GEOLOGIC FRAMEWORK FOR THE ASSESSMENT OF OFFSHORE CO_2 STORAGE RESOURCES: WEST FLORIDA PLATFORM

By

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Bachelor of Science in Geosciences

Oklahoma State University

Stillwater, Oklahoma

2015

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
August, 2018

GEOLOGIC FRAMEWORK FOR THE ASSESSMENT OF OFFSHORE CO_2 STORAGE RESOURCES-WEST FLORIDA PLATFORM

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ACKNOWLEDGEMENTS

First and foremost, I would like to thank my wife for all of her sacrifice she has made while I have consumed an immense amount of time on this project. She is an amazing woman, and I cannot thank her enough.

Secondly I would like to thank my Advisor Dr. Jack Pashin for all of his assistance during the course of this project, as well as Chandra Avinash and Jingyao Meng for their valuable insight and assistance during my time at the Boone Pickens School of Geology.

Acknowledgements reflect the views of the author and are not endorsed by committee members or Oklahoma State University.

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Date of Degree: JULY, 2018

Title of Study: GEOLOGIC FRAMEWORK FOR THE ASSESSMENT OF OFFSHORE CO_2 STORAGE RESOURCES-WEST FLORIDA PLATFORM

Major Field: GEOLOGY

Abstract: The West Florida Platform is a broad continental shelf west of peninsular Florida. The platform contains abundant sinks and seals that appear favorable for future commercial storage of CO_2. Proven offshore storage technologies, like those that have been deployed in the North Sea, are likely transferrable to the West Florida Platform. This thesis is part of a larger study to evaluate the CO_2 storage potential of the Eastern Gulf of Mexico continental shelf adjacent to Mississippi, Alabama, and Florida. This project involves a detailed analysis of data from eight exploratory wells in the area of the Sarasota Arch, and includes analysis of geophysical logs, interpretation of 2D reflection seismic profiles, and volumetric analysis of the CO_2 storage resource.

The Sarasota Arch is the primary controlling structure associated with reservoir development. Porous dolomite is concentrated in this structure, and the dolomite passes into nonporous limestone in the flanks. The porous strata identified in the Sarasota Arch have a potential storage resource of more than 878 Gt of CO_2. Limestone and dolomite in Cretaceous and Paleogene strata are the primary targets for CO_2 storage. The Lower Cretaceous Punta Gorda, Gordon Pass, and Panther Camp assessment units appear suitable for injection and storage of supercritical CO_2 and contain abundant stacked dolomitic reservoirs, which are separated by regionally continuous anhydrite confining units. Reservoirs assessed in the Upper Cretaceous and Lower Paleogene Cedar Keys assessment unit contain a potential storage resource of approximately 600 Gt of CO_2, however the lateral extent of the confining anhydrite beds is not as great as in the older units. Storage potential and sealing potential are greatest in Lower Cretaceous strata, which can hold a potential storage resource of about 278 Gt. Multi-gigatonne storage potential on the West Florida Platform could provide a viable storage option in the Eastern Gulf of Mexico, and consequently reduce the emissions footprint in the south-eastern United States.

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CHAPTER I

INTRODUCTION

Anthropogenic CO_2 emissions generated from the Florida Peninsula constitute a large percentage of the total stationary emissions sourced from coastal coal fired power plants in the Southeastern United States. The United States Environmental Protection Agency estimates that about 40% of anthropogenic CO_2 emissions come from the southeastern U.S. (NETL, 2015). For 2016, the EPA estimated the state of Florida produced 108,000,000 metric tons of greenhouse gas emissions (GHG) from 61 power plants (https://ghgdata.epa.gov/ghgp/main.do). Accordingly, there is a need to investigate and evaluate the potential for storage of CO_2 in an environmentally safe manner. The broad continental shelf of the West Florida Platform may prove to be a reliable geologic sink for the safe, economical, and acceptable storage location for greenhouse gas, but this area has yet to be assessed.

Previous onshore studies have assessed the potential for CO_2 storage in the Southeastern United States (e.g., Pashin et al. 2008, Hills and Pashin 2010; Koperna et al., 2012). The studies have suggested that there is a large potential for CO_2 storage in Miocene sandstone, and additional potential in the deeper Cretaceous formations offshore of Alabama, Mississippi, and Florida. Geophysical log data indicate that water in prospective storage formations have total dissolved solids (TDS) values much greater than 10,000 mg/mL (Breit, 2002), and so water that would be protected onshore does not extend into the offshore area being assessed. An assessment consistent with the methodology outlined by the National Energy Technology Laboratory (NETL) (Goodman et al., 2011; NETL, 2015) will provide the basis for quantitatively identifying the potential of the West Florida Platform for safe storage of CO_2.

Statement of Purpose

The purpose of this study is to evaluate the CO_2 storage potential of the eastern Gulf of Mexico continental shelf adjacent to western Florida. This research is being conducted as part of a larger investigation of the storage resource in the eastern Gulf of Mexico Basin and the Atlantic continental shelf that is supported by the U.S. Department of Energy through the Southern States Energy Board as part of the Southeast Offshore Storage Resource Assessment (SOSRA). This project identified offshore formations that could potentially store CO_2 in the central part of the West Florida Platform (Fig. 1).

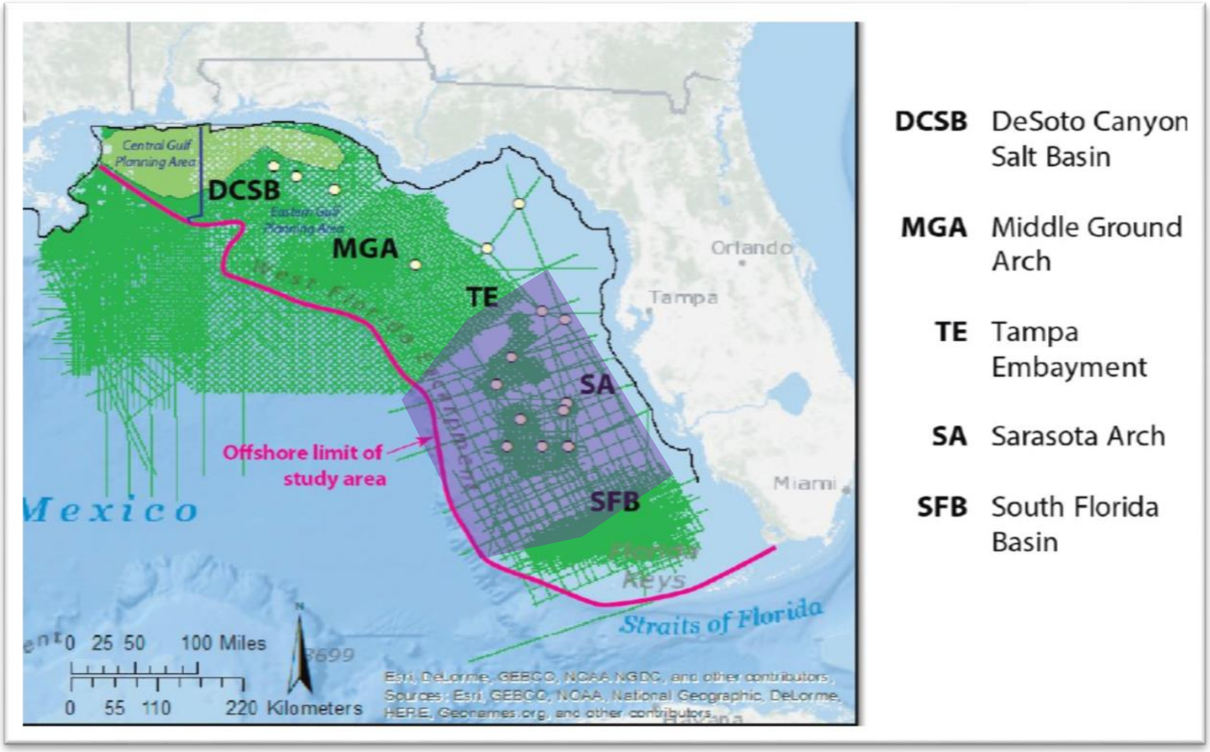

Figure 1. Location of study area outlined in purple box primarily near the Sarasota Arch (after Pashin et al., 2016).

Offshore CO_2 storage technology was initially proven by Statoil and its partners in 1996 with the Sleipner project in the North Sea (Chadwick et al., 2004; Kaarstad, 2004). The Sleipner project stores about 0.9 Mt/yr of CO_2 that has been separated from natural gas and condensate. The Sleipner project, importantly, is the first industrial CO_2 storage project performed specifically for greenhouse gas mitigation (Arts et al., 2009). Many of the technologies employed at Sleipner, as well as at other CO_2 storage facilities, may be transferrable to the West Florida Platform, where significant CO_2 emissions are generated by coal- and natural gas-fired power plants. Geological analysis of the West Florida Platform will provide the data and information needed to assess the storage resource in the Eastern Gulf of Mexico and to identify early opportunities for deployment.

The primary goal of this research is to characterize the geologic framework of the West Florida Platform in order to develop a geologic model of CO_2 storage in and around the Sarasota Arch. I hypothesize that saline formations in Cretaceous and younger strata have significant (i.e., gigatonne-class) capacity for CO_2 storage, and each offshore block (~9.0 mi^2) can store annual anthropogenic greenhouse gas emissions from multiple coal-fired power plants in peninsular Florida. This working hypothesis can be tested by performing a thorough analysis of well logs and 2D seismic data, which provide a basis for identifying prospective storage targets and seals, as well as identifying lateral continuity of the anhydrite topseals described in onshore studies (Roberts-Ashby et al., 2015). Additionally, a model for CO_2 sequestration will be constructed to evaluate the storage potential in the project area using basic reservoir and fluid properties by analyzing seismic and well log data for net thickness, porosity, and applying currently accepted volumetric calculations for estimating CO_2 storage in saline reservoirs. (Goodman et al., 2011, NETL, 2015).

Key objectives of this research include analyzing and correlating geophysical well logs, building stratigraphic cross sections, interpreting 2D seismic profiles, constructing isochore and isolith maps, identifying prospective storage units, and performing a static assessment of the available storage resource. Other objectives include characterizing the stratigraphic framework based on pre-stack time migrated reflection seismic data, as well as analyzing the geologic feasibility and risk associated with prospective sinks and seals. A vital task for interpreting seismic data is identifying key stratigraphic markers that help tie seismic and well data. A preliminary assessment of offshore CO_2 storage in parts of the southeastern United States has been performed by Tew, et al. (2013), who noted that the West Florida Platform has yet to be assessed.

This report begins by presenting the basic geologic framework of the project area, and then the methodology used to characterize the project area and perform volumetric assessment. Next is a detailed discussion of the stratigraphic framework that characterizes the Cretaceous-Paleogene section, which is dominated by numerous successions of carbonate and evaporite strata. Lastly, an assessment of storage potential will be conducted by considering the location and lateral extent of anhydrite beds, which are prospective reservoir seals, as well as a determining the capacity of each prospective CO_2 sink. The U.S. Department of Energy (DOE) employs a basic volumetric approach for the evaluation of CO_2 storage resources that includes saline formations like those that occur offshore of western Florida (NETL, 2007, 2015; Goodman et al., 2011).

Important questions addressed in this study include:

- What are the reservoir properties of limestone and dolomite in the study area?
- What effect will structural features have on the flow and trapping of injected CO_2?
- What is the storage resource in each prospective geologic sink?
- What is the thickness lateral continuity of sealing strata, such as anhydrite and shale?

After characterization of the geologic framework and determination of the storage resource in the study area, recommendations are made regarding the viability of commercial CO_2 storage programs in the Eastern Gulf of Mexico.

CHAPTER II

GEOLOGIC SETTING

The Florida Peninsula is in the eastern portion of a large Mesozoic-Cenozoic carbonate platform and forms the proximal portion of the West Florida shelf-slope system (Hine et al., 2001). The study area is located primarily in the west-central part the West Florida Platform in the area of the Sarasota Arch, with the Tampa Embayment lying to the north, and the South Florida Basin to the south (fig. 1). The platform extends 500 km (270 mi) westward from the shoreline to the West Florida Escarpment (fig. 2), which marks a steep platform margin adjacent to the deep Gulf of Mexico (Hine et al., 2001). During the Late Triassic, the Gulf of Mexico began forming as the North American Plate began rifting from the South American and African plates (Salvador, 1987; Dobson and Buffler, 1997). The basement rocks of the West Florida Platform are of Gondwanan affinity and include Precambrian-Cambrian (0.5-2.0 Ga) plutonic rocks, Ordovician-Devonian sedimentary rocks, and Triassic-Jurassic sedimentary and plutonic rocks (Arthur, 1988; Randazzo, 1997). The West Florida Platform is composed primarily of shallow-marine to coastal carbonate and evaporite deposits (Halley, 1985; Scott, 2001).

Jurassic-Cretaceous carbonates were deposited at tropical to subtropical latitudes, and evaporite beds dominated by anhydrite punctuate the stratigraphy (Hine et al., 2001). Andrew Petty (1995) correlated and characterized anhydrite beds in the platform;

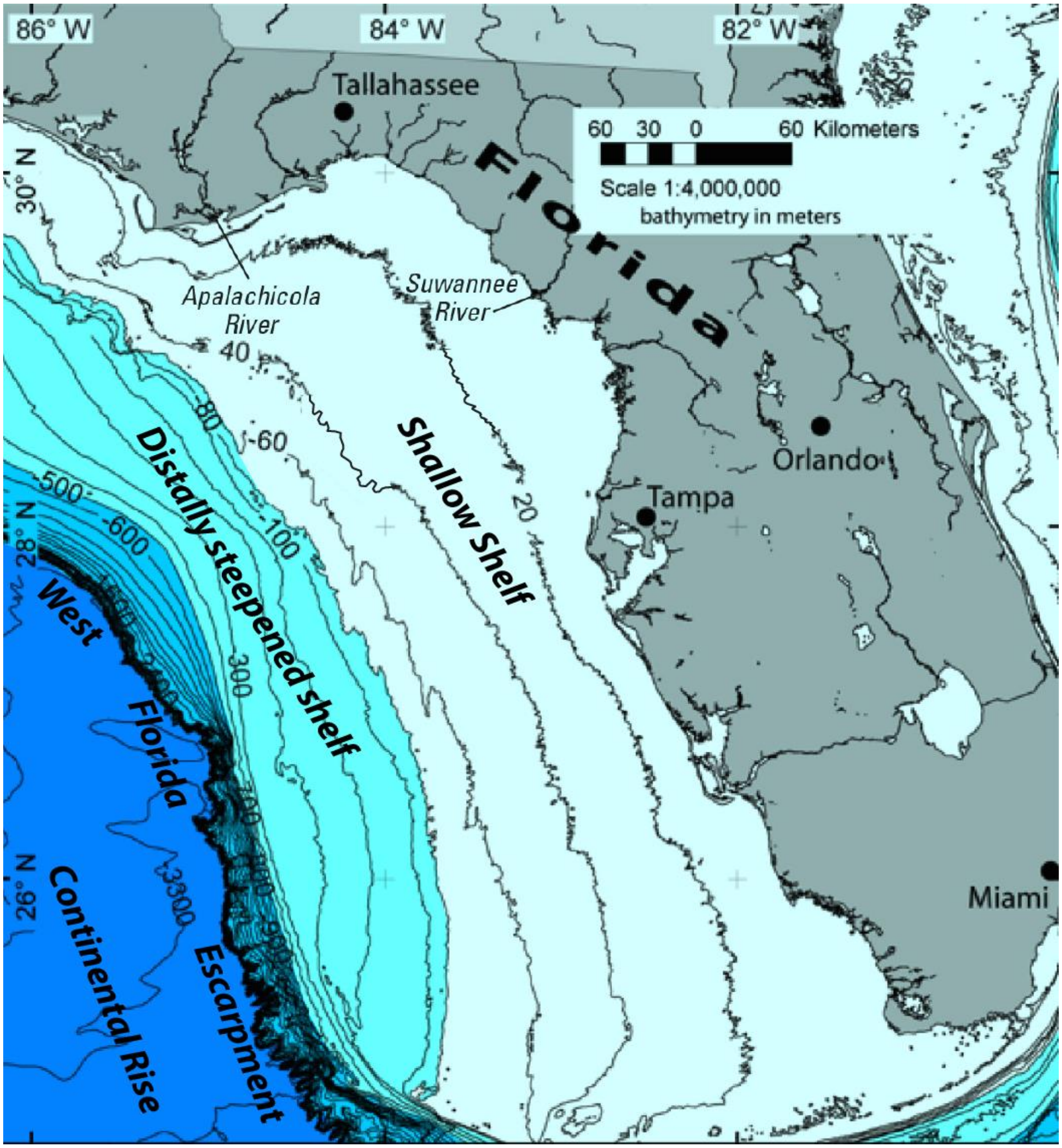

Figure 2. USGS bathymetric map showing the shelf geometry, and the steep Florida Escarpment (after Hine, 2001).

these beds are important topseals for the onshore hydrocarbon reservoirs of the Sunniland trend. Petty stated that the lower Cretaceous Punta Gorda Anhydrite, which is equivalent to the Ferry Lake Anhydrite in the central and western Gulf of Mexico, forms a key marker interval that is traceable from southern Mississippi to southern Florida (Petty, 1995). Organic-rich carbonate mud also accumulated intermittently in the study area and has been interpreted as a product of hypersaline interior lagoons (Halley, 1985). Based on a recent assessment of the onshore South Florida Basin that was performed by the U.S. Geological Survey (Roberts-Ashby et al., 2015), the principal reservoirs favorable for CO_2 storage are in the Lower Cretaceous carbonate-evaporite successions and in the lower part of the Paleogene section. Anhydrite seals in the Paleogene section onshore are laterally extensive and average 650-985 feet in thickness (Roberts-Ashby et al., 2015).

CHAPTER III

ANALYTICAL METHODS

Geologic data, including public-domain well data, 2D seismic surveys, and preliminary Gulf of Mexico log picks obtained from the Bureau of Safety and Environmental Enforcement (BSEE) and the Bureau of Ocean Energy Management (BOEM). Basic well information, including OCSG well identification number, well locations, and stratigraphic picks were compiled. Rasters of geophysical well logs were imported into Adobe Illustrator software for graphic correlation. Seismic surveys were loaded into IHS Kingdom Suite software. Basic well log information is given in table 1. Only two mud logs are available in the study area, but these logs were invaluable for verifying interpretations of rock types in the geophysical logs, which include gamma ray, resistivity, neutron porosity, and density porosity. A combination of log suites revealed trends in the data, and the anhydrite successions were identified by extremely high deep resistivity profiles, low gamma count, bulk density values near 2.9 g/cm^3, and neutron porosity near zero. In contrast, limestone and dolomite were differentiated primarily by the neutron and density porosity logs. Quality control on rock type identification and identifying porous intervals was performed by observing trends in the caliper log for zones of borehole washouts.

Table 1. Summary of well log information within the study area of the Florida platform.

Well Name	SP	GR	Resistivity	Conductivity	Caliper	Bulk Density	Micro log	Porosity	Sonic
G-3917 No. 1 (CH)	X	X	X	X	X	X	X	X	X
G-4950 No. 1 (CH)	X	X	X		X	X	X		X
G-3903 No. 1 (VB)	X	X	X		X	X		X	X
G-3912 No. 1 (CH)	X	X	X	X	X	X	X	X	X
G-3909 No. 1 (CH)	X	X	X	X	X	X		X	X
G-3906 No. 1 (CH)	X	X	X	X	X	X		X	X
G-3341 (EL)	X	X	X		X	X	X	X	X
G-3344 (EL)	X	X	X		X	X		X	X

Formation tops in a database from BOEM were compared with the mud logs and geophysical well logs. The top picks were refined based on well-log correlations and review of available geologic literature. Next, two regional cross sections were constructed, one being a strike section, and the other a dip section. These cross sections were made to establish correlations, delineate facies relationships, and characterize reservoir heterogeneity and seal continuity.

Candidate storage objectives were identified based on the results of well log analysis and lithologic patterns. Similarly, potential reservoir seals were identified based on rock type, thickness, porosity, and continuity. The depth to reservoir is important for storage of CO_2 in a supercritical state. The critical point for CO_2 is at a temperature greater than 31.1° C and a pressure above 73 atm which typically occurs at depths greater than 2,480 ft (756 m).

Once all potential storage locations were identified, digital well logs were used to quantify the porosity of the prospective geologic sinks. Information derived from the well logs includes gross thickness, net thickness, and average porosity. The dataset was organized into a spreadsheet to perform calculations and lithologic corrections. All of the neutron and density porosity logs in the study area were run on a limestone matrix, and corrections for other rock types were made using standard calculations outlined in Asquith and Krygowski (2004). Without this correction, for example, the porosity of dolomite would be underestimated and of sandstone would be overestimated. A minimum cutoff of 15% porosity was chosen to qualify reservoirs as prospective storage units. Primary reservoir thickness within the 15% porosity range must be > 20 feet thick, and the total thickness includes thin porous dolomite beds in close proximity to the primary reservoir. For example, many of the wells containing porous beds with a continuous section of 15 feet of 15% or more porosity are included if an additional 5 feet of porous dolomite is in proximity.

All seismic data were loaded into IHS Kingdom software suite for interpretation. Revised stratigraphic picks were tied to seismic profiles using velocity (checkshot) surveys, which are available for all but one well in the study area (fig. 3). Stratigraphic tops picked during well log interpretation were compiled into a text file (.txt), and each associated formation top pick was linked with their respective unique well identifier (UWI) and imported and into the IHS Kindgom software suite. A well to seismic tie was completed to confirm that the stratigraphic tops match the amplitudes within the 2D seismic surveys (fig. 10). After verifying the seismic to well tie, key marker beds were identified and traced in Kingdom software, and the geometry and continuity of the strata were evaluated. After interpretation, the data were exported into Petrel software to construct subsea structure, net thickness, porosity, and storage resource maps. The minimum curvature method was used to grid structure maps, and a 5,000 m

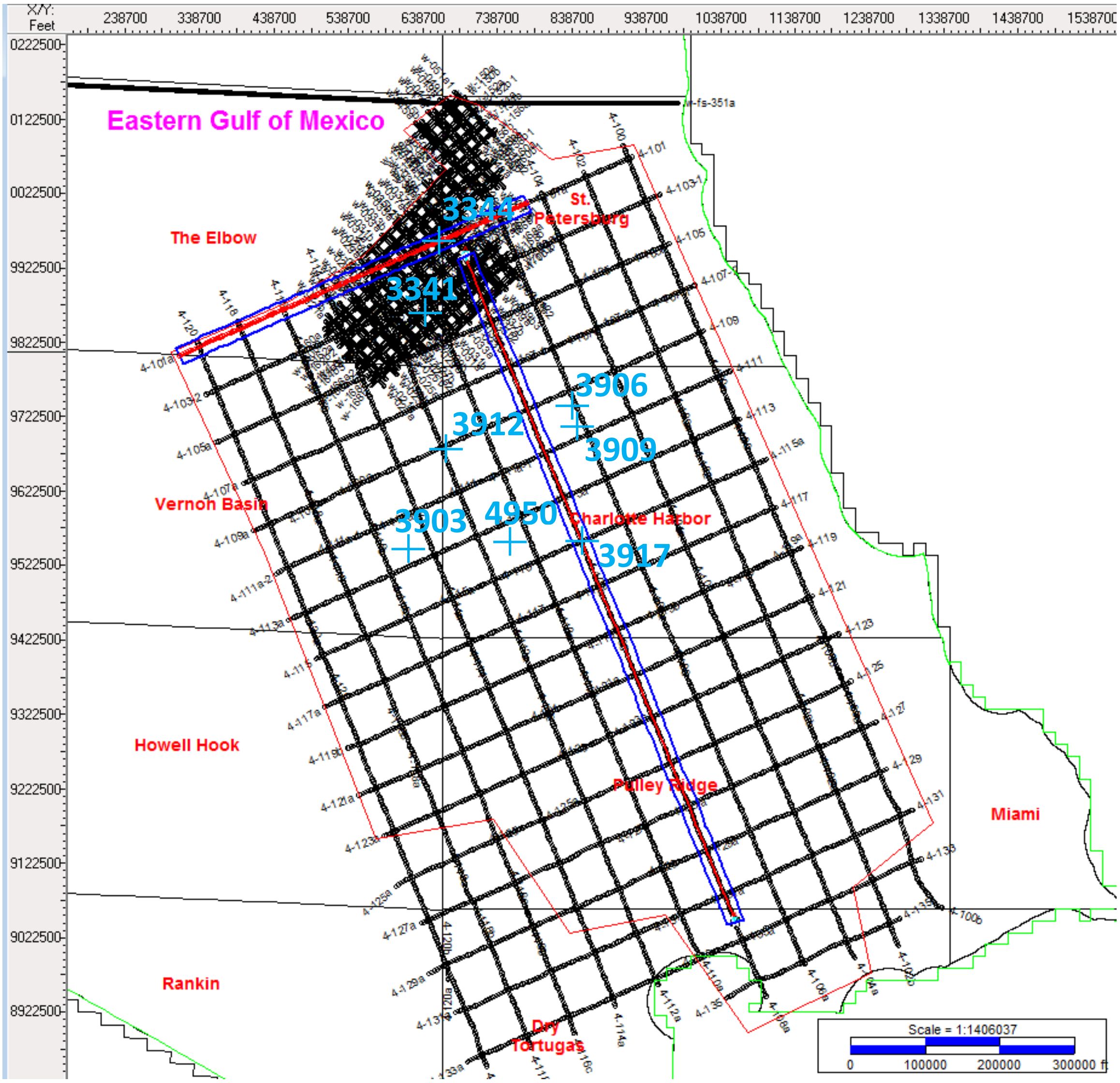

Figure 3. Base map of study area showing well control location of seismic lines.

(~3 mi.) grid was used due to the well spacing being sparse, and due to the large distance between seismic lines. The regional lines have 12-mile separation, and 4-mile separation in the northern survey. Net isolith maps of qualified dolomite and limestone intervals were constructed using the geophysical well logs, and the data were extrapolated using the available seismic data. Further, net-to-gross ratio maps were generated in order to identify areas with a high proportion of porosity within each prospective storage unit.

Information required to calculate storage capacity includes reservoir thickness, porosity, the area of the map polygon, geothermal data, pressure data, and storage efficiency factors. The subsurface storage volume estimates depend on the geologic properties of each assessment unit. Due to the sparse well control within the project area, initial net thickness values calculated from each well needed to be further constrained seismically based on gross interval thickness in order to generate more realistic thickness values for each assessment unit. Mean porosity values derived from well logs and entered into the Petrel software suite were used for each potential reservoir interval that was assessed. It is important to note that the temperature and pressure used to calculate density were derived from equivalent onshore facies near the western end of the SOSRA region (Pashin, 2008). The pressure and temperature information was used to determine the density of CO_2 under projected reservoir conditions. The saline formation efficiency factors based on geologic displacement factors (Goodman et al., 2011) were used in this study to help constrain reservoir volumetrics.

The formula used follows the method employed by the National Energy Technology Laboratory of the U.S. Department of Energy (Goodman et al., 2011; NETL, 2015).

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

G$_{CO_2}$ is the estimated storage capacity
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

Figure 4. NETL formula for calculating CO_2 storage capacity in saline reservoirs (after NETL, 2015).

The storage efficiency factor E_{saline} values were determined using a Monte Carlo analysis as outlined in (Goodman et al., 2011), and represent the fraction of total pore space occupied by injected CO_2. The efficiency factor was calculated from field data from oil and gas reservoirs in conjunction with laboratory data, as well as simulations of relative permeability values for CO_2 in brine systems. In cases where the net-to-total area, net-to-gross thickness, and effective or total porosity are known, only the displacement efficiency factors are needed to estimate storage capacity (Goodman et al., 2011). Efficiency factors based on displacement terms for dolomite over a 10-90% probability range are P_{10} = 16%, P_{50} = 21%, and P_{90} = 26%, while limestone values are; P_{10} = 10%, P_{50} = 15%, and P_{90} = 21% (IEA GHG, 2009).

This methodology is intended for high-level static assessment of CO_2 storage resources at regional and national scales, and is general enough to be applied globally (Goodman, 2011). For the purposes of this study, the assessment units were considered as an open system in which formation brine is displaced by the injected CO_2 (Goodman, 2011). This method only takes into account the physical trapping of CO_2; other trapping mechanisms, such as mineralization and dissolution of CO_2 into brine are excluded (Goodman, 2011).

CHAPTER IV

RESULTS

STRATIGRAPHIC FRAMEWORK

The potential storage units in the study area are primarily in the Cretaceous section, and an additional unit occurs in the lower part of the Paleogene section. The three primary rock types observed in well data are porous dolomite, limestone, and anhydrite. Due to the subtle structure of the Florida platform, most stratigraphic units are continuous throughout the study area. All prospective storage units meet the qualification requirements for depth, porosity, and lateral extent of confining units. The following sections review the stratigraphy of each potential storage interval and follow the assessment units identified onshore by Roberts-Ashby et al. (2015).

Punta Gorda Assessment Unit

The Punta Gorda assessment unit is a Lower Cretaceous composite assessment unit consisting of the Lehigh Acres Formation and the Punta Gorda Anhydrite (fig.5; plates 3, 4). The Lehigh Acres Formation contains the Able Member and Twelve Mile Member, which are composed primarily of limestone and dolomite intercalated with some thin anhydrite beds. The Twelve Mile Member and the Able Member only contain limestone in the Tampa Embayment at depths of approximately 3,200 m (10,500 ft). Geophysical well logs and sample records indicate that the limestone is tight and that the dolomite is porous. Porous dolomite intervals in the Twelve Mile Member have net thickness of about 120 feet, while those in the Able Member are about 160 feet thick. The Upper part of the assessment unit is the Punta Gorda Anhydrite, which is a regionally continuous anhydrite marker that is 200-400 feet thick. It is composed mainly of anhydrite and contains interbeds of dolomite and limestone. The subsea depth of the top of the Lehigh Acres formation is between 9,060-12,250 ft across the entire assessment unit.

Gordon Pass Assessment Unit

The Gordon Pass assessment unit is a Lower Cretaceous composite assessment unit that includes the Marco Junction Formation, the Lake Trafford Formation, and the Gordon Pass Formation (fig.6-7; plates 1, 2). Both the Marco Junction and Gordon Pass Formations are of Early Cretaceous age (Albian) and are included in the Big Cypress Group. Dolomite is abundant in these formations, particularly on the Sarasota Arch, and limestone predominates in the Tampa Embayment. The Marco Junction Formation generally contains 80-120 feet of porous dolomite with interbedded anhydrite. The Lake Trafford Formation generally contains 80-100 feet of porous dolomite with interbedded limestone and anhydrite. Towards the northwest end of the study area, the Lake Trafford Formation is composed principally of limestone (plates 1, 2). The Gordon Pass Formation is a regionally continuous anhydrite marker that is about 180-350 ft thick and contains interbeds of dolomite and limestone. The Gordon Pass anhydrite thins toward the northwest from around 300 ft to 150 ft. However, the anhydrite beds appear to maintain lateral continuity. The depth of the top of the Marco Junction Formation is between 7,780 and 10,200 ft in the study area.

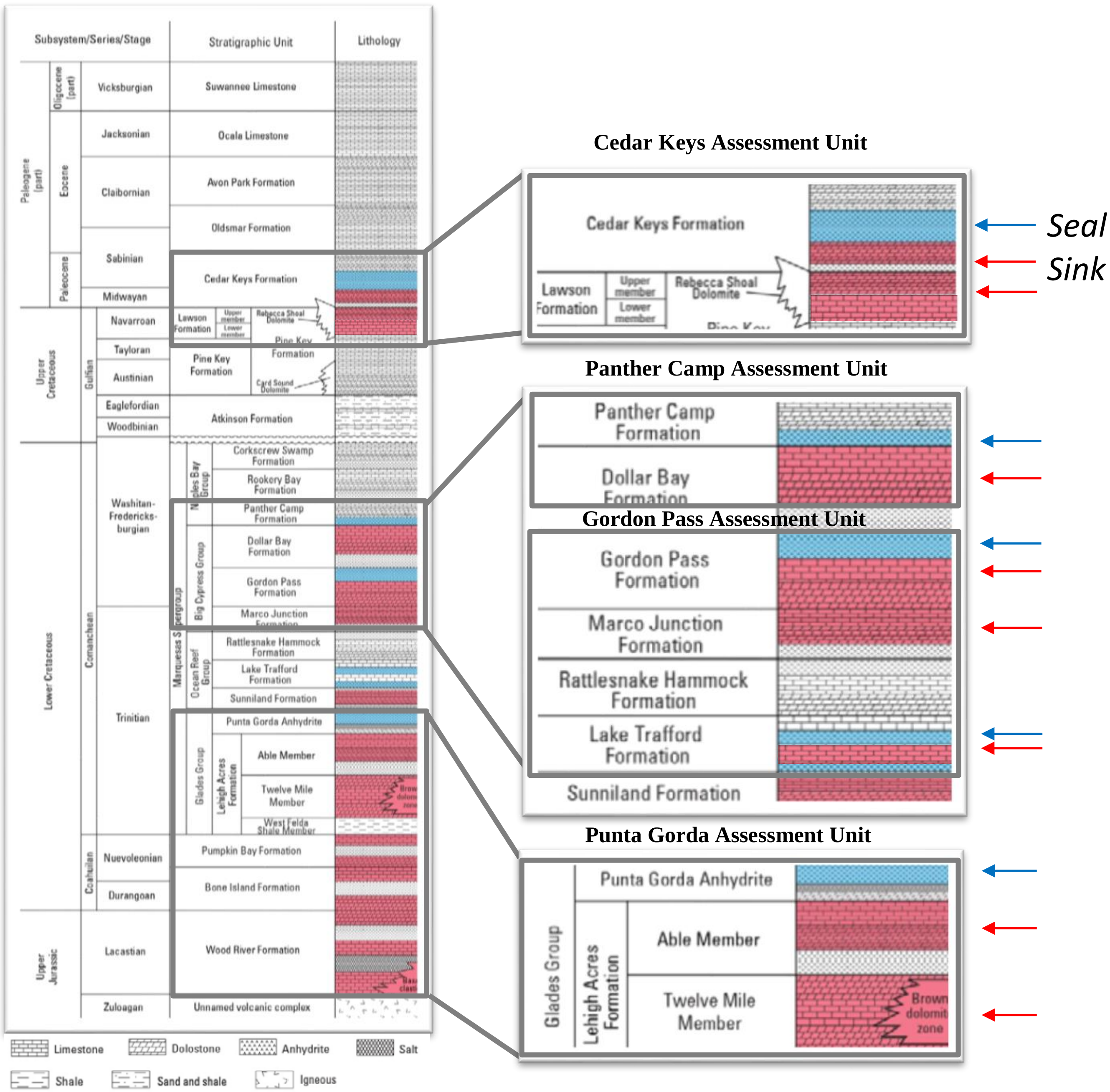

Figure 5. Stratigraphic column showing prospective storage targets and reservoir seals in onshore southern Florida. (after Roberts-Ashby et al., 2015)

Panther Camp Assessment Unit

The Panther Camp assessment unit (Lower Cretaceous) consists of the Dollar Bay Formation (Big Cypress Group) and the Panther Camp Anhydrite (fig. 5, plates 1, 2). The depth to the top of the Dollar Bay Formation is between 6,880-9,800 ft. The base of the Dollar Bay is dominantly tight limestone that thickens with depth and distance from the Sarasota Arch and ranges from 130 ft to 550 ft thick. The upper interval of the Dollar Bay Formation contains several thick intervals (20-40 ft) of dolomite interbedded with lenses of anhydrite. Overlying the Dollar Bay Formation is a regionally continuous section of Panther Camp Anhydrite. The thickness of the Panther Camp anhydrite varies from 65-220 ft and it is the thickest near the crest of the Sarasota Arch.

Rookery Bay Formation (Naples Bay Group)

The Rookery Bay Formation is a thick, nonporous limestone unit that thins towards the West Florida Escarpment and the crest of the Sarasota Arch (fig 5; plates 1, 2). At well OCSG-3344, which is closest to the Tampa Embayment, the limestone thickens to a maximum of 730 ft. Towards the western limits of the study area, which is near the West Florida Escarpment, well OCSG-3903 indicates that the limestone of the Rookery Bay Formation passes into dolomite towards a structural high near the shelf margin. The Rookery Bay Formation is the best representation of how the geometry of the Sarasota Arch and the shelf margin control the thickness of reservoir facies. Closer examination of the strike line cross section reveals that the Rookery Bay tight limestone thickens on both flanks of the Sarasota Arch towards the Tampa Embayment and the

South Florida Basin (plate 1). Further, the Rookery Bay pinches out and passes into dolomite towards the shelf margin (plate 2).

Corkscrew Swamp Formation (Naples Bay Group)

Overlying the Rookery Bay Formation is the Corkscrew Swamp Formation. The dominant rock types in most of the study area are dolomite, which is interbedded with anhydrite. Interestingly, in well OCSG-3912 (plate 1), the limestone thickens on part of the Sarasota Arch. Facies changes from dolomite to limestone indicate that there is a structural low in this portion on the Sarasota Arch during deposition of the Corkscrew Swamp Formation. Although there is abundant dolomite facies, this formation was not considered as an assessment unit. The topseal anhydrite layers are considerably thinner, ranging from 2-8 feet thick with the thin Atkinson shale overlying the Corkscrew Swamp.

Atkinson Formation

The Atkinson Formation is dominantly a marine shale unit that is correlated with the Marine shale of the Tuscaloosa Group (Applin and Applin, 1967). (fig. 3, plates 1, 2). The Atkinson Formation marks the base of the Upper Cretaceous section, and the basal surface of the formation is thought to be a regional disconformity (Buffler et al., 1980). The Atkinson Formation is no more than 50 ft thick in the study area, and is locally as thin as 14 feet thick (plates 1, 2).

Cedar Keys Assessment Unit

The Cedar Keys assessment unit includes the Upper Cretaceous Pine Key and Lawson Formations, as well as the lower part of the Cedar Keys Formation (fig. 3, plates 1, 2). This is the thickest and shallowest assessment unit considered in this project. At the base of the Pine Key Formation is a section of Upper Cretaceous chalk that is most readily identified from a decrease in bulk density values, and further described in mud logs in the southeast portion of the study area. Directly above the chalk is a thick, porous interval of limestone that is generally about 1,000 feet thick and thins downdip towards the southwest (plates 1, 2).

Above the Pine Key is the Lawson Formation, which is composed of porous dolomite, but this formation is logged geophysically only in two wells. Due to limited well log control in this assessment unit, the thickness and lateral extent of the Lawson Formation and younger units is not fully understood. The lithology of the upper member of the Lawson Formation is described as coarse crystalline dolostone containing layers of nodular and lensoid gypsum and anhydrite (Roberts-Ashby et al., 2015).

The overlying Cedar Keys Formation is of Paleocene age and constitutes a succession of porous dolomite interbedded with anhydrite (fig.3, plates 1, 2). Only three of the wells that penetrate the Cedar Keys Formation have a useful log suite; the interval is not logged in most wells. Depth from the surface to the top of the reservoir in the assessment unit varies between 3,950 to 4,200 feet The anhydrite beds in the Cedar Keys Formation appear to be continuous on the proximal shelf, where the Upper Cretaceous-Paleocene section is thickest, but are absent in the west and southwest part of the study area (plates 1, 2). Net thickness of the observed anhydrite beds is 130-150 feet.

Structural Framework

Strata in the West Florida Platform are effectively flat-lying, and major structures in the platform include the Sarasota Arch, the Tampa Embayment, and the South Florida basin (Dobson and Buffler, 1997). The principal structure in the study area is the Sarasota Arch. The axial trace of the structure trends northeast-southwest, plunges towards the West Florida Escarpment, and was likely formed by differential subsidence since the Late Jurassic (Foote, 1985, Martin and Case, 1975). Foote (1985) indicated that the Sarasota Arch was active during the Cretaceous. Differential uplift of the Sarasota Arch relative to the Tampa Embayment and the South Florida Basin resulted in the thinning of strata across the arch (plate 1). Structure maps of the Punta Gorda, Gordon Pass, and Panther Camp Formations show only minor changes in the structure of the Sarasota Arch (figs. 6-8). All three maps show the width of the arch to be approximately 130 miles wide and shows the locations of the Tampa Embayment and the South Florida Basin. In all three maps, a domal structure, which is the highest part of the arch in the study area, is present in the area of well OCSG-3903. In contrast, deposition during the Cedar Keys time indicates that the arch is muted relative to the other intervals mapped and that a domal structure is south of the domal structure in the older beds (fig. 9). Nearly all wells within this project are located near the axial trace of the Sarasota Arch, except OCSG-3341 and OCSG-3344 which are located on the northern limb near the Tampa Embayment.

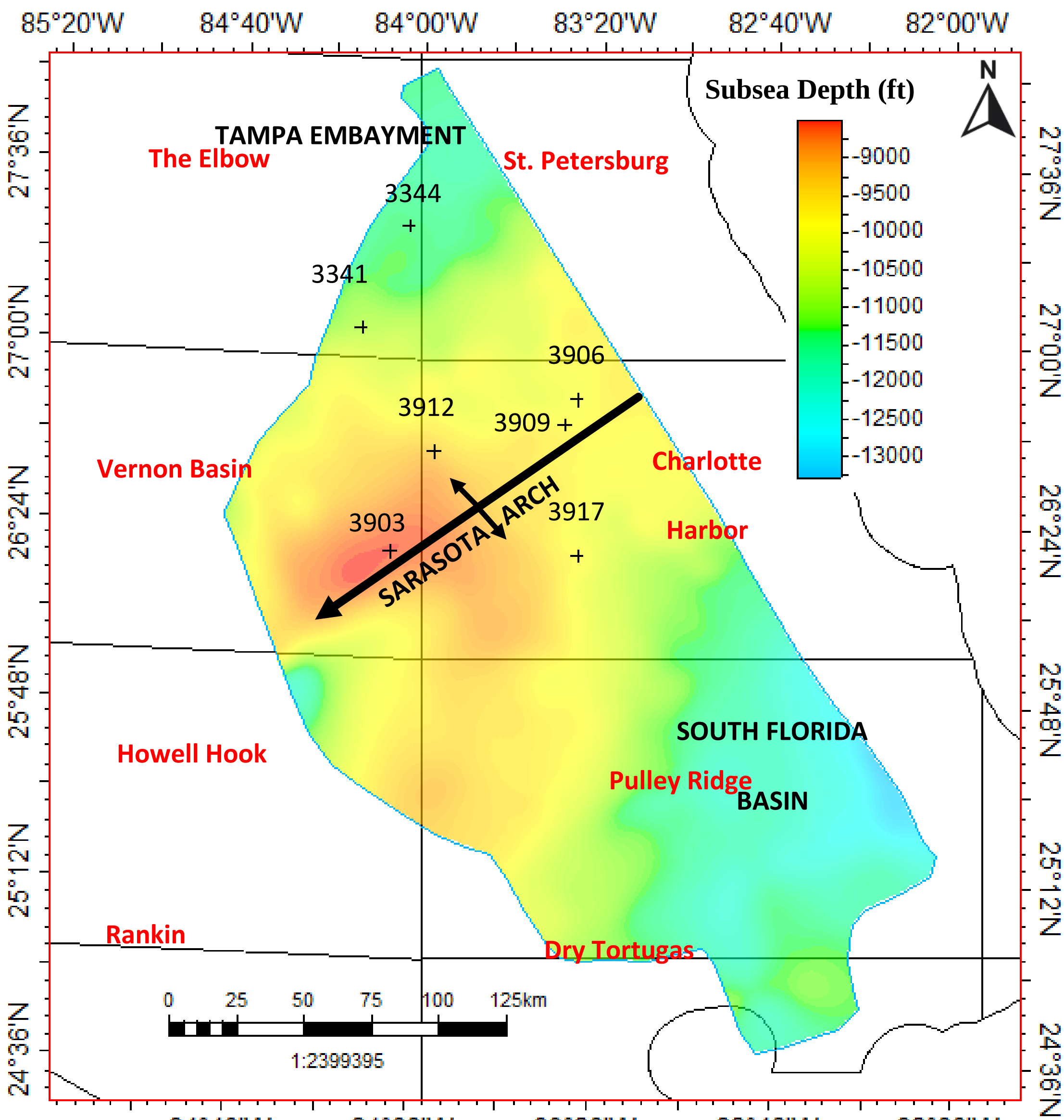

Figure 6. Subsea structure map of the top of the Punta Gorda Formation, West Florida Platform.

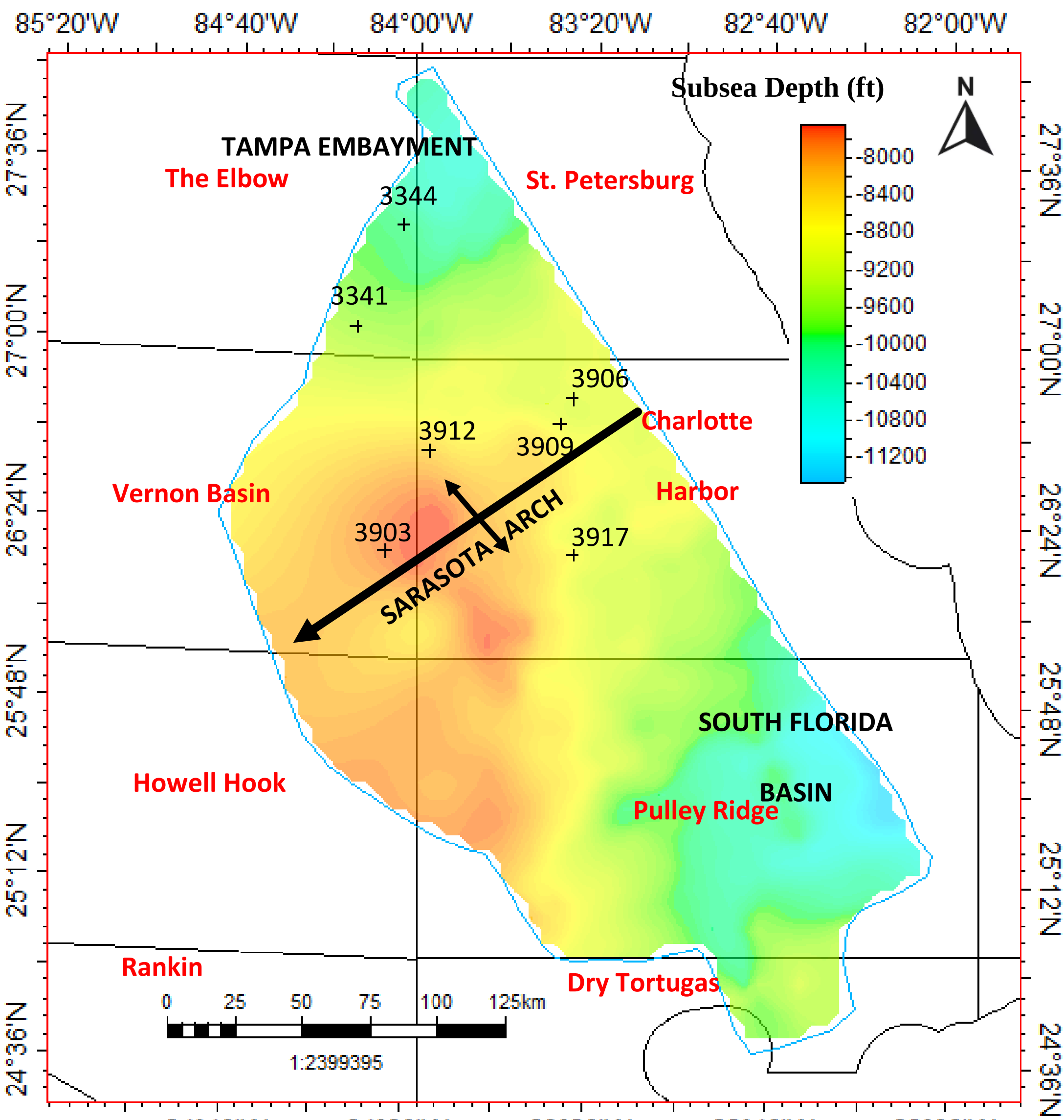

Figure 7. Subsea structure map of the top of the Gordon Pass Formation, and initial development of secondary domal structure, West Florida Platform.

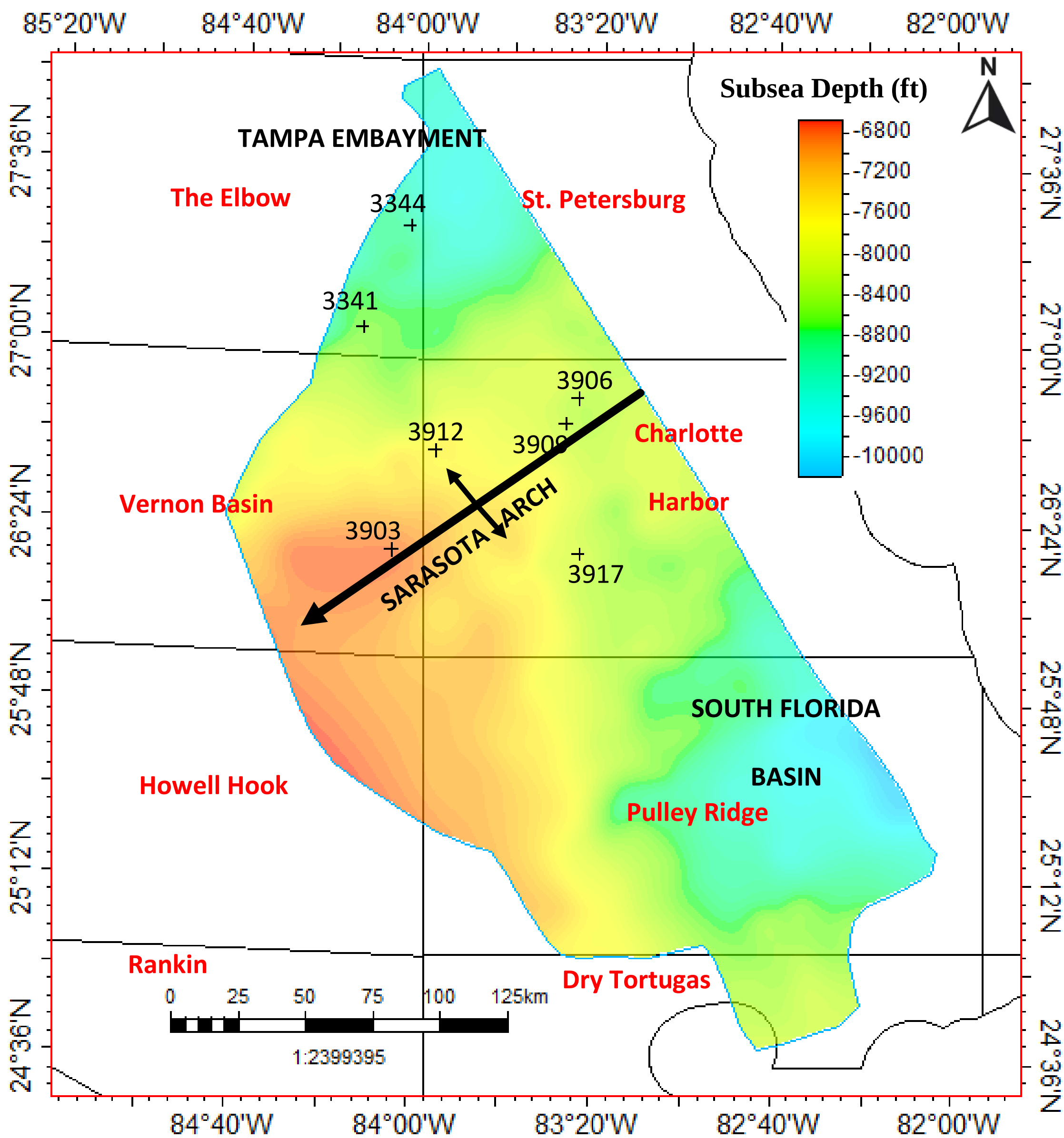

Figure 8. Subsea structure map of the top of the Panther Camp Formation, West Florida Platform.

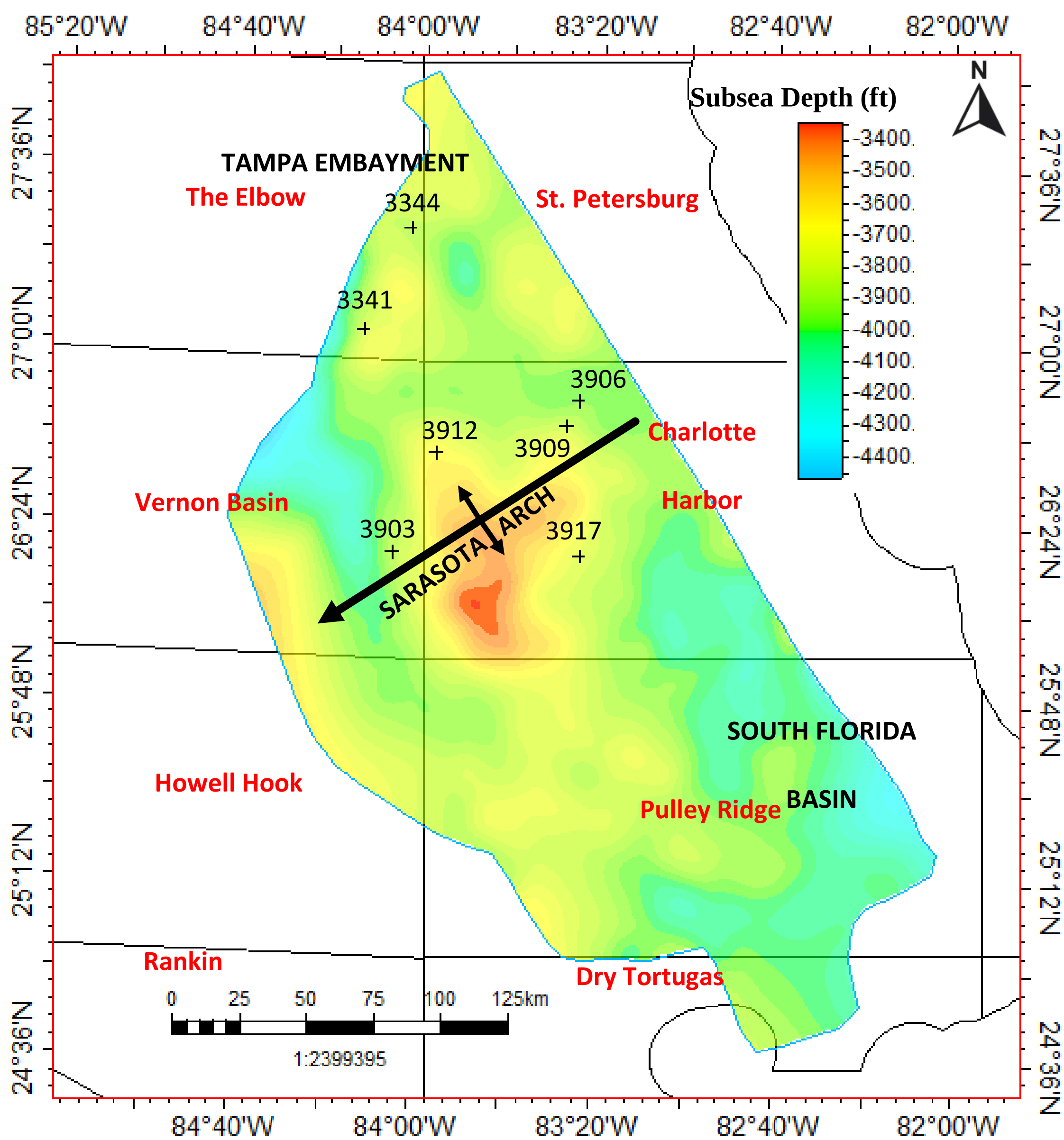

Figure 9. Subsea structure map of the top of the Cedar Keys Formation, West Florida Platform.

Seismic Interpretation

The 2D seismic reflection surveys used in this project cover the southern end of the Tampa Embayment, the Sarasota Arch, and most of the South Florida Basin (figs. 10-11). Figure 10 is a strike line that shows the simplicity of the structure on the shelf, with subparallel reflectors defining the broad, open structure of the Sarasota Arch. Figure 11 is a dip line traversing the shelf and showing the shelf margin and upper part of the West Florida Escarpment. The Lower Cretaceous section is dominated by subparallel reflections, and clinoforms elements are developed near the shelf margin.

The anticlinal structure of the Sarasota Arch is observed in the NE-central portion of the seismic survey (fig. 11). Additionally, the clinoform strata at the shelf margin are slightly elevated relative to the adjacent shelf strata (fig. 11). This figure also shows that the Cedar Keys assessment unit forms a southwestward thinning wedge of sediment that marks the initiation of a major westward progradation from the peninsula and establishment of the distally steepened shelf that persists today. Tertiary strata (post-Cedar Keys) is observed to be channelized in the proximal part of the profile and clinoform in the distal part (fig. 11).

Unfortunately, some of seismic lines do not adequately image the Lower Cretaceous section because of noise related to channeling and paleokarst in the post-Cedar Keys section. Primary strike lines trending SE-NW were relatively flat with only subtle changes in structure of the Sarasota Arch (fig. 10). In contrast, the dip lines depict the distally steepened shelf towards the West Florida Escarpment (fig. 11).

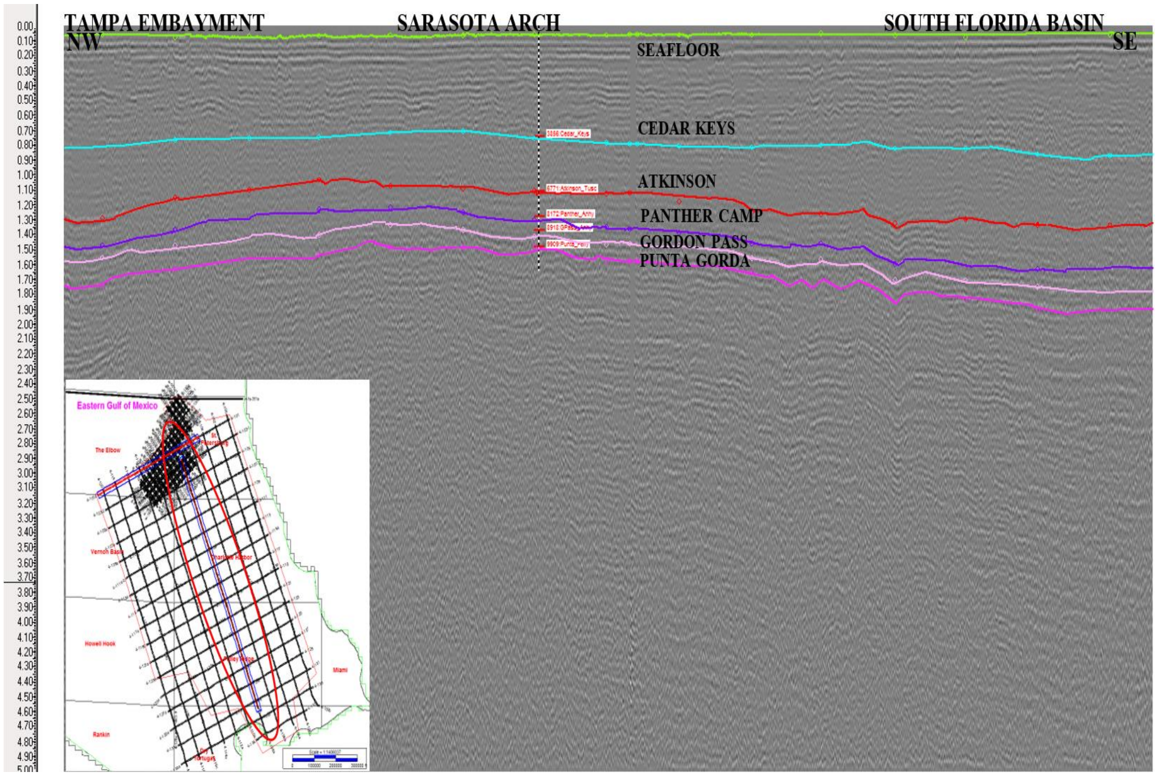

Figure 10. Strike line 4-108a showing regional structure of the West Florida Platform.

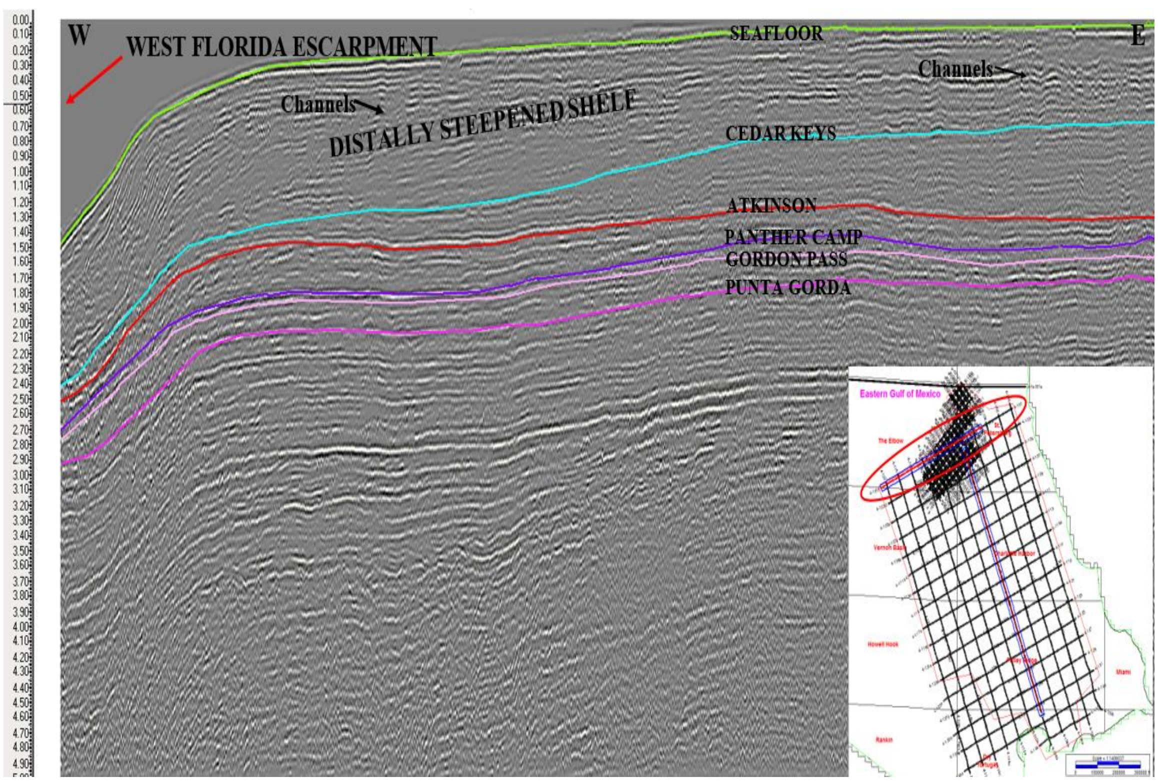

Figure 11. Dip Line 4-101 showing structure of the West Florida Shelf and shelfbreak.

Porosity

Porous strata within the Punta Gorda, Gordon Pass, and Panther camp assessment units are all dolomite, whereas the upper Cretaceous-Paleocene section includes porous limestone in addition to porous dolomite in the Cedar Keys assessment unit. Qualified reservoir (>15% porosity, >20 ft thick) in the Punta Gorda assessment unit is the dolomite of the Lehigh Acres Formation within the Glades Group. Qualified reservoir in the Gordon Pass assessment unit is dolomite of the Marco Junction Formation in the Big Cyprus Group. Porous dolomite of the Dollar Bay Formation constitutes the reservoir for the Panther Camp assessment unit of the Naples Bay Group. The Cretaceous-Paleocene Cedar Keys assessment unit includes dolomite reservoirs in the Cedar Keys and Lawson Formations and the porous limestone reservoir in the Upper Pine Key Formation.

The highest average porosity in the Punta Gorda assessment unit approaches 25% at well OCSG-3912 (fig. 12). Figure 12 establishes the typical reservoir to seal relationship found throughout the study with thick sections of porous dolomite capped by regionally continuous anhydrite. Reservoir quality dolomite of the Lehigh Acres Formation is overlain by the thick Punta Gorda anhydrite topseal (fig. 12). The formation is largely unqualified in the Tampa Embayment and South Florida Basin. Porosity is primarily developed on the northern flank of the Sarasota Arch (fig. 13), and the net thickness map trend (fig. 14) suggests that the paleostructure may be slightly different from modern structure. Where there is porous dolomite in the Punta Gorda assessment unit, the average net interval thickness is 287 ft (fig. 14), and porosity is principally developed on the northwestern limb of the Sarasota Arch (figs. 13, 14). A maximum net

Table 2. Calculated average total porosity for net thickness intervals within each assessment unit on the West Florida Platform.

	Well						
Assessment Unit	**OCSG 3341**	**OCSG 3344**	**OCSG 3903**	**OCSG 3906**	**OCSG 3917**	**OCSG 3909**	**OCSG 3912**
Cedar Keys	N/A	N/A	N/A	26.6	23.7	26.7	N/A
Panther Camp	20.4	21.8	22.4	23.4	21.4	23.3	19.8
Gordon Pass	20.5	20.6	20.6	19.7	20.1	19.8	20.2
Punta Gorda	<15	<15	21	19.6	17.7	19.5	25.6

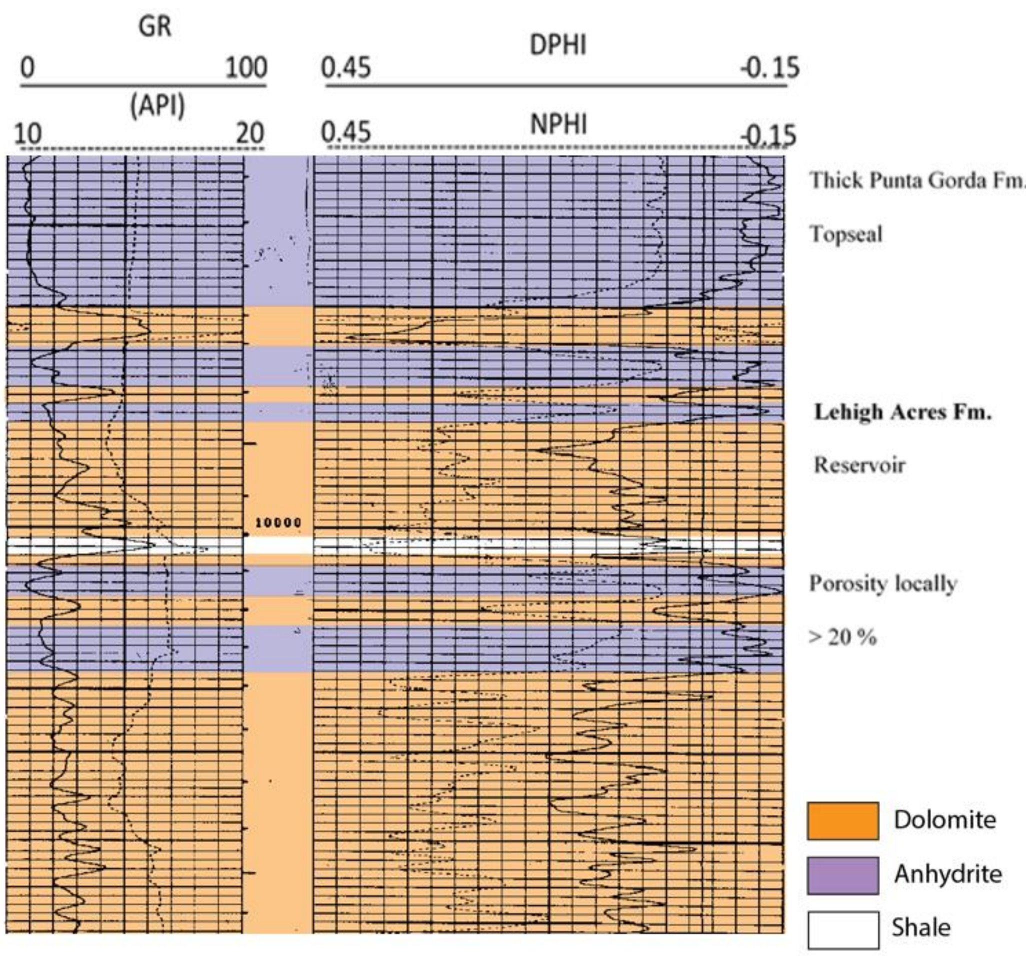

Figure 12. Interpretation of well OCSG-3912 in the Lehigh Acres dolomite reservoir.

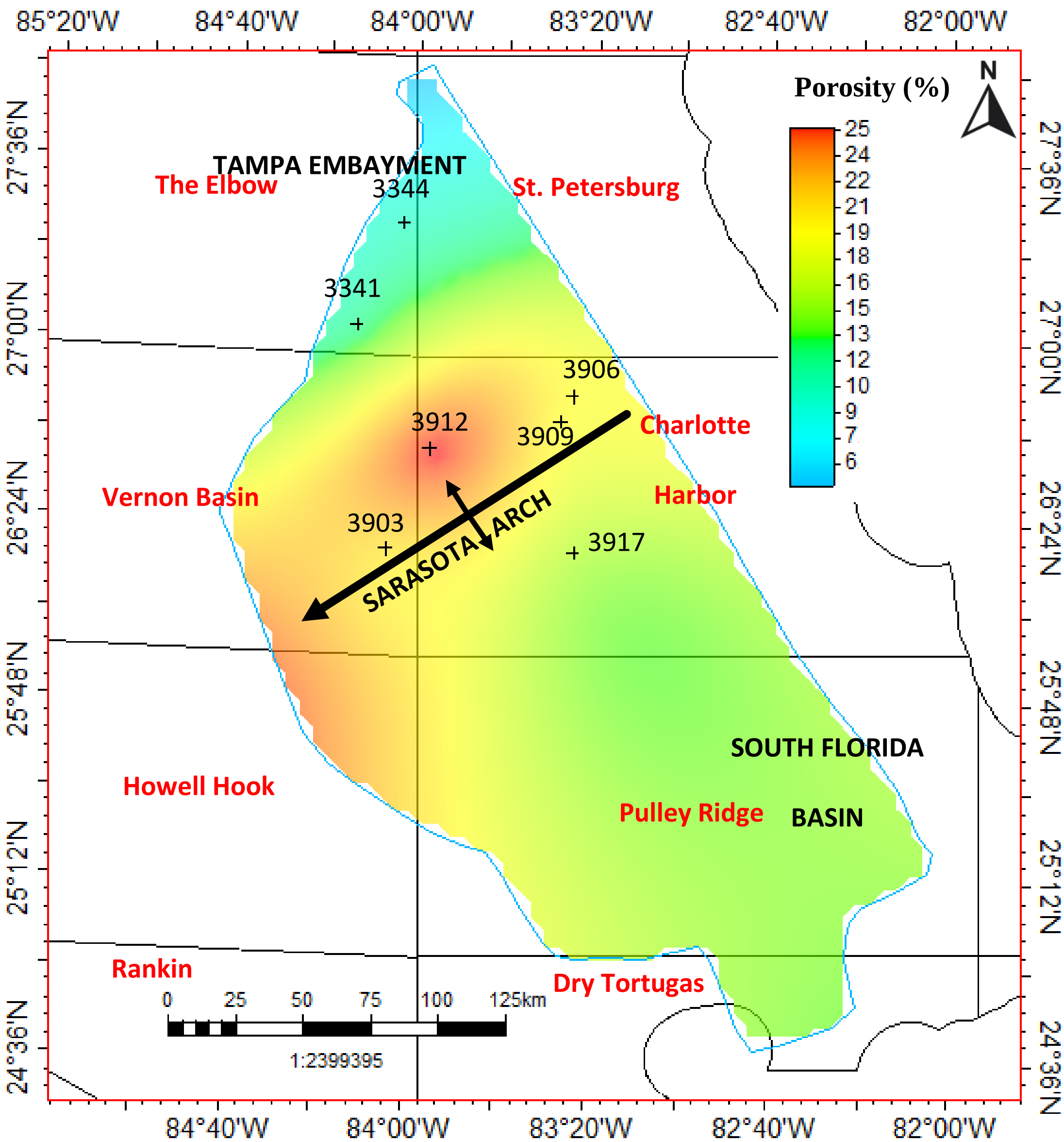

Figure 13. Porosity map of the Lehigh Acres Formation within the Punta Gorda assessment unit, West Florida Platform.

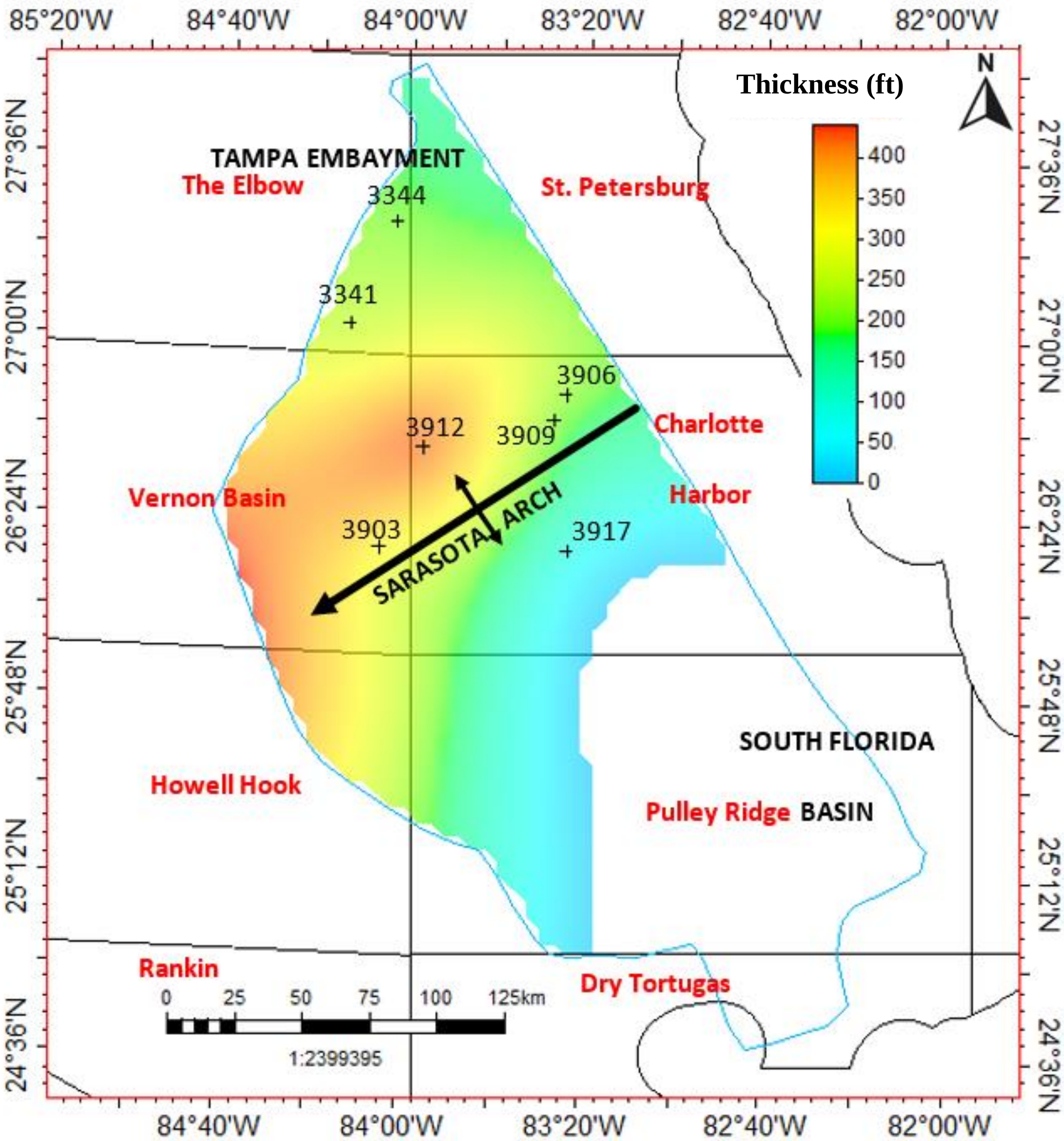

Figure 14. Net porous dolomite isolith map of the Able and Twelve Mile Members of the Lehigh Acres Formation within the Punta Gorda assessment unit, West Florida Platform.

thickness around 400 ft is observed on the northern flank of the arch, and thickens southwest towards the shelf margin (fig. 14). Net porous dolomite is absent towards the Tampa Embayment where minimal reservoir is off observed at well OCSG-3917 (fig. 14). The average total porosity of the Lehigh Acres Formation is about 18.5%.

Reservoir quality dolomite is also developed in the Marco Junction Formation of the Gordon Pass assessment unit as seen in log analysis of well OCSG-3903 (table 2, fig. 15). Alternating sections of reservoir quality dolomite (> 15% porosity) and sealing anhydrite of the Gordon Pass punctuate this section. However, the Sunniland Formation at the base of the storage unit is not a target for sequestration, as the porosity values did not meet the criteria for a minimum 15% porosity cutoff. Porosity is highest near the shelf margin close to well OCSG-3903, and on the northern flank of the Sarasota Arch (fig. 16). The average net thickness of reservoir containing greater than 15 percent porosity within the assessment unit is around 130 feet, and is located in the Marco Junction and Lake Trafford Formations. Due to limited well control, any significant increases in net thickness of reservoir are apparent when analyzing the net porous dolomite isolith map (fig. 17). Net thickness of porous reservoir increases from 100 ft on the eastern portion of the study area, to 395 ft in well OCSG-3903 and is greatest near the shelf margin (fig.17). The average total porosity of the Marco Junction and Lake Trafford Formations range from 19.7% in well OCSG-3906, and 20.6% in wells OCSG-3344 and OCSG-3903 (table 2).

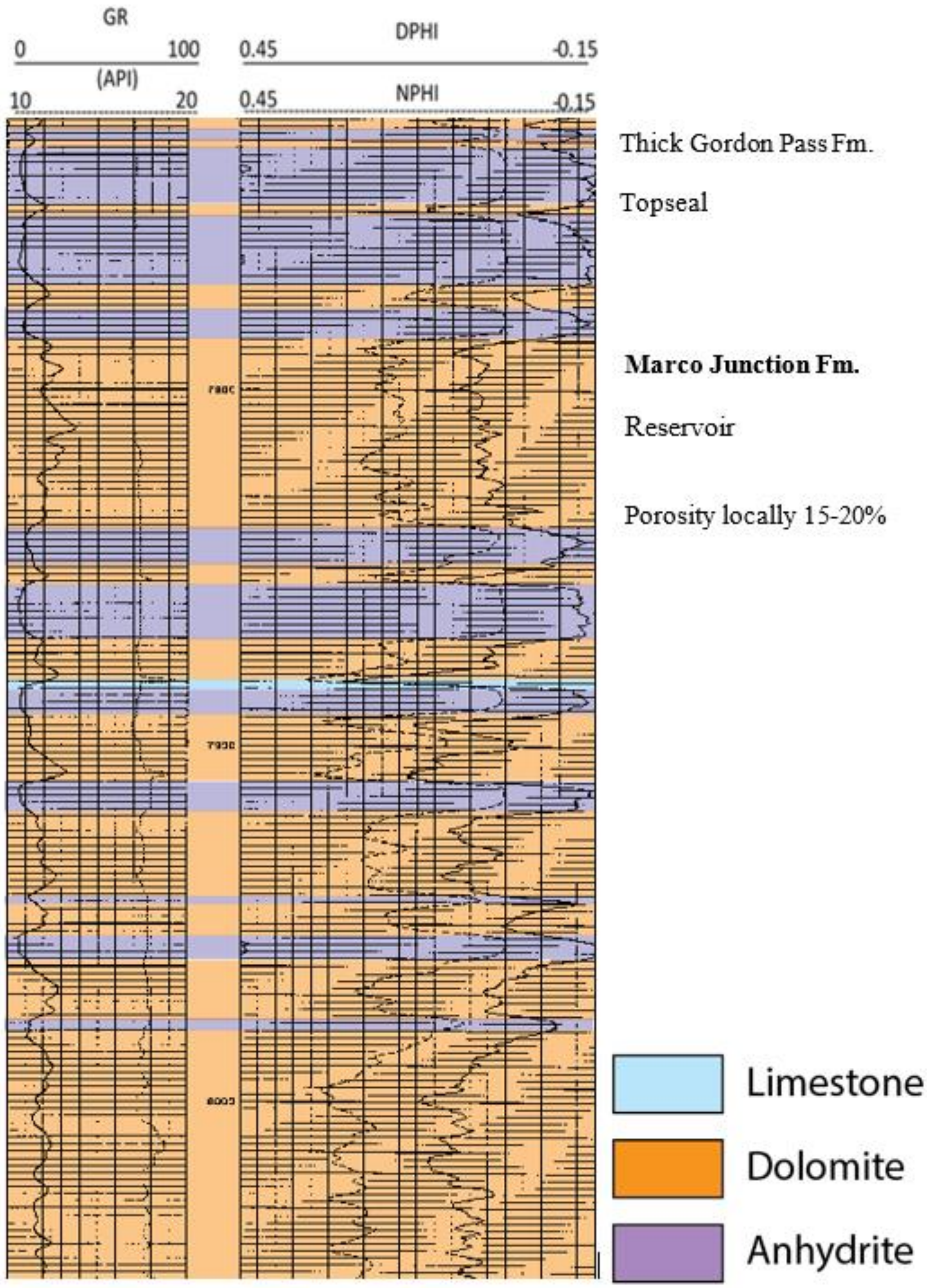

Figure 15. Interpretation of well OCS G-3903 in the Marco Junction dolomite reservoir.

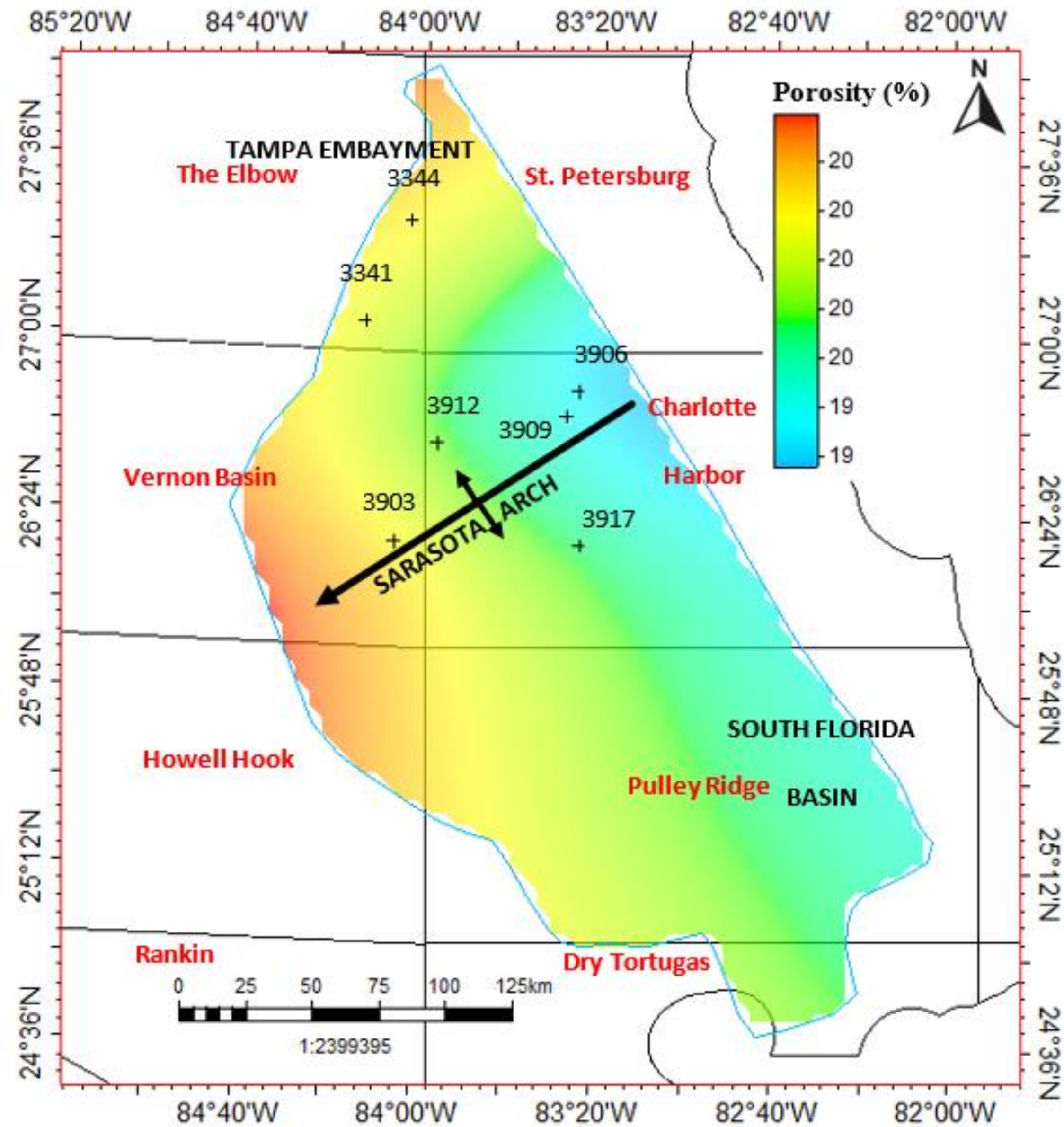

Figure 16. Total porosity map of the Marco Junction, and Lake Trafford Formations within the Gordon Pass assessment unit, West Florida Platform.

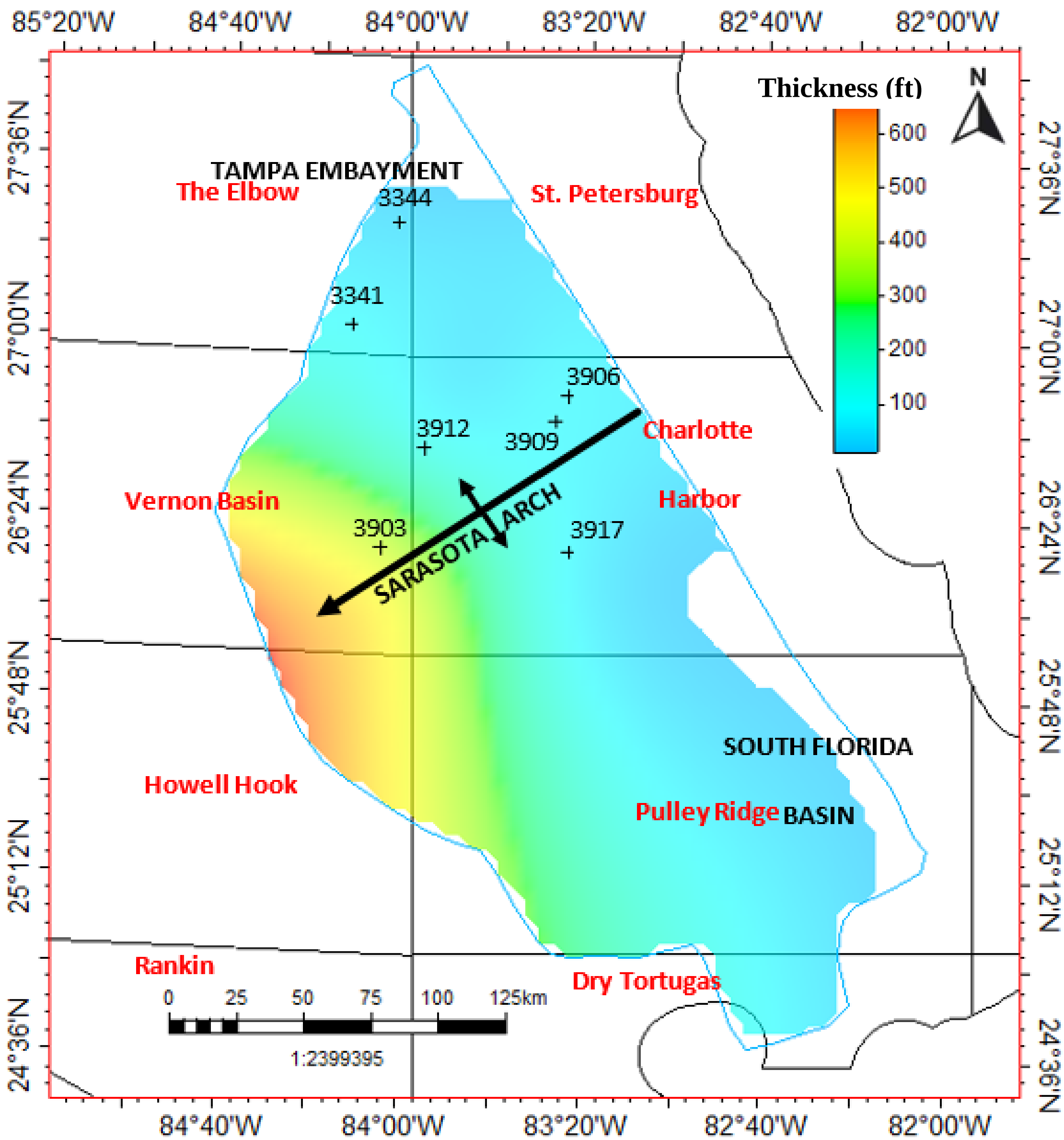

Figure 17. Net porous dolomite isolith map of the Marco Junction and Lake Trafford formations within the Gordon Pass assessment unit, West Florida Platform.

The Dollar Bay Formation within the Panther Camp assessment unit is composed of thick dolomite reservoirs separated by thin anhydrite beds and capped by the Panther Camp anhydrite topseal as seen in well OCSG-3909 (fig. 18). The basal limestone of the Dollar Bay varies in thickness from 130 ft on top of the Sarasota Arch to more than 550 ft in the adjacent basins. This unit is not a target interval for storage and does not meet the minimum 15% porosity cutoff for this study. Increases in porosity/thickness trends are similar to those in the Gordon Pass assessment unit towards the shelf margin (figs. 19, 20). Porosity is highest near wells OCSG-3906 and OCSG-3909 close to the crest of the Sarasota Arch (fig. 19). The net porous thickness of qualified Dollar Bay reservoir ranges from 65-350 feet. The proportion and thickness of dolomite in the Dollar Bay Formation tends to increase toward the crest of the Sarasota Arch and the shelf margin (fig. 20, plate 1). The average total porosity of the Dollar Bay Formation ranges from 19.8% in well OCSG-3912, to 23.4% in well OCSG-3906 (table 2).

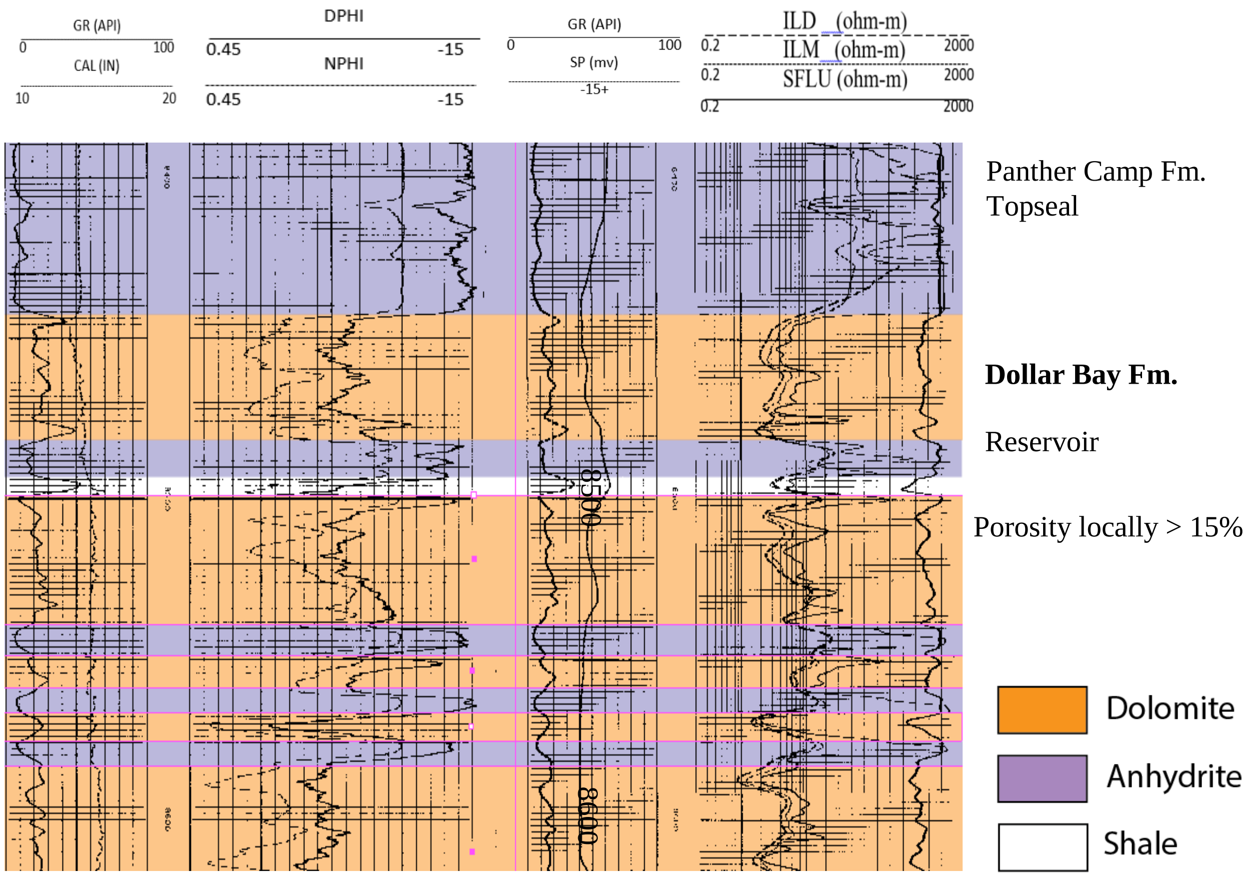

Figure 18. Interpretation of well OCSG-3909 in the Dollar Bay dolomite reservoir.

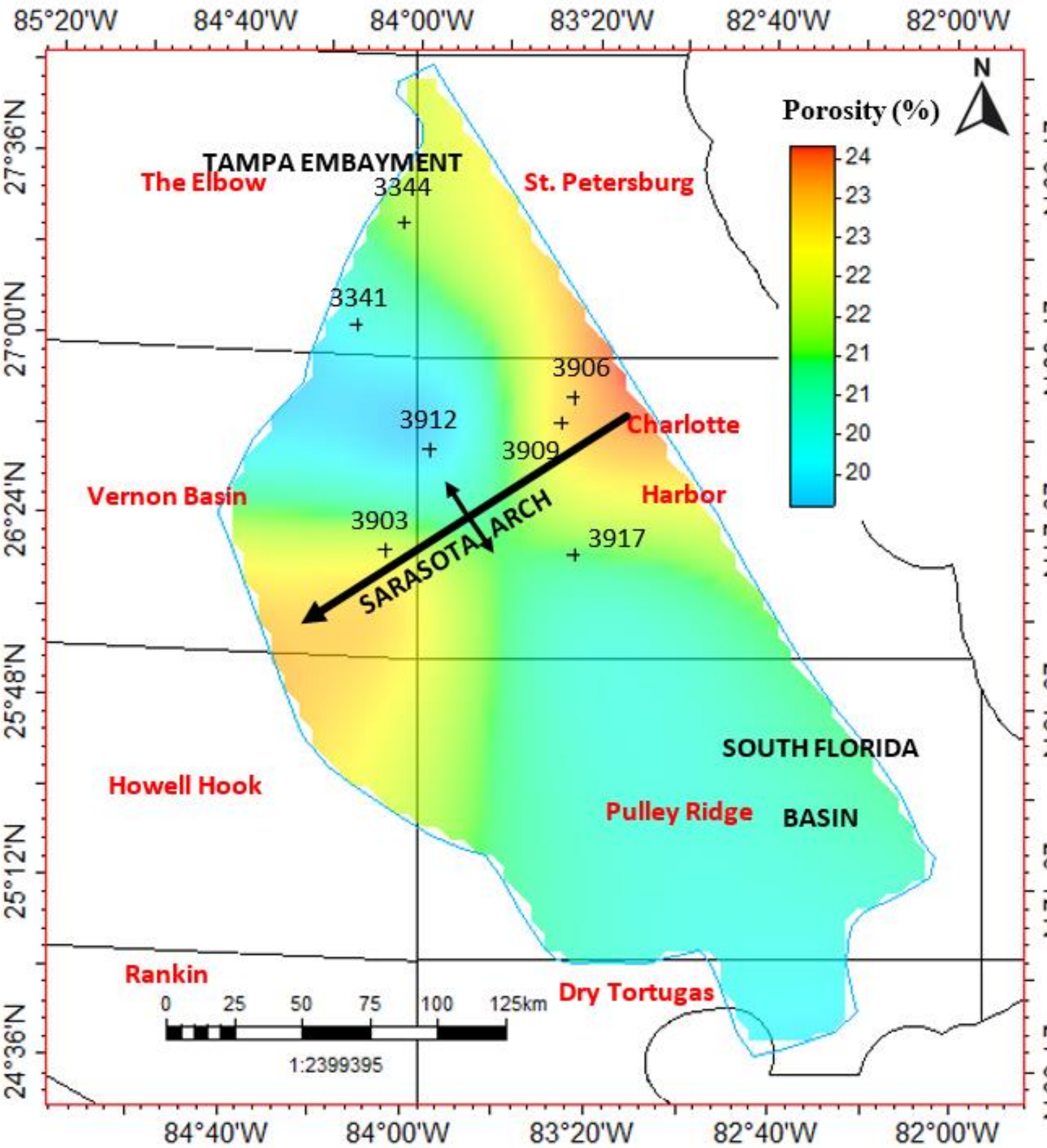

Figure 19. Total porosity map of the Dollar Bay Formation within the Panther Camp assessment unit, West Florida Platform.

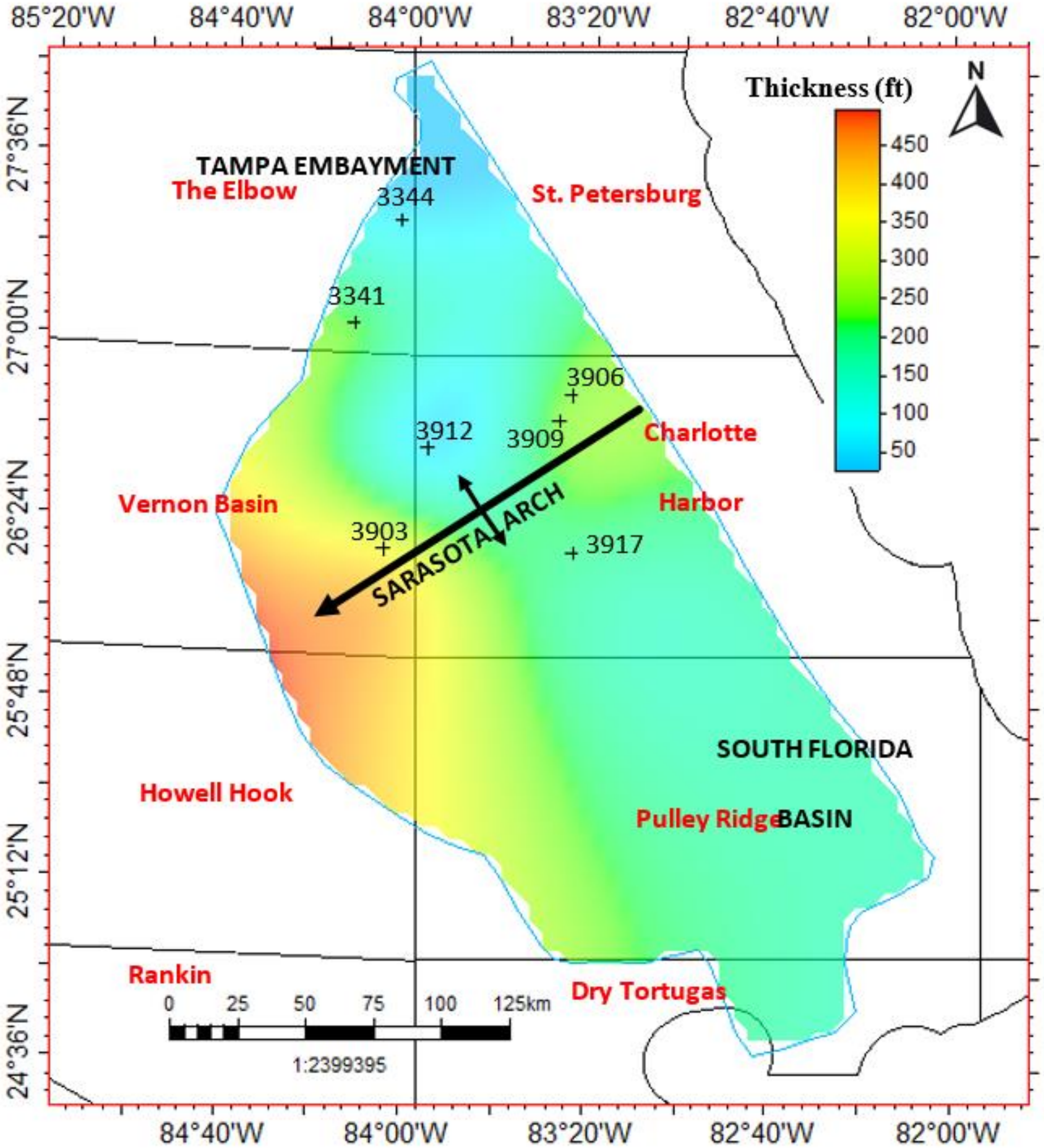

Figure 20. Net porous dolomite isolith map of the Dollar Bay Formation within the Panther Camp assessment unit, West Florida Platform.

The Upper Cretaceous Pine Key and Lawson formations and the Paleocene Cedar Keys formation constitute the youngest assessment unit evaluated in this study. The rocks in these formations contain much higher porosity (up to 30%) than those in the older assessment units (fig. 21). In well OCSG-3917, dolomite reservoir of the Lower Cedar Keys Formation is located at a depth of around 4,000 ft and is overlain by the Middle Cedar Keys anhydrite seal (fig. 21). As stated previously, the basal part of the Pine Key Formation contains a thick section of chalk, which tends to have very low permeability and is thus not included in this assessment. Porosity decreases towards the Tampa Embayment and South Florida Basin areas, and is highest on the northern flank of the Sarasota Arch near the shelf margin at well OCSG-3903, and near the crest at wells OCSG-3909 and OCSG-3906 (fig. 22). The proportion and thickness of reservoir increases towards the eastern portion of the study area to over 2,000 ft near the crest of the Sarasota Arch near wells OCSG-3909 and OCSG-3906 (fig. 23). Due to the westward progradation from the peninsula and southwestward thinning wedge of sediment, the same increases in thickness near the shelf margin in older reservoirs is not observed in the Cedar Keys assessment unit (fig. 23). The Cedar Keys assessment unit has the highest net thickness of porous carbonate, with an average thickness of around 610 m (2,000 ft) of qualified limestone and dolomite (fig. 23, plates 1, 2).

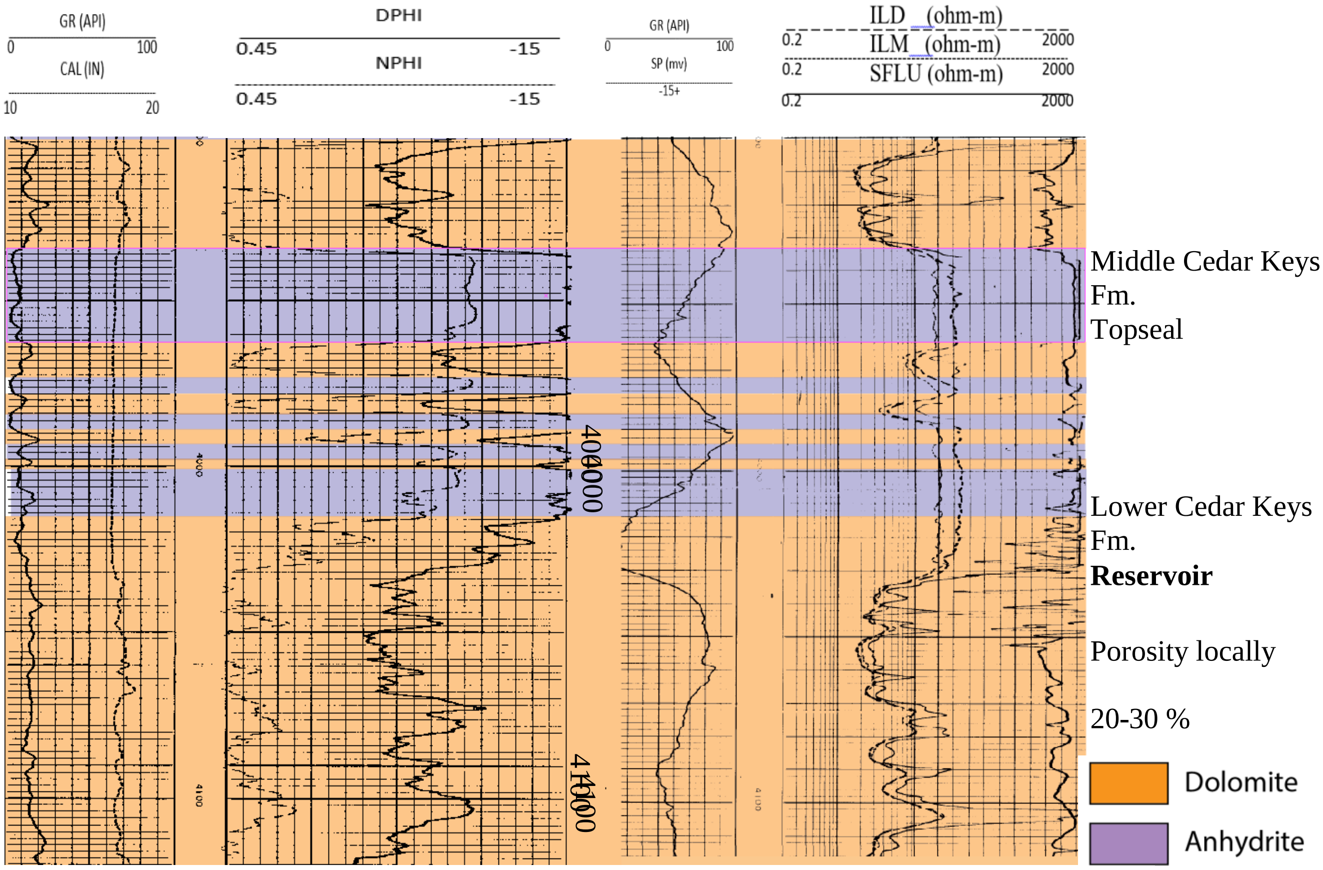

Figure 21. Interpretation of well OCSG-3917 in the Lower Cedar Keys dolomite reservoir.

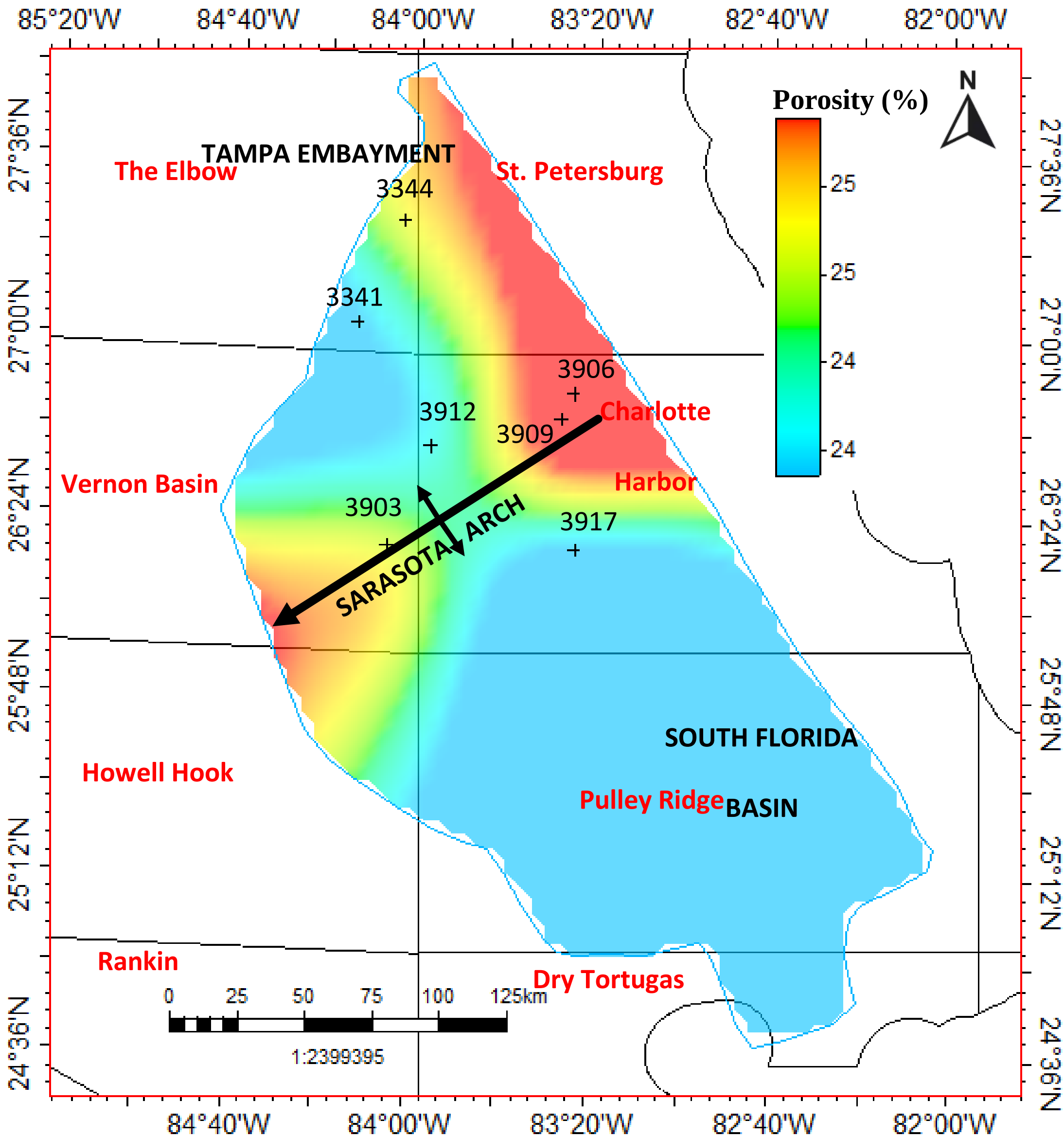

Figure 22. Total porosity map of the Pine Key and Lawson Formations within the Cedar Keys assessment unit, West Florida Platform.

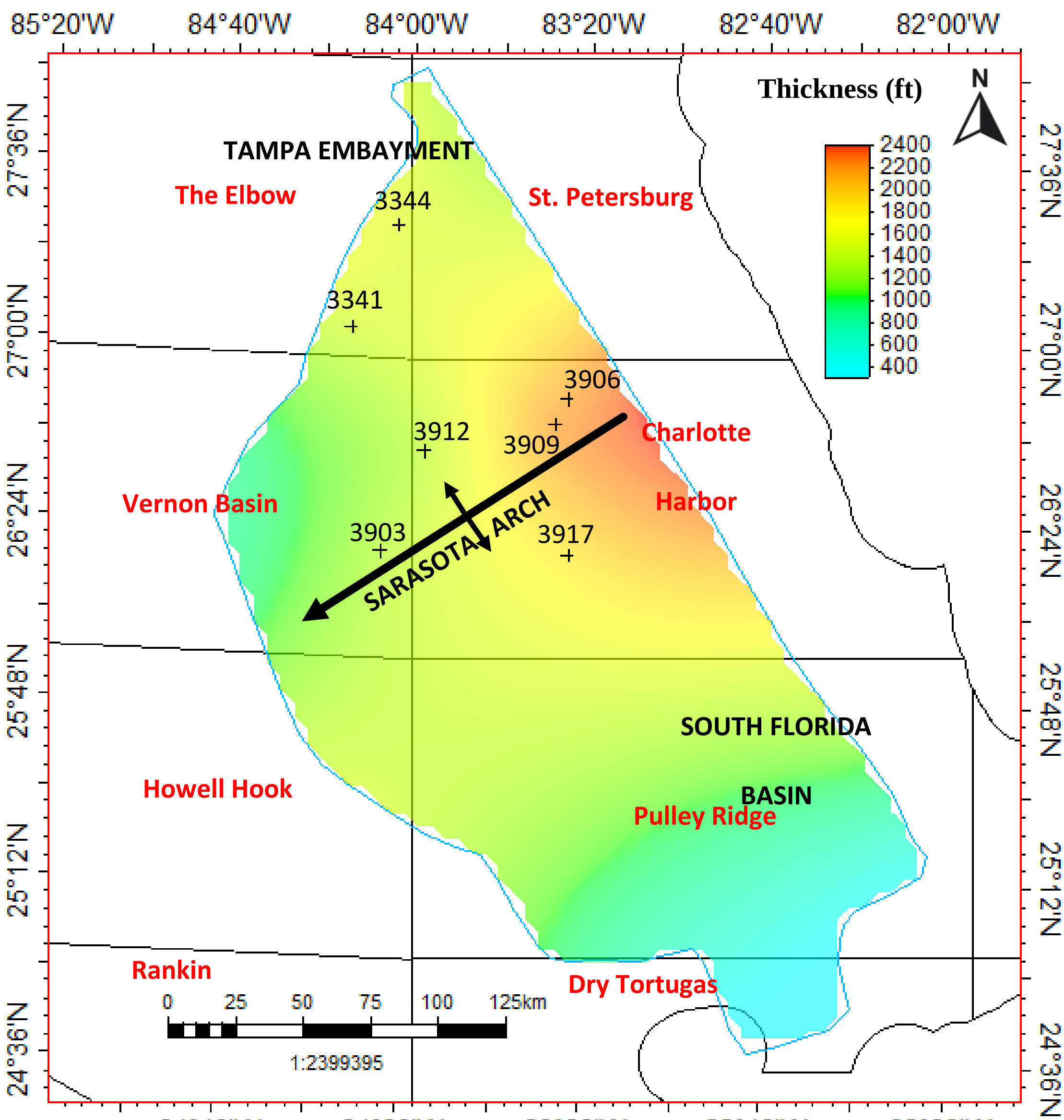

Figure 23. Net porous dolomite and limestone isolith map of the Pine Key and Lawson Formations within the Cedar Keys assessment unit, West Florida Platform.

Volumetrics

The primary reservoirs described in this study are dolomitic in nature, and occur mainly on the Sarasota Arch. CO_2 density values used for volumetric calculations were determined as a function of temperature and pressure, and values range from 700 to 800 kg/m^3. (fig. 24). The calculated storage resource for each assessment unit is summarized in tables 3-5.

The Lehigh Acres Formation within the Punta Gorda assessment unit is a potential storage target for CO_2 and contains reservoir quality dolomite at depths of around 10,500 ft. The best potential target for storage is in the area surrounding well OCSG-3912 due to increased porosity identified during log analysis, with a P_{50} storage resource of around 5 Mt/km^2 (fig. 25; table 4). There is no projected storage potential in the southeastern portion because the net thickness of reservoir was less than 20 feet in well OCSG-3917, and may be absent in the South Florida Basin.

Within the Gordon Pass assessment unit, dolomite of the Marco Junction and Lake Trafford Formations has the highest storage potential near well OCSG-3903, which coincides with the highest point on the subsea structure map (figs.7, 26; plate 2). The P_{50} storage potential of this assessment unit decreases from around 4 Mt/km^2 near well OCSG-3903, to an average of about 1-2 Mt/km^2 near the surrounding wells.

Similarly, the Dollar Bay Formation within the Panther Camp assessment unit contains its highest P_{50} storage capacity values near well OCSG-3903 with a local average of 4 Mt/km^2, and is also the structural high for this assessment interval (figs. 8, 27; plate 2).

In contrast to the other potential reservoirs, the thick limestone and dolomite within the Cedar Keys assessment unit project a much larger storage resource. The limestone in the upper portion of the Pine Key Formation contributes P_{50} storage potential of about 120 Gt, while the dolomite of the Lawson and Lower Cedar Keys Formation are estimated to contain around 480 Gt of P_{50} storage potential (table 4). Storage potential in the area of wells OCSG-3906, and 3909 have P_{50} values near 23 Mt/km^2.

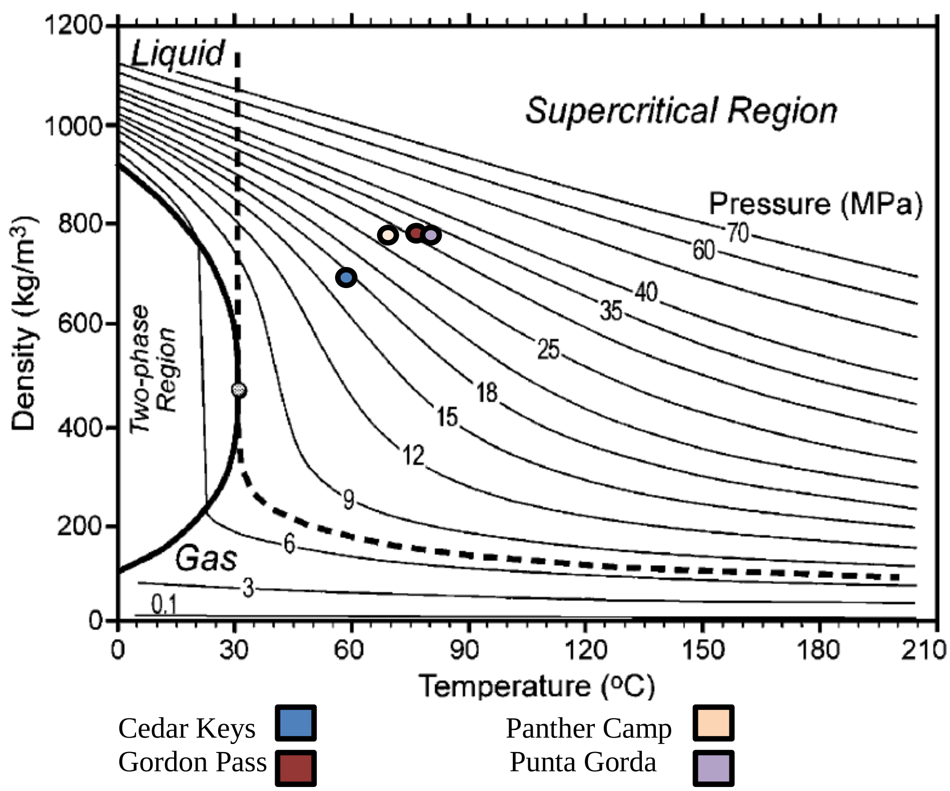

Figure 24. Density values for CO_2 as a function of temperature and pressure (modified from Bachu, 2003).

Table 3. P90 estimated CO_2 storage potential for the Sarasota Arch SOSRA project sub region.

Assessment Unit	Thickness (m)	Mean Porosity	Density (kg/m^3)	P_{90} Efficiency	Storage Resource (Gt)
Upper Cedar Keys	305	0.237	700	0.210	594
Lower Cedar Keys	107	0.237	700	0.150	169
Panther Camp	67	0.214	790	0.210	133
Gordon Pass	55	0.203	800	0.210	105
Punta Gorda	67	0.171	800	0.210	107
Total	**600**				**1108**

Table 4. P50 estimated CO_2 storage potential for the Sarasota Arch SOSRA project sub region.

Assessment Unit	Thickness (m)	Mean Porosity	Density (kg/m^3)	P_{50} Efficiency	Storage Resource (Gt)
Upper Cedar Keys	305	0.237	700	0.210	480
Lower Cedar Keys	107	0.237	700	0.150	121
Panther Camp	67	0.214	790	0.210	107
Gordon Pass	55	0.203	800	0.210	85
Punta Gorda	67	0.171	800	0.210	87
Total	**600**				**879**

Table 5. P10 estimated CO_2 storage potential for the Sarasota Arch SOSRA project sub region.

Assessment Unit	Thickness (m)	Mean Porosity	Density (kg/m^3)	P_{10} Efficiency	Storage Resource (Gt)
Upper Cedar Keys	305	0.237	700	0.16	366
Lower Cedar Keys	107	0.237	700	0.10	80
Panther Camp	67	0.214	790	0.16	82
Gordon Pass	55	0.203	800	0.16	64
Punta Gorda	67	0.171	800	0.16	66
Total	**600**				**658**

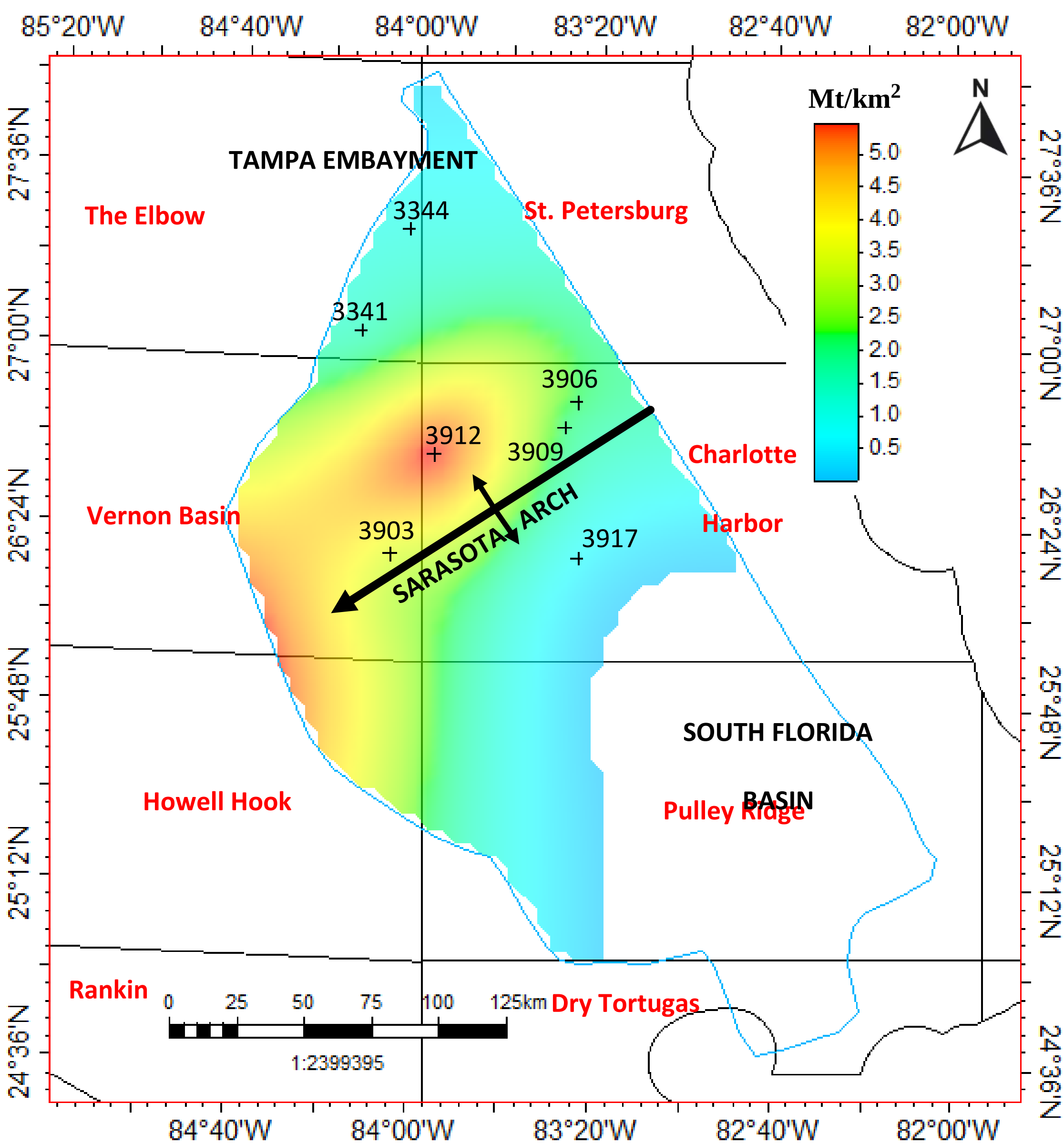

Figure 25. CO_2 storage resource map of the Lehigh Acres Formation within the Punta Gorda assessment unit, West Florida Platform.

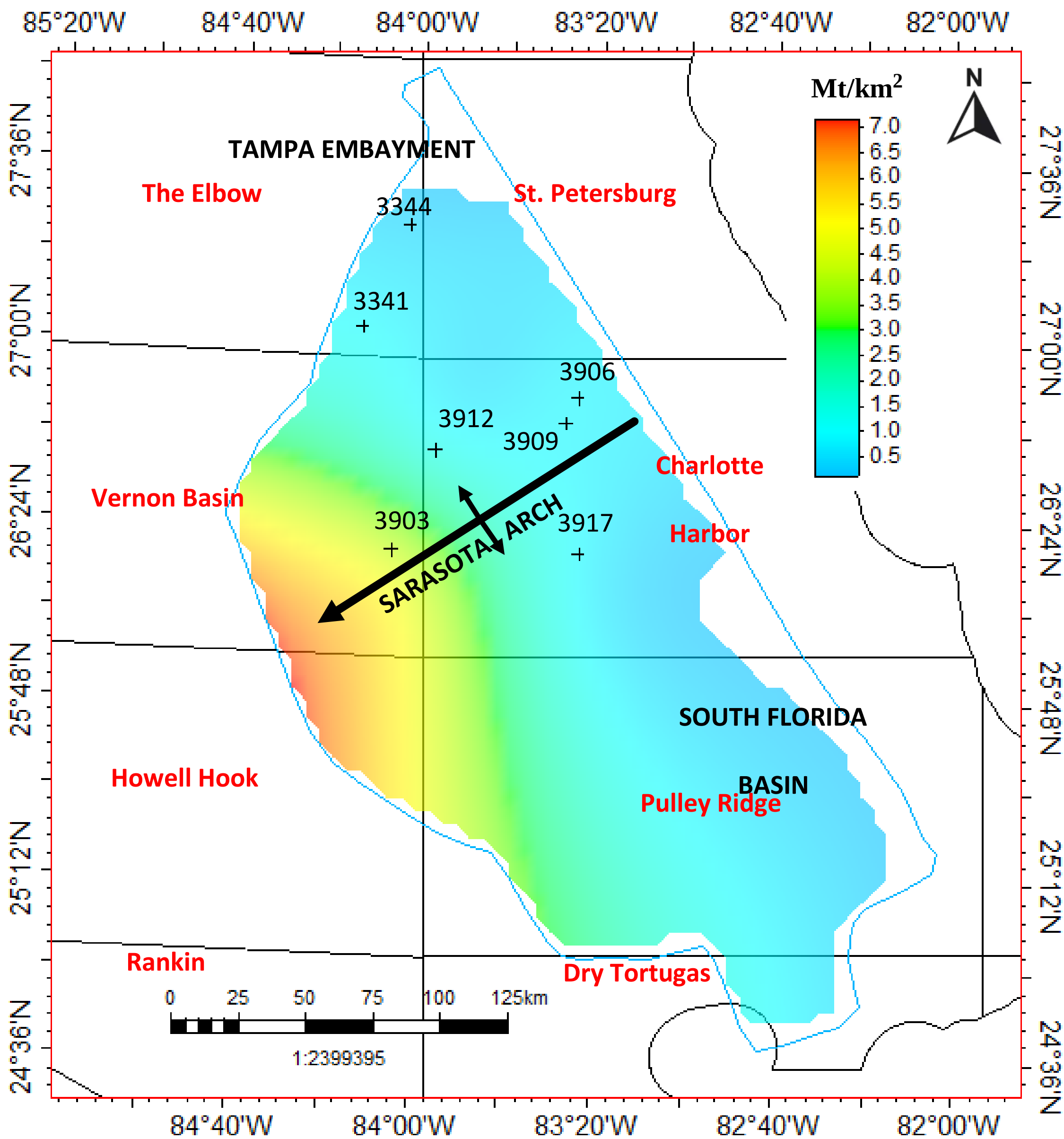

Figure 26. CO_2 storage resource map of the Marco Junction and Lake Trafford Formations within the Gordon Pass assessment unit, West Florida Platform.

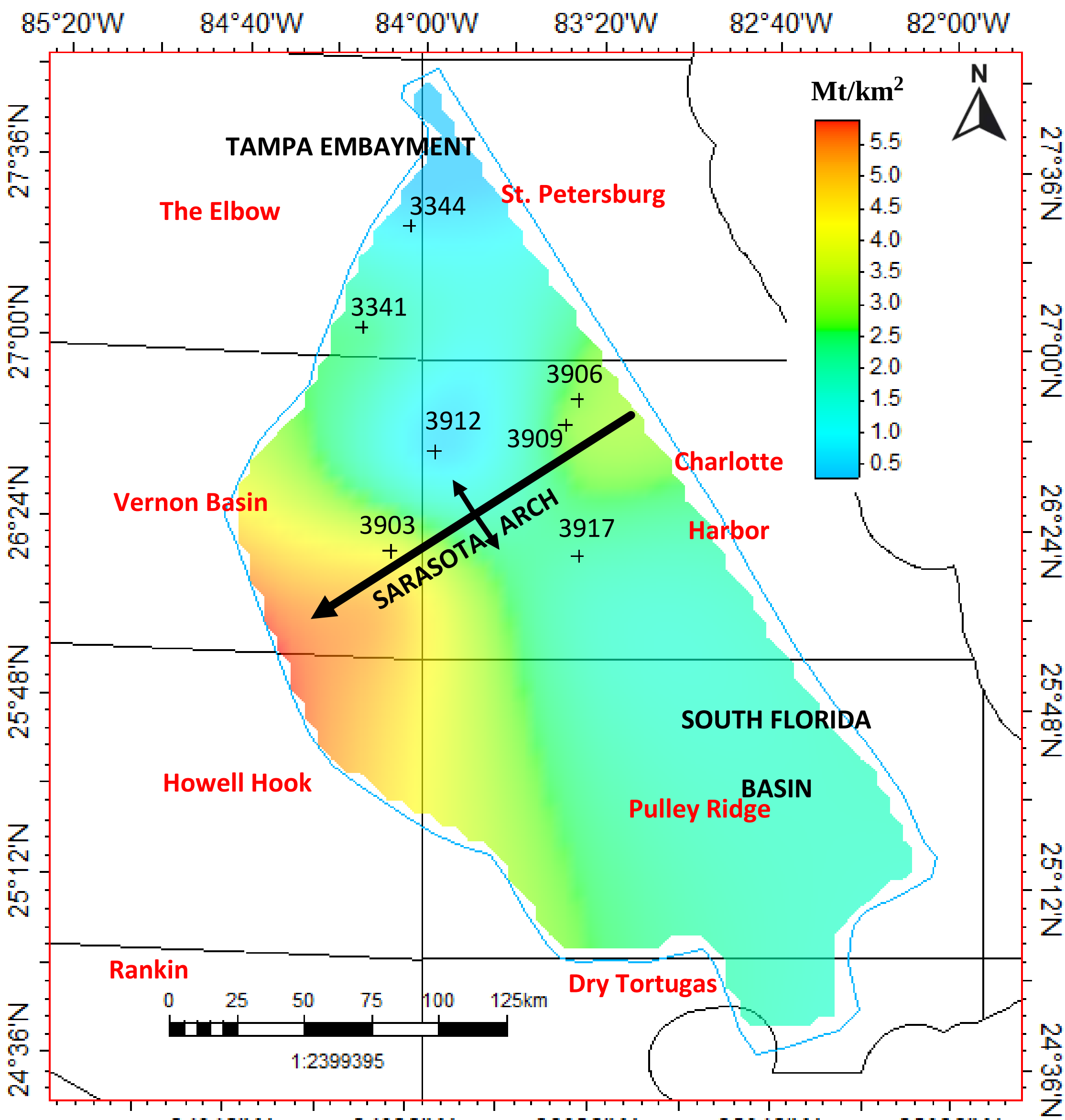

Figure 27. CO_2 storage resource map of the Dollar Bay Formation within the Panther Camp assessment unit, West Florida Platform.

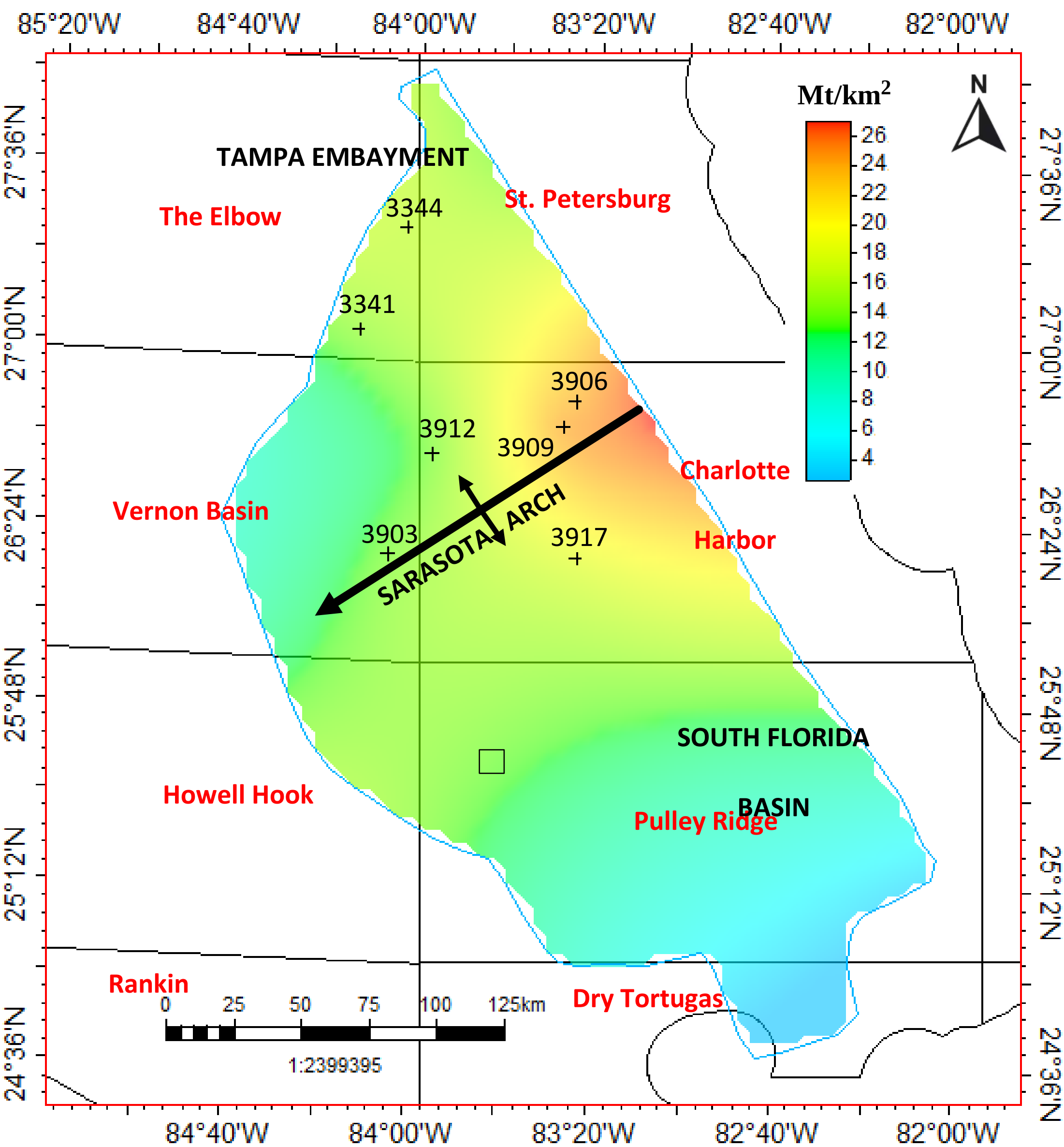

Figure 28. CO_2 storage resource map of the Pine Key, Lawson, and Lower Cedar Keys Formations within the Cedar Keys assessment unit, West Florida Platform.

CHAPTER V

DISCUSSION

Depositional Environment

Abundant anhydrite, dolomite, and limestone beds indicate that the West Florida Platform formed in an arid, tropical to sub-tropical climate, and the major carbonate-anhydrite successions appear to record relative changes of sea level in the platform interior. Changes of sea level and uplift of the Sarasota Ach apparently led to the increase of evaporation reflux on the arch where the development of circulation-restricting barriers led to the formation of shelf wide evaporative lagoons (Adams and Rhodes, 1960; Hardie, 1987; Morse et al., 2007). This caused increases in the salinity of brine, which became dense enough to displace connate water and seep downward through the lagoon floor where magnesium replaced part of the calcium to recrystallize as porous dolomite. The proposed depositional model indicates that the West Florida Platform was primarily deposited in a restricted rimmed platform margin where there are hypersaline conditions favorable for dolomitization and evaporite deposition (fig. 29).

A previous study of chalky limestone and micrite in the Gordon Pass Formation interprets the depositional environment as distal back reef (Winston, 1976). Onshore investigation of the Panther Camp assessment unit suggests that the Dollar Bay Formation was deposited during both sea level regressions and transgressions, and is largely composed of sequences of evaporites and carbonates deposited in a tidal flat/lagoonal restricted marine setting, and in a subtidal platform open marine setting (Mitchell-Tapping, 1990, Pollastro, 2001). The Cedar Keys Formation is thought to have been deposited in a tidal flat environment during the Paleocene, and possibly continuing into the Eocene (Pollastro, 2001).

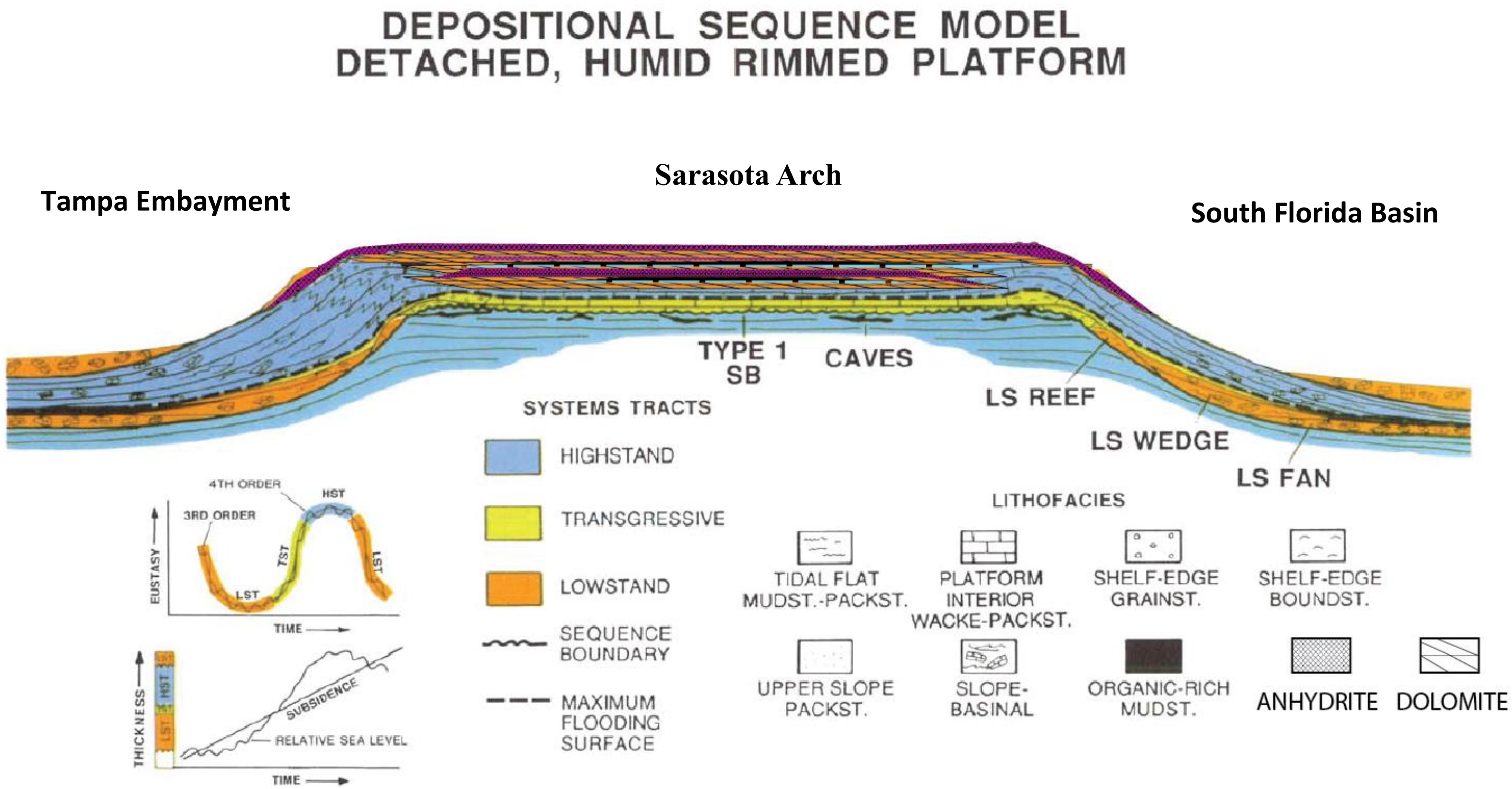

Figure 29. Depositional sequence model of the carbonate platform margin, highlighting the dolomite and anhydrite facies distribution across the Sarasota Arch. (Modified after Hanford and Loucks, 1993).

Reservoirs

As stated previously, porous dolomite is thickest in the crestal region of the Sarasota Arch, and the proportion of limestone increases in the adjacent basins (Tampa Embayment and South Florida Basin) (plates 1, 2). Cross-section A-A' shows that all of the Lower Cretaceous assessment units in the study area thin from the Tampa Embayment onto the Sarasota Arch, indicating that the arch grew during deposition. Sediment deposited on the Sarasota Arch is prone to dolomitization and diagenetically enhanced porosity development due to the evaporation reflux and circulation restricting barriers in the platform margin (Adams and Rhodes, 1960). This is true for the complete Lower Cretaceous section and for the Lawson Formation.

Identification of the storage resource in each assessment unit was achieved by using the defined reservoir properties during well log analysis and seismic interpretation, and leveraging them with CO_2 density values and storage efficiency factors for each assessment unit to generate the storage resource maps and perform the volumetric calculations. Previously discussed storage resource maps of the Punta Gorda, Gordon Pass, and Panther Camp assessment units average 2.5 Mt/km^2, while the Cedar Keys assessment unit averages 15 Mt/km^2. Higher storage potential exists in targeted locations, and indeed reinforces the hypothesis that each offshore block holds the capacity to store annual greenhouse gas emissions from multiple coal-fired power plants in peninsular Florida. Caution should be taken due to the fact that the volumetric calculations include the entire study area, and it is likely that many of the reservoirs do not extend into the Tampa Embayment or South Florida Basin. Thus, the overall storage resource may be overestimated but not confirmed due to the lack of wells in the project area.

The qualified reservoirs within the Lehigh acres Formation of the Punta Gorda Assessment unit are almost entirely porous dolomite. The storage resource map indicates that the best storage location occurs near well OCSG-3912 with 5 Mt/km^2 of storage potential, or 116 Mt per offshore block in the surrounding area. The limestone units within the Punta Gorda assessment interval are generally nonporous and thus do not meet the minimum 15% porosity requirement for qualification. Comparisons between the strike cross section, subsea structure maps, and porosity maps reveal trends of reservoir heterogeneity. Two wells located in the Elbow Area, which is at the southeast end of the Tampa Embayment, contain mainly nonporous limestone in the Lehigh Acres Formation (plate 1). In general, the reservoirs of the Lehigh Acres formation provide an attractive target for CO_2 sequestration on the Sarasota Arch, where porous dolomite predominates.

Potential storage objectives in the Gordon Pass assessment unit are similar to those in the Punta Gorda assessment unit. The qualified reservoirs are in porous dolomite of the Gordon Pass and Marco Junction Formations. The storage resource map indicates that the best storage location is near well OCSG-3903 with 5 Mt/km^2, or 116 Mt per offshore block of storage potential near the shelf margin. The two northernmost wells, OCSG-3344, and OCSG-3341, which are in the Tampa Embayment, are the only wells penetrating the Gordon Pass assessment unit that are dominated by nonporous limestone.

The distribution of porous dolomite in the Dollar Bay Formation of the Panther Camp assessment unit again shows that the Sarasota Arch played an important role in dolomitization and porosity development. The best storage locations are located near wells OCSG-3903 and OCSG-3906 with 4 Mt/km^2 or 93 Mt of storage potential per offshore block. The Dollar Bay reservoir in the Panther Camp assessment unit has similar net thickness to the Lehigh Acres reservoir within the Punta Gorda assessment unit, yet the P_{50} CO_2 storage resource is much larger at about 107 Gt and is attributed primarily to the high porosity and continuity of the reservoir in the study area (table 4; plates 1 and 2).

The youngest reservoirs assessed in this study are the limestone reservoirs of the Pine Key Formation and the dolomitic reservoirs of the Lawson and Cedar Keys Formations. The best storage locations are located near wells OCSG-3909 and OCSG-3906 with greater than 22 Mt/km^2 of storage potential, or 512 Mt per offshore block. This area is the most prospective target location for subsurface CO_2 storage attributed to reservoir thickness, high porosity, shallow depth, and identified overlying seals. The porous limestone unit in the Pine Key Formation is about 110 m (350 ft) thick across the study area, and only the upper Pine Key is considered a target interval. It is important to note that limestone, like that in the Pine Key assessment unit, has a lower P_{50} displacement efficiency factor than dolomite (Goodman, 2011; tables 3-5). CO_2 sequestration in the Pine Key Formation should be considered since the storage resource approaches 120 Gt; however, the overlying Lawson and lower Cedar Keys porous dolomite units may provide even more attractive targets for CO_2 sequestration. Together, the dolomite reservoirs of the Upper Cretaceous Lawson Formation and the Paleocene Cedar Keys Formation have net thickness greater than 300 m (1,000 ft) and accounts for more than half of the total estimated storage resource in the study area (~480 Gt.) (table 4, fig. 29). With mean porosity of about 24 percent, there is value in further analysis of the Cedar Keys assessment unit.

Seals and Storage Risks

Seals

All of the impermeable sealing strata identified as caprocks for the saline formations in the study area are anhydrite, and nonporous limestone may provide additional sealing capacity. As discussed previously in the stratigraphic framework section, there is an abundance of both thick anhydrite beds, and stacked layers of laterally continuous anhydrite interbedded with the dolomite. Many of the thin anhydrite layers (< 10 ft) can be correlated across the study area (plates 1, 2). Furthermore, the thick and laterally continuous anhydrite beds at the top of the Punta Gorda, Gordon Pass, and Panther Camp assessment units are considered low-risk seals.

The Cedar Keys assessment unit does follow some trends similar to those in the other assessment units. The stacked anhydrite beds have net thickness between 130-150 ft, yet this stratigraphic section was not logged in most wells. The lateral extent of the Cedar Keys anhydrite beds is not known due to sparse well control in the study area. The anhydrite layers appear to be absent in the Tampa Embayment at wells OCSG-3341, 3344, and also at well OCSG-3903. This limits potential injection sites to the crestal region of the Sarasota Arch where anhydrite is present. Unfortunately, the thick anhydrite seals onshore do not extend throughout the assessment unit. Generally, the anhydrite beds in the Cedar Keys Formation are about 10 ft thick and are thus much thinner than those in the other assessment units. For purposes of analyzing risks of potential commercial CO_2 sequestration, the Cedar Keys assessment unit is considered higher risk than the other assessment units until further studies can be completed in order to assess the lateral extent of confining units.

CHAPTER VI

CONCLUSION

The West Florida Platform contains a system of arches and basins which play a crucial role in determining the quality of the carbonate reservoirs discussed in this project. All potential reservoirs assessed during this study are at a temperature and pressure favorable for supercritical storage of CO_2. With a total P50 storage resource estimated at 879 Gt, the potential for CO_2 storage in the area of the Sarasota Arch is encouraging for future commercial development.

Data from the U.S. GHG inventory (https://ghgdata.epa.gov/ghgp/main.do) provides estimates of yearly emissions from key power plants along the coast of Florida. Annual CO_2 emissions from the Crystal River, Big Bend, Mcintosh Jr., and Polk power plants are 9.5, 7.7, 1.9, and 1.6 Mt respectively. The combined total emissions generated annually is 20.7 Mt, with an average of about 5.2 Mt/year per power plant. Within the assessed boundaries of this study, each offshore block (~9 mi^2 23.3 km^2) averages 2.5 Mt/km^2 (58 Mt/offshore block) in the Punta Gorda, Gordon Pass, and Panther Camp assessment units. However, the higher net thickness and porosity of the Cedar Keys assessment unit is greater than 15 Mt/km^2 in the area where seal integrity is not in question. Assuming the average in the Punta Gorda, Gordon Pass, and Panther Camp assessment intervals, the annual potential exists to store emissions equal to 11 coal-fired power plant in each offshore block within the assessment unit, and even more potential exists in the Cedar Keys assessment unit.

Reservoir-quality CO_2 sinks in the project area are developed primarily in dolomite, as it is the principal rock type with significant porosity. Stratigraphic analysis demonstrates that dolomite is concentrated on the Sarasota Arch and that limestone predominates in the adjacent Tampa Embayment and the South Florida Basin. The only limestone unit with sufficient porosity (>15 %) to qualify as reservoir in this study is the Upper Cretaceous Pine Key Formation, which is in the Cedar Keys assessment unit. It is worthwhile to note that the association of the Upper Pine Key with chalky carbonate should be approached cautiously, since chalk is known for high porosity and low permeability (e.g., Scholle, 1977).

The dolomitic reservoirs of the Punta Gorda, Gordon Pass, Panther Camp, and Cedar Keys assessment units contain the primary target reservoirs that were assessed, and together contain more than 755 Gt of storage capacity at the P_{50} efficiency factor for saline reservoirs. Additional potential may exist in the dolomite intervals within the Naples Bay Group, but that interval was unassessed due to lack of a viable topseal. Although there is seal risk associated with this interval, anhydrite in the overlying Cedar Keys could seal any fugitive CO_2, however the extent of confining units in the Cedar Keys is limited.

All confining units in the study area are composed of thick, stacked beds of anhydrite, and the major anhydrite markers appear continuous throughout the study area except in the Cedar Keys Formation, where anhydrite beds are restricted to the northeastern part of the study area. The major anhydrite intervals within the Punta Gorda, Gordon Pass, and Panther Camp Formations tend to thin basinward from the Sarasota Arch but still appear to maintain integrity as confining units. Further studies need to be conducted in order to verify the lateral extent of anhydrite in the Cedar Keys Formation, which contains the largest storage resource assessed in this study. Ultimately, the storage potential of the West Florida Platform is vast, and the platform may provide a viable option for the future commercial storage of CO_2 in the Eastern Gulf of Mexico.

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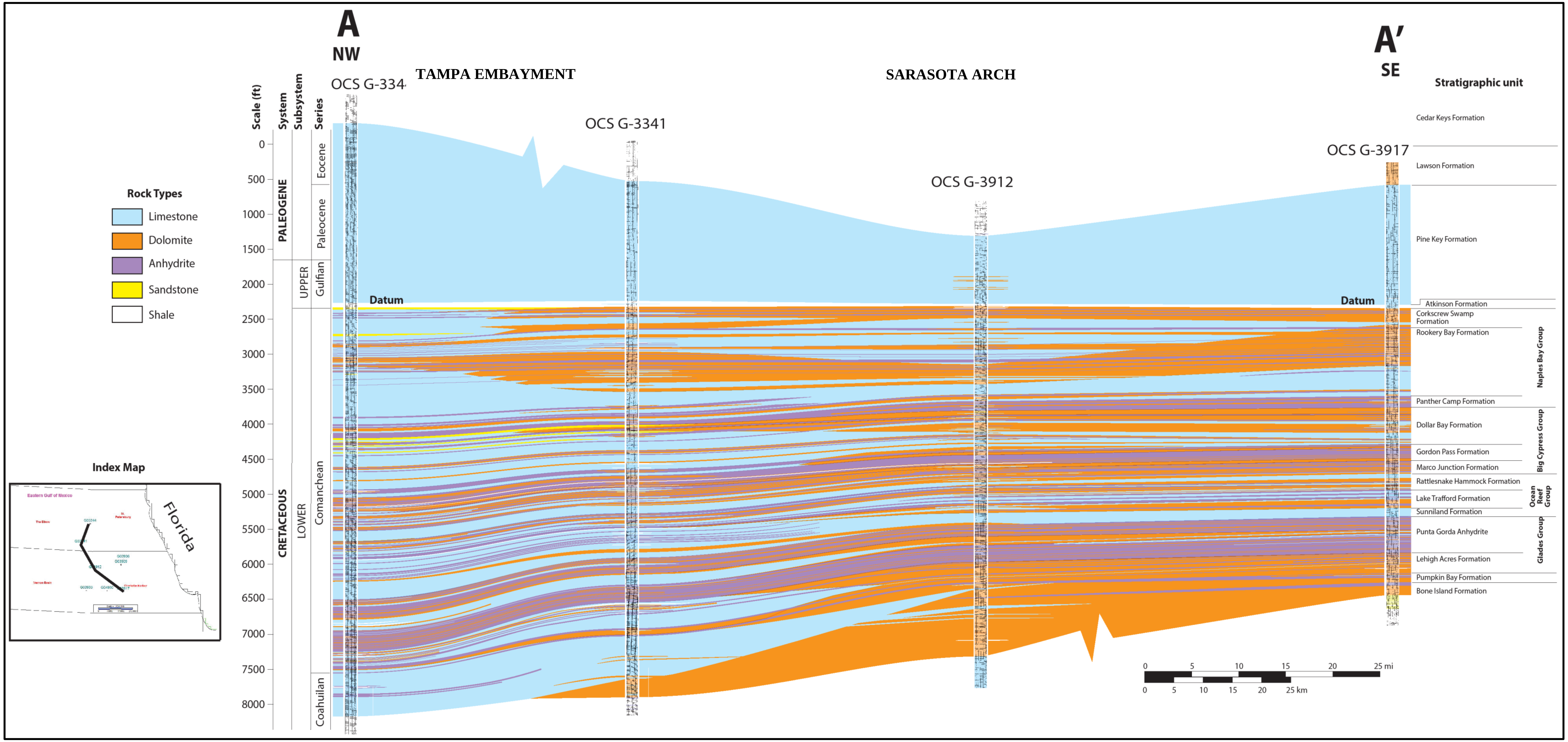
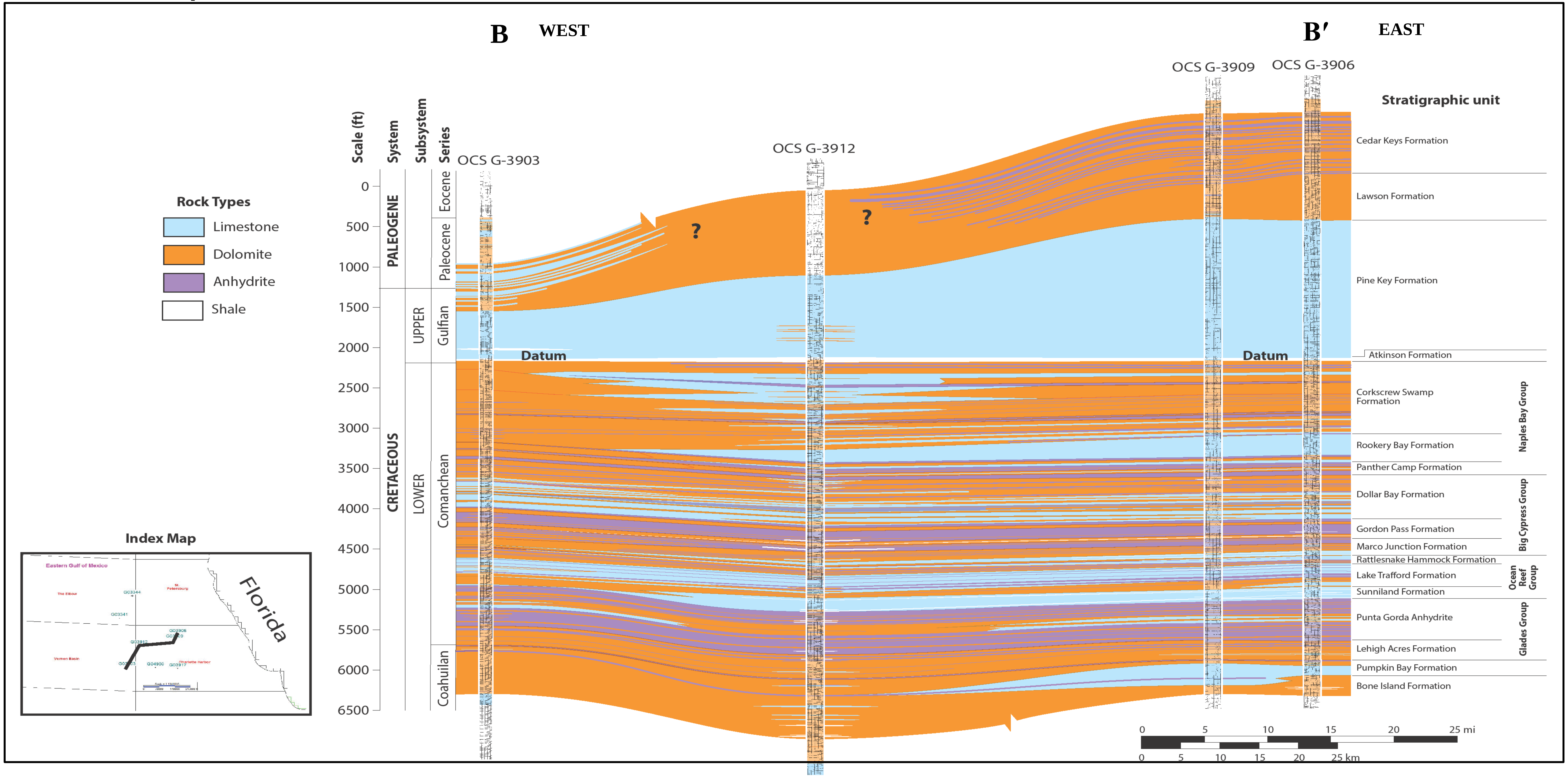
Cross Section Strike Line Across Sarasota Arch **PLATE 1**



Cross Section Dip Line

PLATE 2



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