EGU23-6483, updated on 03 May 2023
https://doi.org/10.5194/egusphere-egu23-6483
EGU General Assembly 2023

A non-hydrostatic stress state forms fabrics during metamorphic reactions

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Many metamorphic rocks have a fabric. What is often not clear is how much deformational or metamorphic processes contributed to the formation of these fabrics. Are foliations always the result of strain? When does intrinsic crystallographic anisotropy alone lead to the formation of structural elements? Understanding the relative contributions of deformation and metamorphism in rock fabrics is fundamentally important because it is foundational to understanding the role of stress in reacting and deforming rocks.

To this end, we make a major advance in our understanding of fabric development in reacting rocks by showing in time-resolved (4D) synchrotron microtomography (μCT) experiments that when a gypsum dehydration reaction occurs in a differentially stressed sample the reaction products develop orthogonally to the largest principal stress. This is an important finding because we can show with our μCT data that this preferred orientation forms early in the reaction and at very small strains (<1%). Using a simple kinematic model we can demonstrate that it cannot have formed because of reorientation during mechanical compaction. It remains to be established if it is nucleation or growth of bassanite that is being affected by the stress or both. Our experiments suggest that metamorphic transformations may be inherently anisotropic when reacting under the influence of a non-hydrostatic stress state.

The consequences of this are many. For example, there will be cases in natural rocks where the interpretation of a lineation, foliation or crystallographic preferred orientation as formed by strain may be incorrect. Moreover, the physical properties (e.g. hydraulic and mechanics) of metamorphic rocks could also be significantly anisotropic from early in a transformation. Mass transport pathways might initialise as channelled or partitioned conduits which would have an impact during subduction and in thin-skinned tectonics. Our data reveal a critical new finding related to the very common geological occurrence of reacting rocks experiencing a differential stress.