Metamorphic evolution of high-pressure, low-temperature mafic rocks near Kini on the island of Syros, Greece

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INTRODUCTION

The island of Syros in the Greek Cyclades exposes Eocene high-pressure, low temperature metamorphic rocks including marbles, blueschists and pelitic schists (Ridley, 1981). It has been proposed that these units have experienced two major eclogite-blueschist facies metamorphic events, the first occurring at 470-520°C and 14-18 kb and the second not exceeding 460°C and 14 kb (Lister, 1996). At approximately 20-25 Ma, these units became regionally overprinted by a medium-pressure metamorphism (Schliestedt, 1987).

A well exposed sequence of metamorphosed mafic and ultra-mafic rocks outcrops along a 2.5 km long coastal cliff near Kini on the western coast of Syros. This suite consists of segments of glaucophane schist, eclogite, omphacite-epidote rock, pelitic schist, and serpentinite with blackwall reaction zones separating the serpentinite from the other rock types. This study combines petrographic and chemical evidence in order to determine whether the difference in the units exposed at Kini is due to differing bulk compositions or to differing metamorphic grades.

FIELD RELATIONS

Lithologies change dramatically over the 2.5 km coastal cliff of Kini. There is no distinct gradational pattern to the rock units exposed. Beginning at the southern tip of the field area and working northward, the rock units are glaucophane schist, omphacite-zoisite rock, glaucophane schist, eclogite, serpentinite and blackwall reaction zones, glaucophane schist, a greenschist facies unit and pelitic schist. The units are separated by marbles, which were not studied. These marbles are in fault contact with the mafic and ultra-mafic rocks at Kini. These are steep, non-layer-parallel faults. The serpentinite and blackwall reaction zones are the only units at Kini that are in direct, non-faulted contact with another unit. The serpentinite and blackwall reaction zones serve as a matrix for a jumble of rounded blocks of eclogite and omphacite-zoisite rocks. The Galissas Fault Zone separates the entire sequence of mafic and ultra-mafic units from the main marble and pelitic schist units of central Syros (Dixon and Ridley, 1987).

PETROGRAPHY

Glaucophane Schist In the field, glaucophane schist is identified by its blue color and distinct foliation. In general, these units are composed of 40% glaucophane, 5-20% garnet, 10-15% epidote, 10-15% chlorite, 10% rutile, 5-10% phengite, 5% titanite, 5% apatite and 5% albite. Although not apparent in all grains, 20% of the glaucophane crystals display color variations in the individual grains, indicating chemical zonation (Figure 1). In the field, the glaucophane schist outcrops are compositionally banded. These bands are on average 15-30 cm thick and are defined by an abundance of either glaucophane, garnet, phengite or chlorite. Glaucophane and phengite define the foliation of the glaucophane schist.

Ecolgite The eclogite units at Kini are not as abundant as the glaucophane schists. The eclogite at Kini is identified by its dark, almost black, color, 1/2-1 cm grain size and absence of a distinct foliation. These units are composed of 20-25% glaucophane, 15-20% epidote, 5-20% garnet, 10-20% chlorite, 5-10% apatite, 10% titanite, 10% albite, 5% rutile, 5% omphacite and <5% phengite. In the field most of the green minerals were identified as omphacite; however, under further examination under the petrographic microscope, most of the green minerals were identified as chlorite. Consequently, due to the small amount of omphacite, these units cannot be classified as true eclogites. Similar to the glaucophane schist, the glaucophane present in the eclogite has color variations within individual grains, indicating chemical zoning. Rutile appears in concentrated clusters through the eclogite samples. These clusters are consistently surrounded by titanite. Garnets in two eclogite samples have a halo of phengite.

Omphacite-Epidote Unit Along the coast of Kini, the omphacite-epidote units are very distinctive white units with large (1-3 cm) green minerals. The unit is composed of 50% clinozoisite/epidote, 20% chlorite, 15% omphacite, 10% rutile, <5% zoisite and <5% phengite. The omphacite-epidote units are mineralogically banded. These bands are approximately 60 cm thick and are distinguished by an abundance (70%) of either clinozoisite/epidote or omphacite.

Serpentinite and Blackwall Reaction Zones The serpentinite units are composed entirely of serpentine and contain a weak, crenulated foliation. Reaction zones of near monomineralogic bands of talc, then actinolite separate the serpentinite from the blocks of eclogite. These reaction zones occur over a distance of 2.5-3.7 m.

GREENSCHIST FACIES OVERPRINTING

Although much of the Eocene eclogite-blueschist facies metamorphism is preserved in the rocks of Kini, alteration of these units did take place during the medium-pressure metamorphism of the Miocene. An outcrop of chlorite rich units is located along the northern coast of the field area at Kini. In addition to this chlorite unit, chlorite rich layers are observed in the banded layers of the glaucophane schist outcrops. The greenschist facies metamorphism is seen in the glaucophane schist, eclogite and omphacite-zoisite rocks. Evidence for this overprinting is the abundance of chlorite, and albite.

MINERAL CHEMISTRY

Four samples have been chemically analyzed with an Oxford ISIS energy dispersive x-ray analyzer on a Scanning Electron Microscope JEOL 6400(SEM). Two samples are eclogites and two samples are glaucophane schists. One sample contains both eclogite and glaucophane schist. One area of interest studied in both the eclogite and glaucophane schist samples was the chemical zoning of the glaucophane crystals evident in thin section. The darker blue rims contain larger amounts of Fe (Fe^{3+} and Fe^{2+}) and a small amount of Ca, whereas the lighter core contains less Fe and Ca and more Na (Figure 2). The garnet crystals analyzed in both the glaucophane schists and eclogite samples are not zoned. These garnets are approximately 57% almandine, 29% grossular, 7% pyrope and 6% spessertine.

Another grain that was analyzed with the SEM/EDS comes from glaucophane schist. This grain was identified as lawsonite in the field due to its rhombic crystal shape. Chemical analysis; however, showed that it is not lawsonite. These grains are composed of epidote and titanite and are surrounded by albite (Figure 3).

DISCUSSION

The focus of this research project is to determine the difference between the eclogite and glaucophane schist units outcropping at Kini. Do the units have the same bulk composition and have responded differently to metamorphic conditions? Or are the differences in the mineralogy of the units due to differences in bulk chemistry. In order to answer to these questions, ternary phase diagrams were constructed using an eclogite, a glaucophane schist, and whole rock chemistries of samples collected by Aaron Grandy and Holly Shiver (Greece Keck, 1999) (Figures 4-7). Plotting mineral chemical data from the eclogite sample shows the mineral assemblage glaucophane, omphacite and garnet. The whole rock chemistry of the eclogites from Kini plot within this triangle. The glaucophane schist sample displays the assemblage glaucophane and garnet. The whole rock chemistry plots along the tie line connecting the two minerals. In addition, Figure 5 displays amphibole chemical compositions that are richer in Fe and Mg. These chemistries cross-cut the tie line connecting the glaucophane and garnet. Due to the presence of albite and chlorite in this particular sample, these analyses are interpreted as evidence of amphibole growth during the greenschist facies overprinting that occurred in the Miocene. Due to the difference in bulk compositions of the glaucophane schist and eclogite samples but the compatibility of the mineral assemblages of the two rock types, we believe the differences between the eclogite and glaucophane schist are due to differences in bulk chemistry rather than differences due to metamorphism. This conclusion corresponds with the conclusion reached by Schliestedt (1986) for similar rocks on the nearby island of Sifnos.

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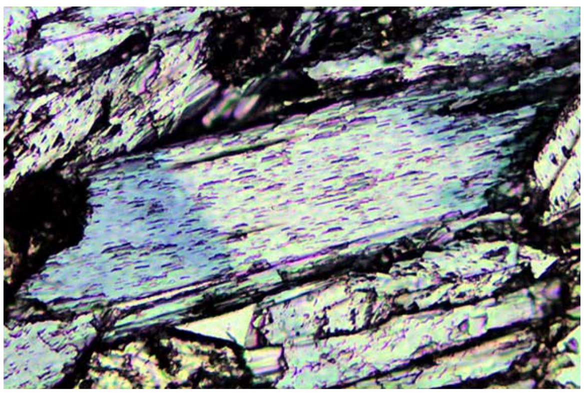

Figure 1. Photomicrograph displaying chemical zonation distinguished by color variations in 0.5mm long grain of glaucophane.

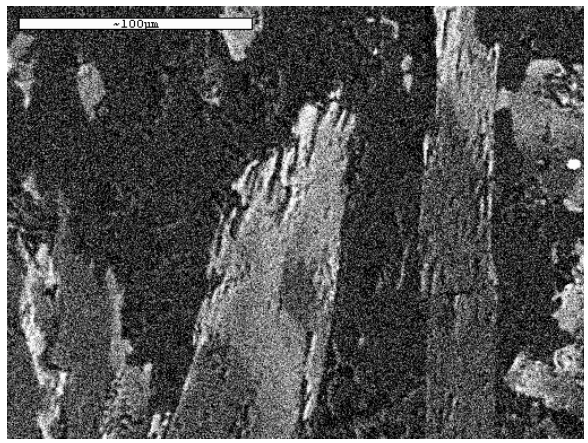

Figure 2. Backscattered electron image of zoned glaucophane.

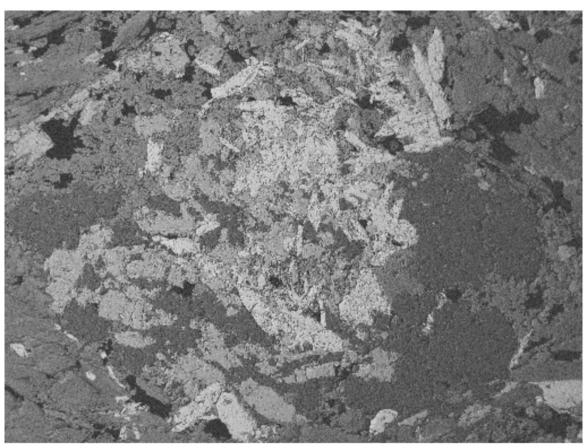

Figure 3. Backscattered electron image of grain thought to be lawsonite in the field. Field of view is 0.5mm.

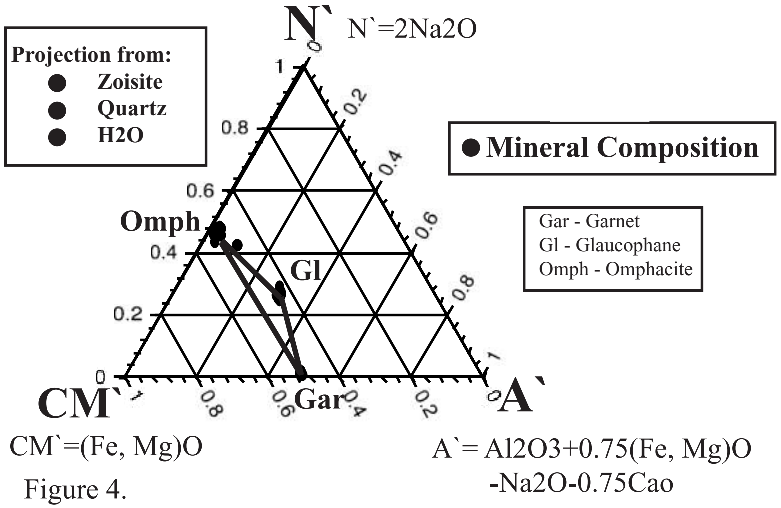

Figure 4.
Ternary Phase Diagram of Eclogite.

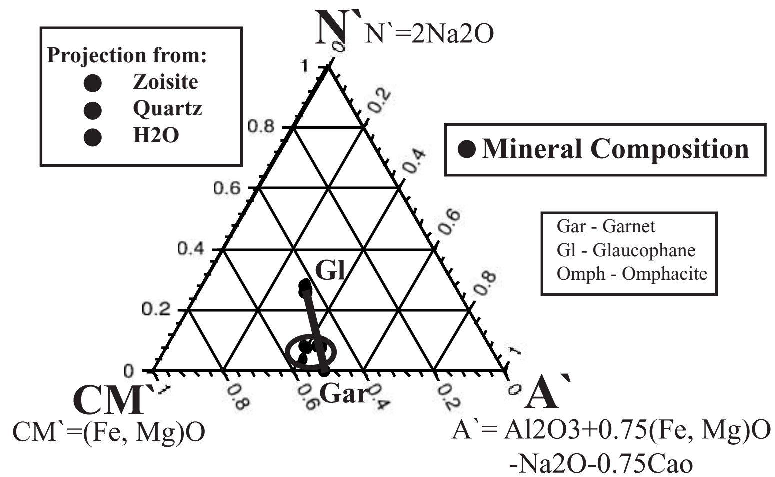

Figure 5.
Ternary Phase Diagram of Glaucophane Schist.
Circled Area Indictaes Greenschist Facies Amphiboles.

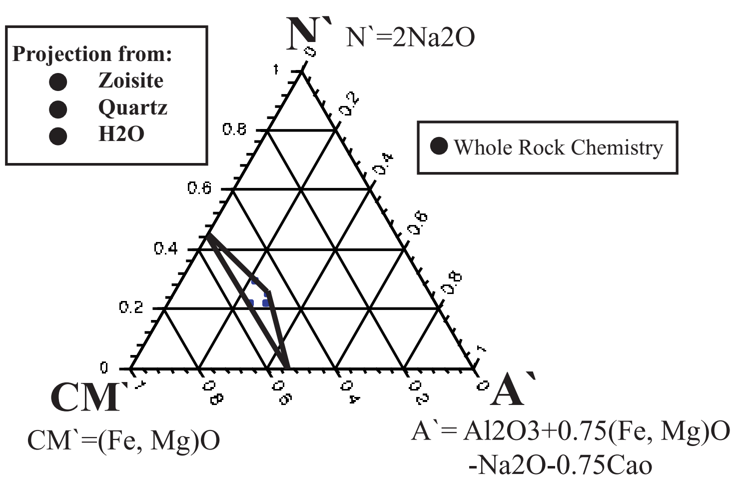

Figure 6.
Ternary Diagram of Whole Rock Chemistry of Eclogite.
(Triangle from Figure 4 plotted.)

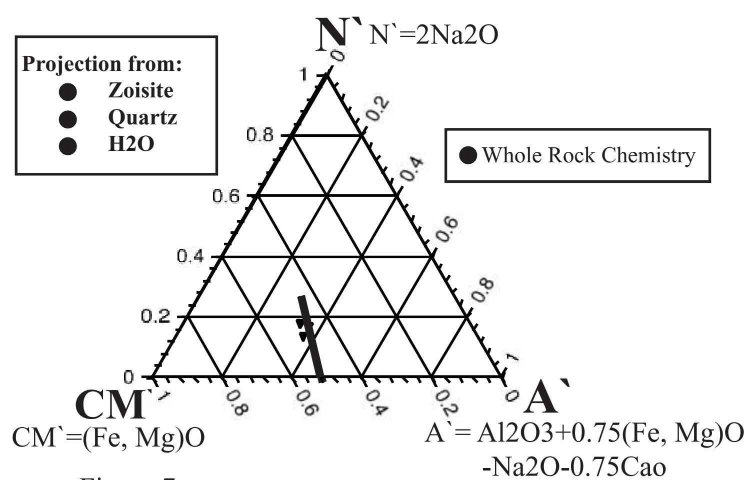

Figure 7.
Ternary Diagram of Whole Rock Chemistry of Glaucophane Schist.
(Tie line from Figure 5 plotted.)