2. GORRINGE BANK – SITE 120

The Shipboard Scientific Party[1]

SITE DATA

Occupied: August 14-17, 1970.

Position: Northern flank of Gorringe Bank:

Water Depth: 1711 meters.

Cores Taken: Eight cores.

Total Penetration: 253.4 meters.

Deepest Unit Recovered: Basement.

MAIN RESULTS

Cored Lower-Middle Miocene and Lower Cretaceous (Albian, Aptian, Barremian) gray and green, partly silicified nannofossil ooze. Bottomed in basement consisting of spilitic basalt, serpentinite, and meta-gabbro.

The inferred stratigraphic section contains two significant unconformities: (1) a hiatus in bathypelagic sedimentation between the Cretaceous and the Miocene; (2) an abrupt change in sediment facies between Cretaceous-Miocene silicified nannofossil ooze yielding poor assemblages of planktonic foraminifera (suggestive of original deposition near or below the lysocline) and younger chalks and oozes unaffected by solution with rich, diverse assemblages.

We interpret that the slab of oceanic crust drilled was uplifted from abyssal depths to its present position as a linear bank during a period of compression along the Azores-Gibraltar seismic zone that commenced in post-Langhian and pre-Tabianian time.

BACKGROUND

Gorringe Bank is an elongate ridge in the eastern North Atlantic Ocean which lies approximately 110 kilometers off the southwestern tip of Portugal (Figure 1). The bank shoals at its crest to less than 50 meters water depth and forms the northern rim of the Horseshoe Seamount chain (Heezen *et al.,* 1959). The precipitous slopes along the flanks of the bank are draped in certain places with a more or less uniform, yet relatively thin cover of sediment, in contrast to rather thick accumulations of sediment beneath the Tagus Abyssal Plain directly to the north, and the Horseshoe Abyssal Plain to the south.

Gorringe Bank is not simply a volcanic cone, or a coalesced chain of cones. A very high free-air gravity anomaly (>350 mgals) over its crest signifies the burial in its core of dense crustal and possibly even upper mantle rocks.

Le Pichon, Bonnin, and Pautot (1970) have suggested that Gorringe Bank is a slab of oceanic crust uplifted during a relatively recent phase of compressive tectonics along the Azores-Gibraltar seismic zone.

Two piston cores (RC 9-206, RC 9-208) and a single dredge haul (RC 9-6) recovered in 1965 by the R/V *Robert D. Conrad* from the crestal area of Gorringe contained numerous fragments of igneous rock, ranging from basaltic tuffs to gabbros. (The petrology of the rock samples is discussed in Chapter 26, Part II of this volume.) Assemblages of ultramafic rocks were also brought up from depths on the order of 2000 meters along the northern flank of the ridge by R/V *Jean Charcot* in January 1970. In light of the preliminary findings it appeared that a site along the northern flank of the bank would offer a reasonable chance to penetrate the sediment cover of the northeast Atlantic sea floor at a site close to the Iberian continental platform and reach basement, perhaps to sample and thus provide new information of the stratigraphic relationship of the sediment directly above the basement rocks and of the basement rocks themselves.

Objectives

The unpublished investigations of Walter Pitman and Manik Talwani at the Lamont-Doherty Geological Observatory on the magnetic lineations of the North Atlantic, in conjunction with the analysis of earthquake focal mechanism along the Azores-Gibraltar seismic zone by McKenzie (1970), showed that a site location on the *northern* flank of Gorringe Bank would be on a strip of oceanic floor created during the separation of Iberia away from North America (that is, Iberian Plate).

Thus a site here (brought to the attention of the Mediterranean drill-site selection panel by X. Le Pichon) could offer several objectives. (1) Drilling through the relatively thin sedimentary cover shown in a *Charcot* flexotir seismic profile (Figure 2) would be able to reach basement with a subbottom penetration of less than 400 meters. (2) The age of the crust west of Portugal would necessarily give the age of the initial rifting and extension in the Bay of Biscay, and the rotation of the Iberian Plate with respect to Europe, an objective of Leg 12 which was not attained when it became possible to reach basement at Sites 118 and 119 in the Bay of Biscay. (3) The recovery of a "deep-water" facies of sediment above the basement at a water-depth of less than 2000 meters would demonstrate that Gorringe Bank was an uplifted slab of the ocean crust. The location in the stratigraphic column of a transition

[1]W. B. F. Ryan, Lamont-Doherty Geological Observatory; K. J. Hsü, Eidg. Technische Hochschule; M. B. Cita, Universita degli Studi di Milano; Paulian Dumitrica, Geological Institute, Bucharest; Jennifer Lort, University of Cambridge; Wolf Maync, Geological Consulting Service, Berne, Switzerland; W. D. Nesteroff, Université de Paris; Guy Pautot, Centre Oceanologique de Bretagne; Herbert Stradner, Geologische Bundesanstalt, Vienna; F. C. Wezel, Universita di Catania.

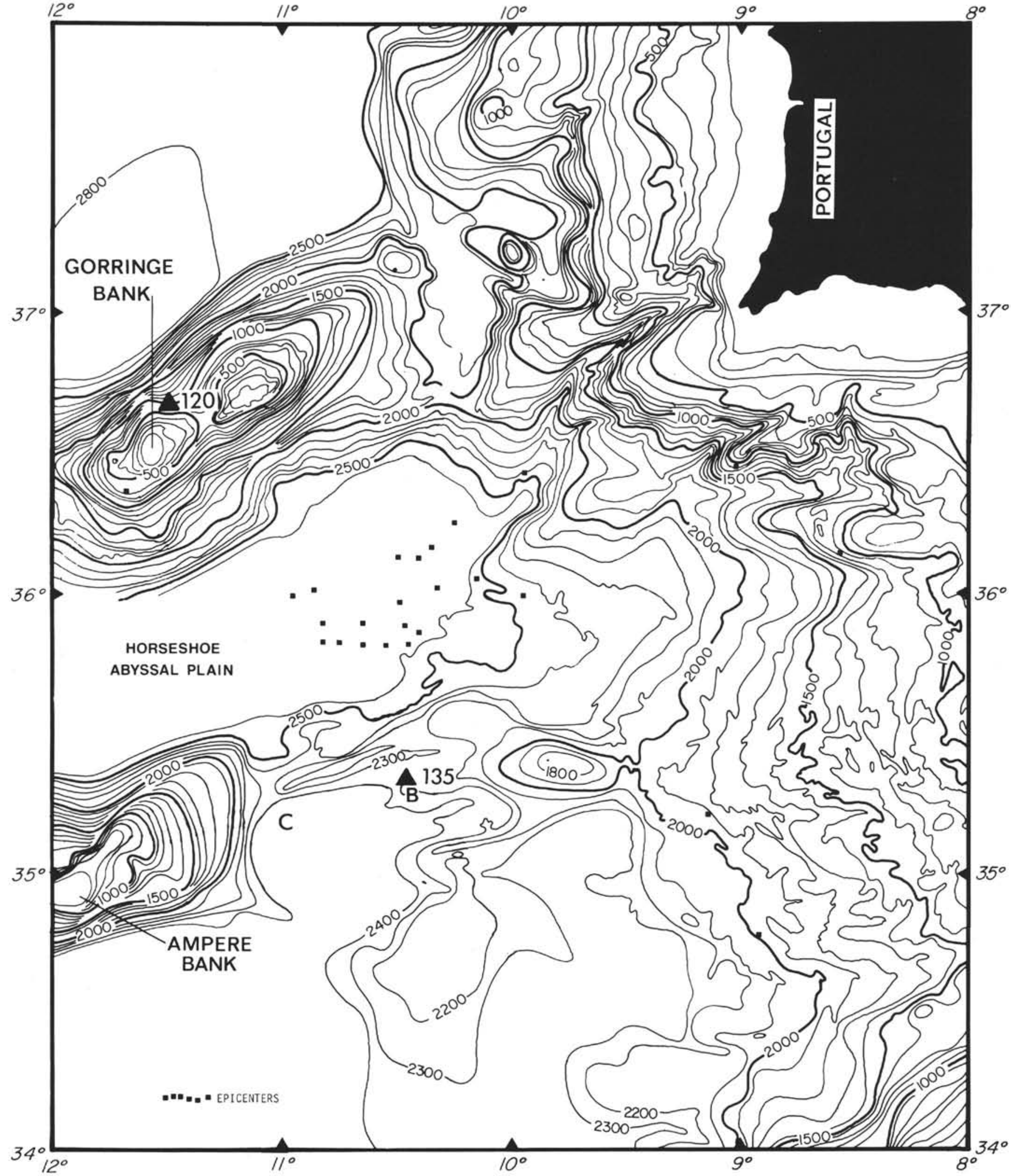


Figure 1. *Gorringe Bank in the eastern North Atlantic. Contours are in fathoms from unpublished maps of A. S. Laughton.*

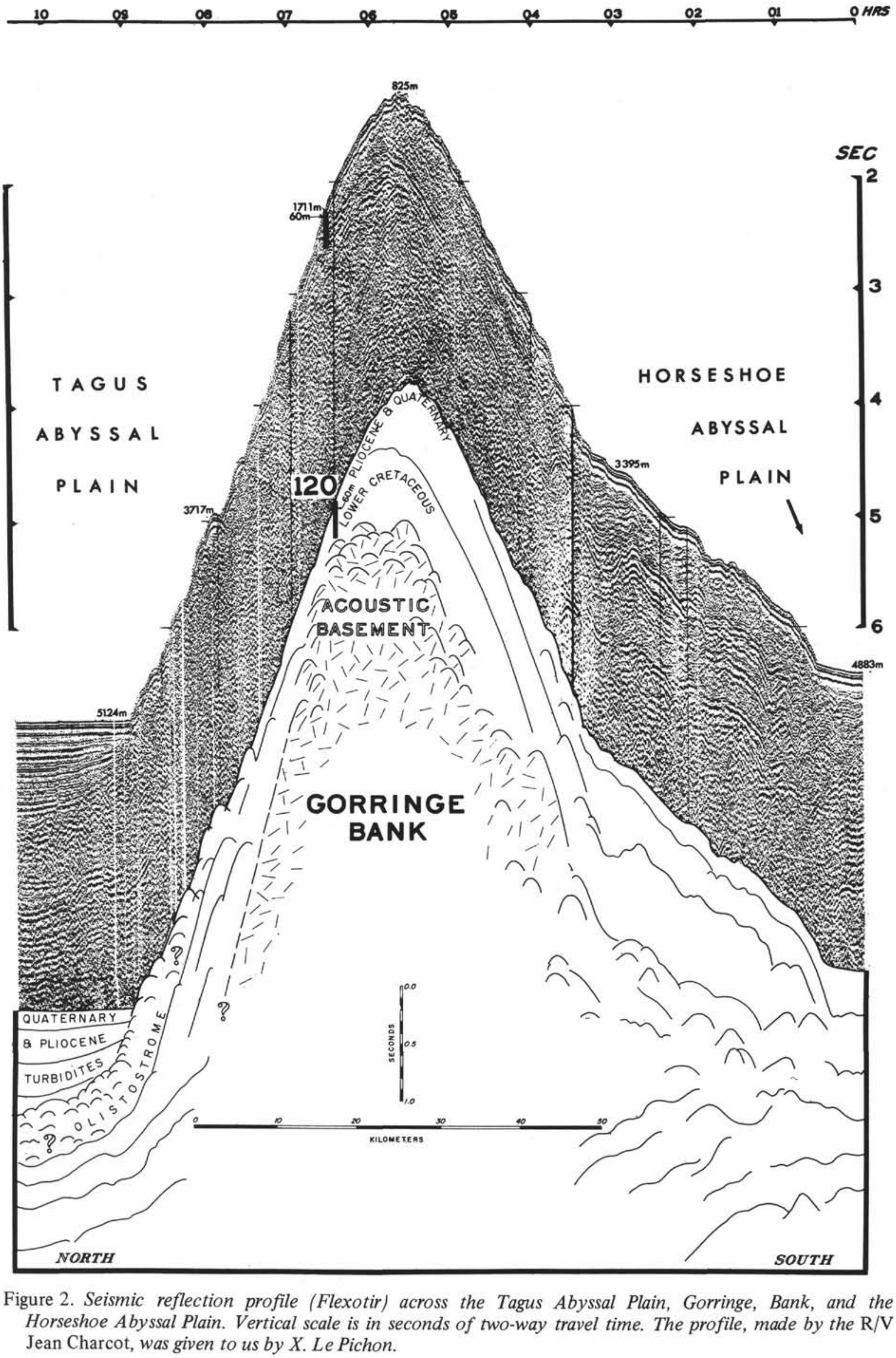


Figure 2. *Seismic reflection profile (Flexotir) across the Tagus Abyssal Plain, Gorringe, Bank, and the Horseshoe Abyssal Plain. Vertical scale is in seconds of two-way travel time. The profile, made by the* R/V Jean Charcot, *was given to us by X. Le Pichon.*

from "deep-water" sediments to those of a shallow "seamount" facies would indicate when the compressive tectonics were activated along the Azores-Gibraltar Plate boundary. It was of interest to find out if this time interval could be correlated with orogenic activity in the Betic and Rif Mountain chains further east along the seismic belt.

Strategy

The site was selected at 36°42.1'N, 11°22.4'W, at 0630 hours, January 1, 1970 on a flexotir profile of *Charcot* cruise No. 9 shown in Figure 2. This location offered an opportunity (1) to spud into a superficial cover of young sediment (in order to stabilize the bottom hole assembly during the first 50 meters of penetration), and (2) to permit entry by subcrop into strata that lay below a series of strongly-reflecting interfacies. It was believed that these layers might consist of chert which possibly would prohibit further penetration. By drilling at a depth of approximately 1700 meters, the operation time for pipe laying and coring would be significantly reduced, and it was hoped that basement could be reached within a minimum of station time.

Challenger Site Approach

The *Challenger* approached the Gorringe Bank site on August 14, on course 224°, dead reckoning from a satellite fix at 1250 hours (Figure 3). Both the 12 kHz echo-sounding system and the satellite receiver failed. At 1635 hours the course was changed to the west at 261 degrees to put the vessel in a position to approach the bank from downslope perpendicular to its strike. The decision was made so that if the navigation system was not operational within a few hours, the site would be located on the basis of crossing the 900 fathom (2.25 second) isobath on the shipboard seismic reflection profile. Fortunately, the satellite navigation system was repaired and a fix was obtained at 1646 hours. This fix indicated the position of the vessel to be 5.5 miles northeast of the target. At 1705 hours, the course was changed to 170 degrees and at 1738 hours a comparison of the *Challenger* seismic-reflection profile with that of the *Charcot* survey indicated we were at a desirable location. A buoy was thrown overboard, and the profiler and magnetometer towing apparatus were secured. The vessel then returned to the vicinity of the buoy with due correction made for the drift to the east, and arrived on site at 1820 hours. The mean position of sixteen satellite fixes—while drilling on station—placed the site a little less than 5 kilometers east-southeast from the original target. The drill string measurement of 1711 meters corresponded to a target depth of 1730 meters (corrected for sound velocity) on the *Charcot* profile.

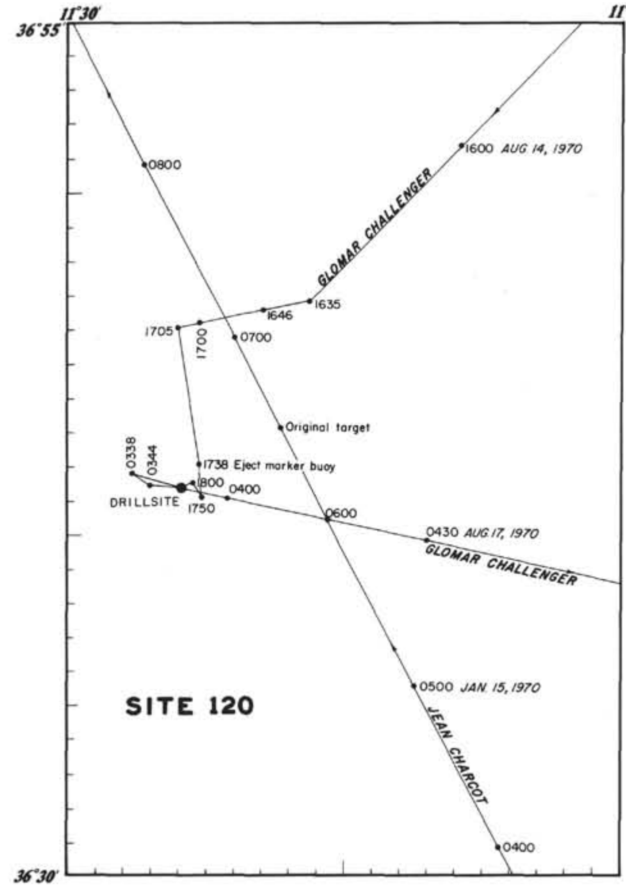


Figure 3. *Details of* Challenger *approach to Site 120, showing also the track of the* Jean Charcot *seismic profile of Figure 2.*

OPERATIONS

The *Challenger* stayed on location for 57 hours, between 1820 hours, 14 August and 0312 hours, 17 August. The hole was terminated at 253.4 subbottom meters after having penetrated 8 meters into the basement rocks. A total of 8 cores were recovered. Table 1 summarizes the core inventory and Figure 4 shows the drilling rate curves.

Several "drill-breaks," including abrupt changes in penetration and/or notable differences in torque were encountered: at 43 meters, 120 meters, and 246 subbottom meters. Those horizons may represent a Pliocene-Lower Miocene disconformity, the Tertiary-Upper Cretaceous sedimentary hiatus and the sediment-basement contact, respectively. Particularly hard strata were penetrated near 175 meters and 190 meters in the Cretaceous marl section; they might represent more highly silicified or cherty intercalations.

We used a Smith 3-cone button bit, which proved quite ineffective in providing reasonable penetration rates in the stiff, waxy Cretaceous marls. The drilling rates ranged from 10 to 20 m/hr when the upper part of the Cretaceous sequence was cut, but eventually were reduced to less than 2 to 6 m/hr in the lower section below 200 meters. Drilling in the gabbroic basement actually proved to be faster than in the overlying marls.

The drilling was carried out under good weather conditions; the pitch and roll of the vessel were less than 2 degrees. A computer failure in the ship's automatic positioning system resulted in a minor loss of drilling time. Attempts to recover the pre-Miocene unconformity by a side-wall coring device failed because a piece of the basement rock had stuck in the drill bit opening. A beacon release-mechanism was tested without success.

In Hole 120 we ran into the twin problems which were to plague us for the rest of the trip; namely, poor recovery

TABLE 1
Core Inventory – Site 120

Core	No. Sections	Date	Time	Cored[a] Interval (m)	Cored (m)	Recovered (m)	Subbottom Penetration (m) Top	Bottom	Lithology	Age
1	CC	8/15	07:50	1781-1790	9.0	0.10	60.0	69.0	Nannofossil ooze	Lower Miocene
2	1	8/15	15:45	1865-1870	6.0	0.80	144.0	149.0	Marl ooze	Albian
3	CC	8/15	19:10	1885-1886.4	1.4	0.14	164.0	165.5	Marl ooze	Albian
4	1	8/15	22:45	1916.2-1920.6	4.4	1.40	199.6	204.0	Marl ooze	Aptian-Barremian
5	1	8/16	05:35	1940-1942.1	2.1	0.70	219.0	221.1	Marl ooze	Barremian
6	CC	8/16	08:35	1947-1948	1.0	0.10	226.0	227.0	Marl ooze	Barremian
7	1	8/16	11:46	1950-1953	3.0	1.20	229.0	232.0	Marl ooze	Barremian
8	CC	8/16	18:10	1972.7-1974.4	1.7	1.00	251.7	253.4	Ophiolite Basement	–
Total					27.6	5.44		253.4		
% Cored					10.9%					
% Recovered						19.7%				

[a]Drill pipe measurements from derrick floor to sea floor: 1721 meters.

and slow penetration-rate. We questioned whether the button-bit which was designed to penetrate chert or other brittle formations was an adequate compromise when drilling in thick formations of waxy shales.

BIOSTRATIGRAPHY

Miocene and Lower Cretaceous (Albian to Barremian) sediments were recovered from the 8 cores at this site. In addition, Lower Pliocene and Quaternary fossiliferous sediments were found adhering to the drill bit.

Calcareous nannoplankton is the best represented fossil group. Planktonic foraminifera are rare or absent, especially in the Mesozoic section; benthonic foraminifera are generally scattered, and never abundant; Radiolaria are common in the Albanian-Aptian interval, and a chip of radiolarian chert was found with fragments of spilitic basalt in the basement core.

Discontinuities in the Section (M.B.C.)

The micropaleontological record at Site 120 reveals the presence of Miocene (Core 1) and Albian/Barremian (Cores 2 through 7) sediments. Quaternary and Lower Pliocene planktonic foraminifera were found in drill bit samples, as the well must have penetrated sediments of those ages somewhere between the sea floor and less than 60 meters (Core 1).

Some 75 meters of uncored strata intervene between the Lower Miocene and Albian. There was no fossil evidence for the existence of any sediments of intermediate ages, either through sediment reworking or downhole contamination. A comparison with Leg 11 sites in the western Atlantic suggested the existence of a major stratigraphic gap. Alternately the uncored interval may be largely represented by an extremely condensed section of deep-sea clays. Also, deposition from Lower Miocene to Pleistocene times cannot have been continuous, as suggested by both the distinct difference in lithology and by the exceedingly small thickness of the section. However, we lack any good evidence to state whether one major gap (between Lower Miocene and Lower Pliocene) or two gaps (the second being intra-Pliocene) exist in this section.

Oldest Sediment (M.B.C.)

The oldest sediment recovered has been found in Core 7, and is dated on the basis of nannofossils and of benthonic foraminifera (see below) as Lower Cretaceous (Barremian). These sediments are the oldest recovered so far from the deep sea in the eastern Atlantic. Sediments of older ages are probably represented by the 14-meter, uncored section immediately above the igneous basement.

Paleoenvironment (M.B.C.)

All the sediments and the fossil assemblages recorded from this site indicate a bathypelagic environment. The possibility of deposition occurring below the lysocline will be further discussed in the section on planktonic foraminifera. No clear evidence of a shallower deposition near the bottom of the section exists.

Sparse bryozoan fragments were found together with the Pliocene and Pleistocene planktonic foraminifera adhering to the drill bit, and in the splines of the bottom-hole assembly. If those megafossils are authochthonous, their presence would indicate that in some time after deposition of the deep-sea Lower Miocene sediments, parts of the Gorringe were elevated into shallow-water environments.

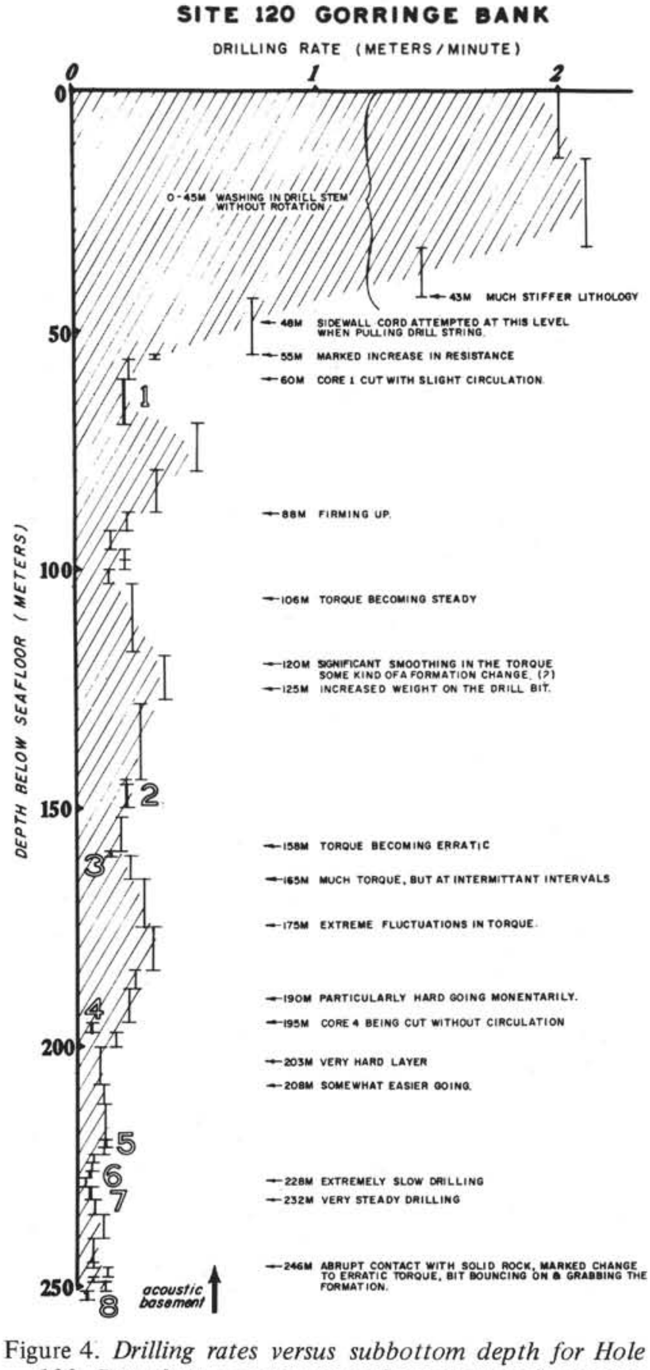


Figure 4. *Drilling rates versus subbottom depth for Hole 120. Bars show average rates of penetration for various intervals of uniform drilling. Intervals of coring are not included in the fitted curve, since they were cut often without circulation and with lesser bit pressures on the formation. Note the basement contact at 246 meters and a major change in formation hardness at 55 meters.*

Sedimentation rates (M.B.C.)

Major gaps exist in the section penetrated at Site 120; coring was discontinuous and some stratigraphic intervals could not be dated precisely. The only interval for which it is reasonable to make a plot of sedimentation-rate is the Lower Cretaceous. With the Barremian documented in Core 7 (approximately 120 million years at 230 meters) and the late Albian present in Core 2 (about 97 million years at 147 meters), the computed rate of sedimentation is 0.4 cm/1000 yrs. The rate is low, but comparable to that of nannofossil oozes devoid of foraminifera (see Maxwell *et al.*, 1970, p. 451).

Planktonic Foraminifera (M.B.C.)

Planktonic foraminifera were recovered at Site 120 in Core 1 (core catcher), but the assemblage is poor, both in abundance and in diversity, and the fauna is poorly preserved. The recorded taxa include:

Catapsydrax unicavus (Bolli)
Catapasydrax sp.
Globigerina venezuelana (Hedberg)
Globigerinoides trilobus (Reuss)
Globigerinoides sp.
Globoquadrina dehiscens (Chapman, Parr and Collins)
Globoquadrina aff. *langhiana* (Cita and Gelati)
Globorotalia obesa (Bolli)

Also present are fragments of large spherical chambers probably belonging to *Orbulina*; they are believed to be downhole contaminants. The age of the assemblage is Lower Miocene.

Late Neogene planktonic foraminifera have been encountered as downhole contaminants in the core catcher of Core 2, Site 120. The recorded taxa include sparse specimens of:

Globigerina bulloides (d'Orbigny)
Globigerinita glutinata (Egger)
Globorotalia inflata (d'Orbigny)
Globorotalia scitula (Brady)
Orbulina universa (d'Orbigny)

Their occurrence (*G. inflata* first appears in the Upper Pliocene) indicates that the uncored section above Core 1 included Upper Pliocene (or younger) sediments. This interpretation is confirmed by the rich assemblages found in the sediments that adhered to the drill bit (see discussion on extra core material).

One single specimen of *Hedbergella* cf. *infracretacea* (Glaessner) has been recorded from Core 2, Section 1 (123 centimeters), while other samples investigated from this core as well as from the lower ones did not yield any specimens of planktonic foraminifera. This absence of one of the most characteristic constituents of calcareous plankton during the later part of the Lower Cretaceous is very puzzling. Solution due to deposition below the carbonate compensation depth has been considered. This assumption is perplexing if the topographic setting of the site has not changed since the original deposition of the sediments, because the *in situ* depth is less than one half of the present day calcium compensation depth (about -4900 meters in the North Atlantic). We could assume, however, that the water depth was much greater during Cretaceous times than it is now at this site—the present elevation of the bank being a result of Neogene tectonic activity. As an unattractive alternative, we may postulate no primary production of foraminifera in the eastern North Atlantic at this time.

The absence of globigerinids in the Lower Cretaceous of the Betic-Balearic Province has also been recorded by Colom (1967), who thinks it is controlled by depth of deposition, which was greatest during Neocomian (Valanginian-Hauterivian) times.

Albian sediments have been penetrated and cored in the Bahama area during DSDP Leg 1 (Sites 4 and 5) and during Leg 11 (Site 105). In both cases they yielded planktonic foraminifera associated with calcareous nannoplankton and other fossil groups, although the *in situ* water depth there (over 5000 meters) is well below the present calcium compensation depth.

Benthonic Foraminifera (W.M.)

Core 1 was assigned to the Lower Miocene on the basis of its planktonic foraminifera and its nannoflora. The very rare benthonic foraminifera present in the core catcher include:

Nonion cf. *soldanii* (d'Orbigny)
Pleurostomella alternans (Schwager)
Gyroidina soldanii (d'Orbigny)
Eponides umbonatus (Reuss)
Pullenia bulloides (d'Orbigny)
Laticarinina pauperata (Parker and Jones)
Cibicides pseudoungerianus (Cushman)

Lower Cretaceous

Fair Lower Cretaceous assemblages of benthonic foraminifera are present in Cores 2, 3, 4, 5, and 7. On account of the presence of *Lingulogavelinella* aff. *ciryi ciryi* Malapris-Brizouard, an Albian age is established for Cores 2 and 3. The presence of *Lenticulina ouachensis multicella* (Bartenstein, Bettenstaedt and Bolli) in Core 4 is suggestive of a Barremian age. The occurrence of *Gavelinella* aff. *barremiana* Bettenstaedt suggests that Core 7 is not older than Barremian.

Noteworthy is the absence of any nearshore elements, such as *Orbitolina, Dictyoconus, Orbitolinopsis, Choffatella*, etc., which are so characteristic for the neritic beds of Barremian-Aptian age all over the world. Other taxa like *Conorotalites* and *Epistomina*, which often occur in beds of that age, are also absent here.

A detailed analysis of the Lower Cretaceous foraminiferal fauna of the Gorringe Bank sequence is presented in Part III (Chapter 41.1) of this volume, including illustrations and a range chart.

Nannofossils (H.S.)

All of the core samples from the sediment sequence (Cores 1 through 7) contain nannoplankton fossils in great abundance. In addition to the core material recovered, drill bit samples from the interval between the sea floor and the first core (60 to 90 meters) were examined; this material, adhering to the bit cones and bottom-hole assembly proved that Quaternary sediments with *Gephyrocapsa oceanica* are present above the Lower Miocene of Core 1.

Core 1 with *Discoaster aulakos, D. challengeri mediterraneus, D. deflandrei* and *D. obtusus* contains an assemblage which corresponds to the assemblages found in Italy from Lower Langhian (*Praeorbulina glomerosa* s.l. Zone) to Middle Serravalian (*Globoquadrina altispira/Globoratalia miozaea* Zone). Cores 2 through 7 contain nannoplankton fossils of Lower Cretaceous age. Nannoconids are not present or are rather rare (Core 4) as compared with the great numbers of coccoliths. The flora indicates that the Lower Cretaceous sequence extends from Albian down to Barremian (Assemblage 2 in Bronnimann, 1955), but a lower age limit cannot be given.

The age-diagnostic coccolith assemblages in selected samples is shown below:

Quaternary

Sample: 13-120, Bits and Subs No. 1:
Coccolithus pelagicus
Cyclococcolithus antillarum
Cyclococcolithus leptoporus
Gephyrocapsa oceanica
Helicosphaera carteri
Pontosphaera japonica
Rhabdosphaera clavigera
Rhabdosphaera stylifera
Sphenolithus abies

Comment: The high frequency of coccoliths indicates a "nanno-ooze" type of sediment. Very rare discoasters (*D. brouweri*, Pliocene) and some Upper Cretaceous nannofossils (*Micula staurophora*) are present, evidently reworked,

Miocene

Samples: 13-120-Bits and Subs No. 1-15; 13-120-1, CC:
Coccolithus pelagicus
Coccolithus marismontium
Cyclolithella rotunda
Discoaster aulakos
Discoaster challengeri
Discoaster deflandrei
Discoaster obtusus
Sphenolithus abies

Comment: The discoasters of this Miocene assemblage seem to be slightly overcalcified, especially in the core bit sample. According to Cati and Borsetti (1970) such an assemblage is characteristic for their "*Discoaster challengeri mediterraneous* Zone," which extends from Lower Langhian to Middle Serravalian (*Praeorbulina glomerosa* s.l. Zone to *Globoquadrina altispira/Globorotalia miozea* Zone).

Lower Cretaceous

Sample: 13-120-2-1, 100 cm:
Biscutum testudinarium
Cricolithus pemmatoides
Cyclococcolithus circumradiatus
Cyclolithella sp.
Lithraphidites carniolensis
Parhabdolithus angustus
Parhabdolithus embergeri

Rhabdolithina splendens
Watznaueria barnesae
Zygolithus crux
Zygolithus diplogrammus
Zygolithus litterarius

Sample: 13-120-2-1, 125 cm:
Arkhangelskiella striata
Cretarhabdus crenulatus
Cyclococcolithus circumradiatus
Lithraphidites carniolensis
Parhabdolithus angustus
Parhabdolithus embergeri
Rhabdolithina splendens
Watznaueria barnesae
Zygolithus crux
Zygolithus erectus

Sample: 13-120-2, CC:
Biscutum testudinarium
Cricolithus pemmatoides
Cretarhabdus crenulatus
Corollithion signum
Cyclococcolithus circumradiatus
Lithraphidites carniolensis
Parhabdolithus embergeri
Reticulofenestra parvidentata
Stephanolithion laffitei
Watznaueria barnesae
Zygolithus crux
Zygolithus diplogrammus
Zygolithus litterarius

Comment: The samples of Core 2 are very abundant in *Watznaueria barnesae*; also *Parhabdolithus embergeri, Cretarhabdus conicus* and *Lithraphidites carniolensis* are common. No nannoconids were found. The assemblage corresponds closely to the nannoflora of the Albian stratotype as described by Manivit, 1965 and to the Albian of Delft 2, Holland, described by Stradner, Adamiker and Maresch (1968).

Sample: 13-120-3, CC:
Arkhangelskiella striata
Biscutum testudinarium
Cricolithus pemmatoides
Cretarhabdus crenulatus
Lithraphidites carniolensis
Parhabdolithus embergeri
Rhabdolithina splendens
Rhagodiscus asper
Stephanolithion laffitei
Watznaueria barnesae
Zygolithus achylosus

Comment: No nannoconids recorded. Assemblage similar to that of Core 2. Albian.

Sample: 13-120-4-1, 1 cm:
Cretarhabdus crenulatus
Lithastrinus floralis
Lithraphidites carniolensis
Parhabdolithus embergeri
Rhagodiscus asper
Watznaueria barnesae

Sample: 13-120-4-1, 40 cm:
Arkhangelskiella striata
Cretarhabdus crenulatus
Cruciplacolithus cuvillieri
Lithraphidites carniolensis
Parhabdolithus embergeri
Rhagodiscus rugosus
Watznaueria barnesae

Sample: 13-120-4-1, 125 cm:
Cretarhabdus crenulatus
Cruciplacolithus cuvillieri
Lithraphidites carniolensis
Nannoconus colomi
Nannoconus kamptneri
Parhabdolithus embergeri
Rhagodiscus asper
Watznaueria barnesae
Zygolithus diplogrammus

Sample: 13-120-4, CC:
Braarudosphaera africana
Cretarhabdus crenulatus
Cruciplacolithus cuvillieri
Cyclococcolithus circumradiatus
Glaucolithus phacelosus
Lithraphidites carniolensis
Micrantholithus obtusus
Nannoconus colomi
Nannoconus steinmanni
Nannoconus truitti
Parhabdolithus embergeri
Watznaueria barnesae
Zygolithus crux
Zygolithus diplogrammus

Comment: The assemblages in the samples of Core 4 are very abundant in *Watznaueria barnesae. Cruciplacolithus cuvillieri* and *Parhabdolithus embergeri* are common. The nannoconids are rather rare, as they usually are in the upper part of the Lower Cretaceous. Barremian to Middle Aptian.

Sample: 13-120-5-1, 109 cm:
Cretarhabdus crenulatus
Cruciplacolithus cuvillieri
Lithraphidites carniolensis
Parhabdolithus embergeri
Watznaueria barnesae
Zygolithus crux
Zygolithus erectus

Sample: 13-120-5, CC:
Braarudosphaera africana
Cretarhabdus crenulatus
Cruciplacolithus cuvillieri
Lithraphidites carniolensis
Parhabdolithus embergeri
Rhagodiscus asper
Watznaueria barnesae
Zygolithus crux

Comment: No nannoconids were found in Core 5. Preservation moderate. Lower Cretaceous.

Sample: 13-120-6, CC:
Cretarhabdus crenulatus
Cruciplacolithus cuvillieri
Cyclagelosphaera margereli
Parhabdolithus embergeri
Rhagodiscus asper
Watznaueria barnesae
Watznaueria britannica

Comment: *Cyclagelosphaera margereli* and *Watznaueria britannica* indicate the lower part of the Lower Cretaceous.

Sample: 13-120-7-1, 55 cm:
Cretarhabdus crenulatus
Cruciplacolithus cuvillieri
Cyclagelosphaera margereli
Parhabdolithus embergeri
Watznaueria barnesae
Watznaueria britannica

Sample: 13-120-7-1, 76 cm:
Same.

Sample: 13-120-7-1, 95 cm:
Arkhangelskiella striata
Biscutum testudinarium
Cruciplacolithus cuvillieri
Cyclagelosphaera margereli
Lithastrinus grilli
Lithraphidites carniolensis
Parhabdolithus embergeri
Watznaueria barnesae
Watznaueria britannica

Sample: 13-120-7, CC:
Cretarhabdus crenulatus
Cruciplacolithus cuvillieri
Cyclagelosphaera margerili
Parhabdolithus embergeri
Rhagodiscus asper
Watznaueria barnesae
Watznaueria britannica

Comment: In Core 7 *Watznaueria barnesae* is the dominant species. *Cyclagelosphaera margereli* and *Watznaueria britannica* are less common. Moderate preservation. No nannoconids. Lower half of Lower Cretaceous.

Sample: 13-120-8:
Down-hole contaminants were found together with the core (spilitic basalt and serpentinized gabbro) inside the core liner: Nannofossils (*Cyclagelosphaera margereli, Rhagodiscus rugosus* and *Watznaueria barnesae*) of similar age as those from Core 7.

Radiolaria (P.D.)

A rich and diversified radiolarian fauna has been found in Cores 2, 3 and 4. All the radiolarian tests are pyritized, similar to those in the Albian and Aptian sediments at Site 105. The tests are filled internally by calcite. The preservation is excellent.

The richest assemblage has been recorded in Section 1, Core 2 (116 centimeters), where it constitutes a radiolarian ooze. The radiolarians become rarer with depth and are absent below Core 4. This assemblage is, for the most part, constituted of cryptothoracic tricyrtids. Unfortunately, the pyritization of their skeletons masks or obliterates the inner structure, so that their generic assignment is in some instances difficult. Furthermore, many species are still undescribed, and the stratigraphical range of the previously described species is not well known. Thus the radiolarian assemblage cannot be used for precise stratigraphical zonation.

The cryptothoracic tricyrtids include:
Cryptamphorella conara (Foreman)
Hemicryptocapsa cf. *tuberosa* (Dumitrica)
Hemicryptocapsa ex gr. *polyhedra* (Dumitrica)
Hemicryptocapsa spp.
Holocryptocanium aff. *barbui* Dumitrica

The polychambered Nassellarids are represented by a few species of:
Dictyomitra
Stichomitra (?) with tuberculate surface
Dictyomitra (?) (n.g.) *hornatissima* Squinabol
Amphipyndax spp.

Spumellarids are subordinate, those recognized include:
Pseudoaulophacus superbus (Squinabol)
?Comosphaera sphaeroconus (Rust)
Stylosphaera spp.
Theodiscus spp.
Other taxa are also present.

There seems to be contradictory evidence as to the age of this fauna. Two species of *Dictyomitra* have been illustrated by E. A. Pessagno (in Ewing *et al.*, 1969, Plate 5, Chapter 25, Figures C and D) from the Albian in the Blake-Bahama Basin area, yet rather similar forms appear in Lower Campanian of Romania, or in Upper Turonian-Lower Senonian of Indonesia. *Pseudoaulophacus superbus* is a long-ranged species, being recorded from Albian to Senonian. Other species, such as *Stichomitra* (?) with tuberculate surface, *Dictyomitra* (n.g.) *hornatissima, Stylosphaera* spp. and others are similar to species known in Upper Cenomanian, Turonian or even Senonian. The predominance of the cryptothoracic species is an aspect typical of the Upper Cenomanian assemblage described from Romania (Dumitrica, 1970). Yet the abundance in such types might be related to similar environmental conditions and not so much to synchronism.

The Albian age of this rich radiolarian fauna has been established by the associated nannoplankton. It is interesting to note that many species seem to belong, or be related to, species hitherto known from the Upper Cretaceous. But, this might be due to the fact that the Upper Cretaceous radiolarian fauna is much better known than that of the Lower Cretaceous. A rich and diversified Albian fauna similar to the assemblage at this site has not yet been described in the literature.

Extra-Core Material (M.B.C.)

A rich, well-preserved and highly diversified foraminiferal fauna has been found adhering to the drill bit and bottom-hole assembly. Since it presumably came from the upper, uncored section penetrated at Site 120 and gives valuable information, it is briefly discussed.

The assemblage yielded by Samples 1 and 2 includes more than 20 taxa of planktonic foraminifera and is dominated by *Globorotalia truncatulinoides* and *G. inflata.*

TABLE 2
Nannofossil Range Chart for Hole 120

Age	Age	Depth Below Sea Floor (m)	Cores	*Cyclococcolithus antillarum* (Cohen)	*Cyclococcolithus leptoporus* (Murray & Blackmann)	*Gephyrocapsa oceanica* Kamptner	*Helicosphaera carteri* Kamptner	*Pontosphaera japonica* (Takayama)	*Rhabdosphaera clavigera* Murray & Blackmann	*Rhabdosphaera stylifera* Lohmann	*Sphenolithus abies* Deflandre	*Coccolithus pelagicus* (Wallich)	*Coccolithus marismontium* Black	*Cyclolithella rotunda* Kamptner	*Discoaster aulakos* Gartner	*Discoaster challengeri* Bramlette & Riedel	*Discoaster deflandrei* Bramlette & Riedel	*Discoaster obtusus* Gartner	*Biscutum testudinarium* Black	*Reticulofenestra parvidentata* (Deflandre)	*Coccolithion signum* Stradner	*Cretarhabdus crenulatus* Bramlette & Martini	*Cricolithus pemmatoides* Deflandre	*Cyclococcolithus circumradiatus* (Stover)	*Cyclolithella* sp.	*Lithraphidites carniolensis* Deflandre	*Parhabdolithus angustus* (Stradner)	*Parhabdolithus embergeri* (Noel)	*Rhagodiscus asper* Stradner	*Watznaueria barnesae* (Black)	*Zygolithus crux* (Deflandre & Fert)	*Zygolithus diplogrammus* (Deflandre)	*Zygolithus litterarius* (Gorka)	*Arkhangelskiella striata* Stradner	*Rhabdolithina splendens* (Deflandre)	*Zygolithus achylosus* Stover	*Stephanolithion laffittei* Noel	*Braarudosphaera africana* Stradner	*Micrantholithus obtusus* Stradner	*Cruciplacolithus cuvillieri* Noel	*Nannoconus colomi* Bronnimann	*Nannoconus kamptneri* Bronnimann	*Nannoconus steinmanni* Kamptner	*Nannoconus truitti* Bronnimann	*Zygolithus erectus* Deflandre	*Cyclagelosphaera margereli* Noel	*Watznaueria britannica* Stradner	*Lithastrinus grilli* Stradner	*Lithastrinus floralis* Stradner
		Sea Floor 1721 m																																															
Quaternary				x	x	x	x	x	x	x	x	x																																					
? early Pliocene ?																																																	
Miocene		60-69	1									x	x	x	x	x	x	x																															
?																																																	
Greenish gray Nannofossil ooze	Albian	144-149	2																x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x		x								x				
Greenish gray Nannofossil ooze	Albian	164-165	3																x			x	x			x	x	x	x	x				x	x	x	x												
Greenish gray Nannofossil ooze	Albian - - - - - - - - - - Aptian-Barremian	200-201	4																			x		x		x		x	x	x	x	x		x				x	x	x	x	x	x	x					x
Greenish gray Nannofossil ooze	Aptian-Barremian	219-221	5																			x				x		x	x	x	x							x		x					x				
Greenish gray Nannofossil ooze	Aptian-Barremian	226-227	6																			x						x	x	x										x						x	x		
Greenish gray Nannofossil ooze	Aptian-Barremian	229-232	7																x			x				x		x	x	x				x						x						x	x	x	
Gabbroid basement rocks		251-253	8																																														

The co-occurrence of phylogenetically advanced, fully-keeled *Globorotalia truncatulinoides* and of rare *G. tosaensis*, transitional to the former, speaks for an attribution to the middle part of Zone N 22 of Blow's zonal scheme. *Pulleniatina obliquiloculata* is present–although not common–also with the variant *finalis*, and is dominantly right-coiling. *Globigerinoides ruber* also shows a number of variants, including the high-spired *pyramidalis* and *elongatus*. Several tests are pink in color, as often recorded in the later part of the Quaternary. Other taxa recorded, in addition to those previously cited, include:

Globigerinoides conglobatus (Brady)
Globigerinoides sacculifer (d'Orbigny)
Hastigerina siphonifera (d'Orbigny)
Globigerina eggeri (Rhumbler)
Globigerina pachyderma (Ehrenberg) (rare, always right-coiling)
Orbulina universa (d'Orbigny).

Globorotalia menardii is extremely rare (just a few specimens, all left-coiling), as well as *Globorotalia hirsuta*. More abundant is *Globorotalia crassaformis*, with large specimens.

It is hard to give a paleoclimatic interpretation of this assemblage, which very probably is not coming from one individual layer. Generally speaking, we may say that it is indicative of warm-temperate surficial waters.

Sample 14 from the drill bit yielded a rich foraminiferal assemblage, consisting of a mixture of Quaternary forms (the same as previously discussed) and of Lower Pliocene ones.

The Lower Pliocene age is demonstrated by the abundance of keeled *Globorotalias*, which are characteristic for this time interval. The species recorded include, *inter alia:*

Globoquadrina altispira (Cushman and Jarvis)
Globoquadrina dehiscens (Chapman, Parr and Collins)
Globoquadrina larmeui (Akers)
Globorotalia acostaensis humerosa (Takayanagi and Saito)
Globorotalia cibaoensis (Bolli and Bermudez)
Globorotalia miozea (Finlay)
Globorotalia crassaformis (Galloway and Wissler)
Globorotalia margaritae (Bolli and Bermudez)
Globorotalia scitula (Brady)
Sphaeroidinellopsis seminulina (Koch)
Sphaeroidinellopsis subdehiscens (Blow).

The assemblage may be placed above the horizon of extinction of *Globigerina nepenthes* (which is not present here) and below the levels of extinction of *Globorotalia margaritae*, of *Sphaeroidinellopsis* spp. and of *Globoquadrina altispira*; more precisely in between the datums VI and VII of Saito (in Hays *et al.*, 1969), or at about 3.5 million years.

In terms of zonal schemes, this age assignment corresponds to the later part of Zone N 19 of Blow's zonal scheme and/or to the later part of the *Globorotalia margaritae* of Bolli's (amended, 1970) zonal scheme.

In terms of stages, it corresponds to the Tabianian and/or to the Zanclian (pars).

The Pliocene fauna recorded from the drill bit, which has to be present somewhere between the ocean floor and Core 1 at less than 60 meters, compares well with the Lower Pliocene recorded from the Cape Verde Site 12, DSDP. The latter, however, is strongly affected by solution, so that the faunal diversity is reduced and some of the stratigraphically interesting taxa are lacking, as for instance, *Globorotalia margaritae* (Cita, 1971).

A comparison with the Lower Pliocene assemblages of the Mediterranean deep sea is very interesting. In fact, the Gorringe Bank has about the same latitude as the Mediterranean Ridge (Ionian Basin) Site 125 (34°N); therefore, the faunal assemblages might be very similar. However, some important differences are apparent: *Globorotalia cibaoensis* is not recorded in the Lower Pliocene of Holes 125, 125A, or from any other Pliocene section recovered in the Mediterranean, as well as *Globorotalia miozea, Globoquadrina dehiscens* and *G. larmeui*. The last three species, however, are known for outcropping sections of middle and late Miocene age in the circum-Mediterranean area. *Globorotalia crassaformis* and *Globoquadrina altispira* very seldom occur in the Lower Pliocene of the Mediterranean drilling sites, while the former blooms in the Upper Pliocene.

In order to explain these apparent anomalies, we have to take into account that the marine fauna living in the Mediterranean was entirely destroyed during the "salinity crisis" which took place at the end of the Miocene (see Chapter 43, Part IV, this volume). The Pliocene fauna re-immigrated from the Atlantic into the Mediterranean, and, consequently it is strongly affected by the local conditions existing in the water masses immediately adjacent to the Straits of Gibraltar today.

The Pliocene fauna investigated from the core bit is not contemporaneous with the lowermost Pliocene transgression which brought oceanic water into the (desiccated) Mediterranean, distinctly younger.

Globorotalia margaritae is present here with the subspecies *margaritae* and *evoluta* (see Chapter 47.1 for further details on these new taxa); the latter is used in this report as zonal marker for the upper part of the Lower Pliocene (or Tabianian). *Globorotalia margaritae* is the most conspicuous taxon of the Mediterranean Lower Pliocene, and practically the only keeled Globorotaliid living at that time in the Mediterranean. At Gorringe Bank, only a few hundred kilometers from the Mediterranean, the Atlantic character of the foraminiferal assemblage is very distinct; *Globorotalia margaritae* is subordinate, both in size and in abundance in respect to other keeled Goloborotaliids.

One element which is common to the Lower Pliocene of the Gorringe Bank and to the deep-sea Mediterranean Pliocene is the near absence of *Sphaeroidinella dehiscens* in levels bearing representatives of the genus *Sphaeroidinellopsis,* where the cited taxa are known to co-exist (stratigraphically). This would suggest that either the depth habitat of *Sphaeroidinella* versus *Sphaeroidinellopsis*, or the temperature sensitivity, or both, are different.

LITHOSTRATIGRAPHY

Intermittent coring in the single hole drilled down to the basement allows an inferred stratigraphic succession to be presented. Five main lithological units are distinguished, which are from top to bottom: 1) Upper Calabrian orange-gray foraminiferal ooze; 2) Lower Pliocene white foraminiferal ooze; 3) Lower Miocene nannofossil-ooze with foraminifera; 4) Lower Cretaceous shaly marl; 5) chert, spilite, gabbro and serpentine of the ophiolite suite.

Table 3
Lithologic Units – Site 120

Unit	Lithology	Age
1	Orange-gray foraminiferal ooze,	Pleistocene
2	White foraminiferal ooze, pelagic	Lower Pliocene
55 m		
3	Nannofossil-ooze with foraminifera, pelagic	Lower Miocene
[69 m] (120?) [144 m]		
4	Laminated shaly marl, pelagic	Lower Cretaceous
246		
5	Ophiolite Suite, basement	
253.4		

Unit 1 – Orange-Gray Foraminiferal Ooze

Lumps of foraminiferal ooze of Upper Calabrian age were recovered from the outside cones of the core bit. Their exact stratigraphical location is not known, but must be situated somewhere between 60 meters subbottom and the seabed. It is possible that this lithologic unit was picked up in the attempt to take a side wall core at 48 meters subbottom. The ooze consists almost entirely of planktonic foraminifera with a few benthonic specimens. All the fauna are in an excellent state of preservation.

The ooze, a typical pelagic deposit, is plastic and orange-gray in color.

Unit 2 – White Foraminiferal Ooze

Lumps of white foraminiferal ooze, containing a lower Pliocene fauna, were found with the lumps of Unit 1. Their exact stratigraphic position is unknown, as in the case of Unit 1. The coarse fraction of this ooze is composed almost entirely of planktonic foraminifera with about 5 per cent of benthonic foraminifera and occasional bryozoa. It is also a typical pelagic deposit.

Unit 3 – Nannofossil-ooze with Foraminifera

A piece of nannofossil-ooze, 8 centimeters long, was recovered in the core catcher of Core 1 at 60 meters. The age of the fauna is Lower Miocene. The ooze is light greenish-gray, massive, homogeneous, stiff to firm, and displays no visible structures. It has a high carbonate content, being mainly composed of nannofossils with rare foraminifera (73 per cent calcium carbonate), accompanied by minor amounts of dolomite. The noncarbonate fraction is made of terrigenous debris: quartz, micas and clays. It is a pelagic deposit with terrigenous influxes.

Only 80 meters separates Core 1 from Core 2, which is Albian and about 80 million years older. Knowing the average sedimentation rates of calcareous oozes in this part of the Atlantic, either a depositional hiatus or a condensed red-clay section could be included in the uncored interval. This suggestion is supported by the absence of lithologies with Eocene and Oligocene faunas adhering to the drill bit or caught in the splines at the bottom-hole assembly, after a thorough search for such possible contaminants.

Unit 4 – Shaly Marl

Marls were cored between 144 and 232 meters. Despite the discontinuous coring, individual cores show a consistent lithology with only small petrographic changes between the top and the bottom. Cores 2 to 7, although containing visual nonconformities (Figure 5) represent a more or less continuous stratigraphic succession, ranging from Albian to Barremian.

Figure 5. *An angular unconformity in Core 2, Section 1 in a stiff Lower Cretaceous (Albian) marl ooze. Small slump balls can be seen above the near-horizontal contact, suggesting some modest sediment deposition from the slump body (or flow?) following the episode of sea-floor erosion. The scale bar represents one centimeter.*

The marls consist mainly of fine terrigenous components: quartz, micas, and clay minerals including illite, montmorillonite, mixed layer clays, chlorite and kaolinite, together with 20 to 35 per cent of calcareous nannofossils. In some horizons authigenic minerals are also noted such as pyrite in Cores 4, 5 and 7, and calcite in Cores 3 through 6. Diagenetic reactions can be seen as sharp color changes along fractures, denoting new oxidation-reduction states introduced by migrating fluids and/or gases (Figure 6).

The marls are dark greenish-gray in Core 2 and gradually become darker towards the bottom of the unit, where variegated green and red streaks occur. They show fine laminations which give a shaly character to the sediments at the base of the unit. Strata in Cores 4 and 5, however, show slump structures suggesting penecontemporaneous displacement of plastic sediment across the ancient seabed (Figure 7). In Core 4 minor amounts of debris of thin-shelled pelecypods were present in association with deep-water benthic foraminifera.

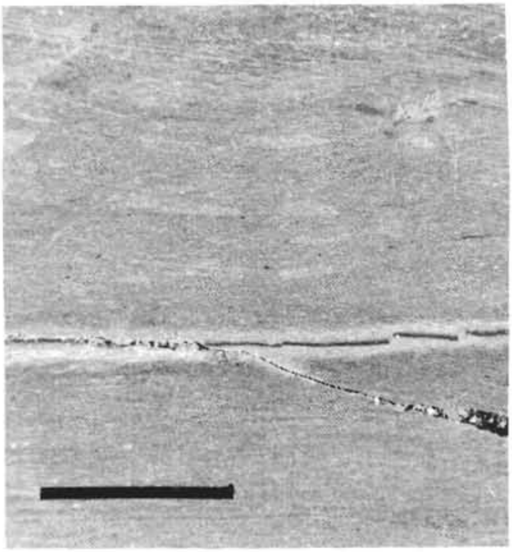


Figure 6. *Evidence of post-depositional reduction is shown by a thin green lamina in brownish-red shaly marl. Slight changes in the valance state of iron accompany local concentrations of organic matter along bedding planes and are common in the semi-indurated Lower Cretaceous sediments (Core 7, Section 1, 72 cm.). Scale bar represents one centimeter.*

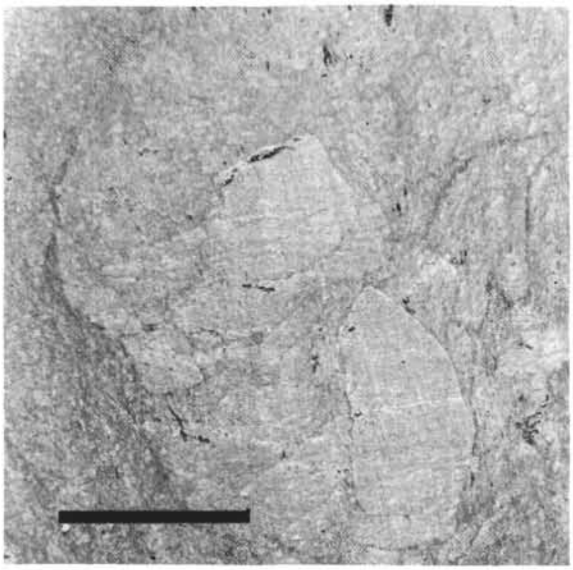


Figure 7. *Intraformational breccia in Aptian-Barremian marls (Core 4, Section 1). One cannot rule out that this unit is a drilling conglomerate, made while cutting the core; however, mud coatings on the rounded fragments are suggestive that they once rolled on the seabed before deposition. Scale bar represents one centimeter.*

Unit 5 – Ophiolite Suite

Core 8, drilled between 251.7 and 253.4 meters produced 0.9 meter of fragmented hard rocks.

Most of the recovered material is a coarse-grained gabbroic breccia (Figure 8) with crystals up to 3 centimeters of gray feldspar and tan bronzite. Smaller crystals include olivine, serpentinized as antigorite, and fibrous chrysotile, and some monoclinic pyroxenes (augite or diallage), which are also chloritized. A few small pebbles of fine-grained, light green-gray rock were recovered from the bumper-sub splines. In thin section, they consist of twinned, plagioclase laths, 0.1 to 1 millimeter long, embedded in a cryptocrystalline matrix. The relief of the plagioclase indicates that it is at least partially albitic. The Fe-Mg minerals are completely replaced by aggregates of chlorite. This rock resembles a spilite of the ophiolite suite.

In the core bit a few chips of dark green-gray, fine-grained serpentinite were recovered, along with fragments of radiolarian chert. The petrology of the basement rocks is discussed in greater detail in Chapter 26.

SUMMARY AND CONCLUSIONS

Two quite distinct facies of sediment were recovered from the northern flank of Gorringe Bank. The first and youngest consists of a highly calcareous biogenic ooze rich in foraminifera and coccoliths. This is the facies that was recovered from the roller cones of the drill bit, and from

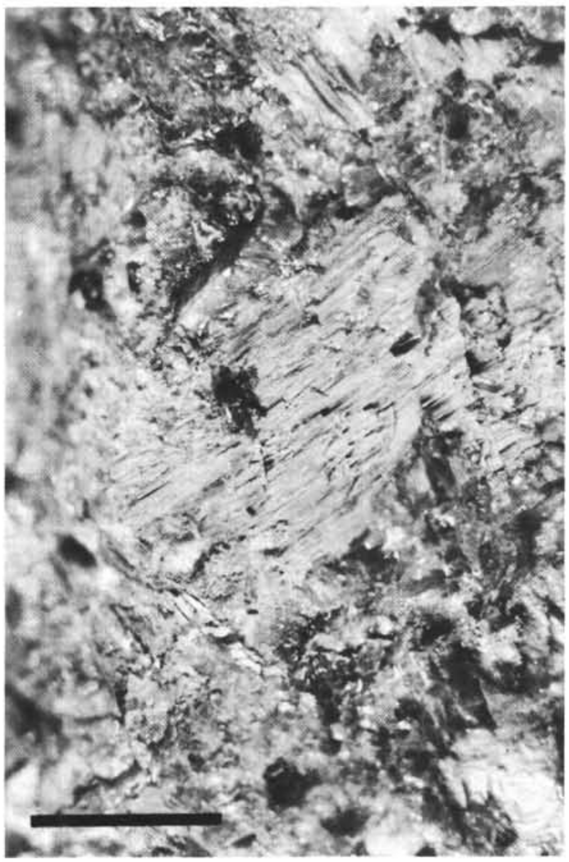


Figure 8. *Massive crystals of gray feldspar in the basement gabbro of Core 8. Scale bar represents one centimeter.*

the splines of the bottom-hole assembly after the drill string was retrieved from the hole. We surmise that this material was picked up from an interval between the sea floor and 60 meters subbottom, most likely when the drill string with the drill bit approximately 48 meters subbottom was run up and down violently in an attempt to send the side wall corer through the bit orifice. The materials recovered which range in age from Lower Pliocene to Pleistocene are light orange to white in color, with diverse assemblages of fauna, and in one sample with some admixture of allochthonous bryozoa.

We conclude that parts of Gorringe Bank must have been near the sea surface at this time (to supply the neritic debris), and thus the site on the northern wall was more or less at its present water depth of 1700 meters. The facies of ooze recovered from the outside of the drill string is very characteristic of the type of sediment which is recovered in piston cores from the flanks of nearby seamounts (Ericson *et al.,* 1961; Kudrass and Thiede, 1970).

The other distinct facies is that of the Lower Cretaceous marls. In these strata the planktonic (calcareous) foraminifera are exceedingly rare, and when present, they are poorly preserved. The coccolith fragments are heavily calcified, and the Radiolaria are seen only as pyritized fillings of former tests (see Figure 9). The sediment is distinctly stratified, except when contorted within intraformational breccias. The benthonic fauna does not include shallow-water species.

The environment at the time of deposition of the Lower Cretaceous marls must have been partly reducing as evidenced in the lack of burrowing organisms and by post-depositional diagenetive changes in the redox potential along fractures and/or gas-cracks. The early Cretaceous site of accumulation must have been sufficiently isolated from the Iberian continent so that no bottom transported terrigenous sediments (for example, turbidites) were intercalated within the shaly marls.

Discontinuities in the Sedimentary Section

Distinct unconformities occur in the sedimentary sequence of the Gorringe Bank site, and additional discontinuities can be inferred. Angular nonconformities are seen in Core 2 (Albian) and intraformational breccias in Cores 4 and 5 (see Figures 5 and 7). Coarsely crystalline basement rocks are found less than 19 meters from unmetamorphosed marls. An apparent hiatus in sedimentation in between the Lower Miocene and Lower Cretaceous is suggested by: 1) the tremendous time span between these age periods represented by a 75-meter uncored interval, and 2) probably more significantly, by the complete absence of faunas of Oligocene to Middle Cretaceous age, either foraminifera, Radiolaria, or nannoplankton, as downhole contaminants or as reworked materials into the younger strata that were recovered. It is a pity that in our impatience to penetrate rapidly to the basement, we did not core this important interval. Nevertheless, we did search carefully in cracks and crevices along the outside of the drill string for allochthonous fragments from this age span, and none were detected, despite a very abundant collection of Pliocene to Quaternary oozes, a moderate assemblage of Lower Miocene ooze, and fragments of Lower Cretaceous marl, chert, spilite, and serpentinite. By process of elimination, we suggest a depositional hiatus of perhaps 80 million years or, alternatively, an episode of Tertiary sea-floor erosion.

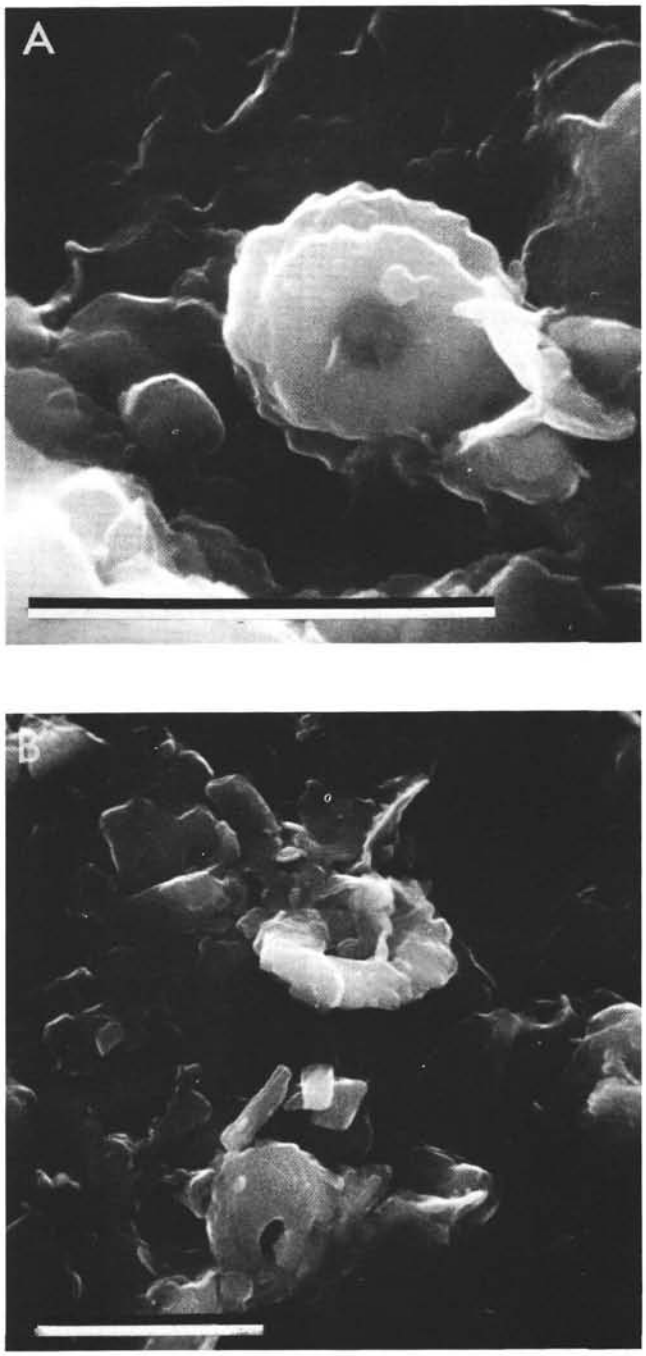


Figure 9. *Examples of badly corroded and heavily calcified coccoliths from the Barremian shaly marls. The coccolith shown in (A) is the best specimen found and has been tentatively identified as being a proximal view of* Cyclagelosphaera margereli *(Noel). The upper coccolith in (B) is shown in an oblique distal view. This form may belong in the genus* Ellipsagelosphaera. *Scale bars represent 5 microns. Identifications and photographs courtesy of Marcus Waring, Cambridge, England.*

For the gap between the Lower Miocene (Core 1 at 60 meters subbottom) and the allochthonous Lower Pliocene to Quaternary oozes, we cannot rule out that this unit might have slumped away downslope into the Tagus basin. In fact, a large intercalation (olistrostrome) in the Tagus Abyssal Plain sedimentary strata can be seen on the *Charcot* reflection profile shown in Figure 2 at a subbottom level consistent with a Pliocene age of emplacement.[2]

Gravity sliding off the northern flank of Gorringe is not unrealistic in light of inferred changes in elevation of the drill site from its former bathypelagic environment (probably at or below the calcium compensation depth) to its present elevation at 1711 meters.

Also of interest is the lack of any evidence in the lowermost unit of the Aptian-Barremian section of a transition downward into a shallower depositional environment. If an allochthonous sea-floor crust exists below these sediments, and if it was created at the axis of the mid-oceanic ridge, we note as an anomaly that either the ridge crest was unusually deep during its formation (and/or the lysocline was much shallower than it is today), or possibly, that the Aptian-Barremian section does not represent the oldest sediment of this region.

It certainly is surprising to have coarsely crystalline rocks so close to sea-floor sediment in an autochthonous setting. No contact metamorphism was noted, although a gap of 19 meters of unknown material exists between that sediment cored (Core 7) and the first basement rocks recovered (Core 8).

The presence (Cores 4 and 5) of contorted sediment with rounded and subrounded mudballs, but without a capping layer of suspension-derived sediment, indicate that the Lower Cretaceous depositional site was on a sloping seabed (that is, on the flanks of a basement ridge rather than at the crest or at the foot). This interpretation is also supported by the finding of an angular unconformity in Core 2. Since Core 2 came from strata 100 meters above the lowermost sediment cored, the topographic relief of the slope must certainly have exceeded this value. The examination of the fragments of the intraformational breccias permits us to conclude that the local sea-floor relief did not rise significantly above the lysocline, nor into a shallower more oxidizing environment.

Emplacement of the Basement Rock

The drilling was terminated in metamorphosed basalts and gabbros. The spilite fragments showed weathering along a single margin and may have come from what was once a chilled surface of a basalt pillow. The gabbros have apparently undergone retro-metamorphism to a level somewhere between an amphibolite to a greenshist facies. For elaboration on the petrology of the basement rocks see Chapter 26. At this time, it is not certain when this metamorphism took place. Metagabbros have been dredged on many occasions from fracture zones in the mid-Atlantic Ridge (Bonatti *et al.*, 1971; Melson and van Andel, 1966; Miyoshiro, *et al.*, 1970; Fox *et al.*, 1969; Aumento *et al.*, 1971).

[2]Piston cores from the Tagus Abyssal Plain studied by one of us (WBFR) have a recent sedimentation rate in the order of 10 cm/1000 yrs.

If igneous (magnetic) activity was present during the tectonic emplacement of the gabbro, and the gabbro is allochthonous into its setting (that is, below previously deposited Cretaceous marls), the local migration of heat from the emplacement to the seabed might account for the very low δO^{18} values measured in samples of recrystallized and calcified nannoplankton in Cores 4 and 7 (see Chapter 30.1). This argument, if valid, might favor an intrusion of the gabbro as a unit of the ophiolite suite during the orogenic uplift of Gorringe Bank between Lower Miocene (deep-sea facies of Core 2) and the Lower Pliocene (shallower facies of extra core material containing reworked bryozoa). Alternatively, the gabbro represents a lower crustal rock unit, possibly an upthrust of layer 3 of the oceanic crust. The metamorphism of the rock, in this case, may reflect shearing within the transform section of an early Cretaceous fracture zone. Its emplacement as an allochthonous unit beneath Gorringe may have involved only a thin zone of shearing (the recovered amphibolite) as has been reported for alpine ophiolite bodies in Cyprus and Greece (Gass, 1968; Temple and Zimmerman, 1969; Moores and Vine, 1971).

Opening of the Atlantic North of the Azores

A north-south geophysical profile across Gorringe Bank reveals a distinct polarity (Figure 10). The high free-air gravity anomaly of the elevated portion of the bank lies north of a gravity low over the Horseshoe Abyssal Plain. The low would be even more accentuated if it were not for the more than 9 kilometers of sediment fill in the Horseshoe Trough (Le Pichon *et al.*, 1970). No such comparable fill occurs to the north beneath the Tagus Abyssal Plain. Earthquake focal mechanisms reported by McKenzie (1970) in this region have a component of compressional stress dipping to the northwest perpendicular to the strike of Gorringe. The lower stratigraphic units of the Horseshoe Abyssal Plain are folded and arched. In reflection profiles of *Vema* Cruise No. 26 (P. J. Fox, personal communication) normal and reverse faults can be seen further south along the Ampere Ridge. The magnetic anomalies associated with the Gorringe come only from very shallow intrusive (?) bodies in the crestal zone. No large, broad-wavelength anomalies—such as those found on Josephine Bank to the west—are seen.

The geophysical parameters are comparable to those observed across oceanic trenches and island arcs. If we assume crustal consumption along the Gibraltar-Azores seismic zone, the polarity of the geophysical profile would indicate that it is the southern plate (part of the African plate) which is dipping and underthrusting beneath Gorringe. At this time it is difficult to say how much of this African plate has been consumed. It is of interest here that the location of Site 120 on the northern flank of Gorringe places that site today on the European (Iberia is now attached to the rest of Europe.) plate.

Since no additional plate boundary can be seen between the drill site and the Iberian continent (nor has one been inferred for the past), we believe that Site 120 occupies a piece of oceanic crust created between Iberia and Newfoundland during an episode of crustal accretion (spreading) as Iberia broke away from North America (and

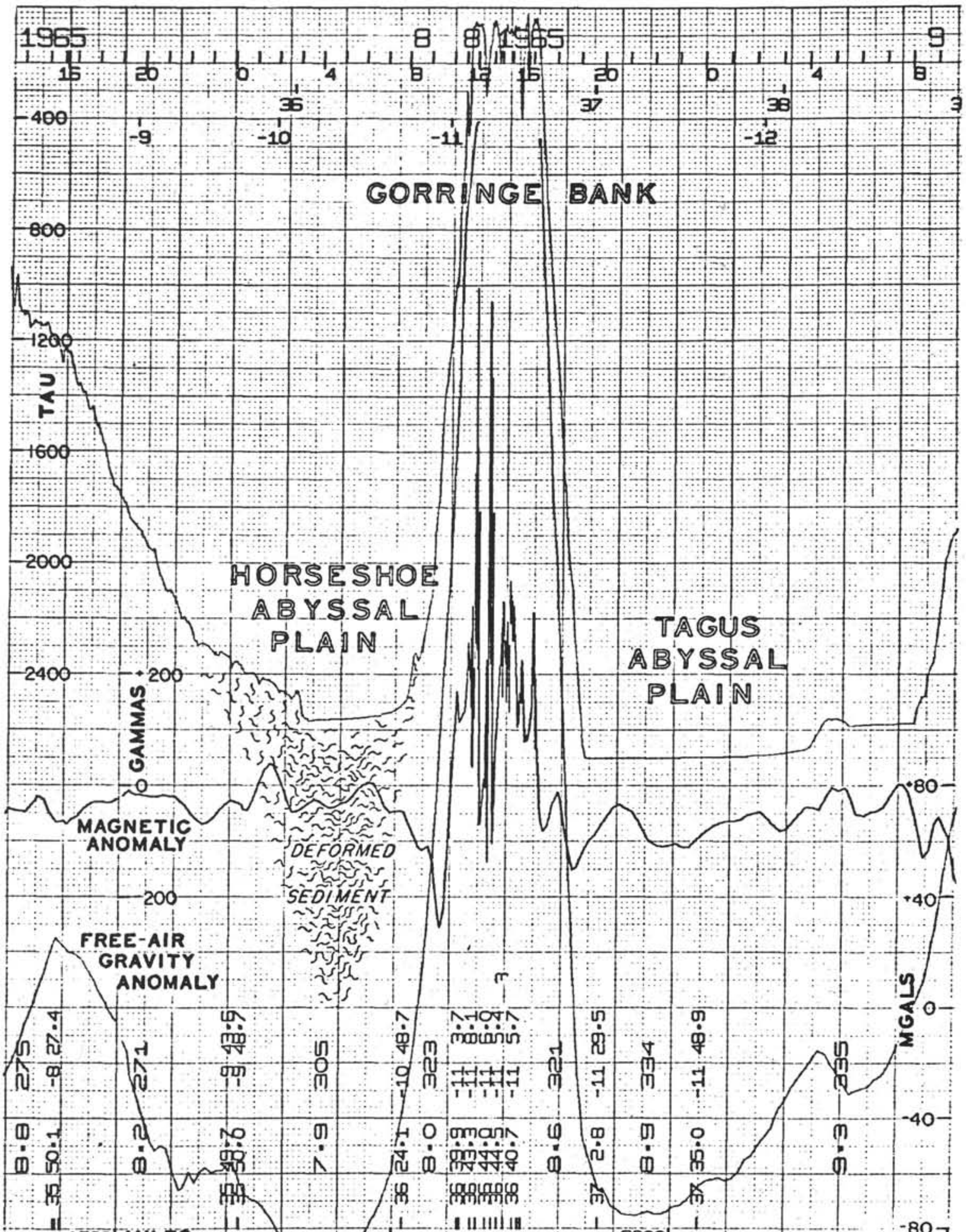


Figure 10. *Geophysical profiles across Gorringe Bank. The extremely high free-air anomaly indicates dense rocks (upper mantle?) within the core of the bank. The present seismicity occurs mostly to the south beneath the Horseshoe Abyssal Plain, which without its 6 kilometers of deformed sediments would be analogous to a Pacific-type oceanic trench. Despite the trench fill there is a considerable negative gravity anomaly here as well. Note, furthermore, the absence of broad, large magnetic anomalies over the bank. The sharp spikes are most likely caused by local extrusions on the crest.*

from Europe also, since Europe was still attached to North America). The Barremian age of the lowermost sediment recovered from the site indicates that the accreted sea-floor crust 110 kilometers west of the Iberian continent is at least 120 million years old. Since a rift between Iberia and North America implies a plate margin between Iberia and Europe, we believe that the investigation of the material from the Gorringe Bank site implies a lowermost Cretaceous or uppermost Jurassic age for the initial opening of the Bay of Biscay.

The transition from a deep-water facies (Core 1) to a shallow-water facies (allochthonous bryozoa in Lower Pliocene biogenic ooze) suggests an elevation of a former deep oceanic seabed, starting in the Lower Miocene and essentially arriving at its present configuration in the Lower Pliocene. The uplift of the bank is related to the consumption of the African plate beneath the European plate along an active plate boundary which extends from the Mediterranean to the mid-Atlantic Ridge (McKenzie, 1970). The northern dip of the Beniof zone has the same orientation as that in the seismically active Rif orogenic belt of Morroco.

REFERENCES

Aumento, F., Loncarevic, B. D. and Ross, D. I., 1971. Hudson Geotraverse: geology of the mid-Atlantic Ridge at 45°N. *Phil. Trans. Roy. Soc. Lond. A.* **268**, 623.

Bolli, H. M., 1970. The foraminifera of Sites 23-31, Leg 4. **In** Bader *et al.*, 1970. *Initial Reports of the Deep Sea Drilling Project, Volume IV*. Washington (U. S. Government Printing Office), 577.

Bonatti, E., Honnorez, J. and Ferrara, G., 1971. Peridotite-gabbro-basalt complex from the equatorial mid-Atlantic Ridge. *Phil. Trans. Roy. Soc. Lond. A.* In press.

Bronnimann, P., 1955. Microfossils *incertae sedis* from the Upper Jurassic and Lower Cretaceous of Cuba. *Micropaleontology.* **1** (1), 28.

Cati, F. and Borsetti, A. M., 1970. I Discoasteridi del Miocene delle Marche. *Giorn. Geol.* **36** (2), 617.

Cita, M. B., 1971. The Pliocene of Cape Verde, North Atlantic. Biostratigraphy, chronostratigraphy and paleoenvironment. *Rev. Micropaleontol.* **14**, in press.

Colom, G., 1967. Sur l'interprétation des sédiments profonds de la zone géosynclinale baléare et subbétique (Espagne). *Paleogeogr., Paleoclim., Paleoecol.* **3**, 299.

Dumitrica, P., 1970. Cryptocepholic and cryptothoracic *Nassellaria* in some Mesozoic deposits of Romania. *Rev. Roum. Geol., Geophys., Geogr.–Serie de Geologie.* 1970 (Bucharest). **14** (1), 45.

Ericson, D. B., Ewing, M., Wollin, G. and Heezen, B. C., 1961. Atlantic deep sea cores. *Bull. Geol. Soc. Am.* **72**, 193.

Fox, P. J., Lowrie, A., Jr. and Heezen, B. C., 1969. Oceanographer Fracure Zone. *Deep-Sea Res.* **16**, 59.

Gass, I. G., 1968. Is the Troodos Massif of Cyprus a fragment of Mesozoic ocean floor?. *Nature.* **220**, 39.

Hays, J. D., Saito, T., Opdyke, N. D. and Burckle, L. H., 1969. Pliocene-Pleistocene sediments of the equatorial Pacific: their paleomagnetic, biostratigraphic and climatic record. *Bull. Geol. Soc. Am.* **80**, 1481.

Heezen, B. C., Tharp, M. and Ewing, M., 1959. The floors of the oceans 1. The North Atlantic. *Geol. Soc. Am., Spec. Paper.* **65**. 122.

Kudrass, H. R. and Thiede, J., 1970. Stratigraphische untersuchungen an sedimentkernen des iberomarokkanischen kontinentalrandes. *Geol. Rundschau.* **60** (1), 294.

LePichon, X., Bonnin, J. and Pautot, G., 1970. The Gibralter end of the Azores-Gibralter Plate boundary: an example of compressive tectonics (Abstract). *Upper Mantle Committee Symposium. Flagstaff, Arizona. July, 1970.*

Maxwell, A. E., et al., 1970. *Initial reports of the Deep Sea Drilling Project, Volume III*. Washington (U. S. Government Printing Office), 441.

McKenzie, D. P., 1970. Plate tectonics of the Mediterranean Region. *Nature.* **226**, 239.

Melson, W. G. and Van Andel, Tj. H., 1966. Metamorphism in the mid-Atlantic Ridge 22°N Latitude. *Marine Geol.* **4**, 165.

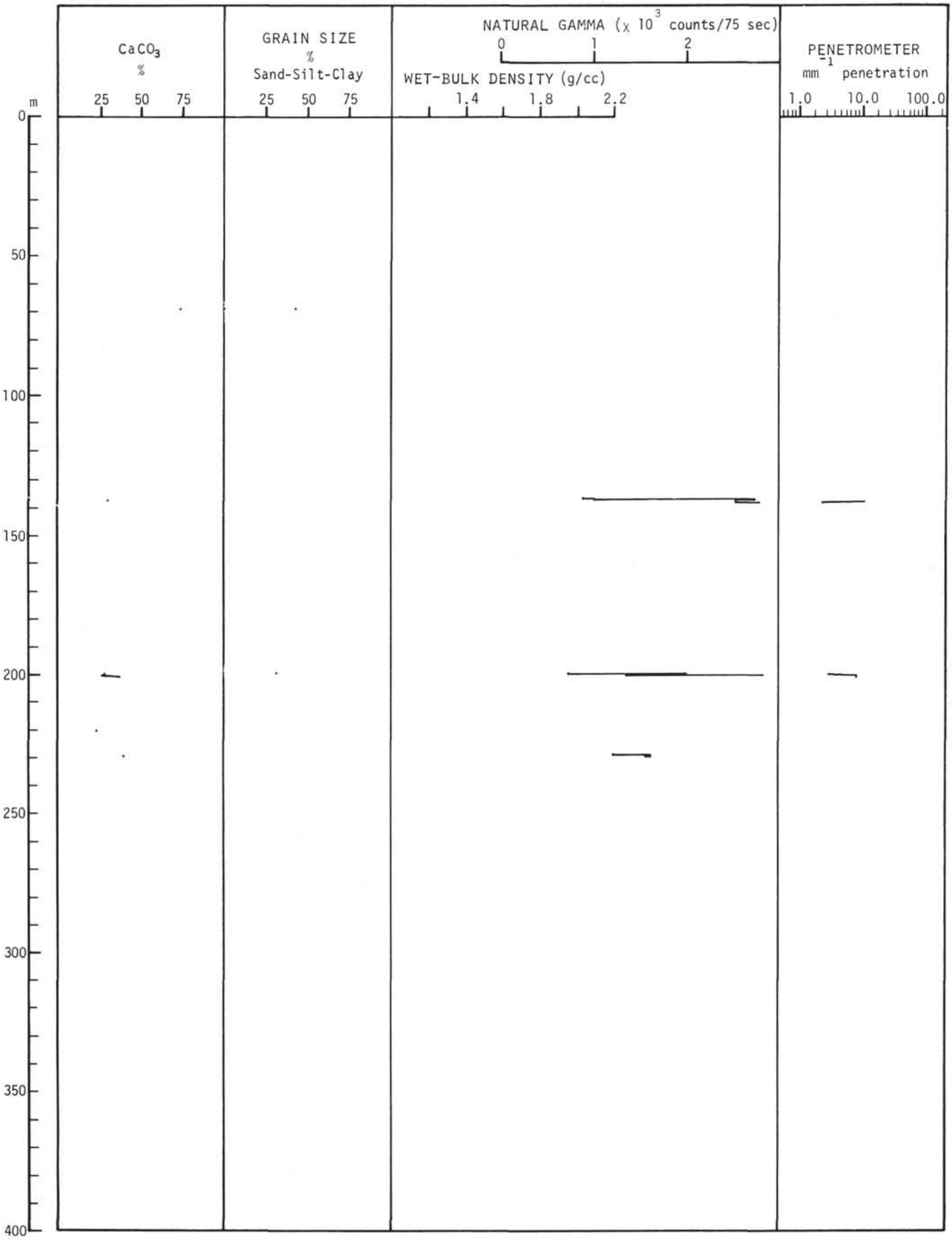
Miyashiro, A., Shido, F. and Ewing, M., 1970. Petrologic models for the mid-Atlantic Ridge. *Deep-Sea Res.* **17**, 109.

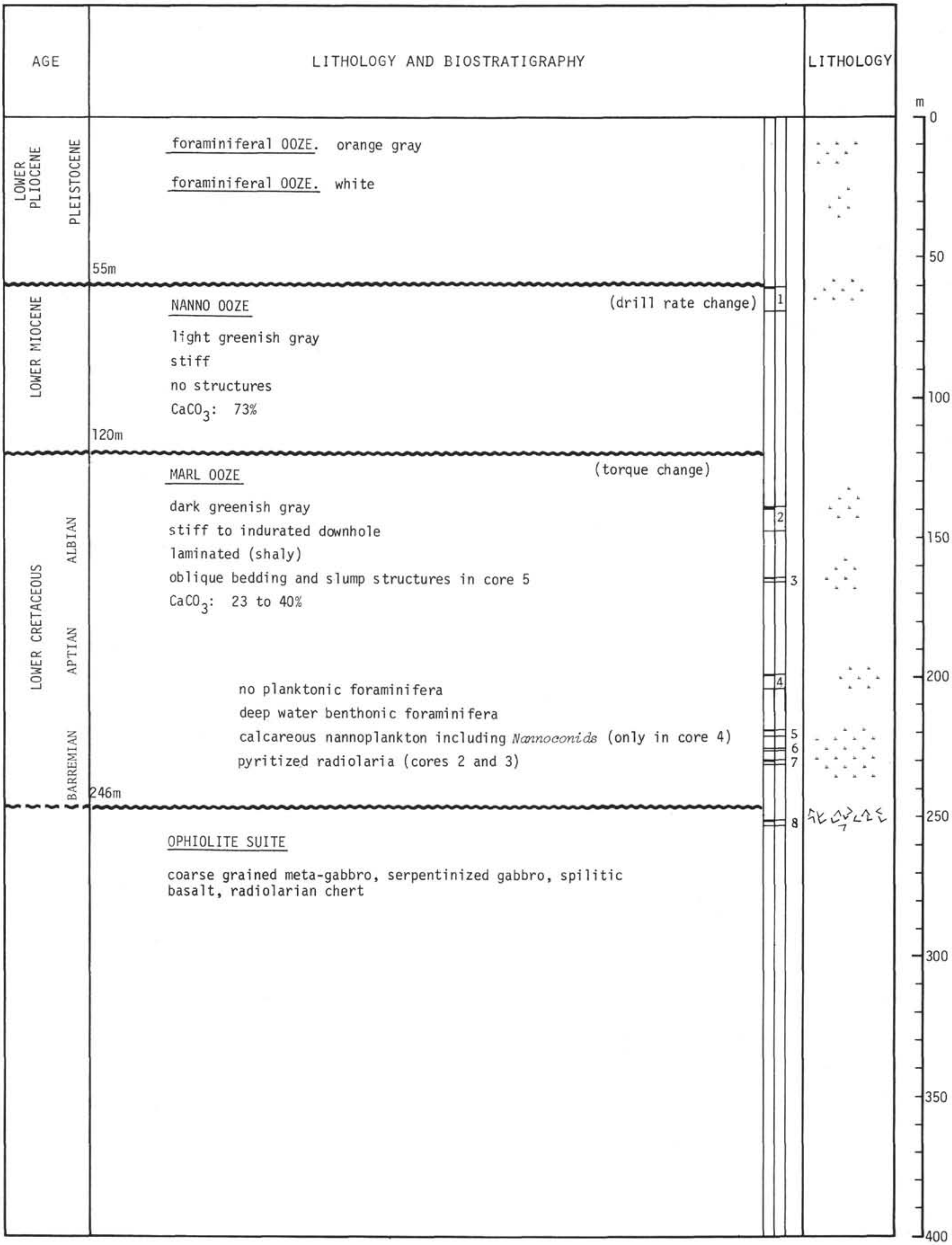
Moores, E. M. and Vine, F. J., 1971. The Troodos Massif, Cyprus and other ophiolites as oceanic crust: evolution and implications. *Phil. Trans. Roy. Soc. London A.* **268**, 443.

Pessagno, E. A., Jr., 1969. Mesozoic planktonic foraminifera and Radiolaria. **In** M. Ewing *et al., Initial Reports of the Deep Sea Drilling Project, Volume I.* Washington (U. S. Government Printing Office), 607.

Temple, P. and Zimmerman, J., Jr., 1969. Tectonic significance of Alpine ophilite in Greece and Turkey (Abstract). *Program for Annual Meeting, Geol. Soc. Am.* **7**, 211.

Site Summary 120




AGE
LITHOLOGY AND BIOSTRATIGRAPHY
LITHOLOGY
m
LOWER PLIOCENE
PLEISTOCENE
foraminiferal OOZE. orange gray
foraminiferal OOZE. white
55m
LOWER MIOCENE
NANNO OOZE
(drill rate change)
light greenish gray
stiff
no structures
CaCO3: 73%
120m
LOWER CRETACEOUS
ALBIAN
APTIAN
BARREMIAN
MARL OOZE
(torque change)
dark greenish gray
stiff to indurated downhole
laminated (shaly)
oblique bedding and slump structures in core 5
CaCO3: 23 to 40%
no planktonic foraminifera
deep water benthonic foraminifera
calcareous nannoplankton including Nannoconids (only in core 4)
pyritized radiolaria (cores 2 and 3)
246m
OPHIOLITE SUITE
coarse grained meta-gabbro, serpentinized gabbro, spilitic basalt, radiolarian chert
1
2
3
4
5
6
7
8
0
50
100
150
200
250
300
350
400

SITE 120 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
LOWER MIOCENE		60	CC		73	core catcher sample only NANNO OOZE light greenish gray (5G 8/1) stiff no structures Smear nannos 75 forams 1 terrigenous debris 24 planktonic and benthonic foraminifera abundant nannofossils	V

SITE 120 CORE 2 Cored Interval 144-149 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
LOWER CRETACEOUS (ALBIAN)		144 145.5	1 CC	VOID	29	MARL OOZE dark greenish gray (5G 6/1) millimetric horizontal laminations, except in the 145.16-145.50 m interval where oblique (45°) laminations occur, with green and purple streaks Smear nannos 30 terrigenous debris 70 planktonic foraminifera practically absent benthic foraminifera fairly abundant and well preserved abundant and diversified radiolaria, all pyritized calcareous nannoplankton dominant	V

SITE 120 CORE 3 Cored Interval 164-165.4 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
LOWER CRETACEOUS (ALBIAN)		164	CC			core catcher sample only MARL OOZE dark greenish gray (5G 4/1) stiff shaly (horizontal laminations) nannofossil assemblage similar to that of core 2 radiolarian fauna similar to that of core 2, pyritized no planktonic foraminifera benthonic foraminifera fairly abundant including Nodosariidae, arenaceous forms, etc.	V

SITE 120 CORE 4 Cored Interval 199.6 - 204 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
LOWER CRETACEOUS - APTIAN-BARREMIAN(?)		199.6 201.1	1 CC	VOID	27 26 37	MARL OOZE semi-indurated medium gray (N5) to olive gray (5GY 4/1) top 20 cm shaley (horizontal laminations) overlay a breccia which may be a drilling artifact benthonic foraminifera fairly well represented nannofossil assemblage rich in coccoliths and nannoconids radiolarian fauna similar to that of cores 2 and 3, always with pyritized tests, but less rich	V D

SITE 120 CORE 5 Cored Interval 219 - 221.1 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
LOWER CRETACEOUS - BARREMIAN		219 220.5	1 CC	VOID	23	NANNO OOZE semi-indurated to indurated medium gray (N5) shistosity at 45°, slump structures burrows benthonic foraminifera fairly abundant nannofossil assemblage rich in coccoliths but without nannoconids no radiolaria no planktonic foraminifera	V

SITE 120 CORE 6 Cored Interval 226 - 227 m

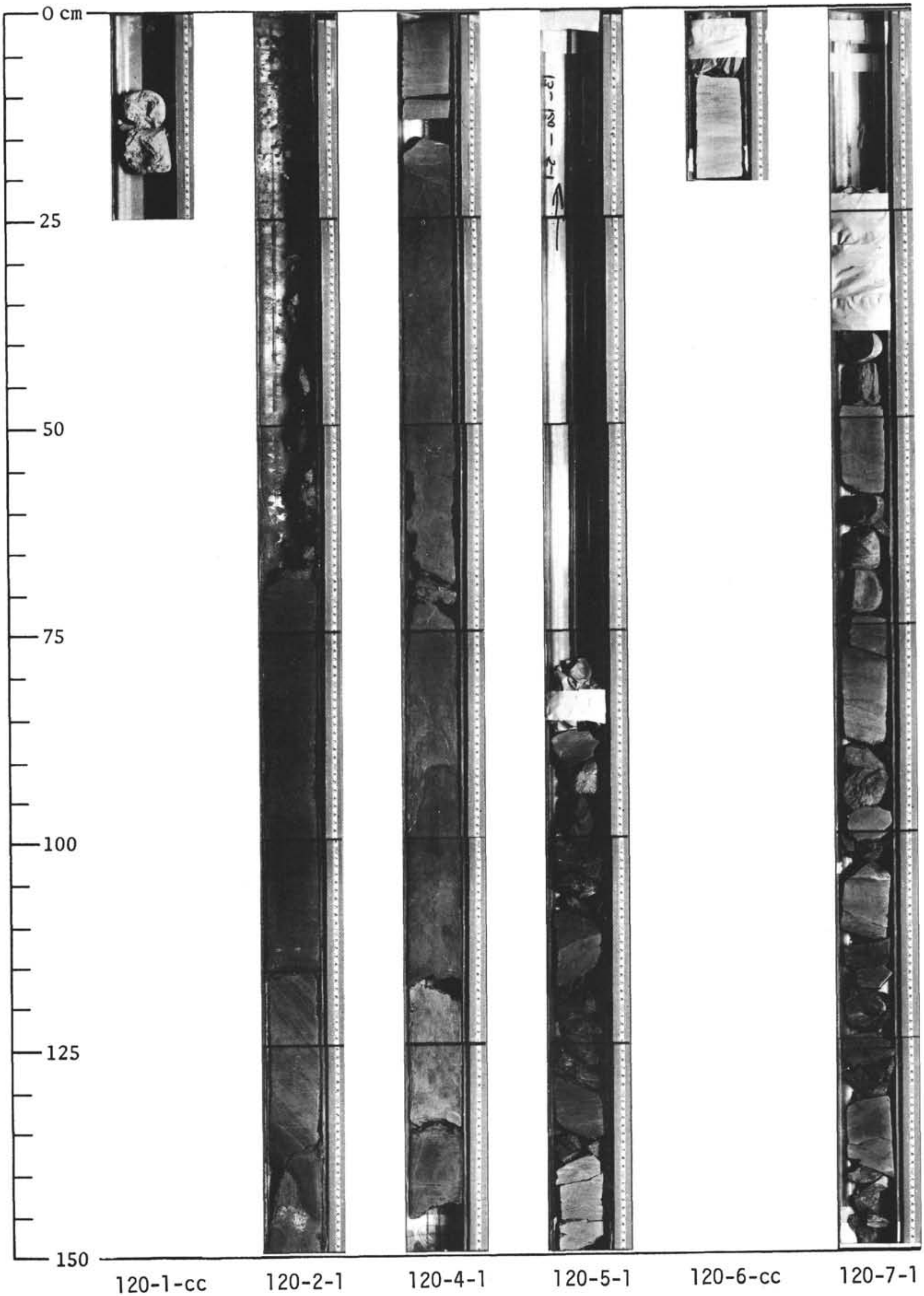
AGE	WET-BULK DENSITY (gm/cc) 1.3 1.6 1.9 2.2 / NATURAL GAMMA RADIATION (10^3 counts) 0.0 0.5 1.0 1.5 2.0	m B. S. FL.	SECTION	LITHOLOGIC SYMBOLS	% $CaCO_3$ (% sand/silt/clay)	LITHOLOGY AND PALEONTOLOGY	DISTURBANCE
LOWER CRETACEOUS - BARREMIAN		226	CC CC			core catcher sample only MARL OOZE semi-indurated medium gray (N5) shaly (horizontal laminations) benthonic foraminifera fairly abundant nannofossil assemblage similar to that of core 5, without nannoconids	V

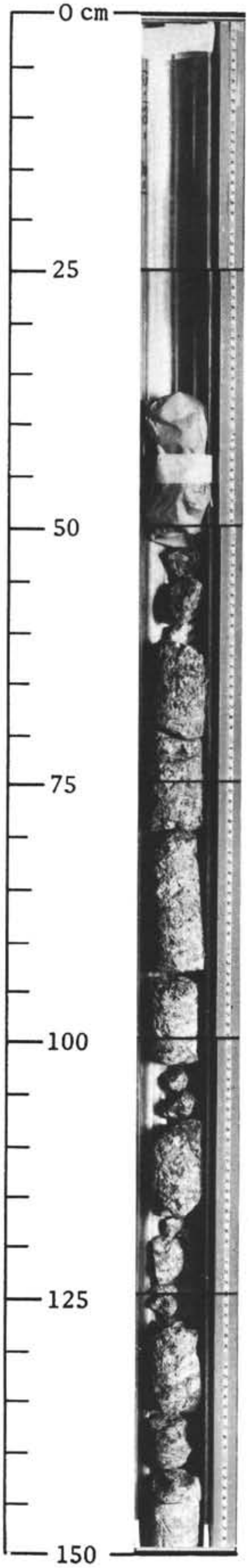
SITE 120 CORE 7 Cored Interval 229 - 232 m

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
LOWER CRETACEOUS - BARREMIAN		229		VOID			
			1		39	MARL OOZE indurated - broken in pieces by the drilling mostly medium light gray (N6) with greenish gray (5G 6/1) and greyish red (10R 4/2) shaly (horizontal laminations) burrows	
		230.5	CC			benthonic foraminifera fairly abundant nannofossil assemblage similar to that of core 6 and 5, without nannoconids	

SITE 120 CORE 8 Cored Interval 251.7 - 253.4 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
		251.7				ROCKS OF THE OPHIOLITIC SUITE coarse grained gabbro, serpentinized gabbro, etc. broken in pieces	
			1				
		253.2	CC				


0 cm
25
50
75
100
125
150
120-1-cc
120-2-1
120-4-1
120-5-1
120-6-cc
120-7-1



120-8-1