

Lawrence Berkeley National Laboratory

Recent Work

Title

A reaction-transport approach for assessing infiltration rates in unsaturated fractured rock from stable isotope compositions

Permalink

<https://escholarship.org/uc/item/1529694c>

Authors

Singleton, Michael J.
Sonnenthal, Eric L.

Publication Date

2004-09-09

A reaction-transport approach for assessing infiltration rates in unsaturated fractured rock from stable isotope compositions

Michael J. Singleton and Eric L. Sonnenthal

We use a reaction-transport model to assess the time scales and infiltration rates as indicated from stable isotope data from the proposed Yucca Mountain nuclear waste repository. These models simulate the response of stable isotope compositions in fracture and matrix water/vapor to various climate and infiltration conditions. The impact of changes in infiltration rate on stable isotope compositions is compared with solutes such as Cl and Sr. The stable isotope composition of water in the unsaturated zone is primarily related to the input composition, transport (downward percolation and upward transpiration), and evaporation. Evaporation increases the concentration of solutes in infiltrating waters and typically shifts stable isotope compositions to higher $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values. However, these effects are minimized to some extent in fractured rock because waters may travel downward along fractures, quickly passing below the evaporation zone. The timescales over which the stable isotope compositions reflect infiltration conditions are affected by advection rates and fracture-matrix interaction. We use the principles of multiple interacting continua (dual permeability) to evaluate the effects of fracture-matrix interaction on stable isotope compositions in fractured rock. Periodic infiltration models that capture winter precipitation followed by summer evaporation suggest that disequilibrium between fracture and matrix waters can persist for decades to centuries depending on fracture spacing and the hydrological properties of the matrix.

When considered in one-dimension, zero or negative infiltration leads to stable isotope profiles that resemble a diffusion profile, extending downward with time from the surface. A two-dimensional, mountain-scale model with variable topography indicates that these profiles may be disturbed by lateral migration from areas where infiltration rates are above zero. Based on these preliminary results, a change in the isotopic composition of infiltrating waters can take up to several thousand to tens of thousands of years to equilibrate with the matrix pore waters at the deeper levels of the repository. The simulation results suggest that samples and water isotope determinations from the upper 100 m will provide the most information about infiltration during the Holocene.