Stratigraphy of Middle Tertiary Rocks in Part of West-Central Florida

GEOLOGICAL SURVEY BULLETIN 1092

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By WILFRED J. CARR *and* DOUGLAS C. ALVERSON

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

By Wilfred J. Carr and Douglas C. Alverson

ABSTRACT

Petrographic studies of the Suwannee limestone (Oligocene), Tampa limestone (lower Miocene), and Hawthorn formation (middle Miocene) yielded data that are useful for correlation in a region where weathering has thoroughly altered the rocks. Mechanical analysis of sand aided in the recognition of formations in weathered exposures. An efficient laboratory method for insoluble-residue and mechanical analysis of sand was developed. Preliminary work indicates that the kind and distribution of heavy minerals, clay minerals, and chert should also be valuable in any further stratigraphic studies of this area.

Mapping of rocks of Oligocene and Miocene age in Hillsborough, Pasco, and Polk Counties has extended the known limits of the Tampa limestone northeastward; some of the sand and clay previously mapped as Hawthorn formation in northeastern Pasco County belongs to the Tampa. Sand of the Hawthorn formation is coarser than that of the Tampa limestone. Although phosphate nodules are not normally present in the Tampa, they are abundant in places, particularly in Polk County. A contact between calcareous and noncalcareous parts of the Hawthorn was mapped in northern Hillsborough and Polk Counties. More than 50 new localities were examined.

Structure contours on the base of the Hawthorn formation, and other evidence from well logs and surface exposures suggest an unconformity between the Tampa limestone and Hawthorn formation. A fault that brings rocks of Eocene age adjacent to the Suwannee and Tampa limestones is believed present in northwestern Polk County. The Suwannee limestone appears to be absent east of this structure.

Weathering in this part of Florida results in local concentration of iron, phosphorus, alumina, and silica. Secondary chert and aluminum phosphate zones form where the parent material is favorable. Leaching forms a weathering profile of increasing solubility downwards, which typically contains, from top to bottom, quartz sand, iron-stained clayey sand with chert and iron and phosphatic hardpans, blue-green sandy clay with local calcium phosphate nodules, and a thin zone of slightly calcareous clay passing abruptly into limestone. The presence of a substantial amount of secondary chert in a weathered section is believed to be evidence that limestone was formerly present. Crenulated bedding, common in weathered exposures in the area, is probably a result of solution of limestone and differential settling of the residue. The presence of weathering products such as chert and aluminum phosphate below beds of virtually unleached limestone suggests periods of intraformational weathering.

Zones consisting of material weathered from the Suwannee limestone are relatively thin and nonphosphatic, and there is a high proportion of clay to sand

and much chert. Material weathered from the Tampa limestone typically shows local silicification and contortion of bedding, and contains clayey residues that are generally low in phosphate. Residue of the Hawthorn formation is commonly phosphatic, lacks chert, and contains a few quartz sand grains that are conspicuously coarser than normal.

Fauna and petrography suggest a shifting lagoonal, insular, and locally fresh-water environment of deposition for the Tampa limestone. Open sea and relatively static conditions of sedimentation characterized Hawthorn time. The rather abrupt change in conditions of deposition from Oligocene to Miocene time, which resulted in an increase in amount and grain size of clastic material in rocks of Miocene age, can be ascribed to currents carrying material into the Florida peninsula from sources to the north, and possibly to ash falls from distant volcanic activity. 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.

Prolonged leaching of zones rich in calcium phosphate (apatite) produces in some areas a hardpan ("leached zone") that consists chiefly of relatively insoluble aluminum phosphate minerals (wavellite, pseudowavellite, and others) that commonly retain small amounts of uranium. In northeastern Hillsborough County, north and west of the boundaries of the land-pebble phosphate deposits, a belt was found that contains zones of aluminum phosphate which resulted from leaching of phosphatic beds, chiefly of the Hawthorn formation. These zones generally have a thin overburden and a moderate uranium content. Phosphate or uranium is not present in commercial quantities in unleached limestone of this area, but the upper surface of limestone of the Hawthorn 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 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 we have studied the stratigraphy of the formations, chiefly limestone, which underlie (or are closely associated with) the land-pebble phosphate deposits of west-central Florida. The unconsolidated residue and sediments above the limestone 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.

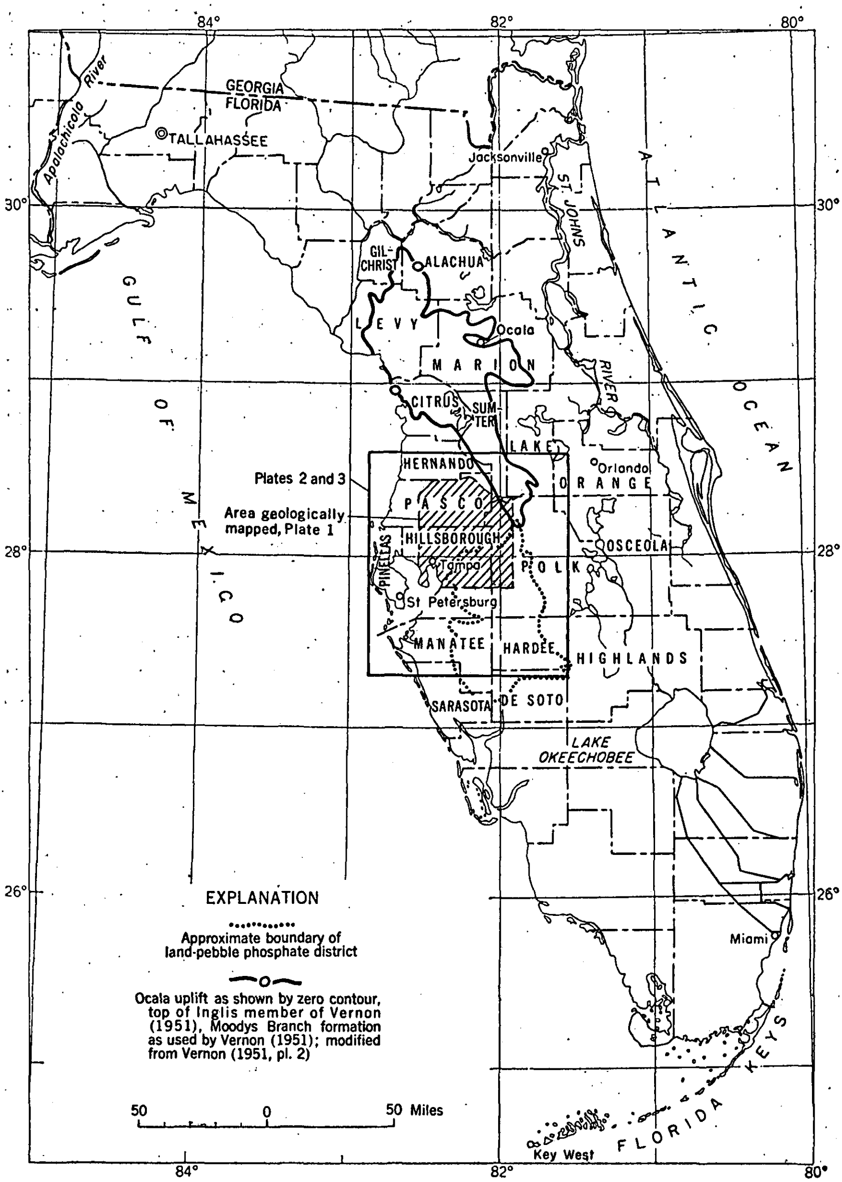

FIGURE 1.—Index map of peninsular Florida showing location of Ocala uplift, land-pebble phosphate district, and areas mapped and studied for this report.

To supplement surface observations holes were drilled with a power auger in critical areas, about 25 core holes drilled by a contractor 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 subordinate 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 have 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.

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 to 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 limestone, modified in some areas by dunelike 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 of the rivers, the Hillsborough and the 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; the Withlacoochee River rises in northern Polk County and flows west and north out of the area. These rivers are sluggish, swamp-bordered streams which have few rapids and are subject to reversal of flow by tides for distances of 5–10 miles from their mouths. In most places the rivers flow on limestone or chert bedrock. Only 9 feet of section is exposed at the thickest limestone outcrop in the mapped area. In most of the area the limestone bedrock is covered by 30–50 feet of unconsolidated sand and clay.

ACKNOWLEDGMENTS

We 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. C. B. Hunt, J. T. Hack, and all the members of the Southeastern Coastal Plains projects of the U.S. Geological Survey have contributed to an understanding of the geology of central Florida.

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

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—carbonate, clay, phosphate—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 cm (centimeter) in diameter. Enough crushed rock was used to provide at least 5 g (gram) of sand residue. The weighed sample was dissolved in a 4,000 ml (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 "milkshake" blender often used in sedimentary laboratories. The agitator revolves at very high speed and has large sharp blades 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 U.S. Standard 230-mesh 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, weighed, 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.

Noncalcareous samples consisted of quartz sand, silt, and clay; they were mostly unconsolidated and were easily disaggregated in the blender. The sand fractions of samples that 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 +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 [1] were determined from the curves.

About 10 representative samples from the +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 sample of sand 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 mm 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 100–300 g 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

[1] The fifth percentile value or P_5 is obtained from the cumulative curve, and is a sensitive measure of the proportionate amount of "coarse" sand in a sample. A P_5 of 0.15 means that 5 percent of the sand in the sample is as coarse, or coarser than, 0.15 mm.

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 limestone 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 Vicksburg. 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 his 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 his 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 Vernon's Inglis and Williston to formational status. He also listed distinctive faunizones for these formations.

Age and extent.—The Ocala limestone is late Eocene in age and is correlated with the Jackson group in 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 that runs 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.

General lithology.—The Ocala is a pure massive marine white to tan granular limestone, which is locally a porous friable coquinalike 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 4. 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 formations in contact with its top.

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 turritellid gastropods, are also abundant, but not as conspicuous as in the later formations.

OLIGOCENE ROCKS

SUWANNEE LIMESTONE

GENERAL FEATURES

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.

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. Limestone typical of the 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 the Suwannee extends to southern Florida, but it is missing from east-central peninsular Florida. In the area mapped the formation averages 150 feet thick; it is missing in eastern Polk County, but is about 300 feet thick near the gulf coast.

The best exposure of the Suwannee limestone visited by us in this area is at locality 62 (see pl. 2 for localities) 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 that is fairly soft and sometimes granular in appearance. It contains only a small percentage of very fine grained quartz sand, but locally it contains 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 nonmarine 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 Suwannee-Tampa 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 in the central part of the peninsula. 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. 2 and 3).

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 Corp. 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 that is called Suwannee on the basis of lithology and the presence at the top of the unit 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 limestone of the Suwannee analyzed from west-central Florida.

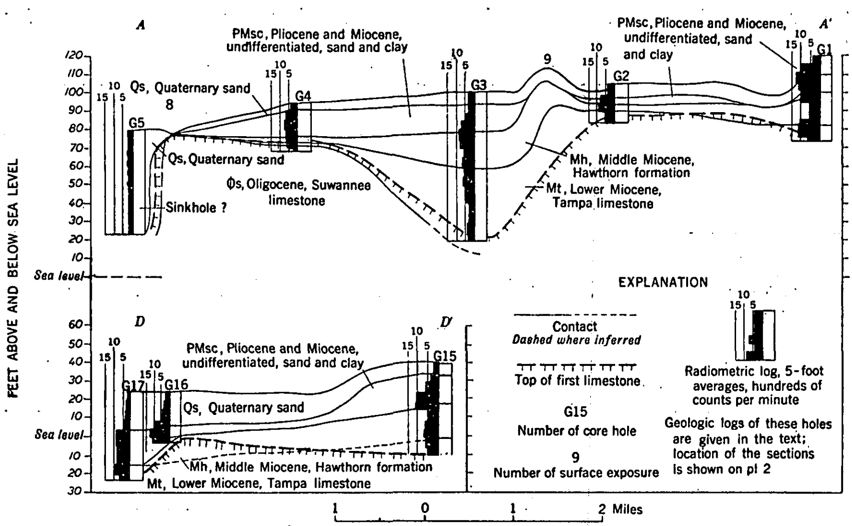

FIGURE 2.—Sections through core holes in northeastern and central Hillsborough County, Fla.

Fauna.—Mollusks and Foraminifera are both abundant in the Suwannee limestone. An echinoid, *Cassidulus gouldii* (Bouvé), is apparently diagnostic.

Fossils in the Suwannee limestone identified for this report are given in table 1.

Localities.—A list of exposures of the Suwannee limestone examined by us is given at the end of the report (p. 72). Some of these localities are new to the literature.

PETROGRAPHIC DETAILS

Examination of the Suwannee limestone under the microscrope shows that it is composed mostly of calcareous mollusk and foraminiferal detritus and 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 chert. 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.

TABLE 1.—*Distribution of fossils in the Suwannee limestone, west-central Florida*

[All fossils except those marked with asterisk (*) were identified by F. S. MacNeil; those marked with asterisk were identified by E. R. Applin. See plate 2 for localities.]

	County and locality No.[1]												
	Hillsborough				Pasco							Polk	
	40	46	G4	G9	63	65	67	70	G109	G112	G113	72	G108
Foraminifera:													
Sorites sp.		×		×		×		×			×		
Rotalia mexicana Nuttall*													×
Asterigerina subacuta floridensis Cushman*										×	×		
Coskinolina floridana Cole*									×				
Echinoidea:													
Cassidulus gouldii (Bouvé)	×				×	×							
Gastropoda:													
Cryoturris? cf. *C. hillsboroensis* Mansfield													×
Fusiturricula sp. aff. *F. silicata* Mansfield		×											
Murex sp.					×								
Orthaulax hernandoensis Mansfield							×						×
Ceritheum pascoensis Mansfield							×						
brooksvillensis Mansfield						×							
sp. cf. *C. suwanneensis* Mansfield							×						
sp. aff. *C. vaginatum* Dall							×						
Tritiaria n. sp.?									×				
Turritella bowenae Mansfield							×						
sp. aff. *T. bowenae* Mansfield			×										
sp. aff. *T. perduensis* Mansfield												×	
halensis Dall													×
n. sp.?			×										
sp.	×												
Ampullina sp.							×						
Amauropsis? sp.													×
Pelecypoda:													
Glycymeris suwanneensis Mansfield													×
sp.										×			
Anadara sp.		×											
Eucrassatella sp. cf. *E. paramesus* Dall													×
Chlamys sp. cf. *C. brooksvillensis* Mansfield				×									
liveoakensis Mansfield		×											
Anatina sp.													×
Venericardia sp.					×								
Phacoides sp. aff. *P. chipolanus* Dall			×										
sp.													×
Divaricella sp.													×
Trigonocardium gadsdenense Mansfield			×										
sp. cf. *T. gadsdenense* Mansfield						×							
sp. aff. *T. gadsdenense* Mansfield							×	×					
Cardium cf. *C. brooksvillense* Mansfield					×								
hernandoense Mansfield							×						
(*Trachycardium*) n. sp?		×											

See footnote at end of table.

TABLE 1.—*Distribution of fossils in the Suwannee limestone, west-central Florida*—Continued

	County and locality No.[1]												
	Hillsborough				Pasco							Polk	
	40	46	G4	G9	63	65	67	70	G109	G112	G113	72	G108
Pelecypoda—Continued													
Callocallista (Pitaria) sp. aff. *C. imitabilis* (Conrad)		×											
Pitar sp. cf. *P. heilprini* Mansfield													×
sp.													×
Pitaria sp.	×												
Chione sp. cf. *C. bainbridgensis* Dall													×
sp. cf. *C. spada* Dall					×								
sp. cf. *C. perduensis* Mansfield												×	
sp.													×
Venus sp.									×				×
Corbula sp.													×
Mytaea sp. cf. *M. taylorensis* Mansfield													×
Kuphus incrassatus (Gabb)			×	×									
Crustacea:													
Barnea sp.									×				

[1] G numbers are drill holes.

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

The Suwannee is a rather pure limestone. By calculation (see table below) samples chemically analyzed for this report contain from 64 to 99 percent calcium carbonate, and the average is 87 percent. Aside from minor amounts of quartz sand, silt, and clay, the percentage of other constituents is negligible.

Average of partial chemical analyses of 7 samples from the Suwannee limestone, Pasco County, Fla.

[Laboratory Nos.: 115964–115968, 115971, and 115972]

	Percent		*Percent*
P_2O_5	0. 2	Fe_2O_3	0. 28
CaO	48. 93	MgO	. 42
Al_2O_3	. 3		

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

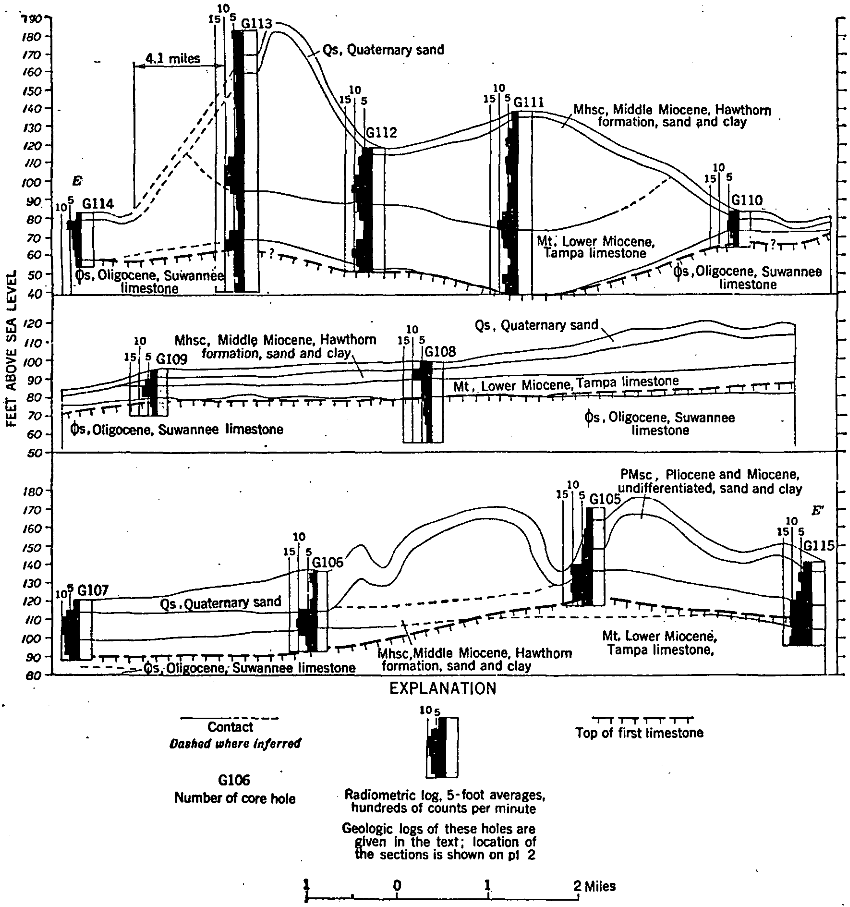

FIGURE 3.—Section through core holes in northwestern Polk and southeastern Pasco Counties, Fla.

are summarized graphically in figures 4–9. 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 and has a median diameter of 0.09 mm, a sorting coefficient of 1.14, and a fifth percentile value of 0.12 mm.

MIOCENE ROCKS

TAMPA LIMESTONE

GENERAL FEATURES

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

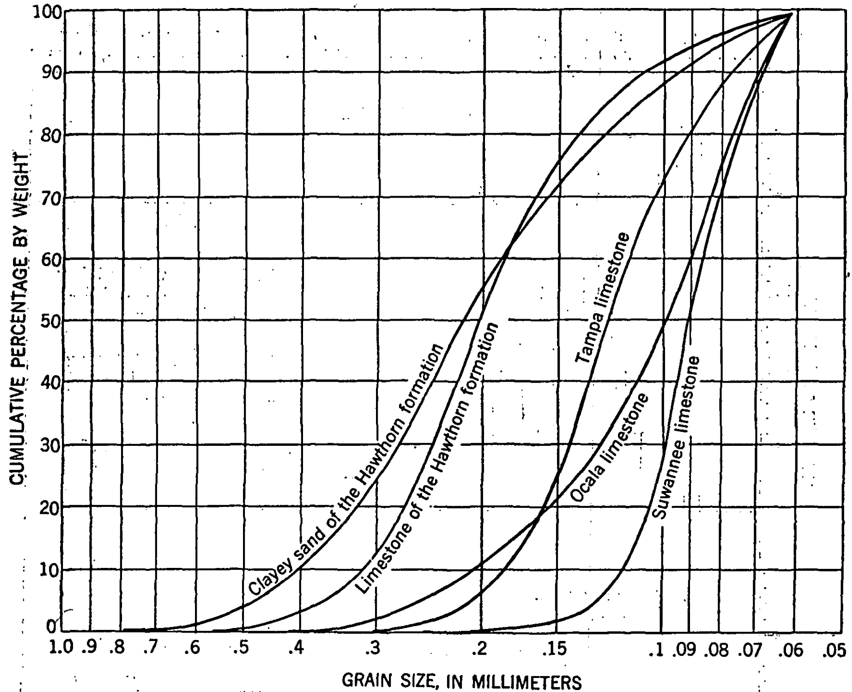

FIGURE 4.—Typical cumulative curves of sand for Ocala, Suwannee, and Tampa limestones and Hawthorn formation in west-central Florida.

to describe rocks exposed near Tampa, Fla. Dall and Harris (1892, p. 112) included in their "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 limestone 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 limestone of peninsular Florida in the Tampa formation. Later Cooke and Mansfield (1936, p. 71) separated the Tampa and Suwannee limestones. Puri (1953b, 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, 1953b, p. 21).

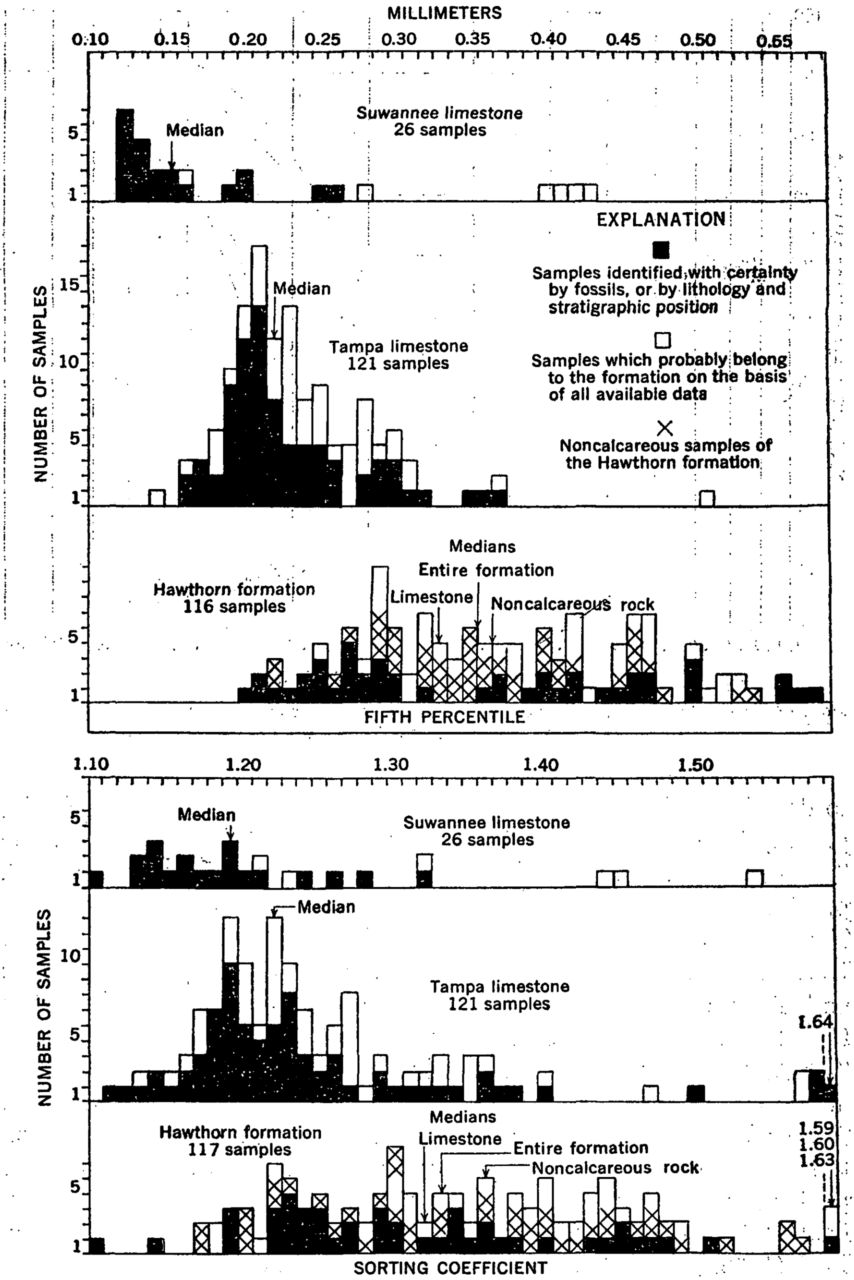

FIGURE 5.—Frequency distribution of fifth percentile value and sorting coefficient in samples of Suwannee and Tampa limestones and Hawthorn formation in west-central Florida.

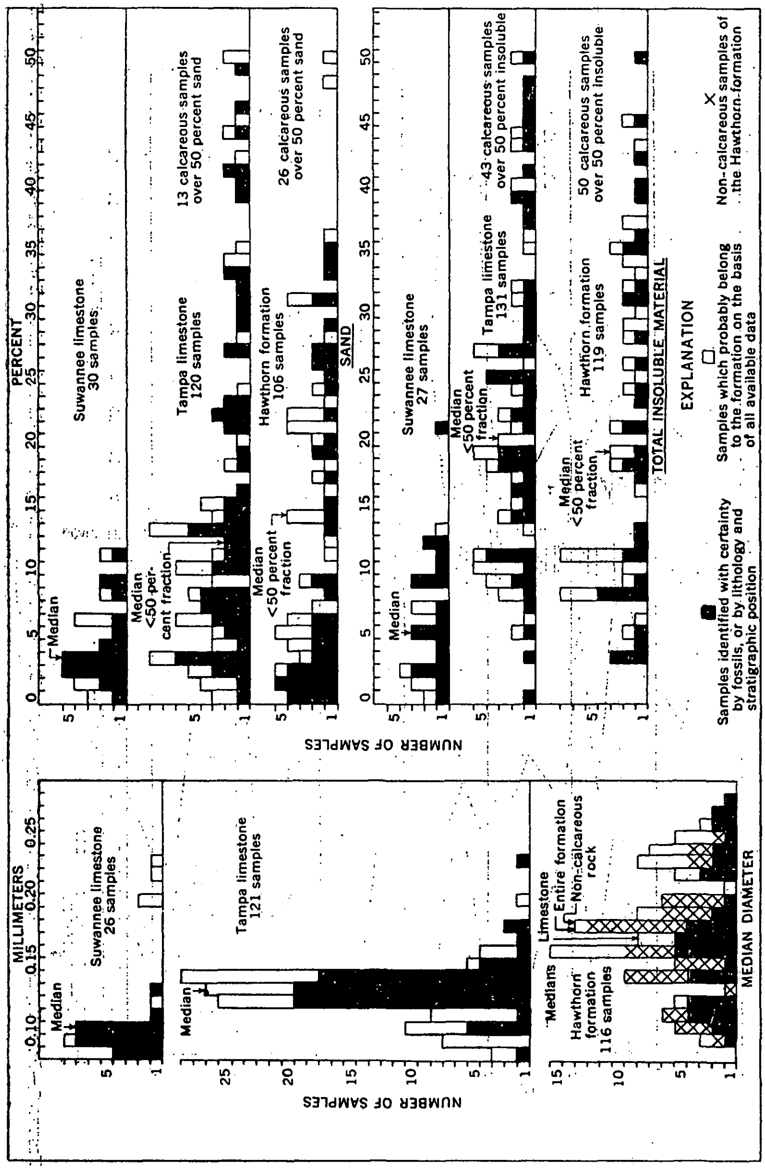

FIGURE 6.—Frequency distribution of median diameter, percent sand, and percent total insoluble material in samples of Suwannee and Tampa limestones and Hawthorn formation in west-central Florida.

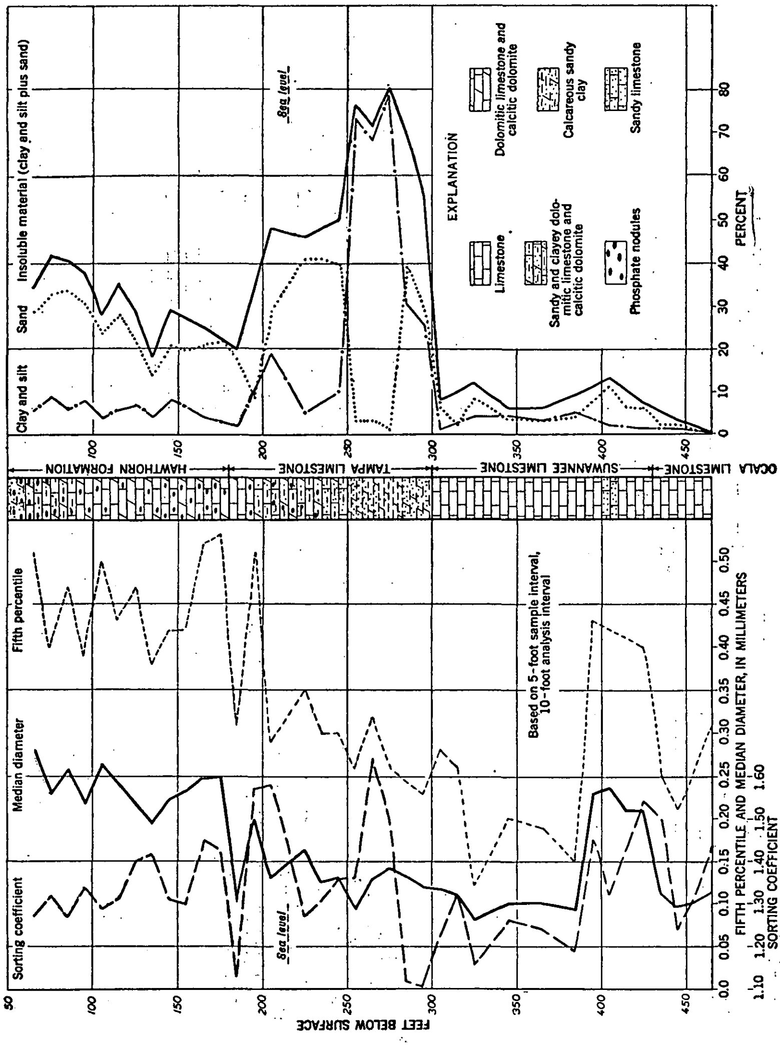

FIGURE 7.—Petrographic and lithologic log of upper part of Davison Chemical Corp. churn-drilled well 3, SE¼NW¼ sec. 4, T. 30 S., R. 24 E., Polk County, Fla.

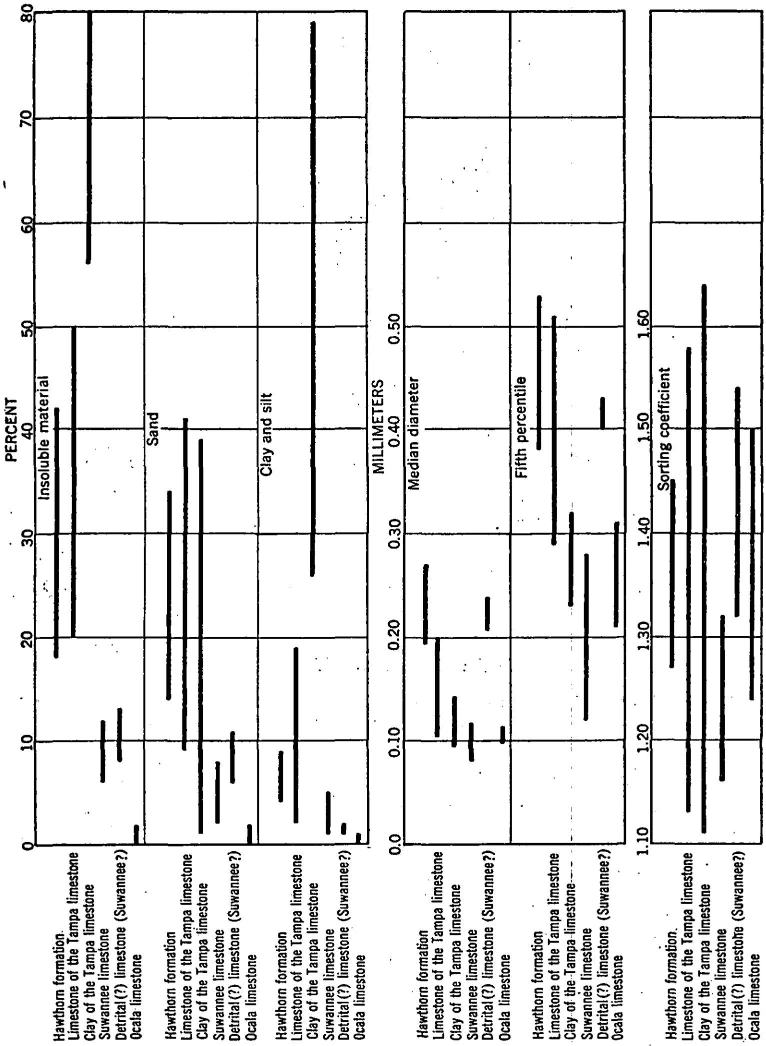

FIGURE 8.—Ranges of petrographic characters of formations and beds in the upper part of Davison Chemical Corp. churn-drilled well 3, SE¼NW¼ sec. 4, T. 30 S., R. 24 E., Polk County, Fla.

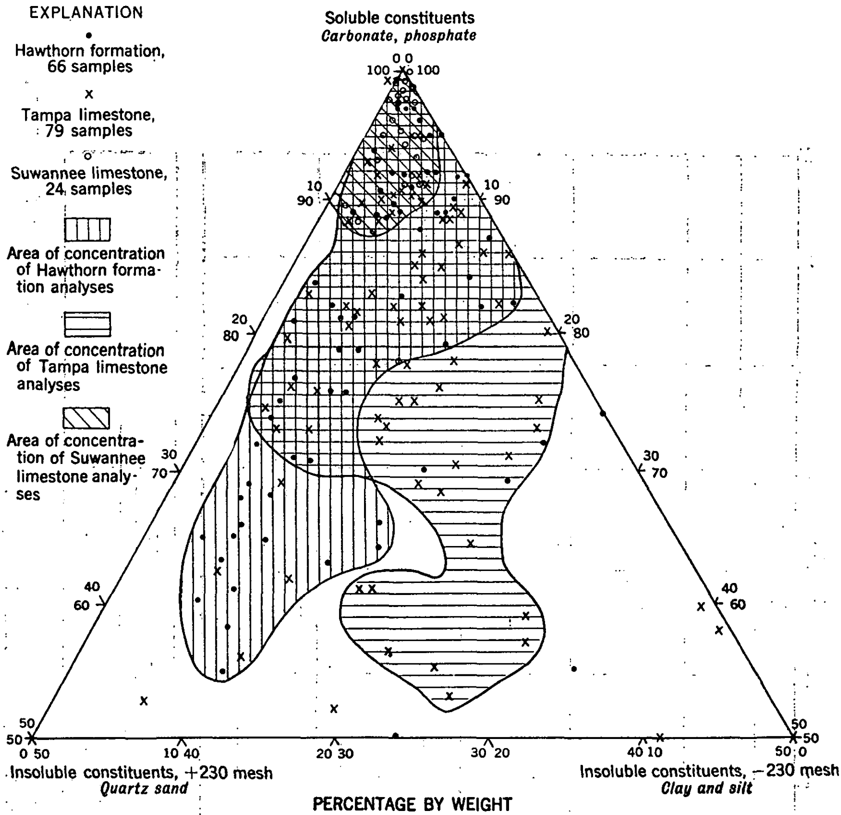

FIGURE 9.—Ternary diagram of soluble and insoluble constituents of limestone samples of the Suwannee and Tampa limestones and Hawthorn formation in west-central Florida.

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

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 is also present in the bottom of two phosphate pits, one northeast of Lakeland, the other west of Bartow (Mansfield, 1937, p. 22). We were unable to locate the exposure at 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 the Tampa limestone remain, however (loc. 100, pl. 2), and in Hernando and northern Pasco Counties several feet of sandy clay have been identified (K. B. Ketner, oral communication, 1954) as Tampa. Thus the mapping of present studies 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 9 feet.

General lithology.—Limestone typical of the Tampa 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 the Tampa limestone at a few localities (loc. 73 and drill holes G90 and G91, pl. 2). In places (locs. 4 and 26) calcareous fossil remains constitute as much as 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 sand, sandy clay, and clay-pebble conglomerate, 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 beautifully silicified in some exposures (locs. 2 and 31).

Stratigraphic relations.—From evidence which will be presented later in the section on geologic history, we believe that erosional unconformities exist at the top as well as at 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 lower and middle Miocene in northern Florida (Cushman and Ponton, 1932, p. 31; Mansfield, 1937, p. 84; Vernon, 1951, p. 153; and Puri, 1953b, p. 38).

Puri (1953b, 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, fig. 10) that are similar to a section with which Puri (1953b, p. 20) illustrates his Chattahoochee facies in northern Florida. We believe that both of Puri's facies may be present in west-central Florida. The intertonguing of relatively pure limestone and calcareous sandy clay is common in this area, but in most of the region such relationships can be studied only by means of well logs.

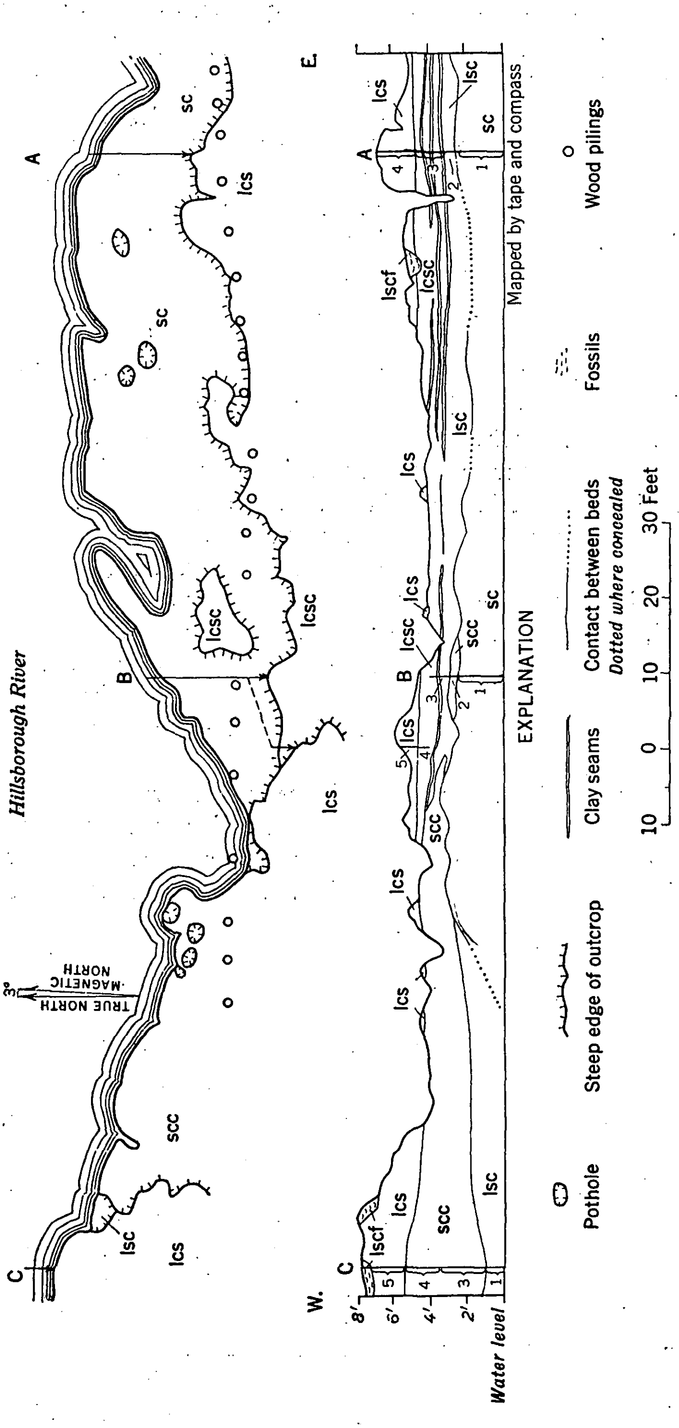

FIGURE 10.—Sketch map and section of Tampa limestone at locality 26, Hillsborough River dam, Hillsborough County, Fla. Explanation of symbols and petrographic properties of samples are given on the facing page.

SYMBOLS USED ON FIGURE 10

lscf—limestone, light-tan to white, slightly sandy, slightly clayey; contains abundant molds and casts of mollusks.

lcs—limestone, white to light-tan, slightly sandy, clayey, fairly hard, fragmental, sparsely fossiliferous; contains light-green to white clay and limestone granules and pebbles, and thin seams of tan secondary carbonate.

lcsc—limestone, light-tan to light-gray, slightly sandy, clayey, soft, locally fragmental; contains thin lenses and partings of very sandy light-green-gray clay.

scc—sand, white, quartz, fine-grained, very clayey, very calcareous, moderately indurated; contains small irregularly distributed patches or fragments of light-gray-green clayey sand.

lsc—limestone, white to light-tan, very sandy, clayey, fairly soft; contains sparse irregular patches of clayey slightly calcareous green-gray sand and abundant pebbles and granules of slightly sandy hard white limestone.

sc—sand, gray-green to white, quartz, fine-grained, very clayey, slightly calcareous, poorly indurated; contains surficially indurated sandy concretionlike structures.

Summary of petrographic properties of samples (locations shown on figure 10) grouped by lithology and stratigraphic position

	sc		lsc			scc			lcsc		lcs		
	26A1	26B1	26A2	26B3	26C1	26B2	26C3	26C4	26A3	26B4	26A4	26B5	26C5
Sand .... percent	60	58	27	22	23	33	27	49	4	12	10	8	8
Clay and silt .... do	29	35	11	17	16	33	24	23	21	18	11	21	10
Ratio of sand to clay	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 material .... percent	89	93	38	39	39	66	51	72	25	30	21	29	18
Soluble material .... do	11	7	62	61	61	34	49	28	75	70	79	71	82
Median diameter of sand .. millimeter	0. 15	0. 13	0. 15	0. 13	0. 14	0. 12	0. 14	0. 14	0. 10	0. 12	0. 13	0. 12	0. 12
Sorting coefficient of sand	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 .... millimeter	0. 22	0. 22	0. 22	0. 23	0. 23	0. 25	0. 24	0. 24	0. 16	0. 21	0. 21	0. 19	0. 20

Fauna.—The Tampa limestone is erratically fossiliferous. In places it is practically a coquina of mollusks whereas other exposures are completely devoid of megafossils. The fauna of the Tampa 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. Exposed at Ballast Point (loc. 2) near Tampa is the "silex bed" or *Orthaulax pugnax* (Heilprin) zone from which Heilprin (1887), Dall (1890–1903, 1915), and Dall and Harris (1892) described a variety of beautifully preserved silicified mollusks. Common at some localities, notably Sixmile 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, 1953b, p. 17). An association of the three Foraminifera *Sorites*, *Camerina*, and *Peneroplis* was noted by F. S. MacNeil in samples collected by us from several localities at which the Tampa is found. *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), 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 table 2.

Localities.—A list of exposures of the Tampa limestone examined by us is given at the end of the report (p. 75). Many of these localities are new to the literature. Localities in operating phosphate mines are usually impossible to relocate, as conditions there change daily.

PETROGRAPHIC DETAILS

The exposure at locality 26 shows some of the features of the Tampa limestone (fig. 10). 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 (fig. 10), 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 veinlets of calcium carbonate. 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 Corp. in western Polk County, were drilled through about 50 feet of rather uniform greenish-gray dolomitic sandy clay (fig. 7). 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* (Bouvé). The wells in which the unit was noted roughly delimit an area with corners near Mulberry, Lakeland, Winter Haven, and Fort Meade.

A limestone breccia, which appears to be characteristic of the Tampa limestone in some areas, is developed in several exposures near Tampa (locs. 1, 19, 20, and 25), and is present, though poorly developed, at many other exposures. Angular to rounded fragments of relatively pure, white fine-grained limestone from a few millimeters to 10 centimeters in diameter are cemented in a matrix of light-gray to light-tan carbonate containing abundant fine-grained quartz sand. 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 by which this structure formed 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.

TABLE 2.—*Distribution of fossils in the Tampa limestone, west-central Florida*

[All fossils were identified by F. S. MacNeil. See plate 2 for localities]

	County and locality No.[1]																												
	Hillsborough																		Pasco			Polk					Pinellas		
	4	6	11	20	24	26	28	29	31	32	33	34	43	G3	G8	G10	G11	G15	65	69	70	73	G90	G91	G107	M10	91	94	95
Foraminifera:																													
Camerina sp.	×				×							×					×							×					
Peneroplis sp.	×				×	×						×												×					
Sorites sp.	×				×							×					×		×		×	×		×					
Gastropoda—nonmarine:																													
?*Cepolis direpta* (Dall)																												×	
Pleurodonte sp.										×																			
Bulimulus heilprinianus Dall																												×	
? sp.																			×										
Cerion anodonta (Dall)				×																									
Helisoma sp.										×				×	×											×			
Gastropoda—marine:																													
Terebra sp.																									×				
Conus sp. cf. *C. illiolus* Dall		×																											
planiceps Heilprin				×																									
sp.					×	×	×						×																
Pleurofusia sp.													×																
Knefastia sp. aff. *K. brooksvillensis* Mansfield																									×				
Olivella sp. cf. *O. posti* Dall																									×				
Ancilla shepardi Dall	×																												
Xancus sp.						×																							
Fasciolaria petrosa Dall																						×							
Latirus sp. cf. *L. floridanus* Heilprin		×																											
? sp.													×																
Busycon sp.										×																			
Melongena turricula Dall																											×		
Solenosteria? *quinquespina* (Dall)						×																							
Murex sp. cf. *M. trophoniformis* Heilprin																		×											
Cypraea sp.																						×							

Morum domingense (Sowerby)						×																							
Orthaulax pugnax (Heilprin) Dall																						×							
Strombus liocyclus Dall		×		×																									
Ceritheum sp. aff. *C. georgianum* Lyell and Sowerby																			×										
sp						×																							
Potamides (*Pyrazisinus*) *hillsboroensis* (Heilprin)						×	×						×																
(*Pyrazisinus*) *campanulatus* Heilprin				×	×	×																×							×
? sp	×																												
Architectonica n. sp.?																									×				
Turritella tampae Heilprin						×																	×						
sp. cf. *T. tampae* Heilprin								×																					
tampae medioconstricta Dall																						×							
pagodaeformis Heilprin													×																
megalobasis Dall				×																		×							
atacta Dall																									×		×		
cf. *T. atacta* Dall									×																				
hillsboroensis Mansfield																							×						
Calyptraea sp. aff. *C. crenata* Gardner																						×							
sp						×																							
Ampullina amphora Heilprin						×	×						×									×							×
sp		×																	×										
Amauropsis ap. aff. *A. burnsii meridionalis* Pilsbry													×																
sp																							×						
Diodora sp										×																			
Pelecypoda:																													
Arca hypomella Dall																													×
irregularis Dall																		×											
Barbatia sp. cf. *B. marylandica* Conrad																						×							
Acar adamsi Shuttleworth																												×	
Arcopsis sp																							×						
Anadara latidentata Dall																									×				
sp. cf. *A. hypomella* Dall						×																							
sp																						×							
Ostrea vaughani Dall													×																
sp			×																										

See footnote at end of table.

TABLE 2.—*Distribution of fossils in the Tampa limestone, west-central Florida*—Continued

[All fossils were identified by F. S. MacNeil. See plate 2 for localities]

	County and locality No.[1]																												
	Hillsborough																		Pasco			Polk					Pinellas		
	4	6	11	20	24	26	28	29	31	32	33	34	43	G3	G8	G10	G11	G15	65	69	70	73	G90	G91	G107	M10	91	94	95
Pelecypoda—Continued																													
Chlamys crocus (Cooke)																							×						
burnetti Tucker																											×		
sp. aff. *C. chipolanus* Dall																												×	
n. sp.																											×	×	
sp.																									×				
Anomia sp.																						×							
Carolia sp.																											×		
Periploma sp.																											×		
Cardita sp.											×																×		
Venericardia serricosta (Heilprin)		×	×						×																				
sp. cf. *V. serricosta* (Heilprin)																						×							
sp.				×							×																		
Cyrena sp. cf. *C. pompholyx* Dall																													×
floridana Dall	×																			×	×								
Chama tampaensis Dall			×																										
Phacoides sp. cf. *P. wacissanus* Dall																							×						
hillsboroensis (Heilprin)						×																×							
sp. cf. *P. hillsboroensis* (Heilprin)													×																
Divaricella n. sp.?						×																							
Trigonocardia alicula Dall			×																	×									
sp.																	×		×										
Cardium delphicum Dall																									×				
sp. cf. *C. anclotensis* Mansfield																		×				×							
sp. cf. *C. pinellasense* Mansfield						×																							
sp. aff. *C. taphrium* Dall										×																			
sp. cf. *C. taphrium* Dall												×																	
n. sp.?						×																							
sp.			×	×			×																						

Callocardia sp																								×				
Antigona glyptoconcha Dall									×																			
shepardi Dall			×																									
sp																										×		
Pitar sp																								×				
Chione nuciformis (Heilprin)		×																										
rhodia Dall								×																				
sp											×																	
Anomalocardia penita (Conrad)			×	×					×			×						×		×							×	
floridana (Conrad)		×																										
Venus halidona Dall						×																×						
sp																							×				×	
Corbula kaghriana Dall									×																			
sp																								×				
Insecta:																												
Celliforma nuda (Brown)											×																	
Charophyta:																												
Charophyte sp. (oogonia)		×													×													

[1] G numbers are drill holes.

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 that 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, uniformly 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 as much as 10 mm in diameter are present locally. The smaller grains are commonly casts of Foraminifera tests. In Tampa limestone that 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 as much as 1 mm across and 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 is completely silicified. At locality 2 (Ballast Point) the rock is a massive chert that contains vugs with chalcedony, quartz crystals, and opal, some of which is dark blue and orange. 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.

Limestone from the Tampa at 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 that occurs mostly as fossil replacements and small veinlets, (2) gray microcrystalline dusky carbonate in the form of detrital rock fragments as much as 10 mm 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 the Tampa limestone, is present with fossil fragments in the brown carbonate between the rock fragments. These rock fragments have only a few very fine quartz sand grains. This occurrence of the 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 (table 2) 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 limestone from the Tampa showed a range in calcium carbonate content from 73 to 96 percent. The average composition of these samples is given below.

Average of partial chemical analyses of 16 samples of limestone from the Tampa limestone, Hillsborough, Polk, and Pinellas Counties, Fla.

[Laboratory Nos.: 115933–115937, 115939, 115940, 115942, 115944–115946, 115948, 115960, 115973, 115988, 115989]

	Percent		Percent
P_2O_5	0.3	Fe_2O_3	0.41
CaO	47.49	MgO	.82
Al_2O_3	1.2		

The Tampa limestone generally contains less than 5 percent MgO. The few known exceptions to this are: (1) a sample from an outcrop (loc. 91) that is presently exposed to sea water, and which contained 15.25 percent MgO; (2) samples from the Davison well where the principal mineral in the lower part of the Tampa limestone is dolomite; (3) samples believed to be from this same zone in the lower part of the Tampa in a well at the Peace Valley mine (loc. 82) of the International Minerals and Chemical Corp.;[2] and (4) one of 18 drill-hole samples

[2] Unpublished log in the files of the Florida Geological Survey.

from southwestern Pasco County, reported by Hopkins (1942, p. 72–73), and which contained 11.02 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 that were megascopically nonphosphatic and that 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 10 of these it was the only clay mineral present. Montmorillonite was found in 8 of the samples, attapulgite (hydrated silicate of aluminum and magnesium) in 4, kaolinite in 2, and chlorite-vermiculite in 1. Thus, illite appears to be the predominant clay mineral in the Tampa limestone, but clay minerals of the other groups are also present.

The presence of attapulgite in the Tampa limestone is previously unreported, although Berman (written communication, 1953) found it in the topmost part of the Hawthorn formation and in the Bone Valley 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 from core hole G3 (table 2; 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, 1955), and studies by Berman (written communication, 1953), show that attapulgite commonly is found 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 +100 mesh are usually present in 100 g 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 10–15 percent of the heavy fraction. Epidote, kyanite, rutile, sillimanite, sphene, topaz, zircon, and zoisite are also present in amounts of 1–10 percent.

Petrographic data obtained from samples of Tampa limestone are summarized graphically in figures 4–9. Quartz sand from the Tampa has a narrow range of median diameters; 65 percent of the samples fall in the range between 0.12 and 0.14 mm, and the median of all samples is 0.13 mm. 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 mm, and the median for all samples is 0.22 mm.

HAWTHORN FORMATION

GENERAL FEATURES

Previous work.—Dall and Harris (1892, p. 108) 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 that Matson and Clapp (1909, p. 69–74) placed in the Hawthorn formation and called Tampa limestone. Cooke (1945, p. 137) dropped the term Oak Grove formation, classifying the Oak Grove as a member of the Shoal River, and also extended the Shoal River formation upward to include basal faunal zones (*Yoldia* and *Arca*) previously included in the Choctawhatchee formation. In 1953, however, Puri (1953b, 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 formation has not been clearly stated in the literature, in the opinion of F. S. MacNeil (oral communication, 1955) it is middle Miocene. Vernon (1951, p. 188) believes the deposits he mapped as Hawthorn formation in Citrus County are of middle Miocene age. In the area of this report the Hawthorn formation includes dolomitic limestone, calcitic dolomite, clay, and sand 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 none 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 that begins in the panhandle of Florida at about long. 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 valleys of the Withlacoochee and Hillsborough Rivers, 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 divisions (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) A lower limestone unit—yellow to white soft irregularly sandy and clayey massive dolomitic limestone and calcitic

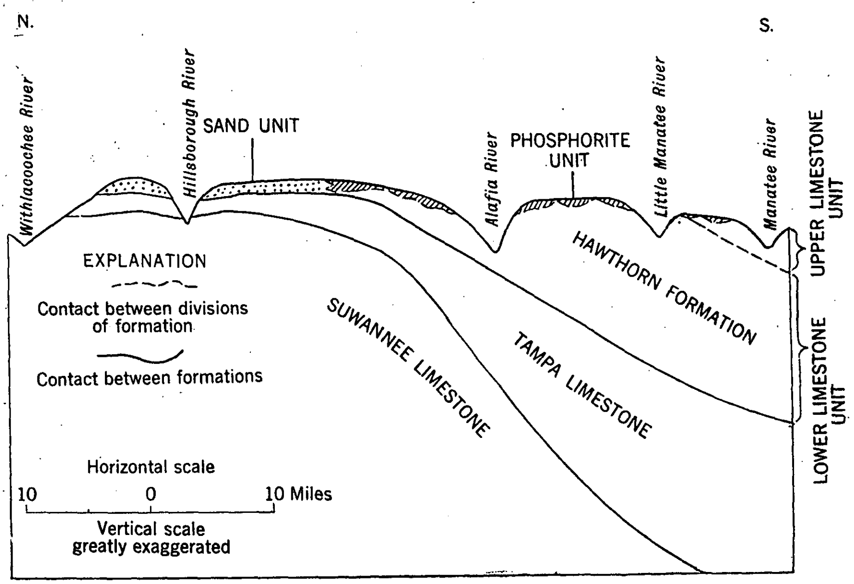

Figure 11.—Diagram showing the relation between the four divisions of the Hawthorn formation in the area between the Withlacoochee and Manatee Rivers in west-central Florida.

dolomite; contains a few clay lenses, sparse phosphate nodules, and a fauna like that of the Oak Grove sand member of the Shoal River formation. (2) An upper limestone unit—gray to white slightly sandy and clayey soft massive dolomitic limestone and calcitic dolomite; contains sparse phosphate nodules of sand size and a fauna similar to the part of the Shoal River formation above the Oak Grove sand member. (3) A phosphorite unit—locally calcareous gray-green to tan sand and clay; contains abundant phosphate nodules, but generally is unfossiliferous. (4) A sand unit—gray to red and orange-brown often mottled sand and clay; contains traces of phosphate nodules, locally abundant secondary phosphates, and rare lower middle Miocene fossils.

These units owe their distinctive lithology, in part at least, to weathering. The upper limestone unit is south of the mapped area (pl. 1) in Hardee and Sarasota Counties; the phosphorite unit and the sand unit are mapped together and shown only where they do not overlie the lower limestone unit.

Stratigraphic relations.—In the panhandle of Florida the Hawthorn formation is replaced by its equivalents in the Alum Bluff group: the Chipola formation and Shoal River formation, which includes the Oak Grove sand member. The Hawthorn formation of the area of this report is equivalent to only the Shoal River formation, but in other areas equivalents of the Chipola are included in the Hawthorn. According to MacNeil (oral communication, 1955) the fauna of the lower limestone unit of the Hawthorn formation, 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 exposed (the upper limestone unit) is younger and faunally like, but not typical of, the part of the Shoal River formation above the Oak Grove sand member.

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

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

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. A list of Hawthorn fossils identified for this report is given in table 3.

Localities.—A list of exposures of the Hawthorn formation examined by us is given at the end of the report (p. 82). Many of these localities are new to the literature. Localities in operating phosphate mines are usually impossible to relocate, as conditions there change daily.

PETROGRAPHIC DETAILS

Limestone of the Hawthorn 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 and Cisney, 1952) as carbonate fluorapatite. Another type of nodule, common in places, ranges from pebble to boulder size,

TABLE 3.—*Distribution of fossils in the Hawthorn formation, west-central Florida*

[All fossils were identified by F. S. MacNeil. See plate 2 for localities]

	County and locality No.[1]																		
	Hillsborough			Polk															Manatee
	10	39	42	74	75	76	77	78	79	80	81	82	83	G72	G77	G78	G79	G82	97
Gastropoda:																			
Clavatula? sp										×									
Conus sp						×													
dodona Gardner							×												
Xancus sp										×									
Fasciolaria sp. cf. *F. kindlei* Maury									×		×								
Busycon radix Gardner			×																
Cypraea sp										×									
Calyptraea sp									×										
Epitonium n. sp										×									
Potamides n. sp. aff. *P. hillsboroensis* Heilprin	×																		
Turritella dalli Gardner		×																	
sp							×												
bicarinata Gardner												×							
Diodora sp									×										
Pelecypoda:																			
Anadara dodona Dall												×							
hypomella Dall									×										
sp														×			×		
Calloarca sp. cf. *C. phalacra* Dall							×												
Glycymeris sp							×												
Pteria sp								×											
Ostrea normalis Dall													×						
rugifera Dall				×															
Chlamys sayanus Dall				×	×		×	×	×	×	×	×	×	×					×
sp. cf. *C. sayanus* Dall	×														×	×		×	
sp. cf. *C. burnsii* Dall							×												
acanikos Gardner										×									
nicholsi Gardner				×						×									
Anomia sp												×							
Modiolus sp											×								
Periploma discus Gardner				×															
Cardita cf. *C. apotega* Gardner		×							×										
sp							×												

See footnote at end of table.

TABLE 3.—*Distribution of fossils in the Hawthorn formation, west-central Florida*—Continued

	County and locality No.[1]																		
	Hillsborough			Polk															Manatee
	10	39	42	74	65	76	77	78	79	80	81	82	83	G72	G77	G78	G79	G82	97
Pelecypoda—Continued																			
Venericardia sp. cf. *V. himerta* Dall										×									
sp. cf. *V. hadra* Dall							×												
sp.					×											×			
Phacoides? sp.																×			
sp. cf. *P. heilprini* Gardner											×								
Diplodonta sp. cf. *D. paralta* Gardner									×										
Cardium sp. cf. *C. plectopleura* Gardner																		×	
sp. cf. *C. compressum* Dall							×												
sp.	×	×							×			×							
Dosinia chipolana Dall									×										
Clementia sp.							×												
Macrocallista acuminata Dall											×								
Chione chipolana Dall																	×		
Venus sp. cf. *V. langdoni* Dall									×										
sp.			×	×		×													
Tellina sp.																		×	
Metis chipolana Dall									×										
Spisula sp.						×													
Solen sp. cf. *S. amphistemma* Dall							×												
Corbula sp. cf. *C. whitfieldi* Dall									×										
sp.		×																	
Crustacea:																			
Balanus sp.											×								

[1] G numbers are drill holes.

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, 1–5 mm in diameter, and is a rather homogeneous yellow brown. 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.

A summary of chemical analyses of limestone of the Hawthorn formation is given below.

Average of partial chemical analyses of 26 samples of limestone of the Hawthorn formation, Hillsborough, Polk, Manatee, and Sarasota Counties, Fla.

[Laboratory Nos.: 115930–115932, 115951–115956, 115974–115980, 115982–115986, 115990–115994]

	Percent		*Percent*
P_2O_5	2. 0	Fe_2O_3	0. 49
CaO	30. 35	MgO	15. 28
Al_2O_3	. 9		

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, written communication, 1953), in the overlying Bone Valley formation. Berman found that attapulgite partly supplants montmorillonite in the top of what he called the Hawthorn formation. He found as much as 35 percent attapulgite in the samples of limestone of the Hawthorn, and as much as 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 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 limestone of the Hawthorn in Manatee and Sarasota Counties, where it is mined for dolomite, has an erratic MgO content. His samples were taken from drill holes that 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 limestone of the Hawthorn was found to be negligible.

Alteration of limestone of the Hawthorn 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 lithology of the lower limestone unit of the Hawthorn. This exposure is near the base of the formation.

Locality 10, W½ sec. 21, T. 30 S., R. 20 E., below bridge in ravine about 1 mile southeast of Riverview, Hillsborough County, Fla.

[Numbers are sample numbers]

	Approximate thickness (ft	*in)*
Quaternary:		
A7. Sand, gray to tan, slightly clayey; contains sparse organic material	3	0
Middle Miocene, Hawthorn formation:		
A6. Limestone, white to light-tan, sparsely to slightly sandy and clayey, soft, dolomitic; contains rounded pebbles of white to very light gray very calcareous clay and a trace of tan, brown, and black phosphate nodules that are mostly sand size; upper contact sharp and undulating		3
A5. Limestone, white to light-tan, very sandy (fine to medium grained), sparsely clayey, hard, dolomitic; contains sparse rounded pebbles of white pure limestone and a trace of sand-size phosphate nodules		3
A4. Limestone, white to light-tan, very sandy (fine to medium grained), sparsely clayey, dolomitic; contains abundant patches of nearly pure carbonate and a trace of brown, black, and amber sand-size phosphate nodules		3
A3. Limestone, white to light-tan, very slightly to very sandy (fine to very fine grained), slightly clayey, dolomitic; contains abundant patches and fragments of gray calcareous clay with phosphate nodules		6
A2. Limestone, white to light-tan, sandy (fine to medium grained), slightly clayey, hard, dolomitic; contains abundant patches of very sandy carbonate and pure carbonate, and sparse black, brown, and gray sand- to pebble-size phosphate nodules		6
A1. Limestone, white to light-tan, sandy (fine to medium grained), slightly clayey, locally porous, dolomitic; contains sparse small fragments of white pure limestone and sparse black, brown sand- to pebble-size phosphate nodules; *Potamides*, n. sp. aff. *P. hillsboroensis* Heilprin, *Chlamys* sp. cf. *C. sayanus* Dall, *Cardium* sp	1	6
Total exposure	6	3
Base of exposure.		

Limestone of the Hawthorn formation is also described in the log of core hole G16 (p.103), and in the list of Hawthorn localities. Exposures of the upper limestone unit are present at localities 98 and 99 and elsewhere in Manatee and Sarasota Counties.

The sand and phosphorite units of the Hawthorn formation generally consist of an alternation of brown to green clay, sand, and sandy clay. Clay predominates in the phosporite unit and sand predominates in the sand unit. Gray green nearly pure waxy clay beds are present at some localities (figs. 12 and 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

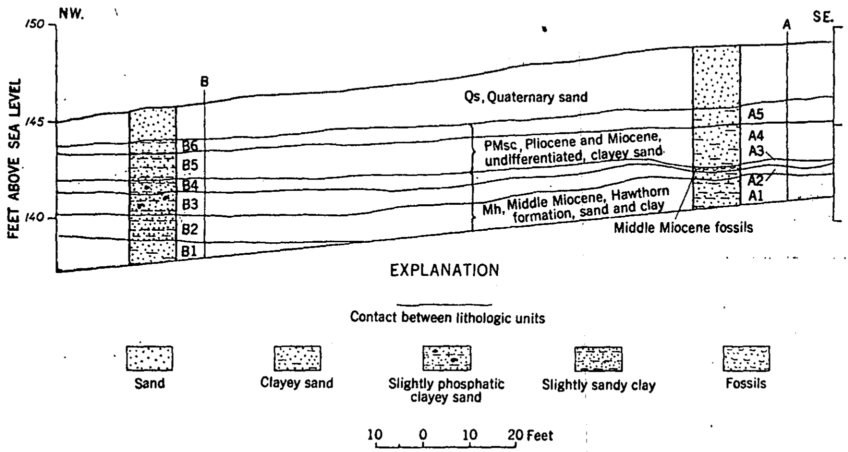

FIGURE 12.—Diagrammatic sketch showing stratigraphic relations of Hawthorn formation, undifferentiated Pliocene and Miocene strata, and Quaternary sand at locality 83 (northwest side of railroad cut, about 0.5 mile northwest of railroad station at Kathleen), SW¼ sec. 17, T. 27 S., R. 23 E., Polk County, Fla. Petrographic properties of samples are given below.

B					A				
Sample	SC	Md	So	P_5	Sample	SC	Md	So	P_5
83B6	1.1	0.12	1.21	0.27	83A5	2.1	0.15	1.41	0.32
83B5	1.8	.12	1.18	.24	83A4	1.9	.13	1.24	.29
83B4	1.1	.22	1.36	.50	83A3	1.3	.22	1.48	.46
83B3	1.9	.23	1.47	.58	83A2	3.4	.24	1.37	.56
83B2	.6	.19	1.30	.40	83A1	.4	.18	1.35	.47
83B1	2.8	.19	1.25	.42					

SC—Ratio of sand to clay.
Md—Median diameter of sand, in millimeters.
So—Sorting coefficient of sand.
P_5—Fifth percentile, in millimeters.

this process is accompanied by oxidation of the iron in heavy minerals, which produces brilliant orange or red-brown iron staining and zones of hardpan.

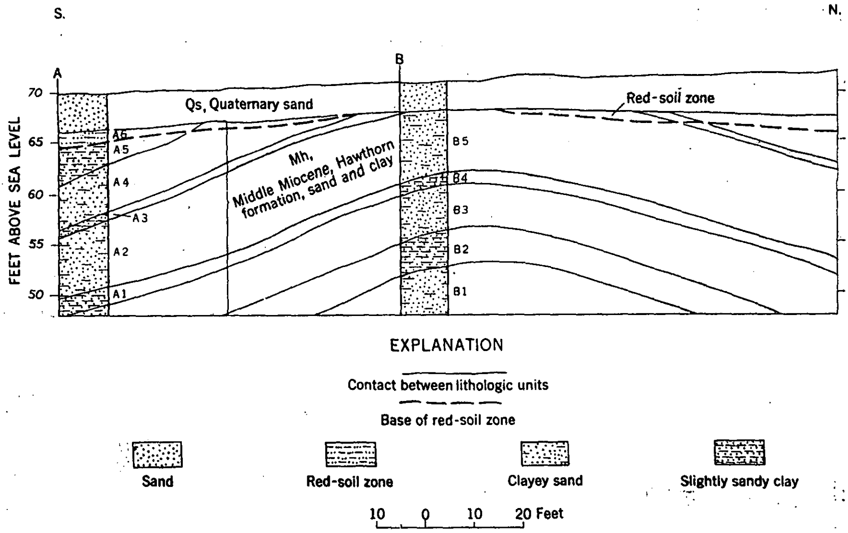

FIGURE 13.—Diagrammatic sketch showing stratigraphic relations of Hawthorn formation and Quaternary sand at locality 13 (northwest corner of claypit on State Highway 579, 0.5 mile north of Mango), NW¼ SW¼ sec. 3, T. 29 S., R. 20 E., Hillsborough County, Fla. Petrographic properties of samples are given below.

A					B				
Sample	SC	Md	So	P_5	Sample	SC	Md	So	P_5
13A6	1.3	0.18	1.49	0.46	13B5	2.4	0.16	1.44	0.34
13A5	3.2	.18	1.52	.47	13B4	.3	.20	1.56	.45
13A4	1.5	.14	1.38	.42	13B3	3.3	.15	1.17	.22
13A3	.2	.13	1.36	.29	13B2	.1	.10	1.36	.22
13A2	2.3	.16	1.39	.32	13B1	2.6	.14	1.25	.29
13A1	.1	.11	1.57	.37					

SC—Ratio of sand to clay.
Md—Median diameter of sand, in millimeters.
So—Sorting coefficient of sand.
P_5—Fifth percentile, in millimeters.

The sand and 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 sand unit, is given below and in figure 12.

Locality 83, SW¼ sec. 17, T. 27 S, R. 23 E., railroad cut, 0.5 mile northwest of railroad station at Kathleen, Polk County, Fla.

[Numbers are sample numbers]

	Approximate thickness (ft)	(in)
Quaternary:		
B7. Sand, tan, loose	1	10
Undifferentiated Pliocene and Miocene:		
B6. Sand, gray, orange-brown iron-stained, fine-grained; contains a trace of muscovite		6
B5. Sand, light-gray, mottled yellow-orange iron-stained, fine-grained, clayey to slightly clayey; contains a trace of muscovite	1	3
Middle Miocene, Hawthorn formation:		
B4. Sand, light-tan to light-gray, local orange iron-stain, fine- to medium-grained, locally vesicular; contains a few very thin lenses of dark-gray clay, 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		6
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; contains sparse small lenses of gray slightly clayey sand, 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
Total exposure	7	11

Base of exposure.

The following section, typical of the lithology of the phosphorite unit, 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, Fla.

[Numbers are sample numbers]

	Approximate thickness (ft)	(in)
Quaternary:		
C8. Sand, tan, loose	4	0
Undifferentiated Pliocene and Miocene (Bone Valley? formation):		
C7. Sand, light-gray to gray, mottled red-brown at top, fine- to medium-grained, clayey to slightly clayey; contains a trace of sand-size phosphate nodules; upper contact sharp	3	6
C6. Clay, light-gray, very sandy (fine- to coarse-grained); contains a trace to abundant white soft sand- to granule-size phosphate nodules	2	0
C5. Clay, light-gray-green with yellow iron staining, sandy (medium- to fine-grained); contains very thin lenses of sand with a trace of phosphate nodules; upper contact sharp	1	0
C4. Sand, light-gray-green, fine- to medium-grained, clayey, interlensing with sandy clay; contains patches of white soft phosphatic(?) clay	1	6
C3. Clay, light-blue-green, brown iron stain at top, sandy (fine- to medium-grained), waxy; contains a trace of white, gray phosphate nodules	1	6
Middle Miocene, Hawthorn formation (phosphorite unit):		
C2. Sand, light-gray-green, locally iron stained, medium- to fine-grained, slightly clayey; contains white, gray, tan sand- to granule-size phosphate nodules and, at top, patches of white soft phosphatic clay; upper contact sharp, undulating	2	0
C1. Clay, white, tan to light-gray, slightly sandy, locally calcareous at base; contains abundant white, gray sand- to pebble-size phosphate nodules	11	0
Total exposure	26	6
Base of exposure.		

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

Lithology typical of the phosphorite unit and the sand unit was also found in core holes in Hillsborough County (fig. 16 and logs of core holes).

Quartz sand in the Hawthorn formation is mostly fine grained but ranges from very fine to medium grained with a trace of coarse grains. The sand is irregularly distributed and is clear and angular to subrounded, except for some of the larger grains which are frosted and well rounded. Petrographic data for the formation are summarized in figures 4–9. Limestone of the formation averages about 20 percent insoluble material. The formation, in samples analyzed, has a range

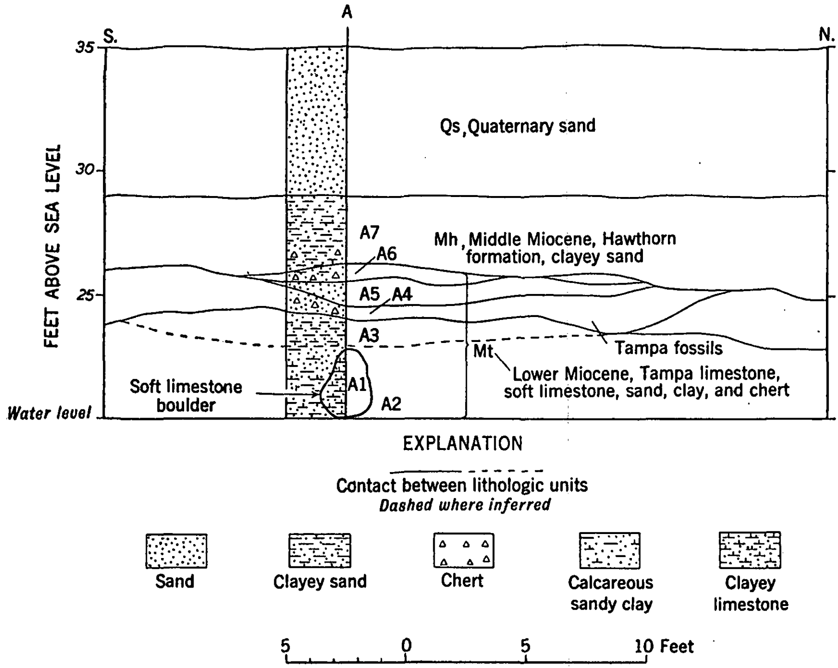

FIGURE 14.—Diagrammatic sketch showing stratigraphic relations of Tampa limestone, Hawthorn formation, and Quaternary sand at locality 24 (northeast corner of sandpit), NE¼ sec. 33, T. 28 S., R. 19 E., Hillsborough County, Fla. Petrographic properties of samples are given below.

A					A				
Sample	SC	Md	So	P_5	Sample	SC	Md	So	P_5
24A7	--------	0.18	1.39	0.35	24A3	1.3	0.16	1.32	0.29
24A6	--------	.13	1.29	.30	24A2	--------	.14	1.24	.24
24A5	--------	.16	1.35	.37	24A1 [2]	1.0	.12	1.23	.19
24A4 [1]	--------	--------	--------	--------					

SC—Ratio of sand to clay.
Md—Median diameter of sand, in millimeters.
So—Sorting coefficient of sand.
P_5—Fifth percentile, in millimeters.
[1] Chert.
[2] Insoluble residue.

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 (P_5) values are consistently high in sand of the Hawthorn, even when the median diameter is low; P_5 ranges from 0.20 to 0.58 and the median is 0.355 mm. The properties of the units of the Hawthorn composed of clay and sand are similar to those of the limestone units, but in the noncalcareous beds the sand is slightly coarser and not quite as well sorted.

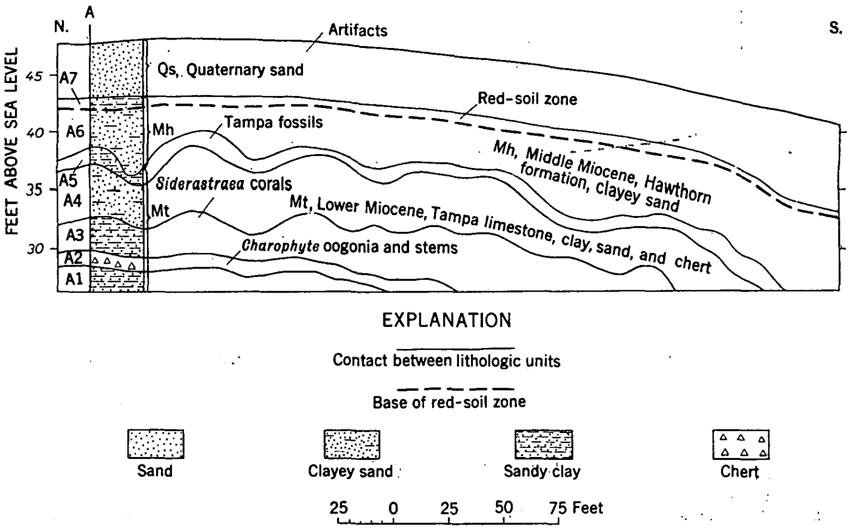

FIGURE 15.—Diagrammatic sketch showing stratigraphic relations of Tampa limestone, Hawthorn formation, and Quaternary sand at locality 6 (east side of roadcut about 100 feet south of railroad bridge), NW¼SW¼ sec. 19, T. 28 S., R. 20 E., Hillsborough County, Fla. Petrographic properties of samples are given below.

A					A				
Sample	SC	Md	So	P_5	Sample	SC	Md	So	P_5
6A7	1.9	0.16	1.43	0.41	6A3	1.0	0.09	1.37	0.23
6A6	3.2	.14	1.30	.36	6A2 [1]				
6A5	.8	.14	1.26	.19	6A1	.8	.09	1.20	.18
6A4	3.8	.10	1.23	.16					

SC—Ratio of sand to clay.
Md—Median diameter of sand, in millimeters.
So—Sorting coefficient of sand.
P_5—Fifth percentile, in millimeters.
[1] Chert.

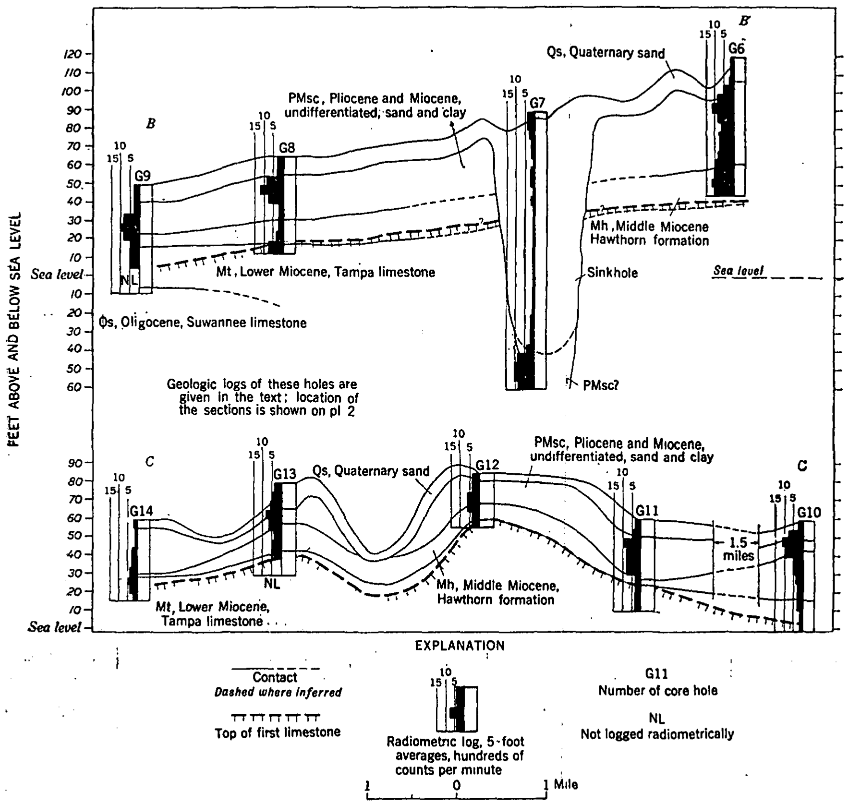

FIGURE 16.—Sections through core holes in northeastern Hillsborough County, Fla.

Heavy minerals are present only in trace amounts in the limestone of the Hawthorn, but are concentrated in the sand and phosphorite units, presumably 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 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.

Three chemical and three spectrographic analyses of different materials from the sand unit of the Hawthorn formation are given in the table below.

Chemical and spectrographic analyses of samples of the sand unit of the Hawthorn formation, southeastern Pasco and northeastern Hillsborough Counties, Fla.

Partial chemical analyses

Locality, field, and laboratory sample No.	Material	Percent				
		P_2O_5	CaO	Al_2O_3	Fe_2O_3	MgO
53B; 115961	Clay, gray, orange-brown, sandy.	0.1	0.22	9.2	3.29	0.13
60A1; 115962	Clay, light-brown to orange, very sandy; contains sparse fragments of sandstone cemented by aluminum phosphate.	1.5	.10	16.1	5.44	1.55
60A2; 115963 (split from 60A1)	Sandstone, white, irregular concretionlike lumps; contains cavities lined with an aluminum phosphate mineral.	18.2	.6	20.7	1.06	.85

Spectrographic analyses

Locality, field, and laboratory sample No.	Material	Elements in percent range—				
		99–10	9–1	0.9–0.1	0.09–0.01	0.009–0.001
9A2; 115721	Sand, tan to brown, contains sparse fragments of sandstone cemented by aluminum phosphate.	Si	Al	Fe, Mg, P, Ca.	Ti, Sr, Cu, Cr, Ba, Na, Ni, B, Co.	Mn, Mo, Pb, V, Y, Ga, Sn, Zr.
61A2; 115751	Sand, violet-gray, slightly clayey, iron-stained.	Si	Al	Fe, Ti, Mg	Cu, Cr, Ca, Sr, Ni, B, Ba.	Mn, Mo, Ga, Sn, Zr, Pb, V, Y.
61C2; 115749	Sand, gray, slightly clayey; contains lumps of hardpan and silicified corals.	Si	Al, P	Fe, Mg, Ti, Ca.	Cu, Cr, Ba, Ni, B, Mn, V, Sr.	Mo, Zr, Ga, Pb, Sn, Y.

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 (1959) and Bergendahl (1956) 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 according to Simpson (1930, p. 184; 1933, p. 91) vertebrate remains indicate that it is Pliocene in age. Simpson (1930, p. 184–185) lists 13 species of vertebrates from the Bone Valley formation, 10 of which he says may range in age from late Miocene through early Pliocene, 1 of which he says occurs elsewhere only in the upper Miocene, and 1 of which he says is typically early Pliocene in age, but whose age range is undefined. He summarizes the fauna as follows—

The evidence of the land mammals * * * indicates approximate equivalence with the upper Snake Creek or the Republican River. With this relative age established, it is of little consequence whether it be called late Miocene or early Pliocene. At present the consensus seems to be that the Republican River and equivalents are referable to the lower Pliocene.

Simpson then points out that the marine mammal fossils of the Bone Valley have been described as being not later than late Miocene in age. He resolves this discrepancy by suggesting that the age or identification of the marine mammal fossils may be in error. In a subsequent publication (Simpson, 1933, p. 91) he lists the Bone Valley as Pliocene in age. In our opinion the question of the age of the Bone Valley is far from settled.

The formation consists of gray and green sand and clay beds containing, in places, as much as 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 P_5, 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 residue 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 that is locally transected by the base of a leaching profile. Whether or not this unconformity coincides with the contact between the Hawthorn and Bone Valley formations is a matter of conjecture in our 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 MIOCENE AND PLIOCENE ROCKS

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 (1959).

These rocks closely resemble the clay and sand beds of the Hawthorn and Bone Valley, 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 4.

WEATHERING

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 white or tan quartz sand which becomes clayey and orange or red downward. Iron and alumina hardpan, aluminum phosphate, and chert nodules are common at the base of this zone. Beneath the hardpan or chert 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 slighly calcareous sandy clay that grades rather abruptly into limestone. The profile is thus principally one of decreasing solubility upwards. The depth of such leaching exceeds 50 feet in some places in this area.

Beds of clay and sand obviously weathered from limestone are 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, is a virtually 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 conditions. One of the most indicative of these is the formation of chert. Leith (1925, p. 513–523) pointed out that secondary silica on erosion surfaces develops on a variety of rocks, of which limestone and dolomite are said to be the best sites for surficial silicification. That most of the chert seen in exposures in Florida is an epigenetic replacement of limestone is indicated by (1) the massive porcelanic, 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, 1954) 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, such as *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 carbonates, but in clay and sand features such as crenulated bedding are good evidence of solution of limestone 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 presence of chert in 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. Secondary silica in at least one of the above forms was found in more than half of the exposures of the Tampa listed in this report, in about 75 percent of the core-drill holes that reached the formation, and in the majority of wells logged of the Tampa. Figures 14 and 15 illustrate two occurrences of chert in exposures. Silicified fossils are present at both these localities. At locality 24 (fig. 14) Tampa fossils (table 2) are present in chert lenses. At locality 6 (fig. 15) Tampa mollusks (table 2) are present 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 beautifully silicified fossils.

The effects of limestone solution on bedding can be seen at locality 6 (fig. 15). A clayey bed at the top of the Tampa has crenulations with amplitude as much as 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 exposures (24, 25) of the Tampa limestone that illustrate the residua problem, masses of soft limestone as much as 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 stratigraphic relations at locality 24, typical of super-Tampa weathering, is given in figure 14. Insoluble-residue analysis 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 [3] of the clay fraction of these two samples revealed quartz, orthoclase, montmorillonite, and pseudowavellite in both the limestone (24A1) and clay (24A2), plus wavellite and apatite in the clay. Spectrographic analysis of raw splits of the two samples detected no phosphorus whatever in the limestone, but 0.0X percent was found in the clay.[4] 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 24A3, a very slightly calcareous sandy clay, and 24A5, a pure white sand, are lenticular and both underlie ledges of chert (24A4, 24A6) that contain lower Miocene fossils (table 2) and small amounts of very fine grained sand. Unit 24A7, a red clayey sand, is unconformable upon units 24A3–24A6 and has petrographic properties that correspond closely with those of the Hawthorn formation. Therefore, we believe that this is an unconformable Tampa-Hawthorn contact, and that units 24A3 and 24A5 represent solution cavities filled by materials from both formations.

A comparison of two stratigraphically equivalent samples of relatively pure limestone of the Tampa, one virtually unweathered, the other moderately weathered, is given below. The two samples were

[3] Informal analysis by R. G. Petersen, U.S. Geological Survey.
[4] Laboratory nos. 115724 and 115725.

taken from the 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 carbonate. The ratio of sand to clay remained almost the same, however. A bed 10 feet thick of this limestone would yield, after weathering removed all carbonate, at most about 1 foot of residue, if changes in porosity are ignored. A possibility remains, however, that as the carbonate 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 the clay beds, so commonly found above limestone in this area, are strictly residual then it is necessary to postulate the existence of 5–10 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.

Comparison of stratigraphically equivalent samples of fresh and weathered limestone of the Tampa limestone from locality 19, Hillsborough County, Fla.

[Laboratory Nos.: 19A2, 115934; 19B1, 115938]

	Fresh (19A2)	Weathered (19B1)
Partial chemical analysis, in percent		
P_2O_5	0.3	0.3
$CaCO_3$	90.1	67.3
Al_2O_3	.8	2.8
Fe_2O_3	.27	.52
$MgCO_3$	1.6	1.5
Total	93.07	72.42
Insoluble-residue analysis, in percent		
Insoluble material:		
Quartz sand	3.2	12.6
Clay and silt	5.7	22.1
Soluble material	91.0	65.0
Total	99.9	99.7
Mechanical analysis		
Ratio of sand to clay	0.56	0.57
Median diameter of sand, millimeters	0.086	0.085
Sorting coefficient of sand	1.38	1.33
Fifth percentile, millimeters	0.22	0.23

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. 2, 3, and 16). Most of the peaks of radioactivity in the Tampa are 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 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 noncalcareous 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 limestone of the Hawthorn formation has produced a phosphatic residuum (phosphorite unit) that 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 stratigraphic units. We have therefore mapped two units (pl. 1), limestone and clayey sand, of the Hawthorn formation, but the Bone Valley formation and noncalcareous residua overlying limestone of the Hawthorn are not shown.

The Hawthorn formation exhibits three general zones of weathering. The first and weakest zone is that commonly seen in the bottoms of the phosphate pits where the limestone is soft, yellow, and has a marly or chalky appearance. This type of limestone is only a few feet thick in most places, and is almost invariably dolomitized; it 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 noncalcareous to calcareous greenish-gray clayey sand with abundant phosphate nodules. The 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 to concentrate, but not otherwise affect, the calcium phosphate nodules.

The third zone of weathering of the 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 Suwannee and Tampa 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-MIDDLE MIOCENE ROCKS

Weathering of post-middle Miocene rocks 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 (Sixmile 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 red-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, virtually unleached Pleistocene shells. At localities 1 and 26 the basal part 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 sand above the Pamlico terrace, 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.

We believe, however, that there is evidence which suggests that earlier periods of weathering are represented in the area; some of these, we 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 limestone in the Tampa, 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 limestone of the Suwannee and Tampa, chert zones of possible secondary origin are present 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 (fig. 15). 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 4–9. It is only necessary to point out the salient features shown by these graphs.

First, and probably most significant, is the general increase in the size of quartz sand from the Suwannee limestone through the Hawthorn formation. The same progression is apparent, though not so strong, in the sorting and percentage of quartz sand. The Hawthorn, for example, has poorer sorting and slightly more sand-size material than the Tampa limestone. 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 that are conspicuously coarser. The latter characteristic is recognizable and useful in the field.

Figure 7 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 those obtained from exposures.

Figure 7 also shows some relations 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 relation, 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 4 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 4.—*Summary of medians of petrographic characteristics for the Ocala, Suwannee, and Tampa limestones, the Hawthorn formation, and rocks of post-middle Miocene and pre-Quaternary age, west-central Florida*

[Phosphate nodules are excluded]

	Total insoluble [1] material (percent)	Quartz sand [1] (percent)	Median diameter (millimeter)	Fifth percentile (millimeter)	Sorting coefficient
Rocks of late Miocene or Pliocene age [2]	100	64	0.17	0.38	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 [3]	2	1	.10	.26	1.37

[1] For samples 50 percent or more soluble, Hawthorn and older formations.
[2] Includes rocks of probable Bone Valley age and other rocks of late Miocene or Pliocene age that immediately overlie the Hawthorn formation.
[3] Average values of 7 samples.

It should be reemphasized 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 relations that deserve further investigation. The dominant clay minerals seem to be montmorillonite in the Hawthorn and illite in the Tampa. Attapulgite occurs in both formations in association with high MgO content; it is found in samples of the Tampa that contain land or fresh-water fauna, and it is common in the Hawthorn at the top of the formation.

GEOLOGIC HISTORY

STRUCTURE

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 and 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" (fig. 1), a gentle arch that 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 are covered by a thin veneer of Miocene and later sediments. The Tampa limestone and older rocks were involved in the deformation that 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 early Miocene time.

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 nondeposition of Miocene rocks on the crest of the uplift seems untenable 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. The formations at most places are higher than, and dip away from, the area which they encircle. 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 us 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 (table 2) Tampa limestone (loc. 100). The Tampa is thin and rests on silicified Ocala limestone in this area. Silicified Tampa fossils (table 2) 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, 1955) 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 Tampa and Hawthorn formations are now missing in large areas on the Ocala uplift is not denied, but the evidence indicates that there was extensive, if not complete, inundation of the uplift by lower and middle Miocene seas. The distribution of phosphate in the Tampa and Hawthorn formations has little areal relation to the crest of the Ocala uplift, because phosphate is found 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. We were able to prove the existence of a structural break, probably a fault, in northern Polk County (pls. 1 and 3).

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 his Inglis member of the Moodys Branch formation as used by him (the lower part of the Ocala limestone of this report). Vernon shows the zero contour of the top of his 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 well-preserved 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 the Suwannee limestone. *T. carinata palmerae* is a species of Claiborne (Avon Park limestone) age, and *Periarchus lyelli* has been reported only from the lower part of the Ocala limestone (Inglis member of Vernon, 1951, of the Moodys Branch formation).

In order to clarify the structure in the Rock Ridge area, 2 holes were drilled with a power auger; one (M9) about 1.5 miles east of and the other (M10) about 1.5 miles south of locality 72. Both the holes and the exposure at locality 72 were at about the same elevation, about 90 feet. In the hole to the east fossiliferous limestone of the Ocala was found within 10 feet of the surface; it was overlain by clayey sand, probably of the Hawthorn formation. The hole to the south passed through about 15 feet of clayey sand and clay, probably the Hawthorn formation, and was bottomed after passing through about 5 feet of clay, sand, and fresh-water limestone, of the Tampa. The limestone contained 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 limestone of the Tampa 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 50–100 feet thick on the west side of the fault, but absent on the east side.

CONTACT BETWEEN THE TAMPA LIMESTONE AND THE HAWTHORN FORMATION

Subsurface features of the base of the Hawthorn formation and the thickness of the Tampa limestone are shown on plate 3. The map is chiefly of the surface of the Tampa limestone; however, in some areas to the east and north of Polk City the Hawthorn lies upon

Eocene rocks. The information is based on 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 us and does not necessarily coincide with the base as placed by the Florida Geological Survey.

North of about lat. 28° there is little correspondence between the structural 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. 25), 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 from west to N. 48° W. depending upon which combination of wells was used. The most persistent component was about N. 50° W. This strike gives a dip for the Tampa limestone of 8–10 feet per mile to the southwest, which is also the direction of greatest thickening of the formation. No reliable 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 3) 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 that show clearly the details of the contact were found, but a contact, believed to be unconformable, between weathered Tampa and Hawthorn sediments is present at localities 6 and 24 (figs. 14 and 15), previously discussed. The presence of chert at the Tampa-Hawthorn contact and the possibility that the rock collected at locality 73 (see p. 31) represents reworked Tampa limestone are also suggested as evidence for an unconformity.

The fauna of the Tampa limestone (table 2) indicates, for some areas at least, a very shallow marine and, locally, a 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 samples from the Davison well, one from the top of the Tampa and the other from near the base of the Hawthorn, were X-rayed[5] to determine whether there are any mineralogic changes across the contact. Quartz, orthoclase, montmorillonite, and illite were found in the Hawthorn sample; quartz, plagioclase, montmorillonite, and attapulgite were found 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 2, 13, and 15 and plate 3 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 which are underlain by orange iron-stained clay and sand. One area of such topographic highs extends from near Thonotosassa 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 undifferentiated Miocene and Pliocene rocks. The thin layer of 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 and Pliocene sediments localized over highs on the surface of the Suwannee or Tampa limestones. On plate 3 note 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 sand, which lies around the flanks of the Ocala uplift. In this area the belt has been breached by the Hillsborough and 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

[5] Informal analyses by R. G. Petersen, U.S. Geological Survey.

original deficiency of carbonate can be explained by the site of deposition. As pointed out by Trask (1932, p. 93, 125) fine material and carbonate tend to be more abundant in deposits of submarine basins, whereas 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. 16) 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 his Inglis member of the Moodys Branch formation as used by him (lower part of the Ocala limestone of this report) 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 and 15). This minor deformation is due to solution of limestone and slumping of the overlying beds.

SEDIMENTATION

SUWANNEE LIMESTONE

The Suwannee limestone represents a period similar to 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 sea during the deposition of the Suwannee and their remains locally comprise a large part of the formation.

The lower part of the Suwannee limestone in the Davison well (see p. 10) 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 deposition of the Tampa, 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 (table 2) 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 nearshore lagoonal or estuarine environment alternating with or associated with basic lakes. The latter were not necessarily undergoing dessication, however. This conclusion 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 limestone 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 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 seas of late Tampa and Hawthorn times is a question that cannot be conclusively answered at present, but we favor the theory of Kazakov (1937; summarized in 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. This 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 Eocene and Oligocene age, and that the sand is coarser than that deposited previously. The sudden influx of these clastic materials in Miocene sediments, particularly limestone, 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. 7, 8, 9, and table 4).

Berry (1916, p. 46) thought that the increase in supply of terrestrial material represented in northern Florida by the sedimentation of the Alum Bluff group was probably due to an inland rise of land. The only obvious means of transferring large quantities of sand into the Florida peninsular area during the Miocene, however, was 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 clastic material is indicated by the lithology of the Hawthorn formation.

The problem remains unsolved, but we 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 (written communication, 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 beds of pure waxy green attapulgite-montmorillonite clay and clayey limestones were found by us 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 arching 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.

In Tampa time the sea 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 Eocene-Oligocene 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.

In Hawthorn time the sea then advanced over a slightly irregular surface depositing calcareous sand and clay 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 sand unit and phosphorite unit of the Hawthorn formation. Radiometric logs of core holes in this belt show (figs. 2, 3, and 16) 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 and 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 a leached portion of the Hawthorn formation, contains abundant aluminum phosphate. A raw grab sample of this rock from locality 44 contained 0.008 percent equivalent uranium.[6] 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 are found also in the Dade

[6] Laboratory No. 115958.

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 10–15 feet thick in drill holes G112 and G113 (fig. 3), 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 found farther north, is 5–10 feet thick in holes G110–G113, 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.[7] The uranium content was negligible.

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.

For further evaluation of the uranium and phosphate resources of this area the reader is referred to Cathcart and McGreevy (1959).

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 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 limestone of the Hawthorn 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.[8] Samples from Sydney, Watson, and Peace Valley mines contained an average of 17.5, 19.9, and 17.5 percent MgO respectively. Composite samples of rock mined at 2 dolomite quarries in Manatee and Sarasota Counties contained 17.3 and 18.5 percent MgO.[9]

[7] Laboratory No. 115969

[8] Laboratory Nos.: loc. 39, 115952-115954; 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.

[9] Laboratory Nos.: 115993, 115994.

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

LITERATURE CITED

Allen, J. H., 1846, Some facts respecting the geology of Tampa Bay, Florida: Am. Jour. Sci., 2d ser., v. 1, p. 38-42.

Altschuler, Z. S., and Cisney, E. A., 1952, X-ray evidence of the nature of the carbonate-apatites [abs.]: Geol. Soc. America Bull., v. 63, no. 12, pt. 2, p. 1230.

Applin, P. L., and Applin, E. R., 1944, Regional subsurface stratigraphy and structure of Florida and southern Georgia: Am. Assoc. Petroleum Geologists Bull., v. 28, no. 12, p. 1673–1753.

Bergendahl, M. H., 1956, Stratigraphy of parts of DeSoto and Hardee Counties, Florida: U.S. Geol. Survey Bull. 1030–B.

Berry, E. W., 1916, The physical conditions and age indicated by the flora of the Alum Bluff formation: U.S. Geol. Survey Prof. Paper 98–E, p. 41–59.

Brown, R. W., 1934, Celliforma spirifer, the fossil larval chambers of mining bees: Washington Acad. Sci. Jour., v. 24, no. 12, p. 532–539.

——— 1935, Further notes on fossil larval chambers of mining bees: Washington Acad. Sci. Jour., v. 25, no. 12, p. 526–528.

Cathcart, J. B., and McGreevy, L. J., 1959, Results of geologic exploration by core drilling, 1953, land-pebble phosphate district, Florida: U.S. Geol. Survey Bull. 1046–K.

Cathcart, J. B., Blade, L. V., Davidson, D. F., and Ketner, K. B., 1953, The geology of the Florida land-pebble phosphate deposits: Internat. Geol. Cong., 19th, Algiers 1952, Comptes rendus, sec. 11, pt. 11, p. 77–91.

Colbert, E. H., 1932, Aphelops from the Hawthorn formation of Florida: Florida Geol. Survey Bull. 10, p. 55–58.

Cole, W. S., 1941, Stratigraphic and paleontologic studies of wells in Florida: Florida Geol. Survey Bull. 19.

Cooke, C. W., 1915, The age of the Ocala limestone: U.S. Geol. Survey Prof. Paper 95–I, p. 107–117.

——— 1931, Seven coastal terraces in the Southeastern States: Washington Acad. Sci. Jour., v. 21, no. 21, p. 503–513.

——— 1943, Geology of the coastal plain of Georgia: U.S. Geol. Survey Bull. 941.

——— 1945, Geology of Florida: Florida Geol. Survey Bull. 29.

Cooke, C. W., and Mansfield, W. C., 1936, Suwannee limestone of Florida [abs.]: Geol. Soc. America Proc. 1935, p. 71–72.

Cooke, C. W., and Mossom, Stuart, 1929, Geology of Florida: Florida Geol. Survey Ann. Rept. 20, p. 29–227.

Cushman, J. A., 1920, Lower Miocene Foraminifera of Florida: U.S. Geol. Survey Prof. Paper 128–B, p. 67–74.

Cushman, J. A., and Ponton, G. M., 1932, The Foraminifera of the upper, middle, and part of the lower Miocene of Florida: Florida Geol. Survey Bull. 9.

Dall, W. H., 1890–1903, Contributions to the Tertiary fauna of Florida, with a special reference to the Miocene silex beds of Tampa and the Pliocene beds of the Caloosahatchie River: Wagner Free Inst. Sci. Trans., v. 3, pts. 1–6.

——— 1915, A monograph of the molluscan fauna of the *Orthaulax pugnax* zone of the Oligocene of Tampa, Florida: U.S. Nat. Mus. Bull. 90.

Dall, W. H., and Harris, G. D., 1892, Correlation papers; Neocene: U.S. Geol. Survey Bull. 84.

Fischer, A. G., 1949, Petrology of Eocene limestones in and around the Citrus-Levy County area, Florida: Florida Geol. Survey Rept. Inv., no. 9, p. 41–70.

Gardner, Julia A., 1926–50, The molluscan fauna of the Alum Bluff group of Florida: U.S. Geol. Survey Prof. Paper 142, pts. 1–9.

Grim, R. E., 1933, Petrography of the fuller's earth deposits, Olmstead, Illinois, with a brief study of some non-Illinois earths: Econ. Geology, v. 28, no. 4, p. 358.

Grim, R. E., Dietz, R. S., and Bradley, W. F., 1949, Clay mineral composition of some sediments from the Pacific Ocean off the California coast and the Gulf of California: Geol. Soc. America Bull., v. 60, p. 1785–1808.

Heath, R. C., and Smith, P. C., 1954, Ground-water resources of Pinellas County, Florida: Florida Geol. Survey Rept. Inv., no. 12.

Heilprin, Angelo, 1887, Explorations on the west coast of Florida and in the Okeechobee wilderness: Wagner Free Inst. Sci. Trans., v. 1.

Hopkins, R. H., 1942, The dolomitic limestones of Florida: Florida Geol. Survey Rept. Inv., no. 3.

Johnson, L. C., 1888, The structure of Florida: Am. Jour. Sci., 3rd ser., v. 36, p. 230–236.

Kazakov, A. V., 1937, The phosphorite facies and the genesis of phosphorites, *in* Himmelfarb, B. M., and others, eds., Geological investigations of agricultural ores USSR: [U.S.S.R.] Sci. Inst. Fertilizers and Insecto-Fungicides Trans., no. 142, Leningrad, p. 95–113. (Translation published for the 17th sess. Internat. Geol. Cong.)

Kerr, P. F., 1937, Attapulgus clay: Am. Mineralogist, v. 22, p. 534–550.

Ketner, K. B., and McGreevy, L. J., 1959, Stratigraphy of the area between Hernando and Hardee Counties, Florida: U.S. Geol. Survey Bull. 1074–C.

Leith, C. K., 1925, Silicification of erosion surfaces: Econ. Geology, v. 20, no. 6, p. 513–523.

MacNeil, F. S., 1944, Oligocene stratigraphy of southeastern United States: Am. Assoc. Petroleum Geologists Bull., v. 28, no. 9, p. 1313–1354.

——— 1946, The Tertiary formations of Alabama: Southeastern Geol. Soc. Guidebook 4th Field Trip, p. 55.

——— 1947, Correlation chart for the outcropping Tertiary formations of the eastern Gulf region: U.S. Geol. Survey Oil and Gas Inv. Prelim. Chart 29.

——— 1949, Pleistocene shorelines in Florida and Georgia: U.S. Geol. Survey Prof. Paper 221–F, p. 95–106.

Mansfield, W. C., 1937, Mollusks of the Tampa and Suwannee limestones of Florida: Florida Geol. Survey Bull. 15.

Matson, G. C., 1915, The phosphate deposits of Florida: U.S. Geol. Survey Bull. 604.

Matson, G. C., and Clapp, F. G., 1909, A preliminary report on the geology of Florida, with special reference to the stratigraphy: Florida Geol. Survey Ann. Rept. 2, p. 25–173.

Matson, G. C., and Sanford, Samuel, 1913, Geology and ground waters of Florida: U.S. Geol. Survey Water-Supply Paper 319.

McKelvey, V. E., Swanson, R. W., and Sheldon, R. P., 1953, The Permian phosphorite deposits of western United States: Internat. Geol. Cong., 19th, Algiers 1952, Comptes rendus, sec. 11, pt. 11, p. 46–64.

Millot, Georges, 1952, Prospecting for useful clays in relation with their conditions of genesis, *in* Problems of clay and laterite genesis—symposium: New York, Am. Inst. Mining Metall. Engineers, p. 107–114.

Mossom, D. S., 1925, A preliminary report on the limestones and marls of Florida: Florida Geol. Survey Ann. Rept. 16, p. 27, 203.

——— 1926, A review of the structure and stratigraphy of Florida, with special reference to the petroleum possibilities: Florida Geol. Survey Ann. Rept. 17, p. 169–275.

Puri, H. S., 1953a, Zonation of the Ocala group in peninsular Florida [abs.]: Jour. Sed. Petrology, v. 23, p. 130.

——— 1953b, Contribution to the study of the Miocene of the Florida panhandle: Florida Geol. Survey Bull. 36.

Sellards, E. H., 1915, The pebble phosphates of Florida: Florida Geol. Survey Ann. Rept. 7, p. 25–116.

——— 1916, Fossil vertebrates from Florida; a new Miocene fauna; new Pliocene species; the Pleistocene fauna: Florida Geol. Survey Ann. Rept. 8, p. 77–119.

Simpson, G. G., 1930, Tertiary land mammals of Florida: Am. Mus. Nat. History Bull., v. 59, art. 3, p. 149–211.

——— 1932, Miocene land mammals from Florida: Florida Geol. Survey Bull. 10, p. 7–41.

——— 1933, Glossary and correlation charts of North American Tertiary mammal-bearing formations: Am. Mus. Nat. History Bull., v. 57, p. 91.

Stephenson, L. W., and Veatch, J. O., 1915, Underground waters of the Coastal Plain of Georgia: U.S. Geol. Survey Water-Supply Paper 341, p. 52–115.

Trask, P. D., 1932, Origin and environment of source sediments of petroleum: Houston, Tex., American Petroleum Institute, 323 p.

Vaughan, T. W., 1910, A contribution to the geologic history of the Floridian Plateau: Carnegie Inst. Washington Pub. 133, Tortugas Lab. Papers, v. 4, p. 99–185.

Vaughan, T. W., and Cooke, C. W., 1914, Correlation of the Hawthorn formation: Washington Acad. Sci. Jour., v. 4, no. 10, p. 250–253.

Vernon, R. O., 1951, Geology of Citrus and Levy Counties, Florida: Florida Geol. Survey Bull. 33.

Wentworth, C. K., 1922, A scale of grade and class terms for clastic sediments: Jour. Geology, v. 30, p. 377–392.

Wetmore, Alexander, 1943, Fossil birds from the Tertiary deposits of Florida: New England Zool. Club Proc., v. 22, p. 59–68.

White, T. E., 1942, The lower Miocene mammal fauna of Florida: Harvard Coll. Mus. Comp. Zoology Bull., v. 92, no. 1.

EXPOSURES OF THE SUWANNEE AND TAMPA LIMESTONES AND THE HAWTHORN FORMATION

[Most of the geographic and locality names used in this table can be found on the Army Map Service 7½-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.]

Locality and No. (pl. 2)	Access	General lithology	Thickness (feet)	Remarks
		SUWANNEE LIMESTONE **Hillsborough County**		
8. Blackwater Creek; NW¼ sec. 18, T. 27 S., R. 22 E.	State Highway 39 about 8.5 miles north of Plant City; spoil banks of ditch.	Limestone, white, slightly sandy, granular, locally silicified.	--------	Mansfield (1937, p. 51) and Cooke (1945, p. 127) report Suwannee-Tampa contact here; fossils of both formations present.
40. Crum property; sec. 9, T. 27 S., R. 22 E.	State Highway 39, 0.4 mile north of Blackwater Creek; turn east through locked gate on woods and pasture roads in an east-northeast direction for about 1.5 miles; boulders of chert and silicified limestone on surface of ground.	Chert, varicolored, fossiliferous, and partly silicified limestone.	--------	
46. Hillsborough River State Park; sec. 8, T. 27 S., R. 21 E.	U.S. Highway 301 to Hillsborough River State Park; take "Rapids Trail" to river; boulders in river.	Chert, gray and brown, sparsely fossiliferous.	--------	
		Pasco County		
51. Crystal Springs; NW¼ sec. 35, T. 26 S., R. 21 E.	State Highway 39 to Crystal Springs town; turn east for about 1.6 miles, then turn north; entrance to spring on west side of road; boulders around spring.	Chert, gray, brown, very fossiliferous.	--------	Cooke (1945, p. 97).

55. Crystal Springs ditch; sec. 36, T. 26 S., R. 21 E.	State Highway 39 to Crystal Springs town; turn west for 0.35 mile, then north on dirt road; exposure in small ditch on west side of road.	Chert and tripoli, cavernous, iron-stained, brown, red, white, cobbles.	--------	Probably Suwannee although some chert residual from the Tampa limestone probably occurs in the area.
56, 57, 58. Crystal Springs pits; secs. 25, 26, T. 26 S., R. 21 E.	Locality 56: State Highway 39, 0.8 mile north of Crystal Springs town; shallow borrow pits east side of road. Locality 57: State Highway 39, 1.4 miles north of Crystal Springs town; shallow borrow pit 100 yds west of road. Locality 58: Stock watering pit on private land, about 0.8 mile west and south of locality 57.	Chert, brown, gray, black, locally pyritic, fossiliferous, tripoli; silicified corals associated with gray to red clayey sand.	--------	Clayey sand and corals; some of the chert may be Miocene. Localities listed here are only a few of many in the Crystal Springs area where chert occurs.
59. New River bridge; SW¼ sec. 13, T. 26 S., R. 20 E.	State Highway 54, about 5.5 miles west of Zephyrhills, at north 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.
62. McLeod pit; SE¼NE¼ sec. 26, T. 23 S., R. 21 E.	From Lacoochee turn south on paved street over railroad tracks, continue south on main dirt road for about 1 mile until road parallels tracks on the east; pit on private land about 0.2 mile west of road.	Limestone, soft, white, granular, slightly sandy, irregularly fossiliferous; upper part thin bedded in places and contains many vertical "pipes" with green clay.	30	Cooke (1945, p. 98).
63. Pasco roadcut; NE¼ sec. 11, T. 25 S., R. 19 E.	State Highway 52 from Dade City, about 2.4 miles west of Pasco in very shallow roadcut near corrals on south side of road; also spoil banks of ditch about 0.3 mile north of roadcut.	Sand, clayey, dark-brown to gray, hardpan; contains brown, orange, and white sparsely fossiliferous chert and tripoli; also (at ditch to north), light-tan hard crystalline, very slightly sandy fossiliferous limestone.	--------	

Locality and No. (pl. 2)	Access	General lithology	Thickness (feet)	Remarks
		SUWANNEE LIMESTONE—Continued **Pasco County—Continued**		
65. Hudson; SW¼ sec. 28, T. 24 S., R. 16 E.	Hudson, west from post office for about 0.3 mile to the gulf; spoil banks along canals.	Limestone, white to light-gray, pure, hard, very fine grained, fossiliferous; and white granular foraminiferal porous very slightly sandy limestone.	--------	Both Tampa and Suwannee limestones probably present; some land snails found here.
66. North Hudson; NW¼ sec. 27, T. 24 S., R. 16 E.	Gravel road north 0.7 mile from Hudson post office; spoil banks of drainage ditch, west side of road.	Limestone, hard, white to light-tan, thin-bedded, very slightly sandy, sparsely fossiliferous.	--------	May be at or near Mansfield's (1937, p. 52) locality.
67. Hudson-Aripeka quarry; sec. 14, T. 24 S., R. 16 E.	Gravel road north about 3 miles from Hudson post office, turn east on trail about 0.3 mile to old pit and crusher; latter visible from road.	Limestone, hard, white, pure, very fine grained, irregularly fossiliferous.	--------	Mossom (1925, p. 171).
70. Griffin pit; S½ sec. 19, T. 26 S., R. 22 E.	From junction of U.S. Highway 301 and State Highway 39 south of Zephyrhills turn east on dirt road at sawmill for about 0.9 mile, turn southeast through gate, past cabin, through another gate and southeast through fields for about 1.3 miles from first gate; shallow, water-filled pit on the edge of Hillsborough River swamp. Property of E. Z. Griffin, Tampa, Fla.	Limestone, 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 limestone; one specimen of *Cyrena floridana*, never recorded from Suwannee limestone, found. Chert of the Suwannee and Tampa(?) corals are common in this region as scattered float.

		Polk County		
72. Rock Ridge; NE¼ sec. 19, T. 25 S., R. 24 E.	From U.S. Highway 98 north of Lakeland, turn northeast on Rock Ridge gravel road for about 8.5 miles; boulders by ditch, northwest side of road, just after first major bend in road.	Chert, tripoli, white to gray, cavernous, iron-stained, very fossiliferous.	--------	Fossils from both Suwannee limestone and Eocene rocks are present. A fault probably is present just east of this locality.
		TAMPA LIMESTONE Hillsborough County		
1. Sixmile Creek (Orient); NW¼ sec. 14, T. 29 S., R. 19 E.	From State Highway 574 east of Tampa, turn south at Orient Road, then east along north side of first railroad tracks to end of road at creek.	Limestone, 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 oI calcareous Pleistocene shells and silicified Tampa fossils overlies limestone in places.
2. Ballast Point; 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.
3. Rocky Point; NE¼ sec. 14, T. 29 S., R. 17 E.	Columbus Dr. (Courtney Campbell Causeway), Tampa; about 3 miles west of municipal airport terminal turn south to end of point and outcrop on beach.	Limestone, white to light-gray, soft, slightly sandy to very sandy, conglomeratic; abundant thin seams of secondary carbonate; top 6 inches recemented in places and contains Pleistocene shells and organic material.	3.5	Most accessible at low tide. Upper 2.0 feet of outcrop may contain sand of Quaternary age.
4. Sweetwater Creek; NW¼ sec. 1, T. 29 S., R. 17 E.	State Highway 580, south side of bridge over creek, about 3.5 miles west of junction with U.S. Highway 92.	Limestone, light-tan, slightly sandy, soft, very fossiliferous.	2.0	Cooke, 1945, p. 126.

Locality and No. (pl. 2)	Access	General lithology	Thickness (feet)	Remarks
		TAMPA LIMESTONE—Continued Hillsborough County—Continued		
6. Temple Terrace underpass; NW¼ SW¼ sec. 19, T. 28 S., R. 20 E.	U.S. Highway 301 about 2.7 miles north of junction with U.S. Highway 92; roadcut.	Sand, clayey to very clayey, and sandy light-gray to gray-green iron-stained clay; chert and tripoli.	12.0	See fig. 15. Silicified lower Miocene fossils and *Siderastraea* corals. Chert is probably silicified fresh-water limestone, containing Charophyte oogonia.
8. Blackwater Creek; NW¼ sec. 18, T. 27 S., R. 22 E.	State Highway 39 about 8.5 miles north of Plant City; spoil banks of ditch.	Limestone, white, slightly sandy, granular, locally silicified.	--------	Mansfield (1937, p. 51) and Cooke (1945, p. 127) report Suwannee - Tampa contact here; fossils of both formations present.
11. 40th Street Bridge; NW¼ sec. 33, T. 28 S., R. 19 E.	40th St., northeast of Tampa at south end of bridge over Hillsborough River; small borrow pit, west side of 40th St.	Limestone, white to light-brown, slightly sandy to sandy; thin seams of silica.	6.5	
12. Howard Ave. ditch	In block between Howard Ave., Columbus Dr., Armenia Ave., and Kathleen St., Tampa.	Limestone, light-tan to white, very clayey, sandy; patches and lenses of blue-green sandy clay.	1.5	Now inaccessible.
18. Morris Bridge; NE¼ sec. 33, T. 27 S., R. 20 E.	Morris Bridge Rd., 0.3 mile northeast of Morris Bridge over Hillsborough River, or about 7 miles north of junction of Morris Bridge Rd. and old U.S. Highway 301; ditch beside road.	Limestone, white, sandy, partly silicified, fossiliferous, and varicolored chert.	--------	Not in place, but probably from drainage ditch.
19. King sinkhole; NW¼ sec. 18, T. 28 S., R. 20 E.	From intersection of Fowler Ave. and Morris Bridge Rd. northeast of Tampa, turn	Limestone, light-tan, hard, slightly sandy, fragmental, sparsely fossiliferous; sec-	9.0	

	south for 0.5 mile, turn east on dirt road for 0.4 mile; sinkhole 200 feet north of road.	ondary carbonate fracture filling.		
20. Temple Terrace; SW¼ sec. 13, T. 28 S., R. 19 E.	Fowler Ave., northeast of Tampa, at 0.3 mile west of Hillsborough River turn south on dirt road for about 0.5 mile, bank west of road.	Limestone, 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 feet of limestone is exposed in a small sink on east side of road about 200 yards east-northeast of main outcrop. Silicified coral *Siderastraea silicensis* present in upper part of outcrop.
21. Cow House Creek; SE¼ sec. 12, T. 28 S., R. 19 E.	Morris Bridge Rd. at bridge over Cow House Creek, 0.03 mile north of Fowler Ave.	Chert and silicified limestone, gray, white, brown, massive, banded, limy pockets in places.	--------	Possibly silicified Suwannee limestone.
24. Lamour pit; NE¼ sec. 33, T. 28 S., R. 19 E.	50th St. and Robles (East Sligh) Ave., northeast Tampa; depression, northeast corner of sand pit.	Limestone, white to light-tan, soft, clayey, sandy; overlain by clay, sand, and chert, the last containing lower Miocene fossils.	5. 0	Limestone and lower part of section may be covered by slump; excellent example of weathering; see figure 14.
25. Harney railroad cut; SW¼ sec. 26, T. 28 S., R. 19 E.	Robles (East Sligh) Ave., north of viaduct over railroad tracks just south of Harney; railroad cut.	Limestone, white to light-tan, sandy, and thin seams of sandy blue-green clay grading upward into white hard very slightly sandy limestone; at top is light-tan slightly sandy fragmental limestone that weathers spheroidally.	8. 0	On east side of cut is red-brown clayey sand, mostly residual from Tampa limestone, but the upper 0.5 feet may be Hawthorn formation.
26. Hillsborough River dam; NW¼ sec. 29, T. 28 S., R. 19 E.	Turn north from East Hillsborough Ave. (U.S. Highway 92) on 30th St. past Tampa waterworks to end of road; outcrop below dam, south side of river.	Sand, white to gray-green, and light-tan soft sandy, clayey limestone.	8. 0	See figure 10. 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.

Locality and No. (pl. 2)	Access	General lithology	Thickness (feet)	Remarks
		TAMPA LIMESTONE—Continued Hillsborough County—Continued		
27. Hillsborough River; SE¼ sec. 30, T. 28 S., R. 19 E.	About 0.2 mile north of Sligh Ave. near end of 18th St., northeast Tampa; boulders at edge of Hillsborough River about 100 yards north of concrete bridge over small tributary creek.	Chert, gray, silicified, and sandy fossiliferous limestone.	--------	Apt to be under water in rainy season.
28. North side of Hillsborough River dam; S½ sec. 20, T. 28 S., R. 19 E.	East Waters Ave. in northeast Tampa, about 1.3 miles east of Nebraska Ave. turn south on dirt road to dam.	Limestone, white, sandy, fragmental, fossiliferous, locally silicified.	2.0	Limestone exposed here is similar to upper units at locality 26 across river.
29. Stinky Creek; E½ sec. 26, T. 28 S., R. 18 E.	North Blvd., Tampa, 0.55 mile north of Sligh Ave., or 0.45 mile south of Waters Ave.; in small creek bottom east and west of bridge.	Limestone, light-gray to light-yellow, sandy, hard, fossiliferous; abundant seams of secondary carbonate; "fresco" weathering.	3.5	
31. Cone sandpit; NW¼ sec. 3, T. 29 S., R. 19 E.	At 52d St., northeast of Tampa, turn north from Harney Ave. (Fort King Highway) at Orange Hill cemetery; large sandpit; limestone exposed in deepest part of west pit.	Limestone, white, slightly sandy, hard, silicified, fossiliferous.	2.0	Well-preserved silicified shells weathered out of limestone could be collected here in 1953.
32. MacDill ditch; SW¼ sec. 26, T. 30 S., R. 18 E.	In southeast part of MacDill U.S. Air Force Base, about 0.7 mile north and 0.3 mile east of Quarantine station at Gadsden Point; spoil banks of canal at west end of golf course.	Limestone, white, slightly sandy, very fossiliferous.	--------	Most southerly exposure of Tampa limestone known.

33. Beach Park; NE¼ sec. 29, T. 29 S., R. 18 E.	Turn east from West Shore Blvd. at Woodmere Ave. in Beach Park; in ditch between divided street.	Limestone, white to tan, very slightly sandy, soft, fossiliferous, abundant secondary carbonate.	--------	Probably in place, but may be contaminated by fill.
34. Gray Rd.; E½ sec. 18, T. 29 S., R. 18 E.	Across from 4821 Gray Rd., about 0.2 mile west of West Shore Blvd., Tampa.	Limestone, light-tan, very slightly sandy, very fossiliferous, cobbles; overlain by irregularly fossiliferous gray chert.	--------	
43. Eureka Springs; NW¼SE¼ sec. 31, T. 28 S., R. 20 E.	U.S. Highway 92, turn north at 0.6 mile west of intersection of U.S. Highway 92 and Faulkenburg Rd., or 0.8 mile east of junction of U.S. Highways 301 and 92; scattered boulders around fish ponds.	Limestone, white, slightly sandy, fragmental, sparse microfossils.	--------	
49. Tampa Waterworks; E½ sec. 29, T. 28 S., R. 19 E.	30th St., northeast Tampa, about 1.3 miles north of Hillsborough Ave. (U.S. Highway 92); construction excavation.	At base: limestone, sandy, clayey, soft, rotten, white to light tan, with lenses and pockets of white fine-grained sand; contacts irregular; overlain by sand and white to green, sparsely fossiliferous sandy clay, residual from limestone.	8.5	No longer accessible.
Pasco County				
54. Cabbage Swamp; NE¼ sec. 22, T. 26 S., R. 19 E.	Denham-Wesley Chapel Rd. (State Highway 209) about 4.8 miles southwest of Wesley Chapel; shallow borrow pit, west side of road.	Limestone, white to gray, impure, hard, sandy, abundant bands of brown carbonate; cobbles.	--------	Probably Tampa limestone; apt to be covered in rainy season; coral *Siderastraea hillsboroensis* in surface rubble.
64. St. Leo borrow pit; SE¼ sec. 6, T. 25 S., R. 21 E.	State Highway 52, about 1.0 mile east of St. Leo or about 2.5 miles southwest of Dade City; shallow borrow pit, south side of road.	Sand, white to brown, fine-grained, hard, indurated, aluminum phosphate cement; abundant silicified corals in rubble on surface.	--------	Similar in appearance to some hardrock phosphate.

Locality and No. (pl. 2)	Access	General lithology	Thickness (feet)	Remarks
		TAMPA LIMESTONE—Continued **Pasco County—Continued**		
65. Hudson; SW¼ sec. 28, T. 24 S., R. 16 E.	Hudson, west from post office for about 0.3 mile to the gulf; spoil banks along canals in new housing area.	Limestone, white to light-gray, pure, hard, very fine grained, and white granular foraminiferal porous very slightly sandy limestone.	--------	Both Suwannee and Tampa limestone probably present.
69. St. Joseph; S½ sec. 21, T. 24 S., R. 20 E.	State Highway 578 about 1.7 miles west of St. Joseph; stock watering pits in pasture about 0.2 mile north of road.	Silicified pelecypods in clayey sand.	--------	
		Polk County		
73 A, B, C. Tenoroc mine, Coronet Phosphate Co; sec. 35, T. 27 S., R. 24 E.	Combee Rd. east of Lakeland; at about 3.8 miles north of U.S. Highway 92 turn east on Ritter Rd. to Coronet mine washer, turn south-southwest across tracks to pits; waste piles in bottom of pit about 0.7 mile south-west of washer.	Limestone, 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 nonphosphatic non-fossiliferous limestone, and abundant brown carbonate, locally very fossiliferous.	--------	Hawthorn formation probably also present here.
		Pinellas County		
89. Belleair Bluffs; NE¼ sec. 29, T. 29 S., R. 15 E.	About 0.7 mile south of Belleview Biltmore Hotel in Belleair, south of Clearwater, at base of bluff overlooking the gulf.	At base: clay, mottled gray-blue, very slightly calcareous, grading upward into light-tan clayey, sandy conglomeratic limestone con-	6.0	Most accessible at low tide.

		taining abundant pebbles and subangular fragments of clay like that below; grades up into violet-blue sandy very slightly calcareous clay containing fragments of leached unfossiliferous limestone.		
90. Phillippe Park; NW¼ sec. 35, T. 28 S., R. 16 E.	About 1.5 mile north of Safety Harbor in bank on shore of Tampa Bay, at foot of large Indian mound in Phillippe Park.	Limestone, white, clayey, chalky, very slightly sandy, possibly dolomitic.	.5	
91. Bayview; SW¼ sec. 16, T. 29 S., R. 16 E.	From the gulf to Bay Blvd. east of Clearwater, turn south to bay about 0.5 mile west of junction with Safety Harbor road; outcrop on beach.	Limestone, light-gray, brittle, hard, sandy, dolomitic, sparsely fossiliferous.	--------	Accessible only at low tide. Rock contains, in addition to lower Miocene fossils, *Carolia*, *Periploma*, and a large *Cardita*, not previously reported from Tampa limestone; may be near or at contact with Hawthorn formation.
94. Crystal Beach; NE¼ sec. 3, T. 28 S., R. 15 E.	U.S. Highway 19, about 1.0 mile north of Palm Harbor turn west at Crystal Beach entrance; turn south 2 blocks after crossing railroad tracks, and continue to end of road at beach.	Limestone, gray to white, soft, slightly sandy, conglomeratic, fossiliferous, and gray fossiliferous chert and tripoli.	--------	Most accessible at low tide.
95. Anclote; E½ sec. 1, T. 27 S., R. 15 E.	State Highway 15 (595) about 0.5 mile north of Anclote River at Tarpon Springs; about 200 feet northeast of railroad crossing in shallow ditch west side of road.	Limestone, light-tan, very slightly sandy, conglomeratic, fossiliferous.	--------	Cooke, 1945, p. 131–132.

Locality and No. (pl. 2)	Access	General lithology	Thickness (feet)	Remarks
		TAMPA LIMESTONE—Continued **Sumter County**		
100. Linden; SW¼ sec. 16, T. 22 S., R. 23 E.	State Highway 50, 1 mile east of Linden; shallow roadcut.	Limestone, white, slightly sandy, fossiliferous.	0.5	The overlying phosphatic sandy clay may be middle Miocene.
		HAWTHORN FORMATION **Hillsborough County**		
6. Temple Terrace Underpass; NW¼ SW¼ sec. 19, T. 28 S., R. 20 E.	U.S. Highway 301, about 2.7 miles north of junction with U.S. Highway 92; roadcut.	Sand, clayey, fine- to medium-grained, gray to reddish-brown.	6.0	The underlying Tampa limestone is also exposed here (fig. 15).
9. Knights; NE¼ sec. 6, T. 28 S., R. 22 E.	State Highway 39, 0.1 mile north of intersection at Knights, 4 miles north of Plant City; railroad cut, east side of road.	Sand, slightly clayey to clayey, fine- to medium-grained, tan to orange-brown; contains vesicular nodules of sand cemented by aluminum phosphate and hardpan.	4.5	A nearby drill hole (M1) showed that at least 30 feet of phosphatic sand and clay assigned to the Hawthorn formation underlie the small hill at this locality.
10. Riverview; W½ sec. 21, T. 30 S., R. 20 E.	U.S. Highway 301, turn south-east 0.1 mile south of south end of bridge over Alafia River; continue 0.8 mile to arch bridge over small creek; outcrop above and below bridge in bottom of ravine.	Limestone, light-tan to white, locally hard, irregularly sandy, and very calcareous light-tan to white sandstone; all contain sparse phosphate nodules.	3.5	Probably the best permanent exposure of limestone of the Hawthorn formation in the area.
13. Mango Hills clay pit; NW¼SW¼ sec. 3, T. 29 S., R. 20 E.	State Highway 579, 0.5 mile north of junction with State Highway 574 at Mango; large clay pit east of road.	Sand, slightly clayey to clayey, fine- to medium-grained, tan to red-brown interbedded with slightly sandy gray-green blocky waxy clay containing sparse platy fragments of aluminum phosphate and chert.	20.0	Possibly post-middle Miocene. Interesting minor structural features, one of which is shown in figure 13.

14. Buckhorn Springs; NW¼ sec. 10, T. 30 S., R. 20 E.	Bloomingdale Rd., turn south on dirt road about 2.2 miles east of junction with U.S. Highway 301, or about 3.5 miles west of Bloomingdale; continue about 0.4 mile to end of road at spring pool; loose boulder dug from spring.	Limestone, tan, sandy		
15. Bell Shoals; W½ sec. 24, T. 30 S., R. 20 E.	Brandon-Boyette Rd., south end of Bell Shoals bridge over Alafia River, about 6 miles south of Brandon; small outcrop at river's edge.	Limestone, tan, sandy, sparsely phosphatic.	.5	Accessible only in dry season.
16. Alderman's ford; SE¼ sec. 18, T. 30 S., R. 22 E.	State Highway 39 (Hopewell-Pinecrest Rd.) about 5 miles south of Hopewell or about 1 mile north of Pinecrest below bridge over Alafia River.	Limestone, tan, sandy, phosphatic.	.5	Accessible only in dry season.
22. Buckhorn Creek; SW¼ sec. 3, T. 30 S., R. 20 E.	Bloomingdale Rd. about 2.4 miles east of junction with U.S. Highway 301, or about 3.2 miles west of Bloomingdale; borrow pit north side of road at Buckhorn Creek.	Sand, light-gray to orange-brown, slightly clayey, fine-grained, with trace of very coarse grains.	5.5	Possibly post-middle Miocene.
24. Lamour pit; NE¼ sec. 33, T. 28 S., R. 19 E.	50th St. and Robles (East Sligh) Ave., northeast Tampa; northeast corner of sandpit.	Sand, clayey, yellow-brown; contains sparse chert fragments.	2.5	Overlies residuum of Tampa limestone.
25. Harney railroad cut; SW¼ sec. 26, T. 28 S., R. 19 E.	Robles (East Sligh) Ave.; north of viaduct over railroad just south of Harney; railroad cut.	Sand, orange-brown, slightly clayey, medium-grained; trace of coarse grains, contains sparse chert fragments; lower contact with Tampa limestone gradational.	.5	

Locality and No. (pl. 2)	Access	General lithology	Thickness (feet)	Remarks
HAWTHORN FORMATION—Continued Hillsborough County—Continued				
31. Cone sandpit; NW¼ sec. 3, T. 29 S., R. 19 E.	At 52d St., northeast of Tampa, turn north from Harney Ave. (Fort King Highway) at Orange Hill cemetery; large sandpit.	Sand, very slightly clayey, medium- to coarse-grained, white, tan, dark-violet-gray; overlies Tampa limestone; contact gradational.	5. 0	Probably Hawthorn formation, but may be post-middle Miocene.
36. Alafia River; S½ sec. 9, T. 30 S., R. 20 E.	By boat on Alafia River; west bank of river, 1.0 mile northeast of Riverview.	Limestone, white to light-gray, very sandy; contains phosphate nodules and lenses of white very slightly sandy hard fine-grained limestone.	1. 0	Most accessible at low tide; probably very near base of Hawthorn formation.
37. Alafia River; SE¼ sec. 15, T. 30 S., R. 20 E.	By boat on Alafia River, about 1.5 miles downstream from Bell Shoals bridge; south bank of river.	Limestone, very sandy, contains phosphate nodules.	1. 0	Best exposed at low tide.
38. Alafia River; NW¼ sec. 23, T. 30 S., R. 20 E.	By boat on Alafia River, about 1.0 mile downstream from Bell Shoals bridge; several outcrops, north bank of river.	Limestone, 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 formation in this region.
39. Sydney mines, American Cyanamid Company; A, B, C, D, E. secs. 22, 34, 36, T. 29 S., R. 21 E.	State Highway 60; north pits, 4.5 miles west of junction of State Highways 60 and 39; south pits, 1 mile south of Sydney washer; east pits, 1 mile south of State Highway 60 on Turkey Creek road.	Limestone, white to light-tan, sandy, chalky, dolomitic; contains phosphate nodules.	--------	
41. Eleanor mine; SE¼ sec. 29, T. 29 S., R. 22 E.	State Highway 39 about 0.7 mile south of State Highway 60 at Hopewell; old waste dumps east of road.	Limestone, white, chalky, dolomitic, slightly sandy; contains phosphate nodules.	--------	Old mine; loose pieces of limestone may be found on dumps.

42. Boyette mine, American Agricultural Chemical Corp.; sec. 15, T. 31 S., R. 21 E.	State Highway 39, about 4 miles south of Pinecrest turn west about 2.5 miles to washer; pits to south of washer.	Limestone, light, yellow, clayey, very slightly sandy, dolomitic, fossiliferous; contains phosphate nodules.	--------	
44. Ichepakesassa ditch, east; NE¼NE¼ sec. 2, and NW¼NW¼ sec. 1, T. 28 S., R. 22 E.	Knights-Griffin Rd., about 4 miles east of Knights above and below bridge over drainage canal.	Sand, 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.
45. Campbell Branch; NW¼ sec. 18, T. 28 S., R. 21 E.	Antioch Rd., 0.4 mile north of Plant City-Thonotosassa Rd., or about 3 miles north of U.S. Highway 92 via McIntosh and Antioch Rds.; small outcrop in creek.	Sand, clayey, fine- to coarse-grained, dark-gray to dark-red-brown; contains a few lumps of aluminum phosphate cemented sand.	1.0	Exposed only in dry season.
50. Valrico railroad cut; SW¼ sec. 24, T. 29 S., R. 20 E.	State Highway 60, turn north about 1.3 miles east of Brandon, cross tracks, turn west for about 0.4 mile; railroad cut.	Sand, very slightly clayey, fine- to coarse-grained, fairly uniform orange-brown.	15.0	
		Pasco County		
53. Borrow pits; NW¼ sec. 26, T. 26 S., R. 21 E.	Old road to Crystal Springs from Zephyrhills, about 0.7 mile south of U.S. Highway 301; shallow pits west side of road.	Clay, sandy, mottled red, gray, and brown; loose chunks of silicified corals and chert, tripoli.	2.0	Residua of Tampa limestone probably present also; coral *Siderastraea hillsborensis* as loose rubble.
60. Pasadena railroad cut; NE¼ sec. 10, T. 25 S., R. 21 E.	U.S. Highway 301; 1.5 miles south of Dade City city limits turn west on paved road ¼ mile to railroad crossing; railroad cut south of crossing.	Clay, very sandy, light-brown to orange, semi-indurated in places; contains fragments and nodules of aluminum phosphate and slightly sandy gray-green clay.	15.0	Both Tampa and Hawthorn formations may be present. Silicified corals, *Siderastraea hillsboroensis*, found in place near bottom of exposure about a foot above a green clay bed.

Locality and No. (pl. 2)	Access	General lithology	Thickness (feet)	Remarks
		HAWTHORN FORMATION—Continued **Pasco County—Continued**		
61. Hound dog ditch; NE¼ sec. 30, T. 25 S., R. 21 E.	From Zephyrhills follow State Highway 41 north and west; at about 2.5 miles from city limits turn west on dirt road, at 3.2 miles turn north, at 3.4 miles turn west, at 5.2 miles turn north; 6.2 miles exposure in ditch, east side of road.	Sand, slightly clayey, gray to violet-gray, fine- to medium-grained, trace of coarse- to granule-size; contains abundant silicified *Siderastraea hillsboroensis* corals as much as 1 foot in diameter, and hardpan layers.	2. 5	
68. Ostrea ditch; NW¼ sec. 28, T. 24 S., R. 20 E.	State Highway 578 about 2 miles west of St. Joseph; shallow ditch south side of road.	Sand, clayey, orange-brown; contains abundant shells of *Ostrea normalis*.	2. 5	Near Tampa limestone loc. 69.
71. Dade City pit; NW¼ sec. 12, T. 25 S., R. 21 E.	State Highway 35A about 1.2 miles north of Ellerslie, or about 2.5 miles southeast of Dade City; large borrow pit west side of road.	Sand, very slightly clayey, fine to very fine grained, tan to red-brown; contains local patches of white sand, and trace of aluminum phosphate cemented nodules.	15. 0	Possibly residuum of Tampa limestone.
		Polk County		
73 A, B, C. Tenoroc mine, Coronet Phosphate Co.; S½ sec. 35, T. 27 S., R. 24 E.	Combee Rd. east of Lakeland; at about 3.8 miles north of U.S. Highway 92 turn east on Ritter Rd. to Coronet mine washer; turn south-southwest across railroad tracks to pits; section lo-	Limestone, slightly sandy, slightly clayey, yellow, soft, fossiliferous; overlain by sandy light-tan clay, containing abundant phosphate nodules, and by clayey gray sand, with abundant thin	9. 0	Tampa limestone occurs on waste piles in pit ¼ mile north.

	cated on east face of cut mined in February 1954.	lenses of sandy very light greenish-gray clay, containing abundant soft white phosphate nodules.		
74 B, C, D. Saddle Creek mine, American Cyanamid Company; secs. 14 and 23, T. 28 S., R. 24 E.	U.S. Highway 92 east from Lakeland; pits are about 2 miles east of city limits; section located near center of sec. 14 about 100 yards north of road on west face of cut mined in February 1954.	Limestone, slightly sandy, slightly clayey, light-tan, soft, slightly phosphatic; overlain by very clayey, sandy limestone containing abundant fragments of blue-gray clay, and very coarse phosphate nodules; overlain by slightly sandy blue-gray clay, with waxy, olive-green patches, and patches and lenses of fine-grained gray sand, containing abundant fine tan phosphate sand; upper contact fairly sharp and irregular.	5. 0	Hawthorn probably thin. Accessible only in actively mined pits.
75. Pauway mine, American Agricultural Chemical Corp.; sec. 32, T. 28 S., R. 24 E.	U.S. Highway 98, southeast of Lakeland; 0.3 mile east of Lake Hollingsworth turn south for 1.3 miles to mine area; section located near center of sec. 32 on west face of cut mined in February 1954.	Limestone, clayey, very slightly sandy, white to brown, fossiliferous, sparsely phosphatic, locally silicified and dolomitic; overlain by slightly sandy white to light-gray slightly calcareous clay, containing abundant sand- to pebble-size phosphate; overlain by slightly clayey light-gray-green sand, containing phosphate sand and granules, and patches of soft white phosphatic clay; upper contact sharp.	13. 0	Material included as Hawthorn formation clearly residual from limestone at point where section was taken.

Locality and No. (pl. 2)	Access	General lithology	Thickness (feet)	Remarks
HAWTHORN FORMATION—Continued Polk County—Continued				
76 A, B. Achan mine, International Minerals and Chemicals Corp.; secs. 23 and 26, T. 30 S., R. 23 E.	State Highway 37, south from Mulberry about 3.5 miles; in SW¼ sec. 23 at south end of cut mined in February 1954.	Limestone, sandy, soft, light-tan, slightly fossiliferous, dolomitic; contains sparse sand- to pebble-size phosphate; upper contact not seen.	3. 0	Most of material above limestone believed to be younger than Hawthorn formation; upper surface of limestone exposed at north end of abandoned pit between State Highway 37 and road to Pierce in W½ sec. 26.
77. Pulp plant pit; SW¼ sec. 6, T. 30 S., R. 25 E.	State Highway 60; turn north 0.1 mile west of Bartow city limits, cross railroad and turn west for 0.2 mile; large pit to north of road.	Limestone, very slightly sandy, white, soft, very fossiliferous; contains sparse phosphate sand and granules.	4. 0	Accessible only in dry season. One of the best localities for fossils in Hawthorn formation.
78. Noralyn mine, International Minerals and Chemicals Corp.; secs. 29 and 32, T. 30 S., R. 25 E.	U.S. Highway 17 south from Bartow; about 2.0 miles south of city limits turn west for about 0.4 mile; turn south for about 1.0 mile to mine area west of road.	Limestone, pure, soft, light-yellow, slightly fossiliferous, dolomitic, contains sparse phosphate sand and granules.	--------	
79. Clear Springs mine, Virginia-Carolina Chemical Corp.; sec. 33, T. 30 S., R. 25 E.	Intersection of U.S. Highway 17 and State Highway 655, 4 miles south of Bartow.	Limestone, very slightly sandy, white to light-gray, fossiliferous, dolomitic.	--------	
80. Varn mine, Swift and Co.; sec. 25, T. 31 S., R. 25 E., and sec. 30, T. 31 S., R. 26 E.	State Highway 630, east from Fort Meade; about 1 mile east of Peace River where road turns south, turn northeast into mine area.	Limestone, slightly sandy, slightly clayey, light-yellow, sparsely fossiliferous, dolomitic; contains sparse sand- to granule-size phosphate.	--------	

81. Watson mine, Swift and Co.; secs. 8, 17 and 20, T. 32 S., R. 25 E.	U.S. Highway 17; about 2 miles south of Fort Meade, turn west to "Sand Mountain" and Watson washer, and thence southwest to mine area.	Limestone, fairly pure, light-tan to white, fossiliferous, dolomitic, contains sparse sand- to granule-size phosphate.	--------	
82. Peace Valley mine, International Minerals and Chemicals Corp.; secs. 8, 9, and 17, T. 31 S., R. 25 E.	Old blacktop road south from town of Homeland about 1.5 miles.	Limestone, clayey, tan to white, slightly fossiliferous, dolomitic.	--------	
83. Kathleen railroad cut; SW¼ sec. 17, T. 27 S., R. 23 E.	State Highway 35A to Kathleen, turn northwest from town, cross railroad tracks, and turn northwest again to end of road beside tracks; railroad cut.	Clay, slightly sandy to sandy, light-gray-green, waxy, blocky fracture; overlain by light-gray to yellow medium-grained slightly clayey sand, with a few coarse grains; upper contact sharp, irregular; overlain by slightly clayey to clayey light-gray, medium-grained sand, trace of coarse grains, containing abundant oysters and pectens composed of soft tripoli, and local traces of phosphate nodules or vesicularity; upper contact gradational with upper Miocene(?) micaceous clayey sand.	4.0	Typical exposure of middle Miocene clay and sand (fig. 12).
86. Orangedale (Foxtown) borrow pit; NE¼SW¼ sec. 8, T. 27 S., R. 24 E.	State Highway 33 north from Lakeland; at about 1.0 mile from city limits keep left on old Polk City road, at about 2.0 miles turn east and follow pavement for about 2 miles more east and north; borrow pit south side of road.	Sand, clayey, medium- to fine-grained, light-gray, mottled red-brown.	1.5	

Locality and No. (pl. 2)	Access	General lithology	Thickness (feet)	Remarks
		HAWTHORN FORMATION—Continued **Manatee County**		
96. Tampa Gap drain; S½ sec. 36, T. 33 S., R. 17 E.	U.S. Highway 41 about 1 mile south of Rubonia; spoil banks of drainage ditch.	Limestone, sandy, clayey, white, soft, slightly fossiliferous; contains trace of fine phosphate sand.	--------	
97. Rocky Bluff; sec. 9 or 16, T. 34 S., R. 18 E.	U.S. Highway 301 (State Highway 43), about 1.3 miles northeast of Ellenton turn south through woods about 200 yards to beach.	Limestone, slightly sandy, clayey, light-yellow, dolomitic; contains sparse phosphate sand.	1. 0	Most accessible at low tide.
98. Southern Dolomite Co. pit; S½ sec. 13, T. 34 S., R. 17 E.	From junction of U.S. Highways 41 and 301 at Palmetto turn east on U.S. 301 for about 0.7 mile to sign of Southern Dolomite Co., turn south about 0.5 mile to pits.	Limestone, light-tan to white, very slightly sandy and clayey, dolomitic, soft, contains trace of phosphate sand.	6. 0	
		Sarasota County		
99. Florida Dolomite Co. pit; N½ sec. 6, T. 36 S., R. 18 E.	State Highway 683, 0.9 mile southeast of U.S. Air Force Base north of Sarasota; dolomite pits.	Limestone, slightly clayey, light-green-gray, massive, dolomitic; trace of very fine phosphate sand.	4. 5	Probably same as locality given by Cooke (1945, p. 160).

LITHOLOGIC LOGS OF CORE HOLES

Drill holes G1–G17 were logged by Carr and Alverson; holes G105–G114 were logged by K. B. Ketner, and hole G115 was logged by R. G. Petersen. The latter logs were interpreted by us, 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.

Terms	*Percent*	*Terms*	*Percent*
Trace, very slightly	<1	Abundant	20–50
Sparse, sparsely, slightly	1–10	Very	>20
No modifier	10–20	Very abundant	>50

Depth From— (ft)	(in)	To— (ft)	(in)	Lithology
				G1, SE¼SE¼ sec. 17, T. 28 S., R. 22 E., Hillsborough County, Fla. Elevation, 120 feet
				Quaternary:
0	0	5	0	Not cored.
5	0	5	8	No recovery.
5	8	6	8	Sand, tan, medium-grained.
6	8	9	1	No recovery.
				Undifferentiated Pliocene and Miocene:
9	1	18	9	Sand, light-tan to gray, medium-grained, slightly clayey; contains sparse lumps of sandstone cemented by aluminum phosphate.
18	9	19	5	Sand, white, medium-grained, slightly clayey, interlensing with light-green very slightly sandy laminated clay.
				Middle Miocene, Hawthorn formation:
19	5	22	7	Clay, very slightly sandy, light-green to light-brown.
22	7	22	11	Sand, light-gray, slightly clayey, interlensing with light-green clay; both contain trace of phosphate nodules.
22	11	25	2	Clay, light-green, mottled light-red-brown to yellow-brown, very slightly sandy at top, laminated.
25	2	26	3	Clay, gray-green to yellow-green, slightly sandy to sandy, laminated; contains 5 percent silt-size black grains.
26	3	32	10	Clay, yellow-gray, very slightly sandy, slightly calcareous; lower contact sharp.
32	10	34	2	Sand, light-gray, medium-grained, calcareous; contains sparse amber sand-size phosphate.
34	2	37	3	Sand, light-gray, fine- to medium-grained; contains sparse amber sand-size phosphate, and trace of silt-size black grains.

Depth From— (ft)	(in)	To— (ft)	(in)	Lithology
				G1—Continued
				Lower Miocene, Tampa limestone:
37	3	37	9	No recovery.
37	9	41	9	Sand, gray-green, fine-grained, clayey, slightly calcareous at bottom; contains trace to sparse tan and amber sand-size phosphate and chert fragments.
41	9	43	6	No recovery.
43	6	44	1	Clay, slightly sandy, slightly calcareous; contains sparse amber and gray sand-size phosphate.
44	1	44	5	Limestone, very slightly sandy, soft; contains abundant hard fragments, and trace (?) of phosphate (?).
45	5	45	11	Limestone, white to light-gray, slightly sandy and clayey; contains fragments of rounded calcareous clay, and trace of phosphate (?).
				G2, SW¼NE¼ sec. 5, T. 28 S., R. 22 E., Hillsborough County, Fla. Elevation, 105 feet
				Quaternary:
0	0	5	0	Not cored.
5	0	7	1	Sand, brown to light-brown, slightly clayey, medium-grained, iron-stained.
7	1	7	4	No recovery.
				Undifferentiated Pliocene and Miocene:
7	4	12	1	Sand, tan to light-green-gray, slightly clayey to clayey, medium- to fine-grained; contains thin lenses of light-green slightly sandy clay, and trace to sparse white sand-size phosphate; lower contact sharp.
				Middle Miocene, Hawthorn formation:
12	1	14	7	Clay, gray, mottled brown, slightly sandy; contains thin lenses of gray to white slightly clayey sand containing trace of phosphate(?).
14	7	15	2	Sand, gray-green to gray, medium- to fine-grained, clayey; contains trace of white phosphate.
				Lower Miocene, Tampa limestone:
15	2	17	11	Clay, gray-yellow, slightly sandy to sandy; contains chert fragments coated with tripoli or white phosphate; lower contact sharp.
17	11	21	8	Limestone, light-gray to light-tan, slightly iron-stained, clayey, slightly sandy, soft to hard at base, contains seams and fragments of green clay, abundant chert fragments, and trace of phosphate(?).
				G3, NE¼SE¼ sec. 31, T. 27 S., R. 22 E., Hillsborough County, Fla. Elevation, 100 feet
				Quaternary:
0	0	7	2	No recovery.
				Undifferentiated Pliocene and Miocene:
7	2	20	6	Sand, light-gray, medium- to fine-grained, very slightly clayey, well-sorted.
20	6	22	0	Sand, light-gray, fine-grained, clayey; contains abundant fragments of sandstone cemented by aluminum phosphate; lower contact sharp.

Depth From— (ft	in)	To— (ft	in)	Lithology
				G3—Continued
				Middle Miocene, Hawthorn formation:
22	0	29	6	Clay, gray, mottled red-brown, very slightly sandy; contains trace to sparse fine sand-size white phosphate; lower contact sharp.
29	6	31	4	Sand, very light gray, medium-grained, slightly clayey, slightly iron stained at top; contains fragments of sandstone cemented by aluminum phosphate, and trace of white soft phosphate.
31	4	32	6	Clay, gray, slightly sandy to sandy; contains trace of white phosphate; lower contact sharp.
32	6	37	7	Sand, gray, slightly clayey to clayey, medium- to fine-grained, locally iron-stained; contains sandstone fragments cemented by aluminum phosphate.
37	7	41	4	Clay, gray-green, silty (quartz), interlaminated with clayey silt, contains trace of white phosphate, and trace of silt-size heavy minerals(?).
				Lower Miocene, Tampa limestone:
41	4	48	6	Poor recovery; probably white medium-grained sand with thin beds of yellow-brown very clayey sand.
48	6	52	5	Clay, light-gray-green, iron-stained, slightly sandy to sandy, laminated; contains twiglike fragments of silica.
52	5	58	9	Sand, white, fine-grained, very slightly clayey; interlenses with green sandy clay; unit contains heavy minerals.
58	9	67	7	Poor recovery; probably a lens of white to red-brown fine-grained very slightly clayey sand, containing visible heavy minerals.
67	7	69	10	Poor recovery; probably white slightly clayey fine-grained sand with thin lenses of gray, clayey sand containing hard white fragments with casts and molds of small mollusks.
69	10	74	6	No recovery; probably the same as 67 ft. 7 in. to 69 ft. 10 in.
74	6	76	6	Sand, light-gray to tan, fine-grained, slightly clayey to clayey; contains thin layer of light-gray chert, and visible heavy minerals.
76	6	78	6	No recovery; probably same as 74 ft. 6 in. to 76 ft. 6 in.
78	6	79	6	Limestone, white to light-tan, very slightly to slightly sandy, clayey; interlenses with yellow-brown very calcareous laminated clay.
79	6	81	0	Limestone, white, hard, very pure; contains casts and molds of mollusks, *Helisoma* sp.

G4, NW¼SE¼ sec. 19, T. 27 S., R. 22 E., Hillsborough County, Fla.
Elevation, 95 feet

				Quaternary:
0	0	5	0	Not cored.
				Undifferentiated Pliocene and Miocene:
5	0	19	4	Sand, light-gray to tan, medium- to fine-grained, locally iron-stained; contains trace to sparse white fine sand-size phosphate, small patches of white aluminum phosphate, and trace of heavy minerals.

Depth From— (ft	in)	Depth To— (ft	in)	Lithology
				G4—Continued
				Middle Miocene, Hawthorn formation:
19	4	23	0	Clay, light-blue to gray-blue and violet, slightly sandy to sandy; contains abundant irregular fragments of soft limestone, and patches of fine- to medium-grained quartz sand.
				Lower Miocene, Tampa limestone:
23	0	24	7	Clay, as in 19 ft. 4 in. to 23 ft. 0 in., but laminated; contains trace of fine fragments of phosphatized(?) limestone, and fragments of brown chert.
				Oligocene, Suwannee limestone:
24	7	24	11	No recovery; possibly a chert layer.
24	11	26	10	Limestone, white, hard, pure, porous; contains *Phacoides* (*Miltha*), sp. aff. *P. chipolanus* Dall, *Turritella* n. sp.(?), *Turritella* sp. aff. *T. bowenae* Mansfield, and *Kuphus incrassatus* (Gabb).
				G5, SE¼SW¼ sec. 7, T. 27 S., R. 22 E., Hillsborough County, Fla. Elevation, 80 feet
				Quaternary:
0	0	5	0	Not cored.
5	0	5	4	Sand, dark-brown, medium-grained; lower contact sharp.
5	4	18	5	Sand, very light gray to tan, fine-grained, very slightly to slightly clayey; intervals of no recovery.
18	5	28	3	Sand, gray to light-gray, medium- to fine-grained, slightly clayey to clayey.
28	3	28	6	Clay, gray, trace of very fine sand.
28	6	29	10	Sand, light-gray, medium-grained, slightly clayey.
29	10	32	1	No recovery.
32	1	34	11	Sand, white, fine-grained.
34	11	38	4	Sand, dark-brown, fine-grained.
38	4	41	5	No recovery.
41	5	50	10	Sand, dark-brown, fine- to medium-grained, slightly clayey; intervals of no recovery.
50	10	57	4	Sand, gray, fine-grained, slightly clayey; intervals of no recovery.
57	4			No recovery, no advance; probably Suwannee chert.
				G6, SE¼NW¼ sec. 35, T. 28 S., R. 21 E., Hillsborough County, Fla. Elevation, 120 feet
				Quaternary:
0	0	6	0	Not cored, no recovery.
6	0	7	0	Sand, red-brown, fine-grained, very slightly clayey.
7	0	8	7	No recovery; probably sand.
8	7	13	6	Sand, light to very dark brown, fine- to medium-grained; contains black organic material at base; lower contact sharp.
				Undifferentiated Pliocene and Miocene:
13	6	17	1	Sand, light-gray to light-brown, fine-grained, clayey, locally iron-stained.
17	1	18	5	No recovery.

Depth From— (ft	in)	Depth To— (ft	in)	Lithology
				G6—Continued
				Undifferentiated Pliocene and Miocene—Continued
18	5	22	4	Sand, light-yellow-brown, medium- to fine-grained, slightly clayey; contains indurated lumps of sandstone at top; lower contact sharp.
22	4	23	2	Sand, light-tan, medium- to fine-grained; contains trace of small indurated fragments.
23	2	24	9	Clay, light-gray to tan, very sandy to sandy; contains trace of white soft coarse sand-size phosphate.
24	9	32	9	Sand, light-gray, medium-grained, very clayey to clayey; contains trace of white soft coarse sand-size phosphate, and sparse sandstone fragments cemented by aluminum phosphate.
32	9	42	1	No recovery.
42	1	44	10	Clay, green-gray, very slightly to slightly sandy, laminated; contains silicified(?) shell fragments, abundant thin lenses of fine-grained sand, and abundant fragments of sandstone cemented by silica; lower contact sharp.
44	10	48	4	Sand, light-gray, very fine grained to medium grained at top, clayey to slightly clayey; contains abundant thin lenses of green very slightly sandy clay.
48	4	55	3	Clay, very slightly sandy (very fine grained), laminated with light-gray to pink fine-grained sand containing abundant heavy minerals.
55	3	57	11	Sand, light-gray, very fine grained, slightly clayey to clayey; interlenses with blue-green slightly sandy to very slightly sandy clay, containing trace of tan hard and soft very coarse sand-size phosphate at base.
				Middle Miocene, Hawthorn formation:
57	11	60	5	Clay, blue-green, very slightly sandy; contains sparse laminae of fine-grained sand and trace of tan coarse sand-size phosphate at top.
60	5	67	7	Claystone, yellow- to olive-green; contains a few lenses of blue-green sandy clay, and pellets of light-gray material, possibly phosphate; lower contact sharp.
67	7	75	4	Sand, tan, fine- to medium-grained, clayey; contains abundant lenses of gray-green very clayey, fine-grained sand, and sparse black and tan very coarse sand- to granule-size phosphate; at 74 ft. 4 in. a few fragments of sandstone cemented by aluminum phosphate.
75	4	75	9	Sand, blue-green to olive-green, fine- to coarse-grained, clayey to very clayey; contains large fragments of black and brown chert, and trace of black sand-size phosphate and silicified shell fragments at base.

G7, SE¼SE¼ sec. 21, T. 28 S., R. 21 E., Hillsborough County, Fla.
Elevation, 90 feet

				Quaternary:
0	0	5	0	Not cored.
5	0	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	27	6	Sand, white to light-gray-brown, medium-grained, slightly clayey in places; contains sparse thin lenses of light-blue sandy clay.

Depth From— (ft	in)	Depth To— (ft	in)	Lithology
				G7—Continued
				Quaternary:
27	6	40	9	Poor recovery; probably light-yellow-brown to violet-brown and white, medium- to fine-grained very slightly clayey sand.
40	9	44	11	Poor recovery; probably gray-brown to violet-brown fine- to medium-grained very slightly clayey sand.
44	11	58	9	Sand, light-brown to gray, fine- to medium-grained, slightly clayey; contains trace of indurated fragments, and thin lenses of gray-blue clayey sand.
58	9	107	1	Sand, light-tan to gray and violet-brown, medium- to fine-grained, very slightly to slightly clayey; contains abundant indurated fragments, and, at base, brown to black carbonaceous material.
107	1	110	9	Wood, black and brown, carbonized, in black medium-grained very slightly clayey sand.
110	9	128	1	Sand, black, medium-grained, very slightly clayey; many intervals of no recovery.
128	1	131	1	Sand, black to brown, medium-grained, slightly clayey to clayey.
				Undifferentiated Pliocene and Miocene:
131	1	137	5	No recovery.
137	5	150	5	Sand, brown to black, fine to very fine grained, very clayey to clayey, laminated; contains organic material, sparse brown pebble-size phosphate, and marcasite replacing phosphate and clay.
				G8, SW¼SW¼ sec. 8, T. 28 S., R. 21 E., Hillsborough County, Fla. Elevation, 65 feet
				Quaternary:
0	0	10	9	No recovery.
				Undifferentiated Pliocene and Miocene:
10	9	12	9	Sand, very light gray, medium- to coarse-grained, slightly clayey; contains trace of white clay, probably phosphatic.
12	9	14	0	No recovery.
14	0	15	6	Sand, light-gray, medium- to fine-grained, slightly clayey to clayey; contains sparse fragments of sandstone cemented by aluminum phosphate; lower contact sharp.
15	6	20	1	Clay, light-gray to green-gray, very slightly to very sandy (medium-grained); contains aluminum phosphate and sparse white soft very coarse sand- to granule-size phosphate.
20	1	27	6	Sand, very light gray to tan, fine to very fine grained, very clayey to clayey; contains aluminum phosphate and sparse white soft coarse sand- to granule-size phosphate.
27	6	33	11	Sand, white to very light gray, fine- to medium-grained, slightly clayey; contains sparse white soft sand-size phosphate.

Depth				Lithology
From— (ft	in)	To— (ft	in)	
				G8—Continued
				Middle Miocene, Hawthorn formation:
33	11	38	11	Clay, light-tan to gray, sandy to very sandy (fine- to medium-grained); contains abundant fragments of white aluminum phosphate and light-brown sandy clay.
38	11	41	5	Sand, light-gray, fine-grained, very clayey; contains abundant fragments of aluminum phosphate.
41	5	43	0	Sand, light-gray to light-blue-gray, fine-grained, slightly clayey; contains sparse sandstone fragments cemented by aluminum phosphate.
43	0	46	0	Sand, gray-green to gray-blue mottled, fine-grained, very clayey; contains sparse thin lenses of white, medium-grained sand.
46	0	47	2	Clay, pinkish-tan, very sandy, and sand, fine-grained, very clayey, slightly calcareous, interlaminated with green-gray sandy clay; lower contact sharp.
				Lower Miocene, Tampa limestone:
47	2	47	5	Tripoli, white; contains *Helisoma* sp.
47	5	48	3	Limestone, gray-blue, clayey, very sandy to sandy; contains fragments of light-tan slightly calcareous clay.
48	3	50	0	Limestone, light-tan to gray-green, clayey; contains trace of very fine-grained sand, and fragments of tan soft limestone, and, at base, claystone and sandstone containing black to brown sand-size phosphate; lower contact sharp.
50	0	51	6	Sand, light-gray, fine-grained, slightly clayey to clayey; contains abundant fragments of weathered limestone, and abundant black very fine grained sand; lower contact sharp.
51	6	51	10	Clay, very light green gray and tan, slightly sandy to sandy; contains sparse thin lenses of white sand.
51	10	53	1	Sand, gray and streaked with yellow-brown, clayey to very clayey; contains abundant small fragments of tripoli and weathered limestone.

G9, NE¼SW¼ sec. 6, T. 28 S., R. 21 E., Hillsborough County, Fla.
Elevation, 50 feet

				Quaternary:
0	0	5	5	Not cored, no recovery.
5	5	10	1	Sand, dark-brown to light-tan, fine- to medium-grained, slightly indurated, very slightly clayey.
				Undifferentiated Pliocene and Miocene:
10	1	17	7	Poor recovery; probably tan sand.
17	7	21	9	Sand, brown-gray, medium- to fine-grained; contains at base sparse fragments of sandstone cemented by aluminum phosphate.
21	9	23	9	Clay, gray to light-green-gray, very sandy to sandy, and very clayey sand; contains abundant small fragments of hard phosphatic (?) clay, and sandstone cemented by aluminum phosphate.
23	9	27	0	Poor recovery; probably tan to gray-green fine-grained slightly clayey sand.

Depth From— (ft)	(in)	Depth To— (ft)	(in)	Lithology
				G9—Continued
				Middle Miocene, Hawthorn formation:
27	0	28	7	Clay, gray-green, very slightly sandy to pure.
28	7	33	7	Sand, light- to dark-gray-green, medium-grained, very clayey, and very sandy clay, contains abundant fragments of sandstone cemented by aluminum phosphate; lower contact sharp.
				Lower Miocene, Tampa limestone:
33	7	36	9	Sand, tan, fine to very fine grained, very slightly clayey.
36	9	38	5	Sand, light-gray-green, fine-grained, clayey to very clayey; contains abundant thin lenses of white sand.
38	5	43	1	Clay, gray to blue-gray and gray-green, slightly sandy to pure; contains thin lenses of white very fine-grained sand, and abundant fragments of white tripoli with unidentifiable casts and molds of gastropod; lower contact sharp.
43	1	47	7	Clay, light-gray, sandy; contains lenses of gray-green pure clay, and very abundant fragments of tripoli, chalcedony, and weathered limestone; lower contact sharp.
47	7	48	11	Clay, blue-green; contains abundant fragments and lenses of soft slightly calcareous clay; lower contact sharp.
48	11	51	0	Clay, same as 43 ft. 1 in. to 47 ft. 7 in.
51	0	52	8	Clay, blue-green to light-tan, slightly calcareous; contains abundant fragments of weathered limestone.
52	8	53	6	No recovery; probably sand.
53	6	55	6	Clay, light-gray to olive- and blue-green, very calcareous; contains abundant fragments of soft limestone and thin clay seams.
55	6	55	10	No recovery; probably sand.
				Oligocene, Suwannee limestone:
55	10	59	10	Limestone, white to light-tan, and trace of sand; contains at top, thin lenses and fragments of blue-green slightly calcareous clay; fossils, *Sorites*, *Peneroplis*, *Chlamys* sp. cf. *C. brooksvillensis* Mansfield, and *Kuphus incrassatus* (Gabb).
				G10, NW¼SE¼ sec. 7, T. 29 S., R. 21 E., Hillsborough County, Fla. Elevation, 60 feet
				Quaternary:
0	0	9	2	Not cored, no recovery.
				Undifferentiated Pliocene and Miocene:
9	2	14	11	Clay, light gray-green to gray, very to slightly sandy; contains sparse to abundant white soft sand- to pebble-size phosphate.
14	11	16	2	Clay, light-gray-green to white, very slightly sandy; contains very abundant white soft coarse sand-size phosphate, and a few fragments of sandstone cemented by aluminum phosphate.
				Middle Miocene, Hawthorn formation:
16	2	24	2	Clay, yellow-green to light-blue-green, very sandy to trace of sand in bottom; contains very thin lenses of very fine grained calcareous sand, and sparse white soft granule-size phosphate.
24	2	28	5	Clay, brown-green, very slightly sandy, laminated, iron-stained.

Depth From— (ft	in)	Depth To— (ft	in)	Lithology
				G10—Continued
				Middle Miocene, Hawthorn formation—Continued
28	5	43	6	Clay, light-gray-green to gray, very sandy, and clayey sand; contains sparse tan and black coarse sand-size phosphate.
				Lower Miocene, Tampa limestone:
43	6	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	56	3	Sand, tan to gray, very fine grained, very to slightly clayey, and very sandy clay; contains sparse fragments of claystone and sandstone with black and brown coarse sand-size phosphate, locally cemented by silica; lower contact sharp.
56	3	59	9	Sand, tan to gray, very fine grained, very clayey, very slightly calcareous; lower contact sharp.
59	9	61	10	Limestone, light tan, soft, slightly sandy, clayey.
61	10	62	2	Limestone, yellow-brown, sandy (fine-grained), clayey; contains thin seams of sandy green and brown clay, and, at base, abundant brown chert fragments; Charophyte oogonia (fresh-water plants).
				G11, SE¼SE¼ sec. 35, T. 28 S., R. 20 E., Hillsborough County, Fla. Elevation, 60 feet
				Quaternary:
0	0	9	6	Poor recovery; probably yellow-brown medium- to fine-grained very slightly clayey sand.
				Undifferentiated Pliocene and Miocene:
9	6	13	1	Sand, light-gray to yellow-brown, medium- to fine-grained, slightly clayey to clayey; contains in lower half, abundant fragments of iron hardpan.
13	1	18	1	Sand, light-gray to white, fine-grained, clayey, locally strong iron staining; contains sparse patches of white poorly indurated sand, cemented by phosphatic (?) clay.
18	1	21	8	Clay, light-gray to tan, sandy to very sandy (very fine grained), heavily streaked by iron staining; contains fragments of phosphatic (?) white claystone, and sparse white soft phosphate.
21	8	22	7	No recovery.
22	7	28	6	Sand, light-gray to yellow-brown, fine to very fine grained, top clayey to very clayey, bottom very slightly clayey, iron streaked; contains 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	33	10	Clay, light-gray to light-yellow, variegated, slightly sandy; contains thin streaks and patches of black carbonaceous material, and at base, a trace of white soft coarse sand-size phosphate.
				Middle Miocene, Hawthorn formation:
33	10	35	1	Sand, light-gray to brown, fine-grained, clayey; contains sparse thin lenses of slightly clayey sand, and white slightly sandy clay and a trace of dark-brown granule-size phosphate.
35	1	36	1	Clay, light-gray to white, slightly sandy.

Depth From— (ft	in)	Depth To— (ft	in)	Lithology
				G11—Continued
				Lower Miocene, Tampa limestone:
36	1	39	0	No recovery; probably sand.
39	0	43	1	Clay, light-yellow-green, slightly sandy to sandy; contains abundant fragments of slightly sandy limestone, and sparse black granule-size phosphate; lower contact sharp; *Trigonocardia* sp., *Camerina* sp., *Sorites* sp.
43	1	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	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.
				G12, NE¼SE¼ sec. 27, T. 28 S., R. 20 E., Hillsborough County, Fla. Elevation, 85 feet
				Quaternary:
0	0	5	0	Not cored.
				Undifferentiated Pliocene and Miocene:
5	0	6	10	Clay, gray, iron-streaked, laminated, very slightly to slightly sandy; lower contact sharp.
6	10	11	8	Sand, light-green-gray, very fine grained, clayey, interlaminated with gray-green to orange, very sandy clay; lower contact sharp.
11	8	15	1	Sand, very light gray green to tan, fine-grained, and very sandy clay; contains abundant fragments of sand, lightly cemented by aluminum phosphate(?).
15	1	17	1	Clay, light-green-gray, slightly sandy to sandy, interlaminated with tan medium-grained, clayey sand; contains sparse white and tan soft coarse sand-size phosphate, and local cementation by aluminum phosphate.
				Middle Miocene, Hawthorn formation:
17	1	19	6	Clay, light-gray-green, iron-streaked, fine- to medium-grained, very sandy to sandy, laminated at top; contains abundant patches of black, probably carbonaceous, material, and sparse small lenses of tan clayey sand, with traces of aluminum phosphate(?).
19	6	21	7	Sand, tan to brown, fine- to medium-grained, clayey to very clayey; contains abundant thin lenses of white sandy phosphatic(?) clay, and a trace of black very coarse sand to granule-size phosphate.
21	7	25	3	Sand, tan to light-green-gray, fine- to medium-grained, at top laminated and iron-streaked; contains abundant heavy minerals, and twiglike fragments of amber silica, and silicified gastropod shell fragments; lower contact sharp and probably irregular.
				Lower Miocene, Tampa limestone:
25	3	28	3	Sand, light-gray-green to tan, fine-grained, very clayey, and very sandy clay; contains, at top and base, abundant fragments of pure white limestone and visible heavy minerals.
28	3	30	5	Limestone, white, slightly sandy (fine-grained), slightly clayey, soft; contains sparse fragments of tan dense slightly sandy limestone.

G13, SE¼NE¼ sec. 20, T. 28 S., R. 20 E., Hillsborough County, Fla.
Elevation, 80 feet

From— (ft	in)	To— (ft	in)	Lithology
				Quaternary:
0	0	8	6	Poor recovery; probably brown fine-grained very slightly clayey sand, containing abundant lumps of sand cemented by clay.
				Undifferentiated Pliocene and Miocene:
8	6	14	0	Sand, yellow- and orange-brown to light-gray, fine- to medium-grained, clayey; contains fragments of sandstone cemented by clay.
14	0	21	0	Clay, light-green-gray to yellow-brown, trace to no sand; contains abundant fragments of sand cemented by aluminum phosphate, and claystone.
21	0	21	9	No recovery.
21	9	22	11	Sand, very light tan, fine-grained, clayey; contains thin lenses of gray-green sandy clay, and sparse white soft coarse sand- to granule-size phosphate; lower contact sharp.
				Middle Miocene, Hawthorn formation:
22	11	37	2	Clay, gray-green to mottled orange, very slightly sandy; contains trace of sandstone cemented by aluminum phosphate, and sparse laminae of clayey sand.
				Lower Miocene, Tampa limestone:
37	2	42	5	Sand, light-gray-green to mottled brown, fine- to medium-grained, clayey to very clayey; contains abundant fragments of white, leached limestone, and tripoli, and a layer of dark-brown iron-cemented sandstone, and trace of fine sand-size phosphate(?).
42	5	44	5	No recovery.
44	5	51	0	Clay, light-gray to very light green gray, sandy to very sandy (very fine grained); contains layers of fragments of weathered limestone in sand, and abundant laminae of very fine grained sand, and light-green noncalcareous clay, and, at base, layer of brown and white chert.
51	0	51	8	Limestone, white, slightly sandy (fine-grained), slightly clayey, soft; contains sparse grains brown carbonate; unidentifiable mollusks and Foraminifera.

G14, NW¼NW¼ sec. 17, T. 28 S., R. 20 E., Hillsborough County, Fla.
Elevation, 60 feet

From— (ft	in)	To— (ft	in)	Lithology
				Quaternary:
0	0	5	0	Not cored.
				Undifferentiated Pliocene and Miocene:
5	0	14	7	Poor recovery; probably tan to light-orange-brown sand.
14	7	27	9	Sand, tan and gray to light-orange-brown, fine- to medium-grained, very slightly clayey to clayey.
27	9	28	10	Clay, light-green-gray to very light orange, very slightly sandy; contains sparse small patches of clayey iron-cemented sand.
28	10	30	1	Sand, light-green-gray, very slightly to slightly clayey.
				Middle Miocene, Hawthorn formation:
30	1	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.

Depth From— (ft	in)	Depth To— (ft	in)	Lithology
				G14—Continued
				Lower Miocene, Tampa limestone:
31	5	32	2	Sand, light-green-gray mottled with orange-brown, medium- to fine-grained, very slightly clayey to clayey.
32	2	34	10	Clay, light-gray-green and mottled orange-brown, very sandy to sandy; contains sparse lenses of white fine-grained sand, and abundant patches of white non-calcareous clay; lower contact sharp.
34	10	35	6	Sand, gray to orange brown, very slightly clayey; lower contact sharp.
35	6	36	9	Clay and sand as in 32 ft. 2 in. to 34 ft. 10 in.; lower contact sharp.
36	9	44	6	Limestone, white to light-gray, slightly sandy to sandy (fine-grained), slightly clayey, soft; contains fragments of white hard limestone, some partly silicified, and sparse thin lenses of white and brown sand.
				G15, SW¼SW¼ sec. 4, T. 30 S., R. 20 E., Hillsborough County, Fla. Elevation, 40 feet
				Quaternary:
0	0	5	0	Not cored.
5	0	7	1	Sand, tan to white, medium- to fine-grained.
				Undifferentiated Pliocene and Miocene:
7	1	13	10	Sand, light-gray to tan mottled with light-orange-brown, very slightly clayey.
13	10	14	8	Clay, gray, very slightly sandy; contains abundant small lenses of white to light-gray sand with heavy minerals.
14	8	16	6	No recovery.
16	6	16	8	Clay, as in 13 ft. 10 in. to 14 ft. 8 in.
16	8	17	5	Sand, light-gray to gray mottled orange-brown, very slightly to slightly clayey; lower contact sharp, irregular.
17	5	19	3	Clay, green, laminated with gray very slightly clayey sand; contains abundant fragments of sand- to cobble-size sandstone cemented by aluminum phosphate.
19	3	21	11	Clay, very light gray, very slightly to slightly sandy; contains abundant white hard coarse sand- to granule-size phosphate nodules.
				Middle Miocene, Hawthorn formation:
21	11	39	9	Sand, very light gray, slightly iron-stained at base, very slightly clayey; contains abundant white phosphate nodules, trace of black sand-size phosphate.
39	9	40	9	Clay, very light yellow, very sandy to sandy, slightly calcareous; lower contact sharp.
				Lower Miocene, Tampa limestone:
40	9	46	11	Clay, dark-red-brown to light-yellow-brown, sandy to very sandy, laminated; contains abundant fragments of red-brown to black hardpan.
46	11	48	0	Clay, very light yellow, slightly iron stained, slightly to very sandy; contains a lens of light-green-gray clayey sand.
48	0	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*.

Depth From— (ft	in)	Depth To— (ft	in)	Lithology
				G16, SW¼SW¼ sec. 18, T. 30 S., R. 20 E., Hillsborough County, Fla. Elevation, 25 feet
				Quaternary:
0	0	5	8	Not cored, no recovery.
5	8	13	1	Poor recovery; probably tan to dark-brown very fine to medium grained, very slightly clayey sand.
13	1	17	7	Sand, tan to dark-gray-brown, fine-grained, slightly iron-stained, very slightly to slightly clayey; lower contact sharp.
				Undifferentiated Pliocene and Miocene:
17	7	24	6	Clay, dark-gray-green, slightly sandy to sandy (very fine grained), and olive-green to tan very fine grained slightly clayey calcareous sand; contains sparse to abundant tan and black soft sand- to granule-size phosphate nodules, heavy minerals, and sparse fragments of very light tan limestone; lower contact sharp.
				Middle Miocene, Hawthorn formation:
24	6	27	5	Limestone, light-tan, very slightly sandy (fine- to medium-grained), very clayey, dolomitic (?); contains abundant lenses of gray calcareous clay, and sparse granule- and pebble-size phosphate nodules; large *Ostrea* sp and other mollusk fragments.
				G17, NW¼SE¼ sec. 13, T. 30 S., R. 19 E., Hillsborough County, Fla. Elevation, 25 feet
				Quaternary:
0	0	5	0	Not cored.
5	0	9	7	Sand, light-brown at top, white in middle, light-gray at base, medium- to fine-grained.
9	7	20	5	Sand, light-gray-brown to dark-gray, very fine to fine grained, very slightly clayey; contains black clayey organic material.
20	5	21	5	Clay, black, very slightly sandy; contains organic material.
				Undifferentiated Pliocene and Miocene:
21	5	26	0	Clay, dark-gray to light-gray-brown, slightly sandy; contains sparse fragments of leached soft limestone, and sparse tan hard sand- to pebble-size phosphate nodules.
26	0	28	7	Clay, dark-gray-green to light-tan, slightly sandy, calcareous along partings; contains, at base, green-gray clay with marcasite along fractures; lower contact sharp.
28	7	40	9	Clay, dark-gray-green, slightly sandy to sandy (fine-grained), with abundant lenses of olive-green to tan very fine grained calcareous sand, contains sparse black and tan sand- to granule-size phosphate nodules, abundant heavy minerals, and sparse fragments of very light tan rounded limestone; lower contact sharp.

Depth From— (ft in)		Depth To— (ft in)		Lithology
				G17—Continued
				Lower Miocene, Tampa limestone:
40	9	41	5	No recovery; probably sand.
41	5	45	5	Clay, light-green-gray to light-tan, sandy to very sandy, slightly calcareous; contains sparse fragments of poorly indurated sand cemented by clay, sparse small fragments of gray chert, sparse black and brown hard pebble-size phosphate nodules, and abundant heavy minerals.
45	5	48	6	Limestone, very light tan, sandy (fine-grained), slightly clayey, soft; contains a trace of fine sand-size phosphate nodules; *Sorites* sp.
				G115, NW¼ sec. 31, T. 27 S., R. 24 E., Polk County, Fla. Elevation, 140 feet
				Quaternary:
0	0	4	0	Not cored.
4	0	5	7	Sand, tan to dark-brown, fine-grained.
				Undifferentiated Pliocene and Miocene:
5	7	12	10	Sand, light-gray to white, fine-grained, very slightly clayey.
12	10	14	8	No recovery.
14	8	23	0	Sand, light-gray to light-brown, medium-grained, no clay to slightly clayey.
				Middle Miocene, Hawthorn formation:
23	0	31	0	Sand, gray to white, medium-grained, clayey; contains sparse tan white sand- to pebble-size phosphate.
31	0	36	1	Clay, light- to dark-brown, slightly sandy (medium-grained), slightly calcareous; contains sparse brown, white sand- to pebble-size phosphate.
				Lower Miocene, Tampa limestone:
36	1	37	10	No recovery.
37	10	45	2	Clay, light- to dark-brown, slightly sandy (fine- to coarse-grained), locally very calcareous; contains sparse brown, white sand- to pebble-size phosphate.
				G105, S½ sec. 18, T. 27 S., R. 24 E., Polk County, Fla. Elevation, 170 feet
				Quaternary:
0	0	5	0	Not cored.
5	0	8	0	Sand, light-brown, medium-grained.
				Undifferentiated Pliocene and Miocene:
8	0	9	0	Sand, light-brown and gray, mottled, medium-grained, slightly clayey to clayey.
9	0	14	0	No recovery; probably loose sand.
14	0	15	0	Sand, tan and gray, mottled, fine- to medium-grained, slightly clayey.
15	0	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	37	0	Clay, brown to green-gray, trace of very fine grained sand.
37	0	41	0	Sand, green-gray, medium- to coarse-grained, very clayey; contains tan medium to coarse sand-size phosphate.

Depth From— (ft in)		Depth To— (ft in)		Lithology
				G105—Continued
				Middle Miocene, Hawthorn formation—Continued
41	0	43	0	Clay, gray, slightly sandy (medium-grained); contains sparse sand-size phosphate.
43	0	43	10	Sand, brown, medium- to coarse-grained, clayey; contains sparse, brown medium to coarse sand-size phosphate.
43	10	45	0	No recovery.
45	0	46	6	Clay, green-gray, sandy (medium-grained); contains dark-brown to tan sand- to pebble-size phosphate.
46	6	47	7	No recovery.
47	7	48	6	Sand, green-gray, medium to very coarse grained, very clayey, slightly calcareous; contains black, brown medium to very coarse sand-size phosphate.
48	6	52	0	Clay, tan, very sandy (medium-grained), very calcareous; contains sparse, black, brown medium to very coarse sand-size phosphate.
52	0	52	10	Limestone, white, very sandy (medium-grained), soft, contains sparse, black, brown medium to very coarse sand-size phosphate.
				G106, W½ sec. 1, T. 27 S., R. 23 E., Polk County, Fla. Elevation, 135 feet
				Quaternary:
0	0	4	0	Not cored.
4	0	20	0	Sand, tan, brown to black, gray, medium- to fine-grained, clayey.
20	0	22	0	No recovery; probably loose sand.
				Middle Miocene, Hawthorn formation:
22	0	29	0	Sand, green to green-gray, fine- to medium-grained, clayey to very clayey; contains tan, sand- to pebble-size phosphate.
29	0	31	0	Clay, green, sandy (fine-grained); contains sparse tan sand- to pebble-size phosphate.
				Lower Miocene, Tampa limestone:
31	0	41	0	Clay, green to dark-green, very slightly to very sandy (very fine grained); contains trace of tan phosphate.
41	0	43	0	Clay, dark-green, very slightly sandy (very fine grained); contains black chert.
43	0	43	9	Sand, green-gray, very fine to fine-grained, very clayey, slightly calcareous.
43	9	43	10	Limestone, white, very slightly sandy, soft.
				G107, NW¼SE¼ sec. 27, T. 26 S., R. 23 E., Polk County, Fla. Elevation, 120 feet
				Quaternary:
0	0	7	2	Not cored; no recovery.
				Middle Miocene, Hawthorn formation:
7	2	12	0	Poor recovery; partly dark-gray medium-grained clayey sand.
12	0	14	3	Sand, blue-gray, medium-grained, clayey.
14	3	15	8	No recovery.
15	8	21	4	Clay, blue to green-brown, very slightly sandy; contains abundant chert.
21	4	22	4	Sand, green-gray, fine- to medium-grained, clayey to very clayey; lower contact sharp.

Depth From— (ft	in)	To— (ft	in)	Lithology
				G107—Continued
				Lower Miocene, Tampa limestone:
22	4	23	0	Clay, blue, very slightly sandy.
23	0	26	0	No recovery.
26	0	28	0	Clay, blue, very slightly to slightly sandy (fine-grained); contains sparse chert.
28	0	31	5	No recovery.
31	5	33	5	Clay, blue-green, slightly sandy (very fine grained), slightly calcareous; contains 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.
				G108, SW¼ sec. 8, T. 26 S., R. 23 E., Polk County, Fla. Elevation, 100 feet
				Quaternary:
0	0	4	0	Not cored.
				Middle Miocene, Hawthorn formation:
4	0	6	0	Sand, gray to brown, mottled, medium-grained, very clayey.
6	0	9	6	Sand, white to green-gray, fine- to coarse-grained, very clayey; contains fragments of white sandstone cemented by silica and aluminum phosphate (?).
9	6	10	2	Sand, tan, medium-grained, slightly clayey.
				Lower Miocene, Tampa limestone:
10	2	12	0	No recovery.
12	0	14	0	Sand, green-gray, fine-grained, very clayey.
14	0	15	8	Clay, green-brown, sandy to very sandy; contains sparse chert.
15	8	17	0	No recovery.
17	0	19	4	Sand, green-gray, fine-grained, slightly to very slightly clayey.
				Oligocene, Suwannee limestone:
19	4	44	8	Limestone, white, very slightly sandy, soft; *Turritella halensis* Dall, *Glycymeris suwannensis* Mansfield, *Divaricella* sp., *Pitar* sp., *Corbula* sp., *Myrtaea* 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, *Anatina* sp., *Venus* sp.
				G109, NW¼NW¼ sec. 1, T. 26 S., R. 22 E., Polk County, Fla. Elevation, 95 feet
				Quaternary:
0	0	4	0	Not cored.
				Middle Miocene, Hawthorn formation:
4	0	6	10	Sand, gray to brown, mottled, medium-grained, clayey to very clayey.
6	10	9	0	Clay, sandy to very sandy (medium-grained); contains siliceous concretions.

Depth				Lithology
From— (ft	in)	To— (ft	in)	
				G109—Continued
				Lower Miocene, Tampa limesone:
9	0	12	6	Sand, green-gray, fine-grained, clayey to very clayey; contains siliceous fragments.
12	6	15	3	Clay, gray, slightly sandy (fine-grained).
				Oligocene, Suwannee limestone:
15	3	16	6	No recovery.
16	6	17	0	Sand, fine-grained, clayey.
17	0	26	4	Limestone, white, soft; *Tritiaria* n sp.?, *Venus* sp., Bryozoa, *Barnea* sp., *Coskinolina floridana*, Ostracods.
				G110, SW¼SW¼ sec. 27, T. 25 S., R. 22 E., Pasco County, Fla. Elevation, 85 feet
				Quaternary:
0	0	4	0	Not cored.
				Lower Miocene, Tampa limestone.
4	0	7	0	Clay, gray, very sandy.
7	0	10	0	Sand, gray to tan, fine- to medium-grained, clayey.
				Oligocene, Suwannee limestone:
10	0	14	0	No recovery.
14	0	19	6	Chert, white.
				G111, NW¼SW¼ sec. 20, T. 25 S., R. 22 E., Pasco County, Fla. Elevation, 140 feet
				Quaternary:
0	0	4	0	Not cored.
				Middle Miocene, Hawthorn formation:
4	0	13	0	Poor recovery; partly red-brown fine- to medium-grained very slightly clayey sand.
13	0	21	0	Sand, tan and gray, mottled, fine- to medium-grained, clayey.
21	0	64	5	Sand, white, fine-grained, very slightly clayey to clayey.
64	5	65	5	Sand, brown, medium-grained, very clayey; contains abundant fragments of sandstone cemented by aluminum phosphate.
				Lower Miocene, Tampa limestone:
65	5	71	5	Clay, yellow-brown, very slightly sandy.
71	5	73	0	Sand, brown, fine- to medium-grained, very clayey.
73	0	91	6	Poor recovery; partly gray and brown mottled fine-grained clayey to very clayey sand, containing sparse fragments of sandstone cemented by aluminum phosphate.
91	6	95	5	Clay, yellow-brown and black, mottled, very slightly sandy, to very sandy.
95	5	96	3	Clay, white, slightly sandy, phosphatic.
96	3	99	0	Clay, brown, slightly sandy.
99	0	100	0	Clay, white, slightly sandy, hard, phosphatic.
100	0	101	0	Clay, tan to gray, white, banded, very sandy.
				Oligocene, Suwannee limestone:
101	0	101	3	Limestone, white and tan, mottled, slightly sandy, clayey, soft.

G112, SE¼ sec. 13, T. 25 S., R. 21 E., Pasco County, Fla.
Elevation, 140 feet

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

G113, NE¼ sec. 14, T. 25 S., R. 21 E., Pasco County, Fla.
Elevation, 185 feet

Depth From— (ft	in)	Depth To— (ft	in)	Lithology
				Quaternary:
0	0	4	0	Not cored.
				Middle Miocene, Hawthorn formation:
4	0	68	0	Sand, dark-brown to light-gray, mottled, fine- to medium-grained, very slightly to very clayey.
68	0	78	0	No recovery; probably loose sand.
78	0	80	0	Clay, brown, very sandy (medium- to coarse-grained); contains fragments of sandstone cemented by aluminum phosphate.
80	0	82	5	Clay, brown, very slightly sandy.
82	5	87	0	Clay, brown, sandy (medium- to coarse-grained); contains abundant white, tan sand- to pebble-size phosphate nodules, and fragments of sandstone cemented by aluminum phosphate.
87	0	89	0	Sand, brown to black, fine- to medium-grained, very clayey.
				Lower Miocene, Tampa limestone:
89	0	105	0	Sand, tan to light-gray, mottled, fine-grained, very clayey.
105	0	111	0	No recovery.
111	0	114	6	Clay, green-gray to brown and white, very sandy, phosphatic.
114	6	116	1	Clay, white, slightly sandy (fine-grained), hard, brittle, phosphatic, encrusted with secondary phosphate.

Depth				Lithology
From— (ft	in)	To— (ft	in)	
				G113—Continued
				Oligocene, Suwannee limestone:
116	1	134	9	No recovery.
134	9	138	7	Poor recovery; partly green-gray and brown very sandy clay.
138	7	144	3	Poor recovery; partly white slightly sandy (very fine grained) limestone; *Sorites* sp., *Asterigerina subacula floridensis*, calcareous algae.
				G114, NE¼ sec. 22, T. 24 S., R. 21 E., Pasco County, Fla. Elevation, 85 feet
				Quaternary:
0	0	4	0	Not cored.
				Lower Miocene, Tampa limestone:
4	0	11	6	Sand, white, fine-grained, clayey.
11	6	23	6	Clay, green-gray, brown, mottled, very sandy to sandy (fine-grained).
23	6	25	8	Clay, white, brown, mottled, sandy (fine-grained), phosphatic; contains chert and secondary phosphate crusts.
25	8	26	0	Limestone, white, tan, slightly sandy (fine-grained), soft, phosphatic.
				Oligocene, Suwannee limestone:
26	0	30	0	Limestone, tan, slightly sandy (fine-grained), slightly phosphatic; *Sorites* sp., calcareous algae.

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