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Simulation of brine migration along geological fault zones using a consistent mesh approach

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Upward brine migration through permeable fault damage zones could endanger near-surface drinking water resources. Deep porous rock formations offer a large potential for gas storage, like e.g. methane or CO_2. But gas injection induces formation pressure build up, that can potentially lead to vertical or horizontal brine displacement. Here fault zones play an important role as they can act either as lateral no-flow boundaries or as permeable pathways, that allow for fluid flow and pressure dissipation. Numerical reservoir simulations, which have become an important tool for investigating these effects quantitatively, have to be performed on a regional scale, in order to include the large-scale geological faults zones. Fault zones have to be implemented into the model in a geometrically and hydraulically flexible way, to account for the variety of natural conditions encountered, as e.g. open or closed fault zone.

In order to model that complexity, the corner point grid approach has been applied by geologists for decades. The corner point grid utilizes a set of hexahedral blocks to represent geological formations. At the fault plane, where geological layers are vertically shifted, hanging nodes appear and the corner point grid cannot be used directly, if permeable fault zones have to be represented in the model. In this study we present an extension of a mesh converter, which removes hanging nodes at the fault plane by point combination, thus providing a consistent finite element mesh. Our numerical model can account for heterogeneous hydraulic properties of the fault damage zone and the enclosed fault core. The fault core is represented by one layer of 3D finite elements on each side of the fault plane. The fault damage zone consists of a continuous layer of quadrangular 2D finite elements, which are attached at the outer face of the 3D fault core elements. This model allows for fluid flow along the fault plane while fluid flow through the fault core could be adjusted by element permeability. This concept was implemented into a workflow using the FEM-simulator OpenGeoSys in combination with a mesh converter.

The concept and workflow are shown to run stable using dedicated test cases for method validation, accounting for the coupled transport of water, heat and salt mass for different fault zone setups in a synthetic multi-layered subsurface. Here we focused on brine displacement and uprising due to formation pressure increase after gas injection, which is numerically realized by Dirichlet pressure boundary conditions. Further, we will investigate the relation between computational efficiency and flow solution differences by comparing this concept with the approach of fully discretized faults. Additionally, we will apply our workflow on a real geological case in the Northern German Basin, where a fault system is close to a potential gas storage side.