Tectonometamorphic evolution of a metamorphosed mafic suite Ermoupoli, Syros, Greece

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INTRODUCTION

The island of Syros is mostly composed of marble and meta-pelite lithologies. Isolated mafic schists occur in a few areas and are embedded in the vast marble units. One of these areas, the Vaporia Bay locality, is a 1-2 km long coastal section located immediately north of Ermoupoli. It is underlain by a heterogeneous sequence of metamorphosed mafic and ultramafic rocks that preserve evidence of multiple phases of metamorphism and deformation. They have been interpreted as a high pressure metamorphosed ophiolite suite, carried into an accretionary wedge, at the Eurasia-Africa subduction zone (Ridley & Dixon, 1984). This study examines the tectonometamorphic evolution of these rocks, and seeks to constrain the pressure and temperature conditions under which they were formed and deformed.

METHODS

In the field, mapping and the construction of a cross section were carried on in order to determine the setting and overall character of each lithology, and the structural relationships among them. Forty-five samples from each different rock type of the metamorphic mafic suite were collected from the section along the coast of Ermoupoli. Twenty-four of those were cut into thin-sections and described for petrology and texture. Seven representative samples from each different lithology, and representing a wide geographical distribution, were chosen for analysis using an SEM/EDS. Traverses and X-ray diffraction mapping were conducted for several representative minerals, in order to determine zoning patterns and the pressure - temperature paths that the rocks followed.

PETROGRAPHY

Lithologies in the area are intercolated and repeated on a scale of 2 to 15 meters, and are sharply bounded. The distribution of each different rock type along the coast is almost equally abundant. The units are laterally continuous and they mostly occur as tabular layers. The structural field relationships among units are shown in the schematic cross-section of figure 2. The rock types of the study site can be divided into five major groups:

1) A medium to fine-grained, moderately to well-foliated (meta-basaltic) blueschist. This lithology consists of a heterogeneous sequence of bands of varying composition and texture. The mineral assemblages for the most typical of these variations (figure 1) all contain sodic amphibole, zoisite (or clinozoisite), quartz and rutile. Blueschsits are the only lithology in the study site that contain the zoisite version of the epidote group minerals; other lithologies most commonly contain ferric iron epidote. In addition to the four basic minerals (sodic amphibole, zoisite, quartz, rutile) that are present in blueschsits, they also contain one of the following assemblages:

A. omphacite + garnet + phengite + paragonite
B. omphacite + phengite + paragonite
C. garnet

D. phengite
E. phengite + paragonite + omphacite + epidote + garnet
The blueschist lithology is commonly overprinted by greenschist minerals (chlorite ±actinolite ±albite +epidote ±sphene). It preserves evidence of shear deformation in several places, as indicated by asymmetric glaucophane tails and pressure shadows on garnets.

2) A coarse-grained, massive to moderately foliated, Fe-Ti rich eclogitic rock (meta-gabbro) characterized by the blueschsist facies assemblage: sodic amphibole + garnet + epidote + omphacite + epidote + phengite + rutile + quartz. Its mineralogy is very similar to that of the blueschist, but it is interpreted as a metagabbro due to the preservation of textural relics of a primary igneous plutonic protolith (Dixon, J. E., & Ridley, J., 1987). Sodic amphibole, garnet, phengite and omphacite appear as porphyroblasts in the rock. The matrix is made up of pseudomorphs of very fine grained epidote and phengite after larger earlier zoisite crystals. This may be an effect of greenschist retrogression (epidote replacing zoisite). Phengite porphyroblasts commonly occur around the garnet. Omphacite and sodic amphibole are commonly intergrown, and in some places omphacite appears as inclusions in larger amphibole crystals.

3) A coarse-grained, massive, Mg-rich meta-gabbro, bearing omphacite + epidote + phengite + quartz. Retrograde minerals (albite, chlorite, actinolite) are prominent throughout the lithology.

4) A medium-grained, well-foliated greenschist containing albite + epidote + chlorite + actinolite + sphene, as well as remnant sodic amphibole. Inclusion trails of epidote and actinolite are very common inside larger albite crystals that grew over the other minerals post-tectonically. Another common variation of the greenschist lithology is one that contains epidote – phengite – paragonite pseudomorphs after earlier lawsonite porphyroblasts. The pseudomorphs are deformed into lenses with asymmetric tails indicating shear deformation in the rock.

5) A serpentinite, occuring mostly in melange zones, with metagabbro and blueschist knockers embedded in it.

COMPOSITIONAL AND CHEMICAL ANALYSIS

Sodic amphibole: The blue amphibole compositions are shown on figure 4. Ferric iron corrections were made on the analyses by normalization to 13 cations excluding Ca, K and Na. All amphiboles are indeed glaucophane, although there is considerable variation in the calculated Fe^{3+} among the samples. The glaucophane in all samples varies in composition due primarily to Fe–Mg zoning (figure 3). This zoning in some cases reflects core to rim variation (blueschists) but in other rocks it is not systematic (Fe-Ti metagabbro). Zoning is interpreted as a result of retrogression and decreasing pressure as the rocks were tectonically carried toward the surface.

Omphacite: Omphacite compositions are shown on figure 6. Ferric iron corrections were performed on omphacite as well, on a 13 cation normalization basis. As in the case of glaucophane, there exists some variation in the Fe^{3+} content among samples. Omphacite is composed of about 50% jadeite, 40% diopside and less than 10% acmite. The amount of variation in Fe, Mg, Al, Ca and Na (figure 5) is considerable but not systematic; no core to rim zoning is observed, instead the zoning of the omphacites is irregular. The inverse relationship between the diopside component (Mg and Ca) and the jadeite component (Al and Na) of omphacite, and the variation in their constituent elements reflect the pressure sensitive diopside-jadeite substitution.

Garnet: Rim to rim traverses were conducted on individual garnet crystals, and show slight growth zoning in the spessartine and grossular components, but relatively flat almandine and pyrope compositions (figure 7). The garnet in most of the samples is composed of 60% almandine, 10% pyrope and 30% spessartine combined with grossular (figure 8). The garnet in some of the lithologies contains a greater core to rim variation in the grossular, spessartine and pyrope compositons (figure 8)

SUMMARY AND CONCLUSIONS

This study addresses whether the lithologies of the Ermoupoli mafic sequence differ mineralogically because of differences in their initial bulk composition, or due to variations of metamorphic pressure and temperature across the study area. For example, one of the most intriguing aspects of the suite is the close spatial juxtaposition of blueschist and greenshcist units. It could be explained by different pressure and temperature conditions across this small coastal section, or by different protoliths. Tectonic processes could also be responsible, through post-metamorphic faulting. An integrated analysis of fabric and mineral equilibria outlines the metamorphic paths of these rocks and is used to evaluate subduction zone models for their genesis.

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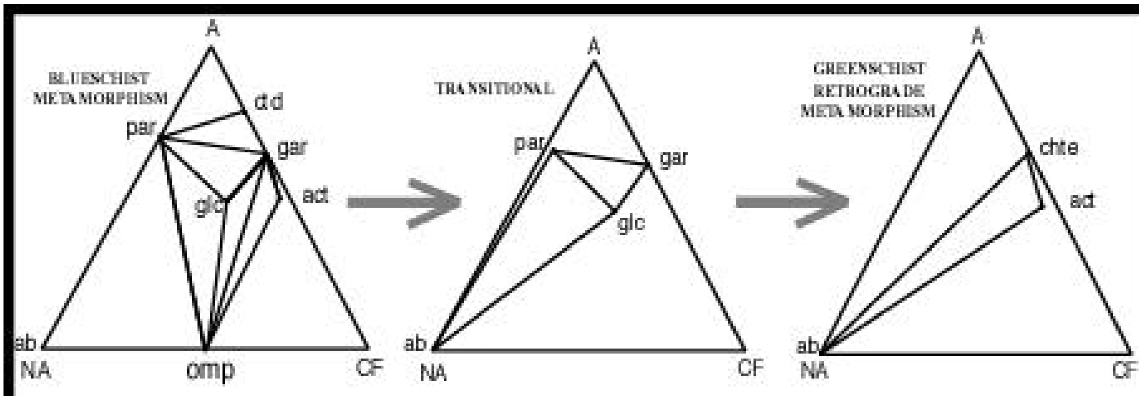

FIGURE 1 : Phase relationships of metabasite assemblages in the NA-A-CFM projection from epidote, quartz and H2O. By Kohlman & Schliestedt (1979) and Brocker (1988).

FIGURE 2 Schematic cross section of study site.

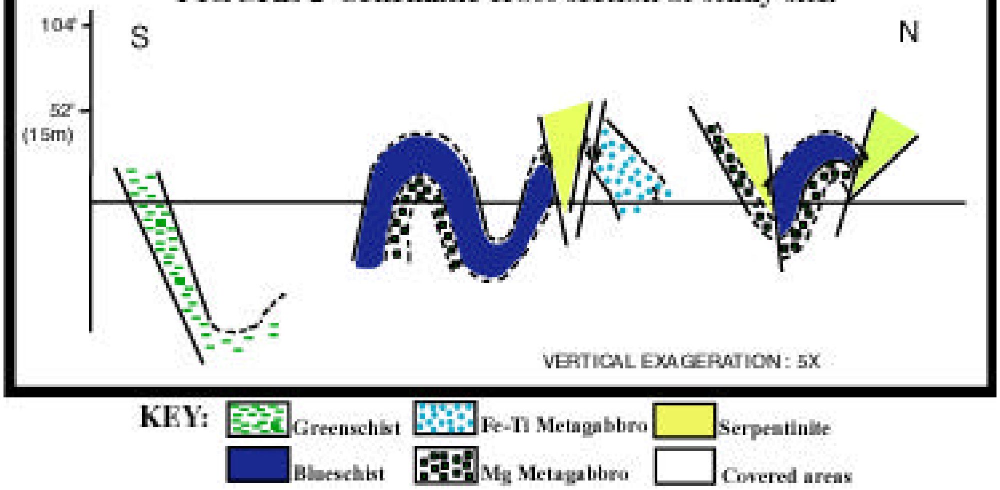

FIGURE 3

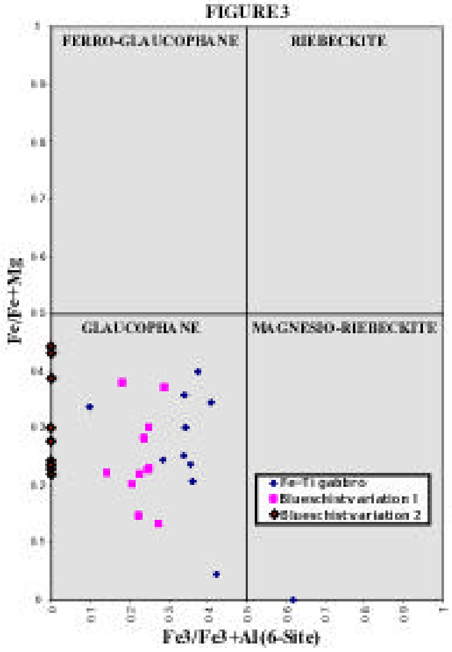

FIGURE 4

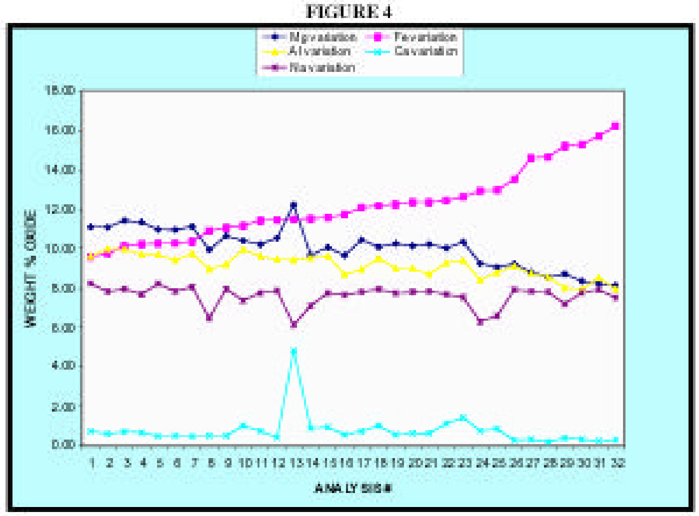

FIGURE 3: Variation of major elements in sodic amphiboles, from the Fe-Ti metagabbro (sample 11A), displaying evidence of irregular zoning in glaucophane.

FIGURE 4: Sodic amphibole chemical composition.

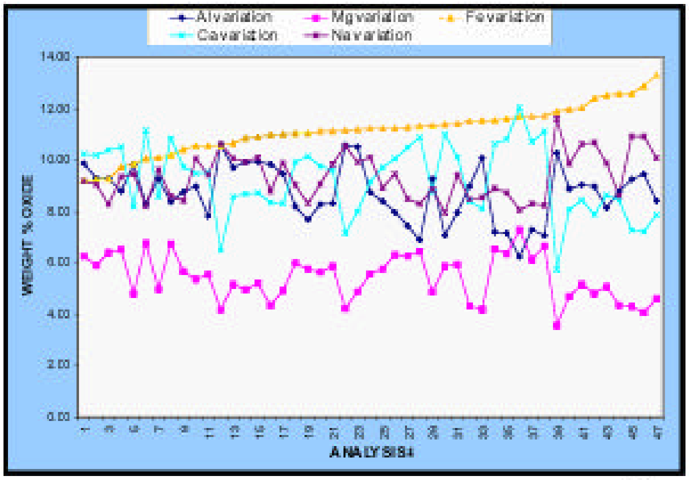

FIGURE 5 : Clinopyroxene Chemical variation according to weight percent distribution of the elements based on multiple analyses on a single slide. The inverse relationship between the dipside and the jadeite component, and the variation in their constituent elements reflect the pressure sensitive diopside-jadeite substitution.

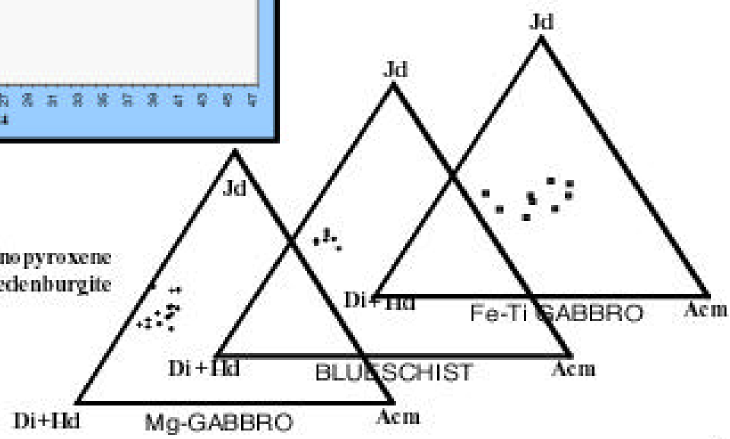

FIGURE 6 : Ternary Diagram showing clinopyroxene compositions based on jadeite, diopside, hedenburgite and acmite.

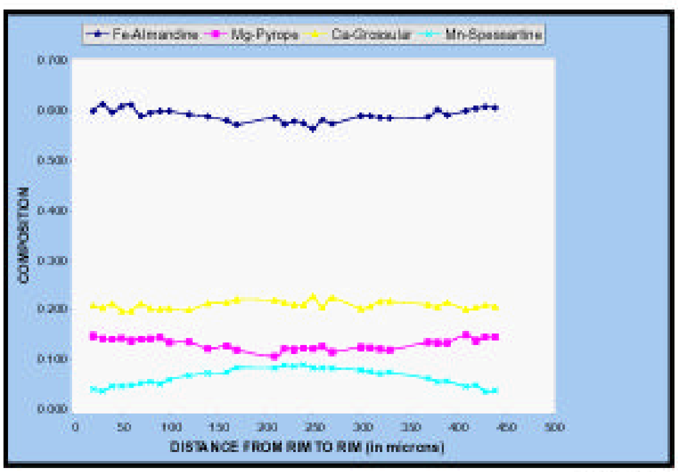

FIGURE 7 : Garnet traverse, from an Fe-Ti metagabbro, showing grossular-spessartine-almandine-pyrope compositions

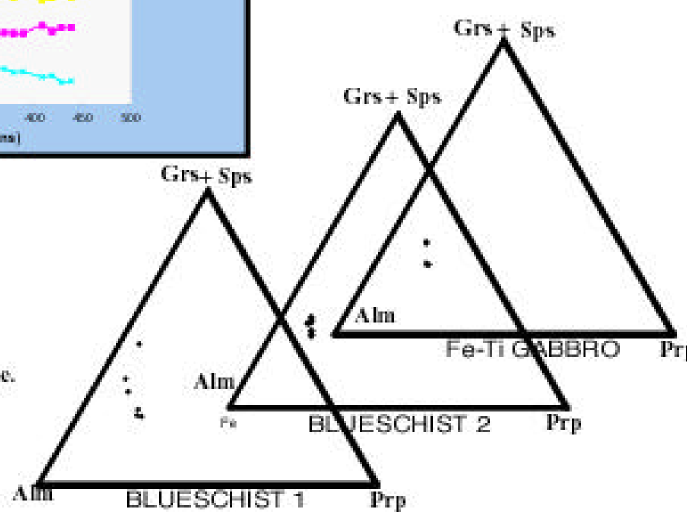

FIGURE 8 : Garnet compositions based on grossular, spessartine, pyrope and almandine.