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Experimental and computational analysis of reactive transport processes in fractured porous media

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Reactive transport processes in fractured porous media have a significant impact on many subsurface energy activities such as enhanced geothermal systems, critical minerals extraction, geologic fluid storage, and unconventional resources recovery. Although our understanding of fluid-rock interactions in fractured porous media has been dramatically improved with both experimental and computational studies over the past two decades, coupled reactive transport processes involving mechanical behaviors of open fracture(s) with chemical reactions (e.g., dissolution) need to be investigated more thoroughly. In this work we employed a fluidic system made of natural limestone to evaluate mineral dissolution under different pH conditions and a small flow-through core experiment to evaluate the permeability changes in a single fracture over a range of confining pressures under mineral dissolution. An open channel over rough surfaces of the limestone is used to evaluate the impact of influent pH solution chemistries on dissolution reaction rates. Experimental data analysis shows that hydrodynamics through an open channel dominates upscaled dissolution rates and changes in surface roughness over time using Zeiss Surface Imaging and Analysis Software (ConfoMap®) at ~0.3 microns revealed the importance of image resolution on accurate estimation of dissolution rates. Permeability changes caused by confining pressure were used to update cubic law values of aperture of the single fracture and to evaluate the impact of dissolution on fracture stiffness. Micro-X-ray tomography provided image of the fractured core before and after dissolution experiments. A hybrid lattice Boltzmann-finite volume (LB-FV) approach for reactive transport processes and a combined conjugate-gradient method and fast-multipole method for determining fracture deformation are used to analyze coupled chemo-mechanical processes against experimental observations. In this presentation we will highlight how experimental observations obtained through imaging, pressure changes as a function of confining pressure, and solution chemistry can be utilized to validate reactive transport and deformation modeling of fluid-rock interactions in the natural limestone. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.