GEOCHEMISTRY AND METAMORPHIC EVOLUTION OF ECLOGITES ON SYROS ISLAND, GREECE

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INTRODUCTION

The island of Syros is located in the blueschist belt of the Aegean Attic-Cycladic crystalline complex. Syros hosts exposures of high grade metamorphic rocks that were subject to regional high pressure blueschist- to eclogite-facies subduction-related metamorphism in the Eocene and medium pressure greenschist- to amphibolite-facies overprinting in the Miocene (Dixon and Ridley, 1987; Okrusch and Bröcker, 1990). The island is composed of north to north-east dipping thrust faulted sheets of alternating marbles, schists and volcanics overlain and juxtaposed by complexes of diverse blocks of mafic metaigneous rocks enclosed in a matrix of highly altered serpentinite (Dixon and Ridley, 1987; Okrusch and Bröcker, 1990). This study concerns the chemical analysis of eclogites from mafic complexes along the western coast of Syros for the purpose of characterizing potential variations in eclogite protolith and constraining PTt paths using omphacite-garnet-phengite geothermobarometry of high-pressure assemblages to construct a picture of the conditions and evolution of subduction and exhumation in the region.

METHODS

Forty-five samples of eclogite and omphacite-garnet-bearing rocks were collected from five localities along the western coast of Syros (Charasonas, Galissas, Kini, Lia Beach, Megga Lakkos; see Cheney, Figure 1, this volume). Samples with appropriate mineral assemblages were chosen that preserved a range of fabrics and grain sizes, and the relationship of the outcrop to the matrix serpentinite was noted at each locality. Thin sections for each sample were petrologically described, mineral compositions for one sample from each location were obtained using the SEM/EDS system, and eleven samples were analyzed chemically using whole rock major and trace element geochemistry. These data were combined with X-ray element maps and traverses to identify potential mineral zonation and to determine the PT evolution of the rocks.

MINERALOGY

The eclogites of Syros are almost exclusively limited in distribution to mafic complexes near the middle of the island (ophiolitic units) and the mafic-serpentinite block-matrix mélange to the island’s north (see Cheney, Figure 1). Samples are typically coarse-grained, massive, omphacite-rich rocks with assemblages that vary from omphacite-garnet-epidote-phengite to omphacite-garnet-epidote-glaucophane, with minimal amounts of rutile, titanite and quartz. Phengite and glaucophane define the foliation in the few samples that are weakly foliated. Chlorite occurs as a common retrograde mineral and apatite occurs as an accessory mineral. Chlorite is especially prevalent in coarse-grained samples from Kini, and largely absent from finer-grained samples from Megga Lakkos (see Cheney, Figure 1).

In these eclogites omphacite occurs in various habits: as small, millimeter sized tabular laths and large, cm sized, long, crystal overgrowths.

Omphacite and glaucophane compositionally zoned with variation in Fe2+ and Fe3+ from core to rim in some samples (Figure 2).

Garnet typically occurs as anhedral, porphyroblastic or aggregate grains ranging in size from <1mm to 3mm. Garnet commonly contains inclusions of omphacite, phengite, titanite and epidote. Inclusions are typically concentrated in garnet cores and show no preferred orientation. Garnet compositions of Alm.6-Alm.7 are typical and in general garnet is only slightly chemically zoned, although SEM analyses and X-ray element maps have shown minor growth-related variations in calcium and manganese contents in some samples (Figure 3).

Rutile occurs in nearly all samples as small, <1mm clusters commonly associated with or rimmed by titanite and ilmenite. Various sulfides and carbonates occur in small proportions.

GEOCHEMISTRY

Whole rock geochemistry was obtained from eleven samples from five localities in an attempt to identify the protolith of the samples and determine the resemblance, if any, they bear to Fe-Ti gabbros that have previously been studied on Syros and elsewhere in the Cyclades. Based on textures, mineralogy and field relations, previous workers (Dixon and Ridley, 1987) have interpreted the mafic rocks as meta-basalt and metagabbros. Immobile, trace and rare earth element studies from neighboring island Sifnos have characterized eclogite protoliths as calc-alkaline basalts, andesites and Fe-rich tholeiites of an island arc setting (Mocek, 2001). Total alkali silica plots of the geochemical data from Syros eclogites suggest that the samples have similar bulk compositions and, consistent with previous interpretations, that they may have been derived from basaltic protoliths (Figure 4).

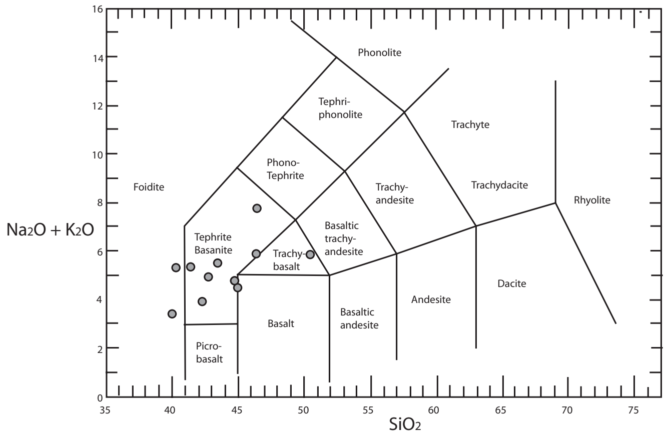

Figure 4: Total alkali silica diagram for eleven eclogite samples.

The alkaline nature of these rocks may be indicative of post-magmatic processes that affected the element mobility, perhaps related to processes of serpentinization that generated the block-matrix association seen across the northern part of the island.

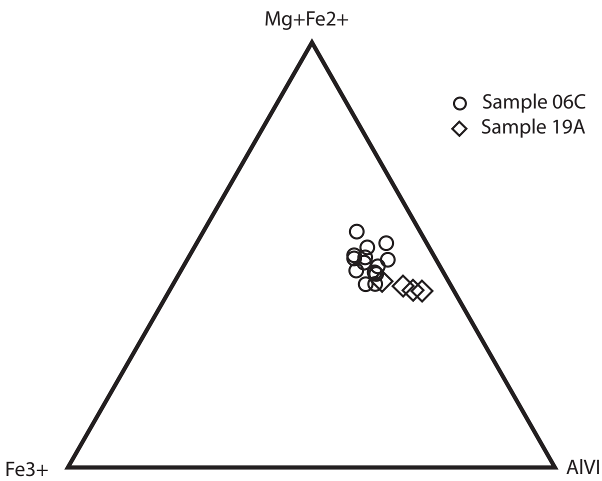

Figure 2: Ternary diagram showing omphacite compositions and Fe2+/Fe3+ zoning over single grains.

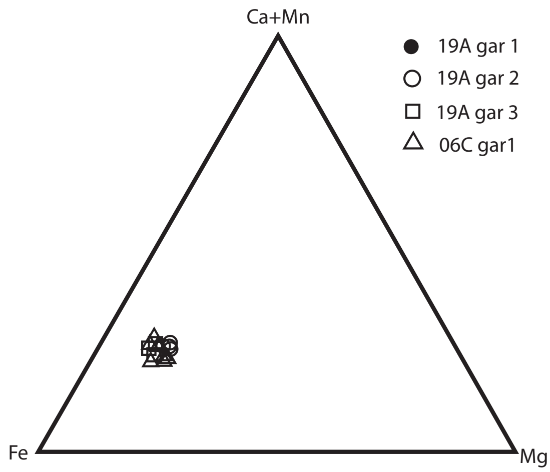

Figure 3: Ternary diagram showing garnet compositions for samples 19A and 06C (~Alm_{60}).

GEOTHERMOMETRY

The main purpose of this study is to characterize the eclogites of Syros chemically and mineralogically and to constrain the P-T paths of the high-pressure assemblages they represent.

A new method of high-pressure geothermobarometry by Ravna and Terry (2004) was applied to obtain temperatures and pressures of equilibration based on determined mineral compositions. This method uses new geothermobarometric expressions for the omphacite-gt-phengite assemblage derived from internally consistent expressions that have been formulated for reactions between gt-cpx-kyanite-phengite-coesite and gt-cpx-kyanite-phengite-qtz. These reactions serve to constrain pressures, and are used to minimize the effect of Fe2+/Fe3+ distribution. The expected error for this method is approximately +/- 65° and +/- 2 kbar.

Preliminary application of this method to one sample from Syros has generated pressures from 23 to 27 kbar and temperatures ranging from 575-700ºC with one exception (Figure 5). The data points on the PT diagram correspond to the intersections of pressure and temperature slopes calculated by Ravna and Terry's method, but the scatter does not appear to correspond to compositional changes in minerals (ex. core to rim in a garnet). These conditions are much higher than the values of 14-15 kbar/450-580ºC calculated by Trotet et al., (2001) in earlier studies of Syros eclogites, but are compatible conditions of 24kbar/680ºC data from studies of eclogites from the Western Alps (Nowlan et al., 2000).

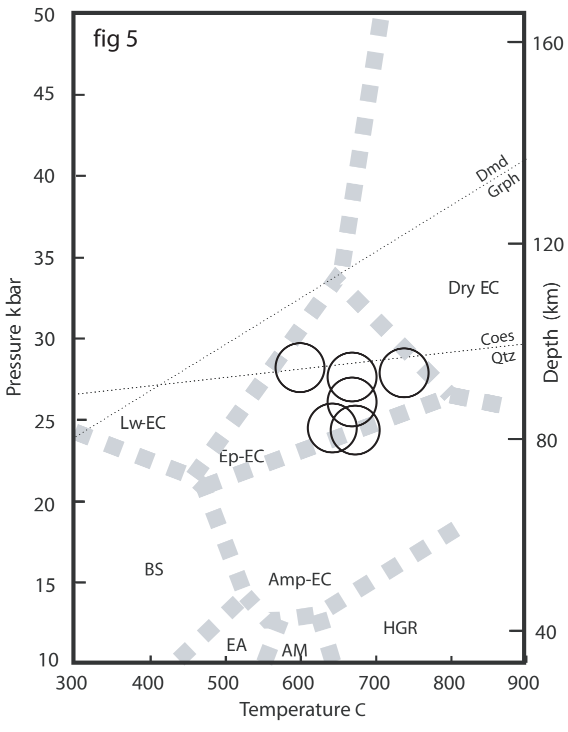

Figure 5: Calculated P-T data for sample 19A based on omph-gt-phengite thermobarometry. From Ravna and Terry (2004).

Further study will determine if data from other samples yields similar results, which would imply that the metamorphic evolution of Syros is more complex than previously reported. Additional analysis of these and the chemical data will be undertaken to further constrain these results further and to attempt to integrate them into a broader history of Cycladic metamorphic evolution.

SUMMARY

This primary goal of this study is to characterize eclogites of Syros chemically and petrologically, and to determine if variations are due to differences in protolith or bulk composition or to due differences in grade across the island of Syros. Whole rock major and minor element geochemistry shows that eclogites from different locations have a similar chemical chemical affinity and likely the same source. This study also attempts to understand the conditions under which those protoliths were metamorphosed within the broader context of the metamorphic evolution of the Cycladic blueschist belt using a new method of omphacite-gt-phengite geothermobarometry.

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