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Numerical and Experimental Simulation of Dissolution and Precipitation: Implications for Fracture Sealing at Yucca Mountain, Nevada

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Abstract

Plugging of flow paths caused by mineral precipitation in fractures above the potential repository at Yucca Mountain, Nevada, would reduce the probability of water seeping into the repository. As part of an ongoing effort to evaluate thermal-hydrologic-chemical (THC) effects on flow in fractured media, we performed a laboratory experiment and numerical simulations to investigate mineral dissolution and precipitation under anticipated temperature and pressure conditions in the repository. To replicate mineral dissolution by vapor condensate in fractured tuff, water was flowed through crushed Yucca Mountain tuff at 94°C. The resulting steady-state fluid composition had a total dissolved solids content of about 140 mg/L; silica was the dominant dissolved constituent. A portion of the steady-state mineralized water was flowed into a vertically oriented planar fracture in a block of welded Topopah Spring Tuff that was maintained at 80°C at the top and 130°C at the bottom. The fracture began to seal with amorphous silica within five days.

A 1-D plug-flow numerical model was used to simulate mineral dissolution, and a similar model was developed to simulate the flow of mineralized water through a planar fracture, where boiling conditions led to mineral precipitation. Predicted concentrations of the major dissolved constituents for the tuff dissolution were within a factor of 2 of the measured average steady-state compositions. The mineral precipitation simulations predicted the precipitation of...
amorphous silica at the base of the boiling front, leading to a greater than fifty-fold decrease in fracture permeability in 5 days, consistent with the laboratory experiment.

These results help validate the use of a numerical model to simulate THC processes at Yucca Mountain. The experiment and simulations indicated that boiling and concomitant precipitation of amorphous silica could cause significant reductions in fracture porosity and permeability on a local scale. However, differences in fluid flow rates and thermal gradients between the experimental setup and anticipated conditions at Yucca Mountain need to be factored into scaling the results of the dissolution/precipitation experiments and associated simulations to THC models for the potential Yucca Mountain repository.

*Keywords:* dissolution, precipitation, porosity, permeability, reactive transport, heat pipe