Fluid and geochemical constraints on the formation and retrogression of high-pressure metamorphic rocks from Sifnos (Greece)

B. Putlitz *Universität Hannover, Germany.*
M. Schliestedt
A. Matthews *Hebrew University of Jerusalem, Israel.*

Introduction

The Alpine metamorphic evolution of the Cycladic Crystalline Complex of the Aegean aera of Greece is characterized by an Eocene eclogite-to-blueschist facies metamorphism and an Oligocene/Miocene greenschist-to-amphibolite facies metamorphism. High pressure assemblages are well preserved in the north of Sifnos island (Blueschist Unit), whereas the rest of the island is dominated by greenschist-facies rocks (Greenschist Unit). However, rocks from Sifnos island preserve a complex record of both metamorphic events at all scales.

In this paper we combine structural and petrological observations with major and trace geochemistry and stable-isotope data to characterize (a) the fluid involvement during high-pressure and greenschist-facies metamorphism and (b) the nature of the retrogression from blueschist to greenschist facies rocks.

Data

Detailed oxygen-isotope profiles (whole-rock and mineral data) across high-pressure sequences of interlayered jadeite gneisses, eclogites, blueschists and micaschists show that pervasive isotopic equilibration has not been attained between layers – neither at cm nor at m scale. Further arguments against large-scale isotopic equilibration come from the Greenschist Unit, where we investigate high pressure mineralogies and their overprinted equivalents from different stratigraphic positions. We observe a regional variation in the isotopic signature throughout the Greenschist Unit, but there is no correlation between stratigraphic position and oxygen-isotopic composition. At any specific locality the oxygen-isotope composition of a certain rock type is constant, but all over the Greenschist Unit values for metabasites range from 10–11‰ – this is as low as in the Blueschist Unit – up to 13–14‰.

There are outcrops in the Greenschist Unit where high-pressure metabasics (blueschists and eclogites) and greenschists are intimately intercalated on cm-scale. Greenschists occur as millimetre to centimetre thick discontinuous layers, 'fingers' or lenses parallel to the blueschist foliation or as centimetre-scale domains along fold hinges. Textural features provide evidence for *in-situ* replacement of the blueschist-facies mineralogy (glaucophane-garnet-epidote-paragonite) by greenschist-facies minerals (albite-chlorite-actinolite-epidote-calcite). Intercalated eclogites, blueschists and greenschists are identical in their whole-rock isotopic composition and considerations from mineral data gave no evidence for changes of the oxygen-isotopic signature during retrogression. Comparing the bulk-rock composition of adjacent blueschist-greenschist pairs a systematic variation between blueschists and greenschists is recognized; the concentrations of calcium, ferric and ferrous iron are higher in the blueschist than in the greenschist. Greenschists on the other hand have a higher sodium content and are more hydrated than blueschists. In their trace element chemistry, however, blueschists and greenschists are almost identical.

Discussion

The oxygen-isotope data from the Blueschist Unit gave evidence that pervasive infiltration of fluids during high pressure metamorphism did not occur, but that fluid movement was limited to local flow along individual layers. Correspondingly, high $\delta^{18}O$ values observed on Sifnos and other islands of the Cyclades, together with trace and major element variations, indicate that the protoliths of the high-pressure rocks were extensively affected by sea-floor alteration prior to subduction. Thus, the fluid mobilization during high-pressure metamorphism was controlled by channelized release of fluids, which were derived from sea-floor altered rocks during subduction.

Although fluid must have been involved in the blueschist-to-greenschist transition, there is no evidence for regional large-scale fluid infiltration during greenschist-facies overprinting. The regional variation in the isotopic composition of metabasites indicates that pervasive isotopic equilibration has not occurred throughout the Greenschist Unit. Thus, to some extent the $\delta^{18}O$ compositions of the metabasites must be taken to represent their state prior to metamorphism. The similarity in the oxygen-isotope composition ot interlayered eclogites, blueschists and greenschists demonstrate that the blueschist-to-greenschist transformation did not involve a change in the oxygen-isotopic composition of the rocks. Rather our work shows that the influx of fluids necessary for the metamorphic transformation to greenschists was controlled by structural and geochemical factors.

Close spatial association of blueschists and greenschists have been described from the adjacent islands of Syros and Tinos (Brücker, 1990a; Barr, 1989) and from other high-pressure terranes (Barrientos and Selverstone 1993; Dungan *et al.*, 1983). When not caused by tectonic juxtaposition, the 'coexistence' of blueschist- and greenschist-facies assemblages has either been related to differences in bulk composition (Dungan *et al.*, 1983) or to selective fluid infiltration (Barrientos and Selverstone, 1993; Brücker, 1990). On Sifnos, structural observations and petrological considerations strongly suggest that channelized fluid infiltration causes the transformation from blueschists to greenschists. The influx of fluid was controlled by lithological and structural differences: the preferential growth of greenschist-facies minerals along foliation planes and in fold hinges indicates that these structures acted as small scale channels for fluid migration.

The degree of retrogression in metabasic rocks appears to be related also to geochemical parameters such as oxidation state of the rocks, sodium and calcium contents. These parameters could in turn reflect, both, variable degrees of sea-floor alteration of protoliths and selective transport of elements during metamorphism. Similarities in the trace-element chemistry of interlayered blueschists and greenschists strongly suggest that they have not been different in their primary igneous composition. Our work, therefore, shows that fluid flow during subduction and exhumation of the Cycladic Complex is dependent on the geochemical nature and origin of the protoliths and on the structures that developed during metamorphism.

References

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