The sensitivity of CO_2 storage simulations to pressure artifacts: indications from the Sleipner Benchmark model

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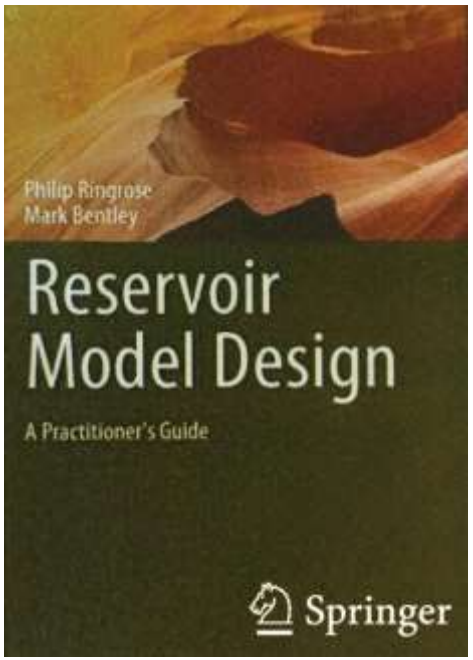
Workflow…



Re-iterate as necessary:

1. Maintain subsurface database;
2. Preserve model build decision track;
3. Discard or archive the model results;
4. Address the next question…

- Decide the model purpose
- Establish conceptual geological models
- Build rock models
- Build property models
- Assign flow properties and functions
- Upscale flow properties and functions
- Make forecasts
- Assess and handle uncertainties
- Compare simulations to observations

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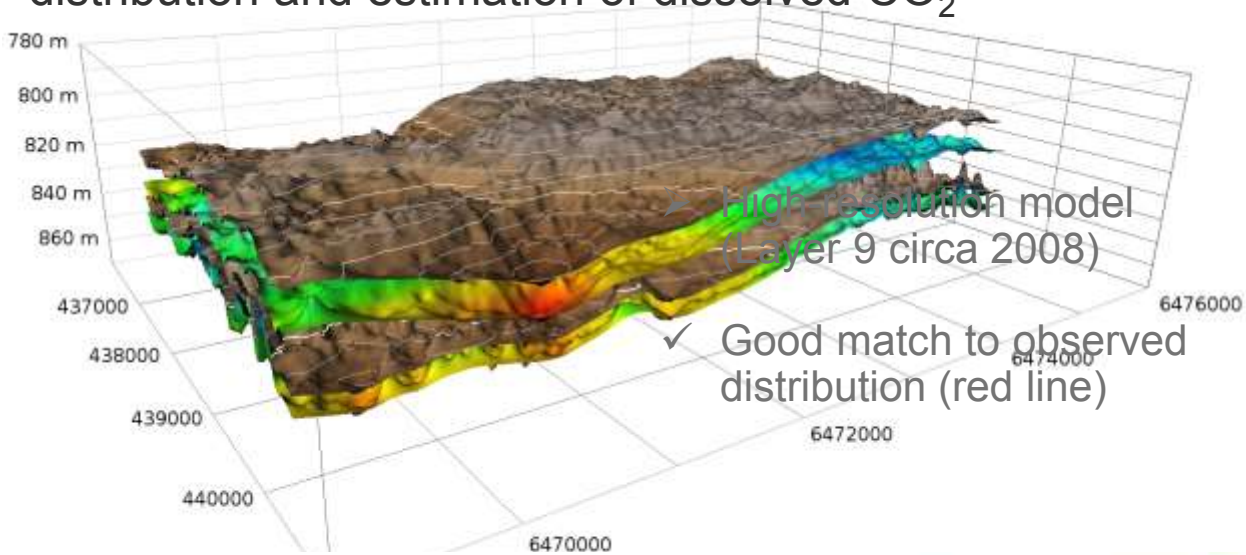
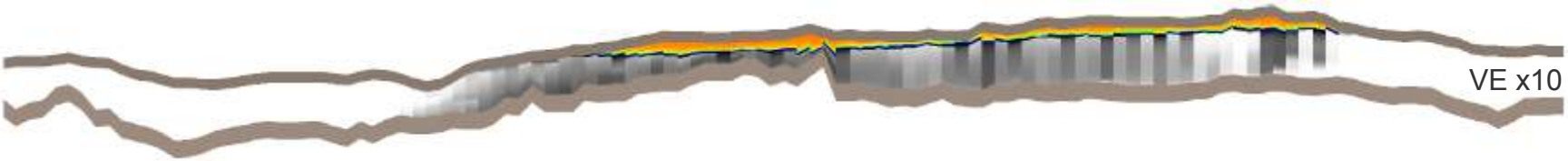
The Sleipner plume

- Seismic monitoring has allowed for significant improvements in understanding CO_2 flow dynamics
- An improved basis for predicting the future plume distribution and estimation of dissolved CO_2

Sleipner Benchmark (IEAGHG)



- High-resolution model (Layer 9 circa 2008)
- ✓ Good match to observed distribution (red line)



(Cavanagh, Energy Procedia 2013)

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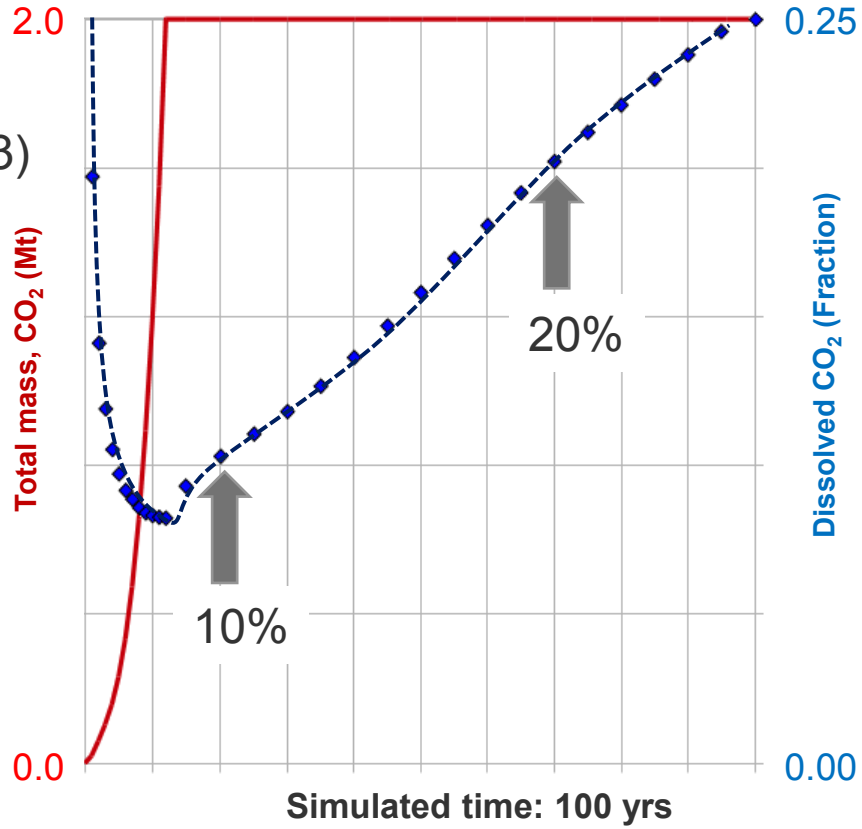
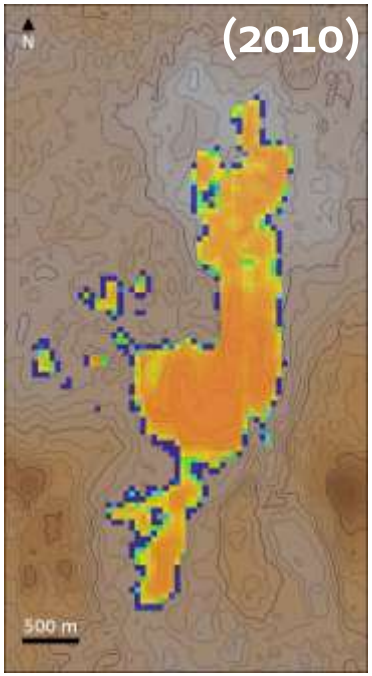
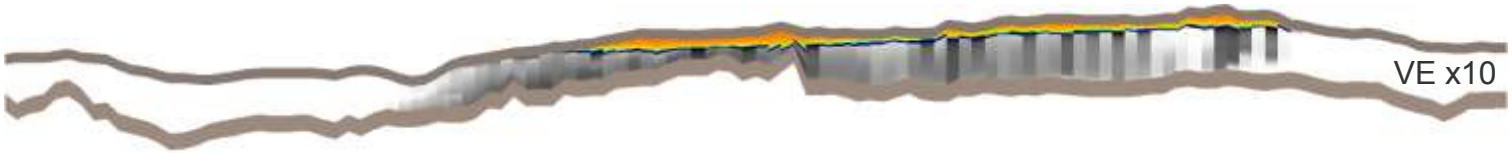
Dissolution estimate

Permedia CO_2 BOS (Cavanagh, EP, 2013)

Implementation after Hassanzadeh et al. (IJGGC, 2008)







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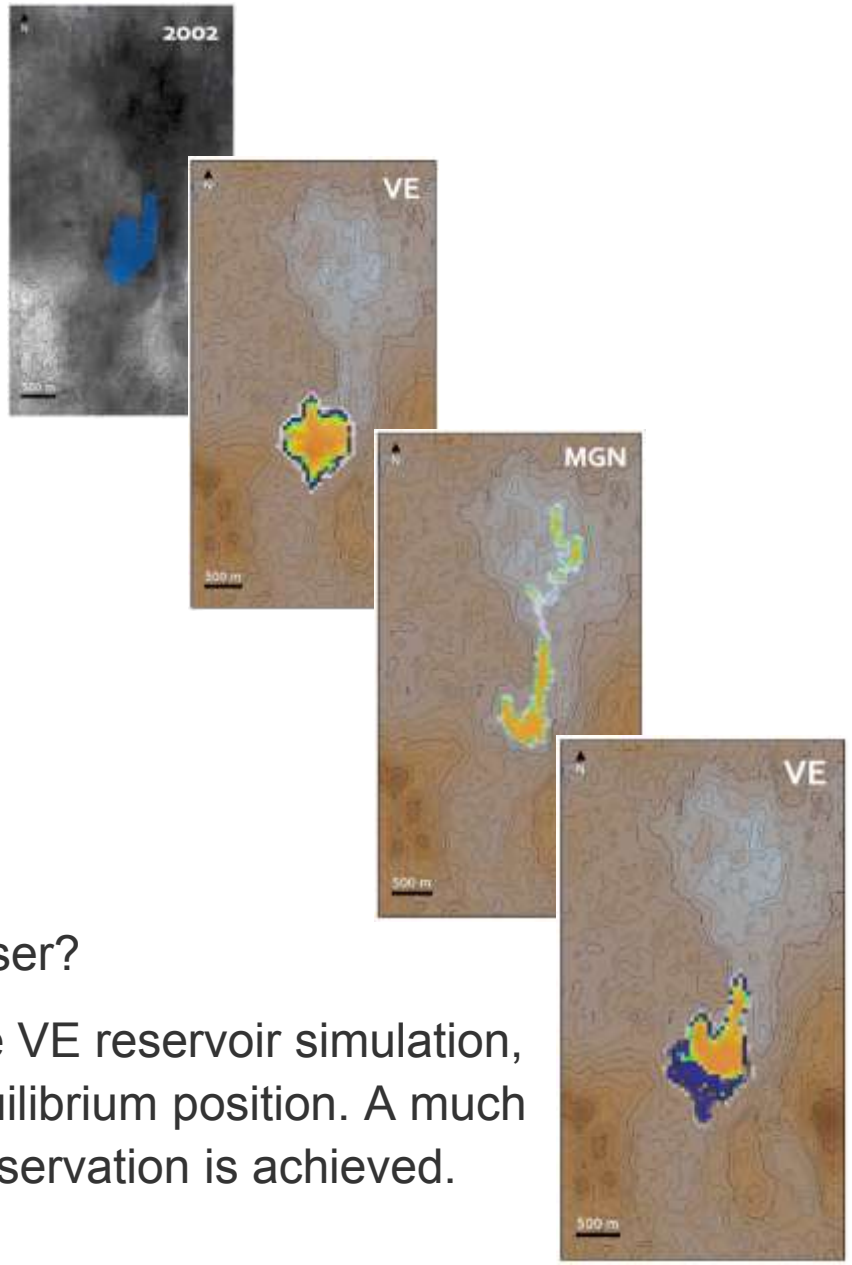
Plume calibration



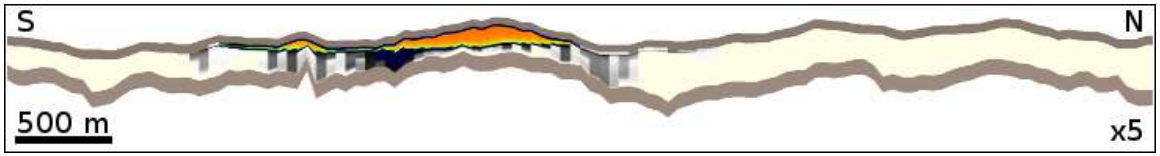
Flow modeling based on seismic

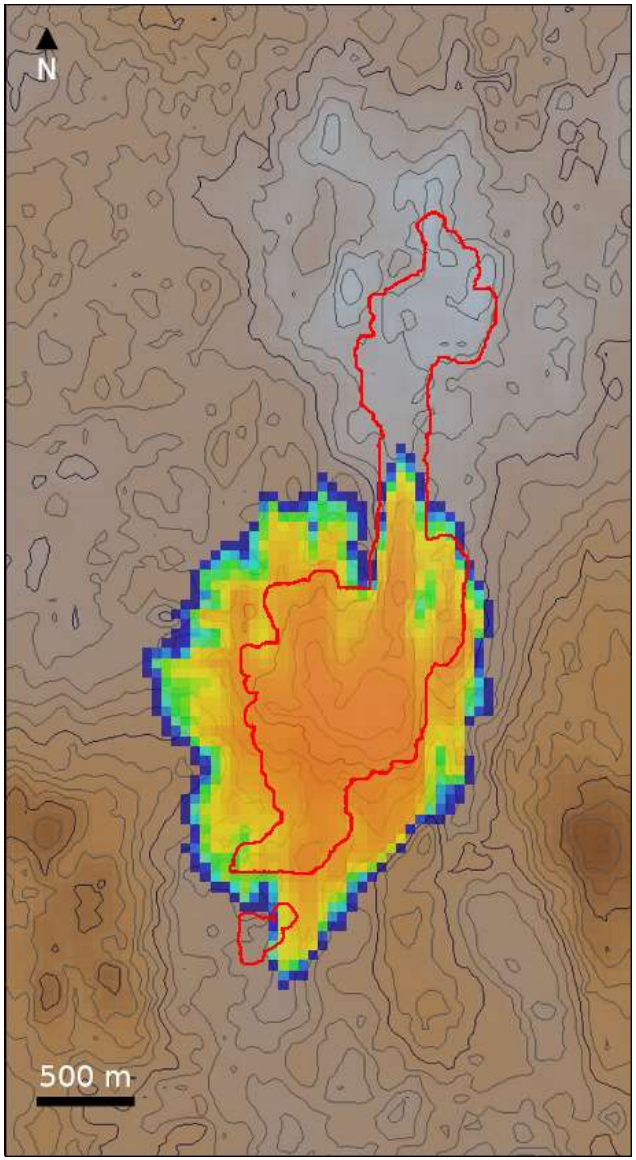
- Darcy flow approach:
  - Viscous forces, reservoir simulation
  - Vertical equilibrium assumption (VE)
  - Poor match, strong pressure artifact
- Percolating flow approach:
  - Capillary forces, basin modeling
  - Gravity assumption for migration (MGN)
  - Equally poor match, but is buoyancy closer?
- We then allow the pressure to dissipate in the VE reservoir simulation, and the plume redistributes to its buoyant equilibrium position. A much better match to the footprint of the seismic observation is achieved.

Reservoir simulation

2-phase black oil model (CO_2 BOS)

- Calibrating for 2008 seismic footprint based on pressure equilibrium
- *Simulation time in years: 1 10 100*
- *Pressure field at the end of injection:*
  ~ 460 to 710 kPa (65-100 psi) overpressure
  ~ 250 kPa (35 psi) drop over 3 km





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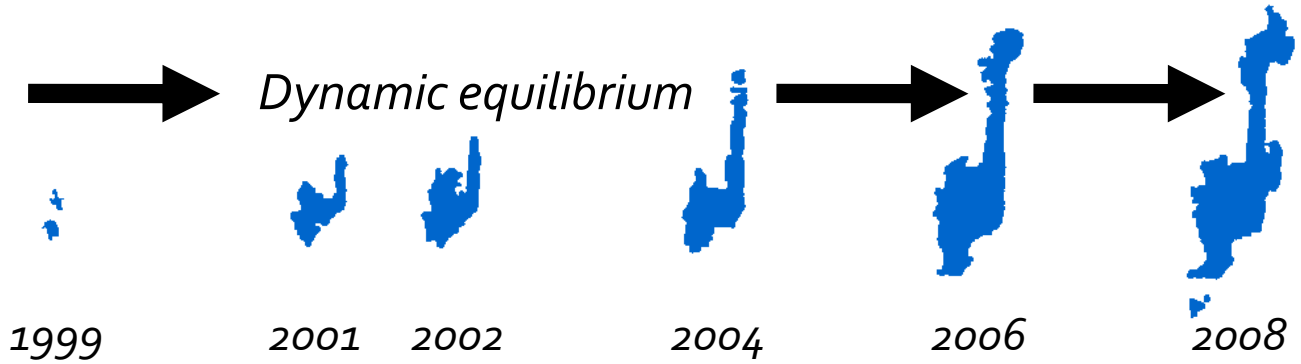
Conclusion



The simulation results clearly indicate that the plume beneath the caprock is gravity-dominated, and close to equilibrium at every observation point (Cavanagh, Energy Procedia, 2013)

Reservoir simulations for CO_2 storage may be susceptible to significant pressure artifacts that distort the model outcome.

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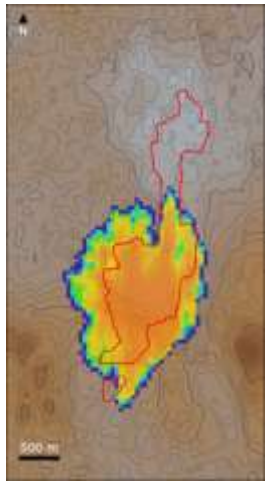
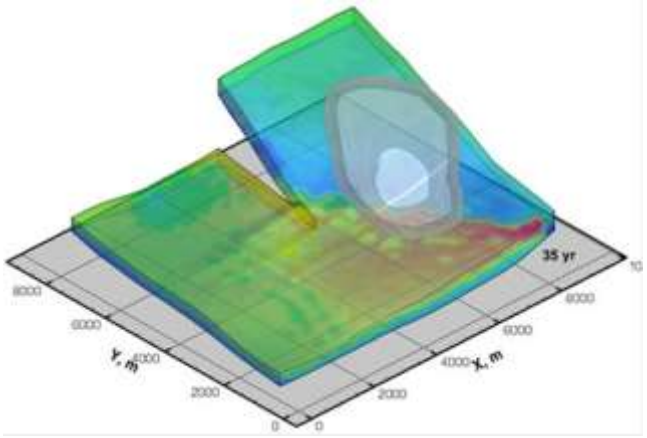
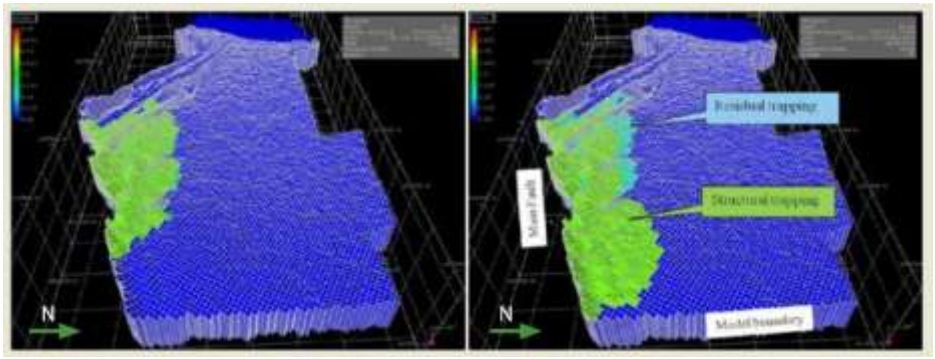
Implication







Without calibration and correction, reservoir simulations are highly likely to be misleading with respect to CO_2 storage.

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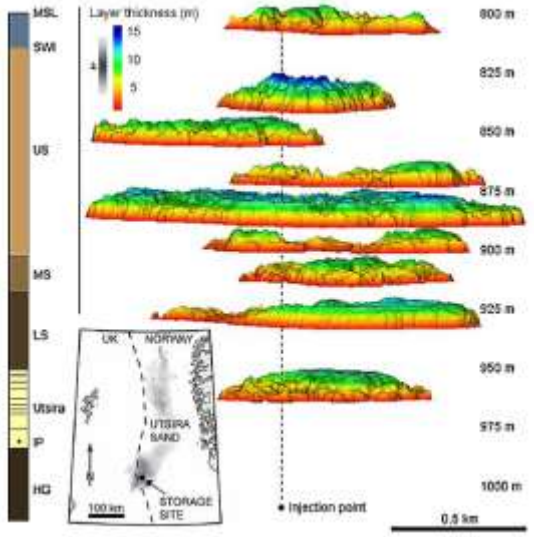
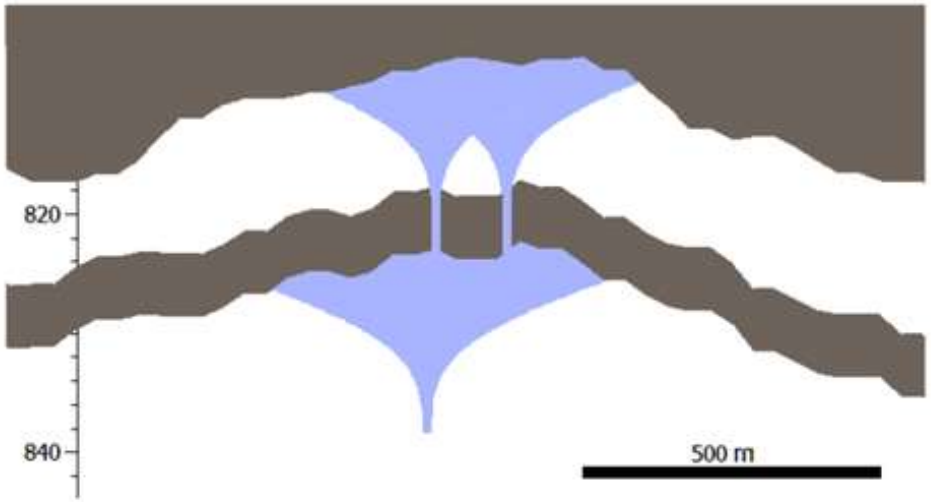
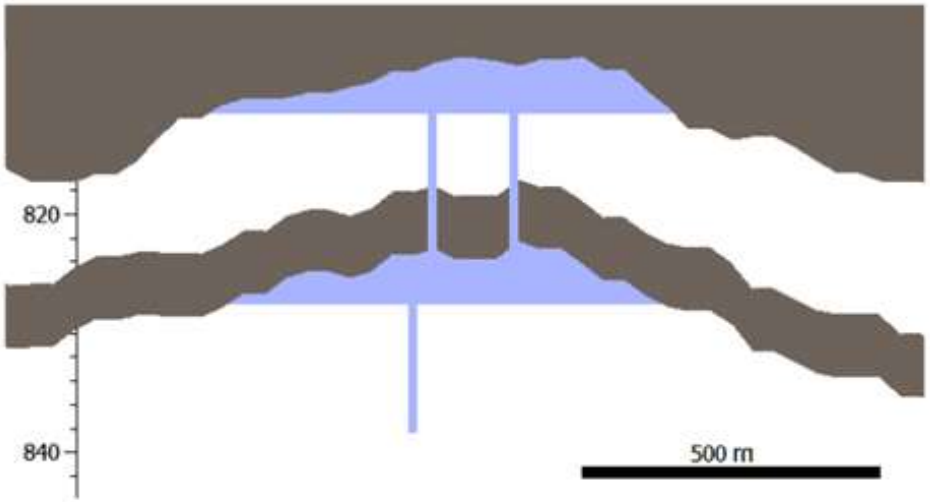
Sleipner Benchmark II

- Area of Interest: 3x6 km
- Cell resolution: 50x50x0.5 m
- Geocellular mesh: 550,000 cells



(Cavanagh & Haszeldine, IJGGC, 2014)





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There's never been a better time for good ideas

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