



Abstract Book

5TH CCS SYMPOSIUM: MULTISCALE APPROACHES TO ASSESS AND ADVANCE CCUS

20-21 OCTOBER

The Geological Society, Burlington House,
Piccadilly, London

Carbon Capture, Utilisation and Storage (CCUS) is advancing rapidly worldwide, yet its success depends on our ability to understand, predict, and optimise subsurface behaviour across multiple spatial and temporal scales. This conference will explore how multiscale approaches can support safe, effective, and commercially viable CCUS deployment.

We invite abstracts presenting new research, case studies, methodologies, or innovations that deepen our understanding of CCUS at any scale. Topics of interest include, but are not limited to:

- Pore- to Core-Scale Processes
- Geomechanics
- Aquifer / Reservoir Characterisation & Performance
- Basin & Regional-Scale Screening
- Understanding Risk & Uncertainty
- Monitoring, Measurement & Verification (MMV)
- Modelling, Simulation & Cross-Scale Integration

We welcome contributions from both academia and industry, including active project insights, real world operational experience, emerging technologies, and current research developments.

We are also delighted to announce the return of the Energy Group Conference Prize for "Best Student or Early Career Contribution", awarded to an eligible student or early career researcher delivering an outstanding oral presentation or poster.

The call for abstracts for this conference is now open until Friday 31 July 2026.

For further information please contact
Email: energygroup@geolsoc.org.uk

Convenors:

Clare Glover

Stuart Gilfillan

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5th CCS Symposium - Multiscale approaches to assess and advance CCUS

20 - 21 October 2026

The Geological Society, Burlington House, London

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14.35	Bridging Enhanced Rock Weathering and CCUS: Multiscale Evaluation of CO₂ Uptake in Mafic-ultramafic Mine Wastes Rosalia Shiimi
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Oral Presentations

Keynote: Looking for 'Goldilocks': multiscale subsurface characterisation to predict and optimise CO₂ storage efficiency

Author(s): Catherine Gibson Poole

Organisation(s): BP

Abstract

Pending

Pragmatic CS Development: Bridging Merchant Challenges and Asset Decarbonization with Fit-for-Purpose Solutions

Author(s): Romain Rubi, Madeleine Bry, William Gordan-Canning

Organisation(s): TotalEnergies

Abstract

The CCS landscape is entering a pivotal phase. While Northern Lights has become the first commercial project to operate and inject CO₂, broader carbon storage (CS) merchant activity is progressing more slowly than anticipated. In this context, TotalEnergies is pursuing a dual-track strategy: advancing merchant CCS hubs while accelerating carbon management solutions for its own operated assets, in alignment with its emission reduction roadmap and wider societal expectations. This paper outlines a pragmatic, fit-for-purpose approach to CCS project development that seeks to balance meaningful emissions abatement with rigorous capital discipline. It highlights the importance of strategic agility in a nascent industry, sustaining continuity in customer-linked merchant services while advancing practical, asset-driven solutions at scale. Two case studies illustrate this approach across contrasting environments: a deep offshore project and an onshore development. These examples highlight key challenges, including value chain integration, infrastructure, reservoir suitability, and cost optimization under uncertain commercial frameworks. By bridging merchant and internal decarbonization needs, TotalEnergies demonstrates how tailored CCS solutions can unlock viable pathways for large-scale deployment while mitigating financial exposure and supporting the energy transition.

Is it time to convert natural gas fields to low carbon hydrogen production?

Author(s): David Hughes

Organisation(s): Subsurface CO2 Dynamics Ltd

Abstract

Producing hydrogen from natural gas using steam methane reforming (SMR) or auto-thermal reforming (ATR) and capturing and storing the CO₂ by-product is a well-known chemical engineering workflow for the production of “blue” hydrogen.

However, the efficiency of the process can be improved and the costs reduced if the hydrogen is produced upstream at the gas processing site, or as nearby as possible, exported through existing pipelines and the CO₂ by-product, together with CO₂ from local energy provision, immediately injected at the base of the gas column in the producing field.

The benefits and challenges of injecting CO₂ into a producing gas field using results from detailed reservoir simulations are explored using a half million grid block dome-drape sector model. The injected CO₂ provides pressure support and, in principle, a bottom-up stable displacement given that it is denser and more viscous than the natural gas; by a factor of ~4 and ~2.5 respectively at the pressures and temperature considered.

Sensitivity to permeability, reservoir heterogeneity, geological correlation, production/injection rates and timing are investigated. Injecting into the connected underlying aquifer is also considered.

It is concluded that geological heterogeneity and the degree of geological correlation are the primary sensitivities. Also that upstream hydrogen production can be introduced at any time, but is technically optimal at the point when natural reservoir pressure can no longer sustain plateau production.

The upstream hydrogen process enables gas field operators to produce low-carbon hydrogen at gas processing sites for industrial use such as methanol, ammonia and steel production. Converting natural gas to hydrogen production upstream can both add value to gas assets and minimise the climate impact of the sales product. Using the CO₂ byproduct for pressure support and long-term storage also benefits the project economics compared to “standard” blue hydrogen production.

Study on the CO₂ hydrate distribution and seepage flow characteristics within NGH reservoirs

Author(s): Ziming Yang, Baixin Chen, Bingbing Chen, Mingjun Yang

Organisation(s): Heriot-Watt University, Dalian University of Technology

Abstract

Under the dual drivers of global energy transition and carbon neutrality objectives, submarine carbon sequestration technology has emerged as a critical strategy for balancing energy security and climate governance. Depleted natural gas hydrate (NGH) reservoirs in seabed sediments exhibit favorable temperature and pressure conditions for carbon dioxide (CO₂) sequestration and hydrate formation. This study focuses on the thermodynamic and kinetic characteristics of phase transitions influenced by multiphase seepage, employing magnetic resonance imaging (MRI) technology to elucidate phase evolution patterns during CO₂ sequestration and the role of hydrate phase transitions in porous media on seepage behavior. The findings indicate that residual NGH frameworks significantly enhance CO₂ hydrate formation kinetics, exhibiting a top-down directional growth mode. However, progressive hydrate formation induces pore throat blockage, thereby constraining CO₂ migration. The continued CO₂ hydrate formation (consuming dissolved CO₂) further intensifies this clogging phenomenon. At an NGH saturation (S_i) of ~15 %, hydrate and CO₂ occupied over 62 % of the reservoir pore space, indicating exceptional carbon storage capacity. Furthermore, the nonlinear evolution of reservoir permeability provides theoretical support for establishing a CO₂ sequestration-in situ hydrate energy synergistic system. These findings advance marine carbon sequestration technologies and provide a scientific foundation for achieving carbon-energy synergy regulation in NGH reservoirs under carbon neutrality goals.

Investigating Water Vapour Sorption and Thermodynamic Characteristics of Clay Minerals under the Influence of Temperature

Author(s): Shubham Kumar, Vikram Vishal, Ranjith Pathegama Gamage

Organisation(s): IITB-Monash Research Academy

Abstract

Nanoscale pore characteristics in clay-rich shales are critical for assessing gas storage and fluid transport within subsurface formations. Moisture content in shales restricts fluid flow through pore spaces, while pore-throat characteristics strongly influence gas adsorption capacity and storage potential. This study examines the solid-liquid interactions, rate kinetics, and thermodynamic properties of clay minerals (CMs), such as Montmorillonite (Mont), Illite-Smectite (IL-Sm) (70:30), and Kaolinite (Kaol), using the experimental water vapour sorption (WVS) method at 10 °C, 20 °C, and 30 °C. The results show that Ca-rich Mont exhibits higher water vapour adsorption (WVA) at low relative humidity (RH), whereas Na-rich Mont dominates at high RH. Na-rich Mt is highly sensitive to temperature changes, notably at higher RH due to capillary condensation. However, Kaol exhibits the lowest adsorption volume among the CMs. In contrast, the adsorption volume generally increases with temperature, except for Ca-Mont at 30 °C. Moreover, the observed isotherm hysteresis behaviour in Na-rich Mont illustrates the rock hydration mechanism. Additionally, the pore size distribution (PSD) indicates the differential pore volume (DPV) of Ca-rich Mont, and IL-Sm is dominant at lower PD (< 5 nm). In contrast, Na-Mt has a bimodal PSD at around (< 5 nm) and (6 – 9 nm), and declines with increasing PD. However, Kaol shows an increase in DPV with increasing PD, while PV becomes significantly higher at 30 °C. The study further provides insight into the change in enthalpy, determined using the Clausius-Clapeyron equation, which ranges from 44–46, 44–45, and 42–44.5 kJ/mol for Mont, IL-Sm, and Kaol, respectively. Thus, the study provides fundamental insights into solid-fluid interactions, which play a crucial role in gas exploration and transport mechanisms in clay-rich subsurface shale formations. The study findings can be applied to geological carbon dioxide sequestration and radioactive nuclear waste disposal in ultra-low-permeability rock formations.

The Impact of Small-Scale Heterogeneities on Carbon Dioxide Saturation and Trapping in Carbonate Rocks.

Author(s): Nihal Darraj, Catherine Spurin, Sojwal MAnoorkar, Steffen Berg, Sajjad Foroughi, Martin Blunt, and Samuel Krevor

Organisation(s): Imperial College London, Stanford University, Ghent University, Shell

Abstract

Small-scale heterogeneity plays a fundamental role in controlling multiphase flow and trapping, yet its influence remains difficult to quantify and underrepresented in standard upscaling frameworks for geological CO₂ storage. To investigate this, we conducted drainage and imbibition experiments on two carbonate rock samples with different scales and orientations of heterogeneity. Core-flooding was carried out under capillary-dominated conditions, and high-resolution micro-computed tomography (micro-CT, ~5 µm voxel size) was used to capture three-dimensional fluid displacement in situ. By linking pore-scale observations to larger core experiments, we were able to identify which displacement and trapping processes upscale and therefore remain relevant to reservoir-scale behaviour. The results highlight that neglecting heterogeneity in models risks underestimating plume migration and storage capacity. Incorporating these effects into reservoir simulations is essential to improve predictions of CO₂ distribution, and optimise injection strategies.

Quantifying CO₂-Induced Reservoir Evolution Through Integrated Digital Rock Physics

Author(s): Lobel Danicic, Olga Lykhachova, Arne Jacob, Christian Hinz, Matthias Halisch, Gordon Burmester

Organisation(s): Math2Market GmbH, LIAG-Institute for Applied Geophysics, OMV Exploration and Production GmbH

Abstract

Geological CO₂ storage requires robust characterization and monitoring strategies to ensure safe injection, long-term containment, and reliable prediction of reservoir performance. Understanding how CO₂ migration, fluid redistribution, and geochemical alteration affect reservoir properties across multiple scales remains a key challenge. While field-scale observations provide valuable information on reservoir evolution, the underlying mechanisms originate at pore-scale. This study demonstrates how integrated Digital Rock Physics (DRP) combines high-resolution imaging, laboratory measurements, and multiple simulation techniques within a unified workflow to quantify CO₂-induced reservoir evolution. The approach links pore-scale processes to monitoring-relevant reservoir properties, enabling a more comprehensive understanding of storage performance over time. The workflow integrates image-based rock characterization, two-phase flow simulation, reactive transport modelling, and elastic property prediction. An area-dependent grain-contact correction method is incorporated to account for grain-to-grain interface geometry, significantly improving the prediction of elastic rock properties compared with conventional contact-based DRP models. Two-phase flow simulations generate realistic CO₂-brine distributions, while reactive transport simulations capture mineral dissolution and the associated evolution of pore structure. The simulations demonstrate that CO₂ migration, capillary trapping, and geochemical alteration produce systematic changes in elastic and acoustic rock properties. In particular, acoustic impedance and Vp/Vs ratio exhibit measurable variations associated with fluid substitution and progressive microstructural modification. The results reveal non-linear responses to increasing cement dissolution, highlighting the coupled effects of fluid flow, mineral reactions, and rock property evolution. By establishing quantitative relationships between pore-scale processes and monitoring observables, the integrated workflow supports improved interpretation of time-lapse monitoring data and more reliable upscaling of digital rock properties. The approach contributes to reservoir characterization, injectivity assessment, monitoring, measurement and verification (MMV), and uncertainty reduction in geological CO₂ storage projects. More broadly, the study demonstrates how DRP supports cross-scale integration by linking pore-scale processes with reservoir-scale characterization, monitoring, and risk assessment throughout the CCUS lifecycle.

Laboratory-to-Field Scale Assessment of Rock–Fluid Interactions on Geochemical and Geomechanical Properties of CO₂-Sequestered Basalt

Author(s): Nitin Nagarkoti, Shruti Malik, Mayur Pal, Ravi Sharma

Organisation(s): Indian Institute of Technology Roorkee, Kaunas University of Technology

Abstract

Reliably predicting changes in seismic rock properties requires integrating geochemical evolution of CO₂-sequestered geological reservoir with rock physics modeling. Previous studies have investigated mineralogical and petrophysical changes in the reservoir due to CO₂-brine-rock interactions but have not translated these changes into corresponding seismic rock property variations. This study uses a multiphysics framework combining reactive transport simulation with a sequestered carbon effective medium model (SCEMM) to quantify the spatiotemporal evolution of seismic properties during CO₂ sequestration in the Wallula basalt. The framework incorporates multiple morphologies of precipitated secondary minerals (cementing, pore-filling, fracture filling) and sensitivity analysis to evaluate uncertainties in seismic rock property predictions. Reactive transport simulations indicate extensive mineralogical alteration, with secondary mineral precipitation exceeding 24% mineral volume fraction and effective porosity shows a decrease from 13% to lower than 6% over 1000 years. Mineralization is dominated by calcite, dolomite, and a very compliant mineral smectite. Secondary mineral precipitation in cementing morphologies increases the overall stiffness of the reservoir, whereas the pore-filling and fracture-filling morphologies, leads to its reduction. The combined hybrid morphology model shows an overall decrease in elastic properties near the well and at the top of the reservoir, attributed to higher secondary mineral precipitation. Core-scale measurements of post-CO₂-injected basalt samples revealed decrease in ultrasonic velocities and elastic moduli. Ultrasonic velocities shows a reduction of 5.71–7.40% whereas elastic moduli decreased by 10.81–17.04%. Sensitivity analysis indicates that the porosity and secondary mineral volume exert the strongest control on seismic properties, highlighting their importance in reducing uncertainty. Collectively, these findings improve the understanding of seismic rock property evolution during CO₂ sequestration and provide valuable insights for reservoir characterization, CO₂ plume monitoring, and long-term storage integrity assessment.

Exploring the controls on CO₂ saturation during vertical buoyancy-driven flow

Author(s): Mateja Macut, Carl Fredrik Berg, Philip Ringrose

Organisation(s): Department of Geoscience (IGV), Norwegian University of Science and Technology (NTNU), The Institution of Environmental Sciences (IES)

Abstract

Geological heterogeneity and associated uncertainties in flow properties remain major challenges for CO₂ storage modelling, and many models struggle to reproduce seismic observations. Monitoring data from the Sleipner injection site provide valuable constraints on plume dynamics and fluid saturations. Recent full-waveform inversion (FWI) studies (Martinez et al., 2026) identified vertical migration pathways between the nine known CO₂ layers and showed that channel architecture and small faults are the primary controls on migration.

We investigate these vertical migration pathways using a series of 3D geostatistical models inspired by Sleipner. The simulations represent far-field conditions, where capillary and gravity forces dominate. We used geostatistical models with different correlation lengths to capture the effects of the intra-sand shales and shale-to-sand ratios. The main goal is to determine the CO₂ saturation at breakthrough into the next layer, to investigate the controls on vertical migration and its relationship to local reservoir heterogeneity. Two modelling approaches were compared: (1) a fully implicit two-phase reservoir simulator and (2) a simplified invasion percolation (IP) method. In general, we find that the saturations for reservoir simulations are significantly higher than for the IP models. We suggest that the IP method, which is suitable for simulating far-field migration, needs careful choice of the minimum saturation value. Laboratory experiments (Macut et al., 2026) further support interpretation of buoyancy-driven CO₂ flow in sandstones. Together, these results provide new insights into the mechanisms governing vertical migration and improve the representation of these pathways in large-scale models.

Martinez, R., Vinje, V., Moore, H., Hollingworth, S., Ringrose, P., Stovas, A., 2026. Unraveling multilayer CO₂ plumes using the entire wavefield: Case study from the Sleipner storage site. *Interpretation* 14, T163–T183. <https://doi.org/10.1190/int-2025-0016>

Macut, M., Selvadurai, P., Madonna, C., Rinaldi, A.P., Zappone, A.S., Ringrose, P. and Berg, C.F., 2026. Experimental Observation of CO₂ Breakthrough in Boise Sandstone (No. EGU26-13247). *Copernicus Meetings*.

Impact of geological and petrophysical uncertainty and capillary heterogeneity upscaling of CO₂ plume dynamics

Author(s): Harry Morris, Max Elizarev, Ann Muggeridge, and Samuel Krevor

Organisation(s): Imperial College London

Abstract

CO₂ storage projects are reliant on predictive simulations to inform the likelihood of the CO₂ plume intersecting sites of high leakage risk. Previous studies have suggested that models which rely upon single phase upscaling of small-scale heterogeneities do not accurately predict plume movement (Cavanagh & Haszeldine 2014, Jackson & Krevor 2020, Wenck et al. 2025). Alternate methods which incorporate capillary heterogeneity upscaling have been shown to produce CO₂ plume distributions which are more consistent with field observations (Jackson & Krevor 2020, Wenck et al. 2025). To date, the sensitivity of these models to key input parameters has not been fully examined.

The method tested in this study uses the 3D open-source upscaling toolkit StrataTrapper, developed by Elizarev et al. (2026) to incorporate the effects of capillary heterogeneity. The toolkit generates upscaled pseudo relative permeabilities and capillary pressures using a macroscopic invasion percolation steady-state capillary limit upscaling process, which are then used as inputs in a conventional field-scale reservoir simulator.

The East Mey (UK Central North Sea) and Endurance (UK Southern North Sea) storage sites are used as case studies in order to test the sensitivity of StrataTrapper upscaled models to key parameters. These include injection rate, shape of the capillary pressure curve and geological heterogeneity on the fine and coarse scale. A fractional factorial experiment design was used to test the plume dynamics compared to a single-phase upscaling method.

Results show that models that used the StrataTrapper upscaling predicted lower vertical migration rates and wider plume sweep than those using single-phase upscaling. Additionally, the parameters with the greatest impact on the mismatch between the two methods were the vertical correlation lengths and the shape of the capillary pressure curve. This further confirms the importance of capillary upscaling where there are small scale heterogeneities.

References

Cavanagh, A. J. & Haszeldine, R. S. (2014), 'The sleipner storage site: Capillary flow modeling of a layered co₂ plume requires fractured shale barriers within the utsira formation', *International Journal of Greenhouse Gas Control* 21, 101–112.

Elizarev, M., Jackson, S. J., An, S., Wenck, N., Muggeridge, A. & Krevor, S.

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Jackson, S. J. & Krevor, S. (2020), 'Small-scale capillary heterogeneity linked to rapid plume migration during co2 storage', *Geophysical Research Letters* 47, e2020GL088616.

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URL: <https://pubs.geoscienceworld.org/gsl/geoenergy/article/3/1/geoenergy2024-029/651857/The-impact-of-capillary-heterogeneity-on-CO2-plum>

Multi-Scale Simulations of CO₂ Storage in the Bunter Sandstone Hydraulic Unit, Southern North Sea: Advances, Challenges, and Key Insights.

Author(s): Luke Jenkins, Ewan Gray, Carwyn Adler, Catherine Gibson-Poole

Organisation(s): bp

Abstract

Understanding and predicting subsurface multiphase behaviour is key to optimising any carbon capture and storage project. This study discusses the many technical, physical, and computational challenges in modelling the Northern Endurance Partnership's (NEP's) commercial CO₂ storage developments in the Bunter Sandstone Hydraulic Unit, Southern North Sea. Robust modelling must provide decision-makers with insights into the impacts of coupled physical processes on key risks and objectives that must be resolved separately at the appropriate scale. Key learnings from the novel construction and simulation of integrated multi-scale models from the Bunter Sandstone Hydraulic Unit are presented. These models capture geological heterogeneities at the appropriate scales and account for pressure interference between neighbouring CO₂ storage developments. Furthermore, they are optimised for efficient simulation. Our workflows integrate modelling of regional-scale pressure dissipation with storage site scale injection and migration, which in turn are supported by parallel mechanistic models which capture core-scale heterogeneity. The resulting modelling and simulation predictions allow development planning and operational decisions to be made.

In addition to sharing these technical static and dynamic recommendations for multi-scale modelling, this work provides practical guidance on balancing subsurface and physical uncertainty with recent operational data from NEP's appraisal wells. Beyond the North Sea, these lessons provide a foundation for efficient and defensible modelling of large-scale CO₂ storage developments in pressure-connected saline aquifers.

Exploring Multiscale Heterogeneity in Upper Triassic Siliciclastic Sequences: Implications for CO₂ Storage Efficiency

Author(s): Abdullah Alqubalee

Organisation(s): King Fahd University of Petroleum and Minerals

Abstract

Multiscale heterogeneity presents substantial challenges, often increasing uncertainty due to limited exploration across different scales and the lack of effective connections among them. To mitigate this, the study combines various methods to analyze heterogeneity at macroscale (outcrop), mesoscale (core), and microscale (thin section). At the macroscale, three assemblages are identified: pre-Minjur, lower Minjur, and upper Minjur. Five lithofacies associations are recognized: sandstone (LA1), mudstone (LA2), sandstone interbedded with mudstone (LA3), mudstone interbedded with sandstone (LA4), and conglomerate (LA5). LA1 and LA3 cover about 75% of the potential CO₂ storage, while LA2 and LA4 account for roughly 24.8%. LA1 and LA3 are mainly found in the Upper Minjur, whereas LA2 and LA4 dominate the pre-Minjur and lower Minjur. At the mesoscale, samples are classified into silica, argillaceous/mudstones, and ferruginous sandstones. Microscale samples form nine clusters, labeled Cluster 1 to Cluster 9. This multiscale heterogeneity study classifies the Upper Triassic sequences into low- and high-heterogeneity groups. The low-heterogeneity group mainly includes the upper Minjur, silica sandstone, and Clusters 2, 3, 4, 7, and 8. The high-heterogeneity group encompasses the pre-Minjur and lower Minjur argillaceous and ferruginous sandstones, as well as Clusters 1, 5, 6, and 9. The heterogeneity of sandstone influences CO₂ storage efficiency: low heterogeneity promotes more uniform CO₂ distribution but may limit trapping, whereas high heterogeneity offers greater trapping potential but can impede pore-fluid flow and accelerate geochemical reactions. Effective understanding of CO₂ storage requires integrating multi-scale approaches. This combined perspective underscores the importance of a multiscale approach to improve understanding, reduce uncertainty, and enhance predictive capabilities in CO₂ storage, aiding sustainable energy and climate change mitigation.

From outcrop to pore scale: multi-scale characterisation of paralic reservoir heterogeneities for early-stage CCS screening workflows.

Author(s): David William Whitworth

Organisation(s): Keele University

Abstract

Carbon Capture, Utilisation and Storage (CCUS) deployment increasingly requires the appraisal of storage resources beyond depleted hydrocarbon provinces. However, many early-stage screening workflows still rely on simplified reservoir-quality proxies inherited from hydrocarbon exploration, including gamma-ray response, porosity, permeability, and broad lithological classifications. These approaches may be poorly suited to heterogeneous paralic and arid-marine transitional systems, where depositional, diagenetic, and petrophysical controls vary across scales.

This study presents a multi-scale characterisation of the Middle Jurassic Temple Cap Formation of southern Utah, an exhumed analogue for mixed aeolian, tidal, lagoonal, and shallow-marine sandstone reservoirs. Basin- to outcrop-scale stratigraphic analysis is integrated with sedimentary logging, facies analysis, field gamma-ray spectrometry, magnetic susceptibility, petrography, and petrophysical datasets to evaluate how reservoir architecture and screening-proxy response change from regional to pore scale.

Results show that reservoir quality is not controlled by a simple progression from clean aeolian sandstone to poorer marine-influenced deposits. Instead, marine-influenced and reworked facies locally preserve favourable pore networks, while permeability is strongly affected by pore-throat geometry, cementation, and facies-scale heterogeneity. Gamma-ray responses are statistically decoupled from facies and reservoir quality, demonstrating that single-proxy screening may mischaracterise storage potential in mixed-process systems.

These findings have direct implications for CCUS site appraisal. Reservoir intervals that may be regarded as suboptimal under historic hydrocarbon-production criteria, owing to internal heterogeneity or reduced permeability, may nevertheless provide favourable CO₂ storage characteristics by promoting plume retardation, residual trapping, and compartmentalisation. The study therefore highlights the importance of cross-scale geological calibration during early-stage CCS screening and argues for storage-specific reservoir evaluation workflows that balance injectivity, containment, and heterogeneity.

Influence of aquifer architecture on CO₂ trapping mechanisms - learnings from dynamic simulation of the G14-AP permit, offshore Australia

Author(s): Mick McCaughey, Alison Isherwood, Keith Milne, Bill Powell and David Went

Organisation(s): Elgol Geoscience, KM Geoscience, Tracs, AJ Isherwood Consulting, TGS

Abstract

We present the results of dynamic aquifer simulation evaluating CO₂ injection into saline aquifers of the G-14-AP greenhouse gas storage permit in the Browse Basin, North-West Shelf, Australia. The permit contains three stacked Jurassic reservoir units: the Plover Formation, Montara Member and Lower Vulcan Formation, together sealed by the Upper Vulcan and overlying Cretaceous shales. The monoclinial basin geometry provides an ideal setting for migration-assisted trapping, with dense-phase CO₂ injected into the downdip portion of the aquifer system and subsequently migrating updip under buoyancy while progressively becoming immobilised.

The geological model incorporates facies-scale heterogeneity and depth-dependent petrophysical trends derived from regional well, core and seismic data. Dynamic simulations include hysteretic relative permeability, facies-dependent capillary pressure functions and CO₂ dissolution in formation brine, enabling the relative importance of the trapping mechanisms to be assessed over millennial timescales.

The three aquifer units exhibit contrasting depositional architectures and petrophysical properties, resulting in different trapping behaviour. The laterally extensive, homogeneous Montara Member promotes rapid lateral migration and convective dissolution, whereas the more heterogeneous fluvio-deltaic Plover Formation and coastal Lower Vulcan Formation enhance capillary trapping through facies variability. Residual trapping, capillary trapping and dissolution all contribute significantly to long-term storage security, although their relative contributions vary between formations and through time.

Simulation results indicate that up to 150 Mt of CO₂ can be injected from a single surface location over a commercial injection period while remaining contained within the permit for at least 1,000 years. The regional extent and high permeability of the connected aquifer system provide excellent pressure dissipation beyond the permit boundaries. Full-field development scenarios demonstrate that multiple injection clusters can operate simultaneously without exceeding fracture pressure constraints, indicating potential storage capacity in the gigatonne range and highlighting the suitability of the G-14-AP permit as a major regional CO₂ storage hub.

Appraisal of the BC39 and BC40 structures for CO2 storage, Southern North Sea, UK

Author(s): James Hamilton-Wright, Catherine M. Gibson-Poole, Lindsey Smith, Bethan Duckett, Carwyn Adler, Kirsty Hitchen, Jon Tarasewicz, Michael Taplin, Fidan Nabizade, Sarah K. Buchanan, Robin Eve

Organisation(s): bp

Abstract

The BC39 and BC40 structures, located within UK Carbon Storage Licence CS006, are undergoing site characterization to assess their suitability for CO2 storage in terms of injectivity, containment and capacity. This assessment may support their tie-in to the Endurance Phase 1 CO2 storage development, planned for injection from 2028. Site characterization is underpinned by interpretation of recently acquired proprietary 3DHR seismic data, publicly available offset well data, and development of in-house sedimentological, petrophysical and CO2 dynamic simulation models.

CO2 will be injected into the Early Triassic Bunter Sandstone Formation, a 250-m-thick interval of dominantly fine-grained sandstones deposited in extensively reworked fluvial, lacustrine and playa lake environments. BC39 and BC40 are characterized as two injection centres within one larger 'CS006' storage site and storage complex. Both injection centres are large, four-way dip-closed anticlinal structures, sealed by laterally extensive mudstones and evaporites of the overlying Triassic Haisborough Group. Together they form a larger multi-crested anticlinal structure, which defines the CS006 storage site and complex.

The containment risk assessment considers both geology and existing wells. Faulting is observed in the overburden but is not interpreted to connect to the storage unit at either structure. There is only one legacy well on-structure (43/23-3 on BC40; BC39 is unpenetrated) with cement and natural salt creep from the Röt Halite being assessed for their suitability as barriers.

An exploration well has very recently been drilled to intersect BC39, with a significant data acquisition program to address remaining risks and uncertainties for CO2 storage suitability. Integration of this new data, along with further development of in-house dynamic simulation models, will focus on assessing plume migration, regional pressurization and multi-store interference effects, as well as well injectivity and placement for future development at CS006 storage site conditions.

A Second Look at CO₂ at Grane: An Integrated Seismic-to-Simulation Assessment of CCUS in a Heavy Oil Reservoir.

Author(s): Saeful Putra, Mads Huuse

Organisation(s): University of Manchester

Abstract

Grane Field produces 18.9° API oil at 12 cP from the unconsolidated Paleocene Heimdal Member, 1,700 m below seabed on the Utsira High, Norwegian North Sea. CO₂ injection was the original 1998 development concept, abandoned on commercial grounds under conditions that no longer apply. This study assesses CCUS at Grane for combined enhanced oil recovery and storage, using quantitative seismic interpretation, petrophysics and 1D geomechanics to a 3D static model, a seismically derived fracture pressure volume, and compositional simulation of three development scenarios over fifteen years. Volumetric analysis gives a P50 STOIP of 238 MSm³ (P10–P90: 226–249). Geomechanical analysis returns fracture pressures of 231 bar for the Heimdal sand against 300 bar for the overlying Lista mudstone, so the reservoir is mechanically weaker than its own seal. EEI inversion at a chi angle of 30°, calibrated against Eaton-derived pressure logs, resolves the two as separable populations at 222–262 and 272–330 bar, and identifies low fracture-pressure anomalies with wing-shaped geometry inside the seal interval, interpreted as sand injectites. Over ten years, natural decline recovers 14.4 MSm³, water injection 17.3 MSm³ and CO₂ injection 21.7 MSm³ creates an uplift of 25% over water injection and 51% over natural decline. The CO₂ increment is achieved at lower reservoir pressure than water injection, so it reflects viscosity reduction and swelling rather than pressure support; displacement remains immiscible, and a 0.5 cP comparison run recovers nearly four times as much, confirming oil viscosity as the governing constraint. Total 29.5 MtCO₂ was injected, 14.2 Mt is retained where it is comparable to the quantity stored at Sleipner since 1996, at a higher annual rate but only 22.5% during co-production against 48.2% across the full horizon, because CO₂ segregating to the crest is cycled back through the producers. Storage efficiency at Grane is therefore governed by production strategy, not reservoir capacity, and the fracture envelope is never the binding constraint. The two objectives are best pursued sequentially. For a field 23 years into production, dedicated storage after cessation is a materially stronger proposition than combined CO₂-EOR and storage where the reservoir could accommodate on the order of 45 Mt before approaching the fracture limit.

Keywords: Grane Field; Heimdal Member; Heavy Oil; CO₂-EOR; CCUS; CO₂ Storage Capacity; Immiscible Displacement; Sand Injectites; Seismic QI; Geomechanics; Seal Integrity

Keynote: Faults in CCS: bridging pore-scale processes and basin-scale containment risk

Author(s): Andreas Busch

Organisation(s): Heriot-Watt University

Abstract

Faults are among the dominant containment uncertainties for geological CO₂ storage. Depending on their architecture, stress state, and the coupled thermo-hydro-mechanical-chemical processes acting on them, faults can behave as barriers that compartmentalise a storage complex, as conduits that leak CO₂ towards shallower formations, or as sources of induced seismicity. Crucially, none of these behaviours can be assessed at a single scale: the controls span single-fracture apertures of micrometres to fault systems of kilometres, and injection timescales of years to containment horizons of millennia.

This keynote draws together more than a decade of work to show how a genuinely multiscale workflow can constrain fault leakage likelihood and rates. At the single-fracture scale, laboratory stress–permeability measurements across a wide range of mudrocks yield an empirical model linking permeability decline under effective stress to bulk rock stiffness. Outcrop analogue studies of caprock damage zones supply the fracture network geometry and connectivity needed to upscale these single-fracture properties to fault-zone permeabilities. Validation against natural leakage systems, notably Green River (Utah), demonstrates that this experimental–modelling approach predicts leakage locations and rates without extensive history matching. Finally, integration with ML-assisted seismic interpretation, fault seal analysis, and constrained reservoir-scale simulations extends the workflow to basin screening, as applied in the Malay Basin.

This work argues that treating faults as barriers, conduits, and seismic sources within one cross-scale framework, rather than as a binary seal/leak question, is essential for de-risking fault-bound storage sites and building the stakeholder confidence needed for large-scale deployment.

Are the fears justified? Observations of fault seal from the US Gulf Coast and implications for CO₂ storage

Author(s): Alexander Bump, Nicolas Espinoza

Organisation(s): University of Texas at Austin

Abstract

Geologic confining systems can provide secure, long-term containment of injected CO₂, but there are widespread concerns that faults may compromise their integrity. Faults are common and sometimes they clearly do form fluid migration paths. However, fault permeability varies widely and many faults form petroleum traps, raising questions about how to recognize the risky ones, particularly in the passive margin setting characteristic of many current storage projects.

To address that question, we mined 12 volumes of historic reports from producing hydrocarbon fields on the US Gulf Coast, documenting fault characteristics, hydrocarbon properties and column heights. From hydrocarbon phase distribution, we can distinguish spill-limited traps from seal-limited ones and compare faulted and unfaulted traps.

We find that sealing faults are common but that column heights and limiting pore throat diameters are highly variable. Faults that do not leak offer statistically better seals than those that do but there is broad overlap in the distributions and little difference with the top seals. Moreover, there is little correlation in the performance of either with commonly used predictors, including age, depositional environment, or fault orientation. The key controls are effective stress and the native properties of the host geology (which are heterogeneous and hard to predict).

For CCS, there are two key findings. First, vertical migration requires buoyancy pressure, which can be largely avoided by choosing flat-lying injection zones. Second, there is no evidence that faults in this environment form fast paths to the surface. The prevalence of stacked pay suggests that fluids migrate only as far as the next reservoir. In aggregate, we can show even with “leaky” faults and buoyancy pressure, these systems retain tens of megatons of CO₂-equivalent.

These results are likely specific to poorly lithified siliciclastics at maximum burial, but they suggest cautious optimism, perhaps backed by above-zone monitoring.

Closing the loop on fault leakage assessment for CCS across scales: A workflow tested for the Malay Basin

Author(s): Phoenix Nguyen, Ellen Mears, Ahmadreza Shojaei, Sarah Perez, Griffin Page, Sarah Perez, Norshida Mohsin, Ahmed ElSheikh, Florian Doster, Andreas Busch, Uisdean Nicholson

Organisation(s): Heriot Watt University (HWU), Petronas

Abstract

Fault leakage remains one of the greatest uncertainties in geological carbon storage (GCS). CO₂ injection increases pore pressure, potentially reactivating pre-existing migration pathways associated with faults. The leakage behaviour is controlled by complex interactions between fault architecture, fault-rock properties, as well as mechanical and fluid flow properties. Therefore, accurately predicting fault leakage is essential for site selection and ensuring the long-term security of stored CO₂.

A basin-wide screening study (2022–2025) in the Malay Basin, offshore Peninsular Malaysia, identified widespread evidence of leakage, including seismic amplitude anomalies along fault planes (*). These observations indicate that many faults have acted as long-term hydrocarbon migration pathways and may pose a significant containment risk for future CO₂ storage. They highlight the need for a multidisciplinary framework that evaluates fault behaviour consistently across methods and scales.

In this study, we present a closed-loop workflow, developed and tested on 3D seismic volumes from the Malay Basin. The workflow comprises four interconnected components: (1) machine learning assisted seismic interpretation for automated fault detection and identification of potential leakage indicators; (2) seismic and petrophysical characterisation of faults and caprocks; (3) laboratory measurement of fault-rock properties from core samples to constrain sealing behaviour; and (4) physics-based fault leakage simulations calibrated using geological observations and laboratory-derived data. The simulation results are subsequently used to refine the seismic interpretation and leakage assessment, thereby closing the loop between observation, characterisation and prediction.

By integrating seismic interpretation, laboratory core analysis and physics-based simulation, the workflow provides a transferable methodology for quantifying fault leakage likelihood, estimating sustainable CO₂ column heights, and reducing uncertainty in GCS site assessment and long-term storage security.

Induced Seismicity at the Quest CCS Site, Alberta

Author(s): James Verdon, Cindy Lim, Germán Rodríguez-Pradilla

Organisation(s): University of Bristol

Abstract

The 1st April and 9th May 2026 $M \geq 4.0$ earthquakes in central Alberta were widely felt across the city of Edmonton. The events were located near to Carbon Capture and Storage (CCS) operations at the Quest site, where CO₂ captured at a heavy oil processing facility is injected into a basal aquifer. In this study we use an established induced seismicity assessment framework, applied with respect to the Quest CCS site as well as other oilfield activities in the area, to assess whether the events were induced. We found that these earthquakes were caused by CO₂ injection at Quest, making this the first known example of induced seismicity caused by CCS operations. We have inverted regional seismic monitoring data to compute event depths and source mechanisms, finding that the events were located in the upper portion of crystalline basement, with oblique strike-slip/reverse focal mechanisms. Structural lineaments have been observed at the top of the basement at the Quest site, which likely provided a route for pressure transfer from the injection target into the underlying basement, reactivating critically stressed faults. We have applied several induced seismicity magnitude forecasting schemes to the earthquake sequence in order to evaluate whether the seismic hazard posed by these events could have been identified. We found that two models – the seismogenic index model and a model based on extreme value theory – would both have forecasted the $M > 4.0$ events prior to their occurrence. These results demonstrate that induced event forecasting methods can be used to support operational decision-making. We conclude by considering options for ongoing induced seismicity hazard mitigation, both at the Quest CCS site, and more generally at all future CCS operations.

Controls of volcanic architecture on carbon storage potential in buried volcanoes: Evidence from seismic data

Author(s): He Yanxin

Organisation(s): University of Leeds

Abstract

Anthropogenic CO₂ emissions continue to drive global climate change, making carbon capture, utilization, and storage (CCUS) a critical strategy for emission mitigation. In situ carbon mineralization in buried volcanoes and igneous rocks has emerged as a promising approach for secure and permanent CO₂ storage. However, the role of internal volcanic architecture in controlling CO₂ reservoir suitability and storage capacity in buried volcanoes remains poorly constrained. Here, we use 3D seismic reflection data from the Baiyun Sag, northern South China Sea, to quantitatively characterize 13 buried, basaltic volcanoes and assess their CO₂ storage potential. We identify four distinct seismic facies (SF1-SF4) that delineate volcanic architecture and assess their feasibility for carbon storage from material compositions, reservoir properties, and trap features. We suggest lava-dominated and interbedded lava-volcaniclastic facies provide the optimal conditions for CO₂ storage, owing to abundant reactive minerals and well-developed interconnected pore-fracture networks, locally sealed by intra-volcano barriers. We estimate the effective rock volume suitable for CO₂ storage is ~35.14 km³. Using analogue-based effective porosity and sequestration ratios, this volume could store 0.07–4.06 Gt CO₂, with a base-case value of ~0.95 Gt CO₂; this capacity is comparable to the lower bound of China's annual CCUS requirement and represents several years of regional emissions from adjacent industrial regions. From a global perspective, buried volcanoes along continental margins represent vast, untapped CO₂ storage potential. Unlike expansive mid-ocean ridge basalts, these continental margin volcanoes provide more spatially constrained and accessible storage targets, characterized by effective trapping configurations, and proximity to major emission sources. Our results therefore highlight buried volcanoes are prospective targets for in situ CO₂ mineralization and establish a quantitative framework linking volcanic architecture to storage potential, thereby supporting future site screening and pilot-scale implementation.

Efficacy of Seawater and Freshwater as Solvents for In-Situ Carbon Mineralisation in Peridotite

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Organisation(s): School of Ocean and Earth Science (University of Southampton), Research and Technical Development, 44.01, Carbon Management Services, Oman

Abstract

Carbon mineralisation provides safe and long-term CO₂ storage over geological timescales but requires large volumes of freshwater to facilitate fluid-rock interactions. To reduce pressure on freshwater resources, seawater could be used as an alternative; however, its effects on ultramafic (e.g., peridotite) mineral dissolution rates are unknown. Here, we report results of laboratory experiments exploring peridotite (dunite) dissolution and mineral precipitation in CO₂-saturated freshwater and seawater. The dunite was obtained from a borehole in Fujairah, UAE, owned by 44.01, where CO₂-rich fluid injection experiments are actively underway. Fluid-rock-CO₂ reactions were conducted in a batch reactor system at 25°C and 1 atm CO₂ for three weeks. Fluid samples were collected throughout the reaction to monitor pH, alkalinity, and major element (Mg, Si, Ca, Fe) concentrations, from which elemental release rates were calculated. At the end of the experiments, remaining fluids were evaporated, and any precipitates formed were analysed by X-ray diffraction. Results showed that the extent of dunite dissolution was lower in seawater than in freshwater due to reduced H⁺ availability resulting from seawater's higher buffer capacity and lower CO₂ solubility. Consequently, CO₂ removal efficiency was ~3.2x lower in seawater. However, seawater showed an initial catalytic effect at pH <5, enhancing early-stage dissolution rates relative to freshwater. Carbonate precipitation phases differed between fluids, with hydromagnesite and siderite forming in freshwater and aragonite forming in seawater. Halite precipitation was also observed in seawater, which may hinder in-situ mineral carbonation by reducing permeability through pore blockage. These observations suggest that seawater could be a promising alternative to freshwater for carbon mineralisation, provided that limitations associated with hydrogen ion availability can be addressed. In particular, the initial catalytic effect observed in seawater may enhance carbonate precipitation by increasing mineral dissolution rates.

Understanding CO₂ mineralisation in basalt through time-resolved spatial imaging

Author(s): Faisal Khudhur, Ian Butler, Ian Watt, Florian Fuisseis, and Stuart M.V. Gilfillan

Organisation(s): The University of Edinburgh, RWTH Aachen University

Abstract

CO₂ mineralisation in basalt is a promising climate change mitigation strategy because it provides permanent CO₂ storage. The reaction pathway of this process is governed by silicate dissolution and carbonate precipitation. As it occurs in subsurface formations, the amount of CO₂ that can be mineralised is controlled by complex interactions between chemical, mechanical and hydrodynamic factors. These interactions can be studied at the grain-scale through time resolved X-ray computed microtomography (XCT), which provides detailed characterization of the microstructural evolution of the host formation as the reaction progresses.

Using a custom-designed X-ray translucent reaction chamber, we can image basalt cores as they react with CO₂-saturated fluids at 200 °C and 5 MPa. This provides XCT data at different stages of the reaction, yielding a 4D dataset (3 spatial dimensions + time). We have used this setup to characterize the CO₂ mineralisation process in Icelandic basalt cores from the Carbfix site. Through the combination of time-resolved X-ray tomography with post-experiment correlative microscopy, we have resolved silicate dissolution and carbonate precipitation reactions in basalt.

Our study demonstrates that reaction pathways can be influenced by adjusting the injection strategy and the composition of the injection fluid. We provide a workflow that addresses how different conventional analyses (e.g., X-ray diffraction and core flooding) can be combined with imaging methods to study the suitability of a given formation for CO₂ mineralisation. We highlight several knowledge gaps that remain to be resolved for obtaining transferable results for up-scaling from image-based analysis of basalt core samples to larger scales.

Reference

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I. D. Watt, I. B. Butler, J. Gilgannon, L. Martins, F. Fuisseis, R. S. Haszeldine et al., *Int. J. Greenhouse Gas Control*, 2024, 137, 104195. <https://doi.org/10.1016/j.ijggc.2024.104195>.

Bridging Enhanced Rock Weathering and CCUS: Multiscale Evaluation of CO₂ Uptake in Mafic-ultramafic Mine Wastes

Author(s): Rosalia Shiimi, Evangelos Mouchos, Anezka Radkova, Lisa Buckley, Steven Pearce

Organisation(s): Mine Environment Management Ltd (MEM)

Abstract

Carbon capture, utilisation and storage (CCUS) and enhanced rock weathering (ERW) have largely developed separately: CCUS focuses on transporting and storing captured CO₂ underground, while ERW uses Mg-, Fe- and Ca-rich minerals to capture CO₂ at surface. Mafic/ultramafic rocks can bridge these approaches because their reactive minerals sequester CO₂ from atmospheric and captured industrial sources through mineral carbonation. This study presents a multiscale workflow for evaluating passive carbon capture and storage in mafic-ultramafic mine waste from Kevitsa, Northern Finland.

The workflow combines laboratory, barrel-scale and field experiments, including CO₂ probe-fitted CarbiSensors, closed-barrel, open-barrel leaching and pore-gas monitoring tests, and sensor-instrumented field trial. Gas-phase CO₂ and O₂ monitoring is integrated with moisture, aqueous geochemistry and solid-phase mineralogical observations. The mineralogical focus is on Mg- and Ca-bearing silicates, including olivine, pyroxene and amphibole, which control carbonate dissolution and precipitation. Carbonate and sulfide minerals are considered because they determine whether mine wastes behave as CO₂ source or sink.

In 30-day CarbiSensor tests, Kevitsa mafic and ultramafic tailings showed apparent CO₂ uptake, indicated by CO₂ concentration decreases of 3,300 and 5,200 ppm, respectively; blank corrections and conversion to mass uptake remain part of method refinement. Closed-barrel tests showed that waste rock removed 41% of elevated CO₂ over 1.6 years, with an initial consumption rate of 0.02 kgCO₂/tonne/year; tailings removed 31% over 3.5 years, with an initial consumption rate of 2.88 kgCO₂/tonne/year. Open-barrel results demonstrate net CO₂ removal can only be quantified by resolving the coupled effects of sulfide oxidation, carbonate dissolution, silicate weathering and secondary carbonate precipitation.

This study proposes an integrated CCUS-ERW framework to assess the feasibility of carbon capture and storage for mine wastes, either passively on-site or underground using CCUS infrastructure. Multiscale gas-water-rock measurements and uncertainty assessment are essential for monitoring, reporting and verification (MRV) of scalable, permanent carbon removals.

Assessing uncertainty and making risk-based decisions using geophysical data

Author(s): Andrew Curtis

Organisation(s):

Abstract

Pending

DAS as a tool for passive seismic monitoring and imaging offshore CCS sites

Author(s): Germán Rodríguez, Tobermory Mackay-Champion, James Verdon

Organisation(s): School of Earth Sciences, University of Bristol

Abstract

Reliable, permanent seismic monitoring systems near carbon storage sites are essential to guarantee safe injection and storage operations, enabling the early detection of induced seismicity, fault reactivation, and potential leakage pathways. In offshore areas, permanent seismic monitoring systems could either be based in nearby monitoring wells and/or on conventional ocean bottom seismometer arrays. However, their long-term implementation may be expensive and logistically challenging. Offshore distributed acoustic sensing (DAS), a fibre-optic monitoring technique that uses Rayleigh backscattering to measure dynamic strain continuously along an optical fibre, offers an alternative, cost-efficient approach to seismic monitoring, particularly when existing submarine telecommunications infrastructure is utilised for acoustic sensing. In this study, we assess the feasibility of pre-existing offshore fibre-optic cables for seismic monitoring on the UK Continental Shelf, where multiple carbon storage areas have been licensed in recent years. Many of the licensed areas are located near to submarine telecommunication cables already deployed (particularly in the East Irish Sea and the Southern North Sea), which could be suitable for offshore DAS monitoring.

Bayesian Ambient Noise Tomography of the Tampnet-ASN Subsea DAS Array for CCS Monitoring

Author(s): Tobermory Mackay-Champion, Germán Rodríguez, James Verdon

Organisation(s): University of Bristol

Abstract

Distributed Acoustic Sensing (DAS) provides dense spatial sampling of seismic wavefields, enabling high-resolution imaging of subsurface velocity variations. At carbon capture and storage (CCS) sites, changes in seismic velocity may provide an early indication of upward CO₂ migration. Ambient Noise Tomography (ANT) uses continuous background seismic noise to recover surface-wave phase velocities, which can be inverted to estimate subsurface elastic properties. Here, we evaluate a Bayesian ANT workflow using subsea DAS data from the Tampnet-ASN dataset, with a particular focus on constraining uncertainty in the inferred subsurface velocity structure.

Our inversion framework is based on Bayes' theorem, which combines prior knowledge with the observed data to estimate the posterior probability distribution of subsurface properties. A reversible-jump, transdimensional Markov chain Monte Carlo (MCMC) algorithm samples the posterior probability distribution, generating an ensemble of plausible shear-wave velocity models rather than a single best-fitting solution. This approach provides rigorous uncertainty quantification for subsurface imaging. The workflow comprises three stages: (1) cross-correlation of ambient seismic recordings between DAS channels, (2) estimation of surface-wave phase velocities using the frequency–Bessel (FJ) transform (Li et al., 2021, *Seismological Research Letters*), and (3) Bayesian inversion of surface-wave travel times for shear-wave velocity using transdimensional MCMC (Sambridge et al., 2013, *Philosophical Transactions of the Royal Society A*). The subsurface is parameterized with Voronoi cells, allowing flexible model complexity while efficiently exploring the solution space.

Initial results from the Tampnet-ASN fibre demonstrate the potential of ambient noise tomography for resolving shallow subsea velocity structure. Combined with Bayesian uncertainty quantification, this approach offers a promising framework for monitoring CCS sites and assessing the detectability of CO₂ leakage, supporting more robust risk-informed decision making.

Environmental and Passive Seismic Monitoring for the Endurance Store

Author(s): Stephen Auld, Sarah Buchanan, Jon Tarasewicz

Organisation(s): Sonardyne, bp

Abstract

The East Coast Cluster's (ECC) carbon capture and storage development will take carbon dioxide (CO₂) from onshore capture projects and safely store it offshore in the Endurance CO₂ store. CO₂ will initially be sourced from capture projects in Teesside, with future plans to connect capture projects in Humberside. The first phase of the project is targeting 100 Mt of CO₂ storage over 25 years, making a significant contribution to the UK's net zero targets.

The Northern Endurance Partnership (NEP) will deliver and maintain the transportation and storage infrastructure for ECC. This will involve piping compressed CO₂ and injecting it into the Endurance store, a saline aquifer anticlinal structural trap in the Triassic Bunter Sandstone Formation in the Southern North Sea.

A detailed monitoring plan for Endurance was approved by the North Sea Transition Authority as part of the UK's regulatory requirements for a storage permit. The plan includes environmental containment monitoring using seabed landers at key locations. It also provides for monitoring of seismicity in the vicinity of Endurance and the surrounding area.

This plan will be put into action during the summer of 2026, with the deployment of three seabed located environmental monitoring landers above and around Endurance. These landers will record a baseline of 12-24 months for future comparison with data collected during the injection phase, which is planned from 2028.

Additionally, three passive seismic monitoring nodes will be deployed close to the seabed landers. The objective of these seismometers is to improve location accuracy of seismic events detected in the vicinity of Endurance to help distinguish between injection-induced and natural or human-induced events outside the store's boundary.

Through continuous measurement of seawater chemistry, micro-seismicity and seafloor morphology, the project will generate high-resolution datasets to assess reservoir behaviour and help verify the secure containment of injected CO₂.

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