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THE COOLING PHASE OF THE YUCCA MOUNTAIN HEATER TEST

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RESEARCH OBJECTIVES

As part of a multilaboratory team, Berkeley Lab is conducting a large-scale *in situ* thermal test, the Drift Scale Test (DST), in an underground facility at Yucca Mountain, Nevada, the site for a proposed high-level nuclear waste repository. The test is presently in the second year of the natural cooling phase following four years of heating, during which an approximate heating rate of 185 kW was supplied by nine canister heaters (placed in a drift 47.5 m in length and 5 m in diameter) and fifty 11-meter-long rod heaters installed in boreholes drilled perpendicular to the drift. The heat thus provided set in motion coupled thermal (T), hydrological (H), chemical (C), and mechanical (M) processes of the type that would be generated from heating in the proposed repository during its postclosure period. The objective of this test is to gain an in-depth understanding of THMC coupled processes within fractured welded volcanic tuff situated above the water table.

APPROACH

The DST has involved a close integration of measurements and numerical modeling. Thousands of sensors installed in nearly 100 boreholes, within a rock block of $60 \times 60 \times 60\ m^3$, continuously monitor the temperature, relative humidity, and mechanical displacement. Geophysical and air-permeability measurements have been performed at quarterly intervals to track moisture redistribution resulting from boiling, vapor transport, and condensation. Water and gas samples have also been collected periodically from the test block for chemical and isotopic analyses. In addition, TH, THC, and THM processes have been simulated using numerical models that realistically incorporate the three-dimensional test configuration and the complex multiple processes. Model predictions have been compared to the aforementioned extensive set of measured data.

ACCOMPLISHMENTS

Manifestations of coupled THMC processes in the rich set of measured data agree well with TH, THC, and THM model predictions. During the heating phase, expanding zones of reduced liquid saturation in the rock matrix around the heaters predicted by TH simulations were consistent with zones of drying shown in neutron logging data, cross-hole radar tomograms, and electrical resistivity tomography data. During (the ongoing) cooling, the geophysical data has indicated slow rewetting at the edge of the drying zone, consistent with model predictions. Simulated fracture liquid-saturation has indicated that little water is likely to be collected during the cooling phase, as has been the case. Figure 1 shows the simulated and measured temperatures at the end of the heating phase and after six months of cooling in three boreholes. The plateau at the nominal boiling temperature of ~ 97°C indicates a liquid and vapor two-phase zone that is a good candidate for water collection. Note the disappearance of these two-phase zones during the cooling phase. Air-permeability measurements confirm modeled predictions of TH processes (drying and wetting in fractures) and THM processes (closing and opening of fractures).

SIGNIFICANCE OF FINDINGS

A close integration of measurements and sophisticated simulations carried out in this large-scale and long-term test has contributed much toward the understanding of THMC coupled processes in fractured rock of the unsaturated zone.

RELATED PUBLICATIONS

Birkholzer, J.T., and Y.W. Tsang, Modeling the thermal-hydrological processes in a large-scale underground heater test in partially saturated fractured tuff. Water Resour. Res, 36(6), 1431–1448, 2000.

ACKNOWLEDGMENTS

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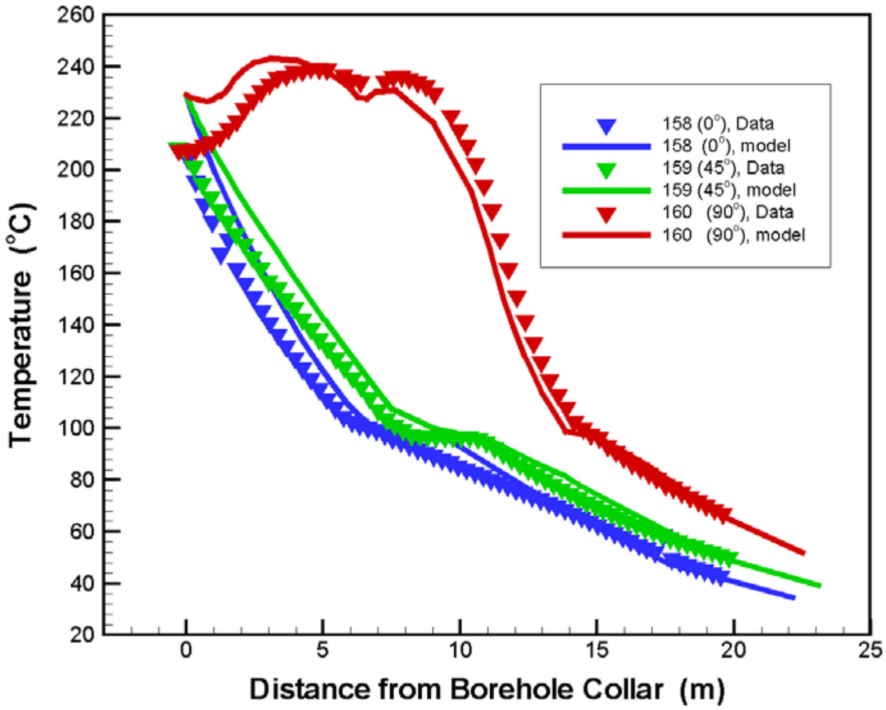
Figure 1. Simulated and measured temperature profiles in boreholes 158, 159, and 160, at (a) 48 months of heating and at (b) 6 months of cooling

(a) 48 Months of Heating



(b) 6 Months of Cooling