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Modeling Reaction-Induced Fracturing from Serpentinization

CARL I STEEFEL, MENGSU HU AND WENMING DONG
Lawrence Berkeley National Laboratory

During serpentinization, the transformation of primary ultramafic minerals like olivine into secondary serpentine can result in a volume increase of up to 50%. Such volumetric expansion can create local stress that can cause fracturing in rock where the crystallization pressure exceeds the confining stress. This phenomenon, known as *reaction-induced fracturing*, may create positive feedbacks in which the permeability is increased, or negative feedbacks due to pore clogging by the secondary serpentine and other reaction products. The crystallization rate of serpentine, however, depends on both the confining stress (or contact pressure) and the supersaturation (or free energy) with respect to serpentine. Thus, the reaction-induced fracturing process involves tightly coupled two-way chemo-mechanical (CM) processes. It is still unknown what the temperature and stress window is for reaction-induced fracturing from serpentinization—a great depths, although temperatures are high, access of H_2O to the ultramafic rock may be limited. Equally important is the potential suppression of crystallization when the confining stress exceeds the "crystallization pressure" defined as the pressure at which the chemical potential associated with the contact pressure equals the chemical supersaturation.

In this work, we present both pore-scale modeling based on the chemo-mechanical software NMM-Crunch and continuum modeling based on CrunchFlow (here named as CrunchSerp). The modeling is supported by a set of hydrothermal batch and flowthrough experiments conducted at 200ºC and 160 bars. Early stress-free experiments at temperature and pressure are being supplemented with a set of experiments with applied normal stress to verify a newly developed reaction rate law that incorporates the effect of crystallization pressure on reaction rates. The new rate law incorporates explicitly both the chemical potential contribution from solution chemistry at whatever fluid pressure is considered and the chemical potential contribution from the contact pressure (or normal stress). This TST-style rate law allows for relatively easy incorporation within a multicomponent reactive transport framework. This flexible reaction framework naturally transitions to one that captures pressure solution where the chemical saturation ($\log Q/K_{eq}$) $< P_c * V_m/RT$, where Q is the ion activity product, P_c is the contact pressure, and V_m is the molar volume of the phase.