Stratigraphy of the Area Between Hernando and Hardee Counties, Florida

By KEITH B. KETNER *and* LAWRENCE J. McGREEVY

CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

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CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

STRATIGRAPHY OF THE AREA BETWEEN HERNANDO AND HARDEE COUNTIES, FLORIDA

By KEITH B. KETNER and LAWRENCE J. MCGREEVY

ABSTRACT

Eocene, Oligocene, Miocene, and Recent rocks are exposed between Hernando and Hardee Counties. Eocene and Oligocene formations are fossiliferous limestones, but Miocene rocks are largely unconsolidated sands and clays in which fossils are scarce. Correlation of Miocene strata, therefore, is based mainly on lithology and stratigraphic position. Where rocks are altered by weathering, correlation is based on original rather than present gross lithology. Quartz sand was found to be valuable in correlation because it is not affected by weathering.

Rocks previously mapped as the Pliocene Alachua and Bone Valley formations range from lower to middle Miocene and are assigned to the Tampa and Hawthorn formations. The Citronelle formation of Pliocene or later age apparently does not extend into peninsular Florida. Clayey, micaceous sand, which has been considered as an equivalent of Citronelle, is late middle Miocene or early late Miocene in age.

Hard-rock phosphate deposits in the area are in beds of early Miocene age, which are assigned to the Tampa limestone. Hard-rock phosphate particles appear to consist of two types: cementation concretions and limestone replacements.

Land-pebble phosphate deposits range from middle Miocene to Pleistocene in age. They are chiefly residual deposits of middle Miocene age.

Uranium is confined mainly to lower and middle Miocene rocks with the greatest concentrations in the Hawthorn formation.

INTRODUCTION

LOCATION OF AREA AND SOURCES OF DATA

In 1953 the U. S. Geological Survey studied formations on the borders of the land-pebble phosphate district to extend the geologic setting of previous and current economic studies.

This report describes Cenozoic rocks on the north and east edges of the land-pebble phosphate district, including part of the hard-rock phosphate belt. Figure 3 and plate 3 show the area which was studied.

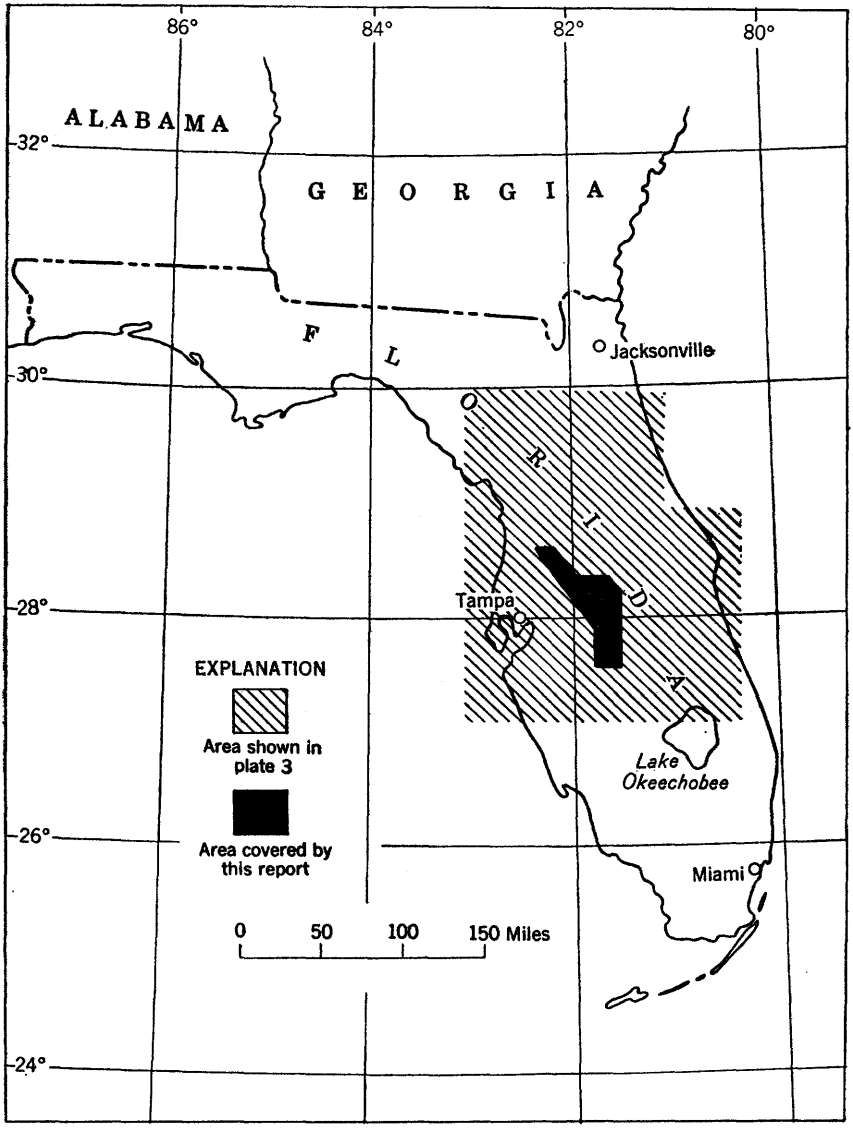

FIGURE 3.—Index map showing location of area covered by this report.

Outcrops of unconsolidated sands and clays that cover the area are poor. However, data were obtained from 71 excavations and core holes which extend in a broad belt about 90 miles long between Hernando and Hardee Counties (pl. 3). Locality numbers correspond to those on plates 3 to 5 and on pages 83–122.

Excavations and core holes

[Numbers correspond to the numbered sections and logs on pages 83-122]

Locality

1. McDonald limestone quarry, sec. 19, T. 22 S., R. 20 E.
2–4. Hard-rock phosphate mine.
   2. Sec. 4, T. 22 S., R. 20 E.
   3. Sec. 18, T. 22 S., R. 21 E.
   4. Sec. 5, T. 23 S., R. 21 E.
5–9. Core hole.
   5. NW¼SE¼ sec. 22, T. 24 S., R. 21 E.
   6. NE¼NE¼ sec. 14, T. 25 S., R. 21 E.
   7. NW¼SE¼ sec. 13, T. 25 S., R. 21 E.
   8. SW¼NE¼ sec. 19, T. 25 S., R. 22 E.
   9. SW¼SW¼ sec. 27, T. 25 S., R. 22 E.
10. Road cut, SW¼ sec. 35, T. 25 S., R. 22 E.
11–12. Core hole.
   11. NW¼SW¼ sec. 1, T. 26 S., R. 22 E.
   12. SW¼SW¼ sec. 8, T. 26 S., R. 23 E.
13. Road cut, N½ sec. 21, T. 26 S., R. 23 E.
14–17. Core hole.
   14. NE¼SW¼ sec. 27, T. 26 S., R. 23 E.
   15. NW¼SW¼ sec. 1, T. 27 S., R. 23 E.
   16. NE¼SW¼ sec. 18, T. 27 S., R. 24 E.
   17. SE¼NW¼ sec. 31, T. 27 S., R. 24 E.
18. Saddle Creek land-pebble phosphate mine, sec. 14, T. 28 S., R. 24 E.
19. Tenoroc land-pebble phosphate mine, sec. 35, T. 27 S., R. 24 E.
20–62. Core hole.
   20. NE¼SE¼ sec. 11, T. 27 S., R. 24 E.
   21. NE¼SW¼ sec. 5, T. 25 S., R. 25 E.
   22. SW¼SW¼ sec. 7, T. 25 S., R. 25 E.
   23. NW¼NE¼ sec. 32, T. 25 S., R. 25 E.
   24. NW¼ sec. 21, T. 26 S., R. 25 E.
   25. SW¼SW¼ sec. 21, T. 26 S., R. 25 E.
   26. SW¼ sec. 28, T. 26 S., R. 25 E.
   27. NW¼SW¼ sec. 6, T. 27 S., R. 25 E.
   28. NE¼NE¼ sec. 8, T. 27 S., R. 25 E.
   29. NW¼NW¼ sec. 3, T. 27 S., R. 25 E.
   30. NE¼ sec. 12, T. 27 S., R. 25 E.
   31. SW¼SW¼ sec. 3, T. 27 S., R. 26 E.
   32. NE¼SW¼ sec. 7, T. 27 S., R. 27 E.
   33. NE¼NE¼ sec. 20, T. 28 S., R. 25 E.
   34. SE¼NE¼ sec. 21, T. 28 S., R. 25 E.
   35. NE¼SE¼ sec. 22, T. 28 S., R. 25 E.
   36. NW¼ sec. 25, T. 28 S., R. 25 E.
   37. NW¼SE¼ sec. 15, T. 28 S., R. 26 E.
   38. NW¼SE¼ sec. 14, T. 28 S., R. 26 E.
   39. SW¼SW¼ sec. 7, T. 30 S., R. 26 E.
   40. NW¼NE¼ sec. 17, T. 30 S., R. 26 E.
   41. NE¼NE¼ sec. 9, T. 30 S., R. 26 E.
   42. NE¼SE¼ sec. 15, T. 30 S., R. 26 E.
   43. NW¼SE¼ sec. 13, T. 30 S., R. 26 E.
   44. SE¼NW¼ sec. 18, T. 30 S., R. 27 E.
   45. SW¼SW¼ sec. 29, T. 30 S., R. 27 E.

Excavations and core holes—Continued

[Numbers correspond to the numbered sections and logs on pages 83–122]

Locality

20–62. Core hole—Continued
- 46. NE¼SE¼ sec. 28, T. 30 S., R. 27 E.
- 47. SW¼NW¼ sec. 33, T. 32 S., R. 25 E.
- 48. SE¼ sec. 22, T. 32 S., R. 25 E.
- 49. SW¼NE¼ sec. 36, T. 31 S., R. 25 E.
- 50. SW¼SW¼ sec. 32, T. 31 S., R. 26 E.
- 51. SW¼SW¼ sec. 33, T. 31 S., R. 26 E.
- 52. SW¼SW¼ sec. 34, T. 31 S., R. 26 E.
- 53. NW¼NE¼ sec. 31, T. 31 S., R. 27 E.
- 54. NE¼SW¼ sec. 33, T. 31 S., R. 27 E.
- 55. NW¼NW¼ sec. 1, T. 34 S., R. 25 E.
- 56. SW¼SE¼ sec. 31, T. 33 S., R. 26 E.
- 57. SE¼NW¼ sec. 4, T. 34 S., R. 26 E.
- 58. SW¼SE¼ sec. 34, T. 33 S., R. 26 E.
- 59. NE¼SE¼ sec. 35, T. 33 S., R. 26 E.
- 60. NE¼SE¼ sec. 31, T. 33 S., R. 27 E.
- 61. NW¼SE¼ sec. 32, T. 33 S., R. 27 E.
- 62. SE¼ sec. 33, T. 33 S., R. 27 E.

63. Spoil bank of pond, sec. 21, T. 24 S., R. 20 E.
64. Railroad cut, sec. 20, T. 27 S., R. 23 E.
65. Road cut, sec. 19, T. 28 S., R. 20 E.
66. Sydney land-pebble phosphate mine, sec. 27, T. 29 S., R. 21 E.
67. Saddle Creek land-pebble phosphate mine, sec. 27, T. 28 S., R. 24 E.
68. Bonny Lake land-pebble phosphate mine, sec. 3, T. 30 S., R. 24 E.

69–70. Limestone quarry.
- 69. Sec. 19, T. 20 S., R. 21 E.
- 70. Sec. 23, T. 21 S., R. 20 E.

71. Achan land-pebble phosphate mine, NE¼ sec. 26, T. 30 S., R. 23 E.

EARLIER WORK

Eldridge (1893), Sellards (1913), Matson (1915), and Vernon (1951) described the geology of the hard-rock phosphate belt; Eldridge (1893), Sellards (1915), Matson (1915), Cathcart (1950), and Cathcart and others (1953) gave detailed accounts of the land-pebble phosphate district. No detailed descriptions of rocks between the two districts have been published.

FIELDWORK AND ACKNOWLEDGMENTS

Most of the fieldwork was done in May, August, and September 1953. Cores 3⅝ inches in diameter were obtained from holes drilled with a truck-mounted core drill. Altitudes were determined by the use of topographic maps and aneroid barometers. Rock samples were decomposed in acid, dried, and classified by sieving.[1] Median diameters of quartz grains were obtained from cumulative curves of the size-class weights.

[1] Size terminology used throughout this report is that of Wentworth (1922).

C. B. Hunt, M. N. Bramlette, F. S. MacNeil, and G. W. Boyes aided in the field examination of mines; R. G. Petersen and J. B. Cathcart aided in logging of drill cores. MacNeil made all fossil identifications. James Gilluly, H. D. Drewes, Z. S. Altschuler, and MacNeil suggested improvements in the manuscript. The authors take responsibility for all interpretations but acknowledge assimilation of ideas from professional associates.

This work was done by members of the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

GEOLOGIC SETTING

The area is relatively low and subdued in relief. Hills rise to 200 feet above sea level in the northern part, and relief is more than 100 feet in places. In the central and southern parts, low parallel ridges trending north-south produce relief of less than 100 feet. The prevailing aspect throughout the area is one of low swamplands and savannas drained by sluggish streams and pocked with innumerable sinks. North of Lakeland, the area is drained by the Withlacoochee and Hillsborough Rivers; south of Lakeland, by the Peace and Alafia Rivers.

A breached northward trending elongate dome known as the Ocala uplift occupies much of peninsular Florida (Vernon, 1951). The area includes parts of the southwestern and southeastern flanks of this uplift.

STRATIGRAPHY

One of the most salient features of Cenozoic stratigraphy in the area and throughout most of Florida is the prevalence of the general sequence, in descending order: (a) loose sand, (b) clayey sand and sandy clay, and (c) limestone.

Limestone in the area ranges from upper Eocene to middle Miocene in age. Much of the clayey sand and sandy clay, which ranges in thickness from about 12 to more than 125 feet, is phosphatic and almost devoid of fossils, although it probably ranges from lower to upper Miocene. Loose surficial sand, commonly less than 15 feet thick, is unfossiliferous. In the northern and northeastern parts of the area, loose surficial sand contains artifacts that indicate it is of Recent age there. Table 1 summarizes Cenozoic stratigraphy in the area.

Plate 4 shows a geologic section extending from the hard-rock phosphate district in Hernando County to the land-pebble phosphate district in Polk County. It represents the writers' interpretation of stratigraphic data as derived from field examinations of mines, road cuts, drill cores, and laboratory examinations of many samples. Measured median diameters of quartz sand grains, percentage of

TABLE 1.—*Generalized section of rocks in the area between Hernando and Hardee Counties, Fla.*

Series	Generalized lithology of stratigraphic units	Maximum thickness (feet)	Formation names used in this report	
			Northern part of area	Southern part of area
Miocene to Recent	Quartz sand, unconsolidated, massive.	15	Surficial sand	Surficial sand.
Middle to upper Miocene.	Quartz sand, clayey, micaceous, very fine- to medium-grained, brown to white.	80	None	Micaceous sand.
Middle Miocene	Quartz sand, clayey, fine-grained, brown to gray; interstitial secondary phosphate.	70	Hawthorn formation, sand unit.	Hawthorn formation, sand unit.
	Quartz and phosphorite sand, clayey, gray to brown; quartz sand, fine-grained; phosphorite nodules up to pebble sizes.	18	Hawthorn formation, phosphorite unit.	Hawthorn formation, phosphorite unit.
	Limestone, clayey, sandy; phosphorite nodules up to pebble sizes.	>100	None	Hawthorn formation, limestone unit.
Lower Miocene	Clay, sandy (very fine grained), green to brown.	25	Tampa limestone, clay unit.	None.
	Limestone, clayey, sandy, yellow; sparse phosphorite nodules of sand size.	100	None	Tampa limestone, limestone unit.
	Clay composed of clay-sized particles of apatite and clay, sandy, concretionary, white, brown.	>10	Tampa limestone, phosphorite unit.	None.
Upper Oligocene	Limestone, sandy (very fine grained).	125	Suwannee limestone.	None.
Upper Eocene	Limestone, pure	500	Ocala limestone	Ocala limestone.

quartz-sand content in spot samples, and relative radioactivity are shown in their stratigraphic positions. Plate 5 shows a fence diagram of the northeast and east edges of the land-pebble phosphate district, based almost entirely on field examinations of drill cores.

NOMENCLATURE

Stratigraphy in Florida has been complicated by one or more periods of intense weathering which have profoundly altered some rocks. It is generally agreed that impure limestone and phosphorite have been altered in places to clayey sand and further altered in places to loose sand. Opinion is divided, however, on the quantitative importance of this alteration in Florida stratigraphy accordingly: (a) some widespread strata consisting of unconsolidated sand and clay are entirely the relatively insoluble residues of impure limestone; (b) all strata are primary depositional units only slightly modified by weathering; (c) apparent lithologic units may be residual in one place and depositional in another. Because of these varied opinions, certain deposits are informally called units in this report to avoid

connotation of primary origin implied by the terms "formation," "member," "lentil," or "tongue."

CORRELATION

Widely separated exposures and drill holes and scarcity of fossils make correlation difficult. Moreover, where strata can be partly reconstituted by weathering only the original lithology, not present gross lithology, can be used in correlation. In this report, some rocks are classified by their general lithologic features into units. A lithologic unit might, however, be derived from weathering of parent material of different lithology; and so, units are grouped into formations according to age and the properties of relatively unalterable constituents—mostly quartz sand.

Quartz sand increases in average diameter upward from the rocks of an older series to the next younger. This is true of Eocene, Oligocene, and Miocene limestones—in which an abundance of fossils makes age determination certain—and appears to be generally true of lower, middle, and upper Miocene sands and clays in which fossils are scarce (pl. 4; W. J. Carr and D. C. Alverson, written communication, 1956).

Clay content is used with quartz sand in places as an aid in correlation. Although it is susceptible to some redistribution and chemical alteration, clay is relatively stable as compared to other common rock components such as carbonate and phosphate.

Uranium is contained in both primary phosphates and their secondary alteration products in the area (Z. S. Altschuler and C. E. Boudreau, written communication, 1949). When primary phosphate, commonly apatite, is decomposed by weathering, enough uranium-bearing secondary phosphate is usually left to indicate the former presence of apatite. Radioactivity in drill holes was measured by a gamma-ray logging apparatus. Graphs showing relative radioactivity in drill holes are given in plate 4. These graphs were used as an aid in correlation on the assumption that a relatively high degree of radioactivity indicates apatite is or was, prior to weathering, present in considerable amounts.

UNCONFORMITIES

Where weathering alters a formation to various depths, an apparent unconformity is commonly produced by the irregular contact at the base of the altered rock and by the change of lithology (Sellards, 1910, p. 34). Where the entire parent formation is altered, causing the altered rock to lie directly upon a distinctly older formation, the illusion of an unconformity is even more striking. Examples are

common in the area. Plate 4 shows the sand unit of the Hawthorn formation overlying the Tampa limestone, at places, without the normally intervening phosphorite and limestone units of the Hawthorn. Erosion or nondeposition of the phosphorite and limestone units is not necessarily a deduction here; these units might have been present before weathering altered both to clayey sand.

EOCENE SERIES

OCALA LIMESTONE

Ocala limestone, the oldest formation exposed in the area, is of late Eocene age (Cooke, 1945). Although it underlies the entire Florida peninsula (Cooke, 1945, p. 55), Ocala limestone was found only at the south end of the hard-rock phosphate belt in 3 mines and on the northeast edge of the land-pebble phosphate district in 3 drill holes (pls. 4 and 5). Its thickness is uncertain.

Ocala limestone is soft, friable, and porous. In many places it consists almost entirely of fossils. Its most conspicuous impurity, green or brown clay, is so sparse that the limestone is almost everywhere white. Two samples (pl. 3, locs. 69 and 70) of Ocala limestone from quarries near the southeast edge of the hard-rock phosphate belt contain 0.12 and 0.04 percent P_2O_5, and 0.45 and 0.14 percent insoluble material—probably quartz silt and clay. Two samples (pls. 3 and 4, locs. 2 and 3) from the hard-rock belt contain 0.10 and 0.08 percent P_2O_5, and 0.68 and 0.32 percent insoluble material. All four samples contain less than 0.1 percent Al_2O_3. Two samples (pls. 3 and 4, locs. 2 and 3) of the Ocala from the hard-rock district, each weighing about 7 pounds, yielded no sand-sized residue when dissolved in acid. Recognition of Ocala limestone is simplified by the extreme purity of the rock and an abundance of fossils of which *Lepidocyclina* is especially common and diagnostic.

The surface of the Ocala limestone in the hard-rock phosphate belt is deeply weathered as indicated by solution features such as sinkholes and pinnacles. The pinnacles, common in hard-rock phosphate mines, range from 2 to 10 feet in thickness and are generally greater in their vertical than horizontal dimension. Many pinnacles are slickensided indicating that overlying sediments have settled around them as a result of compaction or differential limestone solution.

The configuration of the surface of the Ocala limestone, east of the hard-rock phosphate belt, contrasts sharply with the configuration within the hard-rock belt. East of the hard-rock belt the generally flat surface of the Ocala is broken, not by pinnacles, but by nearly

vertical-sided solution "pipes" that range from 2 to 10 feet in diameter and 10 to 30 feet in depth. East of the hard-rock belt, clay—probably derived partly from solution of the Ocala—veneers the limestone surface and fills solution "pipes" and sink-holes. In the hard-rock phosphate belt the insoluble residue of Ocala limestone, derived from limestone removed by solution above and around the pinnacles, collects in depressions between pinnacles but is not usually exposed.

Eocene fossils (pls. 3 and 5, locs. 25 and 24) were collected from core holes in Ocala limestone:

Locality

25 *Chlamys* sp. cf. *C. spillmani* (Gabb)
Tubulostium sp. (coiled worm)
Lepidocyclina ocalana Cushman
24 *Lepidocyclina* sp. cf. *L. pseudomarginata* Cushman
31 *Amusium ocalanum* Dall

OLIGOCENE SERIES

SUWANNEE LIMESTONE

Suwannee limestone, the only formation of Oligocene age, crops out both in northwest and west-central peninsular Florida (Cooke, 1945, pl. 1). Suwannee limestone lies unconformably on Ocala limestone (Cooke, 1945, p. 88). It ranges in thickness from about 125 feet—as indicated by wells at Zephyr Hills (Carr and Alverson, written communication, 1956)—to the vanishing point on the south end of the hard-rock phosphate belt and the northeast edge of the land-pebble phosphate district.

Twenty feet of Suwannee limestone is exposed in the McDonald quarry 3 miles east of Brooksville in Hernando County (pls. 3 and 4, loc. 1). The limestone is widely jointed, hard, and dense at the base of the pit; but closely jointed, much softer, and porous near the top. The top is very irregular, sinkholes are numerous, and the limestone surface between sinkholes is jagged.

In the hard-rock phosphate belt a rubble of Suwannee limestone, ranging from pebble to boulder size, discontinuously overlies Ocala limestone. The maximum thickness of rubble observed is about 15 feet. Although most of the particles of Suwannee limestone are nearly equidimensional, they are not rounded or polished but clearly show effects of solution such as protruding crystals and fossils, pitting, and fluting. Some are encased in crusts of chert, others contain spongelike "skeletons" of chert. Some are replaced by apatite. One displaced boulder of Suwannee limestone found in a hard-rock phos-

phate mine (pls. 3 and 4, loc. 3) is completely replaced by apatite and chert. Oligocene fossils were identified in this boulder:

Locality

3 *Calliostoma silicatum* Mansfield
"Amauropsis" aff. *A. burnsii meridionalis* Pilsbry Mansfield
Cerithium brooksvillensis? Mansfield
aff. *C. vaginatum* Dall
Xenophora sp.
Glycymeris n. sp.? large
Venericardia sp. juvenile
Phacoides hernandoensis Mansfield
Cassidulus gouldii (Bouvé)

Three samples (pls. 3 and 4, locs. 1 and 3) of Suwannee limestone from a limestone quarry and a hard-rock mine contain less than 0.2 percent P_2O_5 and less than 0.1 percent Al_2O_3. The principal noncalcareous constituent is very fine grained and well-sorted quartz sand, which constitutes from 1 to 11 percent of the Suwannee limestone in the area (pl. 4).

In the northern part of the area, Suwannee limestone differs lithologically from Ocala limestone in being dense, coarsely crystalline, tan, and visibly sandy. From Dade City southeastward, however, it more nearly resembles Ocala limestone in being soft, porous, finely crystalline, and white. The characteristics, which distinguish Suwannee from Ocala limestone in this area, are appreciable quartz-sand content and distinctive fossils.[2]

Oligocene fossils (pls. 3 and 4, loc. 12) were collected from a core hole in Suwannee limestone:

Locality		*Feet*
12	*Turritella* sp. cf. *T. bowenae* Mansfield and *T. halensis* Dall	20
	halensis Dall	21–27
	Cryoturris? cf. *C. hillsboroughensis* Mansfield	
	Glycymeris suwannensis Mansfield	
	Divaricella sp	
	Pitar sp	
	Corbula sp	
	Myrtaea sp. cf. *M. taylorensis* Mansfield	
	Turritella sp. cf. *T. halensis* Dall	28–33
	Eucrassatella sp. cf. *E. paramesus* Dall	
	Chlamys sp. cf. *C. brooksvillensis* Mansfield	
	Orthaulax hernandoensis Mansfield	34–38
	Amauropsis sp	
	Glycymeris suwannensis Mansfield	
	Chlamys sp. cf. *C. brooksvillensis* Mansfield	
	Phacoides sp	
	Chione sp. cf. *C. bainbridgensis* Dall	
	sp	
	Pitar sp. cf. *P. heilprini* Mansfield	
	Anatina sp	39–44
	Venus sp	

[2] *Cassidulus gouldii* is a common guide fossil of the Suwannee formation.

MIOCENE SERIES

TAMPA LIMESTONE

The Tampa limestone includes the lower Miocene Tampa limestone as defined by Cooke (1945, p. 111) and lower Miocene strata commonly included in the Alachua formation of Sellards (1914, p. 161). Cooke (1945, p. 114) described the Tampa as "fairly hard, dense, light-colored to yellowish limestone * * *."

Lower Miocene rocks have not previously been recognized in the Alachua formation. In 1910, Sellards (p. 22, 32) applied the term Dunnellon formation to "a mixture of material largely residual from several formations * * *" between the underlying limestone and overlying loose surficial sand in the hard-rock phosphate belt. The Dunnellon formation is commonly composed of basal phosphorite, which is overlain successively by clay lenses and "more or less phosphatic light gray sands." It also contains smaller amounts of water-worn chert conglomerate and interbedded clay, sand, and phosphate rock.

In 1914, Sellards (p. 161) retracted the term Dunnellon formation and substituted Alachua formation, stating that the Dunnellon formation is a local variant of the Alachua clays which had been briefly mentioned by Dall and Harris in 1892 (p. 127). Dall and Harris cite clay—east of the hard-rock belt on the old Mixson farm in the center of sec. 29, T. 12 N., R. 19 E., near Williston—as an example of Alachua clay. Simpson (1930, p. 173, 175) considers the vicinity of Williston as the type locality of the Alachua formation which he describes as follows:

> * * * sandy clay, or argillaceous sand, generally from 0 to 15 feet in thickness save where it fills local sinkholes of greater depth. When fresh it is gray or greenish, but it is usually weathered and of a bright orange to chocolate red color. It appears not to be phosphatic but to be residual and doubtless in part water laid or reworked clay derived from the older limestone by weathering and solution.

Therefore, the Alachua formation as redefined by Sellards in 1914 is generally composed of 4 stratigraphic units in the hard-rock belt and at least 2 in the adjacent area as shown in figure 4. The Alachua formation is said to be composed of both residual and locally reworked material by both Sellards and Simpson. Sellards (1910, p. 32) and Matson and Clapp (1909, p. 133) suggest that the reworked parts are terrestrial rather than marine.

The Alachua clay of Dall and Harris adjacent to the hard-rock belt on the east was not studied and is not further reported upon. The locally reworked part of Sellards' Dunnellon formation in the hard-rock belt was not recognized, but his three older strata were observed in abandoned hard-rock phosphate mines (pls. 3 and 4, locs. 2, 3, 4) and were found by core drilling (locs. 5, 6, 7, 8) in the south end of the hard-rock belt.

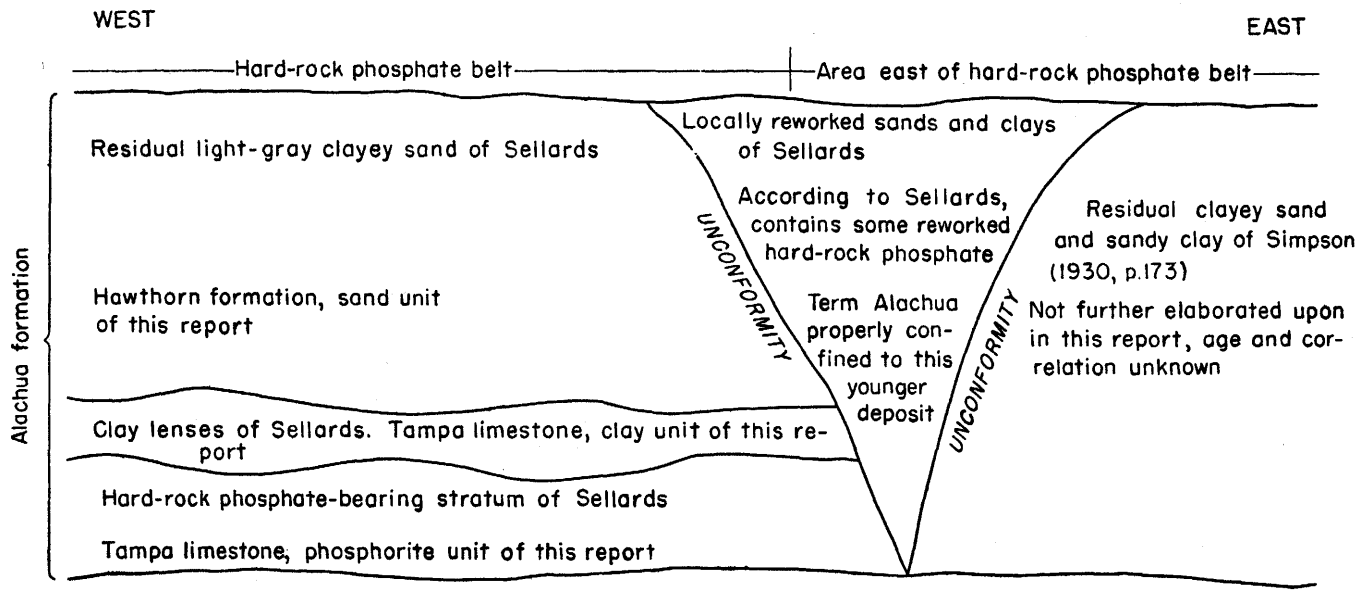

FIGURE 4.—Diagrammatic east-west section showing strata composing the Alachua formation as redefined by Sellards in 1914.

Of the 3 older strata observed, the lower 2—clay lenses and the hard-rock phosphate-bearing stratum—are correlated with Tampa limestone of early Miocene age (pl. 4), and are here termed the clay and phosphorite units of the Tampa limestone. The upper stratum contains basal lenses of nodular phosphorite (not mentioned by Sellards) in a unit that is mostly gray clayey sand. This stratum is correlated with the Hawthorn limestone, which is of middle Miocene age (pl. 4) in the area described by this report. The two units are termed here the phosphorite and sand units of the Hawthorn formation. The bases of these formational assignments are given below.

Simpson (1930, p. 170) reviewed evidence to determine the age of the Alachua formation. He studied vertebrate fossils, which were collected from clay of the Alachua on the Mixson farm and from largely unknown stratigraphic positions in several hard-rock phosphate mines north of the area. Simpson concluded that the Alachua formation is late Miocene or early Pliocene in age. Cooke (1945, p. 199) on the basis of the same fauna designated the age of the Alachua as middle Pliocene.

The discrepancy between the age of the Alachua formation as determined by Simpson and the ages of component strata indicated by this report probably results from a diversity of ages of the component strata rather than from error. Age assignments in this report are based on marine invertebrate fossils (see below). Those of Simpson are based on land vertebrates. The vertebrates studied by Simpson may have come from the terrestrial "reworked" component of Sellards' Alachua formation; whereas only the components that are residual products of older marine rocks are present in this area.

The authors' opinion is that the term Alachua formation should be used only in its original sense; that is, for clay deposits which Simpson (1930) designated to be of late Miocene or early Pliocene age, typified by those on the Mixson farm.

PHOSPHORITE UNIT

The lowest unit of Sellards' Dunnellon, or Alachua, formation in the hard-rock belt, is herein called the phosphorite unit of the Tampa formation. This bed contains hard-rock phosphate at the south end of the hard-rock phosphate belt.

The phosphorite unit extends in a belt—125 miles long and about 10 miles wide—between Dade City, Pasco County, and Fort White, Columbia County. It is well exposed in dry weather at three abandoned hard-rock phosphate mines near the village of Croom, Hernando County (pls. 3 and 4, locs. 2, 3, 4).

The phosphorite unit of the Tampa limestone consists of a nonbedded, mottled, weakly coherent mixture of clay; very fine- to fine-

grained quartz sand; and clay-sized particles of white cryptocrystalline apatite or "collophane" in widely variant proportions. Quartz-sand content of the phosphorite phase ranges from 2 to more than 50 percent in the area (pl. 4). The southernmost tongue, near Dade City, is more sandy than usual.

Rubble of Suwannee limestone and sand- to boulder-sized concretions of hard apatite known as hard-rock phosphate are irregularly distributed in the phosphorite unit. Some of the concretions are brown, hard, concentrically laminated, and complexly veined with layered crystalline apatite. They contain minor amounts of clay and quartz sand and have sharp contacts with the soft sandy apatite and clay matrix. Other concretions, generally white or tan, are more homogenous in structure and have no concentric layers or veins. They are somewhat sandy and their contacts with the soft matrix are gradational. Angular fragments of both types of concretions are common.

The phosphorite unit of the Tampa in the hard-rock belt unconformably overlies the Ocala limestone; and because of the distinct difference in lithology, the phosphorite unit probably also unconformably overlies the Suwannee limestone.

Although the phosphorite unit is unfossiliferous, it is probably early Miocene in age, being underlain unconformably by limestone of Oligocene age and overlain without apparent unconformity by clay of early Miocene age. Furthermore, quartz sand in both the phosphorite and overlying lower Miocene clay unit is nearly identical in size and sorting—indicating probable genetic unity (fig. 5 and pl. 4).

LIMESTONE UNIT

Like Suwannee limestone, the limestone unit crops out in northwestern and west-central peninsular Florida on the flanks of the Ocala uplift (Cooke, 1945, p. 114). The unit underlies the report area only on the north and east edges of the land-pebble phosphate district where it was identified in 1 phosphate mine and in 2 drill holes (pls. 3, 4, and 5, locs. 19, 37, 38). According to Carr and Alverson (written communication, 1956), it is about 100 feet thick in the report area.

The stratigraphic relation between the phosphorite and the limestone units of the Tampa is not certain; however, the authors believe the limestone to be younger than the phosphorite. In one exposure (pls. 3 and 4, loc. 2) fragments of limestone resembling Tampa limestone overlie the phosphorite unit.

In the Tenoroc mine (pls. 3 and 4, loc. 19) the limestone unit is fossiliferous, yellow, somewhat soft, clayey, and sandy. The sand consists of very fine- to fine-grained quartz and sand- to pebble-sized,

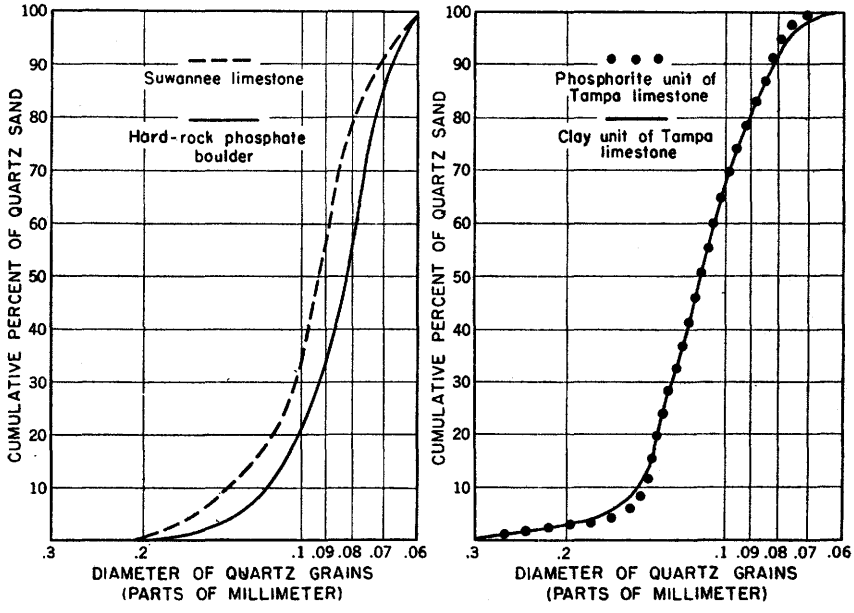

FIGURE 5.—Cumulative curves comparing size and sorting of quartz sand in samples from a hard-rock phosphate mine.

rounded, polished phosphorite nodules. The limestone unit of the Tampa elsewhere has not been reported to contain phosphate. The 2 feet of rock exposed shows no bedding. Tampa limestone at the Tenoroc mine differs lithologically from limestone of the Hawthorn formation, which is exposed in other land-pebble phosphate mines, in having many more well-preserved fossils and less phosphate.

Lower Miocene fossils (pls. 3 and 5, locs. 37 and 38) were collected from core holes in Tampa limestone:

Locality

37 *Turritella tampa* Heilprin
hillsboroughensis Mansfield
Amauropsis sp.
"Acropsis" sp.
Chlamys crocus (Cooke)
Phacoides sp. cf. *P. wacissanus* Dall

38 *Venus?* sp.
Sorites sp.
Camerina sp.
Peneroplis sp.

CLAY UNIT

The second oldest unit of Sellards' Dunnellon or Alachua formation is herein called the clay unit of the Tampa limestone.

The clay unit extends from Brooksville to Lakeland (pls. 3 and 4,

locs. 1–15). Reconnaissance indicates it does not extend into the north end of the hard-rock phosphate belt as does the phosphorite unit. This conforms with the observation of Sellards (1913, p. 29) that hard-rock phosphate is typically associated with clay in the southern part of the hard-rock belt, in contrast with that of the northern part. The clay unit of the Tampa continues west of the report area for an unknown distance. To the south it apparently grades into the limestone unit of the Tampa about where the limestone unit of the Hawthorn formation appears (pl. 4, locs. 15 and 16).

The clay unit ranges in thickness from about 25 feet near Dade City to the vanishing point north and east of the area.

The clay unit of the Tampa limestone consists of greenish-gray to brown clay containing well-sorted, very fine- to fine-grained quartz sand (fig. 5 and pl. 4). Sand ranges from 5 to 80 percent, averaging about 35 percent. Bedding, expressed as various sand-clay ratios, is commonly massive; contacts between beds are gradational. Veinlets of secondary phosphate are common near the top.

The clay unit overlies the phosphorite unit of the Tampa limestone and Suwannee limestone. The contact of the clay unit with the phosphorite unit is generally gradational, but contact with Suwannee limestone is sharp and probably unconformable.

The clay unit (and consequently the underlying phosphorite unit) was reassigned from the Alachua formation to the Tampa limestone (a) partly because it was possibly derived by weathering from the limestone unit of Tampa limestone, assumed to have been more widespread formerly than now, and (b) partly because of its early Miocene age (see below).

Evidence of secondary origin, partly permissive, is as follows: In places (pl. 4, locs. 1, 2, 17) the clay unit is calcareous and contains pitted, softened, irregular particles of limestone lithologically similar to Tampa limestone to the southwest. When dissolved in acid Tampa limestone yields a residue of clay and sand, similar in size and sorting to that of the clay unit (Carr and Alverson, written communication, 1956). The clay unit contains only siliceous fossils, most of which are partly decomposed to tripoli—implying intensive leaching.

The clay unit contains marine invertebrate fossils (pl. 4, loc. 14), which indicate that the unit is lower Miocene; further confirmation is found in the age of overlying strata, which are middle Miocene (see below).

Locality

14 *Terebra* sp.
Knefastia sp. aff. *K. brooksvillensis* Mansfield
Olivella sp. cf. *O. posti* Dall
Turritella atacta Dall

Locality

14 *Architectonica* n. sp.?
Anadara latidentata (Dall)
Chlamys sp. frag.
Cardium (*Trachycardium*) *delphicum* Dall
Callocardia sp.
Pitar sp.
Venus sp.
Corbula sp.

W. J. Carr and D. C. Alverson (written communication, 1956) collected fossils (pl. 3, loc. 65) from the clay unit of the Tampa limestone exposed in a road cut 3½ miles southwest of Thonotosassa, Hillsborough County, where Highway 301 passes under the Atlantic Coast Line railroad.

Locality

65 *Conus* sp. cf. *C. illiolus* Dall
Strombus liocyclas Dall
Latirus sp. cf. *L. floridanus* Heilprin
Cyrena floridana (Dall)
Venericardia serricosta (Heilprin)
Chione (*Chamelaea*) *nuciformis* (Heilprin)
Anomalocardia floridana (Conrad)

The following fossils (pl. 3, loc. 63) were found in a matrix of the clay unit of the Tampa limestone by the edge of an excavated pond about 1 mile west of St. Joseph, Pasco County:

Locality

63 *Trigonocardia alicula* Dall
Anomalocardia penita Dall

HAWTHORN FORMATION

The Hawthorn formation of this report includes: (a) the Hawthorn formation as defined by Cooke (1945, p. 144) and described below, (b) middle Miocene rocks in the hard-rock phosphate belt including those generally assigned to the Alachua formation, and (c) middle Miocene rocks in the land-pebble phosphate district including noncalcareous rocks which have not always been distinguished from the Bone Valley formation.

Cooke and Mossom (1929, p. 115) described the Hawthorn formation as follows:

> The most persistent component of the Hawthorn formation is white or cream-colored sandy limestone containing brown grains of phosphorite. Rock of this kind is widely distributed in the Peninsula and the northern part of the State, but is rarely seen in natural exposures, for it readily disintegrates into sand. An intermediate product of disintegration is gray or white, very light, pumice-like sandstone, from which the lime and phosphate have been dissolved, leaving smooth, rounded blebs in place of the phosphatic grains.

A stratum intermediate in lithology and stratigraphic position between "sandy limestone" and "pumicelike sandstone" is common on

the north edge of the land-pebble district. In this report these three lithologic subdivisions of the Hawthorn formation are called the limestone, phosphorite, and sand units.

In the early days of phosphate mining, two types of phosphate deposits were recognized in the land-pebble district: river-pebble phosphate and land-pebble phosphate. River-pebble phosphate occupies the channels, flood plains, and estuaries of modern rivers; whereas land-pebble phosphate is contained in buried strata not genetically associated with modern streams. Both types generally overlie the limestone unit of the Hawthorn formation, but only the land-pebble deposits are discussed here.

In common usage the term Bone Valley formation probably includes beds of diverse age and origin, although Matson and Clapp (1909, p. 138), who originally defined the term, did not intend this usage. They applied the term Bone Valley gravel to beds containing commercial land-pebble phosphate deposits. They describe the formation as "a fine-grained matrix containing pebbles of phosphate or chert, fragments of bone and other organic remains."

Later Sellards (1910, p. 33) assigned associated sand to the formation, referring to it as the Bone Valley formation. He writes: "This formation includes a lower phosphate-bearing member and an upper sand or sandstone member."

The Bone Valley formation was once thought to contain all the commercial land-pebble phosphate deposits in the land-pebble district. Matson (1915, p. 35), however, noted that phosphate was also mined from parts of the Hawthorn formation, below the Bone Valley formation, and he emphasized that "the name Bone Valley gravel does not include these older phosphate-bearing beds." MacNeil (1950, p. 105) and Cathcart (1950, p. 140) refer to commercial phosphate deposits in parts of the Hawthorn formation from which the carbonate has been leached.[3] Cathcart (1950) states that the leached Hawthorn formation so resembles the overlying Bone Valley formation that the contact is difficult to recognize.

Owing to the similarity of the Bone Valley formation and noncalcareous Hawthorn formation and to the paucity of fossils, the extent of the noncalcareous or "leached" Hawthorn formation has been possibly underestimated in the land-pebble district. M. N. Bramlette (written communication, 1953) suggests that the noncalcareous Hawthorn formation exceeds the Bone Valley formation as a source of commercial phosphate in the northern part of the district. The data of this report indicate that the Bone Valley formation is absent

[3] The term "leached" has recently been applied to zones from which apatite, not carbonate, has been leached.

from both the north and east edges of the land-pebble phosphate district.

LIMESTONE UNIT

The limestone (and dolomite) unit of the Hawthorn formation underlies much of northern and southern Florida but is absent in central peninsular Florida near the crest of the Ocala uplift. Typically it contains fine-grained quartz sand, clay, and nodules of phosphorite—mainly apatite, ranging in size from clay to cobbles. Sand- and larger sized phosphorite nodules are polished and rounded. Many of the larger nodules are aggregates of smaller nodules, quartz sand, and clay. Others consist of limestone cobbles and pebbles encrusted with apatite. Bedding is characteristically massive. Fossils are common but poorly preserved.

Carr and Alverson (written communication, 1956) suggest that the limestone unit ranges in thickness from more than 100 feet in the central and southern parts of the area to the vanishing point in the northern part.

Cooke (1945, p. 145) believes that the contact of the Hawthorn formation with the underlying Tampa limestone is conformable.

Fossils collected from drill cores indicate that limestone at localities 39, 40, 43, and 53 (pls. 3 and 5) is middle Miocene in age, and that at localities 49, 55, and 60 is probably middle Miocene also:

Locality	
39	*Chlamys* sp. cf. *C. sayanus* Dall
	Venericardia sp. fragment
	Phacoides? sp. fragment
40	*Anadara* sp.
	Chione chipolana Dall
43	*Cardium* (*Trachycardium*) sp. cf. *C. plectopleura* Gardner
	Chlamys sp., probably *C. sayanus* Dall
	Tellina sp.
53	*Chlamys*, probably *C. sayanus* Dall
49	*Anadara* sp. fragments
55	*Conus* sp.
	Anadara sp.
	Cardium sp.
	?Macrocallista sp.
60	*Crepidula?* sp.
	Chlamys sp. fragment
	Venerid fragments

PHOSPHORITE UNIT

The phosphorite unit of the Hawthorn formation is best known in the land-pebble phosphate district where it constitutes the "matrix" or minable phosphate in places. However, the unit extends beyond the northern limit of the land-pebble district as lenses and tongues in which the concentration of phosphate is relatively low. It ranges in thickness from about 20 feet to the vanishing point. The phosphorite

unit commonly overlies the limestone unit of the Hawthorn formation in the land-pebble district and also overlies the clay unit of Tampa limestone northward of the north edge of the district. Here a former limestone unit of the Hawthorn formation may have been completely weathered to the phosphorite unit.

The phosphorite unit of the Hawthorn formation generally is a poorly bedded mixture of clay and quartz sand, containing various proportions of rounded and polished phosphorite nodules which are similar to those found in the limestone unit. Most of the quartz sand, which constitutes about 30 percent of the rock, is fine grained but ranges from very fine to medium grained. Phosphorite nodules vary much more widely in size.

Judged by carbonate content, the contact between phosphorite and limestone is gradational from a few inches to 6 feet, grading upward from phosphatic limestone to calcareous phosphorite and finally to noncalcareous phosphorite.

Lithology of the phosphorite unit varies areally in several respects, but most notably in size of phosphorite nodules. In general, nodule size of both the phosphorite and limestone phases is larger west of Bartow, and smaller to the east and south of Bartow.

Although no fossils were found in the phosphorite unit within the area, silicified fossils (pl. 3, loc. 66) were found by M. N. Bramlette at the top of the unit in the Sydney mine on the northwest edge of the land-pebble phosphate district:

Locality

66 *Polystira* aff. *P. tenagos* Gardner
Melongena sp. ct. *M. sculpturata* Dall
Mitrella sp.
Murex sp.
Turritella bicarinata Gardner
Calliostoma harrisii Dall
n. sp.
Glycymeris drymanos grapta Gardner
Chlamys sayanus Dall
Mytilus sp.
Cardita apotega Gardner subsp.?
Macrocallista sp.
Callocardia (*Agripoma*) *prosayana dodona*? Gardner
Venus cf. *V. langdoni* Dall
cf. *V. prodroma* Gardner
Semele cf. *S. smithi* Dall

These fossils show that the underlying phosphorite is not younger than middle Miocene. Support for this age assignment in the area of this report is found in the age of the overlying sand unit, which is middle Miocene (see below).

SAND UNIT

The sand unit of the Hawthorn formation overlies the phosphorite unit of the Hawthorn within the land-pebble phosphate district and the Tampa north of the district (pl. 4). This unit consists of massive-bedded, clayey sand that usually contains vesicles—the size and shape of phosphorite nodules, especially near the base. Quartz sand, mostly fine grained, averages 67 percent of the rock sampled. Veinlets and cement of secondary phosphates are common, especially toward the base of the unit.

The maximum thickness of the sand unit in Florida is unknown but probably does not exceed 100 feet. The sand unit ranges in thickness from about 70 feet to the vanishing point in the area of this report.

The sand unit of the Hawthorn can usually be distinguished from the clay unit of the Tampa by its size of quartz grains and clay content. The clay unit of the Tampa contains much more clay and its quartz sand is finer grained. Where the sand unit of the Hawthorn overlies the phosphorite unit of the Hawthorn, the upper limit of phosphorite nodules is defined as the contact. The contact here is gradational, owing to partial solution of phosphorite nodules in upper parts of the phosphorite unit.

Where the sand unit of the Hawthorn directly overlies the Tampa, one can infer that pre-existing phosphorite and limestone units of the Hawthorn have been completely altered to the sand unit.

The sand unit of the Hawthorn formation has undergone severe weathering. It contains secondary phosphates; and the upper part is oxidized to red, brown, or orange in places. Mottling, resulting from partial reduction of oxidized rock along clay-filled joints, is common in the upper part. Scarce siliceous fossils are now composed of fragile white tripoli.

Reasons for assigning the phosphorite and sand units to the Hawthorn formation rather than to the Bone Valley formation are (a) the possibility that both were derived from a formerly thicker and more widespread limestone phase by weathering in place and (b) their middle Miocene age (see below). Weathered zones are customarily assigned to the same formation as the parent rock.

The mineralogical composition of the three units encourages the interpretation that the phosphorite and sand units may be residues of the limestone unit. Were carbonate removed from the upper part of the limestone unit, a residue similar to the phosphorite unit would remain. If the next most soluble constituent, apatite, were removed from the upper part of the phosphorite unit or converted to secondary phosphates, a residue similar to the sand unit would be left. Sellards (1913, p. 52) recognized this process in the hard-rock district. The

relatively high uranium content of the sand unit indicates a formerly high content of phosphate. Quartz sand—the one major constituent of the Hawthorn which is not altered by weathering—is similar in size in all three units, but is different in beds that are younger or older than the Hawthorn (pl. 4).

Contacts between units of the Hawthorn formation, such as between the limestone and phosphorite units and between the phosphorite and sand units, are gradational for a distance ranging from a few inches to several feet. Specifically, the gradational contacts are expressed as: (a) a gradual decrease upward in carbonate content at the contact between limestone and phosphorite units; (b) a decrease upward throughout the phosphorite unit in carbonate content of the phosphorite nodules; (c) a gradual decrease in hardness and numbers of phosphorite nodules at the contact of the phosphorite and sand units; and (d) presence of vesicles in the sand unit from which phosphate evidently was dissolved.

Areal variations in the sizes of vesicles in the sand unit and nodules in the phosphorite unit correspond to variations in the size of nodules in the limestone unit. Nodules in the phosphorite unit and vesicles in the sand unit are large where phosphorite nodules in the limestone unit of the Hawthorn formation are also relatively large—as at the Bonny Lake mine, 4 miles west of Bartow (pl. 3, loc. 68). Nodules in the phosphorite unit and vesicles in the sand unit are relatively small where the nodules in the limestone unit are relatively small—as to the south and east of Bartow.

Proof that the sand unit of the Hawthorn formation is middle Miocene in age is found in its fossil content and stratigraphic position. Siliceous fossils (pl. 3, loc. 64) were found by Carr and Alverson (written communication, 1956) in the sand unit of the Hawthorn formation in a railroad cut at Kathleen, Polk County:

Locality

64 *Ostrea normalis* Dall
Chlamys sayanus Dall

Fragments of oysters, probably *Ostrea normalis*,[4] are abundant in Hawthorn sand exposed in a road cut between Lakeland and Dade City (pls. 3 and 4, loc. 13). The sand unit of the Hawthorn is overlain by fossiliferous micaceous sand of late middle Miocene or early late Miocene age (see below). The sand unit, therefore, lies between Hawthorn limestone, which is middle Miocene in this area, and micaceous sand of late middle or early late Miocene age.

[4] *Ostrea normalis* is an index fossil of the middle Miocene.

MICACEOUS SAND OF MIOCENE AGE

Matson (1916, p. 167) named beds of sand, gravel, and clay on the gulf coast of Alabama Citronelle formation and dated them Pliocene on the basis of fossil plants. Later Cooke and Mossom (1929, p. 180) assigned certain clayey, micaceous sands of peninsular Florida to the Citronelle. Roy (1939, p. 1553) noted that the fossil plants, which established the age of the Citronelle at the type locality, underlie the Citronelle formation—indicating possibly a younger age than Pliocene. Roy suggests that the name Citronelle be discontinued as applied to the type area until detailed mapping clarifies the stratigraphy of surficial deposits on the gulf coast. The term "micaceous sand" is used in this report for the unit that was previously considered to be the Citronelle formation.

The formation assigned to the Citronelle by Cooke and Mossom—later referred to by Roundy (1941, p. 275), and described by Cooke (1945, p. 229)—was drilled on the northeast and east edges of the land-pebble phosphate district. This formation differs lithologically from the Citronelle formation of the type area in being composed almost entirely of clayey quartz sand. Fossils at its base, near Haines City and east of Fort Meade (see below), show that the formation is late middle Miocene or early late Miocene in age and, therefore, older than the Citronelle. The age is similar to that of the Cancellaria zone (Cooke and Mossom, 1929, p. 140) of Matson and Clapp's Choctawhatchee marl (1909, p. 114). Cooke (1945, p. 181) named the phosphatic limestone beds of this age in Florida Duplin marl; but because the lithology of the micaceous sand is different from the nearest Duplin marl at Rock Spring and Wekiva Spring in Orange County and the type locality in North Carolina, the terms Choctawhatchee marl and Duplin marl are not used in this area. The section of the micaceous sand (pls. 3 and 4, loc. 32) revealed by drilling 4 miles northwest of Haines City, Polk County, is typical in thickness and lithology, and contains many fossils. (See "Stratigraphic sections and lithologic core logs.")

The micaceous sand may be generally coextensive with the Citronelle formation of peninsular Florida as mapped by Cooke (1945, pl. 1), but it was found by Roundy (1941) and the writers to extend farther west than had been shown by Cooke. Plate 4 (locs. 15, 16, and 17) shows the micaceous sand extending westward as far as the northwest edge of the land-pebble district. Patches of micaceous sand are scattered over the northern part of the land-pebble district where they overlie the sand unit of the Hawthorn formation—as in one place in the old Saddle Creek mine (pl. 3, loc. 67); or they overlie the phos-

phorite unit where the sand unit of the Hawthorn formation is absent—as in the Tenoroc mine (pls. 3 and 4, loc. 19). As first noted by M. N. Bramlette (written communication, 1953), phosphorite in parts of the Bonny Lake mine (pl. 3, loc. 68) is overlain unconformably by the micaceous sand, which contains weathered and unweathered phosphorite nodules and slightly indurated fragments of sand of the Hawthorn in the basal part.

On the south edge of the area (pls. 3 and 5, loc. 61), calcareous phosphatic sand and clay overlying micaceous sand suggest that the northernmost edge of certain latest Miocene calcareous sands described by M. H. Bergendahl (1956, p. 73) overlap the southernmost extension of the micaceous sand.

The micaceous sand is composed of an upper coarser grained unit and a lower finer grained unit, which commonly can be distinguished in the field, although the exact position of the contact is uncertain because of blending and interfingering.

FINER GRAINED UNIT

The finer grained unit of the micaceous sand is predominantly massive, weakly coherent, and very fine to fine grained. White mica constitutes less than 1 percent of the rock but is a conspicuous component. Quartz sand comprises about 65 percent of the unit. In places, especially in the southern part of the area, the finer grained unit contains scattered grains and beds of coarse sand making it difficult to distinguish from the coarser grained unit. The unit is mostly white or brown, but is partly dark green in the northeast and southeast corners of the area (pls. 3 and 5, locs. 32, 54, 61, 62). Calcareous late middle or early late Miocene fossils were found in this dark-green zone in one drill hole (pls. 3, 4, and 5, loc. 32) at a depth of 85 feet and in another (pls. 3 and 5, loc. 54) at a depth of 64 feet. In places, such as the area just north of Lakeland (pls. 3 and 4, locs. 17, 19, 20), this unit is a sandy clay—correlative to the more typical clayey sand because of its quartz sand size, mica content, and stratigraphic position. In some places the finer grained unit of micaceous sand contains sparse, rounded and polished sand- to pebble-sized phosphorite nodules near the base.

The finer grained unit of the micaceous sand ranges in thickness from 90 feet to the vanishing point and has an average thickness of about 25 feet.

Calcareous fossils (pls. 3, 4 and 5; locs 32 and 54) show the finer grained unit to be late middle Miocene or early late Miocene in age:

Locality

32 *Olivella sayana* Ravenel
Cancellaria cf. *C. tabulata* Gardner and Aldrich
Turritella sp. aff. *T. alumensis* Mansfield
Crepidula sp.
Anadara fragments cf. *A. idonea harveyensis* Mansfield
Chlamys (*Plagioctenium*) *eboreus* subsp., cf. *watsonensis* Mansfield
Pecten (*Pecten*) sp.
Venus sp.
Spisula (*Hemimactra*) *delumbis* (Conrad)

54 *Anadara* sp. fragment (*A. propatula*?)
Chlamys sp. fragment
Anomia sp. fragment
Phacoides (*Parvilucina*) *multilineatus* (Tuomey and Holmes)
Dosinia sp. fragment
Mulinia orthria Gardner

COARSER GRAINED UNIT

The coarser grained unit of the micaceous sand is weakly coherent, massive- to thin-bedded, and slightly clayey. Quartz grains range from very fine sand- to pebble-sized, but the concentration of pebbles is generally too low to classify any significant part of the formation as gravel. Pebbles are commonly disc shaped. The median diameter of quartz sand and pebbles in the member generally is that of medium-grained sand. Mica is less common in the coarser grained unit than in the finer grained unit. Content of quartz sand and pebbles averages about 75 percent in the coarser unit. The silt and clay-sized constitutents of the member vary from white near the base of the member to dark red at the top. However, pockets of white clay, a few millimeters in diameter, are common in the red upper part. Joints containing dark-gray clay form a network in the upper part of the member. The walls of these joints are commonly bleached to a depth of 1–2 inches, causing the upper part of the member to be mottled. Many quartzite pebbles, which are as much as 1 inch in diameter, are very friable, owing to intergranular weathering.

The coarser grained member, which averages about 30 feet in thickness, ranges from 60 feet in the northeast to the vanishing point in the southeast and west.

MIOCENE TO RECENT SERIES

Loose surficial sand covers virtually the entire area. In the northern and northeastern parts of the area this loose surficial sand is generally variable in thickness, possessing a rolling dunelike surface and commonly containing particles of charcoal and artifacts—mainly chips of chert. The sand usually is finer grained than that of the sand or sandy clay on which it lies. The presence of artifacts indicates that the loose surficial sand is of late Quaternary age.

In the southwestern part of the area—mostly within the land-pebble phosphate district—loose surficial sand is thinner, more regular in surface configuration, and contains no charcoal or artifacts below the top few inches. Its lower contact is usually gradational in clay content with the bed below. The sand above and below the contact is of the same grain size.

CONCLUSIONS

GEOLOGIC HISTORY

Table 2 summarizes, from the viewpoints of the depositionalist and the residualist, the main geologic events which took place in the area beginning with late Eocene time. The two versions illustrate a common conflict in the interpretation of stratigraphic relations in Florida. The residual view is favored by Ketner and McGreevy.

TABLE 2.—*Geologic history in the area between Hernando and Hardee Counties, Fla., from the viewpoints of the depositionalist and the residualist*

Epoch	Depositional	Residual
Pleistocene and Recent	Deposition of loose sand nearly everywhere at the surface, some residual sand.	Conversion of Miocene rocks to loose sand at the surface by weathering; some depositional sand. (Local deposition of Bone Valley formation in channels and sinks nearby during Pliocene.)
Late late Miocene and Pliocene.	Weathering (widespread deposition of Bone Valley formation nearby during Pliocene).	
Late middle Miocene to early late Miocene.	Deposition of micaceous sand	
	Erosion	
Middle Miocene	Deposition of Hawthorn formation as: sand unit phosphorite unit limestone unit	Deposition of Hawthorn formation as limestone, altered later partly to phosphorite and sand units by weathering probably mostly before burial.
	Erosion(?)	
Early Miocene	Deposition of Tampa limestone as: clay unit limestone and phosphorite units	Deposition of Tampa limestone as limestone and phosphorite both of which were later partially altered to clay unit either before or after burial.
	Erosion (Cooke, 1945)	
Oligocene	Deposition of Suwannee limestone	
	Erosion (Cooke, 1945)	
Eocene	Deposition of Ocala limestone subsequently arched to produce Ocala uplift.	

Ocala limestone was folded into an anticline known as the Ocala uplift, but whether Suwannee limestone was deposited before, during, or after the folding is indeterminate from the data of this report. Where Suwannee limestone is thin or missing, it is not clear whether erosion or nondeposition is the cause.

A ridge on the Ocala surface between Brooksville and Croom (pl. 4, locs. 2, 3, 4) might be (a) the locus of greatest upward displacement in the area or (b) a ridge formed by erosion prior to the deposition of the Suwannee limestone, which may or may not coincide with the structural crest of the uplift.

Although some folding of the Tampa limestone and Hawthorn formation could have taken place, the micaceous sand was apparently unaffected. Plate 5 shows the micaceous sand to be essentially horizontal in an area where Vernon (1951, pl. 2) shows the Ocala uplift to have hundreds of feet of structural relief. The Ocala uplift is, therefore, older than late Miocene.

The Tampa limestone might have been deposited as three lithologically distinct members or originally may have consisted of limestone and phosphorite units from which the clay unit was produced by removal of carbonate from the limestone and of phosphate from the phosphorite by weathering. The phosphorite unit is probably not a secondary product resulting from removal of carbonate from phosphatic limestone because: (a) unlike the clay unit, the phosphorite unit does not contain remnants of Tampa limestone—even where underlying the clay unit, which does contain Tampa remnants (pls. 3 and 4, loc. 2); and (b) the limestone unit of the Tampa does not contain phosphate similar to that of the phosphorite unit—clay-sized white apatite.

The Hawthorn formation might also have been originally deposited as three members but from evidence given previously (p. 69), the threefold stratification probably is a result of the weathering of a formerly thicker and more widespread limestone unit. The view that the phosphorite and sand units of the Hawthorn are primary depositional units is based partly on (a) differences in the proportions and properties of minerals among the three units, which allegedly make the derivation of one unit from another by weathering impossible and (b) partly on differences in bedding characteristics among the three units.

If the phosphorite and sand units of the Hawthorn formation are residues, much of the weathering which produced them probably occurred prior to burial by the micaceous sand—before the end of Miocene time—because: (a) the white and green colors, unweathered phosphorite nodules, and calcareous fossils of the lower part of the micaceous sand indicate that post-Miocene weathering, which affected the upper part of the formation, probably did not extend deep enough to alter the underlying limestone unit of the Hawthorn to phosphorite and sand; (b) the micaceous sand apparently overlies a surface of the Hawthorn formation produced by partial erosion of preexisting upper units of the Hawthorn formation. The sand, phosphorite, and limestone units of the Hawthorn formation directly underlie the micaceous sand in places (pls. 3 and 4, locs. 16, 30, and 32). Additional evidence of erosion is indicated in plate 4 (locs. 16, 17, 20, 29, 30, and 31) where gamma-ray logs show the greatest radioactivity to be at the

top of the phosphorite unit. Such maximums usually indicate secondary enrichment in uranium derived from overlying uraniferous sand. Although the sand unit of the Hawthorn is still relatively radioactive after contributing uranium to underlying phosphorite (pl. 4, loc. 16), the micaceous sand shows no evidence of having contained sufficient uranium to produce the enrichment shown in plate 4 at the top of the phosphorite. Therefore, erosion of the sand unit of the Hawthorn formation probably preceded deposition of the micaceous sand in places.

The Bone Valley formation was not identified in the area. Because of its age it would be expected to overlie the sand unit of the Hawthorn formation and probably overlie the younger micaceous sand. Only if these units were absent and the Bone Valley lay directly on the phosphorite or limestone units of the Hawthorn formation would the Bone Valley be mistaken for part of the Hawthorn.

In the northern and northwestern parts of the area, configuration of surficial sand containing charcoal and artifacts in many places is dunelike; this and the absence of marine or freshwater fossils suggest that the loose sand is windblown. This deposit is now stable as shown by its cover of trees—indicating a change of climate since deposition.

In the southwestern part of the area, loose surficial sand was probably derived from underlying material by removal of clay in the weathering process (Sellards, 1912, p. 22) as indicated by (a) the absence of charcoal and artifacts, (b) the gradational contact of surficial sand with underlying clay and clayey sand, and (c) the similarity of quartz grain size immediately above and below the contact.

ORIGIN OF HARD-ROCK PHOSPHATE

The problem of origin of hard-rock phosphate is twofold, consisting of (a) the origin of the phosphorite unit of the Tampa limestone as a stratigraphic unit and (b) the origin of scattered commercial "hard-rock phosphate" within the phosphatic stratum.

Without discriminating between hard-rock phosphate and its soft phosphatic matrix, Sellards (1913, p. 53) theorized that the phosphorite unit of the Tampa limestone—the lowest part of his Dunnellon or Alachua formation—was the product of limestone replacement and cavity filling by phosphate derived from overlying weathered phosphatic rocks. The grain size and abundance of quartz sand in the phosphorite at the south end of the hard-rock phosphate belt indicate that, if Sellards' theory is correct, the phosphatic stratum could not have resulted from replacement of the Ocala limestone or the limestone unit of the Hawthorn formation because the phosphorite contains quartz sand, which is not present in the Ocala and which is finer grained than that of the Hawthorn formation.

The phosphorite unit could have resulted from replacement of Suwannee limestone, but this is unlikely because: (a) the concentration of sand and clay is much greater in the phosphorite than in Suwannee limestone (pl. 4); and (b) the sand of the phosphorite unit is generally not as well sorted as the sand of Suwannee limestone (fig. 5). Grain size and sorting of quartz sand among units of the Tampa limestone are similar—indicating possible replacement of the limestone unit by phosphorite (fig. 5 and pl. 4).

The secondary phosphate of known cavity fillings such as veins is characteristically crystalline, anisotropic, layered, and hard. However most phosphorite of the Tampa is cryptocrystalline, isotropic, largely structureless, and soft—indicating a primary deposit and not a secondary replacement of limestone.

The scattered hard-rock phosphate concretions of the phosphorite unit in the southern part of the hard-rock belt of the Tampa consist of two general types (p. 62), which were probably formed as originally described by Sellards (1913, p. 61):

1. White sandy concretions of uniform structure, which consist of cryptocrystalline and crystalline phosphate—the crystalline variety being a cement. This type is evidently formed in place by slight solution and redeposition of phosphate about scattered centers; concretions thus formed are of questionable commercial value because of their high quartz-sand content, inherited from the parent material.

2. Brown, hard, veined, and layered concretions which are composed mostly of crystalline and birefringent phosphate. The extreme purity of many concretions of this type indicates that reconcentration has taken place since primary deposition.

The pure, brown, layered concretions—which constitute the best commercial hard-rock phosphate—are probably limestone replacements or cavity fillings. At the south end of the hard-rock belt, the concretions are probably replacements of Suwannee limestone—as indicated by their similarity to Suwannee limestone in size, sorting, and amount of quartz sand (fig. 5). One boulder (p. 57) replaced by phosphate and chert, was identified as Suwannee on the basis of fossils preserved in the chert.

Particles of Suwannee limestone and of hard-rock phosphate, some of which are probably Suwannee limestone replaced by phosphate, are dispersed in the phosphorite unit of the Tampa. Whether limestone or phosphatized limestone particles became incorporated into the phosphorite unit of the Tampa at the time of deposition or were subsequently intermixed with the overlying Tampa as a result of unequal settling is not known.

ORIGIN OF LAND-PEBBLE PHOSPHATE

The authors believe that commercial phosphate is extracted from the residual phosphorite of the Hawthorn formation in the area of this report. Vertebrate fossils found in mines in other parts of the land-pebble district, such as those described by Simpson (1930), indicate phosphate was, and probably still is, mined from the Bone Valley formation of Pliocene age. The phosphorite in the lower part of the micaceous sand might be of commercial grade in places. Teeth of the early Pleistocene horse, *Plesippus*, were found in crossbedded phosphorite of possible commercial grade overlying commercial phosphorite of the Hawthorn formation in the Achan phosphate mine near Pierce, Polk County. The origin of the land-pebble phosphate deposits is, therefore, diverse.

URANIUM

Gamma-ray logs shown beside drill holes in plate 4 indicate that some uranium, like phosphate, is concentrated in Miocene rocks throughout the area, although highest concentrations appear to be within the land-pebble district.

Uranium is concentrated in the lower part of the sand unit and upper part of the phosphorite unit of the Hawthorn formation where, according to current interpretation, it is precipitated from solutions carrying it downward from the upper part of the formation.

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STRATIGRAPHIC SECTIONS AND LITHOLOGIC CORE LOGS

STRATIGRAPHIC SECTIONS AND LITHOLOGIC CORE LOGS

The field descriptions of stratigraphic sections were obtained from exposures and drill cores. Comparison of measured grain size of selected samples from exposures and drill cores (pl. 4) with field descriptions shows field estimates of grain size to be usually in error. Despite inaccuracies in absolute sizes, recorded field estimates show changes in relative size from bed to bed at a single locality and permit correlation from site to site.

The term "clay" means materials of clay size but without a preceding adjective it usually also means the clay minerals. "Phosphatic clay" means clay-sized phosphorite. "Sand" means quartz of sand size but "phosphatic sand" is sand composed partly of sand-sized quartz and partly of sand-sized phosphorite nodules.

Quantitative terms used in the following stratigraphic sections and lithologic core logs indicate estimated percentages:

Trace	<0.1
Sparse	0.1–1.0
Very slight	1.0–5.0
Slight	5.0–10.0
Abundant	10.0–20.0
Very	>20.0

An unmodified constituent name such as "clayey" or "sandy" usually means that it is estimated to comprise from 10.0 to 20.0 percent of the rock.

1. Stratigraphic section in McDonald limestone quarry, sec. 19, T. 22 S., R. 20 E., Hernando County

	Feet
Colluvium:	
Sand, colluvial, fine-grained, clayey (20 percent), massive, brown; iron-cemented and phosphate-cemented concretions of sandstone near base	10
Hawthorn formation, sand unit:	
Sand, fine-grained, clayey (25 percent), massive, light-gray mottled with brown; joints filled with clay	7
Clay, sandy (fine grained, 20 percent), massive, green	1
Sand, very fine to fine-grained, clayey (50 percent), massive, gray mottled with brown; joints filled with clay; veinlets of secondary phosphate	2
Tampa limestone, clay unit:	
Clay, sandy (very fine to fine grained, 20 percent), massive, brown	3
Clay, sandy (very fine to fine grained, 30 percent), greenish-gray, massive; weathered limestone and silicified limestone near base	3
Suwannee limestone:	
Limestone, weathered and partly silicified near top, slightly sandy (very fine grained)—exposed	15

2. Stratigraphic section in a hard-rock phosphate pit in sec. 4, T. 22 S., R. 20 E., Hernando County

	Feet
Surficial sand:	
Sand, fine-grained, massive, light-brown	4
Hawthorn formation, sand unit:	
Sand, fine-grained, clayey (30 percent), massive, light-gray; mottled with brown in lower part	3
Tampa limestone, clay unit:	
Clay, sandy (very fine grained, 40 percent), massive, brown	2
Clay, sandy (very fine grained, 20 percent), massive, light-gray mottled with brown; scattered fragments of weathered limestone and silicified limestone, partially cemented with secondary phosphates	2
Tampa limestone, phosphorite unit:	
Phosphatic clay, sandy (very fine grained, 10 percent), massive, white to light-brown, very porous	5
Covered—about	5
Suwannee limestone:	
Limestone mainly silicified (not in place).	
Ocala limestone:	
Limestone, white, pure, soft, porous.	

3. Composite stratigraphic section in a hard-rock phosphate pit in sec. 18, T. 22 S., R. 21 E., Hernando County

	Feet
Surficial sand:	
Sand, fine-grained, massive, light-brown; trace of charcoal	5–15
Hawthorn formation, sand unit:	
Sand, fine-grained, clayey (15 percent), massive, mottled white, light-gray and orange	5–15
Sand, fine-grained, very clayey (40 percent), massive, gray to brown	3
Hawthorn formation(?), phosphorite unit:	
Clay, sandy (fine-grained, 25 percent), massive, light-green; trace of rounded and polished phosphorite nodules	0–5

3. Composite stratigraphic section in a hard-rock phosphate pit in sec. 18, T. 22 S., R. 21 E., Hernando County—Continued

	Feet
Tampa limestone, clay unit:	
Clay, sandy (very fine grained, 20 percent), massive, green	0–5
Tampa limestone, phosphorite unit:	
Phosphatic clay, sandy (very fine grained, 25 percent), massive, white and tan	about 6
Suwannee limestone:	
Limestone, sparsely sandy (very fine grained, 3 percent), tan, visibly crystalline, dense, rubbly	0–10
Ocala limestone:	
Limestone, white, pure, soft, porous.	

4. Stratigraphic section in a hard-rock phosphate pit in sec. 5, T. 23 S., R. 21 E., Hernando County

	Feet
Surficial sand:	
Sand, fine-grained, massive, light-brown	4
Hawthorn formation, sand unit:	
Sand, fine-grained, clayey (25 percent), massive, white mottled with brown	6
Tampa limestone, clay unit:	
Clay, sandy (very fine grained, 30 percent), massive, light greenish-gray mottled with brown	6
Tampa limestone, phosporite unit:	
Phosphatic clay, sandy (very fine grained, 10 percent), white	1
Covered.	
Ocala limestone:	
Limestone, white pure, soft, porous (not in place).	

5. Lithologic log of core from NW¼SE¼ sec. 22, T. 24 S., R. 21 E., Pasco County, originally line 17, hole 11

	Feet	Inches
Not cored	4	0
Sand, fine, clayey, white	11	6
Clay, very sandy at top to sandy at base, greenish-gray at top, mottled brown at base	23	6
Clay, sandy, mottled white and brown; numerous large chert concretions and irregular pockets of soft white phosphatic clay, some of which are cemented with secondary phosphate, forming hard white sandy concretions of granule size	25	8
Limestone, slightly sandy, soft, white and tan. Reacts strongly to chemical phosphate test but no phosphorite nodules visible	26	0
Limestone, slightly sandy, tan; moderate phosphate reaction to chemical test	30	0

6. Lithologic log of core from NE¼NE¼ sec. 14, T. 25 S., R. 21 E., Pasco County, originally line 17, hole 10

	Feet	Inches
Not cored	4	0
Sand, fine- to medium-grained, clayey to very clayey, dark-brown and brown mottled	12	0
Sand, fine-grained, clayey, mottled brown and gray at top to tan at base	29	0

6. Lithologic log of core from NE¼NE¼ sec. 14, T. 25 S., R. 21 E., Pasco County, originally line 17, hole 10—Continued

	Feet	Inches
Sand, fine-grained, clayey to slightly clayey, mottled tan and light gray	47	0
Sand, fine-grained, very slightly to slightly clayey, light-gray	68	0
No recovery	78	0
Clay, very sandy (medium to coarse grained), brown; sandy concretions cemented with secondary phosphate containing veinlets of wavellite	80	0
Clay, very slightly sandy, brown	82	5
Clay, sandy and pebbly, brown; abundant rounded polished phosphorite nodules of sand to small pebble sizes, white to tan, at top. Few phosphorite nodules but many sandy concretions cemented with secondary phosphate in lower part	87	0
Sand, fine to medium-grained, very clayey, brown to black	89	0
Sand, fine, very clayey, mottled tan and light gray	105	0
No recovery	111	0
Clay, very sandy, greenish-gray to brown, contains pockets of soft, white, sandy, clay-sized apatite, some of which are cemented with secondary phosphates	114	6
Phosphatic clay, slightly sandy, white. Partly friable, nonplastic, white, slightly sandy, clay-sized phosphorite similar to matrix in hard-rock phosphate district. Partly hard, brown, and encrusted with secondary phosphate, similar to commercial hard-rock phosphate	116	1
No recovery	134	9
Clay, very sandy, greenish-gray and brown (possibly caved from above). Only 6 in. recovered	138	7
Limestone, fossiliferous, slightly sandy, white. Only 6 in. recovered	144	3

7. Lithologic log of core from NW¼SE¼ sec. 13, T. 25 S., R. 21 E., Pasco County, originally line 17, hole 9

	Feet	Inches
Not cored	4	0
Sand, fine- to medium-grained, slightly clayey, dark reddish-brown	18	6
Sand, fine- to medium-grained, clayey, brown. Wavellitic concretions at 20 ft	22	4
Sand, fine- to medium-grained, clayey, mottled and banded brown and gray	30	5
Clay, very slightly sandy at top to very sandy at bottom, greenish-gray	48	0
Sand, fine-grained, very slightly clayey, light-gray	51	0
Sand, fine-grained, clayey, light greenish-gray	52	9
Clay, very slightly sandy to sandy; greenish-gray at top, white in middle, and brown and green at base. The white part gives strong phosphatic reaction to chemical test	61	0
Clay, slightly sandy to very sandy, brown and white. White material is strongly phosphatic and contains indurated, probably siliceous, fossiliferous concretions	67	0
Limestone, very slightly sandy, white, soft	67	11

8. Lithologic log of core from SW¼NE¼ sec. 19, T. 25 S., R. 22 E., Pasco County, originally line 17, hole 8

	Feet	Inches
Not cored	4	0
Sand, fine- to medium-grained, very slightly clayey, reddish-brown. Poor recovery	13	0
Sand, fine- to medium-grained, clayey, mottled tan and gray	21	0
Sand, fine-grained, very slightly clayey to clayey, white. Poor recovery between 26–32 ft., 56–64 ft	64	5
Sand, medium-grained, very clayey, brown; abundant wavellite-cemented concretions	65	5
Clay, very slightly sandy, yellowish-brown	71	5
Sand, fine- to medium-grained, very clayey, brown	73	0
Sand, fine-grained, clayey to very clayey, mottled gray and brown; some wavellite-cemented concretions. Poor recovery	91	6
Clay, very slightly sandy, yellowish-brown	92	2
Clay, sandy to very sandy, mottled brown and black	95	5
Phosphatic clay, slightly sandy, white; mostly apatite	96	3
Clay, slightly sandy, brown	99	0
Phosphatic clay, slightly sandy, partially cemented, hard, white; mostly apatite	100	0
Clay, very sandy, banded tan, gray, and white	101	0
Limestone, slightly sandy, clayey, mottled white and tan, soft	101	3

9. Lithologic log of core from SW¼SW¼ sec. 27, T. 25 S., R. 22 E., Pasco County, originally line 17, hole 7

	Feet	Inches
Not cored	4	0
Clay, very sandy, gray	7	0
Sand, fine- to medium-grained, clayey, gray and tan	10	0
No recovery	14	0
Limestone, partly silicified, white, fossiliferous	19	6

10. Stratigraphic section in a road cut in SW¼ sec. 35, T. 25 S., R. 22 E., Pasco County

	Feet
Hawthorn formation, sand unit:	
Sand, fine-grained, clayey, brown, massive	2
Hawthorn formation, phosphorite unit:	
Phosphatic sand, pebbly, clayey, gray, massive	4

11. Lithologic log of core from NW¼NW¼ sec. 1, T. 26 S., R. 22 E., Polk County, originally line 17, hole 6

	Feet	Inches
Not cored	4	0
Sand, medium-grained, clayey to very clayey, mottled gray and brown	6	10
Clay, sandy at top to very sandy at base; a few siliceous concretions	9	0
Sand, fine-grained, clayey at top to very clayey at base, greenish-gray; siliceous fossil fragments	12	6
Clay, slightly sandy, gray; upper contact gradational	15	3
No recovery	16	6
Sand, fine- to medium-grained, clayey	17	0
Limestone, white, soft, fossiliferous	26	4

12. Lithologic log of core from SW¼SW¼ sec. 8, T. 26 S., R. 23 E., Polk County, originally line 17, hole 5

	Feet	Inches
Not cored	4	0
Sand, medium-grained, very clayey, mottled gray and brown. Sparse nodules, possibly phosphorite but much weathered	6	0
Sand, fine- to coarse-grained, very clayey, white and greenish-gray; many hard concretionary aggregates of sand and white clay, noncalcareous, probably siliceous. A few poorly preserved siliceous fossils	9	6
Sand, medium-grained, slightly clayey, tan	10	2
No recovery	12	0
Sand, medium-grained, very clayey, greenish-gray	14	0
Clay, sandy to very sandy, greenish-brown. Siliceous concretions at 14 ft., also silicified invertebrate fossils	15	8
No recovery	17	0
Sand, fine-grained, slightly clayey to very slightly clayey, greenish-gray	19	4
Limestone, white, soft, fossiliferous, very slightly sandy	44	8

13. Stratigraphic section in a road cut in N½ sec. 21, T. 26 S., R. 23 E., Polk County

Hawthorn formation, sand unit:	Feet
Sand, fine-grained, gray, clayey; abundant fragments of silicified oyster shells (*Ostrea normalis?*)	3

14. Lithologic log of core from NE¼SW¼ sec. 27, T. 26 S., R. 23 E., Polk County, originally line 17, hole 4

	Feet	Inches
Not cored	4	0
No recovery	7	2
Sand, medium-grained, clayey, dark-gray	9	9
No recovery	12	0
Sand, medium-grained, clayey, bluish-gray	14	3
No recovery	15	8
Clay, very slightly sandy, blue to greenish-brown; much secondary silica	21	4
Sand, fine- to medium-grained, clayey to very clayey, greenish gray; abrupt lower contact	22	4
Clay, very slightly sandy, blue	23	0
No recovery	26	0
Clay, very slightly sandy to slightly sandy, blue. Chert at 28 ft.; chert looks like silicified limestone	28	0
No recovery	31	5
Clay, slightly sandy, bluish-green, large chert nodules, slightly calcareous	33	5

15. Lithologic log of core from NW¼SW¼ sec. 1, T. 27 S., R. 23 E., Polk County, originally line 17, hole 3

	Feet	Inches
Not cored	4	0
Sand, fine- to medium-grained, loose, tan; poor recovery	6	7
Sand, medium-grained, clayey, black at top; brown in middle, gray at base	20	0
No recovery	22	0

15. Lithologic log of core from NW¼SW¼ sec. 1, T. 27 S., R. 23 E., Polk County, originally line 17, hole 3—Continued

	Feet	Inches
Sand, medium-grained, clayey to very clayey, greenish-gray	23	0
Phosphatic sand, fine-grained to pebble-sized, very clayey especially at base, green. Clay increases downward. Quartz sand of fine grains, 50 percent. Clay, 30–40 percent. Phosphorite nodules of medium sand to pebble sizes, tan, 10–20 percent	29	0
Clay, sandy, slightly pebbly, green-clay content increases downward. Clay, 50–80 percent. Quartz sand of fine grains, 20–50 percent. Phosphorite nodules of sand to pebble sizes, tan, 5 percent	31	0
Clay, very slightly sandy at top to very sandy at base, green, trace of tan phosphorite nodules at top. Quartz sand of very fine grains	33	5
No recovery	35	0
Clay, very sandy, green. Quartz sand of very fine grains, almost 50 percent; trace of fine-grained phosphorite nodules at 37 ft	41	0
Clay, very slightly sandy, dark-green. Quartz sand of very fine grains. Black chert concretion at top	43	0
Sand, very fine- to fine-grained, very clayey, greenish-gray, slightly calcareous	43	9
Limestone, very slightly sandy, white, soft	43	11

16. Lithologic log of core from NE¼SW¼ sec. 18, T. 27 S., R. 24 E., Polk County, originally line 17, hole 2

	Feet	Inches
Not cored	5	0
Sand, medium-grained, light-brown, loose	8	0
Sand, medium-grained, slightly clayey to clayey, mottled light-brown and gray	9	0
No recovery	14	0
Sand, fine- to medium-grained, slightly clayey, mottled tan and gray	15	0
Sand, fine-grained, very slightly clayey to slightly clayey, gray. Poor recovery	21	0
Sand, fine-grained, very slightly clayey, mottled brown and gray. Poor recovery	27	0
Sand, fine-grained, very slightly clayey, mottled brown and gray. Fair recovery	34	0
Clay, brown at top, greenish-gray at base; trace of very fine grained sand in lower part	37	0
Phosphatic sand, medium- to coarse-grained, very clayey, greenish-gray. Both quartz and phosphorite nodules vary from medium to coarse sand sizes. Phosphorite nodules are tan	41	0
Clay, gray; sparse medium-grained sand composed of quartz and phosphorite nodules	43	0
Phosphatic sand, medium- to coarse-grained, clayey, brown. Quartz sand of medium to coarse grains, 70 percent. Clay, 20 percent. Phosphorite nodules of medium to coarse sand sizes, brown, 10 percent	43	10
No recovery	45	0

16. Lithologic log of core from NE¼SW¼ sec. 18, T. 27 S., R. 24 E., Polk County, originally line 17, hole 2—Continued

	Feet	Inches
Clay, sandy, pebbly, greenish-gray. Clay, 60 percent. Quartz sand of medium grains, 20 percent. Phosphorite nodules of medium sand to pebble sizes, dark-brown, tan, 20 percent	47	6
Phosphatic sand, medium- to very coarse-grained, very clayey, greenish-gray, slightly calcareous. Quartz sand of medium grains, 50 percent. Clay, 30 percent. Phosphorite nodules of medium to very coarse sand sizes, black, brown, 20 percent	48	6
Clay, very calcareous, very sandy, tan. Calcareous clay, 60 percent. Quartz sand of medium grains, 30 percent. Phosphorite nodules of medium to very coarse sand sizes, black, brown, 10 percent	52	0
Limestone, soft, very sandy, white. Limestone, 60 percent. Quartz sand of medium grains, 30 percent. Phosphorite nodules of medium to very coarse sand sizes, black, brown, 10 percent	52	10

17. Lithologic log of core from SE¼NW¼ sec. 31, T. 27 S., R. 24 E., Polk County, originally line 18, hole 1

	Feet	Inches
Not cored	4	0
Sand, fine-grained, tan to dark-brown	5	7
Sand, fine-grained, very slightly clayey, light-gray to white	12	10
No recovery	14	8
Same as at 12 ft. 10 in., but slightly grayer in color	15	10
Sand, medium-grained, slightly clayey, light grayish-brown	18	7
Sand, clayey, light-brown	23	0
Phosphatic sand, clayey, grayish-white; 5–10 percent light-brown and white phosphorite nodules of sand to pebble sizes	31	0
Clay, slightly sandy, slightly calcareous, mottled light- and dark-brown; 3–10 percent brown and white phosphorite nodules of fine sand to fine pebble sizes	36	1
No recovery	37	10
Same as at 31 ft.–36 ft. 1 in. with one highly calcareous layer from 38 ft.–39 ft. Phosphorite content quite variable	45	2

18. Stratigraphic section in Saddle Creek land-pebble phosphate mine, sec. 14, T. 28 S., R. 24 E., Polk County

	Feet
Surficial sand:	
Sand, massive, gray, loose; contains black organic material	4
Hawthorn formation, sand unit:	
Sand, clayey, massive, gray; weathered phosphorite nodules at base	6
Hawthorn formation, phosphorite unit:	
Phosphatic sand, clayey, pebbly, greenish-gray, massive to thin bedded	9
Hawthorn formation, limestone unit:	
Limestone, phosphatic, clayey, sandy, pebbly, massive, bluish-gray, soft	2
Tampa limestone(?), limestone unit:	
Limestone, slightly phosphatic, clayey, sandy, pebbly, thin-bedded, bluish-gray, hard, fragmental; numerous clay balls. Exposed	6

19. Stratigraphic section in Tenoroc land-pebble phosphate mine, sec. 35, T. 27 S., R. 24 E., Polk County

	Feet
Surficial sand:	
Sand, massive, gray, loose	1
Micaceous sand:	
Sand, medium-grained, massive, mottled brown and gray, slightly clayey	7
Sand, very fine-grained, massive, white, slightly clayey, micaceous	3
Clay, sandy, thin-bedded in part, gray, micaceous	3
Hawthorn formation, phosphorite unit:	
Phosphatic sand, fine- to massive-bedded, clayey, pebbly	9
Hawthorn formation(?), limestone unit:	
Limestone, clayey, sandy, pebbly, phosphatic, (not in place)	?
Tampa limestone, limestone unit:	
Limestone, massive, phosphatic, clayey, sandy, soft, yellow. Exposed	2

20. Lithologic log of core from NE¼ SE¼ sec. 11, T. 27 S., R. 24 E., Polk County, originally line 17, hole 1

	Feet	Inches
Not cored	5	0
Sand, medium- to coarse-grained, clayey, gray; red mottling at base	8	2
Sand, fine-grained, clayey at top to very clayey at base, mottled red and gray at top, gray at base	10	5
No recovery	12	0
Clay, sandy to very sandy, brown and gray	12	5
Sand, fine-grained, clayey to very clayey, gray	16	0
No recovery	19	0
Clay, very slightly sandy at top to slightly sandy at base, green and brown mottled. Slight nodular phosphorite and secondary phosphorite at 22–25 ft	25	0
Phosphatic sand, fine-grained to granule-sized, very clayey; clay especially abundant in upper part. Quartz sand of fine to medium grains, 60 percent; clay, 30 percent; phosphorite nodules of medium sand to granule sizes, tan, brown, 10 percent	28	0
Clay, sandy to very sandy, mottled green and brown; sparse phosphorite sand	33	0
Clay, calcareous, sandy, tan	33	3
Phosphatic sand, medium-grained, clayey, brownish-gray. Quartz sand of medium grains, 70 percent; clay, 20 percent; phosphorite of medium grains, tan, 10 percent	39	3
Phosphatic sand, medium-grained, clayey, brownish-gray, slightly calcareous. Quartz sand of medium grains, 60 percent; clay, 20 percent; phosphorite nodules of medium grain size, tan, 10 percent	39	4

21. Lithologic log of core from NE¼SW¼ sec. 5, T. 25 S., R. 25 E., Polk County, originally line 16, hole 5

	Feet	Inches
Not cored	4	0
Sand, fine- to very coarse-grained, slightly clayey, light-brown	6	9
Sand, fine- to coarse-grained, slightly clayey; sparse mica	12	11
Sand, fine- to medium-grained, slightly clayey; sparse mica; sparse heavy minerals	34	9
No recovery	35	5

21. Lithologic log of core from NE¼SW¼ sec. 5, T. 25 S., R. 25 E., Polk County, originally line 16, hole 5—Continued

	Feet	Inches
Clay, sparsely sandy, bluish-green	36	6
No recovery	39	2
Clay, sandy, light grayish-green, slightly calcareous; 5–10 percent black phosphorite nodules of fine sand to pebble sizes	42	5
Clay, sandy, calcareous, light gray-tan; sparse black phosphorite nodules of fine sand to granule sizes	44	1

22. Lithologic log of core from SW¼SW¼ sec. 7, T. 25 S., R. 25 E., Polk County, originally line 16, hole 4

	Feet	Inches
Not cored	4	0
No recovery	8	0
Sand, medium- to coarse-grained, tan	12	0
Sand, medium- to coarse-grained, clayey, brown at top, mottled reddish-brown and brown in lower part	33	4
Sand, coarse-grained, clayey, mottled pink and gray	38	5
Sand, medium-grained, clayey, tan	40	0
Sand, coarse-grained, slightly clayey, gray; poor recovery	44	0
Sand, medium- to coarse-grained, light pinkish-brown; poor recovery	57	0
No recovery	65	0
Sand, fine-grained, slightly clayey at top grading to very clayey at base; sparse mica in lower half, mottled brown and light-gray; a few quartz granules at base	74	5
Clay, sparse quartz sand, green	82	11
Sand, medium-grained, clayey, brown	87	0
Phosphatic sand, medium-grained, clayey at top to very clayey at base, greenish-gray. Quartz sand of medium grains, 60 percent. Phosphorite nodules of medium to coarse sand sizes, soft and white at top, tan at base, 5 percent	90	0
Clay, slightly sandy at top to very sandy at base, mottled greenish-brown and brown. Quartz sand is fine to medium grained	99	5
Clay, sparsely sandy, green	102	0
No recovery	106	0
Sand, medium-grained, very clayey, mottled brown and greenish-gray. Pocket of white material at 110 ft. 6 in. resembles phosphatic clay but might be cement used by driller to seal drill hole wall. Hole not drilled to bedrock	110	11

23. Lithologic log of core from NW¼NE¼ sec. 32, T. 25 S., R. 25 E., Polk County, originally line 16, hole 3

	Feet	Inches
Not cored	4	0
Sand, medium-grained at top to coarse-grained at base, clayey, mottled brown and gray at top, light-gray at base	11	0
Sand, fine- to medium-grained, clayey, white	13	0
Sand, coarse-grained, clayey, light-gray. Poor recovery	18	0
Sand, fine-grained, poorly sorted near top where some coarse grains occur. Light-gray; clayey sand at top to slightly clayey sand at base; traces of mica	35	6

23. Lithologic log of core from NW¼NE¼ sec. 32, T. 25 S., R. 25 E., Polk County, originally line 16, hole 3—Continued

	Feet	Inches
Phosphatic sand, medium- to coarse-grained, pebbly, clayey, medium-gray. Quartz sand of medium grains to granule size, 60 percent. Phosphorite nodules of medium grains to pebble size, brown and black, 20 percent. Clay, 20 percent	37	5
Clay, very slightly sandy, very slightly phosphatic, dark greenish-brown. Phosphorite nodules of medium sand size, brown, black, 5 percent. Quartz sand, 5 percent	39	0
Phosphatic sand, medium-grained, clayey, bluish- and greenish-gray. Quartz sand of fine to medium grains, 60 percent. Phosphorite nodules of medium to coarse sand sizes, tan, brown, black, 20 percent. Clay, 20 percent	39	5
Limestone, clayey, sandy, phosphatic, tan (some parts hard and free of sand). Quartz sand of fine to medium grains, 20 percent. Phosphorite nodules of medium to coarse sand sizes, tan, brown, black, 10 percent	40	0

24. Lithologic log of core from NW¼ sec. 21, T. 26 S., R. 25 E., Polk County, originally line 16, hole 2

	Feet	Inches
Not cored	4	0
No recovery	6	8
Sand, medium- to coarse-grained, brownish black owing to organic matter	10	5
Sand, coarse-grained, clayey, medium-gray at top to black at 14 ft	14	4
No recovery	16	10
Sand, medium-grained at top grading to coarse-grained at base, clayey, medium-gray	26	2
Sand, fine-grained, clayey, medium-gray, poorly sorted; mica, over 1 percent	29	5
Sand, very fine- to fine-grained, slightly clayey; about 1 percent mica in places, medium gray at top to light gray at base	50	7
Clay, very sandy, dark greenish-gray. Clay, 60 percent. Quartz sand of fine to coarse grains decreasing in abundance downward and increasing in grain size downward, 30 percent. Phosphorite nodules of medium sand to granule sizes, brown to tan, very light tan and soft at top, increasing in abundance and size downward, 5–10 percent	56	5
Clay, very sandy, dark-green, 60 percent. Quartz sand of fine grains, 30 percent. Phosphorite nodules of medium sand size, brown, 5–10 percent	59	10
No recovery	62	10
Limestone, soft, medium-gray; abundant fossil particles	68	1

25. Lithologic log of core from SW¼SW¼ sec. 21, T. 26 S., R. 25 E., Polk County, originally line 16, hole 1½

	Feet	Inches
Not cored	5	4
Sand, fine- to medium-grained, brown to black	14	3
Sand, medium- to coarse-grained, sparsely clayey, light-brown	39	0
Sand, fine- to medium-grained, slightly clayey, white to light-gray; bottom contact gradational for more than 1 ft	58	6

25. Lithologic log of core from SW¼SW¼ sec. 21, T. 26 S., R. 25 E., Polk County, originally line 16, hole 1½—Continued

	Feet	Inches
Phosphatic sand, clayey, slightly calcareous, dark-gray; 5–10 percent black and brown phosphorite nodules of fine sand to pebble sizes	71	7
Clay, very calcareous, light-gray	76	3

26. Lithologic log of core from SW¼ sec. 28, T. 26 S., R. 25 E., Polk County, originally line 16, hole 1

	Feet	Inches
Not cored	4	0
Sand, medium-grained, tan	11	0
Sand, medium-grained, clayey to very clayey, mottled reddish-brown and brown	16	0
No recovery	21	3
Sand, medium-grained, clayey (decreasing in clay content downward), mottled reddish-brown and white	28	5
No recovery	41	3
Sand, coarse-grained, slightly clayey, white	44	6
Sand, medium- to coarse-grained, slightly clayey, white	45	6
Sand, coarse- to very coarse-grained, very slightly clayey, white	47	6
Sand, fine- to medium-grained, slightly clayey, white	47	9
Sand, coarse- to very coarse-grained, slightly clayey, white	49	0
No recovery	54	3
Sand, medium- to coarse-grained, slightly clayey, white	55	4
No recovery	58	0
Sand, fine- to medium-grained, slightly clayey, white	59	0
No recovery	62	6
Sand, medium-grained, very slightly clayey, white	63	6
No recovery	74	10
Sand, fine-grained, very slightly clayey, white	76	3
No recovery	82	0
Clay, sandy, pebbly, greenish-gray; calcareous at base. Calcareous clay, 70 percent. Phosphorite nodules of sand, granule, and pebble sizes, tan to brown, 20 percent. Quartz sand of medium grains, 10 percent	85	0

27. Lithologic log of core from NW¼SW¼ sec. 6, T. 27 S., R. 25 E., Polk County, originally line 15, hole 1

	Feet	Inches
Not cored	8	10
Sand, fine- to medium-grained, clayey to very clayey in places, brown at top to tan at bottom; trace of muscovite	17	10
No recovery	18	11
Sand, fine- to medium-grained, graded bedding, thicknesses highly variable, slightly clayey in some beds to very clayey in others, tan; sparse muscovite; bottom contact gradational for more than 8 in.	24	6
Clay, very sandy (coarse to mostly fine grained), tan; abundant small clay pebbles—some partially phosphatized; 15–20 percent coarse-grained to mostly pebble-sized white phosphorite nodules (sparse, soft, mostly hard); bottom contact sharp	25	5

27. Lithologic log of core from NW¼SW¼ sec. 6, T. 27 S., R. 25 E., Polk County, originally line 15, hole 1—Continued

	Feet	Inches
Clay, sparsely sandy (fine grained), light-green, with abundant streaks and patches of light yellowish-brown; sparse fine-grained white phosphorite(?) nodules	28	4
No recovery	28	8
Phosphatic sand, clayey (40 percent), medium- to coarse-grained, brown and gray mottled. Quartz sand of medium grains; 20 percent phosphorite of medium to coarse sand sizes, tan, brown	29	4
Clay, slightly sandy, brown, calcareous; sparse phosphorite nodules of sand and granule sizes	31	3
No recovery	32	0
Clay, calcareous, sandy, brown, massive. Clay, 50 percent. Quartz sand of medium grains, 30 percent. Phosphorite nodules of medium sand to granule sizes, tan and brown, 20 percent	35	5
Limestone, sandy, tan, soft. Lime and clay, 30 percent. Phosphorite nodules of medium sand to granule sizes, tan, gray, 10 percent. Quartz sand of medium grains, 10 percent	36	6

28. Lithologic log of core from NE¼NE¼ sec. 8, T. 27 S., R. 25 E., Polk County, originally line 15, hole 2

	Feet	Inches
Not cored	5	0
Sand, loose, fine-grained, tan	6	5
Sand, clayey, 20 percent, fine-grained, brown	7	10
Sand, clayey, 20 percent, fine-grained, brown, indurated	8	0
Sand, clayey, 25 percent, fine-grained, grayish-brown	10	0
No recovery	13	0
Sand, fine-grained, white	16	6
No recovery	18	0
Sand, clayey, 5 percent, fine-grained, medium-gray	20	6
Sand, clayey, 5 percent, fine-grained, tan	23	0
Sand, clayey, 5–10 percent, fine- to medium-grained, tan	25	6
No recovery	27	0
Sand, clayey, 5 percent, fine- (grading downward) to very fine-grained, tan	29	0
Sand, clayey, 5 percent, medium- to coarse-grained, tan	32	0
Sand, clayey, 5 percent, fine- to medium-grained, gray	34	4
Sand, clayey, 5–15 percent, fine-grained, gray, trace of mica	40	0
Phosphatic sand, clayey 10 percent, greenish-gray; quartz sand of fine grains; phosphorite nodules of coarse sand to granule sizes, black and tan, 10 percent	42	6
Phosphatic sand, clayey 10 percent, gray, trace of mica; quartz sand of medium to coarse grains; phosphorite of coarse sand to granule sizes, black, 25 percent	45	7
Phosphatic sand, clayey, calcareous, greenish-gray; quartz sand of medium grains, 20 percent. Phosphorite nodules of coarse sand to granule sizes, black, 40 percent	47	0
Limestone, sandy, clayey, tan. Quartz sand of medium grains, 5 percent. Phosphorite nodules of coarse sand to granule sizes, black, 10 percent	47	7

29. Lithologic log of core from NW¼NW¼ sec. 3, T. 27 S., R. 25 E., Polk County, originally line 15, hole 3

	Feet	Inches
Not cored	10	0
Sand, clayey, medium- to coarse-grained; mottled brown clay, about 20 percent	16	8
Sand, clayey to very clayey, pink, medium- to coarse-grained at top grading downward to medium-grained. Clay increases downward from about 20 to about 30 percent	19	0
No recovery	22	0
Sand, clayey, medium- to very coarse-grained, banded and mottled pink and brown; clay content is 15–20 percent except at 23 ft. where it is about 30 percent; very coarse grained sand toward base	28	0
Sand, medium- to coarse-grained, clayey, white; sand grades from medium grained at top to coarse grained at base. Clay content is about 15–20 percent	31	5
Sand, medium- to coarse-grained, slightly clayey, white; trace of mica; sand grades from medium to coarse grained at top to medium grained at base; clay content is about 10–15 percent. No recovery between 33 ft. 1 in.–40 ft., 53–56 ft. 5 in	57	0
Phosphatic sand, medium- to very coarse-grained, some pebble-sized, very clayey, brown. Quartz sand of medium to coarse grains, 40–50 percent. Phosphorite nodules of medium sand to pebble sizes, but mostly of very coarse sand sizes, tan, brown, 10–20 percent	59	0
Clay, sandy, pebbly, brown, stiff. Quartz sand of medium to very coarse grains, 20 percent. Phosphorite nodules of medium sand to pebble sizes, brown, tan, 10 percent	60	5

30. Lithologic log of core from NE¼ sec. 12, T. 27 S., R. 25 E., Polk County, originally line 15, hole 4

	Feet	Inches
Not cored	10	0
Sand, clayey, coarse- to very coarse-grained, some quartz granules, reddish-brown, pink at about 29 ft. and brown below 31 ft. Grain size decreases somewhat in lower part	33	0
No recovery between 20–22 ft., 25 and 28 ft.		
Sand, clayey, medium- to coarse-grained; 2-in. bed of very coarse grains at 35 ft., grain size decreases downward, tan at top, gray at base, trace of mica	38	0
Sand, clayey, medium-grained, tan and gray; gradational contact above, sharp contact below. No recovery between 39–41 ft	42	0
Sand, clayey, medium- to very coarse-grained, brown; a few lenses of pure clay are a quarter of an inch thick	45	0
Sand, slightly clayey, coarse-grained, gray	46	0
Sand, medium- to fine-grained, clayey to very clayey, tan and gray banded and mottled. Medium-grained at top decreasing downward to fine-grained, clayey at top grading downward to very clayey, trace of mica	65	0

30. Lithologic log of core from NE¼ sec. 12, T. 27 S., R. 25 E., Polk County, originally line 15, hole 4—Continued

	Feet	Inches
Phosphatic sand, very clayey, brown; some gray clay lenses are a quarter of an inch thick at top. Quartz sand of medium to coarse grains, 4 percent; clay, 40 percent; phosphorite nodules of medium to very coarse sand sizes, but some granule and pebble sizes; nodules are tan at top of interval and brown at base, 20 percent	68	0
Phosphatic sand, very clayey, greenish-gray. Quartz sand of medium grains, 50 percent; translucent, greenish-gray, slightly calcareous clay, 40 percent; phosphorite nodules of medium to coarse sand sizes, tan and brown, 10 percent	72	6
Limestone, very sandy, clayey, soft, greenish-gray. Lime and clay, 60 percent. Quartz sand of medium grains, 30 percent. Phosphorite nodules of medium sand to granule sizes, brown, 10 percent	73	7

31. Lithologic log of core from SW¼SW¼ sec. 3, T. 27 S., R. 26 E., Polk County, originally line 15, hole 5

	Feet	Inches
Not cored	5	0
Sand, coarse- to very coarse-grained, clayey, mottled and banded with red, brown, gray	8	3
No recovery	11	0
Sand, coarse- to very coarse-grained, clayey, mottled with pink, brown, and gray	13	0
No recovery	14	0
Sand, coarse- to very coarse-grained, clayey, red	15	0
No recovery	19	5
Sand, fine-grained, slightly clayey to clayey, white	21	0
No recovery	26	0
Sand, medium- to very coarse-grained, clayey to slightly clayey, tan	28	5
Sand, fine- to medium-grained, sparsely coarse-grained especially at top, clayey, white; trace of mica	31	0
No recovery	32	5
Sand, medium- to very coarse-grained, slightly clayey to clayey, white	34	0
Sand, fine-grained, some coarse-grained (especially at top), clayey, white	42	4
No recovery	46	10
Sand, fine-grained, clayey, white	48	5
Sand, very fine- to fine-grained, clayey to very clayey, brown and tan banded; some lenses of silty clay are a quarter of an inch thick	52	0
Sand, very fine-grained, very clayey, brown and mottled and banded; trace of mica in places, especially near 53 ft.; clay, about 50 percent	55	4
Phosphatic sand, fine- to very coarse-grained (some quartz pebbles), very clayey, brown. Quartz sand and pebbles, about 40 percent. Clay, about 40 percent. Phosphorite nodules of sand and granule-sizes, 5–20 percent	57	0

31. Lithologic log of core from SW¼SW¼ sec. 3, T. 27 S., R. 26 E., Polk County, originally line 15, hole 5—Continued

	Feet	Inches
Phosphatic sand, fine-grained to granule-sized, clayey to very clayey, brown at top, tan at base. Quartz sand of fine to medium grains, about 60 percent. Clay, 30 percent. Phosphorite nodules of medium sand to granule sizes, brown, tan, 10–20 percent	63	0
Phosphatic sand, fine- to medium-grained, some coarse-grained to pebble-sized, clayey to very clayey, tan. Quartz sand of fine to medium grains, 60 percent. Clay, 35 percent. Phosphorite nodules of medium sand to pebble sizes, 5 percent	70	0
Phosphatic sand, medium-grained, clayey, calcareous; sparse phosphorite nodules, brown	72	0
Limestone, very soft at top, soft at base, clayey; some indistinct fossils, cream	76	7

32. Stratigraphic section of the micaceous sand in a drill hole, NE¼NW¼ sec. 7, T. 27 S., R. 27 E., Polk County

	Feet	Inches
Not cored (probably loose sand)	12	0
Micaceous sand, coarser grained unit:		
Quartz sand, medium-grained, silty and clayey (20 percent), gray, lower contact sharp	15	6
Clay, very sandy (fine to medium grained, 28–62 percent), gray to dark-green and brown	25	1
No recovery (probably sand)	27	0
Micaceous sand, finer-grained unit:		
Quartz sand, very fine- to fine-grained, silty and clayey (10–14 percent), white; coarsens at base and grades into unit below	54	0
Quartz sand, fine-grained, silty and clayey (11 percent), white; trace of mica	59	6
No recovery, probably sand	65	6
Quartz sand, very fine grained, sparse coarse grains, silty and clayey (14 percent), white; trace of mica	70	0
Quartz sand, fine-grained, some coarse grains, silty and clayey (10 percent), white at top to tan at base; sparse phosphorite nodules of coarse sand size; trace of mica	74	6
Quartz sand, very fine-grained, silty and clayey (20 percent), bluish-gray at top to green at base; sparse phosphorite nodules of fine to coarse sand size; trace of mica	83	0
Quartz sand, very fine-grained, silty and clayey (about 15 percent), green; sparse phosphorite nodules of fine to coarse sand size; trace of mica; abundant calcareous fossils	86	0
Hawthorn formation(?), limestone unit:		
Limestone, clayey, sandy, soft; carbonate and clay, about 75 percent; black phosphorite nodules of coarse sand size, about 20 percent; quartz sand of fine size, about 5 percent	86	7

33. Lithologic log of core from NE¼NE¼ sec. 20, T. 28 S., R. 25 E., Polk County, originally line 14, hole 1

	Feet	Inches
Not cored	10	4
Sand, fine- to medium-grained, slightly clayey, black owing to organic matter	13	0
Sand, fine- to medium-grained, clayey, brown, indurated; organic and iron hardpan	14	0
Sand, fine- to medium-grained, very clayey, medium-gray except brownish at top, plastic; sparse white granules, probably of apatite or clay	18	2
Sand, very fine- to fine-grained, slightly clayey, medium-gray, plastic	21	1
Sand, very fine- to fine-grained, very slightly clayey, light-gray	25	0
Sand, fine- to medium-grained, very slightly clayey, light-gray	29	9
No core recovery	35	1
Sand, medium- to coarse-grained, slightly clayey, light-gray, indurated; cemented with crystals of secondary phosphate	35	4
Sand, very fine- to fine-grained, very slightly clayey, white	40	9
Phosphatic sand, very fine- to fine-grained, clayey, white. Phosphorite nodules, 5–10 percent, soft, white and tan	42	0
Phosphatic sand, fine- to very coarse-grained, slightly clayey, brown. Quartz sand of fine to medium grains, 40 percent. Phosphorite nodules of medium to very coarse sand sizes, brown, 40 percent	44	0
Phosphatic sand, fine-grained to granule-sized, very clayey, yellowish-brown, calcareous. Quartz sand of fine to medium grains, 30 percent. Phosphorite nodules of medium to very coarse sand sizes, 30 percent, some granule sizes, white, tan, brown	49	6
Limestone, very sandy, tan, soft. Quartz sand of fine to medium grains, 15 percent. Phosphorite nodules of medium grains to granule size, tan, brown, 15 percent. Clay and carbonate, 70 percent. Phosphorite nodules and quartz sand are dispersed and also concentrated in pockets	51	4

34. Lithologic log of core from SE¼NE¼ sec. 21, T. 28 S., R. 25 E., Polk County, originally line 14, hole 2

	Feet	Inches
Not cored	8	2
Sand, fine- to medium-grained, slightly clayey, very dark-brown at top to brown at bottom	9	10
No recovery	10	4
Sand, fine-grained, clayey to very clayey, light grayish-brown; abundant lenses and patches of brown clay	14	4
No recovery	14	11
Sand, fine- to medium-grained, slightly clayey, brown, bottom contact gradational for more than 3 in	18	9
Sand, fine- to medium-grained, loose, no clay, light-brown and tan; bottom contact gradational for more than 2 in	22	10

34. Lithologic log of core from SE¼NE¼ sec. 21, T. 28 S., R. 25 E., Polk County, originally line 14, hole 2—Continued

	Feet	Inches
Sand, medium- to mostly fine-grained, slightly to very clayey in places, brown at top grading to light-tan at bottom, sugary-textured, somewhat leached	30	6
No recovery	31	3
Sand, fine- to coarse-grained with sparse quartz granules, slightly clayey in patches; sparse fine-grained black heavy minerals; bottom contact sharp	40	6
Sand, fine- to mostly very fine-grained, clayey, tan; sparse, fine-grained black heavy minerals; trace of muscovite; bottom contact gradational for more than 5 in	43	7
Phosphatic sand, fine- to coarse-grained with sparse quartz granules, very clayey, sparsely calcareous, tan to light-grayish tan; unit contains slightly abundant limey shale pebbles; 15–25 percent of coarse-grained to pebble-sized gray and mostly black phosphorite nodules	45	0
No recovery	45	8
Phosphatic sand, medium- to coarse-grained, very clayey, calcareous, dark grayish-brown; sparse limey shale pebbles—some partially phosphatized (black)—mostly at top of unit; sparse soft limestone (clayey), patches increase toward bottom; 25–35 percent of medium-grained to granule-sized brown and mostly black phosphorite nodules; bottom contact gradational for more than 8 in	49	4
Limestone, soft, sparsely sandy (fine grained), very clayey at top with lenses and patches, tan; 5–10 percent of fine-grained to fine pebble-sized black and mostly tan phosphorite nodules; percentage of phosphorite diminishes toward bottom of unit	51	2

35. Lithologic log of core from NE¼SE¼ sec. 22, T. 28 S., R. 25 E., Polk County, originally line 14, hole 3

	Feet	Inches
Not cored	10	0
Sand, medium-grained, clayey, brownish-gray	16	0
Sand, fine-grained at base and top, medium-grained between 20–50 ft., very slightly clayey, tan. No recovery between 27 ft. 5 in.–31 ft., 36–38 ft., 45–47 ft., 49–59 ft., 63–64 ft	64	0
Sand, fine-grained, very slightly clayey; trace of phosphorite nodules of medium sand size, tan; trace mica	65	7
Phosphatic sand, fine- to medium-grained, clayey, dark grayish-green. Quartz sand of fine grains. Phosphorite nodules of medium sand size, black 10 percent; sparse mica	69	0
Sand, fine-grained to granule-sized, very clayey, dark-green, calcareous at base; quartz sand of fine grains, 50 percent; phosphorite of medium sand to granule sizes, black, 20 percent	73	5
Limestone, very sandy, greenish-gray above to light-gray below. Quartz sand of fine to medium grains, 15 percent. Phosphorite nodules of medium to very coarse sand sizes, mostly black, 15 percent. Less sandy at bottom	75	7

36. Lithologic log of core from NW¼ sec. 25, T. 28 S., R. 25 E., Polk County, originally line 14, hole 4

	Feet	Inches
Not cored	10	10
Sand, fine to medium grained, clayey, alternating irregular thin bands of reddish brown, gray, white, and mostly yellowish brown; abundant fine- to medium-grained black heavy minerals	15	0
No recovery	17	1
Same as at 15 ft. but heavy minerals are less abundant	18	7
No recovery	19	1
Sand, medium- to coarse-grained, clayey, yellowish-brown to light-tan	20	4
No recovery	21	0
Sand, fine- to coarse-grained, poorly sorted, slightly clayey, light-tan; sparse streaks of yellowish-brown	27	3
No recovery	28	9
Sand, fine- to coarse-grained, clayey at top to slightly clayey at bottom, light yellowish-brown at top	35	7
No recovery	37	0
Sand, very fine- to very coarse-grained, graded bedding, slightly clayey in places, light grayish-white; some red and yellowish-brown mottling in top 2 ft.; trace of muscovite	49	2
No recovery	51	7
Sand, fine- to very coarse-grained, very poorly sorted, slightly clayey, white	53	2
No recovery	55	8
Sand, coarse- to very coarse-grained, sparse finer grained sizes, slightly clayey and faint bedding in places, white	59	6
No recovery	63	2
Sand, very fine- to fine-grained, slightly clayey at top to very clayey at bottom, white to light-tan; trace of muscovite; bottom contact sharp	68	2
Sand, very fine-grained, sparsely clayey, gray; sparse muscovite	68	5
No recovery	69	11
Clay, slightly sandy in places, gray; abundant irregular lenses of sand; medium-grained, sparse muscovite in clay and sand lenses; bottom contact gradational for more than 6 in	73	6
Phosphatic sand, medium-grained, clayey, dark greenish-gray; abundant scattered lenses of black greenish-gray clay; 1–3 percent of fine-grained to granule-sized black phosphorite nodules; bottom contact gradational for more than 12 in	76	5
Phosphatic sand, fine- to coarse-grained, clayey (patches and seams), gray; slightly abundant scattered small patches of clayey, slightly sandy, phosphatic limestone; 15–25 percent of fine-grained to fine pebble-sized black phosphorite nodules; bottom contact gradational for more than 8 in	81	3
Limestone, soft, very clayey, sandy (mostly fine grained), tan; 5–10 percent of fine-grained to granule-sized tan, brown, and mostly black phosphorite nodules	83	6

37. Lithologic log of core from NW¼SE¼ sec. 15, T. 28 S., R. 26 E., Polk County, originally line 14, hole 7

	Feet	Inches
Not cored	10	0
Clay, sandy (fine to medium grained), light grayish-tan	12	5
No recovery	13	2
Sand, fine- to medium-grained, sparse coarse-grained, very clayey at top to clayey at bottom, light-brown; faint graded bedding	15	6
No recovery	15	9
Sand, fine- to medium-grained, clayey, tan, indurated	15	11
Sand, fine- to coarse-grained (washed by drill water?), sparsely clayey, brown	17	1
Sand, very fine- to medium-grained, clayey, dark-brown to tan at bottom, sugary texture in bottom 3 in.; somewhat leached	17	9
No recovery	18	5
Sand, very fine- to fine-grained, sparse coarse-grained and granule-sized, clayey, tan, appears leached, faintly bedded in places. No recovery between 20 ft. 1 in.–20 ft. 7 in. and 24 ft. 7 in.–25 ft. 11 in	27	9
No recovery	41	3
Sand, very fine grained to sparse granule-sized, slightly clayey to clayey; all washed by drill water	44	2
No recovery	62	10
Sand, fine-grained, sparse medium- to coarse-grained, slightly clayey; trace fine-grained heavy minerals	67	11
No recovery	74	0
Sand, very fine- to fine-grained, slightly clayey, light-gray to tan, sparse muscovite towards bottom; bottom contact gradational for more than 8 in	77	6
Clay, sandy to very sandy, black with abundant patches and streaks of grayish-brown; abundant quartz granules and pebbles in top 6 in.; bottom contact sharp	81	1
Sand, fine- to medium-grained, slightly clayey, tan	81	10
No recovery	85	0
Sand, fine-grained, slightly clayey, light-tan; bottom contact gradational for more than 3 in	86	8
Sand, fine-grained, slightly clayey to very clayey at bottom, greenish-gray; sparse muscovite; bottom contact gradational for more than 6 in	89	0
Clay, very sandy (fine to medium grained), dark grayish-green, bottom contact sharp	89	11
Clay, slightly calcareous, very irregularly laminated; sparse small clayey limestone pebbles, some partially phosphatized; sparse black pebble-sized phosphorite nodules	91	1
Gravel, clayey limestone pebbles, some partially phosphatized; black phosphorite nodules of pebble size; very clayey, very sandy; top and bottom contacts sharp	91	3
Clay, very irregular, laminated, sparsely calcareous in places, gray streaked with black; bottom contact gradational for more than 3 in	93	5

37. Lithologic log of core from NW¼SE¼ sec. 15, T. 28 S., R. 26 E., Polk County, originally line 14, hole 7—Continued

	Feet	Inches
Clay, sandy, calcareous, gray and tan; abundant patches and lenses of clayey phosphatic limestone; abundant clayey limestone pebbles, some with black phosphatic coatings; 4–6 percent of medium-grained to pebble-sized brown and mostly black phosphorite nodules	97	0
Limestone, very clayey, slightly sandy, very fossiliferous (mollusks); abundant large indurated fragments; 6–8 percent of fine-grained to pebble-sized brown and black phosphorite nodules	97	10

38. Lithologic log of core from NW¼SE¼ sec. 14, T. 28 S., R. 26 E., Polk County, originally line 14, hole 8

	Feet	Inches
Not cored	10	0
No recovery	12	5
Sand, loose, fine- to medium-grained, tan	13	0
Sand, clayey, fine- to medium-grained, some coarse-grained especially near base; red, brown, and tan banding and mottling; clay, about 20–30 percent	36	0
No recovery	38	0
Sand, slightly clayey, fine- to medium-grained, white and pink mottling; clay, about 10 percent	43	5
No recovery	46	0
Sand, very slightly clayey, fine-grained, light-pink; clay, 5–10 percent	63	0
No recovery	70	0
Sand, very slightly clayey, very fine to fine-grained, white; clay, about 5–10 percent	85	0
Sand and silt, very clayey, brown. Quartz of silt- to very fine sand sizes; contact with overlying fine-grained sand is gradational for about 1 ft.; clay, more than 20 percent	97	0
Clay, silty and sandy, brown; contacts above and below gradational; trace of mica	97	5
Sand, very fine- to fine-grained, very clayey; brown clay more than 20 percent. Black chert nodules are 3 in. long at 100 ft	101	5
No recovery	104	5
Clay, sandy, pebbly, green; clay, 60 percent. Quartz sand of fine to medium grains, 20 percent; phosphorite of medium sand to pebble sizes, tan, gray, brown, 20 percent	107	0
Clay, sandy, green; clay, 75 percent; quartz sand of very fine to fine grains, 25 percent	107	5
Phosphatic sand, very clayey, bluish-gray. Quartz sand of very fine to medium grains, 50 percent. Clay, 30 percent, translucent. Phosphorite nodules of fine to medium grains, black, tan, brown, scattered pebbles, 20 percent	110	0
No recovery	115	0
Limestone, sandy, clayey, tan, soft. Quartz sand of fine to medium grains, 30 percent. Phosphorite nodules of medium to coarse sand sizes, tan, gray, brown, 10 percent; trace of marcasite or pyrite; small fossils	117	5

39. Lithologic log of core from SW¼SW¼ sec. 7, T. 30 S., R. 26 E., Polk County, originally line 13, hole 1

	Feet	Inches
Not cored	6	3
Sand, medium- to coarse-grained, sparsely clayey, brown	6	10
No recovery	9	7
Sand, fine- to medium-grained, loose, yellowish-tan; bottom contact gradational for more than 4 in	12	10
Sand, medium- to coarse-grained, clayey to very clayey; brown at top grading downward to mottled red and yellowish-brown; bottom contact gradational for more than 1 ft	18	2
Sand, fine- to coarse-grained, compact, very clayey, tan-streaked with white and yellowish-brown; bottom contact gradational for more than 10 in	29	11
Sand, fine-grained to granule-sized, clayey, slightly compact, mottled light-brown and cream, sugary texture in places; appears leached	36	11
No recovery	45	7
Sand, fine-grained to fine pebble-sized, very poorly sorted, slightly clayey, cream; contains very small patches of yellowish-brown clay; lower contact indefinite	48	2
Sand, medium- to mostly fine-grained; sparsely clayey, mottled light yellowish-brown and white	48	9
No recovery	57	0
Sand, fine-grained, slightly clayey, uniform yellowish-white at top to crudely thin banded, yellowish-brown and white at bottom; sparse black heavy minerals; bottom contact gradational for more than 8 in	62	11
Phosphatic sand, fine-grained to granule-sized, sparsely clayey to slightly clayey; irregular bands of clay are yellowish-brown; 35–60 percent of fine-grained sand to fine pebble-sized white, cream, gray, and brown phosphorite nodules (some soft); fine-grained heavy minerals at top; very slightly calcareous in bottom 3 ft.; bottom contact gradational for more than 8 in	73	7
Clay, very sandy (fine grained to granule sized); crudely bedded, yellowish-brown and gray clay, calcareous; 25–35 percent of fine sand to fine pebble-sized gray and tan phosphorite nodules; bottom contact sharp	74	7
Limestone, soft, slightly sandy, clayey, light-cream; 5–10 percent of medium-grained to fine pebble-sized tan, cream, and gray phosphorite nodules; hard limestone in bottom 2 in., same composition as above but with mollusk imprints	75	6

40. Lithologic log of core from NW¼NE¼ sec. 17, T. 30 S., R. 26 E., Polk County, originally line 13, hole 2

	Feet	Inches
Not cored	6	0
Sand, medium-grained to granule-sized, very clayey, light-gray; bottom contact gradational for more than 10 in	9	8
Sand, fine-grained, clayey, grayish-white	11	5
No recovery	16	1
Sand, very fine- to fine-grained, slightly clayey, grayish-white; trace of muscovite; bottom contact gradational for more than 10 in	25	8
Sand, very fine- to fine-grained, slightly clayey, light-gray; abundant thin lenses and patches of light-gray clay	25 29	8 2

40. Lithologic log of core from NW¼NE¼ sec. 17, T. 30 S., R. 26 E., Polk County, originally line 13, hole 2—Continued

	Feet	Inches
No recovery	31	0
Sand, mostly very fine-grained with sparse quartz granules that are very clayey, light greenish-gray; bottom contact gradational for more than 3 in	32	7
Clay, slightly sandy, mottled bluish-green and light-gray; 25–35 percent of medium sand to fine pebble-sized tan phosphorite nodules; bottom contact gradational for more than 2 in	33	10
Clay, sparsely sandy, brown with irregular lenses and patches of bluish-gray clay; 5 percent of fine to medium sand-sized tan phosphorite nodules; bottom contact gradational for more than 2 in	37	4
Clay, slightly sandy, slightly calcareous; mottled and streaked yellowish-brown and greenish-gray; 30–40 percent of medium sand to coarse pebble-sized tan phosphorite nodules, a few large phosphorite nodules have limestone centers; bottom contact obscured	38	10
Clay, sparsely sandy, calcareous, brown with abundant patches of bluish-gray clay; 5–10 percent of fine sand to medium pebble-sized tan phosphorite nodules; top 2 ft. contains sparse slightly phosphatized limestone fragments (mollusk imprints noted); bottom 1 ft. contains patches of soft limestone (slightly sandy with 5–10 percent of tan phosphorite nodules)	43	4
No recovery	44	9
Clay, slightly sandy, very calcareous, light grayish-brown; 5 percent of fine sand to granule-sized tan and cream phosphorite nodules; patches of soft limestone; bottom contact gradational for more than 6 in	46	0
Limestone, soft, sandy, clayey in places, light grayish-tan; 5–15 percent of fine sand to fine pebble-sized cream and mostly tan phosphorite nodules; sparse mollusk imprints	50	9

41. Lithologic log of core from NE¼NE¼ sec. 9, T. 30 S., R. 26 E., Polk County, originally line 13, hole 3

	Feet	Inches
No recovery	6	6
Sand, fine- to medium-grained, very clayey, light-gray, compact	7	6
No recovery	8	8
Sand, fine- to medium-grained, very clayey at top to slightly clayey at bottom, gray	9	6
No recovery	9	11
Sand, fine- to coarse-grained with sparse quartz granules, sparsely to slightly clayey in places, brown	22	3
No recovery	24	9
Sand, medium- to mostly coarse-grained, no clay (appears washed by drill water), mottled brown with some white	27	4
No recovery	31	0
Sand, medium- to mostly coarse-grained, sparsely to slightly clayey, tan	37	1
No recovery	49	5
Sand, fine- to mostly very fine-grained, slightly clayey at top grading to very clayey at bottom; trace to sparse muscovite in places; trace of fine-grained black heavy minerals	71	7

41. Lithologic log of core from NE¼NE¼ sec. 9, T. 30 S., R. 26 E., Polk County, originally line 13, hole 3—Continued

	Feet	Inches
No recovery	72	3
Sand, very fine- to fine-grained, slightly clayey with thin irregular lenses of silt and clay, dark greenish-gray to black; traces of muscovite and fine-grained black phosphorite(?) nodules; bottom contact gradational for more than 5 in	75	9
Phosphatic sand, fine- to medium-grained, (with sparse quartz granules), clayey, grayish-black streaked with dark greenish-brown; 30–45 percent of tan, gray, and mostly black fine sand to fine pebble-sized phosphorite nodules; bottom contact gradational for more than 4 in	77	0
Clay, very sandy in places, calcareous, grayish-black with streaks and patches of tan; small patches of soft tan limestone; sparse hard limestone pebbles of as much as 15 mm in diameter; abundant irregular lenses and beds containing 50–60 percent of fine sand to granule-sized mostly black phosphorite nodules	81	2
No recovery	81	7
Limestone, soft, sparsely sandy; abundant gray clay seams and patches in top 2 ft., gray at top grading to light tan at bottom; 5–10 percent of fine sand to fine pebble-sized tan and mostly black phosphorite nodules; phosphorite percentage decreases toward bottom	85	9

42. Lithologic log of core from NE¼SE¼ sec. 15, T. 30 S., R. 26 E., Polk County, originally line 13, hole 4

	Feet	Inches
Not cored	10	0
Sand, medium- to coarse-grained, loose, white streaks with yellowish-brown	10	8
No recovery	14	2
Sand, fine- to coarse-grained, very clayey, compact, light-brown	19	11
No recovery	23	10
Sand, fine- to medium-grained, coarse in places, clayey, compact, light-brown, sugary-textured; some aluminum phosphate(?) cementing material; top 2 in. indurated	30	7
No recovery	33	2
Sand, medium- to sparse coarse-grained, clayey, compact, tan, sugary-textured	35	4
No recovery	37	0
Same as at 35 ft. 4 in	39	0
No recovery	39	7
Sand, medium- to coarse-grained, slightly clayey, light-tan; bottom contact gradational for more than 3 in	42	3
Sand, very fine- to fine-grained, clayey, cream	44	0
No recovery	44	10
Same as at 44 ft	46	6
No recovery	52	1
Sand, very fine- to fine-grained, clayey at top to very clayey at bottom, cream, sparse fine to medium sand-sized muscovite in places	65	6
No recovery	66	3

42. Lithologic log of core from NE¼SE¼ sec. 15, T. 30 S., R. 26 E., Polk County, originally line 13, hole 4—Continued

	Feet	Inches
Sand, very fine-grained, very clayey, light-tan, sparse fine to medium sand-sized muscovite; bottom contact sharp, appears leached	70	0
Sand, fine- to medium-grained, clayey, irregularly laminated brown and grayish-black; lenses and small patches of brown clay mostly in bottom 1 ft.; bottom contact gradational for more than 6 in	75	0
Phosphatic sand, same as above but with about 5 percent of fine sand to fine pebble-sized black phosphorite nodules and small patches of brown soft clayey limestone; fragment of marcasite at 75 ft. contains black phosphorite nodules	76	0
Phosphatic sand, medium-grained, slightly clayey to clayey in places, slightly calcareous, dark grayish-black; fragments of moderately indurated tan phosphatic limestone; 30–45 percent of fine sand to fine pebble-sized tan and mostly black phosphorite nodules	81	6
No recovery	91	1
Limestone, soft, sandy (fine to coarse grained), grayish-brown; angular fragments of hard brown limestone	94	3

43. Lithologic log of core from NW¼SE ¼sec. 13, T. 30 S., R. 26 E., Polk County, originally line 13, hole 5

	Feet	Inches
Not cored	12	4
Sand, fine- to medium-grained, sparsely clayey, light yellowish-brown	12	10
No recovery	13	6
Sand, fine- to medium-grained, slightly clayey at top to clayey at bottom, yellowish-brown; bottom contact gradational for more than 4 in	14	0
Sand, fine- to medium-grained, clayey to very clayey, very compact, mottled and streaked yellowish-brown, grayish-white, and red	20	4
No recovery	20	11
Same as at 20 ft. 4 in. but colors less intense toward bottom	29	2
No recovery	29	9
Sand, medium- to mostly fine-grained, clayey, light yellowish-brown at top to white at bottom, reddish-brown streaks scattered throughout unit	34	4
No recovery	40	8
Sand, fine- to medium-grained, clayey, white with thin streaks of light yellowish-brown	42	6
No recovery	43	8
Sand, fine- to medium-grained, clayey, white; sparse muscovite	49	3
No recovery	51	2
Same as at 49 ft. 3 in. but mostly fine grained	54	2
No recovery	55	0
Sand, very fine- to fine-grained, clayey, white; fine to coarse sand-sized muscovite, sparse at top and more abundant at bottom	59	11
No recovery	61	9
Sand, very fine- to fine-grained, clayey, white; sparse muscovite throughout unit	64	10
No recovery	65	6
Sand, very fine-grained, clayey, white; sparse muscovite	70	6
No recovery	70	10

43. Lithologic log of core from NW¼SE¼ sec. 13, T. 30 S., R. 26 E., Polk County, originally line 13, hole 5—Continued

	Feet	Inches
Sand, fine-grained, clayey to very clayey, yellowish-brown; abundant streaks and seams of red and grayish-white; sparse muscovite; bottom contact gradational for more than 6 in	72	4
Clay, very sandy (fine grained), gray with abundant closely spaced thin streaks of red and yellowish-brown; sparse muscovite; bottom contact sharp	73	9
Clay, slightly sandy at top to very sandy at bottom, fine-grained, black; sparse mica; bottom contact gradational for more than 10 in	80	10
Phosphatic sand, fine- to medium-grained, clayey, sparsely calcareous at top to calcareous at bottom, dark greenish-black; sparse mica; 4–6 percent of coarse-grained to mostly pebble-sized black phosphorite nodules; bottom 2 ft. contains patches of soft limestone (sandy with 5–10 percent of fine sand to pebble-sized black phosphorite nodules); bottom contact gradational for more than 3 in	84	8
Limestone, soft, slightly sandy, clayey, gray; 10–20 percent of fine sand to pebble-sized tan, cream, and mostly black phosphorite nodules; hard fragments and pebbles of limestone; top 2 in. is well indurated, partially silicified and contains mollusk molds with drusy quartz coatings	85	10

44. Lithologic log of core from SE¼NW¼ sec. 18, T. 30 S., R. 27 E., Polk County, originally line 13, hole 6

	Feet	Inches
Not cored	10	8
Sand, fine- to medium-grained, slightly clayey, brownish-black; iron-stained hardpan layer; bottom contact gradational for more than 3 in	11	1
Sand fine- to medium-grained, clayey, dark-brown; patches of brown clay in top half of unit; bottom 2 ft. appears washed by drill water	15	9
Clay, sandy to very sandy (fine to mostly coarse grained), brown; 1-in. hardpan layer of black clayey sand at bottom of unit	17	9
No recovery	19	0
Sand, medium-grained, sparse coarse-grained, clayey in patches, brown with black streaks	20	2
Sand, medium-grained, sparse coarse-grained and granule-sized, sparsely clayey, light-brown; appears washed by drill water	22	5
Sand, medium- to coarse-grained, very clayey, light-brown, sugary-textured; appears leached	23	10
No recovery	24	6
Sand, coarse-grained to granule-sized, clayey, sugary-textured, light-brown; graded bedding; bottom contact sharp	25	6
Sand, bedded (mostly fine-grained beds with some thin beds of medium grain to granule sizes), clayey to very clayey, light-tan; slight muscovite in places; appears leached	30	0
No recovery	31	0
Sand, washed by drill water, medium-grained, slightly clayey, tan	33	0
No recovery	33	9

44. Lithologic log of core from SE¼NW¼ sec. 18, T. 30 S., R. 27 E., Polk County, originally line 13, hole 6—Continued

	Feet	Inches
Sand, medium- to coarse-grained, slightly clayey, faint graded bedding, light grayish-tan, sugary-textured; appears leached	35	8
No recovery	38	10
Sand, very fine- to fine-grained, clayey, cream; slight muscovite in places	44	5
No recovery	47	5
Sand, very fine-grained, clayey to very clayey in places, grayish-white; sparse to slight muscovite; sparse fine sand-sized heavy minerals; bottom contact sharp	56	2
Sand, very fine-grained, clayey, yellowish-brown; sparse muscovite; bottom 1 in. is tan but same composition; bottom contact sharp	56	11
Clay, slightly sandy in places, dark-green to black; sparse muscovite; patches and lenses of fine-grained sand. Bottom 1 ft. contains 1–5 percent of coarse sand to pebble-sized black phosphorite nodules; bottom contact gradational for more than 4 in	67	4
Clay, slightly sandy, slightly calcareous, greenish-gray; abundant patches of soft, clayey phosphatic tan limestone; sparse pebbles; one hard limestone pebble has partial coating of black phosphate at 69 ft. 6 in.; unit contains 4–8 percent of fine sand to mostly pebble-sized black phosphorite nodules	71	7
No recovery	72	4
Clay, sandy, calcareous, mottled gray and tan; scattered patches and lenses of sand and very abundant patches of soft tan phosphatic limestone; 5–10 percent of fine sand to pebble-sized black phosphorite nodules	81	5

45. Lithologic log of core from SW¼SW¼ sec. 29, T. 30 S., R. 27 E., Polk County, originally line 13, hole 7

	Feet	Inches
Not cored	10	7
Sand, fine- to mostly coarse-grained, clayey to very clayey, tan; faint graded bedding	19	11
No recovery	22	4
Sand, medium-grained to granule-sized, brown (no clay, washed by drill water)	24	8
No recovery	28	2
Sand, fine-grained to sparse granule-sized, sparsely clayey but has been washed by drill water, light-brown; bottom 2 in. not washed, clayey; shows graded bedding from coarse-grained at top to fine-grained at bottom	30	5
No recovery	41	7
Sand, very fine- to fine-grained, clayey, light-tan; sparse to slight muscovite; trace of fine sand-sized black heavy minerals; washed by drill water	50	5
No recovery	51	8
Sand, very fine- to fine-grained, clayey, grayish-tan; sparse muscovite; abundant lenses and patches of brown micaceous clay; bottom contact sharp	54	6
Clay, sandy (fine grained), dark greenish-gray; patches and seams of fine-grained black micaceous sand	55	4
No recovery	56	2

45. Lithologic log of core from SW¼SW¼ sec. 29, T. 30 S., R. 27 E., Polk County, originally line 13, hole 7—Continued

	Feet	Inches
Clay, slightly to very sandy in places; sparse muscovite, dark greenish-gray; bottom contact gradational for more than 3 in	76	10
Sand, medium-grained to granule-sized, clayey, slightly calcareous, dark-gray; abundant patches and streaks of light-tan soft phosphatic limestone; 20–40 percent of fine sand to pebble-sized black phosphorite nodules	78	10
No recovery (bottom was hard rock)	80	8

46. Lithologic log of core from NE¼SE¼ sec. 28, T. 30 S., R. 27 E., Polk County, originally line 13, hole 8

	Feet	Inches
Not cored	10	7
Sand, fine- to medium-grained, clayey to very clayey, light-brown; thin horizontal dark-brown seams	11	11
No recovery	13	6
Sand, fine-grained to granule-sized, slightly to very clayey, brown; graded bedding throughout; fine-grained beds at top to coarse-grained at bottom	17	6
No recovery	19	10
Sand, fine-grained, slight very coarse grains, intermediate sizes subordinate, clayey, light-tan, sugary-textured; appears very much leached	21	3
No recovery	25	9
Sand, fine-grained to granule-sized, slightly clayey to clayey, tan, graded bedding	28	3
No recovery	30	4
Sand, fine-grained, sparse coarse-grained and granule-sized, (not clayey but washed by drill water), mottled tan and white	33	3
No recovery	34	3
Sand, fine- to medium-grained, light-tan and white	35	8
No recovery	40	0
Sand, fine- to medium-grained, sparsely clayey, light-tan; sparse white patches	43	7
No recovery	58	9
Sand, fine- to very coarse-grained, slightly clayey, greenish-brown; sparse muscovite; trace of black phosphorite nodules; bottom contact sharp	59	6
Sand, fine-grained, slightly clayey, gray; sparse muscovite	60	0
No recovery	61	9
Sand, fine- to medium-grained, sparsely clayey, washed by drill water, light-gray; sparse muscovite	65	4
No recovery	69	1
Sand, very fine- to fine-grained, slightly clayey at top to clayey at bottom, greenish-gray; sparse muscovite; trace of black phosphorite nodules in bottom 18 in., varied appearance from 71 ft. 4 in.–72 ft. 4 in.; (alternating light and dark layers are a quarter of an inch thick)	75	7
No recovery	76	0
Clay, very sandy (fine grained), dark greenish-gray; sparse muscovite; sparse fine sand to pebble-sized black phosphorite nodules; bottom contact gradational for more than 2 in	79	10

46. Lithologic log of core from NE¼SE¼ sec. 28, T. 30 S., R. 27 E., Polk County, originally line 13, hole 8—Continued

	Feet	Inches
Clay, sandy, dark greenish-gray; abundant clear quartz pebbles (some flat); small patches of tan clayey limestone; 20–40 percent of fine sand to mostly pebble-sized black phosphorite nodules; bottom contact gradational for more than 3 in	80	8
Clay, very sandy (fine grained), greenish-gray; sparse quartz pebbles; 4–8 percent of fine sand to pebble-sized black phosphorite nodules; bottom contact sharp	83	2
Limestone, soft, clayey, sparsely sandy (fine grained), light grayish-tan; irregular thin lenses containing 8–10 percent of fine to coarse sand-sized black phosphorite nodules	83	11

47. Lithologic log of core from SW¼NW¼ sec. 33, T. 32 S., R. 25 E., Polk County, originally line 10, hole 3

	Feet	Inches
Not cored	6	2
Sand, fine- to medium-grained, clayey, light-tan with thin seams and stringers of yellowish-brown and white	7	4
No recovery	9	0
Same as at 7 ft. 4 in. with bottom 3 ft. slightly coarser-grained and less clayey	19	3
No recovery	20	8
Sand, medium- to coarse-grained, sparsely clayey to clayey, cream to light-tan; lower contact gradational for more than 18 in	27	6
Phosphatic sand, medium-grained to granule-sized, clayey, light-gray; 20 percent of medium sand to mostly pebble-sized (as much as 20 mm in diameter) tan and cream phosphorite nodules; lower contact gradational for more than 2 in	28	5
Phosphatic sand, medium- to coarse-grained, slightly to very clayey, gray with thin yellowish-brown seams; alternating lenses and graded thin beds of greenish-gray clay and highly phosphatic, slightly clayey sand; 25–35 percent of fine to coarse sand-sized tan, brown, cream, and black phosphorite nodules; bottom contact gradational for more than 6 in	32	10
Phosphatic sand, fine- to coarse-grained, brown; highly phosphatic lenses alternating with calcareous brown and greenish-gray clay lenses; 30–45 percent of fine sand to pebble-sized brown, tan, and cream phosphorite nodules; bottom contact sharp	37	0
Limestone, soft, slightly sandy with sparse clay patches mottled light yellowish-tan and white; abundant pelecypod imprints; 5 percent of fine to coarse sand-sized brown phosphorite nodules	38	3

48. Lithologic log of core from SE¼ sec. 22, T. 32 S., R. 25 E., Polk County, originally line 10, hole 2B

	Feet	Inches
Not cored	5	0
Poor recovery, 3 in. at top is clay, 3 in. at base is sand	7	1
Clay, sandy (fine grained), dark-brown; basal contact gradational	8	3
Sand, medium- to coarse-grained, clayey to slightly clayey, grayish-tan; trace of phosphorite particles in basal 6 in.; lower contact gradational	9	7

48. Lithologic log of core from SE¼ sec. 22, T. 32 S., R. 25 E., Polk County, originally line 10, hole 2B—Continued

	Feet	Inches
Phosphatic sand, slightly clayey, medium-grained, crude bedded, light yellowish-tan with very thin green clay lenses (horizontal); 25–35 percent of phosphorite nodules of fine to coarse sand sizes, tan, cream, and brown, some of pebble sizes; basal contact gradational for more than 3 in	11	6
Phosphatic sand, clayey; lenses of light bluish-green clay; more than 25 percent of tan and cream phosphorite nodules and black pebbles	12	8
No recovery	13	7
No recovery	17	2
No recovery except 1 in. or less of limestone at base	17	8

49. Lithologic log of core from SW¼NE¼ sec. 36, T. 31 S., R. 25 E., Polk County, originally line 12, hole 1

	Feet	Inches
Not cored	6	0
Sand, very fine-grained, very clayey, light-brown; abundant indurated lumps of vesicular sandstone in top 5 in	7	4
No recovery	8	3
Sand, fine- to medium-grained, slightly clayey to clayey, light-tan, appears somewhat leached	11	0
Phosphatic sand, fine-grained, sparse coarse-grained, very clayey, cream; 10–15 percent of white coarse-grained phosphorite nodules with sparse fine-grained black phosphorite nodules; bottom contact sharp	12	1
Clay bed, cream with thin streaks of yellowish-brown; bottom contact sharp	12	10
Phosphatic sand, medium- to coarse-grained, very clayey, cream and yellowish-brown, crudely banded; 15–25 percent of fine sand to mostly granule-sized cream and mostly tan phosphorite nodules	19	0
No recovery	20	2
Clay, very slightly sandy, mottled and banded white and yellowish-brown; scattered moderately indurated fragments of white claystone; 20–40 percent of fine sand to pebble-sized cream and tan phosphorite nodules	24	0
No recovery	25	3
Same as at 24 ft. with marked decrease in phosphorite nodules in bottom 18 in	29	4
No recovery	30	7
Clay, slightly sandy, mottled white and yellowish-brown; slightly abundant indurated fragments of sand, clay and phosphorite; slightly calcareous at bottom; 5–15 percent of fine sand to pebble-sized cream and tan phosphorite nodules	32	5
Limestone, soft, abundant hard fragments (mottled white and yellowish brown), clayey, sparsely sandy, fossiliferous (pelecypods); 3–5 percent of fine sand to fine pebble-sized tan phosphorite nodules	33	1

50. Lithologic log of core from SW¼SW¼ sec. 32, T. 31 S., R. 26 E., Polk County, originally line 12, hole 2

	Feet	Inches
Not cored	6	0
Sand, medium-grained, sparse coarse-grained, light-brown	8	0
No recovery	8	6
Sand, medium- to coarse-grained, clayey at top to very clayey at bottom (sugary textured throughout), light-tan; abundant aluminum phosphate; top 6 in. contains abundant indurated vesicular lumps cemented with aluminum phosphate; bottom 2 in. contains small lumps of white claystone; bottom contact gradational for more than 4 in	17	3
Phosphatic sand, medium-grained, very clayey, mottled and crudely banded light-gray and light greenish-brown; 5–10 percent of fine sand to granule-sized white, tan, and black phosphorite nodules; bottom contact gradational for more than 8 in	19	10
Phosphatic sand, fine- to medium-grained, clayey to very clayey, slightly calcareous, light grayish-tan; abundant beds, lenses, and patches of light greenish-gray clay; 10–15 percent of fine sand to fine pebble-sized cream, brown, and tan phosphorite nodules	21	10
Phosphatic sand, medium-grained, clayey, slightly calcareous, laminated, grayish-brown; 40–60 percent of medium to coarse sand-sized brown phosphorite nodules at top decreasing gradually towards bottom to 5–10 percent; abundant laminated light greenish-brown clay with thin seams of fine sand containing very fine- to fine-grained brown phosphorite nodules in bottom 6 in	23	10
No recovery	25	0
Clay, calcareous, crudely laminated, light greenish-brown with horizontal yellowish-brown streaks; abundant lenses and thin seams of fine-grained sand, which includes 40–60 percent of fine-grained, mostly brown phosphorite nodules; bottom contact gradational for more than 8 in	26	6
Limestone, soft very clayey, slightly sandy (fine grained), mottled light-gray and yellowish-brown; sparse fine to medium sand-sized phosphorite nodules at top gradually increasing downward to 30–40 percent of fine sand to granule-sized brown phosphorite nodules	31	0

51. Lithologic log of core from SW¼SW¼ sec. 33, T. 31 S., R. 26 E., Polk County, originally line 12, hole 3

	Feet	Inches
Not cored	5	5
Sand, medium- to coarse-grained, sparsely clayey, brown; scattered lumps of slightly vesicular hardpan	6	10
No recovery	8	2
Sand, fine-grained to granule-sized, sugary-textured, tan, sparsely clayey; quartz pebbles; scattered slightly indurated small lumps cemented with aluminum phosphate(?)	12	7
No recovery	15	11
Sand, fine- to medium-grained, sparsely clayey in places, white; bottom contact gradational for more than 3 in	27	5
Sand, fine- to medium-grained, sparsely clayey at top to slightly clayey at bottom, yellowish-brown	32	10

51. Lithologic log of core from SW¼SW¼ sec. 33, T. 31 S., R. 26 E., Polk County, originally line 12, hole 3—Continued

	Feet	Inches
No recovery	33	5
Clay, slightly sandy, yellowish-brown mottled and streaked white, black, and cream; abundant irregular lenses of white friable kaolinite(?); sparse coarse sand to fine pebble-sized soft, white phosphorite nodules; unit appears to have undergone long weathering	36	9
No recovery	38	2
Clay, sandy, crudely laminated, light-brown; very abundant irregular lenses and seams of fine sand to granule-sized cream and reddish-orange phosphorite nodules; 15–25 percent of total phosphorite nodules in unit; bottom contact gradational for more than 8 in	40	7
Limestone, soft, clayey, sparsely sandy, light-tan; 3–5 percent of very fine sand-sized tan phosphorite nodules	43	1

52. Lithologic log of core from SW¼SW¼ sec. 34, T. 31 S., R. 26 E., Polk County, originally line 12, hole 4

	Feet	Inches
Not cored	7	0
Sand, medium-grained, sparsely clayey, brown; sparse fine-grained black, heavy minerals	9	8
No recovery	12	9
Same as at 9 ft. 8 in.; bottom contact gradational for more than 6 in.	14	6
Sand, fine- to coarse-grained, clayey to very clayey, mottled red, brown, and gray	28	8
No recovery	32	2
Sand, medium-grained, slightly clayey in places, brown at top to tan at bottom; bottom contact gradational for more than 18 in	42	0
Sand, fine- to medium-grained, sparsely clayey to slightly clayey, yellowish-brown; bottom 1 ft. contains sparse very slightly indurated sand lumps cemented with aluminum phosphate; bottom contact gradational for more than 1 ft	49	0
Sand, fine- to medium-grained, sparsely clayey, mottled yellowish-brown and tan; sparse small patches of black organic(?) material	57	0
No recovery	58	3
Same as at 57 ft	60	7
No recovery	62	3
Same as at 57 ft	63	3
No recovery	66	9
Sand, fine- to medium-grained, trace of clay (appears washed by drill water), mottled tan and yellowish-brown; trace of fine sand-sized black phosphorite(?) nodules	67	8
No recovery	79	0
Sand, fine- to medium-grained, light-brown; no clay; trace of fine sand-sized black phosphorite nodules	79	4
No recovery	85	2
Same as at 79 ft. 4 in. but with sparse clay	86	5
No recovery	89	10

52. Lithologic log of core from SW¼SW¼ sec. 34, T. 31 S., R. 26 E., Polk County, originaily line 12, hole 4—Continued

	Feet	Inches
Phosphatic sand, medium-grained to granule-sized, very clayey, yellowish-brown; claystone fragments (phosphorite grains within fragments); 10–20 percent of coarse sand to fine pebble-sized gray and cream phosphorite nodules	91	4
Phosphatic sand, medium- to coarse-grained, clayey to very clayey, mottled and irregularly streaked yellowish-brown and gray, calcareous, crudely bedded; 20–30 percent of medium sand to granule-sized black and mostly cream phosphorite nodules; bottom of unit contains a sparsely sandy, 2-in. claystone bed with 4–6 percent of fine- to medium-grained cream and tan phosphorite nodules	97	0
Clay, calcareous, very sparsely sandy (coarse grained), light grayish-brown, abundant streaks of yellowish-brown; 5 percent of fine sand to granule-sized cream and mostly tan phosphorite nodules	99	1

53. Lithologic log of core from NW¼NE¼ sec. 31, T. 31 S., R. 27 E., Polk County, originally line 12, hole 6

	Feet	Inches
Not cored	8	6
Sand, fine- to medium-grained, loose, brown	9	3
No recovery	10	3
Sand, fine-grained, sparsely clayey at top to slightly clayey at bottom, brown at top to tan at bottom; abundant organic material at 10 ft. 11 in.–12 ft.; hardpan lumps from 12 ft. 6 in.–14 ft. 3 in.; bottom contact gradational for more than 1 ft	18	2
Sand, fine- to medium-grained, slightly clayey to clayey, light grayish-tan; sparse fine-grained black heavy minerals	41	5
No recovery	42	7
Sand, fine-grained, slightly clayey, mottled light-gray and tan	44	9
No recovery	49	0
Sand, fine-grained, slightly clayey, cream	50	1
No recovery	53	4
Sand, fine-grained, clayey, mottled light yellowish-brown and cream	53	6
No recovery	55	0
Same as at 53 ft. 6 in	55	4
No recovery	56	11
Sand, fine- to medium-grained, slightly clayey to clayey, cream	59	7
No recovery	62	7
Sand, fine-grained, sparse coarse-grained, compact, clayey, cream	63	7
No recovery	67	10
Sand, fine-grained, clayey to very clayey, cream; from 71 ft. 2 in.–71 ft. 8 in. very clayey; sparse quartz granules mottled brown and light-gray	73	1
No recovery	75	4
Sand, fine-grained, compact, clayey, light-gray; sparse quartz granules	75	7
No recovery	80	0
Same as at 75 ft. 7 in	81	0
No recovery	82	5

53. Lithologic log of core from NW¼NE¼ sec. 31, T. 31 S., R. 27 E., Polk County, originally line 12, hole 6—Continued

	Feet	Inches
Sand, very fine- to fine-grained, slightly clayey to clayey, light-tan; sparse fine to medium sand-sized muscovite; bottom contact gradational for more than 6 in	89	4
Sand, fine-grained, sparse coarse-grained, clayey, grayish-brown; medium sand-sized muscovite; bottom contact sharp	92	2
Clay, slightly sandy in places (very fine grained), very dark greenish-gray at top to grayish-black at bottom; sparse fine to medium sand-sized muscovite; clay contains abundant beds, lenses, and patches of sand; fine-grained, gray, sparse muscovite; sparse fine to coarse sand-sized black phosphorite nodules in bottom 18 in. mostly in the sand lenses; bottom contact gradational for more than 6 in	101	4
Gravel, slightly sandy, very clayey, very calcareous, grayish-tan; rounded pebbles with black phosphatic exterior coating, interior composed of hardpan limestone containing tan phosphorite grains; angular fragments of hard fossiliferous (mollusks) phosphatic limestone; 10–15 percent of coarse sand to medium pebble-sized tan and black phosphorite nodules; probably conglomerate at top of Hawthorn	103	5

54. Lithologic log of core from NE¼SW¼ sec. 33, T. 31 S., R. 27 E., Polk County, originally line 12, hole 8

	Feet	Inches
Not cored	5	9
Sand, fine- to medium-grained, very clayey, light-tan with thin streaks of yellowish-brown	7	6
No recovery	8	6
Sand, fine- to medium-grained, very clayey, light-tan; trace of muscovite	9	10
No recovery	11	0
Same as at 9 ft. 10 in	12	3
No recovery	13	8
Sand, fine- to medium-grained, very clayey, light-tan, sugary-textured; aluminum phosphate(?) in places	15	6
Sand, fine- to very coarse-grained, very clayey, light-tan; alternating lenses of coarse- and fine-grained sand	17	2
No recovery	18	0
Sand, fine- to medium-grained, clayey, light-tan; appears somewhat leached in places; trace of muscovite	22	9
No recovery	23	4
Sand, fine- to medium-grained, clayey, light-tan; abundant patches of finer grained material, slightly darker in color and with sugary texture, appears somewhat leached; trace to sparse muscovite	30	2
No recovery	39	1
Sand, fine-grained, gray, clayey, light-tan at top to grayish-tan at bottom; sparse muscovite; bottom contact gradational for more than 8 in	50	9

54. Lithologic log of core from NE¼SW¼ sec. 33, T. 31 S., R. 27 E., Polk County, originally line 12, hole 8—Continued

	Feet	Inches
Phosphatic sand, mostly fine-grained, sparse medium-grained to small pebble-sized (some pebbles are quartz), clayey, grayish-tan; abundant irregular beds, lenses, and patches of grayish-green clay; sparse muscovite; 15–25 percent of mostly granule-sized tan and mostly black phosphorite nodules (variably distributed); bottom contact gradational for more than 3 in	59	9
Clay, sandy (very fine grained), calcareous, dark greenish-gray; scattered irregular lenses and seams of fine-grained sand containing sparse muscovite and fine sand-sized black phosphorite nodules; bottom contact gradational for more than 1 ft	64	11
Clay, very sandy (very fine grained), very calcareous, dark greenish-gray, abundant pelecypod shells and shell fragments (whole paper-thin shells average about 10 mm in length); trace of muscovite; 1–2 percent of fine sand to granule-sized black phosphorite nodules; bottom contact sharp	70	1
Limestone, hard, sparsely sandy, light grayish-tan, very fossiliferous, mollusks and Foraminifera(?), slightly porous. Bottom of unit is soft and very clayey with sparse small hard limestone fragments; trace of black phosphorite nodules	71	2
No recovery	72	4
Limestone, soft, very clayey in places, cream with patches of light-gray; abundant lumps of compact but friable limestone of granular texture; trace of black phosphorite nodules	74	6

55. Lithologic log of core from NW¼NW¼ sec. 1, T. 34 S., R. 25 E., Hardee County, originally line 11, hole 1

	Feet	Inches
Not cored	5	5
Sand, medium-grained, clayey, tan	6	8
No recovery	9	1
Sand, medium-grained, clayey, very compact, light greenish-gray with thin, closely spaced, wavy, horizontal, dark brown streaks	10	4
No recovery	11	5
Same as at 10 ft, 4 in.; bottom contact sharp	12	4
Clay, bluish-green; bottom contact sharp	13	4
Limestone, clayey, fossiliferous, tan; top 12 in. contains very soft limestone, rest of unit contains abundant large and small fragments of hard fossiliferous limestone. Many fragments are porous, fossils mostly pelecypods; 5 percent of fine pebble-sized and mostly granule-sized black phosphorite nodules	17	0

56. Lithologic log of core from SW¼SE¼ sec. 31, T. 33 S., R. 26 E., Hardee County, originally line 11, hole 2

	Feet	Inches
Not cored	5	5
Sand, fine-grained, sparsely clayey, black at top to dark brown at bottom; lower contact gradational for more than 12 in	8	0
Sand, fine-grained, sparse medium- to coarse-grained, slightly clayey to clayey in places, dark brown at top to light brown at bottom	13	3
No recovery	14	7

56. Lithologic log of core from SW¼SE¼ sec. 31, T. 33 S., R. 26 E., Hardee County, originally line 11, hole 2—Continued

	Feet	Inches
Same as at 13 ft. 3 in. with abundant indurated lumps; bottom contact gradational for more than 3 in	15	9
Sand, fine- to coarse-grained, slightly clayey in top 2 ft. (but portion of unit below 2 ft. appears washed by drill water), light-tan, indurated vesicular fragments in bottom 3 ft	21	2
Sand, fine- to medium-grained, clayey, light grayish-tan; indurated, slightly vesicular fragments cemented with aluminum phosphate(?). Within unit are zones 5–20 in. thick, some are very clayey, others contain only a trace of clay (some washing by drill water is possible); indurated vesicular fragments are distributed irregularly but diminishing from top to bottom; bottom contact gradational for more than 2 ft	32	0
Sand, medium-grained, slightly clayey, light tan; bottom contact gradational for more than 5 in	39	3
Phosphatic sand, medium- to coarse-grained and granule-sized (some granules are quartz), clayey, grayish-green; 10–15 percent of mostly granule-sized black phosphorite nodules, but some fine sand and pebble sizes also	41	10
Shale, slightly calcareous, tan; 1 in. clayey phosphatic sand lens (same as at 41 ft. 10 in.); sharp contact between shale and phosphatic lens	42	8
No recovery	44	0
Clay, slightly calcareous, tan, small partially indurated lumps; one greenish-gray clay patch with sandy center; black phosphorite grains at top of unit	46	8
Limestone, hard, shaly, very sparsely sandy, fossiliferous, light-tan, slightly porous; pores are mostly molds of Foraminifera; sparse mollusk imprints; 3 percent of mostly granule-sized black phosphorite nodules; very sparse small shark teeth	51	7
Limestone, hard, slightly sandy, light-tan; 2–3 percent of fine-grained black phosphorite nodules. Poor recovery	51	8

57. Lithologic log of core from SE¼NW¼ sec. 4, T. 34 S., R. 26 E., Hardee County, originally line 11, hole 3

	Feet	Inches
Not cored	5	0
Sand, fine-grained, dark brownish-black, iron-stained; probably abundant organic material; contact gradational for more than 8 in	6	10
Sand, fine-grained, sparsely clayey, brown; lower contact gradational for more than 4 in.; hardpan layer between 7 ft. 6 in.–8 ft	8	10
Sand, fine- to medium-grained, sparse coarse-grained, clayey to to very clayey, light greenish-gray; lower contact gradational for more than 6 in	21	4
Phosphatic sand, fine- to coarse-grained, very clayey, light grayish-tan; 4–6 percent of fine sand to fine pebble-sized, soft, weathered, cream and white phosphorite nodules	24	5
No recovery	25	0
Sand, fine- to medium-grained, slightly clayey, tan; trace of cream phosphorite nodules	26	11
No recovery	28	0

57. Lithologic log of core from SE¼NW¼ sec. 4, T. 34 S., R. 26 E., Hardee County, originally line 11, hole 3—Continued

	Feet	Inches
Same as at 26 ft. 11 in	28	5
No recovery	31	3
Phosphatic sand, fine- to medium-grained, slightly clayey to clayey, light-tan at top to light greenish-gray at bottom; 2–5 percent of mostly fine to coarse sand-sized cream and black phosphorite nodules; gradation from cream-colored phosphorite nodules at top to black at bottom; percentage of phosphorite nodules gradually increases from top to bottom; bottom contact gradational for more than 1½ ft	39	8
Phosphatic sand, slightly clayey to sparsely clayey, medium-grained, gray; 15-20 percent of mostly fine- to coarse sand-sized black phosphorite nodules; bottom contact sharp	47	3
Clay, calcareous, slightly sandy at top to very sandy (fine grained) at bottom; 20–30 percent of mostly fine pebble and finer sized tan and mostly black phosphorite nodules	51	5
Limestone, soft, very clayey, slightly sandy (fine grained), light grayish-brown; 10 percent of granule and fine sand-sized (intermediate grain size conspicuously lacking) black phosphorite nodules	53	10

58. Lithologic log of core from SW¼SE¼ sec. 34, T. 33 S., R. 26 E., Hardee County, originally line 11, hole 4

	Feet	Inches
Not cored	5	7
Sand, fine-grained, sparsely clayey, brownish-black at top to dark-brown at bottom; bottom contact gradational for more than 2 in.	8	9
Sand, fine- to medium-grained, sparse coarse-grained, clayey to very clayey, light grayish-tan; slightly leached appearance	15	1
No recovery	16	2
Same as at 15 ft. 1 in	19	7
No recovery	20	8
Phosphatic sand, fine- to coarse-grained (grades downward from finer to coarser sizes), clayey at top to slightly clayey at bottom, light-tan; trace to 2 percent of granule and finer sized cream phosphorite nodules	42	4
No recovery	43	4
Sand, coarse-grained, very sparsely clayey, light-tan; trace of black, gray, and cream, fine- to coarse sand-sized phosphorite nodules	45	8
No recovery	50	4
Sand, medium- to coarse-grained, very sparsely clayey, appears washed by drill water; 25–35 percent of granule and finer sized black phosphorite nodules; bottom contact probably gradational for more than several inches (uncertain because of washed condition)	51	9
Limestone, very soft, very clayey, slightly sandy, green grayish-tan with top 1 ft. more clayey and weathered; 10–20 percent of fine pebble and finer sized tan, brown, and cream phosphorite nodules; faint pelecypod shell fragment imprint noted at 55 ft	56	5

59. Lithologic log of core from NE¼SE¼ sec. 35, T. 33 S., R. 26 E., Hardee County, originally line 11, hole 5

	Feet	Inches
Not cored	5	0
Sand, fine-grained, sparse coarse-grained, sparsely clayey, light orange-brown; bottom contact gradational for more than 3 in	5	2
Clay, very sandy (fine grained), light-tan; abundant, sparsely vesicular, clayey sand lenses; bottom 7 in. is crudely laminated and contains thin irregular reddish- and yellowish-brown streaks with sparse small indurated vesicular lumps of clayey sand	7	10
Clay, sparsely sandy, light-gray; bottom contact sharp	9	4
Sand, fine-grained, sparsely clayey, light-tan; bottom contact gradational for more than 4 in	15	5
Sand, clayey at top to sparsely clayey at bottom, fine- to medium-grained, light grayish-tan; abundant indurated fragments of vesicular sandstone cemented with aluminum phosphate(?)	17	4
No recovery	18	9
Sand, medium-grained, sparsely clayey in places, grayish-white	29	8
No recovery	31	0
Sand, medium-grained, very sparsely clayey, grayish-white; trace at top to about 1 percent at bottom of mostly fine sand-sized black, tan, and cream phosphorite nodules; contact completely gradational	36	0
Phosphatic sand, medium-grained, sparsely clayey to slightly clayey at bottom, light-gray; granule and finer sized cream, tan, and mostly black phosphorite nodules, 1 percent at top to 8 percent at bottom	41	2
No recovery	44	0
Phosphatic sand, medium- to coarse-grained, sparsely clayey, gray; 8–10 percent of fine sand to granule-sized black phosphorite nodules	45	7
No recovery	47	2
Phosphatic sand, coarse-grained to granule-sized, slightly clayey, dark-gray; 10–15 percent of fine pebble to mostly fine sand-sized black phosphorite nodules; bottom contact exceptionally sharp	48	10
Limestone, hard, very fossiliferous, light-tan; *pecten* imprints and minute gastropods(?); trace of fine-grained black phosphorite nodules	52	0

60. Lithologic log of core from NE¼SE¼ sec. 31, T. 33 S., R. 27 E., Hardee County, originally line 11, hole 6

	Feet	Inches
Not cored	7	6
Sand, fine-grained, white	7	8
No recovery	8	6
Same as at 7 ft. 8 in., with light yellowish-brown mottling	8	7
No recovery	9	5
Same as at 8 ft. 7 in	9	6
No recovery	11	2
Sand, fine-grained, sparsely clayey, black at top to brown at bottom of unit; abundant organic material and iron staining; bottom contact gradational for more than 10 in	12	9

60. Lithologic log of core from NE¼SE¼ sec. 31, T. 33 S., R. 27 E., Hardee County, originally line 11, hole 6—Continued

	Feet	Inches
Sand, fine- to medium-grained, sparse coarse-grained, clayey to very clayey, light grayish-tan	19	8
No recovery	21	8
Sand, fine- to medium-grained, very sparsely clayey, washed by drill water, cream; small (5–10 mm in diameter), well indurated clay(?) lumps in bottom 1 ft.; bottom contact gradational for more than 2 in	24	9
Clay, crudely laminated, light-gray; trace of fine-grained sand; abundant clayey fine-grained sand lenses and beds that have widely variant thicknesses	29	9
No recovery	30	1
Sand, medium-grained, clayey, light greenish-gray	32	4
No recovery	32	9
Same as 32 ft. 4 in., except 1-in. thick light-green clay bed	33	3
Sand, fine- to coarse-grained, sparsely clayey, apparently washed by drill water, grayish-white, in places streaked yellowish-brown in top 2 ft.; bottom 1 ft. becomes clayey with a trace of tan and black phosphorite nodules	48	3
No recovery	51	2
Phosphatic sand, medium- to coarse-grained, clayey, gray; sparse coarse sand-sized black phosphorite nodules	54	0
Phosphatic sand, medium-grained, clayey, light greenish-gray; abundant lenses and patches of green clay, lenses and small patches of white sand; trace to 3 percent of fine- to coarse-grained black and tan phosphorite nodules mostly within the sandy lenses; bottom contact gradational for more than 12 in	58	8
Clay, sparsely sandy, dark greenish-gray; abundant irregular medium-grained sand lenses which contain 5–10 percent of fine- to coarse-grained black phosphorite nodules; both clay and sand lenses contain sparse fine-grained white mica	61	0
No recovery	62	0
Same as at 61 ft	65	0
No recovery	66	6
Phosphatic sand, coarse-grained, very sparsely clayey, dark grayish-black; 10–15 percent of coarse sand to granule-sized black phosphorite nodules; a 7-in. dark greenish-black clay bed containing sparse white mica lies between 69 ft. 5 in.–70 ft	70	2
No recovery	70	10
Phosphatic sand, medium- to coarse-grained, clayey to very clayey, dark-gray; 10–15 percent of pebble and finer sized black phosphorite nodules; bottom contact sharp in color change but gradational in composition for more than 4 in	71	10
Limestone, hard, very fossiliferous, slightly sandy, very clayey, grayish-tan in places; abundant pelecypods; 5 percent of mostly granule-sized black phosphorite nodules	73	3

61. Lithologic log of core from NW¼SE¼ sec. 32, T. 33 S., R. 27 E., Hardee County, originally line 11, hole 7

	Feet	Inches
Not cored	2	6
Clay, very sandy, calcareous, light greenish-gray and yellowish-brown; abundant irregular lenses and patches of very calcareous clay and fine clayey sand; hard fragments of tan limestone; trace of black phosphorite at 5 ft. 10 in	7	10
No recovery	13	7
Sand, fine- to medium-grained, clayey to very clayey, dark greenish-gray and grayish-tan, faintly banded; trace of cream phosphorite at top, slightly increasing toward bottom; bottom contact gradational for more than 10 in	21	9
Phosphatic sand, fine- to coarse-grained, slightly clayey with sparse thin seams of green clay; 4–8 percent of fine-grained to granule-sized tan, cream, and mostly black phosphorite nodules. Bottom 1 ft. of section contains alternating lenses of green clay and fine-grained sand with sparse fine-grained black phosphorite nodules and trace of white mica; lower contact gradational for more than 3 in	34	10
Phosphatic sand, medium- to coarse-grained, slightly clayey, light brownish-gray, faintly bedded with alternating layers of greater and lesser amounts of clay; 5–10 percent of mostly fine-grained to pebble-sized black phosphorite nodules; bottom contact gradational for more than 2 in	49	11
Phosphatic sand, medium- to coarse-grained, slightly clayey to very clayey in places, calcareous, dark greenish-gray; sparse quartz granules; bottom 2 ft. contains 2 clay beds that are 2 in. thick; 15–25 percent of fine sand to coarse pebble-sized (diameters, more than 1 in.) black phosphorite nodules; sparse coarse pebbles are 10–15 mm in diameter at 51 ft. 8 in	56	1

62. Lithologic log of core from SE¼ sec. 33, T. 33 S., R. 27 E., Hardee County, originally line 11, hole 8

	Feet	Inches
Not cored	7	0
Sand, fine-grained, light-tan; bottom contact gradational for more than 1 in	9	0
Sand, fine-grained, mottled and crudely banded light-gray and light yellowish-brown	11	10
No recovery	12	2
Sand, very fine grained, sparsely to slightly clayey, light-tan; bottom contact gradational for more than 2 in	14	10
Sand, fine- to coarse-grained; sparse quartz granules, clayey with small streaks of white kaolin; bottom contact gradational for more than 2 in.; trace of cream phosphorite nodules	16	8
Sand, fine- to coarse-grained, slightly clayey, irregularly streaked light reddish-brown, yellowish-brown, and grayish-white (more permeability than overlying and underlying beds may account for strong color staining)	17	11
Clay, light-gray; abundant sand and clayey sand lenses; trace of fine to medium sand-sized black phosphorite nodules in sand lenses; bottom contact gradational for more than 5 in	20	9

62. Lithologic log of core from SE¼ sec. 33, T. 33 S., R. 27 E., Hardee County, originally line 11, hole 8—Continued

	Feet	Inches
Sand, fine- to medium-grained, light-gray, clayey to very clayey at bottom; abundant indurated lumps of sandstone	25	8
Sandstone, well-indurated, fine- to coarse-grained, light-gray; sparse quartz granules; rock contains scattered small worm tubes or burrows 1–2 mm in diameter, 4–8 mm in length	27	0
Sand, fine- to medium-grained, sparsely clayey, mottled yellowish-brown and grayish-white	28	8
No recovery	29	4
Same as at 28 ft. 8 in	31	0
Sand, fine- to medium-grained, light-gray; no clay but appears washed by drill water	34	0
No recovery	35	5
Same as at 34 ft. but sparsely clayey	37	7
No recovery	38	3
Sand, fine- to medium-grained, slightly clayey, cream	40	5
No recovery	45	5
Sand, fine-grained, slightly clayey, cream	49	2
No recovery	51	0
Same as at 49 ft. 2 in	55	6
No recovery	59	1
Sand, medium- to coarse-grained, slightly clayey, light grayish-tan; trace phosphorite nodules in bottom	64	2
No recovery	65	6
Phosphatic sand, medium-grained, slightly clayey, light grayish-tan; 1–3 percent of medium to coarse sand-sized black, tan, and cream phosphorite nodules; bottom contact sharp	70	2
Phosphatic sand, clayey to very clayey, very dark-gray; abundant beds, lenses, and patches of clay are very dark greenish gray; sparse fine-grained muscovite in both clay and sand; sandy material contains 4–6 percent of fine-grained to granule-sized black phosphorite nodules; bottom contact sharp	75	0
Clay, slightly sandy, slightly calcareous, tan with horizontal gray streaks; faint irregular bedding planes; top 3 in. moderately indurated; 2–4 percent of fine- to coarse-grained black phosphorite nodules; bottom contact gradational for more than 4 in	77	0
Limestone, sparsely sandy, clayey, light grayish-tan; top 6 in. soft, friable below; 2–4 percent of medium sand to granule-sized black phosphorite nodules	78	1

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