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Challenges and best practices for modelling fractures in geological repositories

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Abstract. Crystalline rock formations, which are considered potential host rock formations for geological repositories in Germany, often exhibit fractures that complicate the generation of safety assessment models. To quantify the criteria outlined in the Ordinance on Repository Safety Requirements accurately, it is necessary to take these fractures into account and to consider both intact rock and rock mass properties in numerical models.

The consideration of fractures in numerical models is a challenge due to the complex three-dimensional nature of the fractures. In the literature, various methods to approach this challenge are documented, but the combination of assumptions and simplifications often associated with these methods can lead to significant uncertainties in numerical calculations. To address this challenge, we evaluated the suitability of various modelling approaches in fractured media, based on criteria such as accuracy, computational efficiency, ease of implementation, and suitability for specific types of problems. Comparative calculations (benchmarks) are used to develop the corresponding numerical models based on previously defined generic models that contain fractures. In this way, it is possible to clarify the influence of different numerical approaches on modelling results, thus providing a basis for assessing the modelling uncertainties required in the safety case.

We would like to give an overview of two R&D projects, SUSE (Safety analyses for repository systems in crystalline rocks) and PRECODE (Investigating the impacts of mining activities at great depths on the integrity of crystalline rock in the context of high-level radioactive waste disposal). SUSE addresses hydraulic problems, specifically groundwater flow in fractured crystalline rock. Analysing groundwater flow direction and rate is crucial to assess the transport of radionuclides in the geosphere, as they are most likely to be transported by groundwater. Different approaches were tested, such as approaches that consider the fractures in an explicit manner and approaches that try to upscale the heterogeneous fracture properties, and were compared with each other via benchmark cases. The cases specified differ mainly in the number of fractures considered (single fracture and fracture network) and the physical processes to be simulated (fluid flow and solute transport). PRECODE, on the other hand, focuses on mechanical problems, specifically the mechanical integrity of the geological barrier. The integrity must be shown by demonstrating that the dilatant strength and expected fluid pressure do not exceed the strength of the host rock. Different approaches were tested, such as approaches that explicitly represent fractures using discontinuum and continuum methods as well as upscaling approaches that consider only the integral strength of a rock mass, and were compared with each other via benchmark cases. The assumed cases differ mainly in the respective scale considered, such as borehole, tunnel, and repository scales.

Overall, this research provides insight into the challenges and best practices for modelling fractures in geological repositories and for improving the safety of high-level radioactive waste disposal.

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