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CO2 permeability of fractured cap rocks - experiments and numerical simulations (CO2Seals)

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In CO_2 sequestration and underground gas storage the sealing capacity of a cap rock is of paramount importance. The main question is therefore how the leakage of CO_2 through fissures and faults within the cap rock may affect the CO_2 sealing efficiency of low-permeable seal lithotypes. In many cases, these structures provide the main pathways for leakage of CO_2.

Here, we provide an overview of one part of the joint research project CO_2Seals, which deals with the effect of structural features - such as tectonic faults and fissures in the overburden - on the migration of CO_2 in addition to mineralogical, petrophysical, and geochemical properties of different lithotypes.

The primary contribution of the entire project consists of an improvement of the present quantitative understanding of CO_2 transport and retention processes and associated interactions in cap rocks between rock and CO_2 or brine. To this end, we are adapting different numerical tools for simulating the relevant petrophysical and geochemical processes of CO_2 in cap rocks, in close operation with: (1) large-scale CO_2-percolation experiments on fractured cap rock samples; (2) permeability, gas breakthrough, and diffusion experiments; (3) measurements of the mechanical stability of cap rocks and the geochemical alterations of fault zone rock. The observed resulting changes in petrophysical properties, such as porosity, relative rock permeability (CO_2 and brine), and fault permeability provide basics for the following numerical simulations. For example, first permeability tests of a marl and clay cap rock out of Cretaceous and Jurassic formations revealed gas permeability of 10^{-18} m^2 down to 10^{-22} m^2. In addition, first percolation experiments indicated that the influence of fault zones on the measured CO_2 permeability of clays is very low.

Furthermore, numerical bench-scale models are performed to provide confidence for the subsequent transfer to reservoir systems.

Large-scale numerical models were created for this purpose including generic structural geological faults and comprising Mesozoic and Cenozoic formations of the Northern German Basin. The mass of CO_2 retained by a multi-barrier system including reservoirs and cap rocks is estimated by taking into account hydraulic property values of known fault systems and predicted or measured leakage rates, also from natural analogues.

As a result, we provide conclusions with respect to the stability and tightness of cap rocks exposed to CO_2 for long periods. Furthermore, potential CO_2 leakage scenarios on different size- and time-scales are generated in addition to the characterization of the CO_2 sealing efficiency of low-permeable cap rocks.

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