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Analysis of flow and transport pathways in numerical models of fracture networks with small-scale heterogeneity

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There is a need for improved understanding of the mechanisms controlling solute transport in fractured crystalline rocks in order to address long-term safety analysis of repositories for spent nuclear fuel. In this contribution, flow and transport in three-dimensional discrete fracture networks with internal heterogeneity in aperture and permeability is investigated using a numerical model. A coherent triad of heterogeneity textures with identical correlation length and variance but which greatly differ in connectivity structure are created and mapped to each individual fracture of the network. We then demonstrate how the different assumptions on connectivity structure for textures on the scale of individual fractures leads to different transport behaviour at the scale of the network. Through numerical modelling of multiple scales in a stochastic setting we quantify the relative impact of texture correlation length and connectivity type against network scale, and identify key thresholds for cases where flow dispersion is controlled by single-fracture heterogeneity versus network-scale heterogeneity. Furthermore, we highlight enhanced flow channelling for cases where correlation structure continues across intersections in a network, and discuss application to realistic fracture networks using field data of sparsely fractured crystalline rock from the Swedish candidate repository site for spent nuclear fuel.