GEOSTOR: Geology and Modelling

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Assessment of static and dynamic CO_2-storage capacity in geological formations below the German North Sea

Questions to be addressed are:

- Where can CO_2 be stored ?
- How much and how quickly can CO_2 be stored ?
- How big will such a storage site be ?

Methods to be used are:

- Geological modelling
- Dynamic process simulation
- Scenario analysis

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C A U Christian-Albrechts-Universität zu Kiel

Sebastian Bauer
Institut für Geowissenschaften
CAU Kiel

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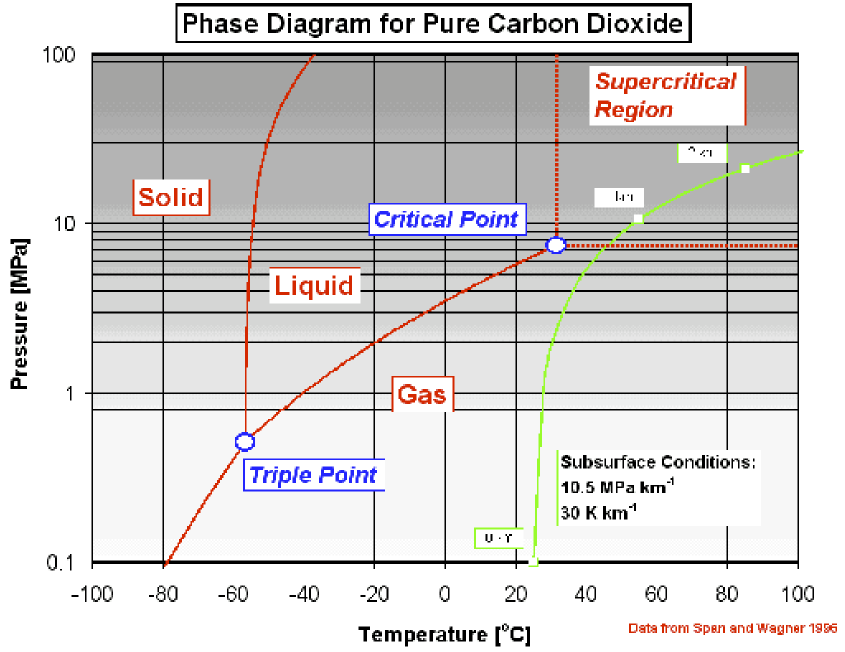
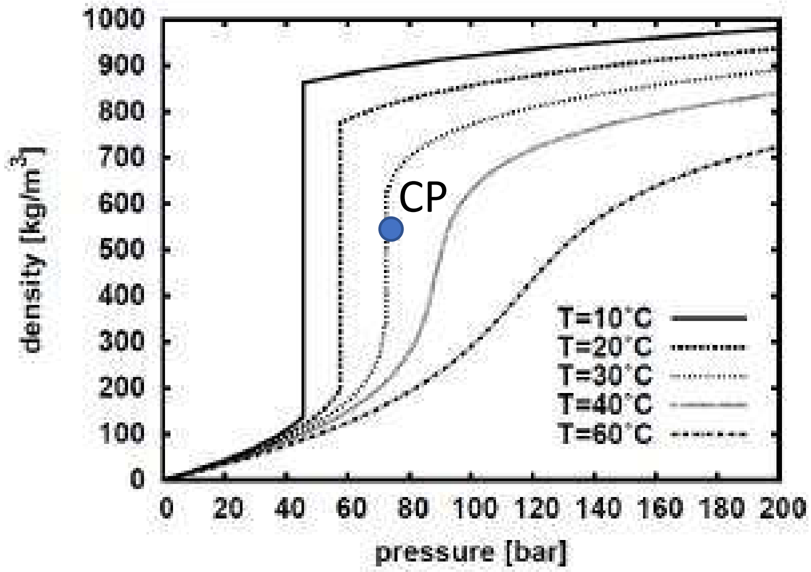
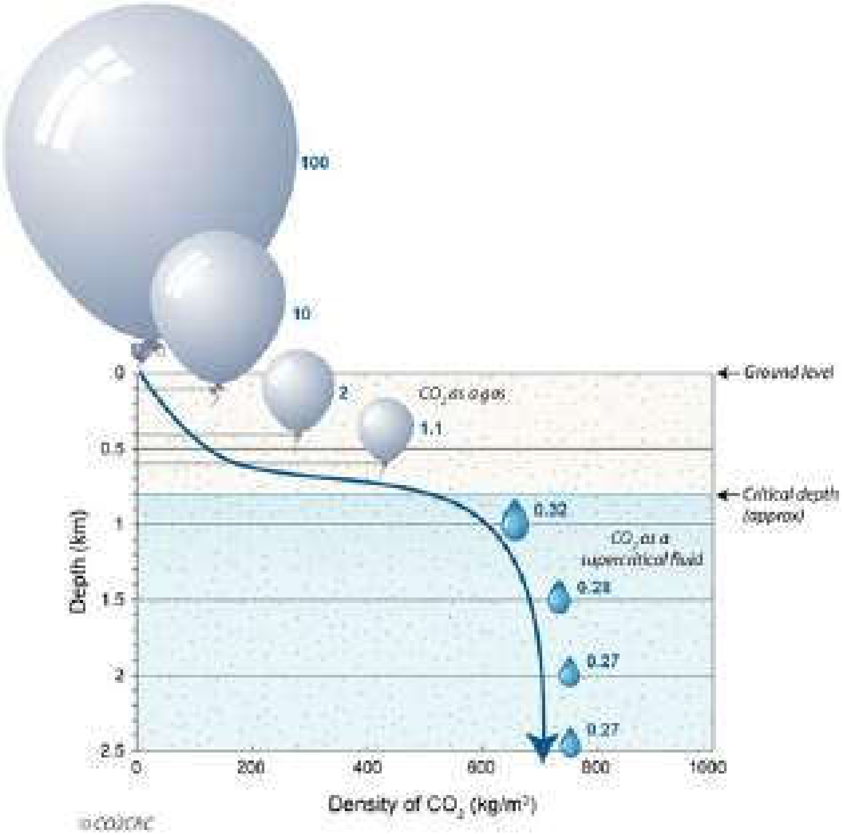
Properties of CO_2







CO_2 Critical Point @ 73.8 bar and 30.95 °C

Suitable storage conditions: below ~ 800 m depth

Density CO_2 < density of formation water, i.e. CO_2 is buoyant -> barrier required

IPCC 2005,Span and Wagner 1996, CO2CRC Bielinski 2007

Sebastian Bauer
Institut für Geowissenschaften
CAU Kiel

Geological storage formations

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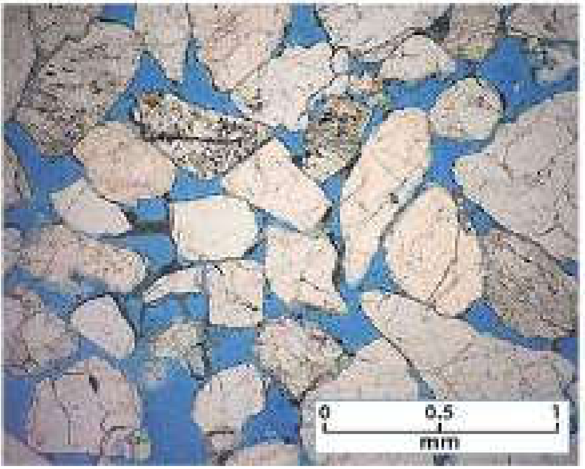
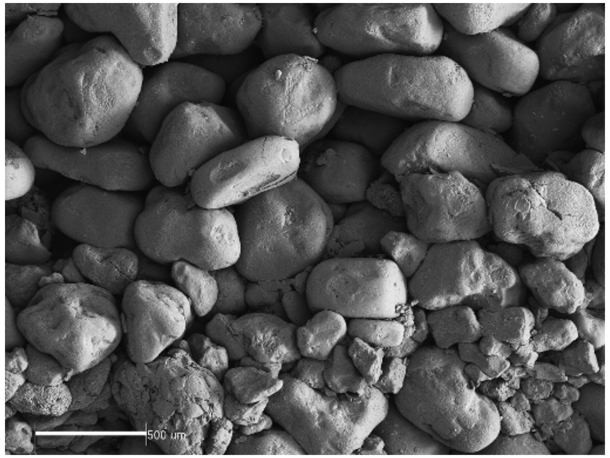
Claystone
→ barrier rock (seal)

Sandstone
→ reservoir rock





1 mm

IZ Klima, 2009; CO2CRC, 2009
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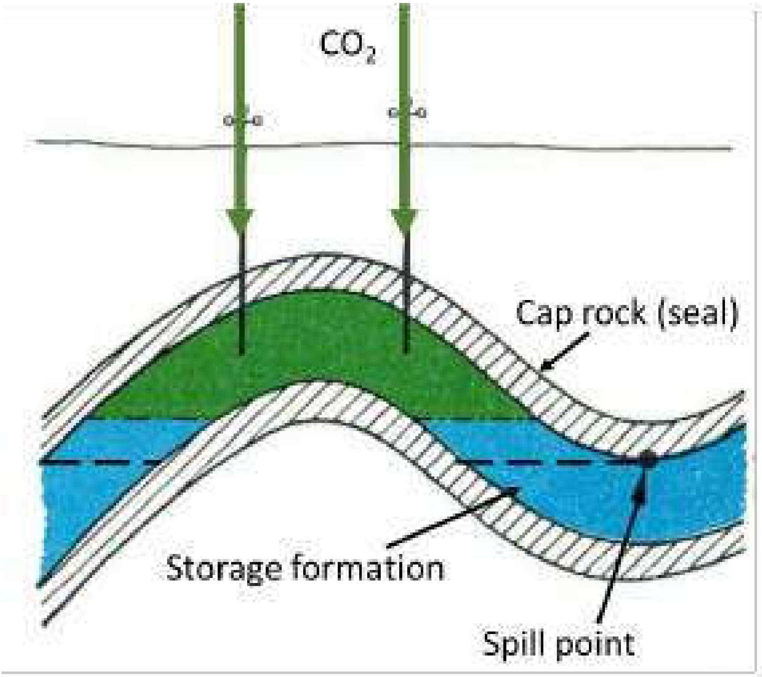
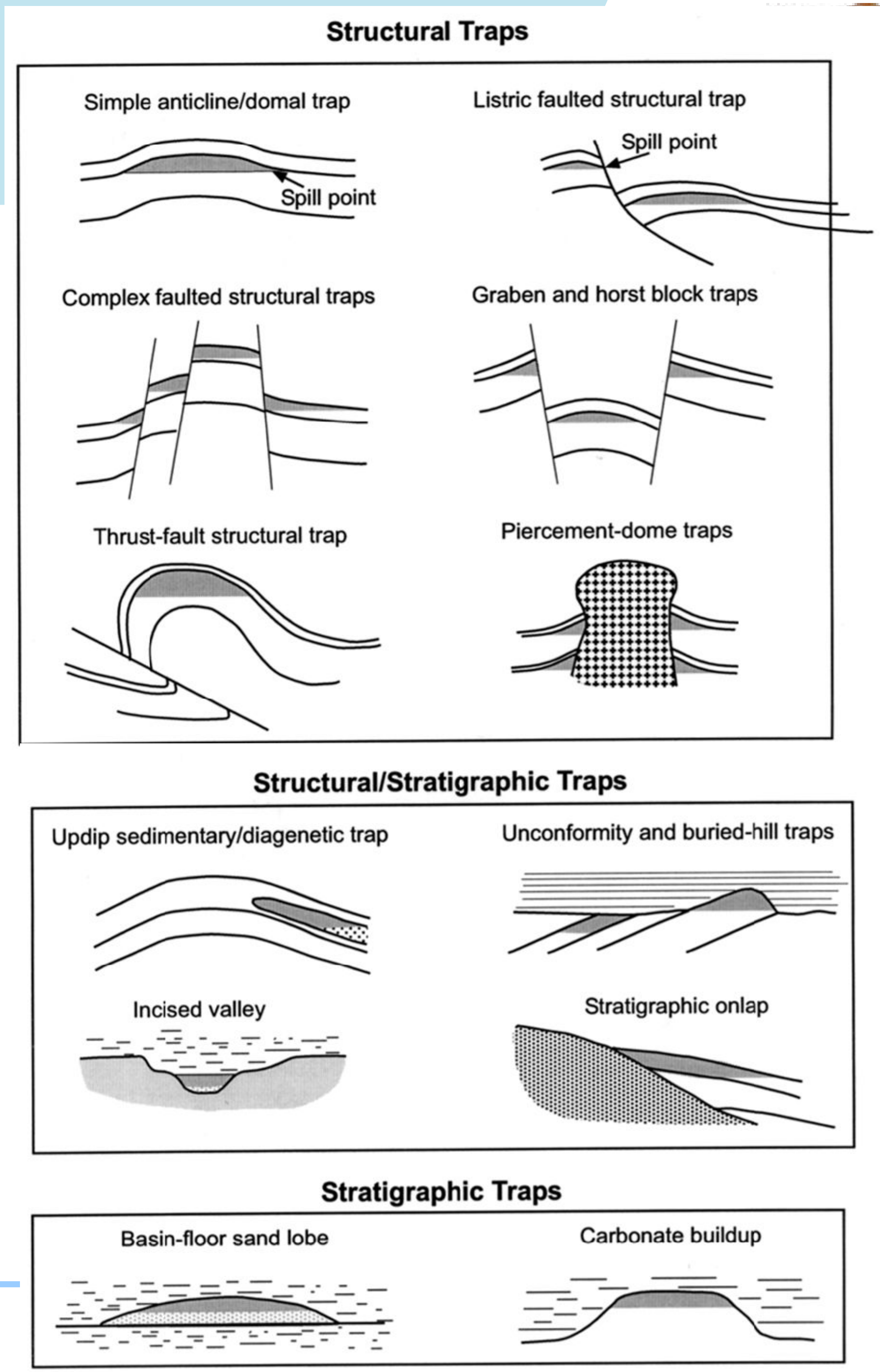
Geological traps



Storage volume in trap V_{trap} determined by formation geometry and spill point depth.

Estimation of static storage potential:

$$M_{CO2} = \rho_{CO2}(P_{res}, T_{res})\, V_{trap}\, n\, \varepsilon_{efficiency}$$



Holloway et al. 1996

Geological modelling

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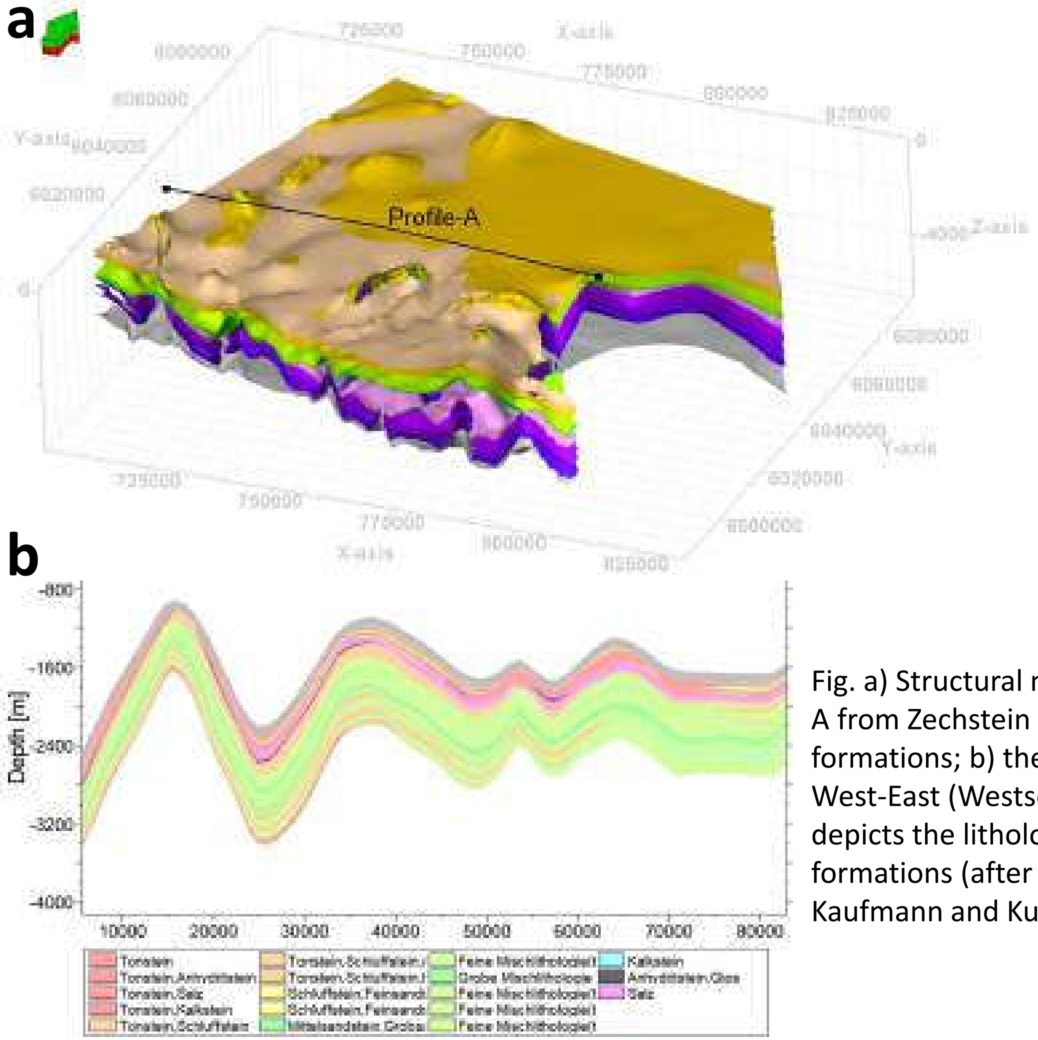

Fig. a) Structural model of study area A from Zechstein till Tertiary formations; b) the profile-A from West-East (Westschleswig block) depicts the lithology units of Triassic formations (after Wolf et al. 2014, Kaufmann and Kuhlmann 2014)

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Task: Estimation of static storage potential

- Interpretation of new seismic data (2D/3D)
- Constructing static geological models
- Representation of geometric details
- Identification of potential storage structures
- Lithofacies modelling for petrophysical parameters, especially porosity
- Mapping of storage structures
- Identification of two representative storage sites

Sebastian Bauer
Institut für Geowissenschaften
CAU Kiel

Dynamic storage capacity

The static CO_2 storage capacity is an overestimation of the realistically achievable capacity.

Dynamic processes to be considered are:
- Limitations due to injection scheme (pressure limitations to prevent fracturing the rock)
- Dynamic effects during injection like gravity override and displacement efficiency, viscous fingering and gravitational instabilities
- Pressure overlap when using multiple injectors
- Partial sweep in formation due to heterogeneity of petrophysical parameters
- temporal effects of trapping mechanisms

Considering these effects will reduce the achievable storage capacity potentially by orders of magnitude.
Numerical simulation of CO_2 injection and of it's long term effects can represent these effects and thus yield more realistic dynamic storage capacity estimates.

Numerical simulations

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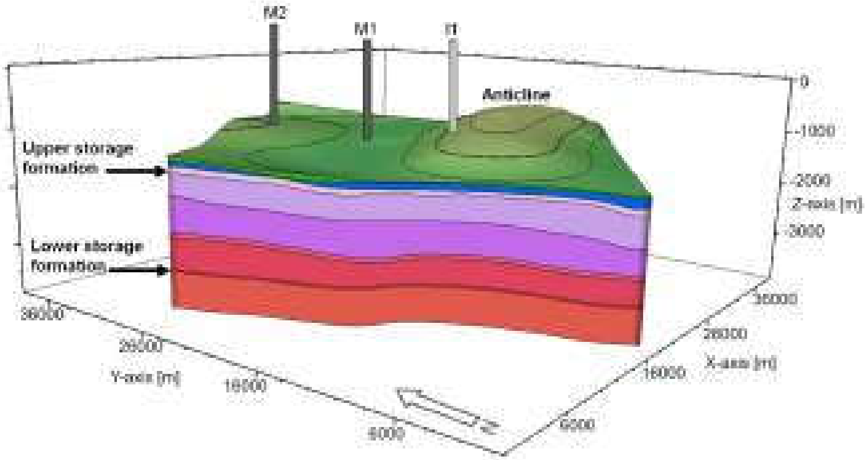
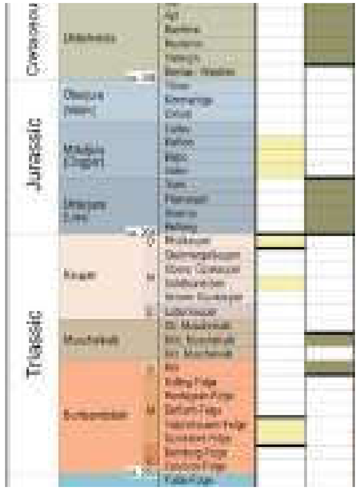
Task: Quantification of the dynamic storage capacity and long-term as well as large-scale effects

- Determination of dynamic storage capacity
- Identification of optimum injection schemes and strategies
- Prediction of large scale and long term pressure and CO_2-phase development both laterally as well as vertically
- Assessment of brine displacement risks
- Quantification of spatial requirements of an individual storage site
- Investigation of potential interferences with e.g. wind-parks or other subsurface uses

This can be achieved using numerical process simulations and will be investigated exemplarily for two representative sites

Numerical simulations

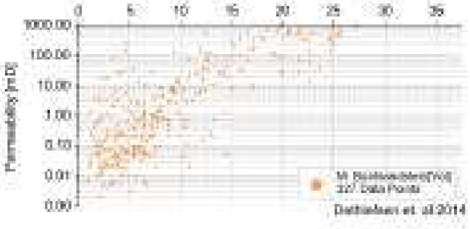


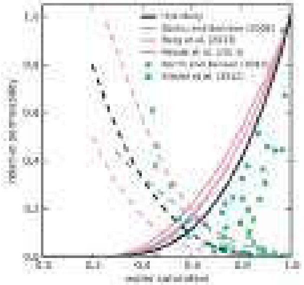


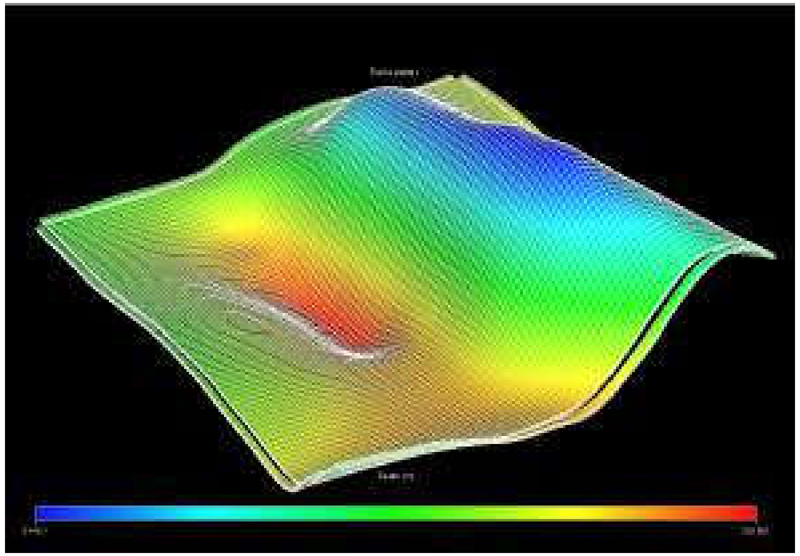
Numerical simulation of multi-phase flow

$$-n\frac{\partial(\rho_w S_n)}{\partial t} - \nabla\cdot\left(\rho_w \frac{k_{rw}k}{\mu_w}(\nabla p_w - \rho_w g)\right) - q_w\rho_w = 0$$

$$n\frac{\partial(\rho_n S_n)}{\partial t} - \nabla\cdot\left(\rho_n \frac{k_{rn}k}{\mu_n}(\nabla p_w + \nabla p_{cnw} - \rho_n g)\right) - q_n\rho_n = 0$$







- model area
- Injection and post injection time
- boundary conditions
- parameterization of rock and fluids
- CO_2 injection schemes

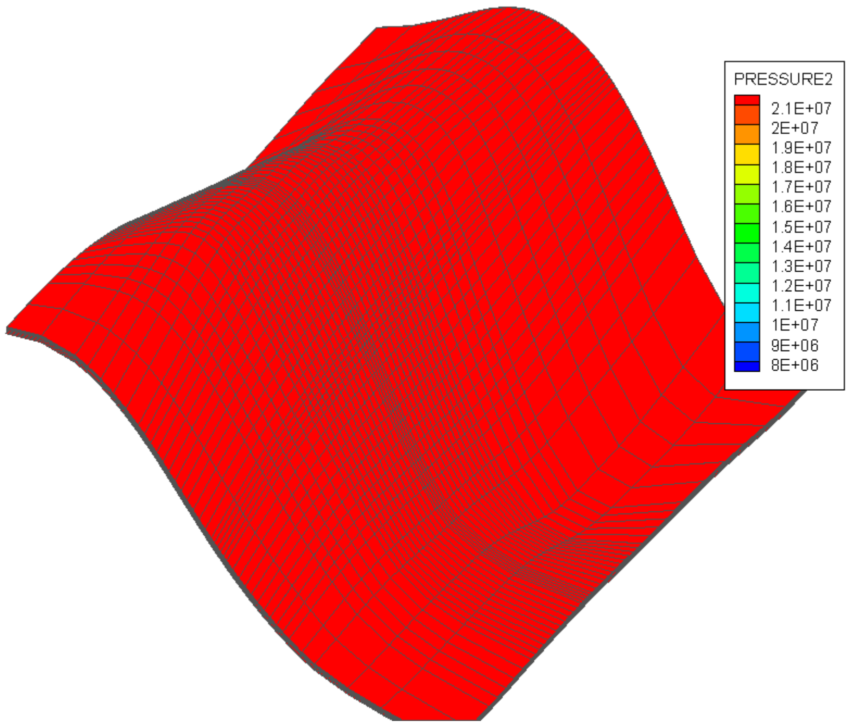
Benisch and Bauer (2013); Singh (2018); Dethlefsen et al. (2014)

Sebastian Bauer
Institut für Geowissenschaften
CAU Kiel

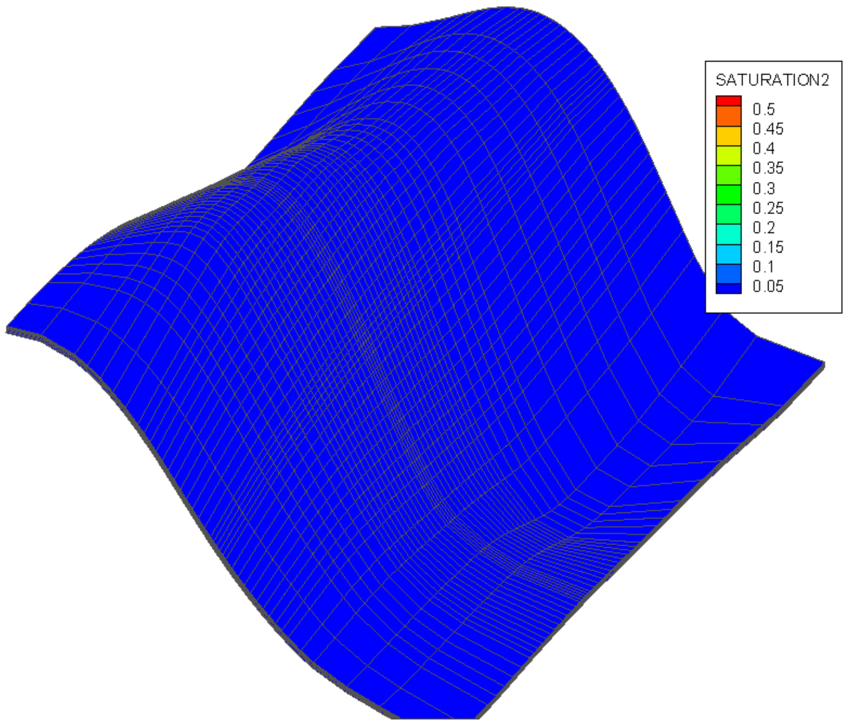
Synthetic example: Anticline trap

20 a injection, 80 a post-injection; 30 km by 30 km;

Formation pressure [Pa]



CO_2 saturation [-]



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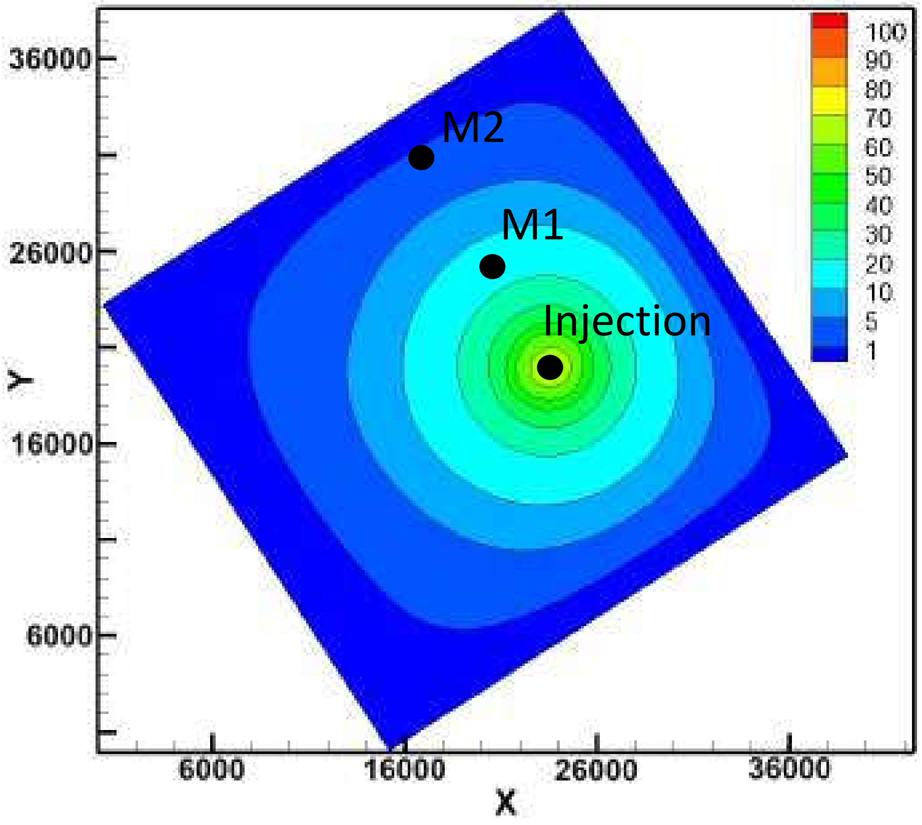
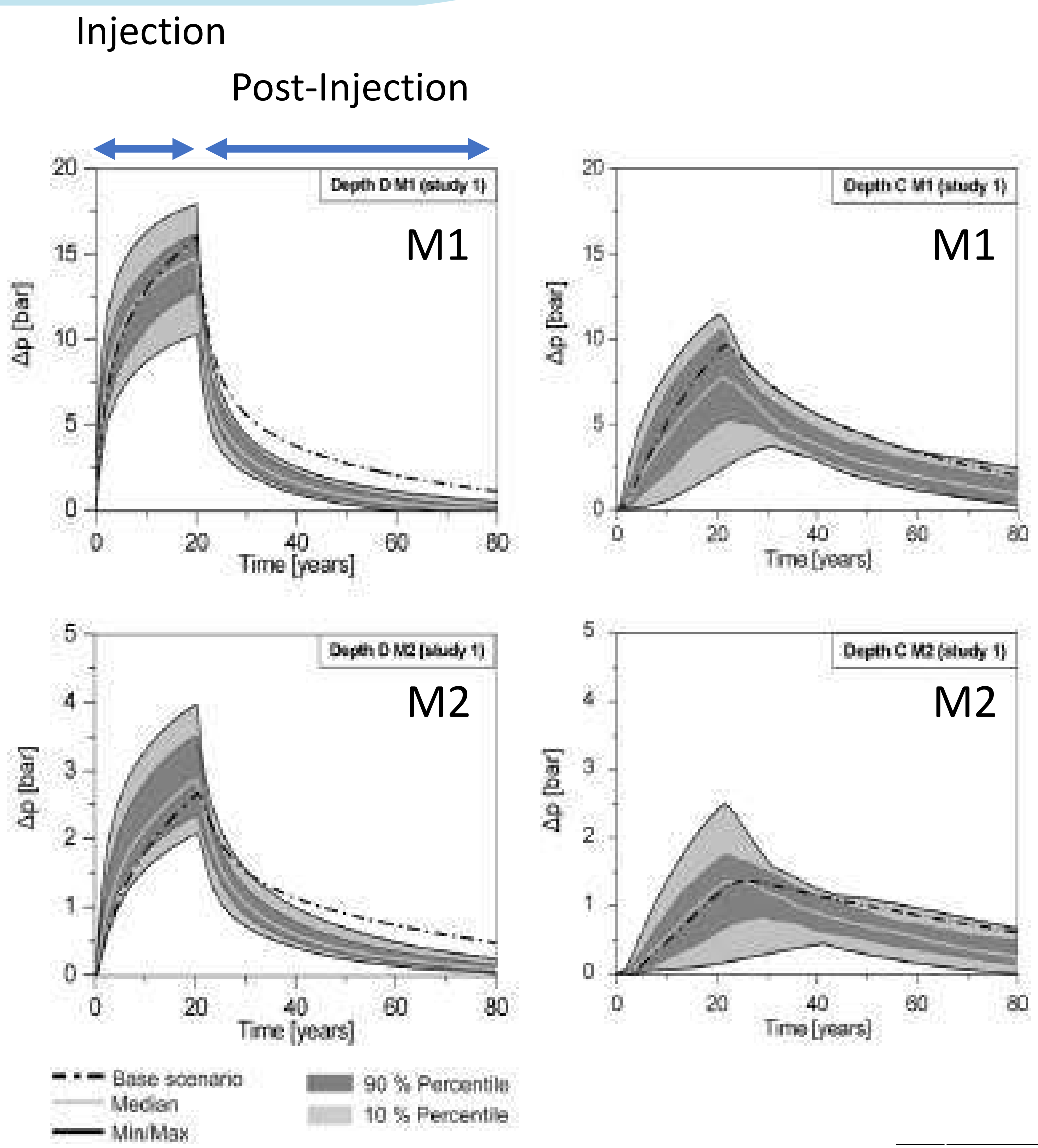
Institut für Geowissenschaften
CAU Kiel

Synthetic example: Far field and long term effects





Benisch and Bauer (2013)

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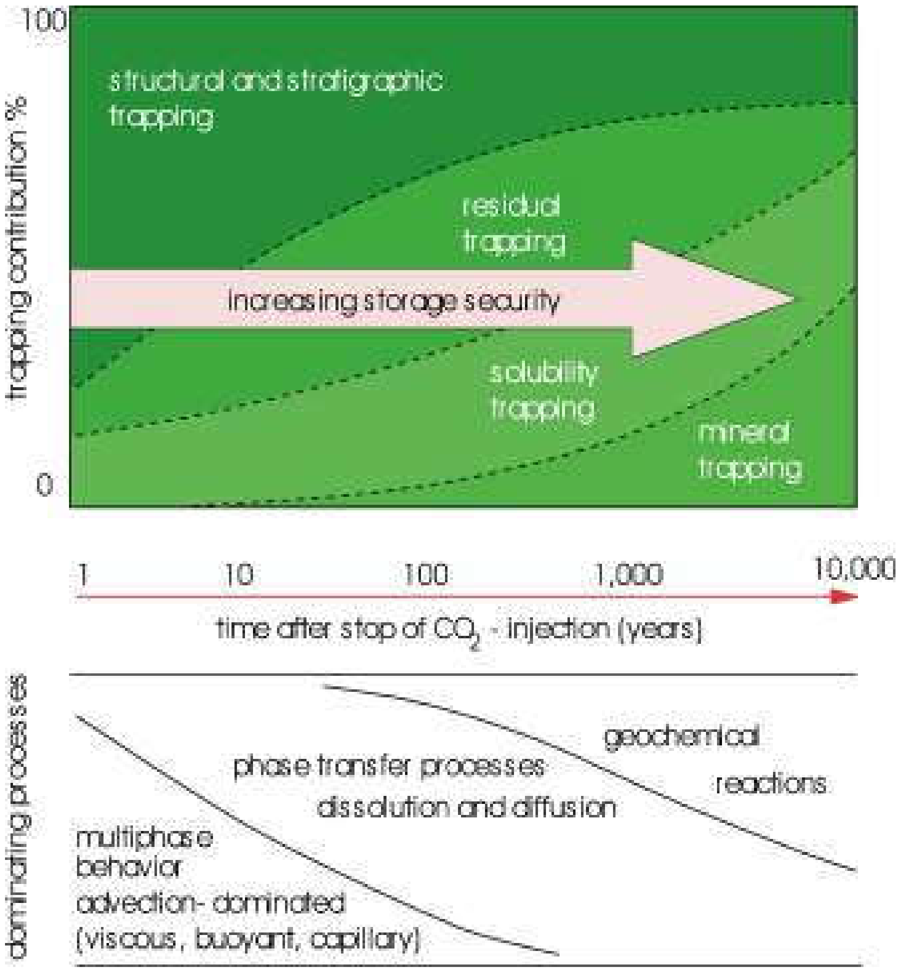
Trapping mechanisms



IPCC (2005); Class et al. (2007)

- structural and stratigraphic trapping:
  hydraulic barrier to CO_2 rise (trap)
- residual trapping:
  immobilization of residual CO_2 in storage formation
- solubility trapping:
  dissolution of CO_2 in formation brine
- mineral trapping:
  geochemical reactions with host rock and formation brine

⇒ Prediction of contribution of individual trapping mechanism to long term storage based on local setting and injection scheme

Sebastian Bauer
Institut für Geowissenschaften
CAU Kiel

Role in GEOSTOR project

This work packages provide:

- the geological setting (geometry and parameters)
- Static storage potential
- Dynamic storage capacity
- Long-term and far-field effects

Basis for other work in GEOSTOR

- Input to monitoring and risk assessment,
- induced geomechanical effects
- Subsurface planning
- Technology and costs