THE FLORIDA STATE UNIVERSITY

COLLEGE OF ARTS AND SCIENCES

THE LABELLE CLAY OF THE TAMIAMI FORMATION

by

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A Thesis submitted to the
Department of Geology
in partial fulfillment of the
requirements for the degree of
Master of Science

Approved:

Professor Directing Thesis

Fall Semester, 1987

ABSTRACT

The age and definition of the Tamiami Formation in southern Florida have been subject to considerable debate since the Formation was originally defined. The Formation definition originally began as consisting of one carbonate unit seen in road and quarry cuts, and since grew to include a thick sequence of marine sandy clays and limestones, believed to be Miocene in age.

Two cores were drilled by the Florida Bureau of Geology (Department of Natural Resources) in cooperation with the U.S. Geological Survey (Water Resources Division) in southern Lee County, in an attempt to obtain a complete section of the Tamiami Formation as delineated in that area by previous workers. Although neither core penetrated the entire section, valuable data were obtained. Of particular interest was a section of dense olive-green clay, herein called the LaBelle clay. The LaBelle clay was mapped throughout Lee County using a set of geophysical logs produced by Mobil Oil Exploration Corporation. The clay has also been traced by others throughout Hendry and Collier Counties.

A diatom assemblage was found in the lower half of the clay dated Pliocene in age by two marker species, Thalassiosira oestrupii (Ostenfeld) Proschkina-Lavrenko, and Cussia tatsunokuchiensis (Koizumi) Schrader. The assemblage suggests a restricted saline environment of deposition.

ACKNOWLEDGMENTS

I very gratefully acknowledge the help and support of Professors Woody Wise, Ken Osmond, and Jim Cowart of Florida State University.

Thanks also to the Florida State Bureau of Geology; the U.S. Geological Survey Water Resources Division, Fort Myers Field Office; and to Dennis Cassidy, Tom Fellers, and Bill Miller.

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CHAPTER I

INTRODUCTION

General Statement

The Tamiami Formation was defined in 1955 by Parker, Ferguson, and Love to include Mansfield's Tamiami limestone and all other upper Miocene materials in southern Florida. It has been the subject of considerable study since Peck (1976) and Slater (1978) discussed the Formation in Lee and Hendry Counties, Florida. Hunter (1978) and Hunter and Wise (1980) recently suggested a need to redefine the Tamiami Formation to include only the Tamiami limestone of Mansfield and its equivalents while relegating the upper Miocene sediments to the Hawthorn Formation. Their division of the two formations was based on a "major regional unconformity" which separates the Ochopee and Buckingham Limestones (Hunter, 1968) from the LaBelle clay (Puri and Vernon, 1964). The LaBelle clay, which was previously considered to be upper Miocene in age, is the subject of this study.

Two cores (W-14071 and W-14072) drilled by the Florida Bureau of Geology (Department of Natural Resources) in the Corkscrew Swamp area of southern Lee and northern Collier Counties were analyzed in an attempt to further refine work performed by Peck (1976) and Slater (1978) in this area. Of particular interest in core W-14072 was a diatom assemblage also found in Peck's (1976) Unit 2 green clay and Slater's Unit 2 green clay which are in part, equivalent to the LaBelle clay described by Puri and Vernon (1964). The diatom assemblage was considered by Peck to be Miocene in age based on the occurrence of Actinoptychus bismarkii Schmidt.

In addition to light microscopy examination, a scanning electron microscopy study was conducted on the assemblage. Also, a geophysical study was undertaken to determine the geometry of the LaBelle clay in Lee County. Data for this study were derived from sixty well sites which had been drilled and geophysically logged by Mobil Oil Corporation as part of their exploration program.

Study Area

Lee County is in the Kissimmee-Everglades area, Flatwood geographic locality (Peck, 1976), an area which is low-lying and poorly drained. Transpiration and evaporation account for a large part of the outflow from the area, and surface runoff occurs primarily during the rainy season (Motz, et.al., 1980).

The County is located on the southwest coast of Florida (Figure 1) bounded by Charlotte County to the north, Hendry and Collier Counties to the east, and Collier County to the

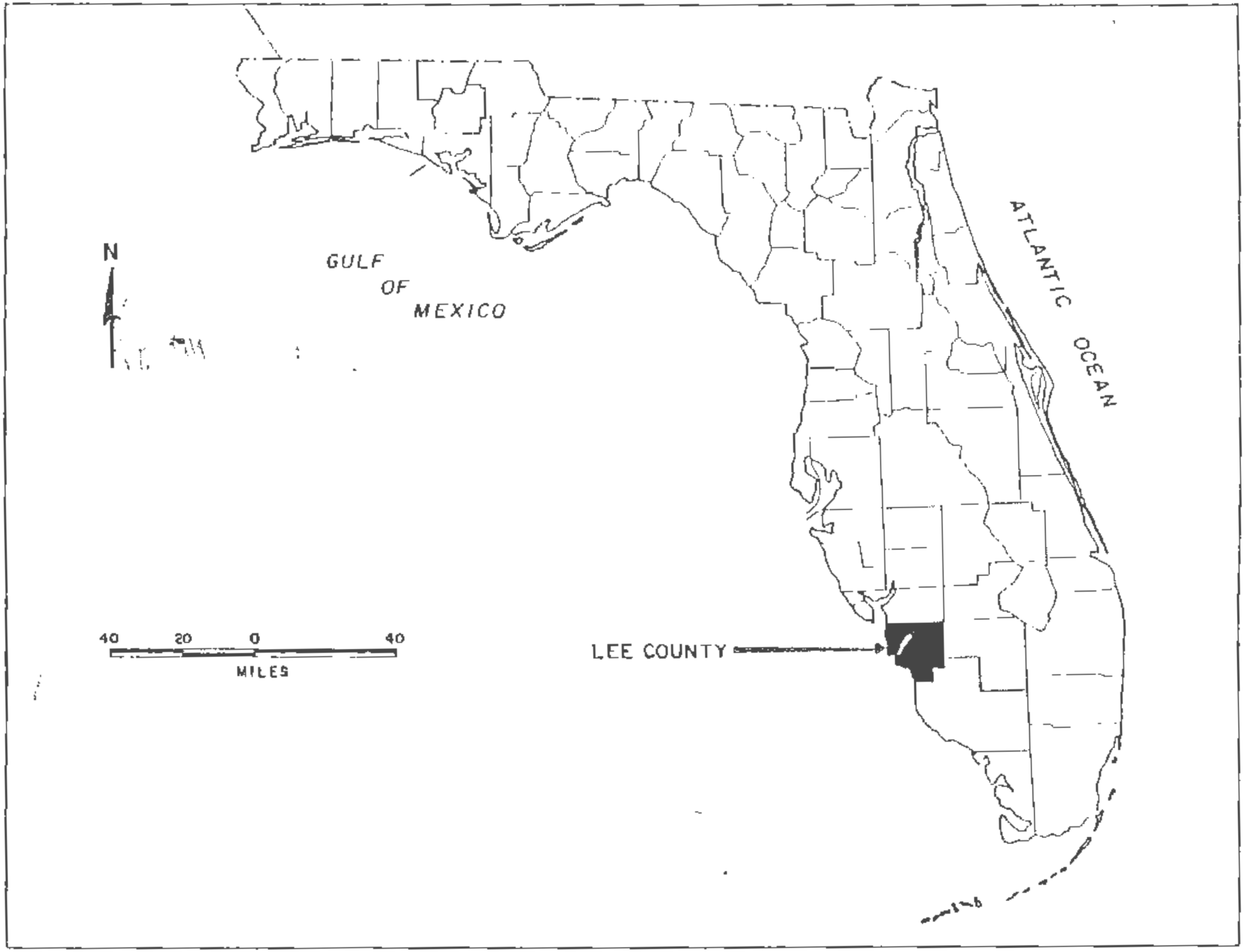


Figure 1. Location Map.

south (26°47' to 26°20'N latitude and 82°25' to 81°44'W longitude).

The two core borings used in the study were taken from the northern limits of Corkscrew Swamp (Figure 2). This area is approximately 25 feet above mean sea level and characterized by poorly drained cypress swamp, and sandy pine flatlands. The core sites are located as follows:

W-14071: 26°27'10"N latitude; 81°41'40"W longitude.

W-14072: 26°28'52"N latitude; 81°42'55"W longitude.

Field Methods

Coring: The coring was initiated by the Florida Bureau of Geology (DNR) in cooperation with the Fort Myers Field Office of the U.S. Geological Survey (Water Resources Division). The first coring site, W-14071, was located on Corkscrew Road in southern Lee County. This site was chosen because it was expected to provide the thickest section of the Tamiami Formation. Drilling operations ceased at 100 feet due to the inability to set surface casing through the upper limestone unit. The site was abandoned, and the hole plugged.

The second site, W-14072, was located on Alico Road, approximately 1-1/2 miles northwest of the initial site. The first 55 feet were drilled using the rotary method, with cutting samples taken at five-foot intervals. Coring began

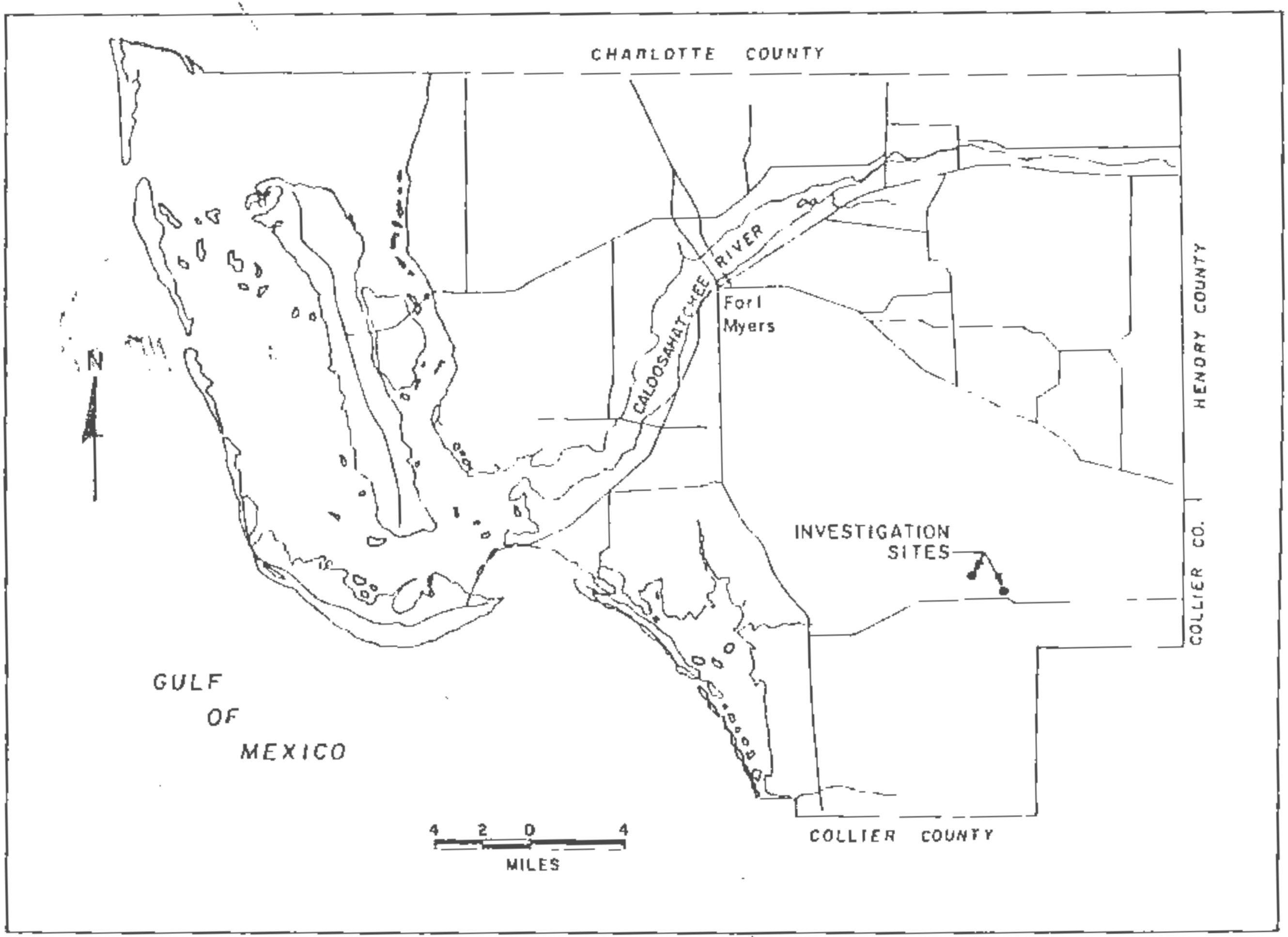


Figure 2. Investigation Sites in Lee County.

at 55 feet below land surface (bls) and continued to 362 feet bls.

The cores were boxed and labeled, with approximately 1-1/2 cubic centimeter samples taken at one-foot intervals for laboratory study. Field descriptions of the cores are included in Appendix A.

Geophysical Logging

The LaBelle clay member of the Tamiami Formation was mapped using approximately 60 well sites, which were drilled and geophysically logged in the early 1960's by Mobile Oil Corporation in cooperation with the Fort Myers Field Office of the U.S. Geological Survey (WRD). The purpose of the initial study was to produce a map of the top of the Hawthorn Formation. From this map, Mobil Oil hoped to define the structure of the Cretaceous sediments which were believed to contain petroleum deposits (Durwood Boggess, personal communication, 1978). Similar studies were performed in Collier, Hendry, and Charlotte Counties. However, the data produced from these studies were not available for public release.

Using gamma ray and electric geophysical logs from each of the sixty sites, the surface elevation and thickness of the upper green clay unit were mapped by the author. Unit picks from the geophysical logs were verified using lithologic descriptions and cuttings produced at the time of the initial study.

Laboratory Methods

The cores were examined under a microscope and described on the basis of color, major and minor constituents, compactness, and presence of fossils. Dunham's (1962) classification of carbonate rocks was followed. Complete descriptions are located in Appendix A.

Smear slides were prepared at five-foot intervals and at lithologic changes to determine the presence of micro- and nannofossils. This was performed by mounting sediment samples in a hyrax base on microscope slides. Results of the smear slide analysis can be found in Appendix B.

Samples were prepared at one-foot intervals to separate diatoms as follows:

> Approximately 1.5 cm^3 samples were dissolved in 15 ml of undiluted hydrochloric acid and heated slightly (200°F) until all dissolution ceased. The samples were allowed to cool, then rinsed in distilled water.
>
> The liquid was poured off, and 20% hydrogen peroxide added. After reaction ceased, samples were then rinsed and centrifuged three times, and sieved through a 38 micron sieve. Slides were made of each fraction by mounting the dried samples in hyrax and toluene.

Scanning electron microscope (SEM) preparations of the diatoms were made at one-foot intervals by drying samples of the material as processed above on an aluminum stub. The material was examined using a Cambridge Stereoscan S4-10.

Foraminifera samples were prepared as follows:

- Samples were boiled to break down the clays and then wet sieved through 707 micron and 106 micron screens.
- The fine fraction was dried and foraminifera separated out using the heavy liquid, perchlorethylene.
- These samples were then dried for examination.

The foraminiferal samples were used only to verify Peck's (1976) original work and the results of the analysis are not included in this study.

Previous Studies

Tamiami Formation: A thorough review of the previous studies of the sedimentary sequence delineated by Peck (1976) and Slater (1978) as the Tamiami Formation is available in theses by those authors. The following is a brief review of their studies and discussion of work done since 1978.

Mansfield (1939) described a limestone at Buckingham in Lee County and named it the Buckingham Limestone. He also observed a limestone on the Tamiami Trail previously described by Cooke and Mossom (1929) and called it the

Tamiami Limestone. Fossil species present led Mansfield to believe that the sediments were Pliocene in age and deposited in a shallow, nearshore marine environment.

Parker (1942) renamed the two limestone units the Tamiami Formation and suggested a Pliocene/Pleistocene age for the sediment. Cooke (1945) redefined the Tamiami Formation to include all strata above the Hawthorn Formation, however, still of Pliocene age.

Schroeder and Bishop (1953, 1954) considered the Tamiami Formation to be Miocene in age based on foraminiferal studies performed on samples from Collier County.

Parker, Ferguson, and Love (1955) redefined the Tamiami Formation to include the Tamiami Limestone of Mansfield and a section of green clayey marls, silty and shelly sands, and calcareous marl, locally indurated to impure limestone. They considered the formation to be late Miocene in age, and include in their definition all sediments in southern Florida of that age. This definition of the Tamiami Formation has been accepted widely in southern Florida until recently. However, studies by Hunter (1978) and Hunter and Wise (1980) have questioned this definition.

Hunter (1978) discussed the "major regional unconformity" found within the Tamiami Formation which separates Pliocene from Miocene sediments. However, she placed the Miocene/Pliocene boundary between the LaBelle clay member (Puri and Vernon, 1964) and the Buckingham Limestone Member (Hunter, 1968). She stated, "[the boundary] appears to represent a time span of as much as perhaps 3.5 to 4 million years, and is correlated with a major regional unconformity that may be global in extent," (Hunter, 1978, p. 65).

Hunter and Wise (1980, p. 41) suggest that the formation should be redefined since it does not meet the U.S. Stratigraphic Code and "has proved impractical to use because it lacks boundaries and includes unrelated strata of patently different lithologies." Their redefinition would include the Ochopee and Buckingham Limestones and/other equivalent facies, such as the Pinecrest Sand, but excludes the sediments of "late Miocene age."

LaBelle Clay: The LaBelle clay is informally defined as consisting of "greenish-gray, blue-gray and green clays" which merge laterally "into an unnamed quartz sand, which occasionally is coarse-grained, phosphoritic, and argillaceous," (Puri and Vernon, 1964, p. 213). Puri and Vernon (1964) mapped the clay using over 100 cores drilled by the U.S. Army Corps of Engineers, along the Caloosahatchee River from Moore Haven to Fort Myers. Peck (1976) and Slater (1978) traced the LaBelle clay throughout Lee and Hendry Counties and included it in Unit 2.

A green clay has also been described by Sutcliffe

(1972) in Charlotte and Sarasota Counties as a confining unit within the Tamiami Formation. The unit is informally called the Venice clay in this area and is considered by Sutcliffe to be Miocene in age. This unit is lithologically similar to the LaBelle clay; however, correlation between the two units has not been established.

Missimer (1978) mapped a green clay throughout most of northern and central Collier County, considering it to be Miocene in age. He informally named this unit the Cape Coral clay.

CHAPTER II

STRATIGRAPHY AND STRUCTURE

Introduction

As mentioned in Chapter I, two core borings were drilled in an attempt to further define the Tamiami Formation in southern Florida. Peck (1976) described (from well cuttings) eight different lithologic units within the Tamiami Formation in Lee County, which consist of sandy limestones, marls and clays. Because of the transgressive-regressive nature of the Tamiami sediments, lateral mapping of some of the eight units has proved to be quite difficult. Units change facies abruptly and pinch out to the north and west.

Although each core was described lithologically, and attempts were made to correlate the cores with Peck's (1976) section, the emphasis of this study was placed on delineating and mapping the LaBelle Clay and the diatom assemblage found within it. For the purposes of this study, the top and thickness of the LaBelle Clay was mapped in Lee County using gamma ray and electric geophysical logs.

Considerable debate has been centered on the nomenclature associated with the Tamiami Formation for many years. Because of the recommended age and boundary changes for the Formation, which will be discussed further in this text, the author suggests that the original, informal name given the uppermost green clay unit by Puri and Vernon (1964) be used. Since this unit, which will be referred to as the LaBelle clay, represents the suggested base of the Tamiami formation, Peck's (1976) numbered units are no longer considered applicable.

Core Description

Figure 3 represents core W-14072, with the suggested age and boundary changes. Since the initial 55 feet of the section was drilled using the rotary method, correlation between W-14071 and W-14072 is difficult. Core W-14071 contains a relatively complete section of the Pliocene/Pleistocene carbonates and sands, which are summarized as follows (See Appendix A for a detailed description):

Depth (bls)	Name/Description
0 - 50	Undifferentiated Pleistocene sands with shell and marl.
50 - 94	Ochopee Limestone/ Limestone, sandy, varying in color from buff to black. Section contains corals, boring mollusks, freshwater mollusks and molds.
94 - 100 (TD)	Buckingham Limestone/Buff to white clay, barren.

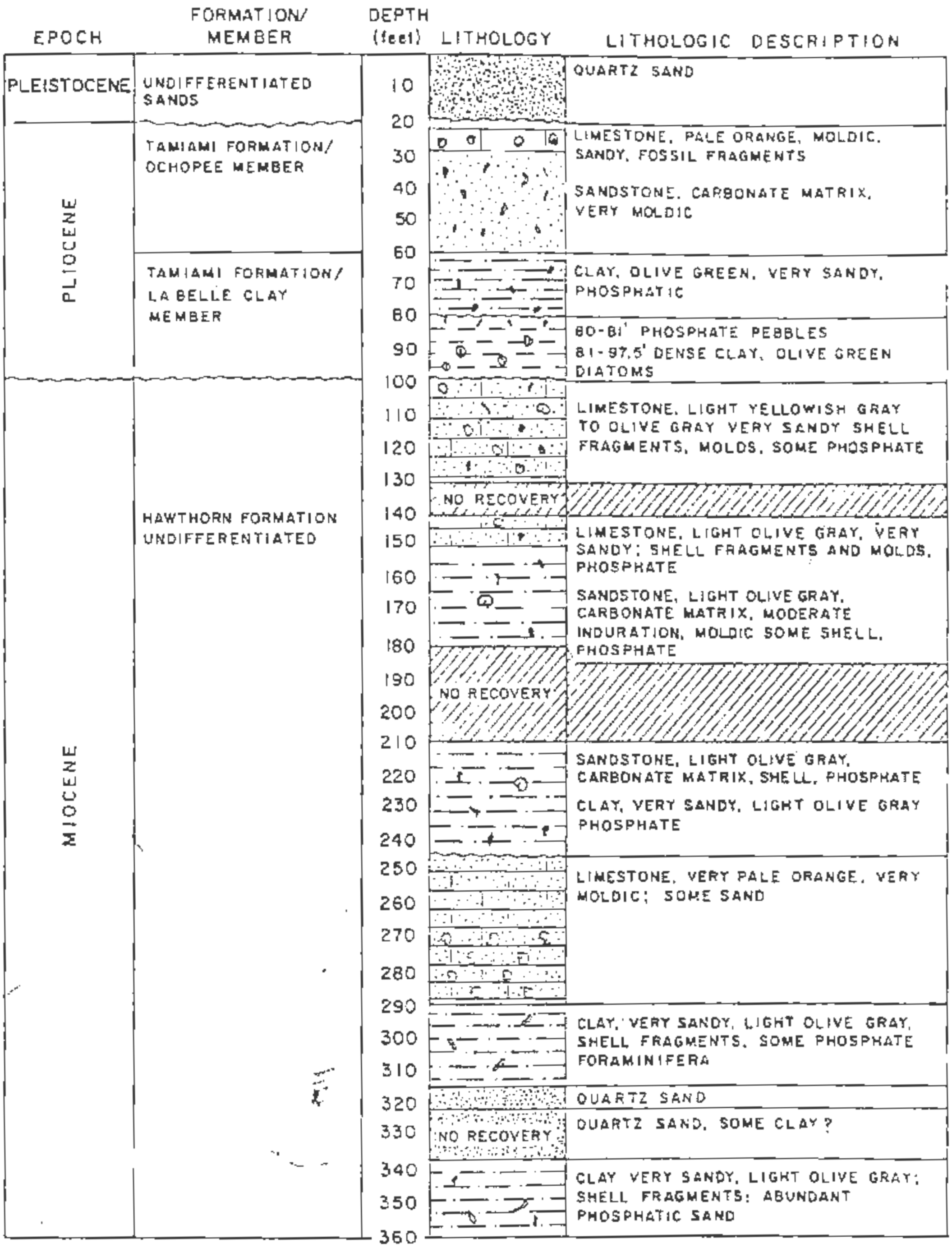


Figure 3. Stratigraphic Columnar Section of W-14072.

The LaBelle clay is found in core W-14072 from 55 feet to 97.5 feet bls. The upper 25 feet of the unit is a very sandy carbonate clay containing phosphate and foraminifera. The next 3-foot section is a dense olive green carbonate mud which contains abundant diatoms. From 93 feet to 97.5 feet bls, the green clay again becomes sandy, and contains diatom fragments, abundant foraminifera, some ostracodes, and phosphatic sand. The uppermost beds are separated at 80 feet bls by a bed of large phosphate pebbles and shell, which is approximately 6 inches thick.

The remainder of core W-14072 is considered to be Hawthorn Formation and is separated from the Tamiami Formation by an erosional disconformity. It consists of a sequence of very sandy limestones and carbonate muds which generally contain phosphatic sand, shell fragments, and molds.

Although Peck (1976) defines six additional units below the LaBelle clay, only three were found in W-14072. The resultant lithologic section appears to be similar to Slater's (1978) Hendry County section. The three units are briefly described as follows, using Peck's (1976) nomenclature:

Unit 3/Unit 5: This unit is a very complex sequence of sandy limestones separated by sandy carbonate clays. This combination of Peck's (1976) Units 3 and 5 is correlative to Slater's (1978) Unit 4.

Unit 4: This unit is a gray-green very sandy clay which grades abruptly into a slightly marly, well rounded quartz gravel (greater than 1,000 microns).

Unit 6/Unit 8: This unit is a gray-green sandy limestone and carbonate clay with abundant phosphatic sand and shall fragments. It is very similar in description to Peck's (1976) Unit 8, Slater's (1978) Unit 6, and Missimer's (1976) Fort Myers clay.

The LaBelle Clay

The composition of the LaBelle clay was analyzed using an X-ray diffractometer. The material is clay-like in appearance and texture, but is comprised of several different minerals. A montmorillonite-chlorite mixed layer clay was identified in combination with a considerable percentage of dolomite. Also identified in lesser percentages were quartz, calcite and biotite. This combination of minerals was observed in all of the green, clay-like material in core W-14072. Samples from the Hawthorn Formation additionally contained pyrite and aragonite.

The surface elevation and thickness of the LaBelle clay were mapped using gamma ray and electric geophysical logs from sixty wells, located throughout Lee County, as shown on Figure 4. The wells were drilled and geophysically logged by Mobil Oil Corporation as part of a project to map the top of the Hawthorn Formation.

Figure 5 represents a typical geophysical log produced by Mobil Oil Corporation, with the resistivity curve on the right side and the gamma ray curve on the left side of the log. A spontaneous potential log was also run, but not used in this study. Resistivity (expressed in ohm-meters^2 per meter) increases to the right as does radioactivity in the gamma ray log.

The LaBelle clay is typified by a very low resistivity, producing a very blunt curve to the far left of the scale. The gamma ray log typically detects the higher radioactivity in clays; however, the presence of abundant (radioactive) phosphate in other units made the gamma ray readings unreliable for identification of clays.

Figures 6 and 7 represent the top and thickness, respectively, of the LaBelle clay in Lee County, as mapped through correlation of the geophysical logs. Mean sea level is used as the datum, and the contour interval is 20 feet.

Figure 6 illustrates a northwest-southeast trending depression in the surface of the LaBelle clay which reaches its lowest elevation in the Corkscrew Swamp area. This

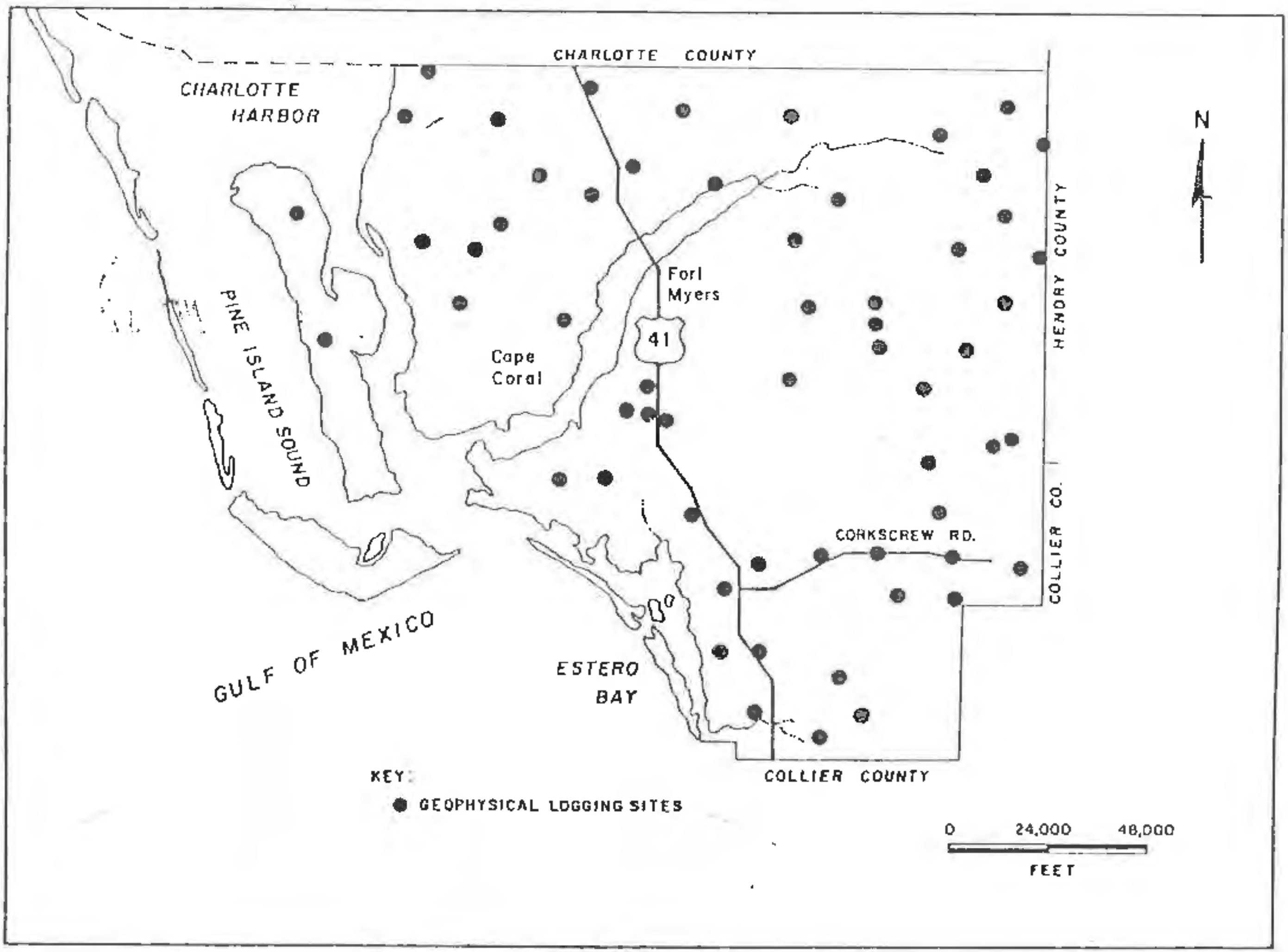


Figure 4. Map for Geophysical Investigations in Lee County.

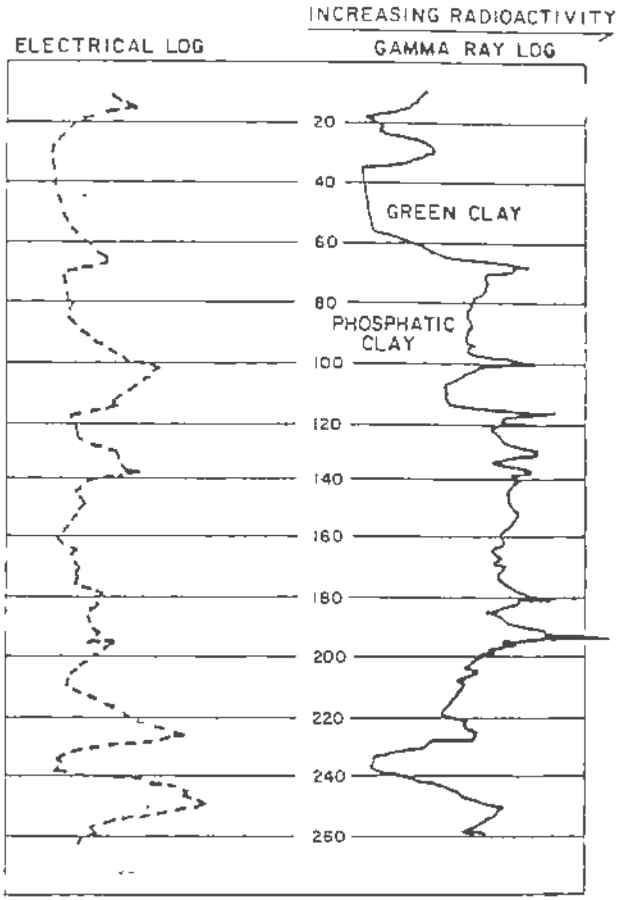


Figure 5. Typical Geophysical Log.

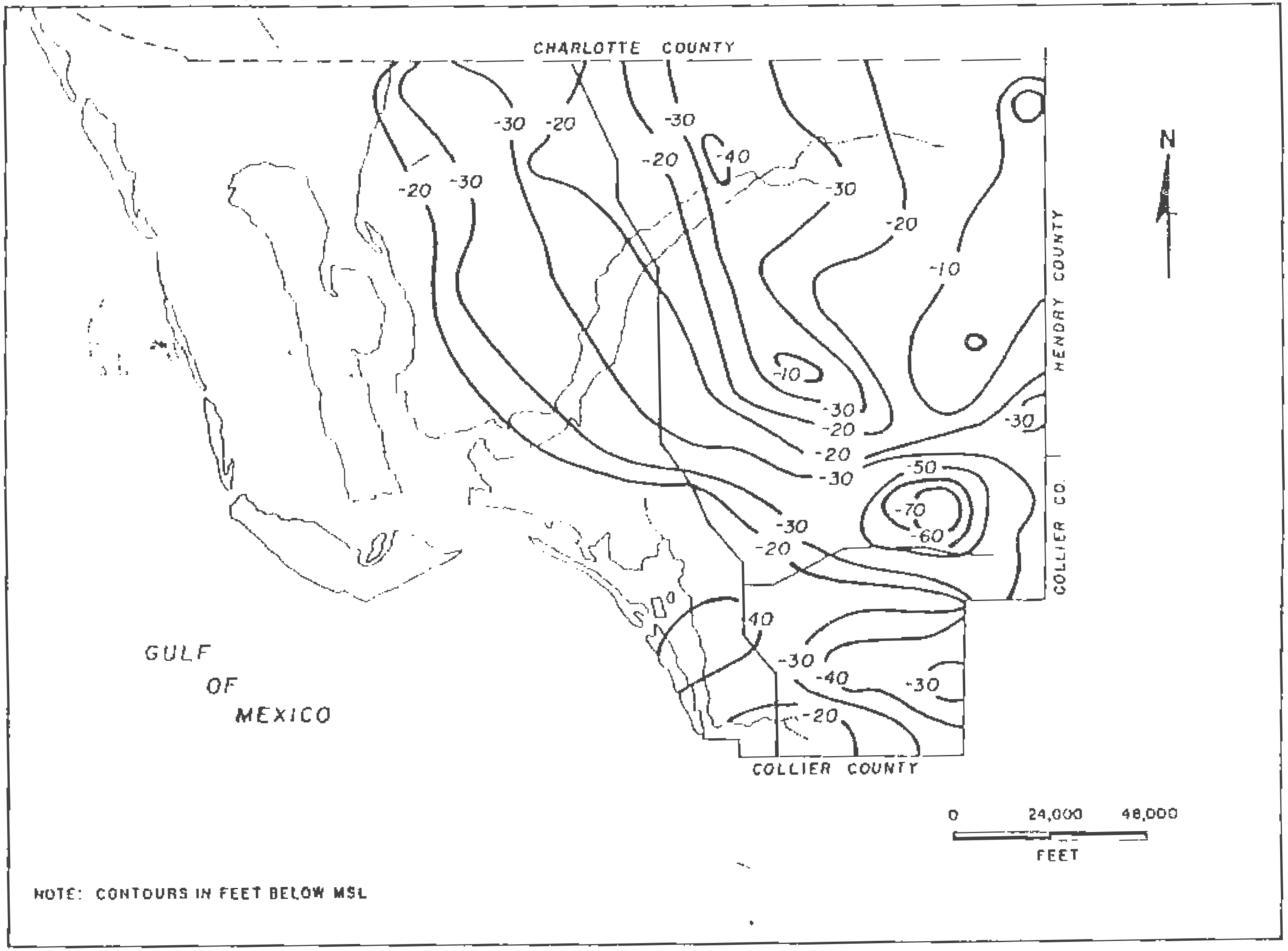


Figure 6. Top of LaBelle Clay in Lee County.

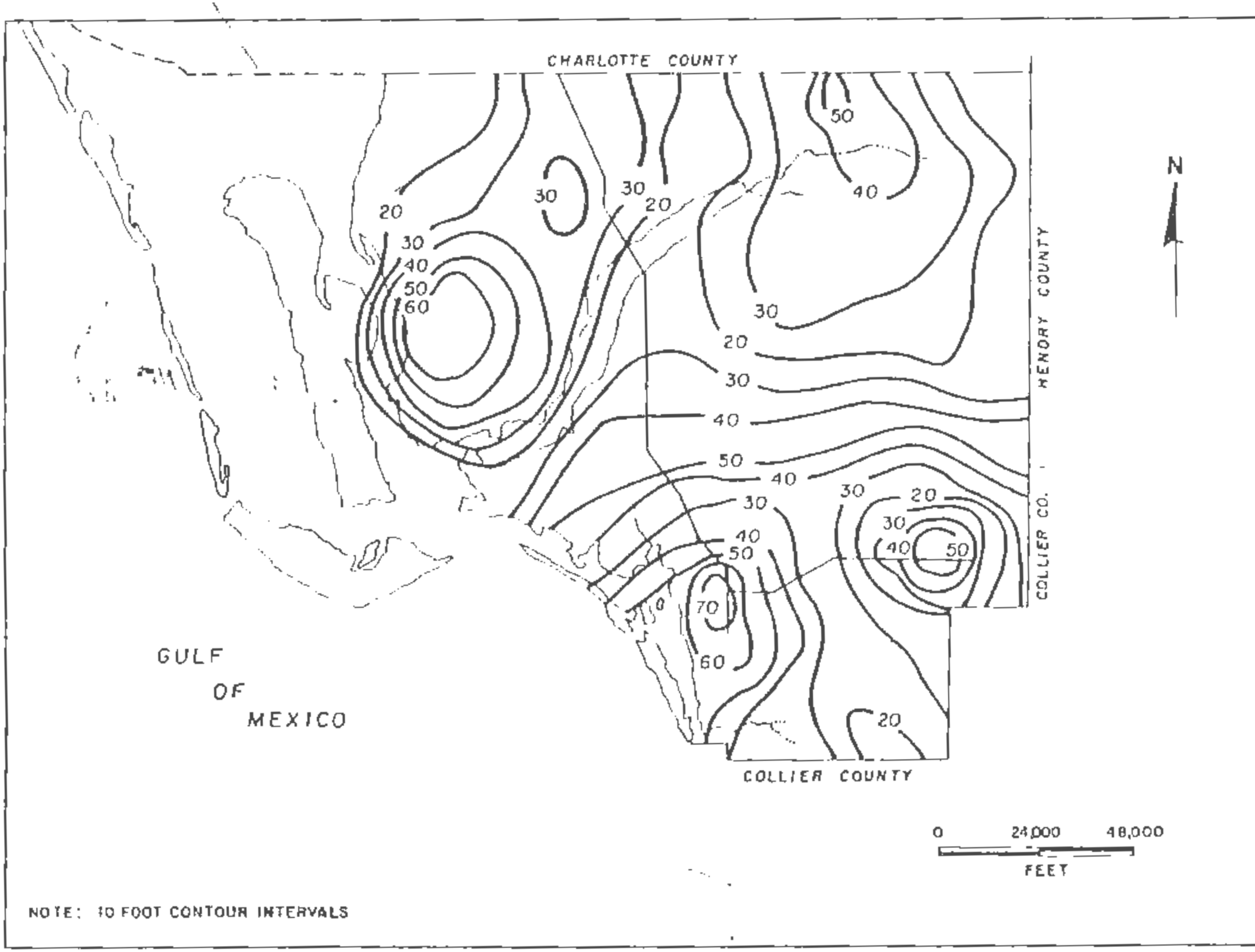


Figure 7. Thickness of LaBelle Clay in Lee County.

trough lies on the eastern flank of a feature known as the Hawthorn High (White, 1958) which also trends northwest-southeast.

The southeastern portion of the trough corresponds to the thickest sequence of the Ochopee Limestone and LaBelle clay in Lee County. In addition, Peck (1976) finds the thickest sequence of the Tamiami Formation (as he describes it) underlying this depression.

The LaBelle clay is shown in Figure 7 to vary in thickness from 20 to 80 feet. No trend is evident in the pattern of thickening, with the exception of the corresponding depression and thickening mentioned above. The clay was identified in all of the geophysical logs evaluated and is mapped as a continuous unit throughout Lee County.

The phosphatic pebble unit found at 80-81 feet bls in core W-14072 was not found by Peck (1976) or Slater (1978). However, Bocskocsky (1980, personal communication) mapped the pebble unit using nine sets of split spoon samples, taken around the coring site in Corkscrew Swamp. The author believes that the nature of the sampling procedure used by Peck (1976) and Slater (1978) prevented recovery of this unit.

CHAPTER III

DIATOMS

Introduction

Peck, et. al. (1979) described the diatom assemblage found in the LaBelle clay in Lee County, and consider it to indicate a coastal marine environment of deposition. They biostratigraphically placed it between the base of the *Dyocibicides biserialis* foraminiferal zone and the top of the *Vavulineria floridana* foraminiferal zone.

Slater (1978) also found the assemblage in his Unit 2 in Hendry County and considers it to be a good stratigraphic indicator throughout the county.

The diatom assemblage in the LaBelle clay which was analyzed for this study is the same assemblage recognized by Peck (1976) and Slater (1978). However, further study of the assemblage indicates that it is not only a good stratigraphic marker, but also defines the strata it is found in as Pliocene in age. In addition, the species support the suggestion of Peck, et. al. (1979) that the clay unit was formed in a restricted, near-shore marine environment of deposition.

Assemblage List

The following is a list of the diatoms identified in the assemblage found in core W-14072. The diatom bed extended from 81 to 93 feet bls with all species found consistently throughout the section. Systematics and descriptions are given in Appendix C.

Actinocyclus ehrenbergii
Actinocyclus octanarius
Actinoptychus senarius
Actinoptychus splendens
Auliscus caelatus var. constricta
Bacteriastrum sp.
Biddulphia rhombus
Biddulphia tuomeyi
Coscinodiscus gigas var. diorama
Coscinodiscus nitidus
Coscinodiscus nodilifera
Coscinodiscus oculus-iridis
Coscinodiscus radiatus
Cussia paleacea
Cussia tatsunokuchiensis
Diploneis crabo
Diploneis ornata var. spinifera
Melosira westii
Navicula hennedyi
Navicula pennata
Opephora schwartzii
Paralia sulcata
Podosira stelligera
Thalassiosira oestrupii
Triceratium spinosum

Assemblage Interpretation

Of the twenty-six species listed in this assemblage, over 75% are found in present day marine environments. The majority of the species are found in temperate seas, generally in littoral and sublittoral zones. The inclusion of several cosmopolitan species suggests that during most of the period of deposition there was open access to marine waters. However, the lack of diversity within this assemblage indicates that deposition occurred within a restricted environment.

The importance of this diatom assemblage to the Tamiami Formation is that it includes three species which first occur in Pliocene age sediments. Andrews (1980) discusses a similar diatom assemblage from Petersburg, Virginia, which he considers to be the only assemblage to yield "meaningful" Pliocene diatoms found to date in the Atlantic Coastal Plain. He dates the Petersburg strata as Pliocene in age, and suggests that it was deposited in a lagoonal-type environment.

Andrews (1980) assemblage includes one previously unreported diatom, Nitzschia imperforata Andrews, which was also identified in the LaBelle assemblage. However, SEM photos of the species proved it to be a girdle view of Navicula pennata (Plate 2, Figures 4 and 5), and not Nitzschia imperforata. (See Appendix C for further discussion.)

Thalassiosira oestrupii (Ostenfield) Proschkina-Lavrenko (Plate 3, Figure 1), was also identified using the SEM in both the Petersburg and LaBelle sections. Andrews (1980, p. 35) states, "The consensus of marine biostratigraphers is that it [T. oestrupii] does not occur in sediments older than early Pliocene in age." Schrader (1973, p. 694) stated that his North Pacific Diatom Zone IX (lower Pliocene) contains the first evolutionary appearance of T. oestrupii. Barron (1976, table 1) reported the first occurrence of T. oestrupii in Unit 18 of the type Bolivina doliqua Zone of California, which he regarded as of probable early Pliocene age. Burckle and Opdyke (1977, P. 280) have stated: "...data from the equatorial Pacific...indicates that T. oestrupii first appears in the earliest Pliocene (Gilbert Epoch) approximately equivalent in time with the North Pacific first occurrence."

Cussia tatsunokuchiensis (Koizumi) Schrader (Plate 3, Figure 5) is found rarely to frequently in the LaBelle section. Koizumi (1972, p. 349) indicates that this species is commonly found in Pliocene age sediments of northeast Japan. He originally placed it in the genus Rhaphoneis, but it was later placed in the genus Cussia by Schrader (1973). Schrader found C. tatsunokuchiensis in his North Pacific Diatom Zone 12, which he considered late Miocene in age.

However, he states that "[Zones 12-14] could not be subdivided in the EMD core and subdivisions on table 3 [which delineates age assignment] are tentative." (1973, p. 676)

Abbott (personal communication, 1980) considers the C. tatsunokuchiensis to be a good Pliocene age marker, and indicated that it had been assigned to the genus Bogorovia. Peck (1976) illustrated this species in his Unit 2 assemblage, calling it Coscinodiscus paleaceus.

Peck (1976) assigned a Miocene age to his assemblage based on the occurrence of Actinoptychus bismarkii Schmidt, which has been reported only from late Miocene age sediments. However, this species is very similar in appearance to A. senarius which ranges in age from late Cretaceous to Recent. The difference in the two species is found in the areolae which are large and square in A. bismarkii, with only a few areolae to each sector.

Actinoptychus splendens (Shadbolt) Ralfs, is also very similar in appearance to A. senerius except that it has a greater number of sectors, and a much finer areolation pattern. Andrews (1980, p. 24) suggests that "the oldest known certain occurrence [of A. splendens] seems to be in the Petersburg deposit, and is a common Recent littoral species." The author is hesitant to use A. splendens as a Pliocene marker species, because it is so similar in appearance to a wide variety of Actinoptychus species.

Based on the occurrence of Thalassiosira oestrupii, Cussia tatsunokuchiensis, and possibly Actinoptychus splendens, the author assigns the base of the LaBelle Clay to an early Pliocene age. Because of the lack of any specific data on salinity tolerances of diatoms, specific paleoenvironmental interpretations cannot be made. However, it is apparent that deposition occurred in a lagoonal-type environment, with influx of silica-rich fresh water.

CHAPTER IV

SUMMARY AND CONCLUSIONS

The Tamiami Formation as previously delineated by Peck (1976), Slater (1978) and Peck, _et_. _al_. (1979) has proved to be impractical. The Code of Stratigraphic Nomenclature defines a formation as "a body of rock characterized by lithologic homogeneity; it is prevailingly but not necessarily tabular and is mappable at the earth's surface or traceable in the subsurface." Because of the transgressive-regressive nature of the Miocene/Pliocene sea level, the sediments deposited at that time are very difficult to trace laterally, with generally indistinct vertical boundaries.

Hunter (1978) and Hunter and Wise (1980) suggested a revision in the definition of the Tamiami Formation to include only the original upper carbonates, placing the LaBelle clay and underlying units in the Hawthorn Formation.

The author believes that the LaBelle clay should be included in the Tamiami Formation, for the reasons outlined below:

1. The LaBelle clay is a regionally extensive, easily recognizable lithologic unit.

2. It has a very distinctive lower boundary, lying unconformably on an erosional surface of limestone or sandstone.

3. The lithology in hand sample and under microscopic examination is relatively consistent and easily recognizable.

4. Although the definition of a formation is that of a rock-stratigraphic unit, the LaBelle clay is Pliocene in age, as are the Ochopee Limestone, Buckingham Limestone, and Pinecrest Sand Members.

5. Although the composition of the LaBelle clay is similar to the clay units of Miocene age in Lee County, the physical nature of the clay is completely different. In hand sample, the clay appears quite dense and sticky, with a lesser amount of sand or no sand at all. The Miocene clays are actually sandstones with green carbonate matrices. This unit is not related to the Miocene units lithologically, as is required under the definition of a Formation.

6. The geometry of the LaBelle clay indicates a deepening and thickening of the unit to the southeast providing for an embayment of sorts in which deposition occurred. The clay is believed by the author to extend laterally into Sarasota County to the north and Collier County to the south, which would suggest a large area of relatively constant sea level for an extended period of time. That, in conjunction with the subareally exposed erosional surface which underlies the LaBelle clay, indicates that it was the first unit deposited in a transgressive sequence which marked a rise in sea level at the start of the Pliocene Epoch. This continually rising sea level was responsible for deposition of the Ochopee Limestone, Buckingham Limestone, and Pinecrest Sand as time equivalent facies.

Although considerable study remains to be conducted before the Tamiami Formation can be formally defined, the author recommends that the Tamiami Formation, as described herein, include the time equivalent facies known as the Ochopee Limestone, Buckingham Limestone, and Pinecrest Sand Members; and the LaBelle Clay Member. The Formation and its diatom assemblage are believed to be Pliocene in age and can be mapped as a continuous unit in Collier, Hendry, and Lee Counties. The author suggests that further attempts be made to define a type section and locality.

APPENDIX A

CORE DESCRIPTION

APPENDIX A

CORE W-14071: Field Log

Depth (in feet)	Description
0.0 - 2.0	Hard pan. No recovery.
2.0 - 4.5	Sand, brown to rust, iron staining.
4.5 - 6.5	Sand, gray, organic material.
6.5 - 9.5	Same as above.
9.5 - 11.5	Poor recovery, sandy clay.
11.5 - 15.0	Sand, gray, some white clay.
15.0 - 16.5	Clay, gray, grading into shell bed.
17.0 - 20.0	Limestone, tan to gray, sandy.
20.0 - 26.0	Sand, tan, shell.
26.0 - 31.0	Limestone, gray, marly, shell.
31.0 - 43.5	Sand, tan, shell.
43.5 - 45.0	Limestone, tan.
45.0 - 50.0	Sand, tan, shelly.
50.0 - 52.5	Limestone, tan to white, sandy; shell and clay
52.5 - 56.0	Same, tan to black.

APPENDIX A (continued)

Depth (in feet)	Description
56.0 - 60.0	Limestone, tan to dark gray, shell.
60.0 - 63.0	Limestone, gray-black, very shelly.
63.0 - 64.5	Limestone, tan, very moldic, shell.
64.5 - 73.0	Limestone, gray, very moldic, some clay.
73.0 - 74.5	Limestone, light gray, micritic, shelly.
74.5 - 79.0	Limestone, gray, moldic, grading into micrite with coral and shell.
79.0 - 80.0	Limestone, black, very moldic.
80.0 - 81.0	Coral, gray limestone, shell.
81.0 - 82.5	Limestone, tan, moldic.
82.5 - 87.0	No recovery.
87.0 - 93.0	Limestone, tan to light gray, sandy, coral, mollusks, molds.
93.0 - 94.0	Marl, light green-gray, sandy, mollusks, coral.
94.0 - 98.0	Clay, white.
98.0 - 100.0	Clay, white, becoming more indurated towards 100 feet.
100.0	Total Depth

APPENDIX A (continued)

CORE W-14072: Field Log

Depth (in feet)	Description
0.0 - 0.5	Top soil.
0.5 - 4.0	Sand, yellow.
4.0 - 6.0	Sand, brown, organics.
6.0 - 12.0	Sand, grayish yellow, clay.
12.0 - 16.0	Sand, white.
16.0 - 17.0	Sand, clayey.
17.0 - 18.0	Clay, blue, limestone.
18.0 - 21.0	Limestone, moldic, tan.
21.0 - 30.0	Limestone, tan to white, clay.
30.0 - 45.0	Limestone, tan, shell.
45.0 - 50.0	Limestone, gray-tan, shell, coral.
50.0 - 55.0	Limestone, tan, clay, gray-green, shell, phosphate.
55.0 - 60.0	Clay, gray-green, phosphate.
60.0 - 66.0	Clay, green.
66.0 - 77.0	Clay, green.
77.0 - 80.0	No recovery.
80.0 - 81.0	Shell, phosphate, green clay.
81.0 - 97.5	Clay, green.
97.5 - 100.0	Limestone, gray, shell.
100.0 - 103.0	Marl, white, sandy.

APPENDIX A (continued)

Depth (in feet)	Description
103.0 - 113.0	Limestone, gray with shell, clay, sand, phosphate, moldic.
113.0 - 119.0	Shell, carbonate matrix, tan yellow.
119.0 - 120.0	Limestone, tan-gray, sandy.
120.0 - 132.0	Limestone, gray, hard, moldic; oyster shell.
132.0 - 140.0	Clay, green, sandy.
140.0 - 143.0	Limestone, gray, hard, moldic; oyster shell.
143.0 - 152.0	Sandstone, poor induration, little recovery.
152.0 - 165.0	Sand, some clay, shell.
165.0 - 173.0	Limestone, gray, hard, sandy, moldic.
173.0 - 180.0	Sand, clay.
180.0 - 210.0	No recovery.
210.0 - 215.0	Sand, very clayey, dark green, phosphatic, shell.
215.0 - 227.5	Clay, green, very sandy, phosphate pebbles, shell.
227.5 - 234.0	Clay, gray phosphatic.
234.0 - 235.5	Limestone, gray, clay.
235.5 - 237.0	Clay, gray-white, shelly.
237.0 - 241.5	Limestone, very moldic, gray-white.
241.5 - 251.0	Clay, gray-white, shell molds.
251.0 - 252.0	Limestone, gray, moldic, clay.

APPENDIX A (continued)

Depth (in feet)	Description
252.0 - 292.5	Limestone, tan, moldic.
292.5 - 313.0	Clay, gray-green, some shell.
313.0 - 318.0	Clay, gray, very sandy, some shell.
318.0 - 337.0	Sand, some clay, little recovery.
337.0 - 348.0	Clay, light green, very well indurated, sandy phosphatic.
348.0 - 362.0	Clay, green, sandy.
362.0	Total Depth.

APPENDIX A (continued)

CORE W-14072: Microscopic Examination

Depth (in feet)	Description
0.0 - 60.0	Cuttings.
0.0 - 17.0	Same as field log.
17.0 - 20.0	Mudstone, very pale orange; vuggy, some recrystallization.
20.0 - 25.0	Wackestone, very pale orange; moldic, mollusks, coral, bryzoans.
25.0 - 30.0	Same as above.
30.0 - 35.0	Packstone, very pale orange; sand 250-500 m, ASM; phosphate 2%, shell.
35.0 - 40.0	Grainstone, very pale orange; 250-500 m.
40.0 - 45.0	Same, more carbonate.
45.0 - 50.0	Grainstone, very pale orange; sand 250-500 m, SAM; 50% carbonate fragments, phosphate 1%, bryzoans, mollusks.
50.0 - 55.0	Packstone, very pale orange; molds in crystalline material with silt and mud, phosphate 2-3%.
55.0 - 60.0	Packstone, light olive gray; shell fragments, sand with green silt matrix, 2% phosphate.
60.0 - 65.0	Wackestone, light olive gray; quartz sand, 177-250 m; pyrite, phosphate -- 10% of both; forams abundant, ostracodes.
65.0 - 67.0	Wackestone, olive gray; sand, shell, forams, ostracodes.
67.0 - 70.0	Packstone, light olive gray; sand, 177-250 m, SAM; phosphate 10%.

APPENDIX A (continued)

Depth (in feet)	Description
70.0 - 75.0	Wackestone, light olive gray; phosphate 5%.
75.0 - 77.0	Wackestone, light olive gray; sand, 177-250 m, SAM; phosphate 25%, teeth, forams.
77.0 - 80.0	N.R.
80.0 - 81.0	Shell bed, some light olive gray clay; large phosphate pebbles; grades into mudstone.
81.0 - 85.0	Mudstone, olive green; diatoms.
85.0 - 90.0	Same.
90.0 - 93.0	Same; shell and phosphate.
93.0 - 97.5	Mudstone, olive green; very fossiliferous -- diatoms, ostracodes; phosphate, quartz sand.
97.5 - 98.5	Contact -- Packstone, light gray; sand 177-500 m, SAM; phosphatic, fossil fragments.
98.5 - 100.0	Boundstone to crystalline, yellowish gray; very moldic, mollusks, worm burrows.
100.0 - 113.0	Packstone, yellowish gray; sand 117-250 m, SAM; trace phosphate.
113.0 - 118.0	Shell bed, light olive gray.
118.0 - 120.0	Packstone, yellowish gray; quartz sand, 250-350 m, SAM; trace phosphate, shell, large oyster fragment.
120.0 - 125.0	Packstone; yellowish gray; quartz sand, 250-350 m, SAM; phosphate 3%, mollusk molds.

APPENDIX A (continued)

Depth (in feet)	Description
125.0 - 140.0	Packstone, light olive gray; quartz sand, 250-350 m, SAM; phosphate, molds.
140.0 - 152.0	Packstone to Grainstone, light olive gray; quartz sand, 177-500 m, SAM; very moldic, large oysters, boring mollusks, forams, phosphate.
152.0 - 173.0	Grainstone to Packstone, grayish olive to light olive gray; quartz sand, 250-300 m, SAM; phosphatic, some shell.
173.0 - 210.0	No recovery.
210.0 - 216.5	Granstone to Packstone, olive gray; quartz sand, 250-500 m, SAM; phosphate pebbles, shell fragments and molds.
216.5 - 221.0	Packstone, moderate olive brown; quartz sand, 250-500 m, SAM; phosphatic, to Wackestone at 221 feet.
221.0 - 222.0	Grainstone, olive gray; quartz sand, 177-350 m, SAM; phosphatic.
222.0 - 225.0	Wackestone, olive gray; quartz sand, 177-250 m, SAM; phosphate.
225.0 - 226.0	Mudstone, moderate olive brown; quartz sand, phosphate, shell fragments, forams.
226.0 - 228.0	Packstone, yellowish gray; with blebs of mudstone, quartz sand and phosphate; reworked.
228.0 - 234.0	Wackestone, yellowish gray; 177-500 m, SRM; phosphate, some molds.
234.0 - 235.5	Mudstone to Wackestone, yellowish gray; quartz sand, 177-500 m, SRM; phosphate, mollusk molds.

APPENDIX A (continued)

Depth (in feet)	Description
235.5 - 242.0	Packstone, very pale orange; quartz sand, 177-350 m, SRM; phosphate, mollusk molds.
242.0 - 251.0	Mudstone, light olive gray; trace phosphatic and quartz sand.
251.0 - 252.0	Erosional contact; Wackestone, yellowish gray and light olive gray; quartz sand, phosphate, mollusk molds.
252.0 - 280.0	Crystalline with mudstone blebs, yellowish gray to very pale orange; very moldic, Turitella sp.; boring mollusks, molds.
280.0 - 293.0	Packstone, very pale orange; very moldic, phosphatic.
293.0 - 296.0	Mudstone, olive gray; forams, trace quartz and phosphate.
296.0 - 302.0	Wackestone, light olive gray; shell fragments and molds, quartz and phosphatic sand.
302.0 - 309.0	Mudstone-Wackestone, light olive gray; quartz sand, 125-177 m, SRM; phosphate, forams.
309.0 - 312.5	Mudstone, very light gray; shell fragments, phosphate.
312.5 - 317.0	Wackestone to packstone, light olive gray; quartz sand, 500-1,000 m, rounded; mollusk fragments, bryzoans.
317.0 - 320.0	Quartz gravel, gray-white; shell fragments.
320.0 - 337.0	No recovery.
337.0 - 341.0	Packstone to Grainstone, yellowish gray to light olive gray; quartz sand, 177-250 m, SRM; phosphate, shell.

APPENDIX A (continued)

Depth (in feet)	Description
341.0 - 343.0	Mudstone and Wackestone, light olive gray; sand, 177-250 m, SAM; phosphate, mollusk molds and fragments.
343.0 - 352.0	Packstone, light olive gray; quartz sand, 177-250 m, SAM; phosphate, shell.
352.0 - 362.0	Wackestone to Mudstone, yellowish gray to light olive gray; quartz sand, 250-1,000 m (with depth); phosphate, shell.
362.0	Total depth.

APPENDIX B

SMEAR SLIDE ANALYSIS

APPENDIX B

SMEAR SLIDE ANALYSIS:

THIS LISTS THE DEPTH OF
OCCURRENCE OF DIATOMS AND NANNOFOSSILS ONLY

W-14071

Depth (in feet)	Fossil Type
0.0 - 36.0	Barren
36.0 - 46.0	Coccoliths
46.0 - 51.0	Coccoliths, discoasters
51.0 - 71.0	Coccoliths
71.0 - 100.0	Barren

W-14072

Depth (in feet)	Fossil Type
0.0 - 50.0	Barren
50.0 - 80.0	Coccoliths
80.0 - 85.0	Coccoliths, discoasters
85.0 - 90.0	Diatoms, coccoliths, discoasters
90.0 - 97.5	Diatoms
97.5 - 150.0	Coccoliths

APPENDIX B (continued)

W-14071

Depth (in feet)	Fossil Type
150.0 - 170.0	Coccoliths, discoasters, diatom fragments
170.0 - 275.0	Barren
275.0 - 285.0	Coccoliths
285.0 - 300.0	Barren
300.0 - 305.0	Coccoliths, discoasters
305.0 - 315.0	Coccoliths
315.0 - 335.0	Barren
335.0 - 355.0	Coccoliths
355.0 - 362.0	Barren

APPENDIX C

SYSTEMATICS

APPENDIX C

SYSTEMATIC PALEONTOLOGY

The taxa of diatoms studied for this thesis are arranged alphabetically, and listed only by genus and species. Only citation of those references used for identification purposes are given here.

Genus ACTINOCYCLUS Ehrenberg, 1838

Actinocyclus ehrenbergii Ralfs (1861)

(Plate 1, Figure 1)

Bukry and Foster, 1973, p. 833, Plate 8, Figures 1 and 2.

Range: Middle Miocene to Upper Pliocene.

Actinocyclus octonarius Ehrenberg

(Plate 1, Figure 2)

Wornardt, 1976, p. 33, Figure 49.

Discussion: A neritic species of cosmopolitan distribution, numerous in temperate seas.

Range: Middle Miocene to Recent.

APPENDIX C (continued)

Genus ACTINOPTYCHUS Ehrenberg, 1839

Actinoptychus senarius Ehrenberg

(Plate 1, Figure 3)

Wornardt, 1967, p. 44, Figure 67.

Andrews, 1980, p. 24, Plate 1, Figure 3.

Range: Cretaceous to Recent.

Actinoptychus splendens (Shadbolt) Ralfs

(Plate 1, Figure 4)

Andrews, 1980, p. 24, Plate 1, Figure 4.

Range: Pliocene to Recent.

Genus AULISCUS

Auliscus caelatus var. constricta Rattray

(Plate 3, Figure 2)

Wornardt, 1976, p. 53, Figures 88-91, 95.

Range: Late Miocene to Middle Pliocene.

APPENDIX C (continued)

Genus BIDDULPHIA GRAY, 1821

Biddulphia rhombus (Ehrenberg) W. Smith

(Plate 1, Figure 5)

Wornardt, 1967, p. 62, Figure 118.

Andrews, 1980, p. 25, Plate 1, Figures 6 and 7; Plate 4 Figures 2 and 3.

Discussion: This species is a characteristic inhabitant of the littoral zone.

Range: Late Miocene to Recent.

Biddulphia tuomeyi (Bailey) Roper

(Plate 2, Figure 3)

Wornardt, 1976, p. 62, Figures 117, 119, 120.

Andrews, 1980, p. 25, Plate 1, Figures 10 and 11; Plate 4, Figure 5.

Range: Late Cretaceous to Recent.

Genus COSCINODISCUS Ehrenberg, 1838

Coscinodiscus gigas var. diorama (Schmidt) Grunow

(Not figured)

Wornardt, 1976, p. 24, Figure 25.

Discussion: This species is found in tropical to subtropical seas in areas of high salinity.

Range: Middle Miocene to Recent.

Coscinodiscus nitidus Gregory

(Plate 1, Figure 6)

Wornardt, 1976, p. 27, Figures 30 and 31.

Andrews, 1980, Plate 1, Figure 18.

Range: Late Cretaceous to Recent.

Coscinodiscus nodulifer Schmidt

(Plate 1, Figure 7)

Bukry and Foster, 1973, p. 834, Plate 8, Figures 1-2.

Discussion: This species is a distinctive warm water diatom.

Range: Upper Miocene to Recent.

Coscinodiscus oculus - iridis Ehrenberg

(Plate 1, Figure 8)

Wornardt, 1967, p. 28, Figures 34 and 35.

Andrews, 1976, p. 11, Plate 2, Figure 8.

Discussion: Species cosmopolitan, neritic.

Range: Late Eocene to Recent.

Coscinodiscus radiatus Ehrenberg

(Plate 2, Figure 1)

Andrews, 1980, p. 28, Plate 2, Figure 1.

Range: Eocene to Recent.

Genus CUSSIA Schrader, 1974

Cussia paleacea (Grunow) Schrader

(Plate 3, Figure 4)

Schrader, 1974, p. 543, Figure 1.

Andrews, 1980, p. 28, Plate 2, Figure 2; Plate 4, Figure 6.

Range: Middle Miocene to Recent.

APPENDIX C (continued)

Cussia tatsunokuchiensis (Koizumi) Schrader

(Plate 3, Figure 5)

Schrader, 1974, p. 543, Figure 7 and 8.

Koizumi, 1972

Range: Pliocene to Recent.

Genus DIPLONEIS Ehrenberg, 1840

Diploneis crabo Ehrenberg

(Plate 3, Figure 6)

Wornardt, 1967, p. 85, Figure 201.

Discussion: This species is common to high-salinity environments.

Range: Late Miocene to Recent.

Diploneis ornata var. spinifera

(Plate 2, Figure 2)

Wornardt, 1967, p. 86, Figure 206-208, 210, 211.

Range: Late Miocene to Recent.

APPENDIX C (continued)

Genus MELOSIRA Agardh (1824)

Melosira westii Wm. Smith

(Plate 2, Figure 3)

Andrews, 1976, p. 8, Plate 1, Figures 1 and 2.

Range: Miocene to Recent.

Genus NAVICULA Bory, 1822

Navicula hennedyi Wm. Smith

(Plate 3, Figure 7)

Andrews, 1976, p. 22, Plate 7, Figures 17 and 18

Wornardt, 1967, p. 81, Figures 187 and 188.

Discussion: This species is found commonly in the littoral zone.

Range: Late Miocene to Recent.

Navicula pennata Schmidt

(Plate 2, Figures 4 and 5)

Andrews, 1976, p. 22, Plate 7, Figures 20 and 21.

Range: Miocene to Recent.

Genus NITZSCHIA Hassall, 1845

Nitzschia imperforata Andrews

(Not figured.)

Andrews, 1980, p. 31, Plate 2, Figures 19 and 22; Plate 5, Figure 1.

Discussion: Andrews, 1980, defines this as a new species, suggesting that it may be a good marker for his Petersburg section. However, examination of this species under the scanning electron microscope indicates what appears to be a girdle view of Navicula pennata. It has been listed here for informational purposes; however, the author believes it has been misidentified.

APPENDIX C (continued)

Genus OPEPHORA PETIT, 1888

Opephora schwartzii (Grunow) Petit

(Plate 2, Figure 6)

Wornardt, 1967, p. 75, Figure 161-165.

Discussion: This species is common in the littoral zone.

Range: Late Miocene to Recent.

Genus PARALIA Heiberg, 1863

Paralia sulcata (Ehrenberg) Cleve

(Plate 2, Figure 7)

Andrews, 1980, p. 31, Plate 2, Figure 23.

Range: Cretaceous to Recent.

Genus PODOSIRA Ehrenberg, 1840

Podosira stelligera (J. W. Bailey) Mann

(Plate 2, Figure 3)

Andrews, 1980, p. 32, Plate 3, Figure 4.

Range: ? Miocene to Recent.

Genus THALASSIOSIRA Cleve, 1873

Thalassiosira oestrupii (Ostenfeld) Proschkina-Lavrenko

(Plate 3, Figure 1)

Andrews, 1980, p. 35, Plate 6, Figure 3-4.

Discussion: This species is a cosmopolitan marine diatom.

Range: Pliocene to Recent.

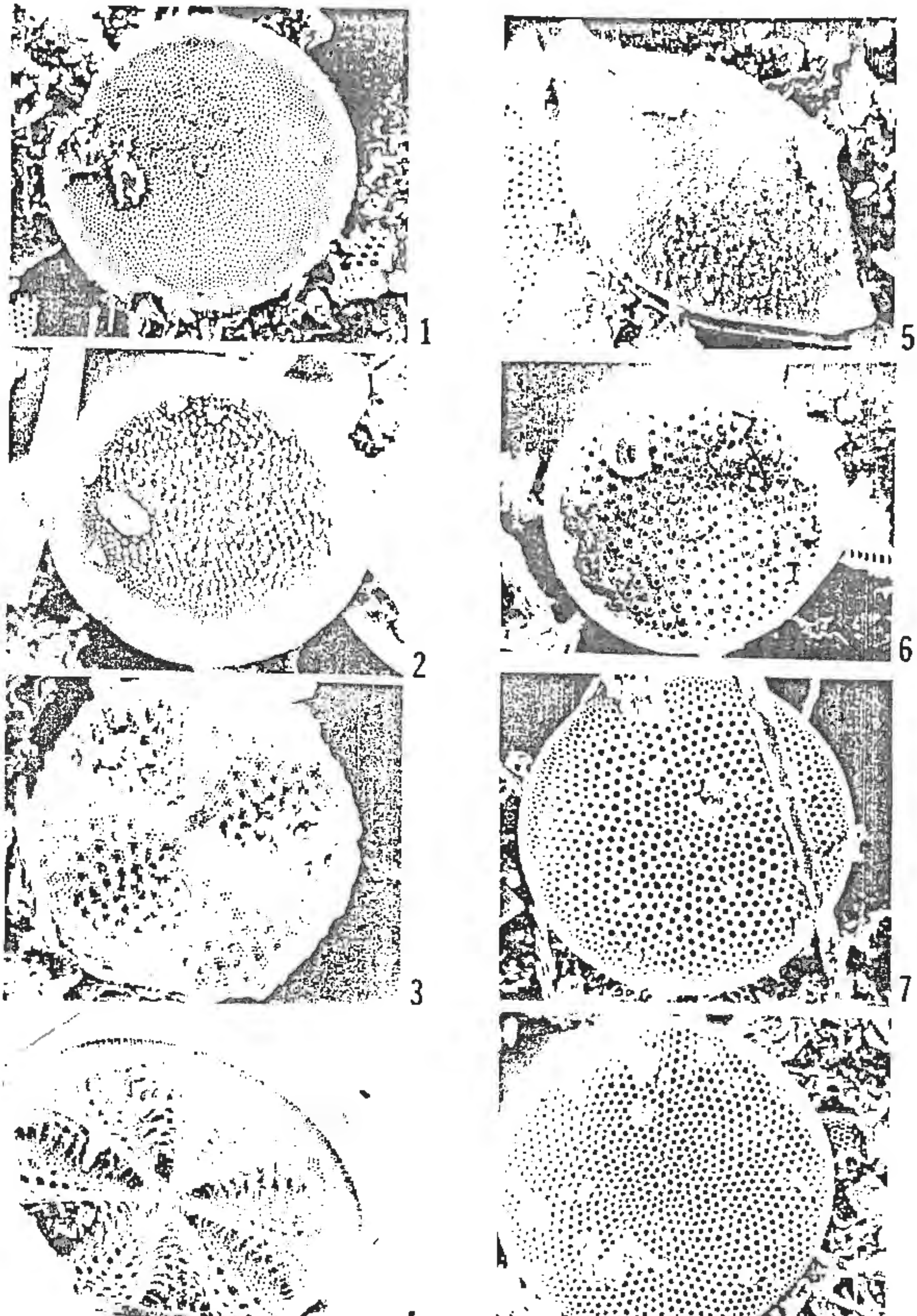
APPENDIX D

DIATOM PLATES

APPENDIX D

PLATE 1

1. *Actinocyclus ehrenbergii* Ralfs
2. *Actinocyclus octonarius* Ehrenberg
3. *Actinoptychus senarius* Ehrenberg
4. *Actinoptychus splendens* (Shadbolt) Ralfs
5. *Biddulphia rhombus* (Ehrenberg) W. Smith
6. *Coscinodiscus nitidus* Gregory
7. *Coscinodiscus nodulifer* Schmidt
8. *Coscinodiscus oculus-iridis* Ehrenberg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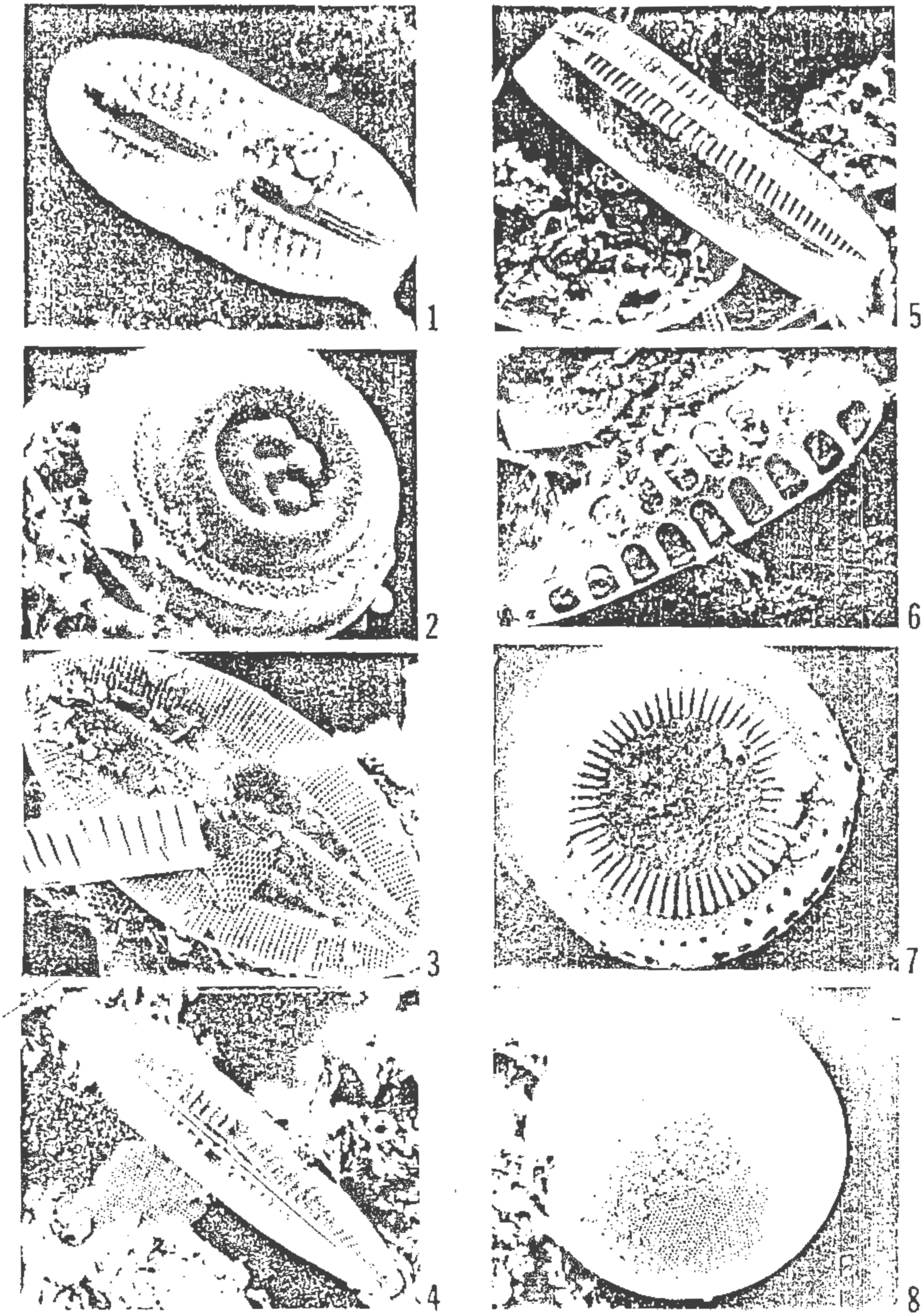
APPENDIX D

PLATE 2

1. *Coscinodiscus radiatus* Ehrenberg
2. *Diploneis ornata var. spinifera*
3. *Melosira westii* Wm. Smith

4,5. *Navicula pennata* Schmidt

6. *Opephora schwartzii* (Grunow) Petit
7. *Paralia sulcata* (Ehrenberg) Cleve
8. *Podosira stelligera* (J. W. Bailey) Mann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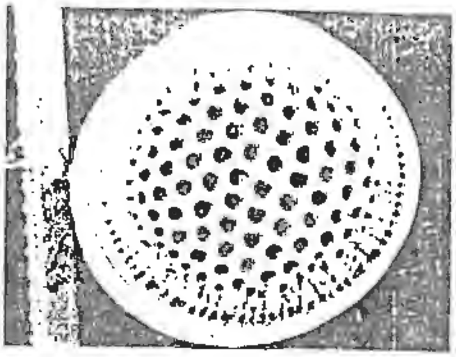
APPENDIX D

PLATE 3

1. Thalassiosira oestrupii (Ostenfeld) Prosckina-Lavrenko
2. Auliscus caelatus var. constricta Rattray
3. Biddulphia tuomeyi (Bailey) Roper
4. Cussia paleacea (Grunow) Schrader
5. Cussia tatsunokuchiensis (Koizumi) Schrader
6. Diploneis crabo Ehrenberg
7. Navicula hennedyi Wm. Smith



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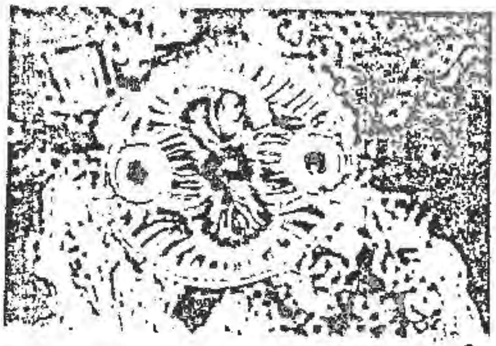

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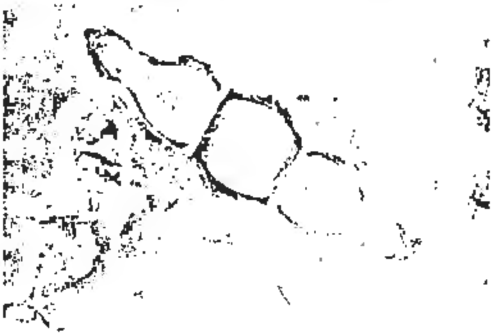

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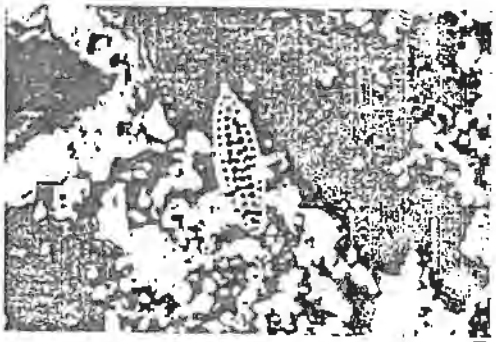

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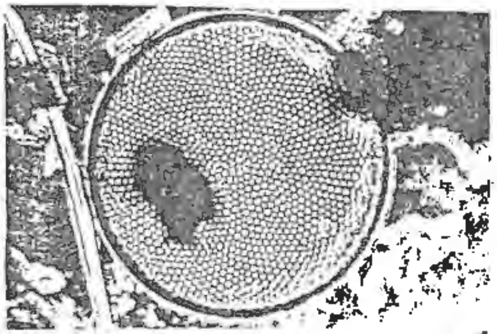

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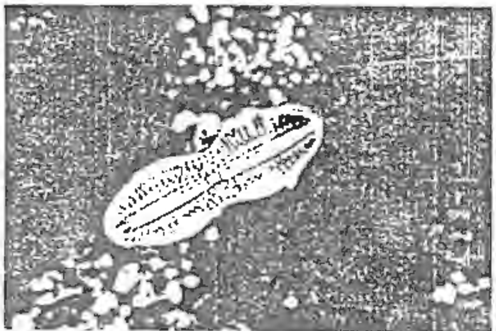

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