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Towards conditioning discrete fracture network models: a Monte Carlo simulation approach including existing site data

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Abstract. Crystalline rocks are inherently more or less densely permeated by fractures at very different scales. They often represent the hydraulically dominant flow paths compared to the low-permeable matrix. Consequently, finding potential sites for high-level waste repositories in crystalline host rock is challenging. Fracture inter-connectivity significantly affects geomechanical integrity and radionuclide transport (Mönig et al., 2020). Hence, an accurate representation of the present-day fracture system is a prerequisite for describing future evolutions of a repository. However, information on fracture properties is spatially limited. This shows the necessity of combining existing fracture data and stochastic fracture network modelling. In this manner, spaces with a lack of information can be considered for modelling (Lei et al., 2017).

In Mrugalla et al. (2020), generic geological models based on statistical parameters were used to test the methodology for a safety analysis in crystalline rock within the scope of the CHRISTA II project. By using representative outcrop data, discrete fracture network (DFN) models of 2D fractures were generated stochastically, upscaled, and mapped onto a finite-element grid. However, individual stochastic fracture network realizations seldom accurately represent geological reality. Additionally, data from existing fractures must be incorporated.

This work aims to understand the uncertainties regarding the location, extent, and other geometrical properties of fractures such as the aperture governing flow patterns. The statistical distributions of these parameters can exhibit significant variations both laterally and depth-wise. Uncertainties are addressed by superimposing a large set of fracture network realizations. For this purpose, Monte Carlo methods are applied to derive a best-guess fracture network. An approximation of the real fracture system will require consideration of known fracture data (e.g. Dorn et al., 2013) from surface and subsequent underground explorations. Site-specific data will be used for demonstration purposes. The focus is on developing a holistic model based on the DFN model and its congruence with field observations. The methodological treatment of underlying data-collection methods, given their different resolutions, accuracies, and restrictions, will be an important aspect.

Moreover, the implications of the effects on three-dimensional radionuclide transport will be exemplarily investigated in the generated model in the sense of what-if scenarios. This is done with special emphasis on matrix–fracture diffusion and adsorption as possible retention mechanisms and parameter sensitivities such as local aperture changes.

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