3. WESTERN ALBORAN BASIN – SITE 121

The Shipboard Scientific Party[1]

SITE DATA

Occupied: August 18-21, 1970.

Position: Over a buried basement ridge north of the central basin plain in the western Alboran Basin.
Latitude: 36° 09.65′N,
Longitude: 04° 22.43′W.

Water Depth: 1163 meters.

Cores Taken: Twenty-four cores.

Total Penetration: 867.2 meters.

Deepest Unit Recovered: Basement suite.

MAIN RESULTS

The sedimentary strata at Site 121 in the Western Alboran Basin consist of Pleistocene marls in conformable contact with Pliocene marls, sands and sandstones. In turn, the Pliocene units lie unconformably over and transgress upon a truncated series of Upper Miocene marls, sands and sandstones. A major hiatus comprising the lowermost part of the Lower Pliocene and the uppermost part of the Upper Miocene (Messinian) exists at an angular unconformity observed in seismic reflection profiles.

The earliest sediments (Tortonian) are marine marls and contain some gypsum in the form of selenite. These marls rest directly on a marine conglomerate whose components are believed to be fragments of the acoustic basement. Recovered rock units include quartzite, biotite-quartz schist, granodiorite, and cordierite-biotite-feldspar hornfels.

The sandstones are cemented by calcite and in part by dolomite. Turbidity currents were major contributors of clastic sediment during the Pliocene. In contrast, the Quaternary strata consists of silty clay whose calcareous component is dominated by nannoplankton. The diversity and relative abundances of the foraminiferal populations indicate climate fluctuations during the Pleistocene. Displacement and reworking of the faunas, particularly the nannoplankton, were noted in the silty clay. A few bedding structures suggest some winnowing by bottom currents. The mean sedimentation rate for the Pliocene and Pleistocene approximates 20 cm/1000 yrs.

BACKGROUND

The Alboran Sea occupies a very curious position in the westernmost extremity of the Mediterranean Sea. In a rather narrow embayment some 150 kilometers in width, an oceanic realm now hides from view the once internal portion of two young Tertiary mountain chains.

The Betics along the southern coast of Spain contain nappes and thrust sheets which, relative to the Iberian foreland, have traveled northward in a direction away from the present seaway. The Rif and Tel Atlas along the northern coast of Africa contain similar allochthonous terrains which have traveled southward. In the region of Gibraltar, the two mountain systems curve in an arc toward each other, and many geologists have proposed a continuity of structural lineaments across the narrow strait.

The Alboran Sea has two small basins of only moderate depth. The basins are separated by a linear volcanic ridge (Alboran Ridge) which strikes northeast-southwest (Figure 1). The western basin is floored by a small circular "basin" plain (Stanley *et al.*, 1970).

The upper stratified sediment cover of the western Alboran Basin observed in seismic reflection profiles (Figure 2) is markedly uniform in thickness with no tendency toward ponding in the "basin" plain.

This configuration, noticed first in 1965 during a reconnaissance survey of the Mediterranean with the R/V *Robert D. Conrad,* is quite unlike the appearance of stratified layering in other Mediterranean Basins. In the flat "abyssal" plains or "sediment ponds" (Hersey, 1965) the internal stratification is related to acoustical reflections from coarse-grained turbidite layers which gradually fill and level the deepest parts of enclosed basins (Figure 3). The uniform draping of acoustically stratified sediments in the western Alboran Basin remained a mystery, and called to mind as an analogue the sedimentary ridge of the Equatorial Pacific (Ewing *et al.*, 1968).

Buried peaks and valleys can be seen beneath the draped sediment cover of a small central ridge in the western basin. Noncoherent reflections from the buried features suggested that they represent the acoustic basement. In reflection profiles made with an air-gun sound source, the stratified sediment cover is separated from the basement by a transparent zone that is preferentially thicker in valleys than over peaks.

Site 121 was selected along a reflection profile obtained by the R/V *Jean Charcot* in a pre-site survey in June, 1970. Using a flexotir sound source, the *Charcot* profile (Figure 4) reveals a continuation of the acoustic basement northward under the western basin and beneath the sediment-draped slope of Spain. Several interesting features are apparent in this profile, and they are illustrated in an interpretation shown in Figure 5.

Five major sedimentary units are recognized. The uppermost correlates with the uniformly stratified layers

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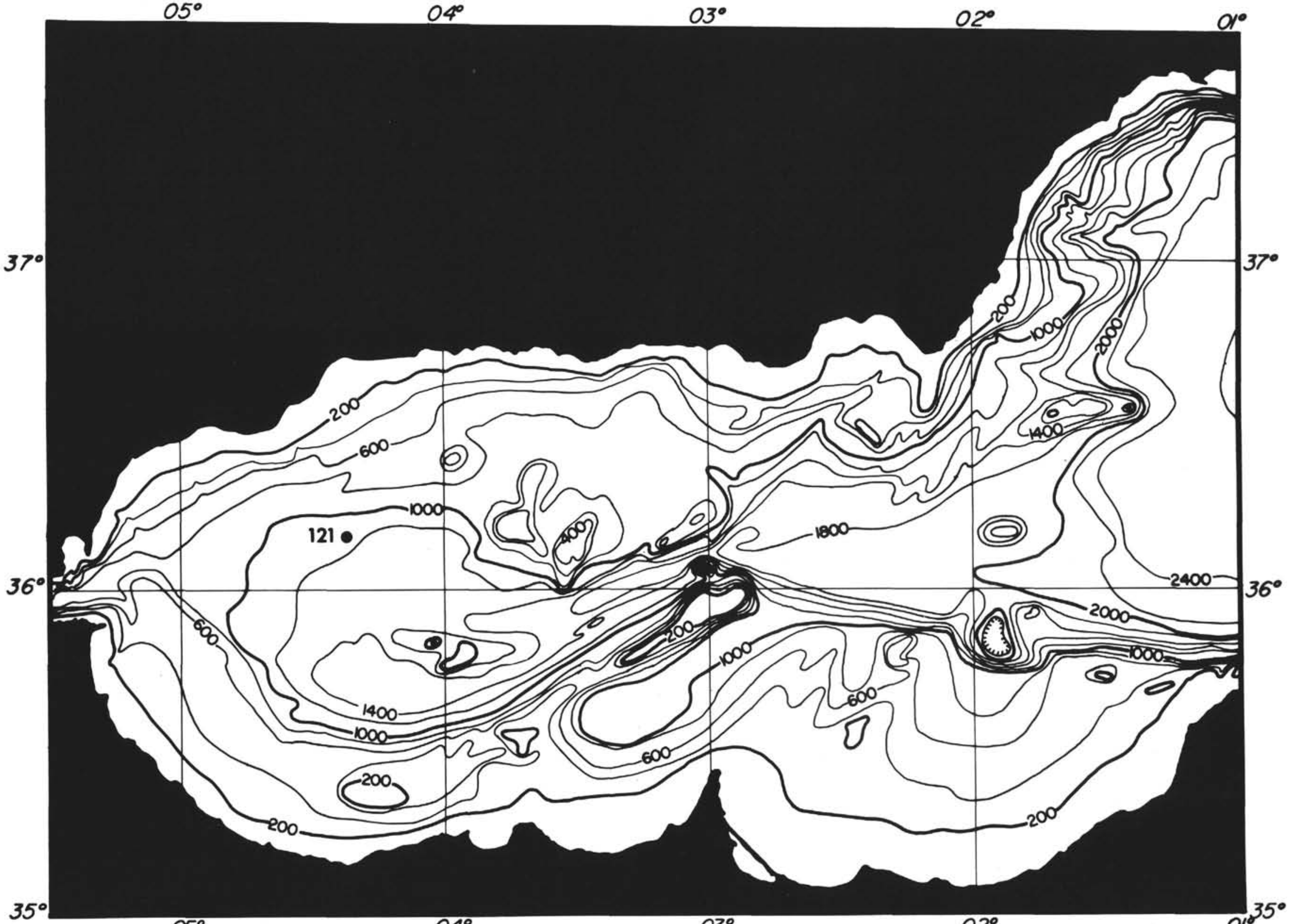

Figure 1. *The Alboran Basin, contours in meters, adapted from Chart 310 of the Defense Mapping Agency Hydrographic Center.*

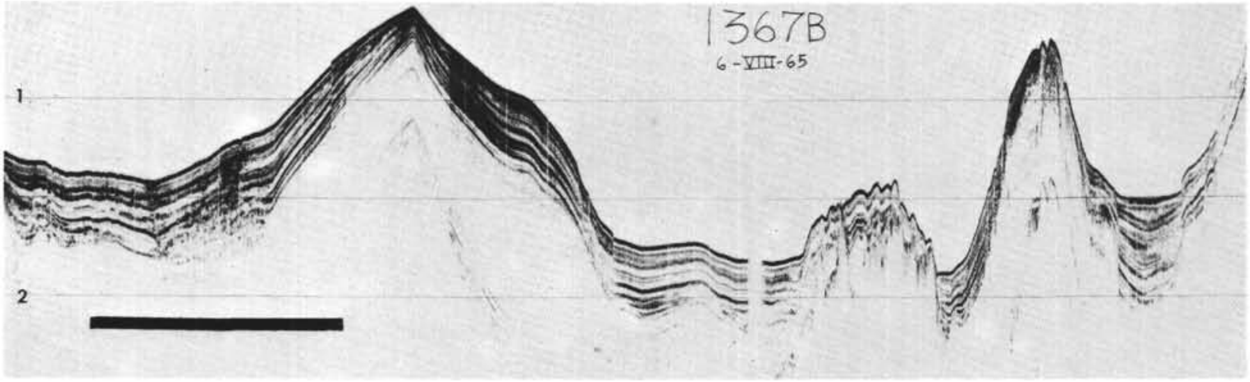

Figure 2. *Reflection profile (air-gun) of the* Robert D. Conrad *across the Alboran Basin showing the small intrabasinal ridge. Note the marked uniform thickness of the upper conformable, stratified sediment cover. Vertical scale is in seconds, two-way travel time.*

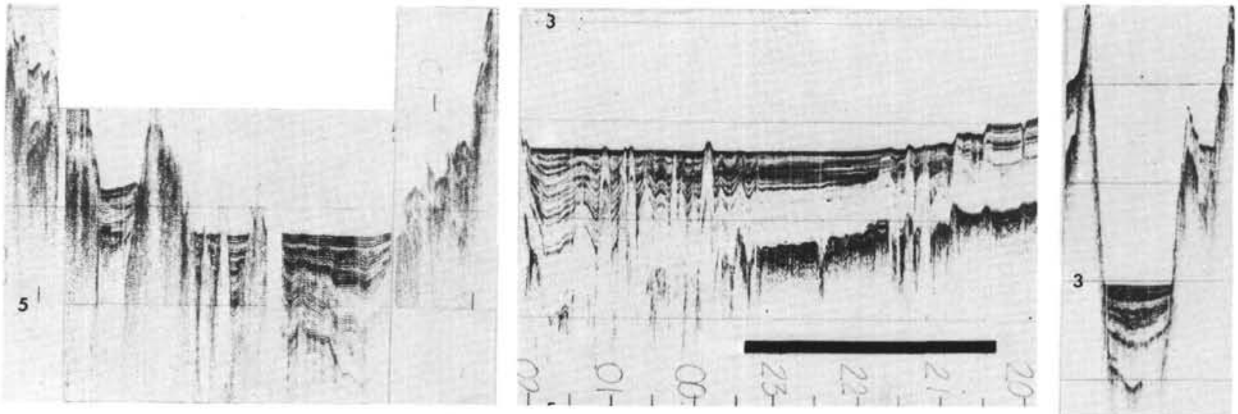

Figure 3. *Examples of acoustically stratified sediments ponded within deep depressions in the Mediterranean Sea. On the left: a profile across the central Tyrrhenian Abyssal Plain; in the center: a profile across the Balearic Abyssal Plain; on the right a profile across a peri-Tyrrhenian Basin. Contrast the flat-lying nature of the abyssal plain sediments with those in the Alboran Basin in Figure 2.*

seen in the airgun profiles and extends down to Reflector Rouge. This unit, arbitrarily called facies 1, maintains nearly a constant thickness across the floor of the basin, over the small central ridge, and up the continental slope. Within facies 1, two particularly sharp reflectors are identified: Reflectors Orange and Yellow. All the internal reflectors of facies 1 are extremely coherent and are continuous across the entire profile without any apparent change in reflector-to-reflector spacing.

Directly below this unit, we note a series of reflectors which are far less coherent. Individual phases cannot be traced over large distances; many small horizons fade in and out along the track, and internal hyperbolae (or side-echoes) are prevalent.

This unit, bounded below by a marked angular unconformity (Horizon Purple), is denoted as facies 2. The strata of facies 2 tend to be horizontal and pinch out and/or merge laterally against a prominent sedimentary wedge to the north. The slight bowing of the facies 2 strata over the buried basement highs is most probably a result of post-depositional differential compaction. Facies 2 is the one unit most similar to that seen in the stratified cover of the true abyssal plains (Ewing and Ewing, 1964), and is called by us the "gravity ponded" facies.

The northern wedge exhibits gently undulating features that markedly resemble the province of abyssal antidunes of the Western North Atlantic (Fox and Heezen, 1968). The crests of the undulations appear to migrate upslope. This unit is termed facies 3, or "the continental rise hills" facies.

Both the "continental rise hills" facies and the "gravity ponded" facies overlie and transgress the previously mentioned angular unconformity that seems to have truncated a gently arched series of subjacent sediments. Within the subjacent sediments we distinguish two additional units (facies 4 and 5). The uppermost of the two (facies 4) has the same internal acoustical character as the "gravity ponded" facies 2, and thus is termed the "tilted gravity ponded" facies. This unit conformably overlies a series of very strong coherent and laterally continuous reflectors. Four phases are discerned: the uppermost is identified as Reflector Green, the lower one as Reflector

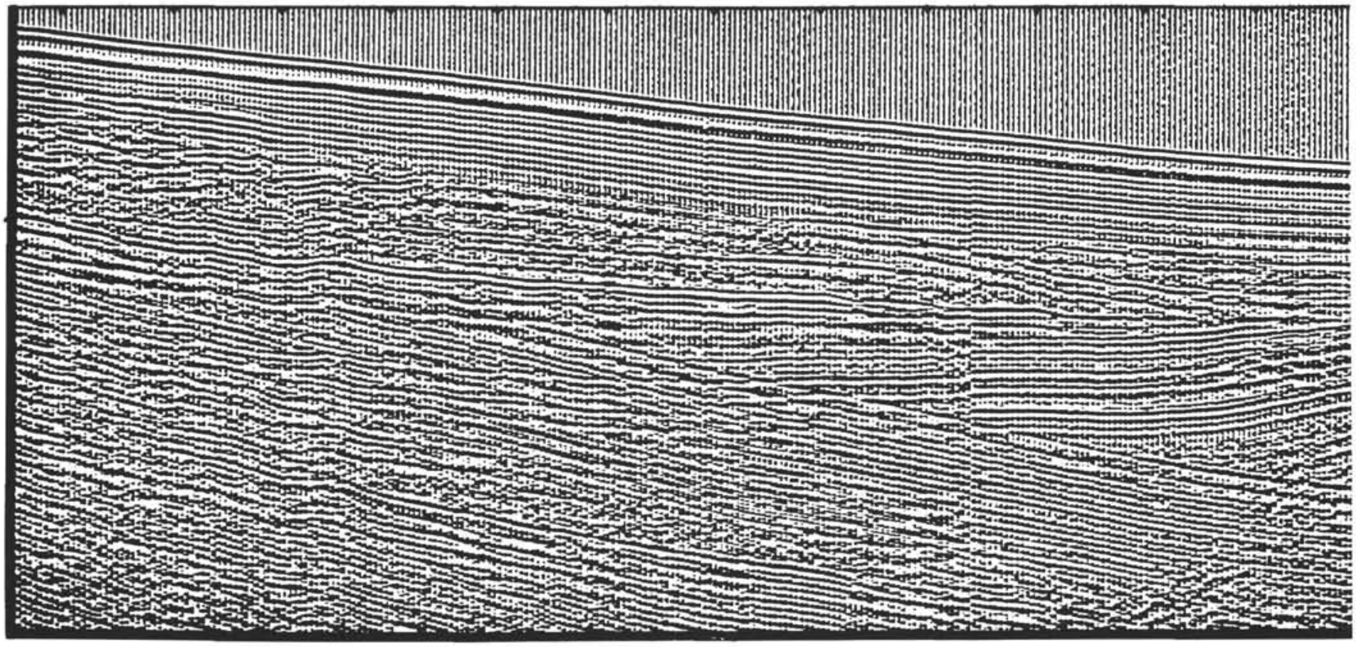

Figure 4. *Seismic reflection profile (Flexotir) across Site 121 in the western Alboran Basin. The illustration is a variable area presentation recorded in June, 1970 by the R/V* Jean Charcot *during a precruise site survey. Vertical exaggeration is 2:1. Courtesy of the Centre Oceanologique de Bretagne.*

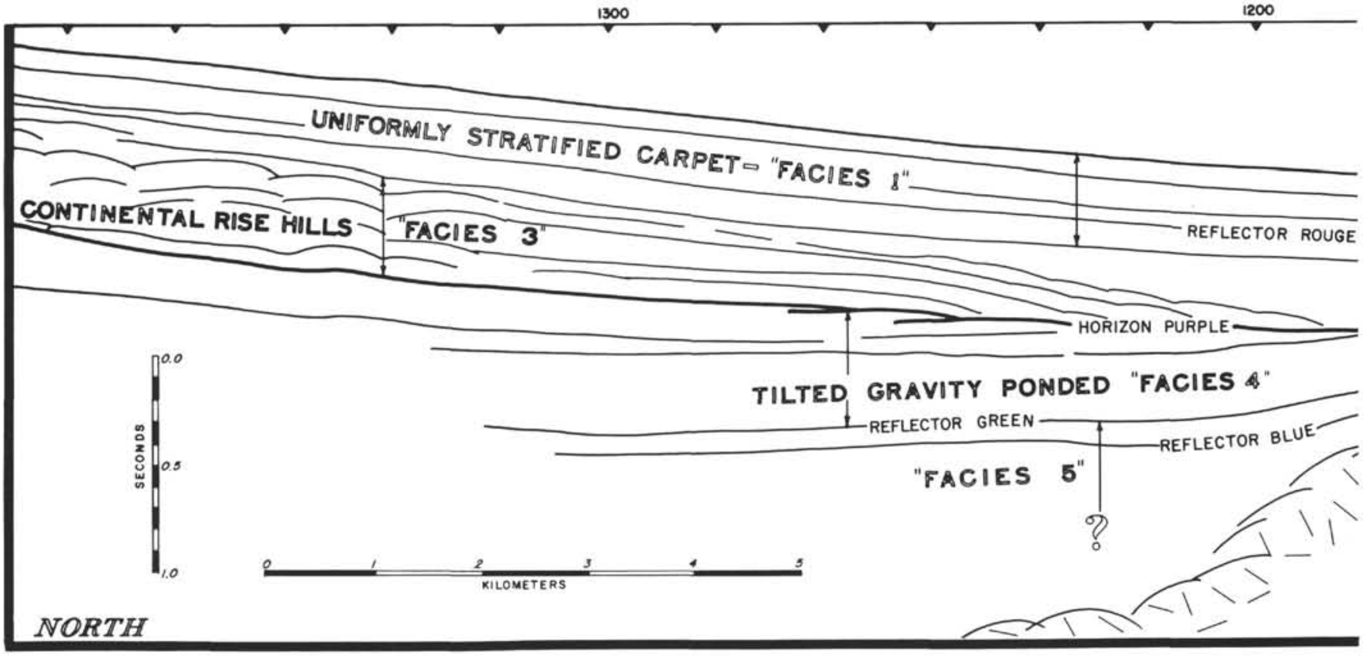

Figure 5. *Schematic interpretation of the* Charcot *profile of Figure 4. The various sedimentary units and reflectors are discussed in the text. Note in particular the marked angular unconformity (labeled here as Horizon Purple). The non-coherent basal reflecting unit is the acoustic basement.*

Blue. The zone of uniform and continuous reflectors is termed facies 5, and in many ways is similar to facies 1.

The sediments below Reflector Blue, and those of facies 5 and facies 4 all pinch out against a buried peak (or ridge) made up of numerous hyperbolae, which lacks any kind of recognizable internal stratification, and is here identified as acoustic basement.

Objectives

The primary objective of Site 121, as outlined by the site selection panel, was to sample the acoustic basement in as deep a part of the Alboran Basin as possible, keeping in mind the technical capabilities of the *Glomar Challenger*.

Because the basement rocks from the Atlantic and Pacific Oceans provided a wealth of data on the origin and

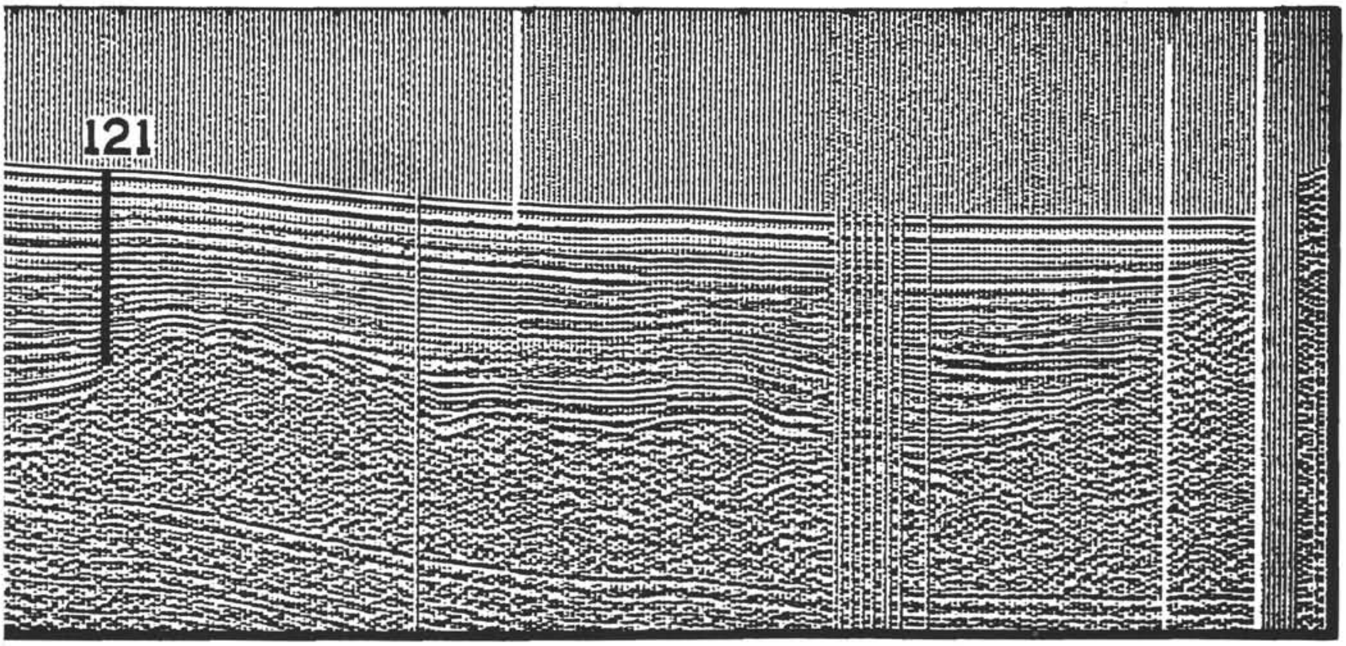

Figure 4. *(Continued).*

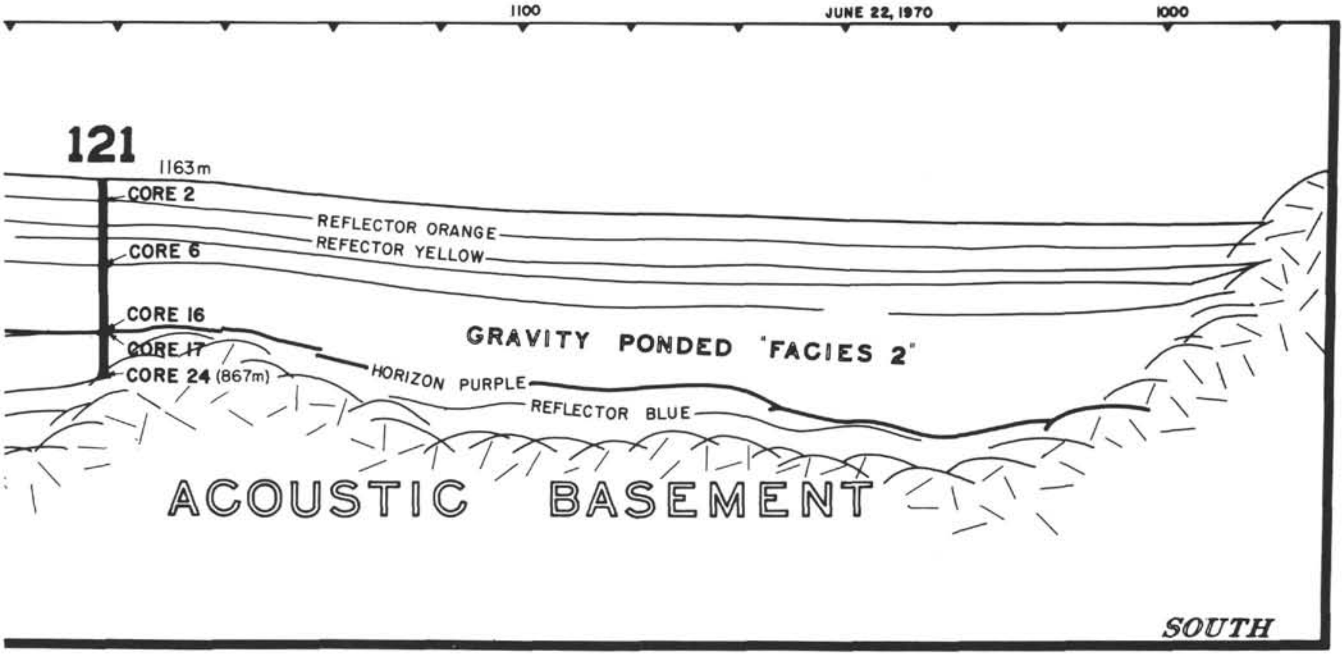

Figure 5. *(Continued).*

history of the oceanic crust, it was anticipated that actual rock samples and their overlying sediment cover from the crust of the western Mediterranean would provide answers to the perplexing questions: (1) whether this present "oceanic" seaway was floored by sialtic roots once part of the internal zone of the Betic and Rif orogens, and now intruded with dense magmas and collapsed, or (2) whether the Alboran Basin and the basins to the east were formed in the recent past by rifting, and subsequent accretion of simatic crustal materials (spreading).

Secondary objectives were to sample the sedimentary units overlying acoustic basement in order to reveal their history and mode of deposition and to determine the origin of the marked angular unconformity. Moreover, it was anticipated that the first hole in the Mediterranean would afford an opportunity to test a major tectonic concept, that of "oceanization."[2]

Strategy

The drill site was selected during discussions among the shipboard scientific team after careful examination of the recently acquired and beautifully detailed *Charcot* profiles. *Charcot* profile No. 269 (see Figures 4 and 5), on the northern slope of a buried peak (later determined as a ridge) where the acoustic basement lay 9.0 seconds below the seabed.

At this location facies 1, 2, 4 and 5 could be sampled. A decision was made not to place the hole farther north and penetrate facies 3, because of the lack of certainty of being able to reach basement there.

Cores would be taken near the prominent reflectors, and continuous coring would be attempted across the unconformity. A single hole was planned.

Challenger Site Approach

The Precision Depth Recorder aboard the drilling vessel was still not operative as we approached the Alboran Basin. Consequently, we decided to travel south of the target some five miles or so until we crossed the *Charcot* profile. We then turned north and proceeded along this profile checking our underway airgun record with the site survey data until we could ascertain that we had arrived (see Figure 6).

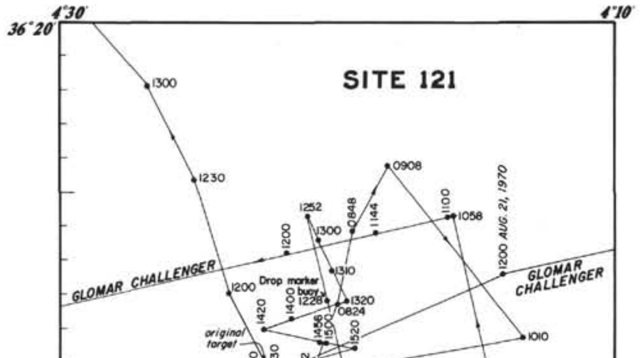

Figure 6. *Details of the* Glomar Challenger *site approach showing the track of the* Jean Charcot *and the original target just to the north of the eventual drill hole.*

[2]See in the references the Symposium volume on the oceanization of the Western Mediterranean published by the Royal Netherlands Geologic and Mining Society, and Ritsema, 1970.

We turned northward at 1136 hours, August 18 onto a steered course of 335°, and reduced speed to 7 knots to enhance the signal-to-noise ratio on our profiler. At 1228 hours a buoy was thrown into the water to mark a desirable location for drilling. However, due to our underestimation of a strong current flowing to the east, our return passage to the buoy after hauling in our eels and magnetometer left us far to the east of the original target. This drift was discovered when computation of a 1310 hour satellite fix was completed at 1320 hours. A decision was made to maneuver at 7 knots to the west at a heading of 265° and dead-reckon to the target. However, the full strength of the current was not appreciated, and the ship was halted at 1412 hours in automatic station-keeping mode, still, as it turned out, to the east. The beacon, however, was not dropped pending a position from a satellite fix at 1456 hours. The position calculated at 1516 hours again placed the vessel to the east of the desired location. A second fix at 1520 hours showed that we were drifting "hove-to" eastward at 2.6 knots. At 1520 hours, the ship was headed at 4.5 knots to the southwest, and a decision was made to at least try to establish the proper longitude for the *Charcot* profile, but to turn conservatively to the south so as to assure that we would be able to reach basement. At 1610 hours the vessel was halted, the beacon was soaked and dropped. The current took us and the beacon half a mile to the east, but our on-site mean fix position placed us in a highly desirable location over the northern slope of the basement ridge, directly on the *Charcot* profile and only one half mile south of the original target.

OPERATIONS

The *Challenger* stayed on location for 66 hours, between 1630 hours August 18 and 1106 hours August 21. The hole was terminated at 867.2 meters below bottom after reaching and recovering a complex rock unit which we believe represents the acoustic basement. Twenty-four cores were recovered as shown in the core inventory of Table 1.

Drill Breaks

Major changes in the rate of drilling, often accompanied by variations in torque, and bouncing of the drill bit on the formation were noted and are illustrated in Figure 7. Changes in the rate of drilling, indicative of passing through major changes in lithology, were noted at 60, 180, 245, 287, 577, 663, 835 and 862 meters. The peaks and valleys of the drilling rate curve correlate remarkably well with the levels of strong reflectors in the seismic reflection profile across the drill site.

Thin, brittle layers, often less than one meter thick were encountered at 591, 663 to 671, 680, 702 to 704, 769, 809, 816, 822, and 862 to 867 meters. The zone from 663 to 671, and at 680 meters corresponds to thin layers of sandstone interbedded with plastic marl. This unit directly overlies a major angular nonconformity between the Lower Pliocene and Tortonian (lower part of the Upper Miocene). The first encounter with the Miocene at 686 meters in Core 17 (cut back-to-back with Core 16) was accompanied by a significant increase in torque. A notable contact with a very hard formation at 862 meters accompanied by high and erratic torque represents the initial penetration of the

TABLE 1
Core Inventory – Site 121

Core	No. Sections	Date	Time	Cored[a] Interval (m)	Cored (m)	Recovered (m)	Subbottom Penetration (m) Top	Bottom	Lithology	Age
1	5	8/18	2115	1233-1242	9	8.0	60	69	Marl ooze	Quaternary
2	6	8/18	2215	1242-1251	9	9.0	69	78	Marl ooze	Quaternary
3	4	8/19	0005	1327-1336	9	5.5	154	163	Marl ooze	Quaternary
4	6	8/19	0310	1420.4-1429.5	9	9.0	247	256	Marl ooze	Quaternary
5	CC	8/19	0520	1469-1478	9	0.5	296	305	Sands & marls	Lower Pleistocene
6	CC	8/19	0737	1513-1522	9	0.1	340	349	Sands & marls	Lower Pleistocene
7	1	8/19	0918	1562-1571	9	0.6	389	398	Sands & marls	Upper Pliocene
8	1	8/19	1115	1609-1618	9	1.5	436	443	Sands & marls	Upper Pliocene
9	1	8/19	1318	1656-1665	9	0.7	483	492	Sands & marls	Lower-Upper Pliocene
10	2	8/19	1450	1690-1699	9	2.7	517	526	Sands & marls	Pliocene
11	1	8/19	1625	1730-1739	9	0.7	557	566	Sands & marls	Middle Pliocene (base)
12	CC	8/19	1830	1768-1774	6	0.2	595	601	Sands & marls	Upper-Lower Pliocene
13	1	8/19	2020	1797-1803	6	0.8	624	630	Sands & marls	Upper-Lower Pliocene
14	1	8/19	2150	1825-1853	9	0.3	652	661	Sands & marls	Lower Pliocene
15	1	8/19	2335	1852-1853	1	1.0	679	680	Sands & marls	Early Pliocene Late Neocene
16	1	8/20	0123	1853-1859	6	0.2	680	686	Sands & marls	(Undiff)
17	CC	8/20	0300	1859-1862	3	Trace	686	689	Sands & marls	(Undiff)
17b	CC	8/20	0430	Center Bit 1862-1881	–	Trace	689	708	Sands & marls	(Undiff)
18	1	8/20	0615	1881-1888	7.5	0.4	708	715.5	Sands & marls	(Undiff)
19	1	8/20	0842	1901-1933	9	0.5	728	737	Sands & marls	(Undiff)
20	CC	8/20	1115	1930-1933	3	0.2	763	770	Sands & marls	(Undiff)
21	CC	8/20	1415	1958-1961	3	0.1	785	788	Sands & marls	(Undiff)
21b	CB	8/20	1630	Center Bit 1961-1992	–	0.001 Trace	788	817	Sands & marls	Upper Miocene Tortonian
22	1	8/20	1710	1992-1994	2	2	819	821	Sands & marls	Upper Miocene Tortonian (N16)
22b	CB	8/20	2115	Center Bit 1994-2032	–	0	821	859	Sands & marls	Upper Miocene Tortonian (N16)
23	1	8/20	2230	2032-2034	2	1.6	859	861	Marl	Upper Miocene Tortonian (N16)
24	2	8/21	0220	2034-2040.2	6.2	1.5	861	867.2	Marls, breccia, basement	Upper Miocene Tortonian (N16)
Total					162.7	47.1		867.2		
% Cored					18.7%					
% Recovered						28.9%				

[a]Drill pipe measurements from derrick floor to sea floor.

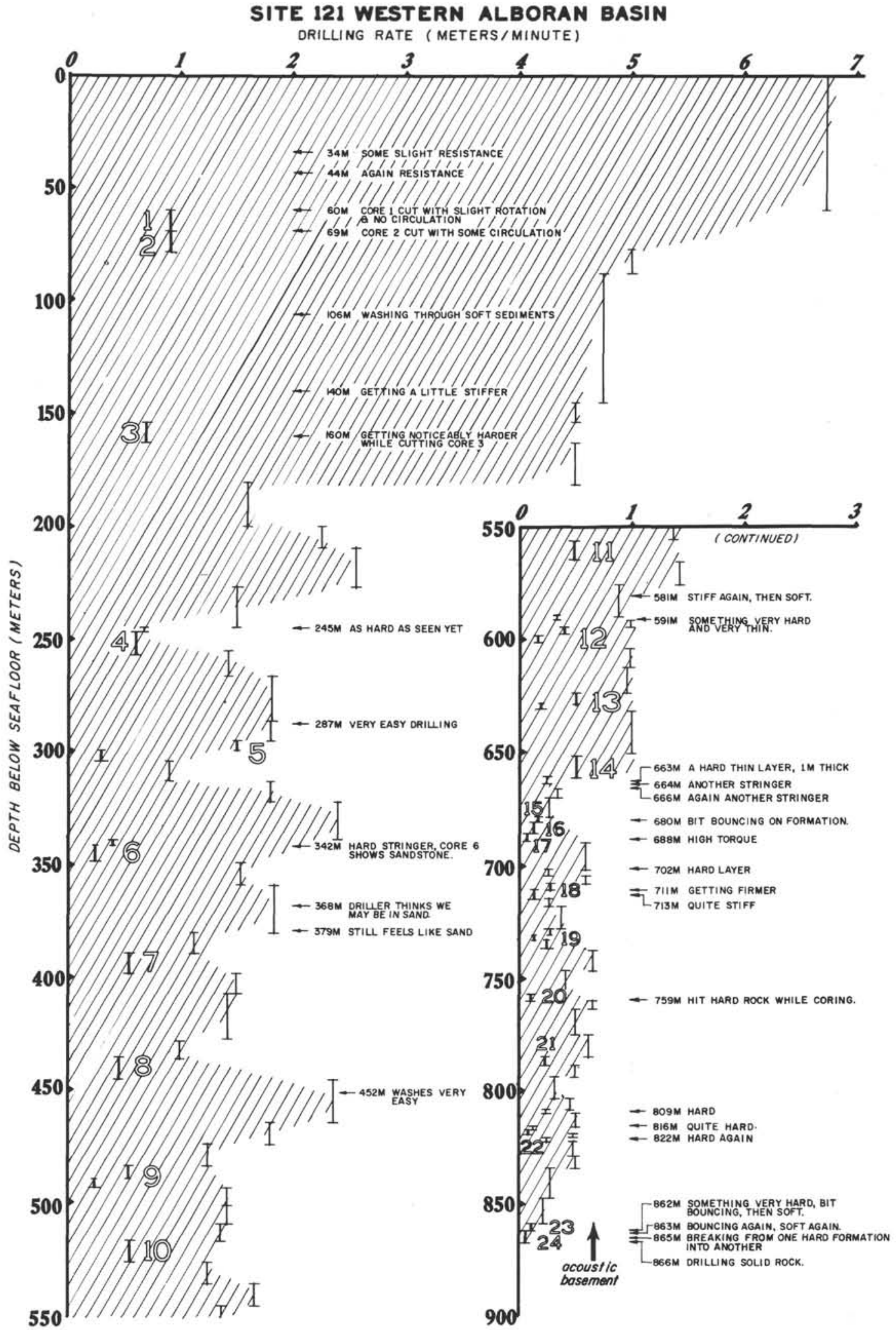

Figure 7. *Rate of penetration of the drill string at Site 121. The curve is smoothed from averaged intervals of more or less uniform drilling (bars). Cored intervals are not included. Note the major changes in long term drilling rates at 180, 577 and 660 meters, and the contrast with the basement at 862 meters. Small spikes below 590 meters usually represented encounters with thin stringers of sandstone.*

basement formation. A few soft spots are correlatable with the recovery of a sedimentary breccia containing angular fragments of the basement lithologies. The lowermost unit recovered was solid rock which came up jammed in the bit-orifice.

The marked decrease in penetration rate at 835 meters is correlated with the first occurrence of gypsum interspersed in the marls in the form of selenite crystals as identified in Cores 23 and 24. The torque and bounce while cutting Cores 19 and 20 may be correlatable with the anomalous appearance of cristobalite in these cores (identified by X-ray diffraction). Limestones were recovered in Core 21, sandstones in Cores 6, 8, 10, 14, 15, 22 and 24. The fragment of sandstone in Core 6 is rounded and may possibly be an erratic.

The drillers believed that the relatively rapid penetration between 440 and 470 meters was a consequence of washing through loose sands. Sand layers some 10 to 20 centimeters thick were recovered in Core 8 between 435 and 445 meters.

Problem of Poor Recovery

A Reed PD-2 tooth bit was used and proved effective in penetration. On the other hand, the recovery of sandy sediments was unsatisfactory. To remedy the situation a plastic sleeve was used in the core catcher of the inner core barrel, but this measure was not satisfactory. Except for the first four barrels, the recovery was generally less than 10 per cent. The difficulty is attributed to the fact that the penetrated sequence consists of interbedded sands and harder marls, with several intercalations of brittle layers. Often it was necessary to use circulation when coring the harder layers, and then upon breaking through these strata, the loose materials below would immediately be washed away.

Down to 680 meters below bottom, the core barrel was left inside the drill pipe and sandy sediments, when encountered, were washed away easily. However, when the rare hard intercalations were penetrated, the inner core barrel tended to become jammed. After Core 17 was taken, it was decided to insert the center bit in order to prevent jamming. Only spot-coring was done in the next 180-meter interval. Rarely could we make a full nine-meter cut because of the jamming tendency of the core barrel. The retrieval of jammed core barrels often proved time-consuming.

We started to cut Core 23 at 2115 hours, August 20. Cutting was slow, indicating that hard rock was being drilled. The barrel jammed after two meters were cut. When the core was hauled on deck at 2230 hours, we discovered a few chips of rock mixed with marls. We decided to confirm this discovery, and invested four hours to cut 6 meters of very hard rock. Core 24 proved that we had indeed penetrated acoustic basement. Since the objective of recovering this unit was accomplished and the drilling rate exceedingly unproductive, the hole was terminated, somewhat reluctantly, at 867.2 meters subbottom depth.

The hole was cemented and the drill pipes were withdrawn above the mud line at 0645 hours on August 21. The bit was found to be badly worn; all the cone teeth were damaged and the majority of them broken off. This bit gave a high penetration rate; we may have saved some two days in drilling time by not using the roller cone bit, but as a result core recovery was poor.

BIOSTRATIGRAPHY-SITE 121

The twenty-four cores from Site 121 in the Western Alboran Sea range in age from late-middle Quaternary (Core 1) to Upper Tortonian (Core 24).

The site bottomed at about 867 meters in a complex suite of basement rocks directly overlain by olive-gray marls that yielded fairly good foraminiferal and calcareous nannoplankton assemblages. No visible contact alteration was seen in the calcareous sediment. Rather, the marls occur as matrix material in an angular conglomerate of inferred basement materials.

Both foraminifera and calcareous nannoplankton are well-represented throughout the cored intervals. However, their preservation is not always good and their occurrence is often too scanty to allow precise age determinations for some intervals. The suitability of planktonic foraminifera and nannofossils for age determinations is shown in Table 2.

The occurrence of diatoms and Radiolaria appears to be restricted to Cores 2 and 3 from the Quaternary section, and Core 18 from the Late Miocene interval.

Other fossils recorded include otoliths and fish teeth, echinoid spines, ostracod valves, spicules of siliceous sponges, fragments of pelecypods, pteropods, fragments of bryozoan colonies, and the fibrous membranes of plants. These findings are recorded in the range chart of planktonic foraminifera (see Table 3).

Oldest Sediment

The oldest sediment recovered from Site 121 in the Western Alboran Sea could be dated with accuracy because it yielded a fairly rich and well-preserved, though not highly diversified, assemblage of foraminifera, including, *inter alia, Globorotalia acostaensis* (Blow), *G. acostaensis humerosa* (Bermudez), *Globorotalia menardii* (d'Orbigny), *Globorotalia merotumida* (Banner and Blow), *G. scitula ventriosa* (Ogniben), *Globigerina decoraperta* (Takayanagi and Saito), *Globigerina* cf. *nepenthes* Todd.

This association is characteristic of the *Globorotalia acostaensis-G. merotumida* Zone (N 16) of Blow's zonal scheme, which may be correlated with the *Globorotalia acostaensis* Zone of Bolli's scheme. Both the zonal indicators (*G. acostaensis* and *G. merotumida*) are also present in the stratotype section of the Tortonian stage, as defined in Italy (see Cita, Premoli Silva and Rossi, 1965; Cita and Blow, 1969). The co-occurrence of *Globorotalia acostaensis* and *G. acostaensis humerosa* places the assemblage in the upper part of Zone N 16, where the latter taxon first occurs (see Blow, 1969, Cita and Blow, 1969). This assumption is confirmed by the occurrence of phylogenetically advanced representatives of *Globorotalia merotumida*, which—on account of their somewhat elongated equatorial periphery—are transitional to *G. plesiotumida*. The latter is a marker used to define Zone N 17 of Blow's scheme (consecutive-range-zone).

TABLE 2
Quality of Fossil Assemblages and Their Suitability for Stratigraphic Work

Core	Foraminifera	Age	Nannoplankton	Age
1	Good	Middle to late Quaternary *Globorotalia truncatulinoides* Total-range-zone	Good	NN 19-20
2	Good	Middle to late Quaternary. As above	Good	NN 19-20
3	Good	Middle Quaternary. As above	Good	NN 19-20
4	Good	Middle Quaternary. As above	Good	NN 19-20
5	Good	Calabrian. As above	Good	NN 19-20
6	Not good	Generalized latest Neogene	Not so good	NN 19-20
7	Good	Upper Pliocene *Globoratalia inflata* Interval-zone	Not so good	NN 18
8	Bad	Generalized late Neogene	Good	NN 18
9	Good	Upper Pliocene *Globigerinoides obliquus extremus* Interval-zone	Good	NN 18
10	Bad	Generalized late Neogene (much reworking)	Not so good	NN 16
11	Good	Upper Pliocene *Globigerinoides obliquus extremus* Interval-zone	Good	NN 16
12		As above but not as good	Good	NN 15
13	Bad	Generalized late Neogene	Good	NN 15
14	Bad	Generalized late Neogene	Good	NN 14 to NN 16
15	Good	Lower Pliocene (*Globorotalia margaritae* Total-range-zone)	Very good	NN 12-14
16	Bad	Late Neogene generalized	Bad	Age assignment by correlation NN 11-NN 14
17	Bad	Late Neogene generalized	Bad	
18	Bad	Late Neogene generalized	Bad	
19	Bad	Late Neogene generalized ("*Globorotalia acostaensis fauna*")	Bad	
20	Bad	Generalized late Neogene	Fairly good	NN 10-11
21	Bad	Generalized late Neogene	Fairly good	NN 10-11
21B	Good	Tortonian, *Globorotalia acostaensis g. merotumids* Zone N 16	Fairly good	NN 10-11
22	Bad	Generalized middle-late Miocene	Fairly good	NN 10-11
22B	Bad	Generalized middle-late Miocene	Bad	NN 10-11
23	Good	Tortonian, Zone N 16	Not so good	NN 10-11
24	Good	As above	Not so good	?NN 10

A fairly good indication of Tortonian age is also given by benthonic foraminifera, which include taxa such as *"Bolivinoides" miocenicus, Bolivina arta* and *G. antiqua.*

The evidence given by calcareous nannoplankton is in agreement with that discussed above: the nannoplankton assemblage of the deepest core lies below the *Ceratolithus tricorniculatus* Zone (NN 12) and does not contradict the foraminiferal zonal assignment.

The olive-gray marl from the core catcher of Core 24 is rich in rock fragments of diverse origins. The sediment overlying the basement may be considered as neritopelagic. The fossil evidence indicates that the first sediment to be deposited on the basement is marine.

Evidence of Climatic Fluctuations in the Quaternary (M.B.C.)

The Quaternary section penetrated at Site 121 (Cores 1 to 6) consists of at least 350 meters (see Figure 8) of dark, greenish-gray marl-ooze (Cores 1 through 4), overlying dominantly sandy sediments (Cores 5 and 6) which yielded foraminiferal and nannoplankton assemblages characteristic of the Calabrian stage (early Pleistocene). Evidence of climatic fluctuations that can be referred to as glacial and interglacial stages was found in Cores 1 to 4 with the most marked fluctuations in Cores 1 and 2.

In using planktonic foraminifera as climatic indicators, reference for this site is made essentially to Todd (1958), who investigated in detail piston cores collected by the Swedish Deep Sea Expedition from the Western Mediterranean. The occurrence of the three different foraminiferal assemblages distinguished by Todd (*op. cit.*) in the samples investigated is indicated in Figure 8. Observations are qualitative, based on visual estimates and not on counts; therefore, they have to be considered as tentative. The occurrence of detritus in significant quantities in the fraction greater than 63 microns is also plotted.

Cores 1 and 2 indicate a fluctuating climate ranging from temperate to cold. Cores 3 and 4 show evidence of temperate to warm climate. It is worthwhile mentioning the occurrence of single specimens of *Pulleniatina obliquiloculata* in the core catcher sample of Core 4, taken 256 meters below the sea floor. This species has a tropical habitat, and is considered a typical warm-water indicator. The only other occurrence of this species in Leg 13 material was at Site 134, at a depth of 199 meters below the sea floor. *Pulleniatina obliquiloculata* has never been recorded

Below Sea Floor (m)	Core	Sample Core-Section (Interval in cm)	Warm	Temperate	Cold	None	Little	Much
−25								
		1-1 (71-74)			*		*	
		1-2 (69-72)			*		*	
−50		1-3 (69-72)			*		*	
		1-4 (69-72)			*		*	
		1-5 (69-72)		Mixed				*
	C1	1-CC			*		*	
		2-1 (69-72)			*		*	
−75	C2	2-2 (1-4)			*		*	
		2-3 (69-72)		*			*	
		2-4 (60-71)		*			*	
		2-5 (81-83)		*			*	
		2-6 (77-79)			*	*		*
−100		2-CC			*			*
−125								
		3-1	Disturbed, therefore not investigated					
−150		3-2	Disturbed, therefore not investigated					
	C3	3-3 (67-70)	*			*		
		3-4 (70-74)		*			*	
		305	Disturbed, therefore not investigated					
−175		3-CC		*		*		
−200								
−225								
		4-1 (77-80)		*		*		
		4-2 (69-72)		*			*	
		4-3 (75-78)		*		*		
−250	C4	4-4 (69-72)	*				*	
		4-5 (70-73)	*				*	
		4-6 (69-72)		*			*	
		4-CC	*					

Figure 8. *Indications of paleoclimatic fluctuations in the Quaternary (Cores 1 to 4). The observations are qualitatives, based on visual estimates of the relative abundance of three different assemblages of planktonic foraminifera. Note that cold assemblages were only found in the latter part of the Pleistocene.*

in the Eastern Mediterranean, even from latitudes lower than those of Sites 121 and 134, which are 36°N and 39°N, respectively.

Paleontological Evidence of Sedimentation by Turbidity Currents During the Miocene-Pliocene Interval (M.B.C.)

The pre-Quaternary section penetrated at Site 121 from 389 meters (Core 7) to 821 meters (Core 22) was cored discontinuously and the recovery was poor (averaging 24 per cent of the cored interval). It contains numerous sandy intervals derived in part, from turbidity currents.

The nannoplankton assemblages show evidence of reworking throughout the interval. This fossil group is most susceptible to reworking, and is often present as allochthonous elements in nonturbidite sediments.

Reworking of foraminiferal assemblages is not so extensive as with the calcareous nannoplankton. In the core-catcher sample of Core 10, one specimen of *Ticinella* sp. (Lower Cretaceous), one of *Globotruncana fornicata* (Upper Cretaceous) and one keeled Paleocene *Globorotalia* were observed.

Planktonic foraminifera are sparse in some of the samples, for example, 8-CC, 16-CC, 20-CC and 21-CC. However, they are always more numerous than benthonic forms. The benthonic fauna is commonly a mixture of deep-water forms such as *Epistomina, Bolivina, Uvigerina,* and *Bulimina*, and shallow-water forms such as *Elphidium* spp., *Nonion boueanum, Asterigerina, Ammonia beccarii,* and miliolids (see Figure 9). The former are considered to be autochthonous, the latter allochthonous. Some specimens of *Elphidium crispum* and of *Ammonia beccarii*, large in size and common at some intervals, as for instance in Core 12, show evident traces of mechanical abrasion.

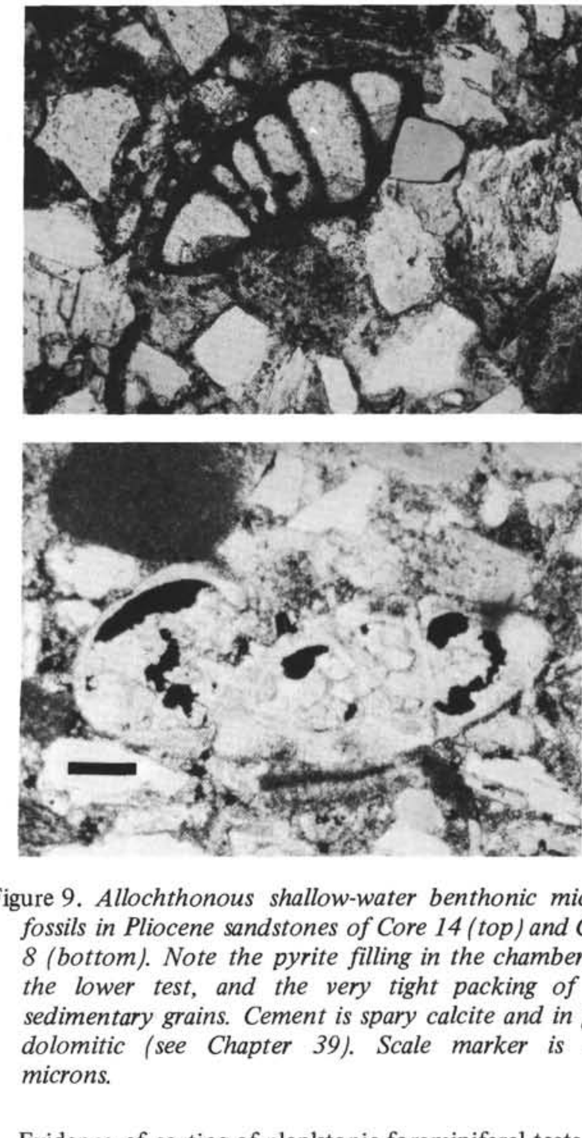

Figure 9. *Allochthonous shallow-water benthonic microfossils in Pliocene sandstones of Core 14 (top) and Core 8 (bottom). Note the pyrite filling in the chambers of the lower test, and the very tight packing of the sedimentary grains. Cement is spary calcite and in part dolomitic (see Chapter 39). Scale marker is 100 microns.*

Evidence of sorting of planktonic foraminiferal tests was noted in Core 17, where practically all the specimens are small. Also, fragmentation of the foraminiferal tests was observed, as for instance in Cores 13, 17 and 19.

A further indication of turbidite sedimentation is represented by the occurrence of abundant detrital material in the fraction greater than 63 microns.

Taking into account all the kinds of evidence previously discussed, the core catcher samples for which a turbidite

TABLE 3
Range Chart of Planktonic Foraminifera – Site 121

Depth Below Sea Floor (m)	Recovery (m)	Core Number	Section Number	Sample Interval (cm from top)	PLANKTONIC FORAMINIFERA *Globigerina*													*Globigerinoides*												*Globorotalia*																							Others							Detritus	Glauconite	Pyrite	Organic matter	Pteropods	Pelecypod fragments	Ostracods	Bryozoa	Otoliths	Fish teeth	Echinoid spines	Displaced shallow water benthic forams	Siliceous sponge spicules	Radiolaria	Age	Zone
					apertura	*atlantisae*	*bulbosa*	*bulloides*	*decoraperta*	*eggeri*	*falconensis*	*microstoma*	*nepenthes*	*pachyderma*	*praebulloides*	*praedigitata*	*quinqueloba*	*bollii*	*conglobatus*	*elongatus*	*helicinus*	*obliquus*	*obliquus extremus*	*pyramidalis*	*quadrilobatus*	*ruber*	*sacculifer*	*tenellus*	*trilobus*	*acostaensis*	*acostaensis humerosa*	*bononiensis*	*aff. conomiozea*	*crassaformis crassaformis*	*crassaformis crassula*	*crassaformis viola*	*inflata*	*margaritae evoluta*	*margaritae praehirsuta*	*margaritae primitiva*	*menardii*	*merotumida*	*obesa*	*oscitans*	*cf. pseudopima*	*puncticulata*	*scitula*	*scitula gigantea*	*scitula ventriosa*	*cf. tosaensis*	*truncatulinoides*	*dutertrei*	*Globigerinita glutinata*	*Globigerinita uvula*	*Globoquadrina altispira*	*Hastigerina siphonifera*	*Orbulina universa*	*Pulleniatina obliquiloculata*	*Sphaeroidinellopsis seminulina*																
60	1	1	1	89-92		●		●		●				●			●									●		●		○							●										●				○		●							●					○	○				●		●		Quaternary	*Globorotalia truncatulinoides* Total-range-zone
			2	69-72		●	●	●		●				●			●													●							●										●					●								●					●	○				●					
			3	69-78		●	●	●		●				●			●																				●										●					●	●							●					●					●					
			4	69-72		●	●	●			●			●			●																				●										●													●					●	○				●					
			5	69-72		●	●	●		●	●			●			●											●									●						●				●				●		●				●					●			●					●					
69			CC					●						●			●								○												●										●				○	●				○	●																		
69		2	1	69-72			●	●		●	●	●		●			●											●		●				X			●							●			●				●	●	●				●			●						○				●	●				
			2	1-4			●	●		●				●			●																				●							●			●			●	●	●				●	●			●					●	○				●					
			3	69-72			●	●		●				●		●	●									●											●										●			●			●			●	○			●						●				●					
			4				●	●		●				●			●									●											○							●			●						●				○			●		●			●	●									
			5	81-83			●	●		●				●			●																				●										●				○	●					○			●		●			●	●				●					
			6	77-79			●	●		●				●			●																														●					●	●				○									○				●					
78			CC					●						●			●							●													●										●					●	●	●			○			○															
154		3	4	70-73			●	●		●		●		●			●							●		●				●							●							●			●				●	●	●				●								●			○		●			●		
163			CC					●						●			●			●		●			●	●				●	●			●			●	●		●				●			●				○						●																		
247		4	1	77-80			●	●						●			●									●				●				X		●	●							●			●			●	●	●	●			●									●					●					
			2	69-72			●	●			●			●			●													●				X			●													●		●	●							○					●			○		●					
			3	75-78			●	●		●	●			●			●				●									●				X			●										●			●	●	●	●			●									●			○		●					
			4	69-72			●	●		●	●			●			●				●									●				X		●	●						●	●			●					●	●				●									○				●	○				
			5	70-73			●	●			●			●			●									●				●							●							●			●			●	●	●	●				●			○			●			○				●					
			6	69-72				●						●			●				○									●				X			●										●			●	●	●	●				●			●						○				●	●				
256			CC				●	●			●			●			●			●	●			●		●				●				●		●	●										●			●	●		●	●		●	●	○					●			○		○							
296 305		5	CC				●	●		●				●			●		○	●						○				●	○			○			●										○			○	○	●	●			●	●			●						●	●			●	●				
360 369		6	CC					○						○												○											○																				○			●				○	●		●			●	●				

389 398	7	CC				●	●		○	●	●		●			●			●	●				○	●				●	○			○		○	●						●	●			●						●			●	●						○	○		○		○						Upper Pliocene	*Globorotalia inflata* Interval-zone
436	8	1	97-100			●	●			●			●								●			●				●													●										●				●			●											●				
443		CC				○	○			○						○			○						○				○				X								○	○									○	○				○			●															
483 492	9	CC		●			●			●	●					●			●			●			●				●				X													●						●	●		●	●			●					●					●				
517		1	120-122	●			●				●					●			●			●			●				●				●	●																	●				●			○									○	●				
	10	2	78-80				●			●			●			●			●			●			●				●				●	●										●								●	●			●			○	○					○		○		○	●				
526		CC				●	●			●	●											●											●	●																									●										●				
557 566	11	CC		●		●	●			●	●					●						●		●		●		●	●	●	●			●	●											●						●	●			●								●					○	●				
595 601	12	CC					●									●	●		●			●		●	●			●			●		●			○																●				●			●					●			○			●				
624 630	13	CC		●							●					●			●			●		●		●		●	●	●																						●			●	●			●					●						●				
652 661	14	CC		X			●												●			●			●	●																		●										●	●			●	●										●				Not zoned
679 680	15	CC					●				●								●			●		●		●			●	●							●	●							●							●			●	●					●	●			○								Lower Pliocene	*Globorotalia margaritae* Total-range-zone
680 686	16	CC		●			●			●	●											●							●								●								●											●			●															
686 689	17	CC				●				●				●		●					●	●						●	●													●				●						●				●			●					●						●			Upper Miocene	*Globorotalia acostaensis-G. merotumida* Zone N 16
708 715	18	CC		●			●			●	●					●	●							●					●	●												●				●						●				●																●		
728 737	19	CC		●			●				●													●					●	●												●														●			○								○						
757 760	20	CC					○																					○																										○			●										○				
785 788	21	CC					X																			X																												○			●													
	21B	CC		●			●			●	●	●				●					●								●	●									●	●					●									●	●		○	●										●			
819 821	22	CC					●					X								●								●																	●	●								●			●										○	●			
	22B	CC				●																						●	●		●								●						●	●	●							●	●			●		●				○				○	○			
859 861	23	CC			●		●	●			●	X				●													●	●		●							●	●					●		●				●				●			●	●								○					
861		1	123-125			●	●	●								●													●	●		●							●	●	●				●	●	●				●				○			●	●		○			○								
867						●	●				●													●		●			●	●		●							X	●	●				●		●				●			●	●				●								○					

origin is best documented include Cores 10, 12, 13, 17, 18, 19 and 22.

Rates of Sedimentation (M.B.C.)

Three time markers could be recognized within the sections penetrated:

1) Base of the Pleistocene at 1.85 million years (the Olduvai event) assumed to fall within the uncored interval between Cores 6 and 7, or arbitrarily at 369 meters below bottom.

2) Top of the *Globorotalia margaritae evoluta*-zone at 3.36 million years (Gilbert-Gauss boundary or Datum VI of Saito in Hays *et al.*, 1969), assumed to fall between Cores 14 and 15, or arbitrarily at 670 meters below bottom.

3) Middle to later part of Zone N.16, corresponding to about 10 million years at the base of the section or at 862 meters below bottom.

The age of the last datum is not so precisely defined as that of the other two, as the pre-Pliocene paleomagnetic record has not yet been refined.

The computed rates of sedimentation are plotted in Figure 10. There is an apparently strong increase in the sedimentation rate from the Miocene-early Pliocene part of the section, where it approaches 2.8 cm/1000 yrs, to the Pliocene, where it exceeds 22 cm/1000 yrs. Even greater rates have been recorded at DSDP Site 1 in the Gulf of Mexico, where a minimum rate of 38 cm/1000 yrs has been calculated (Ewing *et al.*, 1969, p. 80) and at Site 26 in Vema Fracture Zone off the Amazon, where the rate approaches 120 cm/1000 yrs (Benson *et al.*, 1970, p. 662). However, at those sites the sedimentary sections include mainly turbidites. Yet the greatest part of the Quaternary section penetrated in the Alboran Basin consists of silty clay without any of the primary bedding structures characteristic of turbidites (Bouma, 1962). Core 6 is the only Quaternary core with coarse-grained sediment. A significant amount of terrigenous material in the form of clay minerals accounts, in part, for the high rate of accumulation at Site 121. Nevertheless, unusually high organic productivity must have played a significant role.

Abundance and Occurrence of Planktonic Foraminifera (M.B.C.)

Planktonic foraminifera are present in all the 24 cores investigated from Site 121 and, generally, they represent the most important component of the sediment fraction greater than 63 microns.

Their relative abundance and preservation, however, are variable. In many cores they are scattered and not well preserved, so that a precise age assignment was not possible. This is especially true for the turbidite layers of late Miocene to Pliocene age.

The ranges of 57 selected species in 48 samples from Cores 1 through 24 are shown in Table 3; the occurrences of mega-fossils and some detrital mineral grains are also noted on this range chart.

Planktonic Foraminifera of the Pleistocene (M.B.C.)

The sediment fraction greater than 63 microns in Cores 1 to 6, consists of foraminiferal shells, mostly planktonic, with some fine detritus (quartz, mica). All the Quaternary recovered belongs to the *Globorotalia truncatulinoides* Total-range-zone. The non-tropical Pleistocene cannot be subdivided by means of planktonic foraminifera, since no significant evolutionary event occurred during this time.

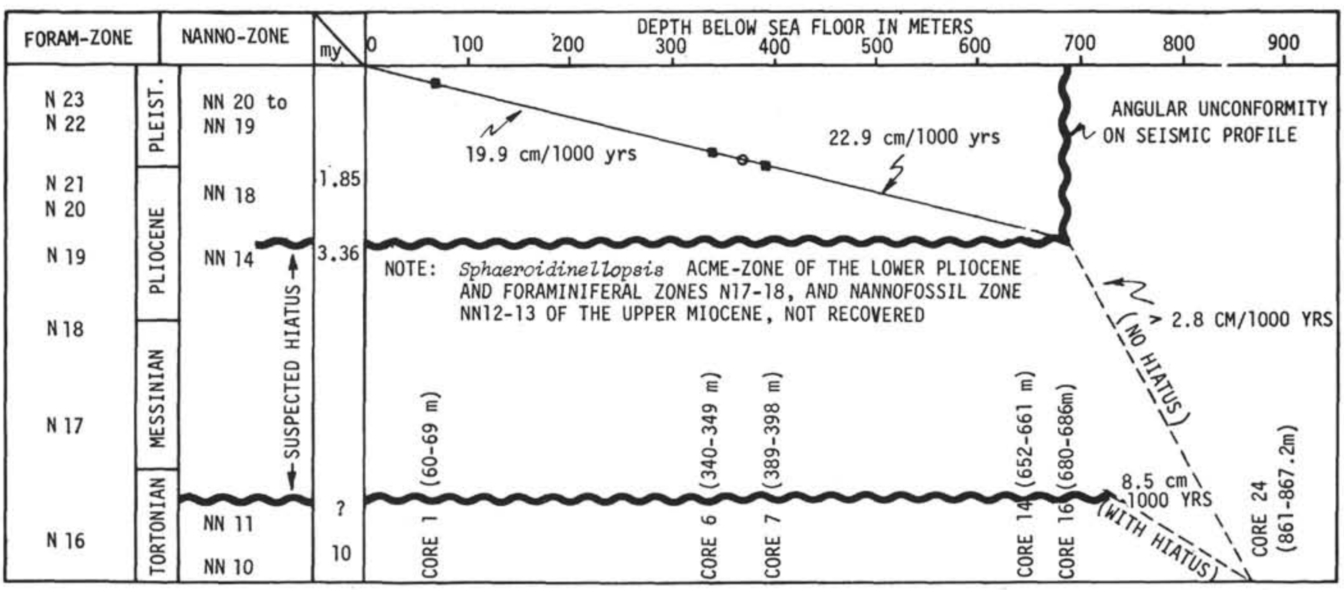

Figure 10. *Graph of interval sedimentation rates for Site 121. The marked break in the curve at 686 meters represents the angular unconformity (Horizon Purple) seen on the reflection profile of Figure 4. Because no sediment indicative of the Uppermost Miocene (Messinian) or lowermost Pliocene was recognized in Cores 17 to 21, a hiatus is inferred for this interval. The value of 2.8 cm/1000 yrs for the Miocene interval is based on continuous sedimentation. Since a major part of the Upper Miocene and Lower Pliocene is believed to have been eroded away, the actual accumulation rate during the Tortonian (Lower part of the Upper Miocene) may approach the present day rates.*

Planktonic Foraminifera of the Pliocene (M.B.C.)

The Pliocene/Pleistocene boundary is not clear-cut in terms of planktonic foraminifera in the deep-sea deposits of the Alboran Basin, as well as in most of the other basins. Core 6, cut from 339 to 348 meters below the sea floor, consists of a coarse sand with a great abundance of displaced shallow-water fossils including bryozoa, and epineritic benthic foraminifera. The bed is placed in the Pleistocene on the basis of its nannofossil content (absence of *Discoaster brouweri*).

The zonation used here for the Pliocene is new (see Chapter 47). Only three of the six Pliocene zones were recognized in the 330-meter thick Pliocene succession penetrated at Site 121. Perhaps the poor, non-diagnostic assemblages in Cores 12, 13, 14 may correspond to the *Sphaeroidinellopsis subdehiscens* Interval-zone of the Upper Pliocene (Piacenzian). We believe that real stratigraphic gaps resulting from submarine erosion may be present. The Lower Pliocene (Tabianian) is represented at Site 121, as demonstrated by the presence of *Globorotalia margaritae* in Cores 15 and 16. The relative thickness of this zone is much reduced, leading us to suspect that the lowermost Pliocene may be missing within the hiatus that separates the Pliocene from the Tortonian.

The Miocene-Pliocene Boundary (M.B.C.)

The Miocene-Pliocene boundary cannot be located precisely on the basis of planktonic foraminifera. Between Core 16, which is certainly Pliocene (occurrence of phylogenetically evoluted *Globorotalia margaritae*) and the Center Bit sample, 21B, which is surely Tortonian (occurrence of *Globorotalia acostaensis, G. merotumida, G. menardii, Globigerina nepenthes*), we have an interval which yielded only poor foraminiferal assemblages. The stratigraphic interval comprising Cores 17 to 21, with a thickness of about 100 meters, cannot be assigned to any definite zone (except that it is post-*Globorotalia acostaensis* datum). Nevertheless, we believe it is certainly within the Upper Miocene. The Messinian stage (Uppermost Miocene) corresponds mainly to the *Globorotalia plesiotumida* Zone (N.17) of Blow's zonal scheme and is apparently not represented at Site 121. Therefore, the Messinian is grouped with the lowermost Pliocene in the stratigraphic hiatus seen as the angular nonconformity in the seismic reflection profile of Figures 4 and 5.

Planktonic Foraminifera of the Upper Miocene (M.B.C.)

The age of the oldest sediments overlying the basaltic basement has already been discussed above. Some additional comments are added here. The faunal assemblages are less diverse than usual with two main populations present: one characterized by thick-walled, flattened turborotaliids, including *Globorotalia acostaensis* and *G. acostaensis humerosa*, the other one characterized by thin-walled, flattened turborotaliids, including *Globorotalia scitula, G. scitula gigantea* and *G. scitula ventriosa*. Representatives of the genus *Globigerinoides* are scarce, and those of *Globoquadrina* are absent. Keeled globorotaliids, which permitted precise zonation, were found only in the deepest cores recovered from Site 121.

Benthonic Foraminifera (W.M.)

The inventory of the main benthonic foraminifera determined from the Pleistocene-Pliocene and Upper Miocene (Tortonian) sequence drilled in Hole 121 from 60 to 867.2 meters below bottom (Cores 1 through 24), is given in Table 4. The age assignment of individual cores is based on the known stratigraphic range of both the planktonic foraminifera and the nannofossils. The first undoubted Miocene benthonic forms were found in Core 19 (*Bolivinoides miocenicus* Gianotti, *Uvigerina auberiana* d'Orbigny).

The 867 meter section of Site 121 is not represented by uniform biogenic pelagic oozes because many cores reveal the presence of clastic material such as quartz, mica (=betic molasse detritus) and particularly the presence of displaced fauna (thick-shelled mollusks, shallow-water benthonic foraminifera, scarce reworked Cretaceous forms, for example, in Core 10). It is obvious that intermittent basinward bottom currents, in part turbidity currents, must have brought in the allochthonous elements. A significant influx of clastic material is displayed in Cores 5, 6, 8 through 15, 18, and 22. The bathyal benthonic forms believed to live at depths below 200 meters include the genera *Bolivina*, costate *Uvigerina, Pullenia, Gyroidina, Epistomina elegans* (d'Orbigny), *Laticarinina pauperate* (Parker and Jones), *Planulina ariminensis-wuellerstorfi, Cassidulina subglobosa* Brady, *Nonion padanum-barleeanum, Nonion pompilioides* (Fichtel and Moll), etc. In Cores 5, 6, 10, 12, 14, 18, 21 and 22, these forms of a normal salinity environment are mixed with brachyhaline or oligo-mesohaline species which are characteristic of the inner shelf region (*Amphistegina lessonii* d'Orbigny in Core 12) or of brackish inshore waters (*Ammonia beccarii*(L.) *Elphidium macellum* Fichtel and Moll), *Hanzawaia boueana* (d'Orbigny and Miliolids). Obviously, these latter elements have been carried from a shallow-water, or even from a lagoonal milieu, to bathyal depths. Many of the displaced tests show signs of corrosion and of abrasion during transportation.

The Nannoplankton (H.S.)

All cores from Site 121 contain nannofossils in great abundance, not only autochthonous ones but also considerable numbers of reworked coccoliths from the Cretaceous, and discoasters and coccoliths from the early Tertiary (See Figure 11).

Cores 1 to 6 are from above the *Discoaster brouweri* extinction horizon and are assigned to the Pleistocene. Cores 1, 2 and 3 are assigned to the *Gephyrocapsa oceanica* Zone (NN 20), Cores 4 to 6 to the *Pseudoemiliania lacunosa* Zone (NN 19). Due to the reworking of nannofossiliferous sediment, the guide-fossils are not so common and thus the stratigraphic boundaries between the nannoplankton zones are not well defined.

The Pliocene section extends from Core 7 to Core 16. The *Discoaster brouweri* Zone was found in Cores 7, 8 and 9 (NN 18, Upper Pliocene). Apparently the *Discoaster pentaradiatus* Zone was not cored. This very thin nannoplankton zone, which in the Tyrrhenian Sea (13-132-10) comprises only three meters, must lie somewhere between Core 9 and Core 10 of Site 121. Cores 10 and 11 are

TABLE 4
Distribution Chart of the Main Benthonic Foraminifera in Hole 121, Alboran Basin

Age	Depth Below Sea Floor (m)	Cores	*Sigmoilina schlumbergeri* (Silv.)	*Quinqueloculina oblonga* (Mont.)	*Quinqueloculina vulgaris* d'Orbigny	*Articulina tubulosa* (Seg.)	*Dentalina leguminiformis* (Batsch)	*Lagena orbignyana* (Seg.)	*Bolivina alata-beyrichi*	*Bolivina catanensis* Seg.	*Bolivina dilatata* Reuss	*Bolivina pseudoplicata* Herr. All. & Earl.	*Bolivina spathulata* (Will.)	*Bolivina subspinescens* Cushman	*Bulimina marginata* d'Orbigny	*Bulimina pupoides* d'Orbigny	*Uvigerina peregrina-mediterranea*	*Planulina ariminensis* (d'Orbigny)	*Planulina wuellerstorfi* (Schwag.)	*Cibicides pseudoungerianus* (Cushman)	*Chilostomella czjzeki* Reuss
	Sea Floor 1173 m																				
Pleistocene	60-69	1	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Pleistocene	69-78	2	x	x			x					x		x	x		x	x		x	
Pleistocene	154-163	3	x	x		x				x			x	x	x		x	x		x	
Pleistocene	247-256	4	x				x							x			x	x	x	x	
Pleistocene	296-305	5	x						x					x			x			x	
Pleistocene	340-349	6	x								x										
Pliocene	389-398	7	x															x		x	
Pliocene	436-443	8	x																		
Pliocene	483-492	9	x														x			x	
Pliocene	517-526	10	x																		
Pliocene	557-566	11	x												x		x				
Pliocene	595-601	12	x							x							x	x			
Pliocene	624-630	13	x				x								x		x				
Pliocene	652-661	14	x								x						x	x	x	x	
Pliocene	679-680	15								x						x	x	x		x	
Pliocene	686-689	17								x								x		x	
Miocene (Tortonian)	708-715.5	18																			
Miocene (Tortonian)	728-737	19															x				
Miocene (Tortonian)	763-770	20																			
Miocene (Tortonian)	785-788	21																			
Miocene (Tortonian)	817	21B															x	x	x	x	
Miocene (Tortonian)	819-821	22																x		x	
Miocene (Tortonian)	821-859	22B																x			
Miocene (Tortonian)	859-861	23																	x	x	
Miocene (Tortonian)	861-867.2	24																x	x	x	

Age	Depth Below Sea Floor (m)	Cores	*Nonion padanum-barleeanum*	*Pullenia bulloides* (d'Orbigny)	*Pullenia quinqueloba* (Reuss)	*Gyroidina neosoldanii* Brotzen	*Karreriella bradyi* (Cushman)	*Pyrgo oblonga* (d'Orbigny)	*Robulus cultratus* Montf.	*Eponides umbonatus* (Reuss)	*Cibicides* cf. *floridanus* (Cushman)	*Cassidulina carinata* Silv.	*Bigenerina nodosaria* d'Orbigny	*Cyclogyra carinata* (Costa)	*Sigmoilina tenuis* (Czjzek)	*Rectobolivina dimorpha* (Parker & Jones)	*Globobulimina pacifica* Cushman	*Hyalinea balthica* (Schroeter)	*Fursenkoina davisi-complanata*	*Epistomina elegans* (d'Orbigny)	*Martinottiella communis* (d'Orbigny)
	Sea Floor 1173 m																				
Pleistocene	60-69	1	x	x	x	x															
Pleistocene	69-78	2				x	x	x	x	x	x	x									
Pleistocene	154-163	3	x			x						x	x	x	x	x	x	x	x	x	
Pleistocene	247-256	4				x							x								x
Pleistocene	296-305	5	x						x			x	x		x						
Pleistocene	340-349	6										x									
Pliocene	389-398	7	x	x							x										x
Pliocene	436-443	8																			
Pliocene	483-492	9	x									x									
Pliocene	517-526	10		x																	
Pliocene	557-566	11	x	x		x	x				x										
Pliocene	595-601	12	x	x							x										
Pliocene	624-630	13	x			x					x										x
Pliocene	652-661	14	x			x	x			x											
Pliocene	679-680	15	x			x				x											x
Pliocene	686-689	17	x			x															
Miocene (Tortonian)	708-715.5	18	x	x																	
Miocene (Tortonian)	728-737	19	x			x									x					x	
Miocene (Tortonian)	763-770	20					x		x												
Miocene (Tortonian)	785-788	21																			
Miocene (Tortonian)	817	21B	x			x	x		x	x											
Miocene (Tortonian)	819-821	22	x	x		x				x											
Miocene (Tortonian)	821-859	22B				x															
Miocene (Tortonian)	859-861	23	x	x		x			x		x				x						x
Miocene (Tortonian)	861-867.2	24	x			x				x	x										

TABLE 4 – *Continued*

Pyrgo bulloides (d'Orbigny)	*Nodosaria inflexa* Reuss	*Dentalina advena* (Cushman)	*Dentalina mucronata* Neugeb.	*Siphonodosaria monilis* (Silv.)	*Cibicides lobatulus* (Walk. & Jac.)	*Textularia sagittula soldanii* Forn.	*Spiroloculina excavata* d'Orbigny	*Dentalina* cf. *filiformis* (d'Orbigny)	*Dentalina intorta* (Derv.)	*Plectofrondicularia raricosta* (Karrer)	*Bulimina* cf. *affinis* d'Orbigny	*Bulimina ovata* d'Orbigny	*Siphonodosaria adolphina* (d'Orbigny)	*Siphonodosaria consobrina* (d'Orbigny)	*Angulogerina angulosa* (Will.)	*Ammonia beccarii* (Linn.)	*Elphidium macellum* (Fichtel & Moll)	*Pleurostomella alternans* Schwag.	*Cassidulina subglobosa* Brady	*Spiroplectammina wrighti* (Silv.)	*Elphidium crispum* (Linn.)	*Nonion boueanum* d'Orbigny	*Orthomorphina jedlitschkai* (Thalm.)	*Bolivina punctata* d'Orbigny	*Laticarinina pauperata* (Parker & Jones)	*Gyroidina umbonata* (Silv.)	*Uvigerina canariensis* d'Orbigny	*Siphonina reticulata* (Czjzek)	*Eponides* cf. *haidingeri* (Brady)	*Bulimina aculeata basispinosa* Ted. & Zanm.	*Robulus orbicularis* (d'Orbigny)	*Bulimina costata* d'Orbigny	*Siphonodosaria* cf. *verneuili* d'Orbigny	*Amphistegina lessonii* d'Orbigny	*Lagena quadricostulata* Reuss	*Saracenaria italica* Defr.	*Plectofrondicularia* cf. *inaequalis* (Costa)	*Uvigerina rutila* Cushman	*Nonion pompilioides* (Fichtel & Moll)	*Reophax* cf. *dentaliniformis* Brady	*Reophax* cf. *fusiformis* (Will.)	*Pyrgo serrata* (Bailey)	*Uvigerina* cf. *auberiana* d'Orbigny	*Vulvulina pennatula* (Batsch)	*Lagena marginata* (Montagu)	*Robulus curviseptus* (Seg.)	*Dentalina* cf. *inornata* d'Orbigny	*Lenticulina* cf. *gibba* d'Orbigny	*Marginulinopsis* sp. aff. *fragaria* Gümbel	*Marginulina glabra* d'Orbigny
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TABLE 4 – *Continued*

Age	Depth Below Sea Floor (m)	Cores	*Bolivinoides miocenicus* Gianotti	*Uvigerina auberiana* d'Orbigny	*Discorbis globularis* d'Orbigny	*Valvulineria bradyana* (Forn.)	*Eponides ecuadorensis* (Gall. & Morrey)	*Gyroidina laevigata* d'Orbigny	*Robulus simplex* (d'Orbigny)	*Bolivina antiqua* d'Orbigny	*Bolivina arta* Mcfad.	*Bulimina* gr. *aculeata* d'Orbigny	*Reussella spinulosa* (Reuss)	*Asterigerina planorbis* d'Orbigny	*Cibicides aknerianus* d'Orbigny	*Cibicides dutemplei* (d'Orbigny)	*Cibicides floridanus miocenicus* Colom	*Cibicides ungerianus* (d'Orbigny)	*Spiroplectammina deperdita* (d'Orbigny)	*Lagena costata* Will.	*Hopkinsina bononiensis* (Forn.)	*Elphidium aculeatum* (d'Orbigny)	*Elphidium* cf. *advenum* (Cushman)	*Elphidium complanatum* (d'Orbigny)	*Elphidium fichtelianum* (d'Orbigny)	*Cibicides maioricensis* Colom	*Astrononion stelligerum* (d'Orbigny)	*Gyroidina girardana* (Reuss)	*Eponides umbonatus stellatus* (Silv.)	*Cibicides robertsonianus* (Brady)	*Pleurostomella* cf. *incrassata* Hantk.	*Chilostomella ovoidea* (Reuss)	*Gyroidina longispira* Ted. & Zanmatti	*Dorothia pupoides* (d'Orbigny)	*Robulus crassus* d'Orbigny	*Bolivina reticulata* Hantk.	*Uvigerina flinti* Cushman	*Cassidulina laevigata* d'Orbigny	*Bulimina inflata* Seg.	*Uvigerina schwageri* Brady	*Cibicides* gr *mexicanus* Nutt.	*Astrononion tumidum* Cush. & Edw.
	Sea Floor 1173 m																																										
Pleistocene	60-69	1																																									
	69-78	2																																									
	154-163	3																																									
	247-256	4																																									
	296-305	5																																									
	340-349	6																																									
Pliocene	389-398	7																																									
	436-443	8																																									
	483-492	9																																									
	517-526	10																																									
	557-566	11																																									
	595-601	12																																									
	624-630	13																																									
	652-661	14																																									
	679-680	15																																									
	686-689	17																																									
Miocene (Tortonian)	708-715.5	18																																									
	728-737	19	x	x	x	x	x	x																																			
	763-770	20							x																																		
	785-788	21																																									
	817	21B	x			x				x	x	x	x	x	x	x	x	x																									
	819-821	22				x			x	x	x		x	x		x			x	x	x	x	x	x	x	x	x	x															
	821-859	22B					x				x				x		x	x							x				x	x	x	x	x										
	859-861	23	x								x			x		x		x																x	x	x	x	x					
	861-867.2	24	x	x							x			x				x										x		x									x	x	x	x

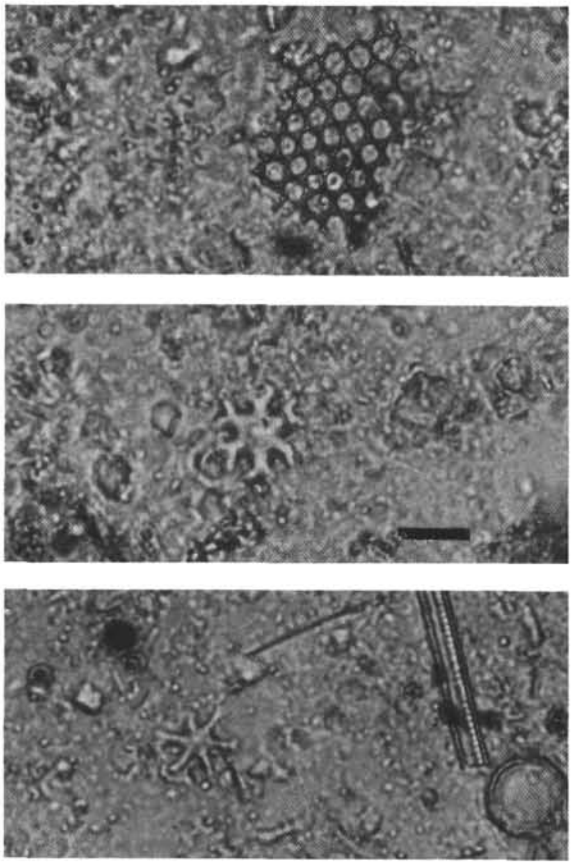

Figure 11. *Allochthonous discoasters in Quaternary marl ooze, accompanied by fragments of diatoms and sponge spicules. These particular components are believed to be reworked from older deposits into the fine-grained Quaternary, hemi-pelagic sediments. Scale bar represents 10 microns.*

assigned to the *Discoaster surculus* Zone; the zone fossil is rather common in Core 10, Section 2 (NN 16), lower part of the Upper Pliocene). Core 12 is from the *Reticulofenestra pseudoumbilica* Zone (NN 15, upper part of the Lower Pliocene, according to Martini and Worsley, 1971; but lower part of Upper Pliocene according to our usage—see Chapter 47). The Cores 13, 14 and 15 contain *Discoaster asymmetricus* and, in Core 15 a single specimen of *Ceratolithus tricorniculatus* was found. Thus Core 15 can be assigned to the NN 14 nannoplankton zone, which is Lower Pliocene. The ceratoliths are rather rare; therefore, the upper boundary between NN 14 and NN 15 cannot be precisely located. Below Core 15 the assemblages are dominated by *Discoaster challengeri* and *Discoaster variabilis*. Discoaster surculus is rare below Core 16. Cores 20 to 24 contain *Discoaster bollii*, which, according to Martini indicates a Middle to Upper Miocene age (NN 9 and NN 11; Core 24-CC). *Sphenolithus abies*, which was found in the deepest sample of this site, has its first occurrence in the lower part of the *Discoaster calcaris* Zone (NN 10) in the Lower Part of the Upper Miocene. For Cores 20 to 24 there is good agreement with the planktonic foraminiferal zonation. Zones N 16-N 17 of the planktonic foraminifera correspond to the NN 10-NN 11 nannoplankton zones—the *Discoaster calcaris* and the *D. quinqueramus* Zones, respectively. These two zonations also coincide in the same horizons at the type locality of the Tortonian in Italy. Even with the marker-fossils lacking, the age of Cores 20 to 24 can be determined through the occurrence of *Discoaster bollii* and *Sphenolithus abies*. Due to the lack of zone markers we are unsure of any precise age assignment, for Cores 17 to 19.

The age-diagnostic nannofossil assemblages are shown below:

Quaternary

Samples: 121-1-1, 73-74 cm; 121-1-2, 70-73 cm; 121-1-3, 76-77 cm; 121-1-4, 73-74 cm; 121-1-5, 77-78 cm; 121-1-CC:

Braarudosphaera bigelowi
Coccolithus pelagicus
Cyclococcolithus leptoporus
Gephyrocapsa oceanica
Helicosphaera carteri
Lithostromation perdurum
Pontosphaera japonica
Reticulofenestra pseudoumbilica

Age: Middle to late Quaternary (NN20).

Samples: 121-2-1, 75-76 cm; 121-2-2, 96-97 cm; 121-2-3, 78-79 cm; 121-2-4, 74-75 cm; 121-2-5, 80-85 cm; 121-2-6, 75-76 cm; 121-2-CC:

Coccolithus pelagicus
Cyclococcolithus leptoporus
Discolithina macropora
Gephyrocapsa oceanica
Helicosphaera carteri
Pontosphaera scuttellum
Pontosphaera multipora
Syracosphaera pulchra

Age: Middle to late Quaternary (NN20).

Samples: 121-3-1, 116-117 cm; 121-3-2, 74-75 cm; 121-3-3, 70-71 cm; 121-3-4, 73-74 cm; 121-3-CC:

Coccolithus pelagicus
Cyclococcolithus leptoporus
Gephyrocapsa oceanica
Helicosphaera carteri
Pontosphaera scutellum
Rhabdosphaera stylifera

Age: Middle to late Quaternary (NN20).

Samples: 121-4-1, 74-75 cm; 121-4-2, 73-74 cm; 121-4-3, 79-80 cm; 121-4-4, 73-74 cm; 121-4-5, 99-80 cm; 121-4-6, 67-68 cm; 121-4-CC:

Braarudosphaera bigelowi
Coccolithus pelagicus
Cyclococcolithus leptoporus
Gephyorcapsa oceanica
Helicosphaera carteri
Pseudoemiliania lacunosa
Pontosphaera scutellum
Sphenolithus abies

Age: Early Quaternary (NN19).

Sample: 121-5-CC:

Braarudosphaera bigelowi
Coccolithus pelagicus

Cyclococcolithus leptoporus
Discolithina macropora
Lithostromation perdurum
Microascidites sp.
Pontosphaera japonica
Pseudoemiliania lacunosa
Rhabdosphaera stylifera
Sphenolithus abies
Thoracosphaera imperforata
Age: Early Quaternary (NN19).

Sample: 121-6-CC:
Coccolithus pelagicus
Cyclococcolithus leptoporus
Gephyrocapsa oceanica
Helicosphaera carteri
Lithostromation perdurum
Pontosphaera scutellum
Pseudoemiliania lacunosa
Rhabdosphaera clavigera
Age: Early Quaternary (NN19).

Pliocene

Sample: 121-7-CC:
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster brouweri (rare)
Discoaster challengeri (very rare)
Helicosphaera carteri
Pontosphaera japonica
Rhabdosphaera clavigera
Rhabdosphaera stylifera
Scapholithus fossilis
Scyphosphaera apsteini
Age: Upper Pliocene (NN 18).

Samples: 121-8-1, 100-101 cm; 121-8-CC:
Braarudosphaera bigelowi
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster brouweri
Discolithina macorpora
Helicosphaera carteri
Lithostromation perdurum
Pontosphaera scutellum
Thoracosphaera imperforata
Age: Upper Pliocene (NN 18).

Sample: 121-9-CC:
Braarudosphaera bigelowi
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster brouweri
Lithostromation perdurum
Pontosphaera scutellum
Scyphosphaera apsteini
Age: Late Pliocene (NN 18).

Samples: 121-10-1, 114-115 cm; 121-10-2, 79-80 cm; 121-10-CC:
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster brouweri
Discoaster surculus
Helicosphaera carteri
Age: Lower part of Upper Pliocene (NN 16).

Sample: 121-11-CC:
Ceratolithus rugosus
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster brouweri
Discoaster surculus
Helicosphaera carteri
Pontosphaera japonica
Pontosphaera multipora
Pontosphaera scutellum
Age: Lower part of Upper Pliocene (NN 16).

Sample: 121-12-CC:
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster brouweri
Discoaster surculus
Discoaster variabilis
Reticulofenestra pseudoumbilica
Thoracosphaera imperforata
Age: Lower part of Upper Pliocene (NN 15).

Sample: 121-13-CC:
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster asymmetricus
Discoaster brouweri
Discoaster surculus
Helicosphaera carteri
Lithostromation perdurum
Pontosphaera scutellum
Reticulofenestra pseudoumbilica
Age: Lower Pliocene (NN 14-NN 15).

Sample: 121-14-CC:
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster asymmetricus
Discoaster surculus
Discoaster variabilis
Lithostromation perdurum
Pontosphaera japonica
Reticulofenestra pseudoumbilica
Rhabdosphaera stylifera
Age: Lower Pliocene (NN 14-NN 15).

Samples: 121-15, 1-1 cm; 121-15-CC:
Ceratolithus tricorniculatus
Coccolithus pelagicus
Cyclococcolithus leptoporus
Cyclolithella rotula
Discoaster brouweri
Discoaster asymmetricus
Discoaster surculus
Discoaster variabilis
Helicosphaera carteri
Lithostromation perdurum
Pontosphaera multipora
Reticulofenestra pseudoumbilica
Scyphosphaera campanula
Age: Lower Pliocene (NN 14).

Miocene

Sample: 121-16-CC:
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster variabilis
Helicosphaera carteri
Pontosphaera japonica
Reticulofenestra pseudoumbilica
Sphenolithus abies
Age: Upper Miocene/Lower Pliocene?

Sample: 121-17-CC:
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster variabilis
Helicosphaera carteri
Pontosphaera japonica
Reticulofenestra pseudoumbilica
Sphenolithus abies
Age: Upper Miocene/Lower Pliocene?

Samples: 121-17B; 121-18-CC:
Braarudosphaera bigelowi
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster challengeri
Discoaster variabilis
Helicosphaera carteri
Lithostromation perdurum
Pontosphaera multipora
Pontosphaera scutellum
Reticulofenestra pseudoumbilica
Sphenolithus abies
Age: Upper Miocene/Lower Pliocene?

Sample: 121-19-CC:
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster variabilis
Helicosphaera carteri
Lithostromation perdurum
Pontosphaera japonica
Pontosphaera multipora
Reticulofenestra pseudoumbilica
Sphenolithus abies
Age: Upper Miocene/Lower Pliocene?

Sample: 121-20-CC:
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster bollii
Discoaster variabilis
Helicosphaera carteri
Lithostromation perdurum
Reticulofenestra pseudoumbilica
Pontosphaera multipora
Sphenolithus abies
Age: Upper Miocene (NN10 - NN11).

Sample: 121-21-CC:
Coccolithus pelagicus
Discoaster bollii
Discolithina macropora
Reticulofenestra pseudoumbilica
Age: Upper Miocene (NN 10-NN 11).

Sample: 121-21B; (Center Bit):
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster bollii
Discoaster variabilis
Helicosphaera carteri
Lithostromation perdurum
Pontosphaera multipora
Pontosphaera scutellum
Reticulofenestra pseudoumbilica
Age: Upper Miocene (NN 10-NN 11).

Sample 121-22-CC:
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster bollii
Discoaster challengeri
Discoaster variabilis
Discolithina macorpora
Lithostromation perdurum
Pontosphaera multipora
Pontosphaera scutellum
Reticulofenestra pseudoumbilica
Thoracosphaera deflandrei
Age: Upper Miocene (NN 10-NN 11).

Sample: 121-23-CC:
Coccolithus pelagicus
Cyclococcolithus leptoporus
Discoaster bollii
Discoaster variabilis
Helicosphaera carteri
Lithostromation perdurum
Pontosphaera japonica
Pontosphaera multipora
Reticulofenestra pseudoumbilica
Sphenolithus abies
Age: Upper Miocene (NN 10-NN 11).

Sample 121-24-CC:
Coccolithus pelagicus
Discoaster bollii
Discoaster brouweri
Discoaster pansus
Discoaster variabilis
Helicosphaera carteri
Lithostromation perdurum
Pontosphaera multipora
Reticulofenestra pseudoumbilica
Sphenolithus abies
Age: Upper Miocene (NN 10-NN 11).

Radiolaria

At Site 121, radiolarian skeletons were found only in Core 3, Section 4, where they appear quite subordinately in a rich planktonic foraminifera association. The radiolarian assemblage is composed of members of the family Actinommiidae (*sensu* Riedel), among which the large specimens of *Actinomma antarcticum* (Haeckel) are most obvious. Besides this, the following species have been encountered:

Panarthus tetrathalamus Haeckel
Heliodiscus asteriscus Haeckel
Porodiscus cf. *flustrella* Haeckel
Amphirhopalum ypsilon Haeckel
Pterocanium trilobum (Haeckel)
Lamprocyclas maritalis Haeckel
Theocorythium trachelium (Ehrenberg)
Eucyrtidium acuminatum (Ehrenberg)
Eucyrtidium cf. *calvertense* Martin

Other species belonging to the genera *Cladococcus, Hexacontium, Carpocanium, Echinomma, Prunopyle, Euchitonia, Spongobrachium, Tholodes, Spirocyrtis* are also present.

This assemblage is very similar to those described from the present-day waters by Haeckel, Hollande and Enjumet, Nigrini, etc. Some species, such as *Panathus tetrathalamus, Heliodiscus asteriscus, Amphirhopalum ypsilon, Pterocanium trilobum*, have a stratigraphic range restricted to the Quaternary. The age established by the calcareous fossils, thus, is clearly supported.

As for the climatic regime, most of the species are known in waters today as having a geographical distribution restricted to low and middle latitudes. They are therefore warm-water indicators.

Besides the radiolarians, in the same assemblage sponge spicules, rare diatom specimens and rare specimens of *Dictyocha fibula* have been recorded. The latter species is also a warm-water indicator.

LITHOSTRATIGRAPHY

Despite poor recovery in the single hole that was drilled down to basement, closely-spaced intermittent coring permitted an inferred stratigraphic succession to be presented. Four main lithological units were distinguished, which are 1) Quaternary marl oozes; 2) Quaternary to Lower Pliocene marls and turbidite sands and sandstones; 3) Miocene marls, sands, and sandstones, and 4) Basement of mafic rocks, granodiorite, and biotite schist.

TABLE 5
Lithologic Units of Site 121

Unit	Lithology	Age
1	Marl ooze, pelagic	Quaternary
290 m		
2	Marls, sands, and sandstones, turbidities	Lower Pleistocene to Lower Pliocene
686 m		
3	Marls, sands, sandstones, mainly pelagic in the lower part	Upper Miocene (Tortonian)
864 m		
4	Basement, gneiss, granodiorite, biotite-quartz schist	
867 m		

Unit 1 – Marl Ooze

Marl oozes were encountered between 60 and 290 meters. The unit is entirely Quaternary, the lower horizons being in the *Pseudoemiliania lacunosa* Zone. The dark greenish-gray oozes are plastic and show few visible structures.

Irregular bedding contacts and thin dark laminae rich in organic plant remains as seen in Core 1 (Figure 12) are suggestive of current reworking and winnowing. Black specks and streaks may indicate hydrotroilite. Foraminiferal tests are occasionally filled with pyrite. Layers with minor amounts of foraminifera in sharp contact with layers without foraminifera are indicative of selective size-sorting by bottom currents. Displacement of shallow fauna, and the occurrence of reworked older nannoplankton have been discussed in the section on Biostratigraphy. Very thin pockets of sand seen in surface piston cores (RC 9-205) and Cores 1 and 4 may have been rafted into the deep basin by ice during the Pleistocene glaciations, or more likely they may be products of traction transport by geostrophic currents. The facies of sediment in Unit 1 has an aspect which calls to mind that seen in outer-ridges above the level of calcium carbonate compensation; that is, DSDP Sites 102, 103, 104. Furthermore the high rate of sediment accumulation calculated at 19.9 cm/1000 yrs for the Pleistocene section of the Alboran Basin is also directly comparable with the rate of 19/cm/1000 yrs calculated for the Middle Miocene of the Blake-Bahama Outer Ridge. The sediments of both localities consist of fine terrigenous debris (silty clays), with a dominant component in the Alboran Basin of fine-grained quartz and clay minerals. The carbonate fraction (25 to 35 per cent) comprises nannoplankton with rare foraminifera and minor amounts of detrital dolomite. Photomicrographs of smear slides of Unit 1 are shown in Figure 13.

Because the surface piston cores from the western basin of the Alboran Sea generally show a similar marl ooze with one thin sand-silt layer (Huang and Stanley, 1971), we suggest that Unit 1 extends to the present sea floor. Therefore, since the Calabrian, the Alboran Basin has been the site of a more or less uniform sedimentary regime conducive to the accumulation of fine-grained silty clays; while during the preceding period, when Unit 2 was deposited, conditions were more favorable for turbidity-current deposition. The bottom of Unit 1 may be represented by an interval of fast drilling at 287 meters where the presence of easily washed sand is suggested.

Unit 2 – Marls, Turbidite Sands, and Sandstones

Sands and marls were encountered between 290 and 686 meters. Their age ranges from Quaternary (Calabrian) to Lower Pliocene.

The deposits consist of alternate layers of marl oozes and sands. The marl ooze layers are dark greenish-gray to olive-gray, and consist of 30 per cent nannoplankton and foraminifera and 70 per cent fine terrigenous debris (mainly quartz, mica, and clays). They show fine horizontal laminations. In the upper part of the unit they are plastic, but become stiffer with depth. In Core 9 (483 meters) and below, they are consolidated to marls, becoming brittle and fissile.

The sand layers are dark-gray to medium-dark-gray. They consist mainly of terrigenous angular quartz (70 per cent), mica (20 per cent), feldspar (5 per cent) (Figure 14),

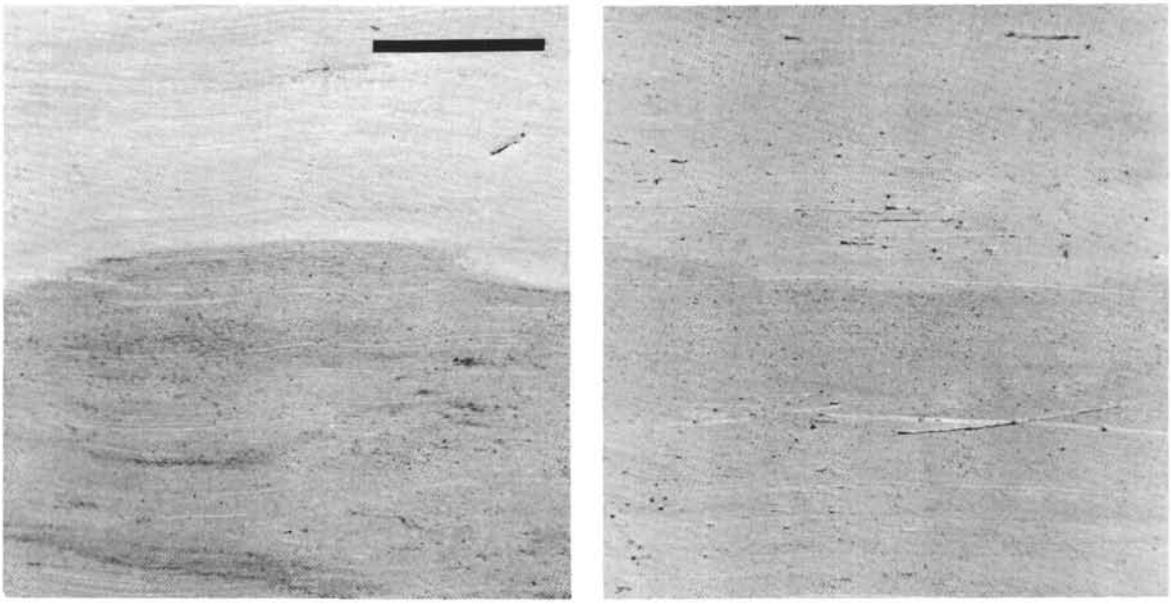

Figure 12. *Examples of current reworking in Unit 1–Quaternary marl ooze. Dark laminae (lower left) and unconformable, abrupt bedding contacts are indicative of controlled deposition (size-sorting of organic matter, grain imbrication, etc.) and erosion. Distinct contacts between oozes with abundant foraminifera (upper right, e.g. the small holes produced by scraping of the core surface) and oozes without foraminifera may result from winnowing and selective deposition of the fine-grained products. Scale bar represents 1 centimeter.*

and small amounts of nannoplankton (2 to 3 per cent) and foraminifera (2 per cent) often reworked, size-sorted, and comprising displaced shallow water benthonic species.

Due to poor recovery, very few sections were seen which contain more than one turbidite sequence. When visible, the lower limits of sequences are always seen to be sharp, while the passage from silt to clay is either sharp or gradational as shown in Figure 15. Some of the sand layers are well-graded, with the "a" interval of the turbidite sequence invariably present when the bed is not broken up by drilling disturbances. Parallel laminations are often present, and often consist of mud laminae, or lenses rich in plant fibers and mica. No convolute laminae or cross-bedding was observed. The basal sand unit is quite muddy, generally poorly sorted, with the matrix consisting of nannofossil ooze and clay minerals, and is often very thin. The transition from the upper laminated "d" interval to the pelite layer is more often abrupt than gradational. On several occasions inverse grading can be noted, and single beds can be made up of a composite of several individual units, each characterized by clastics of different mineralogy and grain size. The ratio of sand to clay in a single core is usually less than 1:4. Minor truncation of underlying clay units can be seen in Core 8 at 94 centimeters (Figure 15). The thickness of the turbidite sequences ranges from 10 centimeters to 1 meter. The first sand, in the form of a sandstone with calcitic cement, was found in Core 6 (349 meters). Below this depth, layers of sandstone occur quite irregularly–often only a single bed of sandstone occurs in each core section, with the other sand layers being unlithified.

On the seismic profiles numerous reflectors are noted, some of which correspond to the indurated non-porous rock units present in Hole 121. In recovered cores we identified four sandstone layers in Unit 2 (at 349, 445, 526 and 661 meters). The uncored intervals undoubtedly contain additional indurated horizons.

The sandstones are fine-grained and contain rounded mud clasts or "mud-balls" (Figure 16). One sandstone unit illustrated contains either a very large mud fragment or the preserved protrusion of a sole mark. The cement consists of a spary-calcite with minor amounts of dolomite. Marls recovered directly above or below the sandstones are unlithified as are the interbedded "mud-balls." X-radiographs did not reveal significant lamination and demonstrated that the mud units were individual fragments rather than the infilling of burrows. Polished faces on the sandstone pieces did not reveal grading or macro-lamination, but only slight grain-imbrication. The units are apparently massively bedded.

The deposits of Unit 2 exhibit sedimentological features characteristic of high energy depositional environments, accompanied by high mean rates of sedimentation (>23 cm/1000 yrs), comparable to those of some Alpine Flysch formations. Although the sands and sandstones have the appearance of turbidites, we cannot discount secondary reworking as the cause of some of the observed bedding structures.

Unit 3 – Marls, Sands and Sandstones

Marls, sands and sandstones were encountered between 686 and 862 meters. They are largely Tortonian in age.

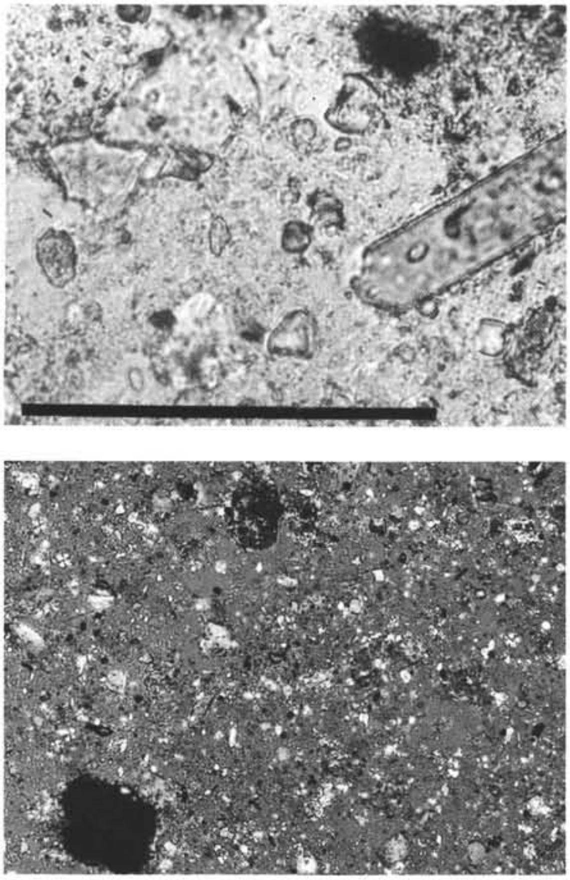

Figure 13. *Smear slide microphotographs of Unit 1 (Core 4) showing coarse-grained, silty clays (top) and fine-grained muds (bottom). Scale bar represents 100 microns. Note pyrite filled foraminifera, and small dolomite rhombs. The fine fraction is generally made up of about 30% coccoliths and 70% clay minerals, the dominant mineral being illite. In the silt and sand fraction, the major mineral component is quartz, both angular and subrounded. Volcanic glass was only found as individual shards, never as layers of tephra.*

These sediments are dark greenish-gray in color, and composed mainly of terrigenous detritus: 70 per cent quartz, mica and clays, together with nannoplankton and foraminifera. A few dolomite layers are intercalated. They are consolidated, brittle and fissile, with fine laminations, imparting a shaly character. Of note is the greater abundance of the clay mineral montmorillonite in Unit 3 while it is less frequent above. In addition, the percentage of mica drops significantly from a mean of 40 per cent in Units 1 and 2 to 24 per cent in Unit 3.

Thin layers of graded sands or sandstones in Cores 18 and 22, indicate some turbidity current activity. In Core 21 a single fragment of limestone was found.

At the base of the unit, between 860 and 863 meters, the marl oozes overlying the basement rocks and the matrix of the basal conglomerate show no obvious signs of baking by contact metamorphism. These oozes are more calcareous (40 per cent calcium carbonate) than above and, in addition to quartz, contain calcite, dolomite and a clay mineral suite containing mostly kaolinite. Illite, montmorillonite and mixed-layered clays are also present.

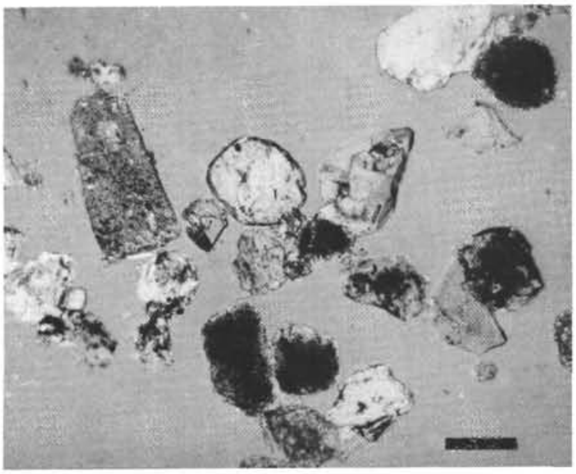

Figure 14. *The washed sand fraction (>62 μ) of Unit 2 (Core 10). Scale bar represents 100 microns. Note the well-rounded quartz grain (center) and the abraded fragments of calcite (lower center). Mica is commonly the second-most abundant mineral component to quartz.*

The lowermost marls of Unit 3 were apparently deposited in a hemipelagic environment similar to that prevalent during the deposition of Unit 1.

Unit 4 – Basement

The hole reached bottom at 867 meters in basement rocks, 0.3 meter of which was recovered in the core catcher of Core 24. They consist of 25 centimeters of breccias, microbreccias, a macro-conglomerate, a sandstone unit, and a massive fragment of biotite hornfels. The conglomerate contains an assemblage of rock fragments including granodiorites, biotite-quartz-schist, and biotite-plagioclase gneiss. The petrology of the Alboran basement rocks is discussed further in Chapter 27.1 of Part II of this volume.

PHYSICAL PROPERTIES

Graphical summaries of the cores show details of the physical properties measured on sediments in the upper 450 meters of the hole only. The deeper cores had poor recovery. Their properties are not plotted.

Penetrometer values were scattered. However, a general increase in induration is detected with depth as the marls become progressively stiffer. Readings fall within the range from 145.7 mm at the top to 13.3×10^{-1} at the bottom, with an anomalously low reading of 7.7×10^{-1} for Core 4, Section 5.

Bulk density values varied between 1.612 and 1.834 gm/cc with minimum values occurring in Core 3 samples, which are plastic marl oozes. Grain density values lie in the range 2.187 to 2.715 gm/cc. An inverse correlation between penetrometer and bulk density values exists. Interstitial water content and porosity were systematically measured only for Cores 1 to 4 (depth 64 to 254 meters), and a downward decrease is seen for both sets of data from 28.8 to 23.4 per cent and 50.2 to 39.4 per cent, respectively. The values increase slightly and fluctuate at around 31 and 53 per cent, respectively, in Cores 2 and3.

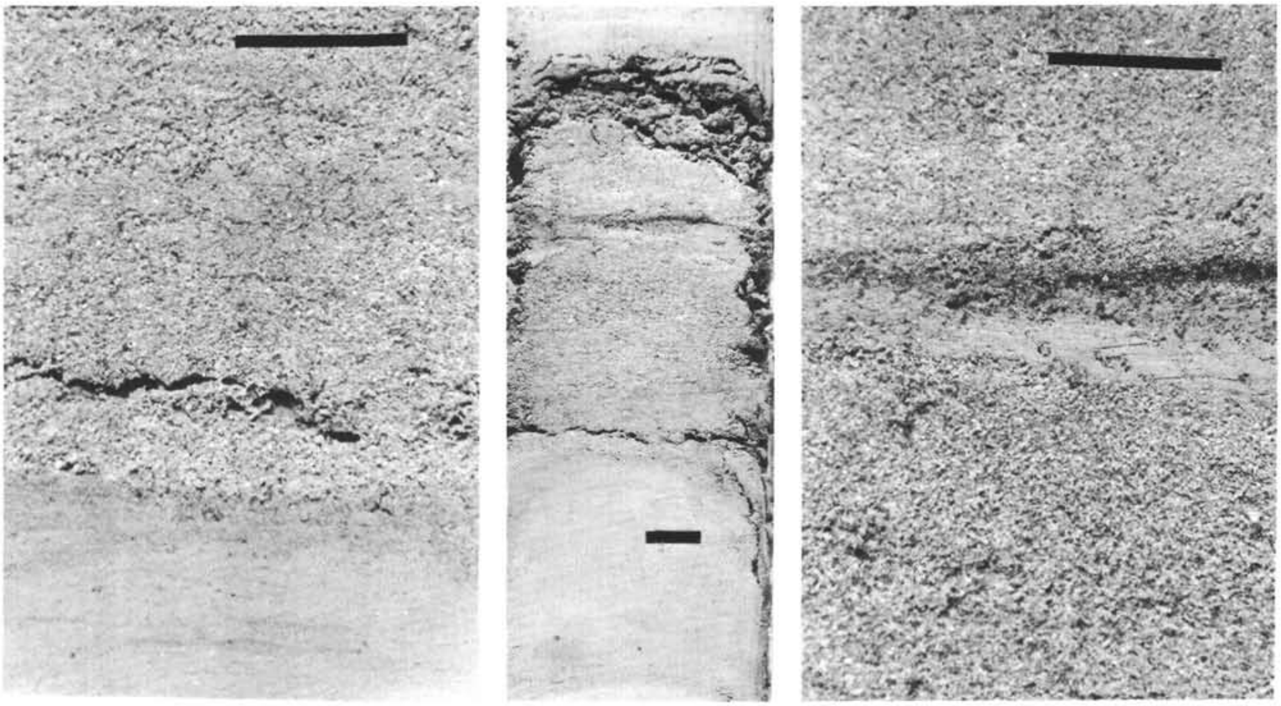

Figure 15. *Examples of sedimentary structures most commonly seen in the sand layers of Unit 2. An enlargement of the sharp basal contrast is illustrated at the left. Note the slight truncation of faint bedding planes in the sub-adjacent marl. The lower part of the sand unit is graded. An enlargement of the upper (?) interval of parallel lamination at the right shows the two types of laminae generally observed. One is very rich in mud (light colored) and the other rich in organic matter (dark). No convolute laminations were seen in the Alboran Basin sand layers. The passage from the interval of parallel lamination to the pelitic interval is, in most cases, abrupt as shown in the central photo of the entire bed (Core 8, Section 1, 90 cm.). Scale bars represent 1 centimeter.*

Natural gamma readings show variation within individual cores which might indicate influxes of terrigenous material containing different proportions of radioactive bearing minerals; there is a high proportion of terrigenous debris in these cores. Counts range from 2400 to 3300 in the marls of the upper cores. Within turbidites of lower cores, singular high counts may be correlated with horizons of sands, such as in Core 10-2 where a peak count of 3500 is registered in contrast to the "background" of 3000 in interbedded oozes.

SUMMARY AND CONCLUSIONS

A most interesting, but at present perplexing history of cycles in clastic input, complex patterns of sediment distribution perhaps controlled at times by near sea-floor currents, periods of unusually high organic productivity, selective fresh-water lithification, even episodes of anomalous high salinity, and a major stratigraphic unconformity, emerges from our preliminary examination of the recovered sedimentary materials from Site 121, in the western Alboran Basin.

Marl Oozes of the Quaternary

As mentioned in the introduction of this chapter, one of the most striking aspects of the seismic reflection profiles in the basin is the occurrence of a highly stratified ($\approx$0.3 seconds thick) carpet of sedimentary materials which lies in uniform thickness and conformable attitude on both the basin floor and on the high relief of the intrabasin ridge and continental slope.

This carpet, identified as facies 1 on the *Charcot* reflection profile, was penetrated by the drill string, and in part recovered in Cores 1 through 4 (see Figure 17). The lithofacies described as Unit 1 (= marl ooze) offers some hints as to the probable cause of the uniform mode of deposition. The marl ooze is generally fine-grained in texture. Of note are the olive-green and black speckled (hydrotriolite?) marls with occasional thin lenses of sands, often accompanied by pteropods, and characterized by foraminiferal populations preferring a temperate environment. Steel blue, homogeneous marls with some terrigenous material are characterized by cold-water assemblages.

In Cores 3 and 4, moderately burrowed olive-green oozes are intercalated with darker green oozes quite sparse in foraminifera. More than twenty such rhythms per meter of core indicate pulses in the sediment source. Laminae rich in plant fibers, and irregular bedding contacts (Figure 12a) indicate, in our opinion, selective sediment transport and/or reworking at the sediment-water interface. The beds without coarse material may be the redeposited winnowed muds; beds rich in the coarse material may be the residues. Evidence of recycling of the sediment is plentiful, with the identification of at least some allochthonous nannoplankton in every smear slide (Figure 11). However, most of the nannoplankton are autochthonous, and since they

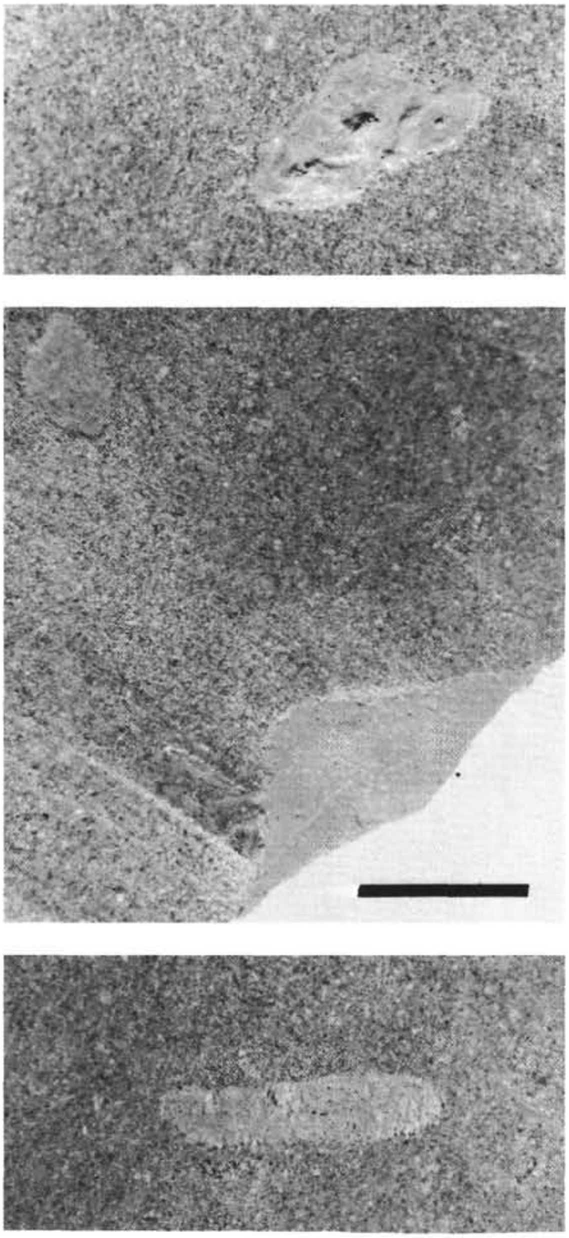

Figure 16. *Examples of mud clasts preserved in sandstone of Unit 2 (Core 15). The "mud-balls" are unlithified. The lower part of the center figure shows an oriented photo of what may be the bedding contact between a sole mark (flute, groove cast, etc.) and the previously deposited marl. The laminations are artifacts (e.g. saw-marks during sectioning). The scale bar represents 1 centimeter.*

dominate the calcareous fraction of the sediment, we are compelled to accept that the high rate of sedimentation for facies 1 (>20 cm/1000 yrs) implies high organic productivity in the Alboran Sea during the Quaternary.[3] At this point in our investigations, we are not sure exactly how organic productivity varies in response to the changes in the oceanic circulation that accompanied the Pleistocene glacial and interglacial stages. We observe that the periods of least interrupted sedimentation correspond to cool periods, with the accumulation of steel gray muds lacking any signs of burrowing and without hydrotriolite stains. Olausson (1961) has suggested that during the cold periods, outflow of a Mediterranean undercurrent was halted, thereby allowing the Mediterranean basins to collect and utilize their natural nutrient supply.

It is premature to draw definite conclusions in this preliminary report. However, we offer tentatively that the uniform distribution of facies 1 reflects basin-wide high organic productivity. We believe that the parallel and conformable attitude of internal reflectors in facies 1 is analogous with those of the equatorial belt of biogenic sediment in the Pacific Ocean. Ewing *et al.* (1968) have interpreted this sedimentary ridge to be the record of continuous high productivity along the equatorial zone of convergence.

The base of the marl ooze unit (found in Core 4, but not below) is placed near Reflector Rouge. The level of the reflector (at 0.3 second) correlates with a zone of very stiff sediment drilled at 245 meters below bottom (see Figure 17).

The Gravity Ponded Facies

Cores 5 through 16 penetrated and sampled the "gravity ponded" facies 2 of the *Charcot* profile. The diagnostic aspect of this sedimentary unit is the presence of layers of sand. The layers can be seen as well-defined beds (Figure 15) in cores with good recovery (8, 9, 10) and in the drilling logs as thin intervals of easy and rapid penetration while circulating at moderate pump pressures. Cores 11, 12 and 13 contain loose sand which was most likely disturbed during the recovery processes and no longer shows its bedding characteristics. Cores 6, 8, 10, 14 and 15 contain lithified sandstones which, based on the drilling records, are probably thinly bedded between soft marls.

The sands of facies 2 are angular (Figure 18A) to rounded (Figure 18B) and range in size up to 4 millimeters. The components include mineral grains, lithic fragments of sedimentary origin (Figure 19A), and igneous and metamorphic rocks (Figure 19B). As discussed in a previous section, shell debris and tests of foraminifera displaced from shallow-water environments are common (Figure 9). In thin section the intergranular cement of the sandstones is generally calcitic (sparry calcite), with some signs of small euhedral dolomite grains at grain contacts. The percentage of fine-grain matrix is low (estimated as less than 5 per cent) as has been observed in most modern marine sand layers (Hollister and Heezen, 1964; Kuenen, 1966). Andesite is often present in the form of porphyritic volcanic fragments, clear glass shards (transparent and brown), and as devitrified remains of glass shards. Montmorillonite in the clay fraction is conspicuously low in relative abundance.

The lithification observed seems very selective. Only sand layers are cemented. Mud-balls within the sand layers, and mud at bedding contacts are still plastic. Judging from

[3]Rates of pelagic sedimentation in the Tyrrhenian Sea and Ionian Sea are 3.2 to 2.6 cm/1000 yrs.

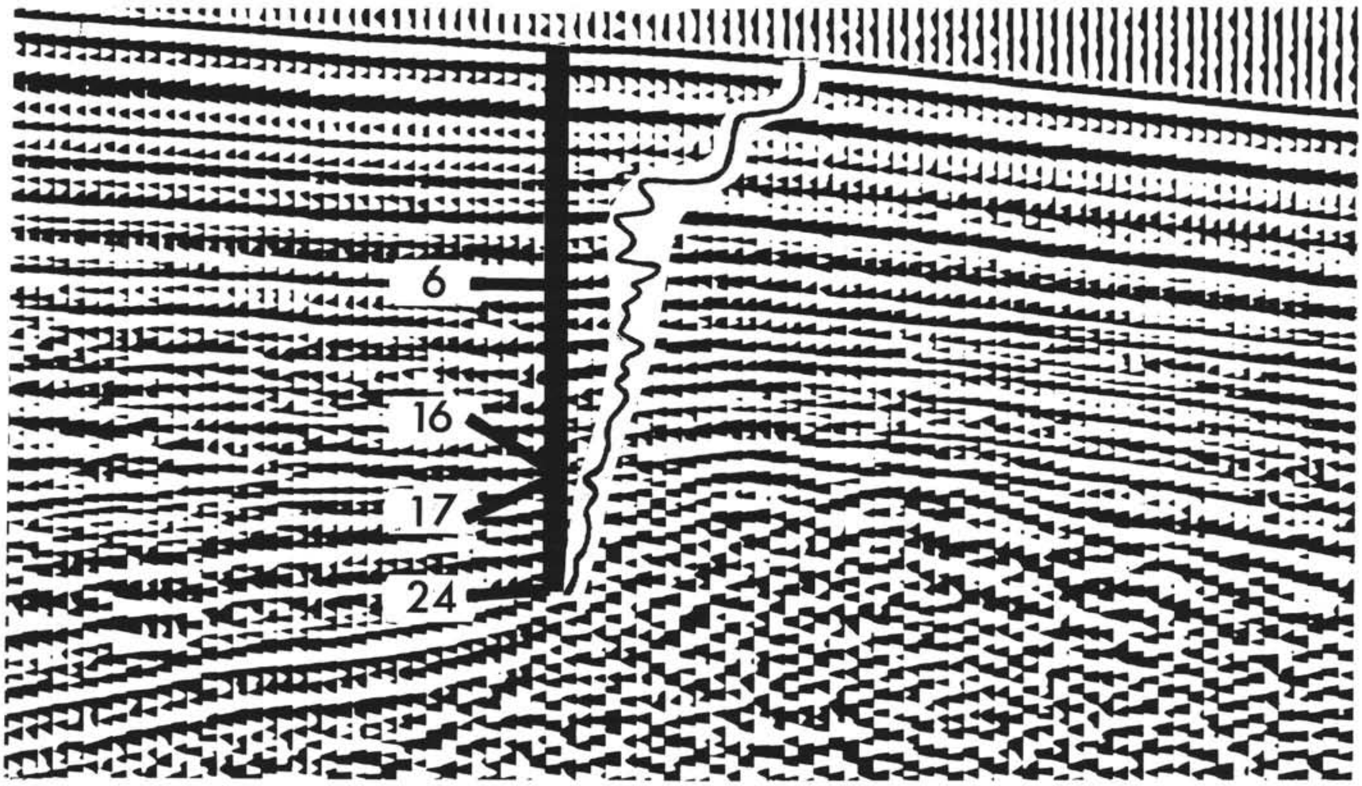

Figure 17. *A remarkable correlation of the major subbottom acoustic reflectors at Site 121 with the peaks and valleys of the drilling site curve. The depth scale on the drilling rate curve has been adjusted according to interval sound velocity values which were, in turn, determined by placing the angular unconformity (Horizon Purple) between Cores 16 and 17 and the crystalline and metamorphic rocks of Core 24-CC at the top of the acoustic basement.*

the drilling logs, we estimate that only a small percentage of the actual number of sand layers are lithified. The greatest concentration of indurated layers exists at the base of the unit directly overlying an angular unconformity that separates the Lower Pliocene from the Tortonian. We speculate that gravel might exist along this contact, judging from the very high torque observed over an interval of only one or two meters. (This judgement is based on the experience of the entire leg and the advice of our drilling crews.)

Where the sand beds were not disturbed in the recovery process, we could recognize bedding structures of the turbidite facies model. This does not presume that these are turbidites, but the evidence of displaced faunas certainly argues for transport of this facies into the basin downslope from shallow shelf or lagoonal environments. The ponding nature of the strata in the reflection profile is interpreted as evidence of gravity transport. Side echoes within facies 2 may originate from channel-like features within this unit.

The Stratigraphic Hiatus

The evidence for an angular nonconformity at Horizon Purple is self-evident in the reflection profile. This level is placed in our drilled sections at 686 meters, between Cores 16 and 17 drilled back to back. Core 16 is most certainly Pliocene, based on the occurrence of phylogenetically evoluted *Globorotalia margaritae*. It was during the cutting of Core 17 that we noticed the major change in torque. Unfortunately, the only sediment recovered at this level consisted of scrapings on the core catcher. As discussed previously, no zonal markers are present below Core 17 until Core 20 at 757 meters. Core 20 is assigned to the Upper Miocene foraminiferal Zone N.16 and nannofossil Zones NN10-NN11. Since Core 20 lies within the Tortonian, and below Core 16 *Discoaster surculus* is always very rare, we concluded (after much debate between all the shipboard crew) that there is no compelling evidence to indicate that we sampled any sediments belonging to the Messinian stage of the Miocene. In fact, we infer a stratigraphic gap between foraminiferal Zones N19 and N16.

Furthermore, the lowermost biozone of the Pliocene, the *Sphaeroidinellopsis* Acme-zone was not seen in the seven-meter section cored above the unconformity. The extinction horizon of *Globorotalia margaritae* between Core 14 and Core 15 (that is, 661 to 679 meters) lies extremely deep in the Alboran sequence. Because this horizon in the Mediterranean has been correlated to the paleomagnetic stratigraphic record at a level near the Gilbert-Gauss boundary (approximately 3.3 million years), we conclude that probably 1.5 million years of the lowermost Pliocene is also missing in the stratigraphic hiatus at Horizon Purple.

On the *Charcot* profile, more and more layers appear above Reflectors Green and Blue toward the north. Eventually, at 25 kilometers along the profile, the angular discordance disappears. The probable origin of the upwarp of the lower sedimentary units (facies 3 and 4) and of the

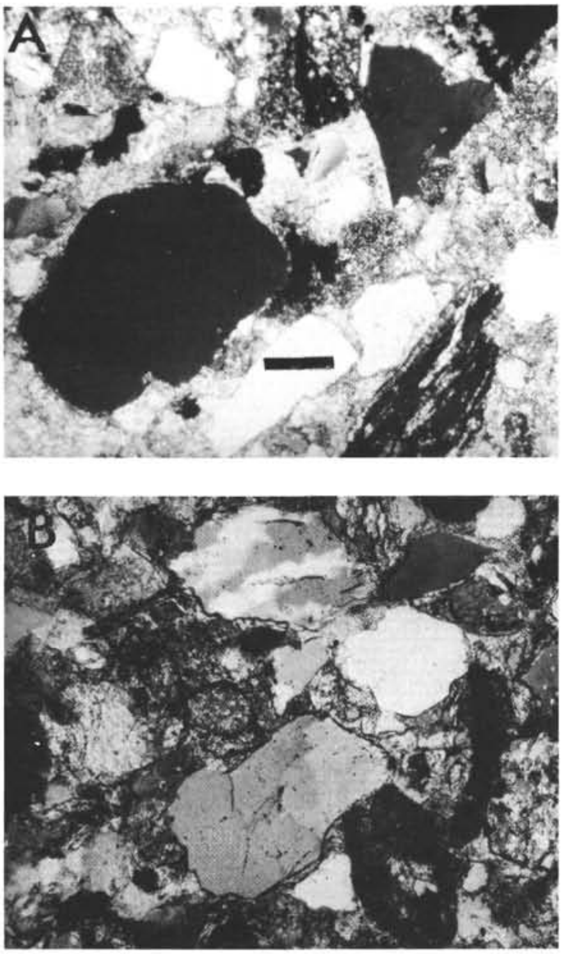

Figure 18. *Examples of rounded (top) and angular (bottom) mineral grains in sandstones of Unit 2 (Core 14). These sandstones are inferred to be turbidites (see text). They are cemented by spary calcite, accompanied by a marked presence of small euhedral dolomite grains within the intergranular matrix. Scale bar represents 100 microns.*

erosional truncation of the sequence was not appreciated until much later in the cruise. It was not until many weeks after Site 121 was completed that we began to look for and then discovered gypsum in the facies 4 sediments. The significance of sulfate minerals is discussed in the Cruise Synthesis in Chapter 43 of Part IV of this volume.

Geological Significance of Basement Rocks

Very hard rock was encountered during the cutting of Core 23. Rapid fluctuations in bit weight and erratic torque were interpreted as evidence that basement had been reached. Only small fragments of rock in a marl matrix were recovered. We immediately started to cut another core, and noticed small "soft zones" in the generally hard formation. At 863 meters we hit solid rock, and ground away for over an hour with only 3 meters of penetration.

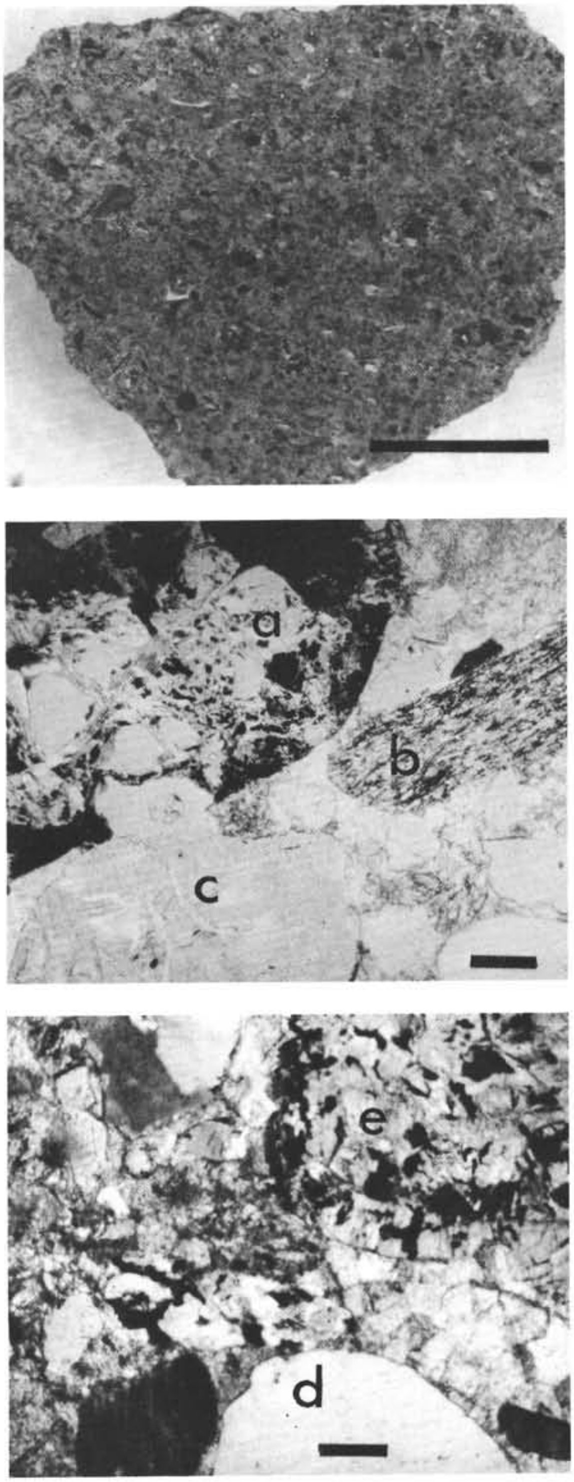

Figure 19. *Illustrations of the macro- and micro-facies of an Alboran sandstone (Core 6-CC). Note the grain imbrication in the upper polished hand specimen (scale bar represents 1 centimeter) and the abundance of very large well-rounded fragments. In fact, many of the sand grains consist of pieces of reworked sandstone (a) andesite, (b) crystalline rock, (c) quartzite, and (d) shell debris. Beds contain both angular and well-rounded grains in the same laminae. The mineral make-up and grain texture is related to variations in the source of the*

sediment and not to transport or depositional processes. Scale bars in the center and bottom figures represent 100 microns.

Additional "soft zones" were noted. At this time the chief scientists on the rig floor were advised that the fragments of Core 23 had been identified as basalt. Feeling that we were in the basement, and worrying about the very slow rate of progress and the fact that the tooth bit would survive at most only a few meters in basalt, we pulled Core 24. The following events were reconstructed in part from memory, and in part from our drill-floor records:

(1) While still cutting Core 24, someone must have thin-sectioned a fragment from Core 23. Our scribbled notes record a dialogue on whether the fragment was andesitic or basaltic, and the presence of labradorite was used to confirm that we had recovered basalt. No trace of this thin-section can now be found, and we now suspect that the section may have been from the previous site (120).

(2) When Core 24 arrived on deck, rock fragments were found in the core-catcher (Figure 20). On the basis of an identification of a hand specimen, we decided to pull the drill string and leave the site.

(3) When the drill string arrived on deck, a large 6 centimeter rock was jammed in the bit orifice. This rock was sectioned and identified as "oceanic basalt" (Geotimes, December 1970).

(4) Not until the completion of the cruise did we discover that this rock had been misidentified, and that it was really a high-grade cordierite-biotite-feldspar hornfels.

(5) Subsequently, we have searched for and sectioned over a dozen rock fragments from both Cores 24 and 23. No basalt was found. Instead, our "basement" consists of a suite of metamorphic and crystalline rocks, including several fragments of biotite-quartz schist, biotite-plagioclase gneiss, muscovite-quartz, plagioclase gneiss and altered granodiorite. The petrology of the various specimens is discussed further in Chapter 27 of Part II of this volume.

This embarassing "about-face" leaves many questions unanswered. If we take Horizon Purple between Cores 16 and 17 as a fixed reference point, and extrapolate downward on the reflection profile, Core 24 at 867 meters below bottom can be located anywhere between 8.2 and 8.8 seconds, assuming an interval sound velocity of 3.0 and 2.0 km/sec, respectively.

The most reasonable location of Core 24 would be around 8.6 seconds. Considering the problem of diffraction of the basement reflectors, 8.6 seconds on the reflection profile is where Reflector Green abuts against the apparent acoustic ridge. We offer two hypotheses on origin of the rocks of Cores 23 and 24.

1) The rocks are from the *in situ* basement. The large piece wedged in the drill bit is from an autochthonous subcrop of high-grade metamorphic rock (amphibolite facies). Smaller fragments, particularly those that are subrounded, indicate erosion of parts of the ridge prior to deposition of the marine marls in the Tortonian.

2) The rocks are allochthonous and their origin is from the north. Their petrologic makeup may be unrelated to basement, which was not cored.

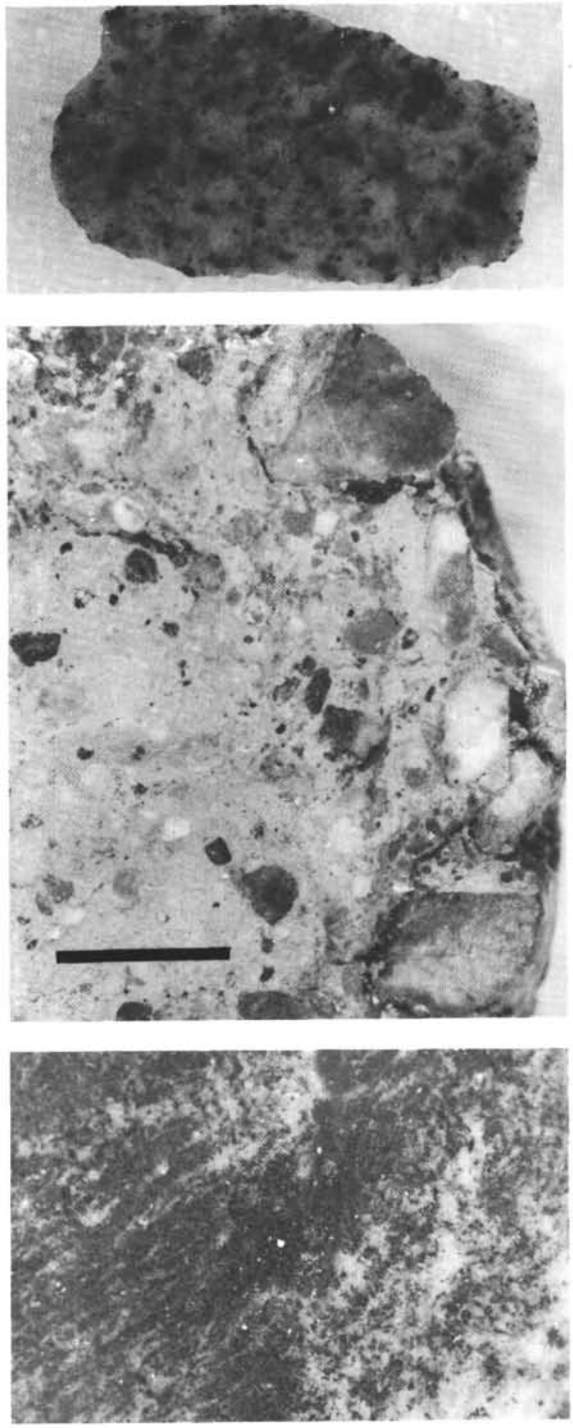

Figure 20. *The Alboran basement suite. The upper figure is a fragment of altered granodiorite found in the core catcher of Core 24 (piece #24cc B1). The center photo shows the basement conglomerate with fragments of quartzite, schist, gneiss, and crystalline rock. The matrix is an Upper Miocene open marine nannofossil-ooze (Tortonian). No contact metamorphism has been observed. The lower photo shows a polished section of a large fragment of garnetiferous muscovite-quartz-plagioclase gneiss recovered from the drill bit oriface (piece #24ccA1). Scale bar represents 1 centimeter. For details of the basement petrology see Chapter 23.*

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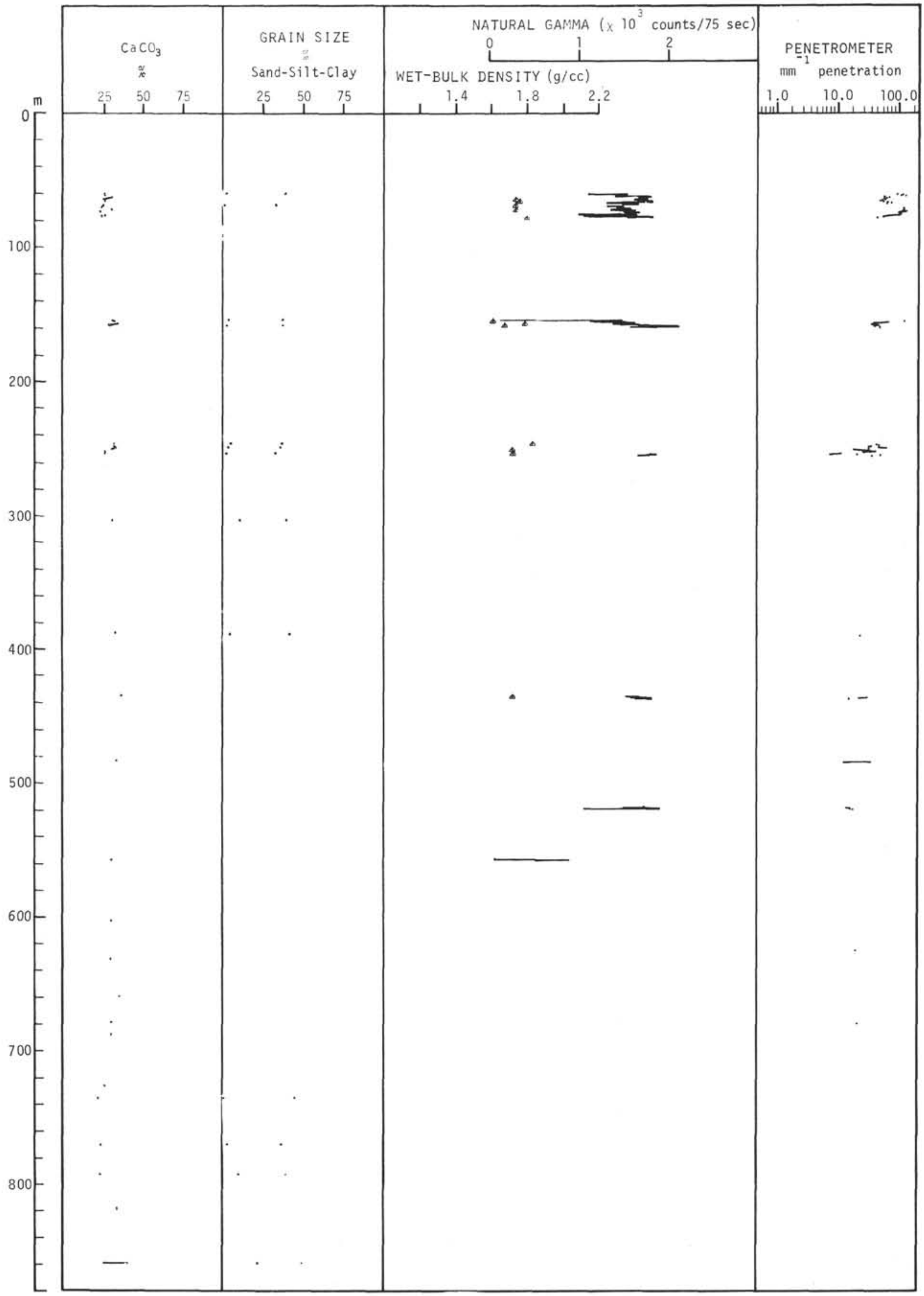
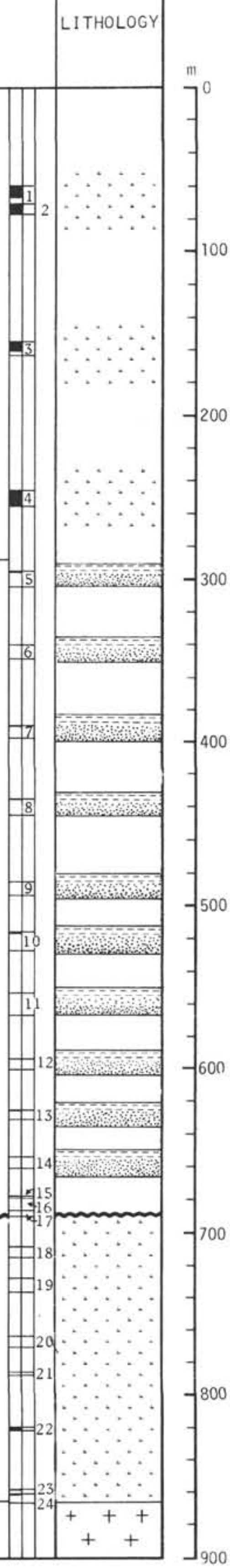
Site Summary 121

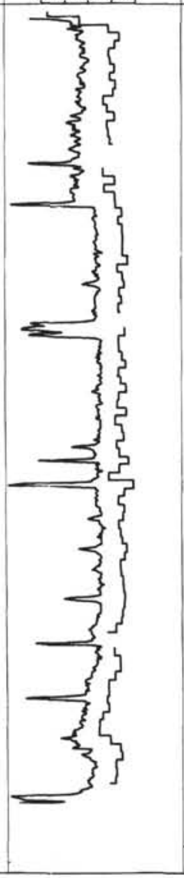


AGE		LITHOLOGY AND BIOSTRATIGRAPHY
PLEISTOCENE		MARL OOZE (pelagics) dark greenish gray, plastic, faint bedding mainly fine terrigenous clastics together with 25-35% of nannoplankton and foraminifera considerable reworking of older nannofossils indications of climatic fluctuations in cores 1 and 2 fairly rich and diverse benthonic fauna 290m
PLIOCENE	UPPER / LOWER	MARL OOZE and GRADED SANDS (turbidites) sequences of quartzose sands grading to marl oozes, sharp boundaries between sequences sands: quartz, mica, feldspar marl oozes: 70% terrigenous clastics, 30% nannoplankton and forams, some layers consolidated in sandstones displaced benthonic fauna in sands 686m
UPPER MIOCENE	TORTONIAN	MARLS (pelagics) with scarce SAND layers (turbidites) mainly fine terrigenous clastics with 25-30% of carbonates rare sand layers, two of which consolidated in sandstone. One limestone layer. dark greenish gray, consolidated, shaly rich planktonic fauna and diagnostic nannofossil only below c.20 864m
≈15 m.y.		BASEMENT: METAMORPHIC ROCKS schist, gneiss, granite, etc.



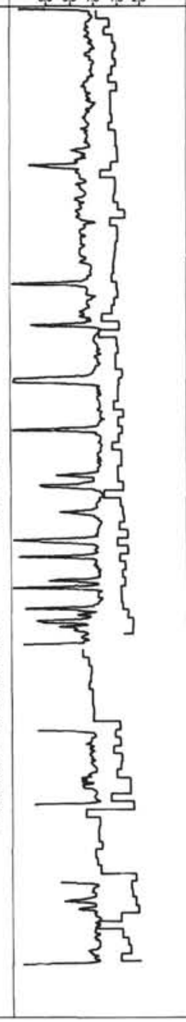
SITE 121 CORE 1 Cored Interval 60 - 69 m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
QUATERNARY		60	1	VOID	26 (3-37-60)	MARL OOZE dark greenish gray (5GY 4/1) plastic no structures to faint bedding	I
			2		27	X-ray: quartz, calcite, dolomite, clays Smear: nannos 30, terrigenous debris 70	
Globorotalia truncatulinoides total-range-zone			3		30	benthonic foraminifera fairly abundant planktonic foraminifera indicating temperate to cold, fluctuating climate nannoplankton belonging to the *Gephyrocapsa oceanica* zone, ostracods, echinoid spines	
			4		25		
			5		26		
		67.5	CC				

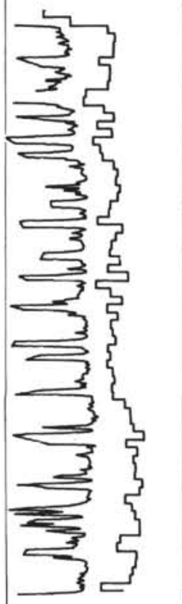


SITE 121 CORE 2 Cored Interval 69 - 78 m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
QUATERNARY		69	1		25 (2-33-65)	MARL OOZE dark greenish grey (5GY 4/1) plastic no visible structures	
			2		24	Smear: nannos 25, terrigenous debris 75 planktonic foraminifera indicating temperate to cold, fluctuating climate benthonic foraminifera fairly abundant nannoplankton abundant (*Gephyrocapsa oceanica* zone) ostracods, echinoid spines	
Globorotalia truncatulinoides total-range-zone			3		30		
			4		23		
			5		24		
		78	6		26		
			CC				



SITE 121 CORE 3 Cored Interval 154 - 163

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY
QUATERNARY				VOID		
		154.5	1		(4-34-62)	
					31	MARL OOZE
						dark greenish gray (5GY 4/1)
						plastic
			2		32	no structures to faint bedding
						Smear: nannos 35, quartz 25, mica 40
Globorotalia truncatulinoides total-range-zone			3		34	planktonic foraminifera indicating temperate to warm, fluctuating climate nannoplankton belonging to the *Gephyrocapsa oceanica* zone
			4		28	
					(3-36-61)	
		160	CC			

DISTURBANCE

SITE 121 CORE 4 Cored Interval 247 - 256

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY
QUATERNARY		247	1		32	
					(5-32-63)	MARL OOZE
						dark greenish gray (5GY 4/1)
						plastic to stiff
					31	no visible structures to faint, well-developed bedding
			2			Smear: nannos 35, quartz 25, mica 40
Globorotalia truncatulinoides total-range-zone			3		33	planktonic foraminifera indicating temperate to warm, fluctuating climate abundant nannofossils belonging to the *Coccolithus doronicoides* zone or *Pseudoemiliania lacunosa* zone, ostracods, organic matter *Pulleniatina obliquiloculata* in the core catcher
					(4-32-64)	
			4		30	
			5		26	
			6		25	
					(3-31-66)	
		256	CC			

DISTURBANCE

SITE 121 CORE 5 Cored Interval 296-305m

AGE	WET-BULK DENSITY(gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay) / LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
QUATERNARY *Globorotalia truncatulinoides* total-range-zone		296	CC		30 (11-29-60)	

SAND and MARL OOZE
Layering suggesting a turbidite sequence

Marl ooze:
medium bluish gray (5B 5/1)

Smear	
nannos	35
quartz	30
mica	35

abundant nannofossils (*Pseudoemiliania lacunosa* zone)

Sand:
dark gray (5Y 4/1
displaced shallow-water benthonic foraminifera

Smear	
nannos	15
quartz	60
feldspar	5
mica	15
calcite	5

SITE 121 CORE 6 Cored Interval 340 - 349 m

AGE	WET-BULK DENSITY(gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay) / LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
QUATERNARY last *Discoaster* extinction datum		340	CC			

SANDSTONE and loose SAND

medium gray (N5)

Smear	
forams	2
quartz	70
feldspar	3
mica	25

displaced shallow water fossils (bryozoa, epineritic benthonic foraminifera)
nannoplankton of the *Pseudoemiliania lacunosa* zone

SITE 121 CORE 7 Cored Interval 389 - 398 m

AGE	WET-BULK DENSITY(gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay) / LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
UPPER PLIOCENE *Globorotalia inflata* interval-zone		389.9	1	VOID	32	V
		390.5	CC		(5-38-57)	

MARL OOZE
dark greenish gray (5G 4/1)
stiff
sparse horizontal stratification

Smear	
nannos	30
quartz	30
muscovite	40

planktonic assemblage with *Globorotalia inflata*, *Globigerinoides obliquus extremus* extinction datum
nannofossils of the *Discoaster brouweri* zone

SITE 121 CORE 8 Cored Interval 436 - 445 m

AGE	WET-BULK DENSITY(gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay) / LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
UPPER PLIOCENE		436	1		36	
		437.4	CC			

graded SANDS and MARL OOZES
dark greenish gray (5GY 4/1)
sequences of graded sands to silts and marl oozes: turbidite structures.

At 437.4 the sand horizon is consolidated in sandstone.

Smear	
nanno	1
quartz	70
feldspar	5
mica	21
pyroxene, etc.	

planktonic foraminifera
displaced sparse benthonic foraminifera
nannoplankton of the *Discoaster brouweri* zone

SITE 121 CORE 9 Cored Interval 483 - 498 m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
UPPER PLIOCENE *Globigerinoides obliquus extremus* Interval-range-zone		483.9 484.5	1 CC	VOID	33	graded SANDS and MARL OOZES dark greenish gray (5GY 4/1) sequences of graded sands to silt and marl oozes: turbidite structures. Smear: nannos 34, quartz 25, mica 40, calcite 1 planktonic foraminifera including *Globigerinoides obliquus extremus* nannofossils of the *Discoaster brouweri* zone	V

SITE 121 CORE 10 Cored Interval 517 - 526 m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
UPPER PLIOCENE Undifferentiated		517.7 520	1 2 CC	VOID		graded SANDS and MARL OOZES dark greenish gray (5GY 4/1) sequences of sands grading to silts and marl oozes: turbidite structures. the sand horizon at 519.85 is consolidated in sandstone. Smear: nannos 40, quartz } mica }=60 poor assemblages displaced shallow water benthonic foraminifera reworked Upper Cretaceous foraminifera in core catcher nannoplankton of the *Discoaster surculus* zone (NN 16)	V

SITE 121 CORE 11 Cored Interval 557 - 566 m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
UPPER PLIOCENE undifferentiated		557.4 558.5	1 CC		30	SAND and MARL OOZE dark greenish gray (5GY 4/1) loose sand with a single marl ooze layer suggesting turbidite structure. Smear: nannos 30, quartz 30, mica 40 displaced shallow water benthonic foraminifera scattered fossils nannoplankton of the *Discoaster surculus* (NN 16) zone	V

SITE 121 CORE 12 Cored Interval 595 - 601 m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
UPPER PLIOCENE undifferentiated		595	CC		30	lumps of MARL OOZE in loose SAND suggesting disturbed turbidite Smear: nannos 30, quartz 30, mica 40 displaced shallow water benthonic foraminifera, rare otoliths, pelecypods. Nannoplankton of the *Reticulofenestra umbilica* (NN 15) Zone	V

SITE 121 CORE 13 Cored Interval 624 - 630 m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
UPPER PLIOCENE undifferentiated		625 625.5	1 CC	VOID	29	SAND and MARL OOZE washed sand above stiff olive gray (5Y 4/1) marl ooze with faint horizontal bedding suggesting turbidite structure. Smear (marl ooze) nannos 30 quartz 30 mica 40 displaced shallow water benthonic foraminifera nannoplankton of the *Reticulofenestra pseudoumbilica* Zone (NN 15)	V

SITE 121 CORE 14 Cored Interval 652 - 661

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
UPPER PLIOCENE undifferentiated		653.2 653.5	1 CC	VOID	35	SANDSTONE and MARL OOZE suggesting a consolidated turbidite Sandstone: medium light gray (N6) Marl ooze: olive gray (5Y 4/1) plastic no structures Smear (marl ooze) nannos 35 terrigenous debris 65 displaced shallow water benthonic foraminifera glauconite nannoplankton of the *Discoaster asymmetricus* Zone (NN 14)	V

SITE 121 CORE 15 Cored Interval 679 - 680 m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
Globorotalia margaritae total-range-zone LOWER PLIOCENE		679.5 680	1 CC	VOID	30	SANDSTONE and MARL OOZE suggesting consolidated turbidite Sandstone: medium light gray (N7) Marl ooze: olive gray (5Y 4/1) stiff horizontal bedding Smear (marl ooze) nannos 30 quartz 30 mica 40 planktonic assemblage with *Globorotalia margaritae* *Discoaster asymmetricus* (?) Ostracods nannoplankton of *Discoaster asymmetricus* zone	V

SITE 121 CORE 16 Cored Interval 680 - 686

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
LOWER PLIOCENE		681.5	1 CC	VOID	30	MARL OOZE olive gray (5Y 4/1) stiff horizontal bedding planktonic foraminifera sparse nannoplankton of the NN11-NN14 zones (Upper Miocene/Lower Pliocene)	V

SITE 121 CORE 17 Cored Interval 686 - 689 m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
UPPER MIOCENE (?) undifferentiated		686	CC			MARL OOZE lumps on core catcher only olive gray (5Y 4/1) stiff Smear nannos 30 terrigenous debris 70 detritus pelecypods fragments displaced shallow water benthonic foraminifera *Globorotalia scitula* and *G. acostaensis* assemblage Nannoplankton of the NN 11 - NN 14 Zones (lower Pliocene/upper Miocene)	

SITE 121 CORE 18 Cored Interval 708 - 715.5 m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
UPPER MIOCENE (?) undifferentiated		708 709.5	1	VOID		Washed SAND coarse to fine Smear nannos 20 forams 2 quartz 78 Radiolaria *Globorotalia acostaensis* assemblage	V

SITE 121 CORE 19 Cored Interval 728 - 737 m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
probably UPPER MIOCENE		729.3 729.5	1 CC	VOID	26 (0.5-44.5-55) 22	MARL OOZE 729.3 - 729.35 m : olive gray (5Y 4/1) shaly (fissile) 729.35 - 729.5 m : greenish gray (5GY 6/1) fractured by drilling Smear nannos 25 quartz 30 mica 40 calcite 5 benthonic foraminifera including *Bolivinoides mioceanicus* and *Uvigerina auberiana* planktonic foraminifera rare Nannoplankton of the NN 11-NN 14 Zones (Lower Pliocene/upper Miocene)	V

SITE 121 CORE 20 Cored Interval 763 - 770 m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
probably UPPER MIOCENE		763	CC		24 (3-33-64)	MARL OOZE olive gray (5Y 4/1) shaly indurated Smear nannos 20 forams 5 quartz 30 muscovite 40 planktonic foraminifera rare nannoplankton of the NN 10-11 zones (Upper Miocene)	

SITE 121 CORE 21 Cored Interval 785 - 788 m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
UPPER MIOCENE (TORTONIAN) *Globorotalia acostaensis/G. merotumida* Zone N.16		785	CC		23 (10-30-60)	MARL OOZE dark greenish gray (5G 4/1) semi-indurated shaly (fissile) Smear: nannos 25; terrigenous debris 75 DOLOMITE fragment gray (5Y 5/1) fine grained X-rays: quartz, dolomite, calcite planktonic foraminifera sparse nannoplankton of the NN 10-11 Zones (upper Miocene)	

SITE 121 CORE 22 Cored Interval 819-821m

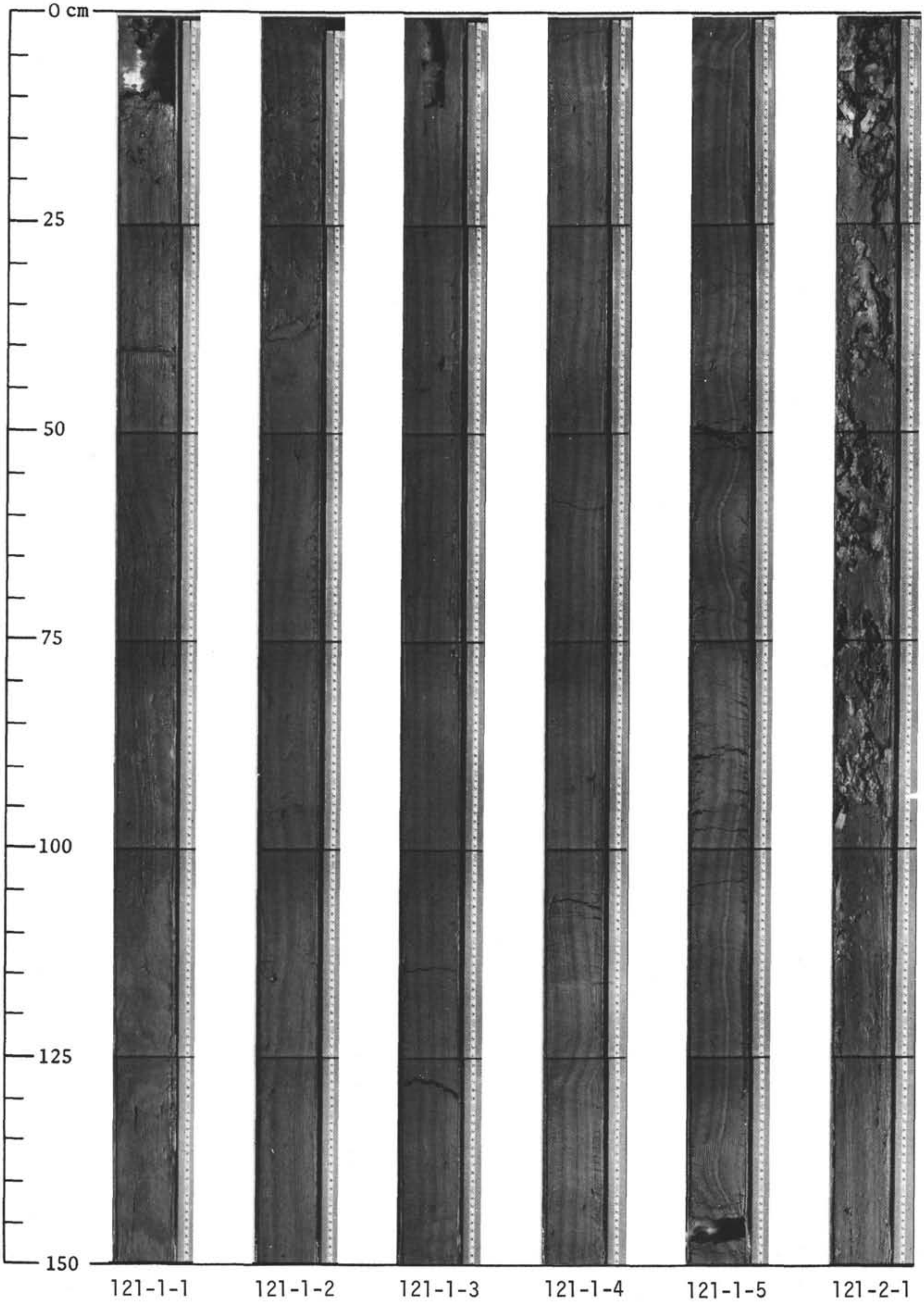
AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
UPPER MIOCENE (TORTONIAN) *Globorotalia acostaensis/G. merotumida* Zone N.16		819 821	1 CC		34	graded SANDS and MARLS sequences of sands grading to silts and marls: turbidite structures Sands: grayish olive (10Y 4/2) graded; the top horizon is consolidated in sandstone Marls: dark greenish gray (5G 4/1) consolidated shaly X-rays: quartz, calcite, dolomite, clays Smear: nannos 33; forams 2; quartz 30; mica 35 rich foraminiferal fauna ostracods including *Beirdia amygdaloides*, *Avrila cicatricone*, etc. nannoplankton of the NN10-11 zones (upper Miocene)	

SITE 121 CORE 23 Cored Interval 859-861m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
UPPER MIOCENE (TORTONIAN) Zone N.16		858.5 861	1 2 CC		25 (22-28-50)	MARLS medium light gray (N5) shaly (bedded) consolidated fragments of rock embedded near the base of the core Smear: nannos 22; forams 3; quartz 35; mica 40 X-rays: quartz, calcite, dolomite, clays rich foraminiferal fauna including keeled globorotalia nannoplankton of the NN 10-11 zones (Upper Miocene)	

SITE 121 CORE 24 Cored Interval 861-867.2m

AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
UPPER MIOCENE (TORTONIAN) Zone N.16		862 864	1 2 CC	VOID VOID	41 45	MARLS olive gray (5Y 4/1) shaly (fissile) occasional rock fragments Smear: nannos 32; forams 8; quartz 25; mica 35 X-ray: calcite, quartz, dolomite, clays rich planktonic foraminiferal fauna including keeled globorotalia nannoplankton of the NN 10-11 zones (upper Miocene) in the Core Bit: marine breccia comprising fragments of metamorphic rock overlying a massive piece of schist. Total Drilling: 867.2 m in metamorphics	V V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100
125
150
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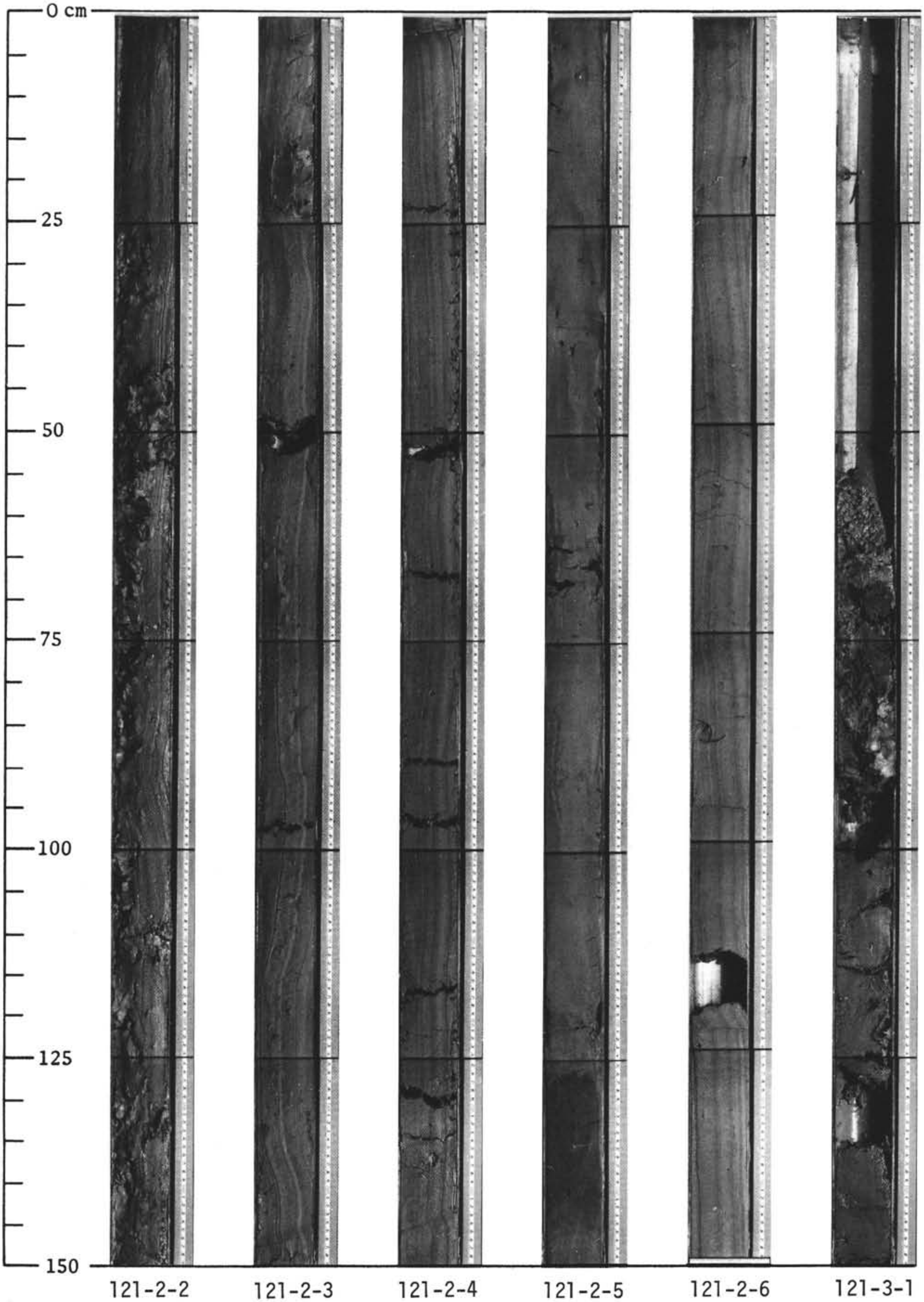
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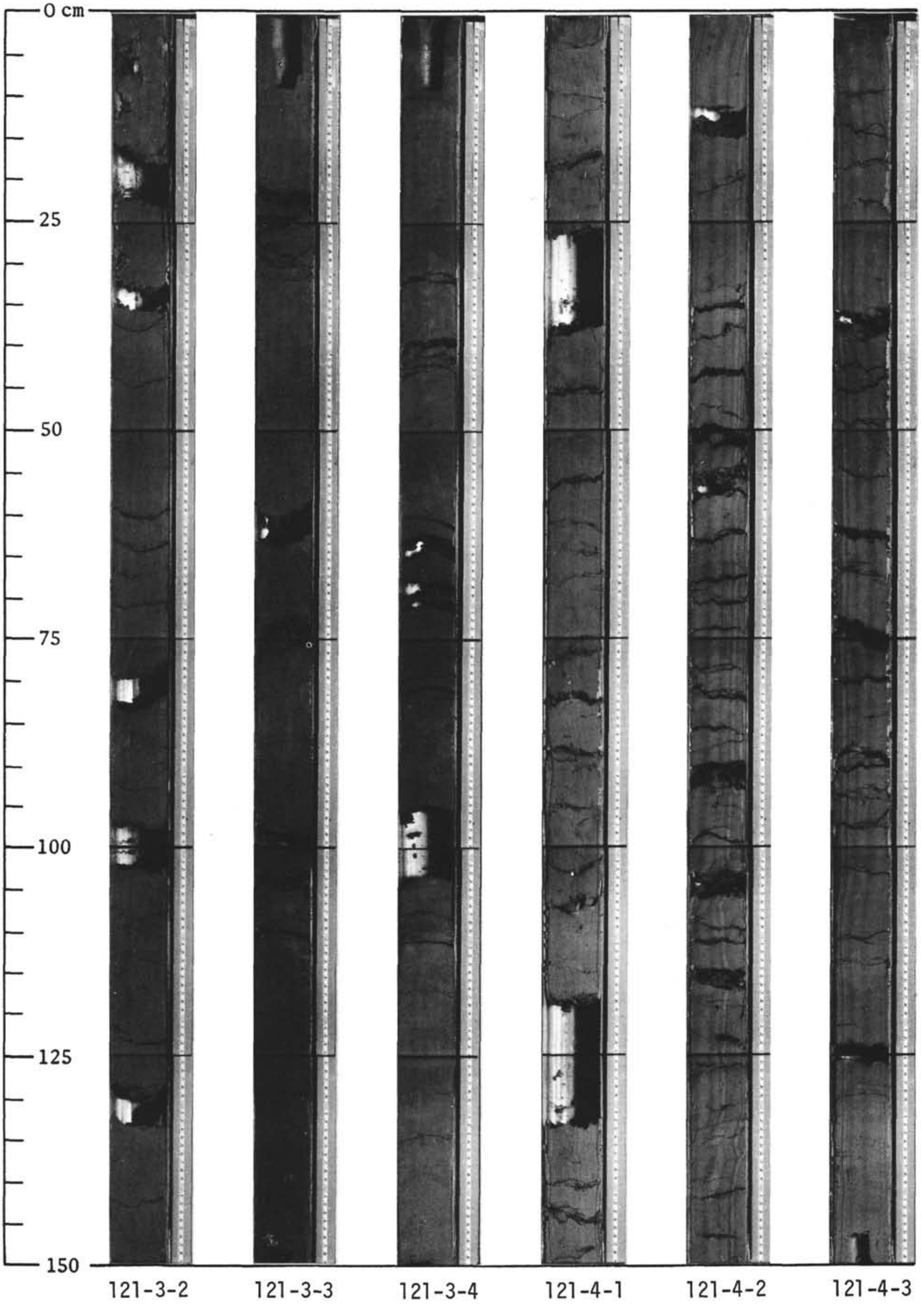
121-3-1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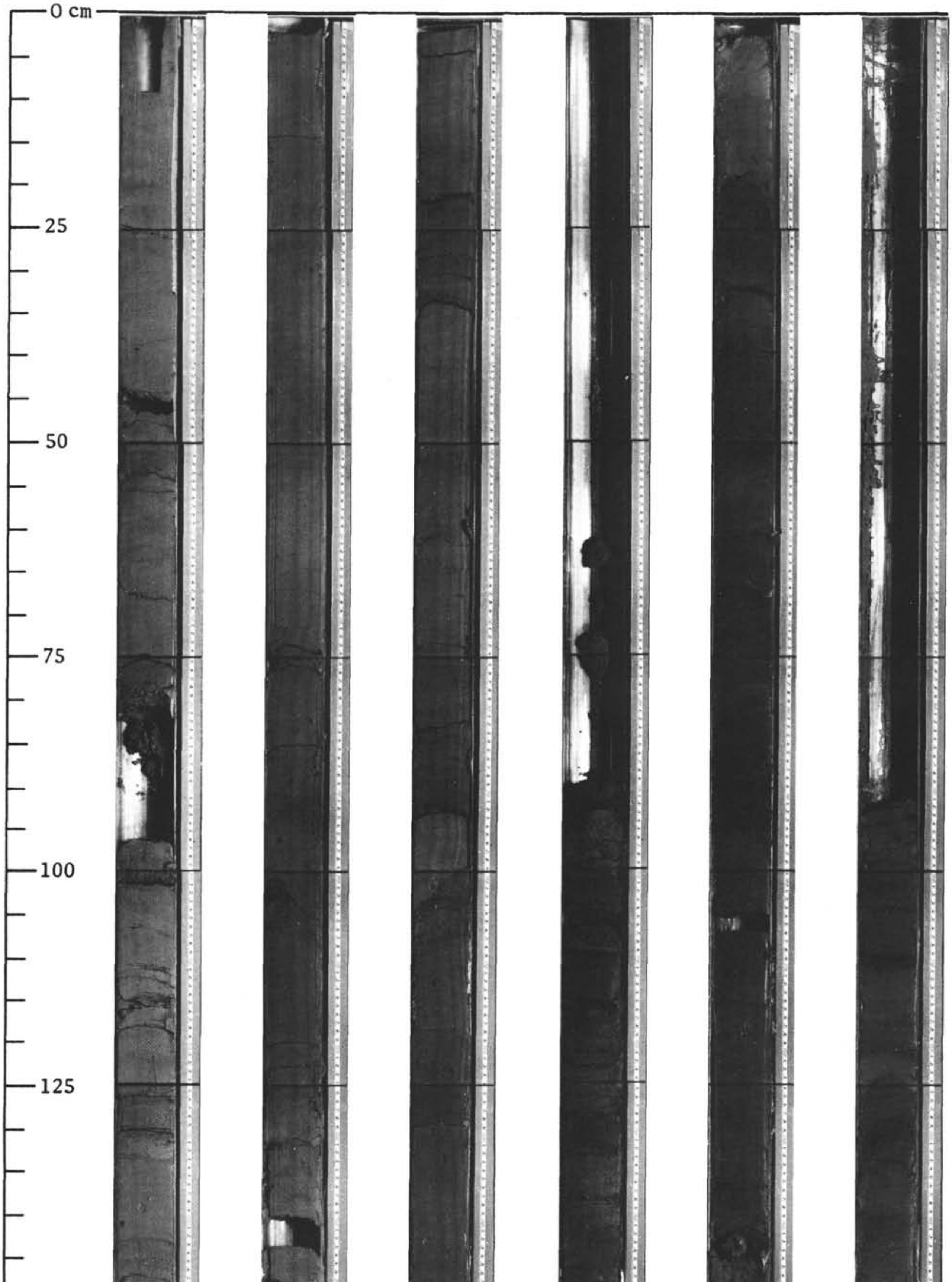
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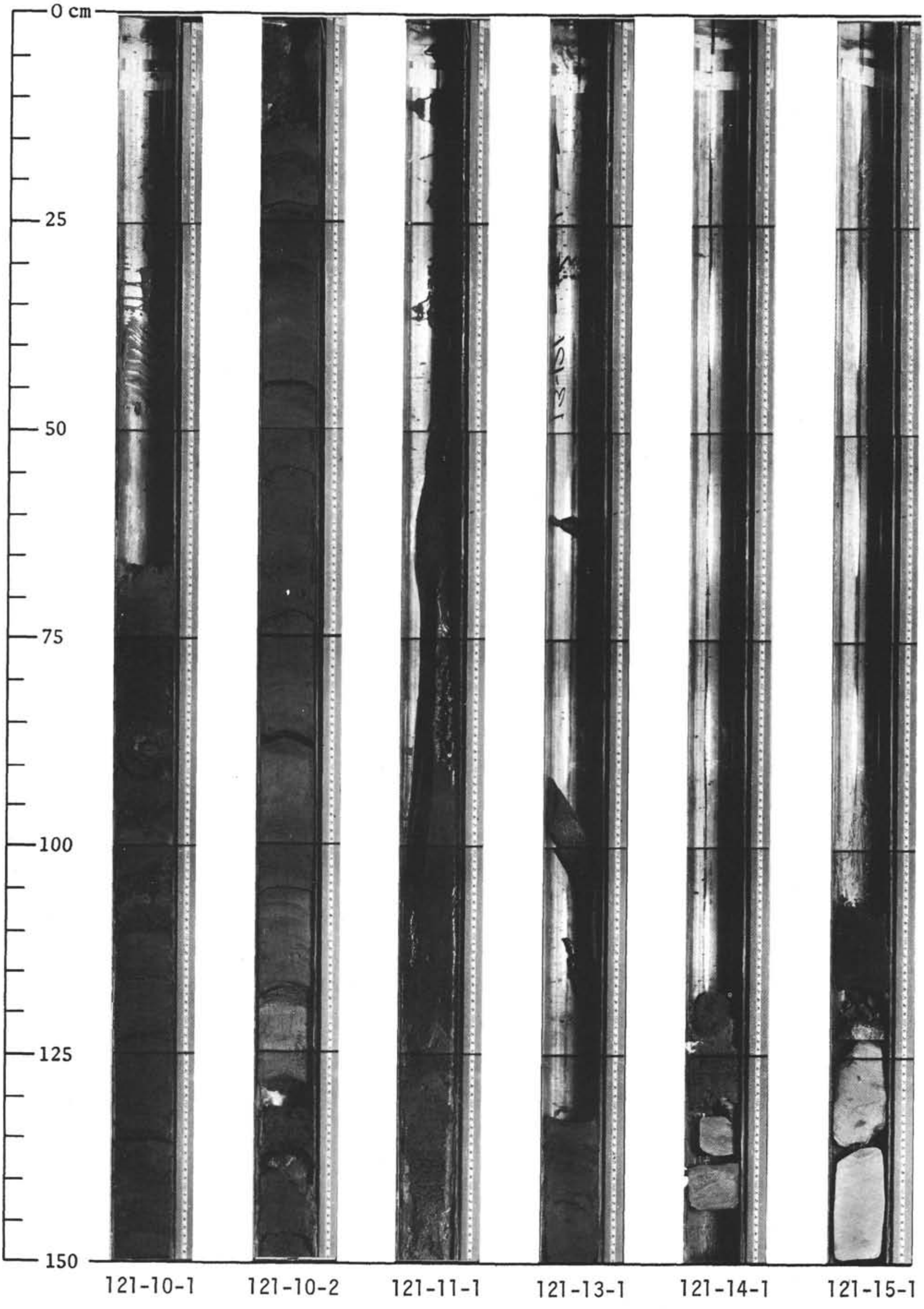
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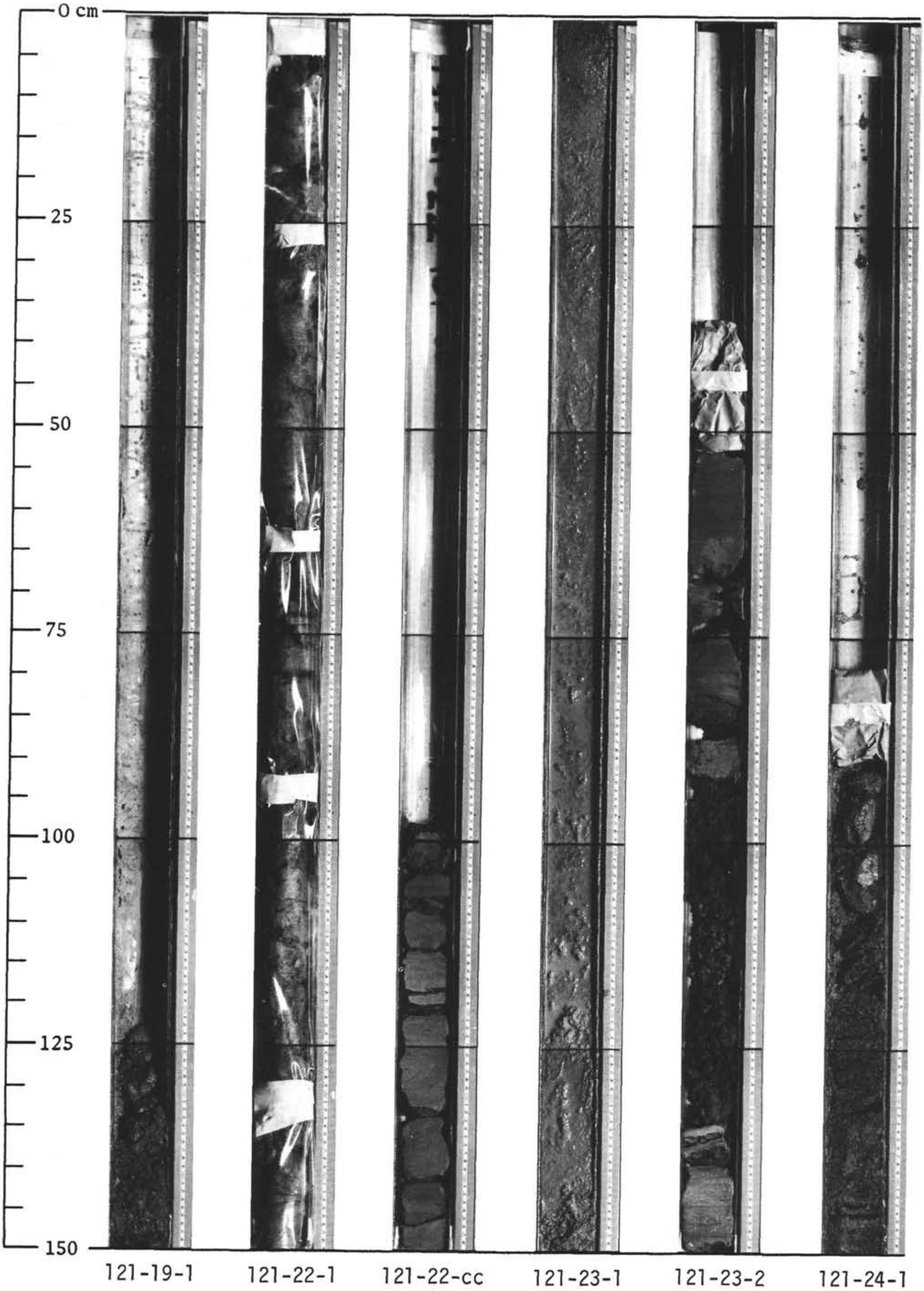
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121-22-1
121-22-cc
121-23-1
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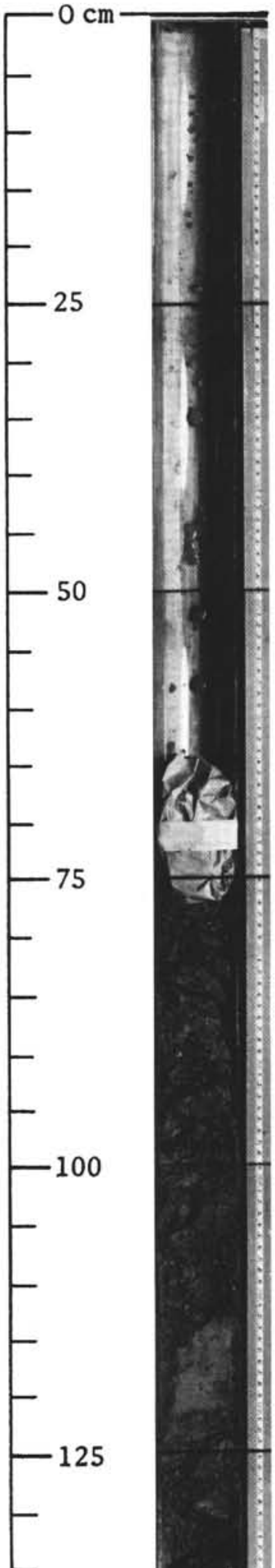

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