Southeast Offshore Storage Resource Assessment (SOSRA)
Project Number: DE-FE0026086

Jack Pashin, Camelia Knapp, James Knapp | Oklahoma State University
Nino Ripepi | Virginia Tech
Patricia Berry | Southern States Energy Board

This material is based upon work supported by the U.S. Department of Energy National Energy Technology Laboratory. Cost share and research support are provided by the Project Partners and an Advisory Committee.

Addressing the Nation’s Energy Needs Through Technology Innovation: CCUS, Oil and Gas Integrated Review Meeting
Pittsburgh, PA
August 26-30, 2019
Presentation Outline

• Goals and Objectives
• Project Team
• Technical Status
• Accomplishments to Date
• Synergy Opportunities
• Summary
Project Overview: Goals and Objectives

• Assess storage capacity of offshore saline formations in the eastern Gulf of Mexico (DeSoto Canyon Salt Basin and West Florida Shelf) and the Atlantic shelf (Mid-Atlantic and South Atlantic (Florida to Virginia)).
• Assess technical risks associated with geologic storage and the implementation of storage technology.
• Develop geologic and reservoir models.
• Develop MVA Inventory and Characterization, Outreach and Risk Inventory.
Technical Status

- Geological characterization and assessment complete.
- MVA Inventory and Characterization, Outreach and Risk Inventory under development.
- Reservoirs models developed.
- Technology Transfer continuing.
- Data being uploaded to EDX.
- Project nearing completion.
Well data, Velocity Surveys
Well and log identification, EGOM

Velocity Surveys, EGOM
One-Way Travel Time (ms)

Depth of investigation

West FL
DCSB

Bathymetry
- 200
- 1000
- 2000
- 3000

Wells with Electric Logs
Wells without Electric Logs
SOSRA E GOM study boundary

0 50 100 200Km
0 50 100 200 Miles
Seismic-Well Ties, Mid Atlantic

Mullendore et al, 2019

Ties Between Esso 1 and Closest 2D Profile

Ties Between Esso 2 and Closest 2D Profile
Structural Model, Top Ferry Lake Anhydrite

Destin dome
Desoto Canyon diapir field
Viosca Knoll diapir
Shelf margin

Time (s)
Top Lower Cretaceous A

Pashin et al., 2016
West Florida Shelf Stratigraphic Cross-Section

Index Map

Charbonneau, 2018
**Geophysical Well Logs, EGOM**

**Well G02468, Desoto Canyon Salt Basin**

- **Paluxy Formation**
  - Major prospects in sandstone of Tuscaloosa Group and Paluxy Fm.

**Well G3912, West Florida Shelf**

- **Punta Gorda Anhydrite**
- **Topseal**
- **Reservoir**
  - Porosity locally >15%
  - Major prospects in porous dolomite associated with anhydrite intervals

Legend:
- Shale
- Sandstone
- Limestone
- Dolomite
- Anhydrite
Seismic Inversion

Acoustic impedance vs. porosity, Upper Cretaceous, South Atlantic

\[ y = -0.000030172 \times +44.904 \]
Correlation: 0.753325

Impedance display

Porosity model
Mapping, South Atlantic

Top Cretaceous structure

Seal thickness

Potential reservoir thickness
Rock Strength (Paluxy Formation, EGOM)

Unconfined compressive stress

Mohr failure analysis

Meng, 2019
Fault Slip and Dilation Tendency, EGOM

Slip tendency
\[ T_s = \frac{\tau}{\sigma_n} \]

Meng, 2019

Dilation tendency
\[ T_d = \frac{(\sigma_1 - \sigma_n)}{\sigma_1 - \sigma_3} \]
Static Volumetric Assessment, DeSoto Canyon Interest Area

\[ G_{CO_2} = A_t h_n \phi_{tot} \rho \varepsilon_{saline} \]

Where,
- \( A_t \) is the reservoir area
- \( h_n \) is net sandstone thickness
- \( \phi_{tot} \) is the total porosity
- \( \rho \) is the \( CO_2 \) density
- \( \varepsilon_{saline} \) is the \( CO_2 \) storage efficiency factor

**Paluxy sandstone**

- \( P_{50} = 17 \text{ Gt} \)
- \( E_{P10} = 7.4\% \)
- \( E_{P50} = 14.0\% \)
- \( E_{P90} = 24.0\% \)
- Porosity cutoff = 15%

**Lower Tuscaloosa sandstone**

- \( P_{50} = 10 \text{ Gt} \)
- \( P_{50} = 3.6 \text{ Gt} \)
Dynamic Volumetric Calculations, Mid Atlantic

<table>
<thead>
<tr>
<th>Facies</th>
<th>Porosity</th>
<th>Permeability $\text{IJ}$ (mD)</th>
<th>Permeability $K$ (mD)</th>
<th>Net-to-Gross</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>0.1-0.4</td>
<td>1-500</td>
<td>0.1-50</td>
<td>0.6-0.9</td>
</tr>
<tr>
<td>Shale</td>
<td>0.2-0.3</td>
<td>0.01-0.1</td>
<td>0.001-0.01</td>
<td>0.1-0.3</td>
</tr>
<tr>
<td>Carbonate</td>
<td>0.1-0.2</td>
<td>0.01-0.1</td>
<td>0.001-0.01</td>
<td>0.1-0.3</td>
</tr>
</tbody>
</table>

Mullendore et al, 2019
Accomplishments to Date

• Storage resource assessed at >1,800 Gt at P_{50}.
• Geologic characterization of reservoirs indicates abundant porosity (>20% in sandstone); net reservoir thickness >> 150 m.
• Seals thick (~100-400 m) and numerous; they have high geomechanical integrity, particularly in carbonates.
• Low slip and dilation tendency along faults.
• Nominal geologic risk; identified risks are manageable.
• MVA inventory being developed to identify applicable technologies.
Lessons Learned

- Large ranges of storage resource potential when comparing P10, 50, 90 values.
- Well control of reservoir properties is source of uncertainty outside areas of major oil and gas exploration; seismic inversion helps reduce uncertainty.
- Reservoir heterogeneity and other factors affecting development strategies not readily apparent without significant well control.
- Seismic data provide great control of interval thickness but do not record facies changes within most intervals.
- Recommendations for development limited by lack of offshore experience in storage and CO₂-enhanced recovery.
Synergy Opportunities

• Limitless opportunities for collaboration with complementary research groups.

• Continued assessment and modeling efforts can employ multidisciplinary teams, leading to development of heuristic decision systems.

• Work with governmental and corporate stakeholders to identify regulatory pathways and best technical approaches to demonstration and deployment.

• Field deployment of technology helps define applicability, limitations, and best practices.
Summary

- Large portfolio of potential sinks and seals in eastern SOSRA region.
- Main storage prospects in Cretaceous-Miocene section.
- Multiple sandstone formations prospective; abundant mudrock and carbonate seals, including chalk.
- Porosity of sandstone commonly > 20%.
- Widespread anhydrite seals; porous dolomite abundant on Sarasota Arch.
- Porosity of dolomite in places > 15%.
- $P_{50}$ storage resource assessed at > 1,800 Gt.
Appendix

- These slides will not be discussed during the presentation, but are mandatory
Benefit to the Program

- Support industry’s ability to predict offshore CO₂ storage capacity in geologic formations of the eastern Gulf of Mexico and Atlantic continental shelves to within ±30 percent.
- Develop Best Practice Manuals related to carbon storage in offshore reservoirs.
- This project is assessing the geologic CO₂ storage resource of offshore formations in the southeastern United States. Risks are being assessed in the study region, preliminary reservoir models are being developed, and best practice manuals are being prepared.
**Project Overview:**
**Goals and Objectives**

- Assess storage capacity of offshore saline formations in the eastern Gulf of Mexico (DeSoto Canyon Salt Basin and West Florida Shelf) and the Atlantic shelf (Mid-Atlantic and South Atlantic (Florida to Virginia)).
- Assess technical risks associated with geologic storage and the implementation of storage technology.
- Develop preliminary reservoir models.
- Develop Best Practices Manuals.
**Decision Making & Communications**

**Advisory Committee:** state geological surveys, universities, state oil and gas boards, oil and gas companies, and utilities

(no contract, no decision making authority)
GO/NO-GO DECISION POINT: The data collected and analyzed in Phase I is sufficient to perform a quality prospective storage resource assessment and the project should proceed to Phase II.

Note: Task 1.0, Project Management and Planning, extends throughout the entire program period.
Bibliography - Eastern Gulf of Mexico


Hills, D. J., Koster, J., and Pashin, J. C., 2018, Seismic reflection data interpretation to support project ECO\textsubscript{2}S, Kemper County, MS: American Association of Petroleum Geologists Annual Convention and Exposition Program, unpaginated CD-ROM.


Jingyao Meng, 2019, Geological and geomechanical characteristics of prospective CO\textsubscript{2} sinks and seals in the DeSoto Canyon Salt Basin, east-central Gulf of Mexico: Stillwater, Oklahoma State University, Doctoral dissertation, 133 p.


Bibliography - South Atlantic


Adil Alshammari, Duke Brantley, Camelia C. Knapp, James Knapp, and Venkataraman Lakshmi, Predicting the Fensile failure Due to Carbon Dioxide Storage, American Geophysical Union (AGU), San Francisco, Dec, 2019.


Gilliland, E., Rossi, M., Schlosser, C., Ripepi, N., Southeast Offshore Storage Resource Assessment: Mid-Atlantic, International Workshop on Offshore Geologic CO2 Storage, Austin, TX, April 19-21, 2016., poster.