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The effects of CO_2 injection on Geochemistry and Aquifer properties investigated at a hypothetical storage site in the north German basin

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The storage of CO_2 in deep saline aquifers is one of the major options for carbon dioxide sequestration. With the injection of CO_2 in the underground a CO_2 phase will migrate through the target reservoir controlled by the pressure gradient and buoyancy. Over the time CO_2 dissolves in water and stimulates geochemical reactions like mineral dissolution due to the acidic conditions that might be followed by mineral precipitation again. Mineral dissolution and precipitation affects the porosity and permeability and thus feeds back on multiphase flow. To evaluate the behaviour of the storage system the coupled simulator OGS-Eclipse-ChemApp was developed, which provides the coupled multiphase flow and reactive transport simulation under conditions typical for CO_2 injection. The open-source scientific software OpenGeoSys (OGS) was used in this investigation to simulate CO_2 injection into a saline formation. To represent the hydraulic and geochemical alteration during CO_2 sequestration under reservoir conditions, OGS was coupled to the widely used multiphase flow simulator ECLIPSE for modelling multiphase flow. Geochemical reactions are considered with an already existing interface between OGS and PhreeqC. Furthermore changes in porosity and permeability were considered.

ECLIPSE and OGS are coupled using an operator splitting approach. Results of the multiphase flow simulation are passed for each time step from ECLIPSE to OGS where transport of dissolved species is calculated. Transport of components can be considered with OGS in the CO_2 as well as in the water phase. Transport in the water phase is of major interest for reactive transport simulations. Subsequently, equilibrium geochemical reactions at each node of the OGS FEM model grid can be calculated using ChemApp. Changes in the brine concentration of dissolved inorganic carbon due to chemical reactions are transferred back to the multiphase flow simulator, which calculates the new phase equilibrium in the next time step.

The coupled OGS-ECLIPSE software was successfully applied to several benchmarks for validating the data transfer between the different simulators. Furthermore the comparability of multiphase flow and component transport results for the simulators OGS and ECLIPSE was investigated. Besides the different numerical methods used for solving the partial differential equations ECLIPSE uses an upwinding scheme that further damps the results compared to OGS. Thus the benchmarks show a high sensitivity of the CO_2 saturation on the vertical model resolution due to the buoyancy effect.

Finally the software is applied for a hypothetical CO_2 reservoir in the north German basin. The reservoir material is sandstone with about 5 mass percent of calcite as cement and about 10 mass percent of feldspar. The main focus of the simulation is the evaluation of the long term geochemical changes induced due to the dissolution of calcite and their feedback on the multiphase flow field. The area close to the injection well faces only limited affects due to the removal of the water phase. Compared to this minerals dissolve in the surrounding area outside the high CO_2 saturation plume. Thus the pore volume increases within that reactive zone.