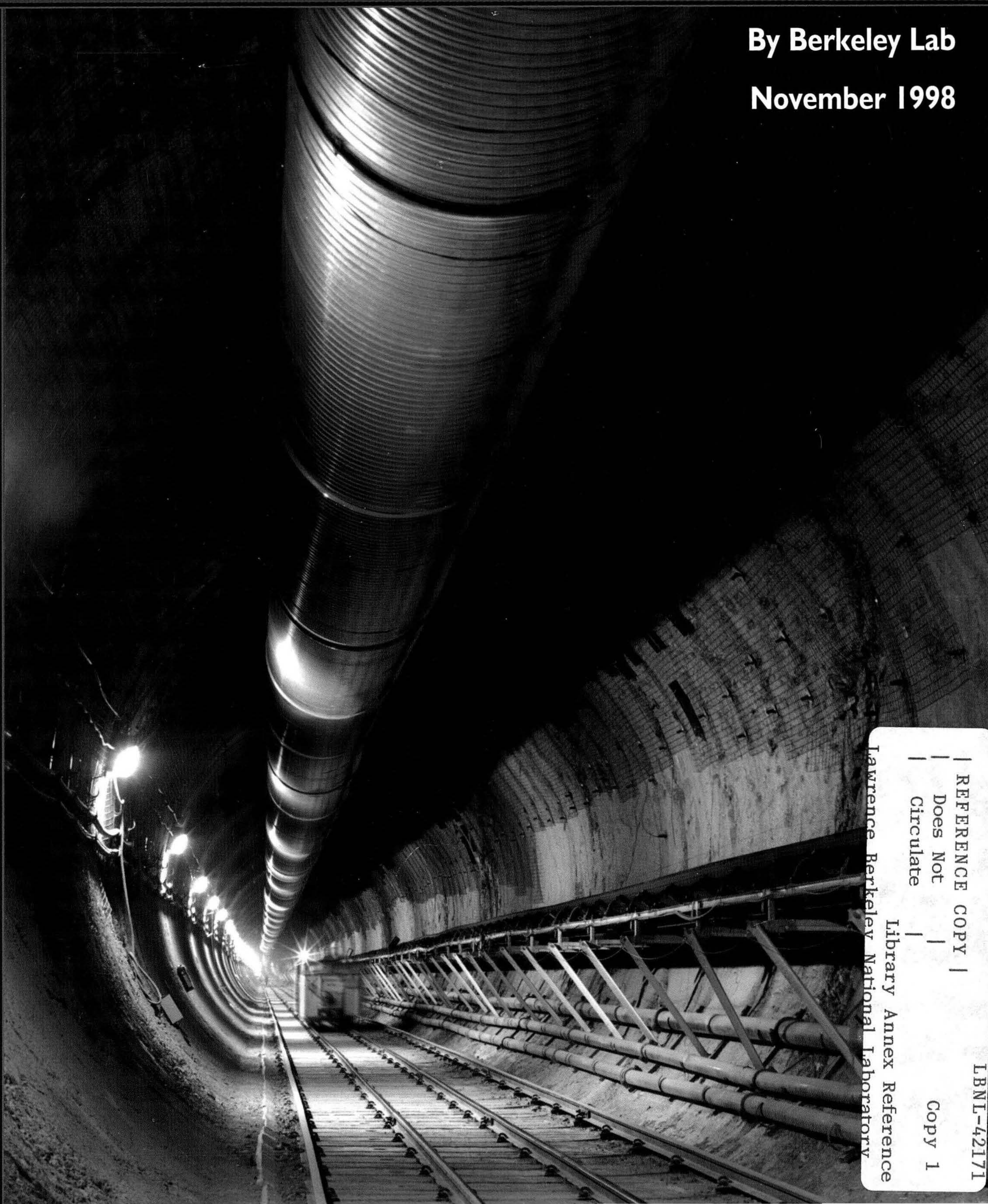
LBNL-42171

Ambient Field Testing

By Berkeley Lab

November 1998

Yucca Mountain Project



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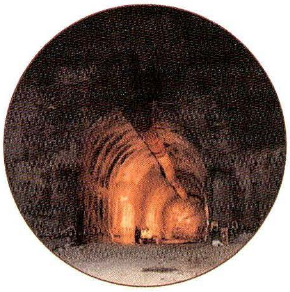

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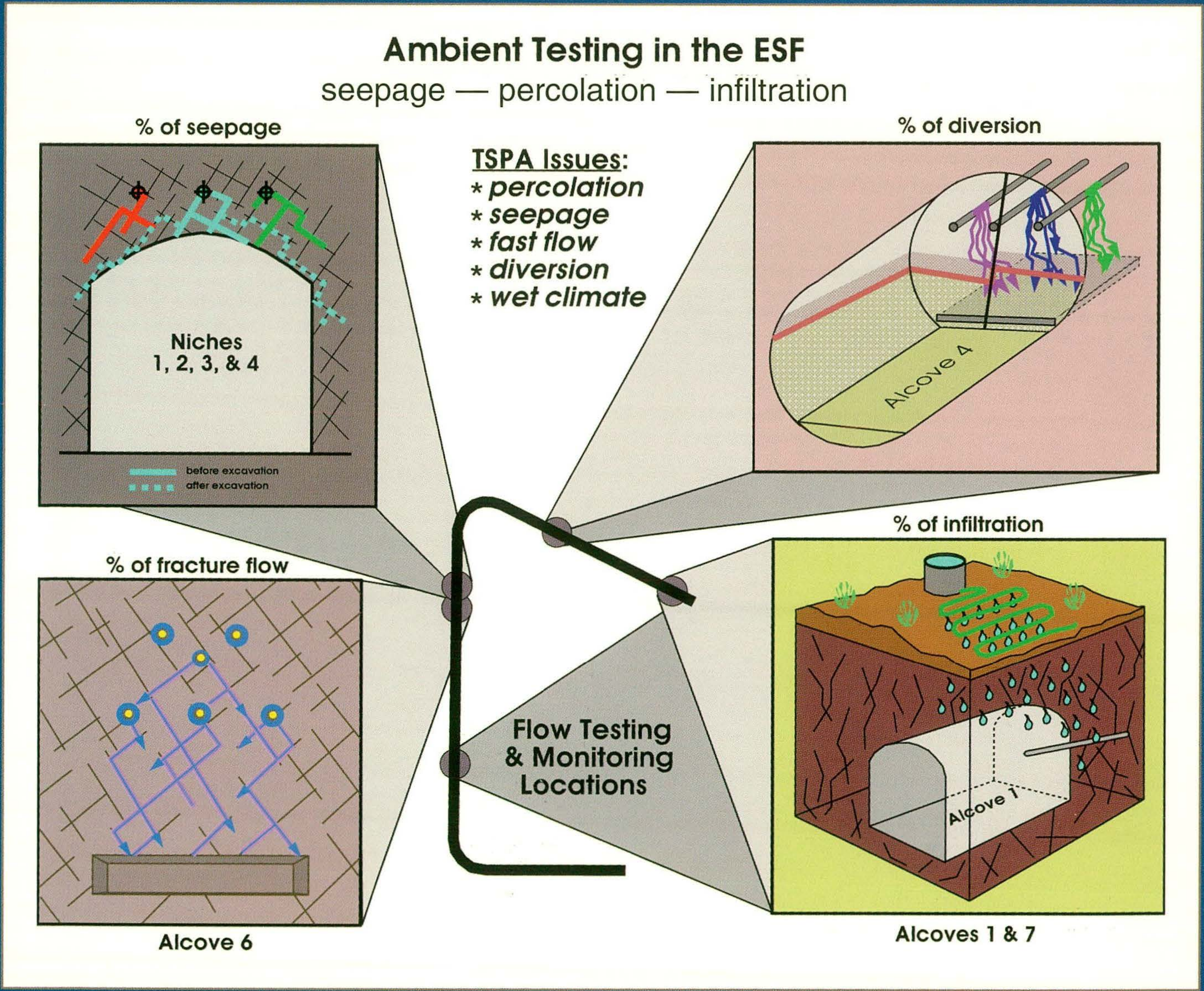
The Current Ambient Field Testing Program has 4 Major Tests:

- **Drift-Scale Seepage Test** —
  To evaluate the % of Seepage
- **Fracture Flow, Fracture-Matrix Interaction Test** —
  To evaluate the % of fracture flow
- **The Paintbrush Flow Test** —
  To evaluate the % of diversion within the PTn
- **Alcoves 1 and 7 Testing** —
  To evaluate the % of infiltration reaching the drift



INTRODUCTION

Yucca Mountain

The mission of the Department of Energy's Office of Civilian Radioactive Waste Management is to safely manage and dispose of the nation's spent nuclear fuel and high-level radioactive waste in a geologic repository. A potential site at Yucca Mountain, Nevada, is currently being evaluated by the DOE to assess if the site is suitable for the long-term containment of high-level waste packages over thousands of years.

Purpose

To investigate important technical issues inherent in the construction, operation, closure, and performance of the repository, a series of experiments have been planned for the Exploratory Studies Facility (ESF) located inside Yucca Mountain. These experiments are in response to the concern that water may flow through the mountain and enter the repository. Resulting moisture could potentially corrode the containers and allow waste degradation products to be released, eventually to areas accessible to human contact. To address this concern, investigators need to understand the hydrologic processes currently existing at Yucca Mountain, especially in the ESF units, where waste will potentially be stored. The Ambient Field Testing Program deals specifically with evaluating how much, how fast, and through which pathways moisture will penetrate from the surface of the mountain into the area of the proposed waste emplacement, and from there to the accessible environment. This program is critical in assessing the performance of Yucca Mountain as a potential site for the national nuclear waste repository.

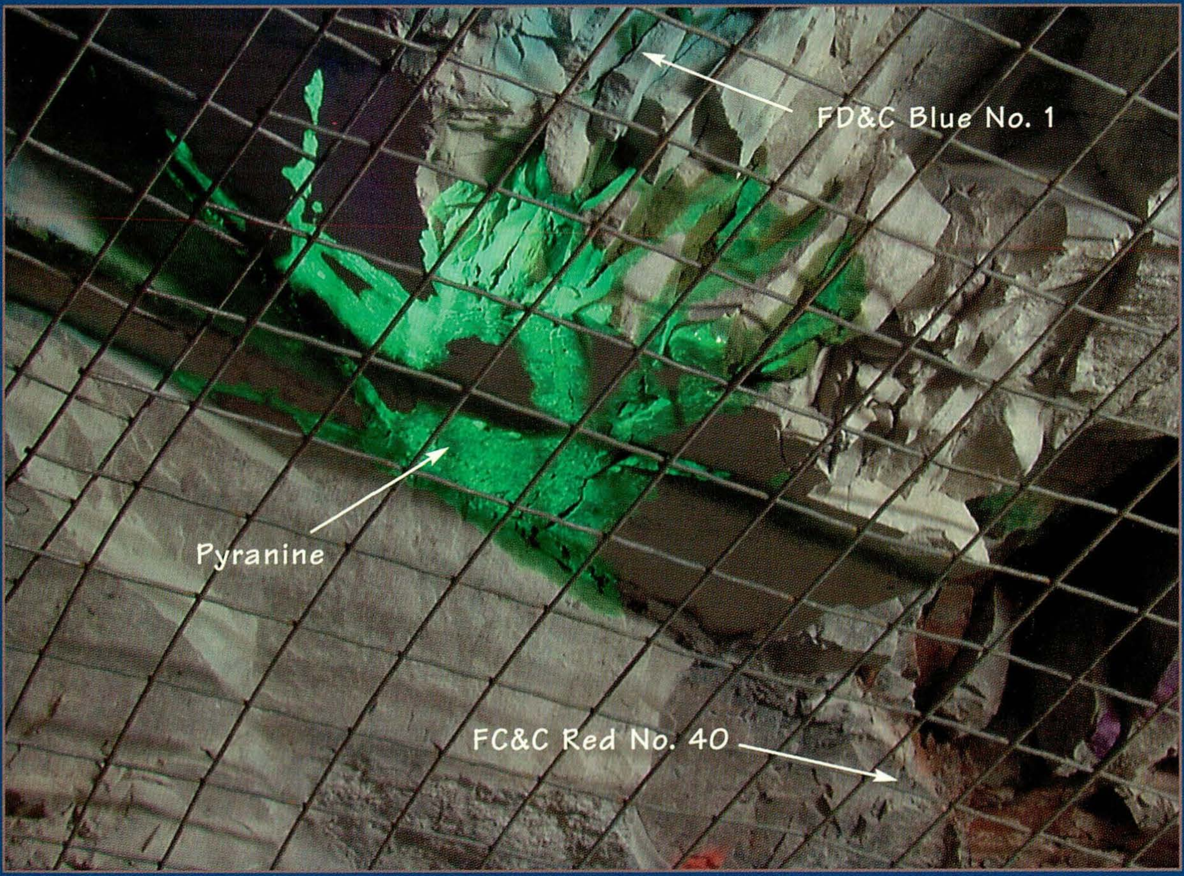
Approach

The unifying purpose of the Ambient Field Testing Program is to acquire a greater understanding of rock permeability — the paths moisture takes and the rate at which moisture travels through the different geological layers of Yucca Mountain. In addition, results of these tests will be used to refine our present conceptual and numerical models of Yucca Mountain, ensuring that models such as the UZ site-scale and drift-scale computer models are as accurate and sophisticated as they need to be in order to faithfully represent and predict moisture flow within the mountain. All of these efforts will be combined to assess the performance of Yucca Mountain as a potential repository site.

The construction of the ESF Main Drift and Cross Drift provides the opportunity to evaluate the process of seepage into drifts at various scales in the three major rock units at the repository level. The field testing program is designed to address the issue of potential seepage into the proposed waste emplacement drifts, and includes integrated tests to evaluate this process—from the smallest scale to the full repository scale. In order to accomplish the evaluation at the various scales, the tests are being conducted within specially designed testing alcoves and in a series of smaller niches that are located at scientifically important locations within the ESF.

The Ambient Field Testing Program was initiated in 1997 to obtain data sufficient to provide an increased understanding of percolation within the mountain and to ensure a credible calibration of the UZ models—critical input for the final Total Systems Performance Assessment (TSPA) that is required as part of the licensing process for the potential repository.

Wetting front containing pyranine beneath 4.27-4.57 m (14-15 ft) test interval at niche 3650.



Drift-Scale Seepage Test

These tests specifically address the conditions under which, and the rate at which, moisture could seep into niches (short drifts) in the repository region. Test goals are to determine the amount of seepage into drifts under a variety of episodic pulse events and to identify potential fast flow paths. Seepage into drifts controls the conditions in the ESF environment, the amount of water contacting waste, the rate of waste mobilization, and the transport of radionuclides within the drift and ultimately outside the repository region.

Ambient hydrologic conditions of the repository rock were measured in borehole clusters and niches located in the ESF. In addition, water containing dye was released in the boreholes to simulate an episodic pulse of natural water moving through the rock.

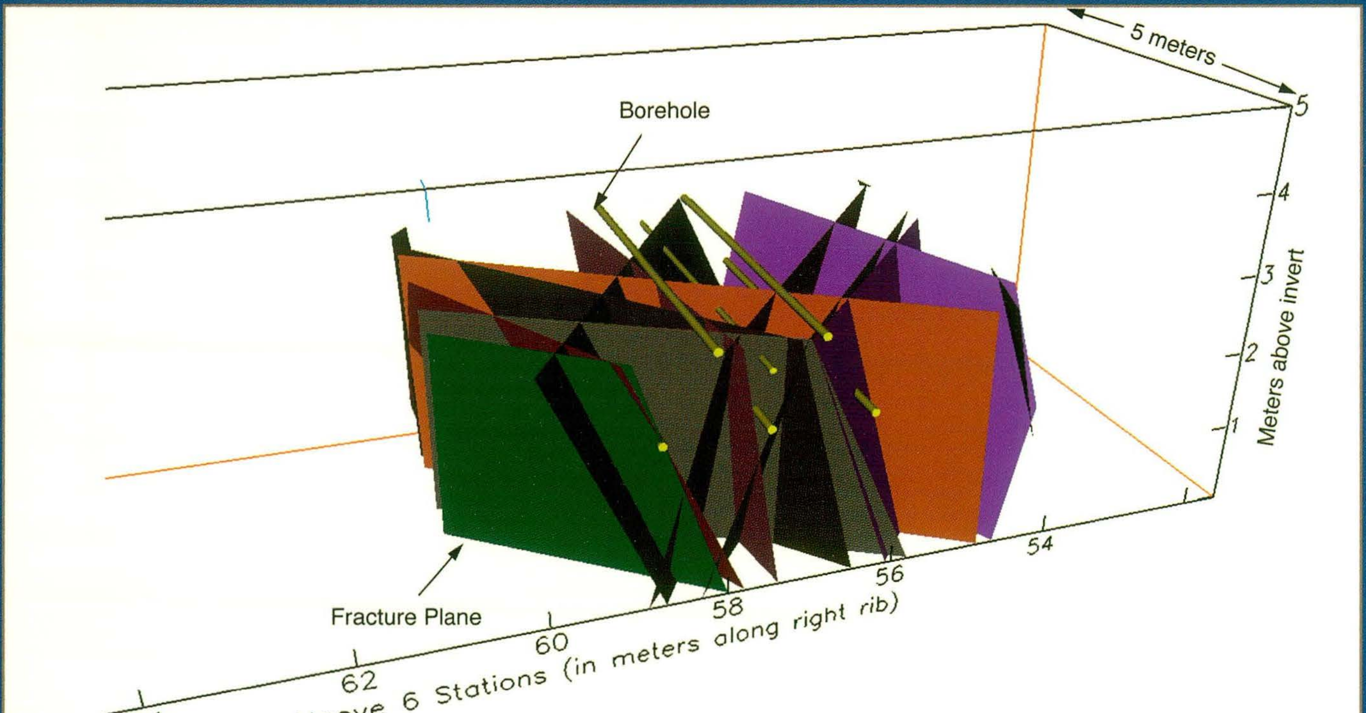
The seepage threshold tests were completed at Niche 3650 (3650m from the ESF North Portal). Moisture monitoring at Niche 3655 by the U.S. Geological Survey (USGS) will continue for one more year. The plan is to switch the testing and monitoring activities between these two niches in the near future.

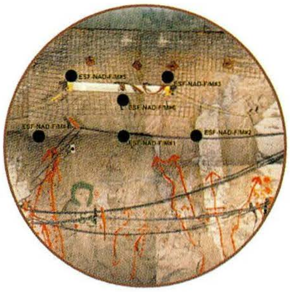
Scientists will use the results to predict whether water percolating downward above a mined opening (waste emplacement drift or tunnel) will drip into the opening because of gravity, or migrate around the opening due to capillary retention (i.e., a drift acting as a barrier). It is important to determine whether a mined opening acts as a capillary barrier because the barrier may help isolate the waste by preventing water from entering the drift and coming into contact with waste packages.

Air-permeability tests in borehole clusters were performed to characterize the rock and to select borehole intervals for subsequent liquid-release tests. These liquid-release tests involved controlled release of water with dye tracers. Niches were then excavated and examined for the presence of dyed water to determine if and how far the dyed water had traveled.

Tests were repeated at various flow rates and injection volumes to further quantify seepage. Numerical modeling was used to design the tests and predict the outcome, and test results were used to further refine the models. After completion of the active testing phase, long-term monitoring of moisture was conducted, using sensors installed in the niches. Moisture measurements were used to calculate water flow and to quantify the interaction between fast flow paths and rock matrix.

Projected Fractures and Boreholes: Fracture-Matrix Interaction Testbed.





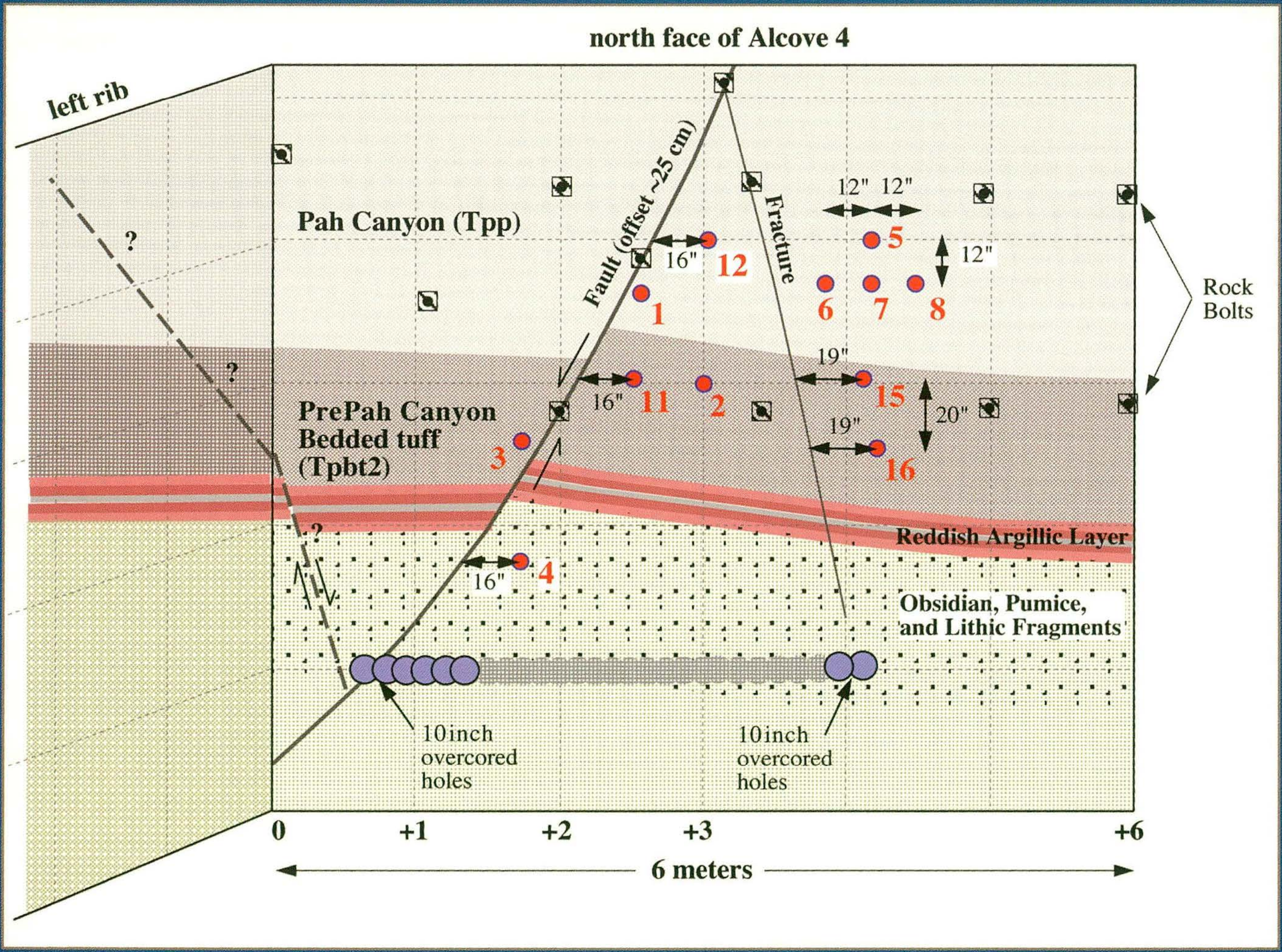
Fracture Flow, Fracture-Matrix Interaction Test

Investigators are conducting tests on site to better understand the relation between fracture flow, fracture-matrix (rock mass) interaction, fracture surface area, and matrix flow processes in the ESF at Yucca Mountain. Such tests can provide the data needed to quantify and differentiate fast fracture flows from percolation through the rock matrix. The ratio of fracture flow versus matrix flow can be used to determine how effective ESF rock barriers will be in isolating waste.

The tests are accomplished with a combination of boreholes and a small-scale excavation (slot) near the floor of the tunnel. The slot is instrumented to collect any traced water injected into the boreholes. After a flow field is established, the fractured rock is sampled between the injection borehole and the slot to quantify the flow processes and fracture-matrix interactions.

The results of these *in-situ* tests will be used to update and refine our present computer models of Yucca Mountain to ensure that the numerical models represent the conditions found within the mountain. Our current understanding of matrix properties, fracture-matrix interaction, and fracture flow processes based on laboratory studies must be verified and improved by the field conditions provided by the ESF.

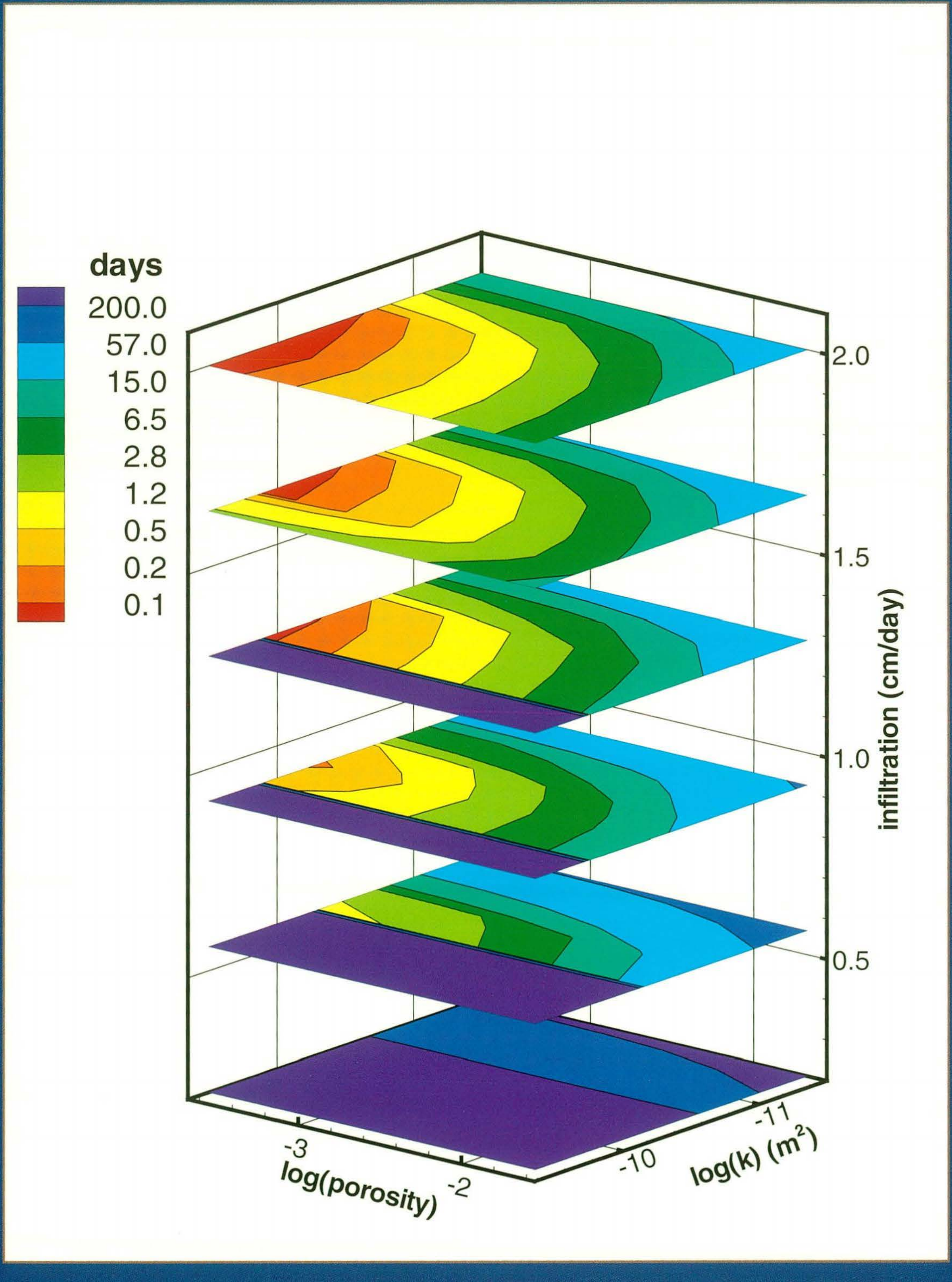
PTn Flow Study:
Geological sketch and borehole/slot layout along north face of Alcove 4.



Paintbrush Flow Test

The rock layer beneath the Tiva Canyon rock unit, the Paintbrush nonwelded unit (PTn), lies between Yucca Mountain's surface and the site of the potential repository. In assessing the effectiveness of the PTn as a natural barrier for infiltration, investigators will measure fracture-matrix flow, evaluate horizontal diversion of flow along interfaces between different lithologies found within the unit, and measure storage effects, all of which may dampen episodic infiltration pulses before they reach the Topopah Spring welded unit (TSw–the repository horizon). These activities will characterize the fracture-flow and fracture-matrix interactions in the PTn, and provide the field data for testing different flow models. The test involves drilling a series of near-horizontal boreholes in a test area located at the end of Alcove 4. The test bed includes the Pah Canyon unit, the Pah Canyon bedded tuff, an argillic layer, a fault, and a fracture trace. Water with tracers is introduced into the boreholes, and the flows through matrix and fractures are monitored with boreholes. A slot below the test bed is instrumented to collect influx. The results of this study will help determine the components of fracture and matrix flow, lateral flow, the effects of lithologic boundaries, and the effects of flows and overall rates of percolation through the PTn. The results will be used to update and refine the site-scale unsaturated zone, hydrologic-flow model that will be used to assess the performance of the Yucca Mountain as a potential repository for radioactive waste.

Sensitivity of wetting front arrival time at Alcove 1 to fracture permeability, fracture porosity, surface infiltration rate, and fracture-matrix connection area (fmx).

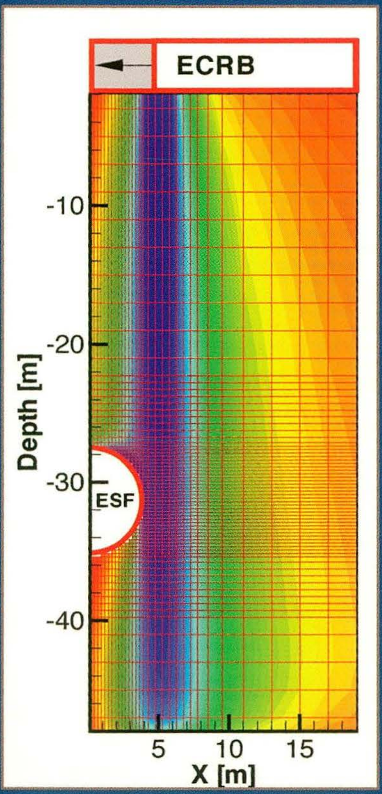


Alcoves 1 and 7 Testing

Large-scale infiltration studies have been conducted by the USGS and Berkeley Lab in Alcoves 1 and 7. Moisture monitoring networks have been installed to identify and measure the location, timing, and quantities of infiltration and deep percolation resulting from the heavy rainfall expected under El Niño conditions. The results of these studies will be used to refine our understanding of the conceptual model of future climate change. These studies will also provide the opportunity to evaluate the role of open surface fractures and their influence on infiltration rates.

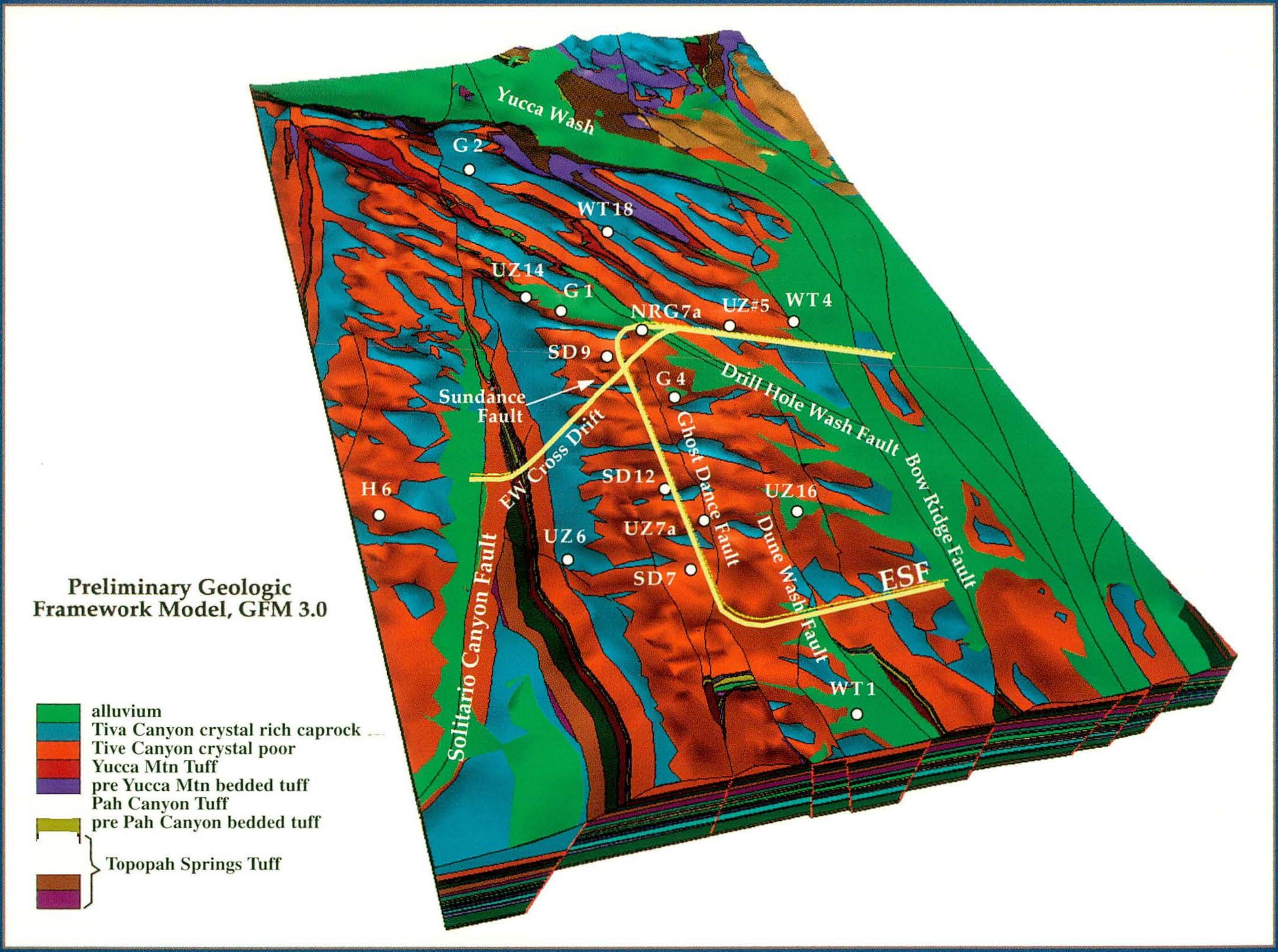
An active infiltration experiment will be initiated at the surface directly above the end of Alcove 1 to introduce controlled volumes of water above the alcove, providing the most likely conditions under which fracture flow and seepage might occur. A percentage of the water introduced at the surface is expected to seep into Alcove 1, which lies approximately 30 meters beneath the land surface. If there is limited seepage into Alcove 1 during the current El Niño event, in combination with artificial introduction of water at the surface, the study will strengthen confidence that seepage into drifts under normal conditions will be minimal. The UZ site-scale and drift-scale models will be used to predict potential seepage, and then after testing they will be refined using the final test data.

The experience from Alcove 1, together with existing data from Alcove 7 walls, cores, and boreholes, will be used to construct models for deep infiltration and percolation through the Ghost Dance Fault zones and in the neighboring nonfaulted rock zones. The amount of percolation required to initiate deep seepage into Alcove 7 (approximately 200 meters beneath the surface) will be evaluated. After completion of testing by USGS, Berkeley Lab will compare the simulated results of seepage with the measured influx in Alcove 7. The presence or absence of measurable seepage in Alcove 7 will be used to evaluate whether surface infiltration can be correlated with percolation at the repository level, and whether drift seepage can be quantified from surface infiltration data. The findings can be used to calibrate models for the unsaturated zone at Yucca Mountain.



Predictions of construction water usage and resulting liquid saturation distribution.

Location of ESF Main Drift and Cross Drift overlays the geological framework model.



Additional Activities in the ESF and Cross Drift

Drift to Drift Study

Prior to the construction of the ESF Cross Drift, computer modeling was used to predict how moisture will flow between the new drift and the ESF Main Drift. After construction of the Cross Drift, instruments were placed in both the Cross Drift and the ESF Main Drift, and tests using controlled release of water will be conducted to determine if water from one drift can be detected in the other drift. The seepage into the lower ESF drift can be used to quantify the travel times between drifts and the potential water seepage rates into drifts. Travel times and seepage rates can determine the performance of most of the waste isolation attributes in drifts. The field testing and monitoring will be performed by Berkeley Lab and the USGS and will be strongly coupled with the UZ Site-Scale Model and Drift Scale Model. The models will be used to design the tests, and the data will be used to calibrate these models. This study also will be used to contribute to the design of performance confirmation drifts, which are planned to monitor the waste emplacement drifts.

Drift-Scale Seepage Test: Additional Niches

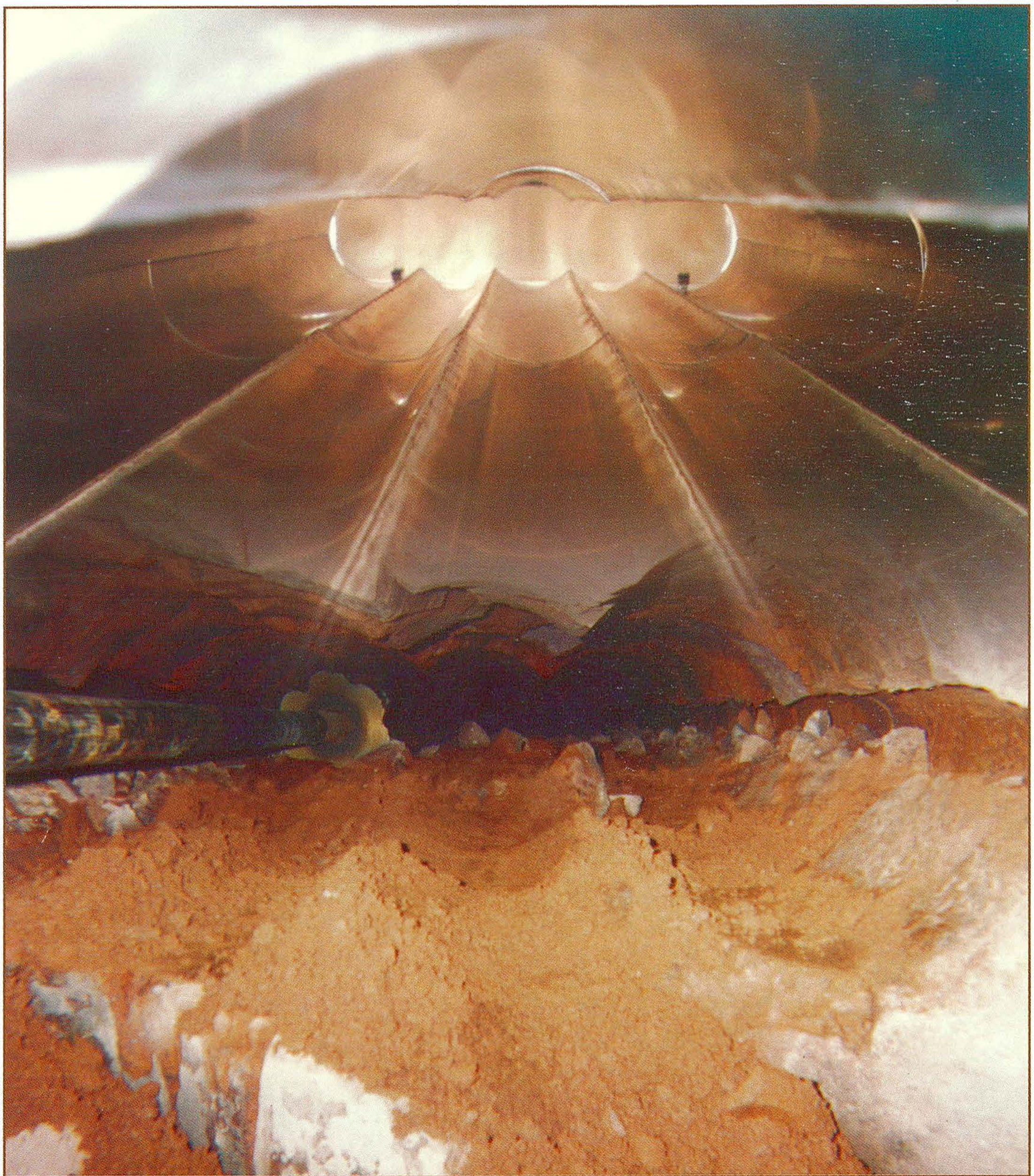
As a continuation of the Drift-Scale Seepage Test, additional niche studies will be conducted in the ESF Drift and in the Cross Drift. Niche 3 is located in the ESF near the cross-over point of the Cross Drift, and Niche 4 is placed in a highly fractured unit of the ESF. The two niches planned for the Cross Drift will be designed to conduct similar tests in the lower lithophysal and the lower nonlithophysal units of the Topopah Spring welded unit. These two units will comprise approximately 80 percent of the rocks in the repository horizon.

Fracture Flow, Fracture-Matrix Interaction Tests in the Cross Drift

As a continuation of work being performed in the middle nonlithophysal zone in the ESF, the fracture flow, fracture-matrix interaction, effective fracture surface area, and matrix imbibition processes will be evaluated in both the lower lithophysal and nonlithophysal units in the Cross Drift. The combination of the two studies will provide an understanding of the fracture-matrix interactions in all three repository units. *In-situ* tests of fracture flows and the competing processes of matrix imbibition and flow will provide the data needed to partition the fast fracture flows from bulk percolation through the matrix. The ratio of fracture flow to matrix flow can determine the waste isolation capacities of the rock barriers.

Moisture Monitoring and Plume Evaluation Along the Cross Drift

Berkeley Lab and the USGS have been monitoring moisture conditions in the Cross Drift during the excavation and evaluating the impact of excavation, ventilation, and construction water usage on the surrounding rocks before, during, and after the drift excavation. Construction water needed for excavation and dust control will predominately migrate downward from the drift to underlying barriers. The field testing and monitoring have been strongly coupled with the UZ Site-Scale Model and Drift Scale Model. The models have been used to design the tests, and the data will be used to calibrate the models for input into the TSPA for License Application. The data collected in the drift monitoring will also be used for evaluation of the ventilation system, dust control, and other issues for design of waste emplacement drifts and performance confirmation drifts.



A composite figure showing the slots drilled for the fracture matrix interaction test in Alcove 6.

PHOTOS BY ROHIT SALVE. COMPOSITE BY MARIA FINK.

On the Front Cover

The main drift of the Exploratory Studies Facility (ESF) at Yucca Mountain, Nevada.
Photo: Yucca Mountain Project Office.

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