# Southeast Offshore Storage Resource Assessment (SOSRA)

Project Number: DE-FE0026086


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U.S. Department of Energy

National Energy Technology Laboratory

Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting

August 13-16, 2018

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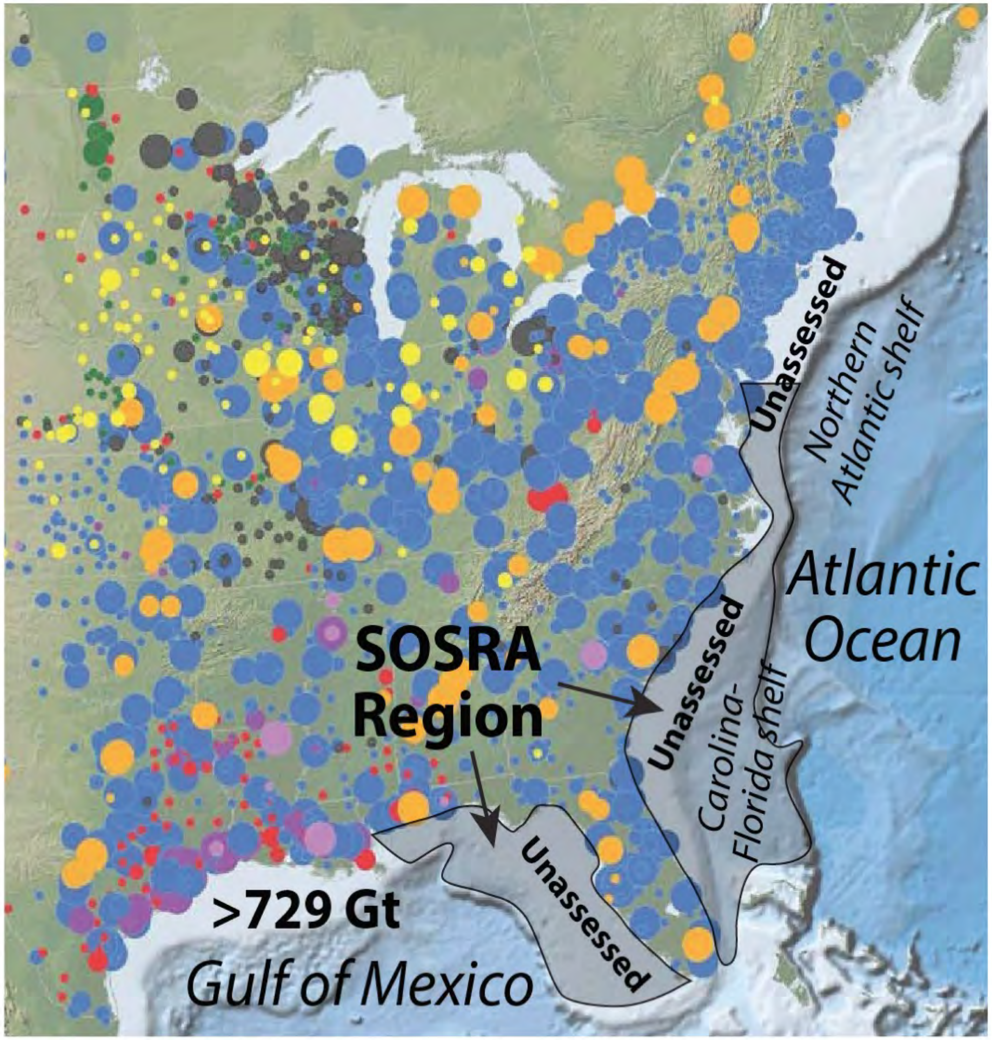
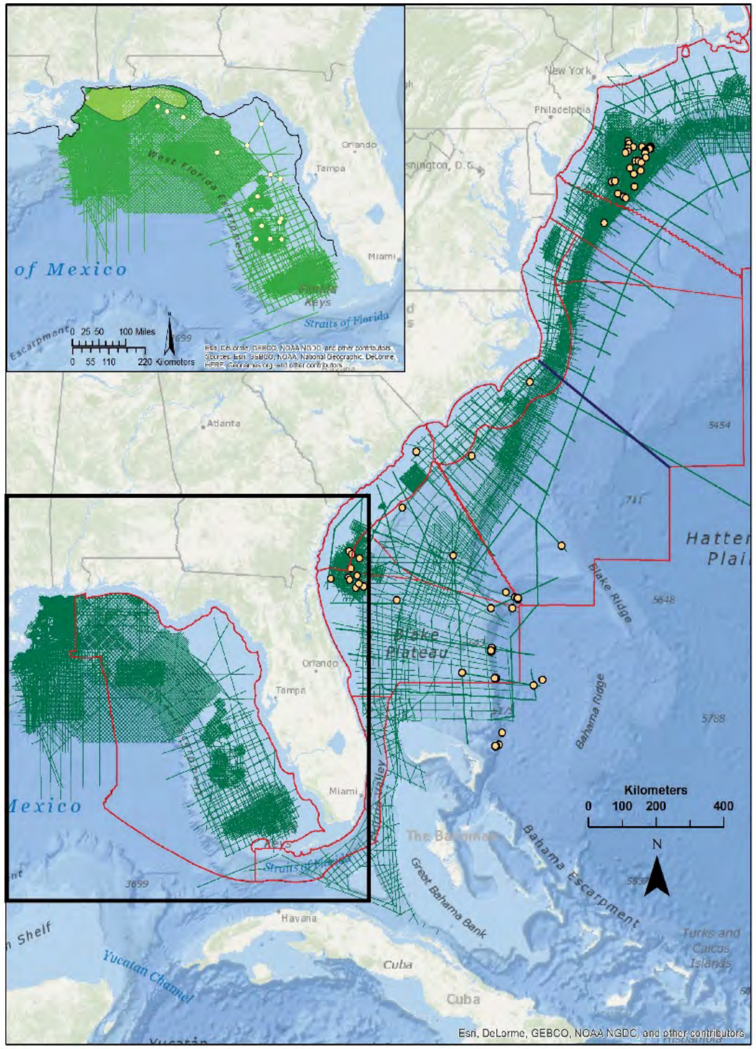
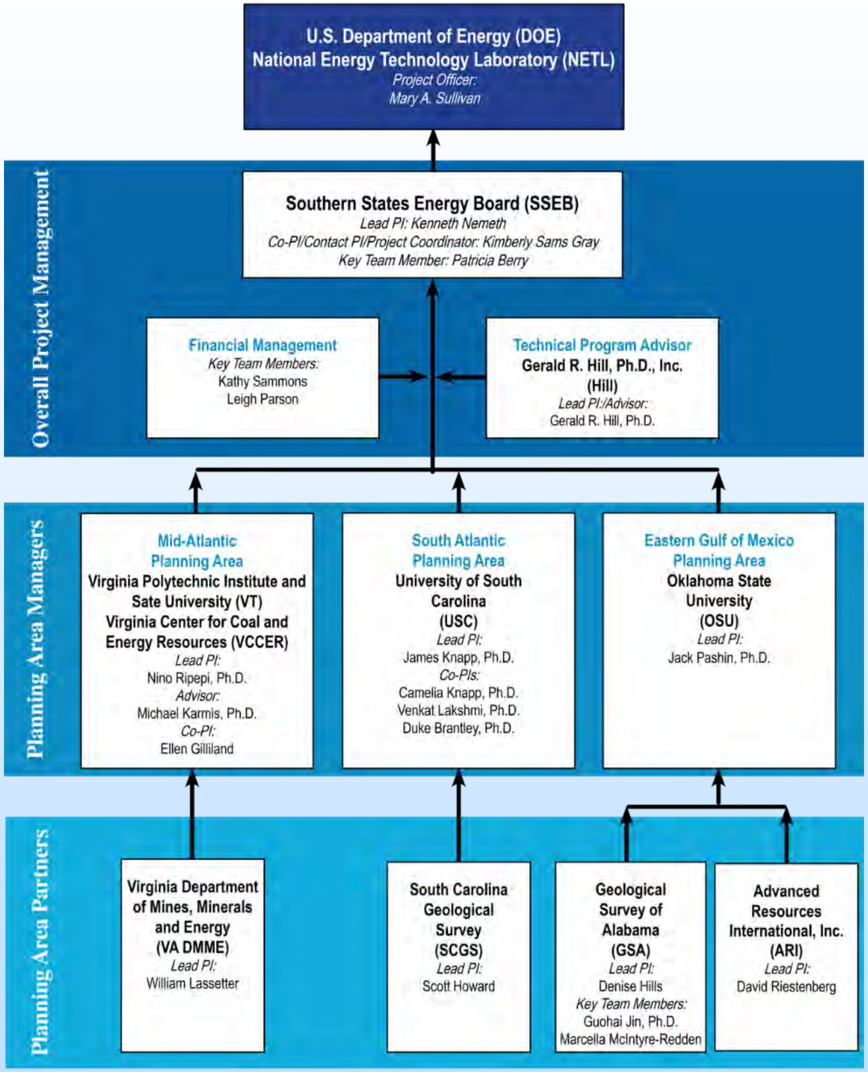





# Organization Chart

**Advisory Committee**:
state geological surveys, universities, state oil and gas boards, oil and gas companies, and utilities
(no contract, no decision making authority)

# Project Overview
## Goals and Objectives

***Goal***

*Provide a high quality prospective carbon dioxide ($CO_2$) storage resource assessment of the eastern Gulf of Mexico and the Mid- and South Atlantic seaboard.*

***Objectives***

Phase I /Budget Period 1 (BP1)

- **Objective 1:** Provide an overview of the basic geologic framework of the SOSRA region, identify potential storage units, and define the key planning areas. [Goal 3]

Phase II /Budget Period 2 (BP2)

- **Objective 2:** Provide a robust characterization of offshore $CO_2$ storage opportunities, as well as conduct a volumetric analysis that is consistent with established procedures employed by the National Energy Technology Laboratory (NETL) for $CO_2$ assessment. [Goal 3]
- **Objective 3:** Provide limited modeling of offshore $CO_2$ storage to identify well and reservoir configurations that are capable of meeting the goal of 30 megatonnes or greater storage in key focus areas. [Goal 3]
- **Objective 4:** Development of Best Practices Manuals (BPMs) based upon this research to advance the state of knowledge by identifying paths to deployment and applicable technologies that improve the effectiveness while reducing the cost of storage operations. [Goal 4]

# Timeline

2016 | 2017 | 2018 | 2019

**9/2016**
**Geologic Overview Completed (Task 2.0)**

**3/2017**
**Data Analysis Completed (Task 4.0)**

**12/2018**
**Geologic Characterization and Volumetric Calculations (Task 5.0)**

**9/2019**
**PROJECT ENDS**

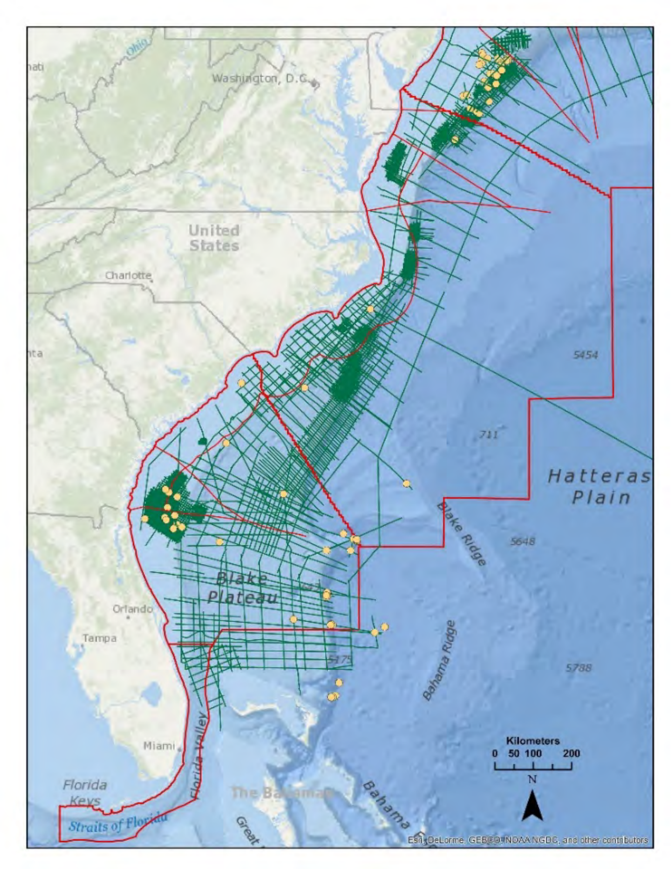
**9/2016**
**Data Collection Completed (Task 3.0)**

**GO / NO-GO DECISION POINT**

**9/2019**
**Best Practices (Task 6.0)**
**Natcarb and Atlas (Task 7.0)**
**Outreach (Task 8.0)**
**Closeout and Reporting (Task 9.0) Completed**

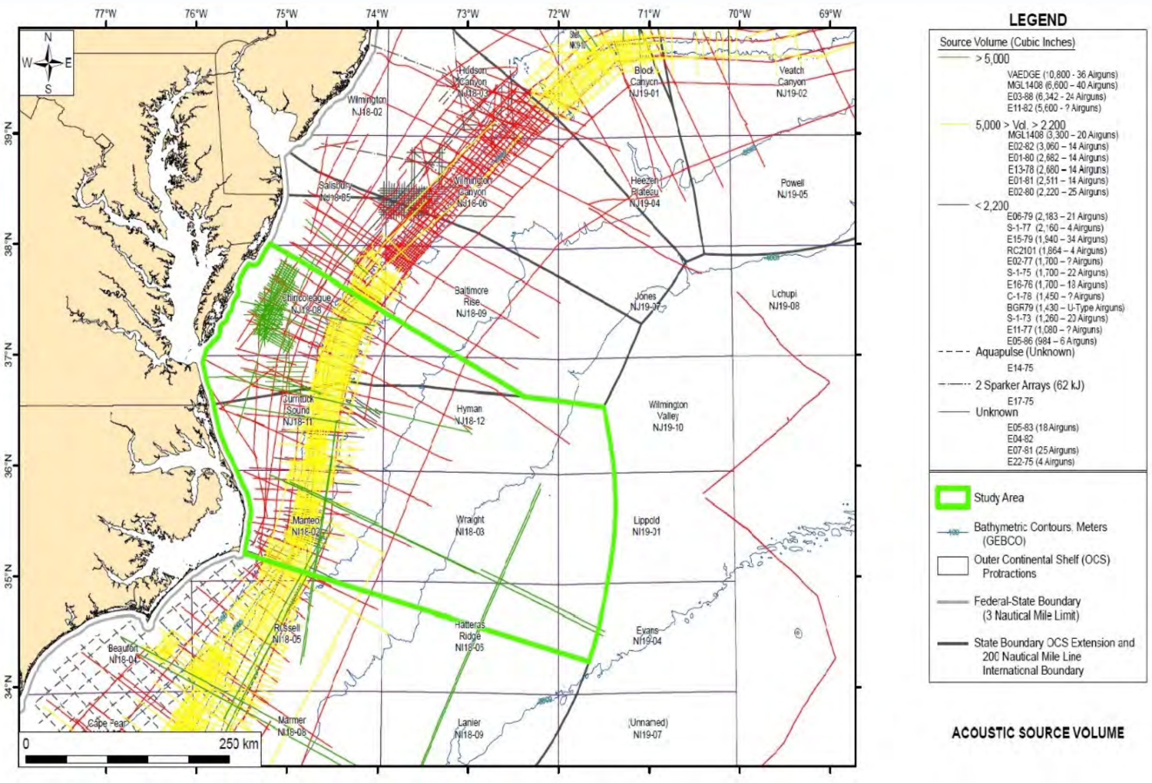
**GO/NO-GO DECISION POINT:** *The data collected and analyzed in Phase I is sufficient to perform a quality prospective storage resource assessment and the project should proceed to Phase II.*

# Mid and South Atlantic Study Area and Data Coverage




- > 200,000 line km 2-D seismic reflection data
- 6 exploration wells plus COST-GE well
- ODP / DSDP / IODP scientific drilling
- Seismic refraction data

# Technical Status in Mid-Atlantic:




- Seismic Interpretation
- Reservoir Identification
- Mapping (Isopachs)
- Preliminary Resource Assessment
- Reservoir Simulation
  - ➢ Sensitivity Analysis
  - ➢ Variation in Well Pattern
  - ➢ Evaluation of Stacked Reservoirs and Single Zone

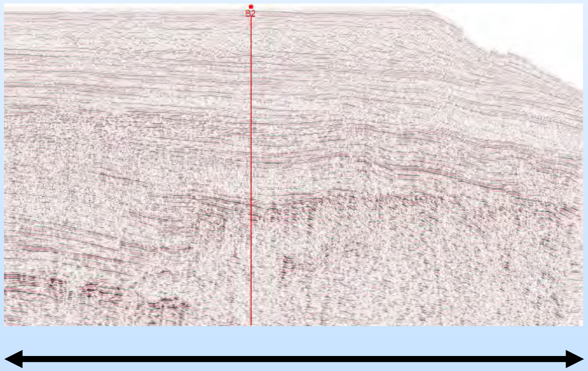
# Seismic Interpretation and Reservoir Characterization Workflow

- Focus on the Continental Shelf of Virginia and North Carolina
- 300 Seismic Profiles Interpreted from (12 Surveys)
- COST-B2 and COST B-3 Used for Seismic Well Ties and Reservoir Parameters
- 11 Sequence Boundaries Regionally Mapped (Sea Floor to Upper Jurassic)
- Fault Zones Regionally Mapped
- Seismic Facies/Lithologies Association and Extrapolation (From COST B-2 and B-3)
- Stacking Velocities (.geo files) Used to Calculate Interval Velocities (DIX Conversion)
- Depth Conversion
- Attribution of Reservoir and Seal Properties to Depth Converted Model (N/G, Porosity, Permeability…)

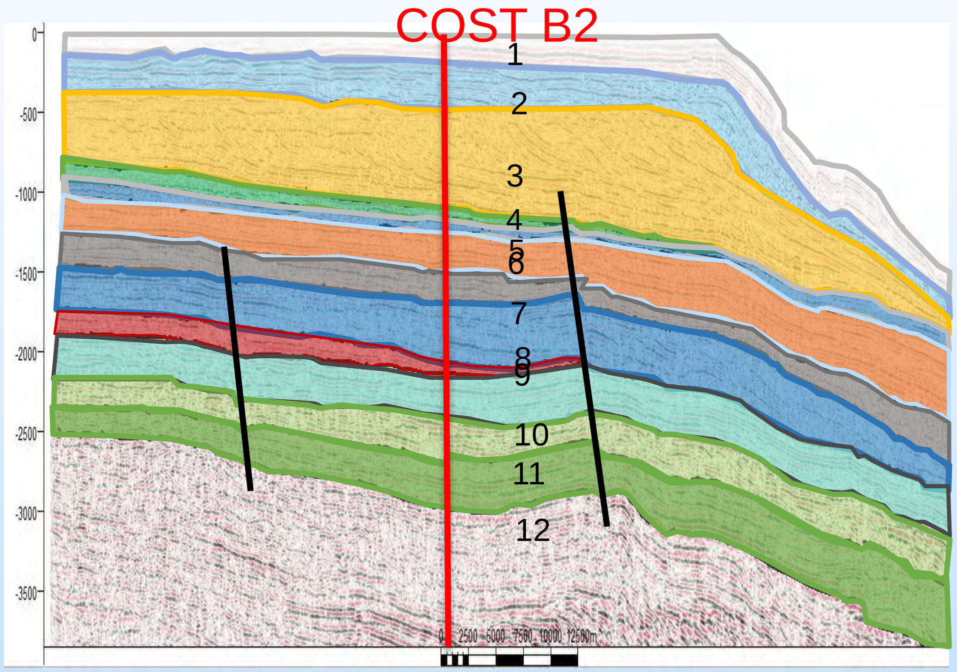
**Dip Line A 125 Survey E-01-75**

12 Geological Units Identified
Based on Sequence Stratigraphy and Well Data

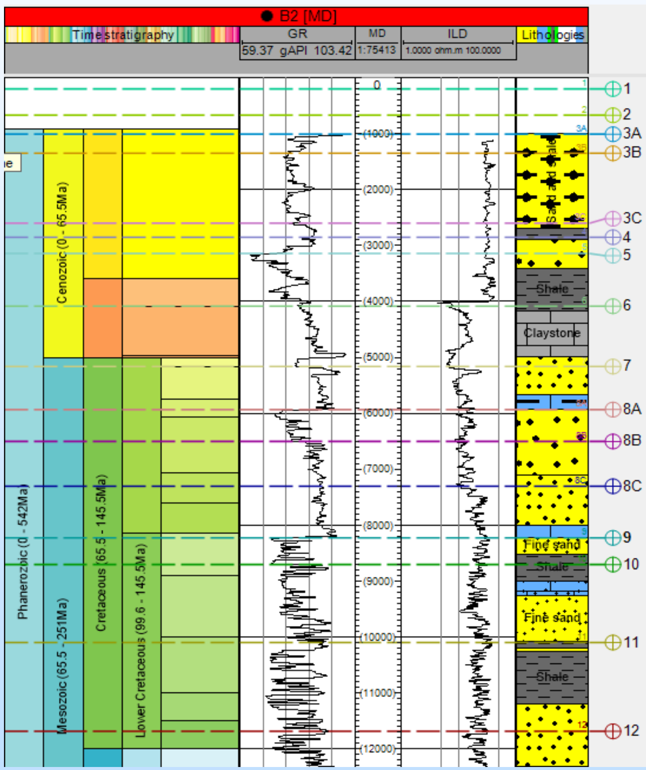
Original Profile



82 km

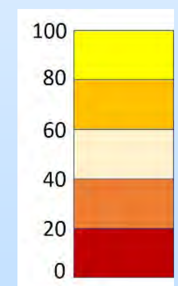


# COST B2 Seismic Facies Lithology Association

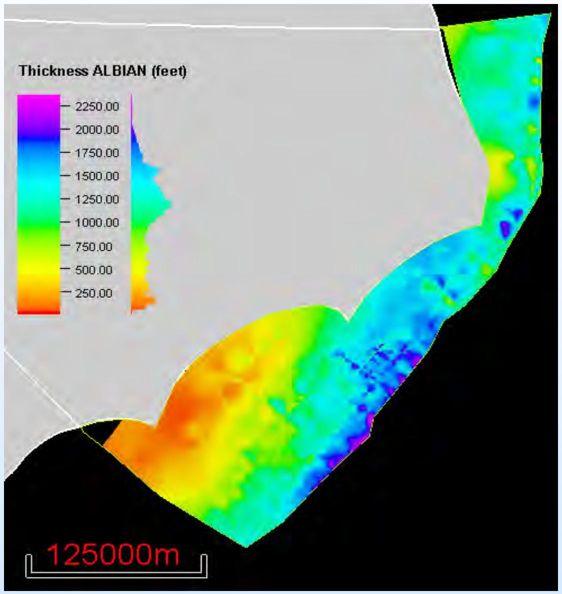


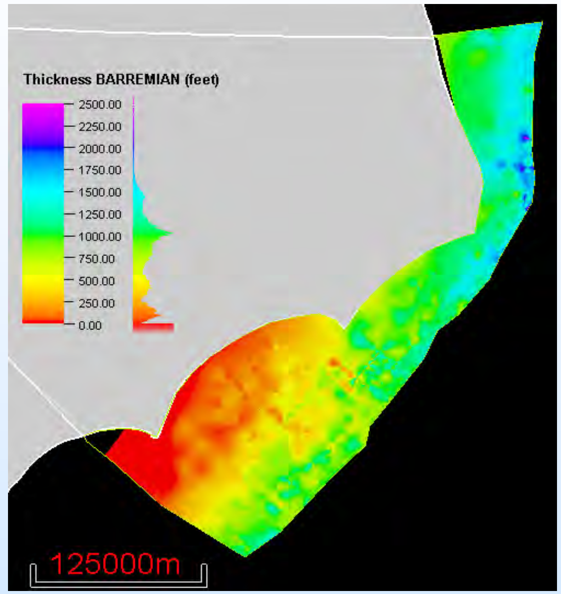

| SEISMIC FACIES LITHOLOGY ASSOCIATIONS: 1 LITHOLOGY MIX, COST B2 EXTRAPOLATION | | | | | | |
|---|---|---|---|---|---|---|
| FACIES # | TOP | AGE | SEISMIC FACIES | | LITHOLOGY MIX | |
| | | | | %SS | %SH | %LS (CEMENT) |
| 1. | 300 | H | High Amp, Continuous Horiz, Low Freq | 95 | 5 | |
| 2. | 670 | PLEIST | High Amp, Semi-Continuous Horiz, High Freq | 90 | 10 | |
| 3. A. | 1009 | PL | Horiz. Low Amp Semi-Cont Horiz-> | 76 | 24 | |
| B. | 1350 | | Semi-Cont. Med-High Amp. Sigmoidal -> | 61 | 39 | |
| C. | 2600 | | Horiz, High Amp Cont | 41 | 59 | |
| 4. | 2850 | MIO | High Amp Semi-Cont Horizo | 40 | 59 | 1 |
| 5. A. | 3140 | OLIG | High Amp Cont Horizo to | 35 | 62 | 3 |
| B. | | | Low Amp SemiCont | 13 | 85 | 2 |
| 6. A. | 4083 | EOC | High Amp Cont Horiz to | 13 | 85 | 2 |
| B. | | | Low Amp SemiCont | 52 | 47 | 2 |
| 7. A. | 5161 | MS/CM/SN/CN | High Amp Cont Horiz to | 51 | 47 | 2 |
| B. | | | Low Amp SemiCont Truncated at top | ? | | |
| 8. A. | 5930 | TUR | Horiz. Low Amp Semi-Cont Horiz-> | 56 | 43 | 1 |
| B. | 6500 | CEN | Semi-Cont. Med-High Amp. Shingled -> | 54 | 44 | 2 |
| C. | 7300 | | Horiz, High Amp Cont | ? | | |
| 9. A. | 8223 | ALB | High Amp Cont to | 28 | 62 | 10 |
| B. | | | Low Amp SemiCont Horiz, Onlapping | ? | | |
| 10. A. | 8700 | APT | High Amp Subparallel SemiCont Horiz to | 44 | 41 | 15 |
| B. | | | Gentle Concave Upaward | ? | | |
| 11. A. | 10093 | BAR/HAU/VAL | Med Amp Subparallel SemiCont Horiz to | 35 | 48 | 17 |
| B. | | | Gentle Concave Upward | ? | | |
| 12. A. | 11680 | TITH/KIM | Low Amp Discontin Subhoriz to | 24 | 64 | 12 |
| B. | | | High Amp Contin Subhoriz | ? | | |

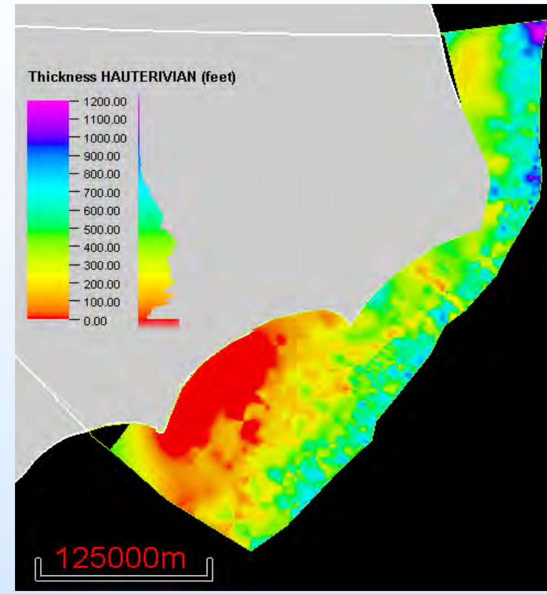
% of Sand



# Lower Cretaceous Reservoirs in NC



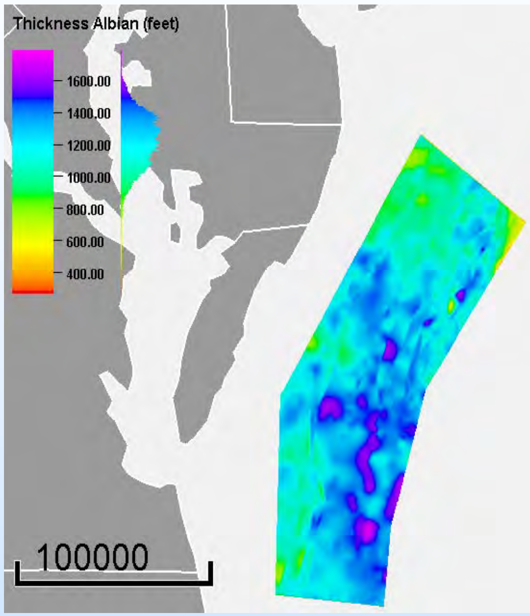



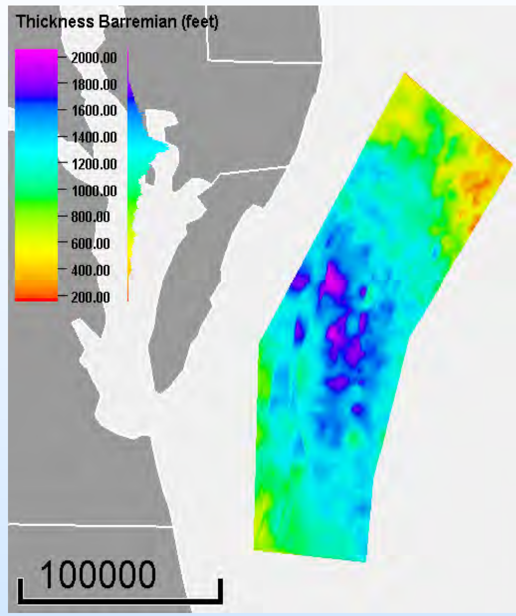

| Albian | | | | |
|---|---|---|---|---|
| COST B-2 | | COST B-3 | | Average Thickness |
| Net/Gross | Core Porosity | Net/Gross | Core Porosity | |
| 0.71 | 0.30 | 0.46 | 0.27 | 306 meters |

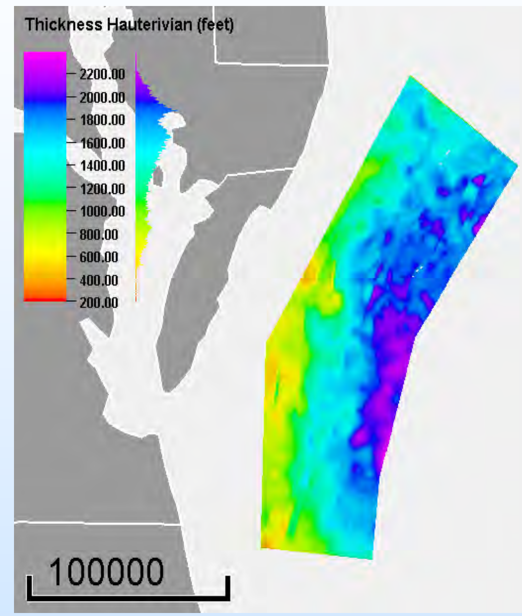
| Barremian | | | | |
|---|---|---|---|---|
| COST B-2 | | COST B-3 | | Average Thickness |
| Net/Gross | Core Porosity | Net/Gross | Core Porosity | |
| 0.74 | 0.26 | 0.51 | 0.17 | 215 meters |

| Hauterivian | | | | |
|---|---|---|---|---|
| COST B-2 | | COST B-3 | | Average Thickness |
| Net/Gross | Core Porosity | Net/Gross | Core Porosity | |
| 0.66 | 0.25 | 0.51 | 0.233 | 94 meters |

# Lower Cretaceous Reservoirs In VA




| Albian | | | | |
|---|---|---|---|---|
| COST B-2 | | COST B-3 | | Average Thickness |
| Net/Gross | Core Porosity | Net/Gross | Core Porosity | |
| 0.71 | 0.31 | 0.46 | 0.28 | 371.6 meters |

| Barremian | | | | |
|---|---|---|---|---|
| COST B-2 | | COST B-3 | | Average Thickness |
| Net/Gross | Core Porosity | Net/Gross | Core Porosity | |
| 0.74 | 0.27 | 0.51 | 0.18 | 364.6 meters |

| Hauterivian | | | | |
|---|---|---|---|---|
| COST B-2 | | COST B-3 | | Average Thickness |
| Net/Gross | Core Porosity | Net/Gross | Core Porosity | |
| 0.66 | 0.25 | 0.51 | 0.23 | 451.8 meters |

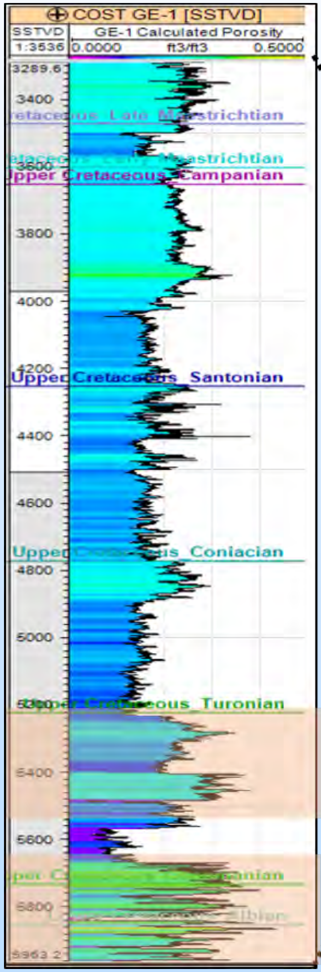
# Preliminary CO2 Storage Potential of the Lower Cretaceous Reservoirs in N.C

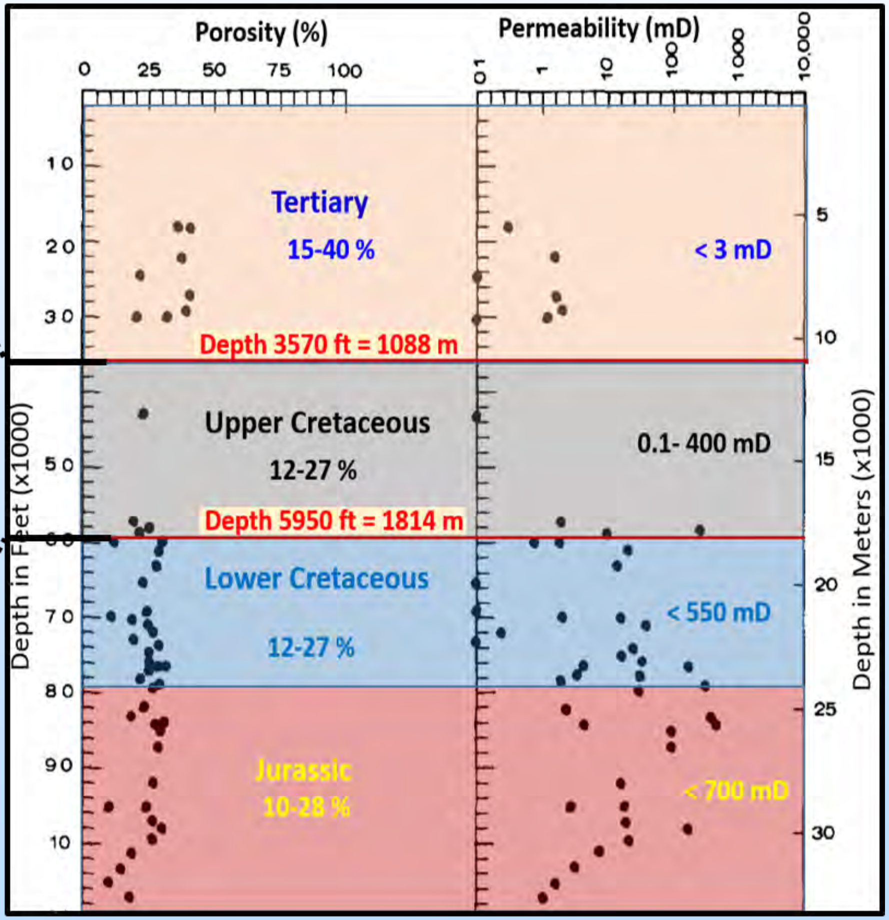
- DOE- Methodology Followed to Estimate Geological Storage in Saline Formations
- Results Displayed for 2 Scenarios: High CO2 Storage Efficiency Factor (5%), Low CO2 Storage Efficiency Factor (0.4%) (10th to 90th % probability range)
- **CO2 Storage Potential Ranges Between 8 and 114 Gigatons of CO2 in N.C**
- **CO2 Storage Potential Ranges Between 7 and 91 Gigatons of CO2 in VA**

| Lower Cretaceous Reservoirs | Reservoir Thickness in m | Average Porosity | Area in m2 | Density in kg/m3 | E for clastics rocks | | Volume in GT | |
|---|---|---|---|---|---|---|---|---|
| | | | | | P10 | P90 | P10 | P90 |
| Albian/Aptian | 179.0 | 0.3 | 3.44E+10 | 700 | 0.004 | 0.05 | 5.0 | 63.0 |
| Barremian | 134.4 | 0.2 | 3.44E+10 | 700 | 0.004 | 0.05 | 2.3 | 35.6 |
| Hauterian | 55.0 | 0.2 | 3.44E+10 | 700 | 0.004 | 0.05 | 1.2 | 16.0 |
| | | | | | | Total Volume | 8.5 | 114.6 |

| Lower Cretaceous Reservoirs | Average Thickness in m | Average N/G | Reservoir Thickness in m | Average Porosity | Area in m2 | Density in kg/m3 | E for clastics rocks | | Volume in GT | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | P10 | P90 | P10 | P90 |
| Albian/Aptian | 371.6 | 0.585 | 217.4 | 0.3 | 1.47E+10 | 700 | 0.004 | 0.05 | 2.61 | 32.60 |
| Barremian | 364.59 | 0.625 | 227.9 | 0.2 | 1.47E+10 | 700 | 0.004 | 0.05 | 2.06 | 25.74 |
| Hauterian | 451.85 | 0.585 | 264.3 | 0.2 | 1.47E+10 | 700 | 0.004 | 0.05 | 2.62 | 32.78 |
| | | | | | | | | Total Volume | 7.29 | 91.12 |

# Target Reservoirs – Limited Well Control (Amato, 1978)

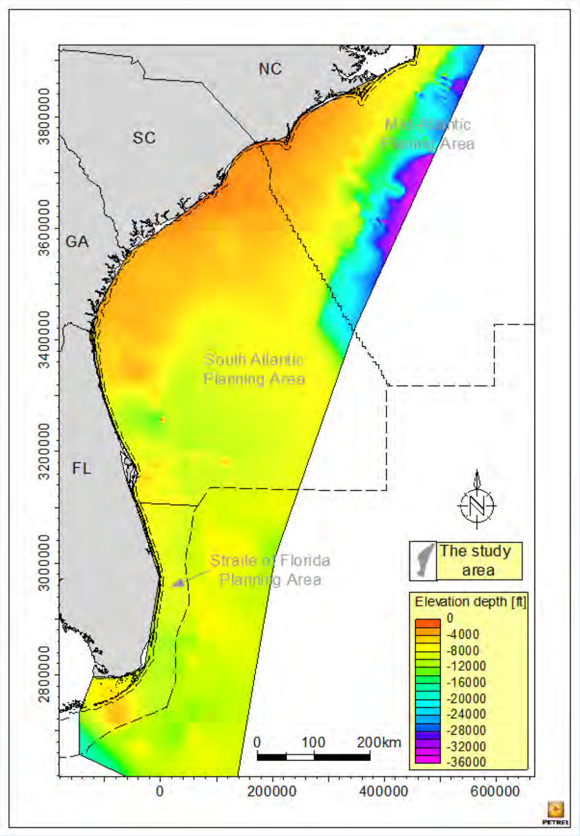


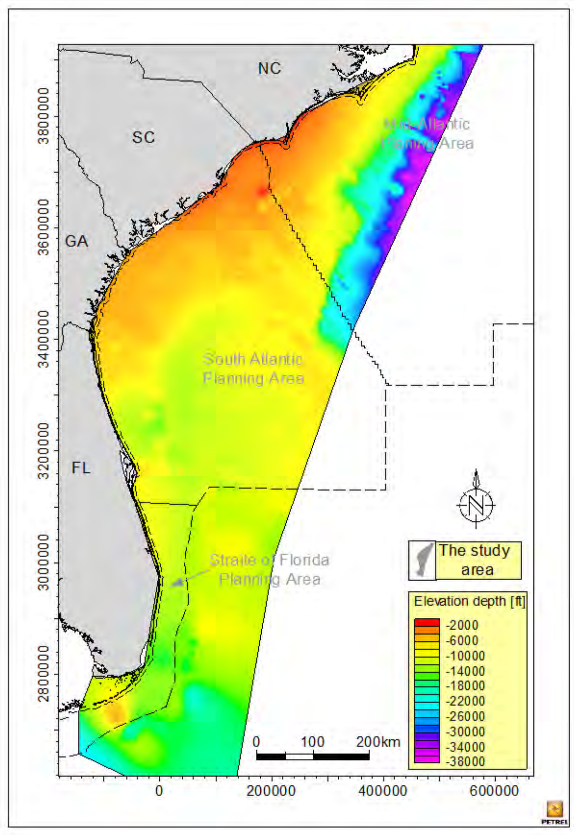
# Regional Structure – Upper Cretaceous and Upper Jurassic

- Mapped across entire dataset
- Depth converted from well velocities
- Largely controlled by regional dip

**Top Lower Cretaceous**




**Top Upper Jurassic**



# Upper Cretaceous – Storage Assessment

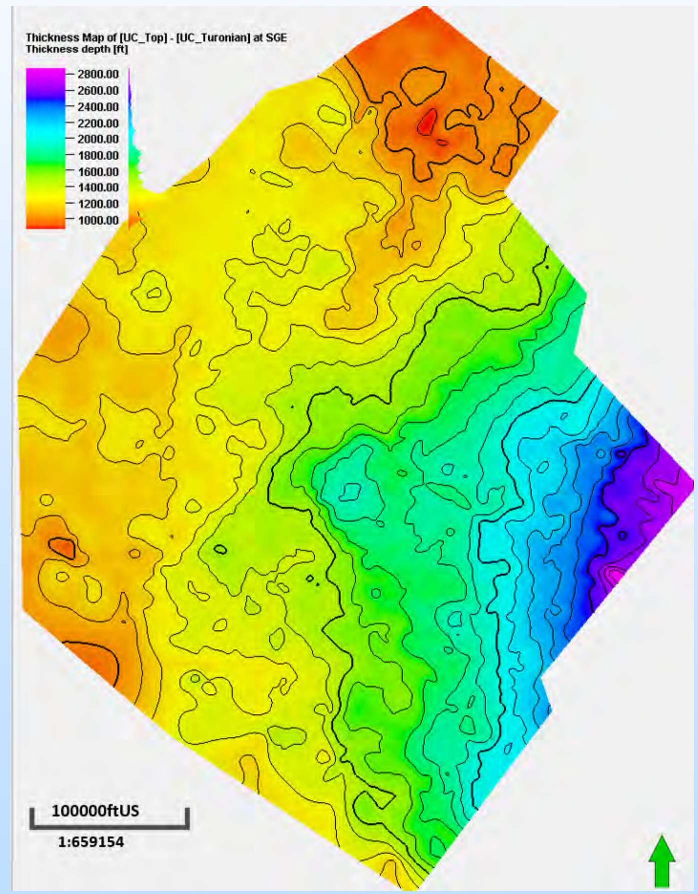
Modern Environmental Science and Engineering (ISSN 2333-2581)
August 2017, Volume 3, No. 8, pp. 532-552
Doi: 10.15341/mese(2333-2581)/08.03.2017/004
Academic Star Publishing Company, 2017
www.academicstar.us

Academic Star

## Assessment of Upper Cretaceous Strata for Offshore $CO_2$ Storage, Southeastern United States

Khaled F. Almutairi, Camelia C. Knapp, James H. Knapp, and Darrell A. Terry
*School of the Earth, Ocean, and Environment, University of South Carolina, Columbia, SC 29208, USA*

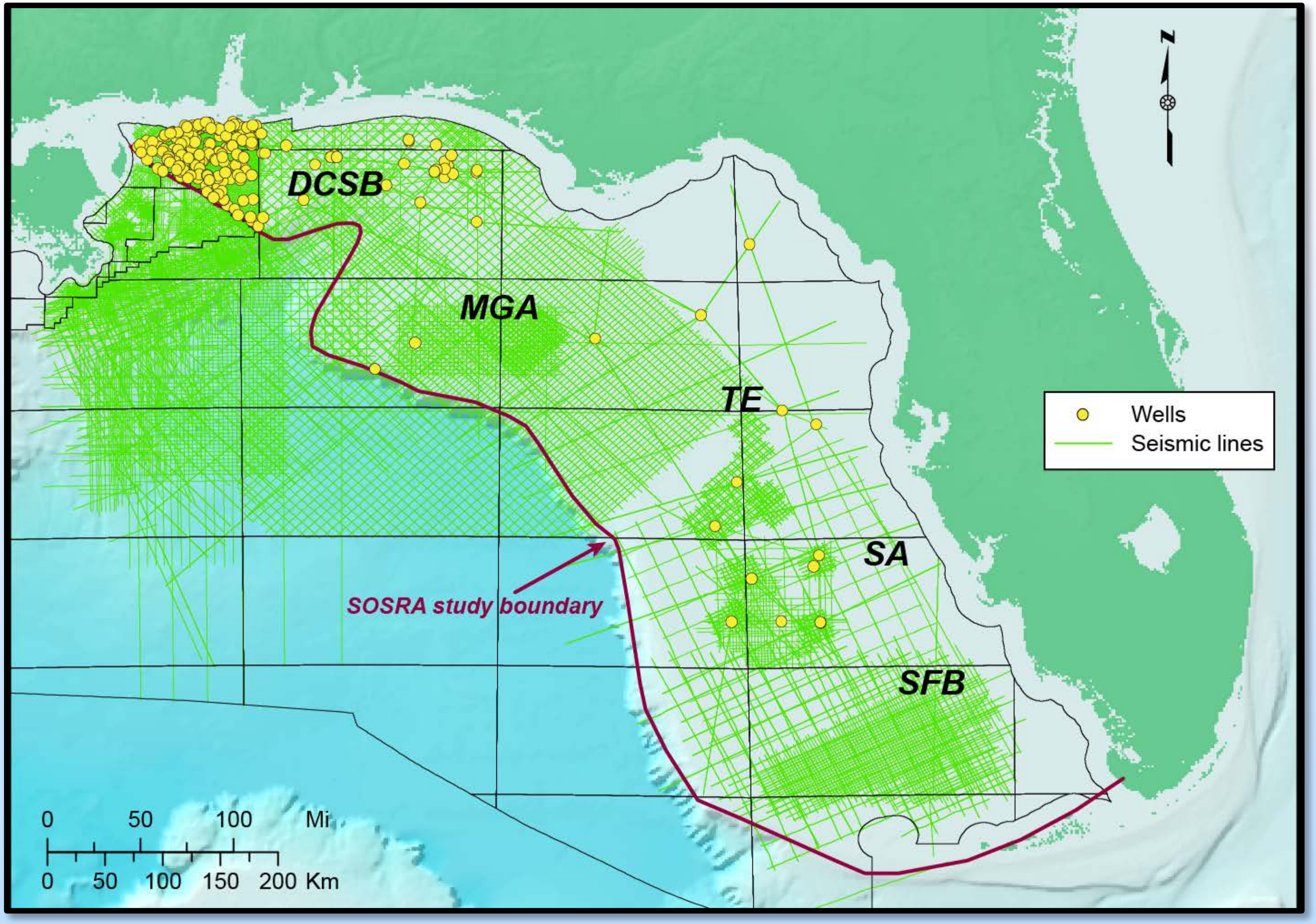
- Capacity assessment of Upper Cretaceous section
- 9 Gt in SE Georgia Embayment
  32 Gt regionally



# Mid and South Atlantic Conclusions

- Variable Data Quality (Fair to Poor) due to different Seismic Acquisition and Processing Vintages
- Sparse Borehole Control
- Interpretation allows for only Basic Reservoir Quality Data Similar limitation for Seal Quality Data
- Uncertainty could be greatly reduced in particular locations with 3D Seismic Data Acquisition and Exploration Wells
- Reservoir: Early Cretaceous Sandstones
- Seals: Shales with a density lower than 2.1g/cm3
- Reservoir Simulation
  - Sensitivity Analysis
  - Test of Different Field Design: Injection Wells Number and Location
  - Estimation of Time Needed to Reach Goal of 30 Megatons of $CO_2$ Stored
  - Single-zone Storage and Stacked Reservoirs Investigated

# EGOM Study Area and Subregions




**DCSB** DeSoto Canyon Salt Basin

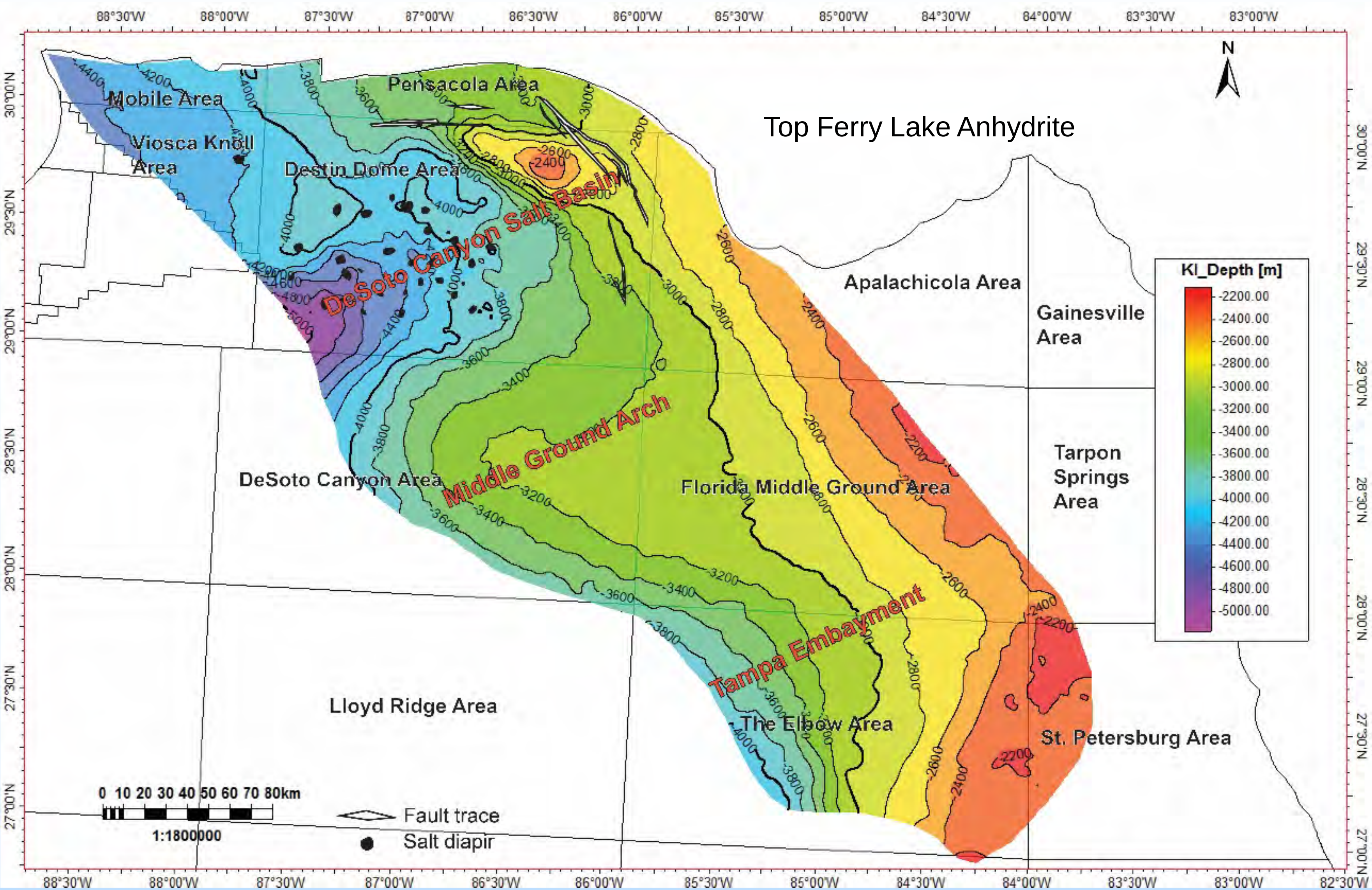
**MGA** Middle Ground Arch

**TE** Tampa Embayment

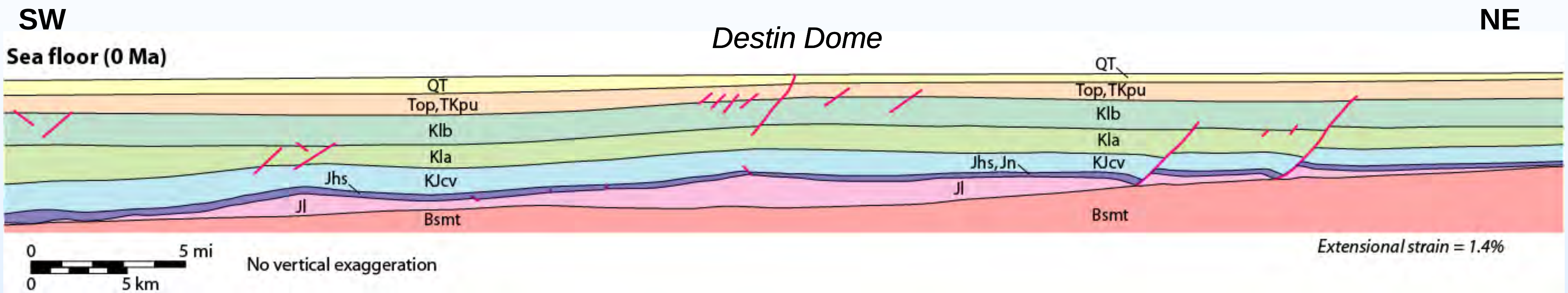
**SA** Sarasota Arch

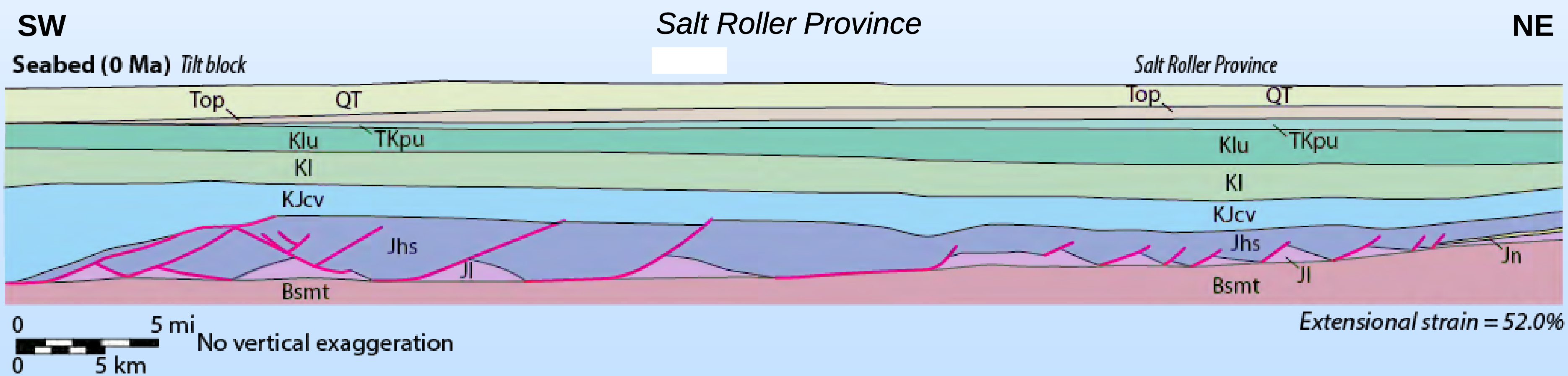
**SFB** South Florida Basin

# Regional Structure—DeSoto Canyon Salt Basin to Tampa Embayment

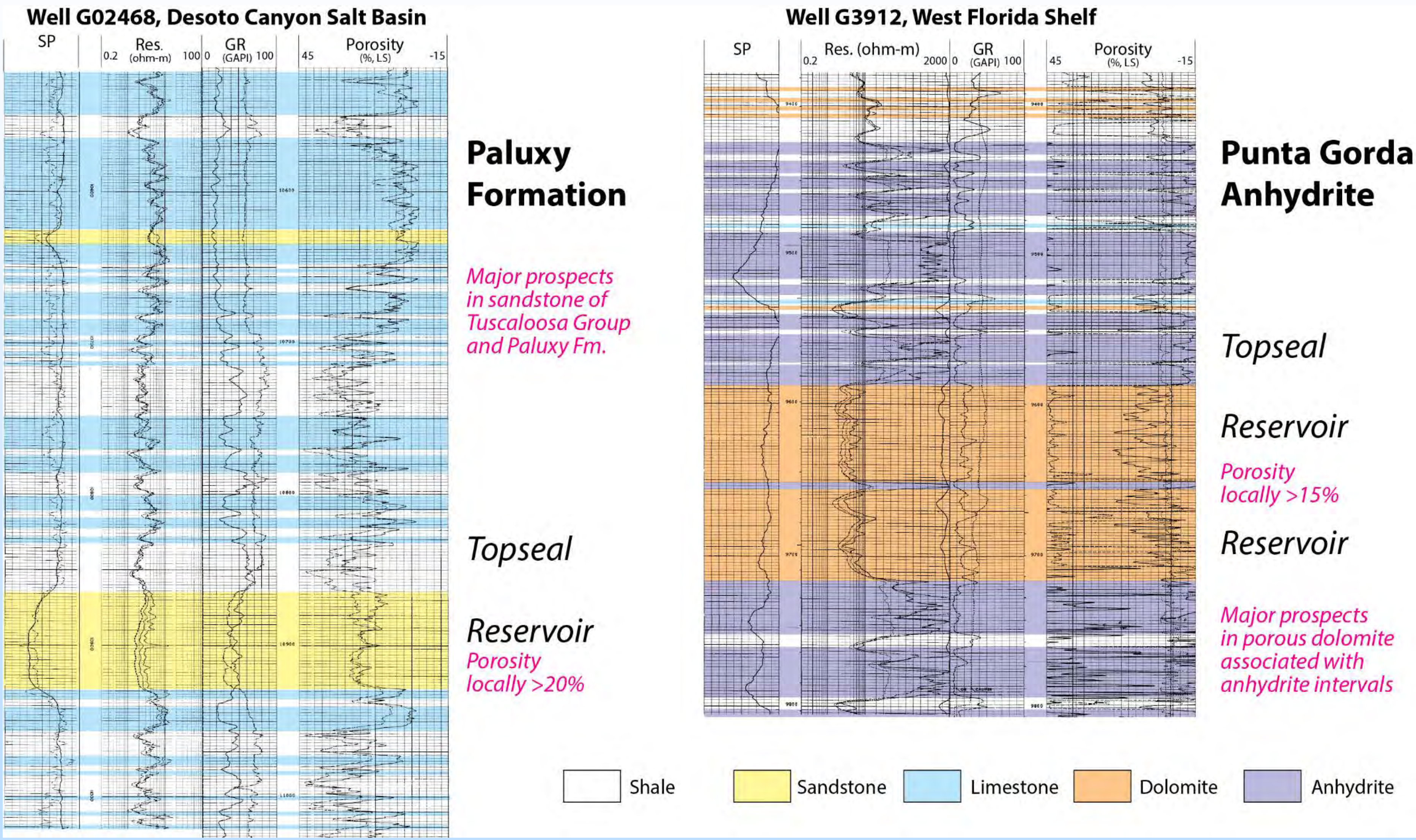


# Depth-Converted Structural Cross Sections, DeSoto Canyon Salt Basin



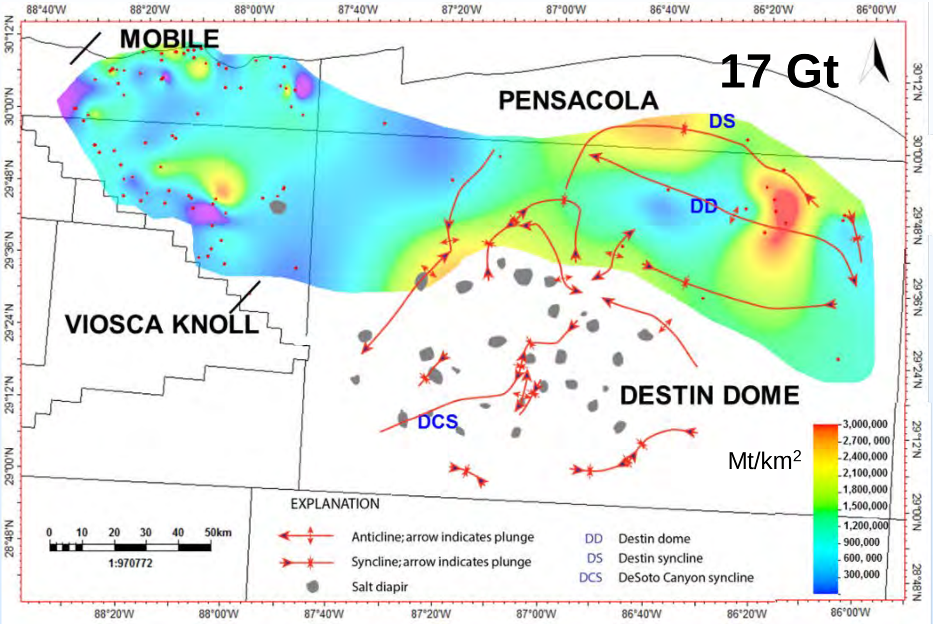



# Prospective EGOM Sinks

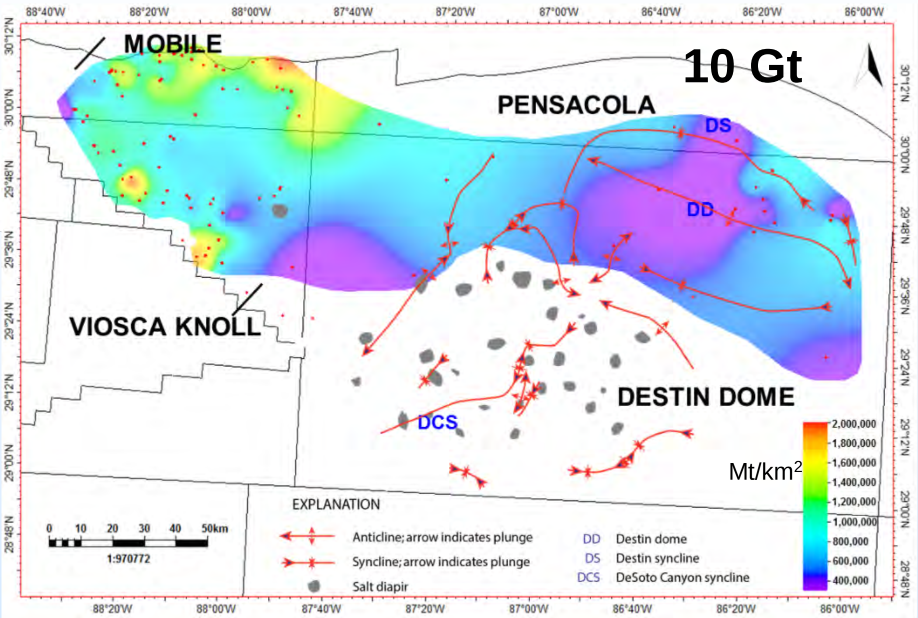


# $P_{50}$ Storage Resource—DeSoto Canyon Salt Basin

*Paluxy Formation*




*Tuscaloosa Group*




| Categories | Paluxy | Washita-Fredericksburg | Lower Tuscaloosa |
|---|---|---|---|
| Reservoir Capacity at 100% $CO_2$ Saturation (Gt) | 122.4 | 7.5 | 69.7 |
| Efficiency Factor ($P_{10}$) % | 7.40 | 7.40 | 7.40 |
| Efficiency Factor ($P_{50}$) % | 14.00 | 14.00 | 14.00 |
| Efficiency Factor ($P_{90}$) % | 24.00 | 24.00 | 24.00 |
| Reservoir $CO_2$ Storage Resource ($P_{10}$) (Gt) | 9.06 | 0.56 | 5.16 |
| Reservoir $CO_2$ Storage Resource ($P_{50}$) (Gt) | 17.13 | 1.06 | 9.76 |
| Reservoir $CO_2$ Storage Resource ($P_{90}$) (Gt) | 29.37 | 1.81 | 16.73 |

Efficiency factors based on displacement terms for sandstone

Qualified sandstone:
Thickness > 6 m
Porosity > 15%

*Individual offshore blocks capable of storing as much as 69 Mt $CO_2$.*

# Accomplishments to Date

- All basic data compiled and loaded into Petra, Petrel, and Kingdom 2D/3D Pak.
- Seismic data depth converted and interpreted.
- Stratigraphic and structural interpretations complete.
- Subsurface mapping completed (Structure, isochore, isolith, porosity, etc.)
- Porosity calculated for candidate storage reservoirs using geophysical logs.
- Preliminary storage resource maps developed for regions with well control.
- Results presented at broad range of meetings (technical conferences, RECS, etc.)

# Lessons Learned

– Seismic control delineates geologic framework, but constraining reservoir properties, volumetrics uncertain in areas with limited well control.
– Lack of permeability data in target sinks.
– Geomechanical analysis based on reservoir stresses required to assess reservoir and seal integrity.

# Synergy Opportunities

- Opportunities for collaboration with other offshore project teams in US and abroad.
- Draw on experience from offshore injection ($CO_2$ storage, EOR, waterflood, etc).
- Compare and contrast onshore and offshore reservoir and seal characteristics, operational logistics.
- Collaborate with onshore and offshore teams to develop predictive frameworks that address data gaps.

# Project Summary

- Geologic framework highly variable within and among study regions (salt basins, stable passive shelves, carbonate-evaporite platforms).
- Diverse portfolio of prospective $CO_2$ storage objectives, reservoir seals.
- Preliminary $CO_2$ storage resource maps indicate large storage capacity in sandstone and carbonate.
- Prospective offshore blocks (9 $mi^2$) appear capable of storing multiple years of emissions from coal-fired power plants.
- Next Step is continued assessment and finalization of reservoir volumetrics.

# Appendix

– These slides will not be discussed during the presentation, but are mandatory.

# Bibliography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# Benefit to the Program: Supporting Carbon Storage Program Goals

- **Goal 3**: "Support industry's ability to predict $CO_2$ storage capacity in geologic formations to within ±30 percent."
  - Conduct a prospective storage resource assessment for offshore regions of the Eastern Gulf of Mexico, Straits of Florida, Mid-Atlantic, and South Atlantic.
- **Goal 4**: "Develop Best Practice Manuals for monitoring, verification, accounting (MVA), and assessment; site screening, selection, and initial characterization; public outreach; well management activities; and risk analysis and simulation."
  - Produce information and develop recommendations that will be useful for inclusion in the DOE Best Practices Manuals (BPMs).
- **Overall Objective**: "Develop and advance technologies that will significantly improve the effectiveness and reduce the cost of implementing carbon storage, both onshore and offshore, and be ready for widespread commercial deployment in the 2025–2035 timeframe."
  - Identify target development areas based on physical and regulatory considerations and computational simulations for $CO_2$ injection and enhanced recovery.
  - Develop outreach program and reporting related to shared data (NatCarb database and Atlas) and commercial deployment of offshore carbon storage operations.