The purpose of this investigation is to improve our understanding of the gas-trapping mechanism, like residual trapping and dissolution-diffusion trapping during forced displacement experiments with CO₂ and water. Towards this goal, experiments were conducted in a micromodel whose homogenous pore space is geometrically and topologically similar to Berea sandstone. High-resolution, micro-visual data, in the form of photographs and video footage, describes the trapping mechanism and especially the disconnection and shrinkage of the CO₂ phase. Results gained from these experiments should help us to understand and to improve storage security and capacity by using WAG injection or storage sites with groundwater flow. In addition storage, sites that have no or insufficient cap rock integrity can be taken into account as possible sinks when dissolution and residual trapping mechanisms provide for prevention of CO₂ migrating to the surface.

### Trapping Mechanism

- **Primary Trapping**
  - Structural/Stratigraphical Trapping
  - Beneath seals of low permeable rocks
- **Secondary Trapping**
  - Residual Trapping
  - Solubility Trapping
  - Mineral Trapping

### Residual Trapping

- **Land Model**
  \[ S'_g(S'_g) = \frac{S'_g - S'_g}{1 + \phi S'_g} \]
- **Carlson Model**
  \[ S_p = S_{p,\text{abs}} - S_g \]

### Dissolution-Diffusion

- Phase equilibrium process
  \[ f_{g,aq} = f_{aq} \]
  \[ f_{aq} \text{ calculate by EOS} \]
- Depends on
  - CO₂ volume
  - Contact area of brine
  - Contact time
  - Mass transfer rate

### Experimental Work

**Setup**

- Water/CO₂
- Micromodel
- Camera/Microscope
- Backpressure Regulator
- Confining Pressure

**Parameters**

<table>
<thead>
<tr>
<th>Test</th>
<th>Pressure (psi)</th>
<th>Confining (psi)</th>
<th>Temperature (°C)</th>
<th>CO₂ Phase</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>11</td>
<td>3</td>
<td>29.8</td>
<td>gas</td>
<td>liquid</td>
</tr>
<tr>
<td>#2</td>
<td>30</td>
<td>2</td>
<td>29.8</td>
<td>gas</td>
<td>liquid</td>
</tr>
<tr>
<td>#3</td>
<td>40</td>
<td>2</td>
<td>29.8</td>
<td>gas</td>
<td>liquid</td>
</tr>
<tr>
<td>#4</td>
<td>40</td>
<td>4</td>
<td>29.8</td>
<td>gas</td>
<td>liquid</td>
</tr>
<tr>
<td>#5</td>
<td>40</td>
<td>6</td>
<td>29.8</td>
<td>gas</td>
<td>liquid</td>
</tr>
<tr>
<td>#6</td>
<td>40</td>
<td>8</td>
<td>29.8</td>
<td>gas</td>
<td>liquid</td>
</tr>
<tr>
<td>#7</td>
<td>40</td>
<td>10</td>
<td>29.8</td>
<td>gas</td>
<td>liquid</td>
</tr>
<tr>
<td>#8</td>
<td>40</td>
<td>10</td>
<td>31.0</td>
<td>gas</td>
<td>liquid</td>
</tr>
<tr>
<td>#9</td>
<td>40</td>
<td>10</td>
<td>36.0</td>
<td>gas</td>
<td>liquid</td>
</tr>
<tr>
<td>#10</td>
<td>40</td>
<td>10</td>
<td>40.0</td>
<td>gas</td>
<td>liquid</td>
</tr>
</tbody>
</table>

**Conclusion**

- Instantaneous behavior at the beginning
  - Continuous gas is separated at random locations
- Heterogeneous shrinkage behavior at the end for low pressure (11 psi)
  - Bubbles are stuck to pore wall roughness or crevices and shrink to nucleus size
- Mixed shrinkage behavior at the end for high pressure (490 and 920 psi)
  - Bubbles either are stuck to pore wall roughness and crevices shrink to nucleus size or they extinguish in the middle of the pore
- At capillary numbers in the range of \(10^2\) to \(10^4\) and bigger no residual gas phase was observed
- At capillary numbers smaller than \(10^4\) residual significant residual gas phase could be observed

**Experimental Results**

- Dissolution @ 0.001 ml/min
  - Snap off @ 0.001 ml/min at pore scale
  - Dissolution @ 0.001 ml/min at pore scale

---

**Micromodel**

- Sandstone image and micromodel representation
  - SEM image of a thin section representation of the image
  - Etched pore network with an etching depth of 25 µm
  - Repeating micromodel unit

**Micromodel Characteristics**

- Wettability – strongly water wet
- H₂O saturated
- CO₂+H₂O saturated
- UV light: cyan = water saturation
- In-outlet ports
- Silicon Wafer
  - Etched pattern = 5 cm x 5 cm
  - 500 000 pores
- Fracture

---

**Contact**

- Markus Buchgraber, Anthony R. Kovscek
- Department of Energy Resources Engineering, Stanford University

---

**Tuesday, September 28, 2010 • Wednesday, September 29, 2010**