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Modeling of brine migration through fault zones as a result of CO_2 injection into a saline aquifer

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Geological storage of CO_2 in deep saline aquifers has become a widely considered option for reducing anthropogenic greenhouse gas concentrations. However, these storage operations also bear the risk of CO_2 leakage and upward brine migration from deep saline formations into potable groundwater, especially in faulted reservoirs. This study investigates the impact of fault-permeability on upward brine migration as a result of CO_2 injection into a saline aquifer. In a first step, we set up a static 3D geological structure model of a prospective CO_2 storage site with a size of 40 km x 40 km x 23 m. Faults are implemented as multiple virtual discrete grid cells, allowing to assign individual flow-related petrophysical properties and taking into account the central fault core of low-permeability and the outer damage zone of high permeability. Subsequently, large-scale numerical multi-phase multi-component (CO_2, NaCl, H_2O) flow simulations were performed on a high performance computing cluster system.

The prospective CO_2 storage site is located in the Northeast German Basin and is characterized by saline multi-layer aquifers located in the Middle Bunter as a part of an anticline structure originating from salt-tectonic processes. The Middle Bunter, Muschelkalk and Keuper formations were selected to assess brine migration through faults triggered by the injection of 1.7 Mt CO_2/year. The NE and SW boundaries of the study area are confined by the Fürstenwalde Gubener and the Lausitzer Abbruch fault systems represented by four discrete faults in the model with a thickness of 20 m each. In order to determine the impacts of fault core and damage zone transmissibility on upward brine migration and pressure elevation in the overburden, different leakage scenarios were investigated taking into account varying fault core and damage zone permeabilities. The undertaken simulation studies underline that detailed knowledge on fault permeability is of uttermost importance for the assessment of brine migration through faulted systems.

Future studies focus on coupling the multi-phase simulations with a geomechanical simulator to identify changes in the initial stress field during CO_2-injection. Furthermore, the undertaken simulation studies are used to support the development of a salinization early warning system.