



ED HOUGH- RESEARCH LEAD, UNDERGROUND ENERGY STORAGE

Geology as an enabler and barrier to underground hydrogen storage- research questions



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Supergen
Energy Storage



THE HYDROGEN AND FUEL CELL RESEARCH HUB



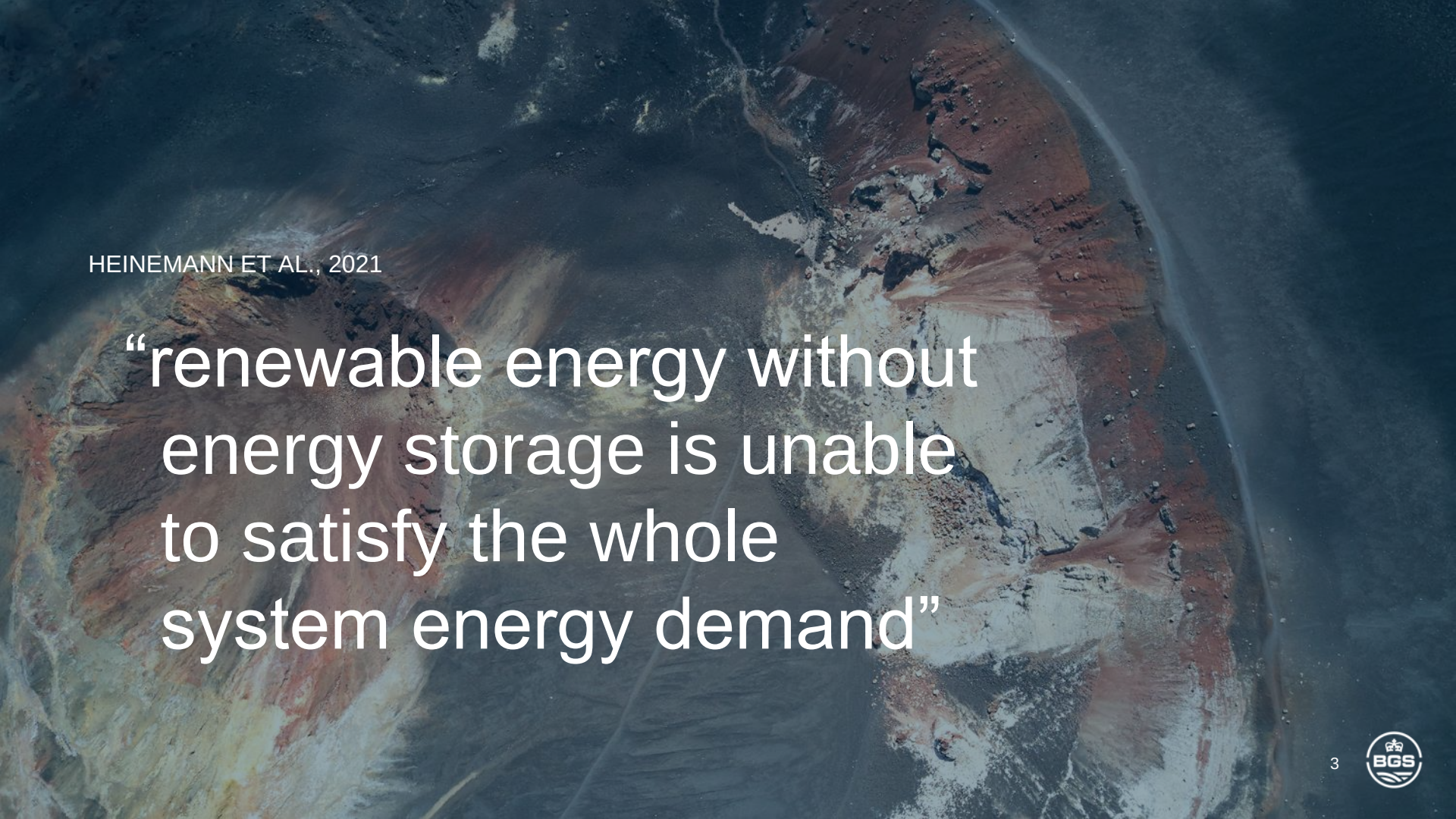
British
Geological
Survey

14 March 2022

Geological Society London
Hydrogen Storage in Caverns

Will there be an increased demand for subsurface energy storage?

- Energy security
- Support uptake of wind and solar energy
- Transition to hydrogen; Compressed Air Energy Storage
- Hydrogen has a very high calorific value (over 2x that of methane)
- ...but a very low density
- Hydrogen has approximately 1/3 the energy of the same volume of methane
- ...so 3 times the storage capacity of hydrogen is required to match the same amount of energy held as methane
- Would hydrogen caverns operate in a similar way to natural gas storage?
 - Rapid cycling of caverns- or seasonal?
 - Larger variations in pressure? (75-90% suggested- Wang et al., 2018; 80% suggested by Evans, 2009)



HEINEMANN ET AL., 2021

“renewable energy without
energy storage is unable
to satisfy the whole
system energy demand”

Geological storage of hydrogen in the subsurface

- Solution-mined caverns
 - Lower storage capacities
 - Spatially restricted
 - Variable pressures (Teesside UK 45 bar; Clemens Dome, Texas 70 – 135 bar)
 - Higher injection and extraction rates
 - Lower cushion gas ratio
 - Limited deployment

- Porous rocks
 - Plenty of data; large potential storage volumes
 - Spatially more widespread
 - Proven containment (for hydrocarbons)
 - Residual hydrocarbons in depleted reservoirs may contaminate H₂
 - Will caprocks and faults enable leakage?
 - Microbial action- potential impact on permeability
 - Potential for loss of H₂ in the formation- residual trapping
 - Untested

Cavern storage- knowledge transfer and technology development

'Uncontrolled' brining
Some examples of poorly engineered caverns (1890s)

Controlled solution mining
Developed in Lancashire and Cheshire (1900s)

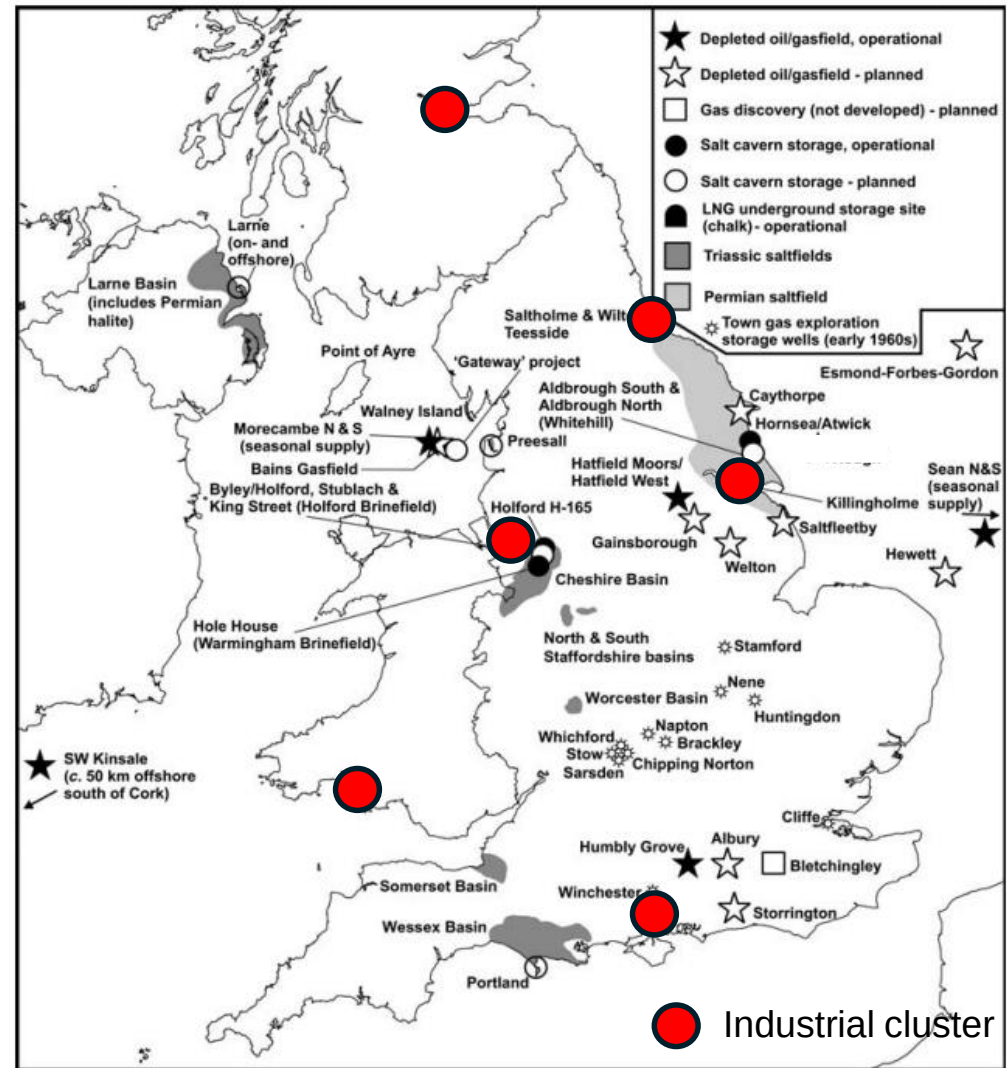
Underground gas storage
Town gas (1960s), Natural gas(1960s)

Limited amount of hydrogen storage (1960s US - 70s UK)

Underground hydrogen storage at scale?
Temporary CO2 storage? Compressed Air Energy Storage

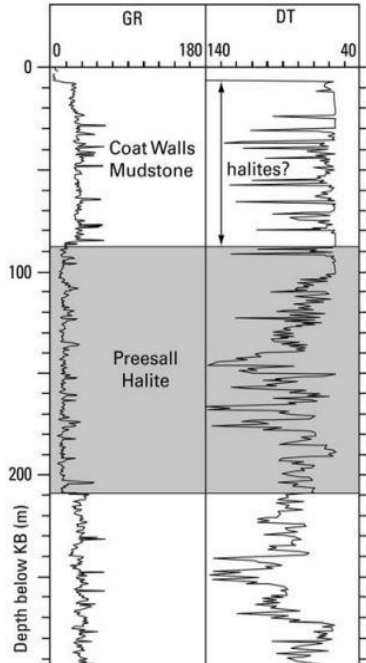
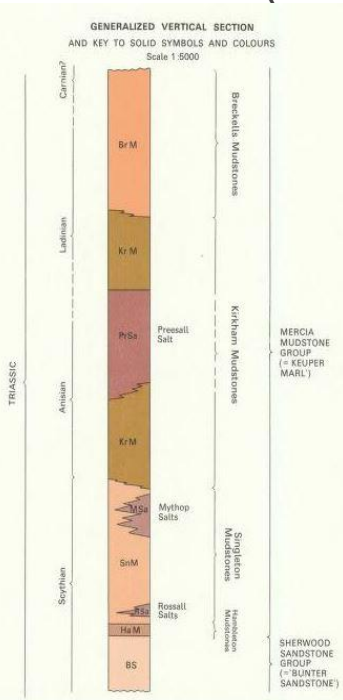
Storage and use

- Halite is a geographically 'fixed asset'- meaning that for it to support hydrogen storage, these locations will need to be serviced by hydrogen production, transport and use

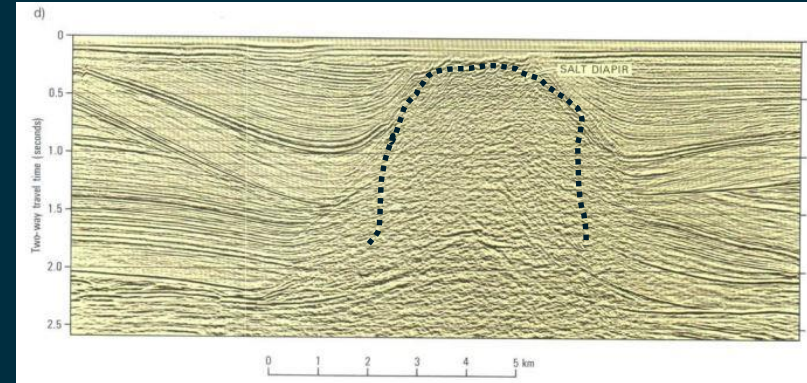


Halite resource in the UK

- Onshore- “Massive” bedded halite
 - 130TWh optimised capacity (locations and capacity)



- Offshore- domal (diapiric) halite

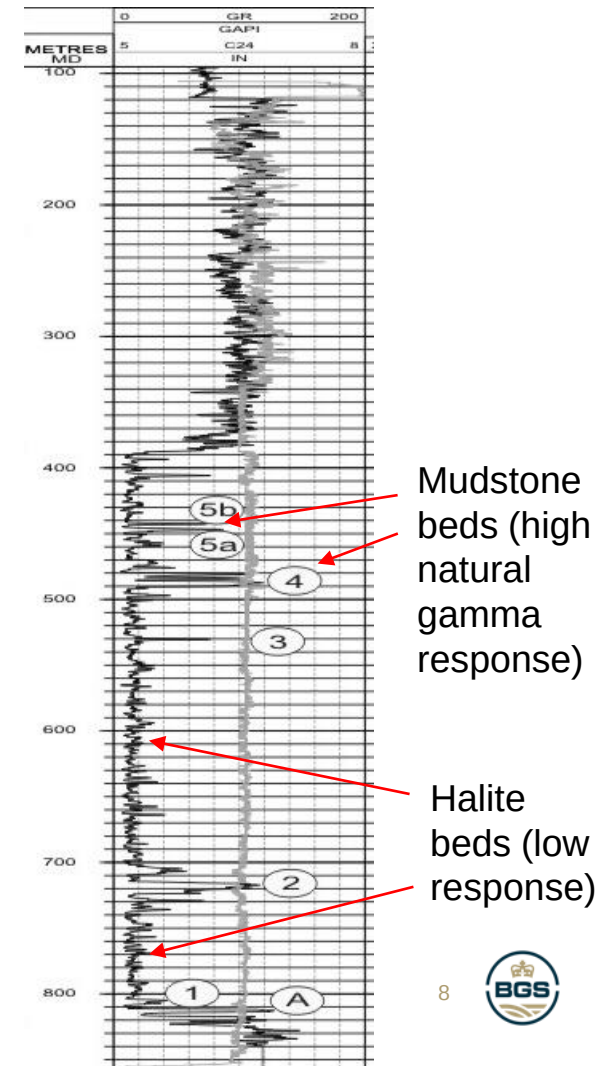


- Bedded- Keuper Halite- up to 150 m thick

Cameron et al., 1992

What is bedded halite?

- Sedimentary evaporite-
 - Predominantly halite but also higher solubility salts (Permian)
 - 100 m plus down to mm-scale
 - Beds of insoluble material- clay and siltstone, anhydrite
 - 15 m (Cheshire) to mm-scale
 - In some areas >50% of succession
- Character of evaporite/insoluble material influences cavern design, placement, development and economic performance
- Do insolubles present a risk to cavern operation?





West Lancashire

Mudstone

Mudstone-halite: 'Haslegebirge'

Chickenwire halite

Clean halite

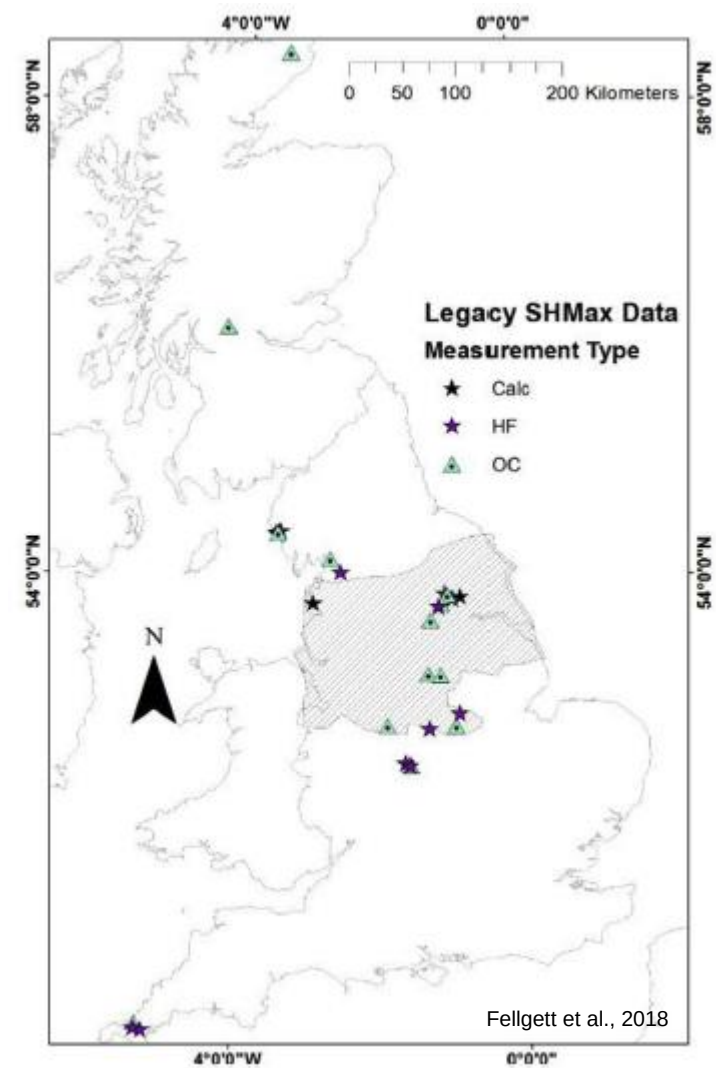
AFTAB ET AL., 2022

“Mineral impurities may
react [with hydrogen];
Some common ions
impurities...can enhance
microbial activity”



Geological influence on caverns

- The geomechanical envelope in which a cavern sits influences:
 - Pillar widths between caverns
 - Stand off distances between caverns and margins of halite
 - Distances to major geological faults
- Regional stress fields will influence cavern morphology and development
- The plastic limit of halite is related to depth
 - Cavern closure due to creep
 - Mitigated by different operating methods



Parameters controlling cavern volumes

Geological

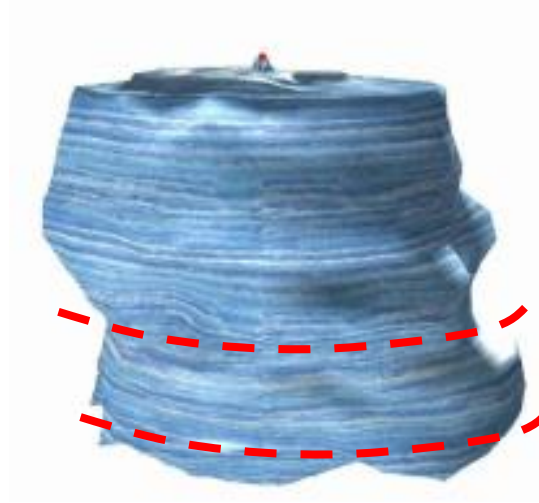
- Minimum thickness of halite- 50 m (accommodates a minimum cavern height 20 m)
- Depth of halite- caverns developed from 240 m (Cheshire) to ~1880 m (Teesside) [1800 m, Hubei]
- Up to 50% volume loss due to insoluble content (25% in areas developed) [40%]
- Potential locations reduced by stand-off from major mapped geological faults

Cavern design-operation

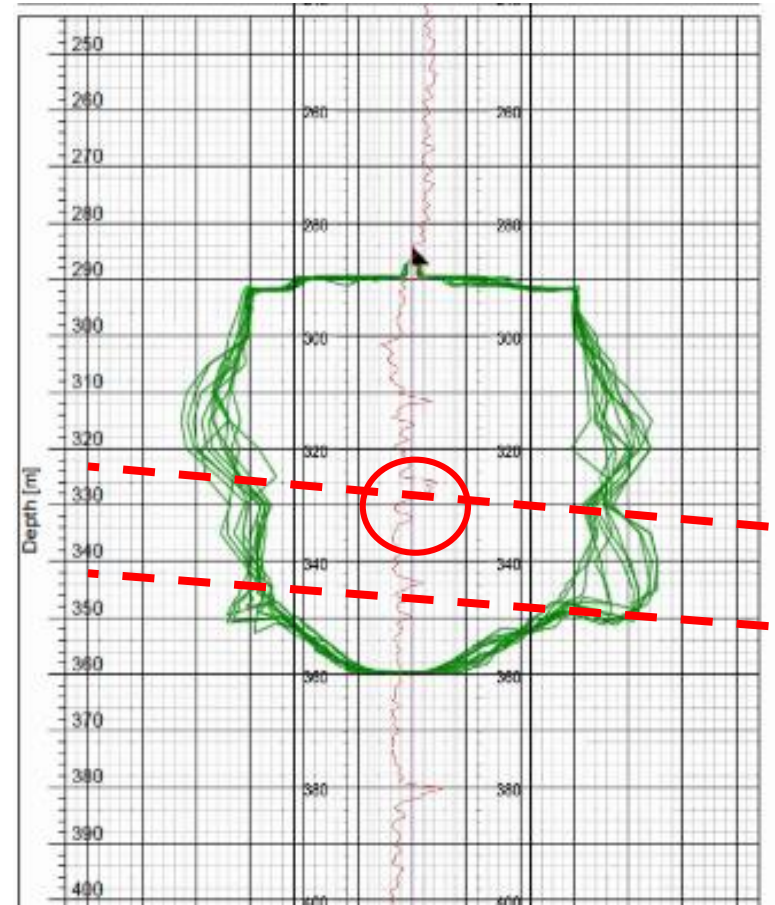
- Cavern dimensions 50 m radius, pillar width 3R (5R at depths over 500 m) [35-50m, pillars at 2.5-3R]
- Pressure ranges 2.9 MPa (Cheshire) – 27 MPa (Teesside) [17-34MPa]
- Assume 30% volume loss due to irregular morphologies

Pre-construction

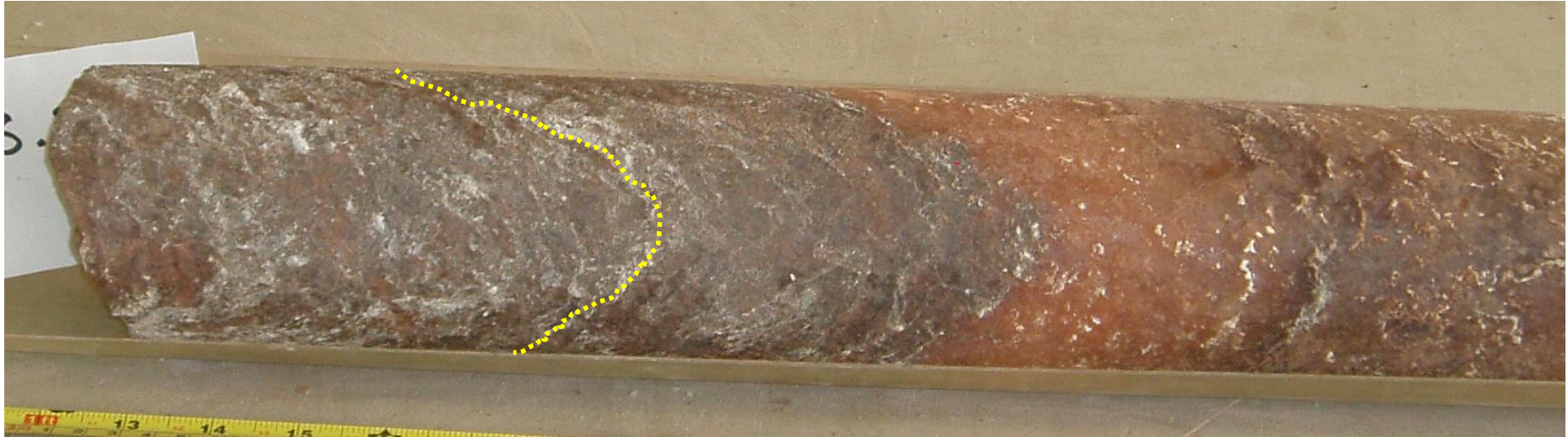
- Estimate cavern volume/morphology



In a cavern, insolubles can make up to 45% of the salt unit- and with bulking factor and brine absorbency, on collapse these can represent 60% of the cavern volume (Peng et al., 2021).

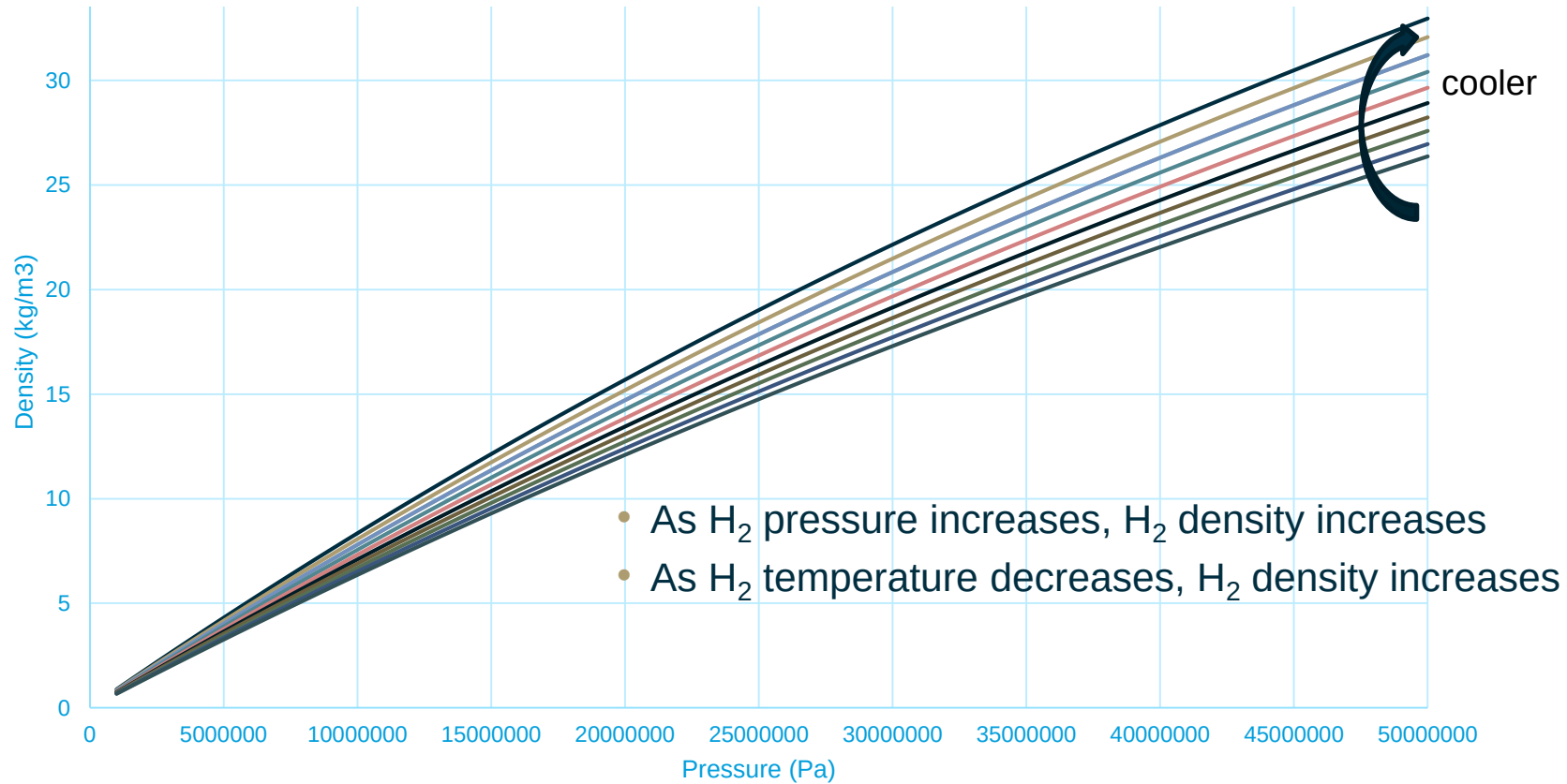


During cavern operation- mechanical and in-situ stress



- Creep- Tersanne cavern (France) lost 60% volume over 35 years (Wang et al., 2018)
 - may necessitate operation in ‘brine compensation mode’
- Development of communication between caverns?
 - E.g., Mineola, Houston, Texas (1993/1995); Brouard, 2009, HSE, 2009

Are there alternative options to increase storage capacity?

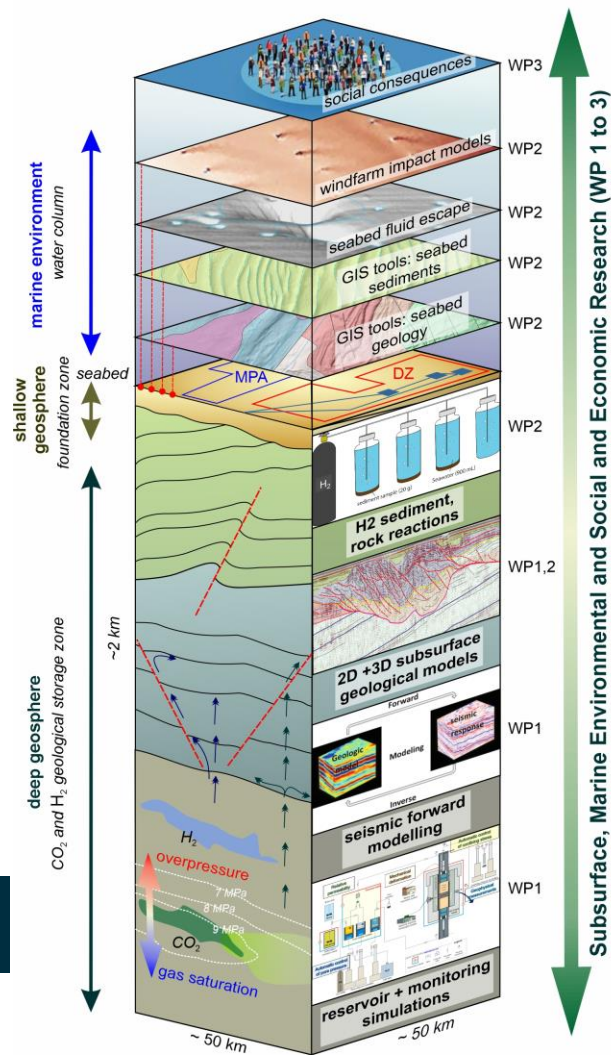
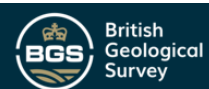


— 273.15	— 283.15	— 293.15	— 293.15
— 303.15	— 313.15	— 323.15	— 333.15
— 343.15	— 353.15	— 363.15	

Degrees Kelvin (ie, 0, 10, 20 degrees C etc)

Managing the offshore energy transition

- Assessing the potential for offshore wind, hydrogen production, CCS- and the cumulative impacts of these



Ultimate Benefits

- Cleaner, healthier environment
- Economic growth
- Sustainable resource use
- Reduction in effects of climate change

Impact

- Improved management and policy approach
- Reduced impact of offshore energy transition on marine environment and natural capital
- Increase in ocean and energy literacy leading to positive behaviour change
- Resource savings enabling efficient delivery of a range of energy options via offshore energy initiatives
- Reduction in CO₂ emissions leading to net zero targets

Outcomes

- Enable a systematic evidence-based approach to planning and siting of offshore energy options (H₂, CO₂, wind)
- Minimise negative marine environment impact
- Engage society in positive action for a greener future
- Inform effective decision making
- Support evidence-based policy development

Outputs

- Mapped H₂, CO₂ capacity
- Datasets to inform use of storage
- Seabed geological maps and models
- Understanding of natural capital implications
- Understanding perceptions of offshore energy
- Policy recommendations
- Decision support framework for offshore management

Engagement

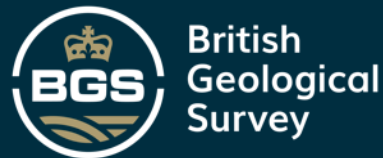
- Stakeholder interviews and workshops leading to co-developed research and outputs
- Engagement sprints – co-design of technical outputs
- Public engagement; focus groups, pop-up events, community engagement

Activities

- Identify and quantify sustainability of offshore H₂ and CO₂
- Explore impacts of shallow and deeper geology on siting options
- Quantify impact of offshore technologies (H₂, CO₂, wind) marine ecosystem services
- Elicit mental models of offshore energy transition
- Integrated, coordinated approach to project delivery

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THANK YOU

Any questions?

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