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Influence of material heterogeneities on the phase transformation distribution under deformation

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Phase transitions affect the physical properties of rocks (e.g. rheology) and control geodynamic processes at different spatial and time scales. However, the influence of deformation on phase transitions and their coupling is not well understood.

We performed deformation experiments for the Calcite-Aragonite system in a (Griggs-Type) solid medium deformation apparatus, using different sample geometries. We present experiments that simulate the heterogeneity of rock material by using a strong, non-reactive inclusion in a weak calcite matrix. The sample confining pressure (P_{conf}) was maintained 70 MPa below the Calcite-Aragonite transition while the first principal stress (σ_{yy}) exceeded the transition pressure by 100-200 MPa. Thus, the bulk sample pressure (mean stress), $P_{3D} = (\sigma_{yy} + 2P_{conf})/3$ was closely varying around the transition pressure.

Light microscopy, Raman spectroscopy and electron backscatter diffraction (EBSD) show systematic, strongly heterogeneous patterns in the distribution of both polymorphs, grain-sizes and deformation. These result from stress, strain and pressure variations within the sample. To better understand the mechanisms contributing to the phase transition and grain size variations, we calculated the local distribution of first order parameters as pressure, stress and strain. We applied analytical and numerical methods to determine the magnitude and distribution of the aforementioned parameters in the sample. The modelled stress and strain patterns are compared to the experimentally produced phase transformation distribution. Our comparison shows that the phase transformation of calcite to aragonite matches the distribution of maximum principal stresses and pressure in the deformed sample.

This experiment shows how mechanical heterogeneities, which are intrinsic to the analysed material, influence their surroundings when subject to differential stress. Our results show a clear evidence that mechanically-induced higher pressure (mean stress) will change the mineralogy, and thus the rheology of rocks. Moreover, our results document that the chemo-mechanical coupling is essential for interpretations of microstructure-forming processes.