Stratigraphy of Parts of De Soto and Hardee Counties Florida

GEOLOGICAL SURVEY BULLETIN 1030-B

This report concerns work done on behalf of the U. S. Atomic Energy Commission and is published with the permission of the Commission

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By M. H. BERGENDAHL

CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

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CONTENTS

ILLUSTRATIONS

[All plates in pocket]

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 early and middle Miocene age, is the oldest rock exposed. Undifferentiated phosphatic sand and clay of late Miocene to Pliocene age may be composed of: (1) the Bone Valley formation, (2) a combination of Bone Valley formation and residuum of weathered Hawthorn formation, or (3) residuum of the Hawthorn alone. The Bone Valley formation and residuum of the Hawthorn formation appear to be almost identical in cuttings from auger drilling in this area. It was neither 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 believed by the writer to be either flood-plain deposits or subaerial top-set beds of a delta made by the Pleistocene Peace River. Stream deposits of Recent age are present locally along the Peace River and its tributaries.

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 by the U. S. Geological Survey are presented in this paper. Work was done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

The area covered by this report is immediately south of the Florida land-pebble phosphate mining district (fig. 6).

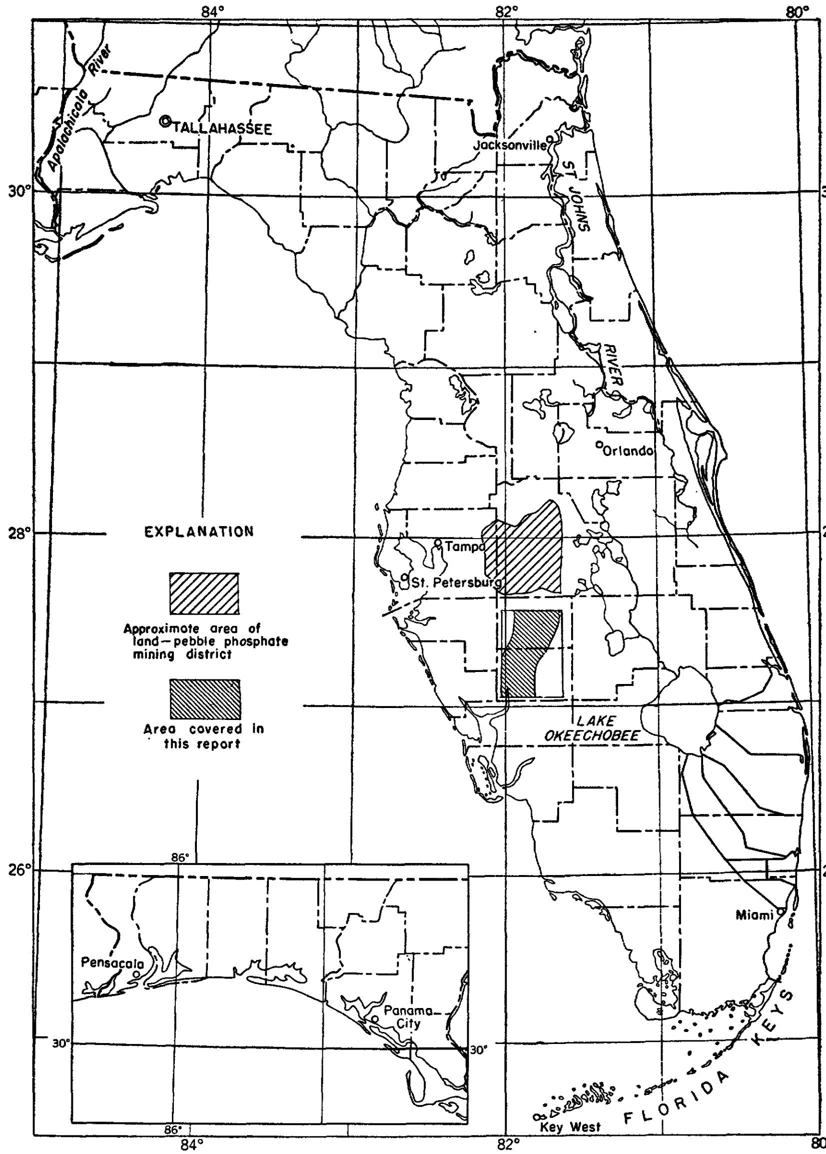

FIGURE 6.—Index map of land-pebble phosphate district, Hardee and De Soto Counties.

Although the geology of Hardee and De Soto Counties is described in a number of reports (Matson and Clapp, 1909; Matson and Sanford, 1913; Cooke and Mossom, 1929; Cooke, 1945), several important problems remained unsolved. The southern extent of the Bone Valley formation, which contains the economic phosphate deposits, was never accurately mapped. The northern limit of the

Caloosahatchee marl, a fossiliferous shallow-water marine rock of Pliocene age that is present throughout southern Florida, was not precisely determined.

This investigation was conducted for two reasons: (1) to 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) to 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 to 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. A power auger, mounted on the rear of a 4-wheel-drive truck, was used to obtain more detailed subsurface information at 92 localities. 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 the U. S. 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 U. S. Geological Survey and U. S. Coast and Geodetic Survey 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 (population 2,872), the county seat of Hardee County, and Arcadia (population 4,764), the county seat of De Soto County. U. S. Highway 17, which passes through Wauchula and Arcadia, is the principal north-south highway (pl. 1). State Highways 70 and 72 link Arcadia with Sarasota, on the west coast, and with Sebring to the east. In De Soto County and southern Hardee County, cattle raising is the chief vocation. 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 generally range 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 area 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 southward 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 impassable, and drilling is difficult because of the flooded roadside conditions.

Streams are degrading at present. 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

Jean Hough identified the vertebrate fossils, and 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.

STRATIGRAPHY

MIOCENE SERIES

HAWTHORN FORMATION

The term "Hawthorn formation" has a complex history in Florida geology. It is essential that at least a brief review be given here.

Originally, the name "Hawthorne" was given by Dall (1892, p. 107) to the phosphatic limestone believed to be of "older" Miocene age (pl. 4) 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", which were assigned by Dall (1892, p. 112) to the Tampa group (pl. 4). 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: Tampa, Chattahoochee, Hawthorne, and Alum Bluff (pl. 4).

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 should be considered Miocene was generally accepted by later workers (pl. 4).

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 of which was characterized by a separate fauna. In descending order these were: Shoal River formation, Oak Grove sand, and Chipola formation (pl. 4).

Cooke and Mossom (1929, p. 98) retained Gardner's Alum Bluff group but reinstated the Hawthorn formation as a lateral equivalent in peninsular Florida of the Alum Bluff group in western 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 the original Hawthorne "beds", the Manatee River marl, the Sopchoppy limestone, and the Jacksonville limestone of Dall. In general, Cooke (1945, p. 144) retained this classification, but he tentatively transferred to the Duplin marl some beds of late Miocene age that Cooke and Mossom (1929, p. 115) assigned to the Hawthorn formation.

The Alum Bluff-Hawthorn equivalence has survived to the present; however, current views do not all agree on the age of the Alum Bluff group. According to F. S. MacNeil (written communication, Sept. 1955), "The Chipola, the basal formation of the Alum Bluff group, is regarded by some as late early Miocene, by others as early middle Miocene."

The term "Hawthorn formation" as used in this report includes all marine rocks in central and southern peninsular Florida that are younger than the Tampa limestone, of early Miocene age, but older than the lowermost sediments of late Miocene age (fig. 7).

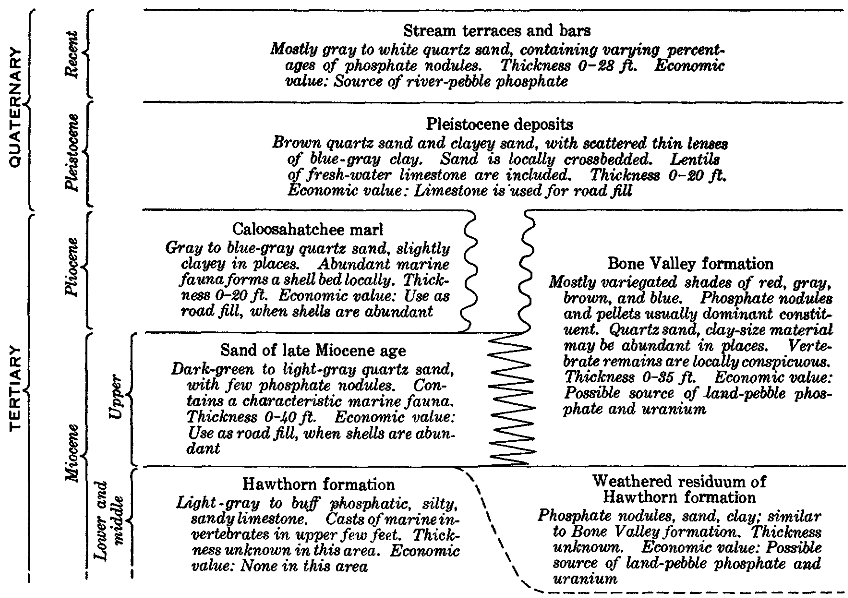

FIGURE 7.—Summary of exposed formations in Hardee and De Soto Counties.

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 and, 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 constituent, 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.

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 (pl. 2, and fig. 8). A slight southward dip is indicated by elevations

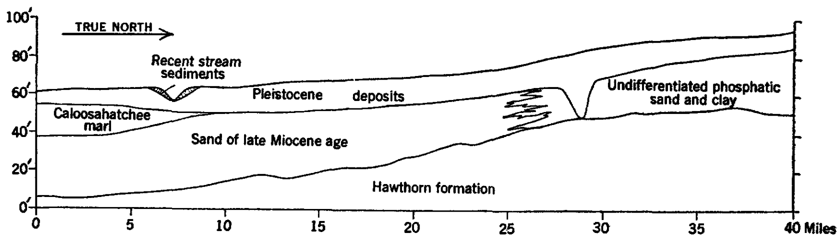

FIGURE 8.—Diagram showing the general stratigraphic relations of the formations in Hardee and De Soto Counties.

of exposures and drill holes, but this is virtually impossible to measure because of the eroded relief on the present upper surface of the Hawthorn formation. Well records show that the Hawthorn formation varies in 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). Greater thicknesses may have been deposited at points farther from the Ocala uplift (Cooke, 1945, p. 5–7), particularly in southern Florida, but much of the present range in thickness in central and northern Florida reflects post-Hawthorn erosion. In southern Hardee and De Soto Counties, the formation has been reached in drill holes; however, 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 fossils or they 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 (loc. 22–53, pl. 1), 0.5 mile north of Zolfo Springs (NE¼SE¼ sec. 22, T. 34 S., R. 25 E., Hardee County). Here, 6 feet of gray indurated limestone is exposed above water level in the river. Chert cobbles and boulders are incorporated within the upper 2 feet of the limestone. The following fossils, identified by F. S. MacNeil, 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 1 mile south of this locality—along the Peace River (loc. 16–53, pl. 1) 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 of pelecypods, identified by F. S. MacNeil, were collected here:

Venericardia sp. aff. *V. hadra* and *V. 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 of the U. S. Atomic Energy Commission. In drill hole 10–8, in SW¼SW¼ sec. 15, T. 34 S., R. 25 E., Hardee County (pl. 1), the following pelecypods were identified (by F. S. MacNeil) 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 NW¼NW¼ sec. 1, T. 34 S., R. 25 E., Hardee County (pl. 1), a tan, sparsely phosphatic, clayey limestone yielded these invertebrates, which were identified by F. S. MacNeil, at depths ranging from 13.6 feet to 17.0 feet below the surface:

Gastropoda:
- *Cancellaria* sp. cf. *C. macneili* Mansfield (description from *Arca* zone of the Choctawhatchee formation of Cooke and Mossom, 1929)
- *Semicassis*?

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 hole 11–5 in NE¼SE¼ sec. 31, T. 33 S., R. 26 E., Hardee County, and drill hole 11–6 in NE¼SE¼ sec. 31, T. 33 S., R. 27 E., Hardee County (pl. 1), the Hawthorn formation was penetrated at depths of 49 feet and 72 feet respectively. The following pelecypods were identified by F. S. MacNeil 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.

In the southern part of the area, an undetermined thickness of strata of late Miocene age overlies the Hawthorn formation. The Hawthorn formation is not exposed in De Soto County. The upper Miocene sediments, some of which are limestones, thicken southward, down dip, and diagnostic fossils are necessary for differentiating the Hawthorn formation from the lower strata of the upper Miocene rocks.

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, which is 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 Hawthorne 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, including many large oysters and barnacles. The characteristic lithology and associated fauna are easily identified, even in auger cuttings. The sand is the youngest of the upper Miocene strata in this area (fig. 7). It is well exposed in a borrow pit (NW¼SE¼ 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. 9). 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 latest Miocene age of the sand. A drill hole near the east end of the pit revealed a thickness of 16 feet of the Miocene sand at this locality. In the borrow pit this late Miocene sand is overlain by 6 feet of a surficial sand and calcareous clayey sand containing fresh-water and

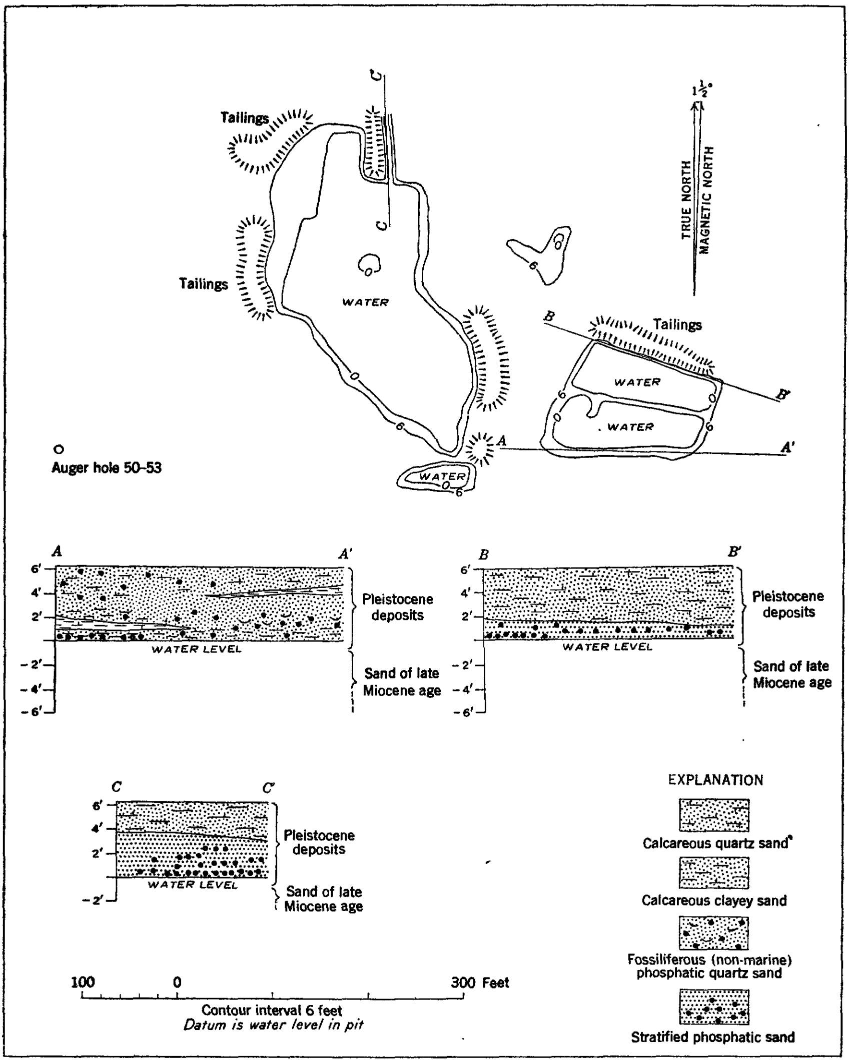

FIGURE 9.—Sketch map and cross sections of borrow pit, 1.6 miles east of Nocatee, De Soto County.

land gastropods of probable Pleistocene age. The upper contact of the late Miocene 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. 9, 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. 9) at a depth of 27 feet below the surface. No limestone sample was recovered. A bed of nonfossiliferous phosphate gravel, 2 feet thick, immediately overlies the limestone at this locality.

No vertebrate fossils were found in the sand of late Miocene age in the area investigated; however, MacNeil (written communication, July 1954) reported that he found remains of the mastodon *Serridentinus floridanus* (a "good lower Pliocene" species) in the lower part of, or immediately below, similar sand in Charlotte County. This apparent coincidence of vertebrate lower Pliocene and invertebrate uppermost Miocene fossils points out the current uncertainty as to the exact stratigraphic position of the Miocene-Pliocene boundary.

On the basis of MacNeil's invertebrate fossil identifications this sand of late Miocene age is either younger than, or equivalent to, the uppermost part of the Tamiami formation, because this formation is now used to include marine rocks of late Miocene age in southern Florida (Parker, 1951, p. 823).

Lithology.—The sand of late Miocene age is a fine-grained, dark-green to light-gray quartz sand, slightly to extremely clayey in places. Phosphate, in sand measuring to gravel size, is a conspicuous, though minor, constituent. The phosphate nodules are hard, dark colored, and smooth surfaced. None of the crumbly white-weathered 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 is present in 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 that is exposed in ditches along the Tamiami Trail in Collier and Monroe Counties. At that time, he regarded the fauna as Pliocene in age, and he considered the limestone to be a facies of the Caloosahatchee marl. Later (W. C. Mansfield, 1939, p. 8), he gave this limestone the name "Tamiami" and assigned it to the lower part of the Pliocene, thus considering it to be older than the Caloosahatchee marl. Mansfield's collection lacked the diagnostic fossils that indicate a Miocene age for the Tamiami formation.

During 1947 and 1948, while working with the U. S. Geological Survey Florida Phosphate Project, F. S. MacNeil made large new collections from the upper Miocene and Pliocene formations in southern Florida. As a result, he was able to revise (unpublished) the age of the faunas involved. The sequence established by Mansfield (1939) for the Buckingham, Tamiami, and Caloosahatchee faunas was supported, but his Buckingham and Tamiami limestones were reassigned to the late Miocene.

Many of the species collected from the sand of late Miocene age in De Soto and Hardee Counties are also found in the Tamiami formation. The following fauna, identified by F. S. MacNeil, was collected from dredged material piled along the sides of the large borrow pit located 1.6 miles east of Nocatee (fig. 9):

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 (=*Omeridionalis* Heilprin?) *disparilis* Conrad subsp.?
- *Pododesmus* n. sp.?
- *Laevicardium* sp.

Cirripedia:
- *Balanus* sp.? A large barnacle, seemingly characteristic of this zone.

Distribution.—Auger holes revealed that the sand of late Miocene age underlies all of De Soto County and extends northward into Hardee County, where it interfingers with the undifferentiated phosphatic sand and clay (pl. 2, fig. 8). Apparently, it occurs over an area much larger than Hardee and De Soto Counties. Gardner (1945, p. 37–41) described fossils from an oyster "reef" of late Miocene age, which was discovered during dredging operations off the southeastern end of Snell Island in Tampa Bay—within the city limits of St. Petersburg. The matrix between the closely packed oysters consists of clear quartz sand and light-gray limy clay. To date, this is the most northwesterly occurrence of the sand of late Miocene age.

In De Soto County the sand attains thicknesses of 40 feet or more, but it 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, which is 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 oysters, barnacles, and pectens that are similar to those occurring in the Caloosahatchee marl. According to Dall, a similar "oyster marl" was found along Joshua Creek near Nocatee and another exposure was found 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 marl.

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 (NE¼SE¼ sec. 31, T. 36 S., R. 25 E., loc. 18–53, pl. 1), 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 SE¼NE¼ sec. 32, T. 36 S., R. 25 E., De Soto County (pl. 1), about 1 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 east of Nocatee. The 50-foot depth, at which this shell bed was penetrated, is at almost 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 the fact that the exposure at the Brownville bridge is a lens of clayey limestone within the sand, which is present in the Arcadia-Nocatee-Brownville area; the Caloosahatchee marl occurs south of Nocatee. Dall's "Arcadia marl" is the lower and more clayey part of the sand in which his "oyster marl" is 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 contact between the Hawthorn formation and sand of late Miocene age is exposed along the west bank of the Peace River (fig. 10), at the site of a former bridge (NW¼SE¼ sec. 17, T. 36 S., R. 25 E., Hardee County, loc. 20–53, pl. 1) located 1½ miles west of Gardner. A section extending 16 feet above water level is exposed. A thick-bedded, phosphatic, slightly clayey calcareous sand disconformably overlies a thin-bedded, sparsely phosphatic, silty, soft limestone. A phosphate conglomerate occurs at the base of the upper calcareous sand. On the basis of similar lithology, the lower thin-bedded unit is tentatively called Hawthorn formation. Results of drilling in the

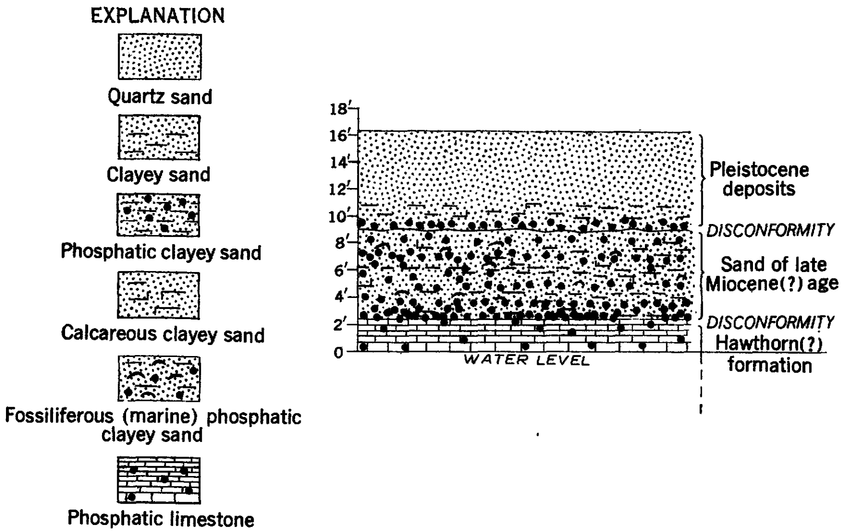

FIGURE 10.—Sketch of section exposed along the west bank of the Peace River, near Gardner, Hardee County.

vicinity favor a late Miocene age for at least the upper thick-bedded, calcareous material. From drill hole 10–14 (N½SE¼ sec. 21, T. 36 S., R. 25 E., De Soto County), located slightly more than 1 mile southeast of the 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 pelecypods, which were identified by F. S. MacNeil:

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. 10). Conversely, the phosphatic sand at the Gardner bridge could be a more sandy, and more phosphatic phase of the limestone in the drill hole.

Origin.—The sand of late Miocene age was deposited in a shallow marine environment. In southern Florida, the Tamiami formation and the Buckingham marl of Mansfield (1939) 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 volumes of rivers might create unfavorable conditions for organisms.
3. Lack of well-defined beach deposits or bars.

MIOCENE TO PLIOCENE SERIES

UNDIFFERENTIATED PHOSPHATIC SAND AND CLAY

The phosphorite, which underlies the northern two-thirds of Hardee County (pl. 1), is composed of either the Bone Valley formation or weathered residuum of Hawthorn formation, or both. These two units appear almost identical and are composed of phosphate nodules, sand, and clay. In Polk and eastern Hillsborough Counties, the phosphatic beds are well exposed on mine faces. Separate mapping of the Bone Valley formation and the residuum of Hawthorn formation 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 depends 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.

Two of 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. 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, from vertebrate fossil evidence, Matson (1915, p. 21) suggested a late Miocene age for the Bone Valley gravel. Horse teeth (species of *Merychippus* or *Neohipparion*), a mastodon upper jaw (*Tetrabelodon*), and a second upper molar that 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. 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," because 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."

Altschuler and Boudreau (unpublished material, 1949) studied in detail the mineralogy and petrogrophy of the Bone Valley formation. Cathcart (unpublished material, 1949, 1950) discussed the importance of the leached upper portion of the Bone Valley formation as a source of uranium.

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 nonphosphatic 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, which originally was present as nodules of carbonate fluorapatite, is altered to crandallite (pseudowavellite), which is the hydrous phosphate of aluminum and calcium, and to wavellite, which is the hydrous phosphate of aluminum (Altschuler and Boudreau, unpublished material, 1949, p. 36–38). The former presence of phosphate nodules is marked by molds in vesicular clayey sand loosely cemented by wavellite and crandallite.

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

Occurrences of marine invertebrates in the Bone Valley formation are rare; however, MacNeil (written communication, July 1954) reported that marine razor clams were found in exposures in southern Polk County.

Vertebrate fossils are abundant. Remains of manatees, whales, crocodiles, mastodons, and horses have been recovered from the Bone Valley formation during phosphate mining operations. Sharks' teeth, which are plentiful, possibly were derived from the subjacent Hawthorn formation.

Generally, the Bone Valley formation is considered to be Pliocene in age, but until the Miocene-Pliocene boundary is re-established the age of this formation cannot be categorically stated.

The vertebrate fauna 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 fossils of land mammals were found by people with no geologic training during hydraulic mining of the phosphate beds.

Distribution.—Auger holes were necessary to determine the extent of the undifferentiated phosphatic sand and clay. In Hardee County, north of about 27°25′ latitude (pl. 1), the Hawthorn formation is overlain by noncalcareous phosphatic sand and clay. The sand of late Miocene age 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 (pl. 2).

Details.—Exposures of the upper part of the undifferentiated phosphatic sand and clayey sand were found at only three localities in Hardee County, as follows:

The Bone Valley (?) formation is exposed in the bottom of a ditch along the east side of a dirt road in the NW¼NW¼ sec. 18, T. 33 S., R. 26 E., Hardee County (loc. 11–53, pl. 1). Only the upper 2 feet of stratified clayey sand and sand, which contains abundant phosphate nodules, can be seen.

At the bridge over the Peace River (loc. 27–53, pl. 1), 1 mile southeast of Wauchula, Hardee County (NW¼ sec. 11, T. 34 S., R. 25 E.), along the east bank of the river, the following section is exposed:

Formation	Depth from surface (in feet)	Description
Pleistocene deposits	0–2½	Sand, fine-grained, quartz, tan.
	2½–3½	Clayey sand, dark-brown, iron-stained; contains scattered soft, white (weathered) phosphate nodules.
	3½–6	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-sized phosphate, fish teeth, worn bone fragments. No diagnostic fossils.
Disconformity	----------	Bottom of conglomerate stratum in Pleistocene deposits.
Undifferentiated phosphatic sand and clay.	6–11½	Clayey sand; contains very abundant sand-sized phosphate. Interval is slightly iron-stained in upper 7 inches, buff to olive color below. Entire interval is noncalcareous; 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 relict from the parent Hawthorn formation, or it could be 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 (loc. 10–53, pl. 1), 0.3 mile west of the Peace River bridge (NE¼ sec. 28, T. 34 S., R. 25 E., Hardee County) 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. The stratification is distinct below a zone of iron accumulation. Individual layers are 2 to 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 crandallite. 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 thick, 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 indicate a redeposition of previously weathered material, rather than an accumulation in place of the residual products of a parent rock such as the Hawthorn formation.

Origin.—While forming hypotheses of the origin of the Bone Valley formation, many of the earlier workers presupposed a phosphatic residuum of Hawthorn formation that was modified by a variety of agents during Pliocene time.

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

Matson and Clapp (1909, p. 138–139) interpreted the poor sorting and the 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.

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 (1915, p. 58) postulated an advancing sea that redeposited material derived from the underlying phosphatic marl.

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.

MacNeil (written communication, July 1954) considers the Bone Valley formation to be of marine origin, equivalent stratigraphically to the unnamed sand of late Miocene age of this report.

The undifferentiated phosphatic sand and clay and the sand of late Miocene age interfinger in southern Hardee County (pl. 2). If the Bone Valley formation is a marine sediment, it is probable that the late Miocene sea inundated all of Hardee County, thus completely reworking the phosphatic Hawthorn residuum and redepositing it as Bone Valley formation.

If the Bone Valley formation is of fluvial origin, the incomplete reworking of weathered Hawthorn formation would preserve patches of residuum, especially on higher areas. Under this hypothesis, the late Miocene shoreline may have been approximately parallel to the present northern limit of the sand of late Miocene age. The age of this phosphorite, if undifferentiated, would range from middle Miocene through Pliocene, because Pliocene marine deposits have never been reported as overlying the phosphorite.

Therefore, as long as any possibility exists that the Bone Valley formation is a fluvial deposit, it is necessary to refer to the phosphorite in this area as undifferentiated phosphatic sand and clay.

PLIOCENE SERIES

CALOOSAHATCHEE MARL

During his explorations in southern 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. At that time, his "Arcadia marl" and "oyster marl" were considered to be equivalent to the "Caloosahatchie beds."

Cooke (1945, p. 216–217) believed the Caloosahatchee marl to be present in 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, 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 into De Soto and Hardee Counties; actually, it does not extend this far to the north.

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 fossils of present-day species. In some places the Caloosahatchee marl is composed primarily of shells—for example, along Prairie Creek in De Soto County, where it is mined for road fill. Exposures along Prairie Creek are surficially cemented by iron oxide. Unweathered material is gray to blue-gray. Delicate shells are unusually well preserved, which is an indication of deposition with little wave action.

Distribution.—Auger holes disclosed that the Caloosahatchee marl is restricted to the southeastern 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 nonfossiliferous calcareous clayey sand are present beneath the Pleistocene sediments. This material may be Caloosahatchee marl, but it probably is sand of late Miocene age, because fossiliferous sand of late Miocene age is close to the surface here (pl. 2).

Shell fragments in the interval from 5 to 14 feet from an auger hole in the SE¼SW¼ sec. 22, T. 38 S., R, 25 E., De Soto County (loc. 42–53, pl. 1) mark the northernmost known occurrence of the Caloosahatchee marl in the area. Locally, the abundance of land and fresh-water snails in the Caloosahatchee fauna suggests that the known distribution of this formation is very close to the Pliocene shoreline. Drill records show that the Caloosahatchee marl does not exceed a thickness of 20 feet in De Soto County (pl. 2).

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

At a borrow pit in the SW¼ sec. 26, T. 39 S., R. 25 E. (loc. 1–53, pl. 1), 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 NW¼ sec. 33, T. 39 S., R. 25 E., De Soto County (loc. 8–53, pl. 1). At this location, the following species, identified by F. S. MacNeil, 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 Mansfield's 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, who identified them (written communication, January 1954), are common in Mansfield's Buckingham marl:

Pelecypoda:
- *Chlamys* (*Plagioctenium*) *eboreus buckinghamensis* Mansfield
- *Chione athleta* Conrad

Cirripedia:
- *Balanus* sp., which is a medium-sized barnacle that apparently occurs abundantly at Buckingham, Lee County.

The upper 6 inches of Caloosahatchee marl is exposed above water level near the bottom of a drainage ditch in southern De Soto County (SW¼SW¼ sec. 28, T. 38 S., R. 25 E., map loc. 25–33, pl. 1). 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 is 3½ feet thick here. The species listed below, identified by F. S. MacNeil, 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
  - *apicalis* Heilprin
  - *perattenuata* Heilprin

Pelecypoda:
- *Anadara lienosa* (Say)
- *Chlamys harrisi* Dall
- *Anomia simplex* d'Orbigny
- *Ostrea sculpturata* Conrad
  - *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. It is possible that 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 the 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 that 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).

A number of marine terraces are recognized by geomorphological evidence. These terraces are remnants of higher shorelines that were 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 ranging from 70 to 100 feet above sea level. The surficial sediments at elevations ranging from 40 to 60 feet above sea level represented a later Tsala Apopka terrace. The lowest terrace, which they called the Pensacola, covered a broad plain that was less than 40 feet above sea level; 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. Above 25 feet, sediments of Pleistocene age contained no fossils; he believed that this land stood relatively high during most of the Pleistocene.

Cooke (1945, p. 247–248) identified seven, and possibly eight, shorelines that represent stands of sea level during Pleistocene time.

Terrace	*Altitude (feet)*
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 shorelines, which he believed to represent peaks of marine transgression.

Terrace	*Altitude (feet)*	*Age*
Okefenokee	150	Yarmouth interglacial stage
Wicomico	100	Sangamon interglacial stage
Pamlico	25–35	Middle Wisconsin glacial recession
Silver Bluff	8–10	Post-Wisconsin

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

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. Crossbedding 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. 9), where a waxy blue clay grades laterally to a coarse sand within a distance of less than 100 feet. Similarly, the section along Horse Creek reveals a layer of brownish clay pinching out within a crossbedded sand stratum 2 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 thick, and locally it may be an indurated crust or layer of ferruginous 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 sandy 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 thick, 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 (NW¼ sec. 33, T. 39 S., R. 25 E., De Soto County; loc. 8–53, pl. 1), the Caloosahatchee marl is overlain by 6 feet of Pleistocene deposits. 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*, which was identified by Jean Hough. The age of *Aphelops* is early to middle Pliocene.

At a borrow pit near Nocatee, part of an upper molar of *Neohipparion*, identified by Jean Hough, 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. 9), and at a borrow pit northwest of Nocatee (SE¼SW¼ sec. 11, T. 38 S., R. 23 E., De Soto County), molars of a horse, probably *Neohipparion*, identified by Jean Hough, were collected from the surficial sediments.

Although the vertebrate 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 southern Florida. In addition, the unit unconformably overlies the Caloosahatchee marl, which is definitely Pliocene, possibly late Pliocene, in age. The vertebrate teeth, which are resistant to erosion and weathering, were probably derived from the Bone Valley formation. Erosion of these earlier 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 by W. C. Mansfield (1939, p. 33–45). The fauna listed by Sellards was associated with human remains at an exposure near Vero Beach. The fossils described by W. C. Mansfield were collected from numerous localities throughout southern Florida.

At the borrow pit east of Nocatee (fig. 9) the following invertebrates, identified by F. S. MacNeil, were collected from the phosphatic sand directly overlying sand of late Miocene age:

Gastropoda:
- Fresh water:
  - *Viviparus georgianus* Lea
  - *Campeloma* sp.
  - *Goniobasis* 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 (SW¼SW¼ sec. 24, T. 35 S., R. 24 E.), the gastropods listed below, identified by F. S. MacNeil, were collected from a 2½-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. Cooke and Mossom (1929, p. 211) later changed the name to Fort Thompson *formation.* On the basis of invertebrate fossils and stratigraphic position, the unnamed Pleistocene strata of this report are correlated with the Fort Thompson formation.

Distribution.—The Pleistocene strata are flat-lying surficial deposits: Auger holes disclosed that they cover the entire area, except where stream erosion has bared the older rocks or where Recent sediments are present. Vertical exposures are found along Payne's Creek, Peace River (fig. 10), 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 the Pleistocene strata is variable, but it generally does not exceed 20 feet.

Origin.—The general character of the Pleistocene strata 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 areas during floods. Channel sediments are characterized by lenticular bodies of sand and clay and by crosslamination. Scattered occurrences of fresh-water limestone were deposited in flood-plain lakes.

It is possible that part of these beds was 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 where 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, there is abundant evidence of invasions at other places in the Atlantic Coastal Plain. 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; 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, exposed stream terraces are clearly younger than the Pleistocene deposits (figs. 7 and 8). 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 and 2). The dominant lithology is fine quartz sand, with a negligible amount of clay. 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 (loc. 32–53, pl. 1 and fig. 11), shows the contact of a Recent stream deposit with Pleistocene strata.

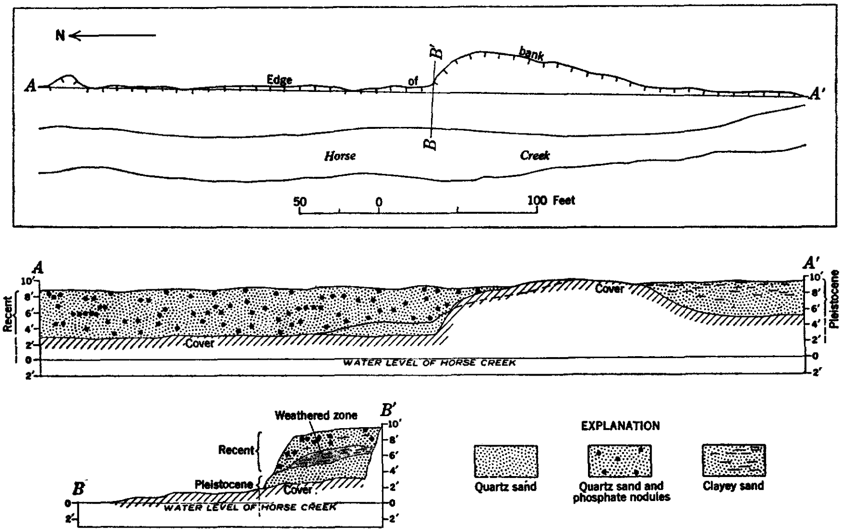

FIGURE 11.—Plan and profile sketch of exposure along Horse Creek, at bridge on Florida Route 72, De Soto County.

MECHANICAL ANALYSIS

Mechanical analyses of the Pleistocene deposits, the sand of late Miocene age, and the undifferentiated phosphatic sand and clay were made to determine the existence of significant differences in grain size and to see whether such differences were characteristic of the formation or whether they were merely local variations. Striking and consistent interformational differences in median diameter of quartz sand, for example, would be useful for correlation purposes 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 mechanical shaker. Samples, before sieving, weighed approximately 60 grams. The samples were run through the following screen sizes:

Tyler screen no.	*Mesh size (in millimeters)*	*Tyler screen no.*	*Mesh size (in millimeters)*
20	0.833	65	0.208
28	.589	100	.147
35	.417	150	.104
48	.295	200	.074

All material below 0.074 mm (200 mesh) was discarded. All soluble components had been dissolved in the acid, therefore 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. 3).

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	Sand of late Miocene age	Undifferentiated phosphatic sand and clay
Median-grain size (in millimeters)	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. 3) 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 sand of the Pleistocene deposits is less than that of the sand of late Miocene age or of the undifferentiated phosphatic sand and clay.

GEOLOGIC HISTORY

MIOCENE

Submergence during the middle Miocene 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, 1945, p. 5–7), exposed the Hawthorn formation to weathering and erosion as far south as Hardee County and perhaps as far as De Soto County. 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 nodules, clay, and quartz sand. Periodic fluvial reworking of the residual weathered products occurred during this time.

During late Miocene time, the sea again advanced, and all of the southern part of the Florida peninsula, including De Soto County and possibly all of Hardee County, was submerged. The Tamiami formation and the Buckingham marl of Mansfield record this inundation in southern Florida. Slightly later, as the sea transgressed farther inland, the sand of late Miocene age was deposited in the more shallow water to the north. If the Bone Valley formation is of marine origin, it was deposited in this sea.

PLIOCENE

Marine deposition in Florida during the Pliocene epoch is marked by the Caloosahatchee marl. There is no knowledge of an important erosion interval after the late Miocene. Shallow Pliocene seas covered all of southern Florida and extended at least as far north in this area as southern De Soto County (pl. 1). There is no evidence of an extensive submergence during Pliocene time. The Caloosahatchee marl has not been found at altitudes of more than 40 to 45 feet.

PLEISTOCENE

After withdrawal of the Caloosahatchee sea, much of peninsular Florida was exposed. The post-Pliocene exposure was of brief duration, as evidenced by the fact that much of the thin Caloosahatchee marl is still preserved; furthermore, the upper part of the Caloosahatchee is relatively fresh and unweathered.

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 oscillations of sea level during the Pleistocene than is exhibited in Hardee and De Soto Counties. The Pleistocene strata in this area were deposited by the aggrading Peace River while the sea was at a higher level than at present. No precise record of earlier and higher stands of the sea during the Pleistocene is present here, although Cooke (1945, p. 245–

312) and MacNeil (1950, p. 95–107) mapped shorelines elsewhere in Florida at elevations of more than 100 feet. These shorelines represent pauses during the latest general retreat of the sea.

RECENT

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 the 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 economic conditions.

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 sand of late Miocene age, Caloosahatchee marl, and the Pleistocene deposits.

Prospecting data in this region are nonexistent. Mansfield (1942, p. 35) noted that there was no prospecting information available in regard to the area south of T. 34 S., Hardee County. Exploration since 1942 has been concentrated in the land-pebble phosphate district, and the writer could find no record of recent prospecting in Hardee County.

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 percent equivalent uranium. The results ranged from less than 0.001 percent to 0.009 percent. The summarized values are shown below:

Number of samples	*Percent equivalent uranium*	*Number of samples*	*Percent equivalent uranium*
1	0.009	16	0.004
3	.008	23	.003
4	.007	36	.002
6	.006	13	.001
6	.005	27	<.001

The average of the percent equivalent uranium for each stratigraphic 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 deposits	. 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.

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INDEX

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