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Adding the third dimension to the textural and chemical analysis of metamorphic rocks and implications for petrological models

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Textural analysis and chemical characterization of metamorphic rocks are commonly restricted to a two-dimensional analysis of thin sections using various tools for imaging and chemical analysis. Quantitative compositional mapping by electron microprobe allows for example the chemical composition of the minerals to be measured in 2D, which is critical for the interpretation of chemical variations in a microtextural context. The most advanced petrological models, on the other hand, rely on the determination of bulk rock compositions to simulate the stable mineral assemblage, mineral modes and compositions assuming chemical equilibrium at the pressure (P) and temperature (T) conditions of interest. Metamorphic rocks commonly exhibit local chemical heterogeneities at the centimeter scale (e.g. layering) and it remains unclear if those variations can affect (or not) the predictions of the petrological models that are mode dependent.

We developed a new approach combining the 3D analysis of a rock cylinder using micro computed tomography (Micro-CT) followed by the 2D analysis of the same sample via quantitative compositional mapping. The collected data (both 2D and 3D) are then combined in the software package XMapTools, which was expanded to enable the quantification of chemical heterogeneities in 3D for a given volume of rock. The effects of local chemical variations on the predictions of the petrological models can be quantified using such a dataset.

We applied this approach to the investigation of a migmatitic metapelite sample from the Central Alps that experienced Barrovian metamorphism during the Alpine collision with peak metamorphic conditions of ~700 °C. A rock volume of ~15 cm^3 was scanned with a resolution of 15 µm before cutting the cylinder for the preparation of a polished thin section. The Bingo-Antidote software was used to run the thermodynamic simulations and to explore the potential effects of local chemical heterogeneities on the chemical models. This study provides a first example of how the 3D characterization of metamorphic rocks can enhance our ability to simulate metamorphism using equilibrium thermodynamics.

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