EGU24-2031, updated on 16 Feb 2025
https://doi.org/10.5194/egusphere-egu24-2031
EGU General Assembly 2024

4D visualisation and analysis of fluid-rock interactions in a caprock for the implication of carbon sequestration and storage

Jingyue Hao[1], Lin Ma[2], Takshak Shende[3], Cathy Hollis[1], and Kevin Taylor[1]
[1]Department of Earth and Environmental Sciences, University of Manchester, Manchester, United Kingdom of Great Britain – England, Scotland, Wales (jingyue.hao@manchester.ac.uk)
[2]Department of Chemical Engineering, University of Manchester, Manchester, United Kingdom of Great Britain – England, Scotland, Wales
[3]Department of Mechanical Engineering, University College London, London, United Kingdom of Great Britain – England, Scotland, Wales

The assessment of caprock sealing capability is a crucial component for the safety evaluation of geological carbon storage. This study imaged and modelled acid-rock interactions in a mudstone utilising time-lapse X-ray 3D imaging techniques and direct simulation at micro-scale, providing a unique perspective to comprehend the reality and predict the outcome of this topic. Different acid concentrations were used to mimic a range of possible acid concentrations during CO_2 injection and storage. Changes observed in samples subjected to acid interaction include initial closure of pre-existing fractures, followed by growth of existing-fractures and slight sample swelling. Due to the heterogeneity of mudstone, acid migration and dissolution followed preferential pathways such as along laminations or fractures. The reactive transport models demonstrate that the majority of dissolution occurs in close proximity to the inlet, while downstream of the fracture, primarily owing to the reduction of H^+ concentration along the fluid pathways. The distribution of dissolved areas is primarily controlled by carbonate distribution within the sample. Carbonates located near fractures dissolved first and contribute to the connection of individual fractures. Both the experimental and numerical data indicate that calcite dissolution rate and dissolution front migration rate decrease with time. Numerical results demonstrate a significant decrease in shear stress after acid injection, especially with low-pH acids, resulting in slower fluid flow behaviour. Consequently, the mobile and immobile zones of fluid flow were predicted based on image and modelling results. The acid moved slowly and stayed longer in immobile zones, leading to more extensive calcite dissolution than in mobile zones. The study of fluid-rock interaction provides a valuable analogue for predicting the microstructural changes that may occur in a caprock after CO_2 injection. It is worth noting that the risk of leakage is likely exacerbated by the development of fractures induced by acidic interaction.