Draft Report on Lower and Upper Cretaceous Characterization

SECARB Phase III Work Product 1.4.b

Prepared for:
United States Department of Energy
National Energy Technology Laboratory

Performed by:
Advanced Resources International, Inc.
4501 Fairfax Drive, Suite 910
Arlington, VA 22203

11490 Westheimer Rd., Suite 520
Houston, TX 77077

603 Main Street, Suite 906
Knoxville, TN 37902

July 7, 2011

Advanced Resources International, Inc.

Disclaimers

U.S. Department of Energy

Advanced Resources International, Inc.

Executive Summary

The United States Department of Energy's (DOE's) National Energy Technological Laboratory (NETL) is engaged in a research and development Carbon Sequestration Program which focuses on carbon, capture and storage (CCS) technology. CCS has the potential to provide significant reduction of domestic greenhouse gas emissions. Geologic carbon sequestration separates and captures carbon dioxide (CO_2) at the point of emissions from a stationary source such as a coal-fired electric power plant followed by permanent storage in deep underground geologic formations. This report will assess potential geologic CO_2 storage capacity of Lower and Upper Cretaceous formations in the Southeast Regional Carbon Sequestration Partnership (SECARB) along the eastern Gulf Coast region.

This capacity assessment incorporates regional variation in average reservoir porosity, net formation (sandstone) thickness, and storage reservoir depth and pressure. The assessed area covers the onshore region where the Washita-Fredericksburg, Paluxy, and Eutaw Formations occur at depths from -3,000 to -14,000 feet (ft) below sea level and include southern Mississippi, southern Alabama, southern Georgia and the western panhandle of Florida. Note that the Lower Cretaceous is undifferentiated in portions of southeastern Alabama and southern Georgia and were assessed as a single unit in those areas. Cretaceous sandstones in offshore locations were not assessed. This report estimates total CO_2 storage capacity of 513 metric gigatons (Gt) to 1,661 Gt for all four units (**Table EX-1**).

Table EX1: Estimated CO_2 Total Storage Capacity of the Lower and Upper Cretaceous Reservoirs

Gulf Coast Reservoir	Total CO_2 Storage Capacity			
	Trillion Standard Cubic Feet (Tscf)		Billion Metric Tons (Gt)	
	Low Estimate P(10)	High Estimate P(90)	Low Estimate P(10)	High Estimate P(90)
Eutaw	430	1,380	22	73
Washita-Fredericksburg	4,190	13,800	226	729
Paluxy	3,350	10,840	177	573
Lower Cretaceous Undiff.	1,660	5,400	88	286
Total	9,630	31,420	513	1,661

Table of Contents

Disclaimers ..... **i**

Executive Summary ..... **ii**

1.0 Introduction **1**

1.1 CO_2 Storage Capacity Methodology *1*

2.0 The Lower and Upper Cretaceous CO2 Storage Capacity Assessments **4**

2.1 Lower and Upper Cretaceous Geology *4*

2.2 Reservoir Properties and Capacity Estimates *7*

2.3 The Lower and Upper Cretaceous CO_2 Storage Capacity Assessed by Saline Reservoir *8*

3.0 CO_2 Storage Capacity of the Lower and Upper Cretaceous Saline Reservoirs **10**

3.1 Methodology *10*

3.2 Lower and Upper Cretaceous Saline Reservoir – CO_2 Storage Capacity *10*

3.3 CO_2 Storage Capacity Example Calculation *14*

References **1**

List of Figures

Figure 1. Major Geologic Features along the Gulf Coast. 15

Figure 2. Stratigraphic column of the Lower and Upper Cretaceous. 16

Figure 3. Structure Map on Top of the Paluxy formation. 17

Figure 4. Isopach Map of the Paluxy formation. 17

Figure 5. Structure Map on Top of the Washita-Fredericksburg Group. 18

Figure 6. Isopach Map of the Washita-Fredericksburg Group. 18

Figure 7. Structure Map on Top of the Eutaw Formation. 19

Figure 8. Isopach Map of the Eutaw formation. 19

Figure 9. Stratigraphic (top) and structural (bottom) west-east schematic cross-sections L1-L1' showing the Paluxy Formation and the Washita-Fredericksburg Group, west Mississippi to western panhandle of Florida. 1

Figure 10. Stratigraphic (top) and structural (bottom) west-east schematic cross-sections U1-U1' showing the Eutaw Formation and the Selma Group, west Mississippi to southwest Georgia. 2

List of Tables

Table EX1: Estimated CO_2 Total Storage Capacity of the Lower and Upper Cretaceous Reservoirs iii
Table 1 Key Reservoir Parameters Used to Assess CO2 Storage Capacity 2
Table 4: CO2 Storage Assessment Input for the Paluxy Saline Reservoir..9
Table 5: CO2 Storage Assessment Input for the Washita-Fredericksburg Reservoir 9
Table 6: CO_2 Storage Assessment Input for the Eutaw Reservoir 9
Table 7: CO_2 Storage Assessment Input for the Lower Cretaceous undifferentiated Reservoir 9
Table 8: Estimated CO_2 Storage Capacity of the Paluxy Saline Reservoir 12
Table 9: Estimated CO_2 Storage Capacity of the Washita-Fredericksburg Saline Reservoir...................12
Table 10: Estimated CO_2 Storage Capacity of the Lower Cretaceous undifferentiated Saline Reservoir 13
Table 11: Estimated CO_2 Storage Capacity of the Eutaw Saline Reservoir..13
Table 12: Estimated CO_2 Total Storage Capacity of the Lower and Upper Cretaceous Reservoirs........14

1.0 Introduction

This report provides potential geologic carbon dioxide (CO_2) storage capacities of deep underground geologic formations for the purpose of carbon, capture and storage (CCS) to reduce greenhouse gas emissions. Thick, porous sandstone formations of the Lower and Upper Cretaceous offering large CO_2 storage capacity are present along the eastern Mississippi Gulf Coast the Southeast Regional Carbon Sequestration Partnership (SECARB) and are the subject of this assessment. This includes parts of Mississippi, Alabama, Florida, and Georgia. The reservoirs that will be assessed in this report include the Upper Cretaceous Eutaw Formation, the Lower Cretaceous Washita-Fredericksburg Group, including the Dantzler Formation, and the Lower Cretaceous Paluxy Formation. The Lower Cretaceous is undifferentiated in the eastern portion of the study area and is assessed as one unit.

Thick, impermeable shales in the Washita-Fredericksburg Group and the Middle Tuscaloosa Group (also called the 'Marine Tuscaloosa') offer regional seals overlying the Dantzler and Paluxy Formations, while low permeability carbonates from the thick Selma Group provide a regional seal for the Eutaw Formation. The Marine Tuscaloosa shale provides a regional seal for undifferentiated Lower Cretaceous sandstones in the eastern part of the study area. Note that the Lower Tuscaloosa Formation of the Upper Cretaceous is a significant saline reservoir that also occurs in the same region. The Lower Tuscaloosa CO_2 storage capacity was assessed in the DOE report titled *Geologic Storage Capacity for CO_2 of the Lower Tuscaloosa Group and Woodbine Formations (Advanced Resources International, Inc., 2009 A).*

1.1 CO_2 Storage Capacity Methodology

Our approach to calculate the CO_2 storage capacity of the Lower and Upper Cretaceous saline reservoirs follows the capacity assessment methodology set forth by the DOE's Regional Carbon Sequestration Partnerships Capacity Estimation Subgroup (DOE/NETL 2010). The DOE methodology provides a volumetric estimate for useable CO_2 storage capacity based on geographical area (A), net formation thickness (h), effective porosity (ϕ) and CO_2 density (ρ_{CO2}). A storage coefficient (E) is used to represent the fraction of the total pore volume that would be filled by CO_2. The efficiency factor (E) incorporates a series of variables that limit the ability of injected CO_2 to occupy 100% of the pore space in a given formation, such as geologic heterogeneity, gravity or buoyancy effects, and limited sweep efficiency. The simplified DOE CO_2 storage capacity (G_{CO2}) equation for calculating effective CO_2 storage within a particular saline formation is as follows:

$$G_{CO2} = A_t * h_g * \phi_{tot} * \rho * E$$

The terms used in this equation are discussed in Table **1** below:

Table 1: Key Reservoir Parameters Used to Assess CO_2 Storage Capacity

Parameters	Units	Description
G_{CO2}	M	Usable CO_2 storage capacity (M, is mass in metric tons).
A_t	L^2	Geographical area that defines the basin or region being assessed for CO_2 storage (L is length).
h_g	L	Gross thickness of saline formation for which CO_2 storage is assessed within the basin or region defined by A_t.
ϕ_{tot}	fraction	Average porosity of entire saline formation over thickness h_g.
ρ	M/L^3	Density of CO_2 at pressure and temperature representative of storage conditions.
E	fraction	CO_2 storage efficiency factor that reflects the fraction of the total pore volume that is filled by CO_2.

The composite storage coefficient E accounts for inefficiencies in displacement, including volumetric displacement (E_v) and microscopic displacement (E_d) as discussed in **Table 2** below.

Table 2: Displacement Components of Site Specific CO_2 Storage Efficiency Coefficient

Term	Symbol	P10/P90 Values by Lithology for Clastics	Description
Volumetric Displacement	EV	0.16/0.39	Combined fraction of immediate volume surrounding an injection well that can be contacted by CO2 and fraction of net thickness that is contacted by CO2 as a consequence of the density difference between CO2 and in situ water.
Microscopic Displacement	Ed	0.35/0.76	Fraction of pore space unavailable due to immobile in situ fluids.

When applied at a regional or basin level, the CO_2 storage efficiency coefficient (E_{saline}) also incorporates the following three limitations on accessibility related to geologic heterogeneity, as presented in **Table 3**. However, enough reservoir data were available for this assessment so the application of these limiting components was not necessary. As such, only the displacement components of the CO_2 storage efficiency coefficient (**Table 2**) were applied.

Table 3: Geologic Components of Regional CO_2 Storage Efficiency Coefficient

Term	Symbol	P10/P90 Values by Lithology for Clastics	Description
Net to Total Area	EAn/At	0.2/0.8	Fraction of total basin or region area that has a suitable formation present.
Net to Gross Thickness	Ehn/hg	0.21/0.76	Fraction of total geologic unit that meets minimum porosity and permeability requirements for injection.
Ratio of Effective to Total Porosity	$\phi E_{\varepsilon}\phi/_{\tau o \tau}$	0.64/0.77	Fraction of total porosity that is effective, i.e., interconnected.

For this assessment, data availability allowed for the areas of interest to be defined and the areas where the reservoirs were either were too shallow or thin were excluded from any calculations. Regional log data was used to correlate Cretaceous units and structure and isopach maps were generated from these correlations. Log data was also used to approximately determine net sand thickness for each target reservoir. The sandstone porosity for the Cretaceous reservoirs was also determined from regional log and core data. Therefore, net sandstone values were used in all calculations instead of the more generalized total interval porosity. From these data the net-to-total area $E_{An/At}$, net-to-gross thickness $E_{hh/hg}$, and net-to-total porosity $E_{\phi e/\phi tot}$ are assumed to be known and the storage limitations shown in Table 3 were not applied. As such, efficiency factors range from 7.4 – 26 percent (Table 4). These vales are equivalent to Table 8 in the 2010 Atlas Appendix B (Summary of the Methodology for Development of Geologic Storage Estimates for Carbon Dioxide).

Table 4: Saline Formation Efficiency Factors for Displacement Terms Only

Lithology	P_{10}	P_{50}	P_{90}
Clastics	7.4%	14%	24%

2.0 The Lower and Upper Cretaceous CO2 Storage Capacity Assessments

2.1 Lower and Upper Cretaceous Geology

Major eastern Mississippi Gulf Coast geologic features include a number of alternating relict basement highs and lows, peripheral fault systems, subsurface salt flow influenced structures, and extensive salt basins. Within this study area the Cretaceous units extend from the Monroe Uplift-Sharkey Platform in the west, the Upper Cretaceous Paleogeographic Outcrop limit to the north, the central Georgia arch in the east and the Gulf of Mexico to the south **(Figure 1)**. Regionally significant geologic features located in the study area are the Mississippi Interior Salt Basin, the Wiggins Arch, the Citronelle and Jackson Domes, and the Mobile Graben **(Figure 1)**. Geologic characterization of the Gulf Coast basin is described in detail in the companion report titled *Geologic Storage Capacity for CO_2 of the Lower Tuscaloosa Group and Woodbine Formations* (*Advanced Resources International, Inc., 2009 A*). Refer to this report for further geologic review.

Figure 2 shows a generalized Cretaceous stratigraphic column for the study area and indicates potential CO_2 storage reservoirs and confining units. The Lower Cretaceous in the northern Gulf of Mexico consists of the Hosston Formation, the Sligo Formation, the Pine Island Shale, the James Limestone, the Rodessa Formation, the Ferry Lake Anhydrite, the Mooringsport Formation, the Paluxy Formation and the Washita-Fredericksburg Group (ascending from oldest to youngest). However, this assessment covers only saline reservoirs which lie above the Ferry Lake Anhydrite and Mooringsport Formation starting with the Paluxy Formation.

The Paluxy sandstones (Albian age) were deposited in a complex association of continental, coastal and deltaic environments. The Paluxy contains pink and white fine- to coarse-grained sandstone bodies interbedded with dark red and gray shale (Devery, 1982). Above the Paluxy Formation lies the Washita-Fredericksburg Group (early Cenomanian age) deposited during a period of marine transgression that includes a sequence of shale, limestone and sandstone. The Washita-Fredericksburg deposition was followed by regional uplift and erosion which produced a regional unconformity over areas in the Gulf Coast and marked the end of the Lower Cretaceous.

Washita-Fredericksburg Group potentially serves as both a saline reservoir, and a confining unit as several shales within the unit may also serve as confining zones for either the Paluxy or sandstones within the Washita-Fredericksburg Group. For example, the basal shale of the Washita-Fredericksburg Group is regionally widespread, extending from Mississippi to Georgia, and could serve as a confining unit in some areas. However, thickness varies greatly across the region from thicknesses of 30 ft to greater than 400 ft.

The Lower Cretaceous is undifferentiated in portions of southeastern Alabama and southern Georgia and contains porous sandstones and low permeability shales are age equivalent to the Washita-Fredericksburg Group and Paluxy Formation in areas of southwestern Alabama and the western portion of the panhandle of Florida.

The Upper Cretaceous in the northern Gulf of Mexico consists of the Tuscaloosa Group, the Eutaw Formation and the Selma Group (ascending from oldest to youngest). The Tuscaloosa Group of Cenomanian age lies above the Washita-Fredericksburg Group. The Tuscaloosa in southeast Mississippi and southwest Alabama represents a complex association of deltaic, marginal marine and shallow marine deposition. The Tuscaloosa Group is divided into three informal divisions: the Lower Tuscaloosa, the Middle Tuscaloosa (Marine) and the Upper Tuscaloosa. The Lower Tuscaloosa sandstones represent a regionally-extensive, large-capacity CO_2 storage reservoir (*Advanced Resources International, Inc., 2009 A*). The Marine Tuscaloosa Formation was deposited during a period of marine transgression composed of red, gray and black shales. The Upper Tuscaloosa Formation represents a fluvial-deltaic and marginal marine environment that consists of medium- to coarse-grained sandstones, gray siltstones, shales, and mudstones and may serve as a minor CO_2 storage reservoir (un-assessed). The Lower Tuscaloosa Marine Shale is a seal for Tuscaloosa oil accumulations throughout the eastern Gulf Coast and could serve as a potential confining unit for the Washita-Fredericksburg Group and the Paluxy Formation.

Above the Upper Tuscaloosa lies the Eutaw Formation of Turonian to Santonian age. From Mississippi to western Georgia, the Eutaw represents a shallow marine and shoreline environment including beach-barrier systems; whereas, in central Georgia, the Eutaw shows evidence of fluvial systems (Pashin, 2008; Furcron, 1952). Overlying the Eutaw Formation is the Selma Group of early Santonian to Maastrichtian age. From Mississippi to western Alabama, the Selma represents a broad, muddy carbonate shelf and was deposited during a time of unusually high sea level (Pashin, 2008).

The thick, low permeability chalk, marl and limestone of the Selma Group could provide containment for Eutaw CO_2 storage reservoirs. In Alabama, the Selma is the primary seal for oil accumulations in the underlying Eutaw Formation (Pashin et al., 2008). In Mississippi and western Alabama, the Selma is predominately bioturbated and fossilferous chalk with significant amounts of marl and grain-supported limestone (Pashin et al, 2008).

Figures 3-10 show structure and isopach maps for the saline reservoirs assessed in this study. **Figure 11** shows east-west regional structural and stratigraphic cross sections of the Lower Cretaceous reservoirs assessed in this report (the Paluxy and Washita-Fredericksburg Formations). **Figure 12** shows east-west regional structural and stratigraphic cross sections of the Upper Cretaceous reservoir assessed in this report (the Eutaw Formation) as well as the Selma Group confining unit.

2.2 Reservoir Properties and 100% Capacity Estimates

Estimating potential CO_2 storage capacity for the Lower and Upper Cretaceous saline reservoirs first requires estimating the reservoir pore volume using a standard volumetric approach, then calculating the theoretical volume of CO_2 that can be stored in 100 percent of the available pore space, and finally, using CO_2 storage efficiency factors (E) to generate low- and high-confidence storage capacity estimates. The following approach was used to estimate the CO_2 storage capacity for the Upper Cretaceous Eutaw Formation and the Lower Cretaceous Washita-Fredericksburg Group and Paluxy Formation.

Total Pore Volume = A* $h_g * \phi_{tot}$

Where:

A is the reservoir area

h_g is the net reservoir thickness

ϕ_{tot} is the total porosity of the gross interval (including shales)

To calculate the area and thickness for each saline reservoir, structure and isopach maps were created in the *Petra* geologic mapping and analysis software (IHS Inc). Depth limits were confined to -3,000 ft to -14,000 ft (elevation, subsea) and structure and thickness maps were developed using "formation tops" data provided in the IHS Energy database of U.S. oil and gas wells. Each reservoir map was quality checked using more than 200 raster logs from across the study region. To find the total area for each reservoir, polygons were drawn on the structure maps, which included areas between the -3000 ft contour and the -14,000 ft contour within each state. The net reservoir thickness was derived, first, from the gross formation thickness and then applying a net to gross ratio. Gross thickness for each saline reservoir was calculated by subtracting the top depth of the unit located immediately below the assessed formation from the top of the assessed formation. For example, gross thickness of the Eutaw Formation was calculated by subtracting the top of the Upper Tuscaloosa from the top of the Eutaw Formation (see **Figure 8**). Then the gross thickness from wells within each state was averaged to give the average gross thickness for the assessed reservoir by state. Net reservoir thickness was then derived using net sand to gross interval ratios obtained from regional log data.

Sandstone (effective) porosity data was obtained from geologic literature (Pashin et al., 2008; Devery, 1982) and/or calculated from selected porosity log data.

Theoretical Maximum (100%) CO_2 Storage Capacity

The theoretical maximum CO_2 storage volume assumes that 100% of the reservoir pore volume is occupied by CO_2. Theoretical maximum storage is calculated by applying an appropriate CO_2 formation volume factor based on the reservoir's estimated average native pressure and temperature condition. The CO_2 formation volume factor (CO_2Bg) was calculated assuming normal temperature and pressure gradients, a condition expected for the assessed reservoirs at depths of less than 15,000 ft. The temperature gradient used in this study is 1.85 °F per 100 feet plus 70 °F (ambient surface temperature) and the pressure gradient is 0.43 psi per foot.

2.3 The Lower and Upper Cretaceous CO_2 Storage Capacity Assessed by Saline Reservoir

Each reservoir capacity assessment incorporates regional variation in average reservoir effective (sandstone) porosity, net formation thickness, depth and pressure. The assessed area covers the onshore region where the Washita-Fredericksburg, the Paluxy, the Eutaw Formations and the Lower Cretaceous undifferentiated sandstones occur at elevations from -3,000 to -14,000 feet (ft, subsea) and include southern Mississippi, southern Alabama, southern Georgia and the western panhandle of Florida. Cretaceous sandstones in offshore locations were not assessed.

Tables 5-8 show the average values used to calculate the theoretical maximum storage capacity by state.

Table 5: CO_2 Storage Assessment Input for the 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 (Tscf) (E=100%)
Alabama	**15,240**	**-8,470**	**470**	**23%**	**47**	**0.0030**	**15,470**
Florida	**8,620**	**-6,630**	**480**	**23%**	**27**	**0.0031**	**8,680**
Mississippi	**23,050**	**-9,450**	**650**	**15%**	**63**	**0.0030**	**21,040**

Table 6: CO_2 Storage Assessment Input for the Washita-Fredericksburg Reservoir

STATES	*Total Area (Mi^2)*	*Avg Depth (ft)*	*Avg Gross Thickness (ft)*	*Avg Total Porosity*	*Pore Volume (tcf)*	*CO_2 BG (res cf/scf)*	CO_2 Capacity (Tscf) (E=100%)
Alabama	**12,810**	**-6,720**	**870**	**25%**	**76**	**0.0030**	**25,530**
Florida	**9,710**	**-5,460**	**680**	**25%**	**45**	**0.0031**	**14,440**
Mississippi	**22,430**	**-8,270**	**480**	**18%**	**52**	**0.0030**	**17,510**

Table 7: CO_2 Storage Assessment Input for the Eutaw Reservoir

STATES	*Total Area (Mi^2)*	*Avg Depth (ft)*	*Avg Gross Thickness (ft)*	*Avg Total Porosity*	*Pore Volume (tcf)*	*CO_2 BG (res cf/scf)*	CO_2 Capacity (Tscf) (E=100%)
Alabama	**8,830**	**-5,120**	**50**	**25%**	**3**	**0.0037**	**890**
Florida	**11,920**	**-4,430**	**40**	**24%**	**3**	**0.0042**	**740**
Mississippi	**27,330**	**-6,060**	**70**	**25%**	**14**	**0.0034**	**4,090**
Georgia	**860**	**-3,100**	**50**	**20%**	**0.3**	**0.0061**	**40**

Table 8: CO_2 Storage Assessment Input for the Lower Cretaceous Undifferentiated Reservoir

STATES	*Total Area (Mi^2)*	*Avg Depth (ft)*	*Avg Gross Thickness (ft)*	*Avg Total Porosity*	*Pore Volume (tcf)*	*CO_2 BG (res cf/scf)*	CO_2 Capacity (Tscf) (E=100%)
Alabama	**3,490**	**-3,720**	**820**	**23%**	**18**	**0.0028**	**6,640**
Florida	**3,150**	**-3,940**	**680**	**20%**	**12**	**0.0029**	**4,070**
Georgia	**16,180**	**-3,570**	**520**	**20%**	**47**	**0.0040**	**11,780**

3.0 CO_2 Storage Capacity of the Lower and Upper Cretaceous Saline Reservoirs

3.1 Methodology

CO_2 storage capacity estimates for the Eutaw Formation, the Washita-Fredericksburg Group, the Paluxy Formation and the Lower Cretaceous undifferentiated were computed using the methodology set forth in the *U.S. DOE's 2010 Carbon Sequestration Atlas of the United States and Canada.* The storage efficiency values recommended in the Carbon Sequestration Atlas assessment methodology for clastic reservoirs were used to estimate potential CO_2 storage capacity from calculated total pore volume (P_{10}=7.4% and P_{90}=24%).

3.2 CO_2 Storage Capacity Example Calculation

The storage efficiency values recommended for saline reservoirs in the atlas (DOE/NETL 2010) assessment methodology were used to estimate achievable CO_2 storage capacity from calculated total pore volume. A brief summary of the capacity methodology follows:

1. The basic approach for all capacity estimations begins with quantifying the magnitude of the storage resource (pore volume) for each saline reservoir.
2. The theoretical volume of CO_2 that can be stored in 100 percent of the available pore space is calculated by applying an appropriate CO_2 formation volume factor for the reservoir's estimated average native pressure and temperature conditions.
3. The CO_2 storage efficiencies (E) suggested for clastic saline reservoirs in the atlas (DOE/NETL 2010) are applied to generate low- and high-confidence storage capacity estimates, resulting in a range of estimated

CO_2 storage capacity for each reservoir partition. The capacity estimates are then rolled-up to state values.

Following is an example calculation of practical CO_2 storage volume for the Eutaw Formation in Alabama. Using structure and isopach maps it was determined that the Eutaw Formation in Alabama covers an area of 8,830 square miles and has an average net thickness of 54 ft (Pratt Turner Land Company #B-31-5) (Pashin et al., 2008). A porosity value of 25 percent was calculated using data taken from a study of various saline reservoirs in southwest Alabama (Pashin et al., 2008). A formation volume factor of 3.67×10^{-3} reservoir cubic feet per standard cubic feet (res cf/scf) was estimated using regional temperature and pressure gradients.

1) Theoretical Storage Volume in Standard Cubic Ft for the Eutaw Formation in Alabama:

$A * h * \Phi / Bg_{CO2}$ = ($8,830\ mi^2$ * 54 ft * 0.248) / (0.00367 res cf/scf)

= $892x10^{12}$ *scf* CO_2 *= 892 Tscf*

2 Storage Efficiency and Practical CO_2 ***Storage Volume:***

The overall efficiency for saline formations ranges from 7.4 to 24 percent for the Eutaw lithology (clastic) over the 10 and 90 percent probability range, respectively (DOE/NETL, 2010).

*Low Case: P (10%) = 892 Tcf * 7.4% = 66 Tscf*

*High Case: P (90%) = 892 Tcf * 24% = 214 Tscf*

3) Volume of Stored CO_2 ***Converted from Tscf to Gigatonnes:***

Low Case: P (10%) = 66 Tcf /18.9 Mcf per metric ton = 3.5 Gt

High Case: P (90%) = 214 Tcf *//18.9 Mcf per metric ton* = 11.3 Gt

3.3 Lower and Upper Cretaceous Saline Reservoir – CO_2 Storage Capacity

Tables 9–12 summarize estimated CO_2 storage capacity for the Lower and Upper Cretaceous saline reservoirs by state. Total CO_2 storage capacity for the combined reservoirs is estimated to range from 513 Gt and 1,661 Gt is shown in **Table 13**.

Table 9: Estimated CO_2 Storage Capacity of the Paluxy Saline Reservoir

Gulf Coast State	CO_2 Storage Capacity			
	Trillion Standard Cubic Feet (Tscf)		Billion Metric Tons (Gt)	
	Low Estimate P(10)	High Estimate P(90)	Low Estimate P(10)	High Estimate P(90)
Alabama	1,150	3,710	61	196
Florida	640	2,080	34	110
Mississippi	1,560	5,050	82	267
Total	3,350	10,840	177	573

Table 10: Estimated CO_2 Storage Capacity of the Washita-Fredericksburg Saline Reservoir

Gulf Coast State	CO_2 Storage Capacity			
	Trillion Standard Cubic Feet (Tscf)		Billion Metric Tons (Gt)	
	Low Estimate P(10)	High Estimate P(90)	Low Estimate P(10)	High Estimate P(90)
Alabama	1,890	6,130	100	324
Florida	1,070	3,470	57	183
Mississippi	1,230	4,200	69	222
Total	4,190	13,800	226	729

Table 11: Estimated CO_2 Storage Capacity of the Lower Cretaceous Undifferentiated Saline Reservoir

Gulf Coast State	CO_2 Storage Capacity			
	Trillion Standard Cubic Feet (Tscf)		Billion Metric Tons (Gt)	
	Low Estimate P(10)	High Estimate P(90)	Low Estimate P(10)	High Estimate P(90)
Alabama	490	1,590	26	84
Florida	300	980	16	52
Georgia	870	2,830	46	150
Total	1,660	5,400	88	286

Table 12: Estimated CO_2 Storage Capacity of the Eutaw Saline Reservoir

Gulf Coast State	CO_2 Storage Capacity			
	Trillion Standard Cubic Feet (Tscf)		Billion Metric Tons (Gt)	
	Low Estimate P(10)	High Estimate P(90)	Low Estimate P(10)	High Estimate P(90)
Alabama	70	210	3	11
Florida	60	180	3	9
Georgia	3	10	0.2	0.5
Mississippi	300	980	16	52
Total	430	1,380	22	73

Table 13: Estimated CO_2 Total Storage Capacity of the Lower and Upper Cretaceous Reservoirs

Gulf Coast Reservoir	CO_2 Storage Capacity			
	Trillion Standard Cubic Feet (Tscf)		Billion Metric Tons (Gt)	
	Low Estimate P(10)	High Estimate P(90)	Low Estimate P(10)	High Estimate P(90)
Eutaw	430	1,380	22	73
Washita-Fredericksburg	4,190	13,800	226	729
Paluxy	3,350	10,840	177	573
Lower Cretaceous undifferentiated	1,660	5,400	88	286
Total	9,630	31,420	513	1,661

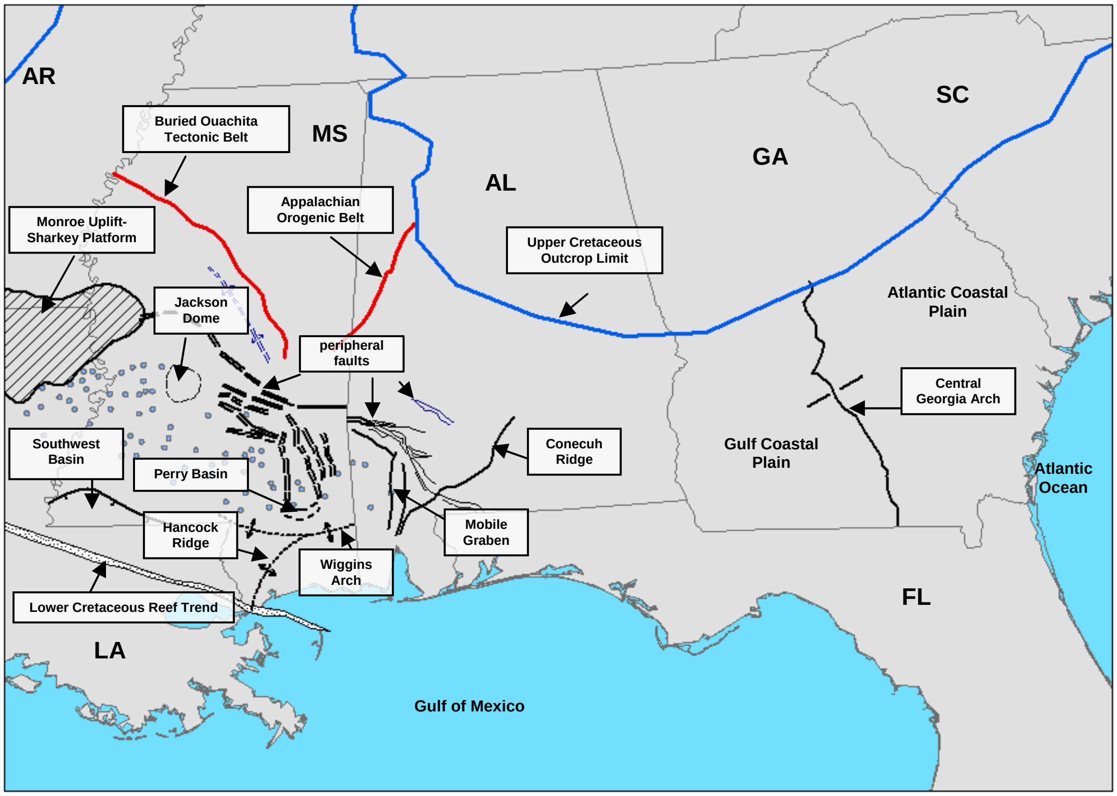

Figure 1. Major Geologic Features along the Gulf Coast.

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
Cretaceous	Lower	Washita-Fredericksburg Interval	Dantzler Ss		Saline Reservoir
			Shale		Primary Confining Unit
		Paluxy Formation	'Upper' 'Middle' 'Lower'		Proposed Injection Zone
		Mooringsport Formation			Confining Unit
		Ferry Lake Anhydrite			Confining Unit

Figure 2. Stratigraphic Column of the Lower and Upper Cretaceous.

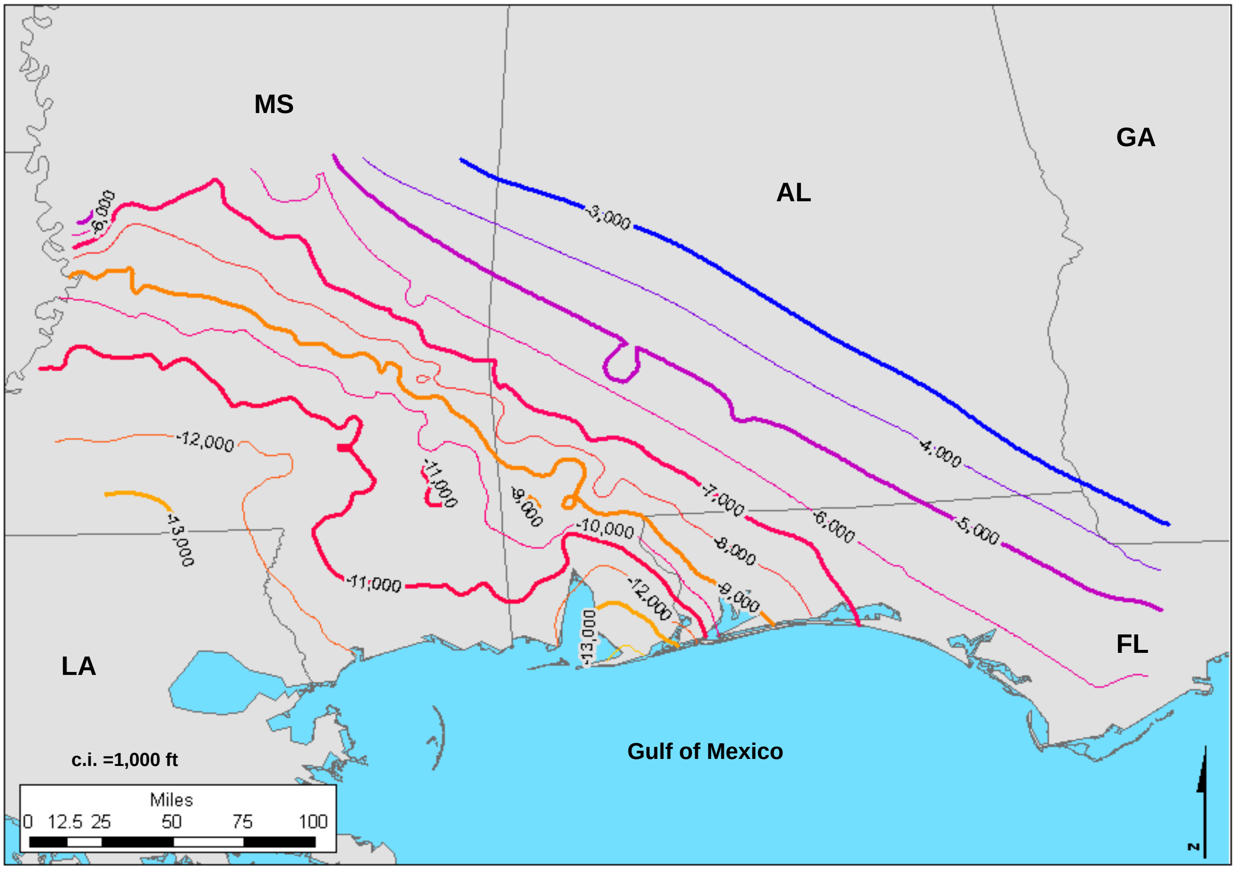

Figure 3. Structure Map on Top of the Paluxy Formation (elevation, subsea).

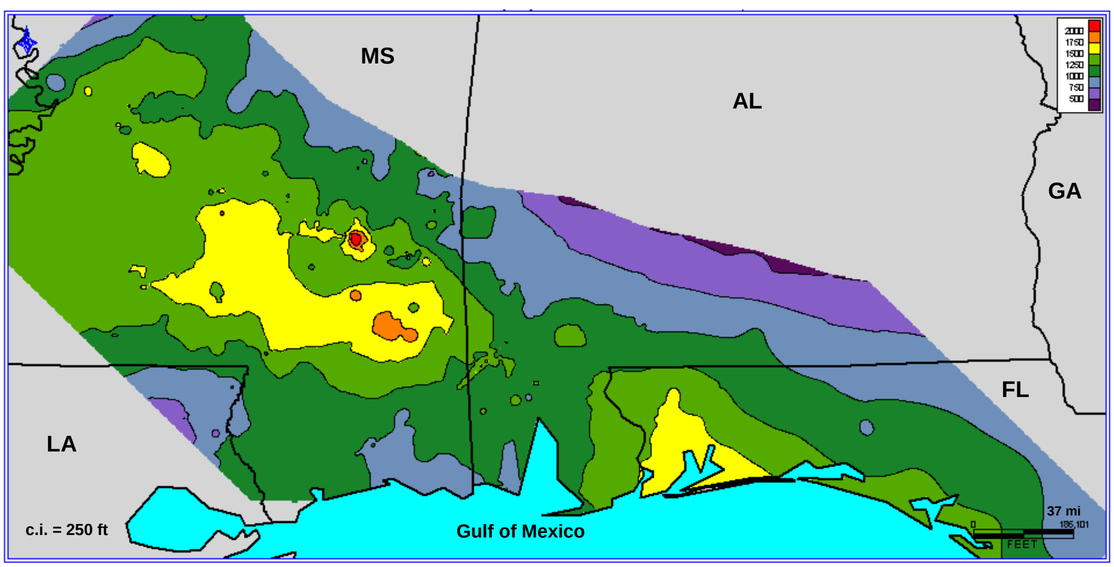

Figure 4. Isopach Map of the Paluxy Formation.

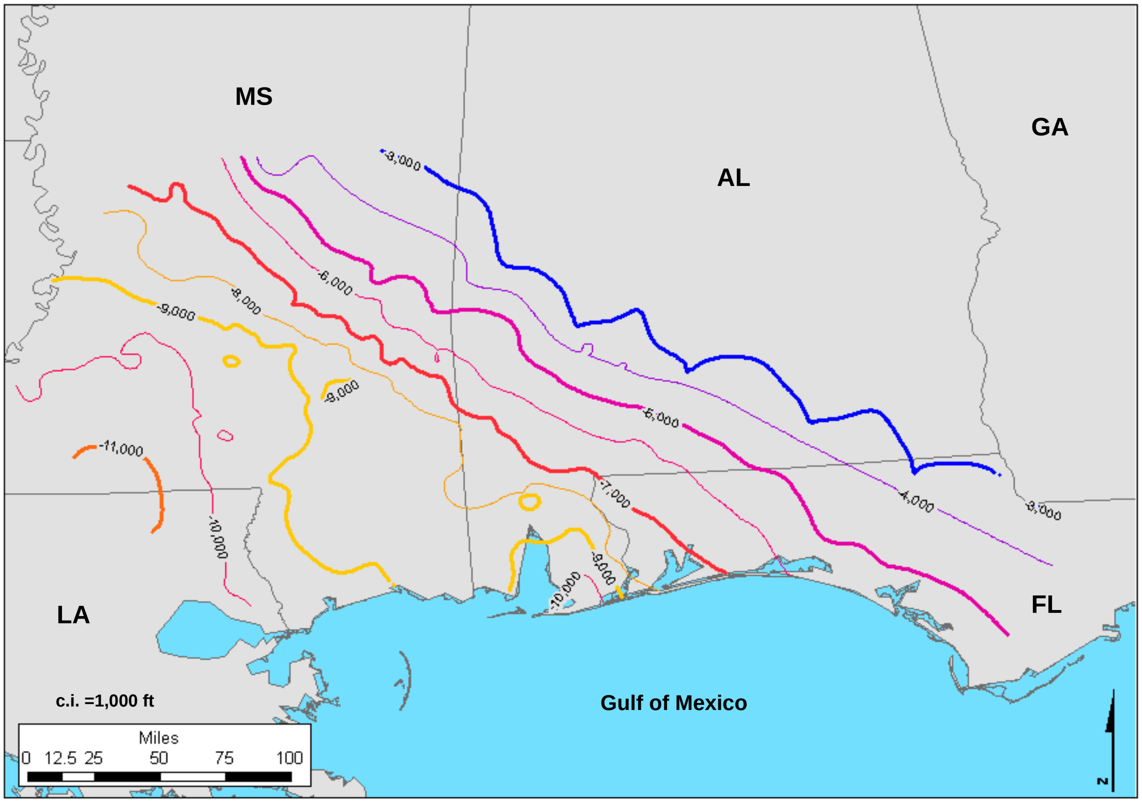

Figure 5. Structure Map on Top of the Washita-Fredericksburg Group (elevation, subsea).

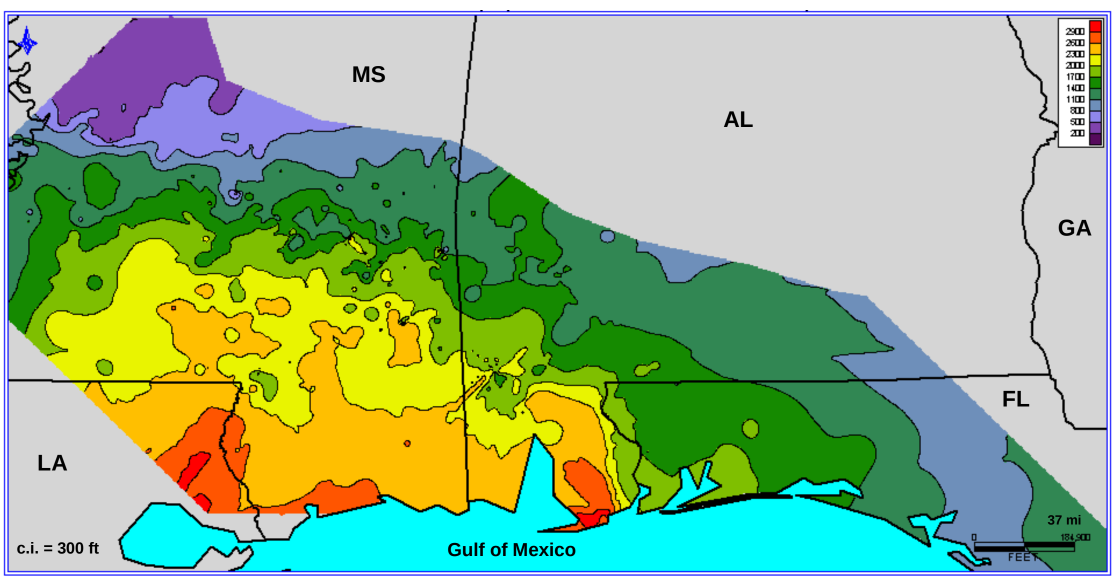

Figure 6. Isopach Map of the Washita-Fredericksburg Group.

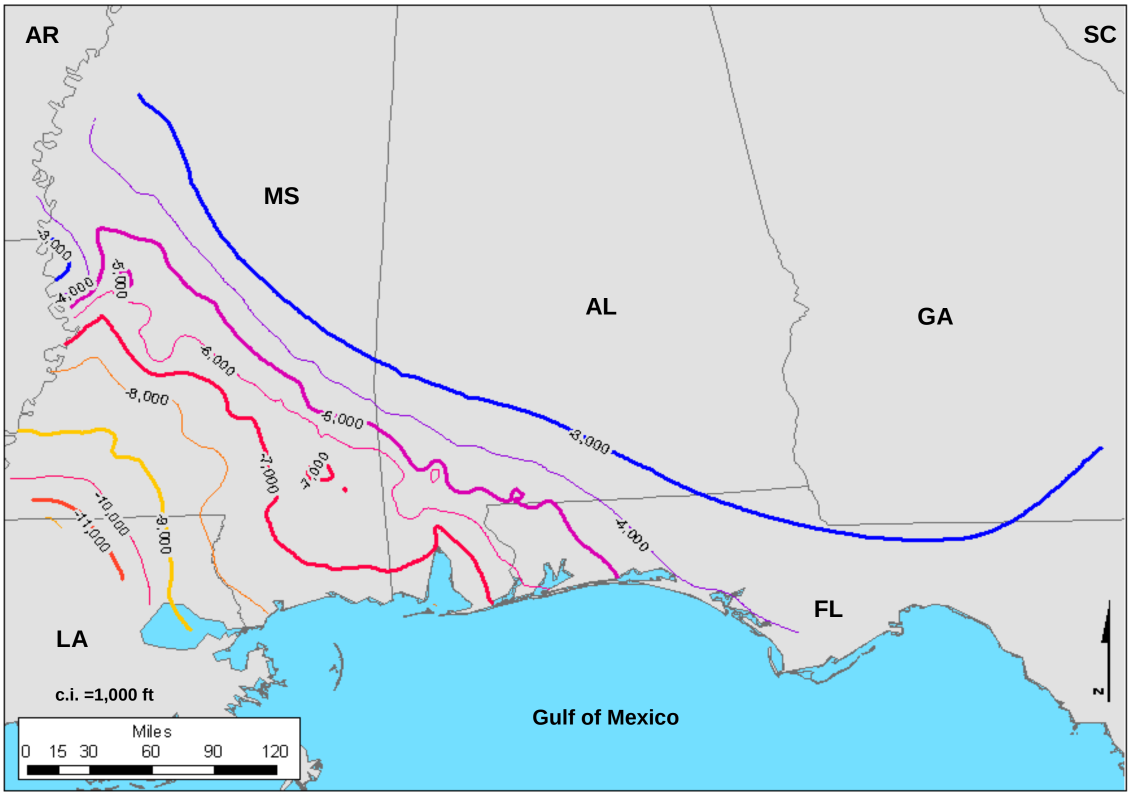

Figure 7. Structure Map on Top of the Eutaw Formation (elevation, subsea).

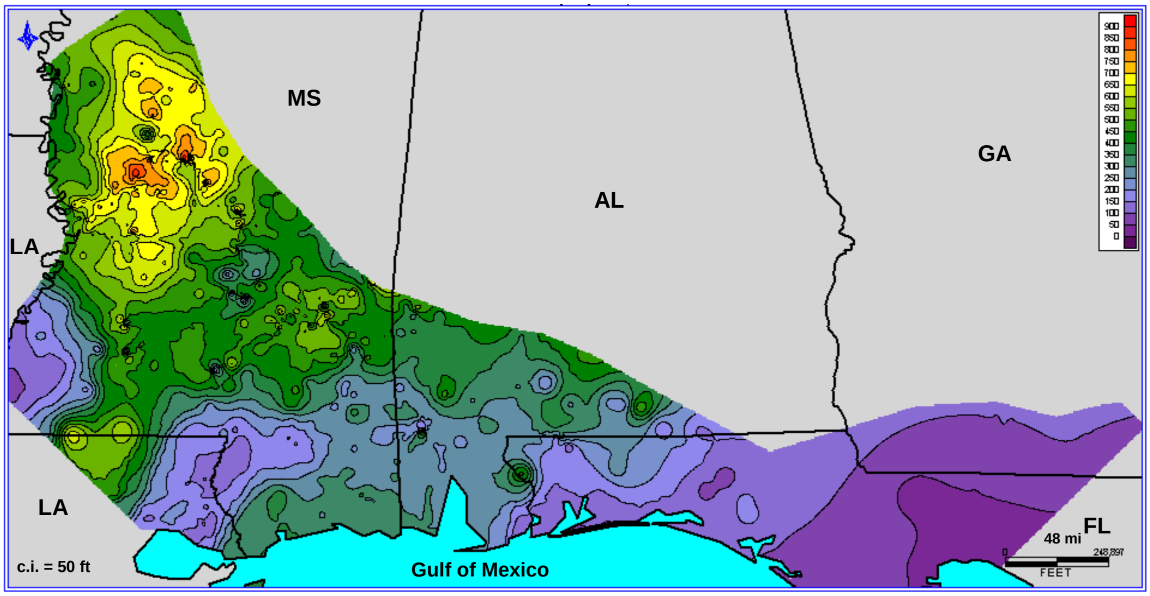

Figure 8. Isopach Map of the Eutaw formation.

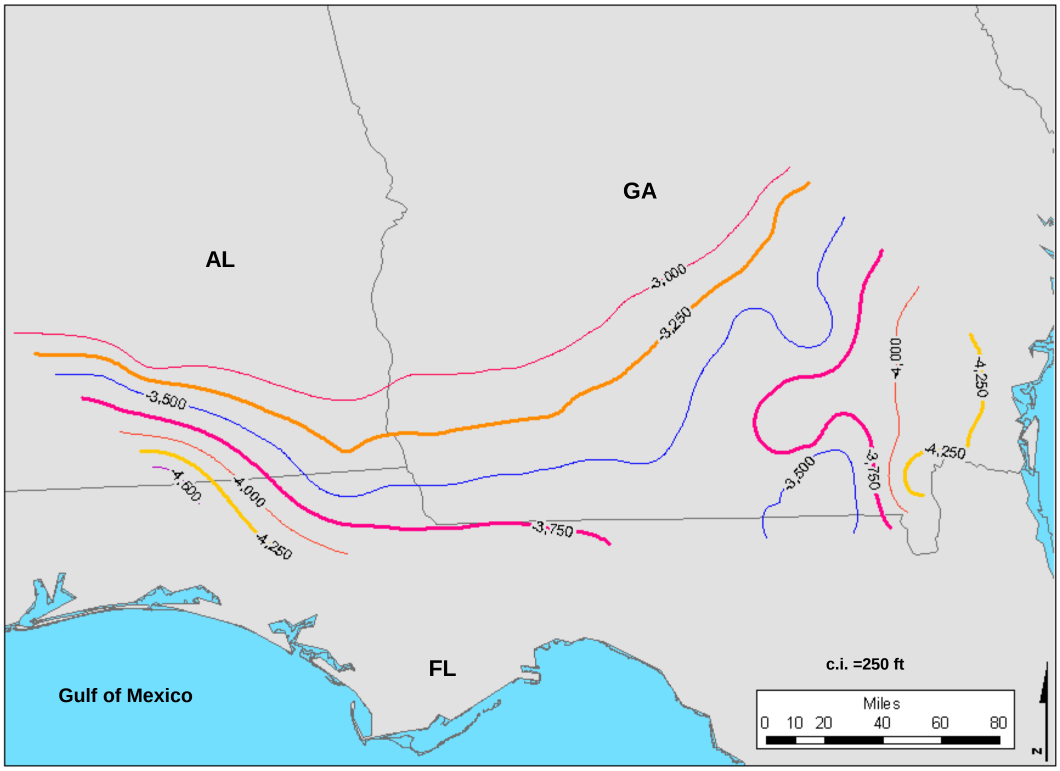

Figure 9. Structure Map on Top of the Lower Cretaceous Undifferentiated (elevation, subsea).

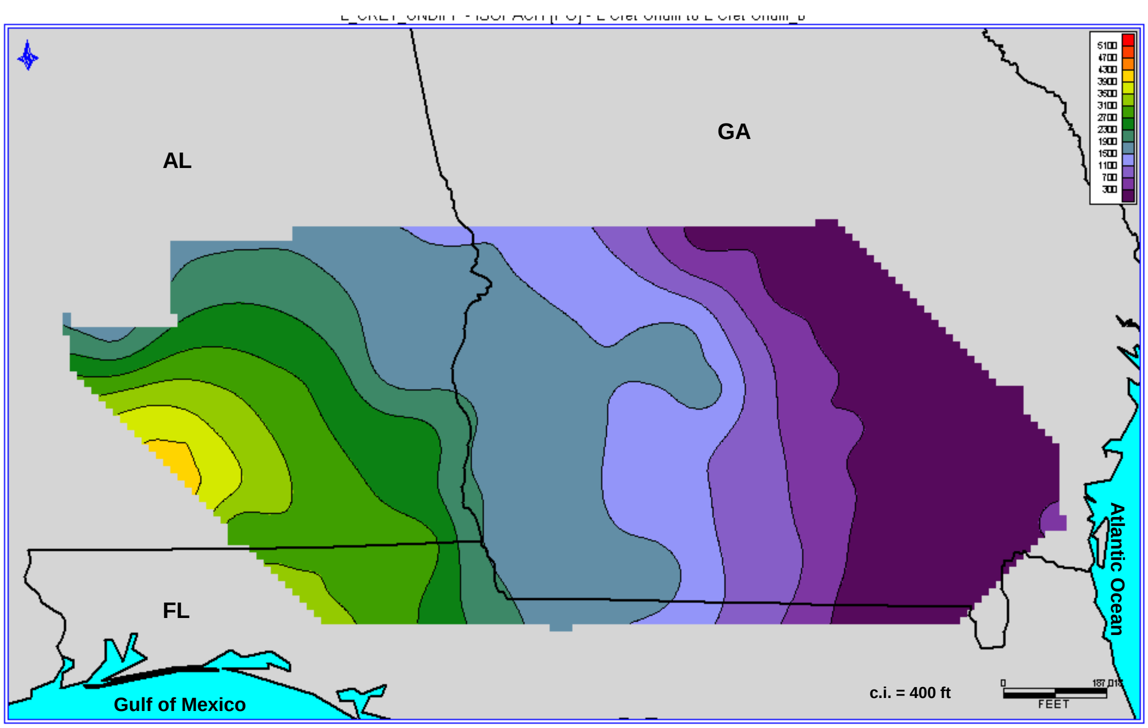

Figure 10. Isopach Map of the Lower Cretaceous Undifferentiated.

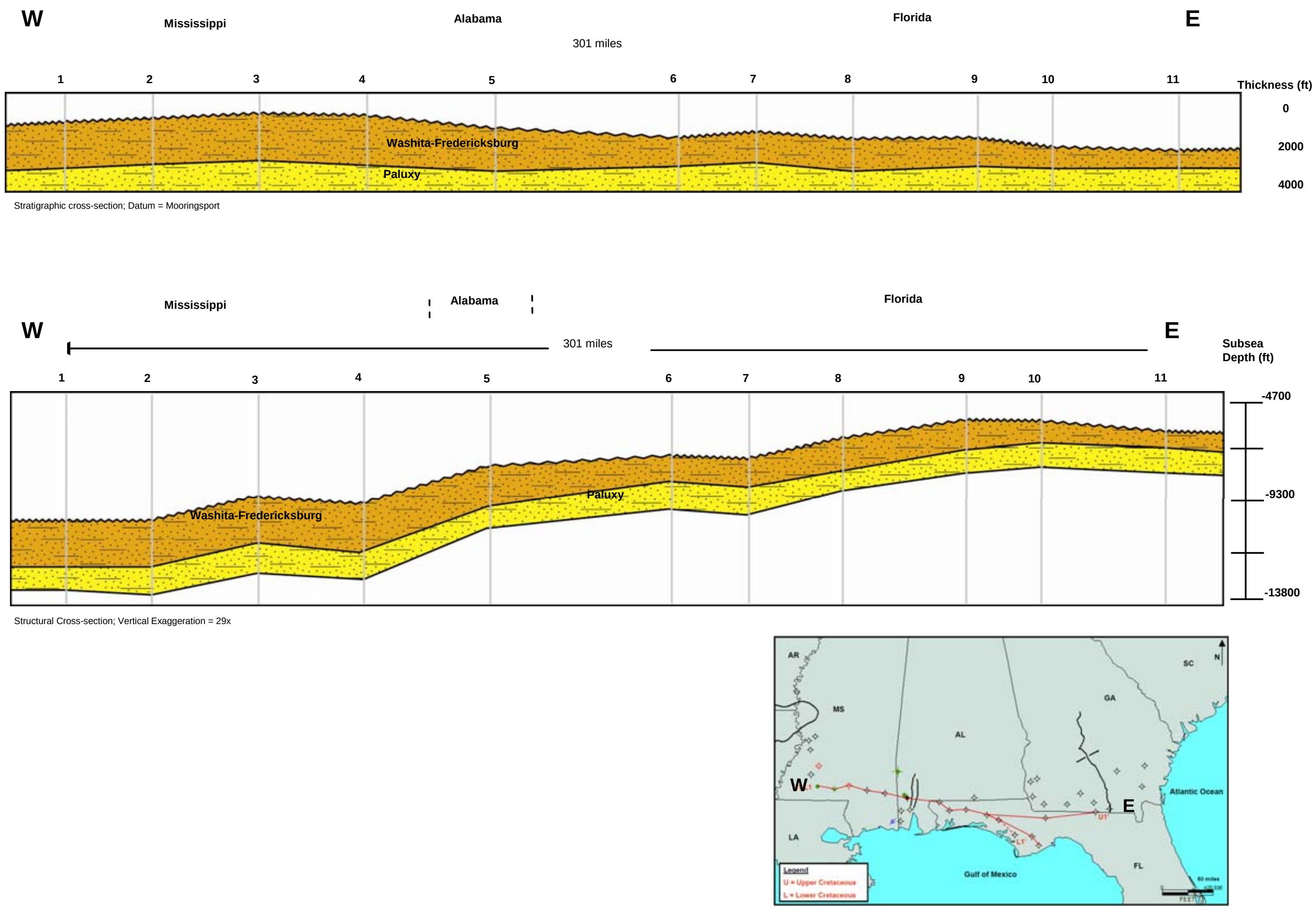

Figure 11. Stratigraphic (top) and Structural (bottom) West-East Schematic Cross-Sections Showing the Paluxy Formation and the Washita-Fredericksburg Group, West Mississippi to Western Panhandle of Florida.

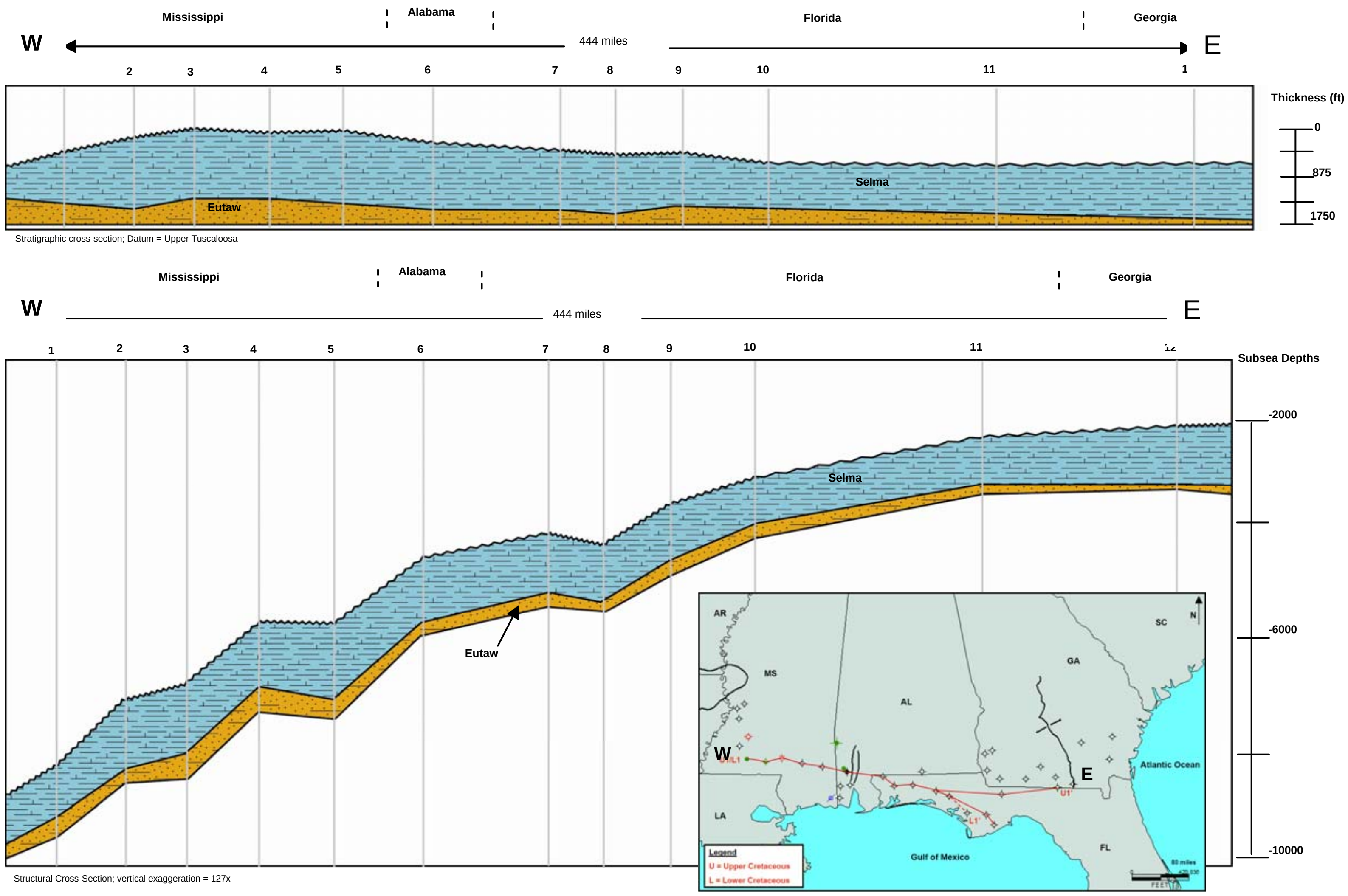

Figure 12. Stratigraphic (top) and Structural (bottom) West-East Schematic Cross-Sections Showing the Eutaw Formation and the Selma Group, West Mississippi to Southwest Georgia.

References

1. Advanced Resources International, Inc., 2008, *Geologic Characterization of the Lower Tuscaloosa Formation for the Phase II Saline Reservoir Injection Pilot Test, Jackson County, Mississippi*, Prepared for the US DOE-NETL, July, 2008.
2. Advanced Resources International, Inc., 2009 A, *Geologic Storage Capacity for CO_2 of the Lower Tuscaloosa Group and Woodbine Formations for the Phase III Work Product 1.1.c.*
3. Advanced Resources International, Inc., 2009 B , *Geologic Characterization of the Lower Tuscaloosa Group,* Geologic Characterization Task Southeast Regional Carbon Sequestration Partnership (SECARB) FY 2009 Annual Report, October 2009.
4. Advanced Resources International, Inc., 2010 A, *Report on Subsurface Characterization of the Phase III Anthropogenic Test Project Site for SECARB Phase III Work Product 4.2.1.d*.
5. Advanced Resources International, Inc., 2010 B, *Plant Daniel Project Closure Report*, Prepared for the US DOE-NETL
6. Alverson, R.M., 1970, *Deep Water Disposal Study for Baldwin, Escambia, and Mobile Counties*, *Alabama*, Geological Survey of Alabama, Circular 58.
7. Devery, D.M., 1982,*Subsurface Cretaceous Strata of Mississippi*, Mississippi Department of Natural Resources, Bureau of Geology and Energy Resources: Information Series, vol. 82-1, 24 pp.
8. Furcon, A.S., “The Georgia Story (The Geological History of Georgia),” *Georgia Mineral Newsletter* 1-5 (1948-1952).
9. Huddlestun, P., Braunstein, J., Beil, R., 1988, *Correlation of Stratigraphic Units in North America-Gulf Coast Region Correlation Chart*, AAPG Correlation Chart Series.
10. Liu, K., 2005, *Facies Changes of the Eutaw Formation (Coniacian-Santonian), Onshore to Offshore, Northeastern Gulf of Mexico Area*, Gulf Coast Association of Geological Societies Transactions, v.55, p. 431-441.
11. Mancini, E.A. et al., 1987, “Environments of Deposition and Petroleum Geology of Tuscaloosa Group (Upper Cretaceous), South Carlton and Pollard Fields, Southwestern Alabama”, American Association of Petroleum Geologists *Bulletin*, v.71, No 10, p 1128-1142, 1987.
12. Mancini, E. A., et al., 2008, “Mesozoic (Upper Jurassic-Lower Cretaceous) deep gas reservoir play, central and eastern Gulf coastal plain,” American Association of Petroleum Geologists *Bulletin*, v. 92, No. 3 p. 283-308.

13. National Energy Technology Laboratory (NETL), 2010, *2010 Carbon Sequestration Atlas of the United States and Canada*, United States Department of Energy.

14. Pashin, J. C, McIntyre, M. R., Grace, R. L. B., Hills, D. J., 2008, *Southeastern Regional Carbon Sequestration Partnership (SECARB) Phase III, Final Report*, Report to Advanced Resources International by Geological Survey of Alabama, Tuscaloosa.