Structure and petrology of mafic and siliceous schist at Katergaki Point, Syros, Greece

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INTRODUCTION

The Greek Cyclades are part of the Attic-Cycladic crystalline complex, which experienced high-pressure metamorphism in an Eocene subduction zone, followed by a lower pressure metamorphic event in the Miocene (Schliestedt et al., 1987). Evidence of the high-pressure metamorphism is best preserved on the islands of Syros and Sifnos. Syros is composed of sheets of penetratively deformed marble, siliceous schist, and metabasite, containing evidence of blueschist facies metamorphism with partial to complete greenschist facies overprint (Ridley, 1984). The area around Katergaki Point, a marble peninsula on Syros's southeast coast, was originally described by Papavassiliou et al. (1985) as greenschist facies metapelite. In fact, the area consists of interlayered blueschist facies mafic and siliceous schist with an adjoining serpentinite matrix melange unit to the southwest. This study documents and analyzes the rock sequence along a 500m coastal exposure near Katergaki Point, using analyses of mineralogy, chemistry, and microstructures to constrain the deformational and metamorphic history, with emphasis on relationships between shear fabric development and mineral growth.

METHODS

Three weeks of field study were conducted on Syros in the summer of 1999. Samples were collected along the coast near Katergaki Point for more detailed laboratory study. Notes, photographs, and sketches produced in the field are an essential part of the data used to determine the medium to large scale structural relationships among the Katergaki Point units. Thin sections were petrographically studied with the goals of documenting mineralogy, determining mineral growth relationships, and interpreting microstructures. Mineral compositions were obtained using the SEM/EDS. These data were integrated in the development of a cross-section for the study area (Figure 1).

DISTRIBUTION OF ROCK TYPES

The rocks of the Katergaki Point area can be divided into five main types based on mineralogy and textures observed in the field and in thin section. The cross section in Figure 1 labels the main rock types with Roman numerals. (i) Unique to the southwestern 50m of the study area is a unit of elongate 2-5m schistose boulders of various compositions embedded in a strongly deformed serpentinite matrix. Contacts between the heterogeneous boulders and the serpentinite feature "blackwall" reaction minerals and textures, such as unaligned actinolite and talc. This unit is interpreted to be a sliver of a serpentinite matrix melange. (ii) Resistant white marble makes up Katergaki Point itself. It is massive with some tabular banding. (iii) Medium to coarse grained epidote-glaucophane schist with common garnet appears dark olive-green in outcrop. Phengite forms a fair foliation, and in some places glaucophane and epidote form a fair to good lineation, but in other places lineation is absent. Evidence of retrograding includes abundant chlorite and the presence of dark pleochroic iron-rich rims on glaucophane. (iv) Quartz-phengite schist is heterogeneous, ranging in color from white to pink to pale blue-green, and containing varying proportions of quartz, carbonate, garnet, glaucophane, epidote, and chlorite. Some layers of this schist host spectacular hexagonal garnet grains up to 5cm in diameter. (v) Fine to medium grained glaucophane-epidote-phengite schist is interlayered with fine grained garnet-omphacite-phengite eclogitic schist. Phengite defines a good foliation, and glaucophane and epidote define a fair lineation. Retrograde chlorite and veins of quartz and carbonate are common.

Several units in the study area are interpreted as combinations of the main rock types. An example is a unit of pale quartz-phengite schist with blue-green boudins of fine grained glaucophane-epidote schist. It is interpreted that this unit was initially a series of continuous layers of alternating siliceous and mafic mineralogy, which had different responses to strain due to different degrees of ductility. Another combination unit, located at the northeast end of the study area, consists of white quartz-phengite schist alternating with green glaucophane-epidote-phengite schist in 0.5m-2m thick layers.

Northeast of Katergaki Point, units are arranged in a series of layers 5m to 20m thick, separated by foliation-parallel, commonly gradational contacts with a few zones of faulting and alteration. Penetrative weathering of the fault zones prevents analysis of orientation of fault planes or direction of displacement. At the southwest end of the study area, the serpentinite-matrix melange is juxtaposed with the marble of Katergaki Point by a 15m wide fault zone.

The foliation-parallel compositional layering of the units justifies an attempt to construct a provisional metamorphic "stratigraphy" for the Katergaki Point area. Because the original "up" direction cannot be determined from metamorphic structures and textures, the modern "up" direction was arbitrarily chosen to correspond to the ancient one. Figure 2 shows the four units that fit into the "stratigraphic" column: (1) dark green glaucophane-epidote-phengite schist, type (iii) in the list of principal rock types; (2) a combination type, glaucophane-epidote-phengite boudinaged layers in quartz-phengite schist with minor glaucophane and epidote; (3) main type (iv), quartz-phengite-garnet schist featuring up to 5cm garnet crystals with quartz inclusions and pressure shadows; and (4) main type (v), blue glaucophane-epidote-garnet-phengite schist.

This series is repeated within the study area, as noted on the cross section (Figure 1). A likely explanation for the repetition of units in the order observed is thrust faulting in an altered zone 250m south of the northern end of the section.

MINERALOGY

In Figure 3, the main equilibrium assemblages are plotted on a compatibility diagram after Okrusch and Brocker (1990). Blueschist facies assemblages dominate for most units, including those in the "stratigraphy." Eclogite assemblages (garnet + omphacite + paragonite) also occur. Slight greenschist facies overprint is common, but complete replacement of high pressure minerals is uncommon; only one of the samples collected has a pure greenschist assemblage.

The study area is characterized by wide variation in the presence or absence of important minerals such as omphacite, paragonite, and free quartz. The layering and close spatial distribution of mineralogically diverse units suggest that all parts of the study area were metamorphosed to the same grade, and that differences in assemblages are accounted for by differences in bulk composition. The mineralogy of the four units in the metamorphic "stratigraphy" is consistent with a protolith composed of interlayered siliceous mud and mafic volcanic rock such as basalt.

Some minerals vary in composition and habit. Garnet ranges from dark red and euhedral with very few inclusions, mainly of omphacite, to pink and anhedral with abundant quartz inclusions. Garnet and associated omphacite may serve as thermobarometric indicators. Glaucophane has several habits and patterns of zoning. In the quartz-rich schist it is commonly subhedral, wispy, and aligned with foliation, pale in thin section with slight graded concentric zoning. The mafic blocks in the serpentinite matrix melange unit also have this habit, as well as another: coarse (1-4mm), euhedral, non-aligned glaucophane with sharply delineated cores of hornblende composition. In many samples the glaucophane has 0.05mm iron-rich rims consistent with greenschist retrograding. The growth of the non-aligned glaucophane and greenschist minerals post-dates the strain conditions responsible for development of foliation. The different habits of glaucophane and other minerals show that the history of mineral growth in the Katergaki Point rock suite involves multiple stages.

FABRICS AND SHEAR

Throughout the study area, the schist has moderate to good foliation defined principally by phengite. Foliation is generally shallowly north dipping, but is gently folded to dip southward in some places. Steeply north dipping foliation and some isoclinal folding were observed in a localized zone about 50m of Katergaki Point.

Lineation is not uniform; alignment of elongate minerals is common in most units, but in some, such as the glaucophane-epidote-phengite schist, lineation varies on a scale of a few meters within the unit. Such close spatial juxtaposition of lineated and non-lineated rocks suggests a possible local variation in rheology. Some areas may have been surrounded by rigid material that protected them from the strain that caused lineation.

Many samples show evidence of simple shear. Shear indicators include quartz subgrains, asymmetrically shaped mica and epidote grains, shear bands, and asymmetric pressure shadows on porphyroblasts. These were studied both in the field and under the microscope to ascertain the direction of transport and the relative timing of shear.

Interdigitated to serrate quartz subgrains are common in the quartz-mica schist. In a few samples, the quartz subgrains are fairly polygonal, suggesting some post-deformational annealing. The close spatial association of rocks with serrate and annealed quartz textures suggests that post-shear heating was narrowly localized.

Shear bands and grain asymmetries, particularly in the quartz-rich schist, indicate two fabrics: a flattening fabric and a shear fabric. A top to northeast sense of shear is reasonably consistent throughout the Katergaki Point area, and agrees with the sense of shear determined in nearby areas such as Vari (Koontz, 2000).

Asymmetric pressure shadows on garnet grains occur in rocks of several compositions. In the quartz-rich schist, the tails are similar in mineralogy to the matrix, but in quartz-poor samples, the tails are high in quartz relative to the matrix. The presence of blueschist minerals within many pressure shadows suggests that simple shear occurred simultaneously with high pressure mineral growth. Systematic asymmetry in the orientation of the pressure shadows may be useful in further analysis of shear for the rock suite.

SUMMARY

The Katergaki Point area is characterized by previously unmapped blueschist facies mafic and siliceous schist with an adjoining serpentinite matrix melange unit to the southwest. The main rock types are distributed in a series of layers with foliation-parallel contacts, allowing development of a possible stratigraphy of interlayered volcanic and sedimentary protoliths. Fabrics include penetrative foliation, varying lineation, and top to northeast simple shear. Relationships between mineral habits and fabrics indicate multiple stages of metamorphism. Development of flattening and shear fabrics was probably most pronounced during the blueschist facies metamorphic event. Subsequent events included localized annealing and greenschist facies overprinting. Continued integration of observations will illuminate more about the history of metamorphism and deformation for southern Syros.

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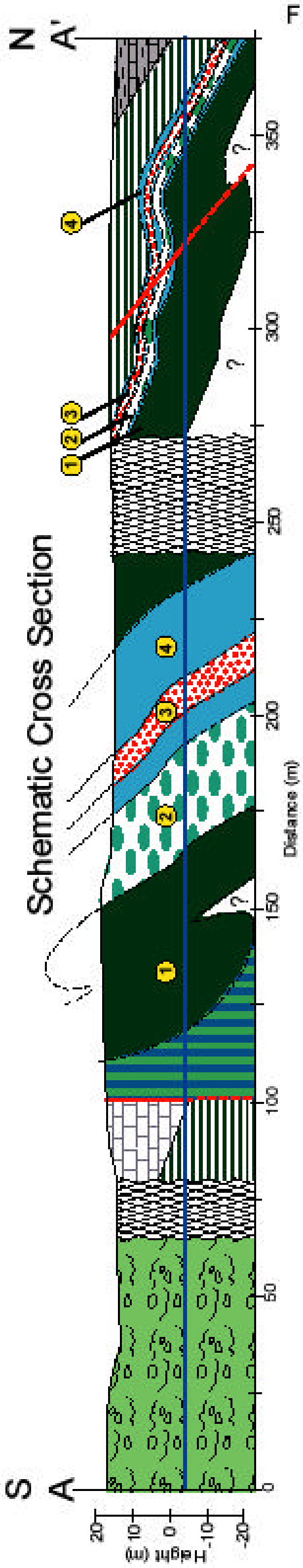
Figure 1



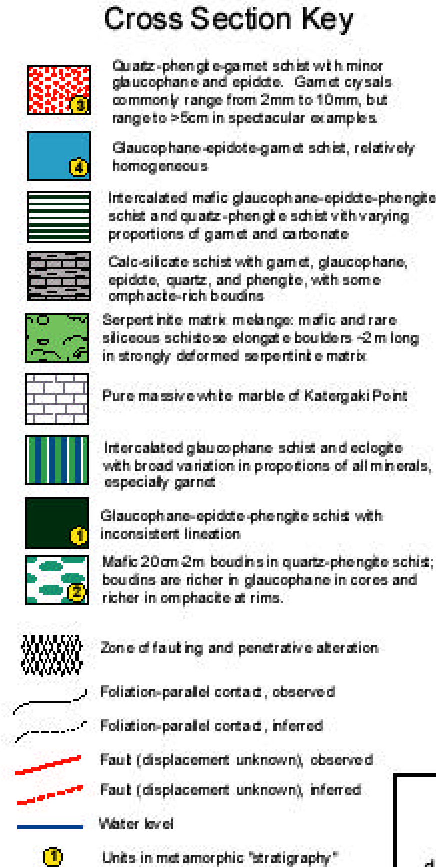
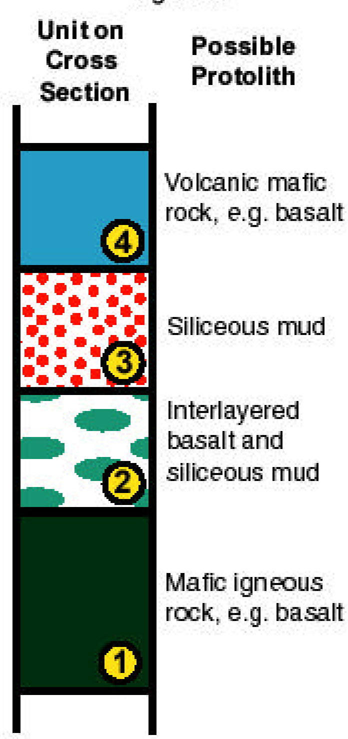
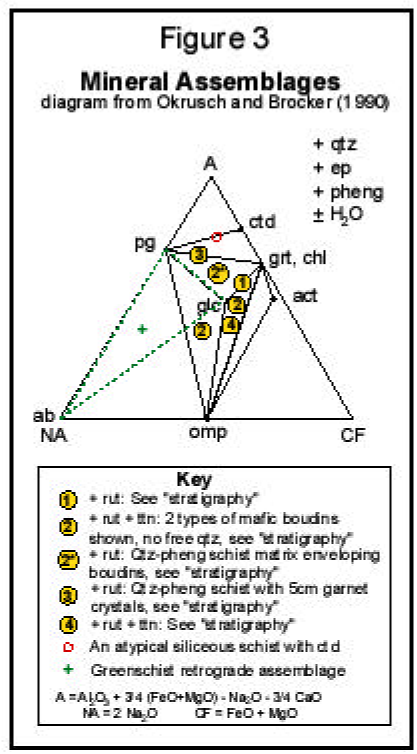


Figure 2





Figures

Left and above: Figure 1. Cross section of study area with key.

Above right: Figure 2. Provisional metamorphic "stratigraphy" indicating inferred protoliths.

Right: Figure 3. Schematic diagram illustrating mineral assemblages for the Katergaki Point schist.