



Unlocking the storage capacity of Paleogene sandstones in the Central North Sea

Introduction

The UK Government aims to store 20 to 30 million metric tons (Mt) of CO₂ per year by 2030, at least 50 Mt per year by 2035, and up to 170 Mt per year in 2050 (DESNZ, 2023). These targets indicate a requirement to develop multiple gigaton scale storage resources. Saline aquifers will be important in enabling significant emissions reductions on a global scale (Ringrose et al. 2021). One example of a large saline aquifer where large-scale CO₂ storage is planned in the UK is the Bunter Sandstone Formation in the Southern North Sea. Studies have shown that the extensive and apparently well-connected nature of the formation will allow brine to be displaced effectively during injection, enabling storage of a significant mass of CO₂ (Abel et al. 2025; De Luca et al. 2025). De-risking of similarly large saline aquifer storage resources would help to meet future demand for CO₂ storage in support of government targets.

Around 50% of the UK's theoretical storage resource is situated in the Central North Sea region (Bentham et al. 2014). Despite this, only a small number of carbon storage licenses have been granted in this area (Figure 1), with licensing activity in other parts of the UK Continental Shelf prioritized to date. Open aquifer storage options in this region include the extensive deep-marine fan sandstones of Paleogene age deposited during a period of post-rift thermal subsidence following Mesozoic rifting. Large volumes of sediment primarily sourced from the Scottish Highlands and Shetland Platform were transported to depocenters by deep marine turbidity currents. Consequently, the system is characterized by a complex sequence of stacked and amalgamated fan sandstones with lateral transitions from shelf and slope facies in the north and west to basinal facies in the basin centers. Estimated theoretical CO₂ storage capacities are comparable to those of the Bunter Sandstone in the Southern North Sea.

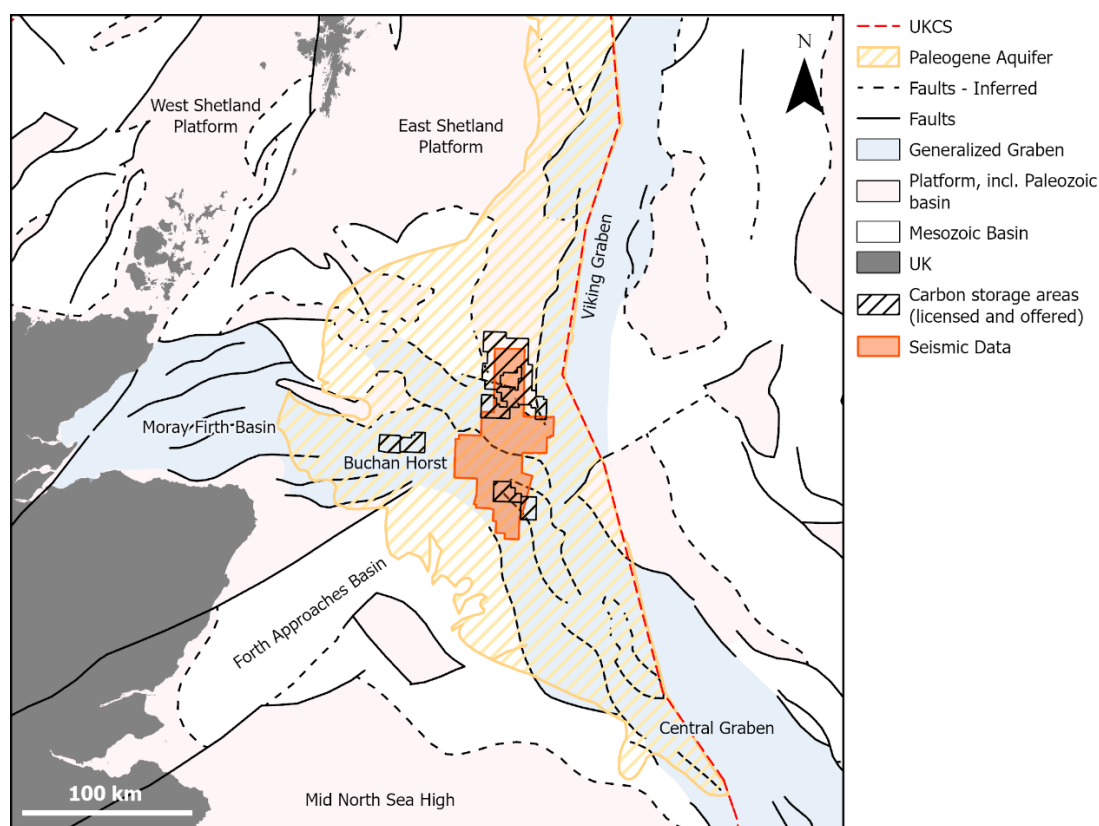


Figure 1 Summed distribution of the multiple marine fan sandstones of Paleogene age within the study region. Sandstone extent from the UK's online storage atlas, CO₂Stored. Carbon storage licenses contain information provided by the North Sea Transition Authority and/or other third parties.



Subsurface database

In this study, we identify some of the key geoscience challenges that will impact the future exploitation of the Paleogene sandstone CO₂ storage resource. First, the UK's online CO₂ storage atlas, CO₂Stored (www.co2stored.co.uk/home), was interrogated to extract storage capacity estimates for the lithostratigraphic units of interest. The CO₂Stored database is described elsewhere (Gammer et al. 2011; Bentham et al. 2014). Figure 2 illustrates the Paleogene aged units within the database for which storage capacities have been calculated. The largest sand-dominated units in terms of storage resource are the Mey Sandstone Member of the Montrose Group and the Forties Sandstone Member of the Moray Group, which together account for approximately 5 Gt of theoretical storage capacity.

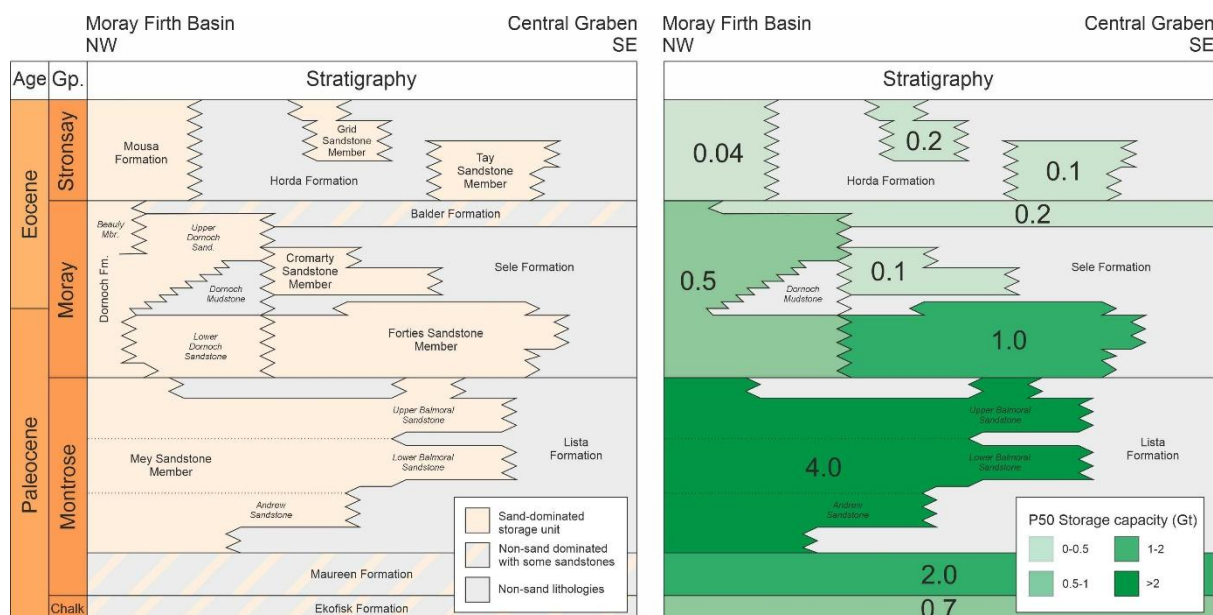


Figure 2 Generalized lithostratigraphic column showing stratigraphic distribution of potential Paleogene storage units in the Central North Sea region (left). Most likely (P50) storage capacity estimates for the units based on the CO₂Stored database (right) in units of gigatons (Gt).

Following identification of the potential storage reservoirs and their distribution, a substantial data gathering and quality control exercise was undertaken to establish a high-fidelity subsurface database for purposes of identifying and exploring the key challenges for future CO₂ storage development. In this study we utilize interpretation of five 3D seismic survey datasets along a broad corridor between existing license areas (Figure 1), and stratigraphic interpretation of 99 wells to explore the potential connectivity of the Paleogene system. In addition, collation of an extensive petrophysical database and pressure measurements provide complementary insights into the likely dynamic behavior of the system.

Hydraulic connectivity

The stacked and amalgamated nature of the system as shown in Figure 2, leads to potential for lateral and vertical connectivity within and between different reservoir units. The time-contour map in Figure 3 shows that aside from some topographic variability related to underlying Mesozoic structures, the study area is lacking in major compartmentalizing structural features. Consequently, for purposes of defining hydraulic units, the larger sandstone fan systems such as the Forties and Mey sandstones might form largely continuous sandstone bodies if their individual channel systems are connected. Therefore, these extensive sandstone units might be subject to widespread pressure increases during CO₂ storage operations. Conversely, pressure responses in the younger fan systems such as the Cromarty, Tay and Grid sandstones, might be more spatially limited, however this could lead to a greater build-up of pore pressure, a limit to injectivity. However, the thin nature of some of the intervening top seals might allow



for some hydraulic connectivity with the larger underlying sandstone units. Faults, sand injectites, channel incisions and legacy wells are among the potential seal bypass systems identified within the study area. Consequently, lateral and vertical storage complex boundaries need to be carefully considered given the potential for CO₂ and/or brine migration within the system.

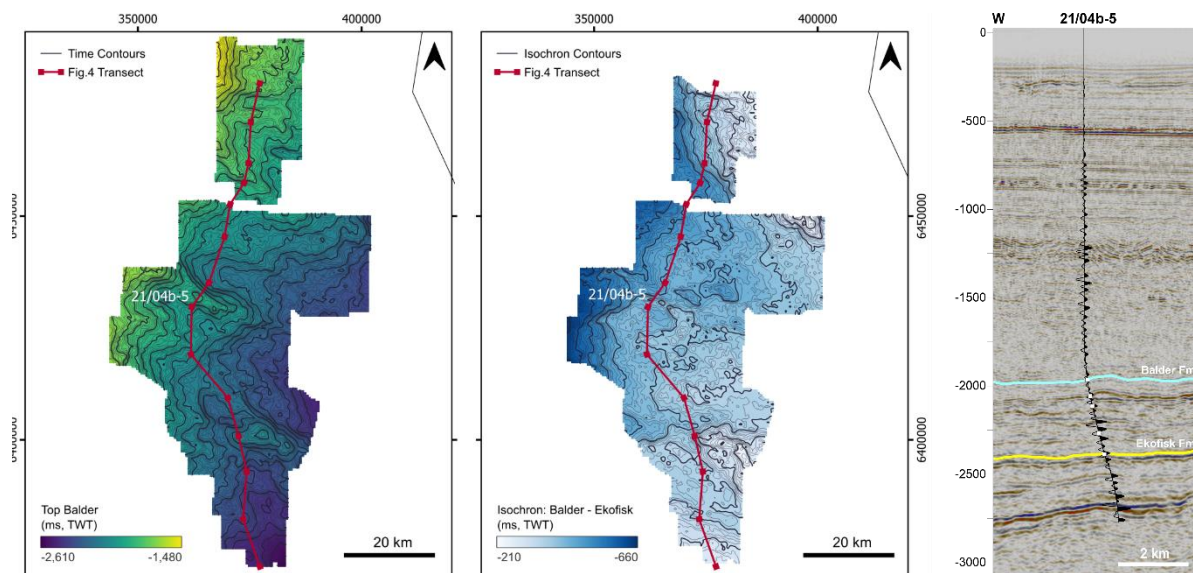


Figure 3 Results from seismic interpretation studies showing structure at top Balder Formation level (left) and time thickness of the Balder to Ekofisk Formation interval (right). A seismic well tie is also shown. Contains information provided by the North Sea Transition Authority and/or other third parties.

While the Mey and Forties sandstones are generally separated by Lista and/or Sele claystones, these units are very thin in some places, leading to potential for pressure communication between these two major units (Figure 4). Consequently, it is possible that pressure space at any future CO₂ storage licenses might be adversely affected by early-mover projects operating in adjacent areas, even if projects target different injection intervals. The Maureen Formation underlies the Mey Sandstone. It is a heterogeneous unit comprising of claystones, limestones, reworked chalk, silstones and sandstones, which might allow further pressure dispersal, alleviating pressure build-up if sufficiently connected to the Mey sandstones.

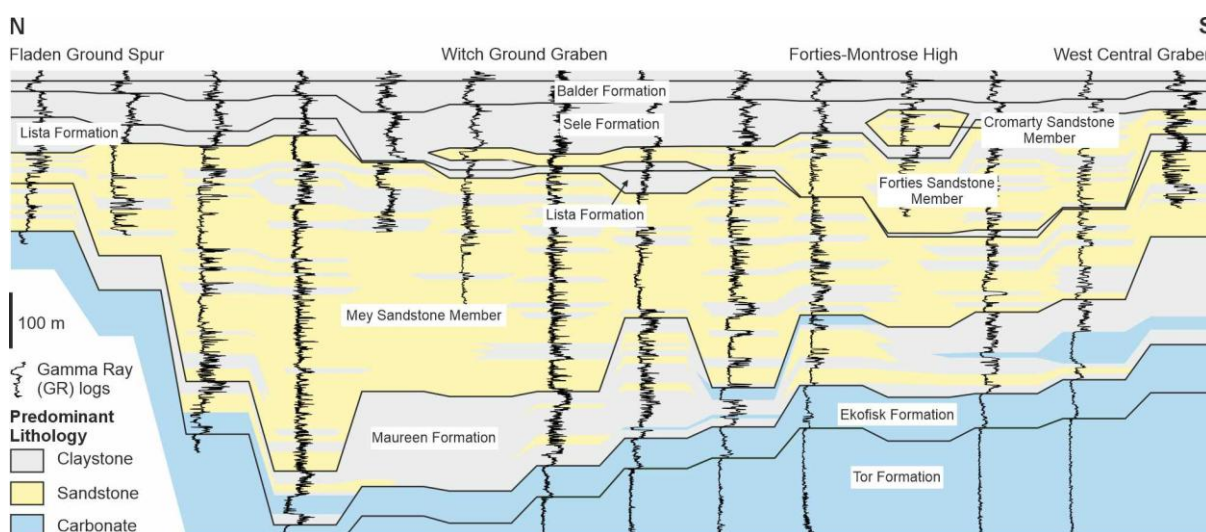


Figure 4 Well correlation panel illustrating the broad lithostratigraphic relationships and schematized lithological variations across the study area (line of section is shown on Figure 3). Contains information provided by the North Sea Transition Authority and/or other third parties.



Conclusions

The interpretation of an extensive subsurface database has enabled the identification and assessment of the challenges posed by the stacked nature of the potential Paleogene CO₂ storage system. The main storage concept is that of open aquifers lacking large closures within which to trap buoyant CO₂. Residual and solubility trapping mechanisms will therefore play an important role in arresting the up-dip migration of CO₂. As the area occupied by resultant CO₂ plumes could be extensive, larger storage complexes and monitoring footprints might be required. The potential for hydraulic connectivity between sandstone units, as identified here, can be potentially both a positive aspect in terms of multi-layered trapping potential and pressure dispersal, while also posing a challenge in terms of unwanted fluid migration. The extent and magnitude of widespread pressure perturbations that could result from large-scale CO₂ storage operations need to be assessed to provide insights into the consequent risks (both positive and negative). Crossflow of brines and/or *in situ* hydrocarbons in legacy wells is one possible outcome of injection-induced pressure increases which merits attention given the high density of wells in the region. It is a requirement of all projects to ensure that potential pressure effects and containment risks are carefully considered during CO₂ storage appraisal. Notwithstanding this, understanding pressure connectivity is a particularly important key to unlocking the CO₂ storage capacity of the Paleogene saline aquifer systems of the Central North Sea.

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References

- Abel, L.E., Williams, J.D.O., Wright, K.A., Randles, T.A., Bridger, P., Morris, H.A., Dodd, T.J.H., Plenderleith, G.E. and White, J.C. [2025]. Structural controls on pressure communication across the Bunter Sandstone Formation, UK Southern North Sea. *Geoenergy*, **3**, geoenergy2024-027.
- Bentham, M., Mallows, T., Lowndes, J. and Green, A. [2014]. CO₂ STORAge Evaluation Database (CO₂ Stored). The UK's online storage atlas. *Energy Procedia*, **63**, 5103-5113.
- De Luca, M., Mackay, E.J., Good, T.R., Scisciani, V., MacBeth, C., Patruno, S. and Sutcliffe, J. [2025]. Regional pressure response to large-scale carbon storage in the bunter sandstone formation, Silverpit Basin (Southern North Sea, UK). *International Journal of Greenhouse Gas Control*, **148**, 104530.
- DESNZ. [2023]. Carbon Capture, Usage and Storage: A Vision to Establish a Competitive Market. Department for Energy Security & Net Zero. Policy paper.
- Gammer, D., Green, A., Holloway, S and Smith, G. [2011]. The Energy Technologies Institute's UK CO₂ Storage Appraisal Project (UKSAP). *Paper presented at the SPE Offshore Europe Oil and Gas Conference and Exhibition, Aberdeen, UK, September 2011*. Paper Number: SPE-148426-MS.
- Ringrose, P.S., Furre, A-K., Gilfillan, S.M.V., Krevor, S., Landrø, M., Leslie, R., Meckel, T., Nazarian, B. and Zahid, A. [2021]. Storage of Carbon Dioxide in Saline Aquifers: Physicochemical Processes, Key Constraints, and Scale-Up Potential. *Annual Review of Chemical and Biomolecular Engineering*, **12**, 471-494.