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

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Presented by:
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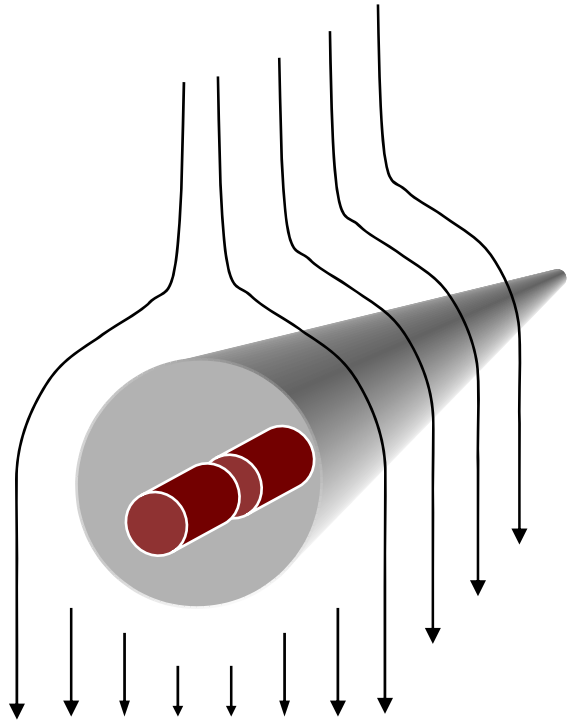
Overview

- Background and Objectives
- Test Approach
- Results
- Next Steps

Background and Objectives

- Capillary diversion around tunnel may cause “drift shadow” effect
- Current Performance Assessment assumes flux under the drift the same as flux away from the drift
- With evidence of drift shadow, may be able to decrease the flux under the drift in future performance assessment calculations
- Decreased flux leads to decreased transport of radionuclides immediately beneath the repository
- IMPROVE PERFORMANCE
- Evaluate flow distribution around and beneath cavity in fractured tuff using X-ray absorption imaging



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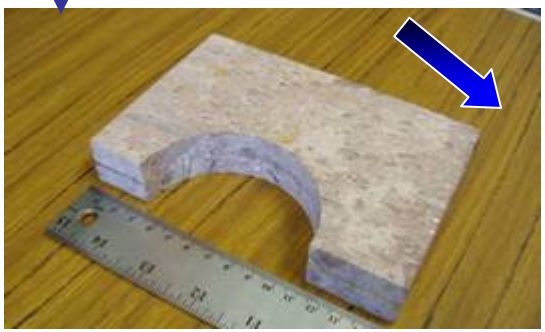
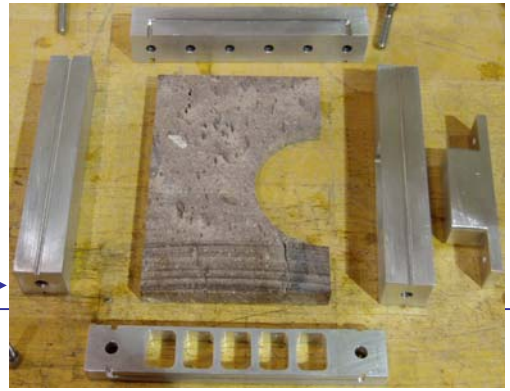
Experimental Procedure

Cut and Prepare Rock Samples



Put Rock Samples in Test Cells



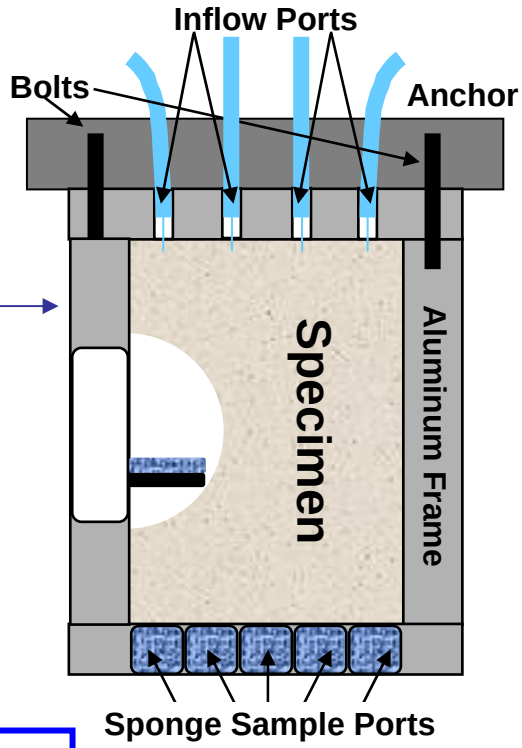
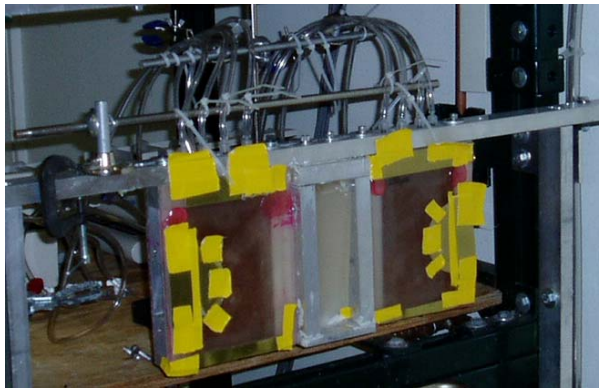


Image Dry Rock Samples

Saturate Samples with DI Water

Image Saturated Samples



Drip KI Through Samples

Start Experiments

Image Samples Periodically During Experiment

Data Analysis

Digitize X-Ray Film

Grey-Level Adjust Film

Image Analysis

$$\phi_{i,j} = \frac{\ln(I_s) - \ln(I_d)}{E[\ln(I_s) - \ln(I_d)]}\phi_{bulk}$$

Pixel Size = 0.09 mm x 0.09 mm

Image of Dry Sample

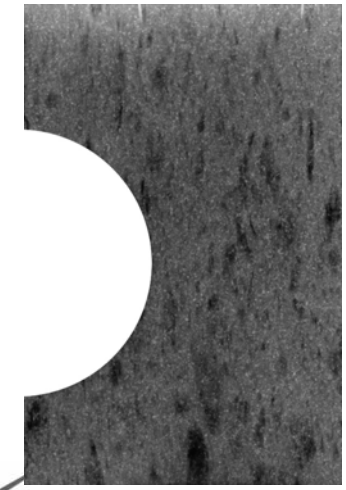
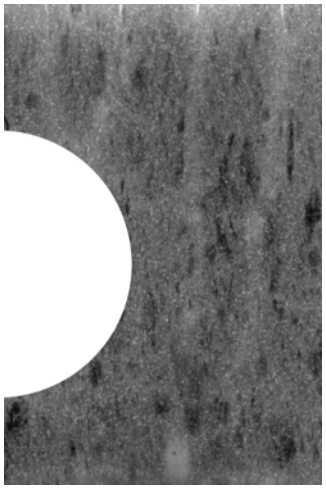
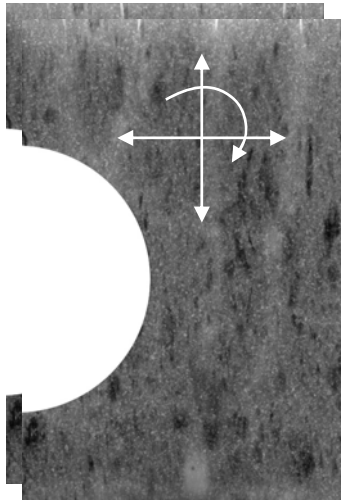


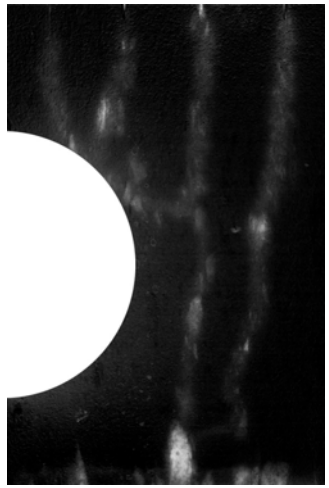
Image of sample taken at t= 2 hrs



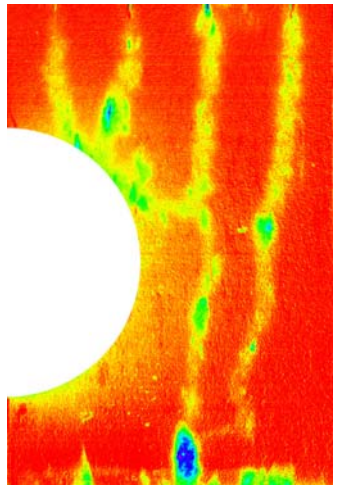
Align two images



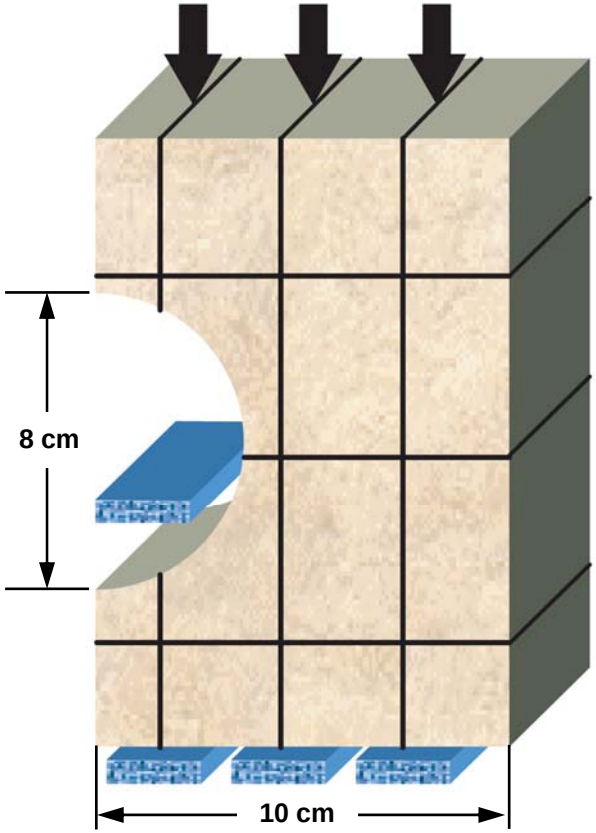
Subtract dry image from t = 2 hrs image



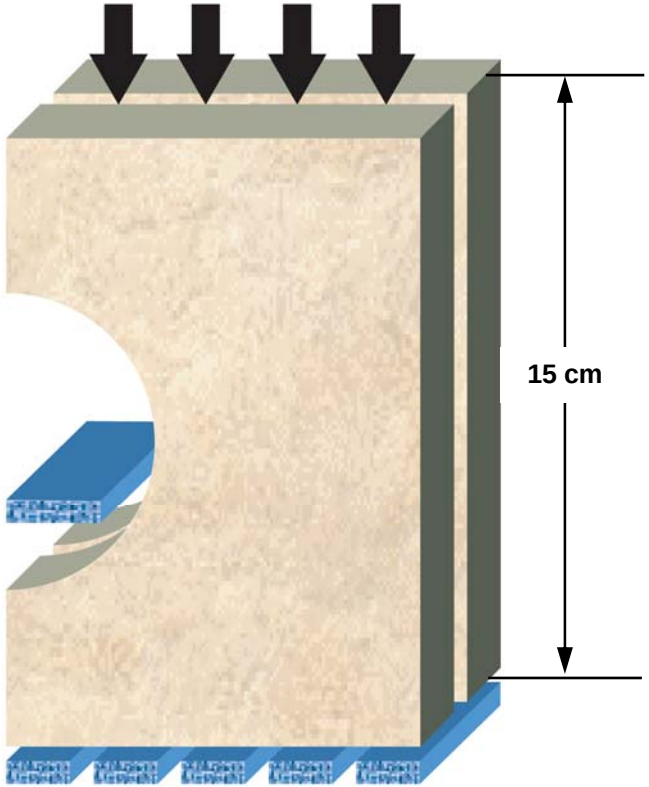
Color Enhance



Alternative Test Designs



Multi-Fracture System



In-Plane System

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Summary of Results

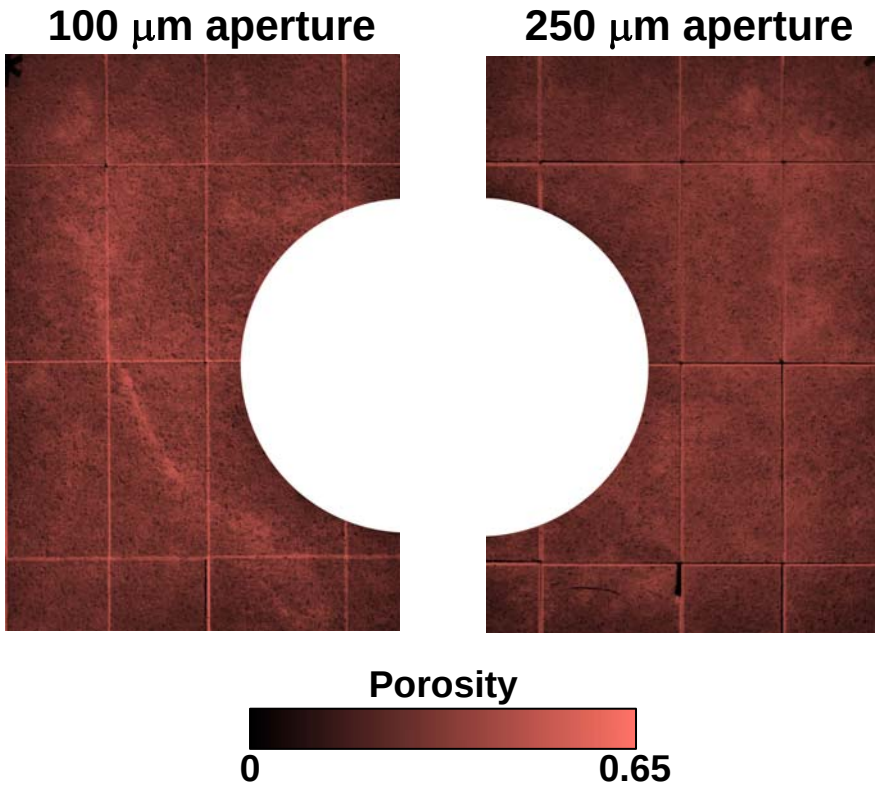
- Ran 17 successful experiments
  - 12 on the In-Plane Fracture System
  - 5 on the Multi-Fracture System
- Determined porosity of multi-fracture samples
- Discharge data give evidence for drift shadow
- X-ray images give evidence for drift shadow

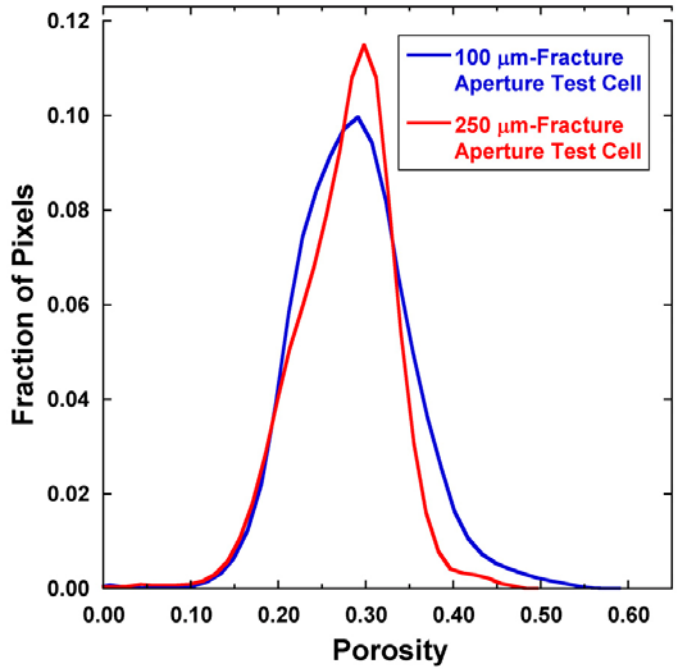
Ran 17 Successful Experiments

Date Run	Test #	Flow Rate (ml/min)	Fracture Aperture (μm)	Test Duration (min)	Mass Balance Error (%)	Cum. Mass into Drift (%)
In-Plane Fracture Tests						
07/27/2005	5P	0.01	100	485	10	0.9
07/27/2005	5P	0.01	250	485	-6.4	0.0
10/20/2005	3B	0.01	500	360	4.2	1.8
06/2/2005	2P	0.05	100	320	11	0.6
06/2/2005	2P	0.05	250	320	10	1.2
05/10/2005	1P	0.09	100	126	7.9	0.2
05/10/2005	1P	0.09	250	126	1.6	0.3
08/24/2005	2B	0.10	250	300	10.4	0.2
06/22/2005	3P	0.12	100	132	9.9	0.9
06/22/2005	3P	0.13	250	132	9.7	0.3
10/12/2005	7P	0.24	250	213	7.2	0.1
10/12/2005	7P	0.23	500	213	11.2	0.1
Multi-fracture Tests						
08/17/2005	1B	0.01	100	421	-10.0	3.0
02/17/2005	1M	0.1	100	141	3.8	0.8
02/17/2005	1M	0.1	250	141	3.4	0.3
05/25/2005	3M	0.1	250	146	11.4	0.5
08/24/2005	2B	0.1	100	300	8.7	0.5

- **Suite of flow rates**
  - **0.01 - 0.25 ml/min**
- **Suite of fracture apertures**
  - **100, 250, and 500 μm**
- **Mass balance errors generally less than 10%**
- **Percent of inflow discharging into the drift generally less than 1%**

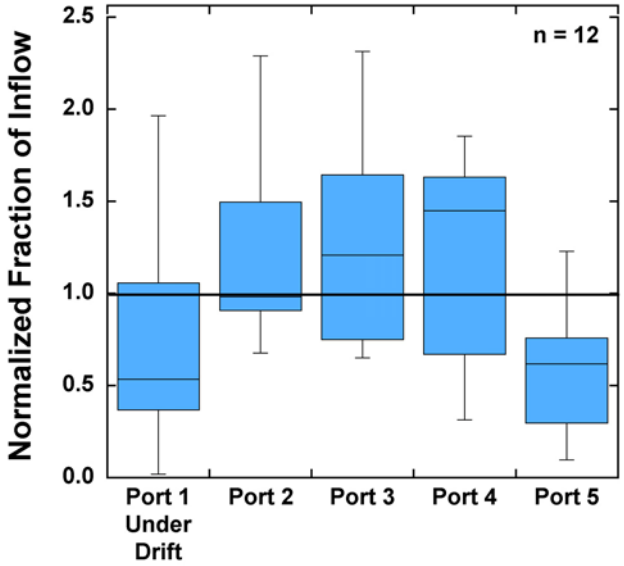
Determined Porosity Of The Multi-fracture Samples

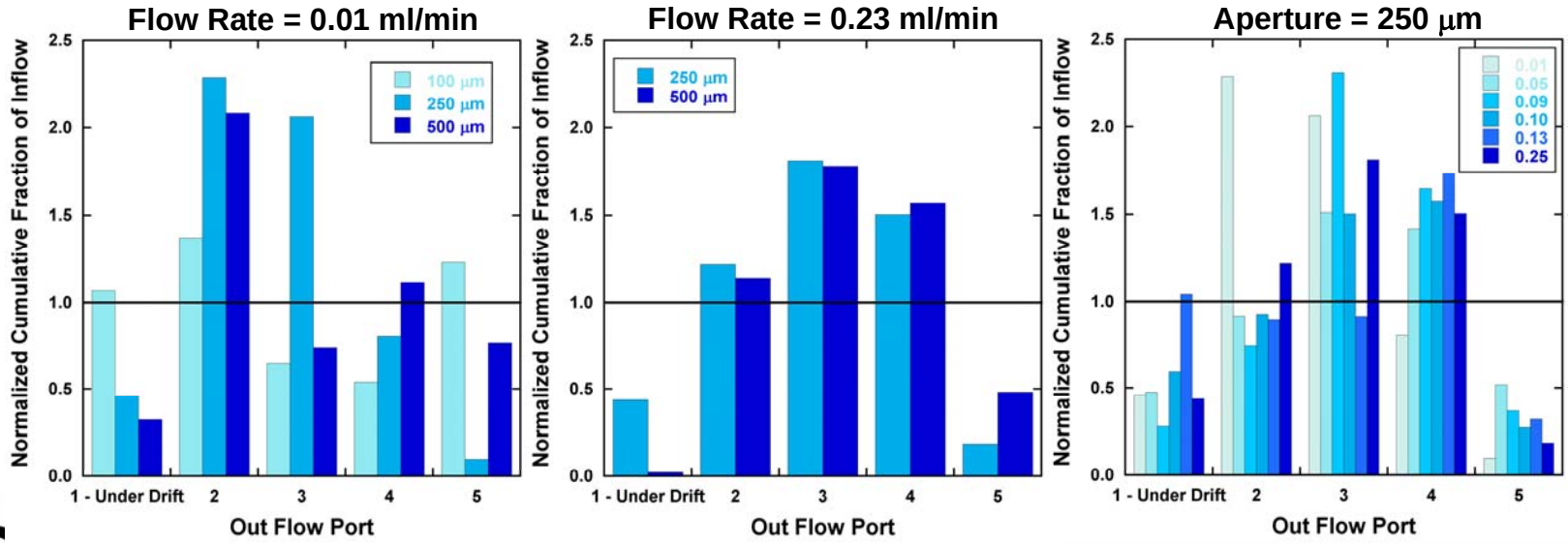




Discharge Data Give Evidence for Drift Shadow

- Less than expected discharge (if flow was vertical) through port under the drift.
- Discharge under the drift decreases with increasing fracture aperture.
- Majority of discharge through ports 3 and 4 (ports away from the drift).

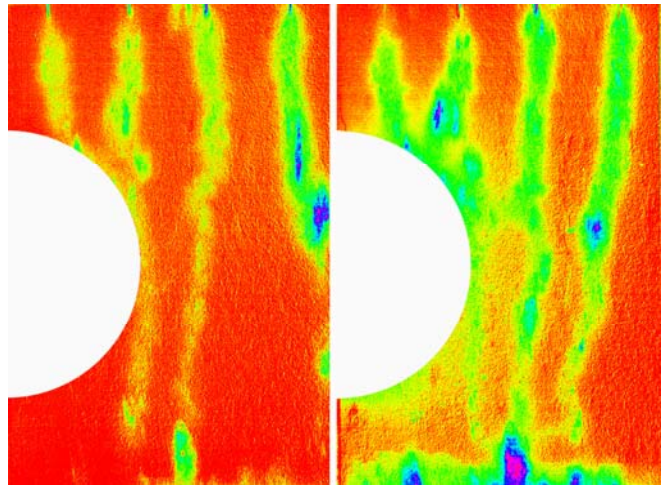




X-Ray Images Give Evidence for Drift Shadow

- Tracer being diverted around the drift
- Tracer shedding off the drift and not under the drift
- Capillary fringe at the bottom of the test cell for tests with higher flow rates

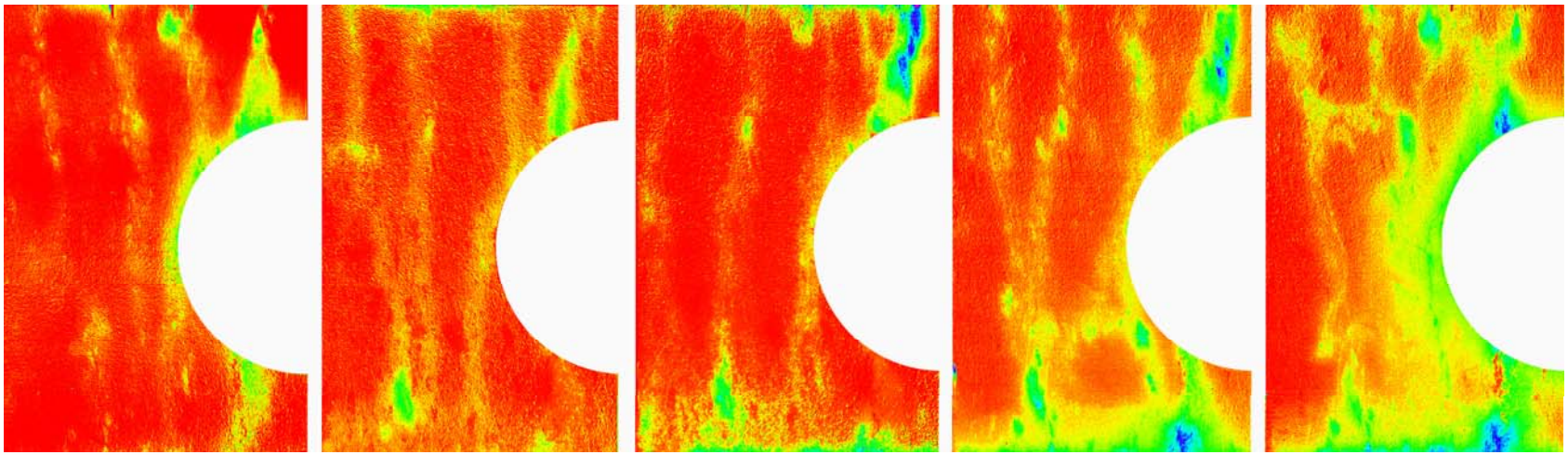
500 μm aperture fracture



0.01 ml/min #2

0.23 ml/min #1

250 μm aperture fracture



0.01 ml/min #4

0.05 ml/min #2

0.09 ml/min #1

0.13 ml/min #3

0.24 ml/min #6

Summary of Results

- 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
  - Evidence for a capillary barrier
  - Evidence for a drift shadow
- Experimental design needs to be improved to minimize the capillary barrier effects along the lower boundary of the test cells
- Heterogeneities in the system lead to different discharge distributions than would be expected in a homogeneous system
- Further assessment is needed in order to quantify the amount and variability of flux below the drift
- Decreased flux under the drift could impact performance assessment at Yucca Mountain

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Future Work Will Focus on Modeling

- Perform numerical simulations of experiments using current conceptual models of flow through fractures (e.g., DKM)
- Provide verification of relevant model features and processes observed in experiments
- Conduct parametric analyses to understand and verify impacts of flow rate, aperture size, and possibly heterogeneities on drift-shadow effect