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Elastic strains of quartz inclusions and microstructures from pressure solution in garnet reveal orientation and low magnitude of differential stress during subduction metamorphism

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Determining the stress state during metamorphism is a key challenge in metamorphic petrology as the effect of differential stress on metamorphic reactions is currently debated. Conventional piezometry generally gives stresses that correspond to overprinting deformation rather than to mineral growth of high-grade metamorphism, so an alternative approach is required. Garnetite lenses from the ultrahigh-pressure, low-temperature metamorphic Lago di Cignana unit (Western Alps, Italy) record compaction by a high degree of mineral dissolution in the fluid-rich environment of a cold subduction zone. This work combines microstructural analysis of deformed garnet with elastic strains of quartz inclusions to study the stresses in these metasedimentary rocks.

Garnet exhibits abundant evidence for incongruent pressure solution (IPS), most notably as truncated zones that mismatch across grain boundaries, interlocking structures, and shape-preferred orientation (SPO). The gap in garnet compositions represented by overgrown truncated zonation corresponds to undeformed garnet with inclusions of quartz and coesite, indicating that IPS operated during prograde to peak metamorphism. The distribution of aspect ratios in the garnet grain population suggests that pressure solution preferentially affected smaller grains. SPO analysis of many subregions across a garnetite sample reveals a complex distribution, however the local SPO is consistent with the stress orientation expected for local microstructures such as layering, garnet stacks, or fine-grained internal fluid pathways. Locally, two different preferential orientations are observed, interpreted as the result of two subsequent deformation stages under different stress configurations.

Quartz inclusions in prograde euhedral garnet, grown on the outer margin of coevally deformed garnetite, were analysed with Raman spectroscopy. Elastic strains obtained for these inclusions are in agreement with predicted strains for entrapment along the prograde *P*-*T* path for the Lago di Cignana unit (~1.5–2.0 GPa; ~450–500 °C), whereas significant differential stress during entrapment is expected to result in deviating strain components.

By combining microstructural analysis of garnet with elastic-strain analysis of quartz inclusions,

stress orientations obtained from deformed garnet are combined with the stress magnitude for coeval garnet growth. The results indicate that the garnetite lenses were deformed and metamorphosed under low differential stress of variable orientation during subduction. These results are in agreement with a system where garnet is wet by a fluid phase that allows IPS.

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