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Lithostratigraphy, Geophysics, Biostratigraphy, and Strontium-Isotope Stratigraphy of the Surficial Aquifer System of Eastern Collier County and Northern Monroe County, Florida

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CONTENTS

FIGURES

TABLES

APPENDIXES

ABSTRACT

In 1997, ten cores were drilled in eastern Collier County and northern Monroe County, within the limits of the Big Cypress National Preserve. These cores represent a continuation of the study of seven cores in western Collier County begun in 1996 and reported in Weedman and others (1997) and Edwards and others (1998). This joint U.S. Geological Survey and Florida Geological Survey project is designed to acquire subsurface geologic and hydrologic data in southwest Florida to extend current ground-water models, thereby expanding the utility of these models for land and water management. In this report we describe the lithostratigraphy, geophysical logging, sedimentological analysis, dinocyst biostratigraphy, and strontium-isotope stratigraphy of these ten cores.

The three geophysical logs (natural gamma-ray, induction conductivity, and neutron porosity) assumed to be related to formation lithology and water quality show that a number of clay-rich zones are present in all of the boreholes, and that pore-water conductivity increases with depth. The clay-rich zones are confirmed by visual examination of core material and sedimentological analysis.

The relative transmissivity calculated at 10-foot-thick intervals shows that in six of the boreholes, high values are associated with the shallow aquifer in the 0-40 ft interval. Two of the boreholes (the most northerly and the most easterly) showed relatively higher values of transmissivity in permeable zones at or somewhat below 100 ft in depth. Core geology and logs indicate that the deeper aquifers are not more permeable than similar deeper zones in the other boreholes, but rather that the shallow aquifer appears to be less permeable in these two coreholes.

The Arcadia (?) Formation was only penetrated in the deepest core where it is late Miocene in age. The Peace River Formation was penetrated in all but the two westernmost cores. It yields a late Miocene age, based on both dinocysts and strontium-isotope stratigraphy. The top is an irregular surface. Age and stratigraphic relations suggest that the upper part of the Peace River and lower part of the unnamed formation are at least partially equivalent laterally.

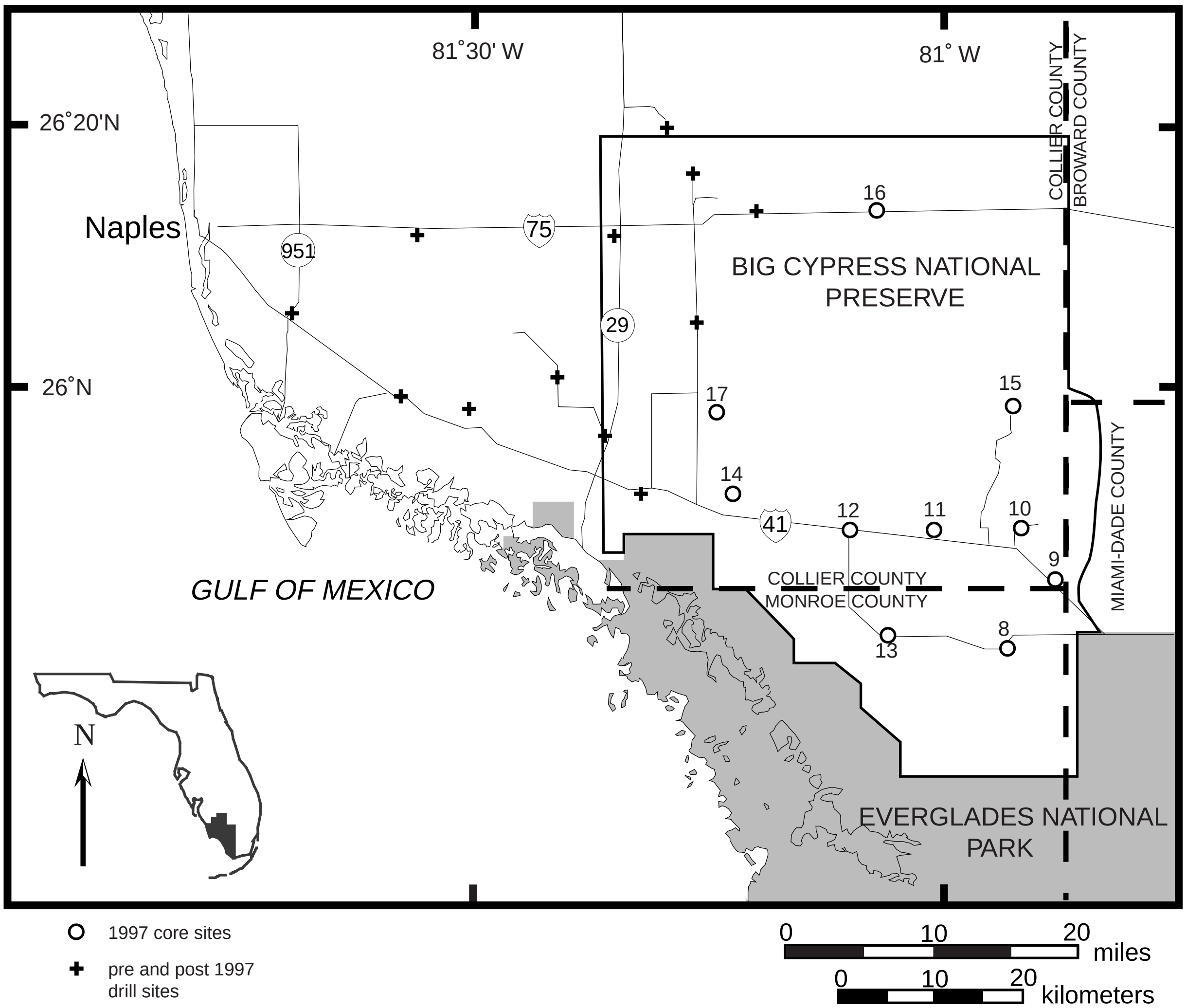
The unnamed formation was recovered in every core. It is thinnest in the northernmost core and thickest to the west. Ages calculated from strontium isotopes range from 6.9 to 4.6 million years ago (late Miocene to early Pliocene). The top of the unnamed formation is deepest to the north and it becomes shallower to the southwest.

The Tamiami Formation also was recovered in every core and consistently yields early Pliocene ages; it yields late Pliocene ages near the top in two cores. The age and lateral relations strongly suggest that the lower part of the Tamiami Formation and the upper part of the unnamed formation are lateral facies of each other.

The Fort Thompson (?) Formation, Miami Limestone, and undifferentiated siliciclastic sediments and limestone at the very top of the cores were not dated.

INTRODUCTION

At the turn of the century, the Kissimmee River-Lake Okeechobee-Everglades wetland ecosystem in south Florida covered about 2.9 million acres (Davis, 1943), and seasonal flooding of the lake sent water flowing over its southern rim as overland sheet flow on a sluggish journey to Florida Bay and the Gulf of Mexico. To control flooding and drain the wetlands for residential and agricultural use, the state of Florida began the construction of canals, and later levees in the early part of this century. In the 1930's and 1940's, cross-peninsula highways, like the Tamiami Trail (Rte. 41) and Alligator Alley (I-75) (fig. 1), not only brought development and cypress logging into southwest Florida, but also created obstructions to surface water flowing across the Big Cypress Swamp to the southwest coast. In the 1960's, drainage of the Big Cypress Swamp of southwest Florida accelerated with the construction of the Golden Gate-Faka Union canal system, designed for residential and recreational use. Much of this area drained by that canal system is now owned by the State of Florida and has become the Picayune Strand State Forest, and is scheduled for rehydration in the near future (Abbot and Nath, 1996). Because of these alterations in the natural



8. Golightly
9. Trail Center
10. Dade-Collier Airport
11. FAA Radar
12. Monroe Station
13. West Loop Road
14. Doerr's Lake
15. Raccoon Point
16. Nobles Road
17. Bass

Figure 1. Map of Collier and Monroe Counties, Florida, showing locations of corehole sites. Core numbers begin with number 8 because the 1996 core sites were numbered 1-7 (Weedman and others, 1997, Edwards and others, 1998).

hydrologic system in southwest Florida, there has been a reduction in aquifer storage, increased saltwater intrusion, invasion of upland vegetation, and an increase in frequency of fresh-water shock loads to coastal estuaries (Abbot and Nath, 1996).

In 1973, the state of Florida passed the Big Cypress Conservation Act, which for the first time protected a large portion of eastern Collier County from ecosystem stress coming from large-scale drainage projects like the Golden Gate development on the west and the Dade-Collier Transition and Training Airport on the east. The following year, Congress created the Big Cypress National Preserve authorizing purchase of 581,760 acres, later augmented by 147,280 acres from adjacent areas.

By the 1990's, nearly half of the greater Everglades wetlands was drained and the size of the ecosystem drastically reduced, diminishing wildlife habitats and seriously threatening commercial aquatic habitats along the coasts. Public concern over this long-term degradation of the south Florida ecosystem recently has mandated local, state, and federal agencies, as well as private businesses, to change some of their detrimental practices and to begin the long process of restoration of the ecosystem toward the pre-development state. The U.S. Geological Survey (USGS) has joined with the Army Corps of Engineers, the Environmental Protection Agency, the National Park Service, the South Florida Water Management District (SFWMD), the Florida Department of Environmental Protection, and other state and local agencies, to determine and re-establish a more natural water regime and to manage and maintain the wetlands of south Florida so that the natural ecosystem can recover.

Restoration of the ecosystem requires restoration of the natural hydrologic system. The return of natural sheet flow will have several beneficial effects: hydroperiods should lengthen, habitats should expand, recharge of the water table aquifer should increase, and the fresh-water lens may enlarge and suppress saltwater intrusion along the coasts. Long-term land and water management decisions in south Florida will be based, in part, on computer models that simulate both the natural hydrologic system (both ground- and surface-water flow), and the engineering structures that have been added to that system. Local and state agencies depend on these models to assess restoration plans and to predict their effect. However, current models, such as the South Florida Water Management Model and the Natural System Model, do not cover the entire ecosystem area; sufficient subsurface data are available only in southeastern Florida (Causaras, 1985; 1987; Fish, 1988; Fish and Stewart, 1991).

The purpose of this joint USGS and Florida Geological Survey (FGS) project is to acquire subsurface geologic and hydrologic data in southwest Florida, which will form the basic data for extending current ground-water models to the southwest coast, thereby expanding the utility of these models for land and water management. The first goal of this study is to develop a geologically reasonable conceptual model for the surficial aquifer system in southwest Florida, the first step in designing a mathematical model. The second goal is to provide reasonable values for permeability of the different sediment and rock types in the aquifer system and to map their spatial distribution.

Past geologic studies have been based largely on drill cuttings from widely spaced exploratory and water wells. In this study, we improve sample quality by drilling continuous cores through the aquifer system. A challenge to all subsurface studies is the correlation of strata from widely spaced coreholes. We will demonstrate continuity (or discontinuity) of lithologic units as well as hydrologic (i.e., aquifers and confining) units, using a multi-disciplinary approach. Continuity of lithologic units can be demonstrated by similar age (biostratigraphic and chemostratigraphic), and by similar sedimentologic succession. Continuity of hydrologic units will be demonstrated with hydrologic testing and geophysical methods.

This report summarizes research accomplished in the second year of a four-year project and describes corehole drilling, core analysis, geophysical logging, and monitor well installation in eastern Collier County during 1997. These initial tasks have identified the primary lithologies, their ages, and the aquifers and confining units at each site and their geophysical signatures.

The current conceptual model for the surficial aquifer system in southwest Florida has evolved over the last 50 years, and is currently, in western Collier County, a two-aquifer system of a water-table aquifer separated by a discontinuous semi-confining unit from the deeper lower Tamiami aquifer (Bennett, 1992). Further east in Big Cypress National Preserve, far less is known. In 1969, the USGS evaluated the hydrology of the area, collecting data from November 1969 through May 1970 (Klein and others, 1970). Klein's study indicated an east-shallowing aquifer system under the preserve, underlain by a thick low permeability zone.

Acknowledgments

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PREVIOUS STUDIES

Geology

The first detailed observations of the geology in Florida occurred in the late 1800's on surface exposures from the central and northern parts of the state, such as Dall (1887; 1890-1903); geologic investigations extended into the subsurface in the 1920's and 1930's. Some important subsurface units of the surficial aquifer system in southern Florida were first described and named in these early studies. A generalized column for southern Florida is shown in figure 2, and is currently under revision. Numerous changes in the stratigraphic terminology of south Florida have led to considerable confusion among both geologists and hydrologists. The lithostratigraphic definitions, the unit boundaries, and the assumed ages of the stratigraphic units cored have evolved since the first descriptions in the early part of this century as new data have become available. The units encountered in the cores discussed here are the Arcadia (?) Formation, the Peace River Formation, the unnamed formation, the Tamiami Formation (Ochopee and Pinecrest Members, and sand and silt facies), Ft. Thompson (?) Formation, and Miami Limestone. The unnamed formation occurs above the Peace River Formation and below the Tamiami Formation and it may be correlative in part with the Peace River Formation and with a newly proposed formation from the Florida Keys, the Long Key Formation (Cunningham and others, 1998). The definition of the stratigraphic units of the surficial aquifer system are discussed more thoroughly in Edwards and others (1998).

Hydrostratigraphy and Hydrology

Ground-water and geologic investigations began to be integrated as the population expanded in southern Florida and interest in ground-water resources increased. Several early ground-water studies determined the approximate spatial extent of the surficial aquifer system, which was then called the shallow aquifer of southwest Florida (e.g., McCoy, 1962, 1967, 1972; Sherwood and Klein, 1961; Klein and others, 1964, 1970; Klein, 1972) However, many of these early studies were based on drilling to depths of no more that 80 ft. Stewart (1982) completed a surface resistivity survey and demonstrated its application to water resources in Collier County. Jakob (1983) investigated the hydrogeology of the shallow aquifer south of Naples. The geology of the surficial and

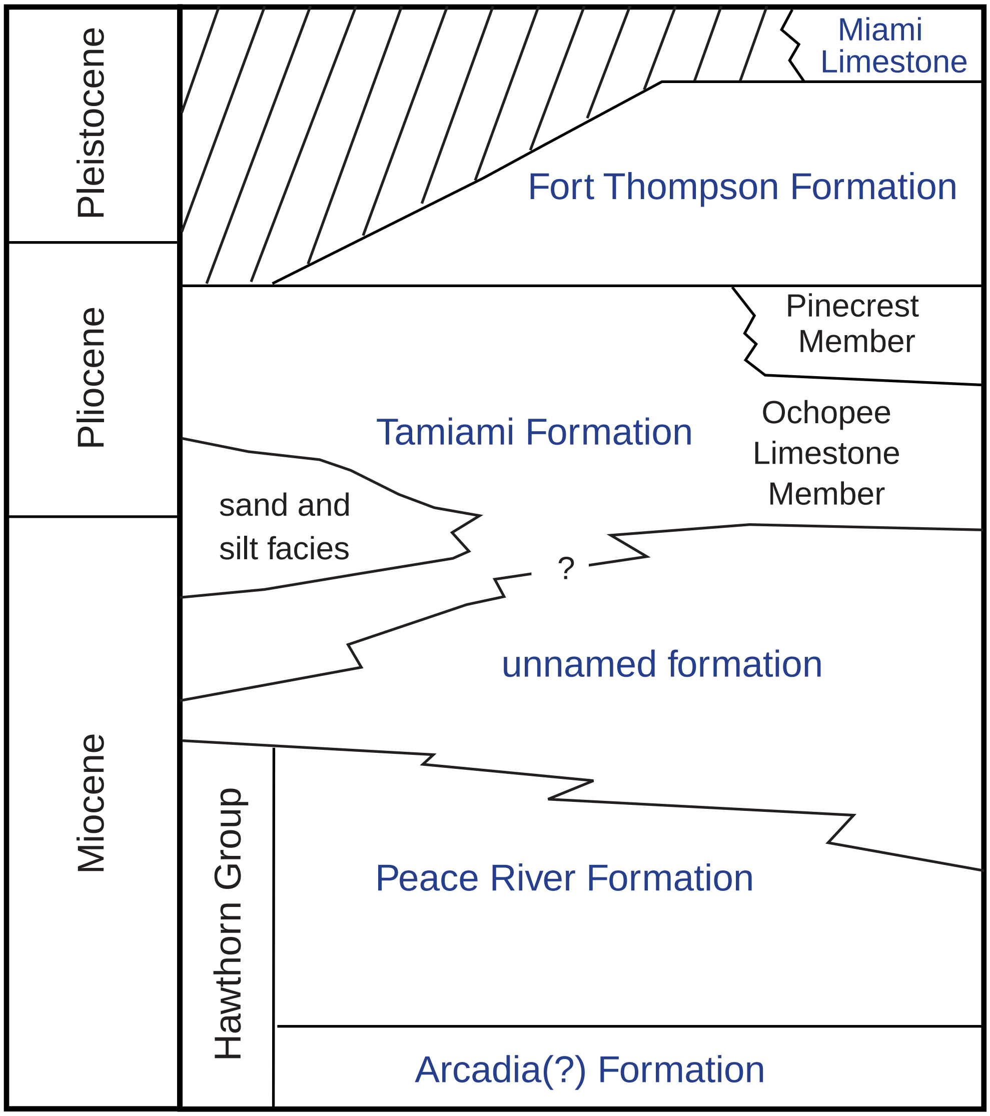

Figure 2. Generalized stratigraphic column for the study area.

intermediate aquifer systems of southern Collier County was investigated by Peacock (1983), the hydrologic resources of western Collier County by Knapp and others (1986), and a three-dimensional ground-water model was developed for western Collier County by Bennett (1992). No groundwater model exists for eastern Collier County. A time-domain electromagnetics (TDEM) study has been completed in conjunction with this study (Shoemaker, 1998; Paillet and others, 1999).

The current model for the surficial aquifer system of southwest Florida comprises two aquifers: the water-table and the lower Tamiami aquifers, separated by a semi-confining unit (Southeastern Geological Society, 1986; Bennett, 1992). In addition, the gray limestone aquifer has been identified within the surficial system, and described from Dade County by Fish and Stewart (1991). The gray limestone aquifer is assumed to extend westward into Collier and perhaps Monroe counties, and may be correlative with the lower Tamiami aquifer. The base of the system is considered to be the laterally extensive fine-grained, clayey sediments of the Hawthorn Group (Knapp and others, 1986; Bennett, 1992). Hydraulic conductivity of the water-table aquifer is reported to range from 500 to 2500 ft /day in western Collier County. The transmissivity of the lower Tamiami aquifer is reported to range from 10,000 to 320,000 ft^2/day (Bennett, 1992).

SETTING

Study Area

In 1997, ten cores were drilled in eastern Collier County and northern Monroe County, entirely within the limits of the Big Cypress National Preserve (fig. 1, table 1). These ten cores represent a continuation of the study of seven cores in western Collier County reported in Weedman and others (1997) and Edwards and others (1998). They are numbered in the order that they were drilled beginning with number 8. Cores were drilled at two sites on the Loop Road (West Loop Road and Golightly corehole sites), four sites on or near Tamiami Trail (Trail Center, Dade-Collier Airport, FAA Radar, and Doerr's Lake corehole sites), one site on a drill pad of the Calumet Oil Company and the end of 11-Mile Road (Raccoon Point corehole site), one site about 2 miles off Turner River Road (Bass corehole site), and one site a few hundred yards north of I-75, near a newly completed rest area (Nobles Road corehole site). Most drill sites, of necessity, were drilled on surfaces of artificial land fill to support the drill rig and other vehicles.

Several canals and borrow pits may have an impact on the natural drainage of the study area. The Golightly, Trail Center, Dade-Collier Airport, and Doerr's Lake sites are near borrow pits. The Nobles Road, FAA Radar, Trail Center, and Doerr's Lake sites are within about half a mile of major canals such as the canal along I-75 and along Tamiami Trail (Rte. 41). In contrast to the coreholes in western Collier County drilled in 1996, however, the eastern Collier and northern Monroe County sites show little effect from the presence of the nearby hydrologic disturbed areas.

Stratigraphic Framework

Arcadia (?) Formation.--The Arcadia Formation is a part of the Hawthorn Group, which was raised from formation to group status and subdivided into component formations by Scott (1988a). In southern Florida, the Hawthorn Group comprises the upper Oligocene to middle Miocene Arcadia Formation and the middle Miocene to lower Pliocene Peace River Formation (Scott, 1988a). The Arcadia Formation is composed of carbonate with varying amounts of interbedded siliciclastics (Scott, 1988a). The top of the Arcadia Formation is questionably identified near the base of the deep Trail Center core in this study, where silts and fine sands overlie carbonates and a prominent increase in gamma-ray values occur. The age of this Arcadia (?) is late Miocene which would extend its age.

Peace River Formation.--The Peace River Formation is the upper formation of the Hawthorn Group in southern Florida, where it is middle Miocene to early Pliocene (Scott, 1988a). The Peace River Formation was encountered in eight of the cores in the study area. It is absent in the two westernmost cores (Bass and Doerr's Lake).

The sediments now assigned to the Peace River Formation by Scott (1988a) have been referred to previously as the Tamiami

Table 1. Corehole site locations

Corehole site (1:24,000 USGS map) FGS no.	Date drilled	TD (ft)	Latitude Longitude	Section Township Range	Elevation (ft)
8. Golightly (Lostman's Trail) W-17968	1-19-97	200	25°44'55.952"N. 80°55'57.520"W.	T. 54 S., R. 34 E.	8
9. Trail Center (Fifty-mile Bend) W-17969	1-28-97 4-3-97	464	25°48'14.575"N. 80°52'30.954"W.	NE1/4 sec. 1 T. 54 S., R. 34 E.	10
10. Dade-Collier Airport (Fiftymile Bend) W-17970	2-1-97	200	25°51'51.996"N. 80°55'30.686"W.	SW1/4SW1/4 sec. 10, T. 53 S., R. 34 E.	10
11. FAA Radar Site (Monroe Station) W-17971	2-7-97	205	25°51'45.500"N. 81°00'38.177"W.	NW1/4NE1/4 sec. 15, T. 53 S., R. 33 E.	12
12. Monroe Station (Monroe Station) W-17972	2-14-97	200	25°51'45.087"N. 81°06'00.927"W.	NW1/4NW1/4 sec. 14, T. 53 S., R. 32 E.	10
13. West Loop Road (Monroe Station) W-17973	2-25-97	250	25°45'39.788"N. 81°03'34.384"W.	T. 54 S., R. 33 E.	6
14. Doerr's Lake (Burns Lake) W-17974	3-4-97	200	25°53'51.075"N. 81°13'27.947"W.	NE1/4SW1/4 sec. 33, T. 52 S., R. 31 E.	6
15. Raccoon Point (North of Fiftymile Bend) W-17975	3-9-97	185	25°58'55.673"N. 80°55'33.494"W.	SE1/4SE1/4 sec. 33, T. 51 S., R. 34 E.	10
16. Nobles Road (Whidden Lake) W-17976	3-16-97	200	26°10'12.427"N. 81°04'18.195"W.	NE1/4SW1/4 sec. 31, T. 49 S., R. 33 E.	10
17. Bass (Burns Lake) W-17977	3-25-97	200	25°58'31.840"N. 81°14'30.873"W.	NE1/4NW1/4 sec. 5, T. 52 S., R. 31 E.	8

Formation (Parker and others, 1955; Peck and others, 1979). Later, Hunter and Wise (1980) redefined the Tamiami Formation restricting it to the originally defined sandy carbonate lithofacies. Missimer and Banks (1982) utilized this concept and further refined the understanding of the Hawthorn and Tamiami relationship. Missimer (1997) has provided significant new information on the age of the Peace River Formation, in southwestern Florida, and has demonstrated that the formation occurs as two units representing deposition from 11.0 to 8.5 million years ago (Ma) and from 5.23 to 4.29 Ma respectively, separated by a hiatus of more than 3 million years.

The Peace River Formation, in its type area in east central DeSoto County, consists of siliciclastic and carbonate sediment with variable but significant quantities of phosphate grains (Scott, 1988a). The portion of the Peace River Formation encountered in this study is a siliciclastic unit consisting of olive green to light greenish gray, unconsolidated to very poorly indurated, variably clayey and calcareous, very fine to coarse quartz sands. Olive green sandy, silty clays are interspersed with the quartz sands. Carbonate sediments are a minor component of the formation and occur as matrix and as thin zones of dolosilt. Bedding is typically destroyed by bioturbation, although some zones have preserved thin bedding and laminations. Whole and fragmented fossils are scattered within the formation, and include typically chalky mollusks, barnacles, foraminifers, and diatoms.

This formation contains a more coarse component in the study area than in the type area to the northwest, which suggests that, at least in part, the Peace River Formation in southernmost Florida grades into the unnamed formation of Edwards and others (1998). Phosphate grain content generally decreases to the south of the type area, and within the study area, is typically one percent or less.

The top of the Peace River ranges from 227 ft below sea level to 83 ft below sea level. The unit is 227 ft thick in the Trail Center core; its base was not encountered in other cores.

Unnamed formation.--The unnamed formation consists of variably phosphatic and fossiliferous combinations of quartz gravel, sand, and silt; clay; and carbonate rock and sediment. Fossils occur as whole entities, fragments, molds, and casts. The fossils recognized in this unit include mollusks, foraminifers, ostracodes, echinoids, barnacles, bryozoans, corals, dinocysts, and red algae. Regionally, these sediments have variously been placed in the Miocene Coarse Clastics, the Hawthorn Group, and the lower portion of the 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 sediments that occur below the Tamiami Formation and above the Peace River Formation are placed in an unnamed formation until more data are obtained to facilitate regional correlations. While these sediments are similar to the Peace River Formation of the Hawthorn Group, there remain differences that warrant separation into different lithostratigraphic units. In general, the unnamed formation has lower concentrations of phosphate grains, more coarse sand and gravel, less silt and clay, and in some areas, less carbonate facies than the Peace River Formation. Missimer (1997) included the unit that we call unnamed formation in his Peace River Formation to the northwest of the study area of this report.

Clay typically 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.

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

Discoid quartzite pebbles and well-rounded, pea-sized gravel are scattered within the unnamed formation in many of the cores. Discoid quartzite pebbles similar to those observed in these cores have been noted in the Pliocene Cypresshead Formation, in the Hawthorn Group, and in 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) and in the Florida Keys (Cunningham and others, 1998).

The unnamed formation appears to be laterally equivalent to and interfingering with at least part of the Peace River Formation, and the upper portion of the 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 gradational across the study area. The determination of the nature of the contact is problematic in some cores because of poor recovery.

The siliciclastic sediments forming the foundation of the central and northern Florida Keys and underlying the southernmost peninsular Florida have been named the Long Key Formation and are uppermost Miocene to upper Pliocene (Cunningham and others, 1998; Guertin, 1998). Therefore the Long Key Formation appears to be span a similar time as part of the Peace River Formation, the unnamed formation, and the Tamiami Formation. The unnamed formation of this report could be the updip extension of the Long Key Formation; however, its inclusion in the Long Key Formation cannot be verified at this time.

The top of the unnamed formation ranges from 116 ft below sea level to 34 ft below sea level in the ten cores studied. Its thickness varies from 160 ft in the Doerr's Lake core to 21 ft in the Nobles Road core.

Tamiami Formation.--The Tamiami Formation overlies the unnamed formation throughout the study area. It is the primary stratigraphic unit of the water-table aquifer and of the lower Tamiami aquifer in southwest Florida. The Tamiami Limestone was first described from exposures in the shallow canal excavated during construction of the Tamiami Trail, by Cooke and Mossom (1929), and later named the Tamiami Formation by Mansfield (1939). The unit has been redefined in numerous studies since that time (e.g., Parker, 1942; Parker and others, 1955; Olsson, 1964; Hunter, 1968; Missimer 1978, 1992; Meeder, 1979; Hunter and Wise, 1980). 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 is recognized in all the cores (figs. 3-12). 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 ranges in content from five 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, barnacles, and dinocysts. The sand is typically very fine to medium. Sand content of the Ochopee Limestone Member decreases upward. In the studied cores, the Ochopee grades upward from a loose sand to a calcareous-cemented sand to a limestone. In the Trail Center core, the Pinecrest Member of the Tamiami is present above the Ochopee. Here, the Pinecrest is a poorly sorted quartz sand and carbonate mud with scattered aragonitic shells. In the Nobles Road core, a sand and silt facies of the Tamiami is present between limestones of the Tamiami.

Fort Thompson (?) Formation.--The Fort Thompson (?) Formation may occur just below the top of the Trail Center core, where it is a mottled, very well indurated sandy wackestone.

Miami Limestone.--Less than one foot of the Miami Limestone is present at the top of the Trail Center core, based on the presence of the bryozoan *Schizoporella* and common pelloid molds (Kevin Cunningham, oral communication, 1998).

METHODS

Coring Operations

The coreholes were drilled by the USGS with a Mobile B-61 drill rig using wireline coring methods. The rig is equipped with a structurally heavy tower and a 6 ft stroke, allowing two five-foot core runs on a single ten-foot drill rod.

The drillers use a mud rotary drilling system with HQ and NQ oversized drill bits

(4 1/4” and 4 1/8”). An inner barrel casing diameter of 5 in creates a 3/4 in and 7/8 in annulus, depending on bit size, for the upward removal of crushed rock and drilling mud. The drilling mud consists a mixture of bentonite, liquitroll®, easy mud®, and water. The consistency of the mud is monitored and periodically altered to desired viscosity during drilling.

The USGS drillers have developed a delicate core sampling method that has greatly improved the recovery of unconsolidated material. Interbeds of cemented and uncemented lithologies is common in south Florida stratigraphy, and greatly complicates good core recovery. A Christianson Drill wireline system was used to retrieve the core samples in the core barrel, pulling the core barrel up out of the drill stem, which stays in place in the hole. Cores were recovered, boxed, and initially described on site, and further examined and described in Miami, Fla., and Reston, Va., by USGS and FGS geologists.

Most sites have a 3- to 5-ft veneer of man-made fill that is necessary to provide well drained access to vehicles into the wetland environment. Because fill material is excavated locally from borrow pits, the rock and sediment comprising the fill is the same as the material of the local natural surface. Therefore, the contact between man-made fill and the natural surface in the lithologic logs is an estimate and is based on relative degree of disruption of the bedrock and sudden color change. In some cases, the natural surface could be seen close to the drill site and the thickness estimated from topographic rise.

Casing Configuration of Coreholes

Corehole stability was a major concern for all aspects of geophysical logging. In this study, corehole stability was affected by the casing configuration, by the amount of flushing with fresh water used to remove mud from the corehole, and by the degree of consolidation of the formation. Using a screened plastic casing the full length of the corehole keeps the corehole open but permits the drilling mud to be removed and the formation developed. However, there are potential problems in that the annulus between the casing and the formation may not fill in uniformly with unconsolidated materials. Also, we experienced problems when the surging during well flushing caused the casing to separate and part of the corehole to be filled with debris, and finally, the screened casing precludes caliper and acoustic imaging logs. The flow meter log can be run under ambient and injection conditions, but at some sites, there were indications that part of the ambient and injection flow was being conducted through intervals of open annulus, as well as within casing, giving spurious results.

Drilling-Mud Removal from Coreholes

Some corehole geophysical measurements, especially flow meter logging, depend on the removal of drilling mud from the corehole fluid column and the development of formation permeability immediately around the well. Drilling-mud flushing was performed by injecting fresh water into the corehole. The turbulent agitation of this water flow was assumed to develop the formation adjacent to the corehole. The amount of "surging" and the length of time over which the flushing was applied was necessarily more limited in open corehole intervals to minimize corehole collapse. More extensive and intensive flushing was applied when the corehole was lined with a slotted casing. However, it remained impossible to determine whether the annulus between casing and formation was completely filled with collapsed sediments or whether intervals of connected voids remained as a possible flow path over certain intervals. It was also uncertain whether drilling mud was flushed uniformly from the formation adjacent to the corehole or whether flushing occurred discontinuously over limited intervals. During flushing, injected water initially returned to the surface within the screened pipe and, after displacement of drilling mud there, returned from the annulus between the pipe and the corehole wall. This flow pattern indicates that water circulated from within the pipe, through the screen slots and up the annulus, removing drilling mud from within the pipe, from the screen openings, and from the annulus. Flushing time varied from 2-3 hours duration, until water ran nearly clear.

Geophysical Logging

Geophysical logs were run in each of the ten coreholes after 3-inch diameter, fully-slotted PVC casing was installed, drilling mud flushed out of the borehole by circulation with fresh water, and the unconsolidated formation allowed to collapse to fill the annulus around the casing. The suite of logs run in each corehole consisted of natural gamma, induction conductivity, neutron porosity, fluid column resistivity, fluid temperature, and heat-pulse flowmeter. Partial borehole collapse before installation of slotted casing or heaving of sand into the bottom of casing after installation prevented logging of the full length of some boreholes. Neutron logs were not run in the Golightly, Airport, and Monroe Station boreholes for logistical reasons. The fluid column logs were run under ambient and injection conditions for all of the boreholes where logistics and site conditions allowed conducting injection as well as ambient flow measurements. The only exception to this procedure was a deeper (464 ft) corehole at the Trail Center site. This corehole was lined with solid PVC casing, and drilling mud was not flushed from the borehole before logging. Geophysical logs related to lithology (gamma, induction conductivity, and neutron porosity) were run in this corehole, but no fluid column or flowmeter logs were obtained because those logs would not give meaningful results under the given corehole conditions.

All geophysical logs and the heat-pulse flowmeter logs were obtained using a PC-based digital logging system as described by Keys (1986). Depth scales on the digitized logs are given in ft below land surface, and were verified by ensuring that the depth indicator returned to the zero point within an error of 0.4 ft (0.2 percent error for typical corehole depths of about 200 ft) at the end of each logging run. Depth scales also were checked to ensure that all obvious contacts indicated on the logs occurred at the same depth for all of the logs run. Logs such as gamma-ray and neutron porosity obtained with nuclear counters were run at logging speeds (20 ft per minute) that were slow enough to ensure that nuclear statistical errors were negligible. Nuclear statistics were suppressed by using an N-point averaging filter such that

$$(N-1)\,\Delta z = 1 \qquad (1)$$

where N is the number of points in the filter, Δz is the log digitizing interval, and the sample volume for the nuclear log is assumed to be slightly larger than one foot. This averaging applies as much smoothing to the nuclear logs as possible without degrading the spatial resolution by averaging over intervals larger than the sample volume of the logging tool.

Natural gamma-ray log.--The natural gamma-ray log provides a measure of the natural gamma-ray activity of a formation produced by the radioactive decay of naturally occurring isotopes of uranium, thorium, and potassium. It was acquired from a multi-function probe which also collects data for other logs listed below, logging up from the bottom of the borehole to maintain steady tension on the measuring wheel. This log is used as an indicator of formation lithology, where the measurement responds to differences in abundance of radioactive elements in different combinations of minerals. The gamma-ray log measurement is commonly interpreted to indicate the relative amount of phosphatic or clay minerals present in the formation because radioisotopes occur as exchange cations associated with those minerals.

Induction conductivity log.--The induction log measures the electrical conductivity of the formation by measuring the electromagnetic signal from a torroidally-shaped volume around the borehole. The log is acquired with the induction probe, which makes both gamma-ray and formation resistivity measurements using the induction method. The gamma-ray log thus acquired with the induction tools is similar to the gamma-ray log acquired from the multi-function probe except that the scale (in counts per second) differs by a constant determined by gamma-ray detector size and efficiency. The induction conductivity measurement can be made in air or water-filled coreholes, and through electrically non-conductive (plastic) casing. The measurement needs no correction for the salinity of corehole fluid, and is automatically corrected for skin effect (the partial shielding of minerals by their own electrical conductivity).

Neutron porosity log.--The neutron porosity log measures the ability of the formation to attenuate and absorb high-energy neutrons emitted by a radioactive source. The neutron log is obtained from a dual-detector neutron probe which contains a 3-Curie AmBe neutron source and two He^3 neutron detectors located at different spacings on the probe. The log records the flux of neutrons at each detector (in counts per second). Neutron-log data (the two count rates) are calibrated in units of formation porosity. The calibration is based on the ratio of the count rates (far detector count rate divided by near detector count rate) using limestone calibration blocks of known porosity maintained by the American Petroleum Institute at the University of Houston. Therefore, porosity estimated by the neutron log applies to limestone, and may be as much as 2 and 4 percent, respectively, in error for strata containing dolomite and quartz sand. Much larger porosity errors are induced by the presence of borehole wall openings and "washouts" where the effectively 100 percent porosity of the openings is averaged with the much lower porosity of the undamaged formation. The presence of such errors is often indicated by variations of diameter on the caliper log. If neutron logs are run inside of plastic casing, the casing introduces a slight systematic error (apparent increase) in porosity, and voids in the incompletely filled annulus between casing and formation cannot be distinguished from formation porosity. The reduction in neutron flux is caused primarily by the hydrogen in water, so that the measured neutron counts given by the log can be calibrated in units of fluid-filled porosity. The hydrogen in plastic or steel casing and corehole enlargements can produce spurious measurements, so that neutron logs are routinely corrected for casing and diameter effects.

Fluid column resistivity log.--The resistivity of the fluid filling the borehole column is measured by electrodes installed on the electric logging probe, logging down the hole from the top, into the undisturbed fluid column. This measurement applies to the fluid (mud or water) in the borehole, and not necessarily to the water saturating the formation at the same nominal depth. The effectiveness of the fluid column resistivity measurement is influenced by the plugging of ports that allow borehole fluid to circulate around the logging probe as the probe is moved along the borehole.

Fluid temperature log.--The fluid temperature log is similar to the fluid column resistivity log, with temperature measured by a small probe protruding from the bottom of the multi-function probe. Temperature logs are most effective when the logging tool is run into undisturbed corehole fluid. However, this mode of operation can cause minor depth errors when the smooth lowering of the logging probe is prevented by the probe lodging on a "ledge" or other obstruction.

Heat-pulse flowmeter.--The heat-pulse flowmeter (HPFM) is a high-resolution flow measurement device that can detect vertical flow in boreholes as small as about 0.01 gallons per minute (Hess, 1986; Paillet and others, 1996). The HPFM detects the velocity of flow through the central section of the logging probe, but probe response is calibrated in units of borehole discharge using flow columns of various diameters. The HPFM is most often used with a flexible cylindrical disk to block the annulus between probe measurement section and the borehole wall. This disk increases the sensitivity of the flow measurement, but the HPFM response can be calibrated for use either with or without the annulus blocking disk. The buoyancy of the heat pulse induces a very small upflow bias in the measurement, so that a very weak upflow (less than 0.02 gpm) may be indicated in a static environment. Thermally-driven convection within boreholes is rare because the narrow diameter of coreholes inhibits convective cells which have small aspect ratios (ratio of vertical to horizontal scales). However, thermally driven convection can occasionally be mistaken for net vertical flow. Abrupt changes in the vertical temperature gradient on the temperature log may sometimes be identified to indicate the presence of thermal convection in the borehole. In this study, we found the best flowmeter logs were obtained with a flow measurement section centralized in the slotted casing without the flow diverter. The presence of the diverter often seemed to distort streamlines in borehole flow, forcing flow to accelerate in areas where formation collapse left voids outside of casing. We used a flowmeter measurement section sized to nearly fill the inside of the casing, so that the lower limit of flow detection without the diverter was only slightly greater than it would have been with the diverter working as designed, while providing minimal disturbance to the ambient flow field. Most of the coreholes were logged with the heat-pulse flowmeter after a fully slotted 3-in diameter PVC screen was installed in the mud-filled borehole, and the mud flushed from the borehole. Flow profiles were made under ambient conditions, and during steady injection at a few gallons per minute. Water for injection was obtained from nearby surface water supplies, or from adjacent shallow water supply wells at the drill sites. Valid pairs of ambient and injection profiles were obtained in eight of the ten boreholes drilled for this study. Flow logs were obtained under ambient conditions only in the Loop Road borehole because of a lack of injection water supply. No ambient flow was measured in the Raccoon Point corehole, and the corehole refused to accept injection. It is possible that these results indicate all formations intersected by the corehole were impermeable. More likely, the results indicate that the permeable formations in this borehole had not been adequately developed prior to the flow logging, and this flowmeter test is considered invalid.

Sediment Analysis

One hundred and forty-six sediment samples were taken from eight of the ten cores and individually processed to measure their abundance of insoluble sand, insoluble silt and clay, and calcium carbonate. Individual sample sizes ranged from 23 to 153 g and averaged 90 g. Samples of known weight were first treated with 10 to 30 percent hydrochloric acid to remove the calcium-carbonate faction completely. The samples were then rinsed in de-ionized water and dried at room temperature. The dry sample was again weighed and the amount of calcium-carbonate was determined by subtraction. The remaining insoluble material was washed through a wet sieve of 270 mesh and the particulate matter of 0.053 mm or less was removed. The sand-size (and larger) grains remaining in the sieve were dried at room temperature and weighed. The silt and clay fraction was calculated by subtraction. In one of the cores, the Trail Center core, the weighed samples were treated with hydrochloric acid to calculate percent calcium-carbonate, but the remaining insoluble material was not sieved. In this core only, the insoluble material is reported as a single category.

Dinocyst Analysis

Core material was examined for dinocysts. Dinocyst 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, approximately 0.5 ft of core (1/2-diameter) was processed for each sample. Sample depth is given to the nearest foot in table 4 and the text. Appendix 3 lists the full depth interval sampled.

Strontium-Isotope Analysis of Shells Recovered from Cores

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 oxidized Ta filament. Isotope ratios were measured on the USGS's VG54 Sector thermal-ionization mass spectrometer in dynamic mode. Each data point is the average of two or more individual runs of 180 ratios each, measured on a $5x10^{-10}$ 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 March 1997 and September 1998, 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 0.709193 + 0.000015 (2 standard deviations, n=42) and 0.709216 +0.000015 (2 standard deviations, n=24). Ages in millions of years ago (Ma) are assigned using the data table of Howarth and McArthur (1997).

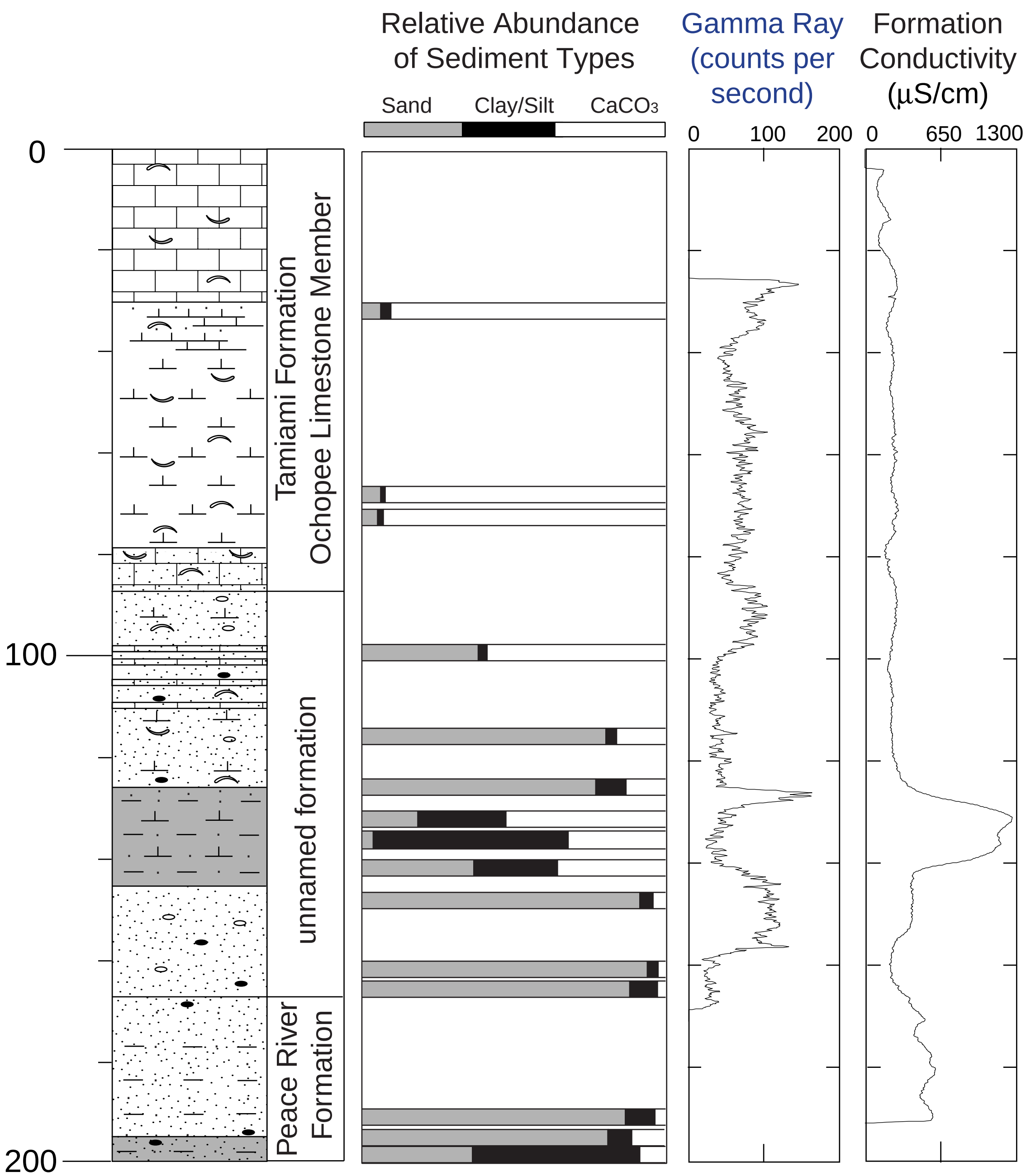

Figure 3a. Lithology, lithostratigraphy, sediment analysis, and geophysical information for the Golightly core.

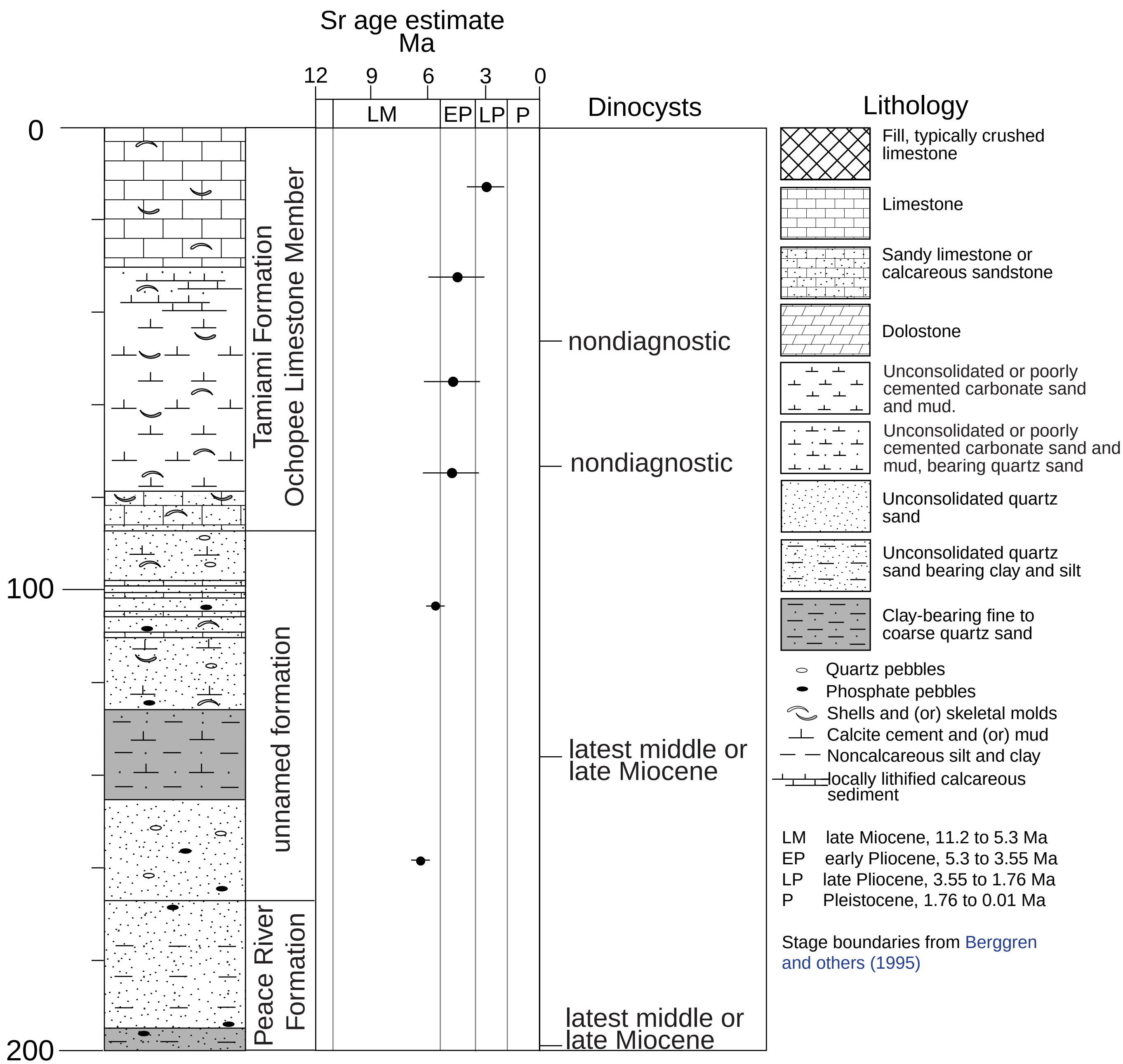

Figure 3b. Lithology, lithostratigraphy, and age information for the Golightly core.

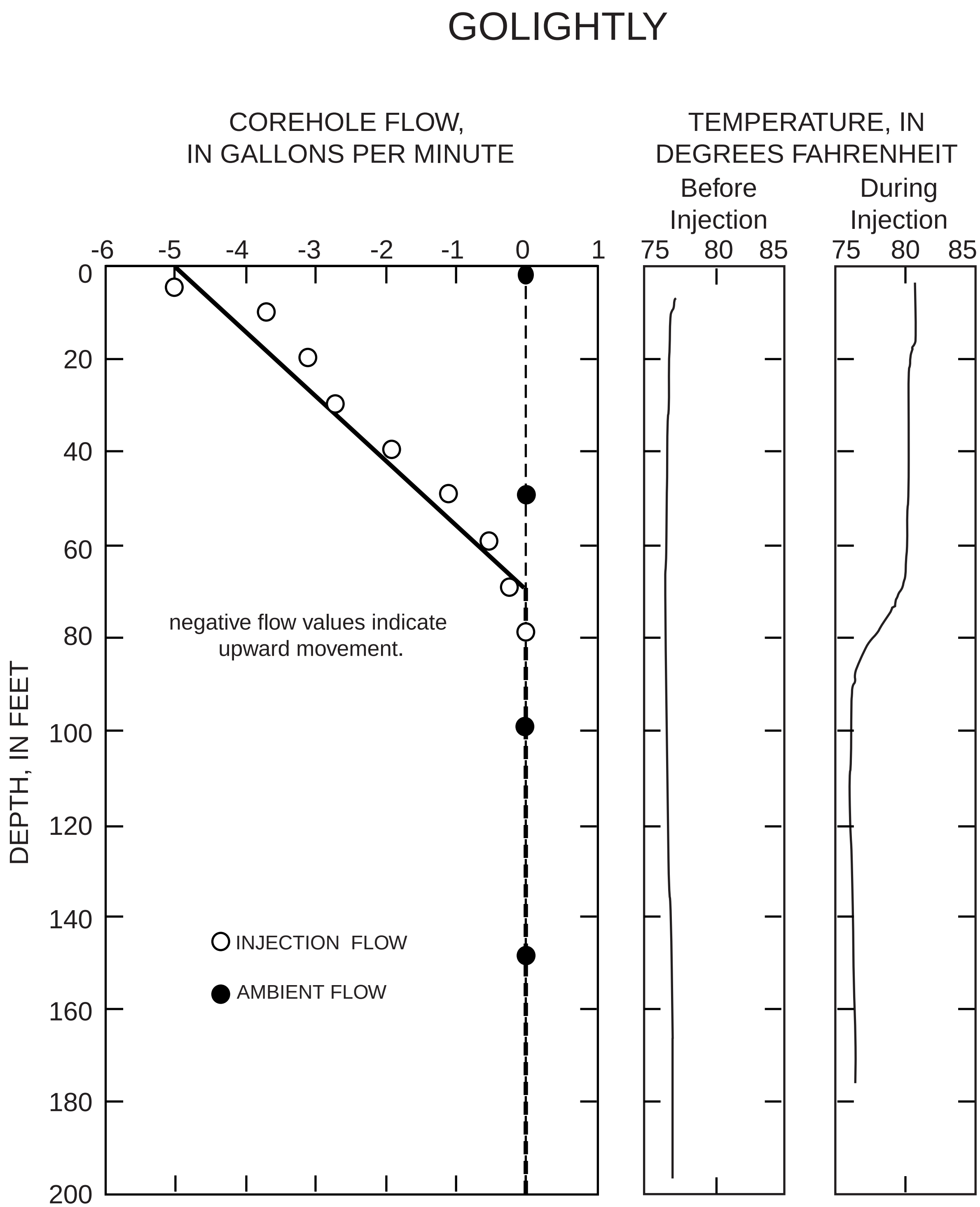

Figure 3c. Corehole flow information for the Golightly core.

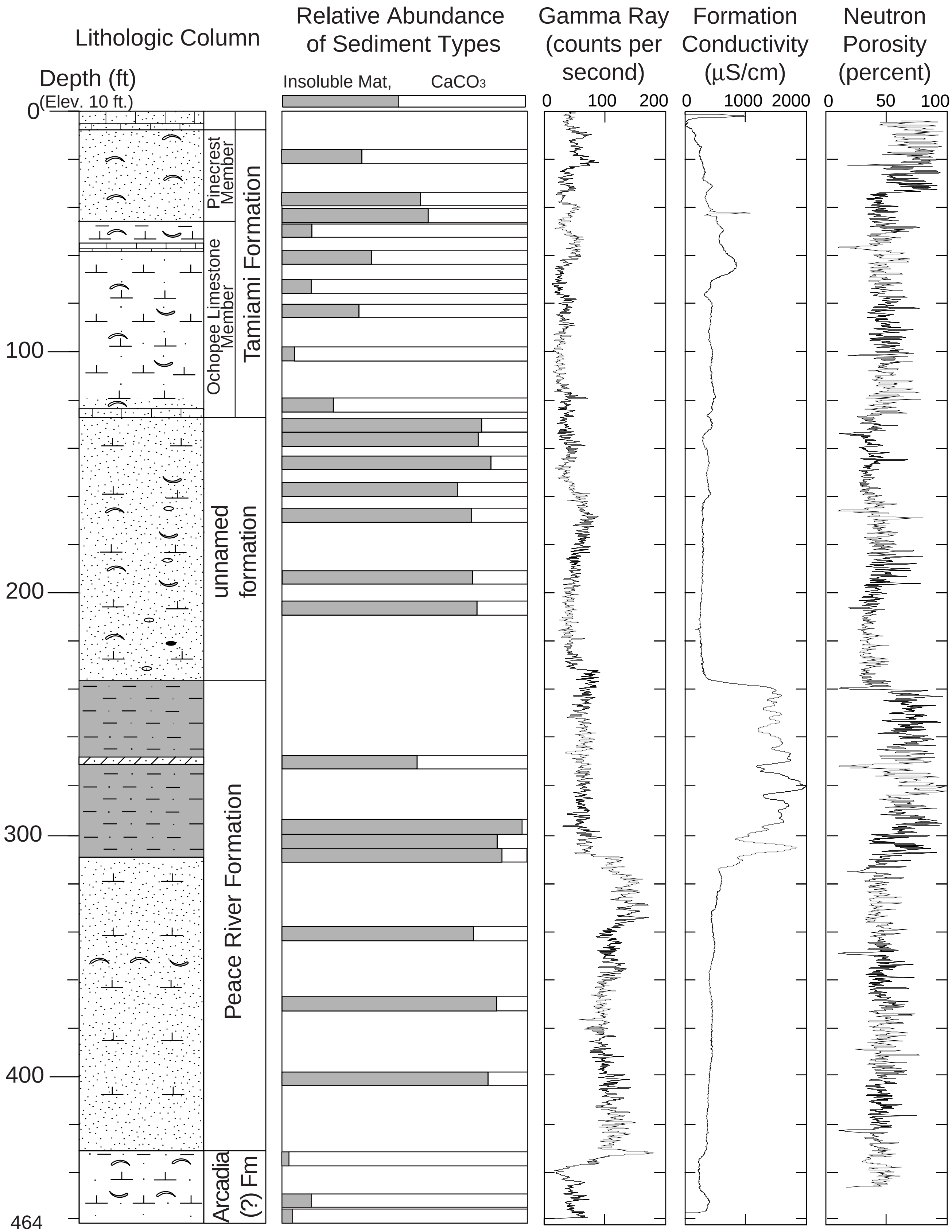

Figure 4a. Lithology, lithostratigraphy, sediment analysis, and geophysical information for the Trail Center core.

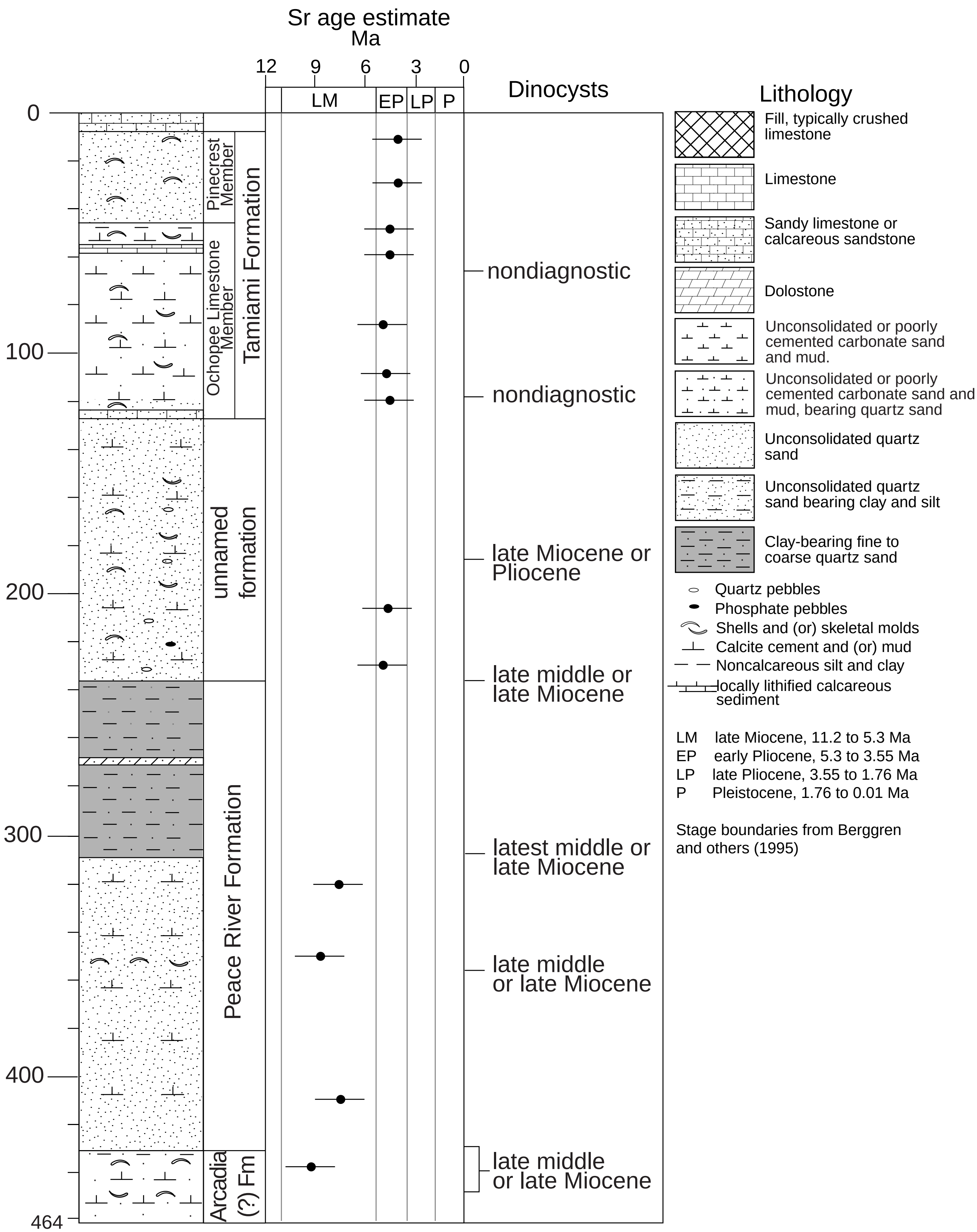

Figure 4b. Lithology, lithostratigraphy, and age information for the Trail Center core.

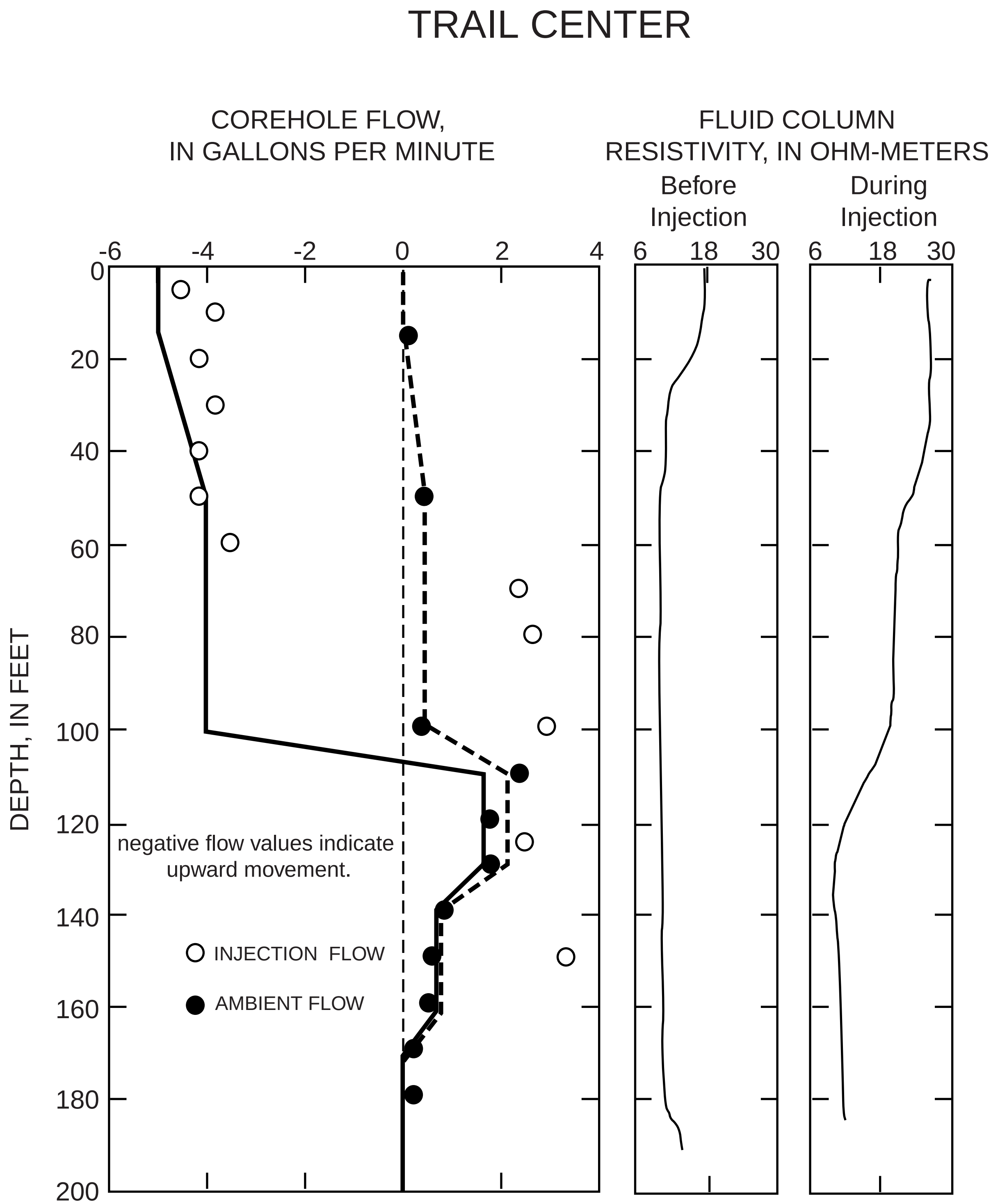

Figure 4c. Corehole flow information for the Trail Center core.

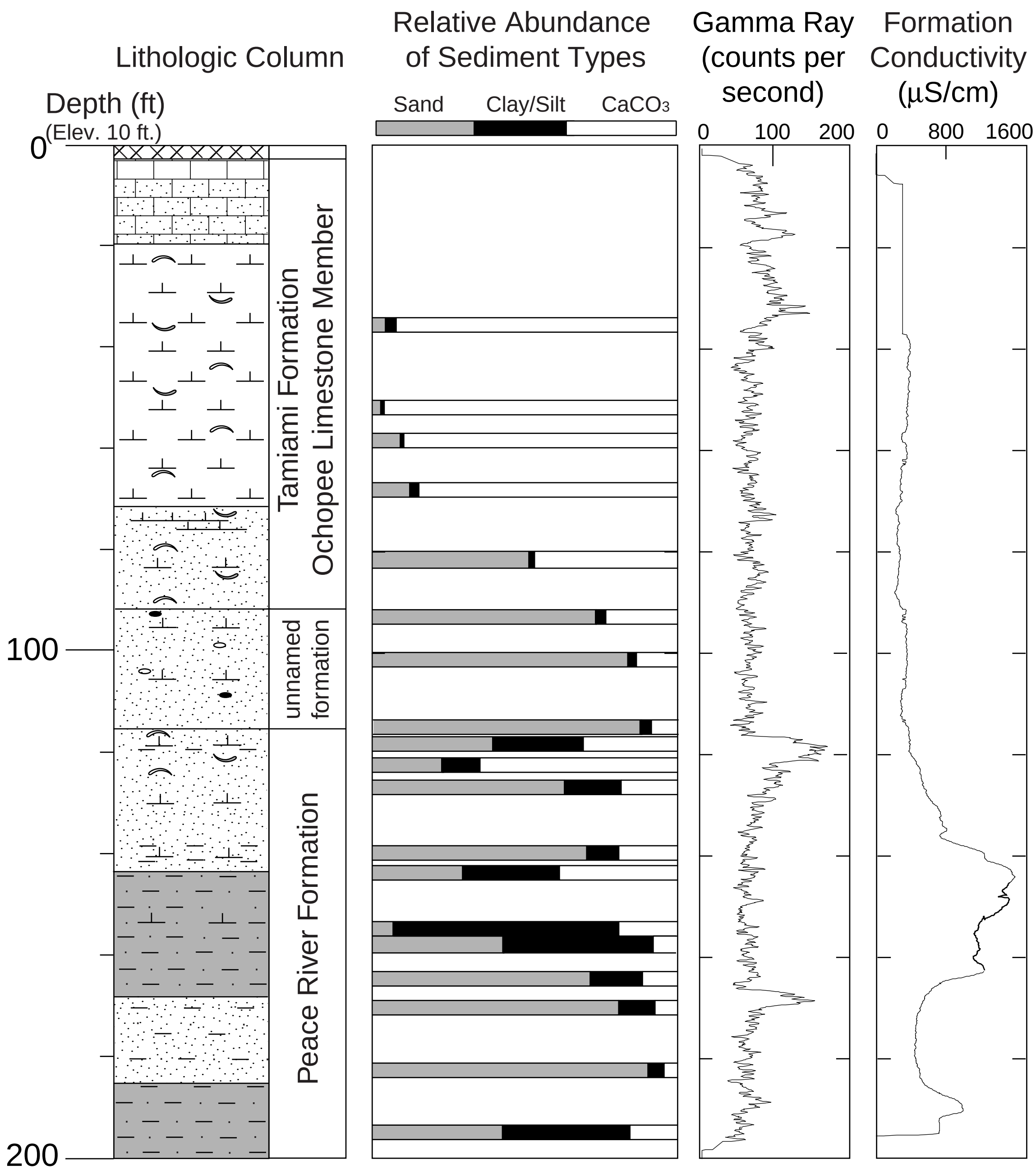

Figure 5a. Lithology, lithostratigraphy, sediment analysis, and geophysical information for the Dade-Collier Airport core.

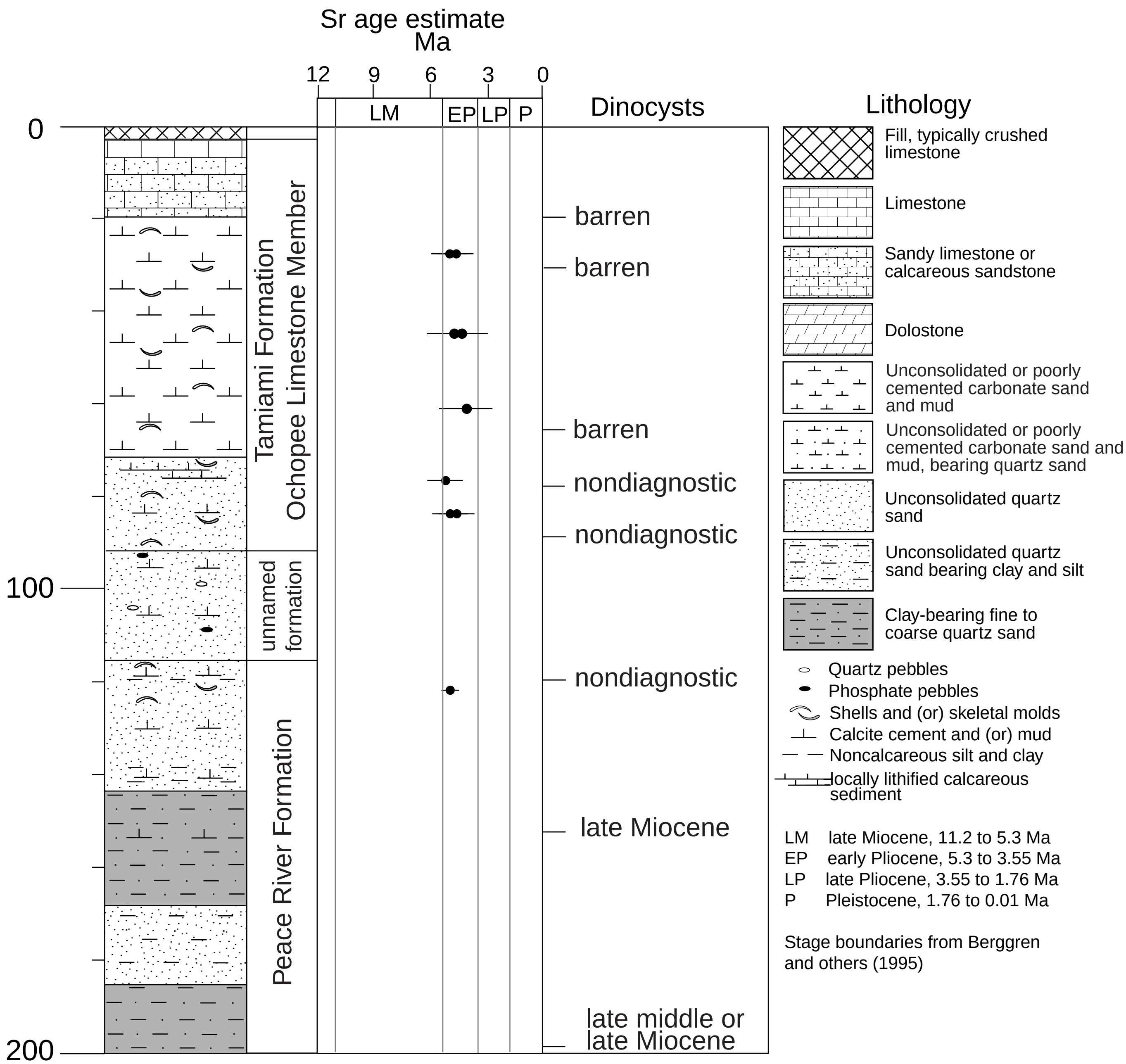

Figure 5b. Lithology, lithostratigraphy, and age information for the Dade-Collier Airport core.

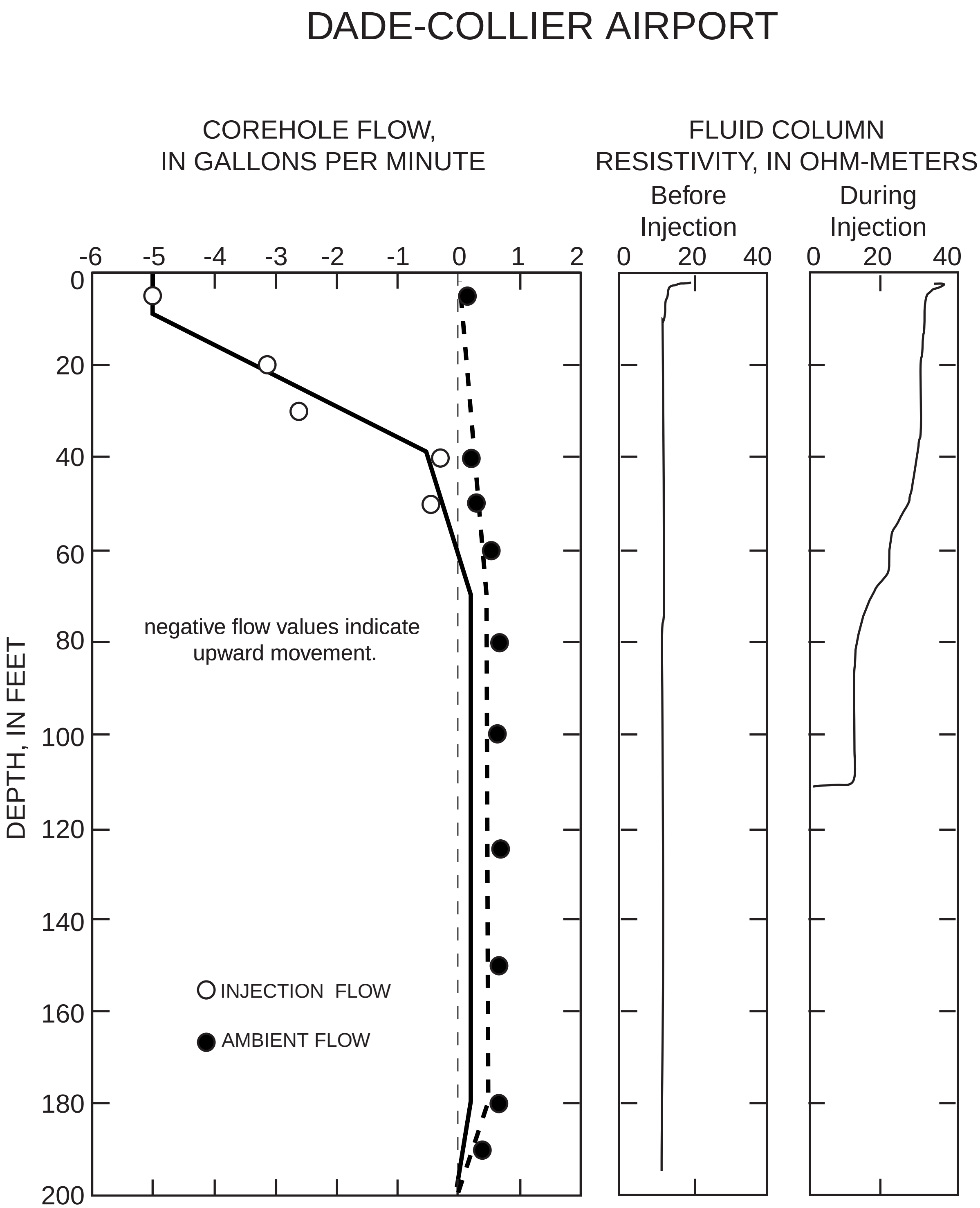

Figure 5c. Corehole flow information for the Dade-Collier Airport core.

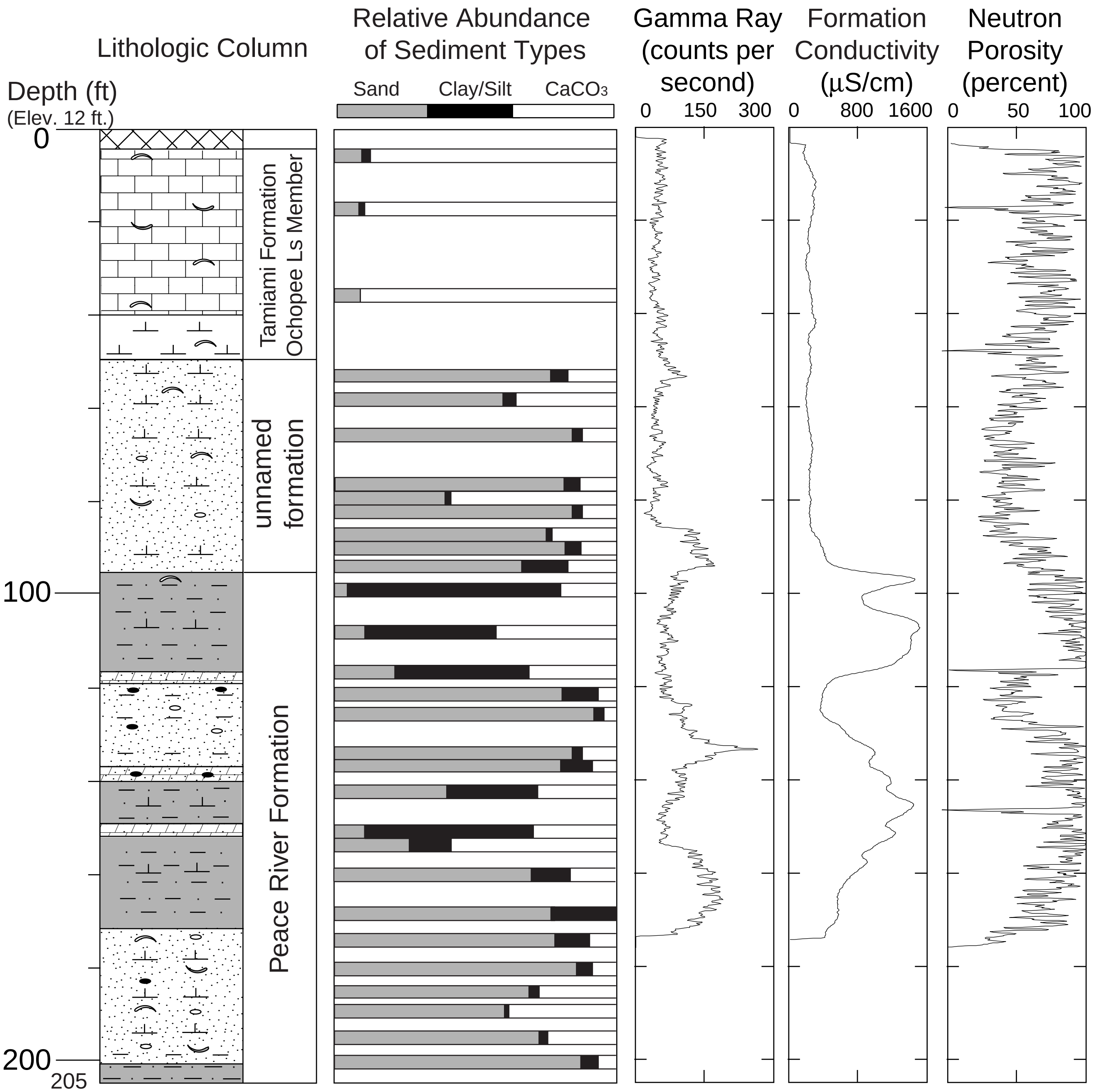

Figure 6a. Lithology, lithostratigraphy, sediment analysis, and geophysical information for the FAA Radar core.

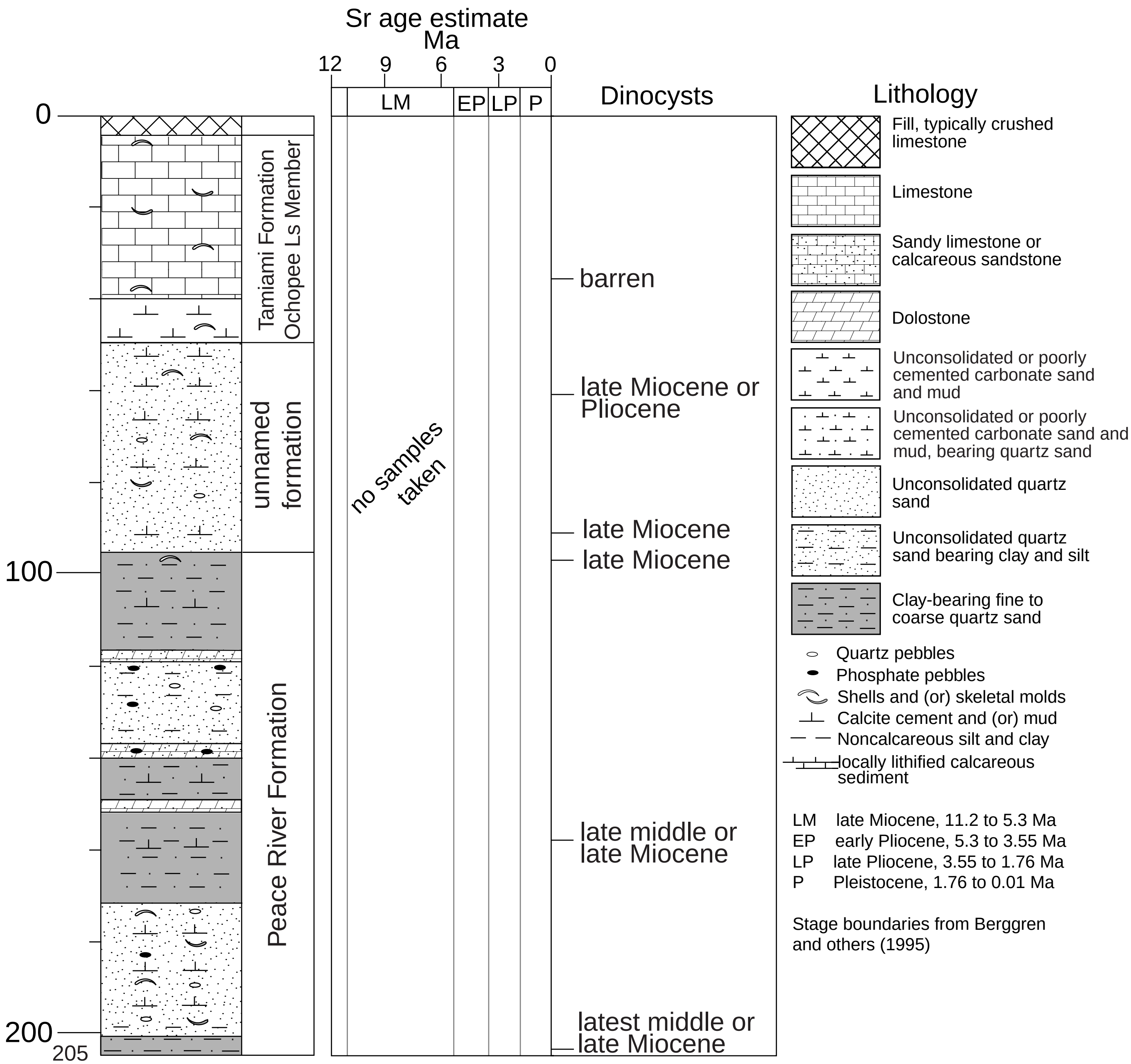

Figure 6b. Lithology, lithostratigraphy, and age information for the FAA Radar core.

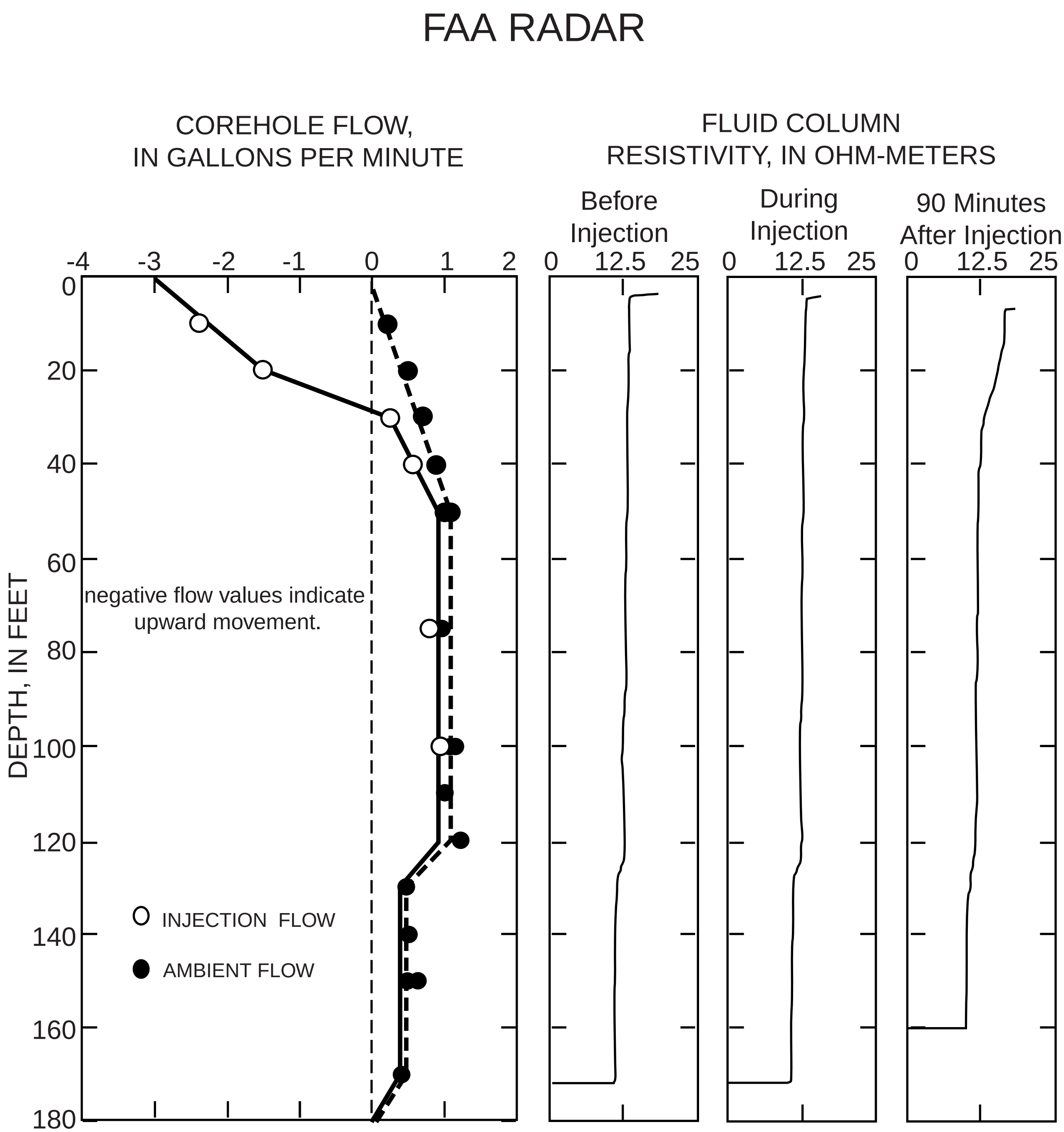

Figure 6c. Corehole flow information for the FAA Radar core.

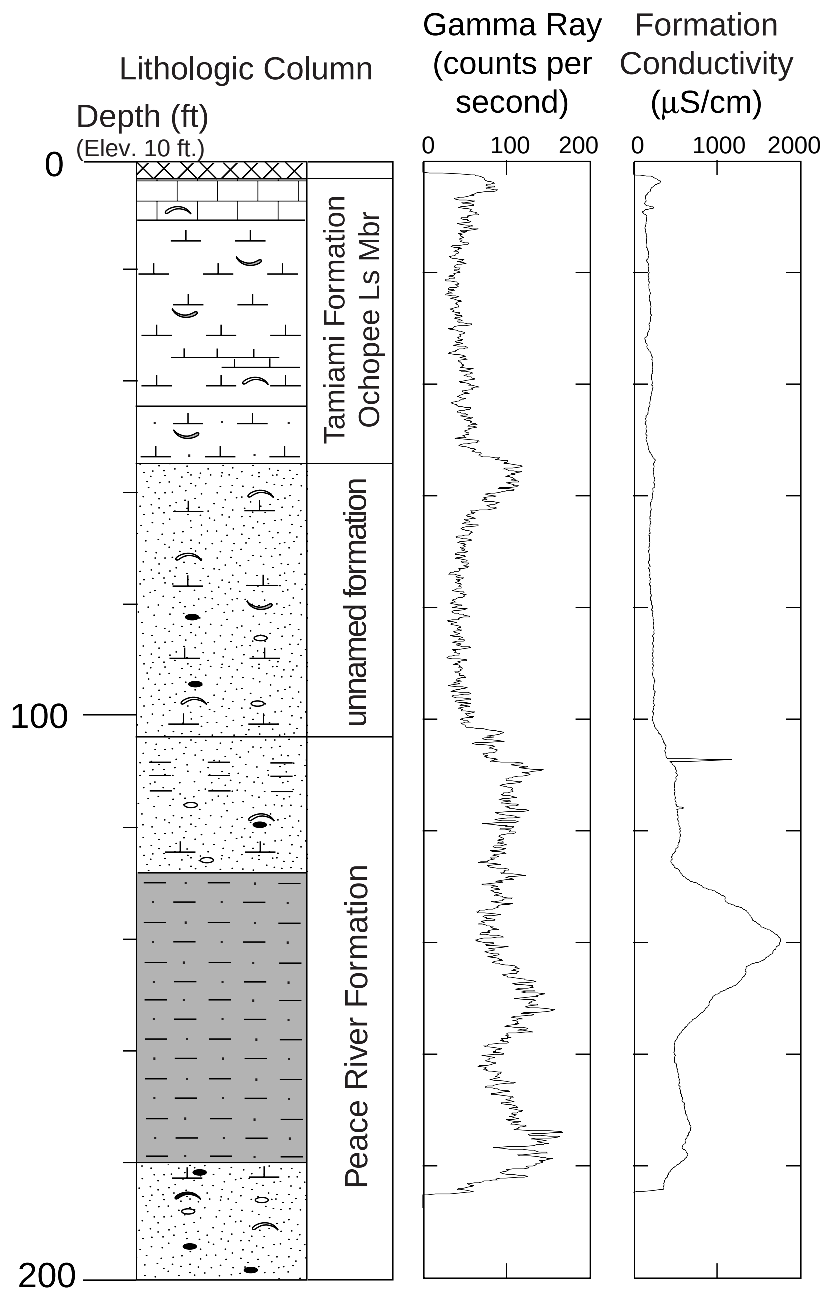

Figure 7a. Lithology, lithostratigraphy, and geophysical information for the Monroe Station core.

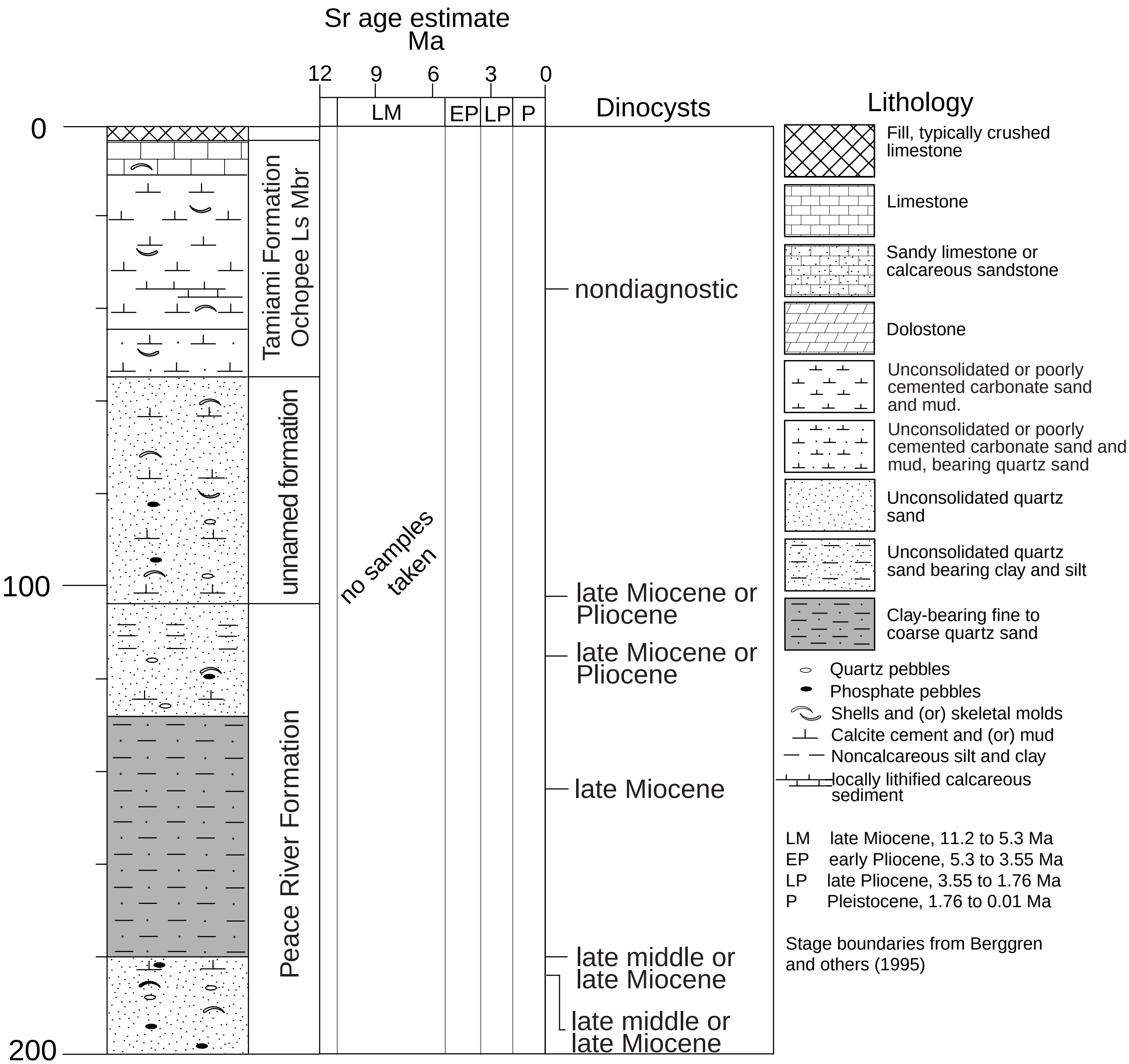

Figure 7b. Lithology, lithostratigraphy, and age information for the Monroe Station core.

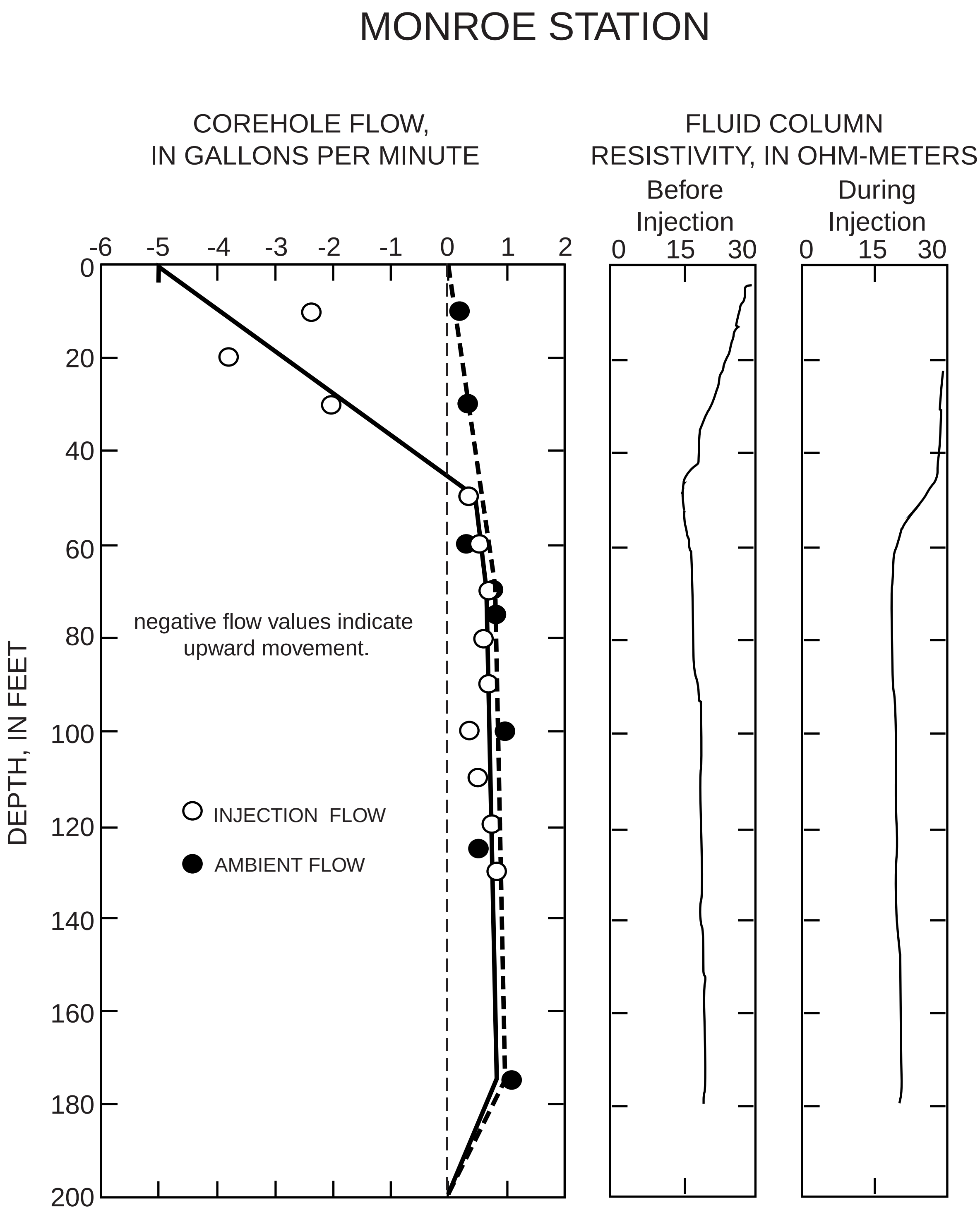

Figure 7c. Corehole flow information for the Monroe Station core.

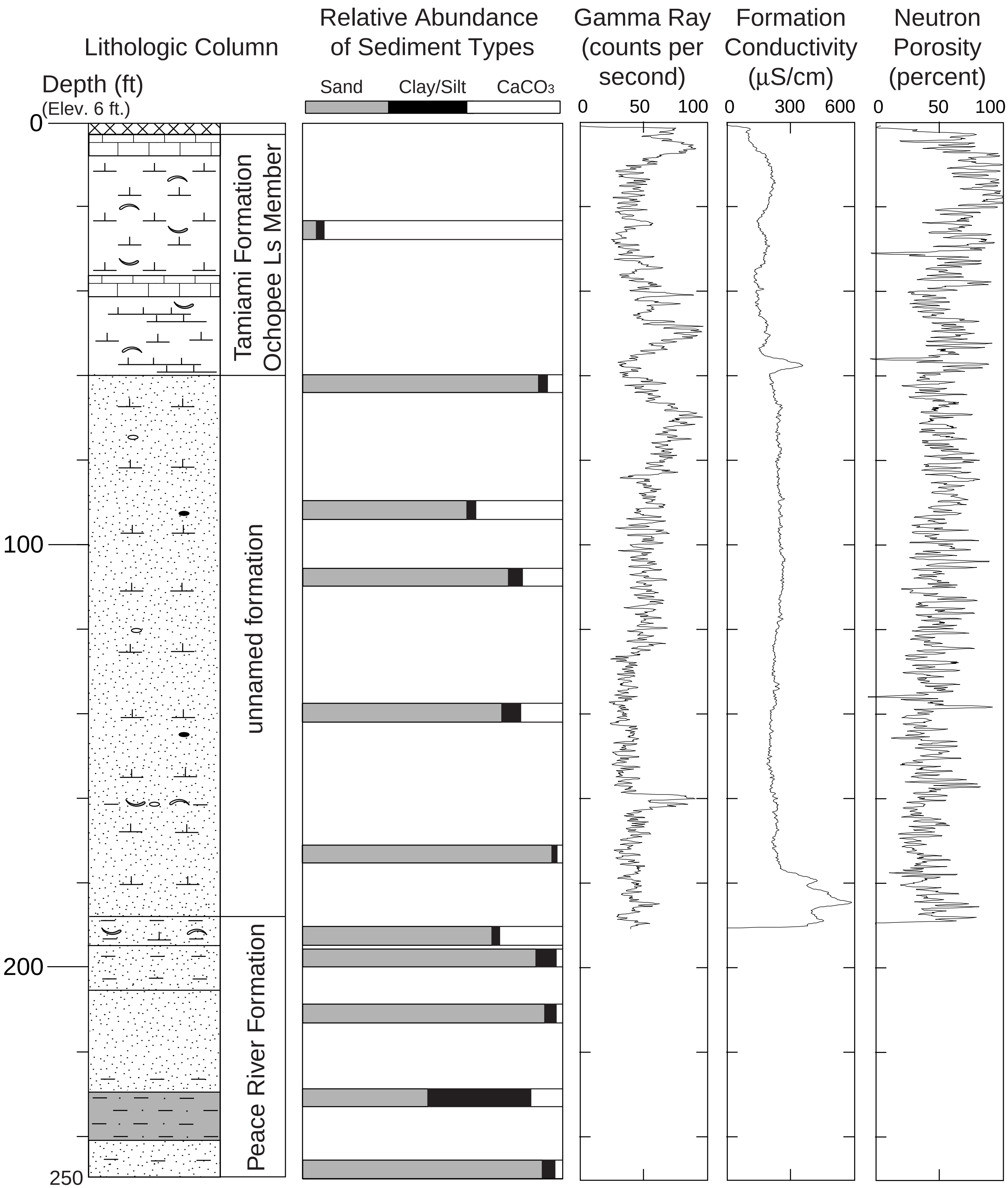

Figure 8a. Lithology, lithostratigraphy, sediment analysis, and geophysical information for the West Loop Road core.

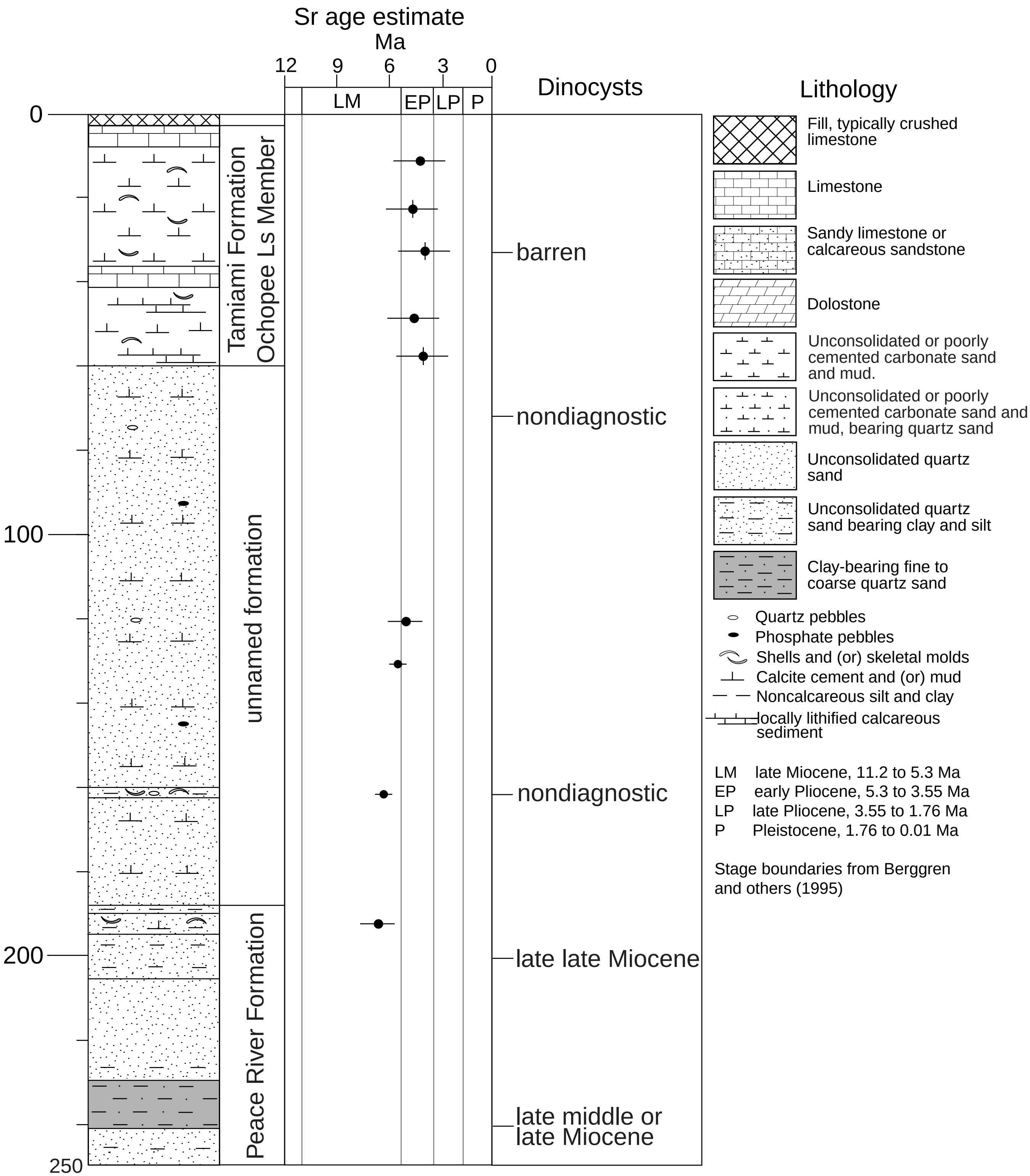

Figure 8b. Lithology, lithostratigraphy, and age information for the West Loop Road core.

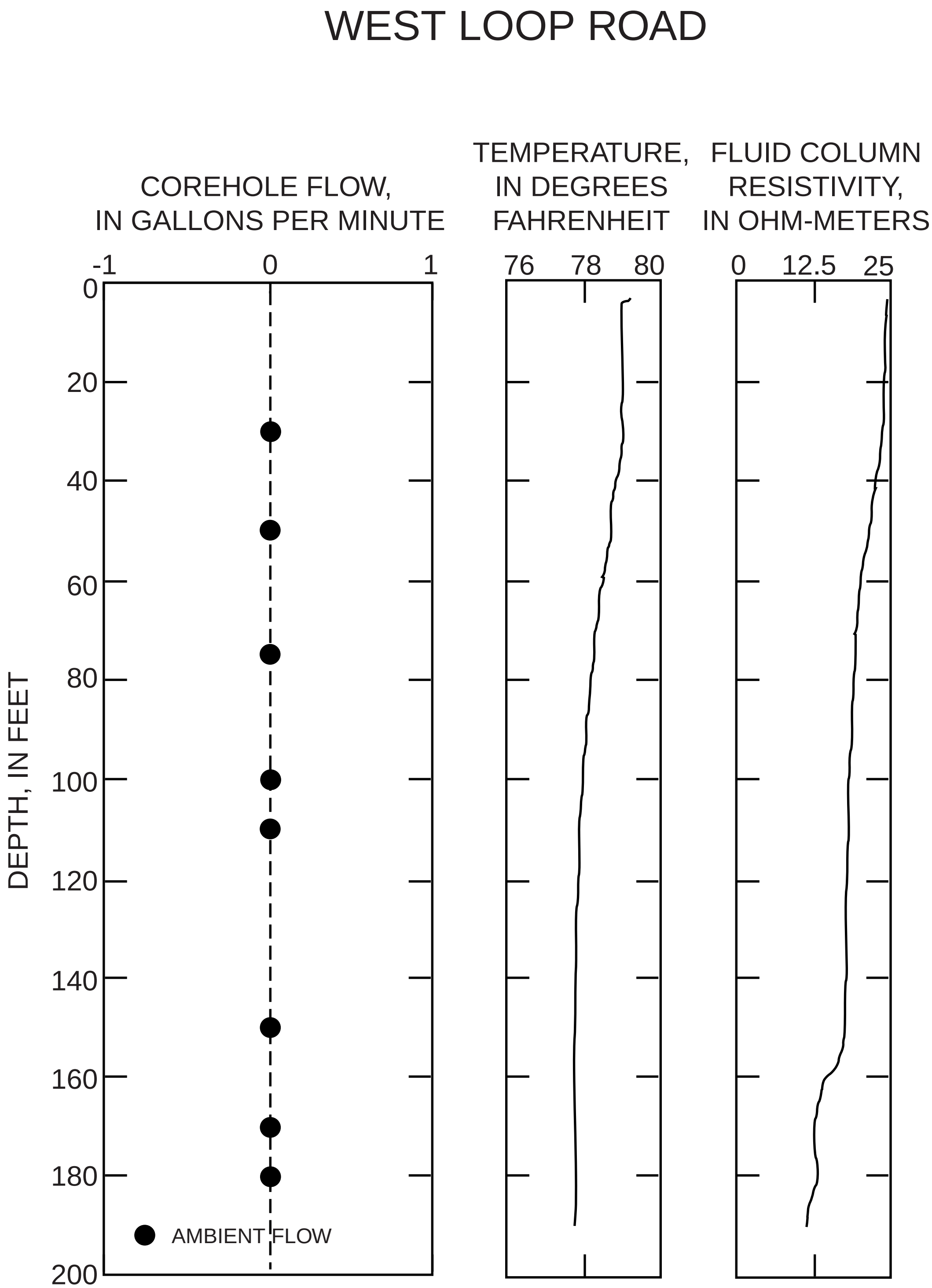

Figure 8c. Corehole flow information for the West Loop Road core.

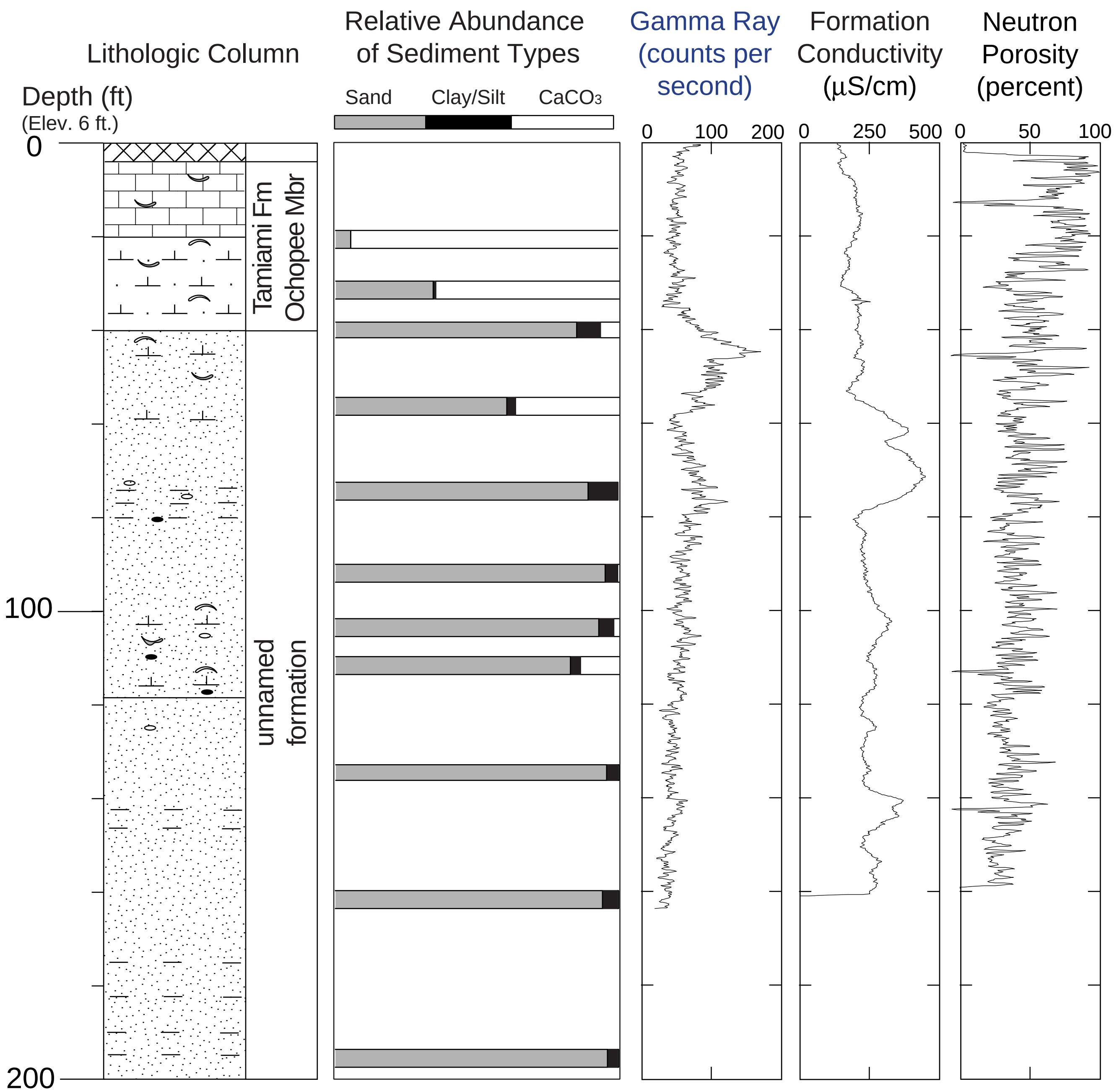

Figure 9a. Lithology, lithostratigraphy, sediment analysis, and geophysical information for the Doerr's Lake core.

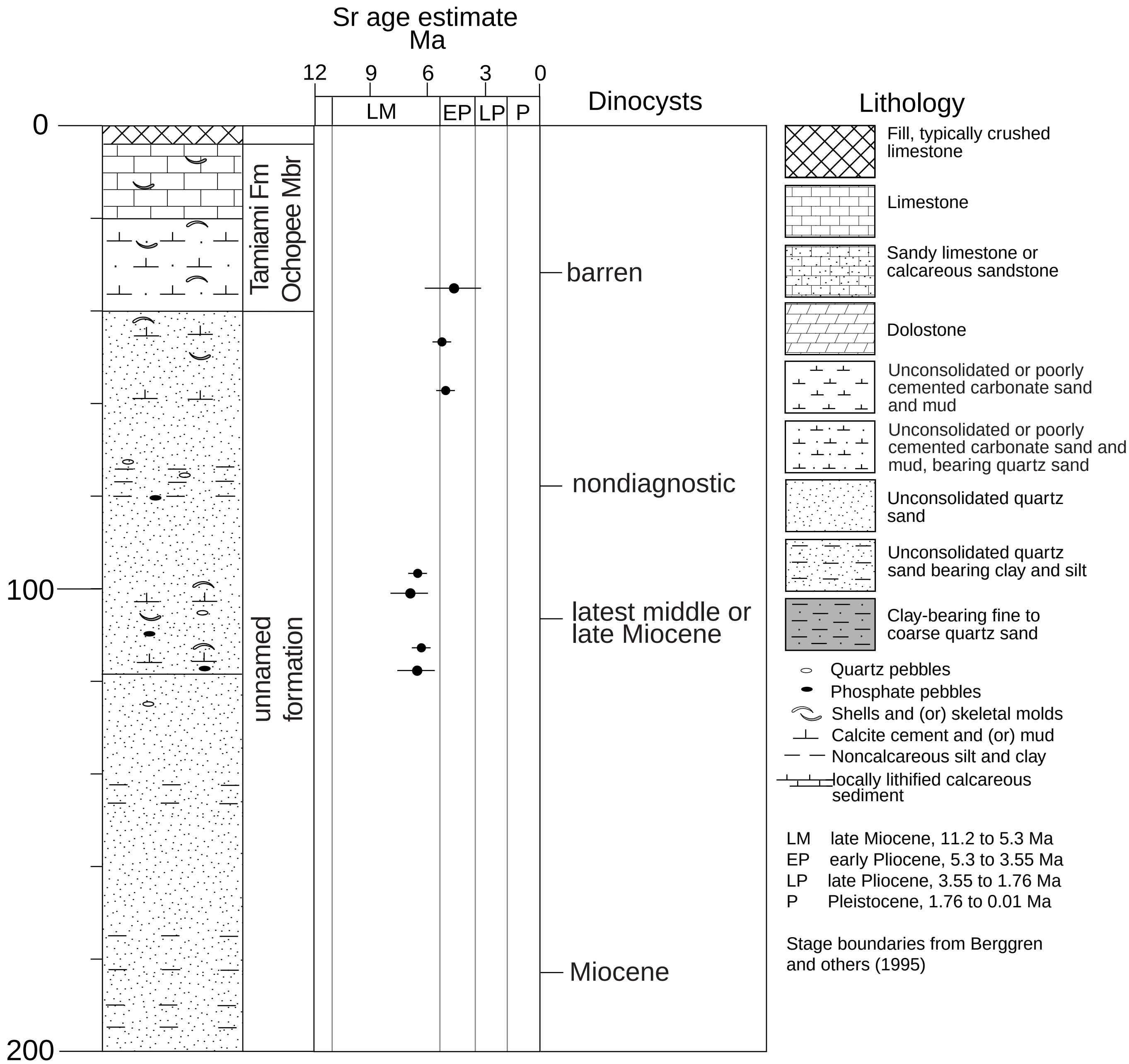

Figure 9b. Lithology, lithostratigraphy, and age information for the Doerr's Lake core.

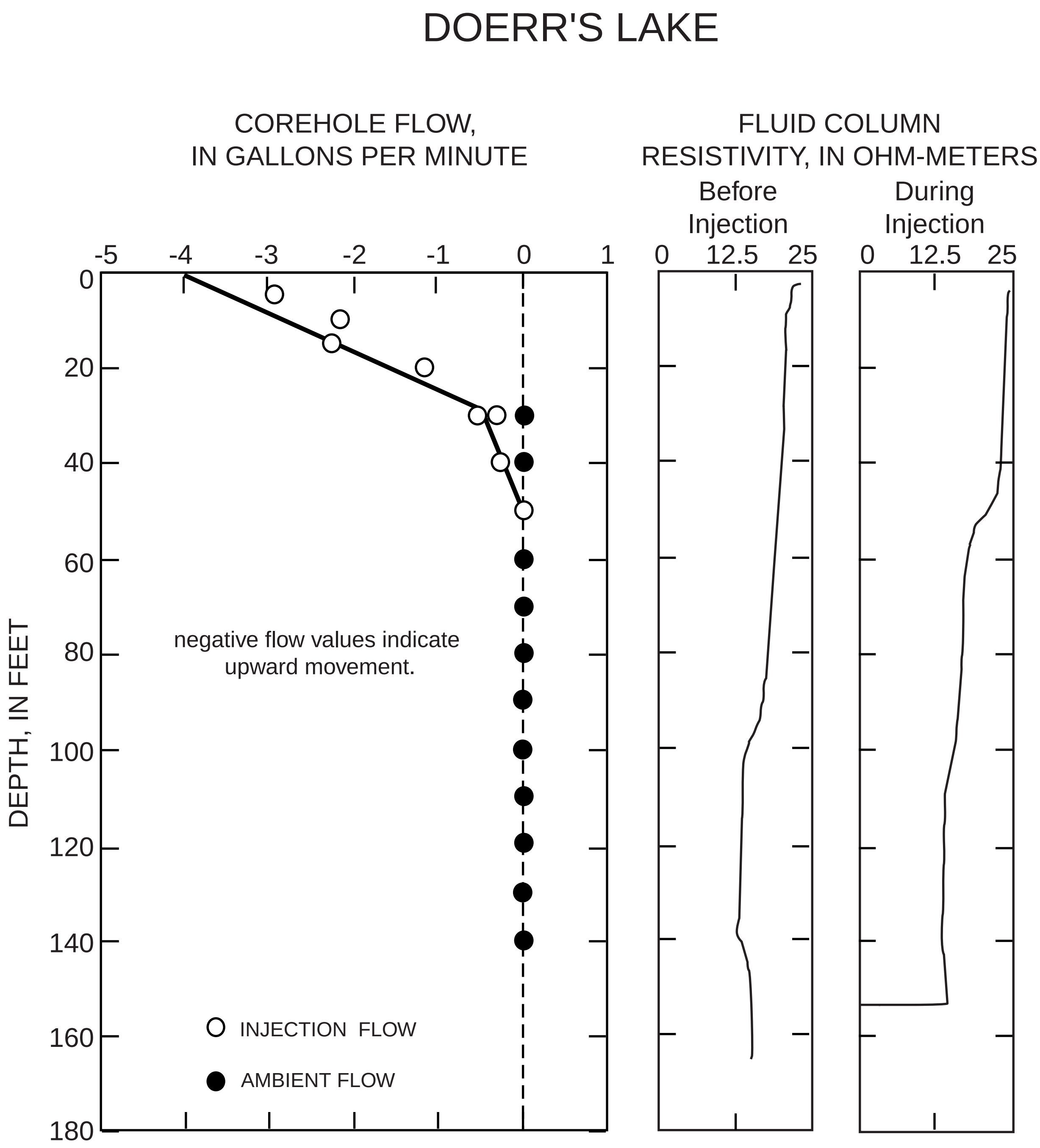

Figure 9c. Corehole flow information for the Doerr's Lake core.

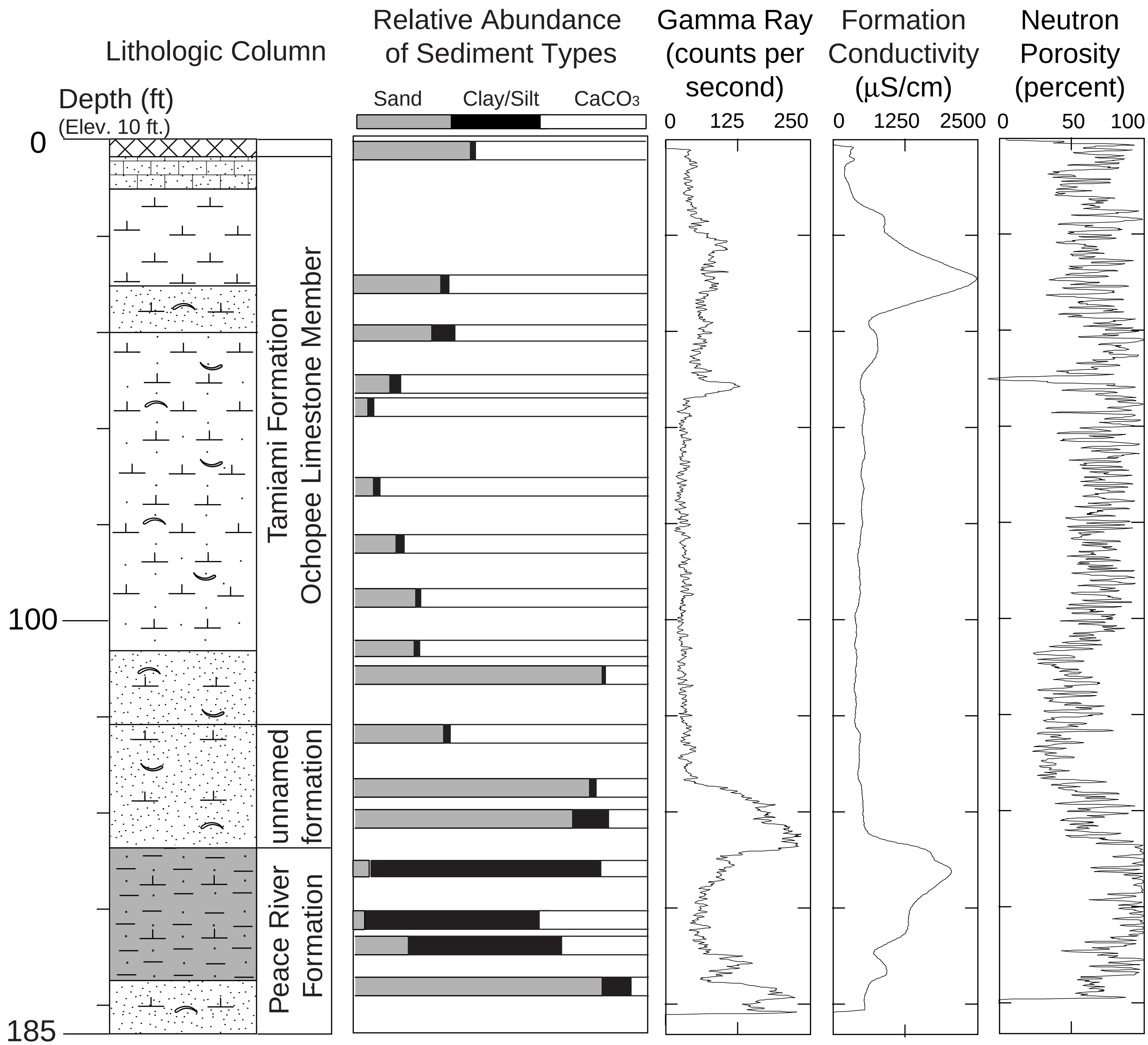

Figure 10a. Lithology, lithostratigraphy, sediment analysis, and geophysical information for the Raccoon Point core.

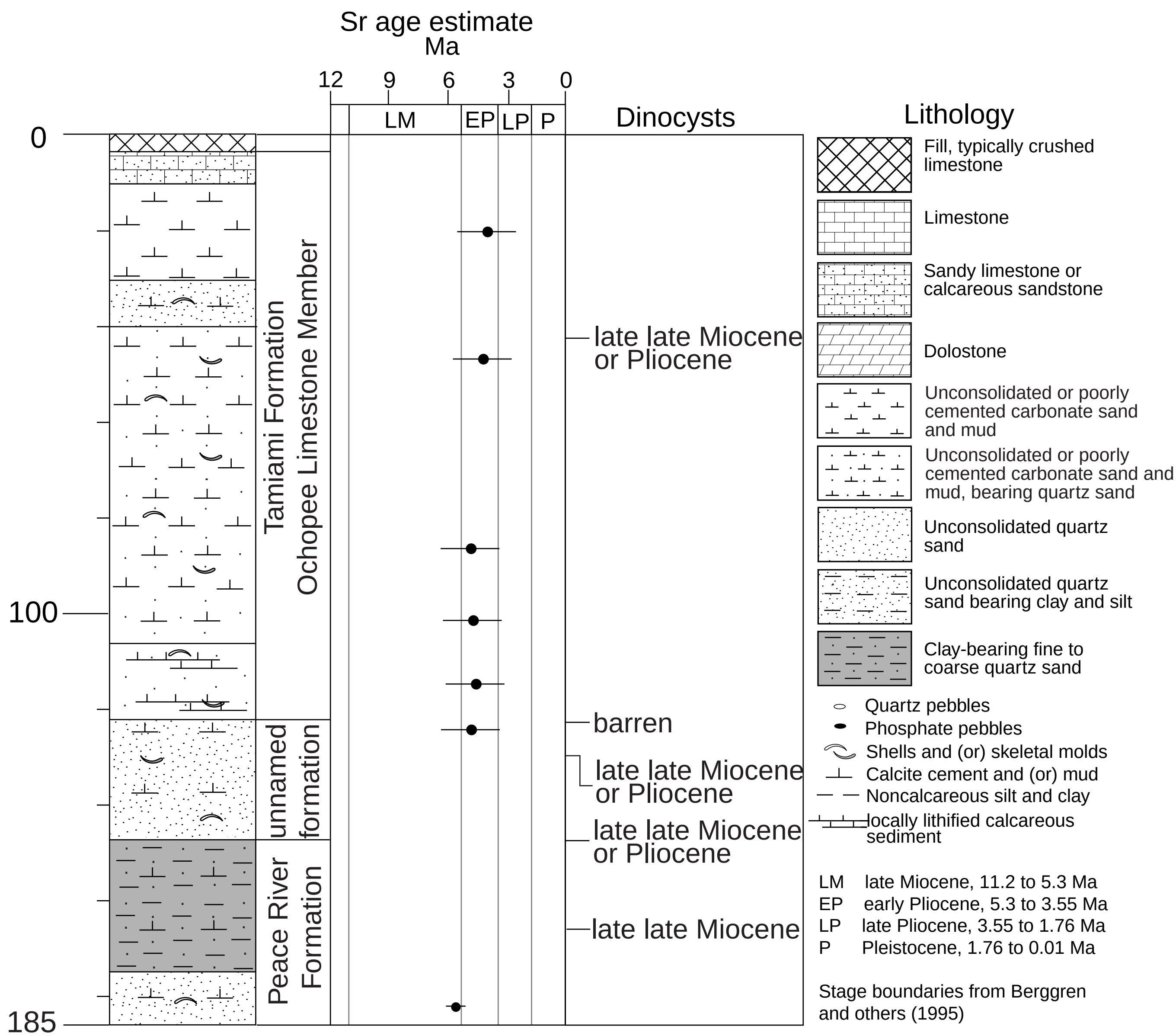

Figure 10b. Lithology, lithostratigraphy, and age information for the Raccoon Point core.

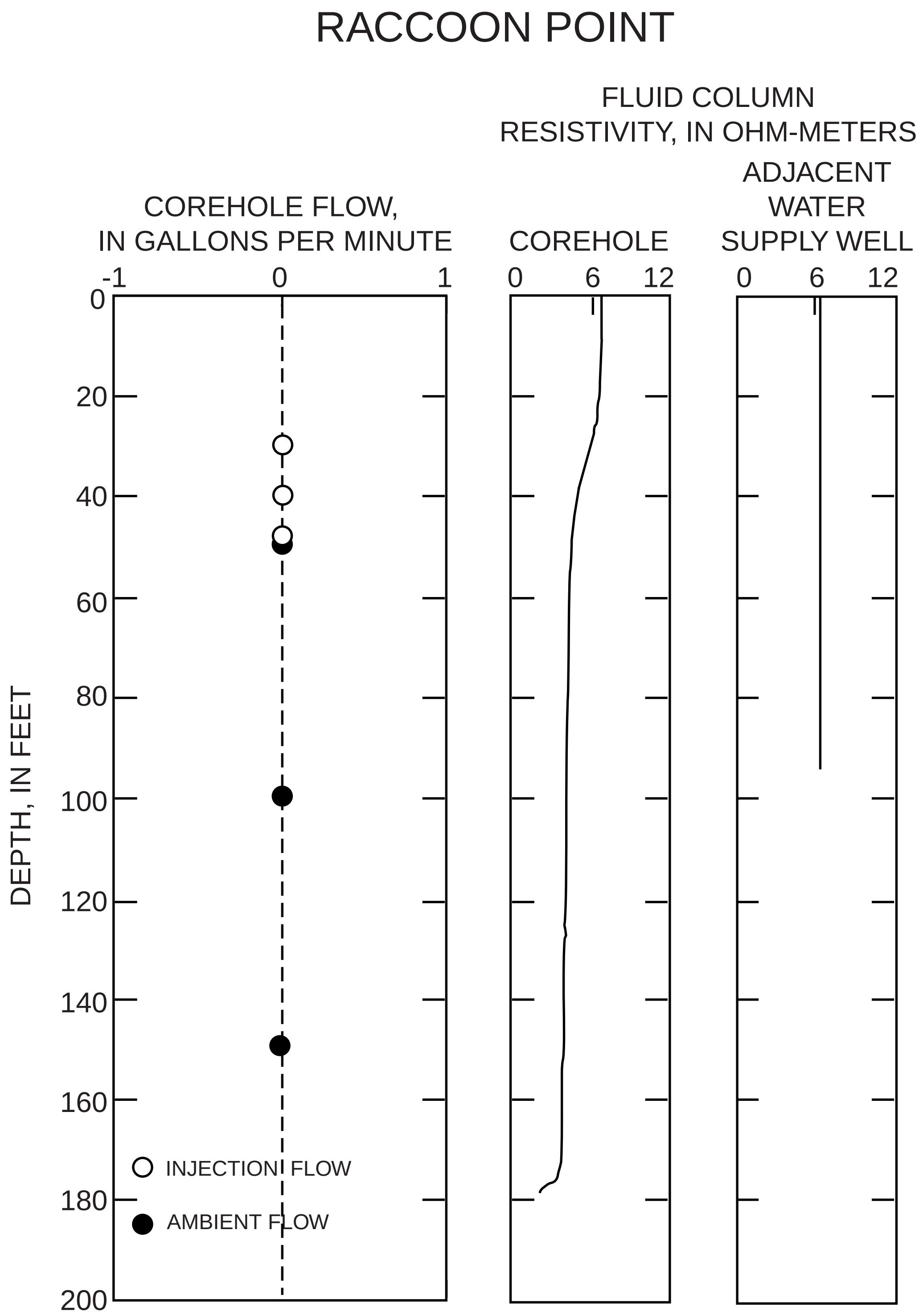

Figure 10c. Corehole flow information for Raccoon Point core.

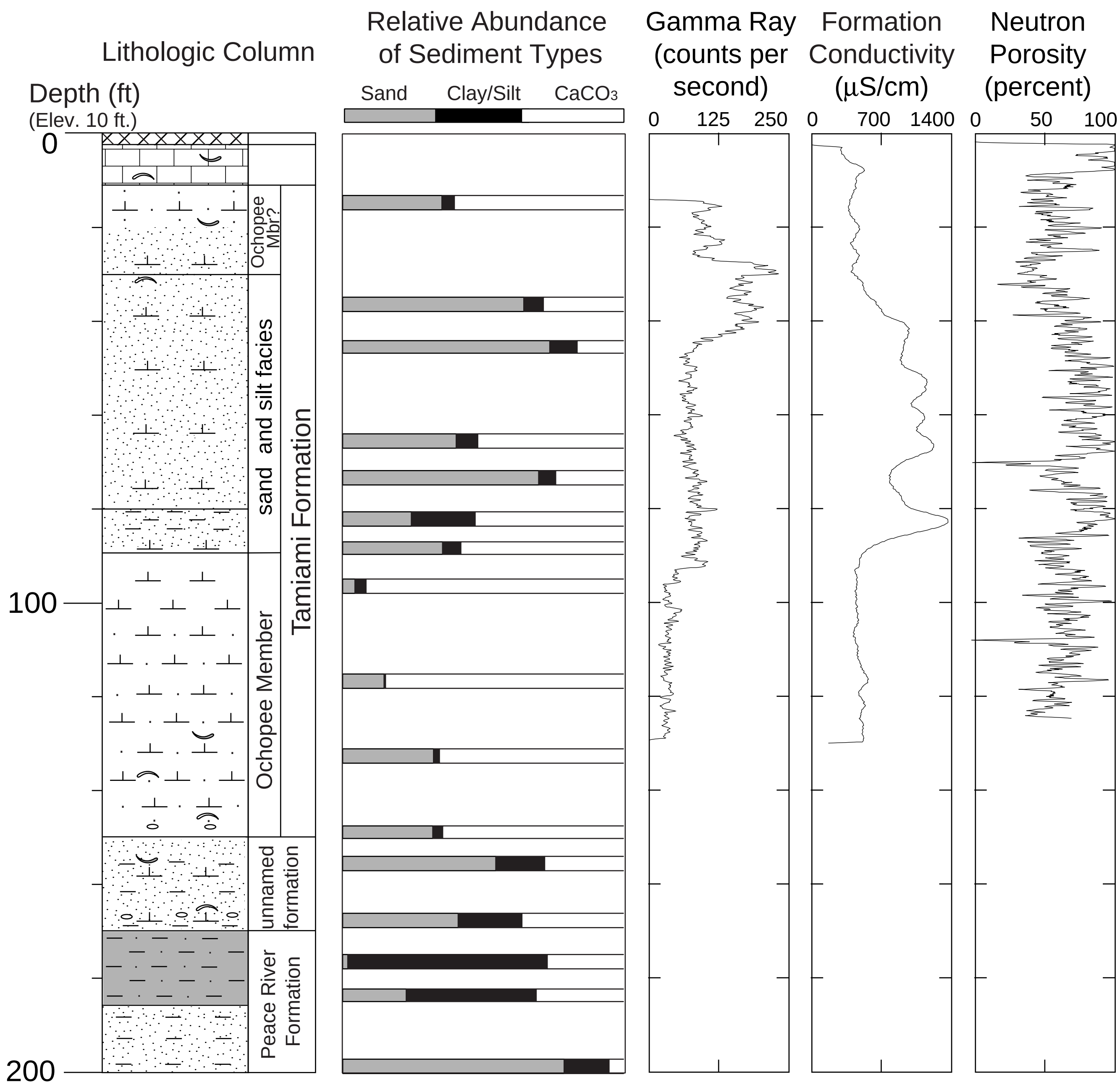

Figure 11a. Lithology, lithostratigraphy, sediment analysis, and geophysical information for the Nobles Road core.

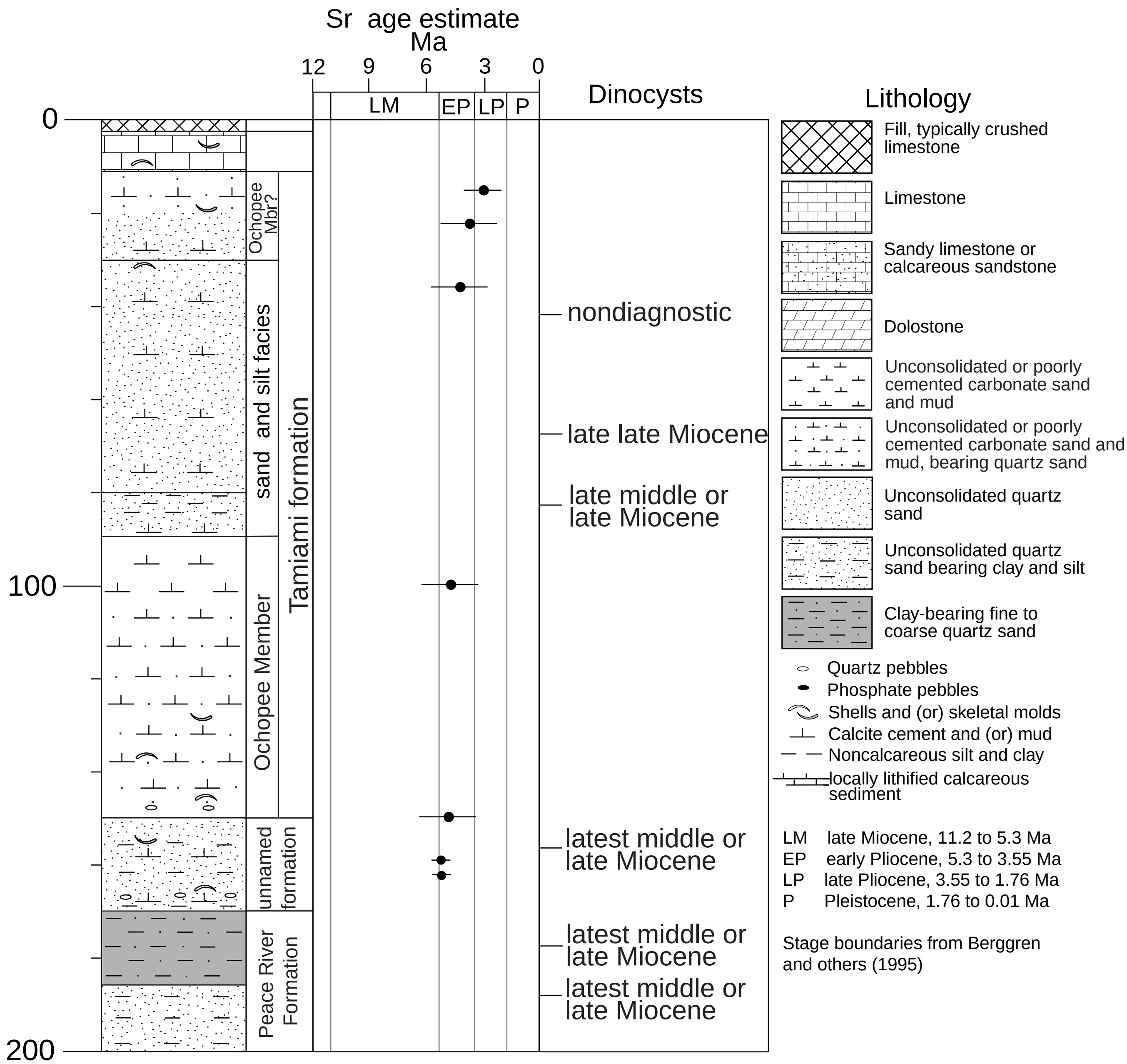

Figure 11b. Lithology, lithostratigraphy, and age information for the Nobles Road core.

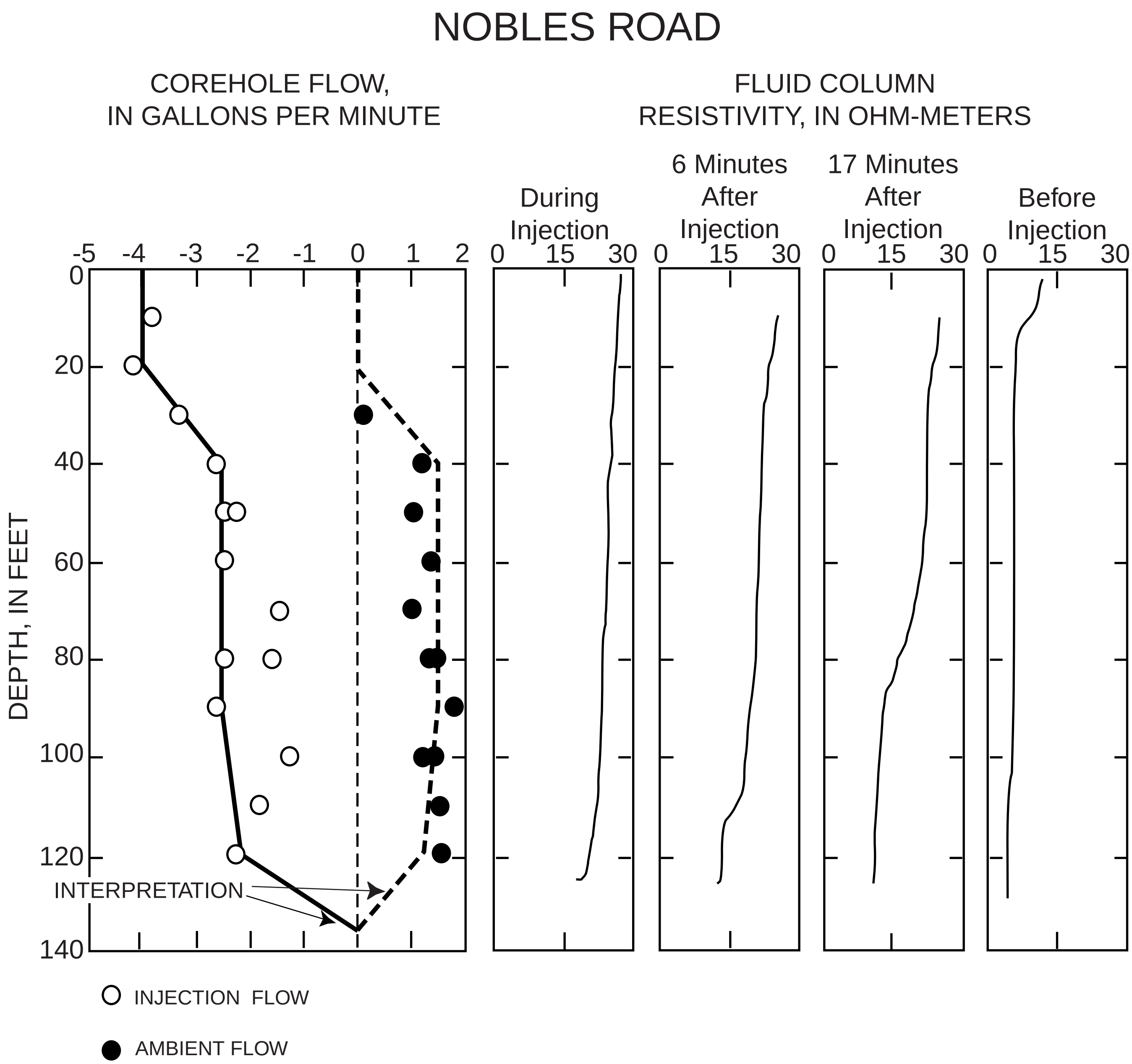

Figure 11c. Corehole flow information for the Nobles Road core.

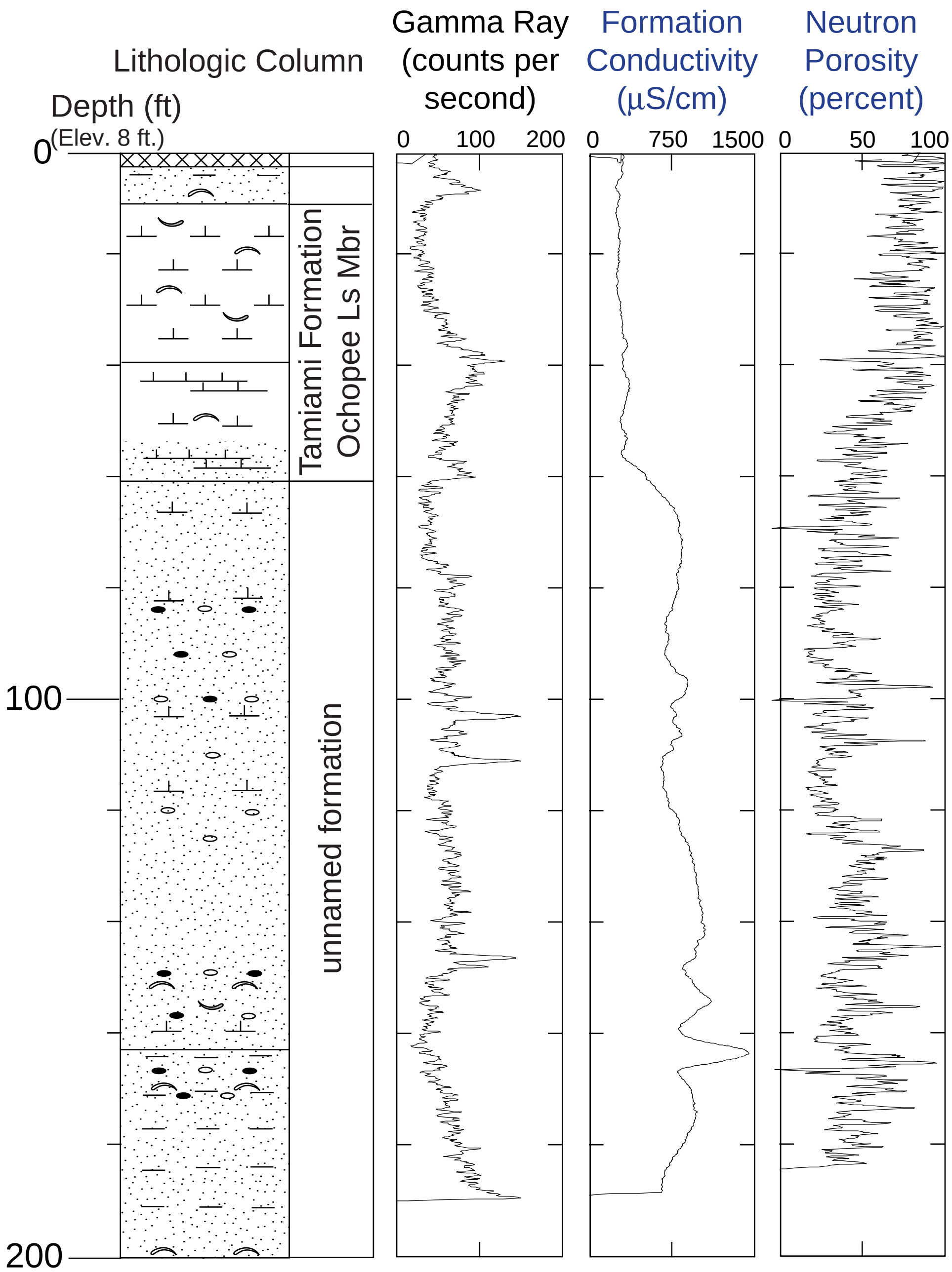

Figure 12a. Lithology, lithostratigraphy, and geophysical information for the Bass core.

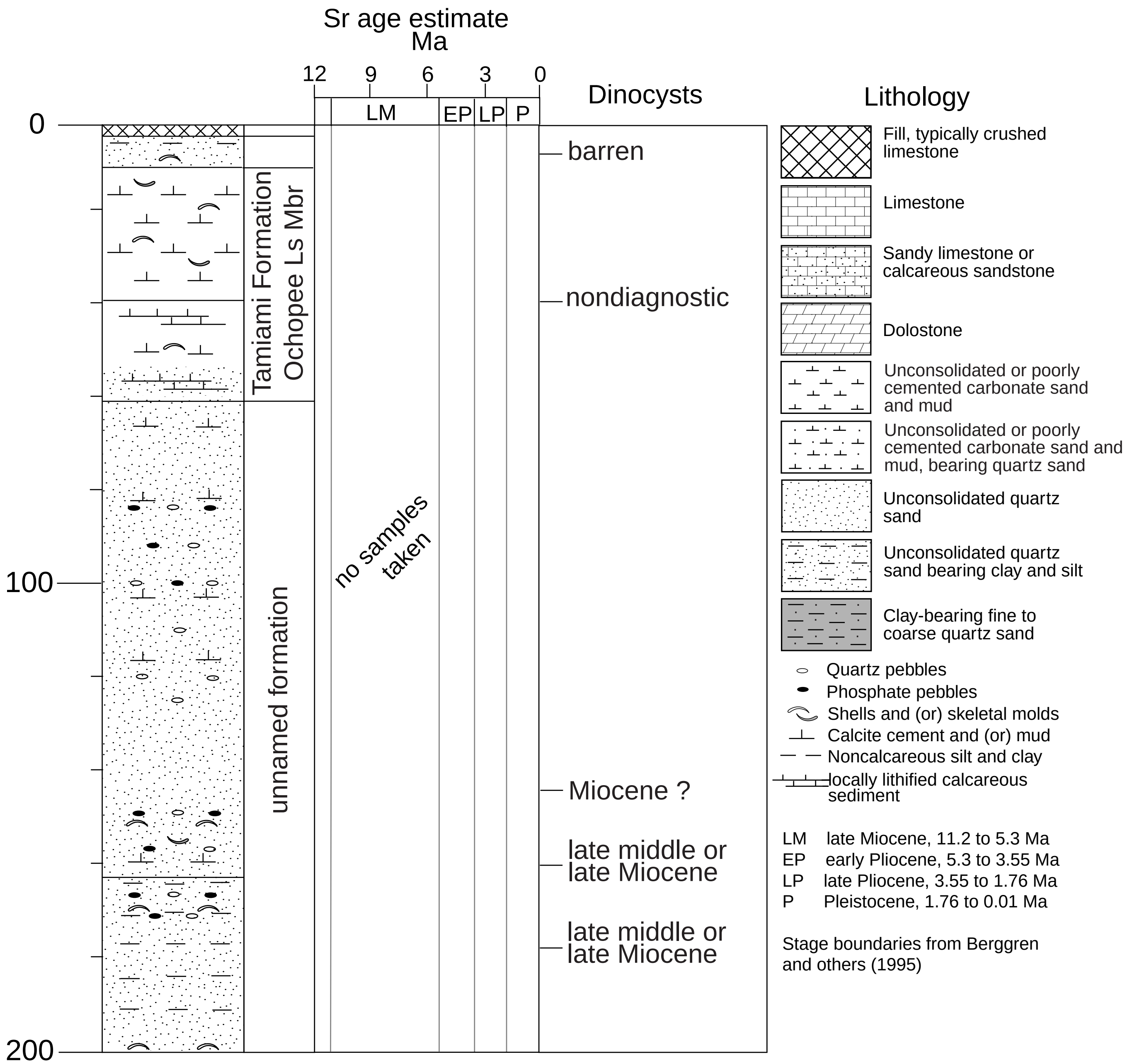

Figure 12b. Lithology, lithostratigraphy, and age information for the Bass core.

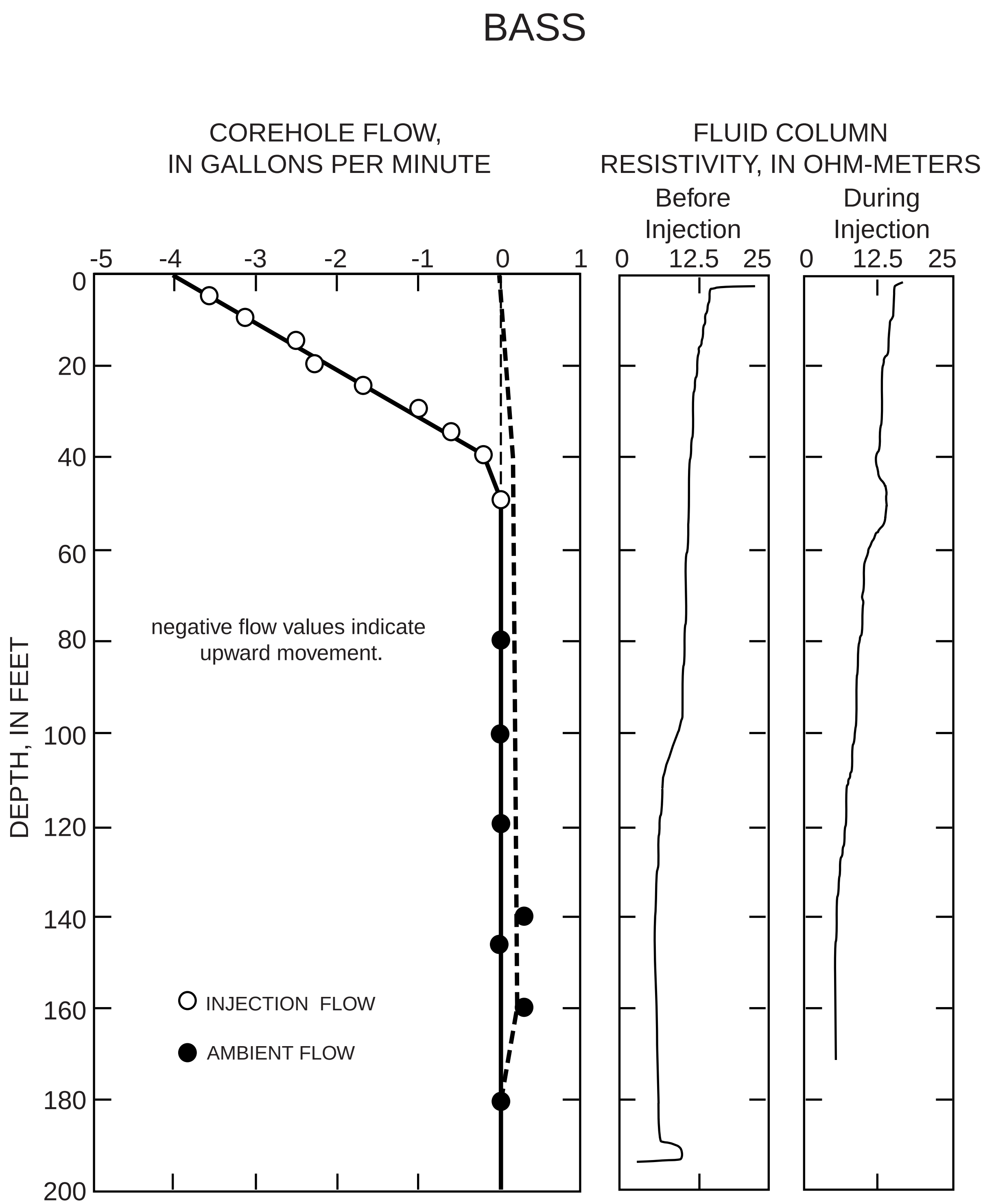

Figure 12c. Corehole flow information for the Bass core.

GEOPHYSICAL RESULTS

Geophysical Logs

The geophysical logs are plotted relative to the lithology and lithostratigraphy (figs. 3-12). The first set (figs. 3a-12a) gives logs related to formation lithology (gamma, induction conductivity, and neutron porosity; Hearst and Nelson, 1985), where logs are compared to lithologic descriptions from core. The second set (figs. 3c-12c) give logs related to flow in the boreholes under ambient and injection conditions (heat-pulse flowmeter, and fluid column temperature and/or resistivity; Paillet and others, 1996). Because several sets of fluid column logs were usually obtained during the course of flowmeter logging, only those fluid column logs most relevant to interpretation of flow profiles are given in each of the flow log composites in figures 3c-11c. Figure 4 gives the lithology log for the deep Trail Center corehole, but only the upper 200 ft was measured for flow (fig. 4c). A complete listing of all logs run in each corehole and the corehole conditions at the time of logging are listed in appendix 2.

The gamma logs from the coreholes show a very irregular distribution of gamma activity that does not appear uniquely related to any particular lithology given on core descriptions. There is no obvious correlation between gamma activity and clay mineral content, so that the gamma log cannot be used as a clay mineral indicator as it is often used in other geological regions (Paillet and Crowder, 1996). Changes in character on the gamma log can sometimes be used to indicate contacts inferred from core inspection. An example of such a pronounced shift in gamma activity is apparent near 310 ft in the deep Trail Center corehole (fig. 4a), or near 125 ft in the Golightly corehole (fig. 3a). In some cases a gradational shift in gamma ray values represents a contact (near 70 ft in the Doerr's Lake corehole; fig. 9a), or a sharp spike represents a single bed (near 160 ft in the West Loop Road corehole; fig. 8a).

The induction and neutron logs show a much more consistent relation to lithology determined from core than does the gamma log. The induction log is influenced by formation lithology (clays), pore water conductivity (salinity), and formation permeability (ion mobility) (Jorgensen, 1991). The neutron log is influenced by lithology (clays), and formation porosity (Keys, 1990). Therefore, the two logs together indicate trends in clay mineral content and permeability. Differences in the two logs indicate the effects of pore water salinity. For example, the induction and neutron logs show similar trends over the interval from 140 to 70 ft in the Bass corehole (fig. 12a). However, there is an abrupt shift in the induction log in the 55-65 ft interval that is not reflected in the neutron log. This shift is attributed to an increase in pore water salinity with depth that influences the induction log, but does not affect the neutron log (Kwader, 1985). In contrast, a sharp deflection on the induction log just below 160 ft is matched by a similar deflection on the neutron log. This deflection is interpreted to represent an abrupt increase in clay content.

On the basis of the interpretation of the three logs assumed to be related to formation lithology and water quality (gamma, induction, and neutron), the logs indicate the presence of a number of clay-rich zones in all of the coreholes, and increasing pore water conductivity with depth. Qualitative interpretation of the logs consists of identifying various lithology zones for correlation with core, use of the logs to adjust lithologic contacts on core descriptions in zones where core recovery was incomplete, and identification of possible aquitards. Quantitative log interpretation is based on modeling two specific log responses: (1) formation electrical conductivity as a function of clay mineral content, pore water conductivity, and formation permeability; and (2) borehole flow as a function of relative interval permeability. These quantitative interpretations are discussed in detail in the following sections of this report.

Formation Conductivity Analysis

The conduction of electrical current through a porous material is often modeled as current flow along three parallel paths, where the net formation conductivity is given as the sum of the conductivity along the three paths (Worthington, 1985):

$$\sigma_F=\sigma_M+\sigma_W+\sigma_B=\{(1/R_M)+(1/R_W)+(1/R_B)\} \quad (2)$$

In this expression, σ and R denote electrical conductivity and resistivity, and the subscripts M, W, and B denote mineral matrix, pore water, and "bound water." Carbonate minerals and quartz grains are assumed to be electrical insulators, so that all of the mineral matrix conductivity is attributed to electrically conductive clay minerals. The electrical conductivity of a given clay mineral is usually assumed to be proportional to the cation exchange capacity of the particular clay. A simplifying assumption is that there are no significant variations in clay mineral, so that the conductivity of the formation mineral matrix is directly proportional to clay mineral fraction. The bound water conductivity is associated with a layer of water interacting with unbalanced ionic bonds in the surface of the mineral grains (the "dual water model"). Ions in the pore spaces become loosely bound in this layer, so that there is an electrically conductive surface layer lining the pore passageways. The electrical conductivity of this layer is shown to become significant in equation 2 whenever the conductivity of the pore water is less than 1000 μS/cm, and where there are no clays in the formation (Biella and others, 1983). Pore water conductivity is found to vary from about 500 to more than 10,000 μS/cm in the boreholes described in this report, so that the bound water effects on formation conductivity can be neglected with only a minor loss of accuracy.

When bound water effects are neglected, the electrical conductivity of a formation measured by the induction log is assumed to depend on only the salinity of the water in pores and the electrical conductivity of the formation minerals. The clay-free fraction of the formation is assumed to consist of non-conductive mineral grains such that the formation conductivity is linearly related to the conductivity of the water saturating the formation:

$$\sigma_W = F\sigma_F \qquad (3)$$

In this expression, the constant F (formation factor) is assumed to be a material property of the matrix (Archie, 1942). Then, the conductivity of the formation can be related to the conductivity of pore water and the amount of clay present using the equation:

$$\sigma_F = \sigma_W / F + N_{CL}\,\sigma_C \qquad (4)$$

In this equation, N_{CL} is the volume fraction of clay in the formation, and σ_C is the electrical conductivity of the clay mineral.

If pore water conductivity and formation factor can be estimated, then the proportion of clay present in the formation can be quantified using the values of σ_F given by the induction log:

$$N_{CL} = \{\sigma_F - F\sigma_W\}/\{\sigma_C\} \qquad (5)$$

Inspection of the log data obtained in intervals where the core contains thick clay units indicates that a good estimate for the conductivity of clay in this equation is about 1000 μS/cm. According to this equation, depth intervals containing clays and the approximate volume fraction of clays present in those intervals can be estimated for each of the ten coreholes (table 2). The number, thickness, and average clay mineral fraction indicate an increasing trend towards the east in the study area.

In the other core intervals, the formation is assumed to be free of clay, and measured formation electrical conductivity can be related to pore water conductivity. In most intervals of corehole, the water in the borehole fluid column could not be related to the water in pores adjacent to the borehole at any given depth. However, corehole flow logs were obtained as part of the routine logging suite. Flow logs indicated where water was entering the corehole under ambient conditions. In those specific situations, the measured resistivity of the water column in the corehole could be related to the resistivity of the pore water in the intervals where flow was entering the borehole (table 3). Using those data points, the water conductivity can be regressed against the measured formation electrical conductivity (fig. 13). The regression gives an expression for predicting water conductivity on the basis of formation conductivity in the form:

$$\sigma_W = 2.14\sigma_F + 131.46 \qquad (6)$$

Table 2. List of clay intervals and approximate volume of clay fraction for the Collier and Monroe County coreholes

COREHOLE	DEPTH INTERVAL (feet)	BASELINE CONDUCTIVITY (μS/cm)	ZONE CONDUCTIVITY (μS/cm)	CLAY FRACTION (N_{CL})
Golightly	28-140	300	1200	0.90
	165-190	300	550	0.25
Trail Center	58-67	400	850	0.45
Dade-Collier Airport	142-166	350	1200	0.85
FAA Radar	95-115	300	1300	1.00
	136-158	400	1200	0.80
Monroe Station	132-146	500	1500	1.00
West Loop Road	155-158	200	350	0.15
	177-190	250	300	0.25
Doerr's Lake	55-76	200	400	0.20
	138-145	200	350	0.15
Raccoon Point	22-34	600	3000[1]	1.00[1]
	145-165	600	2200	1.00
Nobles Road	35-60	400	1000	0.60
Bass	162-168	900	1400[2]	0.50[2]

[1]Conductivity of this zone is so much larger than that of other clay zones that a second clay type with greater cation exchange capacity may be present.
[2]Bed is so thin that full log deflection probably not reached; actual clay fraction of thin bed may be much greater than 50 percent.

with a correlation coefficient (r^2) of 0.951. By comparison with equation 5, the slope in this expression indicates a formation factor of 2.14. This value applies to producing zones where water enters the borehole under ambient hydraulic-head differences, and can be used to estimate pore water conductivity from measured values of σ_F in other clay free, permeable zones. The formation conductivity of permeable zones indicates that the uppermost part of the formation is characterized by very fresh water with conductivity in the range of 450-600 μS/cm. The conductivity of water in permeable units beneath aquitards under the surficial aquifer vary from 1000 to 2000 μS/cm, with pore water conductivity decreasing to the southeast.

Flowmeter Profile Analysis

Flowmeter measurements were made under ambient conditions in all ten coreholes. Upflow was measured in all but four (Doerr's Lake, West Loop Road, Golightly, and Raccoon Point). Ambient flow at rates too small to measure with the flowmeter (0.1 gpm or less) was probably also present in these four coreholes, based on inspection of fluid column logs, which showed long intervals of constant values, and prominent steps correlated with permeable zones on core where water was probably entering the corehole. Measured ambient upflow varied from less than 0.5 gpm in several coreholes (Bass, Monroe Station, and Dade-Collier

Table 3. Comparison of pore water conductivity given by fluid column resistivity log with the formation conductivity of the zone where flowmeter logs showed water entering the borehole under ambient conditions

BOREHOLE	INTERVAL (feet)	FORMATION COND (µS/cm)	PORE WATER COND (µS/cm)	RATIO ($F=\sigma_W/\sigma_F$)
Golightly	20-50	250	600	2.40
Trail Center	160-170	350	945	2.70
Dade-Collier Airport	180-185	390	920	2.36
FAA Radar	170-180	400[1]	1000	2.50
FAA Radar Production[1]	20-30	140	590	4.21
Monroe Station	180-120	250[1]	600	2.40
Doerr's Lake	120-150	250	770	3.08
Nobles Road	120-140	450	915	2.03
Bass	170-200	900	2140	2.37
Bass Sup[2]	0-40	270	650	2.41

[1]Fluid column log in water supply well adjacent to corehole; data related to formation conductivity in equivalent zone in corehole.
[2]Induction log available for only a fraction of the flow zone because of borehole collapse.

Airport coreholes) to more than 1.0 gpm (Nobles Road, FAA Radar, and Trail Center coreholes). Ambient borehole flow is taken as a definite indication that aquitards are present to maintain hydraulic-head differences between compartments within the surficial aquifer. In some of the coreholes such as Nobles Road and FAA Radar, thick clay aquitards are clearly present, as indicated by both core inspection and induction logs. In others such as the Trail Center corehole and the upper part of the Bass corehole, there are no apparent clay aquitards at some depths where flow logs indicate aquitards must be present, and aquifer compartments are probably "sealed" by tightly cemented horizons. Ambient hydraulic-head differences were measured at two of the sites where observation boreholes were completed in specific aquifer units. At the FAA radar site, the water level near the bottom of the corehole was 2.3 ft above that in the surficial aquifer. At the Trail Center site, water level differences in observation wells indicate a hydraulic-head difference of a few inches between the 110 and 90 ft zones.

Because hydraulic theory indicates that two steady profiles are required to estimate the distribution of hydraulic conductivity along the corehole, a second steady flow profile under injection conditions (in addition to the ambient flow profile) was measured wherever possible. The hydraulic conductivity is given in the form of vertically averaged product of permeability and thickness known as transmissivity (units of ft^2/day). It can be shown that the relative amount of flow entering or exiting the corehole under any given set of conditions cannot be taken as directly proportional to transmissivity (Paillet, 1998). For example, if it is assumed that there is steady radial flow through a given producing zone into or out of a corehole, then the flow is given by (Davis and DeWeist, 1966):

$$q_k^a = 2T_k\left(H_k - w^a\right)\ln\left(\frac{R_0}{R}\right) \qquad (7)$$

where q_k^a is the flow into the well from zone k under conditions denoted by the superscript a, T_k is the transmissivity of the producing zone, H_k is the far-field head in the aquifer, w^a is the water level in the corehole, R_0 is the distance to the recharge boundary of the producing zone, and R is the corehole radius. The measured inflow is proportional to the product of T_k and (H_k - w^a), rather than T_k alone. If we measure flow under two different quasi-steady conditions (for example, ambient flow and steady pumping), then the difference between the flows is (Paillet, 1998):

$$q_k^b - q_k^a = 2T_k\left(w^a - w^b\right)\ln\left(\frac{R_0}{R}\right) \qquad (8)$$

which does not depend on the unknown value H_k. This difference is directly proportional to zone transmissivity. Quantitative estimates of transmissivity can be obtained if the water level difference w^a - w^b (drawdown) is measured. In this study, the relative change in water level induced by the injection was either negligible or it was impossible to separate head losses from flow through screen from head losses associated with flow into the aquifer. It was likewise not possible to scale the water level build-up for a given small injection rate from the larger build-up associated with much greater injection rates because most of the build-up would have been caused by screen losses and not the hydraulic resistance of the formation. Therefore, the analysis could only give the relative transmissivity of each producing zone, and not the absolute value of transmissivity.

The paired flow profiles for each corehole where valid profile pairs were generated were analyzed using equation 8. However, the presence of an annulus outside the slotted casing was a complicating factor in the analysis. The well development process was assumed to cause the unconsolidated formation to collapse around the screen, forcing all corehole flow to occur within the slotted casing. There were probably some situations where collapse was not complete, and the flow measured inside casing was not the total flow. There were also some indications that thermally driven convection cells locally reversed the measured flow in the center of the slotted screen (most notably, the

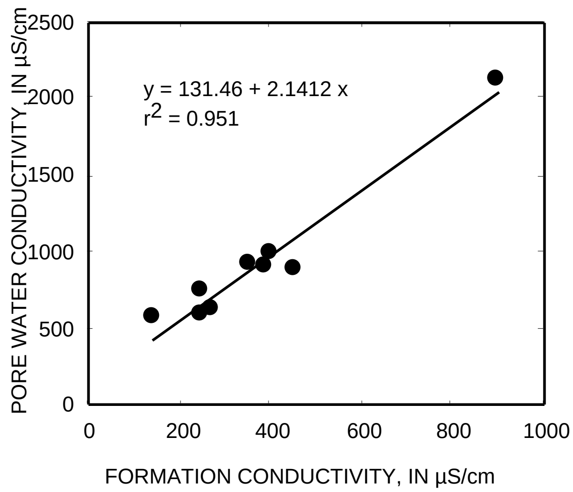

Figure 13. Plot of formation conductivity and pore water conductivity where flowmeter logs showed water entering the borehole. Data are from Table 3.

flow profile for the Trail Center corehole, fig. 4c). For these reasons, the flow profile measured with the heat-pulse flowmeter were first fit to smoothed interpretation lines which were believed to give a more realistic representation of vertical flows. These smoothed profiles could then be differenced at regular intervals to estimate the water entering or exiting the boreholes. The inflow is estimated using a simple mass balance:

$$Q = F_2 - F_1 \qquad (9)$$

where Q is the inflow in a depth interval, and F_2 and F_1 are the flows measured at the top and bottom of the zone, using the usual convention that upward flow is positive and downward flow is negative. In this expression, negative values for Q can occur, and correspond to outflow from the corehole. In fact, most flow during injection was outflow. In estimating relative zone transmissivity, equation 8 is applied by subtracting the inflow during injection from the inflow under ambient conditions. This convention is adapted to insure that all of the differences are positive, because the water level during injection was always assumed greater than the water level in the corehole under ambient conditions. In those few situations where a second flow profile was obtained under pumping conditions, the ambient inflows were subtracted from the generally positive pumping inflows.

The relative transmissivity of 10-foot intervals in the eight coreholes where valid flowmeter profiles were made are illustrated in figure 14. In six of these coreholes (Bass, Doerr's Lake, Monroe Station, FAA Radar, Golightly, and Dade-Collier Airport), most of the transmissivity is associated with the water-table aquifer in the 0-40 ft interval. Although these profiles show approximately the same relative transmissivity in percent, the absolute values of transmissivity in these zones may vary. Two of the coreholes (Nobles Road and Trail Center) showed relatively greater transmissivity in permeable zones at or somewhat below 100 ft in depth. Although these profiles give only relative transmissivity for each zone, inspection of core geology and logs indicates that the deeper aquifers are not disproportionately more permeable than similar deeper zones in the other coreholes. Instead, the shallow aquifer appears to be relatively low in permeability in these two coreholes, accounting for the shape of the transmissivity profiles in those coreholes.

In the analysis of the flow profiles, 10-ft intervals were used for the differencing of flow profiles because greater vertical resolution was not considered possible. Because of possibly incomplete filling of the annulus, flow might not enter the formation at the exact depth where it left the screen. The depth resolution of the flowmeter profiles was checked by repeating flow profiles in observation and production wells installed at the Trail Center and FAA Radar sites. These wells were completed over specified intervals with the annulus filled with sand or gravel, and with the annulus above the screened interval plugged with bentonite. Therefore, flowmeter profiles in these boreholes unambiguously indicated the precise depth where water entered or exited during hydraulic tests. The FAA Radar production well was logged under ambient and pumped conditions over the screened interval from 10 to 50 ft (fig. 14). The flow log analysis indicates that the transmissivity associated with the upper 40 ft of the FAA Radar borehole during the corehole flow logging is actually concentrated in the 24-32 ft interval. The flowmeter data from the Trail Center production well and two observation wells (fig. 14) indicated that the transmissive zone originally assigned to the 90-110 ft interval is divided into two separate zones. The presence of an aquitard in the center of this zone was interpreted from the corehole flowmeter log analysis (fig. 4c), and is confirmed by the production and observation well flowmeter logs, which show flow from the lower part of the zone into the upper part of the zone in observation wells screened over the 120-90 ft interval.

Another check on the validity of flowmeter log interpretation is given by fluid column logs obtained in the developed corehole before logging, and during and after injection. Intervals of constant fluid resistivity or temperature can indicate intervals where there is flow along the borehole (Keys, 1990). Abrupt shifts or "steps" in fluid column logs can indicate the depth intervals where water enters the borehole fluid column. Changes in the character of fluid columns logs before, during, and after pumping and injection can further indicate the depth of producing zones. For example, there was no measured ambient flow in the Golightly borehole, but the fluid column resistivity log before injection was a nearly a straight vertical line, indicating the possible presence of flow too slow to measure. Because upward hydraulic-head gradients were measured in other study area coreholes, upward flow might be assumed, but could not be verified. The water used for injection was produced from this borehole, and then allowed to warm by passive solar heating for nearly a day. Thus, the injection water used to obtain a flow profile under stressed conditions was at a different temperature form that in the formation. The borehole fluid temperature profile obtained during injection corroborates the flow profile made during injection, because both data sets show that the "bottom" of the upper permeable zone occurs at 70 ft in depth. In addition, the temperature log indicates that none of the injected water is flowing down below 70 ft (fig. 3c). This is interpreted to indicate that the injection did not produce enough water level build-up to overcome a weak upward flow in the zone below 70 ft.

In a few situations, the fluid column logs before, during, and after injection provide quantitative as well as qualitative confirmation

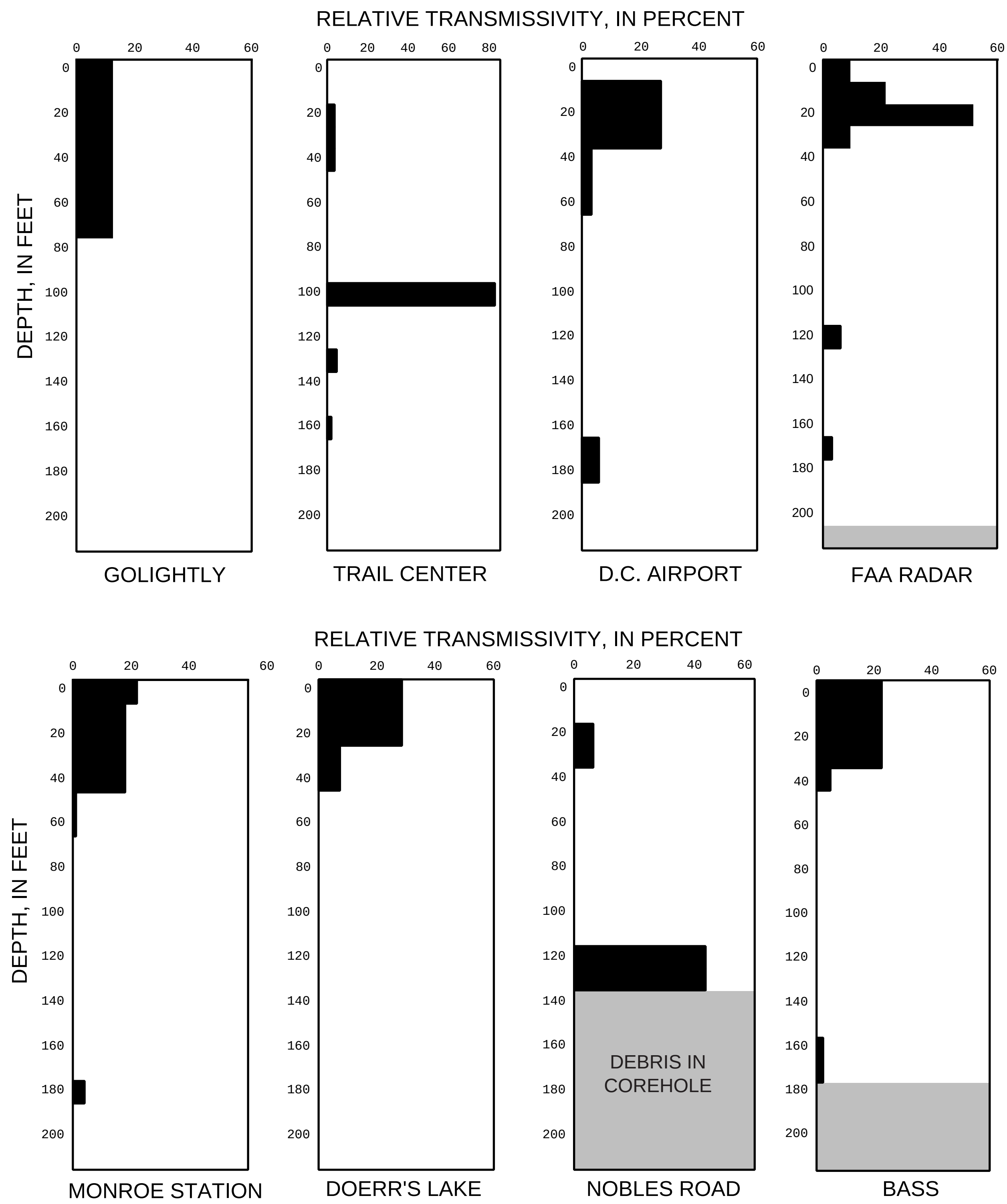

Figure 14. Flowmeter interpretation, showing relative transmissivity calculated in ten-foot intervals.

of flowmeter profiles. For example, upward flow of more than a gallon per minute was measured in the Nobles Road corehole. During injection, the injected water was forced down into the producing zone below 100 ft in depth. After the end of injection, the natural flow began to force the injected water back up the fluid column. The rate of movement of the interface between formation and injected water confirmed that the ambient flow was slightly more than one gallon per minute.

STRATIGRAPHIC RESULTS

Golightly Core

The Golightly corehole (fig. 3a, b) was completed on January 19, 1997 to a depth of 200 feet, beside a borrow pit to the south of a large barn at an abandoned home site that now belongs to the Big Cypress National Preserve. The original corehole was filled with concrete after geophysical logging, however, a monitor well was drilled on the same property by the South Florida Water Management District, near the house. The site (fig. 1) is located at 25°44'55.952"N. and 80°55'57.520"W. and is on the Lostman's Trail 1:24,000 USGS topographic map at an elevation of about 8 ft.

Lithostratigraphy.--The Peace River Formation occurs from the base of this core to 168.8 ft. It ranges in color from light gray to yellowish gray to light and medium olive gray, and is primarily unconsolidated, bioturbated, fine quartz sand interbedded with silt and clay. There are a few quartz granules near 196.0 ft, and scattered chalky shell fragments throughout.

Overlying the Peace River Formation is the unnamed formation which extends from 168.8 to 86.8 ft. The unnamed formation ranges from a light olive gray to yellowish gray to dusky yellow to yellowish brown. It is primarily an unconsolidated fine to medium sand with scattered quartz and phosphate granules throughout, and contains a shell bed from 159.0 to 156.0 ft. It differs from the Peace River Formation by having a lower clay content, and carbonate mud in the matrix, especially from 145.0 to 86.8 ft. There are four thin moldic lithified zones between 110.0 and 97.0 ft.

The Tamiami Formation occurs from 86.8 to the top of the core. There may be some fill at the top of the core, but recovery was poor near the top, and the fill would have been retrieved from the nearby borrow pit and of the same material as the upper few feet. There is a *Turritella* mold-bearing sandstone from 86.1 to 78.8, at the base of the Tamiami Formation. This sandstone has blackened skeletal mold surfaces and scattered coarse quartz sand, and the top of the zone is capped with heavily bored oyster shells. We interpret the top of this sandstone as a significant surface of non-deposition. The formation is light gray to olive gray from 78.8 to 40.0 ft, and primarily unconsolidated with abundant oysters and pectens, and echinoids in a carbonate sand and mud matrix with minor quartz sand. From 40 to 4.0 ft, the formation is primarily a white moldic molluscan packstone, with oysters, bryozoans, echinoids, gastropods, and minor quartz sand; some aragonitic mollusks occur in this interval. Near the top of the core, a drusy yellowish gray to dusky yellow calcite cement lines voids and mold surfaces. The upper four feet are a mottled, pale orange to moderate yellowish brown, well indurated sandy moldic packstone, locally referred to as "caprock."

Biostratigraphy.--Four samples were examined for dinocysts (appendix 3, table 4). The two lowest samples (199, 136 ft) contain dinocyst assemblages of latest middle or late Miocene age, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary) and *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa* (latest occurrence in the late Miocene). The samples at 73 and 47 ft contain single specimens each of long ranging forms and are not age diagnostic.

Strontium-isotope stratigraphy.--Six samples were analyzed for strontium isotopes (table 5). The lowest samples from 158.8 and 103.4 ft give calculated ages of 6.4 Ma ± 0.5 m.y. and 5.6 Ma ± 0.5 m.y., respectively (late Miocene). Higher samples from 74.8 to 32.4 ft have calculated ages of 4.7 to 4.3 Ma ± 1.5 m.y. (early Pliocene, but with a margin of error that includes both latest late Miocene and late Pliocene). The highest sample at 12.8 ft has a calculated age of 2.8 Ma ± 1.0 m.y. (late

Table 4. Dinocyst occurrences

Taxon	Golightly		Trail Center								Dade-Collier Airport					FAA-Radar					Monroe Station				
	R5300	R5300	R5275	R5275	R5275	R5275	R5275	R5275	R5275	R5275	R5265	R5265	R5265	R5265	R5265	R5264	R5264	R5264	R5264	R5264	R5365	R5365	R5365	R5365	R5365
	A	B	A	B	C	D	E	F	G	H	A	C	D	B	E	A	B	E	C	F	C	A	D	B	E
approx. depth (ft)	199	136	450	441	431	361	312	239	188	67	200	153	120	89	78	204	158	96	91	61	183	179	143	114	102
Achomosphaera andalousiensis	X	X	.	.	.	.	X	X	.	.	X	X	X	.	.	X	.	X	X	X	X	X	.	.	X
Achomosphaera spp.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	X	X	X	X	.	X	.	X
Amiculosphaera umbracula	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.
Ataxiodinium ? n. sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.
Batiacasphaera hirsuta ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	X	.	.	X	.	.
Batiacasphaera sphaerica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Brigantedinium spp.	.	.	.	.	?	X	.	.	.	.	.	.	.	.	.	.	X	.	X	.	X	.	.	.	.
Cyclopsiella ? sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dapsilidinium pseudocolligerum	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	X	.	.	.	X	.	.
Erymnodinium delectabile	.	.	X	X	X	X	.	X	.	.	X	?	.	.	.	X	X	.	.	.	X	.	X	.	.
Geonettia clineae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
Habibacysta sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	?	.	.	.	.	.	.	.	.	.	.	.
Habibacysta tectata	X	.	?	?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.	X
Hystrichokolpoma sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hystrichokolpoma rigaudiae	X	.	.	X	X	X	X	X	X	.	.	.	X	X	X	X	.	.	.	X	.	.	.	X	X
Hystrichosphaeropsis obscura	.	.	X	X	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.
Impagidinium paradoxum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X
Impagidinium patulum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X
Impagidinium sphaericum	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Impagidinium spp.	.	.	.	X	.	.	.	.	.	.	.	.	X	X	.	X	.	.	.	.	.	.	.	.	.
Invertocysta lacrymosa	.	.	.	X	.	.	.	.	X	.	.	X	.	.	.	.	.	X	X	.	.	.	.	.	X
Invertocysta sp.	.	.	.	.	.	.	.	.	.	.	.	X	.	?	.	.	.	.	.	.	.	.	.	.	.
Labyrinthodinium truncatum subsp. *truncatum*	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lejeunecysta spp.	X	X	X	.	X	X	X	X	X	.	X	X	.	.	.	X	X	X	.	.	X	X	X	.	.
Lingulodinium machaerophorum	X	X	X	X	X	X	.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Melitasphaeridium choanophorum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	X	.	.
Melitasphaeridium sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	X
Multispinula quanta	X	X	.	.	.	X	X	X	.	.	X	X	X	.	.	X	.	X	X	.	X	X	X	.	.
Muraticysta microornata	.	.	.	.	?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Nematosphaeropsis spp.	X	.	X	X	X	X	.	.	.	.	X	X	.	.	.	.	.	X	X	.	X	X	X	.	.
Operculodinium ? eirikianum	X	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	X	.	X	.	X	.	.	.
Operculodinium centrocarpum	X	X	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Operculodinium spp.	X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	X	X	X	X	X
cyst of *Polykrikos*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polysphaeridium zoharyi	X	X	X	X	X	X	.	.	X	.	.	.	X	X	X	.	.	.	X	X	.	X	X	X	X
Quadrina ? condita	X	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Reticulatasphaera actinocoronata	X	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X
Selenopemphix armageddonensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Selenopemphix brevispinosa subsp. *brevispinosa*	.	X	.	.	X	X	X	X	.	.	.	.	.	.	.	X	X	.	X	.	X	.	X	.	.
Selenopemphix brevispinosa subsp. *conspicua*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.
Selenopemphix nephroides	X	.	X	.	.	X	.	.	.	X	X	X	.	.	.	X	.	X	X	.	.	.	X	.	.
Selenopemphix sp.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spiniferites mirabilis	X	.	.	X	X	X	.	.	X	X	X	X	.	.	.	X	.	X	X	X	X	X	.	X	X
Spiniferites pseudofurcatus	.	.	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spiniferites spp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sumatradinium soucouyantiae	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sumatradinium spp.	X	X	X	.	X	X	X	X	.	.	X	X	.	.	.	X	X	.	X	.	.	X	X	.	.
Tectatodinium pellitum	X	X	X	.	X	X	.	X	X	X	X	X	X	X	.	.	X	.	.	X	X	X	X	.	X
Trinovantedinium capitatum	X	X	.	.	.	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trinovantedinium ferugnomatum	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trinovantedinium glorianum	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	?	.	.	.
Trinovantedinium harpagonium	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trinovantedinium papulum	.	.	.	.	X	.	.	.	.	.	X	.	.	.	.	X	.	X	.	.	.	.	.	.	.
Trinovantedinium ? xylochoporum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.
Trinovantedinium spp.	.	.	X	.	.	.	X	.	.	.	.	X	.	.	.	.	X	X	X	.	X	.	.	.	.
Tuberculodinium rossignoliae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tuberculodinium vancampoae	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	X	X	X	X	X	X	X	X
miscellaneous Congruentidiaceae	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	X	.
new gonyaulacacean form	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
freshwater alga *Pediastrum*	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.

Table 4. Dinocyst occurrences (cont.)

Taxon	West Loop Road				Doerr's Lake			Raccoon Point				Nobles Road						Bass			
	R5299	R5299	R5299	R5299	R5266	R5266	R5266	R5254	R5254	R5254	R5254	R5366	R5366	R5366	R5366	R5366	R5366	R5364	R5364	R5364	R5364
	A	B	D	E	C	D	A	A	B	D	C	A	E	B	C	F	D	A	B	C	D
approx. depth (ft)	241	201	162	72	182	106	77	165	147	129	42	188	177	156	83	67	41	185	166	150	40
Achomosphaera andalousiensis	.	X	?	.	.	?	.	?	X	.	.	?	X	X	.	.	.	.	.	.	.
Achomosphaera spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	X	.	.	X	.
Amiculosphaera umbracula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ataxiodinium ? n. sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Batiacasphaera hirsuta ?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Batiacasphaera sphaerica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	?	.
Brigantedinium spp.	.	X	.	.	.	.	.	X	X	.	X	.	.	.	.	.	.	.	.	.	.
Cyclopsiella ? sp.	.	.	X	.	.	X	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.
Dapsilidinium pseudocolligerum	.	.	.	.	.	.	.	.	.	.	X	.	.	X	.	.	.	.	.	.	.
Erymnodinium delectabile	X	X	.	.	.	X	.	X	.	.	.	.	.	.	.	.	.	X	.	.	.
Geonettia clineae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	?	.	.	.
Habibacysta sp.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.
Habibacysta tectata	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.
Hystrichokolpoma sp.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.
Hystrichokolpoma rigaudiae	.	X	X	X	X	.	.	X	X	X	X	X	.	X	.	.	.	.	.	.	.
Hystrichosphaeropsis obscura	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Impagidinium paradoxum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Impagidinium patulum	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.
Impagidinium sphaericum	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.
Impagidinium spp.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.
Invertocysta lacrymosa	.	X	.	.	.	.	.	X	.	.	.	.	X	.	X	?	.	.	.	X	.
Invertocysta sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Labyrinthodinium truncatum subsp. *truncatum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lejeunecysta spp.	X	X	.	.	.	X	X	.	.	.	.	X	X	.	X	X	.	X	X	X	.
Lingulodinium machaerophorum	X	.	.	.	.	X	X	X	X	.	X	X	X	X	X	X	X	X	X	X	.
Melitasphaeridium choanophorum	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.
Melitasphaeridium sp.	.	.	.	.	.	.	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.
Multispinula quanta	X	X	X	.	X	X	.	X	X	.	.	X	X	.	X	X	?	.	X	.	.
Muraticysta microornata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Nematosphaeropsis spp.	X	X	.	.	X	X	.	X	.	.	X	.	.	X	.	.	.	.	.	X	.
Operculodinium ? *eirikianum*	.	.	.	X	X	.	.	.	.	X	.	.	.	X	X	.	.	X	.	.	.
Operculodinium centrocarpum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.
Operculodinium spp.	X	X	.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X
cyst of *Polykrikos*	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.
Polysphaeridium zoharyi	.	.	.	X	.	.	.	.	X	X	X	.	.	X	.	X	.	X	.	X	.
Quadrina ? *condita*	X	X	.	.	X	X	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.
Reticulatasphaera actinocoronata	.	.	.	.	.	X	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.
Selenopemphix armageddonensis	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.	X	.	.	.	.	.
Selenopemphix brevispinosa subsp. *brevispinosa*	.	.	.	.	.	X	?	X	.	.	.	.	X	.	.	.	.	.	X	.	.
Selenopemphix brevispinosa subsp. *conspicua*	X	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.
Selenopemphix nephroides	X	X	.	.	X	X	.	X	X	.	X	.	.	.	.	.	.	.	X	.	.
Selenopemphix sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spiniferites mirabilis	.	X	.	.	.	.	.	X	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	X	X	X	X	X	X
Sumatradinium soucouyantiae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sumatradinium spp.	.	.	.	.	.	.	.	X	.	.	.	?	.	.	.	.	.	.	.	.	.
Tectatodinium pellitum	X	X	X	.	.	X	.	X	X	.	X	X	.	X	.	X	X	X	.	X	.
Trinovantedinium capitatum	X	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.
Trinovantedinium ferugnomatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trinovantedinium glorianum	.	.	.	.	.	.	.	.	.	.	?	.	.	.	.	.	.	.	.	.	.
Trinovantedinium harpagonium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trinovantedinium papulum	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trinovantedinium ? *xylochoporum*	X	X	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trinovantedinium spp.	.	X	.	.	.	X	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.
Tuberculodinium rossignoliae	?	.	.	.	.	.	.	?	.	.	.	.	.	.	.	.	.	.	.	.	.
Tuberculodinium vancampoae	X	X	.	X	X	X	X	X	X	X	X	.	.	X	.	X	X	X	.	X	.
miscellaneous Congruentidiaceae	X	X	X	.	X	X	.	X	X	X	X	X	.	.	.	.	.	.	X	.	.
new gonyaulacacean form	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
freshwater alga *Pediastrum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 5. Strontium-isotope analyses

[Fm. = Formation; do. =ditto; FT=Fort Thompson; T=Tamiami, U=unnamed; PR=Peace River; dup.=duplicate sample]

Core name	Depth (ft)	Fm.	$^{87/88}Sr$*	plus/-	Age (Ma†)	Age plus/-	Notes
Golightly	12.8	T	0.709074	0.000005	2.81	1.0	
do.	32.4	T	0.709054	0.000006	4.34	1.5	
do.	55.0	T	0.709050	0.000006	4.65	1.5	
do.	74.8	T	0.709049	0.000006	4.69	1.5	
do.	103.4	U	0.709017	0.000004	5.59	0.5	
do.	158.8	U	0.708972	0.000005	6.40	0.5	
Trail Center	11.1	T	0.709058	0.000006	4.03	1.5	
do.	29.4	T	0.709058	0.000006	4.03	1.5	
do.	48.8	T	0.709052	0.000003	4.50	1.5	
do.	59.4	T	0.709052	0.000003	4.50	1.5	
do.	89.0	T	0.709045	0.000005	4.86	1.5	
do.	109.5	T	0.709049	0.000009	4.69	1.5	
do.	120.8	T	0.709052	0.000006	4.50	1.5	
do.	208.2	U	0.709051	0.000006	4.57	1.5	
do.	232.0	U	0.709044	0.000006	4.90	1.5	
do.	324.2	PR	0.708944	0.000003	7.59	1.5	
do.	354.5	PR	0.708931	0.000003	8.71	1.5	
do.	414.5	PR	0.708946	0.000005	7.46	1.5	
do.	443.0	Arcadia (?)	0.708916	0.000006	9.32	0.5	
DC Airport	27.5	T	0.709043	0.000008	4.94	1.0	
do.	27.5-d	T	0.709051	0.000006	4.57	1.5	dup.
do.	44.8	T	0.709049	0.000007	4.69	1.5	
do.	44.8.d	T	0.709055	0.000007	4.26	1.5	dup.
do.	61.1	T	0.709058	0.000004	4.03	1.5	
do.	76.6	T	0.709037	0.000005	5.15	0.5	
do.	83.8	T	0.709043	0.000005	4.94	1.0	
do.	83.8-d	T	0.709051	0.000008	4.57	1.5	dup.
do.	119.5	PR	0.709041	0.000005	5.03	0.5	
West Loop Road	10-12	T	0.709057	0.000005	4.11	1.5	
do.	20-25	T	0.709051	0.000003	4.57	1.5	
do.	30-35	T	0.709060	0.000003	3.88	1.5	
do.	47-50	T	0.709052	0.000004	4.50	1.5	
do.	55-60	T	0.709059	0.000003	3.96	1.5	
do.	120.7	U	0.709043	0.000005	4.94	1.0	
do.	130.9	U	0.709024	0.000004	5.46	0.5	
do.	161.8	U	0.708977	0.000004	6.26	0.5	
do.	192.7	PR	0.708968	0.000005	6.53	1.0	
Doerr's Lake	0-20	T	0.709056	0.000006	4.19	1.5	
do.	34.6	T	0.709051	0.000004	4.57	1.5	
do.	46.2	U	0.709034	0.000007	5.24	0.5	
do.	56.7	U	0.709042	0.000004	4.99	0.5	
do.	96.0	U	0.708970	0.000005	6.45	0.5	
do.	100.2	U	0.708958	0.000005	6.91	1.0	
do.	112.1	U	0.708975	0.000003	6.32	0.5	
do.	117.0	U	0.708969	0.000012	6.49	1.0	
Raccoon Point	20.2	T	0.709059	0.000025	3.96	1.5	
do.	46.7	T	0.709056	0.000006	4.19	1.5	
do.	86.0	T	0.709046	0.000005	4.83	1.5	
do.	100.9	T	0.709048	0.000006	4.73	1.5	
do.	114.2	T	0.709051	0.000006	4.57	1.5	
do.	123.6	U	0.709047	0.000005	4.78	1.5	
do.	123.6-d	U	0.709048	0.000005	4.83	1.5	dup.
do.	181.1	PR	0.709015	0.000004	5.62	0.5	
Nobles Road	15.3	T	0.709073	0.000004	2.89	1.0	
do.	20-25	T	0.709082	0.000005	3.73	1.5	
do.	36.0	T	0.709056	0.000004	4.19	1.5	
do.	100.0	T	0.709050	0.000004	4.65	1.5	
do.	149.7	T	0.709047	0.000007	4.78	1.5	
do.	159.1	U	0.709034	0.000004	5.24	0.5	
do.	162.0	U	0.709035	0.000006	5.21	0.5	

*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).

Pliocene).

Age summary.--The Peace River Formation (200-168.8 ft) in the Golightly core is late middle and (or) late Miocene based on the presence of the dinocyst species *Achomosphaera andalousiensis* and *Selenopemphix brevispinosa* subsp. *brevispinosa*. The unnamed formation (168.8-86.8 ft) is late Miocene up to at least 103 ft, based on both dinocysts and strontium-isotope stratigraphy. The Tamiami Formation (86.8-0 ft) is Pliocene, and calculated ages range from early to late Pliocene.

Trail Center Core

The Trail Center corehole (fig. 4a, b) was completed to a depth of 200 ft, on January 28, 1997, and extended to 464 ft on April 3, 1997, on the southeast edge of a borrow pit within a compound of residences of Everglades National Park and USGS-BRD employees. The site (fig. 1) is located at 25°48'14.575"N. and 80°52'.02.954"W. on the Fifty Mile Bend 1:24,000 USGS topographic map. The original corehole was developed in the depth range of 452 to 412 ft by USGS drillers, as a monitor well, and several other holes have been drilled nearby for monitoring purposes and for aquifer testing.

Lithostratigraphy.--The Arcadia(?) Formation occurs in this core from the base at 464 to 432.6 ft. Its color ranges from a yellowish gray to dusky yellow to olive brown, and is primarily an unconsolidated, shelly (mollusk and bryozoan fragments) carbonate sand in a silty clay and carbonate mud matrix, with minor quartz sand. There is oyster rubble at the top of the formation from 435 to 432.6 ft in a poorly sorted fine quartz sand and clay matrix.

The Peace River Formation occurs from 432.6 to 237.3 ft and is the greatest thickness of this formation observed in the study cores. The formation is primarily an unconsolidated and bioturbated, olive gray, calcareous fine quartz sand and silt. The formation is bioturbated with scattered clay-lined burrows from 432.6 to 312 ft, and the upper portion of the formation, from 312 to 237.3 ft, is characterized by laminated, interbedded fine sand and silty clay. In general, preservation of lamination increases upward in this formation. Shells are rare, occurring at 354.6 ft, from 314 to 312 ft, and from 320 to 318 ft, where they are deposited with quartz and phosphate granules and pebbles. Thin dolomite beds occur at 272.2 to 270.8 ft.

The unnamed formation occurs from 237.3 to 126.5 ft, and is a yellowish gray to very pale orange to white, unconsolidated fine to medium quartz sand in a carbonate mud matrix, with scattered shell fragments and carbonate sand, and scattered quartz granules to small pebbles. The largest pebbles occur near the base of the formation at 236 ft.

The Tamiami Formation occurs from 126.5 to 6.8 ft, and is divided here into two members: the Ochopee Limestone Member and the Pinecrest Member. The Ochopee Limestone Member of the Tamiami Formation occurs from 126.5 to 46.5 ft, and is an unconsolidated light gray to light olive gray to pale yellowish brown carbonate and fine quartz sand in a carbonate mud matrix. It is fossiliferous throughout with fragments and whole specimens of oysters, pectens, and echinoids; some steinkerns are from articulated specimens, and their surfaces are dark gray. There are clay-rich beds within the Ochopee Limestone Member that may serve as a local confining unit from 96 to 80 ft, and from 70 to 67.4 ft.

The Pinecrest Member of the Tamiami Formation occurs from 46.5 to 10.5 ft, and is a pale yellowish brown to pale orange, unconsolidated fine to medium, poorly sorted quartz sand and carbonate mud with scattered aragonitic shells. No core was recovered from 10.5 to 6.8 ft.

The Ft. Thompson(?) Formation and Miami Limestone occur at the top of the core from 6.8 to 0 ft., where a mottled, pale reddish brown to pale yellowish orange to light olive gray, very well indurated sandy wackestone forms the "caprock" at this site.

Biostratigraphy.--Nine samples were examined for dinocysts (appendix 3, table 4). The three lowest samples (450, 441, 431 ft) contain dinocyst assemblages of late middle or late but not latest Miocene age, based on the presence of *E. delectabile* (late middle and late Miocene) and stratigraphic position below the highest *Labyrinthodinium truncatum* Piasecki subsp. *truncatum*. The presence of species of

Impagidinium Stover & Evitt in the lower two samples suggests an environment of deposition that is more offshore than that suggested by higher samples. The three lowest samples are probably older than any of the material in the 1996 Collier County cores, because they contain *Labyrinthodinium truncatum* and *Sumatradinium soucouyantiae* (both of these species have their highest occurrences in the late Miocene, but not far into it).

Three samples from 361 to 239 ft contain assemblages of late middle or late Miocene age. The lowest occurrence of *Achomosphaera andalousiensis* Jan du Chêne at 311 ft may approximate the middle/late Miocene boundary, or may be younger due to environmental limitations. The sample at 188 ft could be late Miocene or Pliocene and the sample at 119 ft contains only a single fragment. The highest sample, at 67 ft, is Miocene, Pliocene, or Pleistocene (based on the presence of *Operculodinium* ? *eirikianum* Head et al.).

Strontium-isotope stratigraphy.--Thirteen samples were analyzed for strontium isotopes (table 5). The lowest sample from 443.0 ft gives a calculated age of 9.3 Ma ± 0.5 m.y. (late Miocene). Three higher samples from 414.5 to 324.2 ft are also late Miocene (calculated ages of 8.7 to 7.5 Ma ± 1.5 m.y.) The nine higher samples (232.0 to 11.1 ft) all have calculated ages from 4.9 to 4.0 Ma (early Pliocene, but with a margin of error that includes both latest late Miocene and late Pliocene).

Age summary.--The Arcadia (?) Formation in the Trail Center core (465-432.6 ft) is late Miocene. Dinocysts indicate a late middle or late, but not latest, Miocene age; strontium-isotope stratigraphy yields a calculated age of 9.3 Ma ± 0.5 m.y. The Peace River Formation (432.6-237.3 ft) in the Trail Center core is also late Miocene. Dinocysts indicate a late middle or late Miocene age and strontium-isotope stratigraphy yields calculated ages of 8.7 to 7.5 Ma ± 1.5 m.y. The unnamed formation (237.3-126.5 ft) yields nondiagnostic dinocysts and early Pliocene calculated isotopic ages (4.9-4.6 Ma ± 1.5 m.y.). Similarly, both the Ochopee Limestone (126.5-46.5 ft) and the Pinecrest (46.5-10.5 ft) Members of the Tamiami Formation yield nondiagnostic dinocysts and early Pliocene calculated ages (4.9-4.5 Ma ± 1.5 m.y.). The Fort Thompson (?) (6.8-0 ft.) was not dated.

Dade-Collier Airport Core

The Dade-Collier Airport core (fig. 1) was completed beside a borrow pit in the NW corner of the Dade-Collier Transition and Training Airport on February 1, 1997, to a depth of 200 feet. The site is located at 25°51'51.996"N. and 80°55'03.686"W. (SW 1/4, SW1/4, Sec. 10, T. 53 W., R. 34 E.) and is on the Fifty Mile Bend 1:24,000 USGS topographic map. The elevation of the site is approximately 10 ft. One corehole (fig. 5a, b, c) and two monitor wells were drilled at this site; the original corehole was filled with cement to the surface.

Lithostratigraphy.--The Peace River Formation occurs in this core from the base of the core to 116 ft. It varies from an olive gray to yellowish gray to pale yellowish brown, unconsolidated fine to medium quartz sand interbedded in places with a calcareous mud and clayey silt. There is a laminated carbonate and clay mud from 168 to 161.5 ft. There is a coarse zone of quartz and phosphate pebbles near 170 ft, chalky shells with some aragonite preserved occur from 143 to 142 ft, and from 125 to 116 ft ,where they are deposited with scattered very coarse quartz grains, near the top of the formation.

The unnamed formation occurs from 116 to 93.2 ft, and is a very pale orange, fine quartz sand with scattered coarse quartz sand and pebbles with rare skeletal grains.

The Ochopee Limestone Member of the Tamiami Formation occurs from 93.2 to 3.3 ft and is light gray to very pale orange to moderate yellowish brown to white, unconsolidated to moderately well indurated calcareous sandstone to sandy packstone. Skeletal grains include aragonitic and calcitic mollusks, bryozoans, and barnacles. Overlying the sandstone is an unconsolidated, to slightly lithified and moldic, carbonate sand with scattered mollusk molds and chalky shell fragments in a carbonate mud matrix, with minor quartz sand. A well lithified sandy wackestone with a light olive calcite cement on void surfaces occurs from 20 to 7.5 ft, and is overlain by a very well indurated, mottled vuggy sandy wackestone, the “caprock.”

Biostratigraphy.--Eight samples were examined for dinocysts (appendix 3, table 4). The two lowest samples (199, 153 ft) contain dinocyst assemblages of latest middle or late Miocene age, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary) and *E. delectabile* (late middle and late Miocene). Three higher samples (120, 89, and 78 ft) contain relatively nondiagnostic dinocysts of Miocene, Pliocene, or Pleistocene age. The three highest samples (66, 31, and 20 ft) did not yield dinocysts.

Strontium-isotope stratigraphy. --Nine samples (including three duplicate pairs) were analyzed for strontium isotopes (table 5). All samples, from 119.5 to 27.5 ft have calculated ages of 5.1 to 4.0 Ma ± 0.5 to 1.5 m.y. (early Pliocene, but with a margin of error that includes both latest late Miocene and late Pliocene).

Age summary.--The Peace River Formation (200-116 ft) in the Dade-Collier Airport core is late Miocene; dinocysts yield an age of latest middle or late Miocene whereas strontium-isotope stratigraphy yields a calculated age of early Pliocene with a margin of error that includes both late Miocene and late Pliocene. The unnamed formation (116-93.2 ft) in this core was not sampled for either dinocysts or strontium-isotope analysis. The Ochopee Limestone Member of the Tamiami Formation (93.2-3.3 ft) yielded nondiagnostic or no dinocysts and strontium-isotope calculated ages in the early Pliocene, again with a margin of error that includes both latest late Miocene and late Pliocene.

FAA Radar Core

The FAA Radar corehole (fig. 6a, b, c) was drilled on a gravel road off Tamiami Trail about 5.5 miles to the east of the Oasis Visitor’s Center of the Big Cypress National Preserve. The site (fig. 1) is 0.6 miles north of Tamiami Trail. The corehole was completed to a depth of 205 ft on February 7, 1997. The location of the site is 25°51’45.500”N. and 81°00’38.177”W. (NW1/4, NE1/4, Sec. 14, T. 53 S., R. 33 E.) and is on the Monroe Station 1:24,000 USGS topographic map. Several monitor wells have been drilled by the South Florida Water Management District for an aquifer test at this site (appendix 2).

Lithostratigraphy.--The Peace River Formation occurs in this core from the base up to 95.7 ft. The formation ranges in color from grayish olive to light olive gray to dusky yellow to yellowish gray to moderate olive brown and is primarily an unconsolidated, laminated to bioturbated clayey silt and sand, with very coarse to pebble grains of quartz and phosphate that occur near the base from 200 to 182 ft and from 132 to 120 ft. Shell hash is uncommon and occurs from 198 to 173 ft and from 105 to 98 ft.

The unnamed formation occurs from 95.7 to 52.8 ft, and is a yellowish gray to yellowish white, medium to scattered coarse quartz sand and pebbles with calcite mud matrix and scattered skeletal debris; quartz sand decreases upward. The upper part is a partially lithified carbonate and quartz sand.

The Ochopee Limestone Member of the Tamiami Formation occurs from 52.8 to 5.0 ft, and ranges from an unconsolidated carbonate skeletal and quartz sand in a calcareous mud, to a well lithified moldic molluscan packstone to partially lithified packstone. Skeletal grains include pectens, oysters, and other pelecypods, and echinoids. The upper four feet of the formation, from 9 to 5 ft., is light orange to yellowish gray and very well indurated.

Biostratigraphy.--Six samples were examined for dinocysts (appendix 3, table 4). The four lowest samples (204, 158, 96, 91 ft) contain dinocyst assemblages of latest middle or late Miocene age, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary) and *E. delectabile* (late middle and late Miocene) or *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa* (latest occurrence in the late Miocene). One higher sample (61 ft) contains relatively nondiagnostic dinocysts of Miocene or Pliocene age, including a new species of *Ataxiodinium* Reid. The highest sample (35 ft) did not yield dinocysts.

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 Peace River Formation (205-95.7 ft) in the FAA Radar core contains dinocyst assemblages of latest middle or late Miocene age. The unnamed formation (95.7-52.8 ft) in this core contains latest middle or late Miocene dinocysts at 91 ft and yielded nondiagnostic dinocysts at 61 ft. The Ochopee Limestone Member of the Tamiami Formation (52.8-5.0 ft) yielded no dinocysts at 35 ft .

Monroe Station Core

The Monroe Station corehole (fig. 7a, b, c) was drilled near the western intersection of the Loop Road and Tamiami Trail, at a gated parking facility for preserve and private swamp buggies managed by the Big Cypress National Preserve. The corehole was drilled in the back yard of a white wooden frame two-story building and completed to a depth of 200 feet on February 14, 1997. The location (fig. 1) is 25°51’45.087”N. and 81°06’00.927”W (NW1/4, NW1/4, Sec. 14, T. 53 S., R. 32 E.) and is on the Monroe Station 1:24,000 USGS topographic map at an elevation of about 10 ft. The corehole was filled with concrete and another monitor well was drilled to 52 ft, and screened from 45 to 25 ft.

Lithostratigraphy.--The Peace River Formation occurs from the base of the core to 105 ft, and is an unconsolidated, laminated to bioturbated, yellowish gray to olive gray to dusky yellow, clayey quartz silt and sand with rare scattered skeletal grains, and very coarse quartz sand to pebbles from 196 to 190 ft and from 127 to 117 ft.

The unnamed formation occurs from 105 to 60 ft (no recovery 60-55 ft), and is a yellowish gray to light olive gray to very pale orange, fine quartz sand with scattered coarse grains and chalky shells. Calcite mud is a small component near the base; calcite content as sand and mud increase upward. There is partial lithification of the formation and moldic cementation from 72 to 69 ft.

The Tamiami Formation (Ochopee Limestone Member) occurs from 55 to 2 ft in this core. The formation is poorly recovered in this core and ranges from a white unconsolidated carbonate sand in a calcite mud matrix to a partially lithified molluscan and echinoid packstone with drusy yellowish gray calcite cement from 40 to 22 ft. Mollusks include oysters, pectens, and quartz sand is a minor matrix component from 55 to 43 ft. The formation is a mottled yellowish brown to yellowish gray, sandy molluscan packstone and very well indurated from 6 to 2 ft.

Biostratigraphy.--Six samples were examined for dinocysts (appendix 3, table 4). The two lowest samples (183 and 179 ft) contain dinocyst assemblages of latest middle or late Miocene age, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary) and *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa* (latest occurrence in the late Miocene). The sample at 142 ft is late Miocene, based on the presence of *Geonettia clineae* de Verteuil & Norris (reported range is late Miocene only). The samples at 114 and 102 are late Miocene or Pliocene based on the presence of *Invertocysta lacrymosa* Edwards (latest occurrence of *I. lacrymosa* is in the early Pliocene, questionable occurrences higher). The highest sample (35 ft) yielded only a few nondiagnostic specimens.

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 Peace River Formation (200-105 ft) in the Monroe Station core contains dinocyst assemblages of latest middle and late Miocene, late Miocene, and late Miocene or Pliocene age. The unnamed formation (105-60 ft) in this core contains late Miocene or Pliocene dinocysts. The Ochopee Limestone Member of the Tamiami Formation (55-2 ft) yielded only a few, nondiagnostic dinocysts at 35 ft.

West Loop Road Core

The West Loop Road corehole (fig. 8a, b, c) was drilled on an abandoned residential lot at the end of a narrow gravel driveway off of the Loop Road about 7.5 miles from the intersection with Tamiami Trail at Monroe

Station. The corehole was completed on February 25, 1997 to a depth of 250 feet. The location (fig. 1) is 25°45'39.788"N. and 81°03'34.384"W., and is on the Monroe Station 1:24,000 USGS topographic map at an elevation of about 6 ft. The hole was filled with concrete after geophysical logging; no monitor well installation is planned.

Lithostratigraphy.--The Peace River Formation occurs from the base of the core to 187 ft. The formation is primarily light olive gray to yellowish gray, unconsolidated, laminated and bioturbated, interbedded quartz sand, silt, and clay. The formation becomes calcareous with chalky shells near the top from 195.1 to 190.1 ft.

The unnamed formation occurs from 187.0 to 60 ft, and is a yellowish gray to light olive gray, unconsolidated, fine to medium quartz sand in a carbonate mud matrix, with scattered intervals of coarse sand and granules of quartz and phosphate, especially at the base, and scattered hard calcareous concretions from about 95 to 60 ft. There are very few macrofossils.

The Ochopee Limestone Member of the Tamiami Formation occurs from 60 to 3 ft, and ranges from a white, partially lithified moldic molluscan skeletal sand with drusy yellowish gray calcite cement to a slightly lithified carbonate skeletal sand in a carbonate mud matrix. The upper four feet from 7 to 3 ft, is a very well lithified, sandy, white to grayish orange moldic molluscan packstone with bryozoans.

Biostratigraphy.--Five samples were examined for dinocysts (appendix 3, table 4). The lowest sample (241 ft) is late middle or late Miocene, based on the presence of *E. delectabile*. The next higher sample (201 ft) is late in the late Miocene, based on the overlap of *E. delectabile* (late middle and late Miocene) and *S. armageddonensis* (earliest occurrence in the late late Miocene). Two higher samples (162 and 72 ft) contain relatively nondiagnostic dinocysts of Miocene, Pliocene, or Pleistocene age. The highest sample (33 ft) did not yield dinocysts.

Strontium-isotope stratigraphy.--Nine samples were analyzed for strontium isotopes (table 5). The two lowest samples from 192.7 and 161.8 ft give calculated ages of 6.5 Ma ± 1.0 m.y. and 6.3 Ma ± 0.5 m.y., respectively (late Miocene). The next higher sample at 130.9 is probably latest Miocene (calculated age 5.5 Ma ± 0.5 m.y.). Samples from 120.7 to 10-12 ft have calculated ages of 4.9 to 3.9 Ma ± 1.5 m.y. (early Pliocene, but with a margin of error that includes both latest late Miocene and late Pliocene).

Age summary.--The Peace River Formation (250-187 ft) in the West Loop Road core is late Miocene; dinocysts yield an age of latest middle or late Miocene and latest late Miocene whereas strontium-isotope stratigraphy yields a calculated age of late Miocene (6.5 Ma ± 1.0 m.y.). The unnamed formation (187-60 ft) in this core is probably both late Miocene and early Pliocene. It contains relatively nondiagnostic dinocysts and yields calculated ages of 6.3 to 4.9 Ma ± 1.5 to 0.5 m.y. The Ochopee Limestone Member of the Tamiami Formation (60-3 ft) did not yield dinocysts but yields strontium-isotope calculated ages in the early Pliocene, with a margin of error that includes both latest late Miocene and late Pliocene.

Doerr's Lake Core

The Doerr's Lake corehole (fig. 9a, b, c) was completed on March 4, 1997 on private property near the Burn's Lake campground (fig. 1) to a depth of 200 feet, was filled with concrete to about 45 ft, and was completed by the owner as a private water supply well after geophysical logging. The location is 25°53'51.075"N. and 81°13'27.947"W. (NE1/4, SW1/4, Sec. 33, T. 52 S., R. 31 E.) and is on the Burn's Lake 1:24,000 USGS topographic map at and elevation of about 6 ft.

Lithostratigraphy.--No Peace River Formation was observed in this core. The unnamed formation extends from the base of the core to 40 ft, and is primarily an unconsolidated, fine to medium quartz sand that is relatively unfossiliferous with clay beds and laminae in the lower part from 200 to 120.5 ft, and shelly, calcareous, and burrowed from 120.5 to 40 ft with well-preserved aragonitic mollusks from 120.5 to 95 ft. Coarse sand to quartz granules commonly occur from 120.5 to 75 ft and are more scattered from 75 to 40 ft.

The Tamiami Formation (Ochopee Limestone Member) occurs from 40.0 to 3 ft, and ranges from a white skeletal carbonate sand in a calcite mud matrix, to a white partially lithified molluscan wackestone, to a very well indurated, light orange sandy wackestone.

Biostratigraphy.--Four samples were examined for dinocysts (appendix 3, table 4). The lowest sample (182 ft) is Miocene, but the assemblage is not very diagnostic. The next higher sample (106 ft) contains a dinocyst assemblage of latest middle or late Miocene age, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary) and *E. delectabile* (late middle and late Miocene) or *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa* (latest occurrence in the late Miocene). One higher sample (77 ft) contains relatively nondiagnostic dinocysts of possible Miocene age. The highest sample (31 ft) did not yield dinocysts.

Strontium-isotope stratigraphy.--Eight samples were analyzed for strontium isotopes (table 5). The four lowest samples from 118.0 to 96.0 ft give calculated ages of 6.9 to 6.3 Ma ± 1.0 to 0.5 m.y. (late Miocene). The four highest samples from 56.7 to 0-20 ft have calculated ages of 5.2 to 4.1 Ma ± 1.5 to 0.5 m.y. (early Pliocene, but with a margin of error that includes both latest late Miocene and late Pliocene).

Age summary.--The unnamed formation (200-40 ft) in the Doerr's Lake core is late Miocene and possibly early Pliocene. It contains a dinocyst assemblage of latest middle or late Miocene age at 106 ft and yields calculated ages of late Miocene (6.9 to 6.3 Ma ± 1.0 to 0.5 m.y.) up to 96 ft. Above 57 ft, it may be Pliocene (calculated age 5.2-5.0 Ma ± 1.5 m.y.) The Tamiami Formation (40-3 ft) yields strontium-isotope calculated ages in the early Pliocene (4.6-4.2 Ma ± 1.5 m.y.), with a margin of error that includes both latest late Miocene and late Pliocene, and did not yield dinocysts.

Raccoon Point Core

The Raccoon Point corehole (fig. 10a, b, c) was completed on March 9, 1997 at pad #1 of the Calumet Oil Company, on 11-Mile Road, off Tamiami Trail, 1.6 miles west of the entrance to Dade-Collier Transition and Training Airport (fig. 1), to a depth of 185 feet. The corehole was filled with concrete after geophysical logging. The location is 25°58'55.673"N. and 80°55'33.494"W. (SE1/4, SE1/4, Sec. 33, T. 51 S., R. 34 E.) and is on the North of 50 Mile Bend 1:24,000 USGS topographic map at an elevation of about 10 feet.

Lithostratigraphy.--The Peace River Formation occurs from 185 to 147.5 ft in this core, and ranges from a yellowish gray to olive gray calcareous fine sand and silt with interbeds of calcareous mudstone and claystone. Large diatoms and foraminifers are common on bedding planes from 185 to 152.6 ft.

The unnamed formation occurs from 147.5 to 123.6 ft, and ranges from a light olive gray calcareous very fine quartz sand with scattered skeletal grains to a pinkish to yellowish gray medium quartz sand in a carbonate mud matrix; coarse quartz and phosphate grains occur near 134 ft. The interval from 147.5 to 135.5 ft is transitional between the lower Peace River Formation and the unnamed formation.

The Tamiami Formation occurs from 123.6 to 2.5 ft and ranges from a pinkish gray, partially lithified sandy molluscan wackestone to a light gray muddy carbonate sand to a yellowish gray, carbonate mud. Fossils observed include mollusks, foraminifers, bryozoans, and echinoids. The interval from 40 to 9 ft is very poorly recovered but appears to be carbonate and quartz sand and carbonate mud with an upward decrease in quartz sand. The interval from 9 to 2.5 ft is a light orange, very well indurated mottled moldic calcareous sandstone to very sandy limestone.

Biostratigraphy.--Six samples were examined for dinocysts (appendix 3, table 4). The lowest sample (165 ft) is late in the late Miocene, based on the overlap of *E. delectabile* (late middle and late Miocene) and *S. armageddonensis* (earliest occurrence in the late late Miocene), and closely resembles the sample at 201 ft in the West Loop Road core. Two higher samples (147 and 129 ft) contain relatively nondiagnostic dinocysts that must be either late Miocene or Pliocene based on stratigraphic position. The next higher sample (122 ft) did not yield dinocysts. The highest sample (42 ft) is no younger than Pliocene, based the presence of *D. pseudocolligerum* (highest occurrence in the Pliocene).

Strontium-isotope stratigraphy.--Eight samples (including one duplicate pair) were analyzed for strontium isotopes (table 5). The lowest sample from 181.1 has a calculated age of 5.6 Ma ± 0.5 m.y. (late Miocene). Higher samples from 123.8 to 20.2 ft have calculated ages of 4.8 to 4.0 Ma ± 1.5 m.y. (early Pliocene, but with a margin of error that includes both latest late Miocene and late Pliocene).

Age summary.--The Peace River Formation (185-147.5 ft) in the Raccoon Point core is late in the late Miocene as evidenced by both dinocysts and strontium-isotope stratigraphy (5.6 Ma ± 0.5 m.y.). The unnamed formation (147.5-123.6 ft) in this core is probably early Pliocene. It contains relatively nondiagnostic dinocysts and yields calculated ages of 4.8 Ma ± 1.5 m.y. The Tamiami Formation (123.5-2.5 ft) yields strontium-isotope calculated ages in the early Pliocene, with a margin of error that includes both latest late Miocene and late Pliocene, and dinocysts no younger than Pliocene.

Nobles Road Core

The Nobles Road corehole site is at an abandoned drilling pad at the end of a dirt road just north of I-75 near a newly completed rest area. The corehole (fig. 11a, b, c) was completed on March 16, 1997 to 200 ft, and was filled in with concrete. A monitor well was drilled nearby for hydrologic testing. The location (fig. 1) is 26°10’12.427”N. and 81°04’18.195”W. (NE1/4, SW1/4, Sec. 31, T. 49 S., R. 33 E.) on the Whidden Lake 1:24,000 USGS topographic map at an elevation of about 10 ft.

Lithostratigraphy.--The Peace River Formation occurs from the base of the core to 170 ft, and ranges from an olive gray to a light olive gray poorly sorted clayey bioturbated silty to coarse sand to a muddy, diatom-rich, burrowed clay.

The unnamed formation occurs from 170 to 148.5 ft, and is a light olive gray muddy fine sand with scattered coarse quartz and phosphatic grains, with an upward increase in carbonate mud in the matrix.

The Tamiami Formation occurs from 148.5 to 10 ft, and includes the Ochopee Limestone Member from 148.5 to 84.7 ft, a sand and clay facies from 84.7 to 36.3 ft, and the Ochopee Limestone Member from 36.3 to 10 ft. The lower Ochopee Limestone Member is a white to yellowish gray skeletal carbonate mud with poorly sorted quartz sand to granules and is partially lithified and moldic near the base. This unit contains echinoids, barnacles, and mollusks.

The sand and silt facies of the Tamiami Formation extends from 84.7 to 36.3 ft and is a slightly calcareous, olive to light olive gray fine sand and silt with scattered thin clay beds, especially from 70 to 65 ft.

The upper Ochopee Limestone Member of the Tamiami Formation occurs from 36.3 to 10 ft and is a white molluscan carbonate mud with minor quartz sand, and a medium gray lithified zone at 28 ft. Aragonitic mollusks occur from 36.3 to 35 ft. The interval from 10 to 8.5 ft was not recovered.

There is a limestone from 8.5 to 1.3 that ranges from very pale orange to light orange to white moldic skeletal mudstone to a very well indurated, laminar sandy limestone with void-lining cements. A thin layer of dark brown mud within the well indurated portion of the core may be cavity fill. This unit may be a freshwater deposit.

Biostratigraphy.--Six samples were examined for dinocysts (appendix 3, table 4). The two lowest samples (187 and 177 ft) contain dinocyst assemblages of latest middle or late Miocene age, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary) and *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa* (latest occurrence in the late Miocene). Higher samples at 156 and 83 ft contain relatively nondiagnostic dinocysts. The sample at 67 ft contains the late late Miocene species *Selenopemphix armageddonensis*. The sample at 41 ft is not diagnostic.

Strontium-isotope stratigraphy.--Seven samples were analyzed for strontium isotopes (table 5). The six lowest samples from 162.0 to 20-25 ft give calculated ages of 5.2 to 3.7 Ma ± 1.5 to 0.5 m.y. (early Pliocene, but with a margin of error that includes both latest late Miocene and, for all but the two lowest samples, late Pliocene). The highest sample from 15.3 ft has a calculated age of 2.9 Ma ± 1.0 m.y. (late Pliocene).

Age summary.--The Peace River Formation (200-170 ft) in the Nobles Road core contains dinocyst assemblages of latest middle or late Miocene age. The unnamed formation (170-148.5 ft) in this core is late Miocene or early Pliocene. It contains relatively nondiagnostic dinocysts and yields calculated ages of 5.2-5.0 Ma ± 1.5 m.y. The lower Ochopee Limestone Member of the Tamiami Formation (148.5-92.5 ft), by stratigraphic position, is late Miocene or Pliocene. It yields dinocysts that are no younger than Pliocene and a single strontium-isotope calculated age in the early Pliocene (4.7 Ma ± 1.5 m.y.), with a margin of error that includes both latest late Miocene and late Pliocene. The sand and silt facies of the Tamiami Formation (92.5-31.7 ft) is latest late Miocene and (or) early Pliocene. It contains the species *S. armageddonensis* at 67 ft and yields a calculated age of 4.2 Ma ± 1.5 m.y. at 36 ft. The strontium-isotope ages suggest that *S. armageddonensis* may actually range into the Pliocene. The upper Ochopee Limestone Member of the Tamiami at 15.3 ft is late Pliocene (calculated age of 2.9 Ma ± 1.0 m.y.). The limestone from 8.5 to 1.3 ft was not dated.

Bass Core

The Bass corehole (fig. 12 a, b, c) was completed on March 25, 1997 to a depth of 200 feet at an abandoned oil well drilling pad on a gravel road about 2.2 miles east of Turner River Road (fig. 1). The location is on the Burns Lake 1:24,000 USGS topographic map at 25°58'31.840"N. and 81°14'30.873"W. (NE1/4, NW1/4, Sec. 5, T. 52 S., R. 31 E.) at an elevation of about 8 ft. The corehole was filled with concrete after geophysical logging.

Lithostratigraphy.--No Peace River Formation was observed in this core. The unnamed formation occurs in this core from the base to 61 ft, and ranges from yellowish gray to light olive gray to a very pale orange unconsolidated muddy fine sand to medium quartz sand with scattered coarse granules and pebbles. The formation is shelly from 171.7 to 148.8 ft and may be dolomitic from 85 to 75 ft.

The Ochopee Limestone Member of the Tamiami Formation extends from 61.0 to 9.5 ft, and varies from a very light gray sandy, slightly lithified and moldic molluscan packstone to an unconsolidated yellowish gray carbonate sand and mud with white mollusks and barnacles.

Above the Tamiami Formation are undifferentiated brown clayey fine quartz sand and a light greenish gray sandy clay.

Biostratigraphy.--Five samples were examined for dinocysts (appendix 3, table 4). The two lowest samples (185 and 166 ft) are late middle or late Miocene, based on the presence of *E. delectabile* and *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa* (latest occurrence in the late Miocene). One higher sample (150 ft) is probably Miocene, based on the questionable identification of *B. sphaerica*. The sample at 39 ft contains rare, nondiagnostic dinocysts. The highest sample (6 ft) did not yield dinocysts.

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 (200-61 ft) in the Bass core contains late middle or late Miocene dinocysts in its lower part (up to 150 ft). The Ochopee Limestone Member of the Tamiami Formation (61-9.5 ft) contains rare, nondiagnostic dinocysts. The undifferentiated, brown, clayey fine quartz sand and light greenish gray sandy clay above 9.5 ft are undated.

Stratigraphic Summary

Two transects (figs. 15-16) show the lithostratigraphic correlations, thickness variations, and formation depths across the study area.

The Arcadia (?) Formation was only

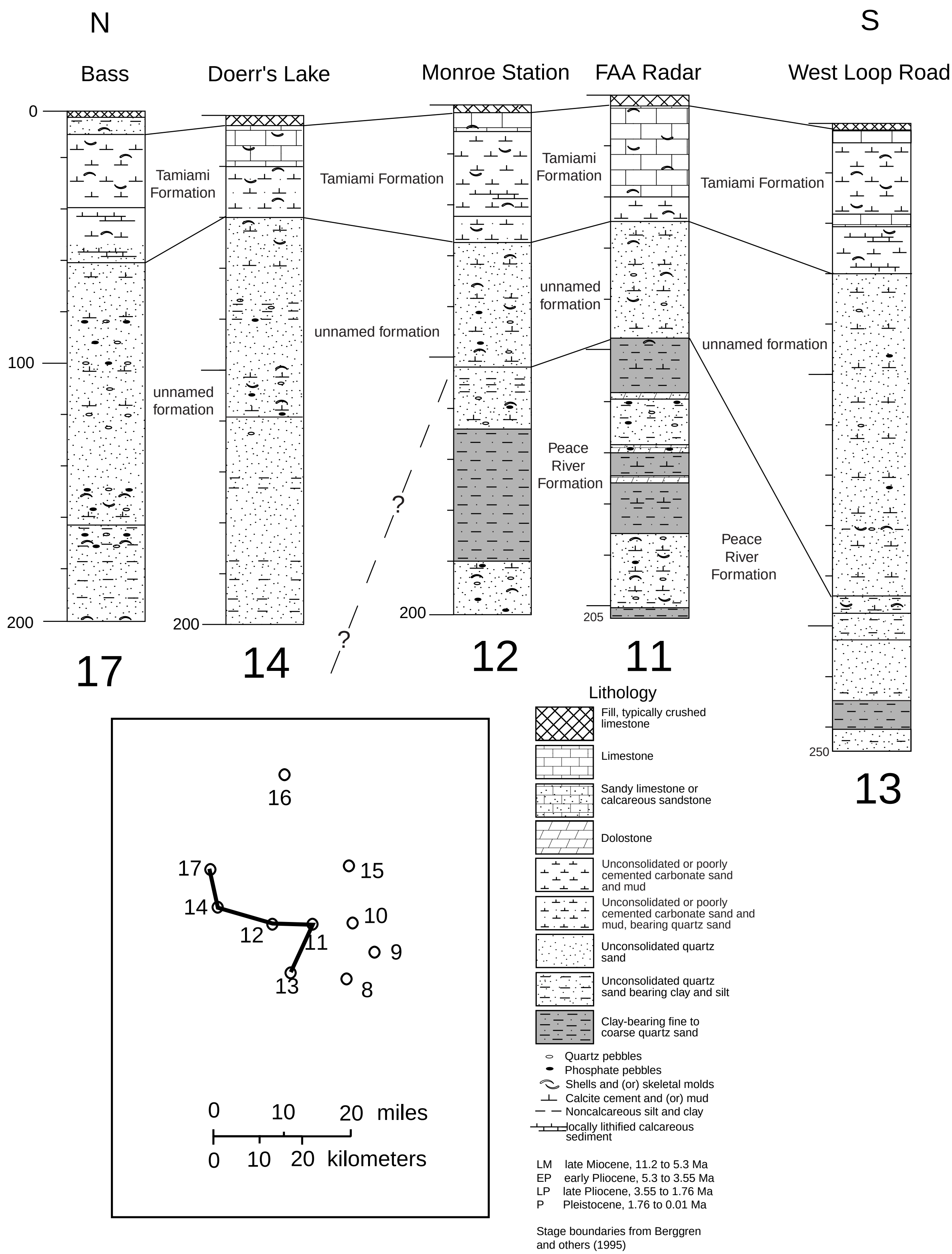

Figure 15. Northwest to south-central transect across the study area. Inset shows section locations.

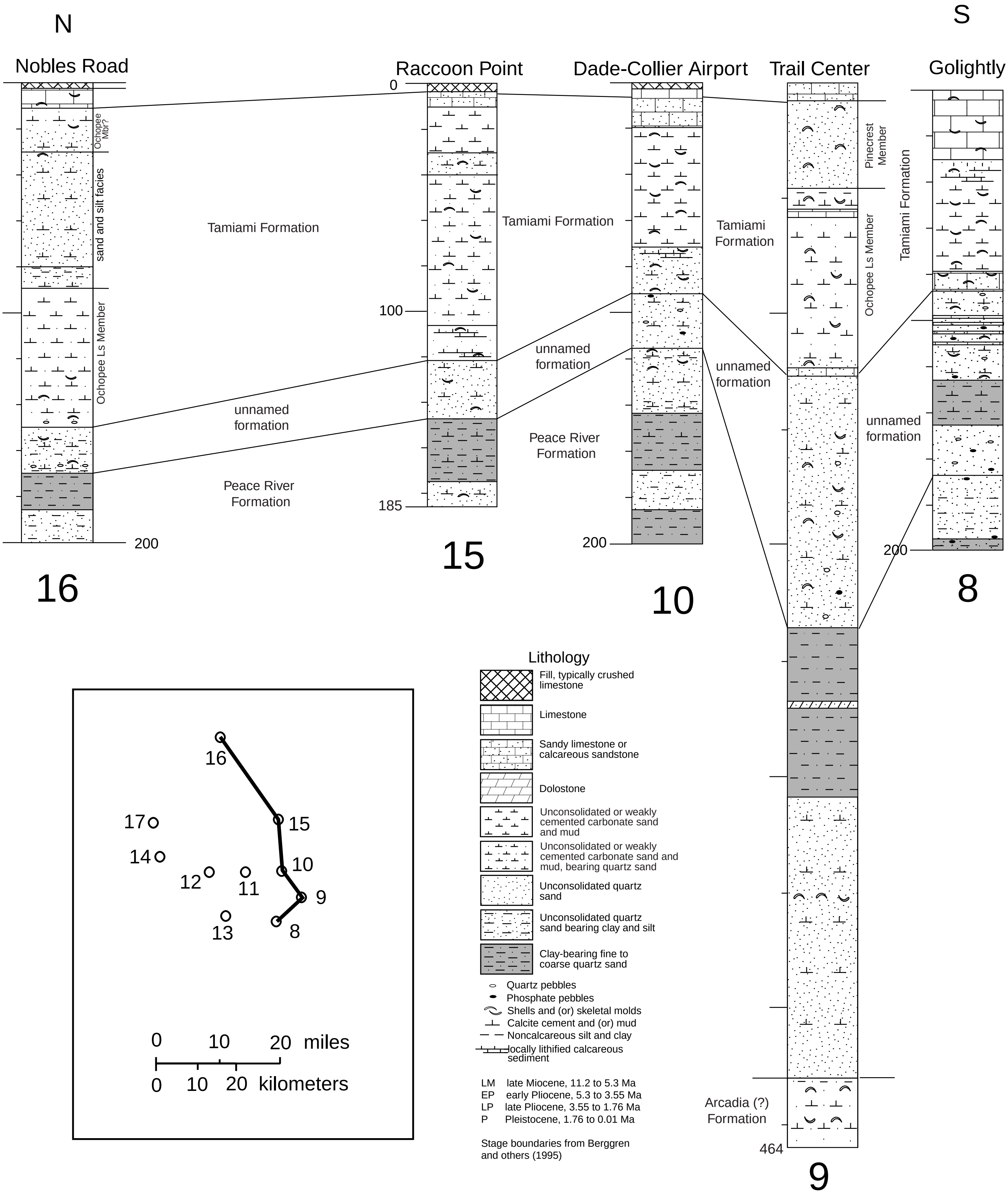

Figure 16. North to south transect across the study area. Inset shows section locations.

penetrated in the Trail Center Core where it is late Miocene in age. No sharp unconformity was observed between the Arcadia (?) and the overlying Peace River as has been reported from some cores in southwest Florida; however, the oyster rubble at top may represent a lag deposit. The sharp spike in the gamma-ray log that reflects the contact is a widespread geophysical marker for the top of the Arcadia (Cunningham, written commun., 1998). The depth to the top of the formation (432.6 ft) is compatible with that shown for northeastern Monroe County by Cunningham and others (1998) based on extensive study of well cuttings. The late Miocene age is younger than other reported ages for the Arcadia.

The Peace River Formation was penetrated in all but the two westernmost cores. It yields a late Miocene age, based on both dinocysts and strontium-isotope stratigraphy. The top of the Peace River is an irregular surface that varies nearly 150 ft over the study area and is nearest the surface in a trend following the Tamiami Trail in the central part of the study area (in the Dade-Collier Airport, FAA Radar, and Monroe Station cores). In two of these cores, the Peace River could be as young as early Pliocene. The nature of the Peace River and unnamed formations contact being at variable depth and the Peace River being younger where it is shallower suggests these two units are at least partially equivalent and the top of the Peace River and the bottom of the unnamed formation are lateral facies of each other.

The unnamed formation was recovered in every core. It is thinnest in the northernmost core (Nobles Road) and thickest to the west (Doerr's Lake core) where its maximum thickness was not penetrated. The unnamed formation typically contains nondiagnostic dinocyst assemblages, but in at least four cores it contains late Miocene dinocysts. Ages calculated from strontium isotopes range from 6.9 to 4.6 Ma (late Miocene to early Pliocene). The top of the unnamed formation is deepest to the north and it becomes shallower to the southwest. Its age in the northeast, where it is thin and deep, is late Miocene. In the southwest it probably contains the Miocene/Pliocene boundary and its upper part is early Pliocene.

The Tamiami Formation was also recovered in every core and is represented by the Ochopee Limestone Member in every core and the Pinecrest Member at Trail Center and a sand and clay facies at Nobles Road. The Tamiami consistently yields early Pliocene calculated ages (5.1 to 3.7 Ma, but with a relatively large margin of error) and dinocysts that indicate an age no younger than Pliocene. Two samples in the upper part of the Tamiami (Nobles Road core at 15 ft and Golightly core at 12.8 ft) yield younger calculated ages (2.9 to 2.8 Ma, late Pliocene). The Tamiami is thickest to the north and east and the age and lateral relations strongly suggest that the lower part of the Tamiami and the upper part of the unnamed formations are lateral facies of each other.

The Fort Thompson (?) Formation and Miami Limestone in the Trail Center core were not dated. Similarly, the undifferentiated, brown, clayey fine quartz sand and light greenish gray sandy clay above 9.5 ft in the Bass core and the limestone from 8.5 to 1.3 ft in the Nobles Road core are not dated.

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Appendix 1.
Lithologic Logs

8. Golightly Core

Depth (ft)	**Lithology**
--Tamiami Formation, Ochopee Limestone Member--	
0.0 - 4.0	**Packstone (Caprock)**, moldic, sandy, well indurated, mottled, pale orange to moderate yellowish brown.
4.0 - 13.0	**Packstone/wackestone**, molluscan, moldic, white to yellowish white, with drusy yellowish gray to dusky yellow calcite cement lining molds; echinoids, oysters, gastropods, and bryozoans.
13.0 - 16.0	**Limestone**, poorly recovered granules.
16.0 - 30.0	**Packstone**, molluscan, moldic, well indurated, white to yellowish gray, with minor quartz sand; oysters, void-lining calcite cement.
30.0 - 40.0	**Packstone**, molluscan, moldic, partially lithified, white to very light gray; bryozoans; some aragonitic shell; minor fine quartz sand.
40.0 - 78.8	**Carbonate sand**, unconsolidated sand and granules in a carbonate mud matrix, light gray to light olive gray; oysters, pectens, echinoids; scattered darker clayey zones; minor quartz sand.
78.8 - 86.8	**Wackestone to sandstone**, very sandy wackestone to calcareous sandstone, yellowish brown to light gray, with abundant *Turritella* and other mollusk molds, scattered coarse quartz sand; blackened mold surfaces; capped with bored and mottled oysters [to some authors this unit clearly belongs to the underlying unnamed formation and represents the cemented exposure surface at the top of that unit].
--unnamed formation--	
86.8 - 126.1	**Sand**, quartz, medium, calcareous, poorly sorted, light gray, with fine to coarse grains with four moldic calcite-cemented zones (approx. 92, 99, 104, and 109 ft); phosphate pebbles and granules from 103 to 126.1 ft.
126.1 - 145.0	**Mud**, carbonate mud, clay, and quartz silt, yellowish gray to dusky yellow, thickly laminated and bioturbated, no skeletal grains.
145.0 - 156.0	**Sand**, quartz, fine, yellowish gray, with scattered shell and coarse sand; bioturbated with silty sand interbeds; bedding poorly preserved, especially at the top.
156.0 - 159.0	**Sand**, quartz and phosphate, pinkish gray mollusks in a light olive gray clayey sand, granules, and pebbles, poorly sorted.
159.0 - 168.6	**Sand**, quartz, fine to medium, light olive gray to yellowish gray, scattered coarse quartz, shell, and phosphate grains.
--Peace River Formation--	
168.8 - 183.6	**Sand and mud**, interbedded fine quartz sand and light olive gray mud (clay/silt), bioturbated, disrupted bedding, less clay near the top, scattered chalky shell fragments, bedding is better defined below 183.6, and grains are better sorted.
183.6 - 196.1	**Sand**, quartz, fine, muddy, medium olive gray, bioturbated, scattered chalky skeletal grains, moderate to dark yellowish brown in the top 0.4 ft, burrowed and filled with olive gray, coarse granules at the base of unit.

196.1 - 199.8 **Sand and clay**, light olive gray, silty quartz sand with olive gray clay beds and wispy disrupted clay drapes, bioturbated, chalky skeletal grains.

199.8 - 200.0 **Sand and mud**, fine quartz sand and dolomitic(?) mud, light gray to yellowish gray, faint disrupted laminae.

9. Trail Center Core

Depth (ft)	Lithology
--Fort Thompson (?) Formation and Miami Limestone	
0.0 - 6.8	**Wackestone (Caprock)**, sandy, well indurated, mottled pale reddish brown to pale yellowish orange to grayish orange to light olive gray.
6.8 - 10.5	No recovery.
--Tamiami Formation, Pinecrest Member--	
10.5 - 25.0	**Sand**, quartz, fine to medium, skeletal grains, poorly sorted, pale orange; aragonitic shell.
25.0 - 46.5	**Sand**, quartz, fine to medium, skeletal grains, poorly sorted, pale yellowish brown; aragonitic shell.
--Tamiami Formation, Ochopee Limestone Member--	
46.5 - 57.3	**Carbonate sand**, muddy, light brownish gray, mollusk steinkerns and shell fragments, minor quartz sand; minor cementation in lower 1.3 ft becoming a white to yellowish gray molluscan muddy carbonate sand with minor quartz sand.
57.3 - 67.4	**Mud**, carbonate mud and clay/silt mud, pale yellowish brown, becoming sandy upwards, with articulated mollusk steinkerns.
67.4 - 70.0	Transition from carbonate sand below to mud above.
70.0 - 80.0	**Carbonate sand**, very light gray, with minor fine quartz sand and less clay than below; oysters, mollusk molds.
80.0 - 96.2	**Sand**, carbonate and fine quartz sand in a clay and carbonate mud matrix, light olive gray; scattered oyster shell and other shell granule fragments; darkened steinkern surfaces.
96.2 - 114.8	**Carbonate sand**, skeletal, light gray, with minor quartz sand; mollusks, echinoids, oysters, and pectens; differs from beds below by color and sand content.
114.8 - 117.2	**Sand**, carbonate and fine quartz sand, Yellowish gray, carbonate and fine quartz sand.
117.2 - 120.0	**Carbonate mud**, skeletal, sandy, very light gray.
120.0 - 125.0	**Sand**, carbonate and fine quartz sand, yellowish gray, with thin-walled mollusks.
125.0 - 126.5	**Packstone**, molluscan, sandy, moldic, white to yellowish gray to light gray; carbonate mud and medium to coarse quartz sand matrix; minor aragonitic shell fragments.
--unnamed formation--	
126.5 - 146.5	**Sand**, quartz, fine, calcareous, yellowish gray, with floating coarse quartz sand; similar to 152.0 to 158.9 ft; no recovery from 127 to 130 ft.
146.5 - 152.0	**Sand**, quartz, fine to medium, yellowish gray.
152.0 - 158.9	**Sand**, quartz, medium with some fine, very pale orange to white, with common coarse carbonate sand and shell fragments.

158.9 - 237.3 **Sand**, quartz, medium, poorly sorted, yellowish gray, with quartz and phosphate granules and pebbles in calcareous mud, with scattered chalky shell fragments and a few whole pectens; pebbles are largest at base of unit, and granule to small quartz pebbles scattered throughout; lightly better sorted and finer sand above 188 ft than below; medium sand scattered in fine sand around 168 ft, and fine to medium, calcareous quartz sand with rare scattered shell fragments near the top.

--Peace River Formation--

237.3 - 270.8 **Mud and sand**, interbedded olive gray laminated mud (clay/silt) and fine laminated sand and bioturbated sand; this interval differs from the one below (272.2 - 312.0 ft) by better preservation of laminae in sand, and absence of thick sand beds (greater than 1.4 ft); beds are typically a few inches; very poorly recovered interval from 255 to 265 ft.

270.8 - 272.2 **Sand**, dolomitic, fine, clayey, light olive gray, capped by thin hard siltstone.

272.2 - 312.0 **Clay and sand**, interbedded olive gray finely laminated, silty clay layers (less than 1.4 ft) with light olive gray, well sorted, fine to medium quart sand beds (0.3 to 1.3 ft), clay layers are disrupted at contacts with sand.

312.0 - 432.6 **Sand**, quartz, fine, silty, clayey, olive; bioturbated and burrowed with very faint lamination preserved locally; variably calcareous; 1-3% fine phosphate sand, clay-lined burrows; faintly laminated, well sorted, calcareous, fine sand bed, at 330.7 to 331.2 ft; molluscan shell hash at 354.6 ft.

--Arcadia(?) Formation--

432.6 - 435.0 **Shell rubble**, oyster, pale olive to dusky yellow, in a fine quartz sand and clay matrix.

435.0 - 447.1 **Sand**, carbonate and quartz sand in a carbonate and clay mud matrix, skeletal (oyster dominated), yellowish gray to dusky yellow, unconsolidated; mollusks, bryozoans.

447.1 - 455.5 **Clay**, silty, calcareous, bioturbated, moderate olive brown to olive brown, with white mollusk and bryozoan fragments; some bedding preserved.

455.5 - 463.9 **Sand and clay**, poorly sorted, unconsolidated, granular skeletal grains in a matrix of clay, carbonate mud, and fine and medium quartz sand, yellowish gray to light olive brown; clayey sand in the matrix at the base is gradational to sandy clay at the top; this facies is transitional to the overlying beds.

10. Dade-Collier Airport Core

Depth (ft)	**Lithology**
0.0 - 3.3	**Fill**, crushed limestone.
--Tamiami Formation, Ochopee Limestone Member--	
3.3 - 7.5	**Wackestone (Caprock)**, sandy, vuggy, very well indurated, mottled, moderate yellowish brown to white; oysters.
7.5 - 20.0	**Wackestone**, sandy, moldic, pale orange, with a light olive calcite cement.
20.0 - 35.0	**Carbonate sand**, very light gray, with common large shells (oysters and pectens), moldic where lithified into a packstone, in a carbonate mud matrix.
35.0 - 73.0	**Carbonate sand**, light gray, with scattered mollusk molds and rare chalky shell fragments, in a carbonate mud matrix.
73.0 - 75.0	**Carbonate sand**, medium light gray zone, with aragonitic shell.
75.0 - 93.2	**Sand**, quartz, fine to medium, moldic, calcareous, very pale orange, sand to moderately indurated sandstone with intervals of sandy packstone; mollusks, bryozoans, barnacles; lithification increases upward; *Turritella* zone from 77.0 to 79.8 ft.
--unnamed formation--	
93.2 - 116.0	**Sand**, quartz, fine, calcareous, very pale orange, with scattered very coarse sand and pebbles; rare skeletal grains.
--Peace River Formation--	
116.0 - 125.0	**Sand**, quartz, fine, muddy, calcareous, pale yellowish brown, with abundant chalky skeletal grains and scattered very coarse quartz sand; pectens at 120 ft; some aragonitic mollusks.
125.0 - 144.5	**Mud and sand**, interbedded carbonate mud and fine quartz sand with chalky shell fragments; 125.0 to 138.4 ft is a light olive gray, bioturbated muddy sand; 138.4 to 144.5 ft consists of silty clay (non-carbonate mud) laminae.
144.5 - 150.4	**Mud**, laminated, grayish olive clay and silt and light olive gray carbonate mud and clay.
150.4 - 161.5	**Clay and mud**, interbedded grayish olive clay laminae interbedded with thickly laminated light olive gray calcareous mud; minor bioturbated zones; large diatoms near 156 ft.
161.5 - 164.0	**Mud and clay**, carbonate mud and clay, non-laminated, yellowish gray.
164.0 - 168.0	**Clay**, laminated, slightly calcareous, grayish olive.
168.0 - 169.0	Transition from fine to medium quartz sand below to overlying clay.
169.0 - 184.5	**Sand**, quartz, fine to medium, burrowed, muddy, poorly sorted, light olive gray, with scattered coarse grains near the top; non-calcareous; faintly bedded.
184.5 - 188.0	**Sand**, quartz, medium, yellowish gray, better sorted than below.
188.0 - 191.5	**Clay and sand**, clay and medium (fine to very coarse) quartz sand, bioturbated, olive gray.

191.5 - 200.0 **Mud and sand**, interbedded olive gray mud (clay and silt) and pinkish gray slightly calcareous fine quartz sand; bedding is thickly laminated, and slightly disrupted.

11. FAA Radar Core

Depth (ft)	Lithology
0.0 - 5.0	**Fill**, crushed limestone and sand.
--Tamiami Formation, Ochopee Limestone Member--	
5.0 - 9.0	**Packstone to wackestone (Caprock)**, light orange to yellowish gray, with mollusks and scattered fine quartz sand.
9.0 - 15.5	**Packstone/wackestone**, moderately well cemented, with pectens, oysters, and clams (variously ground up by the drill bit).
15.5 - 25.0	**Packstone/wackestone**, molluscan, poorly cemented, with pectens, oysters, and clams.
25.0 - 32.5	**Packstone**, moderately well lithified, with echinoids, mollusk molds, and void-filling cements.
32.5 - 40.0	**Limestone and carbonate sand**, poorly lithified; where lithified a packstone; pectens and other mollusks, and echinoids.
40.0 - 48.9	**Carbonate sand**, skeletal, granular, white, poorly recovered, in carbonate mud; mollusks and echinoids.
48.9 - 52.8	**Carbonate sand**, fine, granular, yellowish white, few mollusks, no cemented chunks as below.
--unnamed formation--	
52.8 - 62.8	**Sand**, carbonate and quartz, granular, yellowish white, molluscan molds, partially lithified, some original chalky shell; mollusks and echinoids.
62.8 - 95.7	**Sand**, medium to scattered coarse and pebble, yellowish gray; carbonate mud content increases upward, no clay; scattered skeletal debris; decreasing quartz sand content upward.
--Peace River Formation--	
95.7 - 98.0	**Clay and sand**, olive gray clay and interbedded fine sand and clay; bioturbated.
98.0 - 105.4	**Sand and clay**, laminated fine quartz sand and silty clay; chalky shells form wispy laminae.
105.4 - 117.4	**Clay and silt**, interlaminated as wispy to regular lamination, some bioturbation, yellowish gray to light olive to moderate olive brown .
117.4 - 119.2	**Mudstone**, dolomitic, yellowish gray.
119.2 - 128.5	**Sand**, quartz, coarse, poorly sorted, light olive gray, with phosphate pebbles and olive green clay blebs.
128.5 - 130.0	**Sand**, quartz, fine, poorly sorted, dusky olive, with scattered coarse grains; bioturbated with clay-filled burrows; coarse phosphate grains.
130.0 - 132.7	**Sand and pebbles**, fine to coarse quartz sand, poorly sorted, light olive gray; 8 mm phosphate pebbles.
132.1 - 137.5	**Sand**, quartz, fine with scattered coarse grains, poorly sorted, dusky olive; bioturbated with clay-filled burrows; coarse phosphate grains.

137.5 - 149.6	**Sand and clay**, regular fine sand and clay laminae, thickly laminated, dusky yellow to moderate olive brown; bioturbated from 145.0 to 145.9 ft, regular thick and wispy laminae, less disrupted from 145.9 to 149.6 ft, bioturbated and dolomitic (yellowish gray) at the top and phosphatic; horizontal cracking near the top.
149.6 - 160.0	**Silt and clay**, irregularly thickly laminated, dusky yellow to moderate olive brown, capped at 149.6 ft with dolomite; diatoms at 153.4 ft.
160.0 - 173.0	**Sand**, quartz, fine, bioturbated, clayey, dusky yellow and moderate brown; clay-filled burrows near the top; dusky olive green near the base.
173.0 - 174.1	**Sand and shells**, coarse quartz sand; poorly sorted, dusky yellow.
174.1 - 178.3	**Sand**, quartz, fine to medium with scattered coarse grains, dusky yellow and olive green, mottled; chalky shell fragments, scattered clay blebs; calcareous.
178.3 - 193.9	**Sand**, quartz and carbonate sand, coarse, poorly sorted, with clay blebs, light gray; oysters, barnacles, and shell fragments; discoidal quartz pebbles <16 mm; highly bioturbated.
193.9 - 198.0	**Sand**, quartz and carbonate sand, coarse, poorly sorted, shell fragments, mud matrix.
198.0 - 201.4	**Sand**, quartz, fine, light olive gray; heavily burrowed; rare coarse quartz, clay rip-up clasts.
201.4 - 205.0	**Sand and clay**, grayish olive, burrowed silty fine quartz sand and grayish olive green clay.

12. Monroe Station Core

Depth (ft)	Lithology
0.0 - 2.0	**Fill**, crushed limestone and sand.
--Tamiami Formation, Ochopee Limestone Member--	
2.0 - 6.0	**Packstone (Caprock)**, molluscan, well indurated, poorly recovered, mottled yellowish brown to yellowish gray, with fine quartz sand in the matrix.
6.0 - 8.0	**Sand**, quartz, medium brown.
8.0 - 55.0	**Carbonate sand**, unconsolidated, poorly recovered, white, in a carbonate mud matrix, lithified in places to a molluscan packstone with a yellowish gray, drusy cement from 22.5 to 40.0 ft; oysters, pectens, and echinoids; quartz sand in the matrix from about 43.0 to 55.0 ft.
--unnamed formation--	
55.0 - 60.0	No recovery.
60.0 - 103.0	**Sand**, medium carbonate and fine to medium quartz, very pale orange, in a carbonate mud matrix, with scattered coarse grains; chalky shells at 68 ft; cement lining and filling molds from 69.0 to 72.0 ft; shell debris at 86.0 ft.
103.0 - 105.0	No recovery.
--Peace River Formation--	
105.0 - 128.8	**Sand**, quartz, fine, yellowish gray to light olive gray, with rare coarse quartz grains; poorly sorted dusky yellowish brown fine micaceous quartz sand from 110 to 115 ft.; light olive gray fine bioturbated sand with scattered coarse quartz from 115.0 to 128.8 ft; slightly calcareous near the base with small clay component.
128.8 - 136.0	**Sand, clay, and mud**, quartz sand, fine, interbedded with clay and mud (clay/silt), light olive gray; clay at the top.
136.0 - 150.0	**Clay and silt**, olive gray clay and light olive gray silt laminae, poorly laminated; more clay rich from 136 to 146 ft, and more silty from 146 to 150 ft.
150.0 - 157.0	**Sand**, quartz, fine, non-calcareous, bioturbated, olive gray to dusky yellow, in a clay matrix.
157.0 - 177.0	**Sand**, quartz, fine, olive gray to dusky yellow, with variable clay content from 157 to 165 ft; dark yellowish brown fine sand from 165.0 to 170 ft; olive gray to dark yellowish brown clayey fine quartz sand and silt with clay laminae and clay-filled burrows from 170.0 to 177.0 ft; bioturbated from 160.0 to 177.0 ft.
177.0 - 180.5	**Silt to sand**, dolomite?, fine sand grains, light olive gray to yellowish gray, with scattered coarse quartz sand.
180.5 - 185.4	**Sand**, quartz, fine to coarse, bioturbated, clayey, olive gray; burrows from 182 to 182.4 ft; olive gray clay and fine to coarse quartz sand and quartz and phosphate granules and skeletal grains; very poorly sorted from 183.0 to 185.4 ft.

185.4 - 200.0	**Sand**, quartz, and skeletal (carbonate) sand, yellowish gray, medium quartz grains from 185.4 to 190 ft, and coarse quartz and skeletal sand from 190.0 to 193.2 ft; olive gray clay laminae at 193.2 ft; yellowish gray medium to coarse quartz and phosphate grains with scattered granules to bottom.

13. West Loop Road Core

Depth (ft)	Lithology
0.0 - 3.0	**Fill**, crushed limestone.
--Tamiami Formation, Ochopee Limestone Member--	
3.0 - 7.0	**Packstone (Caprock)**, moldic, molluscan, very well lithified, white to grayish orange, with bryozoans, scattered quartz sand and very sandy at the top.
7.0 - 17.0	**Carbonate sand**, yellowish gray to white, very poorly recovered, in a carbonate mud matrix.
17.0 - 36.0	**Carbonate sand**, skeletal, slightly lithified, white, in a carbonate mud matrix; mollusks.
36.0 - 60.0	**Carbonate sand**, skeletal, molluscan, moldic, partially lithified, white, with drusy yellowish gray calcite cement in voids from 36 to 41 ft.
--unnamed formation--	
60.0 - 160.0	**Sand**, quartz, fine to medium, calcareous, yellowish gray, in a carbonate mud matrix; poorly sorted; coarse at the base with intervals of coarse sand and granules of quartz and phosphate with a background of fine to medium quartz sand and no apparent structures or megafossils; scattered lithified concretions or cemented large burrows.
160.0 - 162.5	**Sand**, quartz, fine to pebble sized grains, clayey, shelly, light olive gray, with very pale orange shell fragments.
162.5 - 185.0	**Sand**, quartz, fine, very light gray to yellowish gray, with scattered olive gray clay disrupted laminae and rip-up clasts and clay-filled burrows; with intervals of medium to fine quartz sand near the base and scattered coarse sand and granule quartz grains.
185.0-187.0	No recovery.
--Peace River Formation--	
187 .0 - 190.1	**Sand**, quartz, medium to fine, light olive gray, with scattered coarse grains; slightly calcareous, clay-filled burrows, disrupted clay laminae.
190.1 - 195.1	**Sand**, quartz, fine to pebble sized grains, poorly sorted, calcareous, shelly and clayey, light olive gray; shells are chalky.
195.1 - 205.0	**Sand and clay**, yellowish gray quartz sand and olive clay, laminated near base, bioturbated and large clay-lined burrows; clay diminishes upward and sand coarsens slightly; well sorted.
205.0 - 229.3	**Sand**, quartz, fine to medium, light olive brown to olive gray, bioturbated and burrowed; faintly laminated from 208.2 to 209.6 ft.
229.3 - 241.5	**Clay and sand**, olive gray clay, with fine stringers of silt; interbedded with yellowish gray, poorly sorted medium quartz sand with fine to coarse grains; some sandy zones have clay blebs where bioturbated.
241.5 - 241.9	Transition from clayey sand below to interlaminated clay and fine sand.
241.9 - 245.0	**Sand**, quartz, fine, light olive gray to olive gray, bioturbated with clay-filled burrows.

245.0 - 245.2 **Clay**, olive gray.

245.2 - 249.2 **Sand**, quartz, fine, light olive gray to olive gray, bioturbated with clay-filled burrows.

249.2 - 250.0 **Sand**, quartz, fine, micaceous, light olive gray, well sorted, with minor clay blebs.

14. Doerr's Lake Core

Depth (ft)	Lithology
0.0 - 3.0	**Fill**, crushed limestone.
--Tamiami Formation, Ochopee Limestone Member--	
3.0 - 10.0	**Limestone (Caprock)**, sandy, well indurated, light orange to 7.0 ft; yellowish gray to 10.0 ft. (Note: this box fell and the determination of caprock depth was based on photographs taken soon after coring.)
10.0 - 40.0	**Wackestone and skeletal carbonate mudstone**, skeletal, partially lithified, white; drusy calcite cement at approx. 29.3 ft in a sandy interval; pectens and other mollusks.
--unnamed formation--	
40.0 - 51.7	**Sand**, quartz, fine, yellowish gray, with a few scattered coarse sand grains in a carbonate mud matrix; chalky shells.
51.7 - 59.0	**Carbonate mud**, shelly, sandy, white to very light gray; shells are chalky.
59.0 - 60.0	No recovery.
60.0 - 75.0	**Sand**, quartz, medium, faintly burrowed, bioturbated, faintly bedded, dark yellowish brown (60.0 - 62.2 ft) to dark yellowish brown (62.2 - 64.5 ft) and dark yellowish brown (64.5 - 75.0 ft).
75.0 - 81.5	**Sand**, quartz, fine to granule, poorly sorted, olive gray; coarser grains near the base; scattered clay blebs (burrow fill?); non-calcareous.
81.5 - 85.0	**Sand**, quartz and phosphate, fine to granule, very poorly sorted, yellowish gay to light olive gray, burrowed and filled with material from above.
85.0 - 90.0	No recovery.
90.0 - 95.0	**Sand**, quartz, fine, non-calcareous, no shells, with scattered coarse quartz sand; micaceous.
95.0 - 102.0	**Sand**, quartz, yellowish gray, transition from calcareous sand below to clean sand above, fines upward; razor clam zone; micaceous; minor carbonate mud matrix.
102.0 - 120.5	**Sand**, quartz, fine to granule, poorly sorted, in a clay and carbonate mud matrix, light olive gray, very shelly with aragonitic fragments (mother of pearl), and scattered phosphate and quartz pebbles.
120.5 - 200.0	**Sand**, quartz, fine, clean, yellowish gray, with scattered medium to coarse grains; noncalcareous, becoming slightly calcareous near the top; olive gray clay beds are concentrated in bands and laminae generally below 141 ft.

15. Raccoon Point Core

Depth (ft)	Lithology
0 - 2.5	No recovery, probably fill.
--Tamiami Formation, Ochopee Limestone Member--	
2.5 - 9.0	**Limestone and sandstone (Caprock)**, from 2.5 to 4.5 ft moldic, calcareous sandstone to very sandy limestone, mottled, well indurated, light orange; from 4.5 to 9.0 ft very sandy limestone to calcareous sandstone, light olive gray.
9.0 - 14.0	**Carbonate sand and mud**, very poorly recovered carbonate sand and mud; may have fallen in from above.
14.0 - 20.0	No recovery.
20.0 - 24.0	**Carbonate sand and mud**, no quartz.
24.0 - 30.0	No recovery.
30.0 - 40.0	**Carbonate sand**, very poorly recovered, muddy carbonate and quartz sand.
40.0 - 50.4	**Carbonate mud**, yellowish gray, with small amount of quartz and phosphate fine sand and silt; scattered chalky skeletal grains; foraminifers; few coarse quartz sand grains that may have fallen in from above.
50.4 - 107.3	**Carbonate sand**, muddy, very light gray to light gray, with poorly sorted medium to coarse quartz sand; mollusks, bryozoans, echinoids, foraminifers, pectens (90 - 94.2 ft); locally cemented where shell-rich; dark gray "nodules" near the top from 50.4 to 52.3 ft.
107.3 - 123.6	**Wackestone**, molluscan, sandy, partially lithified, pinkish gray, with scattered medium quartz grains in a carbonate mud; pectens; fine calcareous sand from 115.2 to 118.5 ft.
--unnamed formation--	
123.6 - 134.6	**Sand**, quartz, medium, calcareous, pinkish gray to yellowish gray, with scattered coarse quartz sand (near base), and a carbonate mud matrix.
135.5 - 147.5	**Sand**, quartz, very fine, calcareous, well sorted, light olive gray; scattered sparse skeletal grains.
--Peace River Formation--	
147.5 - 152.6	**Clay and sand**, calcareous clay interbedded with fine quartz sand, olive gray.
152.6 - 159.6	**Clay**, calcareous, olive gray; foraminifers common.
159.6 - 175.0	**Clay**, sandy (fine sand), calcareous, yellowish gray; common foraminifers and diatoms, locally on bedding planes.
175.0 - 178.4	**Sand**, quartz, fine, calcareous, muddy, yellowish gray; scattered chalky skeletal grains.
178.4 - 179.7	**Clay**, silty, light olive gray.
179.7 - 185.0	**Sand**, quartz, fine, calcareous, light olive gray to olive gray, with chalky mollusks (pectens), bioturbated but faintly bedded near the top, slightly clayey; diatoms and foraminifers.

16. Nobles Road Core

Depth (ft)	Lithology
0 - 1.3	**Fill**, crushed limestone.
1.3 - 4.5	**Limestone (Caprock)**, sandy, laminar, very well indurated and dense, white to light orange, with chalky shells and molds; void-lining cements; thin layer of dark brown mud that may be cavity fill.
4.5 - 8.5	**Carbonate mudstone**, skeletal, moldic, very pale orange, with about 10% quartz sand; no void lining cements below 4.5 ft.
8.5 - 10.0	No recovery.

--Tamiami Formation, Ochopee Limestone Member (?)--

10.0 - 36.3	**Carbonate mud**, skeletal, white, with minor quartz sand and medium gray lithified zone at 28 ft, with *Turritellas* and other mollusks; original mollusk shell below 35 ft; 10 to 20 ft is very poorly recovered.

--Tamiami Formation, sand and silt facies

36.3 - 80.6	**Sand**, quartz, fine, light olive gray, well sorted, slightly calcareous, small clay component (especially from 65 to 70 ft).
80.6 - 81.7	**Sand and silt**, fine quartz sand, light olive gray, small amount of clay.
81.7 - 84.7	**Mudstone**, olive gray; shrinkage with drying; fine sand burrows.

--Tamiami Formation, Ochopee Limestone Member--

84.7 - 148.5	**Carbonate mud**, skeletal, white to yellowish gray, with poorly sorted quartz sand to granules; partially lithified and moldic near the base; where lithified, a packstone; more muddy from 114 to 129 ft, echinoids, barnacles, mollusks (pelecypods and gastropods); 84.7 to 92.5 is light olive gray with increased clay content and fewer shells; 92.5 to 100 ft is light gray; 130 to 138 ft is medium gray.

--unnamed formation--

148.5 - 164.0	**Sand**, quartz, silty, very fine, light olive gray, with scattered coarse phosphatic and quartz grains in a calcite mud matrix; skeletal sand (carbonate); white micritized shell (chalky mollusks).
164.0 - 170.0	**Sand**, quartz, very fine, muddy, light olive gray, with scattered coarse and granule quartz and phosphate; common sand-sized skeletal (carbonate) debris.

--Peace River Formation--

170.0 - 173.6	**Clay**, olive gray, with very fine sand-filled burrows.
173.6 - 179.0	**Clay**, olive gray; nearly 25% shrinkage with drying; diatoms common from 179.0 to 180.0 ft.
179.0 - 186.5	**Clay**, muddy, light olive gray; approx. 15% shrinkage with drying; diatoms abundant from 179.0 to 186.5 ft.
186.5 - 200.0	**Mud and sand**, clayey quartz silt (mud) to coarse quartz sand, poorly sorted, light olive gray; bioturbated rare scattered disrupted laminae near the top.

17. Bass Core

Depth (ft)	**Lithology**
--undifferentiated--	
0.0 - 5.0	**Fill**, crushed limestone and sand.
5.0 - 7.0	**Clay**, light greenish gray with fine quartz sand and skeletal grains, calcite nodules.
7.0 - 9.5	**Sand**, quartz, clayey fine, dark yellowish brown, with skeletal sand; thin limestone bed at the base with brown clay in voids..
--Tamiami Formation, Ochopee Limestone Member--	
9.5 - 38.5	**Carbonate sand and granules**, very poorly preserved, white to yellowish gray, in a carbonate mud matrix; mollusks and barnacles; upward increase in carbonate mud.
38.5 - 45.0	**Packstone**, slightly lithified, moldic, very light gray, and carbonate sand in a carbonate mud.
50.0 - 53.0	**Carbonate sand and mud**, yellowish gray, and white mollusks.
53.0 - 61.0	**Packstone**, sandy, very light gray, slightly lithified; medium quartz sand.
--unnamed formation--	
61.0 - 85.0	**Sand**, quartz, medium to coarse, skeletal, calcareous, very poorly sorted, very pale orange; primarily medium from 61 to 75.0 ft; barnacles; may be dolomitic from 75.0 to 85.0 ft.
85.0 - 87.6	**Sand**, quartz and phosphatic, fine to coarse, poorly sorted, pale yellowish brown, with scattered granules.
87.6 - 103.3	**Sand**, quartz and phosphatic, fine to coarse, poorly sorted, upward coarsening, very pale orange, with scattered granules; 20 mm quartz pebble at the top; micaceous at base.
103.3 - 110.0	**Sand**, quartz and phosphatic, fine to granule, poorly sorted, very pale orange to yellowish gray; slightly calcareous.
110.0 - 128.5	**Sand**, bimodal (fine sand "matrix" with coarse to very coarse floating quartz grains), slightly calcareous, yellowish gray; very fine quartz with coarse grains from 123.5 - 128.5 ft.
128.5 - 148.8	**Sand**, quartz, micaceous, very fine, yellowish gray, with scattered coarse grains; no shells or carbonate mud; rare clay beds; bioturbated.
148.8 - 154.1	**Sand**, quartz, medium, poorly sorted, yellowish gray, with granules to pebbles of quartz and phosphate; shelly.
154.1 - 160.5	**Sand**, quartz, fine, yellowish gray to light olive gray (burrow fill), with scattered chalky shells and coarse to granule quartz; bioturbated with clay-lined burrows.
160.5 - 163.7	**Sand and mud**, quartz sand and carbonate mud, medium to coarse sand, poorly sorted, white to yellowish gray; clay-filled burrows at top.
163.7 - 167.5	**Sand**, quartz, fine, muddy, light olive gray, scattered chalky shells at 166.2 ft and near the top; bioturbated.

167.5 - 171.3	**Sand**, quartz, fine, muddy, white to light olive gray, muddy, with scattered coarse and granule quartz and phosphate grains, especially at the top.
171.3 - 173.7	**Sand**, quartz, transition from a fine sand below to a shelly, muddy, light olive gray fine sand above with coarse to granule quartz and chalky mollusks.
173.7 - 200.0	**Sand**, quartz, non-calcareous, fine, muddy, yellowish gray; burrowed and bioturbated; few scattered mollusk molds from 195.7 to 200.0 ft; small amount of calcite mud from 188.0 to 195.7 ft; may be dolomitic from 185.0 to 187.0 ft; bioturbation decreases upward from 173.7 to 186.0 ft.

Appendix 2.

Geophysical data

8. Golightly Core

Summary of Geophysical Logs and Corehole Conditions during Logging

Log Identification	Log	Tool and Configuration	Date Log Run	Interval Logged	Comments
Cored continuously to 200 ft, screened well developed by flushing					
8a	GAMMA	Multi-func	2/12/97	0-164	
Additional flushing to remove debris, filled tank with water					
8b	INDUCTION		2/13/97	0-191	
8c	GAMMA	Multi-func	2/13/97	0-198	
8d	HP FLWMTR	Small diam, bare	2/13/97	0-150	static + inject at 5 gpm
8e	TEMPERATURE	Multi-func	2/13/97	0-176	during injection with water temp=80°

Flowmeter Profile Interpretation

DEPTH TOP	INTERVAL BOTTOM	AMBIENT FLOW	INJECTION FLOW	DIFF	PERCENT
0	10	0	-0.7	0.7	14
10	20	0	-0.7	0.7	14
20	30	0	-0.7	0.7	14
30	40	0	-0.7	0.7	14
40	50	0	-0.7	0.7	14
50	60	0	-0.7	0.7	14
60	70	0	-0.7	0.7	14
70	80	0	-0.7	0.7	14
80	90	0	0	0	0
90	100	0	0	0	0
100	110	0	0	0	0
110	120	0	0	0	0
120	130	0	0	0	0
130	140	0	0	0	0
140	150	0	0	0	0
150	160	0	0	0	0
160	170	0	0	0	0
170	180	0	0	0	0
180	190	0	0	0	0
190	200	0	0	0	0
TOTAL:				4.9	98

9. Trail Center Core

Summary of Geophysical Logs and Corehole Conditions during Logging

Log Identification	Log	Tool and Configuration	Date Log Run	Interval Logged	Comments
Cored continuously to 200 ft, screened well developed by flushing					
9a	GAMMA	Multi-func	2/15/97	0-197	
9b	INDUCTION		2/15/97	0-195	
9c	HP FLWMTR	Small diam, bare	2/15/97	0-180	static and inject at 5 gpm
9d	FLUID R		2/15/97	0-190	during injection with 22 ohm-m water
Coring continued in same hole down to 464 ft; hole left mudded up and open except for 28 ft surface PVC casing					
9e	GAMMA	Multi-func	4/3/97	0-460	depth error due to sticking measuring wheel
9f	INDUCTION		4/3/97	0-460	
9g	CALIPER	3-arm	4/3/97	0-460	24-ft depth error due to sticking measuring wheel
9h	NEUTRON	Dual detector with centralizer	4/3/97	0-460	
150-ft-deep monitoring well at 40 Mile Bend logged for stratigraphic comparison; 6-in. PVC casing to 101 ft and open hole to 150 ft					
9i	GAMMA	Multi-func	4/3/97	0-150	
9j	INDUCTION		4/3/97	0-150	
120-ft production well drilled using 12-in. bit; 6-in. casing to 120 ft installed with screen from 90-115 ft					
9k	FLUID R	Multi-func	3/2/98	0-115	
9l	SINGLE PT	Multi-func	3/2/98	0-115	shows casing
9m	INDUCTION		3/2/98	0-115	
9n	HP FLWMTR	Small diam, diverter	3/2/98	0-115	static and pump at 0.75 gpm
120-ft observation well drilled about 80 ft west of production well; 2-in. PVC installed with screen from 95-120 ft (TC-1)					
9o	INDUCTION		3/2/98	0-118	
9p	HP FLWMTR	Small diam, bare	3/2/98	0-118	static and pump at 1.1 gpm
130-ft observation well drilled about 80 ft north of production well and next to lake; 2-in. PVC installed with screen from 93-118 (TC-2)					
9q	INDUCTION		3/5/98	0-115	
9r	HP FLWMTR	Small diam, bare	3/5/98	0-115	static and pump at 1 gpm

Flowmeter Profile Interpretation

DEPTH TOP	INTERVAL BOTTOM	AMBIENT FLOW	INJECTION FLOW	DIFF	PERCENT
0	10	0	0	0	0
10	20	0	0	0	0
20	30	-0.15	-0.3	0.15	3.5
30	40	-0.15	-0.3	0.15	3.5
40	50	-0.15	-0.3	0.15	3.5
50	60	0	0	0	0
60	70	0	0	0	0
70	80	0	0	0	0
80	90	0	0	0	0
90	100	0	0	0	0
100	110	-1.5	-5.0	3.5	82
110	120	0	0	0	0
120	130	0	0	0	0
130	140	+1.5	+1.3	0.2	5
140	150	0	0	0	0
150	160	0	0	0	0
160	170	+0.5	+0.4	0.1	2
170	180	0	0	0	0
180	190	0	0	0	0
190	200	0	0	0	0
TOTAL:				4.25	99.5

10. Dade-Collier Airport Core

Summary of Geophysical Logs and Corehole Conditions during Logging

Log Identification	Log	Tool and Configuration	Date Log Run	Interval Logged	Comments
Cored continuously to 200 ft, screened well developed by flushing					
10a	FLUID R	Multi-func	2.15/97	0-200	log down
10b	GAMMA	Multi-func	2/15/97	0-200	
10c	INDUCTION		2/15/97	0-198	tool fails about 50 ft
10d	INDUCTION		2/15/97	0-50	repeat to 50 ft
10e	HP FLWMTR	Small diam, bare	2/15/97	0-190	static + inject at 5 gpm
10f	FLUID R	Multi-func	2/15/97	0-150	log up during injection with 29 ohm-m water

Flowmeter Profile Interpretation

DEPTH TOP	INTERVAL BOTTOM	AMBIENT FLOW	INJECTION FLOW	DIFF	PERCENT
0	10	0	0	0	0
10	20	-0.1	-1.5	1.4	27
20	30	-0.1	-1.5	1.4	27
30	40	-0.1	-1.5	1.4	27
40	50	-0.1	-0.25	0.15	3
50	60	-0.1	-0.25	0.15	3
60	70	-0.1	-0.25	0.15	3
70	80	0	0	0	0
80	90	0	0	0	0
90	100	0	0	0	0
100	110	0	0	0	0
110	120	0	0	0	0
120	130	0	0	0	0
130	140	0	0	0	0
140	150	0	0	0	0
150	160	0	0	0	0
160	170	0	0	0	0
170	180	+0.3	0	.3	5
180	190	+0.3	0	.3	5
190	200	0	0	0	0
TOTAL:				5.25	100

11. FAA Radar Core

Summary of Geophysical Logs and Corehole Conditions during Logging

Log Identification	Log	Tool and Configuration	Date Log Run	Interval Logged	Comments
Cored continuously to 205 ft, screened well developed by flushing					
11a	GAMMA	Multi-func	2/16/97	0-176	
11b	INDUCTION		2/16/97	0-174	
11c	HP FLWMTR	Small diam, bare	2/16/97	0-170	static + inject at 3 gpm
11d	FLUID R	Multi-func	2/16/97	0-156	log down during injection with 21 ohm-m water
11e	NEUTRON	Dual detector	3/9/97	0-175	
11f	HP FLWMTR	Small diam, bare	3/9/97	0-175	static only; also test large diam tool, bare
11g	TVA/EM FLOWMETER	No packer	3/11/97	0-175	static + inject at 4 gpm
Attempt to further develop well with air surging					
11h	FLUID R	Multi-func	4/3/97	0-164	no change from earlier logs
11i	HP FLWMTR	Small diam, bare	4/3/97	0-150	ambient flow only; no change from earlier logs
Production well drilled 50-ft using 12-in. bit; 8-in. PVC casing installed and screened from 10-50 ft					
11k	FLUID R	Multi-func	3/5/98	0-50	
11l	GAMMA	Multi-func	3/5/98	0-50	
11m	FLUID R	Multi-func	3/5/98	0-50	
11n	GAMMA	Multi-func	3/5/98	0-50	
11o	INDUCTION		3/5/98	0-50	
11p	HP FLWMTR	Small diam, 6-in. diverter	3/5/98	0-50	static and pump at 2.5 gpm
11q	FLUID R	Multi-func	3/5/98	0-50	during pumping at 2.5 gpm

Flowmeter Profile Interpretation

DEPTH TOP	INTERVAL BOTTOM	AMBIENT FLOW	INJECTION FLOW	DIFF	PERCENT
0	10	-0.2	-0.5	0.3	9
10	20	-0.3	-1.0	0.7	21
20	30	-0.2	-1.7	1.7	52
30	40	-0.2	-0.5	0.3	9
40	50	0	0	0	0
50	60	0	0	0	0
60	70	0	0	0	0
70	80	0	0	0	0
80	90	0	0	0	0
90	100	0	0	0	0
100	110	0	0	0	0
110	120	0	0	0	0
120	130	+0.6	40.4	0.2	6
130	140	0	0	0	0
140	150	0	0	0	0
150	160	0	0	0	0
160	170	0	0	0	0
170	180	+0.4	40.3	0.1	3
180	190	0	0	0	0
190	200	0	0	0	0
TOTAL:				3.3	100

12. Monroe Station Core

Summary of Geophysical Logs and Corehole Conditions during Logging

Log Identification	Log	Tool and Configuration	Date Log Run	Interval Logged	Comments
Cored continuously to 200 ft, screened well developed by flushing					
12a	GAMMA	Multi-func	2/16/97	0-185	
12b	INDUCTION		2/16/97	0-185	
12c	HP FLWMTR	Small diam, bare	2/16/97	0-175	static + inject at 5 gpm
12d	FLUID R	Multi-func	2/16/97	0-180	

Flowmeter Profile Interpretation

DEPTH TOP	INTERVAL BOTTOM	AMBIENT FLOW	INJECTION FLOW	DIFF	PERCENT
0	10	0	-1.1	1.1	22
10	20	-0.2	-1.1	0.9	18
20	30	-0.2	-1.1	0.9	18
30	40	-0.2	-1.1	0.9	18
40	50	-0.2	-1.1	0.9	18
50	60	-0.05	-0.1	0.05	1
60	70	-0.05	-0.1	0.05	1
70	80	0	0	0	0
80	90	0	0	0	0
90	100	0	0	0	0
100	110	0	0	0	0
110	120	0	0	0	0
120	130	0	0	0	0
130	140	0	0	0	0
140	150	0	0	0	0
150	160	0	0	0	0
160	170	0	0	0	0
170	180	0	0	0	0
180	190	0.9	0.7	0.2	4
190	200	0	0	0	0
TOTAL:				5.0	100

13. West Loop Road Core

Summary of Geophysical Logs and Corehole Conditions during Logging

Log Identification	Log	Tool and Configuration	Date Log Run	Interval Logged	Comments
Cored continuously to 250 ft, screened well developed by flushing					
14a	GAMMA	Multi-func	3/9/97	0-190	
14b	INDUCTION		3/9/97	0-190	
14c	NEUTRON	Dual detector	3/10/97	0-190	
14d	HP FLWMTR	Small diam, bare	3/10/97	0-190	static only

No Flowmeter Profile Interpretation

14. Doerr's Lake Core

Summary of Geophysical Logs and Corehole Conditions during Logging

Log Identification	Log	Tool and Configuration	Date Log Run	Interval Logged	Comments
Cored continuously to 200 ft, screened well developed by flushing					
13a	GAMMA	Multi-func	3/9/97	0-160	
13b	INDUCTION		3/9/97	0-160	
13c	NEUTRON	Dual detector	3/9/97	0-160	
13d	HP FLWMTR	Small diam, bare	3/9/97	0-160	static + inject at 5 gpm
13e	FLUID R	Multi-func	3/9/97	0-160	

Flowmeter Profile Interpretation

DEPTH TOP	INTERVAL BOTTOM	AMBIENT FLOW	INJECTION FLOW	DIFF	PERCENT
0	10	0	-1.2	1.2	29
10	20	0	-1.2	1.2	29
20	30	0	-1.2	1.2	29
30	40	0	-0.3	0.3	7
40	50	0	-0.3	0.3	7
50	60	0	0	0	0
60	70	0	0	0	0
70	80	0	0	0	0
80	90	0	0	0	0
90	100	0	0	0	0
100	110	0	0	0	0
110	120	0	0	0	0
120	130	0	0	0	0
130	140	0	0	0	0
140	150	0	0	0	0
150	160	0	0	0	0
160	170	0	0	0	0
170	180	0	0	0	0
180	190	0	0	0	0
190	200	0	0	0	0
TOTAL:				4.2	101

15. Raccoon Point Core

Summary of Geophysical Logs and Corehole Conditions during Logging

Log Identification	Log	Tool and Configuration	Date Log Run	Interval Logged	Comments
Cored continuously to 185 ft, screened well developed by flushing					
15a	GAMMA	Multi-func	3/10/97	0-182	
15b	INDUCTION		3/10/97	0-182	
15c	NEUTRON	Dual detector	3/10/97	0-182	
15d	HP FLWMTR	Small diam, bare	3/10/97	0-180	static + inject with water from adjacent supply well
15e	GAMMA	Multi-func	3/10/97	0-100	adjacent water supply well

No Flowmeter Profile Interpretation

16. Nobles Road Core

Summary of Geophysical Logs and Corehole Conditions during Logging

Log Identification	Log	Tool and Configuration	Date Log Run	Interval Logged	Comments
Cored continuously to 200 ft, screened well developed by flushing					
16a	GAMMA	Multi-func	2/4/97	0-130	
16b	INDUCTION		4/4/97	0-130	
16c	HP FLWMTR	Small diam, bare	4/4/97	0-120	static + inject at 4 gpm
16d	NEUTRON	Dual detector	4/4/97	0-125	
16e	FLUID R	Multi-func	4/4/97	0-130	during injection with 27 ohm-m ditch water
16f	FLUID R	Multi-func	4/4/97	0-130	stop 6 min after injection stops
16g	FLUID R	Multi-func	4/4/97	0-130	start 17 min after injection stops

Flowmeter Profile Interpretation

DEPTH TOP	INTERVAL BOTTOM	AMBIENT FLOW	INJECTION FLOW	DIFF	PERCENT
0	10	0	0	0	0
10	20	0	0	0	0
20	30	-0.75	-1.0	0.25	6
30	40	-0.75	-1.0	0.25	6
40	50	0	0	0	0
50	60	0	0	0	0
60	70	0	0	0	0
70	80	0	0	0	0
80	90	0	0	0	0
90	100	0	0	0	0
100	110	0	0	0	0
110	120	0	0	0	0
120	130	0.75	-1.0	1.75	44
130	140	0.75	-1.0	1.75	44
TOTAL:				4.0	100

17. Bass Core

Summary of Geophysical Logs and Corehole Conditions during Logging

Log Identification	Log	Tool and Configuration	Date Log Run	Interval Logged	Comments
Cored continuously to 200 ft, screened well developed by flushing					
17a	GAMMA	Multi-func	4/2/97	0-190	
17b	INDUCTION		4/2/97	0-190	
17c	NEUTRON	Dual detector	4/2/97	0-190	
17d	HP FLWMTR	Small diam, bare	4/2/97	0-180	static + inject at 4 gpm
17e	FLUID R	Multi-func	4/2/97	0-190	with 12 ohm-m water from supply well during injection

Flowmeter Profile Interpretation

DEPTH TOP	INTERVAL BOTTOM	AMBIENT FLOW	INJECTION FLOW	DIFF	PERCENT
0	10	-0.05	-1.0	0.95	23
10	20	-0.06	-1.0	0.95	23
20	30	-0.05	-1.0	0.95	23
30	40	-0.05	-1.0	0.95	23
40	50	0.0	-0.2	0.20	5
50	60	0	0	0	0
60	70	0	0	0	0
70	80	0	0	0	0
80	90	0	0	0	0
90	100	0	0	0	0
100	110	0	0	0	0
110	120	0	0	0	0
120	130	0	0	0	0
130	140	0	0	0	0
140	150	0	0	0	0
150	160	0	0	0	0
160	170	0.1	0.0	0.1	2
170	180	0.1	0.0	0.1	2
TOTAL:				4.2	101

Appendix 3

Dinocyst sample descriptions

8. Golightly Core

The Golightly core was assigned U.S. Geological Survey Paleobotanical number R5300.

Tamiami Formation (Ochopee Limestone Member)

46.4-46.8 ft depth (R5300 D) contains a single specimen of *Spiniferites* Mantell spp.
Age: Cenozoic.

73.3-73.7 ft depth (R5300 C) contains a single specimen of *Polysphaeridium zoharyi* (Rossignol) Bujak et al. and a gonyaulacacean specimen possibly reworked from the Mesozoic.
Age: Cenozoic.

unnamed formation

136.0-136.4 ft depth (R5300 B) contains a moderately diverse dinocyst assemblage in which no particular species is dominant. Preservation is good. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Lejeunecysta Artzner & Dörhöfer sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Quadrina ? *condita* de Verteuil & Norris
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams spp.
Tectatodinium pellitum Wall
Trinovantedinium capitatum Reid
Trinovantedinium glorianum (Head et al.) de Verteuil & Norris
Tuberculodinium vancampoae (Rossignol) Wall

Age: latest middle or late Miocene, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary) and *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa* (latest occurrence in the late Miocene).

Peace River Formation

198.8-199.2 ft depth (R5300A) contains a diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell and *Operculodinium* Wall. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Habibacysta tectata Head et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Lejeunecysta Artzner & Dörhöfer sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium ? *eirikianum* Head et al.
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.

Quadrina ? *condita* de Verteuil & Norris
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka
Selenopemphix nephroides Benedek
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams sp.
Sumatradinium soucouyantiae de Verteuil & Norris
Tectatodinium pellitum Wall
Trinovantedinium capitatum Reid
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: latest middle or late Miocene, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary) and *Multispinula quanta* Bradford and *Sumatradinium soucouyantiae* de Verteuil & Norris (latest occurrence in the late Miocene).

9. Trail Center Core

The Trail Center core was assigned U.S. Geological Survey Paleobotanical number R5275.

Tamiami Formation (Ochopee Limestone Member)

66.6-67.0 ft depth (R5275 H) contains a well preserved, low diversity dinocyst assemblage dominated by *Operculodinium* Wall spp. Dinocysts are:

Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Operculodinium ? *eirikianum* Head et al.
Operculodinium Wall spp.
Selenopemphix nephroides Benedek
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Trinovantedinium capitatum Reid
Tuberculodinium vancampoae (Rossignol) Wall

Age: Miocene, Pliocene, or Pleistocene (based on the presence of *Operculodinium* ? *eirikianum* Head et al.).

119.1-119.6 ft depth (R5275 I) contains a single fragment of *Operculodinium* Wall sp.

unnamed formation

187.5-187.9 ft depth (R5275 G) contains a well preserved, low diversity dinocyst assemblage dominated by *Operculodinium* Wall spp. Dinocysts are:

Hystrichokolpoma rigaudiae Deflandre & Cookson
Invertocysta lacrymosa Edwards
Lejeunecysta Artzner & Dörhöfer sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

Age: late Miocene or Pliocene (latest occurrence of *I. lacrymosa* is in the early Pliocene, questionable occurrences higher).

Peace River Formation

238.7-239.1 ft depth (R5275 F) contains a moderately diverse dinocyst assemblage dominated by *Tuberculodinium vancampoae* (Rossignol) Wall. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Lejeunecysta Artzner & Dörhöfer sp.
Multispinula quanta Bradford
Operculodinium Wall spp.
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams sp.
Tectatodinium pellitum Wall
Trinovantedinium harpagonium de Verteuil & Norris

Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

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

311.3-311.7 ft depth (R5275 E) contains a moderately diverse dinocyst assemblage dominated by species of *Operculodinium* Wall. Preservation is poor as the residue consists primarily of amorphous blebs. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Hystrichokolpoma rigaudiae Deflandre & Cookson
Lejeunecysta Artzner & Dörhöfer sp.
Multispinula quanta Bradford
Operculodinium Wall spp.
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams sp.
Trinovantedinium Reid sp.
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: latest middle or late Miocene, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary) and *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa* (latest occurrence in the late Miocene).

360.6-361.0 ft depth (R5275 D) contains a moderately diverse dinocyst assemblage dominated by *Spiniferites* Mantell spp. and *Polysphaeridium zoharyi* (Rossignol) Bujak et al. Preservation is fair. Dinocysts are:

Brigantedinium cariacoense (Wall) Lentin & Williams
Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson spp.
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Quadrina ? *condita* de Verteuil & Norris
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Selenopemphix nephroides Benedek
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Sumatradinium Lentin & Williams sp.
Tectatodinium pellitum Wall
Trinovantedinium capitatum Reid
Tuberculodinium vancampoae (Rossignol) Wall

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

430.5-431.0 ft depth (R5275 C) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell and *Operculodinium* Wall. Preservation is fair and amorphous blebs are common. Dinocysts are:

Brigantedinium cariacoense (Wall) Lentin & Williams ?
Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson

Labyrinthodinium truncatum Piasecki subsp. *truncatum*
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Muraticysta microornata Head et al. ?
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Selenopemphix Benedek sp.
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams sp.
Sumatradinium soucouyantiae de Verteuil & Norris
Tectatodinium pellitum Wall
Trinovantedinium papulum de Verteuil & Norris
Tuberculodinium vancampoae (Rossignol) Wall

Age: late middle or late but not latest Miocene, based on the overlap of ranges of *E. delectabile* (late middle and late Miocene), *Labyrinthodinium truncatum* Piasecki subsp. *truncatum* (and *S. brevispinosa brevispinosa* (latest occurrence in the late Miocene).

Arcadia (?) Formation

440.4-440.8 ft depth (R5275 B) contains a well preserved, moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. The presence of species of *Impagidinium* Stover & Evitt suggests an offshore environment. Dinocysts are:
Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Habibacysta tectata Head et al. ?
Hystrichokolpoma rigaudiae Deflandre & Cookson
Hystrichosphaeropsis obscura Habib
Impagidinium sphaericum (Wall) Lentin & Williams
Impagidinium Stover & Evitt sp.
Invertocysta lacrymosa Edwards
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites Mantell spp.
Tuberculodinium vancampoae (Rossignol) Wall
Age: late middle or late but not latest Miocene, based on the presence of *E. delectabile* (late middle and late Miocene) and stratigraphic position below the highest *Labyrinthodinium truncatum* Piasecki subsp. *truncatum*.

449.3-449.7 ft depth (R5275 A) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell and *Operculodinium* Wall. Preservation is fair. The presence of species of *Impagidinium* Stover & Evitt suggests an offshore environment. Dinocysts are:
Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Habibacysta tectata Head et al. ?
Hystrichosphaeropsis obscura Habib
Impagidinium sphaericum (Wall) Lentin & Williams
Lejeunecysta Artzner & Dörhöfer spp.

Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka
Selenopemphix nephroides Benedek
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams sp.
Tectatodinium pellitum Wall
Trinovantedinium Reid sp.
Tuberculodinium vancampoae (Rossignol) Wall
new gonyaulacacean form

Age: late middle or late but not latest Miocene, based on the presence of *E. delectabile* (late middle and late Miocene) and stratigraphic position below the highest *Labyrinthodinium truncatum* Piasecki subsp. *truncatum.*

10. Dade-Collier Airport Core

The Dade-Collier Airport core was assigned U.S. Geological Survey Paleobotanical number R5265.

Tamiami Formation (Ochopee Limestone Member)

19.5-20.0 ft depth (R5265 H) did not yield dinocysts.

30.5-31.0 ft depth (R5265 G) did not yield dinocysts.

65.5-66.0 ft depth (R5265 F) did not yield dinocysts.

78.0-78.5 ft depth (R5265 E) contains a low diversity dinocyst assemblage dominated by species of *Spiniferites* Mantell and *Operculodinium* Wall. Preservation is fair. Dinocysts are:

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

Age: Miocene, Pliocene, or Pleistocene.

88.8-89.4 ft depth (R5265 B) contains a low diversity dinocyst assemblage dominated by *Spiniferites* Mantell spp. and *Polysphaeridium zoharyi* (Rossignol) Bujak et al. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Achomosphaera Evitt sp.
Habibacysta ? Head et al. sp.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Impagidinium Stover & Evitt sp. (fragment)
Invertocysta Edwards ? sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

Age: Miocene, Pliocene, or Pleistocene.

Peace River Formation

120.0-120.5 ft depth (R5265 D) contains a low diversity dinocyst assemblage in which no particular species dominates. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Hystrichokolpoma rigaudiae Deflandre & Cookson
Impagidinium Stover & Evitt sp. (fragment)
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Operculodinium Wall sp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall
freshwater alga *Pediastrum*

Age: Miocene, Pliocene, or Pleistocene.

153.1-153.6 ft depth (R5265 C) contains a diverse dinocyst assemblage dominated by *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall. Preservation is good. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Achomosphaera Evitt sp.
Amiculosphaera umbracula Harland
Erymnodinium delectabile (de Verteuil & Norris) Lentin et al. ?
Hystrichosphaeropsis obscura Habib
Invertocysta Edwards sp.
Invertocysta lacrymosa Edwards
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson spp.
Operculodinium ? *eirikianum* Head et al.
Operculodinium Wall sp.
Selenopemphix nephroides Benedek
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams spp.
Tectatodinium pellitum Wall
Trinovantedinium Reid sp.
Tuberculodinium vancampoae (Rossignol) Wall

Age: late Miocene, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary), *Operculodinium* ? *eirikianum* (earliest occurrence in the late Miocene); DN 9 of de Verteuil & Norris (1996), and *Hystrichosphaeropsis obscura* Habib (latest occurrence in the late Miocene).

199.3-199.7 ft depth (R5265 A) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair and amorphous blebs are common. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium Wall spp.
Selenopemphix nephroides Benedek
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams sp.
Tectatodinium pellitum Wall
Trinovantedinium ferugnomatum de Verteuil & Norris
Trinovantedinium papulum de Verteuil & Norris
Tuberculodinium vancampoae (Rossignol) Wall

Age: latest middle or late Miocene, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary) and *E. delectabile* (late middle and late Miocene).

11. FAA Radar Core

The FAA-Radar Site core was assigned U.S. Geological Survey Paleobotanical number R5264.

Tamiami Formation (Ochopee Limestone Member)

35-36 ft depth (R5264 D) did not yield dinocysts.

unnamed formation

60.5-61.0 ft depth (R5264 F) contains a moderately diverse dinocyst assemblage dominated by *Polysphaeridium zoharyi* (Rossignol) Bujak et al. and species of *Spiniferites* Mantell. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Achomosphaera Evitt sp.
Ataxiodinium Reid ? n. sp.
Batiacasphaera hirsuta Stover ?
Hystrichokolpoma rigaudiae Deflandre & Cookson
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium choanophorum (Deflandre & Cookson) Harland & Hill
Operculodinium ? *eirikianum* Head et al.
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

Age: late Miocene or Pliocene.

90.4-91.0 ft depth (R5264 C) contains a moderate diversity dinocyst assemblage in which no particular species dominates. Preservation is good. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Achomosphaera Evitt sp.
Brigantedinium Reid sp.
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Invertocysta lacrymosa Edwards
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 al. subsp. *brevispinosa*
Selenopemphix nephroides Benedek
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams sp.
Trinovantedinium Reid sp.
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: late Miocene, based on stratigraphic position and the presence of *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa* (latest occurrence in the late Miocene).

Peace River Formation

96.0-96.5 ft depth (R5264 E) contains a moderate diversity dinocyst assemblage in which no particular species dominates. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Achomosphaera Evitt sp.
Impagidinium patulum (Wall) Stover & Evitt
Invertocysta lacrymosa Edwards
Lejeunecysta Artzner & Dörhöfer sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium ? *eirikianum* Head et al.
Selenopemphix brevispinosa Head et al. subsp. *conspicua* de Verteuil & Norris
Selenopemphix nephroides Benedek
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Trinovantedinium glorianum (Head et al.) de Verteuil & Norris
Trinovantedinium papulum de Verteuil & Norris
Trinovantedinium Reid sp.
Tuberculodinium vancampoae (Rossignol) Wall

Age: late Miocene, based on the lowest occurrence of *Operculodinium* ? *eirikianum*

158.0-158.4 ft depth (R5264 B) contains a low diversity dinocyst assemblage dominated by species of *Operculodinium* Wall. Preservation is fair. Dinocysts are:

Brigantedinium cariacoense (Wall) Lentin & Williams
Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium Wall spp.
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams sp.
Tectatodinium pellitum Wall
Trinovantedinium Reid sp.
Tuberculodinium vancampoae (Rossignol) Wall

Age: latest middle or late Miocene, based on the presence of *E. delectabile* (late middle and late Miocene).

204.0-204.5 ft depth (R5264 A) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair and amorphous blebs are common. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Batiacasphaera hirsuta Stover ?
Erymnodinium delectabile (de 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
Operculodinium Wall spp.
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Selenopemphix nephroides Benedek
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams sp.
Trinovantedinium ? *xylochoporum* de Verteuil & Norris
Trinovantedinium papulum de Verteuil & Norris

Tuberculodinium vancampoae (Rossignol) Wall

Age: latest middle or late Miocene, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary) and *E. delectabile* (late middle and late Miocene).

12. Monroe Station Core

The Monroe Station core was assigned U.S. Geological Survey Paleobotanical number R5365.

Tamiami Formation (Ochopee Limestone Member)

34.5-35.0 ft depth (R5365 F) contains only a couple of specimens of *Operculodinium* Wall sp.

unnamed formation

101.5-102.0 ft depth (R5365 E) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Achomosphaera Evitt sp.
Habibacysta tectata Head et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Impagidinium paradoxum (Wall) Stover and Evitt
Impagidinium patulum (Wall) Stover & Evitt
Invertocysta lacrymosa Edwards
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium Harland & Hill sp.
Operculodinium Wall spp. including Martin's new one
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Tuberculodinium vancampoae (Rossignol) Wall
Tectatodinium pellitum Wall

Age: late Miocene, or Pliocene, based on stratigraphic position and the presence of *Reticulatasphaera actinocoronata* (Benedek) Bujak & Matsuoka and *Invertocysta lacrymosa* Edwards (latest occurrence of *I. lacrymosa* is in the early Pliocene, questionable occurrences higher).

Peace River Formation

113.9-114.4 ft depth (R5365 B) 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 Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: late Miocene, or Pliocene, based on stratigraphic position and the presence of *Reticulatasphaera actinocoronata* (Benedek) Bujak & Matsuoka

142.3-142.7 ft depth (R5365 D) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell and *Operculodinium* Wall. Preservation is fair. Dinocysts are:

Achomosphaera Evitt sp.
Batiacasphaera hirsuta Stover ?
Dapsilidinium pseudocolligerum (Stover) Bujak et al.

Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Geonettia clineae de Verteuil & Norris
Lejeunecysta Artzner & Dörhöfer sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium choanophorum (Deflandre & Cookson) Harland & Hill
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Selenopemphix nephroides Benedek
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams sp.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

Age: late Miocene, based on the presence of *E. delectabile* (late middle and late Miocene), *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa* (latest occurrence in the late Miocene), and *Geonettia clineae* de Verteuil & Norris (reported range is late Miocene only).

179.0-179.6 ft depth (R5365 A) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is poor and amorphous blebs are common. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Ataxiodinium Reid ? n. sp.
Habibacysta tectata Head et al.
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium ? *eirikianum* Head et al.
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams sp.
Tectatodinium pellitum Wall
Trinovantedinium glorianum (Head et al.) de Verteuil & Norris ?
Tuberculodinium vancampoae (Rossignol) Wall

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

183.0-183.5 ft depth (R5365 C) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell and *Operculodinium* Wall. Preservation is fair and amorphous are common. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Achomosphaera Evitt sp.
Brigantedinium cariacoense (Wall) Lentin & Williams
Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Habibacysta tectata Head et al.
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium Harland & Hill sp.
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson spp.
Operculodinium Wall spp.
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Spiniferites mirabilis (Rossignol) Sarjeant

Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Trinovantedinium Reid sp.
Tuberculodinium vancampoae (Rossignol) Wall

Age: latest middle or late Miocene, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary), *E. delectabile* (late middle and late Miocene), and *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa* (latest occurrence in the late Miocene).

13. West Loop Road Core

The West Loop Road core was assigned U.S. Geological Survey Paleobotanical number R5299.

Tamiami Formation (Ochopee Limestone Member)

33.0-33.4 ft depth (R5299 C) did not yield dinocysts.

unnamed formation

71.5-72.0 ft (R5299 E) contains a low diversity dinocyst assemblage, dominated by *Polysphaeridium zoharyi* (Rossignol) Bujak et al. Preservation is poor. Dinocysts are:

Hystrichokolpoma rigaudiae Deflandre & Cookson
Operculodinium ? *eirikianum* Head et al.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites Mantell spp.
Tuberculodinium vancampoae (Rossignol) Wall

Age: late late Miocene, Pliocene, or Pleistocene, based on stratigraphic position and the presence of *Hystrichokolpoma rigaudiae* Deflandre & Cookson and *Operculodinium* ? *eirikianum* Head et al.

161.5-162.0 ft depth (R5299 D) contains a low diversity dinocyst assemblage in which no particular species dominates. Preservation is poor and amorphous blebs are common. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne ?
Cyclopsiella Drugg & Loeblich ? sp.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Multispinula quanta Bradford
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
miscellaneous Congruentidiaceae

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

Peace River Formation

200.7-201.1 ft depth (R5299 B) contains a moderate diversity dinocyst assemblage in which no particular species dominates. Preservation is fair and amorphous blebs are common. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Brigantedinium cariacoense (Wall) Lentin & Williams
Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Habibacysta tectata Head et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Invertocysta lacrymosa Edwards
Lejeunecysta Artzner & Dörhöfer sp.
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium Wall spp.
Quadrina ? *condita* de Verteuil & Norris
Selenopemphix armageddonensis de Verteuil & Norris
Selenopemphix nephroides Benedek
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Trinovantedinium ? *xylochoporum* de Verteuil & Norris
Trinovantedinium Reid sp.

Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: late in the late Miocene, based on the overlap of *E. delectabile* (late middle and late Miocene) and *S. armageddonensis* (earliest occurrence in the late late Miocene).

240.6-241.0 ft depth (R5299 A) contains a moderate diversity dinocyst assemblage in which no particular species dominates. Preservation is fair. Dinocysts are:

Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Impagidinium Stover & Evitt sp.
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium Wall sp.
Quadrina ? *condita* de Verteuil & Norris
Selenopemphix brevispinosa Head et al. subsp. *conspicua* de Verteuil & Norris
Selenopemphix nephroides Benedek
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Trinovantedinium capitatum Reid
Trinovantedinium papulum de Verteuil & Norris
Trinovantedinium ? *xylochoporum* de Verteuil & Norris
Tuberculodinium rossignoliae Drugg ?
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: late middle or late Miocene, based on the presence of *E. delectabile*.

14. Doerr's Lake Core

The Doerr's Lake core was assigned U.S. Geological Survey Paleobotanical number R5266.

Tamiami Formation (Ochopee Limestone Member)

31.0-31.6 ft depth (R5266 B) did not yield dinocysts.

unnamed formation

77.0-77.3 ft depth (R5266 A) contains a low diversity dinocyst assemblage dominated by species of *Spiniferites* Mantell and *Operculodinium* Wall. Preservation is fair and dinocysts are very sparse. Dinocysts are:

Lejeunecysta Artzner & Dörhöfer sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium Wall spp.
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa* ?
Spiniferites Mantell spp.
Tuberculodinium vancampoae (Rossignol) Wall

Age: late Miocene or younger, based on stratigraphic position; probably no younger than Miocene based on the questionable identification of *S. brevispinosa*.

105.5-106.0 ft depth (R5266 D) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is good. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne ?
Cyclopsiella Drugg & Loeblich ? sp.
Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Lejeunecysta Artzner & Dörhöfer sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium Wall sp.
Quadrina ? *condita* de Verteuil & Norris
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Selenopemphix nephroides Benedek
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Trinovantedinium capitatum Reid
Trinovantedinium Reid sp.
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: latest middle or late Miocene, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary), *E. delectabile* (late middle and late Miocene), and *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa* (latest occurrence in the late Miocene).

181.8-182.0 ft depth (R5266 C) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is poor and amorphous blebs are common. Dinocysts are:

Hystrichokolpoma rigaudiae Deflandre & Cookson
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium ? *eirikianum* Head et al.
Operculodinium Wall sp.
Quadrina ? *condita* de Verteuil & Norris

Selenopemphix nephroides Benedek
Spiniferites Mantell spp.
Trinovantedinium capitatum Reid
Trinovantedinium ? *xylochoporum* de Verteuil & Norris
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

Age: Miocene, based on the presence of *Quadrina* ? *condita* de Verteuil & Norris and *Trinovantedinium* ? *xylochoporum* de Verteuil & Norris; no younger than late Miocene, based on stratigraphic position.

15. Raccoon Point Core

The Raccoon Point core was assigned U.S. Geological Survey Paleobotanical number R5254.

Tamiami Formation (Ochopee Limestone Member)

41.8-42.3 ft depth (R5254 C) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair. Dinocysts are:

Brigantedinium Reid sp.
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Selenopemphix nephroides Benedek
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Trinovantedinium glorianum (Head et al.) de Verteuil & Norris ?
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

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

122.2-122.7 ft depth (R5254 E) did not yield dinocysts.

unnamed formation

129.1-129.6 ft (R5254 D) contains a low diversity dinocyst assemblage, dominated by species of *Spiniferites* Mantell and *Polysphaeridium zoharyi* (Rossignol) Bujak et al. Preservation is fair. Dinocysts are:

Hystrichokolpoma rigaudiae Deflandre & Cookson
Operculodinium ? *eirikianum* Head et al.
Operculodinium Wall sp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites Mantell spp.
Tuberculodinium vancampoae (Rossignol) Wall
miscellaneous Congruentidiaceae

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

146.5-146.9 ft depth (R5254 B) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Brigantedinium Reid sp.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Selenopemphix nephroides Benedek
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

miscellaneous Congruentidiaceae

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

Peace River Formation

164.4-164.8 ft depth (R5254 A) contains a diverse dinocyst assemblage in which no particular species dominates. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne ?
Brigantedinium cariacoense (Wall) Lentin & Williams
Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Habibacysta Head et al. sp.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Impagidinium patulum (Wall) Stover & Evitt
Impagidinium sphaericum (Wall) Lentin & Williams
Invertocysta lacrymosa Edwards
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium Harland & Hill sp.
Multispinula quanta Bradford
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium Wall spp.
Quadrina ? *condita* de Verteuil & Norris
Selenopemphix armageddonensis de Verteuil & Norris
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Selenopemphix brevispinosa Head et al. subsp. *conspicua* de Verteuil & Norris
Selenopemphix nephroides Benedek
Spiniferites Mantell spp.
Spiniferites mirabilis (Rossignol) Sarjeant
Sumatradinium Lentin & Williams sp.
Tectatodinium pellitum Wall
Trinovantedinium Reid sp.
Tuberculodinium rossignoliae Drugg ?
Tuberculodinium vancampoae (Rossignol) Wall
cyst of *Polykrikos* Bütschli
miscellaneous Congruentidiaceae

Age: late in the late Miocene, based on the overlap of *E. delectabile* (late middle and late Miocene) and *S. armageddonensis* (earliest occurrence in the late late Miocene).

16. Nobles Road Core

The Nobles Road core was assigned U.S. Geological Survey Paleobotanical number R5366.

Tamiami Formation (sand and clay facies)

40.6-41.1 ft depth (R5366 D) contains a low diversity dinocyst assemblage dominated by species of *Spiniferites* Mantell and *Operculodinium* Wall. Preservation is poor, dinocysts are very sparse, and amorphous blebs are common. Dinocysts are:

Achomosphaera Evitt sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford ?
Operculodinium Wall spp.
Spiniferites Mantell spp.
Spiniferites mirabilis (Rossignol) Sarjeant
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

Age: late in the late Miocene or younger, based on stratigraphic position.

67.2-67.7 ft depth (R5366 F) contains a moderately low diversity dinocyst assemblage in which no particular species dominates. Preservation is poor and dinocysts are sparse. Dinocysts are:

Invertocysta lacrymosa Edwards ?
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Selenopemphix armageddonensis de Verteuil & Norris
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

Age: late in the late Miocene based *S. armageddonensis* (earliest occurrence in the late late Miocene).

82.4-83.1 ft depth (R5366 C) contains a low diversity dinocyst assemblage dominated by species of *Spiniferites* Mantell and *Operculodinium* Wall. Preservation is poor, dinocysts are very sparse, and amorphous blebs are common. Dinocysts are:

Achomosphaera Evitt sp.
Invertocysta lacrymosa Edwards
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Operculodinium ? *eirikianum* Head et al.
Operculodinium Wall spp.
Spiniferites Mantell spp.

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

unnamed formation

155.9-156.5 ft depth (R5366 B) contains a moderately diverse dinocyst assemblage dominated by *Polysphaeridium zoharyi* (Rossignol) Bujak et al. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Achomosphaera Evitt sp.

Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium Harland & Hill sp.
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium ? *eirikianum* Head et al.
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

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

Peace River Formation

177.0-177.5 ft depth (R5366 E) contains a moderate diversity dinocyst assemblage in which no particular species dominates. Preservation is poor, dinocysts are sparse, and amorphous blebs are common. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Hystrichokolpoma Deflandre & Cookson sp.
Invertocysta lacrymosa Edwards
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Operculodinium Wall sp.
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.

Age: latest middle or late Miocene, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary) and *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa* (latest occurrence in the late Miocene).

187.8-188.4 ft depth (R5366 A) contains a moderately low diversity dinocyst assemblage dominated by species of *Operculodinium* Wall. Preservation is fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne ?
Hystrichokolpoma rigaudiae Deflandre & Cookson
Lejeunecysta Artzner & Dörhöfer sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium choanophorum (Deflandre & Cookson) Harland & Hill
Multispinula quanta Bradford
Operculodinium Wall spp.
Spiniferites Mantell spp.
Sumatradinium Lentin & Williams sp. ?
Tectatodinium pellitum Wall
miscellaneous Congruentidiaceae

Age: latest middle or late Miocene, based on the presence of *Achomosphaera andalousiensis* Jan du Chêne (earliest occurrence near the middle/late Miocene boundary), and on stratigraphic position.

17. Bass Core

The Bass core was assigned U.S. Geological Survey Paleobotanical number R5364.

Tamiami Formation (Ochopee Limestone Member)

6.3-6.7 ft depth (R5364 E) did not yield dinocysts.

39.5-39.9 ft depth (R5364 D) yielded only two specimens of species of *Spiniferites* Mantell and a few fragments of *Operculodinium* Wall sp.

unnamed formation

149.3-149.7 ft depth (R5364 C) contains a moderately diverse dinocyst assemblage in which no particular species dominates. Preservation is poor and dinocysts are sparse. Dinocysts are:

Achomosphaera Evitt sp.
Batiacasphaera sphaerica Stover ?
Habibacysta tectata Head et al.
Impagidinium Stover & Evitt sp.
Invertocysta lacrymosa Edwards
Lejeunecysta Artzner & Dörhöfer sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Nematosphaeropsis Deflandre & Cookson sp.
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Trinovantedinium capitatum Reid
Tuberculodinium vancampoae (Rossignol) Wall

Age: Miocene (?), based on the questionable identification of *B. sphaerica*.

165.9-166.4 ft depth (R5364 B) contains a moderately diverse dinocyst assemblage dominated by members of the Family Congruentidiaceae. Preservation is poor and amorphous blebs are common. Dinocysts are:

Impagidinium Stover & Evitt sp.
Lejeunecysta Artzner & Dörhöfer spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Multispinula quanta Bradford
Operculodinium Wall spp.
Quadrina ? *condita* de Verteuil & Norris
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Selenopemphix nephroides Benedek
Spiniferites Mantell spp.
Trinovantedinium Reid sp.
miscellaneous Congruentidiaceae

Age: late middle or late Miocene, based on the presence of *Selenopemphix brevispinosa* Head et al. subsp. *brevispinosa* (latest occurrence in the late Miocene).

184.5-185.0 ft depth (R5364 A) contains a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* Mantell. Preservation is poor. Dinocysts are:

Cyclopsiella Drugg & Loeblich ? sp.
Erymnodinium delectabile (de Verteuil & Norris) Lentin et al.
Geonettia clineae de Verteuil & Norris ?
Habibacysta tectata Head et al.

Impagidinium Stover & Evitt sp.
Lejeunecysta Artzner & Dörhöfer sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium ? *eirikianum* Head et al.
Operculodinium Wall spp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites Mantell spp.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

Age: late middle or late Miocene, based on the presence of *E. delectabile* (late middle and late Miocene).