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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D. C.

May 24, 1957

AEC - 390/7

Mr. Robert D. Nininger
Assistant Director for Exploration
Division of Raw Materials
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Bob:

Transmitted herewith are three copies of TEI-625, "Stratigraphy of middle Tertiary rocks in part of west-central Florida," by Wilfred J. Carr and Douglas C. Alverson, August 1956.

We plan to publish this report as a chapter of a Geological Survey bulletin.

Sincerely yours,

John H. Eric

for W. H. Bradley
Chief Geologist

Geology and Mineralogy

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

STRATIGRAPHY OF MIDDLE TERTIARY ROCKS IN PART OF WEST-CENTRAL FLORIDA*

By

Wilfred J. Carr and Douglas C. Alverson

August 1956

Trace Elements Investigations Report 625

This preliminary report is distributed without editorial and technical review for conformity with official standards and nomenclature. It is not for public inspection or quotation.

*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

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By Wilfred J. Carr and
Douglas C. Alverson

ABSTRACT

Petrographic studies of the Suwannee limestone, Tampa limestone, and Hawthorn formation yielded data that are useful in correlation in a region where weathering has profoundly altered the rocks. Mechanical analysis of sand from these formations was found to be helpful in reconstructing weathered sections. Sand of the Hawthorn formation is coarser than that of the Tampa limestone. Preliminary work indicates that the kind and distribution of heavy and clay minerals should also be valuable in any further stratigraphic studies of this area.

A laboratory method for rapid insoluble residue and mechanical analysis of sand was developed.

Mapping of rocks of Oligocene and Miocene age in Hillsborough, Pasco, and Polk Counties extended the Tampa limestone northeastward from its former limits; some of the sand and clay previously mapped as Hawthorn formation in northeastern Pasco County belong to the Tampa. A contact between calcareous and noncalcareous parts of the Hawthorn was mapped in northern Hillsborough and Polk Counties. More than 50 localities new to the literature were examined. Several sketches of exposures illustrate structures and textures found in

weathered Tampa limestone and Hawthorn formation. The occurrence of chert in weathered sections may help to indicate the pre-weathering lithology. The period of major weathering in the area probably took place in late Pliocene or early Pleistocene, but evidence of periods of older weathering is believed to be present.

Structural studies indicate a fault in northwestern Polk County which brings rocks of Eocene age adjacent to the Tampa and Suwannee limestones. Structural and other evidence suggests an unconformity between the Tampa limestone and Hawthorn formation.

Faunal and petrographic evidence indicate a shifting lagoonal, insular, and locally fresh-water environment of deposition for the Tampa limestone, and open sea and relatively static conditions of sedimentation in Hawthorn time. The increase in, and coarsening of, clastic material in Miocene deposition can be ascribed to currents carrying material into the Florida peninsula from sources to the north, and possibly to distant volcanic activity.

A belt of leached phosphatic material with thin overburden and moderate uranium content was delimited by mapping in northeastern Hillsborough County. Phosphate or uranium is not present in commercial quantities in unleached limestones of this area, but the upper surface of the Hawthorn formation in the land-pebble phosphate district was found to contain locally nearly 20 percent MgO.

INTRODUCTION

Purpose and extent of work

This report presents the results of part of a geologic study of the phosphate deposits in central Florida. The area in Hillsborough and Polk Counties called the land-pebble phosphate district produces about three-fourths of the phosphate mined in the United States. The present investigation was begun in March 1953 by the U. S. Geological Survey on behalf of the Division of Raw Materials, U. S. Atomic Energy Commission. The ultimate objective of the work in Florida is to determine the geologic history of the phosphate deposits and associated sediments, in order that the distribution of phosphate and uranium will be more clearly understood.

As a contribution to this objective the authors have studied the stratigraphy of the formations, chiefly limestones, which underlie (or are closely associated with) the land-pebble phosphate deposits of west-central Florida. The unconsolidated residue and sediments above the limestones received less detailed study. For this report work was concentrated on the northwestern fringes of the land-pebble district because this area contained the bulk of the exposures and seemed to be the most critical in the solution of stratigraphic problems. The area mapped (fig. 1) contains about 1,700 square miles in Hillsborough, Polk, and Pasco Counties. The Hawthorn formation of middle Miocene age, the Tampa limestone of early Miocene age, and the Suwannee limestone of Oligocene age were mapped and sampled in detail. Rocks older than Oligocene and younger than middle Miocene age were not extensively studied.

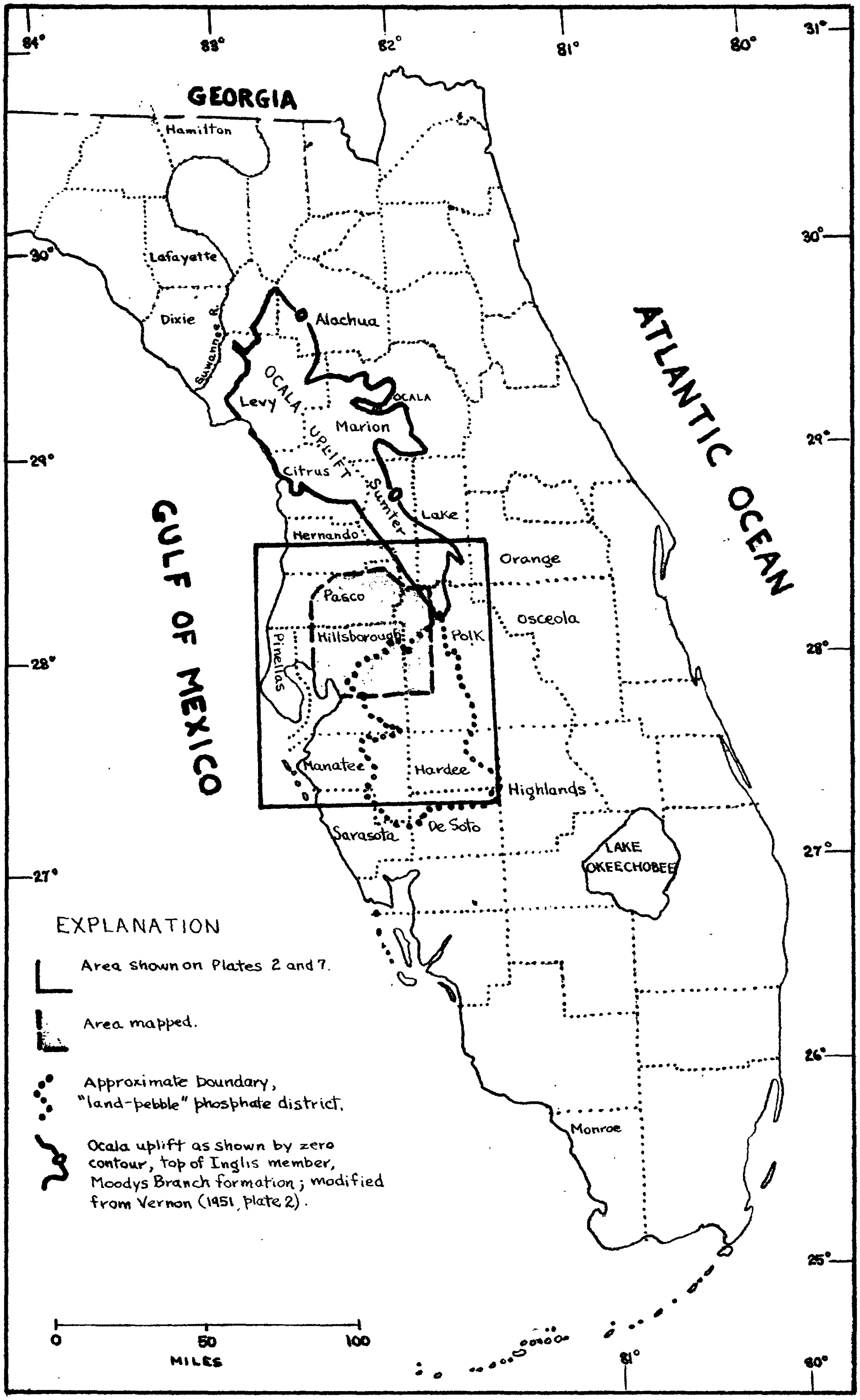


Figure 1.-- Index map of peninsular Florida showing location of Ocala uplift, "land-pebble" phosphate district, and areas mapped and studied for this report.

To supplement surface observations holes were drilled with a power auger in critical areas, about 25 core-drilled holes were logged in detail, and well logs were studied.

Laboratory work, a major portion of the study, consisted of insoluble-residue analysis of limestone samples, mechanical analysis of the residues, and subordinant study of heavy minerals. A number of thin sections of limestone, chert, and phosphatic material were examined. Spectrographic, chemical, and X-ray analyses were made by the Geological Survey laboratories.

The extensive laboratory work done for this study was prompted by the need for a uniform means of comparing and delimiting formations in a region where weathering and lithologic similarity of formations, scarcity of fossils, and lack of good exposures has made mapping difficult.

Previous work

Geology of the area mapped for this report has not been studied previously in detail, although Mansfield (1937), Cooke (1945) and others have studied fossils or mapped the area on a small scale. Sellards (1915) and Matson (1915) described the Florida phosphate deposits. More recent work on the phosphate deposits has been summarized by Cathcart, Blade, Davidson, and Ketner (1953). Applin and Applin (1944, p. 1674-1677) give a summary of the important contributions to Florida stratigraphy. A table of names of Cenozoic formations in Florida is given in figure 2.

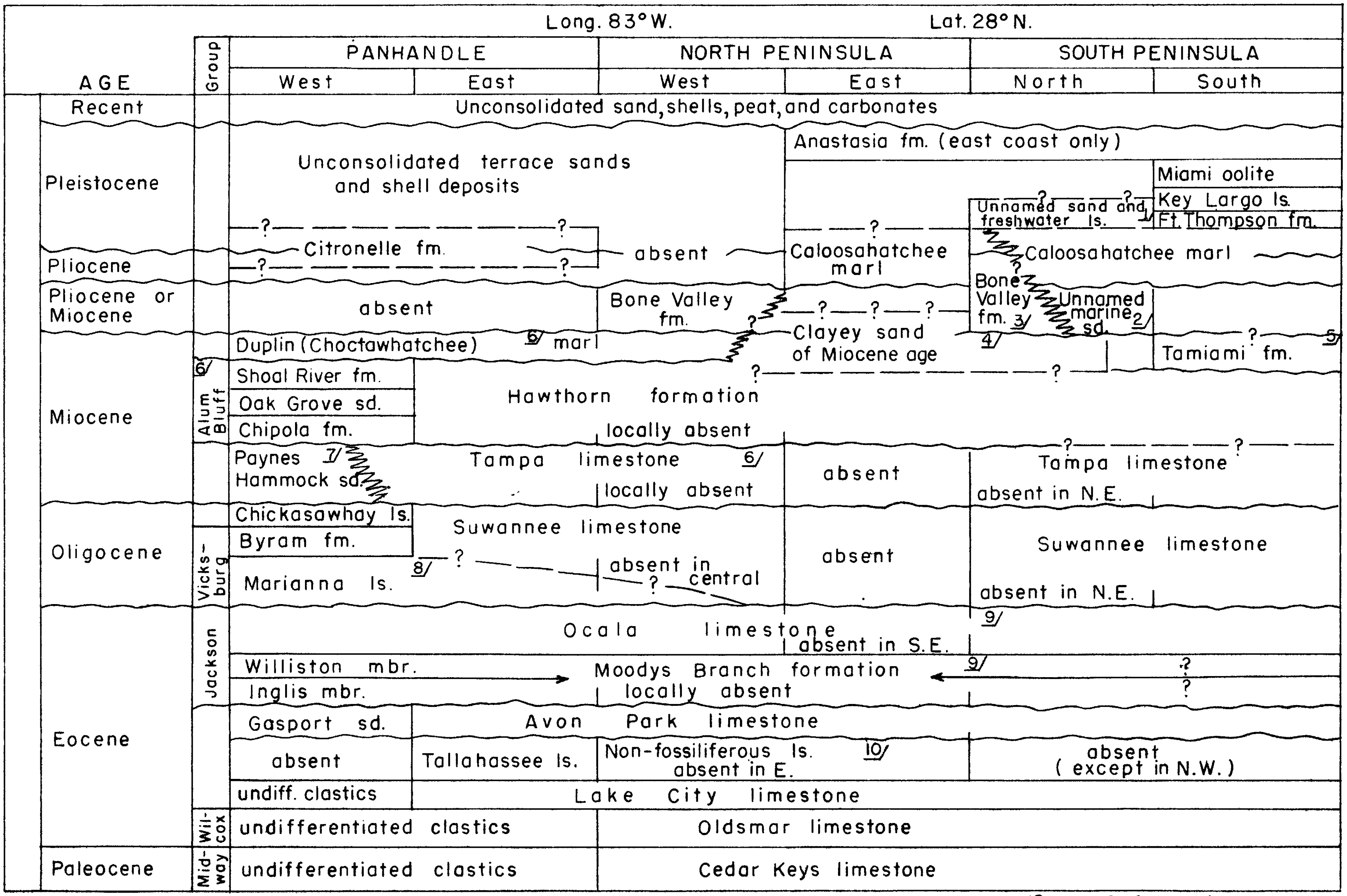


FIGURE 2.—CENOZOIC FORMATIONS OF FLORIDA. (See text for footnotes)

Ten footnotes for figure 2, Cenozoic formations of Florida, follow:

1/ Bergendahl, M. H., 1954, p. 45-50. Fluvial sand and fresh-water limestone in Hardee and De Soto Counties. Probably correlative with the Fort Thompson formation.

2/ Bergendahl, M. H., 1954, p. 21-29. Marine sand in Hardee and De Soto Counties, which, according to F. S. MacNeil (oral communication) is very late Miocene in age.

3/ The age of the Bone Valley formation has not been conclusively determined, and the exact stratigraphic relationships of upper Miocene and Pliocene formations in central Florida are not clear. Ketner and McGreevy (report in preparation) exclude from the Bone Valley a weathered zone of the Hawthorn formation.

4/ Ketner, K. B. and McGreevy, L. J., U. S. Geol. Survey Bull. (in preparation). Fine, green, micaceous, clayey sands, and brown coarse sands in Polk County. The lower part of this unit may be uppermost middle Miocene, or upper Miocene; the upper part is possibly Pliocene in age. In southern Polk County the sand of Ketner and McGreevy probably underlies the unnamed marine sand which Bergendahl (see note 2) states is late Miocene in age. As Bergendahl correlates his unit with the Bone Valley formation, Ketner's sand may be slightly older than the Bone Valley in some areas, but possibly equivalent to it in others.

5/ The Tamiami formation comprises all the upper Miocene of southernmost Florida (Schroeder, and Bishop, 1953, p. 2182) and includes some beds previously called formations, such as the Buckingham marl.

6/ Puri (1953, fig. 2) proposed that the Miocene in northern Florida be divided into 3 stages: Choctawhatchee, stage 3 (includes Arca, Yoldia, Cancellaria, and Ecphora facies), Alum Bluff stage (includes Oak Grove, Shoal River, Chipola, and Hawthorn facies), and Tampa stage (includes Chattahoochee and St. Marks facies).

7/ MacNeil, F. S., 1944, p. 1344.

8/ Marianna fauna is locally present in a thin zone at the base of the Suwannee limestone in peninsular Florida (MacNeil, F. S., oral communication).

9/ Vernon, R. O., 1951, p. 111. In the type area of the Moodys Branch formation in Mississippi, the formation is a glauconitic sand with local beds of impure limestone. Vernon's Moodys Branch formation of Florida is a pure limestone which he divided into the Williston and Inglis members on the basis of faunal assemblages. Puri (1953a, p. 130) proposed that all sediments of Jackson age in Florida be called the Ocala group. He suggested a new name, Crystal River formation, for Vernon's Ocala limestone (restricted) and favored raising the Inglis and Williston to formational status.

10/ Applin, P. L. and Applin, E. R., 1944, p. 1688-1693.

Physiography

Central Florida has a subtropical climate, with a range of average monthly temperature from about 60° in January to about 80° in July. The yearly precipitation for the area mapped is a little over 50 inches, most of which falls from June through October.

Total relief in the area is about 250 feet, from sea level at the Gulf Coast to 250 feet on the hills near Dade City, Pasco County, and the ridge north and south of Lakeland, Polk County (pl. 1).

Most of west-central Florida is a sandy plain with minor depressions and ridges, which in general trend north-northwest. The surface topography reflects in a subdued manner subsurface features of the limestones, modified in some areas by dune-like sand hills. There are several ill-defined belts of limestone solution depressions, sinkholes, and springs in the area. One such belt trends northwest across central Hillsborough County. Small lakes or swamps fill most of the depressions. Lakes are particularly numerous north of Tampa and in the Dade City and Lakeland highlands. Four rivers drain the mapped area; two, the Hillsborough and Alafia, flow westward into Hillsborough Bay and the Gulf of Mexico. The Peace River begins southeast of Lakeland and flows southward out of the area, and the Withlacoochee rises in northern Polk County and flows west and north out of the area. These rivers are sluggish, swamp-bordered streams which have a few rapids and are subject to reversal of flow by tides for distances of 5 to 10 miles from their mouths. In most places the rivers flow on limestone or chert bedrock. Only 8 feet of section are exposed at the thickest limestone outcrop in the mapped area. In most of the area the limestone bedrock is covered by 30 to 50 feet of unconsolidated sands and clays.

Acknowledgments

The writers gratefully acknowledge the assistance of F. S. MacNeil of the U. S. Geological Survey for his identification of fossils, and suggestions on the basic stratigraphic problems. J. W. Wells of the U. S. Geological Survey identified several coral specimens.

Analytical work was done by the U. S. Geological Survey: W. F. Outerbridge and R. G. Petersen performed the X-ray analyses, Ivan Barlow, Harry Levine, Roberta Smith, Wendell Tucker, and Maryse Delevaux made the chemical analyses, Julius Goode and Benjamin McCall did the radiometric analyses, and Helen W. Worthing and Joseph Haffty performed the spectrographic analyses.

Special thanks are due to the members of the Florida Geological Survey, Dr. Herman Gunter, Director, for supplying well logs from their files.

LABORATORY WORK

Introduction

This investigation presented special problems in stratigraphic correlation, chiefly because of (1) scarcity and small size of outcrops and their uneven geographic distribution, (2) lithologic similarity of the formations, (3) difficulty of locating the vertical position of exposures within formations, (4) intensity of weathering and similarity of residues, and (5) unconsolidated nature of many of the rocks.

A laboratory procedure was therefore developed to process a large number of samples in order to obtain sufficient data for valid correlation of formations. Quartz sand and heavy minerals are the most stable components of these rocks. Under the influence of weathering all other constituents--carbonates, clays, phosphates--are subject to change in relative amount and composition. Accordingly, methods of insoluble residue and mechanical analysis were employed in the laboratory. The Wentworth (1922) grade scale was used throughout the work.

Procedures

After experimentation the following laboratory procedures were found to be the most practical. The calcareous rocks were broken until most of the pieces were 2 or 3 centimeters in diameter. Enough crushed rock was used to provide at least 5 grams of sand residue. The weighed sample was dissolved in a 4,000 milliliter Pyrex beaker by half-strength hydrochloric acid. The sample was left in the acid for at least 16 hours. Washing and decantation were repeated until the acidity was low.

The wet residue was washed into the jar of an electric food blender. This type of mixer was found to be superior to the "milk shake" blender often used in sedimentary laboratories. The agitator revolves at very high speed and has large sharp blades which are at the bottom of the container. Four minutes of agitation in the blender was found to be ample. In the few cases when a sample did not disaggregate completely in the blender the clayey lumps were carefully crushed with a rubber soil pestle.

After disaggregation the samples were washed through a 230 mesh U. S. Standard screen in order to separate sand from clay and silt. Time did not permit size studies of the clay and silt fractions, but the total amount of fine material was determined by drying and weighing. Sand fractions were dried in evaporating dishes, weigned, and screened with a mechanical shaker. The coarser particles of impurities such as chert and aluminum phosphate minerals in the sand samples were screened out, hand sorted, and the percentage of the remaining finer impurities estimated, but those samples which contained too much foreign material were not used in size studies.

Non-calcareous samples consisted of quartz sand, silt, and clay, and were mostly unconsolidated. They were easily disaggregated in the blender. The sand fractions of samples which contained calcium phosphate nodules were treated with full-strength hydrochloric acid, and the dissolved phosphate considered part of the clay fractions for purposes of uniformity. Most of the calcareous samples contained negligible amounts of phosphate nodules.

All the sand fractions were screened with a mechanical shaker for 5 minutes. U. S. Standard 20, 30, 40, 50, 70, 100, 140, 200, and 230 mesh screens were used. Weights of screen fractions were obtained by accumulative weighing. Later all plus 100 mesh material from each sample was combined for heavy-mineral study. The weight percentages of the sand were plotted on cumulative curves as 100 percent of the sample, and median diameter, Trask (1932, p. 71-72) sorting coefficient, and fifth percentile values _/ were determined from the curves.

_/ The fifth percentile value or P5 is obtained from the cumulative curve, and is a sensitive measure of the proportionate amount of "coarse" sand in a sample. A P5 of 0.15 means that 5 percent of the sand in the sample is as coarse, or coarser than, 0.15 mm.

About 10 representative samples from the plus 100 mesh fraction of each formation were separated with bromoform and the heavy minerals identified.

Evaluation of results

There are several sources of possible error in the laboratory methods, such as loss of clay in decantation and in acidulation, attrition of sand, and errors in weighing. Only the latter two factors influence the median diameter, sorting coefficient and fifth percentile values of the cumulative curves.

Care was taken to prevent loss of clay in decantation by allowing plenty of settling time. Grim, Dietz and Bradley (1949, p. 1788) found that acidulation did not remove a significant amount of aluminum and silicon from residues. In order to test the effects of attrition in the blender, a sand sample was mechanically analyzed before and after agitation in the blender for 8 minutes, twice the normal time. The sand lost only 3½ percent of its weight and was reduced only 0.001 of a millimeter in median diameter.

To check the reliability of the insoluble residue method and the consistency of lithology within samples, 2 splits each of 29 samples were dissolved and total insoluble material measured. The maximum difference between percent of total insoluble residue in the first and second determinations was 8.2. The average difference was 2.7, a reasonably small variation.

It should be emphasized that the objective of the laboratory work was to compare uniformly obtained data on samples of known age and formation rather than absolute values for individual samples.

In heavy-mineral analysis, it was found that solution of 100 to 300 grams of limestone was necessary to provide 100 grains of heavy minerals, and not enough samples could be examined in the time available to permit strict comparisons of formations. However, the small amount of data obtained disclosed some mineralogical differences which, when used with other information, were helpful in reaching a decision on doubtful samples and outcrops.

Some of the illustrations which accompany this report show the kind of comparisons that may be made with the data. Although there is considerable overlap in characteristics, there is a definite progression in data from one formation to another, indicating that at any particular point a vertical section through the formations will be characterized by shifts in petrographic values at formational boundaries.

STRATIGRAPHY

Eocene rocks

Ocala limestone

Previous work.--Dall and Harris (1892, p. 103) first used the name Ocala to include limestones exposed in quarries near Ocala in Marion County, Fla. They correlated the Ocala limestone with rocks which they then regarded as Eocene in age. Matson and Sanford (1913, p. 70) placed the Ocala limestone in the Oligocene, but Cooke (1915) proved that it is of Jackson (late Eocene) age and that it underlies the Vicksburg group. Applin and Applin (1944, p. 1683-1684) recognized a twofold faunal division of the formation. Vernon (1951, p. 111) restricted the name Ocala to the upper part of the formation and correlated the lower part with the Moodys Branch formation of Alabama and Mississippi. On the basis of faunal zones Vernon (1951, p. 115) proposed the names Inglis and Williston for the lower and upper members respectively of the Moodys Branch formation as exposed in Citrus and Levy Counties in Florida. Vernon (1951, pl. 2) used the top of the Inglis member, a conformable surface, in his structural studies of northern peninsular Florida. Puri (1953a, p. 130) proposed that all sediments of Jackson age in Florida be called the Ocala group. He suggested a new name, Crystal River formation, for Vernon's Ocala limestone (restricted), and suggested raising the Inglis and Williston to formational status. He also listed distinctive faunizones for these formations.

Age and extent.--The Ocala limestone is late Eocene and is correlated with the Jackson group of Alabama (MacNeil, 1947). In this report Ocala is retained for all rocks of late Eocene age in west-central Florida. The Ocala limestone is locally exposed in a belt from Lafayette County on the northwest to northern Pasco and Polk Counties on the southeast. It is present in the subsurface over much of northern and probably southern peninsular Florida, but is missing from many scattered wells in the central part of the peninsula. The average thickness of the formation is about 150 feet, but it is over 300 feet thick in wells in southern Polk County.

Lithology.--The Ocala is a pure, massive, marine, white to tan granular limestone, which is locally a porous friable coquina-like mass of foraminifera and mollusks in a chalky or pasty carbonate matrix. Solution pipes filled with clay and large irregular masses of chert are common locally. A summary of petrographic data for the Ocala limestone is given in table 10. Details of Ocala petrology have been studied by Fischer (1949, p. 41-70).

Stratigraphic relations.--The Ocala lies unconformably upon the Avon Park, Lake City, and Tallahassee limestones (Cooke, 1945, p. 56) and is overlain unconformably by all later formations.

Fauna.--Large miliolid and camerinid foraminifera are very abundant in, and characteristic of, the Ocala limestone. Echinoids are abundant, particularly in the lower part. Mollusks, including pectens and turritella gastropods, are also abundant but not as conspicuous as in the later formations.

Oligocene rocks

Suwannee limestone

Previous work.--Cooke and Mansfield (1936, p. 71) proposed the name Suwannee for limestone of late Oligocene age exposed along the Suwannee River in northern Florida. Previously Matson and Clapp (1909, p. 73) had referred these rocks to the Hawthorn formation, and Mossom (1925, p. 73-77; 1926, p. 81-82) correlated them with the Glendon limestone, now considered a member of the Byram formation in Alabama (MacNeil, 1944, fig. 1). Cooke and Mossom (1929, p. 89-91) had included the present Suwannee limestone in the Tampa limestone, which was then thought to be Oligocene in age. Vaughan (1910, p. 155) recognized the absence of Oligocene rocks from an area in east-central Florida. The Applins (1944, p. 1681) divided the Oligocene into two faunal units in northern Florida, the upper of which is much more extensive and is correlated with the Suwannee limestone. In northwestern Florida MacNeil (1944, p. 1316) restricted the Vicksburg group to the middle Oligocene, namely the Marianna limestone and the Byram formation. The Suwannee limestone is now considered by MacNeil (1946, p. 55) to be equivalent to the Byram and Chickasawhay formations combined (fig. 2).

Age and extent.--The Suwannee limestone is late Oligocene in age. As used in this report it includes all sediments of Oligocene age in west-central Florida. The formation is locally exposed in northwestern peninsular Florida. Typical Suwannee limestone crops out along the upper Suwannee River. It is also exposed locally in southern Citrus and Sumter Counties, most of Hernando County, northwestern and eastern Pasco County, the northeast corner of Hillsborough County, and the northwest corner of Polk County. In the subsurface it extends to southern Florida, but is missing from east-central peninsular Florida. In the area mapped the formation averages 150 feet thick, is missing in eastern Polk County, but is about 300 feet thick near the Gulf Coast.

The best exposure of Suwannee limestone visited by the authors in this area is at locality 62, (pl. 2) in Pasco County. Fairly good exposures are also present at localities 67 and 70.

General lithology.--The Suwannee is a pure, massive, homogeneous white to light tan limestone which is fairly soft and sometimes granular in appearance. It contains only a few percent of very fine-grained quartz sand but locally has abundant fossil detritus and organic structures including casts, molds, and borings of mollusks and tests of foraminifera and bryozoa. The top of the formation, where it is not deeply buried by later deposits, has been locally silicified to irregular vitreous masses of translucent brown, red, and gray to black chert, some of which has been altered to porous white tripoli.

Stratigraphic relations.--Elsewhere in Florida the Suwannee limestone is known to be (Cooke, 1945, p. 88) unconformable upon older Oligocene (Marianna limestone) or Eocene rocks (Vernon, 1951, p. 177) and is overlain unconformably by the Tampa or Hawthorn formation (Cooke, 1945, p. 88). The contacts of the Suwannee limestone were not observed in the area mapped for this report, although the contact with the Tampa limestone is probably present at localities

8, 65, and 70. At locality 65 a piece of rock dredged from a waterway contained two kinds of limestone in sharp contact. Part of the rock was compact and contained molds of a non-marine gastropod; the other part was porous and granular and contained foraminifera. Other pieces of rock similar to the latter type contained Cassidulus gouldii, the Oligocene echinoid. Probably the Tampa-Suwannee contact was cut by dredging at this locality.

The Suwannee limestone is missing in parts of peninsular Florida, notably in the northeast corner of the area mapped and beyond, and the Tampa limestone, and even the Hawthorn formation rest directly upon the Ocala limestone in some areas. Subsurface data show that the upper contact of the Suwannee limestone is irregular (pl. 1 and figs. 3 and 4).

A limestone unit which may be an equivalent of either the Byram formation or Marianna limestone of northern Florida is present in a well drilled for the Davison Chemical Corporation in Polk County. Petrographic characteristics different from those usually shown by the Suwannee limestone were found in approximately the lower 40 feet of a limestone which is called Suwannee on the basis of lithology and the presence at the top of a fragment of Cassidulus gouldii. The anomalous lower 40 feet of limestone contained no fossils, but the quartz sand is coarser, the percentage of sand is higher, and the sorting poorer than in other Suwannee limestone analyzed from west-central Florida.

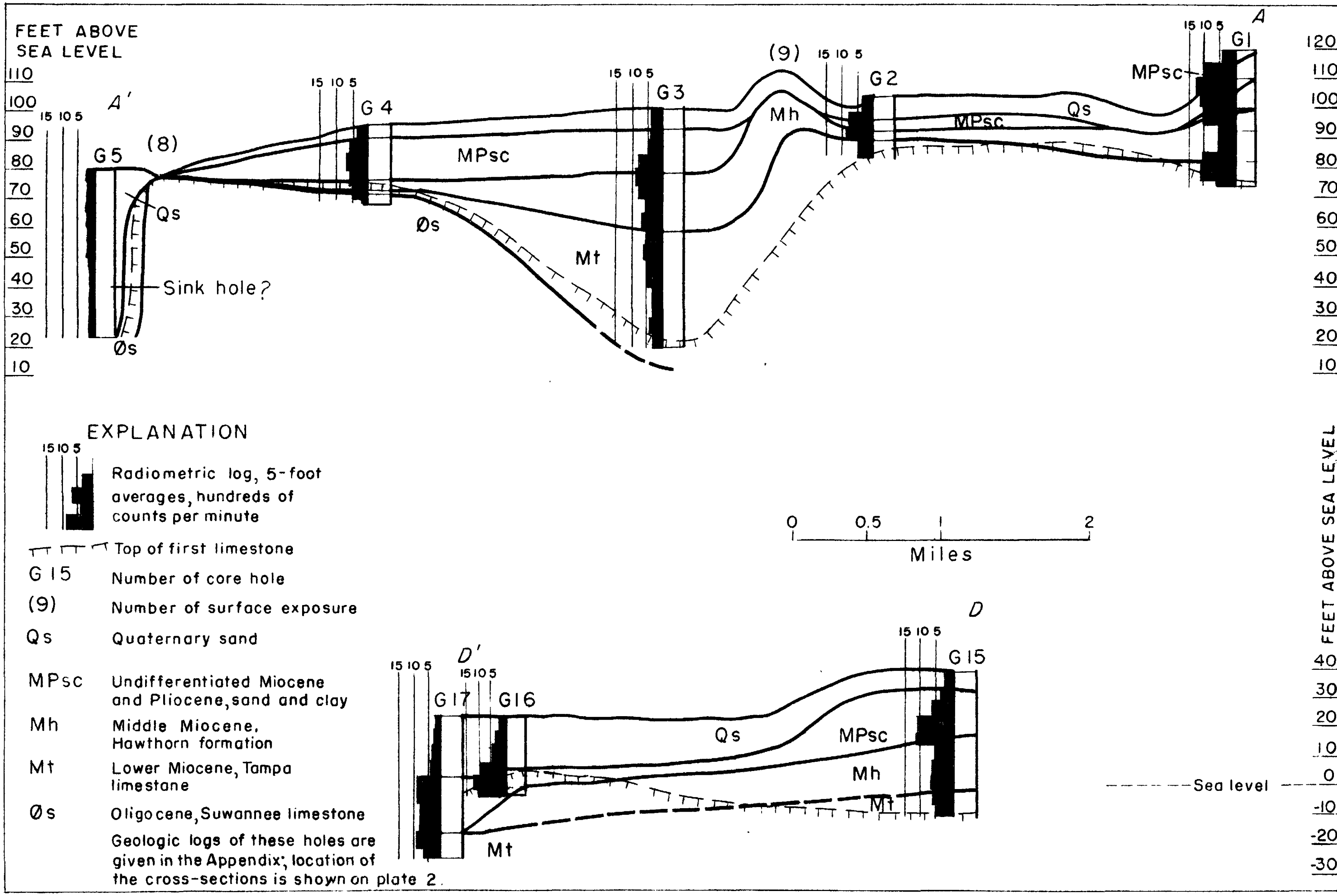


FIGURE 3.—CROSS-SECTIONS THROUGH CORE HOLES IN NORTHEASTERN AND CENTRAL HILLSBOROUGH COUNTY, FLORIDA.

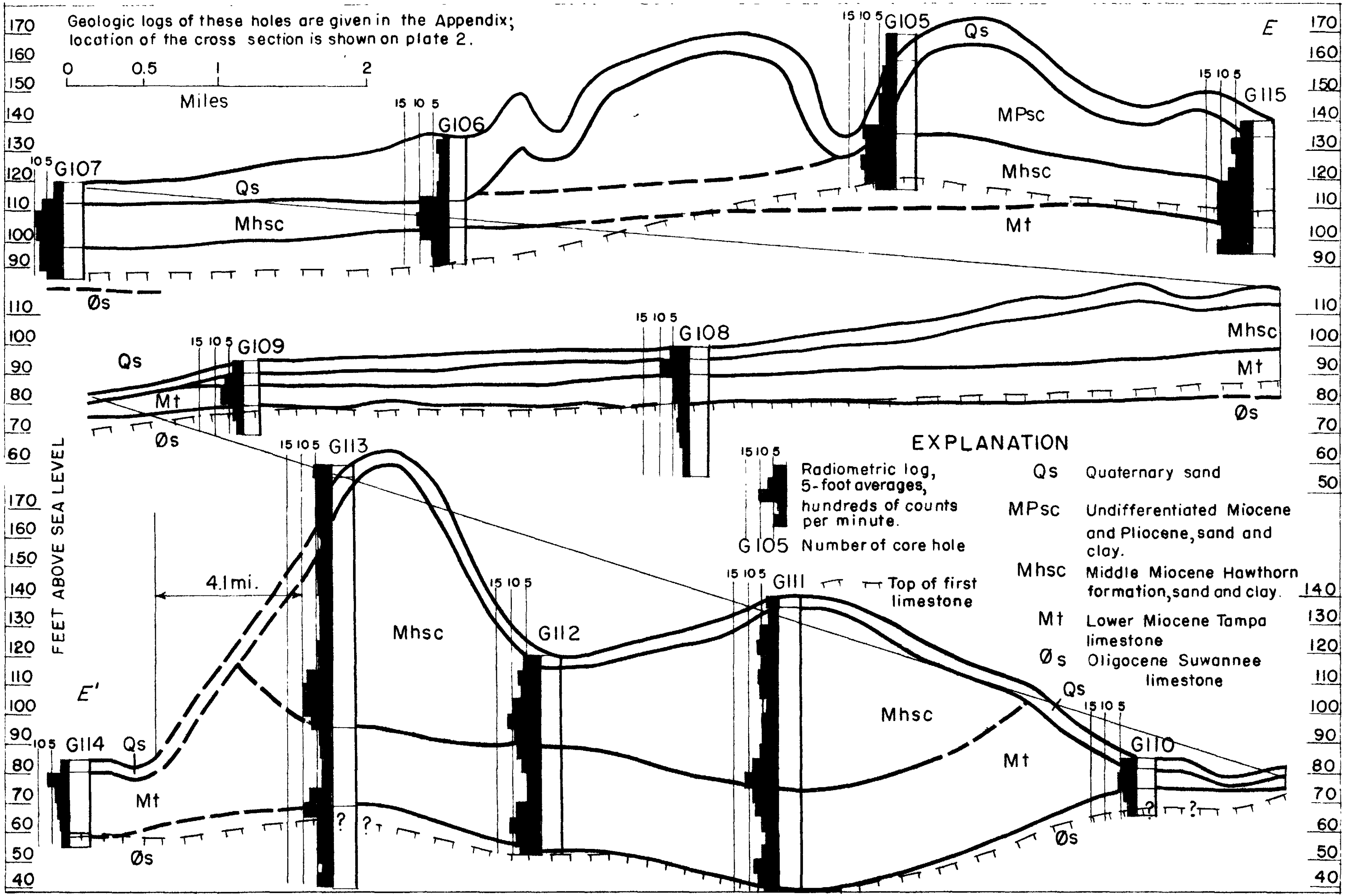


FIGURE 4.- CROSS SECTION THROUGH CORE HOLES IN NORTHWESTERN POLK AND SOUTHEASTERN PASCO COUNTIES, FLORIDA.

Fauna.--Mollusks and foraminifera are both abundant in the Suwannee limestone. An echinoid, *Cassidulus gouldii* (Bouve), is apparently diagnostic.

Fossils in the Suwannee limestone identified for this report are given in plate 3.

Petrographic details.--The microscope shows that the Suwannee limestone is composed mostly of calcareous mollusk and foraminiferal detritus with a few scattered very fine quartz grains cemented by microcrystalline dusky anhedral calcite or secondary quartz. Alteration textures include incipient fracture-filling and minor replacement in and around fossils by fresh, euhedral, fine-grained calcite, and replacement of carbonate by crystalline and cryptocrystalline quartz. Silicification varies from tiny fossil molds filled with spherulitic chalcedony to massive chert replacement with only a few relicts of fossils. Some of the chert contains vugs lined with small quartz crystals. Pyrite is common in the darker cherts. Much of the chert exposed to leaching has been partially altered to tripoli. Minor dolomitization shown by roughly rhomb-shaped areas of fine-grained, optically continuous carbonate, is also common in some specimens.

The Suwannee and most other Florida limestones have high porosity, partly because of abundant fossil casts and molds.

Where it does not contain chert the Suwannee limestone has few impurities. By calculation, (table 1); samples chemically analyzed for this report contain from 64 to 99 percent calcium carbonate, and the average is 87 percent. Aside from minor quartz sand, silt, and clay, the percentage of other constituents is negligible.

Table 1.--Average of partial chemical analyses of 7 samples of Suwannee limestone from Pasco County, Florida /

	P_2O_5	CaO	Al_2O_3	Fe_2O_3	MgO
Percent	0.2	48.93	0.3	0.28	0.42

/ Laboratory nos.: 115964 to 115968 and 115971, 115972. Analysts: Ivan Barlow, Harry Levine, Roberta Smith, Wendell Tucker, Maryse Delevaux.

The Suwannee limestone contains very few heavy minerals; several hundred grams of limestone yield only a few grains. In some samples muscovite is the predominant heavy mineral. In a composite sample from core-drill hole G108 nearly all of the heavy minerals were fine flakes of muscovite.

Quartz sand in the Suwannee limestone is very fine-grained, extremely well sorted, rounded to subangular, and fairly uniformly distributed. Petrographic data obtained from samples of the Suwannee are summarized graphically in figures 5 through 10. The data show that a typical sample of Suwannee limestone contains about 5 percent insoluble material; the sand fraction is about 2 percent of the sample, has a median diameter of 0.09 mm, a sorting coefficient of 1.14, and a fifth percentile value of 0.12 mm.

Localities.--A gazetteer of exposures of the Suwannee limestone examined by the authors is given in table 2. Some of these localities are new to the literature.

(Text continued on p. 44)

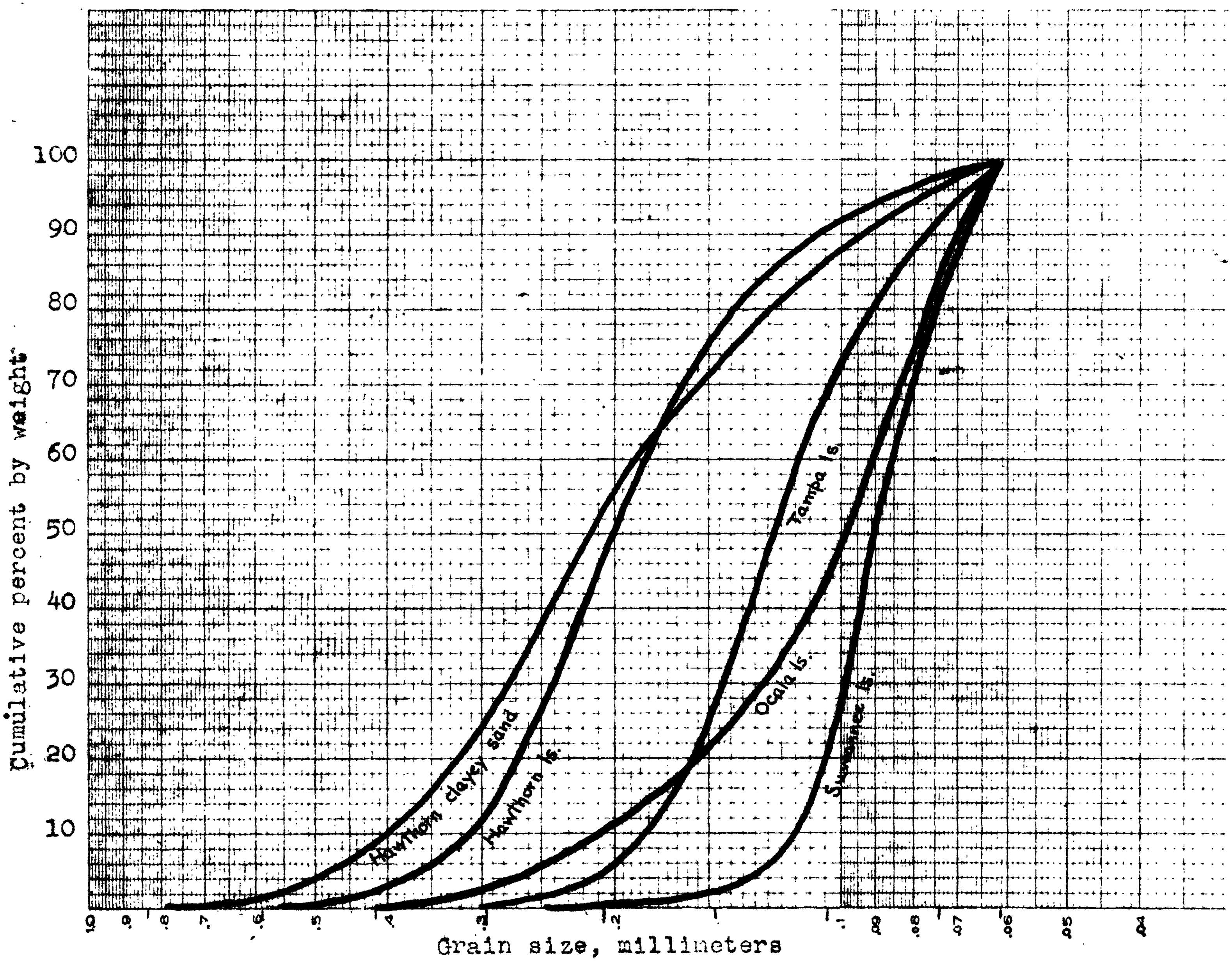


Figure 5. Typical cumulative curves of sand for Ocala, Suwannee, and Tampa limestones, and Hawthorn formation in west-central Florida.

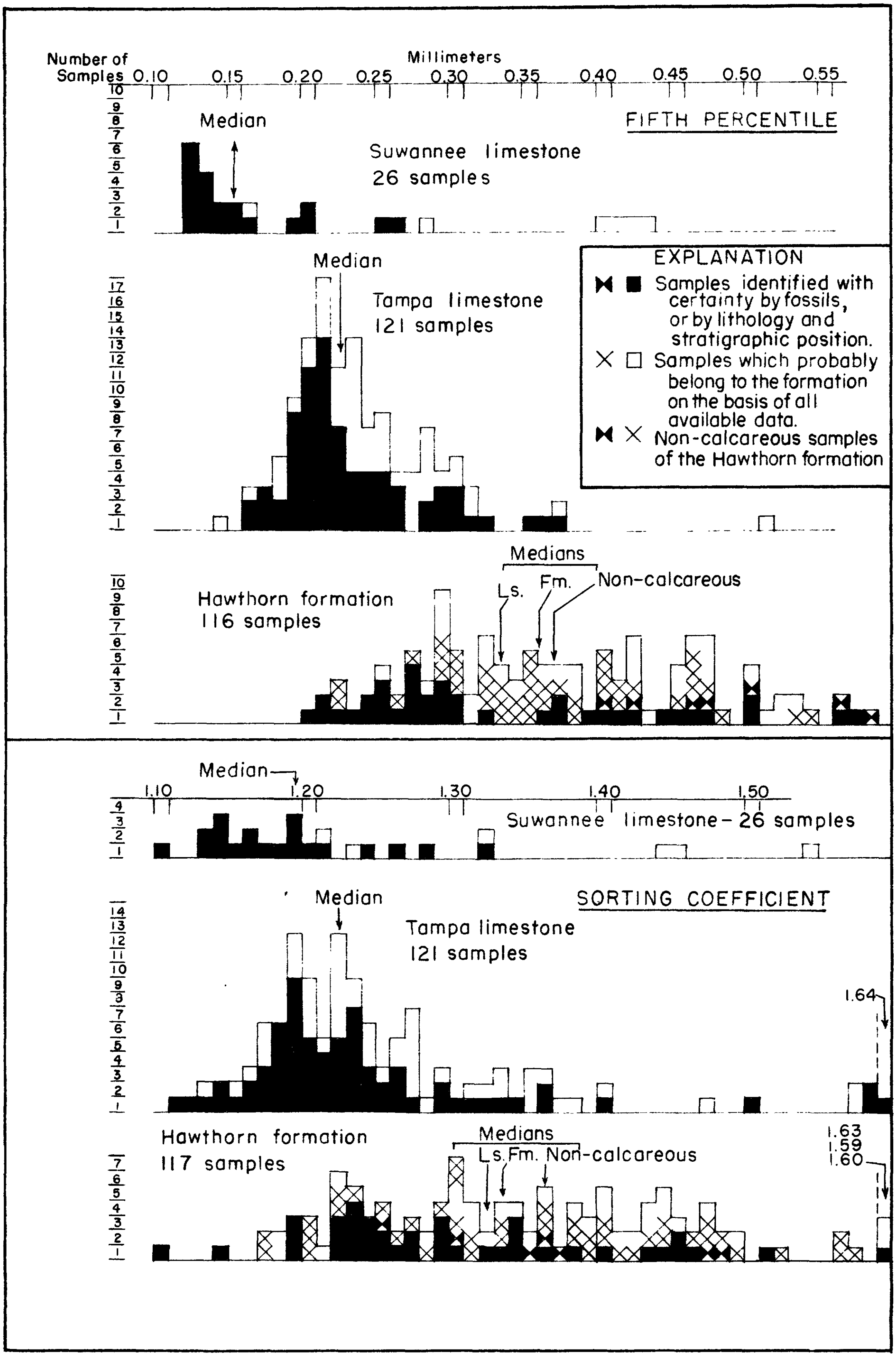


FIGURE 6.—FREQUENCY DISTRIBUTION OF FIFTH PERCENTILE VALUE AND SORTING COEFFICIENT IN SAMPLES OF SUWANNEE AND TAMPA LIMESTONES AND HAWTHORN FORMATION IN WEST-CENTRAL FLORIDA.

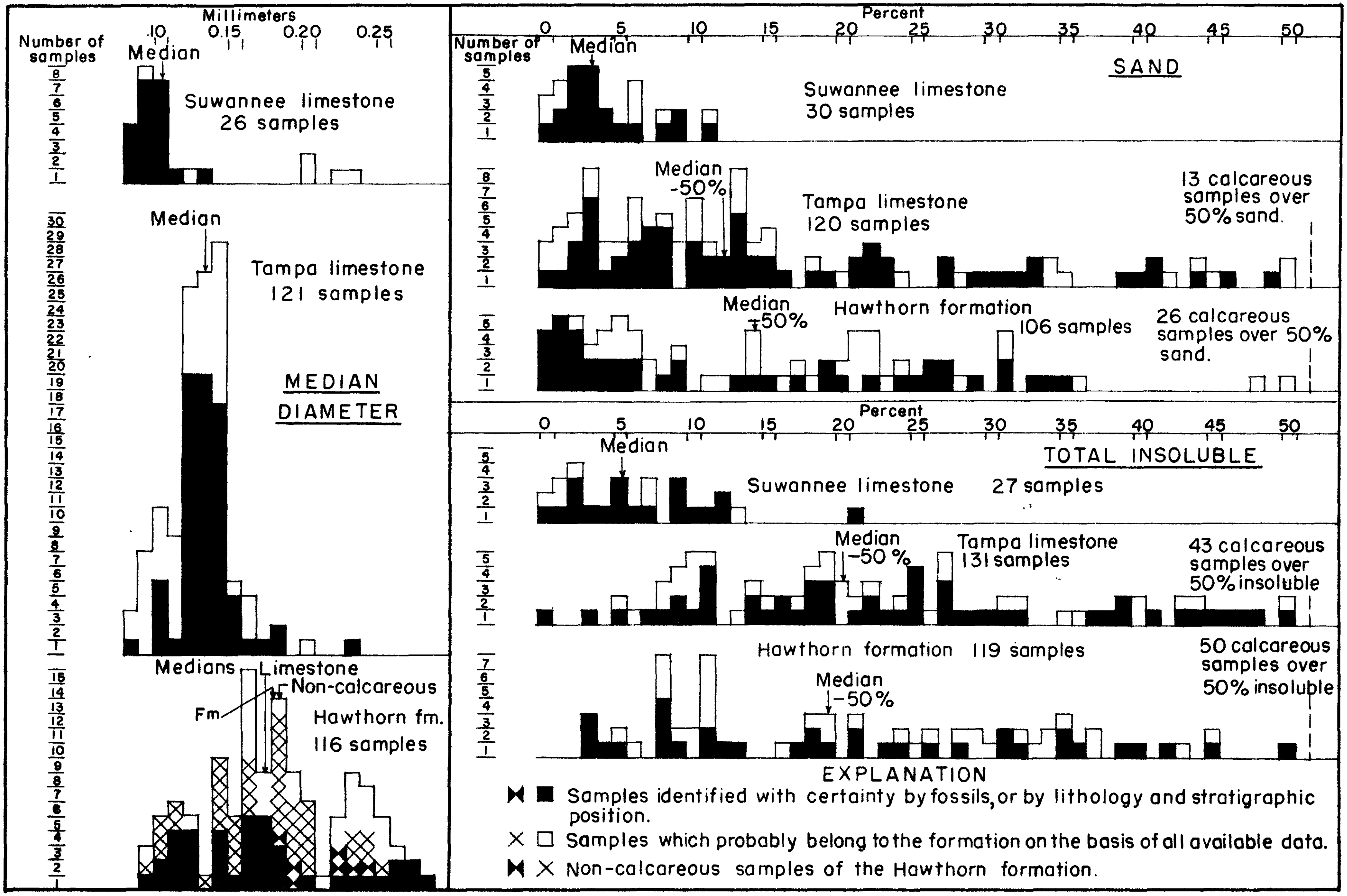


FIGURE 7.—FREQUENCY DISTRIBUTION OF MEDIAN DIAMETER, PERCENT SAND AND PERCENT TOTAL INSOLUBLE IN SAMPLES OF SUWANNEE AND TAMPA LIMESTONES AND HAWTHORN FORMATION IN WEST-CENTRAL FLORIDA.

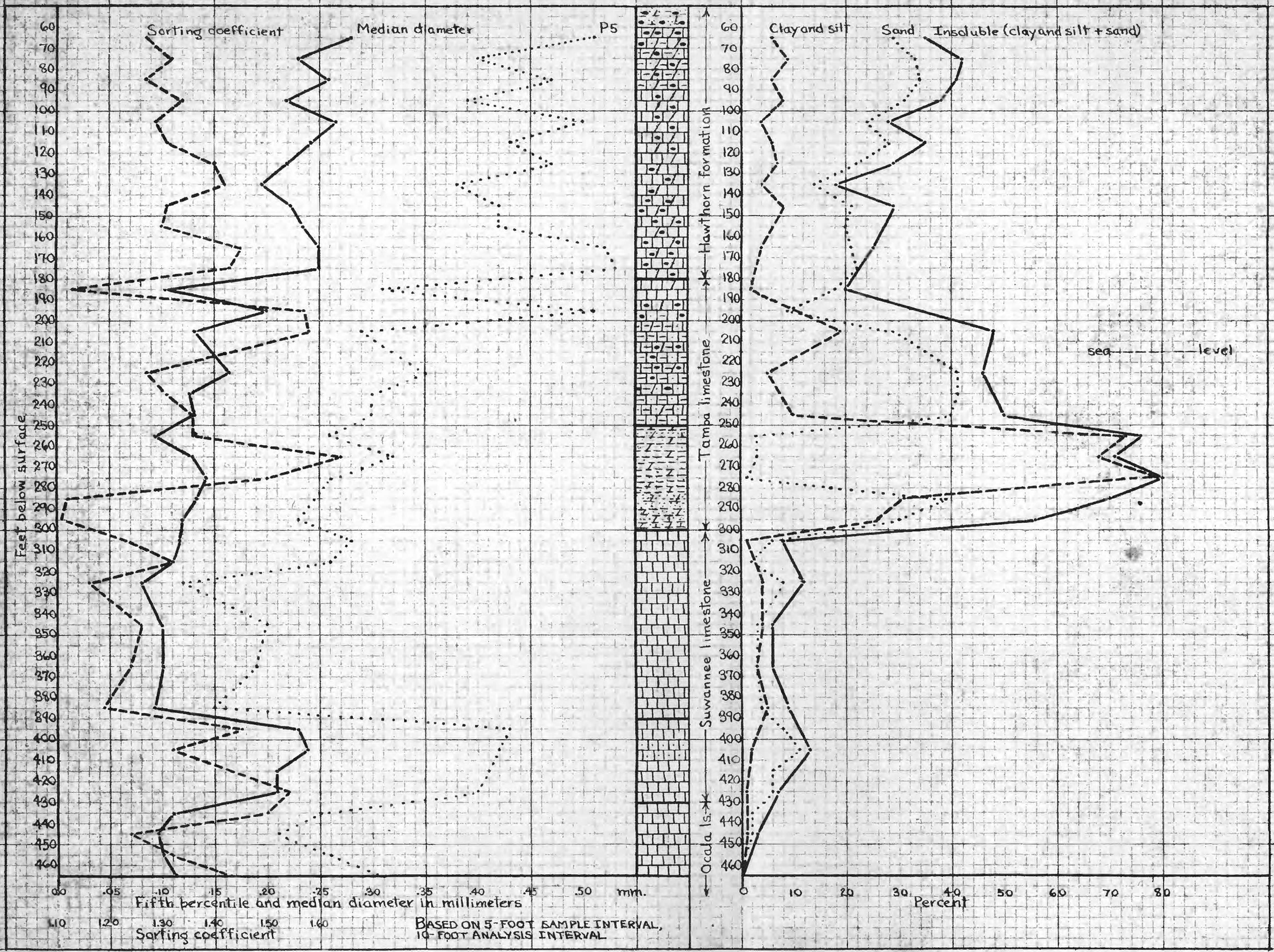


FIGURE 8. PETROGRAPHIC AND LITHOLOGIC LOG OF UPPER PART OF DAVISON CHEMICAL CORPORATION CHURN-DRILLED WELL NO. 3, S.E.¼, N.W.¼ SEC. 4, T. 30 S., R. 24 E., POLK COUNTY, FLORIDA

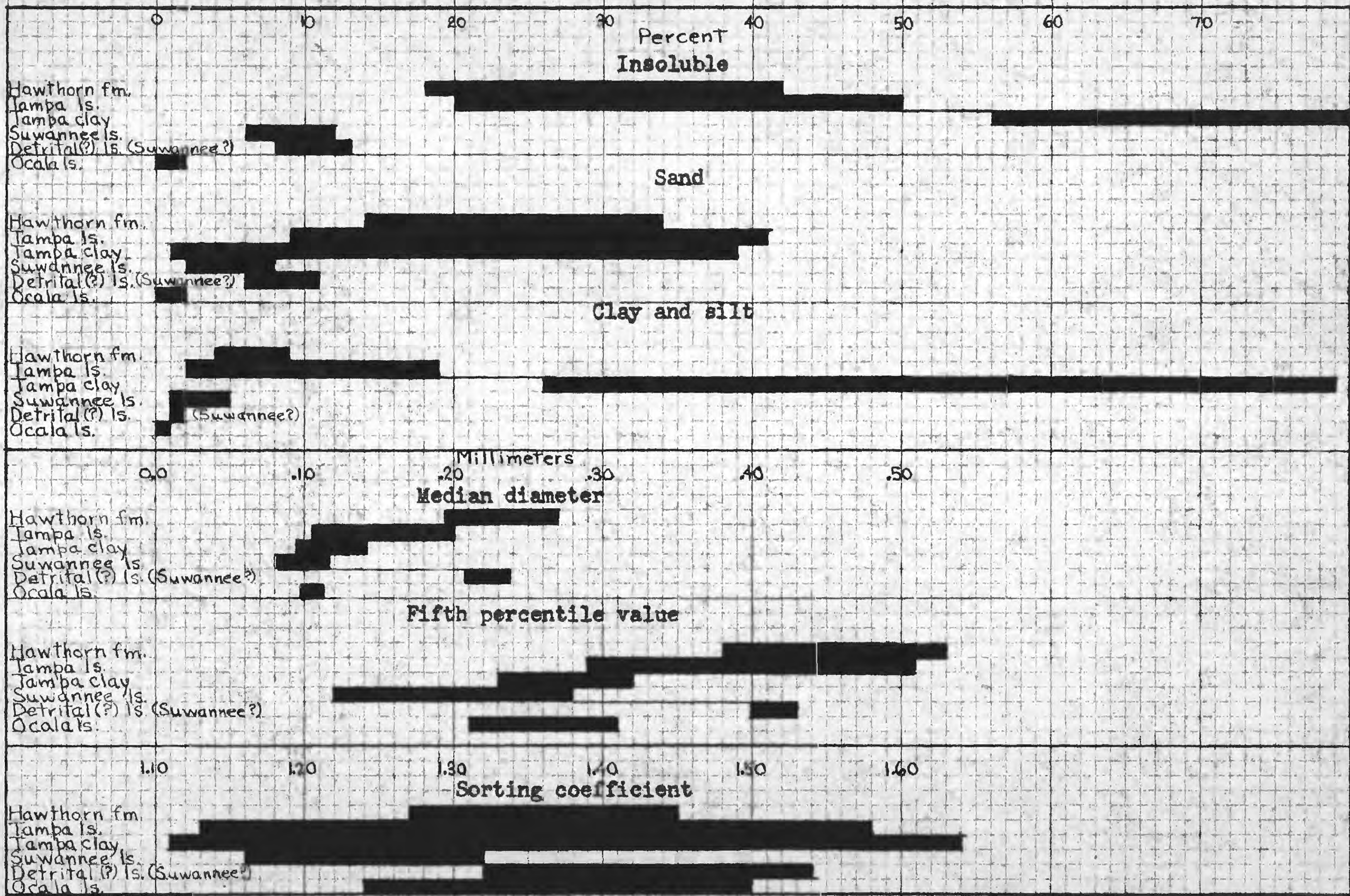


FIGURE 9. RANGES OF PETROGRAPHIC CHARACTERS OF FORMATIONS AND BEDS IN THE UPPER PART OF DAVISON CHEMICAL CORPORATION CHURN-DRILLED WELL NO. 3, S.E.¼, N.W.¼ SEC. 4, T. 30 S., R. 24 E., POLK COUNTY, FLORIDA

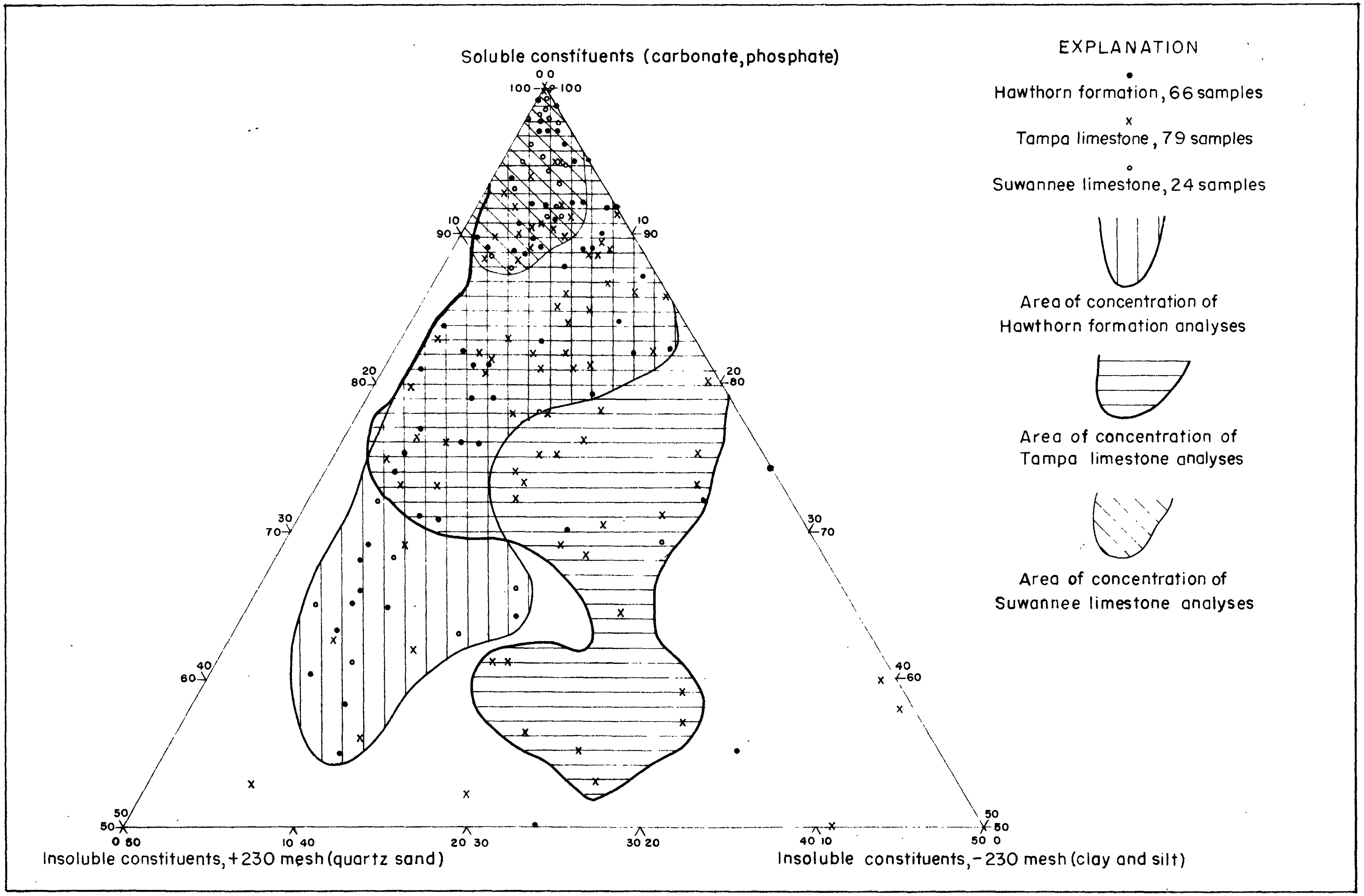


FIGURE 10.—TERNARY DIAGRAM OF SOLUBLE AND INSOLUBLE CONSTITUENTS OF LIMESTONE SAMPLES OF THE HAWTHORN FORMATION, AND TAMPA AND SUWANNEE LIMESTONES IN WEST-CENTRAL FLORIDA.

Table 2.--Exposures of the Suwannee limestone in Hillsborough, Pasco, and Polk Counties, Florida

Locality,[1/] name and number	Access[1/]	General lithology	Thickness (feet)	Remarks
		Hillsborough County		
Blackwater Creek 8 NW$\frac{1}{4}$ sec. 18, T. 27 S., R. 22 E.	St. Hwy. 39 about 8.5 mi. N. of Plant City; spoil banks of ditch.	Ls., white, slightly sandy, granular, locally silicified	-	Mansfield (1937, p. 51) and Cooke (1945, p. 127) report Tampa-Suwannee contact here; fossils of both formations present.
Crum property 40 Sec. 9, T. 27 S., R. 22 E.	St. Hwy. 39, 0.4 mi. N. of Blackwater Cr. turn E. through locked gate on woods and pasture roads in an ENE direction for about 1.5 mi.; boulders of chert and silicified ls. on surface of ground.	Chert, varicolored, fossiliferous, and ls., partly silicified.	-	

1/ Most of the geographic and locality names used in these tables can be found on the Army Map Service 7$\frac{1}{2}$ minute quadrangles which cover most of this area. Unmapped areas are shown on county road maps distributed by the Florida State Road Department, Tallahassee, Fla.

Table 2.--Exposures of the Suwannee limestone in Hillsborough, Pasco, and Polk Counties, Florida--Continued

		Hillsborough County--Continued		
Hillsborough River State Park 46 Sec. 8, T. 27 S., R. 21 E.	U. S. Hwy. 301 to Hillsborough R. State Park; take "Rapids Trail" to river; boulders in river.	Chert, gray and brown sparsely fossiliferous.	-	
		Pasco County		
Crystal Springs 51 NW$\frac{1}{4}$ sec. 35, T. 26 S., R. 21 E.	St. Hwy. 39, turn E. at Crystal Springs town for about 1.6 mi., turn N.; entrance to spring on W. side of road; boulders around spring.	Chert, gray, brown, very fossiliferous.	-	Cooke (1945, p. 97).
Crystal Springs ditch 55 Sec. 36, T. 26 S., R. 21 E.	St. Hwy. 39 to Crystal Springs town, turn W. for 0.35 mi., then N. on dirt road; exposure in small ditch W. side of road.	Chert and tripoli, cavernous, iron-stained, brown, red, white, cobbles.	-	Probably Suwannee although some chert residual from the Tampa ls. probably occurs in the area.

Table 2.--Exposures of the Suwannee limestone in Hillsborough, Pasco, and Polk Counties, Florida--Continued

		Pasco County--Continued		
Crystal Springs pits 56, 57, 58 Secs. 25, 26, T. 26 S., R. 21 E.	Locality 56: St. Hwy. 39, 0.8 mi. N. of Crystal Springs town; shallow borrow pits E. side of road. Loc. 57: St. Hwy. 39, 1.4 mi. N. of Crystal Springs town; shallow borrow pit 100 yds. W. of road. Loc. 58: stock watering pit on private land, about 0.8 mi. W. and S. of loc. 57.	Chert, brown, gray, black, locally pyritic, fossiliferous, tripoli, silicified corals associated with sand, gray to red, clayey.	-	Clayey sand, corals, and some of the chert may be Miocene. Localities listed here are only a few of many in the Crystal Springs area where chert occurs.
New River Bridge 59 $SW\frac{1}{4}$ sec. 13, T. 26 S., R. 20 E.	St. Hwy. 54, about 5.5 mi. W. of Zephyrhills, at N. side of bridge over New River; fragments dug from creek.	Chert, gray, and tripoli, chert contains abundant minute quartz spherulites.	-	Age uncertain, but probably replacement of Oligocene rocks.

Table 2.--Exposures of the Suwannee limestone in Hillsborough, Pasco, and Polk Counties, Florida--Continued

		Pasco County--Continued		
McLeod pit 62 $SE\frac{1}{4}NE\frac{1}{4}$ sec. 26, T. 23 S., R. 21 E.	From Lacoochee turn S. on paved street over railroad tracks, continue S. on main dirt road for about 1 mi. until road parallels tracks on the E.; pit on private land about 0.2 mi. W. of road.	Ls., soft, white, granular, slightly sandy, irregularly fossiliferous, upper part thin-bedded in places and contains many vertical "pipes" with greenish clay.	30	Cooke (1945, p. 98)
Pasco road cut 63 $NE\frac{1}{4}$ sec. 11, T. 25 S., R. 19 E.	St. Hwy. 52 from Dade City, about 2.4 mi. W. of Pasco in very shallow roadcut near corrals on S. side of road; also spoil banks of ditch about 0.3 mi. N. of road cut.	Sand, clayey, dark brown to gray, hardpan, containing chert, and tripoli, brown, orange, and white, sparsely fossiliferous; also (at ditch to N.) ls., light tan, hard crystalline, very slightly sandy, fossiliferous.	-	

Table 2.--Exposures of the Suwannee limestone in Hillsborough, Pasco, and Polk Counties, Florida--Continued

		Pasco County--Continued		
Hudson 65 SW$\frac{1}{4}$ sec. 28, T. 24 S., R. 16 E.	Hudson, W. from Post Office for about 0.3 mi. to Gulf, spoil banks along canals.	Ls., white to light gray, pure, hard, very fine-grained, fossiliferous; and ls., white, granular, foraminiferal, porous, very slightly sandy.	-	Both Tampa and Suwannee limestones probably present; some land snails occur here.
North Hudson 66 NW$\frac{1}{4}$ sec. 27, T. 24 S., R. 16 E.	Gravel road N. 0.7 mi. from Post Office at Hudson, spoil banks of drainage ditch, W. side of road.	Ls., hard white to light tan, thin-bedded, very slightly sandy, sparsely fossiliferous.	-	May be at or near Mansfield's (1937, p. 52) locality.
Hudson-Aripeka quarry 67 Sec. 14, T. 24 S., R. 16 E.	Gravel road N. about 3 mi. from Hudson Post Office, turn E. on trail about 0.3 mi. to old pit and crusher; latter visible from road.	Ls., hard, white, pure, very fine-grained, irregularly fossiliferous.	-	Mossom (1925, p. 171)

Table 2.--Exposures of the Suwannee limestone in Hillsborough, Pasco, and Polk Counties, Florida--Continued

		Pasco County--Continued		
Griffin pit 70 $S\frac{1}{2}$ sec. 19, T. 26 S., R. 22 E.	From U. S. Hwy. 301 - St. Hwy. 39 junction S. of Zephyrhills turn E. on dirt road at sawmill for about 0.9 mi., turn SE through gate, past cabin, through another gate and SE through fields for about 1.3 mi. from first gate; shallow, water-filled pit on the edge of Hillsborough R. swamp. Property of E. Z. Griffin, Tampa Florida.	Ls., white to light tan, very slightly sandy, locally silicified, fossiliferous, locally encrusted with iron oxides and carbonized material.	2.0	Probably same locality reported by Mansfield (1937, p. 51-52). Possibly some Tampa ls.; one specimen of *Cyrena floridana*, never recorded from Suwannee ls., found. Suwannee chert and Tampa(?) corals are common in this region as scattered float.
		Polk County		
Rock Ridge 72 $NE\frac{1}{4}$ sec. 19, T. 25 S., R. 24 E.	From U.S. Hwy. 98 N. of Lakeland, turn NE on Rock Ridge gravel road for about 8.5 miles; boulders by ditch, NW side of road, just after first major bend in road.	Chert, tripoli, white to gray, cavernous, iron-stained, very fossiliferous.	-	Fossils from both Suwannee ls. and Eocene rocks are present. A fault probably is present just E. of this locality.

Miocene rocks

Tampa limestone

Previous work.--Allen (1846) was apparently the first to record observations of the rocks now known as Tampa limestone. In 1887 Heilprin (1887) assigned the rocks at Ballast Point on Hillsborough Bay to the lower Miocene, the present accepted age of the Tampa limestone, but Johnson (1888, p. 235) was the first to use the name Tampa to describe rocks exposed near Tampa, Fla. Dall (1892, p. 112) included in his "Tampa group" the "Chipola beds," the "Tampa beds," and the "Alum Bluff beds." Matson and Clapp (1909, p. 84-91) restricted the name Tampa to the limestones exposed near Tampa, but Mossom (1925, p. 77-82) included limestone exposed in Hernando County in the Tampa, and later (1926, p. 182-184) he added the so-called Glendon limestone of Suwannee and Hamilton Counties to the Tampa. In these reports Mossom used the name "Chattahoochee" formation for limestone and calcareous clay in northwest Florida which he considered contemporaneous with the Tampa limestone. Cooke and Mossom (1929, p. 78-93) abandoned the name Chattahoochee and included these rocks with limestones of peninsular Florida in the Tampa formation. Later Cooke and Mansfield (1936, p. 71) separated the Tampa and Suwannee limestones. Puri (1953, p. 19-20, 38) divided the Miocene in the Florida panhandle into 3 time-stratigraphic units, each separated by unconformities. He divided the lower Miocene Tampa stage into an updip clayey and silty Chattahoochee facies and a downdip calcareous St. Marks facies. He considered the St. Marks facies to be present in the Tampa area (Puri, 1953, p. 21).

Age and extent.--The Tampa limestone is of early Miocene age and in this report comprises all strata lying between the late Oligocene Suwannee limestone and the middle Miocene Hawthorn formation.

The formation is near the surface from the Alafia River in west-central Hillsborough County northward and northeastward to central Pasco and north central Polk Counties. Most of the exposures in this area are along the Gulf Coast from the vicinity of Clearwater in Pinellas County to Hudson in northwestern Pasco County, and along the shores of Tampa Bay and the Hillsborough River. Tampa limestone also occurs in the bottom of two phosphate pits, one northeast of Lakeland, the other west of Bartow (Mansfield, 1937, p. 22). The authors were unable to locate the occurrence west of Bartow and the location of the collection may be in error. The formation is also exposed in scattered areas in northwestern Florida. It has been found in wells throughout much of northwestern Florida, and is present in the subsurface as far east as central Polk County in central Florida. The Tampa limestone appears to extend to extreme southern Florida where it was identified from a deep well in Monroe County (Cole, 1941, p. 11). The formation once extended northward from the area mapped in this report but has been weathered and eroded from much of Sumter and Hernando Counties. Patches of Tampa limestone remain, however (loc. 100, pl. 2), and in Hernando and northern Pasco Counties several feet of sandy clay have been identified (Ketner, K. B., oral communication) as Tampa. Thus the present mapping has extended the Tampa northward from the area mapped by Cooke (1945).

In the area of this report the Tampa limestone averages about 75 feet thick, but the maximum exposure of limestone is only 8 feet.

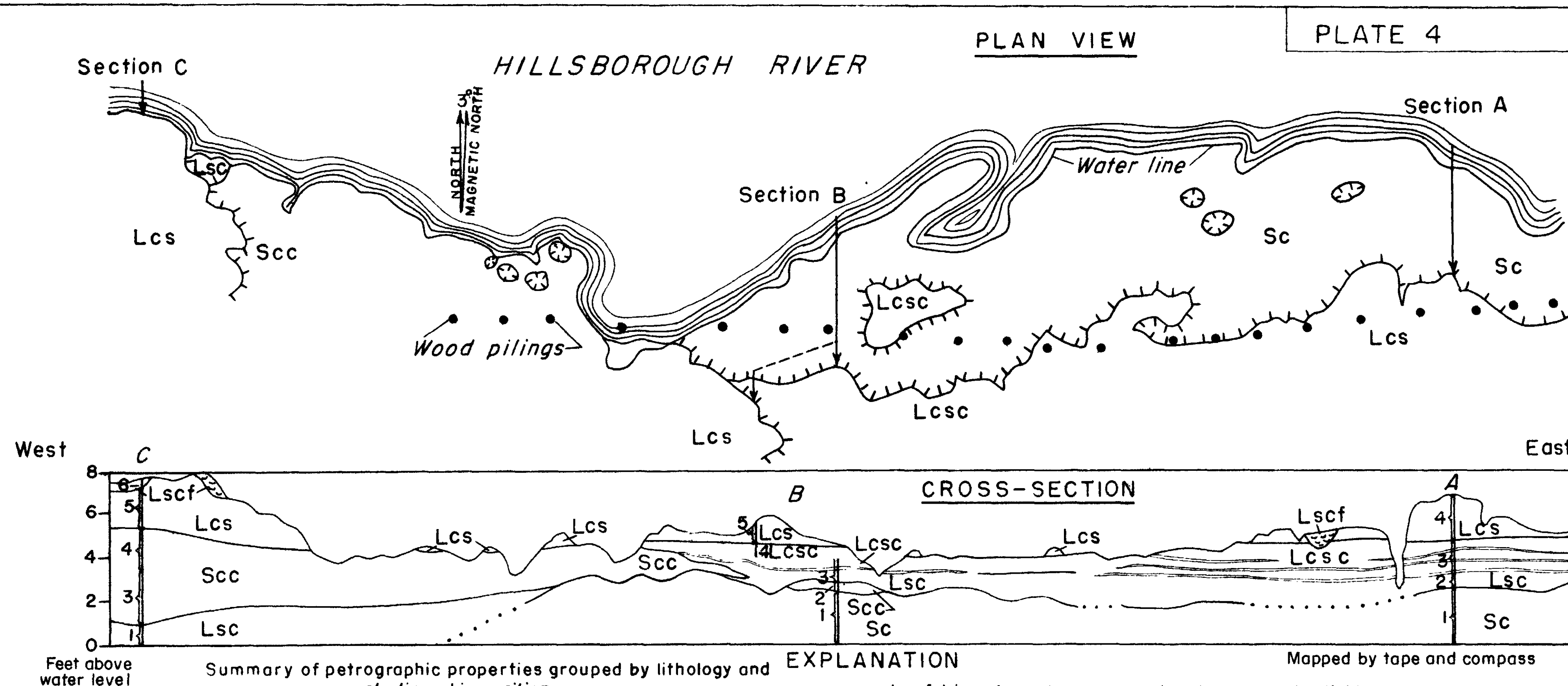
General lithology.--Typical Tampa limestone is white to light yellow, soft, moderately sandy and clayey, finely granular and locally fossiliferous. Both marine and fresh-water limestones are present. Phosphate nodules occur in Tampa limestone at a few localities (loc. 73 and drill holes G90 and G91, pl. 2). In places (locs. 4, 26) calcareous fossil remains constitute up to 90 percent of the rock. Many fossil molds give this type of rock a high porosity. Also present in the formation are lenses of limestone conglomerate, green and gray clayey sands, sandy clays, and clay-pebble conglomerates, all more or less calcareous, except where they have been deeply weathered. Chert is common, both as surficial crusts, and throughout the formation as platy fragments. Fossils are thoroughly silicified in some exposures (locs. 2, 31).

Stratigraphic relations.--From evidence which will be presented later in the section on geologic history, the writers believe that erosional unconformities exist at the top as well as the bottom of the Tampa limestone in most of west-central Florida. Few good exposures of the contacts are known in this area. Cooke (1945, p. 115) was not certain of the nature of the Tampa contacts, although he thought the Tampa limestone is probably unconformable upon the Suwannee at locality 8. No previous workers have conclusively stated the nature of the Tampa-Hawthorn contact in the area mapped for this report, but an unconformity has been demonstrated between the middle and lower Miocene in northern Florida (Cushman and Ponton, 1932, p. 31; Mansfield, 1937, p. 84; Vernon, 1951, p. 153; and Puri, 1953, p. 38).

Puri (1953, p. 21) did not mention the existence of his Chattahoochee facies in the Tampa area, although lithologic zones are present in the formation in west-central Florida (loc. 26, pl. 4) which are similar to a section with which Puri (1953, p. 20) illustrates his Chattahoochee facies in northern Florida. The writers believe that both of Puri's facies may be present in west-central Florida. The intertonguing of relatively pure limestones and calcareous sandy clays is common in this area, but in most of the region such relationships can be studied only by means of well logs.

Fauna.--The Tampa limestone is erratically fossiliferous. In places it is practically a coquina of mollusks whereas other exposures are completely devoid of megafossils. Tampa fauna in west-central Florida is characterized by abundant marine mollusks, and several species of land and fresh-water snails are present. Charophyte (fresh water plant) seeds and insect borings are locally abundant. At Ballast Point (loc. 2) near Tampa the "silex bed" or Orthaulax pugnax (Heilprin) zone is exposed from which Heilprin (1887) and Dall (1892, 1890-1903, 1915) described a variety of well preserved silicified mollusks. Common at some localities, notably Six Mile Creek (loc. 1), is Celliforma nuda (Dall) which is thought (Brown, 1934, 1935) to be the silicified larval chamber of a mining bee. Foraminifera are present, particularly in the lower part of the formation (Puri, 1953, p. 17). An association of the three foraminifera Sorites, Camerina, and Peneroplis was noted by F. S. MacNeil in samples collected by the

PLATE 4



Summary of petrographic properties grouped by lithology and stratigraphic position.

Section and sample number	Sc		Lsc			Scc			Lcsc		Lcs		
	A1	B1	A2	B3	C1	B2	C3	C4	A3	B4	A4	B5	C5
Sand, percent	60	58	27	22	23	33	27	49	4	12	10	8	8
Clay and silt, percent	29	35	11	17	16	33	24	23	21	18	11	21	10
Sand to clay ratio	2.1	1.7	2.5	1.3	1.4	1.0	1.1	2.1	0.2	0.7	0.9	0.4	0.8
Insoluble, percent	89	93	38	39	39	66	51	72	25	30	21	29	18
Soluble, percent	11	7	62	61	61	34	49	28	75	70	79	71	82
Sand median diameter, m m.	.15	.13	.15	.13	.14	.12	.14	.14	.10	.12	.13	.12	.12
Sand sorting coefficient	1.20	1.22	1.23	1.22	1.20	1.34	1.23	1.21	1.19	1.23	1.21	1.22	1.23
Fifth percentile, m m.	.22	.22	.22	.23	.23	.25	.24	.24	.16	.21	.21	.19	.20

Pothole — Steep edge of outcrop — Clay seams — Contact between beds, *Dotted where obscured*

EXPLANATION

Mapped by tape and compass

Lscf-Limestone, light tan to white, slightly sandy, slightly clayey, containing abundant molds and casts of mollusks.

Lcs-Limestone, white to light tan, slightly sandy, clayey, fairly hard, fragmental, sparsely fossiliferous, containing clay and limestone granules and pebbles, light green to white, and thin seams of secondary carbonate, tan.

Lcsc-Limestone, light tan to light gray, slightly sandy, clayey, soft, locally fragmental, containing thin lenses and partings of clay, very sandy, light green-gray.

Scc-Sand, white, quartz, fine-grained, very clayey, very calcareous, moderately indurated, containing small irregularly distributed patches or fragments of sand, clayey, light gray-green.

Lsc-Limestone, white to light tan, very sandy, clayey, fairly soft, containing sparse irregular patches of sand, clayey, slightly calcareous, green-gray, and abundant pebbles and granules of limestone, slightly sandy, hard, white.

Sc-Sand, gray-green to white, quartz, fine-grained, very clayey, slightly calcareous, poorly indurated, containing sandy concretion-like structures, surficially indurated

SKETCH MAP AND CROSS-SECTION OF TAMPA LIMESTONE AT LOCALITY 26, HILLSBOROUGH RIVER DAM, HILLSBOROUGH COUNTY, FLORIDA.

0 10 20 Feet

authors from several Tampa localities. Archias is one of the most abundant forms identified in well logs of the Tampa. Only one echinoid, Lovenia clarki (Lambert), has been found in the Tampa limestone.

Terrestrial vertebrate fossils, some of which have lower Miocene affinities, and are associated with depressions or sinkholes in the Tampa, Suwannee, and Ocala limestones in northern Florida, are described by Colbert (1932, p. 55-58), Sellards (1916, p. 82-90), Simpson (1930, p. 160; 1932, p. 7-41), White (1942) and Wetmore (1943), and others, but none of these remains have been found in the Tampa formation proper.

Silicified corals of the genus Siderastraea from several localities were identified by J. W. Wells of the Geological Survey. All but one of these were identified as S. hillsboroensis Vaughan; the remaining one was S. silicensis Vaughan. Siderastraea hillsboroensis seems to be associated with the Tampa-Hawthorn contact, or the lower part of the Hawthorn where the Tampa is absent.

Fossils from the Tampa limestone identified for this report are given in plate 5.

Petrographic details.--Locality 26 shows some of the features of the Tampa limestone (pl. 4). Lithology varies from a relatively pure limestone at the top of the section to a slightly calcareous clayey sand at the bottom. The beds are only a few inches to a foot or so thick and pinch out or merge laterally into different lithologies. Note (pl. 4), however, the lateral continuity of petrographic data of samples from the same beds. Contacts between most beds are gradational over an inch or two and are gently undulating to irregular. Clay fragments are abundant in places; some are cemented by a network of lime veinlets. Pockets of clayey sand surrounded by calcareous clayey sand are common.

Most clayey beds in the Tampa limestone are small lenses, but several wells in Polk County, including two drilled in 1952 at the Davison Chemical Corporation in western Polk County, penetrated about 50 feet of rather uniform greenish-gray dolomitic sandy clay (fig. 8). This unit is tentatively placed at the base of the Tampa; in the Davison wells it rests in sharp contact upon pure white limestone containing fragments of the Oligocene echinoid, Cassidulus gouldii (Bouve). The wells in which the unit was noted roughly delimit an area with corners near Mulberry, Lakeland, Winterhaven, and Fort Meade.

A limestone breccia which appears to be characterisitc of the Tampa limestone in some areas is developed in several exposures near Tampa (locs. 1, 19, 20, 25), and is present, though poorly developed, at many other exposures. Fragments of relatively pure, white, fine-grained limestone from a few millimeters to 10 centimeters in diameter are cememted in a matrix of light gray to light tan carbonate containing abundant fine-grained quartz sand. Most of the fragments are angular, although a few are rounded. Cooke (1943, p. 87), and Stevenson and Veatch (1915, p. 88) noted a similar structure in Tampa limestone of southern Georgia.

At least two methods of developing this structure may be considered. Much of the Tampa limestone, which is relatively soft when wet, becomes quite hard when dried by exposure to the air. Smooth vertical grooves made by the teeth of a power shovel when the limestone was wet and soft are plainly preserved in one exposure (loc. 20) of dry hard limestone. Alternate wetting and drying of the limestone due to fluctuations of the water table could produce a network of cracks into which sand grains could work down from the surficial cover. A prolonged rise of the water table might then cause the cracks to be sealed by precipitation of secondary carbonate. Several observations support this theory. First, most of the fragments are angular; only a few show any rounding. Some of the fragments "fit together" as if they have been separated only a few millimeters. There is a tendency in some exposures for the fragments to decrease in size upward in the outcrop, and for the "fractures" to become tighter downward.

It is also possible that the fragmental structure was formed by breaking up of limestone along a beach in early Miocene time, the resulting fragments being immediately buried by beach sands and recemented by carbonate without much reworking. The shallow marine and fresh-water environment of the Tampa, the presence of a few fragments which are well-rounded, a possibility that most of the occurrences of this feature are near the same stratigraphic level, and the fact that in some places the fragmentation does not extend to the upper surface of the limestone, support the latter theory.

Chert similar to that developed locally on the Suwannee limestone is found on or near the top of the Tampa, but well logs indicate (Heath and Smith, 1954, p. 13) that thin seams of chert are also present throughout the formation. Some of this chert within limestone may be syngenetic; some or all of it may have developed during periods of local intraformational weathering.

A variety of textures may be seen in thin-sections of the Tampa limestone. The rock is dominantly microcrystalline but may be largely organic. Locally it shows much alteration.

The chief constituent, calcite, is microcrystalline, uniform-grained, and usually cloudy in appearance due to inclusion of minute clay particles. Very fine-grained subrounded to angular clear quartz sand is rather irregularly distributed through the rock. Detrital particles of limestone and clay up to 10 millimeters in diameter are present locally. The smaller grains are commonly casts of foraminifera tests. In Tampa limestone which contains clay and limestone fragments the quartz sand is invariably more abundant and usually coarser in the interstitial carbonate.

Crystalloblastic textures are common in the Tampa limestone. A thin section of a sample from locality 11 showed a microcrystalline limestone cut by veinlets up to a millimeter across containing, in order of deposition, fresh calcite, thin septa of collophane, and microcrystalline and spherulitic quartz. Most of the veinlets seen in thin section seem to be replacements, but a few were apparently open fractures, as they alternately pinch and swell like some metalliferous veins. Some veinlets appear to have been localized along concentrations of microfossils.

Locally, as at localities 2 and 27, the Tampa limestone has been completely silicified. At locality 2 (Ballast Point) the rock is massive chert, containing vugs with chalcedony, quartz crystals, and opal, some of which is dark blue and orange in color. Replacements of fossils by quartz are common. At locality 27 the rock is a silicified sandstone in which the quartz grains are nearly in contact and the cement is microcrystalline and spherulitic quartz. Silicification such as this, in which the quartz sand may be seen, is rare, however. Chert is most common in the purer beds of limestone of the formation, particularly those which may have been deposited in fresh water.

Tampa limestone from locality 73 deserves special mention, because it differs texturally from the majority of other Tampa samples studied. There are three types of carbonate present in this rock: (1) fresh, coarse-grained crystalline carbonate, occuring mostly as fossil replacements and small veinlets; (2) gray, microcrystalline dusky carbonate in the form of detrital rock fragments up to 10 millimeters in diameter, some of which are partially replaced and cemented by (3), a brown, iron-stained microcrystalline carbonate. The quartz sand, which is unusually coarse grained for Tampa limestone, occurs with fossil fragments in the brown carbonate between the rock fragments. These fragments have only a few very fine quartz sand grains. This occurrence of Tampa limestone must be very near the top of the formation; elsewhere in pits in the same area, and at the same level, pieces of limestone, probably Hawthorn, were found. Although the fossils (pl. 5) in the rock described above indicate an early Miocene age, the cementing material, including the coarser quartz sand, may be middle Miocene in age.

In contrast with the Suwannee the Tampa limestone as a whole is relatively impure, and contains considerable clay and sand. There is, however, much pure limestone in the formation. Chemical analyses of 16 samples of relatively fresh Tampa limestone showed a range in calcium carbonate content from 73 to 96 percent. The average composition of these samples is given in table 3.

Table 3.--Average of partial chemical analyses of 16 samples of Tampa limestone from Hillsborough, Polk, and Pinellas Counties, Florida_/

	P_2O_5	CaO	Al_2O_3	Fe_2O_3	MgO
Percent	0.3	47.49	1.2	0.41	0.82

_/ Laboratory nos.: 115933 to 115937, 115939, 115940, 115942, 115944 to 115946, 115948, 115950, 115973, 115988, 115989. Analysts: Ivan Barlow, Harry Levine, Roberta Smith, Wendell Tucker, Maryse Delevaux.

Only three occurrences of Tampa limestone from this area are known to contain over 5 percent MgO, and one of these is from an outcrop (91) which is now exposed to sea water. The other occurrences are in wells in Polk County; one is the Davison well where the principal mineral in the lower part of the Tampa limestone is dolomite. This same zone contained a relatively high percent of MgO (unpublished log in the files of the Florida Geological Survey) in a well at the Peace Valley mine (loc. 82) of the International Minerals and Chemical Corporation. Hopkins (1942, p. 72) reports one sample of Tampa limestone from drill holes in Pasco County on the Gulf Coast that contained over 5 percent MgO.

Phosphate nodules were found in the Tampa limestone, particularly in northern and central Polk County. At two localities (1 and 26) of the Tampa limestone secondary phosphate minerals, wavellite or pseudowavellite, were detected by X-ray in samples which were megascopically non-phosphatic, and were overlain by relatively fresh limestone.

Nineteen samples of clay fractions of the Tampa limestone, both fresh and weathered, were analyzed by X-ray spectrometry. In 11 of these samples illite was detected, and in ten of these it was the only clay mineral present. Montmorillonite was found in eight of the samples, attapulgite (hydrated silicate of aluminum and magnesium) in four, kaolinite in two, and chlorite-vermiculite in one sample. Thus, illite appears to be the predominant clay mineral in the Tampa limestone, but clay minerals of the other groups are also present.

The occurrence of attapulgite in Tampa limestone is previously unreported, although Berman (1953, p. 11) found that it occurs in the Bone Valley formation and the topmost part of the Hawthorn formation. Attapulgite was found in Tampa limestone from localities 1 and 20, at the probable top of the formation in core hole G3, and in the Davison well. Fresh-water plants or gastropods have been recorded from these two localities and core hole G3 (pl. 5 and Mansfield, 1937, p. 20). Attapulgus clays have been reported (Kerr, 1937) from the Hawthorn formation in northern Florida and southern Georgia in beds associated with terrestrial vertebrate remains. X-ray analyses by R. G. Petersen (oral communication), and studies by Berman (1953), show that attapulgite commonly occurs with the dolomite in the uppermost part of the Hawthorn formation which underlies the phosphate deposits in the land-pebble phosphate district.

Heavy minerals are far more abundant in the Tampa than in the Suwannee limestone, but the amount is still very small. About 100 grains plus 100 mesh are usually present in 100 grams of limestone. Pale pink garnet is by far the most abundant heavy mineral, often exceeding 40 percent of the heavy fraction. Staurolite, tourmaline, and opaque minerals, which include considerable black tourmaline and a small amount of collophane, are present in about equal amounts, and each comprises 10 to 15 percent of the heavy fraction. Epidote, kyanite, rutile, sillimanite, sphene, topaz, zircon, and zoisite are also present in amounts from 1 to 10 percent.

Petrographic data obtained from samples of Tampa limestone are summarized graphically in figures 5 through 10. Tampa quartz sand has a narrow range of median diameters; 65 percent of the samples fall in the range between 0.12 and 0.14 millimeters, and the median of all samples is 0.13 millimeters. Sixty-six percent of the Tampa samples have a sorting coefficient between 1.17 and 1.27, and the median of all samples is 1.22. Sixty-four percent of the Tampa samples have a fifth percentile value between 0.19 and 0.25 millimeters, and the median for all samples is 0.22 millimeters.

Localities.--A gazetteer of exposures of the Tampa limestone examined by the authors is given in table 4. Many of these localities are new to the literature. Localities in operating phosphate mines are usually impossible to relocate, as conditions there change daily.

(Text continued on p. 76)

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk, and Sumter Counties, Florida

Locality,[1/] name and number	Access[1/]	General lithology	Thickness (feet)	Remarks
		Hillsborough County		
Six Mile Creek (Orient) 1 NW$\frac{1}{4}$ sec. 14, T. 29 S., R. 19 E.	From St. Hwy. 574 E. of Tampa, turn S. at Orient Road, then E. along N. side of first railroad tracks to end of road at creek.	Ls., white to light tan, sandy, clayey, fragmental in places, moderately fossiliferous.	6.0	Mansfield (1937, p. 20) reports *Celliforma nuda* and 56 species of mollusks. Bed of calcareous Pleistocene shells and silicified Tampa fossils overlies ls. in places.
Ballast Point 2 Sec. 11, T. 30 S., R. 18 E.	Bayshore Blvd., Tampa, in Ballast Point Park on beach.	Chert, varicolored, very fossiliferous.	-	Dall (1915) reports over 300 species of mollusks, inaccessible at high tide.

1/ Most of the geographic and locality names used in these tables can be found on the Army Map Service $7\frac{1}{2}$ minute quadrangles, which cover most of this area. Unmapped areas are shown on county road maps, distributed by the Florida State Road Department, Tallahassee, Fla.

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk, and Sumter Counties, Florida--Continued

		Hillsborough County--Continued		
Rocky Point 3 $NE\frac{1}{4}$ sec. 14, T. 29 S., R. 17 E.	Columbus Drive (Courtney Campbell Causeway), Tampa; about 3 mi. W. of municipal airport terminal turn S. to end of point and outcrop on beach.	Ls., white to light gray, soft, slightly sandy, to very sandy, conglomeratic, abundant thin seams secondary carbonate; top 6 in. recemented in places and contains Pleistocene shells and organic material.	3.5	Most accessible at low tide. Upper 2.0 ft. of outcrop may contain sand of Quaternary age.
Sweetwater Creek 4 $NW\frac{1}{4}$ sec. 1, T. 29 S., R. 17 E.	St. Hwy. 580, S. side of bridge over creek, about 3.5 mi. W. of junction with U.S. Hwy. 92	Ls., light tan, slightly sandy, soft, very fossiliferous.	2.0	Cooke, 1945, p. 126.

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk, and Sumter Counties, Florida--Continued

		Hillsborough County--Continued		
Temple Terrace underpass 6 $NW\frac{1}{4}SW\frac{1}{4}$ sec. 19 T. 28 S., R. 20 E.	U. S. Hwy. 301 about 2.7 mi. N. of junction with U. S. Hwy. 92; road cut.	Sd., clayey to very clayey, and clay, sandy, light gray to gray-green iron-stained; chert and tripoli.	12.0	See figs. 15, and 16. Silicified lower Miocene fossils and *Siderastraea* corals. Chert is probably silicified fresh-water ls., containing *Charophyte* oogonia.
Blackwater Creek 8 $NW\frac{1}{4}$ sec. 18, T. 27 S., R. 22 E.	St. Hwy. 39 about 8.5 mi. N. of Plant City; spoil banks of ditch.	Ls., white, slightly sandy, granular, locally silic.	-	Mansfield (1937, p. 51) and Cooke (1945, p. 127) report Tampa-Suwannee contact here; fossils of both formation present.

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk, and Sumter Counties, Florida--Continued

		Hillsborough County--Continued		
40th St. Bridge 11 $NW\frac{1}{4}$ sec. 33, T. 28 S., R. 19 E.	40th St., NE Tampa at S. end of bridge over Hillsborough R.; small borrow pit, W. side of 40th St.	Ls., white to light brown, slightly sandy to sandy; thin seams silica.	6.5	
Howard Ave. ditch 12	In block between Howard Ave., Columbus Dr., Armenia Ave., and Kathleen St., Tampa.	Ls., lt. tan to white, very clayey, sandy, with patches and lenses of clay, blue-green, sandy.	1.5	Now inaccessible.
Morris Bridge 18 $NE\frac{1}{4}$ sec. 33, T. 27 S., R. 20 E.	Morris Bridge Road, 0.3 mi. NE of Morris Bridge over Hillsborough R., or about 7 mi. N. of junction of Morris Bridge Road and old U. S. Hwy. 301; ditch beside road.	Ls., white, sandy, partly silicified, fossiliferous, and chert, varicolored.	-	Not in place, but probably from drainage ditch.

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk, and Sumter Counties, Florida--Continued

		Hillsborough County--Continued		
King sinkhole 19 NW$\frac{1}{4}$ sec. 18, T. 28 S., R. 20 E.	From intersection of Fowler Ave., and Morris Bridge Rd. NE of Tampa, turn S. for 0.5 mi., turn E. on dirt road for 0.4 mi.; sinkhole 200 ft. N. of road.	Ls., light tan, hard, slightly sandy, fragmental, secondary carbonate fracture filling, sparsely fossiliferous.		
Temple Terrace 20 SW$\frac{1}{4}$ sec. 13, T. 28 S., R. 19 E.	Fowler Ave., NE of Tampa, at 0.3 mi. W. of Hillsborough R. turn S. on dirt road for about 0.5 mi., bank W. of road.	Ls., white to light tan, slightly sandy to sandy, hard, fragmental, secondary carbonate fracture filling; sparse green clay balls, sparsely fossiliferous; overlain by residual chert and clay.	5.0	An additional 3.0 ft. of ls. is exposed in a small sink on E. side of road about 200 yds. E-NE of main outcrop. Silicified coral *Siderastraea silicensis* present.

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk, and Sumter Counties, Florida--Continued

		Hillsborough County--Continued		
Cow House Creek 21 SE$\frac{1}{4}$ sec. 12, T. 28 S., R. 19 E.	Morris Bridge Rd. at bridge over Cow House Creek, 0.03 mi. N. of Fowler Ave.	Chert and silicified ls., gray, white, brown, massive, banded, limy pockets in places.	-	Possibly silicified Suwannee ls.
Lamour pit 24 NE$\frac{1}{4}$ sec. 33, T. 28 S., R. 19 E.	50th St. and E. Sligh(Robles) Ave., NE Tampa; depression, NE corner of sand pit.	Ls., white to light tan, soft, clayey, sandy, overlain by clay, sand, and chert, the latter containing lower Miocene fossils.	5.0	Ls. and lower part of section may be covered by slump; excellent example of weathering; see figure 14.

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk, and Sumter Counties, Florida--Continued

		Hillsborough County--Continued		
Harney railroad cut 25 SW$\frac{1}{4}$ sec. 26, T. 28 S., R. 19 E.	Robles (Sligh) Ave., N. of viaduct over railroad tracks just S. of Harney; railroad cut.	Ls., white to light tan, sandy, with thin seams clay, sandy, blue-green, grading upward into ls., white, hard, very slightly sandy; at top ls., light tan, slightly sandy, fragmental, weathers spheroidally.	8.0	On E. side of cut is red-brown clayey sand, mostly residual from Tampa ls., but the upper 0.5 ft. may be Hawthorn fm.

Table 4.--Exposures of the Tampa limestone in Hillsborough Pasco, Pinellas, Polk and Sumter Counties, Florida--Continued

		Hillsborough County--Continued		
Hillsborough River dam NW$\frac{1}{4}$ sec. 29, T. 28 S., R. 19 E.	Turn N. from E. Hillsborough Ave. (U. S. Hwy. 92) on 30th St. past Tampa waterworks to end of road; outcrop below dam, S. side of river.	Sd., white to gray-green, and limestone, light tan, soft, sandy, clayey.	8.0	See plate 4. Best exposure of Tampa limestone found in west-central Florida, and the only one where originally noncalcareous beds of the formation are well exposed. Usually under water in summer and fall.
Hillsborough River 27 SE$\frac{1}{4}$ sec. 30, T. 28 S., R. 19 E.	About 0.2 mi. N. of Sligh Ave. near end of 18th St., NE Tampa; boulders at edge of Hillsborough R., about 100 yds. N. of concrete bridge over small tributary creek.	Chert, gray, silicified ls., sandy, fossiliferous.	--	Apt to be under water in rainy season.

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk and Sumter Counties, Florida--Continued

		Hillsborough County--Continued		
N. side Hillsborough River dam 28 $S\frac{1}{2}$ sec. 20, T. 28 S., R. 19 E.	E. Waters Ave. in NE Tampa, about 1.3 mi. E. of Nebraska Ave. turn S. on dirt road to dam.	Ls., white, sandy, fragmental, fossiliferous, locally silicified.	2.0	Ls. exposed here is similar to upper units at loc. 26 across river.
Stinky Creek 29 $E\frac{1}{2}$ sec. 26, T. 28 S., R. 18 E.	North Blvd., Tampa, 0.55 mi. N. of Sligh Ave., or 0.45 mi. S. of Waters Ave.; in small creek bottom E. and W. of bridge.	Ls., light gray to light yellow, sandy, hard, abundant seams secondary carbonate, fossiliferous, "fresco" weathering.	3.5	

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk and Sumter Counties, Florida--Continued

Hillsborough County--Continued

Cone sandpit 31 $NW\frac{1}{4}$ sec. 3, T. 29 S., R. 19 E.	At 52nd St., NE of Tampa, turn N. from Harney Ave. (Ft. King Hwy.) at Orange Hill cemetery; large sandpit; ls. exposed in deepest part of W. pit.	Ls., white, slightly sandy, hard, silicified, fossiliferous.	2.0	Well-preserved silicified shells weathered out of ls. could be collected here in 1953.
MacDill ditch 32 $SW\frac{1}{4}$ sec. 26, T. 30 S., R. 18 E.	In SE part of MacDill U. S. Air Force Base, about 0.7 mi. N. and 0.3 mi. E. of Quarantine station at Gadsden Point; spoil banks of canal at W. end of golf course.	Ls., white, slightly sandy, very fossiliferous.		Most southerly exposure of Tampa ls. known.
Beach Park 33 $NE\frac{1}{4}$ sec. 29, T. 29 S., R. 18 E.	Turn E. from West Shore Blvd. at Woodmere Ave. in Beach Park; in ditch between divided street.	Ls., white to tan, very slightly sandy, soft, fossiliferous, abundant secondary carbonate.	-	Probably in place, but may be contaminated by fill.

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk and Sumter Counties, Florida--Continued

	Hillsborough County--Continued		
Gray Road 34 $E\frac{1}{2}$ sec. 18, T. 29 S., R. 18 E.	Across from 4821 Gray Road, about 0.2 mi. W. of West Shore Blvd., Tampa.	Ls., light tan, very slightly sandy, very fossiliferous, cobbles overlain by irregularly fossiliferous gray chert.	-
Eureka Springs 43 $NW\frac{1}{4}SE\frac{1}{4}$ sec. 31, T. 28 S., R. 20 E.	U.S. Hwy. 92, turn N. at 0.6 mi. W. of U.S. 92 - Faulkenburg Road intersection, or 0.8 mi. E. of junction of U.S. Hwys. 301 and 92; scattered boulders around fish ponds.	Ls., white, slightly sandy, fragmental, sparse microfossils.	-

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk and Sumter Counties, Florida--Continued

		Hillsborough County--Continued		
Tampa Waterworks 49 $E\frac{1}{2}$ sec. 29, T. 28 S., R. 19 E.	30th St., NE Tampa, about 1.3 mi. N. of Hillsborough Ave. (U.S. Hwy. 92); construction excavation.	At base: Ls., sandy, clayey, soft, rotten, white to light tan with lenses and pockets of sd., white, fine-grained, contacts irregular, overlain by sd. and sandy clay, white to green, sparsely fossiliferous, residual from ls.	8.5	No longer accessible.

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk, and Sumter Counties, Florida--Continued

		Pasco County		
Cabbage Swamp 54 NE$\frac{1}{4}$ sec. 22, T. 26 S., R. 19 E.	Denham-Wesley Chapel Rd. (St. Hwy. 209) about 4.8 mi. SW of Wesley Chapel; shallow borrow pit, W. side of road.	Ls., white to gray, impure, hard, sandy, abundant bands brown carbonate; cobbles	-	Probably Tampa ls., apt to be covered in rainy season; coral _Siderastraea hillsboroensis_ in surface rubble.
St. Leo borrow pit 64 SE$\frac{1}{4}$ sec. 6, T. 25 S., R. 21 E.	St. Hwy. 52, about 1.0 mi. E. of St. Leo or about 2.5 mi. SW of Dade City; shallow borrow pit, S. side of road.	Sd., white to brown, fine-grained, hard, indurated, aluminum phosphate cement; abundant silicified corals; rubble on surface.	-	Similar in appearance to some hardrock phosphate.

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk and Sumter Counties, Florida--Continued

		Pasco County--Continued		
Hudson 65 $SW\frac{1}{4}$ sec. 28, T. 24 S., R. 16 E.	Hudson, W. from Post Office for about 0.3 mi. to Gulf; spoil banks along canals in new housing area.	Ls., white to light gray, pure, hard, very fine-grained and ls., white, granular, foraminiferal, porous, very slightly sandy.	-	Both Tampa and Suwannee limestone probably present.
St. Joseph 69 $S\frac{1}{2}$ sec. 21, T. 24 S., R. 20 E.	St. Hwy. 578 about 1.7 mi. W. of St. Joseph; stock watering pits in pasture about 0.2 mi. N. of road.	Silicified pelecypods in sandy, clayey.	-	

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk and Sumter Counties, Florida--Continued

		Polk County		
Tenoroc mine Coronet Phosphate Co. 73 A, B, C Sec. 35, T. 27 S., R. 24 E.	Combee Rd. E. of Lakeland; at about 3.8 mi. N. of U.S. Hwy. 92 turn E. on Ritter Rd. to Coronet mine washer, turn S.-SW across tracks to pits; waste piles in bottom of pit about 0.7 mi. SW of washer.	Ls., light tan to brown, hard, very slightly sandy, to very sandy, sparse brown phosphate nodules; contains fragments of rounded and angular, pure, very fine-grained, non-phosphatic nonfossiliferous ls., and abundant brown carbonate, locally very fossiliferous.	-	Hawthorn fm. probably also present here.

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk and Sumter Counties, Florida--Continued

		Pinellas County		
Belleair Bluffs 89 NE$\frac{1}{2}$ sec. 29, T. 29 S., R. 15 E.	About 0.7 mi. S. of Belleview Biltmore Hotel in Belleair, S. of Clearwater, at base of bluff overlooking Gulf.	At base: clay, mottled gray-blue, very slightly calcareous, grading upward into ls., light tan, clayey, sandy, conglomeratic containing abundant pebbles and subangular fragments of clay like that below; grades up into clay, violet-blue, sandy, very slightly calcareous, containing fragments of leached ls.; unfossiliferous.	6.0	Most accessible at low tide.

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk and Sumter Counties, Florida--Continued

		Pinellas County-Continued		
Phillippe Park 90 $NW\frac{1}{4}$ sec. 35, T. 28 S., R. 16 E.	About 1.5 mi. N. of Safety Harbor in bank on shore of Tampa Bay, at foot of large Indian mound in Phillippe Park.	Ls., white, cly., chalky, very slightly sandy, possibly dolomitic.	0.5	
Bayview 91 $SW\frac{1}{4}$ sec. 16, T. 29 S., R. 16 E.	Gulf to Bay Blvd. E. of Clearwater, turn S. to bay about 0.5 mi. W. of junction with Safety Harbor road; outcrop on beach.	Ls., light gray, brittle, hard, sandy, dolomitic, sparsely fossiliferous.	-	Accessible only at low tide. Rock contains, in addition to lower Miocene fossils, <u>Carolia</u>, <u>Periploma</u>, and a large <u>Gardita</u>, not previously reported from Tampa ls.; may be near or at contact with Hawthorn fm.

Table 4.--Exposures of Tampa limestone in Hillsborough, Pasco, Pinellas, Polk and Sumter Counties, Florida--Continued

		Pinellas County--Continued		
Crystal Beach 94 $NE\frac{1}{4}$ sec. 3, T. 28 S., R. 15 E.	U.S. Hwy. 19, about 1.0 mi. N. of Palm Harbor turn W. at Crystal Beach entrance; turn S. 2 blocks after crossing railroad tracks, and continue to end of road at beach.	Ls., gray to white, soft, slightly sandy, conglomeratic, fossiliferous, and chert, tripoli, gray, fossiliferous.	-	Most accessible at low tide.
Anclote 95 $E\frac{1}{2}$ sec. 1, T. 27 S., R. 15 E.	St. Hwy. 15 (595) about C.5 mi. N. of Anclote R. at Tarpon Springs; about 200 feet NE of railroad crossing in shallow ditch W. side of road.	Ls., light tan, very slightly sandy, conglomeratic, fossiliferous.	-	Cooke, 1945, p. 131-132.

Table 4.--Exposures of the Tampa limestone in Hillsborough, Pasco, Pinellas, Polk and Sumter Counties, Florida--Continued

		Sumter County		
Linden 100 SW$\frac{1}{4}$ sec. 16, T. 22 S., R. 23 E.	St. Hwy. 50, 1 mi. E. of Linden; shallow road cut.	Ls., white, slightly sandy, fossiliferous.	0.5	The overlying phosphatic sandy clay may be middle Miocene.

Hawthorn formation

Previous work.--Dall (1892, p. 107) named the Hawthorn formation from exposures in Alachua County, Fla. Matson and Clapp (1909, p. 69-74) included in the Hawthorn part of the limestone now called Suwannee, and designated beds of phosphatic limestone, sand, and clay in central Florida as the Hawthorn formation. The name Hawthorn was abandoned by Vaughan and Cooke (1914, p. 251) who showed that the Hawthorn is nearly equivalent to the Alum Bluff formation as defined by Matson and Clapp (1909, p. 91). Gardner (1926, p. 2) raised the Alum Bluff formation to the rank of a group, divided it (ascending) into the Chipola formation, Oak Grove sand, and Shoal River formation, and expressed the opinion that the abandoned Hawthorn formation was equivalent to the Chipola formation of the Alum Bluff group. Cooke and Mossom (1929, p. 115, 116, 133-135) revived the name Hawthorn for beds in Florida originally defined by Matson and Clapp (1909, p. 91), and also concluded that the Hawthorn is equivalent to the Chipola formation. They extended the Hawthorn formation into the land-pebble phosphate district, but excluded the Oligocene beds which Matson and Clapp (1909, p. 69-74) placed in the Hawthorn formation and called Tampa limestone. Cooke (1945, p. 35, 137) dropped the term Oak Grove formation from the Alum Bluff group and extended the Shoal River formation upward to include basal faunal zones (Yoldia and Arca) previously included in the Choctawhatchee formation. In 1953, however, Puri (1953,

p. 21-22) proposed the Alum Bluff and Choctawhatchee as stages, with Oak Grove, Shoal River, Chipola, and Hawthorn as facies of the Alum Bluff stage. He excluded from the Alum Bluff stage the Yoldia and Arca faunizones.

Age and extent.--Although the exact age of the Hawthorn limestone has not been clearly stated in the literature, in the opinion of F. S. MacNeil (oral communication), Vernon (1951, p. 188) and others, it is middle Miocene. In this report the Hawthorn formation includes all beds in peninsular Florida of middle Miocene age above the Tampa limestone and below deposits of late Miocene age. There are numerous areas in northern peninsular Florida where unfossiliferous clayey phosphatic sands have been placed in the formation on the basis of their non-too-distinctive lithology.

The Hawthorn is the most extensive upper Tertiary formation in Florida, and is missing only from parts of the Ocala uplift in northwestern peninsular Florida. The formation also extends across southeastern Georgia into southern South Carolina. In Florida it lies near the surface in a long, curving, discontinuous belt which begins in the panhandle of Florida at about longitude 85° W., extends eastward along the Georgia border, and thence south-southeastward into central peninsular Florida. In the area of this report the formation is exposed in northeastern Pasco County, in the phosphate district of Hillsborough, Polk, Hardee, and Manatee Counties, and in western Sarasota County. In southern Hillsborough and Polk Counties the formation is about 100 feet thick, but it thickens southward to about 300 feet near Sarasota. Northward from the land-pebble phosphate district it thins rapidly, is almost completely eroded from the Withlacoochee and Hillsborough River Valleys, and then reappears in the highlands of northeastern Pasco County. There it is not over 100 feet thick and may average only about 25 feet thick.

General lithology.--Four lithologic types (fig. 11) of the Hawthorn formation were recognized during this work. Their relations are obscured by weathering and scarcity of good outcrops and fossils. The four units are (1) Alafia limestone--limestone, dolomitic, and dolomite, calcitic, yellow to white, soft, irregularly sandy and clayey, massive, containing a few clay lenses, sparse phosphate nodules, and a fauna like that of the Oak Grove and Chipola formations; (2) Lakeland phosphorite--sand and clay, locally calcareous, gray-green to tan, containing abundant phosphate nodules, but generally unfossiliferous; (3) Kathleen sand--sand and clay, gray to red and orange-brown, often mottled, containing traces of phosphate nodules, locally abundant secondary phosphates, and rare lower middle Miocene fossils; (4) Sarasota limestone--limestone, dolomitic, and dolomite, calcitic, gray to white, slightly sandy and clayey, soft, massive, containing sparse phosphate nodules of sand-size, and a fauna similar to the Shoal River formation.

In this report the preceding names are used informally for convenience in referring to these units which owe their distinctive lithology, in part at least, to weathering. The names are taken from areas or places where the unit is best exposed or where it

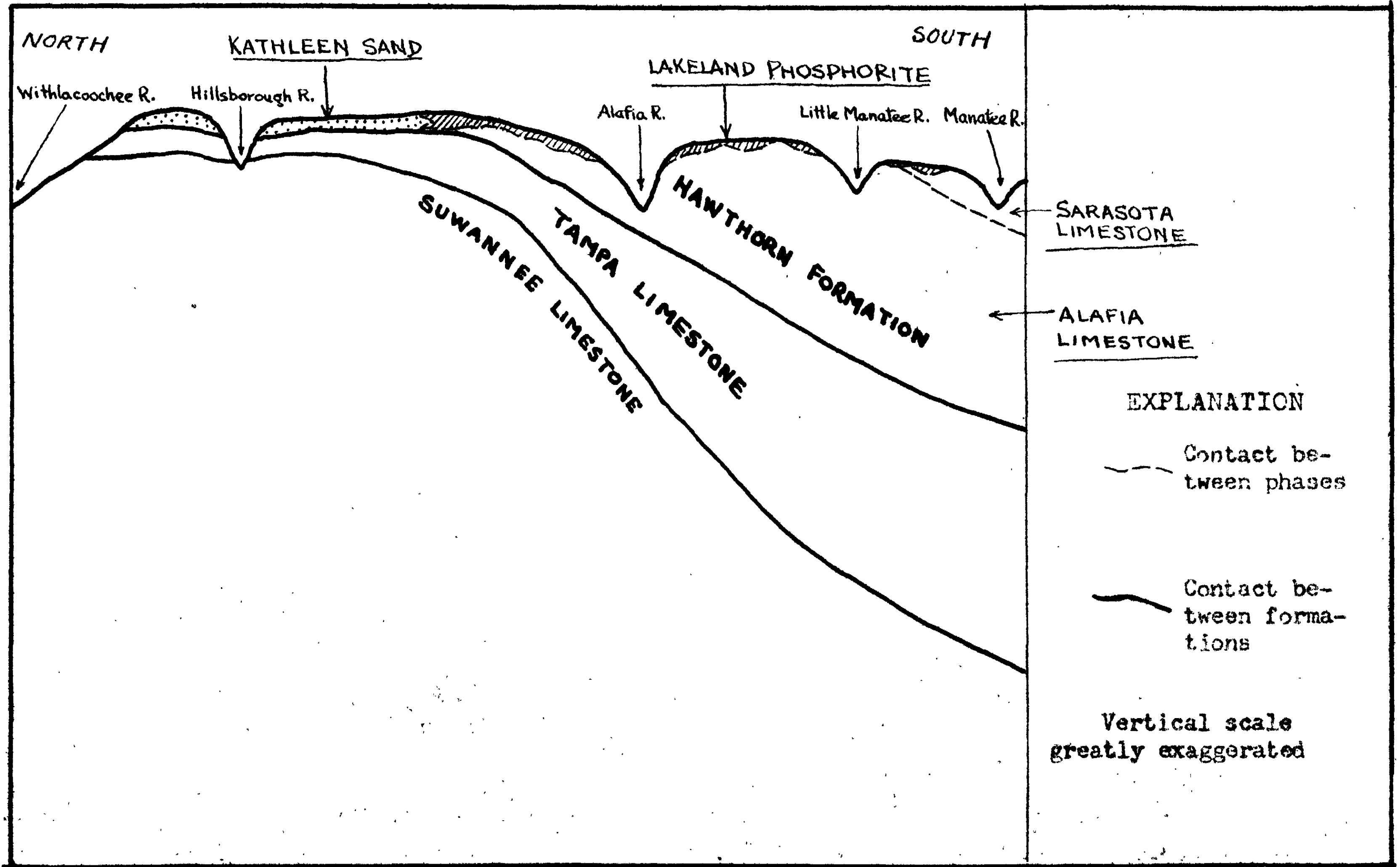


Figure 11. DIAGRAM SHOWING THE RELATION BETWEEN THE FOUR PHASES OF THE HAWTHORN FORMATION BETWEEN THE WITHLACOOCHEE AND MANATEE RIVERS IN WEST-CENTRAL FLORIDA

contains fossils. The first three units lie within the mapped area (pl. 1), but Lakeland phosphorite and Kathleen sand are mapped together and shown only where they do not overlie Alafia limestone. The Sarasota limestone occurs south of the mapped area in Hardee and Sarasota Counties.

Stratigraphic relations.--In the panhandle of Florida the Hawthorn is replaced by its equivalents in the Alum Bluff group: the Chipola formation, Oak Grove sand, and Shoal River formation. According to MacNeil (oral communication) the fauna of the Hawthorn formation (Alafia limestone) which underlies the phosphate deposits of Polk and Hillsborough Counties is most like the fauna of the Oak Grove, but to the south of the phosphate district the limestone (Sarasota limestone) exposed is younger and faunally like, but not typical of, the Shoal River formation.

The Hawthorn formation is unconformable upon the Tampa limestone. It overlaps the Tampa and rests in places upon the Suwannee and Ocala limestone although in some areas sands and clays of the Tampa limestone intervene between the Hawthorn and pre-Miocene formations. The Hawthorn is overlain unconformably by the upper Miocene, Pliocene, and Quaternary beds. Of these beds the Bone Valley formation is the most important economically in the land-pebble phosphate district.

The Lakeland phosphorite lies upon (fig. 11), and is a result of weathering of the Alafia (and Sarasota) limestone, but the relation between the Alafia limestone and Kathleen sand lithologies is not clear. The Kathleen may be a weathered equivalent of part or all of the Alafia, or it may be an originally clayey and sandy facies of the formation. In addition, no exposures are known which show the relation between the Kathleen and the Lakeland phosphorite, but it is inferred that the Kathleen passes southward into the Lakeland phosphorite by increase in clay and phosphate content.

Fauna.--Locally limestone of the Hawthorn formation is quite fossiliferous, but the fossils are usually poorly preserved as a result of leaching and dolomitization. Mollusks, particularly large oysters and pectens, are conspicuous in the fauna of the formation. The oyster, *Ostrea normalis* Dall, is apparently diagnostic, but similar oysters occur in the Tampa limestone. The large pectens, *Chlamys acanikos* Gardner and *Chlamys sayanus* Dall are characteristic. Other common molluscan genera include *Arca*, *Chione*, *Cardium*, and *Venus*. Foraminifera are rare in exposures of the formation. Cushman (1920) reported a few species from the Alum Bluff group. A few silicified fossils are found in weathered portions of the formation. As discussed under Tampa fauna, *Siderastraea* corals are the most common of these, but silicified oysters are also locally abundant.

Sharks teeth are particularly common in the Hawthorn, and other vertebrate fossils have been found in it in northern Florida. (See p. 49.) A list of Hawthorn fossils identified for this report is given in plate 6.

Petrographic details.--Hawthorn limestone is microcrystalline in texture; in thin-section it is a highly birefringent mass composed of uniform anhedral calcite crystals and evenly dispersed dolomite rhombs. Irregularly distributed through this matrix are variable amounts of phosphate nodules and quartz grains. Most of the dolomite crystals have round nuclei and appear to have grown at the expense of the calcite. In some specimens there are irregular areas of more sandy slightly coarser-grained carbonate which probably fill cavities left by removal of fossil remains.

Phosphate nodules are more widely distributed than in the Tampa limestone, but seldom constitute more than 15 percent of the rock. Phosphate is most abundant in the sandy clay beds, and much of it, together with quartz sand, occupies small irregular pockets in the rock. The phosphate nodules may be almost any color and size, but tan, gray, and brown sand to pebble-size nodules are most common. They are typically oval in cross-section, but some are flat. The exterior of the nodules has a soft greasy lustre. They have been identified (Altschuler, Cisney, and Barlow, 1952) as carbonate fluorapatite. Another type of nodule, common in places, ranges from pebble to boulder size, and is apt to be pitted, porous, and irregular in shape. These are apparently pieces of phosphatized limestone, as many have only a thin coating of collophane over an interior of partially phosphatized limestone which may contain quartz sand, fossils, and smaller phosphate nodules. This type of nodule occurs mostly at the top of, or just above, the limestone in the phosphate mines, and in many places may be a basal conglomerate of the overlying Bone Valley formation.

The typical collophane nodule as seen under the microscope is isotropic, oval in outline, 1 to 5 millimeters in diameter, and has a rather homogeneous yellow-brown color. The phosphatized limestone type of nodule is usually weakly anisotropic. None of the phosphate nodules seen in thin section exhibited any concentric structure. The carbonate surrounding the nodules is apparently undisturbed, except in rare cases where a thin zone of later carbonate peripherally replaces the nodules. Table 5 gives a summary of chemical analyses of limestone of the Hawthorn formation.

Table 5.--Average of partial chemical analyses of 26 samples of Hawthorn limestone from Hillsborough, Polk, Manatee, and Sarasota Counties, Florida._/

	P_2O_5	CaO	Al_2O_3	Fe_2O_3	MgO
Percent	2.0	30.35	0.9	0.49	15.28

_/ Laboratory nos.: 115930 to 115932, 115951 to 115956, 115974 to 115980, 115982 to 115986, 115990 to 115994.
Analysts: Ivan Barlow, Harry Levine, Roberta Smith, Wendell Tucker, Maryse Delevaux.

From calculation the average ratio of $CaCO_3$ to $MgCO_3$ in these samples is about 1.7 to 1. Some of the magnesium is in clay minerals. Montmorillonite is present (Berman, 1953, p. 13), in the overlying Bone Valley formation. Berman (1953, p. 13, 14) found that attapulgite partly supplants montmorillonite in the top of what he called the Hawthorn formation. He found up to 35 percent attapulgite in the samples of limestone of the Hawthorn formation, and up to 73 percent in the base of what he called the Bone Valley formation. Several samples of the Hawthorn formation from phosphate mines, and one sample of Hawthorn formation from 160 to 170 feet in the Davison well were X-rayed by R. G. Petersen. The well sample contained montmorillonite and illite; all the mine samples contained attapulgite associated with dolomite.

Every sample of limestone of the Hawthorn formation chemically analyzed contained at least 9 percent MgO, but all the samples came from within a few feet of the upper surface of the limestone, so that these analyses are not representative of the formation. Hopkins (1942) in a study of dolomitic limestones of Florida found that the Hawthorn formation in Manatee and Sarasota Counties, where it is mined for dolomite, has an erratic MgO content. His samples were taken from drill holes which did not penetrate more than 30 or 40 feet into the formation. The MgO content ranged from 1 to 20 percent.

The P_2O_5 content of the limestone is low in all samples and does not exceed 9 percent. The uranium content of raw samples of Hawthorn limestone was found to be negligible.

Alteration of limestone of the Hawthorn formation consists of dolomitization, rare incipient replacement of carbonate by microcrystalline spherulitic quartz, and formation of residues of phosphatic clayey sand by weathering.

The following section illustrates in detail the Alafia limestone lithology of the Hawthorn. This exposure is near the base of the formation.

Locality 10, W. ½ sec. 21, T. 30 S., R. 20 E., below bridge in ravine about 1 mile southeast of Riverview, Hillsborough County, Fla.

Sample no.	Lithology	Approx. thickness feet-inches
	Quaternary	
A7	Sand, gray to tan, slightly clayey, containing sparse organic material.	3-0
	Middle Miocene, Hawthorn formation	
A6	Limestone, white to light tan, sparsely to slightly sandy and clayey, soft, dolomitic, containing rounded pebbles of clay, white to very light gray, very calcareous, and a trace of phosphate nodules, tan, brown, black, mostly sand-size; upper contact sharp, undulating. . .	0-3
A5	Limestone, white to light tan, very sandy (fine- to medium-grained) sparsely clayey, hard, dolomitic, containing sparse rounded pebbles of limestone, white, pure, and a trace of phosphate nodules, sand-size	0-3
A4	Limestone, white to light tan, very sandy (fine- to medium-grained), sparsely clayey, dolomitic, containing abundant patches of nearly pure carbonate, and a trace of phosphate nodules, brown, black, amber, sand-size.	0-3

A3 Limestone, white to light tan, very slightly to very sandy (fine- to very fine-grained), slightly clayey, dolomitic, containing abundant patches and fragments of clay, gray, calcareous, with phosphate nodules 0-6

A2 Limestone, white to light tan, sandy (fine- to medium-grained), slightly clayey, hard, dolomitic, containing abundant patches of carbonate, very sandy, and carbonate, pure, and sparse phosphate nodules, black, brown, gray, sand- to pebble-size. 0-6

A1 Limestone, white to light tan, sandy (fine- to medium-grained), slightly clayey, locally porous, dolomitic, containing sparse small fragments of limestone, white, pure, and sparse phosphate nodules, black, brown, sand- to pebble-size; Potamides, n. sp. aff. P. hillsboroensis Heilprin, Chlamys sp. cf. C. sayanus Dall, Cardium sp. 1-6

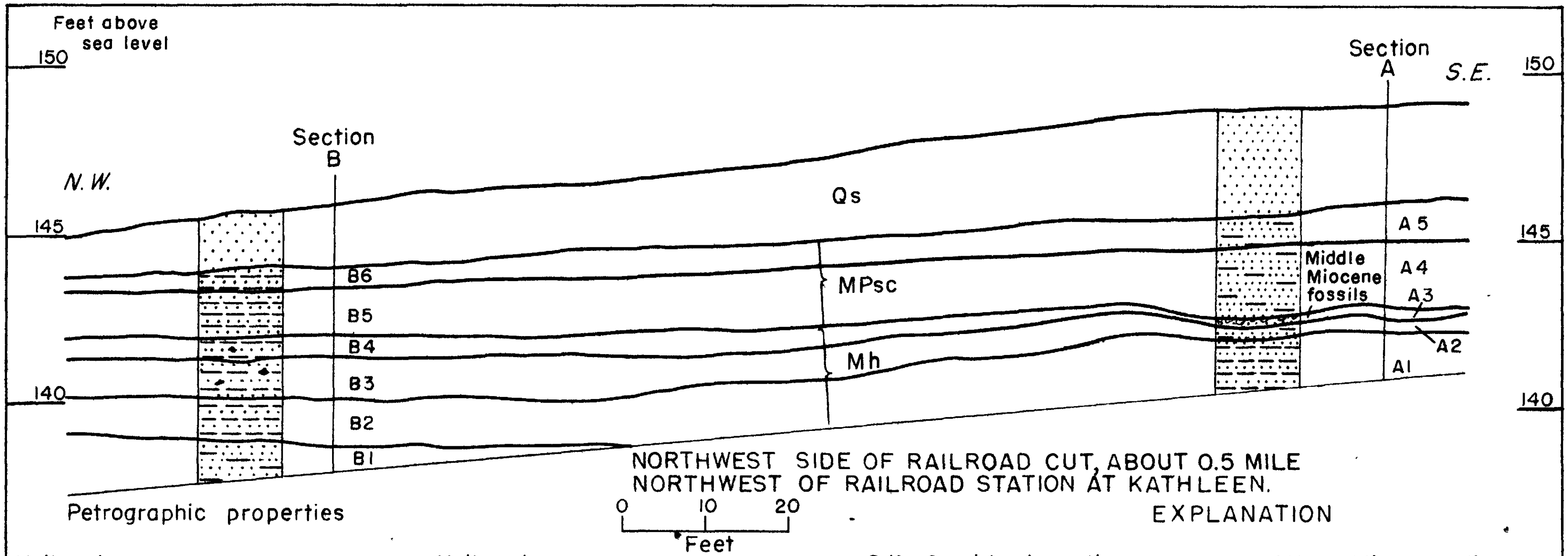
Base of exposure Total 6 feet, 3 ins.

Limestone of the Hawthorn formation is also described in the log of core hole G 16 (Appendix), and in the gazetteer of Hawthorn localities. Exposures of the Sarasota limestone type are present at localities 98 and 99 and elsewhere in Manatee and Sarasota Counties.

The Kathleen and Lakeland phosphorite phases of the Hawthorn formation generally consist of an alternation of brown to green clay, sand, and sandy clay. Clay predominates in the Lakeland, sand in the Kathleen. Gray-green nearly pure waxy clay beds are present at some localities (figs. 12, 13). Beds pinch out or merge laterally into different lithologies within a few hundred feet. The phosphate is similar to, but locally more abundant than, that in the limestone units. Many of the nodules are leached and soft, however, and in places they have been completely removed, leaving an indurated rock full of small vesicles. Weathering has locally produced a white sandstone cemented by secondary aluminum phosphate minerals. In some areas this process is accompanied by oxidation of the iron in heavy minerals to produce brilliant orange or red-brown iron staining and zones of hardpan.

The Kathleen sand and Lakeland phosphorite units are best exposed around Dade City (locs. 60, 61, 68, and 71) in Pasco County, and in some of the northern phosphate mines such as Sydney (loc. 39), Tenoroc (loc. 73), and Pauway (loc. 75). A section (loc. 83) near Kathleen, typical of the less phosphatic Kathleen unit, is given below and in figure 12.

(Text continued on p. 94)



Petrographic properties

Unit and sample No.	S/C	Md	So	P5
B6	1.1	.12	1.21	.27
B5	1.8	.12	1.18	.24
B4	1.1	.22	1.36	.50
B3	1.9	.23	1.47	.58
B2	0.6	.19	1.30	.40
B1	2.8	.19	1.25	.42

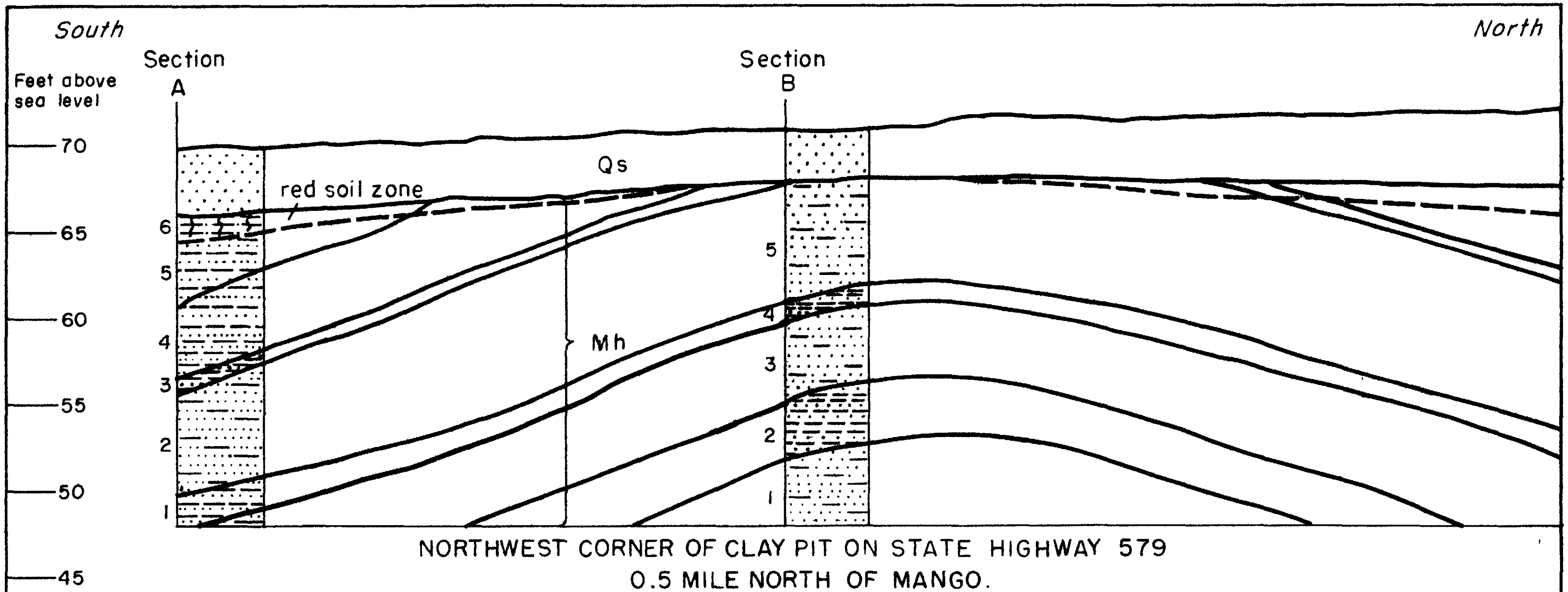
Unit and sample No.	S/C	Md	So	P5
A5	2.1	.15	1.41	.32
A4	1.9	.13	1.24	.29
A3	1.3	.22	1.48	.46
A2	3.4	.24	1.37	.56
A1	0.4	.18	1.35	.47

EXPLANATION

- S/C Sand to clay ratio
- Md Sand median diameter, mm
- So Sand sorting coefficient
- P5 Fifth percentile value, mm
- Qs Quaternary sand
- MPsc Miocene-Pliocene undifferentiated, clayey sand.
- Mh Middle Miocene Hawthorn formation sand and clay.

- Sand
- Clayey sand
- Slightly phosphatic clayey sand
- Slightly sandy clay

FIGURE 12.- DIAGRAMMATIC SKETCH SHOWING STRATIGRAPHIC RELATIONS AND PETROGRAPHIC PROPERTIES AT LOCALITY 83, S.W. 1/4 SEC. 17, T. 27 S., R. 23 E., POLK COUNTY, FLORIDA.



NORTHWEST CORNER OF CLAY PIT ON STATE HIGHWAY 579
0.5 MILE NORTH OF MANGO.

0 10 20
Feet

Petrographic properties

Unit and sample No.	S/C	Md	So	P5
A 6	1.3	.18	1.49	.46
A 5	3.2	.18	1.52	.47
A 4	1.5	.14	1.38	.42
A 3	0.2	.13	1.36	.29
A 2	2.3	.16	1.39	.32
A 1	0.1	.11	1.57	.37

Unit and sample No.	S/C	Md	So	P5
B 5	2.4	.16	1.44	.34
B 4	0.3	.20	1.56	.45
B 3	3.3	.15	1.17	.22
B 2	0.1	.10	1.36	.22
B 1	2.6	.14	1.25	.29

EXPLANATION

S/C Sand to clay ratio
Md Sand median diameter, mm.
So Sand sorting coefficient
P5 Fifth percentile value, mm.

Qs Quaternary sand
Mh Middle Miocene Hawthorn formation, sand and clay.

Sand
Red soil zone
Clayey sand
Slightly sandy clay

FIGURE 13.–DIAGRAMMATIC SKETCH SHOWING STRATIGRAPHIC RELATIONS AND PETROGRAPHIC PROPERTIES AT LOCALITY 13, N.W. 1/4 S.W. 1/4 Sec. 3, T. 29 S., R. 20 E., HILLSBOROUGH COUNTY, FLORIDA.

Sample no.	Lithology	Approx. Thickness (feet-inches)
	Quaternary	
B7	Sand, tan, loose	1-10
	Undifferentiated Pliocene-Miocene	
B6	Sand, gray, orange-brown iron staining, fine-grained, containing a trace of muscovite	0-6
B5	Sand, light gray, mottled yellow-orange iron staining, fine-grained, clayey to slightly clayey, containing a trace of muscovite	1-3
	Middle Miocene, Hawthorn formation	
B4	Sand, light tan to light gray, local orange iron staining, fine- to medium-grained, locally vesicular, containing a few very thin lenses of clay, dark gray, a trace of phosphate nodules and soft white phosphatic (?) patches, and fossils of white, soft, tripoli: Ostrea normalis Dall, Chlamys sayanus Dall; upper and lower contacts undulating	0-6

Locality 83--Continued

Middle Miocene, Hawthorn formation

B3 Sand, light gray to light tan, yellow-brown iron stain at top, fine- to coarse-grained, slightly clayey; upper contact sharp 1-4

B2 Clay, gray-green, dark red-brown iron stain at top, slightly sandy (fine- to medium-grained), waxy, blocky fracture, containing sparse small lenses of sand, gray, slightly clayey, and trace of sandstone fragments cemented by aluminum phosphate (?); upper contact undulating 1-6

B1 Sand, light gray-green to tan, slightly iron-stained at top, fine- to medium-grained; upper contact sharp 1-0

Base of exposure. Total 7 feet, 11 ins.

The following section, typical of the Lakeland phosphorite lithology, was exposed in February 1954.

Locality 75, Pauway mine, American Agricultural Chemicals Corp., section near center of sec. 32, T. 28 S., R. 24 E., Polk County.

Sample no.	Lithology	Approx. thickness (feet-inches)
	Quaternary	
C8	Sand, tan, loose	4-0
	Undifferentiated Pliocene-Miocene	
C7	(Bone Valley formation (?)	
	Sand, light gray to gray, mottled red-brown at top, fine- to medium-grained, clayey to slightly clayey, containing a trace of phosphate nodules, sand-size; upper contact sharp	3-6
C6	Clay, light gray, very sandy (fine- to coarse-grained), containing a trace to abundant phosphate nodules, white, soft, sand- to granule-size	2-0
C5	Clay, light gray-green with yellow iron staining, sandy (medium- to fine-grained), containing very thin lenses of sand with a trace of phosphate nodules; upper contact sharp	1-0

Locality 75--Continued

C4 Sand, light gray-green, fine- to medium-grained, clayey, interlensing with clay, sandy, containing patches of clay, white, soft, phosphatic (?) 1-6

C3 Clay, light blue-green, brown iron stain at top, sandy (fine- to medium-grained), waxy, containing a trace of phosphate nodules, white, gray 1-6

Middle Miocene, Hawthorn formation (Lakeland phosphorite)

C2 Sand, light gray-green, locally iron stained, medium- to fine-grained, slightly clayey, containing phosphate nodules, white, gray, tan, sand- to granule-size and, at top, patches of clay, white, soft, phosphatic; upper contact sharp, undulating 2-0

C1 Clay, white, tan to light gray, slightly sandy, locally calcareous at base, containing abundant phosphate nodules, white, gray, sand- to pebble-size 11-0

Total: 26 feet, 6 inches

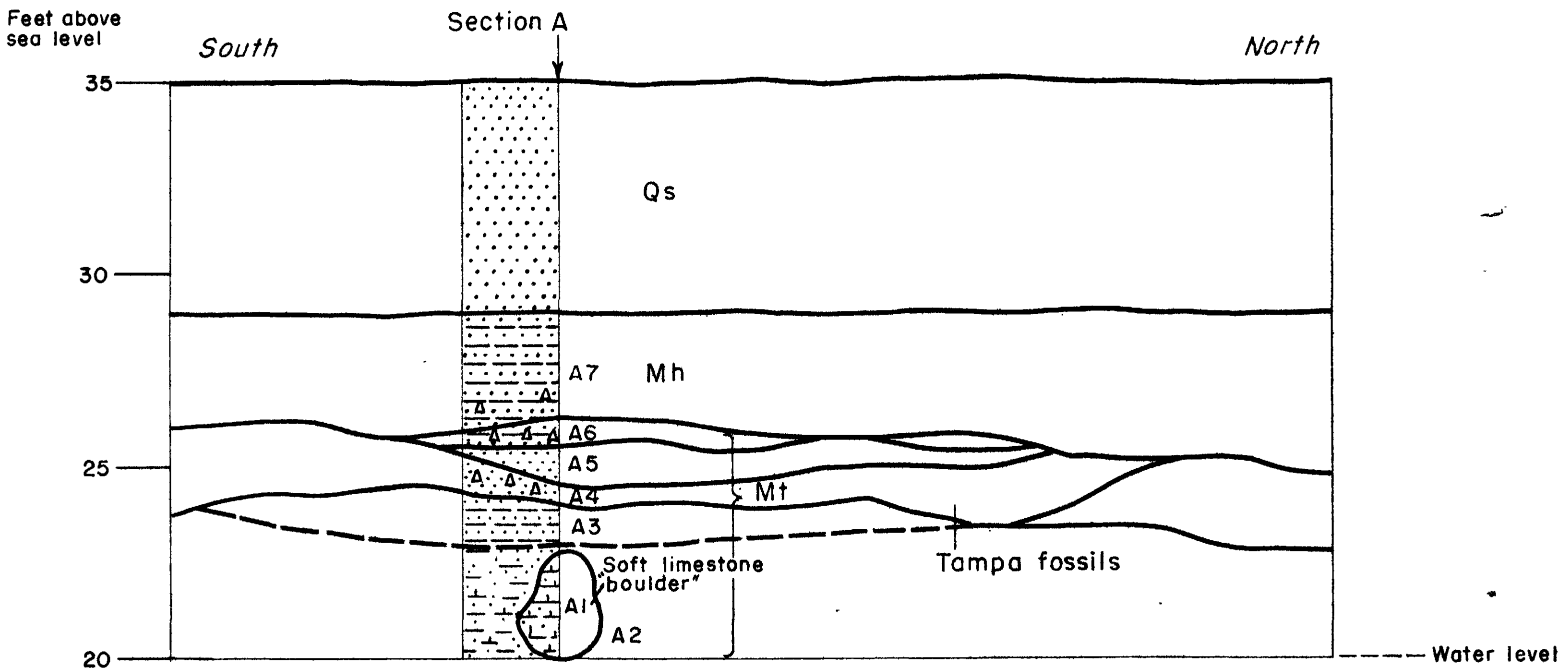
Base of exposure.

Other exposures where sand and clay beds assigned to the Hawthorn formation are exposed are shown in figures 13, 14 15, and 16.

Lakeland phosphorite and Kathleen sand lithology was also encountered in core holes in Hillsborough County (fig. 17 and Appendix).

Quartz sand in the Hawthorn formation is mostly fine grained but ranges from very fine- to medium-grained with a trace of coarse grains. It is irregularly distributed, clear and angular to subround, except for some of the larger grains which are frosted and well rounded. Petrographic data for the formation are summarized in figures 5 through 10. Limestone of the formation averages about 20 percent insoluble material. The formation, in samples analyzed, has a range of sand median diameter from 0.09 to 0.28 mm and the median for all samples is 0.175 mm. The sand is well sorted but the sorting coefficient shows a range from 1.10 to 1.63. Fifth percentile (P5) values are consistently high in Hawthorn sand, even when the median diameter is low. P5 ranges from 0.20 to 0.58 and the median is 0.355 mm. The properties of the clay and sand units of the Hawthorn are similar to those of the limestone, but in the non-calcareous beds the sand is slightly coarser and not quite as well sorted.

Heavy minerals are present only in trace amounts in Hawthorn limestone but are concentrated in the Kathleen and Lakeland phosphorite by weathering. In general the percentages of garnet and staurolite in the heavy fraction are about equal, each comprising about 25 percent. Some heavy mineral fractions contained as much as 50 percent garnet. The percentage of staurolite remains relatively constant, however, and most samples contain more than twice



SECTION LOCATED IN NORTHEAST CORNER OF SAND PIT, VIEWED FACING WEST

0 — 5 Feet

Petrographic properties

Unit and sample no.	S/C	Md	So	P5
A7	nd	.18	1.39	.35
A6	nd	.13	1.29	.30
A5	nd	.16	1.35	.37
A4	nd	(chert)		—
A3	1.3	.16	1.32	.29
A2	nd	.14	1.24	.24
1/ A1	1.0	.12	1.23	.19

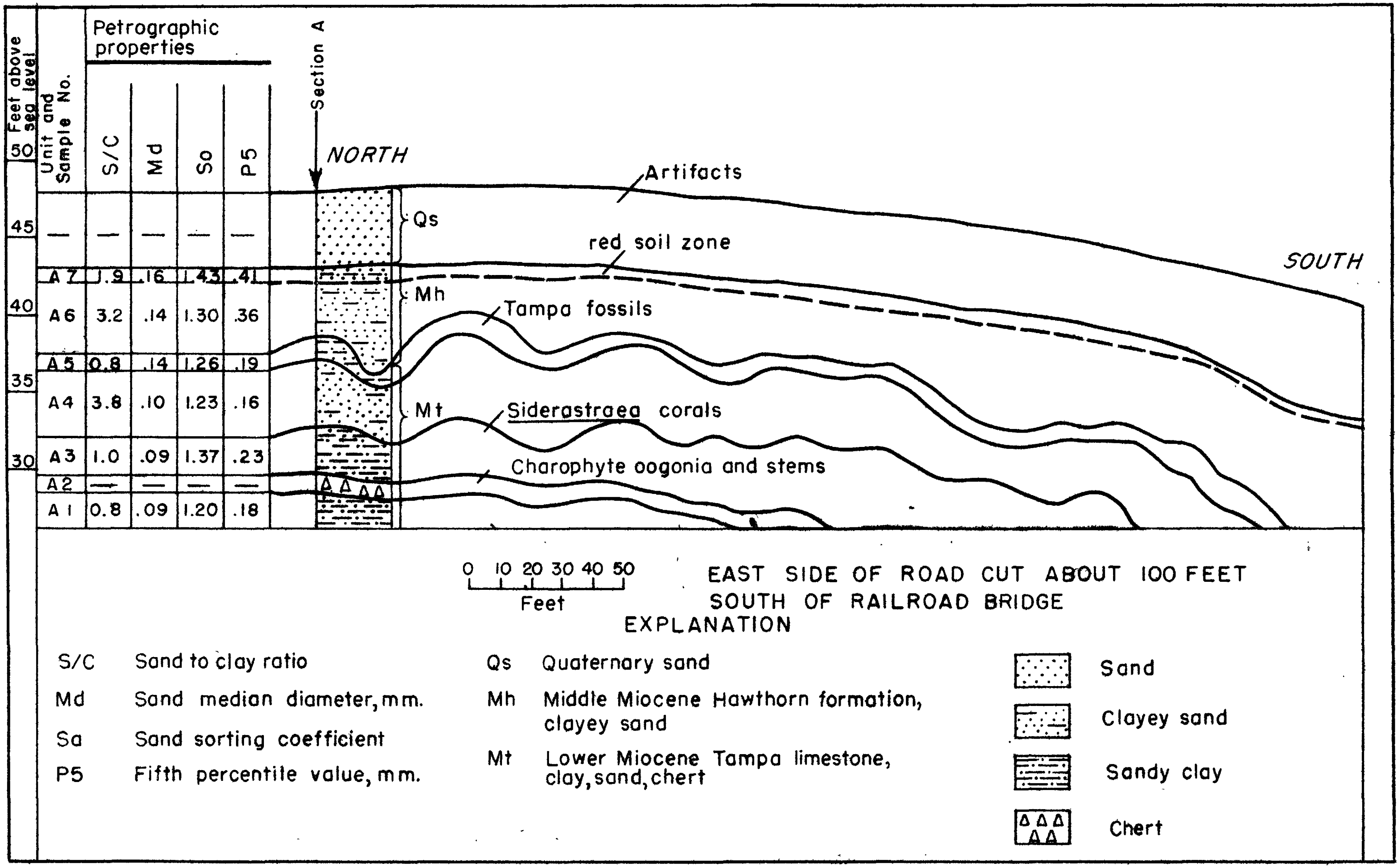
EXPLANATION

S/C Sand to clay ratio
Md Sand median diameter, mm.
So Sand sorting coefficient
P5 Fifth percentile value, mm.
nd No data
1/ Insoluble residue

Qs Quaternary sand
Mh Middle Miocene Hawthorn formation, clayey sand
Mt Lower Miocene Tampa limestone, soft limestone, sand, clay, chert

Sand
Clayey sand
Chert
Calcareous sandy clay
Clayey limestone

FIGURE 14.—DIAGRAMMATIC SKETCH SHOWING STRATIGRAPHIC RELATIONS AND PETROGRAPHIC PROPERTIES AT LOCALITY 24, N.E. 1/4 SEC. 33, T.28 S., R.19 E., HILLSBOROUGH COUNTY, FLORIDA.



Unit and Sample No.	S/C	Md	So	P5
—	—	—	—	—
A 7	.9	.16	1.43	.41
A 6	3.2	.14	1.30	.36
A 5	0.8	.14	1.26	.19
A 4	3.8	.10	1.23	.16
A 3	1.0	.09	1.37	.23
A 2	—	—	—	—
A 1	0.8	.09	1.20	.18

FIGURE 15.–DIAGRAMMATIC SKETCH SHOWING STRATIGRAPHIC RELATIONS AND PETROGRAPHIC PROPERTIES AT LOCALITY 6, N.W. 1/4 S.W. 1/4 Sec. 19, T. 28S., R. 20E., HILLSBOROUGH COUNTY, FLORIDA.

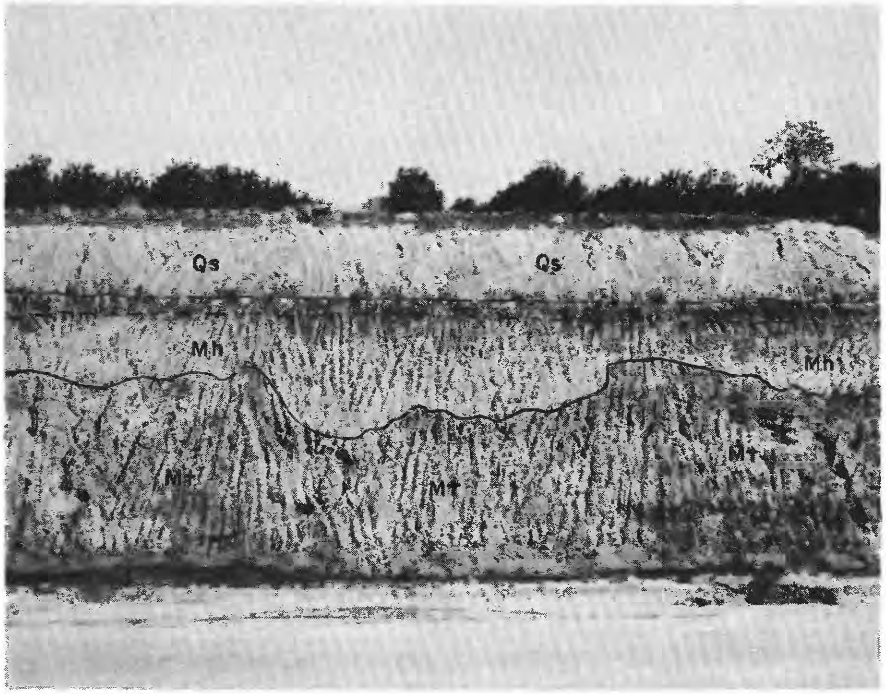


Figure 16.-- Contacts between Hawthorn formation and Quaternary sand and Tampa limestone at locality 6, Hillsborough County, Florida. The grooves were made by excavating machinery.

Qs- Quaternary sand
Mhs-Miocene Hawthorn formation, soil zone
Mh- Miocene Hawthorn formation
Mt- Miocene Tampa limestone

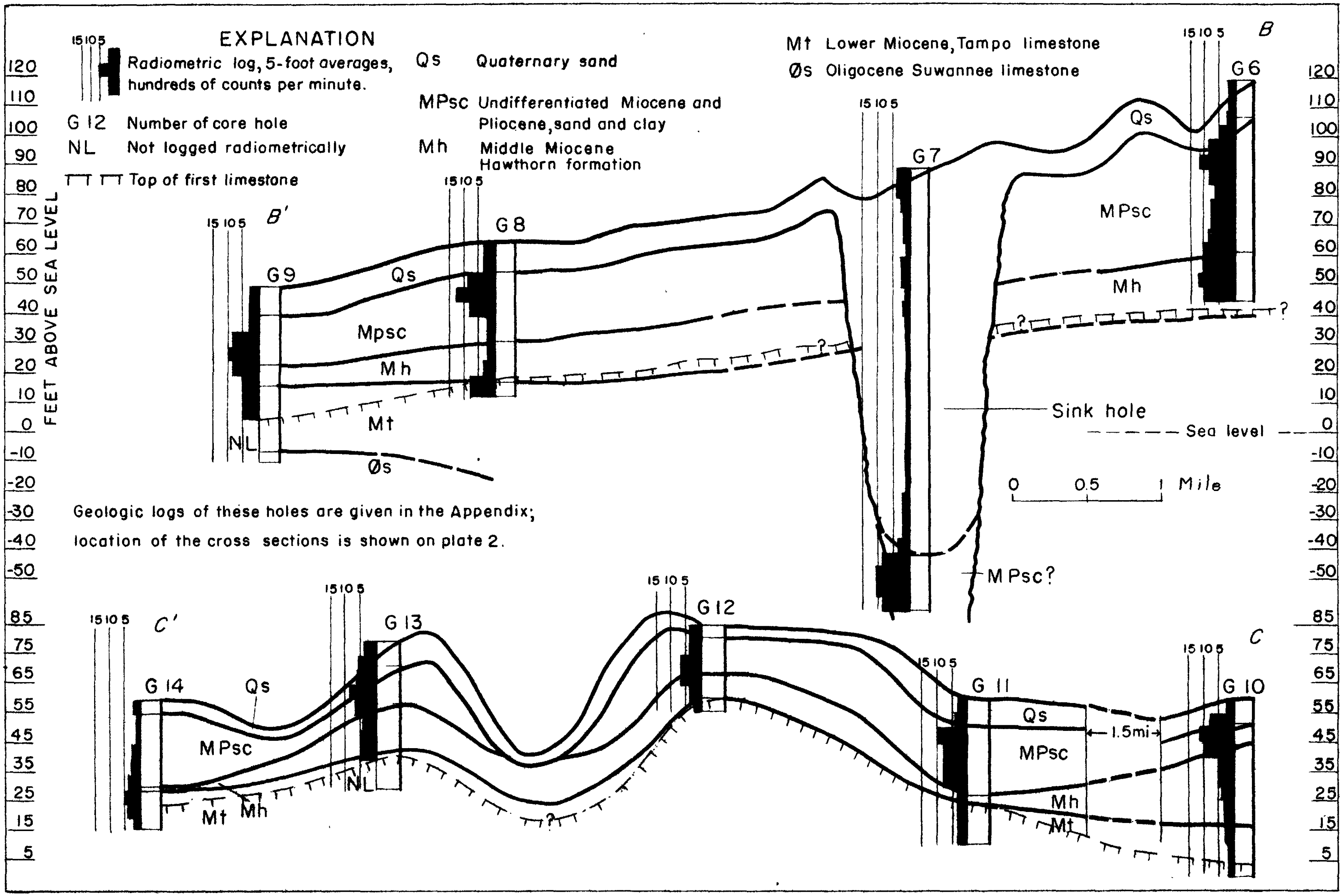


FIGURE 17.—CROSS SECTIONS THROUGH CORE HOLES IN NORTHEASTERN HILLSBOROUGH COUNTY, FLORIDA.

as much as the Tampa limestone. Opaque minerals range from 10 to 50 percent, partly due to the inclusion of dark isotropic phosphate particles in this group. Other heavy minerals present, in amounts generally less than 10 percent, are epidote, kyanite, rutile, tourmaline, sillimanite, sphene, topaz, zircon, and muscovite.

Localities.--A gazetteer of exposures of the Hawthorn formation examined by the authors is given in table 6. Many of these localities are new to the literature. Localities in operating phosphate mines are usually impossible to relocate, as conditions there change daily.

Post-middle Miocene rocks

Formations younger than the Hawthorn were not mapped, although some samples of the later formations were mechanically analyzed. Ketner and McGreevy (U. S. Geol. Survey Bull., in preparation), Altschuler (report in preparation), and Bergendahl (1954) describe these formations in detail. Some of these rocks are described briefly here.

Bone Valley formation

The Bone Valley formation (Matson and Clapp, 1909, p. 138-141), which overlies the Hawthorn, is the source of a large part of the phosphate mined in the land-pebble district. Its exact age has never been proved, partly because of a lack of invertebrate fossils, but vertebrate remains indicate that it is early Pliocene or late Miocene (Simpson, 1930, p. 184).

(Text continued on p. 122)

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida

Locality[1/] name and number	Access[1/]	General lithology	Thickness (feet)	Remarks
		Hillsborough County		
Temple Terrace Underpass 6 NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 19, T. 28 S., R. 20 E.	U.S. Hwy. 301, about 2.7 mi. N. of jct. with U.S. Hwy. 92; road cut.	Sand, clayey, fine- to medium-grained, gray to red-brown.	6.0	The underlying Tampa ls. is also exposed here (figs. 15 and 16)
Knights 9 NE$\frac{1}{4}$ sec. 6, T. 28 S., R. 22 E.	St. Hwy. 39, 0.1 mi. N. of intersection at Knights, 4 mi. N. of Plant City; railroad cut, E. side of road.	Sd., slightly clayey to clayey, fine- to medium-grained, tan to orange-brown, containing vesicular nodules of aluminum phosphate cemented sd., and hardpan.	4.5	A nearby drill hole (M1) showed that at least 30 ft. of phosphatic sd. and clay assigned to the Hawthorn fm. underlie the small hill at this locality.

1/ Most of the geographic and locality names used in these tables can be found on the Army Map Service $7\frac{1}{2}$ minute quadrangles, which cover most of this area. Unmapped areas are shown on county road maps distributed by the Florida State Road Department, Tallahassee, Fla.

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee, and Sarasota Counties, Florida--Continued

		Hillsborough County -- Continued		
Riverview 10 $W\frac{1}{2}$ sec. 21, T. 30 S., R. 20 E.	U.S. Hwy. 301, turn SE 0.1 mi. S. of S. end of bridge over Alafia R., continue 0.8 mi. to arch bridge over small creek; outcrop above and below bridge in bottom of ravine.	Ls., light tan to white, locally hard, irregularly sandy, and ss., very calcareous, light tan to white, all containing sparse phosphate nodules.	3.5	Probably the best permanent exposure of ls. of the Hawthorn fm. in the area.
Mango Hills clay pit 13 $NW\frac{1}{4}SW\frac{1}{4}$ sec. 3, T. 29 S., R. 20 E.	St. Hwy. 579, 0.5 mi. N. of jct. with St. Hwy. 574 at Mango; large clay pit E. of road.	Sd., slightly clayey to clayey, fine- to medium-grained, tan to red-brown, interbedded with clay, slightly sandy, gray-green, blocky, waxy, containing sparse platy fragments of aluminum phosphate and chert.	20.0	Possibly post-middle Miocene. Interesting structural features, one of which is shown in figure 13.

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee, and Sarasota Counties, Florida--Continued

	Hillsborough County--Continued			
Buckhorn Springs 14 $NW\frac{1}{4}$ sec. 10, T. 30 S., R. 20 E.	Bloomingdale Rd., turn S. on dirt road about 2.2 mi. E. of jct. with U.S. Hwy. 301, or about 3.5 mi. W. of Bloomingdale; continue about 0.4 mi. to end of road at spring pool; loose boulder dug from spring.	Ls., tan, sandy.	-	
Bell Shoals 15 $W\frac{1}{2}$ sec. 24, T. 30 S., R. 20 E.	Brandon-Boyette Rd., S. end of Bell Shoals bridge over Alafia R. about 6 mi. S. of Brandon; small outcrop at river's edge.	Ls., tan, sandy, sparsely phosphatic.	0.5	Accessible only in dry season.
Alderman's ford 16 $SE\frac{1}{4}$ sec. 18, T. 30 S., R. 22 E.	St. Hwy. 39 (Hopewell-Pinecrest Rd.) about 5 mi. S. of Hopewell or about 1 mi. N. of Pinecrest below bridge over Alafia R.	Ls., tan, sandy, phosphatic.	0.5	Accessible only in dry season.

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee, and Sarasota Counties, Florida--Continued

		Hillsborough County--Continued		
Buckhorn Creek 22 SW$\frac{1}{4}$ sec. 3, T. 30 S., R. 20 E.	Bloomingdale Rd. about 2.4 mi. E. of jct. with U.S. Hwy. 301, or about 3.2 mi. W. of Bloomingdale; borrow pit N. side of road at Buckhorn Creek.	Sd., slightly clayey, fine-grained, with trace very coarse grains, light gray to orange-brown.	5.5	Possibly post-middle Miocene.
Lamour pit 24 NE$\frac{1}{4}$ sec. 33, T. 28 S., R. 19 E.	50th St. and E. Sligh (Robles) Ave., NE Tampa; NE corner of sandpit.	Sd., clayey, yellow-brown; contains sparse chert fragments.	2.5	Overlies residuum of Tampa ls.
Harney railroad cut 25 SW$\frac{1}{4}$ sec. 26, T. 28 S., R. 19 E.	Robles (Sligh) Ave.; N. of viaduct over railroad just S. of Harney; railroad cut.	Sd., slightly clayey, medium-grained, trace coarse grains, orange-brown; contains sparse chert fragments; lower contact with Tampa ls. gradational.	0.5	

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee, and Sarasota Counties, Florida--Continued

		Hillsborough County--Continued		
Cone sandpit 31 NW$\frac{1}{4}$ sec. 3, T. 29 S., R. 19 E.	At 52nd St., NE of Tampa, turn N. from Harney Ave. (Ft. King Hwy.) at Orange Hill cemetery; large sand pit.	Sd., very slightly clayey, medium- to coarse-grained, white, tan, dark violet-gray; overlies Tampa ls.; contact gradational.	5.0	Probably Hawthorn fm., but may be post-middle Miocene.
Alafia River 36 S$\frac{1}{2}$ sec. 9, T. 30 S., R. 20 E.	By boat on Alafia R.; W. bank of river, 1.0 mi. NE of Riverview.	Ls., white to light gray, very sandy; contains phosphate nodules and lenses of ls., white, very slightly sandy, hard, fine-grained.	1.0	Most accessible at low tide; probably very near base of Hawthorn fm.

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee, and Sarasota Counties, Florida--Continued

		Hillsborough County--Continued		
Alafia River 37 $SE\frac{1}{4}$ sec. 15, T. 30 S., R. 20 E.	By boat on Alafia R., about 1.5 mi. downstream from Bell Shoals bridge; S. bank of river.	Ls., very sandy, contains phosphate nodules.	1.0	Best-exposed at low tide.
Alafia River 38 $NW\frac{1}{4}$ sec. 23, T. 30 S., R. 20 E.	By boat on Alafia R., about 1.0 mi. downstream from Bell Shoals bridge; several outcrops, N. bank of river.	Ls., hard, sandy, light tan to light gray, clayey, locally dolomitic, sparsely fossiliferous, contains abundant phosphate nodules and phosphatic cement.	5.0	Best-exposed at low tide in dry season; the largest known permanent exposure of limestone of the Hawthorn fm. in this region.

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

		Hillsborough County--Continued		
Sydney mines American Cyanamid Company 39A, B, C, D, E Secs. 22, 34, 36, T. 29 S., R. 21 E.	St. Hwy. 60; N. pits, 4.5 mi. W. of jct. of St. Hwys. 60 and 39; S. pits, 1 mi. S. of Sydney washer; E. pits, 1 mi. S. of St. Hwy. 60 on Turkey Creek road.	Ls., white to light tan, sandy, chalky, dolomitic, containing phosphate nodules.	-	
Eleanor mine 41 SE$\frac{1}{4}$ sec. 29, T. 29 S., R. 22 E.	St. Hwy. 39 about 0.7 mi. S. of St. Hwy. 60 at Hopewell; old overburden dumps E. of road.	Ls., white, chalky, dolomitic, slightly sandy, containing phosphate nodules.	-	Old mine; loose pieces of ls. may be found on dumps.
Boyette mine American Agricultural Chemical Corp. 42 Sec. 15, T. 31 S., R. 21 E.	St. Hwy. 39, about 4 mi. S. of Pinecrest turn W. about 2.5 mi. to washer; pits to S. of washer.	Ls., light, yellow, clayey, very slightly sandy, dolomitic, fossiliferous, contains phosphate nodules.	-	

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

		Hillsborough County--Continued		
Ichepakesassa ditch, east 44 $NE\frac{1}{4}NE\frac{1}{4}$ sec. 2, and $NW\frac{1}{4}NW\frac{1}{4}$ sec. 1, T. 28 S., R. 22 E.	Knights-Griffin rd., about 4 mi. E. of Knights above and below bridge over drainage canal.	Sd., white to light gray, clayey, fine- to coarse-grained, indurated, highly vesicular, cemented by aluminum phosphate.	3.0	Best-exposed in dry season; outcrop extends for a mile or so along ditch.
Campbell Branch 45 $NW\frac{1}{4}$ sec. 18, T. 28 S., R. 21 E.	Antioch Rd., 0.4 mi. N. of Plant City-Thonotosassa Rd., or about 3 mi. N. of U.S. Hwy. 92 via McIntosh and Antioch Rds.; small outcrop in creek.	Sd., clayey, fine- to coarse-grained, dark gray to dark red-brown; contains few lumps aluminum phosphate cemented sand.	1.0	Exposed only in dry season.

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

		Hillsborough County--Continued		
Valrico railroad cut 50 SW$\frac{1}{4}$ sec. 24, T. 29 S., R. 20 E.	St. Hwy. 60, turn N. about 1.3 mi. E. of Brandon, cross tracks, turn W. for about 0.4 mi.; railroad cut.	Sd., very slightly clayey, fine- to coarse-grained, fairly uniform orange-brown.	15.0	
		Pasco County		
Borrow pits 53 NW$\frac{1}{4}$ sec. 26, T. 26 S., R. 21 E.	Old road to Crystal Springs from Zephyrhills, about 0.7 mi. S. of U. S. Hwy. 301; shallow pits W. side of road.	Clay, sandy, mottled red, gray, and brown; loose chunks of silicified corals and chert, tripoli.	2.0	Residua of Tampa ls. probably present also; coral Siderastraea hillsboroensis as loose rubble.

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

		Pasco County--Continued		
Pasadena railroad cut 60 NE$\frac{1}{4}$ sec. 10, T. 25 S., R. 21 E.	U.S. Hwy. 301; 1.5 mi. S. of Dade City city limits turn W. on paved road $\frac{1}{4}$ mi. to railroad crossing; railroad cut S. of crossing.	Clay, very sandy, light brown to orange, semi-indurated in places, containing fragments and nodules of aluminum phosphate and clay, slightly sandy, gray-green.	15.0	Both Tampa and Hawthorn fms. may be present. Silicified corals, <u>Siderastraea hillsboroensis</u>, found in place near bottom of exposure about a foot above a green clay bed.
Hound dog ditch 61 NE$\frac{1}{4}$ sec. 30 T. 25 S., R. 21 E.	From Zephyrhills follow St. Hwy. 41 N. and W; at about 2.5 mi. from city limits turn W. on dirt road, at 3.2 mi. turn N., at 3.4 mi. turn W., at 5.2 mi. turn N.; 6.2 mi. exposure in ditch, E. side of road.	Sd., slightly clayey, gray to violet-gray, fine- to medium-grained, containing trace of coarse- to granule-size; contains abundant	2.5	

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

		<u>Pasco County</u>--Continued		
Hound dog ditch (Continued)		silicified <u>Siderastraea hillsboroensis</u> corals up to 1 ft. diameter, and hardpan layers.		
Ostrea ditch 68 NW$\frac{1}{4}$ sec. 28, T. 24 S., R. 20 E.	St. Hwy. 578 about 2 mi. W. of St. Joseph; shallow ditch S. side of road.	Sd., clayey, orange-brown, containing abundant shells of <u>Ostrea normalis</u>.	2.5	Near Tampa ls. loc. 69.
Dade City pit 71 NW$\frac{1}{4}$ sec. 12, T. 25 S., R. 21 E.	St. Hwy. 35A, about 1.2 mi. N. of Ellerslie, or about 2.5 mi. SE of Dade City; large borrow pit W. side of road.	Sd., very slightly clayey, fine- to very fine-grained, tan to red-brown, containing local patches of sd., white, and trace of aluminum phosphate cemented nodules.	15.0	Possibly residuum of Tampa ls.

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

		Polk County		
Tenoroc mine Coronet Phosphate Co. 73A, B, C. $S\frac{1}{2}$ sec. 35, T. 27 S., R. 24 E.	Combee Rd. E. of Lakeland; at about 3.8 mi. N. of U.S. Hwy. 92 turn E. on Ritter Rd. to Coronet mine washer; turn S.-SW across railroad tracks to pits; section located on E. face of cut mined in February 1954.	Ls., slightly sandy, slightly clayey, yellow, soft, fossiliferous, overlain by clay, sandy, light tan, containing abundant phosphate nodules, and by sand, clayey, gray, with abundant thin lenses of clay, sandy, very light greenish gray, containing abundant soft white phosphate nodules.	9.0	Tampa ls. occurs on waste piles in pit $\frac{1}{4}$ mi. N.

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

		Polk County--Continued		
Saddle Creek mine American Cyanamid Company 74 Secs. 14 and 23, T. 28 S., R. 24 E.	U.S. Hwy. 92 E. from Lakeland; pits are about 2 mi. E. of city limits; section located near center of sec. 14 about 100 yds. N. of road on W. face of cut mined in Feb. 1954.	Ls., slightly sandy, slightly clayey, light tan, soft, slightly phosphatic; overlain by ls., very clayey, sandy, containing abundant fragments of clay, blue-gray, and very coarse phosphate nodules; overlain by clay, slightly sandy, blue-gray with olive-green patches, waxy, with patches and lenses of sand, fine-grained, gray, containing abundant fine tan phosphate sd.; upper contact fairly sharp and irregular.	5.0	Hawthorn probably thin. Accessible only in actively mined pits.

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

		Polk County--Continued		
Pauway mine American Agricultural Chemical Corp. 75 Sec. 32, T. 28 S., R. 24 E.	U.S. Hwy. 98, SE of Lakeland; 0.3 mi. E. of Lake Hollingsworth turn S. for 1.3 mi. to mine area; section located near center of sec. 32 on W. face of cut mined in Feb. 1954.	Ls., clayey, very slightly sandy, white to brown, fossiliferous, sparsely phosphatic, locally silicified and dolomitic; overlain by clay, slightly sandy, white to light gray, slightly calcareous, containing abundant phosphate, sand to pebble-size; overlain by sd., slightly clayey, light gray-green,	13.0	Material included as Hawthorn fm. clearly residual from ls. at point where section was taken.

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

		Polk County--Continued		
Pauway mine (Continued)		containing phosphate sd. and granules, and patches of soft white phosphatic clay; upper contact sharp.		
Achan mine International Minerals and Chemicals Corp. 76 Sec. 23 and 26, T. 30 S., R. 23 E.	St. Hwy. 37, S. from Mulberry about 3.5 mi.; in SW$\frac{1}{4}$ sec. 23 at S. end of cut mined in Feb. 1954.	Ls., sandy, soft, light tan, slightly fossiliferous, dolomitic, containing sparse phosphate, sand- to pebble-size; upper contact not seen.	3.0	Most of material above ls. believed to be post-Hawthorn fm.; upper surface of ls. exposed at N. end of abandoned pit between St. Hwy. 37 and rd. to Pierce in W$\frac{1}{2}$ sec. 26.

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

		Polk County--Continued		
Pulp plant pit 77 SW¼ sec. 6, T. 30 S., R. 25 E.	St. Hwy. 60; turn N. 0.1 mi. W. of Bartow city limits, cross railroad and turn W. for 0.2 mi.; large pit to N. of rd.	Ls., very slightly sandy, white, soft, very fossiliferous, containing sparse phosphate sand and granules.	4.0	Accessible only in dry season. One of the best localities for Hawthorn fm. fossils.
Noralyn mine International Minerals and Chemicals Corp. 78 Secs. 29 and 32 T. 30 S., R. 25 E.	U.S. Hwy. 17 S. from Bartow; about 2.0 mi. S. of city limits turn W. for about 0.4 mi.; turn S. for about 1.0 mi. to mine area W. of road.	Ls., pure, soft, light yellow, slightly fossiliferous, dolomitic, containing sparse phosphate sand and granules.	-	

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

		Polk County--Continued	
Clear Springs mine Virginia-Carolina Chemical Corp. 79 Sec. 33, T. 30 S., R. 25 E.	Intersection of U.S. Hwy. 17 and St. Hwy. 655, 4 mi. S. of Bartow.	Ls., very slightly sandy, white to light gray, fossiliferous, dolomitic.	-
Varn mine Swift and Co. 80 Sec. 25, T. 31 S., R. 25 E., and sec. 30, T. 31 S., R. 26 E.	St. Hwy. 630, E. from Ft. Meade; about 1 mi. E. of Peace R. where road turns S., turn NE into mine area.	Ls., slightly sandy, slightly clayey, light yellow, sparsely fossiliferous, dolomitic; contains sparse sand to granule-size phosphate.	-

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

	Polk County--Continued		
Watson mine Swift and Co. 81 Secs. 8, 17 and 20, T. 32 S., R. 25 E.	U.S. Hwy. 17; about 2 mi. S. of Ft. Meade, turn W. to "Sand Mountain" and Watson washer, and thence SW to mine area.	Ls., fairly pure, lt. tan to white, fossiliferous, dolomitic, containing sparse sand to granule-size phosphate.	-
Peace Valley mine International Minerals and Chemicals Corp. 82 Secs. 8, 9, and 17, T. 31 S., R. 25 E.	Old blacktop road S. from town of Homeland about 1.5 mi.	Ls., clayey, tan to white, slightly fossiliferous, dolomitic.	-

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

Polk County--Continued

Kathleen railroad cut 83 SW$\frac{1}{4}$ sec. 17, T. 27 S., R. 23 E.	St. Hwy. 35A to Kathleen, turn NW from town, cross railroad tracks, and turn NW again to end of road beside tracks; railroad cut.	Clay, slightly sandy to sandy, light gray-green, waxy, blocky fracture; overlain by sd., medium-grained; trace coarse grains, slightly clayey, light gray to yellow, upper contact sharp, irregular; overlain by sd., slightly clayey to clayey, light gray, medium-grained, trace coarse grains, containing abundant oysters and pectens composed of soft tripoli, and local traces of phosphate nodules	4.0	Typical exposure of middle Miocene clays and sands (fig. 12).

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

		Polk County--Continued	
Kathleen railroad cut (Continued)		or vesicularity; upper contact gradational with upper Miocene(?) micaceous clayey sand.	
Orangedale (Fox-town) borrow pit 86 NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 8, T. 27 S., R. 24 E.	St. Hwy. 33 N. from Lakeland; at about 1.0 mi. from city limits keep left on old Polk City road, at about 2.0 mi. turn E. and follow pavement for about 2 more mi. E. and N.; borrow pit S. side of road.	Sd., clayey, medium- to fine-grained, light gray, mottled red-brown.	1-5

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee and Sarasota Counties, Florida--Continued

Manatee County

Tampa Gap drain 96 $S\frac{1}{2}$ sec. 36, T. 33 S., R. 17 E.	U.S. Hwy. 41 about 1 mi. S. of Rubonia; spoil banks of drainage ditch.	Ls., sandy, clayey, white, soft, slightly fossiliferous, containing trace fine phosphate sand.	-	
Rocky Bluff 97 Secs. 9 or 16, T. 34 S., R. 18 E.	U.S. Hwy. 301 (St. Hwy. 43), about 1.3 mi. NE of Ellenton. Turn S. through woods about 200 yds. to beach.	Ls., slightly sandy, clayey, light yellow, dolomitic, containing sparse phosphate sand.	1.0	Most accessible at low tide.

Table 6.--Exposures of the Hawthorn formation in Hillsborough, Pasco, Polk, Manatee, and Sarasota Counties, Florida--Continued

		Manatee County--Continued		
Southern Dolomite Co. pit 98 $S\frac{1}{2}$ sec. 13, T. 34 S., R. 17 E.	From junction of U.S. Hwys. 41 and 301 at Palmetto turn E. on U.S. 301 for about 0.7 mi. to sign of Southern Dolomite Co., turn S. about 0.5 mi. to pits.	Ls., light tan to white, very slightly sandy and clayey, dolomitic, soft, containing trace phosphate sand.	6.0	
		Sarasota County		
Florida Dolomite Co. pit 99 $N\frac{1}{2}$ sec. 6, T. 36 S., R. 18 E.	St. Hwy. 683, 0.9 mi. SE of U. S. Air Force Base N. of Sarasota; dolomite pits.	Ls., slightly clayey, light green-gray, massive, dolomitic, trace very fine phosphate sand.	4.5	Probably same as locality given by Cooke (1945, p. 160).

The formation consists of gray and green sand and clay beds containing, in places, up to 75 percent phosphate nodules. The sand in these beds consists of quartz and phosphate nodules which, when taken together, are rather poorly sorted as a rule. Stratification is poor in many exposures. The quartz sand has size properties very much like those of the Hawthorn, but the Bone Valley seems to show poorer sorting and more variation from sample to sample in a vertical section. In samples analyzed the medians of P5, median diameter and sorting coefficient are 0.39 mm, 0.18 mm, and 1.42 respectively.

Weathering has made the contact between the Bone Valley formation and residuum of the Hawthorn formation difficult to locate in exposures and impossible in drill holes. Traditionally, noncalcareous beds mined for phosphate ("matrix") in the land-pebble district have been referred to the Bone Valley regardless of their age. A contact occasionally seen in the phosphate pits is an undulating unconformity which is locally transected by the base of a leaching profile. Whether or not this unconformity coincides with the contact between the Bone Valley and Hawthorn formations is a matter of conjecture in the authors' opinion, but it is certain that much of the material mined for phosphate, particularly in the northern part of the district, is actually residuum of the Hawthorn formation.

Undifferentiated Pliocene-Miocene formations

Above the Hawthorn formation in Polk and Hillsborough Counties are beds of sandy clay which were not differentiated in this work. Some of these beds may be of Bone Valley age, others are probably correlative with a clayey sand described by Ketner and McGreevy (U. S. Geol. Survey Bull., in preparation).

These rocks closely resemble the Hawthorn and Bone Valley clay and sand beds, but generally have less phosphate and locally contain abundant fine-grained muscovite flakes (loc. 83). Analytical data for rocks of post-middle Miocene, pre-Quaternary age, are summarized in table 10.

WEATHERING

Introduction

Throughout subtropical Florida the climate, topography, drainage, vegetation, and rock types are very favorable to the formation of residua. The weathering is largely lateritic and iron- and alumina-rich zones are typically developed. Where the parent material is favorable secondary chert and aluminum phosphate zones commonly form.

The typical weathering profile begins at the surface with several feet of loose pure quartz sand which becomes more clayey and orange or reddish downward. Iron and alumina hardpan, aluminum phosphate, and chert nodules are common at the base of this zone. Beneath this is a zone of generally blue or gray-green clay and sandy clay locally containing calcium phosphate nodules. At the base of the profile is a thin zone of slightly calcareous sandy clay grading rather abruptly into limestone. The profile is thus essentially one of decreasing solubility upwards. The depth of such leaching exceeds 50 feet in some places in this area.

Clay and sand clearly weathered from limestone is present at many localities in the area mapped. In a few places such beds contain chert lenses with fossils. Usually, however, it is difficult to determine whether an unfossiliferous sandy clay above limestone at an exposure is residual from the limestone, an essentially unweathered bed of the formation, or belongs to a formation of later age.

Several criteria may be used to help ascertain the relations under such condtions. One of the most indicative of these is the formation of chert. Leith (1925, p. 513-523) pointed out the occurrence of secondary silica on erosion surfaces developed on a variety of rocks, of which limestones and dolomites are said to be the best sites for superficial silicification. That most of the chert seen in exposures in Florida is an epigenetic replacement of limestone is indicated by (1) the massive, porcellanic, vitreous appearance of the chert, (2) the irregular shape of the masses, (3) the inclusion within chert of calcite grains and patches, and pockets of calcareous material, and (4) the inclusion of silicified fossils within the chert. MacNeil (oral communication) noted that only the protruding parts of mollusks in the wall of a limestone sinkhole in northern Florida were silicified. The part of the shells remaining in the limestone was carbonate.

The abundant examples of replacement of limestone by chert, of silicified originally calcareous fossils in clay beds, and the texture of the chert itself lead the writers to conclude that chert, at least in this part of Florida, forms in significant amounts only in the presence of limestone; therefore, its occurrence as a fairly continuous zone in a deeply weathered section is good evidence, barring reworking, that the bed containing the chert was originally calcareous.

One of the best examples of a chert bed in a weathered section is at locality 6 (fig. 15). This chert contains fresh-water plant seeds which suggest that the chert has replaced a fresh-water limestone bed.

The presence of unreworked silicified head corals, like *Siderastraea*, in a weathered section is also evidence that the beds on which they rest were originally limestone, if it is accepted that growing corals can survive only in a mud-free environment.

Solution textures are usually obliterated by prolonged weathering and complete removal of lime, but structures in clay and sand, such as crenulated bedding are good evidence that solution of limestone has occurred below the contortions.

Suwannee limestone

Only small amounts of residual clay have been seen on top of the Suwannee limestone in this area. Weathering could not produce significant amounts of residuum because the formation contains very little insoluble material. A possibility remains, however, that a clay residuum overlying a pure limestone like the Suwannee may be a result of replacement plus concentration by weathering.

The chert in the Suwannee limestone is almost entirely surficial and shows very irregular contacts with the replaced limestone. Chert is widespread on top of the Suwannee, particularly in northern Hillsborough and southern Pasco Counties where the formation crops out. Some of the chert has rinds of porous white and brown tripoli, an indication of intense leaching, possibly brought about by removal of the surficial protecting cover of sand and clay.

Tampa limestone

Effects of weathering upon Tampa limestone are especially well shown in the Tampa area by silicification, contortion of bedding, and clayey residues.

The occurrence of chert on the Tampa limestone is similar to that in the Suwannee, but massive blanket zones of chert are not so common in the Tampa. Commonly secondary silica in the Tampa occurs as angular or platy masses of chert, as thin fissure fillings, or as silicified fossils. More than half of the exposures of the Tampa given in this report, about 75 percent of the core drill holes which reached the formation, and the majority of well logs of the Tampa, revealed secondary silica in at least one of the above forms. Figures 14 and 15 illustrate two occurences of chert in exposures. Silicified fossils are present at both these localities. At locality 24 (fig. 14) Tampa fossils (pl. 5) are present in chert lenses. At locality 6 (figs. 15, 16) Tampa mollusks (pl. 5) occur as soft tripoli; silicified Siderastraea corals are present, and a silicified bed, partly tripoli, contains fresh-water plant remains. At Ballast Point (loc. 2) the "silex bed" contains numerous well silicified fossils.

Locality 6 (figs. 15, 16) shows the effects of limestone solution upon bedding. A clayey bed at the top of the Tampa has crenulations with amplitide up to 4 feet, and in short lateral distances varies from a few inches to a foot and a half thick. Lower beds in the exposure are similarly distorted to a lesser degree.

At two Tampa limestone localities (24, 25) which illustrate the residua problem, masses of soft limestone measuring up to 3 feet in diameter are surrounded by clay. These "boulders" are pierced by thin seams of calcareous clay, but the contact between limestone mass and surrounding clay is quite sharp. A sketch of the relationships at locality 24, typical of super-Tampa weathering, is given in figure 14. Insoluble residue of a sample (24A1) of the mass of limestone and a raw sample (24A2) of the clay immediately adjacent showed that the sand has median diameters of 0.12 and 0.14 mm. respectively. X-ray analysis of the clay fraction of these two samples revealed quartz, orthoclase, montmorillonite and pseudowavellite in the limestone (24A1).[1] The same constituents were present in the clay (24A2),[1] with the addition of wavellite and apatite. Spectrographic analysis of raw splits of the two samples detected no phosphorous whatever in the limestone, but 0.0X percent was found in the clay.[2] The data, both petrographic and analytical, suggest that the clay is residual from the limestone, and that the weathering has concentrated phosphorus in the clay. Units A3, a very slightly calcareous sandy clay, and A5, a pure white sand, are lenticular and both underlie ledges of chert (A4, A6) which contain lower Miocene fossils (pl. 5) and small amounts of very fine-grained sand. Unit A7, a reddish clayey sand, is unconformable upon units A3 to A6 and has petrographic properties which correspond closely with those of the Hawthorn formation. Therefore, the writers believe that this is an unconformable Tampa-Hawthorn contact, and that units A3 and A5 represent solution cavities filled by material from both formations.

Table 7 compares two stratigraphically equivalent samples of relatively pure Tampa limestone, one essentially fresh, the other moderately weathered. The two samples were taken on the

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1/ Analysis by R. G. Petersen, U. S. Geol. Survey.

2/ Laboratory nos: 115724 and 115725.

Table 7.--Chemical and mechanical analysis comparison of stratigraphically equivalent samples of fresh and weathered Tampa limestone from locality 19, Hillsborough County, Florida.

	19A2(fresh)	19B1(weathered)
	Percent	
Partial chemical analysis[1]		
P_2O_5	0.3	0.3
$CaCO_3$	90.1	67.3
Al_2O_3	0.8	2.8
Fe_2O_3	0.27	0.52
$MgCO_3$	1.6	1.5
Insoluble residue		
quartz sand	3.2	12.6
clay and silt	5.7	22.1
Total	101.97	107.12
Soluble	91.0	65.0

sand to clay ratio	0.56	0.57
median diameter, mm	.086	.085
sorting coefficient	1.38	1.33
fifth percentile, mm	.22	.23

[1] Laboratory nos.: 19A2 - 115934; 19B1 - 115938.

wall of a sinkhole from points about 15 feet apart laterally. Note that the petrographic data from the two samples agree very closely, and that the percentages of carbonate obtained by calculation from the chemical analyses are close to the percentages of soluble material obtained by insoluble-residue analysis. The percentage of insoluble materials has increased nearly 4 times in the weathering which removed about 25 percent of the lime. The ratio of sand to clay remained essentially the same, however. A bed of this limestone 10 feet thick would yield, after weathering removed all carbonate, at most about one foot of residue, if changes in porosity are ignored. A possibility remains, however, that as the lime is removed it may be replaced by clay minerals under special conditions of weathering, but if this occurs then the ratio of sand to clay should decrease in the replaced sample. On the other hand, if one assumes that clay beds so commonly found above limestone in this area are strictly residual then it is necessary to postulate the existence of 5 to 10 feet of original limestone for each foot of residue.

Other changes in composition shown by the analyses below are slight. The percentage of Al_2O_3 increases in proportion to the increase in clay, and there is a slight increase in Fe_2O_3 in the weathered sample.

As the Tampa contains only small amounts of phosphate nodules in most places, highly phosphatic residues are not commonly formed. However, radiometric logs of many of the drill holes indicate local zones of abnormal radioactivity within the Tampa (figs. 3, 4, 17).

Most of the peaks of radioactivity in the Tampa occur at the top of the formation, although in Pasco County a secondary peak was noted at the base. The lithologic logs of these core holes show that the radioactivity at the top of the Tampa is due to the presence of aluminum phosphate cement formed by leaching of calcium phosphate nodules. The radioactive zone at the base of the Tampa in Pasco County appears to be due to essentially unleached colloidal apatite. In the core holes southeast of Dade City weathered material extends to a depth of at least 100 feet, judging from the presence of secondary phosphate minerals at the top of the Tampa, but the presence of calcium phosphate at the base of the formation in these holes suggests that leaching has been absent or much weaker toward the bottom of the formation. In core holes G111 and G112 non-calcareous lower Miocene clayey sand rests directly upon unleached Suwannee limestone.

Hawthorn formation

Of the limestone formations described in this report, the Hawthorn is the one most affected by weathering, primarily because it is close to the surface in much of the area. Weathering has resulted in clayey sand of two types, as discussed in the section on stratigraphy.

In the land-pebble phosphate district weathering of Hawthorn limestone has produced a phosphatic residuum (Lakeland phosphorite, fig. 15) which is often indistinguishable from, and mined with, the overlying Bone Valley formation. In order to map these beds it would be advantageous to regard phosphatic clayey sand and limestone phases as separate mappable units regardless of age. The objection is then raised that such a map would show only a leaching profile crosscutting stratigraphy. The authors have therefore mapped two units (pl. 1), limestone and clayey sand, of the Hawthorn formation, but the Bone Valley formation and non-calcareous residua overlying Hawthorn limestone are not shown.

The Hawthorn formation exhibits 3 general zones of weathering. The first and weakest is that commonly seen in the bottoms of the phosphate pits where the limestone is soft, yellowish, and has a marly or chalky appearance. This uppermost type of limestone is only a few feet thick in most places. It is almost invariably dolomitized, has poorly preserved fossils, scattered phosphate nodules, and blotchy areas of alteration. The second zone of weathering of the Hawthorn lies above the limestone and consists of non-calcareous to calcareous greenish-gray clayey sand with abundant phosphate nodules. This material is apt to be structureless but in some places contains wavy distorted beds of green clay and occasional lenses of incoherent phosphatic sand. This lithology represents an intermediate stage in weathering where leaching has been strong enough to remove most of the carbonate and concentrate, but not otherwise affect, the calcium phosphate nodules. The third type of leached Hawthorn formation is best exposed in northern Polk (fig. 12) and Hillsborough Counties (fig. 13) and eastern Pasco County, but is rarely seen in the phosphate pits. It consists of loosely cemented brown to red clayey sand, with local hardpan layers made up of iron oxide and aluminum phosphate cemented sand. Distorted green waxy clay beds are common, and an occasional altered calcium phosphate nodule may be present. This lithology represents a severe stage of weathering in which carbonate, if originally present, has been completely removed, calcium phosphate has been altered to form concretions and hardpans of aluminum phosphate, and some of the heavy minerals have been oxidized to produce iron-staining.

The scarcity of secondary chert in the Hawthorn is notable. There are occasional silicified fossils or small chert fragments in weathered exposures of the Hawthorn, but no massive chert like that of the Tampa and Suwannee limestones was found anywhere in the formation in this area. The reason for the scarcity of chert in the Hawthorn is not clear, but a partial answer may be that impurities in the limestone, perhaps magnesium or phosphorus, inhibit chert formation. If this is true, then the presence of abundant chert in a weathered outcrop of clayey sand may be taken as evidence of the former presence of a rather pure limestone.

Post-Hawthorn formations

Weathering of post-middle Miocene sediments was not studied in detail. In general, however, features of weathering of upper Miocene and Pliocene beds appear similar to those of the Hawthorn, thus adding to the difficulty of distinguishing them from deposits of middle Miocene age.

At locality 1 (Six Mile Creek), calcareous well-preserved shells of Pleistocene age are found in a sand resting upon Tampa limestone. Everywhere that Pleistocene shell beds were seen they seemed to be little altered in spite of their proximity to the surface.

Date of weathering

The exact age of the major weathering period in west-central Florida is difficult to determine. The ubiquitous surficial sand generally thought to be Pleistocene in age (MacNeil, 1949, Cooke, 1931) may be seen (fig. 13) to rest unconformably upon a reddish soil zone or zones developed principally on Miocene or Pliocene rocks. Pleistocene (Mansfield, 1937, p. 22) sand beds of the Pamlico terrace in the Tampa Bay area (loc. 1) are within a few feet of the surface, yet they contain calcareous, essentially unleached Pleistocene shells. At localities 1 and 26 the base of the Pleistocene rests directly upon Tampa limestone and contains numerous silicified shells and corals reworked from the Tampa limestone. No Pleistocene shells have been found in this area in surficial sands above the Pamlico, which is about 30 feet above present sea level.

As the aforementioned red soil zone apparently transects all exposed formations older than Pleistocene, the evidence indicates that a period of major weathering occurred in late Pliocene or early Pleistocene, probably at a time when sea level stood lower than it does today.

The writers believe, however, that there is evidence which suggests that earlier periods of weathering are represented in the area; some of these, the writers contend, occurred at the end of, and possibly during, early Miocene deposition. The evidence is as follows: (1) wavellite, a secondary phosphate mineral, is present in clayey sand between beds of Tampa limestone, and secondary peaks of radioactivity occur locally at the top of the Tampa in well logs; (2) a widespread zone of silicification is present across the top of the Tampa and Suwannee limestone, chert zones of possible secondary origin occur within the Tampa, and virtually no silicification is present on top of Hawthorn limestone; (3) leaching reaches to extreme depths in some areas (over 100 feet in the Dade City highlands); (4) exposures of the Tampa-Hawthorn contact show that crenulations due to slumping from solution of Tampa limestone are not always present in material of probable middle Miocene age (figs. 15, 16). The fact that an unconformity exists between Tampa limestone and the Hawthorn formation also supports this view.

PETROGRAPHIC COMPARISONS

The petrographic data obtained in laboratory work are summarized graphically in figures 5 through 10. It is only necessary to point out the salient features shown by these graphs.

First, and probably most significant, is the general increase in quartz sand size from the Suwannee limestone through the Hawthorn formation. The same progression is apparent, though not so strong, in the sorting and percent of quartz sand. The Hawthorn, for example, has poorer sorting and slightly more sand-size material than the Tampa. However, the Tampa contains slightly more clay and silt than the Hawthorn formation. In all parameters determined the Hawthorn shows more variability than the older rocks, and it contains more grains of sand which are conspicuously coarser. The latter characteristic is recognizable and useful in the field.

Figure 8 shows that rather sharp changes in properties occur at or near formation contacts, and that the data from well samples agree in trend, though not always in absolute value, with that obtained from exposures.

Figure 8 also shows some relationships between the petrographic characteristics themselves. The graphs of median diameter and fifth percentile values maintain a close parallelism throughout the log. In addition, there seems to be a relation between the sorting coefficient and fifth percentile and median diameter values. With a few exceptions, below 140 feet the two show a direct relationship, but above this point they show an inverse relation. In other words, below 140 feet the coarser the sand the poorer the sorting as compared to adjacent samples, and above 140 feet the coarser the sand the better the sorting becomes.

All data are condensed in table 8 to give a general picture of the petrography of formations in this area. Note in particular the similarity in size characteristics between the Hawthorn and overlying formations.

Table 8.--Summary of medians of petrographic characteristics for the Ocala, Suwannee, and Tampa limestones, Hawthorn formation, and rocks of post-middle Miocene, pre-Quaternary age, in west-central Florida.1/

	Total insoluble 2/ (percent)	Sand quartz 2/ (percent)	Median diameter (mm.)	Fifth percentile (mm.)	Sorting coefficient
Rocks of late Miocene or Pliocene age 3/	100	64	.17	.38	1.40
Hawthorn formation	19	14	.175	.355	1.33
Tampa limestone	20	12	.12	.22	1.22
Suwannee limestone	3	5	.10	.15	1.19
Ocala limestone 4/	2	1	.10	.26	1.37

1/ Phosphate nodules excluded.

2/ For samples 50% or more soluble, Hawthorn and older formations.

3/ Includes rocks of probable Bone Valley age and other rocks of late Miocene or Pliocene age which immediately overlie the Hawthorn formation.

4/ Average values of 7 samples.

It should be re-emphasized that the chief value of the insoluble residue-mechanical analyses lies not in absolute figures for particular samples, but in comparisons between formations based upon uniform analysis of many samples.

Clays of the Tampa and Hawthorn show some relationships which deserve further investigation. The dominant clay mineral of the Hawthorn appears to be montmorillonite; of the Tampa, illite. Attapulgite occurs in both formations in association with high MgO content, in the Tampa it occurs in samples containing land or fresh-water fauna, and in the Hawthorn it is common at the top of the formation.

GEOLOGIC HISTORY

Structural history

Introduction

Tertiary structural deformation in Florida was confined to minor upwarping, subsidence, and faulting of small displacement. The Florida peninsula has been a relatively stable area throughout most of geologic time. No deep ocean basin deposits are known (Vernon, 1951, p. 64).

The Tertiary formations normally dip a few feet per mile in a southerly direction. However, as most of these formations are less than 150 feet thick even a small displacement can affect the outcrop pattern. Several gentle domes or arches are present in the Florida peninsula which cause local variations in the dip of the formations.

Ocala uplift and distribution of Miocene rocks

The dominant mid-Tertiary structural feature of west-central peninsular Florida is the "Ocala uplift" (U. S. Geol. Survey, 1920) (fig. 1), a gentle arch which extends from Polk County northwest to the Georgia border. Most of the subordinate structural features in west-central Florida appear to be related to this arch. The crest of the Ocala uplift follows a line from northern Polk County through Lake, Sumter, Citrus, Marion and Levy Counties. In much of this area Eocene rocks, including the Avon Park limestone, are exposed or are near the surface and covered with a thin veneer of Miocene and later sediments. The Tampa limestone and older rocks were involved in the deformation which paralleled the axis of the arch, and formations younger than the Tampa may have been affected slightly. Vernon believes (1951, p. 62) that the evidence favors placing the major structural movements associated with the uplift in the early Miocene.

Vernon contends that the Miocene formations never extended completely across the Ocala uplift but pinched out against it. His conclusions are based partly upon an effort to find a source for phosphate in the Hawthorn formation. He thought that the most logical source for the phosphate would have been a land mass centered on the crest of the Ocala uplift in early Miocene time upon which large deposits of guano and phosphatized limestone accumulated. The erosion of this material, he theorized, contributed the phosphate for the Hawthorn deposited around the uplift. The theory is an interesting one, but the non-deposition of Miocene rocks on the crest of the uplift seems untenable to the authors for several reasons.

The Ocala uplift is adjoined on the north, northeast, and southwest by a discontinuous arcuate belt of outcropping Tampa and Hawthorn formations which lie at most places at higher elevations than the area which they encircle, and dip away from it. The base of the Hawthorn in much of this belt is from 10 to 50 feet higher than the present surface of Eocene rocks on the crest of the uplift. In the area studied by the authors rocks of early and middle Miocene age crop out at several localities on some of the structurally highest parts of the Ocala uplift as well as on its flanks. Near Linden in Sumter County is a thin patch of phosphatic clay and sand, probably of the Hawthorn formation, overlying fossiliferous (pl. 5) Tampa limestone (loc. 100). The Tampa is thin and rests on silicified Ocala limestone in this area. Silicified Tampa fossils (pl. 5) were found (loc. 69) by K. B. Ketner in clayey sand about 7 miles west of Dade City, at an elevation of about 110 feet. Large Miocene corals that occur near the base of the Hawthorn or the top of the Tampa were found (loc. 61) in clayey sand 5 miles southwest of Dade City at an elevation of over 200 feet. Ketner (oral communication) has traced the

Tampa and Hawthorn formations, with but few interruptions, from the land-pebble phosphate district northward through the Dade City area to the Ocala uplift and the hardrock phosphate district in Hernando County.

That the Hawthorn and Tampa formations are now missing in large areas on the Ocala uplift is not denied, but the evidence indicates that extensive, if not complete, inundation of the uplift by early and middle Miocene seas occurred. The distribution of phosphate in the Tampa and Hawthorn formations has little areal relation to the crest of the Ocala uplift, for phosphate occurs in the Hawthorn formation from South Carolina to southern Florida.

Faulting

Previous to Vernon's (1951) work in Citrus and Levy Counties, Tertiary faulting had not been recognized in peninsular Florida. The writers were able to prove the existence of a structural break, probably a fault, in northern Polk County (pls. 1 and 7).

The strike of this displacement is about N. 40° W. with the upthrown side to the northeast. This structure appears to affect rocks up through the Suwannee limestone markedly, and even the Tampa and Hawthorn formations seem to be slightly displaced in some areas. Projected to the northwest the fault alines very well with faults shown by Vernon (1951, pl. 2) in Sumter and Citrus Counties. It also follows closely the major subsurface ridge which Vernon shows in Polk County on the top of the Inglis member of the Moodys Branch formation. Vernon shows the zero contour of the top of the Inglis displaced about 40 miles to the southeast by this fault zone; the present work indicates this displacement may extend more than 50 miles. To the east of the fault line in Polk County the Suwannee limestone, according to well logs, is missing, and Miocene rocks rest upon the Ocala limestone.

Locality 72 near Rock Ridge in northwestern Polk County lies near the projection of this fault. Chert boulders containing good fossils were found in a drainage ditch at this locality. The boulders were not in place but were probably dug from limestone immediately below. The chert contained the following fossils identified by F. S. MacNeil: Turritella sp. aff. T. perduensis Mansfield, Cardium sp., Chione sp. cf. C. perduensis Mansfield, Turritella martinensis Dall var.? and/or T. carinata palmerae Bowles, and Periarchus lyelli Cooke subsp?. The first 3 fossils probably indicate Suwannee limestone. T. carinata palmerae is a Claiborne (Avon Park limestone) species, and Periarchus lyelli has been reported only from the lower part of the Ocala limestone (Inglis member of the Moodys Branch formation).

In order to clarify the structure in the Rock Ridge area, two holes were drilled with a power auger, one about 1.5 miles east, the other about 1.5 miles south of locality 72. Both holes and locality 72 were at about the same elevation, approximately 90 feet. In the hole to the east good fossiliferous Ocala limestone was penetrated within 10 feet of the surface. It was overlain by clayey sand, probably of the Hawthorn formation.

The hole to the south penetrated about 15 feet of clayey sand and clay, probably the Hawthorn formation, and was bottomed after passing through about 5 feet of Tampa clay, sand, and fresh-water limestone containing the land snail Helisoma. Thus the stratigraphy in this area indicates a fault with a displacement of 100 feet or more. The combination of Eocene and Oligocene fossils at locality 72 can be accounted for by material reworked into the Suwannee limestone.

Fossiliferous phosphatic Tampa limestone was found farther south in holes G90 and G91 (pl. 2) just east of the fault near Winter Haven, and to the north in Sumter County at locality 100 (pl. 2). Well logs in central Polk County show that the Suwannee limestone is 50 to 100 feet thick on the west side of the fault, but absent on the east side.

Contact between the Tampa limestone and Hawthorn formation

Subsurface features of the base of the Hawthorn formation and the thickness of the Tampa limestone are shown on plate 7. It is essentially a map of the surface of the Tampa limestone, but in some areas to the east and northeast the Hawthorn lies upon Eocene rocks. The information is based upon outcrops of the formations, holes drilled during the course of this work, and well logs supplied by the Florida Geological Survey. It should be kept in mind that in many of these wells the base of the Hawthorn formation has been picked by the authors and does not necessarily coincide with the base as placed by the Florida Geological Survey.

North of about latitude 28° there is little correspondence between the structure contours on the base of the Hawthorn and the isopachs of the Tampa limestone. Highs and lows on the top of the Tampa limestone do not match thick and thin portions of the formation. Unfortunately not enough information was available to permit structure contouring of the top of the Suwannee limestone, the erosional surface of which affects the thickness of the Tampa. However, the irregularity of the base of the Hawthorn alone is submitted as evidence of some erosion of the Tampa limestone.

An approximate strike of the Tampa limestone was determined from the top of a fairly persistent unit of green, sandy, dolomitic clay (see p. 50) which was noted in several wells in Polk County. The strike of the top of these beds, presumably a conformable surface within the Tampa, varied depending upon which combination of wells was used, from west to N. 48° W. The most persistent component was about N. 50° W. This strike gives a dip for the Tampa limestone of 8 to 10 feet per mile to the southwest, which is also the direction of greatest thickening of the formation. No good information on the attitude of the Hawthorn formation could be obtained because of a lack of traceable beds. Local dips are meaningless because of deformation caused by solution and slumping. However, it is evident (pls. 1 and 7) that the boundary of the Hawthorn formation in northern Hillsborough and

Polk Counties trends approximately N. 60° E. across rising topography. Thus, a strike in this area of about N. 30° W. is indicated, with a dip to the west-southwest. If correct, these attitudes indicate a slight regional disconformity between the two formations in this area.

No exposures were found which show clearly the details of the contact, but a contact, believed to be unconformable, between weathered Tampa and Hawthorn sediments is present at localities 6 and 24 (figs. 14, 15, 16), previously discussed. The occurrence of chert at the Tampa-Hawthorn contact and the possibility that the rock collected at locality 73 (see p. 53) represents reworked Tampa limestone are also suggested as evidence for an unconformity.

The fauna of the Tampa limestone (pl. 5) indicates, for some areas at least, a very shallow marine, and locally fresh-water environment of deposition, suggesting that only minor uplift or recession of the sea would have been necessary to initiate erosion of the formation.

The clay and silt fraction of two Davison well samples, one from the top of the Tampa, the other from near the base of the Hawthorn were X-rayed_/ to determine if there are any mineralogic

_/ Analyses by R. G. Petersen, U. S. Geol. Survey.

changes across the contact. Quartz, orthoclase, montmorillonite, and illite were found in the Hawthorn sample. Quartz, plagioclase, montmorillonite, and attapulgite were detected in the Tampa sample. This change in mineralogy reflects a change in depositional environment or a shift in source area.

Structural features of Miocene rocks

Figures 3, 13, 15, 16, and plate 7 show some of the structural features, both large and small, present in western Polk, northeastern Hillsborough, and eastern Pasco Counties.

The larger structural features consist of hills and ridges which rise gently above the surrounding level terrain and are covered with orange, iron-stained clay and sand. One area of such topographic highs extends from near Thonotossassa southward to the Alafia River. A small group of very low hills lies around the town of Knights north of Plant City. The higher hills in eastern Pasco County and the Lakeland ridge are similar features on a larger scale.

All of the hills and ridges mentioned appear to be underlain by orange sand and clay of the Tampa, Hawthorn, and Miocene-Pliocene formations. The Quaternary sand at the surface usually shows no such iron staining and is unconformable upon the older beds (fig. 13). Logs of drill holes show that the iron-stained zone follows the topography rather closely.

In most cases where subsurface data are available the formations rise under the topographic highs; the hills are due to thicker Miocene-Pliocene sediments localized over highs on the surface of the Tampa or Suwannee limestones. Note (pl. 7) the closed contours, hills and basins east and northeast of Tampa, and the continuity of the structural high across the upper Hillsborough River. This high matches well the present Lakeland ridge and Dade City highlands.

These hills are apparently part of the belt of Miocene clay and sands which lies around the flanks of the Ocala uplift. In this area this belt has been breached by the Hillsborough-Withlacoochee River systems.

In detail, the persistence of some of these remnants of clay and sand may be due to their originally lower carbonate content, and resultant higher resistance to weathering and erosion. Possibly this original deficiency of carbonate can be explained by the site of deposition. As pointed out by Trask (1932, p. 93, 125) fine material and carbonates tend to be more abundant in deposits of submarine basins, while coarser material and less carbonate are deposited on submarine ridges and hills. The submarine topography (irregularities in the surface of the Tampa limestone) in Hawthorn time could have caused deposition of fine material and carbonate in the valleys, and coarser material with less carbonate upon the hilltops and ridges.

Some of the relief, particularly in the area northeast of Tampa, probably is due to solution depressions and sinkholes. Drill hole G7 (fig. 8) shows that very deep sinkholes exist in this area. Small-scale faulting may also be responsible for some of the features. Vernon (1951, pl. 2) shows a structural high on the Inglis member of the Moodys Branch formation which approximates the location of the Lakeland ridge.

Two good exposures, localities 6 and 13, show some of the minor structural features and details of distortion in this area (figs. 13, 15, 16). This minor deformation is due to solution of limestone and slumping of the overlying beds.

Sedimentary history

Suwannee limestone

The Suwannee limestone represents a period like that of the Ocala limestone, during which conditions promoted deposition of a pure limestone with only traces of very well-sorted clastic material. Marine mollusks and foraminifera flourished in the Suwannee sea and their remains locally comprise a large part of the formation.

The lower part of the Suwannee limestone in the Davison Well (p. 27) is somewhat anomalous to the rest of the formation, but it is not known whether the lithology represented there is a result of a local or regional variation in deposition.

A quiet marine environment in warm waters of shallow to moderate depth is indicated for the Suwannee limestone.

Tampa limestone

The beginning of the Miocene brought a distinct change in sedimentation, both in environment and source area. Throughout the Eocene and Oligocene very little sand and clay had been supplied to the sediments. In west-central Florida the beginning of

Tampa deposition, however, is marked by beds of calcareous or dolomitic clayey sand and clay which accumulated locally in the western Polk County and Tampa areas. At the same time, and apparently throughout the early Miocene, islands, estuaries, and fresh-water lakes became prevalent. From the fossil distribution chart (pl. 5) it may be seen that the Tampa contains land and fresh-water fauna at several localities which range from the base to near the top of the formation. These localities also show a wide areal distribution, but most of them are in the vicinity of Tampa and the Gulf Coast.

The clay mineral, attapulgite, found in parts of the Tampa limestone may indicate a specific type of depositional environment. According to Millot (1952, p. 110, 113), "attapulgites apparently are found only in special environments of the basic lake series." The association of attapulgite with illite and with land and fresh-water fauna and montmorillonite clays in the Tampa therefore suggests a near-shore lagoonal or estuarine environment alternating or associated with basic lakes. The latter were not necessarily undergoing dessication, however. This premise agrees well with the faunal characteristics of the formation.

Thus, the environment of the Tampa limestone was one of varied and shifting conditions. The water was shallow; islands and lagoons were common and persisted until nearly the end of Tampa deposition. Increased activity of ocean currents and the irregularity of the sea floor were probably responsible for transfer and localization of clastic materials. Pure limestones accumulated in local areas of fresh water lakes. Probably minor weathering and erosion of the formation occurred in some areas while deposition was proceeding in others. As a result of these conditions the time-stratigraphic sequence of the Tampa is complex.

Hawthorn formation

Conditions which prevailed during most of early Miocene deposition began to change toward the close of Tampa time, and by Hawthorn time insular and lagoonal environments had given way to a more open marine setting as the Hawthorn sea transgressed.

The fauna of the Hawthorn formation consists almost entirely of mollusks which prefer moderately shallow water but avoid stagnant brackish conditions. Such an environment would require a free circulation of water over a broad relatively flat and stable sea bottom. Once established, these conditions must have remained stable for a long time, and they seem to have been especially conducive to the deposition of phosphate.

The source of the phosphorus in the waters of the late Tampa and Hawthorn seas is a question that cannot be conclusively answered at present, but the authors favor the theory of Kazakov (1938, summarized by McKelvey, and others, 1953, p. 55), in which chemical precipitation of phosphate is brought about by the upwelling of cold currents from deep ocean basins over a shelving platform such as the Florida peninsula. The hypothesis limits the precipitation of phosphate to a depth of water between about 150 and 650 feet.

Sand and clay of the Miocene

The petrographic data obtained in this study show clearly that the sediments of Miocene age contain much more sand, and clay and silt, than the rocks of Oligocene and Eocene age, and that the sand is coarser than that deposited previously. The sudden influx of these clastics in Miocene sediments, particularly limestones, of peninsular Florida is a problem because of the great distance to an obvious source of supply.

Some of the sand in the Miocene rocks of west-central Florida was doubtless derived locally from weathering and erosion of older rocks, and through weathering and reworking a gradual concentration of coarser particles was effected. This is suggested by the relatively consistent increase in grain size in beds of younger age from the Suwannee through the Hawthorn. That a few sand grains as large as those found in later formations exist in the older rocks is shown by the fifth percentile values.

Extra-local sources for most of the clastic material are indicated, however, by other evidence. For example, sand reworked from formation to formation should show better and better sorting if no new material were added. The data suggest that this is not the case, although sorting in all samples is very good. Furthermore, if a winnowing process occurred to remove more fine material for each succeeding formation, then the percentage of clay and silt should decrease with younger age, other conditions remaining constant. The opposite appears to be true (figs. 8, 9, 10 and table 8).

Berry (1916, p. 46) thought that the increase in supply of terrestrial material represented in northern Florida by Alum Bluff sedimentation was probably due to a rise of land inland. The only obvious means of transferring large quantities of sand into the Florida peninsular area, however, during the Miocene is through coastal movement of sand by longshore currents. This migration of sand would require a fairly continuous coastline or delta system extending some 400 miles from the site of deposition to source areas near the Piedmont of central Georgia and Alabama. The increase in the amount of garnet, staurolite, and other heavy minerals with the beginning of Miocene sedimentation tends to support this theory. This condition could have occurred in the early Miocene according to the paleogeography of Tampa time (Cooke, 1945, p. 112), but by mid-Hawthorn time such "land bridges" may have been inundated, cutting off the central peninsula from further supply of terrigenous material. However, no such impoverishment of clastics is indicated by the lithology of the Hawthorn formation.

The problem remains unsolved, but the writers point out that increase in clay and silt in the Miocene could be partly explained by a change in weathering conditions and the possibility of addition of clay-forming minerals by ash falls from distant volcanic activity. Grim (1933, p. 358) noted that in the fuller's earth deposits of the Superior Earth Co., Ocala, Fla., "many of the fragments of isotropic material, which have a maximum diameter of 0.12 mm, have a cellular structure suggesting that they are organic remains; others strongly resemble bubble and shard remnants of volcanic glass." Bramlette (1953) stated that "the high content of montmorillonite and attapulgite could perhaps be explained, however, as the alteration product of the relatively coarse fraction only of vitric pyroclastics that might thus have accumulated along with the quartz sand that is an important constituent of the Hawthorn dolomite." Numerous occurrences of pure, waxy, green attapulgite-montmorillonite clays were found by the authors (see p. 83, 91, 127) in the Miocene rocks of west-central Florida.

Summary of geologic history

The mid-Tertiary geologic history of this area may be summarized as follows: The Suwannee limestone was laid down in warm quiet waters over the eroded surface of the Ocala limestone. "Coarse" sandy limestone was deposited locally on this surface as the sea advanced and fragments of Eocene rocks were locally reworked into the base of the Suwannee. In eastern Polk County the Suwannee was thin and probably wedged out against the higher parts of this area. Near the close of the Oligocene, perhaps before deposition was completed in some areas, gentle uparching and minor faulting occurred along the axis of the Ocala uplift, bringing Oligocene and Eocene rocks adjacent to one another in some places. Erosion cut gentle valleys in the Suwannee limestone and removed most of the Suwannee that was present in the northeast half of Polk County. The Tampa sea then advanced over the erosion surface on rocks of

Oligocene and Eocene age, deposition beginning in some places with beds of clayey sand and clay. The deposits thinned to the north and east, but overlapped the Oligocene-Eocene contacts, and in some places probably spread beyond the limits of Oligocene deposition. Islands, lagoons, and fresh-water lakes followed the shifting shoreline. The greatest extent of the shallow Tampa sea covered most, if not all, of western peninsular Florida. Toward the end of Tampa time the island-lagoon environment began to give way to a more regular shoreline as the sea retreated. Probably at the close of Tampa time renewed movement occurred on the fault in Polk County, and erosion locally removed some of the thin Tampa sediments from the east side of the fault in northern Polk County. The Hawthorn sea then advanced over a slightly irregular surface depositing calcareous sands and clays near the shore and on the higher parts of the sea floor, and limestone elsewhere. As marine transgression continued, the Hawthorn sediments overlapped rocks from early Miocene to middle Eocene in age and a broad, relatively open seaway was developed in Polk and Hillsborough Counties. The Hawthorn accumulated slowly and conditions favorable to the deposition of phosphate persisted over a wide area for a long time. There may have been additions to the Miocene sedimentation by volcanic ash falls. Only minor adjustments in the structure occurred after the Hawthorn was deposited.

ECONOMIC GEOLOGY

Phosphate and uranium

Near-surface deposits of secondary phosphates containing concentrations of uranium are present around the northwest fringe of the land-pebble phosphate district in a narrow discontinuous belt which begins near the Alafia River northeast of Riverview and curves northeastward north of Plant City. Most of the uranium and phosphate deposits in this fringe area lie in the belt mapped (pl. 1) as Tampa limestone and sand and clay phases of the Hawthorn formation. Radiometric logs of core holes in this belt show (figs. 3, 4, 17) in places two zones or peaks of abnormal radioactivity. The upper zone, where present, is in the unit designated as undifferentiated sand and clay of Miocene to Pliocene age. The lower zone, not as well developed, usually is found at the top of the Tampa limestone.

At locality 44 and other places north and west of Plant City vesicular white sandstone, probably leached Hawthorn formation, contains abundant aluminum phosphate. A raw grab sample of this rock from locality 44 contained 0.008 percent equivalent uranium.[/]

[/] Laboratory no.: 115958

Some of the deposits of secondary phosphate, particularly in the lower zone, are associated with chert fragments.

Locally, where the two radioactive zones mentioned above are superimposed by weathering and downward migration of uranium, relatively high concentrations of uranium may exist within 10 or 15 feet of the surface. The aforementioned belt should be prospected if it becomes feasible to utilize deposits of uranium of the leached zone type which have thin overburden and are not underlain by economic phosphate deposits.

Two zones of phosphate and uranium also occur in the Dade City highland area - an upper zone near the base of the Hawthorn formation, and a lower zone near the base of the Tampa limestone. The upper zone, which is similar to the vesicular white sandstone of the aluminum phosphate zone in the land-pebble phosphate district, is 10 to 15 feet thick in drill holes G112 and 113 (fig. 4), and lies about 100 feet above sea level. The lower zone, which consists of lenses of massive, white, slightly uraniferous phosphate, chiefly colloidal apatite similar to the hardrock phosphate occurring farther north, is 5 to 10 feet thick in holes G110, 111, 112, and 113, and ranges from 80 to 50 feet above sea level. One exposure, locality 64, of this hardrock type phosphate was found southwest of Dade City at an elevation of about 120 feet. A raw grab sample of this rock was 70 percent soluble in hydrochloric acid, and contained 26.9 percent P_2O_5, 37.3 percent CaO, but only 1.9 percent Al_2O_3.[/] The uranium content was negligible.

/ Laboratory no.: 115969

The limestone of the Tampa and Hawthorn formations contains only sparse phosphate nodules and traces of uranium, except in the land-pebble district where a concentration has been effected by weathering of the Hawthorn formation.

Limestone and dolomite

Analyses suggest that there are, in the land-pebble phosphate district, deposits of dolomite as high grade as those now mined in Manatee and Sarasota Counties. The possibility of recovering some of the bedrock as a byproduct of phosphate mining deserves further investigation.

Every sample of limestone of the Hawthorn formation analyzed contained at least 9 percent MgO. Many of the samples are bedrock from the bottoms of phosphate pits. The average MgO content of 16 grab samples of Hawthorn limestone from phosphate mines was 15.8 percent. These mines include Sydney (loc. 39), Eleanor (loc. 41), Saddle Creek (loc. 74), Pauway (loc. 75), Achan (loc. 76), Noralyn (loc. 78), Clear Springs (loc. 79), Varn (loc. 80), Watson (loc. 81), and Peace Valley (loc. 82), and an old pit (loc. 77) near Bartow.[/] Samples from Sydney, Watson, and Peace Valley mines

[/] Laboratory nos.: loc. 39: 115952, 115953, 115954; loc. 41: 115955, 115956; loc. 74: 115974; loc. 75: 115976; loc. 76: 115977; loc. 78: 115980; loc. 79: 115982; loc. 80: 115983; loc. 81: 115984; loc. 82: 115985, 115986; loc. 77: 115978, 115979.

contained an average of 17.5, 19.9, and 17.5 percent MgO respectively. Composite samples of rock mined at two dolomite quarries in Manatee and Sarasota Counties contained 17.3 and 18.5 percent MgO.[/]

[/] Laboratory nos.: 115994, 115993.

There are no deposits of lime of present economic value in the area mapped. Hawthorn limestone is too thickly covered and generally too impure. The Tampa limestone contains some pure lime beds, but these zones are discontinuous and thin. The Suwannee is a relatively pure limestone but in this area it contains considerable chert.

APPENDIX

Lithologic logs of core holes

Drill holes G1 through G17 were logged by Carr and Alverson; holes G105 through 114 were logged by K. B. Ketner, and hole G115 was logged by R. G. Petersen. The latter logs were interpreted by the writers, however. The formational contacts were picked primarily on the basis of lithology.

In the lithologic description, the primary constituent is given first, followed by modification. Contacts between the units are gradational, unless otherwise specified. Terms denoting abundance of constituents, as used in these logs, are defined below.

trace, very slightly:	less than 1 percent
sparse, sparsely, slightly;	1 to 10 percent
no modifier:	10 to 20 percent
abundant:	20 to 50 percent
very:	greater than 20 percent
very abundant:	greater than 50 percent

Log of core hole G1, SE$\frac{1}{4}$, SE$\frac{1}{4}$ sec. 17, T. 28 S., R. 22 E.,

Hillsborough County, Florida

Elevation 120 feet

Depth, Ft.-in.	Lithology
	Quaternary
0-0 to 5-0	Not cored.
5-0 to 5-8	No recovery.
5-8 to 6-8	Sand, tan, medium-grained.
6-8 to 9-1	No recovery.
	Undifferentiated Pliocene-Miocene
9-1 to 18-9	Sand, light tan to gray, medium-grained, slightly clayey, containing sparse lumps of sandstone cemented by aluminum phosphate.
18-9 to 19-5	Sand, white, medium-grained, slightly clayey, interlensing with clay, light green, very slightly sandy, laminated.
	Middle Miocene, Hawthorn formation
19-5 to 22-7	Clay, very slightly sandy, light green to light brown.
22-7 to 22-11	Sand, light gray, slightly clayey, interlensing with clay, light green, both containing trace of phosphate nodules.
22-11 to 25-2	Clay, light green, mottled light red- to yellow-brown, very slightly sandy at top, laminated.
25-2 to 26-3	Clay, gray-green to yellow-green, slightly sandy to sandy, laminated, containing 5 percent silt-size black grains.

26-3 to 32-10	Clay, yellow-gray, very slightly sandy, slightly calcareous; lower contact sharp.
32-10 to 34-2	Sand, light gray, medium-grained, calcareous, containing sparse phosphate, amber, sand-size.
34-2 to 37-3	Sand, light gray, fine- to medium-grained, containing sparse phosphate, amber, sand-size, and trace of silt-size black grains.
	Lower Miocene, Tampa limestone
37-3 to 37-9	No recovery.
37-9 to 41-9	Sand, gray-green, fine-grained, clayey, slightly calcareous at bottom, containing trace to sparse phosphate, tan and amber, sand-size, and chert fragments.
41-9 to 43-6	No recovery.
43-6 to 44-1	Clay, slightly sandy, slightly calcareous, containing sparse phosphate, amber and gray, sand-size.
44-1 to 44-5	Limestone, very slightly sandy, soft, containing abundant hard fragments, and trace (?) of phosphate (?).
45-5 to 45-11	Limestone, white to light gray, slightly sandy and clayey, containing fragments of clay, rounded, calcareous, and trace of phosphate (?).

Log of core hole G2, SW¼, NE¼ sec. 5, T. 28 S., R. 22 E.,

Hillsborough County, Florida

Elevation 105 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 5-0	Not cored.
5-0 to 7-1	Sand, brown to light brown, slightly clayey, medium-grained, iron-stained.
7-1 to 7-4	No recovery.
	Undifferentiated Pliocene-Miocene
7-4 to 12-1	Sand, tan to light green-gray, slightly clayey to clayey, medium- to fine-grained, containing thin lenses of clay, light green, slightly sandy, and trace to sparse phosphate, white, sand-size; lower contact sharp.
	Middle Miocene, Hawthorn formation
12-1 to 14-7	Clay, gray, mottled brown, slightly sandy, containing thin lenses of sand, gray to white, slightly clayey, containing trace of phosphate (?).
14-7 to 15-2	Sand, gray-green to gray, medium- to fine-grained, clayey, containing trace of phosphate, white.
	Lower Miocene, Tampa limestone
15-2 to 17-11	Clay, gray-yellow, slightly sandy to sandy, containing chert fragments coated with tripoli or white phosphate; lower contact sharp.
17-11 to 21-8	Limestone, light gray to light tan, slightly iron-stained, clayey, slightly sandy, soft to hard at base, containing seams and fragments of clay, green, [illegible]

Log of core hole G3, NE$\frac{1}{4}$, SE$\frac{1}{4}$ sec. 31, T. 27 S., R. 22 E.,

Hillsborough County, Florida

Elevation 100 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 7-2	No recovery.
	Undifferentiated Pliocene-Miocene
7-2 to 20-6	Sand, light gray, medium- to fine-grained, very slightly clayey, well-sorted.
20-6 to 22-0	Sand, light gray, fine-grained, clayey, containing abundant fragments of sandstone cemented by aluminum phosphate; lower contact sharp.
	Middle Miocene, Hawthorn formation
22-0 to 29-6	Clay, gray, mottled red-brown, very slightly sandy, containing trace to sparse phosphate, fine sand-size, white; lower contact sharp.
29-6 to 31-4	Sand, very light gray, slightly iron-stained at top, medium-grained, slightly clayey, containing fragments of sandstone cemented by aluminum phosphate, and trace of phosphate, white, soft.
31-4 to 32-6	Clay, gray, slightly sandy to sandy, containing trace of phosphate, white; lower contact sharp.
32-6 to 37-7	Sand, gray, locally iron-stained, slightly clayey to clayey, medium- to fine-grained, containing sandstone fragments cemented by aluminum phosphate.
37-7 to 41-4	Clay, gray-green, silty (quartz), interlaminated with silt, clayey, containing trace of phosphate, white, and trace of silt-size heavy minerals (?).

Lower Miocene, Tampa limestone

41-4 to 48-6	Poor recovery; probably sand, white, medium-grained, with thin beds of sand, yellow-brown, very clayey.
48-6 to 52-5	Clay, light gray-green, iron-stained, slightly sandy to sandy, laminated, containing twig-like fragments of silica.
52-5 to 58-9	Sand, white, fine-grained, very slightly clayey, interlensing with clay, green, sandy; unit contains heavy minerals.
58-9 to 67-7	Poor recovery; probably a lens of sand, white to red-brown, fine-grained, very slightly clayey, containing visible heavy minerals.
67-7 to 69-10	Poor recovery; probably sand, white, slightly clayey, fine-grained, with thin lenses of sand, gray, clayey, containing hard white fragments with casts and molds of small mollusks.
69-10 to 74-6	No recovery; probably the same as 67-7 to 69-10.
74-6 to 76-6	Sand, light gray to tan, fine-grained, slightly clayey to clayey, containing thin layer of light gray chert, and visible heavy minerals.
76-6 to 78-6	No recovery; probably same as 74-6 to 76-6.
78-6 to 79-6	Limestone, white to light tan, very slightly to slightly sandy, clayey, interlensing with clay, yellow-brown, very calcareous, laminated.
79-6 to 81-0	Limestone, white, hard, very pure, containing casts and molds of mollusks, Helisoma sp.

Log of core hole, G4, NW¼, SE¼ sec. 19, T. 27 S., R. 22 E.,

Hillsborough County, Florida

Elevation 95 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 5-0	Not cored.
	Undifferentiated Pliocene-Miocene
5-0 to 19-4	Sand, light gray to tan, medium- to fine-grained, locally iron-stained, containing trace to sparse phosphate, white, fine sand-size, small patches of white aluminum phosphate, and trace of heavy minerals.
	Middle Miocene, Hawthorn formation
19-4 to 23-0	Clay, light blue to gray-blue and violet, slightly sandy to sandy, containing abundant irregular fragments of soft limestone, and patches of fine- to medium-grained quartz sand.
	Lower Miocene, Tampa limestone
23-0 to 24-7	Clay, as in 19-4 to 23-0, but laminated, containing trace of fine fragments of limestone, phosphatized (?), and fragments of brown chert.
	Oligocene, Suwannee limestone
24-7 to 24-11	No recovery; possibly a chert layer.
24-11 to 26-10	Limestone, white, hard, pure, porous, containing *Phacoides* (*Miltha*), sp. aff. *p.* *chipolanus* Dall, *Turritella*, n. sp. (?), *Turritella*, sp. aff. *T.* *bowenae* Mansfield, and *Kuphus* *incrassatus* (Gabb).

Log of core hole G5, SE$\frac{1}{4}$, SW$\frac{1}{4}$ sec. 7, T. 27 S., R. 22 E.,

Hillsborough County, Florida

Elevation 80 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 5-0	Not cored.
5-0 to 5-4	Sand, dark brown, medium-grained; lower contact sharp.
5-4 to 18-5	Sand, very light gray to tan, fine-grained, very slightly to slightly clayey; intervals of no recovery.
18-5 to 28-3	Sand, gray to light gray, medium- to fine-grained, slightly clayey to clayey.
28-3 to 28-6	Clay, gray, trace of very fine sand.
28-6 to 29-10	Sand, light gray, medium-grained, slightly clayey.
29-10 to 32-1	No recovery.
32-1 to 34-11	Sand, white, fine-grained.
34-11 to 38-4	Sand, dark brown, fine-grained.
38-4 to 41-5	No recovery.
41-5 to 50-10	Sand, dark brown, fine- to medium-grained, slightly clayey; intervals of no recovery.
50-10 to 57-4	Sand, gray, fine-grained, slightly clayey; intervals of no recovery.
57-4	No recovery; probably Suwannee chert.

Log of core hole G6, SE$\frac{1}{4}$, NW$\frac{1}{4}$ sec. 35, T. 28 S., R. 21 E.,

Hillsborough County, Florida

Elevation 120 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 6-0	Not cored, no recovery.
6-0 to 7-0	Sand, red-brown, fine-grained, very slightly clayey.
7-0 to 8-7	No recovery; probably sand.
8-7 to 13-6	Sand, light to very dark brown, fine- to medium-grained, containing black organic material at base; lower contact sharp.
	Undifferentiated Pliocene-Miocene
13-6 to 17-1	Sand, light gray to light brown, fine-grained, clayey, locally iron-stained.
17-1 to 18-5	No recovery.
18-5 to 22-4	Sand, light yellow-brown, medium- to fine-grained, slightly clayey, containing indurated lumps of sandstone at top; lower contact sharp.
22-4 to 23-2	Sand, light tan, medium- to fine-grained, containing trace of small indurated fragments.
23-2 to 24-9	Clay, light gray to tan, very sandy to sandy, containing trace of phosphate, white, soft, coarse sand-size.
24-9 to 32-9	Sand, light gray, medium-grained, very clayey to clayey, containing trace of phosphate, white, soft, coarse sand-size, and sparse sandstone fragments cemented by aluminum phosphate.
32-9 to 42-1	No recovery.

42-1 to 44-10	Clay, green-gray, very slightly to slightly sandy, laminated, containing silicified (?) shell fragments, abundant thin lenses of sand, fine-grained, and abundant fragments of sandstone cemented by silica; lower contact sharp.
44-10 to 48-4	Sand, light gray, very fine-grained to medium-grained at top, clayey to slightly clayey, containing abundant thin lenses of clay, green, very slightly sandy.
48-4 to 55-3	Clay, very slightly sandy (very fine-grained), laminated with sand, light gray to pink, fine-grained, containing abundant heavy minerals.
55-3 to 57-11	Sand, light gray, very fine-grained, slightly clayey to clayey, interlensing with clay, blue-green, slightly sandy to very slightly sandy, containing trace of phosphate, tan, hard and soft, very coarse sand-size at base.
	Middle Miocene, Hawthorn formation
57-11 to 60-5	Clay, blue-green, very slightly sandy, containing sparse laminae of sand, fine-grained, and trace of phosphate, tan, coarse sand-size at top.
60-5 to 67-7	Claystone, yellow- to olive-green, containing a few lenses of clay, blue-green, sandy, and pellets of light gray material, possibly phosphate; lower contact sharp.

67-7 to 75-4 Sand, tan, fine- to medium-grained, clayey, containing abundant lenses of sand, gray-green, very clayey, fine-grained, and sparse phosphate, black and tan, very coarse sand- to granule-size; at 74-4 a few fragments of sandstone cemented by aluminum phosphate.

75-4 to 75-9 Sand, blue-green to olive-green, fine- to coarse-grained, clayey to very clayey, containing large fragments of chert, black and brown, and trace of phosphate, black, sand-size, and silicified shell fragments at base.

Log of core hole G7, SE$\frac{1}{4}$, SE$\frac{1}{4}$ sec. 21, T. 28 S., R. 21 E.,

Hillsborough County, Florida

Elevation 90 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 5-0	Not cored.
5-0 to 17-2	Sand, gray to light brown, slightly iron-stained, medium- to fine-grained, very slightly to slightly clayey, locally indurated; many intervals of no recovery.
17-2 to 27-6	Sand, white to light gray-brown, medium-grained, slightly clayey in places, containing sparse thin lenses of clay, light blue, sandy.
27-6 to 40-9	Poor recovery; probably sand, light yellow-brown to violet-brown and white, medium- to fine-grained, very slightly clayey.
40-9 to 44-11	Poor recovery; probably sand, gray-brown to violet-brown, fine- to medium-grained, very slightly clayey.
44-11 to 58-9	Sand, light brown to gray, fine- to medium-grained, slightly clayey, containing trace of indurated fragments, and thin lenses of sand, gray-blue, clayey.
58-9 to 107-1	Sand, light tan to gray and violet-brown, medium- to fine-grained, very slightly to slightly clayey, containing abundant indurated fragments, and, at base, carbonaceous material, brown to black.

107-1 to 110-9	Wood, black and brown, carbonized in sand, black, medium-grained, very slightly clayey.
110-9 to 128-1	Sand, black, medium-grained, very slightly clayey; many intervals of no recovery.
128-1 to 131-1	Sand, black to brown, medium-grained, slightly clayey to clayey.
	Undifferentiated Pliocene-Miocene
131-1 to 137-5	No recovery.
137-5 to 150-5	Sand, brown to black, fine to very fine-grained, very clayey to clayey, laminated, containing organic material, sparse phosphate, brown, pebble-size, and marcasite replacing phosphate and clay.

Log of core hole G8, $SW\frac{1}{4}$, $SW\frac{1}{4}$ sec. 8, T. 28 S., R. 21 E.,

Hillsborough County, Florida

Elevation 65 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 10-9	No recovery.
	Undifferentiated Pliocene-Miocene
10-9 to 12-9	Sand, very light gray, medium- to coarse-grained, slightly clayey, containing trace of clay, white, probably phosphatic.
12-9 to 14-0	No recovery.
14-0 to 15-6	Sand, light gray, medium- to fine-grained, slightly clayey to clayey, containing sparse fragments of sandstone cemented by aluminum phosphate; lower contact sharp.
15-6 to 20-1	Clay, light gray to green-gray, very slightly to very sandy (medium-grained), containing aluminum phosphate and sparse phosphate, white, soft, very coarse sand- to granule-size.
20-1 to 27-6	Sand, very light gray to tan, fine- to very fine-grained, very clayey to clayey, containing aluminum phosphate and sparse phosphate, white, soft, coarse sand- to granule-size.
27-6 to 33-11	Sand, white to very light gray, fine- to medium-grained, slightly clayey, containing sparse phosphate, white, soft, sand-size.

Middle Miocene, Hawthorn formation

33-11 to 38-11	Clay, light tan to gray, sandy to very sandy (fine- to medium-grained), containing abundant fragments of white aluminum phosphate and light brown sandy clay.
38-11 to 41-5	Sand, light gray, fine-grained, very clayey, containing abundant fragments of aluminum phosphate.
41-5 to 43-0	Sand, light gray to light blue-gray, fine-grained, slightly clayey, containing sparse sandstone fragments cemented by aluminum phosphate.
43-0 to 46-0	Sand, gray-green to gray-blue mottled, fine-grained, very clayey, containing sparse thin lenses of sand, white, medium-grained.
46-0 to 47-2	Clay, pinkish-tan, very sandy, and sand, fine-grained, very clayey, slightly calcareous, interlaminated with clay, green-gray, sandy; lower contact sharp.

Lower Miocene, Tampa limestone

47-2 to 47-5	Tripoli, white, containing Helisoma sp.
47-5 to 48-3	Limestone, gray-blue, clayey, very sandy to sandy, containing fragments of clay, light tan, slightly calcareous.
48-3 to 50-0	Limestone, light tan to gray-green, clayey, containing trace of very fine-grained sand, and fragments of limestone, tan, soft, and, at base, claystone and sandstone containing phosphate, black to brown, sand-size; lower contact sharp.

50-0 to 51-6	Sand, light-gray, fine-grained, slightly clayey to clayey, containing abundant fragments of limestone, weathered, and abundant sand, black, very fine-grained; lower contact sharp.
51-6 to 51-10	Clay, very light green-gray and tan, slightly sandy to sandy, containing sparse thin lenses of sand, white.
51-10 to 53-1	Sand, gray and streaked with yellow-brown, clayey to very clayey, containing abundant small fragments of tripoli and weathered limestone.

Log of core hole G9, NE¼, SW¼ sec. 6, T. 28 S., R. 21 E.,

Hillsborough County, Florida

Elevation 50 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 5-5	Not cored, no recovery.
5-5 to 10-1	Sand, dark brown to light tan, fine- to medium-grained, slightly indurated, very slightly clayey.
	Undifferentiated Pliocene-Miocene
10-1 to 17-7	Poor recovery; probably sand, tan.
17-7 to 21-9	Sand, brown-gray, medium- to fine-grained, containing at base sparse fragments of sandstone cemented by aluminum phosphate.
21-9 to 23-9	Clay, gray to light green-gray, very sandy to sandy, and sand, very clayey, containing abundant small fragments of clay, hard, phosphatic (?), and sandstone cemented by aluminum phosphate.
23-9 to 27-0	Poor recovery; probably sand, tan to gray-green, fine-grained, slightly clayey.
	Middle Miocene, Hawthorn formation
27-0 to 28-7	Clay, gray-green, very slightly sandy to pure.
28-7 to 33-7	Sand, light to dark gray-green, medium-grained, very clayey, and clay, very sandy, containing abundant fragments of sandstone cemented by aluminum phosphate; lower contact sharp.
	Lower Miocene, Tampa limestone
33-7 to 36-9	Sand, tan, fine- to very fine-grained, very slightly clayey.

36-9 to 38-5	Sand, light gray-green, fine-grained, clayey to very clayey, containing abundant thin lenses of sand, white.
38-5 to 43-1	Clay, gray to blue-gray and gray-green, slightly sandy to pure, containing thin lenses of sand, white, very fine-grained, and abundant fragments of tripoli, white, with unidentifiable casts and molds of gastropod; lower contact sharp.
43-1 to 47-7	Clay, light gray, sandy, containing lenses of clay, gray-green, pure, and very abundant fragments of tripoli, chalcedony, and weathered limestone; lower contact sharp.
47-7 to 48-11	Clay, blue-green, containing abundant fragments and lenses of clay, soft, slightly calcareous; lower contact sharp.
48-11 to 51-0	Clay, same as 43-1 to 47-7.
51-0 to 52-8	Clay, blue-green to light tan, slightly calcareous, containing abundant fragments of limestone, weathered.
52-8 to 53-6	No recovery; probably sand.
53-6 to 55-6	Clay, light gray to olive- and blue-green, very calcareous, containing abundant fragments of soft limestone and thin clay seams.
55-6 to 55-10	No recovery; probably sand.
	Oligocene, Suwannee limestone
55-10 to 59-10	Limestone, white to light tan, trace of sand, containing, at top, thin lenses and fragments of clay, blue-green, slightly calcareous; fossils: *Sorites*, *Peneroplis*, *Chlamys* sp. cf. *C. brooksvillensis* Mansfield, and Kuphus incrassatus (Gabb).

Log of core hole G10, NW$\frac{1}{4}$, SE$\frac{1}{4}$ sec. 7, T. 29 S., R. 21 E.,

Hillsborough County, Florida

Elevation 60 feet

Depth, ft.-in.	Lithology
0 to 9-2	Quaternary
0-0 to 9-2	Not cored, no recovery.
	Undifferentiated Pliocene-Miocene.
9-2 to 14-11	Clay, light gray-green to gray, very to slightly sandy, containing sparse to abundant phosphate, white, soft, sand- to pebble-size.
14-11 to 16-2	Clay, light gray-green to white, very slightly sandy, containing very abundant phosphate, white, soft, coarse sand-size, and a few fragments of sandstone cemented by aluminum phosphate.
	Middle Miocene, Hawthorn formation
16-2 to 24-2	Clay, yellow-green to light blue-green, very sandy to trace of sand in bottom, containing very thin lenses of sand, very fine-grained, calcareous, and sparse phosphate, white, soft, granule-size.
24-2 to 28-5	Clay, brown-green, very slightly sandy, laminated, iron-stained.
28-5 to 43-6	Clay, light gray-green to gray, very sandy, and sand, clayey, containing sparse phosphate, tan and black, coarse sand-size.
	Lower Miocene, Tampa limestone
43-6 to 48-4	Sand, light tan to very light gray-green, fine- to very fine-grained, heavily iron-stained at top; lower contact sharp.

48-4 to 56-3	Sand, tan to gray, very fine-grained, very to slightly clayey, and clay, very sandy, containing sparse fragments of claystone and sandstone with phosphate, black and brown, coarse sand-size, locally cemented by silica; lower contact sharp.
56-3 to 59-9	Sand, tan to gray, very fine-grained, very clayey, very slightly calcareous; lower contact sharp.
59-9 to 61-10	Limestone, light tan, soft, slightly sandy, clayey.
61-10 to 62-2	Limestone, yellow-brown, sandy (fine-grained), clayey, containing thin seams of clay, ssndy, green and brown, and, at base, abundant brown chert fragments; Charophyte oogonia (fresh-water plants).

Log of core hole G11, SE$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 35, T. 28 S., R. 20 E.,

Hillsborough County, Florida

Elevation 60 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 9-6	Poor recovery; probably sand, yellow-brown, medium- to fine-grained, very slightly clayey.
	Undifferentiated Pliocene-Miocene
9-6 to 13-1	Sand, light gray to yellow-brown, medium- to fine-grained, slightly clayey to clayey, containing, in lower half, abundant fragments of iron hardpan.
13-1 to 18-1	Sand, light gray to white, fine-grained, clayey, locally strong iron-staining, containing sparse patches of sand, white, poorly indurated, cemented by clay, phosphatic (?).
18-1 to 21-8	Clay, light gray to tan, sandy to very sandy (very fine-grained), heavily streaked by iron-staining, containing fragments of white claystone, phosphatic (?), and sparse phosphate, white, soft.
21-8 to 22-7	No recovery.
22-7 to 28-6	Sand, light gray to yellow-brown, fine- to very fine-grained, top clayey to very clayey, bottom very slightly clayey, iron streaked, containing visible heavy minerals, sparse poorly indurated patches of sand cemented by clay and aluminum phosphate, and a thin zone of iron-stained black carbonaceous material; lower contact sharp.

28-6 to 33-10 Clay, light gray to light yellow, variegated, slightly sandy, containing thin streaks and patches of black carbonaceous material, and a trace, at base, of phosphate, white, soft, coarse sand-size.

Middle Miocene, Hawthorn formation

33-10 to 35-1 Sand, light gray to brown, fine-grained, clayey, containing sparse thin lenses of sand, slightly clayey, and clay, white, slightly sandy, and a trace of phosphate, dark brown, granule-size.

35-1 to 36-1 Clay, light gray to white, slightly sandy.

Lower Miocene, Tampa limestone

36-1 to 39-0 No recovery; probably sand.

39-0 to 43-1 Clay, light yellow-green, slightly sandy to sandy, containing abundant fragments of limestone, slightly sandy, and sparse phosphate, black, granule-size; lower contact sharp; *Trigonocardia* sp., *Camerina* sp., *Sorites* sp.

43-1 to 46-11 Sand, light green to very light gray and white, fine-grained, slightly clayey to clayey, slightly calcareous; *Sorites* sp. and coral fragments.

46-11 to 50-0 Sand, light gray to white, fine-grained, slightly clayey to clayey, very calcareous, locally indurated; contains small barnacles, bryozoa, crab fragments, and mollusk molds, none identifiable.

Log of core hole G12, NE$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 27, T. 28 S., R. 20 E.,

Hillsborough County, Florida

Elevation 85 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 5-0	Not cored.
	Undifferentiated Pliocene-Miocene
5-0 to 6-10	Clay, gray, iron-streaked, laminated, very slightly to slightly sandy; lower contact sharp.
6-10 to 11-8	Sand, light green-gray, very fine-grained, clayey, interlaminated with clay, gray-green to orange, very sandy; lower contact sharp.
11-8 to 15-1	Sand, very light gray-green to tan, fine-grained, and clay, very sandy, containing abundant fragments of sand, lightly cemented by aluminum phosphate (?).
15-1 to 17-1	Clay, light green-gray, slightly sandy to sandy, interlaminated with sand, tan, medium-grained, clayey, containing sparse phosphate, white and tan, soft, coarse sand-size, and local cementation by aluminum phosphate.
	Middle Miocene, Hawthorn formation
17-1 to 19-6	Clay, light gray-green, iron-streaked, fine- to medium-grained, very sandy to sandy, laminated at top, containing abundant patches of black, probably carbonaceous material, and sparse small lenses of sand, tan, clayey with traces of aluminum phosphate (?).

19-6 to 21-7 Sand, tan to brown, fine- to medium-grained, clayey to very clayey, containing abundant thin lenses of clay, white, sandy, phosphatic (?), and a trace of phosphate, black, very coarse sand- to granule-size.

21-7 to 25-3 Sand, tan to light green-gray, fine- to medium-grained, at top laminated and iron-streaked containing abundant heavy minerals, and twig-like fragments of amber silica, and silicified gastropod shell fragments; lower contact sharp and probably irregular.

Lower Miocene, Tampa limestone

25-3 to 28-3 Sand, light gray-green to tan, fine-grained, very clayey, and clay very sandy, containing, at top and base, abundant fragments of limestone, pure, white, and visible heavy minerals.

28-3 to 30-5 Limestone, white, slightly sandy (fine-grained), slightly clayey, soft, containing sparse fragments of limestone, tan, dense, slightly sandy.

Log of core hole G13, SE$\frac{1}{4}$, NE$\frac{1}{4}$ sec. 20, T. 28 S., R. 20 E.,

Hillsborough County, Florida

Elevation 80 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 8-6	Poor recovery; probably sand, brown, fine-grained, very slightly clayey, containing abundant lumps of sand cemented by clay.
	Undifferentiated Pliocene-Miocene
8-6 to 14-0	Sand, yellow- and orange-brown to light gray, fine- to medium-grained, clayey, containing fragments of sandstone cemented by clay.
14-0 to 21-0	Clay, light green-gray to yellow-brown, trace to no sand, containing abundant fragments of sand cemented by aluminum phosphate, and claystone.
21-0 to 21-9	No recovery.
21-9 to 22-11	Sand, very light tan, fine-grained, clayey, containing thin lenses of clay, gray-green, sandy, and sparse phosphate, white, soft, coarse sand- to granule-size; lower contact sharp.
	Middle Miocene, Hawthorn formation
22-11 to 37-2	Clay, gray-green to mottled orange, very slightly sandy, containing trace of sandstone cemented by aluminum phosphate, and sparse laminae of sand, clayey.

Lower Miocene, Tampa limestone

37-2 to 42-5	Sand, light gray-green to mottled brown, fine- to medium-grained, clayey to very clayey, containing abundant fragments of limestone, white, leached, and tripoli, and a layer of sandstone, dark brown, iron-cemented, and trace of phosphate (?), fine sand-size.
42-5 to 44-5	No recovery.
44-5 to 51-0	Clay, light gray to very light green-gray, sandy to very sandy (very fine-grained), containing layers of fragments of weathered limestone in sand, and abundant laminae of sand, very fine-grained, and clay, light green, noncalcareous, and, at base, layer of chert, brown and white.
51-0 to 51-8	Limestone, white, slightly sandy (fine-grained), slightly clayey, soft, containing sparse grains brown carbonate; unidentifiable mollusks and forams.

Log of core hole G14, NW$\frac{1}{4}$, NW$\frac{1}{4}$ sec. 17, T. 28., S., R. 20 E.,

Hillsborough County, Florida

Elevation 60 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 5-0	Not cored.
	Undifferentiated Pliocene-Miocene
5-0 to 14-7	Poor recovery; probably sand, tan to light orange-brown.
14-7 to 27-9	Sand, tan and gray to light orange-brown, fine- to medium-grained, very slightly clayey to clayey.
27-9 to 28-10	Clay, light green-gray to very light orange, very slightly sandy, containing sparse small patches of sand, clayey, iron-cemented.
28-10 to 30-1	Sand, light green-gray, very slightly to slightly clayey.
	Middle Miocene, Hawthorn formation
30-1 to 31-5	Clay, light green-gray, patches and streaks of orange- and violet-brown and light gray, abundant fragments of sandstone cemented by aluminum phosphate.
	Lower Miocene, Tampa limestone
31-5 to 32-2	Sand, light green-gray mottled with orange-brown, medium- to fine-grained, very slightly clayey to clayey.
32-2 to 34-10	Clay, light gray-green and mottled orange-brown, very sandy to sandy, containing sparse lenses of sand, white, fine-grained, and abundant patches of clay, white, non-calcareous; lower contact sharp.

34-10 to 35-6	Sand, gray to orange brown, very slightly clayey; lower contact sharp.
35-6 to 36-9	Clay and sand like 32-2 to 34-10; lower contact sharp.
36-9 to 44-6	Limestone, white to light gray, slightly sandy to sandy, (fine-grained), slightly clayey, soft, containing fragments of limestone, white, hard, some partly silicified, and sparse thin lenses of sand, white and brown.

Log of core hole G15, $SW\frac{1}{4}$, $SW\frac{1}{4}$ sec. 4, T. 30 S., R. 20 E.,

Hillsborough County, Florida

Elevation 40 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 5-0	Not cored.
5-0 to 7-1	Sand, tan to white, medium- to fine-grained,
	Undifferentiated Pliocene-Miocene
7-1 to 13-10	Sand, light gray to tan mottled with light orange-brown, very slightly clayey.
13-10 to 14-8	Clay, gray, very slightly sandy, containing abundant small lenses of sand, white to light gray, with heavy minerals.
14-8 to 16-6	No recovery.
16-6 to 16-8	Clay, as in 13-10 to 14-8.
16-8 to 17-5	Sand, light gray to gray mottled orange-brown, very slightly to slightly clayey; lower contact sharp, irregular.
17-5 to 19-3	Clay, green, laminated with sand, gray, very slightly clayey, containing abundant fragments of sandstone, sand- to cobble-size, cemented by aluminum phosphate.
19-3 to 21-11	Clay, very light gray, very slightly to slightly sandy, containing abundant phosphate nodules, white, hard, coarse sand- to granule-size.

Middle Miocene, Hawthorn formation

21-11 to 39-9 Sand, very light gray, slightly iron-stained at base, very slightly clayey, containing abundant phosphate nodules, white, trace of black, sand-size.

39-9 to 40-9 Clay, very light yellow, very sandy to sandy, slightly calcareous; lower contact sharp.

Lower Miocene, Tampa limestone

40-9 to 46-11 Clay, dark red-brown to light-yellow-brown, sandy to very sandy, laminated, containing abundant fragments of hardpan, red-brown to black.

46-11 to 48-0 Clay, very light yellow, slightly iron-stained, slightly to very sandy, containing a lens of sand, light green-gray, clayey.

48-0 to 49-3 Limestone, white, slightly sandy, hard, very slightly clayey; *Murex* sp. cf. *M. trophoniformis* Heilprin, *Arca irregularis*, *cardium* sp. cf. *C. anclotense* Mansfield, *Anomalocardia penita*.

Log of core hole G16, SW¼, SW¼ sec. 18, T. 30 S., R 20 E.,

Hillsborough County, Florida

Elevation 25 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 5-8	Not cored, no recovery.
5-8 to 13-1	Poor recovery; probably sand, tan to dark brown, very fine- to medium-grained, very slightly clayey.
13-1 to 17-1	Sand, tan to dark gray-brown, fine-grained, slightly iron-stained, very slightly to slightly clayey; lower contact sharp.
	Undifferentiated Pliocene-Miocene
17-7 to 24-6	Clay, dark gray-green slightly sandy to sandy (very fine-grained), and sand, olive-green to tan, very fine-grained, slightly clayey, calcareous, containing sparse to abundant phosphate nodules, tan and black, soft, sand-to granule-size, heavy minerals, and sparse fragments of limestone, very light tan; lower contact sharp.
	Middle Miocene, Hawthorn formation
24-6 to 27-5	Limestone, light tan, very slightly sandy (fine- to medium-grained), very clayey, dolomitic (?), containing abundant lenses of clay, gray, calcareous, and sparse phosphate nodules, granule- and pebble-size; large <u>Ostrea</u> sp. and other mollusk fragments.

Log of core hole G17, NW$\frac{1}{4}$, SE$\frac{1}{4}$ sec. 13, T. 30 S., R. 19 E.,

Hillsborough County, Florida

Elevation 25 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 5-0	Not cored.
5-0 to 9-7	Sand, light brown at top, white in middle, light gray at base, medium- to fine-grained.
9-7 to 20-5	Sand, light gray-brown to dark gray, very fine- to fine-grained, very slightly clayey, containing organic material, black, clayey.
20-5 to 21-5	Clay, black, very slightly sandy, containing organic material.
	Undifferentiated Pliocene-Miocene.
21-5 to 26-0	Clay, dark gray to light gray-brown, slightly sandy, containing sparse fragments of limestone, leached, soft, and sparse phosphate nodules, tan, hard, sand- to pebble-size.
26-0 to 28-7	Clay, dark gray-green to light tan, slightly sandy, calcareous along partings, containing, at base, clay, green-gray with marcasite along fractures; lower contact sharp.
28-7 to 40-9	Clay, dark gray-green, slightly sandy to sandy (fine-grained), with abundant lenses of sand, olive-green to tan, very fine-grained, calcareous, containing sparse phosphate nodules, black and tan, sand- to granule-size, abundant heavy minerals, and sparse fragments of limestone, very light tan, rounded; lower contact sharp.

Lower Miocene, Tampa limestone

40-9 to 41-5	No recovery; probably sand.
41-5 to 45-5	Clay, light green-gray to light tan, sandy to very sandy, slightly calcareous, containing sparse fragments of poorly indurated sand cemented by clay, sparse small fragments of chert, gray, sparse phosphate nodules, black and brown, hard, pebble-size, and abundant heavy minerals.
45-5 to 48-6	Limestone, very light tan, sandy (fine-grained), slightly clayey, soft, containing a trace of phosphate nodules, fine sand-size; <u>Sorites</u> sp.

Log of core hole G115, NW$\frac{1}{4}$ sec. 31, T. 27 S., R. 24 E.,

Polk County, Florida

Elevation 140 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 4-0	Not cored.
4-0 to 5-7	Sand, tan to dark brown, fine-grained.
	Undifferentiated Pliocene-Miocene
5-7 to 12-10	Sand, light gray to white, fine-grained, very slightly clayey.
12-10 to 14-8	No recovery.
14-8 to 23-0	Sand, light gray to light brown, medium-grained, no clay to slightly clayey.
	Middle Miocene, Hawthorn formation
23-0 to 31-0	Sand, gray to white, medium-grained, clayey, containing sparse phosphate, tan, white, sand- to pebble-size.
31-0 to 36-1	Clay, light to dark brown, slightly sandy (medium-grained), slightly calcareous, containing sparse phosphate, brown, white, sand- to pebble-size.
	Lower Miocene, Tampa limestone
36-1 to 37-10	No recovery.
37-10 to 45-2	Clay, light to dark brown, slightly sandy (fine- to coarse-grained), locally very calcareous, containing sparse phosphate, brown, white, sand- to pebble-size.

Log of core hole G105, $S\frac{1}{2}$ sec. 18, T. 27 S., R. 24 E.,

Polk County, Florida

Elevation 170 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 5-0	Not cored.
5-0 to 8-0	Sand, light brown, medium-grained.
	Undifferentiated Pliocene-Miocene
8-0 to 9-0	Sand, light brown and gray, mottled, mediun-grained, slightly clayey to clayey.
9-0 to 14-0	No recovery; probably sand, loose.
14-0 to 15-0	Sand, tan and gray, mottled, fine- to medium-grained, slightly clayey.
15-0 to 34-0	Poor recovery; sand, gray to brown and gray, mottled, fine- to medium-grained, very slightly to slightly clayey.
	Middle Miocene, Hawthorn formation
34-0 to 37-0	Clay, brown to green-gray, trace of sand, very fine-grained.
37-0 to 41-0	Sand, green-gray, medium- to coarse-grained, very clayey, containing phosphate, tan, medium to coarse sand-size.
41-0 to 43-0	Clay, gray, slightly sandy (medium-grained), containing sparse phosphate, sand-size.
43-0 to 43-10	Sand, brown, medium- to coarse-grained, clayey, containing sparse phosphate, brown, medium to coarse sand-size.

43-10 to 45-0	No recovery.
45-0 to 46-6	Clay, green-gray, sandy (medium-grained), containing phosphate, dark brown to tan, sand- to pebble-size.
46-6 to 47-7	No recovery.
47-7 to 48-6	Sand, green-gray, medium to very coarse-grained, very clayey, slightly calcareous, containing phosphate, black, brown, medium to very coarse sand-size.
48-6 to 52-0	Clay, tan, very sandy (medium-grained), very calcareous, containing sparse phosphate, black, brown, medium to very coarse sand-size.
52-0 to 52-10	Limestone, white, very sandy (medium-grained), soft, containing sparse phosphate, black, brown, medium to very coarse sand-size.

Log of core hole G106, $W\frac{1}{2}$ sec. 1, T. 27 S., R. 23 E.,

Polk County, Florida

Elevation 135 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 4-0	Not cored.
4-0 to 20-0	Sand, tan, brown, to black, gray, medium- to fine-grained, clayey.
20-0 to 22-0	No recovery; probably sand, loose.
	Middle Miocene, Hawthorn formation
22-0 to 29-0	Sand, green to green-gray, fine- to medium-grained, clayey to very clayey, containing phosphate, tan, sand- to pebble-size.
29-0 to 31-0	Clay, green, sandy (fine-grained), containing sparse phosphate, tan, sand- to pebble-size.
	Lower Miocene, Tampa limestone
31-0 to 41-0	Clay, green to dark green, very slightly to very sandy (very fine-grained), containing trace of phosphate, tan.
41-0 to 43-0	Clay, dark green, very slightly sandy (very fine-grained), containing chert, black.
43-0 to 43-9	Sand, green-gray, very fine- to fine-grained, very clayey, slightly calcareous.
43-9	Limestone, white, very slightly sandy, soft.

Log of core hole G107, NW$\frac{1}{4}$, SE$\frac{1}{4}$ sec. 27, T. 26 S., R. 23 E.,

Polk County, Florida

Elevation 120 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 7-2	Not cored; no recovery.
	Middle Miocene, Hawthorn formation
7-2 to 12-0	Poor recovery; partly sand, dark gray, medium-grained, clayey.
12-0 to 14-3	Sand, blue-gray, medium-grained, clayey.
14-3 to 15-8	No recovery.
15-8 to 21-4	Clay, blue to green-brown, very slightly sandy, containing abundant chert.
21-4 to 22-4	Sand, green-gray, fine- to medium-grained, clayey to very clayey; lower contact sharp.
	Lower Miocene, Tampa limestone
22-4 to 23-0	Clay, blue, very slightly sandy.
23-0 to 26-0	No recovery.
26-0 to 28-0	Clay, blue, very slightly to slightly sandy (fine-grained), containing sparse chert.
28-0 to 31-5	No recovery.
31-5 to 33-5	Clay, blue-green, slightly sandy (very fine-grained), slightly calcareous, containing chert; *Terebra* sp., *Knefastia* sp., aff. *K. brooksvillensis* Mansfield, *Olivella* sp. cf. *O. posti* Dall, *Turritella atacta* Dall, *Architectonica* n. sp?, *Anadara latidentata* (Dall), *Chlamys* sp., *Cardium delphicum* Dall, *Callocardia* sp., *Pitar* sp., *Venus* sp., *Corbula* sp.

Log of core hole G108, SW¼ sec. 8, T. 26 S., R. 23 E.,

Polk County, Florida

Elevation 100 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 4-0	Not cored.
	Middle Miocene, Hawthorn formation
4-0 to 6-0	Sand, gray to brown, mottled, medium-grained, very clayey.
6-0 to 9-6	Sand, white to green-gray, fine- to coarse-grained, very clayey, containing fragments of sandstone, white, cemented by silica and aluminum phosphate (?).
9-6 to 10-2	Sand, tan, medium-grained, slightly clayey.
	Lower Miocene, Tampa limestone
10-2 to 12-0	No recovery.
12-0 to 14-0	Sand, green-gray, fine-grained, very clayey.
14-0 to 15-8	Clay, green-brown, sandy to very sandy, containing sparse chert.
15-8 to 17-0	No recovery.
17-0 to 19-4	Sand, green-gray, fine-grained, slightly to very slightly clayey.
	Oligocene, Suwannee limestone
19-4 to 44-8	Limestone, white, very slightly sandy, soft; *Turritella halensis* Dall, *Glycymeris suwannensis* Mansfield, *Divaricella* sp., *Pitar* sp., *Corbula* sp., *Myrtea* sp. cf. *M. taylorensis* Mansfield, *Eucrassatella* sp. cf. *E. paramesus* Dall, *Chlamys* sp. cf. *C. brooksvillensis* Mansfield, *Orthaulax hernandoensis* Mansfield, *Amauropsis*(?) sp., *Phacoides* sp., *Chione* sp. cf. *C. bainbridgensis* Dall, *Chione* sp., *Pitar* sp. cf. *P. heilprini* Mansfield, *Anatin* sp., *Venus* sp.

Log of core hole G109, $NW\frac{1}{4}$, $NW\frac{1}{4}$, sec. 1, T. 26 S., R. 22 E.,

Polk County, Florida

Elevation 95 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 4-0	Not cored.
	Middle Miocene, Hawthorn formation
4-0 to 6-10	Sand, gray to brown, mottled, medium-grained, clayey to very clayey.
6-10 to 9-0	Clay, sandy to very sandy (medium-grained), containing siliceous concretions.
	Lower Miocene, Tampa limestone
9-0 to 12-6	Sand, green-gray, fine-grained, clayey to very clayey, containing siliceous fragments.
12-6 to 15-3	Clay, gray, slightly sandy (fine-grained).
	Oligocene, Suwannee limestone
15-3 to 16-6	No recovery.
16-6 to 17-0	Sand, fine-grained, clayey.
17-0 to 26-4	Limestone, white, soft; Tritiaria n. sp?, Venus sp., Bryozoa, Barnea sp., Coskinolina floridana, Ostracods.

Log of core hole G110, SW¼, SW¼ sec. 27, T. 25 S., R. 22 E.,

Pasco County, Florida

Elevation 85 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 4-0	Not cored.
	Lower Miocene, Tampa limestone
4-0 to 7-0	Clay, gray, very sandy.
7-0 to 10-0	Sand, gray to tan, fine- to medium-grained, clayey.
	Oligocene, Suwannee limestone
10-0 to 14-0	No recovery.
14-0 to 19-6	Chert, white.

Log of core hole G111, NW$\frac{1}{4}$, SW$\frac{1}{4}$ sec. 20, T. 25 S., R. 22 E.,

Pasco County, Florida

Elevation 140 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 4-0	Not cored.
	Middle Miocene, Hawthorn formation
4-0 to 13-0	Poor recovery; partly sand, red-brown, fine- to medium-grained, very slightly clayey.
13-0 to 21-0	Sand, tan and gray, mottled, fine- to medium-grained, clayey.
21-0 to 64-5	Sand, white, fine-grained, very slightly clayey to clayey.
64-5 to 65-5	Sand, brown, medium-grained, very clayey, containing abundant fragments of sandstone cemented by aluminum phosphate.
	Lower Miocene, Tampa limestone
65-5 to 71-5	Clay, yellow-brown, very slightly sandy.
71-5 to 73-0	Sand, brown, fine- to medium-grained, very clayey.
73-0 to 91-6	Poor recovery, partly sand, gray and brown, mottled, fine-grained, clayey to very clayey, containing sparse fragments of sandstone cemented by aluminum phosphate.
91-6 to 95-5	Clay, yellow-brown and black, mottled, very slightly sandy, to very sandy.

95-5 to 96-3	Clay, white, slightly sandy, phosphatic.
96-3 to 99-0	Clay, brown, slightly sandy.
99-0 to 100-0	Clay, white, slightly sandy, hard, phosphatic.
100-0 to 101-0	Clay, tan to gray, white, banded, very sandy.

Oligocene, Suwannee limestone

101-0 to 101-3	Limestone, white and tan, mottled, slightly sandy, clayey, soft.

Log of core hole G112, SE$\frac{1}{4}$ sec. 13, T. 25 S., R. 21 E.,

Pasco County, Florida

Elevation 140 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 4-0	Not cored.
	Middle Miocene, Hawthorn formation
4-0 to 18-6	Sand, dark red-brown, fine- to medium-grained, slightly clayey.
18-6 to 22-4	Sand, brown, fine- to medium-grained, clayey, containing fragments of sandstone cemented by aluminum phosphate.
22-4 to 30-5	Sand, brown, gray, mottled and banded, fine- to medium-grained.
	Lower Miocene, Tampa limestone
30-5 to 48-0	Clay, green-gray, very slightly to very sandy (fine-grained).
48-0 to 52-9	Sand, light gray to light green-gray, fine-grained, very slightly clayey to clayey.
52-9 to 61-0	Clay, green-gray, white, brown, very slightly sandy to sandy (fine- to medium-grained), phosphatic.
61-0 to 67-0	Clay, brown to white, slightly to very sandy. phosphatic; _Glycymeris_ sp.
	Oligocene, Suwannee limestone
67-0 to 67-11	Limestone, white, very slightly sandy (very fine-grained), soft; _Peneroplis_ sp., _Asterigerina subacula floridensis_.

Log of core hole G113, NE$\frac{1}{4}$ sec. 14, T. 25 S., R. 21 E.,

Pasco County, Florida

Elevation 185 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 4-0	Not cored.
	Middle Miocene, Hawthorn formation
4-0 to 68-0	Sand, dark brown to light gray, mottled, fine- to medium-grained, very slightly to very clayey.
68-0 to 78-0	No recovery; probably sand, loose.
78-0 to 80-0	Clay, brown, very sandy (medium- to coarse-grained), containing fragments of sandstone cemented by aluminum phosphate.
80-0 to 82-5	Clay, brown, very slightly sandy.
82-5 to 87-0	Clay, brown, sandy (medium- to coarse-grained), containing abundant phosphate nodules, white, tan, sand- to pebble-size, and fragments of sandstone cemented by aluminum phosphate.
87-0 to 89-0	Sand, brown to black, fine- to medium-grained, very clayey.
	Lower Miocene, Tampa limestone
89-0 to 105-0	Sand, tan to light gray, mottled, fine-grained, very clayey.
105-0 to 111-0	No recovery.

111-0 to 114-6	Clay, green-gray to brown and white, very sandy, phosphatic.
114-6 to 116-1	Clay, white, slightly sandy (fine-grained), hard, brittle, phosphatic, encrusted with secondary phosphate.
	Oligocene, Suwannee limestone
116-1 to 134-9	No recovery.
134-9 to 138-7	Poor recovery; partly clay, green-gray and brown, very sandy.
138-7 to 144-3	Poor recovery; partly limestone, white, slightly sandy (very fine-grained); *Sorites* sp., *Asterigerina subacula floridensis*, calcareous algae.

Log of core hole G114, NE¼ sec. 22, T. 24 S., R. 21 E.,

Pasco County, Florida

Elevation 85 feet

Depth, ft.-in.	Lithology
	Quaternary
0-0 to 4-0	Not cored.
	Lower Miocene, Tampa limestone
4-0 to 11-6	Sand, white, fine-grained, clayey.
11-6 to 23-6	Clay, green-gray, brown, mottled, very sandy to sandy (fine-grained).
23-6 to 25-8	Clay, white, brown, mottled, sandy (fine-grained), phosphatic, containing chert and secondary phosphate crusts.
25-8 to 26-0	Limestone, white, tan, slightly sandy (fine-grained), soft, phosphatic.
	Oligocene, Suwannee limestone
26-0 to 30-0	Limestone, tan, slightly sandy (fine-grained), slightly phosphatic; Sorites sp., calcareous algae.

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