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Taking the temperature of low-grade and very low-grade ductile fabrics: equilibrium and disequilibrium mineral assemblages

Shuyun Cao, Franz Neubauer, Manfred Bernroider, and Johann Genser
Salzburg University, Fachbereich Geographie und Geologie, Salzburg, Austria (shuyun.cao@sbg.ac.at)

Many ductile shear zones like ductile low-angle normal faults on top of, and oblique-slip faults bordering, metamorphic core complexes exhibit a regular pattern of fabrics which usually show decreasing temperature and pressure conditions during their formation. This is because the presence of rocks with a dominant but different mineralogy results in shear concentration in the rheological weakest layer. These dominant fabric-forming minerals are with decreasing temperature: feldspar at >450 °C, quartz at >300 °C and calcite <300 °C. Fabrics and textures formed at higher temperatures are preserved in microlithons surrounded by micro-shear zones. This allows determine semiquantitively the temperature and pressure of several fabric-forming events within one rock, where generally disequilibrium is present between micro-lithon and surrounding micro-shear zones. We tested this approach using the white mica barometry and chlorite on two shear zones bordering two distinct metamorphic core complexes.

The low-grade Rechnitz metamorphic core complex at the eastern termination of the Eastern Alps, which formed within an extensional setting and is surrounded by a contemporaneously formed Neogene sedimentary basin. Microstructural and textural analysis has revealed the co-existence of microstructures ranging from middle-temperatures to low-temperatures, which overprinted deformation features within the Rechnitz metamorphic core complex. Quartz displays abundant evidence for early high-temperature plastic deformation (e.g. dynamic recrystallization, polygonal grains with straight grain boundaries forming 120° triple junctions) (D2). In some cases, preferred orientations of crystallographic axes are missing and white mica was overgrowing the penetrative foliation. These features suggest annealing during subsequent metamorphism and deformation at high temperature conditions. The high-temperature microstructures and textures are in part or entirely altered by subsequent late low-temperature shearing. Certain minerals such as white mica showed extensive grain-size reduction in mylonites and some are completely transformed into extremely fine grains. The later low-temperature deformational overprint during shearing was affected by ductile low-angle normal faulting. According to backscatter electron analysis (BSE), two microfabric types are observed in white mica and chlorite, (1) type I-microlithons, the older generation with coarse-grained white mica and chlorite occurring in the micro-lithons, where chlorite is sometimes associated with white mica, are seemingly in equilibrium with the surrounding mineral assemblage; and (2) type II-micro-shear zones. The sheared generation has very fine-grained sheared bands, which represent mixtures of white mica and chlorite with apparent disequilibrium boundaries. In most cases, the thermometry calculations from the coarse chlorite grains (microfabric type-I) yield a main result ranging from 328 to 376 ^{0}C. In the microfabric type II, the thermometry results from the sheared chlorite grains yield a temperature ranging from 305 to 132 ^{0}C. The later temperature is clearly sub-greenschist facies. The lower temperature group is interpreted to result from late-stage hydrothermal overprint, which affected older microfabrics. Chlorite is seemingly accessible to late-stage resetting. Phengitic compositions with high-Si white micas occur in the microfabric type I micro-lithons, however, some phengitic high-Si compositions are also from the micro-shear zone (micro-type II). We note that there is a continuous range of phengitic white mica to nearly pure muscovite. Phengitic white mica is common in all samples of the lower unit together with white mica of lower phengite content. The lower unit experienced, therefore, high-pressure metamorphism, and white mica grains are partly reset to low-pressure white mica indicating decompression. Decompression occurred during shearing and as a result of tectonic exhumation.

Detailed microstructural and textural analysis reveals that the movement along the Moutsounas shear zone bordering the Naxos metamorphic core complex is associated with retrograde greenschist facies overprint of the early high-temperature rocks within ductile to ductile-brittle transition occurs at greenschist-facies conditions. For mylonitic rocks, paleopiezometry applied on recrystallized quartz and calcite, yields differential stresses of 20–77 MPa and a strain rate of 10-15–10-13 s-1 ca. 350 °C for quartz and ca. 300 °C for calcite. Phengitic mica from the Eocene high-pressure metamorphism is still preserved within late stages of final subgreenschist facies shear zone. Chlorite geothermometry of the shear zone yields two main temperatures groups, 300–360 °C, and 200–250 °C.

The lower temperature group is interpreted to result from late-stage hydrothermal and/or sub-greenschist facies metamorphic overprint, which affected fabrics. In this case, chlorite is seemingly accessible to late-stage thermal resetting.