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Comparing Heat and Solute Transport in a Discrete Rock Fracture with Variable Aperture Under Natural Groundwater Flow Conditions

Issam Bou Jaoude, Kent Novakowski, and Bernard Kueper
Queen's University, Civil Engineering, Kingston, Canada (4ib5@queensu.ca)

The application of heat and solute transport in fractured rock can provide different but valuable information, especially with the need to characterize underground conditions for the application of renewable energy storage systems, treatment mechanisms at contaminated sites and isolation of energy byproducts, such as radioactive waste. A small number of papers have concurrently studied heat and solute transport to explore transport mechanisms in fractured bedrock groundwater settings. In this research we have compared heat and solute transport in a discrete fracture using numerical modeling. The domain considered for the simulations is an 80-m by 80-m by 60-m thick block with a single horizontal fracture dividing the domain in half. Fracture aperture heterogeneity was described from geostatistical properties with fracture aperture means of up to 1,000 μm, variances as high as 30,000 μm2 and isotropic correlation lengths up to 10 m. A uniform temperature of 10°C was set for the initial condition, and a constant line heat source of 20°C extending 1 m into the matrix along either side of the fracture was assigned. The groundwater flow in the matrix was assumed to be negligible and flow in the fracture was set to values typical of natural groundwater conditions with velocities less than 100 m/day and associated gradients of less than 0.05. A uniform isotropic thermal conductivity varying between 2 and 4 W/m °C was considered for the matrix. HydroGeoSphere, a 3-D numerical model based on the control-volume finite element method was employed for the simulations. In a fracture under natural groundwater conditions, heat will propagate into closed fracture aperture areas from all directions, thus transferring heat from both the heated matrix above and below, and from the heated fluid enveloping it. The movement of heat in closed aperture areas consequently smoothens the spatial distribution of the thermal front in the fracture. It is concluded that the effect of heterogeneity of the fracture aperture can be better understood using solute transport while heat transport provides a better estimate of the mean fracture aperture.