U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Preliminary Analysis of Integrated Stratigraphic Data from the Phred #1 Corehole, Indian River County, Florida

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U.S. Geological Survey Open-File Report 95-824 1995
Prepared in cooperation with the Florida Geological Survey, Tallahassee, Florida

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INTRODUCTION

The Phred #1 corehole (Florida Geological Survey # W-13958) was drilled in March 1978, by the Florida Geological Survey as a lithostratigraphic test boring, penetrating 476 ft (145 m) of upper Paleogene, Neogene, and Quaternary rocks and sediments. The corehole is located in Indian River County, at an elevation of 23 ft (7 m) on the east-central coast of peninsular Florida (N 27° 41'50", W 80° 26'09"; sec. 16, T. 32 S., R. 39 E.) (Figure 1). The Phred #1 core is poorly indurated with incomplete recovery and has been heavily sampled; consequently, much valuable sedimentologic and paleontologic information has been lost and interpretation is somewhat limited. However, it is the eastern most core on the exposed Florida Platform and has a distinctively different stratigraphy than the cores examined from the west coast; therefore, it is extremely valuable for deriving a regional depositional history.

The stratigraphic interval penetrated by the corehole hosts the ground-water resources of Indian River County. Ground water is withdrawn primarily from two aquifer systems: the surficial and the underlying Floridan. The geohydrology of Indian River County has been investigated in two cooperative efforts of the U.S. Geological Survey with Indian River County and with the St. Johns River Water Management District (Crain and others, 1975; Schiner and others, 1988). Public-water supplies are withdrawn almost entirely from the surficial aquifer system comprising Pliocene to Pleistocene sands and shell beds (Crain and others, 1975). Ground water for crop irrigation is withdrawn from the deeper, more brackish Floridan aquifer system which encompasses Paleogene carbonate sediments (Crain and others, 1975).

As water resources are increasingly stressed by demands from Florida's growing east-coast population, a thorough understanding of the geologic units through which the water flows is essential. Full utilization of this subsurface resource requires high-resolution lithostratigraphic, biostratigraphic, sedimentologic, and diagenetic assessment of the aquifer rocks. While quarries and pits provide partial access to Pleistocene and younger rocks and sediments of the surficial aquifer system, examination of the geologic framework of the Floridan aquifer system in Indian River County can be accomplished only with cores.

This report compiles lithostratigraphic, biostratigraphic, and diagenetic analyses of the Phred #1 core as part of an on-going cooperative study between the U.S. Geological Survey and the Florida Geological Survey, to interpret the age, depositional, and diagenetic history of subsurface units in southern Florida. This report is the second in a series that began with a study of the South Venice (W-16814) corehole in Sarasota County (Wingard and others, 1994). The development of an integrated stratigraphic framework for Florida is critical to understanding the distribution and correlation of geologic and hydrologic units in the subsurface in the southern portion of the state.

Regional Stratigraphy and Geologic Setting

The Phred #1 corehole, located in east-central Florida in Indian River County, lies near the eastern edge of the Florida Platform. The exposed part of the platform forms the State of Florida; the submerged part forms a broad continental shelf beneath the Gulf of Mexico on the west, and a narrow continental shelf beneath the Atlantic Ocean on the east. The main structural

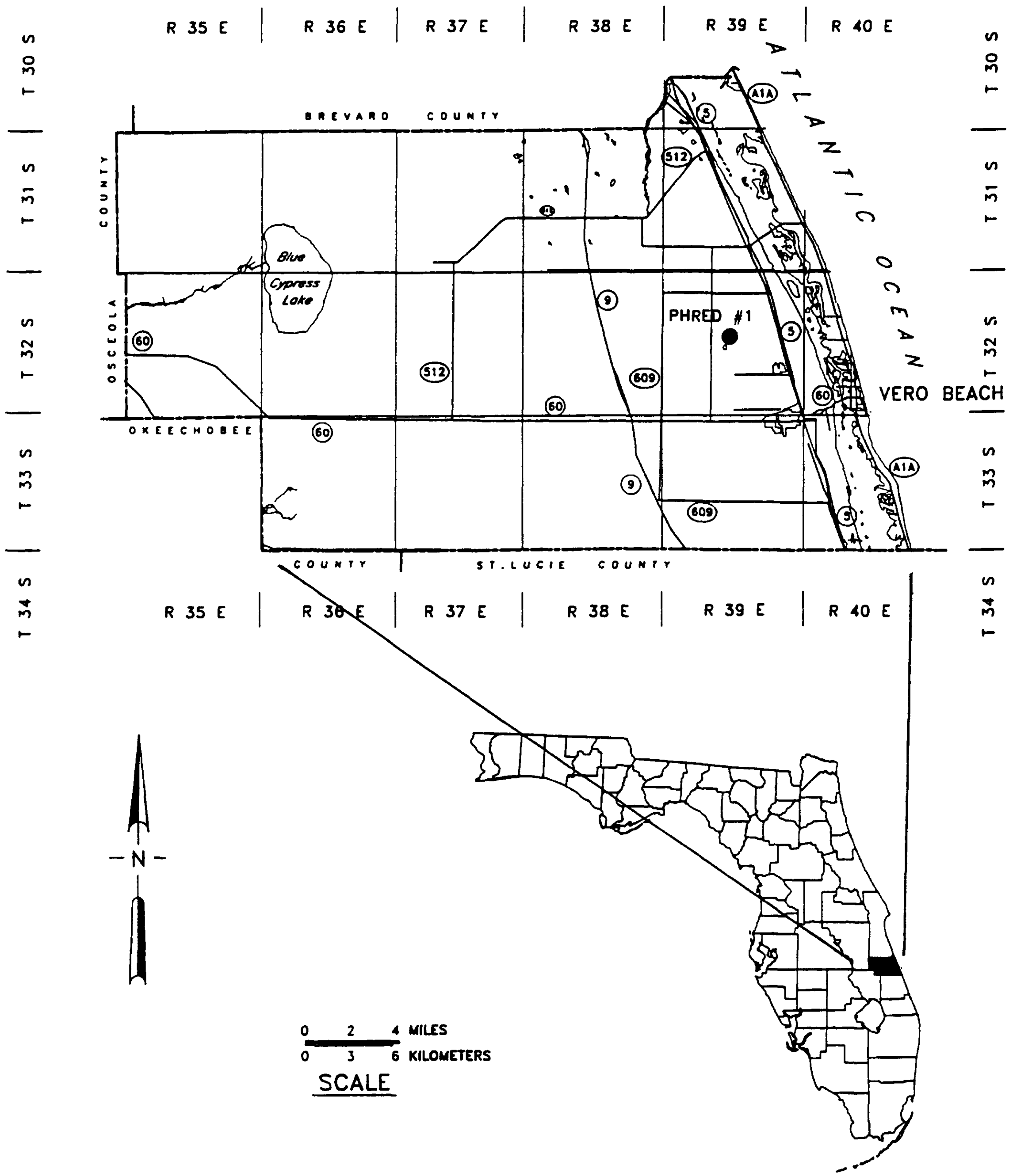


Figure 1: Location map and corehole site in Indian River County (enlarged).

features that affected Cenozoic deposition in the study area include the Peninsular Arch, South Florida Basin, Ocala Platform, Brevard Platform, and Okeechobee Basin (Figure 2). Isopach patterns indicate that the Peninsular Arch and the South Florida Basin affected deposition during the Paleogene, whereas the Ocala Platform, Brevard Platform, and the Okeechobee Basin affected deposition during the late Paleogene, the Neogene, and the Quaternary (Miller, 1986; Scott, 1988).

The definition and recognition of mappable lithostratigraphic units in the upper Paleogene and Neogene section in southern Florida have been hindered by abrupt vertical and lateral facies changes and by the interfingering of both siliciclastic and carbonate sediments. Scott (1988) redefined the subsurface stratigraphy of this section in southern Florida when he raised the Hawthorn Formation to group status and defined the Arcadia and Peace River Formations (Figure 3), thus establishing a lithostratigraphic framework that conforms to the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983). The paucity of subsurface data, however, has left many questions unanswered about the age of these lithostratigraphic units and the depositional history of the region.

The top of the Floridan aquifer system, in the Phred #1 corehole, is at or near the top of a limestone at about 318 ft, referred to as the Suwannee Limestone by Schiner and others (1988) on the basis of its stratigraphic position. However, in this report, the limestone occurring in the interval between 380 to 318 ft is referred to as the unnamed limestone, on the basis of differences in lithology from the type Suwannee Limestone. Much of the Hawthorn Group, which is primarily siliciclastic in this core, acts as a confining unit and separates the Floridan aquifer system from the overlying surficial aquifer system. The surficial aquifer system, in the vicinity of the Phred #1 corehole, includes all sediments and rocks from about 125 ft depth, approximately the top of the Hawthorn Group as recognized in this study, up to the surface (Schiner and others, 1988).

Methods

The purpose of this cooperative study is to determine the age and geologic history of southern Florida within the lithostratigraphic framework established by Scott (1988). Samples from the Phred #1 corehole were collected during July 1993, May 1994, and February 1995 for paleontologic, isotopic ($^{87}Sr/^{86}Sr$), and petrographic analyses.

Paleontologic samples were selected and processed primarily for mollusks and dinoflagellate cysts (dinocysts). Dinocysts were processed according to standard palynological techniques. 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 using Nomarski interference contrast.

Mollusks present in the Phred #1 core from 476 to 343 ft primarily occur as molds or casts. Latex castings were prepared from the best preserved molds to facilitate comparison to published species. Castings and core pieces were examined under a binocular microscope to observe diagnostic characters. Mollusks present in the unconsolidated sediments from 128 to 20 ft were dry-sieved and separated into two size-fractions; all specimens greater than 850 μm were picked and identified with a binocular microscope.

Thirty-eight samples were selected for X-ray diffraction analysis, at or between lithologic changes in the core. Samples were pipetted into a test tube containing defloculant, mixed, and then centrifuged to concentrate clay-sized particles. This concentrated material was then

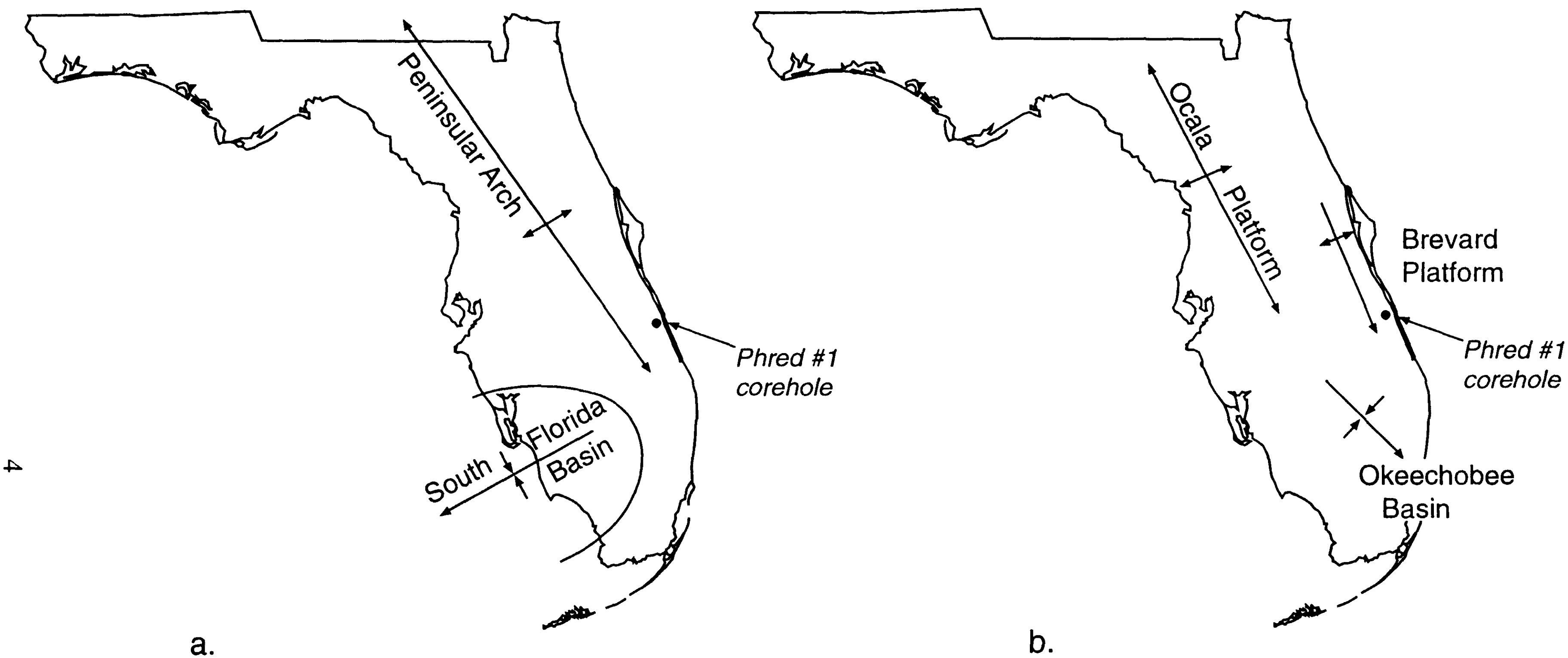


Figure 2. Structural features near the study area. a) The South Florida Basin and the Peninsular Arch affected deposition during the Paleocene, Eocene, and Oligocene. b) The Ocala and Brevard Platforms and the Okeechobee Basin controlled deposition during the Miocene and Pliocene.

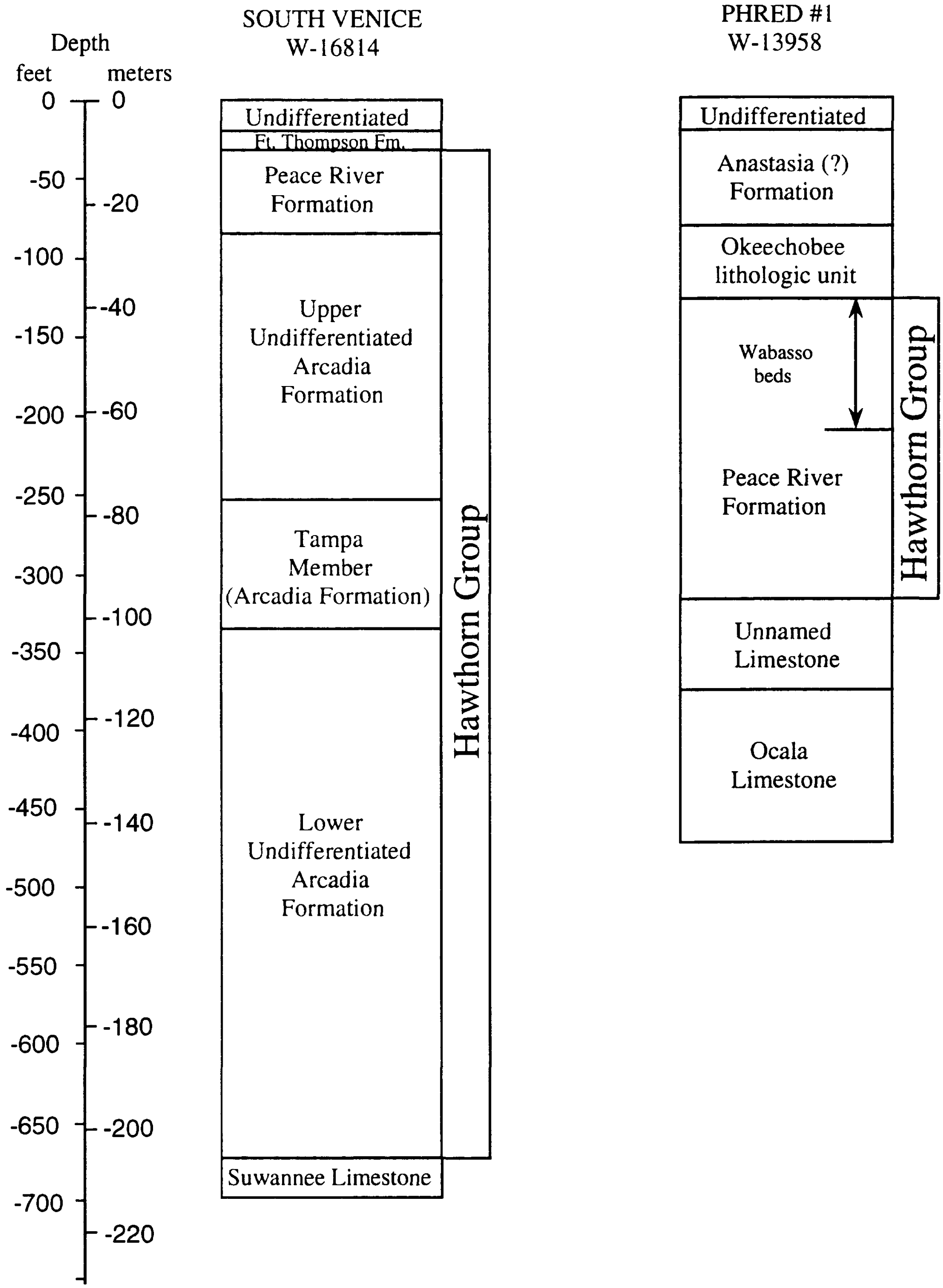


Figure 3. Stratigraphic units observed in the South Venice core from the west coast of Florida and in the Phred #1 core from the east coast of Florida. This figure shows depths and thicknesses of stratigraphic units in the two corehole sites; no age correlation is implied.

pipetted onto a slide, allowed to dry, and placed in a glycolator to differentiate mixed-layer illite/smectite from vermiculite and smectite. X-ray diffraction was performed on a DIANO diffractometer, and samples were scanned from 2 to 40 degrees, with CuK_α radiation.

Twelve samples, from 462 to 128 ft, were selected for petrographic analysis, and impregnated with blue-stained epoxy, and made into standard thin sections. They were examined petrographically to identify grains and pore types, determine cement compositions, describe textures, and assess the degree of diagenetic alteration. No samples were collected above 128 ft because the sediments there are poorly lithified.

LITHOSTRATIGRAPHY

The Phred #1 corehole penetrates 476 ft (145 m) of upper Paleogene, Neogene, and Quaternary carbonate and siliciclastic sediments, and was completed in the upper Eocene Ocala Limestone. The corehole site is located between two northwest-trending normal faults that are parallel to, and within a few miles of, the Atlantic Coast in Indian River County (Bermes, 1958). In ascending order, the units encountered are the Ocala Limestone, an unnamed limestone, the Peace River Formation, the informal Okeechobee lithologic unit (usage of Scott, 1992), the Anastasia(?) Formation, and Pleistocene or Holocene sands. The Peace River Formation is part of the Hawthorn Group (Figure 3). Complete lithologic descriptions of the core are presented in Appendix 1.

The Phred #1 corehole penetrates 96 ft (29.3 m) of the Ocala Limestone, where it comprises white to light-orange, moderately to well-indurated, fossiliferous packstones and grainstones. In the study area, the Ocala Limestone ranges from 50 to greater than 200 ft in thickness (Crain and others, 1975). The Ocala Limestone occurs throughout most of southern Florida; it crops out on the crest and flanks of the Ocala Platform, thins across the Brevard Platform due to erosion, thickens into the South Florida Basin, and is absent only in a limited area of southern-most Florida (see Miller, 1986).

An unnamed limestone lies suprajacent to the Ocala Limestone in the study area (Armstrong, 1980). This limestone has been identified by others as Suwannee Limestone based on stratigraphic position (Schiner and others, 1988). They have indicated on their cross sections that it occurs in the subsurface along the east coast, at a location near the Phred #1 corehole site, but pinches out to the west, approximately 25 miles (40 km) inland (Schiner and others, 1988, their Figure 11). The Phred #1 corehole penetrates 62 ft (18.9 m) of yellowish-gray to white, moderately to well-indurated, fossiliferous packstone to grainstone, with quartz and phosphatic sand and silt, and these sediments are lithologically distinct from the type Suwannee Limestone. The regional extent and variability of this unnamed limestone are unknown.

Bermes (1958) considered this unnamed limestone to be Oligocene based on foraminifers, and assumed it was upper Oligocene, citing Cooke (1945) who claimed that there were no lower Oligocene strata in Florida. His cross sections indicate that the Oligocene series along the coast in Indian River County is preserved in downdropped fault blocks. However, planktonic foraminifers and coccoliths were examined in this unit in eastern Martin and St. Lucie Counties, to the south of the study area, by Armstrong and others (1985), and found to be early Oligocene. Armstrong and others (1985) have recognized phosphorite in the unnamed limestone, as well, and speculate that it may be the earliest deposition of phosphates in Florida.

The Peace River Formation of the Hawthorn Group overlies the unnamed limestone in the Phred #1 corehole. The corehole penetrates 190 ft (57.9 m) of sediments of the Peace River

Formation and consists of poorly to moderately indurated variably fossiliferous, calcareous to dolomitic quartz sand, silt and clay, and sandy to clayey limestones and dolostones. Virtually all lithologies contain phosphatic grains. Two formations are recognized in the Hawthorn Group in southern Florida: the Arcadia and Peace River Formations (Scott, 1988). However, the Arcadia Formation was not encountered in this corehole. Arcadia Formation sediments were identified from 343 to 311 feet during the initial description of this core (Johnson, 1986). Re-examination of the sediments within this interval has led to the re-interpretation of the formational assignment; the sediments from 343 to 318 ft now are assigned to the unnamed limestone, and those from 318 to 311 ft are placed in the Peace River Formation. The absence of the Arcadia Formation from this core requires that the limits of the occurrence of the unit as defined by Scott (1988) be modified. The Arcadia Formation also may be absent from the area north of the Phred #1 core along the east coast.

Within the Peace River Formation the Wabasso beds have been recognized as an informal unit in the top 83 ft (25.3 m) of the Hawthorn Group (Huddlestun, 1988). Huddlestun (1988) has suggested that Phred #1 core be a reference core for the Wabasso beds. The Wabasso beds are composed of slightly phosphatic, poorly to moderately indurated, fossiliferous (foraminiferal) quartz sand, silt, and clay, with a calcareous to rarely dolomitic matrix. The relatively small amount of dolomite and phosphorite and the high foraminiferal grain content distinguish the Wabasso beds from the rest of the Peace River Formation.

Overlying the Peace River Formation are 128 ft (39 m) of upper Pliocene to Pleistocene or Holocene poorly to moderately indurated, fossiliferous quartz sands, silts, shell beds, and limestone. This interval is differentiated into three units: the informal Okeechobee lithologic unit, the Anastasia(?) Formation, and unlithified, undifferentiated quartz sands.

The informal Okeechobee lithologic unit, as proposed by Scott (1992), is recognized from 128 to 80 ft. This unit consists of alternating poorly to moderately indurated fossiliferous quartz sands, shell beds, and sandy limestones that include Caloosahatchee, Bermont, and Fort Thompson faunal units. Historically, these biostratigraphic units have been treated as formal lithostratigraphic units. The practice of defining formations on the basis of the fauna they contain, though commonly accepted in the past in the coastal plain (Scott and Wingard, 1995), does not conform to the current North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983).

The Anastasia(?) Formation is tentatively recognized from 80 to 20 ft. This interval consists of nonindurated to poorly indurated coquinoid quartz sands and shell beds. The molluscan taxonomy of the type Anastasia Formation needs to be assessed and compared to the Fort Thompson faunal unit before this portion of the Phred #1 core can be confidently assigned to the Anastasia Formation. The upper 20 ft of the core consist of unlithified, undifferentiated quartz sand.

Huddlestun (1988) refers to the sediments that disconformably overlie the Wabasso beds in the Phred #1 core (at 128 ft) as the Nashua Formation, a Pleistocene unit recognized in northeastern Florida that consists of variably clayey, calcareous, shelly quartz sand. The variably calcareous, shelly quartz sands, shelly sandy limestones, and sandy shell beds, found from 128 to 80 ft, differ from the Nashua Formation. These sediments are included within the concept of the informal Okeechobee lithologic unit and, therefore, are assigned to this unit.

Frazee and Johnson (1983) and Johnson (1993) have reported the occurrence of the Tamiami Formation in the subsurface along the east coast from central Brevard County, through Indian River County, to St. Lucie County. Their interpretation that the Tamiami Formation occurs in this area was made on the basis of geophysical log correlation from southern Florida; they did not utilize faunal data to support their interpretation. Also, Schiner and others (1988) have applied the names Tamiami Formation, Fort Thompson Formation, and Anastasia Formation to a portion of the section that we have designated as the informal Okeechobee lithologic unit and the Anastasia(?) Formation. The Tamiami Formation is not recognized lithologically or faunally in the Phred #1 core.

BIOSTRATIGRAPHY

Dinocyst assemblages and molluscan occurrences were examined to determine relative ages of samples of the Phred #1 core. Dinocysts are generally well preserved where they were sampled. Occurrences of age-diagnostic species and the stratigraphic succession of lowest and highest occurrences of dinocyst taxa were used to assign ages and suggest correlations to other Gulf Coast formations. Complete dinocyst assemblage data are given in Table 1 and Appendix 2. The mollusks identified in the Phred # 1 core are preserved as internal and external molds in the indurated carbonate deposits from 476 (total depth) to 343 ft, and as original or altered material in the unconsolidated siliciclastic deposits from 128 to 20 ft. Mollusks that could be identified with some level of confidence in the samples studied are given in Table 2; this table is not considered a complete list of all mollusks present. The remainder of the core is relatively devoid of mollusks; those that are present occur only as unrecognizable fragments or faint impressions. Biostratigraphic data also are included in Appendix 1. The biostratigraphic data are combined here and presented by stratigraphic unit and shown in Figure 4 a, b, and c.

Ocala Limestone

In this core, the Ocala Limestone occurs from 476 (at total depth) to 380 ft. Both dinocysts and mollusks were recovered and identified. A single dinocyst sample from 408.8 to 408.3 ft contained a moderately well preserved assemblage of dinocysts with no particularly dominant species. The presence of *Batiacasphaera compta* Drugg indicates a late middle or late Eocene age (Williams and others, 1993) at that depth, and suggests correlation with the Yazoo Formation in the Gulf Coast (Edwards, 1977).

The mollusks *Chlamys spillmani* (Gabb, 1860), *Turritella alveata* Conrad, 1854? and the echinoid *Oligopygus haldemani* (Conrad, 1850) were identified from the Ocala Limestone. These species have been reported from upper Eocene deposits in the Gulf Coast, Florida, and Georgia by Bowles (1939), Cooke (1959), and Toulmin (1977). A third mollusk species, *Turritella boycensis* MacNeil, 1984 is found at 398.5 to 397.8 ft, near the top of the Ocala Limestone; this species has been reported from the lower Oligocene Mint Springs Formation in Mississippi by MacNeil and Dockery (1984). This somewhat anomalous occurrence suggests that this species may have a longer range than previously reported, and (or) that strata near the top of the Ocala Limestone may have been deposited near the Eocene-Oligocene boundary.

Unnamed Limestone

An unnamed limestone occurs from 380 to 318 ft in this core. Both dinocysts and mollusks were recovered and identified. Six samples were examined for dinocysts; the assemblages present and the succession of lowest- and highest-occurrence events indicate an age

Table 1. Dinocyst occurrences in the Phred #1 Core

	Ocala	Unnamed Limestone						Peace River Formation															
								undifferentiated Peace River Formation											Wabasso beds			
R4809[1]	FA	EA	EB	BA	EC	ED	BB	HA	AA	CA	CB	CC	CD	DA	BC	AD	AE	DD	AF	DE	AH	CH
Taxon depth (ft)	409	360	356	346	336	331	321	314	313	309	301	293	286	264	249	237	230	212	189	160	143	130
Achomosphaera alcicornu																					X	X
Operculodinium sp.																					X	
Impagidinium patulum																			X			
Operculodinium cf. *giganteum* of Manum																			X			
Nematosphaeropsis labyrinthus																		X	X			
Achomosphaera andalousiensis																	X	X	X		X	X
Multispinula quanta																	X	X	X		X	X
Operculodinium? sp.																	X	X				
Erymnodinium delectabile																	X					
Impagidinium paradoxum																	X					
Nematosphaeropsis rigida																	X					
Pyxidiella? *simplex*																	X					
Apteodinium tectatum																	?r					
Invertocysta spp.																X		X	X		X	X
Melitasphaeridium choanophorum																X	X	X				
Sumatradinium druggii																X						
Labyrinthodinium truncatum															X	X	X	X				
Sumatradinium hispidum															X	X						
Barssidinium spp.															X							
Selenopemphix brevispinosa brevispinosa															X							
Trinovantedinium papulum														?								
Batiacasphaera sphaerica														X	X	X	X	X	X			
Brigantedinium cariacoense														X								
Habibacysta tectata													X									
Spiniferites grp. sp. II													X									
Cerebrocysta sp.												X										
Melitasphaeridium sp.											X								?		X	X
Sumatradinium spp.										?		X		?		X						
Operculodinium israelianum									X											X	X	
Pentadinium sp. cf. *P. laticinctum granulatum*									X				X	X		X						
Impagidinium sphaericum									?													
Cannosphaeropsis n. sp.									X													
Nematosphaeropsis sp.									X													
Hystrichosphaeropsis obscura								X	X	X	X	X	X	X	X	X	X					
Selenopemphix spp.								X		X							X					
Sumatradinium soucouyantiae								X			X					X						
Trinovantedinium spp.								X	X						X		X					
Exochosphaeridium sp.								X	X	X	X	X	X			?r						
cf. *Pentadinium goniferum*								X														
Reticulatasphaera actinocoronata							X	X			X				X				X			X
Palaeocystodinium golzowense							X			X	X				X							
Deflandrea spinulosa							X															
Phthanoperidinium multispinum							X															
Turbiosphaera n. sp.							X															
Tuberculodinium vancampoae							cf	X	cf	X	X	X	X	X	X	X	X	X	X	X	X	X
Cordosphaeridium fibrospinosum						X	X	X	X				X									
Apteodinium australiense						X		X		X												
Operculodinium placitum						X				cf	cf											
Operculodinium divergens						X	X															
Deflandrea heterophlycta						X																

[1] U.S. Geological Survey Paleobotanical Number (e.g.: RA4809 FA).
X present
? questionably present
cf specimen present compares with named taxon

Table 1. (continued) Dinocyst occurrences in the Phred #1 Core

	Ocala	Unnamed Limestone						Peace River Formation														
								undifferentiated Peace River Formation											Wabasso beds			
R4809[1]	FA	EA	EB	BA	EC	ED	BB	HA	AA	CA	CB	CC	CD	DA	BC	AD	AE	DD	AF	DE	AH	CH
Taxon depth (ft.)	409	360	356	346	336	331	321	314	313	309	301	293	286	264	249	237	230	212	189	160	143	130
Lanternosphaeridium cf. *L. lanosum*						X																
Cribroperidinium tenuitabulatum					X			X	X	X	X	X	X									
Ascostomocystis potane				X	X		X															
Phthanoperidinium comatum				X		X																
Tuberculodinium n. sp.				X	X	X																
Cordosphaeridium inodes				X	X																	
Achilleodinium biformoides				X																		
Distatodinium virgatum				X																		
Wetzeliella gochtii				X																		
Heteraulacacysta spp.			X		X			X	X	X	X	X	X	X								
Distatodinium paradoxum?			X			X		X				X	X									
Cyclopsiella vieta			X	X	X	X	X															
Kallosphaeridium biornatum			X	X	X																	
Cordosphaeridium gracile			X																			
Dapsilidinium pseudocolligerum		X		X		X	X	X	X			X		X		X	X	X			X	X
Hystrichokolpoma rigaudiae		X	X	X	X	X	X	X	X	X	X	X	X	X				X		X	X	X
Spiniferites mirabilis		X	X				X	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
Lejeunecysta spp.		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Systematophora placacantha		X	X	X	X	X	X			X	X	X	X	X	X	X	?r		?r			
Cordosphaeridium cantharellus		X	X	X			X	X			?	X										
Tectatodinium spp.		?						X														
Charlesdowniea coleothrypta		X	X	X		X	X															
Deflandrea phosphoritica		X	X	X		X	X															
Homotryblium plectilum		X	X	X	X	X	X															
Membranophoridium aspinatum		X	X			X	X															
Pentadinium laticinctum		X	X	X	X	X	X															
Thalassiphora pelagica		X	X	X		X	X															
Microdinium group spp.		X				X																
Cribroperidinium giuseppei		X	X	X																		
Lentinia spp.		X		X																		
Phthanoperidinium echinatum		X		X																		
Glaphyrocysta semitecta		X																				
Homotryblium vallum		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
Operculodinium centrocarpum s.l.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Polysphaeridium zoharyi	X		X	X	X	X	?	X	?	?	X	X	X	X	X	X	X	X	X	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
Spiniferites pseudofurcatus	X		X	X	X	X	X	X				X		X	X	X		X		X		
Hystrichokolpoma spp.	X														X	X	X					
Areoligera spp.	X			X		X	X															
Samlandia chlamydophora	?	X	X	X		X	X															
Cyclopsiella chateauneufii	X			X		X																
Diphyes colligerum	X	X		X	X	X																
Impagidinium dispertitum	X					X																
Enneadocysta arcuata	?	X	X	X	X																	
Distatodinium ellipticum	X			X																		
Melitasphaeridium pseudorecurvatum	X		X																			
Batiacasphaera compta	X																					
Hemiplacophora? n. sp.	X																					
Rottnestia borussica	X																					
Saturnodinium? n. sp.	X																					

[1] U.S. Geological Survey Paleobotanical Number (e.g.: RA4809 FA).
X present
? questionably present
cf specimen present compares with named taxon

Table 2: Molluscan Occurrence in Phred #1 Core (W-13958)

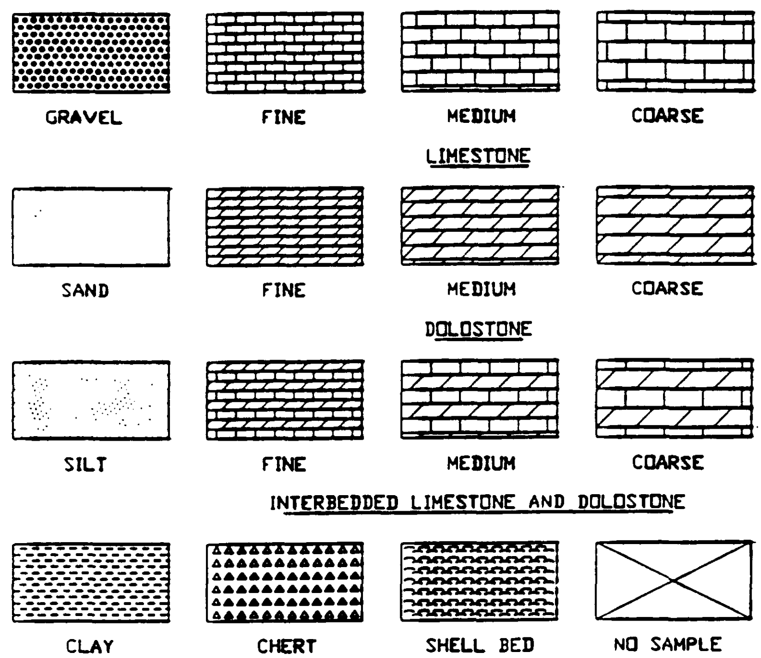
	Species Name[1]	Ocala Limestone						Unnamed Limestone		Okee-chobee unit [2]			Anastasia Formation?		
		409.3'-409'	407.4'	398.3'-398.5'	397.8'	392'	387'	351'	345.6'-346.1'	122.5'	120'	114'	70-75'	60-65'	30-35'
	Mollusks:														
Pleistocene to Holocene Assemblage	*Chione grus* (Holmes, 1858)														X
	Glycymeris americana (Defrance, 1826)														X
	Macrocallista maculata (Linné, 1758)														X
	Pleuromeris tridentata (Say,1826)														X
	Anachis sp.												X	X	?
	Anadara transversa (Say, 1822)												X	X	X
	Crepidula convexa Say, 1822												X	X	X
	Donax variablis Say, 1822												X	X	X
	Mactra fragilis Gmelin, 1791											X	X	X	X
	Mitrella ? sp.													X	X
	Mulinia lateralis (Say, 1822)												X	X	X
	Olivella mutica (Say, 1822)												X	X	X
	Acteocina candei (d'Orbigny, 1841)												X	X	
	Cerithium sp.												X	X	
	Anachis obesa (C.B. Adams, 1845)												X		
	Bittium varium (Pfeiffer, 1840)												X		
	Turbonilla sp.												X		
	Nuculana acuta (Conrad, 1832)									X	X	X	X		
	Linga amiantus (Dall, 1901)											X			
	Linga multilineata (Tuomey & Holmes, 1856)									X	X	X			
Lower Oligocene Assemblage	*Turritella caelatura* Conrad, 1848 ?								X						
	Turritella caseyi MacNeil, 1984 ?								X						
	Chlamys brooksvillensis Mansfield, 1937							X							
	Turritella boycensis MacNeil, 1984			X	X										
Upper Eocene Assemblage	*Chlamys spillmani* (Gabb, 1860)		X				X								
	Turritella alveata Conrad, 1854 ?	X													
	Echinoderm:														
	Oligopygus haldemani (Conrad, 1850)					X									

[1] Listed in order of occurrence within the core.

[2] Informal Okeechobee lithologic unit (proposed by Scott, 1992).

EXPLANATION

HATCHING PATTERNS



COMMENTS

M	MICRITE	T	SILT
S	SAND	C	CLAY
P	PHOSPHATE GRAVEL	Sh	SHELL
p	PHOSPHATE SAND	D	DOLOSTONE
O	ORGANICS	L	LIMESTONE
R	SPAR	H	HEAVY MINERALS
I	IRON STAIN	NO SPL	NO SAMPLE
Q	QUARTZ	G	GYPSUM
A	ANHYDRITE	Py	PYRITE
Ch	CHERT		

Figure 4a: Lithologic symbols used in Figure 4b.

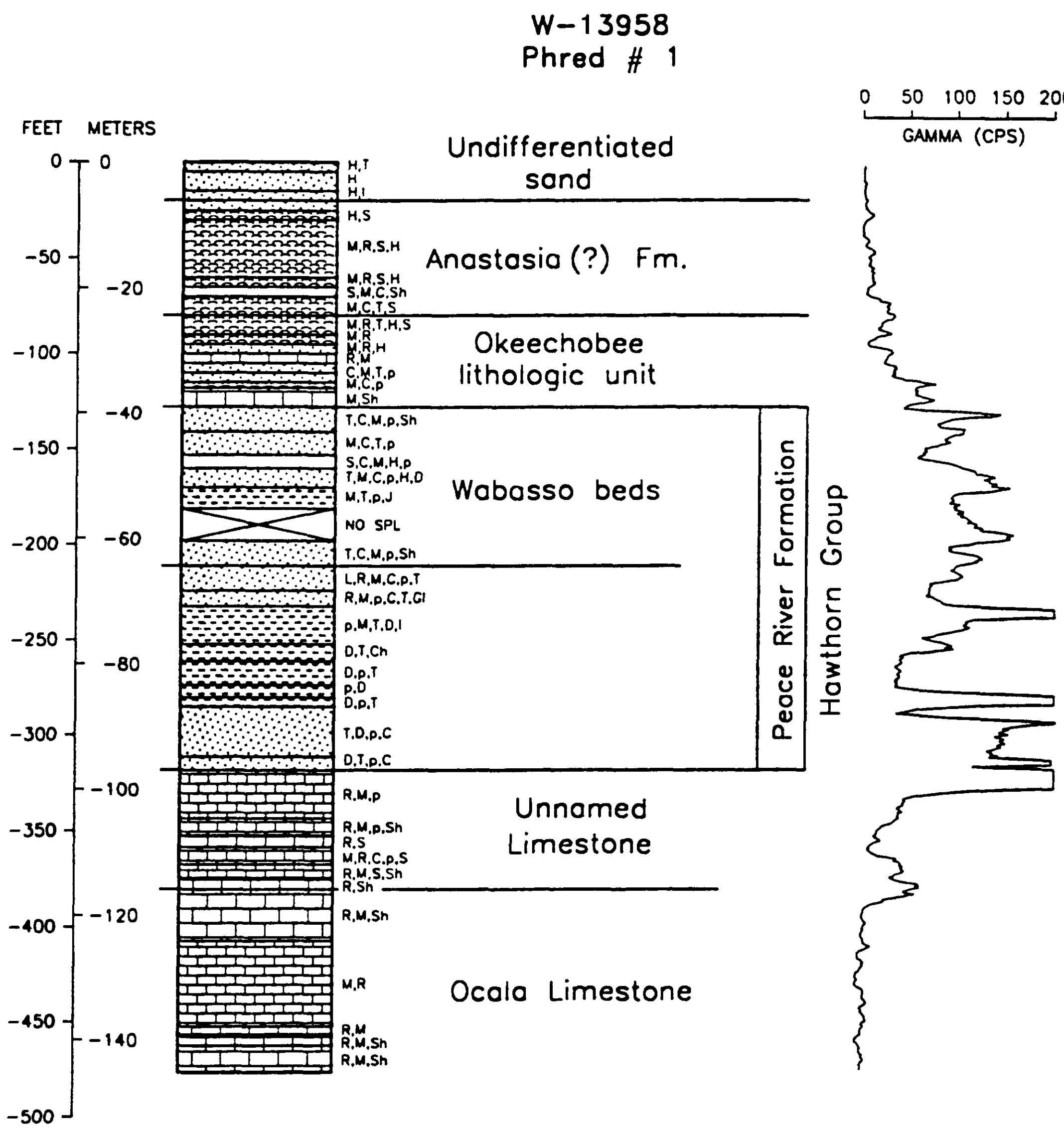


Figure 4b: Lithologic column and gamma ray log for the Phred #1 corehole.

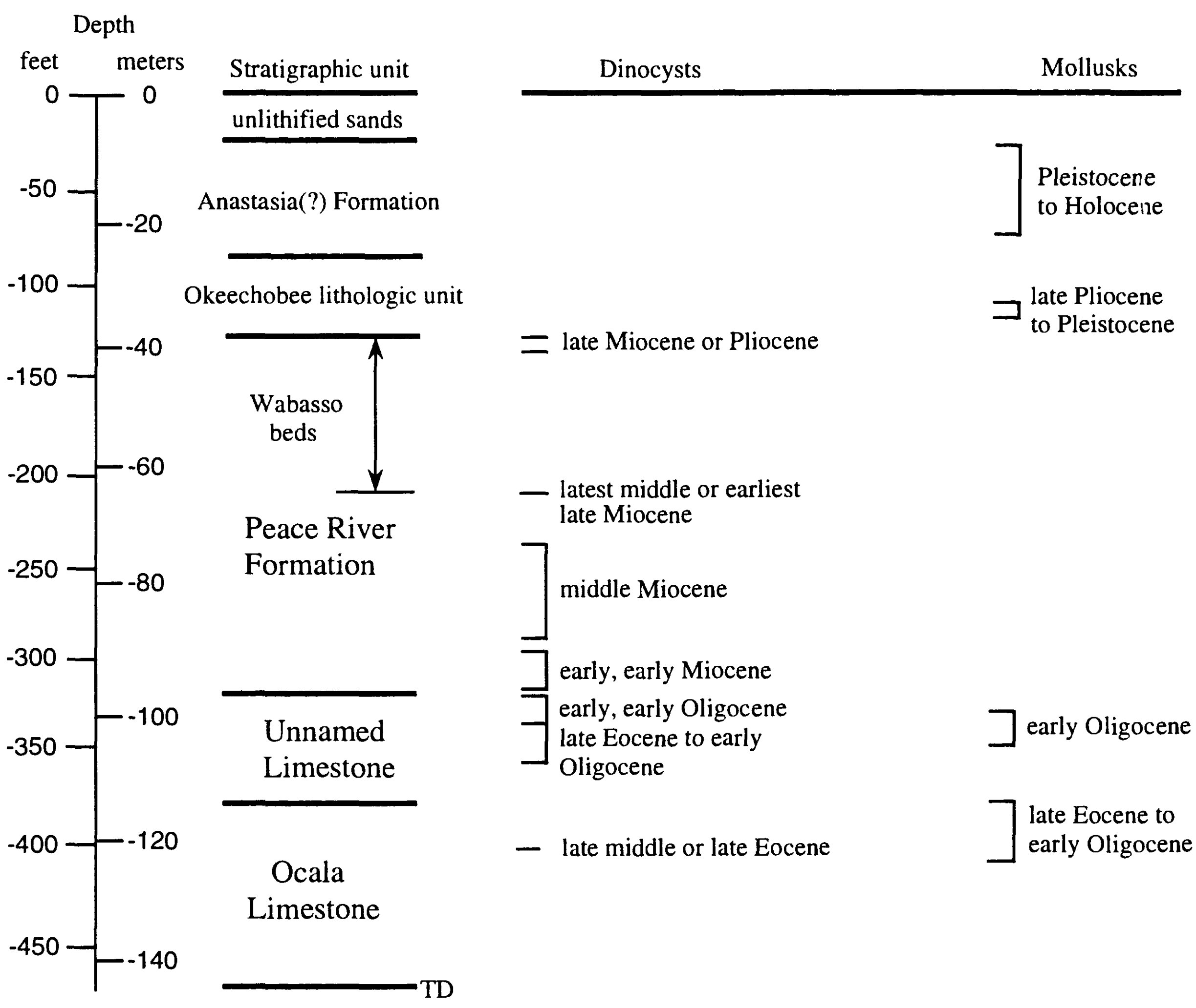


Figure 4c. Distribution of faunal and floral age data.

near the Eocene-Oligocene boundary. Based on the lowest occurrence of *Glaphyrocysta semitecta* (Bujak) Lentin & Williams and dinocyst correlation with the newly ratified Eocene-Oligocene stratotype at Massignano, Italy (Brinkhuis and Biffi, 1993), the Eocene-Oligocene boundary lies below the sample at 360.8 to 360 ft, and all studied samples are of Oligocene age. Important dinocyst lowest- and highest-occurrence datums in the lower Oligocene in this interval include the highest occurrences of *Melitasphaeridium pseudorecurvatum* (Morgenroth) Bujak et al., *Ennaedocysta arcuata* (Eaton) Stover & Williams, and *Diphyes colligerum* (Deflandre & Cookson) Cookson, and the lowest occurrences of *Ascostomocystis potane* Drugg & Loeblich, *Kallosphaeridium biornatum* Stover, *Operculodinium placitum* Drugg & Loeblich, *Operculodinium divergens* (Eisenack) Stover & Evitt, and *Reticulatasphaera actinocoronata* (Benedek) Bujak & Matsuoka. *Charlesdowniea coleothrypta* (Williams & Downie) Lentin & Vozzhennikova, typically considered an Eocene form, is present in the highest sample (321.6 to 321.1 ft). The assemblages present indicate correlation with several Oligocene units such as the uppermost Shubuta Member of the Yazoo Formation, the Bumpnose Formation, the Red Bluff Formation, and (or) the Marianna Limestone in the Gulf Coast (Edwards, unpubl. data).

The molluscan assemblage observed in the unnamed limestone also indicates deposition during the early Oligocene. *Chlamys brooksvillensis* Mansfield, 1937 has been reported from the Suwannee Limestone (Mansfield, 1937); *Turritella caelatura* Conrad, 1848? and *Turritella caseyi* MacNeil, 1984? have been reported from the lower Oligocene Mint Spring Formation in Mississippi (MacNeil and Dockery, 1984). *T. caelatura* and *C. brooksvillensis* also have been identified in Suwannee Limestone deposits in the Ellaville #1 core (W-10657) near the type area of the Suwannee Limestone in Suwannee County in northern Florida (Wingard, unpublished data); their presence in both units indicates that the unnamed limestone may be correlative, at least in part, with the type Suwannee Limestone. Despite apparent age equivalence, we do not call this limestone the Suwannee Limestone because of its quartz sand and silt, and phosphatic grain content, which are absent in the type Suwannee Limestone.

Hawthorn Group, Peace River Formation

Sediments of the Hawthorn Group occur from 318 to 128 ft. Only dinocysts were recovered from this interval; they indicate that the age of the base of the Peace River Formation is early, but not the earliest part of, early Miocene. Consequently, there is a major unconformity between the top of the unnamed limestone and the base of the Peace River Formation in this core; sediments representing most of the Oligocene and the earliest Miocene are not present. The overlap in ranges of *Sumatradinium soucouyantiae* de Verteuil & Norris and *Cordosphaeridium cantharellus* (Brosius) Gocht in the samples from 314 to 293 ft places these in zone DN 2 of de Verteuil & Norris (in press), which they calibrate to 21.4 to 19.7 Ma (early Miocene). The sample at 286 ft is middle Miocene, based on the lowest occurrence of *Habibacysta tectata* Head et al. The co-occurrence of this species with *Distatodinium paradoxum* (Brosius) Eaton, an unnamed species of *Exochosphaeridium*, and *Cordosphaeridium fibrospinosum* suggests the presence of an unconformity below this sample. Because these species previously have not been reported together, the interval where they were collected may be a lag deposit.

The dinocyst asemblages suggest that another unconformity may be present between 237 and 230 ft. The highest occurrence (237 ft) of *Systematophora placacantha* (Deflandre & Cookson) Davey et al. marks the top of zone DN 5 of de Verteuil and Norris (in press) in the middle part of the middle Miocene. The lowest occurrence (230 ft) of *Achomosphaera* *andalousiensis* Jan du Chêne lies within or at the base of their zone DN 8 near the middle/late Miocene boundary. Other authors (Powell, 1992; Williams and others, 1993) indicate an overlap of the ranges of these two species in the middle Miocene. The overlap in the ranges of dinocysts *Labyrinthodinium truncatum* and *Achomosphaera andalousiensis* indicate an age range in the latest middle Miocene or the late Miocene.

Huddlestun (1988) presents convincin [illegible] aminiferal evidence that Wabasso beds (from 211 to 128 ft) in the Phred #1 core are lowe [illegible] e, and were deposited in an open marine, continental shelf environment. In the zona [illegible] Verteuil and Norris (in press), the overlap of *A. andalousiensis* and *Dapsilidinium pseudocol* [illegible] would place these beds in either their zone DN 8 or DN 9, both of late Miocene age, whe [illegible] highest occurrence of *Hystrichosphaeropsis obscura* Habib below these beds [illegible] ould place them in their zone DN 10 or higher (latest Miocene or younger).

Pliocene, Pleistocene, and Holocene(?) sediments

This interval, from 128 ft to the top of the core, was not sampled for dinocysts, however, mollusks were sampled and identified. The mollusks in the upper 128 ft can be divided into two assemblages. The first assemblage is seen in three samples from 122.5 to 114 ft, and is represented by a poorly preserved, sparse, low-diversity fauna. Only three species could be identified: *Nuculana acuta* (Conrad, 1831), *Linga amiantus* (Dall, 1901) [= *L. waccamawensis* (Dall, 1903)] and *Linga multilineata* (Tuomey and Holmes, 1857). These species all range from late Pliocene or early Pleistocene to Recent (Portell and others, 1992, report that *L. amiantus* is extinct) in Gulf Coast and Atlantic Coast deposits. In Florida these three species are reported from the Caloosahatchee, Bermont, and Ft. Thompson faunal units, which correspond to the proposed informal Okeechobee lithologic unit (usage after Scott, 1992). The molluscan assemblage in this portion of the core could correlate to any of those three faunal units, and is late Pliocene to Holocene on the basis of the published ranges of the three identified species. However, none of these species has been reported from the Tamiami Formation. Consequently, there is no molluscan evidence of the occurrence of the Tamiami Formation in this part of Indian River County, as indicated by Schiner and others (1988) and Frazee and Johnson (1983).

The second assemblage in the upper portion of the core is seen in three samples from 75 to 30 ft; the mollusks are extremely well preserved (color bands are still present on many specimens), relatively diverse, and abundant. The mollusks are so abundant in some beds that they constitute the dominant component of the sediment and little to no siliciclastic sediment is present. The distribution of mollusks in this portion of the core indicates a shallowing upward sequence. The sample at 35 to 30 ft is representative of a beach assemblage; the assemblage at 65 to 60 ft is typical of a shallow nearshore environment; the sample at 75 to 70 ft contains a significant number of grass-dwelling gastropods and pelecypods indicating quiet water deposition, perhaps farther offshore than the sample at 65 to 60 ft, but still fairly shallow. All of the species present in this interval range from early Pleistocene to Holocene, with the exception of *Donax variablis* Say, 1822, which has been reported only from upper Pleistocene to Holocene units. Of the eighteen species recorded in this portion of the core, six have been reported from the Caloosahatchee faunal unit (Dubar, 1958), nine from the Bermont faunal unit (Portell and others, 1992), eight from the Fort Thompson faunal unit (Portell and others, 1992), and two from the Anastasia Formation (Lovejoy, 1992). None of the species present has been reported from the Tamiami Formation. Although this assemblage has some affinities to all of the southern

Florida Pleistocene units, the abundance of *Donax variablis* and the pristine preservation of most of the shells indicate that this unit most likely correlates with the uppermost Pleistocene Anastasia Formation, or that it represents Holocene deposition. The stratigraphic and geographic position of the sediments indicate that the section from 80 to 20 ft correlates with the Anastasia Formation.

PETROGRAPHY

The bulk composition of samples from this core was determined with X-ray diffraction (Table 3). Analysis of the clay-sized fraction indicates several mineralogical zones. Below 318 ft, the primary mineral of the Ocala Limestone and the unnamed limestone is calcite; minor amounts of illite occur as a secondary mineral. A second zone, dominated by palygorskite, sepiolite, and dolomite, all magnesium-rich minerals, occurs from 318 ft , near the base of the Peace River Formation, to about 236 ft. From 236 to 128 ft (primarily the Wabasso beds and the underlying sands) is a third zone characterized by dolomite, calcite, and illite. The largely unconsolidated sand, clay, and shells in the upper 121 ft were not sampled for X-ray diffraction due to possible contamination from corehole walls and drilling mud.

Thin section analysis of twelve samples from this core are described in Appendix 3, and listed in the comment column of Appendix 1. Emphasis has been given to the diagenetic processes related to subaerial exposure, dissolution, and dolomitization, because these processes tend to control porosity and permeability. The units sampled include the Ocala Limestone, the unnamed limestone, the Peace River Formation (of the Hawthorn Group), and the Okeechobee lithologic unit.

Samples range from wackestones to grainstones in texture, i.e., all samples contained at least 10% skeletal grains, and most have a micrite matrix, using the Dunham (1962) classification (shown at the end of Appendix 3). Porosity is generally either interparticle and (or) leached-grain type in the wackestones and packstones. Quartz, feldspar, and phosphate silt and sand, the dominant grain type in the Peace River Formation, are present but rare constituents of the unnamed limestone; silt and sand are not observed in thin sections below depths of 346 ft (105 m), though they are documented in hand sample down to 374 ft in the lithologic descriptions of Appendix 1.

Most skeletal grains in the carbonates of the unnamed limestone and the Ocala Limestone have been micritized to some degree, probably soon after deposition in the marine environment, which obscures their internal structures. Intergranular calcite cement is rare and occurs in very small quantities, generally as a single layer of blocky or dogtooth crystals; porosity is rarely occluded by calcite cement. Syntaxial calcite overgrowth cement commonly is observed on echinoid fragments, and in some samples, seems to be the primary grain-binding cement. Primary skeletal voids (such as foraminiferal chambers) as well as leached skeletal voids (intragranular pores) commonly either are mud-filled or empty. Dolomitization, which is quite common in the limestones of the Peace River and Arcadia Formations on the west coast (Wingard and others, 1994), is rare at this site on the east coast. Dolomite was not observed in thin section, although it was detected in X-ray analysis of the siliciclastic portions of the core.

All samples have experienced some degree of dissolution of skeletal fragments derived from aragonitic mollusks (gastropods and some pelecypods). The widespread occurrence of minor dissolution textures suggests that contact with meteoric waters (perhaps subaerial exposure) may have occurred in the history of these rocks. However, the dissolution has affected

Table 3: X-ray Diffraction Data

Depth (feet)	Major minerals	Minor minerals	Formation
120.9	calcite, quartz	illite/smectite, illite, kaolinite	Okeechobee lith. unit
128.0-129.0	calcite		Wabasso beds of the Peace River Formation
138.0	calcite	illite, dolomite	
143.0	calcite		
145.3	dolomite,calcite	illite	
150.0	gypsum		
154.9	dolomite	calcite, illite, quartz	
171.0	dolomite	quartz	
180.5-181.0	illite		
187.5	dolomite		
189.0	dolomite,illite,calcite	gypsum	
225.5	dolomite,illite,calcite		Peace River Formation
236.0	palygorskite, sepiolite		
240.3-240.5	dolomite	sepiolite, palygorskite	
243.6	sepiolite, palygorskite		
246.5	sepiolite, palygorskite		
253.0	palygorskite, sepiolite	quartz, gypsum	
265.0	palygorskite, sepiolite		
269.0	palygorskite, sepiolite		
274.5	palygorskite, sepiolite	dolomite	
278.8	dolomite		
280.3	sepiolite, palygorskite		
286.0	sepiolite, palygorskite		
295.0	dolomite	sepiolite?	
303.0	dolomite		
308.5	sepiolite	dolomite	
313.5	dolomite	palygorskite	
314.0-318.0	dolomite	sepiolite	
321.8	calcite		unnamed limestone
328.0	calcite		
335.5	calcite		
358.5	calcite	illite/smectite	
363.0	calcite		
377.0	calcite		
382.5	calcite		Ocala Limestone
442.0	calcite		

primarily the aragonitic mollusks; small foraminifers show some dissolution textures in only three samples examined in thin section, and all other skeletal groups are largely unleached. Dissolution of aragonitic skeletal grains alone, however, is not sufficient evidence of subaerial exposure; marine-water dissolution of aragonite has been demonstrated (Melim and others, 1995). The presence of aragonite-grain porosity, however, does suggest that mineralogical stabilization (i.e., the conversion of aragonite to calcite with shell-structure preservation) did not occur before dissolution; dissolution of aragonitic skeletal grains is ubiquitous in Tertiary carbonates in Florida (Weedman, 1995). Compared to the South Venice core examined on the west coast of Florida (Wingard and others, 1994), this core exhibits no extremely leached samples (Table 4). In fact, samples from 128 ft and shallower in the Phred #1 core have fragments of primary aragonitic mollusks still preserved. In addition, soil textures and other signs of subaerial exposure, observed in the South Venice core (Wingard and others, 1994), have not been observed in thin sections from the Phred #1 core. Extensive dissolution was observed in the South Venice core from 240 to 81 ft depth, at the top of the Arcadia Formation, spanning rocks that are lower to middle Miocene.

SUMMARY

The Phred #1 core is poorly indurated with incomplete recovery and has been heavily sampled; consequently, much valuable sedimentologic and paleontologic information has been lost and interpretation is somewhat limited. However, we have been able to constrain the age of deposition and the occurrence of unconformities quite well. Dinocyst and molluscan data document that the sediments in the Phred #1 core are upper Eocene to Pleistocene or perhaps Holocene, and data from both fossil groups are consistent.

Dinocyst and molluscan data all consistently support a late Eocene age for the Ocala Limestone. In addition, there is some indication in the molluscan assemblage that the Eocene-Oligocene boundary may occur within the Ocala Limestone. The formation is typically a limestone, with no quartz sand, phosphate grains, or dolomite. Thin-section examination reveals little evidence of meteoric leaching of skeletal grains. There is no evidence from faunal or petrographic observations that there might be an unconformity within or at the top of the Ocala Limestone.

Dinocyst and molluscan data indicate that the unnamed limestone that overlies the Ocala Limestone was deposited during the earliest part of the early Oligocene. The unnamed limestone appears to be, in part, time-equivalent with the Suwannee Limestone in southwestern Florida and in the type area, but differs in lithologic characteristics. The unnamed limestone contains quartz silt and sand, and phosphatic grains that the type Suwannee Limestone lacks. Suwannee Limestone deposition in southwest Florida probably extended through a significant part of the early Oligocene, whereas deposition of the unnamed limestone appears to be limited to the earliest Oligocene. This informal unit is entirely limestone with minor amounts of illite and smectite. The absence of extensive leaching within and at the top of the unnamed limestone, despite the indication of a major unconformity there, indicates that there may not have been subaerial exposure, and that erosion that removed the missing section may have been subaqueous.

Unconformably overlying the unnamed limestone is the Peace River Formation of the Hawthorn Group. The Arcadia Formation, which generally occurs at this stratigraphic position, is absent in this core. The age of the Peace River Formation, as indicated by dinocysts, ranges from early to late Miocene or Pliocene; Huddlestun's (1988) foraminiferal data from the Wabasso

Table 4. Dissolution of Skeletal Grains

Depth (ft)	Formation	Lithology	Aragonitic mollusks	Foraminifers	Bryozoans	Ostracodes	Calcareous mollusks	Echinoids	Red algae
128	Okeechobee lith. unit	limestone	XXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX
318	unnamed limestone	limestone	....	XXXXXXX		XXXXXXX		XXXXXXX	
343	unnamed limestone	limestone	....	XXXX			XXXXXXX	XXXXXXX	XXXXXXX
346	unnamed limestone	limestone	....	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	
350	unnamed limestone	limestone	....	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	
357	unnamed limestone	limestone		XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	
380	Ocala Limestone	limestone	....	XXXX		XXXXXXX		XXXXXXX	XXXXXXX
387	Ocala Limestone	limestone		XXXX				XXXXXXX	
438	Ocala Limestone	limestone		XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX
453	Ocala Limestone	limestone		XXXXXXX	XXXXXXX			XXXXXXX	XXXXXXX
462	Ocala Limestone	limestone		XXXXXXX			XXXXXXX	XXXXXXX	XXXXXXX

.... Dissolved skeletal grain

.......XXXX Partially dissolved skeletal grain

XXXXXXX Skeletal grain present, any dissolution present not resolvable at the petrographic scale.

beds in this same core, further refine the age of the top of the Peace River Formation to early Pliocene. Therefore, a portion of the Peace River Formation on the east coast is time-equivalent with a portion of the upper Oligocene to middle Miocene Arcadia Formation on the west coast of Florida, at the South Venice (W-16814) corehole (Wingard and others, 1994). Consequently, siliciclastic deposition of the Peace River Formation was occurring on the east coast of the Florida peninsula while carbonate deposition of the Arcadia Formation was occurring on the west coast.

Molluscan data indicate that the sediments in the upper 128 ft of the core are upper Pliocene or lowest Pleistocene to possibly Holocene, and that the sediments from 80 ft and shallower are probably no older than late Pleistocene. This interval is differentiated into the informal Okeechobee lithologic unit (usage of Scott, 1992), the Anastasia(?) Formation, and undifferentiated unlithified sands. We note unaltered remnants of aragonitic mollusks, typically preserved in sediments of this age, in thin section at 128 ft, and in hand samples from 80 ft and shallower.

The biostratigraphic data collected in this study suggest the occurrence of three unconformities in the Phred #1 corehole. The first is indicated at the contact between the unnamed limestone and the overlying Peace River Formation, where sediments containing dinocysts from the early, but not earliest part of, the early Miocene overlie a limestone that contains dinocysts and mollusks from the early or middle part of the early Oligocene. Consequently, there are no upper lower Oligocene to lowest Miocene sediments preserved in this core. A second unconformity occurs within the lower portion of the Peace River Formation, where a claystone containing middle Miocene dinocysts overlies a sandstone containing dinocysts from the early part of the early Miocene, indicating that part of the early Miocene is unrepresented. A third unconformity is indicated at the top of the Peace River Formation by molluscan data from this study coupled with foraminiferal data from a previous study. Near the base of the informal Okeechobee lithologic unit, a late Pliocene to Holocene assemblage of mollusks overlie, within 6 feet, lower Pliocene sediments of the Wabasso beds of the Peace River Formation (Huddlestun, 1988). The absence of the Pliocene Tamiami Formation and its associated fauna is additional evidence of the unconformity at the top of the Peace River Formation.

There has been very little diagenetic alteration of these sediments other than minor dissolution of aragonitic mollusks and a few foraminifers, and minor precipitation of calcite sparry cement on void surfaces and as echinoid overgrowths. The presence of dolomite in the poorly lithified siliciclastic portions of this core indicates minor dolomite cementation. The relatively unaltered nature of this core stands in stark contrast to the extensively dolomitized and leached, middle to upper Miocene section of a core on the west coast of Florida at the South Venice corehole site (Wingard and others, 1994).

This report is a preliminary compilation of integrated lithostratigraphy, biostratigraphy, and petrographic data. Without the combination of two independent age indicators, the age of these lithologic units could not have been refined. Dinocysts are particularly abundant and diverse in this core, giving us good age control in much of the core, and molluscan occurrences in the upper 128 ft have allowed us to subdivide this section, which was previously undifferentiated. Other reference cores will be examined in a similar way to determine the spatial and temporal correlation of the subsurface lithostratigraphic units in southern Florida.

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APPENDIX 1

ANNOTATED CORE LOG

The left side of the page contains summary comments and age information. The right side of the page is the litholog of the Florida Geological Survey for the Phred #1 core, W-13958.

Comments | **Age Indicators**

0-20': Undifferentiated and unlithified sand; no macrofossils.

20': top of the Anastasia(?) Formation

20-80': Mollusks preserved predominantly as unaltered aragonite.

Source: Florida Geological Survey

Well number: W-13958
Total depth: 476 ft.

County: Indian River
Location: T32S R39E S16 cb
Lat. = 27° 41' 50"
Long. = 80° 26' 09"
Elevation: 23 ft

Completion date: 3/78
Other types of logs available: caliper, gamma, temperature, electric

Owner/driller: Florida Geological Survey [Phred #l]

Worked by: Thomas M. Scott (9/82; 2/95)
128-211' is the informal Wabasso beds of the Peace River Formation.
211-318' is an unnamed member of the Peace River Formation.
Additional internal formation picks (T. Scott) added by S. Campbell derived from F.G.S. Information Circular #103, p. 155. Core is heavily sampled and broken up.

0	-	20	090udss	Undifferentiated sand
20	-	80		Anastasia (?) Formation
80	-	128		Okeechobee lithologic unit
128	-	318	122htrn	Hawthorn group
128	-	318	122pcrv	Peace River Fm.
128	-	211	Wabasso	Wabasso beds
318	-	380	1230lgc	Unnamed limestone
380	-	t.d.	1240cal	Ocala Limestone

0 - 5 Sand; light brownish gray.
35% porosity: intergranular.
Grain size: medium; range: fine to coarse.
Roundness: sub-angular to rounded; unconsolidated.
Accessory minerals: heavy minerals, 1%; silt, 1%.

5 - 10 Sand, transparent.
35% porosity: intergranular.
Grain size: medium; range: medium to coarse.
Roundness: angular to sub-angular; unconsolidated.
Accessory minerals: heavy minerals, 1%.

10 - 15 Same as above

15 - 20 Sand; moderate brown.
35% porosity: intergranular.
Grain size: medium; range: medium to coarse.
Roundness: angular to sub-angular; unconsolidated.
Accessory minerals: iron stained.
Scattered mollusks.

20 - 25 Sand; very light gray.
35% porosity: intergranular.
Grain size: medium; range: fine to medium.
Roundness: angular to sub-angular; unconsolidated.
Accessory minerals: heavy minerals, 1%.
Fossils: mollusks; *Donax* abundant.

Comments

25-60': *Donax variabilis*-dominated molluscan assemblage, typical of a beach deposit. Shells are pristine; color bands are preserved on many specimens.

60-65': Molluscan assemblage dominated by *Mulinia lateralis* and *Mactra fragilis;* typical shallow, near-shore assemblage.

70-75': Molluscan asemblage dominated by *Mactra fragilis* with a significant number of grass-dwelling gastropods and pelecypods. This assemblage indicates quiet-water deposition, perhaps farther offshore than samples at 60-65', but still fairly shallow.

Age Indicators

30-70': Molluscan assemblage indicates Pleistocene to Holocene. Presence of *Donax variabilis* and nature of preservation implies late Pleistocene to Holocene. This interval may correlate to Anastasia Formation.

80': top of the informal Okeechobee lithologic unit (usage of Scott, 1992)

80-128': Aragonitic mollusks are leached (as seen in hand sample).

25 - 30	Shell bed; very light gray to light gray. 30% porosity: intergranular; unconsolidated. Accessory minerals: heavy minerals, 1%, quartz sand. Fossils: mollusks.
30 - 35	Shell bed; pinkish gray. 25% porosity: intergranular, moldic, pin point vugs unconsolidated. Cement type(s): calcilutite matrix, sparry calcite cement. Accessory minerals: quartz sand, heavy minerals, 1%. Fossils: mollusks, unconsolidated shell; *Donax* dominated.
35 - 40	Same as above (in bags).
40 - 45	Same as above, unconsolidated shell hash (in bags).
45 - 50	Same as above, unconsolidated shell hash. Mostly pelecypods, some gastropods (in bags).
50 - 55	Same as above, unconsolidated shell hash (in bags).
55 - 60	Same as above unconsolidated shell hash (in bags).
60 - 65	Shell bed; pinkish gray. 30% porosity: intergranular, poor induration. Cement type(s): calcilutite matrix, sparry calcite cement. Accessory minerals: quartz sand, heavy minerals, 1%. Fossils: mollusks.
65 - 70	Silt; light olive gray. 3% porosity: intergranular, moldic, pin point vugs. Poor induration. Cement type(s): calcilutite matrix, clay matrix. Accessory minerals: clay, quartz sand 35%. Fossils: mollusks, benthic foraminifera.
70 - 75	Shell bed; olive gray. 5% porosity: intergranular, moldic, pin point vugs. Poor induration. Cement type(s): calcilutite matrix, clay matrix. Accessory minerals: clay, silt, quartz sand. Fossils: mollusks, benthic foraminifera.
75 - 80	Same as above.
80 - 85	Shell bed; light gray. 15% porosity: intergranular, moldic, pin point vugs. Poor induration. Cement type(s): calcilutite matrix, sparry calcite cement. Accessory minerals: silt (trace), heavy minerals, 1%; quartz sand (trace). Fossils: mollusks.
85 - 90	Same as above

Comments

Age Indicators

114-122.5': Molluscan assemblage is a poorly preserved, sparse, low-diversity fauna.

114-122.5': Molluscan assemblage indicates late Pliocene to Holocene. This section contains fauna found in Caloosahatchee, Bermont, and Fort Thompson faunal units, all part of the informal Okeechobee lithologic unit (usage of Scott, 1992).

90 - 95 Shell bed; very light gray to white.
3% porosity: intergranular, moldic, pin point vugs.
Unconsolidated.
Cement type(s): calcilutite matrix, sparry calcite cement.
Accessory minerals: quartz sand, 10%.
Fossils: mollusks.

95 - 100 Sandstone; very light gray.
3% porosity: low permeability, intergranular, moldic, moderate induration.
Cement type(s): calcilutite matrix, sparry calcite cement.
Accessory minerals: heavy minerals, 1%.
Other features: medium recrystallization.
Fossils: mollusks, large gastropod and pelecypod fragments.

100 - 105 Limestone; very light gray.
3% porosity: low permeability, intergranular, moldic.
Grain type: skeletal, biogenic, calcilutite.
60% allochemical constituents, moderate induration.
Cement type(s): sparry calcite cement, calcilutite matrix.
Accessory minerals: quartz sand, 15%.
Other features: medium recrystallization.
Fossils: mollusks.

105 - 110 Sand; very light gray.
5% porosity: intergranular, moldic, pin point vugs.
Grain size: fine; range: very fine to medium roundness: angular to sub-angular, poor induration.
Cement type(s): calcilutite matrix.
Accessory minerals: heavy minerals, 2%.
Other features: calcareous fossils: mollusks, benthic foraminifera, ostracodes, abundant forams.
Grades into lean green.

110 - 115 Sand; light olive gray.
3% porosity: intergranular, moldic, pin point vugs.
Grain size: fine; range: very fine to fine.
Roundness: sub-angular to angular; poor induration.
Cement type(s): clay matrix, calcilutite matrix.
Accessory minerals: clay, quartz silt, phosphatic sand, 2%.
Fossils: mollusks, benthic foraminifera, spicules.

115 - 118 Shell bed; yellowish gray 15% porosity: intergranular, moldic, pin point vugs poor induration.
Cement type(s): calcilutite matrix, clay matrix.
Accessory minerals: quartz sand, 10%; clay, 25%; calcilutite, 20%; phosphatic sand, 1%.
Fossils: mollusks, benthic foraminifera, spicules, aragonite mollusk shells, *Linga*.

Comments / **Age Indicators**

128': Thin section: (Base of the limestone overlying the Wabasso beds.) Packstone/ wackestone. Mollusks (some leached), micritized foraminifers, echinoids, ostracodes, bryozoans, red algae, medium quartz sand (~5%), and no phosphate grains. Some original aragonite mollusk fragments; some phosphatized forminifers. Cements include echinoid syntaxial overgrowths and patches of bladed and blocky calcite within foraminifer chambers.

128': top of the Hawthorn Group

Wabasso beds (128-211')

128-200': Only a few scattered mollusks are present.

129.8-130': Well preserved, moderately diverse dinocyst assemblage dominated by species of *Spiniferites.*

129.8-130': Dinocyst assemblage indicates late Miocene or Pliocene. The overlap of *Achomosphaera andalousiensis* and *Dapsilidinium pseudocolligerum* places this sample in either zone DN 8 or DN 9 of de Verteuil and Norris (in press), both zones are late Miocene. Huddlestun (1988) placed from 211 to 128.5 ft. in this core in his Wabasso beds, and identified early Pliocene foraminifera. If this sample is Pliocene, the occurrence of *D. pseudocolligerum* here would extend its known range.

142.5': Moderately diverse dinocyst assemblage dominated by species of *Spiniferites.* Preservation is fair; blobs of amorphous material are common.

142.5': Dinocyst assemblage indicates late Miocene or Pliocene. In the zonation a de Verteuil and Norris (in press), the overlap of *Achomosphaera andalousiensis* and *Dapsilidinium pseudocolligerum* would place this sample in either their zone DN 8 or DN 9, both of late Miocene age. Huddlestun (1988) placed from 211 -128.5 ft. in this core in his informal Wabasso beds, and identified early Pliocene foraminifera.

118 - 120 Limestone; very light gray.
15% porosity: intergranular, moldic, pin point vugs.
Grain type: skeletal, biogenic, calcilutite.
85% allochemical constituents poor induration.
Cement type(s): calcilutite matrix.
Accessory minerals: quartz sand, 15%.
Fossils: mollusks, benthic foraminifera.

120 - 128 Limestone; very light gray.
15% porosity: intergranular, moldic, pin point vugs.
Grain type: skeletal, biogenic, calcilutite.
50% allochemical constituents poor induration.
Cement type(s): calcilutite matrix.
Accessory minerals: quartz sand, 15%.
Fossils: mollusks, benthic foraminifera 121-123', large mollusks present, oysters, *Anodontia.*

128 - 130 Sand; yellowish gray.
15% porosity: intergranular, moldic, pin point vugs.
Grain size: very fine; range: very fine to fine roundness: angular to sub-angular; poor induration, clay content highly variable.
Cement type(s): calcilutite matrix.
Accessory minerals: silt, calcilutite phosphatic sand, 2%; clay, 20%.
Fossils: mollusks, benthic foraminifera.

130 - 141 Sand; yellowish gray to light olive gray.
10% porosity: intergranular, moldic, pin point vugs.
Grain size: very fine; range: very fine to fine roundness: angular to sub-angular; poor induration.
Cement type(s): calcilutite matrix, clay matrix (clay content varies).
Accessory minerals: clay, 10%; quartz silt, 40%; phosphatic sand, 2%.
Other features: calcareous, dolomitic near 138', may be detrital.
Fossils: spicules, mollusks, benthic foraminifera, (very abundant forams).

141 - 147 Sand; light olive gray to light olive gray.
20% porosity: intergranular, moldic, pin point vugs.
Grain size: fine; range: very fine to coarse roundness: angular to rounded; poor induration.
Cement type(s): calcilutite matrix, clay matrix.
Accessory minerals: phosphatic sand, 2%; silt/clay, 1%.
Other features: calcareous.
Fossils: benthic foraminifera.
Coarse fraction increases with depth.

147 - 153 Sand; light olive gray to light olive gray.
20% porosity: intergranular, moldic, pin point vugs.
Grain size: coarse; range: very fine to coarse roundness: sub-angular to rounded; poor induration.
Cement type(s): clay and calcilutite matrix.
Accessory minerals: phosphatic sand, 1%; clay; quartz silt (trace).

Comments	Age Indicators
160': Well preserved dinocyst assemblage dominated by *Polysphaeridium zoharyi.*	**160'**: Age constraints on the age of this sample are based on dinocyst assemblages from the samples above and below. The highest occurrence of *Spiniferites pseudofurcatus* was given in Head and others (1989) as within the middle part of the late Miocene. Huddlestun (1988) placed from 211 to 128.5 ft in this core in his informal Wabasso beds and identified early Pliocene foraminifera.
189': Moderately diverse dinocyst assemblage dominated by species of *Spiniferites* and *Operculodinium centrocarpum.* Preservation is fair.	**189'** : The highest occurrence of the dinocyst *Labyrinthodinium truncatum* is found in the sample below this one. The presence of *Batiacasphaera sphaerica* suggests a middle or late Miocene (Williams and others, 1993 place the top of this species near the middle-late Miocene boundary; de Verteuil and Norris, in press, place the top higher). Huddlestun (1988) placed from 211 to 128.5 ft in this core in his informal Wabasso beds and identified early Pliocene foraminifera.
200 to 343': No recognizable mollusks are present.	

153 - 160 Silt; light olive gray.
30% porosity: intergranular, moldic; poor induration.
Cement type(s): calcilutite matrix, clay matrix.
Accessory minerals: quartz sand, 40%; heavy minerals, 1%; phosphatic sand, 2%, clay (trace).
Other features: dolomitic at 155'.
Fossils: benthic foraminifera, clay content varies.
Abundant well preserved diatoms at 153.5 feet.

160 - 170 Sand; light olive gray.
30% porosity: intergranular, moldic.
Grain size: very fine; range: very fine to fine roundness: angular to sub-angular; poor induration; clay content varies.
Cement type(s): calcilutite matrix, clay matrix.
Accessory minerals: silt, 40%; heavy minerals, 1%; phosphatic sand, 2%; clay.
Fossils: benthic foraminifera
Varies to silt, becomes dolomitic with depth.

170 - 181 Clay; olive gray.
Porosity: low permeability, intergranular, moldic moderate induration.
Cement type(s): clay matrix, calcilutite matrix.
Accessory minerals: quartz sand,10%; silt (trace), phosphatic sand, 1%; mica, 1%.
Other features: calcareous.
Fossils: fossil molds, diatoms.
Silt and fine quartz sand increase toward 181 ft.

181 - 190 Quartz sand.
Grain size: silt to fine sand.
Accessory minerals: clay, phosphatic sand.
Other features: few fossil fragments.

190 - 198 Missing core.

198 - 200 Sand; light olive gray.
5% porosity: intergranular, moldic, pin point vugs.
Grain size: very fine; range: very fine to fine, roundness: angular to sub-angular, moderate induration.
Cement type(s): clay matrix, calcilutite matrix. clay, 3%; phosphatic sand, 1%.
Fossils: benthic foraminifera, fossil fragments occasional clayey sand lenses.

200 - 211 Sand; transparent to light olive gray.
30% porosity: intergranular, moldic, pin point vugs.
Grain size: coarse; range: fine to very coarse roundness: sub-angular to rounded, poor induration.
Cement type(s): calcilutite matrix, clay matrix accessory minerals: phosphatic sand, 1%, silt.
Other features: calcareous fossils: mollusks.

Comments	Age Indicators
211.9-212.1': Moderately diverse dinocyst assemblage dominated by species of *Spiniferites*. Preservation is fair; blobs of amorphous material are common.	**211.9-212.1'**: The overlap in the ranges of *Labyrinthodinium truncatum* and *Achomosphaera andalousiensis* indicates a narrow age range in the latest middle Miocene or the early part of the late Miocene (DN8-DN9 of de Verteuil and Norris, in press).
230': Moderately diverse dinocyst assemblage dominated by species of *Spiniferites*. Preservation is fair; blobs of amorphous material are common.	**230'**: Dinocyst assemblage indicates probably middle Miocene. Oldest *Achomosphaera andalousiensis* is late in the middle Miocene. Single specimens of *Apteodinium tectatum* and *Systematophora placacantha* are probably reworked.
237-237.1': Moderately diverse dinocyst assemblage with no dominant species. Preservation is fair; blobs of amorphous material are common.	**237-237.1**: Dinocyst assemblage indicates middle Miocene. The youngest occurrence of *Systematopora placacantha* is used by de Verteuil and Norris (in press) to mark the top of their zone DN 5, which they place in the middle Miocene.
248.6-248.8': Moderately diverse, well preserved assemblage of dinocysts with no dominant species.	**248.6-248.8**: Dinocyst assemblage indicates middle Miocene, based on the overlap of *Systematopora placacantha* and *Labyrinthodinium truncatum.*

211 - 212 Limestone; yellowish gray.
3% porosity: intergranular, moldic, pin point vugs.
Grain type: skeletal, biogenic, calcilutite.
75%, allochemical constituents
Moderate induration.
Cement type(s): calcilutite matrix, sparry calcite cement.
Accessory minerals: quartz sand, 35%; phosphatic sand, 1%; silt, trace.
Other features: calcareous fossils: planktonic foraminifera, benthic foraminifera.

212 - 224 Sand; yellowish gray to light olive gray.
15% porosity: intergranular, moldic, pin point vugs.
Grain size: coarse; range: very fine to coarse roundness: angular to rounded; poor induration. Varies to very sandy limestone.
Cement type(s): calcilutite matrix, sparry calcite cement clay matrix.
Accessory minerals: sparry calcite, 30%; phosphatic sand, 2%; clay, 2%, silt (trace).
Fossils: fossil molds, planktonic foraminifera benthic foraminifera, spicules, echinoid.

224 - 230 Sand; light olive gray to yellowish gray.
20% porosity: intergranular, moldic, pin point vugs.
Grain size: coarse; range: very fine to coarse roundness: angular to rounded; poor induration.
Cement type(s): sparry calcite cement, clay matrix, calcilutite matrix.
Accessory minerals: phosphatic sand-10%, clay/silt, trace.
Fossils: planktonic foraminifera, benthic foraminifera, spicules at 228'; is highly bioturbated.

230 - 232 Sand; olive gray to light olive gray.
3% porosity: intergranular, moldic, pin point vugs.
Grain size: coarse; range: very fine to coarse roundness: angular to rounded; poor induration.
Cement type(s): clay matrix, calcilutite matrix.
Accessory minerals: phosphatic sand, 35% ; clay, 30%; glauconite, 2%; silt (trace).
Other features: calcareous fossils: fossil fragments, sharks teeth, few clay lenses. Very phosphatic.

232 - 234 Clay; olive gray to light olive gray porosity: low permeability, intergranular, moldic poor induration.
Cement type(s): clay matrix, calcilutite matrix.
Accessory minerals: phosphatic sand, 35%; quartz sand, 10%; silt, trace.
Other features: calcareous phosphate at higher concentration at 233.5'.

234 - 252 Clay; yellowish gray.
Porosity: low permeability, intergranular, moldic poor induration.
Cement type(s): dolomite cement, clay matrix (kaolinite at 243'; sepiolite and palygorskite at 236' 240' and 243').
Accessory minerals: quartz sand, 10%; phosphatic sand, 3%; silt (trace); iron stain.
Other features: frosted fossils: fossil fragments variable dolomite and phosphate.

Comments	Age Indicators
264.0-264.3': Moderately diverse dinocyst assemblage dominated by *Spiniferites pseudofurcatus.* Preservation is fair; blobs of amorphous material are common.	**264.0-264.3'**: Dinocyst assemblage indicates middle Miocene, below the range top of *Systematophora placacantha.*
285.4-285.8': Moderately diverse, well preserved assemblage of dinocysts with no dominant species.	**285.4-285.8'**: Dinocyst assemblage indicates middle Miocene, based on the lowest occurrence of *Habibacysta tectata.* The overlap of occurrence of *Distatodinium paradoxum* and *Habibacysta tectata* indicate that this sample correlates with the DN 4/DN5 boundary of de Verteuil and Norris (in press).
292.6-292.8': Moderately diverse, moderately well preserved assemblage of dinocysts with no dominant species.	**292.6-292.8'**: Dinocyst assemblage indicates early or middle Miocene. If *Cordosphaeridium cantharellus* is not reworked, the age is the early part of the early Miocene and there is an unconformity between this and the underlying sample.
	-Unconformity(?) indicated by dinocysts here-
300.8-301.1': Moderately diverse, well preserved assemblage of dinocysts dominated by species of *Spinifertes* and *Hystrichokolpoma rigaudiae.*	**300.8-301.1'**: Dinocyst assemblage indicates early or middle Miocene.
308.8-312.8': Moderately diverse, well preserved assemblage of dinocysts dominated by *Cribroperidinium tenuitabulatum.*	**308.8-312.8'**: Dinocyst assemblage indicates early or middle Miocene.

252 - 260 Clay; olive gray.
Porosity: low permeability, intergranular, moldic moderate induration.
Cement type(s): clay matrix (sepiolite and palygorskite), dolomite cement.
Accessory minerals: silt (trace), dolomite, 40%.

260 - 261 Chert; light olive gray to olive gray.
Porosity: low permeability, intergranular, moldic good induration.
Cement type: silica.

261 - 272.5 Clay; yellowish gray.
10% porosity: intercrystalline, moldic, pin point vugs moderate induration.
Cement type(s): dolomite cement, clay matrix.
Accessory minerals: quartz sand, 10%; dolomite, 35%; clay (sepiolite and palygorskite); phosphatic sand, 5 %.
Varies from dolosilt to dolomitic clay, alternating fine sand and clay lenses.

272.5 - 273.5 Clay; light olive gray.
3% porosity: intergranular, moldic, pin point vugs moderate induration.
Cement type(s): clay matrix (sepiolite and palygorskite), dolomite cement.
Accessory minerals: quartz sand, 10%; silt (trace); dolomite, 30%, phosphatic sand, 1%.

273.5 - 280 Clay; yellowish gray.
5% porosity: intercrystalline, moldic, pin point vugs.
Moderate induration.
Cement type(s): dolomite cement, clay matrix.
Accessory minerals: quartz sand, 15%; phosphatic sand, 30%.
Fossils: fossil molds, fossil fragments, planktonic foraminifera, benthic foraminifera, phosphatized planktic forams.
Bored pebble at 279' bored, pebble (?) at 280'.

280 - 281 Dolostone; yellowish gray.
7% porosity: intergranular, intercrystalline, moldic, 50-90% altered; subhedral.
Grain size: microcrystalline range: microcrystalline to very fine; moderate induration.
Cement type(s): dolomite cement, clay matrix.
Accessory minerals: quartz sand, 25%; dolomite; clay (sepiolite and palygorskite); phosphatic sand, 1%;
Lenses of dolosilt and silty dolomitic clay.
Clay content increases with depth.

281 - 285 Clay; yellowish gray.
Porosity: low permeability, intergranular, moldic poor induration.
Cement type(s): clay matrix, dolomite cement.
Accessory minerals: phosphatic sand, 1%; quartz sand; iron stain.

285 - 311 Sand; yellowish gray to light olive gray.
30% porosity: intergranular, moldic, pin point vugs.
Grain size: very fine; range: very fine to fine roundness: angular to sub-angular; poor induration.

Comments

312.7-312.8': Moderately well preserved assemblage of dinocysts dominated by *Polysphaeridium zoharyi* and species of *Spiniferites.*

314': Well preserved assemblage of dinocysts.

318': top of the unnamed limestone

318': Thin section: fine-grained, porous packstone. Ostracodes, foraminifers, mollusks, red algae, echinoid fragments, <5% quartz silt. Cements: micrite and syntaxial echinoid overgrowths.

321.1-321.6': Diverse, well preserved dinocysts, dominated by *Phthanoperidinium multispinum.*

330.5-331.0': Diverse, well preserved assemblage of dinocysts.

336.1-336.4': Moderately diverse, well preserved of dinocysts dominated by *Systematophora placacantha* .

343.5-476': Mollusks preserved as molds and casts; 343.5-351' molds well preserved.

346': Thin section: packstone. Micritized foraminifers, oysters (with silica-filled borings), red algae, spicules, ostracodes, and mollusk voids. Thin layer of bladed calcite on some shell surfaces; echinoid syntaxial overgrowths.

345.6-346.1': Diverse, well preserved dinocysts dominated by *Systematophora placacantha.*

350': Thin section: packstone. Large (2-4 mm) oyster, bryozoan fragments, and small foraminifers micrite matrix. Virtually no pore-filling cement.

355.5-355.8': Diverse, well preserved dinocysts dominated by *Membranophoridium aspinatum.*

357': Thin section: packstone. Foraminifers, ostracodes, echinoid, oyster, and micritized red algae. Minor cement within foraminifer chambers, and on oyster surfaces; patches of microspar.

360-360.8': Diverse, well preserved dinocysts.

Age Indicators

312.7-312.8': Dinocysts suggest early Miocene(?). See notes in Appendix 1.

314': Dinocysts indicate early, but not earliest, part of the early Miocene, by the overlap of reported ranges of *Sumatradinium soucouyantiae* and *Cordosphaeridium cantharellus.* (Sample falls in zone DN 2 of de Verteuil and Norris, in press, which they calibrate via Sr ratios to 21.4 -19.7 Ma.)

-Unconformity between 314' and 321' indicated by dinocysts-

321.1-321.6': Dinocysts indicate early part of early Oligocene, based on the highest known occurrences of *Charlesdowniea coleothrypta, Operculodinium divergens*, and *Samlandia chlamydophora.*

330.5-331.0': Dinocysts indicates early part of the early Oligocene. Sample contains the highest occurrence of *Diphyes colligerum*, with a range top near the Eocene/Oligocene boundary or just into the Oligocene, and lowest occurrence of *Operculodinium divergens.*

336.1-336.4': Dinocysts indicate late Eocene or early Oligocene. *Kallosphaeridinium biornatum* indicates lower part of the Oligocene; *Ascostomocystis potane* has lowest occurrence low in the Rupelian in Belgium and in the uppermost Shubuta Member of the Yazoo Clay in St. Stephens Alabama. These species limit the sample to calcareous nannofossil zone NP 21; the position of the Eocene/Oligocene boundary falls within this zone.

345.6-346.1': Dinocysts indicate late Eocene or early Oligocene. The dinoflora is like the uppermost Shubuta and lowest Bumpnose at St. Stephens Quarry, Alabama (Edwards, unpublished data).

345.6-346.1': Mollusks include *Turritella caelatura?* and *Turritella caseyi?*; *T. caelatura* and *T. caseyi* are reported from the lower Oligocene Mint Springs Formation, Mississippi.

351': Mollusk *Chlamys brooksvillensis*, reported from the lower Oligocene Suwannee Limestone.

355.5-355.8': Dinocysts indicate late Eocene or early Oligocene.

360-360.8': Dinocysts indicate late Eocene or early Oligocene. The lowest occurrence of *Glaphyrocysta semitecta* (Bujak) Lentin & Williams indicates that the Eocene-Oligocene boundary lies below the sample at 360.8 to 360 ft, and all studied samples are of Oligocene age. The occurrence of *Homotryblium vallum* extends its known range.

Cement type(s): dolomite cement, clay matrix.
Accessory minerals: silt, 25%; clay (palygorskite and sepiolite); phosphatic sand, 20% (phosphate locally variable to 60%).

311 - 314 Silt-size dolomite; yellowish gray.
15% porosity: intercrystalline, moldic, pin point vugs, moderate induration.
Cement type(s): dolomite cement.
Accessory minerals: silt; 35%, quartz sand, 5 %; phosphatic sand, 1%; clay (palygorskite).
Other features: platy.

314 - 318 Sand; light olive gray.
25% porosity: intergranular, moldic, pin point vugs grain size: very fine; range: very fine to fine roundness: angular to sub-angular; poor induration.
Cement type(s): dolomite cement.
Accessory minerals: silt, phosphatic sand, 5%; clay (sepiolite and palygorskite).

318 - 343 Limestone; very light gray to pinkish gray.
20% porosity: intergranular, moldic, pin point vugs grain type: crystals, biogenic, calcilutite, 90%.
Allochemical constituents grain size: fine; range: very fine to medium moderate induration.
Cement type(s): sparry calcite cement.
Accessory minerals: quartz sand, 15%; phosphatic sand, 1%.
Other features: high recrystallization of fossils: fossil fragments, fossil molds.

343 - 352 Limestone; yellowish gray to very light gray.
30% porosity: intergranular, moldic, pin point vugs
Grain type: crystals, biogenic, skeletal.
70% allochemical constituents.
Grain size: fine; range: very fine to coarse, moderate induration.
Cement type(s): sparry calcite cement, calcilutite matrix.
Accessory minerals: quartz sand, 5%, phosphatic sand, 1%.
Other features: high recrystallization.
Fossils: fossil fragments, mollusks, benthic foraminifera very recrystallized shell bed. Highly moldic. Shells gone except for ostreids.

352 - 358 Calcarenite; white to very light orange.
30% porosity: intergranular, moldic, pin point vugs.
Grain type: skeletal, biogenic, crystals, 97%.
Allochemical constituents grain size: medium; range: very fine to very coarse moderate induration.
Cement type(s): sparry calcite cement.
Accessory minerals: quartz sand, 2%.
Other features: high recrystallization.
Fossils: fossil fragments, mollusks, benthic foraminifera.

358 - 367 Limestone; yellowish gray.
15% porosity: intergranular, moldic, pin point vugs.
Grain type: skeletal, biogenic.
Grain size: very fine; range: microcrystalline to fine.

Comments

380': top of the Ocala Limestone

380': Thin section: foraminiferal packstone/ wackestone. Large and small foraminifers (some leached), leached mollusks, ostracodes, and red algae; peloidal micrite matrix. Most chambers are mud-filled, other interparticle porosity is void, with little sparry cement.

387': Thin section: foraminiferal packstone. The micrite matrix is clotted (microspar) in patches. Grains: well preserved large and small foraminifers, bryozoans (one is partially leached), echinoid fragments, red algae and ostracodes. There is virtually no sparry calcite cement.

387-409.3': Molluscan molds well preserved.

408.3-408.8': Moderately well preserved assemblage of dinocysts with no dominant species.

438': Thin section: packstone/wackestone. Grains: slightly rounded and micrite-coated micritized red algae and foraminifers, and bryozoans and mollusk molds. Most intraparticle porosity is mud-filled. There is a thin layer of blocky and dogtooth calcite on some micrite surfaces.

453': Thin section: packstone. Grains: large and small foraminifers, bryozoans, echinoid fragments, encrusting red algae, and ostracodes in a micrite matrix. Most skeletal grains are broken, slightly rounded, but well preserved. There is a small amount of dogtooth calcite cement on some surfaces.

Age Indicators

387': Mollusk *Chlamys spillmani*, reported from upper Eocene deposits of the Gulf Coast, Florida, and Georgia.

392': Echinoid *Oligopygus haldemani*, reported from upper Eocene deposits in the Gulf Coast, Florida, and Georgia.

397.8': Mollusk *Turritella boycensis*, reported from early Oligocene Mint Springs Formation, Mississippi.Occurrence here indicates a longer range than previously reported, and (or) that this sample is near the Eocene/ Oligocene boundary.

398.3-398.5': Mollusk *Turritella boycensis*(see notes for 397.8').

407.3': Mollusk *Chlamys spillmani*, reported from upper Eocene deposits of the Gulf Coast, Florida, and Georgia.

408.3-408.8': Dinocyst assemblages indicate late middle or late Eocene, based on the range of *Batiacasphaera compta*.

409-409.3': Mollusk *Turritella alveata*? reported from upper Eocene deposits of the Gulf Coast, Florida, and Georgia.

Moderate induration.
Cement type(s): calcilutite matrix, sparry calcite cement.
Accessory minerals: clay, quartz sand, 1%.
Phosphatic sand, 1%.
Fossils: fossil fragments, benthic foraminifera, mollusks, planktonic foraminifera.

367 - 374 Calcarenite; yellowish gray.
20% porosity: intergranular, moldic, pin point vugs.
Grain type: skeletal, biogenic.
90% allochemical constituents.
Grain size: fine; range: microcrystalline to medium.
Moderate induration.
Cement type(s): sparry calcite cement, calcilutite matrix.
Accessory minerals: quartz sand, 1%.
Other features: high recrystallization.
Fossils: fossil fragments, benthic foraminifera, mollusks.

374 - 380 Limestone; white to very light orange.
Porosity: low permeability, intergranular, moldic.
Grain type: skeletal, biogenic, crystals.
Good induration.
Cement type(s): sparry calcite cement.
Other features: high recrystallization.
Fossils: fossil fragments, mollusks, benthic foraminifera.

380 - 407 Calcarenite; white.
15% porosity: intergranular, moldic, pin point vugs.
Grain type: skeletal, biogenic, calcilutite.
85% allochemical constituents
Grain size: medium; range: fine to very coarse, moderate induration.
Cement type(s): sparry calcite cement, calcilutite matrix other features: medium recrystallization.
Fossils: benthic foraminifera, mollusks, bryozoa, *Asterocyclina* at approximately 389.5'.
Amount of recrystalization varies from low at 387 ft to high at 407 ft.
(Core from 407 to 442 ft mix up due to accident.)

407 - 452 Calcarenite; white to very light orange.
15% porosity: intergranular, moldic, pin point vugs.
Grain type: skeletal, biogenic, calcilutite.
75% allochemical constituents grain size: fine; range: very fine to medium moderate induration.
Cement type(s): sparry calcite cement, calcilutite matrix fossils: benthic foraminifera, mollusks, fossil molds.
Accessory minerals: clay (palygorskite).

452 - 456 Calcarenite; white.
7% porosity: intergranular, moldic, pin point vugs.
Grain type: skeletal, biogenic, calcilutite.
Good induration.
Cement type(s): sparry calcite cement, calcilutite matrix.
Other features: medium recrystallization.

Comments

Age Indicators

462': Thin section: coarse, foraminiferal grainstone. (The only real grainstone observed in this core). Small forams, encrusting red algae and rhodoliths, echinoids, oysters with large syntaxial overgrowth. Most grains are rounded and many are broken. Dogtooth calcite cement coats most external surfaces of skeletal grains.

High recrystallization.
Fossils: benthic foraminifera, mollusks, fossil molds.

456 - 462 Calcarenite; white 12%.
Porosity: intergranular, moldic, pin point vugs grain type: skeletal, biogenic, calcilutite.
95% allochemical constituents.
Grain size: medium; range: fine to coarse; good induration.
Cement type(s): sparry calcite cement, calcilutite matrix.
Other features: medium recrystallization.
Fossils: benthic foraminifera, mollusks, fossil molds highly recrystalized zone from 457 to 462 ft.

462 - 475 Calcarenite; white to very light orange
30% porosity: intergranular, moldic, pin point vugs.
Grain type: skeletal.
98% allochemical constituents.
Grain size: medium; range: fine to very coarse.
Good induration.
Cement type(s): sparry calcite cement.
Other features: medium recrystallization.
Fossils: benthic foraminifera, mollusks, fossil fragments.

475 - 476 Calcarenite; white to very light orange.
20% porosity: intergranular, moldic, pin point vugs.
Grain type: skeletal.
85% allochemical constituents.
Grain size: medium; range: fine to very coarse.
Good induration.
Cement type(s): sparry calcite cement, calcilutite matrix.
Other features: medium recrystallization.
High recrystallization.
Fossils: benthic foraminifera, mollusks, fossil fragments.

476 Total depth

Carbonate lithologic terms used in the litholog:

calcilutite: containing clay-sized calcareous particles
calcarenite: cantaining sand-sized carbonate particles
calcirudite: containing gravel-sized carbonate particles
allochems: intraclasts, oolites, skeletal grains, and pellets
sparry calcite: pore-filling calcite cement

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APPENDIX 2

DINOCYST SAMPLE DISCRIPTIONS

Appendix 2.

Dinocyst sample descriptions

The Phred #1 core (W-13958) was assigned U.S. Geological Survey Paleobotanical Number R4809.

129.8-130 ft depth (R4809 CH) contained a well preserved, moderately diverse dinocyst assemblage dominated by species of *Spiniferites*. Dinocysts are:

Achomosphaera alcicornu (Eisenack) Davey & Williams
Achomosphaera andalousiensis Jan du Chêne
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Invertocysta spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium sp.
Multispinula quanta Bradford
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka[net-like ectophragm]
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites spp.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

Age: late Miocene or Pliocene. In the zonation of de Verteuil and Norris (in press), the overlap of *A. andalousiensis* and *D. pseudocolligerum* would place this sample in either their zone DN 8 or DN 9, both of late Miocene age. Note that Huddlestun (1988) placed 128.5-211 ft in this core in his informal "Wabasso beds" and listed foraminifera supporting an early Pliocene age; this extends the known range of *D. pseudocolligerum* .

142.5 ft depth (R4809 AH) contained a moderately diverse dinocyst assemblage dominated by species of *Spiniferites*. Preservation is only fair and blobs of amorphous material are common. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Invertocysta sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium sp.
Multispinula quanta Bradford
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Operculodinium isralieanum (Rossignol) Wall
Operculodinium sp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites spp.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

Age: late Miocene or Pliocene. In the zonation of de Verteuil and Norris (in press), the overlap of *A. andalousiensis* and *D. pseudocolligerum* would place this sample in either their zone DN 8 or DN 9, both of late Miocene age. Note that Huddlestun (1988) placed 128.5-211 ft in this core in his informal "Wabasso beds" and listed foraminifera supporting an early Pliocene age.

160 ft depth (R4809 DE) contained a sparse, well preserved dinocyst assemblage dominated by *P. zoharyi*. Dinocysts are:

Hystrichokolpoma rigaudiae Deflandre & Cookson
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Operculodinium israelianum (Rossignol) Wall
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites spp.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

Age: Constraints on the age of this sample are the ages of the samples above and below. The highest occurrence of *S. pseudofurcatus* was given in Head and others (1989) as within the middle part of the late Miocene. Note that Huddlestun (1988) placed 128.5-211 ft in this core in his informal "Wabasso beds" and listed foraminifera supporting an early Pliocene age.

189 ft depth (R4809 AF) contained a moderately diverse dinocyst assemblage dominated by species of *Spiniferites* and *O. centrocarpum*. Preservation is only fair. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Batiacasphaera sphaerica Stover
Impagidinium patulum (Wall) Stover & Evitt
Invertocysta lacrymosa Edwards
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium ? sp.
Multispinula quanta Bradford
Nematosphaeropsis labyrinthus (Ostenfeld) Reid
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Operculodinium cf. *giganteum* of Manum and others (1989)
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka[net-like ecto]
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites spp.
Systematophora placacantha (single specimen)
Tuberculodinium vancampoae (Rossignol) Wall

Age: The highest occurrence of *L. truncatum* is found in the sample below this one. The presence of *B. sphaerica* suggests a middle or late Miocene age (Williams and others, 1993 place the top of this species near the middle-late Miocene boundary; de Verteuil and Norris, in press, place the top higher). Note that Huddlestun (1988) placed 128.5-211 ft in this core in his informal "Wabasso beds" and lists foraminifera supporting an early Pliocene age.

211.9-212.1 ft depth (R4809 DD) contained a moderately diverse dinocyst assemblage dominated by species of *Spiniferites*. Preservation is only fair and blobs of amorphous material are common. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Batiacasphaera sphaerica Stover
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Invertocysta lacrymosa Edwards
Labyrinthodinium truncatum Piasecki s.s.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall

Melitasphaeridium choanophorum (Deflandre & Cookson) Harland & Hill
Multispinula quanta Bradford
Nematosphaeropsis labyrinthus (Ostenfeld) Reid
Operculodinium ? sp.
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites spp.
Tuberculodinium vancampoae (Rossignol) Wall

Age: The overlap in the ranges of *L. truncatum* and *A. andalousiensis* indicate a narrow age range in the latest middle Miocene or the early part of the late Miocene (DN8-DN9 of de Verteuil and Norris, in press).

230 ft depth (R4809 AE) contained a moderately diverse dinocyst assemblage dominated by species of *Spiniferites*. Preservation is only fair and blobs of amorphous material are common. Dinocysts are:

Achomosphaera andalousiensis Jan du Chêne
Apteodinium tectatum Piasecki (single specimen)
Batiacasphaera sphaerica Stover
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Erymnodinium delectabile (Verteuil & Norris) Lentin et al.
Hystrichokolpoma sp.
Hystrichosphaeropsis obscura Habib
Impagidinium paradoxum (Wall) Stover & Evitt
Labyrinthodinium truncatum Piasecki [prob. deV& Norris' new subsp.]
Lejeunecysta sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall [epicystal]
Melitasphaeridium choanophorum (Deflandre & Cookson) Harland & Hill
Multispinula quanta Bradford
Nematosphaeropsis rigida Wrenn
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Operculodinium ? sp.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Pyxidiella? simplex Harland
Selenopemphix nephroides Benedek
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites spp.
Systematophora placantha (Deflandre & Cookson) Davey et al. (single specimen)
Trinovantedinium sp.
Tuberculodinium vancampoae (Rossignol) Wall

Age: The overlap in the ranges of *L. truncatum* and *A. andalousiensis* indicate a narrow age range in the latest middle Miocene or the early part of the late Miocene (DN8-DN9 of de Verteuil and Norris, in press). Single specimens of *A. tectatum* and *S. placacantha* are most likely reworked.

237-237.1 ft depth (R4809 AD) contained a moderately diverse dinocyst assemblage with no particularly dominant species. Preservation is only fair and blobs of amorphous material are common. Dinocysts are:

Batiacasphaera sphaerica Stover
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Exochosphaeridium sp.
Hystrichokolpoma sp.

Hystrichosphaeropsis obscura Habib
Invertocysta sp.
Labyrinthodinium truncatum Piasecki [prob. deV& Norris' new subsp.]
Lejeunecysta spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall [epicystal]
Melitasphaeridium choanophorum (Deflandre & Cookson) Harland & Hill
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Pentadinium sp. cf. *P. laticinctum granulatum* Gocht
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites spp.
Sumatradinium druggii Lentin et al.
Sumatradinium hispidum (Drugg) Lentin & Williams
Sumatradinium soucouyantiae de Verteuil & Norris
Sumatradinium sp.
Systematophora placacantha (Deflandre & Cookson) Davey et al.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

Age: middle Miocene. The highest occurrence of *S. placacantha* is used by de Verteuil and Norris (in press) to mark the top of their zone DN 5, which they place in the middle Miocene.

248.6-248.8 ft depth (R4809 BC) contained a moderately diverse, well preserved assemblage of dinocysts with no particularly dominant species. Dinocysts are:
Barssidinium sp.
Batiacasphaera sphaerica Stover
Hystrichokolpoma sp.
Hystrichosphaeropsis obscura Habib
Labyrinthodinium truncatum Piasecki [prob. deV& Norris' new subsp.]
Lejeunecysta spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall [epicystal]
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Palaeocystodinium golzowense Alberti
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka[net-like ecto]
Selenopemphix brevispinosa Head et al. subsp. *brevispinosa*
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites spp.
Sumatradinium hispidum (Drugg) Lentin & Williams
Systematophora placacantha (Deflandre & Cookson) Davey et al.
Tectatodinium pellitum Wall
Trinovantedinium sp.
Tuberculodinium vancampoae (Rossignol) Wall

Age: middle Miocene based on the overlap of *S. placacantha* and *L. truncatum*.

264.0-264.3 ft depth (R4809 DA) contained a moderately diverse dinocyst assemblage dominated by *S. pseudofurcatus*. Preservation is only fair and blobs of amorphous material are common. Dinocysts are:
Batiacasphaera sphaerica Stover
Brigantedinium cariacoense (Wall) Lentin & Williams
Dapsilidinium pseudocolligerum (Stover) Bujak et al.

Heteraulacacysta sp.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Hystrichosphaeropsis obscura Habib
Lejeunecysta spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Pentadinium sp. cf. *P. laticinctum granulatum* Gocht
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites spp.
Sumatradinium sp. ?
Systematophora placacantha (Deflandre & Cookson) Davey et al.
Tectatodinium pellitum Wall
Trinovantedinium papulum de Verteuil & Norris ?
Tuberculodinium vancampoae (Rossignol) Wall

Age: middle Miocene below the range top of *S. placacantha.*

285.4-285.8 ft depth (R4809 CD) contained a moderately diverse, well preserved assemblage of dinocysts with no particularly dominant species. Dinocysts are:
Cordosphaeridium fibrospinosum Davey & Williams
Cribroperidinium tenuitabulatum (Gerlach) Helenes
Distatodinium paradoxum (Brosius) Eaton ?
Exochosphaeridium sp.
Habibacysta tectata Head et al.
Heteraulacacysta campanula Drugg & Loeblich
Hystrichokolpoma rigaudiae Deflandre & Cookson
Hystrichosphaeropsis obscura Habib
Impagidinium cf. *I. aculeatum* (see *Spiniferites* group sp. II in Edwards, 1984)
Lejeunecysta sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Pentadinium sp. cf. *P. laticinctum granulatum* Gocht
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites spp.
Systematophora placacantha (Deflandre & Cookson) Davey et al.
Tuberculodinium vancampoae (Rossignol) Wall

Age: middle Miocene, based on the lowest occurrence of *H. tectata*. If in place, the overlap of occurrence of *D. paradoxum* and *H. tectata* indicate that this sample correlates with the DN 4/DN 5 boundary of de Verteuil and Norris (in press).

292.6-292.8 ft depth (R4809 CC) contained a moderately diverse, moderately well preserved assemblage of dinocysts with no particularly dominant species. Dinocysts are:
Cerebrocysta sp.
Cordosphaeridium cantharellus (Brosius) Gocht
Cribroperidinium tenuitabulatum (Gerlach) Helenes
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Distatodinium paradoxum (Brosius) Eaton ?
Exochosphaeridium sp.
Heteraulacacysta campanula Drugg & Loeblich
Hystrichokolpoma rigaudiae Deflandre & Cookson
Hystrichosphaeropsis obscura Habib

Lejeunecysta spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites spp.
Sumatradinium sp.
Systematophora placacantha (Deflandre & Cookson) Davey et al.
Tuberculodinium vancampoae (Rossignol) Wall

Age: early or middle Miocene. If *C. cantharellus* is not reworked, the age is the early part of the early Miocene and there is an unconformity between this and the overlying sample.

300.8-301.1 ft depth (R4809 CB) contained a moderately diverse, well preserved assemblage of dinocysts dominated by species of *Spiniferites* and *H. rigaudiae*. Dinocysts are:
Cordosphaeridium cantharellus (Brosius) Gocht ?
Cribroperidinium tenuitabulatum (Gerlach) Helenes
Exochosphaeridium sp.
Heteraulacacysta campanula Drugg & Loeblich
Hystrichokolpoma rigaudiae Deflandre & Cookson
Hystrichosphaeropsis obscura Habib
Lejeunecysta sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium cf. *O. placitum*
Palaeocystodinium golzwense Alberti
Melitasphaeridium pseudorecurvatum (Morgenroth) Bujak et al.
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites spp.
Sumatradinium soucoayantias de Verteuil & Norris
Systematophora placacantha (Deflandre & Cookson) Davey et al.
Tectatodinium pellitum Wall
Tuberculodinium vancampoae (Rossignol) Wall

Age: early or middle Miocene.

308.8-310.0 ft depth (R4809 CA) contained a moderately diverse, well preserved assemblage of dinocysts dominated by *C. tenuitabulatum* Dinocysts are:
Apteodinium australiense (Deflandre & Cookson) Williams
Cribroperidinium tenuitabulatum (Gerlach) Helenes
Exchosphaeridium sp.
Heteraulacacysta campanula Drugg & Loeblich
Hystrichokolpoma rigaudiae Deflandre & Cookson
Hystrichosphaeropsis obscura Habib
Lejeunecysta spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Operculodinium cf. *O. placitum*
Palaeocystodinium golzowense Alberti
Polysphaeridium zoharyi (Rossignol) Bujak et al. ?
Selenopemphix sp.

Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites spp.
Sumatradinium ?
Systematophora placacantha (Deflandre & Cookson) Davey et al.
Trinovantedinium sp.
Tuberculodinium vancampoae (Rossignol) Wall

Age: early or middle Miocene.

312.7-312.8 ft depth (R4809 AA) contained a diverse, moderately well preserved assemblage of dinocysts dominated by *P. zoharyi* and species of *Spiniferites*. Dinocysts are:

Cannosphaeropsis n. sp.
Cordosphaeridium fibrospinosum Davey & Williams
Cribroperidinium tenuitabulatum (Gerlach) Helenes
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Exochosphaeridium sp.
Heteraulacacysta campanula Drugg & Loeblich
Hystrichokolpoma rigaudiae Deflandre & Cookson
Hystrichosphaeropsis obscura Habib
Impagidinium sphaericum (Wall) Lentin & Williams ?
Lejeunecysta spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Nematosphaeropsis sp.
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Operculodinium israelianum (Rossignol) Wall
Pentadinium sp. cf. *P. laticinctum granulatum* Gocht
Polysphaeridium zoharyi (Rossignol) Bujak et al. ?
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites spp.
Tectatodinium pellitum Wall
Trinovantedinium sp.
Tuberculodinium cf. *T. vancampoae*

Age: probably early Miocene. If the unnamed species of *Exochosphaeridium* is conspecific with the new species of de Verteuil and Norris, this sample is their zone DN2. The unnamed species of *Cannosphaeropsis* is not conspecific with their new species and is probably a new early Miocene form (pers. comm., de Verteuil).

314 ft depth (R4809 HA) contained a diverse, well preserved assemblage of dinocysts with no particularly dominant species. Dinocysts are:

Apteodinium australiense (Deflandre & Cookson) Williams
Cordosphaeridium cantharellus (Brosius) Gocht
Cordosphaeridium fibrospinosum Davey & Williams
Cribroperidinium tenuitabulatum (Gerlach) Helenes
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Distatodinium paradoxum (Brosius) Eaton ?
Exochosphaeridium sp.
Heteraulacacysta sp.
Hystrichokolpoma rigaudiae Deflandre & Cookson
Hystrichosphaeropsis obscura Habib
Lejeunecysta sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Polysphaeridium zoharyi (Rossignol) Bujak et al. ?

Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka
Selenopemphix sp.
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites spp.
Sumatradinium soucouyantiae de Verteuil & Norris
Tectatodinium sp.
Trinovantedinium spp.
Tuberculodinium vancampoae (Rossignol) Wall
cf. *Pentadinium goniferum*

Age: The dinocysts place very narrow constraints on the age of this sample. The overlap of reported ranges of *S. soucouyantiae* and *C. cantharellus* is a brief interval in the early, but not earliest, part of the early Miocene. The absence of *Homotryblium* and *Chiropteridium* spp., which have their youngest occurrences in the very earliest Miocene, corroborate this age call. This sample falls in de Verteuil and Norris' DN 2 which they calibrate via Sr to 21.4 -19.7 Ma.

-unconformity indicated here-

321.1-321.6 ft depth (R4809 BB) contained a diverse, well preserved assemblage of dinocysts dominated by *Phthanoperidinium multispinum*. Dinocysts are:
Areoligera spp.
Ascostomocystis potane Drugg & Loeblich
Charlesdowniea coleothrypta (Williams & Downie) Lentin & Vozzhennikova
Cordosphaeridium cantharellus (Brosius) Gocht
Cordosphaeridium fibrospinosum Davey & Williams
Cyclopsiella vieta Drugg & Loeblich
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Deflandrea phosphoritica Eisenack
Deflandrea spinulosa Alberti
Homotryblium plectilum Drugg & Loeblich
Hystrichokolpoma rigaudiae Deflandre & Cookson
Lejeunecysta sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Membranophoridium aspinatum Gerlach
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Operculodinium divergens (Eisenack) Stover & Evitt
Palaeocystodinium golzowense Alberti
Pentadinium laticinctum Gerlach
Phthanoperidinium multispinum Bujak
Polysphaeridium zoharyi (Rossignol) Bujak et al. ?
Reticulatasphaera actinocoronata (Benedek) Bujak & Matsuoka
Samlandia chlamydophora Eisenack s. l.
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites spp.
Systematophora placacantha (Deflandre & Cookson) Davey et al.
Tectatodinium pellitum Wall
Thalassiphora pelagica (Eisenack) Eisenack & Gocht
Tuberculodinium cf. *T. vancampoae*
Turbiosphaera n. sp.

Age: early part of early Oligocene, based on the highest known occurrences of *C. coleothrypta, O. divergens*, and *S. chlamydophora*.

330.5-331.0 ft depth (R4809 ED) contained a diverse, well preserved assemblage of dinocysts with no particularly dominant species. Dinocysts are:

Apteodinium australiense (Deflandre & Cookson) Williams
Areoligera sp.
Charlesdowniea coleothrypta (Williams & Downie) Lentin & Vozzhennikova
Cordosphaeridium fibrospinosum Davey & Williams
Cyclopsiella chateauneufii Head et al.
Cyclopsiella vieta Drugg & Loeblich
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Deflandrea heterophlycta Deflandre & Cookson
Deflandrea phosphoritica Eisenack
Diphyes colligerum (Deflandre & Cookson) Cookson
Distatodinium paradoxum (Brosius) Eaton ?
Homotryblium plectilum Drugg & Loeblich
Hystrichokolpoma rigaudiae Deflandre & Cookson
Impagidinium dispertitum (Cookson & Eisenack) Stover & Evitt
Lanternosphaeridium cf. *L. lanosum*
Lejeunecysta sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Membranophoridium aspinatum Gerlach
Microdinium group sp.
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Operculodinium divergens (Eisenack) Stover & Evitt
Operculodinium placitum Drugg & Loeblich
Pentadinium laticinctum Gerlach s.s.
Phthanoperidinium comatum (Morgenroth) Eisenack & Kjellström
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Samlandia chlamydophora Eisenack
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites spp.
Systematophora placacantha (Deflandre & Cookson) Davey et al.
Tectatodinium pellitum Wall
Thalassiphora pelagica (Eisenack) Eisenack & Gocht
Tuberculodinium n. sp.

Age: early part of the early Oligocene. This sample contains the highest occurrence of *D. colligerum*, which has a range top near the Eocene/Oligocene boundary (Williams and others, 1993) or just into the Oligocene (Powell, 1992). It contains the lowest occurrence of *O. divergens*. At St. Stephens, Alabama, this species has its lowest occurrence in the early Oligocene (Bumpnose Formation, Edwards, unpubl. data).

336.1-336.4 ft depth (R4809 EC) contained a moderately diverse, well preserved assemblage of dinocysts dominated by *Systematophora placacantha*.. Dinocysts are:

Ascostomocystis potane Drugg & Loeblich
Cordosphaeridium inodes (Klumpp) Eisenack
Cribroperidinium tenuitabulatum (Gerlach) Helenes
Cyclopsiella vieta Drugg & Loeblich
Diphyes colligerum (Deflandre & Cookson) Cookson
Enneadocysta arcuata (Eaton) Stover & Williams
Heteraulacacysta sp.
Homotryblium plectilum Drugg & Loeblich
Hystrichokolpoma rigaudiae Deflandre & Cookson

Kallosphaeridium biornatum Stover
Lejeunecysta spp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Pentadinium laticinctum Gerlach s.s.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites spp.
Systematophora placacantha (Deflandre & Cookson) Davey et al.
Tectatodinium pellitum Wall
Tuberculodinium n. sp.

Age: probably early Oligocene. *K. biornatum* is known from the lower part of the Oligocene (Stover, 1977). *A. potane* has its lowest occurrence low in the Rupelian (Stover and Hardenbol, 1994) in Belgium and in the uppermost Shubuta Member of the Yazoo Clay in St. Stephens Alabama (Edwards, unpubl. data). By most correlations, these species limit the sample to calcareous nannofossil zone NP 21, and the position of the Eocene/Oligocene boundary falls within this zone.

345.6-346.1 ft depth (R4809 BA) contained a diverse, well preserved assemblage of dinocysts dominated by *Systematophora placacantha* . Dinocysts are:

Achilleodinium biformoides (Eisenack) Eaton
Areoligera sp.
Ascostomocystis potane Drugg & Loeblich
Charlesdowniea coleothrypta (Williams & Downie) Lentin & Vozzhennikova
Cordosphaeridium cantharellus (Brosius) Gocht
Cordosphaeridium inodes (Klumpp) Eisenack
Cribroperidinium giuseppei (Morgenroth) Helenes
Cyclopsiella chateauneufii Head et al.
Cyclopsiella vieta Drugg & Loeblich
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Deflandrea phosphoritica Eisenack
Diphyes colligerum (Deflandre & Cookson) Cookson
Distatodinium ellipticum (Cookson) Eaton
Distatodinium virgatum Stover
Enneadocysta arcuata (Eaton) Stover & Williams
Homotryblium plectilum Drugg & Loeblich
Hystrichokolpoma rigaudiae Deflandre & Cookson
Kallosphaeridium biornatum Stover
Lejeunecysta spp.
Lentinia sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Pentadinium laticinctum Gerlach s.s.
Phthanoperidinium comatum (Morgenroth) Eisenack & Kjellström
Phthanoperidinium echinatum Eaton
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Samlandia chlamydophora Eisenack s.l.
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites spp.
Systematophora placacantha (Deflandre & Cookson) Davey et al.
Tectatodinium pellitum Wall
Thalassiphora pelagica (Eisenack) Eisenack & Gocht
Tuberculodinium n. sp.

Wetzeliella gochtii Costa & Downie

Age: probably early Oligocene. Again, the dinoflora is like the uppermost Shubuta and lowest Bumpnose at St. Stephens Quarry Alabama (Edwards, unpublished data).

355.5-355.8 ft depth (R4809 EB) contained a diverse, well preserved assemblage of dinocysts dominated by *Membranophoridium aspinatum*.. Dinocysts are:

Charlesdowniea coleothrypta (Williams & Downie) Lentin & Vozzhennikova
Cordosphaeridium cantharellus (Brosius) Gocht
Cordosphaeridium gracile (Eisenack) Davey & Williams
Cribroperidinium giuseppei (Morgenroth) Helenes
Cyclopsiella vieta Drugg & Loeblich
Deflandrea phosphoritica Eisenack
Distatodinium paradoxum (Brosius) Eaton ?
Enneadocysta arcuata (Eaton) Stover & Williams
Heteraulacacysta spp.
Homotryblium plectilum Drugg & Loeblich
Hystrichokolpoma rigaudiae Deflandre & Cookson
Kallosphaeridium biornatum Stover
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium pseudorecurvatum (Morgenroth) Bujak et al. ?
Membranophoridium aspinatum Gerlach
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Pentadinium laticinctum Gerlach s.s.
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Samlandia chlamydophora Eisenack
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites spp.
Systematophora placacantha (Deflandre & Cookson) Davey et al.
Thalassiphora pelagica (Eisenack) Eisenack & Gocht

Age: probably early Oligocene (same as sample below)

360-360.8 ft depth (R4809 EA) contained a diverse, well preserved assemblage of dinocysts with no particularly dominant species. Dinocysts are:

Charlesdowniea coleothrypta (Williams & Downie) Lentin & Vozzhennikova
Cordosphaeridium cantharellus (Brosius) Gocht
Cribroperidinium giuseppei (Morgenroth) Helenes
Dapsilidinium pseudocolligerum (Stover) Bujak et al.
Deflandrea phosphoritica Eisenack
Diphyes colligerum (Deflandre & Cookson) Cookson
Enneadocysta arcuata (Eaton) Stover & Williams
Glaphyrocysta semitecta (Bujak) Lentin & Williams
Homotryblium plectilum Drugg & Loeblich
Homotryblium vallum Stover
Hystrichokolpoma rigaudiae Deflandre & Cookson
Lejeunecysta spp.
Lentinia sp.
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Membranophoridium aspinatum Gerlach
Microdinium group sp.
Operculodinium centrocarpum (Deflandre & Cookson) Wall
Pentadinium laticinctum Gerlach s.s.

Phthanoperidinium echinatum Eaton
Samlandia chlamydophora Eisenack s.l.
Spiniferites mirabilis (Rossignol) Sarjeant
Spiniferites spp.
Systematophora placacantha (Deflandre & Cookson) Davey et al.
Tectatodinium pellitum Wall
Tectatodinium? sp.
Thalassiphora pelagica (Eisenack) Eisenack & Gocht

Age:probably early Oligocene. The co-occurrence of *M. aspinatum, D. colligerum*, and *S. chlamydophora*, below the lowest occurrence of *O. divergens* suggests that the age of this sample is near the Eocene/Oligocene boundary. The occurrence of *H. vallum* extends its known range (base in the middle part of the early Oligocene, Stover, 1977 and Stover and Hardenbol, 1994). The lowest occurrence of *G. semitecta* indicate correlation with the early Oligocene at the Eocene/Oligocene boundary stratotype (Brinkhuis and Biffi, 1993). Based on the lowest occurrence of *Glaphyrocysta semitecta* (Bujak) Lentin & Williams and dinocyst correlation with the newly ratified Eocene-Oligocene stratotype at Massignano, Italy (Brinkhuis and Biffi, 1993), the Eocene-Oligocene boundary lies below the sample at 360.8 to 360 ft, and all studied samples are of Oligocene age.

408.3-408.8 ft depth (R4809 FA) contained a moderately well preserved assemblage of dinocysts with no particularly dominant species. Dinocysts are:
Areoligera sp.
Batiacasphaera compta Drugg
Cyclopsiella chateauneufii Head et al.
Diphyes colligerum (Deflandre & Cookson) Cookson
Distatodinium ellipticum (Cookson) Eaton
Enneadocysta sp.
Hemiplacophora? n. sp.
Hystrichokolpoma sp.
Impagidinium dispertitum (Cookson & Eisenack) Stover & Evitt
Lingulodinium machaerophorum (Deflandre & Cookson) Wall
Melitasphaeridium pseudorecurvatum (Morgenroth) Bujak et al.
Operculodinium centrocarpum sensu Wall (1967)
Polysphaeridium zoharyi (Rossignol) Bujak et al.
Rottnestia borussica (Eisenack) Cookson & Eisenack
Samlandia sp. (frag.)
Saturnodinium? n. sp.
Spiniferites pseudofurcatus (Klumpp) Sarjeant
Spiniferites spp.

Age: late middle or late Eocene, based on the range of *B. compta*.

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APPENDIX 3

THIN SECTION DESCRIPTIONS

Appendix 3.

Thin section descriptions

Okeechobee lithologic unit (informal)

feet (meters)

128' (46m) Packstone/wackestone. Some micrite matrix appears to have been either washed out or have fallen out in thin section preparation. Skeletal grains include mollusks (some are leached), micritized foraminifers, echinoids, ostracodes, bryozoans, and red algae. Some original aragonite mollusks, identified by Feigl's solution, are not totally leached; some forminifers are phosphatized. Other grains include medium quartz sand (~5%), and no phosphate grains. Minor cements include echinoid syntaxial overgrowths and irregular patches of bladed and blocky calcite cement within foraminifer chambers. Unidentified amorphous yellow green mineral partly replaces some foraminifers. This sample is taken from the base of a limestone overlying the Wabasso beds.

Unnamed Limestone

318' (97m) Fine-grained, porous packstone. Matrix is clumpy micrite, whose clumps may be micritized small foramanifers, the internal structures are very indistinct. Other skeletal grains include ostracodes, foraminifers, mollusks, red algae, and a few echinoid fragments. Cements are micrite and a few syntaxial overgrowths on echinoid fragments. Other grains include <5% quartz silt. Unidentified amorphous yellow green mineral that occurs as rounded grains may be phosphatic mineral. Porosity is estimated at about 15-20%. This sample was taken from the top of a limestone bed at 318'.

343' (104.5m) Packstone. Skeletal grains include foraminifers, oysters (with silica-filled borings), red algae, spicules, ostracodes, and mollusk voids. Most skeletal grains are micritized. Cements include a thin layer of bladed calcite on some shell surfaces and echinoid syntaxial overgrowths that enclose adjoining grains. There is virtually no quartz sand.

346' (105.5m) Molluscan packstone with a microspar matrix. Skeletal grains include gastropod molds, small and large foraminifers, oysters, echinoids, and bryozoans (?). Other grains include phosphate granules (<1%) and quartz sands (<1%). There is a thin layer of bladed, void-lining calcite cement in some fossil molds. This is the deepest occurrence of quartz sand observed in thin section in this core.

350' (107m) Packstone. Skeletal grains include large (2-4 mm) oyster and bryozoan fragments which support the rock, and small foraminifers in the micrite matrix. There is virtually no porefilling cement except a thin layer of sparry calcite on the oyster surfaces.

357' (109m) Packstone, very fine grained in part. This sample has two textures: one is very similar to the sample at 350' with large oyster and bryozoan fragments and the other is fine grained with much smaller (.1 to 1 mm) skeletal grains that include foraminifers, ostracodes, echinoid and oyster fragments. The coarser portion of the thin section has structureless platy grains that may be either micritized red algae or mollusk shells, or rip-up clasts. There is a little intraparticle cement in the foraminifers chambers, and some on the surfaces of the oysters, and patches of microspar in the micritic matrix.

Ocala Limestone

380' (116m) Foraminiferal packstone/wackestone. Skeletal grains include large and small foraminifers (some leached), leached mollusks, ostracodes, and red algae in a micrite matrix that is peloidal in places. Most internal chambers are mud filled, other interparticle porosity is void, with little sparry cement.

387' (118m) Foraminiferal packstone. The micrite matrix is clotted (microspar) in patches. Skeletal grains are dominated by well preserved large and small foraminifers, bryozoans (one is partially leached), echinoid fragments, red algae and ostracodes. There is virtually no sparry calcite cement.

438' (134m) Packstone/wackestone. Skeletal grains are slightly rounded and micrite-coated, and comprise micritized red algae and fairly well preserved foraminifers. Other skeletal grains include bryozoans and mollusk molds; some foraminifers are slightly phosphatized. Most intraparticle porosity is mud filled. There is a thin layer of blocky and dogtooth calcite on some micrite surfaces, including geopetal micrite within articulated shells.

450' (137m) Foraminiferal wackestone (very similar to sample at 380'). Skeletal grains include large and small foraminifers in a dark grey micrite matrix, ostracodes, bryozoans (?), echinoids. The small foraminifers are recrystallized and have lost strucural detail. A green phosphatic mineral replaces some foraminifers and other grains. No real pore-filling cements.

453' (138m) Packstone. Skeletal grains include large and small foraminifers, bryozoans, echinoid fragments, encrusting red algae, and ostracodes in a micrite matrix. Most skeletal grains are broken, slightly rounded, but well preserved. There is a small amount of dogtooth calcite cement on some surfaces.

462' (141m) Coarse, foraminiferal grainstone. (The first real grainstone observed in this core). Skeletal grains include small forams, encrusting red algae and rhodoliths, echinoids, oysters with large syntaxial overgrowth. Most grains are rounded and many are broken. Dogtooth calcite cement coats most external surfaces of skeletal grains.

Carbonate classification used:

Dunham's (1962) classification of carbonate rocks

<table>
<tr><td colspan="5">Depostional Texture Recognizable</td><td rowspan="5">Depositional texture not recognizable</td></tr>
<tr><td colspan="4">Original components not bound together during deposition</td><td rowspan="4">Original components were bound together during deposition as shown by intergrown skeletal matter, lamination contrary to gravity, or sediment-floored cavitities that are roofed over by organic or questionably organic matter and are too large to be intersticies.</td></tr>
<tr><td colspan="3">Contains carbonte mud (clay and silt size grains)</td><td rowspan="3">Lacks mud and is grain-supported</td></tr>
<tr><td colspan="2">Mud supported</td><td rowspan="2">Grain-supported</td></tr>
<tr><td><10 % grains</td><td>> 10 % grains</td></tr>
<tr><td>MUDSTONE</td><td>WACKESTONE</td><td>PACKSTONE</td><td>GRAINSTONE</td><td>BOUNDSTONE</td><td>CRYSTALLINE CARBONATE</td></tr>
</table>