TECTONOMETAMORPHIC EVOLUTION OF CYCLADIC SUBDUCTION ZONE ROCKS: THE SYROS BLUESCHIST-ECLOGITE TERRANE

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REGIONAL INTRODUCTION

The Cycladic islands are located in the Aegean Sea, southeast of mainland Greece (Figure 1). These islands are underlain by high pressure metamorphic rocks that represent the crustal roots of the Cycladic (Alpine) orogenic belt. This orogen was fragmented during the continental extension that followed collapse in the Aegean area (Lister and Raouzaios, 1996). The high pressure metamorphic rocks (Figure 1) now preserved in the islands are believed to be the dismembered roots of the mountain belt formed during the Eocene collisional orogeny.

The Cyclades are part of the Attic-Cycladic complex, an island belt of crystalline culminations linking continental Greece with Turkey (Figure 1). The complex consists of two main tectonic units. The upper unit contains various intercalated fragments of ophiolites, Permian sedimentary rocks and high temperature metamorphic rocks. In contrast, the lower unit is polymetamorphic and consists of a series of thrust sheets containing pre-Alpine basement, Mesozoic marble, metavolcanics and metapelites. The polymetamorphic nature of this lower unit is manifest by: 1) Eocene (~ 42 Ma) high-pressure, blueschist facies metamorphism. 2) Oligocene/Miocene (20-25 Ma), normal regional metamorphism and 3) Miocene (14-20 Ma) contact metamorphism associated with the intrusion of I-type granitic rocks (Schliestedt et al. 1987).

The Eocene high pressure rocks from this lower unit are best preserved on the islands of Sifnos and Syros and also to a less documented extent on Tinos (Figure. 1). Mineral assemblages vary with protolith and include metabasalts with clinopyroxene (omphacite) + garnet+ glaucophane+ epidote, felsic metavolcanics with jadeite + quartz, metapelites with muscovite+glaucophane +garnet+epidote, marbles containing dolomite+ calcite± quartz± epidote, ±phlogopite, ultramafic rocks and, quartzites - some of which contain deerite+magnetite +clinopyroxene (agerine) (Schliestedt, 1986; Ridley, 1984b: Dixon and Ridley, 1987). Maximum metamorphic conditions of 460°C and 14 kilobars for the high pressure event at Sifnos may be somewhat lower than P-T conditions on Syros, where eclogites are more common (Schliestedt, 1986; Dixon and Ridley, 1987).

The second metamorphic event, related to widespread late Oligocene/ early Miocene extension throughout the Attic-Cycladic belt (Wijbrans et al., 1993), overprints the earlier blueschists and eclogites, culminating at Naxos in a migmatite dome. However on most islands and in particular on Syros and Sifnos, this second event is a extensive- yet incomplete- greenschist facies overprinting. On Sifnos the blueschists and greenschists are separated by a relatively sharp

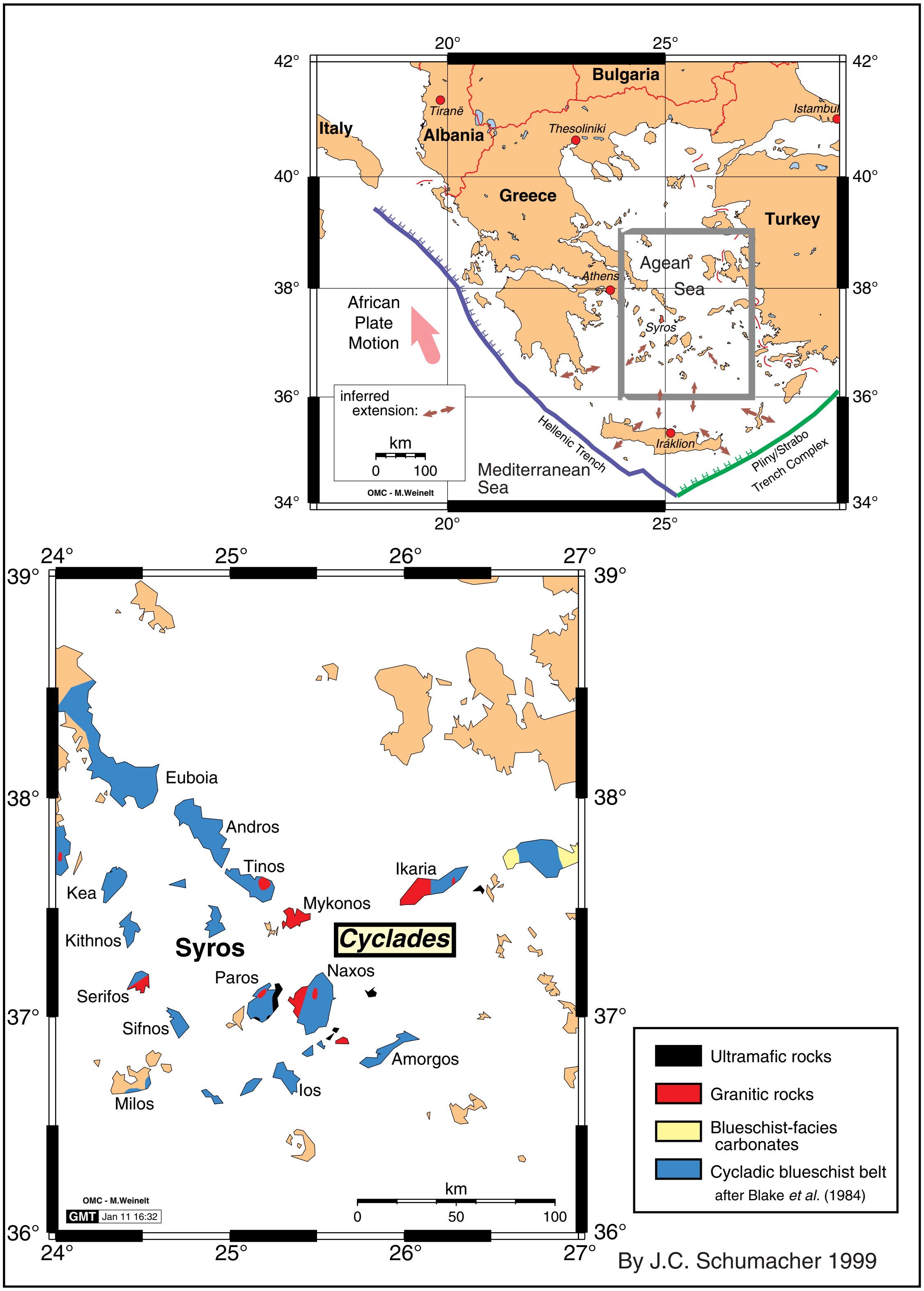

Figure 1. Tectonic map of the Agean Sea with the location of Syros and the Cycladic Islands (top) and the important rock types in the Attic-Cycladic complex (bottom).

boundary that has been interpreted by Schliestedt and Matthews (1987) as resulting from fluid flow upward to the main marble unit. The marble acted as an impermeable layer that protected the overlying blueschists from rehydration. Alteratively Avigad (1993) has suggested that the boundary is a low angle tectonic surface and that the greenschist facies overprinting occurred prior to juxtaposition of the two domains. In this model, the high pressure rocks are thought to have been uplifted to shallow levels prior to assembly and thus preserved. Wijbrans et al. (1993) have suggested that delamination of lighter supracrustal rocks proximal to active subduction provided the cooling mechanism to preserve the blueschists and eclogites. In particular, reversal of movement along subduction zone faults exhumed deeply buried (>50 km) rocks.

The rocks from these islands have been intensely deformed and significantly recrystallized so that most of the original igneous and sedimentary textures have been obliterated (Lister and Raouzaios, 1996; Dixon and Ridley, 1987). The rocks are isoclinaly folded and extensively sheared and flattened. Four generations of deformation have been recognized in terms of fabric and porphyroblast relations in rocks from Sifnos (Lister and Raouzaios, 1996).

GEOLOGY OF SYROS

As developed by Dixon and Ridley (1987) and shown on Figure 2, the geology of Syros consists of a northward dipping sequence of alternating schists, marbles and metabasites. The sequence forms a relative autochthon that has undergone high-pressure metamorphism. In the north, at the top of the sequence, the pervasive post tectonic greenschist metamorphism is sporadically developed; whereas in the south (at the base), the greenschists are more extensive. Because there are no unmetamorphosed sequences similar in lithologic variation or thickness elsewhere in the Aegean, the sequence likely results from tectonic duplication of a thinner sedimentary sequence, possibly in an accretionary wedge. The sequence is punctuated by heterogeneous mafic igneous suites consisting of serpentinite, metagabbro and metabasalt (labeled as “the main ophiolite unit” on Figure 2). These mafic igneous rocks have also been metamorphosed at high-pressure and are postulated to underlie the marble/schist, thus lending some credibility to the idea of tectonic assembly of the sequence by thrust faulting. Near Mega Lakkos (Figure 2) there is a serpentinite belt that may represent a metamorphosed olistostrome or ophiolitic debris -flow (Dixon and Ridley, 1987) or a subduction related melange. The serpentinite belt (melange) contains scattered blocks of mafic igneous rocks that have a variety of mineralogy and textures, resembling a dismembered ophiolite. According to Dixon and Ridley (1987), there is but one penetrative fabric that effects nearly all in the rocks of Syros. This foliation is defined by high-pressure minerals and it is parallel to lithologic contacts. There is some strain partitioning reflected by the massive cores of the metagabbros and some of the breccias.

STUDENT PROJECTS

Student projects range in scope from a single rock type that occurs over most of the island to the relationships among many rock types from a single exposure. These projects focus as a group upon the description and evaluation of the geological impact of relatively recent subduction on a variety of protoliths with particular attention to the mineralogic and textural consequences of the processes involved in the evolution of the Syros Blueschist-Eclogite Terrane.

Rob Tonnsen (Whitman) and Josh Otis (Amherst) have studied the two most common rock types on the island of Syros, both of metasedimentary origin. Rob is focused upon the systematic mineralogy of impure calcite marbles that locally contain variable amount of glaucophane, agerine, garnet, and/or phengite. Josh is studying the mineralogy and fabric of the phengite schists that are intercalated with the marbles. Study of these rocks provides access to the variation in metamorphic pressures and temperatures over the whole island from two different yet most common bulk compositions.

Three students described the rock types and structural relationships of mafic igneous suites that occur as fault-bounded metamorphic sequences. As these sequences contain metamorphosed

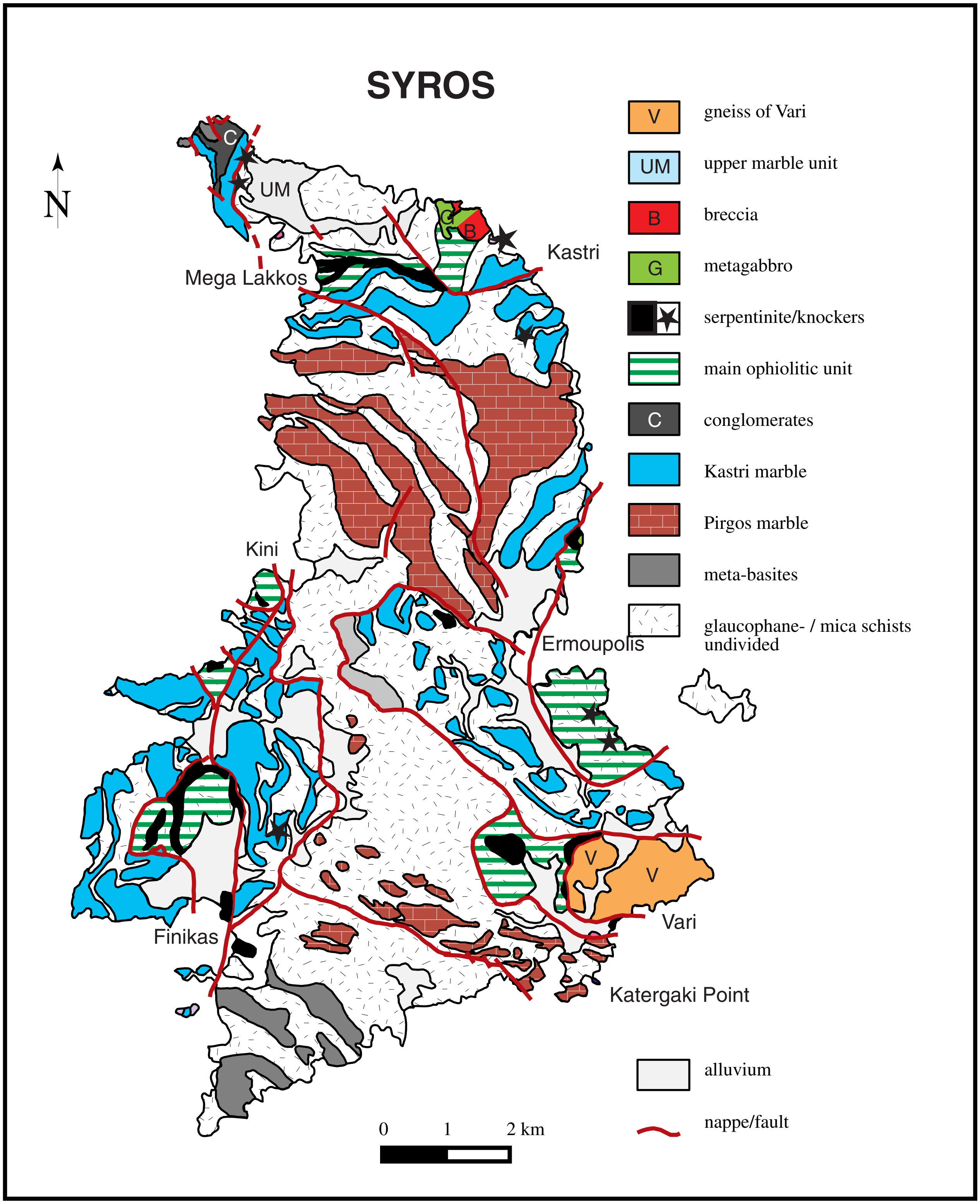

Figure 2. Generalized Geology of Syros modified from Höpfer and Schumacher (1997)

basalt, gabbro and peridotite one likely origin is as ophiolite fragments. Julia Sable (Amherst) is concentrating upon characterizing a previously undocumented and unmapped mafic igneous suite st of at Katergaki Point (Figure 2). Erica DiFilippo (Smith) and Elli Argyrou (Amherst) are studying two separate heterogenous and more extensive sequences of metamorphosed mafic igneous rocks at Kini and Ermoupoli (Figure 2) respectively. What are the similarities and differences among these complex sequences? Are they genetically related or disparate tectonic fragments of ocean crust or arcs or hot spots?

Two other students collected samples of these mafic rocks primarily for geochemical analyses. Holly Shiver (Washington &Lee) studied the protoliths of the glaucophane schists (mafic volcanics). Are these MORB-like or were derived they from some other tectonic setting? Aaron Grandy (Southern Utah University) has described the disparate group of metagabbros from these same suites of rocks. Are they genetically related to the basalts?

The significance of the occurrence and distribution of lawsonite and zoisite-rich pseudomorphs of lawsonite in several different lithologies including blueschists, phengite schists and meta gabbros is the focus of Arianne Sperry's (Amherst) project. In particular, Arianne considered the effect of bulk composition on the stability of lawsonite and the tectonometamorphic significance of the occurrence of the pseudomorphs.

Phil Skemer (Pomona) has studied the serpentine matrix melange originally identified by Ridley (1984). Phil examined mafic to ultramafic samples of tectonic blocks from the melange near Megos Lakkos (Figure 2) in an attempt to determine if the melange formed with or after the accretionary wedge.

One unique rock type is the Vari Gneiss (Figure 2), a strongly deformed granitic gneiss that may have a distinct burial history that does not involve high pressure metamorphism. Cliff Koontz (Colorado College) is conducting a fabric and petrologic analysis of the Vari Gneiss to compare its burial history with that of adjacent, tectonically juxtaposed high-pressure rocks.

RESULTS

Some preliminary results from the group contradict previous conclusions about the geology of Syros. For example, we have shown that the mafic rock sequences overly the marbles, that the southern part of the island does in fact have high pressure rocks, that there is more than one generation of glaucophane and lawsonite in these rocks, and that the mafic sequences are not simple ophiolites in that they lack significant ultramafic rocks. We have also recognized that the greenschist facies overprint is highly localized and that the greenschists are either tectonic slivers and/or the result of metamorphism of a bulk composition different than the nearby blueschists and eclogites.

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