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Mineral Precipitation-Induced Alteration of Fracture Permeability

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Many target subsurface reservoirs for emerging low-carbon energy technologies and CO_2 sequestration rely on flow through natural or induced fractures, which can be critically altered by coupled geochemical and geomechanical deformation processes. Specifically, mineral dissolution-precipitation reactions can lead to net permeability enhancement (e.g. through free surface dissolution or volume-expanding precipitation) or reduction (e.g. through pore blocking or dissolution-driven mechanical compaction). This presentaion will discuss a suite of experiments that explore the roles of fluid chemistry, rock mineralogy, and fracture geometry in determining the extent and location of permeability alteration in fractured rocks.

A series of core flooding experiments were conducted where CO_2-acidified fluids were injected into fractured basalt core samples under both advection- and diffusion-dominated flow regimes at relevant geologic injection conditions. The results confirmed that reactive fluid injection leads to net dissolution under advection-dominated conditions, while diffusion-dominated regimes favor precipitation. In general, precipitates were strongly localized and were non-uniformly distributed due to chemical and physical heterogeneities.

To more explicitly evaluate reactive systems in which precipitation induces chemically- or mechanically-mediated permeability alterations, a set of triaxial direct shear experiments was conducted within an x-ray computed tomography (xCT) scanner. Here, carbonate-rich shale cores were sheared with $BaCl_2$-rich fluids to promote precipitation of barium carbonates that would be highly visible in x-ray imaging. In all experiments, reaction products were characterized with a suite of imaging techniques (e.g. xCT, Raman, SEM/EDS).

In combination, results indicate that the rate, extent, and distribution of precipitation reactions will determine their implications for fluid flow. Precipitates that formed in dead-end fractures failed to notably impact permeability or fracture microstructure, while precipitates in freshly generated shear fractures dramatically reduced permeability when they formed at critical asperities or choke points. Experiments also indicated that localized precipitates may act as proppants that resist mechanical compaction under increasing external stress conditions.