Southeast Offshore Storage Resource Assessment: Opportunities in the Eastern Gulf of Mexico for CO_2 Storage*

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Abstract

Subsurface geologic storage of CO_2 (i.e., sequestration) can play a major role in offsetting greenhouse gas emissions in a manner that is safe, economical, and acceptable to the public. While onshore resources have been quantified, no comprehensive assessment of the offshore storage resource in the southeastern United States has yet been performed. The Southeast Offshore Storage Resource Assessment (SOSRA) is designed to fill this gap in knowledge by assessing storage potential in the eastern Gulf of Mexico (EGOM) and along the southeastern seaboard. An estimated 40% of U.S. anthropogenic CO_2 emissions are generated in the southeast, and a large proportion of these emissions are generated within 100 km of the coastline. A preliminary assessment of Miocene strata offshore of Alabama and Mississippi indicates that offshore storage capacity exceeds 200 Gt in these strata alone. Indeed, the EGOM region contains diverse opportunities for geologic storage. Strata deeper than 3,000 m are geopressured; therefore efforts are focusing on Cretaceous-Oligocene strata between 1,000 and 3,000 m. Salt basins in the northwest part of the study area contain large salt-tectonic structures hosting a broad array of storage prospects. The West Florida Shelf spans the southeastern part of the study. The shelf can be characterized as a broad carbonate bank and structurally simple compared to the salt basins. Phase I is underway and is providing an overview of the basic geologic framework of the SOSRA region, identifying potential storage units, and defining the key planning areas. Phase II, set to begin in April 2017, will include a robust characterization of offshore CO_2 storage reservoirs and seals, as well as a probabilistic assessment of storage capacity.

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

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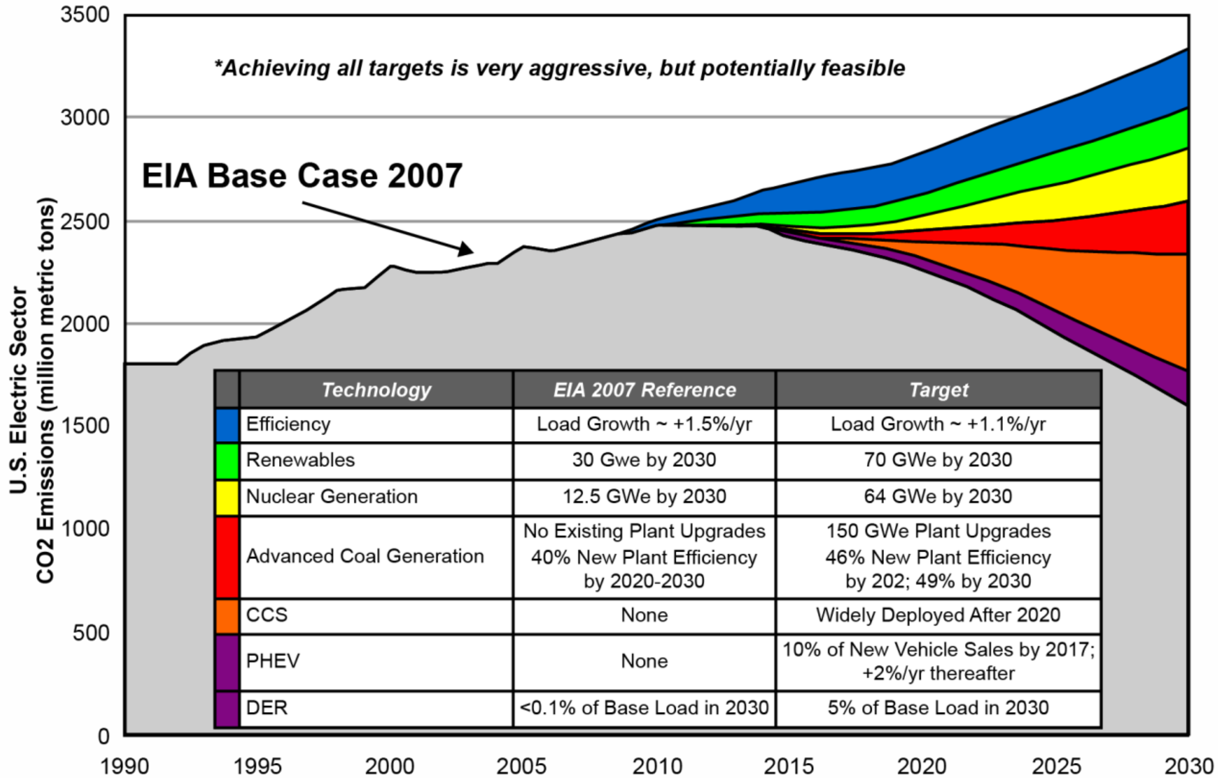
Why CCUS?

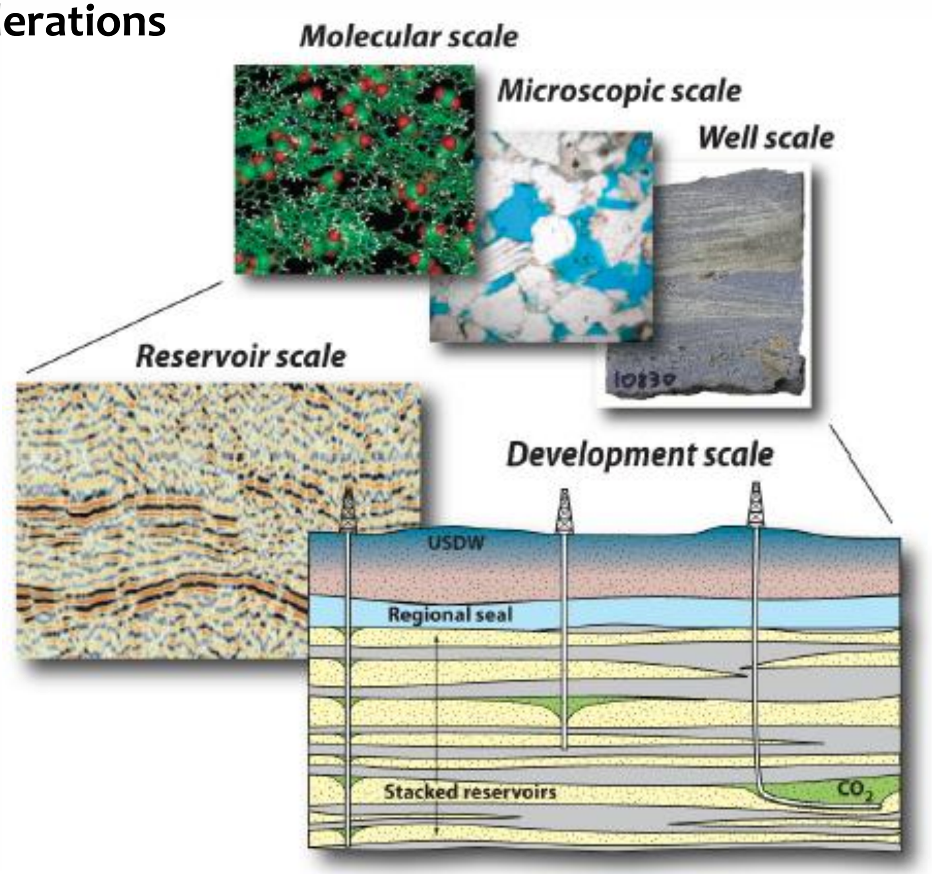


Technology	EIA 2007 Reference	Target
Efficiency	Load Growth ~ +1.5%/yr	Load Growth ~ +1.1%/yr
Renewables	30 Gwe by 2030	70 GWe by 2030
Nuclear Generation	12.5 GWe by 2030	64 GWe by 2030
Advanced Coal Generation	No Existing Plant Upgrades 40% New Plant Efficiency by 2020-2030	150 GWe Plant Upgrades 46% New Plant Efficiency by 202; 49% by 2030
CCS	None	Widely Deployed After 2020
PHEV	None	10% of New Vehicle Sales by 2017; +2%/yr thereafter
DER	<0.1% of Base Load in 2030	5% of Base Load in 2030

EPRI "Prism" report: http://mydocs.epri.com/docs/public/DiscussionPaper2007.pdf

Presenter's notes: CCUS: Carbon Capture Utilization and Storage.

Geological Considerations



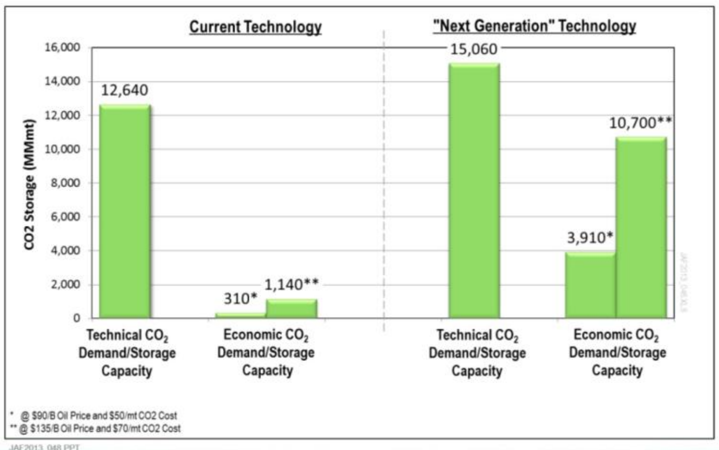
Presenter's notes: (Image from IOGC Report): Site characterization and selection requires the consideration of reservoir properties and infrastructure at multiple scales.

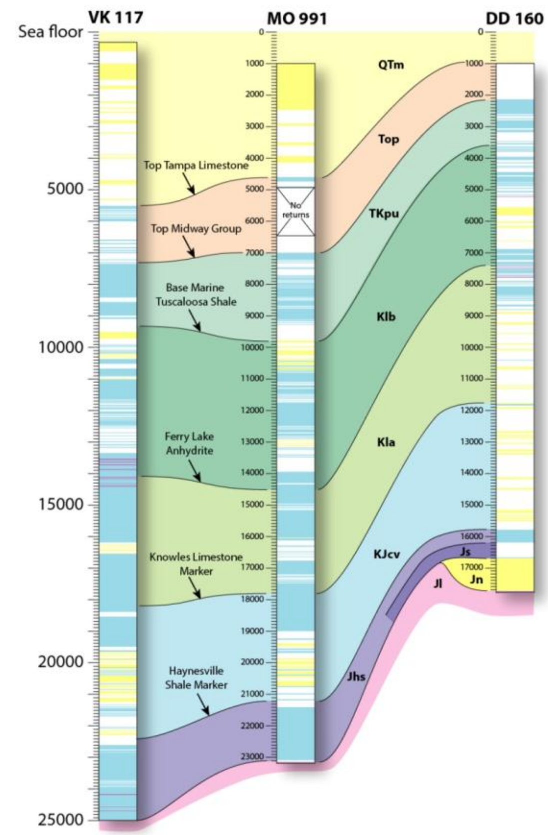
Geologic considerations:

- Reservoir thickness, extent, and heterogeneity
- Depth, pressure, and temperature
- Formation composition, geochemistry
- Geologic structure (i.e., folding, faulting, fracturing)
- Seal integrity

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





Presenter's notes:
Image (left): GOM OCS CO_2 storage potential: current vs "next generation" CO2-EOR technology (Vidas et al., 2012)
Image (right): offshore sections (from Hills and Pashin, 2010)

Why offshore?
- Lots of CO_2 capacity (supplements onshore)

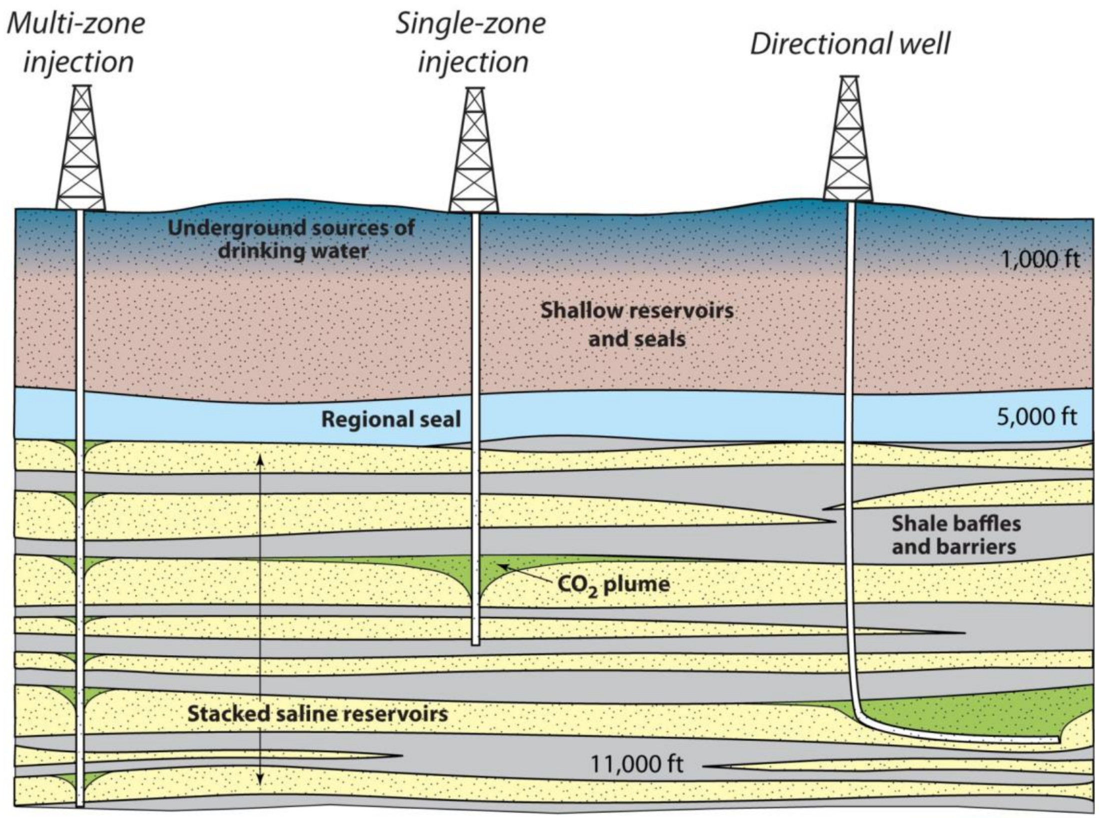
(Presenter's notes continued on next slide)

(Presenter's notes continued from previous slide)

- 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.

How Do We Adapt Proven Storage Strategies?



Presenter's notes: Lots of options for development in offshore areas. Which strategies will be most technically effective and cost-effective in offshore areas?

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

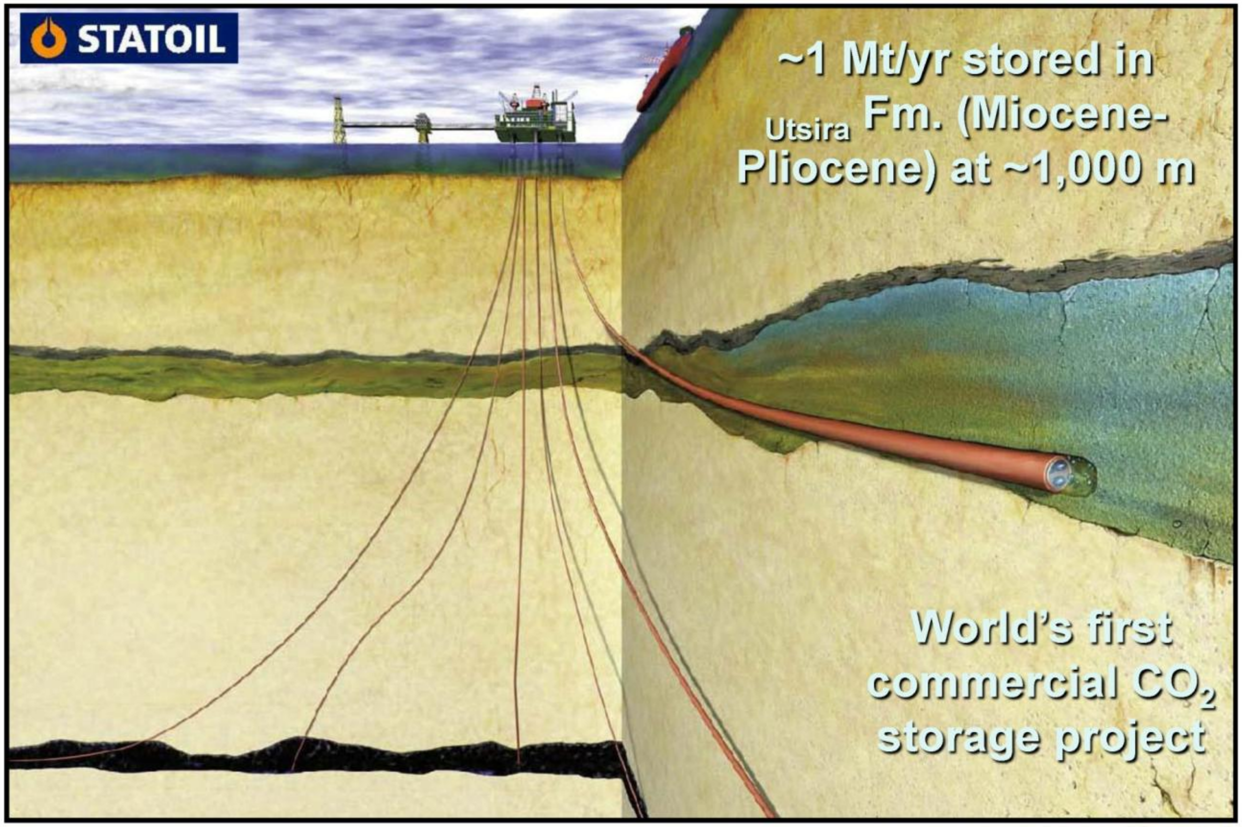
(Presenter's notes continued on next slide)

(Presenter's notes continued from previous slide)

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)

Offshore CO_2 Storage: Sleipner, North Sea



Kaarstad (2004)

Presenter's notes: Offshore sequestration technology established in North Sea, Barents Sea by Norwegians. They have a ~$50/ton carbon tax that is significant driver.

Sleipner demonstrates feasibility of offshore sequestration. Sleipner directed at separation of CO2 from gas-condensate stream with sequestration in shallow saline formation above hydrocarbon target.

Summary of Sleipner project:
Located in the North Sea off Norway.

(Presenter's notes continued on next slide)

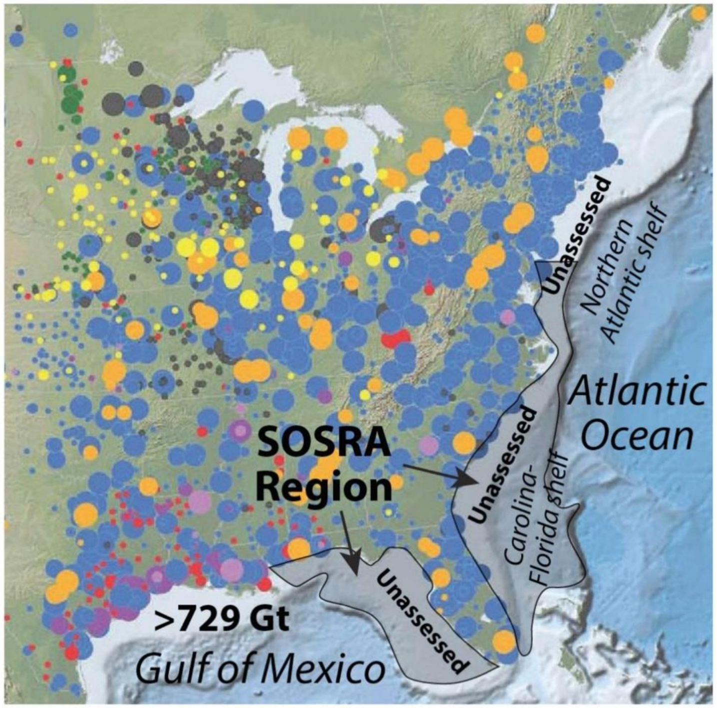
(Presenter’s notes continued from previous slide)

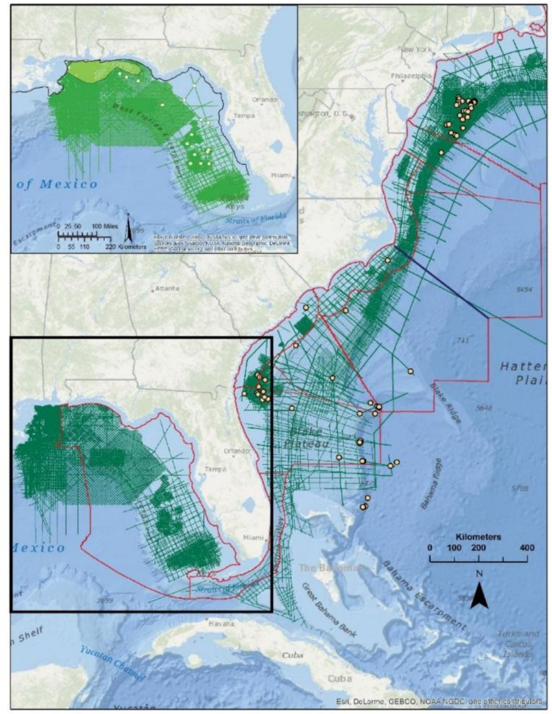
Run by Statoil
Stores 0.9 Mt/yr in the Utsira Formation, a deep saline reservoir 800-1000 m (2600-3000ft) below the sea floor

First commercial CO_2 storage project. CO_2 is removed from produced gas to meet export specifications and customer requirements. The CO_2 is removed from the produced hydrocarbons at an offshore platform before being pumped back into the ground and the hydrocarbons pumped to land.

The Utsira Formation is a 200-250m thick massive sandstone. Estimated capacity of 600 billion tons of CO_2.
Since the project’s inception through June 2015, around 15.5 million tonnes of CO_2 have been injected.

Southeast Offshore Storage Resource Assessment (SOSRA)

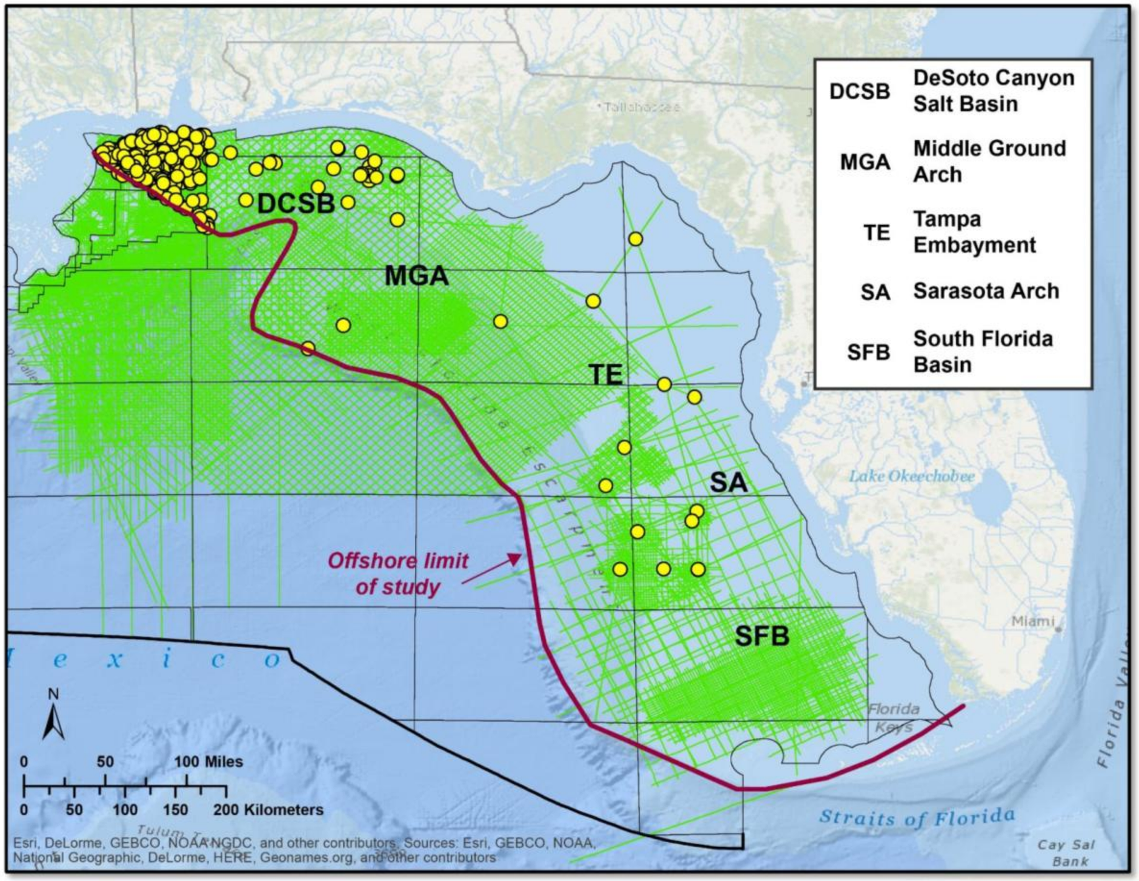




Presenter's notes: Southeast Offshore Storage Resource Assessment (SOSRA)
Project Number: DE-FE0026086
Summary:
Southeast Offshore Storage Resource Assessment (SOSRA) project will assess prospective geologic storage resources for CO_2 in the State and Federal waters of the Mid-Atlantic, South Atlantic, and the eastern Gulf of Mexico.

Goal: Develop a high-level approximation of the amount of CO_2 that might be stored utilizing key geologic and environmental factors that influence the storage potential.
To date, only limited studies have been conducted.
OSU and GSA will be focused on work in the Eastern GOM.

Study Area and Subregions



Presenter's notes: OSU and GSA will be focused on work in the Eastern GOM.

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 (Tampa Embayment and South Florida Basin).

(Presenter's notes continued on next slide)

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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 Tampa Embayment and South Florida Basin constitute the West Florida Shelf, which has been a site of limited hydrocarbon exploration and thus sparse well control.

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.

Although offshore petroleum production has yet to be proven in this area, the strata that form the shelf contain significant source rocks, reservoirs, and seals onshore in the Sunniland trend (Mitchell-Tapping, 1984) and have significant CO_2 storage potential (Roberts-Ashby et al., in review).

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 logs types. Sonic/velocity logs are scarcer.

A Tale of Two Platforms

Ultradeep gas platform

Shallow gas well

Presenter's notes: Preliminary targets for CO_2 sequestration have been identified (e.g., Hills and Pashin, 2010) in northern part of study area

- Miocene sands (both state and federal waters)
- Cretaceous strata (federal waters)

Additional targets in Western FL escarpment
There are challenges in the EGOM:

(Presenter's notes continued on next slide)

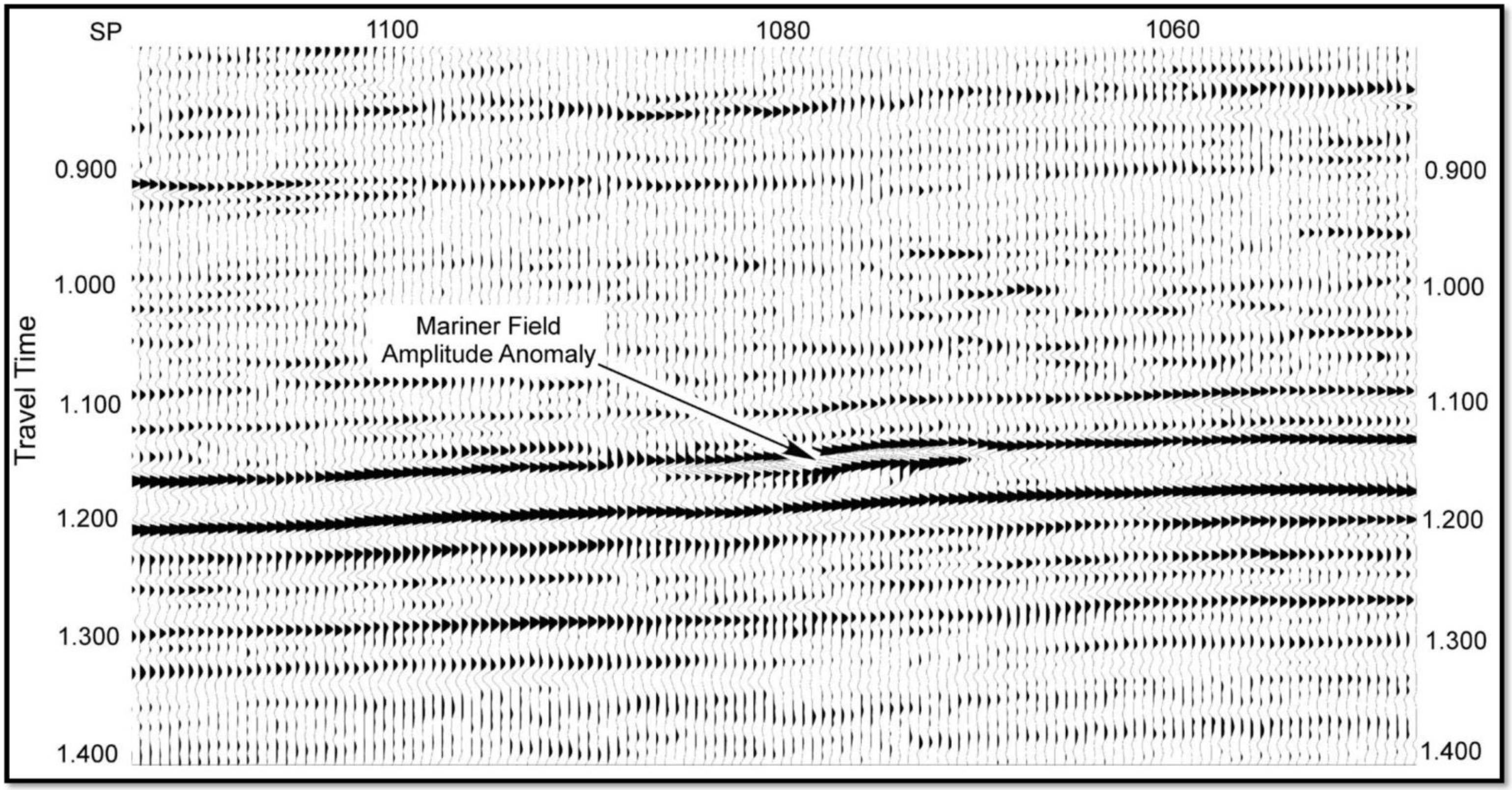
(Presenter's notes continued from previous slide)

Petroleum exploration, however, has proven technically challenging in the region, and the greatest success has been found in the ultra-deep (>20,000ft) natural gas reservoirs of the Mobile area. Although the proven petroleum reservoirs in the region are too deep to facilitate economically viable CO2- enhanced recovery operations, porous intervals have been identified in shallower carbonate and siliciclastic strata (Petty, 1997, 1999).

Offshore infrastructure quite variable. Giant Norphlet platform contrasted with tiny Miocene platform, all in Alabama state waters in Mobile area.

View shed issue major constraint on offshore development. Subsea operations could keep wells out of sight.

Miocene Gas Sands

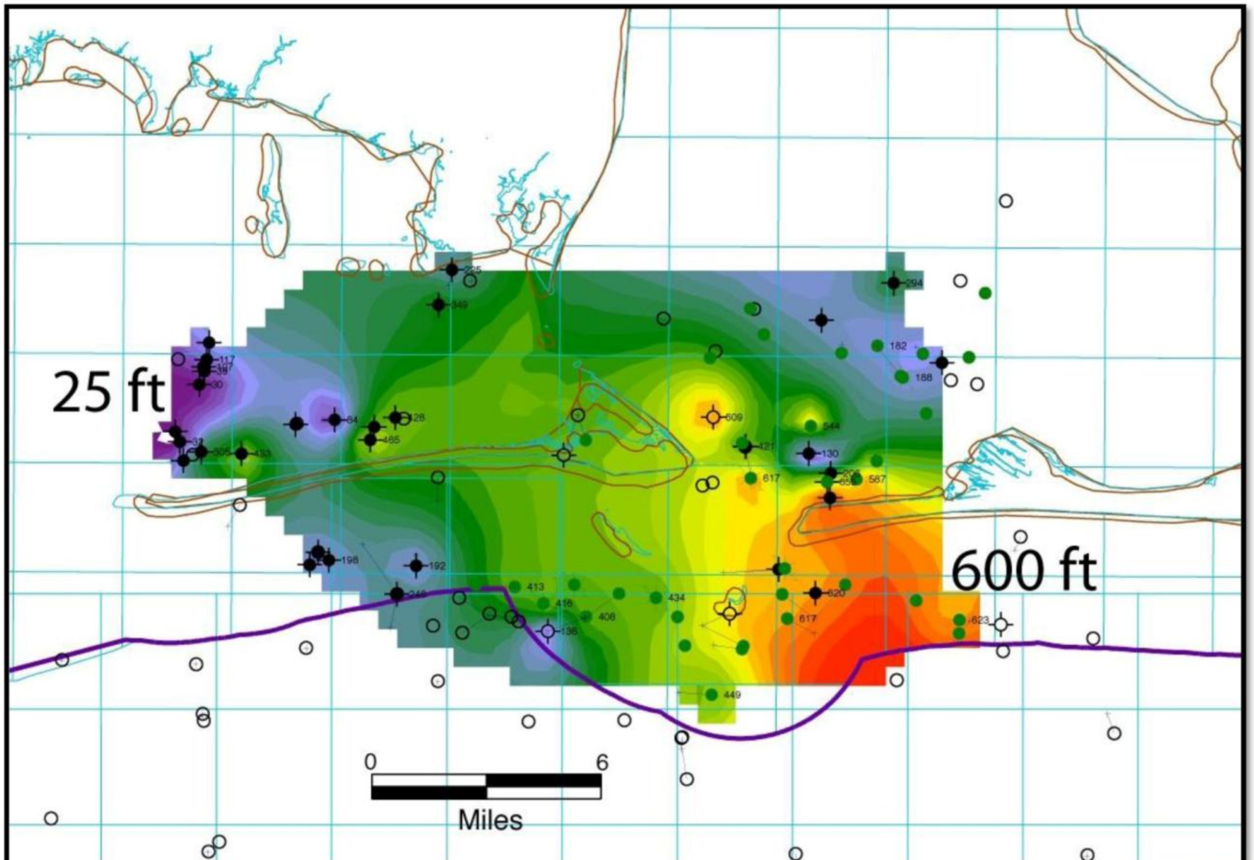


Handford and Baria (2003)

Presenter's notes: Seismic profile from Mariner Field, southern Mississippi, showing amplitude anomaly (bright spot) associated with gas accumulation.
Miocene bright spot plays provide shallow opportunities. Amplitude anomalies associated with gas accumulations readily identified in seismic, but these are just tips of the iceberg. Water-filled sands don't image as bright spots.

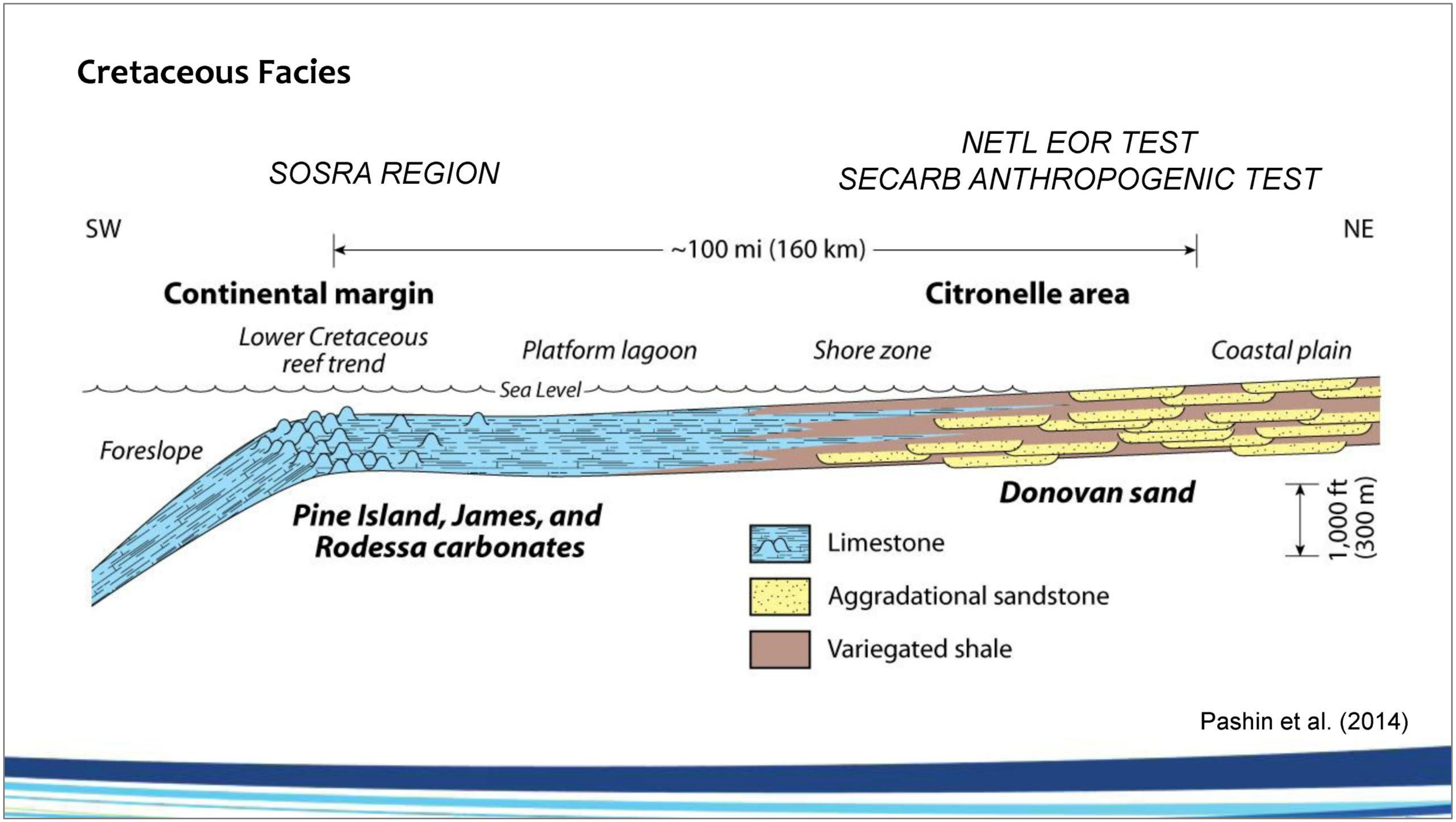
Preliminary analysis indicates that the bulk of the storage capacity in Miocene sandstone resides in saline formations below the commercial gas accumulations.

Net Miocene Sand >2,500 ft Deep, Offshore Alabama



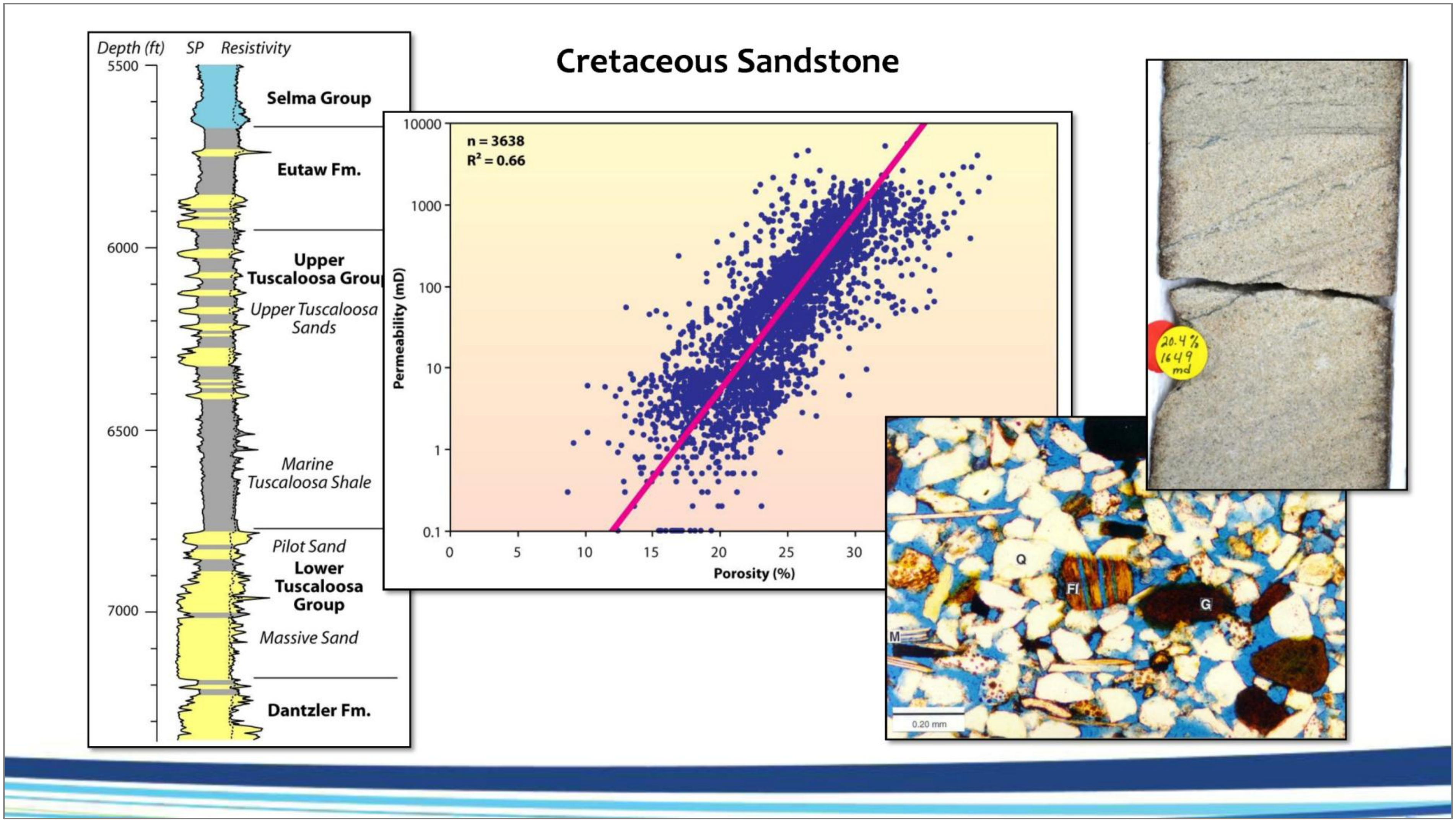
Hills (2010)

Presenter's notes: Preliminary work: Preliminary work (Hills and Pashin, 2010):
Figure: Net Miocene Sand, AL State waters. Sands shallower than 2480 were excluded (to reach CO_2 super-critical/be below any potential USDW)
Variable sand distribution, but major sequestration potential where the sands are stacked. Pore volume was calculated using a porosity of 25%. Using an efficiency factor of 10%, and a CO_2 density of 0.7 g/cc
Storage of 9.1 x 10^9 mt (Fed), 1.0 x10^9 mt (state)
Capacity 3.4 x 10^7 (fed), 9.4 x 10^5 mt/mi2(state)



Presenter's notes: Diverse sandstone and carbonate facies in Cretaceous, including reef-rimmed continental margin. Cretaceous facies in the region are dominated by sliliciclastic coastal plain deposits that pass basinward into reef-rimmed carbonate platform deposits. Siliciclastic strata include formations that have been tested for CO2 storage potential onshore, whereas the storage potential of carbonate formations is less certain.

Previous work on the Cretaceous strata has largely been on-shore.
Preliminary offshore capacity estimates (Hills and Pashin, 2010):
min volume >8.9 x 10^10 mt;
min capacity of 3.3 x 10^6 mt/mi^2

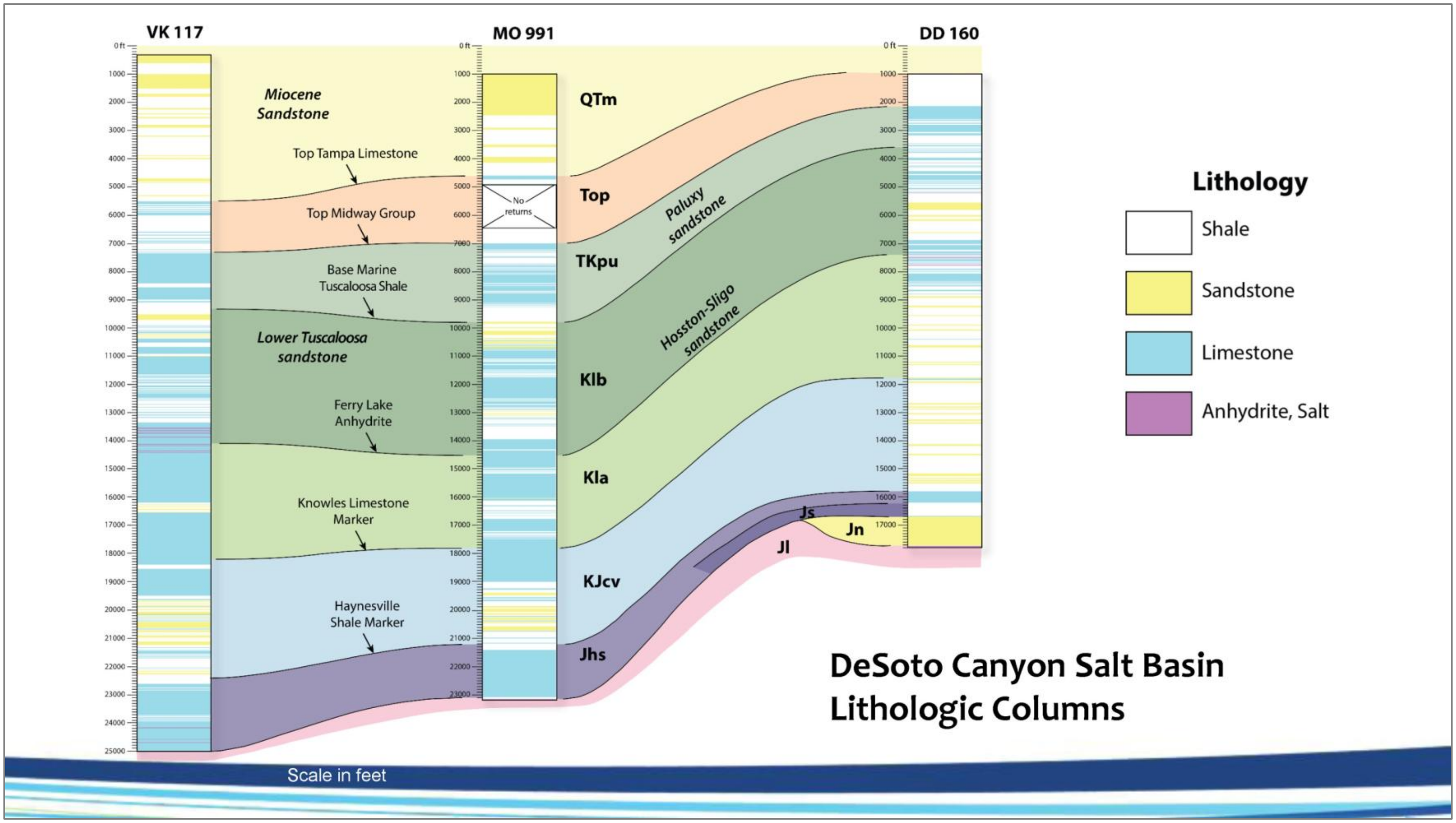


Presenter's notes: Cretaceous Gulf Coast sands are trés bien. Lots of stuff like this in Cretaceous-Tertiary section in offshore EGOM.

Onshore, much of the sequestration potential has been identified in the Upper and Lower Tuscaloosa Group.

Upper right figure (Figure 3, Pashin et al., 2008): Cross-plot of porosity and permeability data from core analyses of sandstone from the Paluxy Formation through the Eutaw Formation in southwestern Alabama.

Consistent mean porosity values above 23.3 % have been observed in all the analyzed stratigraphic units.



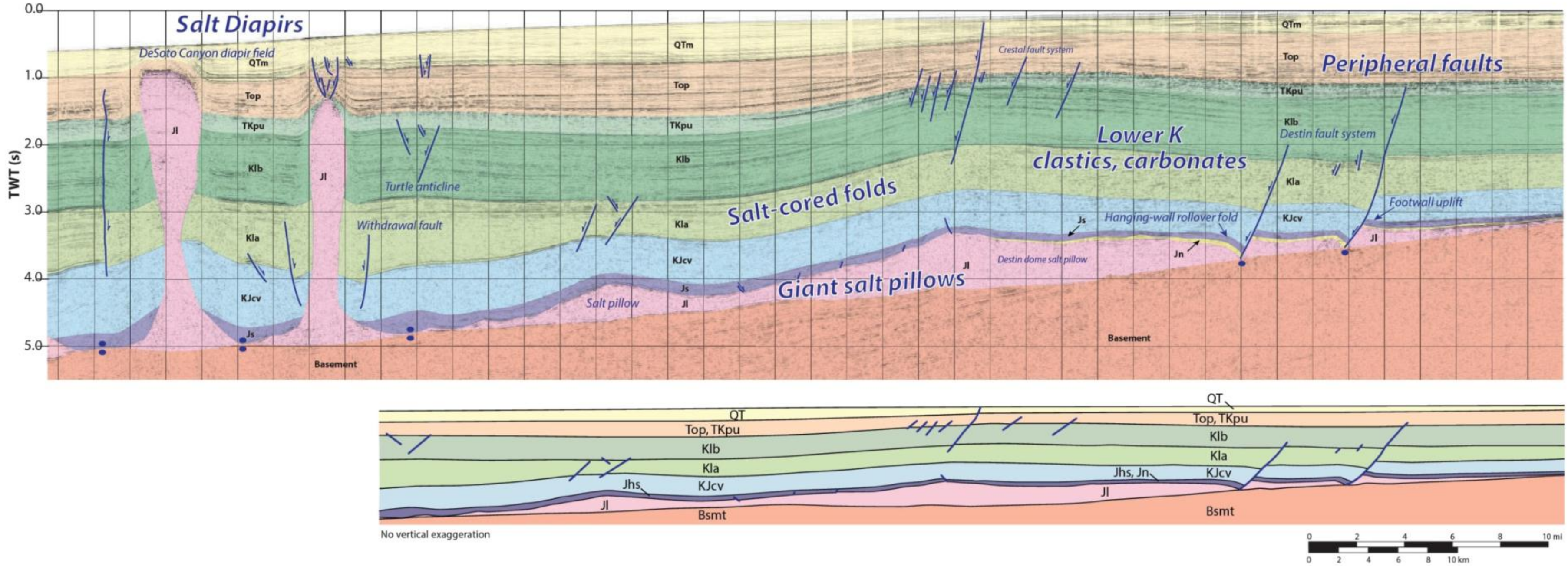
Presenter's notes: Lithologic logs showing rock types and major mappable stratigraphic units in the DeSoto Canyon Salt Basin. (enlarged in next slide)

Cretaceous sandstone targets would most likely be found in the Lower Cretaceous B and A and more commonly in the the Cotton Valley Group. Multiple seals are present above these strata (Ferry Lake Anhydrite, the Marine Tuscaloosa Shale)

QTm – Quaternary-Miocene
TKpu – Paleocene-Upper Cretaceous
Kla – Lower Cretaceous A
Jhs – Haynesville and Smackover Fms
Jn – Norphlet Fm

Top – Oligocene-Paleocene
Klb – Lower Cretaceous B
KJcv – Cotton Valley Group
Js – Smackover Fm
Jl – Louann Salt

DCSB Destin Dome

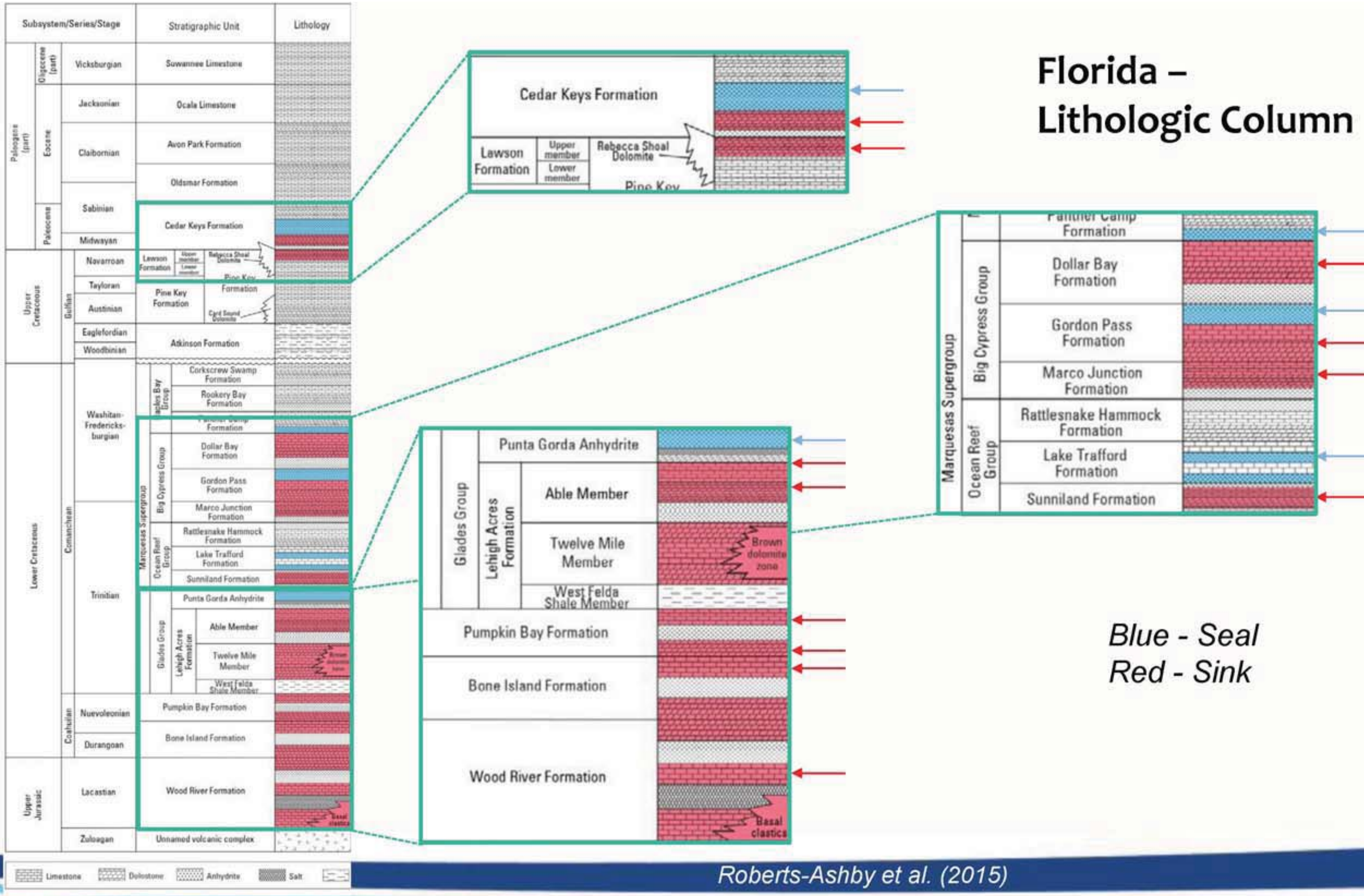


Presenter's notes: Structural Style, Northeastern Salt Basin.
Seismic profile showing structural style of the northeastern DeSoto Canyon Salt Basin.

QTm – Quaternary-Miocene
TKu – Paleocene-Upper Cretaceous
Kla – Lower Cretaceous A
Jhs – Haynesville and Smackover Formations
Basement – Paleozoic and Mesozoic basement

Top – Oligocene-Paleocene
Klb – Lower Cretaceous B
KJcv – Cotton Valley Group
Jl –Louann Salt

Florida – Lithologic Column

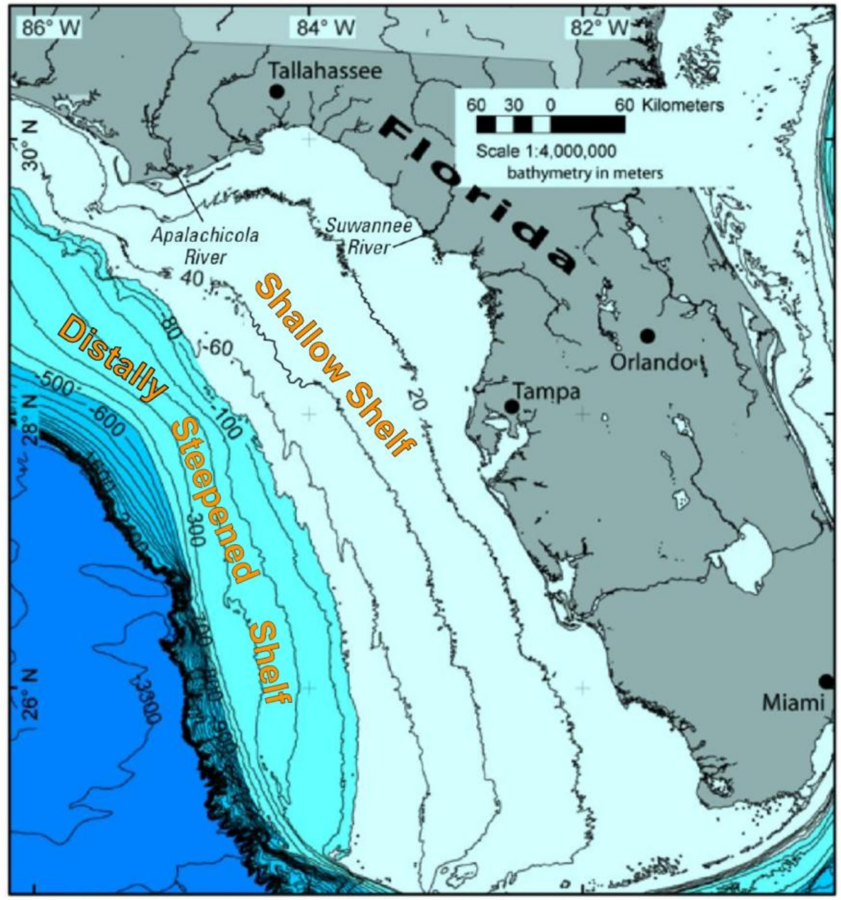


Blue - Seal
Red - Sink

Roberts-Ashby et al. (2015)

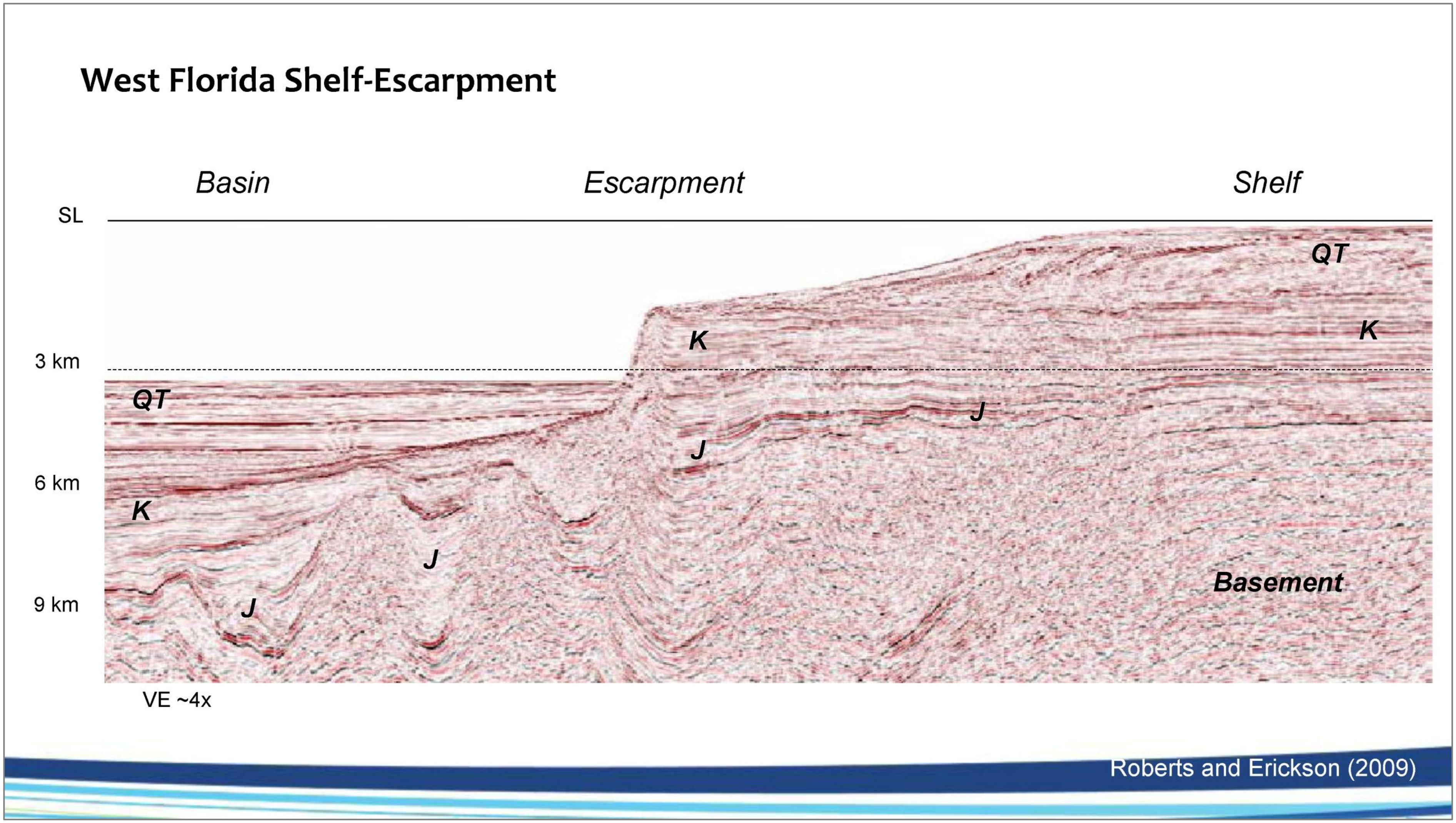
West Florida Shelf Bathymetry

- Broad, shallow, region near shore (NE of 80 m contour).
- Distally steepening outer shelf leading to West Florida Escarpment.



Presenter’s notes: Bathymetric map of the West Florida Shelf (source: USGS). Note progressive steepening of the continental slope, culminating in the West Florida Escarpment.

Broad, shallow, region near shore (NE of 80 m contour).
Distally steepening outer shelf leading to West Florida Escarpment



Presenter's notes: Pre-stack, depth converted seismic profile showing geologic architecture along a transect from the West Florida Shelf to the continental rise (after Roberts and Erickson, 2009). Note major carbonate platform bounded by Cretaceous reef trend and overlain by prograded shelf. Structures southwest of platform include apparent Mesozoic mini basins below subhorizontal Cenozoic strata of the continental rise.

Thick Jurassic/Cretaceous section in the deepwater outboard of the escarpment showing all the plays associated with an autochthonous salt basin.

(Also evidence for an extension of the Norphlet SS along foot of escarpment)

Observations and Further Questions

- Large portfolio of potential sinks and seals in eastern Gulf of Mexico region.
  - Complex structural chronology, stratigraphic architecture in DeSoto Canyon Salt Basin.
  - Relatively simple Cretaceous carbonate platform and distally steepened Cenozoic shelf in West Florida.
  - Geopressure >12,000 ft; main storage prospects in Cretaceous-Miocene section.
- Seismic and well data currently being compiled and analyzed to address questions:
  - Is sufficient porosity, permeability available in carbonate units to support commercial offshore storage?
  - Are robust reservoir seals developed above Miocene sand units?

Presenter's notes:

•High-quality public 2D seismic data available.
•Geophysical log coverage spotty above Jurassic.