CO₂ Storage in Texas Gulf Coast: Insights and Challenges

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Outline

• Motivation
• Oil and Gas Fields in Texas Gulf Coast
• Texas Gulf Coast Geology
• Insights for storing CO$_2$
• Opportunities and Challenges for CCS in Texas Gulf Coast
Motivation

- US Gulf Coast has large concentration of CO₂ sources
- Large cheaper to capture CO₂ sources (e.g. Ethanol, Natural Gas, AGRU in LNG)
- Infrastructure, skills, familiarity with subsurface activities

US Stationary Sources of CO₂ Emissions by Type (DOE Atlas V 2015)
Oil and Gas Fields in Gulf of Mexico

In Texas and Louisiana shallow waters, large number of O&G fields are < 10 MOEB
Reservoir-Seal Systems in Texas Gulf Coast

Two primary reservoir-seal systems: Frio sands and Anahuac seal & Miocene sand and Amph. B seal

Gulf Coast Section Along Strike. Miocene Sands

- Relatively thick interval (up to 2 km) of sand/shale pairs of normally pressured reservoirs
- Regional flooding surfaces that can be associated lithologically as sealing intervals (e.g., Amph B, etc.)
- Top of overpressure in the NE TX Gulf Coast shelf lies between 2500-3400 m subsea.

Fault systems associated with salt mobilization may form independent closures.

Salt diapers are common.

Depth of overpressure can be related to the general lack of sand observed in wells between the Marginulina A and Anahuac MFS surfaces.

Gulf Coast Sands Thickness and Permeability Compared

Favorable permeability and thickness in US Gulf Coast sands compared to on-going CCS projects worldwide
Frio and other consolidated sands have pore volume compressibility of about 2 - 5 microsips in the range of stresses that are of interest to CCS projects in TX/LA Gulf Coast.
Limits on Use of Sand Thickness for CCS

- Bulk compressibility of rock ~1 μsips (pore compressibility 5 μsips)
- Assume pressure increase 400 psi (~2.8 MPa) due to CO₂ injection

<table>
<thead>
<tr>
<th>Total Thickness, ft</th>
<th>Sand Thickness, ft</th>
<th>Reservoir uplift, ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>250</td>
<td>0.1</td>
</tr>
<tr>
<td>1000</td>
<td>500</td>
<td>0.2</td>
</tr>
<tr>
<td>1500</td>
<td>750</td>
<td>0.3</td>
</tr>
<tr>
<td>2000</td>
<td>1000</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Drive Mechanisms Vary in TX/LA Onshore/Shallow Water Fields

- Majority of onshore/shallow water O&G reservoirs have aquifer support
- Older depleted reservoirs in these shallow waters are likely to be at hydrostatic pressure


Source: SPE 77640. Friendswood Field – A case study in reservoir management

Stress Changes due to Depletion and Injection

Stiff Rocks

Dashed Lines: Soft Rocks

Summary of Uniaxial Laboratory Tests

\[
\frac{dSh}{dP} = \frac{1 - 2v}{1 - v}
\]

\[
\frac{dSh}{dP} = \frac{2}{3} \quad \text{for} \ v = 0.25
\]

\[
\frac{dSh}{dP} = \frac{1}{3} \quad \text{for} \ v = 0.4
\]


<table>
<thead>
<tr>
<th>Region</th>
<th>(\frac{d\sigma_{y}}{dP})</th>
<th>(\frac{dSh}{dP})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vicksburg Formation</td>
<td>0.53</td>
<td>0.32</td>
</tr>
<tr>
<td>Ekofisk Field</td>
<td>0.80</td>
<td>0.17</td>
</tr>
<tr>
<td>Waskom Field</td>
<td>0.46</td>
<td>0.35</td>
</tr>
<tr>
<td>Waskom Field</td>
<td>0.57</td>
<td>0.30</td>
</tr>
<tr>
<td>Magnus Field</td>
<td>0.68</td>
<td>0.24</td>
</tr>
<tr>
<td>West Sole Field</td>
<td>1.18</td>
<td>-</td>
</tr>
<tr>
<td>Wytch Farm Field</td>
<td>0.65</td>
<td>0.26</td>
</tr>
<tr>
<td>Venture Field</td>
<td>0.56</td>
<td>0.30</td>
</tr>
<tr>
<td>Gulf Coast</td>
<td>0.46</td>
<td>0.35</td>
</tr>
<tr>
<td>Lake Maracaibo</td>
<td>0.56</td>
<td>0.3</td>
</tr>
<tr>
<td>Brunei</td>
<td>0.486</td>
<td>0.34</td>
</tr>
</tbody>
</table>
Stress Changes due to Depletion and “Injection” in O&G Fields

AB = Depletion (\(dSh/dP = 0.45\))
BC = Injection (\(dSh/dP = 0.6\))

- Injection leads to a geomechanically stable state
- Gulf Coast replenished depleted O&G fields are desired

AB = Depletion (\(dSh/dP = 0.45\))
BC = Injection (\(dSh/dP = 0.3\))

- Injection leads to a geomechanically unstable state
- Gulf Coast replenished depleted O&G fields are not desired
Challenges and Opportunities to Store CO$_2$ in Gulf Coast – I

- What is the injection path (BC)? What are the controls?
- Can we address this question using existing laboratory data or laboratory tests on representative sand samples
Challenges and Opportunities to Store CO$_2$ in Gulf Coast - II

How to maximize storage in stacked sand–shale sequences by minimizing rock deformation (legacy wells, fault reactivation)?

Challenges and Opportunities to Store CO₂ in Gulf Coast – III

When does the heterogeneity cross-over from favorable to unfavorable condition occurs? How can we quantify the contribution of heterogeneity and account for it in site selection?

Reservoir scale heterogeneity
At High Island 24L Field

Source: Cavanagh et. al. (2015)

Impact of heterogeneity on CO₂ plume at Sleipner

Source Ruiz (2019)
Questions?