SECARB Offshore: Understanding the Potential for Subsea CO_2 Storage in the Eastern Gulf of Mexico

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Southeast Regional Carbon Storage Partnership: Offshore Gulf of Mexico
(SECARB Offshore)
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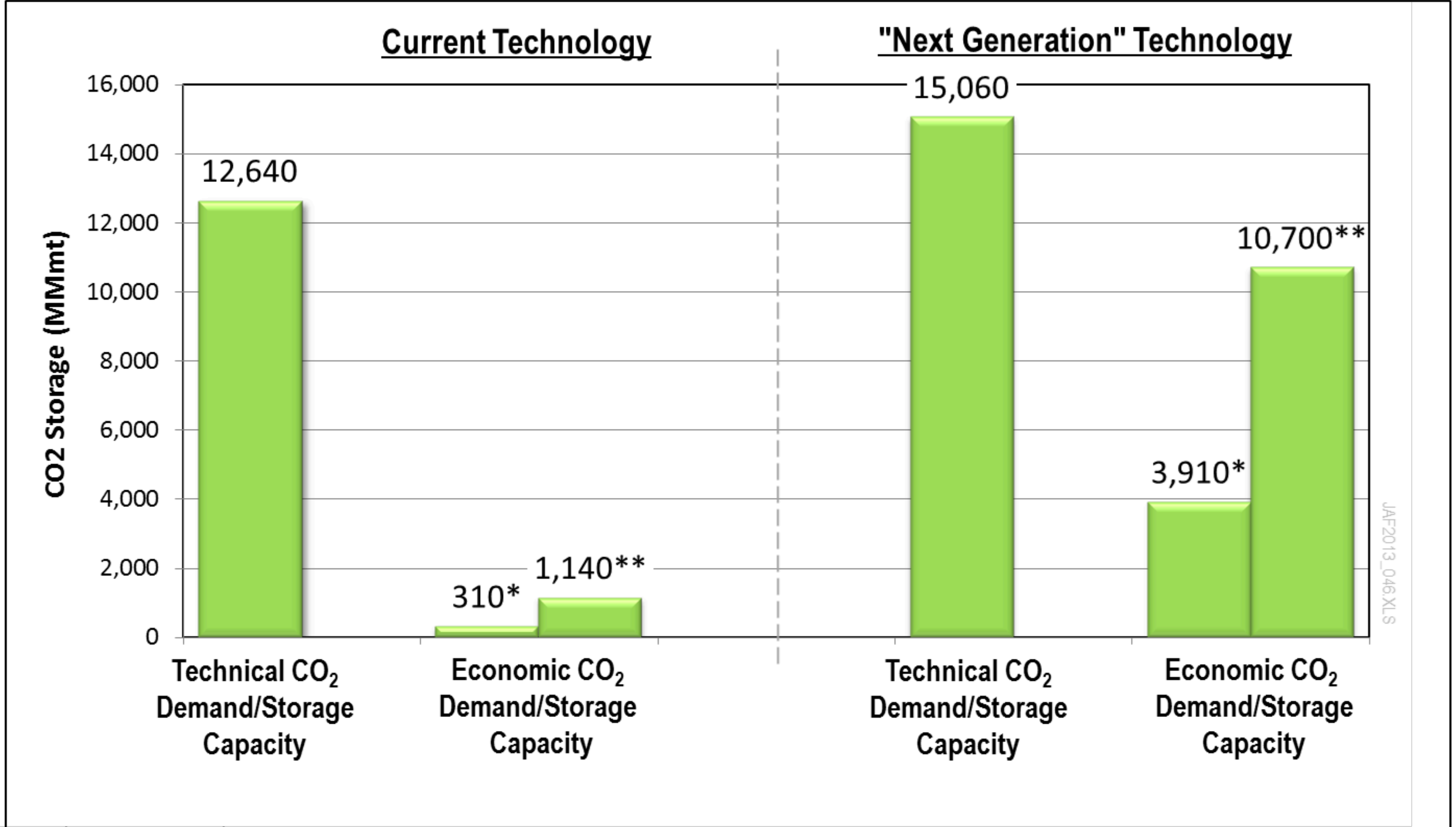
Why Offshore Reservoirs?

- Potentially giant CO_2 capacity
- Abundant stacked saline formations and depleted oil and gas reservoirs
- Significant infrastructure in place
- Proven offshore sequestration technology
- Favorable ownership and access



* @ $90/B Oil Price and $50/mt CO2 Cost
** @ $135/B Oil Price and $70/mt CO2 Cost

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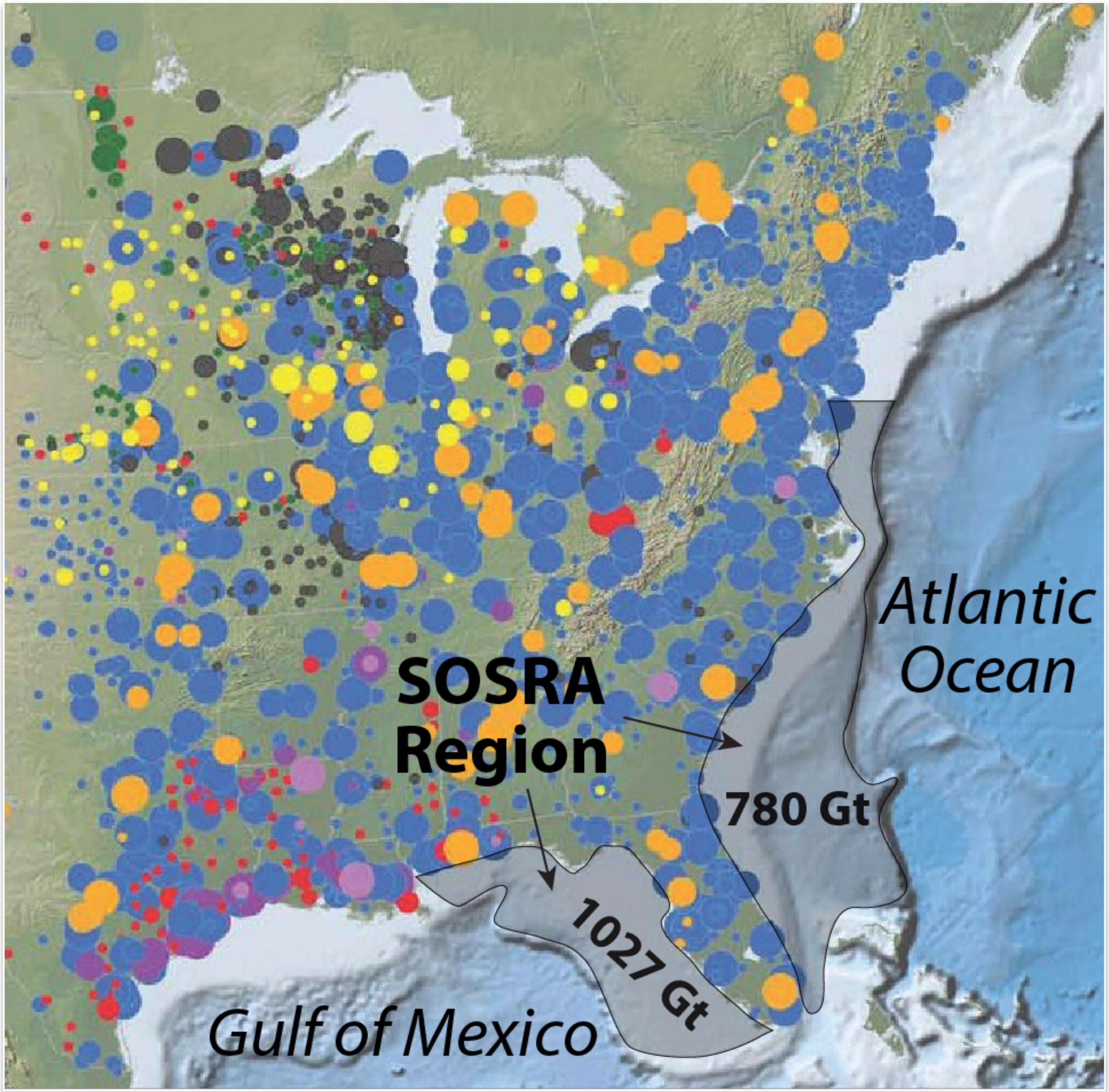
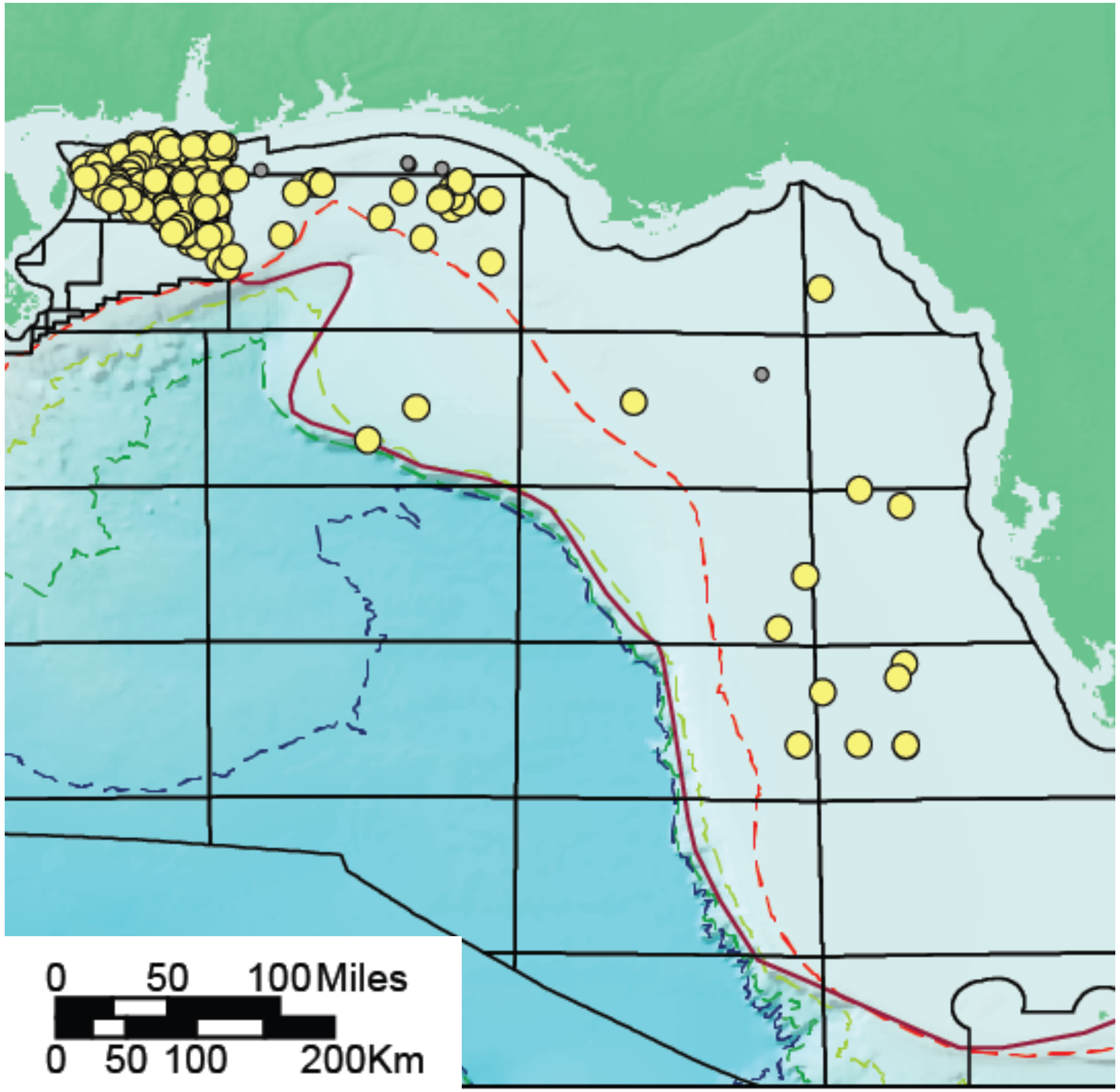
SETTING

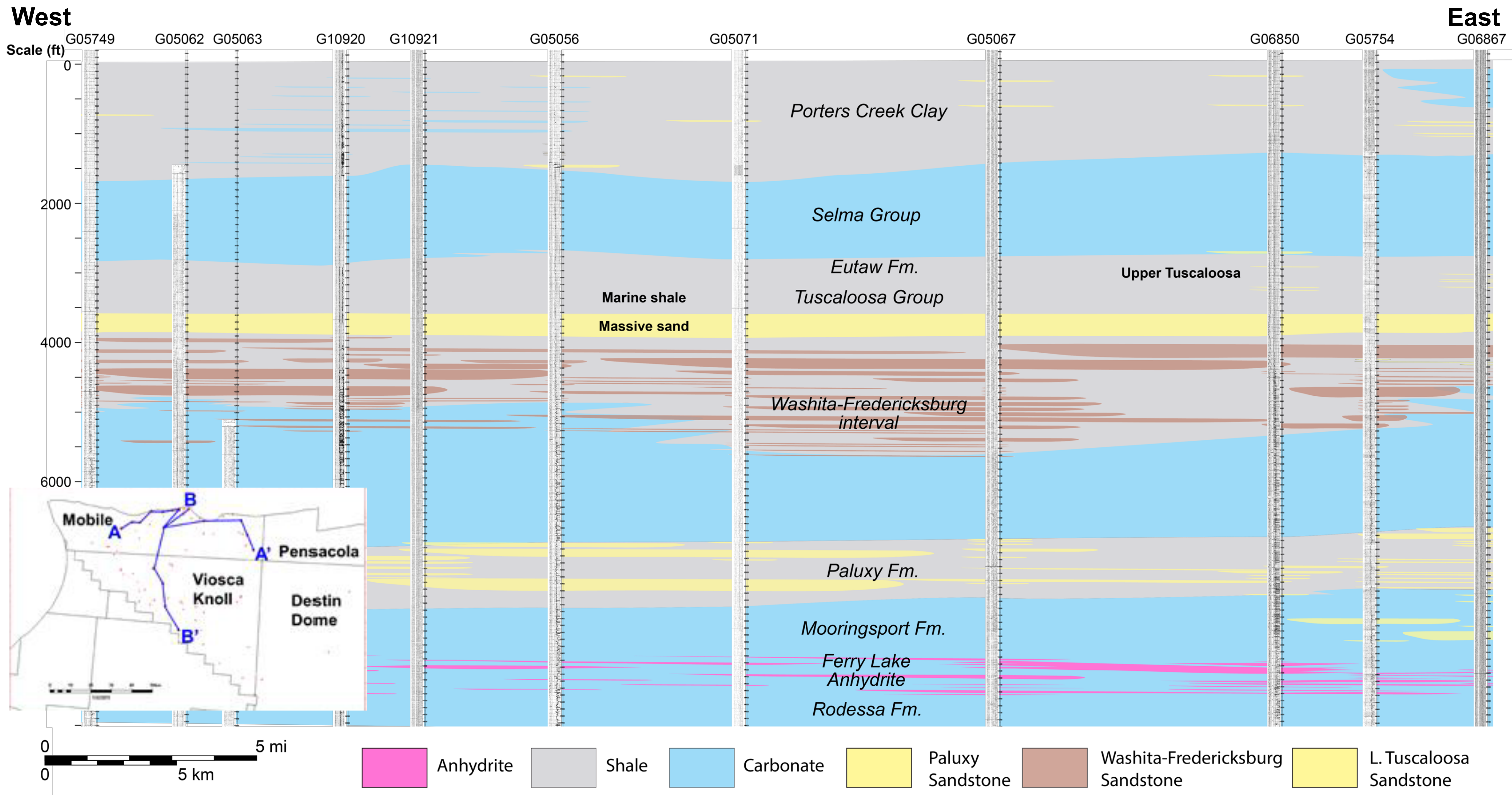
Southeast Offshore Storage Resource Assessment (SOSRA)





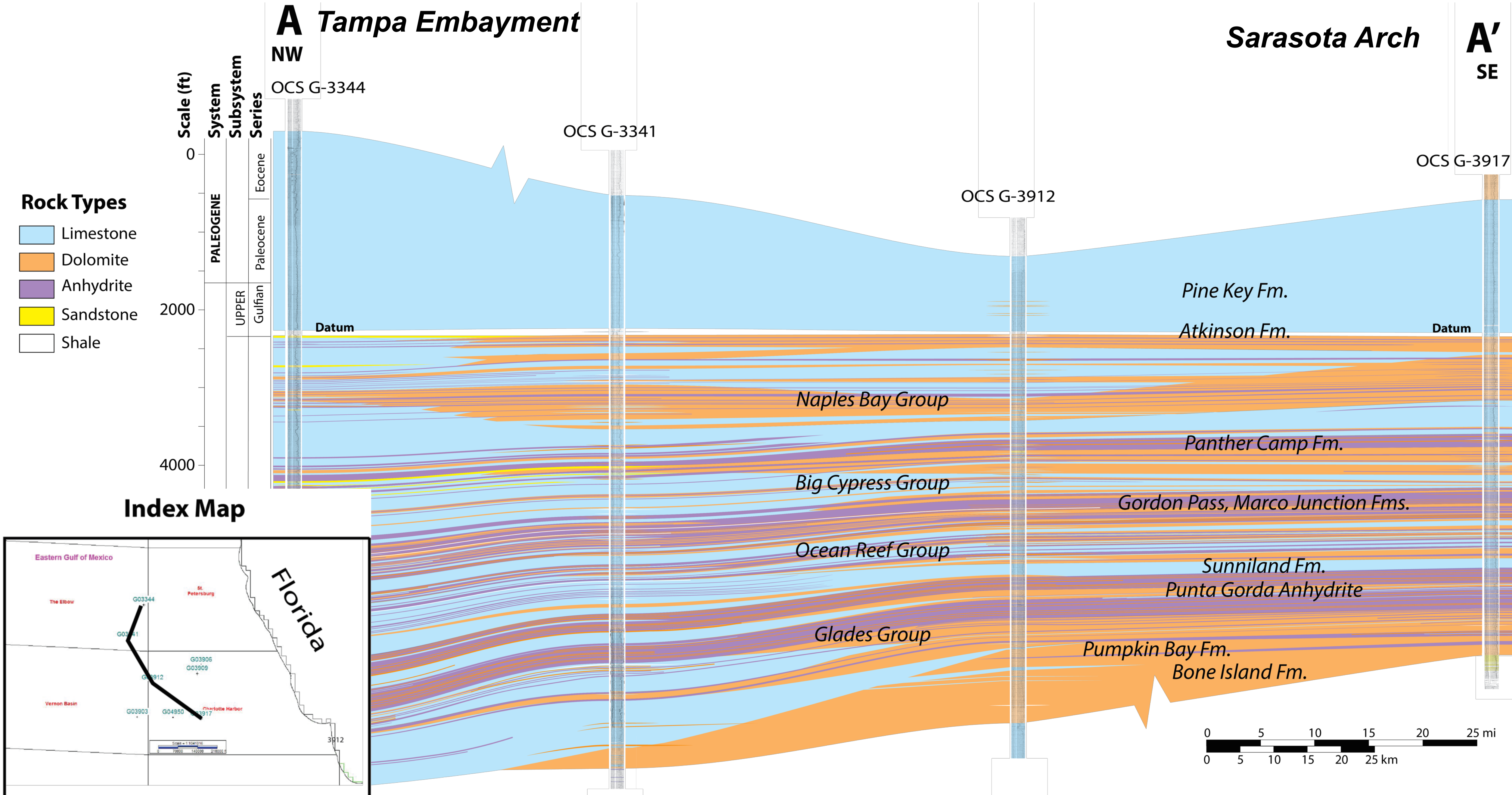
DeSoto Canyon Salt Basin

Chandra (2018)



West Florida Shelf

Charbonneau (2018)



CO_2 STORAGE CAPACITY ESTIMATION

Storage Capacity

$$G_{CO_2} = A_t h_g \Phi_{tot} \rho E_{saline}$$

Where,

A_t is the reservoir area

h_g is the gross formation thickness

Φ_{tot} is the total porosity

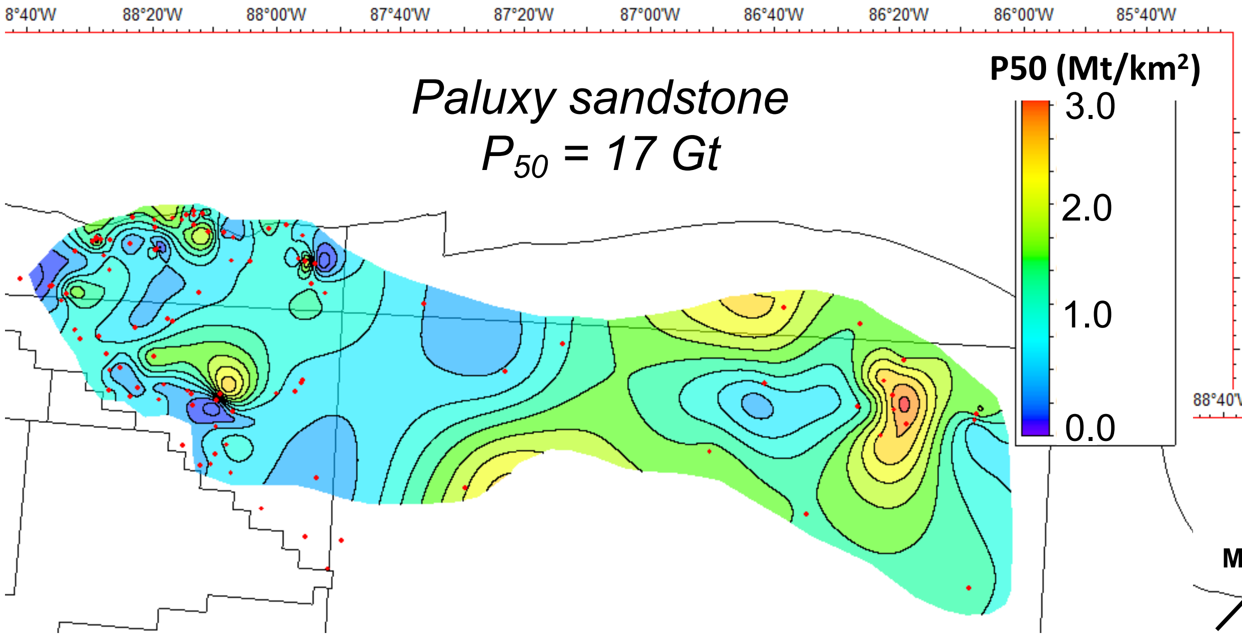
ρ is the CO_2 density

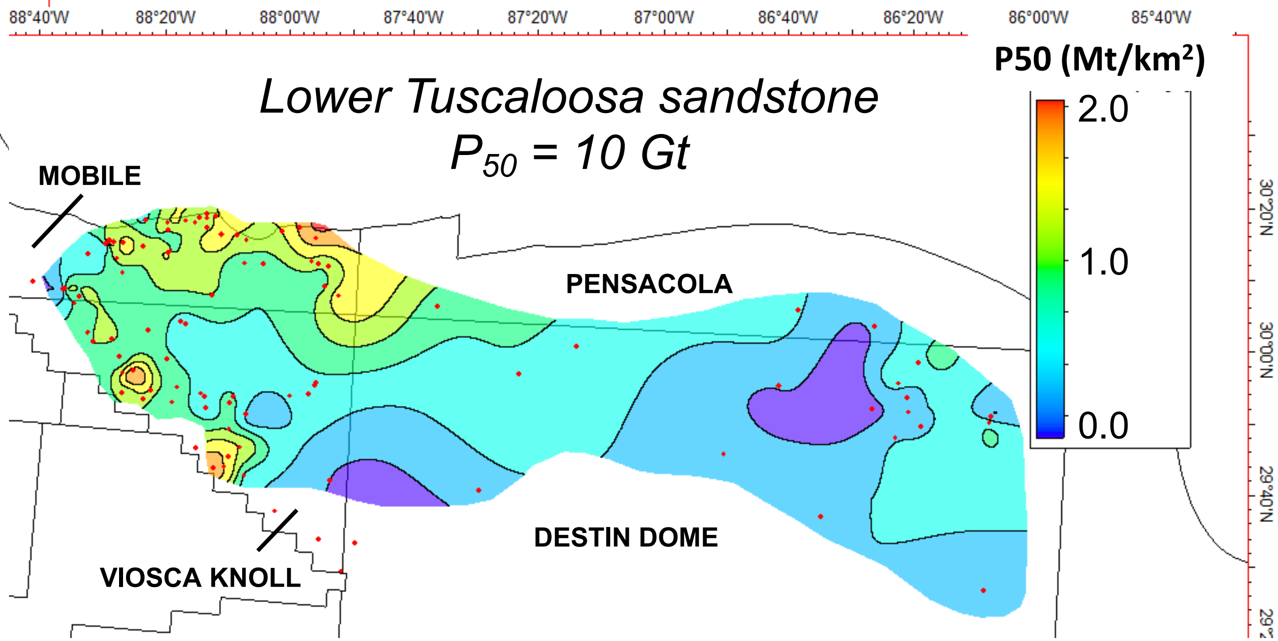
E_{saline} is the CO_2 storage efficiency factor

E_{P10} = 7.4%
E_{P50} = 14.0%
E_{P90} = 24.0%

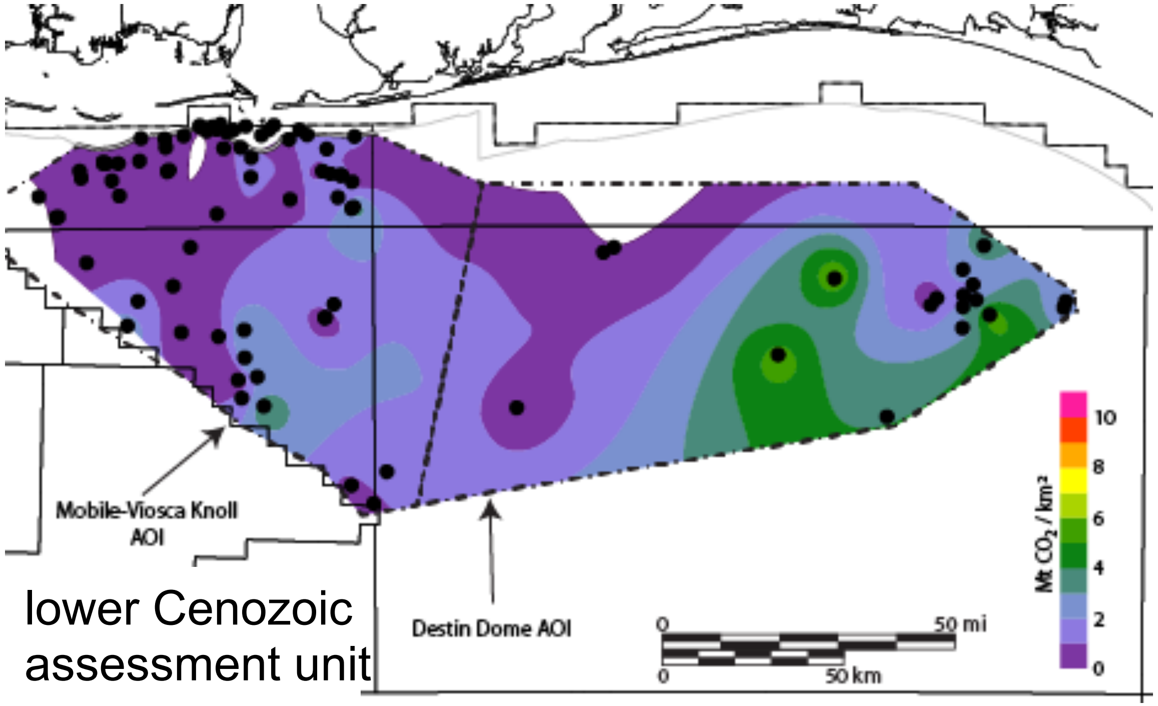
Porosity cutoff = 15%

DSCB Estimated CO_2 Storage Resource (P50) - Cretaceous

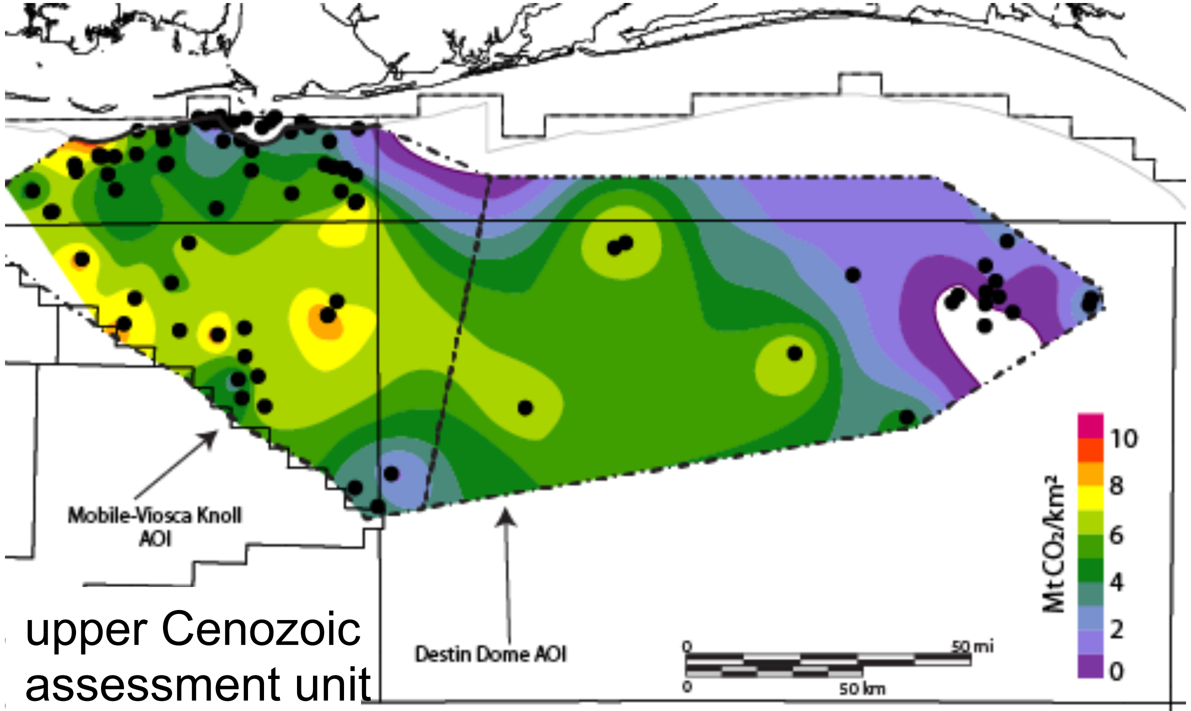




DSCB Estimated CO_2 Storage Resource (P50) - Cenozoic



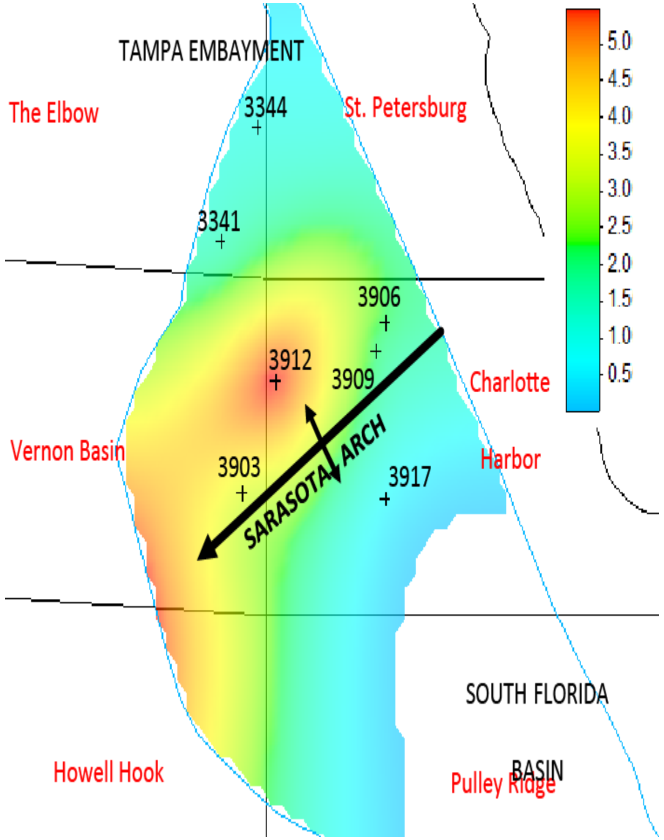
lower Cenozoic assessment unit



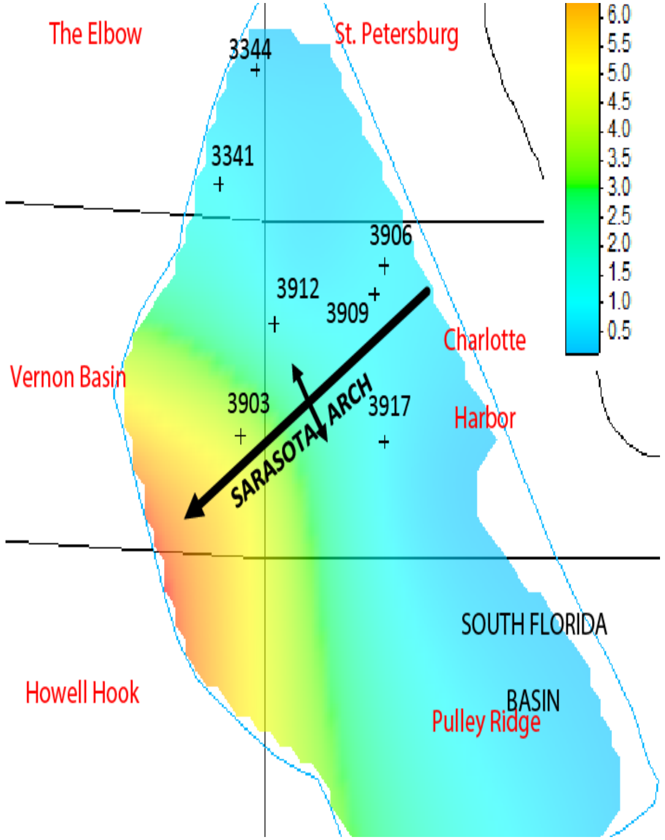
upper Cenozoic assessment unit

WFS Estimated CO_2 Storage Resource (P50) – Cretaceous

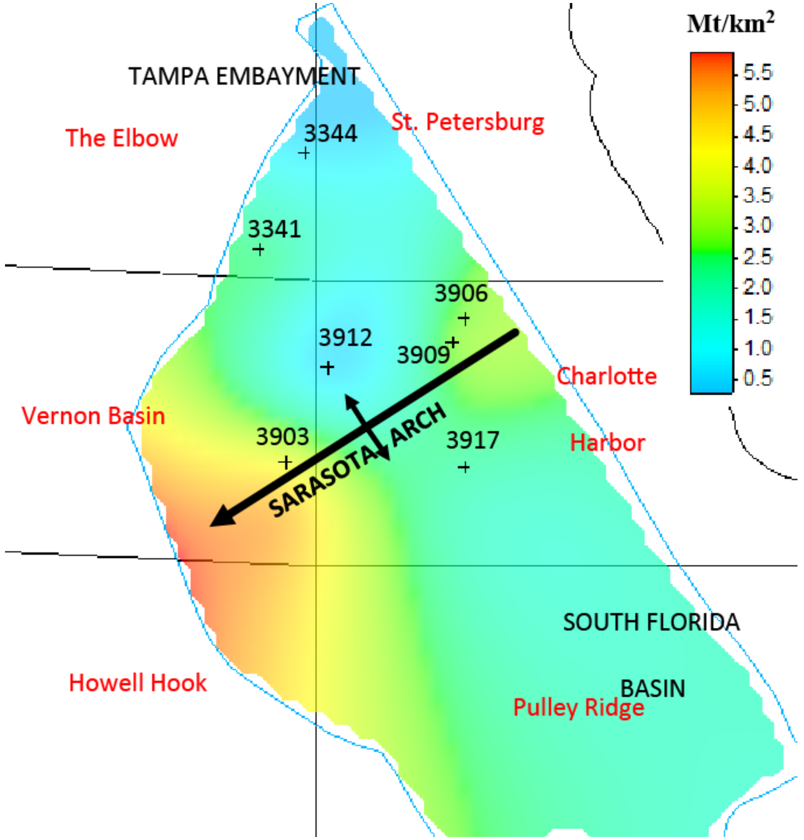
Punta Gorda assessment unit



Gordon Pass assessment unit

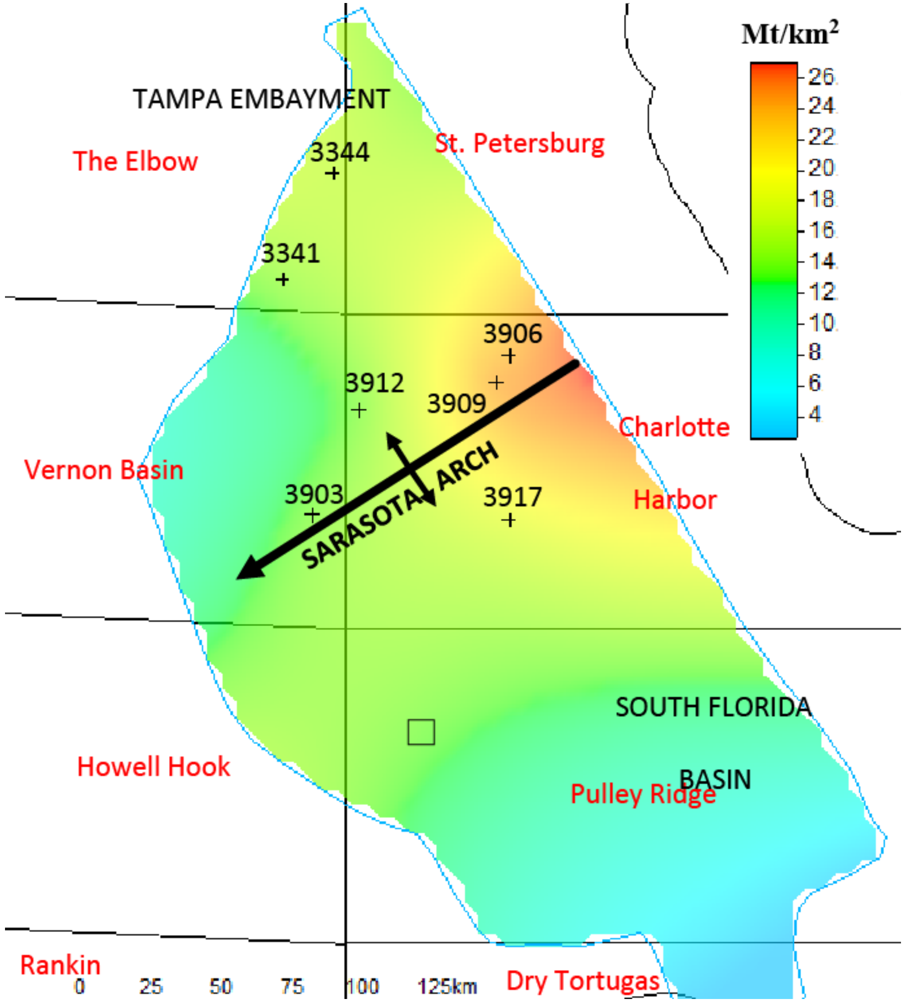


Panther Camp assessment unit



WFS Estimated CO_2 Storage Resource (P50) – Cenozoic

Cedar Keys assessment unit



CO_2 Storage Resource Estimates

DeSoto Canyon Salt Basin

Reservoir	P50 (Mt)
Paluxy	1.27
Washita-Fredericksburg	0.08
Lower Tuscaloosa	0.72
Paleocene – mid Eocene	32,000
upper Eocene – Miocene	88,000

Sarasota Arch

Reservoir	P50 (Mt)
Punta Gorda	87,000
Gordon Pass	85,000
Panther Camp	107,000
Lower Cedar Keys	121,000
Upper Cedar Keys	480,000

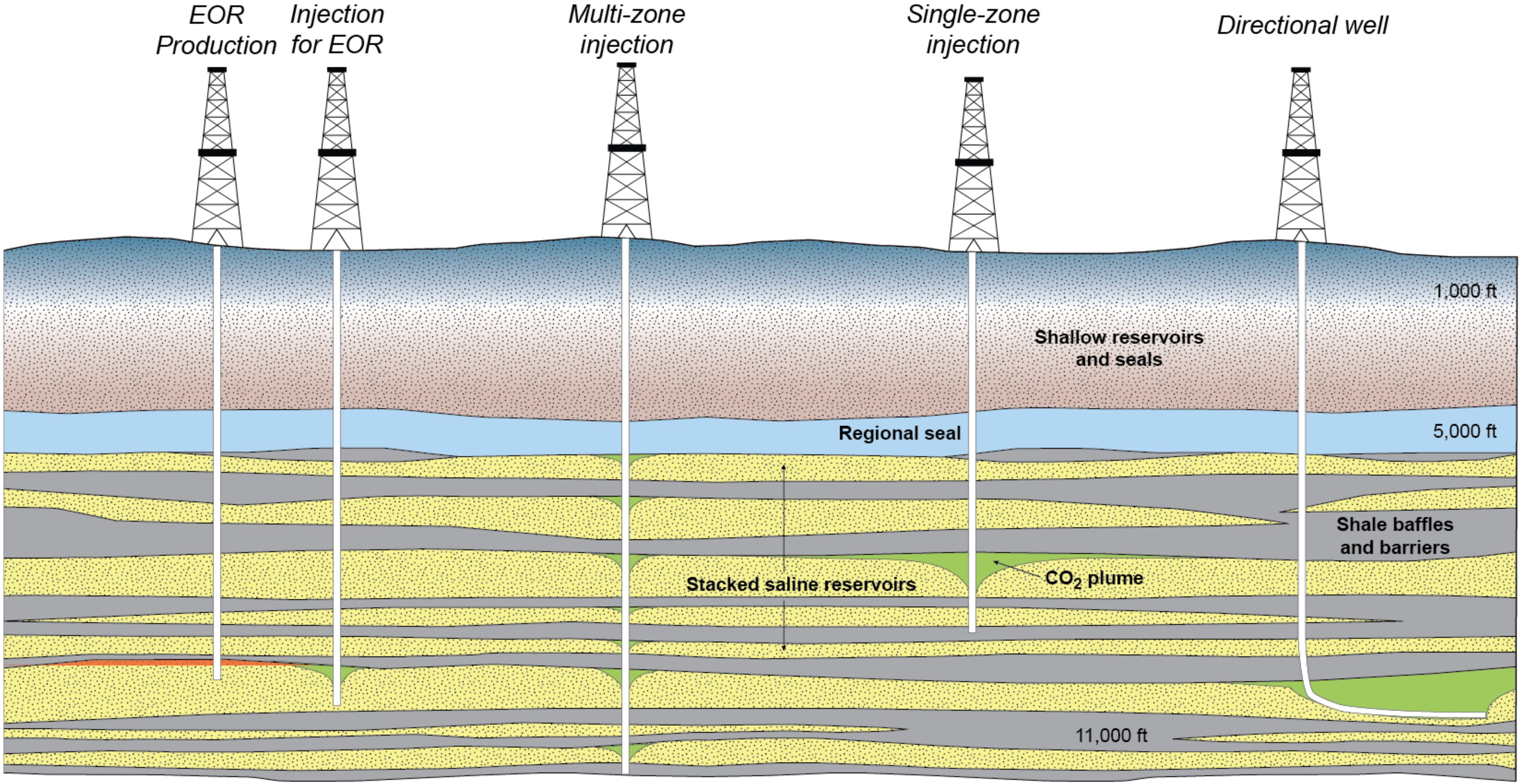
Total for the DSCB and WFA – 1,000 Gigatonnes (billion metric tonnes)

Summary of Potential CCUS Resource

- Large portfolio of potential sinks and seals in eastern Gulf of Mexico continental shelf.
- Main storage prospects in Cretaceous-Miocene section.
- Porosity of sandstone in DeSoto Canyon Salt Basin commonly > 20%; mudrock and chalk seals common.
- West Florida Shelf contains dolomite with porosity > 15% and anhydrite seals on Sarasota Arch.
- P_{50} storage resource of 1,027 Gt (148 Gt in DeSoto Canyon Salt basin, 879 Gt in West Florida Shelf).

NEXT STEPS
LEADING PRACTICES FOR CCUS DEVELOPMENT: COMPARING ONSHORE VS OFFSHORE STRATEGIES

Development Strategies



Geologic Characterization – Site Selection

Onshore Action	Description for BPM	Comparison to Offshore
Subsurface Geological Data Analysis - Storage Reservoir	Identify storage reservoirs and injection zones; Develop stratigraphic and structural framework using all available well and outcrop data.	No difference
Subsurface Geological Data Analysis - Confining Zone	Analyze confining zones; Create stratigraphic and structural framework of suitable confining zones, based on existing data.	No difference
Subsurface Geological Data Analysis - Trapping	Establish baseline geomechanical characteristics of targeted injection and confining zones.	No difference
Subsurface Geological Data Analysis - Mechanism	Evaluate trapping mechanisms for Selected Areas using available well, outcrop, and seismic data.	No difference
Subsurface Geological Data Analysis - Potential	Establish hydrogeological characteristics of injection and confining zones to assure reliable containment of injected CO_2.	No difference
Subsurface Geological Data Analysis - Injectivity	Perform initial estimate of injectivity of candidate injection zones, using available production history data, hydrologic test data, and analyses of core plugs.	No difference

Geologic Characterization – Site Selection

Onshore Action	Description for BPM	Comparison to Offshore
Model development - Modeling parameters	Identify types of models and modeling parameters needed to characterize the storage reservoir, confining zone, and fluid properties for Selected Areas.	No difference
Model development - Data Requirements and cost	Identify data requirements to optimize modeling results; conduct cost vs. benefit analysis to determine value of acquiring new data.	Data acquisition costs offshore tend to be significantly higher; data tends to be lower density due to higher cost
Model development - Boundary conditions/uncertainty	Identify and characterize uncertainties in modeling results; select boundary conditions which minimize uncertainties in modeling results.	No difference
Model development - Existing seismic data	If available, integrate existing seismic data in development of static and dynamic models for Selected Areas.	Offshore seismic data tends to be easier to work with due to no need for topographic corrections and easier avoidance of obstacles,

Geologic Characterization – Initial Site Characterization

Onshore Action	Description for BPM	Comparison to Offshore
Characterize Subsurface Geology - Geological and Geophysical	Establish geologic and geophysical framework of targeted injection and confining intervals for each Potential Site.	No difference
Characterize Subsurface Geology - Geochemical	Establish baseline geochemical data on fluids in the injection zone and in shallow groundwater aquifers above the injection zone.	Not necessary for offshore, as shallow aquifers are not an issue (?)
Characterize Subsurface Geology - Geomechanical	Establish baseline geomechanical characteristics of targeted injection and confining zones.	Less critical
Characterize Subsurface Geology - Hydrogeological	Establish hydrogeological characteristics of injection and confining zones to assure reliable containment of injected CO2.	No difference
Build and Calibrate Models	For each Potential Site, build static and dynamic model frameworks and populate with site-specific data for target reservoir.	Existing data may be sparser, leading to less control on model
Test Models	Test scenarios for a range of reservoir parameters and boundary conditions.	No difference
Compare Model Outputs	Compare model outputs to ensure consistency and reliability of models.	No difference

Geologic Characterization – Detailed Site Characterization

Onshore Action	Description for BPM	Comparison to Offshore
Acquire and Analyze New Data - Outcrop Studies	Conduct detailed mapping, sampling, and analysis of storage reservoir and caprock intervals within the vicinity of the designated Potential Site.	Existing data will be sparser, and new data more difficult to obtain, due to significantly higher cost and more difficult logistics
Acquire and Analyze New Data - Geophysical Data Acquisition	Conduct 2D or 3D seismic or other geophysical survey for improved stratigraphic and structural characterization of reservoir and caprock intervals.	Marine surveys generally have more complete data coverage than onshore; likely to already exist for areas of interest so may not be necessary to acquire new data - may just need to license existing data.
Acquire and Analyze New Data - Appraisal Well	Drill and log appraisal well, if needed, to constrain site-specific reservoir properties and caprock integrity.	Offshore wells are significantly more expensive and can be more difficult logistically.
Acquire and Analyze New Data - Pre-Injection CO2 Baseline	Establish pre-injection CO2 baseline levels to support future monitoring.	?? Potentially unnecessary
Update Models - Data Integration	Integrate all newly acquired outcrop, seismic, and well data into static and dynamic models for the designated Potential Site.	No difference
Update Models - Model Refinements	Refine static geologic model and reservoir simulations.	No difference

Risk Framework – Geologic Considerations

Attribute/Risk	Offshore GOM	Comparison to Onshore
Caprock seal properties	Generic risk of CO_2 leaking through the caprock, through the overburden, and to the seabed is considered negligible.	No difference between onshore and offshore
Geologic structure/lateral containment	Conventional stratigraphic and structural traps	No difference between onshore and offshore
Induced seismicity; stress	Low risk item (Soft rocks and large sedimentary stack above crystalline basement) but micro-seismic monitoring is an option onshore (surface or well based)	Risk not as critical due to a lack of buildings offshore; also, basin characteristics in the Gulf not prone to significant seismicity concerns
Existing faults. fractures	While the controlling mechanisms, location and nature of faults are well understood, the potential scale and duration of an event resulting in leakage depends uniquely on the nature and location of the fault. However, the generic risk of leakage is expected to be very low provided the fault does not extend from the storage site to the seabed.	No difference between onshore and offshore
Ground surface/seabed	Difficult, expense to monitor; lower density that onshore	Easier access to monitoring locations onshore; lends itself to frequent, high density monitoring

Risk Framework – Operational Considerations

Attribute/Risk	Offshore GOM	Comparison to Onshore
Legacy wells; P&A'd wells	Probably highest risk category for leakage from offshore operations	Similar relative risks in the offshore
Reservoir properties	Generally porous and permeable clastics	No difference between onshore and offshore
Monitoring Wells	Very expensive. Focus in offshore will be limiting new wells, little or no dedicated monitoring wells offshore	Relatively inexpensive
Injection strategy	Plume area offshore is of lesser concern a long as there are manageable leakage risks within AoR. Goal is to limit number of injection wells	Goal is generally to limit plume area/AoR

MVA Inventory – Examples with Probability of Successful Deployment

Atmospheric	Aqueous Column	Shallow Subsurface	Deep Subsurface
Intelligent Monitoring Systems (IMS) and SCADA[1]			
optical CO2 sensors[2]	seafloor penetrometers	Well integrity testing tests (internal and external integrity)[3]	
atmospheric tracers[2]	seafloor penetrometers	remote sensing (satellite imagery)[4]	wireline logging
	aqueous geochemistry and salinometers	soil/vadose zone geochemistry[5]	tracers (PFCs, isotopes)
	echo sounder systems (acoustic monitoring for bubbles)	shallow groundwater geochemistry[5]	borehole fluid sampling
	surface deformation (tiltmeters, extensometers, accelerometers, nano bottom pressure recorders)	ecosystem stress monitoring (including remote sensing)[6]	Crosswell geophysical methods, including electrical methods and crosswell seismic[7]

High	Moderate	Low

Moving Forward

- Continued work on resource assessment, refining current estimates on targeted reservoirs
  - Large portfolio of potential sinks and seals in eastern Gulf of Mexico continental shelf.
  - Main storage prospects in Cretaceous-Miocene section.
  - Porosity of sandstone in DeSoto Canyon Salt Basin commonly > 20%; mudrock and chalk seals common.
  - West Florida Shelf contains dolomite with porosity > 15% and anhydrite seals on Sarasota Arch.
  - P_{50} storage resource of 1,027 Gt (148 Gt in DeSoto Canyon Salt basin, 879 Gt in West Florida Shelf).
- Refinement of offshore CCUS leading practices guides for geologic characterization, MVA, risk evaluation and mitigation, and public outreach
  - Evaluation of alternative MVA techniques
  - Refinement of potential risks and mitigations
  - Identifying likely pain points in public outreach

SLIDE NOTES

SLIDE 1: TITLE (with abstract)

SECARB Offshore: Understanding the Potential for Subsea CO2 Storage in the Eastern Gulf of Mexico

Denise Hills, Marcella Redden, and John Koster, Geological Survey of Alabama

Abstract:

An estimated 40% of U.S. anthropogenic CO_2 emissions are generated in the southeast with a large portion of these emissions generated within 100 km of the coastline; this makes offshore geologic carbon dioxide (CO_2) subsea storage in the Gulf of Mexico (GOM) an attractive prospective. The project, "Southeast Regional Carbon Storage Partnership: Offshore Gulf of Mexico" (SECARB Offshore), is assembling the knowledge base required for secure, long-term, large-scale CO_2 subsea storage in the GOM with or without CO_2 enhanced hydrocarbon recovery (CO_2-EOR). SECARB Offshore supports the Department of Energy's (DOE) long-term objective to ensure a comprehensive assessment of the potential to implement offshore CO_2 subsea storage in all Bureau of Ocean Energy Management (BOEM) Outer Continental Shelf (OCS) Oil and Gas Leasing Program Planning areas in the GOM.

While onshore resources in the southeastern U.S. have been well-quantified, offshore resources are less understood and have different technical challenges. Building on the preliminary work conducted in previous studies, SECARB Offshore is undertaking a comprehensive resource characterization in the eastern GOM with more detailed evaluation of storage opportunities in federal and state waters (exclusive of Texas state waters), in active and depleted oil and gas fields (including those potentially associated with CO_2- EOR) as well as deep saline aquifers. When available, existing data are being utilized, with gaps being identified and addressed when possible.

Quantifying the potential resources is only the first step in understanding the potential for subsea CO_2 storage in the eastern GOM. Monitoring techniques will require modifications to address the unique challenges presented by offshore subsea CO_2 storage. For example, onshore monitoring often utilizes dedicated monitoring wells; this could be prohibitively expensive in an offshore setting. Thus, alternative monitoring methodologies are being evaluated as part of SECARB Offshore.

SLIDE 2: DISCLAIMER

SLIDE 3: PROJECT TEAMS

SOSRA Team: DOE/NETL; SSEB. OSU, GSA, ARI for EGOM; VT & USC with DMME and SC Geo Survey for Atlantic. (logos not pictured)

SECARB Offshore: DOE/NETL; SSEB; GSA; ARI; Battelle; SAS; Pale Blue Dot Energy; OSU; VT; LSU; Aker Solutions; IOM Law; Schlumberger

SLIDE 4: Why Offshore Reservoirs

Image: GOM OCS CO2 storage potential: current vs "next generation" CO2- EOR technology (Vidas et al., 2012)

Why offshore?

- Lots of CO_2 capacity (supplements onshore)
- Abundant stacked saline formations and depleted oil and gas reservoirs Offshore storage capacity near high production (heavily populated areas)
    - Eliminates NIMBY
- USDW protection
    - Fluids already have high TDS similar to sea water
    - Few USDW exist offshore
- Significant infrastructure in place
- Favorable ownership and access
    - Single entity primarily responsible for leasing, permitting, regulation
- Potentially more economical despite higher capital costs
- Proven offshore sequestration technology

Greatest volume of offshore potential is in saline reservoirs, with large volumes assessed in the GOM.

SLIDE 5: SETTING

SLIDE 6: SOSRA BACKGROUND

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

Summary:

Southeast Offshore Storage Resource Assessment (SOSRA) project will assess prospective geologic storage resources for CO2 in the State and Federal waters of the Mid-Atlantic, South Atlantic, and the eastern Gulf of Mexico. This study is just wrapping up, with a comprehensive baseline assessment of the potential capacity for CCUS offshore Atlantic and the EGOM.

Goal: Develop a high-level approximation of the amount of CO2 that might be stored utilizing key geologic and environmental factors that influence the storage potential.

Well control and velocity surveys for the EGOM. Jurassic through Miocene production. Lots of well control in Mobile and Viosca Knoll areas and right around Destin Dome (DeSoto Salt Canyon Basin); scattered wells elsewhere (West Florida Shelf – Tampa Embayment, Sarasota Arch, and South Florida Basin). All told, for the approximately 400 wells within the study area, there are about 3400 available logs. Log coverage is fairly good, but not for all log types. Sonic/velocity logs are scarcer.

The EGOM Basin hosts a sedimentary succession that is generally 20,000- 40,000 ft thick and includes the DeSoto Canyon Salt Basin and a giant carbonate platform (West Florida Shelf).

Paleozoic-Mesozoic basement rocks include large continental margin volcanic wedges. Triassic rift basins are developed locally, and a regionally extensive breakup unconformity is overlain the by Jurassic Louann Salt. Jurassic and Early Cretaceous strata above the salt contain a variety of extensional structures, including salt rollers, diapirs, and giant salt pillows. Upper Cretaceous strata are gently deformed and were deposited mainly on a stable continental shelf. Mesozoic strata include a complex array of carbonate and siliciclastic rock types.

The West Florida Shelf is very shallow and is dominated by carbonate strata of Mesozoic and Cenozoic age. Regionally, stratigraphic markers can be traced across large regions of the shelf. The west margin of the shelf, called the West Florida Escarpment, is very steep and forms a distinctive curvilinear feature bound by the Cretaceous reef trend.

SLIDE 7: DSCB STRATIGRAPHY

Regional stratigraphic cross-section for the Cretaceous in the Mobile area (Chandra 2018)

Paluxy (>20% porosity regionally)

Washita-Fredericksburg (>20% porosity regionally) Lower Tuscaloosa Group (>20% porosity regionally)

SLIDE 8: WFS STRATIGRAPHY

(Charbonneau 2018)

Stratigraphic column for the South Florida Basin study area. Storage assessment units consist of a reservoir (orange) and regional seal (white and purple). Modified from Braunstein and others (1988), Pollastro and others (2001), and Faulkner and Applegate (1986).

Of particular interest (shallowest to deepest)

- Cedar Keys SAU (seal middle Cedar Keys Fm, reservoir upper member of Lawson Fm and lower Cedar Keys Fm) porosity locally >20-30%
- Panther Camp SAU (seal Panther Camp Formation; reservoir Dollar Bay Fm) porosity locally >15%
- Gordon Pass SAU (seal upper Gordo Pass Fm; reservoir Marco Junction and Gordon Pass Fm) local porosity >15-20%
- Punta Gorda units SAU (seal Punta Forda Anhydrite, reservoir Wood River, Bone Island, Pumpkin Bay, and Lehigh Acres) local porosity >20%

SLIDE 9: CO2 CAPACITY

SLIDE 10: STORAGE CAPACITY CALCULATION

NETL's saline aquifer volumetric storage estimation method (NETL, 2015, Carbon Storage Atlas (5th Edition): Pittsburgh, National Energy Technology Laboratory, 114 p.)

SLIDE 11: STORAGE CAPACITY DSCB CRETACEOUS

CO2 storage resource assessments (P50) for the Paluxy sandstone and Lower Tuscaloosa sandstone. (SSEB, 2018, Chandra, 2018)

Note that capacity is generally controlled by unit thickness.

SLIDE 12: STORAGE CAPACITY DSCB CENOZOIC

Upper map: CO_2 storage resource estimate in (Mt/km2) for the upper Eocene through Miocene

Lower map: CO_2 storage resource estimate in (Mt/km2) for the Paleocene through mid Eocene

Again, primary control is sedimentary thickness

SLIDE 13: STORAGE CAPACITY WFS CRETACEOUS

Punta Gorda, Gordon Pass, and Panther Camp Assessment Units Mt/Km2

SLIDE 14: STORAGE CAPACITY WFS CENOZOIC

Resource estimate Upper Cedar Keys (Cenozoic) Mt/km2

SLIDE 15: STORAGE CAPACITY BY THE NUMBERS

Sum of the area under the surfaces – Total estimates assumes you could fill 14% of the pore space for the ENTIRE area.

SLIDE 16: SUMMARY OF POTENTIAL CCUS RESOURCE EGOM

SLIDE 17: ASSESSING LEADING PRACTICES FOR CCUS DEVELOPMENT, ONSHORE V OFFSHORE

SLIDE 18: DEVELOPMENT STRATEGIES

Single-Zone injection – relatively simple to drill and complete Multi-zone injection – smaller areal footprint than single zone Directional well – contact more of the reservoir with one well

What strategy will work best offshore? How to assess? Potential risks:

- Transport (pipeline)
- Injection (overpressure, well integrity)
- Leakage from confining zone (either through wells or faults)
- Groundwater interaction (saltwater incursion)
- Potential impacts on fauna

Legal, regulatory, engineering considerations

- Ownership/leasing (may be easier offshore)
- Well design, drilling, injection control
- Well direction (vertical, directional, single-zone, multi-zone)
- EOR (unlikely but discuss a bit more in another slide)
- Navigation fairways
- Tubulars and cement
- Completion and injection design
- Facilities (surface, subsea)
- Pipeline infrastructure (what exists, can it handle CO_2)

SLIDE 19: GEOLOGIC CHARACTERIZATION – SITE SELECTION

Geologic Characterization – Differences between onshore/offshore Site Selection (initial phase)

Actions in the DOE BPM for site selection are generally similar for subsurface geological data analysis; however there are some different challenges once you enter model development

SLIDE 20: GEOLOGIC CHARACTERIZATION – SITE SELECTION

Geologic Characterization – Differences between onshore/offshore Site Selection (initial phase)

While some phases of model development will be unchanged, data acquisition costs tend to be higher with the counter that the offshore data is often easier to work with.

SLIDE 21: GEOLOGIC CHARACTERIZATION – INITIAL SITE CHARACTERIZATION

Geologic Characterization – Differences between onshore/offshore Initial Site Characterization (phase II)

Actions in the DOE BPM for initial site characterization are again generally similar for subsurface geological data analysis, with less concern for shallow aquifers necessary. The modeling work is similar, with challenges primarily in data availability leading to less control on the model.

SLIDE 22: GEOLOGIC CHARACTERIZATION – DETAILED SITE CHARACTERIZATION

Geologic Characterization – Differences between onshore/offshore Detailed Site Characterization (phase III)

This is where there are the most differences with regard to Geologic Characterization. Again the primary issues are around data availability (existing data sparse; new data expensive). And in fact, a key element of onshore detailed site characterization is the drilling, logging, and coring an appraisal well, which may be cost-prohibitive offshore.

SLIDE 23: RISK FRAMEWORK– GEOLOGIC CONSIDERATIONS

Risk Framework for CO2 Injection in the Offshore GOM

Risks offshore related to geologic concerns are generally the same, or lower risk (e.g., induced seismicity less of a concern)

Most challenging risk is monitoring at the seabed due to operational expense. However, there is less concern with leakage at the seabed than in onshore environments.

SLIDE 24: RISK FRAMEWORK – OPERATIONAL CONSIDERATIONS

Risk Framework for CO2 Injection in the Offshore GOM – Operational (well bore) considerations

Risks themselves are similar, but operational expense is a concern – much more expensive to install monitoring wells, for example, so alternative ways of monitoring will need to be explored

The injection strategy may also change – onshore, the goal is generally to limit the plume area/AoR, but the concern offshore is to limit the number of injection wells due to expense.

SLIDE 25: MVA INVENTORY

MVA Inventory Framework

Many tested techniques for onshore have no offshore equivalent; however there are systems, tools, and techniques that have been proven for other uses.

Most of the methods identified so far have a high to moderate probability of successful deployment within the aqueous column and the deep subsurface. More challenging are MVA techniques for Atmospheric and the Shallow Subsurface. Work is continuing on identifying appropriate MVA technologies to exam those risks.

SLIDE 26: MOVING FORWARD

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"Best Practices: Site Screening, Site Selection, and Site Characterization for Geologic Storage Projects": https://www.netl.doe.gov/sites/default/files/2018-10/BPM-SiteScreening.pdf

"Best Practices: Risk Management and Simulation for Geologic Storage Projects": https://www.netl.doe.gov/sites/default/files/2018-10/BPM_RiskAnalysisSimulation.pdf

"Best Practices: Monitoring, Verification, and Accounting (MVA) for Geologic Storage Projects": https://www.netl.doe.gov/sites/default/files/2018-10/BPM-MVA-2012.pdf

"Best Practices: Operations for Geologic Storage Projects": https://www.netl.doe.gov/sites/default/files/2019-02/BPM_Operations_GeologicStorageClassification.pdf

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