Modelling of advective and capillary flows in sandstone cores during the injection of supercritical CO2.

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Numerical simulations of injection of CO2sc or of a mixture (aqueous solution + CO2sc) in sandstone cores were carried out. These preliminary numerical tests have twofold targets: i) helping for designing lab experiments and to anticipate the experimental behaviors of such complex systems and ii) to explore complex conditions (flow-pressure-temperature-salinity) that could not be easily achieved in laboratory experiments.
These 1D simulations were done using the numerical code TOUGH2 (Pruess et al., 1999), with the ECO2N module (Pruess, 2005). This code allows performing multiphasic reactive transport (THC) modelling considering gas-liquid equilibria and the possibility for halite to precipitate (according to thermodynamic equilibrium) with potential feedback on the petrophysical properties (k-phi) of the rock. During these simulations, the rock matrix is supposed to not react significantly (i.e., no dissolution of the sandstone at the scale of the simulation time).
To get closer to the experimental constraints, all THC simulations were done through cores the dimensions of which correspond to the actual samples used in lab tests. The hydrodynamic and petrographic properties are those of a Vosges sandstone sample taken in a quarry in the East of France. The duration of the simulated injections is about 15 hours. In order to characterize the hydrodynamic and salt deposition processes in the core, a very fine mesh was set up: the core was divided into 75 cells of 1 mm thickness and of identical hydrodynamic properties. Initially, the core is saturated with NaCl-bearing brines (with salinity from 3 to 6 molal).
Among the various simulations performed, one corresponds to a low-pressure gradient, i.e., a low gas flow rate. The time needed to dry out the column is extremely long and the risk of clogging is important. Indeed, after the piston effect happens (flush of the most mobile water), water evaporation (i.e., water transfer into the CO2-rich fluid) is the only mechanism able to dry the porous medium. TOUGH2 allows modelling a capillary feedback (opposite to the advective flow of the CO2-rich phase), which maintains a quasi-stationary backflow of the more concentrated brine toward the core entrance. Thus, the porosity close to the core inlet is continuously fed with brine, the evaporation of which provokes a massive precipitation of salt at the column inlet. Successive cycles of injection/stop further increase these risks by allowing brine flowing back towards the inlet of the core because of the re-distribution of fluids during the stop phases.
In conclusion, although the numerical code is devoted to simulations at the reservoir scale, it is possible to represent processes at small (centimeter) scales helping smart lab experimentations. The advantage of the numerical approach is also to perform a large number of simulations to better determine the key processes and critical parameters and thus define the most relevant experimental tests to perform for more focused locks and mechanisms. The global methodology of these exploratory modeling will be presented at this minisymposium. The experimental results will be discussed and the relation “Flowrate-Pressure-Temperature” will be discussed regarding the injectivity of sandstone saline reservoirs.

References

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