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Two-phase flow characterization of CO_2-brine-rock systems: complementary experimental and numerical approaches

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Current field work: geologic carbon storage
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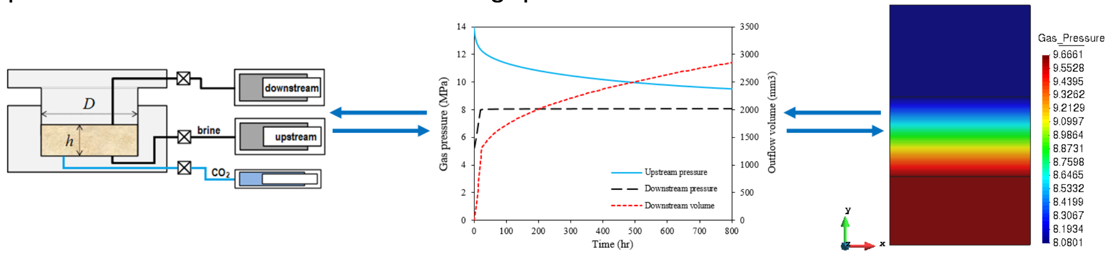
ABSTRACT

Global warming has sped up during the last decades due to huge anthropogenic emissions of greenhouse gases, among them carbon dioxide (CO_2). With the current trajectory of burning fossil fuels as the main source of producing CO_2, global warming threatens life on Earth. Therefore, shifting toward carbon-free energy sources, such as solar, wind and geothermal energy, should be set as a priority. However, the latest studies suggest that we need a faster CO_2 emission reduction than what can be achieved just by shifting to renewables. To speed up the reduction, CO_2 can be captured and stored in deep geological formations. Geologic CO_2 Storage (GCS) provides a promising mitigation strategy by its potential to store thousands of gigatonnes of CO_2 in suitable underground geologic structures. Besides high storage capacity and injectivity, given the CO_2 buoyancy, a prosperous storage site requires an overlaying low-permeability and thick caprock to prevent upward migration of CO_2 to the surface over long geological periods. This necessitates precise investigation of the caprock sealing capacity in contact with CO_2.

To accurately predict the caprock sealing capacity in the field scale, numerical models have to be suitably parameterized and calibrated to account for the complexities associated with fluid-fluid and fluid-rock interfacial interactions. We develop in this work a comprehensive workflow to derive the corresponding multiphase-flow properties from a combination of experimental data and laboratory-scale simulations of the testing process. The proposed laboratory testing protocol includes injection of CO_2 into a caprock sample initially saturated with brine and well-characterized with respect to single-phase flow at representative in-situ stress, temperature and pressure conditions. Obtained data in the laboratory are interpreted to determine the breakthrough pressure required to overcome a critical pore radius to constitute a continuous CO_2 filament through the sample and the relative permeability for CO_2. These parameters are then incorporated into a multiphase-flow code, already capable of dealing with variations of different thermodynamic properties, to numerically simulate the experiments and reproduce the recorded flow and pressure evolution curves. We conduct a sensitivity analysis of the main parameters affecting the experiments including the sample size, applied boundary conditions, and flow and storage characteristics of the testing apparatus. This multi-disciplinary interactive approach results in an in-depth knowledge of the dominant two-phase CO_2-brine flow regimes in tight rocks and comes up with an integrated and targeted laboratory testing plan to fill in the associated research gaps.



Keywords: carbon capture and storage (CCS), two-phase flow, low-permeable rock characterization, experimental results, numerical simulations, global warming.

Key Contribution: An integrated experimental and numerical study is presented to attain a better understanding of the two-phase CO_2-brine flow in low-permeability clay-rich rock.