Geochemical Reactivity associated with Geological Hydrogen Storage in Sandstone and Shale Reservoirs

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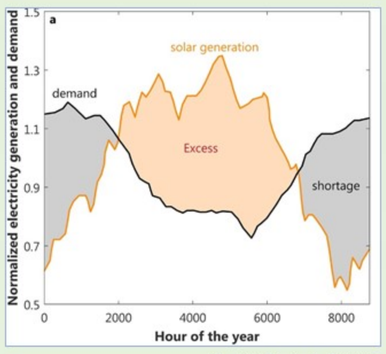
Introduction

Requirements:

- Achieve NZ2050, Paris Agreement, targets via low-carbon energy
- Address inherent variability in renewable energy production

Solutions:

- Large-scale energy storage systems: depleted gas reservoirs
- Constrain geochemical reactivity of alternative energy vector, hydrogen



(Gabrielli et al, 2020)

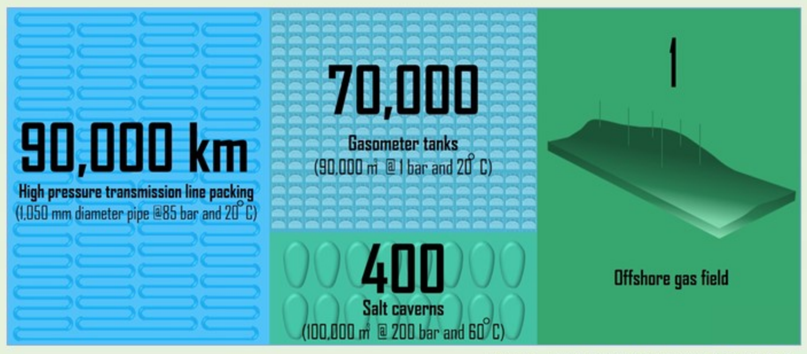


Image courtesy of Katriona Edlmann[1]

Aims:

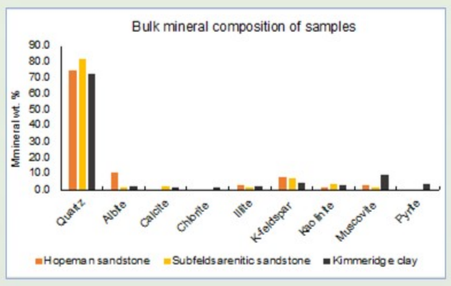
- Determine the geochemical reactivity of hydrogen in depleted gas reservoirs and caprock
- Conduct sensitivity studies into the effect of changing pressure, temperature and salinity conditions

Objectives:

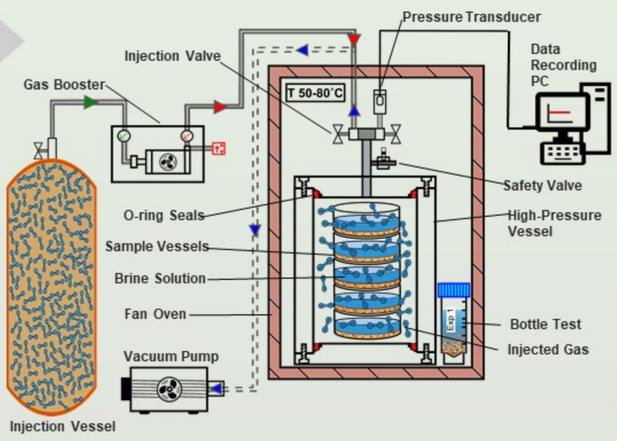
- Identify the effect of geological hydrogen storage on sandstone and shale minerals
- Prove geological hydrogen storage in sandstone and shale reservoirs is safe from a geochemical perspective

Research Methodology

1. Selected and characterised (XRD) North Sea 'representative' sandstone and shale samples



2. High-pressure static batch reaction experiments at: 0.1 - 20.68 Mpa, 50 – 80˚C and 3.5 – 10 wt.% NaCl



3. Geochemical modelling using PHREEQC identified the geochemical reactions promoted by hydrogen at thermodynamic equilibrium

4. ICP-OES analysis determined the elemental composition of batch reacted 'reservoir' fluids

5. Compared modelled data from systems at equilibrium to experimental data to identify geochemical reactions promoted by hydrogen

Modelled and Experimental Results

Equilibrium Reaction Modelling

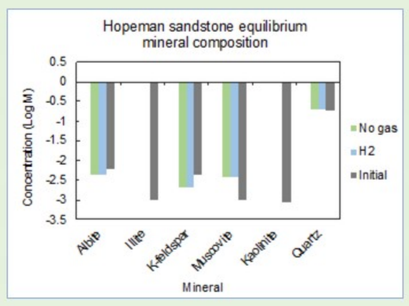
Hydrogen-induced reactions:

- Calcite and K-feldspar dissolution
- Albite and muscovite precipitation

Brine Composition Analysis

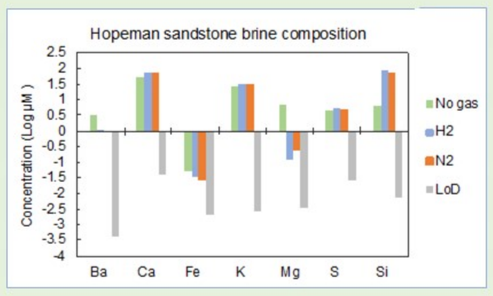
Hydrogen reactions (non-equilibrium):

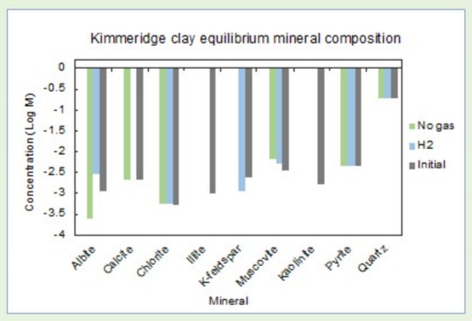
- Elements from modelled reactive mineral phases were analysed
- No significant reactions observed



Modelled and Experimental Conditions:

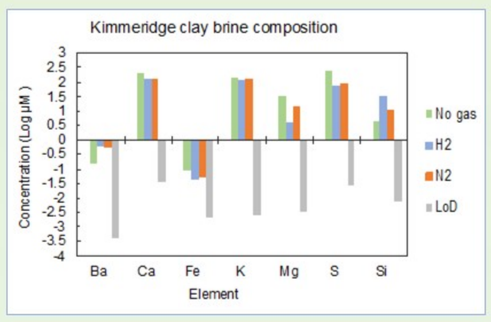
- 50 °C
- 10.34 MPa
- 3.5 wt.% salinity





Experimental Controls:

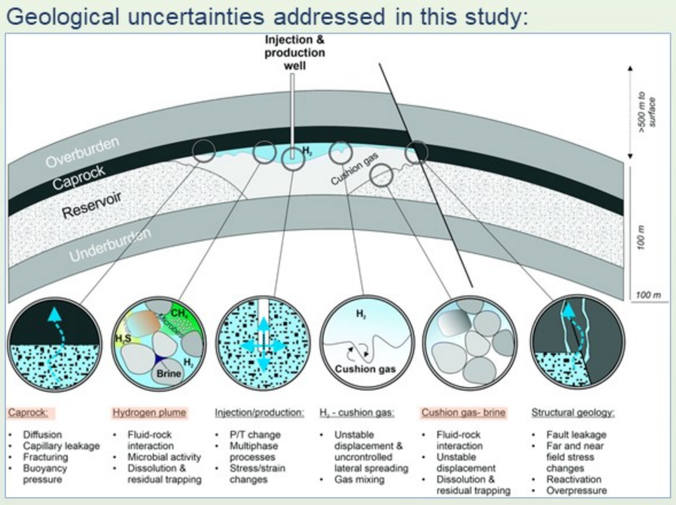
- no gas
- nitrogen
- no rock



Discussion and Conclusions

- Pore-blocking can affect storage capacity, injection efficiency and gas recoverability
- Hydrogen sulphide gas souring via pyrite to pyrrhotite reactions can cause infrastructure degradation
- Permeability-enhancing geochemical reactions in the caprock and reservoir flanks can cause capillary leakages and viscous fingering

Geological uncertainties addressed in this study:



(Heinemann et al, 2021)

- Albite, calcite, K-feldspar and muscovite reactions are not promoted by hydrogen at non-equilibrium thermodynamic conditions
- Hydrogen does not promote geochemical reactivity in typical sandstones and caprock at 10.34 – 20.68 MPa, 50 – 80 ˚C and 3.5 – 10 wt.% salinity over 2-month cycles

Underground hydrogen storage in sandstone and shale reservoirs, over seasonal cycles, at these conditions, is safe from a geochemical perspective

Acknowledgements and Contact Details

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