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The Effect of Fracture Aperture Variability on Heat Transport in Discrete Rock Fractures Under Natural Groundwater Flow Conditions

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The growing demand for renewable energy, the increasing usage of heat as a treatment mechanism in contaminated sites and the developing need for long term isolation of energy byproducts, such as radioactive waste, has resulted in the need to characterize heat transfer in low-porosity fractured media. Numerical modeling of heat transfer in low porosity fractured rock is particularly challenging because of the complexity associated with characterization of fracture aperture heterogeneity. Flow channeling associated with heterogeneity in the fracture aperture may cause non-uniform temperature distribution in the adjacent rock body. In this research we have assessed the effect of heterogeneity in the fracture aperture on the spatial distribution of a migrating thermal front in a discrete fracture setting. The domain considered for the simulation is an 80-m by 80-m by 60-m block with a single horizontal fracture dividing the domain in half. A uniform temperature of 10˚C was initially set for the model, and a constant line heat source of 20˚C extending 1 m into the matrix along either side of the fracture was used. The flow in the matrix was assumed to be extremely small, with a uniform isotropic thermal conductivity varying between 2 and 4 W/m ˚C. *HydroGeoSphere*, a 3-D numerical model based on the control-volume finite element method was used for the simulations. In this research we have demonstrated that under natural groundwater conditions with velocities less than 100 m/day, associated gradients of less than 0.05 and with fracture aperture means of up to 1000 μm, variances as high as 30,000 μm^2 and correlation lengths up to 10 m, the effect of heterogeneity on the spatial distribution of the thermal front is mainly curbed by the thermal conductivity of the rock matrix. The effect of flow channeling on the spatial distribution of the thermal front is minimal. The thermal conductivity of the matrix advances the front at closure points and where aperture sizes are restricted. Where the thermal conductivity of the rock matrix is between 3 and 4 W/m ˚C the spatial distribution of the thermal front for variable aperture fields can be fairly estimated using a uniform field approximation under most natural flow conditions. Our research has also shown that at smaller aperture values (between 125 and 300 μm, for example), the fracture itself plays no significant role in the spatial distribution of the thermal front irrespective of the aperture distribution.