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An experimentally validated conceptual model for numerical simulation of accelerated dissolution trapping of CO2 in low-permeable fractured reservoirs

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The dissolution trapping of CO2 in water, often accelerated by gravity-driven convection of overlying CO2 plume in high permeable water-saturated rocks, can ensure safe long-term sequestration of CO2 but can take thousands of years in low permeable rocks (< 1 mD). We hypothesize that in naturally fractured reservoirs, even with low to no fracture network connectivity, the density-driven convective flux of CO2 in the water-saturated vertical fractures can reduce the required time for dissolution trapping to several years to few decades depending on fracture density. We validate the numerical model with pressure decline curves obtained in a novel experimental setup, in which the lateral area of a brine-saturated low-permeable chalk core (< 1 mD) is in contact with supercritical CO2 in a closed PVT cell at reservoir temperature and pressure of a Danish North Sea chalk field. Our model consists of CO2 transport with advection and diffusion and the continuity equation for a slightly compressible system of brine with dissolved CO2. The solubility of CO2 and the density of CO2-water mixture are modelled with Phreeqc, which utilizes the Peng-Robinson equation of state for the fugacity of CO2 and water in the gas phase and the Pitzer model for the activity of CO2 and other ions in the aqueous phase. We also use the default values of partial molar volumes in the Phreeqc database and validate the results against published experimental data for CO2-brine solubility and density. We then solve the equations both in our in-house finite volume solver (with TVD scheme for the advection term and backward Euler for time) and COMSOL multiphysics (finite element with added artificial diffusion for numerical stability). We model the 2D dissolution of CO2 in a water saturated fracture (with rough surfaces) and show that for a fracture aperture in the range of 0.03 to 3 mm, a long fracture will be filled with CO2-saturated brine in less than a few days. We then show that these saturated fractures serve as boundary conditions for fast dissolution of CO2 in the low-permeable matrix with diffusion-controlled mechanisms for permeabilities less than 1 mD and convection-dominated flow for permeabilities higher than 10 mD. We also discuss the implications of the results on the capacity of the Danish waterflooded chalk reservoirs for the storage of CO2 without displacing the formation fluids, which is currently not allowed in Denmark.

Participation

In-Person

References

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