Heterogeneities in the reservoir models; effect on CO_2 storage capacity and plume modelling in areas with pressure depletion

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Introduction

CO_2 storage capacity for reservoir units depends on several properties like structural trapping, faults (sealing properties, size and pattern), and sedimentary facies with associated heterogeneities. The heterogeneities will influence the irreducible water saturation to CO_2, irreducible CO_2 saturation to water and the CO_2 dissolution in brine. Effect of heterogeneities are investigated varying the effective flow properties of thin shale layers.

Study area

The study area covers the Horda Platform in the northern North Sea (Fig. 1a, b) with the Smeaheia area located in the eastern margin of the Horda Platform. The Sognefjord Fm. is the main reservoir in the area (100-170 m thick, Fig. 1c).

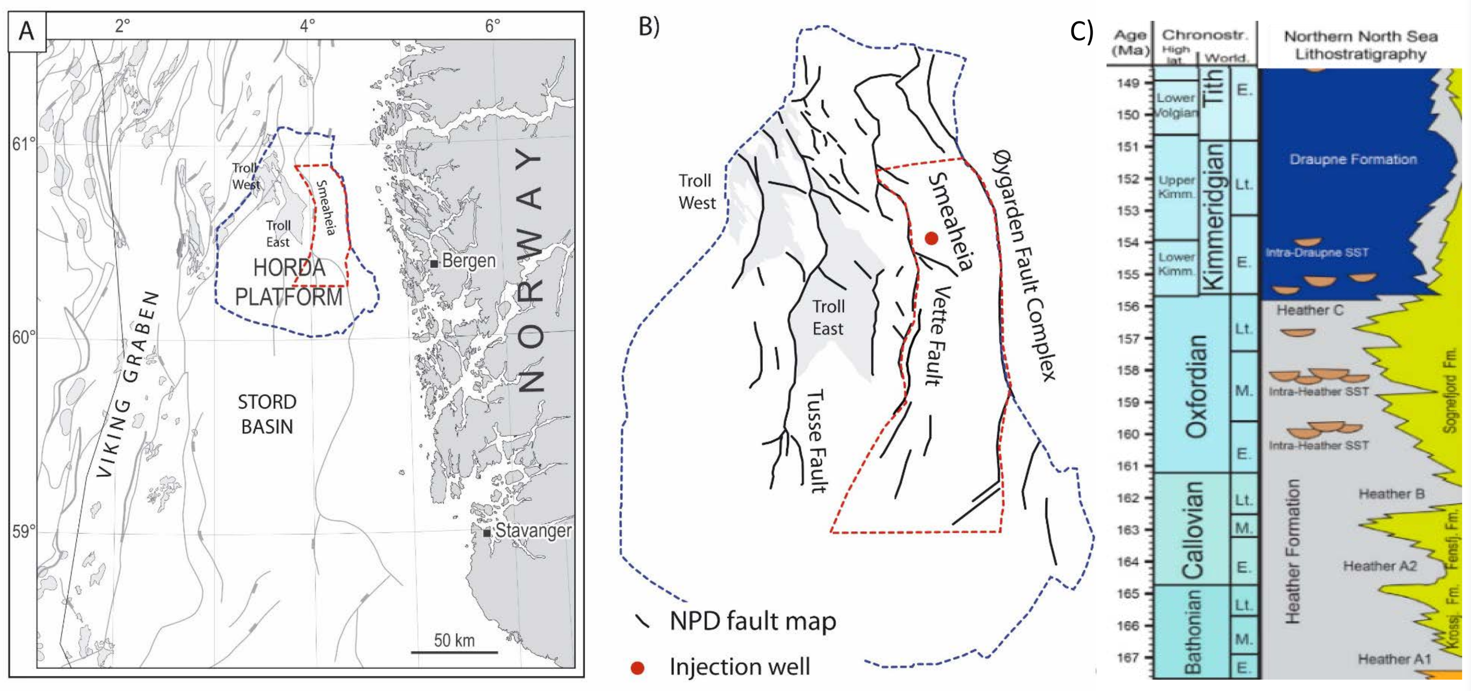

Fig. 1. a) Map of the northern North Sea with the study area indicated by the dashed red line. (b) Fault map in used in the modelling approach. (c) Lithostratigraphic column for the Northern North Sea; Patruno et al. (2015).

Pressure distribution – input

Simulated pore pressure from Lothe et al. (2018) is used as input for the basin wide effect of depletion from the Troll Field (blue dashed line, Fig. 1b). Pseudo-production wells mimic the pressure drawdown in the Smeaheia area (red dashed line Fig 1). Vette Fault influence the pressure in the Smeaheia area (Fig.3).

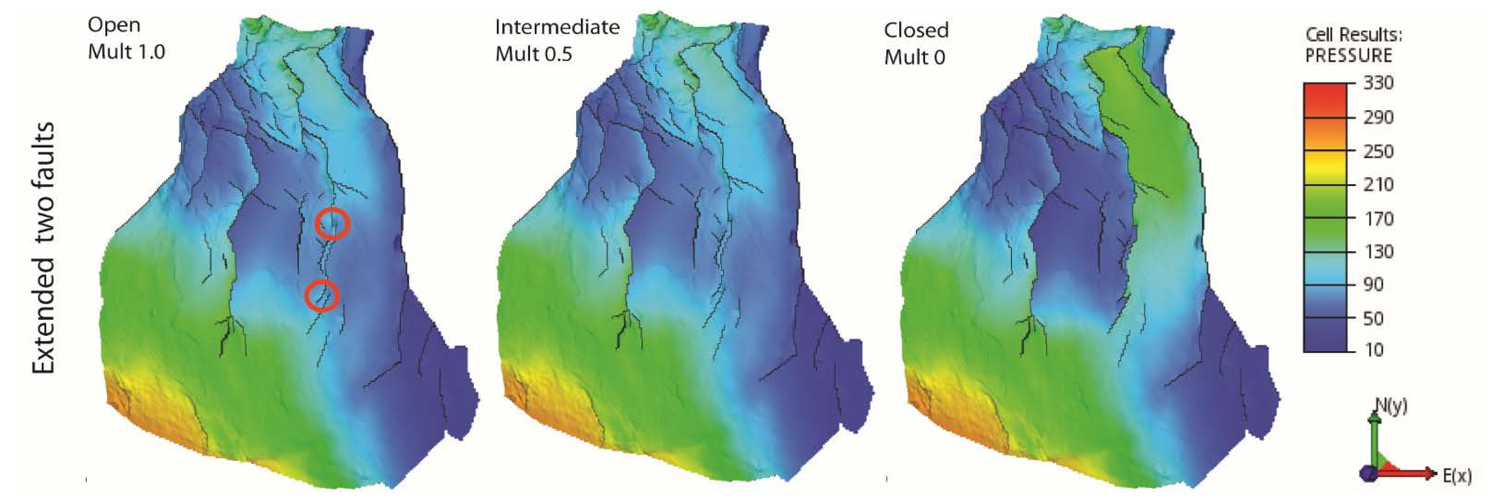

Fig. 3. The maps show modelled pressures in year 2072 with extended faults in the relay zones along the Vette Fault (marked with red), using open (mult 1.0), intermediate (mult 0.5) to sealing (mult 0.0) faults. From Lothe et al. (2018).

Model setup Smeaheia

In this study we focus on the effect of facies related heterogeneities in a simulation model (400x400 m grid block) using 27 layers (Fig. 2a). A reservoir model was set up for the Sognefjord Fm., the Fensfjord Fm. and Krossfjord Fm. (Fig. 1c and 2b). They represent three costal shallow marine sands that interfinger with the Heather Fm. on the Horda Platform (Fig. 1c). We focus on the injection into the alpha structure in the NW part of the working area (red dot, Fig. 1b).

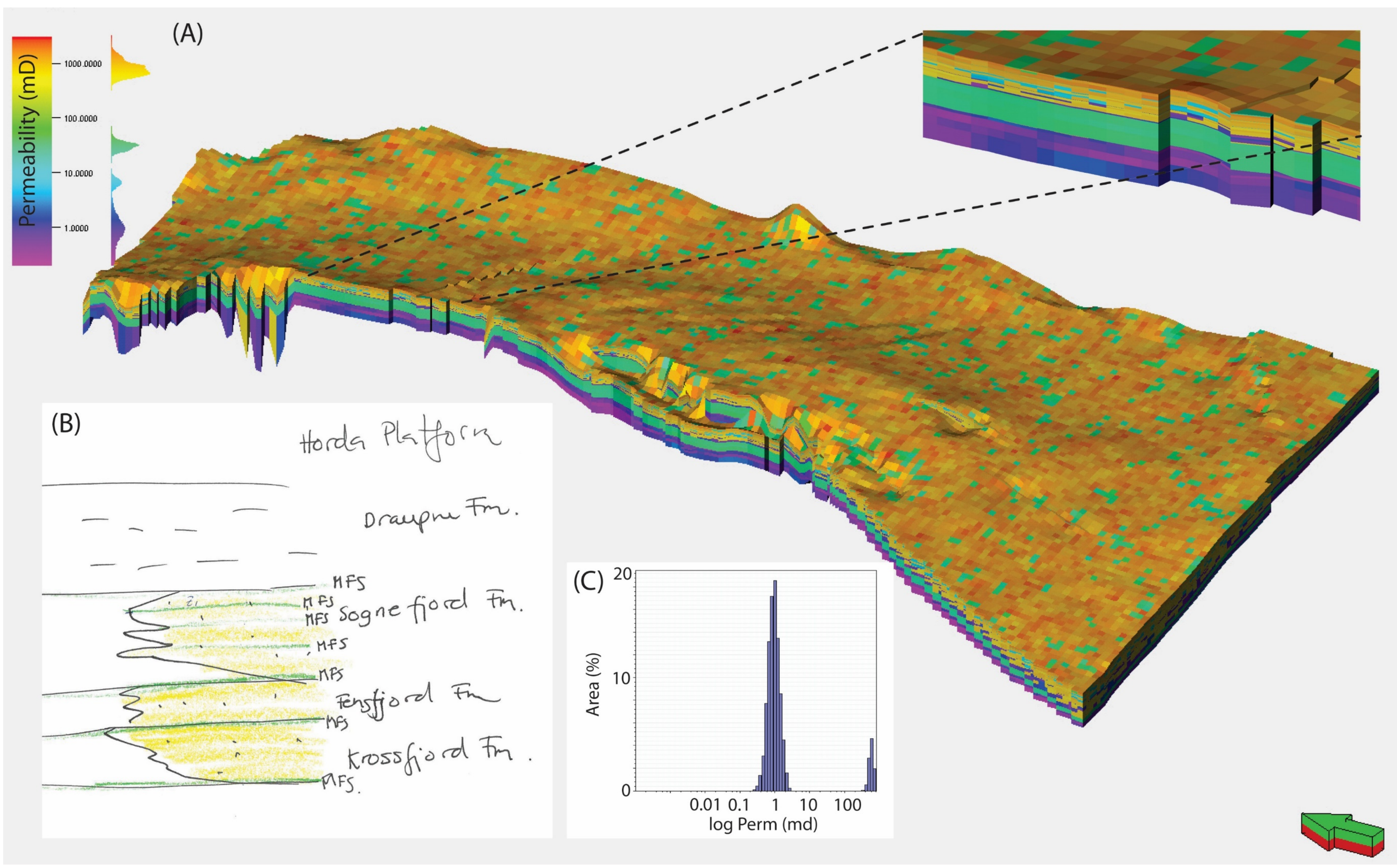

Fig. 2. a) *Reservoir model setup, b) Conceptual overview of the stratigraphy, c) base case permeability distribution for the clay-rich layers, with patches of sands.*

Results

The base case is a stochastic model with clay layers and localized zones of high permeability (Fig. 2). CO_2 injection rate is constant at 3 Mt/yr for 50 yrs in all cases.

- Injected CO_2 migrates rapidly toward east, using open to sealing faults (Fig. 4).
- The CO_2 density decreases rapidly after the injection period (Fig. 5).
- Tighter clay layers result in more dissolved gas (Fig. 6).

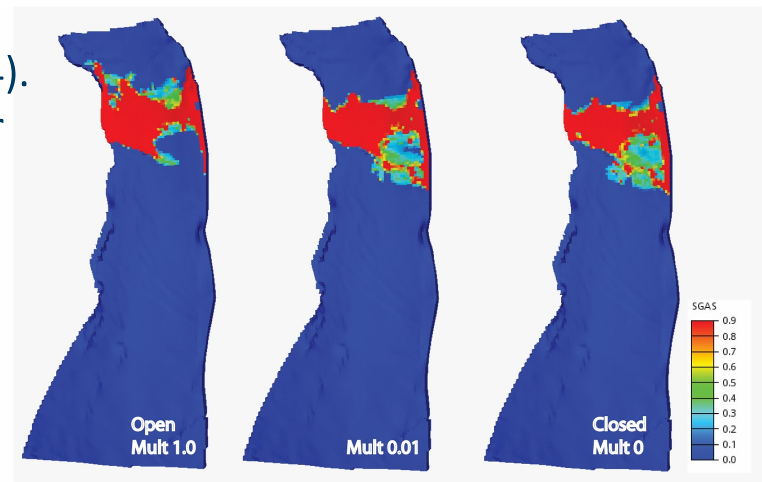

Fig. 4. *Base case with vertical injection well. CO_2 saturation after the injection period shows rapid eastward migration into the Øygarden Fault zone using different fault multipliers.*

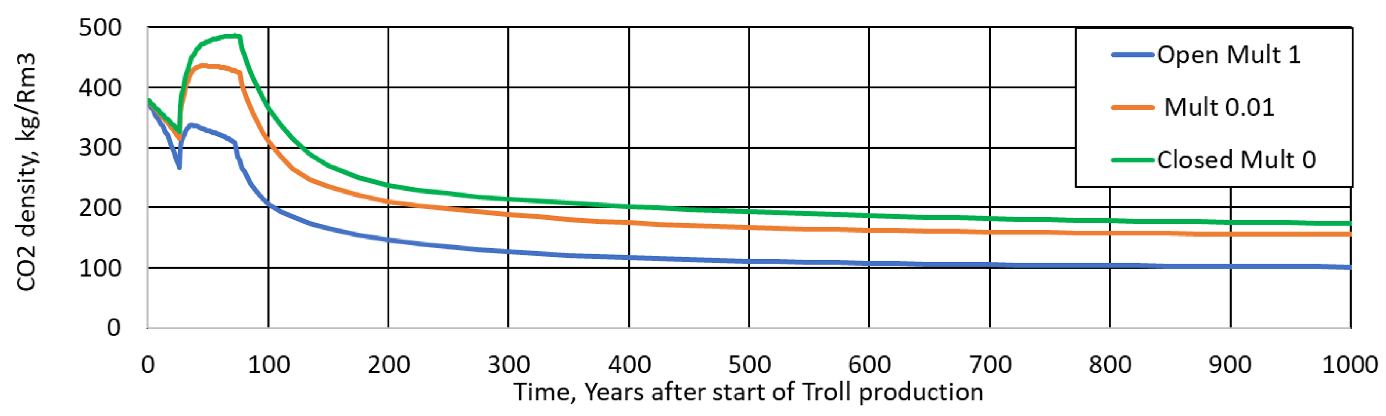

Fig. 5. *CO_2 density at the top of the alpha structure as a function of time.* Density decreases due to pressure depletion in the model.

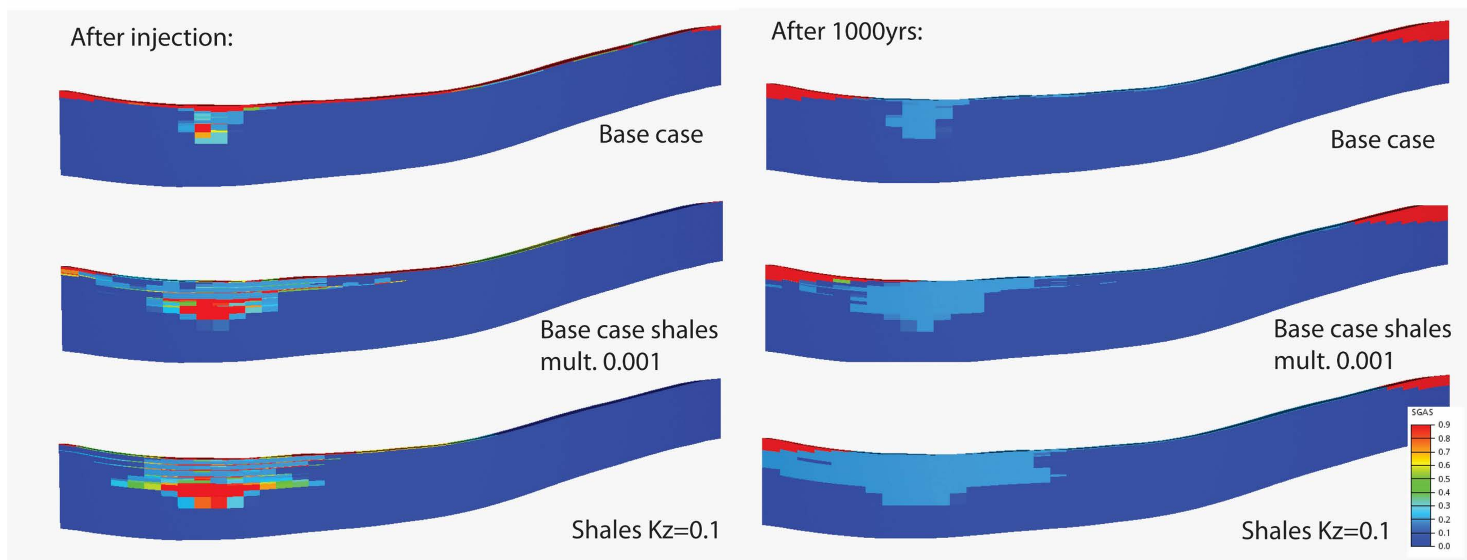

Fig. 6 *E-W cross sections at injection site showing effects of reservoir facies heterogeneities (varying shale layer flow properties). CO_2 is injected in a horizontal well into the Fensfjord Fm.*

References:

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- Patruno S, Hampson GJ, Jackson A-LC et al. 2015: Clinoform geometry, geomorphology, facies character and stratigraphic architecture of a sand-rich subaqueous delta: Jurassic Sognefjord Formation, offshore Norway. Sedimentology, 62, 350-388.

Conclusions

- We use regional pressure simulations as input for CO_2 gas injection modelling in the Smeaheia area. Fault sealing properties are varied, and the Vette Fault has extended faults in the two ramp structures.
- All cases injecting 3 Mt/year (total 150 Mt) results in migration of CO_2 into the Øygarden Fault Complex.
- Heterogeneities within the reservoir facies controls the dissolution of CO_2 in the reservoir. With homogeneous layers, the gas will migrate rapidly to the top of the structures.
- Assuming discontinuous clay layers, the localised high permeable zones will control vertical migration.
- The topography of the top reservoir is the main controlling factor for CO_2 migration on longer time scale .

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