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The interaction between solid micro- and nano-inclusions and host garnet during deformation: a high resolution microstructural, -textural and chemical study

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Permian pegmatitic almandine-spessartine garnets from the Saualpe-Koralpe crystalline basement complex (Eastern Alps, locality Wirtbartl, Austria) possess extremely high abundances of micro- to nano-inclusions (<200 nm – 1 μm sized). High resolution microstructural, -textural and chemical analyses provide information on re-equilibration and material transport in the garnet interior during metamorphic overprinting and deformation.

Spatial changes in micro- and nano-inclusion density reflect concentric, oscillatory and sector zoning of garnet. Six different inclusion phases have been identified by electron beam microanalysis: corundum, xenotime, zircon, rutile, ilmenite and a Na-Mg-Al-rich $(AB)_5(PO_4)_3$ phosphate belonging to the wyllieite group. Individual inclusions show well developed negative crystal faces of garnet, and often occur as multiphase inclusion aggregates. Rutile inclusions form needles with a shape preferred orientation with respect to the garnet host. The distribution and grain shapes of submicron sized inclusions suggest the formation of the micro- to nano-inclusions via an exsolution mechanism.

During the Cretaceous tectono-metamorphic event at ca. 90 Ma (Thöni 2006) the Saualpe-Koralpe complex experienced an eclogite facies metamorphic overprint. Microstructural, optical and EBSD analyses have shown that the meta-pegmatite garnet deformed crystal-plastically at this metamorphic stage (Bestmann et al. 2008).

Trails of coarser inclusions (up to 10μm in diameter) are found within discrete straight or curved planes in the host mineral whereas original $\leq 1\mu$m sized inclusions are absent in 10-40μm broad zones flanking the inclusion trails. This lack of submicron inclusions defines characteristic bleaching zones. In addition to the phases described above, apatite and occasionally also kyanite occur within the trails.

From their microstructural characteristics, and the correlation of trail orientation and external strain in the rock matrix, it is inferred that the trails represent healed brittle cracks. Phase distributions and full crystallographic orientations of the chemically analysed areas have been obtained using electron back scattered diffraction. EBSD data shows that trails of coarsened inclusions are sometimes but not always related to adjacent garnet lattice distortion or subgrain formation. The width of bleaching zones appears to positively correlate with the intensity of crystal-plastic deformation of garnet. Nano-scale textural and chemical characteristics of garnet adjacent to inclusions were analysed in order to correlate garnet lattice strain with potential chemical reactions between garnet and inclusions.

Chemical compositions of sub-micron inclusions and adjacent garnet domains have been obtained both inside and outside selected inclusion trails using field emission source electron microanalysis. They allow quantification of material transfer between different garnet interior domains as well as between garnet and the external rock matrix.

Combining knowledge of host crystal deformation with highly spatially resolved microstructural and chemical analysis will contribute to an understanding of mechanical – chemical feedbacks during metamorphic overprinting and deformation.

References

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