TULANE STUDIES IN GEOLOGY

Volume 4, Number 2 May 27, 1966

STRATIGRAPHY OF THE UPPER MIOCENE DEPOSITS IN SARASOTA COUNTY, FLORIDA

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I. ABSTRACT

The presence of undisputed Upper Miocene sediments in Sarasota County, Florida, has not been widely known. Most authors have stated that the Middle Miocene Hawthorn Formation is overlain by Pliocene to Recent deposits. The Upper Miocene is represented in southern Florida by the Tamiami Formation. The Upper Miocene age determination is based on the characteristic faunal assemblage, *Ostrea disparalis, Chione ulocyma,* and *Ecphora quadricostata umbilicata.* Fossil mollusks, echinoderms, and bryozoans collected from outcrops, quarries, and sinkholes in this area definitely confirm the presence of Upper Miocene sediments in Sarasota County. Typical Upper Miocene species include *Anadara* cf. *A. idonea, Chione ulocyma, Ostrea* cf. *O. tamiamiensis, Ostrea tamiamiensis monroensis,* and *Encope macrophora tamiamiensis.*

Within the Upper Miocene deposits exists an impermeable but porous bed characterized by a decrease in radioactivity and electrical resistivity. These characteristics are indicative of clay and the interpretation of x-ray diffraction patterns verified the predominance of clay minerals in the aquiclude. Montmorillonite was the dominant clay mineral with lesser amounts of attapulgite and alpha sepiolite.

Based on evidence presented in this paper, the Upper Miocene deposits occurring in Sarasota County are considered to be a lithosome of the Tamiami Formation.

II. Introduction

Undisputed Upper Miocene deposits[1] previously have not been recognized in Sarasota County, Florida. It generally has been assumed that "Pliocene" to Recent sands overlie the Middle Miocene Hawthorn Formation. Fossil mollusks from quarries in Sarasota County and southern Manatee County definitely confirm the presence of Upper Miocene strata overlying the recognized Middle Miocene Hawthorn Formation. It is within these deposits that the confining bed, described below, occurs. These deposits are here referred stratigraphically to a lithosome of the upper part of the Tamiami Formation.

During the summer of 1962, the United States Geological Survey, in co-operation with the Florida Geological Survey, conducted a pumping test on the well field of Venice, Sarasota County, Florida, to determine the probable effects of salt water from the proposed intercoastal waterway on the city's water supply. The author served as a member of the field party (Florida Geological Survey).

Prior to the tests, electric and gamma-ray logs were obtained for as many wells as possible. These logs revealed the presence in each well of an impermeable bed characterized by a pronounced decrease in electrical resistivity and radioactivity (see Figure 1). Data from wells in other portions of Sarasota and adjoining counties also were used in delimitation of the confining lithologic unit.

All known Neogene exposures were examined, measured, and mapped. Information obtained from the field during 1962-1963 was supplemented from the paleontological and petrological collections of the Florida Geological Survey and the Florida State Museum.

[1] It may be noted that Puri and Vernon (1959, revised 1964), in their "Geologic Map of Florida," show the Bone Valley Formation extending into extreme northeastern Sarasota County, Florida. This diachronous formation is assigned variously to the "Alum Bluff Stage," "Choctawhatchee Stage," or "Alum Bluff and Choctawhatchee Stages" in different portions of their reports, but evidently (Vernon, personal communication, 1966) considered it to be Upper Miocene age in Sarasota County, Florida. This writer believes the evidence upon which this age assignment is based to be inconclusive.

III. Acknowledgments

The author wishes to express his gratitude to Dr. H. K. Brooks for his helpful advice, sincere interest, and willing assistance in many matters which made the completion of this study possible. Particular thanks are due to Dr. Robert O. Vernon for his suggestion of the problem and for furnishing all well samples, electric and radioactive logs, and his helpful comments.

The author appreciates the helpful suggestions of the following persons, who critically read the manuscript: Dr. H. K. Brooks, Dr. Hubert C. Skinner, Dr. Harold E. Vokes, Dr. Robert O Vernon, and Arnold Ross.

The author appreciates the assistance and helpful suggestions of the following persons, who verified the author's identification of the fauna: Dr. H. K. Brooks, Arnold Ross, and Reginald Scolaro. The author is indebted to Clifton T. Mansfield and Dr. Guerry H. McClellan for their assistance in preparation and interpretation of the x-ray diffraction patterns.

This paper would not have gone to press without the insistence, encouragement, and editorial guidance of Dr. Hubert C. Skinner of Tulane University.

IV. Procedure

Outcrop samples, well cuttings, and electrical and radioactivity logs were studied. The outcrops in Sarasota County are limited to a few dolomite quarries located in the northern part of the county and one dolomite quarry in the southern portion. In these quarries there is rarely more than 30 feet of rock exposed, of which approximately 10 feet are termed "Pliocene" to Recent sands. In the southern part of the county at least 200 feet are exposed in Warm Mineral Springs.

The limited exposures in Sarasota County required special emphasis to be placed on well cuttings and geophysical logs. The latter were used to trace the vertical and horizontal extent of the confining bed. Well cuttings were used to verify the identification of this bed in each well, to provide stratigraphic information concerning the age of this unit, and for the mineralogical analyses of the aquiclude.

Sampling and study of the section at Warm Mineral Springs were accomplished with the aid of self-contained underwater breathing apparatus.

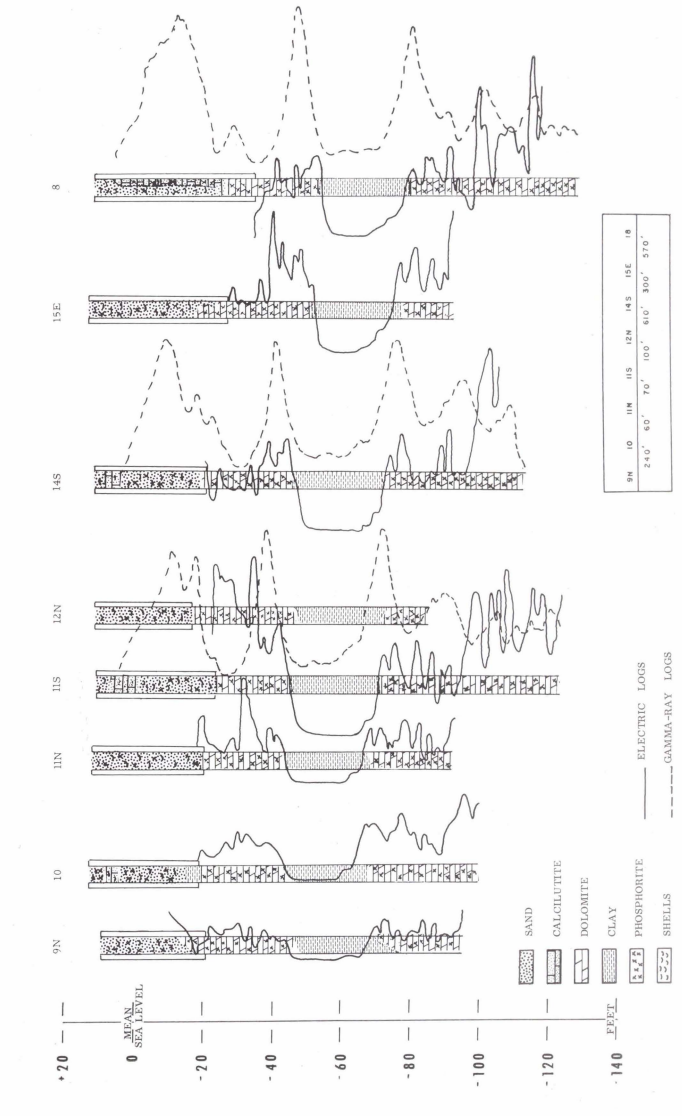

Figure 1. ELECTRIC AND GAMMA-LOGS DEFINING THE AQUICLUDE IN THE VENICE WELL FIELD

V. Stratigraphy

Upper Miocene deposits of Florida are limited mainly to two areas, the panhandle and the southern peninsula. According to Langdon (1889, p. 323) the Carolinian Miocene of Heilprin (1887, p. 127) is represented in the Florida panhandle by the uppermost bed at Alum Bluff, Liberty County, Florida. This age determination was based on the presence of the characteristic Upper Miocene gastropod *Ecphora quadricostata umbilicata.* Puri (1953, p. 27) recognized the four faunal zones, *"Yoldia," "Arca," "Ecphora,"* and *"Cancellaria"* of Cooke and Mossom (1929) and Mansfield and Ponton (1932) as biozones at Alum Bluff. He referred this formation, a stratigraphic unit, to the rank of stage, a time-stratigraphic unit (Puri, 1953, p. 28).[2] The "Choctawhatchee Stage" as defined by Puri includes all Miocene sediments of post-Alum Bluff age in northwestern Florida.

DuBar and Beardsley (1961, p. 160) recognized the fact that Puri had changed the rank of the Choctawhatchee from formation to that of stage "without a stated reason." They refer to the Late Miocene rocks of the Florida panhandle as the "Choctawhatchee deposits" and "as a matter of convenience for reference have temporarily retained Puri's facies nomenclature for all but the exposures at Alum Bluff and Jackson Bluff."

The Tamiami Formation as redescribed by Parker (1951, p. 823) includes all deposits of Upper Miocene age in southern Florida. His formation includes the Tamiami Limestone and Buckingham Limestone of Mansfield (1939, p. 8), which were designated facies by Parker. Based on the characteristic faunal assemblage, *Ostrea disparalis, Chione ulocyma,* and *Ecphora quadricostata umbilicata,* the deposits were referred to as the Upper Miocene (Parker, p. 823).

Olsson and Petit (1964, p. 516) proposed the name "Pinecrest beds" for certain strata in the region of 40-mile Bend on the Tamiami Trial. This exposure extends from western Dade County into Collier County. These late Neogene beds lie conformably on the Tamiami Formation in certain localities and unconformably in others. Further work may establish whether these beds are Upper Miocene or Pliocene.

Along the west coast of Florida (between the panhandle and the southern tip of the state), the presence of Upper Miocene sediments has not been widely known. However, as early as 1887 (Heilprin, p. 13), the probable equivalence of the fossiliferous limestones exposed at Rocky Bluff, Manatee County, Florida, to the Carolinian Miocene was recognized. In addition, material dredged from Tampa Bay was referred to the Upper Miocene by Mansfield (Cooke and Mossom, 1929, p. 148). Aside from these two localities, no sediments in west central Florida have been assigned an Upper Miocene age.

Biostratigraphic studies of the Upper Miocene of Sarasota and Manatee Counties are presently being made under the direction of Dr. H. K. Brooks. His results earlier suggested the presence of Upper Miocene deposits in Sarasota County. The present study was undertaken as a part of this project.

Study of the impermeable lithologic unit in the supply wells of Venice, Sarasota County, raised the question of the age of the bounding strata. This problem and that of determining the mineralogic composition of the unit are treated herein.

The Aquiclude in Sarasota County

This confining layer acts as an aquiclude between the aquifers above and below. All subsurface logs available from Sarasota County and many of those from the bordering counties were examined to determine the horizontal extent of this bed.

Three separate cross sections were plotted: one, from west to east, across the northern part of the county (wells 36-17-13-3, W-5966, W-5974, 36-18-24-1, 19-36-22-2, W-938, 20-36-3-1, and the Kaimee Ranch test well); the second, from north to south along the Gulf coast (wells 36-17-13-3, W-6131, W-4947, and W-1917); and the third, from northwest to southeast along the southern part of the county (wells 9 N, W-5421, SA-90, C-46, and the section from Warm Mineral Springs). The three sections were connected to construct the fence diagram (Figure 2). Data available were insufficient to prepare an isopach or struc-

[2] Dr. R. O. Vernon (personal communication, January 27, 1966) suggests, "Dr. Puri chose as a means of convenience, so as not to complicate the literature further, to refer to these formations as stages rather than as stratigraphic units."

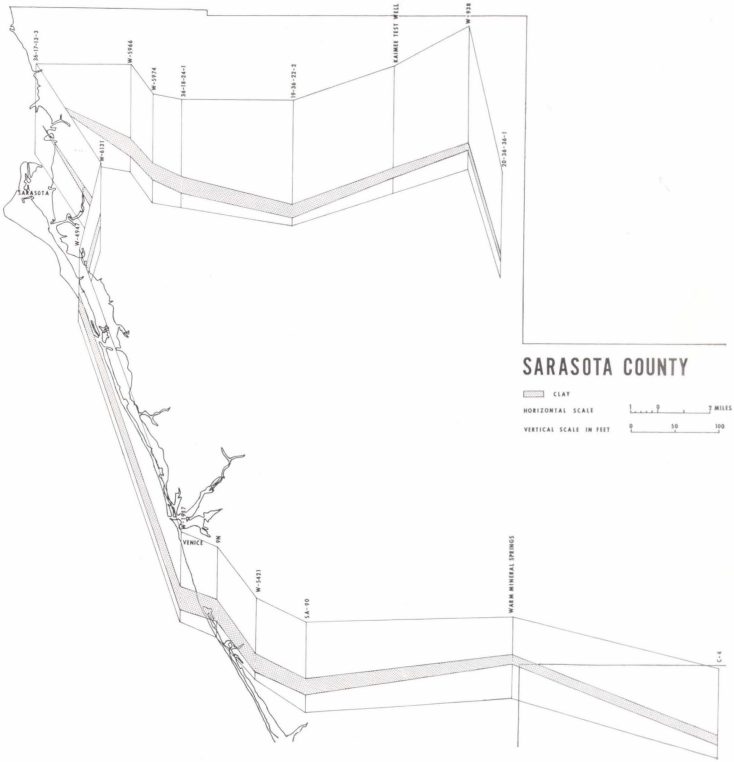

Figure 2. Fence diagram indicating the relative position of the aquiclude in Sarasota County, Florida.

tural contour map, largely due to the variation in thickness from well to well.

The recorded decrease in electrical resistivity of this unit indicates the increase in porosity and decrease in permeability characteristic of clays. Most clays are porous and contain water but are not permeable. The x-ray diffraction patterns confirmed the identification of clay minerals.

The clay is thickest in the Venice area (see Figure 2), where it reaches the maximum thickness of 28 feet. Southeastward it thins to eight feet in well C-46 in Charlotte County. North of well C-46 (in the NW/4, NW/4 sec. 30, T38S, R22E) the clay bed was not penetrated. The unit thins to the north and northeast (in wells W-4947 and W-6131) to a point no more than two miles from the Gulf of Mexico. In well W-5118, southwest of well W-4947, the confining bed is not present. Eastward from the coast the clay bed again thickens (well W-5966) to 18 feet in the northern part of the county. In well W-938 in the northeast corner of the county the bed is approximately eight feet thick, the same as in well 20-36-36-1, the control well in the northeastern part of the county.

The areal extent of the confining bed is determined from the following control

wells: 36-17-13-3, 20-36-36-1, W-938, W-1917, and C-46, which occur respectively in the northwest, northeast, north, southwest, and southeast sections of the county.

The available information from subsurface logs and lithologic samples indicates that this clay bed strikes parallel to the coast to the city limits of Sarasota along the mainland side of Sarasota Bay. It is thickest in a belt extending from the eastern portion of Range 18 in the north through all of Range 19 in the southern part of the county. The bed is thinner in the southeastern section (Range 22) and in the northeastern section (Range 21) of the county.

Upper Miocene Deposits of Sarasota County

Introduction

It generally has been assumed that the aquiclude studied is a member of the Hawthorn Formation (Dall, 1892). The Hawthorn is extremely variable in lithology and consists of from 60 to several hundred feet of interbedded clays, sands, sandy limestones, dolomites, and marls. In Sarasota County, a sandy dolomite containing brown phosphorite grains is the predominant component.

The only extensive geological investigation in Sarasota County was that of V. T. Stringfield (1933, p. 121-227), in which he described the geology and existing ground water conditions. Previously, the geology and ground water of Sarasota County were mentioned only in several reports of the United States Geological Survey and the Florida Geological Survey (Matson, 1913; Sellards and Gunter, 1913; Mossom, 1926; and Cooke and Mossom, 1929). Matson (1913, p. 319, 362-364) briefly described the geology of Manatee County and part of Sarasota County. Sellards and Gunter (1913, p. 269) mentioned only the wells in Sarasota County. Mossom (1926, p. 171-268) described the general geological structure of Florida. The most detailed study prior to Stringfield's report was that of Cooke and Mossom (1929, p. 29), who described the general stratigraphy of Florida and included a geologic map showing the areal extent of the formation at or near the surface. Cooke (1945) described the geology of Florida and mentioned the formations exposed in Sarasota County: the Hawthorn, Bone Valley, and Calooshatchee. Puri and Vernon (1959, 1964), in the most recently published studies on the geology of Florida, also referred to the geology of Sarasota County.

Lower Neogene strata crop out in a few drainage ditches, along the banks of creeks, and along the shore of Sarasota Bay. Seldom is more than a few feet of rock exposed. The most extensive exposures occur in quarries near the Sarasota-Manatee County line and east of Venice. The available thickness of these exposures depends upon the level of the water table. Under dry conditions no more than 20 feet is exposed, a portion of which is Quaternary sand. Nearly all the geological information available is obtained from well cuttings. A stratigraphic section at Warm Mineral Springs (from approximately eight feet above to about 80 feet below mean sea level) is presented below.

Previous studies of Sarasota County well logs and the sections described reveal that the Pliocene to Recent sediments supposedly rest directly upon the Middle Miocene Hawthorn Formation, thus excluding Upper Miocene deposits in most parts of the county. The dolomites and limestones quarried in southern Manatee and northern Sarasota Counties are referred to the Hawthorn Formation by Cooke and Mossom (1926), Stringfield (1933), Cooke (1945), Peek (1958), and Puri and Vernon (1959, 1964). In all quarries visited by the writer it was possible to collect fossils. Many specimens recovered are pseudomorphs; some are well preserved mollusks and bryozoans. Identification of the fossils collected confirms the existence of Upper Miocene faunas in beds overlying the Hawthorn Formation.

The Tamiami Formation, as described by Parker (1951, p. 823), includes all the deposits of Late Miocene age in southern Florida. Both the Tamiami Limestone and the Buckingham Limestone of Mansfield (1939, p. 8) are included in Parker's definition. Parker based this correlation on his discovery of *Ecphora quadricostata umbilicata* (Wagner) in the marl along the Caloosahatchee River, at Banana Creek. This index fossil established the Tamiami Formation as Upper Miocene age. Other key mollusks were identified from Alligator Creek in Charlotte County, including *Ostrea disparalis, Chione ulocyma,* and *Turritella pon-*

toni. These are diagnostic Upper Miocene species. Specimens of *Ecphora quadricostata umbilicata* (Wagner) from near Fort Myers and near Buckingham, Lee County, Florida (in the Florida State Museum collection, University of Florida) further support the Upper Miocene age of the Tamiami Formation (Brooks, Ross, and Eppert, 1963).

The lithology of the Tamiami Formation is extremely variable. As described by Mansfield (1939), the Tamiami Limestone consists of calcareous sandstone, sandy limestone, and beds and pockets of quartz sand; and, the Buckingham Limestone consists of creamy white to green calcareous clay. Where exposed to weathering, the Buckingham Limestone has been case-hardened, stained a light brown, and riddled by solution holes. It also contains considerable amounts of phosphoritic particles ranging in size from sand to pebbles.

Exposures of the Tamiami Formation south of Sarasota County extends in a belt from north of Acline in Charlotte County, eastward to Denaud, in Hendry County. Along the west coast, it extends from north of Acline south to Fort Myers Beach and to the coast at Bonita Springs, in Lee County.

Upper Miocene deposits north of Sarasota County consist solely of a sandy phosphoritic limestone dredged from Tampa Bay in the vicinity of St. Petersburg, Pinellas County. The age assignment of these deposits is based on the fauna identified by Mansfield (Cooke and Mossom, 1929, p. 148), apparently from the same horizon as Puri's Choctawhatchee Stage (1953, p. 27-67).

The Choctawhatchee Marl, as defined by Matson and Clapp (1909, p. 114), consisted of the *"Ecphora* bed" and aluminous "clay" of Dall (Dall and Stanley-Brown, 1894, p. 168-169). Cooke and Mossom (1929, p. 138) elevated the marl to formational rank. Mansfield (Cooke and Mossom, 1929, p. 140) recognized three faunizones, the *"Arca," "Ecphora,"* and *"Cancellaria,"* in the Choctawhatchee Formation. Later, Mansfield and Ponton (1932, p. 84-88) added a fourth zone, the *"Yoldia."* Cooke (1945) discarded the term Choctawhatchee and placed the two lower faunizones, *"Arca"* and *"Yoldia,"* in the Shoal River Formation of Upper Middle Miocene, and the upper two, *"Cancellaria"* and *"Ecphora,"* in the Duplin Marl. Puri (1953), however, assigned all four of these biofacies to his "Choctawhatchee Stage," in which he included all Miocene sediments of post-Alum Bluff age in the Florida panhandle and their equivalents in the central and western Gulf states.

Heilprin (1887, p. 13) described an outcrop at Rocky Bluff, Manatee County, one mile east of Ellenton on the Manatee River, consisting of a fossiliferous basal white marl and yellow sandstone and an overlying barren siliceous conglomerate. He believed the fauna identified from the basal unit to be distinctly of Upper Miocene age. Mansfield (Cooke and Mossom, 1929, p. 136-137) recognized the deposit as Miocene, but believed it to be older than had been indicated by Heilprin. Cooke (1945, p. 158) referred the clayey sand and yellow phosphatic marl near Ellenton to the Hawthorn Formation. He included in the Hawthorn a white sandstone exposed in a ditch on U.S. Highway 41, two miles south of Bradenton. Though the fauna from these localities has been noted in the Upper Miocene of other areas, there still is some question as to whether these deposits are upper Middle Miocene or lower Upper Miocene. Both paleontological and stratigraphical evidence from the present investigation confirm the existence of Upper Miocene deposits in Sarasota County.

Discussion

All of southern Florida (including Sarasota County) is underlain by the Hawthorn Formation. The boundary between the interbedded clay, sand and sandy limestone, dolomite, and marl of the Hawthorn Formation and the silty, sandy clays and limestones of the overlying Tamiami Formation is transitional and difficult to recognize.

Stratigraphic data obtained from quarries, well samples, and Warm Mineral Springs demonstrate that the upper 130 feet of the strata in Sarasota County consist essentially of phosphoritic dolomite and limestone with interbedded layers of clay. There is less lithologic variation in the sediments than in the typical Hawthorn or Tamiami formations.

In the area studied, the lithology of the rocks is similar; however, color variation proved valid for local correlation. The color variations in the sections studied ranged

from white to pale orange to yellowish gray to olive gray. Some of the clays encountered showed a slight bluish color, especially when wet. An abrupt color change from pale orange to pale olive was noted in the dolomite from the quarry at Oneco, Manatee County, Florida. This general color change is also present in the Manatee Rock Company Quarry located 1.7 miles north of the city limits of Samoset, Manatee County, Florida.

Many of the dolomites being mined in northern Sarasota and southern Manatee Counties are case-hardened. Below the case-hardened layer is a soft marly dolomite. Alternation of soft marly and lithified dolomites occurs throughout a 20- to 30-foot section in the aforementioned quarries. In well samples from Sarasota County this alternating characteristic was observed. At greater depths crystalline dolomites also are interbedded.

The upper 40 feet of sediments are poorly fossiliferous. This is, in part, due to the leaching action of ground water.

X-ray diffraction patterns were obtained from numerous samples to determine the minerals present. The dominant mineral in each sample was dolomite, with lesser amounts of quartz, calcite, and phosphorite. Similar results were obtained by Pittsburg Testing Laboratories analyzing rock samples for the Manatee Rock Company while developing the quarry.

The amount and size of the phosphorite grains vary vertically in nearly all of the sections studied. Well 16, located in the Venice well field, is typical. A sample collected from 34-43 feet below the surface contained very small amounts of fine phosphorite grains. The sample from 43-50 feet contained pebble-size grains of phosphorite and the sample from 50-60 feet contained very slight amounts of fine grains. The variation in the size of the phosphorite grains also proved useful for local correlation.

The aquiclude illustrated in the fence diagram is the only continuous clay layer in the upper 130 feet of the stratigraphic section of Sarasota County. In the northeastern and northern part of the county and in Sarasota Bay, thin silt and clay beds are interbedded with sand and limestone in the upper 35 feet of the stratigraphic section.

The following section is exposed at Rocky Bluff on the Manatee River, about one mile east of Ellenton. This is the outcrop from which Heilprin (1887, p. 63) described the first Late Miocene fauna reported from southern Florida.

Section at Rocky Bluff, Manatee County

Bed		Thickness
Quaternary		
4	Loam, sandy, light and dark	1 foot
3	Loam, black, clayey with bone fragments	1 foot
Miocene		
2	Fuller's earth, light gray	2-3 feet
1	Limestone, light gray to pale yellow, impure, fossiliferous; extending at least nine feet below the water level	13 feet

The first report of Upper Miocene fauna south of the Manatee River was from the Manatee Rock Company Quarry, located 1.7 miles north of the city limits of Samoset, Florida (NE/4, SW/4, sec. 32, T34S, R18E); an Upper Miocene fauna was collected. Between beds 2 and 3 are voids representing solution channels trending east-west.

The color changes abruptly from pale orange to pale olive in the dolomite section at Oneco Quarry, Manatee County, Florida

Section at Manatee Rock Company Quarry

Bed		Thickness
Quaternary		
6	Sand, fine quartz, angular with abundance of *Chione cancellata*	10 feet
Miocene		
5	Clay, greenish gray, blocky, sandy	2 feet
4	Dolomite, very pale orange, case-hardened, phosphoritic, few mulusk impressions; varying in thickness from two to five feet	5 feet
3	Dolomite, pale orange, soft, very fossiliferous, phosphoritic	5 feet
2	Dolomite, pale orange, hard, phosphoritic	5 feet
1	Dolomite, pale orange to pale olive hard to soft, phosphoritic with few fossil impressions; thickness greater than 10 feet	10 feet

(west central part of sec. 7, T35S, R18E). Approximately three feet of rock are exposed above average water level in this quarry, but no fossils were collected here.

Section at Oneco Quarry

Bed		Thickness
Quaternary		
4	Sand, fine quartz, angular, with abundance of *Chione cancellata*	12 feet
Miocene		
3	Dolomite, pale orange, soft, phosphoritic	4 feet
2	Dolomite, phosphoritic, pale orange, case-hardened	4 feet
1	Dolomite, phosphoritic, pale olive, case-hardened	2 feet

An abandoned dolomite quarry, one mile east of the Sarasota-Bradenton Airport (N/2, sec. 6, T36S, R18E) was visited during the fall of 1962. Fill material excavated from the center portion of the quarry exposed a 24-foot section. At the base is a dense dark clay. Above the clay is a thin bed of fossiliferous dolomite, from which well preserved mollusks were collected.

Section at Abandoned Dolomite Quarry

Bed		Thickness
Quaternary		
7	Sand, fine angular quartz; abundance of *Chione cancellata*	2 feet
Miocene		
6	Dolomite, pale orange, case-hardened, with fine phosphorite grains	8 feet
5	Claystone, greenish gray, pure	4 feet
4	Dolomite, very light gray to yellowish gray, hard, fossiliferous	2 feet
3	Clay, light gray to yellow gray, mottled with nodules of dolomite	1 foot
2	Clay, yellowish gray to light green	1 foot
1	Clay, dark greenish gray, dense	6 feet

The following section is exposed in the West Coast Dolomite Company Quarry east of Venice, Sarasota County, Florida (SW/4, NE/4, sec. 6, T39S, R20E). The quarry is located in an old river valley and most of the fossils are leached out of the upper sands. The lithology is not as variable as in the abandoned dolomite quarry. A spring line between beds 3 and 4 is visible.

Section at West Coast Dolomite Company Quarry

Bed		Thickness
Quaternary		
5	Sand, fine to medium, subangular to rounded; very few shell fragments	8 feet
Miocene		
4	Dolomite, finely phosphoritic, pale orange, case-hardened, fossiliferous	5 feet
3	Marl finely phosphoritic, pale orange, dolomite, few fossil impressions	3 feet
2	Dolomite, finely phosphoritic, pale orange, case-hardened, very fossiliferous	4 feet
	Water level	
1	Dolomite, finely phosphoritic, grayish green, crystalline, very fossiliferous	3 feet

Warm Mineral Springs is located in the southern part of Sarasota County (NW/4, NW/4, sec. 25, T39S, R20E). Bed 10 is represented in the fence diagram as the aquiclude. Poorly preserved mollusk impressions are recognizable throughout the section. The sample from the clay bed was collected in 1961 by Dr. H. K. Brooks.

Heilprin (1887, p. 63) recognized several mollusks from Rocky Bluff which are distinctive of the Upper Miocene formations in the northeastern United States. The species, identified from casts and impressions, included *Pecten madisonius, P. jeffersonius, Perna maxillata, Venus alveata,* and *Arca idonea* (?). Heilprin believed these indicative of an Upper Miocene fauna.

A locality near the north end of Little Sarasota Bay known as White Beach was described by Heilprin (1887, p. 64-65) and Dall (1892, p. 114-115). The exposure consists of a yellowish limestone, badly waterworn and covered in places with a thin veneer of Recent sediments. The rock contains distorted molds of many species which cannot be identified, but in some places these molds have become filled with pseudomorphs of the original shells. The specimens resemble closely the following species: *Pecten jeffersonius, P. madisonius,* and *Venus alveata.*

Section from Warm Mineral Springs

Bed		Thickness
Quaternary		
17	Sand, fine, angular	6 feet
16	Sand, light olive gray, angular, fine-grain quartz, calcareous, abundance of *Chione cancellata*	5 feet
Miocene		
15	Limestone, whitish gray, fine grain, dolomitic, sandy, hard, fine phosphoritic grains	8 feet
14	Dolomite, very pale orange, fairly hard, sandy, fine phosphorite grains; outer layer of travertine	7 feet
13	Limestone, yellowish gray, fairly hard, sandy dolomitic, fine phosphorite grains; outer layer of travertine	10 feet
12	Dolomite, yellowish gray, hard, calcareous, fine phosphorite grains, fossil impressions; outer layer of travertine	4 feet
11	Limestone, pale greenish yellow, fairly hard, fine phosphorite grains	10 feet
10	Silt, greenish gray	6 feet
9	Dolomite, very pale orange, hard, phosphorite grains, fossil impressions; outer layer of travertine	3 feet
8	Siltstone, pale greenish yellow, chalky, dolomitic, phosphorite grains	3 feet
7	Dolomite, yellowish gray, hard, calcareous, phosphorite grains, fossil impressions; outer layer of travertine	9 feet
6	Limestone, yellowish gray, sandy, fairly hard, dolomitic	5 feet
5	Limestone, yellowish gray, porous to indurated; outer layer of travertine	6 feet
4	Dolomite, yellowish gray, chalky to indurated, phosphorite grains, fossil impressions	3 feet
3	Dolomite, yellowish gray, hard, fossil impressions	3 feet
2	Limestone, grayish yellow, hard, phosphorite grains	3 feet
1	Dolomite, yellowish gray, hard, phosphorite grains, fossil impressions	2 feet

Modified from unpublished section measured by H. K. Brooks, 1959.

On the banks of Phillippi Creek, which flows into Sarasota Bay, Heilprin (1887, p. 16) found casts of *Pecten jeffersonius, P. madisonius,* and *Arca idonea,* and others which appeared identical to those described from Rocky Bluff.

Dall (1892, p. 126) reported a specimen of *Ecphora quadricostata umbilicata* collected from the beach of Long Key in Manatee and Sarasota Counties. This waterworn shell probably washed ashore from a more westerly submerged stratum.

The fauna collected from the Manatee Rock Company Quarry by Dr. H. K. Brooks and the writer was very poorly preserved. Most specimens were impressions of pseudomorphs of the original shells. One ectoproctous bryozoan was found, *Cupuladria canariensis.* This species ranges from lower Middle Miocene (Chipola Formation) to Recent. The following species were identified from the quarry:

Bryozoa
- *Cupuladria canariensis* Busk

Echinodermata
- *Encope tamiamiensis* Mansfield

Gastropoda
- *Cypraea* sp.
- *Conus* sp.
- *Lyria* cf. *L. pycnopleura* Gardner

Pelecypoda
- *Anadara* cf. *A. idonea* (Conrad)
- *Venericardia* sp.
- *Chione* cf. *C. cancellata* (Linnaeus)
- *Mercenaria* cf. *M. prodrama* (Gardner)

Two species, *Lyria* cf. *L. pycnopleura* and *Mercenaria* cf. *M. prodrama,* commonly are reported from horizons of Middle Miocene age in northern Florida. *Chione cancellata* ranges from Upper Miocene to Recent.

Anadara cf. *A. idonea* is a characteristic Upper Miocene species reported from the "*Ecphora* zone" of the "Choctawhatchee Stage" and from the Tamiami Formation on Banana Creek, Hendry County, Florida. *Encope tamiamiensis* is characteristic of the Tamiami Formation. *Chlamys* cf. *C. madisonia* is synonymous with *Pecten madisonius* reported from the Upper Miocene Calvert and Choptank formations in Virginia and Maryland.

The fauna identified from the old dolomite quarry east of the Sarasota-Bradenton Airport (see below) contained only two species found in the quarry just mentioned.

The matrix in which they occurred is located below the pale orange dolomite occurring in the Manatee Rock Company Quarry. The bed is very thin and consists of light gray, hard, clayey dolomite. The preservation of the fossils here is much better, especially the oysters, which still possess part of their original shell.

The following is a list of species identified from this quarry:

Bryozoa
- *Cupuladria canariensis* Busk
- *Trigonopora ariculatum* (Canu and Bassler)

Gastropoda
- *Polinices judsoni* (Maury)
- *Conus* cf. *C. daucus* Hwass
- *Turbinella* cf. *T. regina* Heilprin

Pelecypoda
- *Ostrea tamiamiensis* Mansfield
- *Pecten* sp.
- *Chlamys condylomatus* Dall
- *Lima (Mantellum) carolinensis* Dall
- *Venericardia* sp.
- *Echinochama* sp.
- *Chione* cf. *C. cancellata* (Linnaeus)

There are three distinct Upper Miocene species in this quarry, *Lima carolinensis, Ostrea tamiamiensis,* and *Cupuladria canariensis. Lima carolinensis* has been described from both the "*Cancellaria* zone" of the "Choctawhatchee Stage" and the Buckingham Limestone facies of the Tamiami Formation. *Ostrea tamiamiensis* is one of the most abundant mollusks found in the Tamiami Formation.

The section exposed in the West Coast Dolomite Quarry east of Venice, Sarasota County, Florida, consists of at least 12 feet of fossiliferous dolomite. Fossils are well preserved as casts and impressions. Several of the species retain their original shell material. The dolomite is "dense" throughout the whole section. The following species were identified from the quarry:

Gastropoda
- *Petaloconchus sculpturatus* Lea

Pelecypoda
- *Ostrea meridionalis* Heilprin
- *Ostrea tamiamiensis* Mansfield
- *Lima (Mantellum) carolinensis* Dall
- *Venericardia* sp.
- *Chione cf. C. cancellata* (Linnaeus)
- *Chione latilirata athleta* (Conrad)
- *Chione ulocyma* Dall

Petaloconchus sculpturatus ranges from Lower Middle Miocene (Chipola Formation) to Upper Miocene. Both *Ostrea meridionalis* and *Ostrea tamiamiensis* were originally described from the Tamiami Formation. *Chione ulocyma* occurs in deposits no younger than Upper Miocene; *Chione latilerata athleta* ranges from Upper Miocene to Recent.

The West Coast Dolomite Company Quarry is the most southerly exposure in Sarasota County from which fossils were collected.

The Florida State Museum collections, at the University of Florida, contain specimens of *Ostrea tamiamiensis monroensis* dredged from lower Sarasota Bay, approximately eight miles south of Sarasota. *Ostrea tamiamiensis monroensis* is extremely abundant in the Tamiami Formation and generally exhibits an excellent state of preservation.

Stratigraphic Conclusions

Lithologically, it is impossible to distinguish the boundary between the upper Miocene and Middle Miocene. There is gradational change with no clear lithologic boundary. It is possible to trace the pale orange, fossiliferous dolomite from the Manatee Rock Company Quarry all the way to Warm Mineral Springs. In some sections this dolomite is more fossiliferous than in others. Heilprin (1887) and Dall (1892) described this fossiliferous dolomite also from Rocky Bluff on the Manatee River and Phillippi Creek, south of Sarasota.

The fauna listed from the outcrops, quarries and from Sarasota Bay correlate with deposits herein considered Upper Miocene. Four species were identified that are known to occur in Middle Miocene deposits. Four species range from Middle Miocene to Upper Miocene and six have been reported only from the Upper Miocene. Two are known to range from Upper Miocene to Recent and two from Pliocene to Recent. One species ranges from Lower Miocene to Upper Miocene.

Based on the evidence presented in this paper, Upper Miocene deposits definitely exist in Sarasota County. The deposits are referable to a lithosome of the Tamiami Formation of southern Florida. The total thickness of the Upper Miocene Sarasota County deposits here described is not known.

VI. Mineral Analysis of the Aquiclude

The mineralogic composition of the lithologic unit presented in Figure 2 is based on the interpretation of x-ray diffraction patterns. The outcrop of the confining bed in Warm Mineral Springs provided the only uncontaminated sample. The final results of the mineralogical study were based on the analysis of the Warm Mineral Springs sample.

Samples from cable and rotary tools are rarely satisfactory for percentage determinations unless the caving intervals have been cased. The contamination from overlying debris obscures diagnostic features and makes uncertain the identification of indigenous fine clastic material.

The samples analyzed were obtained from wells W-4476, W-4477, W-4488, W-5974, and the outcrop sample from Warm Mineral Springs. The samples were taken from the central interval of the confining bed at each station.

The clay minerals identified from the aforementioned wells consist of predominantly montmorillonite and attapulgite with a minor amount of alpha sepiolite. The intensity of the reflections from montmorillonite surpassed both attapulgite and alpha sepiolite in all the samples, indicating that montmorillonite is the dominant clay mineral.

The patterns indicate that the clay minerals are poorly crystalline, especially the montmorillonite. It is believed that the poorly crystalline nature of all the clays would indicate a detrital origin with a short distance of transportation. If the material had been transported very far, the attapulgite would likely have been destroyed. Weathering causes attapulgite to break down to form montmorillonite. This has not been demonstrated conclusively, though structurally the idea is quite permissible. Ralph E. Grim (McClellan, 1962) has indicated that, in his opinion, this transition is possible.

The impurities identified in the sedimented and glycolated samples are quartz, calcite, and dolomite.

The confining bed was presumed to consist essentially of clay, based on the characteristic decrease in electrical resistivity indicating a porous but impermeable stratum. This was verified by x-ray analysis.

VII. Summary

The geologic investigation of an aquiclude (see Figure 2) in Sarasota County resulted in a stratigraphic study of the adjoining strata. Fossils were collected from three quarries, one in southern Manatee County and the others in Sarasota County. The age of the specimens identified ranges from Lower Miocene to Recent. Typical Upper Miocene species included *Anadara* cf. *A. idonea, Chione latilerata athleta, Chione ulocyma, Lima (Mantellum) carolinensis, Ostrea* cf. *O. tamiamiensis, Ostrea* cf. *O. meridionalis, Ostrea tamiamiensis monroensis,* and *Encope macrophora tamiamiensis.* Two of these, *Ostrea tamiamiensis* and *Ostrea tamiamiensis monroensis,* are the most common mollusks in the Upper Miocene Tamiami Formation of southern Florida. *Encope macrophora tamiamiensis* is considered an index fossil for the Upper Miocene in southern Florida. Thus, paleontological evidence definitely places these strata from Sarasota County in the Upper Miocene.

The occurrence of Upper Miocene deposits in Sarasota County was first reported by Heilprin (1887, p. 127). Heilprin reported several species of mollusks *(Pecten jeffersonius, Pecten madisonius,* and *Venus alveata)* collected from a yellow arenaceous limestone near the mouth of Phillippi Creek. The specimens were in a poor state of preservation, but were similar to species collected from an outcrop at Rocky Bluff, Manatee County. Heilprin's specimens were characteristic Upper Miocene species originally described from the Upper Miocene deposits of Maryland and New Jersey. Mansfield (Cooke and Mossom, 1929, p. 136-137) visited these same localities and suggested that the deposits were somewhat older than indicated by Heilprin. Prior to the present study, it had been assumed that "Pliocene" to Recent sands unconformably overlie the Middle Miocene Hawthorn Formation in Sarasota County.

The deposits here are referred to a lithosome of the Tamiami Formation. The exact thickness is not known. The boundary between the Hawthorn Formation and the overlying Tamiami Formation is transitional and it cannot be differentiated lithologically or faunally. The stratigraphic section exposed at Warm Mineral Springs contains approximately 120 feet of phosphoritic dolo-

mite and clay. The upper 90 feet of this section contain mollusk impressions so poorly preserved as to prevent identification.

The aquiclude studied is a lithologic unit within the Tamiami Formation of Upper Miocene age in Sarasota County, Florida. This aquiclude separates two aquifers in the Venice area. It was traced throughout the county by electric and gamma-ray logs of water wells. The correlations were confirmed by analysis of well cuttings. X-ray diffraction patterns were run on samples of the aquiclude and the results indicate that montmorillonite is the dominant clay mineral, with lesser amounts of attapulgite and alpha sepiolite. The patterns also showed minor amounts of dolomite, quartz, and calcite. The dolomite and calcite are believed to be contamination from collapse material in the course of drilling and sampling of the wells.

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