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Hydrogen recovery from porous media decreases with brine injection pressure and increases with brine flow rate

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Zero carbon energy generation from renewable sources can reduce climate change by mitigating carbon emissions. A major challenge of renewable energy generation is the imbalance between supply and demand. To overcome the energy imbalances, subsurface storage of hydrogen in porous mediais suggested as a large-scale and economic solution, yet its mechanisms are not fully understood. Important unknowns are the effect of the high migration potential of the small and mobile hydrogen molecule and the volume of recoverable hydrogen.

We conducted non-steady state, cyclic hydrogen and brine injection experiments at 2-7 MPa and flow rates of 2-80 µl min^{-1} using water-wet Clashach sandstone cylinders of 4.7 mm diameter and 53-57 mm length (Clashach composition: ~96 wt.% quartz, 2% K-feldspar, 1% calcite, 1% ankerite). Two sets of experiments were performed using our new transparent flow-cell designed for x-ray computed microtomography: 1) Experiments using a laboratory x-ray source (University of Edinburgh) imaged the flow, displacement and capillary trapping of hydrogen by brine as a function of saturation after primary drainage and secondary imbibition. 2) Experiments using synchrotron radiation (Diamond Light Source, I12-JEEP tomography beamline) captured time-resolved hydrogen and brine flow and displacement processes. Pressure and mass flow measurements across the experimental apparatus complemented the microtomography volumes in both sets of experiments.

Results from a water-wet rock show that hydrogen behaves as a non-wetting phase and sits in the centre of the pore bodies, while residual brine sits in corners and pore throats. Hydrogen saturation in the pore volume is independent of the injection pressure and increases with increasing hydrogen/brine injection ratio up to ~50% saturation at 100 % hydrogen. Capillary trapping of hydrogen during brine imbibition occurs via snap off and is greatest at higher brine injection pressures, with 10 %, 12% and 21% hydrogen trapped at 2, 5 and 7 MPa, respectively. Higher brine flow rates reduce capillary trapping and increase hydrogen recovery at any given injection pressure. Based on these results, future hydrogen storage operations should inject 100% hydrogen and manage the reservoir pressure to avoid high pressures and minimize capillary trapping of hydrogen during brine reinjection.

Ongoing analysis of time-resolved experimental data will provide further insight into the critical

pore-scale processes that ultimately influence the potential for geological hydrogen storage and recovery.