Contribution ID: **223** Type: **Oral 20 Minutes**

Contribution of Heterogeneity within Semi-Confining Shale Layers to Mixing and Storage of Dissolved CO2

Thursday, 17 May 2018 14:38 (15 minutes)

Dissolution trapping is one of the mechanisms that contributes to stable storage of carbon dioxide (CO2) in deep geologic formations with brine. Basic to the process is the supercritical CO2 (scCO2) dissolving in the formation brine and the subsequent mixing of dissolved CO2 and brine in the deeper zones of the formation. In most conceptual models, it is assumed that the mixing is controlled by convection of the heavier solute moving vertically as unstable fingers. In our previous work, we have shown that presence of heterogeneity in the formation disrupts the convective fingers and thus affecting the effective mixing rates. In one of our previous studies that used field-scale modeling, we highlighted two key mechanisms, i.e. convective mixing and diffusion controlled trapping, contributing to dissolution trapping in multilayered systems with homogeneous low-permeability layers (e.g. shales). However, these low-permeability layers are not always homogeneous due to their composition and texture variations in addition to the presence of faults, fractures and fissures. The purpose of this study is to investigate the potential outcomes of heterogeneity present within these semi-confining low-permeability layers in regards to mixing and storage of dissolved CO2. An intermediate-scale laboratory experiment representing a multilayer system with a heterogeneous low-permeability layer was designed to investigate the contribution of convective mixing, diffusion controlled trapping and back diffusion to long-term storage of dissolved CO2. The experiment was performed using a surrogate fluid combination, NaBr solution and water, to represent dissolved CO2 and brine, respectively, under ambient pressure and temperature conditions. In order to investigate the observed mechanisms in detail for the different distributions of the same low-permeability materials having similar volume ratios with the experimentally studied scenario, first the numerical model was verified with the experimental results. Then, several heterogeneous low-permeability layer scenarios were tested numerically. The experimental and modeling results showed that connectivity of higher permeability material within the semi-confining low-permeability layers contributes to mixing through brine leakage between upper and lower aquifers, storage through diffusion, and in the long term, back diffusion of stored mass due to reversed concentration gradients.

References

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Primary author: Dr AGARTAN, Elif (Colorado School of Mines)

Co-authors: Dr ILLANGASEKARE, Tissa (Colorado School of Mines); Mr VARGAS-JOHNSON, Javier (Colorado School of Mines); Dr CIHAN, Abdullah (Lawrence Berkeley National Laboratory); Dr BIRKHOLZER, Jens

T. (Lawrence Berkeley National Laboratory)

Presenter: Dr AGARTAN, Elif (Colorado School of Mines)

Session Classification: Parallel 11-A

Track Classification: MS 1.07: Advances in solubility trapping of CO_2 in geological formations