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Modeling CO_2 distribution in a heterogeneous sandstone reservoir: the Johansen Formation, northern North Sea

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The last few years there has been broad attention towards finding permanent storage options for CO_2. The Norwegian continental margin holds great potential for storage in saline aquifers. Common for many of these reservoir candidates, however, is that geological data are sparse relative to thoroughly mapped hydrocarbon reservoirs in the region. Scenario modeling provides a method for estimating reservoir performances for potential CO_2 storage sites and for testing injection strategies. This approach is particularly useful in the evaluation of uncertainties related to reservoir properties and geometry. In this study we have tested the effect of geological heterogeneities in the Johansen Formation, which is a laterally extensive sandstone and saline aquifer at burial depths of 2 – 4 km, proposed as a suitable candidate for CO_2 storage by Norwegian authorities.

The central parts of the Johansen Formation are underlying the operating hydrocarbon field Troll. In order not to interfere with ongoing gas production, a potential CO_2 injection well should be located at a safe distance from the gas reservoir, which consequently implies areas presently without well control. From 3D seismic data, prediction of spatial extent of sandstone is possible to a certain degree, whereas intra-reservoir flow baffles such as draping mudstone beds and calcite cemented layers are below seismic resolution. The number and lateral extent of flow baffles, as well as porosity- and permeability distributions are dependent of sedimentary facies and diagenesis. The interpretation of depositional environment and burial history is thus of crucial importance.

A suite of scenario models was established for a potential injection area south of the Troll field. The model grids where made in Petrel based on our interpretations of seismic data, wire line logs, core and cuttings samples. Using Eclipse 300 the distribution of CO_2 is modeled for different geological settings; with and without the presence of pervasive low permeability draping mudstone layers, and with varying lateral extent of potential calcite cemented layers in 8 to 15 intra-reservoir depth levels. The modeled area covers 10 x 15.8 km, with a thickness of 110 m at the injection point. Simulations were run with an injection phase of 30 years plus 100 years of migration.

The presence of meso-scale flow baffles causes a reduction in vertical permeability in addition to the facies related variation on the micro-scale. Scenarios including potential flow baffles as separate layers in the model grids were compared to scenarios in which the effect of flow baffles were included using harmonic mean average of vertical permeability. The subsequent differences in CO_2 distribution are important in estimating the contact area between the plume front and reservoir brine. A heterogeneous reservoir with internal flow baffles is not necessarily a disadvantage as long as sufficient injectivity is maintained within individual sandstone bodies. In each scenario we aim to adapt a suitable injection strategy with respect to utilizing local effects such as the delimitation of gravitational flow, in order to increase reservoir sweep and maximize the effect of trapping mechanisms (i.e. residual, stratigraphic, mineral and dissolution).