ORIGIN OF BLUESCHIST BRECCIA, SYROS, GREECE

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INTRODUCTION

The Cycladic islands have undergone two periods of Alpine-Himalayan-type metamorphism. The first episode, late Cretaceous or Eocene high-pressure blueschist facies metamorphism, is associated with subduction zone metamorphism. A second Miocene greenschist overprint is associated with extensional exhumation of these rocks. The greenschist overprint completely effaced the blueschist metamorphic events on all but two of the Cycladic islands, Syros and Sifnos (Dixon and Ridley, 1987).

On Syros, there is a continuous alternating sequence of N to NE dipping pelitic schists, marbles and metamorphosed mafic igneous rocks. Protolith textures and assemblages have been obscured during the deformation and metamorphic events (Dixon and Ridley, 1987). We focus on a breccia that is found along the NNE coast of the island. Various workers have understood the protolith of this breccia as sedimentary, tectonic, or igneous. In a combined petrographic, structural, and geochemical study, we are comparing the clasts and matrix of the breccia to other meta-igneous rocks in the region to understand the protolith of the breccia.

PETROGRAPHY

The rocks in this study can be divided into five groups.

Glaucophane Schist. Glaucophane schist occurs in the field as breccia matrix and within the breccia as coarser grained clasts. Oriented glaucophane and paragonite and clast shapes define the NE striking, shallowly W dipping foliation. In some samples, top to the NW sense of shear indicators are associated with a moderately NW dipping lineation. Concentrations of mica, fuchsite, quartz or coarse glaucophane from 5mm to 3cm long are common. Glaucophane + epidote + garnet + paragonite + albite – chlorite are the main minerals in the glaucophane schist. Titanite, calcite, rutile, and zircon are present as accessories. Often garnets touch each other, pinching the foliation between them. Garnets contain inclusions of quartz, muscovite and biotite. Some glaucophane crystals have epidote inclusions. Chlorite is concentrated around anhedral garnets, suggesting that it is a secondary alteration product. Inclusion relationships suggest that quartz, muscovite, and biotite formed before garnet, and epidote formed before glaucophane. Foliation drapes around garnet suggesting that flattening along this foliation occurred after garnet growth. This indicates that the rock could have experienced late flattening perpendicular to the foliation.

Mica Schist. Mica schist occurs as clasts in metabreccia and to a lesser extent in chlorite schist and metagabbro. Alternating layers of mica and quartz + albite define the NE striking shallowly dipping foliation. In samples where glaucophane is present, it defines a lineation parallel to the foliation. Mica + quartz + albite + epidote – garnet – chlorite make up the largest percent of each sample while rutile, titanite, glaucophane, and tourmaline can be found as accessories.

Quartz has straight to serrate grain boundaries and undulose extinction. Euhedral garnets edged with chlorite contain inclusions of quartz and mica. Quartz textures suggest metamorphic recrystallization. Inclusions in garnet suggest that quartz and mica formed before garnet. The foliation drapes garnet, which often touch each other, suggesting late flattening perpendicular to foliation. Isoclinal fold hinges in mica, quartz and chlorite parallel to the foliation may preserve an earlier deformational event.

Metagabbro. The metagabbro is characterized by a weak foliation, large omphacite crystals, up to 2 cm long, and rusty weathering. It contains the assemblage pyroxene + epidote / clinozoisite + albite with minor chlorite, actinolite, pumpellyite, and white mica. There are large bodies of metagabbro to the south, west and north of the metabreccia outcrop. Within the metabreccia body, there are metagabbro clasts and smaller units of metagabbro in fault contact above and below the metabreccia. To the west and south, the contact between metabreccia and metagabbro is gradational. Towards the breccia, the metagabbro starts to become richer in glaucophane and contains some clasts of mica schist and glaucophane schist. Closer to the breccia, glaucophane becomes more abundant than omphacite, and mica schist clasts and metagabbro clasts become more common.

Felsic dike. Dikes are in an outcrop of metagabbro along the coast, north of the metabreccia. It averages about 60 cm wide. The contact between dikes and the metagabbro is sharp. Dikes crosscut each other. White mica defines a weak foliation. Medium grained and equigranular, the rock contains quartz +

mica + zoisite + feldspar + chlorite – garnet + clinozoisite + epidote + opaques. Quartz has straight to serrate boundaries suggesting metamorphic recrystallization.

Chlorite Schist. Chlorite and mica define the foliation. Glaucophane defines a lineation in some samples. The schist is medium grained and green to dark green in color, often with orange weathering dolomite. The minerals associated with chlorite schist are chlorite + mica + epidote + dolomite; quartz, garnet, glaucophane, titanite, and rutile are common accessories. The foliation drapes dolomite and epidote. Isoclinal fold hinges, defined by mica, have axial planes parallel to foliation. Anhedral chlorite is often at a high angle to the foliation. This suggests it formed after the foliation. The mica folds may preserve evidence of a previous deformational event. Foliation draping dolomite and epidote records late flattening.

STRUCTURE

Figure 1 shows foliation and lineation in the glaucophane schist breccia. Foliation in the glaucophane schist that forms the matrix for the breccia strikes NE and dips approximately 30¡ to the W. This is consistent with the general N to NE strike all of the rocks units on Syros have.

Clasts in the breccia define a stretching lineation that plunges moderately NW. The clasts are elongate parallel to the lineation and are flattened parallel to the contacts between breccia, metagabbro, and chlorite schist. Clasts have a prolate shape and aspect ratios of approximately 30:1.

The only crosscutting relationship between the five rock types in this area is the felsic dike cutting the metagabbro, otherwise all contacts are approximately parallel to the breccia foliation. The breccia contains metagabbro and mica schist clasts and there are glaucophane schist and mica schist clasts in the metagabbro.

Figure 2 shows the contacts between the five rock types. In outcrops where the contact between metagabbro and breccia is visible, it is parallel to this foliation. The same is true of the contacts between breccia and chlorite schist. The chlorite schist has a well- defined foliation and it is also parallel to the contact. A gradational contact between breccia and metagabbro exists. The matrix becomes richer in pyroxene, there are fewer clasts, it becomes less schistose. Over 8-15 m metagabbro will have taken over, with the occasional mica or glaucophane schist clast. Most of the other contacts between breccia and metagabbro are sharp.

GEOCHEMISTRY

Figure 3 shows metagabbro (open circles) and breccia matrix (filled circles) plotted on an alkalis vs. silica graph. Figure 4 shows the same samples plotted on a MgO vs. SiO_2 graph. Metagabbro samples display how crystal fractionalization of more primitive magma will drive the composition towards higher silica and alkalis and lower MgO. The arrows in figures 3 and 4 illustrate the trend towards more evolved rocks as the magma continues to crystallize minerals rich in calcium and magnesium. The composition of the breccia matrix samples do not lie along this trend, they are more alkalic and lower in silica. Magmatic processes cannot derive the metagabbro from the breccia composition either, since the breccia is lower in MgO and higher in silica. Assuming that both the metagabbro and the breccia matrix were closed systems during metamorphism, it is unlikely that they are co-magmatic.

SUMMARY

Geochemical analysis shows that the composition of the breccia matrix is that of an alkalic basalt similar to an ocean island alkali basalt. Despite this similarity the geochemical data does not rule out the possibility that the breccia matrix protolith was sedimentary. Field observations did not yield any signs of sedimentary structures, but in light of the metamorphic and deformation history of the Cyclades, this is to be expected.

Assuming that the protolith of the breccia was igneous, it is unlikely that it is co-magmatic with the metagabbro. Compositionally, the protolith for the metagabbro is closer to MORB. This difference could help to constrain the tectonic environments in which each of these rocks formed. This information in the context of the geologic history of Syros, will further our understanding of where the clasts came from and how they became part of the breccia.

REFERENCES

Dixon, J.E. and Ridley, J., 1987. Syros (fieldtrip excursion). In: Chemical transport in metasomatic processes (ed. Helgeson, H.C.) Nato Advanced Study Institutes Series. Series C, pp. 489-500, D. Reidel Publishing Company, Dordrecht.

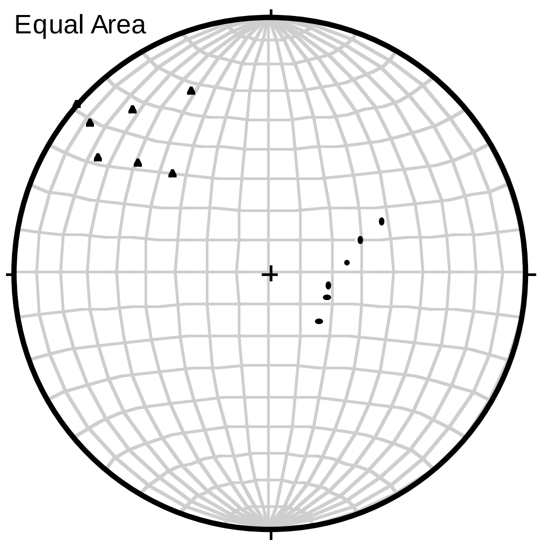

Figure 1. Equal area stereonet showing poles to foliation (circles) and lineation defined by long axes of clasts (triangles).

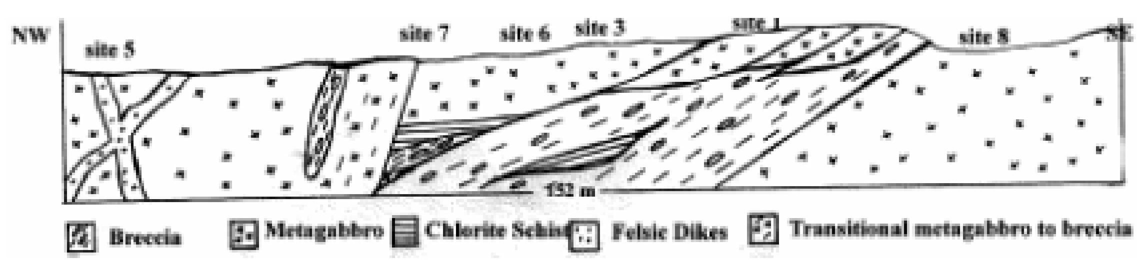

Figure 2. Schematic cross section of NNE coast of Syros.

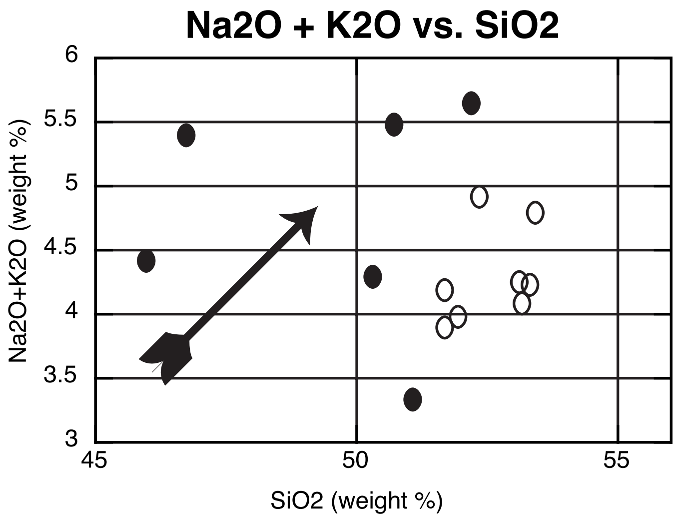

Figure 3. Breccia matrix represented by filled circles, metagabbro represented by open circles, arrow shows fractional crystallization trend.

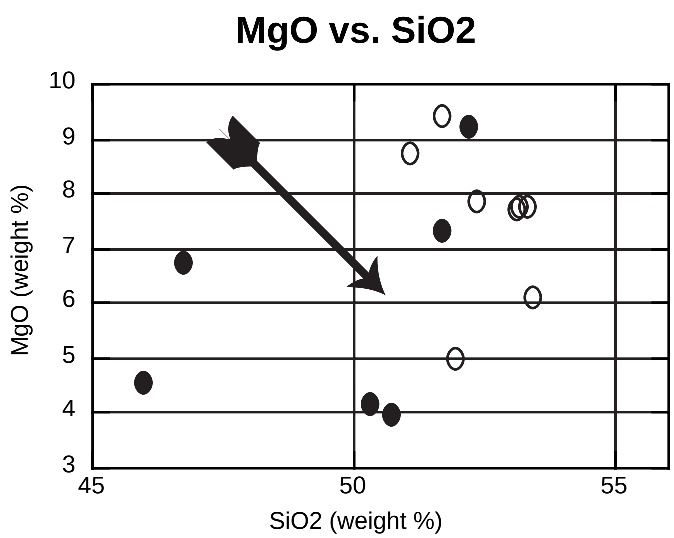

Figure 4. Breccia matrix represented by filled circles, metagabbro represented by open circles, arrow shows fractional crystallization trend.