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Horstberg, NW Germany: a unique test site for CO2-sequestration in saline aquifers

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CO2 sequestration in deep saline aquifers is regarded as one of the most feasible options to store anthropogenic greenhouse gas over geological time scales mitigating global warming effects. Both large potential storage capacity and broad global availability of these geological formations give this technology an important advantage over possible alternatives. However, before a widespread commercial application can be safely and successfully implemented research has to address existing knowledge gaps including cap rock integrity, up-fault leakage and interactions with abandoned boreholes.
Hostberg Z1 in N Germany is an ideal test site to investigate this technology for a unique combination of geological features such as its great depth of the targeted saline aquifers of about 3800 m, its structural context of being affected by a complex deep cutting inversion structure, its low permeability of about 1 mD and being surrounded by a large number of wells due to extensive oil and gas exploration within the area. Borehole and 2D seismic data from the public domain as well as a detailed industrial 3D seismic dataset were evaluated building both a large scale (> 60 km) and small scale ($\sim$ 7 km) structural 3D model describing distribution and thickness of lithologies, classifications in cap rocks and aquifers, and geometry and pattern of faults. The 3D seismic dataset covers an area of 7.5 x 7.0 km and resolves geological features as deep as 2600 msec TWT. This depth coincides with the base of the Permian Zechstein formation allowing interpretation of relevant geometries in the Triassic Bunter formations in great detail.
The targeted saline aquifers are represented by typical layer cake sandstones of the Triassic Middle Bunter formation and are overlain by a 300 m thick halite layer of the Upper Bunter formation forming an effective seal. The three targeted aquifers (Solling sandstone (20 m thick), Detfurth-sandstone (50 m thick) and Volpriehausen sandstone (20 m thick)) are at a depth between 3875 and 3650 m and are interbedded with mudstones. These strata are underlain by a predominantly arenaceous sequence which changes down-sequence into a predominantly argillaceous facies of the Upper Bunter formation. The Bunter formation in turn is underlain by massive evaporite deposits of the Permian Zechstein formation. The sandstones forming the saline aquifers show a gradual decrease of grain size transitioning into silt and clay as well as a decrease in thicknesses with increasing distance towards the north. The Horstberg area is thoroughly faulted exhibiting the Upper Cretaceous Fassberg inversion structure which is about 15 km long, WSW-ENE striking and steeply south-dipping. This inversion structure is confined by the two salt diapers Bahnsen und Dethlingen in the west and east, respectively.
The geological models developed form the basis to a cutting-edge transient numerical modelling approach in three spatial dimensions to advance the understanding of the fate of CO2 at a temporal and spatial scale by simulating flow, transport, reactive transport, thermal and chemical processes occurring to the fluids and to the rock matrix during injection and storage. Possible CO2 leakage along abandoned wells and existing or reactivated faults are quantified while comparison between a small and large scale model indicates a required length scale of CO2 transport and trapping mechanisms.