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Modeling of heat transport through Fractures with emphasis to roughness and aperture variability

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Fractured media are characterized by multi-scale heterogeneities implying high spatial variability of hydraulic properties. At the fracture network scale, spatial organization of fluxes is controlled by the fracture network geometry, itself characterized by fracture connectivity, fracture density, and the respective lengths and apertures of the fractures within the network. At the fracture scale, the variability of the fluxes is mainly controlled by fracture roughness and aperture variability. The multi-scale heterogeneities of fractured rocks imply complexities for prediction of solute and heat transport in space and time, and often lead to the so-called “anomalous transport” behavior. In homogeneous media, heat transport can be described using Fourier′s law opening the possibility to apply the advection-dispersion equation to predict transport behavior. However, in real fractured media a “non-Fourier transport” often dominates. The latter phenomenon, characterized by asymmetric breakthrough shape, early breakthrough and long tailing cannot be described by the classical advection-dispersion equation.

In the present study, we focus on heat transport within a single fracture and we explore the respective roles of fracture roughness and aperture variability. Fracture roughness has two main effects on heat transport, flow channeling and a spatial variation of heat exchange area between fluid and rock. Fracture aperture variability controls the variability of fracture flow, and thus induces spatial variation of heat transport in a fracture. Micro- to macro-scale fracture roughness measurements will be performed in the field and the laboratory using a terrestrial LIDAR, a X-Ray CT-Scanner Alpha, and a Microscope Keyence VHX 100. Thereafter the measurements will be used to better describe fracture geometry taking in account discontinuity type. To further improve the understanding of heat transfer between fracture and matrix, we will numerically model heat transport as function of fracture roughness and variable aperture using fracture roughness measurements from micro- to macro-scale natural fractures. Fracture roughness measurements will be analyzed by geostatistical and spectral methods in order to characterize fracture heterogeneities and to evaluate and simulate synthetic fracture geometries. Measured and calibrated synthetic fractures will be used to parameterize numerical heat transport models. We anticipate that these models will reproduce adequately anomalous (non-Fourier) transport behavior and will permit to better understand this behavior.