Economic Geology of the Chicora Quadrangle Florida

GEOLOGICAL SURVEY BULLETIN 1162-A

Prepared on behalf of the U.S. Atomic Energy Commission

Economic Geology of the Chicora Quadrangle Florida

By JAMES B. CATHCART

CONTRIBUTIONS TO ECONOMIC GEOLOGY

GEOLOGICAL SURVEY BULLETIN 1162-A

Prepared on behalf of the
U.S. Atomic Energy Commission

A study of the phosphate deposits of the southern part of the land-pebble phosphate district of Florida

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1963

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402

CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

TABLES

ECONOMIC GEOLOGY OF THE CHICORA QUADRANGLE, FLORIDA

By James B. Cathcart

ABSTRACT

The Chicora quadrangle, in west-central peninsular Florida, is within the southern part, and at the western edge of, the land-pebble phosphate district. The quadrangle is covered by a blanket of loose quartz sand of Quaternary age. Older formations do not crop out in the quadrangle, and their geology is known only from drilling.

All holes drilled in the quadrangle bottomed in limestone or clastic material of the Hawthorn Formation of middle Miocene age. This formation consists of limestone or dolomite and residual calcareous clay overlain by interbedded and lenticular clastic rocks—clay, sandy clay, clayey sand, and sand. Clastic rocks of the Hawthorn Formation are present only in the southwestern part of the quadrangle. They range in thickness from 0 to almost 70 feet, and thicken to the south. Only small isolated patches, probably outliers, are present elsewhere in the quadrangle.

Phosphate nodules occur in minable amounts only in the residual calcareous clay. In the hard limestone and in the upper part they are usually too sparse and too low in P_2O_5 content to be of economic value; in all three units the phosphate nodules are dominantly fine grained.

The Bone Valley Formation of middle Pliocene age unconformably overlies the Hawthorn Formation. The Bone Valley is divided into a lower phosphorite unit and an upper, slightly clayey sand unit.

The lower unit of the Bone Valley Formation consists chiefly of quartz and phosphate sand but includes minor quantities of clay; clay is most common in the unit in the northern part of the quadrangle. The phosphate is usually black and coarse grained; the ratio of coarse to fine phosphate nodules is almost always greater than 1. A conglomerate of coarse black phosphate, tan phosphatized limestone granules, and rounded phosphatized bone fragments commonly rests on the limestone, residual clay, or clastic unit of the Hawthorn Formation. The phosphate particles in the lower unit are medium to low in phosphate content, and the phosphate content tends to diminish southward. The lower unit ranges in thickness from 0 to about 40 feet, and its greatest thickness coincides with depressions on the Hawthorn surface.

The upper unit of the Bone Valley Formation is a uniformly gray and tan gray, slightly clayey sand containing minor amounts of phosphate nodules. It ranges

in thickness from 0 to more than 30 feet, and gradationally overlies the lower unit.

Loose, well-sorted quartz sands of Pleistocene and Recent ages overlie the Bone Valley. The contact is not exposed and contact relations are uncertain. The sand ranges from about 10 to about 50 feet in thickness.

Details of the structure in the Chicora quadrangle could not be mapped. But, basically, the structure is simple: The beds dip toward the south at a few feet per mile.

Three periods of intense weathering have altered the rocks of the quadrangle. Weathering altered the limestone of the Hawthorn Formation and produced a karst topography on the surface of the Hawthorn. Soluble carbonates were removed, leaving a residuum enriched in phosphate and quartz. The upper clastic part of the formation was eroded from the northern part of the quadrangle prior to the deposition of the Bone Valley. The erosion products were reworked into the base of the Bone Valley Formation.

After the deposition of the Bone Valley Formation, a period of intense lateritic weathering changed the calcium phosphate mineral (apatite) in the upper unit and in the top part of the lower unit to aluminum phosphate minerals. Montmorillonite, the characteristic clay mineral of the Bone Valley Formation, was changed to kaolinite. The alteration was not noted in the formation in the southwestern part of the quadrangle, probably because this area was not exposed to subaerial weathering.

A third period of weathering, after the deposition of the loose surficial sand, formed a ground-water podzol in this sand and in the underlying clayey sand of the Bone Valley Formation.

The economic phosphate deposits are in the calcium phosphate zone. The zone consists of unconsolidated sedimentary rocks, characterized by abundant rounded particles of carbonate fluorapatite, and includes both the lower unit of the Bone Valley Formation, and calcareous clay, residual from the Hawthorn Formation. Most of the reserves of recoverable phosphate nodules are in the Bone Valley Formation; they total about 134 million long tons of phosphate and 16,000 tons of uranium in the one-third of the quadrangle that has been prospected.

A potential resource of phosphate, uranium, and alumina occurs in the aluminum phosphate zone, the zone produced by the intense lateritic weathering. A total of about 200 million long tons of aluminum phosphate rock, in beds more than 3 feet thick, is available in the quadrangle. This rock may contain about 4 percent P_2O_5 and 0.006 percent uranium.

Data are insufficient to compute the reserves in the Hawthorn Formation, but phosphate nodules in the formation probably total billions of tons.

INTRODUCTION

The Chicora quadrangle is in west-central peninsular Florida between lat 27°30′ and 27°45′ N., and long 82°00′ and 82°15′ W., (fig. 1). It includes parts of southern Hillsborough, southwestern Polk, northern Manatee, and northwestern Hardee Counties.

The topography of the quadrangle is flat; elevations range from about 50 feet in the western part of the quadrangle to 145 feet above sea level in the central and eastern parts of the quadrangle (fig. 2). The maximum elevation of 145 feet is in a small area at the eastern edge of the quadrangle in T. 32 S., R. 23 E.

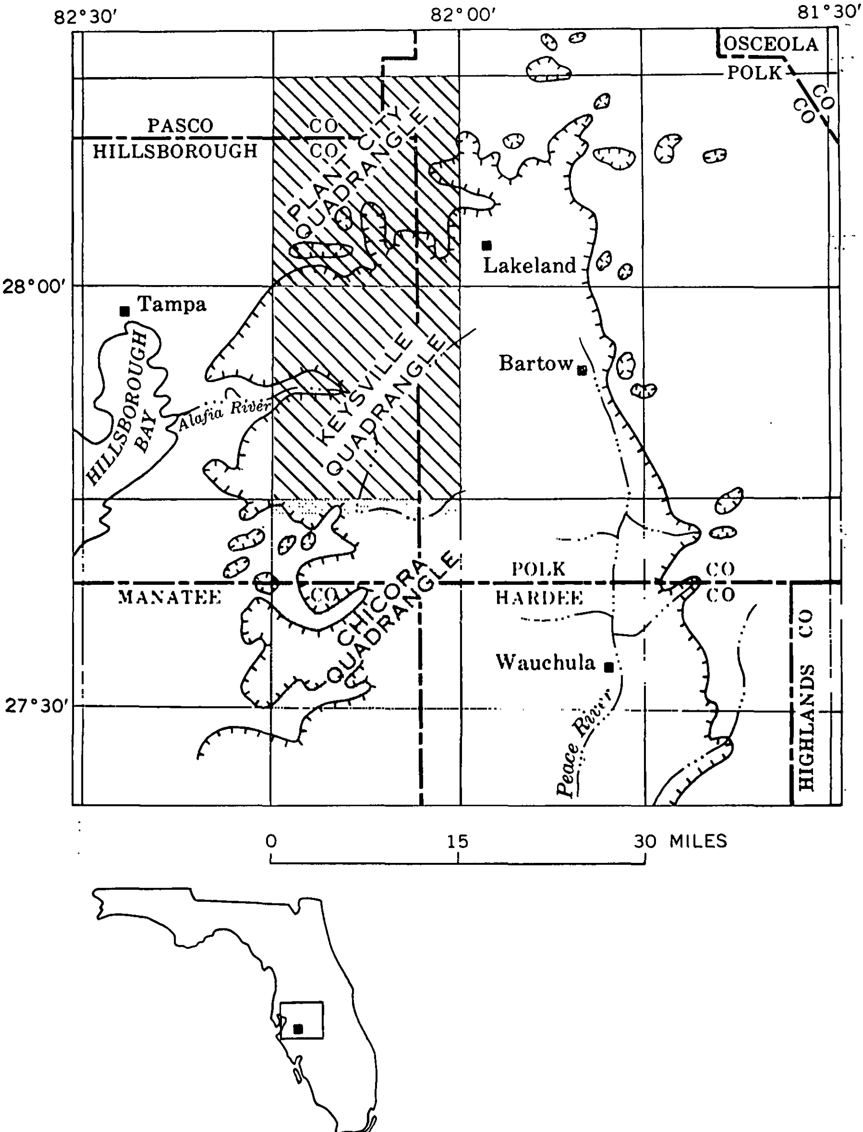

FIGURE 1.—Index map of west-central peninsular Florida, showing location of Chicora quadrangle (stippled). Diagonal rules indicate quadrangles in the land-pebble phosphate district previously described (Cathcart, 1963a; 1963b); hachures indicate approximate limits of the land-pebble phosphate district.

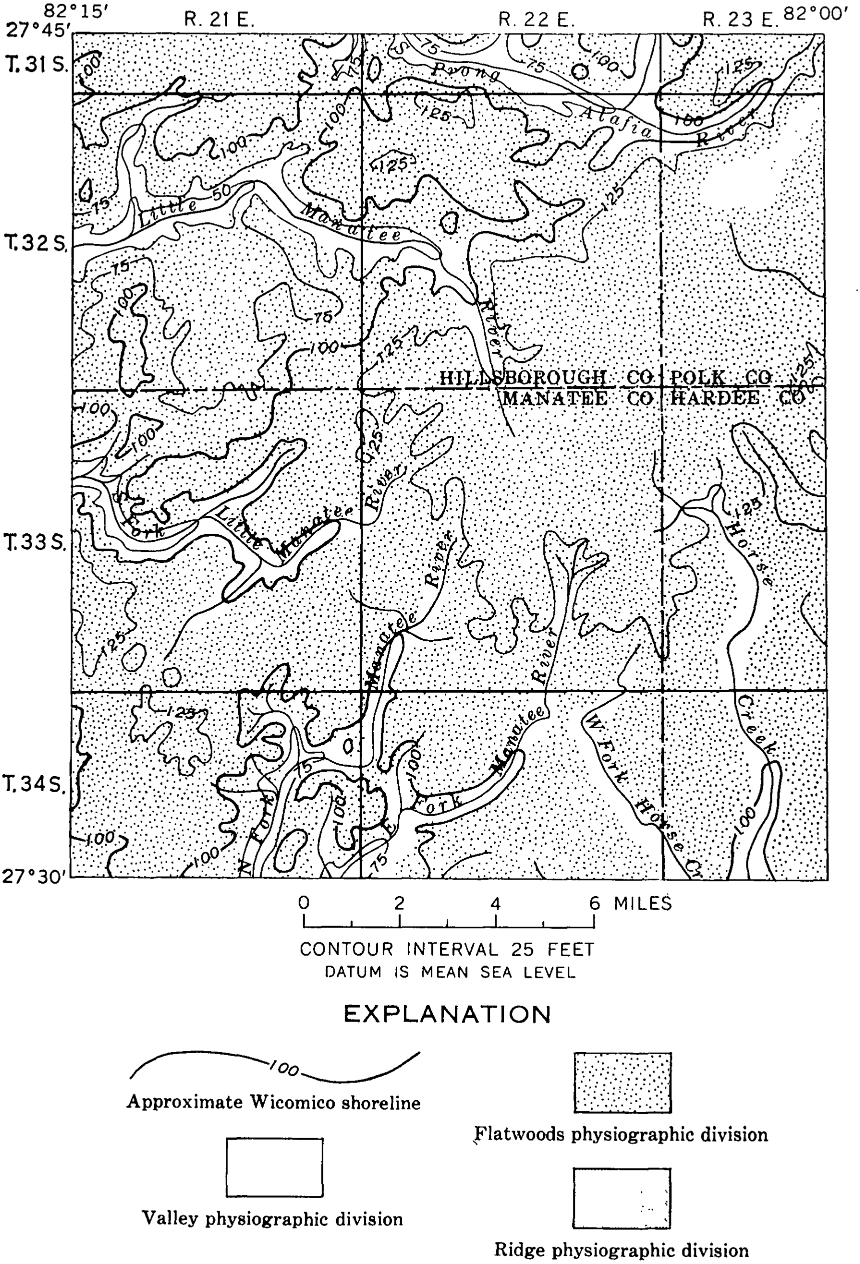

FIGURE 2.—Sketch map of topography and drainage, Chicora quadrangle, showing approximate position of Pleistocene shorelines (after MacNeil, 1950) and physiographic divisions.

The quadrangle is drained to the west by the Manatee and Little Manatee Rivers and their tributaries, to the north by the South Prong of the Alafia River, and to the south by Horse Creek, a tributary to the Peace River. All drainage is to the Gulf of Mexico.

The area is divided into narrow stream valleys and flatwoods (fig. 2), except for one small area in secs. 3, 4, 7, 8, and 9, T. 32 S., R. 23 E., that may be a part of the well-drained ridge province.

The stream valleys are shallow. Although the channels of the main streams are well defined, their tributaries flow in poorly defined channels in swampland. The rivers readily overflow into the swamps in the rainy season. The waters of the streams are dark brown, but they carry very little material in suspension. The valleys slope gradually to the adjacent flatwoods.

The flatwoods area is lowlying, level, and wooded; it is characterized by small depressions called cypress or grass ponds. Common trees are slash and longleaf pine; wiregrass and palmetto constitute underbrush. Drainage is generally poor.

The climate is subtropical and the average rainfall is about 50 inches per year.

The major part of the land-pebble phosphate district is included in six 15-minute quadrangles; fieldwork in the district was carried on from October 1947 to September 1953. Data on two of these quadrangles, the Keysville and the Plant City, have already been published (Cathcart, 1963a; 1963b); this report on the Chicora quadrangle is the third in the series. Many of the isopach maps, compiled from the mining companies' data, were drawn by S. W. Maher, R. G. Peterson, T. E. Wayland, and S. L. Houser. L. J. McGreevy assisted in the preparation of the isograde maps. Lithologic logs of drill holes were made by D. C. Alverson, J. R. Brooks, W. J. Carr, H. M. Icke, K. B. Ketner, F. S. MacNeil, L. J. McGreevy, S. W. Maher, Louis Pavlides, R. H. Stewart, and the author. Tonnage data were compiled, in part, by A. M. Coleman.

The work was done on behalf of the Division of Raw Materials of the U.S. Atomic Energy Commission.

GLOSSARY

Terms used in this report are briefly defined as follows:

Aluminum phosphate zone: Zone of ground-water alteration, characterized by aluminum phosphate minerals.

Bedclay: Plastic, water-saturated calcareous clay containing phosphate nodules. Residuum of the Hawthorn limestone.

BPL: Bone phosphate of lime=percent $P_2O_5 \times 2.185$.

Calcium phosphate zone: Unconsolidated sandy clay or clayey sand, characterized by rounded particles of carbonate fluorapatite.

Concentrate: Fine phosphate product, —14+150 mesh (—1 mm+0.1 mm) in size. Separated from quartz sand by flotation methods.

Driftrock: Coarse sand or conglomerate of phosphate nodules and minor amounts of quartz grains. Trace or no clay.

Hardpan: Sand or clayey sand cemented with iron (limonite).
mented with iron (limonite).

Leached zone: Mining company term to designate the possibly economic part of the aluminum phosphate zone.

Matrix: The economic part of the calcium phosphate zone.

Nodule: Irregular rounded particle of any size. Used in this report to designate the phosphate particles.

Overburden: Waste material above the matrix.

Pebble: Coarse phosphate product, +14 mesh (+1 mm) in size.

Sandrock: Sand cemented by aluminum phosphate minerals or by silica.

Slime: —150 mesh (—0.1 mm) size particles. Includes silt and clay.

Tailings: —14+150 mesh quartz sand, separated from phosphate particles by flotation methods.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the cooperation of all the mining companies in the land-pebble phosphate district. The Chicora quadrangle is south of the mining area; prospect drilling by the companies was the source of most of the information used to compile this report. The American Agricultural Chemical Co.; American Cyanamid Co.; Coronet Phosphate division of Smith-Douglas Co., Inc.; Davison Chemical Co., division of W. R. Grace and Co.; and International Minerals and Chemical Corp., all active mining companies, provided prospecting data and samples from drilling. Government land in the Chicora quadrangle was prospected in 1948 by the Tennessee Valley Authority. Mr. Wayne Thomas, a consultant in phosphate lands, gave freely of his information on prospecting in the quadrangle. Mr. O. H. Wright prospected lands in Hardee and Manatee Counties for the American Metals Climax, Inc.

The maps of uranium distribution were compiled from hundreds of chemical and radiometric analyses for uranium made by the U.S. Geological Survey. Radiometric analyses were made by E. A. Cisney, F. J. Flanagan, J. H. Goode, Jr., E. H. Humphrey, B. A. McCall, Roosevelt Moore, J. N. Rosholt, Jr., and J. J. Warr, Jr. Chemical analyses were made by H. Alberty, I. H. Barlow, Sam Bethea, G. W. Boyes, Jr., A. B. Caemmerer, Frank Cuttita, G. J. Daniels, M. H. Delevaux, David Diebler, M. E. F. Eiland, T. A. Farley, J. H. Goode, Jr., J. L. Greene, C. R. Johnson, H. B. Kessler, R. Kreher, Dorothy Lee, R. G. Milkey, Roosevelt Moore, Wayne Mountjoy, A. Pietsch, R. Randolph, J. J. Rowe, J. Smith, Roberta Smith, L. Steele, W. P. Tucker, David Venesky, James Wahlberg, J. J. Warr, Jr., and A. L. White.

REGIONAL GEOLOGY

The Chicora quadrangle is within the general limits of the land-pebble phosphate district. The eastern half of the quadrangle is underlain by deposits of phosphorite, and the western half contains only remnants of the phosphorite deposits. The remnants are on the interstream divides of major streams, and they probably are outliers of a blanket deposit that formerly covered the quadrangle.

The quadrangle is a part of the Gulf Coastal Plain. Thin formations of Tertiary and Quaternary age, present in the subsurface, dip to the south or southwest at a few feet per mile. A blanket of loose quartz sand of Pleistocene and Recent ages covers the entire quadrangle. Exposures of older rocks may be present along the South Prong of the Alafia River, but drilling close to the stream indicates that even here, loose sands—probably bars or flood-plain deposits—cover the older rocks.

The oldest rock found in drilling was either too hard to penetrate with the hand auger or was calcareous clay with minor amounts of phosphate nodules. These materials are assigned to the Hawthorn Formation of middle Miocene age. The Hawthorn Formation is overlain by the lower phosphorite unit of the Bone Valley Formation of Pliocene age, which is a blanket deposit in the eastern part of the quadrangle, but which is preserved as outliers in the western part of the quadrangle. The upper unit of the Bone Valley Formation, a clayey sand containing minor amounts of phosphate nodules, is present throughout the quadrangle, except along the present stream channels where it has been eroded.

Formations older than the Hawthorn are present in the subsurface. Drilling outside the quadrangle indicates that the Tampa Limestone of early Miocene age, the Suwannee Limestone of late Oligocene age, and the Ocala Limestone of late Eocene age are present in the general region and would be penetrated by deep drilling in the quadrangle.

A geologic map of the Chicora quadrangle (pl. 1) was compiled from data obtained by drilling. From the lithologic logs of drill holes, the rocks were divided into formations following the characteristic lithologies shown by Cathcart and McGreevy (1959, p. 245). The units shown on the map include the upper and lower parts of the Hawthorn Formation and the lower and upper units of the Bone Valley Formation. The Hawthorn Formation includes calcareous sandy clay, containing phosphate nodules, hard limestone or dolomite; it also contains phosphate nodules and interbedded green or blue clay and sandy clay which overlies the calcareous clay or the hard limestone. The break in lithology between these materials and a sand of phosphate and quartz of the lower unit of the Bone Valley Formation is distinct throughout the quadrangle. In many areas, a conglomerate of coarse phosphate particles in a quartz sand rests on the hard bedrock or on the green or blue clay. The contact of the upper and lower units of the Bone Valley Formation is determined by economic criteria, and it can readily be determined in drill holes. The contact of the upper unit of the Bone Valley and the sands of Pleistocene and Recent ages is the lithologic break between the clayey and the loose sand.

Although no fossils were found in the area, the geologic units are probably valid because the different lithologies are repeated throughout the quadrangle, and fossils have been found in units of similar lithology and age in other quadrangles in the land-pebble phosphate district.

A cross section through the Chicora quadrangle has been published (Cathcart and McGreevy, 1959, pl. 22). The lithology of the beds in this cross section illustrates the lithology as used in correlations in this report.

STRATIGRAPHY

The general stratigraphy, lithology, and mining terminology are summarized in table 1. Formations older than the Hawthorn are not included in table 1 because they were not penetrated by any drill holes known to the author.

Stratigraphic relations in the Chicora quadrangle are shown graphically in figure 3. The clastic upper part of the Hawthorn Formation is present at holes 1, 2, 3, and 4, in thicknesses ranging from 40 to 53 feet. It is only 5.5 feet thick at hole 6, and is not present at holes 5 and 7. Limestone is present at all drill holes as the material on which the holes terminate. At hole 5, calcareous clay residual from the limestone is 17.5 feet thick; in other holes it is absent. Holes 2, 3, and 4 penetrated thin limestone beds that are within the upper part of the Hawthorn Formation. Individual beds within the upper part of the Hawthorn Formation cannot be correlated between drill holes.

The lower phosphorite unit of the Bone Valley rests on limestone at hole 7, on calcareous clay at hole 5, and on clastics of the Hawthorn Formation at the rest of the drill holes. The lower unit changes from a clayey sand in the northern part of the section (at holes 5, 6, and 7) to a sand with only minor amounts of clay in the southern part of the section. The upper unit of the Bone Valley Formation, a clayey sand to a slightly sandy clay, is present at all drill holes. The unit has sandrock fragments (aluminum phosphate-cemented sand) only in the northern part of the section, and contains fresh, highly polished black phosphate nodules at hole 1, the southernmost drill hole. At holes 2, 3, and 4, the upper unit has no sandrock fragments nor any visible phosphate, but trace amounts of fresh phosphate are present at

TABLE 1.—*Summary of stratigraphy, lithology, and mining terminology, Chicora quadrangle, Florida*

[Only the top part of the Hawthorn is known from drill holes. A few holes penetrated the formation; none have passed through it in the Chicora quadrangle]

Age	Formation or deposits		Unweathered material: Lithology	Unweathered material: Mining terminology		Weathered material: Lithology	Weathered material: Mining terminology	
Pleistocene or Recent	Terrace sands		Loose quartz sand	Overburden		Loose quartz sand	Overburden	Overburden
Pliocene	Bone Valley Formation	Upper unit	Gray or gray-green sand or clayey sand. Minor amounts of black or brown phosphate nodules, particularly at base. —Contact gradational—	Overburden		White, slightly clayey sand. May contain some soft, white phosphate particularly at base. —Contact gradational—	Overburden[1] / Leached zone	Aluminum phosphate zone
Pliocene	Bone Valley Formation	Lower unit	Sand, clayey to slightly clayey, containing black or brown phosphate. Often a basal conglomerate of phosphate and quartz at base. —Contact disconformable—	Matrix	Drift-rock	White clayey sand, vesicular. Some phosphate, dull and white. Grades downward to: Slightly clayey sand, containing abundant nodules of black and brown phosphate. —Contact disconformable—	Matrix	Calcium phosphate zone
Miocene	Hawthorn Formation	Upper part	Green or blue clay interbedded with sandy clay or clayey sand containing brown or tan phosphate nodules. Contact relations uncertain	May be matrix		Where limestone underlies the lower unit, it may be altered to calcareous sandy clay, containing phosphate nodules. The clay of the Hawthorn is unaltered.	Bedclay matrix	Calcium phosphate zone
Miocene	Hawthorn Formation	Lower part	Limestone, sandy, clayey, buff, yellow, or white, containing phosphate nodules, that are brown or gray.	Bedrock		Grades downward into limestone.	Bedrock	

[1] Contact determined by chemical analysis or by gamma-ray log.

other drill holes in this part of the quadrangle. Leaching by acid ground waters was not effective in the southwestern part of the quadrangle.

The loose quartz sand of the Pleistocene thickens southward. Hardpan is present at all drill holes. Although it ranges from 1 to 15 feet in thickness, its top follows the surface topography. At hole 7 where the loose sand is thin, the hardpan extends down into the upper unit of the Bone Valley Formation.

MIOCENE SERIES

HAWTHORN FORMATION

The Hawthorn Formation of middle Miocene age (Cooke, 1945; MacNeil, 1947) is the oldest formation known from drilling in the Chicora quadrangle. Hard limestone or dolomite of the formation is the bedrock or basement rock to which company prospect holes are drilled in the phosphate district. The formation does not crop out in

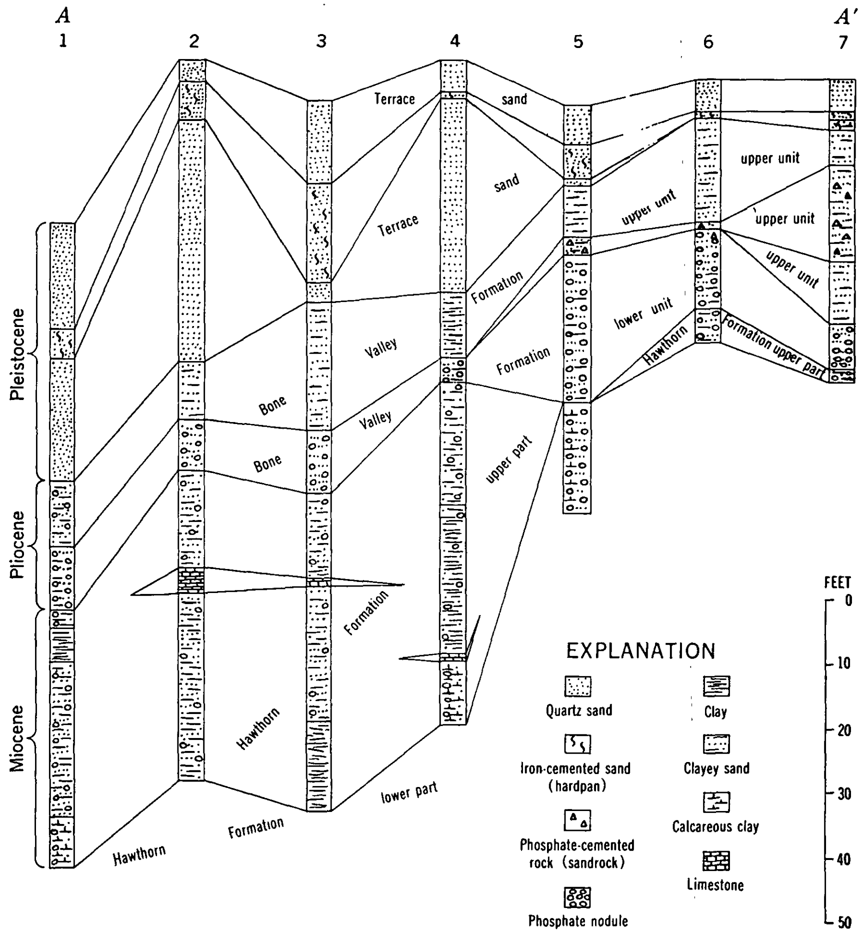

FIGURE 3.—Section *A–A'*, showing stratigraphic relations, Chicora quadrangle, Florida

the quadrangle, but along parts of the courses of the South Prong of the Alafia River and its tributaries and along the Little Manatee River, limestone or dolomite of the Hawthorn Formation is covered only by loose sand. The formation is shown on the geologic map (pl. 1).

THICKNESS

The thickness of the Hawthorn Formation is not known from drilling in the Chicora quadrangle. All the prospect holes were drilled into the Hawthorn Formation, but none passed through the formation into older rocks. In the southern part of the Keysville quadrangle, the Hawthorn Formation is about 100 feet thick (Cathcart, 1963a). To the southwest of the Chicora quadrangle, at a well in T. 34 S., R.

17 E., the formation is almost 300 feet thick (table 2). The formation, then, thickens to the south and southwest and probably averages 200 feet in thickness in the Chicora quadrangle.

UPPER SURFACE OF THE HAWTHORN FORMATION

The subsurface topography of the upper surface of the Hawthorn Formation is shown on plate 2. The map was drawn entirely from drill records. Some of the drill records were prepared by personnel of the U.S. Geologic Survey, and others were made by the mining companies' drill foremen; however, many of the data are from company records which show only the thicknesses of the overburden and of the matrix. For these records, the sum of the overburden thickness plus the matrix thickness was assumed to be the depth to the Hawthorn Formation. This assumption introduces an error because the matrix includes a part of the residual clay of the Hawthorn Formation. Lithologic logs of drill holes, from all parts of the quadrangle, indicate that more than 5 feet of matrix seldom can be assigned to the Hawthorn Formation. The introduced error, therefore, is less than half the contour interval, and the map is correct within that limit.

Plate 2 shows that the surface of the Hawthorn in the northern part of the quadrangle is a karst topography. This area is dotted with small, roughly circular depressions. Many large irregular deep depressions are present throughout the north half of the quadrangle.

The drainage pattern on the Hawthorn surface differs considerably in detail from that of the modern surface, but the overall patterns of the two generally coincide even in the northern part of the quadrangle where data are close enough to provide adequate control for mapping. For example, there was a stream on the Hawthorn surface in about the position of the Little Manatee River, in the north part of T. 32 S.; its drainage, like that of the Little Manatee, was to the west. In the same way, stream channels on the Hawthorn surface occur in about the position of the South Prong of the Alafia River, Long Branch, and the North and East Forks of the Manatee River.

The similarity in the positions of the streams on the Hawthorn surface with those of the modern streams is due, in part, to the erosion of the present streams, but a stream pattern probably was developed on the Hawthorn Formation prior to the deposition of the Bone Valley Formation.

PHYSICAL CHARACTERISTICS

The lower part of the Hawthorn Formation consists of hard limestone or dolomite or calcareous clay derived from carbonate rock. The lower part is overlain by an upper part composed of green, gray-

681-436—63——2

green, or mottled brown and green clay, sandy clay, clayey sand, and sand, together with a few thin beds of limestone.

Drill holes throughout the Chicora quadrangle bottomed on rock too hard to be penetrated by hand auger. The material was cored at only a few holes, but it is thought to be the same throughout the area. The material is gray-white to buff limestone or dolomitic limestone and includes very fine grained clay. The limestone contains fine- to medium-grained clear rounded quartz grains, and rounded, highly polished black, gray, and brown phosphate nodules. The dark phosphate grains stand out against the light groundmass and give the rock a salt-and-pepper appearance. Very thin beds of similar limestone are interbedded with the clay or sandy clay of the upper part of the Hawthorn Formation in the southwestern part of the quadrangle (log of drill hole B; fig. 3).

All drill holes in the north half and the southeast quarter of the quadrangle bottomed on limestone. Most of them penetrated a few feet of white, gray, or yellow-brown sandy calcareous clay containing fine-grained, brown, amber, black, and gray phosphate nodules. This clay is the "bedclay," and is a residuum of the underlying limestone. It is a part of the calcium phosphate zone, and may be a part of the matrix.

At a few localities in the northern part of the quadrangle, a green or gray-green laminated clay as much as 5 feet thick lies above the calcareous clay (hole 6, fig. 3). The clay either contains thin lenses of sandy material or is interlaminated with thin films of fine-grained quartz and phosphate sand. The clay beds may or may not contain phosphate nodules; all the sandy beds are phosphatic. In the southwest quarter of the quadrangle, the upper part was present at all drill holes; it ranges in thickness from 0 at about the middle of the quadrangle to about 70 feet at the southwestern corner. In this area, the upper part rests directly on hard limestone. Except for some of the clay beds, different amounts of phosphate nodules are present throughout the upper part. The phosphate nodules usually are brown or black and fine grained; the pebble to concentrate ratio is always less than 1.

The distribution of the clastic rocks of the Hawthorn Formation suggests that the upper part was once continuous across the Chicora quadrangle. Thin beds of laminated clay are found at scattered localities as far north as the Sydney mine in T. 29 S., R. 21 E., in the Keysville quadrangle (Cathcart, 1963a). These rocks apparently thinned to the north, perhaps because the Ocala uplift was rising as they were being deposited (Cathcart, 1963b). Erosion after deposition would explain the observed pattern of distribution.

The changes in lithology of the Hawthorn Formation in the Chicora quadrangle are shown in figure 3 and in the drill-hole logs which follow.

Log of drill hole A in SE¼SE¼ sec. 31, T. 31 S., R. 23 E.

[Adapted from lithologic log by W. J. Carr]

	Thickness (feet)
Pleistocene:	
Terrace sand:	
Sand, gray to white, loose, quartz	3
Sand, iron-stained and cemented (hardpan), dark-brown	7
Total Pleistocene	10
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, clayey, brown and tan; contains rounded lumps of vesicular phosphate-cemented sand (sandrock)	5
Sand, clayey, light-gray; contains a few lumps of phosphate-cemented sand, and a trace of soft white phosphate	12
Bone Valley Formation (lower unit):	
Sand, clayey, light-gray; contains very abundant coarse black phosphate, and minor amounts of fine sand-size phosphate	3
Clay, very sandy, gray; contains abundant amounts of coarse black phosphate and trace amounts of coarse rounded fragments of phosphatized limestone	1
Total Bone Valley	21
Miocene:	
Hawthorn Formation:	
Clay, chalky, calcareous, gray-green and tan; contains minor phosphate nodules, all fine grained	5.5
Partial total, Hawthorn	5.5

Hole bottomed on material too hard to penetrate with the hand auger, probably limestone of the Hawthorn Formation.

Log of drill hole B (No. 3 on fig. 5) in SW¼SW¼ sec. 12, T. 33 S., R. 21 E.

[Adapted from lithologic log by Louis Pavlides. Hole drilled by the Tennessee Valley Authority]

	Thickness (feet)
Pleistocene:	
Terrace sand:	
Sand, fine-grained, loose, white to brown	13
Sand, iron-cemented (hardpan), dark-brown	15
Sand, fine-grained, loose, tan	3
Total Pleistocene	31
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, slightly clayey; contains some indurated fragments (sandrock)	20

Pliocene—Continued

	Thickness (feet)
Bone Valley Formation (lower unit):	
Sand, loose, gray; contains coarse- to medium-grained black phosphate nodules	10
Total Bone Valley	30
Miocene:	
Hawthorn Formation:	
Sand, clayey, gray-green; interbedded with dark-gray clay; some black phosphate and phosphatized limestone nodules	13
Limestone, sandy, hard, white; trace amounts of black phosphate	1
Sand, clayey, gray-green; interbedded with gray sandy clay and minor amounts of black phosphate	21
Clay, stiff, green; trace amounts of quartz sand, no phosphate	14
Partial total, Hawthorn	49

Hole bottomed on material too hard to penetrate with the hand auger, probably limestone of the Hawthorn Formation.

At drill hole A, only the upper part of the Hawthorn Formation is represented, but typically the Hawthorn consists of limestone, or limestone residuum, the calcareous bedclay in the northern part of the Chicora quadrangle.

At the locality of drill hole B, the Hawthorn Formation consists of a thick section of greenish-gray or gray-green clayey sand and sandy clay containing a thin limestone bed, and a green clay bed at the base. The clayey sand and sandy clay are not calcareous, and they contain only minor amounts of phosphate nodules, except for the green clay which contains no phosphate. The green nonphosphatic clay rests directly on hard limestone. This lithology is typical of the formation in the southwestern part of the quadrangle.

HAWTHORN-BONE VALLEY CONTACT

The contact between the Hawthorn and Bone Valley Formations is not exposed in the Chicora quadrangle. It is marked by a change from calcareous clay, green laminated clay, or limestone of the Hawthorn to the quartz sands containing coarse black phosphate of the overlying Bone Valley (fig. 3). The contrast in lithology is consistent throughout the quadrangle, and it can be recognized at most drill holes. In many places, a conglomerate of coarse phosphate and rounded phosphatized bone fragments, the so-called driftrock, is at the base of the material assigned to the Bone Valley. The following drill-hole logs indicate the nature of the material below and above the contact.

Log of drill hole C in NW¼SW¼ sec. 29, T. 32 S., R. 23 E.

[Adapted from lithologic log by H. B. Dutro]

	Thickness (feet)
Pleistocene:	
Terrace sand:	
Sand, quartz, loose, gray and tan	5
Sand, iron-cemented (hardpan), dark-brown	5
Total Pleistocene	10
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, slightly clayey, tan-gray	28
Bone Valley Formation (lower unit):	
Sand, slightly clayey, gray, quartz and phosphate; phosphate is mostly black, but partly white	2
Sand, loose, brown and black, quartz, and phosphate; phosphate is black, coarse grained (driftrock)	4
Total Bone Valley	34
Miocene:	
Hawthorn Formation:	

Hole bottomed on material too hard to penetrate with the hand auger, probably limestone or dolomite of the Hawthorn formation.

Log of drill hole D in SE¼SE¼ sec. 9, T. 32 S., R. 22 E.

	Thickness (feet)
Pleistocene:	
Terrace sand:	
Sand, loose, white, gray at top	11
Total Pleistocene	11
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, clayey, white	7
Sand, clayey, blue-gray; trace amounts of white phosphate	3
Bone Valley Formation (lower unit):	
Sand, slightly clayey; contains abundant coarse black and brown prosphate nodules	11
Sand, very slightly clayey; contains black fine-granule-size phosphate nodules	11
Sand, quartz and dominantly black phosphate, coarse-grained (driftrock)	3
Total Bone Valley	35
Miocene:	
Hawthorn Formation:	
Clay, sandy, calcareous, white to cream; contains minor amounts of fine-grained dominantly brown and tan phosphate nodules	4
Partial total, Hawthorn	4

Hole bottomed on rock too hard to penetrate with the hand auger, probably limestone or dolomite of the Hawthorn Formation.

Log of drill hole E in SW¼SE¼ sec. 31, T. 31 S., R. 23 E.

[Adapted from lithologic log by W. J. Carr]

	Thickness (feet)
Pleistocene:	
Terrace sand:	
Sand, loose, gray, brown and tan	5
Sand, loose, iron-stained, dark-brown; indurated (hardpan) in bottom foot	2
Total Pleistocene	7
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, clayey, brown and tan; contains lumps of phosphate-cemented sand (sandrock)	2
Sand, slightly clayey, brown, tan, and gray; minor amounts of phosphate-cemented sand at base	13
Bone Valley Formation (lower unit):	
Sand, loose, tan; contains abundant black phosphate granules, and boulders of tan phosphatized limestone (driftrock)	1
Total Bone Valley	16
Miocene:	
Hawthorn Formation:	
Sand, clayey, gray-green; contains abundant fine-grained black, brown, and tan phosphate pellets	4
Clay, gray-green, interlaminated with quartz and phosphate sand	2
Clay, sandy, calcareous, blue-gray; contains abundant fine-grained phosphate nodules	1
Partial total, Hawthorn	7

Hole bottomed in sandy cream calcareous clay that contains trace amounts of fine- to very fine-grained phosphate pellets.

Drill holes C, D, and E are in the north half of the quadrangle. Each of these drill holes shows that the Bone Valley and Hawthorn Formations are separated by a lithologic break. The basal conglomerate of the Bone Valley Formation (the driftrock) rests on different parts of the Hawthorn Formation at each drill-hole locality. The upper part of the Hawthorn Formation (drill hole E) is present in this area only as isolated patches, probably erosional remnants. A comparison of data from the three drill holes indicates an erosional break after the deposition of the Hawthorn Formation and before the deposition of the Bone Valley.

The log of drill hole B (p. 13) shows a quartz and phosphate sand resting on the green clay of the Hawthorn Formation. This relationship is the same as shown in log E, except that drill hole B is in the southern part of the area and the sediments assigned to the Bone Valley contain too little phosphate to be called driftrock.

At the locality of drill hole A (p. 13), a sandy clay, containing abundant coarse phosphate grains, rests on calcareous clay of the

Hawthorn. At this locality the contact is a little more difficult to select, but the lithologic differences are sufficiently great that there seems to be little doubt that the contact between the two formations is marked by a change from sandy to calcareous clay.

At a drill hole in sec. 14, T. 34 S., R. 21 E. (hole 3, fig. 9) in the southernmost part of the quadrangle, the lower unit of the Bone Valley Formation is a gray sand with pebbles of black phosphate and abundant rounded pebbles of hard green clay. The green clay pebbles are lithologically identical with the green laminated clays, typical of the upper part of the Hawthorn Formation in the southern part of the quadrangle. The green clay pebbles are undoubtedly reworked fragments of clay from the upper part of the Hawthorn, and are further evidence of the hiatus separating the Hawthorn and the Bone Valley Formations.

PLIOCENE SERIES

BONE VALLEY FORMATION

The Bone Valley Formation, as originally described by Matson and Clapp (1909, p. 138–141) and Sellards (1910, p. 33), included the minable phosphate deposit, together with overlying clayey sand. Loose, surficial sands of Pleistocene age were excluded. Sellards (1910) divided the formation into a lower member containing the minable phosphate and an upper member of clayey sand or sandstone. Because the minable phosphate deposit includes both residuum of the Hawthorn Formation and reworked material of the Bone Valley, the original description of the formation is in error. In this report, the residuum of Hawthorn limestone is excluded from the Bone Valley Formation.

AGE

The Bone Valley Formation is Pliocene in age, although the lowermost part of the formation may be late Miocene age. No fossils were found in the formation in the Chicora quadrangle in the course of the field investigation—not surprising, because all information is from drilling.

Sellards (1915) shows several plates of fossils taken from phosphate beds exposed in the pits of the American Cyanamid Co. (formerly Amalgamated Phosphate Co.) mine near Brewster, Fla. The Brewster mine included some pits in the northeast corner of the Chicora quadrangle in secs. 27 and 34, T. 31 S., R. 23 E. The fossils illustrated by Sellards include a gavial, *Tomistoma americana* (1915, figs. 29, 30, p. 100–101), the tusk of a mastodon—" * * * probably *M.* (*Trilophodon*) *floridanus*" (1915, fig. 35, p. 106–107), and the jaws of a rhinoceros (1915, figs. 37, 38, 39, p. 106–109).

Sellards (1915, p. 72) points out that the mastodon is "* * * not unlike the form described by Leidy from near Archer as *Castodon* (*Trilophodon*) *floridanus* * * *" and further points out that it is probable that more than one species is represented. In addition, Sellards thought it likely that at least two species of rhinoceros were present. He notes that Gidley identified *Teleoceras fossiger* from a tooth found near Mulberry, Fla., but that the specimen from the Amalgamated pit is clearly distinct from this species.

In summing up the fossil evidence, Sellards (1915, p. 75) says: "The fossils that have been obtained from the formation indicate that the land pebble phosphate deposits were accumulated during either late Miocene or early Pliocene time."

Evidence from the Chicora quadrangle indicates that the Bone Valley Formation is younger than Hawthorn Formation of middle Miocene age. It is separated from that formation by an erosional break, and it is older than the sands of Pleistocene age.

DISTRIBUTION AND THICKNESS

The Bone Valley Formation is divided into two units—a lower phosphorite unit, and an upper slightly clayey sand unit containing only minor amounts of phosphate.

The lower phosphorite unit underlies most of the Chicora quadrangle; however, it is not present along the courses of the modern streams, where it has been removed by erosion. Only patches of the lower unit remain on the interstream divides in the western part of the quadrangle. The west boundary of the quadrangle is close to the west limits of the lower phosphorite unit of the Bone Valley Formation; the geologic map (pl. 1) shows a part of the west limit of the unit. This limit is deeply indented along the major streams (the Manatee and Little Manatee Rivers) because of erosion. The thickness of the lower unit ranges from 0 to about 40 feet, and probably averages about 15 feet.

The upper unit of the Bone Valley Formation underlies all the Chicora quadrangle, except along streams where it has been removed by erosion. The unit contains so little clay that it is difficult to separate it from the overlying loose sands assigned to the Pleistocene, but the basal contact with the lower unit of the Bone Valley Formation is clear, although it is gradational over a few inches. The thickness of the unit ranges from 0 to about 30 feet, and probably averages between 10 and 15 feet.

PHYSICAL CHARACTERISTICS

The lower unit of the Bone Valley Formation is dominantly a gray, very slightly clayey to loose quartz sand containing abundant black coarse sand- to granule-size phosphate nodules. A coarse phosphate sand or a conglomerate composed of black phosphate granules, tan phosphatized limestone fragments, and gray phosphatized bone fragments commonly occur at the base of the lower unit of the Bone Valley Formation. Logs of drill holes C, D, and E (p. 15 to 16) show characteristic lithologies of the lower unit of the Bone Valley Formation.

In some areas, beds of gray-green, gray, or brown clayey sand to sandy clay occur with the more characteristic gray sand of the lower unit (log F, below; log H, p. 20).

The following logs show characteristic lithologies of the Bone Valley Formation in areas where the basal conglomerate is not present.

Log of drill hole F in SE¼SE¼ sec. 6, T. 32 S., R. 22 E.

	Thickness (feet)
Pleistocene:	
Terrace sand:	
Sand, quartz, loose, white and tan	10
Total Pleistocene	10
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, slightly clayey, white; contains trace amounts of soft white phosphate, and fragments of sandrock	8
Sandstone (sandrock)	5
Sand, slightly clayey, tan and white	12
Bone Valley Formation (lower unit):	
Sand, quartz, loose; contains black and brown phosphate	2
Clay, sandy, brown; contains abundant coarse brown phosphate nodules and minor amounts of white phosphate nodules; phosphate is mostly granule size	3
Total Bone Valley	30
Miocene:	
Hawthorn Formation:	
Clay, sandy, calcareous, yellow-brown; contains trace amounts of fine-grained brown phosphate	4
Partial total, Hawthorn	4

Hole bottomed on rock too hard to penetrate with the hand auger, probably limestone or dolomite of the Hawthorn Formation.

Analysis of samples from drill hole F shows that the Bone Valley contains twice as much recoverable phosphate as the Hawthorn. The pebble-to-concentrate ratio of the phosphate nodules in the Bone Valley is 1.5; that of the Hawthorn is 0.1. The nodules of the Bone Valley Formation contain 31.6 percent P_2O_5, whereas nodules from the Hawthorn Formation contain only 27.9 percent P_2O_5. Analytical data are from the American Cyanamid Co., and are used with their permission.

Log of drill hole G (hole 5, fig. 3) NW¼SE¼ sec. 30, T. 32 S., R. 22 E.

[Adapted from Cathcart and McGreevy, 1959, pl. 22, hole 2]

	Thickness (feet)
Pleistocene:	
Terrace sands:	
Sand, quartz, loose, gray to white	6
Sand, iron-cemented (hardpan), brown	5
Sand, quartz, loose, tan	1
Total Pleistocene	12
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, very slightly clayey, tan	1.5
Sand, clayey, tan-gray	6.5
Sand, clayey, tan; contains abundant rounded lumps of aluminum phosphate-cemented sand	3.0
Bone Valley Formation (lower unit):	
Sand, slightly clayey to clayey, gray; contains mostly coarse-grained, black, and minor amounts of tan phosphate nodules	22.5
Total Bone Valley	33.5
Miocene:	
Hawthorn Formation:	
Sand, clayey, calcareous, gray-green; contains mostly black phosphate nodules. Some very thin limestone beds in the basal 2 feet	17.5
Partial total, Hawthorn	17.5

Hole bottomed on material too hard to penetrate with the hand auger; limestone of the Hawthorn Formation.

Log of drill hole H (hole 1, fig. 3) in SW¼NE¼ sec. 14, T. 34 S., R. 21 E.

[Adapted from lithologic log by Louis Pavlides; drilling by the Tennessee Valley Authority]

	Thickness (feet)
Pleistocene:	
Terrace sands:	
Sand, fine-grained, loose, brown	16
Sand, iron-cemented (hardpan), dark-brown	5
Sand, fine-grained, loose, iron-stained, brown	19
Total Pleistocene	40
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, very slightly clayey, gray; contains trace amounts of fine-grained, highly polished phosphate pellets	10
Bone Valley Formation (lower unit):	
Sand, slightly clayey, gray-green; contains coarse black phosphate that is more abundant toward base	10
Total Bone Valley	20

	Thickness (feet)
Miocene:	
Hawthorn Formation:	
Clay, sandy, green; contains trace amounts of black phosphate	3
Clay, green; no phosphate	5
Clay, sandy, green; contains trace amounts of fine-grained black phosphate. In the middle of the unit, a bed 1 foot thick contains about 15 percent black phosphate	24
Clay, sandy, calcareous, blue-gray; contains trace amounts of fine-grained black phosphate	8
Partial total, Hawthorn	40

Hole bottomed on material too hard to penetrate with the hand auger, probably limestone of the Hawthorn Formation.

A description of the lithology of the lower unit of the Bone Valley Formation is given in the logs of drill holes F, G, and H. At drill hole F in the northern part of the quadrangle, the lower unit contains more clay than at other localities and the phosphate nodules are brown, rather than black. At drill holes G and H, the lower unit is a sand composed of quartz, phosphate, and only minor amounts of clay. The phosphate nodules are black and are coarse sand to granule in size; they tend to increase in size toward the base of the unit. The logs of these holes show that the change in lithology from north to south is from a clayey sand to a sand—a change typical of the lower unit of the Bone Valley Formation in the Chicora quadrangle (fig. 3; p. 8).

The lower unit is much sandier in the southern part of the quadrangle than in the northern part, but the change is gradational and data are not sufficiently abundant to map the facies change.

The lower unit is bedded and crossbedded, and shows good graded bedding in the mine exposures in the Keysville quadrangle (Cathcart, 1963a). It is not possible to determine crossbedding from drill hole cuttings, but bedding and graded bedding are suggested in the logs of some of the drill holes. The log of drill hole I suggests graded bedding in the lower unit of the Bone Valley Formation.

Log of drill hole I in NW¼NW¼ sec. 33, T. 31 S., R. 23 E.

	Thickness (feet)
Recent:	
Swamp deposit:	
Clay, sandy; contains abundant amounts of black organic material	2
Total Recent	2

	Thickness (feet)
Pleistocene:	
Terrace sand:	
Sand, quartz, loose, tan and light brown	4
Total Pleistocene	4
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, slightly clayey, light-gray; contains minor amounts of sandrock and trace amounts of soft white phosphate	14.5
Bone Valley Formation (lower unit):	
Sand, clayey, greenish-gray; contains black, and minor amounts of white phosphate. Phosphate increases in amount toward base	3.5
Gravel, phosphate, black and minor amounts of white; and quartz and phosphate sand (driftrock)	1.0
Sand, clayey, light-gray; contains black, white, and brown sand- to granule-size phosphate. Sand fraction increases in amount toward base	1.5
Clay, sandy, gray-green; grades downward to gray clayey sand; contains black and white fine- to medium-sand-sized phosphate nodules which become coarser toward base. At base phosphate is all granule size	10.5
Total Bone Valley	31.0
Miocene:	
Hawthorn Formation:	

Hole bottomed in silty calcareous soft clay of the Hawthorn Formation; contains trace amounts of fine- to very fine-grained phosphate nodules.

At the locality of drill hole I, the basal bed of the Bone Valley Formation is a sandy clay that grades downward to clayey sand. The phosphate fraction is coarsest and most abundant at the base of this bed. This succession may be one set of graded bedding. The bed above is a clayey sand in which the sand fraction increases in amount toward the base. This clayey sand may be a second set of graded bedding. Resting on the clayey sand is a phosphate gravel. This grades upward to clayey sand which in turn grades to slightly clayey sand with minor amounts of white phosphate, the upper unit of the Bone Valley Formation. This group possibly is a third set of graded bedding.

The phosphate nodules in the lower unit of the Bone Valley Formation are predominantly black, and are coarse sand to granule size. The ratio of pebble to concentrate is always greater than 1 to 1. At nearly all the drill holes the amount and the size of the phosphate nodules increase toward the base of the unit, and in many of the holes the base of the lower unit is marked by a phosphate conglomerate in which the pebbles are tan phosphatized limestone, gray phosphatized bone fragments, and black phosphate nodules.

Some brown nodules are found at most of the drill holes, and white and gray nodules are characteristic of the top of the formation. These white and gray nodules may represent partially leached darker nodules, but at some of the drill holes the white and gray nodules are highly polished and show no evidence of leaching.

The upper unit of the Bone Valley Formation is a gray clayey sand. The unit is very constant, lithologically, throughout the Chicora quadrangle. The clay content of the unit ranges from a very slight amount to about 30 percent by volume, and in almost every hole the unit is described as a gray, gray-white, or gray-tan slightly clayey to clayey sand. About half of the holes logged had phosphate-cemented lumps of sandrock in the upper unit of the Bone Valley Formation; all these holes were in the northern part of the quadrangle. Soft white phosphate nodules characterize the upper unit in the northern part of the quadrangle. In some places these nodules are at the base of the unit; in other places they are higher in the unit. Soft white phosphate nodules are not found in the upper unit in the southwest quarter of the quadrangle; there the sparse phosphate nodules are black and polished, and are not leached.

BONE VALLEY-PLEISTOCENE CONTACT

The contact of the upper unit of the Bone Valley Formation with the overlying sands of Pleistocene age is placed at a lithologic break that marks a change from clayey sand to loose sand. This contact is difficult to select in some of the drill holes, because the upper unit is not only very slightly clayey but in some places is a loose sand containing a few rounded fragments of phosphate-cemented sand; ground water may have moved some of the clay downward. In some areas, particularly where the loose sand is thick, the lower part of the loose sand may be a thoroughly leached remnant of the upper part of the upper unit of the Bone Valley Formation. Nevertheless, the contact between the loose sand and the clayey sand is the only lithologic break at the top of the section, and it is arbitrarily selected as the break between the Bone Valley Formation and beds of Pleistocene age.

PLEISTOCENE SERIES

TERRACE SANDS

Loose quartz sands, assigned to the Pleistocene, cover the surface throughout the Chicora quadrangle. The sands range in thickness from about 10 to about 50 feet, and probably average about 20 feet. Of the several shorelines recognized by MacNeil (1950, p. 99), only the 100-foot or Wicomico shoreline is present in the Chicora quadrangle. As indicated in figure 2, the 100-foot contour line is deeply indented along the major rivers, the Manatee and Little Manatee, and the South Prong of the Alafia. In this area the 100-foot contour has been modified strongly by erosion along these rivers, and it does not represent a shoreline, except possibly at the west edge of the area. The 100-foot shoreline, however, probably is just to the west and to the south of the quadrangle. No other major shorelines are represented in the quadrangle.

The sands of the Pleistocene are well sorted, fine to medium grained, and composed almost entirely of quartz. Many of the quartz grains are clear or milky, but some are stained by either iron oxide or organic material.

Hardpan is common in the sands of the Pleistocene; however, it is a secondary cement, and it may extend downward into the upper clayey sand of the Bone Valley Formation where that unit is close to the surface (fig. 3).

RECENT DEPOSITS

RIVER PEBBLE DEPOSITS

Deposits of coarse phosphate and quartz sand found as bars along the major streams and in their flood plains are called river pebble deposits; they have been mined at the mouths of the Manatee and Little Manatee Rivers. The phosphate was derived by erosion of phosphate deposits in the Hawthorn Formation and in the lower unit of the Bone Valley Formation. Clay, fine sand, and fine phosphate has been removed by sorting action of the streams; the river pebble consists only of coarse phosphate and quartz.

OTHER RECENT DEPOSITS

Surficial deposits of windblown sand, soil, and swamp muck are probably of Recent age. No attempt was made to distinguish the windblown sands from the terrace sands of Pleistocene age, and the muck deposits were not mapped. Recent deposits are not extensive, and they are usually small.

STRUCTURE

As shown by drilling in adjacent quadrangles, the general structure of the rocks of the Chicora quadrangle is a southerly regional dip away from the Ocala uplift. Formation tops at two wells, one to the north of the area, one to the southwest, are shown in table 2. As shown in the table, except for the Hawthorn Formation, thicknesses are about the same and the tops of the formations are much deeper to the south; this indicates a southerly dip. It seems likely that, as in the Keysville and Plant City quadrangles to the north (Cathcart, 1963a and 1963b), minor structures are superimposed on the gentle regional southerly dip, though none were determined in the Chicora quadrangle.

TABLE 2.—*Summary of data from deep well logs*

[Formation tops are in feet below sea level]

Formation	Drill hole in T. 31 S., R. 22 E. (Cathcart, 1963a, table 2)	Drill hole in T. 34 S., R. 17 E. (Log, Florida Geol. Survey, written communication, 1951)
Hawthorn	−30	−26
Tampa Limestone	−80	−321
Suwannee Limestone	−120	−400
Ocala Limestone	−335	−683

MINERALOGY

The mineralogy of the rocks of the Chicora quadrangle is basically simple; only a few mineral species are represented. Details of the mineralogy can be found in several papers (Altschuler and others, 1956; Altschuler and others, 1958; Berman, 1953; and Cathcart, 1963a).

The Hawthorn Formation consists of limestone or dolomite and clay or sandy clay. These materials all contain phosphate nodules. The phosphate mineral is a carbonate fluorapatite (Altschuler and others, 1952), and the principal clay mineral is montmorillonite, although attapulgite has been found (Berman, 1953).

The lower unit of the Bone Valley Formation is a sand or clayey sand of phosphorite nodules and quartz. The phosphate mineral is carbonate fluorapatite and the principal clay mineral is montmorillonite.

The mineralogy of the aluminum phosphate zone has been described by Altschuler and others (1956). The upper part of the section, which has been most thoroughly leached, is characterized by wavellite and kaolinite. Crandallite and millisite are more abundant toward the base of the section, and kaolinite and montmorillonite are both present. At the base of the weathered section, carbonate fluorapatite containing some crandallite and montmorillonite containing minor kaolinite are the principal minerals.

The loose surficial sands are almost pure quartz; only a trace of the heavy minerals is present. Fine-grained nodules of fresh phosphorite commonly occur in the surficial sands.

WEATHERING

Several periods of intense weathering have altered the phosphatic sedimentary rocks of the land-pebble phosphate district, and at least three periods can be inferred from drill data in the Chicora quadrangle.

Weathering that altered the limestone of the Hawthorn Formation was largely chemical, as indicated by the karst topography on the surface of the formation (pl. 2). Carbonate was removed in solution; a residuum of clay, quartz sand, and phosphate particles was left. The upper part of the Hawthorn Formation overlies fresh hard limestone in the southwest quarter of the quadrangle; here the residuum probably was never formed. Erosion must have removed the upper part from most of the northern half of the quadrangle prior to the deposition of the Bone Valley Formation.

The calcareous clay and the erosion products were reworked into the lower unit of the Bone Valley.

Intense lateritic weathering (Altschuler and others, 1958) altered the rocks of the Bone Valley Formation. In most of this quadrangle, the alteration is confined to the rocks of the upper unit of the formation. In very few places has it affected the lower phosphorite unit, or the upper part of the Hawthorn where the lower unit of the Bone Valley is absent. The rocks of the upper unit of the Bone Valley in the southwestern part of the quadrangle, contain fresh black phosphate which apparently was not affected by leaching. The alteration changed the calcium phosphate mineral to aluminum phosphate minerals and montmorillonite to kaolinite (Altschuler and others, 1956). The residual calcareous clay (bedclay) of the Hawthorn Formation formed, at least in part, during this cycle of weathering.

The stratigraphic sections that follow illustrate the effects of leaching in the Chicora quadrangle.

Log of drill hole J in NW¼NW¼ sec. 6, T. 32 S., R. 23 E.

	Thickness (feet)
Pleistocene:	
Terrace sand:	
Sand, fine-grained, loose, white	5
Total Pleistocene	5
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, very slightly clayey, light-gray and tan	11
Sand, slightly clayey, gray-white; contains trace amounts of soft white phosphate grains	4
Sand, slightly clayey, white	12
Sand, very slightly clayey, light-gray; contains trace amounts of black, highly polished phosphate nodules	2
Bone Valley Formation (lower unit):	
Sand, loose; contains quartz and coarse black and brown phosphate nodules	3
Sand, clayey, gray; contains black and some white phosphate	2
Total Bone Valley	34

	Thickness (feet)
Miocene:	
Hawthorn Formation:	
Clay, sandy, calcareous, cream; contains trace amounts of fine-grained black phosphate	1.5
Partial total, Hawthorn	1.5

Hole bottomed on material too hard to penetrate with the hand auger, probably limestone of the Hawthorn Formation.

Log of drill hole K in SE¼NE¼ sec. 31, T. 31 S., R. 23 E.

[Adapted from lithologic log by W. J. Carr]

	Thickness (feet)
Pleistocene:	
Terrace sand:	
Sand, medium- to coarse-grained, loose, gray, brown and tan	4
Sand, loose, iron-stained, brown to black	3
Sand, iron-cemented (hardpan), dark-brown	7
Sand, coarse-grained, loose, brown to tan	6
Total Pleistocene	20
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, slightly clayey, tan to gray; contains lumps of sand cemented by aluminum phosphate minerals. Soft white phosphate nodules occur sparsely at top, increase in number toward base	7
Bone Valley Formation (lower unit):	
Sand, clayey, gray; contains black and brown phosphate	1
Clay, sandy, gray; black phosphate nodules occur in sand size at top, increase to granule size at base	4
Sand, phosphate and quartz, brown; no clay	2
Conglomerate; coarse black phosphate nodules, bone fragments, and hard sandstone	1
Total Bone Valley	15
Miocene:	
Hawthorn Formation:	
Clay, sandy, calcareous, light-gray; contains trace amounts of fine-grained phosphate nodules	3
Partial total, Hawthorn	3

Hole bottomed on material too hard to penetrate with the hand auger, probably limestone or dolomite of the Hawthorn Formation.

Log of drill hole L (hole 6, fig. 5) in NW¼SW¼ sec. 8, T. 32 S., R. 22 E.

[Adapted from lithologic log by D. C. Alverson. See also fig. 7]

	Thickness (feet)
Pleistocene:	
Terrace sands:	
Sand, loose, gray and tan	5
Sand, iron-cemented (hardpan), brown	1
Total Pleistocene	6

681–436—63——3

	Thickness (feet)
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, very slightly clayey, white to light-gray	16
Sand, cemented with phosphate (sandrock)	1
Bone Valley Formation (lower unit):	
Sand, slightly clayey; contains black, gray, and brown phosphate nodules, and fragments of phosphate-cemented sand	2
Sand, clayey, dark gray-green; contains brown sand- to granule-size phosphate nodules	10
Total Bone Valley	29
Miocene:	
Hawthorn Formation:	
Sand, clayey, green; contains brown sand-sized phosphate nodules; sand interbedded with olive-green nonphosphatic clay	5.5
Partial total, Hawthorn	5.5

Hole bottomed on material too hard to penetrate with the hand auger, probably limestone of the Hawthorn Formation.

At the locality of drill hole J, the upper part of the upper unit of the Bone Valley Formation is leached, as indicated by the presence of the soft white phosphate nodules. The basal 2 feet of the upper unit, however, contains trace amounts of fresh, highly polished black phosphate nodules that indicate that this material has not been leached. The leaching profile extends downward into the clayey sand beneath the zone of soft white phosphate, but it does not reach the basal part of the upper unit.

At the locality of drill hole K, the entire upper unit of the Bone Valley Formation has been leached. Soft white phosphate nodules are present throughout the unit, and they increase in number downward. The contact between the upper and lower units is placed at a change from leached white phosphate nodules to unleached black nodules. Although this change has economic significance, it may have little stratigraphic meaning because the base of the leached material may be in the lower unit.

At the locality of drill hole L, the upper unit and the top part of the lower unit of the Bone Valley Formation have been leached. Aluminum phosphate minerals extend down into the top 2 feet of the lower unit at the locality. The top foot of the lower unit contained so much aluminum phosphate-cemented sand that this part of the lower unit must be excluded from the matrix (fig. 7).

The log of drill hole H (p. 20) is typical of those areas where the Bone Valley Formation has not been leached. The entire upper unit of the formation contains small amounts of fresh, highly polished black phosphate, whose presence precludes any leaching of the phosphate.

A soil profile illustrates a third period of weathering. It is characterized by a gray to white, fine-grained sand at the surface that is underlain by brown, dark-brown, or black hardpan, and is located in the surficial sand or is superimposed on the altered clayey sand. The position of this soil zone is shown on figure 3. The zone follows the surface topography and is entirely in loose sand where these sands are thick, as at holes 1 through 4. Where the sands are thin, the hardpan is close to the base of the sand, as at hole 5; at the contact of the sand with the underlying clayey sand of the upper unit of the Bone Valley Formation, as at hole 6; or in both the sand and the clayey sand, as at hole 7.

This soil profile, the Leon soil, was formed by acid ground water (Fowler and others, 1927), and the acid ground water is probably continuing the lateritic weathering of the post-Bone Valley and pre-Pleistocene interval.

ECONOMIC GEOLOGY

HISTORY OF MINING

The only mining in the Chicora quadrangle was in the northeast corner of the area into which the western part of the Brewster mine of the American Cyanamid Co. extends. The pits are now small open lakes surrounded by gentle rounded hills of overburden. The area was first mined by the Amalgamated Phosphate Co., a predecessor of the American Cyanamid Co., using hydraulic methods. According to J. L. Weaver (written communication, 1961), mining began in 1912 and continued until 1937; the last mining was by the American Cyanamid Co. Only the pebble fraction was recovered; the concentrate fraction is not present in economic quantities.

River pebble was never mined in the Chicora quadrangle. Eldridge (1893, map, p. 197) shows two river-pebble mines on the Little Manatee River, one at the mouth of the river and the other several miles upstream and to the east. This latter locality probably is close to the west boundary of the Chicora quadrangle. Three river-pebble mines are shown grouped at the mouth of the Manatee River on Eldridge's map. These river-pebble mines were not being mined in 1908, for in that year Sellards (1909, pl. 12) shows only one river-pebble mine, located on the Peace River. Although river-pebble deposits are probably present along the Manatee and Little Manatee Rivers, it is not likely that any of this material will be mined, except in conjunction with mining of land-pebble phosphate that may be done adjacent to the rivers.

CALCIUM PHOSPHATE ZONE

The calcium phosphate zone consists of unconsolidated sediments—sands, clays, and all mixtures of these materials—that are characterized by abundant grains of apatite. The zone is economically important. It contains sufficient phosphate, recoverable under presently known metallurgical processes, to be minable now or at some time in the future. In the northern part of the Chicora quadrangle, the zone overlies hard phosphatic limestone or dolomite of the Hawthorn Formation. This zone is not considered a part of the calcium phosphate zone because of the practical impossibility of mining and processing these rocks in the foreseeable future.

In the southwestern part of the quadrangle, the calcium phosphate zone overlies the upper part of the Hawthorn Formation that appears to be too lean in phosphate to be included in the zone.

The calcium phosphate zone underlies all the Chicora quadrangle, except where it has been removed by erosion along the present streams (pl. 3). At the west edge of the quadrangle, the available drilling information indicates that the zone is present only as outliers grouped along interstream divides.

A screen pattern on figure 7 outlines areas where the thickness of the calcium phosphate zone is 1 foot or less; it indicates areas which are not minable and shows the general extent of the zone.

The calcium phosphate zone ranges in thickness from 0 along the present streams to about 40 feet in sec. 30, T. 32 S., R. 22 E. The average thickness of the zone is 10 to 15 feet.

The zone is not a stratigraphic unit. It may include phosphate of the Hawthorn Formation, phosphate of the Bone Valley Formation, or, most commonly, phosphate of both formations.

The matrix is that part of the calcium phosphate zone which is exploitable. Although the matrix is always a part of the calcium phosphate zone, all the zone may not be matrix. For example, if the top part of the calcium phosphate zone is partly leached, the phosphate content of the nodules may be less than the minimum grade, or the base of the zone may be low in grade or low in tonnage, and hence unminable.

The factors that determine whether a phosphate deposit can be exploited have been discussed by Cathcart and McGreevy (1959). To recapitulate briefly: The phosphate particles must contain more than 66 percent BPL and less than 5 percent combined iron and aluminum oxides. The overburden that must be removed must be less than a certain maximum; this factor is computed as cubic yards of material moved per ton of recoverable product. The total thickness of overburden that can be moved is dependent on the digging depth of the draglines. If the thickness of the overburden plus the thickness of the matrix exceeds this depth, the deposit must be mined in two stages; first, the top part of the overburden must be removed and the dragline lowered to the bench thus created; then the rest of the deposit can be mined. This two-stage operation obviously adds to the cost of mining. According to most of the mining companies' engineers, 3 feet is the minimum thickness that can be mined with large draglines.

The amount of recoverable phosphate particles must exceed a given minimum figure. This figure increases as the P_2O_5 content of the particles decreases. In the Chicora quadrangle, the matrix of the Bone Valley Formation and the matrix of the Hawthorn Formation have such different characteristics that a decision as to what part will be mined will have a pronounced effect on the type of beneficiation. Table 3 shows a typical variation.

There are three possible ways of mining the phosphate deposit in the area of drill hole 9–1, and they present problems as stated:

(a) If only that part of the calcium phosphate zone in the Bone Valley were mined, slime disposal would not be a problem. Because of the very small tonnage of concentrate, a washer would be used to recover the pebble fraction and a flotation plant would not be needed. (b) If only that part of the zone in the Hawthorn were mined, a flotation plant would have to be installed, slime disposal would be a distinct problem, and the pebble fraction is so low in BPL content that it would be discarded. (c) If all the zone were mined, the pebble and concentrate would be recovered, a washer and a flotation plant would be necessary, and slime disposal would have to be considered. At this drill-hole locality, economic considerations favor mining of the calcium phosphate zone in the Bone Valley Formation.

TABLE 3.—*Comparison of phosphate products and the slime fraction, calcium phosphate zone, drill hole 9–1, sec. 3, T. 32 S., R. 23 E.*

[Data from Cathcart and McGreevy, 1959, pl. 24]

Formation	Description	Thickness (feet)	Phosphate products (tons per acre-foot)			Slime (weight percent)	BPL (percent)	
			Pebble	Concentrate	Pebble: concentrate ratio		Pebble	Concentrate
Bone Valley	Black phosphate and quartz sand.	8.8	185	70	2.6	2.8	68.1	69.0
Hawthorn	Calcareous clayey sand containing brown and black phosphate.	7.9	115	265	.4	38.6	48.9	66.0
Weighted average, total calcium phosphate zone.		16.7	150	165	.9	19.5	60.7	66.6

RELATIONS TO THE SURFACE OF THE HAWTHORN

A comparison of plates 2 and 3 indicates that the relations of the calcium phosphate zone to the topography of the surface of the Hawthorn Formation are not as obvious as in the Keysville quadrangle to the north (Cathcart, 1963a). However, in many areas where the calcium phosphate zone is thickest, it overlies and, therefore, fills depressions or low areas on the surface of the Hawthorn Formation.

In sec. 33, T. 31 S., R. 23 E., the calcium phosphate zone reaches a maximum thickness of 40 feet, and at this location the zone overlies a saddle on the Hawthorn surface. The two highs adjacent to the saddle are overlain by 10 feet or less of calcium phosphate zone. In sec. 30, T. 32 S., R. 22 E., the calcium phosphate zone reaches a maximum thickness of 40 feet and overlies a sinkhole on the Hawthorn surface. Thick areas of calcium phosphate zone also overlie valleys on the Hawthorn surface, as for example in secs. 14 and 17, T. 32 S., R. 22 E.

A thick calcium phosphate zone apparently lies on the flanks of ridges on the Hawthorn surface, as in sec. 11, T. 33 S., R. 22 E., and it seems to occupy the crests of Hawthorn ridges in a few places, as for example in sec. 1, T. 33 S., R. 22 E. In these examples, however, the topographic details of the Hawthorn surface are not fully known, and these apparent relations may not be real.

Those low areas on the Hawthorn surface which represent throughgoing streams—for example, the ancestor of the Little Manatee River in the northern part of the quadrangle—are overlain by a thin calcium phosphate zone. Because these ancestral streams are in the same relative positions as the present streams, the thinning of the calcium phosphate zone at these places may be related to erosion.

Some of the sinkholes on the Hawthorn surface are not filled with the calcium phosphate zone. The sinkhole in sec. 28, T. 32 S., R. 22 E., is filled with overburden that includes both the loose sands of Pleistocene age and clayey sands of the upper unit of the Bone Valley Formation. This sink probably formed after deposition of the phosphate and before deposition of the overburden.

RELATIONS TO THE OVERBURDEN

The overburden includes all the material from the top of the calcium phosphate zone to the surface of the ground. It consists, therefore, of quartz sand of Pleistocene and Recent ages, clayey sand of the upper unit of the Bone Valley Formation, and leached material of the aluminum phosphate zone. An isopach map of the overburden (pl. 4) was compiled from mining company prospect maps and logs. It shows that the overburden thickens to the south. For example, the overburden is about 10 feet thick along modern streams in the northern part of the quadrangle, but is as much as 30 feet thick along the modern streams in the southern part of the quadrangle. The overburden reaches a maximum thickness of about 90 feet in a sinkhole in sec. 28., T. 32 S., R. 22 E.

The relation of the overburden to the calcium phosphate zone can be seen by comparing plates 3 and 4. Both units are thinned along the modern streams. In the northern part of the quadrangle, where the calcium phosphate zone exceeds 20 feet in thickness, it is overlain by 30 feet or less of overburden. Aside from these, there is no consistent relation between the overburden and the calcium phosphate zone.

ANALYTICAL DATA

Chemical information on the calcium phosphate zone in the Chicora quadrangle consists entirely of analyses of the separated phosphate particles. The analyses were made by mining company chemists except those for uranium and the analysis of a few samples from holes drilled in 1953 (Cathcart and McGreevy, 1959).

Most of the company information is from prospect maps. It includes data on BPL content and tonnage of the recoverable phosphate. A large part of the information is for the pebble fraction only. The feed fraction was analyzed, but it was so low in BPL content that a flotation concentrate was not made.

In making comparisons, only those samples that could be determined as being from either the Bone Valley or the Hawthorn Formations were used. The calcium phosphate zone is composed of phosphate from both the Bone Valley and Hawthorn Formations, and drill holes from which only single samples were taken could not be used because of the possibility that both formations were represented. The comparisons made probably are valid, however, because the formation from which a large number of samples came could be identified with reasonable certainty.

A comparison of the acid-insoluble content and the BPL content of the pebble fraction of the Hawthorn and Bone Valley Formations is shown in figure 4. In the pebble fraction of the Bone Valley Formation, the acid-insoluble content (principally silica in the form of quartz grains) has a strong inverse relation to the BPL content; that is, as the BPL increases, the acid-insoluble decreases. In the samples of pebble from the Hawthorn Formation, however, the acid-insoluble content has no consistent relation to the BPL content. All samples range from 7 to 14 percent acid insoluble, whereas the BPL ranges from 33 to 67 percent. The amount of acid insoluble (quartz) is relatively constant in the pebble fraction of the Hawthorn Formation; some other constituent of the pebble, most probably calcite (Cathcart and McGreevy, 1959), is therefore the principal diluent.

These relations indicate that much of the phosphate in the Bone Valley Formation was not derived directly from the Hawthorn Formation. If calcite were the principal diluent in the pebble in the Hawthorn and if the pebble samples were reworked and enriched—as indicated by many samples of the Bone Valley that show evidence of the replacement of calcite by fluorapatite—all the samples on the diagram (fig. 4) would be in the 65–70-percent group for BPL, and in the 7–14-percent group for acid insoluble and there would be no correlation. Much of the coarse pebble of the Bone Valley Formation, therefore, probably formed on the sea floor. Inasmuch as the Bone Valley contains abundant grains of quartz sand, the high insoluble content of some samples is due to the inclusion of sand grains in the phosphate nodules.

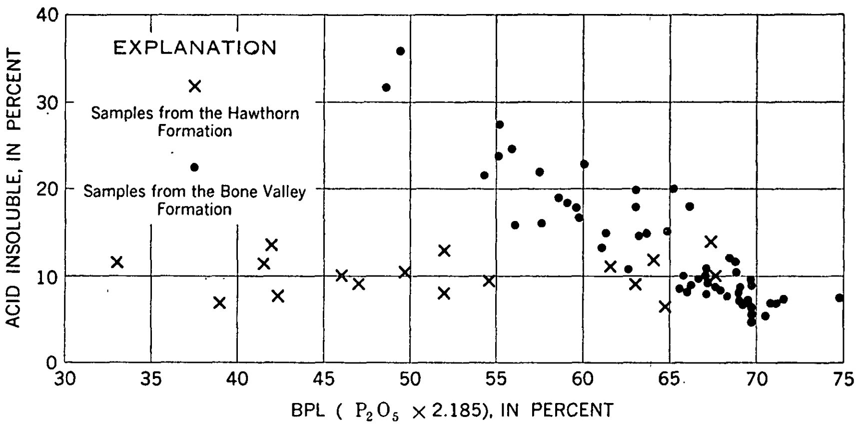

FIGURE 4.—Scatter diagram showing relation of BPL to acid-insoluble content of samples of the pebble fraction of the calcium phosphate zone.

DISTRIBUTION OF PHOSPHATE

Because almost all the data on the P_2O_5 content of the phosphate nodules were obtained from confidential mining company records, detailed information cannot be given. However, certain generalizations can be drawn from the data without violating any confidences. Table 4 was compiled only from those samples that could be assigned either to the Hawthorn or to the Bone Valley. The analyses were averaged for each of the four townships in the quadrangle. Only the southern tier of sections from T. 31 S. are in the Chicora quadrangle, and the information in this township was compiled from fewer samples than that from the remaining townships. However, data on samples from the Keysville quadrangle to the north (Cathcart, 1963a) indicate that the P_2O_5 content of both the pebble and concentrate fractions in T. 31 S. is higher than shown on table 4, so the general conclusions are probably valid. The P_2O_5 contents shown on the table may not represent the averages, for only a small part of the analytical information could be used, but the variations indicated probably are valid.

TABLE 4.—*Average P_2O_5 content and abundance of phosphate nodules in the Bone Valley and Hawthorn Formations, Chicora quadrangle, Florida*

[Analysis by mining company chemists, of several hundred samples]

Location	Bone Valley Formation					Hawthorn Formation				
	Pebble		Volume ratio	Concentrate		Pebble		Volume ratio	Concentrate	
	Tons per acre-foot	P_2O_5 (percent)	Pebble: concentrate	Tons per acre-foot	P_2O_5 (percent)	Tons per acre-foot	P_2O_5 (percent)	Pebble: concentrate	Tons per acre-foot	P_2O_5 (percent)
T. 31 S.	150	31.1	0.5	300	32.7	50	21.9	--------	[1]	--------
T. 32 S.	250	30.9	1.6	150	32.9	150	29.8	0.6	250	30.6
T. 33 S.	200	28.8	1.7	120	30.6	80	27.0	.3	200	30.6
T. 34 S.	100	27.9	[2]	--------	--------	80	26.1	--------	[1]	--------

[1] Pebble data only. No feed or concentrate.
[2] Pebble and feed analyzed. Feed data indicate pebble tonnage greater than concentrate tonnage.

It has been known for many years that phosphate nodules in the southern part of the land-pebble phosphate district are lower in P_2O_5 content than nodules in the northern part (Mansfield, 1942). A general lowering of the P_2O_5 content of phosphate nodules to the south was indicated by Cathcart and McGreevy (1959) from a single line of drill holes (see discussion of cross section 9). Table 4 shows that in the Chicora quadrangle, there is a general lowering of the P_2O_5 content of the phosphate nodules to the south. The decrease in grade is particularly evident in the phosphate of the Bone Valley Formation; it is not so obvious in the phosphate of the Hawthorn Formation. The concentrate fraction of the Hawthorn, for example, has the same P_2O_5 content in the two townships for which analyses were available.

Table 4 also shows that the concentrate fraction of the Bone Valley Formation has the highest P_2O_5 content; the pebble fraction of the Bone Valley and the concentrate fraction of the Hawthorn are next highest in P_2O_5 content; the pebble fraction of the Hawthorn Formation contains the least P_2O_5. In each township, the concentrate fraction is higher in P_2O_5 content than the pebble fraction.

681-486—63——4

RELATION OF PHOSPHOROUS PENTOXIDE TO FLUORINE, CALCIUM OXIDE, AND URANIUM

Fourteen holes were drilled in the Chicora quadrangle as a part of the drilling program by the U.S. Geological Survey in 1953 (Cathcart and McGreevy, 1959). These holes are randomly spaced throughout the quadrangle, and they probably provide a representative sampling of the calcium phosphate zone in the quadrangle. Samples of the calcium phosphate zone were divided into those from the Bone Valley Formation and those from the Hawthorn Formation. Analytical data from the samples were arithmetically averaged and are shown in table 5.

The P_2O_5 contents of the phosphate particles of the Bone Valley and Hawthorn Formations as shown on table 5 are very close to the arithmetic averages of these fractions as shown on table 4. The pebble to concentrate ratios of the two tables are also similar. The chemical analyses shown on table 5 are probably representative of the different fractions of recoverable phosphate of the calcium phosphate zone from the Bone Valley and Hawthorn Formations in the Chicora quadrangle.

TABLE 5.—*Analytical data, calcium phosphate zone, Chicora quadrangle, Florida*

[Analyses from Cathcart and McGreevy, 1959. Fifteen samples each of pebble and of concentrate from the Bone Valley Formation, and the same number from the Hawthorn were used in compiling this table]

	Bone Valley Formation		Hawthorn Formation	
	Pebble	Concentrate	Pebble	Concentrate
Tons per acre-foot	210	150	100	190
Analysis (in percent)				
P_2O_5	30.8	32.5	23.8	29.9
CaO	43.7	43.2	40.0	44.8
F	3.4	3.6	2.7	3.3
U	.015	.010	.009	.007
Ratios				
CaO to P_2O_5	1.42	1.33	1.68	1.53
F to P_2O_5	.11	.11	.11	.11
U to P_2O_5	4.87×10^{-4}	3.08×10^{-4}	3.74×10^{-4}	2.34×10^{-4}
Pebble to concentrate	1.4		0.5	

URANIUM DISTRIBUTION

Uranium analyses of the pebble and concentrate fractions of the calcium phosphate zone were made by the U.S. Geological Survey. The analyses for all samples from each drill hole were arithmetically averaged into one value for the pebble fraction and one value for the concentrate fraction. These analytical data were plotted on a base map at the drill-hole location to show the areal distribution of uranium (pl. 5).

Pebble data are far more abundant than concentrate data—a reflection of the low tonnage of the concentrate fraction. The mining companies analyze the feed fraction (−14+150 mesh), and flotation tests are made only if the grade of the feed exceeds about 20 percent BPL. Where flotation tests were made, the phosphate content of the concentrate fraction was, in general, high enough to be of economic value; tonnages are usually too low to warrant the expense of a flotation plant.

The isograde lines on figure 10 are similar to topographic contours; they are deeply indented up the valleys of the present streams and form closed contours of higher uranium content on the interstream divides. This pattern is a repetition of the distribution in the Keysville and Plant City quadrangles (Cathcart, 1963a and 1963b).

Generalizations about the chemical content of the phosphate particles of the calcium phosphate zone were made by Cathcart and McGreevy (1959). The ratio of fluorine to phosphate is nearly identical in all samples; it is very close to the theoretical ratio for fluorapatite (Palache and others, 1951). The CaO to P_2O_5 ratio in fluorapatite is slightly in excess of 1.3 (Palache and others, 1951), as is the CaO to P_2O_5 ratio in the concentrate fraction of the Bone Valley Formation. Other samples, however, contain an excess of calcium, the pebble fraction of the Hawthorn showing the greatest excess.

The U to P_2O_5 ratio is highest in the pebble fraction and lowest in the concentrates. The ratio is higher in the pebble and concentrate from the Bone Valley Formation than in those fractions from the Hawthorn Formation, and indicates an enrichment of uranium in the phosphate of the Bone Valley Formation. For example, the ratio of U to P_2O_5 is 23 percent greater in the pebble fraction of the Bone Valley than in the pebble fraction of the Hawthorn, and the ratio in the concentrate of the Bone Valley is 24 percent greater than the ratio in the concentrate of the Hawthorn Formation.

The uranium content of the pebble fraction is higher than the uranium content of the concentrate fraction. For example, the concentrate fraction contains more than 0.015 percent uranium only in two small areas, one in sec. 9, T. 32 S., R. 23 E., the other in sec. 8, T. 33 S., R. 22 E. The pebble fraction, on the other hand, contains more than 0.015 percent uranium in several large areas in the north half of the quadrangle. No single average pebble analysis showed less than 0.010 percent uranium; that is, the 0.005-percent contour cannot be drawn for the pebble fraction, but a large area along the Little Manatee River is underlain by concentrate containing less than 0.005 percent uranium.

The uranium content of the phosphate particles is lower in the south half of the quadrangle than in the north half. The south half of the quadrangle has no areas that are underlain by pebble fraction containing as much as 0.015 percent uranium, and the only area underlain by pebble fraction containing less than 0.005 percent uranium is in the south half of the quadrangle. The reasons for this lowering of uranium grade are not known, but the decrease in uranium content to the south parallels the decrease in P_2O_5 content of the nodules.

AMOUNT OF PHOSPHATE

The amount of phosphate nodules in the calcium phosphate zone is computed by the mining companies as tons per acre (Cathcart and McGreevy, 1959). In order to compare figures from strata of varying thicknesses, the number of tons per acre was divided by the thickness, in feet, to give tons per acre-foot. The calcium phosphate zone includes phosphatic sedimentary rocks from both the Hawthorn and the Bone Valley Formations. The phosphate particles in the Bone Valley are dominantly black and coarse grained. The ratio of pebble to concentrate is usually greater than 1. In many places, the concentrate fraction is negligible, and the ratio approaches infinity.

The phosphate particles of the Hawthorn Formation, on the other hand, are brown and white and fine grained. The ratio of pebble to concentrate is usually less than 1. At many places, the pebble fraction is so minor in amount that the ratio approaches zero.

The pebble fraction of the Bone Valley ranges from less than 100 tons per acre-foot to more than 1,000 tons per acre-foot and averages perhaps 350 tons per acre-foot in areas that can be mined. Table 4 shows the tonnages of pebble from the Bone Valley in the different townships in the Chicora quadrangle. The highest tonnage shown is 250 tons per acre-foot, but this table includes all information for the quadrangle and is not confined to areas that may be minable. The pebble fraction of the Hawthorn Formation, however, ranges from about 50 to 300 tons per acre-foot and averages only about 90 tons per acre-foot. The contrast between the amount of pebble in the two formations is striking.

The contrast in the amount of concentrate is equally striking. Very few samples of the calcium phosphate zone from the Bone Valley Formation contain large amounts of concentrate, except in T. 31 S. In most samples, the mining companies either did not compute the amount of concentrate obtainable from the Bone Valley Formation, or combined the concentrate with that from the underlying Hawthorn Formation to form a single sample.

The concentrate in the Bone Valley Formation ranges from less than 100 tons per acre-foot to more than 300 tons per acre-foot, but averages less than 100 tons per acre-foot; the concentrate in the Hawthorn Formation ranges from 200 tons per acre-foot to more than 500 tons per acre-foot and averages about 250 tons per acre-foot.

It was not possible to make a size-distribution map, as was done for the Keysville quadrangle (Cathcart, 1963a), because the large number of drill holes that included only one sample made impossible the detailed differentiation of the pebble-to-concentrate ratios. Many of the samples were not treated by flotation; as a consequence, the amount of concentrate and the difference in the pebble-to-concentrate ratios in the Bone Valley and Hawthorn Formations is not known.

ALUMINUM PHOSPHATE ZONE

The aluminum phosphate zone was formed by the leaching action of acid ground water on the Bone Valley Formation. It is characterized by the presence of aluminum or calcium aluminum phosphate minerals, by a generally light color, and by a relatively high uranium content. The zone in the Chicora quadrangle is typically a gray or whitish-gray, clayey to slightly clayey sand, and it is described in almost all the lithologic logs of drill holes in the quadrangle as a gray clayey sand. In a few holes, somewhat indurated brown clayey sands are found. Lumps, fragments, or thin beds of sandrock are described from about half of the drill holes. Thin beds of sandrock, where present, are always at the base of the zone, but fragments or lumps of sandrock in the clayey sand may be present in any part of the section. Grains or nodules of soft white phosphate were found in cores from about one-third of the drill holes. This material probably represents the first effect of leaching. In half of the holes where it occurs, it is at the base of aluminum phosphate zone. In the other half, it is higher in the section, and is underlain by apparently unleached fresh black or brown phosphate nodules. At most places the leaching that formed the aluminum phosphate zone altered only the upper unit of the Bone Valley Formation, and in only a few places was the leaching deep enough to alter the lower phosphorite unit.

The aluminum phosphate zone underlies all the Chicora quadrangle, except along the courses of the modern streams where it has been removed by erosion, and in the southwest quarter of the quadrangle where it probably was not formed (pl. 6).

The zone is generally thin. It reaches a maximum thickness of slightly more than 15 feet only in a few very small areas in the northeastern part of the quadrangle. In the south half of the quadrangle, the zone exceeds 5 feet in thickness only in scattered small areas. The zone, therefore, thins to the south or to the southwest.

Analytical data on the aluminum phosphate zone are very sparse. Only a few samples of the zone in T. 32 S., R. 23 E., were screened, and only the −150 mesh fractions were analyzed. The analytical data are shown on table 6. The analyses indicate, generally, the direct relation of P_2O_5 to U. The alumina content is high, and except in one sample (No. 100980) it is relatively uniform. The clay minerals are concentrated in the −150 mesh fraction, and they account for the excess alumina beyond that required by the phosphate mineral.

TABLE 6.—*Analytical data, —150 mesh fraction, aluminum phosphate zone, Chicora quadrangle, Florida*

[Chemical analyses by Dorothy Lee, M. H. Delevaux, Roberta Smith, and W. P. Tucker; radiometric (eU) analyses by B. A. McCall and J. H. Goode, Jr.]

Laboratory sample	Location			Depth below surface (feet)	Weight percent −150 mesh	Analyses, in percent, of the −150 mesh fraction			
	Sec.	T.(S.)	R.(E.)			P_2O_5	U	eU	Al_2O_3
100695	30	32	23	5–8	15.6	1.7	0.002	0.002	32.6
100699	30	32	23	8–13	22.9	2.7	.005	.004	32.4
100980	5	32	23	21–27	10.0	4.3	.004	.005	21.4
100990	4	32	23	7–20	11.9	6.9	.013	.011	31.5
100713	30	32	23	13–32	5.5	9.8	.011	.009	30.6
101005	5	32	23	6–21	21.4	10.7	.006	.007	29.8
100708	29	32	23	10–38	5.6	11.8	.012	.008	29.3
100738	29	32	23	23–31	8.9	14.4	.031	.025	28.3
100995	4	32	23	9–17	12.3	15.9	.024	.022	29.3

A few additional samples taken by the phosphate companies were analyzed for uranium by the U.S. Geological Survey. These samples are from the 2 to 3 feet of material that is directly above the matrix, and most are from T. 32 S., R. 23 E. The samples were not screened. None contained more than 0.005 percent uranium, and the average uranium content was only 0.002 percent.

Uranium, then, is concentrated in the −150 mesh fraction, as indicated by the high uranium contents of some of the samples on table 6.

The map of distribution of uranium (pl. 7) was made almost entirely from gamma-ray logs. The pattern of uranium distribution is similar to that in the Keysville quadrangle (Cathcart, 1963a). The uranium content of the zone is lowest along river courses and highest in the interstream divides, where the isograde lines form small closed contours.

The uranium content of the aluminum phosphate zone is less than 0.005 percent along the streams. It reaches a maximum of somewhat more than 0.015 percent in one small area in the northeastern part of the quadrangle. The distribution of uranium closely follows the thickness of the zone; the amount of uranium decreases to the south and southwest.

The decrease in uranium content toward the southwest is shown by the gamma-ray logs on figure 5. These drill holes form a north-

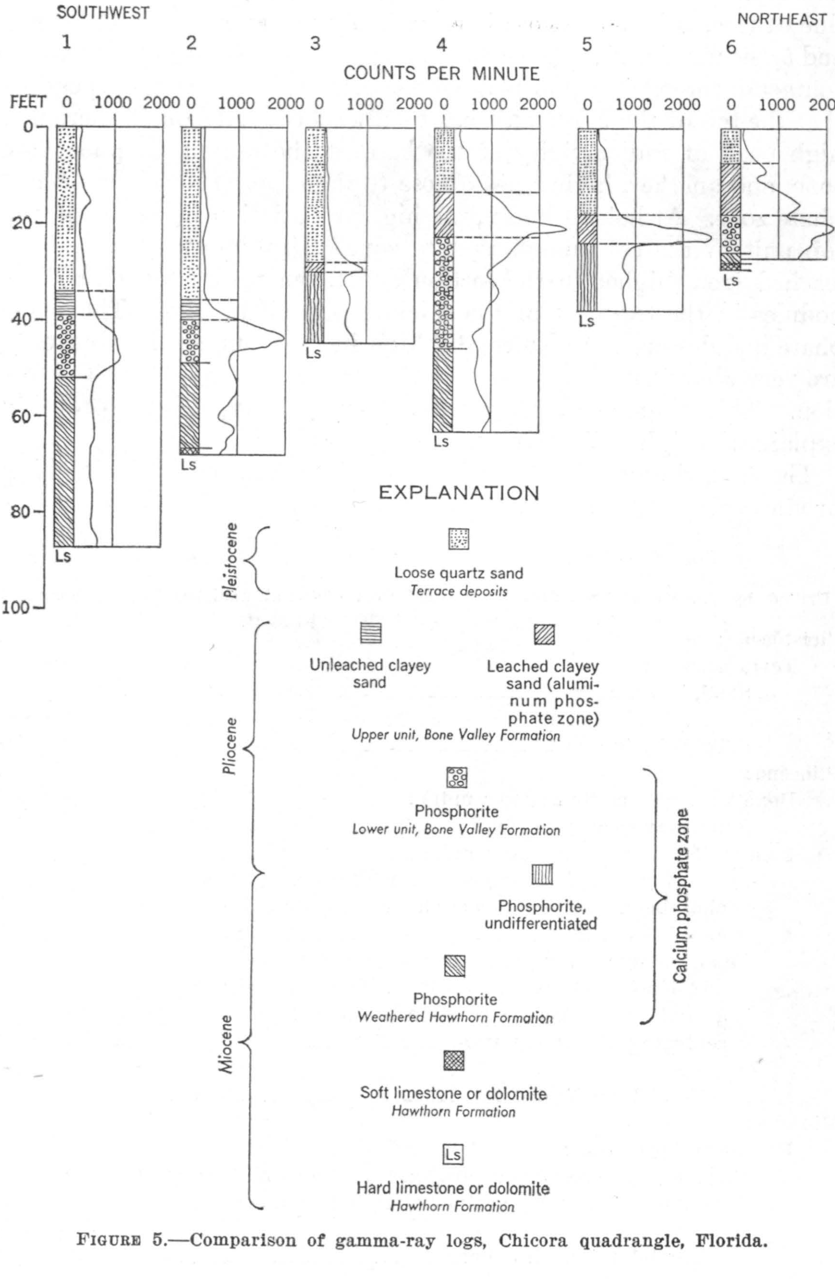

FIGURE 5.—Comparison of gamma-ray logs, Chicora quadrangle, Florida.

east-southwest cross section. At holes 1 and 2, the most southern holes, the clayey sand does not show any anomalous radioactivity. Minor amounts of fresh black phosphate are present in the cuttings from these intervals and indicate that there has been no leaching. At hole 3, the clayey sand contains the highest uranium content along the line of the section, although it is probably not economic. At holes 4 and 5, the uranium is concentrated at the base of the clayey sand at the contact of the calcium phosphate zone. At these two holes, it is possible that the top of the lower unit has been leached. At hole 6, there is a high peak of radioactivity at the base of the aluminum phosphate zone, and another, higher peak close to the top of the calcium phosphate zone. At holes 1 and 2, the highest radiation peaks are in the top unit of the calcium phosphate zone. Uranium may have been leached from higher in the section and taken up by the phosphate nodules in the top part of the calcium phosphate zone. The phosphate nodules are not abnormally high in uranium content, but they are very abundant—much more so than in the lower parts of the section. This abundance of uraniferous phosphate nodules probably explains the high radioactivity.

The following logs M, N, and O show the variations in the leaching profile typical of the aluminum phosphate zone.

Log of drill hole M in the center of sec. 31, T. 31 S., R. 22 E.

[Drilled by American Agricultural Chemical Co.; chemical analyses by the company, used with their permission]

	Thickness (feet)
Pleistocene:	
Terrace sands:	
Sand, loose, gray	10
Total Pleistocene	10
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, clayey, gray to white	16
Bone Valley Formation (lower unit):	
Sand, clayey, light gray-green to white; contains soft dull white phosphate. Pebble fraction contains 13.7 percent P_2O_5 (leached)	7
Sand, clayey to clay, sandy, gray-green; contains abundant brown and black phosphate, mostly of fine sand size, but some of granule size. Pebble fraction contains 28 percent P_2O_5; concentrate 31.5 percent P_2O_5	7
Total Bone Valley	30
Miocene:	
Hawthorn Formation:	
Clay, sandy, calcareous, gray-green to cream; contains minor amounts of very fine grained phosphate nodules	3
Partial total, Hawthorn	3

Hole bottomed on material too hard to penetrate with the hand auger, probably limestone or dolomite of the Hawthorn Formation.

Log of drill hole N in the NE¼SW¼ sec. 28, T. 32 S., R. 23 E.

	Thickness (feet)
Pleistocene:	
Terrace sand:	
Sand, loose, tan and brown, medium- to fine-grained	4
Total Pleistocene	4
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, slightly clayey, white and light-gray; contains a few fine-grained nodules of soft dull white phosphate near the base	16
Sand, slightly clayey, gray-tan; contains a very few highly polished black phosphate nodules in the basal foot	19
Bone Valley Formation (lower unit):	
Sand, slightly clayey, light-gray; contains highly polished black and white phosphate nodules, mostly greater than 14 mesh in size (pebble)	4
Total Bone Valley	39
Miocene:	
Hawthorn Formation:	
Clay, white, sandy, calcareous; contains brown and black fine-grained phosphate grains	1
Partial total, Hawthorn	1

Hole bottomed on material too hard to penetrate with hand auger, probably limestone or dolomite of the Hawthorn.

Log of drill hole O in NE¼NW¼ sec. 18, T. 33 S., R. 22 E.

[Adapted from lithologic log by Louis Pavlides. Hole drilled by the Tennessee Valley Authority]

	Thickness (feet)
Pleistocene:	
Terrace sand:	
Sand, quartz, loose, black, gray, and brown	8
Sand, dark-brown; indurated with iron-oxide	12
Sand, quartz, loose, tan, fine-grained	18
Total Pleistocene	38
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, slightly clayey, gray-tan; contains black, highly polished phosphate. Phosphate increases from a trace at the top to about 3 percent at the base of the unit	11
Sand, clayey, gray-green; contains minor amount (3 to 5 percent) of black, highly polished phosphate grains	5
Bone Valley Formation (lower unit):	
Sand, practically loose, gray; contains abundant (15 percent) fine-grained black phosphate	5
Total Bone Valley	21

	Thickness (feet)
Miocene:	
Hawthorn Formation:	
Clay, sandy, green; contains trace amounts of black phosphate	6.5
Clay, sandy, cream, calcareous; a trace of fine-grained black phosphate	3.5
Partial Total Hawthorn	10.0
Hole bottomed in material above.	

At drill hole M in sec. 31, T. 31 S., R. 22 E., in the northern part of the quadrangle, the upper unit is a gray clayey sand. This unit probably is thoroughly leached, although there are no visible phosphate minerals. The top of the lower unit contains soft white phosphate of very low P_2O_5 content; this material has been leached. The locality is a good example of the leaching which extends down into the top part of the lower unit of the Bone Valley Formation.

At drill hole N in sec. 28, T. 32 S., R. 23 E., in the east-central part of the quadrangle, the upper part of the upper unit of the Bone Valley Formation has been leached, as indicated by the trace of soft white phosphate. The lower part of the upper unit contains minor amounts of unleached black phosphate; this drill hole shows a profile of leaching which extended only to about the middle of the upper unit of the Bone Valley Formation.

At drill hole O in sec. 18, T. 33 S., R. 22 E., in the south half of the quadrangle, the entire upper unit of the Bone Valley Formation contains unleached black phosphate.

ORIGIN

Rounded, highly polished phosphate nodules are present in all the lithologic types of the Hawthorn Formation throughout the Chicora quadrangle. The phosphate nodules were deposited as one of the constituents of the limestone (Cathcart, 1963a, fig. 10) or were formed as a replacement of the groundmass of the limestone (Cathcart, 1963a, fig. 9). In both cases, the nodules are essentially syngenetic: Those that replaced limestone were probably formed at about the time of deposition. All nodules have sharp clear boundaries; evidence of massive, sheetlike, or irregular replacement of the limestone has not been observed.

No analyses were mode of the phosphate nodules from the limestone of the Hawthorn Formation in the Chicora quadrangle, but analytical data from the district as summarized by Cathcart and McGreevy (1959) are as follows: P_2O_5—average 18 percent; U—average less than 0.005 percent; CaO : P_2O_5 ratio—average 2.5; amount of nodules—average about 50 tons per acre-foot.

The Hawthorn Formation was deposited in a shallow marine environment on the south flank of the rising Ocala uplift (Cathcart, 1963b). Weathering after deposition was chemical; calcium carbonate was removed, and a residuum of phosphate nodules, quartz sand, and clay remained. This residuum probably is very similar to the present bedclay. Phosphate nodules are much more abundant in the bedclay than in the limestone; they are higher in P_2O_5 content, averaging 26 percent in the pebble fraction and 31 percent in the concentrate (table 4); they contain less excess calcium oxide and slightly more uranium than the nodules in limestone of the Hawthorn. The phosphate nodules, therefore, are concentrated and enriched in the residuum.

The residual clay was reworked into the lower unit of the Bone Valley Formation. The reworked phosphate, quartz sand, and clay were sorted and deposited over the irregular surface of the Hawthorn Formation by the advancing sea. At many places a conglomerate of coarse phosphate, rounded phosphatized limestone boulders, and rounded phosphatized bone fragments is the initial deposit of the Bone Valley Formation.

The Hawthorn Formation is the source of much of the phosphate in the Bone Valley Formation, but not all the phosphate nodules in the Bone Valley were reworked from the Hawthorn. The relations of acid insoluble to BPL content (fig. 4) indicate that much of the pebble fraction of the Bone Valley was formed on the sea floor; the phosphatized limestone boulders were probably formed at this time.

Both P_2O_5 and uranium are much higher in the phosphate nodules in the Bone Valley Formation than in the Hawthorn, and there is little or no excess calcium oxide. The $CaO:P_2O_5$ ratio for the nodules in the Bone Valley is close to 1.4, the theoretical ratio for carbonate fluorapatite (Altschuler and others, 1958). The high uranium content and the fact that uranium is most abundant in the coarse-pebble fraction that has the lowest P_2O_5 content indicate that uranium came from sea water and that the coarse nodules were probably exposed to sea water during more than one interval.

The rocks of the Bone Valley Formation were altered by lateritic weathering in late Pliocene or early Pleistocene to form the aluminum phosphate zone. At this time, the underlying limestone was altered to form the bedclay, and magnesium oxide, released when montmorillonite was changed to kaolinite, dolomitized the limestone. Carbonate rock of the Hawthorn Formation is dolomitic only near the present surface. Cores taken at depth show that the carbonate rock is limestone (Berman, 1953). Phosphate nodules in the lower part of the Bone Valley and in the bedclay may have been enriched in P_2O_5 during this weathering.

Erosion during the late Pleistocene and Recent has removed the Bone Valley Formation along the courses of the modern streams.

The phosphate deposits, therefore, are complex—they are partly residual, partly transported and depositional, and partly altered by chemical weathering.

RESOURCES

CALCIUM PHOSPHATE ZONE

The area of the Chicora quadrangle is about 166,000 acres. Almost 36,000 acres, or about 22 percent of the area, has been prospected, largely in the north half of the quadrangle. The total measured, indicated, and inferred reserves are 94.3 million long tons of the pebble fraction and 39.8 million long tons of the concentrate fraction. No data are available for other parts of the quadrangle. The Bone Valley Formation is known to be absent along the stream valleys in the western part of the quadrangle; these valleys comprise about 10 percent of the area of the quadrangle. The remaining two-thirds of the quadrangle is underlain by phosphate resources known to be lower in grade and lower in tonnage than the part that has been prospected. It is also known that the pebble-to-concentrate ratio increases to the south; that is, the concentrate fraction is much less abundant in the southern part of the quadrangle. Therefore, although tonnage figures have not been computed for the rest of the quadrangle, it is likely that there is at least as much of the pebble fraction present in the unprospected area as there is in the prospected area, and that there will be some concentrate, although probably not as much as computed for the prospected area.

The average uranium content of analyzed samples of the pebble fraction from 237 drill holes is 0.013 percent. The concentrate fraction averages 0.010 percent uranium in samples from 104 drill holes. If these average figures are correct for the area prospected, there are 16,000 long tons of uranium in the recoverable phosphate products in the quadrangle.

ALUMINUM PHOSPHATE ZONE

Prospecting for the aluminum phosphate zone was done only in the years the field party of the U.S. Geological Survey was active. Most of the other prospecting in the Chicora quadrangle was done before that time. As a consequence, gamma-ray logs, the principal source of data for the zone, are available for only 63 drill holes representing 2,160 acres or about 1.3 percent of the total area of the quadrangle.

Only a few samples were taken of the zone, and most of these were analyzed only for uranium. The slime fraction of nine samples was analyzed for uranium, phosphate, and alumina (table 6).

In the area prospected, the indicated reserves (three or more drill holes per 40-acre block) total 1.1 million long tons having an average uranium content of 0.006 percent. Total inferred reserves (one or two drill holes per 40 acres) are 26.7 million long tons having an average uranium content of 0.007 percent uranium.

The southwest quarter of the quadrangle is underlain by rocks that have not been leached. This area includes about 40,000 acres (pl. 7) or slightly less than 25 percent of the total area of the quadrangle.

About 22,000 acres in the remainder of the quadrangle is underlain by aluminum phosphate zone that is more than 3 feet thick and that contains more than 0.005 percent uranium (pl. 7 and fig. 5). Included in this 22,000 acres is the 2,160 acres for which prospecting data are available.

There are, then, about 20,000 (22,000−2,160) acres underlain by potentially minable aluminum phosphate zone. The average thickness of the zone in the area is about 6 feet (fig. 12). An acre-foot contains about 1,600 cubic yards of material (Cathcart and McGreevy, 1959, p. 266), and there are 9,600 cubic yards per acre of leached zone material, or, in 20,000 acres, 192 million cubic yards. If the average weight per cubic foot is 90 pounds for the aluminum phosphate zone, the quadrangle has an additional potential resource of somewhat more than 208 million long tons of aluminum phosphate zone material of an average grade of about 0.006 percent uranium (fig. 5).

No analytical data on P_2O_5 content of the zone are available. However, it has been shown that the uranium and phosphate contents are related (Cathcart, 1956), and, because of the low content of uranium in the aluminum phosphate zone in the quadrangle, it seems likely that the phosphate content is from 4 to 5 percent, somewhat below the lower economic limit for exploitation of the zone (Cathcart and McGreevy, 1959).

PHOSPHATE RESOURCES OF THE HAWTHORN FORMATION

The Hawthorn Formation underlies all the Chicora quadrangle. The formation thickens from about 100 feet in the north to about 300 feet in the south, and its thickness probably averages about 200 feet (p. 11).

Except for the top 50 feet, the lithology of the formation is not known, and therefore, the amount and grade of the phosphate nodules are also unknown. Phosphate nodules are characteristic of the formation at the deep-well holes to the north and to the south of the quadrangle, and the sedimentary rocks of the Hawthorn Formation, penetrated in the drilling in the quadrangle, contain phosphate nodules. The meager data indicate that the phosphate content and the grade of the phosphate nodules are both low.

The tonnage and grade figures must be considered tentative, but the formation is about three times as thick in the Chicora quadrangle as in the Keysville quadrangle, and could, therefore, contain about three times as much phosphate; if it does, the Hawthorn Formation contains about 3 billion long tons of phosphate nodules having a BPL content of about 50 percent.

TRACT DESCRIPTIONS

Prospecting by mining companies is concentrated in relatively small tracts of land; the results of the prospecting can be discussed in terms of these tracts. The names of the tracts were assigned by the writer on the basis of some geographic feature, and they may not be the same as those used by the company. Company names are used where available.

FORT LONESOME TRACT

The Fort Lonesome tract is in secs. 5, 6, 7, 8, 9, 10, and 15, T. 32 S., R. 22 E., in the northern part of the quadrangle. It was drilled by the American Cyanamid Co. and the American Agricultural Chemical Co.

STRATIGRAPHY

The stratigraphic succession, as determined from drilling, is remarkably uniform throughout the Fort Lonesome area. The following composite stratigraphic section is typical of the area.

Composite log, Ft. Lonesome tract

	Thickness (feet)
Pleistocene:	
Terrace sands:	
Sand, loose, white and gray	6–12
Sand, brown, iron-stained or cemented (hardpan)	2–4
Sand, loose, brown	2–12
Total Pleistocene	10–28
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, very slightly clayey, gray, tan, or light-brown; commonly contains aluminum phosphate minerals, and, at the base, white phosphate nodules	5–25
Bone Valley Formation (lower unit):	
Sand, loose to slightly clayey, gray, white, or brown; contains black phosphate nodules. The phosphate nodules increase in size and in amount toward the base. Ratio of pebble to concentrate is greater than 1	0–14
Total Bone Valley	5–39

	Thickness (feet)
Miocene:	
Hawthorn Formation:	
Clay, sandy, calcareous, gray, white, or yellow-brown; or clayey sand containing brown, gray, and white phosphate nodules. Ratio of pebble to concentrate is less than 1	0–8
Partial total, Hawthorn	0–8

Hole bottomed on rock too hard to penetrate with the hand auger; probably limestone or dolomite of the Hawthorn Formation.

Hawthorn Formation.—The Hawthorn Formation consists of calcareous sandy clay and clayey sand containing brown, gray, white, and minor amounts of black phosphate nodules. The clay is residual from the underlying limestone. At a few scattered drill holes, thin beds of green laminated clay overlie calcareous clay. In all the drill holes, the fine phosphate fraction (concentrate) was more abundant than the coarse phosphate fraction (pebble). The clay rests on material, presumably limestone or dolomite of the Hawthorn Formation, that was too hard to penetrate with the hand auger. In the Fort Lonesome area, limestone was cored in the drilling for the U.S. Geological Survey in 1953 (Cathcart and McGreevy, 1959). The limestone is buff and contains some medium-grained quartz sand and fine-grained brown phosphate nodules.

Bone Valley Formation.—The lower unit of the Bone Valley Formation rests on the clay of the Hawthorn Formation in about half the holes drilled. Phosphatic sand of the Bone Valley rests on the hard limestone of the Hawthorn in the other holes.

The Bone Valley Formation consists of two units, (1) a basal unit of sand containing only minor amounts of clay but very abundant black phosphate nodules, and (2) an upper unit of very slightly clayey to clayey sand containing minor amounts of phosphate nodules. The phosphate nodules in the upper unit normally occur only in the base of the unit.

In the lower unit phosphate nodules are most abundant and are largest toward the base. At many of the drill holes, the basal 1 to 2 feet is a phosphate conglomerate which rests on either the clay or the limestone of the Hawthorn Formation. The contact between the Hawthorn and the Bone Valley, therefore, is disconformable. Figure 6 is a graphic log of a drill hole in which a phosphate conglomerate rests on material too hard to penetrate with the hand auger. The phosphate conglomerate grades upward to a phosphate sand and finally to a clayey sand that contains much less phosphate. The sequence suggests graded bedding.

The upper unit of the Bone Valley Formation overlies the lower unit with a gradational contact marking a change to clayey sand containing only minor amounts of phosphate. At all drill holes examined, the change from a phosphatic sand to a nonphosphatic clayey sand occurs in a very short vertical distance and represents a stratigraphic as well as an economic contact.

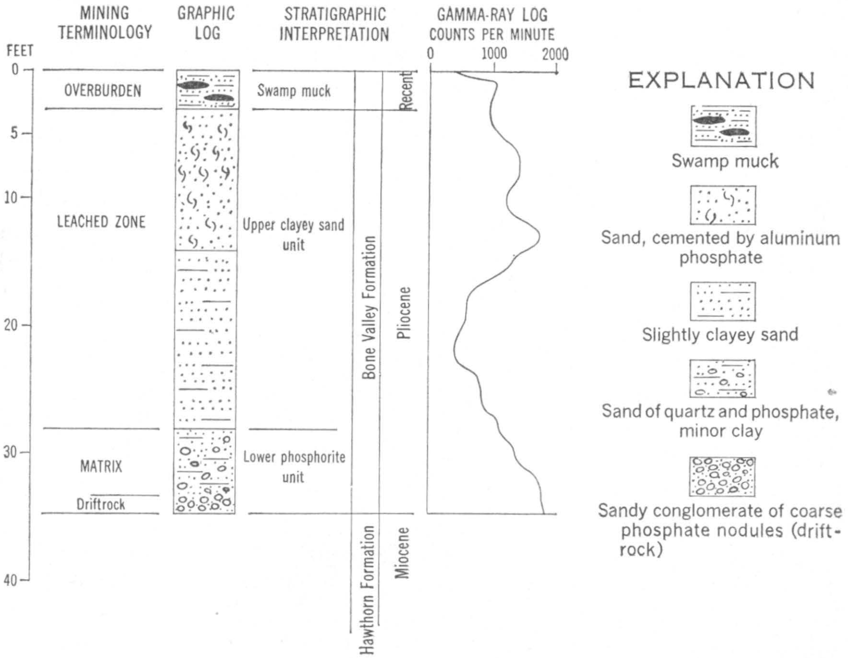

FIGURE 6.—Graphic log of drill hole in the SW¼SW¼ sec. 5, T. 32 S., R. 22 E.

Terrace sand.—Loose quartz sand at the surface throughout most of the Fort Lonesome tract is assigned to the Pleistocene. Swamp muck and windblown sand are probably of Recent age. At one drill hole (fig. 6), swamp muck at the surface rests on aluminum phosphate-cemented sand of the upper unit of the Bone Valley Formation. The sand of Pleistocene age is not present. At the other drill holes in the tract, loose quartz sand, assigned to the Pleistocene, overlies the upper unit of the Bone Valley Formation. No attempt was made to distinguish the sand of Pleistocene age from the windblown sand and swamp muck of Recent age.

ECONOMIC GEOLOGY

Calcium phosphate zone.—The calcium phosphate zone generally includes both the Hawthorn Formation and the lower unit of the Bone Valley Formation. However, as indicated on figure 6, it may consist of only the lower unit of the Bone Valley Formation. Figure 7 shows an average example in which the calcium phosphate zone is composed of both the Bone Valley and Hawthorn Formations.

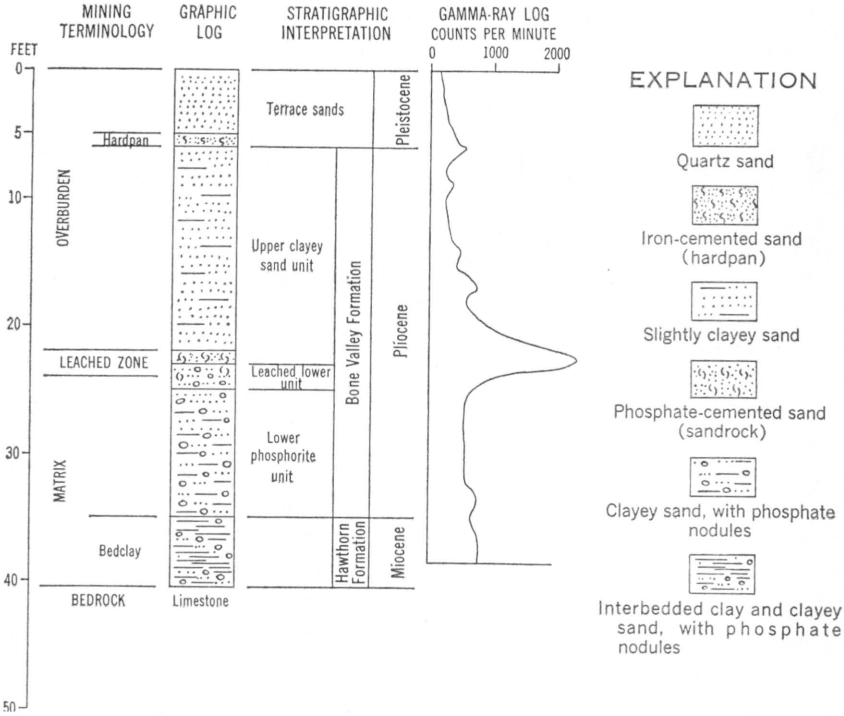

FIGURE 7.—Graphic log of drill hole in the NW¼SW¼ sec. 8, T. 32 S., R. 22 E.

In most of the Fort Lonesome tract the calcium phosphate zone and matrix are nearly synonymous. In a few places, phosphatic clays at the bottom of the section contain too little phosphate to be exploitable. For example, some of the mining companies' logs indicate a few feet of bedclay at the bottom of the drill holes. The material, which is presumably phosphatic calcareous clay, was not analyzed. This clay is a part of the calcium phosphate zone, but it is excluded from the matrix.

The matrix from the Bone Valley Formation and that from the Hawthorn Formation differ. The matrix from the Bone Valley is a sand of quartz and predominantly black phosphate containing very little clay. The phosphate fraction of the matrix is commonly about 20 percent by weight at the top of the section and increases downward. At the base, it constitutes as much as 70 percent of the rock. Most of the phosphate is coarse grained and is in the pebble fraction. The phosphate particles commonly are coarser with depth, and in many of the drill holes the base of the Bone Valley matrix is a phosphate conglomerate, the so-called driftrock. The ratio of the pebble fraction to the concentrate fraction ranges from about 1.5 to infinity.

The matrix from the Hawthorn is a green, blue, or brown clay that is sandy to slightly sandy and usually only slightly calcareous. The clay is interbedded with clayey sand which contains predominantly fine-grained phosphate (the concentrate fraction). The phosphate nodules are predominantly shades of brown; a few are black and some are white. The pebble-to-concentrate ratio is less than 1, and is usually from 0.1 to 0.5.

The contrast in the lithology and in the phosphate content of the Bone Valley and the Hawthorn Formations is very pronounced; this contrast holds throughout the Fort Lonesome tract.

Aluminum phosphate zone.—The aluminum phosphate zone has been delineated in the Fort Lonesome tract exclusively by the use of gamma-ray logs. No analytical data are available. Figures 6 and 7 show gamma-ray logs of two typical variations that recur in the Fort Lonesome area. The log of the drill hole in sec. 8, T. 32 S., R. 22 E. (fig. 7), is typical of a section where the upper unit of the Bone Valley Formation has been thoroughly leached. Most of the aluminum phosphate minerals and the uranium are concentrated in a thin bed at the base of the upper unit. The top of the lower unit also has been leached. At the drill hole, the aluminum phosphate zone includes all the upper unit and the top 2 feet of the lower unit. The upper unit has been so completely leached that almost no uranium remains in it, except in the bottom 1 foot, which is a sand cemented by aluminum phosphate minerals. The gamma-ray log shows a very sharp, narrow peak at this bed.

The leached zone is that part of the aluminum phosphate zone which might be profitably mined; it includes the basal 1 foot of the upper zone of the Bone Valley and the top 1 foot of the lower unit. The leaching which altered the lower unit has not been so severe as to make it unprofitable to mine this material as matrix. The matrix, as determined by the phosphate company, includes the bottom foot of the leached lower unit; the top 1 foot is discarded as overburden. The severe leaching, as shown in the aluminum phosphate-cemented sand at the base of the upper unit, apparently was an earlier stage of leaching than that which has begun to alter the lower unit.

The log of the drill hole in sec. 5, T. 32 S., R. 22 E. (fig. 6), is typical of that of many of the holes drilled in the Fort Lonesome tract. The upper half of the upper unit of the Bone Valley Formation consists of sand cemented by aluminum phosphate minerals; the bottom half of the unit consists of slightly clayey sand having no visible phosphate minerals. The gamma-ray log shows that the average equivalent uranium content of the upper half of the unit, as represented by an average of more than 1,000 counts per minute, is about twice that of the lower half. The log shows an increase of equivalent uranium content in the lower unit of the Bone Valley Formation. The radioactivity reaches a maximum at the base of the log, in the phosphate conglomerate. In this example, either the section that was leached contained more phosphate at the top, or the top part of the section (the aluminum phosphate-cemented sand) represents reworked leached material which was deposited in the sand of Pleistocene age; if the second alternative is true, the top of the Bone Valley Formation is at the base of the aluminum phosphate-cemented sand. Inasmuch as no evidence of reworking was seen in the cuttings from the drill hole, the difference in the leached section probably is due to original differences in the sediment.

The leached zone and the aluminum phosphate zone are synonymous at this drill hole. Any mining of the aluminum phosphate zone at this section would have to include all the upper unit of the Bone Valley Formation.

Distribution of phosphatic materials.—The calcium phosphate zone is present throughout the Fort Lonesome tract, except along the courses of Hurrah Creek, the Little Manatee River, and the South Prong of the Alafia River. The zone reaches a maximum thickness of more than 20 feet in the interstream divides (pl. 3). Although elsewhere in the quadrangle the thickest parts of the calcium phosphate zone tend to overlie the low areas on the Hawthorn surface (pl. 2), this relation is not particularly evident in the Fort Lonesome tract. The overburden ranges in thickness from less than 10 feet along the modern streams to about 50 feet under the interstream divides (pl. 4). Both the overburden and the matrix thin along the present streams, and the areas underlain by the thickest calcium phosphate zone are never overlain by more than 30 feet of overburden. Where the overburden is more than 40 feet thick, the calcium phosphate zone is not more than 10 feet thick.

The aluminum phosphate zone is present throughout the Fort Lonesome tract, except along modern streams. It reaches a maximum thickness of about 15 feet in only one small area in sec. 16, T. 32 S., R. 22 E., just north of Little Manatee River.

ROUX-DAVISON TRACT

The Roux-Davison tract, owned by The American Cyanamid Co., includes about 2,700 acres in parts of secs. 27, 28, 31, 32, 33, and 34, T. 31 S., R. 23 E., and secs. 4, 5, and 6, T. 32 S., R. 23 E., Polk County, Fla. The property was explored by drilling in 1952. The drill holes were logged by D. C. Alverson, J. R. Brooks, W. J. Carr, and the author, all of the U.S. Geological Survey. Many of the drill holes were logged with a gamma-ray unit, but no samples of the aluminum phosphate zone were analyzed. Samples of the calcium phosphate zone were analyzed for uranium in the Geological Survey's laboratories in Washington, D.C. The property is in the northeastern part of the Chicora quadrangle, and has not been mined.

STRATIGRAPHY

The stratigraphy in the Roux-Davison tract is based on the lithology of drill cuttings. All drill holes bottomed on calcareous clay (bedclay), soft limestone (soft bedrock), or dolomite or limestone (hard bedrock)—material too hard to penetrate with the hand auger. These materials are assigned to the Hawthorn Formation. Both the upper and lower units of the Bone Valley Formation are present at most drill-hole locations, and the area is covered with a blanket of loose sand of Pleistocene age.

Hawthorn Formation.—The principal lithologic constituent of the Hawthorn Formation is a calcareous sandy clay containing fine-grained to very fine-grained phosphate particles. The clay is residual from the underlying limestone or dolomite; it is light colored, being described from most drill holes as white, cream, tan, light gray, or shades of yellow or brown. The phosphate particles are dominantly brown, amber, or gray. Black nodules are common, but are usually sparse. Some coarse phosphate nodules (the pebble fraction) are present, these are dominantly black. The pebble-to-concentrate ratio at all drill holes is less than 1.

At one drill hole in the westernmost part of the tract, a green clay interlaminated with fine-grained quartz sand rests on calcareous clay. This clay is lithologically similar to the clay in the southern part of the quadrangle, and probably is an outlier of the upper part of the Hawthorn Formation.

Soft white to buff sandy limestone or dolomite was recovered at one drill location. The sand fraction of the limestone is fine to very fine grained and consists of quartz and minor amounts of black and brown phosphate.

The material at the bottom of all the drill holes in the tract, which is too hard to penetrate with the hand auger, is probably limestone or dolomite; it is assigned to the Hawthorn Formation.

Bone Valley Formation.—Both units of the Bone Valley Formation, the lower phosphorite and the upper clayey sand, are present everywhere except along modern streams, where they have been removed by erosion.

The lower phosphorite unit rests on calcareous clay, laminated clay, and in a few places, on hard limestone or dolomite—all of the Hawthorn Formation. The contrast in lithology between the phosphorite of the Bone Valley and the underlying materials assigned to the Hawthorn is very striking, and the contact can be identified with confidence, even in drill cuttings.

The lower unit consists of dominantly medium- to coarse-grained sand of quartz and phosphate and some clayey sand or sandy clay. The phosphate is black and brown, and minor amounts of gray and tan nodules are present. The phosphate nodules are coarse sand to granule size, and tend to increase in size downward; the basal bed at some of the drill locations is a conglomerate of phosphate containing no clay and only minor amounts of coarse quartz sand. Many of the drill-hole logs suggest graded bedding. The conglomerate at the base grades upward to coarse sand, then to medium-grained clayey sand, and finally, in some places, to fine-grained sandy clay. At all drills holes the pebble-to-concentrate ratio in the lower unit of the Bone Valley Formation is greater than 1.

The upper unit of the Bone Valley Formation is a gray clayey sand. The lithology of this unit is remarkably constant in this area. Soft white phosphate grains are common, though sparse, near the base of the unit, and lumps or fragments of sandrock are common in the unit. Both of these features suggest that the upper unit of the formation has been thoroughly leached by acid ground water. The thin bed of soft white phosphate probably indicates the base of the leaching. The base of the upper unit, however, contains fresh black phosphate grains at many drill locations. The fresh phosphate, in some of the drill holes, is overlain by a zone of soft white phosphate. It seems probable that over most of this area, leaching did not extend into the lower unit.

The contact between the upper and the lower units is gradational over a very short section. The gradation is almost entirely restricted to the phosphate nodules; the quartz and clay fractions are the same in both units. The phosphate constitutes as much as 70 percent by volume of the lower unit; it decreases to a trace amount in the upper unit.

Terrace sands.—Loose quartz sand of Pleistocene age forms the surface throughout the Roux-Davision tract. Some windblown sand at the surface is Recent in age, but no distinction is made in the drill holes. All loose quartz sand above the clayey sand of the upper unit of the Bone Valley is assigned to the Pleistocene.

The contact between the loose sand of Pleistocene age and the clayey sand of the upper unit of the Bone Valley is drawn somewhat arbitrarily. In some areas, where the upper unit contains very small amounts of clay, the contact is difficult to identify, especially from drill cuttings.

ECONOMIC GEOLOGY

Calcium phosphate zone.—The calcium phosphate zone in almost all the Roux-Davison tract includes the lower phosphorite unit of the Bone Valley Formation and calcareous clay residual from the limestone of the Hawthorn Formation. At a very few drill-hole locations, the lower phosphorite of the Bone Valley Formation rests on hard limestone or dolomite of the Hawthorn Formation, and the calcium phosphate zone is entirely in the lower unit of the Bone Valley Formation. At the location of drill hole P the lower phosphorite of the Bone Valley Formation rests on hard material, either limestone or dolomite, of the Hawthorn Formation.

The log of drill hole Q illustrates the normal relation in which the calcium phosphate zone includes both the Bone Valley and Hawthorn Formations.

Log of drill hole P in the NE¼NE¼ sec. 32, T. 31 S., R. 23 E.

[Adapted from lithologic log by D. C. Alverson]

	Thickness (feet)
Pleistocene:	
Terrace sand:	
Sand, loose, gray; some carbonaceous material	5
Total Pleistocene	5
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, clayey, light-gray; contains abundant phosphate-cemented lumps (sandrock)	10.5
Bone Valley Formation (lower unit):	
Sand, clayey, greenish-gray; contains abundant nodules of black, brown, tan, and gray phosphate. Phosphate is coarse sand to granule size; amount increases toward the base of the unit. At the bottom of the unit the phosphate is dominantly black	16.5
Total Bone Valley	27.0

Hole bottomed on material too hard to penetrate with the hand auger; probably limestone or dolomite of the Miocene Hawthorn Formation.

Log of drill hole Q in the SE¼NW¼ sec. 4, T. 32 S., R. 23 E.

[Adapted from lithologic log by W. J. Carr]

	Thickness (feet)
Peistocene:	
Terrace sand:	
Sand, loose, gray and tan	3
Total Pleistocene	3

	Thickness (feet)
Pliocene:	
Bone Valley Formation (upper unit):	
Sand, clayey, tan, iron-stained	7
Sand, clayey, light-gray; amount of clay decreases downward. Lumps of phosphate-cemented sand (sandrock) are more abundant with depth, and a few soft white phosphate nodules are present in the basal 5 feet	17
Bone Valley Formation (lower unit):	
Sand, clayey, gray; contains abundant black, brown and tan phosphate nodules, which increase in size and number toward base of bed	9
Sand, slightly clayey, tan; contains tan phosphate nodules. Phosphate more abundant and coarser toward base	11
Total Bone Valley	44
Miocene:	
Hawthorn Formation:	
Sand, clayey, brown, calcareous; contains abundant fine-grained brown, black, and gray phosphate nodules	1
Clay, sandy, gray-brown; contains brown and gray phosphate nodules	2
Sand, clayey, calcareous; contains abundant black phosphate nodules	3
Partial total, Hawthorn	6

Hole bottomed in gray-brown calcareous clay; contains only minor amounts of phosphate nodules.

Figure 8, a cross section of the Roux-Davison tract, shows that the calcium phosphate zone and the matrix are identical at holes 1, 3, and 5, and that at holes 2 and 6, only one-half foot at the base of the calcium phosphate zone is not a part of the matrix. The calcium phosphate zone is much thicker than the matrix only at holes 7 and 8. The thickness of the matrix in this section uniformly ranges only from 7 to 10.5 feet, except at the hole closest to a small stream (hole 1), where it is only 5 feet. Although the calcium phosphate zone is composed of roughly equal thicknesses of the Hawthorn and the Bone Valley Formations, the matrix is predominantly in the Bone Valley Formation.

The phosphate nodules in the Bone Valley differ from those in the Hawthorn. Most of the nodules in the Bone Valley are coarse sand to granule size, and the ratio of pebble to concentrate in most samples is greater than 1. In the Hawthorn Formation, the phosphate nodules are fine-sand sized and the ratio of pebble to concentrate in most samples is less than 1. Assay data are not available for the parts of the matrix within the Hawthorn and Bone Valley, but the coarser material in the Bone Valley probably contains less P_2O_5 than the finer material of the Hawthorn. The phosphate nodules of the calcareous

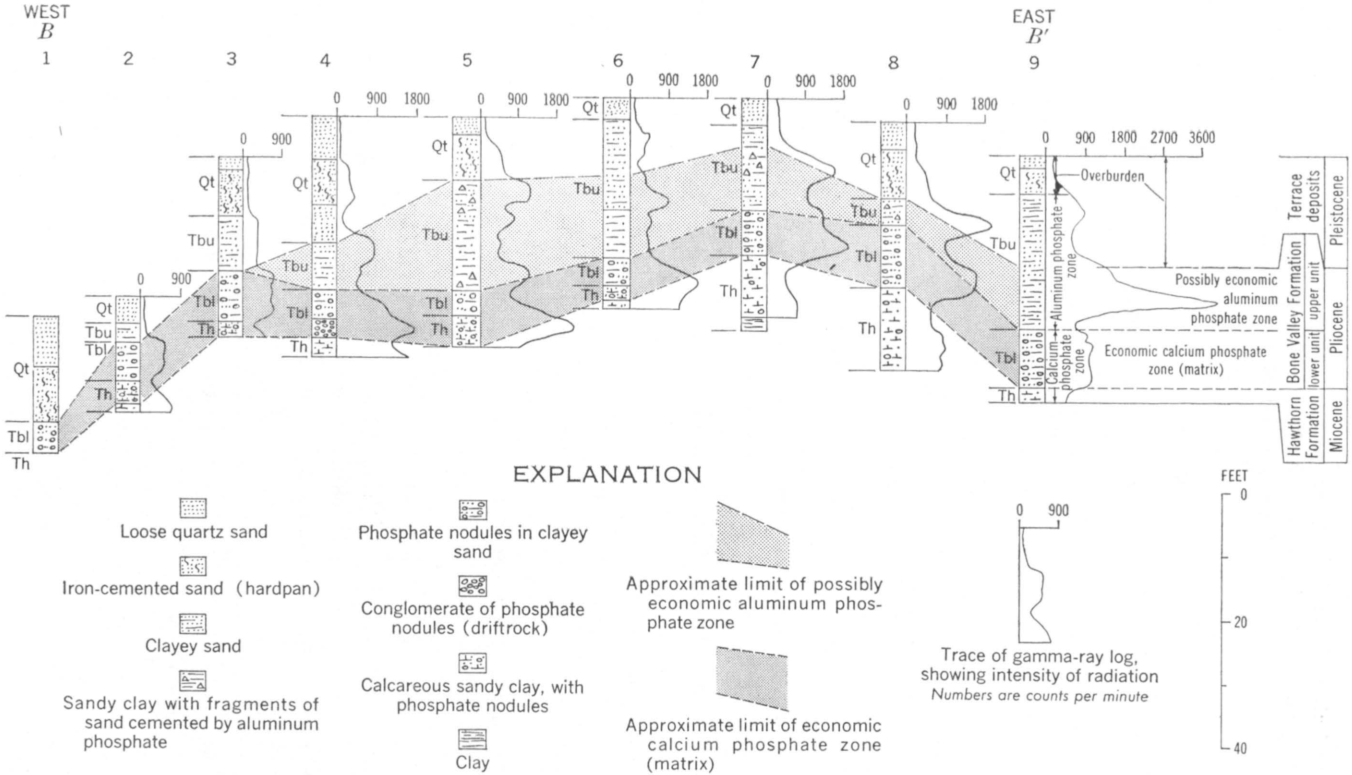

Figure 8.—Section *B–B′*, Roux-Davison tract, showing relations of the calcium phosphate zone and the aluminum phosphate zone to stratigraphy and economic geology.

clays that are not considered a part of the matrix, however, probably contain uneconomic amounts of P_2O_5.

Aluminum phosphate zone.—All information on the aluminum phosphate zone in the Roux-Davison tract is from gamma-ray logs. Figure 8 shows gamma-ray logs of a typical section. Hole 1, near Lake Branch (a tributary to the Alafia River), intersected no upper unit of the Bone Valley Formation. Loose sand rests on unleached phosphorite of the lower unit of the Bone Valley; the aluminum phosphate zone, if it was formed here, was removed by erosion. Although the upper clayey sand is present at holes 2 and 3, the gamma-ray logs show no radioactivity above background, except in the lower phosphorite of the Bone Valley. If leaching affected the upper clayey sand at these locations, it evidently was so intense that the uranium was removed. These holes are on the slope above the river; ground water, moving rapidly through this slope, probably carried any uranium present to the river. Gamma-ray logs of the remaining holes in this section, all on the interstream divide, show high radioactivity in the upper clayey sand; the aluminum phosphate zone is present in the rest of the section. Gamma-ray logs show that holes 4, 5, 6, and 7 have a high peak of radiation at the top of the aluminum phosphate zone; the radiation curve drops off in the lower part of the clayey sand, but rises again in the calcium phosphate zone. Holes 8 and 9 have a high peak of radiation at the base of the aluminum phosphate zone, and the radiation is somewhat lower in the calcium phosphate zone. The holes that have a high peak at or close to the top of the clayey sand are on the highest parts of the interstream divide. It is possible that this peak of radiation represents the base of the zone of leaching and that the lower parts of the clayey sand were below the zone of leaching or below the water table at the time of the formation of the leached zone. If this postulation is true, leaching may be in progress again. At hole 5, for example, some soft white phosphate has been formed at the base of the clayey sand, just above the economic phosphate deposit.

Another possible explanation of the high peak of radiation at the top of the clayey sand is that this material represents leached rock that was originally high in phosphate content. For example, at holes 5 and 7 the highest radiation peaks coincide with zones that are characterized by a high content of lumps of sandrock. The phosphate that forms the cement for this material may have been originally present in the rock as apatite nodules. Material below the zones of sandrock in both of the holes is a uniform, slightly clayey sand containing little phosphate, a lithology which may be similar to that of the original rock.

The leached zone, that part of the aluminum phosphate zone that may be minable, is the bottom part of the aluminum phosphate zone at most of the drill holes shown on figure 8. At holes 4, 5, and 8, the two zones are synonymous and the entire zone of clayey sand would have to be mined. In the other holes, the top part of the aluminum phosphate zone is of too low grade to be included in the leached zone.

Distribution of phosphatic materials.—The calcium phosphate zone underlies all the Roux-Davision tract, except along the course of Lake Branch and the South Prong of the Alafia River, where it has been removed by erosion (pl. 3). The zone reaches a maximum thickness of 40 feet in sec. 33, T. 31 S., R. 23 E. to the east of the South Prong of the Alafia River. In the interstream divide between Lake Branch and the Alafia River (fig. 8), the zone ranges uniformly from 0 to 10 feet in thickness, except for small patches that are more than 10 feet thick (pl. 3).

The thickest areas of the calcium phosphate zone tend to coincide with low areas on the Hawthorn surface (pls. 2 and 3), particularly in sec. 33, T. 31 S., R. 23 E., east of the Alafia River. In the rest of the area, the relation is not too obvious.

The aluminum phosphate zone is present throughout the area, except along the courses of the present streams (pl. 6). The zone ranges from 0 to about 15 feet in thickness, and it tends to be thickest in the eastern part of the tract. The uranium content of the zone is low, ranging from 0.005 to 0.010 percent; it reaches a maximum of more than 0.015 percent uranium only in one small area in the northeastern part of the tract.

NORTH MANATEE RIVER TRACT

The North Manatee River tract includes about 440 acres in secs. 14 and 23, T. 34 S., R. 21 E., in Manatee County. This area was drilled by the Tennessee Valley Authority in June and July 1948 as a part of their program of prospecting lands on which the government had retained mineral rights. The drill holes were logged by H. M. Icke and Louis Pavlides of the U.S. Geological Survey. Splits of the cores were analyzed for uranium in the Washington laboratory of the Survey, and P_2O_5 analyses were made by the Tennessee Valley Authority.

STRATIGRAPHY

The stratigraphy in the area was determined from the drill cuttings or from an examination of the cores. The lithologic sequence is shown on figure 9.

Hawthorn Formation.—The Hawthorn Formation in the North Manatee River tract consists of interbedded and probably lenticular

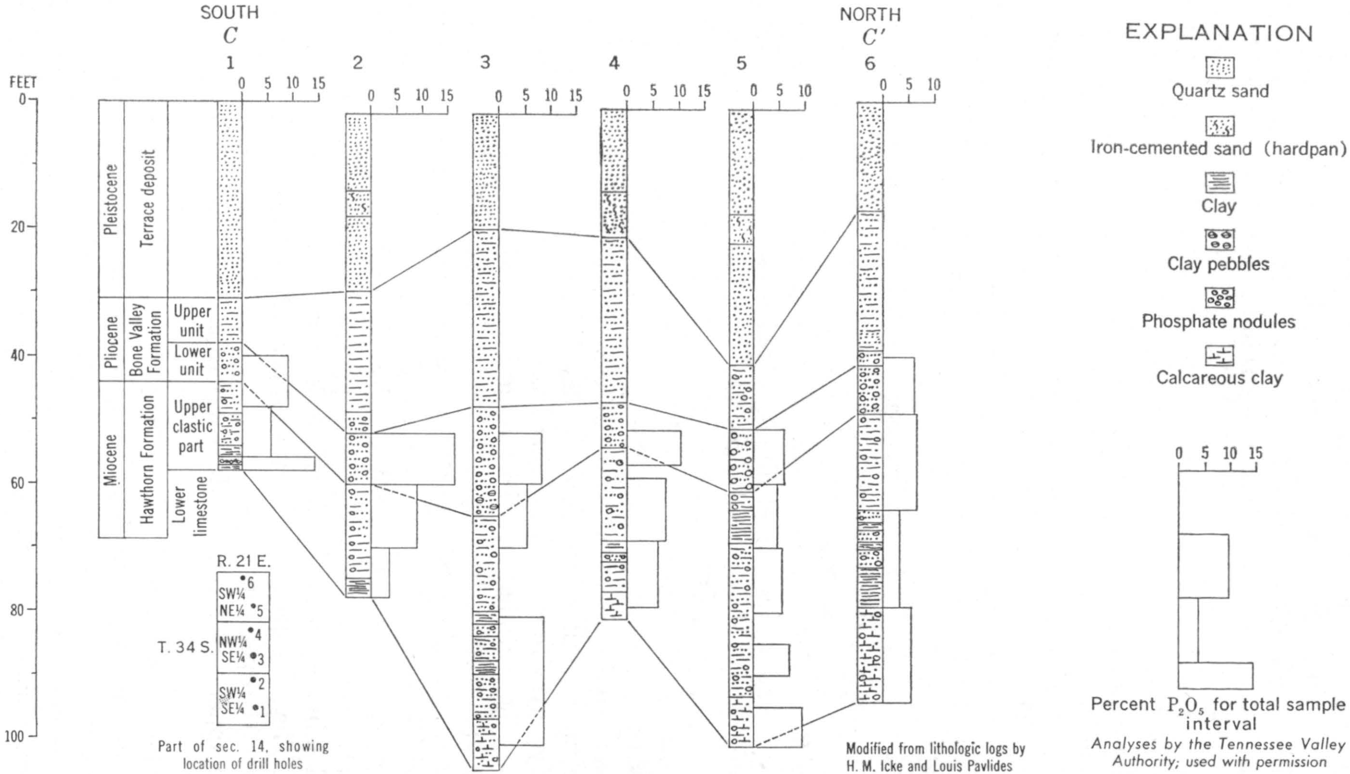

FIGURE 9.—Section C–C′, North Manatee River tract, showing typical lithology, particularly of the upper part of the Hawthorn Formation.

sand, sandy clay, clayey sand, and clay, of different shades of green and containing shiny black fine-grained phosphate nodules. Individual beds cannot be correlated between drill holes (fig. 9). At drill holes 3 to 6, the clastic units overlie a thin-bedded blue-gray or blue-green calcareous sandy clay that is probably a part of the upper part rather than a residuum of the underlying limestone. All drill holes bottomed on a hard limestone, similar in lithology to limestone of the Hawthorn Formation at drill holes in the northern part of the quadrangle.

Although all the beds of the clastic unit contain phosphate nodules, some of the least sandy of the clay beds contain only trace amounts.

Most of the phosphate nodules are fine grained, but the basal bed at hole 1 (fig. 9) contains very abundant coarse phosphate in a clay or sandy clay.

Clastic beds in the Hawthorn range in thickness from 5 to 68 feet in the North Manatee tract.

Bone Valley Formation.—The lower phosphorite unit of the Bone Valley Formation is a tan to gray sand or slightly clayey sand containing abundant fine- to medium-grained phosphate nodules which are sand to granule size and black and gray in color. At drill hole 3 (fig. 9), pebbles of hard green clay, lithologically similar to the green clays of the Hawthorn, are found in the basal part of the lower unit of the Bone Valley. The lower phosphorite unit ranges in thickness from 2 to 40 feet and averages 12 feet.

The upper unit of the Bone Valley Formation is a gray or tan slightly clayey to clayey sand that has minor amounts of black phosphate. The phosphate particles normally are at or close to the base of the upper unit; they are fresh and shiny, and show no signs of leaching. Aluminum phosphate minerals are not noted in the logs of the drill holes; the clay minerals, which are minor in amount, are usually green or gray, and not the white color characteristic of leached sections. Only one sample of the upper unit was analyzed; it contained minor amounts of fresh black phosphate and only traces of clay. The phosphate content was 3.6 percent P_2O_5; the uranium content was 0.001 percent.

The upper unit ranges in thickness from 7 to 28 feet and averages 18 feet.

Terrace sand.—Loose sands at the surface and above the clayey sand of the upper unit of the Bone Valley are assigned to the Pleistocene. These sands typically form a soil profile, characterized by the presence of brown hardpan, close to the surface. The surface is a thin zone of gray carbonaceous sand; it is underlain by white, leached sand, which is underlain, in turn, by brown sand; the brown sand may or may not be cemented to hardpan. The hardpan or brown sand layer is underlain by brown or tan loose unleached sand. The terrace deposits range in thickness from 12 to 48 feet and average 29 feet.

ECONOMIC GEOLOGY

Calcium phosphate zone.—The calcium phosphate zone includes all unconsolidated sediments containing abundant grains of fluorapatite. The material is a potential resource of phosphate. In the North Manatee River tract, the calcium phosphate zone may include all the lower unit of the Bone Valley Formation and all the upper part of the Hawthorn Formation. By this criterion, the zone ranges in thickness from 20 to about 70 feet. However, throughout most of the tract, the clastic rocks of the Hawthorn Formation contain such a small percentage of recoverable phosphate nodules that the ratio of cubic yards of material per ton of product is far too high for the rocks to be mined. In most parts of this tract, only the lower unit of the Bone Valley Formation is included in the calcium phosphate zone. The zone thickens from 0, near the North Fork of the Manatee River, to about 20 feet in the interstream divide between the North and East Forks of the Manatee River, and averages about 12 feet in thickness.

The P_2O_5 contents shown on figure 9 are for the total sample and are typical of raw samples of the calcium phosphate zone. The P_2O_5 content of the Bone Valley is probably economic at holes 2 and 4 and possibly so at holes 1 and 3. Most samples of the Hawthorn from all six holes of figure 9 and of the Bone Valley from holes 5 and 6 contain less than 5 percent P_2O_5, probably about half of that necessary for mining. An exception is the basal bed at hole 1, where the P_2O_5 content is 15 percent. The bed is only 2 feet thick, however, and is overlain by 8 feet of material that contains only 5 percent P_2O_5. The analyses for uranium are for the total sample; they show uniformly low contents ranging from 0.001 to 0.004 percent and averaging about 0.002 percent. No analyses of the phosphate particles were made, but data from mining company drilling to the north indicate that the black phosphate nodules are probably low in phosphate content (from 60 to 65 percent BPL), and contain medium amounts of uranium (about 0.010 percent).

The aluminum phosphate zone was not formed in this area.

REFERENCES CITED

Altschuler, Z. S., Cisney, E. A., and Barlow, I. H., 1952, X-ray evidence of the nature of carbonate-apatite [abs.]: Geol. Soc. America Bull., v. 63, no. 12, pt. 2, p. 1230–1231.

Altschuler, Z. S., Clarke, R. S., Jr., and Young, E. J., 1958, Geochemistry of uranium in apatite and phosphorite: U.S. Geol. Survey Prof. Paper 314–D, p. 45–90.

Altschuler, Z. S., Jaffe, E. B., and Cuttita, Frank, 1956, The aluminum phosphate zone of the Bone Valley Formation, Florida, and its uranium deposits [Florida], *in* Page, L. R., Stocking, H. E., and Smith, H. B., compilers, Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955: U.S. Geol. Survey Prof. Paper 300, p. 495–504.

Berman, Robert, 1953, A mineralogic study of churn drill cuttings from a well through the Bone Valley Formation, Hillsborough County, Florida [abs.]: Nuclear Sci. Abs., v. 7, no. 18A, abs. 5060, p. 616.

Cathcart, J. B., 1956, Distribution and occurrence of uranium in the calcium phosphate zone of the land-pebble phosphate district of Florida, *in* Page, L. R., Stocking, H. E., and Smith, H. B., compilers, Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955: U.S. Geol. Survey Prof. Paper 300, p. 489–494.

——— 1963a, Economic geology of the Keysville quadrangle, Florida: U.S. Geol. Survey Bull. 1128 82 p.

——— 1963b, Economic geology of the Plant City quadrangle, Florida: U.S. Geol. Survey Bull. 1142–D 56 p.

Cathcart, J. B., and McGreevy, L. J., 1959, Results of geologic exploration by core-drilling, 1953, land-pebble phosphate district, Florida: U.S. Geol. Survey Bull. 1046–K, p. 221–298.

Cooke, C. W., 1945, Geology of Florida: Florida Geol. Survey Bull. 29, 339 p.

Eldridge, G. H., 1893, A preliminary sketch of the phosphates of Florida: Am. Inst. Mining Metall. Engineers Trans., v. 21, p. 196–231.

Fowler, E. D., and others, 1927, Soil survey of Polk County, Florida: Bur. Chemistry and Soils, Soil Survey Rept. 39, 39 p.

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

——— 1950, Pleistocene shorelines in Florida and Georgia: U.S. Geol. Survey Prof. Paper 221–F, p. 95–107 [1951].

Mansfield, G. R., 1942, Phosphate resources of Florida: U.S. Geol. Survey Bull. 934, 82 p.

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

Palache, Charles, Berman, Harry, and Frondel, Clifford, 1951, The system of mineralogy of James Dwight Dana and Edward Salisbury Dana: 7th ed., revised, New York, John Wiley and Sons, Inc., v. 2, 1124 p.

Sellards, E. H., 1909, Mineral industries. Phosphate: Florida Geol. Survey 2d Ann. Rept., p. 235–242.

——— 1910, A preliminary paper on the Florida phosphate deposits: Florida Geol. Survey 3d Ann. Rept., p. 17–41.

——— 1913, Production of phosphate rock in Florida during 1912: Florida Geol. Survey 5th Ann. Rept., p. 291–294.

——— 1915, The pebble phosphates of Florida: Florida Geol. Survey 7th Ann. Rept., p. 25–116.

INDEX

[Major references are in italic]