

CO_2 Storage Capacity in the Eastern Gulf Coast Portion of the SECARB Region

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SECARB Stakeholders Briefing

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Unconventional Resources • Enhanced Recovery • Carbon Sequestration

Advanced Resources International, Inc.

Presentation Outline

1. Regional CO_2 Storage Capacity in Cretaceous-Age Saline Reservoirs: Eastern Gulf Coast.
2. Utilization of CO_2 for Enhanced Oil Recovery: Eastern Gulf Coast.
3. Site Specific CO_2 Storage Capacity in Cretaceous-Age Saline Reservoirs: Eastern Gulf Coast.
4. CO_2 Storage Capacity in the Basal Sandstone Saline Reservoir: Central Tennessee.

1. Regional CO_2 Storage Capacity in Cretaceous-Age Saline Reservoirs: Eastern Gulf Coast

The "stacked", thick and porous Cretaceous-age saline reservoir along the Eastern Gulf Coast (Alabama, Georgia, Florida Panhandle and Mississippi) offer highly concentrated (10 to 50 MMt of CO_2 per mi^2) capacities for storing CO_2.

In April 2011, Advanced Resources completed a geological study and CO_2 storage assessment for four of these "stacked" Cretaceous saline formations - - Eutaw, Washita-Fredericksburg, Paluxy and Lower Cretaceous Undifferentiated.*

A previous CO_2 storage assessment for the Lower Tuscaloosa saline formation, conducted by Advanced Resources in 2009, was added to establish overall saline formation CO_2 storage capacity for the Eastern Gulf Coast portion of the SECARB area.**

*"Lower and Upper Cretaceous Characterization Report", SECARB Phase III Work Product 1.4.c, prepared for: U. S. Department of Energy, National Energy Technology Laboratory, prepared by: Advanced Resources International, Inc., April 30, 2011.

**Advanced Resources International, Inc., 2009 A, Geologic Storage Capacity for CO2 of the Lower Tuscaloosa Group and Woodbine Formations for the Phase III Work Product 1.1.c.

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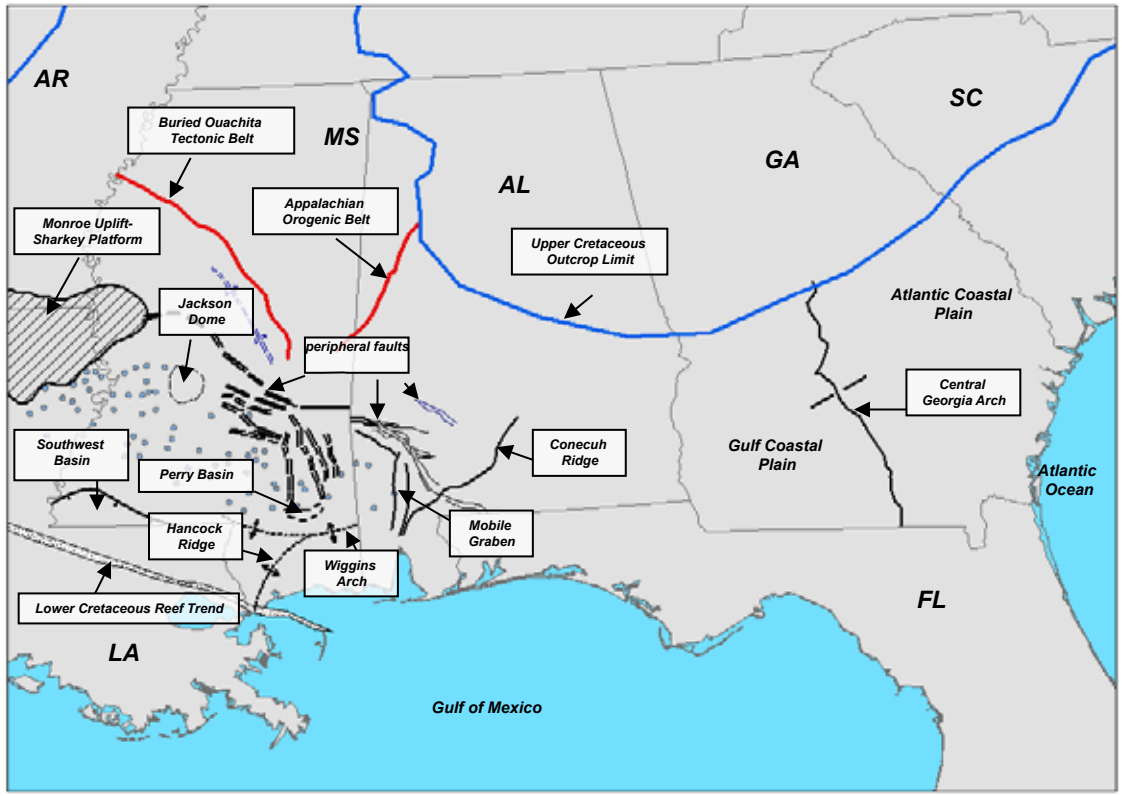
1. Regional CO_2 Storage Capacity in Cretaceous-Age Saline Reservoirs: Eastern Gulf Coast

Stratigraphic Column

System	Series	Stratigraphic Unit	Major Sub Units		Potential Reservoirs and Confining Zones
Cretaceous	Upper	Selma Group			Confining Unit
		Eutaw Formation			Minor Saline Reservoir
		Tuscaloosa Group	Upper Tusc.		Minor Saline Reservoir
			Mid. Tusc.	Marine Shale	Confining Unit
			Lower Tusc.	Pilot Ss Massive Ss	Saline Reservoir Small Scale Injection Test/ Plant Daniel (MS)
Cretaceous	Lower	Washita-Fredericksburg Interval	Dantzler Ss		Saline Reservoir
			Shale		Primary Confining Unit
		Paluxy Formation	'Upper' 'Middle' 'Lower'		Saline Reservoir Anthropogenic Test Site/Plant Barry (AL)(Citronelle Dome)
		Mooringsport Formation			Confining Unit
		Ferry Lake Anhydrite			Confining Unit

Eastern Gulf Coast Portion of the SECARB Region



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CO_2 Storage Assessment: Methodology, Data and Criteria

The CO_2 storage assessment methodology involved: (1) assembling reservoir data and interpreting over 200 well logs; (2) using these data to construct a series of regional cross-sections; and (3) establishing key reservoir properties for each of these five "stacked" Cretaceous-age formations in the Eastern Gulf Coast.

- Storage reservoir depth of greater than 3,000 feet and less than 14,000 feet.
- Presence of regional seals, including the Midway Shale, the Selma Chalk and the Marine Tuscaloosa Shale.
- Incorporation of porosity, pressure/temperature and reservoir thickness (gross/net) to calculate theoretical CO_2 storage capacity.
- Use of CO_2 storage efficiency factors (from 2010 DOE Carbon Sequestration Atlas) (to calculate usable CO_2 storage capacity.

CO_2 Storage Capacity: Eutaw Saline Formation

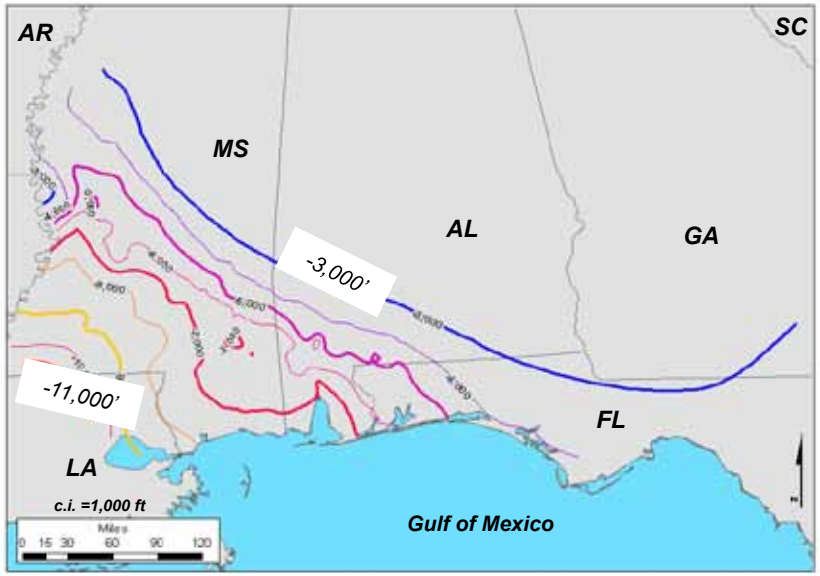
The Eutaw saline formation is the shallowest of the five "stacked" Cretaceous-age reservoirs.

The gross thickness in the favorable depth interval (3,000 to 14,000 feet) ranges from 100 to 600 feet, with a net thickness of 40 to 70 feet.

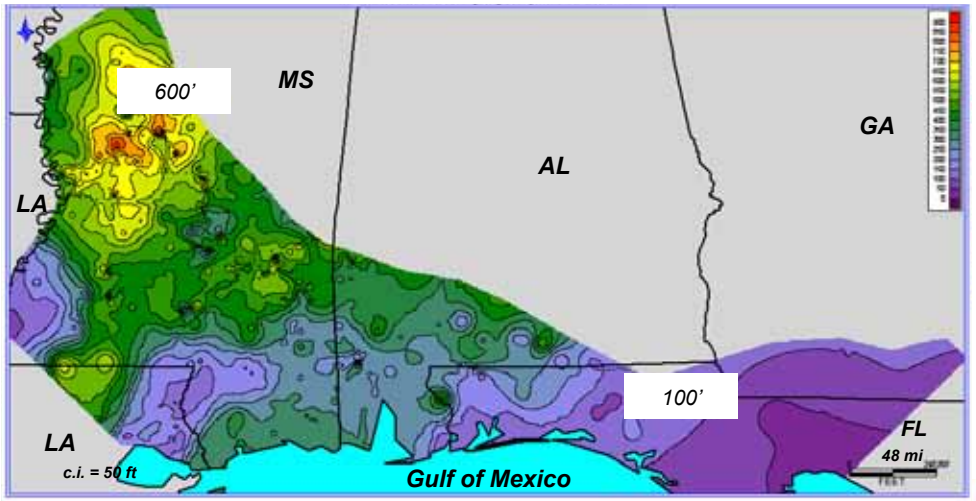
CO_2 Storage Assessment Input Data: Eutaw Saline Reservoir

STATES	Total Area (Mi^2)	Avg Depth (ft)	Avg Net Thickness (ft)	Avg Porosity (%)	Pore Volume (tcf)	CO_2 BG (res cf/scf)	CO_2 Capacity (Gt) (E=100%)
Alabama	8,830	-5,120	50	25%	3	0.0037	47
Florida	11,920	-4,430	40	24%	3	0.0042	39
Mississippi	27,330	-6,060	70	25%	14	0.0034	216
Georgia	860	-3,100	50	20%	0.3	0.0061	2

Eutaw Formation, Depth (Subsea)



Eutaw Formation, Gross Interval Thickness



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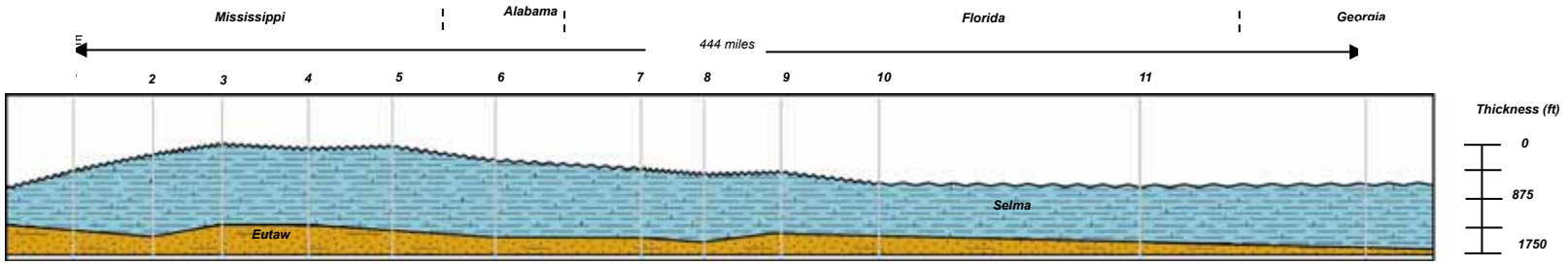
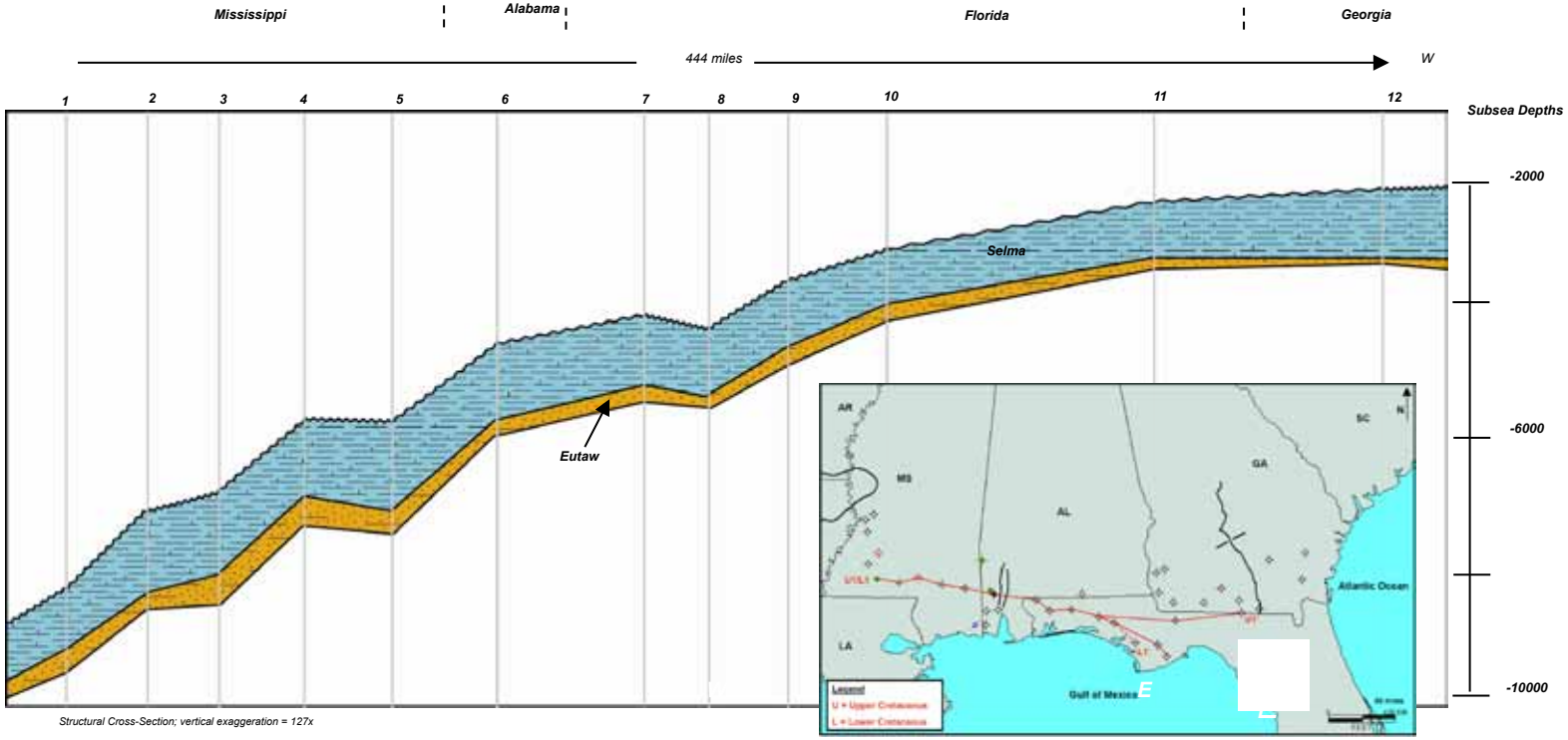
Stratigraphic and Structural Cross-Sections for Eutaw Formation and Selma Group, West Mississippi to Southwest Georgia



Stratigraphic cross-section; Datum = Upper Tuscaloosa



Structural Cross-Section; vertical exaggeration = 127x

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CO_2 Storage Capacity: Washita-Fredericksburg Group Saline Formation

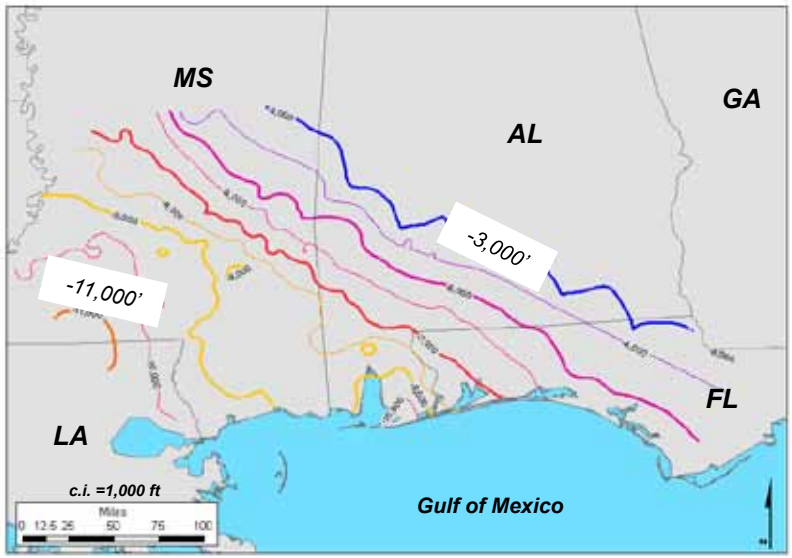
The Washita-Fredericksburg Group saline formation (below the Lower Tuscaloosa) is the third of the five Cretaceous-age "stacked" reservoirs in the Eastern Gulf Coast.

The gross thickness in the favorable depth interval (3,000 to 14,000 feet) ranges from 1,200 to 2,500+ feet, with a net thickness of 480 to 870 feet.

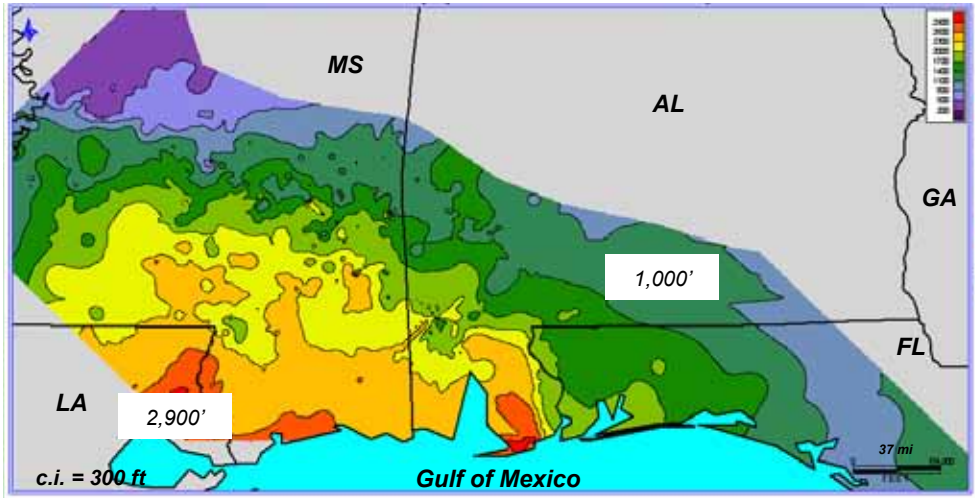
CO_2 Storage Assessment Input Data: Washita-Fredericksburg Group Saline Reservoir

STATES	Total Area (Mi^2)	Avg Depth (ft)	Avg Net Thickness (ft)	Avg Porosity (%)	Pore Volume (tcf)	CO_2 BG (res cf/scf)	CO_2 Capacity (Gt) (E=100%)
Alabama	12,810	-6,720	870	25%	76	0.0030	1,351
Florida	9,710	-5,460	680	25%	45	0.0031	764
Mississippi	22,430	-8,270	480	18%	52	0.0030	927

Washita-Fredericksburg Group, Depth (Subsea)



Washita-Fredericksburg Group, Gross Interval Thickness



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CO_2 Storage Capacity: Paluxy Saline Formation

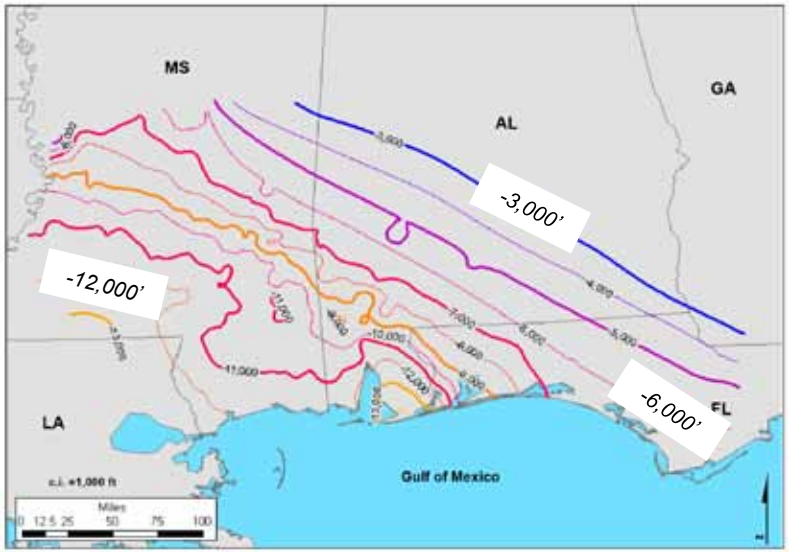
The Paluxy saline formation is the fourth of the five Cretaceous-age "stacked" reservoirs in the Eastern Gulf Coast.

The gross thickness in the favorable depth interval (3,000 to 14,000 feet) ranges from 500 to 1,500 feet, with a net thickness of 470 to 650 feet.

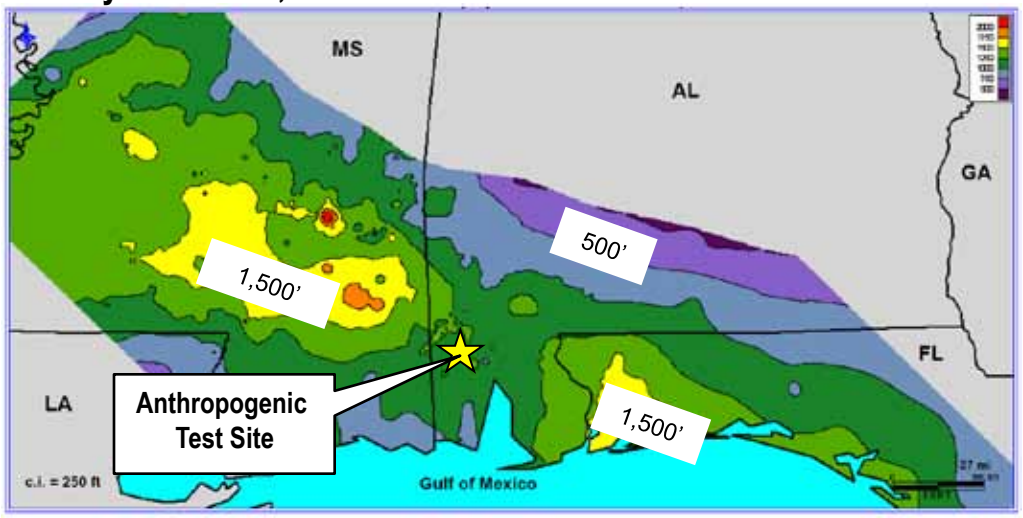
CO_2 Storage Assessment Input Data: Paluxy Saline Reservoir

STATES	Total Area (Mi^2)	Avg Depth (ft)	Avg Net Thickness (ft)	Avg Porosity (%)	Pore Volume (tcf)	CO_2 BG (res cf/scf)	CO_2 Capacity (Gt) (E=100%)
Alabama	15,240	-8,470	470	23%	47	0.0030	819
Florida	8,620	-6,630	480	23%	27	0.0031	459
Mississippi	23,050	-9,450	650	15%	63	0.0030	1,113

Paluxy Formation, Depth (Subsea)



Paluxy Formation, Gross Interval Thickness



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CO_2 Storage Capacity: Lower Cretaceous Undifferentiated Saline Formation

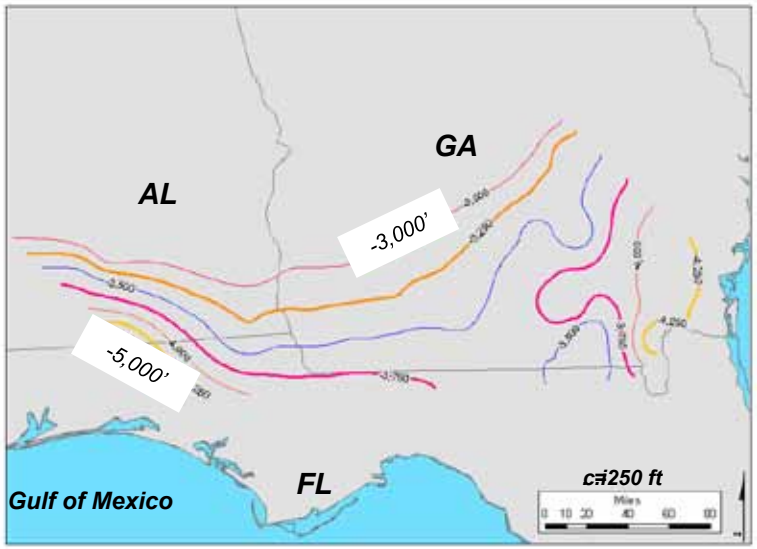
The Lower Cretaceous Undifferentiated saline formation in southeast Alabama and southern Georgia was assessed as a single unit.

The gross thickness ranges from 300 to 4,000 feet with a net thickness of 520 to 820 feet.

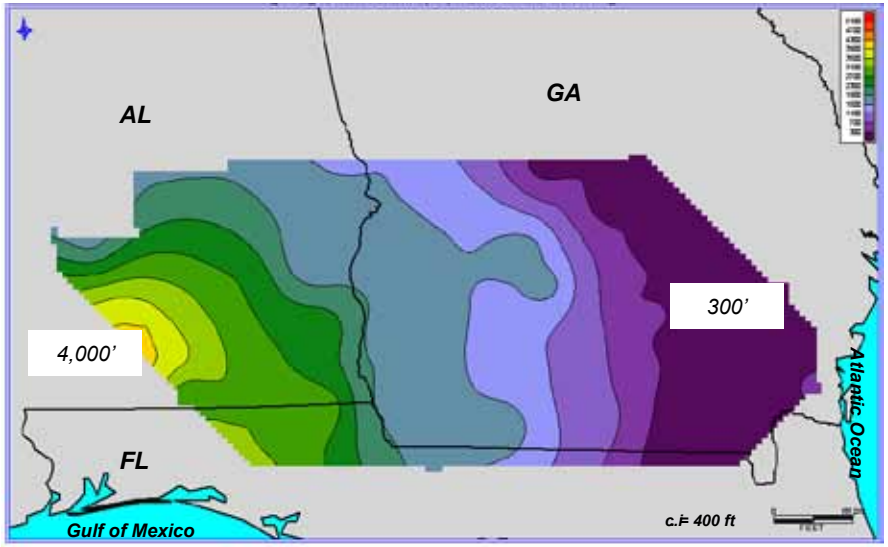
CO_2 Storage Assessment Input Data: Lower Cretaceous Undifferentiated Saline Reservoir

STATES	Total Area (Mi^2)	Avg Depth (ft)	Avg Net Thickness (ft)	Avg Porosity (%)	Pore Volume (tcf)	CO_2 BG (res cf/scf)	CO_2 Capacity (Gt) (E=100%)
Alabama	3,490	-3,720	820	23%	18	0.0028	351
Florida	3,150	-3,940	680	20%	12	0.0029	216
Georgia	16,180	-3,570	520	20%	47	0.0040	623

Lower Cretaceous Undifferentiated, Depth (Subsea)



Lower Cretaceous Undifferentiated, Gross Interval Thickness



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1. Regional CO_2 Storage Capacity in Cretaceous-Age Saline Reservoirs: Eastern Gulf Coast

- The usable regional CO_2 storage capacity incorporates the geologic and reservoir study by Advanced Resources with the DOE Atlas' suggested efficiency factor (E) for clastic reservoirs having sufficient data on net thickness and effective porosity.
- Based on the ARI study and applying DOE's capacity utilization (efficiency) factor, the CO_2 storage capacity is sufficient for over 6,000 1-GW size coal-fired power plants operating for 30 years.*

Saline Reservoir	Theoretical Capacity (Gt, E = 100%)	P50 Capacity (Gt, E = 14%)
Eutaw	305	43
Lower Tuscaloosa (2009 assessment)	2,200	308
Washita-Fredericksburg	3,040	426
Paluxy	2,390	335
Lower Cretaceous undifferentiated	1,190	167
Total	**9,125**	**1,279**

*Assuming 7 MMmt/yr of CO_2 emissions and 90% capture per 1 GW of capacity.

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2. Utilization of CO_2 for Enhanced Oil Recovery: Eastern Gulf Coast

The Eastern Gulf Coast oil reservoirs in Alabama, Florida, Mississippi and Louisiana offer considerable potential for utilizing CO_2 for miscible enhanced oil recovery (CO_2-EOR).

With currently available state of art (SOA) technology, the technically feasible potential is:

- 5.4 billion barrels of oil recovery
- 2.6 billion metric tons of purchased CO_2 utilization

Important next steps in defining and optimizing the CO_2 utilization potential in this region includes:

- Assessing the increase in CO_2 utilization due to advances in CO_2-EOR technology from R&D and field demos of “next generation” technology.
- Incorporating economics (oil price and CO_2 costs) into the assessment to establish a market demand for CO_2.
- Examining the upside potential for CO_2 utilization offered by the Offshore GOM, the Residual Oil Zone and immiscible/near-miscible CO_2-EOR technology in this region.

2. Utilization of CO_2 for Enhanced Oil Recovery: Eastern Gulf Coast (Cont'd)

The Eastern Gulf Coast oil reservoirs favorable for "state of art" miscible CO_2–EOR technology have a technical CO_2 utilization and storage capacity of 2,586 million metric tons, based on the 2011 NETL/ARI study.*

State	Number of Large Oil Fields Favorable for Miscible CO_2-EOR	Technically Recoverable Oil from CO_2-EOR (State of Art)		Technical Storage Capacity from CO_2-EOR (State of Art)	
		Data Base	Extrapolated	Data Base	Extrapolated
Alabama	9	175	292	66	109
Florida	6	210	350	100	167
Mississippi	24	284	423	120	199
Louisiana	63	2,594	4,373	1,267	2,111
Total	**102**	**3,263**	**5,438**	**1,553**	**2,586**

*"Improving Domestic Energy Security and Lowering CO2 Emissions with "Next Generation" CO2-Enhanced Oil Recovery (CO2-EOR)", DOE/NETL-2011/1504, July 2011, prepared by Advanced Resources International, Inc., V. Kuuskraa, T. Van Leeuwen and M. Wallace.

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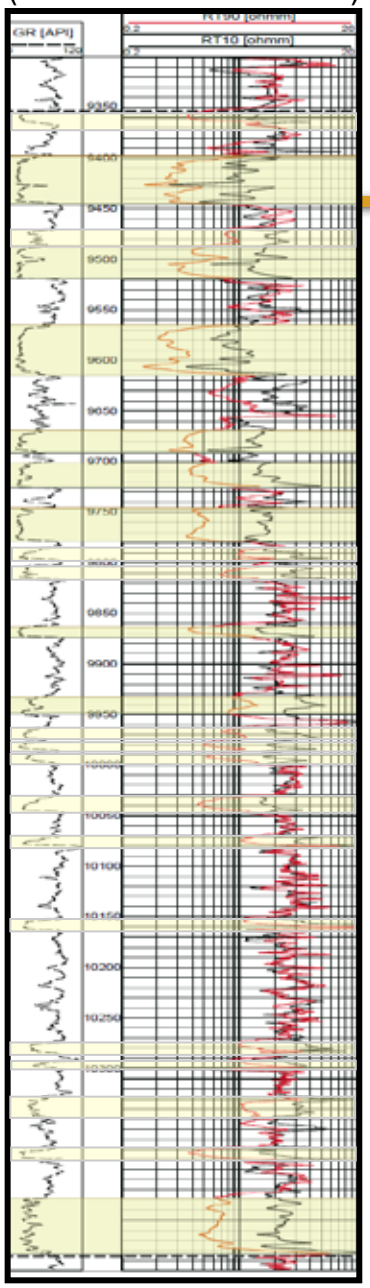
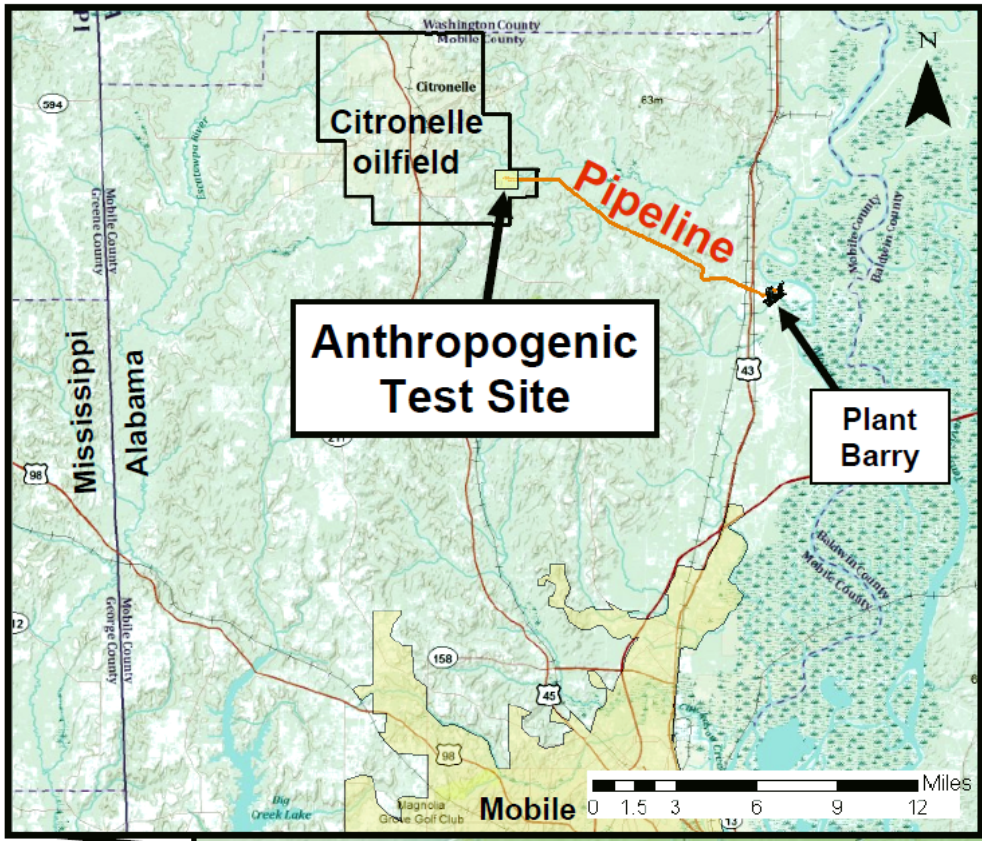
Paluxy Type Log
(370 Net Feet of Sand)



3. Site Specific CO_2 Storage Capacity in Cretaceous-Age Reservoirs: Eastern Gulf Coast



- SECARB's Anthropogenic Test Site at Citronelle Dome provides a more in-depth look at site specific CO_2 storage capacity.
- Detailed well logs and cores were used to assess net sand thickness and porosity for four "stacked" Cretaceous-age saline reservoirs at the site.

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Site Specific CO_2 Storage Capacity in Cretaceous-Age Reservoirs: Eastern Gulf Coast

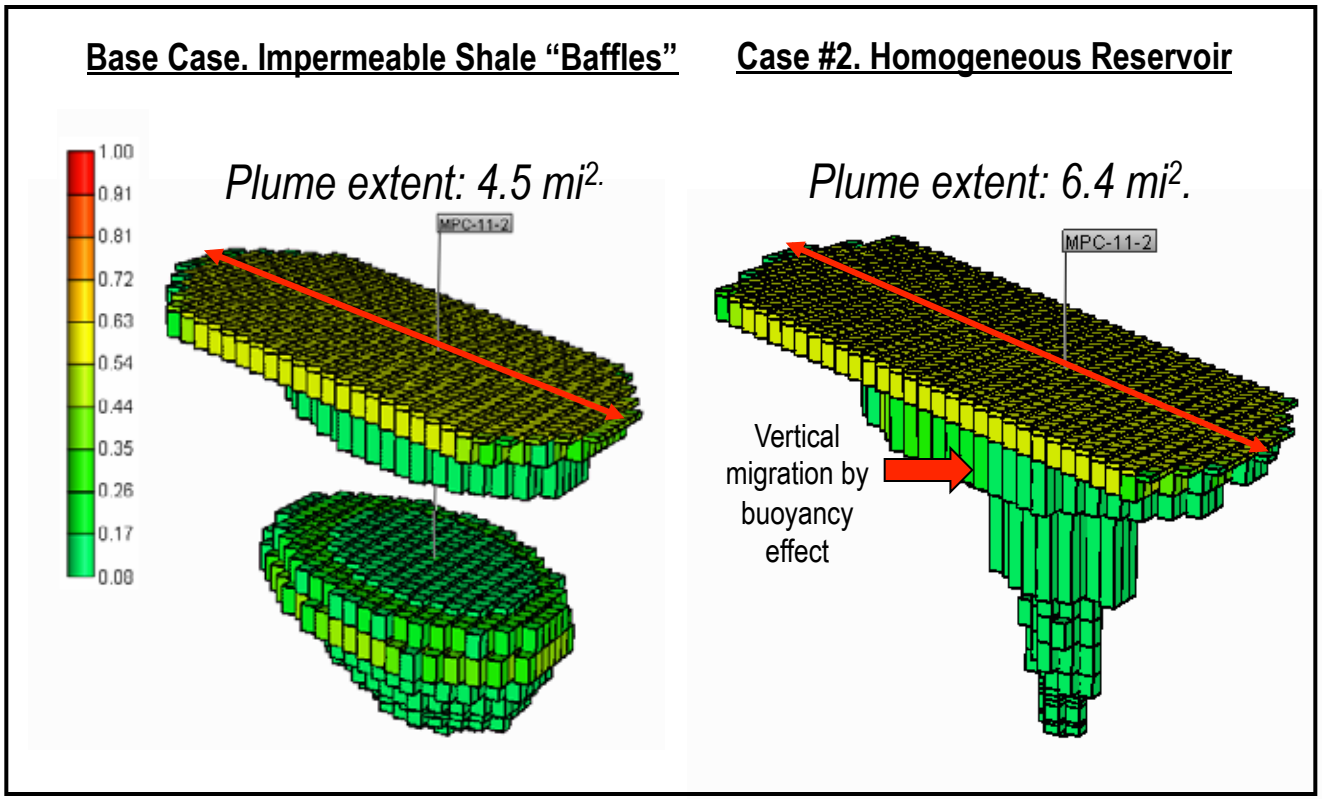
- A 1 GW coal-fired power plant, operated for 30 years, requires 190 million metric tons of CO_2 storage capacity.*
- With 25 million metric tons of CO_2 storage capacity per square mile in the four stacked Cretaceous-age saline reservoirs and the Donovan oil reservoir, a 1 GW coal-fired power plant would require a storage area of 7.6 square miles at Citronelle Dome:

Cretaceous Reservoirs	Net Thickness (ft)	Effective Porosity (%)	Theoretical Capacity Estimate (MMt/mi^2) (E= 100%)**	P50 Capacity Estimate (MMt/mi^2) (E=14%)
Eutaw	100	12%	5	1
Lower Tuscaloosa	150	24%	17	2
Washita-Fred.	900	22%	94	13
Paluxy	370	19%	35	8
Donovan Sand* **				1
Total				**25**

*Assuming 7 MMmt/yr of CO_2 emissions and 90% capture per 1 GW of capacity.
**Theortecial and usable CO_2 storage efficiency (E).
***Based on work by Esposito et al (2008) and ARI (2011).

Increasing Storage Capacity With Optimum Use of Reservoir Architecture

Optimizing the areal extent of the CO_2 plume, a proxy for storage efficiency, requires two steps:



- Detailed characterization of the individual sand bodies and flow units.
- Using this data to optimally complete the CO_2 injection well (placement of perforations and selection of CO_2 injection intervals).
- Incorporation of reservoir characterization into the CO_2 injection protocol reduced the areal extent of the CO_2 plume by 30%.*

*Assumes CO_2 injection of 20 MMcfd (1,058 mt/d) for 30 years.

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4. CO_2 Storage Capacity in the Basal Sandstone Saline Reservoir: Central Tennessee

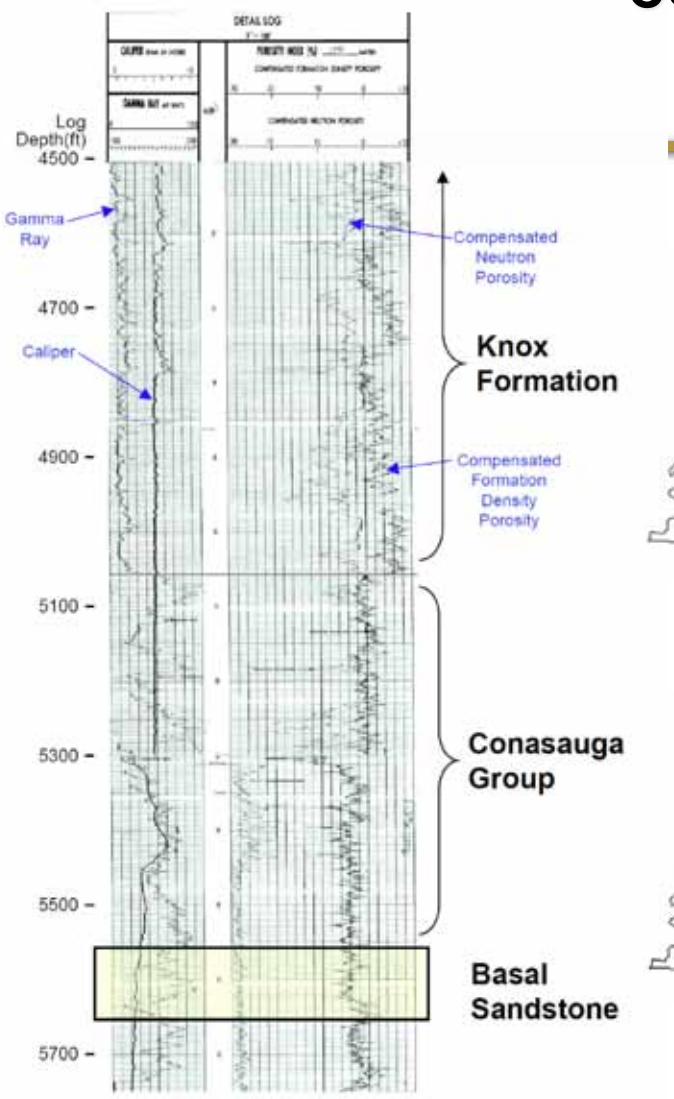
An additional geologic study and CO_2 storage assessment was conducted for the "Basal Sandstone" (equivalent to Mt. Simon Formation in the Illinois Basin) in Central Tennessee - - Nashville Dome (Area #1) and Cumberland Plateau (Area #2).

- Limited well data (less than 20 wells)
- Low porosity (7% to 8%), moderately thin sands (110' to 130' gross)
- Depth limits of 3,000 to 10,000 feet
- Low permeability units of the Conasauga Group provide the regional seal.

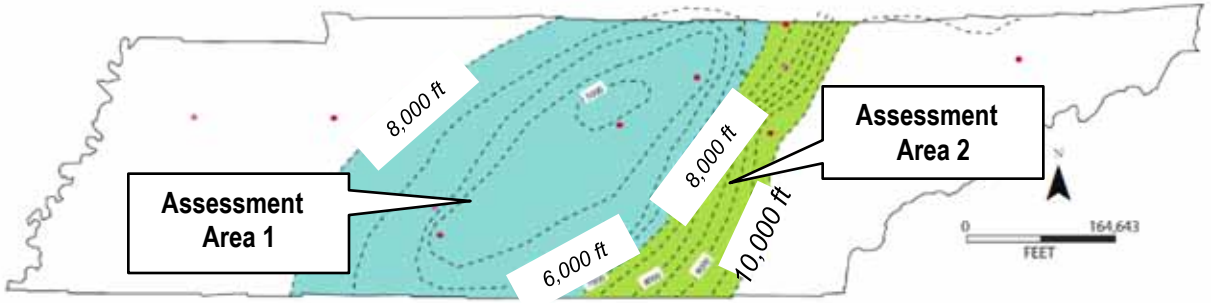
Results indicate low to moderate regional CO_2 storage capacities of 0.02 to 0.2 MMt/mi^2; however site specific studies could lead to higher localized increase CO_2 storage capacity.

Total usable Central Tennessee CO_2 storage capacity of 400 to 3,600 MMt is sufficient for 2 to 19 one-GW size coal-fired power plants operated for 30 years.

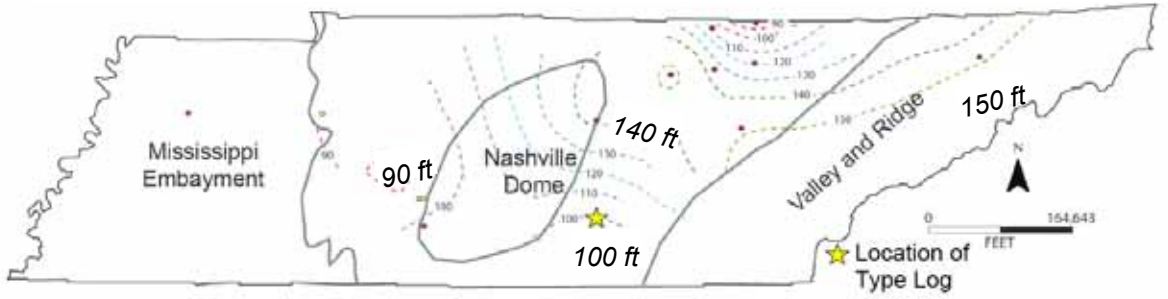
CO_2 Storage Capacity in the Basal Sandstone Saline Reservoir: Central Tennessee



Depth of 5,000 ft to 10,000+ ft.



Thickness is 100 ft to 150+ ft



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