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Strain relaxation around stressed quartz inclusions in garnet

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The measurement of residual stresses in exhumed rocks yields valuable information about metamorphic temperature and pressure, deformation and rheology, and stress state. However, the state of elastic strain and stress at the surface of a sample does not necessarily correspond to the state well below the surface. When a sample under elastic strain is cut, polished, or otherwise prepared for analysis, a part of the constraining rock is removed, allowing for the partial relaxation of the elastic strain. To be able to work with residual elastic strain and stress with analytical methods that probe the upper few microns of a sample, the process of strain relaxation must be well understood.

For this work we used high-angular resolution EBSD to analyse stressed quartz inclusions in natural garnet from a range of settings, and in several samples grown in piston-cylinder experiments that were previously analysed with Raman spectroscopy for inclusion pressures. The experimental samples are not expected to have undergone plastic deformation in the garnet during cooling, as the majority of the pressure within the inclusion built up during decompression at room temperature. Additionally, the inclusion pressures in buried inclusions matches what is expected for the experimental conditions, suggesting no plastic yielding. Thus, in these samples we can isolate elastic strain from potential plastic deformation. One of the experimental samples was analysed with TEM to test this expectation.

Forescatter images reveal topographical effects resembling quartz and adjacent garnet “extruding” out of the sample. Furthermore, rotations of the quartz lattice and the garnet lattice immediately around the quartz inclusion are observed. The rotation axis of the misorientation generally lies in the plane of the sample surface. TEM analysis revealed a number of dislocations in experimental garnet where these were not expected. However, a significant degree of bending of a wedge of garnet between the original sample surface and a quartz inclusion is also observed.

The dislocations observed with TEM do not fit with the model of the experiments. Also, the formation of dislocations before sample preparation does not explain the dependence of the rotation axis on the surface orientation. A likely scenario for the deformation measured with EBSD

is that the partial relaxation of elastic strains in stressed quartz inclusions in garnet as result of sample preparation induced local distortion of the inclusion and host. Additionally, the persistence of topographical features related to this relaxation despite several steps of polishing suggests that relaxation is not instantaneous but occurs over time.