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3D reactive transport modeling of laboratory-scale CO2 injection in limestone leading to wormhole formation

Monday, 30 May 2022 15:10 (1h 10m)

Carbon capture and storage in deep saline aquifers is a promising approach to mitigate global warming as a first-rate challenge of the world today. The injected CO2 dissolves in brine, making it acidified and promoting geochemical interactions with the rock. Such interactions likely alter CO2 trapping and transport mechanisms, which are directly linked with the carbon mitigation capacity of this technology. In this study, we combine laboratory experiments with 3D reactive transport simulations to better understand geochemical controls on the evolution of carbonate rock structure. A 28-day percolation experiment was conducted on a Pont Du Gard limestone specimen (a cylindrical core of 2.5 cm in diameter and 4.4 cm long) with CO2-saturated water at an injection pressure and temperature of 100 bar and 60℃, respectively, replicating subsurface conditions. We integrate fluid chemistry analyses, X-ray imaging, porosity, and permeability measurements to assess the temporal evolution of rock structure, porosity, and permeability in the altering specimen throughout the injection. The employed monitoring procedures consistently point to a porosity enhancement of 9.6% and permeability increase of 3 orders of magnitude. X-ray images depict that the porosity enhancement coincides with the formation of a large wormhole inside the specimen, most likely developed in response to the specimen's natural heterogeneity. A three-dimensional permeability map was built using imaging data to capture the effect of rock heterogeneity on the dynamics of wormhole formation and the evolution of the fluid flow. Preliminary modeling results show that our model can reproduce the total dissolved mineral mass and porosity enhancement of the reacted specimen with high accuracy (2-5% error). The porosity-permeability relationship and mineral surface area are found to impact model predictions. Thus, we calibrate the model against these parameters to precisely track wormhole evolution inside the specimen (i.e., structure and orientation). Sensitivity analyses conducted using the calibrated model reveal the dependency of the dissolution patterns on the injection flow rate to a large extent. Combined experimental and simulation results provide insights into wormhole formation and evolution that will be important during field injection.

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References

Time Block Preference

Time Block B (14:00-17:00 CET)

Participation

Online

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