Zechstein halites as a potential hydrogen storage solution – Interim Results

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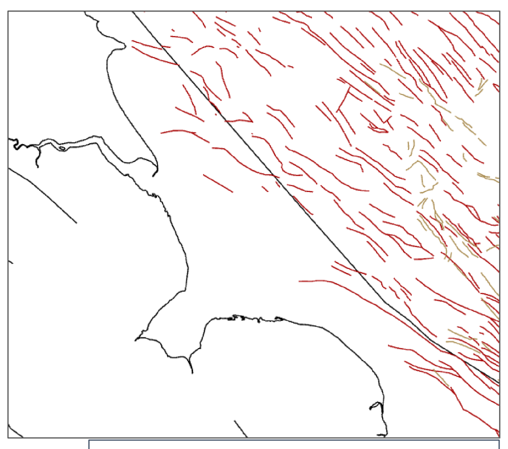
British Geological Survey

MOET Managing the Offshore Energy Transition

INTRODUCTION

Energy Storage is a key component in the UK's strategy for decarbonising the economy by 2050. Hydrogen and compressed-air energy storage (CAES) are both core elements required to integrate renewable energy technologies into electricity grids and domestic heating networks. Bulk energy storage technologies are required to accommodate the UK's fluctuating daily and seasonal energy supply requirements. To support the development of low carbon solutions for net zero the UK's underground storage capacity should therefore be increased. Subsurface salt caverns and depleted oil and gas fields have been identified as potential sites for CAES or hydrogen storage, with hydrogen storage in porous rocks at early stages of commercial consideration. We present some interim results from a study seeking to understand the potential capacity for hydrogen salt cavern storage in the Southern North Sea (SNS), with particular focus on Permian halite deposits.



Permian structural framework

1. Seismic Mapping

Key marker horizons within the Zechstein Group have been mapped across 2D and 3D seismic surveys to derive thickness maps of the Stassfurt, Leine, and Aller Halite Formations

Additional horizons have been modelled using a database of well formation tops and an implicit modelling approach

Depth and thickness maps have been calibrated to available well markers

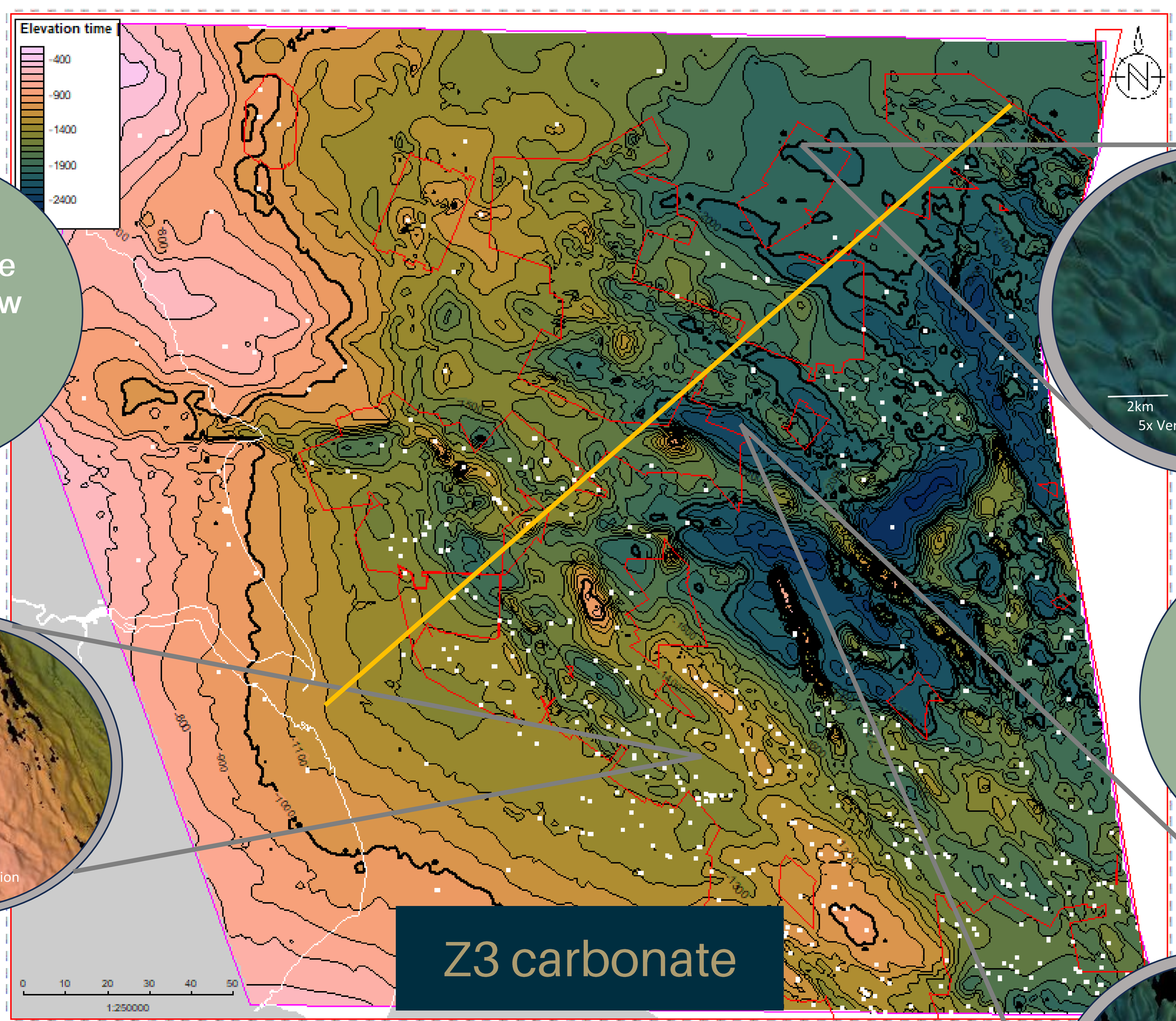
Two dominant structural trends are seen either side of a proposed structural change line:

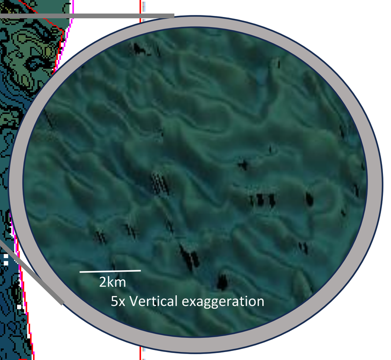
In the south, NW-SE regional trend: inherited from underlying Caledonian lineaments, potentially reactivated during Variscan tectonic cycle[2]. Major salt diapir structures in south exploit these structures

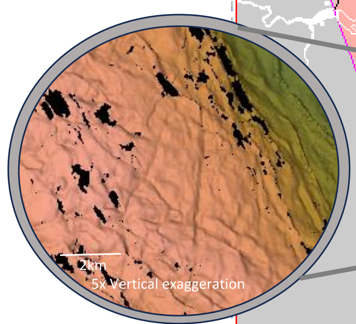
To the north, E-W trend in north: associated with regional extension during Cimmerian-Alpine tectonic cycle[2], reflected in trend of salt pillow structures

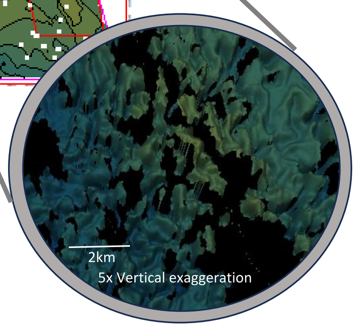
Evidence of buckle folds and mullion features associated with competency contrast between carbonate layers and surrounding evaporites. Related to differential shortening and variable flow rates between layers[1]

Z3 carbonate thins to below seismic resolution









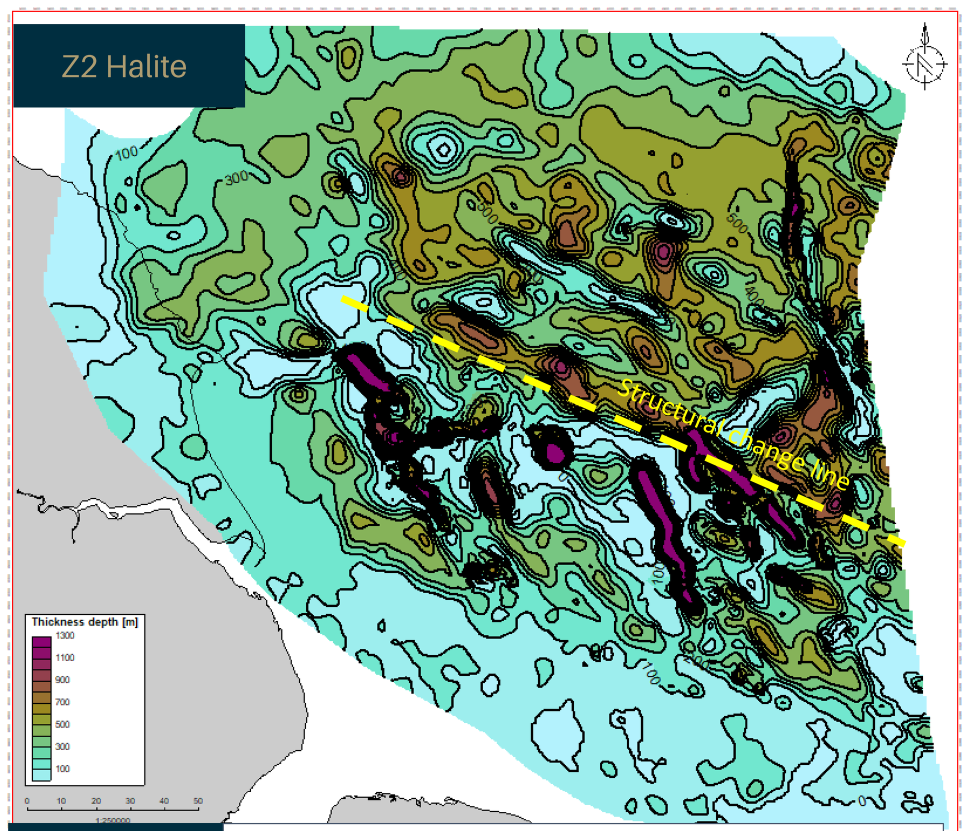
White - well data
Red - survey outline
Pink - grid outline
Yellow – Zechstein cross-section

Z3 carbonate is a key marker horizon within the Zechstein Group

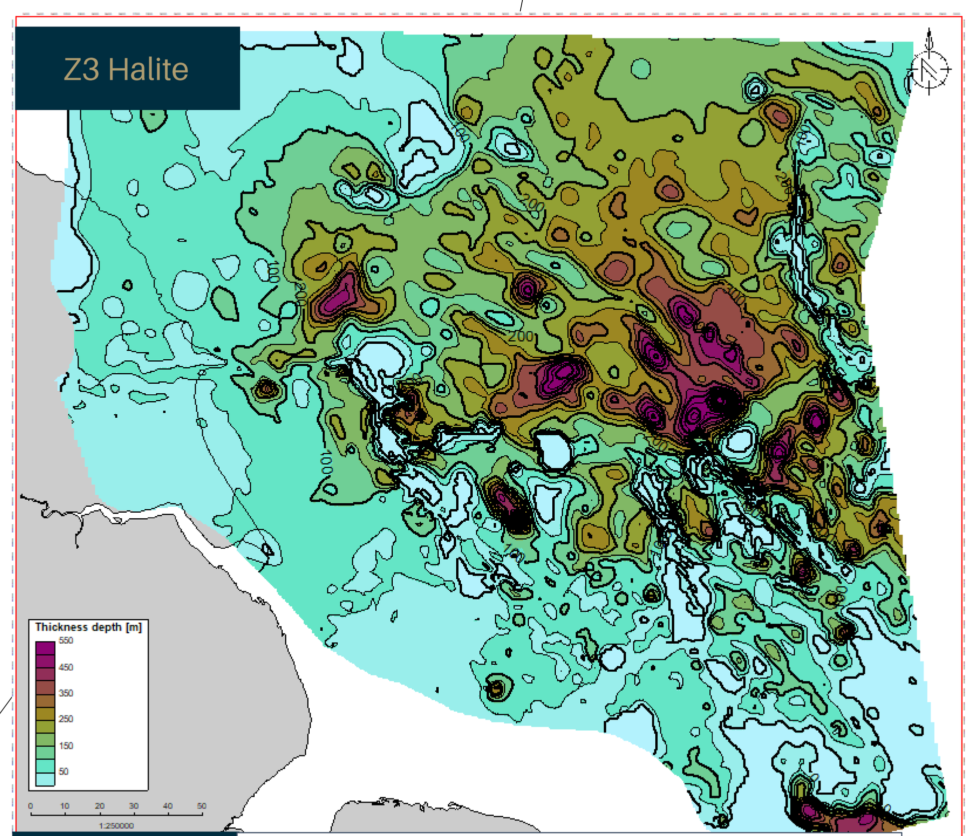
Evidence of constrictional folds and boudins

Extension-related features in the Plattendolomit are consistent with Permo-Triassic regional tectonic framework[2]

Halite intervals show generally thicker deposits to the south associated with salt diapir structures. To the NE, towards the basin depocenter, thicker deposits align with E-W trending salt pillow structures



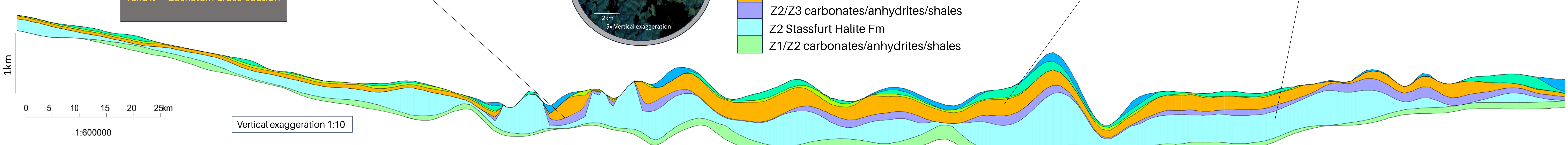
Isopach | Thickness of the Z2 Stassfurt Halite Formation. Contour interval 100m



Isopach | Thickness of the Z3 Leine Halite Formation.

Key units

- Upper Permian Marls
- Z4 Aller Halite Fm
- Z3/Z4 carbonates/anhydrites/shales
- Z3 Leine Halite Fm
- Z2/Z3 carbonates/anhydrites/shales
- Z2 Stassfurt Halite Fm
- Z1/Z2 carbonates/anhydrites/shales



2. Interpretation techniques

Seismic interpretation: Key marker horizons including top/base Zechstein, top Plattendolomit, Top/base of halite intervals. Legacy BGS 2D seismic interpretation used to constrain nearshore and onshore areas.

Seismic attributes: Interpretation guided by pseudorelief, chaos, and reflection strength attributes. Curvature and dip-angle used to refine salt wall locations

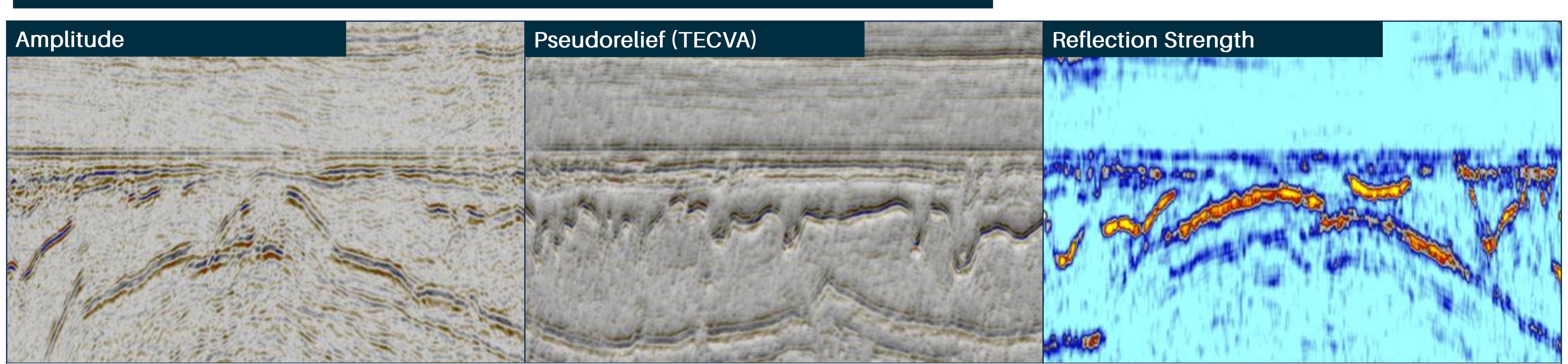
Lateral variation in Lithology: nearshore shelf-anhydrite-carbonate to thick basin-halite deposits further offshore change the seismic character of each unit.

Regionally-mappable horizons (e.g. Plattendolomit) used to guide modelling of poorly-imaged horizons (e.g. base Aller Halite (Z4), top Stassfurt Halite (Z2), using isopachs generated from well markers and conformal gridding methods.

Depth conversion: Regional layer-cake velocity model based on interpolated interval velocity maps.

Intra-Zechstein Surface Construction Workflow

- Amplitudes with Pseudorelief overlay time picks
- Co-volume propagation
- Conformal Gridding
- Depth Conversion
- Well top map
- Depth corrected manually
- Well top Isopach map
- Isopach +/- Depth corrected surface
- Depth corrected manually
- Structural model



Pseudorelief attribute: used to enhance contrast between high-amplitude carbonate/anhydrite intervals and low-amplitude halite units

Reflection strength attribute: used as a co-volume to guide 3D autotracking

3. Cavern Storage Modelling

- Define spatial distribution and thickness of halite formations in Petrel
- Python script to model theoretical cavern locations and capacity using methodology described in Parkes et al (2018)
- Model an idealised storage cavern scenario based on halite depth and thickness at each cavern location
- Apply volumetric correction factors to calculate usable cavern volume
- Calculate theoretical energy storage capacity and deliverability potential
- Estimate cavern operating conditions for each cavern location

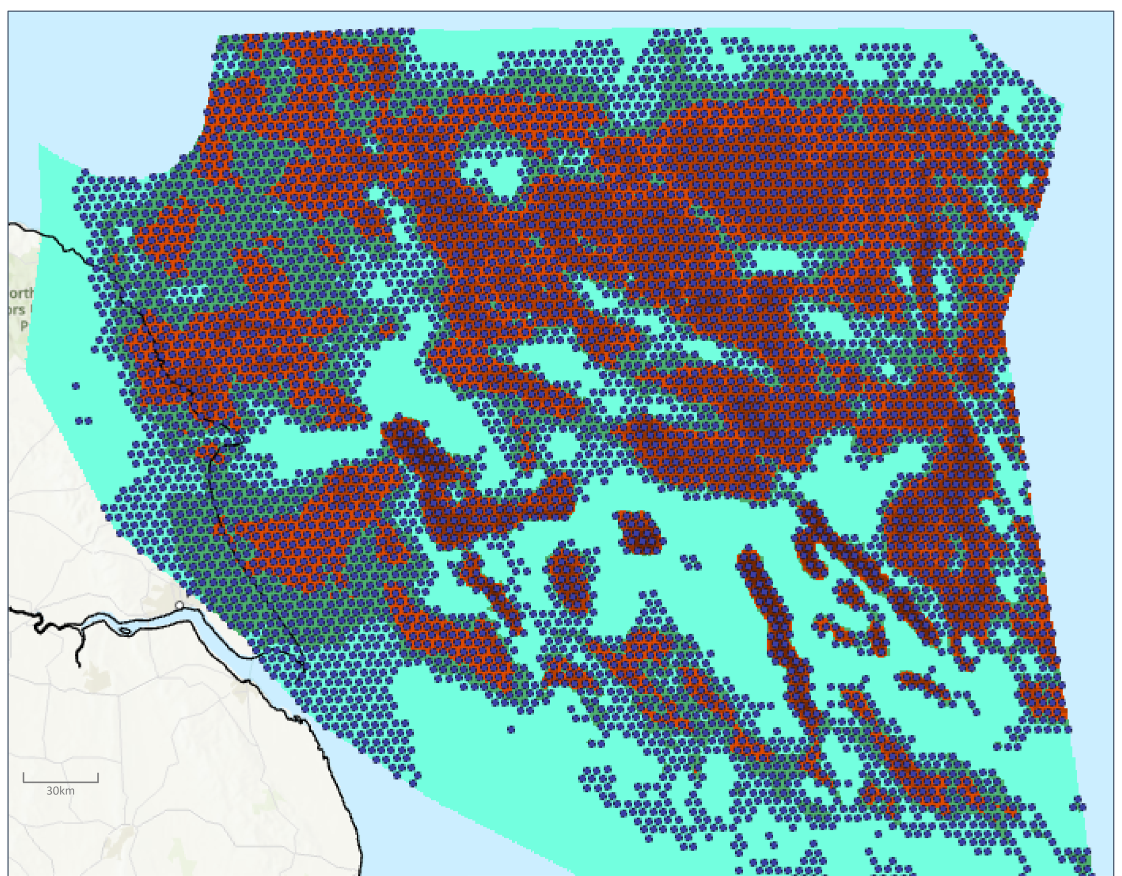
Methodology for estimating hydrogen storage capacity, adapted from Williams et al (2022)[3] and Parkes et al (2018)[4]

Cavern design/volume constraints based on Preesall gas storage project:

- Pill shaped cavern with 50m radius
- 150m fixed pillar width
- Salt insoluble fraction: 0.2

Near-shore and offshore locations are typically subject to fewer planning and social acceptance restraints. Potential for co-location with other offshore infrastructure projects such as windfarms.

Maximum cavern height used is 300m with a minimum height of 20m.



Theoretical hydrogen storage cavern locations | Example output from theoretical hydrogen cavern storage modelling workflow, based on interim mapping of the Stassfurt Halite Fm

Conclusions

This study will generate halite distribution and thickness maps for the Zechstein Formation which can be used to assess potential cavern storage for the Southern North Sea. Depth corrected surfaces and isopach maps for halite-bearing intervals provide input into a cavern capacity modelling workflow to understand the distribution and theoretical capacity of potential cavern storage solutions.

Thickness maps of the Stassfurt and Leine Halite indicate sufficient sufficient thickness for theoretical potential storage across parts of the nearshore area and in salt pillows and salt walls further offshore.

Detailed surface mapping of the Plattendolomit (Z3 carbonate) highlights various styles of structural deformation related to halokinesis and regional extension. Improved understanding of deformational styles across the basin may help to identify suitable geological conditions for cavern storage.

Preliminary results for hydrogen storage cavern locations generated align with isopach map of Stassfurt Halite (Z2). Initial estimates of storage capacity for Stassfurt Halite shown from one iteration of modelling process.

Future Work

Further refinement of depth and thickness maps in areas with limited data constraint.

Further refinements to cavern storage calculation workflow to test a range of cavern design scenarios.

Acknowledgements

This study is part of the Managing the Offshore Energy Transition (MOET) Project , in collaboration with the National Oceanographic Centre and Plymouth Marine Laboratories. Funded by the NERC National Capability Multi-Centre Science programme

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[3]Williams, J. D. O., et al. (2022). "Does the United Kingdom have sufficient geological storage capacity to support a hydrogen economy? Estimating the salt cavern storage potential of bedded halite formations." Journal of Energy Storage **53**
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