Fracture Sealing by Mineral Dissolution and Precipitation at Yucca Mountain

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RESEARCH OBJECTIVES

The emplacement of heat-generating waste at the proposed Yucca Mountain repository site will induce several processes to occur. Water naturally present in the rock will evaporate or boil, and this vapor will condense at a distance from the proposed repository, where the rock is cooler. The condensate will dissolve the host rock (tuff), and the dissolved constituents will precipitate if the water is boiled away. Mineral precipitation in fractures above the proposed repository could plug flow paths and reduce the probability of water seeping into the repository. Our research objectives are to provide a better understanding of (1) tuff dissolution under conditions expected in the proposed repository, (2) mineral precipitation in fractures, and (3) how these processes might affect the performance of such a proposed repository.

APPROACH

Our approach was to experimentally and numerically investigate tuff dissolution caused by water condensation in fractures and mineral precipitation in fractures subjected to a thermal gradient with a boiling region. We used anticipated temperature and pressure conditions in the proposed repository.

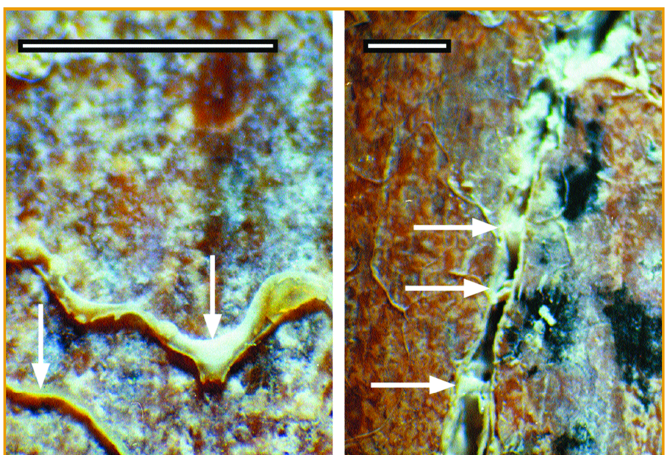

Figure 1. Bridging structures (identified with arrows): (a) extending outward from flat fracture face; (b) spanning aperture in cross-cutting natural fracture. Scale bars are 0.5 mm.

ACCOMPLISHMENTS

We replicated mineral dissolution by vapor condensate in fractured tuff by flowing water through crushed Yucca Mountain tuff at 94°C. We monitored the chemistry of the water passing through the crushed tuff to provide information on tuff dissolution. The steady-state fluid composition had a total-dissolved-solids content of about 140 mg/L, and silica was the dominant dissolved constituent. We flowed a portion of this mineral-laden water into a vertically oriented planar (saw cut) fracture in a block of welded Topopah Spring Tuff that was maintained at 80°C at the top and 130°C at the bottom. In the boiling region, the precipitation of amorphous silica from the water began to seal the fracture within 5 days. Upon opening the fracture, we observed the structure of the precipitate: precipitate coated the fracture walls and formed bridging structures that plugged the aperture. On the right side of Figure 1, we see bridging structures extending out from the fracture wall, and in the cross-cutting fracture shown on the left, both the fracture coating and bridging structures are visible.

A one-dimensional 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 50-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 thermal-hydrological-chemical processes at Yucca Mountain.

SIGNIFICANCE OF FINDINGS

The experiment and simulations indicated that 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 of the results.

RELATED PUBLICATION

Dobson, P.F., T.J. Kneafsey, E.L. Sonnenthal, N. Spycher, and J.A. Apps, Experimental and numerical simulation of dissolution and precipitation: Implications for fracture sealing at Yucca Mountain, Nevada. Journal of Contaminant Hydrology, 62–63, 459–476, 2003.

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