Understanding the impact of regional structures on pressure communication within the Bunter Sandstone Formation, UK Southern North Sea

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The Lower Triassic Bunter Sandstone Formation is one of the UK's principal targets for carbon capture and storage. Located in the Southern North Sea, the formation contains several periclinal closures which provide potential carbon storage opportunities for industrial clusters in eastern England. Numerical simulation studies, investigating the dynamic behaviour of industrial scale CO_2 injection, have highlighted that CO_2 storage can result in widespread pressurisation of the aquifer. Understanding the potential for pressure communication in the Bunter Sandstone is therefore important in the context of pore pressure management, as injection activities at one site could potentially impact negatively on operations elsewhere.

The Bunter Sandstone Formation is regionally divided by recognised fault systems and salt walls, such as the Dowsing Graben System, North Dogger Fault Zone, Audrey Salt Wall and Outer Silverpit Salt Wall. The Bunter Sandstone Formation is underlain by the Permian Zechstein Salt. Extension and transtension during the Mid-Late Triassic, Jurassic and Early Cretaceous, associated with the breakup of Pangea, and inversion during the Alpine Orogeny in the Late Cretaceous and into the Palaeogene, has resulted in mobilisation of the Zechstein Salt and the deformation of the Bunter Sandstone and its overburden.

Recently, localised studies have been completed which map zones of separation of the Lower Triassic strata within the Dowsing Graben System (Grant et al 2019; Grant et al 2020) and regionally the distribution and evolution of salt walls (Gaitan & Adam, 2023). However, there is little investigation into the characteristics of these boundaries as a whole and their likely impact on the migration pathways of fluids within the aquifer, and therefore pressure, during large-scale CO_2 injection. This study uses a large seismic database to evaluate these bounding structures at Bunter level. Each boundary has been investigated and the structural variation described. A new structural map has been created for the Top Bunter Sandstone Formation and a classification scheme has been developed to map the variation in the structural character and therefore the likelihood of pressure communication across each boundary.

The structural boundaries predominantly provided distinct separation of the Bunter Sandstone Formation. Areas of uncertainty remain where: the structures are highly complex, there is little well control, and the seismic imaging is of lower resolution. Legacy well data has been sourced from the NSTA's National Data Repository to investigate formation pressures within the Bunter Sandstone Formation. These data indicate that

different structural regions in the UKSNS are subject to distinct pressure gradients supporting the lack of aquifer connectivity inferred from the seismic interpretation.

Current national development plans (NSTA, 2023) envisage multiple storage sites within the wider connected aquifers. Strategic management and pressure control may become a key factor in the development and operation of these storage sites. To investigate the impact of the boundary classification on regional pressure, numerical flow modelling was used with the ELCIPSE300 simulator and the CO2STORE option. Regionally appropriate parameter values were used, primarily sourced from the CO2Stored database and other publicly available data. A realistic but ambitious CO_2 injection strategy has been used with staggered injection into multiple closures, including the Endurance structure. For boundaries with uncertain connectivity, cases of closed, semi-closed and open boundaries were run and the flow of pore fluids through permeable boundaries quantified. The flow simulations provide an insight into the potential implications for pressure management for effective utilisation of storage capacity, and could be used to inform development of monitoring strategies.