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

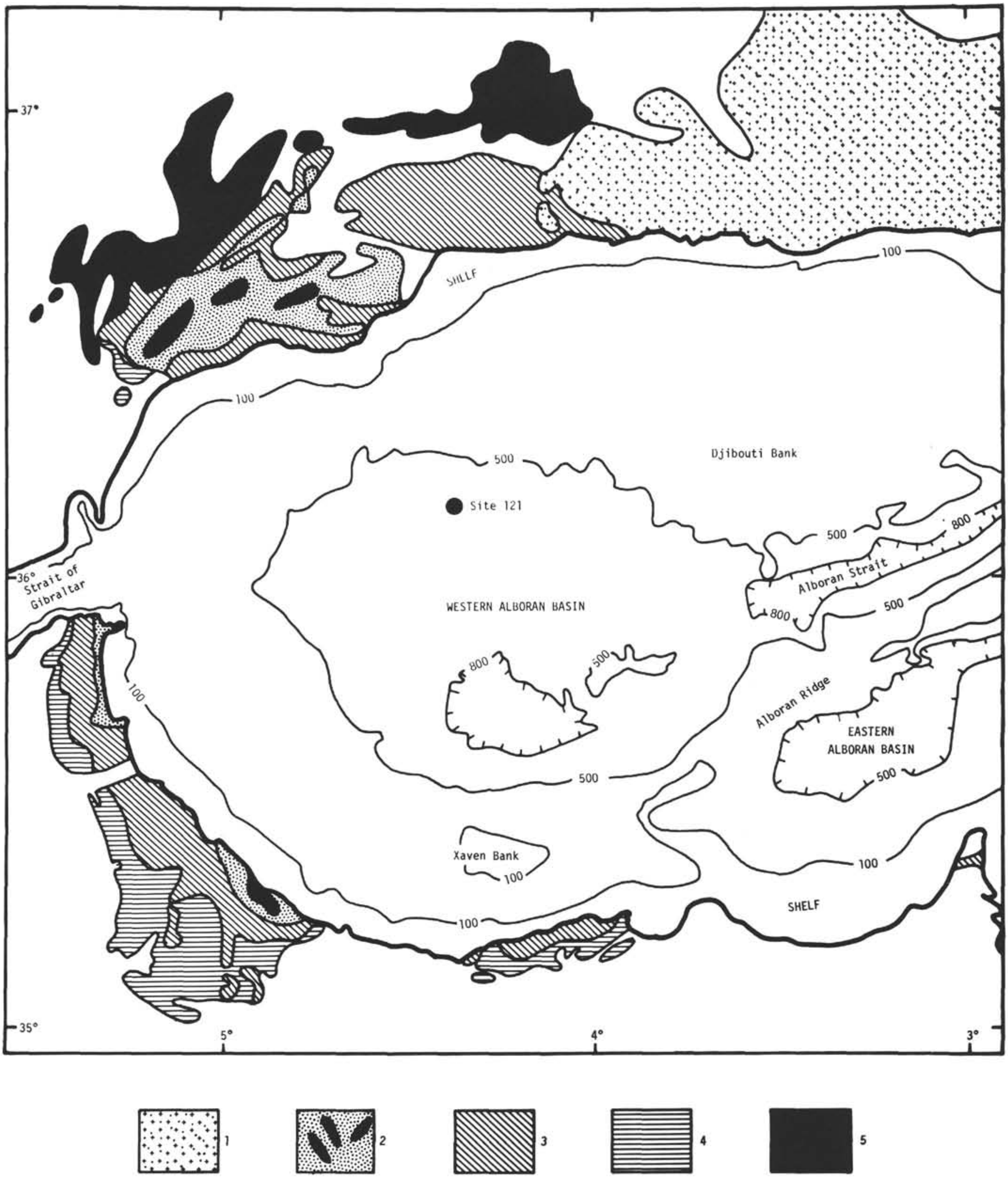

Figure 1. *Geologic setting of Site 121 in the western Alboran Basin. Contours in fathoms (corrected for sound-velocity) from Stanley* et al., *1970. Legend: (1) Crystalline rocks in the Betics and Rif with ultramafic intrusions; (2) Crystalline rocks of the Sierra Nevada and of the "Mischung zone";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

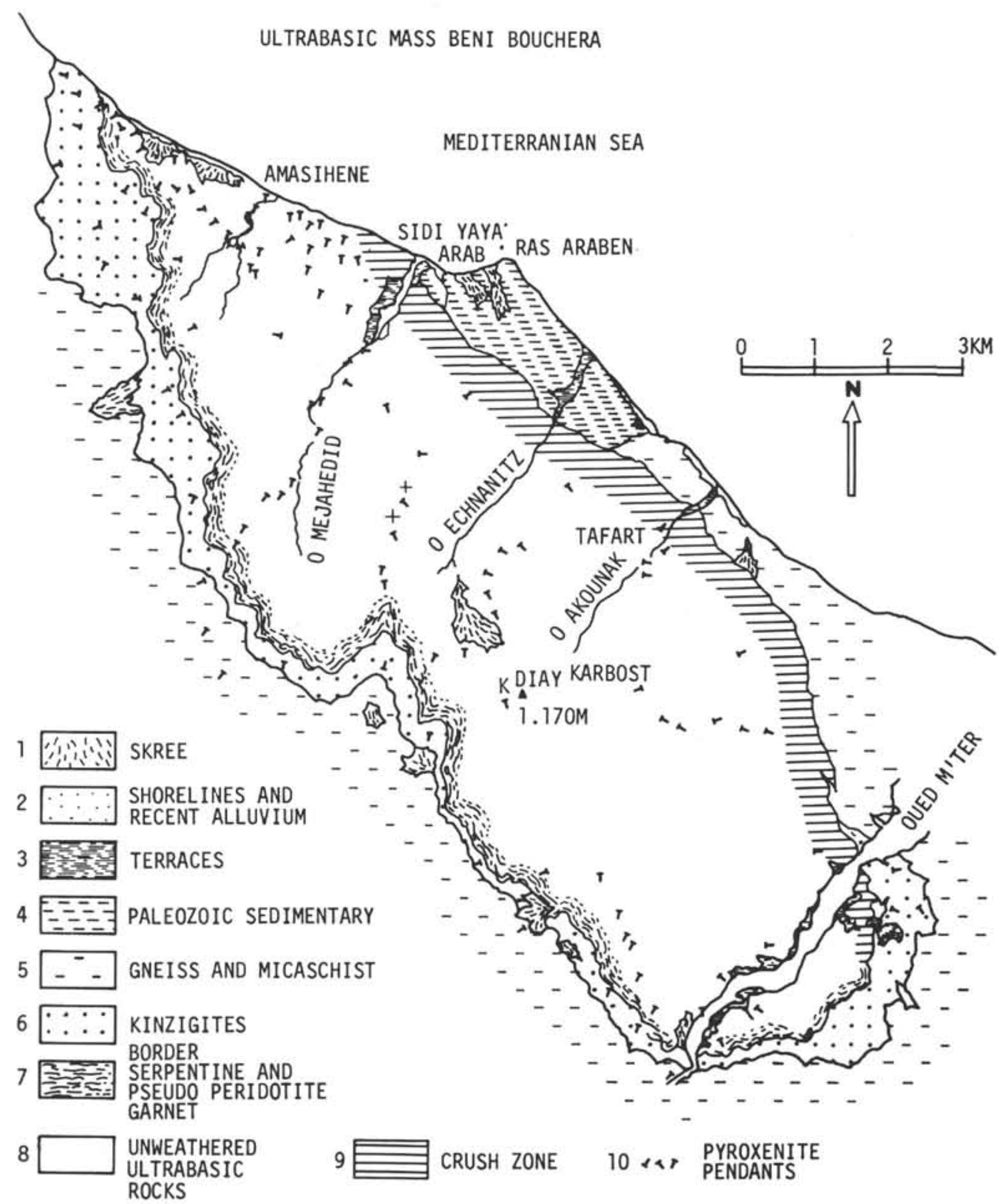

Figure 2. *The ultrabasic massif of Beni Bouchera in Morocco (from Kornprobst, 1971). Legend: (1) Talus and scree from the mountains; (2) Recent alluvial and beach deposits; (3) terraces; (4) Paleozoic sedimentary rocks; (5) Gneiss and mica schists (biotite gneiss); (6) Kinzigites including garnet gneiss 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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