

Physical and chemical alteration of shales during hydraulic fracturing

A.L. HARRISON^{1,2*}, A.D. JEW^{1,2}, M.K. DUSTIN¹, A.M. KISS², A.H. KOHLI^{1,2}, D.L. THOMAS¹, C. M. JOE-WONG¹, Y.LIU², J.-H. LIM³, G. E. BROWN, JR.^{1,2}, K. MAHER¹, AND J.R. BARGAR²

¹Stanford University, Stanford, 94305, USA

(*correspondence: anna.harrison@stanford.edu, adamjew@stanford.edu, mdustin@stanford.edu; ahkohli@stanford.edu, danat@stanford.edu, joewongc@stanford.edu, gebjr@stanford.edu, kmaher@stanford.edu)

²SLAC National Accelerator Laboratory, Menlo Park, 94025, USA (andykiss@slac.stanford.edu, liuyijin@slac.stanford.edu, bargar@slac.stanford.edu)

³Pohang Accelerator Laboratory, Pohang, 790-784, Korea (limjh@postech.ac.kr)

Hydraulic fracturing is employed to help extract oil and gas from low permeability rock such as shale. It involves the injection of fluids into the subsurface that may react with shale minerals, potentially altering permeability and releasing contaminants. Yet, the complex mineralogy and pore structure of shales hinders prediction of reaction rate and progress upon injection of such fluids. A combined experimental, imaging, and modeling approach was employed to evaluate the impact of shale mineralogy on its physical and chemical alteration when exposed to fracture fluids.

Batch reactor experiments contained shales from four localities with unique mineralogical compositions that were exposed to simulated hydraulic fracturing fluid. While the availability of O₂ was found to be an important control on the reaction of Fe(II)-bearing minerals and precipitation of secondary phases, the dominant control on shale alteration was the buffering capacity, or carbonate mineral content, of the rock. In experiments with carbonate-rich shale, fluid pH was rapidly recovered to circum-neutral conditions, but remained acidic in reactors with carbonate-poor shales. X-ray computed micro-tomography data illustrated significant differences in reaction front propagation, with a calcite-rich shale exhibiting a much more uniform reaction front in contrast to a heterogeneous reaction distribution in relatively carbonate-poor shales. The capacity of the shale to buffer fluid pH is a key control on subsequent reactions including silicate dissolution and precipitation of secondary minerals, which can control the mobility of contaminants. These results provide important insight into the potential impacts of hydraulic fracturing on fluid flow and contaminant release in shales, and fundamental relationships between mineral distribution and porosity evolution in low-porosity media.