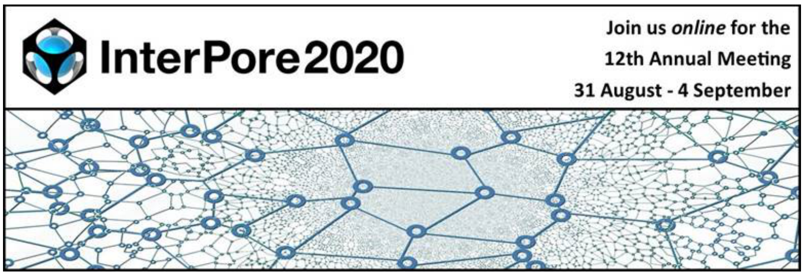

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A deformation-dependent permeability model for polycrystalline rocks

In order to achieve the goal of the Paris Climate Agreement and to reduce CO₂ emissions, renewable energies are mandatory. Their volatile nature necessitates the expansion of energy storage systems. Underground caverns for storing energy sources –so far mainly natural gas or compressed air –offer a promising option. The storage of hydrogen produced from renewable sources can improve the use of volatile renewable energies.

To ensure long-term stability of cavern storage systems, simulations are used to predict material behaviour and, if necessary, adapt the operating framework to a safe state. Caverns for energy storage are usually build in salt deposits underground due to the favorable low permeability of the rock salt. The material model plays a central part in the simulation. Salt rock behaves in an elastic-viscoplastic way and was tried to be depicted in an accurate way by different models in the past. A crucial detail regarding the tightness of cavern boundaries is the effect of fluid infiltration into the grain boundaries of the host rock, which consequently influences the stability.

Expanding on the work of Olivella and Alonso (2008) a deformation-dependent permeability model for polycrystalline material is developed, based on embedding fractures in finite elements. The model is numerically implemented in the open source multiphysics simulation framework OpenGeoSys (Kolditz et al., 2012; Bilke et al., 2019). Using the hydromechanical process, which relies on the theory of porous media, the model is validated with multiple benchmarks and tested against experimental data from percolation experiments on rock samples (Kamlot, 2009).

The simulation results demonstrate the ability of the model to produce anisotropic behaviour as well as quasi-isotropic behaviour. Modeling and simulating the percolation experiment showed that our model reproduces the same preferential directions of the infiltrating fluid and can match the pressure and time at fluid breakthrough. In comparing simulations with parameter variations, the influence of each parameter of the model is shown. These promising results indicate that the permeability model may prove useful in depicting the fluid infiltration effect in cavern simulations and will be further developed to account for plastic effects.

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