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Development and application of numerical models for THM-coupled problems in geotechnics in the framework of the OpenGeoSys project

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Present and future key environmental issues are often closely linked to geotechnical problems. This especially concerns the energy sector. Topics are, among others, the underground storage of energy, geothermal energy as well as the disposal of carbon dioxide and heat-generating radioactive waste in deep geological formations. In this context, the safety assessment of complex geologic-geotechnical systems is obligatory. One important assessment methodology are multiphysical simulations based on numerical models. In a joint working group of the German Federal Institute for Geosciences and Natural Resources (BGR) and the Helmholtz Centre for Environmental Research (UFZ), scientists of the UFZ are developing and implementing models for thermo-hydro-mechanically (THM) coupled processes while BGR scientists are performing large and small-scale analyses based on these models. They link their expertise for the advancement of simulation methods in the framework of the open-source project OpenGeoSys. In this contribution, we highlight recent progress in this context: the consideration of heterogeneities on different spatial scales in numerical modeling and the development of an efficient model for simulating the THM processes caused by carbon dioxide injection into deep aquifers.

The THM behavior of rocks is highly influenced by heterogeneities. Depending on the specific question, the scale and the geological properties, different strategies can be applied to represent such heterogeneities. We will present approaches for upscaling as well as discrete representation of faults by applying lower-dimensional interface elements in clayey rocks.

To keep the computational effort at bay when simulating coupled THM processes in large-scale triphasic systems, consisting of solid grains, sodium chloride, water and carbon dioxide, efficient and robust approaches are required. We will illustrate a non-iterative method for the description of the vapour-liquid and solution equilibria, following well-known and established thermodynamical relations and empirical models.

We illustrate the workflow from model development and implementation, over verification and quality assurance by the definition of suitable reference solutions and application for different geotechnical problems.