Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.16811

A deep-learning approach to trace fluid-driven garnet dissolution in 3D.

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Influx of fluid during the exhumation of metamorphic rocks can trigger retrogression of the peak mineral assemblage. Whilst this may hinder estimation of the peak pressure-temperature conditions, it offers the opportunity to investigate fluid pathways and reactivity during exhumation. Our understanding of retrogressive re-hydration relies on the observation and quantification of reaction textures. Resorption of garnet cores resulting in atoll-shaped porphyroblasts is such a dissolution texture. Quantifying the distribution of atoll garnet in a rock allows tracing the spatial distribution and extent of retrograde reaction. However, this quantitative petrography is challenging since atoll-shaped resorption is a complex 3D geometrical feature requiring thorough examination of individual grains.

To address this problem, we developed GarNET, a deep-learning based grain shape classifier. X-ray micro computed tomography is used to analyse rocks in 3D, recording shape, size and position of thousands of garnet grains per sample. This dataset is then automatically classified by a convolutional neural network, trained on >700 human-labelled garnet grains. By classifying all garnet grains in a rock sample, the micro-spatial and crystal size distribution for garnet with an atoll-shaped reaction texture can be analysed.

This approach was applied to a retrogressed eclogite from the Zermatt-Saas Zone in the Western Alps. Textural observations from thin sections and EPMA compositional mapping show that garnet cores were replaced by a hydrous mineral assemblage rich in amphibole, clinozoisite and paragonite. Whilst the absolute number of garnet crystals varies between different regions of the sample, a similar proportion of garnet in each domain is atoll-shaped (i.e., 40%), implying a pervasive fluid-driven garnet resorption. Larger garnets are preferentially resorbed, which is interpreted to result from increasing compositional gradients with grain size. Cores of the biggest garnets are thought to be farthest from equilibrium conditions. To explain the constant portion of atoll formation throughout the sample a minimum distance from equilibrium to initialise retrograde garnet resorption is proposed.

This project has received funding from the European Research Council (ERC) under the European Union’s Horizon 2020 research and innovation programme (grant agreement No 850530).