27. "BASEMENT" ROCKS OF THE WESTERN ALBORAN BASIN

PREFACE

Metamorphic rocks were sampled from Hole 121 in the western Alboran basin. The site was located at 36° 09.65′N, 4° 22.43′W, at 1163 meters water depth, on the northern slope of a buried peak within the abyssal plain province (see Chapter 3 of this volume). The acoustic basement lay 9.0 seconds (or 850-990 m) below the seabed. Fragments of metamorphic and ultramafic rocks were recovered, in Cores 23 and 24, from 859-867 meters subbottom. In addition, a large piece, some 6 cm long, was jammed in the orifice of the drillbit.

Samples from the 121-24-CC are now recognized to be the clasts in a breccia, and are given numbers 13-121-24 CC-B1 to B5. The piece jammed in the bit has been designated 13-121-24 CC-A1. This large specimen may either represent a large cobble in the breccia or the actual basement at Site 121. A second smaller rock recovered from the drillbit above piece A1 is labeled 13-121-24 CC-A2. This Chapter gives petrographic descriptions, radiometric data, and trace-element analysis of these samples, and discusses their correlation with similar rocks on land nearby.

27.1. PETROGRAPHY OF THE WESTERN ALBORAN BASIN "BASEMENT"

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Seven samples of metamorphic rocks were examined petrographically. Samples 13-121-24 CC-A1 and 13-121-24 CC-A2 may represent the *in situ* basement. Other samples are clasts in a basal breccia (Figure 1) underlying Upper Miocene Tortonian marl oozes. The possible "basement" rock is a cordierite-biotite-feldspar hornfels. The detritus in the breccia includes altered granodiorite, biotite-plagioclase gneiss, biotite-quartz schist, and muscovite granodiorite gneiss. The mineral assemblages of all these rocks are indicative of crystallization under amphibolite-facies and retrograde metamorphism under greenschist facies conditions. It is remarkable that the detrital components of the breccia do not contain any element foreign to amphibolite-facies plutonism. This fact tends to favor the idea that the local basement, even if Sample 121-24 CC-A2 is a detrital cobble, includes only plutonic rocks of the amphibolite facies.

Detailed petrographic descriptions of the thin-sections are given in the following sections.

13-121-24-CC-A1 – Cordierite-Biotite-Feldspar Hornfels

The specimen (Figure 2) is a layered hornfel composed of cordierite (40%), potash feldspar (30%), biotite (20%), plagioclase (10%) and lesser amounts of chlorite and sericite. The anhedral potash feldspar occurs interstitially with the subhedral to anhedral cordierite. The reddish brown biotite occurs in plate aggregates and semi-parallel bands. The albite twinned plagioclase occurs in subhedral aggregates and as discrete subhedral crystals. Interlayered in the hornfels are thin stringers of chlorite-sericite aggregates accompanied by biotite, plagioclase, and magnetite. The chlorite aggregates seem to be pseudomorphs after large garnet crystals up to 5 mm in diameter.

Sample 13-121-24 CC-A2 – Micaceous Quartz-Feldspar Gneiss

The major components of this rock (Figure 3) are quartz (50%), potash feldspar (25%) biotite (8%) and muscovite (5%). Present in small amounts are plagioclase, garnet, blue green amphibole, chlorite, sericite, and opaque iron minerals. The quartz crystals are anhedral, granoblastic, with undulatory extinction. Their sizes are variable, ranging up to 1 mm. The potash feldspar is subhedral to nearly euhedral and is porphyroblastic. Twinning is present in some and minute inclusions are common. The larger porphroblasts are more than 2 mm long. The biotite is reddish brown and shows signs of being deformed. The white micas are present both as lepidoblastic flakes and as sericitic aggregates replacing potash feldspar or garnet. The plagioclase has a composition of andesine, is twinned and slightly zoned. The garnet crystals range up to 1.5 mm in size, but they were partially or wholly altered during retrograde metamorphism. A protective rim of chlorite aggregates is present around some of the altered crystals. Blue green amphibole which is a strongly pleochroic actinolite, is in slender crystals less than 0.5 mm long. The major constituents of the metamorphic rock indicate that this medium-grained plutonic rock was crystallized as a gneiss under the conditions of amphibolite-facies metamorphism. The rock was altered again during a later episode,

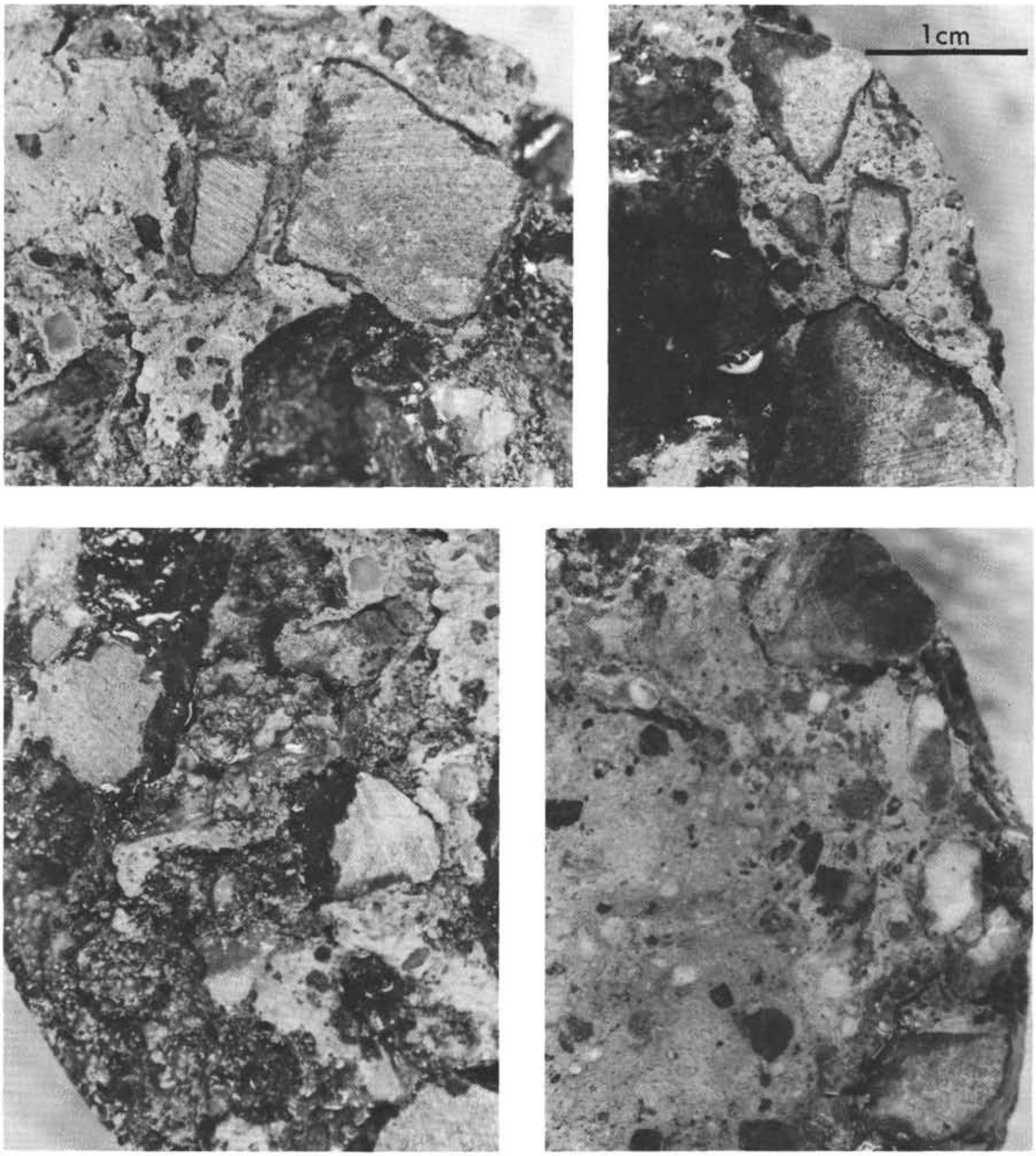

Figure 1. *Slices through the basal breccia in the Core Catcher sample of Core 24, Site 121 in the western Alboran Basin. Several of the rock fragments have been thin-sectioned and are designated in the descriptions of the test with the prefix B. The mineral assemblages of all these rocks are indicative of crystallization under amphibolite-facies and retrograde metamorphism under greenschist facies conditions. The light colored marl matrix has not been baked and contains marine microfossils of Tortonian age and flakes of serpentinite.*

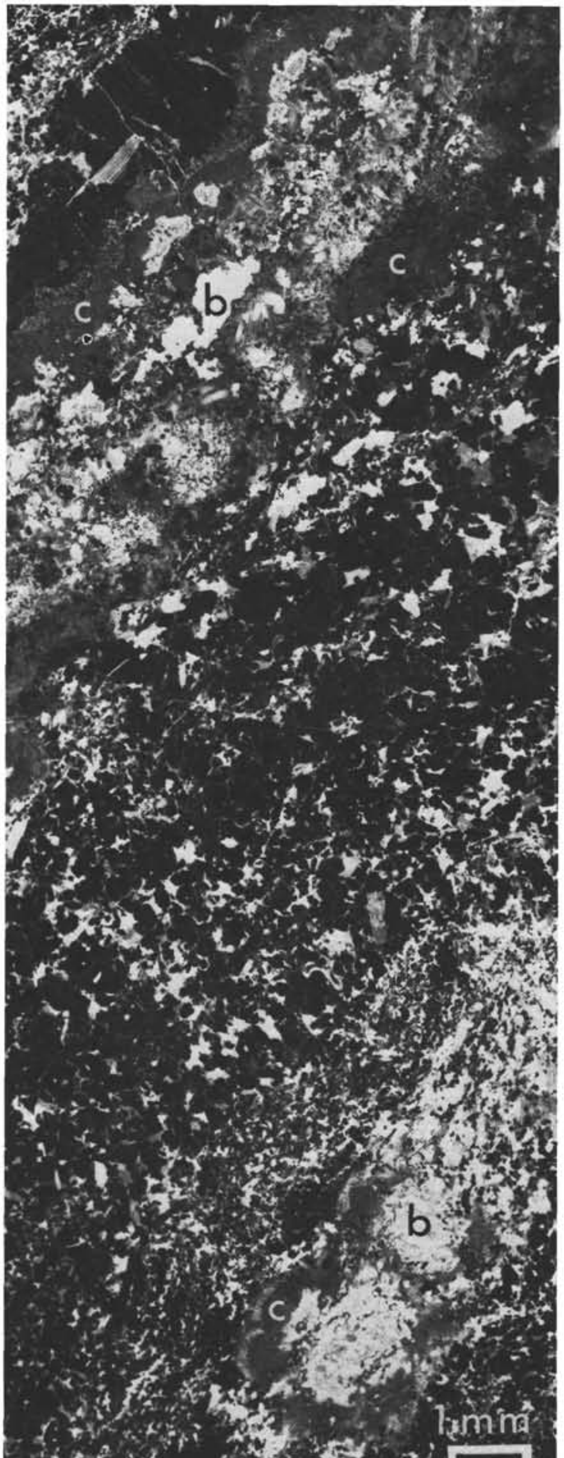

Figure 2. *Sample 13-121-24 CC-A1 is a cordierite-biotite-feldspar hornfels. This coarse-grained irregularly banded rock is dominated by equidimensional grains of cordierite (a) and potash feldspars. It is particularly rich in biotite (b) occurring in elongate patches (light colored) rimmed by sericite-muscovite and chlorite (c). Reverse print, plane-polarized light.*

producing the actinolite-chlorite-sericite assemblage. This is indicative of retrograde changes under the conditions of the greenschist-facies.

Sample 13-121-24 CC-B1 – Altered Granodiorite

The specimen (Figure 4) consists of euhedral crystals of altered feldspar (45%), quartz (40%), plagioclase (10%) and muscovite (5%). The euhedral feldspar crystals are almost completely altered to very-fine-grained sericitic aggregates. They may have been potash-feldspar. The largest crystal is more than 2 mm. Quartz is anhedral, with undulatory extinction and fractures; the largest grain is about 3 mm. Muscovite, present as 1-mm-long flakes, is probably a primary mineral. On the other hand, sericitic aggregates are obviously replacement products during secondary alteration. Traces of chlorite and magnetite have also been recognized.

This rock belongs to a gneiss basement. The secondary alteration may have been related to a later orogenic event.

Sample 13-121-24 CC-B2 – Biotite-Plagioclase Gneiss

The slide consists mainly of twinned plagioclase (60%) and reddish brown biotite (40%). The plagioclase is a calcic andesine or labradorite. Traces of apatite and sphene are present. This specimen is a metamorphic rock of amphibolite facies.

Sample 13-121-24 CC-B3 – Diopsidic Biotite-Quartz Schist

The specimen (Figure 5) consists mainly of fine-grained quartz (65%) and biotite (25%). The biotite-flakes are mostly 0.1-0.2 mm long and are considerably finer than those in 121-24-B2. Present in small amounts are diopside (5%) and potash-feldspar (5%). Relic garnet crystals, broken and replaced by biotite have also been identified.

The metamorphic assemblage is typical of the amphibolite facies.

Sample 13-121-24 CC-B4 – Altered Granodiorite

This sample consists of anhedral quartz (50%), anhedral potash feldspar (30%), plagioclase (15%) and muscovite (5%). The euhedral plagioclase has been almost completely altered to very-fine-grained sericite aggregates. The quartz has undulatory extinction and is thoroughly fractured. The sericite aggregates appear to be replacement products produced during secondary alteration.

Sample 13-121-24 CC-B5 – Muscovite-Granodiorite Gneiss

The rock (Figure 5) consists mainly of potash-feldspar (30%), quartz (40%), and white micas (20%). The potash-feldspar is characterized by its Carlsbad twinning; subhedral crystals range up to 2 mm. The quartz is, as usual, anhedral and shows undulatory extinction. The white micas include both muscovite flakes up to 1 mm long and very-fine-grained sericite aggregates. The latter are common alteration products of feldspars. Plagioclase is present in small amounts (5%) and slightly zoned. Traces of epidote, magnetite, sphene and chlorite are present.

This rock, either an orthogneiss or a paragneiss, belongs to a part of an amphibolite-facies crystalline complex.

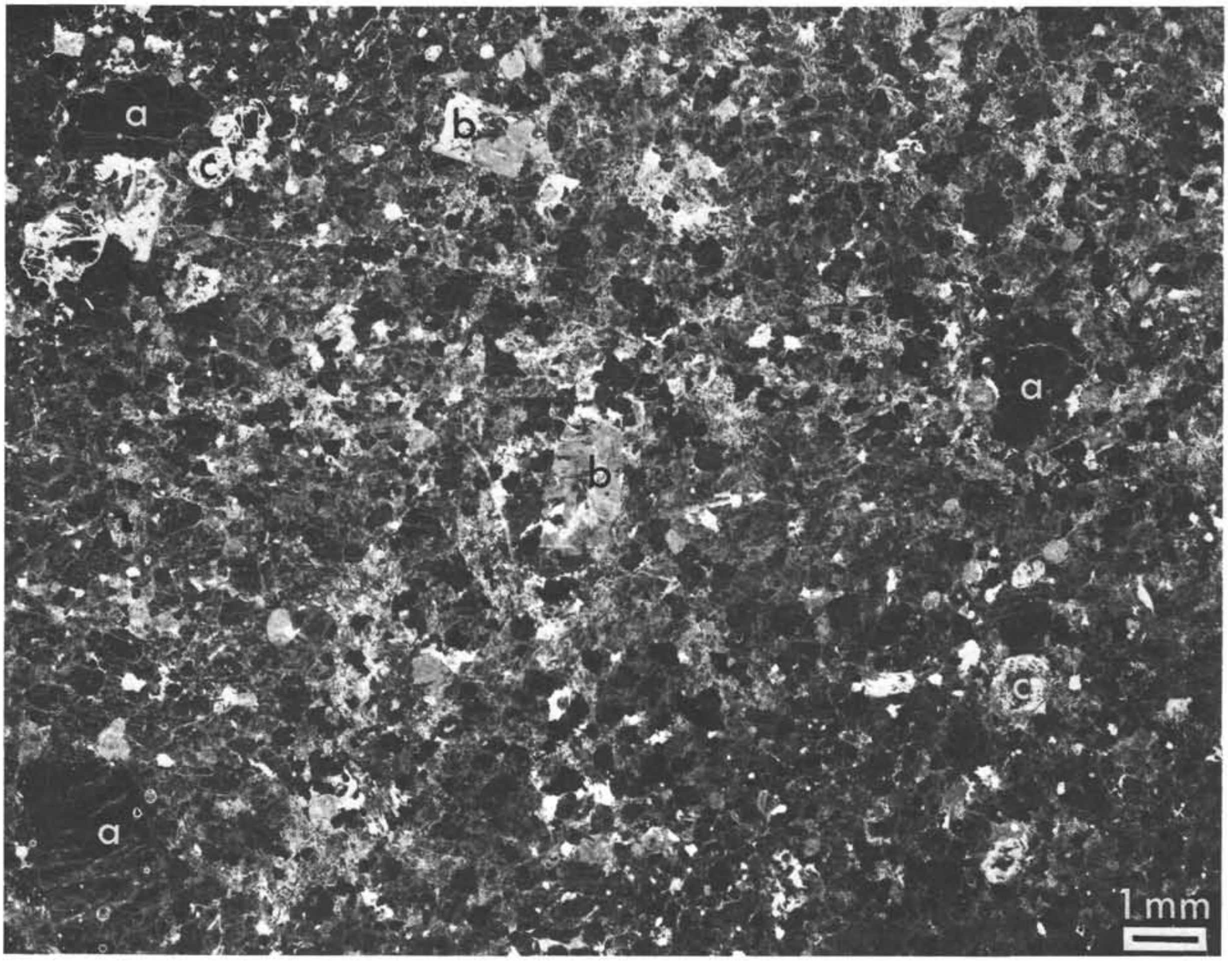

Figure 3. *Sample 13-121-24 CC-A2 is a micaceous quartz-feldspar gneiss. The dominant mineral, quartz (a), is anhedral and granoblastic with undulatory extinction. The potash feldspars (b) are occasionally nearly euhedral and are porphroblastic, some reach 2 mm in length. Garnet crystals (c) are partially or wholly altered during retrograde metamorphism. Reverse print, plane-polarized light.*

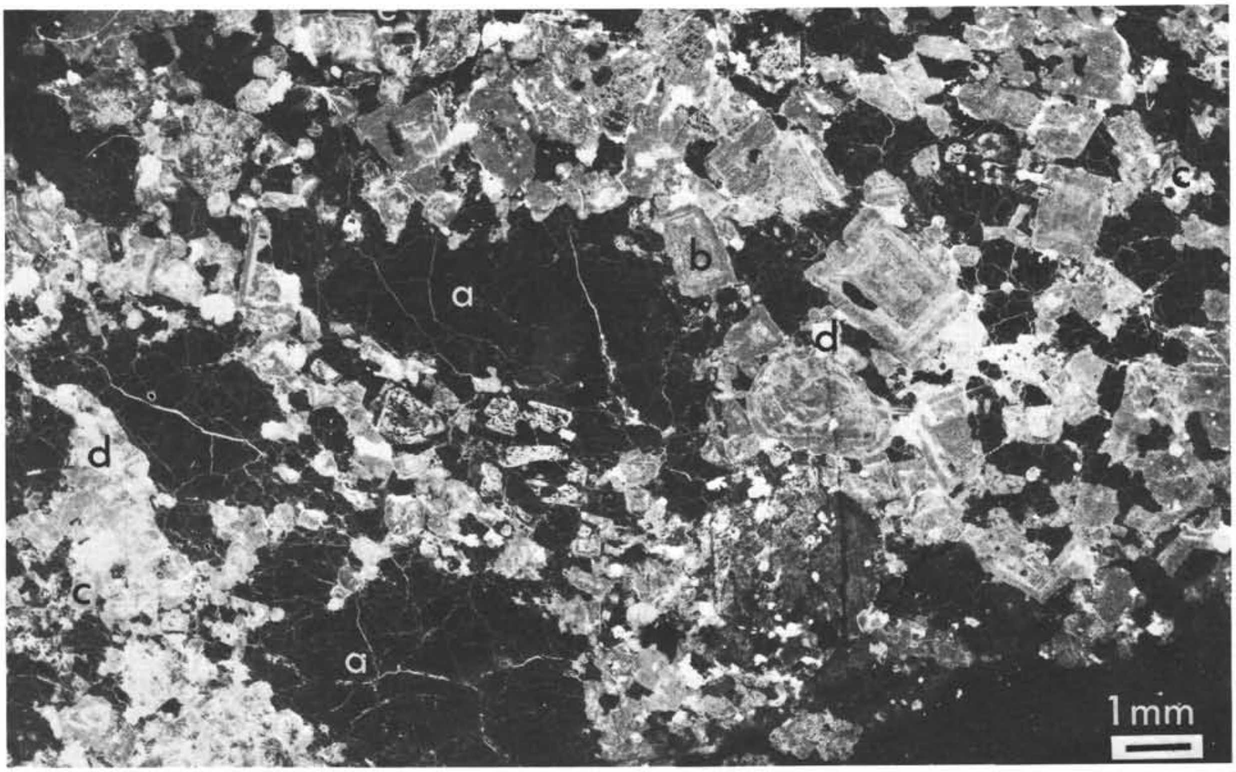

Figure 4. *Sample 13-121-24 CC-B1 is an altered granodiorite. The quartz grains (a) are very large, heavily fractured, and show undulatory extinction. The euhedral feldspars (b) are almost completely altered to sericite and chlorite. Some muscovite (c) is present in elongated flakes along with opaque inclusions of ilmenite-magnetite (d). Zoned plagioclase (e) with anhedral cores of sericite and chlorite are, according to T. Loomis (personal communication), identical to hornfel occurrences around the Ronda ultramafic massif. Reverse print, plane-polarized light.*

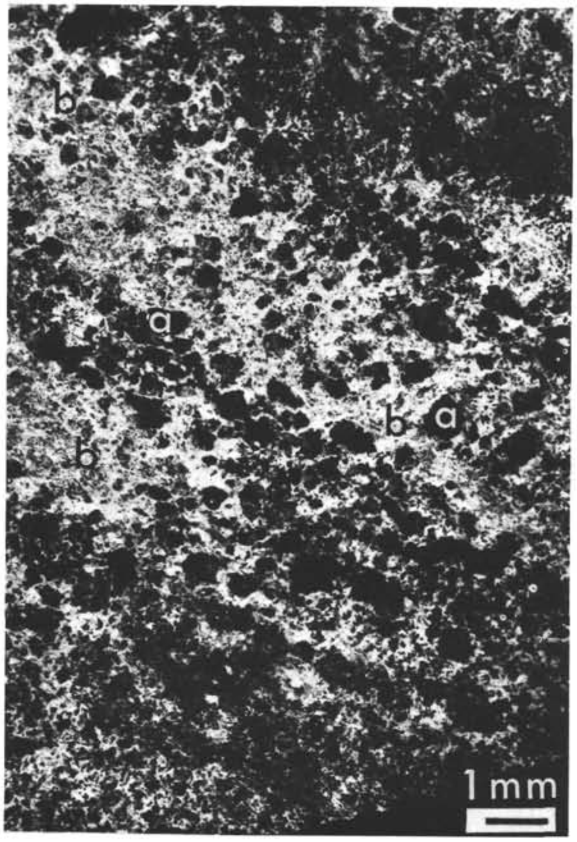

Figure 5. *Sample 13-121-24 CC-B3 is a diopsidic biotite-quartz schist. The foliation is most marked with parallel bands of quartz (a) sometimes elongated, alternating with reddish brown biotite color, (b), usually as quite small flakes. Reverse print, plane-polarized light.*

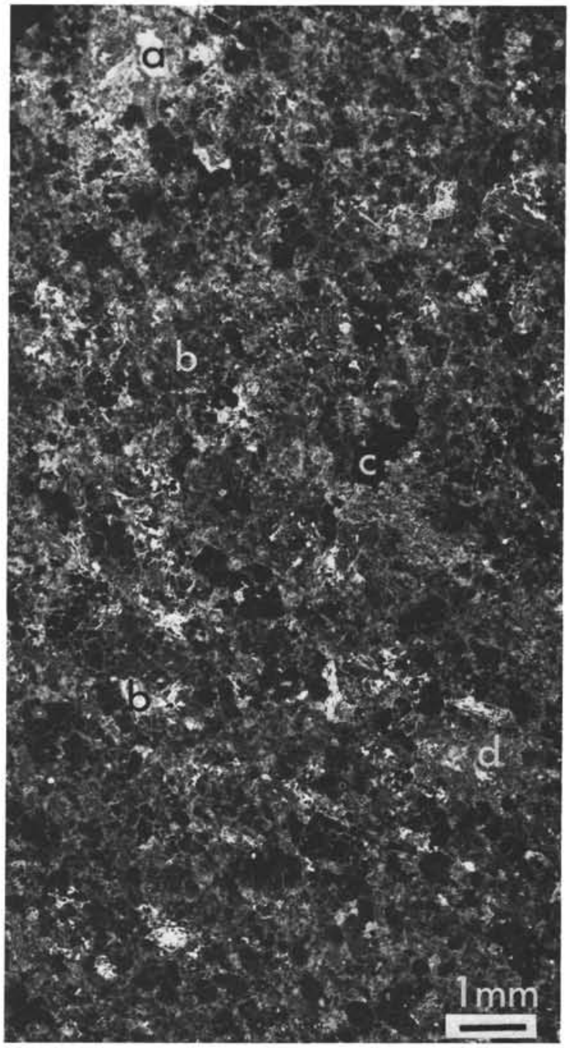

Figure 6. *Sample 13-121-24 CC-B5 is a muscovite-granodiorite gneiss. The white micas in this specimen include flakes of muscovite (a) up to 1 mm in length. The potash-feldspar (b) is characterized by Carlsbad twinning with subhedral crystals up to 2 mm in length. The quartz (c) is cataclastic and shows undulatory extinction. A large sericite clot (d) has low birefringence and is length fast with a reddish pleochroism, characteristic of andalusite left over from a lower-grade assemblage. Reverse print, plane-polarized light.*

27.2. PETROGRAPHICAL STUDY OF "ACOUSTIC BASEMENT" AND ASSOCIATED BRECCIA AT SITE 121 – WESTERN ALBORAN BASIN: A COMPARISON WITH THE BETICO-RIFEAN BASEMENT

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ABSTRACT

Fifteen slides have been cut both in "acoustic basement" and pebbles from the associated sedimentary breccia at Site 121 (western Alboran Basin). Observed facies (mostly cordierite leptynites and alumino-silicate granites, together with sharp single crystals of brown spinel extracted from peridotites) come from petrographical associations very similar to those described in the Betico-Rifean metamorphic basement, particularly in its lower unit (Monte Hacho/Blanca Unit).

INTRODUCTION

The western part of the Betico-Rifean inner zone, in the vicinity of Site 121 (Figure 1), is essentially composed of peridotites and overlying metamorphic rocks. Two main units have been described (Buntfüss, 1970; Didon *et al.*, in press; Dürr, 1967; Kornprobst, 1962, 1971; Mollat, 1968) as follows:

1. The Monte Hacho/Blanca lower unit with the following association: peridotites (base), low pressure granulite facies rocks (cordierite leptynites and marbles), and gneisses and mica schists (top).

2. The Filali-Beni Bousera/Casares upper unit, including from bottom to top: peridotites, high pressure granulite facies rocks (kyanite bearing kinzigites), and gneisses and mica schists.

Cordierite leptynites from the former clearly show secondary assemblages, with primary garnet sometimes present as scarce and minute relics.

The petrographical study of both "acoustic basement" and associated sedimentary breccia at Site 121, leads to a comparison with the rock types that outcrop on either side of the Straits of Gibraltar, on the banks of the Alboran Sea.

PETROGRAPHY

"Acoustic Basement"

Three slides from rocks supposed to belong to the acoustic basement have been studied.

1. **Core Bit 1**: All the rock is strongly altered. Subidiomorphic plagioclases (An=35) are associated with large, fully transformed cordierite crystals, with inclusions of deep green spinel and prismatic sillimanite. Ore minerals are abundant; quartz is scarce. Secondary phases often mask this assemblage, mostly biotite/quartz intergrowths with static development, which probably represent K-feldspar and sillimanite destabilization.

Similar but unaltered rocks occur as numerous discrete pebbles in the breccia (see below).

2. **Core Bit 2**: Showing granoblastic texture, this rock is strongly altered. Xenomorphic quartz is abundant and associated with idiomorphic cordierite and probably plagioclase, both being replaced by mica-rich assemblages. Fibrolite is present. A common secondary phase is red brown biotite, sometimes chloritized, and white mica, crystallizing at the expense of cordierite. A small relic of garnet is present in cordierite.

Exactly similar rocks occur among the "gneiss du Monte Hacho" at the eastern part of the Ceuta Peninsula.

3. **Core Bit 3**: The texture is typically granitoid quartz with subidiomorphic crystals. Quartz is granular but with interstitial apophyses. The mineralogical composition is granitic. It contains high temperature, finely perthitic orthoclase, twinned acidic andesine, and quartz. Accessory minerals are red brown biotite, altered cordierite, and fibrolite. Interstitial yellow green tourmaline is present, and muscovite is secondary.

Similar samples have been found in the breccia (see below). This rock type occurs commonly as thin dikes in the metamorphic and ultrabasic bodies of the Betico-Rifean basement.

Breccia

The breccia is made up of numerous pebbles and single minerals in a calcareous cement containing biogenic material.

Pebbles

Eleven sections were cut. The following five rock types (showing sections cut) were found: (a) altered kinzigite (one section); (b) cordierite leptynites (five sections); (c) labradorite gneiss (one section); (d) phlogopite marble (two sections); (e) aluminosilicate granites (two sections).

1. Kinzigite is fibrolite bearing, with residual garnet, altered cordierite, red brown secondary biotite, graphite, and quartz.

2. Cordierite leptynites are very similar to Core Bit 1, but are generally unaltered. Essentially, they are made of Ca-rich andesine and twinned cordierite (with lamellar and cyclic twins). They also contain prismatic sillimanite and deep green spinel; some also include potash feldspar. Sometimes relic garnet is included in cordierite or feldspar. One can interpret these assemblages as a result of the reaction: garnet + sillimanite + quartz = anorthite + cordierite + spinel. This is characteristic of the Monte Hacho/Blanca Unit. Biotite and muscovite are secondary phases.

Figure 1. *Position of the main units in the western inner zone of the Betico-Rifean belt. Star indicates the location of Site 121. Black: Filali-Beni Bousera/Casares Unit. Striped: Monte Hacho/Blanca Unit. Dotted: Ghomarides and Malaguides, sedimentary units. (In Spain, the relationships are simplified and provisional.) Data from Buntfuss (1970), Didon* et al. *(1972), Durr (1967), Kornprobst (1962, 1971) and Mollat (1968).*

3. Labradorite gneiss shows essentially subidiomorphic plagioclase (An 50 to An 60), xenomorphic potash feldspar, and red brown biotite; quartz is scarce. Ore minerals and rutile needles are accessory phases. Similar rocks are known at Ras Tarf Cape, Filali Unit.

4. Coarse grained marble contains large phlogopite blades, associated with serpentinized crystals (altered forsterite (?) or humite (?)). This is often seen in the marbles of the Blanca Unit.

5. Alumino-silicate granites are texturally identical with Core Bit 3, showing, however, two assemblages: (a) quartz-feldspar-biotite-cordierite-fibrolite, and (b) quartz-feldspar-biotite-cordierite-andalusite. Cordierite is generally unaltered, with cyclic twinning, and andalusite, as idiomorphic crystals, is generally zoned with a pink colored center.

A sequence of kyanite bearing, sillimanite bearing, then andalusite bearing granitic dikes cuts the basement (ultrabasic gneisses) at Beni Bousera (Kornprobst, 1971).

Single Minerals

Quartz is abundant (as generally sharp grains) together with chlorite, biotite, and muscovite. Numerous glauconite pellets are also present. Other phases are scarce, but may be particularly significant; especially:

1. **Garnet** as sharp pink crystals. Refractive index and unit cell, depicted (after Winchell, 1958) in Figure 2, show close similarity with relic garnet from cordierite leptynites occuring in the Blanca Unit.

2. **Clinopyroxene** as yellowish green prisms. It has a particularly high refractive index (n_g = 1730 ± 0005). It is thus similar with the ferro-salite occuring in numerous pyroxenites and in quartz pyroxenites found as lenses and layers in gneisses and mica schists from Betico-Rifean basement.

3. **Spinel** as sharp grains. It is present with the following aspects: (a) deep green spinel similar to spinel from cordierite leptynites, and (b) deep brown or red brown spinel; with characters (coloration, a and n) identical to those of picotites present in peridotites from Blanca and Beni Bousera Units (Figure 3).

CONCLUSIONS

The study of both "acoustic basement" and breccia at Site 121 (Alboran Sea) shows a variety of samples and single minerals from metamorphic rocks which are very

Figure 2. *Composition of pink garnets extracted from the breccia (stars), as determined by cell parameter and refractive index measurements (Winchell, 1958); comparison with garnets extracted from different rock-types of the Betico-Rifean inner zone (Kornprobst, 1971, and unpublished data).*

similar to those occurring in the western part of the Betico-Rifean basement, and particularly with those from the Monte Hacho/Blanca lower unit (Figure 1). The presence of sharp red brown picotite in the breccia indicates the proximity of ultrabasic (peridotitic) outcrops. As in the case in the Blanca Unit, cordierite leptynites would be closely associated with these peridotites whereas in the Beni Bousera Unit, peridotites are found with kyanite-bearing kinzigites.

ACKNOWLEDGMENTS

I am grateful to W. D. Nesteroff and G. Pautot for the slides and samples. I thank D. Velde for reviewing the manuscript.

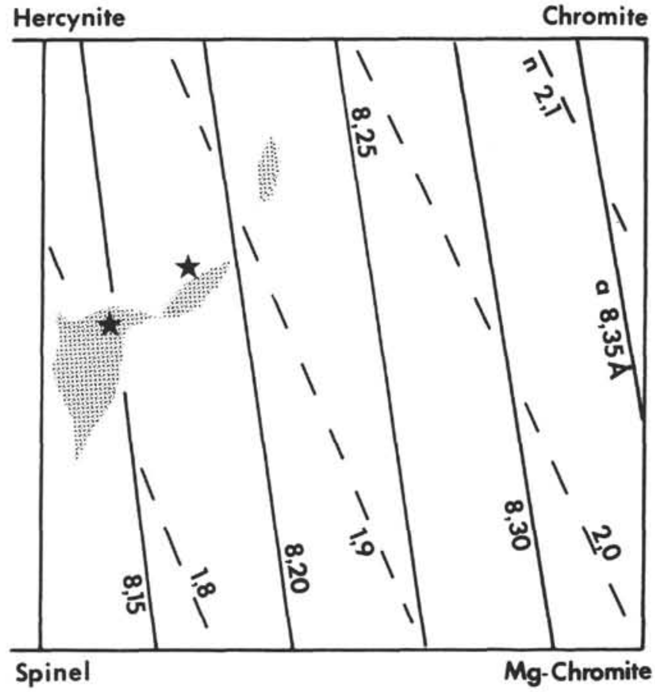

Figure 3. *Composition of deep-brown and red brown spinels extracted from the breccia, determined by cell parameter and refractive index (Deer* et al.*, 1962). Comparison with spinels extracted from Beni Bousera ultrabasic rocks (dotted area; Kornprobst, 1969).*

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27.3. ISOTOPIC DATING OF ALBORAN "BASEMENT"

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The large piece of metamorphic rock caught in the drillbit (Sample 13-121-24 CC-A1) was cut in half. One half was made into a thin-section; the other was sent for isotopic dating to the Laboratory for Isotope Geochemistry and Mass Spectrometry, Swiss Federal Institute of Technology, Zurich. This rock is a cordierite-biotite-feldspar hornfels. However, there is considerable evidence of retrograde metamorphism, whereby the primary metamorphic minerals were altered to sericite, chlorite, and actinolite.

Biotite was separated out. Its potassium content was determined by both the isotope dilution and the atomic absorption methods. The argon content was determined in a Nier-type mass spectrometer by the peak height method. The accuracy and precision of this method is comparable to that of the isotope dilution method as verified by measuring the USGS interlaboratory standard muscovite P 207. The analytical results are shown by Table 1.

TABLE 1
Radiometric Data of Alboran Basement Sample

Mineral	Biotite
K, by isotope dilution	8.14%
K, by atom-absorption	7.80%
rad. A^{40}, cc STP	$(5.20 \pm 0.10) \times 10^{-6}$
Air argon	51.5%

From these data we compute an age of 16 ± 1 million years. The possibility includes the uncertainty caused by the correction of the rather high air argon content. We emphasize that only one sample was analyzed. As the biotite K-Ar ages are easily affected by thermal or regional metamorphism, we have to interpret the age of 16 million years as the minimum age (cooling age) for the last metamorphic event in this particular area.

27.4. TRACE-ELEMENT COMPOSITION OF ALBORAN BASIN "BASEMENT"

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Sample 13-121-24 CC-A1 was sent for trace-element analysis to the University of East Anglia, Norwich, England. This sample is a cordierite-biotite-feldspar hornfels and may represent the basement at Site 121. The analytical results give: Rb 325 ppm, Sr 1350 ppm, Y 20 ppm, Zr 200 ppm, and Nb 6.5 ppm. Although this is a metamorphic rock of amphibolite facies, its trace-element composition bears considerable resemblance to that of andesitic volcanics behind island arcs. Further investigations are necessary to determine if this similarity is purely coincidental.

27.5. COMMENTS ON ALBORAN BASIN "BASEMENT" SAMPLES

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INTRODUCTION

We are not completely certain if we reached the acoustic basement at Site 121, or if we have only sampled the basal conglomerate of the Neogene sedimentary sequence (see Chapter 3). The acoustic basement was believed to lie some 0.9 second below the bottom. Core 24 at 867 meters subbottom could be anywhere between 0.6 and 0.9 second (assuming an interval sound-velocity of 3.0 and 2.0 km/sec respectively). However, we are certain that an unfossiliferous sedimentary breccia is present beneath the upper Miocene Tortonian ooze. Some of the fragments described this chapter are clasts in this breccia. On the other hand, we suspect that the 6-cm-long piece jammed in the bit orifice is a piece of the *in situ* basement. It should be recalled that Site 121 was situated on the northern slope of a buried peak. Elevated above the abyssal plain, this site should have been bypassed by turbidity currents carrying large pebbles and cobbles. Thus, the breccia is probably a local deposit. We further are impressed by the fact that all the clasts have been derived from an amphibolite-facies plutonic terrain. The absence of exotic elements also indicates a short distance of transport. Therefore, the basement at Site 121 is very probably a plutonic formation composed of rock-types represented by the clasts in the breccia, even if we have not actually penetrated the basement itself.

GEOLOGICAL SETTING

Metamorphic rocks of amphibolite facies are present both northwest, west, and southwest of the Alboran Basin (Figure 1). Those in the Internal Zone of the Morroco Rif were investigated by Milliard (1959) and by Kornprobst (1966, 1971). Those in the Betic Cordillera were recently studied by T. Loomis (Ph. D. Thesis, Princeton University). All those high grade rocks are associated with periodotite masses. Commonly, the peridotite occupies a central position, being ringed by a zone of granulite-facies metamorphics, which in turn are rimmed by amphibolite-facies gneisses and schists. The outermost zone is a low grade sericite schist and quartzite (see Figure 2). The gneisses and schists from the Alboran Basin site bear considerable resemblance to the amphibolite-facies metamorphics from the internal zone of the Morrow Rif described by Milliard (1959, p. 129-133). The cordierite-biotite-feldspar-hornfels in Sample 13-121-24 CC-A1 is comparable to kinzigites in contact with ultrabasic intrusions such as the Beni-Bousera peridotite massif (Kornprobst, 1971). In fact, we have noted abundant serpentinite flakes mixed into the marls of Core 24. These could have been derived as detritus from the central mass of the intrusion as a hydration product of the peridotite core.

For comparison with similar ultramafic masses in the Betics, we sent the Site 121 thin-sections to Timothy P. Loomis at Yale University. He reported in a written communication (December 14, 1971) that: "several of the samples, especially B1, A2 and B5, are very similar to the low-pressure hornfels formed on top of the Ronda massif. . . .

"The metamorphic assemblage of these pelitic rocks is probably Q-plagioclase-cordierite-biotite-K-feldspar-sillimanite? The sillimanite and andalusite may be metastable and some Fe-rich garnet is a possible phase.

"A description of the Ronda rocks which are almost identical to these samples and the P-T limits which can be placed on the origin of the above assemblages are described in my paper for BGSA (in press). In general, a high temperature (T greater than andalusite-sillimanite transition) and low pressure (P probably less than approx. 4 kb $P_t + P_{H_2O}$) metamorphic environment is indicated. The medium to coarse-grained texture is indicative of relatively slow cooling in contact with a massive intrusion. . . .

"The conclusion is that the samples could certainly have come from the north, since peridotite debris from the Ronda massif is found in Miocene molasse on shore (Dürr, 1967, p. 46) and the metamorphic contact rocks were exposed. If the high-grade metamorphic rock is in place, it should be within a 100 m or so of the intrusion, perhaps represented by the acoustic ridge?"

This petrographic similarity and the geographic proximity lead us to believe that the basement under the buried peak of the Alboran Basin is also a plutonic complex which is most likely similar to that around either the Beni-Bousera peridotite massif in the Rif province or the Ronda massif in the Betics.

GEOLOGICAL SIGNIFICANCE

The geological significance of the metamorphic rocks in the Betic-Rif zone is unfortunately somewhat uncertain. The French authors (Fallot, 1948; Milliard, 1959; Kornprobst, 1971) tended to correlate the Betic and the Rif metamorphics to that in the Small Kabylie Range in Algeria, where Durand Delga (1951) dated the metamorphism as pre-Silurian. Milliard advanced some arguments in favor of a pre-Carboniferous age for the Rif metamorphics despite the local evidence of post-Triassic metamorphism. Kornprobst (1971, p. 343) discussed some Rb/Sr radiometric data which also spoke in favor of a Paleozoic date for the Beni Bousera metamorphics. On the other hand, Blumenthal noted already in 1928 that the ultramafic intrusion may have been Alpine, an opinion shared by Fallot (1948). Recently Loomis confirmed this interpretation, and he further considered the associated metamorphic rocks a product of contact metamorphism caused by the intrusion of the peridotite. His work is not yet published; however, the evidence (including filed mapping and radiometric dating), which he communicated to us orally, seems convincing.

Our one radiometric date of the Alboran "basement" of 16 my does not resolve the problem, but rather, renders the question even more tantalizing. We could follow Loomis and throw in our date in support of the postulate of Alpine metamorphism. Alternately, we might agree with our French colleagues and accept their evidence of Paleozoic metamorphism. Then we would postulate that the young K/Ar age records only on Alpine overprint. In any case, it is likely that the 16 my date is not the age of the metamorphic event but a cooling age. It is interesting to note that this age is but slightly older than the immediately overlying unbaked Tortonian ooze.

Metamorphic rocks are also present east and northeast of the Malaga in the Betic of the Sierra Nevada and in the so-called Mischungszone (see Figure 1). Those rocks are mainly mica schists, although the "Mischungszone" includes marble, quartzites, and some gneisses; they have been compared to the Pennine metamorphics of the Alps. The Sierra Nevada rocks seem to be petrographically too distinct and geographically too distant to have any relation to the Alboran Basin "basement", although such a possibility cannot be ruled out.

In concluding, we would like to emphasize that the recovery of metamorphic rocks and serpentinite detritus at Site 121 provides no magical answer to the origin of the western Alboran Basin.

Sampling of the Mediterranean basement by dredging or by drilling has been biased because of technical difficulties of penetrating through the thick sedimentary layers in

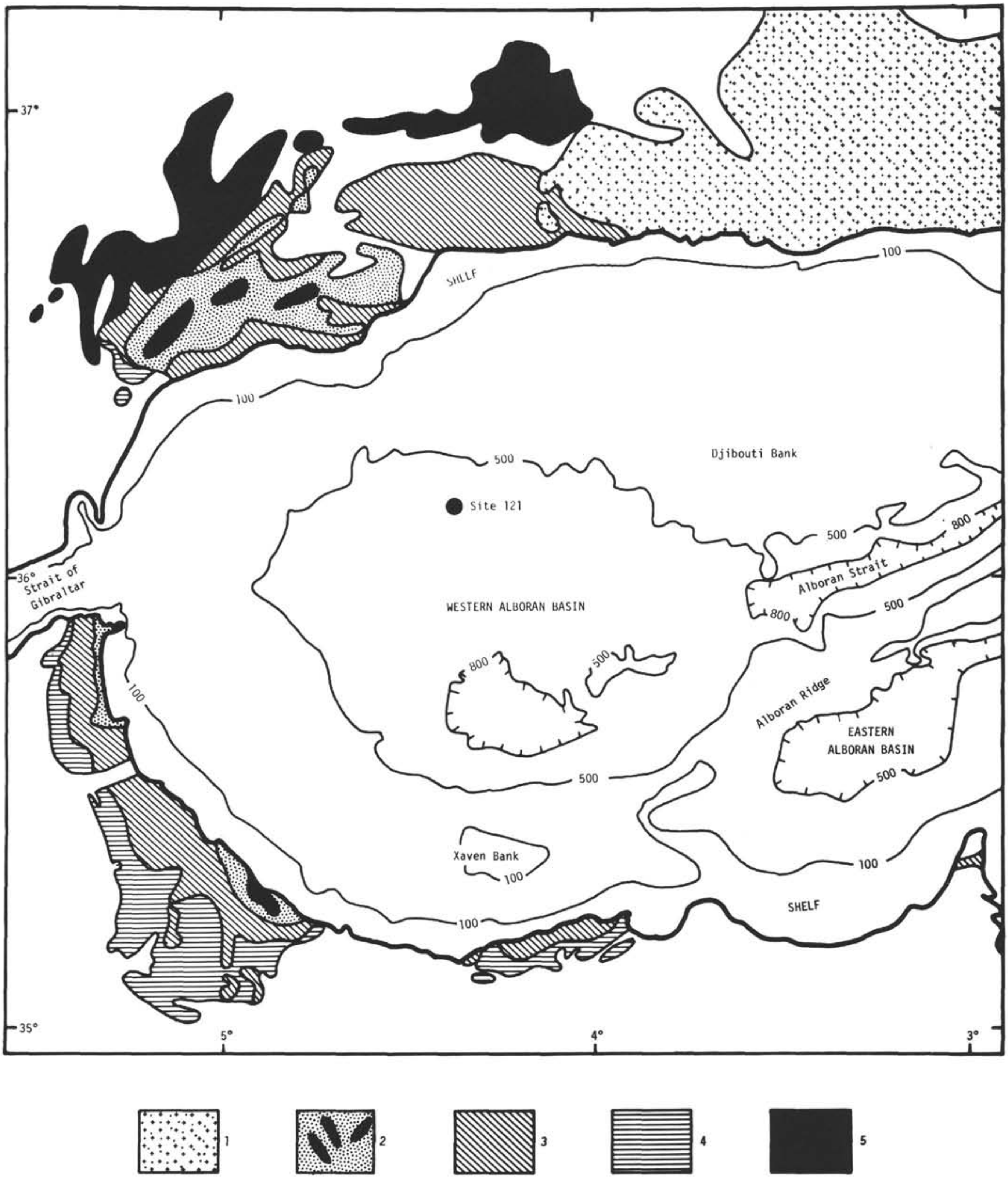

Figure 1. *Geologic setting of Site 121 in the western Alboran Basin. Contours in fathoms (corrected for sound-velocity) from Stanley* et al., *1970. Legend: (1) Crystalline rocks in the Betics and Rif with ultramafic intrusions; (2) Crystalline rocks of the Sierra Nevada and of the "Mischung zone"; (3) Paleozoic sedimentary rocks; (4) Triassic – Lower Jurassic sediments of the internal Betics and Rif; (5) Jurassic and Cretaceous sediments of the external Betics.*

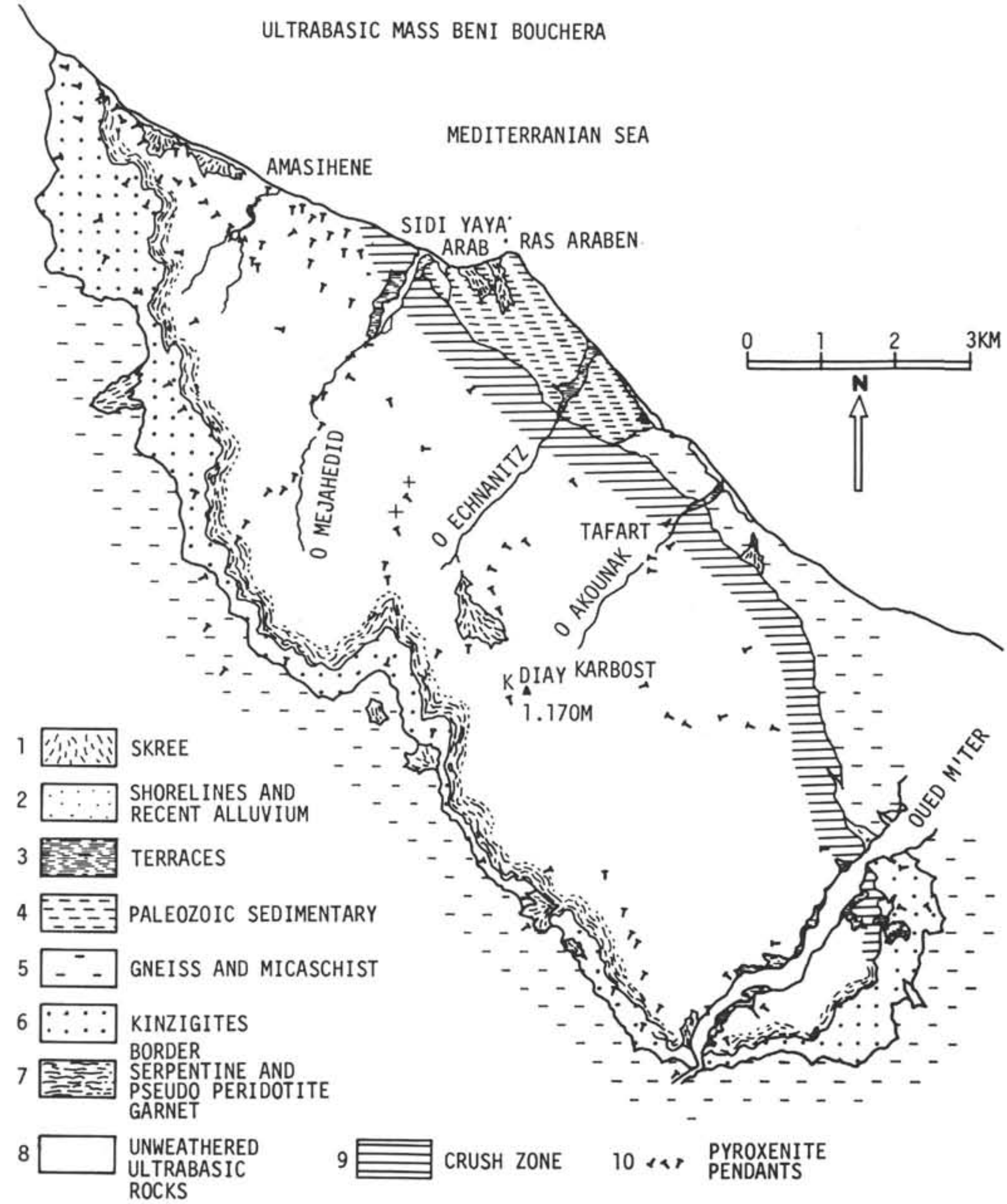

Figure 2. *The ultrabasic massif of Beni Bouchera in Morocco (from Kornprobst, 1971). Legend: (1) Talus and scree from the mountains; (2) Recent alluvial and beach deposits; (3) terraces; (4) Paleozoic sedimentary rocks; (5) Gneiss and mica schists (biotite gneiss); (6) Kinzigites including garnet gneiss and sillimonite-garnet gneiss; (7) Serpentinite rim and pseudo-peridotite with garnet; (8) Ultrabasic rocks, mainly peridotite; (9) Zone of crushing and deformation; (10) Strikes of the bands of pyroxenites.*

abyssal plain provinces. Thus we were forced to dredge or drill on "seismic highs" or "buried peaks", which may represent the upthrown blocks of normal faults. Those blocks should be sialic, according to either the hypothesis of rifting or that of basification. Meanwhile the basement in the downthrown block under the abyssal plain remains unattainable. Perhaps the mantle diapirism associated with the ultramafic intrusions is connected with a mechanism of crustal genesis in the inner arc setting of this region. However, we cannot settle this question until we can manage to drill as well in the basin depression, presently "unattainable" with the state-of-the-art deep sea drilling techniques.

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