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

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Summary

Meeting ambitious Net Zero targets will require the identification and de-risking of large saline aquifers for CO_2 storage. With around 50% of the UK's theoretical storage resource situated in the Central North Sea region, sandstones of Paleogene age are identified as a significant open aquifer storage concept. The system is characterized by a complex sequence of stacked and amalgamated fan sandstones. This study identifies some of the key challenges that will impact the future exploitation of the potential CO_2 storage resource. Storage capacity estimates were first extracted from the UK's online CO_2 storage atlas, with the Mey and Forties sandstones identified amongst the units with the greatest potential. A substantial subsurface database was interpreted to identify and explore the key issues. The stacked and amalgamated nature of the sandstones leads to potential for lateral and vertical connectivity within and between different reservoir units. This can be potentially both a positive aspect in terms of multi-layered trapping potential and pressure dispersal, but also poses a challenge in terms of unwanted fluid migration. The study concludes that understanding pressure connectivity is a particularly important key to unlocking the CO_2 storage capacity of the Paleogene saline aquifer systems of the Central North Sea.

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Introduction

The UK Government aims to store 20 to 30 million metric tons (Mt) of CO_2 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 CO_2 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 CO_2 (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 CO_2 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 CO_2 storage capacities are comparable to those of the Bunter Sandstone in the Southern North Sea.

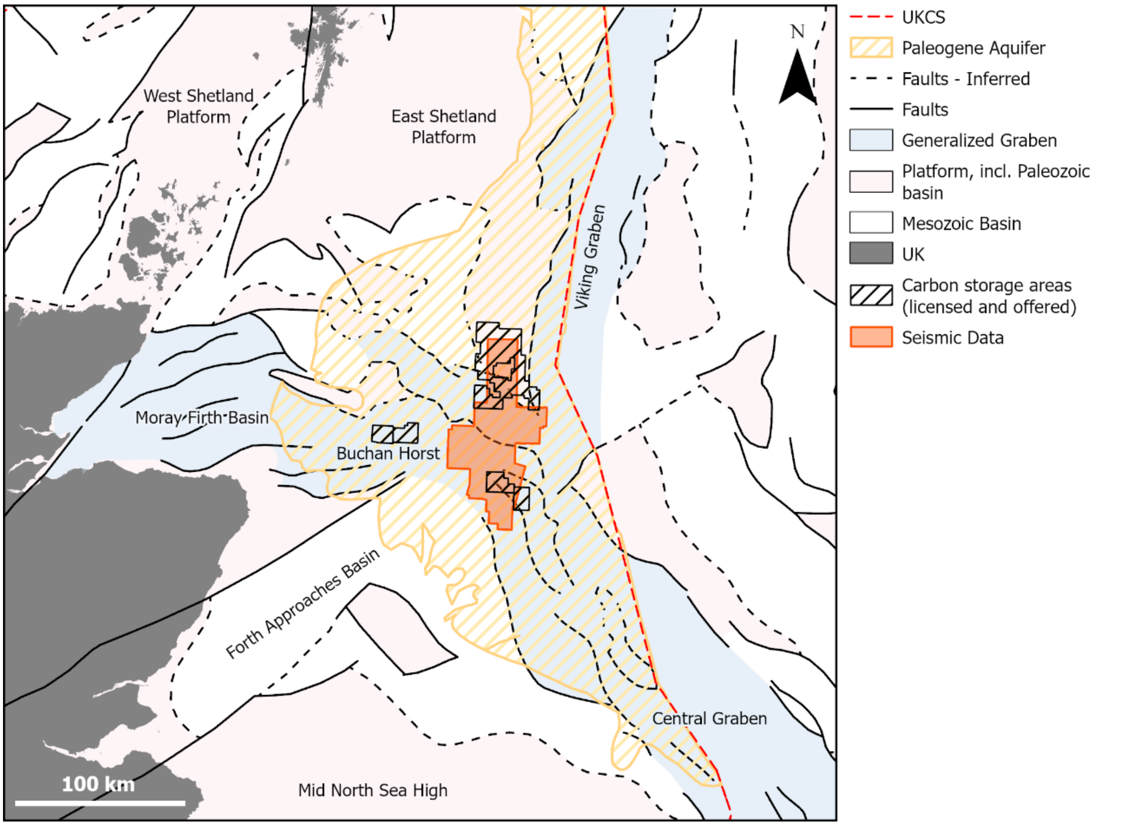

Figure 1 *Summed distribution of the multiple marine fan sandstones of Paleogene age within the study region. Sandstone extent from the UK's online storage atlas, CO_2Stored. Carbon storage licenses contain information provided by the North Sea Transition Authority and/or other third parties.*

Subsurface database

In this study, we identify some of the key geoscience challenges that will impact the future exploitation of the Paleogene sandstone CO_2 storage resource. First, the UK's online CO_2 storage atlas, CO_2Stored (www.co2stored.co.uk/home), was interrogated to extract storage capacity estimates for the lithostratigraphic units of interest. The CO_2Stored 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.

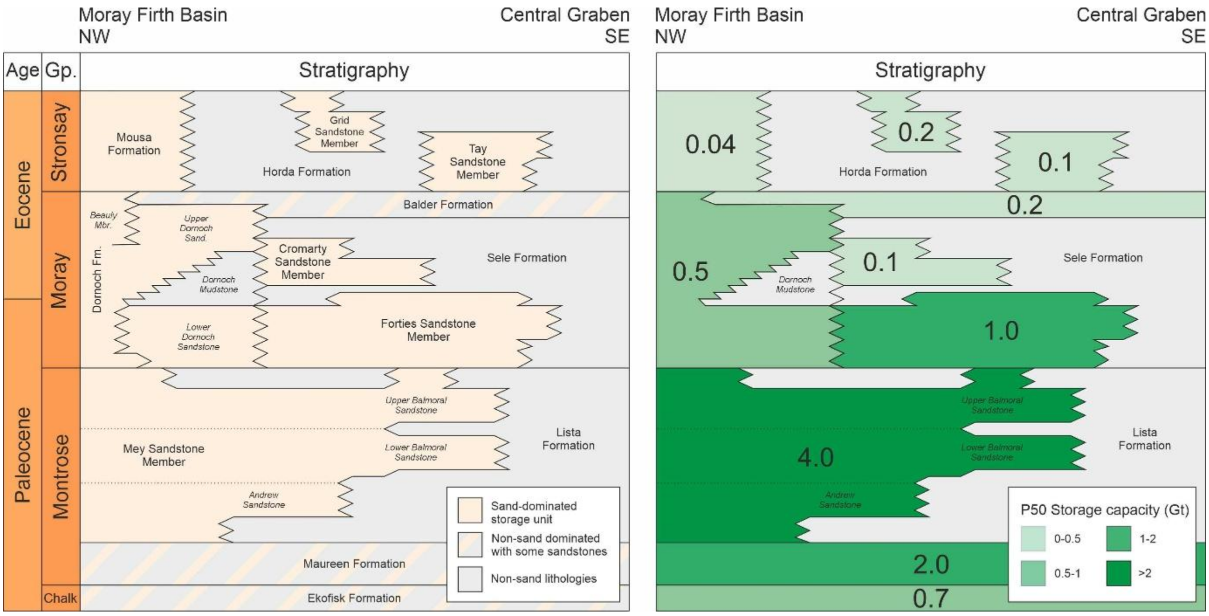

Figure 2 *Generalized lithostratigraphic column showing stratigraphic distribution of potential Paleogene storage units in the Central North Sea region (left). Most likely (P50) storage capacity estimates for the units based on the CO_2Stored database (right) in units of gigatons (Gt).*

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 CO_2 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 CO_2 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 CO_2 and/or brine migration within the system.

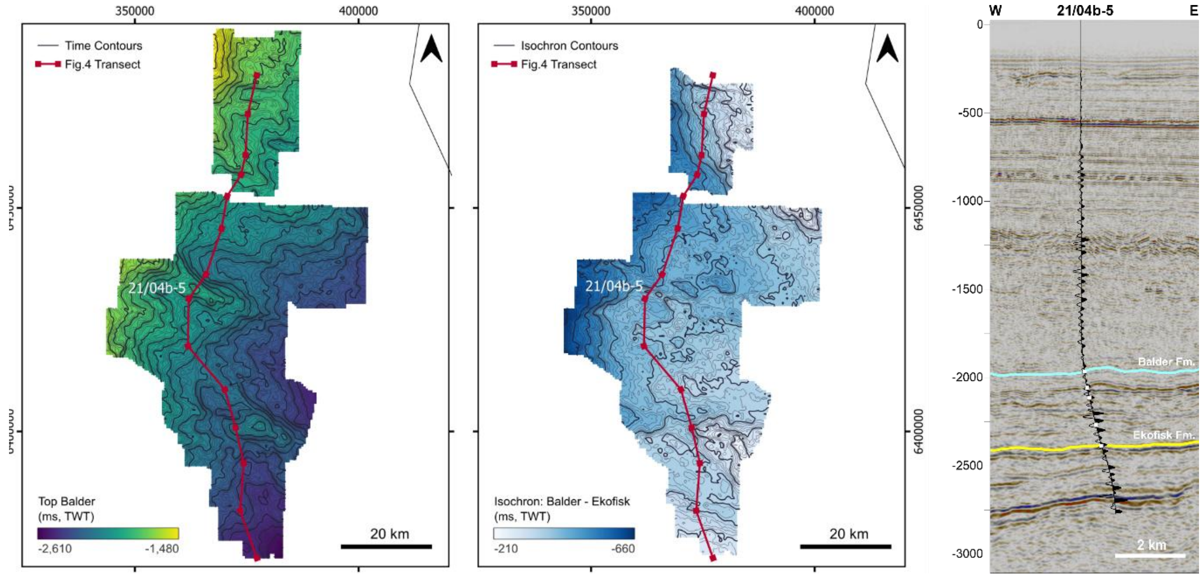

Figure 3 *Results from seismic interpretation studies showing structure at top Balder Formation level (left) and time thickness of the Balder to Ekofisk Formation interval (right). A seismic well tie is also shown. Contains information provided by the North Sea Transition Authority and/or other third 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 CO_2 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 heterogenous 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.

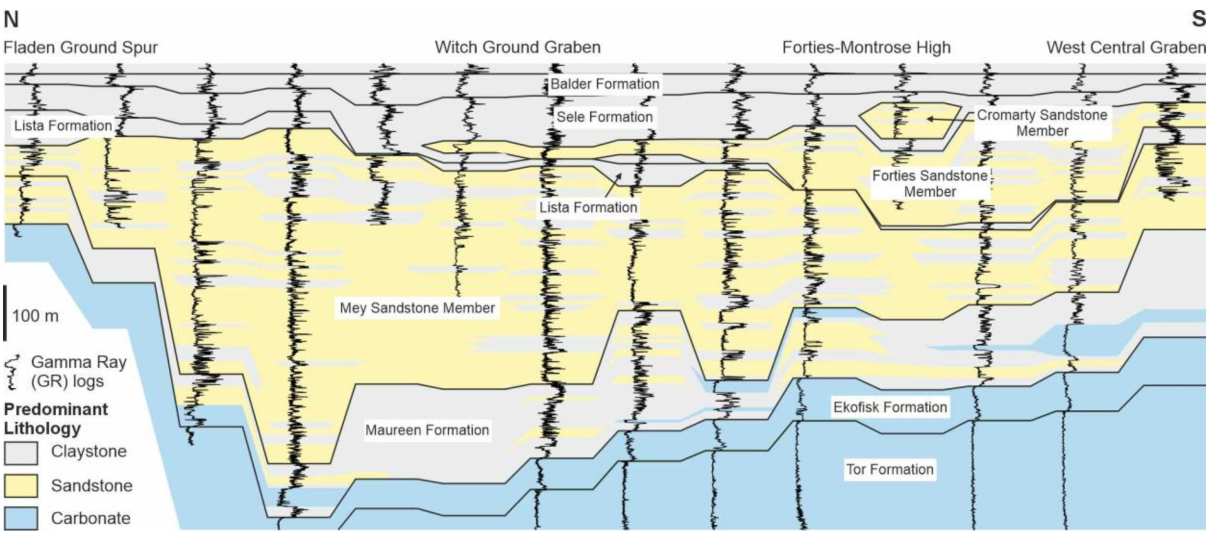

Figure 4 *Well correlation panel illustrating the broad lithostratigraphic relationships and schematized lithological variations across the study area (line of section is shown on Figure 3). Contains information provided by the North Sea Transition Authority and/or other third parties.*

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 CO_2 storage system. The main storage concept is that of open aquifers lacking large closures within which to trap buoyant CO_2. Residual and solubility trapping mechanisms will therefore play an important role in arresting the up-dip migration of CO_2. As the area occupied by resultant CO_2 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 CO_2 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 CO_2 storage appraisal. Notwithstanding this, understanding pressure connectivity is a particularly important key to unlocking the CO_2 storage capacity of the Paleogene saline aquifer systems of the Central North Sea.

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