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Comparison of Model Approaches for Gas Transport in Compacted Bentonite: A Current Task in the International DECOVALEX Project

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The DECOVALEX project is an international research and model comparison collaboration for advancing the understanding and modeling of coupled thermo-hydro-mechanical (THM) processes in geological systems. Prediction of these coupled effects is an essential part of the safety assessment of geologic disposal systems for radioactive waste and spent nuclear fuel, but also for a range of other sub-surface engineering activities such as carbon dioxide subsurface storage, enhanced geothermal systems, and unconventional oil and gas production through hydraulic fracturing. DECOVALEX involves analysis and comparative modeling of state-of-the-art laboratory and field experiments, with various international research teams providing a wide range of perspectives and solutions to these complex problems.

One of the analysis and modeling tasks of the current DECOVALEX phase centers on the transport of gas through low-permeability clay-based materials such as bentonite or argillite rock. In a geological repository for radioactive waste, the corrosion of the ferrous materials, radioactive decay of the waste, radiolysis of organic materials and water, and the microbial breakdown of organic materials will produce gas, the most important of which (by volume) is hydrogen. As gas is produced, it will initially accumulate until gas pressure is eventually high enough to drive gas away from its source. Understanding the long-term fate of such gas transport and its impact on the surrounding materials is therefore important in the development of a geological disposal facility for radioactive waste.

Research teams involved in the modeling task use a range of different approaches to simulate gas transport data from a series of well-controlled laboratory tests, in a staged manner building in complexity (both in terms of the experimental and modelling approaches). Special attention is given to the THM mechanisms controlling factors for initiation and evolution of gas flow, such as gas entry, mechanical damage, pathway dilation and flow, as well as pathway stability and sealing, all of which will impact barrier performance. This presentation will provide an overview of process understanding and model approaches, and then will discuss in more details two specific numerical models to analyze gas-migration laboratory experiments on mechanically confined bentonite samples. The first model is a continuum model based on multiphase fluid flow, linear poro-elasticity and moisture swelling, with gas permeability related to the minimum effective compressive stress. The second model is a discrete fracture model based on continuum multiphase fluid flow linked with a lattice model to represent discrete fracture developments. In the continuum model, the key to capture observed responses is the stress-dependent gas permeability and moisture shrinkage. In the discontinuum model, the key processes involved are shear failure creating a dense discrete fracture network and abrupt permeability enhancement. Both models capture reasonable well the measured evolution of gas flow, pressure and stress, including the abrupt responses observed once an apparent threshold gas pressure is exceeded. Further modeling of other experiments conducted on the same type of bentonite (e.g. spherical flow versus linear flow) will be necessary to better distinguish between different underlying and controlling processes occurring within the sample.

References

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