FLORIDA PENINSULA PROVINCE (050)

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INTRODUCTION

The Florida Peninsula, Province 50, includes all of the State of Florida east of the Apalachicola River, and the adjoining State waters. It excludes the part of the Florida panhandle west of the Apalachicola. The boundary between Province (050) and Province (049) in the panhandle is a generally north-south trending line between the counties of Gadsden, Liberty, and Franklin to the east and the counties of Jackson, Calhoun, and Gulf to the west.

The province is approximately 150 mi wide and about 400 mi long, inclusive of State waters, totaling about 70,000 sq mi. It is bounded to the north by the State boundary with Georgia and to the east, south, and southwest by the boundaries of the Florida State waters. The State water boundaries extend to 3 leagues (10.36 statute miles) on the Gulf of Mexico side of Florida and to 3 miles on the Atlantic Ocean side (the Gulf-Atlantic boundary line runs westward from the Marquesas Keys along latitude 24û35' N and then turns southward, just west of the Dry Tortugas, along the 83rd west meridian.)

The most prominent positive structural element within the province is the Peninsular Arch which is a crystalline basement high plunging south-southeast along the axis of the Florida Peninsula. Other smaller positive structural elements generally define the boundaries of the associated South Florida Basin, the Apalachicola Embayment, and the Southeast Georgia Embayment, with the South Florida Basin being the most prominent of these and having the greatest petroleum potential.

The South Florida Basin is a structurally simple basin containing an estimated 25,000 ft or more of sediment in the apparent depocenter, that lies northwest of the Florida Keys under present-day Florida Bay. Sedimentation in the basin kept pace with subsidence, producing nearly continuous carbonate-evaporite deposition from the Jurassic(?) almost to the present. The basin covers some 50,000 sq mi and incorporates the bottom third or more of the peninsula of Florida including the Florida Keys and the easternmost Gulf of Mexico. Onshore, the basin has only subtle structures with no major faults or vertical fractures. However, more complex structural elements are believed to exist in the offshore portion of the basin, thus allowing greater opportunity for hydrocarbon

accumulation. The basin has a generally low (~1.0¡F/100 ft) geothermal gradient; however, the gradient of some onshore oil fields may reach 1.5¡F/100 ft.

The Southeast Georgia Embayment in the notheastern portion of the province contains as much as about 6,000 ft of sedimentary rock. Because this area has only shallow, thermally immature sequences and lacks potential petroleum source rocks, its potential for undiscovered petroleum resources is classified as slight. The Apalachicola Embayment in the northwestern part of the province, however, has some petroleum potential in the proven Jurassic Smackover Formation, that produces in the western Florida panhandle in Province (049).

Of the six conventional plays defined for this province, two are confirmed, Upper Sunniland Tidal Shoal Oil Play (5001) and Lower Sunniland Fractured "Dark Carbonate" Oil Play (5002). The other four are hypothetical. They are Dollar-Bay Shoal-Reef Dolomite Oil Play (5003), Lower Cretaceous Carbonate Composite Oil Play (5004), Extended Upper Sunniland Tidal Shoal Oil Play (5005), and Wood River Dolomite Deep Gas Play (5006). The Smackover Alabama/Florida Updip Oil Play (4911) occurs in the Florida Peninsula Province but is described in Louisiana-Mississippi Salt Basins Province (049).

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CONVENTIONAL PLAYS

5001. UPPER SUNNILAND TIDAL SHOAL OIL PLAY

The Lower Cretaceous Sunniland Formation is known only in the subsurface and is the basal unit of the Ocean Reef Group. Onshore, the formation is relatively uniform in thickness and consists of limestone, dolomite, and anhydrite. The Sunniland produces marginally mature crude oils onshore from porous bioclastic debris mounds, banks, and pods on the eastern updip margins of the South Florida Basin. The reservoir facies of the upper Sunniland Formation is defined in part by eight >1 MMBO fields and five smaller fields, which form an arcuate northwest-southeast trend, the "Sunniland Trend," about 20 mi wide and 150 mi long. Generally, the updip limit of the Sunniland varies from about 50 to 60 miles to the northeast of the producing trend. The first upper Sunniland oil field discovery was the Sunniland field in 1943; the largest is the West Felda field, discovered in 1966, with a total production through July, 1993 of over 44 MMBO. Cumulative production from the upper Sunniland Formation in south Florida through July, 1993 was about 100 MMBO.

The northern and updip play boundary for the Upper Sunniland Tidal Shoal Play (5001) is defined here by an area where the upper Sunniland consists of only micritic limestone and contains no reservoir mounds within its intertidal, lagoonal mudflat facies. Moreover, the lower Sunniland dark carbonate source rock is also absent. The downdip southern boundary of the play is limited by an area where wells identify an anhydrite-cemented, nonporous, sabkha-like facies.

Reservoirs and traps: The existing reservoirs in the upper Sunniland Formation consist mostly of isolated fossil-shell hash (skeletal grainstones) probably deposited during storms as shoals in a regionally restricted, back-reef lagoonal area in the warm, shallow marine shelf setting of the eastern South Florida Basin during the Late Early Cretaceous (Mitchell-Tapping, 1987). These tidal shoals were deposited on subtle bathymetric highs probably related to underlying basement structure. Later, the upper portions of these porous shoal mounds were subaerially exposed, leached, and dolomitized during a low sea-level stand, further enhancing the reservoir quality of the upper porous zones. Individual debris mounds vary in thickness between about 40 and 100 ft (Means, 1977; Montgomery, 1987). Most mounds are overlain by impermeable lagoonal mudstones and wackestones, some of which have been dolomitized. Porosities of primary (interparticle) and secondary (dissolution and dolomitization) origin range from about 10-25 percent and average about 15-18 percent (Mitchell-Tapping, 1987). Impermeable

micritic carbonate and nodular anhydrite beds within the upper Sunniland have enclosed many of the porous reservoirs, and the entire formation is sealed above and below by thick anhydrites. Most hydrocarbon traps are stratigraphic; however, some mixed stratigraphic/structural traps have been recognized. Depth to the upper Sunniland tidal shoal reservoirs in the producing trend is from about 11,200 to 11,600 ft.

Source rocks: Oils produced from the upper Sunniland grainstones are immature, having API gravities that range from about 21¡ to 28¡ and average about 25¡-26¡; on average, the GOR is about 85 (Palacas and others, 1984; Tootle, 1991). The source rocks are in a dark, micritic carbonate unit (informally referred to as the "dark carbonate" interval) in the lower part of the formation. These micritic carbonates are commonly algal laminated and have total organic carbon (TOC) ranging from <0.4 to 3.0 weight percent. Potential source rocks (>0.4 weight percent TOC) average about 1.8 weight percent TOC and > 80 percent of the organic matter within them is composed of algal-amorphous (oil-prone) kerogen. The hydrocarbon-generating potential of the lower Sunniland dark carbonate facies varies from poor in wells updip from the producing trend to good just downdip to excellent near the depocenter of the basin (Applegate and Pontigo, 1984). Onshore, the dark carbonate facies varies in thickness from zero at the updip limit of the Sunniland to >150 ft in the producing trend. It is generally thought that the oil produced from reservoirs in the Sunniland Trend was generated downdip where the organic matter in the dark carbonate facies is richer and more mature. The petroleum then migrated updip and accumulated in the porous grainstone facies of the upper Sunniland (Palacas and others, 1984).

Exploration status and resource potential: The drilling history and well distribution in the play area show that exploration and development of the upper Sunniland Formation has been minimal. The eight upper Sunniland fields >1 MMBO are Bear Island, Corkscrew, West Felda, Lehigh Park, Mid-Felda, Raccoon Point, Sunniland, and Sunoco-Felda. Factors such as environmental and political concerns and the present oil prices for Sunniland crude probably have discouraged full development. These factors, coupled with the success of wells drilled in the past few decades, indicate that the Upper Sunniland Tidal Shoal Play has good potential for undiscovered accumulations of moderate size.

5002. LOWER SUNNILAND FRACTURED "DARK CARBONATE" OIL PLAY (HYPOTHETICAL)

The Lower Sunniland Fractured "Dark Carbonate" Oil Play is proposed here based on the discovery of the Lake Trafford field in Collier County. The dark carbonate unit of the lower Sunniland Formation is believed to contain the primary source beds for oils produced in the upper Sunniland tidal shoal grainstones of this play. Although no accumulations are proven of minimum (>1 MMBO) size, one well defining the Lake Trafford field has produced commercial quantities of oil since its discovery in March 1969 from fractured limestone at a depth of about 11,800 ft. The producing zone is often referred to as the "rubble zone" of the dark carbonate unit in the lower Sunniland Formation (Means, 1977). The log-measured matrix porosity of the producing zone is about 9 percent and the pore space is oil saturated. Core of the rubble zone from the discovery well has been described as burrowed, fractured, and stylolitized (Lloyd, 1991); these characteristics are thought to be responsible for creating the porosity and permeability for commercial production. The discovery well was shut in March 1988, after a total oil production of about 278,000 barrels. Two offset vertical wells, to the northwest and south of the producing well, and a recent horizontal test well were dry holes. Based on the history of the one vertical well, horizontal wells penetrating the rubble zone of the dark carbonate unit could potentially produce a few hundred BOPD. Owner/operator Brian Richter (oral commun., 1994) reports that the targeted zone was missed in the horizontal test.

The play boundary is defined by thick (>60 ft) section of the dark carbonate unit, as partly determined from cross sections and isopachs of Applegate and Pontigo (1984) and from offshore well summaries of Lloyd (1991).

Reservoirs and traps: Potential productive fractured reservoirs are in the lower dark carbonate zone of the lower Sunniland and are enclosed by impermeable, micritic, tidal flat, lime mudstones. The unit is sealed below by the Punta Gorda Anhydrite.

Source rocks: Indigenous hydrocarbons are produced from brown and medium-dark-gray micritic and argillaceous limestones with total carbonate content averaging 76 weight percent, and ranging from 50 to 98 weight percent. These micritic carbonates are commonly algal laminated and have total organic carbon (TOC) ranging from <0.4 to 3.0 weight percent. Potential source beds (>0.4 weight percent TOC) within the unit average about 1.8 weight percent TOC.

Oil produced from the one well at the Lake Trafford field has an API gravity of about 26û, similar to the values found for upper Sunniland producers (21û-28û). Inasmuch as oils in the upper Sunniland are derived from sources in the lower dark carbonate, the similarity in AGI gravities is expected. The lower Sunniland oil should also have a GOR similar to that of upper Sunniland oils (85 on average). The lower Sunniland in the area of the play was also determined from reference wells to have good source-rock quality and to include either the "rubble zone" or at least some fracturing (Montgomery, 1987).

Exploration status and resource potential: The size and number of accumulations were estimated through analogies with both the Sligo/Pettet Salt Basin Oil Play (4929) and the larger fractured Buda Down-dip Oil Play (Play 4708). In addition, the history of the Mobil well at the Lake Trafford field and the proven Upper Sunniland Tidal Shoal Oil Play (5001) were used as supplemental guides for the estimates. The Lower Sunniland Fractured Dark Carbonate Play is assigned fair potential in the assessment evaluation, and the most favorable part of the play is in an area northwest of the Lake Trafford field. Expected depths of production within the play area are estimated between 10,000 and 13,000 ft, with a median depth of about 11,800 ft.

5003. DOLLAR BAY SHOAL-REEF DOLOMITE OIL PLAY (HYPOTHETICAL)

The Dollar Bay Shoal-Reef Dolomite Oil hypothetical play is based on (1) interpretations of the data from a series of onshore wells having numerous shows (Winston, 1971) and on (2) the paleoenvironmental reconstructions of Winston (1971) and Mitchell-Tapping (1990) of the reservoir tidal shoal and patch reef facies; the data of Faulkner and Applegate (1986) was also used in the evaluation.

The Lower Cretaceous Fredericksburgian Dollar Bay Formation, the uppermost unit of the Big Cypress Group, is the youngest formation in the onshore portion of the South Florida Basin that shows characteristics favorable for petroleum generation and accumulation. The unit lies about 1500 ft or more above the Sunniland Formation and is as much as 620 ft thick in some parts of the basin. Many wells penetrating the Dollar Bay Formation in south Florida have reported low-gravity (~17¡ API) oil shows or tarry residues in both limestone biohermal deposits and an upper dolomite section; however, no commercial production has occurred. Like the Sunniland Formation, the Dollar Bay commonly consists of evaporite-carbonate cycles of anhydrites, dolomites, and limestones formed during a transgressive-regressive cycle; some thin beds of calcareous shale, salt, and lignite are also present (Applin and Applin, 1965; Mitchell-Tapping,

1990). In certain areas of the basin, however, the dominant lithology of the formation is limestone. Speculative production in the Dollar Bay Formation is from leached limestones in the middle part, or from a dolomite section in the upper part of the formation. The unit is overlain by dense nodular anhydrites of the Gordan Pass Formation.

Reservoirs: Reservoirs are believed to exist in tidal shoal deposits and patch reefs in a tidal flat, lagoonal, restricted-marine setting, and in a subtidal platform, open-marine setting (Mitchell-Tapping, 1990). Potential reservoirs include the porous, leached, and dolomitized grainstones in the upper portions of isolated debris mounds and isolated patch reefs in the middle part of the Dollar Bay Formation and a porous dolomite in the upper part (Mitchell-Tapping, 1990). Potential reservoirs have measured porosities ranging from about 10-30 percent and permeabilities on the order of 5-60 mD. Traps are created because these reservoirs are draped with impermeable, micritic, tidal flat, sometimes argillaceous lime mudstones and anhydrite. The formation is overlain by a thick anhydrite of Lake Trafford Formation.

Source rocks: Oil and tarry residues recorded in Dollar Bay wells are believed to originate within the formation (Palacas, 1978a,b; Winston, 1971). The organic-matter content of the Dollar Bay Formation ranges from very lean to fairly rich, with some beds containing more than 3 weight percent TOC; the average TOC of the Dollar Bay is reported as about 0.6 weight percent (Palacas, 1978a,b). Most petroleum explorationists infer that the Dollar Bay Formation updip and to the northeast of the "Sunniland Trend" is thermally immature and has probably not generated hydrocarbons of commercial quality and quantity (Montgomery, 1987); however, others strongly disagree (Winston, 1971; Palacas, 1978a,b; Mitchell-Tapping, 1990). Offshore, in the more central portion of the basin where the Dollar Bay lies at depths >10,000 ft, the formation should be more thermally mature. API gravities expected for this play are low and probably in the range of 15¡- 20¡, averaging about 17¡. Sulfur contents are similar to those of Sunniland-type oils (2-4 percent). Moreover, the speculative presence of patch reefs and more complex structures offshore enhances the potential for new field discoveries and commercial oil production.

Resource potential: The play carries a probability of occurrence of 0.4; the greatest risk is attributed to charge. Estimates of the size and number of undiscovered accumulations were made using the proven Upper Sunniland Tidal Shoal Oil Play (5001) as an analog. Data from the upper Sunniland about discovery, production, and

distribution and spacing of accumulations were used in combination with a facies reconstruction of the Dollar Bay Formation within the play area to project the same kinds of data for the hypothetical Dollar Bay Shoal-Reef Dolomite Oil Play.

5004. LOWER CRETACEOUS CARBONATE COMPOSITE OIL PLAY (HYPOTHETICAL)

The hypothetical Lower Cretaceous Composite Oil Play comprises two units in the South Florida Basin: the Lehigh Acres "Brown Dolomite" zone and a potentially porous dolomite unit within the Pumpkin Bay Formation. Both units in this play are believed to have oil derived mainly from organic-rich beds in the upper part of the Pumpkin Bay Formation.

The extent of the play is defined by two areas: one centered in Lee County and intersecting the "Sunniland trend," the other centered near the Marquesas Keys. The northern area (Lee County and vicinity) includes the area of the porous Brown Dolomite outlined by Applegate (1987) and the area within the Pumpkin Bay Formation shown to contain live oil, porous dolomite (6-16 percent porosity), and good to excellent source-rock potential in its thickest section (as much as 1,200 ft thick), as defined by reference wells in State waters near Charlotte Harbor and onshore in Collier and Hendry Counties (Means, 1977; Applegate and others, 1981; Palacas and others, 1981; Attilio and Blake, 1983; Faulkner and Applegate, 1986; Applegate, 1987; Montgomery, 1987) This northern area also corresponds to an area shown by Saul (1987) within which, he suggests, porosity in the Brown Dolomite is caused by epigenic dolomitization from an active geothermal lineament system. The southern part of the play area, centered near Marquesas Keys, is the area where several oil shows are reported in thick, porous dolomite sections (Faulkner and Applegate, 1986; Lloyd, 1991).

Reservoirs: The "Brown Dolomite zone" is an informal name referring to a dolomite unit often found within the Twelve Mile Member of the Lower Cretaceous Lehigh Acres Formation (Aptian). The Brown Dolomite lies about 300 ft below the base of the Punta Gorda Anhydrite and about 1,000 ft below the Sunniland Limestone. The unit is best developed onshore in Charlotte County and surrounding counties at a depth of ~12,000 ft where thickest (~100 ft) and most porous (10-22 percent). Good oil shows are reported, and the oil have higher API gravity (20û-50û?) and thermal maturity than Sunniland oils. Reservoirs consist of sucrosic dolomite having pinpoint to vuggy pore spaces found at least 50 feet below the top of the Twelve Mile Member of the Lehigh Acres Formation. As much as 50 ft of porous dolomite has been found onshore where

the Brown Dolomite zone reaches a maximum thickness of about 100 ft. An area having highest potential onshore is defined mostly by the porous zones shown by Applegate (1987) in Charlotte, Lee, Hendry, Collier, Highlands and Glades Counties and adjacent Gulf State waters. Good oil shows were observed in the Bass Collier 12-2 well in Collier County in dolomite having sonic porosities from 10 to 22 percent and core porosities as high as 18 percent. Good potential is also predicted offshore and within State and Federal waters. In particular, oil stains were noted in wells where about 350 ft of mostly porous dolomite has been penetrated near the Marquesas Keys (Faulkner and Applegate, 1986; Lloyd, 1991).

The Lower Cretaceous Pumpkin Bay Formation is considered the thickest and deepest interval in the South Florida Basin with significant reservoir potential. The formation has been described as thick as 1,200 ft in offshore Florida State waters of Charlotte Harbor. The Pumpkin Bay is found at depths from about 12,500 to 14,000 ft onshore and is projected to thicken to the west offshore into the basin depocenter. The formation is mostly limestone except at its northern limit, where it has been found to be mostly dolomite. Porosities are generally lower in the Pumpkin Bay Formation than in potential reservoirs found in younger units; Pumpkin Bay core porosities range up to about 20 percent, and its sonic porosities measure slightly higher. Generally, it is believed that the best potential for the Pumpkin Bay Formation is offshore in the Pulley Ridge area. Projections suggest that the formation is as much as 1,500 ft thick in this area and that good reservoirs exist within a thick porous dolomite zone (300-350 ft thick; pinpoint to vuggy porosity as great as 25 percent) in the middle to upper part of the formation, at depths from about 12,500 ft to >15,000 ft.

Source rocks: Source-rock studies by Palacas and others (1981) suggest that organic rich beds in the upper Pumpkin Bay Formation are likely source rocks for oils that could be reservoired both within the middle and upper Pumpkin Bay and in the porous Brown Dolomite zone. Palacas and others (1981) identified organic-rich, argillaceous carbonate beds with high (0.43-3.2 weight percent) TOC in the upper Pumpkin Bay and concluded that these beds had the highest petroleum-generating potential of all pre-Punta Gorda rocks studied. The high TOC contents of these rocks, however, varies within the basin. Most rocks within the Twelve Mile Member of the Lehigh Acres Formation contain too little organic matter (average ~0.3 percent TOC) to have generated commercial amounts of petroleum. Some richer source beds occur within the unit, however, having marginal (~0.5 percent TOC) to good source potential, particularly a relatively thin (~1 ft thick) limestone bed in the West Felda field that

contains >2.0 percent TOC. The thermal maturation level for oil generation is greater in this play than that for the upper and lower Sunniland plays (5001 and 5002). Thus, oils of this play are expected to be marginally to moderately mature and to have higher API gravities (25¡ to 50¡) and higher gas-to-oil ratios than Sunniland oils produced at depths from about 12,000 to 15,000 ft.

Exploration status and resource potential: This play was assigned a risk probability of 0.4 with greatest risk attributed to charge. Sizes and numbers of accumulations were estimated by analog comparison using a downscaled version of the Sligo/Pettet Salt Basin Gas and Oil Play (4929) in the Louisiana-Mississippi Salt Basins Province (049).

5005. EXTENDED UPPER SUNNILAND TIDAL SHOAL OIL PLAY (HYPOTHETICAL)

This hypothetical play is an extension to the east and south of the productive "Sunniland Trend" in the Upper Sunniland Tidal Shoal Oil Play (5001). This play forms a southwest to-northeast arcuate trend approximately 20 mi wide and 250 mi long from the State waters of the Dry Tortugas northeast through the Florida Keys and along the southeastern Atlantic Coast of the Florida Peninsula to Broward County. Bioclastic mounds of smaller size than those in currently productive upper Sunniland units accumulated on subtle structural highs in an updip, less thermally mature area of the basin to the east and far south. Prominent positive structural elements include the Pine Key arch and the Largo high. Some oil shows having very low API gravity (10û-14¡) have been reported in wells in the northern portion of play area; however, 22¡ API gravity oil was reported in shows from wells near the Marquesas Keys in the west and southernmost part of play area (Faulkner and Applegate, 1986; Lloyd, 1991).

This play is defined by an area of suspected porous tidal-shoal facies forming on topographic/bathymetric highs. The lower Sunniland dark carbonate source unit thins toward the east and south margins of the basin below the play area, making it less favorable than the proven upper Sunniland play. The Sunniland in this area is also less mature than in play 5001. The eastern and southern Atlantic coastal boundaries of the play are determined by the 3-mi line, and the northern, Gulf of Mexico boundary by the 3-league Florida State waters boundary.

See play 5001 for a discussion of reservoirs and source rocks.

5006. WOOD RIVER DOLOMITE DEEP GAS PLAY (HYPOTHETICAL)

In the hypothetical Wood River Dolomite Deep Gas Play, the Upper Jurassic(?)/Lower Cretaceous Wood River Formation averages about 1,700 ft thick and is the lowest

sedimentary unit in the South Florida Basin. The few wells that have penetrated this formation show that a 100- to 150-ft thick clastic unit forms the basal part of the Wood River Formation and consists of dark red shale and fine- to coarse-grained arkosic sandstone and calcareous sandstone. These basal clastics possibly represent fan, fan-delta, and fluvial-lacustrine or marine deposits. Overlying these clastic rocks is a thick sequence of anhydrite, dolomite, and limestone with occasional interbedded salt stringers, indicating marine transgression.

One well, the Mobil-Phillips Seminole "C" in Hendry County, produced measurable gas and water flows from perforations at depths of about 15,700 ft in a dolomite zone having about 8 percent porosity. Moreover, logs from the well indicated higher porosities and increased resistivities just above the perforated section possibly indicating the presence of gas. Although formation damage occurred in the well bore, this well had potential for commercial gas production (J. G. Palacas, oral commun., 1994). There is some question, however, whether there is a sufficient quantity of organic matter in the Wood River Formation to permit economic production. Nevertheless, the occurrence of a potentially commercial well indicates a possible source of deep gas. Marine beds, generally regarded as potential petroleum sources, are predominant, and the depositional environment, especially in the southern areas, probably favored reef growth; thus a source, a seal, and a reservoir should be present.

Organic geochemistry studies of well samples from the Wood River Formation indicate that the hydrocarbon-generating potential of the unit ranges from poor to excellent (Palacas and others, 1981; Faulkner and Applegate, 1986). The scarcity of wells penetrating the Wood River Formation, however, makes any evaluation inconclusive. Potential reservoirs in the Wood River are porous (8 percent or greater) dolomites enclosed by anhydrite, salt stringers, and/or micritic limestone at depths from about 15,000 to 19,000 ft onshore and in State waters. The play area includes areas of the southern part of basin where reef growth is favored. It is possible that gas in the Wood River in the area of the Sunniland Trend may have originated in deeper portions of the basin and migrated updip, perhaps as a single, large accumulation.

This play was not assessed due to high risk.

UNCONVENTIONAL PLAYS

There are no unconventional plays described in this province report. However, unconventional plays listed in the surrounding provinces may include parts of this province. Individual unconventional plays are usually discussed under the province in which the play is principally located.

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