Testing the Concept of Drift Shadow with X-Ray Absorption Imaging Experiments

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Research Objectives

X-ray absorption imaging is used to test the concept of the drift shadow in geological samples. The drift shadow model predicts that water travels around underground tunnels, or drifts, leaving areas of high saturation along the sides of the drift (roof-drip lobe) and an area of low saturation beneath the drift (drift shadow). The drift shadow model could impact nuclear waste repositories designed with open tunnels, such as Yucca Mountain, by impacting the flux available to transport waste beneath the repository. However, without strong evidence for the drift shadow effect, it is difficult to justify its inclusion in performance assessment calculations.

Approach

Our study uses X-ray absorption imaging to test the concept of the drift shadow. X-ray absorption imaging techniques have been shown to be a powerful tool to visualize and quantify flow and transport in opaque systems (Altman et al., 2004; Tidwell et al., 2000). Laboratory-scale volcanic tuff samples are imaged to directly visualize pathways of infiltrating water in the vicinity of the drift. In addition, outflow samples are collected in and beneath the model drift to further confirm the visualization results. Through the use of geological samples we not only test the drift-shadow concept, but also provide data in heterogeneous materials to assist in future numerical modeling.

Samples of Topopah Spring welded tuff (Tsw), collected from Busted Butte, Nevada Test Site were used for this study. Test cells were prepared with different fracture apertures (Figure 1). Prior to starting an experiment, test-cells were saturated with water. At the start of the experiment, a tracer was dripped at a controlled flow rate through four ports at the top of the test cells. Transport through the cell was measured by collecting and weighing sponges both in the drift and at collection ports at the bottom of the flow cell. X-ray images were collected prior to the start of the experiment and at different times during the experiment. By subtracting the image taken prior to the start of the experiment from the images taken during the experiment, the X-ray absorption due to the geological media was removed, and the tracer pathways in the geological samples become visible.

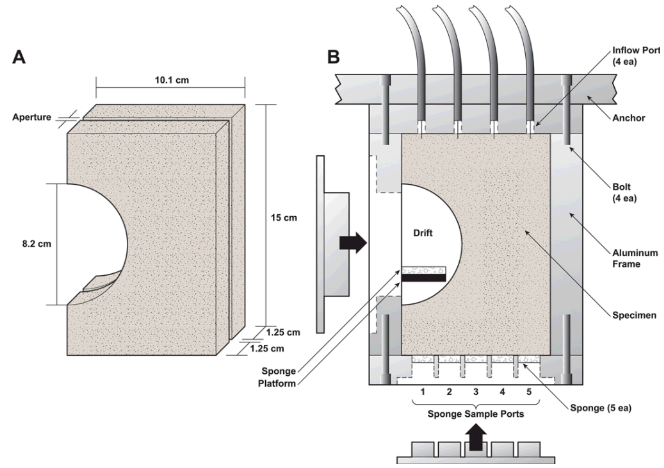

Figure 1: Schematic of specimen after sample preparation (A) and in the test cell (B).

Accomplishments

Experiments were completed the summer of 2006. Since this time our focus has been on presenting and publishing our interpretations of the experimental results. Presentations have been made at the Geological Society of America Annual Meeting (October 2005) and the International High-Level Radioactive Waste Management Conference (May 2006). Publications include the proceedings for the International High-Level Radioactive Waste Management Conference (Altman et al., 2006) and a manuscript submitted to the Journal of Hydrology (Altman et al., in review). A modified version of the conclusions from the Journal of Hydrology manuscript is presented below:

X-ray absorption experiments provide clear images of a roof-drip lobe and drift shadow forming in real time on geological samples (Figure 2). The imaging shows a tracer-solution flow path above the drift being diverted around the drift and shedding beyond the drift. In all but 2 of the tests, less than 1% of the inflow mass was discharged into the drift. The evidence for a drift shadow is generally demonstrated through the observation of less discharge under the drift and greater discharge just beyond the drift than if flow was uniformly vertical (Figure 3). However, there is also evidence that under the right conditions (low flow rates and small-fracture apertures) water might be transported back under the drift. In addition

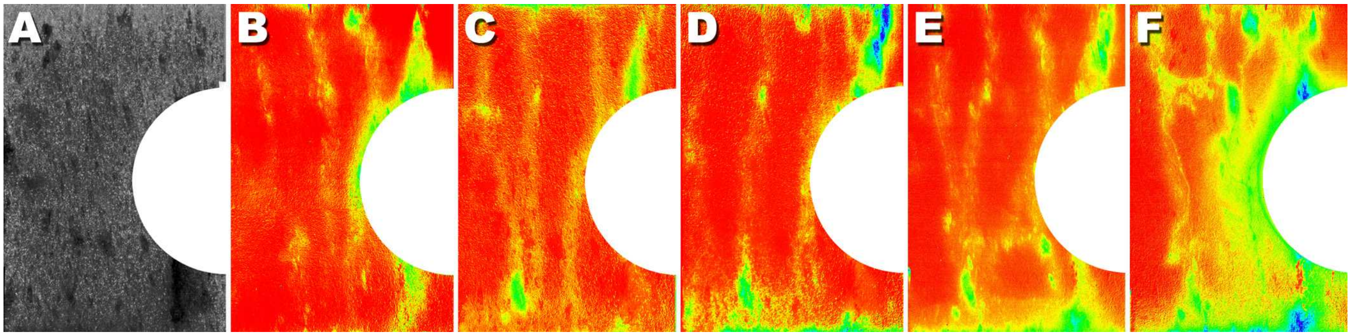

Figure 2: X-ray absorption images of the 250 µm aperture test cell taken before (A) and 5 hours (B-F) after the start of experiments. Flow rates are 0.01, 0.05, 0.09, 0.13, and 0.24 ml/min for tests B, C, D, E, and F, respectively. Red going to yellow, green, blue and purple indicates increasing tracer concentration. Image of cell without tracer (A) shows more porous pumice fragments as darker areas.

natural heterogeneities can influence the extent of the drift shadow effect.

While these studies provide quantitative and visual evidence that only a fraction of the total percolation flux is available for transporting radionuclides immediately beneath the repository, further work is needed to quantify the effect of the drift shadow on radionuclide transport. The experiments presented here can feed into a numerical modeling exercise that can more fully capture the impact of heterogeneities and the range of hydrogeological parameters (e.g., infiltration rates, fracture apertures). This modeling exercise can also account for the impact of the smaller scale of our experiments relative to field-scale drifts on the experimental results. Thus, these experiments coupled with future modeling can provide the data needed for performance assessment calculations to account for the impact of the drift shadow on radionuclide transport. If implemented, such studies could lead to improved natural barrier performance in future calculations.

References

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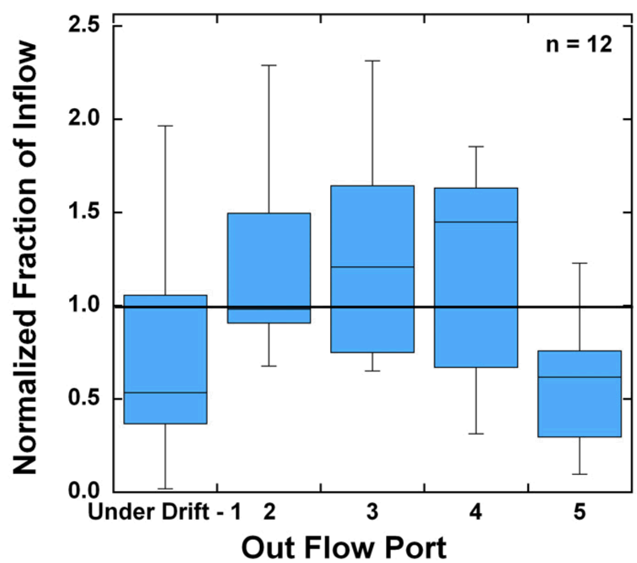

Figure 3: Normalized fraction of inflow discharging through outflow ports for 12 tests presented in Altman et al. (in review). Each box encloses 50% of the values with the central line representing the median value. The bars show the minimum and maximum values. Fractions are normalized such that if the inflow was discharged uniformly the normalized discharge would be 1.