26. "BASEMENT" ROCKS OF GORRINGE BANK

PREFACE

Igneous rocks have been recovered from the Gorringe Bank in the eastern North Atlantic, through deep drilling (see Chapter 2), dredging and piston coring. The results are presented here. Two interesting and contrasting suites of rock have been discovered. One is an "ophiolite" suite thought to represent the original oceanic crustal layer generated by accretion at the axis of a Mid-Oceanic Ridge. The other, a silica deficient alkaline suite, more closely resembles igneous bodies located behind subducting zones and may be associated with younger intrusions accompanying the development of a compressive plate boundary along the Azores-Gibraltar seismic belt (Le Pichon *et al.*, 1970; and McKenzie, 1970). This chapter gives petrographic descriptions and a single chemical analysis of selected samples and offers brief discussions of their geological significance.

REFERENCES

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

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

26.1. PETROGRAPHY OF THE GORRINGE BANK "BASEMENT"

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INTRODUCTION

Igneous rocks were obtained at Site 120 on the northern flank of Gorringe Bank (water depth 1711 meters, see Chapter 2). Core 8 recovered approximately 0.9 meter of basement rocks below Lower Cretaceous, partly silicified pelagic sediment. The basement was encountered at 246 meters below the sea floor and was penetrated to 253.4 meters before the hole was abandoned.

RESULTS

Most of the recovered igneous material is a holocrystalline metagabbro composed of large crystals (ranging from 0.5-1 cm in length) of gray feldspar and tan pyroxene with interstitial patches of dark minerals. The texture is panallotriomorphic granular (Figure 1). The Ca-plagioclases are generally twinned according to albite and/or pericline, and/or Carlsbad laws. They are typically slightly zoned with a core An content of about 55-60 per cent. Largest crystals of Ca-plagioclase are often broken resulting in twisted and offset twin planes. The partial alteration of the pyroxene has produced a dense network of dark parallel lines which have clouded the pyroxenes and thereby obscured the interference colors. As a result, the pyroxene species could not be identified with certainty. The outer portion of the pyroxenes grades into an amphibole, generally actinolite, which surrounds the pyroxene by a felty growth of fibers. In some instances, however, the actinolite is in optical continuity with pyroxene. Upon occasion the mantling amphibole is a zoned pleochroic hornblende with pleochroism ranging from either bright orange to dark red brown, or from light green to dark blue green. The hornblende often contains small euhedral prisms of apatite. The finer grained material filling the interstices between the pyroxene and plagioclase crystals is made up of fine fibrous green chlorite, an unidentified mineral (similar to chlorite), and longer blades of a colorless amphibole (tremolite?). Rare patches of quartz are associated with the chlorite. The accessory opaques are small round bodies which have been partly replaced by a submicroscopic colorless material. The results of a major element chemical analysis and normative mineral computation for a metagabbro sample (120-8-7) are given in Table 1 (analysis by J. Honnorez).

DISCUSSION

The basement sample recovered at Site 120 is a gabbro originally composed of Ca-plagioclase, pyroxene, and opaque minerals which have subsequently reequilibrated to changing physiochemical conditions. Occurrence of the secondary amphiboles (actinolite and hornblende), chlorite, and quartz suggest that the gabbro recrystallized under amphibolite greenschist metamorphic conditions.

A few small chips of light green gray, glomeroporphyritic metabasalt were found accompanying the core of

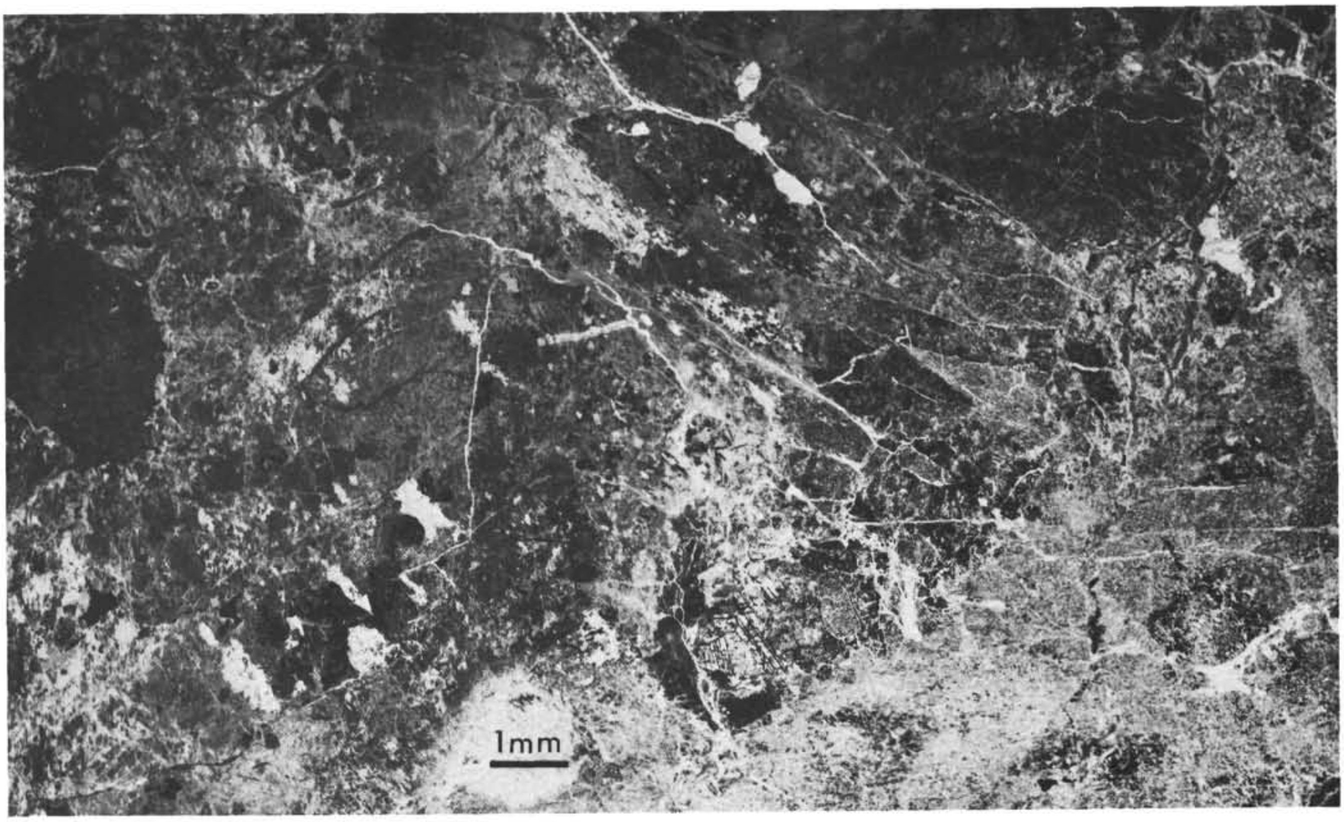

Figure 1. *Reverse print of a thin section enlargement of the holocrystalline meta-gabbro of Core 8, Site 120, Gorringe Bank, illustrating the cataclastic texture developed under amphibolite/greenschist metamorphic conditions.*

TABLE 1
Chemical Analysis and CIPW Normative Minerals: Sample 120-8-7

Chemical Analysis (Per Cent)		CIPW Normative Minerals (Per Cent)	
SiO_2	48.61	OR	1.18
Al_2O_3	17.18	AB	25.80
Fe_2O_3	1.19	AN	32.60
FeO	5.61	DI	8.11
MnO	0.14	HY	12.02
MgO	9.94	OL	12.65
CaO	8.65	MT	1.73
Na_2O	3.05	IL	0.97
K_2O	0.20	AP	0.07
TiO_2	0.51	H_2O^+	3.62
P_2O_5	0.03	H_2O^-	0.97
H_2O	0.97	Total	99.70
H_2O^+	3.62		
Total	99.70		

metagabbro at Site 120 (Figure 2). The 0.1-1.0 mm phenocrysts are predominantly twinned plagioclases which have been partially albitized. There are lesser amounts of chlorite-pseudomorphed olivine. The phenocrysts are set in a fine grained matrix of acicular plagioclase, microlites, chlorite, and other alteration products.

The basaltic samples suggest that a basalt originally composed of calcic plagioclase phenocrysts and fine-grained matrix underwent metamorphism which partially albitized the calcic plagioclase and produced the chlorite. The albitization of the plagioclase and the occurrence of chlorite indicate a greenschist facies metamorphism.

Metabasalt in the greenschist facies and metagabbro in the greenschist amphibolite facies are often recovered by dredging from the tectonic escarpments of the Mid-Oceanic Ridge System and fracture zones (for example, see discussion in Melson *et al.*, 1968; Cann, 1969; and Miyashiro *et al.*, 1971). The occurrence and abundance of these rock types have led investigators to conclude that metabasalt in the greenschist facies and metagabbro in the greenschist and amphibolite facies are representative of a portion of oceanic basement (Layer 2) and oceanic crust (Layer 3). The metamorphic gabbros and basalts recovered at Site 120 are similar to some of the metagabbros and metabasalts dredged from the escarpments of the Mid-Oceanic Ridge and fracture zones. (see Miyashiro *et al.*, 1971 for a description of oceanic metamorphic rocks.) The occurrence of metagabbros and lesser amounts of metabasalts at the base of Hole 120 on the north flank of Gorringe Bank supports the suggestion of Le Pichon *et al.* (1970) that Gorringe Bank is a slab of uplifted oceanic crust.

REFERENCES

Cann, J. R., 1969. Spilites from the Carlsberg Ridge, Indian Ocean. *J. Petrol.* **10**, 1.

Le Pichon, X., Bonnin, J. and Pautot, G., 1970. The Gibraltar end of the Azores-Gibraltar Plate boundary: an example of compressional tectonics (Abstract). *Upper Mantle Committee Symposium.* Flagstaff, Arizona, July, 1970.
Melson, W. G., Thompson, G. and van Andel, Tj. M., 1968. Volcanism and metamorphism in the Mid-Atlantic Ridge, 22°N latitude. *J. Geophys. Res.* **73**, 5925.
Miyashiro, A., Shido, F. and Ewing, M., 1971. Metamorphism in the Mid-Atlantic Ridge near 24° and 30°N. In A discussion on the petrology of igneous and metamorphic rocks from the ocean floor. Bullard, E., Cann, J. R. and Matthews, D. H., (Eds.). *Phil. Trans. Roy. Soc. London A,* **268**, 589.

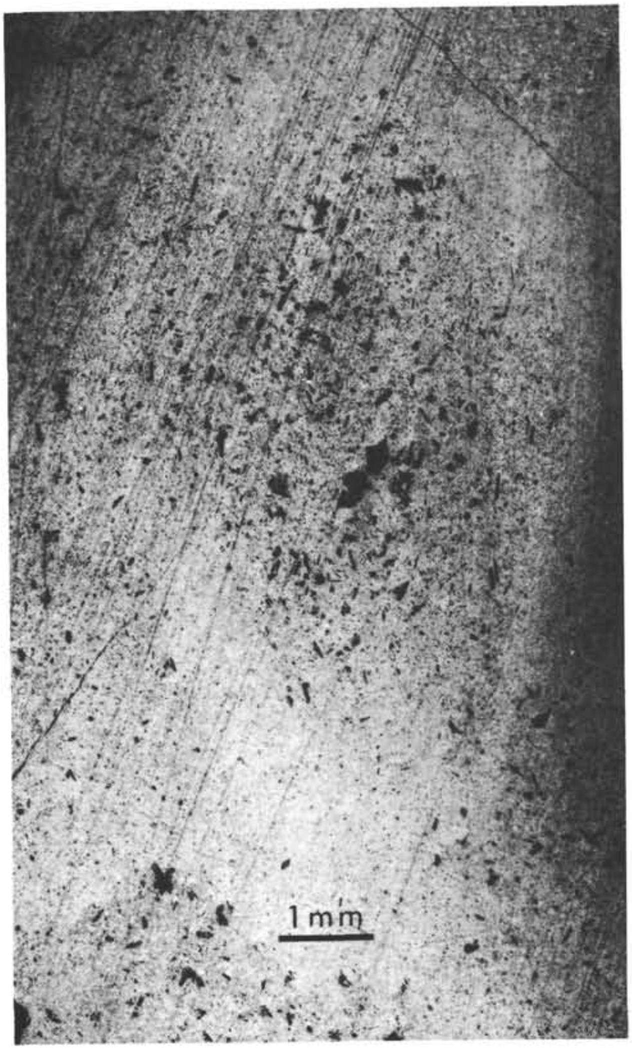

Figure 2. *Reverse print of a metabasalt (spilite) from a drill bit sample. The dark patches are porphyritic and glomeroporphyritic clusters of plagioclase accompanied by chlorite pseudomorphs set in a very fine-grained matrix of acicular feldspar, chlorite, and alteration products. Relic crystal outlines suggest that olivine, now replaced by chlorite, was originally present.*

26.2. PETROGRAPHY OF ROCKS FROM THE CRESTAL AREA OF THE GORRINGE BANK

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INTRODUCTION

Samples of igneous rock were recovered from the crestal area of Gorringe Bank in 1965 by coring and dredging from the R/V *Robert D. Conrad* of the Lamont-Doherty Geological Observatory. The sampling objective was to obtain materials which would shed light on the composition and geological history of this uplifted part of the Azores-Gibraltar seismic zone. Numerous boulders and rock fragments were obtained in one dredge, RC 9-7 (36°44.6'N, 11°05.8'W; water depth = 104-130 m), and two piston cores, RC 9-206 (36°40.5'N, 11°04.4'W; water depth = 736 m) and RC 9-208 (36°42'N, 11°07.3'W; water depth = 104 m).

Much of the recovered material was badly weathered, and most of the exposed rock faces were encrusted with carbonate crusts including colonies of byrozoa and coral. Smaller pebbles were often rounded, probably indicating abrasion near an ancient surf-zone on the bank.

Twenty samples were studied in thin section with a petrographic microscope. The analyses are presented in Tables 1 and 2 according to the two igneous rock suites recognized.

TABLE 1
Oceanic Suite

Sample	Rock Type	Major Mineral Composition	Metamorphic Facies
Oceanic Crustal Rocks			
RC9-206-2	Metagabbro	Labradorite, hornblende	Amphibolite
RC9-206-3	Cataclastic metagabbro	Labradorite, diallage, iron oxides	Greenschist amphibolite
RC9-206-5	Cataclastic metagabbro	Labradorite, diallage, apatite, iron oxides	Greenschist amphibolite
RC9-206-6	Cataclastic metagabbro	Labradorite, diallage, apatite, iron oxides	Greenschist amphibolite
RC9-206-11	Cataclastic metagabbro	Labradorite, diallage, apatite, iron oxides	Greenschist amphibolite
RC9-206-13	Cataclastic metaanorthosite (gabbro fragment)	Labradorite, diallage	Greenschist amphibolite
RC9-208-1	Cataclastic metagabbro (anorthosite)	Labradorite	Amphibolite
Ultramafic (Mantle?) Rocks			
RC9-206-12	Amphibole-biotite pyroxene	Augite, aegerine-augite, brown hornblende, biotite, apatite, interstitial zeolites	Amphibolite
RC9-208-250$_2$	Pyroxene bearing hornblendite	Brown hornblende, augite, interstitial apatite, sphene, zeolite(?)	Amphibolite

TABLE 2
Alkaline Suite[a]

Sample	Rock Type	Major Mineral Composition	Metamorphic Facies
Alkaline Intermediate Series			
RC9-208-2	Aegirine phonolite	Aegirine, sanidine, nepheline, analcite, iron oxides	Zeolite
RC9-208-4	Aegirine phonolite	Aegirine, sanidine, nepheline, zeolites	Zeolite
RC9-208-5	Sanidine phonolite	Sanidine, nepheline, aegirine, nosean, iron oxides, zeolites	Zeolite
RC9-208-6	Nosean phonolite	Nosean(?), sanidine, nepheline, aegirine, zeolites, andesite	Zeolite
RC9-208-8	Sanidine phonolite	Sanidine, nepheline, aegerine, analcite, zeolites	Zeolite
RC9-208-250$_4$	Sanidine-nosean phonolite	Sanidine, nosean, nepheline, aegirine, analcite(?), zeolites	Zeolite
Alkaline Mafic Series			
RC9-208-3	Mafic phonolite	Sanidine, analcite, nosean(?), aegirine-augite, aegirine, zeolites	Zeolite
RC9-206-1	Mafic phonolite	Aegirine, sanidine, nepheline, nosean, zeolite, kaolinite	Zeolite
RC9-208-250$_1$	Mafic phonolite	Nosean, aegirine, nepheline, sanidine, biotite, anorthoclase	Zeolite
RC9-208-250$_3$	Welded tuff (or devitrified lava)	Nosean, hornblende, biotite, pyroxene, leucite(?), aegirine-augite, aegirine, sanidine, anorthclase, glassy matrix	Zeolite
RC9-206-7	Alkalic metabasalt	Altered olivine, augite, plagioclase, interstitial feldspatoid (nosean:), melilite(?)	Zeolite

[a]>10 per cent feldspathoids.

OCEANIC SUITE

The first group of rocks (7 of 20 specimens) is characterized by cataclastic metagabbro which is composed of primary labradorite, diallage, and iron oxides with varying amounts of secondary amphibole (blue green hornblende, and/or actinolite), chlorite, and in some samples, quartz and epidote. Most of the metagabbro samples exhibit cataclastic textures. These metagabbro samples are similar to the metagabbro sample cored at Site 120 on the north flank of Gorringe Bank (described in Chapter 26.1) as well as the metagabbros recovered from the bounding walls of transform faults (see Miyashiro *et al.*, 1971), and they are thought to compose the oceanic crust (Layer 3).

Two of the twenty samples are ultramafic specimens. One is an amphibole-biotite pyroxenite characterized by augite, aegirene-augite, brown hornblende, biotite, apatite, and interstitial zeolites. The other is a pyroxene-bearing hornblendite (Figure 1). The occurrence of actinolite and blue green hornblende, which mantle the primary brown hornblende and pyroxene, indicates amphibolite facies metamorphism; the occurrence of zeolite in veins and interstitial zeolite suggests later stage retrogressive zeolite metamorphism. Ultramafic rocks of this type have been recovered in dredge hauls from the base of transform fault escarpments (Dmitriev *et al.*, 1971; Bonatti *et al.*, 1971). The ultramafic rocks recovered from transform faults are interpreted as representing the lower part of oceanic crust or upper mantle(?).

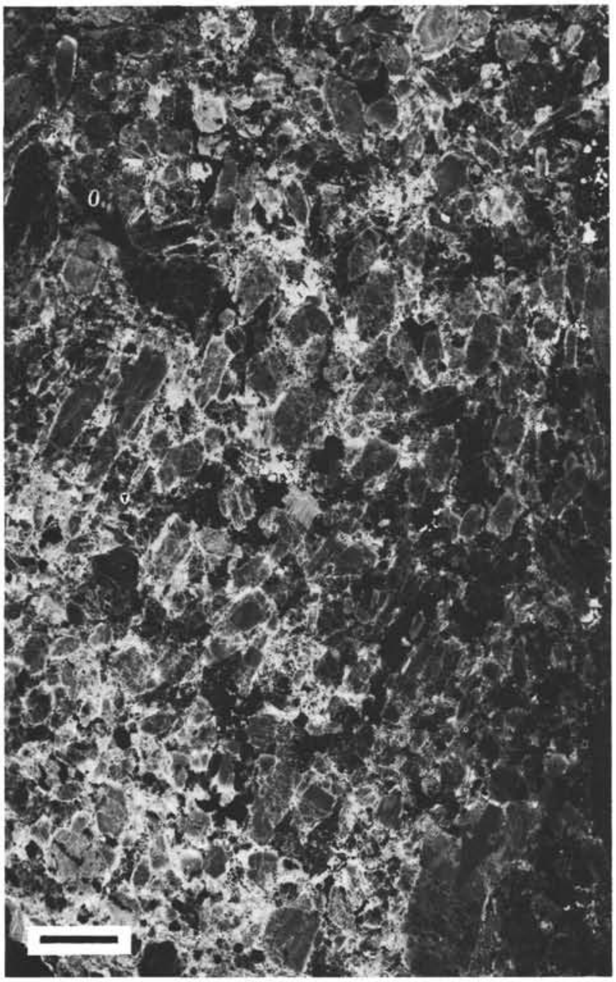

Figure 1. *Reverse print enlargement of a thin section of pyroxene bearing hornblendite (RC 9-208-250$_2$); revealing a medium-grained fabric and brecciated appearance. The larger crystals (arrows) are brown amphibole of an edenite composition. Scale bar represents 1 millimeter.*

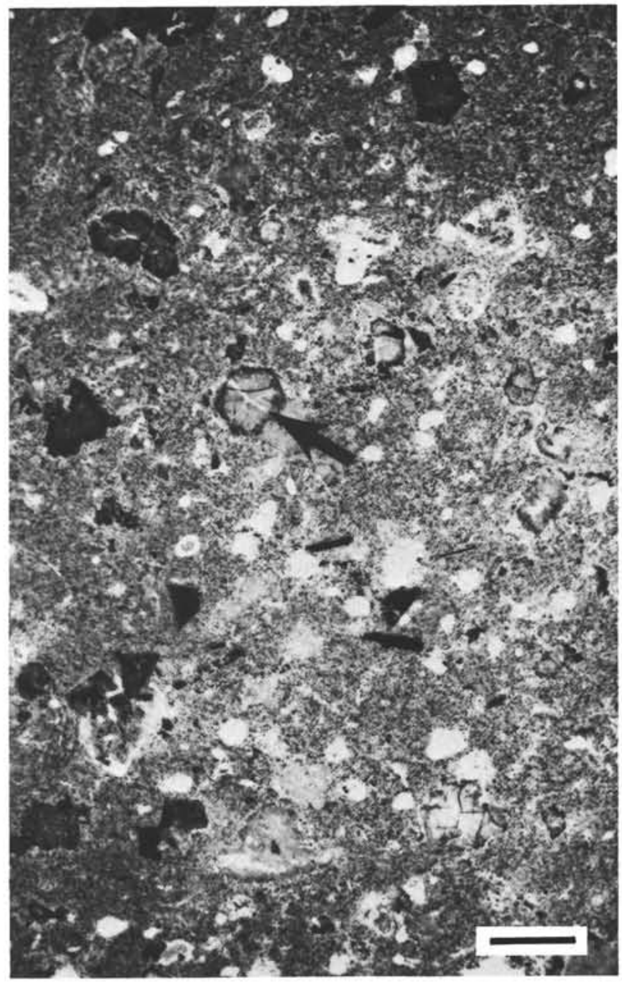

Figure 2. *Reverse print enlargement of a thin section of mafic phonolite (RC 9-208-250$_1$), containing large crystals of nosean (arrow) and numerous thin laths of sanidine. Many of the more mafic minerals are replaced by dark green pyroxene and iron oxides. Biotite is also replaced and has inclusions of zircon without a pleocroic halo. Scale bar represents 1 millimeter.*

ALKALINE SUITE

The second group of samples (11 of 20 specimens) is a suite of silica deficient, alkaline rocks (Figure 2) and is characterized by the occurrence of pyroxene (aegirine), feldspar (sanidine), and feldspathoids (nepheline and/or nosean) as the principal minerals and, depending on the sample, lesser amounts of analcite, hornblende, pyroxene (augite, or aegirine-augite), and iron oxides. The occurrence of zeolite in the matrix and in veins in all the samples suggests zeolite facies metamorphism. The occurrence of such undersaturated alkaline rocks in the cores and a dredge located on the crest of Gorringe Bank is unusual because this igneous rock type (phonolite) is not characteristic of the rock types typically recovered from the ocean floor (dredge hauls invariably recover one or a combination of the following rock types: tholeiitic basalt, alkaline basalt, metabasalt (zeolite and greenschist facies), gabbro, metagabbro (greenschist and amphibolite facies), and serpentinized periodotite. Although phonolite rocks occur in minor amounts in a late stage differentiate in association with alkaline basalts on some volcanic oceanic islands (e.g., Ascension and St. Helena), phonolites are more generally found in association with igneous bodies located behind subducting zones (e.g., Andes).

The occurrence of metagabbros in bottom samples from the crest of Gorringe Bank, a part of the Azores-Gibraltar Ridge, is not surprising and in fact these rocks suggest that the oceanic crust (Layer 3) is exposed along a portion of Gorringe Bank. The occurrence of a suite of intermediate and mafic alkaline rocks composed of feldspathoids, however, is not similar to rocks previously sampled from the ocean basin, and this suite is certainly not compatible with the rock types thought to be generated along accreting plate margins of the Mid-Oceanic Ridge System. Rather, these feldspathoid rich rocks are characteristic of igneous rocks found behind some subducting margins. Although the feldspathoidal phonolites could represent later stage differentiates associated with an alkaline basalt seamount on the Azores-Gibraltar Ridge, we interpret the occurrence of the feldspathoidal phonolites as reflecting a short and rapid subducting phase which accompanied the deformation of the Horseshoe Abyssal Plain sediments and uplift of the Gorringe Bank. As to the age of the intrusions, we have noted welded tuffs containing xenoliths of mafic phonolite in direct association with baked skeletal debris of former neritic fauna. This evidence would place the intrusion of the phonolite at a time when the bank was already shallow. According to the facies sequence of pelagic sediment recovered at Site 120, the transition there from a deep oceanic sea bed commenced during or after the Early Miocene, and was essentially completed by the Early Pliocene.

REFERENCES

Bonatti, E., Honnorez, J. and Ferrera, G., 1971. Peridotite-gabbro-basalt complex from the equatorial Mid-Atlantic Ridge. **In** A discussion on the petrology of igneous and metamorphic rocks from the ocean floor. Bullard, E., Cann, J. R., and Matthews, D. H., (Eds.). *Phil. Trans. Roy. Soc. London A.* **268**, 385.

Dmitriev, L. V., Vinogradov, A. P. and Udintsev, G. B., 1971. Petrology of ultrabasic rocks from rift zones of the Mid-Indian Ocean Ridge. **In** A discussion on the petrology of igneous and metamorphic rocks from the ocean floor. Bullard, E., Cann, J. R. and Matthews, D. H. (Eds.). *Phil. Trans. Roy. Soc. London A.* **268**, 403.

Miyashiro, A., Shido, F. and Ewing, M., 1971. Metamorphism in the Mid-Atlantic Ridge near 24° and 30°N. **In** A discussion on the petrology of igneous and metamorphic rocks from the ocean floor. Bullard, E., Cann, J. R., and Matthews, D. H., (Eds.). *Phil. Trans. Roy. Soc. London, A.* **268**, 589.