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Microstructural origins of chemomechanical changes in novaculite

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In geological environments chemical and mechanical processes are not necessarily separate. In fact, in many cases they act in concert as a positive feedback loop, with changes in one enhancing the rate of the other. For instance, chemical alteration of a given rock is very likely to affect its mechanical properties. Dissolution, precipitation, and replacement during reaction are expected to directly affect the Young's and shear moduli, Poisson's ratio and internal friction. From a geophysical perspective such change will affect the fracture properties of the material, as well as S and P wave velocities critical to interpreting both deep and shallow seismic analyses (e.g. earthquake and nuclear explosion analysis, oil and gas exploration, deep earth structures). Even in a nominally dry, nonreactive rock such as novaculite reactions occur at grain boundaries on heating that can significantly affect mechanical behavior. In addition, in a wet, multiscale porous system the boiling point of water is expected to increase in nano pores well beyond its normal value at 1 atm., much as the freezing point drops under such conditions. Thus, rocks at temperatures above 100°C are expected to contain superheated liquid water in nanopores, coexisting with water vapor in larger pores. As solubility in water is a function of the liquid density, such a system may be dissolving material from small pores and reprecipitating it elsewhere, which should have a dramatic effect on the mechanical properties of the material.

Paired experiments in wet (steam) and dry environments are being undertaken on simple, monomineralic rock types (novaculite (quartz)) and limestone (calcite)) of varying initial porosities and permeabilities at 300°C with times at temperature beginning at 1 hour and increasing in powers of two. Changes in the microstructure have been observed by SEM, (U)SANS and (U)SAXS, and coupled with both impact excitation and three-point bend experiments to quantify the relationship between recrystallization and mechanics. In addition, DFTB calculations and QENS analysis have been undertaken to better understand the nature of boiling in nanoscale confined environments such as those observed in these materials. Significant changes in both the pore structures and mechanical properties have been observed.