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Quantifying reaction-induced stresses using high angular resolution electron backscatter diffraction (HR-EBSD): Implications for metamorphic hydration reactions

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Hydration reactions are a fundamental metamorphic process and play a critical role in Earth's tectonics and water budget. Petrological observations previously emphasized that volume expansion was accommodated by pressure-solution or tectonic extension. Hydration can also generate significant non-hydrostatic stresses. Resultant dilatant fracturing can increase permeability, driving reaction fronts forward, but constraints on reaction-induced stress magnitude and distribution and the contribution of thermal contraction to this stress remain to be set. The authors apply high-angular resolution electron backscatter diffraction (HR-EBSD) to the simple case of deformed calcite surrounding brucite after periclase. By cross-correlating regions of interest within diffraction patterns, HR-EBSD provides precise determination of lattice strains and residual stresses. Using finite element modelling we estimate the stresses induced by thermal contraction, indicating that the minimum reaction-induced residual stresses are roughly one gigapascal. The stress fields extend tens of micrometres away from hydration sites. High twin, fracture, and dislocation densities in calcite near brucite likely formed by relaxation of these stresses. HR-EBSD efficiently quantifies reaction-induced stresses. These strongly non-hydrostatic stresses are large enough to lead to deformation, possibly influence the far-field stress state and potentially affect local reaction thermodynamics.