Two-D Simulations of Flow and Transport on a Meter-Sized Unsaturated Fractured Tuff Block

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Abstract

Two-D numerical flow and transport experiments were performed with a meter-sized unsaturated fractured block in an attempt to validate the active fracture model (AFM) by estimating γ, a positive constant relating the fraction of active fractures to the effective water saturation for the block. Two different models developed for the study include a discrete fracture network model (DFNM) and a dual continuum model (DCM). The DFNM served to synthetically generate experimental measurements for water flow rates and tracer breakthroughs, against which numerical simulation data with DCM was calibrated to estimate γ values for the fracture network. Water flow rates were monitored at both top and bottom to find balanced ("pseudo-steady") states, when a pulse of tracer injection was initiated from the top of the block. During the transient state, water flow rates in DCM did not closely predict the measurements from DFNM, which show step-wise increments with time. Based on goodness-of-fit values, the water flow rates in the range of 7.12×10^{-8} and 7.12×10^{-7} kg/s (0.2 – 2.0 % of the saturated flow rate) provide better estimates of γ. The DCM may be not suitable to estimate γ when the injection rates are too high or low. Water flows predominantly through a few major fractures as preferential fast flow when the injection rate is high (> 10 % of saturated flow rate), and capillary pressure solely governs water flow when the injection rate is low (<0.02%). At pseudo-steady state, tracer breakthrough curves show that DCM simulates very well the tracer transport in DFNM, however, the breakthroughs were not strongly sensitive to γ. The results suggest that transient flow experiments within a certain range of injection rates would provide more reliable estimates of γ.