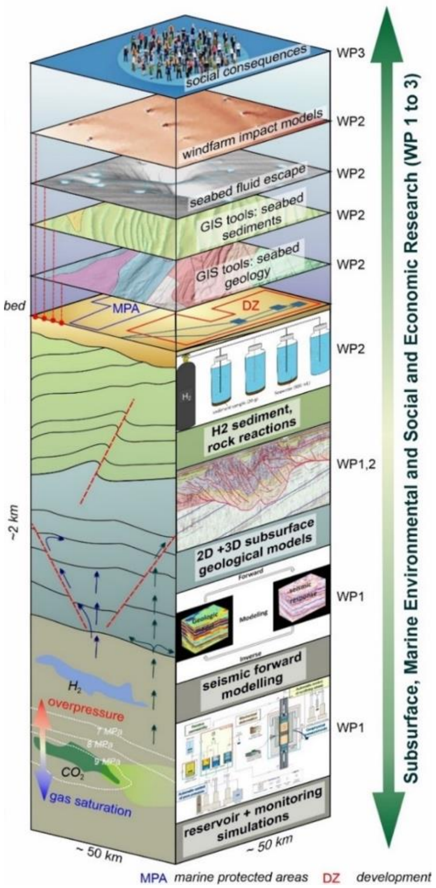
EMMA BEDDA, HARRY MORRIS, TOM RANDLES, ED HOUGH

Zechstein halites as a potential hydrogen storage solution – Interim Results

British Geological Survey

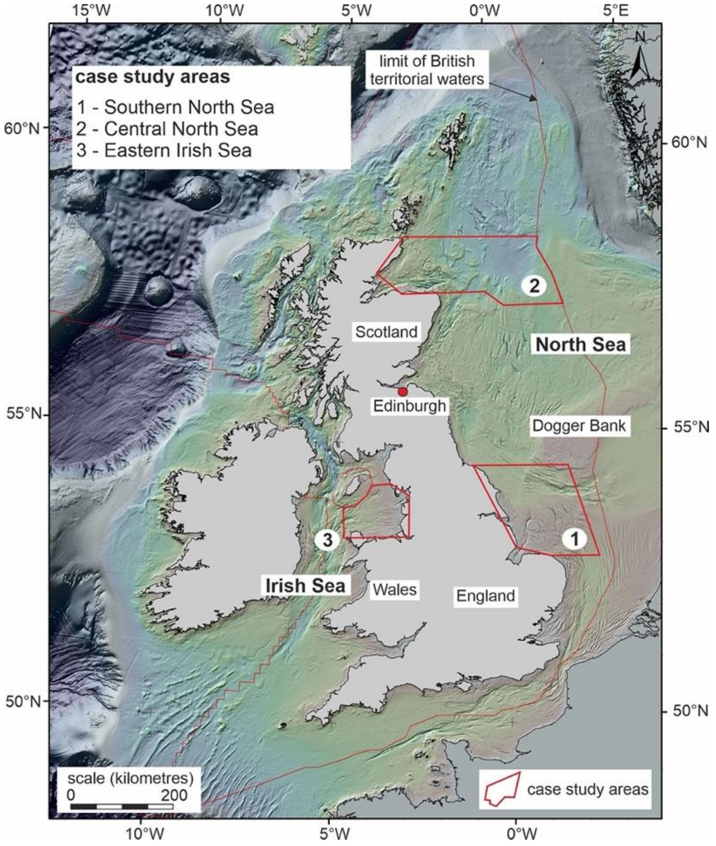


Managing the Offshore Energy Transition

What are the requirements for subsurface geological H_2 & CO_2 to enable the energy transition?

- Offshore UK is already busy, seabed and subsurface
- Transition to low-carbon technologies, existing and new uses
- Low-carbon subsurface technologies:
  - Temporary storage of hydrogen in salt caverns
  - Temporary storage of hydrogen in porous strata
  - Permanent storage of CO_2
- Physical interaction of storage facilities & infrastructure, also offshore operations.
- Assessing synergies & minimising conflicts of subsurface use

MOET AOI and work package one (WP1)

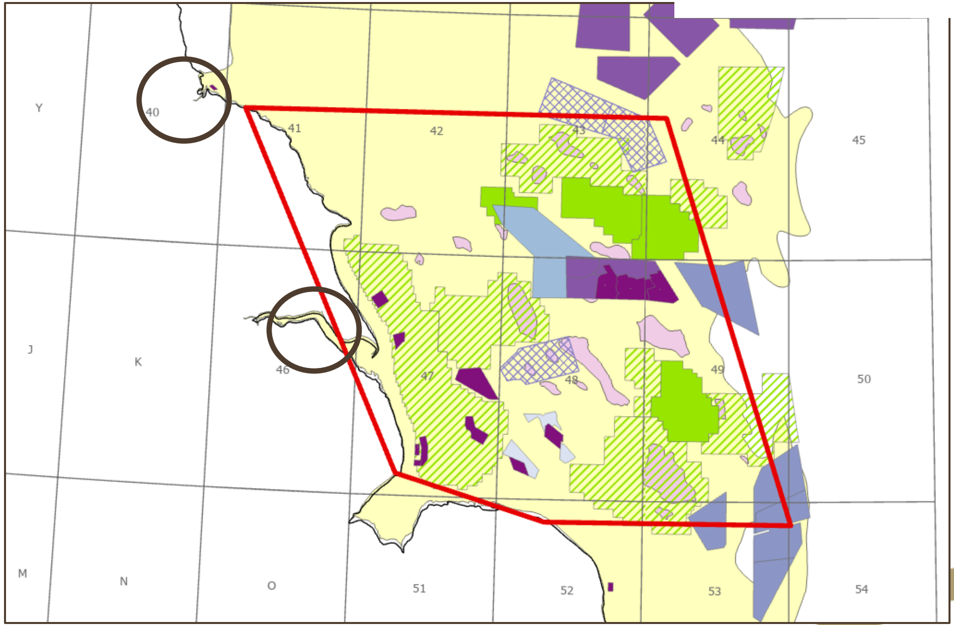


- UK industrial decarbonisation clusters
- Three main clusters
  - Humberside & Teesside, southern North Sea
  - Hynet, Liverpool Bay
  - Scotland, outer Moray Firth (reserve cluster)
- Experimental work & modelling of storage operations informed by the experimental results
- Investigation of subsurface low-technology uses
- Fully integrated to consider synergies & avoid conflicts

Southern North Sea Area of Interest

Managing the Offshore Energy Transition

- WindSiteAgreements_EnglandWalesAndNI_TheCrownEstate
  - Active/In Operation
  - Under Construction
  - Consented
  - Government Support on Offer
  - In Planning
  - Pre-planning Application
  - Preferred Project – Subject to HRA
- Offshore Wind Leasing Round 4 Preferred Projects (England, Wales and
- Offshore Wind Leasing Round 4 Characterisation Areas (England, Wale
- Offshore Wind Leasing Round 4 Bidding Areas (England, Wales and NI)
  - Offshore Wind Leasing Round 4 Bidding Areas (England, Wales and I
- CCS
- UKCS_CarbonStorage_Licences_ED50
  - CS_Licences_ED50
  - Carbon Storage Areas Offered for Application (ED50)



BGS

Introduction

Managing the Offshore Energy Transition

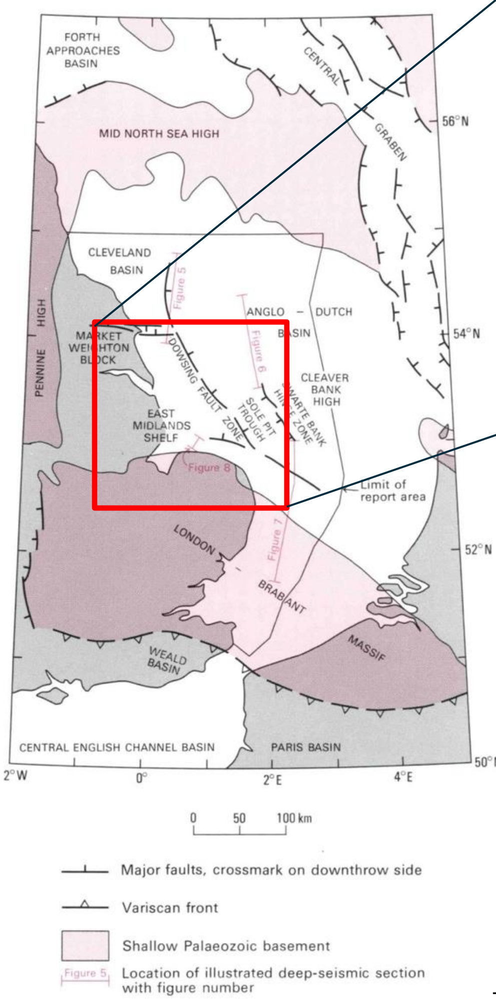
- Part of a program of detailed work investigating interactions between energy transition uses for east coast industry cluster.
- Ensuring the effective and optimal use of subsurface geological resources for temporary H_2 and permanent CO_2 storage.

- *Aim of this study is to determine distribution and thickness of halite deposits to support cavern storage capacity.*

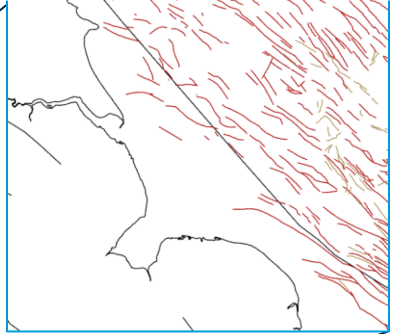
Study is part of the Managing the Offshore Energy Transition (MOET) project. In collaboration with the National Oceanographic Centre and Plymouth Marine Laboratories. Funded by the NERC National Capability Multi-Centre Science Programme.

Geological setting

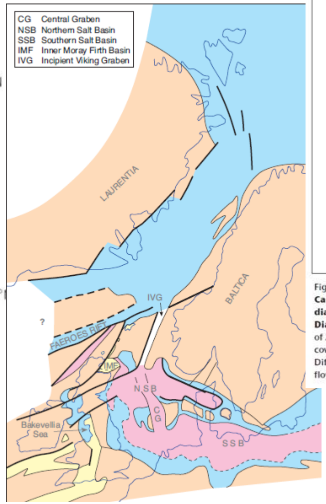
		Onshore	Offshore	Lithology
Bacton				
Zechstein Supergroup	Z5			
	Z4		**Aller Halite Fm**	Z4 Salt
				Z4 Anhydrite
				Z4 Clay
	Z3	**Boulby Halite Fm**	**Leine Halite Fm**	Z3 Salt
		Upper Magnesian Limestone	Plattendolomit Fm	Z3 Anhydrite Z3 Carbonate Z3 Clay
	Z2			Z2 Anhydrite
		Fordon evaporate Fm	**Stassfurt Halite Fm**	Z2 Salt
			Basalanhydrit Fm	Z2 Anydrite
		Lower Magnesian Limestone (aka Kirkham Abbey Fm)	Hauptdolomit Halite Fm	Z2 Carbonate
	Z1			Z1 Anhydrite Z1 Carbonate Z1 Coppershale
Rotliegend				
Carboniferous				



BGS offshore regional report 1992



Permian structural framework



The Millennium Atlas 2003

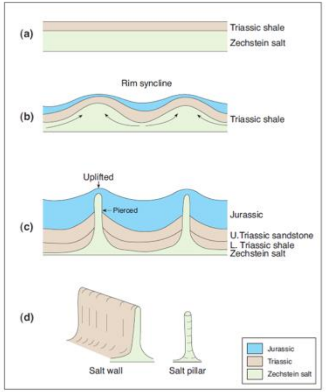
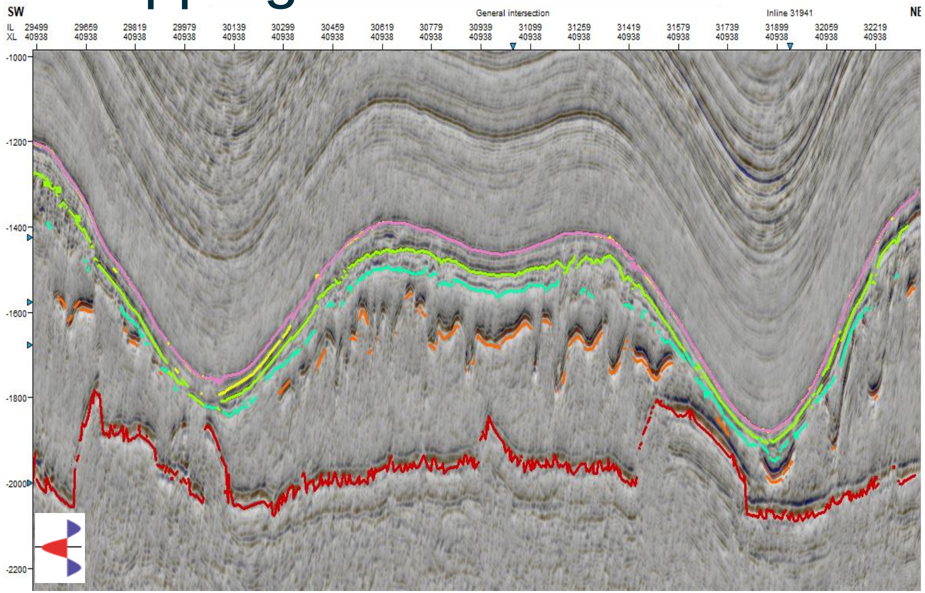


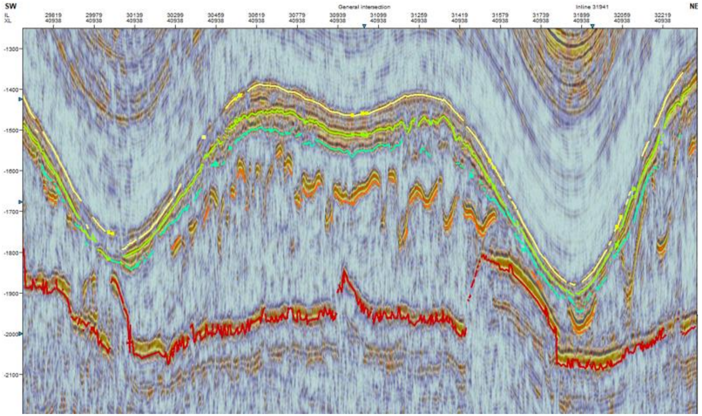
Figure 8.28
Cartoons of salt-induced diapiric structures.
Diagram a shows the deposition of Zechstein salt followed by a cover of Triassic sediments. Differential loading causes salt to flow, creating salt pillows and rim synclines, which are infilled with lenses of sediment (b). Continued sedimentation and movement of salt can lead to the growth of cylindrical salt pillars (c) and, if triggered by fault movement, of salt walls (d).

Mapping Zechstein sub-divisions



Amplitude with 'pseudo-relief' (TECVA) overlay

Top Zechstein	Seismic attributes used to define seismic packages
Aller Halite	
Leine Halite	
Plattendolomit	
Base Zechstein	



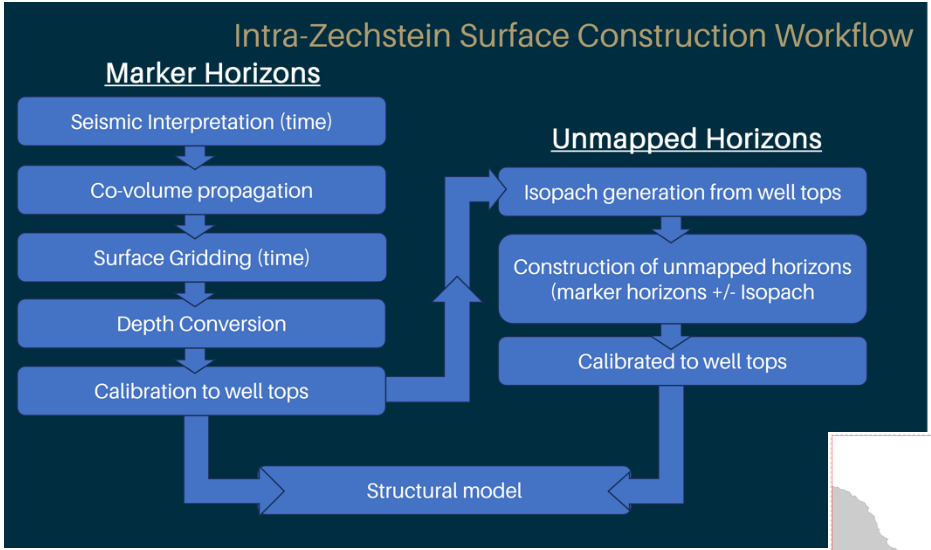
Reflection intensity

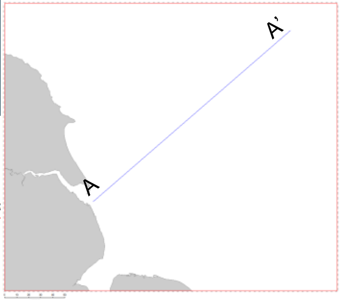
- Pseudo-relief attribute – high amplitude carbonate/anhydrite intervals and low-amplitude halite units
- Reflection strength – co-volume in autotracking
- Curvature and dip angle refine salt wall locations

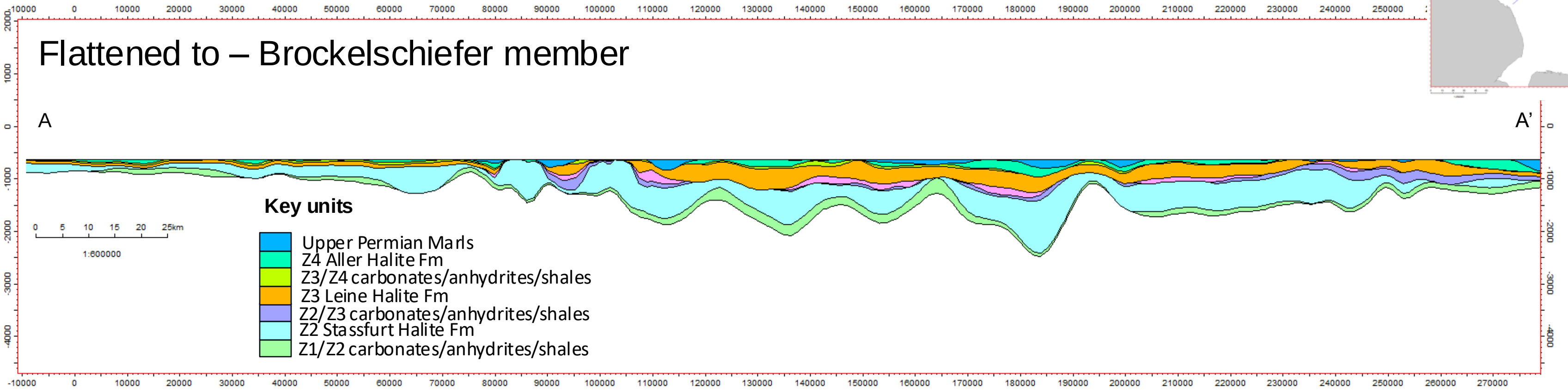
MC3D SNS MegaSurvey (PGS). Contains information provided by the OGA.

Seismic Mapping

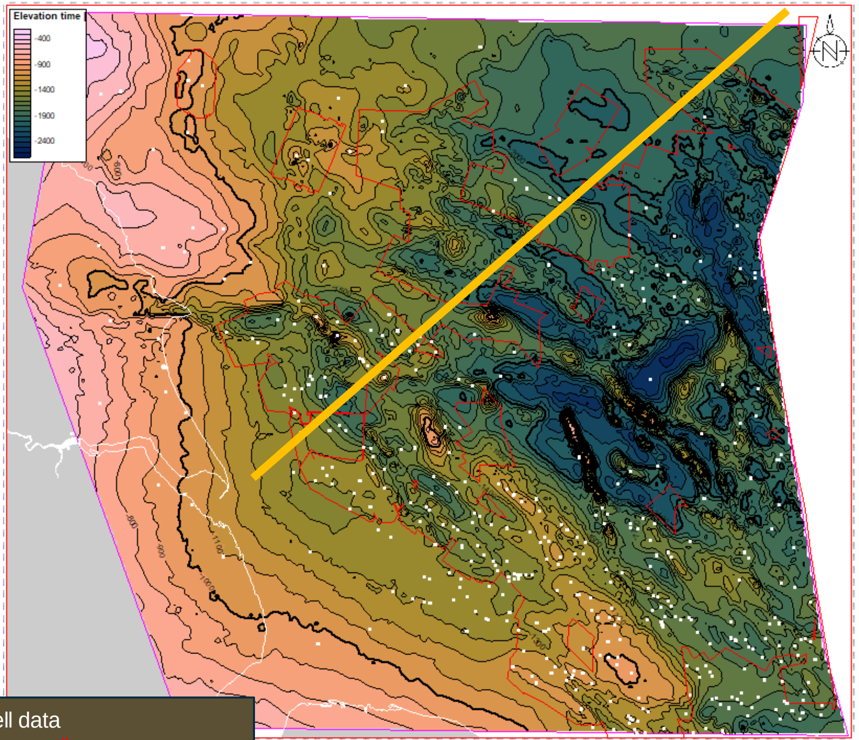
- Lateral variation in lithology
- Regionally mappable horizons
- Additional horizons modelled in depth using well formation tops and implicit modelling approach







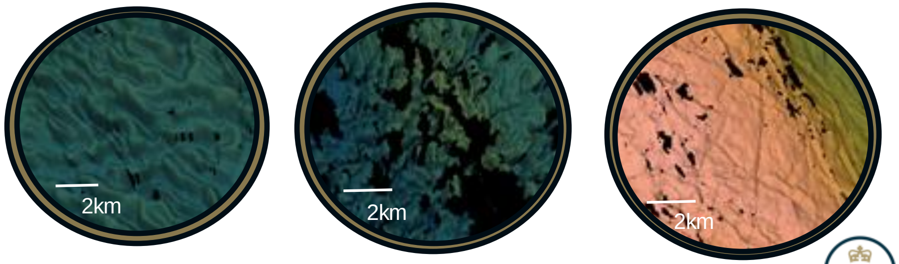
Plattendolomit – key surface



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

Z3 – Carbonate (Plattendolomit)

- Key marker horizon used to derive isopach maps of Stassfurt, Leine and Aller Halite Formations
- Varying deformation patterns
- 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 (Cartwright (2012)
- Thins to below seismic resolution

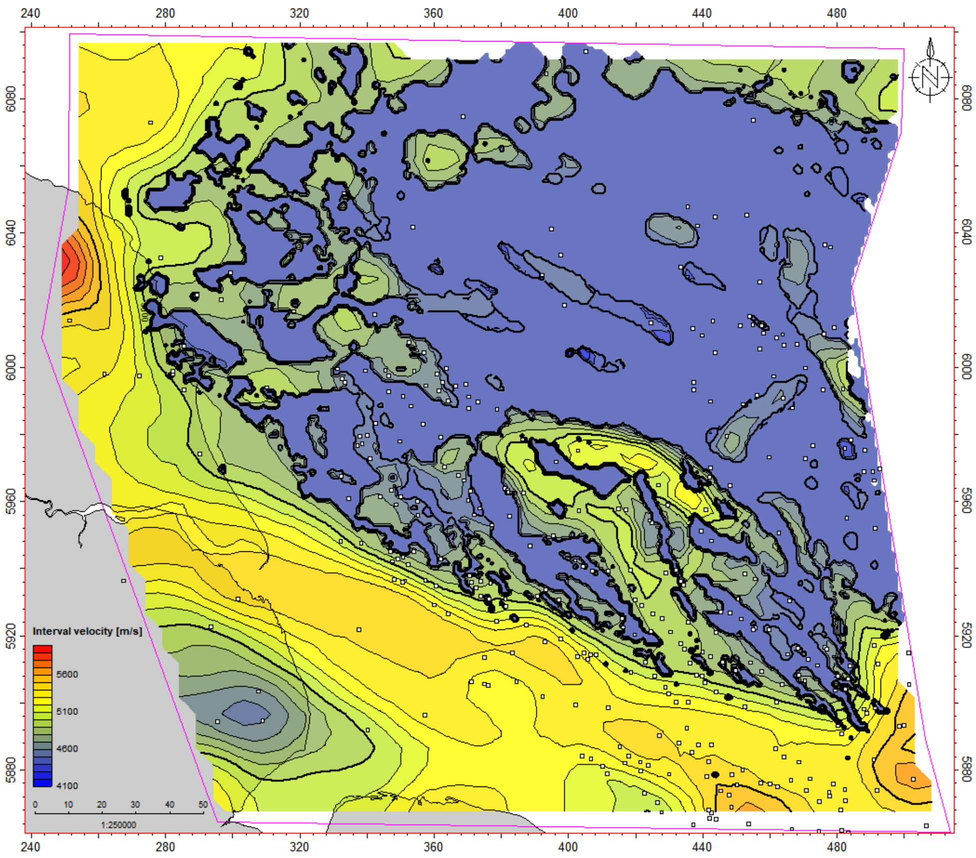


5x Vertical exaggeration

Depth Conversion

- Laterally varying regional velocity model
- Based on time-depth picks from ~400 wells
- 39 wells with sonic log penetrating Zechstein
- Pseudo-well Interval velocities generated from interval thickness
- Interval velocity maps generated using cokriging
- Depth converted and calibrated to well tops

Zechstein interval velocity map



Contour 100m/s

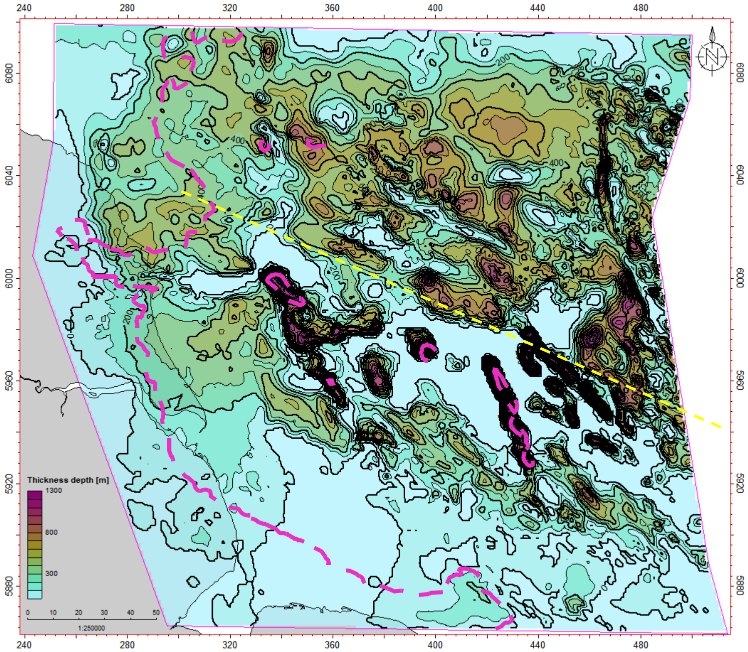
Key

□ Vint (calculated from well thickness)

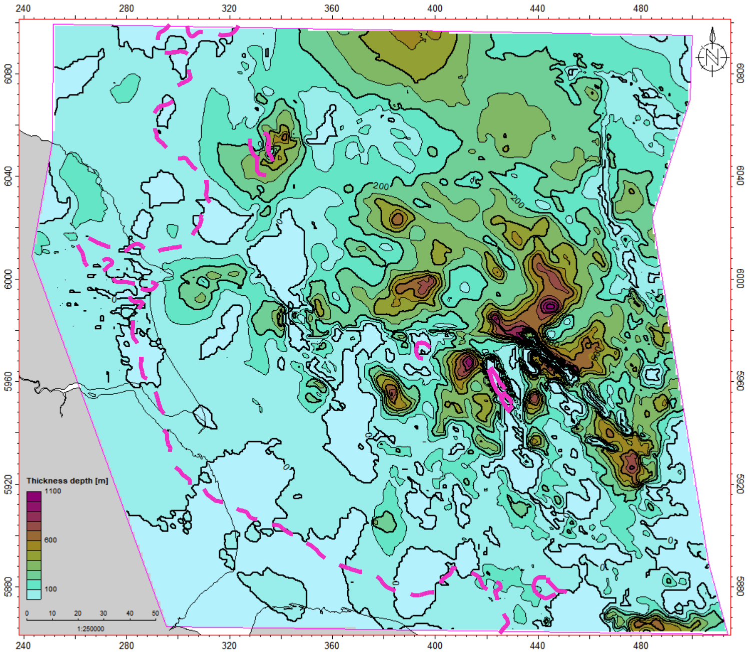
Isopach

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

Fordon/Stassfurt Halite



Boulby/Leine Halite



Contour 100m

0 - 800m

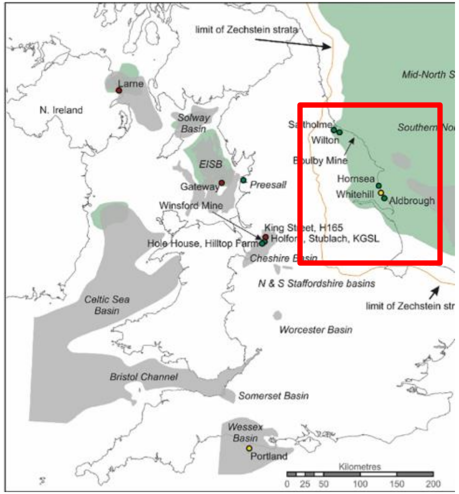
0 - 550m

1500m depth contour

Structural change line

Estimating CAES in East Yorkshire and North Lincolnshire Coast

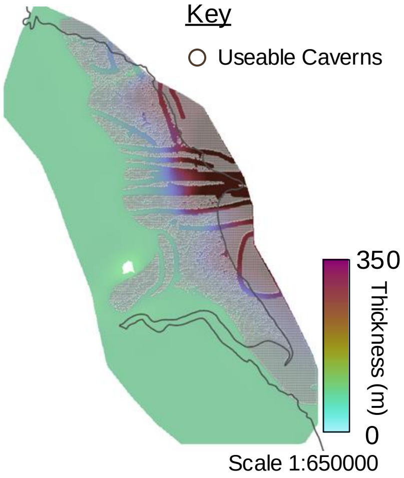
- Proof of concept
- Focused on Fordon/Stassfurt Halite
- Filtered caverns near urban infrastructure i.e. roads, railways etc…



Williams et al 2022

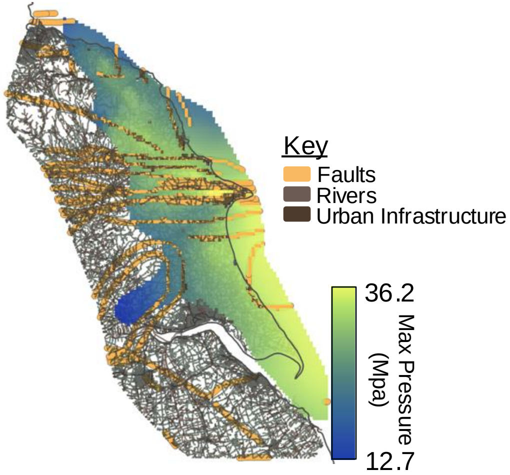
- Filtered caverns unsuitable for compressed air storage
- Generated output showing max operating pressures of filtered caverns

Viable CAES Caverns



Thickness map of Fordon overlaid with Viable CAES Caverns

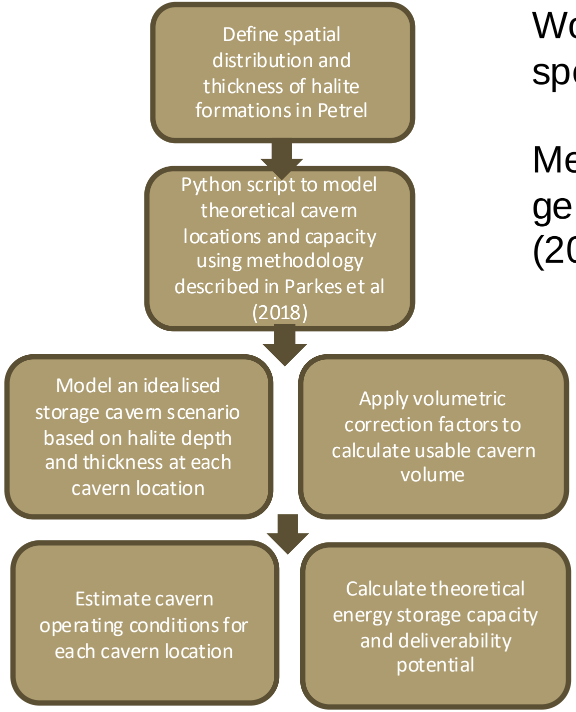
Max Operating pressures



Max operating pressures of Fordon with urban and geological hazards overlaid

Acknowledgement work by Ed Hough, Harry Morris and Xiaoyang Wu

Cavern Storage Modelling Workflow



Adapted from Williams et al 2022

Workflow intends to give estimates for solution-mined caverns in a specified area where geometry of top and base halites are known

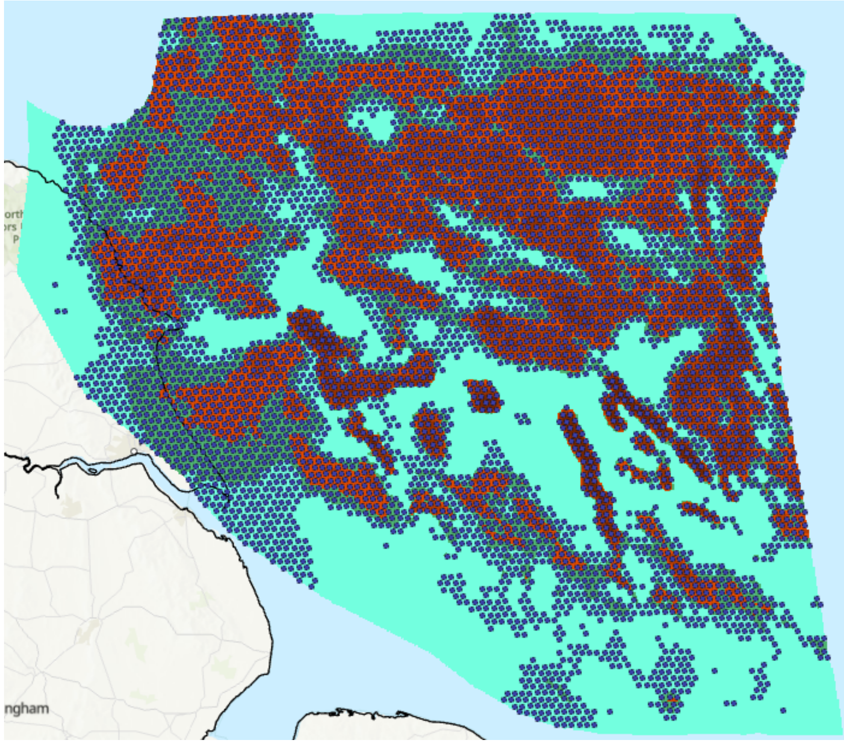
Methodology was adapted from python scripts and QGIS plugins generated by P. Williamson. Workflow documented in Williams et al (2022) and Parkes et al (2018)

Cavern design/volume constraints based on Preesall Saltfield Underground 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

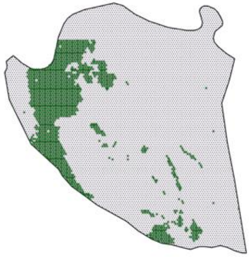
Cavern Storage Modelling – initial results



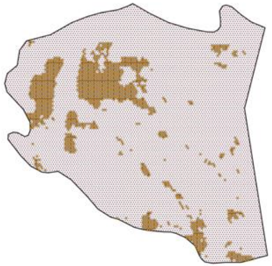
Theoretical hydrogen storage cavern locations – example output from theoretical hydrogen cavern storage modelling workflow, based on interim mapping of the Stassfurt Halite Fm.

Caverns were filtered based on geological model and geothermal gradient constraints. Interim results below are from one iteration of cavern modelling workflow.

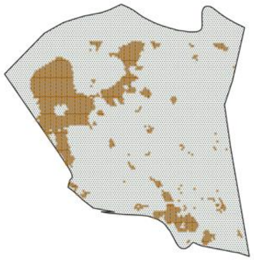
Z2 - Stassfurt



Z3 - Leine



Z4 - Aller



Conclusions

- Generate halite distribution and thickness maps for the Zechstein Formation for use in assessing potential cavern storage for the Southern North Sea.
- Isopach maps generated from depth corrected surfaces as inputs to cavern capacity modelling workflow.
- Interim results indicate Stassfurt and Leine Halite provide sufficient thickness for theoretical potential storage.
- Detailed mapping of Z3 carbonate (Plattendolomit) highlights various styles of structural deformation related to halokinesis and regional extension. Improved understanding of deformational styles across basin may help identify suitable geological conditions for cavern storage.
- Proof of concept running cavern storage workflow for CAES can apply methodology to hydrogen storage

Researchers involved:

Tom Randles, Harry Morris and Ed Hough

British Geological Survey

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

P. Williamson retired BGS staff

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