Estimating the Large-Scale Fracture Permeability of Unsaturated Rock Using Barometric Pressure Data

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RESEARCH OBJECTIVES

Fracture permeability is a key parameter for flow and transport simulations using dual-continuum approaches. However, how to properly estimate fracture permeability at large spatial scales is still a challenging task. The large-scale model parameters for fractures are in general more difficult to measure at the site than those for the rock matrix. The main objective of this study is to develop an approach for estimating large-scale fracture permeability, using the changes in subsurface pneumatic pressure in response to barometric pressure changes at the land surface.

APPROACH

Large-scale fracture permeabilities for the Yucca Mountain site are estimated through a comprehensive modeling effort by using pneumatic data measured from boreholes at the site. The modeling approach, built on a three-dimensional (3-D) mountain-scale unsaturated zone (UZ) flow model, incorporates pneumatic data into a modeling analysis of two-phase liquid and gas flow under ambient geothermal conditions. The gas-flow modeling studies are performed under present-day infiltration conditions using the site-specific geological model and characterization data. Calibration of model-predicted gas pressures against field-measured pneumatic data leads to a methodology for estimating fracture permeability in the unsaturated fractured rock.

ACCOMPLISHMENTS

A three-dimensional model of gas flow in the unsaturated fractured rock of Yucca Mountain has been developed. Large-scale fracture permeabilities of the site have been calculated through model calibration. This calibration was done through comparing gas-flow simulation results with the measured pneumatic data from underground boreholes. Fracture permeabilities, initially estimated by small-scale air-injection testing and 1-D model inversion, were adjusted to obtain an overall good match between the 3-D model predictions and pneumatic data (see Figure 1). The ability to match field pneumatic data observed from multiple sources, including pneumatic data over a long time, indicates the reliability of the numerical model in describing air and water flow processes within the Yucca Mountain UZ system, through better estimates of fracture flow properties.

SIGNIFICANCE OF FINDINGS

The results of this study indicate that using field-measured pneumatic data, in combination with numerical modeling analyses, provides a practical and powerful technique for estimating flow properties of vadose zone formations. Periodic responses of subsurface gas-pressure signals to surface barometric-pressure changes, which are easy to measure, may reveal invaluable information on gas mobility in unsaturated porous media. In addition, this work demonstrates that multidimensional effects on model-estimated permeability are significant when determining fracture permeability in heterogeneous fractured media. These effects can be captured only by 3-D modeling analyses on relevant model scales.

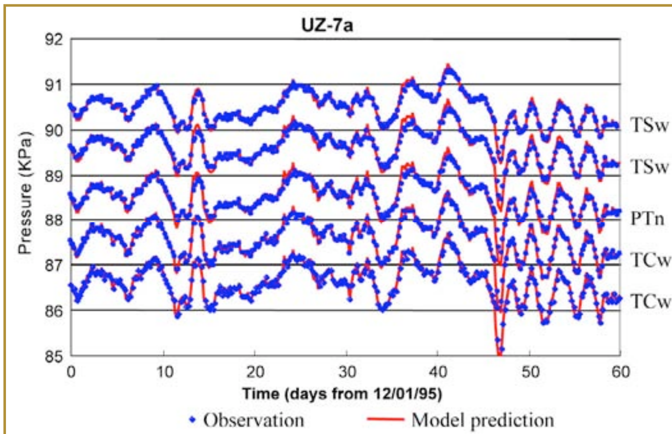

Figure 1. Comparison of simulated and observed gas pressures at borehole UZ-7a over a 60-day period, with 3-D model calibration.

RELATED PUBLICATIONS

Wu, Yu-Shu, Keni Zhang, and Hui-Hai Liu, Estimating large-scale fracture permeability of unsaturated rock using barometric pressure data. LBNL-57614. Vadose Zone Journal, 5, 1129–1142, 2006.

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