Reaction-induced porous fracture surfaces: Effects on fracture friction and permeability during shear

SPOKAS, K.[1], FANG, Y.[2], ELSWORTH, D.[2], FITTS, J.P.[1], PETERS, C.A.[1]

[1]Civil & Environmental Engineering Department, Princeton University, NJ, USA. kspokas@princeton.edu
[2]Energy and Mineral Engineering Department, Pennsylvania State University, PA, USA.

Subsurface rock fractures present a risk for fluid leakage and mechanical failure in engineered subsurface processes, such as geologic carbon storage, natural gas storage, oil and gas extraction, geothermal energy, and injected waste disposal. In this work, we focus on the exposure of fractures to acidified fluids that can dissolve reactive minerals, such as calcite. This study couples geochemistry with geomechanics through the investigation of the effect of mineral dissolution at the fracture surface on fracture frictional parameters.

Experiments involved saw-cut fractures of the Eagle Ford Shale, a calcite-rich layered shale from a hydraulic fracturing region in Texas. One set of fractured specimens was exposed to reactive brine with a pH of 2.5 and another set was exposed to non-reactive brine with a pH of 7.8, both with a salinity of 1 M. X-ray CT imaging revealed that for the fractures exposed to low pH brine an altered layer had formed, made up of a porous matrix of non-reactive minerals. Fractures exposed to non-reactive brine show limited alteration.

Then, hydro-shearing experiments were performed in a triaxial testing apparatus that independently applied normal stress and pore pressure to shear samples at a prescribed velocity. The fractures that had a porous altered layer had a lower frictional strength compared to the unaltered fractures, but no clear change in frictional stability. Visual inspection revealed the formation of a layer of clay-rich gouge due to the compaction of the calcite-depleted porous layer. This gouge layer also keeps permeability of the altered fractures consistently low, while the unaltered fractures show more variation in the permeability during shear.

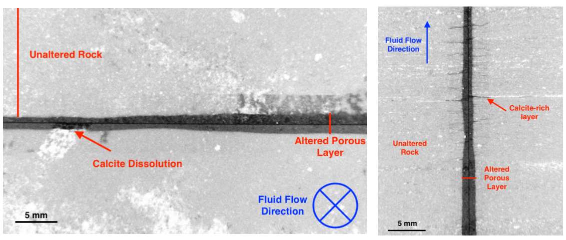

Figure 1. X-ray CT images of cross-section and profile of an altered fracture that was exposed to pH 2.5 brine.