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DISTRIBUTION OF ORGANIC CARBON AND PETROLEUM SOURCE ROCK POTENTIAL OF CRETACEOUS AND LOWER TERTIARY CARBONATES, SOUTH FLORIDA BASIN: PRELIMINARY RESULTS

by

James G. Palacas

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ABSTRACT

Analyses of 134 core samples from the South Florida Basin show that the carbonates of Comanchean age are relatively richer in average organic carbon (0.41 percent) than those of Coahuilan age (0.28 percent), Gulfian age (0.18 percent) and Paleocene age (0.20 percent). They are also nearly twice as rich as the average world-wide carbonate (average 0.24 percent). The majority of carbonates have organic carbons less than 0.30 percent but the presence of many relatively organic rich beds composed of highly bituminous, argillaceous, highly stylolitic, and algal-bearing limestones and dolomites accounts for the higher percentage of organic carbon in some of the stratigraphic units.

Carbonate rocks that contain greater than 0.4 percent organic carbon and that might be considered as possible petroleum sources, were noted in almost each subdivision of the Coahuilan and Comanchean Series but particularly the units of Fredericksburg 'B', Trinity 'A', Trinity 'F', and Upper Sunniland. Possible source rocks have been ascribed by others to the Lower Sunniland, but lack of sufficient samples precluded any firm assessment in this initial report.

In the shallower section of the basin, organic-rich carbonates containing as much as 3.2 percent organic carbon, were observed in the lowermost part of the Gulfian Series and carbonate rocks with oil staining or "dead" and "live oil" were noted by others in the uppermost Gulfian and upper Cedar Keys Formation. It is questionable whether these shallower rocks are of sufficient thermal maturity to have generated commercial oil.

The South Florida basin is still sparsely drilled and produces only from the Sunniland Limestone at an average depth of 11,500 feet (3500 m). Because the Sunniland contains good reservoir rocks and apparently adequate source rocks, and because the success rate of new oil field discoveries has increased in recent years, the chances of finding additional oil reserves in the Sunniland are promising. Furthermore, the presence of possible source rocks in many of the other stratigraphic units, in particular, the Fredericksburg, should give further impetus to exploring for other productive horizons.

AKNOWLEDGMENTS

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INTRODUCTION

This report describes the amount and distribution of organic carbon in carbonate rocks ranging in age from Lower Cretaceous (Coahuilan) to Lower Tertiary (Paleocene) in the South Florida Basin, Florida. Organic carbon together with other geochemical and geological criteria are used to assess the petroleum source potential of these rocks. In addition, these preliminary results also will be used as part of a study of the geochemistry and petroleum source potential of carbonate rocks in general. In comparison to sandstone-shale sequences, little information has been published on the accumulation, generation, expulsion, and migration of hydrocarbons in carbonate sequences. The South Florida Basin appears to be a good sedimentary basin to evaluate the evolution of petroleum in carbonates, first because it contains a thick section of limestones, dolomites, and anhydrites, with very minor amounts of shale; second because it is uncomplicated by any major tectonic deformation, particularly in the South Florida Shelf area; and finally because it produces petroleum. Production to date is limited to carbonate reservoirs in the Lower Cretaceous Sunniland Formation at an average producing depth of 11,500 feet (3,500 m).

Three factors--quantity, type, and thermal maturity of organic matter--are commonly used to rate source rocks of petroleum. Criteria have been developed for evaluating these factors, particularly for shales (Philippi, 1957; Ronov, 1958; Hunt, 1961; Baker, 1962; Welte, 1965; Nixon, 1973; Tissot and others, 1974; Dow, 1977). An objective of our studies is to evaluate these criteria for carbonate rocks.

In this preliminary report organic carbon is evaluated. It is used not only as a measure of organic richness but also, by virtue of its inherent type of organic matter, it is judged as a reasonable measure of the hydrocarbon-generating potential of a carbonate rock. This is based on the assumption that most of the solid organic matter in carbonate rocks, such as in the South Florida Basin, is of the autochthonous, marine, hydrogen-rich, oil-prone type of kerogen. The assumption is supported by numerous studies such as those of Hunt (1961, 1967), Gehman (1962), and Baker (1962) who reported that carbonate rocks, in contrast to shales, yield a higher amount of hydrocarbons per unit of organic carbon. Furthermore, preliminary unpublished kerogen analyses in this present study clearly demonstrate that in most of the carbonate samples examined, 80 percent or more of the organic matter is of the amorphous, algal, hydrogen-rich kerogen.

Because of the presumed nature of the organic matter in these carbonate rocks, the criteria for evaluating petroleum source rock potential on the basis of organic richness may have to be modified. A value of 0.4 percent organic carbon, which is equivalent to about 0.5 percent organic matter, is often cited as a lower limit, below which a rock should not be considered as a possible source of petroleum (Ronov, 1958; Dow, 1977). This may be valid for organic matter evenly disseminated in rocks, but when the organic matter is concentrated along continuous surfaces, such as laminations or stylolites, as is common in many carbonate sections in the South Florida Basin, the acceptable whole rock organic carbon content for consideration as a possible source rock may be lower.

The presence of a significant volume of apparently indigenous petroleum in the Sunniland Limestone is taken as evidence of sufficient thermal maturity for hydrocarbon generation. It is estimated that about 300 to 500 million barrels of oil in place have been discovered to date. Likewise, the presence of oil shows in the Fredericksburg, which is some 2,000 feet (610 m) above the Sunniland, suggests that at least the initial stages of oil maturity also have been reached in this zone. However, any interpretation of maturity based on shows and oil occurrences should be confirmed by analyses of the kerogen. Such analyses will be emphasized in subsequent phases of this study.

In addition to organic carbon, quantitative measurements of acid-soluble calcium and magnesium were made. From these analyses total carbonate and approximate argillaceous content were determined (Table 1) and a carbonate classification scheme based on Ca/Mg molal ratios was established.

GEOLOGIC SETTING

The South Florida basin encompasses an area of some 77,000 square miles (200,000 sq. km), approximately 30 to 40 percent of which is onshore, the remainder offshore (Oglesby, 1965). The basin contains some 15,000 feet (4570 m) to perhaps as much as 20,000 feet (6,100 m) of sediment composed predominantly of Cenozoic and Mesozoic carbonates and evaporites with trace amounts of shale (Pressler, 1947). In the shelf area of the basin (Fig. 1), clastic facies are confined generally to the stratigraphic section above the Eocene Series and below the lowermost Cretaceous or uppermost Jurassic (?) interval. According to Fietz (1976), the known maximum thickness of clastic facies immediately above the basement is 510 feet (155 m) and the average is 296 feet (90 m).

Some of the major structural features and boundaries of the South Florida Basin are illustrated in Figure 1. The basin is bounded on the western flank by the Early Cretaceous reef trend located along the Florida escarpment (Antoine and others, 1967; Bryant and others, 1969), on the northeast by the Peninsula Arch, on the northwest by the Middle Grounds Arch, and on the southern flank by the Pine Key Arch (Winston, 1971b). The eastern portion of the basin, where the rocks are characterized by shelf-type facies, has been designated as the South Florida Shelf (Applin and Applin, 1965). West and southwest of the shelf is the synclinal axis of the South Florida embayment, a region which includes not only the South Florida Basin but also the island of Cuba, the Bahama Islands, and the intervening submerged areas (Pressler, 1947). The axis of the embayment appears to coincide with the central and deepest part of the South Florida Basin.

In the South Florida shelf region, shallow warm tropical seas encroached upon a slowly subsiding sea bottom and deposited a thick sequence of predominantly shallow water carbonates. Rate of deposition apparently kept pace with rate of subsidence. However, numerous thick cyclic and thin alternating deposits of marine limestone facies and evaporite-dolomite facies suggest that the shallow seas experienced many local transgressions and regressions.

On the shelf proper, at the Sunniland level, regional dip of the sedimentary strata is to the southwest at the rate of about 20 feet per mile (3.7 m/km) (Fietz, 1976; Tyler and Erwin, 1976). Dips of 60 to 155 feet per mile (11-29 m/km), however, are found in local areas where low relief structures and patch reefs are present (Fietz, 1976; Tyler and Erwin, 1976). It is these isolated patch reefs and bioclastic banks, mounds, or pods, with only very subtle relief, that are the present oil reservoirs in the Sunniland trend.

HISTORY OF PETROLEUM EXPLORATION AND PRODUCTION

The history of oil and gas exploration in South Florida can be divided into three major periods (Fietz, 1976). The first period from 1920-1942 was marked by relatively few unsuccessful wildcat wells. Most wells drilled prior to 1939 were less than 4,000 feet (1,220 m). In 1939 the first "deep" test, the Peninsula #1 Cory, located in sec. 6,T.55S., R.34E., Monroe County, was drilled to a depth of 10,006 feet (3,050 m). It reached only upper Trinity aged rocks and not the Sunniland zone.

The discovery of the Sunniland field in Collier County in 1943 ushered in the second period of petroleum exploration from 1943-1963, and sparked considerable geophysical activity, leasing, and drilling. The Humble Oil and Refining Company #1 Gulf Coast Realties Corporation discovery well reached the Sunniland formation and on initial test pumped 110 barrels of 20° API gravity oil and 475 barrels of salt water per day from a bioclastic limestone interval at 11,613-11,626 feet (3,540-3,544 m).

During this second exploration period, 55 Sunniland wildcat wells were drilled. The results were disappointing, only one non-commercial oil field being discovered. The only glimmer of hope was the discovery in 1954 of the Forty Mile Bend field in Dade County by the Gulf Refining Company and others #1 Wisehart-State of Florida well which produced from the Sunniland Limestone at 11,322-11,339 feet (3,451-3,456 m). This field, however, was short lived and was abandoned in 1956 after producing only 32,888 barrels of oil (Rainwater, 1971).

Exploration activity was rekindled in 1964 when the Sunoco Oil Company #2 Red Cattle Company well, Hendry County, was completed as the discovery well of the Sunoco-Felda field; this started the third exploration period. The well pumped 427 barrels of oil per day from the Sunniland Limestone from the interval 11,472-11,485 feet (3,497-3,501 m) (Babcock, 1966). The Sunoco Felda field had produced 8,122,000 barrels of oil until May 1976, and the estimated original oil in place is 34 million barrels of oil (Means, 1977). Exploration activity in the South Florida basin has continued at an increasing rate until the present; from 1964 to 1965, 99 Sunniland wildcats were drilled giving rise to a rate of 8.25 wildcats per year in contrast to 2.6 wildcats per year in the previous period (Fietz, 1976). During this period six new fields were discovered, namely, West Felda, Lake Trafford, LeHigh Acres, Bear Island, Seminole and LeHigh Park. Production data for each of the fields is shown in Table 2. In addition, the original volume of oil in place for the West Felda field is reported to be approximately 100 million barrels (Means, 1977).

To add to the increasing success of exploration activity, another oil field may be in the offing. Exxon Company, U.S.A. recently drilled the No. 33-4 Oleum Corporation wildcat in sec. 33, T.51S., R.34E., Collier County (Fig. 2) and reported excellent shows in the upper Sunniland Limestone. No production data are available but pipe has already been set to put the well on production.

LABORATORY PROCEDURES

Cores from seven different wells located in Glades, Hendry, Collier, and Lee counties (Fig. 2) were made available by the Exploration Department Southeastern Division, Exxon Company, U.S.A. Representative samples of the majority of recognizable lithologic units in each core were selected and briefly described at Exxon's core laboratory in New Orleans, Louisiana. In the Denver USGS laboratory, the lithology of each sample was further described with the aid of a binocular microscope and hydrochloric acid treatment. Prior to grinding for subsequent analysis, the outer portion of each core chunk was removed with a diamond saw to eliminate or reduce the possibility of contamination. Samples were ground to a powder size of 100 mesh or less and representative splits taken for organic carbon, calcium, and magnesium analysis.

Organic carbon was determined directly by a wet oxidation-gravimetric method modified after Bush (1970). Most of the reported carbon values are the means of duplicate analyses. Calcium and magnesium were determined by the versenate titration method as described in Guerrero and Kenner (1955). In Table 1, total carbonate contents are listed but in the bar graphs of Figures 5-11, the complementary, or noncarbonate contents, are illustrated. The noncarbonate content (100 percent minus carbonate content) is a measure of the argillaceous or shaly content of the carbonate rock sample. However, the noncarbonate content may also include silt- and sand-size materials, as well as anhydrite and organic matter, the last of which in most cases is minor. In a few cases, where the organic carbon is relatively high (such as sample no. 12, Table 1), the sum of the total carbonate content plus total organic matter content (organic carbon x 1.3) should be subtracted from 100 percent by the reader in order to accurately determine the noncarbonate, mineral content.

The Ca/Mg molal ratios were used to classify the carbonate rocks according to a scheme modified after Guerrero and Kenner (1955). Although magnesium limestone (molal ratio 17.67-36.19) is a common lithology in the South Florida Basin (Table 1), it has been tentatively lumped with the limestone category, primarily to simplify the classification. The classification is as follows:

Ca/Mg molal ratios	Rock classification
1.00 - 1.19	Dolomite
1.20 - 2.84	Calcitic Dolomite
2.85 -17.67	Dolomitic limestone
17.68-100.00	Limestone

STRATIGRAPHIC DISTRIBUTION OF ORGANIC CARBON IN SOUTH FLORIDA BASIN

General

The organic carbon content of 134 Cretaceous and Lower Paleocene carbonate core samples ranges from 0.05-3.19 percent. The majority of these carbonates have organic carbons less than 0.30 percent and the average carbon content is estimated to be about 0.26 percent.

Figure 3 compares the average organic carbon content of the four major stratigraphic units studied. The Comanchean carbonates, with an average organic carbon content of 0.41 percent, are as a whole relatively richer in organic carbon than the Coahuilan, Gulfian, and Lower Paleocene carbonates which have average organic contents of 0.28, 0.18, and 0.20 percent, respectively. The Comanchean carbonates are also nearly twice as rich as the average of worldwide carbonates (average 0.24 percent; Hunt, 1961). The presence of varying thicknesses of relatively organic rich carbonates composed of bituminous, argillaceous, highly stylolitic, and algal-bearing limestones and dolomites accounts for the higher average organic carbon value for the Comanchean rocks.

Figure 4 shows the vertical variation of average organic carbon contents in carbonate rocks of each stratigraphic unit, on a formation level, extending from the Paleocene Cedar Keys formation to the Lower Cretaceous Coahuilan series. In addition to the informal subdivisions of many of the stratigraphic units provided by Exxon Co., U.S.A., the Gulfian rocks have also been subdivided into three informal units by the author, in an attempt to underscore the significant differences in organic carbon content and in lithology. These subdivisions and average organic carbon contents of all the stratigraphic units should be considered tentative subject to the analyses of many more samples.

The average organic carbon values reported above are weighted and are based on analyses of core samples which are representative of distinct lithologic units. Following the same procedure as Baker (1962), computations were made by weighting the organic carbon analysis of each lithologic unit according to its thickness, summing the results, and then dividing by the total thickness of all the rock units within the stratigraphic interval being averaged. Average organic carbon values of comparable lithologies were also applied to other lithologic units where core samples were not available. Excluded from these computations were oil-stained carbonate reservoir rocks and rocks that contained 50 percent or more of argillaceous material.

In Figures 5-11, bar graphs illustrate the vertical distribution of organic carbon content and total noncarbonate or shaly content of each core sample analyzed. In addition, the electric log characteristics of each core interval and the gross lithologic description of each core sample are given.

A description of the stratigraphy, lithology, distribution of organic carbon and tentative assessment of the source rock potential of each stratigraphic unit is given below.

Beds of Coahuilan Age

The oldest and deepest rocks that were studied in this report are the Coahuilan rocks that generally occur below a depth of 12,000 feet (3,660 m). The average thickness of the Coahuilan is about 1000 feet (305 m) (Fig. 4), but may vary considerably depending upon the location in the basin and particularly upon where the top and bottom of the Coahuilan was picked. Winston (1971, p. 19) estimated the thickness of the Coahuilan to be 3000 feet (915 m) in the center of the basin.

The Coahuilan rocks consist chiefly of limestones and dolomites with some interbeds of anhydrite and calcareous shale. The limestones are tan to brown and light to dark grey in color, fossiliferous to non-fossiliferous, often streaked with argillaceous material, commonly stylolitic, fine grained to calcarenitic, and in part oolitic. The dolomites are grey to brown, dense, hard, argillaceous, anhydritic, and generally microcrystalline.

For this initial phase of the study, core samples from only the Coastal Petroleum-Tiedtke No. 1 well (Fig. 11 and Table 1) in Glades County were available. Analyses of 6 of these samples, which are representative of at least 60 feet (18 m) and perhaps as much as 150 feet (46 m) of core, showed a range of organic carbon of 0.12-0.82 percent and an average of 0.28 percent. Undoubtedly, with the acquisition of more samples, the range of organic carbon values will be expanded and possibly the average value will be modified.

The only Coahuilan sample analyzed to date that might be considered a possible source rock of petroleum is a dark grey to brown, very argillaceous, laminated, dense dolomite that contains 0.82 percent organic carbon. This sample (no. 138) represents a 10-foot (3m) zone at a depth of 12,780 feet (3895 m). Based on lithologic descriptions of core samples immediately above and below this 10-foot bed, in the interval 12,754-12,947 feet (3887-3964 m), there appears to be an additional 35 feet (11 m) of dolomite beds of similar lithology, that also may be possible source beds of petroleum. The bulk of the other rocks in this interval are anhydrites, and are presumed to have low organic carbon contents.

Based on the relatively low average content of organic carbon, the majority of carbonates (excluding the above dolomites) in the Coahuilan are rated as poor or non source rocks.

Beds of Trinity Age

Overlying the Coahuilan rocks are limestones, dolomites, anhydrites and minor amounts of shale of Trinity age that have been subdivided into six units and average about 2,800 feet (850 m) in thickness. The formal names of only two of the units, Punta Gorda Anhydrite and Sunniland Limestone, are included in this initial report. These rocks generally occur between depths of 10,000-13,000 feet (3,050-3,960 m).

Trinity 'F'

Analyses of 15 carbonate samples of Trinity 'F' (Exxon's combined 'F' and 'G' units), from the Humble Kirchboff No. 1 (Fig. 7) and Coastal Petroleum Tiedtke No. 1 (Fig. 11) wells, indicate that the organic carbon content ranges from 0.13 to 2.23 percent and averages 0.40 percent.

The majority of samples have less than 0.30 percent organic carbon and are rated as poor source rocks of petroleum. Four of the samples, however, which are representative of at least 40 feet (12m) of carbonate beds, have organic carbon contents greater than 0.50 percent and may be considered as possible sources of petroleum.

Sample 67 represents an 11-foot (3.4-m) interval composed of interbedded dark grey, highly argillaceous limestones and highly calcareous shales and contains 1.77 percent organic carbon. The relatively high organic carbon content seems to correlate with the very high argillaceous content which is about 42 percent. Yet, sample 74, which is a dark grey, dense, nearly "pure" limestone (with less than 6 percent argillaceous content), contains an even higher organic carbon content, (2.23 percent) indicating that amount of organic carbon does not necessarily always correlate with amount of "shaly" content. Sample 74 represents a 3-foot (1-m) thick bed that occurs below porous dolomites in the potential "Brown Dolomite" reservoir zone (Fig. 7). Although this limestone may be a source rock, it is too thin to have generated oil of any substantial quantity. However, it may have contributed to the staining observed in the porous rocks of the "Brown Dolomite" zone.

Incidentally, in this report the top of the "Brown Dolomite Zone" as defined by Exxon Company, U.S.A., is shown at 11,570 feet (3527 m) in the Coastal Petroleum-Tiedtke No. 1 well (Fig. 11) whereas in a report by Winston (1971b, p. 26) it is shown at about 12,030 feet (3667 m) for the same well. Apparently, there are two different zones referred to as the same "Brown Dolomite Zone".

The other two samples that warrant further consideration as to their source rock potential are shown in Figure 11. Samples 133 and 135 are both medium to dark grey, argillaceous, dolomitic limestones that contain 0.51 and 0.94 percent organic carbon and represent 8-foot (2.4-m) and 18-foot (5.5-m) intervals, respectively.

Punta Gorda Anhydrite

Above Trinity 'F' is the Punta Gorda Anhydrite composed chiefly of thick beds of anhydrite and lesser amounts of interspersed thin beds of limestone, dolomite and shale. Bedded salts have also been observed in several scattered wells but they are a minor constituent (Applin and Applin, 1965, p 39). The organic carbon contents of 8 core samples collected from 4 different wells (Figs. 5, 7, 9, 11), range from 0.18 to 0.49 percent and average 0.35 percent. One calcareous shale that was also analyzed (sample 64) contained 0.94 percent organic carbon. This shale and several of the limestones might be considered as possible source rocks, but because they generally are thin and are almost entirely encased in impervious anhydrite beds, they may not be effective source rocks. Outside of the studied area, however, the carbonate rocks of the Punta Gorda Formation may display larger amounts of organic matter and consequently the average organic carbon for the entire formation might be increased significantly. For example, in the Gulf Oil Company No. 1 State Lease 826-G well in Monroe County, out of the top 350 feet (107 m) of cored rock composed mostly of anhydrite, Oglesby (1965) reported that there are 60 feet (18.3 m) of dark-brown, tight, cryptocrystalline limestones that are saturated with apparently indigenous oil. He concluded that these limestones are likely source beds of petroleum.

Sunniland Limestone

The Sunniland Limestone, the only oil-producing formation to date in the South Florida Basin occurs between two thick sections of anhydrite, often referred to as the "Lower Massive Anhydrite" (Punta Gorda Formation) and the "Upper Massive Anhydrite" (Lake Trafford Formation). The Sunniland

Limestone is of early Cretaceous, late Trinity age and correlates with the Mooringsport Formation of Mississippi, Louisiana, and Texas. It is about 250-280 feet (76-85 m) thick, particularly along the Sunniland producing trend area and has been tentatively subdivided into an upper zone that is about 150-200 feet (46-61 m) thick and a lower zone that is 60-100 feet (18-30 m) thick.

The Lower Sunniland is composed principally of three rock types: (1) dark brown, hard, dense, often fractured, stylolitic, laminated, micritic, highly bituminous limestones, with stylolites and laminae commonly oil stained; (2) grey to brown, hard, dense, sucrosic dolomites; and (3) dark grey, hard, very calcareous "shales" or carbonate mudstones. It is these bituminous limestones and highly calcareous "shales" that are considered by some petroleum geologists to be the source rocks for the oil in the Upper Sunniland reservoirs (Banks, 1960, p 1743; Babcock, 1970, p.12; Tyler and Erwin, 1976, p 290; Fietz, 1976, oral commun.).

Even less questionable, however, is the interpretation that these highly bituminous limestones and/or calcareous "shales" are the probable source for the limited commercial oil production and non-commercial oil shows found in the Lower Sunniland limestone reservoirs. For example, the one-well (Mobil No. 1 Barron Collier Jr.) Lake Trafford field in Collier County (Sec. 9, T.47 S., R.28 E.), discovered in 1969, produces from highly fractured, micritic limestones near the base of the Lower Sunniland zone. It is, however, the only field to date in the South Florida Basin that yields commercial oil from the Lower Sunniland interval and it has produced a total of 134,000 barrels of oil (26.5° API gravity) as of May 1976 (Fietz, 1976, p.78). Another well that initially looked promising in the Lower Sunniland zone but was subsequently abandoned without any commercial production was the Commonwealth No. 1 Wiseheart in the now abandoned Forty Mile Bend Field in Dade County (sec. 16, T.54 S., R.35 E.). It initially pumped a 23° API gravity oil at a rate of 20 barrels per day plus considerable salt water through an acidized 22-foot (6.7-m) perforated zone in the Lower Sunniland interval (Banks, 1960, p 1740). Two other wells in the South Florida Basin had good drill stem test recoveries from the Lower Sunniland Limestone (Babcock, 1970, p 14): (1) The Humble No. C-1 Gulf Coast Realties Corp., about 2 miles south of the Lake Trafford discovery well, drilled in 1948, yielded in its second drill stem test, 2,325 feet of oil (20.4° API gravity) and 528 feet of oil-cut mud; (2) The Humble No. 1 Kirchoff, located just south of Fort Myers in Lee County, yielded 75 feet of oil (28° API gravity) and 225 feet of oil- and gas-cut mud.

Although the Lower Sunniland zone is reputed by some petroleum geologists to be a major source rock interval, only a few core samples were available for this initial phase of the study. Moreover, lithologic examination indicates that these samples are not fully representative of all the major lithologies of the Lower Sunniland interval. For example, no highly bituminous, petroliferous, laminated or stylolitic, micritic limestones, as described by Banks (1960), were observed by the author. Of possible significance is the fact that some of these bituminous limestones contained 1-9 (weight?) percent solid hydrocarbons (Banks, 1960, p 1738).

Three of the five core samples from the Lower Sunniland that were examined microscopically (Nos. 90, 91, Fig. 8; and No. 105, Fig. 9) appeared to be dark grey, dense, highly calcareous shales, which, according to some geologists, are the probable major oil source rocks of the Sunniland limestone.

Yet, analyses revealed that they are primarily limestones, containing from 11-22 percent argillaceous material and 0.38-0.59 percent organic carbon. The other two core samples (Nos. 92 and 106) are medium to brown grey, dense, limestones with argillaceous streaks that contained only 0.12 and 0.18 percent organic carbon, respectively.

The upper Sunniland zone, which contains the principal oil reservoirs, is composed chiefly of (1) tan and light-to medium-grey, miliolid-bearing, fine-grained, chalky and argillaceous limestones; (2) porous and permeable bioclastic limestones; and (3) thin interbeds of dolomite. It is the bioclastic limestones, composed predominantly of algal, rudistid, foraminiferal and pelletal debris, that build up into patch reefs, mounds, or banks and that make up the principal reservoirs in the Sunniland producing trend.

The organic carbon contents of 18 Upper Sunniland carbonate samples (excluding oil-saturated reservoir samples), taken from the Superior Oil Co. No. 29-3 Gerry Bros. (Fig. 8) and Exxon Company, U.S.A. No. 18-3 Turner (Fig. 9) wells, range from 0.10 to 1.62 percent and average 0.38 percent. The majority of carbonate samples have less than 0.31 percent organic carbon, but there are a significant number of samples that have organic carbons greater than or close to 0.4 percent. For example, in the Superior No. 29-3 Gerry Bros. well, samples 82, 83, 85, and 87, that represent 22 feet (6.7 m) out of 58 feet (18 m) of carbonate rocks that were examined, have an average organic carbon of 0.68 percent. These beds, and probably others like them for which analyses were not available, may have generated at least some, if not most, of the oil found in the adjoining reservoirs.

Thus, not only dark calcareous "shales" but also interbedded carbonates may be the source rocks of the Upper Sunniland. However, many more samples from the Upper Sunniland as well as Lower Sunniland zones must be examined, and other organic geochemical analyses coupled with careful oil-source rock correlations must be made before any definite conclusions may be drawn.

Trinity 'C"

Above the Sunniland Limestone and extending to the base of the Fredericksburg are a series of carbonates and anhydrites of upper Trinity age that are designated as Trinity units 'A', 'B', and 'C'. The oldest of these units, Trinity 'C', which averages about 300 feet (91 m) in thickness, contains abundant anhydrite beds especially in the lower part, which is often referred to by the oil industry as the "Upper Massive Anhydrite", now formally named the Lake Trafford formation (Oglesby, 1965). Because of unavailability of core samples no attempt was made to characterize the distribution of organic carbon in this unit.

Trinity 'B'

Trinity 'B' averages about 350 feet (110 m) of carbonates and anhydrites. No "pure" shales were observed. In general, the carbonates vary from light grey, tan, brown, slightly argillaceous, slightly anhydritic limestones and dolomites in the upper part of the unit to dark grey, very argillaceous or shaly carbonates in the lower part. Anhydrite beds, are common in the upper half of the unit, and in the Humble Collier No. 1 well make up about 40 percent of the entire section. The rocks throughout the

Trinity 'B' show little evidence of reported oil shows. The organic carbon content ranges from 0.11 to 0.53 percent and averages 0.31 percent. The lower 100-200 feet (30-60 m) of carbonates contain 0.36-0.53 percent organic carbon and at best may be considered as marginal source rocks of petroleum. The carbonate rocks in the upper part of the unit are rated as poor or nonsource rocks.

Trinity 'A'

Trinity 'A' averages 850 feet (260 m) and, like unit 'B', is composed of limestones, dolomites, anhydrites and apparently no "pure" shales. The carbonates, however, differ from those in unit 'B' in that they are generally higher in organic carbon, contain less argillaceous material (especially with respect to the lower part of unit 'B'), exhibit abundant stylolites, and have numerous oil shows. Organic carbon content of 8 core samples from the Humble Collier No. 1 well (Fig. 5) ranges from 0.2 to 1.31 percent and averages 0.46 percent. This unit, in contrast to Trinity 'B', is rated at having a slightly higher source rock potential.

To date, the two carbonate samples that seemingly have the highest potential of being possible source rocks are nos. 35 and 31. Sample 35 represents a 7-foot (2-m) bed at 10,823 feet (3,299 m) and contains 1.31 percent organic carbon. It consists of light grey, hard, chalky, slightly argillaceous, very stylolitic, fossiliferous limestone with oil stains along stylolites. The oil is believed to be indigenous to the host rock. Sample 31 is representative of as much as 23 feet (7 m) of dark grey, very argillaceous, dense limestone, in the interval 10,567-10,590 feet (3,221-3,228 m), and contains 0.92 percent organic carbon. No oil stains, however, were observed in this interval.

Beds of Fredericksburg Age

Directly overlying the Trinity are beds of Fredericksburg age that are divided into an upper unit 'A' and a lower unit 'B'. These beds generally occur at depths between 9,000 and 10,000 feet (2,740-3,050 m).

Fredericksburg 'B'

Unit 'B' averages about 570 feet (174 m) and is approximately equivalent to the Dollar Bay formation which was named and amply described by Winston (1972). The sediments consist of dense, calcilutitic, fossiliferous, calcarenitic, slightly to highly argillaceous, chalky, in part, anhydritic and stylolitic limestones and dolomites. Interbeds of anhydrite are common; shales are rare.

In general, Fredericksburg 'B' carbonates are marked by abundant oil stains; strong oil odors and tarry residues are also not uncommon. The oil stains, some of which were originally reported as "bleeding" or "live" oil (Applin and Applin, 1965; Exxon Company, U.S.A., 1976, written commun.) may occur as spots or splotches but they are more commonly observed along stylolites and along argillaceous or organic-rich streaks, laminae, and bands, and sometimes along fractures. Most, if not all, of these oil stains are believed to be indigenous to the host rock. In the Humble Collier No. B-1 well, oil stains occur throughout the entire Fredericksburg 'B' whereas in the Humble Collier No. 1 well they are confined generally to the upper half of the unit. The distribution of oil staining in the other wells is not given because of the unavailability of core descriptions. According to Winston (1972, p. 30), however, 26 oil shows were reported in the Dollar Bay formation (which is equivalent to Fredericksburg 'B'), one of which consisted of 15 feet of free oil recovered from a 20-hour drill stem test.

Organic carbon content of 22 carbonate samples from 3 wells (Figs. 5,7, and 10) ranges from 0.16 to 3.17 percent and averages 0.68 percent. The relatively high average value is due to the presence of many carbonate beds scattered throughout the section that have organic carbons greater than 0.4 percent (see Table 1). These beds are considered as possible source rocks of petroleum.

Three samples that merit special consideration for their source rock potential are samples 125, 126, and 127 taken near the middle of the unit in the interval 9700-9839 feet (2957-2999 m) in the Humble Collier No. B-1 well (Fig. 10). These samples are relatively rich for carbonates, having organic carbons ranging from 2.72 to 3.17 percent, and are believed representative of about 40 feet (12 m) and probably as much as 70 feet (21 m) or more of carbonate beds. It should also be pointed out that between samples 125 and 126 there are about 30 feet of anhydrites.

In summary, the combination of possible source rocks, abundant oil shows, and as much as 120 feet (37 m) of porous and permeable reservoir beds (Winston, 1971a) make this Fredericksburg 'B' unit another drilling target second only to the Sunniland Limestone.

Fredericksburg 'A'

Above Fredericksburg 'B' there are about 450 feet (137 m) of sediment assigned to Fredericksburg 'A' although we recognize that Applin and Applin (1965) and Winston (1971a) have placed these strata in the lower part of the Washita.

Fredericksburg 'A' rocks are principally dolomites and anhydrites, with subordinate amounts of thin interbedded limestones and rare shale. The carbonates are generally light grey, cream, tan-to-brown in color, slightly argillaceous, fine grained, and they contain abundant anhydrite. Anhydrite occurs chiefly as inclusions of brown crystals in the carbonates and also as interbeds from 1 to 30 feet (0.3-10 m) thick. Anhydrite beds in the Humble Collier No. 1 well make up about 40 percent of the entire unit.

Organic carbon content of three core samples, from the Humble Collier No. 1 well (Fig. 5), ranges from 0.1 to 0.73 percent and averages 0.33 percent. In contrast to Fredericksburg 'B' carbonates, unit 'A' carbonates are leaner in organic carbon and most do not appear to be possible source rocks. There are, however, minor oil stains scattered throughout the unit. Based on the limited data available the only rock interval that might be considered as a possible source rock is a 16-foot (5-m) sequence of carbonates at 9643 feet (2939 m). This interval, as represented by sample 21, consists chiefly of grey to dark grey, fine-grained, massive, argillaceous limestones and some dolomites and contains 0.73 percent organic carbon. The carbonates are characterized by oil stains that occur principally along argillaceous laminae but also as spots and patches.

Beds of Washita Age

The beds of Washita age average 600 feet (185 m) of interbedded dolomites, limestones, and anhydrites. They extend from the top of the Fredericksburg to the base of the Upper Cretaceous (Gulfian) between 8,300-9,000 feet (2,530-2,745 m).

The carbonates generally are grey, cream to tan colored, soft to hard, porous to dense, slightly argillaceous, chalky, anhydritic, miliolid-bearing limestones and dolomites. Only a few very minor oil shows have been reported in this interval. Organic carbon content of four core samples, taken from the Humble Collier No. 1 well (Fig. 5), ranges from 0.18 to 1.37 percent and averages 0.27 percent. The most significant rock interval in terms of organic richness is an 8-foot (2.4 m), brown to dark grey, argillaceous, microcrystalline, anhydritic dolomite interval that contains 1.37 percent organic carbon. No apparent oil shows, however, are associated with this interval. As a whole, most Washita carbonates do not look promising as source rocks of petroleum.

Beds of Gulfian Age

The Gulfian or Upper Cretaceous section consists of about 3,000 feet (915 m) of predominantly chalk, and the top lies at an average depth of 5,400 feet (1,645 m). This thick section of carbonate rock has been provisionally divided into three units, namely, 'A', 'B', and 'C'.

Gulfian 'C'

Unit 'C' comprises the lowermost 350 feet (107 m) of Gulfian rocks, and in the Humble Collier No. 1 well the top of the unit is at 8,250 feet (2515 m). In the interval 8365-8520 (2550-2597 m) some of the carbonates display the highest organic carbon contents analyzed so far in this preliminary study. The carbonates are tan, grey brown to dark grey in color, argillaceous, laminated in part, uniquely speckled and streaked with bituminous or "petroliferous" material, generally massive, calcilutitic, and often contain large shell fragments, such as *Inoceramus*, but also scattered fine shell fragments. And, in at least the upper 50 feet (15 m) of this interval, according to Caldwell (1976, written commun.), there are also numerous occurrences of fish remains, such as teeth and scales.

Sample 12, which is believed to be representative of about 22 feet (7 m) and perhaps as much as 80 feet (24 m) of carbonate beds in the above interval, contains 3.19 percent organic carbon. It should be emphasized that this sample is not a shale nor a highly argillaceous limestone but a pure, probably algal type limestone with less than 3 percent of total noncarbonate mineral matter.

In the upper 100 feet (30 m) of unit 'C', the Humble Collier No. 1 well contains white chalky limestones that appear organically lean. However, one sample (No. 11), representative of at least a 15-foot (4.6-m) carbonate bed, had 0.66 percent organic carbon. It is a tan to grey, chalky limestone that appears to be an intraformational conglomerate. It is characterized by adundant irregular and wavy streaks and bands of argillaceous and carbonaceous material, some of which are black in color, resembling bituminous or "petroliferous" material (Caldwell, 1976, written commun.).

Organic carbon contents of unit 'C' carbonates range from 0.19 to 3.19 percent and average 0.54 percent. Judging from the organic richness of some of these carbonate beds, it would seem that they would make possible source rocks of petroleum. However, these rocks probably have not been buried deep enough or subjected to higher geothermal gradients in this part of the basin to have experienced temperatures sufficient to have generated any commercial amounts of oil. Further tests will determine the state of maturation in these rocks.

Gulfian 'B'

Unit 'B' consists of about 2,000 feet (610 m) of principally pure white, soft, massive chalks that sometimes are argillaceous and stylolitic and sparsely fossiliferous. Although only two samples of pure chalk were analyzed (nos. 9, 10, Table 1), the one taken from the 74-foot (23-m) interval (sample 9) is believed to be most representative, and hence the estimated average organic carbon content is 0.11 percent. Based primarily on the relatively very low amount of organic matter, these chalks are not considered petroleum source rocks.

Gulfian 'A'

Gulfian 'A' consists of about 650 feet (200 m) of carbonates with dolomites predominating in approximately the upper third of the unit, interbedded dolomites and limestones in the middle third, and limestones in the lower third. Several scattered anhydrite beds 1-15 feet (0.3-4.6 m) thick are interbedded with the dolomites and are generally confined to the upper third of unit 'A'.

The dolomites generally are cream to light grey in color, chalky in part, porous to dense, soft to hard, slightly argillaceous, anhydritic, and micritic to fossiliferous (mainly miliolids). The limestones generally are cream and light to medium grey in color, streaked and sometimes laminated with argillaceous material or dark grey to black organic matter, occasionally stylolitic, porous to dense, sometimes vuggy, micritic to fossiliferous, including microfossils (mainly miliolids) and megafossils (rudistids). Some of the limestones contain such a proliferation of microfossils that they are referred to as microcoquinas.

Organic carbon content of nine samples that are representative of at least 150 feet (46 m) of unit 'A', taken from four different wells (Figs.5, 6, 7, 10), ranges from 0.10 to 0.33 percent and averages 0.20 percent.

The leanness of organic matter coupled with the probable thermal immaturity of the rock bodies (assumed from the relative shallow depth of burial) suggest that these carbonates are poor or non source rocks of petroleum. However, there is an approximately 30-foot (9-m) section of carbonates observed in two wells some 37 miles (60 km) apart that deserves further goechemical investigation. The carbonates in this section are predominantly limestones that are light to dark grey, speckled, laminated, or banded with argillaceous and/or dark grey to black organic (bituminous) material and lesser amounts of interbedded dolomites. In the downdip basinal well (the Humble-Collier No. 1), spotted oil stains, oil-stained fossils, oil stains along black, organic-rich bands, and faint to good oil odors were reported. The updip Humble Collier B-1 well had comparable oil shows with additional reports of strong oil odor and "dead" and "live" oil. The only sample (No. 114) representative of this zone was taken from the latter well; it had an organic carbon of 0.33 percent, the highest value obtained so far for unit 'A' carbonates.

The top of this unique section of carbonates is about 5,811 feet (1,771 m) in the Collier No. 1 well and about 5,595 feet (1,705 m) in the Collier B-1 well. Based on comparable lithologic and oil-show descriptions and on approximate stratigraphic position, it would seem that these sections correlate in the two wells. For example, using the readily recognizable and widespread green shale stratigraphic marker at the top of the Lower Cretaceous as a datum plane, the section is 2,795 feet (852 m) and 2,775 feet (846 m) above the datum in the Collier No. 1 and Collier No. B-1 wells, respectively. However, if one were to correlate this rock section using the less definitive Upper Cretaceous top as the datum, then the oil-stained zone is 268 feet (82 m) and 163 feet (50 m) below the datum in the Collier No. 1 and Collier No. B-1, respectively, suggesting that there are two distinct rock bodies rather than one. More detailed electric log and sample log correlations are needed to resolve the apparent discrepancy.

Beds of Paleocene Age

Above the Cretaceous is the Cedar Keys Formation of Lower Tertiary (Paleocene) age, which lies at a depth of about 3,500-4,000 feet (1,067-1,219 m). The Cedar Keys is about 2,000 feet (610 m) thick and consists of light colored, firm to soft, porous, microfossilferous limestones, dolomitic limestones, hard, dense microcrystalline dolomites, and anhydrites. According to Cole (1944, p. 28), who named the formation, it is stratigraphically equivalent to the Midway Formation of the Gulf Coast area. In this report, due to the unavailability of a full section of core samples, the discussion is limited to only the lower 1,000 feet (305 m).

The lower half of the Cedar Keys Formation consists predominantly of dolomites interbedded with thin and thick beds of anhydrite. The combined thickness of anhydrites makes up about one-fourth of the lower 1,000-foot (305-m) section. The dolomites generally are cream to light grey in color, hard, dense to porous, carbonaceous, cryptocrystalline anhydritic and often microfossiliferous (with abundant miliolids), and occasionally macrofossiliferous (especially near the base of the Cedar Keys, where "reef-like" rudistid and coral fragments are present).

Analyses of 14 core samples from 4 different wells (Figs. 5, 6, 7, and 10) indicate that the organic carbon content of the lower Cedar Keys dolomites ranges from 0.09 to 0.47 percent and averages 0.20 percent. Again because of the generally low amount of organic matter and the probable thermal immaturity of the rock strata, which are not unlike the immediately underlying older carbonate rocks, most of the lower Paleocene carbonates are considered poor or nonsource rocks of petroleum. Yet, there are some samples (nos. 2 and 51) that contain appreciable amounts of organic matter (0.47 and 0.35 percent organic carbon) as well as other potentially oil indicating properties, that certainly merit further attention. For example, according to core descriptions (Caldwell, written commun., 1976) sample No. 51 yielded gas and oil stains upon exposure to the sun. This phenomenon is not unusual and was also reported for other core samples collected from depths between 5,100-5,300 feet (1,554-1,615 m) in the Collier No. 2 well.

Another interval which is worthy of mention because it contains one of the relatively few oil shows reported from the Tertiary section occurs in the uppermost part of the Cedar Keys formation at a depth of 3,567 feet (1,087 m) in the Coastal Petroleum-Tiedtke No. 1 well. The 20-foot (6-m) interval consists of porous dolomite with thin interbeds of shale and is overlain by a 28-foot (8.5-m) bed of anhydrite. The show was described by the Coastal Petroleum Company as "orange brown, sticky hydrocarbon spotted in porosity. Black Shale is oily. Good cut with CCl_4." (Babcock, 1962, p. 34).

SUMMARY AND CONCLUSIONS

This report marks the first phase of investigation of the petroleum source rock potential of Cretaceous and Lower Tertiary carbonate rocks in the South Florida Basin. A viable framework has been established based primarily on the distribution, amount, and significance of organic carbon. Future studies will be directed to the petroleum hydrocarbons generated from this organic carbon, and to kerogen analysis, thermal maturation and oil-source rock correlations in the Sunniland formation.

Samples representative of about 9,000 feet (2,745 m) of carbonate rocks in the South Florida Basin have organic carbon contents that range from 0.05 to 3.19 percent, with the majority of samples having less that 0.3 percent. The presence, however, of a significant number of samples that have higher organic carbon contents and that are composed of bituminous, argillaceous, stylolitic, and algal-bearing limestones and dolomites accounts for the higher organic carbon averages in some of the stratigraphic units.

The weighted average organic carbon content of 0.41 percent in Lower Cretaceous Comanchean carbonate samples is significantly higher than that in carbonate samples of Coahuilan age (0.28 percent), Gulfian age (0.18 percent), and Lower Tertiary Paleocene age (0.20 percent). Similarly, the Comanchean carbonates are nearly twice as high in organic carbon as the average (0.24 percent) of worldwide carbonates.

Within the Comanchean Series there are several stratigraphic units that have average organic carbons greater than or close to 0.4 percent and consequently deserve careful attention as to their source rock potential. Trinity 'F' has an average organic carbon of 0.40 percent; Upper Sunniland Limestone, 0.38 percent, Trinity 'A', 0.46 percent; and Fredericksburg 'B', 0.68 percent. Although there are insufficient data to assess the source rock potential of the Lower Sunniland zone, a possible source of oil for the Upper Sunniland reservoirs, data from the published literature indicate that the bituminous limestones and possibly some of the calcareous shales or shaly limestones contain adequate oil-generating organic matter. A limited number of carbonate samples from the Punta Gorda Formation had an average organic carbon content of 0.35 percent, but Oglesby (1965) reported that there are 60 feet (18 m) of oil-saturated limestones that are likely source rocks of petroleum in the southern part of the basin, in the offshore area of Monroe County.

In the lower part of the Upper Cretaceous (Gulfian) section, designated Gulfian 'C', there are limestone samples that have organic carbon contents that average 0.54 percent and are as high as 3.19 percent. Although these carbonate samples may appear to be possible source rocks, they may not be adequately mature to have generated significant hydrocarbons, and a similar reservation applies to younger carbonate beds in the Gulfian 'A' unit, and in the lower and upper Cedar Keys Formation.

Examination of cores and study of core descriptions in most cases indicate that wherever oil staining was prominent in possible source rock sequences, there were also invariably stylolites. For example, abundant stylolites are present in the Sunniland formation, which currently is the only oil producer, and in Fredericksburg 'B' which may possibly become another oil producer. This suggests that stylolitization may be associated with hydrocarbon accumulation.

In conclusion, organic carbon contents and visual evidence of petroleum-like substances suggest that, in addition to the proven Sunniland zones, other potentially productive horizons are present in the South Florida Basin. In the next phase of this study we will attempt to confirm this preliminary assessment with additional and more detailed geochemical methods.

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Table 1. - Chemical data on rock core samples of Cretaceous and Lower Tertiary age, South Florida Basin

[Most organic carbon values are averages of duplicate analyses determined by a direct organic carbon wet oxidation method; Rinehart Labs, Wheat Ridge, Colorado 80001. Total carbonate and Ca/Mg molal ratios determined by a versenate titration method; Rinehart Labs, Wheat Ridge, Colorado 80001. *, refers to anhydrite; --, not determined; 1000 ft = 305 m.]

Stratigraphic unit	Sample No.	Core Interval (ft)	Organic Carbon (%)	Total Carbonate (%)	Ca/Mg Molal Ratio
		Humble Collier No. 1			
Paleocene	1	4,912-4,919	0.26	88.1	1.46
Paleocene	2	4,956-4,965	.47	98.5	1.04
Paleocene	3	5,182-5,200	.21	96.9	1.10
Paleocene	4	5,410-5,430	.13	90.8	1.24
Paleocene	5	5,492-5,504	.09	96.1	1.21
Gulf [illegible] 'A'	6	5,638-5,654	.22	91.3	1.27
Gulf [illegible] 'A'	7	5,782-5,807	.18	99.1	12.02
Gulf [illegible] 'A'	8	5,885-5,900	.27	97.9	37.47
Gulf [illegible] 'B'	9	7,710-7,784	.11	99.6	61.12
Gulf [illegible] 'B'	10	7,835-7,840	.05	99.4	27.56
Gulf [illegible] 'C'	11	8,255-8,270	.66	97.1	64.64
Gulf [illegible] 'C'	12	8,413-8,435	3.19	93.1	100.00
Gulf [illegible] 'C'	13	8,568-8,577	.27	71.2	40.29
Gulf [illegible] 'C'	14	8,600-8,606	.19	81.3	1.25
Washita	15	8,782-8,790	1.37	87.2	1.36
Washita	16	8,917-8,921	.18	89.7	1.47
Washita	17	9,026-9,049	.27	96.3	6.93
Washita	18	9,104-9,110	.26	99.5	19.63
Fredericksburg 'A'	19	9,315-9,324	.10	95.2	52.89
Fredericksburg 'A'	20	9,574-9,584	.38	95.8	1.18
Fredericksburg 'A'	21	9,643-9,659	.73	86.4	2.11
Fredericksburg 'B'	22	9,721-9,727	.43	94.9	27.60
Fredericksburg 'B'	23	9,791-9,796	.18	84.3	15.40
		Humble-Collier No. 1 - Continued			
Fredericksburg 'B'	24	9,826-9,830	--	--	--
Fredericksburg 'B'	25	9,832-9,852	0.68	97.5	40.80
Fredericksburg 'B'	26	9,901-9,909	.54	97.1	23.20
Fredericksburg 'B'	27	9,947-9,952	1.46	86.2	19.87
Fredericksburg 'B'	28	10,106-10,121	1.19	86.3	47.85
Fredericksburg 'B'	29	10,250-10,261	.37	90.0	46.64
Trinity 'A'	30	10,451-10,458	.39	94.1	2.98
Trinity 'A'	31	10,567-10,590	.92	80.3	30.08
Trinity 'A'	32	10,694-10,700	.20	96.8	6.77
Trinity 'A'	33	10,739-10,744	.46	92.1	10.39
Trinity 'A'	34	10,818-10,822	.28	96.4	7.69
Trinity 'A'	35	10,823-10,830	1.31	95.3	35.31
Trinity 'A'	36	10,941-10,949	.43	88.0	39.46
Trinity 'A'	37	11,060-11,070	.23	88.9	1.75
Trinity 'B'	38	11,189-11,205	.11	94.8	16.59
Trinity 'B'	39	11,391-11,397	.25	91.7	19.57
Trinity 'B'	40	11,579-11,585	.19	85.9	2.44
Trinity 'B'	41	11,632-11,642	.22	96.9	17.82
Trinity 'B'	42	11,722-11,729	.53	78.7	2.31
Trinity 'B'	43	11,824-11,832	.49	78.4	21.56
Trinity 'B'	44	11,896-11,943	.36	67.9	22.06
Punta Gorda	45	12,440-12,447*	--	--	--
Punta Gorda	46	12,447-12,449	.41	71.3	1.88

Table 1. - Continued

Stratigraphic Unit	Sample No.	Core Interval (ft)	Organic Carbon (%)	Total Carbonate (%)	Ca/Mg Molal Ratio
		Humble Collier No. 2			
Paleocene	47	4,550-4,555	0.19	86.1	1.64
Paleocene	48	4,555-4,585*	--	--	--
Paleocene	49	4,593-4,603	.19	89.1	1.40
Paleocene	50	4,804-4,812	.15	93.0	1.50
Paleocene	51	4,888-4,898	.35	75.7	1.40
Paleocene	52	4,915-4,919	.27	87.5	1.61
Paleocene	53	4,961-5,134*	--	--	--
Gulfian 'A'	54	5,471-5,492	.11	84.9	1.47
		Humble Kirchhoff No. 1			
Pal.	55	5,488-5,495	.16	94.9	1.25
Pal.	56	5,519-5,530	.16	97.0	1.12
Gulf. 'A'	57	5,540-5,551	.19	94.5	1.24
Fredericksburg 'B'	58	9,509-9,515	.20	92.6	1.34
Fredericksburg 'B'	59	9,515-9,516	.50	92.1	3.57
Fredericksburg 'B'	60	9,516-9,520	.16	98.4	12.58
Fredericksburg 'B'	61	9,547-9,555*	--	--	--
Fredericksburg 'B'	62	9,578-9,583	.22	91.6	2.33
Punta Gorda	63	12,447-12,457	.49	70.6	1.68
Punta Gorda	64	12,496-12,498	.94	34.9	.17
Punta Gorda	65	12,498-12,502	.31	74.5	1.88
Trinity 'F'	66	12,523-12,534	.31	69.8	1.60
Trinity 'F'	67	12,636-12,647	1.77	56.0	18.04
Trinity 'F'	68	12,690-12,700	.28	72.2	15.53
Trinity 'F'	69	12,745-12,755	.34	66.4	6.10
Trinity 'F'	70	12,755-12,758	.24	86.3	29.97
Trinity 'F'	71	12,802-12,821	.16	96.6	44.23
Trinity "Brown Dol."	72	12,831-12,838	.18	92.9	1.29
Trinity "Brown Dol."	73	12,843-12,853	.16	93.2	1.27
Trinity "Brown Dol."	74	12,872-12,875	2.23	91.8	17.72

Stratigraphic Unit	Sample No.	Core Interval (ft)	Organic Carbon (%)	Total Carbonate (%)	Ca/Mg Molal Ratio
		Superior Gerry No. 29-3[1]			
Trinity 'C'	75	11,562-11,566*	0.11	--	--
Trinity 'C'	76	11,566-11,575	.62	75.3	29.17
Trinity 'C'	77	11,576-11,582	.22	71.6	1.92
Trinity Upper Sunniland	78	11,605-11,609	.64	97.2	75.26
Trinity Upper Sunniland	79	11,623-11,625	.10	97.5	50.27
Trinity Upper Sunniland	80	11,652-11,660	.17	98.5	60.46
Trinity Upper Sunniland	81	11,670-11,682	.31	99.1	39.95
Trinity Upper Sunniland	82	11,696-11,701	.55	96.9	21.57
Trinity Upper Sunniland	83	11,701-11,712	.56	90.4	1.40
Trinity Upper Sunniland	84	11,722-11,728	.31	98.6	25.56
Trinity Upper Sunniland	85	11,730-11,734	1.62	97.2	46.37
Trinity Upper Sunniland	86	11,735-11,745	.36	95.0	26.30
Trinity Upper Sunniland	87	11,748-11,751	.37	83.4	7.16
Trinity Upper Sunniland	88	11,752-11,761	.44	98.7	47.08
Trinity Upper Sunniland	89	11,763-11,765	.31	99.1	50.31
Trinity L. Sunn	90	11,784-11,800	.38	77.6	26.84
Trinity L. Sunn	91	11,800-11,805	.40	82.4	18.20
Trinity L. Sunn	92	11,808-11,809	.12	98.4	45.09
		Exxon Turner Corp. No. 18-3			
Trinity Upper Sunniland	93	11,476-11,480	.12	92.3	20.49
Trinity Upper Sunniland	94	11,480-11,481	.19	92.2	1.37
Trinity Upper Sunniland	95	11,489-11,490	.24	96.7	3.56
Trinity Upper Sunniland	96	11,491-11,495	.25	92.8	5.65
Trinity Upper Sunniland	97	11,500-11,502	.73	97.5	38.60
Trinity Upper Sunniland	98	11,503-11,504	.50	89.3	12.70
Trinity Upper Sunniland	99	11,508-11,513	.94	94.3	37.96
Trinity Upper Sunniland	100	11,519-11,522	.28	91.5	3.90
Trinity Upper Sunniland	101	11,524-11,531	.29	98.8	30.79
Trinity Upper Sunniland	102	11,533-11,538	.11	98.3	25.09

[1] Twelve feet were subtracted from driller's core depths to correct up to electric log measurements.

Table 1. - Continued

Exxon Turner Corp. No. 18-3 - Continued

Stratigraphic Unit	Sample No.	Core Interval (ft)	Organic Carbon (%)	Total Carbonate (%)	Ca/Mg Molal Ratio
Trinity – U. Sunn.	103	11,538-11,540	0.09	98.6	24.61
	104	11,555-11,557	.20	98.4	41.06
Trinity – L. Sunn.	105	11,660-11,668	.59	88.6	32.76
	106	11,668-11,682	.17	92.5	37.22
Trinity – Punta Gorda	107	11,682-11,692	.26	86.3	46.74
	108	11,695-11,708 *	.06	--	--
	109	11,709-11,720 *	.05	--	--

Humble Collier No. B-1

Stratigraphic Unit	Sample No.	Core Interval (ft)	Organic Carbon (%)	Total Carbonate (%)	Ca/Mg Molal Ratio
Paleocene	110	5,325-5,341	.20	93.6	1.05
	111	5,398-5,408 *	--	--	--
	112	5,408-5,414	.15	98.8	1.06
Gulfian 'A'	113	5,531-5,539	.10	99.7	1.27
	114	5,614-5,627	.33	98.3	8.27
	115	5,718-5,728	.16	97.9	28.86
	116	5,755-5,764	.17	95.1	5.64
Fredericksburg 'B'	117	9,395-9,404 *	.04	--	--
	118	9,404-9,419	.37	97.0	2.22
	119	9,446-9,472	.34	97.3	1.47
	120	9,503-9,508	.49	95.2	4.71
	120A	9,508-9,510	.71	92.0	23.17
	121	9,521-9,526	.45	96.2	1.12
	122	9,528-9,534	.53	96.9	9.75
	123	9,551-9,555	.28	98.2	16.55
	124	9,634-9,637	.38	95.4	1.30
	125	9,700-9,710	2.72	66.3	18.10
	126	9,740-9,761	2.15	93.8	35.89
	127	9,781-9,800	3.17	90.4	38.33

Coastal Petroleum Co. Tietdke No. 1

Stratigraphic Unit	Sample No.	Core Interval (ft)	Organic Carbon (%)	Total Carbonate (%)	Ca/Mg Molal Ratio
Trinity – Punta Gorda	128	11,048-11,054	0.26	81.9	26.39
	129	11,151-11,154	.24	85.9	35.73
	130	11,264-11,269	.30	82.7	1.67
Trinity – 'F'	131	11,362-11,367	.29	66.8	1.35
	132	11,402-11,408	.30	82.4	6.62
	133	11,432-11,440	.51	75.5	7.97
	134	11,460-11,470	.13	94.1	14.91
	135	11,470-11,488	.94	84.9	10.61
	136	11,491-11,498	.19	83.6	4.37
Coahuilan	137	12,718-12,745	.19	91.8	39.66
	138	12,780-12,790	.82	68.5	1.28
	139	12,854-12,886 *	.09	--	--
	140	12,888-12,932 *	--	--	--
	141	13,045-13,058	.12	91.2	17.77
	142	13,128-13,130	.22	90.1	4.17
	143	13,130-13,133	.21	89.6	3.80
	144	13,222-13,224	.19	92.5	19.95

Table 2 - Production data of South Florida oil fields (modified from Fietz, 1976)

Field Name	Year Discovered	Productive Acres	Daily oil production barrels May 1976	Cumulative oil production 1000 barrels May 1976
Sunniland	1943	2,400	1,332	15,477
Forty Mile Bend	1954	320	abnd. 1956	32
Sunco-Felda	1964	4,500	1,588	8,122
West Felda	1966	6,400	8,527	19,516
Lake Trafford	1969	160	S.I.	134
LeHigh Acres	1970	COMBINED WITH WEST FELDA FIELD		
Bear Island	1972	1,280	967	736
Seminole	1973	320	62	42
LeHigh Park	1974	320	536	118
TOTALS			13,012	44,177

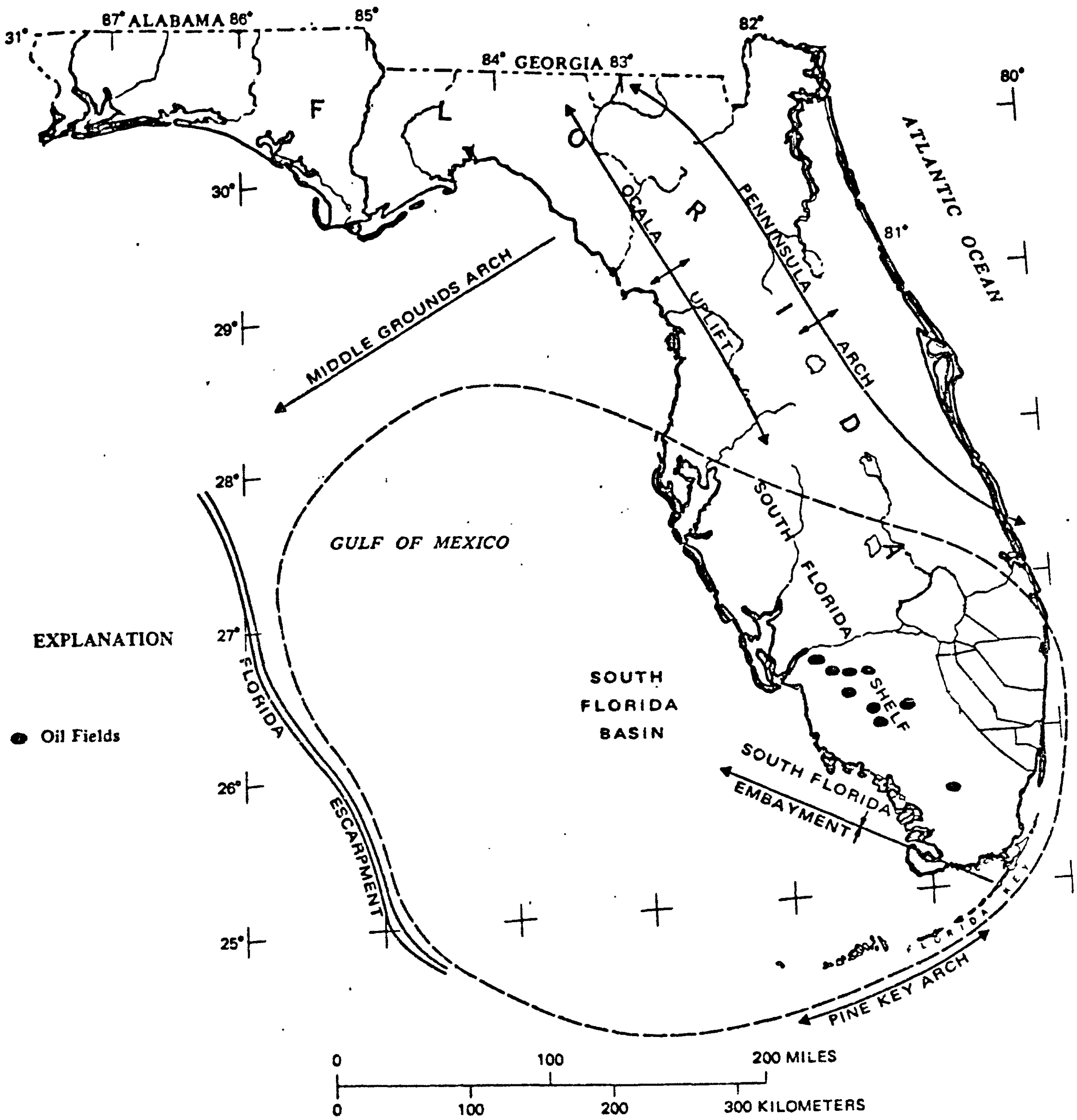

Figure 1.--Map showing approximate outline of South Florida Basin, major structural features, and oil fields. Modified from Applin and Applin (1965) and Winston (1971b).

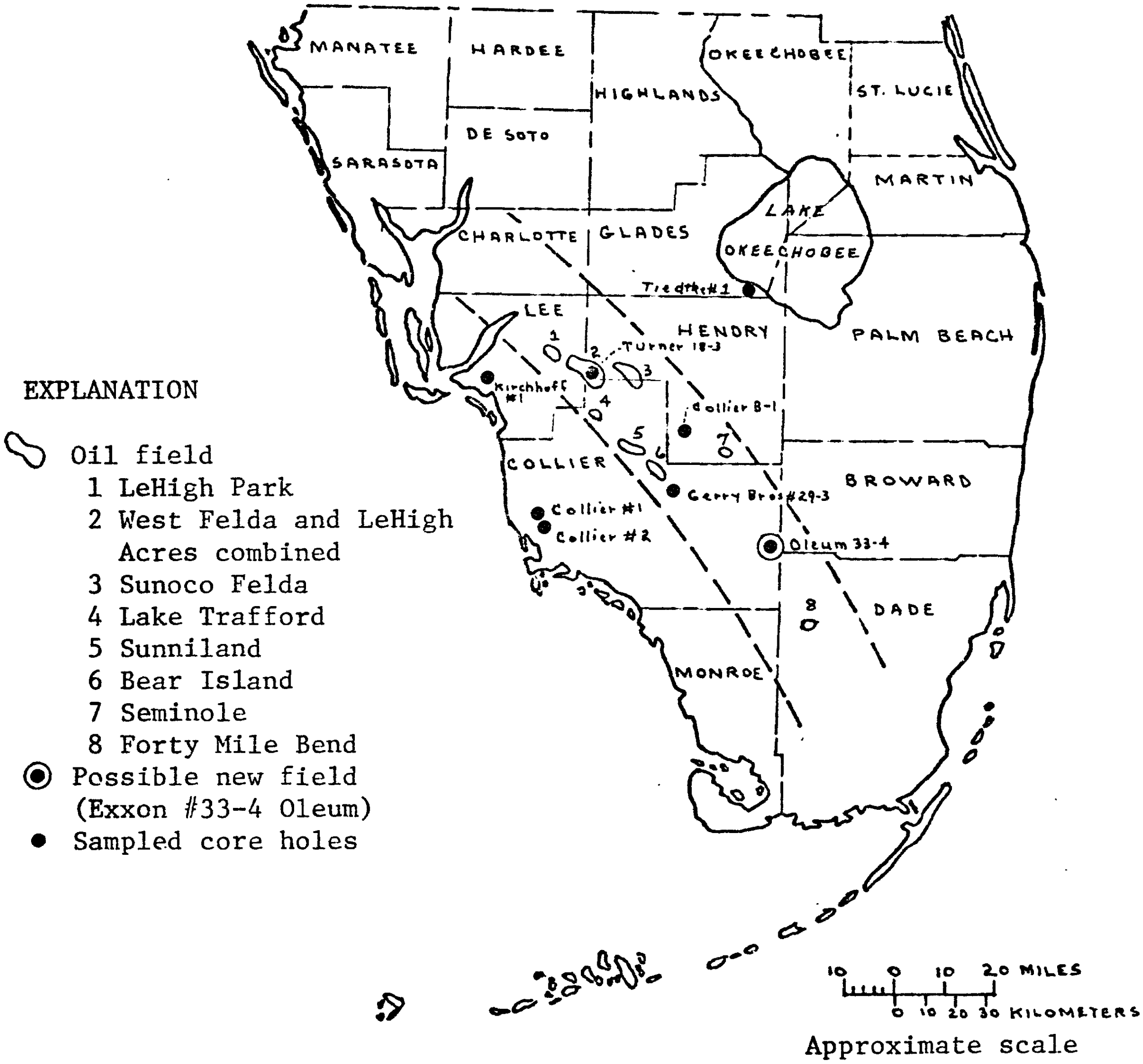

Figure 2. Map showing location of oil fields, core holes that were sampled, and approximate boundary of present Sunniland producing trend.

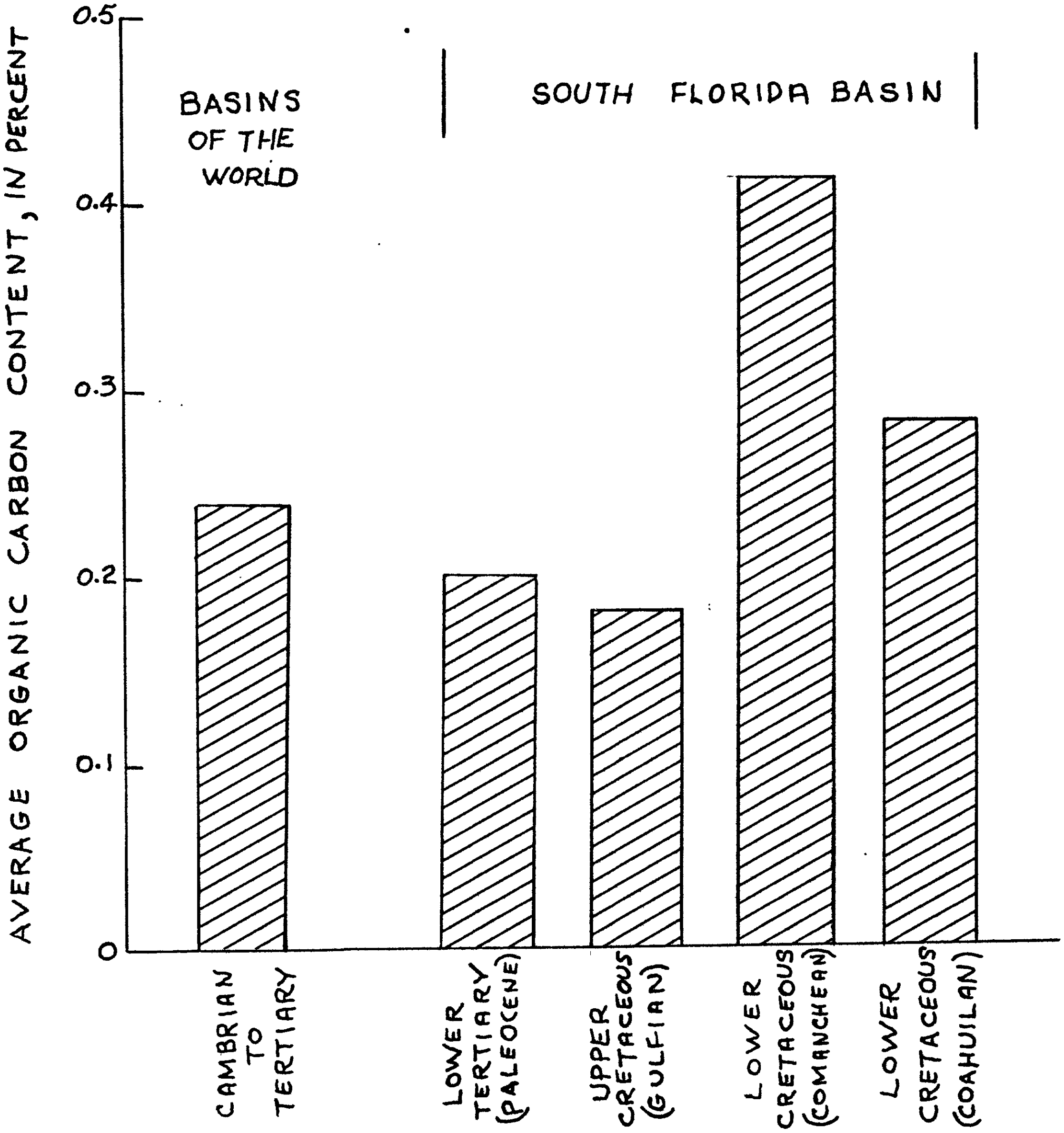

Figure 3 - Comparison of average organic carbon in carbonate rocks of South Florida Basin and in sedimentary basins of the world. (World data taken from Hunt (1961).

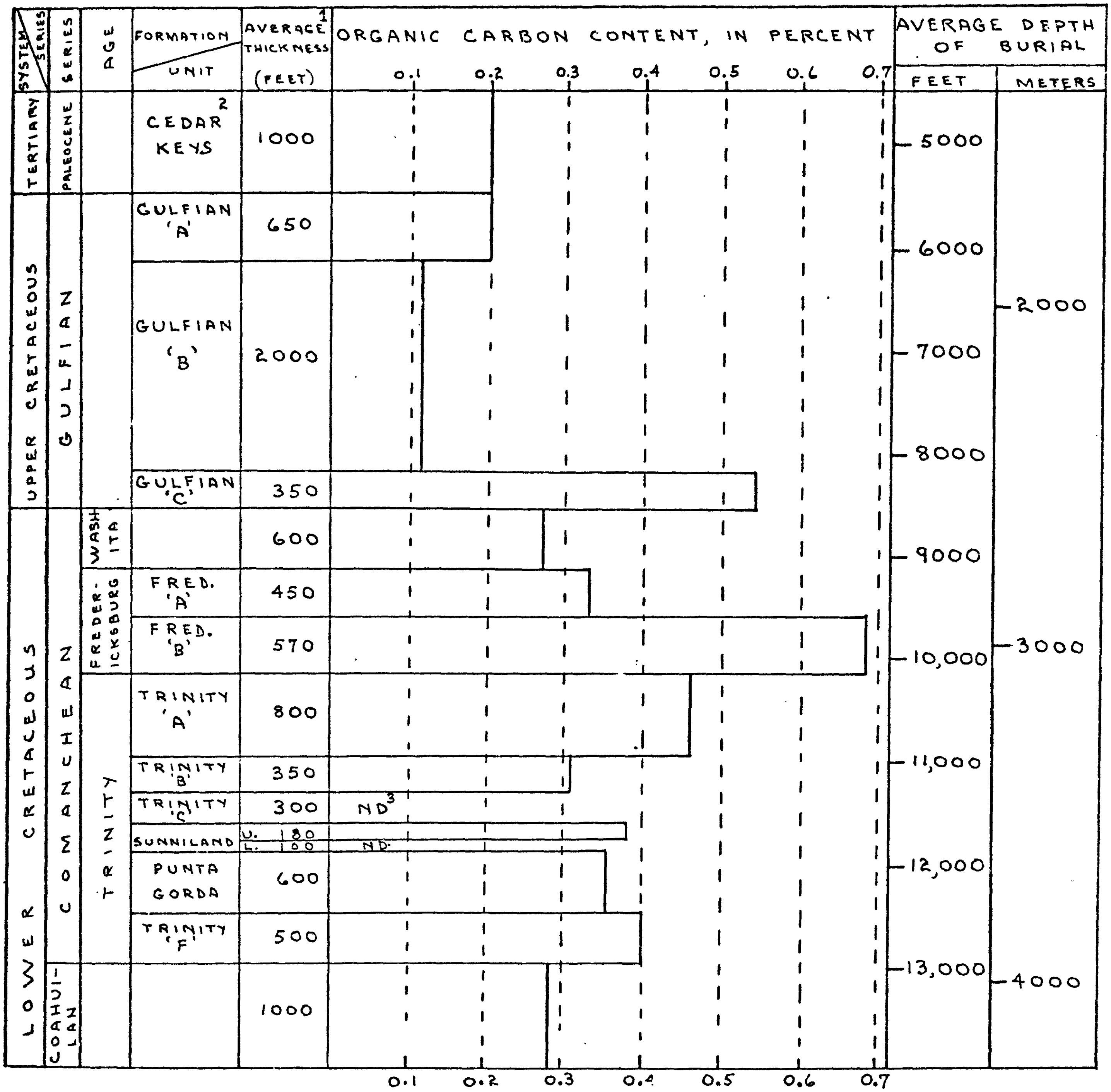

Figure 4.--Stratigraphic distribution of organic carbon content in carbonate rocks of a composite section, South Florida Basin.

[1]Refers to total average thickness of all rock types, including anhydrites, in each stratigraphic unit.
[2]Only the lowermost 1000 feet of the Cedar Keys have been studied in this report.
[3]ND, not determined.