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Quantitative compositional mapping to unravel the relationships between the geochemical record and microstructures in metamorphic rocks

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Metamorphic rocks are common targets to obtain detailed Pressure-Temperature-time-Deformation (P-T-t-D) paths as these rocks can preserve different generations of mineral parageneses, reflecting multiple stages of equilibration. To obtain P-T-t-D paths, it is critical to link the P-T conditions retrieved from the mineral compositions to specific deformation phases (D). In most instances, this link is empirical and based on microstructural arguments such as the preservation of textural equilibrium features. One of the key assumptions is that the metamorphic minerals in each microstructure preserve their initial compositions without significant re-equilibration. However, recent studies have shown that metamorphic fluids promote re-equilibration through pseudomorphic replacement and can therefore affect the mineral record.

In this contribution, we will present a few case studies in which quantitative compositional mapping has been combined with thermodynamic models to investigate the possible effects of fluids on the preservation of mineral relics. The systematic analysis of microstructures and compositional zoning in both garnet and muscovite shows that fluids strongly affected the preservation of mineral relics. In some cases the apparent textural equilibrium in a microstructure is not confirmed by compositional mapping, which shows partial replacement of minerals by subsequent fluid–rock interaction. Surprisingly, the inversion of equilibrium models has proven to be of great help to predict the amount of replacement and thus to link a given re-equilibration stage to the presence of an internally- or externally-derived fluid. This method is especially powerful to reconstruct fluid-rock interactions occurring at high pressure and to retrieve information on fluid pathways in subduction zones.