Caprock Systems for CO₂
Geological Storage in Deep Saline Formations

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## Capacity Estimates (Gt CO₂)

<table>
<thead>
<tr>
<th>Storage Type</th>
<th>Global (IPCC 2005)</th>
<th>Global (IEAGHG)</th>
<th>USA (Natcarb 2008)</th>
<th>Europe (Geocapacity Project)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSF</td>
<td>1,000 – 10,000</td>
<td>3,300 – 13,000</td>
<td>90 – 330</td>
<td></td>
</tr>
<tr>
<td>Depleted Gas</td>
<td>680 – 900</td>
<td>160</td>
<td>140</td>
<td>20 - 32</td>
</tr>
<tr>
<td>CO2-EOR</td>
<td>65</td>
<td></td>
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</tbody>
</table>
Recent IEAGHG Studies on Caprocks

• Pressurisation and Brine Displacement, Permedia, Canada
  • Literature review and modelling to assess pressure and brine displacement effects in DSF storage
  • Implications for capacity and injectivity

• Caprock Systems for Geological Storage of CO$_2$, CO2CRC, Australia
  • Literature review to assess current state of knowledge
  • Identification of knowledge gaps and R&D priorities
Seal Potential

• Overall seal potential is a function of capacity, geometry and integrity of a caprock.
• Capacity refers to maximum CO$_2$ column height that can be retained.
• Geometry refers to the thickness and lateral extent of the caprock.
• Integrity refers to geomechanical properties.
• CO2CRC present a qualitative assessment methodology for basin-level screening.
Seal Capacity

- Controlling factors:
  - Pore throat size
  - Interfacial tension (IFT)
  - Wettability

- Effects of wettability assumptions on capacity

- Wettability/IFT of water-scCO$_2$ systems is a knowledge gap
Seal Geometry

- Structural position, thickness and areal extent of caprocks
- Estimated by integrated studies of seismics, core data, well correlations and geological/depositional models
- Caprock thickness does not directly influence capillary entry pressure
Seal Integrity

• Influencing factors:
  • Lithology
  • Pre-existing planes of weakness
  • Regional stress
  • Induced stress
• Compressible/ductile strata less likely to develop permeability
• Determine via strength tests on samples
Geomechanics

- Bulk permeability of caprocks may be controlled by fractures and faults
- Factors affecting fluid flow properties:
  - Absolute and relative permeabilities
  - P, T conditions
  - Inter-connection of fractures
- Knowledge gap: how/where/why fractures affect caprock integrity
Hydrodynamics

- Differential excess pressures above and below caprock can affect sealing capacity
- Over-pressured aquifers above caprock may control seal capacity
- Over-pressures either side of faults control seal capacity
- Idealised scenarios described – note effects of heterogeneity
Closed versus Open Systems

- Open systems: regional lateral brine flux, transient pressurisation
- Closed systems: brine flux within storage compartment, rapid loss of injectivity
- Semi-closed systems: more realistic?
Model Boundary Conditions

- Realistic assumptions vital
- Regional shale permeability uncertain
- Literature review compilation of shale permeability
  - CO₂ storage and petroleum systems studies: microdarcy (E-18 m²) to sub-nanodarcy (E-22 m²)
  - North Sea field evidence: microdarcy range (E-18 to E-19 m²)
- Permedia then considered empirical relationships between depth, porosity, permeability and caprock threshold pressure
Shale Porosity-Permeability Transform
(Young and Aplin 2009)
Empirical Relationships affecting Regional Shale Permeability

- CO2 Storage Window
- Upscaled Shale Permeability
- North Sea Caprock Calibration

Depth [m]
Porosity [%]
Absolute Permeability [mD]
Threshold Pressure, hg-air [kPa]
Geochemistry

- Geochemical effects can theoretically increase or decrease caprock permeability
- Long timescale predictions difficult – reaction kinetics
- Heterogeneity
- Buffering capacity of caprock minerals
- Report presents case studies of different lithologies
Conclusions

• Assessment of caprock systems highly site-specific
• Seal potential is a function of capacity, geometry and integrity
• Key knowledge gaps identified include:
  • Wettability and IFT for water-rock-scCO₂ systems
  • Hydrodynamic effects on caprocks during large scale storage
  • Role of faults in caprock systems
  • Caprocks database
• Characterisation of regional shale properties is problematic (e.g. scale effects from lab tests)
• Shale caprocks with microdarcy permeability will allow brine migration to alleviate pressurisation
• Closed system assumption only valid for small pressure compartments with very low permeability shale boundaries
Thanks for your attention

IEAGHG Modelling Network

http://www.ieaghg.org