Update of Busted Butte Transport Test: Phase 1 Preliminary Results

Presentation to:
Nuclear Waste Technical Review Board (NWTRB)

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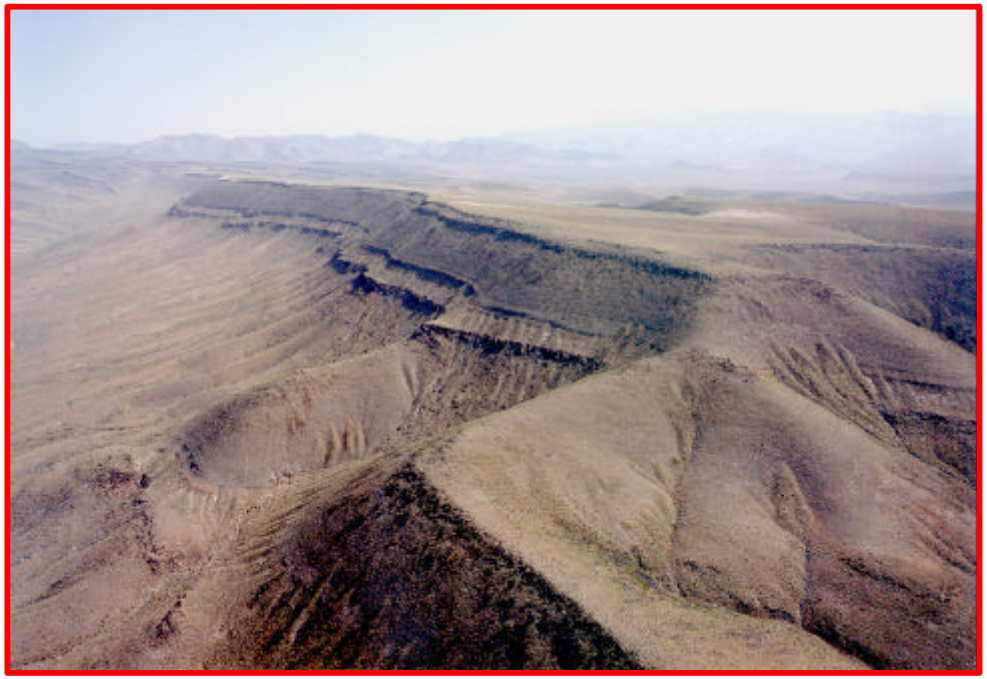
U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Yucca Mountain Project

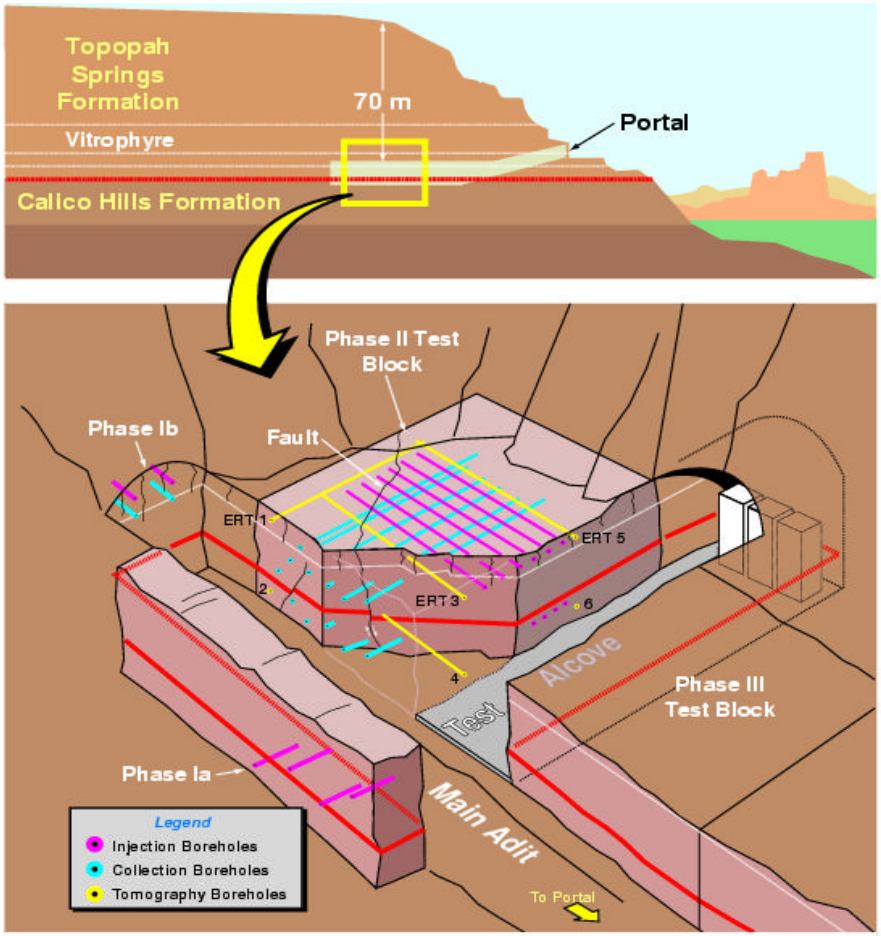
The Yucca Mountain Vicinity



Yucca Mountain
From Southwest

Busted Butte
From Northwest

The Unsaturated Zone Transport Test at Busted Butte



Earth and Environmental Sciences — Los Alamos National Laboratory

Test Objectives

- Evaluate influence of heterogeneities on flow and transport
- Evaluate other aspects of site, including fracture/matrix interactions and permeability contrast boundaries
- Consider colloid migration in unsaturated zone
- Test use of laboratory sorption data at field scale
- Calibrate and validate site-scale flow and transport model
- Address scaling issues

The Busted Butte Test Plan

- **UZ field test designed to proceed in three phases. The first two Phases support the Site Recommendation and License Application.**
- **Phase I consists of short (2m long) closely spaced injection or injection/collection boreholes to give early results.**
- **Phase 2 consists of a larger scale and longer duration test which uses radionuclide analogue tracers.**
- **Phases I and II are being run concurrently.**
- **Phase III tests will support Performance Confirmation transport testing and it may have a thermal component.**

Busted Butte Tracers for Phase I and Phase II

Phase I:

- Lithium Bromide
- Potassium Iodide
- Fluorescent polystyrene latex microspheres (two sizes)
  Plutonium Analogs, (colloidal form)
- Sodium Fluorescein
- Pyridone
- 2,4-difluorobenzoic acid
- 2,6-difluorobenzoic acid
- 2,4,5-trifluorobenzoic acid
- 2,3,4,5-tetrafluorobenzoic acid
- Pentafluorobenzoic acid

Phase II (Same as Phase I plus the additional tracers listed):

- Neptunium Analogues (Np^{5+}):
  - Nickel (II) chloride hexahydrate
  - Cobalt chloride hexahydrate
  - Manganese chloride tetrahydrate
- Plutonium Analogue, (Pu^{3+}):
  - Samarium Chloride hexahydrate
- Americium Analogs (Am^{3+}):
  - Cerium (III) chloride hepahydrate
- Rhodamine WT

Laboratory Data on Unsaturated Hydrologic Properties

Data collection and interpretation performed by L. E. Flint, U.S. Geologic Survey

Sample	Porosity	Bulk Density	Ks (m/s)	alpha (1/bars)	n	air entry (bars)
Inj1-21.8	0.46	1.00	1.0E-05	18.7	1.2	0.05
Inj3-3.5	0.34	1.29	1.0E-05	8.6	1.3	0.12
Inj3-8.2	0.30	1.43	3.4E-06	1.3	1.4	0.77
Inj3-23.0	0.32	1.36		4.5	1.3	0.22
Inj4-7.7	0.32	1.48	6.7E-06	9.0	1.3	0.11
Inj4-12.0	0.36	1.31	2.6E-06	6.1	1.2	0.16
Inj6-11.5	0.33	1.41	3.0E-06	9.7	1.2	0.10

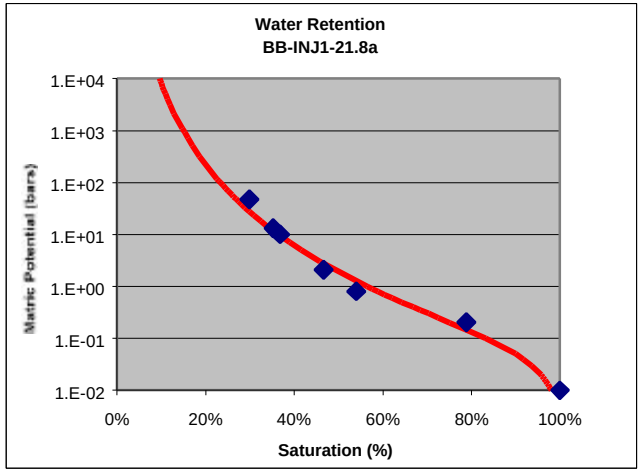
Laboratory Data on Unsaturated Hydrologic Properties

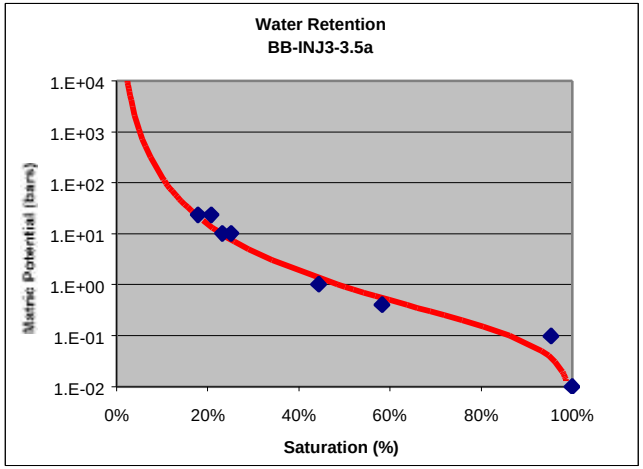
Data collection and interpretation performed by L. E. Flint, U.S. Geologic Survey

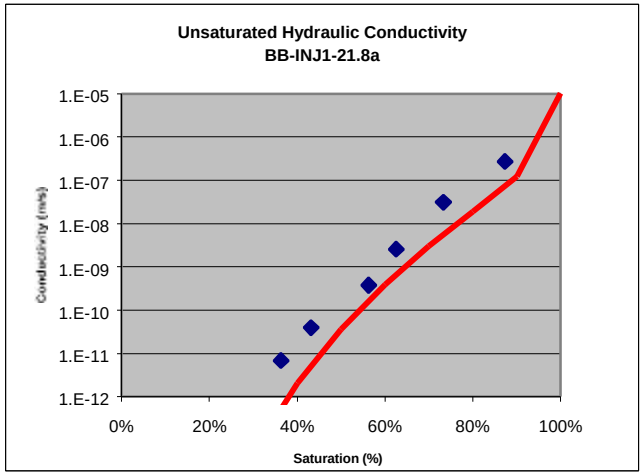
Fit to moisture retention curve data

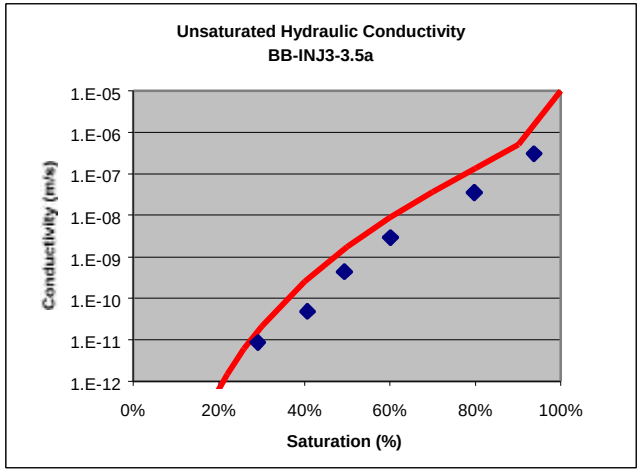
Direct measurements of the unsaturated hydraulic conductivity agree well with the van Genuchten model

Model result compared to conductivity data





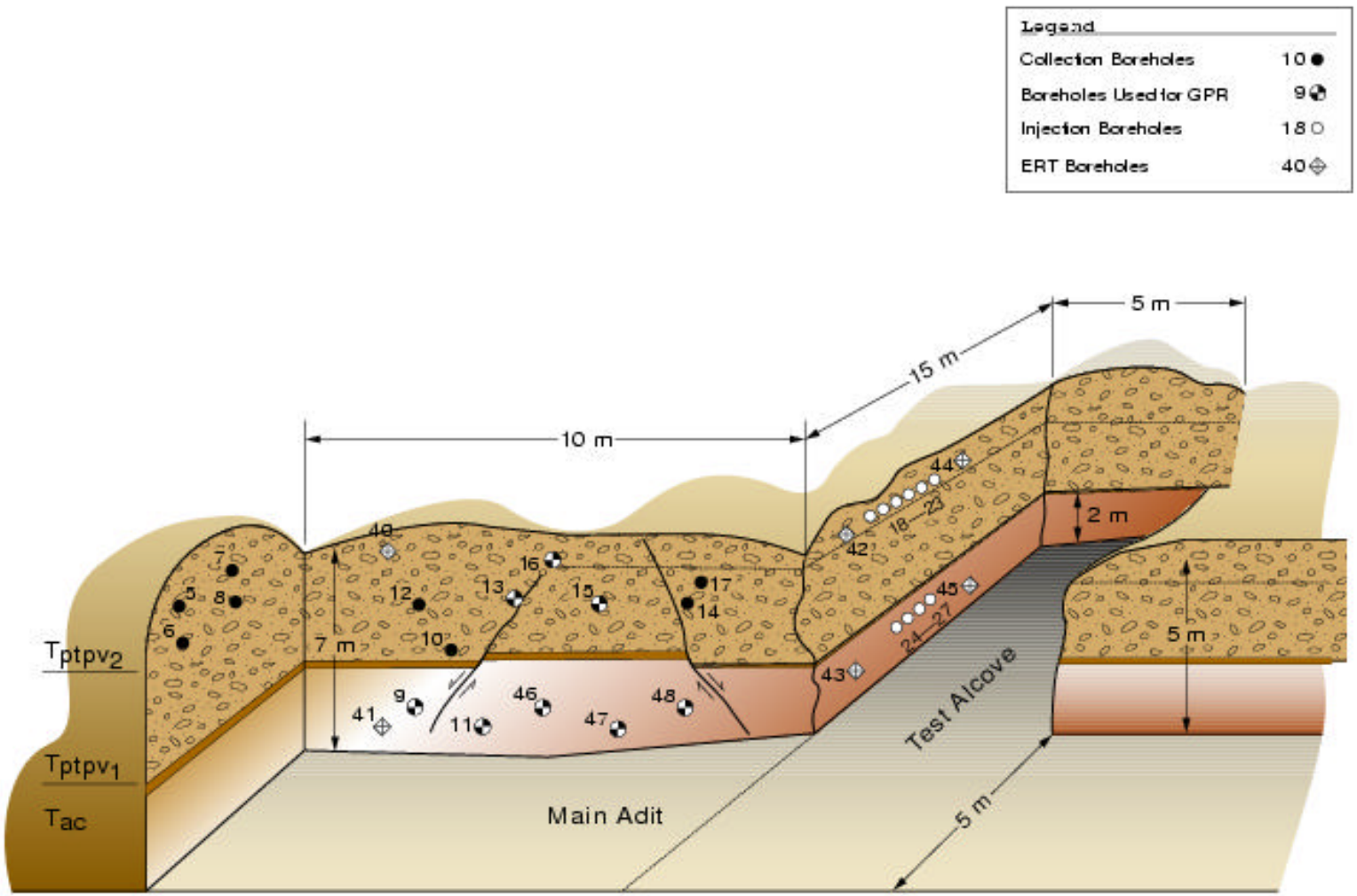




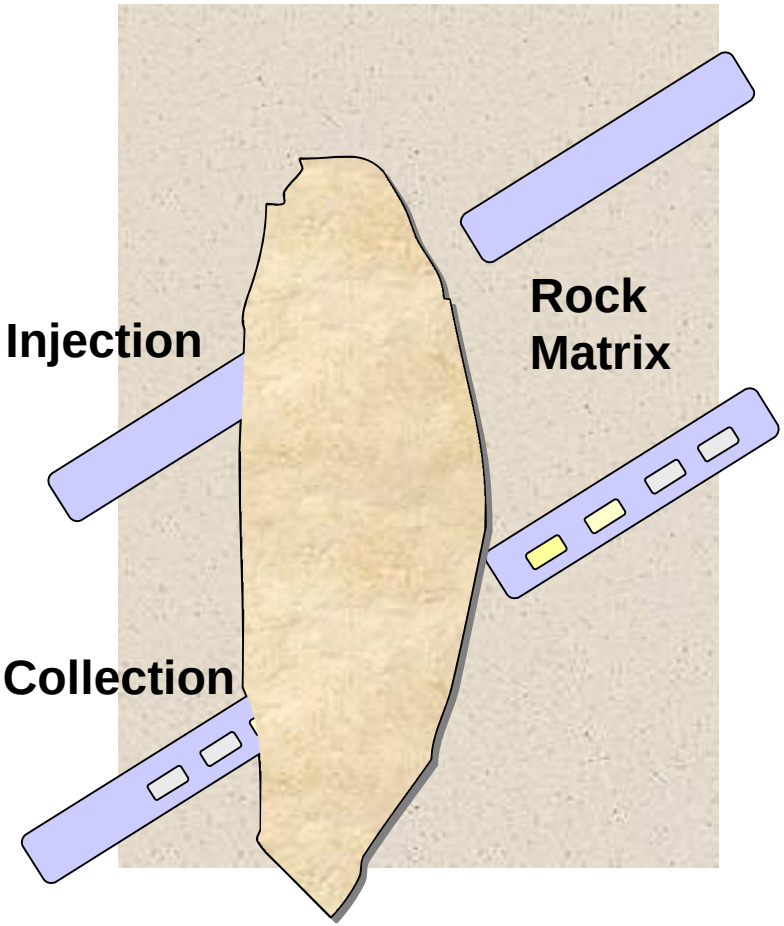
Chemical Analyses Performed June 30, 1999

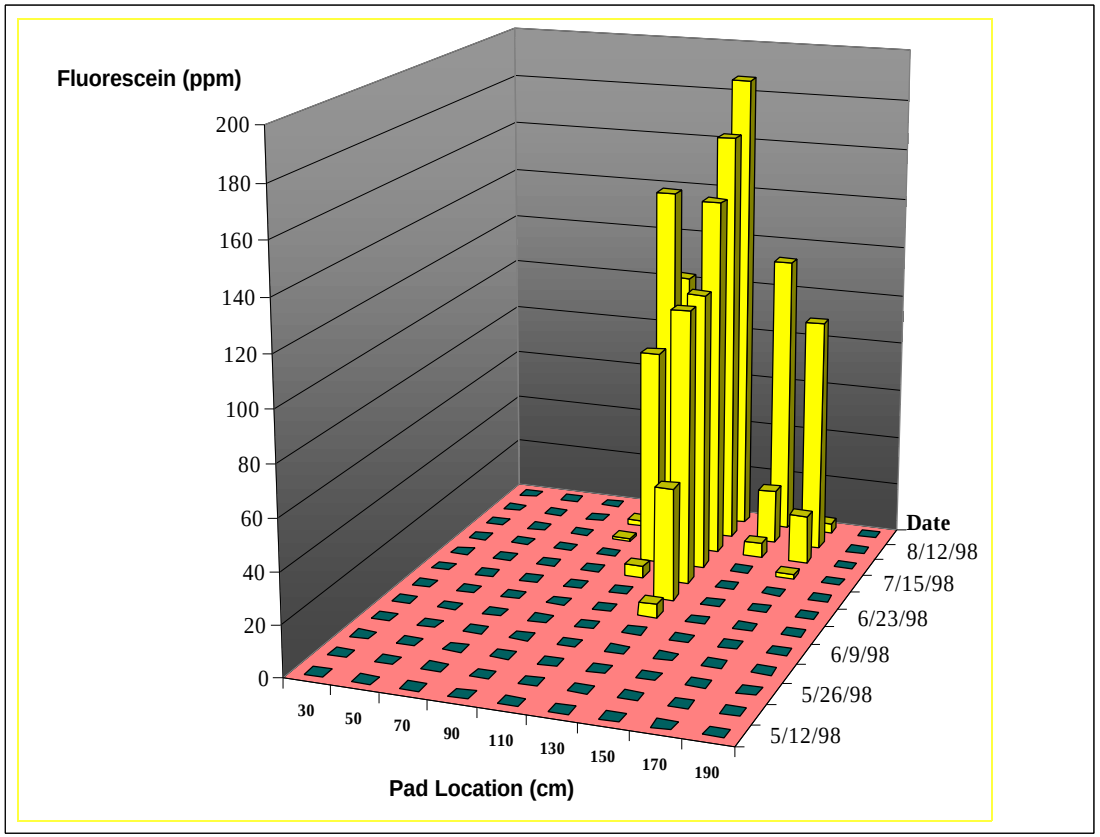
- **~7000 pads collected**
- **~1000 pads extracted for all except metals and microspheres**
- **Over 10,000 separate analyses (FBAs, bromide, and dyes)**

Busted Butte Test Layout



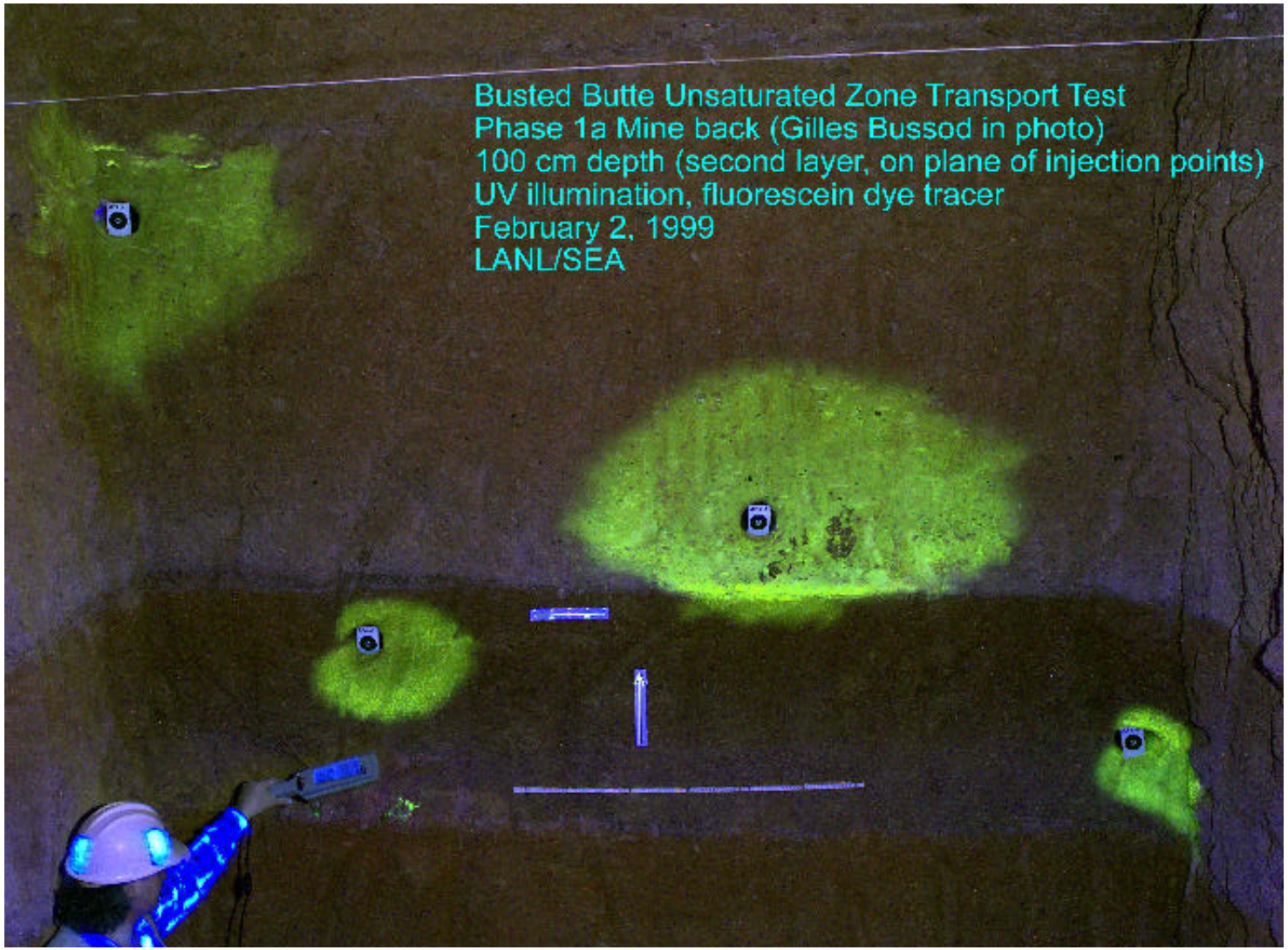
Phase IB Results



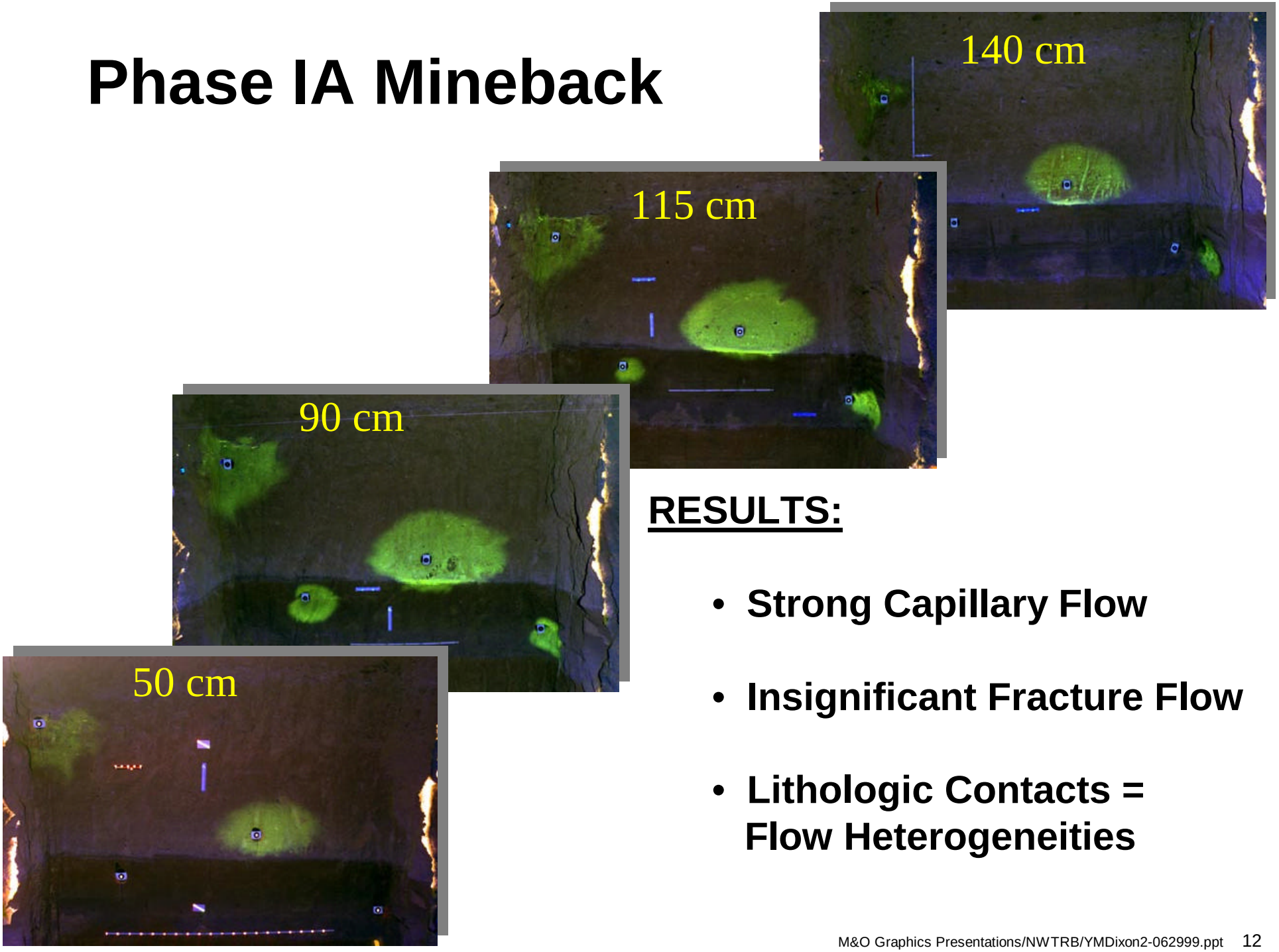


Water is readily imbibed into the rock matrix even when injected directly into the fracture.

Phase IA Mine Back



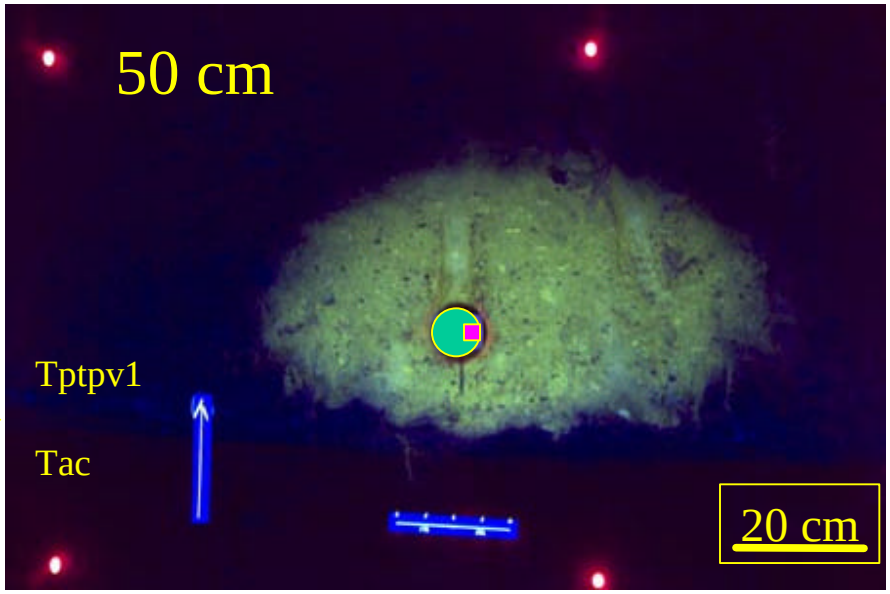
Phase IA Mineback

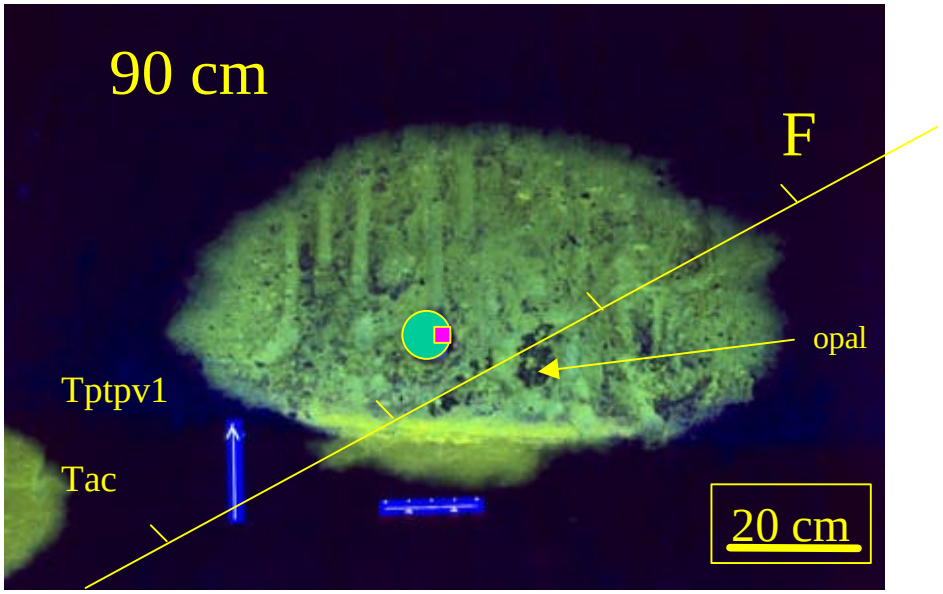


RESULTS:

- **Strong Capillary Flow**
- **Insignificant Fracture Flow**
- **Lithologic Contacts = Flow Heterogeneities**

Phase IA Results:
Matrix Flow in CHn





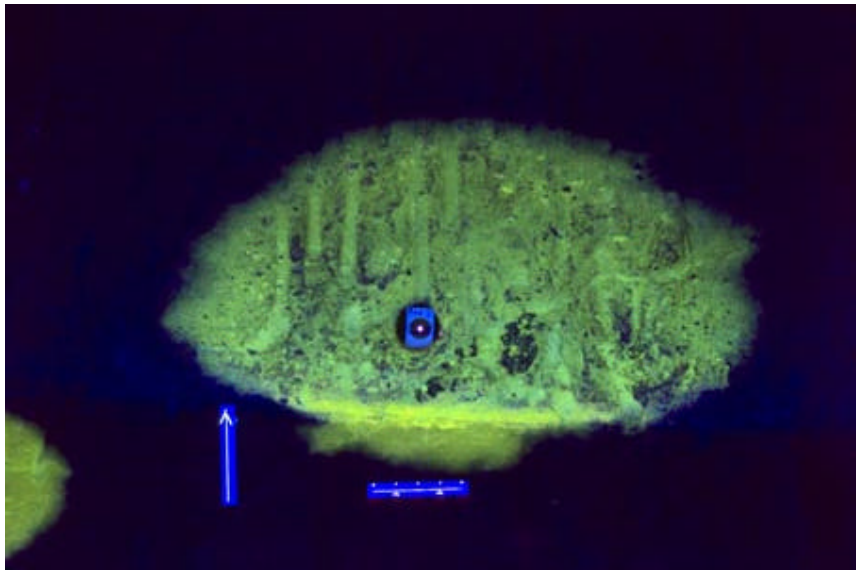
UZTT-BB-PH1-3: 8 month injection @ 10 ml/h

Phase I Modeling

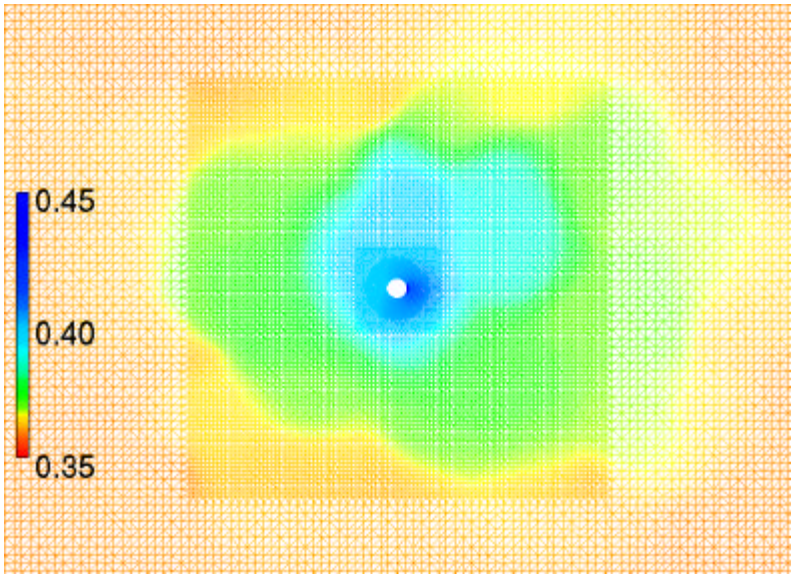
- **Three-dimensional pre-test predictions to aid in the design of the tests**
- **Two-dimensional heterogeneous simulations used for pre-test predictions - unfractured (Phase IA) and fractured (Phase IB)**
- **Stochastic models use for pre-test predictions and to understand uncertainty**

Transport Field Testing to Confirm Modeling Results

Field Test Results

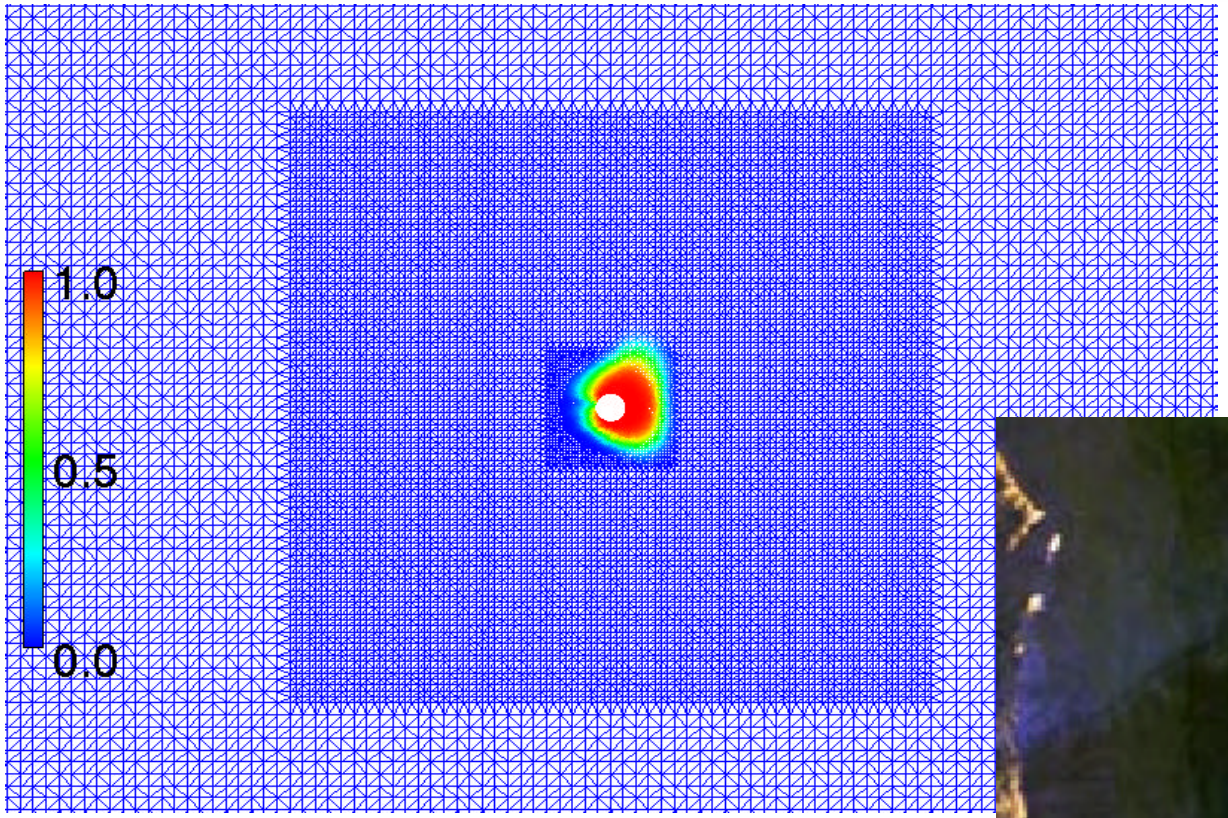


Numerical Simulation



Fluid saturation during injection

Confirmation of Transport Processes



Field Result Phase IA

Busted Butte Transport Test: Current Status Phases IA/IB

Tentative Conclusions:

- Long travel times in Calico Hills unit
- Migration of water from fractures into the rock matrix, where sorption can take place

Other Short-Term Expected Results:

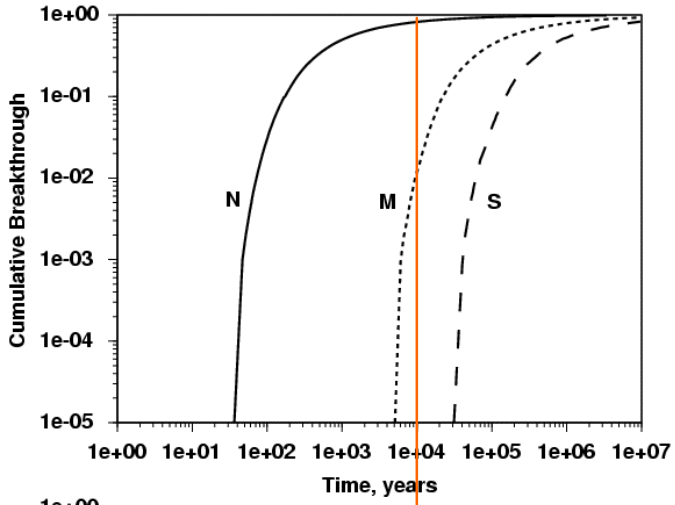
- Information on movement of colloids in unsaturated rock
- Data on sorptive retardation in the Calico Hills

Data and analyses from the test will be used as part of the scientific and technical basis for the preparation of the License Application

Site Scale Performance Predictions for the Unsaturated Zone

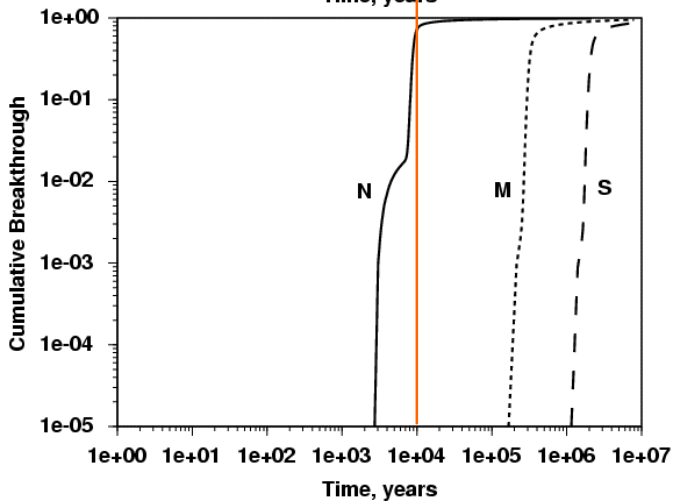
The Calico Hills formation is predicted to be the main barrier to radionuclide migration, yet its flow and transport characteristics have not been measured until this test.

Breakthrough curve assuming fracture flow from repository to water table →

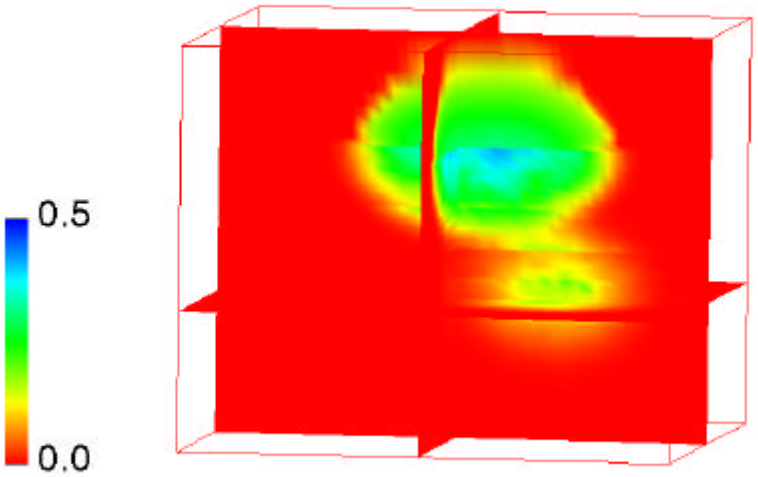


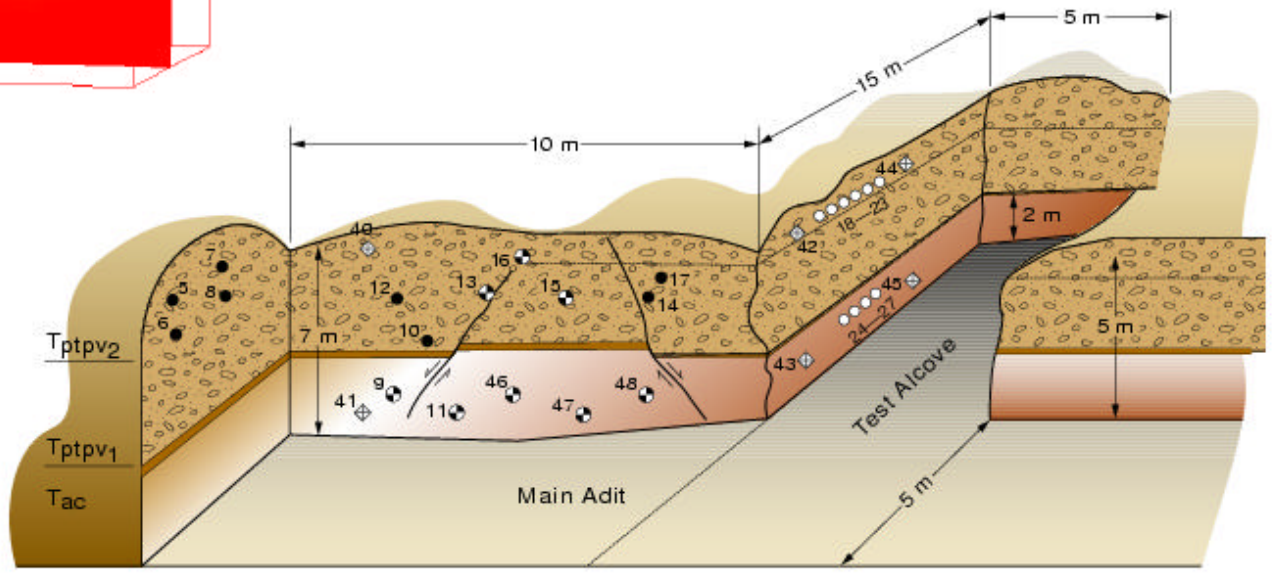
N - nonsorbing
M - moderately sorbing
S - strongly sorbing

Breakthrough curve assuming matrix flow in the Calico Hills formation →

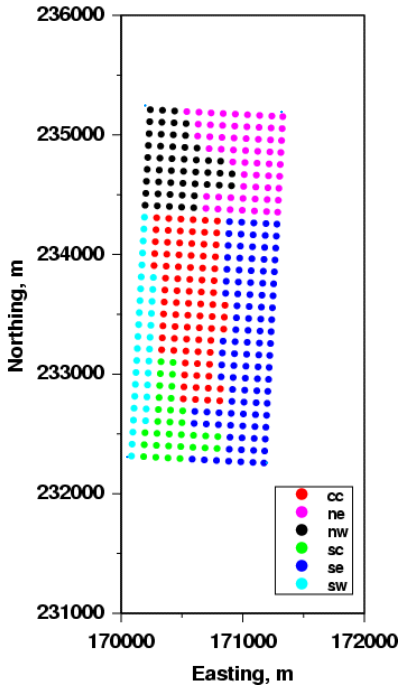


Phase II Modeling: Predicted Moisture Front

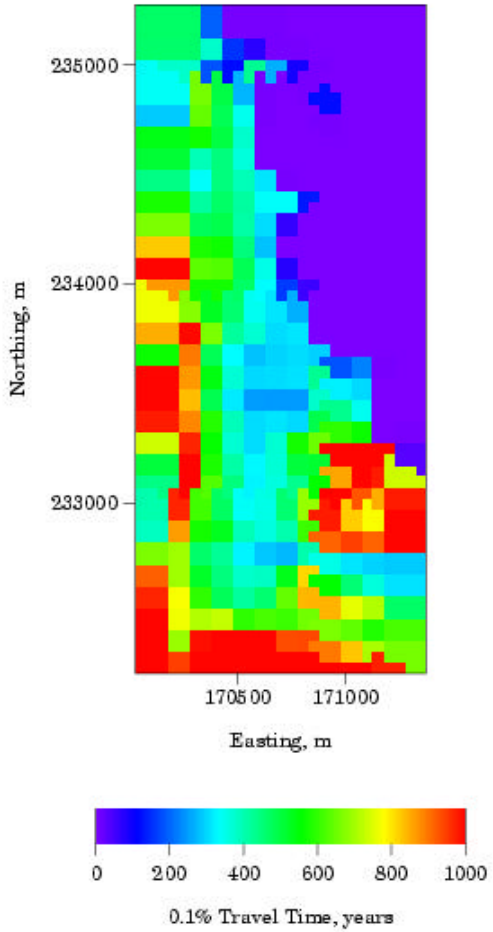




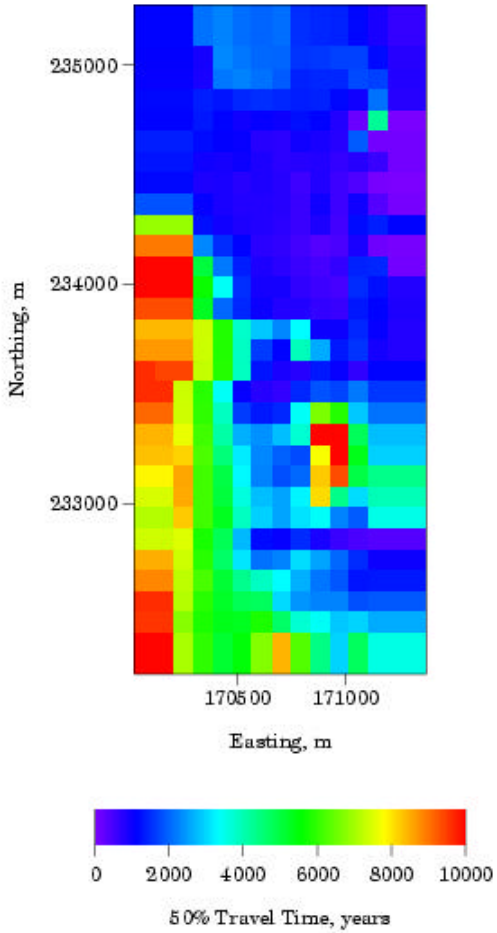
Travel Times to the Water Table



0.1% Arrival

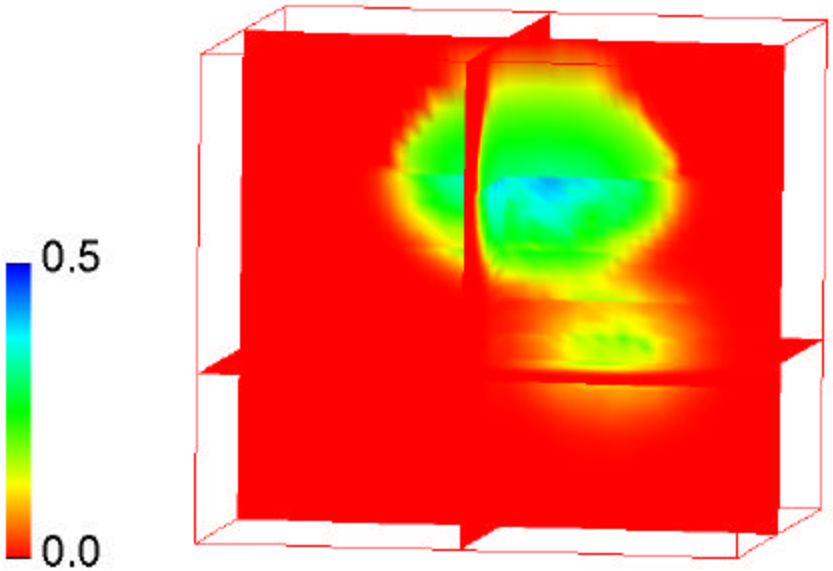


50% Arrival

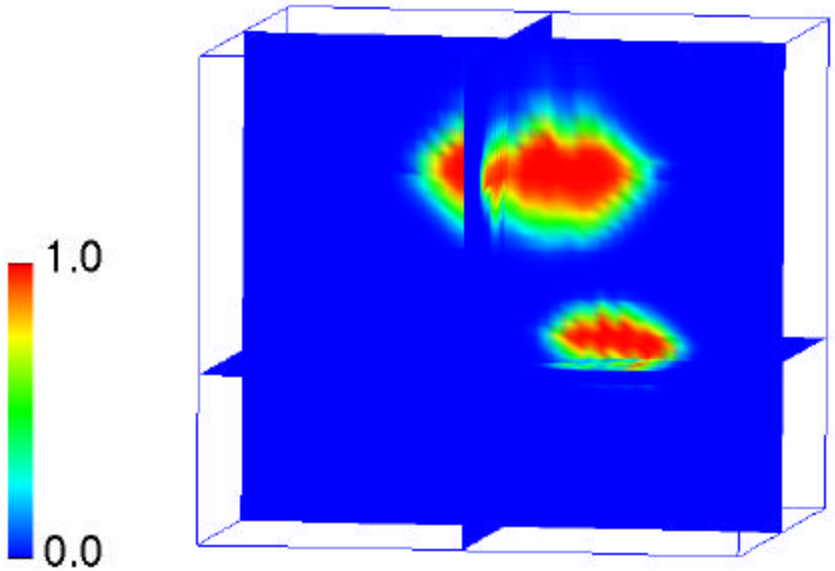


Phase II Modeling: Fluid and Tracer Front Prediction

Fluid Saturation Difference



Tracer Concentration



Simulation Time: 1 year

Phase II Pre-Test Predictions of Tracer Breakthrough Times

Table 20. Fluorescein from Upper Injection Boreholes.
(Refer to M&O/YMP file: cons.trc, generated July 9, 1998.)

Borehole number	5% breakthrough concentration	50% breakthrough concentration	Normalized concentration at 1 yr
16	27 days	68 days	1.0
17	48 days	118 days	1.0
14	118 days	238 days	0.87
15	103 days	218 days	0.90
13	103 days	218 days	0.90
12	212 days	> 1 yr	0.46
Remaining collection boreholes	> 1 yr	> 1 yr	0.0

Phase II Modeling: Fluid Saturation Distribution Simulation

Initial

After 1 year on injection