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Quantification of micro-scale processes in metamorphic rocks

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Metamorphic reactions within the Earth's interior including deformation and fluid/melt flow are responsible for mountain building, volcanic eruptions and triggering earthquakes. Petrologists and structural geologists are driven by the same essential curiosity about metamorphic processes affecting the Earth's lithosphere and use different tools to understand these processes.

Recent decades have been connected with an impressively accelerating pace in the development and availability of new analytical techniques to earth scientists. Interestingly, the smaller the scale considered, the more heterogeneous an apparently uniform rock sample is. This heterogeneity is not only characterized by variation in chemical composition but also in mechanical properties. The mechanical effects may influence element transport and mineral assemblage in rocks which can, in turn, significantly control the mechanical-chemical coupling rates and mechanisms of various processes in the Earth's interior.

Considering the interplay of metamorphic reaction and mechanical properties in our quantification approaches is critical for correct interpretation of observations in metamorphic rocks. In my contribution, I will show major applications of the new quantification approaches, the accompanying obstacles and the consequences for our petrological interpretations.

I will also discuss new theories and quantification approaches that have been suggested based on the observations from deformation experiments focused on the quartz-coesite transition. On one hand, the observation led to interpretations that the maximum principal stress has a major impact on mineral reactions and phase transitions. On the other hand, theoretical studies suggested that the heterogeneous nucleation of high-pressure polymorphs is related to the spatially heterogeneous strain or pressure. I will show results from the combination of deformation experiments together with numerical modelling of rock deformation confirmed the presence of stress and pressure variations during deformation of heterogeneous samples. The combined results suggest that the evolving sample geometry is responsible for significant variations in all mechanical parameters that need to be considered in high-stress deformation experiments. Based on these new findings, it is essential to be able to quantify the stress/pressure distribution in the sample before any complex thermodynamic interpretations. In fact, any thermodynamic interpretation of a stressed system must take into account the locally-resolved state of stress during sample deformation.