Using 2D seismic line data to estimate impact of caprock morphology on CO₂ migration in the Gassum Formation

Odd Andersen¹, Anja Sundal²
¹SINTEF Digital, ²Dept. of Geosciences, University of Oslo

---

(1) – Introduction and motivation
- The CO₂-Upslope project studies how CO₂ migration in sloping open aquifers is limited by factors that may immobilize the plume over the long term (physical and chemical trapping mechanisms) [1, 5].
- A case study is carried out on the Gassum Formation - a sloping open aquifer (Skagerak, south of Norway), for which data from several 2D seismic surveys are available.
- The work presented below aims to assess the potential for structural trapping and plume retardation from caprock topographical features that we try to infer from available data.
- Ultimately the Gassum aquifer crops out on the sea floor, and sufficient plume retardation is essential to avoid leakage.

Seismic cross-section of the Gassum Formation (image from GEUS).

(2) – Input data
- Domain under study: 1900 km²
- CO₂ migration is strongly affected by caprock topography. To simulate migration, we must establish top surfaces that are consistent with available data.
- 13 seismic lines from 3 surveys (IKUBB, SKAGGER6 and FSB88) cross the domain (red, green and blue on figure).
- Each line intersected by a large number of faults.
- Most identified faults are minor and can only be identified on a single line (unregistered faults)[2].

(3) – Constructing base surface and small-scale detail
- We use thin-plate splines to construct a base surface representing general caprock shape.
- Small-scale variations are important when simulating CO₂ migration, but only available along seismic lines.
- We measure the difference between seismic lines and base surface, and use these residuals to derive variograms.
- We generate corresponding Gaussian fields, which allow us to extend small-scale features from seismic lines to the whole surface in a stochastic manner.

(4) – Fault modeling
- We use a conceptual fault model from [3].
- Fault surface is modeled as an ellipse, and vertical displacement δ as a function from the center of the ellipse.
- Important ratios are δ/fault length L, fault height H to L, extent of displacement zone D to L, fault orientation θ and throw T.

(5) – Final top surface
- By combining the base surface with randomly generated small-scale detail (cf. box 3) and faults (cf. box 4), we create top surface representations that are statistically compatible with the 2D seismic line and fault data.

(6) – Global trapping analysis
- Structural trapping capacity significantly impacted by small-scale features and faults.
- We use MRST-co2lab to compute structural traps for base surface and 310 realizations of added detail and faults.
- Results suggest a significant additional structural capacity, but also with large variation between realizations.

(7) – Simulated injections
- To assess impact of top surface structure on CO₂ migration, we run flow simulations. The vertical-equilibrium simulator in MRST-co2lab lets us run many simulations quickly.
- We consider 3 alternative injectors and 3 megatons of CO₂ per year for 30 years, followed by 470 years of migration.
- We compare base surface (left plot), base with small-scale detail (middle plot) and base with small scale detail and faults (right plot), and three different realizations for each.

(8) – Fault parameter sensitivity
- Our fault model ratios δ/L, D/L and δ are highly uncertain.
- To assess the sensitivity of migration to these parameters, we vary each of them in turn, and run flow simulations on an ensemble of 10 realizations for each combination.
- We plot the mean and standard deviation in outcomes for each scenario.

(9) – Conclusion and references
- Small-scale topographical features amount to a significant share of total structural trapping capacity, although variation is high between realizations.
- The presence of faults and small-scale detail appears to slow down overall plume migration with about 10-35 percent.
- Choice of ratios in the fault model seem to have limited impact on plume migration speed.
- General orientation of small-scale fault may have non-negligible impact on overall migration direction.

---

Footnotes:
[1] The upslope project: Optimized co₂ storage in sloping aquifers (upslope), 2017-2019. URL: https://www.mn.uio.no/geo/english/research/projects/upslope/

Optimized CO₂ storage in sloping aquifers (Upslope) Research Council of Norway grant no. 268512 odd.andersen@sintef.no