

Prediction of dissolution regimes in complex carbonate rocks using reservoir-condition 4D XMT and a laboratory source

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Understanding of geochemical reaction between brine and rock at the fluid/solid boundary is imperative for accurate predictive modelling of storage capacity and fluid movement in the carbon storage and petroleum industries. We study the impact of brine acidity and initial pore structure on the dynamics of fluid/solid reaction at high Péclet numbers and low Damköhler numbers. A laboratory μ -CT scanner was used to image the dissolution of Ketton, Estailades, and Portland limestone in the presence of CO₂-acidified brine at reservoir conditions (10 MPa and 50°C) at two injected acid strengths for a period of 4 hours. Each sample was scanned between 6 and 10 times at ~ 4 μ m resolution and multiple effluent samples were extracted. The images were used as inputs into flow simulations, and analysed for dynamic changes in porosity, permeability, and reaction rate. Additionally, the effluent samples were used to verify the image-measured porosity changes.

We find that initial brine acidity and pore structure determine the type of dissolution. Dissolution is either uniform or occurs as channelling where the porosity increase is concentrated in preferential flow paths. Ketton, which has a relatively homogeneous pore structure, dissolved uniformly at the higher pH and showed more channelized flow at lower pH. In Estailades and Portland, increasingly complex carbonates, channelized flow was observed at both acidities with the channel forming faster at lower pH. It was found that the effluent pH, which is higher than that injected, is a reasonably good predictor of effective reaction rate during uniform dissolution, but a poor predictor during channelling. The overall effective reaction rate was up to 18 times lower than the batch reaction rate measured on a flat surface at the effluent pH, with the lowest reaction rates in the samples with the most channelized flow, confirming that transport limitations are the dominant mechanism in determining reaction dynamics at the fluid/solid boundary.