Carbon Sequestration in the Southeastern United States: Past, Present, and Future

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ABSTRACT

Eighty percent of the world's energy relies on fossil fuels and under increasingly stricter national and international regulations on greenhouse gas emissions storage of CO_2 in geologic repositories seems to be not only a feasible, but also and vital solution for near/ mid-term reduction of carbon emissions. Researchers at the University of South Carolina and partners have evaluated the feasibility of CO_2 storage in saline formations of the Eastern North American Margin (ENAM) including (1) the Jurassic/Triassic (J/TR) sandstones of the buried South Georgia Rift (SGR) basin, and (2) Mesozoic and Cenozoic geologic formations along the Mid- and South Atlantic seaboard. These analyses have included integration of subsurface geophysical data with core samples, well logs as well as uses of geological databases and geospatial analysis leading to CO_2 injection simulation models. ENAM is a complex and regionally extensive mature Mesozoic passive margin rift system encompassing: (1) a large volume and regional extent of related magmatism known as the Central Atlantic Magmatic Province (CAMP), (2) a complete stratigraphic column that records the post-rift evolution in several basins, (3) preserved lithospheric-scale pre-rift structures including Paleozoic sutures, and (4) a wide range of geological, geochemical, and geophysical studies both onshore and offshore. Our onshore analyses have included integration of 2- and 3-D seismic surveys with core samples and geophysical well logs leading to a detailed stratigraphic, structural, petrophysical, and injection simulation models. While the target reservoirs onshore show heterogeneity and a highly complex geologic evolution they also show promising conditions for significant safe CO_2 storage away from the underground acquifers. Our offshore study (the Southeast Offshore Storage Resource Assessment - SOSRA) is focused on the outer continental shelf from North Carolina to the southern tip of Florida and relies on detailed interpretation of legacy 2-D seismic reflection (~200,000 km) and well data. This is the first comprehensive assessment of the offshore storage resource capacity in the southeastern United States outer continental shelf. Three old exploration wells are available to provide additional constraints on the seismic reflection profiles. Two of these wells (TRANSCO 1005-1 and COST GE-1) penetrate the pre-rift Paleozoic sedimentary formations while the EXXON 564-1 well penetrates the post-rift unconformity into the Mesozoic rocks. Preliminary results from the southeast Georgia Embayment suggest that Mesozoic strata can be good reservoirs for CO_2 storage while Paleozoic and Cenozoic strata can be good lower and, respectively, upper seals.

Southeast Offshore Storage Resource Assessment (SOSRA)

This is the first comprehensive assessment of the offshore storage resource in the southeastern United States. Smyth et al. (2008) considered storage options in the Carolinas and recognized that significant storage potential exists along the length of the Atlantic continental shelf. In an analysis of a 10,000 mi^2 area of offshore Alabama and the western Florida Panhandle, Hills and Pashin (2010) suggested that about 170 Gt of CO_2 could be stored in Miocene sandstone and that at least 30 Gt could be stored in deeper Cretaceous formations. The University of South Carolina leads the effort of data analyses of the South Atlantic Continental Shelf covering the project planning areas offshore of North Carolina, South Carolina, Georgia, and Florida (Figure 1). The major depocenters and geologic provinces in these planning areas from north to south include the Baltimore Canyon Trough, the Carolina Trough, the Southeast Georgia Embayment, and the Blake Plateau Basin (Figure 2). The range of sediment column thicknesses are 10,000-25,000 ft (Maher and Applin, 1971). The post-rift sediments overlie a regional unconformity known as the "post rift unconformity" that cuts across the entire region after rifting between Africa and North America ceased and marks the transition to wide-spread sediment deposition during the "drift" phase around 165-190Ma (Poag, 1991). Our research to date indicates that the Mesozoic strata within the South Atlantic study area fit the criteria for ideal CO_2 reservoirs and the Cenozoic strata fit the criteria for seals. Further, it is inferred from the seismic interpretation that these reservoir and seal formations have an extensive spatial distribution in the South Atlantic study area.

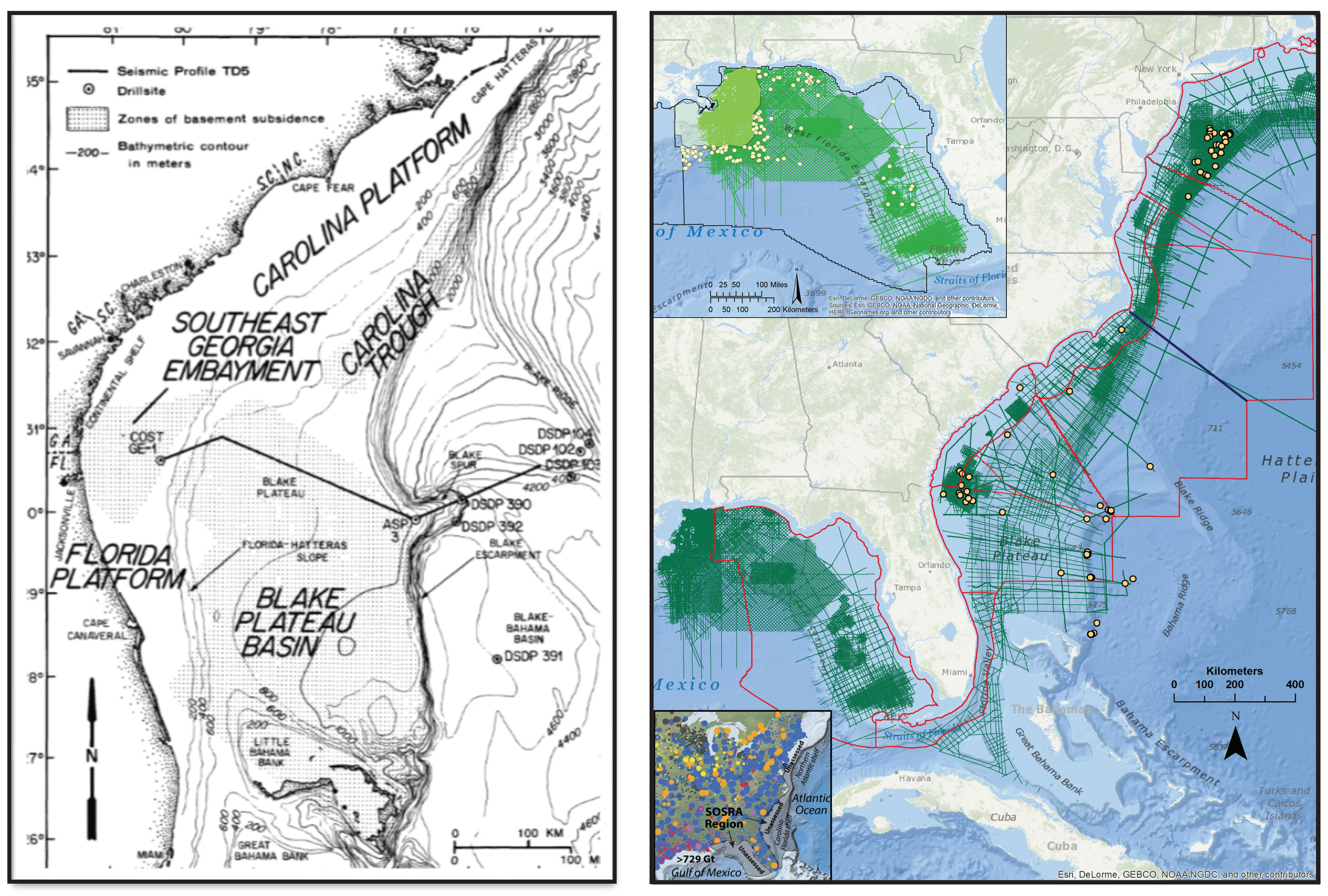


Figure 1. (left) Regional geologic features map and contour map showing major sedimentary basins in South Atlantic Continental Margin (Maher and Applin, 1971). (Right) Data coverage map of the eastern Gulf of Mexico, and Mid- and South Atlantic regions showing the locations of seismic reflection profiles available through BOEM and USGS (green lines) and wells (yellow dots). Thick red boundaries indicate planning area boundaries, and thin red lines indicate projections of state boundaries within federal waters. Inset shows the three areas which are executed by: 1-The Virginia Polytechnic Institute and State University, 2-University of South Carolina, and 3-Oklahoma State University.

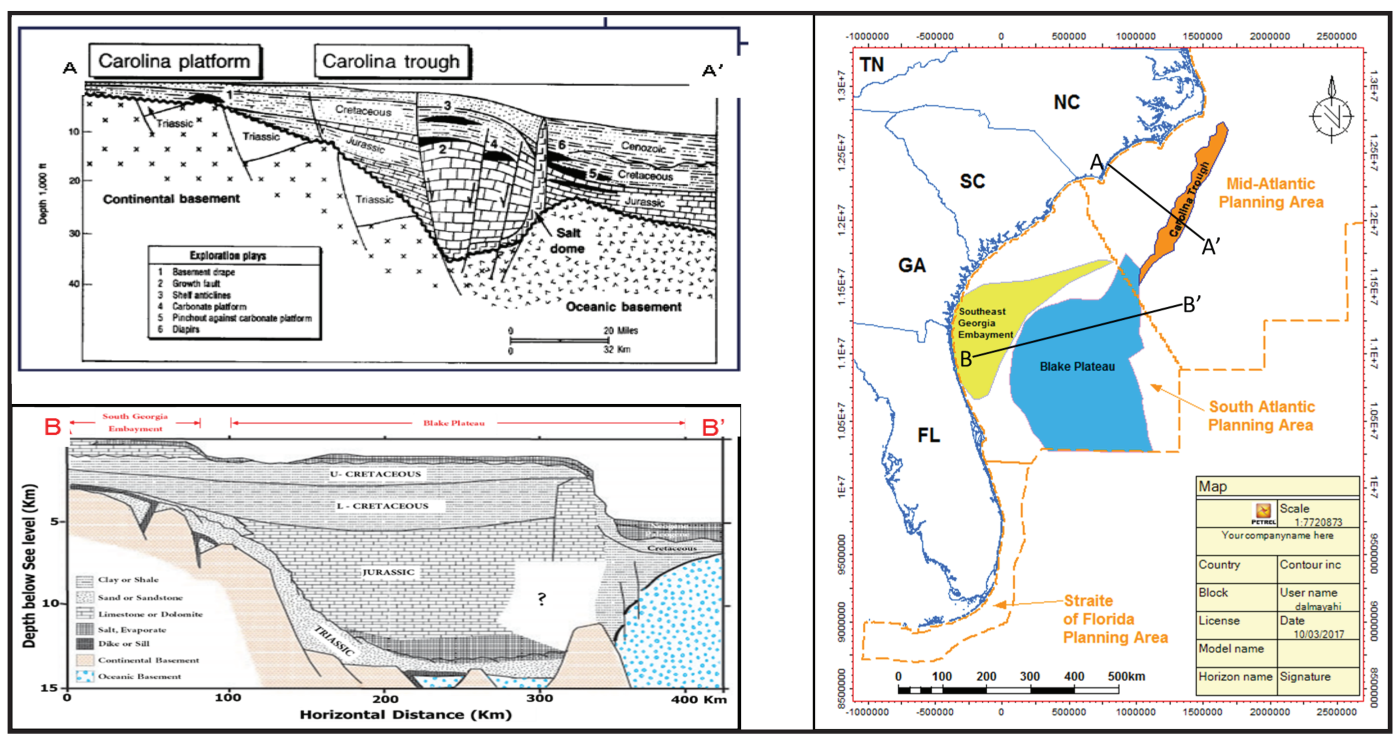
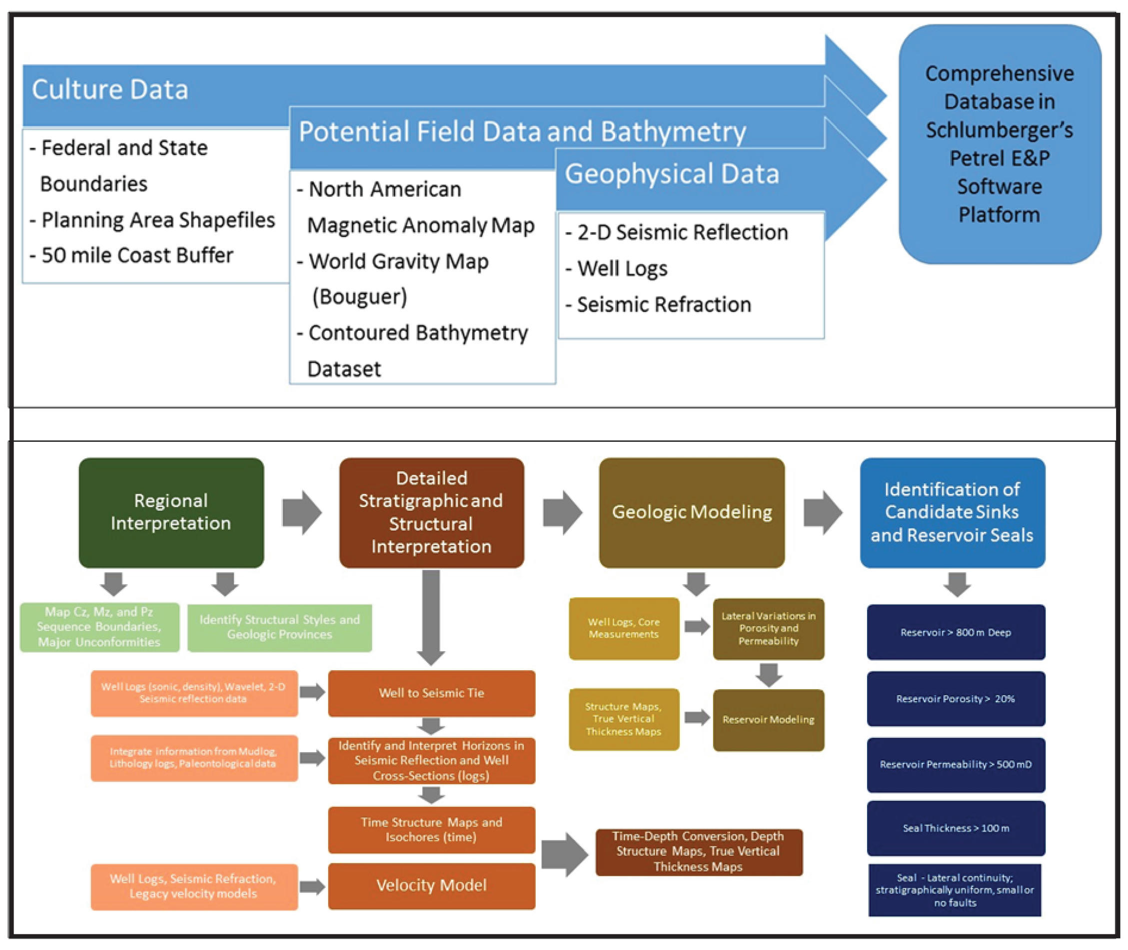


Figure 2. Offshore geological provinces that seem prospective for CO_2 storage: Carolina Trough, Blake Plateau, and Southeast Georgia Embayment (modified after Poag, 1978 and Dillon et al.,1978).

Workflow



Well Logs and Cores

Geological Criteria to Evaluate CO_2 Storage (Chadwick et al., 2008)

Reservoir Properties	Positive Indicators	Cautionary Indicators
Depth	>800 m, <2500 m	<800 m, >2500 m
Reservoir thickness	>50 m	<20 m
Porosity	>20%	<10%
Permeability	>500 mD	<200 mD
Salinity	>100 gl–1	<30 gl–1
Stratigraphy	Uniform	Complex lateral variation and complex connectivity of reservoir facies
Capacity	Estimated effective capacity much larger than total amount of CO2 to be injected	Estimated effective capacity similar to total amount of CO2 to be injected
Caprock Properties		
Lateral continuity	Stratigraphically uniform, small or no faults	Lateral variations, medium to large faults
Thickness	>100 m	<20 m

COST GE-1: Porosity and permeability (Scholle, 1979)

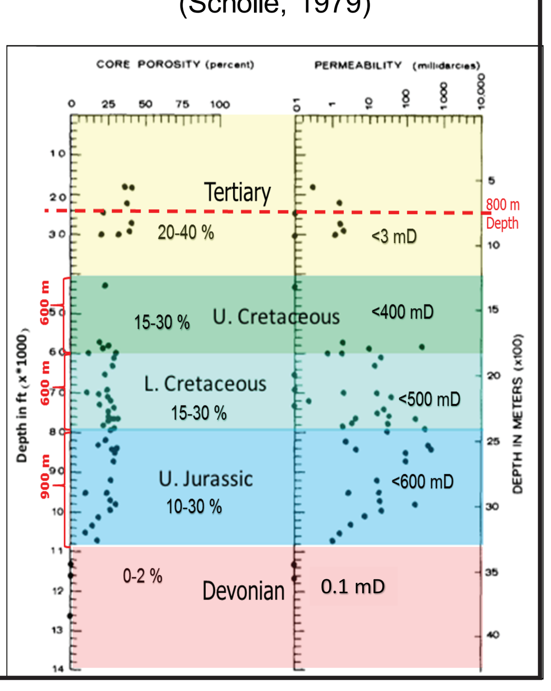


Figure 3. Geologic criteria for CO_2 sequestration and porosity and permeability measured on conventional and sidewall cores from the COST GE-1 well as a function of depth (modified from Scholle, 1979). The figure shows high porosity (25-40% range) of carbonates in the 1,000- to 3,000 ft (300- to 900 m) depth range.

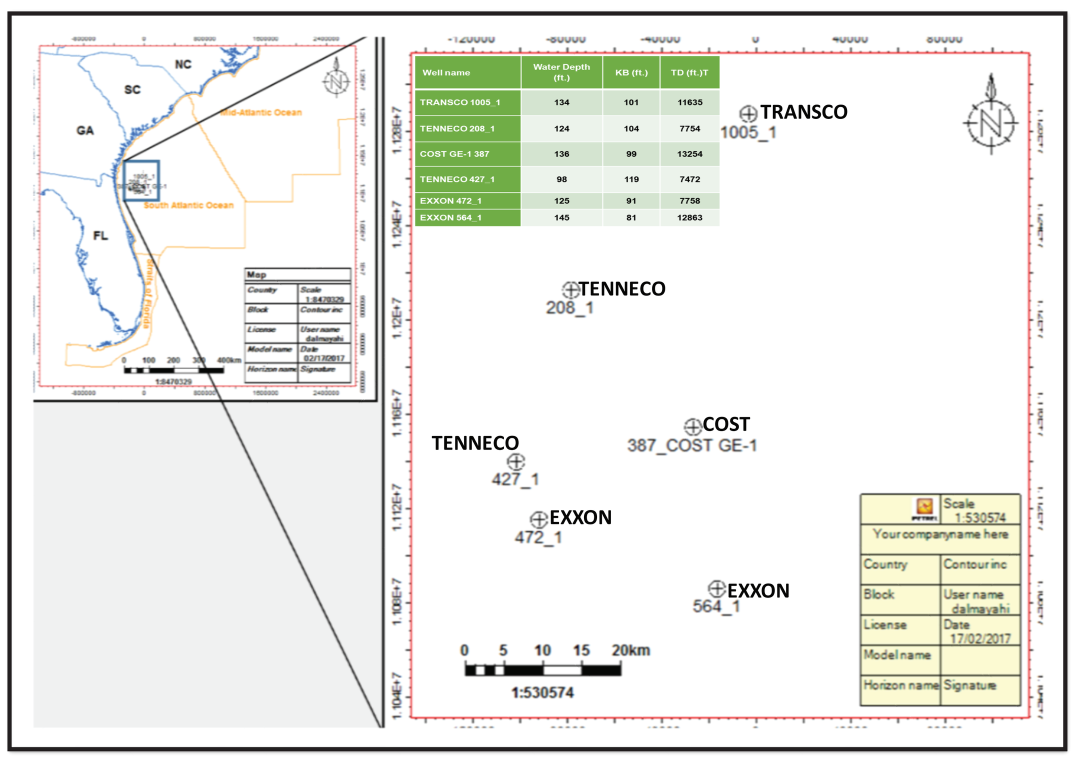
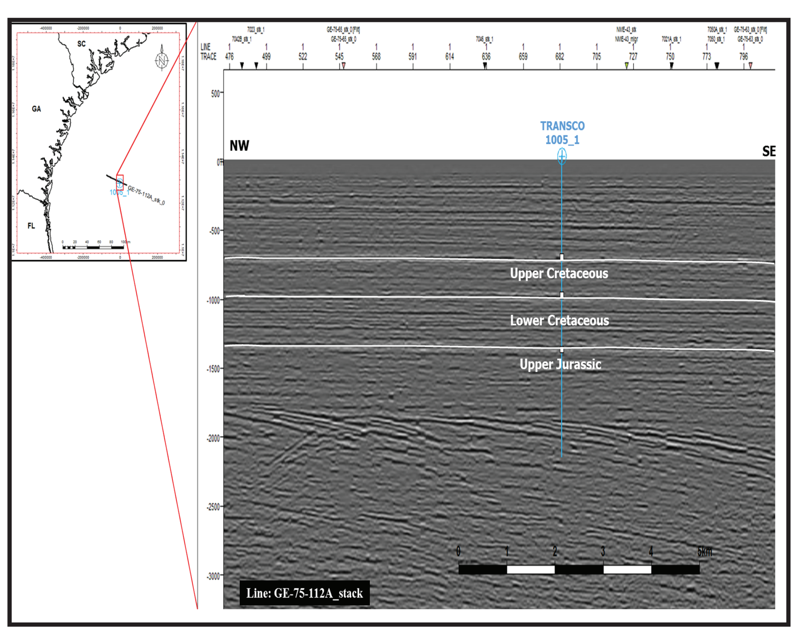
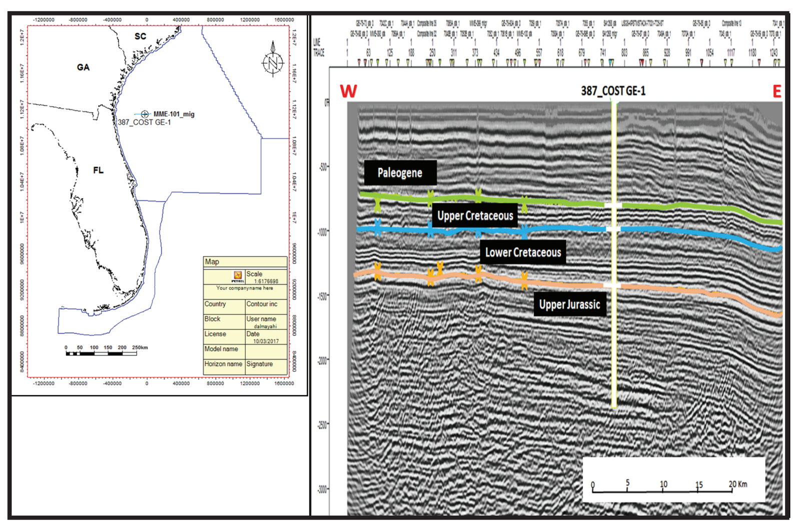
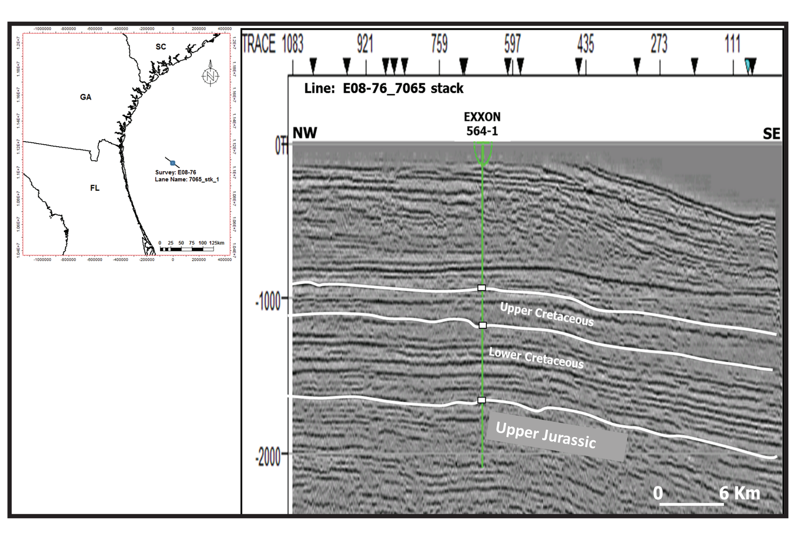


Figure 4. Petrel map window showing the geographic location of the six deep exploration wells within the study area.

Seismic Data







Seismic - Well Tie Analysis

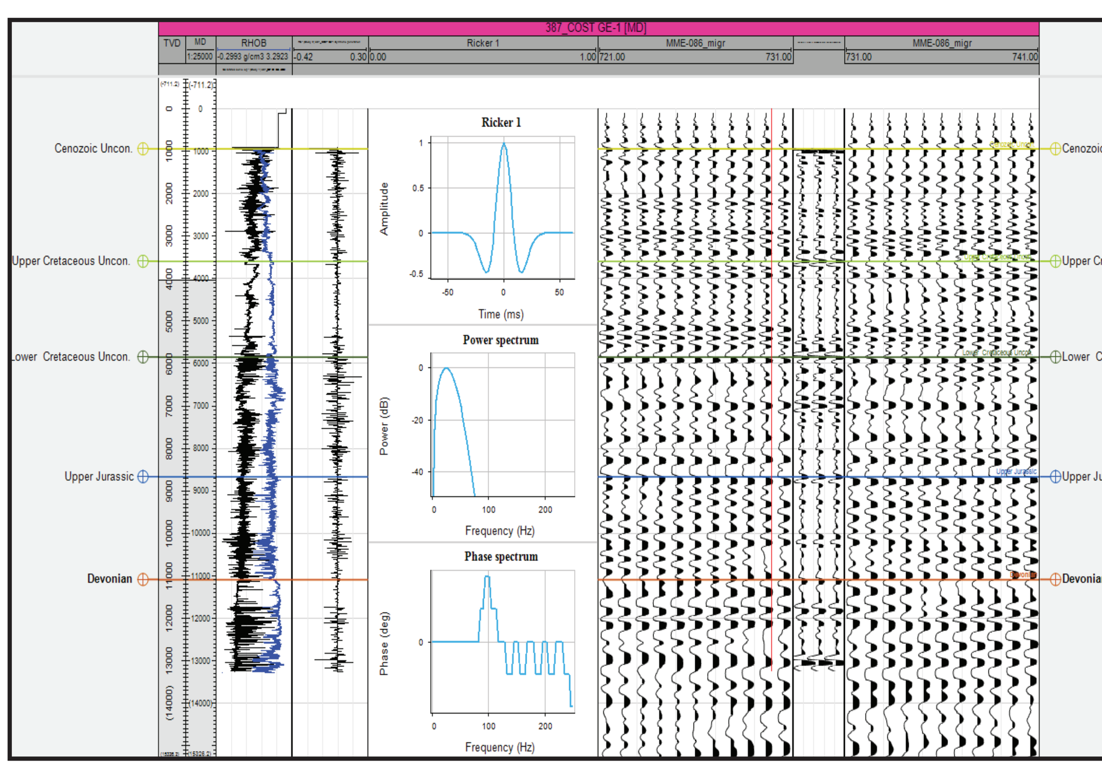


Figure 5. Example of seismic to well tie analysis involving well 307 COST-GE-1 and seismic profile MME_101.

Stratigraphic Interpretation

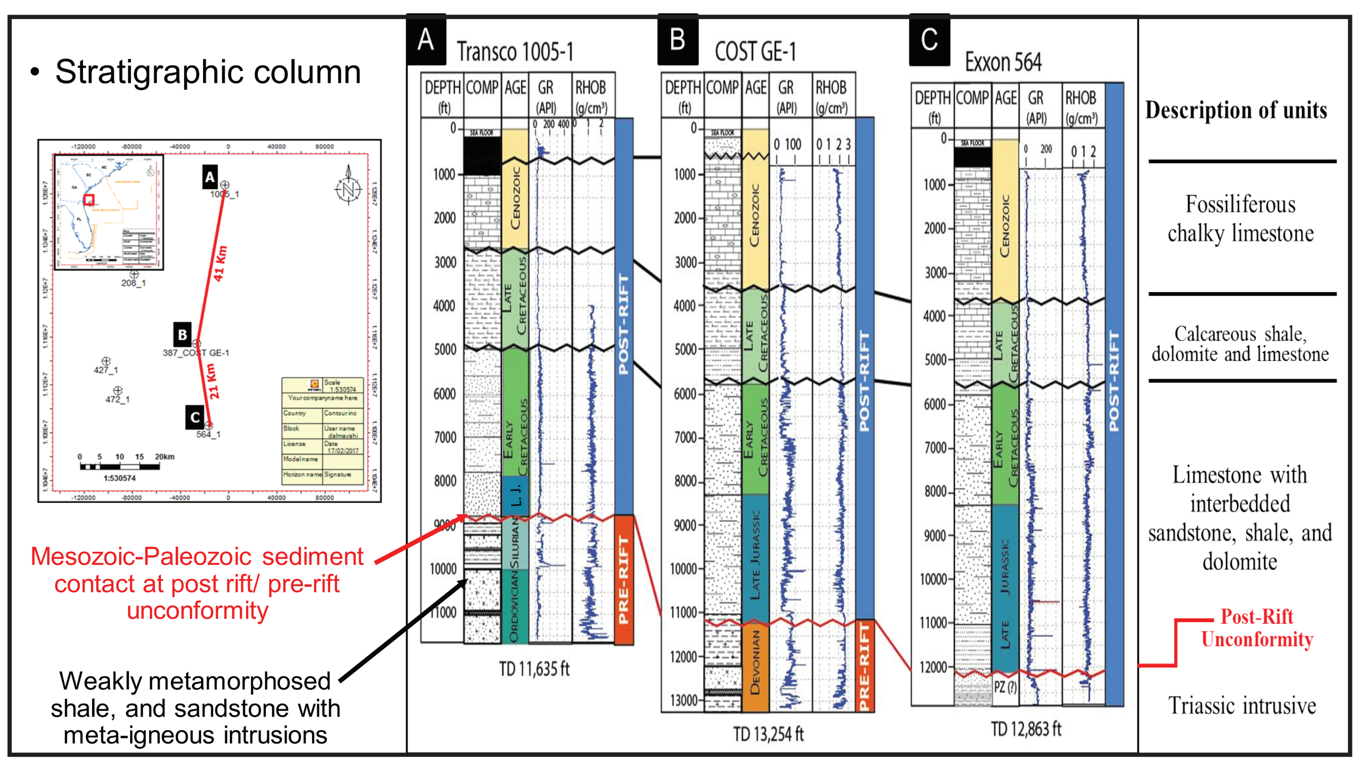


Figure 6. Stratigraphic correlations of Exxon 564-1, COST GE-1, and Transco 1005-1 offshore wells (Scholle, 1979; Poppe, 1995; Boote and Knapp, 2016).

Preliminary Results

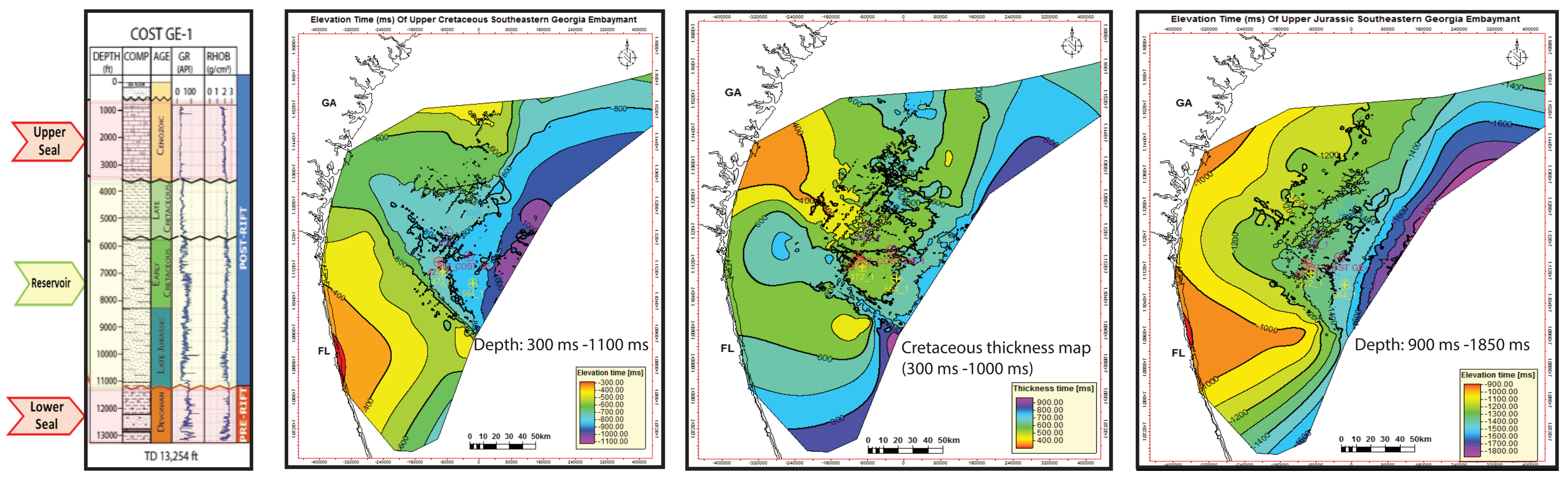


Figure 7. Preliminary isochrons and isopachs of the Mesozoic strata of the Southeastern Georgia Embayment that seem to hold promise for CO_2 storage.

Acknowledgements

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