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Microstructural heterogeneity and alteration of reservoir sandstones with experimental exposure to hydrogen

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Energy storage is becoming an increasing concern as the world transitions towards unpredictable renewable energy production. Hydrogen is expected be a key player as it can be produced through electrolysis of water using renewable electricity and used as a clean energy carrier to decarbonise industry, hence hydrogen storage is energy storage. Its small molecule size and low density means large-scale storage (TWh) is only feasible in the subsurface, such as porous reservoirs of saline aquifers. These are stratigraphically and geographically widespread globally. Porous storage of hydrogen is yet to be implemented, hence the influence of injected hydrogen on the subsurface under reservoir conditions (elevated temperatures and pressures) remains unknown. This includes geochemical reactions instigated from interactions between minerals, pore-fluid, and hydrogen within rock microstructure. It is essential that containment of hydrogen in porous rocks is proven prior to implementation, and that reservoir behaviour is comprehensively understood. As hydrogen must remain in the reservoir as expected and be recoverable in high volumes and purity.

This study relates to a larger collaboration between the British Geological Survey, Industrial Decarbonisation Research and Innovation Centre, and the University of Manchester. That provides lab-based microstructural characterisation and assessment of changes in reservoir rock properties caused by exposure to hydrogen in batch-reactor experiments under reservoir conditions (50oC & 150 bar). Reservoir rocks analysed are considered representative of possible targets for onshore hydrogen storage in the UK (Sherwood Sandstone and Lower Greensand reservoirs). Samples were thoroughly characterised pre- and post- experiment through a multitude of multi-scale imaging and measurement techniques, with a particular focus on x-ray computed tomography to reveal internal structure non-destructively. This exposed the microstructural heterogeneity within sandstone reservoirs, as well as microstructural alteration following hydrogen exposure. Sherwood Sandstone samples, although compositionally similar, exhibit two prominent textures. Channel-base with moderately sorted grains and a restricted pore network containing preferential alignment (porosity 8.95%; mean pore size 41.54μm). And the more dominant channel-fill, also moderately sorted but the pore-network is well-connected (porosity 24.47%; mean pore size 187.33μm). Lower Greensand samples have extremely variable microstructure and composition dependent on sample formation. Hythe Formation is well-sorted with a well-connected pore network (porosity 28.42%; mean pore size 174.90μm) dominated by quartz, glauconite, and muscovite. Instead, the Sandgate Formation is poorly sorted with a restricted pore network (porosity is much lower 15.34% and mean pore size 36.36μm) and is composed of quartz, calcite, and feldspar.

Overall, no major changes to rock microstructure or composition were observed following hydrogen exposure. This is important as it suggests the reservoir investigated are safe for hydrogen storage, which is promising for the UK. However, the migration of a fine particle was seen within one sample. The experimental design may have influenced other minor changes observed, such as grain loss around the edges of samples. Although no conclusive alterations have been seen in the results of these experiments, it remains possible that geochemical reactions will occur in reservoir compositions containing more reactive minerals, such as those rich in pyrite and anhydrite. Hence further investigation is required.

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Primary author: BRAID, Heather (PhD Student)

Co-authors: ROCHELLE, Christopher (British Geological Survey); HOUGH, Edward (British Geological Survey); Prof. TAYLOR, Kevin (University of Manchester); MA, Lin (University of Manchester)

Presenter: BRAID, Heather (PhD Student)

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