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Effects of faults as barriers or conduits to displaced brine flow on a putative CO_2 storage site in the Southern North Sea

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The Bunter Sandstone Formation in the Southern North Sea is a potential reservoir being considered for carbon dioxide storage as a climate change mitigation option. A geological model of a putative storage site within this saline aquifer was built from 3D seismic and well data to investigate potential reservoir pressure changes and their effects on fault movement, brine and CO_2 migration as a result of CO_2 injection. The model is located directly beneath the Dogger Bank Special Area of Conservation, close to the UK-Netherlands median line.

Analysis of the seismic data reveals two large fault zones, one in each of the UK and Netherlands sectors, many tens of kilometres in length, extending from reservoir level to the sea bed. Although it has been shown that similar faults compartmentalise gas fields elsewhere in the Netherlands sector, significant uncertainty remains surrounding the properties of the faults in our model area; in particular their cross- and along-fault permeability and geomechanical behaviour. Despite lying outside the anticipated CO_2 plume, these faults could provide potential barriers to pore fluid migration and pressure dissipation, until, under elevated pressures, they provide vertical migration pathways for brine. In this case, the faults will act to enhance injectivity, but potential environmental impacts, should the displaced brine be expelled at the sea bed, will require consideration.

Pressure gradients deduced from regional leak-off test data have been input into a simple geomechanical model to estimate the threshold pressure gradient at which faults cutting the Mesozoic succession will fail, assuming reactivation of fault segments will cause an increase in vertical permeability. Various 4D scenarios were run using a single-phase groundwater modelling code, calibrated to results from a multi-phase commercial simulator. Possible end-member ranges of fault parameters were input to investigate the pressure change with time and quantify brine flux to the seabed in potentially reactivated sections of each fault zone. Combining the modelled pressure field with the calculated fault failure criterion suggests that only the fault in the Netherlands sector reactivates, allowing brine displacement at a maximum rate of 800 — 900 m^3/d. Model results indicate that the extent of brine displacement is most sensitive to the fault reactivation pressure gradient and fault zone thickness.

In conclusion, CO_2 injection into a saline aquifer results in a significant increase in pore-fluid pressure gradients. In this case, brine displacement along faults acting as pressure relief valves could increase injectivity in a similar manner to pressure management wells, thereby facilitating the storage operation. However, if the faults act as brine migration pathways, an understanding of seabed flux rates and environmental impacts will need to be demonstrated to regulators prior to injection. This study, close to an international border, also highlights the need to inform neighbouring countries authorities of proposed operations and, potentially, to obtain licences to increase reservoir pressure and/or displace brine across international borders.