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Geometry evolution and fracture alteration controlled by spatial mineral heterogeneity during CO2 sequestration –A reactive transport study

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Geological CO2 storage and CCS have a crucial role in reducing CO2 emission and therefore mitigating climate change. One of the prerequisites for selecting CO2 storage sites is a low permeability caprock preventing potential CO2 leakage and migration from the storage reservoir. The presence of fractures in the caprock can adversely affect the sealing capacity of caprocks. Chemical interactions between CO2, brine, and caprock-forming minerals can cause fracture evolution, which results in changes in the transmissivity of fractures within the sealing layers. One factor that can affect the chemically induced fracture alterations is mineral heterogeneity in the caprock. In the present work, we investigate the effect of mineral heterogeneity on fracture geometry evolution when CO2-rich brine flows through a single fracture scribed on different carbonate-rich caprock samples. The rock samples have different carbonate contents and different levels of mineral heterogeneities. They can represent carbonate-rich caprocks such as some intervals of the Upper Jurassic (Kimmeridgian) Draupne shales, the caprock for Smeaheia CO2 storage in Norway. An HPHT geomaterial microfluidic experimental setup is used to monitor the evolution of the fractures. Results indicate that the homogeneous caprock samples, i.e., the samples mainly composed of calcite, show a uniform fracture wall dissolution while fracture wall roughness increases for heterogeneous samples. The effluent chemistry analyses show that the sample-scale calcite dissolution rate decreases over time, which can be due to the mass transfer limitations in the boundary layer near the fracture wall (for the homogeneous sample) or the altered layer formed around the fracture (for the heterogeneous samples). Microfluidic experiments were also done for one carbonate-rich fine-grained shale sample, which showed dissolution of calcite with no macroscopic fracture alteration during the ten-day experiment. This indicates that in shale samples where the carbonate minerals, mainly calcite, are armored with other slow reacting minerals such as clays, the rate of fracture geometry evolution will be prolonged, which might be a positive point for the caprock integrity. However, the confirmed fluid-rock geochemical interactions within the shaly sample in a short time frame call for further investigations on the consequent impacts on caprock samples' geomechanical-hydrological properties for more extended periods relevant for subsurface CO2 storage. The microfluidic experiments are also used to validate a reactive transport model. The model will then be utilized to study changes in transport properties of different samples during experiments. The LBM-based model outputs, such as porosity-permeability relationships, can inform reactive models at larger scales to develop a better predictive numerical simulator for processes involved in CO2 storage projects.

Time Block Preference

Time Block A (09:00-12:00 CET)

References

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