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Simulating the metamorphic evolution of rocks in the laboratory: experimental modelling of orogenic metamorphism of metapelites using a piston cylinder apparatus

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Metamorphic rocks contain a more or less complex mineral assemblage reflecting their metamorphic evolution. If the complex mineral assemblage is of multi-stage origin how do we know which mineral grew at which stage during the P-T evolution? To answer this question one needs to put constraints on the geological evolution of a given rock. The metamorphic evolution of a rock can be deciphered using three approaches: 1.) the practical geothermobarometric approach (inverse modelling), 2.) the theoretical pseudosection approach (forward modelling) and 3.) the experimental approach. Whereas with the first two approaches it is possible to constrain several stages of the P-T-X evolution but how do we know what assemblage is actually present at the desired P-T conditions? This question leads to the experimental approach, which allows a detailed mineralogical investigation of a given rock at distinct P-T conditions. Therefore, experimental investigations should be viewed as a forward modelling technique, which allow putting additional constraints on the evolution of a rock under defined P and T conditions and hence represents a snap-shot of a P-T point of the evolution of a given rock! For this purpose, simple experiments using natural rocks as starting materials can easily be conducted. The disadvantage of this method lies in the complex chemical composition of natural rocks and the deviation from chemical end-member systems. Therefore these experiments need to be evaluated not only 1.) in terms of their ability to reproduce the natural observations but also 2.) in their ability to reproduce theoretical calculations.

In this study experimental investigations of orogenic metamorphism of metapelites (quartzphyllites with Grt1 + Ms1 + Ch1 + Bt1 + Rt) was investigated. Four different P-T conditions were chosen to represent an orogenic clockwise P-T loop: 400°C, 0.8 GPa, 600°C, 1.2 GPa, 700°C, 1 GPa and 500°C, 0.4 GPa. Two experiments with a duration of 16 and 33 days were conducted, where a complete P-T loop involving all four P-T conditions was simulated. In addition four separate experiments at each of these P-T conditions were done with a duration of 8 days each in order to identify the characteristic mineral assemblages at each of these P-T conditions. The P-T loop experiments yielded the overall mineral assemblage: Grt2,3 + Sta + Ms2 + Bt2 + Chl2 + Ilm. Garnet started to grow in the 600°C and 1.2 GPa experiment and continued to grow at 700°C and 1 GPa. Interestingly the loop experiments yielded staurolite with hercynite inclusions while the single P-T experiment at 700°C and 1 GPa only yielded chloritoid inclusions in quartz. The reason fort his discrepancy probably lies in fast overstepping of chloritoid-in reactions, while staurolite grew in the experiments where the change in P-T conditions was nit so drastic. To check fort he validity of these experiments, thermodynamic testing of the experiments was also done using the software DOMINO-THERIAK. Pseudosection modelling using DOMINO-THERIAK yields a very good agreement between calculated and observed assemblages except for calculated chloritoid and observed staurolite stability.

This study also shows that experimental simulation of geodynamic processes by forward modelling using whole-rock piston-cylinder experiments allows attribution of mineral growth to distinct P-T stages of the P-T path and hence a comprehensive mineralogical characterization of metamorphic rocks from orogenic belts.