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Lithostratigraphy, Petrography, Biostratigraphy, and Strontium-Isotope Stratigraphy of the Surficial Aquifer System of Western Collier County, Florida

U.S. Geological Survey
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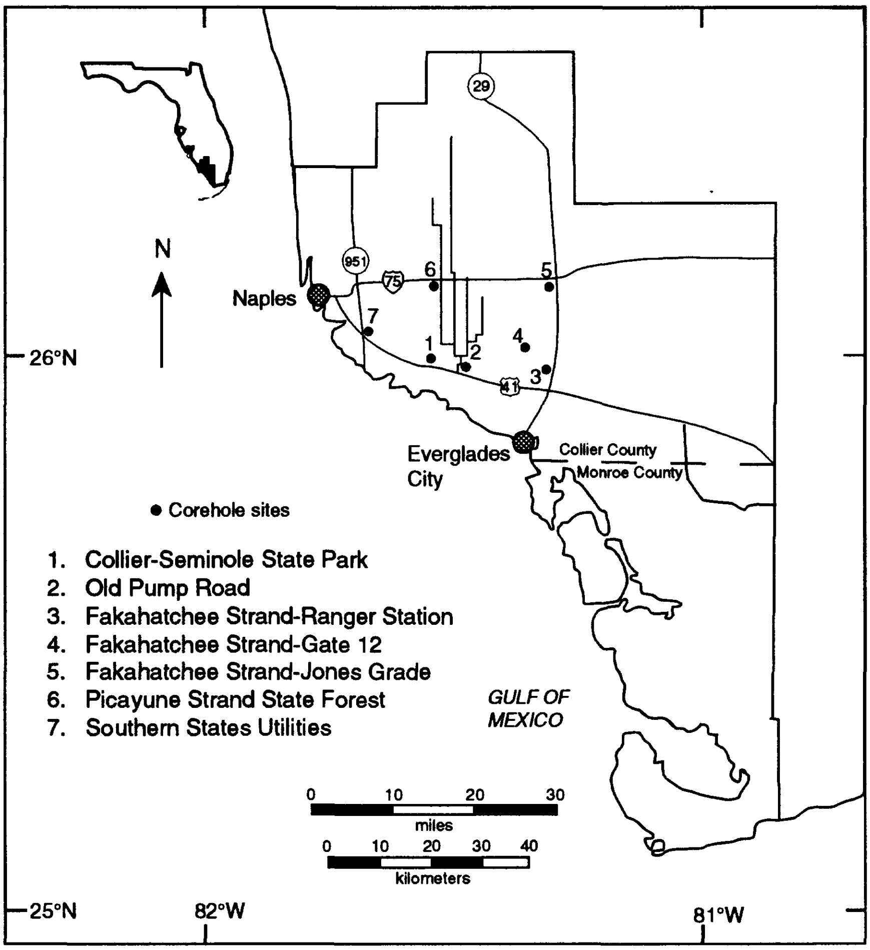

Prepared in cooperation with the Florida Geological Survey

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Lithostratigraphy, Petrography, Biostratigraphy, and Strontium-Isotope Stratigraphy of the Surficial Aquifer System of Western Collier County, Florida

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ABSTRACT

In 1996, seven cores were recovered in western Collier County, southwestern Florida, to acquire subsurface geologic and hydrologic data to support ground-water modeling efforts. This report presents the lithostratigraphy, X-ray diffraction analyses, petrography, biostratigraphy, and strontium-isotope stratigraphy of these cores.

The oldest unit encountered in the study cores is an unnamed formation that is late Miocene. At least four depositional sequences are present within this formation. Calculated age of the formation, based on strontium-isotope stratigraphy, ranges from 9.5 to 5.7 Ma (million years ago). An unconformity within this formation that represents a hiatus of at least 2 million years is indicated in the Old Pump Road core. In two cores, Collier-Seminole and Old Pump Road, the uppermost sediments of the unnamed formation are not dated by strontium isotopes, and, based on the fossils present, these sediments could be as young as Pliocene. In another core (Fakahatchee Strand-Ranger Station), the upper part of the unnamed formation is dated by mollusks as Pliocene.

The Tamiami Formation overlies the unnamed formation throughout the study area and is represented by the Ochopee Limestone Member. The unit is Pliocene and probably includes the interval of time near the early/late Pliocene boundary. Strontium-isotope analysis indicates an early Pliocene age (calculated ages range from 5.1 to 3.5 Ma), but the margin of error includes the latest Miocene and the late Pliocene. The dinocyst assemblages in the Ochopee typically are not age-diagnostic, but, near the base of the unit in the Collier-Seminole, Jones Grade, and Fakahatchee Strand State Forest cores, they indicate an age of late Miocene or Pliocene. The molluscan assemblages indicate a Pliocene age for the Ochopee, and a distinctive assemblage of *Carditimera arata* ? and *Chione cortinaria* ? in several of the cores specifically indicates an age near the early/late Pliocene boundary.

Undifferentiated sands overlie the Pliocene limestones in two cores in the southern part of the study area. Artificial fill occurs at the top of most of the cores.

The hydrologic confining units penetrated by these cores are different in different parts of the study area. To the west, a hard tightly cemented dolostone forms the first major confining unit below the water table. In the eastern part of the study area, confinement is more difficult to determine. A tightly cemented sandstone, much younger than the dolostones to the west and probably not laterally connected to them, forms a slight confining unit in one core. Thick zones of poorly sorted muddy unconsolidated sands form a slight confining unit in other cores; these probably are not correlative to either the sandstone or the dolostones to the west. The age and sedimentologic observations suggest a complex compartmentalization of the surficial aquifer system in southwestern Florida.

The calibrations of dinocyst and molluscan occurrences with strontium-isotope stratigraphy allows us to expand and document the reported ranges of many taxa.

INTRODUCTION

Collier County in southern Florida (fig. 1) includes the southwestern part of the Kissimmee River-Lake Okeechobee-Everglades wetland ecosystem. The construction of canals, levees, and cross-peninsula highways has created obstructions to natural sheet flow of surface water to the southwestern coast and allowed salt water to penetrate inland. Recent public concern over changes in the southern Florida ecosystem has mandated local, state, and federal agencies, as well as private businesses, to halt some of their practices and to begin the long process of restoration of the ecosystem toward its pre-development state. The U.S. Geological Survey (USGS) and the Florida Geological Survey (FGS) have joined with the Army Corps of Engineers, the Environmental Protection Agency, the National Park Service, the South Florida Water Management District (SFWMD), and other state and local agencies to examine the hydrology and ecology in southwestern Florida and to begin to understand their system dynamics.

In 1996, seven cores were recovered in western Collier County, in the area between Alligator Alley (I-75), Tamiami Trail (U.S. Route 41), State Route 29, and State Route 951, as part of a joint USGS and FGS project (fig. 1). The objective is to acquire subsurface

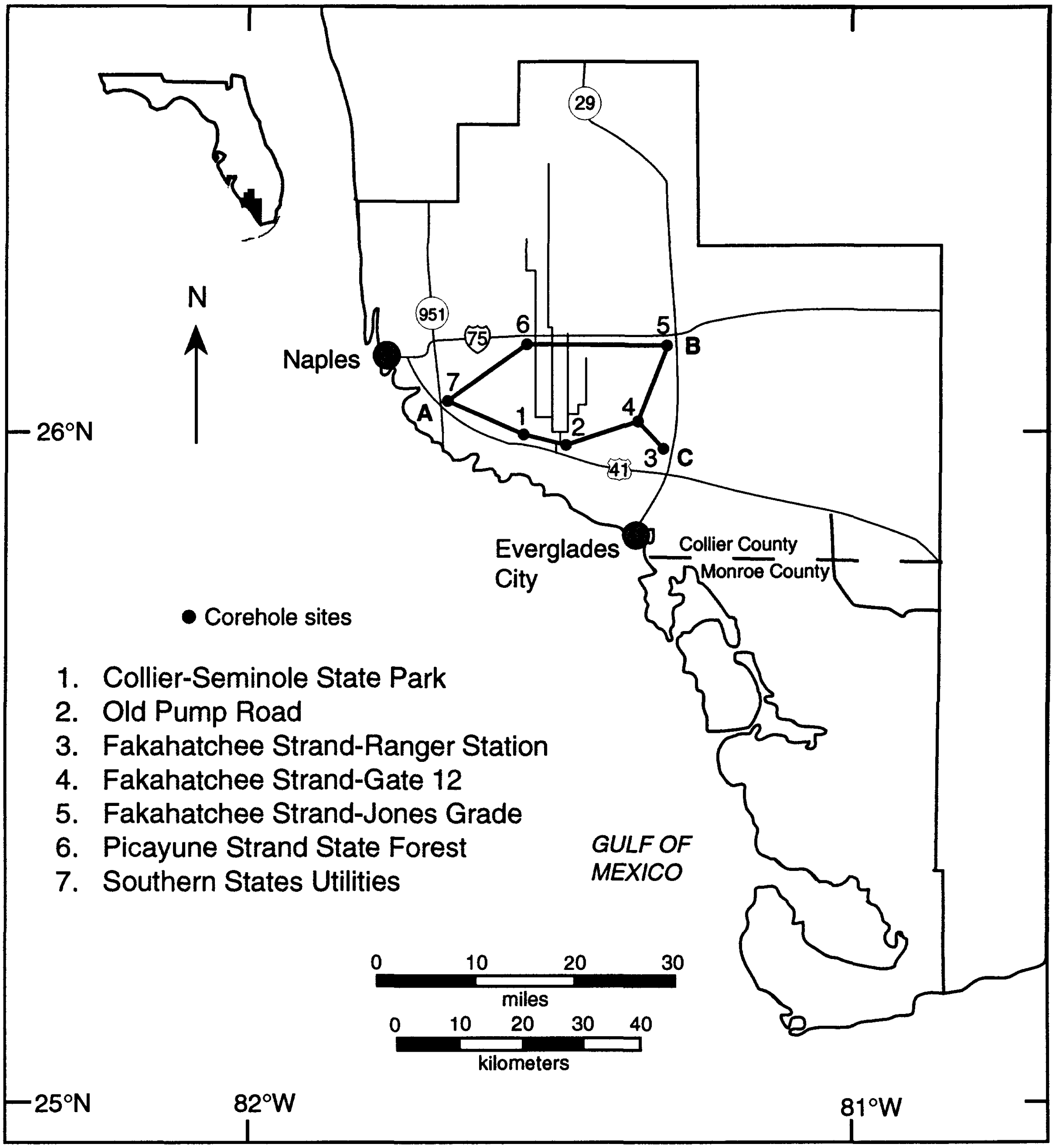

Figure 1. Map of Collier and Monroe Counties, southwestern Florida (inset) showing locations of the corehole sites, numbered and identified on the figure, and the lines of cross-sections, A-B, B-C, and A-C, shown in Figures 10, 11, and 12.

geologic and hydrologic data in southwestern Florida to support ground-water modeling in that region, thereby expanding the utility of these models for land and water management. The lithology and geophysics of these cores were summarized by Weedman and others (1997). This report describes the lithostratigraphy, X-ray diffraction analyses, petrography, biostratigraphy, and strontium (Sr) isotope stratigraphy of the same cores.

Previous geologic and hydrologic studies were discussed by Weedman and others (1997). The current model for the surficial aquifer system of southwestern Florida consists of two aquifers: the water-table and the lower Tamiami aquifers, separated by a semi-confining unit (Southeastern Geological Society, 1986; Bennett, 1992). An additional aquifer has been identified within the surficial system in south-central and southeastern Florida. The gray limestone aquifer, described from Dade County by Fish and Stewart (1991), is assumed to extend westward into Collier and perhaps Monroe counties, and may be correlative with the lower Tamiami aquifer. In this study we have identified the Tamiami Formation and we recognize an unnamed formation below the Tamiami Formation. Some of the unnamed formation is possibly correlative with a newly described and proposed formation recognized in the Florida Keys to the south, the proposed Long Key Formation (Cunningham and others, 1998). The Tamiami Formation is the primary stratigraphic unit comprising the water table aquifer, and perhaps some of the lower Tamiami aquifer, in southwestern Florida. The Hawthorn Group and its constituents, the Peace River and Arcadia Formations, were not recognized in any of the cores discussed here, although the unnamed formation may be correlative in part.

Acknowledgments

We thank drillers Jim Trindell (FGS), Don Queen (USGS), Alex Howell (FGS), Frank Rush (FGS), and Roger van Landingham (FGS). We also extend our thanks to Bob Henry from Collier-Seminole State Park, Mike Owen, Jolen Mabry, Jim Nelson, and the late Eddy Lowery from Fakahatchee Strand State Preserve, Erv Crosby and Sonja Durrwachter of the Florida State Division of Forestry, Mel Fisher and Mike Quigley of the Southern States Utilities Company, Gary Susdorf of Viro Group, Inc., and Kevin Rohrer of SFWMD in West Palm Beach, Florida. Processing for dinocysts was done by Tom Sheehan and Lisa Weimer; Tom Sheehan also assisted in the collection of samples and Lisa Weimer performed preliminary examination of samples. Mollusk samples were collected with the assistance of Harley Means and Tom Sheehan. Mollusk sample preparation was by Steve Wandrei and Jill D'Ambrosio. Sample preparation for foraminifers was performed by Ian Graham and Kevin McKinney. We wish to thank John Jackson (USGS) for sharing his expertise on the use of the Diano X-ray diffraction spectrometer, calibration, and interpretation of results. We thank Frank Dulong (USGS) for his guidance in sample preparation and the interpretation of X-ray diffraction results. Bruce Wardlaw and Rob Weems provided valuable comments on the manuscript.

MATERIAL AND METHODS

Corehole sites

Continuous cores were recovered from seven sites in western Collier County listed in table 1. Descriptions of the cores are given in Weedman and others (1997).

X-ray diffraction

Semi-quantitative analysis of X-ray diffraction of samples from the Collier-Seminole State Park, Old Pump Road, Fakahatchee Strand-Ranger Station (lower part of the core only), Fakahatchee Strand-Gate 12, Fakahatchee Strand-Jones Grade, and Picayune Strand State Forest cores was done on a Diano X-ray diffraction spectrometer. Digitized X-ray data were collected every 0.02 degrees 2-theta, for 0.95 seconds per step. Data were collected from 5.00 to 60.00 degrees 2-theta. Copper K-alpha radiation was generated at 45 KV and 25 MA. A 1-degree sollor slit, a 0.1-degree detector slit, a graphite monochromator, and a 6-degree take-off angle were used. Each sample were was split or quartered, and ground in a mortar until all of the material passed through a 75-µm or smaller sieve. The samples were prepared as smear mounts. The program used to evaluate each run was designed by Hosterman and Dulong (1989). This program uses a library file of the

Table 1. Corehole site information

Corehole site, (1:24,000 USGS map), FGS No.	Latitude Longitude	Section, Township, Range	Elevation (ft)
Collier-Seminole State Park (Royal Palm Hammock) W-17360	25°59'20"N. 81°34'43"W.	sec. 35, T. 51 S., R. 27 E.	5
Old Pump Road (Royal Palm Hammock) W-17361	25°58'37.594"N. 81°30'22.182"W.	sec. 4, T. 52 S., R. 28 E.	5
Fakahatchee Strand-Ranger Station (Ochopee) W-17393	25°57'05.857"N 81°21'38.693"W.	sec. 12, T. 52 S., R. 29 E.	5
Fakahatchee Strand-Gate 12 (Deep Lake SW) W-17389	26°00'25.290"N. 81°24'40.686"W.	sec. 21, T. 51 S., R. 29 E.	9
Fakahatchee Strand-Jones Grade (Miles City) W-17394	26°08'33.815"N. 81°21'00.151"W.	sec. 6, T. 50 S., R. 30 E.	13
Picayune Strand State Forest (Belle Meade NE) W-17450	26°08'33.754"N. 81°33'45.154"W.	sec. 1, T. 50 S., R. 27 E.	13
Southern States Utilities (Belle Meade) W-17454	26°04'03.497"N. 81°41'41.782"W.	sec. 34, T. 50 S., R. 26 E.	7

peaks of selected minerals, in this case calcite, dolomite, aragonite, and quartz, against which it compares the peaks of the sample unknowns. The library file contains reference intensity ratios, which are weighting factors used to put the pattern of each of the minerals into proportion with the others. Before analysis, the reference intensity ratios of calcite, aragonite, and dolomite were set by running a series of known mixtures. These mixtures were:

25 percent quartz, 75 percent calcite
50 percent quartz, 50 percent calcite
50 percent quartz, 50 percent dolomite
50 percent quartz, 50 percent aragonite
95 percent quartz, 5 percent calcite
95 percent quartz, 5 percent dolomite
95 percent quartz, 5 percent aragonite

The resulting ratios were compared to the known ratios, and the reference intensity ratios were then set to achieve the best fit.

Two slides were made for each known mixture to check the quality of the mixture. Based on the results of these known mixtures, the overall reliability of the results reported is within ± 5 percent. The detection limit is estimated to be around 1 percent. Pure samples of each of the four minerals also were run to check the peak intensity values in the library file. For all runs, the d-spacings were computer-adjusted to the quartz 3.343 Å peak. All results were rounded to the nearest 5 percent. Minerals that were identified, but present in concentrations of less than 5 percent of the sample, were reported as "trace." Potassium feldspar and plagioclase were identified in many samples. Together with various unidentified minor peaks, these minerals generally comprise less than 5 percent of the total sample composition and were not included in the percent calculations.

Petrography

Seventy-six samples were selected for petrographic analysis from all cores except for Southern States Utilities. Samples were impregnated with blue-stained epoxy and made into standard thin sections. These were examined petrographically to identify grains and pore types, determine cement compositions, describe textures, and assess the degree of diagenetic alteration. Skeletal-grain molds are pores; however, they are included in descriptions as grains to document their occurrences as original grains. Samples were examined from the unnamed formation and the Ochopee Limestone Member of the Tamiami Formation. Unconsolidated sediments were not prepared as thin sections.

Paleontological material

Core material was examined for dinocysts, pollen, mollusks, and foraminifers. Dinocyst and pollen samples were treated with hydrochloric and hydrofluoric acids, oxidized with nitric acid, and stained with Bismark brown. All samples were observed with a light microscope under differential interference contrast. A total of 61 samples were examined; over half (38) yielded dinocysts. Due to the relative rarity of dinocysts in the material, up to 1.2 ft of material was processed. Sample depth is given to the nearest foot in table 3 and the text. Appendix 2 lists the full depth interval sampled. For sections with abundant molluscan material, representative samples were taken where an apparent change in faunal or lithologic content occurred, and at least one sample was taken every 10 ft. For sections with sparse molluscan material, samples were taken wherever calcareous material was observed. Unconsolidated sediments were washed through an 850-µm and a 63-µm sieve; samples greater than 850 µm were picked for molluscan material. Latex molds and casts or clay impressions were prepared to aid in the identification of the mollusks preserved as molds and casts in the limestones. Readily identifiable mollusks are included; additional species present that would require further investigation are not included. Foraminiferal samples from the Collier Seminole and Fakahatchee Strand-Ranger Station cores consisted of well to poorly lithified limestone, calcareous sandstone, and dolostone. Due to the lithified nature of the samples, a freeze-thaw processing procedure was used to liberate the microfaunal components (ostracodes and foraminifers) from the samples. The sample residues were sieved at greater than 63 µm, which was then analyzed for planktonic foraminifers only. Studies on ostracodes are ongoing. Pollen samples were sparse and not age-diagnostic (Debra Willard, personal communication, 1997).

Strontium-isotope stratigraphy

Individual shells or shell fragments of calcitic mollusks were collected for strontium-isotope analysis. Samples were dissolved in 5M acetic acid and the soluble fraction was centrifuged and separated by standard ion-exchange techniques. Strontium was loaded on a single Ta oxidized filament. Isotope ratios were measured on a VG54 Sector thermal ionization mass spectrometer in dynamic mode. Each data value is the average of two or more individual runs of 180 ratios each, measured on a 5×10^{-10} amp beam. Ratios were averaged using Isoplot (Ludwig, 1990). All $^{87}Sr/^{86}Sr$ data have been normalized to a value of 0.1194 for $^{86}Sr/^{88}Sr$. The data were collected between November 1996 and March 1997, during two different periods of analysis. Measured values for the USGS modern-carbonate standard EN-1, a large *Tridacna* shell collected live from Enewetak lagoon were 0.709198 ± 0.000017 (2 standard deviations, n=36) and 0.709213 ± 0.000015 (2 standard deviations, n=23). Ages in millions of years ago (Ma) are assigned using the data table of Howarth and McArthur (1997).

LITHOSTRATIGRAPHY

The stratigraphic concepts expressed by Scott (1988a; 1992a, b), Scott and Wingard (1995), and Missimer (1992, 1993, 1997) provide the basic framework within which the

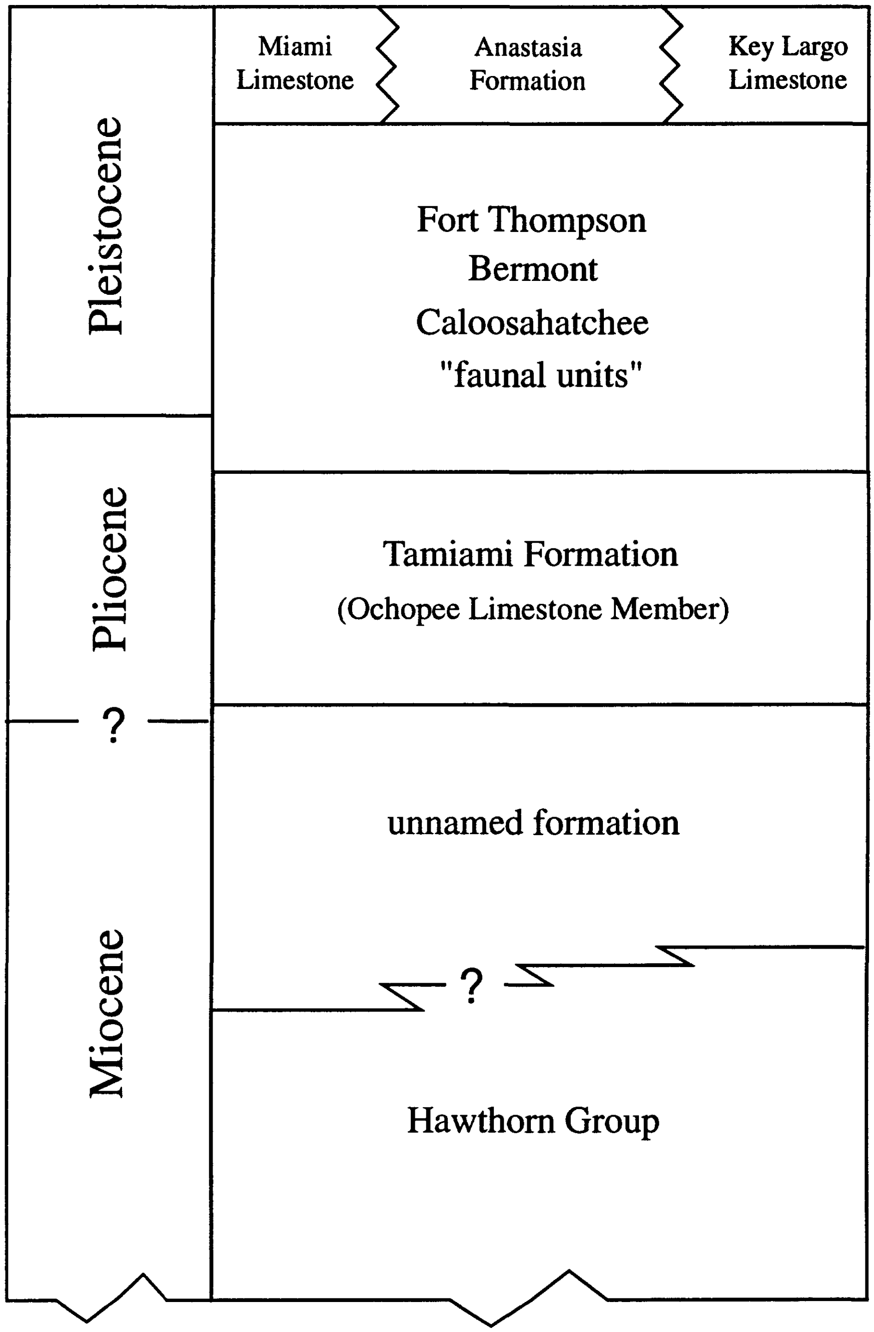

Figure 2. Generalized stratigraphic column for southern Florida. Of the late Pleistocene interfingering units, only the Miami Limestone might be expected in the study area. The lithostratigraphic classification for the section from the Tamiami Formation to the Hawthorn Group is currently being revised by the Florida Geological Survey (figure is modified after Allmon, 1992 and Scott, 1992b).

lithostratigraphy of the sediments from the Collier County cores is interpreted (fig. 2). The framework has been further modified based upon the ongoing investigations by Cunningham, McNeill, and Guertin (unpublished data) at the University of Miami and this project. The ongoing research in this portion of Florida undoubtedly will provide a better understanding of the late Cenozoic lithostratigraphy. Here, we recognize an unnamed formation and, stratigraphically above it, the Tamiami Formation. Artificial fill, natural soil, and, in two cores, undifferentiated sands form the uppermost material. Figures 3-9 show the lithology, lithostratigraphy, and age information from the seven cores, and figures 10-12 show schematic cross-sections across the study area.

Unnamed formation

In the studied cores, the sediments from the bottoms of the cores to the base of the Tamiami Formation are dominantly siliciclastics with subordinate carbonates. Regionally, these sediments have variously been placed in the Miocene Coarse Clastics, Hawthorn Group and lower Tamiami Formation (Knapp and others, 1986; Smith and Adams, 1988), within the Tamiami Formation (Peck and others, 1979), or entirely within the Hawthorn Group (Peacock, 1983; Campbell, 1988; Missimer, 1997). Green and others (1990) referred to these sediments as "undifferentiated coarse siliciclastics" and suggested that the sediments were, at least in part, Pliocene. For this investigation, the sub-Tamiami sediments are placed in an unnamed formation until more data are obtained to facilitate regional correlations.

The unnamed formation consists of variably phosphatic and fossiliferous combinations of quartz gravel, sand, silt, clay, and carbonate rock and sediments. Fossils occur as whole entities, fragments, molds, and casts. The fossils recognized in this unit include mollusks, foraminifers, ostracodes, echinoids, bryozoans, corals, dinocysts, and red algae.

Clay generally occurs as matrix within the siliciclastic and carbonate sediments, although scattered, variably silty, sandy clay beds are recognized within the section. Mica, phosphate, feldspar, and heavy mineral grains are widespread, but generally minor, components of the sediment. These sediments range from unconsolidated to well indurated. The top of this unit ranges from 106 feet below sea level to 31 feet below sea level (figs. 3-9). The unit is as much as 187 ft thick in the studied cores, and its base was not encountered.

Limestone and dolostone are present and generally subordinate within the unnamed formation. The carbonates contain varying proportions of quartz gravel, sand, silt, clay, and phosphate, and vary from poorly indurated to well indurated.

Discoid quartzite pebbles and well-rounded pea-gravel are scattered within the unnamed formation in many of the cores. Pebbles range up to nearly 2 cm (longest dimension) within an apparent beach deposit at 171 feet below land surface in the Collier-Seminole core. Discoid quartzite pebbles similar to those observed in these cores have been noted in the Pliocene Cypresshead Formation, Hawthorn Group and associated sediments in central and northern Florida (Scott, 1988b). In southern Florida, the pebbles have been recognized both in sediments assigned to the Hawthorn Group and in the unnamed formation. Concentrations of large pebbles have been noted in cores to the north and west of the present study area (T. Scott, unpublished data, 1997).

The unnamed formation appears to be laterally equivalent to and interfingering with at least part of the Peace River Formation, Hawthorn Group; few beds within this section consist of lithologies characteristic of the Peace River Formation. The carbonate beds at the base of the Picayune Strand core are lithologically similar to carbonates in the upper Arcadia Formation, Hawthorn Group in southern Florida. However, the top of the Arcadia Formation is projected to be nearly 400 feet below sea level in this area, well below the base of the core (Scott, 1988a). Also, discoid quartzite pebbles, such as those in the carbonate sediments at Picayune Strand (at 187 ft), have not been recognized from the Arcadia Formation.

The upper portion of the unnamed formation may grade laterally into the basal Tamiami Formation. The upper contact between the unnamed formation and the Tamiami Formation appears to vary from sharp to rapidly gradational across the study area. The determination of the nature of the contact

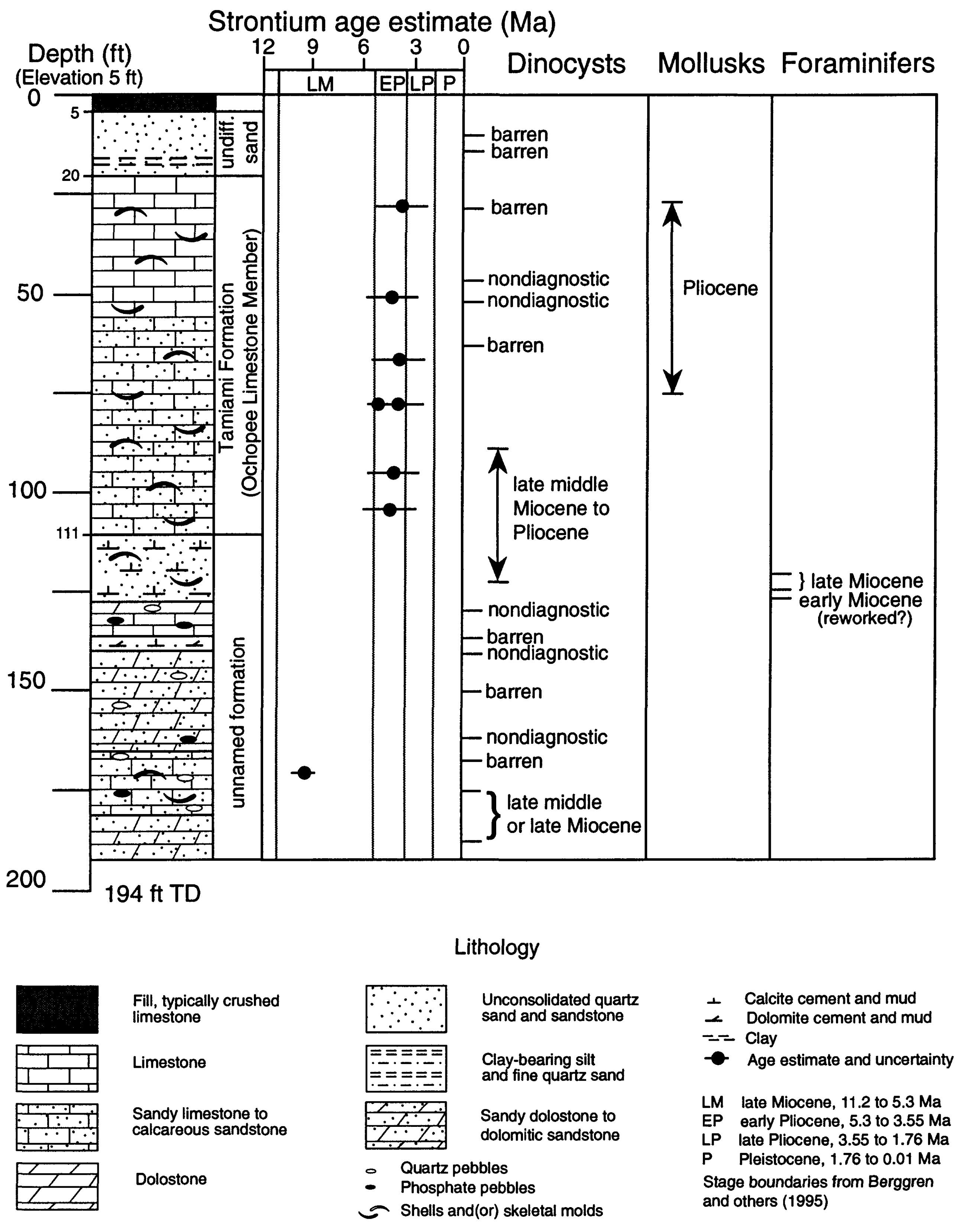

Figure 3. Lithology, lithostratigraphy, and age information for the Collier-Seminole State Park core.

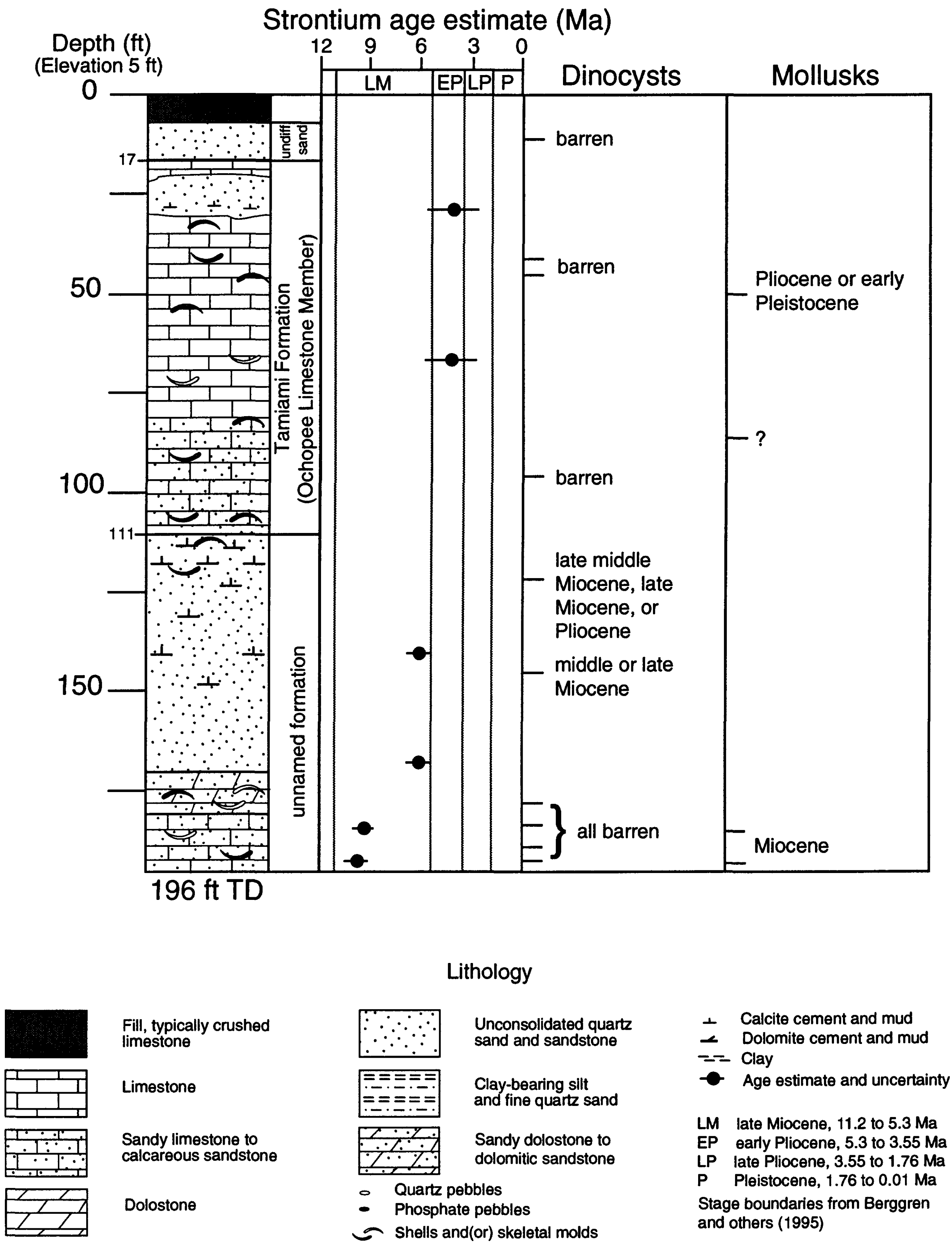

Figure 4. Lithology, lithostratigraphy, and age information for the Old Pump Road core.

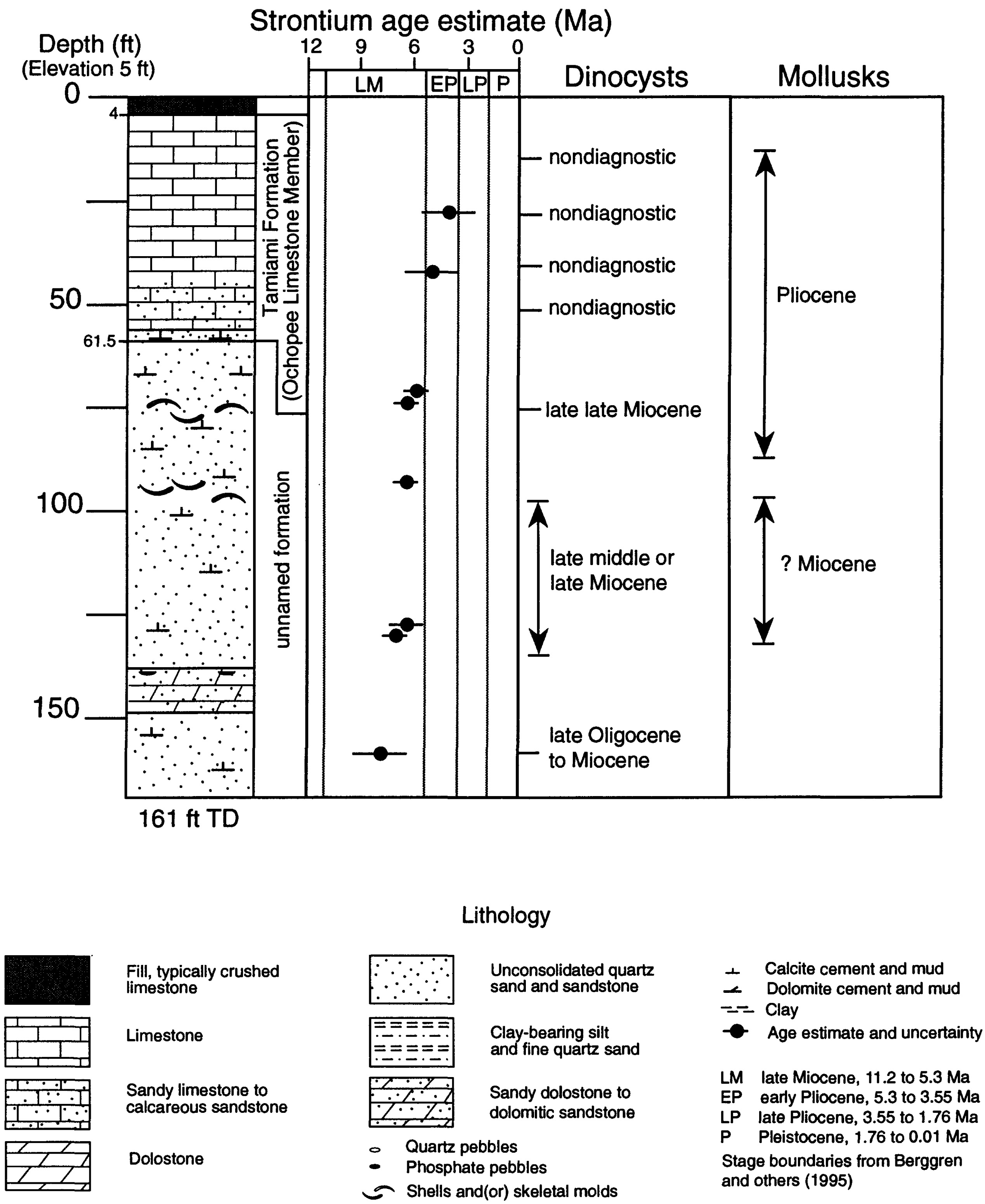

Figure 5. Lithology, lithstratigraphy, and age information for the Fakahatchee Strand-Ranger Station core

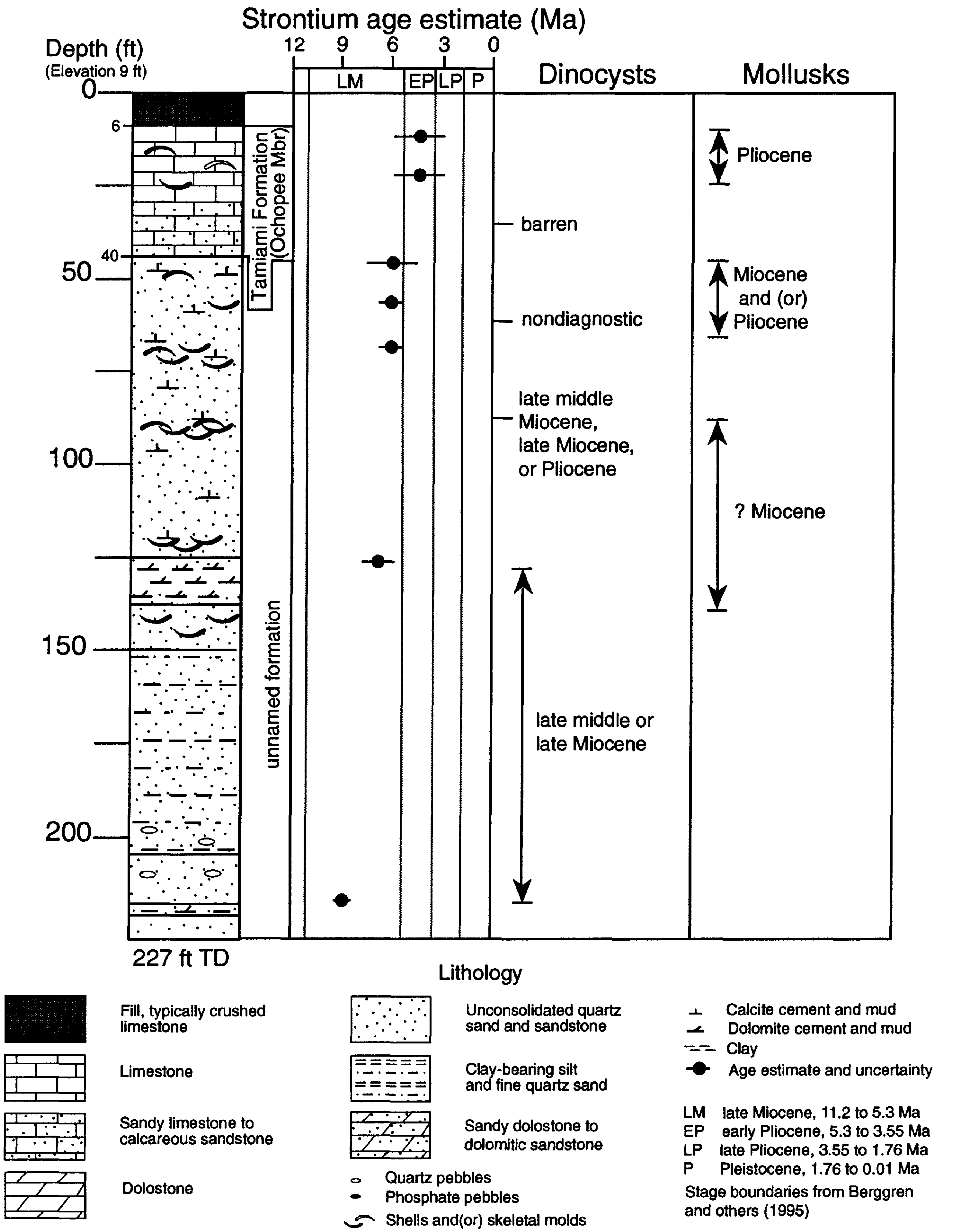

Figure 6. Lithology, lithostratigraphy, and age information for the Fakahatchee Strand-Gate 12 core.

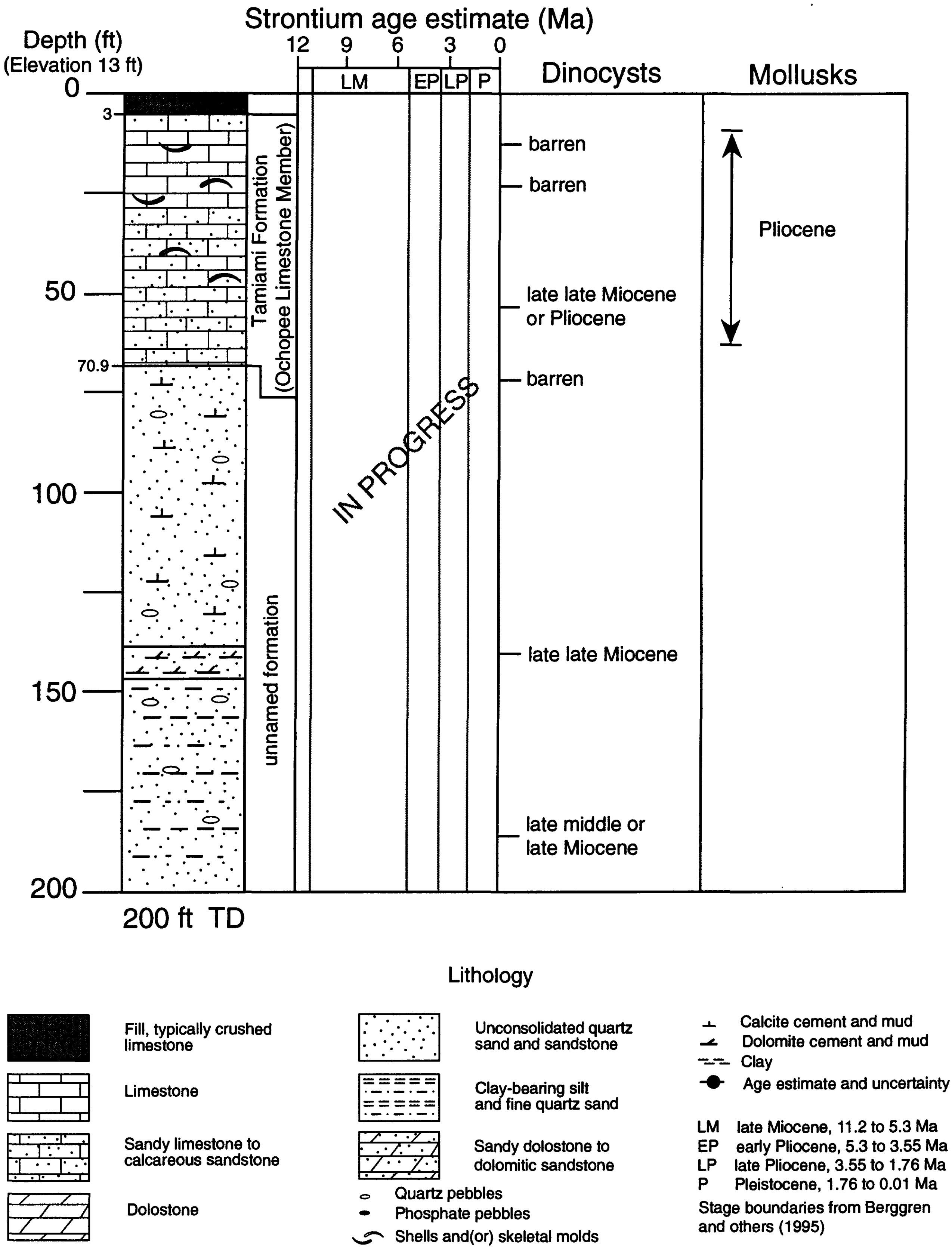

Figure 7. Lithology, lithostratigraphy, and age information for the Fakahatchee Strand-Jones Grade core.

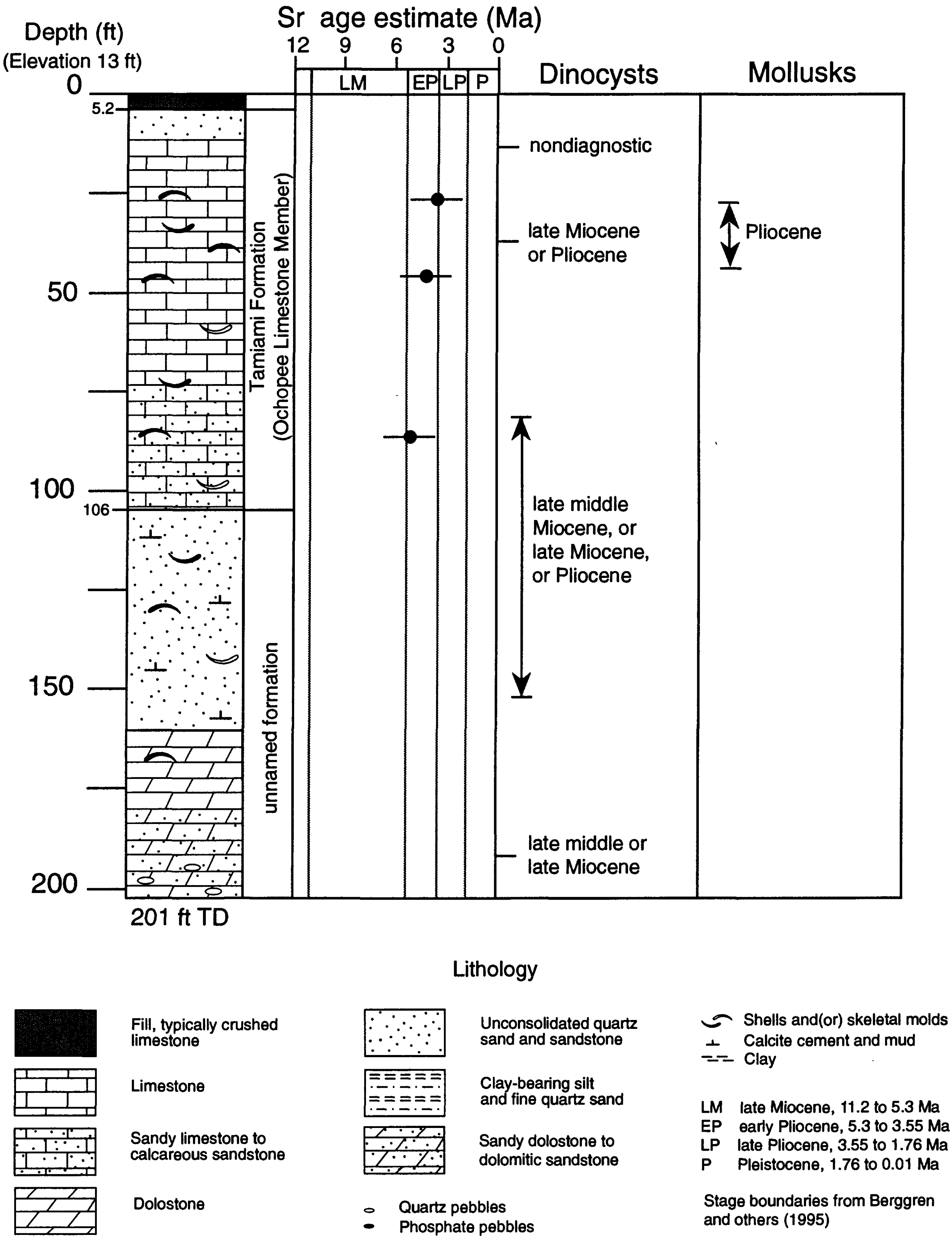

Figure 8. Lithology, lithostratigraphy, and age information for the Picayune Strand State Forest core.

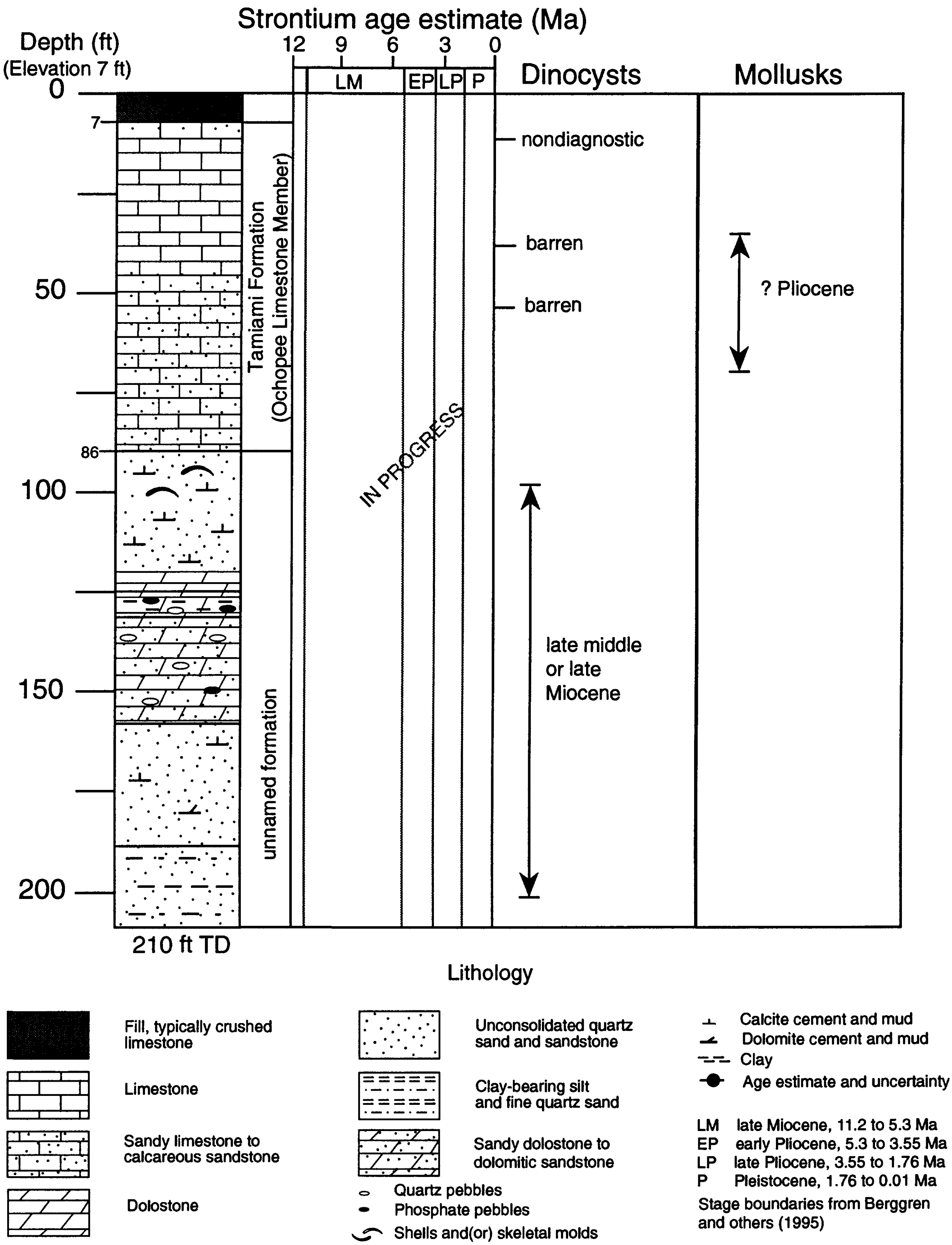

Figure 9. Lithology, lithostratigraphy, and age information for the Southern States Utilities core.

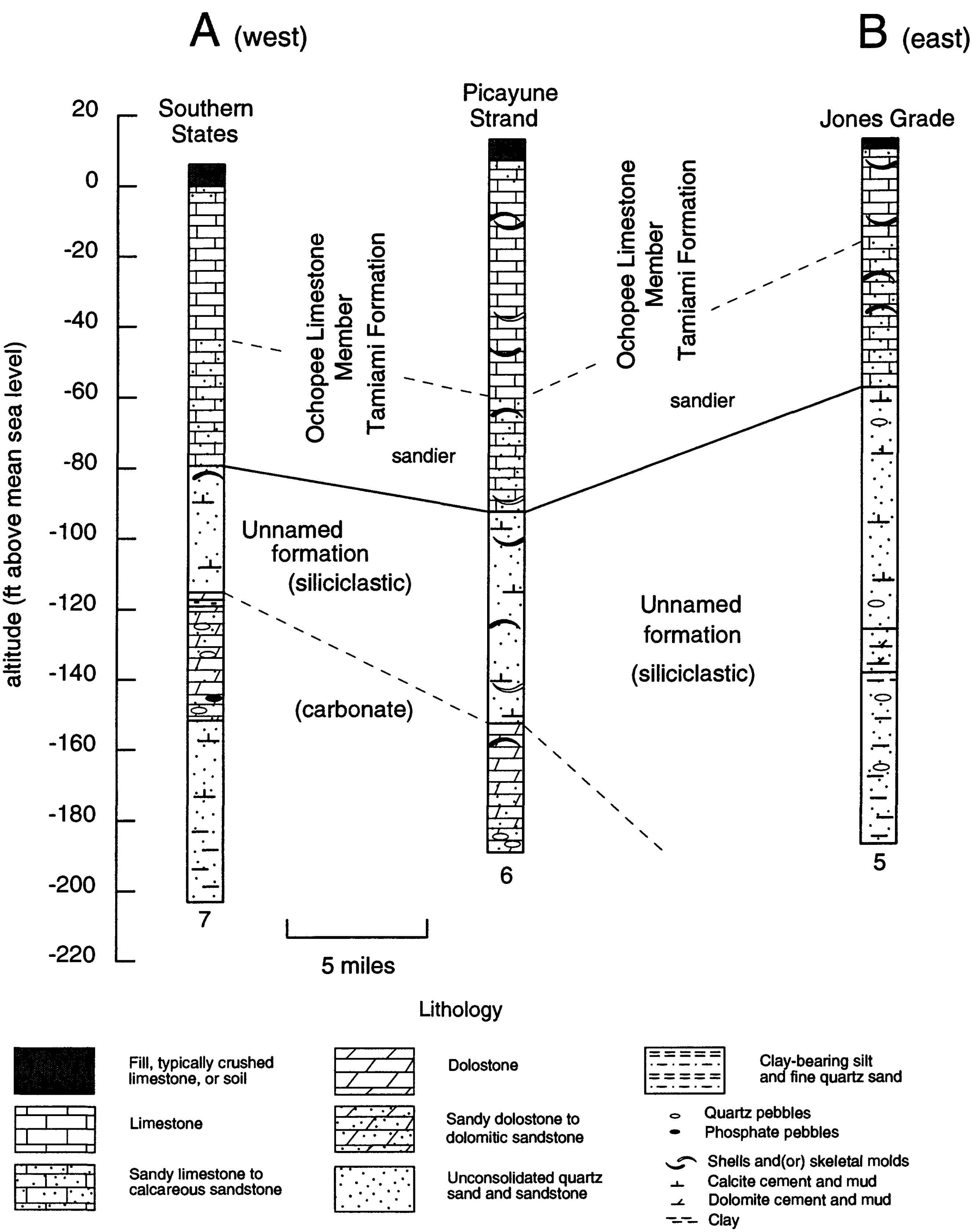

Figure 10. West to east transect along and near Interstate 75, in the northern part of the study area. Dashed lines indicate lithic changes within formations. (See fig. 1 for location, line A-B.)

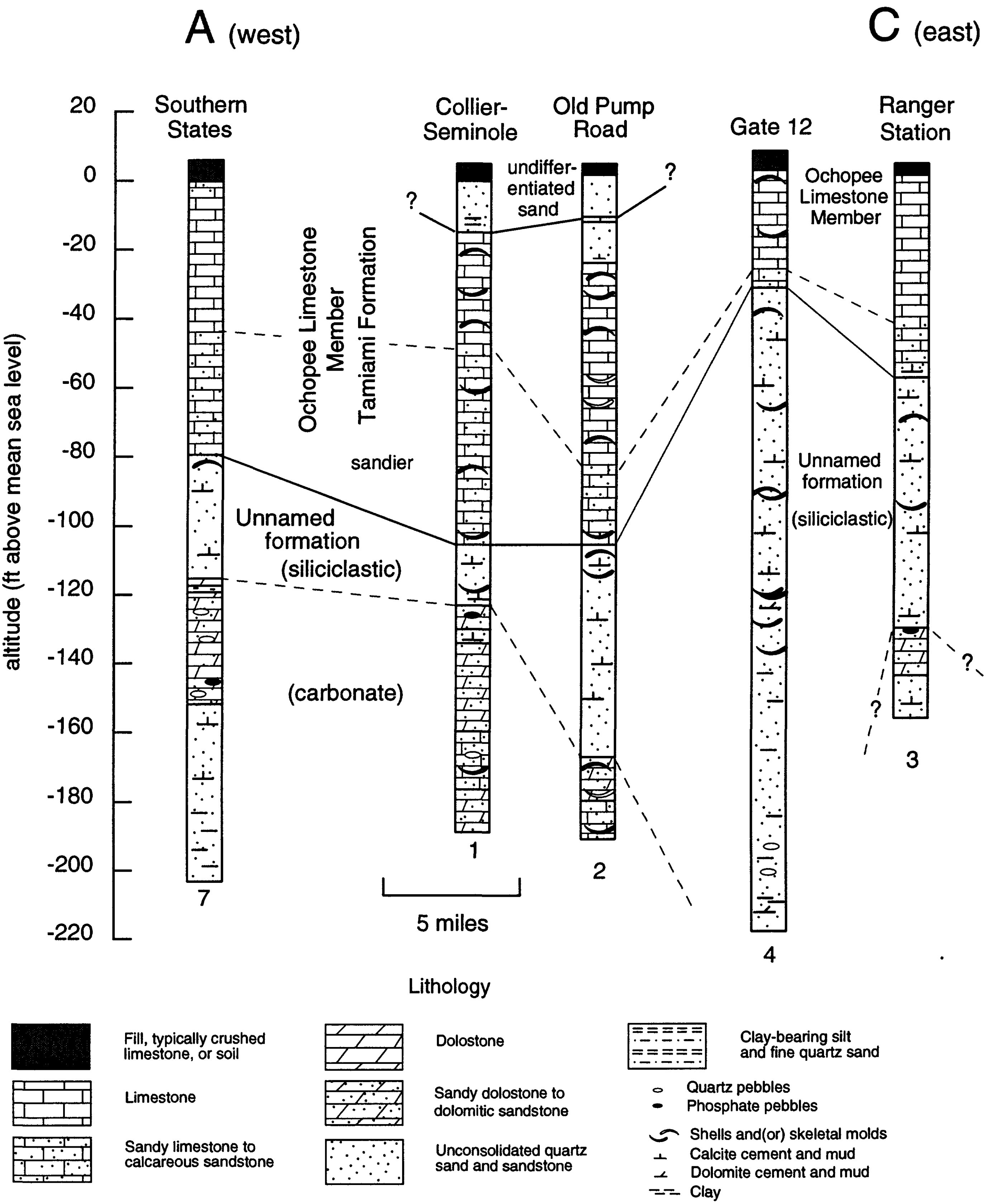

Figure 11. West to east transect along and near U.S. Route 41, in the southern part of the study area. Dashed lines indicate lithic changes within formations. (See fig. 1 for location, line A-C.)

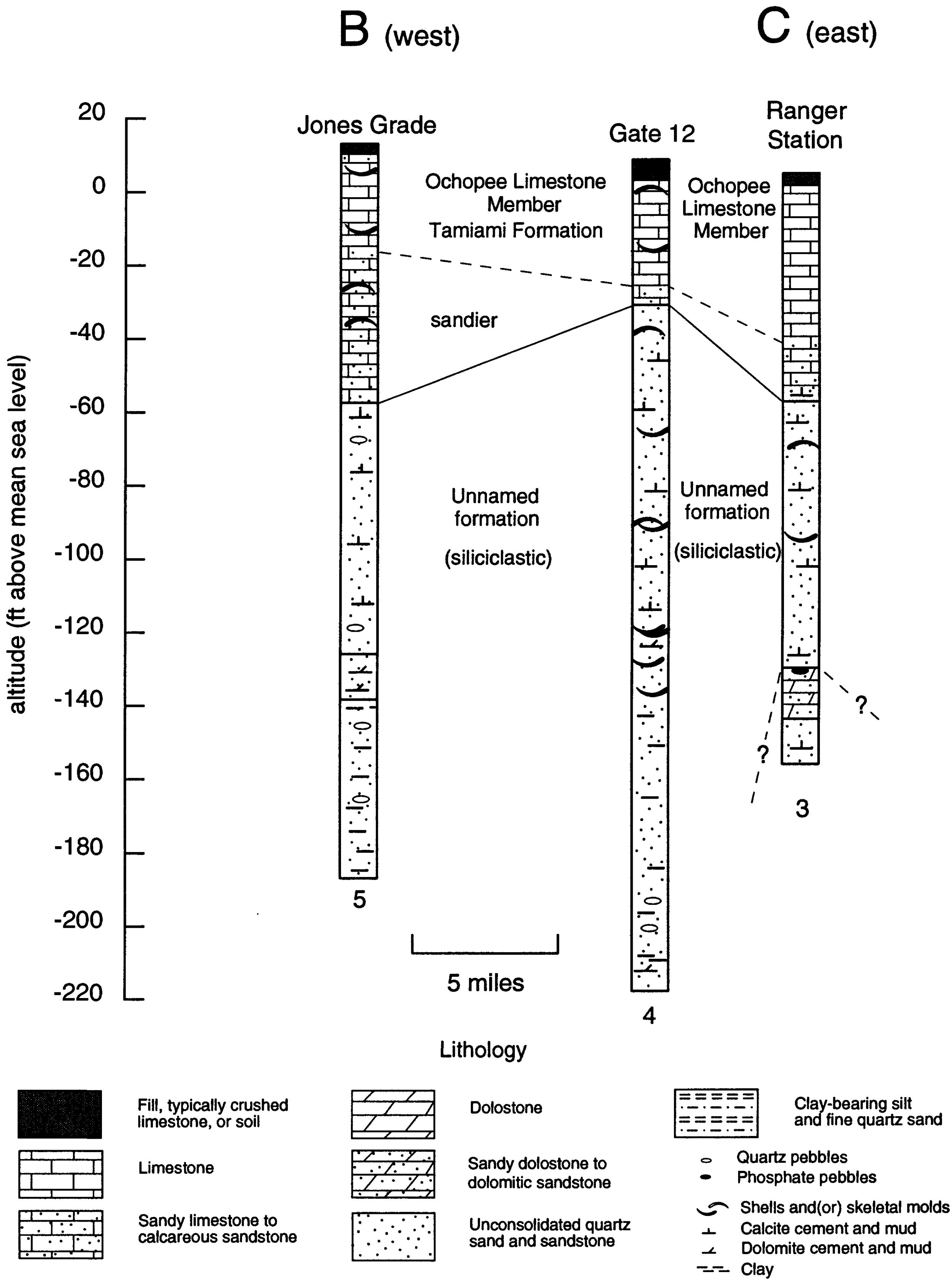

Figure 12. North to south transect along and near State Route 29, in the eastern part of the study area. Dashed lines indicate lithic changes within formations. (See fig. 1 for location, line B-C.)

is hampered in some cores by poor recovery.

The siliciclastic sediments forming the foundation of the Florida Keys and underlying southernmost peninsular Florida have been named the Long Key Formation (Cunningham and others, 1998). The unnamed formation could possibly be the updip extension of the Long Key Formation; however, its inclusion in the Long Key Formation cannot be verified at this time.

Tamiami Formation

The Tamiami Formation overlies the unnamed formation throughout the study area. The complexity of the facies relations within the Tamiami Formation and the predominantly subsurface nature of the formation have rendered correlations difficult (see Missimer, 1992). The concepts of Missimer (1992) were utilized in recognizing the subdivisions of the Tamiami Formation in the study area. The Ochopee Limestone Member of the Tamiami is widespread in southern Florida and was recognized in all the cores (figs. 3-12). Further coring and analyses of the sediment will aid in better understanding of the Tamiami.

The Ochopee Limestone Member, as described by Hunter (1968), is "a light gray to white, sandy calcarenite, containing abundant, identifiable molds of aragonite fossils together with specimens of calcite fossils. . ." The quartz sand content can range from five percent to eighty percent, from a slightly sandy limestone to a calcareous sand to sandstone (Missimer, 1992). The Ochopee Limestone Member recognized in the study cores is a white to light gray, variably sandy, unconsolidated to well-indurated, variably moldic, fossiliferous limestone (packstone to wackestone) to a light gray, variably calcareous, unconsolidated to moderately indurated, variably moldic, fossiliferous sand to sandstone. Phosphate grains occur scattered throughout these sediments. Fossils include mollusks, foraminifers, echinoids, corals, bryozoans, ostracodes, and dinocysts. The sand is generally very fine to medium. Sand content of the Ochopee Limestone Member decreases with decreasing depth. In the studied cores, the Ochopee grades from a sand into a sandstone into a limestone.

The Ochopee Limestone Member is unconformably overlain by undifferentiated sand in the Collier-Seminole State Park and Old Pump Road cores (figs. 3, 4), by artificial fill in the Fakahatchee Strand-Ranger Station, Fakahatchee Strand-Gate 12, Fakahatchee Strand-Jones Grade, and Picayune Strand State Forest cores (figs. 5-8), and by natural soil in the Southern States core (fig. 9). The top of the unit ranges from 24 feet below sea level to 10 feet above sea level. The greatest thickness of the Ochopee Limestone Member is 101 feet in the Picayune Strand State Forest core; the thinnest section encountered is 34 feet in the Fakahatchee Strand Gate 12 core.

Undifferentiated sand and artificial fill

Unnamed quartz sands overlie the limestones in the Collier-Seminole State Park core and the Old Pump Road core (figs. 3, 4). These unconsolidated, very fine to medium sands may have been deposited in erosional lows on the top of the Tamiami Formation. Artificial fill occurs at the top of all cores except the Southern States Utilities core, where a sandy soil lies on top of the limestone.

PETROGRAPHY, BIOSTRATIGRAPHY, STRONTIUM-ISOTOPE ANALYSIS

Collier-Seminole State Park core

The Collier Seminole State Park corehole was drilled in February 1996 beside a pond near the head of a nature trail in Collier-Seminole State Park (fig. 1, table 1). It was drilled to a depth of 194 ft, and the core (fig. 3) was sampled for thin sections, X-ray diffraction, strontium analysis of shells, and foraminifer, ostracode, mollusk, dinocyst, and pollen content.

The unnamed formation was identified from 194 to 111 ft. From 194 to 128 ft, this unit ranges in lithology from a well lithified, very sandy dolostone and (or) limestone, to an unconsolidated, possibly clayey, dolomitic silt, to a calcareous sandstone with scattered discoidal quartz pebbles; the unit is an unconsolidated calcareous quartz sand from 128 to 111 ft. The Ochopee Limestone Member of the Tamiami Formation was recovered from 111 to 20 ft, and is a white, moldic, molluscan, sandy wackestone to packstone. Undifferentiated unconsolidated quartz sand was recovered from 20 to 5 ft. The upper five feet of this core is man-made fill and unconsolidated quartz sand.

Semi-quantitative X-ray diffraction data for this core are shown in table 2. The unnamed formation contains abundant quartz sand in most samples. Sandy limestones, dolomitic sandstones, and dolostones occur in the lower part of the core. Dolomite is present as a subordinate mineral in most samples below 111 ft and is the dominant mineral in one sample (141.7 ft). Aragonite is rare but was detected in trace amounts at 187.5 and 186.0 ft, and in more abundant quantities at 138.2 and 134 ft. In the unconsolidated sediments of the unnamed formation, from 128 to 111 ft, calcite is subordinate to quartz. Within the Ochopee Limestone Member of the Tamiami Formation, quartz is the dominant mineral in most of the lower samples and calcite is the dominant mineral in the upper samples. A sharp decrease in quartz, from 40 to 25 percent, occurs at about 53 ft and down to 10 percent or less at 46.8 ft and shallower. Samples from the undifferentiated sand above the Ochopee (above 20 ft) are predominantly quartz.

Petrography. Sixteen thin sections (appendix 1) were examined from the unnamed formation (194-111 ft), from samples that range in depth from 188.0 to 128.0 feet. Much of this interval, in contrast to most of the other cores, is lithified, and it provides the highest number of samples appropriate for thin sections from the cores examined. This unit is highly variable, ranging from unconsolidated quartz sand to dolomitic and calcareous sandstone to sandy dolostone and sandy limestone, and includes at least four distinct lithologies. Samples are grouped by their lithologic similarity, although they may be part of a larger, genetically related package.

The deepest sample at 188 ft is a uniform, low-porosity dolostone composed of silt-sized dolomite rhombs, very little quartz sand, and no skeletal grains. It comes from a laminated interval of dolostone interbedded with a coarse dolomitic sandstone. Most of the core below this depth interval is a moderately cohesive, poorly sorted, unconsolidated, fine to very coarse quartz sand.

Overlying the dolostone from 181 to 166 ft is a calcareous sandstone (samples at 177.9, 176.5, and 171.9 ft) of bimodal quartz grains (fine and very coarse sand) with very well rounded, pebble-sized, skeletal (primarily mollusk) grains. This unit exhibits an upward decrease in porosity over this depth range due to an upward increase in calcite cementation in intergranular and moldic pores.

Overlying the calcareous sandstone from 166 to 140 ft, at an apparent sharp contact, is a dolomitic sandstone to sandy dolostone (samples from 163.4 to 140.1 ft); the quartz sand grains are poorly sorted and range from medium to very coarse. The quartz sand content of this unit decreases upward, especially from 146 to 145.4 ft, while the dolomicrite content increases upward. Skeletal-grain content (as indicated by molds, not necessarily calcareous shells) decreases upward, and desiccation cracks occur from 145.4 to 140.1 ft.

Overlying the dolomitic sandstone to sandy dolostone at a sharp contact, is a clayey, unconsolidated fine quartz sand from 140 to 133.0 ft, which is gradational into a moderately well lithified sandy wackestone to packstone (samples examined from 133.0 to 129.8 ft). The wackestone has a highly variable quartz-sand content (from less than 1 to 50 percent) in the three samples examined and a diverse skeletal-grain content that includes molluscan molds and fragments, benthic foraminifers, ostracodes, echinoids, and bryozoans. There is minor blocky calcite cement on void surfaces that is overlain by a thin veneer of dolomite rhombs in the uppermost sample at 131 ft. The packstone at 129.8 ft is similar to the wackestone at 131 ft, but it has less micrite matrix and slightly more dolomite cement in the voids. Dolomite content increases from a small amount of void-filling cement observed at 129.8 ft to a dolostone with no calcite at 129.5 ft. In the core, the dolostone was observed to extend up to 128.0 ft, where it ends at a blackened and bored surface, and is overlain by an unconsolidated quartz sand (Weedman and others, 1997). Porosity in samples at 129.5 and 129.0 ft is low due to dolomitic cement in both molds and interparticle voids and to a dolomicrite matrix filling interparticle voids; most skeletal grains are leached.

Twenty-five thin sections were made from samples of the Ochopee Limestone Member of the Tamiami Formation, from about 111 to 20 ft. Petrographic examination indicates that the unit ranges from a calcareous

Table 2. Results from semi-quantitative X-ray analysis of the Collier-Seminole State Park core

[Semi-quantitative analysis for quartz, calcite, dolomite, and aragonite. Other minerals, which may include potassium feldspar, plagioclase, muscovite, and (or) apatite, are assumed to represent less than five percent of each sample. Under Fm. (formation), T=Tamiami, U=unnamed, sand=undifferentiated sand. Results are to the nearest five percent and do not necessarily add up to 100 percent. "Trace" refers to minerals present but less than five percent of the sample]

Depth (ft)	Fm.	Mineral Composition (percent)			
		Quartz	Calcite	Dolomite	Aragonite
8.6	sand	100	trace	0	0
12.4	sand	100	0	0	0
16.2	sand	100	0	0	0
17.3	sand	100	0	0	0
18.5	sand	85	15	0	0
24.0	T	trace	95	0	0
27.7	T	15	85	0	0
37.5	T	trace	100	0	0
38.1	T	trace	95	0	0
46.8	T	10	90	0	0
53.3	T	25	75	0	0
57.6	T	40	60	0	0
60.2	T	30	70	0	0
62.5	T	40	60	0	0
66.0	T	40	60	0	0
71.9	T	40	45	0	20
79.0	T	45	55	0	0
82.4	T	35	65	0	0
86.1	T	50	50	0	0
90.0	T	50	50	0	0
94.0	T	30	70	0	0
100.0	T	60	40	0	0
103.0	T	50	50	0	0
111.0	T	45	40	15	0
118.9	U	80	20	trace	0
122.0	U	65	30	5	0
125.6	U	50	45	5	0
127.5	U	50	40	10	0
134.0	U	15	60	0	25
138.2	U	55	trace	30	10
141.7	U	30	0	70	0
147.5	U	70	0	30	0
152.2	U	75	0	25	0
157.2	U	70	0	30	0
163.8	U	85	0	15	0
168.7	U	20	80	0	0
169.4	U	70	30	0	0

Table 2. Results from semi-quantitative X-ray analysis of Collier-Seminole State Park core -- continued

Depth (ft)	Fm.	Mineral Composition (percent)			
		Quartz	Calcite	Dolomite	Aragonite
173.8	U	75	25	trace	0
178.3	U	70	30	0	0
180.2	U	75	25	trace	0
186.0	U	10	90	0	trace
187.5	U	70	trace	30	trace
193.2	U	85	0	15	0

sandstone in samples examined from 111 to 81 ft, to a very sandy molluscan packstone in samples examined from 79 to 54 ft, to a molluscan wackestone to packstone in samples examined from 54 to 20 ft. Mollusks and benthic foraminifers are common throughout the formation; planktonic foraminifers are present from 97 to 75 ft.

The calcareous sandstone (samples from 111 to 81 ft) varies from 5 to 20 percent micrite matrix and generally contains molluscan molds and fragments, benthic and planktonic foraminifers, ostracodes, bryozoans, red algae, and echinoids. In general, this interval has a high porosity due to the low micrite content and high interparticle porosity. There is commonly a meniscus micrite cement at quartz grain contacts. In most samples, the mollusk shells are micritized and then leached, but are not infilled with blocky or sparry cement, as is common in other parts of the core. There is commonly a single layer of dogtooth calcite spar on molluscan micrite envelopes and on skeletal grain surfaces.

The very sandy packstone from 79 to 54 ft is similar to the underlying sandstone but with less quartz sand and more skeletal grains. From 79 to about 65 ft, the packstone has only minor blocky and dogtooth calcite cement on surfaces such as skeletal grains and molds. Porosity in that zone is moderate to high, and micrite matrix varies from 10 to 20 percent. However, from 65 to 50 ft, there is a pronounced increase in pore-filling cement, and consequently a decrease in porosity; neomorphism of matrix occurs from 60 to 47 ft.

A molluscan wackestone to packstone occurs from 54 to 24 ft. Sand content decreases abruptly at about 54 ft from 40 to 5 percent. The pore-filling cement is typically blocky. Original molluscan aragonite is preserved from about 54 to 24 ft, and there is evidence for a now-leached, early, probably aragonitic isopachous, bladed to fibrous cement in samples from about 40 to 24 ft.

Lithologic and petrographic summary. There are at least four depositional units in the unnamed formation at this site. From 194.6 to 181 ft is an unfossiliferous, laminated dolostone to unconsolidated dolomitic quartz sand. From 181 to 166 ft is a calcareous bimodal sandstone with rounded molluscan fragments. The top of this sandstone is pale orange suggesting subaerial exposure. This unit is tentatively interpreted as a high energy beach, or perhaps eolian, deposit. It also forms a tight confining unit (Weedman and others, 1997).

Overlying the bimodal sandstone is another dolostone, from 166 to 140 ft, that is quartz-rich at the base (which may be due to re-mobilized sand from the lower unit) and more dolomicritic near the top. The dolostone has relatively few skeletal grains and some desiccation cracks, and may have formed in a supratidal environment.

The dolostone is overlain by an unconsolidated, clayey siliciclastic unit at 140 ft that grades upward into a calcareous

Table 3. Dinocyst occurrences

	Collier-Seminole State Park									Old Pump		Fakahatchee Strand Ranger Station									
	R5195A	R5195B	R5195C	R5195E	R5195I	R5195J	R5195K	R5195L	R5195O	R5193G	R5193I	R5196A	R5196BC	R5196D	R5196E	R5196F	R5196G	R5196H	R5196I	R5196J
approx. depth (ft)	188	179	176	159	129	124	101	88	47	146	122	160	158	137	98	79	56	41	29	13
Achomosphaera andalusiense	X	.	.	.	.	X	X	X	.	.	X	.	.	X	X	.	.	.	.	.
Ataxiodinium ? n. sp.	.	.	.	.	.	.	.	X	.	.	X	.	.	.	.	.	.	.	.	.
Barssidinium sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Batiacasphaera hirsuta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Batiacasphaera sphaerica	.	.	?	.	.	.	.	.	.	.	.	.	.	?	.	.	.	.	.	.
Brigantedinium spp.	.	.	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyclopsiella sp.	.	X	.	.	.	.	.	?	.	.	.	.	.	?	?	.	.	.	.	.
Dapsilidinium pseudocolligerum	X	.	.	.	.	X	X	X	.	.	X	.	.	.	.	.	.	.	.	.
Erymnodinium delectabile	X	X	.	.	.	.	.	.	.	.	.	.	.	.	?	X	.	.	.	.
Forma D of Wrenn and Kokinos (1986)	.	.	.	.	.	.	X	.	.	X	.	.	.	.	X	.	.	.	.	.
Habibacysta tectata	.	.	.	.	.	.	.	.	.	X	.	.	.	.	X	X	.	.	.	.
Heteraulacacysta spp.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hystrichokolpoma rigaudiae	X	X	.	X	.	X	.	.	.	X	X	X	X	.	.	.	.	.	.	.
Hystrichosphaeropsis obscura	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Impagidinium paradoxum or *sphaericum*	.	.	.	.	.	.	X	.	.	.	X	.	?	.	.	.	.	.	.	.
Impagidinium patulum	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.
Impagidinium sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Invertocysta lacrymosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.
Invertocysta sp.	.	.	.	.	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.
Lejeunecysta spp.	X	.	X	.	.	X	.	.	.	X	X	.	.	.	.	.	.	.	.	.
Lingulodinium machaerophorum	X	X	X	.	X	X	X	X	.	X	X	X	X	.	X	X	.	.	.	.
Melitasphaeridium spp.	X	.	.	.	.	X	X	X	.	.	.	.	X	.	.	.	.	.	.	.
Multispinula quanta	X	.	.	.	.	X	X	X	.	X	X	.	.	X	.	X	.	.	.	.
Nematosphaeropsis spp.	X	X	.	.	.	.	.	.	.	X	.	.	X	X	X	X	.	.	.	.
Operculodinium spp.	X	X	X	X	.	X	X	X	.	X	.	X	X	X	X	X	X	X	.	X
Polysphaeridium zoharyi	.	X	X	X	X	X	X	X	X	X	X	.	.	.	.	?	.	.	.	X
Quadrina ? *condita*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Reticulatasphaera actinocoronata	.	.	.	.	.	.	.	X	.	.	X	.	.	.	.	.	.	.	.	.
Selenopemphix armageddonensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.
Selenopemphix brevispinosa brevispinosa	.	X	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.
Selenopemphix brevispinosa conspicua	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Selenopemphix spp.	.	X	.	.	.	X	.	X	.	X	X	.	.	.	.	?	.	.	.	.
Spiniferites mirabilis	.	.	.	.	.	X	X	.	.	.	X	X	.	.	X	X	.	.	.	.
Spiniferites pseudofurcatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spiniferites spp.	.	X	X	X	X	X	X	X	.	X	X	X	X	X	X	X	.	.	X	.
Sumatradinium spp.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tectatodinium pellitum	X	X	.	.	.	X	X	.	.	.	X	.	.	X	X	.	.	.	.	.
Trinovantedinium harpagonum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trinovantedinium papulum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trinovantedinium spp.	X	X	.	.	.	X	.	.	.	.	.	.	?	.	.	.	.	.	.	.
Trinovantedinium xylochoporum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tuberculodinium vancampoae	X	X	.	.	.	X	X	X	.	X	X	X	X	X	X	X	.	.	.	.
misc. Congruentidiaceae	X	X	.	.	.	X	X	.	.	.	X	.	X	X	X	X	.	.	.	.

Table 3. Dinocyst occurrences

	Gate 12				Jones Grade			Picayune Strand					S. States		
	R5194 A	R5194 C	R5194 E	R5194 F	R5222 C	R5222 H	R5222 K	R5223 A	R5223 D	R5223 F	R5223 I	R5223 J	R5221 A	R5221 G	R5221 J
approx. depth (ft)	218	126	88	63	185	142	57	188	153	91	34	13	205	98	9
Achomosphaera andalusiense	.	X	X	.	.	X	X	.	.	.	.	.	.	X	.
Ataxiodinium ? n. sp.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.
Barssidinium sp.	.	.	.	?	.	.	.	.	.	.	.	.	.	.	.
Batiacasphaera hirsuta	.	.	.	.	.	.	?	.	.	?	.	.	.	?	.
Batiacasphaera sphaerica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Brigantedinium spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyclopsiella sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dapsilidinium pseudocolligerum	.	X	X	.	.	.	X	.	.	X	.	.	.	.	.
Erymnodinium delectibile	X	X	.	.	X	X	.	X	.	.	.	.	X	X	.
Forma D of Wrenn and Kokinos (1986)	.	.	X	.	.	.	.	.	X	.	.	.	.	X	.
Habibacysta tectata	.	.	X	?	?	X	.	.	X	.	.	.	.	.	.
Heteraulacacysta spp.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hystrichokolpoma rigaudiae	.	X	X	.	.	.	.	X	X	.	.	.	X	.	.
Hystrichosphaeropsis obscura	X	.	.	.	.	.	.	X	.	.	.	.	X	.	.
Impagidinium paradoxum	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.
Impagidinium patulum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Impagidinium sp.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.
Invertocysta lacrymosa	.	.	.	.	X	.	.	.	.	.	X	.	.	.	.
Invertocysta sp.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.
Lejeunecysta spp.	X	X	.	X	X	X	.	.	.	.	.	.	X	X	.
Lingulodinium machaerophorum	X	X	X	.	X	X	X	X	X	X	X	.	X	X	.
Melitasphaeridium spp.	.	.	.	.	.	X	X	.	.	.	.	.	.	X	.
Multispinula quanta	X	X	.	X	X	X	?	X	.	.	.	.	X	X	.
Nematosphaeropsis spp.	X	X	X	.	.	.	.	X	.	.	.	.	X	.	.
Operculodinium spp.	X	X	X	X	X	X	X	X	X	X	X	.	X	X	.
Polysphaeridium zoharyi	.	X	.	X	.	.	.	X	.	X	.	X	X	X	X
Quadrina ? condita	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.
Reticulatasphaera actinocoronata	.	.	.	.	.	.	X	.	.	.	.	.	.	X	.
Selenopemphix armageddonensis	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.
Selenopemphix brevispinosa brevispinosa	X	X	.	.	X	.	.	.	.	.	.	.	X	.	.
Selenopemphix brevispinosa conspicua	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.
Selenopemphix spp.	X	.	.	X	X	.	.	.	.	X	.	.	.	.	.
Spiniferites mirabilis	X	X	.	.	.	.	X	.	.	.	X	.	.	X	.
Spiniferites pseudofurcatus	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.
Spiniferites spp.	X	X	X	X	X	X	X	X	X	X	X	.	X	X	.
Sumatradinium spp.	X	.	.	.	.	.	.	.	X	.	.	.	X	X	.
Tectatodinium pellitum	X	X	X	.	X	.	X	.	X	X	X	.	X	X	.
Trinovantedinium harpagonum	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
Trinovantedinium papulum	.	X	.	X	.	.	.	.	.	.	.	.	.	.	.
Trinovantedinium spp.	X	.	.	.	X	X	.	.	.	.	.	.	X	.	.
Trinovantedinium xylochoporum	.	.	.	.	X	X	.	.	.	.	.	.	.	.	.
Tuberculodinium vancampoae	X	X	.	X	X	X	X	X	X	X	.	.	.	X	.
misc. Congruentidiaceae	.	.	.	X	.	.	X	.	X	.	.	.	X	X	.

unconsolidated sand, a limestone at 133 ft, and a dolostone at 129.5 ft to the top of the unit at 128 ft. All lithologic transitions are gradational, and the interval from 140 to 128 ft may represent a single upward-shallowing depositional unit. The phosphatic content, the borings, and dense cementation at 128 ft indicate a submarine hardground. At this site, the dense zone from about 133 to 128 ft forms the first major confining unit below the water table aquifer in the surficial aquifer system. Contact with the overlying unconsolidated quartz sand is sharp.

Deposition appears continuous for the Ochopee Limestone Member of the Tamiami, and a sudden decrease in delivery of quartz sand to the depositional environment is evident at about 54 ft. Planktonic foraminifers occur in samples from 97 to 75 ft, and these sediments may represent the most open marine environment in this core, or perhaps a zone where planktonic foraminifers were not dissolved. Samples from all other depths contain only benthic foraminifers.

Most upward porosity and permeability changes in the Ochopee Limestone can be attributed to diagenetic rather than depositional processes. Porosity is controlled by the distribution of micrite matrix and pore-filling blocky cement. The most porous zone is from 110 to 65 ft, and this zone has a low micrite content (5 to 20 percent). The most cemented zone is from about 60 to 24 ft, where blocky calcite fills most pore space. Neomorphic microspar and the abundance of blocky calcite coincide with the preservation of aragonitic skeletal grains, which may have been protected from dissolution by early calcite cement. An early aragonitic cement that preceded precipitation of blocky calcite occurs from 47 to at least 24 ft and is now leached, perhaps by modern meteoric water. The thin, isopachous, aragonitic cement may occur deeper in the core and be overgrown by calcite cement, obscuring its presence.

Biostratigraphy. Eighteen samples were examined for dinocysts; nine yielded dinocysts (appendix 2, table 3). Samples from 188, 179, and 176 ft contain late middle or late Miocene assemblages including *Achomosphaera andalousiensis* Jan du Chêne, *Erymnodinium delectabile* (Verteuil & Norris) Lentin et al., and *Hystrichosphaeropsis obscura* Habib. Samples from 159 and 130 ft contain long-ranging species. Samples from 124, 101, and 88 ft contain *Achomosphaera andalousiensis*, *Dapsilidinium pseudocolligerum* (Stover) Bujak et al., and *Invertocysta* sp. They are of late middle or late Miocene or Pliocene age, and because they are above the highest occurrence of *E. delectabile* and *H. obscura*, they may be Pliocene. Higher samples were either nondiagnostic or barren.

Forty-three samples were examined for molluscan faunal content; eleven samples from 86 to 26 ft contained material identified for this report (table 4). Three samples from 85.5 to 83.5 ft contain only questionably identified forms. Eight samples from 76 to 26 ft are Pliocene, based primarily on the occurrence of *Anadara lienosa*, *Carditimera arata*, and *Chione cortinaria* ?. *Anadara lienosa* occurs in molluscan zone M5 of Blackwelder (1981) as well as younger material. Zone M5 is mid-early through late Pliocene and includes the upper portion of the Yorktown Formation. *Carditimera arata* has been reported from the Pinecrest Beds of the Tamiami Formation and the Caloosahatchee faunal unit in Florida, and from the Yorktown (upper portion), Raysor, Chowan River, and James City Formations in the mid-Atlantic Coastal Plain (Ward, 1992a). These units are late Pliocene (or possibly late early Pliocene) to Pleistocene in age. *Chione cortinaria* is questionably identified in two samples (38 and 26 ft); this species is restricted to molluscan zone M6 (lower Pliocene = Zone 1 Yorktown) and has been reported from the Sunken Meadow Member, the lowest member, of the Yorktown Formation and the *Ecphora* zone of the Jackson Bluff Formation (Mansfield, 1932; Lyle Campbell, written communication, 1997). The overlap of species from molluscan zone M6 and M5 indicates that either the identification is incorrect or the published ranges should be extended to include overlap near the lower/upper Pliocene boundary. *Turritella apicalis* and *T. perattenuata* have been reported from the Caloosahatchee faunal unit (Dubar, 1958); however, data from the Fakahatchee-Ranger Station and Fakahatchee Gate 12 cores indicate that the full ranges of these species may be much longer.

Eight samples were examined for foraminifers (table 5). Six of these samples yielded planktonic forms, and five of these

Table 4. Molluscan faunal occurrences

Core	Collier Seminole State Park W-17360											Old Pump Road W-17361								
Depth in Core (ft)	85.5	84.0-84.3	83.5-84.0	75.8-76.0	75.3-75.5	72.0-72.5	56.5	38	29	28.7	26	195.9	188.1	107	95.8	86.2-86.4	67.9	64.7	50.3-50.5	26.5
Species																				
Gastropoda:																				
Buscycon pyrum ?	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.
Conus chipolanus ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crepidula costata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crepidula plana ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crucibulum grande	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crucibulum multilineatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	?	.	.	.	.	.
Marginella sp. aff. *M. precursor*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mitra sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Olivella mutica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Terebra aclinica ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trochita floridana ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Turritella apicalis	.	.	.	.	.	.	X	?	X	.	.	.	.	.	.	.	.	.	.	.
Turritella perattenuata	.	.	.	.	.	.	X	?	.	X	.	.	.	.	.	X	.	?	?	?
Turritella pontoni	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Turritella segmenta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Turritella subvariabilis	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.
Pelecypoda:																				
Anadara callicestosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Anadara lienosa	?	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arcinella cornuta	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arcopsis adamsi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carditimera arata	.	.	.	X	.	.	.	.	.	.	X	.	.	.	.	.	?	.	X	.
Carditimera apotegea ?	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.
Chione cancellata ?	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chione cortinaria ?	.	.	.	.	.	.	.	X	.	.	X	.	.	.	.	.	.	.	.	.
Chione latilirata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chione procancellata	.	?	?	.	.	.	.	.	.	.	.	.	.	?	.	.	.	.	.	.
Costaglycymeris mixoni ? [=*Glycymeris tumulus* of Gardner]	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gemma magna	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Perna sp. aff. *P. conradina*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Parvilucina multilineata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trigoniocardia sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Indicated Ages	?			Pliocene								Miocene		?					Plio. or e. Pleist.	
Age range indicated for each sample, based on published species ranges. (Asterisk (*) indicates data gathered in this study imply published ranges need revision. Slash (/) indicates contradictory published age information within sample.)	?	?	?	mid-early Pliocene-early Pleistocene	middle Miocene-Recent	mid-early-late Pliocene (M5)	* late Pliocene-Pleistocene	? early Pliocene (M6)	* late Pliocene-Pleistocene	* late Pliocene-Pleistocene	early Pliocene	late early-early middle/late Miocene	late early-early middle Miocene	?	?	* late Pliocene-Pleistocene	?	?	mid-early Pliocene-early Pleistocene	?

Table 4. Molluscan faunal occurrences

Core	Fakahatchee Strand-Ranger Station W-17393																				
Depth in Core (ft)	132-133	126-129	123-126	113.4-121	98.1-98.5	97.4	96.4-97.0	83-87	80-81	79-80	77-78	60	57.5	52.5-52.8	46-47	40-42	37-40	34.2-34.5	24.9-25.3	22.2-22.8	12	11.0-11.4
Species																						
Gastropoda:																						
Buscycon pyrum ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Conus chipolanus ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crepidula costata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crepidula plana ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crucibulum grande	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crucibulum multilineatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
Marginella sp. aff. *M. precursor*	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.
Mitra sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X
Olivella mutica	.	.	.	.	.	.	.	?	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Terebra aclinica ?	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.
Trochita floridana ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Turritella apicalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Turritella perattenuata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	?
Turritella pontoni	X	X	X	.	.	.	.	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.
Turritella segmenta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Turritella subvariabilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pelecypoda:																						
Anadara callicestosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Anadara lienosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arcinella cornuta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arcopsis adamsi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carditimera arata	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.
Carditimera apotegea ?	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chione cancellata ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chione cortinaria ?	.	.	.	.	.	.	.	.	.	.	.	X	.	.	X	X	X	?	?	.	X	X
Chione latilirata	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	?	.	.	.	.
Chione procancellata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Costaglycymeris mixoni ? [=*Glycymeris tumulus* of Gardner]	.	.	.	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gemma magna	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Perna sp. aff. *P. conradina*	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.
Parvilucina multilineata	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trigoniocardia sp.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Indicated Ages	? Miocene							Pliocene														
Age range indicated for each sample, based on published species ranges. (Asterisk (*) indicates data gathered in this study imply published ranges need revision. Slash (/) indicates contradictory published age information within sample.)	* mid-early-late Pliocene	* mid-early-late Pliocene	middle Mio./*mid-early-late Plio.	? late Miocene (M7)	? late Miocene (M7)	? late Miocene (M7)	? late Miocene (M7)	* mid-early-late Pliocene	* mid-early-late Pliocene	* mid-early-late Pliocene	* mid-early-late Pliocene	? early Pliocene (M6)	early Miocene (M13) - Recent	mid-early-late Pliocene	? early Pliocene (M6)	? early Pliocene (M6)	? early Pliocene (M6)	?	?	* late Pliocene-Pleistocene	? early Pliocene (M6)	? early Pliocene (M6)

Table 4. Molluscan faunal occurrences

Core	Fakahatchee Strand-Gate 12 W-17389																
Depth in Core (ft)	136.0-136.3	126.0-126.3	117.0-117.3	89.6-89.8	88.4-88.8	87.9-88.1	63.0-63.2	62.1-62.3	55.8-56.0	53.2-53.3	50.8-51.1	48.3-48.5	42-43	24.3-24.7	23.0-23.1	21.4-21.5	10.7-10.9
Species																	
Gastropoda:																	
Buscycon pyrum ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Conus chipolanus ?	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.
Crepidula costata	.	.	.	.	.	.	.	.	.	X	X	.	.	.	.	.	.
Crepidula plana ?	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crucibulum grande	.	.	.	.	.	.	X	.	X	X	X	X	X	.	.	.	.
Crucibulum multilineatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Marginella sp. aff. *M. precursor*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mitra sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Olivella mutica	.	.	.	.	.	.	?	.	.	.	.	.	.	.	.	.	.
Terebra aclinica ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trochita floridana ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Turritella apicalis	.	X	.	.	.	.	?	?	?	X	?	X	?	.	.	.	.
Turritella perattenuata	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.
Turritella pontoni	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.
Turritella segmenta	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Turritella subvariabilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pelecypoda:																	
Anadara callicestosa	.	.	.	X	X		X	.	.	.	.	.	.	.	.	.	.
Anadara lienosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arcinella cornuta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arcopsis adamsi	.	.	.	.	.	.	.	X	.	.	.	X	.	.	.	.	.
Carditimera arata	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.
Carditimera apotegea ?	X	.	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.
Chione cancellata ?	?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chione cortinaria ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X
Chione latilirata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chione procancellata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Costaglycymeris mixoni ? [=*Glycymeris tumulus* of Gardner]	X	X	.	.	X	X	?	.	.	.	.	.	.	.	.	.	.
Gemma magna	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pema sp. aff. *P. conradina*	.	.	.	?	X	X	?	?		?	X		.	.	.	.	.
Parvilucina multilineata	.	.	?	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trigoniocardia sp.	.	.	.	X	X	.	.	.	.	X	X	.	.	.	.	.	.
Indicated Ages	? Miocene						Miocene and (or) Pliocene							Pliocene			
Age range indicated for each sample, based on published species ranges. (Asterisk (*) indicates data gathered in this study imply published ranges need revision. Slash (/) indicates contradictory published age information within sample.)	middle Miocene / late Miocene	late Mio./ late Pliocene-Pleisto.	middle Miocene	middle Mio./mid-early-late Plio.	middle/late Mio./*early-late Plio.	middle Miocene / late Miocene	mid-early-late Pliocene	Miocene-Recent	middle Miocene - late Pliocene	middle Mio.-late Plio./*late Plio.	middle Miocene - Pleistocene	middle Mio.-late Plio./*late Plio.	middle Miocene - late Pliocene	* late Pliocene - Pleistocene	* late Pliocene - Pleistocene	* late Pliocene - Pleistocene	? early Pliocene (M6)

Table 4. Molluscan faunal occurrences

Core	Jones Grade W-17394				Picayune Strand State Forest W-17450								Southern States Utilities W-17454							
Depth in Core (ft)	67	66.3	30.1	10.0-10.3	175.1-175.5	84.7-85.0	76.7-77.0	48.5	40.4	39.2	31.4	26.5	146.3-146.5	70.1	65.5-65.8	42	41.3	35.8	35	8.3-8.5
Species																				
Gastropoda:																				
Buscycon pyrum ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Conus chipolanus ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crepidula costata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crepidula plana ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crucibulum grande	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Crucibulum multilineatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Marginella sp. aff. *M. precursor*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mitra sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Olivella mutica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Terebra aclinica ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trochita floridana ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
Turritella apicalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.	.	.
Turritella perattenuata	X	.	.	.	X	X	?	X	?	.	.	.	.	X	X	.	X	.	.	.
Turritella pontoni	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.
Turritella segmenta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Turritella subvariabilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pelecypoda:																				
Anadara callicestosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Anadara lienosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arcinella cornuta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arcopsis adamsi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carditimera arata	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	?	.
Carditimera apotegea ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chione cancellata ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chione cortinaria ?	.	X	X	X	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.
Chione latilirata	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chione procancellata	.	X	.	.	.	.	?	.	.	.	.	X	.	.	.	.	.	.	.	?
Costaglycymeris mixoni ? [=*Glycymeris tumulus* of Gardner]	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gemma magna	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Perna sp. aff. *P. conradina*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Parvilucina multilineata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trigoniocardia sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Indicated Ages	?	Pliocene			?					Pliocene			?	? Pliocene					?	
Age range indicated for each sample, based on published species ranges. (Asterisk (*) indicates data gathered in this study imply published ranges need revision. Slash (/) indicates contradictory published age information within sample.)	* late Pliocene - Pleistocene	? early Pliocene/late Pliocene	mid-early-late Pliocene (M5)	? early Pliocene	* late Pliocene - Pleistocene	* late Pliocene - Pleistocene	?	* late Pliocene - Pleistocene	?	mid-early-late Pliocene (M5)	? early Pliocene (M6)	late Pliocene	* mid-early-late Pliocene	* late Pliocene - Pleistocene	* late Pliocene - Pleistocene	* late Pliocene - Pleistocene	* late Pliocene - Pleistocene	late Pliocene	?	?

yielded identifiable, age-diagnostic planktonic species. The sample at 127.5-128 ft contains the early Miocene species *Globigerinoides altiapertura* Bolli. The sample at 126.5-126.8 ft could be either middle Miocene or late Miocene without definitive late Miocene taxa. Samples from 126 to 119 ft are late, but not latest, Miocene, based on the overlap of ranges of *Globigerina praebulloides* Blow and *Globigerina apertura* Cushman.

Table 5. Foraminifer occurrences in the Collier-Seminole State Park core

Species / Depth (ft)	Collier-Seminole				
	approx. 127.5-128.0*	approx. 126.5-126.8*	125.6-126.0	123.6-124.0	118.9-119.2
Globigerinoides trilobus	.	.	.	X	.
Globigerinoides obliquus	.	.	.	X	X
Globigerina apertura	.	.	X	X	X
Globigerinoides praebulloides	.	X	.	X	X
Globigerinoides immaturus	X	X	.	.	.
Globigerinoides altiapertura	X	.	.	.	.
Globigerina woodi	X	.	.	.	.

*excess core recovered, depth ranges are approximate

Strontium-isotope stratigraphy. Eight samples (including one duplicate pair) were analyzed for strontium isotopes (table 6). The lowest sample at 171.5 ft gives a calculated age of 9.17 Ma $\pm$ 0.5 m.y. (late Miocene). Higher samples from 105 to 26.6 ft have calculated ages of 5.1 to 3.88 Ma $\pm$ 1.5 m.y. (early Pliocene, but with a margin of error that includes both latest late Miocene and late Pliocene).

Age summary. The unnamed formation (194 to 111 ft) is late Miocene in the Collier-Seminole core. Near the bottom, the unit contains late middle or late Miocene dinocysts and has a calculated age of 9.2 Ma. Planktonic foraminifers at 127.5-128 ft indicate reworked early Miocene forms just above a prominent exposure surface. In the upper part of the unit, dinocysts indicate an age of Miocene or Pliocene, and planktonic foraminifers indicate a late, but not latest, Miocene age.

The Ochopee Limestone Member of Tamiami Formation (111 to 20 ft) is Pliocene and spans an interval of time from the early Pliocene to near the early/late Pliocene boundary (the boundary is 3.55 Ma on the timescale of Berggren and others, 1995). The dinocysts indicate that samples from this unit up to 88 ft are no younger than Pliocene. Strontium-isotope stratigraphy indicates an early Pliocene age throughout the unit, and calculated ages range from 5.1 to 3.9 Ma with a margin of error that includes late Miocene and late Pliocene. Pliocene mollusks are found from 76 to 26 ft.

The undifferentiated quartz sand (20 to 5 ft) is undated. It overlies material containing late Pliocene mollusks.

Old Pump Road core

The Old Pump Road corehole site (fig. 1, table 1) is near the intersection of Union Road with Old Pump Road, on the South Florida Water Management District easement on the east side of the Faka Union Canal, about 1/4 mile behind the Port of the Islands Resort, north of U.S. Route 41. Drilling was completed in March 1996 to a depth of 196 ft. The core (fig. 4) was sampled for thin sections, X-ray diffraction, strontium analysis of shells, and for its foraminifer, mollusk, ostracode, pollen, and dinocyst content.

Core recovery was very poor in this corehole, and depths, therefore, are uncertain. From 196 to 111 ft is the unnamed formation. The unit is moderately well-lithified dolostone and limestone from 196 to 171 ft and is overlain by unconsolidated calcareous quartz sand. Well-lithified limestone of the Ochopee Limestone Member of the Tamiami Formation occurs from about 101 to 17 ft (moderate induration from 111-101 ft). Sediments from about 29 to 17 ft include limestone rubble, sand, and more limestone. The sand may be a channel-fill into the Ochopee. From about 17 to 3 ft is an unconsolidated sand. The upper 3 feet of sediment in this core appears to be man-made fill.

Semi-quantitative, X-ray diffraction results for this core are shown in table 7. Quartz sand is common in most samples analyzed from the unnamed formation, including the limestones and dolostones from

Table 6. Strontium-isotope analyses

[Fm. = Formation; do. =ditto; T=Tamiami, U=unnamed; dup.=duplicate sample]

Core Name	depth (ft)	Fm.	$^{87/86}Sr$*	plus/-	AGE (Ma†)	AGE plus/-	Notes
Collier-Seminole	26.6	T	0.709060	0.000004	3.88	1.5	
do.	50.0	T	0.709053	0.000005	4.42	1.5	
do.	65.0	T	0.709054	0.000004	4.34	1.5	
do.	77.0	T	0.709039	0.000004	5.10	0.5	dup.
do.	77.0	T	0.709054	0.000004	4.34	1.5	dup.
do.	93.4	T	0.709053	0.000006	4.42	1.5	
do.	105.0	T	0.709051	0.000006	4.57	1.5	
do.	171.5	U	0.708920	0.000006	9.17	0.5	
Old Pump Road	27.3	T	0.709057	0.000007	4.11	1.5	
do.	67.4	T	0.709055	0.000006	4.26	1.5	
do.	141.0	U	0.708998	0.000004	5.86	0.5	
do.	170.8	U	0.709009	0.000004	5.70	0.5	dup.
do.	170.8	U	0.709007	0.000005	5.73	0.5	dup.
do.	188.1	U	0.708923	0.000005	9.06	0.3	
do.	189.1	U	0.708924	0.000006	9.03	0.3	
do.	190.0	U	0.708921	0.000004	9.13	0.5	
do.	195.1	U	0.708922	0.000005	9.10	0.3	dup.
do.	195.1	U	0.708912	0.000005	9.48	0.4	dup.
Fak. Strand-RS	27.6	T	0.709054	0.000005	4.34	1.5	
do.	44.0	T	0.709049	0.000005	4.69	1.5	
do.	70.0	U	0.708993	0.000006	5.93	0.5	dup.
do.	70.0	U	0.708990	0.000004	5.98	0.5	dup.
do.	76.5	U	0.708987	0.000005	6.04	0.5	
do.	91.4	U	0.708966	0.000006	6.61	0.5	
do.	127.5	U	0.708968	0.000006	6.49	1.0	
do.	132.5	U	0.708985	0.000006	6.08	0.5	
do.	159.5	U	0.708941	0.000005	7.78	1.5	
Fak. Strand-Gate 12	12.5	T	0.709053	0.000003	4.42	1.5	
do.	24.5	T	0.709053	0.000004	4.42	1.5	
do.	48.0	U	0.708991	0.000006	5.96	0.5	
do.	58.4	U	0.708984	0.000007	6.10	0.5	
do.	66.2	U	0.708986	0.000004	6.06	0.5	
do.	126.2	U	0.708960	0.000005	6.84	1.0	
do.	218.6	U	0.708927	0.000004	8.92	0.3	
Picayune Strand SF	25.0	T	0.709063	0.000005	3.66	1.5	
do.	44.0	T	0.709055	0.000006	4.26	1.5	
do.	84.7	T	0.709044	0.000004	4.90	1.5	

*Ratios corrected to 0.709175, which is the value of EN-1 used by Howarth and McArthur (1997).
†Ages are assigned using the data table of Howarth and McArthur (1997). The data from 0-7 Ma use the time scale of Shackleton and others (1994); the rest of the data use the time scale of Cande and Kent (1995).

Table 7. Results from semi-quantitative X-ray analysis of Old Pump Road core

[Semi-quantitative analysis for quartz, calcite, dolomite, and aragonite. Other minerals, which may include potassium feldspar, plagioclase, muscovite, and (or) apatite, are assumed to represent less than five percent of each sample. Under Fm. (formation), T=Tamiami, U=unnamed, sand=undifferentiated sand and possible channel-fill. Results are to the nearest five percent and do not necessarily add up to 100 percent. "Trace" refers to minerals present but less than five percent of the sample]

Depth (ft)	Fm.	Mineral Composition (percent)			
		Quartz	Calcite	Dolomite	Aragonite
6.0	sand	100	trace	0	0
11.7	sand	100	0	0	0
17.0	sand	100	trace	0	0
24.3	sand	100	0	0	0
29.8	T	10	90	0	0
39.7	T	0	100	0	0
50.5	T	trace	100	0	0
64.5	T	5	95	0	0
74.4	T	trace	95	0	0
81.8	T	5	70	0	25
88.8	T	25	70	5	0
91.8	T	40	60	0	0
95.2	T	35	65	trace	0
110.5	T	75	20	trace	trace
114.7	U	45	50	trace	trace
122.8	U	70	25	5	0
127.9	U	80	trace	trace	15
130.7	U	90	10	0	0
133.5	U	100	0	trace	0
136.4	U	80	20	0	trace
141.0	U	90	5	trace	0
146.3	U	100	trace	0	trace
160.8	U	100	0	0	0
165.3	U	100	trace	0	0
169.8	U	95	5	0	trace
175.8	U	40	0	50	15
180.3	U	10	15	55	20
183.1	U	15	5	60	15
188.9	U	trace	70	0	30
190.4	U	5	70	0	25

the lower part of the formation. Calcite is the dominant mineral in samples near the base of the core from 190.4 to 188.9 ft and a minor component in most of the samples from the formation. Dolomite is rare in most of the core except in samples from 183.1 to 175.8 ft. It occurs in trace amounts in higher samples. Aragonite is rare in most of the core, but well represented from 190.4 to 175.8 ft, and in trace amounts in the depth range of 169.8 to 110.5 ft. Within the Ochopee Limestone Member of the Tamiami, calcite is a subordinate mineral that forms cement for the quartz sandstone at 110.0 ft. In samples from 96.2 to 29.8 ft, calcite is the primary mineral. Aragonite constitutes 25 percent of the sample at 81.8 ft.

Petrography. Eleven thin sections were made from samples of the unnamed formation in the Old Pump Road core. This unit is highly variable in composition and texture, from a molluscan wackestone-packstone to sandy dolostone to unconsolidated quartz sand and silt.

Samples from 195.2 to 186.1 ft are similar in composition and texture, typically a pisolitic molluscan wackestone with 5 to 20 percent medium quartz sand. The sample at 189.1 ft is anomalous in that the micrite does not form a matrix but coats grains, and this sample may be called a grainstone. Skeletal grains in this depth range include mollusks with some original aragonite still present (table 7), benthic foraminifers, ostracodes, echinoid and coral fragments, and barnacles. Mollusks, coral, and foraminifers show some leaching. Porosity is typically moldic and in vugs and channels, and there is minor precipitation of a sparry calcite cement on void surfaces in most samples. Pisolites are common to all but the deepest sample. The core at 186 ft is pale orange and distinctly different in texture and color from the overlying limestone and dolostone.

The sample at 184.0 ft is a molluscan wackestone with about 20 percent medium quartz and 40 percent micrite matrix. It differs in several ways from the underlying rock in the absence of pisolites, a greater amount of micrite matrix, a greater amount of blocky void-filling cement, and a yellowish-gray color instead of pale orange. The skeletal grains are similar with molluscan molds and fragments, benthic foraminifers, ostracodes, and echinoid fragments.

Overlying the molluscan wackestone, in a gradational contact, is a dolostone that extends from 186 to 171 ft (table 7). The samples at 176.6, 176.8, and 180.9 ft contain small amounts of biogenic calcite (mollusks, ostracodes, bryozoans, red algae) and peloidal mud clasts in a dolomicrite matrix and dolospar on void surfaces. Quartz-sand content of the dolostone decreases from the base to the top of this interval from 30 to 10 percent; sand ranges from fine to medium. Skeletal grain concentration decreases upward; grains include mollusks, ostracodes, bryozoans, and red algae at 180.9 to 176.6 ft, and sparse foraminifer and molluscan molds at 174.8 ft.

There is unconsolidated quartz sand from 171 to 111 ft that is part of the unnamed formation. No thin sections were made of this sand, which was described by Weedman and others (1997).

Thirteen thin sections were made of samples from the Ochopee Limestone Member from the Old Pump Road core. The member ranges from 111 to 17 ft and is primarily a molluscan wackestone to packstone, with abundant quartz sand from 111 to 75 ft. The lower four samples from 95.5 to 74.7 ft are recrystallized; skeletal grains are difficult to identify, the matrix is a microspar to blocky calcite (neomorphosed micrite), and voids are lined with dogtooth spar. Aragonite shells are preserved in samples from 95.5 to 74.7 ft and from 56.4 to 39.2 ft. Planktonic foraminifers occur in samples from 86 to 64.6 ft.

There is a reduction in quartz-sand content at about 75 ft depth, and the overlying limestone has less than 5 percent quartz silt and sand in the matrix. Skeletal grains include benthic and planktonic foraminifers (to 64.6 ft; only benthics occur in higher samples), molluscan molds and fragments, echinoid fragments, ostracodes, bryozoans, and barnacles. Nearly all skeletal grains are bored in the sample from 39.2 ft; leaching typically occurs in the mollusks and some foraminifers.

Evidence for an early, leached fibrous cement is seen in samples from 56.4 to 47.6 ft as fibrous-shaped space between echinoid fragments and in the syntaxial overgrowths, and as a similar jagged void around mollusk grains. Fragments of aragonitic mollusks are preserved in this depth interval as well. Several of the samples higher in the core have traces of quartz silt.

Lithologic and petrographic summary. At least two carbonate and one siliciclastic depositional units occur within the unnamed formation. The lower one, a sandy limestone, occurs from the bottom of the core, and probably deeper, to about 186 ft. The top of this unit is identified by the pale orange color, typically associated with subaerial exposure, and the occurrence of pisoids, commonly associated with vadose and pedogenic processes.

The second carbonate unit is predominantly a dolostone and ranges from 186 to 171 ft; it exhibits an upward decrease in quartz sand from 180.9 to 171 ft. An oyster bed occurs between this dolomite and the overlying unconsolidated quartz sand at 171 ft.

The Ochopee Limestone Member of the Tamiami Formation in this core is similar to that in the core at Collier-Seminole State Park, in that it appears to be one depositional unit of a sandy wackestone at the base and a nearly sand-free wackestone-packstone in the upper part. There is a zone of planktonic foraminifers from 86 to 64.6 ft and evidence for a now-leached fibrous (perhaps aragonite) cement in the upper part of the formation (56.4 to 47.6 ft). The uppermost samples do not show an early cement; however, in those samples the grains are surrounded with micrite and do not provide a nucleation surface for cements to precipitate.

Biostratigraphy. Although nine samples were examined for dinocysts, only two contain them (appendix 2, table 3). The sample at 146 ft is middle or late Miocene based on the overlapping ranges of *Habibacysta tectata* Head et al. and *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa*. The sample at 120 ft could be middle Miocene, late Miocene, or Pliocene, based on the dinocysts present. The assemblage is similar to the samples from 101 and 88 ft in the Collier-Seminole core; however, the absence of typical late Miocene forms is less compelling in the Old Pump Road core because so many lower samples were unproductive.

Twelve samples were examined for molluscan faunal content. Nine samples from 196 to 27 ft contained mollusks identified for this report (table 4). Two samples from 195.9 and 188.1 ft contain late early to early middle and late Miocene mollusks. *Turritella subvariabilis*, present at 195.9 ft, has been reported from the lower upper Miocene, molluscan zone M9 (Ward, 1992b). *Carditimera apotegea* (questionably identified at 195.9 and 188.1 ft) was reported from the Chipola Formation and ?Oak Grove Sand (upper lower and (or) lower middle Miocene). Identifiable mollusks are sparse in the samples from 107 to 26.5 ft. The sample at 86 ft contains *Turritella perattenuata* and the sample at 50.3 ft contains *Carditimera arata*. According to published range data for *T. perattenuata*, samples containing this species should be restricted to the late Pliocene or early Pleistocene. Data gathered in this study, however, indicate *T. perattenuata* may have a much longer range than previously discovered. *Carditimera arata* has been reported from the Pinecrest Beds of the Tamiami Formation and the Caloosahatchee faunal unit in Florida, and from the Yorktown (upper portion), Raysor, Chowan River, and James City Formations in the mid-Atlantic region (Ward, 1992a). These units are late Pliocene (or possibly late early Pliocene) to Pleistocene in age.

Strontium-isotope stratigraphy. Samples in the lower part of the core (195 to 188 ft) produce calculated ages of 9.5 to 9.0 Ma $\pm$ 0.5 m.y. (late Miocene). Samples somewhat higher (170.8, 141 ft) yield younger calculated ages around 5.8 Ma $\pm$ 0.5 m.y. (very late Miocene). Two higher samples (67, 27 ft) yield calculated ages around 4 Ma $\pm$ 1.5 m.y. (early Pliocene, but with a margin of error that includes both latest late Miocene and late Pliocene) (table 6).

Age summary. The unnamed formation (196 to 101 ft) in the Old Pump Road core is late Miocene from the base up to about 140 ft. Strontium-isotope stratigraphy indicates that the lithologic break at 171 ft is an unconformity that represents a hiatus of approximately 2 m.y. Dinocysts and mollusks corroborate the strontium-derived Miocene age up to 146 ft. Material above this could be either late Miocene or Pliocene, on the basis of the dinocysts present.

The Ochopee Limestone Member of the

Tamiami Formation (111 to 17 ft) is Pliocene. Mollusks suggest a Pliocene and (or) Pleistocene age, which is consistent with strontium-isotopes analysis (early Pliocene age with a margin of error that includes the latest Miocene and the late Pliocene).

The unnamed, undifferentiated quartz sand (17 to 3 ft) is undated. It overlies material containing late Pliocene and (or) early Pleistocene mollusks.

Fakahatchee Strand-Ranger Station core

The Fakahatchee Strand-Ranger Station corehole site (fig. 1, table 1) was drilled to the east of a group of cypress trees between the ranger's residence and the headquarters office of the Fakahatchee Strand State Preserve. It was drilled to 161 ft in April 1996. The core (fig. 5) was sampled for thin sections, X-ray diffraction, strontium analysis of shells, and for mollusk, foraminifer, pollen, dinocyst, and ostracode content.

The unnamed formation is found from the bottom of the core at 161 ft to a depth of 61.5 ft. It is an unconsolidated, calcareous, medium to coarse, quartz sand that contains a relatively thin dolomite-cemented sandstone from 149 to 139 ft. From 139 to 137 ft, quartz and phosphate discoidal pebbles were observed in a dolomitic quartz sand that continues upward. From 61.5 to 4 ft is the Ochopee Limestone Member of the Tamiami Limestone. The unit is poorly recovered in this core and consists of white to gray to yellowish-gray, moldic, molluscan packstone to wackestone with minor amounts of quartz sand. At 61.5 to 61.0 ft, there is a 6-inch-thick, tightly calcite-cemented sandstone, which forms a confining unit of the aquifer at this site (Weedman and others, 1997). At about 48 ft, the limestone grades into a very sandy limestone to calcareous sandstone. The upper 4 feet of sediment is artificial fill.

X-ray diffraction data for the lower part of this core, unnamed formation only, are shown in table 8. Quartz sand is common in most samples analyzed, including the limestones and dolostones. Calcite is rare except at 138.4 ft. Dolomite is present in trace amounts at 158.8, is a major component in samples from 148.8 to 138.4 ft, and is not observed in any shallower samples. Aragonite occurs in small amounts in most samples from 158.8 to 110.3 ft.

Petrography. One thin section was made from the unnamed formation in this core. It is a dolostone from 139.8 ft with minor quartz sand in a dolomicrite matrix. The only skeletal grains that can be recognized are now-leached molluscan molds. There was no additional precipitation of dolomite cement after dissolution of skeletal grains.

Between this dolomite and the Tamiami Formation is a thick interval of unconsolidated quartz sand; some portions are quite shelly with aragonitic mollusks.

One thin section was made of a lithified portion of the Ochopee Limestone Member of the Tamiami Formation at 61.5 ft. It is a calcareous sandstone interbedded with a pisolitic mudstone to wackestone. There are no skeletal grains and the sample has extremely low porosity.

Eight additional thin sections were made from samples of the Ochopee Limestone Member. Samples at 53.8 and 51.5 ft are similar molluscan wackestone to packstones, with 10 to 20 percent quartz silt to medium sand. They contain molluscan fragments and molds, foraminifers, ostracodes, bryozoans, echinoids, and barnacles. The lower sample has some microspar in the matrix, and porosity in both is moldic. Planktonic foraminifers occur at 53.8 and at 34.0 ft. Cement in the lower part of the formation is typically very fine dogtooth calcite.

From 34 to 8.3 ft, the Ochopee Limestone Member is a molluscan packstone to grainstone that has less micrite matrix and considerably less quartz silt and sand than the lower part has. There is evidence for an earlier, now-leached fibrous to bladed cement (aragonite?) in the samples from 22.7 to 8.3 ft. Cements in the upper part of the formation are more variable: there is blocky calcite filling voids at 10.7 and 8.3 ft and lining voids at 17.6 ft, as well as a finely crystalline dogtooth spar at 34.0 ft.

Lithologic and petrographic summary. None of the carbonate depositional units that were observed in cores to the west are observed in the Fakahatchee Strand-Ranger Station core. However, this corehole was drilled to 161 ft and may not have reached those units.

The sample at the base of the Ochopee

Table 8. Results from semi-quantitative X-ray analysis of Fakahatchee Strand-Ranger Station core

[Semi-quantitative analysis for quartz, calcite, dolomite, and aragonite. Other minerals, which may include potassium feldspar, plagioclase, muscovite, and (or) apatite, are assumed to represent less than five percent of each sample. Under Fm. (formation), T=Tamiami, U=unnamed. Results are to the nearest five percent and do not necessarily add up to 100 percent. "Trace" refers to minerals present but less than five percent of the sample]

Depth (ft)	Fm.	Mineral Composition (percent)			
		Quartz	Calcite	Dolomite	Aragonite
110.3	U	75	trace	5	20
112.5	U	100	trace	0	0
118.1	U	100	0	0	0
120.6	U	70	trace	trace	25
128.6	U	80	5	0	10
129.7	U	100	trace	0	0
132.0	U	100	trace	0	0
138.4	U	30	25	30	15
148.5	U	50	trace	45	5
148.8	U	30	0	60	10
156.8	U	70	trace	0	30
158.8	U	85	0	trace	15

Limestone Member at 61.5 ft looks very much like the pisoidal wackestone in the unnamed formation in the Old Pump Road core, except that here it lacks skeletal grains.

The depositional pattern within the Ochopee in this core is similar to that in the two previous cores: the lower portion (61.5 to 47 ft) is sandy and the upper portion (47 to 4 ft) has less than 5 percent quartz sand. There are planktonic foraminifers from 50 to 30 ft, overlain by a zone with evidence of an earlier, now-leached fibrous to bladed (aragonitic?) cement.

Biostratigraphy. Nine samples were examined for dinocysts (appendix 2, table 3). The two lowest samples (160, 158 ft) contain long-ranging taxa that are late Oligocene or younger. The next higher samples (137, 99 ft) are late middle or late Miocene based on the overlapping ranges of *Erymnodinium delectabile* and *Achomosphaera andalousiensis*. The sample at 79 ft is late in the late Miocene, based on the ranges of *E. delectabile* and *Selenopemphix armageddonensis*. Samples above 79 ft had very few, non-diagnostic dinocysts. Reworked Cretaceous material was noted at 56 ft.

Forty-five samples were examined for molluscan faunal content. Twenty-two samples from 133 to 11 ft contain mollusks identified for this report (table 4). Samples from 133 to 123 ft contain a species reported from the Pliocene Pinecrest beds and Buckingham Marl of the Tamiami Formation (*Turritella pontoni*). The sample at 123 to 126 ft contains both an apparent Miocene (*Carditimera apotegea* ?) and an apparent Pliocene species (*T. pontoni*), and the samples from 121 to 96 ft contain an apparent Miocene species (*Costaglycymeris mixoni* ?). *Costaglycymeris mixoni* is reported from the upper Miocene Cobham Bay Member of the Eastover Formation, molluscan zone M7 (Ward, 1992b). This entire interval from 133 to 97 ft is therefore a mixed Miocene/Pliocene assemblage based on the published fossil ranges. However, the most likely explanation for this mixed assemblage is that the full ranges for some of these species have not been reported yet. The fossils do not show any signs of reworking and the interval of the mixed assemblage is relatively thick; therefore reworking seems an unlikely explanation for the mixing. The interval from 133 to 97 ft is tentatively assigned a Miocene age. Samples from 87 to 11 ft are no older than mid-early Pliocene, based on the lowest occurrences of *Gemma magna* and *Parvilucina multilineata*. *Parvilucina multilineata* ranges from mid-early Pliocene to the Recent; it has been reported from the *Cancellaria* and *Arca* zones of the Choctawhatchee Formation (now Jackson Bluff) in Florida, and from the Yorktown, Waccamaw, Chowan River, and James City Formations in the mid-Atlantic Coastal Plain (Gardner, 1943; Ward and Blackwelder, 1987). *Gemma magna* ranges from mid-early Pliocene to Pleistocene; it has been reported from the Yorktown, Duplin, Waccamaw, and James City Formations (Ward and Blackwelder, 1987), from the *Ecphora* zone, Jackson Bluff Formation (Mansfield, 1932), and from the Caloosahatchee faunal unit (Gardner, 1943). *Chione cortinaria* is questionably identified in eight samples from 60 to 11 ft; this species is restricted to molluscan zone M6 (equals Zone 1 Yorktown) and has been reported from the Sunken Meadow Member of the Yorktown Formation and the *Ecphora* zone of the Jackson Bluff Formation (Mansfield, 1932; Lyle Campbell, written communication, 1997). Here, as in the Collier Seminole core, the overlap of *C. cortinaria* and *Carditimera arata* suggests an age near the early/late Pliocene boundary. *Chione latilirata* ranges from Miocene? to Recent and has been identified in Bed 11 of the Pinecrest Beds at APAC mine (Ketcher, 1992) and the Caloosahatchee faunal unit (Dubar, 1958).

Twenty-two samples were examined that contained foraminifers. All specimens identified are benthic forms; none are age diagnostic.

Strontium-isotope stratigraphy. Nine samples (including one duplicate pair) were analyzed for strontium isotopes (table 6). The lowest sample at 159-160 ft gives a calculated age of 7.78 Ma ± 1.5 m.y. (late Miocene). Higher samples from 132.5 to 70.0 ft have calculated ages of 6.5 to 5.9 Ma ± 0.5 m.y. (late Miocene). The two highest samples (44, 26.7 ft) have calculated ages of early Pliocene, but have a margin of error that includes both latest Miocene and late Pliocene (4.7 to 4.3 Ma ± 1.5 m.y.)

Age summary. The unnamed formation (161-61.5 ft) in the Fakahatchee Strand-Ranger Station core is late Miocene, based on strontium-isotope stratigraphy. Dinocysts are less diagnostic in the lower part of the unit, but are in general agreement with the strontium-isotope stratigraphy. Above 133 ft, the strontium-derived ages suggest that the mixed Miocene-Pliocene mollusk assemblage is actually Miocene and that *Turritella pontoni*, whose published range does not extend below the Pliocene, does indeed extend into the late Miocene. At 79 ft, dinocysts indicate a latest Miocene age. Above 70 ft, the possibility that the unnamed formation ranges into the Pliocene must be considered: mollusks suggest a mid-early Pliocene age.

The Ochopee Limestone Member of the Tamiami Formation (61.5 to 4 ft) is Pliocene. Mollusks suggest a Pliocene age, and strontium-isotope analysis indicates an early Pliocene age with a margin of error that includes the latest Miocene and the late Pliocene. As in the Ochopee in the Collier Seminole core, an age near the early/late Pliocene boundary is indicated from 53-11 ft. Only nondiagnostic dinocysts were found in the Ochopee.

Fakahatchee Strand-Gate 12 core

The Fakahatchee Strand-Gate 12 corehole site (fig. 1, table 1) is on Janes Memorial Scenic Drive about 6 miles past the Fakahatchee Strand State Preserve headquarters. The corehole was drilled to 227 ft in June 1996. The core (fig. 6) was sampled for thin sections, X-ray diffraction, strontium analysis of shells, and for mollusk, pollen, foraminifer, ostracode, and dinocyst content.

The unnamed formation is found from the bottom of the core at 227 ft to a depth of 40 ft. Discoidal quartz pebbles were observed in the unconsolidated sand from about 212 to 187 ft. There are aragonitic mollusks preserved

Table 9. Results from semi-quantitative X-ray analysis of Fakahatchee Strand-Gate 12 core

[Semi-quantitative analysis for quartz, calcite, dolomite, and aragonite. Other minerals, which may include potassium feldspar, plagioclase, muscovite, and (or) apatite, are assumed to represent less than five percent of each sample. Under Fm. (formation), T=Tamiami, U=unnamed. Results are to the nearest five percent and do not necessarily add up to 100 percent. "Trace" refers to minerals present but less than five percent of the sample]

Depth (ft)	Fm.	Mineral Composition (percent)			
		Quartz	Calcite	Dolomite	Aragonite
5.9	T	70	30	0	0
6.8	T	10	60	0	30
13.0	T	trace	95	0	0
17.5	T	5	95	0	0
26.5	T	10	90	0	0
41.2	U	80	5	0	15
41.9	U	75	0	0	25
48.0	U	40	15	0	45
72.2	U	80	10	0	15
86.4	U	55	5	0	35
88.2	U	35	5	0	60
99.0	U	95	0	trace	0
110.0	U	75	5	0	15
129.9	U	85	0	15	0
131.1	U	70	5	10	15
135.6	U	50	0	45	trace
198.2	U	100	0	0	0
219.0	U	65	20	0	20

from 50 to 46 ft. At the top of the unnamed formation at 40 ft is 5 to 6 inches of sandstone. The Ochopee Limestone Member of the Tamiami consists of a very sandy limestone to calcareous sandstone from 40 to 33 ft and a yellowish-gray, moldic, molluscan packstone from about 33 to 6 ft. The upper 6 ft in this core is artificial fill and is primarily silt and quartz sand.

This corehole site differs from cores drilled to the west in this study in that there is no lithified sediment below the transition from limestone to unconsolidated quartz sand at about 40 ft. However, within the unconsolidated sand are two zones that are dolomitized: one from 133 to 127 ft, and another clayey dolomitic zone from 220 to 217 ft. Hydrologic and geophysical data indicate that the confining zones in this corehole are thicker than in coreholes to the west, although no densely cemented zone occurs in this core.

Semi-quantitative X-ray diffraction data for this core are shown in table 9. Quartz sand is common in most samples analyzed from the unnamed formation. Calcite is observed in minor amounts in samples from 219.0 to 41.2 ft. Dolomite is common only in the samples from 135.6 to 129.9 ft in an unconsolidated clayey quartz sand, and in a trace amount in a sample from 99.0 ft. Aragonite is found in most samples from the unnamed formation. In the Ochopee Limestone Member of the Tamiami, calcite is the predominant mineral in samples from 26.5 to 6.8 ft. Aragonite is found in a sample at 6.8 ft.

Petrography. Five thin sections were made from samples from the Ochopee Limestone Member in this core that range in depth from 36 to 7 ft. The deepest two samples from 36.0 and 32.3 ft are sandy skeletal wackestones to grainstones with minor amounts of micrite. The lower sample has a microspar matrix that apparently has replaced the micrite (neomorphic). Skeletal grains include molluscan molds and fragments, foraminifers (planktonics at 32.3 ft), ostracodes, bryozoan and echinoid fragments, and barnacles. Blocky spar occurs in both samples.

Above the sandy limestone is a molluscan wackestone to grainstone that has a trace of quartz silt and sand, and 5 to 30 percent micrite matrix (at 17.7 ft), and a similar assortment of skeletal grains as observed deeper (36 to 32.3 ft), with the addition of red algae. The shallowest sample at 7.0 ft has preserved original molluscan aragonite remnants.

Lithologic and petrographic summary. As in the Fakahatchee Strand-Ranger Station core, there is no lithified carbonate depositional unit in the lower part of Fakahatchee Strand-Gate 12 core. The Ochopee Limestone Member in the Gate 12 core is thinner than in the other cores but still has the two lithofaces of a lower sandy wackestone to grainstone, and an upper nearly sand-free wackestone to grainstone. Also, planktonic foraminifers occur abundantly at 32.3 ft; similar horizons in the other cores may be correlative. A major difference in this core, as compared to the previous ones discussed, is the absence of dolomitized limestone and the absence of the early leached fibrous to bladed cement in the upper portion of the Ochopee. These differences may be related to location on the Florida platform with respect to paleo-shoreline.

Biostratigraphy. Six samples were examined for dinocysts (appendix 2, table 3). Of the three lowest samples, the middle one was barren but the other two (218, 126 ft) contain dinocyst assemblages of late middle or late Miocene age. The sample at 88 ft is late middle Miocene, late Miocene, or Pliocene, based on the overlap of *A. andalousiensis* and *D. pseudocolligerum*, and because it is above the highest occurrence of *E. delectabile* and *H. obscura*, it is likely to be Pliocene. The sample at 62 ft contains long ranging forms and the sample at 36 ft is barren.

Thirty-six samples were examined for molluscan faunal content. Seventeen samples from 136.3 to 10.7 ft contained mollusks identified for this report (table 4). Samples from 136.3 to 87.9 ft contain a relatively diverse mixed assemblage of fossils reported from Miocene and Pliocene units. As in the Fakahatchee Strand-Ranger Station core, the most likely explanation for this mixed assemblage is that the full ranges for some of these species have not been discovered yet. Seven samples from 63.2 to 42 ft may be late Miocene and (or) Pliocene. Three species (*Crepidula costata*, *Crucibulum grande*, and *Arcopsis adamsi*) positively identified in this interval range from Miocene through at least Pliocene (Ward, 1992a; Gardner, 1947). *Anadara callicestosa* (63 ft) is reported from the *Ecphora* and *Cancellaria* zones of the Jackson Bluff Formation (Mansfield, 1932), so its reported age is mid-early to late Pliocene, but its presence in the lower portion of this core indicates it may range into the Miocene. Samples from 24.7 to 10.7 ft contain an assemblage no older than mid-early Pliocene based on the occurrence of *Carditimera arata*.

Strontium-isotope stratigraphy. Seven samples were analyzed for strontium isotopes (table 6). The lowest, at 218.6 ft, yields a calculated age of 8.92 Ma ± 0.3 m.y. (late Miocene). Four higher samples from 126.2 to 48 ft give calculated ages of 6.8 Ma ± 1 m.y. (late Miocene) for the sample at 126.2 ft and 6.1 to 6.0 ± 0.5 m.y. for the higher samples (late Miocene). Samples from 24.5 to 12.5 ft give calculated ages of 4.4 Ma ± 1.5 m.y., early Pliocene, but have a margin of error that includes both latest Miocene and late Pliocene.

Age summary. The unnamed formation (227-40 ft) in the Fakahatchee Strand-Gate 12 core is late Miocene and possibly Pliocene. The strontium-derived ages and the dinocyst assemblage at 126 ft suggest that at least some of the samples that contain a mixed Miocene-Pliocene mollusk assemblage are Miocene. If this age assessment is correct, some taxa whose published ranges do not extend below the Pliocene do indeed have ranges that extend into the late Miocene, as in this unit in the Fakahatchee Strand-Ranger Station core. The unnamed formation above 126 ft is late

Miocene and (or) early Pliocene. Strontium analysis yields calculated ages of late Miocene up to 48 ft. Dinocysts indicate an age of Miocene or Pliocene at 88 ft. The mollusks present above 63 ft indicate a Miocene and (or) Pliocene age.

The Ochopee Limestone Member of the Tamiami Formation (40-6 ft) is Pliocene. The unit is dated by using mollusks as mid-early and (or) late Pliocene, and here again, *Carditimera arata* and *Chione cortinaria* suggest an age near the early/late Pliocene boundary. Strontium-isotope analysis indicates an early Pliocene age with a margin of error that includes the latest Miocene and the late Pliocene. Only nondiagnostic dinocysts were found in the Ochopee.

Fakahatchee Strand-Jones Grade core

The Fakahatchee Strand-Jones Grade corehole site (fig. 1, table 1) is in the driveway of the first house on the south side of Jones Grade, west of State Route 29, about 1/2 mile south of the intersection of I-75 and Rte. 29 (Miles City). The core was drilled to 200 ft in July 1996. This core (fig. 7) has been sampled for thin sections, X-ray diffraction, strontium analysis of shells, and for mollusk, dinocyst, pollen, ostracode, and foraminifer content.

The unnamed formation occurs from the bottom of the core at 200 ft to 70.9 ft and consists of an unconsolidated, medium to coarse quartz and phosphatic sand with scattered quartz pebbles. The sand is dolomitic from 150 to 140 ft. The Ochopee Member of the Tamiami Formation is present from 70.9 to 3 ft and is a poorly recovered, moldic molluscan limestone and sandy limestone, which is partially unconsolidated. The upper 3 ft of this core is clay and quartz sand that is probably artificial fill brought in for the residence.

Semi-quantitative X-ray diffraction data for this core are shown in table 10. Within the unnamed formation, the unconsolidated quartz sands were assumed to be primarily quartz: quartz is the predominant mineral, and calcite is absent, in both samples analyzed (174.5 and 141.4 ft). Only a trace of dolomite was detected at 141.4 ft and no aragonite was detected. Calcite is the dominant mineral in samples from the Ochopee Limestone Member of the Tamiami Formation (53.0 to 3.1 ft), where no dolomite or aragonite was detected.

Petrography. Two thin sections were made from the Ochopee Limestone Member of the Tamiami Formation in this core at 15.2 and 11.0 ft. Each is a molluscan packstone with a trace to 15 percent quartz sand and skeletal grains that include molluscan molds and fragments, benthic foraminifers, bryozoans, and echinoid fragments. Cements are minor dogtooth spar on surfaces.

Lithologic and Petrographic summary. As in the Fakahatchee Strand-Ranger Station and Fakahatchee Strand-Gate 12 cores, there is no lithified carbonate depositional unit in the lower part of the Fakahatchee Strand-Jones Grade core. Samples from the Ochopee in the Jones Grade core are similar to samples from the Ochopee in other cores, except that they lack a planktonic foraminifer horizon, preserved aragonite, and early (now-leached) fibrous cement.

Biostratigraphy. Six samples were examined for dinocysts (appendix 2, table 3). The sample at 185 ft is late Miocene, and contains *Erymnodinium delectabile, Invertocysta lacrymosa, Selenopemphix brevispinosa brevispinosa*, and *Trinovantedinium* ? *xylochoporum*. The sample at 142 is late in the late Miocene, based on the overlap of *S. armageddonensis* and *E. delectabile*. The sample at 72 ft is barren. The sample at 57 ft contains *Achomosphaera andalousiensis, Dapsilidinium pseudocolligerum,* and *Invertocysta* sp. Like the samples from the Ochopee in the Collier-Seminole core, this sample is late Miocene or Pliocene, and because it is above the highest occurrence of *E. delectabile*, it is likely to be Pliocene. Higher samples were barren.

Ten samples were examined for molluscan faunal content. Four samples from 67 to 10 ft contained mollusks identified for this report (table 4). *Turritella perattenuata* (67 ft) is reported from late Pliocene or early Pleistocene units, but data gathered in this study indicate a longer range than previously discovered. Mollusks identified from 66.3 to 10 ft are Pliocene. The questionable identification of *Chione cortinaria* indicates a probable early Pliocene age (molluscan zone

Table 10. Results from semi-quantitative X-ray analysis of Fakahatchee Strand-Jones Grade core

[Semi-quantitative analysis for quartz, calcite, dolomite, and aragonite. Other minerals, which may include potassium feldspar, plagioclase, muscovite, and (or) apatite, are assumed to represent less than five percent of each sample. Under Fm. (formation), T=Tamiami, U=unnamed. Results are to the nearest five percent and do not necessarily add up to 100 percent. "Trace" refers to minerals present but less than five percent of the sample]

Depth (ft)	Fm.	Mineral Composition (percent)			
		Quartz	Calcite	Dolomite	Aragonite
3.1	T	35	65	0	0
3.8	T	45	55	0	0
14.3	T	trace	95	0	0
19.0	T	15	85	0	0
29.9	T	10	90	0	0
42.8	T	40	60	0	0
53.0	T	35	65	0	0
141.4	U	95	0	trace	0
174.5	U	100	0	0	0

M6), but the presence of *Chione procancellata* (66.3 ft) indicates a probable late Pliocene age (Mansfield, 1932). As in other cores, the overlap of these species may suggest an age near the early/late Pliocene boundary.

Strontium-isotope stratigraphy. No samples from this core are included in the present study.

Age summary. The unnamed formation (200-70.9 ft) in the Fakahatchee Strand-Jones Grade core is late Miocene. Dinocysts near the base of the unit are late Miocene, and the assemblage is clearly the same as in the other cores where late Miocene strontium-derived ages are available. At 142 ft, the dinocysts indicate a late late Miocene age. Above this, the unit is undated.

The Ochopee Limestone Member of the Tamiami Formation (70.9-3 ft) is late late Miocene or Pliocene. Mollusks above 66.3 ft suggest an age near the early/late Pliocene boundary.

Picayune Strand State Forest core

The Picayune Strand State Forest corehole site (fig. 1, table 1) is in the back pasture of a residence on 52nd Street, S.E., in the Southern Golden Gate Estates. The corehole was drilled to 201 ft in August 1996. The core (fig. 8) was sampled for thin sections, X-ray diffraction, strontium analysis of shells, and for mollusk, pollen, dinocyst, foraminifer, and ostracode content.

The unnamed formation occurs from the bottom of the core at 201 ft to 106 ft and is a sandy, dolomitic, moldic packstone that has scattered quartz pebbles in its lower part (from the bottom of the core to 181 ft). From 165 to 106 ft, the formation is an unconsolidated quartz sand, more clay-rich at its base. The Ochopee Limestone Member of the Tamiami Formation was recovered from 106 to 5.2 ft. It is a very sandy moldic limestone and calcareous sandstone that grades upward into a moldic molluscan packstone. The upper 5.2 ft of this core is artificial fill.

Semi-quantitative X-ray diffraction data for this core are shown in table 11. Dolomite occurs as the dominant mineral at 189.6 ft in the unnamed formation. In the Ochopee Limestone Member of the Tamiami Formation, calcite is the dominant mineral in all samples, and quartz is present in minor and trace amounts. Aragonite occurs as a co-dominant mineral at 38.0 ft.

Petrography. Two thin sections were made from the unnamed formation in the core at Picayune Strand State Forest. Both samples (181, 169 ft) are dolostones with dolomicrite matrix and minor quartz sand. Skeletal grains are sparse but include mollusks (now leached), echinoid fragments, barnacles, and coral.

Seven thin sections were made of the Ochopee Limestone Member of the Tamiami from this core. The lower two (85.2 and 75.0 ft) are very sandy with 10 to 40 percent micrite matrix. Skeletal grains include molluscan fragments and molds, benthic foraminifers, bryozoans, red algae, echinoid fragments, and barnacles. Meniscus cement occurs at 85.2 ft, and there is minor dogtooth spar on surfaces in both samples.

The middle three thin sections (53.0 to 31.3 ft) come from a molluscan wackestone to grainstone with only a trace of quartz silt in a micrite matrix of 25 to 40 percent. Skeletal grains are similar to the sandy limestone below, and cements are minor.

Two thin sections were made from 11.8 and 9.0 ft of this core. Both samples are quite similar and are very low porosity molluscan packstones with neomorphosed microspar matrix and about 15 percent micrite matrix; both samples contain blocky calcite-filled skeletal molds, benthic foraminifers, ostracodes, and echinoid fragments, and minor quartz sand (trace to 10 percent).

Lithologic and petrographic summary. As in the other cores from the western part of the study area, there is a lithified carbonate within the unnamed formation in the lower part of the Picayune Strand State Forest core. The dolomite of the unnamed formation here is similar to the dolomite in the cores from the Collier-Seminole and Old Pump Road sites. In the Picayune Strand core, the distinctive yellow to orange color suggests a surface of exposure at the top of the dolostone at 165.5 ft.

The Ochopee Limestone Member of the Tamiami Formation at this site is similar to that in the other sites in that there is a lower sandy limestone and an upper nearly sand-free limestone. Cements are rare here, and there is no relict aragonite observed, no planktonic foraminifer zone, and no evidence for an early fibrous to bladed, now-leached cement as observed in the Collier-Seminole, Old Pump Road, and Fakahatchee Strand-Ranger Station cores. The upper part of the Ochopee looks like caprock, a highly recrystallized limestone of very low porosity commonly observed near the ground surface in the study area. The grains are not extensively leached, but all molds are spar-filled. There is no evidence of relict aragonite nor of an early aragonitic cement.

Biostratigraphy. Seven samples were studied for dinocysts; two of these were barren (appendix 2, table 3). The lowest sample (188 ft) contains *Erymnodinium delectabile* and is late middle or late Miocene. The sample at 153 ft contains a relatively nondiagnostic assemblage. The sample at 91 ft is late middle or late Miocene or Pliocene, and because this sample is above the highest occurrence of *E. delectabile* and *H. obscura*, it is likely to be very early Pliocene. The sample at 34 ft is no younger than Pliocene based on the presence of *Invertocysta lacrymosa.* The highest sample (13 ft) is not diagnostic.

Twelve samples were examined for molluscan faunal content. Eight samples from 175.5 to 26.5 ft contained mollusks identified for this report (table 4). The lowermost samples contain *Turritella perattenuata*, a species that has been reported from late Pliocene or early Pleistocene units. The large gap between deposition at 175.5 and 85 ft, and additional data gathered in this study, indicate a longer range for this species. The age of samples containing only *T. perattenuata* therefore is considered unknown. The sample at 39.2 ft is mid-early to late Pliocene based on the occurrence of *Carditimera arata.* However, the sample at 31.4 ft is tentatively restricted to the mid-early Pliocene (mollusk zone M6) based on the questionable identification of *Chione cortinaria*, reported from the *Ecphora* zone of the Jackson Bluff Formation and the Sunken Meadow Member of the Yorktown Formation (Mansfield, 1932). *Chione procancellata* (26.5 ft) is from the *Cancellaria* zone of the Jackson Bluff Formation (Mansfield, 1932). As in other cores, these species may suggest an age near the early/late Pliocene boundary.

Table 11. Results from semi-quantitative X-ray analysis of Picayune Strand State Forest core

[Semi-quantitative analysis for quartz, calcite, dolomite, and aragonite. Other minerals, which may include potassium feldspar, plagioclase, muscovite, and (or) apatite, are assumed to represent less than five percent of each sample. Under Fm. (formation), T=Tamiami, U=unnamed. Results are to the nearest five percent and do not necessarily add up to 100 percent. "Trace" refers to minerals present but less than five percent of the sample]

Depth (ft)	Fm.	Mineral Composition (percent)			
		Quartz	Calcite	Dolomite	Aragonite
35.3	T	10	85	trace	0
38.0	T	trace	45	0	50
46.0	T	trace	95	0	0
50.0	T	trace	95	trace	0
54.5	T	trace	95	0	0
63.0	T	trace	90	5	0
189.6	U	15	0	85	0

Strontium-isotope stratigraphy. Three samples were analyzed for strontium isotopes (table 6). They show a monotonic decrease in calculated ages from 4.9 Ma (84.7 ft) to 4.26 Ma (44 ft) to 3.66 Ma (25 ft), all with a margin of error ± 1.5 m.y. These values are early Pliocene, but the margin of error includes both late Miocene and late Pliocene.

Age summary. The unnamed formation (201-106 ft) in the Picayune Strand State Forest core is late middle or late Miocene based on the presence of the dinocyst species *E. delectabile* at 188 ft. Above this, the unit could be as young as Pliocene. Mollusks are not diagnostic and no samples were analyzed for strontium in this unit.

The Ochopee Limestone Member of the Tamiami Formation (106-5.2 ft) is Pliocene. Strontium-isotope analysis suggests an early Pliocene age with a margin of error that includes the latest Miocene and the late Pliocene. Dinocysts at 91 ft are consistent with a Pliocene age. Mollusks from 39.2 to 26.5 ft indicate a Pliocene age and may suggest an age near the early/late Pliocene boundary. Material above 13 ft is not diagnostic.

Southern States Utilities core

The Southern States Utilities corehole site (fig. 1, table 1) is on the property of Southern States Utilities at the northeast quadrant of the intersection of Rtes. 951 and 41. In September 1996, the corehole was drilled to a depth of 210 ft (fig. 9). The core has been sampled for thin sections, X-ray diffraction, strontium analysis of shells, and for dinocyst, pollen, mollusk, foraminifer, and ostracode content.

The unnamed formation occurs from the bottom of the core at 210 ft to 86 ft. It consists of unconsolidated dolomitic clay, silt, and quartz sand from the bottom of the core up to 165 ft; a sandy dolostone to dolomite-cemented sandstone up to 121.5 ft; and an unconsolidated, calcareous quartz sand up to 86 ft. Quartz pebbles were observed from about 120 to 97 ft. The Ochopee Limestone Member of the Tamiami Formation extends from 86 to 7 ft in this core. From 86 to 38 ft, the Ochopee is a well lithified, moldic limestone that forms the main part of the aquifer, locally referred to as the lower Tamiami aquifer (Gary Susdorf, personal communication, 1996). From 38 to 21 ft, it is poorly consolidated moldic limestone; from 21 to 10 ft, it is poorly recovered clay with carbonate concretions; and from 9.5 to 7 ft it is a tightly cemented limestone. The upper 7 ft in this core appears to be a natural soil. X-ray diffraction and petrographic analyses of samples from this core will be presented in a later report.

Biostratigraphy. Six samples were examined for dinocysts; three were barren (appendix 2, table 3). The samples at 205 and 98 ft are late middle or late Miocene, and contain *Erymnodinium delectabile;* the lower sample also contains *Hystrichosphaeropsis obscura*, whereas the upper sample contains *Achomosphaera andalousiensis.* The highest sample (9 ft) is not diagnostic.

Ten samples were examined for molluscan faunal content. Eight samples from 146.5 to 8.3 ft contained mollusks identified for this report (table 4). A single recognizable species is present at 146 ft (*Turritella pontoni*). This species has been reported only from the Pinecrest Beds of the Tamiami (late Pliocene). However, based on the occurrence of this species in the Fakahatchee Strand-Ranger Station and Fakahatchee Strand-Gate 12 cores, it is possible the first appearance of this species occurred in the Miocene and the range should be revised. The full ranges of *Turritella apicalis* and *T. perattenuata* also appear to be longer than has been recorded previously. The questionable occurrence of *Trochita floridana* at 35.8 ft indicates that the sample may be late Pliocene. *Trochita floridana* has been reported from the Pinecrest beds of the Tamiami (Olsson and Petit, 1964). Samples at 35 and 8 ft did not yield diagnostic mollusks.

Strontium-isotope stratigraphy. No samples from this core are included in the present study. Strontium-isotope data from this core will be presented in a later report.

Age summary. The unnamed formation (210-86 ft) in the Southern States Utility core is late middle or late Miocene based on the presence of the dinocyst species *E. delectabile.*

The Ochopee Limestone Member of the Tamiami Formation (86-7 ft) contains Pliocene mollusks and nondiagnostic dinocysts.

CONCLUSIONS

The lithostratigraphy of the southern Florida Miocene to Pleistocene sediments has been investigated for many years. These efforts have been hampered by the paucity of exposures, the predominantly subsurface nature of the units, and the complex nature of the sediment facies. The formations encountered often have been identified on the basis of molluscan fauna rather than lithology. This investigation utilizes lithologic parameters to identify the formations and component members. Biostratigraphic and strontium-isotope analyses aid in the correlation and in determination of ages of the units.

The oldest unit encountered in the study cores is the unnamed formation. The formation consists of variably fossiliferous, clay- to gravel-sized siliciclastics and carbonates. These sediments appear to be equivalent in age to the upper Peace River Formation of the Hawthorn Group and possibly may be an updip portion of the Long Key Formation. The maximum recovered thickness of the unnamed formation was 187 ft, although the entire unit was not penetrated. At least four depositional sequences are present in the carbonate unit below the siliciclastics in the western part of the study area. An orange surface with soil textures, indicating subaerial exposure, was found at the top of the carbonate in several cores. The unnamed formation may or may not be indurated. In all cores, it contains dolomite. It is mostly or entirely late Miocene. Calculated age, based on strontium-isotope analysis, ranges from 9 to 5.7 Ma. Within the unnamed formation there appear to be two genetically and lithologically distinct units: a lower carbonate (dolostone and limestone) that occurs in the western cores of Southern States, Collier-Seminole, Old Pump Road, Picayune Strand, and possibly Fakahatchee Strand-Ranger Station, and an unconsolidated quartz sand that contains varying amounts of shells and calcite mud, and minor amounts of dolomite mud and sandstone. The unconsolidated quartz sand increases in thickness from west to east. Calculated ages based on strontium-isotope analysis suggest that the hiatus between the carbonate unit and the siliciclastic unit is 2 m.y. in the Old Pump Road core. The dinocyst and mollusk ranges in several of the cores allow the possibility of a late middle Miocene age for at least part of the unnamed formation, but where these sediments are dated by strontium isotopes, they are late Miocene.

In two cores, Collier-Seminole and Old Pump Road, the uppermost sediments of the unnamed formation are not dated by strontium isotopes and contain fossils that could be as young as Pliocene. In the Fakahatchee Strand-Ranger Station core, the possibility that this unit ranges into the Pliocene must be considered: dinocysts suggest a latest Miocene age, whereas mollusks in the upper part of the unit suggest a mid-early Pliocene age. In the Fakahatchee Strand-Gate 12 core, mollusk assemblages in part of the unit contain mollusks reported from the Miocene, intermixed with species reported from the Pliocene. The fossils do not show signs of reworking, the mixed interval is relatively thick, and the strontium-derived ages suggest that at least some samples containing a mixed Miocene-Pliocene mollusk assemblage are Miocene. Subaerial exposure is indicated for the top of the unnamed formation in the Fakahatchee Strand-Ranger Station core by pisolitic grains.

The Tamiami Formation overlies the unnamed formation throughout the study area and consists of the Ochopee Limestone Member in all the study cores. The lithology varies from an unconsolidated to moderately indurated sand or sandstone to a slightly sandy, moldic, fossiliferous, unconsolidated to well-indurated limestone. A maximum of 101 ft of the Ochopee sediments was encountered in the study area. Deposition appears continuous for the Ochopee Limestone, and all cores show an abrupt decrease in quartz-sand content that indicates a decrease in transport of sand to the site of deposition. The Ochopee Limestone Member of the Tamiami Formation is Pliocene and probably spans an interval of time from the early Pliocene to near the early/late Pliocene boundary. Strontium-isotope analysis indicates an early Pliocene age with a margin of error that includes the latest Miocene and the late Pliocene; calculated ages range from 5.1 to 3.5 Ma. The dinocyst assemblages often are not diagnostic, but where they are, they indicate a late Miocene or Pliocene age. Mollusks indicate a Pliocene age, and a distinctive assemblage that includes the overlapping ranges of *Carditimera arata* and *Chione cortinaria* ? may indicate an age near the early/late Pliocene boundary.

Unnamed, undifferentiated sands overlie the Pliocene limestones in two cores in the southern part of the study area. The very fine to medium sands fill a low on top of the Ochopee Limestone Member. This unnamed quartz sand is dated as Pliocene in the Old Pump Road core. This sand overlies material containing late Pliocene and (or) early Pleistocene mollusks.

Artificial fill or natural soil occurs a the top of the cores.

Implications for the structure of the surficial aquifer system

The confining units in the 200-ft interval penetrated by most of these seven cores are different in different parts of the study area. To the west, at the sites of the Southern States, Picayune Strand, Collier-Seminole, and possibly at Old Pump Road cores, a hard tightly cemented dolostone forms the first major confining unit below the water table. In the eastern part of the study area, confinement is more difficult to determine. At Fakahatchee Strand-Ranger Station the confining unit at 61 feet is a tightly cemented sandstone, which is much younger than the dolostones to the west, and which probably is not laterally connected to them. At the other two sites, Gate 12 and Jones Grade, thick zones of poorly sorted, muddy unconsolidated sands form a slight confining unit. These sands probably are not correlative to the sandstone at the Ranger Station site, nor to the dolostones to the west.

These age and sedimentologic observations suggest a complex compartmentalization of the surficial aquifer system in southwestern Florida. The current model for the system is two aquifers separated by a discontinuous confining unit. That model is clearly too simple, and a more realistic model would be several discontinuous confining units of different ages, lithologies, and vertical transmissivities that occur at different depths.

The next phase of this project is to move farther to the east to document changes in lithology and aquifer properties in eastern Collier County.

Biostratigraphic implications

The calibrations of dinocyst and molluscan occurrences with strontium-isotope stratigraphy allows us to expand and document the reported ranges of taxa. Mollusks reported here from the late Miocene (9-6.5 Ma, based on strontium analysis) include: *Conus* *chipolanus* ?, *Crepidula plana* ?, *Turritella apicalis*, *T. pontoni*, *T. segmenta*, *T. subvariabilis*, *Anadara callicestosa*, *Carditimera apotegea* ?, and *Costaglycymeris mixoni* ?. A distinctive early/late Pliocene assemblage consisting of *Turritella apicalis*, *T. perattenuata*, *Carditimera arata*, *Chione cortinaria* ?, and *C. latilirata* is dated as 4.7 to 3.7 Ma by strontium analysis.

Strontium-isotope calibration supports the use of the highest occurrence of *Erymnodinium delectabile* (Verteuil & Norris) Lentin et al. to mark the top of the Miocene. *Dapsilidinium pseudocolligerum* extends into the Pliocene.

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APPENDIX 1

Petrographic Descriptions (all percentages are visual estimates)

Collier-Seminole State Park core

Depth (ft)	Description
	Undifferentiated, unconsolidated quartz sand
9.3	Medium quartz sand (scattered coarse grains) with organic-rich clay coatings (10%); non-carbonate.
13.8	Same as above but with a few molluscan molds.
	Tamiami Formation (Ochopee Limestone Member)
24.0	Molluscan packstone with 1-3% fine quartz sand and silt in a matrix of microspar and a small amount of micrite; evidence for an early leached isopachous bladed cement; skeletal grains include mollusks, bryozoans, and partially leached echinoids, most skeletal grains are bored; intergranular blocky calcite overlies early leached cement; porosity is inter- and intraparticle, moldic, and shelter.
27.7	Molluscan wackestone-packstone; similar to sample at 24 ft, but less skeletal and cement leaching, more tightly cemented with more matrix micrite; 3-5% fine quartz sand in micrite matrix 20%, early leached cement overlain by later blocky isopachous (in voids) and pore-filling cement; skeletal grains include mollusks molds and fragments, ostracodes, partially leached foraminifers, bryozoans, partially leached echinoids; porosity is primarily intraparticle and moldic, with minor shelter; nearly all interparticle space is filled with matrix or cement.
29.3	Echinoid wackestone with <1% quartz and phosphate silt and about 30% micrite matrix with a small amount of microspar; large echinoid fragment dominates thin section with calcite mud-supported grains on either side; skeletal grains include mollusks, benthic foraminifers, ostracodes, bryozoans, and echinoids; an early cement was leached; an isopachous dogtooth calcite cement in voids is overlain in places by an intergranular blocky calcite cement; >30% porosity is intraparticle and moldic.
38.3	Molluscan wackestone-packstone with 1-3% fine quartz sand and silt, well-cemented with carbonate mud matrix (30%) with benthic foraminifer, mollusk, barnacle, ostracode, and echinoid (partially leached) fragments; dogtooth spar in voids; syntaxial overgrowths on echinoid fragments; porosity is interparticle, intraparticle and moldic.
47.0	Molluscan packstone with <5% medium quartz and phosphatic sand and possible neomorphism of micrite matrix; bored skeletal grains include benthic foraminifer, echinoid, and molluscan fragments; blocky calcite cement on grain surfaces, very high inter- and intraparticle, vuggy, and moldic porosity (>30%); blocky calcite cement on surfaces and syntaxial overgrowths on echinoids; possible pendant cements under foraminifers.
50.0	Molluscan wackestone-packstone with 5% fine quartz and phosphatic sand and silt with clotted texture in micrite matrix (neomorphic spar?); skeletal grains include bored mollusks (partially leached aragonitic and calcitic), partially leached echinoid fragments, partially leached benthic foraminifers, and ostracodes, blocky calcite on surfaces; low

porosity (<3%) with minor interparticle and moldic pore space.

52.5 Molluscan packstone with 5% fine quartz and phosphatic sand and silt, with a clotted texture in micrite matrix (neomorphic spar), skeletal grains include bored mollusk (partially leached aragonitic and calcitic) shells, partially leached echinoid fragments, foraminifers (partially leached), ostracodes; blocky calcite on skeletal surfaces; low porosity (<3%) with minor interparticle and moldic pore space. Grain leaching occurred after precipitation of overgrowth cement on echinoids.

54.9 Very sandy bryozoan packstone to calcareous sandstone, 40% medium to coarse quartz sand with <1% feldspar grains; matrix may have originally been micrite but now all sparry calcite; isopachous blocky cement on grains; skeletal grains include micritized molluscan molds, partially leached bryozoans, foraminifers, ostracodes, and echinoids; cement growth continued after leaching with cement on inside and outside of micrite envelopes; geopetal structures in bryozoan cavities.

55.6 Same as above, with molluscan fragments, 20% medium quartz sand in a microspar matrix; blocky to dogtooth void-filling cements, few foraminifers, and partially leached bryozoans (leached after cement precipitation); porosity is inter-and intraparticle, and moldic.

56.0 Same as above, with molluscan molds and fragments, partially leached foraminifers, partially leached bryozoans, and partially leached echinoid fragments with non-leached overgrowths; 30% medium quartz, feldspar (<1%), and phosphatic (<1%) sand in a partially recrystallized matrix (microspar); some cement may be meniscus.

60.0 Very sandy molluscan packstone with 30% medium quartz sand in patches of micrite (20%) matrix, with minor microspar, overlain by blocky and dog-tooth sparry calcite cement (cement is finer than at 56 ft); moldic porosity is in mollusk and echinoid voids; foraminifers, calcitic mollusk, and bryozoan fragments.

65.0 Molluscan wackestone-packstone to calcareous sandstone with <15% micrite matrix and nearly 40% medium quartz and phosphatic (<1%) sand; skeletal grains include molds and fragments, partially leached benthic foraminifers, bryozoans, and echinoids; blocky calcite cement on surfaces, some micrite-coated; micrite cement is meniscus; porosity is high (30%) inter- and intraparticle, and moldic.

66.5 Similar to above, molluscan packstone, with ~30% fine to medium quartz sand, barely cemented with micrite (~10%); skeletal leached benthic foraminifers and mollusks; echinoid, bryozoan, foraminifer, and molluscan fragments; minor void-filling blocky and dogtooth cement; porosity is very high (~30%), inter-, intraparticle, and moldic.

67.7 Molluscan packstone with ~30% medium quartz sand and ~10% micrite matrix; blocky and dogtooth spar; patches of micrite (10%); skeletal grains include bryozoans, echinoids, and partially leached benthic foraminifers and mollusks; very high inter- and intraparticle, and moldic porosity (30%); similar to 65 and 66.5 ft.

69.6 Sandy packstone with 20% fine quartz sand to silt and 5% micrite matrix; skeletal grains include bryozoan, ostracode, and partially leached mollusk, benthic foraminifers, echinoid, and red algae (not observed in higher samples) fragments (this sample is more leached than the one above); blocky and dogtooth surfaces; micrite envelopes serve as nucleation sites for cement; high inter- and intraparticle and moldic porosity (30%); geopetal structures in bryozoan and ostracode chambers.

71.7	Sandy packstone with 20% micrite matrix and 20% medium quartz and phosphatic (<1%) sand; one generation of blocky to dogtooth void-filling cement and syntaxial echinoid overgrowths, skeletal grains include ostracodes and bryozoans and partially leached red algae, mollusk, foram, echinoid, and barnacle fragments; high intraparticle and moldic porosity (30%).
75.2	Sandy packstone with 15% micrite matrix and 30% fine phosphatic and medium quartz sand; skeletal grains include planktonic and benthic foraminifers, ostracodes, echinoids, and mollusks molds and fragments; meniscus micrite cement overlain by a dogtooth-rhombic calcite cement.
79.2	Similar to above but less cement, isopachous cement has more needle shape; 10% micrite matrix, and less leached skeletal grains; 30% fine phosphatic and quartz sand, skeletal grains include benthic and planktonic foraminifers, bryozoans, echinoids, and molluscan molds and fragments; syntaxial echinoid overgrowths; high porosity.
81.8	Similar to sample above, molluscan packstone to calcareous sandstone with 30% medium quartz and fine phosphatic (<1%) sand and 10% micrite matrix adhering to grains, some may be meniscus; minor amount of dogtooth sparry calcite cement primarily on foraminifers; skeletal grains include benthic and planktonic foraminifers, ostracodes, leached red algae, and echinoids with thin syntaxial overgrowths; high intraparticle and moldic porosity.
85.0	Very sandy packstone to calcareous sandstone with about 20% micrite matrix; fine quartz (30%) and phosphatic (1%) sand; skeletal grains include molluscan molds and fragments, benthic and planktonic foraminifers, ostracodes, bryozoans, red algae, echinoid (with syntaxial overgrowths), and barnacles; porosity is inter- and intraparticle, and moldic, with no sparry calcite filling in the molds, thin layer of dogtooth spar on micrite envelopes and foraminifers.
87.8	Calcareous, molluscan sandstone with about 10% patchy meniscus(?) micrite cement/matrix; fine quartz (~50%) and phosphatic (1%) sand; molluscan molds with micrite envelopes and bored fragments, partially leached benthic and planktonic foraminifers, leached echinoids; dogtooth spar is rare on skeletal grains; porosity is high (>39%) and is interparticle and moldic.
90.6	Calcareous skeletal sandstone with patchy meniscus micrite cement/matrix; fine to medium quartz (45%) and phosphatic (<1%) sand; skeletal grains include molluscan molds (with micrite envelopes) and fragments, benthic and planktonic foraminifers, ostracodes, bryozoans, red algae, and echinoids with syntaxial overgrowths; rare dogtooth spar on skeletal grains, no void-filling cement; porosity is high (30%) and is inter- and intraparticle, and moldic.
94.7	Calcareous molluscan sandstone with 5% micrite matrix or cement; fine quartz (45%) and phosphatic (<1%) silt and sand; skeletal grains include molluscan molds (with micrite envelopes) and fragments, benthic and planktonic foraminifers, ostracodes, bryozoans, and echinoids; porosity is high (30%) and is inter- and intraparticle and moldic; rare dogtooth spar on skeletal grains.
96.9	Calcareous molluscan sandstone with 5% micrite matrix or cement; fine quartz (50%) and phosphatic (<1%) silt and sand; skeletal grains include molluscan molds (micrite envelopes) and fragments, benthic and planktonic foraminifers, ostracodes, and echinoids with syntaxial overgrowths; porosity is interparticle and moldic, no void-filling cements; small amount of blocky to dogtooth spar on skeletal grains and micrite envelopes.

110.0 Packstone to calcareous sandstone with about 20% micrite matrix; fine to medium quartz sand (40%) and phosphatic silt (<1%) and peloids; skeletal grains include molluscan molds and fragments, benthic foraminifers, ostracodes, and echinoids; moderate porosity is 15% and is inter- and intraparticle, and moldic; small amount of dogtooth spar on some skeletal grains.

Unnamed formation

129.0 Dolostone with 40% burrowed(?) dolomicrite matrix; medium quartz sand (10%); skeletal grains include molluscan molds with micrite envelopes and bored in-infilled fragments, leached benthic foraminifers and bryozoans, ostracodes, and barnacles; moderate porosity is about 10% and primarily moldic and in vugs and channels; dolomite rhombs are 50 μm, both euhedral and anhedral, void-filling dolomite, cement grain-size increases away from grain surfaces.

129.5 Dolo-packstone with 30% dolomicrite matrix and quartz silt (5%); skeletal grains include molluscan molds with micrite envelopes, leached benthic foraminifers, and ostracodes; dolomite is 30 to 50 μm, euhedral and anhedral; porosity is low and moldic with minor shelter porosity.

129.8 Packstone with 15% peloidal micrite matrix and <5% quartz silt to fine sand; skeletal grains include molluscan molds and bored micritized fragments, partially leached benthic foraminifers, and ostracodes; dogtooth and blocky calcite fill voids, and minor void-filling dolomite (40 μm) precipitated after the calcite; porosity is moldic.

131.0 Wackestone to calcareous sandstone of medium quartz (50%) and fine phosphatic (<1%) sand with a micrite matrix (30%); skeletal grains include molluscan molds with micrite envelopes and bored fragments, leached benthic foraminifers, and bryozoans; early bladed calcite cement overlain by small amount of dolomite in voids; porosity is low, intraparticle and moldic; geopetal structures.

132.0 Wackestone with up to 60% micrite matrix and <1% quartz and phosphatic silt; unevenly distributed; skeletal grains include molluscan molds and fragments, benthic foraminifers, ostracodes, and echinoids; blocky calcite cement in voids; porosity is moldic.

133.0 Wackestone with 50% micrite matrix and fine quartz sand (20%), peloids; skeletal grains include molluscan molds and micritized fragments, some bored benthic foraminifers, ostracodes, and leached echinoids; virtually no cement except in chambers of leached gastropod on geopetal mud; possible desiccation cracks.

140.1 Dolostone of nearly 70% dolomicrite with 5% medium quartz sand and very few molluscan molds; dolomite rhombs are <40 μm, euhedral to anhedral; desiccation cracks; porosity is low (<10%) and moldic.

142.3 Dolostone, very similar to above sample, but dolomite rhombs are smaller (10 μm); there is slightly more quartz sand; all molds are mud-filled.

145.4 Dolostone, with 5% medium quartz sand in a dolomicrite matrix (60%); a few molluscan molds and leached foraminifers; desiccation cracks.

146.0 Dolostone, with 20% medium to very coarse quartz sand in a dolomicrite matrix (60%); skeletal grains include mollusk and benthic foraminifer molds; sand is clumpy and unevenly distributed; porosity is high (25-30%) and is primarily moldic; dolomite grain size is very small.

154.5 Sandy dolostone with minor dolomite (micrite to 50-µm grains) concentrated at grain contacts as meniscus cement; skeletal grains include mollusk and benthic foraminifer molds; some euhedral dolomite rhombs have hollow centers; medium to very coarse quartz sand (35%); poorly sorted; porosity is moldic.

163.4 Dolomitic sandstone with 50% fine to very coarse quartz sand and 50-µm dolomite rhombs (no hollow center as above) concentrated at grain contacts; no skeletal grains.

171.9 Calcareous sandstone, with >50% fine and very coarse quartz sand in bimodal distribution; virtually no matrix; rounded molluscan fragments, some leached; very low porosity; pores filled with calcite cement almost poikilotopic, but individual crystals do not engulf several quartz grains.

176.5 Calcareous sandstone with >50% fine and very coarse bimodal quartz sand; rounded mollusk and bryozoan fragments, less well-cemented and more leached than sample above; porosity is high (25%), interparticle, and moldic; calcite cement, as above.

177.9 Calcareous sandstone, with 60% fine to very coarse bimodal quartz sand, rounded molluscan fragments, slight meniscus microspar cements on quartz grains; blocky and dogtooth sparry cements; very high (>30%) porosity, both interparticle and moldic.

188.0 Dolostone, uniform silt-sized dolomite rhombs with <5% quartz silt; no skeletal grains and very low porosity.

Old Pump Road core

Depth (ft)	Description
	Tamiami Formation (Ochopee Limestone Member)
18.3	Molluscan wackestone with <5% silt to medium quartz sand in the micrite and microspar matrix; other skeletal grains include foraminifers (some leached), ostracodes, and echinoid fragments; some skeletal grains are phosphatized. The predominantly micritic matrix has been neomorphosed to a microspar and has a clotted texture in places; blocky calcite cement fills the voids and the porosity is very low.
27.1	Molluscan packstone with 20 to 30% fine quartz sand in the micritic matrix; other skeletal grains include foraminifers (some leached), ostracodes, bryozoans, red algae, and echinoid fragments; most skeletal grains are micritized; the matrix has been neomorphosed to a microspar that has a clotted texture in places; geopetal structures; porosity is very low, some is moldic.
39.2	Skeletal wackestone-packstone with <1% quartz silt in the micrite matrix (~25%); skeletal grains include micritized and leached aragonitic mollusks, calcitic mollusks, partially leached foraminifers, ostracodes, large bryozoan fragment, and echinoid fragments; nearly all skeletal grains are bored; porosity is highly variable due to patchy nature of micrite distribution.
44.5	Skeletal packstone with trace amounts of silt-sized quartz in the micrite matrix (30%); skeletal grains include leached and infilled aragonitic mollusks, calcitic mollusks, partially leached foraminifers, rare ostracodes, bored echinoid fragments, and barnacles; porosity is low due to matrix and is predominantly moldic and intraparticle.
47.6	Molluscan packstone with <5% very fine to fine quartz sand; other skeletal grains include foraminifers, ostracodes, and some partially leached echinoid fragments; some aragonitic molluscan fragments are unleached; evidence for an early, now leached cement between the echinoid fragment and the overgrowth; the matrix is a patchy microspar and some mollusks are now faint micrite envelopes within the microspar; porosity is primarily moldic.
55.7	Molluscan packstone with <5% quartz silt and fine sand; other skeletal grains include foraminifers, ostracodes, echinoid fragments, and barnacles; micrite makes up about 15% of the matrix and there is evidence for an early, leached cement, perhaps aragonite; some aragonitic mollusks are unleached; porosity is primarily moldic and pore-lining cement is dogtooth calcite.
56.4	Molluscan packstone with <5% quartz silt and fine sand in a micrite matrix (30%); other skeletal grains include foraminifers, ostracodes, bryozoans, and echinoid fragments; some aragonitic mollusks are unleached, mollusks are bored; evidence for a fibrous early cement on echinoid and mollusk grains; other cement is blocky and dogtooth calcite: blocky cement occurs inside large molluscan voids and dogtooth cement occurs along void surfaces; porosity is moldic and in vugs and channels.
64.6	Molluscan wackestone-packstone with <5% fine quartz sand (and few fine sand phosphate grains) in the micrite matrix (15%); other skeletal grains include partially leached benthic and planktonic foraminifers, ostracodes, bryozoans, echinoid fragments with overgrowths, and barnacles; small amount of dogtooth calcite cement on planktonic foraminifers; porosity is moldic and in vugs and channels.

67.4	Molluscan wackestone-packstone with <5% quartz silt and fine sand in a micrite matrix (20%); other skeletal grains include benthic and planktonic foraminifers, ostracodes, bryozoans, echinoids, and barnacles; dogtooth cement is similar to sample at 64.6, but less amount, porosity is moldic and in vugs and channels.
74.7	Recrystallized wackestone, ~10% medium quartz sand in the microspar matrix (formerly micrite?); skeletal grains include molluscan molds and fragments, benthic foraminifers, bryozoans, echinoids; skeletal grains are recrystallized and difficult to identify; cement is blocky calcite on surfaces and in voids; and porosity is moldic and in vugs and channels. Compared to samples above, the quartz sand is far more abundant and coarser, and the cement is coarser and more abundant.
86.0	Recrystallized wackestone, 20% medium quartz and <5% phosphatic sand in the micrite/microspar matrix (20%); skeletal grains include aragonitic mollusks and molds and calcitic mollusks, planktonic and benthic foraminifers, and echinoid fragments; skeletal grains are recrystallized and difficult to identify; cement is blocky calcite; porosity is moldic and in vugs and channels.
89.7, 95.5	Recrystallized wackestone, 20% medium quartz and <5% phosphatic sand in the micrite/microspar matrix (15%); skeletal grains include aragonitic mollusks and molds and calcitic mollusks, benthic foraminifers, ostracodes, and echinoid fragments; skeletal grains in microspar matrix are recrystallized and difficult to identify; cement is blocky in the matrix and dogtooth calcite on void surfaces; porosity is high and is moldic and in vugs and channels.

Unnamed formation

174.8	Dolostone with 10% fine to medium quartz sand, and sparse dolomitized foraminifers; dolomite rhombs are primarily anhedral and about 30 µm and form the "matrix" of the rock, suggesting replacement of micrite; porosity is very low.
175.2	Dolostone with 15% fine to medium quartz sand, and molluscan molds; similar to sample at 174.8 but more skeletal molds and scattered phosphatic clasts (hardground fragments?); porosity is moldic and in vugs and channels.
176.6	Dolostone with 30% sand; skeletal grains include mollusk and foraminifer molds and a large red algae (partly calcareous) fragment that covers about half of the thin section, *Halimeda*; matrix is dolomicrite (30%) and dolospar rhombs (50 µm) line voids; geopetal structures.
176.8	Dolostone, very similar to 174.8, above.
180.9	Sandy dolostone, with 30% medium quartz sand, calcareous mollusks, ostracodes, bryozoans and red algae; muddy peloidal clasts are partly calcareous and hold skeletal grains; matrix is primarily dolomicrite; dolomite rhombs in voids are ~50 µm, and primarily euhedral; desiccation(?) cracks.
184.0	Molluscan wackestone with ~20% medium quartz sand; skeletal grains include molluscan molds and fragments, foraminifers, ostracodes, and echinoid fragments with syntaxial overgrowths; micrite matrix is about 40%; porosity is high due to large connected molluscan molds; blocky calcite cement covers void surfaces.

186.1	Pisoidal wackestone with sparse skeletal grains and 10% medium quartz sand; skeletal grains include partially leached mollusks and benthic foraminifers, and barnacles; minor sparry calcite on void surfaces; porosity is moldic, in vugs and channels, and interparticle.
188.1	Pisoidal molluscan wackestone with 15% medium quartz sand; skeletal grains include bored, partially leached mollusks and coral fragments; porosity is high in molds, vugs and channels; micrite matrix (15%) is peloidal.
189.1	Pisoidal molluscan grainstone, with <5% fine quartz sand, and 30% micrite as a grain coating; skeletal grains include partially leached mollusks and coral; porosity is high and is interparticle, moldic, in vugs and channels.
190.9	Pisoidal wackestone with 10% quartz silt to medium sand; skeletal grains include molluscan molds and bored fragments, phosphatized benthic foraminifers, ostracodes, echinoids and coral fragments; pisoids fill some voids; porosity is interparticle, moldic, in vugs and channels; micrite matrix (15%).
195.2	Molluscan wackestone-packstone with 20% medium quartz sand, and 30% peloidal micrite matrix; skeletal grains include well preserved calcitic and aragonitic mollusks, benthic foraminifers, and ostracodes; very little surface cement.

Fakahatchee Strand-Ranger Station core

Depth (ft)	Description
	Tamiami Formation (Ochopee Limestone Member)
8.3	Molluscan packstone with <10% very fine quartz sand in a micrite matrix (40%); skeletal grains include leached mollusks with micrite envelopes and molluscan fragments, benthic foraminifers, bryozoans, echinoids; minor amount of grain-coating chalcedony in voids; blocky calcite cement in voids; evidence for an early leached fibrous cement, porosity is moldic.
10.7	Skeletal packstone with <5% very fine quartz sand, and 20% micrite matrix; skeletal grains include micritized molluscan fragments, benthic foraminifers, ostracodes, bryozoans, echinoids, and barnacles; geopetal structures; blocky void-filling calcite cement, evidence for an early fibrous leached cement; porosity is interparticle and moldic.
12.7	Molluscan packstone with <3% quartz silt and microspar matrix; skeletal grains include partially leached mollusks, benthic foraminifers, echinoids, and barnacles; minor micrite matrix; porosity is interparticle and moldic; geopetal structures.
17.6	Molluscan grainstone with <3% quartz silt and fine sand and <5% micrite matrix; skeletal grains include molluscan fragments (bores) and molds, partially leached benthic foraminifers, echinoids and barnacles; evidence for an early fibrous leached cement on echinoids; isopachous blocky cement on all surfaces, some dogtooth cement, high porosity as interparticle, intraparticle, and moldic.
22.7	Molluscan grainstone with <1% quartz and phosphatic silt to fine sand in a sparse micrite matrix (10%) with microspar and blocky calcite void-filling cement; skeletal grains include molluscan molds and fragments, foraminifers, bryozoans, partially leached echinoids, and barnacles; geopetal structures; evidence of an early leached cement; porosity is moldic.
34.0	Molluscan packstone with <3% quartz and phosphatic silt and fine sand in a micrite matrix (10%); skeletal grains include molluscan molds and fragments, benthic and planktonic foraminifers, bryozoans, red algae, and barnacles; very porous with interparticle, intraparticle, and moldic porosity; cement is sparse and finely crystalline dogtooth calcite (16-62 μm).
51.5	Molluscan wackestone to packstone with 10% quartz silt and <1% phosphatic silt and fine sand in a micrite matrix (15%); skeletal grains include molluscan molds (some original aragonite present) and fragments, partially leached benthic foraminifers, ostracodes, bryozoans, partially leached echinoids, and barnacles; sample dominated by bored oyster fragment; cement is finely crystalline dogtooth calcite (16-62 μm); porosity is moldic.
53.8	Molluscan wackestone to packstone with 20% quartz fine to medium sand and <1% phosphatic fine sand in a micrite matrix (30%); skeletal grains include molluscan molds and fragments, benthic and planktonic foraminifers, bryozoans, echinoids and barnacles; matrix is neomorphosed to microspar and has a clotted texture in places; porosity is moldic and in vugs and channels.
61.5	Calcareous sandstone with 40% medium quartz sand, and sand-free, pisolitic mudstone to wackestone with microspar and clotted texture; no skeletal grains; extremely low

porosity.

Unnamed formation

139.8 Dolostone with <5% medium quartz sand; skeletal grains include mollusks molds, and other nondescript molds and vugs; all matrix is dolomicrite and very finely crystalline, no additional cement precipitation after leaching of skeletal grains; dolomite rhombs are 15 μm, are euhedral and uniform, and form about 80% of the sample.

Fakahatchee Strand Gate 12 core

Depth (ft)	Description
	Tamiami Formation (Ochopee Limestone Member)
7.0	Molluscan wackestone with <1% quartz silt in a micrite matrix (15%); skeletal grains include molluscan molds (with remnants of aragonitic shell remaining) and fragments, partially leached benthic foraminifers, ostracodes, red algae, echinoids and barnacles; isopachous blocky cement on upper sides of molluscan fragments; porosity is moldic and in vugs and channels.
17.7	Molluscan packstone to grainstone with <1% quartz silt in a peloidal micrite matrix (<5%); skeletal grains include molluscan molds (?) and fragments, micritized benthic foraminifers, bryozoans, echinoids, and barnacles; matrix has microspar and clotted textures; porosity is very low and interparticle; geopetal structures.
23.8	Molluscan packstone with trace of quartz and phosphatic silt, and fine sand in a micrite matrix (30%); skeletal grains include molluscan molds (with remnant original shell present) and fragments, benthic and planktonic foraminifers, ostracode, bryozoan, echinoid fragments, and barnacles; dogtooth calcite cement on nearly all surfaces; porosity is high and moldic.
32.3	Skeletal packstone to grainstone with 10% medium quartz sand and <1% phosphatic fine sand in a micrite matrix (10%); skeletal grains include molluscan molds and fragments, benthic and planktonic foraminifers, ostracodes, bryozoans, echinoid fragments, and barnacles; minor microspar formation in matrix; cement is blocky and dogtooth calcite, and porosity is interparticle, moldic, and in vugs and channels.
36.0	Sandy wackestone with >30% medium quartz sand in a micrite matrix (5%); skeletal grains include micritized molluscan fragments, foraminifers, ostracodes, and bryozoans; matrix is microspar and has a clotted textures; cement is all blocky calcite; porosity is very low due to cement precipitation in voids.

Fakahatchee Strand-Jones Grade core

Depth (ft)	Description
	Tamiami Formation (Ochopee Limestone Member)
11.0	Molluscan packstone with trace of quartz silt in a micrite matrix (20%); skeletal grains include molluscan molds and fragments, partially leached benthic foraminifers, ostracodes, bryozoans, echinoid fragments, and barnacles; minor dogtooth calcite cement on some surfaces; porosity is high and moldic, and in vugs and channels.
15.2	Oyster fragment with patch of skeletal packstone adhering to the surface; micrite has 15% medium quartz sand, and fragments of mollusks, benthic foraminifers, bryozoans, and echinoids; minor dogtooth calcite on oyster surfaces; porosity is moldic and interparticle.

Picayune Strand State Forest core

Depth (ft)	Description
	Tamiami Formation (Ochopee Limestone Member)
9.0	Molluscan packstone with 10% quartz silt and trace of phosphatic silt in a micrite matrix (15%); skeletal grains include molluscan molds (infilled with blocky calcite cement), benthic foraminifers, ostracodes, and echinoid fragments; some matrix is neomorphosed to microspar and has a clotted texture; porosity is moldic and in vugs and channels.
11.8	Molluscan packstone with trace of quartz silt in a micrite matrix (15%) neomorphosed to microspar with a clotted texture; skeletal grains include molluscan molds (infilled with blocky calcite cement) and fragments, foraminifers (?), bryozoans, and echinoid fragments; blocky calcite cement fills in nearly all moldic porosity; very low porosity.
31.3	Molluscan wackestone to packstone with a trace of quartz silt in a micrite matrix (30%); skeletal grains include molluscan molds and fragments, benthic foraminifers, ostracodes, bryozoans, echinoid fragments, and barnacles; minor dogtooth calcite spar on skeletal fragments; porosity is moldic.
41.0	Molluscan packstone to grainstone with a trace of quartz silt in a micrite matrix (25%); skeletal grains include molluscan molds and fragments, benthic foraminifers, ostracodes, partially leached bryozoans, echinoid fragments, and barnacles; virtually no void-filling cement; porosity is primarily moldic.
53.0	Molluscan wackestone to packstone with trace of quartz silt in a micrite matrix (40%); skeletal grains include molluscan molds and fragments, partially leached benthic foraminifers, bryozoans, echinoids, and barnacles; minor amount of dogtooth calcite spar on skeletal surfaces; porosity is moldic and in vugs and channels.
75.0	Sandy molluscan packstone with 20% medium quartz sand in a micrite matrix (40%); skeletal grains include molluscan molds and fragments, benthic foraminifers, ostracodes, red algae, and partially leached echinoids; isopachous layer of dogtooth calcite on most surfaces; porosity is moldic and in vugs and channels.
85.2	Calcareous sandstone with 50% medium quartz sand and <10% micrite matrix adhering to grains as meniscus cement; skeletal grains include molluscan molds and fragments, partially leached benthic foraminifers, bryozoans, and barnacles; dogtooth spar grows on micrite matrix/cement; high interparticle porosity with minor moldic porosity.
	Unnamed formation
169.2	Dolostone with <5% fine quartz sand, in a dolomicrite matrix (10%); skeletal grains are rare molluscan molds, bryozoans, echinoid fragments, and barnacles; dolomite rhombs are both euhedral and anhedral and 30-50 µm; porosity is interparticle and moldic.
181.3	Dolostone with rare molluscan molds, and a peloidal dolomicrite matrix (30%), and dolomite rhombs (euhedral and anhedral) (30 µm) on void surfaces; coral molds; pyrite framboids (10-20 µm) occur in dolomicrite.

APPENDIX 2
Dinocyst sample descriptions.

Collier-Seminole State Park core

The Collier-Seminole State Park core (W-17360) was assigned U.S. Geological Survey Paleobotanical Number R5195.

Undifferentiated, unconsolidated quartz sand

9.3-9.6 ft depth (R5195 R) did not yield dinocysts.

14.9-15.2 ft depth (R5195 Q) did not yield dinocysts.

Tamiami Formation (Ochopee Limestone Member)

27.7-28.1 ft depth (R5195 P) did not yield dinocysts.

46.8-47.1 ft depth (R5195 0) contains two specimens of *Polysphaeridium zoharyi* (Rossignol) Bujak et al.
Age: Cenozoic.

54.0-54.5 ft depth (R5195 N) contains a single gonyaulacacean specimen that is presumably reworked.
Age: Cenozoic.

65.5-66.0 ft depth (R5195 M) did not yield dinocysts.

87.4-87.8 ft depth (R5195 L) contains a moderately well preserved, moderately diverse dinocyst assemblage dominated by *Spiniferites* spp. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Ataxiodinium Reid ? n. sp.
Cyclopsiella? Drugg & Loeblich sp.
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Invertocysta Edwards sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium Harland & Hill sp.
Multispinula quanta Bradford
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka
Selenopemphix Benedek sp.
Spiniferites Mantell spp.
Tuberculodinium vancampoae (Rossignol) Wall

Age: late middle Miocene, late Miocene, or Pliocene, based on the overlap of *A. andalousiensis* (earliest occurrence near the middle/late Miocene boundary) and *D. pseudocolligerum* (latest occurrence in the Pliocene).

100.4-100.8 ft depth (R5195 K) contains a well preserved, diverse dinocyst assemblage dominated by *Spiniferites* spp. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Brigantedinium Reid sp.
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Forma D of Wrenn and Kokinos (1986)
Impagidinium paradoxum (Wall) Stover and Evitt
Impagidinium patulum (Wall) Stover & Evitt
Invertocysta Edwards sp.

Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium Harland & Hill sp.
Multispinula quanta Bradford
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites Mantell spp.
Spiniferites mirabilis (Rossignol) Sarjeant
Tectatodinium pellitum Wall
Trinovantedinium Reid sp.
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: late middle Miocene, late Miocene, or Pliocene, based on the overlap of *A. andalousiensis* (earliest occurrence near the middle/late Miocene boundary) and *D. pseudocolligerum* (latest occurrence in the Pliocene). The presence of *Impagidinium* spp. may indicate a more offshore depositional environment than other samples from this core.

Unnamed formation

124.0-124.6 ft depth (R5195 J) contains a moderately diverse dinocyst assemblage dominated by *Spiniferites* spp. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Brigantedinium Reid sp.
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Invertocysta Edwards sp.
Lejeunecysta Artzner & Dörhöfer sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium Harland & Hill sp.
Multispinula quanta Bradford
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Selenopemphix Benedek sp.
Spiniferites Mantell spp.
Spiniferites mirabilis (Rossignol) Sarjeant
Tectatodinium pellitum Wall
Trinovantedinium Reid sp.
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: late middle Miocene, late Miocene, or Pliocene, based on the overlap of *A. andalousiensis* (earliest occurrence near the middle/late Miocene boundary) and *D. pseudocolligerum* (latest occurrence in the Pliocene).

128.6-129.0 ft depth (R5195 I) contains abundant black organic material (charcoal) and a sparse, poorly preserved dinocyst assemblage dominated by *P. zoharyi*. Dinocysts are:

Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites Mantell spp.

Age: Cenozoic.

139.3-139.9 ft depth (R5195 H) did not yield dinocysts.

141.4- 141.7 ft depth (R5195 G) contains a single specimen of *Spiniferites* Mantell spp.
Age: Cenozoic.

151.7-152.2 ft depth (R5195 F) did not yield dinocysts.

159.3-159.7 ft depth (R5195 E) contains a very sparse, poorly preserved dinocyst assemblage dominated by *Spiniferites* Mantell spp. Dinocysts are:

Hystrichokolpoma rigaudiae Deflandre & Cookson
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites Mantell spp.

Age: Cenozoic.

170.2-170.8 ft depth (R5195 D) did not yield dinocysts.

175.4-175.8 ft depth (R5195 C) contains a very sparse, poorly preserved dinocyst assemblage dominated by a flat, oblong form that may or may not be a dinocyst. Dinocysts are:

unknown oblong form
Batiacasphaera sphaerica Stover ?
Hystrichosphaeropsis obscura Habib
Lejeunecysta Artzner & Dörhöfer sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites Mantell spp.
freshwater alga *Pediastrum*

Age: late middle or late Miocene, based on stratigraphic position and the presence of *H. obscura* (latest occurrence in the late Miocene).

179.2-179.7 ft depth (R5195 B) contains a well preserved, moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Clear platy debris is conspicuously present. Dinocysts are:

Cyclopsiella Drugg & Loeblich ? sp.
Erymnodinium delectabile (Verteuil & Norris) Lentin et al.
Heteraulacacysta Drugg & Loeblich sp.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Hystrichosphaeropsis obscura Habib
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Trinovantedinium Reid sp.
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: late middle Miocene or late Miocene, based on the ranges of *E. delectabile* (late middle and late Miocene) and *H. obscura* (latest occurrence in the late Miocene).

187.8-188.0 ft depth (R5195 A) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Erymnodinium delectabile (Verteuil & Norris) Lentin et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Hystrichosphaeropsis obscura Habib
Lejeunecysta Artzner & Dörhöfer spp.

Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium choanophorum (Deflandre & Cookson) Harland & Hill
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Spiniferites Mantell spp.
Sumatradinium hispidum (Drugg) Lentin & Williams
Tectatodinium pellitum Wall
Trinovantedinium Reid sp.
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: late middle Miocene or late Miocene, based on the ranges of *E. delectabile* (late middle and late Miocene), *A. andalousiensis* (earliest occurrence near the middle/late Miocene boundary), and *H. obscura* (latest occurrence in the late Miocene).

Old Pump Road core

The Old Pump Road core (W-17361) was assigned U.S. Geological Survey Paleobotanical Number R5193.

Undifferentiated, unconsolidated quartz sand

9.9-10.7 ft depth (R5193 M) did not yield dinocysts.

Tamiami Formation (Ochopee Limestone Member)

39.7-45.0 ft depth (R5193 L) did not yield dinocysts.

95.2-96.0 ft depth (R5193 J) did not yield dinocysts.

Unnamed formation

122.0-122.4 ft depth (R5193 I) contains a moderately diverse dinocyst assemblage dominated by *Polysphaeridium zoharyi* (Rossignol) Bujak et al. Preservation is fair. Dinocysts are:

- *Achomosphaera andalousiensis* Jan du Chêne
- *Ataxiodinium* Reid ? n. sp.
- *Dapsilidinium pseudocolligerum* (Stover) Bujak et al.
- *Hystrichokolpoma rigaudiae* Deflandre & Cookson
- *Impagidinium paradoxum* (Wall) Stover and Evitt
- *Lejeunecysta* Artzner & Dörhöfer spp.
- *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall
- *Multispinula quanta* Bradford
- *Operculodinium* Wall spp.
- *Polysphaeridium zoharyi* (Rossignol) Bujak et al.
- *Reticulatasphaera actinocoronata* (Benedek) Bujak & Matsuoka
- *Selenopemphix* Benedek sp.
- *Spiniferites mirabilis* (Rossignol) Sarjeant
- *Spiniferites* Mantell spp.
- *Tectatodinium pellitum* Wall
- *Tuberculodinium vancampoae* (Rossignol) Wall

Age: late middle Miocene, late Miocene, or Pliocene, based on the overlap of *A. andalousiensis* (earliest occurrence near the middle/late Miocene boundary) and *D. pseudocolligerum* (latest occurrence in the Pliocene).

145.4-146.0 ft depth (R5193 G) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair; reworked specimens are present. Dinocysts are:

- Forma D of Wrenn and Kokinos (1986)
- *Habibacysta tectata* Head et al.
- *Hystrichokolpoma rigaudiae* Deflandre & Cookson
- *Lejeunecysta* Artzner & Dörhöfer spp.
- *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall
- *Multispinula quanta* Bradford
- *Nematosphaeropsis* Deflandre & Cookson sp.
- *Operculodinium* Wall spp.
- *Polysphaeridium zoharyi* (Rossignol) Bujak et al.
- *Selenopemphix brevispinosa* Head et a. subsp. *brevispinosa*
- *Selenopemphix* Benedek sp.
- *Spiniferites* Mantell spp.
- *Tuberculodinium vancampoae* (Rossignol) Wall
- reworked specimens, Paleocene or older

Age: middle or late Miocene, based on the range overlap of *H. tectata* (earliest occurrence in the middle Miocene) and

S. brevispinosa brevispinosa (latest occurrence in the late Miocene)

183.8-185.0 ft depth (R5193 D) did not yield dinocysts.

186.0-186.9 ft depth (R5193 C) did not yield dinocysts.

189.4-189.7 ft depth (R5193 B) did not yield dinocysts.

195.2-196.0 ft depth (R5193 A) did not yield dinocysts.

Fakahatchee Strand-Ranger Station core

The Fakahatchee Strand-Ranger Station core (W-17393) was assigned U.S. Geological Survey Paleobotanical Number R5196.

Tamiami Formation (Ochopee Limestone Member)

13.3-13.6 ft depth (R5196 J) contains a single specimen of *Polysphaeridium zoharyi* (Rossignol) Bujak et al. and single fragment of *Operculodinium* Wall sp.

28.4-28.8 ft depth (R5196 I) contains a single specimen of *Spiniferites* Mantell sp. and an unidentifiable dinocyst fragment.

40.5-40.8 ft depth (R5196 H) contains a single fragment of *Operculodinium* Wall sp.

55.8-56.3 ft depth (R5196 G) contains a single specimen of *Operculodinium* Wall sp., two unidentifiable dinocyst fragments, and two specimens of the Cretaceous genus *Ovoidinium* Davey.

Unnamed formation

78.3-78.8 ft depth (R5196 F) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair. Dinocysts are:

- *Ataxiodinium* Reid ? n. sp.
- *Erymnodinium delectabile* (de Verteuil & Norris) Lentin et al.
- *Habibacysta tectata* Head et al.
- *Invertocysta lacrymosa* Edwards
- *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall
- *Multispinula quanta* Bradford
- *Nematosphaeropsis rigida* Wrenn
- *Operculodinium* Wall spp.
- *Polysphaeridium zoharyi* (Rossignol) Bujak et al.
- *Selenopemphix armageddonensis* de Verteuil & Norris
- *Selenopemphix* Benedek sp.
- *Spiniferites* Mantell spp.
- *Spiniferites mirabilis* (Rossignol) Sarjeant
- *Tuberculodinium vancampoae* (Rossignol) Wall
- miscellaneous Congruentidiaceae

Age: late Miocene. *S. armageddonensis* and *E. delectabile* overlap in zone DN 10 of de Verteuil and Norris (1996) in the late late Miocene.

97.9-98.6 ft depth (R5196 E) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair. Dinocysts are:

- *Achomosphaera andalousiensis* Jan du Chêne
- *Cyclopsiella* Drugg & Loeblich ? sp.
- *Erymnodinium delectabile* (Verteuil & Norris) Lentin et al. ?
- Forma D of Wrenn and Kokinos (1986)
- *Habibacysta tectata* Head et al.
- *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall
- *Nematosphaeropsis* Deflandre & Cookson sp.
- *Nematosphaeropsis rigida* Wrenn
- *Operculodinium centrocarpum* (Deflandre & Cookson) Wall
- *Operculodinium* Wall spp.
- *Spiniferites* Mantell spp.
- *Spiniferites mirabilis* (Rossignol) Sarjeant

Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: late middle Miocene or late Miocene, based on stratigraphic position and the presence of *H. tectata* (earliest occurrence in the middle Miocene).

136.4-137.0 ft depth (R5196 D) contains a low diversity dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Batiacasphaera sphaerica Stover ?
Cyclopsiella Drugg & Loeblich ? sp.
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium Wall spp.
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Trinovantedinium Reid ? sp.
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: late middle or late Miocene, based on the overlapping ranges of *A. andalousiensis* (earliest occurrence near the middle/late Miocene boundary) and *B. sphaerica* (latest occurrence in the late Miocene).

157.0-158.1 ft depth (R5196 B/C) contains a low diversity dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair. Dinocysts are:

Hystrichokolpoma rigaudiae Deflandre & Cookson
Impagidinium paradoxum (Wall) Stover and Evitt ?
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium Harland & Hill sp.
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Spiniferites Mantell spp.
Trinovantedinium Reid sp. ?
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: late Oligocene, Miocene, Pliocene, or Pleistocene, based on the ranges of the taxa present; however, Pliocene and Pleistocene can be excluded based on the Miocene age assigned to overlying samples.

159.8-160.3 ft depth (R5196 A) contains a low diversity dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair. Dinocysts are:

Hystrichokolpoma rigaudiae Deflandre & Cookson
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Spiniferites Mantell spp.
Spiniferites mirabilis (Rossignol) Sarjeant
Tuberculodinium vancampoae (Rossignol) Wall

Age: late Oligocene, Miocene, Pliocene, or Pleistocene, based on the ranges of the taxa present; however, Pliocene and Pleistocene can be excluded based on the Miocene age assigned to overlying samples.

Fakahatchee Strand Gate 12 core

The Fakahatchee Strand Gate 12 core (W-17389) was assigned U.S. Geological Survey Paleobotanical Number R5194.

Tamiami Formation (Ochopee Limestone Member)

36.0-36.3 ft depth (R5194 G) did not yield dinocysts.

Unnamed formation

62.5-63.0 ft depth (R5194 F) contains a well preserved, moderately diverse dinocyst assemblage dominated by *Polysphaeridium zoharyi* (Rossignol) Bujak et al. Dinocysts are:

Habibacysta tectata Head et al. ?
Multispinula quanta Bradford
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Selenopemphix Benedek sp.
Spiniferites Mantell spp.
Sumatradinium or *Barssidinium* sp.
Trinovantedinium papulum de Verteuil & Norris
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: Miocene or younger.

88.1-88.5 ft depth (R5194 E) contains a well preserved, moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell and *Habibacysta tectata* Head et al. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Forma D of Wrenn and Kokinos (1986)
Habibacysta tectata Head et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium Wall spp.
Spiniferites Mantell spp.
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Tectatodinium pellitum Wall

Age: late middle Miocene, late Miocene, or Pliocene, based on the overlap of *A. andalousiensis* (earliest occurrence near the middle/late Miocene boundary) and *D. pseudocolligerum* (latest occurrence in the Pliocene).

126.2-126.5 ft depth (R5194 C) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell and *Operculodinium* Wall. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Ataxiodinium Reid ? n. sp.
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Erymnodinium delectabile (Verteuil & Norris) Lentin et al. ?
Hystrichokolpoma rigaudiae Deflandre & Cookson
Impagidinium Stover & Evitt sp.
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford

Nematosphaeropsis rigida Wrenn
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Spiniferites Mantell spp.
Spiniferites mirabilis (Rossignol) Sarjeant
Tectatodinium pellitum Wall
Trinovantedinium papulum de Verteuil & Norris
Tuberculodinium vancampoae (Rossignol) Wall

Age: late middle Miocene or late Miocene, based on the ranges of *E. delectabile* (late middle and late Miocene) and *A. andalousiensis* (earliest occurrence near the middle/late Miocene boundary).

157.5-158.0 ft depth (R5194 B) did not yield dinocysts.

218.2-218.5 ft depth (R5194 A) contains a moderately diverse, well preserved dinocyst assemblage dominated by *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall, *Erymnodinium delectabile* (Verteuil & Norris) Lentin et al., and *Lejeunecysta* Artzner & Dörhöfer spp. Dinocysts are:

Erymnodinium delectabile (Verteuil & Norris) Lentin et al. ?
Heteraulacacysta Drugg & Loeblich sp.
Hystrichosphaeropsis obscura Habib
Impagidinium Stover & Evitt sp.
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium Wall sp.
Selenopemphix Benedek sp.
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Selenopemphix brevispinosa Head et al. subsp. *conspicua* de Verteuil & Norris
Spiniferites Mantell spp.
Spiniferites mirabilis (Rossignol) Sarjeant
Sumatradinium druggii Lentin et al.
Sumatradinium hispidum (Drugg) Lentin & Williams
Tectatodinium pellitum Wall
Trinovantedinium Reid spp.
Tuberculodinium vancampoae (Rossignol) Wall

Age: late middle Miocene or late Miocene, based on the ranges of *E. delectabile* (late middle and late Miocene) and *H. obscura* (latest occurrence in the late Miocene).

Fakahatchee Strand-Jones Grade core

The Fakahatchee Strand-Jones Grade core (W-17394) was assigned U.S. Geological Survey Paleobotanical Number R5222.

Tamiami Formation (Ochopee Limestone Member)

11.4-12.0 ft depth (R5222 M) did not yield dinocysts.

23.8-24.4 ft (R5222 L) did not yield dinocysts.

56.5-57.0 ft depth (R5222 K) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Batiacasphaera hirsuta Stover ?
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Invertocysta Edwards sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium Harland & Hill sp.
Multispinula quanta Bradford
Operculodinium Wall spp.
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka
Spiniferites Mantell spp.
Spiniferites mirabilis (Rossignol) Sarjeant
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: late late Miocene or Pliocene, based on stratigraphic position and the overlap of *A. andalousiensis* (earliest occurrence near the middle/late Miocene boundary) and *D. pseudocolligerum* (latest occurrence in the Pliocene).

Unnamed formation

71.2-71.9 ft depth (R5222 J) did not yield dinocysts.

141.4-142.4 ft depth (R5222 H) contains a well preserved, moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Habibacysta tectata Head et al.
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium choanophorum (Deflandre & Cookson) Harland & Hill
Multispinula quanta Bradford
Operculodinium Wall spp.
Quadrina ? *condita* de Verteuil & Norris
Selenopemphix armageddonensis de Verteuil & Norris
Selenopemphix brevispinosa Head et al. subsp. *conspicua* de Verteuil & Norris
Spiniferites Mantell spp.
Trinovantedinium ? *xylochoporum* de Verteuil & Norris
Trinovantedinium papulum de Verteuil & Norris
Tuberculodinium vancampoae (Rossignol) Wall

Age: late late Miocene. *S. armageddonensis* and *E. delectabile* overlap in zone DN 10 of de Verteuil and Norris (1996) in the late late Miocene.

185.0-185.5 ft depth (R5222 C) contains a well preserved, moderately diverse dinocyst assemblage in which no particular species is dominant. Dinocysts are:

Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Habibacysta tectata Head et al. ?
Invertocysta lacrymosa Edwards
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Nematosphaeropsis rigida Wrenn
Operculodinium Wall spp.
Selenopemphix Benedek sp.
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Trinovantedinium ? *xylochoporum* de Verteuil & Norris
Trinovantedinium Reid sp.
Tuberculodinium vancampoae (Rossignol) Wall

Age: late Miocene, based on the overlap of ranges of *E. delectabile* (late middle and late Miocene), *I. lacrymosa* (late Miocene and Pliocene), and *S. brevispinosa brevispinosa* (latest occurrence in the late Miocene).

Picayune Strand State Forest core

The Picayune Strand State Forest core (W-17450) was assigned U.S. Geological Survey Paleobotanical Number R5223.

Tamiami Formation (Ochopee Limestone Member)

12.4-12.8 ft depth (R5223 J) contains a sparse, monospecific assemblage of *Polysphaeridium zoharyi* (Rossignol) Bujak et al.

Age: Cenozoic.

34.1-34.6 ft depth (R5223 I) contains a low diversity dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair to poor. Dinocysts are:

Invertocysta Edwards sp.
Invertocysta lacrymosa Edwards
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium Wall spp.
Spiniferites Mantell spp.
Spiniferites mirabilis (Rossignol) Sarjeant
Tectatodinium pellitum Wall
miscellaneous chorate fragment, presumed reworked.

Age: late Miocene or Pliocene based on the presence of *I. lacrymosa*.

54.3-54.7 ft depth (R5222 G) did not yield dinocysts.

79.0 -79.4 ft depth (R5222 H) did not yield dinocysts.

90.5-91.0 ft depth (R5223 F) contains a sparse, moderately low diversity dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair. Dinocysts are:

Achomosphaera Evitt sp.
Batiacasphaera hirsuta Stover ?
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Selenopemphix Benedek sp.
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

Age: late middle or late Miocene or Pliocene, based on stratigraphic position and the presence of *D. pseudocolligerum* (latest occurrence in the Pliocene).

Unnamed formation

152.8-153.5 ft depth (R5223 D) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell and *Habibacysta tectata* Head et al. Preservation is fair. Dinocysts are:

Forma D of Wrenn and Kokinos (1986)
Habibacysta tectata Head et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium Wall spp.
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams sp.

Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: late middle Miocene, late Miocene, or early Pliocene, based on stratigraphic position.

187.9-188.5 ft depth (R5223 A) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair. Dinocysts are:

Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Hystrichosphaeropsis obscura Habib
Impagidinium sphaericum (Wall) Lentin & Williams
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites Mantell spp.
Tuberculodinium vancampoae (Rossignol) Wall

Age: late middle Miocene or late Miocene, based on the ranges of *E. delectabile* (late middle and late Miocene) and *H. obscura* (latest occurrence in the late Miocene).

Southern States Utilities core

The Southern States Utilities core (W-17454) was assigned U.S. Geological Survey Paleobotanical Number R5221.

Tamiami Formation (Ochopee Limestone Member)

8.5-9.0 ft depth (R5221 J) contains a monospecific assemblage of *Polysphaeridium zoharyi* (Rossignol) Bujak et al.

Age: Cenozoic.

36.4-37.0 ft depth (R5221 I) did not yield dinocysts.

54.5-55.0 ft depth (R5221 H) did not yield dinocysts.

Unnamed formation

97.6-98.3 ft depth (R5221 G) contains a well preserved, moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell and *Operculodinium* Wall. Dinocysts are:

- *Achomosphaera andalousiensis* Jan du Chêne
- *Batiacasphaera hirsuta* Stover ?
- *Erymnodinium delectabile* (de Verteuil & Norris) Lentin et al.
- Forma D of Wrenn and Kokinos (1986)
- *Lejeunecysta* Artzner & Dörhöfer spp.
- *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall
- *Melitasphaeridium choanophorum* (Deflandre & Cookson) Harland & Hill
- *Multispinula quanta* Bradford
- *Operculodinium* Wall spp.
- *Polysphaeridium zoharyi* (Rossignol) Bujak et al.
- *Reticulatasphaera actinocoronata* (Benedek) Bujak & Matsuoka
- *Spiniferites* Mantell spp.
- *Spiniferites mirabilis* (Rossignol) Sarjeant
- *Sumatradinium druggii* Lentin et al. ?
- *Tectatodinium pellitum* Wall
- *Tuberculodinium vancampoae* (Rossignol) Wall
- miscellaneous Congruentidiaceae

Age: late middle Miocene or late Miocene, based on the ranges of *E. delectabile* (late middle and late Miocene) and *A. andalousiensis* (earliest occurrence near the middle/late Miocene boundary).

140.5-141.0 ft depth (R5221 E) did not yield dinocysts.

204.3-204.8 ft depth (R5221 A) contains a well preserved, moderately diverse dinocyst assemblage in which no particular species is dominant. Dinocysts are:

- *Erymnodinium delectabile* (de Verteuil & Norris) Lentin et al.
- *Hystrichokolpoma rigaudiae* Deflandre & Cookson
- *Hystrichosphaeropsis obscura* Habib
- *Lejeunecysta* Artzner & Dörhöfer spp.
- *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall
- *Multispinula quanta* Bradford
- *Nematosphaeropsis* Deflandre & Cookson sp.
- *Operculodinium* Wall spp.
- *Polysphaeridium zoharyi* (Rossignol) Bujak et al.
- *Selenopemphix brevispinosa* Head et a. subsp. *brevispinosa*
- *Spiniferites* Mantell spp.
- *Sumatradinium hispidum* (Drugg) Lentin & Williams

Tectatodinium pellitum Wall
Trinovantedinium harpagonium de Verteuil & Norris
Trinovantedinium Reid sp.
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: late middle Miocene or late Miocene, based on the ranges of *E. delectabile* (late middle and late Miocene) and *H. obscura* (latest occurrence in the late Miocene).