Clay Mineralogy and Pore-Scale Characterization During and After CO₂ Flow and Saturation in the Mt. Simon Sandstone, Illinois Basin, USA

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Background

The Cambrian-age Lower Mt. Simon Sandstone serves as the reservoir for the Illinois Basin – Decatur Project (IBDP), a 1 million tonne carbon capture and storage demonstration project located in Decatur, Illinois, USA. Authigenic illite is the most prevalent clay mineral in the Mt. Simon and most commonly forms a thin coating over detrital quartz grains. This clay coating acts as a barrier to the early authigenic quartz precipitation and thus preventing abundant primary porosity. However, in the Lower Mt. Simon Sandstone, clay minerals notably clay pore volume decreasing reservoir permeability. To predict the fate of CO₂ and its long term effect on reservoir properties, CO₂-water-rock interaction experiments are being completed.

Mt. Simon Sandstone

The Cambrian-age Mt. Simon Sandstone is over 700 m thick in areas of Illinois (Fig. 1). With porosity reaching 27% and permeability up to 1 Darcy, the Lower Mt. Simon is being used as a reservoir to demonstrate carbon dioxide storage that may coexist with a secondary reservoir. To predict the fate of CO₂ and its long-term effect on reservoir properties, CO₂-water-rock interaction experiments are being completed.

Experimental Procedure

To understand CO₂-brine-rock interaction, experiments were completed in Parr pressure vessels. CO₂, brine-rock was reacted at reservoir pressures (3,000 psi) and temperatures (325°C) for 5 months. Geotechnical modeling suggested clay minerals and feldspar would react with a lower pH/buffer after CO₂ injection (Table 1 and Fig. S). Pre-experiment XRD analyses indicated that the sandstone samples were composed of quartz, feldspar, and illite (Fig. 6). Pre- and post-experiment characterization of the sample was completed with illite changes observed in thin sections (Fig. 7B and D) and major changes observed using SEM imaging (Fig. 7C and D). Under SEM, clay minerals in pore space and throats in the post-experiment sample appear to have been dissolved as suggested by brine analyses (Table 2).

Table 1: Dissolution rates (Lasaga, 1995; Bethke, 1996; Storn and Price, 1997) in an experiment on the Mt. Simon sandstone rock. The dissolution rates (along with CO₂ flow through experiment) was set up with in-situ micro-CT imaging of the sample. In order to speed up reaction of the 48-hour experiment at ambient temperature (Table 1) and 1,000 psi, DI water was used instead of brine. This sample was scanned three times; dry, saturated with DI water, and post CO₂ water flow through (Fig. 8). Comparison of the three scans suggests treatment of clay after water saturation and dissolution in flushing of clay post CO₂ water flow through. Swelling can be explored by minor crackle layered illite-terminate (Fig. 6). Clay subtraction post-CO₂ water flow is confirmed by SEM imaging before and after the experiment (Fig. 9). Water chemistry before and after the experiment is in progress. With suggested dissolution of clay minerals during CO₂-water reaction, porosity and permeability in the Mt. Simon should increase (Fig. 10).

Further characterization and experimentation is needed to understand CO₂-water-rock interaction and long-term alteration of the rock as a result of CO₂ storage.

References: