(200)
T 67r
No. 458

Stratigraphy of Parts of De Soto and Hardee Counties, Florida

By M. H. Bergendahl

U. S. GEOLOGICAL SURVEY
RESTON, VA.
JUN 25 1980
LIBRARY

Trace Elements Investigations Report 458

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Geology and Mineralogy

This document consists of 58 pages,
plus 8 plates.
Series A

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

STRATIGRAPHY OF PARTS OF DE SOTO AND HARDEE COUNTIES, FLORIDA*

By

M. H. Bergendahl

April 1954

Trace Elements Investigations Report 458

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

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

USGS - TEI-458

GEOLOGY AND MINERALOGY

Distribution (Series A)	No. of copies
Atomic Energy Commission, Washington.	2
Division of Raw Materials, Denver	1
Division of Raw Materials, Salt Lake City	1
Division of Raw Materials, Washington	3
Grand Junction Operations Office.	1
Technical Information Service, Oak Ridge.	6
Tennessee Valley Authority, Wilson Dam.	1
U. S. Geological Survey:	
Fuels Branch, Washington.	1
General Geology Branch, Denver.	1
Geochemistry and Petrology Branch, Washington	1
Geophysics Branch, Washington	1
Mineral Deposits Branch, Washington	1
K. L. Buck, Denver.	1
W. L. Emerick, Plant City	2
G. H. Espenshade, Washington.	1
M. R. Klepper, Washington	1
R. A. Laurence, Knoxville	1
D. M. Lemmon, Washington.	1
V. E. McKelvey, Menlo Park.	1
A. E. Weissenborn, Spokane.	1
TEPCO, Denver	2
TEPCO, RPS, Washington. (Including master)	3
	34

CONTENTS

ILLUSTRATIONS

STRATIGRAPHY OF PARTS OF DE SOTO AND HARDEE COUNTIES, FLORIDA

By M. H. Bergendahl

ABSTRACT

The late Cenozoic stratigraphy of part of central Florida immediately south of the land-pebble phosphate district was studied in detail to determine the southern limit of the economically important Bone Valley formation and its relations with marine rocks of late Miocene and Pliocene age in south-central Florida. In addition, a reconnaissance type appraisal of the phosphate and uranium resources of this area was desired. The upper Tertiary and Quaternary rocks were mapped, and the economic geology was studied in a general manner.

The Hawthorn formation, of middle Miocene age, is the oldest rock exposed. Undifferentiated phosphatic sand and clay may be composed of the Bone Valley formation, of late Miocene to Pliocene age; a combination of Bone Valley formation and residuum of weathered Hawthorn formation; or Hawthorn residuum alone. The Bone Valley formation and residuum of Hawthorn formation appear almost identical in cuttings from auger drilling in this area. It was not feasible nor practical to map these two units separately. The undifferentiated phosphatic sand and clay interfingers with a marine sand of late Miocene age. The Caloosahatchee marl, of Pliocene age, is present in the southeast corner of the area investigated. It is apparent that the undifferentiated phosphatic sand and clay was undergoing subaerial erosion and reworking during deposition of the Caloosahatchee marl. Stratified sand and clayey sand containing scattered thin lenses of fresh-water limestone and marl of Pleistocene

age are either floodplain deposits or subaerial topset beds of a delta made by the Pleistocene Peace River. Sediments of Recent age are local stream deposits.

Bars and shoals in the Peace River south of Brownville, De Soto County, contain appreciable tonnages of low grade "river-pebble" phosphate. The phosphate and uranium content of the undifferentiated phosphatic sand and clay in Hardee County is too low to be of economic significance.

INTRODUCTION

Purpose and scope

The results of one part of the investigations of the regional geology of central Florida are presented in this paper. Work was done on behalf of the Raw Materials Division, U. S. Atomic Energy Commission.

Within the Florida land-pebble phosphate district (fig. 1), detailed studies have been made of the mineralogy, thickness, phosphate content, and distribution of the sediments containing the economic concentrations of phosphate nodules. This unpublished work, which was done by geologists of the U. S. Geological Survey, was primarily of an economic nature, and little attention was given to the genesis of the phosphate deposits and to regional stratigraphy.

The geology of Hardee and De Soto Counties, which are immediately south of the phosphate mining district, has been described in a number of reports of a regional or statewide scope. No detailed work in this area has been published. The southern extent of the formation that contains the economic phosphate deposits, the Bone Valley formation,

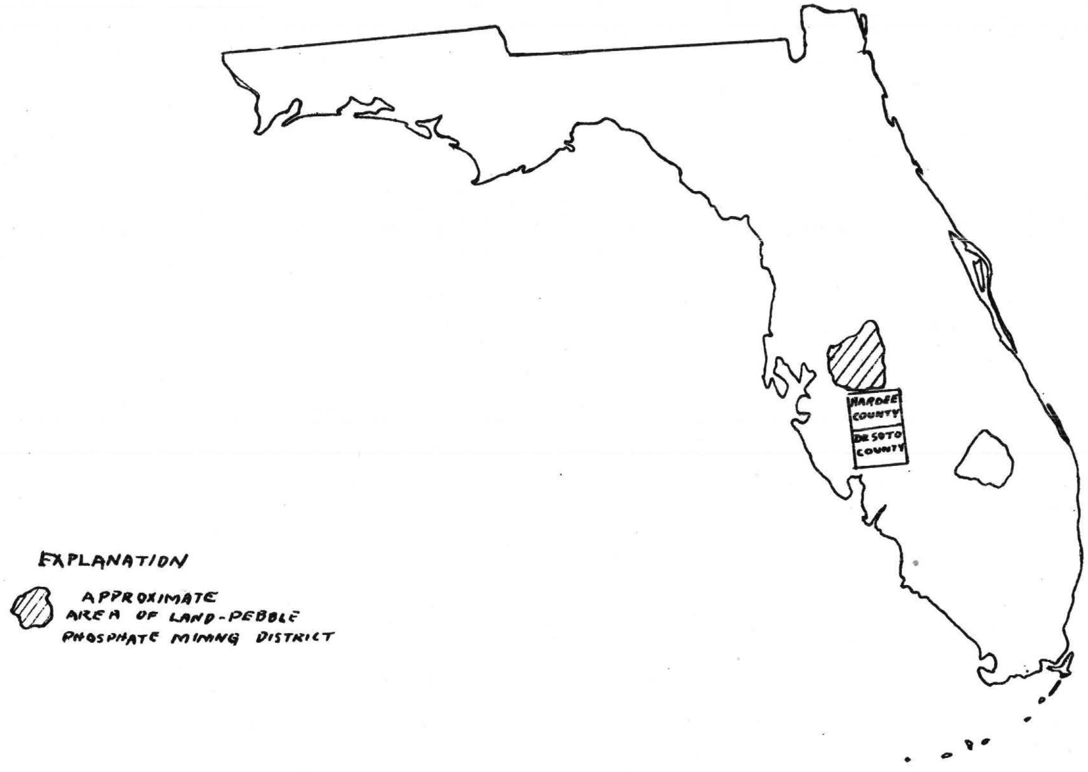

FIG. 1 INDEX MAP OF LAND- PEBBLE PHOSPHATE DISTRICT AND HARDEE AND DE SOTO COUNTIES, FLORIDA.

has never been accurately mapped. The northern limit of the Caloosahatchee marl, a fossiliferous shallow water marine rock of Pliocene age which is present throughout southern Florida, was not precisely determined. Cooke (1945, p. 216, 217) believed that the Bone Valley formation extended south into De Soto County where it merged with the Caloosahatchee marl. On the other hand, Matson and Clapp (1909), Matson and Sanford (1913), and Cooke and Mossom (1929) had previously put the contact between the Bone Valley formation and Caloosahatchee marl considerably further north in central Hardee County. All of these authors agreed that both formations were Pliocene in age.

This investigation was conducted to:

1. Clarify the late Cenozoic stratigraphy south of the land-pebble phosphate district, particularly the relations of the Bone Valley formation with the Caloosahatchee marl.
2. Appraise the potential economic value of the area for phosphate and uranium.

Methods of investigation

The area mapped in Hardee and De Soto Counties is a strip 42 miles long and 15 to 17 miles wide, roughly parallel to the Peace River (pl. 1). It includes about 700 square miles within the approximate boundaries of 27° 2' to 27° 39' north latitude and 81° 40' to 82° 3' west longitude. Gardner, which is near the center of the area, is about 58 miles airline southeast of Tampa and about 50 miles airline south of Lakeland.

The region is of such low relief that exposures are limited to the banks of streams and shallow borrow pits. In addition, a mantle of surficial alluvium and wind blown sand effectively conceals the older sediments. Less than 40 outcrops were found; the maximum section was 16 feet thick. To obtain more detailed sub-surface information, 92 holes were drilled with a mobile drill, a power auger mounted on the rear of a 4-wheel drive truck. In general, holes were drilled at intervals of 1 to 2 miles along the rights-of-way of state and county roads. In addition, well logs and limestone cores from Atomic Energy Commission-contract drilling in this area were studied.

Topographic maps for this region were not available when field work was in progress. Planimetric county road maps published on a scale of 1:125,000 by the Florida State Road Department were used as a base for geologic mapping.

Altitudes of outcrops and drill holes were obtained by aneroid barometer traverses. It was possible during traverses to visit USGS and USC&GS bench marks within time intervals of less than 10 minutes. These elevations should be accurate to within 5 feet.

The period May through part of September 1953 was spent in the field.

Culture

The major towns in the area are Wauchula, the county seat of Hardee County, and Arcadia, the county seat of De Soto County. The population of each is about 5,000. U. S. Highway 17, which passes through Wauchula and Arcadia, is the principal north-south highway.

State Highways 70 and 72 link Arcadia with Sarasota, on the west coast, and Sebring to the east. In De Soto County and southern Hardee County, cattle raising is the chief activity. In northern Hardee County, the well-drained sandy soil is adaptable to orange groves and truck farming.

Topography

The area includes two natural topographic subdivisions, the Central Highlands and the Coastal Lowlands (Cooke, 1939, p. 14). The northern part of Hardee County is within the Central Highlands. The topography is gently rolling, and altitudes are generally between 90 and 150 feet.

Immediately south of Zolfo Springs and Ona, the Central Highlands give way to the prairie country of the Coastal Lowlands. This is a conspicuously flat plain, sloping slightly to the south. Altitudes range from 35 to 70 feet. In southern De Soto County the banks of the Peace River are less than 20 feet above sea level. The water table is close to the surface in this region, and many temporary shallow ponds appear during the rainy season.

Drainage

The area is drained principally by the Peace River which flows due south from its source in central Polk County for about 70 miles to Charlotte Harbor, near Punta Gorda, in Charlotte County. Major tributaries in Hardee and De Soto Counties are Payne's Creek, Charlie Apopka Creek, Joshua Creek, Horse Creek, and Prairie Creek. Intense rainfall during the summer and fall often causes the stream levels to rise 15 to 20 feet. During such periods, pastures adjacent to the streams are flooded for weeks at a time, and occasionally bridges are swept away. Outcrops are submerged by swollen streams, dirt roads are impassible, and drilling is difficult because of the flooded roadside conditions.

Streams are at present degrading. At many points along the Peace River and Charlie Apopka Creek, the banks are vertical. Pre-Pleistocene phosphatic formations are being eroded, and the phosphate is being redeposited in shoals and bars along the lower reaches of the streams.

Acknowledgments

Vertebrate fossils were identified by Jean Hough_/. F. S. MacNeil_/ examined and identified collections of invertebrate fossils. Radiometric analyses for percent equivalent uranium were made by B. A. McCall_/. Anthony Cerkel assisted the writer in the field. This work was done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

STRATIGRAPHY

Miocene Series

Hawthorn formation

In this area, the Hawthorn formation, of middle Miocene age, is a sandy, clayey, phosphatic limestone.

_/ U. S. Geological Survey

Originally the name Hawthorne was given by Dall (1892, p. 107) to the phosphatic limestone believed of "older" Miocene age (fig. 2) near the town of Hawthorne in Alachua County. Younger than the Hawthorne "beds", but still of "older" Miocene age, were the Tampa, Chipola, and Alum Bluff "beds" assigned by Dall (1892, p. 112) to the Tampa group (fig. 2). Later, due to a readjustment of the Oligocene-Miocene boundary, the Tampa group was regarded as Oligocene by Dall and others.

Matson and Clapp (1909, p. 67-69) combined rocks of the upper Oligocene into the Apalachicola group which consisted of the following four formations: Chattahoochee, Hawthorne, Tampa, and Alum Bluff (fig. 2).

Matson and Sanford (1913, p. 87-88) shortened the name Hawthorne to Hawthorn. They (Matson and Sanford, 1913, p. 145) believed that the land-pebble phosphate deposits lie upon an eroded surface of the Alum Bluff formation.

According to Sellards (1915, p. 34-35) the Alum Bluff formation was the parent rock from which the land-pebble phosphates were derived. Sellards (1916, p. 91-92) later introduced evidence of a Miocene vertebrate fauna in the Alum Bluff formation. The opinion that the Alum Bluff formation be considered Miocene was generally accepted by later workers (fig. 2).

Gardner (1926, p. 1-2) recognized three distinct marine faunas of Miocene age, and, on the basis of these faunas, she raised the Alum Bluff to the rank of a group divided into three formations, each characterized by a separate fauna. In descending order these were: Shoal River formation, Oak Grove sand, and Chipola formation (fig. 2).

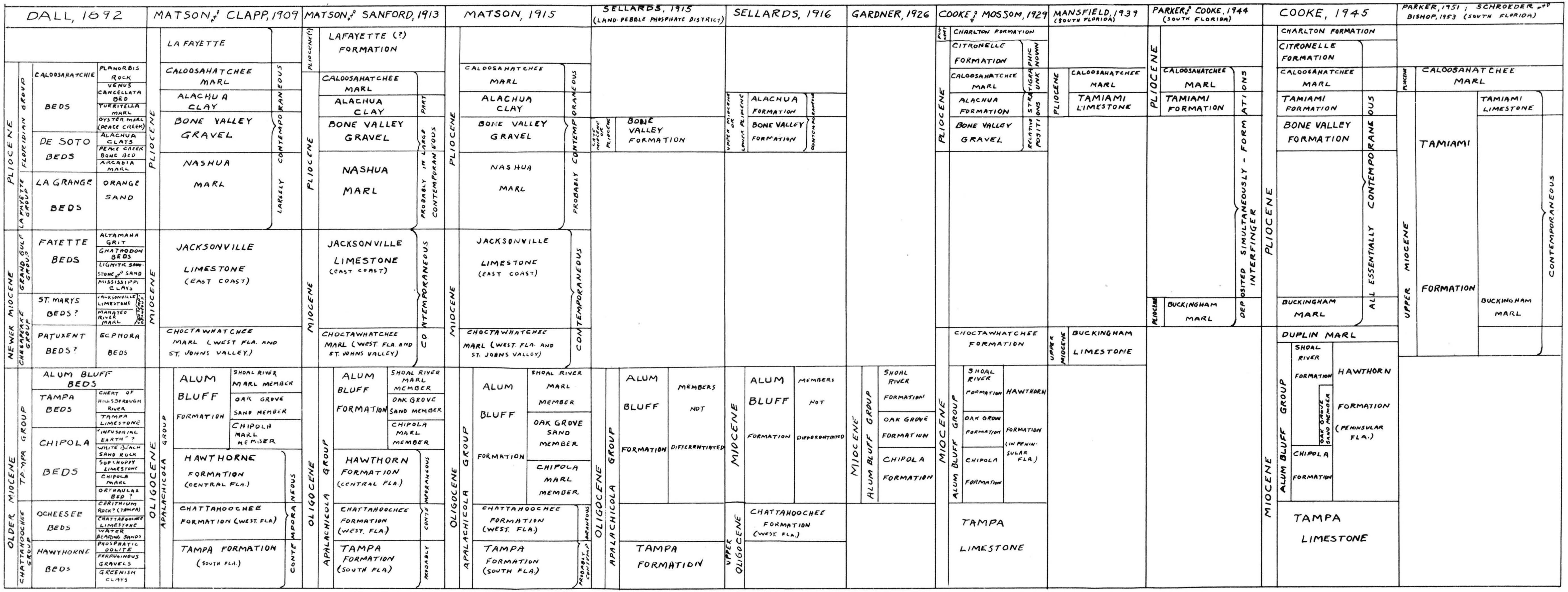

FIG. 2 CLASSIFICATION OF THE UPPER TERTIARY ROCKS IN FLORIDA, SHOWING STRATIGRAPHIC TERMS USED BY VARIOUS AUTHORS.

Cooke and Mossom (1929, p. 98) retained Gardner's Alum Bluff group but added a fourth formation, the resuscitated Hawthorn, which is representative of the Alum Bluff group east of the Apalachicola River in peninsular Florida. Within the Hawthorn formation, Cooke and Mossom (1929, p. 115) included the earlier Alum Bluff formation of Matson and Clapp (1909, p. 91) and Dall's original Hawthorn "beds", Manatee River marl, Sopchoppy limestone, and Jacksonville limestone (fig. 2). Cooke (1945, p. 144) in general retained this classification.

The redefinition of the Hawthorn formation by Cooke and Mossom (1929, p. 115) to include marine rocks of middle Miocene age on peninsular Florida has survived to the present, and the term Hawthorn is so used in this report (fig. 3).

Lithology.--As seen at outcrops along streams in this area and in the phosphate mines to the north, the Hawthorn formation is a gray to cream, locally buff-colored limestone. Stratification is indistinct, in places is marked by concentrations of phosphate grains in beds or lenses. Commonly the Hawthorn formation is consolidated; locally it is indurated.

Fine-grained quartz sand, quartz silt, clay-size particles, phosphate nodules, and calcium carbonate are the chief constituents. Magnesium carbonate is usually a minor constitutent, but it may be present locally in sufficient quantity to make the formation dolomitic. Individual sand grains are sub-angular to rounded. Phosphate nodules range from fine sand to cobbles. The phosphate in the Hawthorn formation is predominantly brown; individual grains are glossy-surfaced.

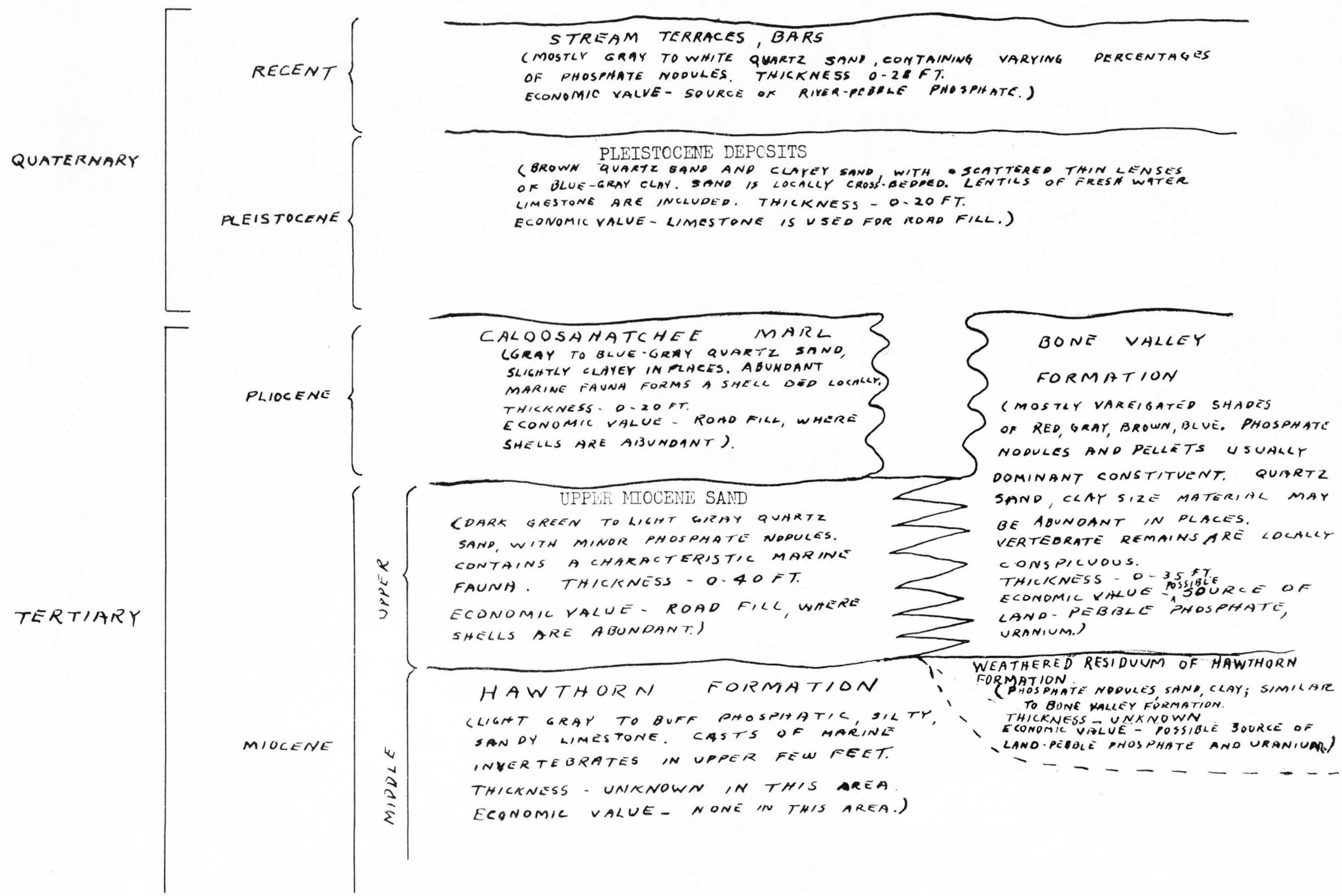

FIG. 3 SUMMARY OF EXPOSED FORMATIONS IN HARDEE AND DE SOTO COUNTIES, FLORIDA.

Irregular chert nodules of cobble to boulder size are locally common in the upper part of the Hawthorn formation. Some nodules are lenticular, others are in a variety of shapes. The nodules are distributed randomly, and the long axes have no apparent relation to the bedding in the limestone. These characteristics suggest an authigenic origin for the chert.

Internal and external molds of pelecypods and gastropods are abundant in the upper part of the Hawthorn formation.

Distribution.--The Hawthorn formation underlies the undifferentiated phosphatic sand and clay throughout most of Hardee County (pls. 2, 3, and fig. 4). A slight southward dip is indicated, but this is virtually impossible to measure because of the relief of the upper surface of the formation due to erosion (pl. 6). From well records, the Hawthorn formation is of variable thickness. A well drilled at Quincy, in Gadsden County, revealed 210 feet of Hawthorn formation (Cooke, 1945, p. 145). Near Hilliard, in Nassau County, nearly 400 feet of Hawthorn formation was identified from well cuttings (Cooke, 1945, p. 145). In southern Hardee and De Soto Counties, the formation has been reached in drill holes. The thickness in this region is unknown.

Details and fauna.--Nearly all of the fossils listed in this section are described by Gardner (1926) in her detailed work on the middle Miocene molluscan fauna of Florida.

Because natural exposures of the Hawthorn formation are limited to the upper few feet, details on lithology, sedimentary structures, and fauna are difficult to obtain. Many outcrops are either barren of

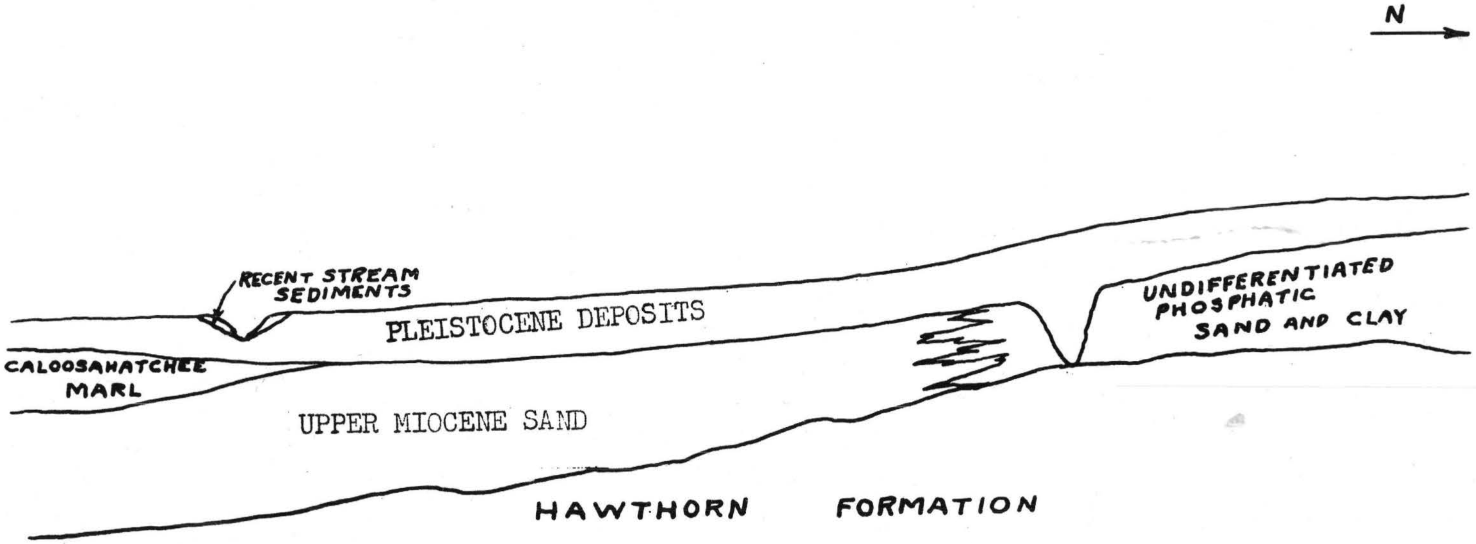

FIG. 4 DIAGRAM SHOWING GENERAL STRATIGRAPHIC RELATIONS OF THE FORMATIONS IN HARDEE AND DE SOTO COUNTIES, FLA.

fossils or else are so close to water level of streams that extensive investigation is impossible.

The thickest section of Hawthorn formation in this region was found along the north bank of the Peace River, at the bridge on U. S. Highway 17, map locality 22-53 (pl. 7) 0.5 mile north of Zolfo Springs (NE$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 22, T. 34 S., R. 25 E., Hardee County, Florida). Here 6 feet of gray indurated limestone is exposed above water level in the river. Chert cobbles and boulders are incorporated within the upper two feet of the limestone. The following fossils were collected:

Pelecypoda:

Chlamys sp.

Venericardia sp.

Bryozoa

Although these invertebrates are not diagnostic of the middle Miocene, the lithology of the limestone is typical of the Hawthorn formation in this area; furthermore, less than a mile south of this locality along the Peace River (map locality 16-53, pl. 7) at the northwest corner of the bridge over the Peace River on State Highway 64, 1.3 miles west of Zolfo Springs, similar limestone containing a probable Hawthorn fauna is exposed at water level. The following external molds were collected here:

Pelecypoda:

Venericardia sp. aff. *V. hadra* and *himerta* Dall fragment of external mold.

Cardium (Trachycardium) sp. Sculpture resembles that of *C. malacum* Dall. Fragments of external mold.

Additional evidence for the middle Miocene age of the limestone in this region was furnished from fossiliferous limestone cores recovered from the AEC drilling program. In drill hole 10-8 in SW$\frac{1}{4}$, SW$\frac{1}{4}$, sec. 15, T. 34 S., R. 25 E., Hardee County, Fla. (pl. 7), the following pelecypods were identified in a soft, phosphatic limestone at 36.4 feet below the surface:

Anadara sp.

Chione sp. aff. *C. sellardsi* Gardner

From drill hole 11-1 in NW$\frac{1}{4}$, NW$\frac{1}{4}$, sec. 1, T. 34 S., R. 25 E., Hardee County, Fla. (pl. 7), a tan, sparsely phosphatic, clayey limestone yielded these invertebrates from 13.6 feet to 17.0 feet below the surface:

Gastropoda:

Cancellaria sp. cf. *C. macneili* Mansfield (desc. from Arca zone of the Choctawhatchee fm.)

Semicassus ?

Pelecypoda:

Glycymeris sp. aff. *G. subovata* (Say)

Anadara sp. cf. *A. gunteri* Gardner

Plicatula sp. cf. *P. densata* Conrad

Phacoides sp. cf. *P. contractus* (Say)

Venericardia sp.

Cardium sp.

Dosinia sp.

Venus sp.

This assemblage is probably late middle Miocene and would therefore be from the upper part of the Hawthorn formation.

In drill holes 11-5 in NE$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 31, T. 35 S., R. 27 E., Hardee County, Fla., and 11-6 in NE$\frac{1}{4}$ SE$\frac{1}{4}$, sec. 31, T. 35 S., R. 27 E., Hardee County, Fla. (pl. 7), the Hawthorn formation was penetrated at depths of 49 feet and 72 feet respectively. The following pelecypods were identified from the core in drill hole 11-5:

Glycymeris sp.

Phacoides sp. cf. *P.* *contractus* Say

The limestone in drill hole 11-6 contained these pelecypods:

Chlamys sp. aff. *C.* *nicolsi* Gardner. Fragments of external mold.

Venericardia sp. Internal mold.

Chione sp. aff. *C.* *Chipolana* Dall

Venus sp. Internal mold.

Without diagnostic fossils it is difficult at many places to determine the exact boundary between the Hawthorn formation and the unnamed sand which overlies the Hawthorn in the southern part of the area. The lower part of the sand contains scattered lenses of phosphatic limestone and calcareous clay which are identical to the lithology of the Hawthorn formation. The Hawthorn is not exposed in De Soto County; however, indurated phosphatic limestone, presumably Hawthorn, was encountered beneath the sand in several auger holes at depths of from 40 to more than 60 feet.

Origin.--The lithology of the Hawthorn formation indicates deposition in a shallow sea. North of the land-pebble phosphate district, in Pasco and Hernando Counties, the Hawthorn formation is predominantly sand, suggestive of deposition in a near-shore environment. Most writers (Eldridge, 1893, p. 196-231; Matson and Clapp, 1909, p. 139, 167; Matson and Sanford, 1913, p. 145-206; Matson, 1915, p. 65; Sellards, 1915, p. 58) believed the subjacent Hawthorn formation to be the source rock for the phosphate in the economic land-pebble phosphate deposits.

Sand of late Miocene age

A gray to green, slightly phosphatic, marine sand underlies all of De Soto County and the southern part of Hardee County and contains an invertebrate fauna of which large oysters and barnacles comprise a conspicuous fraction. The characteristic lithology and associated fauna are easily identified, even in auger cuttings. The sand represents the upper Miocene in this area (fig. 3). It is well exposed in a borrow pit (NW$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 24, T. 38 S., R. 24 E.) along Florida Route 760, 1.6 miles east of the junction of U. S. Route 17 and Florida Route 760 at Nocatee (fig. 5). Fossiliferous sand is exposed at or below water level in the pit. Piles of dredged material around the sides of the pit yielded marine fossils which establish the late Miocene age of the sand. A drill hole near the east end of the pit revealed a thickness of 16 feet for the sand at this locality. In the borrow pit this sand is overlain by 6 feet of a surficial sand and calcareous clayey sand containing fresh water and land gastropods which are of probable Pleistocene age. The upper contact of the sand with this surficial material is sharp and, at several places in the pit, is marked by a 3 to 6 inch bed of phosphate pebbles and cobbles comprising the basal unit of the Pleistocene section (fig. 5, sec. A-A', B-B', C-C'). The lower contact of the sand with the Hawthorn formation is not exposed at this locality. Indurated limestone (Hawthorn formation ?) was encountered in the auger hole (fig. 5)

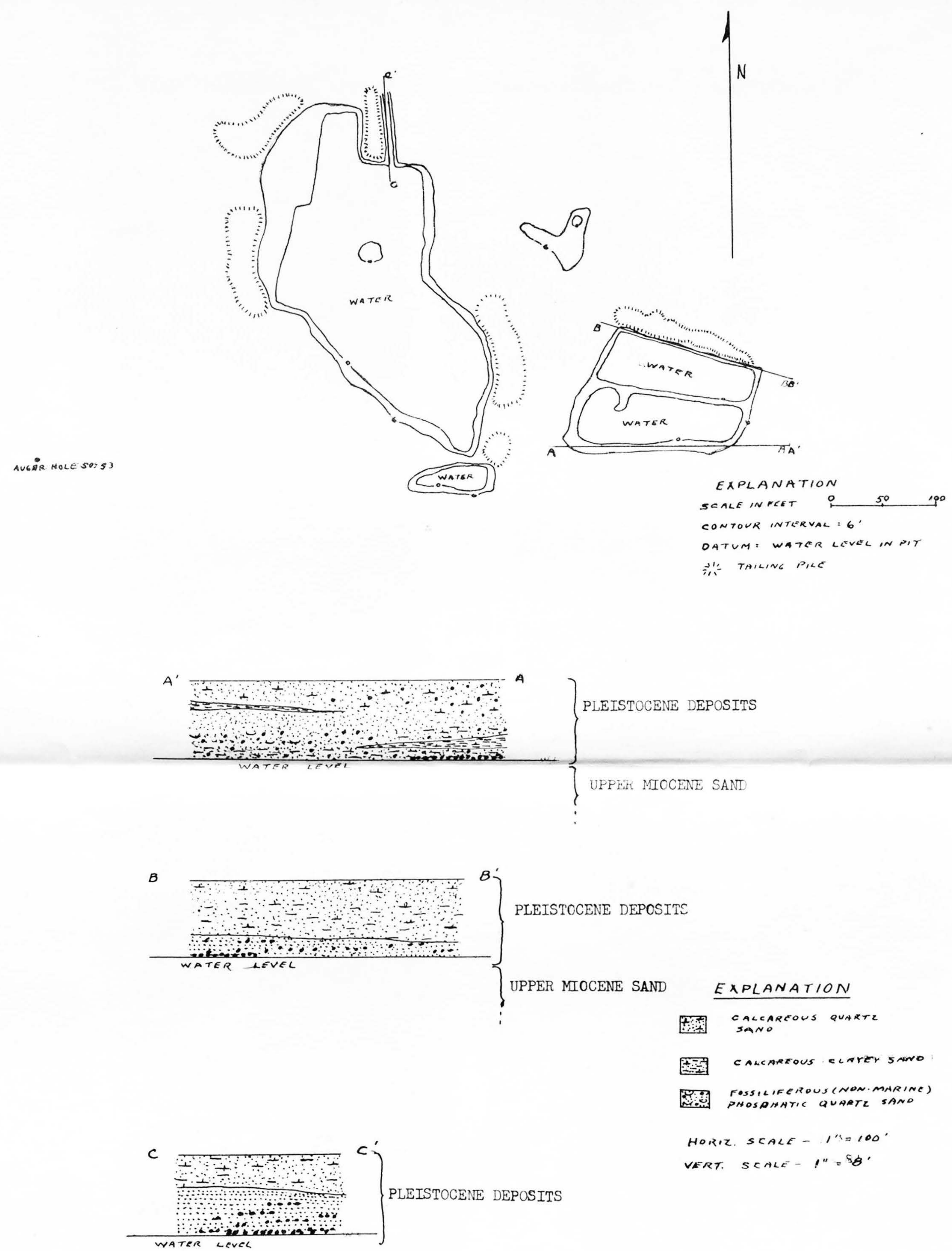

FIG. 5 SKETCH MAP AND CROSS SECTIONS OF BORROW PIT 1.6 MILES EAST OF NOCATEE, DE SOTO COUNTY, FLA. (NW$\frac{1}{4}$, SE$\frac{1}{4}$, SEC. 24, T. 38 S., R. 24 E.). THE TOP OF THE UPPER MIOCENE SAND OCCURS JUST BELOW WATER LEVEL. PILES OF FOSSILIFEROUS UPPER MIOCENE SAND SURROUND THE PITS AS SHOWN. THE SURFICIAL SAND, CLAYEY SAND AND CLAY, SHOWN IN SEC. A-A', B-B', C-C', COMPRISE THE PLEISTOCENE DEPOSITS.

at a depth of 27 feet below the surface. No limestone sample was recovered. A bed of unfossiliferous phosphate gravel 2 feet thick immediately overlies the limestone at this locality.

Lithology.--The upper Miocene sand is a fine-grained gray to green quartz sand, slightly clayey to extremely clayey in places. Phosphate, in sand to gravel size, is a conspicuous, though minor, constituent. The phosphate nodules are hard, dark colored, and smooth-surfaced. None of the crumbly white phosphate, common in the undifferentiated phosphatic sand and clay, is present.

In general the lower part of the unit contains appreciably more clayey material than the upper part. Beds of green calcareous clay and scattered lenses of soft sandy limestone are encountered beneath the typical gray to green sand facies during drilling.

The lithology changes somewhat in southern Hardee County. The unit is thinner, more clayey, and contains moderate amounts of phosphate. Fossils are absent in this area.

Fauna.--W. C. Mansfield (1932, p. 43-56) listed and described the marine invertebrates collected from the limestone exposed in ditches along the Tamiami Trail. At that time he regarded the fauna as Pliocene in age and the limestone a facies of the Caloosahatchee marl. This limestone is now called Tamiami formation and is considered late Miocene in age.

Many of the species collected from the upper Miocene sand in De Soto and Hardee Counties are also found in the Tamiami formation. From the locality described above (fig. 5), the following fauna was collected from dredged material piled along the sides of the large pit:

Gastropoda:

Rapana ? or *Ecphora* n. sp.

Pelecypoda:

Chlamys (*Plagioctenium*) n. sp. ? aff. *C. eboreus watsonensis* Mansfield and *C. caloosensis* Mansfield, both upper Miocene.

Ostrea tamiamiensis monroensis Mansfield (= *meridionalis* Heilprin ?)

Ostrea disparilis Conrad subsp. ?

Pododesmus n. sp. ?

Laevicardium sp.

Cirripedia:

Balanus sp. ? A large barnacle which seems to characterize this zone.

Distribution.--Auger drilling revealed that the sand of late Miocene age underlies all of De Soto and extends northward into Hardee County, where it interfingers with the undifferentiated phosphatic sand and clay (pl. 2, fig. 4). It is apparent that it occurs over an area much larger than Hardee and De Soto Counties. Gardner (1945, p. 37-41) described an oyster "reef" of later Miocene age which was discovered during dredging operations off the southeastern end of Snell Island in Tampa Bay. The matrix between the closely packed oysters consists of clear quartz sand and light gray limy clay. This may be a northwestward extension of the unit.

In De Soto County the sand attains thicknesses of 40 feet or more, but gradually becomes thinner northward. In southern Hardee County the unit is usually less than 20 feet thick.

Details.--Dall (1892, p. 131-133) reported a light colored, phosphatized calcareous sand at a locality 6 miles north of Arcadia, on Mare Branch, a tributary of the Peace River. He named this rock the "Arcadia marl" and considered it early Pliocene in age. Dall (1892, p. 131-133) also described an outcrop along the Peace River at Shell Point, about 3 miles north of Arcadia. He called this rock an "oyster marl" and reported that it contained the same oysters, barnacles, and pecten that occur in the Caloosahatchee marl. This same "oyster marl", according to Dall, was found along Joshua Creek near Nocatee and also in the banks of a small stream just north of Zolfo Springs. The shell bed at Zolfo Springs is overlain by 20 to 25 feet of partly indurated yellow sand. Matson and Clapp (1909, p. 123) regarded Dall's "Arcadia marl" as a phase of the Caloosahatchee formation.

The "Arcadia marl" and "oyster marl" of Dall are both included in the unnamed sand of late Miocene age described herein. At the southwest corner of the bridge over the Peace River, 1.2 miles west of Brownville, De Soto County (NE$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 31, T. 36 S., R. 25 E., map locality 18-53, pl. 7) a soft, buff colored, phosphatic, sandy limestone exposed at water level is probably the "Arcadia marl" described by Dall. Core from drill hole 10-15 in SE$\frac{1}{4}$, NE$\frac{1}{4}$, sec. 32, T. 36 S., R. 25 E., De Soto County (pl. 7), about one mile east of the above exposure, contained *Balanus* sp., bryozoa, and echinoid spines in a sandy shell bed at a depth of 50 feet. This assemblage compares favorably with the upper Miocene fauna collected from the borrow pit at Nocatee. The 50-foot depth at which this shell bed was penetrated is nearly the same elevation as both the limestone along the Peace River near Brownville and the shell bed at the pit near Nocatee. Results of auger drilling in the immediate area further substantiated that the exposure at the Brownville bridge is a lens of clayey limestone within the sand, which is present in the Aracadia-Nocatee-Brownville area; the Caloosahatchee marl occurs south of Nocatee. Dall's "Arcadia marl" is the lower, more clayey part of the sand; his "oyster marl", the typical material. The occurrence of "Arcadia marl" near Zolfo Springs is considered Hawthorn formation. The northern limit of upper Miocene and Pliocene marine rocks in this region is about 5 miles south of Zolfo Springs.

The difficulty in distinguishing the lower part of the sand from the Hawthorn formation is exemplified in the section exposed along the west bank of the Peace River (fig. 6), at the site of a former bridge (NW$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 17, T. 36 S., R. 25 E., Hardee County, Fla., map locality 20-53, pl. 7), 1$\frac{1}{2}$ miles west of Gardner. A section extending 16 feet above water level is exposed. An internal mold, strongly resembling Eontia of the E. incile group, was found in the thick-bedded, phosphatic, calcareous clay and clayey sand which overlies 2$\frac{1}{2}$ feet of sparsely phosphatic, thin-bedded silty soft limestone. This lower thin-bedded unit was barren of fossils. The single-shell imprint suggests an upper Miocene classification for the upper calcareous, more phosphatic beds; however, this lone Eontia is not conclusive evidence. On the basis of similar lithology, the lower thin-bedded unit is tentatively called Hawthorn formation. Results of drilling in the vicinity favor a late Miocene age for at least the upper thick-bedded calcareous material. From drill hole 10-14 (N$\frac{1}{2}$, SE$\frac{1}{4}$, sec. 21, T. 36 S., R. 25 E., De Soto County, Fla.), slightly more than one mile to the southeast of the

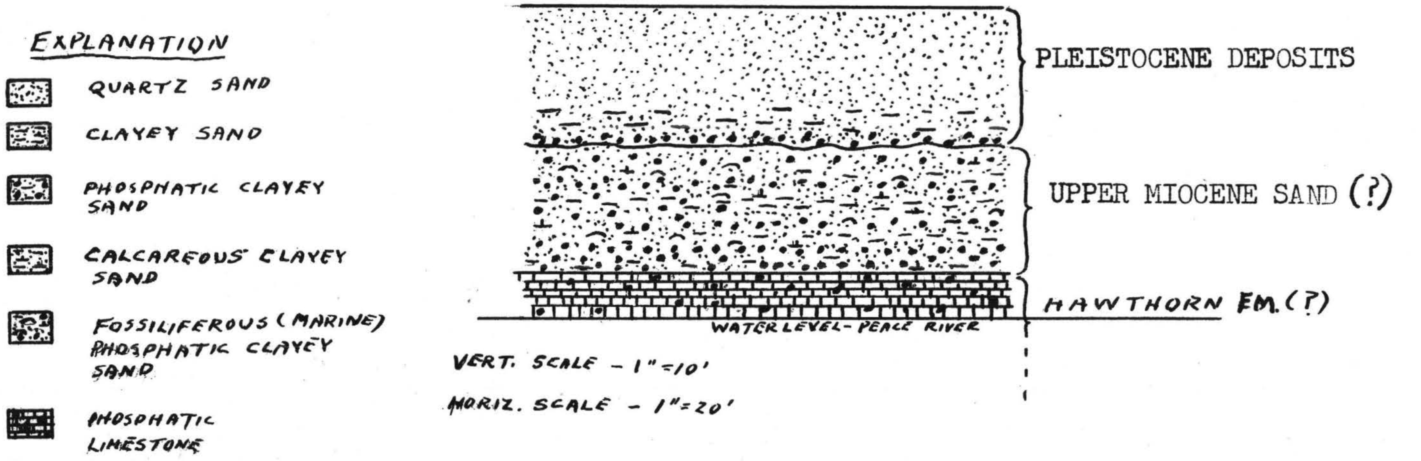

FIG. 6. SKETCH OF SECTION EXPOSED ALONG WEST BANK OF PEACE RIVER AT OLD BRIDGE 1.5 MILES WEST OF GARDNER, HARDEE COUNTY, FLA. (NE $\frac{1}{4}$ SEC. 17, T 36 S, R 25 E)

exposure just described, limestone was encountered from 27 to 37 feet below the surface. Drilling was discontinued at 37 feet. Limestone core from 33 to 35.5 feet contained the following:

Pelecypoda:

Ostrea sp. aff. *O.* *puelchana* d'Orbigny

Chlamys sp.

Cardita sp.

Cardium sp.

Venus ?

Spisula ?

The oyster is unlike any found in the Hawthorn formation, and this assemblage is tentatively identified as upper Miocene.

The limestone in drill hole 10-14 could be equivalent to the thin-bedded limestone at the exposure near Gardner (fig. 6). Conversely the beds containing *Eontia* (fig. 6) could be a more clayey, more phosphatic phase of the limestone in the drill hole.

Origin.--The upper Miocene sand was deposited in a shallow marine environment. In south Florida, the Tamiami limestone and Buckingham marl are deeper water sediments of the same sea. In southern Hardee County the character of the sand changes, and the following features suggest an estuarine environment in this immediate area:

1. Preponderance of fine grained sand and clayey sand within the formation..
2. Absence of fossils. Changes in pH of the estuarine waters caused by fluctuations in the discharge volume of the Peace River might create unfavorable conditions for organisms.

3. Proximity to the strand line and the mouth of the Peace River during late Miocene time.
4. Lack of any well defined beach deposits or bars.

Miocene-Pliocene series

Undifferentiated phosphatic sand and clay

The phosphorite which underlies the northern two-thirds of Hardee County (pl. 1) is composed of either or both of the following: Bone Valley formation and weathered residuum of Hawthorn formation. These two units appear almost identical and are composed of phosphate nodules, sand, and clay. In Polk and eastern Hillsborough Counties, Fla., the phosphatic beds are well exposed on mine faces. Mapping of the Bone Valley formation and residuum of Hawthorn formation separately may be possible where outcrops are relatively abundant and where observations of sedimentary structures and textures of the rocks in place reveal discrete strata. Where subsurface information is dependent primarily on interpretation of auger cuttings, no practical basis exists for discriminating between two stratigraphic units of such similar lithology. For this reason the phosphorite in Hardee County is mapped as undifferentiated.

Among the earliest workers in the land-pebble phosphate district of central Florida were Dall (1892, p. 141-142) and Eldridge (1893, p. 196-231).

Matson and Clapp (1909, p. 138-141) named these phosphate deposits Bone Valley gravel from a locality west of Bartow, Polk County, Fla.

As defined by them, the Bone Valley gravel consists of poorly sorted phosphate pebbles, clay, and sand of Pliocene age. Matson and Clapp (1909, p. 140-141) divided the Bone Valley gravel into lower beds rich in phosphate nodules and an upper non-economic unit containing very little phosphate. According to these writers an unconformity separated the Bone Valley gravel from the overlying surficial sand of Pleistocene age. Relations between the Bone Valley gravel and the older formations were not known at that time.

Sellards (1915, p. 58) agreed with most of the earlier writers on the Pliocene age of the Bone Valley gravel.

Later Matson (1915, p. 21) suggested a late Miocene age for the Bone Valley gravel on vertebrate fossil evidence. Horse teeth (species of Merychippus or Neohipparion), a mastodon upper jaw (Tetrabelodon), and a second upper molar which differed only slightly from the corresponding tooth of Teleoceras fossiger, all of which were found in the Bone Valley gravel, are indicative of an upper Miocene fauna. Matson (1915, p. 22) located the southern boundary of the Bone Valley gravel in the vicinity of Zolfo Springs, Hardee County.

Cooke and Mossom (1929, p. 134) stated that the Bone Valley gravel lies unconformably on the Hawthorn formation in the phosphate mines in Polk County, Fla. They also reported an unconformity at the top of the Bone Valley gravel.

Cooke (1945, p. 203) suggested that the name Bone Valley formation was more appropriate than Bone Valley gravel, as gravel makes up only a small fraction of the rock. Cooke (1945, p. 206) proposed that some of the Bone Valley formation "may be the residual products of the decomposition in place of the Hawthorn formation."

Lithology.--The undifferentiated phosphatic sand and clay is an unconsolidated rock of a prevailing brownish to buff color. Individual lithologic units may be blue-green, brown, white, or gray.

The Bone Valley formation may display distinct bedding locally. Seams of blue to green clay are disseminated throughout the formation. Residuum of Hawthorn formation is similar in color and lithology to the Bone Valley formation, but bedding is rarely preserved. Phosphate in clay to granule size is usually the most abundant component of both the Hawthorn residuum and Bone Valley formation. Fine-grained quartz sand, silt-sized quartz, and clay minerals comprise the non-phosphatic fraction. The phosphate grains are polished and are brown, black, gray, and white.

The upper few feet of the Bone Valley formation is generally severely leached and weathered. Where the Bone Valley formation is thin or absent, this intense weathering is superimposed on the upper part of the Hawthorn residuum. In this leached zone, sometimes called the aluminum phosphate zone, the phosphate, originally present as nodules of carbonate fluorapatite, is altered to the minerals pseudowavellite--the hydrous phosphate of aluminum and calcium, and wavellite--the hydrous phosphate of aluminum. The former presence of phosphate nodules is marked by molds in vesicular clayey sand loosely cemented by wavellite and pseudowavellite.

Fauna.--No fossils were found in the undifferentiated phosphatic sand and clay during this investigation.

The Bone Valley formation, which is regarded as Pliocene in age (Matson and Clapp, 1909; Sellards, 1915; Cooke and Mossom, 1929; Simpson, 1929, 1930; Cooke, 1945), is dated on the basis of stratigraphic position and vertebrate fossils. Occurrences of Pliocene marine invertebrates in the Bone Valley formation are unrecorded. Sellards (1915, p. 75) reported silicified Ostrea mauricensis in the upper part of the Bone Valley formation at the Pembroke Mine of the Coronet Phosphate Company in Polk County, Fla. This species, which Gardner (1926, p. 43) reclassified as Ostrea normalis Dall, is of Miocene age and is abundantly distributed in the Hawthorn formation. Silicified molluscs were collected from the phosphorite exposed in the Sydney mine in Hillsborough County, Fla., by M. N. Bramlette during a visit in September 1953. These shells were later identified as middle Miocene by F. S. MacNeil. This evidence suggests that the phosphorite at Pembroke and Sydney is a residuum of Hawthorn formation; on the other hand, the possibility that the middle Miocene fossils are reworked into later Bone Valley sediments cannot be discounted.

Vertebrate fossils are fairly abundant. Remains of manatees, whales, crocodiles, mastodons, and horses have been recovered during mining operations. Sharks teeth, which are plentiful, were probably derived from the subjacent Hawthorn. The vertebrate fauna collected from the Bone Valley formation is considered Pliocene (Simpson, 1929, p. 257; 1930, p. 180), but this dating is flexible. Most of the vertebrate remains could be late Miocene as well as Pliocene in age. Simpson (1929, p. 257) admits that "The possibility of derivation of fossils from older beds and of accidental mixture with younger fossils on collecting or in the compilation of 'faunal lists' based on general localities is obviously great." Simpson (1930, p. 179-180) again discussed possibilities of false association of the Tertiary land mammals in the Bone Valley formation. Most of the land mammals were found by non-geologists during hydraulic mining of the phosphate beds.

Distribution.--Auger drilling was necessary to determine the extent of the undifferentiated phosphatic sand and clay. In Hardee County north of 27° 25' latitude (pl. 1) the Hawthorn formation is overlain by noncalcareous phosphatic sand and clay. The upper Miocene sand interfingers with the undifferentiated phosphatic sand and clay in southern Hardee County (pl. 2). The thickness of the phosphorite in this area ranges from less than 10 feet to more than 30 feet (pls. 2 and 3).

Details.--Exposures of the upper part of the undifferentiated phosphatic sand and clayey sand were found at only three localities in Hardee County.

The Bone Valley formation(?) is exposed in the bottom of a ditch along the east side of a dirt road in the NW$\frac{1}{4}$, NW$\frac{1}{4}$, sec. 18, T. 33 S., R. 26 E., Hardee County (map locality 11-53, pl. 7). Only the upper two feet of stratified clayey sand and sand containing abundant phosphate nodules can be seen.

At the bridge over the Peace River (map locality 27-53, pl. 7), 1 mile southeast of Wauchula, Hardee County (NW$\frac{1}{4}$, sec. 11, T. 34 S., R. 25 E.,), along the east bank of the river, the following section is exposed:

Formation	Feet from surface	Description
	0-$2\frac{1}{2}$	Sand; fine grained, quartz, tan.
	$2\frac{1}{2}$-$3\frac{1}{2}$	Clayey sand; dark brown, iron-stained, contains scattered soft, white (weathered) phosphate nodules.
Pleistocene beds	$3\frac{1}{2}$-6	Slightly clayey sand; contains scattered fresh phosphate nodules. Lower 1 foot is coarse grained sand; bottom 4 inches is a bed of gravel to pebble size phosphate, fish teeth, worn bone fragments. No diagnostic fossils.
------unconformity (bottom of conglomerate stratum in Pleistocene beds)		
Undifferentiated phosphatic sand and clay	6-$11\frac{1}{2}$	Clayey sand; contains very abundant sand size phosphate. Interval is slightly iron-stained in upper 7 inches, buff to olive color below. Entire interval is non-calcareous; bedding indistinct.

At this exposure it was not possible to determine whether the phosphorite is Bone Valley formation, Hawthorn residuum, or a combination of both. The obscure stratification could be either relict from the parent Hawthorn formation or a primary structure of Bone Valley sedimentation. The lower contact of the phosphatic sand and clay with calcareous Hawthorn formation is below water level in the river.

In a borrow pit (map location 10-53, pl. 7) 0.3 mile west of the Peace River bridge (NE$\frac{1}{4}$, sec. 28, T. 34 S., R. 25 E., Hardee County, Fla.) on Florida State Highway 64, 1.3 miles west of Zolfo Springs, the upper part of the Bone Valley formation is exposed beneath sand of Pleistocene age.

Below the zone of iron accumulation, the stratification is distinct. Individual layers are 2-6 inches thick and are differentiated by variations in the amounts of clay and phosphate. Phosphate is present as partly leached nodules and possibly also as clay sized wavellite and pseudowavellite. Partly indurated sand cobbles, which comprise single beds, still retain small voids previously occupied by phosphate grains. Several tiny phosphatized shell fragments, which could not be identified, were in the indurated sandy cobbles. Phosphate was very abundant at one point. Individual strata 2 to 3 inches in thickness, composed of leached phosphate nodules and quartz sand, are conspicuous. The bedded phosphatic material in this pit is interpreted as a reworked deposit of the aluminum phosphate zone of the undifferentiated phosphatic sand and clay. The preservation of bedding, the stratification of the sandy cobbles, and the variation of phosphate content along the face of the pit all point to redeposition of previously weathered material, rather than to an accumulation in situ of the residual products of a parent rock such as the Hawthorn formation.

Origin.--Many of the earlier workers, in their hypotheses of origin of the Bone Valley formation, presupposed a phosphatic residuum of Hawthorn formation which was modified by a variety of agents during Pliocene time.

Eldridge (1893, p. 196-231) considered the phosphate deposits as a residuum which was later reworked by marine action.

Matson and Clapp (1909, p. 138-139) interpreted the poor sorting and absence of distinct local stratification as evidence of a fluviatile origin. They admitted that some deposition may have occurred in the margins of estuaries. Fragments of bone and sharks teeth were assumed to have been derived from older formations containing such material.

Matson and Sanford (1913, p. 145-206) described this formation as a deposit in a shallow sea. Submergence during Pliocene time resulted in the reassorting and redeposition of residual weathered material by wave action.

Sellards (1951, p. 58) postulated an advancing sea redepositing material derived from the phosphatic marl beneath.

Cooke and Mossom (1929, p. 164) believed that the phosphate deposits were accumulations within the lower reaches of a river and adjacent to its low-lying banks. Cooke (1945, p. 206) reasoned that these phosphatic sediments were deposited in the delta of a southward-flowing river. Estuarine deposition occurred seaward from the delta. Cooke also stated that some of the Bone Valley formation may be the residual product of weathered Hawthorn formation.

The topography developed on the surface of the Hawthorn formation (pl. 6) and the stratigraphic relations between the unnamed upper Miocene sand and the undifferentiated phosphatic sand and clay (pl. 2) suggest certain characteristics of late Miocene geography which may be directly related to the origin of the Bone Valley formation.

The configuration of the surface of the Hawthorn formation (pl. 6) resembles the valley of an ancestral Peace River. The surface of the overlying sand (pl. 6) shows no continuity of this pattern; therefore, this drainage is older than or contemporaneous with the upper Miocene sand. Withdrawal of the middle Miocene sea exposed the Hawthorn formation to subaerial weathering, and a mantle of phosphate nodules, clay, and

check topog.

quartz sand slowly accumulated on the land surface. The upper Miocene sea inundated south Florida, but central and northern Hardee County was exposed. The distribution of the sand indicates that the shore line at this time was not higher than 90 feet above present sea level. The ancestral Peace River, which carved a wide valley into the Hawthorn formation, probably was instrumental in reworking much of the Hawthorn residuum into the Bone Valley formation during late Miocene and Pliocene time. It is likely that in certain places the residuum was undisturbed. Marine sediments of Pliocene age in this area are restricted to the low-lying part of southeastern De Soto County (pl. 1). The Pliocene submergence of peninsula Florida was probably not extensive.

The upper Miocene sand and the undifferentiated phosphatic sand and clay interfinger in the vicinity of 27° 25' latitude (pls. 1 and 2). The sediments are thin and are lithologically similar. Slight rises in the level of the sea caused resorting and redeposition of part of the Hawthorn residuum near the strand line. Minor recessions exposed part of the littoral zone. The sediments deposited in this environment would be gradational from Bone Valley formation on the old land surface, through a reworked zone of Bone Valley formation and the upper Miocene sand, to undisturbed sand to the south, or seaward. In a low, flat region such as Florida a change in sea level of only a few feet would expose or inundate a large area.

An alternative explanation for the origin of the Bone Valley formation in this region postulates a much more extensive marine transgression during late Miocene time. It is possible that the upper Miocene sand at one time covered Hardee County completely and that the components of the phosphorite originated during the Pliocene epoch as a residuum of weathered sand rather than Hawthorn formation. Pliocene seas probably covered most of De Soto County, and the sand was exposed farther north in Hardee County. Periodic reworking and resorting by streams converted much of the residual sand to Bone Valley formation. This reworking obviously was not complete, and residual upper Miocene sand may be present at places. The stream valley (pl. 6) under this hypothesis was eroded into the Hawthorn formation before the sand was deposited.

Evidence that the Upper Miocene sand once covered all of Hardee County is lacking. Explaining the derivation of the Bone Valley formation from leached sand is difficult where both the sand and weathered Bone Valley occur essentially at the same altitude (pl. 2), and must have been approximately an equal distance above the ground water table since deposition. Either the Pliocene sea covered a larger area than is indicated by the geology, or else a previously weathered sand was downwarped or faulted downward to its present position. Both of these alternatives are unsupported by field evidence. The original extent of the Pliocene sea in this area is not known. The relations between the Bone Valley formation and the marine sediments of Pliocene age could not be determined because their closest occurrence in the subsurface is more than 15 miles apart. Faulting and folding cannot be seriously considered. The sediments appear undisturbed; no displacement or contortion was noted anywhere. In addition, if the components of the Bone Valley formation were derived from the upper Miocene sand, remnants of unweathered sand should be present beneath the Bone Valley, but such is not the case.

For these reasons, the latter hypothesis of origin is rejected, and the Bone Valley formation is believed to be a reworked residuum of Hawthorn formation.

fluviatile reworking mainly — see p. 37

Pliocene series

Caloosahatchee marl

During his explorations in south Florida, Angelo Heilprin (1887) first identified fossiliferous beds exposed along the Caloosahatchee River as Pliocene in age.

Dall (1892, p. 140-149) named these beds "Caloosahatchie" and extended the marine Pliocene as far northward as Zolfo Springs in Hardee County. His "Arcadia marl" and "oyster marl" were at that time considered equivalent to the "Caloosahatchie beds."

Cooke (1945, p. 216-217) believed the Caloosahatchee marl to underlie the southern part of De Soto County. He thought that the Bone Valley formation and Caloosahatchee marl merged somewhere to the north.

The fauna of the Caloosahatchee marl is well known, and the Pliocene age of this formation has never been seriously questioned. Outcrops along the Caloosahatchee River near La Belle in Hendry County are collecting grounds for the large and well-preserved fauna. The precise boundaries and the stratigraphic relations of the Caloosahatchee marl with formations to the north were largely speculative because of the limited number of outcrops along the streams. Many writers, following Dall's pioneer work, extended the Caloosahatchee marl much farther north than it actually occurs.

Lithology.--The Caloosahatchee marl in this area is a gray fine-grained sand, slightly clayey to clayey in places. It is predominantly a sand rather than a marl. The marine invertebrate fauna is large, and it contains many species still living. In some places the Caloosahatchee marl is composed primarily of shells, as along Prairie Creek in De Soto County, where it is mined for road fill. Exposures along Prairie Ceeek are surficially cemented by iron oxide. Unweathered material is gray to blue-gray. Delicate shells are unusually well-preserved, an indication of deposition with little wave action.

Distribution.--Auger drilling disclosed that the Caloosahatchee marl is restricted to the southeast part of De Soto County (pl. 1). In the vicinity of Pine Level, 9 miles northwest of Arcadia (sec. 10, T. 37 S., R. 23 E., De Soto County) and along Horse Creek (sec. 1, T. 38 S., R. 23 E., De Soto County) discontinuous, thin patches of unfossiliferous calcareous clayey sand are present beneath the Pleistocene sediments. This material may be Caloosahatchee marl, but it is more likely upper Miocene sand, as fossiliferous upper Miocene sand is close to the surface here (pl. 4).

Shell fragments from an auger hole at map locality 42-53 (SE$\frac{1}{4}$, SW$\frac{1}{4}$. sec. 22, T. 38 S., R. 25 E., De Soto County) in the interval from 5 to 14 feet mark the northernmost occurrence of the Caloosahatchee marl in the area. The abrupt northern termination of the Pliocene marine fauna may indicate that the Caloosahatchee marl originally covered a more extensive region and that post-Pliocene erosion removed much of this thin formation at higher elevations. Drill records show that the Caloosahatchee marl does not exceed a thickness of 20 feet (pl. 5) in De Soto County.

Details and fauna.--The fauna of the Caloosahatchee marl is described by Heilprin (1887) and Dall (1903). More than 600 species were identified by Dall. Mollusks are predominant among the excellently preserved shells.

At a borrow pit in the SW$\frac{1}{4}$, sec. 26, T. 39 S., R. 25 E., (map location 1-53, pl. 7) about 1,500 feet west of Florida State Highway 31, along Prairie Creek, the upper 2 feet of a shell bed is exposed above water level in the pit. Such Pliocene species as *Arca wagneriana* Dall, *Strombus leidyi* Heilprin, and *Turritella perattenuata* Heilprin are common among a large molluscan fauna. This Caloosahatchee shell bed extends westward at least as far as the NW$\frac{1}{4}$, sec. 33, T. 39 S., R. 25 E., De Soto County (map locality 8-53, pl. 7). At this location the following species were collected from the top of the shell bed exposed at water level along Prairie Creek:

Gastropoda:

Turritella apicalis Heilprin

Pelecypoda:

Echinochama arcinella Linnaeus

Chione cancellata Linnaeus

Two limestone pebbles, apparently derived from the Buckingham marl, of late Miocene age, were incorporated in the Caloosahatchee marl at this locality. These pebbles contained the following shells which, according to MacNeil (personal communication, January 1954), are common in the Buckingham marl:

Pelecypoda:

Chlamys (Plagioctenium) eboreus buckinghamensis Mansfield

Chione Athleta Conrad

Cirripedia:

Balanus sp. a medium-sized barnacle, apparently one occurring abundantly at Buckingham, in Lee County.

At the bottom of a drainage ditch in southern De Soto County (SW$\frac{1}{4}$, SW$\frac{1}{4}$, sec. 28, T. 38 S., R. 25 E., map location 25-53, pl. 7), the upper 6 inches of Caloosahatchee marl is exposed above water level. A 4-inch layer of iron-stained phosphate gravel overlies the Pliocene shell bed. This gravel is the basal unit of the surficial sand and clayey sand of Pleistocene age which here is 3$\frac{1}{2}$ feet thick. The species listed below were collected from the spoil banks along the ditch. The assemblage is clearly a Caloosahatchee fauna.

Gastropoda:

Conus sp. (juvenile)

Oliva frag. cf. O. sayana Ravenel

Turritella subannulata Heilprin

Turritella apicalis Heilprin

Turritella perattenuata Heilprin

Pelecypoda:

Anadara lienosa (Say)

Chlamys harrisi Dall

Anomia simplex d'Orbigny

Ostrea sculpturata Conrad

Ostrea virginica Linnaeus

Cardita arata Conrad

Phacoides caloosaensis (Dall) (mold)

Echinochama arcinella (Linnaeus)

Chione cancellata Linnaeus

Origin.--The Caloosahatchee marl was deposited in a shallow sea. The preservation of fragile shells indicates that wave action was negligible. Perhaps offshore bars or groups of islands acted as barriers against storms. Phosphate nodules were not deposited during this submergence.

Pleistocene series

Differentiation of the Pleistocene sediments into formations is difficult in Florida because of the intensely weathered condition and lithologic similarity of the surficial material, especially in the interior of the peninsula. Much of the study of rocks of Pleistocene age has been limited to the fossiliferous limestones and marls which are exposed in the southern part of the state. The alternating fresh water and marine limestones and clayey sands of Pleistocene age, comprising the Fort Thompson formation, have been described by Cooke and Mossom (1929), Parker and Cooke (1944), and Cooke (1945).

On geomorphological evidence a number of marine terraces are recognized. These terraces are remnants of higher shorelines developed during pauses in the oscillations of the Pleistocene sea. The surficial sediments associated with each terrace have been given formation names by some writers.

Matson and Sanford (1913, p. 32-35) recognized three terrace deposits of Pleistocene age. The highest of these, called the Newberry, included surficial sand and clay at elevations of from 70 to 100 feet above sea level. The surficial sediments from 40 to 60 feet elevation represented a later Tsala Apopka terrace. The lowest terrace, which they called the

Pensacola, covered a broad plain less than 40 feet above sea level, and it was composed of limestone in the southern part of the state.

Richards (1938, p. 1284-1285) found no evidence of marine deposits of Pleistocene age above 25 feet altitude along either coast of Florida. Sediments of Pleistocene age above 25 feet contained no fossils, and he believed this land stood relatively high during most of the Pleistocene.

Cooke (1945, p. 247-248) identified seven and possibly eight shorelines which represent stands of sea level during Pleistocene time. They are:

Terrace	Feet above sea level
Brandywine	270
Coharie	215
Sunderland	170
Wicomico	100
Penholoway	70
Talbot	42
Pamlico	25

With these seven shorelines he assigned corresponding formations comprising the surficial sand within each topographic interval. The possible eighth shoreline of Cooke, the Silver Bluff, is 5 feet above present sea level. Cooke (1945, p. 289) postulated that most of De Soto County is covered by the Penholoway formation.

MacNeil (1950, p. 99) reported that the terraces below 150 feet are entirely of marine origin. He recognized the following Pleistocene shore lines:

Terrace	Elevation	Age
Okefenokee	150	Yarmouth interglacial stage
Wicomico	100	Sangamon interglacial stage
Pamlico	25-35	Mid-Wisconsin glacial recession
Silver Bluff	8-10	Post-Wisconsin

These, MacNeil believed, represented peaks of marine transgression.

In the area investigated in this report, no evidence of marine deposition during Pleistocene time was found.

Deposits of Pleistocene age

Lithology.--The Pleistocene deposits in the area are made up of lenticular strata of varying percentages of quartz sand, silt, and clay-sized material. These beds are generally brown to tan. Cross-bedding is conspicuous, especially in the lower part of the formation. A conglomerate or gravel composed primarily of phosphate granules and pebbles is nearly always present within the lower 1 foot. Along Payne's Creek the deposits are cross-stratified, and a phosphatic gravel rests directly on the Hawthorn formation.

The lenticularity of the lithologic units is exhibited at the borrow pit near Nocatee (fig. 5), where a waxy blue clay grades laterally to a coarse sand within a distance of less than 100 feet (fig. 5). Similarly, the section along Horse Creek reveals a layer of brownish clay pinching out within a cross-bedded sand stratum two feet thick.

At every outcrop the depth and intensity of the weathering profile developed on the Pleistocene deposits are similar. An iron-cemented zone is always present from 3 to 6 feet below the surface. This zone is usually less than 2 feet in thickness, and it may be locally an indurated crust or layer of ferruginuous cobbles and boulders. Several feet below this zone of iron accumulation, the color gradually changes to tan, and the rock is relatively fresh.

Scattered thin deposits of sand fresh-water limestone are included within the unit (pl. 1). These limestones contain fresh water fossils. Root structures which have been replaced by calcium carbonate are common. The limestone is friable, and it normally grades laterally into a blue-gray marl or calcareous clayey sand.

Fine-grained quartz sand is the most abundant constituent. Lenses of blue-gray clayey sand and clay, 1 to 3 feet in thickness, are scattered throughout the sand. Phosphate nodules may be abundant locally.

The grain size of the quartz sand is generally greatest near the bottom of the formation. Phosphate nodules, if present, are more abundant near the lower contact, regardless of the lithology of the underlying rock.

Fauna.--At an exposure along Prairie Creek (NW$\frac{1}{4}$, sec. 33, T. 39 S., R. 25 E., De Soto County, map locality 8-53, pl. 7), the Caloosahatchee marl is overlain by 6 feet of Pleistocene beds. A 6-inch stratum of coarse sand, bone fragments, and minor phosphate gravel is the basal unit. Within this basal gravel was found a lower incisor of a rhinoceros, probably *Aphelops*. The age of *Aphelops* is early to middle Pliocene.

At the borrow pit at Nocatee, part of an upper molar of *Neohipparion* was found in the stratified surficial sand. *Neohipparion* is a horse of early to middle Pliocene age. At the borrow pit east of Nocatee (fig. 5) and at a borrow pit northwest of Nocatee ($SE\frac{1}{4}$, $SW\frac{1}{4}$, sec. 11, T. 38 S., R. 25 E., De Soto County) molars of a horse, probably Neohipparion, were collected from the surficial sediments.

Although the invertebrate teeth suggest that the deposits are Pliocene, other evidence points more conclusively to a Pleistocene age. The invertebrate fauna, which consists predominantly of a fresh-water and land assemblage of gastropods, is different from the fresh water mollusks in the Caloosahatchee marl. Many of the species are also common in the brackish and fresh-water sediments of Pleistocene age throughout south Florida. In addition, the unit unconformably overlies the Caloosahatchee marl which is definitely Pliocene, possible late Pliocene in age. The vertebrate teeth are resistant to erosion and weathering. They were probably derived from the Bone Valley formation. During late Miocene and Pliocene time, the area now covered by the Bone Valley formation was a land mass. Remains of mammals were incorporated into the fluvial sediments. Erosion of these sediments supplied the components of the Pleistocene deposits.

Most of the invertebrate species listed in this section also appear in Pleistocene faunal lists by Sellards (1916, p. 144) and W. C. Mansfield (1939, p. 33-45). The fauna listed by Sellards was associated with human remains at an exposure near Vero, Florida. The fossils described by W. C. Mansfield were collected from numerous localities throughout south Florida.

At the borrow pit east of Nocatee (fig. 5) the following invertebrates were collected from the phosphatic sand directly overlying upper Miocene sand:

Gastropoda:

Fresh water:

Viviparus georgianus Lea

Campeloma sp.

Coniobasis sp. - strong axials

Helisoma (*Seminolina*) *duryi* (Wetherby) var.?

Land:

Euglandina sp. cf. *E.* *rosea* (Ferussac)

Polygyra septemvolva volvoxis, Pfeiffer

Pelecypoda:

Rangia sp.

In a shallow ditch along Florida Route 661, 3.5 miles north of Limestone, Hardee County (SW$\frac{1}{4}$, SW$\frac{1}{4}$, sec. 24, T. 35 S., R. 24 E.), the gastropods listed below were collected from a 2$\frac{1}{2}$ foot section of surficial sandy limestone exposed above water level.

Land snails:

Polygyra sp. cf. *P.* *cereolus* (Muhlfeld) var. *floridana* Hemphill?

Succinea sp. (very inflated) aff. *S.* *campestris* Say?

Under the heading "Fort Thompson beds", Sellards (1919, p. 71-73) included alternating fresh water and marine marl and limestone of Pleistocene age in the vicinity of La Belle and Fort Thompson in Hendry County, Fla. Cooke and Mossom (1929, p. 211) later changed the name to Fort Thompson formation.

Distribution.--The Pleistocene beds are flat-lying surficial deposits. Auger drilling disclosed that it covers the entire area, except where stream erosion has bared the older rocks or where Recent sediments are present. Exposures are found along Payne's Creek, Peace River (fig. 6), Charlie Apopka Creek, Horse Creek, and Joshua Creek. In each drill hole, similar lithology and degree of weathering were noted in the surficial sediments. Pebbles of phosphate from the basal conglomerate were observed in the cuttings from several holes. The thickness of this formation is variable, but it generally does not exceed 20 feet.

Origin.--The general character of the Pleistocene beds suggests deposition in the lower reaches of a river flood plain. Aggrading streams threading channels across a flat plain close to sea level spread a thin veneer of silt and fine sand on the interfluvial area during floods. Channel sediments are characterized by lenticular bodies of sand and clay and by cross-lamination. Scattered occurrences of fresh water limestone were deposited in flood plain lakes.

It is possible that part of these beds were deposited in a subaerial deltaic environment. In an area of such low relief and poor exposures it is difficult to determine where the flood plain ends and the delta begins. Regardless of the precise environment, the evidence is clear that the unit was deposited by subaerial agents not far from a Pleistocene strand.

Although no evidence exists of any Pleistocene marine invasions in this area, evidence elsewhere in the Atlantic Coastal Plain is abundant. Flint (1940, p. 757-787) critically examined the literature dealing with Atlantic Coastal Plain sediments of Pleistocene age. South of the James

River in Virginia he found that morphologic evidence favored widespread marine deposition, while north of the James, the sediments are regarded largely as alluvial.

Sediments of Recent age

At many places along the banks of the Peace River and its tributaries stream terraces are exposed which are clearly younger than the Pleistocene beds (figs. 3 and 4). Included with these deposits are the "river-pebble" phosphate gravels that were mined prior to 1908.

These stream sediments are not extensive. They are confined chiefly to the present banks of streams (pls. 1, 3, 4, and 5). The dominant lithology is fine quartz sand. Clay is a negligible fraction. Phosphate occurs in sand to cobble size. At many places along the Peace River near Nocatee, Arcadia, and Brownville, the sediments of Recent age consist of natural levees of fine white quartz sand which line both banks. Phosphate concentrated in bars and shoals in the Peace River is abundant from Brownville southward.

These river sediments are not conspicuously weathered. The stratigraphic position, fresh appearance, and limitation of these sediments to present stream courses indicate that they are of Recent age. An outcrop on Horse Creek along the east bank of the stream, about 8 miles west of Arcadia, on Florida State Highway 72 (map locality 32-53, pl. 7), shows the contact of a Recent stream deposit with Pleistocene beds.

MECHANICAL ANALYSIS

Mechanical analyses of the Pleistocene deposits, the upper Miocene sand, and the undifferentiated phosphatic sand and clay were made to determine the existence of any significant differences in grain size and to see whether such differences were characteristic of the formation or merely local variations. Striking and consistent interformational differences in median diameter of quartz sand, for example, would be useful for correlation in instances where fossils were lacking or where lithology and sedimentary features were altered and obscured by the effects of weathering.

Sampling was done on a lithologic basis. Each sample represents a lithologic unit, regardless of thickness. Samples from 12 auger holes were submerged in muriatic acid for 24 hours, weighed, and screened for 7 minutes in a Ro-Tap mechanical shaker. Samples, before sieving, weighed approximately 60 grams. The samples were run through the following screen sizes:

Tyler screen number	Mesh size in mm
20	0.833
28	.589
35	.417
48	.295
65	.208
100	.147
150	.104
200	.074

All material below .074 mm (200 mesh) was discarded. As all soluble components had been dissolved in the acid, only quartz sand and a minor amount of accessory heavy minerals were screened. For each sample a cumulative curve was plotted from which the median grain diameter was determined (pl. 8).

The results of the work described in this section are not considered absolute values for these sediments. Certain inaccuracies were introduced because of the possible contamination of the auger cuttings. Even though the method of sampling was not precise, any consistent differences in grain-size distribution among the various sediments would still be valid.

The average of the median-grain diameters from all samples was computed for each formation. The table below summarizes the results:

	Pleistocene deposits	Upper Miocene sand	Undifferentiated phosphatic sand and clay
Median grain size in mm	0.174	0.210	0.244

All of the above averages are within the fine-sand range (0.125-0.250 mm) of the Wentworth grade scale. Slight differences such as these are not considered significant in themselves; however, an inspection of the cumulative curves for drill holes 62, 75, 86, 90, 99, and 124 (pl. 8) shows a slight but very noticeable increase in grain size of the sediments underlying the surficial material. The finer grain size of the Pleistocene deposits seems to be consistent throughout this area. In each drill hole except 117 and 85, the median-grain diameter of the Pleistocene sand is less than that of the upper Miocene sand or the undifferentiated phosphatic sand and clay.

GEOLOGIC HISTORY

Miocene events

The middle Miocene submergence was extensive, and much of peninsular Florida was inundated. The Hawthorn formation was deposited in this shallow marine environment. The recession of the middle Miocene sea, probably accomplished in part by crustal upwarping associated with the closing stages of the Ocala uplift (Cooke, 1954, p. 3-7), exposed the Hawthorn formation to weathering and erosion as far south as Hardee and perhaps De Soto Counties. A drainage system, similar in pattern to present drainage, was developed on this land surface, and a weathered residuum of the less soluble components of the limestone slowly accumulated. This mantle consisted of phosphate noldules, clay, and quartz sand. A wide shallow valley was cut into the surface of the Hawthorn formation (pl. 6) by the ancestral Peace River. Periodic fluvial reworking of the residual weathered products produced the Bone Valley formation.

During late Miocene time, the sea again advanced, and all of the southern part of the Florida peninsula including De Soto and southern Hardee Counties was inundated. The Tamiami limestone and the Buckingham marl record this submergence in south Florida, while the upper Miocene sand was deposited in the shallow water covering De Soto and part of Hardee Counties (pls. 1 and 2). Landward from the late Miocene shoreline, weathering of the Hawthorn formation and reworking of the residuum continued. No recognizable beach deposits mark the late Miocene shoreline. The argillaceous character of the upper Miocene sand in southern Hardee County suggests estuarine conditions near the mouth of the Peace River.

Pliocene events

Marine deposition in Florida during the Pliocene epoch is marked by the Caloosahatchee marl. Whether or not an erosion interval of any significance followed the late Miocene is unknown. Shallow Pliocene seas covered all of south Florida and extended at least as far north as southern De Soto County (pl. 1). Evidence deos not indicate any marine transgression across the land area exposed during late Miocene. It is probable that the late Miocene and Pliocene shorelines roughly coincided, and that most of Hardee County was exposed to subaerial agents throughout the Pliocene.

Pleistocene events

After withdrawal of the Caloosahatchee sea, much of peninsular Florida was exposed. The thin Caloosahatchee marl was eroded from relatively high areas.

The retraction and release of tremendous volumes of water during glacial and interglacial stages caused extraordinary fluctuations in sea level during Pleistocene time. Elsewhere in Florida and northward into Georgia, the Carolinas, Virginia, and Maryland, terraced Coastal Plain sediments present more graphic evidence of Pleistocene oscillations of sea level than is exhibited in Hardee and De Soto Counties. The Pleistocene beds were deposited by the aggrading Peace River, while the sea was at a higher level than at present. No precise record of any earlier and higher stands of the sea during the Pleistocene is present here, although elsewhere in Florida (MacNeil, 1950, p. 95-107; Cooke, 1945, p. 245-312) shorelines which represent pauses during the latest general retreat of the sea have been mapped at elevations of more than 100 feet above present sea level.

Recent events

The stream deposits of Recent age indicate very little change from the present environment. Terraces are not more than 15 feet above water levels in the streams. The Peace River and its tributaries are incised and are establishing a new base level adjusted to the present strand.

The Recent history of this area has been essentially a minor readjustment of the drainage to present sea level. Accelerated erosion of the Bone Valley formation, the Hawthorn formation, and Hawthorn residuum in the region to the north is reflected in the accumulations of "river-pebble" phosphate in the streams south of Brownville, De Soto County.

ECONOMIC CONSIDERATIONS

Field studies and radiometric analyses of samples indicate that the phosphate and uranium resources of the area covered in this report are unimportant under present mining economy.

Examination of samples of the undifferentiated phosphatic sand and clay showed a substantially lower percentage of phosphate nodules than is characteristic of the phosphorite in the mining district to the north. Phosphate is a minor constituent in the upper Miocene sand, Caloosahatchee marl, and the Pleistocene deposits.

Prospecting data in this region is non-existent. Mansfield (1942, p. 35) noted that no information on prospecting was available south of

T. 34 S., Hardee County. Exploration since 1942 has been concentrated in the mining district, and no record of any recent prospecting in Hardee County was available to the writer.

The aluminum phosphate zone of the phosphorite is thin and discontinuous in this area. It cannot be considered a significant source of uranium. The low phosphate content in the sediments is a further deterrent to consideration of this area for uranium possibilities.

A total of 135 unsieved samples were analyzed radiometrically for equivalent uranium percent. The results ranged from less than .001 percent to .009 percent. The results of values is shown below:

	Percent equivalent uranium									
	0.009	.008	.007	.006	.005	.004	.003	.002	.001	<.001
Number of samples	1	3	4	6	6	16	23	36	13	27

The weighted average of the percent equivalent uranium for each unit was determined from the 135 samples. The results appear as follows:

Formation	Percent equivalent uranium
Pleistocene deposits	0.001
Caloosahatchee marl	.003
Undifferentiated phosphatic sand and clay	.003
Upper Miocene	.002
Hawthorn formation	.003

G. R. Mansfield (1942, p. 24-27) reported that "river pebble" phosphate was mined in the Peace River from 1888 to 1908. Competition from the land-pebble and hard-rock districts, rather than depletion of reserves, was responsible for the death of this industry. Large, but unmapped, reserves of low grade "river pebble" phosphate are still present in De Soto County in the lower reaches of the Peace River and Joshua, Horse, and Prairie Creeks.

LITERATURE CITED

Cooke, C. W., 1939, Scenery of Florida, interpreted by a geologist: Florida Geol. Survey Bull. 17, p. 14.

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

Cooke, C. W., and Mossom, Stuart, 1929, Geology of Florida: Florida Geol. Survey 20th Ann. Rept.

Dall, W. H., 1892, The Neocene of North America: U. S. Geol. Survey Bull. 84.

__________, 1903, Contributions to the Tertiary fauna of Florida with especial reference to the Miocene silex beds of Tampa and the Pliocene beds of the Caloosahatchie River: Wagner Free Inst. Sci. Trans., v. 3, pt. 6.

Eldridge, G. H., 1893, A preliminary sketch of the phosphates of Florida: Am. Inst. Min. Eng. Trans., v. 21, p. 196-231.

Flint, R. F., 1940, Pleistocene features of the Atlantic coastal plain: Am. Jour. Sci., 5th ser., v. 238, no. 11, p. 757-787.

Gardner, Julia A., 1926, The molluscan fauna of the Alum Bluff group of Florida: U. S. Geol. Survey Prof. Paper 142-A, p. 1-3.

______________, 1945, Three new species from an upper Miocene oyster reef in Tampa Bay: The Nautilus, v. 69, no. 2, p. 37-41.

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

MacNeil, F. S., 1950, Pleistocene shorelines in Florida and Georgia: U. S. Geol. Survey Prof. Paper 221-F, p. 95-107.

Mansfield, G. R., 1942, Phosphate resources of Florida: U. S. Geol. Survey Bull. 934.

Mansfield, W. S., 1932, Pliocene fossils from limestone in southern Florida: U. S. Geol. Survey Prof. Paper 170, p. 43-56.

_______________, 1939, Notes on the upper Tertiary and Pleistocene mollusks of peninsular Florida: Florida Geol. Survey Bull. 18.

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 2nd Ann. Rept., p. 25-173.

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

Parker, G. G., 1951, Geologic and hydrologic factors in the perennial yield of the Biscayne aquifer: Am. Jour. Water Works Assoc., v. 43, no. 10, p. 817-833.

Parker, G. G., amd Cooke, C. W., 1944, Late Cenozoic geology of southern Florida, with a discussion of the ground water: Florida Geol. Survey Bull. 27, p. 56-64.

Richards, H. G., 1938, Marine Pleistocene of Florida: Geol. Soc. America Bull., v. 49, p. 1267-1296.

Schroeder, M. C., and Bishop, E. W., 1953, Foraminifera of late Cenozoic in southern Florida: Am. Assoc. Petroleum Geologists Bull., v. 37, no. 9, p. 2182-2186.

Sellards, E. H., 1915, The pebble phosphates of Florida: Florida Geol. Survey 7th Ann. Rept.

_______________, 1916, Fossil vertebrates from Florida; a new Miocene fauna; new Pliocene species; the Pleistocene fauna: Florida Geol. Survey 8th Ann. Rept., p. 91-95, 144.

_______________, 1919, Geologic sections across the Everglades of Florida: Florida Geol. Survey 12th Ann. Rept., p. 67-76.

Simpson, G. G., 1929, The extinct land mammals of Florida: Florida Geol. Survey 20th Ann. Rept., p. 229-279.

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