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On the stress sensitivity of the dehydration kinetics of gypsum: insights from fast in-situ synchrotron X-ray scattering

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The potential role of differential stress for mineral stability and the kinetics of mineral replacement reactions remains a matter of hot debate. We present a series of unique in-situ laboratory experiments on the dehydration of polycrystalline natural gypsum to hemihydrate, which were designed to test if the application of small differential stresses affects the mineral transformation rate. The dehydration experiments were conducted in a purpose-built loading cell suitable for in-situ monitoring with synchrotron transmission small- and wide-angle X-ray scattering (SAXS/WAXS). The time-resolved SAXS/WAXS data provide measurements of the transformation kinetics and the evolution of nano-pores of the dehydrating samples.

In our experiments, the kinetic effects of two principal variables were examined: dehydration temperature and axial confinement of the sample discs. In contrast to most previous dehydration experiments conducted in triaxial deformation apparatus, we applied different axial pre-stresses to the radially unconfined sample discs, which were well below the uniaxial compressive strength of the test material. This loading condition corresponds to constant-displacement rather than constant-stress boundary conditions. We find that in natural gypsum alabaster with randomly oriented grains an increase in axial pre-stress leads to a significant acceleration of the dehydration rate. Simple estimates of the energy budget suggest that the acceleration of the dehydration rate due to elastic straining is significantly cheaper energetically than due to heating. We hypothesise that the observed strong effect of differential stress on dehydration kinetics can be explained by geometry-energy interactions in the granular sample microstructure.