CHIMNEY and James Cook 152

Constraining fluid flow processes and the physical properties of sediments relevant to CCS

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CHIMNEY: Characterisation of major overburden leakage pathways above sub-seafloor CO2 storage reservoirs in the North Sea

CHIMNEY Partners: University of Southampton; University of Edinburgh; National Oceanography Centre;
Project partners: GEOMAR, CGG, Lawrence Berkeley NL, Applied Acoustics

Designed to be complimentary to STEMM-CCS, written after STEMM-CCS was funded as a means of funding additional but complimentary work. Scanner pock mark complex studied by MSM63 (STEMM-CCS) and JC152. CHIMNEY not related to gas release experiment in 2019.

Funded by NERC (Highlights call related to Carbon Capture and Storage)

May 2016 – September 2021
Motivations

• Understanding mechanisms for vertical/sub-vertical fluid flow in the sub-surface that do not involve large faults. “Seal Bypass Systems”.
• Understand the ubiquitous(?) seismic chimneys/pipes found in offshore sedimentary basins. What are they and how do they form?
• Constrain sub-surface permeability
• Increase knowledge on understanding likely impacts of (marine) Carbon Capture and Storage
Carbon Capture and Storage (CCS) Implementation

Limited experience with the monitoring, verification and reporting of actual physical leakage rates and associated uncertainties.
The QICS experiment

- CO₂ Store
- Boat, diver and in situ monitoring
- 11m water depth
- Silty sand
- Unconsolidated muds
- Bedrock

350m bore hole
Diffuser 11m water below seafloor

May 2012: Pre-release
Injection
Recovery
Sept 2012
Time-lapse seismic reflection profiles and cartoon illustrating gas pathways above the site of CO₂ release at the QICS experiment (Cevatoglu et al, 2015 and unpub) with propagation of the gas and generation of seismic chimneys during the release. The position of the CO₂ injection site 11m beneath the seabed is indicated (red dots). Note that two years post-release the seismic chimneys disappear, but there is still enhanced reflectivity on Horizon 2.
Chimney / Pipe structures in Offshore sedimentary basins

- Natural fluid pathways
- Chimneys: diffuse seismic image
- Pipe structures: sharp vertical boundaries

Karstens, 2015
Hypothesis tests - CHIMNEY

We will test the hypothesis that many chimney and pipe structures imaged on seismic reflection profiles in the North Sea are the consequence of:

(1) a fracture network that has been reactivated by pore fluid pressure which facilitates the migration of fluids upwards; and

(2) shallow sub-seafloor lateral migration of fluids along stratigraphic interfaces and near-surface fractures.

We will address the critical questions: what is their in-situ permeability now; and could a \( \text{CO}_2 \) fluid use these structures as a conduit?
CHIMNEY components

• **A** - novel broad-band seismic anisotropy experiment over a North Sea chimney in order to understand its structure and origin, derive fracture geometry and topology and ascertain if fractures are open or closed. *Additional high-frequency seismic reflection imaging.*

• **B** - rock physics experiments on synthetic samples to constrain chimney, and surrounding rock permeability.

• **C** – Geochemical characterisation of chimney material and pore fluids. Core samples from the North Sea chimney will be used to assess hydraulic connectivity, water-rock reactions that affect permeability and the longevity of fluid flow, and to constrain reactive transport modelling.

• **D** – Flow and reactive transport modelling to integrate outcomes of the three other WPs and do scenario modelling. Use fluid flow simulator (TOUGHREACT).
Site selection based on industry data
Scanner Pockmark – UK Sector

- Clear seabed expression and very active methane venting
- Not certain about pipe at depth
JC152 actual cruise track

Two legs; Aberdeen to pick up streamer repairs; offload crew members

James Cook 152 very successful to Scanner and Challenger Pockmark complexes
JC152 - Anisotropy and imaging of Chimney structures - I

• Grid of 25 OBS around Scanner Pockmark
• Five acoustic Sources – Bolt airguns, GI guns, Surface sparkers (Squid and Duraspark), Deep Tow Sparker
• Two multichannel streamers – 60 and 120 channels
• Multibeam bathymetry; 12 kHz sub-bottom profilers; EK60 profilers
• Songmeter passive acoustic recorder; two deployments
JC152 - Anisotropy and imaging of Chimney structures - II

• Bonus 7 OBS – deployed around second pock mark complex – Challenger
• Anisotropy survey completed over Scanner with all sources
• Very close Multichannel seismic reflection line spacing over Scanner and Challenger Pockmark complexes using GI gun and surface sparker sources. Very good data quality. (see poster).
• Sparser Deep Tow Sparker (single channel) profiles. Variable but some good data.
• Ocean Bottom Seismometer data looks excellent (see poster).
Two OBS deployments:

25 for anisotropy experiment around Scanner

6 positions around Challenger pockmark
Scotia Pockmarks
North c. 15 m deep
South c. 12 m deep

Scanner West and East Pockmarks
Western c. 17 m deep
Eastern c. 15 m deep

c. 500 m long
EK60 – OBS deployment and flares
JC152 Example seismic reflection data

- Sub-bottom Profiler
- Deep-tow Sparker (DTS)
- Squid Sparker
- Gi gun

Processed by Tim H.

Limited Interpretation
JMB
Questions?

JC152 – Scientific Party