globorotalia margaritae* becomes extinct at Sample 7, CC.

The *Globorotalia margaritae evoluta* Zone can be recognized from Sample 7, CC (in association with *Globorotalia puncticulata, Globorotalia margaritae*) to Sample 8-4, 110 cm.

The interval from Sample 8, CC to 10, CC is assigned to the *Globorotalia margaritae* Zone.

Samples 11-1, 90 cm and 11-1, 109 cm were investigated in detail. Planktonic foraminifers are always abundant, but more or less completely dolomitized. In Samples 11-2, 20 cm and 11-2, 80 cm, some specimens of planktonic foraminifers were found which could belong to the genus *Sphaeroidinellopsis.* They are completely recrystallized, and the determination is questionable.

Over the interval from Samples 11-2, 114 cm to 15, CC. several samples were investigated in the dolomitic mudstone. Some *Turborotalita* aff. *quinqueloba* were found, and several layers contained cysts of algae which belong to the family *Prasinophyceae,* genus *Pachysphaera.* Sample 15, CC contained Radiolaria, diatoms, and sponge spicules. The Radiolaria were investigated by J. P. Caulet and are indicative of the *Stichocorys peregrina* Zone, which extends from the uppermost Miocene to the lower Pliocene. Reworked species from the lower Cretaceous were also identified.

Benthic Foraminifers

The well-preserved but uncommon specimens of the Pleistocene section at this site are generally well sorted and small. That portion of the sample which is less than 149μm generally consists of a mixture of shelf, upper epibathyal, lower epibathyal, and upper mesobathyal species. The small size, good sorting, and mixed assemblages lead to the conclusion that most of these assemblages were displaced downslope into a mesobathyal environment by turbidity currents and that these samples are taken from the distal elements of turbidites. The specimens which are >149 μm are usually upper mesobathyal (>1000-1300 m) and mid mesobathyal (>1800m) species, including *Articulina tubulosa* and *Quinqueloculina venusta.* These presumably in situ specimens are greatly outnumbered by the displaced specimens.

The upper Pliocene sequence (Samples 5-2, 95 cm to 7-2, 80 cm) contains a less diverse but more in situ fauna than the Pleistocene samples. Except for the presence of displaced shelf species near the top of the section (5-2, 95 cm), the taxa are indicative of an upper mesobathyal environment. The absence of deeper elements is a little surprising in view of the 4000-meter water depth today at the site. This difference may be real, i.e., a post-Pliocene deepening, or may be due to the relatively sparse mid and deep mesobathyal species being diluted by displaced shelf species to the extent that they are rarely encountered. The latter explanation seems more reasonable in view of the discovery of deeper water species in the lower Pliocene section below.

The lower Pliocene section contains a low diversity benthic foraminiferal fauna, which becomes even less diverse and very poorly preserved near the Mio-Pliocene boundary. The specimens near that boundary were strongly overgrown with dolomite. The fauna contains a variety of lower epibathyal (>500-700 m) and upper mesobathyal forms. All the specimens were smaller than normal. Two species which were relatively abundant in the cores, *Epistominella rugosa convexa* and *Eponides pusillus,* showed a gradual increase in size upward in the section. The small specimen size and uphole increase in size of some species may be due to the change from a restricted, evaporating, biotically hostile environment to normal marine mesobathyal conditions in the early and late Pliocene.

All cores lower than 11-1-86 cm were essentially barren of benthic foraminifers.

SEDIMENTATION RATES

Sedimentation rates for the late Neogene section penetrated at Site 374, in this the deepest abyssal plain of the Mediterranean, are evaluated with differing degrees of precision because (a) the Pleistocene and late Pliocene section was cored intermittently (Cores 1-6); (b) the Pliocene section was continuously cored in Cores 6 to 10; while (c) the pre-Pliocene (Messinian) evaporitic sequence (Cores 11 to 22) was continuously cored, but recovery was poor and much of the sediment was unfossiliferous. Figure 14 illustrates the sedimentation rates, which change considerably in time, in response to fundamental paleoenvironmental changes.

Quaternary

The Pliocene/Pleistocene boundary, with an interpolated age of 1.85 m.y., was assumed by Cita to be located halfway between Cores 4 (the lowest core referable to the Pleistocene on its fossil content) and 5 (the highest yielding Pliocene microfossils) at a depth of about 280 meters subbottom. The resulting sedimen-

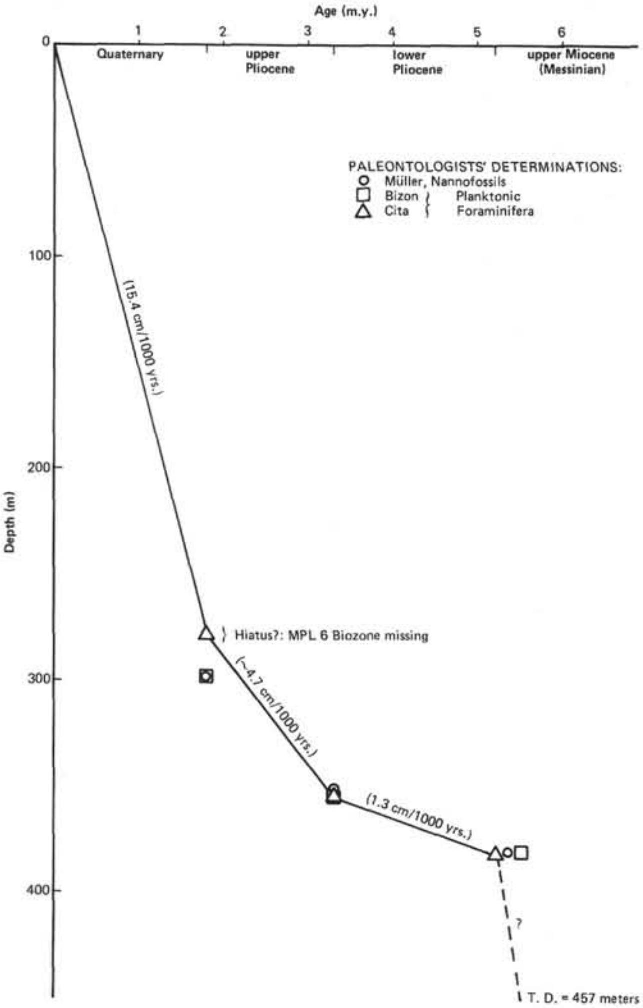

Figure 14. *Sedimentation rates at Site 374.*

tation rate for the Quaternary is 15.4cm/10^3 yr. This value is consistent with the lithologies recorded, which include turbidites and hemipelagic sediments with a substantial terrigenous component. Bizon found *Globorotalia truncatulinoides* co-occurring with *G. tosaensis* at 64-65 cm in Section 2 of Core 5. This finding implies a Pleistocene-Pliocene boundary within Core 5. Thus the sedimentation rate during the Quaternary may be slightly higher at about 16.0 cm/10^3 yr and during the late Pliocene consequently, slightly lower.

Pliocene

The uppermost Pliocene foraminiferal biozone (MPl-6) appears to be missing. The late/early Pliocene boundary is placed at 349.5 meters subbottom. This gives a sedimentation rate for the late Pliocene (MPl-5 and MPl-4) of about 4.7 cm/10^3 yr.

In accepting that Core 11 is made up of diagenetically altered early Pliocene sediment and that the base of the Pliocene is therefore at 381.5 meters subbottom, the early Pliocene sedimentation rate is about 1.3 cm/10^3 yr.

This progressive lowering of sedimentation rates through the Plio/Pleistocene section reflects the lessening influence downhole of terrigenous sedimentation. This is interpreted by Cita, Ryan, and Kidd, this volume as entrapment of sediment on the margins of the Ionian Basin, which followed an early Pliocene flooding of a desiccated Mediterranean.

Miocene

No sedimentation rates can be calculated for the Messinian sediments since no age assignments could be given to their meager fossil assemblages.

CORRELATION OF SEISMIC REFLECTION PROFILES WITH DRILLING RESULTS

Site 374 was located at shot point 870 on the CEPM-CNEXO multichannel seismic profile OD 22. The 1974 IFP site survey showed a more complicated structure than expected in this area, with some evidence of late Miocene volcanic activity influencing the deposition of the Messinian evaporites. The Plio-Quaternary sequence and the upper evaporitic sequence above the "salt layer" are particularly well developed (Figure 15).

On the OD 22 seismic profile, the following main reflectors can be determined in the upper part of the very thick sedimentary sequence under the Messina Abyssal Plain (3 to 4 sec two-way travel time). (For each reflector, the two-way travel time in msec, the depth in m and the estimated thickness of each layer are shown derived from the interval velocities known from analysis of multichannel seismic data.)

Horizons	Two-Way Travel Time (msec)	Depth (m)	Thickness (m)
Sea bottom	0	0	400
Top upper evaporite-reflector	380	400	450
Top salt-reflector	640	850	800
Base salt	1020	1650	

On the *Glomar Challenger* profile the M-reflector is well defined. Because of the horizontal compression of the profile it appears undulated; the two-way travel time is about 375 msec, which is in good accordance with the multichannel profile. In the Plio-Quaternary sequence above this, numerous reflectors are visible, but are somewhat difficult to pick out, because of the "bubble effect." Correlation with the drilling results is also tentative, because of the spot coring.

Site 374 showed a sharp lithologic contrast between the two sidewall cores at –370.5 meters and –375 meters. In the upper one, SW 26, foram-bearing nannofossil marls were present while in the lower one, SW 25, there were dolomitic muds. These muds extend downwards to –406.5 meters, where the first thick layer of gypsum appears, in Core 16.

The velocity measurements made onboard (see Physical Properties Section) show only a relatively small increase in velocity at the top of the dolomitic muds (from 1.819 km/sec to 2.65 km/sec) when compared with the sharp increase in the gypsum layers (4.6 to 5.1 km/sec). Therefore it seems probable that

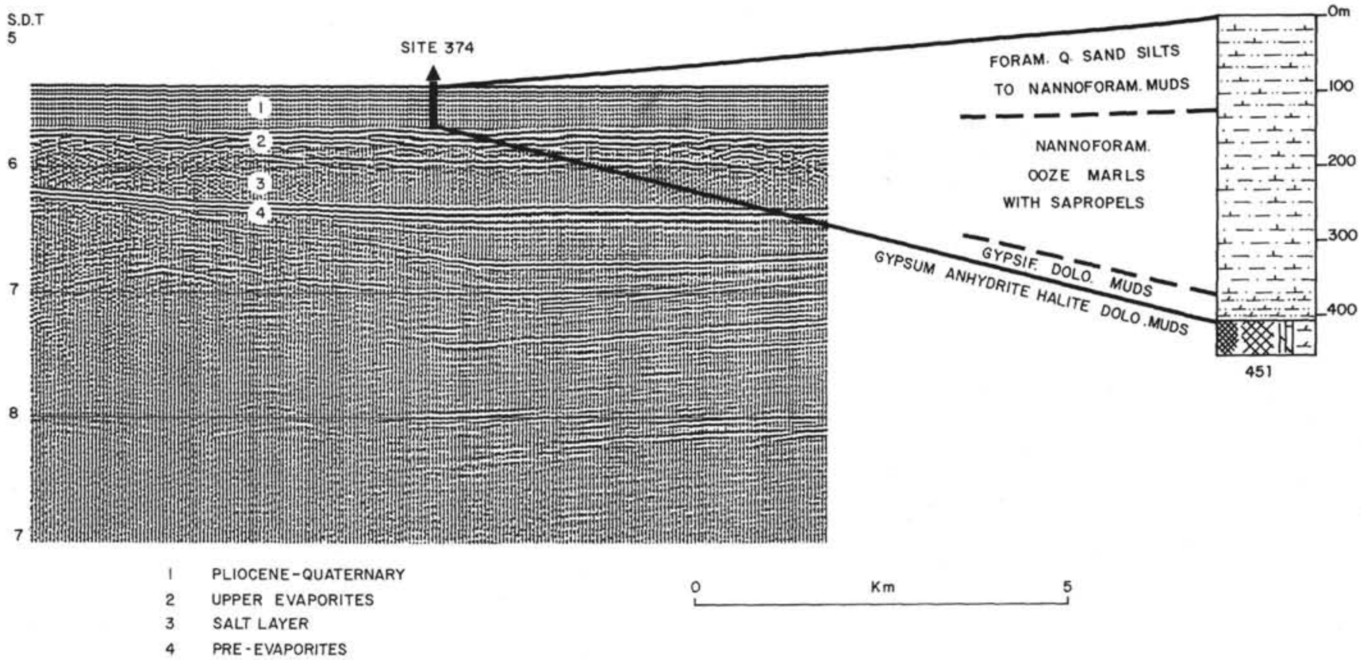

Figure 15. *Correlation of CEPM-CNEXO OD-22 seismic reflection profile with drilling results at Site 374.*

the first strong seismic reflector does not correspond with the top of the evaporites (dolomitic muds) but with the first appearance of the gypsum, i.e., at about 406.5 meters depth, which is in good agreement with the velocity prediction. The hole was terminated at 457 meters subbottom within the upper evaporitic sequence. Figure 15 illustrates this correlation.

Although halite was cored at 435 meters subbottom, this halite deposit is believed to be a part of the "Upper Evaporite Unit," and not the reflecting layer of the main salt unit, which should lie at about 850 meters subbottom.

SUMMARY AND CONCLUSIONS

The site was located in the central part of the Messina Abyssal Plain at 35°50.87N, 18°11.78E in 4078 meters of water. The hole penetrated 457 meters and into the Messinian evaporites before it was abandoned in accordance with a ruling by the JOIDES Safety Panel that the drilling should be terminated at this location at a depth less than 50 meters below the M-reflector. The broad objective of the drilling was to test the different models of evaporite deposition by obtaining new information on the succession of evaporite types and on the environmental change which occurred at the beginning of the Pliocene. The site was located on an IFP site survey profile in the central part of the abyssal plain, where the Pliocene is thickest. We hoped to sample the earliest Pliocene at this basinal location.

The hole was cored intermittently to 330.5 meters subbottom and then continuously to a depth of 457 meters. Two successful sidewall cores were taken to locate the Pliocene-Messinian contact more accurately in a part of the hole where the recovery was very poor.

The section penetrated can be divided into three stratigraphic units ranging in age from Quaternary to Messinian. Units I and II range from Quaternary to early Pliocene in age. The units are mainly hemipelagic muds, marls, and sapropels, with intercalations of sand and silt layers. The thickest layer, a dark greenish gray foraminiferal sand deposited by turbidity currents, was found in Core 1. Also the nannofossil marls sampled for $CaCO_3$ analysis from Core 1 gave significantly higher values (45%-55%) than the nannofossil muds of Cores 2 and 3 (10%-20%). These observations led to the separation of Subunit Ia from Ib and Ic, the first two at an arbitrarily chosen boundary at 130 meters subbottom in the uncored interval between Cores 1 and 2. Subunits Ib and Ic are mainly nannofossil marls; two minor graded beds are present in Ib and pelagic oozes are intercalated in Ic. The average content of biogenic carbonates shows a gradual increase downward, reaching a maximum of 56% at Core 8, whereas the terrigenous content decreases. A boundary between the lower subunits is placed between Cores 5 and 6; smectite is the main clay mineral above this boundary, whereas it is rare in the cores below.

The hemipelagic sediments of Unit I are of two major types: (1) nannofossil muds, marls, and oozes deposited when the basin was well ventilated; and (2) dark organic-rich, sapropels and sapropelic layers, which are here interpreted as having been deposited when the basin was stagnant (see also Kidd et al., this volume).

Muds, marls, and oozes have been classified on the basis of their $CaCO_3$ content. These fine-grained sediments are composed of calcareous skeletons, detrital carbonates, and terrigeneous minerals. The sediments have been burrowed to varying degrees. Colors range from pale olive, to yellowish-green, greenish-gray, dusky yellow, grayish-orange, yellowish-brown, and to very light gray.

The "dark" organic-rich layers were found in all Unit I cores except Cores 1 and 7. Seventeen true sapropels (greater than 2% organic carbon), some of which include double or triple layers, were identified from 29 individual dark layers. The discovery of sapropels as old as early Pliocene (MPl-2) is of particular interest since such old sapropels have not been previously recognized in the Mediterranean.

The sapropels are hemipelagic nannofossil sediments, rich in organic and carbonaceous matter. Some are laminated, most are devoid of bioturbation, and range from a few millimeters to 7 cm in thickness. Aside from their richness in organic matter (up to 16.7%), the sediments consist of nannofossils, planktonic foraminifers, clay minerals, pyrite, and rare detrital grains. The planktonic foraminifers vary in abundance and in diversity; benthic foraminifers are absent. Plant debris and spores are common, and pteropods are present in the Quaternary sapropels.

The origin of sapropels is commonly related to basin stagnation. However, the cause of basin stagnation is not always clear. The stagnation of the eastern Mediterranean during the post-glacial time (9000-5000 m.y. B.P.) has been related to abnormal fresh-water influx (especially from the Black Sea) as glaciers melted. This influx is believed to have sufficiently lowered the salinity of the surface water to prevent its descent as currents of bottom circulation (Olausson, 1961). However, the preglacial, especially the early Pliocene, episodes of basin stagnation must have been related to some more complicated paleooceanographic factors (see Kidd et al., this volume).

The Plio-Quaternary sediments show a gradual increase in terrigenous influx, with time together with more frequent turbidite sedimentation. There has been a corresponding increase in sedimentation rate from as low as 1.3 cm/10^3 yr in early Pliocene times to about 4.7 cm/10^3 yr in late Pliocene, and to as much as 15.4 cm/10^3 yr in the Quaternary. Such a trend can be interpreted differently. Some of the shipboard party suggested a change of conditions in the source area citing the Quaternary uplift of Calabria. Others suggested the change was evidence for a gradual deepening of the Ionian Basin (Müller et al., this volume). Still others related the change of sedimentation rate to the entrapment of sediment on the margins following an early Pliocene flooding of a desiccated Mediterranean (Cita, Ryan, and Kidd, this volume). Benthic foraminiferal faunas indicative of water depths in excess of 1200 meters have been found in the early Pliocene (MPl-2) core at this site. There was also an upward increase in abundance and in diversity of the benthic foraminifers, suggestive of a gradual repopulation of a seabottom sterilized by the Messinian salinity crisis. This basinal site has remained in an abyssal plain environment at water depths of more than 1200 meters since the earliest Pliocene; there is no paleoecological evidence for a substantial Plio-Quaternary deepening.

As is common in other Plio-Quaternary sections overlying evaporites or salt deposits in the Mediterranean and Red seas, the salinity of interstitial water increased downward and reached almost 40% (or slightly above halite saturation) in the lowest Pliocene sediments recovered. The salinity gradient was related to ionic migration from the brines in underlying salt deposits. The presence of gypsum in lower Pliocene sediments (Cores 7 to 10) may be explained in terms of diagenetic precipitation from interstitial brines. Unit I sediments are not dolomitized.

Unit II is a diagenetically altered sediment in the interval between 373 and 381.5 meters depth. It separates the open marine deposits of Unit I and the dolomitic marls of Unit III. The unit consists of a thin layer (10 m thick) of dolomitized nannofossil marls. Nannofossils, in varying states of preservation, are still recognizable in Section 1 of Core 11, but are not identifiable in Section 2. The original existence of foraminiferal tests is indicated by the presence of numerous fossil molds. Trace fossils (*Zoophycos* and *Chondrites*) document the activity of burrowing organisms. It seems that this unit represents the earliest Pliocene sediment, which has been dolomitized. A gypsum veinlet is present in Section 2 of Core 11; it is thought to be secondary.

The dolomitization of Unit II probably took place after burial, as a consequence of ionic migration across a steep Mg-concentration gradient (McDuff and Gieskes, this volume).

Unit III is an evaporite sequence. Interpretations of seismic profiles indicate that these sediments belong to the "Upper Evaporite" member of the Mediterranean Evaporite formation. Three subunits have been recognized: Subunit IIIa, dolomitic mudstones; Subunit IIIb, gypsum-dolomitic mudstone cycles; Subunit IIIc, anhydrite, halite, and potash salts.

The dolomitic mudstones of Subunit III are dark greenish-gray, rich in organic matter, and pyrite-bearing in part. Most are barren of fossils. However, evidence of marine influence was afforded by very rare occurrences of algal cysts, sponge spicules, Radiolaria, and diatoms.

Subunit III includes several cycles of muddy and gypsiferous sediments. An idealized cycle, as shown by Figure 5, is in descending order: (c) wavy bedded and nodular gypsum; (b) laminated gypsum (balatino); (a) dolomitic mudstone with small gypsum nodules, locally diatomaceous, and organic-rich.

Similar cycles have been recognized in the evaporite interval core in Hole 124 in the Balearic Basin, except that member c at Site 374 is a nodular anhydrite and is far more prominently represented. Such cycles are interpreted as due to alternate periods of flooding and desiccation (Hsü et al., 1972; Garrison et al., this volume).

Subunit III consists of nodular anhydrite, together with K- and Mg-salts.

On the basis of a chemical analysis supplemented by X-ray diffraction studies (see Kuehn and Hsü, this volume), one sample (22-3, 24-34 cm) was found to contain: halite (NaCl), 89.35%; polyhalite (K_2Mg

$Ca_2[SO_4]_4 \cdot 2\ H_2O$), 7.14%; bischofite ($MgCl_2 \cdot 6H_2O$), 1.66%; sulfoborite ($MgF_2 \cdot 2MgSO_4 \cdot 3Mg[OH]_2 \cdot 4B[OH]_3$), 0.22%; sylvite (KCl), 0.06%; MgO, 0.47%.

Another sample (22-3, 107-130 cm) contained: kainite ($MgSO_4 \cdot KCl \cdot 3H_2O$), 62.6%; halite, 37.80%; polyhalite, 5.31%; Insoluble, 0.57%.

The highly soluble Mg- and B-bearing minerals apparently provided these ions for diagenesis, leading to the formation of lüneburgite in Cores 12 through 15 (Müller and Fabricius, this volume) and of dolomite in Core 11.

Origin of the Evaporites

Site 374 penetrated only about 80 meters beneath the base of the Pliocene and some 40 meters into gypsum-bearing and salt horizons. We have thus sampled only the very uppermost part of the Upper Evaporite member of the Mediterranean Evaporite formation, which is estimated to be more than 1000 meters thick here on the basis of seismic evidence (see Background and Objectives section). We shall, therefore, limit our discussion to an interpretation of this Upper Evaporite member.

Our sampling revealed changes in environment during the late Messinian towards the termination of the salinity crisis. First, conditions were still favorable for salt deposition. Then there was a period of alternating conditions resulting in cyclic sedimentation of dolomitic mudstones and gypsum. Finally, conditions became more stable causing deposition of the rather monotonous sequence of dolomitic mudstones.

The mineralogy of the Site 374 salts (see Kuehn and Hsü, this volume) is similar to member B of the Sicilian salt formation. Member B at Porto Empedocle includes numerous intercalations of kainite and has a Br content averaging about 200 ppm (Decima, 1975). However, the member B of Sicily belongs to the Lower Evaporite member, whereas the Site 374 salts were of the Upper Evaporites. The similarity might be attributed to the fact that both deposits have derived their salt ions from a marine source, in contrast to the upper C and D members of the Sicilian salts which were recycled by continental waters (with practically no Br) and consist of halite only (Decima, 1975).

The environment of salt-deposition at Site 374 may have been varied. The halite associated with kainite changes its bromine content from 479 to 283 ppm. within a stratigraphic interval of less than 5 cm. The halite associated with the polyhalite also has a rapidly oscillating bromine profile, changing, for example, from 114 to 203 ppm within a 2-cm stratigraphic interval (see Kuehn and Hsü, this volume). Such rapid variations have been interpreted to represent salt deposition in shallow brine pools (Kuehn and Hsü, 1974). This interpretation is reinforced by the association of nodular anhydrite directly above the salt, as this may have been deposited when the brine pool was desiccated and subaerially exposed.

Our interpretation of these data is that the area of today's Messina Abyssal Plain was at times covered by shallowwater bodies and at other times was subaerially exposed, when dolomitic mudstones and gypsum were cyclically deposited. This interpreation is proven beyond a reasonable doubt by the occurrence of algal stromatolites (Awramik, 1977), and of shallow and brackish water diatoms (Schrader and Gersonde, 1977) in the cored sequence.

The Messina Abyssal Plain was probably fully submerged when the dolomitic mudstones were deposited. Isotopic evidence suggests that the water was not marine, but was derived largely from continental sources (see Pierre and Fontes; McKenzie and Ricchiuto; Ricchiuto and McKenzie, all this volume). The continued influx and evaporation may have been balanced to such an extent that neither evaporite deposition nor subaerial exposure took place. The depth of this lake, which may be a part of a "Lago Mare" system, (see Cita, Wright, Ryan, and Longinelli, this volume) is unknown. The *Cyprideis* and *Ammonia* faunas commonly present in "Lago Mare" deposits of land sections are not found in our cores. Their absence suggests that the depth of this latest Messinian Ionian Basin was sufficiently great to permit the development of a thermocline together with a stagnant bottom layer (indicated by the organic carbon richness of the sediment) somewhat analogous to the present Black Sea. The dolomite was either a primary precipitate or was formed by subaqueous diagenesis, probably similar in origin to the Plio-Quaternary dolomite of the Black Sea (Ross, Neprochnov, in press), or to the dolomite formed during the submergent stages in West Texas Lakes (see Parry et al., 1970).

There was a sudden change from the previously abiotic environment of the Ionian "Lago Mare" to a normal marine condition in the Pliocene. The age of the earliest Pliocene sediments was obscured by late-diagenetic dolomitization, and the oldest datable Pliocene is MPl-2. The water depth was then greater than 1200 meters and has remained at least this until the present day.

Heat Flow

Five downhole temperature measurements made between 109 and 306 meters subbottom, together with shipboard thermal conductivity measurements, were used to calculate a heat-flow value of 0.80 cal/cm^2 sec at this site. Temperature increases almost linearly with depth, indicating that this area has not been subject to large amplitude, long-term fluctuations in bottom water temperature within the last 2000 years. The observed borehole heat-flow value is much lower than the global heat-flow average and is in good agreement with the average (0.74 $\pm$0.30 cal/cm^2 sec) of thirty three other conventional eastern Mediterranean heat-flow values (Erickson, 1970). The very low eastern Mediterranean heat flow, in contrast to high heat flow through the floor of the western Mediterranean, supports other geophysical evidence indicating that the two areas are fundamentally different in both origin and geologic history. It is interesting to speculate whether the observed low heat flow may be a consequence of the downward depression of isotherms as the floor of the eastern Mediterranean is subducted beneath the Tyrrhenian and Aegean seas. For additional details of the heat-flow operations at this site see Erickson and Von Herzen (this volume).

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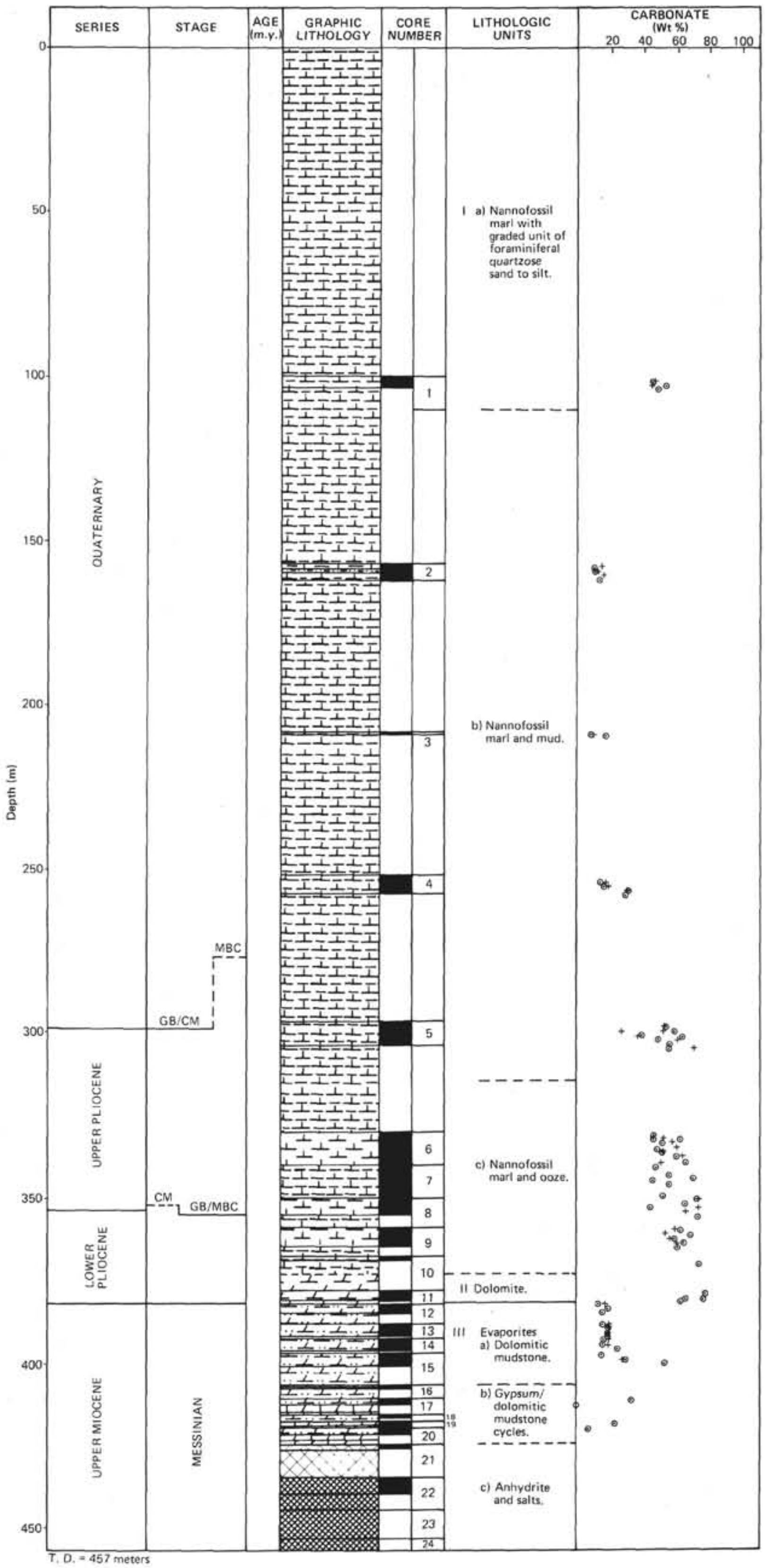
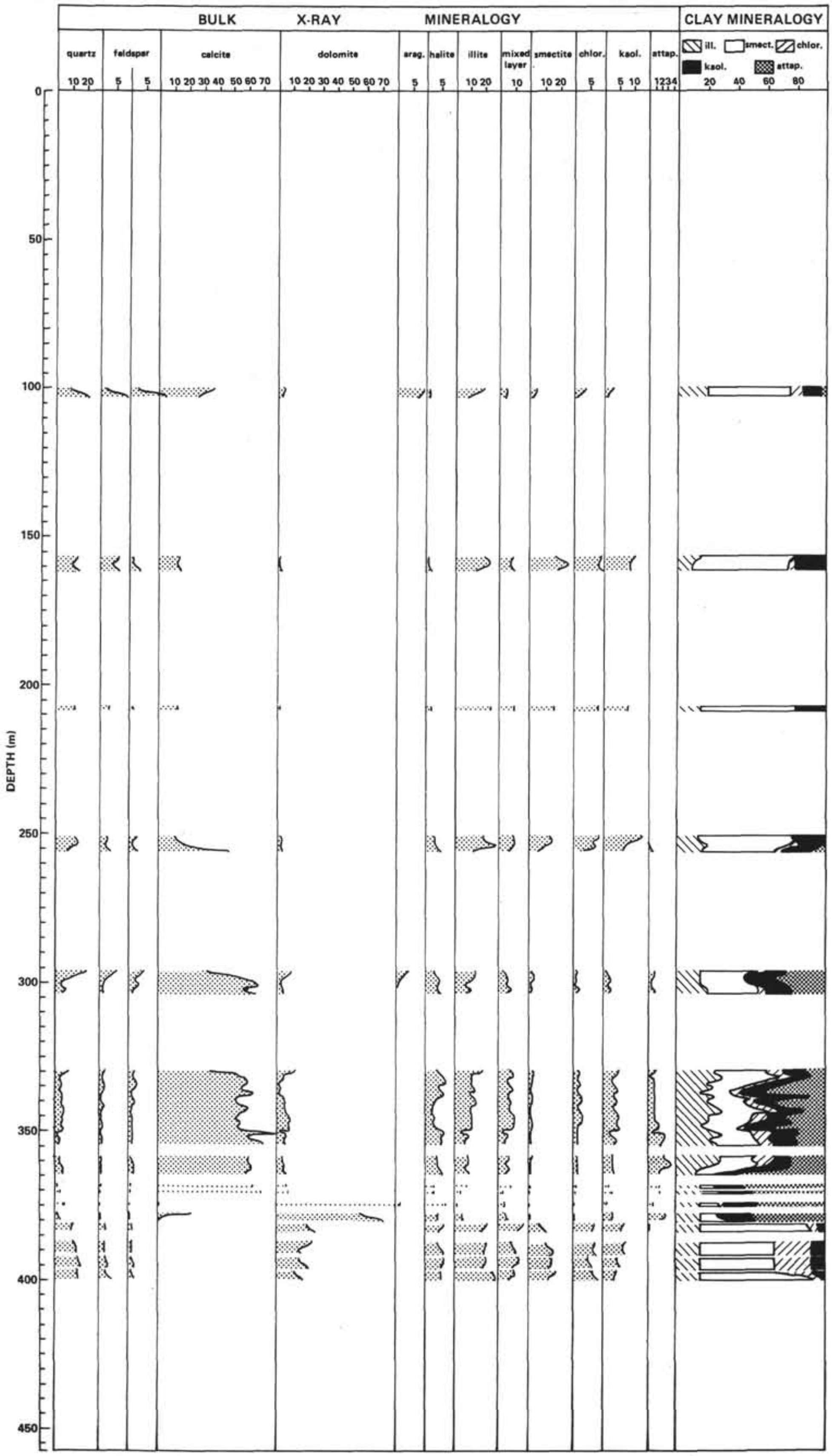
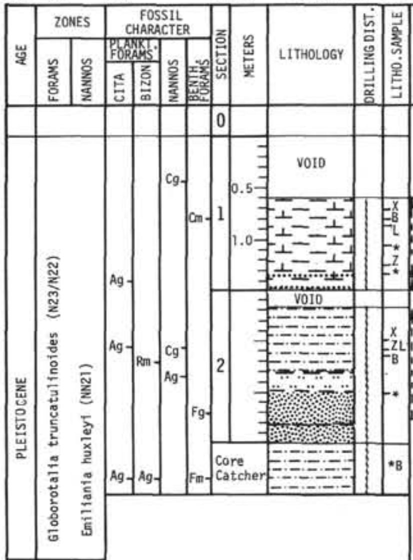

SERIES
STAGE
AGE (m.y.)
GRAPHIC LITHOLOGY
CORE NUMBER
LITHOLOGIC UNITS
CARBONATE (Wt %)
20 40 60 80 100
Depth (m)
0
50
100
150
200
250
300
350
400
450
QUATERNARY
UPPER PLIOCENE
LOWER PLIOCENE
UPPER MIOCENE
MBC
GB/CM
CM
GB/MBC
MESSINIAN
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
I a) Nannofossil marl with graded unit of foraminiferal quartzose sand to silt.
b) Nannofossil marl and mud.
c) Nannofossil marl and ooze.
II Dolomite.
III Evaporites
a) Dolomitic mudstone.
b) Gypsum/ dolomitic mudstone cycles.
c) Anhydrite and salts.
T. D. = 457 meters


BULK X-RAY MINERALOGY
CLAY MINERALOGY
quartz
feldspar
calcite
dolomite
arag.
halite
illite
mixed layer
smectite
chlor.
kaol.
attap.
ill.
smect.
chlor.
kaol.
attap.
DEPTH (m)

Site 374 Hole Core 1 Cored Interval: 100.5-110.0 m



10Y 7/4

5Y 6/4

5GY 4/1

LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARL TO FORAM QUARTZ SAND

Intensely deformed, soft. Soupy pale olive (10Y 7/4) nannofossil marl to dark greenish gray (5GY 4/1) foram quartz sand in graded sub-units. Silty layers in Section 1 have sharp lower contacts and normal grading.

MAJOR LITHOLOGIES

CALCAREOUS NANNOFOSSIL MÁRL
SS 1-115

Nannos	A	Forams	R
Clay	A	Dolomite	R
Quartz	C	Feldspar	R
Carb. unspec.	C	Sponge spicules	R
Volc. glass	C	Heavy mins.	T

X-ray:
1-73 to 75

Illite	19%	Quartz	9%
Mixed layer clay mins.	4% 5%	Aragonite	9%
		Dolomite	5%
Smectite	4%	Plag. feldspar	2%
Chlorite	3%	K-feldspar	3%
Kaolinite	36%	Halite	1%
Calcite	9%		

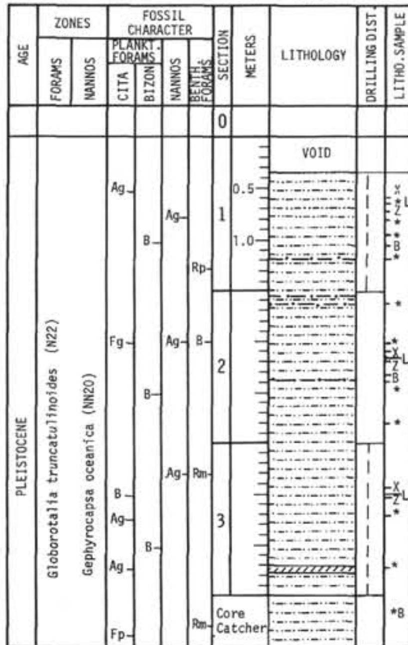
Grain size:
1-128
Sand 7.5%
Silt 52.0%
Clay 40.5%

FORAM QUARTZ SAND
SS 2-100

Quartz	A	Skeletal frags.	C
Forams	C	Nannos	C
Carb. unspec.	C	Heavy mins.	C
Limestone frags.	C	Sponge spicules	R

BOMB:
1-80 to 82 cm = 47% $CaCO_3$
2-65 to 66 cm = 55% $CaCO_3$
CC = 50% $CaCO_3$

Site 374 Hole Core 2 Cored Interval: 157.0-161.5 m



10Y 6/1

5G 6/1

5G 4/1

5G 4/1

5G 4/1

5G 4/1

LITHOLOGIC DESCRIPTION

NANNOFOSSIL MUD WITH SAPROPELS AND SILTY LAYERS

Slightly disturbed to undisturbed. Firm, homogeneous to faintly laminated. Dark greenish gray (5G 4/1) to pale olive (10Y 6/2) nannofossil marl. Olive black (5Y 2/1) sapropelic layers at 1-65, 2-22, 2-51, 2-95 and in core catcher. Sapropel at 3-123 to 127 cm. Silty layers at 1-123, 2-12, 2-17, (laminated) and 2-89.

MAJOR LITHOLOGY

NANNOFOSSIL MUD
SS 1-80

Clay	A	Volc. glass	R
Nannos	C	Pyrite	R
Carb. unspec.	C	Dolomite	T
Quartz	C		

X-ray:
1-60

Illite	19%	Plag. feldspar	6%
Mixed layer	8%	K-feldspar	1%
Smectite	17%	Calcite	14%
Chlorite	9%	Dolomite	1%
Kaolinite	10%	Halite	1%
Quartz	14%		

Grain size:
1-72
Sand 0.0%
Silt 22.3%
Clay 77.7%

MINOR LITHOLOGIES

SAPROPEL
SS 3-124

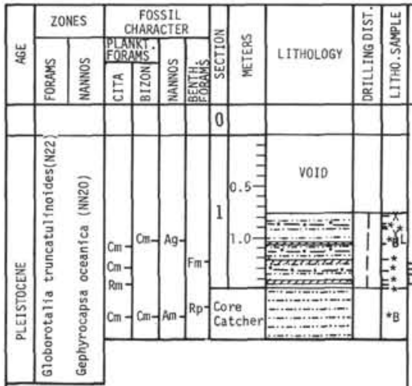
Organic matter	A	Heavy mins.	C
Nannos	C	Quartz	R
Forams	C	Pyrite	R
Carb. unspec.	C		

SILTY NANNOFOSSIL MARL
SS 2-89

Nannos	A	Quartz	C
Carb. unspec.	C	Dolomite	R

BOMB:
1-107 to 108 cm = 12% $CaCO_3$
2-84 to 85 cm = 12% $CaCO_3$
CC = 15% $CaCO_3$

Site 374 Hole Core 3 Cored Interval: 208.0-209.0 m



5G 4/1

LITHOLOGIC DESCRIPTION

NANNOFOSSIL MUD WITH SAPROPELS AND SILTY LAYERS

Slightly disturbed, firm, dark greenish gray (5G 4/1) nannofossil mud. Sapropel layers at 1-103 to 105 cm; 1-121 to 122 plus 1-125 to 129 cm (multiple); 1-140 to 143 cm and sapropelic sediment in Core Catcher. Mottling 1-95 to 100 cm. Silty layers at 85 cm, 119 cm and 133.5 cm.

MAJOR LITHOLOGY

NANNOFOSSIL MUD
SS 1-88

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

X-ray:
1-80

Illite	23%	Plag. feldspar	3%
Smectite	17%	K-feldspar	1%
Mixed layer	10%	Calcite	13%
Chlorite	8%	Dolomite	2%
Kaolinite	8%	Aragonite	T
Quartz	13%	Halite	2%

Grain size:
1-78

Sand	0.2%
Silt	30.8%
Clay	69.0%

MINOR LITHOLOGIES

SAPROPEL
SS 1-122

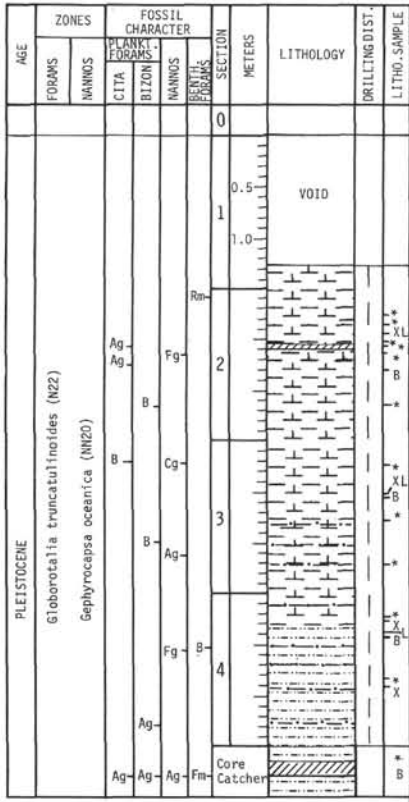
Organic matter	A	Clay	C
Nannos	C	Quartz	C
Forams	C	Dolomite	R
Carb. unspec.	C		

SILTY CARCAREOUS SAND
SS 1-85

Quartz	A	Heavy mins.	R
Carb. unspec.	A	Forams	R
Feldspar	R	Nannos	R
Mica	R	Glauconite	T

BOMB:
1-109 to 110 cm = 10% $CaCO_3$
CC = 19% $CaCO_3$

Site 374 Hole Core 4 Cored Interval: 251.5-256.5 m



5G 4/1

5YR 6/1

5Y 6/4

5GY 6/1

LITHOLOGIC DESCRIPTION

CALCAREOUS NANNOFOSSIL MUD TO MARL WITH SAPROPELS AND SILTY INTERBEDS

Slightly disturbed, firm, dark greenish gray (5G 4/1), dusky yellow (5Y 6/4) and variegated multicolored nannofossil.

Sapropelic layer, a multiple of 2 beds at Section 2, 56 to 60 cm and in core catcher. Sapropelic layer at 2-62 to 64 cm. Silty interbeds, fragment in Sections 3 and 4. One graded (80 cm), most nongraded. All with sharp basal contact and internally laminated. One at 3-118 cm with convolute lamination and some with sharp upper contacts also.

MAJOR LITHOLOGY

NANNOFOSSIL MARL
SS 2-37

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

MINOR LITHOLOGIES

SAPROPEL
SS 2-63, 2-57

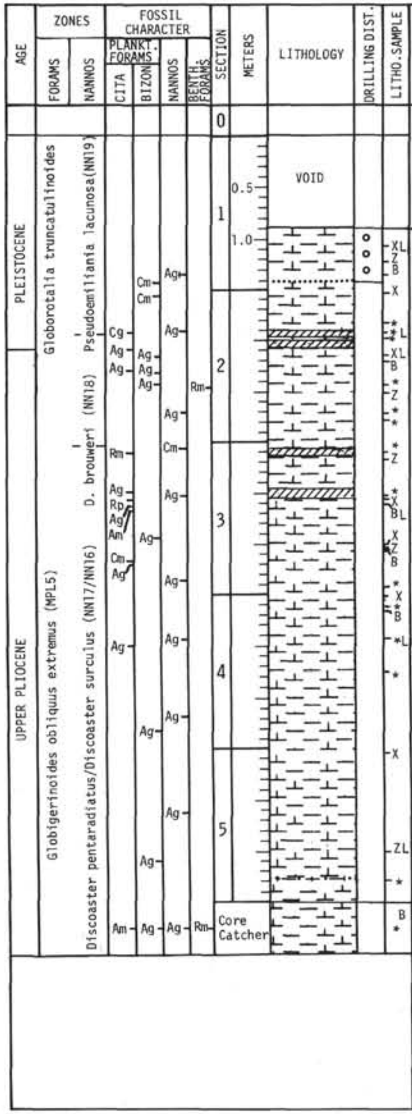
Organic matter	A	Clay	C
Nannos	C	Carb. unspec.	C
Forams	C		

SILTY CALCAREOUS SAND

Carb. unspec.	A	Mica	C
Quartz	A	Feldspar	R
Forams	C	Glauconite	R
Nannos	C	Heavy mins.	T

BOMB:
2-80 to 81 cm = 16% $CaCO_3$
3-55 to 56 cm = 18% $CaCO_3$
4-46 to 47 cm = 33% $CaCO_3$
CC = 31% $CaCO_3$

Site 374 Hole Core 5 Cored Interval: 297.0-304.0 m



LITHOLOGIC DESCRIPTION

5GY 6/1
5Y 6/4
5Y 2/1
5G 4/1
10YR 7/4
5B 7/1
5GY 6/1
10YR 7/4
5G 6/1
10YR 5/4
10YR 7/4 to 5YR 5/6

NANNOFOSSIL MARLS WITH SAPROPELS AND SILTY LAYERS

Undisturbed, firm and stiff, except at top. Greenish gray (5GY 6/1) and light bluish gray (5B 7/1) to multicolored variegated brown and orange (10YR 7/4, 10YR 5/4, 5YR 5/6) nannofossil marls.
Dark sapropelic layers, olive black (5Y 2/1) at 2-33 to 35 cm and 2-121 to 122 cm. Sapropels at 2-38 to 44 cm, 2-48 to 51 cm, 3-10 to 12 cm and 3-49 to 52 cm.
Silty laminae and beds interspersed in finely laminated sediments e.g. 1-140 cm and 5-130 cm. Mottled intervals frequent with *Zoophycos* burrows at 2-130 cm and *Chondrites* at 3-70 to 82 cm and 4-26 to 33 cm.

MAJOR LITHOLOGY

NANNOFOSSIL MARL
SS 2-127

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

X-ray:
4-7

Illite	11%	Calcite	56%
Mixed layer	8%	Quartz	6%
Kaolinite	5%	Dolomite	3%
Smectite	2%	K-feldspar	2%
Chlorite	2%	Plag. feldspar	1%
Attapulgite	1%	Halite	4%

Grain size:
3-19
Sand 4.2%
Silt 76.3%
Clay 19.5%

MINOR LITHOLOGIES

CALCAREOUS SAPROPEL
SS 2-34

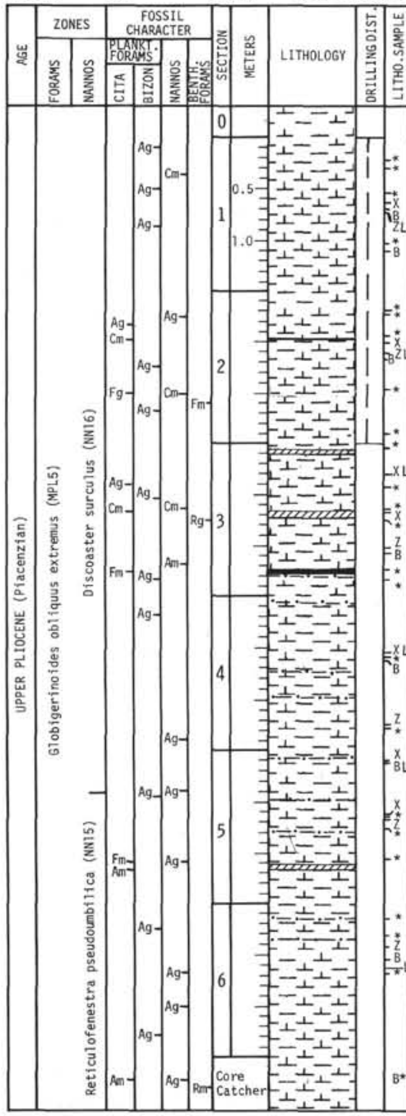
Organic matter	A	Quartz	C
Carb. unspec.	C	Mica	R
Clay	C	Dolomite	R
Nannos	C		

FORAMINIFERAL SILT
SS 1-140

Quartz	A	Dolomite	C
Clay	A	Volc. glass	R
Carb. unspec.	C	Fe-oxides	R
Forams	C	Mica	T
Nannos	C		

BOMB:
1-133 to 134 cm = 56% $CaCO_3$
2-70 to 71 cm = 61% $CaCO_3$
3-60 to 61 cm = 41% $CaCO_3$
3-103 to 104 cm = 66% $CaCO_3$
4-13 to 14 cm = 51% $CaCO_3$
5-12 to 13 cm = 59% $CaCO_3$
CC = 58% $CaCO_3$

Site 374 Hole Core 6 Cored Interval: 330.5-340.0 m



LITHOLOGIC DESCRIPTION

10YR 7/4
5Y 7/2
10YR 7/2
5G 6/1
5GY 6/1
5GY 6/1
5GY 6/1
10YR 7/4
5Y 6/4
10YR 6/4
5GY 6/1
5GY 6/1
5GY 7/2
5Y 6/4

NANNOFOSSIL MARLS WITH SAPROPELS AND SILTY LAYERS

Firm to stiff, slightly deformed to undisturbed but microfaulted by drilling(?), grayish orange (10YR 7/4) to greenish gray (5GY 7/2) nannofossil marls.

Some intervals of increased foram abundance.

Sapropels (5Y 2/1) at 2-42 to 43, 3-7 to 9, 3-66 to 69, 3-124 to 126, and 5-110 to 111 cm. Sapropelic layers at 2-20, 2-97 and 3-50. Silty beds and laminae, most nongraded with sharp basal contacts. Two exceptions, in Sections 4 and 5 are normally graded. Mottling slight to moderate, mostly *Chondrites*. Burrowing.

MAJOR LITHOLOGY

NANNOFOSSIL MARL SS 2-142

Nannos	A	Quartz	R
Clay	A	Volc. glass	R
Forams	R	Dolomite	T
Carb. unspec.	R	Fe-oxides	T

X-ray: 6-32

Illite	11%	Calcite	59%
Mixed layer	8%	Dolomite	1%
Kaolinite	3%	Quartz	4%
Chlorite	2%	K-feldspar	4%
Smectite	1%	Plag. feldspar	2%
Attapulgite	1%	Halite	4%

MINOR LITHOLOGIES

FORAM-NANNOFOSSIL MARL SS 2-25

Nannos	A	Quartz	C
Clay	A	Volc. glass	R
Forams	C	Pyrite	R
Carb. unspec.	C		

SAPROPEL SS 3-66

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

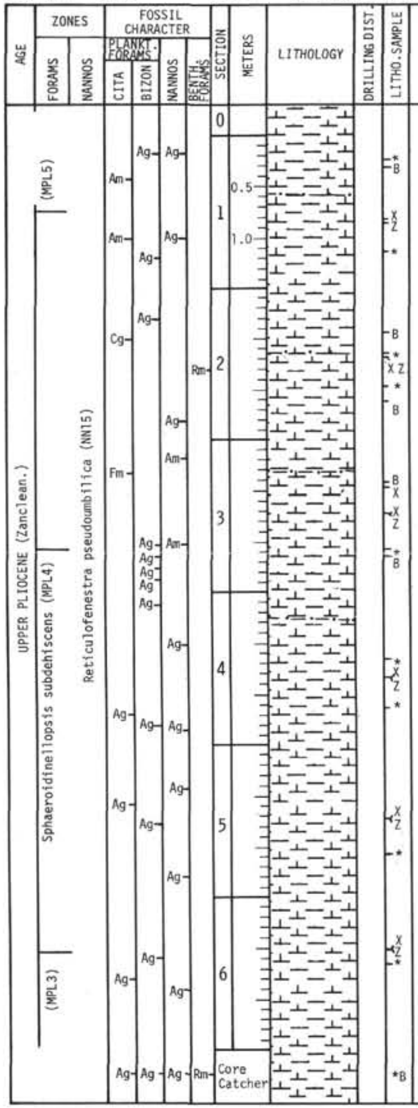
SILTY FORAMINIFERAL SAND SS 5-66

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

BOMB:
0-22 to 23 cm = 48% $CaCO_3$
1-69 to 70 cm = 48% $CaCO_3$
1-110 to 111 cm = 65% $CaCO_3$
2-69 to 70 cm = 54% $CaCO_3$
3-108.5-109.5 cm = 51% $CaCO_3$
4-61 to 62 cm = 54% $CaCO_3$
5-14 to 15 cm = 63% $CaCO_3$
6-54 to 55 cm = 68% $CaCO_3$

48 cm Zero Section - split

Site 374 Hole Core 7 Cored Interval: 340.0-349.5 m



←Gypsum crystals 100 to 108 cm

LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARL AND OOZE WITH SILTY BEDS AND LAMINAE

Firm, multicolored, alternating browns and light grays (5YR 5/6, 10YR 7/4, 10R 4/6 and 5GY 8/1, 5Y 8/2, 5Y 6/1, 5G 8/1) nannofossil marl with ooze layers. Silty, nongraded interbeds, laminated with sharp basalt contacts and laminae, forams abundant. Most color transitions mottled over intervals of 2 to 5 cm. Also thoroughly mottled intervals up to 40 cm thick. Burrowing, mainly Chondrites type with Zoophycos at 4-105 to 122 cm. Layer of gypsum crystals at 3-100 to 108 cm.

MAJOR LITHOLOGY

NANNOFOSSIL MARL SS 5-109

Nannos	A	Quartz	R
Clay	A	Fe-oxides	R
Carb. unspec.	C	Forams	R

X-ray: 5-71

Illite	11%	Calcite	54%
Mixed layer	9%	Dolomite	7%
Kaolinite	4%	Quartz	5%
Smectite	2%	Plag. feldspar	1%
Chlorite	2%	K-feldspar	1%
Attapulgite	1%	Halite	2%

Grain size: 5-71

Sand	3.1%
Silt	38.8%
Clay	58.1%

MINOR LITHOLOGIES

NANNOFOSSIL OOZE

X-ray: 2-45

Illite	3%	Calcite	78%
Mixed layer	3%	Dolomite	2%
Kaolinite	1%	Quartz	2%
Chlorite	1%	Plag. feldspar	1%
Attapulgite	1%	K-feldspar	1%

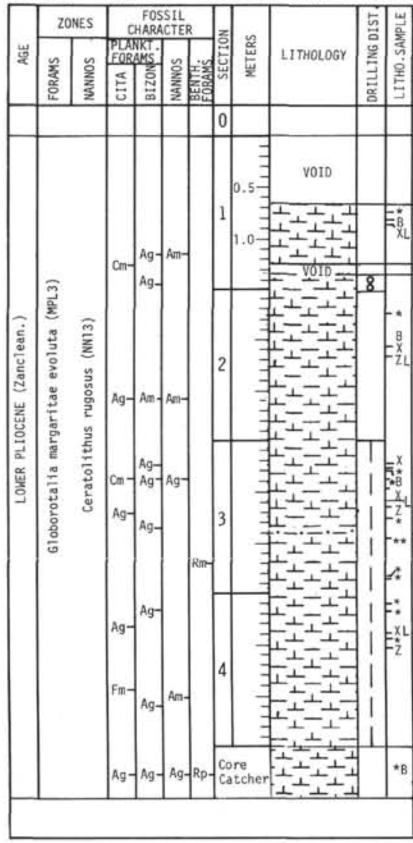
FORAMINIFERAL SAND SS 2-63

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

BOMB:
1-30 to 31 cm = 50% $CaCO_3$
2-114 to 115 cm = 58% $CaCO_3$
3-43 to 44 cm = 73% $CaCO_3$
3-112 to 113 cm = 48% $CaCO_3$
4-116 to 117 cm = 58% $CaCO_3$
CC = 54% $CaCO_3$

40 cm Zero Section - not described

Site 374 Hole Core 8 Cored Interval: 349.5-359.0 m



←Gypsum fragment

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE TO MARL

Stiff, moderately to slightly disturbed gray (5Y 8/1, 10YR 6/2, 5G 8/1, 5G 6/1, 5B 5/1, 10YR 5/4) to brown (10YR 5/4, 5YR 6/4, 10YR 6/2, 5YR 5/6) nannofossil ooze to marl with foram-rich intervals. Dark organic-rich interval at 3-36 to 39 cm. A silty layer at 3-91 cm and a gypsum fragment at 4-43 cm. Mottling almost throughout, minor intervals of (color banding?) lamination e.g. 3-97 to 110 cm. Zoophycos and Chondrites burrow traces. Microfaulting (by drilling) in Section 3.

MAJOR LITHOLOGY

NANNOFOSSIL MARL
SS 3-77

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

X-ray:
3-23

Illite	8%	Calcite	55%
Mixed layer	6%	Dolomite	6%
Chlorite	1%	Quartz	6%
Kaolinite	5%	Plag. feldspar	1%
Attapulgite	3%	K-feldspar	1%
Smectite	1%	Halite	6%

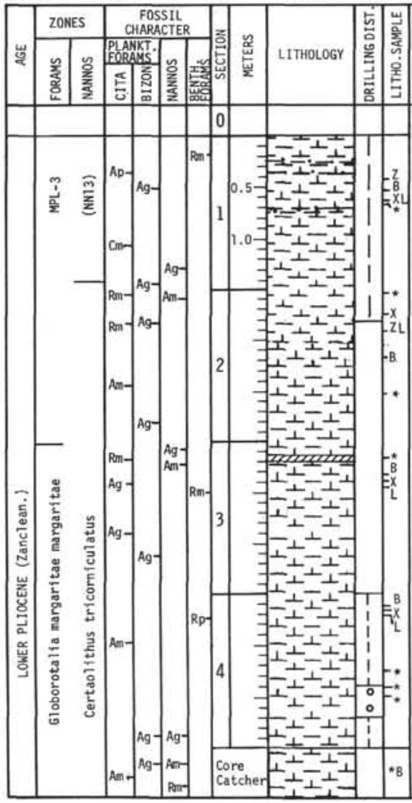
MINOR LITHOLOGY

ORGANIC-RICH NANNOFOSSIL MARL
SS 3-39

Nannos	A	Forams	C
Clay	A	Quartz	R
Organic matter	C	Volc. glass	R
Carb. unspec.	C		

BOMB:
1-81 to 82 cm = 75% $CaCO_3$
2-56 to 57 cm = 68% $CaCO_3$
3-26 to 37 cm = 47% $CaCO_3$
CC = 75% $CaCO_3$

Site 374 Hole Core 9 Cored Interval: 359.0-368.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARL WITH OOZE AND SAPROPELIC LAYERS AND SILTY LAMINAE

Slightly disturbed to undisturbed. Light gray (5GY 8/1, 5G 6/1, 5B 7/1) to brown (5YR 5/6, 10YR 7/4) nannofossil ooze with olive black (5Y 2/1) sapropelic layers at 1-150 to 2-7 and sapropel at 3-14 to 16 cm. Silty laminae in Section one. Mottled throughout. Zoophycos burrow traces at 3-72 cm. Gypsum layer at 4-90 cm. Sediments firm and brecciated. Microfaulted or veined (drilling artifacts?).

MAJOR LITHOLOGY

NANNOFOSSIL MARL
SS 1-66

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

X-ray:
1-60

Illite	9%	Halite	4%
Mixed layer	7%	Dolomite	4%
Kaolinite	3%	Calcite	60%
Attapulgite	3%	Quartz	4%
Smectite	3%	Plag. feldspar	1%
Chlorite	1%	K-feldspar	1%

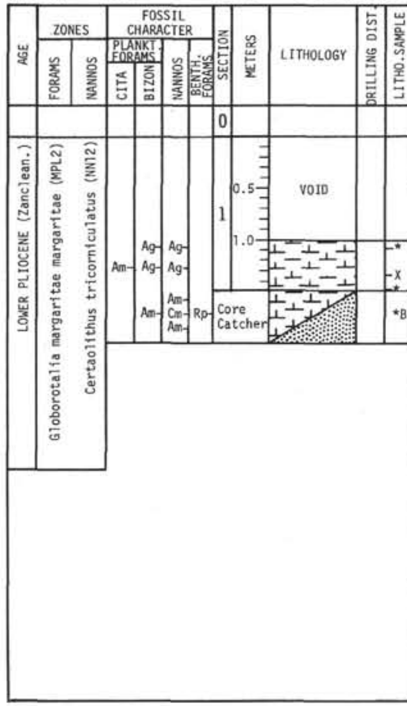
MINOR LITHOLOGY

SAPROPELIC MARL
SS 2-3

Nannos	A	Carb. unspec.	C
Clay	A	Quartz	R
Organic matter	C	Plant debris	R

BOMB:
1-57 to 58 cm = 65% $CaCO_3$
2-69 to 70 cm = 71% $CaCO_3$
3-37 to 38 cm = 61% $CaCO_3$
4-13 to 14 cm = 67% $CaCO_3$
CC = 63% $CaCO_3$

Site 374 Hole Core 10 Cored Interval: 368.5-378.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARL TO OOZE

Firm, stiff, light brown (5YR 6/4) to grayish orange (10YR 7/4) nannofossil marl to ooze. Intensely mottled to homogeneous Core Catcher is a drilling breccia of nannofossil ooze with injected gypsum fragments, calcareous mud, gypsum sand and sapropelic sediment traces.

MAJOR LITHOLOGY

NANNOFOSSIL MARL
SS 1-109

Nannos	A	Quartz	R
Clay	A	Forams	R
Carb. unspec.	C	Fe-oxides	T

X-ray:
1-109

Illite	8%	Halite	3%
Mixed layer	8%	Calcite	59%
Attapulgite	2%	Dolomite	7%
Kaolinite	2%	Quartz	2%
Smectite	1%	Plag. feldspar	1%
Chlorite	1%	K-feldspar	1%

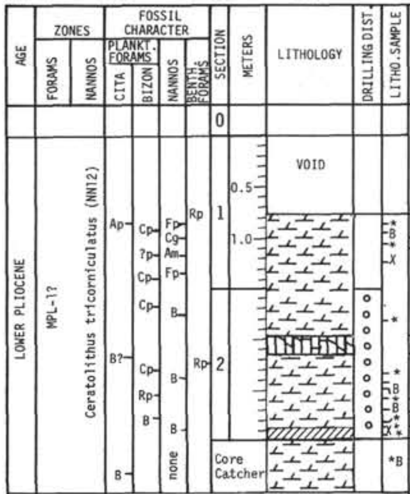
MINOR LITHOLOGY

NANNOFOSSIL BEARING GYPSUM SAND
CC

Gypsum	D	Forams	R
Nannos	C	Anhydrite	R
Carb. unspec.	C		

BOMB:
CC = 76% $CaCO_3$

Site 374 Hole Core 11 Cored Interval: 378.0-381.5 m



LITHOLOGIC DESCRIPTION

DOLOMITE WITH SAPROPELIC LAYERS

Indurated, broken by drilling, micro-faulted (drilling artifact?), light olive gray (5Y 6/1), dark greenish gray (5G 6/1) and medium bluish gray (5B 5/1), dolomite, with gypsiferous and sapropelic layers. Broken, laminated gypsum layer at 2-48 to 64 cm. Sapropelic layers at 1-91 to 93, 1-100 to 101, 1-110 to 111, 2-57 to 61, 2-112 to 121, and 2-137 to 150 cm and in Core Catcher. Associated Zoophycos and Chondrites burrow traces. Generally sediments moderately to intensely mottled.

MAJOR LITHOLOGY

DOLOMITIC LIMESTONE
SS 2-30

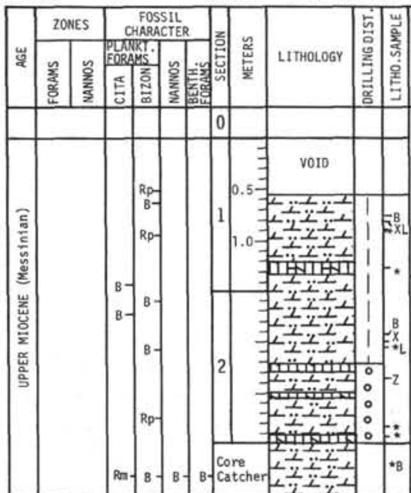
Dolomite	A	Clay	C
Gypsum	C	Mica	T

X-ray:
1-124

Illite	5%	Dolomite	55%
Mixed layer	5%	Calcite	21%
Attapulgite	3%	Quartz	3%
Kaolinite	3%	Halite	4%
Smectite	1%		

BOMB:
1-93 to 94 cm = 80% total carbonate
2-91 to 92 cm = 68% total carbonate
2-112 to 113 cm = 78.6% total carbonate
CC = 65% total carbonate

Site 374 Hole Core 12 Cored Interval: 381.5-387.5 m



LITHOLOGIC DESCRIPTION

DOLOMITIC MUDSTONE WITH GYPSUM LAYERS

Slightly deformed to broken, mottled and indurated dark greenish gray dolomitic mudstone with gypsum layers and nodules.

MAJOR LITHOLOGY

DOLOMITIC MUDSTONE
SS 1-90

Clay	A	Anhydrite	R
Dolomite	C	Pyrite	R
Gypsum	R		

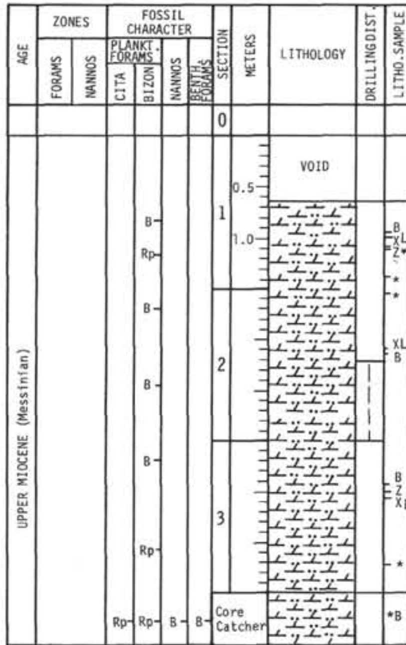
X-ray:
1-80

Illite	22%	Quartz	13%
Smectite	6%	Plag. feldspar	2%
Mixed layer	16%	K-feldspar	1%
Chlorite	7%	Halite	6%
Kaolinite	7%		
Dolomite	20%		

Grain size:
2-88
Sand 0.1%
Silt 91.4%
Clay 8.5%

BOMB:
1-78 to 79 cm = 15% total carbonate
2-48 to 49 cm = 21% total carbonate
CC = 18% total carbonate

Site 374 Hole Core 13 Cored Interval: 387.5-392.5 m



LITHOLOGIC DESCRIPTION

→Pyrite nodule

GYPSIFEROUS DOLOMITIC MUDSTONE

Slightly disturbed to undisturbed, homogeneous and laminated, dark greenish gray (5G 4/1) gypsiferous, organic-rich, dolomitic mud. Pyrite nodule at 1-135 cm Mg-phosphate balls in Section 3.

MAJOR LITHOLOGY

GYPSIFEROUS DOLOMITIC MUDSTONE
SS 3-121

Clay	A	Quartz	C
Dolomite	C	Volc. glass	T
Gypsum	C	Plant debris	T

X-ray:
3-56

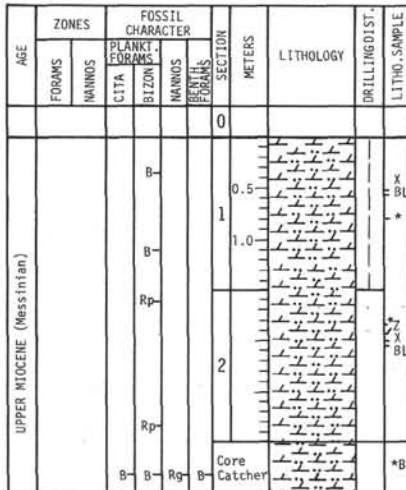
Illite	20%	Quartz	14%
Smectite	14%	Plag. feldspar	2%
Mixed layer	11%	K-feldspar	1%
Chlorite	8%	Halite	6%
Kaolinite	7%		
Dolomite	17%		

Grain size:
3-50
Sand 0.0%
Silt 91.5%
Clay 8.5%

LECO: 3-53 cm
Total Carb. 2.9%
Organic Carb. 0.4%
$CaCO_3$ 21%

BOMB:
1-95 to 96 cm = 18% total carbonate
2-64 to 65 cm = 21% total carbonate
3-48 to 49 cm = 21% total carbonate
CC = 21% total carbonate

Site 374 Hole Core 14 Cored Interval: 392.5-397.0 m



LITHOLOGIC DESCRIPTION

DOLOMITIC MUDSTONE

Slightly deformed to undisturbed, homogeneous, dark greenish gray organic-rich, (5G 4/1) dolomitic mudstone, speckled with spherical white Mg-phosphate balls. Bituminous odor on cutting.

MAJOR LITHOLOGY

DOLOMITIC MUDSTONE
SS 1-80

Clay	A	Quartz	C
Dolomite	C	Pyrite	R
Gypsum	R	Volc. glass	T

X-ray:
1-50

Illite	21%	Quartz	16%
Smectite	16%	Plag. feldspar	2%
Mixed layer	14%	K-feldspar	1%
Chlorite	5%	Halite	6%
Kaolinite	4%		
Dolomite	15%		

BOMB:
1-57 to 58 cm = 18% total carbonate
2-57 to 58 cm = 18% total carbonate
CC = 27% total carbonate

Site 374 Hole Core 15 Cored Interval: 397.0-406.5 m

AGE | ZONES: FORAMS, NANNOS | FOSSIL CHARACTER: PLANKT. FORAMS (CITA, BIZON), NANNOS, BENTH. FORAMS | SECTION | METERS | LITHOLOGY | DRILLING DIST. | LITHO. SAMPLE | LITHOLOGIC DESCRIPTION

UPPER MIOCENE (Messinian)

Section 0; Section 1 (0.5, 1.0); Section 2; Core Catcher

Fossil character: Rp, B, B; Core Catcher: B B B B

Litho. sample: X * L B; X * L B; * B

DOLOMITIC MUDSTONE

Slightly deformed, homogeneous, organic-rich, dark greenish gray (5G 4/1) dolomitic mudstone, speckled with spherical white Mg-phosphate balls. Bituminous odor on cutting. A crystalline gypsum layer at 1-55 cm. Calcite content appears to increase towards base.

MAJOR LITHOLOGY

DOLOMITIC MUDSTONE
SS 2-50

Clay	A	Feldspar	R
Dolomite	C	Mica	T
Quartz	C	Volc. glass	T
Pyrite	R		

X-ray:
2-50

Illite	27%	Dolomite	16%
Smectite	12%	Quartz	16%
Chlorite	8%	Plag. feldspar	5%
Mixed layer	6%	K-feldspar	2%
Kaolinite	3%		

BOMB:
1-69 to 70 cm = 17% total carbonate
2-69 to 70 cm = 32% total carbonate
CC = 56% total carbonate

Site 374 Hole Core 16 Cored Interval: 406.5-411.0 m

AGE | ZONES: FORAMS, NANNOS | FOSSIL CHARACTER: PLANKT. FORAMS (CITA, BIZON), NANNOS, BENTH. FORAMS | SECTION | METERS | LITHOLOGY | DRILLING DIST. | LITHO. SAMPLE | LITHOLOGIC DESCRIPTION

UPPER MIOCENE (Messinian)

Section 0; Section 1 (0.5, 1.0), VOID; Core Catcher

Litho. sample: * * *

GYPSUM

Coarsely crystalline gray to white gypsum. Organic-rich where dark colored. Generally crenulated but displaying complex diagenetic fabrics.

Site 374 Hole Core 17 Cored Interval: 411.0-416.0 m

AGE | ZONES: FORAMS, NANNOS | FOSSIL CHARACTER: PLANKT. FORAMS (CITA, BIZON), NANNOS, BENTH. FORAMS | SECTION | METERS | LITHOLOGY | DRILLING DIST. | LITHO. SAMPLE | LITHOLOGIC DESCRIPTION

UPPER MIOCENE (Messinian)

Section 0; Section 1 (VOID, 0.5, 1.0); Core Catcher

Litho. sample: * * B * B *

DOLOMITIC MUDSTONE OVERLAYING GYPSUM

21-33 cm: Black very coarsely crystalline. Gypsum.
33-67 cm: Olive gray to black dolomitic mudstone, laminated. Laminae in places show low amplitude crenulations (stromatolitic?); others are deformed by secondary gypsum crystal growth.
67-84 cm: Dolomitic mudstone is organic-rich, diatomaceous and faintly laminated.
84-97 cm: Breccia of mudstone pieces.
128-150 cm: Coarsely crystalline white gypsum with thin irregular layers of dark yellowish brown mudstone; alternations on a cm to mm scale.

Gypsum veining at 45.0 to 47.5 m.

MINOR LITHOLOGY

DIATOMACEOUS ORGANIC-RICH MUDSTONE
SS 1-69

Diatoms	A	Plant spores	R
Organic matter	A	Dolomite	R
Clay	C	Pyrite	R
Gypsum and anhydrite(?)	C		

BOMB:
1-67 to 68 cm = 36.5% total carbonate
1-97 to 98 cm = 0.0% total carbonate

Site 374 Hole Core 18 Cored Interval: 416.0-418.0 m

AGE | ZONES: FORAMS, NANNOS | FOSSIL CHARACTER: PLANKT. FORAMS (CITA, BIZON), NANNOS, BENTH. FORAMS | SECTION | METERS | LITHOLOGY | DRILLING DIST. | LITHO. SAMPLE | LITHOLOGIC DESCRIPTION

UPPER MIOCENE (Messinian)

Section 0; Section 1 (0.5, VOID, 1.0); Core Catcher

Litho. sample: * * *

GYPSUM OVERLAYING DOLOMITIC MUDSTONE

105-131 cm: Banded white gypsum and anhydrite with thin interlayers of brown dolomitic mudstone which are crenulated.
131-137.5 cm: Evenly laminated alternations of white and brown to black gypsum only very slight disturbance of the laminae.
137.5-150 cm: As above but laminae highly deformed and brecciated with extensive recrystallization.

Site 374 Hole Core 19 Cored Interval: 418.0-420.0 m

AGE	ZONES: FORAMS	ZONES: NANNOS	FOSSIL CHARACTER: PLANKT. FORAMS: CITA	BIZON	NANNOS	BENTH. FORAMS	SECTION	METERS	LITHOLOGY	DRILLING DIST.	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
UPPER MIOCENE (Messinian)					Rp		0, 1, Core Catcher	0.5, 1.0	VOID		* B * * * *	see below

DOLOMITIC MUDSTONE OVERLAYING GYPSUM

20-73 cm: Soft dolomitic mudstone with large (neomorphic) gypsum crystals and elongate nodules. Brecciated.
73-88 cm: Coarsely crystalline gypsum with a few irregular patches (relics?) of dolomitic mudstone.
88-134.5 cm: Evenly laminated white and brown gypsum and anhydrite.
134.5-150 cm: Laminated dolomitic mudstones, deformed, brecciated and recemented by (neomorphic) coarse-grained gypsum.

MAJOR LITHOLOGY

DOLOMITIC MUDSTONE
SS 1-46

Dolomite	A	Pyrite	R
Clay	A	Anhydrite	R
Gypsum	C	Plant debris	R
Organic matter	C		

BOMB:
1-52 to 53 cm = 25% total carbonate

Site 374 Hole Core 20 Cored Interval: 420.0-425.5 m

AGE	ZONES: FORAMS	ZONES: NANNOS	FOSSIL CHARACTER: PLANKT. FORAMS: CITA	BIZON	NANNOS	BENTH. FORAMS	SECTION	METERS	LITHOLOGY	DRILLING DIST.	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
UPPER MIOCENE (Messinian)							0, 1, Core Catcher	0.5, 1.0	VOID		* B * *	see below

DOLOMITIC MUDSTONE OVERLAYING GYPSUM

20-23 cm: Laminated dolomitic mudstone, highly deformed and brecciated, with large gypsum nodules.
23-61 cm: Interlayered coarse gypsum and thin irregular, crenulated dolomitic mudstone laminae. Gypsum becomes increasingly recrystallized downwards. Mudstone very organic-rich at top.
61-150 cm: Laminated gypsum with thin mudstone laminae. Modified by crystal growth.

BOMB:
1-24 to 25 cm = 10% total carbonate

Site 374 Hole Core 21 Cored Interval: 425.5-435.0 m

AGE	ZONES: FORAMS	ZONES: NANNOS	FOSSIL CHARACTER: PLANKT. FORAMS: CITA	BIZON	NANNOS	BENTH. FORAMS	SECTION	METERS	LITHOLOGY	DRILLING DIST.	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
UPPER MIOCENE (Messinian)							0, 1, Core Catcher	0.5, 1.0	VOID		* * *	see below

ANHYDRITE

99.5-113 cm: Light olive gray anhydrite with laminae of dolomitic mudstone.
113-116 cm: Soft mudstone with gypsum nodules.
116 to 135 cm: Anhydrite, vuggy, strongly corroded to thinly laminated with vugs filled with salt.
135-143 cm: Banded brown to gray anhydrite.
143-150 cm: White anhydrite with vugs filled by clear salt.

Site 374 Hole Core 22 Cored Interval: 435.0-444.5 m

AGE	ZONES: FORAMS	ZONES: NANNOS	FOSSIL CHARACTER: PLANKT. FORAMS: CITA	BIZON	NANNOS	BENTH. FORAMS	SECTION	METERS	LITHOLOGY	DRILLING DIST.	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
UPPER MIOCENE (Messinian)							0, 1, 2, 3, Core Catcher	0.5, 1.0	VOID	o o o o	* * * * * * * *	see below

ANHYDRITE UNDERLAIN BY HALITE

White anhydrite with irregular crenulated seams of greenish gray anhydrite. Irregular vugs filled with clear salt.

Overlies crystalline, translucent, colorless to dark gray halite with thin interbeds of clay-size gypsum. Interbeds accentuated due to solution of the salt during drilling.

Site 374, Core 23, 444.5-454.0 m: NO RECOVERY
Site 374, Core 24, 454.0-457.0 m: NO RECOVERY

Site 374 Hole Core 25 Cored Interval: 375m (Sidewall Core)

AGE	ZONES: FORAMS	ZONES: NANNOS	FOSSIL CHARACTER: PLANKT. FORAMS: CITA	BIZON	BENTH. FORAMS	SECTION	METERS	LITHOLOGY	DRILLING DIST.	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LOWER PLIOCENE?			B, B, Rg	B		0, Core Catcher			| |	** **	see below

42 cm long sidewall core

DOLOMITIC MUD WITH PIECES OF UNIDENTIFIED GYPSUM-LIKE MINERAL

Sediment organic-rich at 35 cm.

X-ray:

Dolomite	84%	Attapulgite	1%
Mixed layer clay mins.	4%	Smectite	T
Illite	1%	Halite	7%
Kaolinite	1%	Quartz	1%

Site 374 Hole Core 26 Cored Interval: 370.5-371.0 m (Sidewall core)

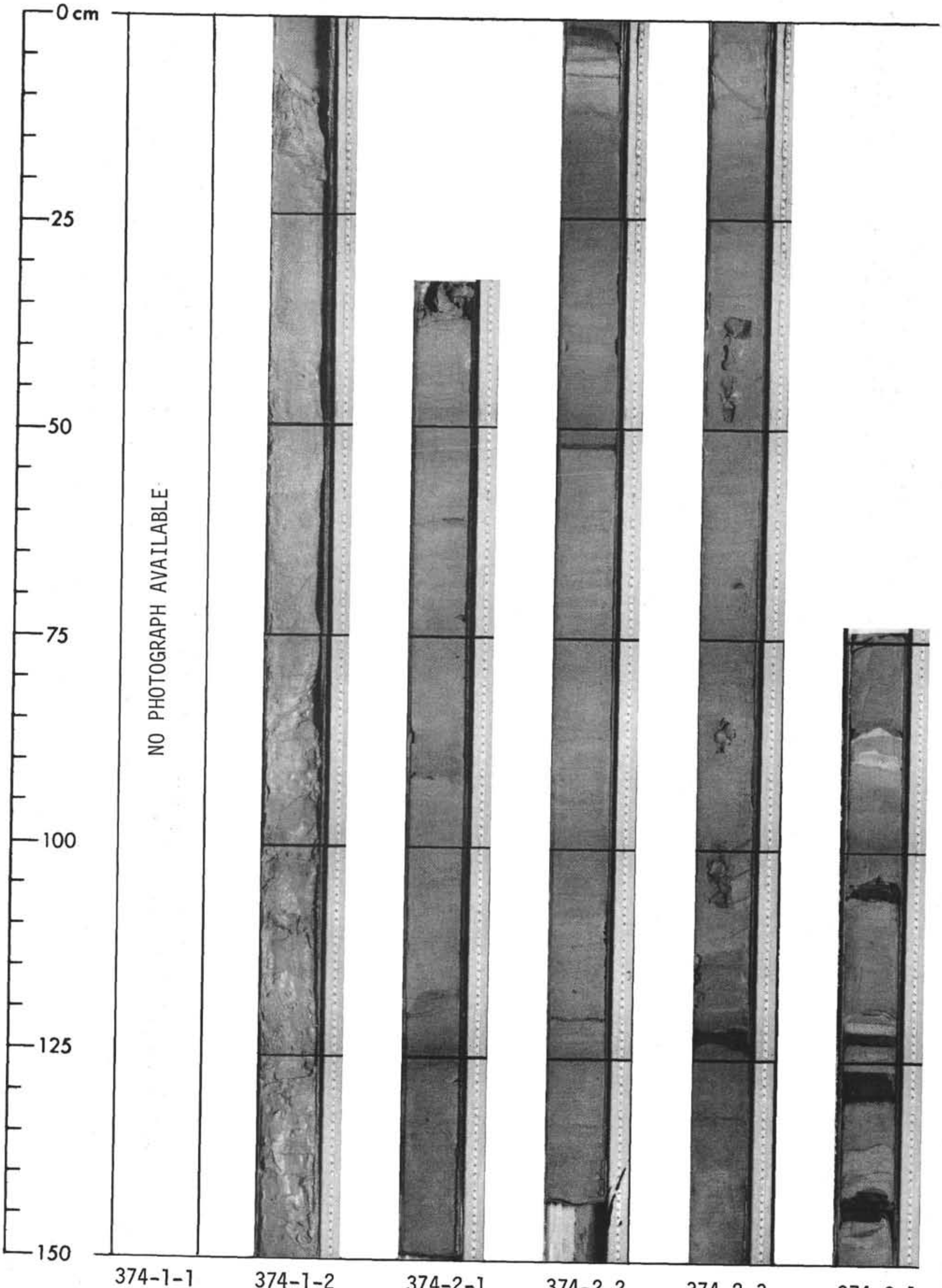
AGE	ZONES: FORAMS	ZONES: NANNOS	FOSSIL CHARACTER: PLANKT. FORAMS: CITA	BIZON	NANNOS	BENTH. FORAMS	SECTION	METERS	LITHOLOGY	DRILLING DIST.	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
UPPER MIOCENE / LOWER PLIOCENE (MPL2)			Cm, Cm, Am, B	B			0, Core Catcher			o o	* **	see below

30 cm long sidewall core

NANNOFOSSIL OOZE WITH INTERMIXED PIECES OF GYPSUM AND UNIDENTIFIED MINERAL

X-ray:

Illite	4%	Dolomite	7%
Kaolinite	3%	Quartz	4%
Mixed layer	3%	K-feldspar	1%
Attapulgite	2%	Halite	3%
Chlorite	1%	Unidentified	6%
Calcite	70%		


0 cm
25
50
75
100
125
150
NO PHOTOGRAPH AVAILABLE
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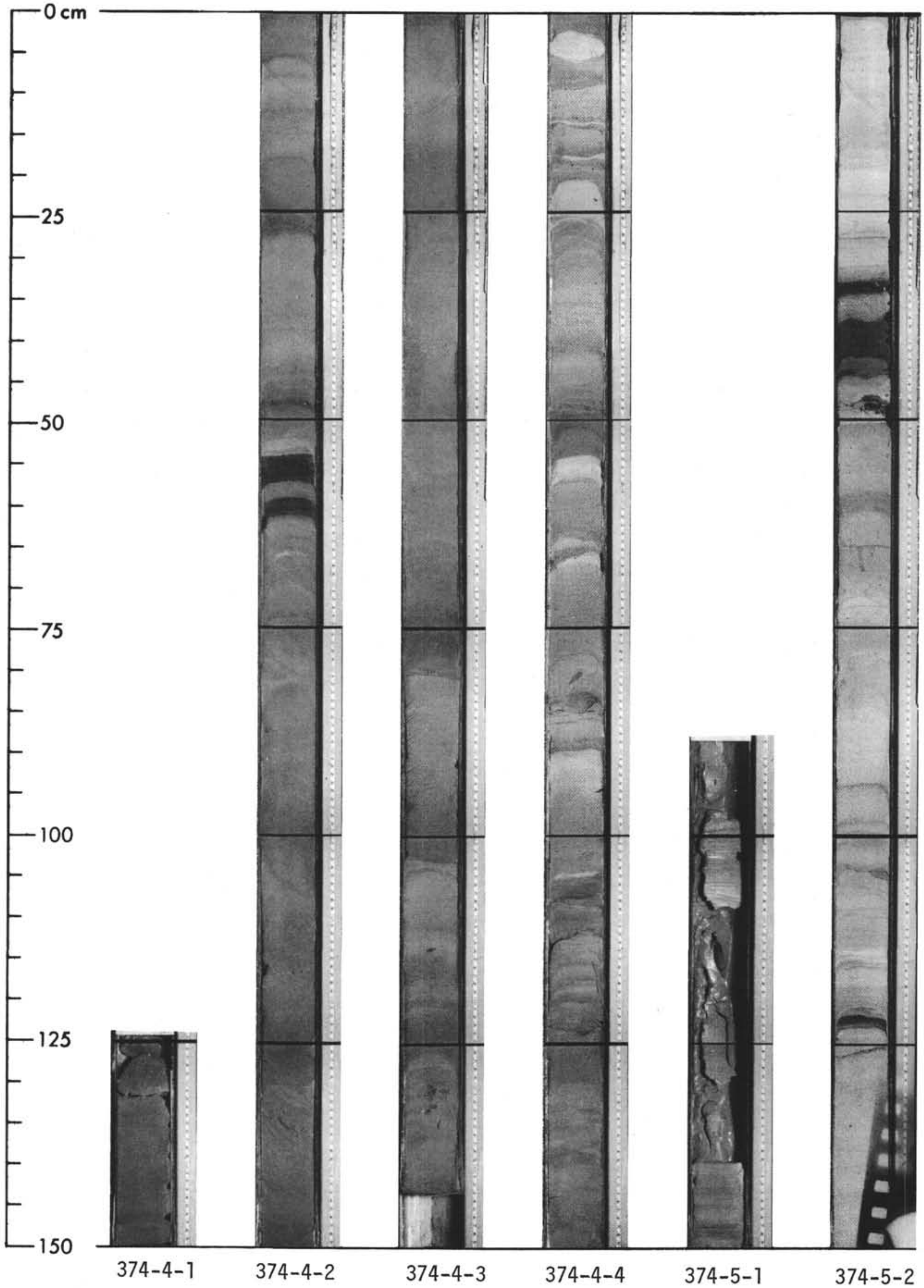
374-1-2
374-2-1
374-2-2
374-2-3
374-3-1


0 cm
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75
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125
150
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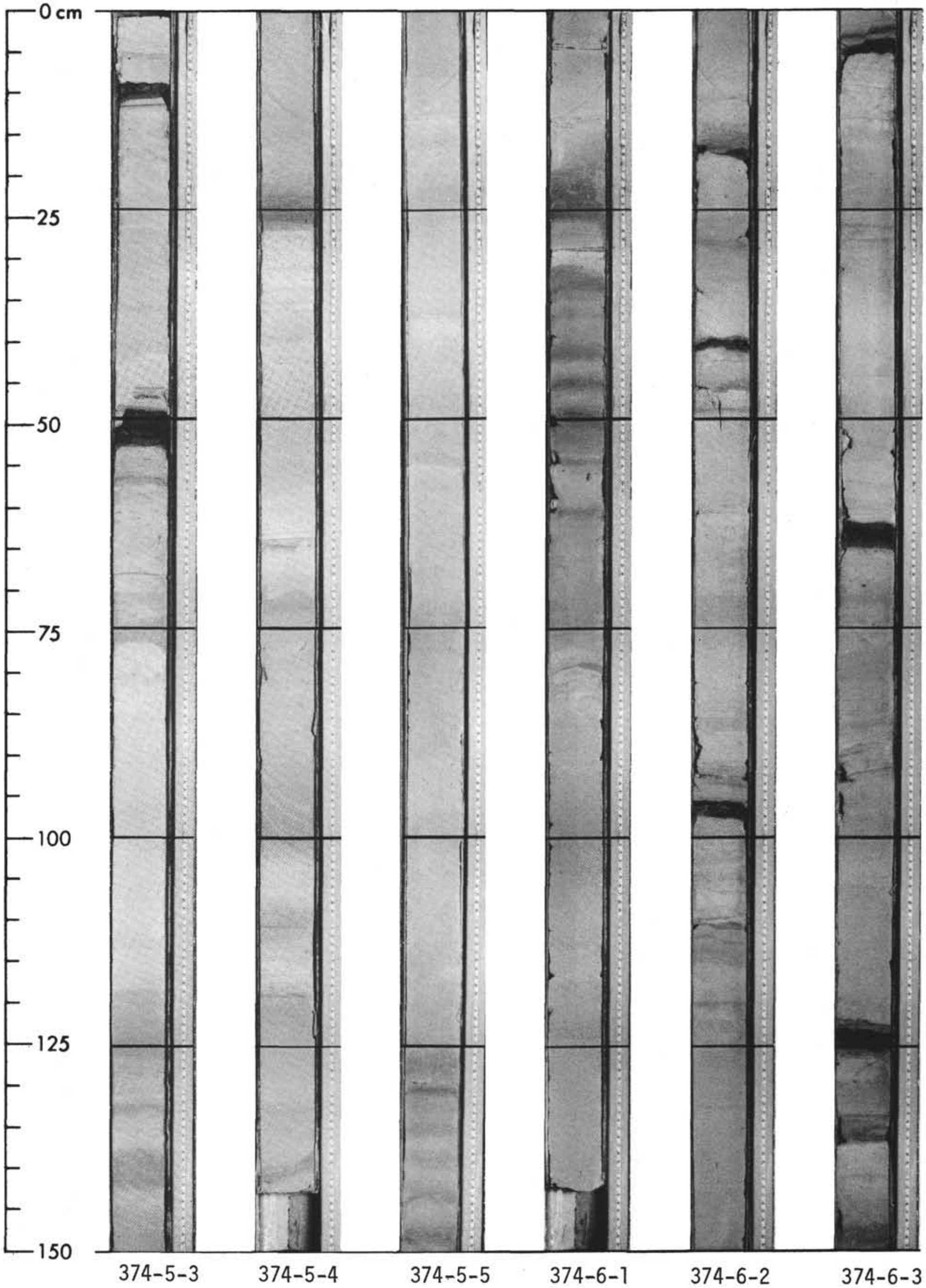
374-4-2
374-4-3
374-4-4
374-5-1
374-5-2


0 cm
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75
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125
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374-6-1
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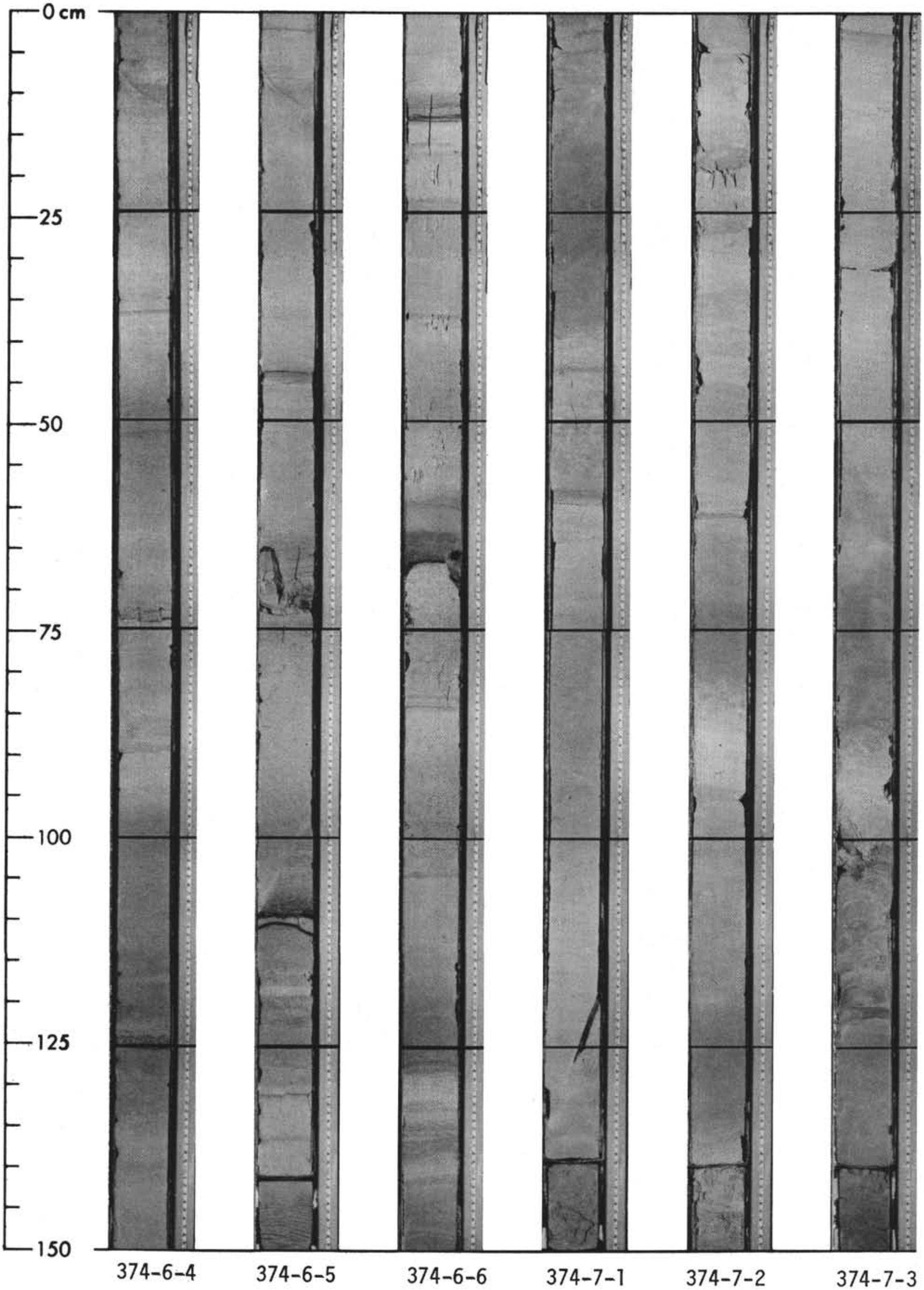
374-6-3


0 cm
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374-7-1
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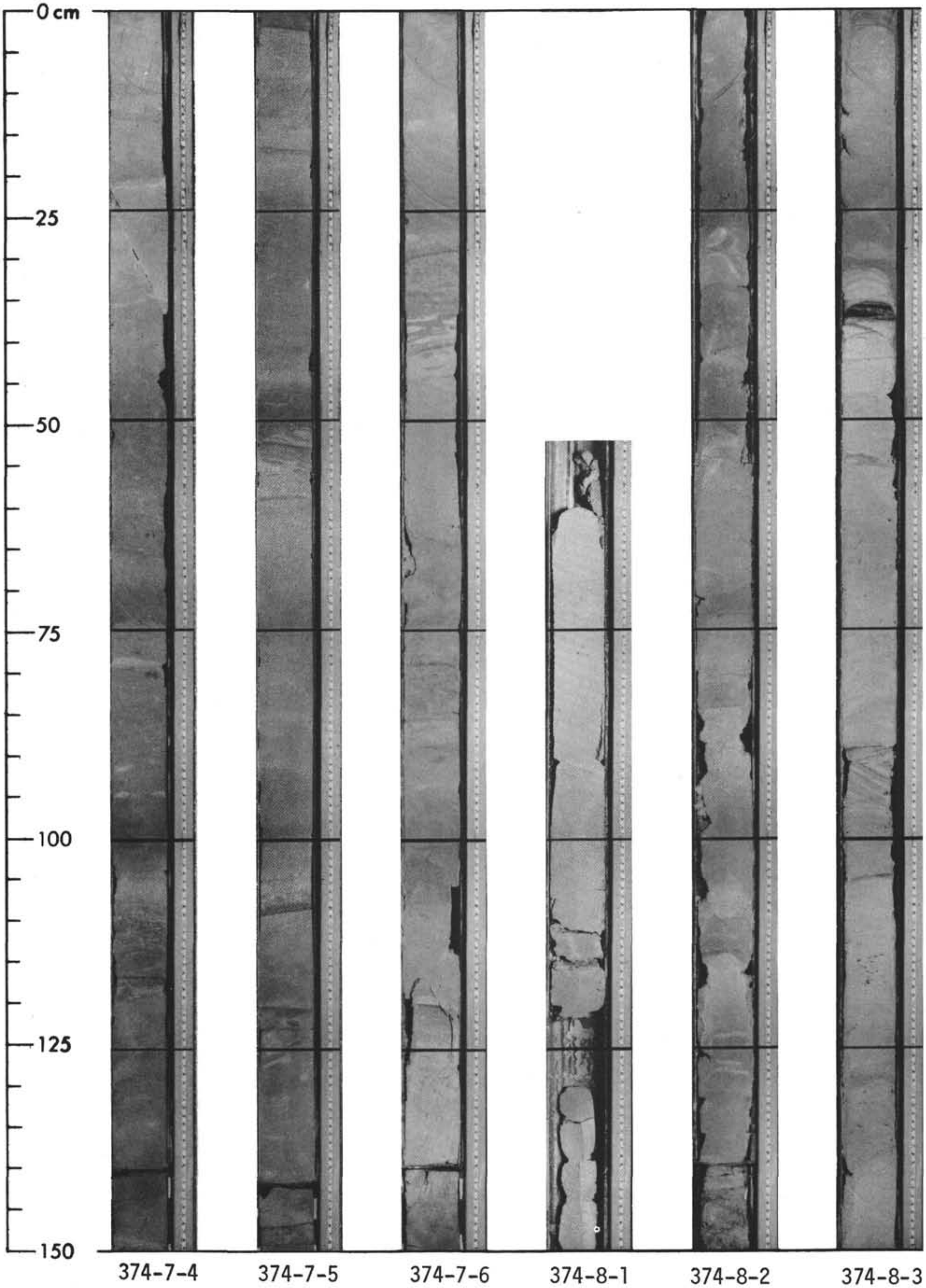
374-7-3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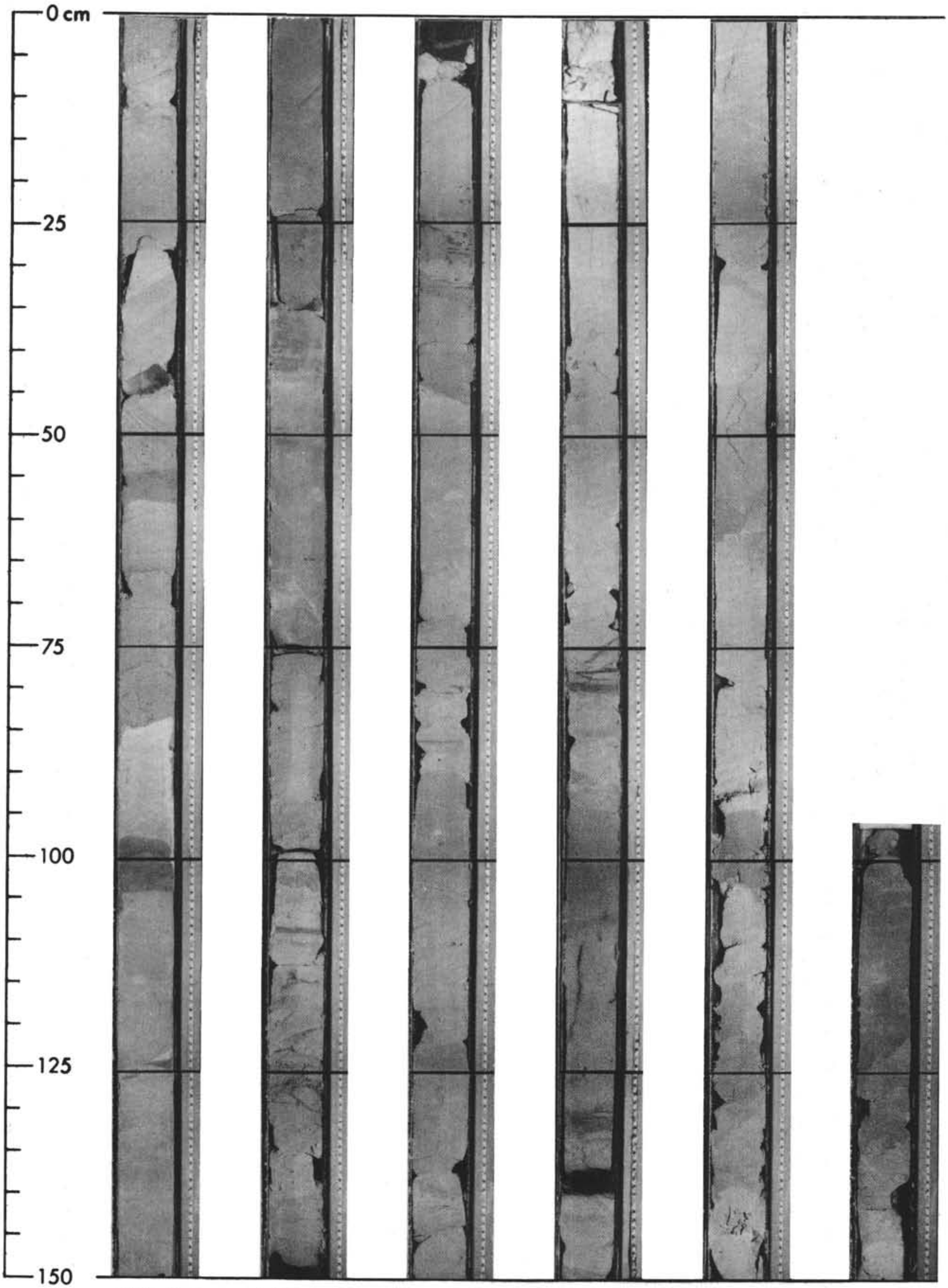
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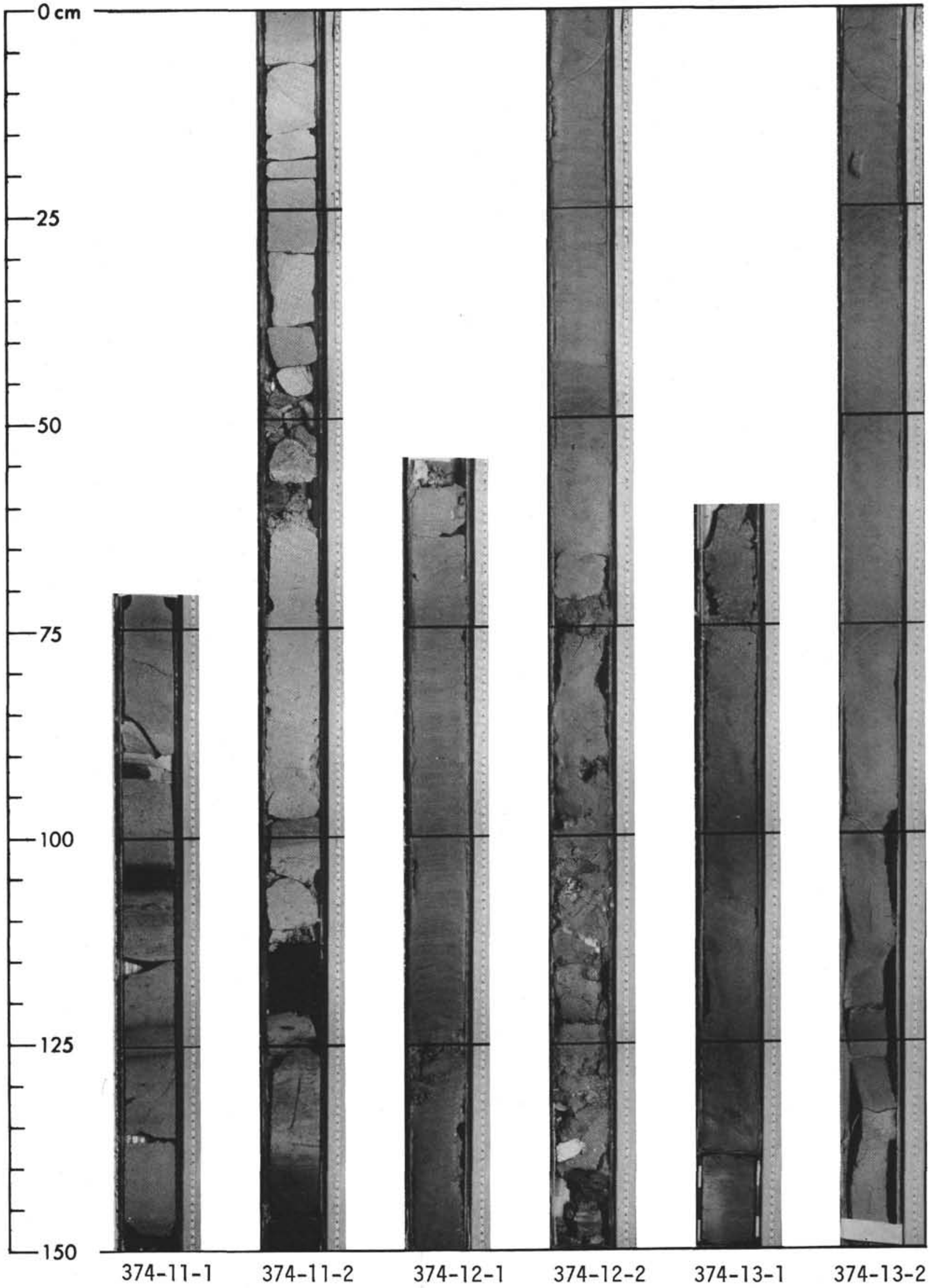
374-10-1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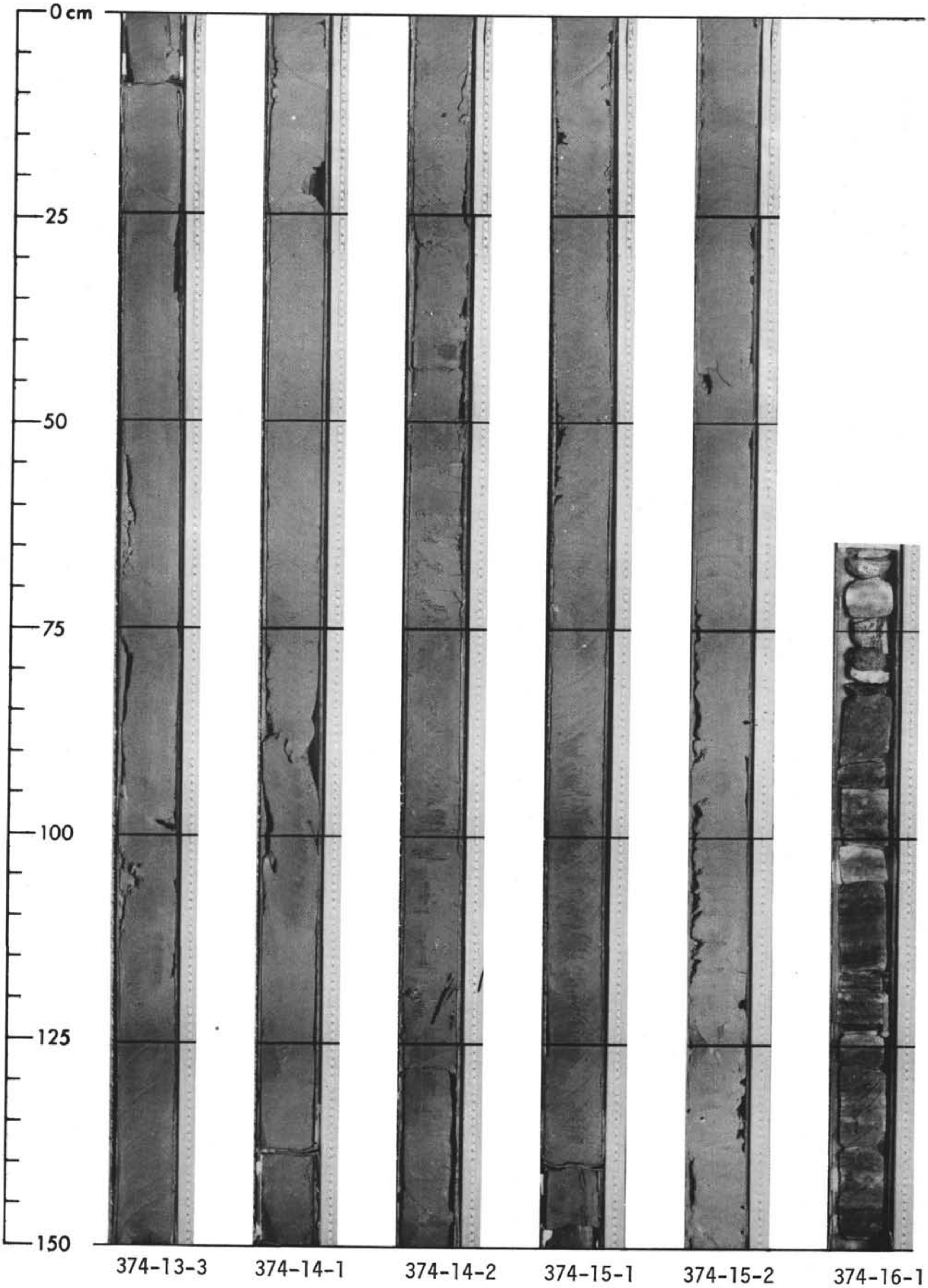
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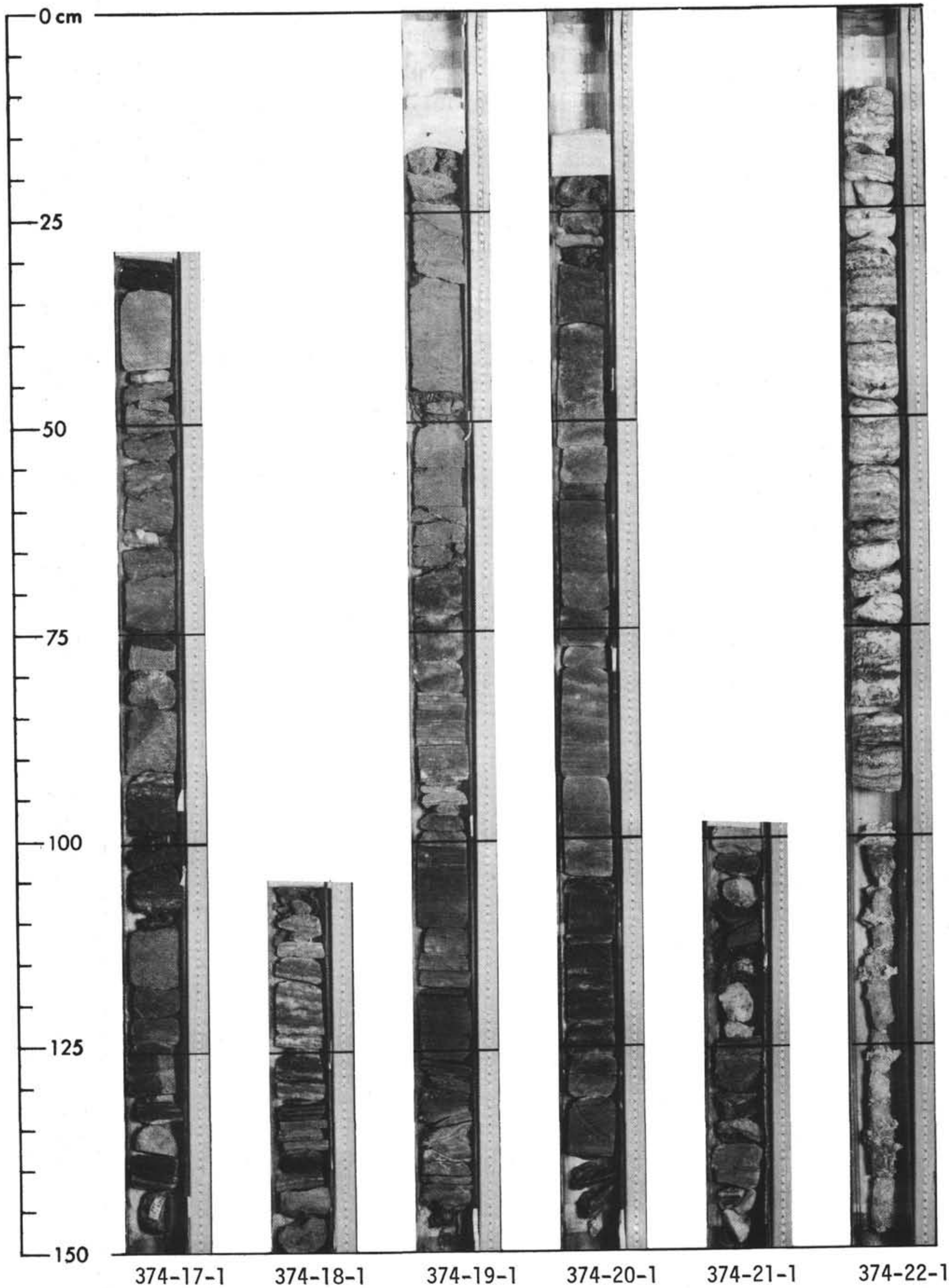
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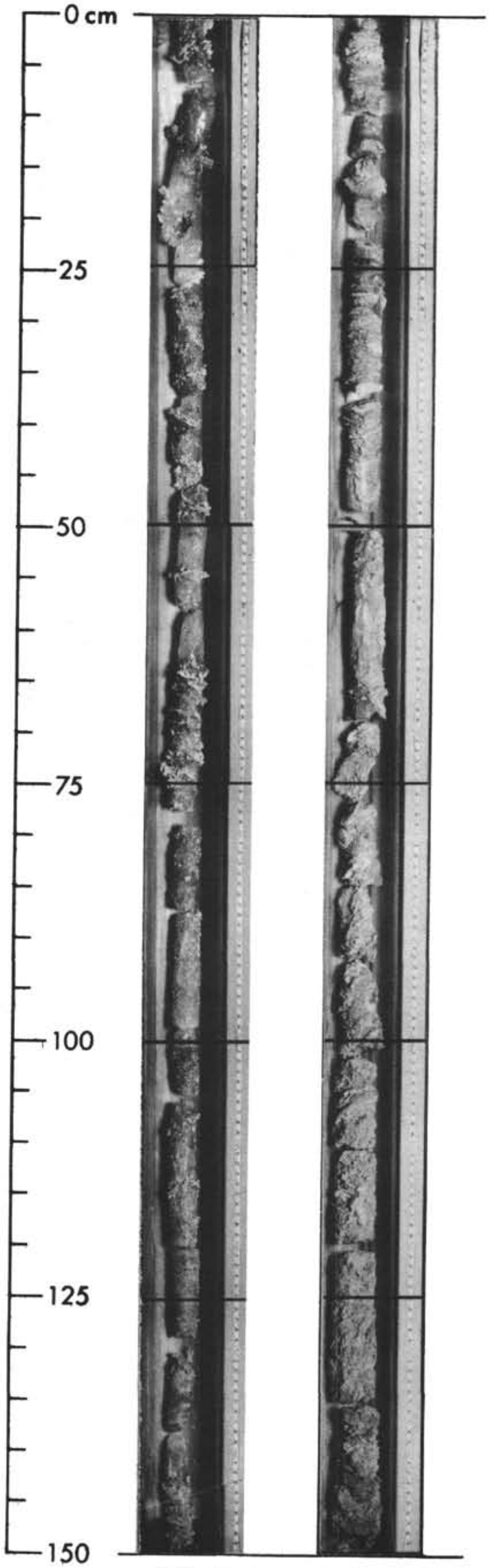
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