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Tracer-assisted characterization of Horstberg site in the N-German Sedimentary Basin: bad news, or good news for georeservoir use?

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The Horstberg structure in the Northern-German Sedimentary Basin [1] [2] lies within a succession of sandstone, claystone, carbonates and halite layers whose host-rock hydrogeological characteristics in 2-4 km depth appear as promising for various geotechnical uses, with geothermal energy extraction in the first place [3], but not excluding CO2 storage [2] [4]. Whereas the virgin rock matrix is virtually free of fractures/fissures, the presence of large-scale natural faults must not necessarily pose a risk to geotechnical applications, but can be used for 'smart georeservoir' design (with natural faults acting either as flow barriers or as drainage pathways).

The Horstberg location itself is not intended as a CCS site. Used as a gas exploration well in 4-5 km depth in the nineties, the borehole Horstberg-Z1 was then refilled to 4 km depth and served since 2003 for testing innovative single-well techniques for direct use of geothermal heat [5] [6]. Its peculiar geometrical, hydrogeological, thermal, geomechanical and hydrogeochemical features also recommend it as a highly interesting site for
– testing innovative single-well experimental methods for determining reservoir parameters (including forced-gradient tracer tests in single-layer push-pull and inter-layer vertical push configurations)
– simulating CO2 injection in selected sandstone layers, and assessing some problems that may occur during CO2 injection in similar formations (saline aquifers in 2-4 km depth in the Northern-German Sedimentary Basin).

Judged by general criteria for CCS site selection, as stipulated by [7] (permeability > 10 mD, effective thickness > 10 m, porosity > 10 % for storage layers, plus requirements on caprock depth, thickness etc.), the Horstberg location is not, strictly-speaking, adequate for CO2 storage (the only criterion it matches with certainty is 'sufficient depth'). However, its hydraulic and hydrogeological characteristics are not far from fulfilling the normative. Its most permeable layer ('Solling' sandstone) has permeability less than 10 mD but probably higher than 1 mD, thickness $\sim$20 m, static porosity $\sim$11% from laboratory measurements on core samples. Its second-best permeable layer ('Detfurth' sandstone) has enough thickness, but permeability definitely less than 1 mD and static porosity less than 10%. In the Solling sandstone, injection-induced fracturing is unlikely to occur at significant scale. Hydrofracturing was proven to be possible in the Detfurth sandstone, yet induced fractures propagating from the Detfurth layer upwards through neighboring claystone become arrested in the Solling sandstone layer, owing to its significantly higher permeability. As an overall methodical limitation (not specific to the Horstberg site), transport-effective porosities of these layers cannot be determined from borehole logs or laboratory measurements on core samples, nor from hydraulic tests; they can only be determined from in-situ transport experiments, involving fluid transport on a macroscopic scale.

We show how transport-effective porosities (a parameter crucial to CCS) can be determined from single-well tracer tests, and illustrate this with tracer tests conducted at the Horstberg-Z1 well as of 2004. Further, we simulate CO2 injection in selected layers at various rates, and from pressure buildup thus predicted we assess the risk of injection-induced fracturing. We show how tracer tests can be used to check that, if a vertical fracture propagates from the injection screen, the layer in which it becomes arrested upwards will act as a (more or less effective) drainage for the 'spill' case.

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