

PEBBLE PHOSPHATE OF ALACHUA COUNTY, FLORIDA

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by

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## ABSTRACT

The pebble phosphate concentrations at the top of the Hawthorne formation in the plateau area of Alachua County, Florida were studied as to mode of accumulation and economic possibilities. The Hawthorne formation was evaluated as a possible source for "hard-rock" and "soft-rock" phosphate now found in the Alachua formation. The solution of these problems required a study of the physiographic development and post-Eocene stratigraphy of this region.

The solution-pitted surface of the Ocala limestone suggests subjection to sub-aerial weathering and erosion before the deposition of all later beds except possibly the Suwannee limestone. During the Oligocene a large part, if not all, of western Alachua County was beneath the sea, and the Suwannee limestone accumulated as is evidenced by scattered residual boulders of that limestone. In the Lower Miocene at least part of Alachua County was land, for remains of land vertebrates of that age have been found in the county. During this terrestrial interval most of the Suwannee limestone probably was eroded from western Alachua County.

With the advance of the Middle Miocene sea, Hawthorne sediments were laid down over all the county. In parts of northeastern Alachua County marine sediments of Choctawhatchee age, late Middle Miocene and/or Upper Miocene, were deposited. During much of Pliocene time the area again was above sea

level, as indicated by the many land vertebrate fossils of Pliocene age known from the County.

During the Pleistocene the area was inundated from time to time by the sea. The "thick" sands north of Gainesville, the red and yellow clayey sands and sandy clays of northeastern Alachua County, and the orange-tan clayey sands south of Gainesville and in parts of southwestern and western Alachua County are believed to represent marine Pleistocene deposits. Land vertebrate fossils of Pleistocene age are present in sediments filling solution cavities in the Ocala limestone south of Gainesville and throughout western Alachua County.

The Hawthorne formation as herein considered consists of two different types of sediments. The main body of the formation is marine and of Middle Miocene age. At its top is a concentration of pebbles and grains of phosphate mixed with varying portions of sand, clay and carbonate. The primary accumulations of this pebble phosphate are believed to have formed under marine conditions during the Miocene. In some places the original marine deposits were subsequently modified or reworked by weathering, rainwash and streams. These materials add to the low grade phosphate reserves of the State of Florida a minimum of between 30 and 50 million tons of phosphate particles which average at least 50 percent Bone Phosphate of Lime (BPL).

The Alachua formation in Alachua County is restricted to the plains area and the more highly dissected portions of the plateau. It consists largely of the residual detritus of weathered and eroded post-Eocene strata often mixed with boulders of Ocala limestone. Some of this material was formed in situ, whereas other parts represent material carried by streams and rainwash into joints, sink holes, shallow lakes and other low places in the Ocala limestone. Such materials, terrestrial in origin, range widely in age. The phosphate found in the Alachua is most probably derived from the Hawthorne formation.

The phosphate particles found in the Hawthorne formation are of different origins. The dominant types include concretionary oolites and nodules, aggregated masses, steinkerns, replacement of skeletal remains, replacement of carbonate in fragments of shell marls and limestones and phosphatic clay balls. These pebbles and grains reflect various environments under which the particles formed. The dominant types of phosphate particles in a deposit appear to be a factor in "high-grade" as compared to "low-grade" properties.

## INTRODUCTION

The purposes of this investigation were to determine the mode of accumulation and economic possibilities of pebble phosphate in Alachua County, as well as to determine if the phosphatic sediments of the Hawthorne formation could have served as the immediate source for the phosphate in the Alachua formation.

Although pebble phosphate was reported from Alachua County in 1892 (Johnson, 1893), only recently was it realized that large concentrations of such phosphate exist. No reports have been published concerning these accumulations.

Until 1951 it was generally agreed that the phosphate in the Hawthorne formation was the immediate source for the hard-rock phosphate now found in the Ocala limestone and in the Alachua formation overlying the Ocala and filling enlarged joint depressions and sink holes in it. This concept has recently been challenged by R. O. Vernon (1951) in his report on Citrus and Levy Counties, in which he presented considerable data from which he concluded that the Hawthorne formation never was deposited over areas now containing hard-rock phosphate. As a possible source for the phosphate in the Alachua formation, Vernon revived the bird rookery theory. Thus, it is evident that a problem still remains, and the essence of it is whether or not the Hawthorne formation once

covered the area where the residual Alachua formation is now found. If it did, the phosphate in the Alachua formation might well be residual from the Hawthorne; if it did not, it might be necessary to look to bird rookeries as a source.

In spite of the fact that the Hawthorne and the Alachua formations were named from exposures within the county, the problem concerning their mutual relationships can not be solved without some understanding of the physiography and late Cenozoic history of the region. As there are several diverse ideas concerning the development of most landforms in Alachua County and no general agreement concerning the age and origin of any of the late Cenozoic formations in the area, a brief consideration of the physiography and a discussion of certain post-Eocene formations are undertaken before attempting to draw conclusions concerning the phosphate problems. The plateau area of Alachua County was chosen for the most thorough study because the sediments there are not disturbed and stratigraphic relationships can be established more clearly than elsewhere.

Conditions are favorable for a study of the mode of accumulation of the different types of phosphate in Alachua County. Within the county are concentrations of pebble phosphate, hard-rock phosphate of the Alachua formation and a few excellent exposures of the Hawthorne formation.

## FIELD WORK

The field work for this study was carried out at intervals over a five year period, from 1950-1955. During that time the well cuttings and cores from several hundred wells drilled in Alachua County were obtained and studied. In addition, cuttings on file at the Florida State Survey in Tallahassee from many wells throughout the state were examined.

## ACKNOWLEDGMENTS

The writer is indebted to many individuals and companies for aid and advice received while making this study. The mention of all these people and companies is impossible, but the help from each is greatly appreciated.

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Many drillers have collected samples for the writer. Among those companies furnishing samples are the Central Florida Well Drillers, Libby Freeman and Company and the Gainesville Equipment Company. Special thanks are due to Mr. O. W. Babb, Mr. J. A. Merrell and Mr. C. D. Schenck of the Gainesville Equipment Company for saving and furnishing the writer samples from every well drilled by that Company for a period of several years. Mr. William Bussey, while a student at the University of Florida, drilled many wells in the County and made available samples from all such borings. Mr. James Cathcart of the United States Geological Survey logged several wells drilled in the County and ran a mechanical analysis for the writer.

Special thanks are due to the American Metal Company, Limited for drilling the property of Mr. Roy Brown and making that data available for this study. Many chemical analyses were run by that Company and furnished the writer. The writer is indebted to the American Cyanamid Company for making available a number of well logs and chemical analyses.

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with lists of vertebrate fossils from a number of localities.

Diagrams and photographs (except where specific mention is made otherwise) were made by Mr. William Winnie under the direction of the writer.

## LOCATION

Alachua County, covering an area of 961 square miles, is in the north-central part of peninsular Florida (see figure 1). There is no complete, accurate topographic map of the County, but most of its central, southeastern and northeastern portions are covered by the U. S. Geological Survey's Arredondo, Hawthorn and Waldo quadrangle sheets respectively. None of the western area of the County has been mapped. Aerial photographs for the complete County are available.

## PHYSIOGRAPHY

A number of different subdivisions have been proposed for the Floridian Section of the Coastal Plain Province as defined by Fenneman (1938). According to Cooke (1939, p. 14, 1945, p. 8), Alachua County lies in the Central Highlands division of Florida (see figure 2). Vernon (1951, p. 16) proposed the term "The Delta Plain Highlands" to include Cooke's "Central Highlands." The inclusion of Alachua County in "The Delta Plain Highlands" presupposes a knowledge of the origin of the late Cenozoic formations in the County.

For convenience, Alachua County can be divided into the following three major physiographic areas as indicated by Sellards (1912, p. 34).

- (1) A plateau-like region north of Gainesville and including most of northeastern Alachua County.
- (2) A western plains region.
- (3) An area in the south-central and southeastern part characterized by flat-bottomed lakes, prairies and erosional remnants of the plateau.

These areas can be visualized by an examination of the topographic map, figure 3.

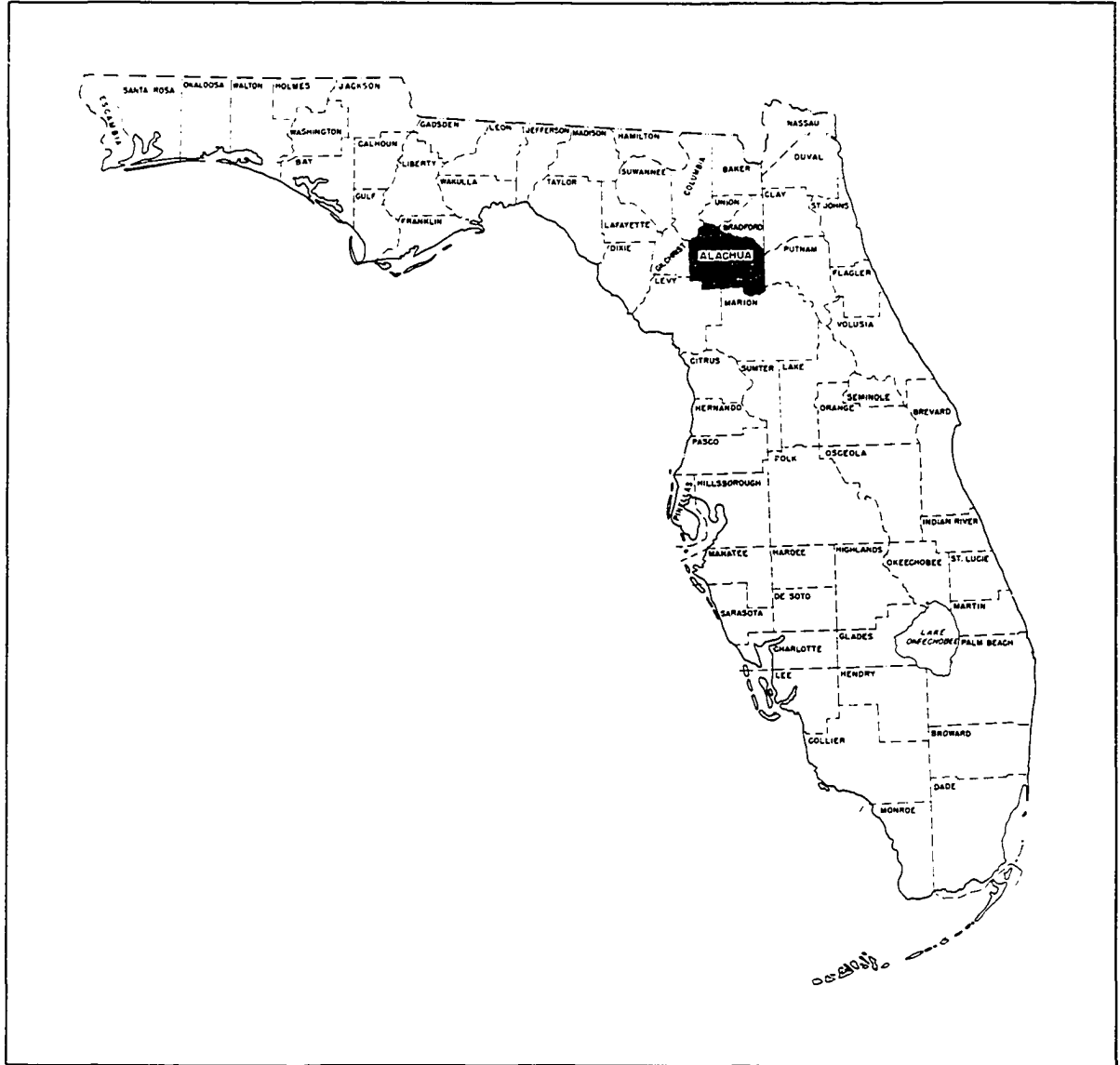


Figure 1. Location of Alachua County, Florida

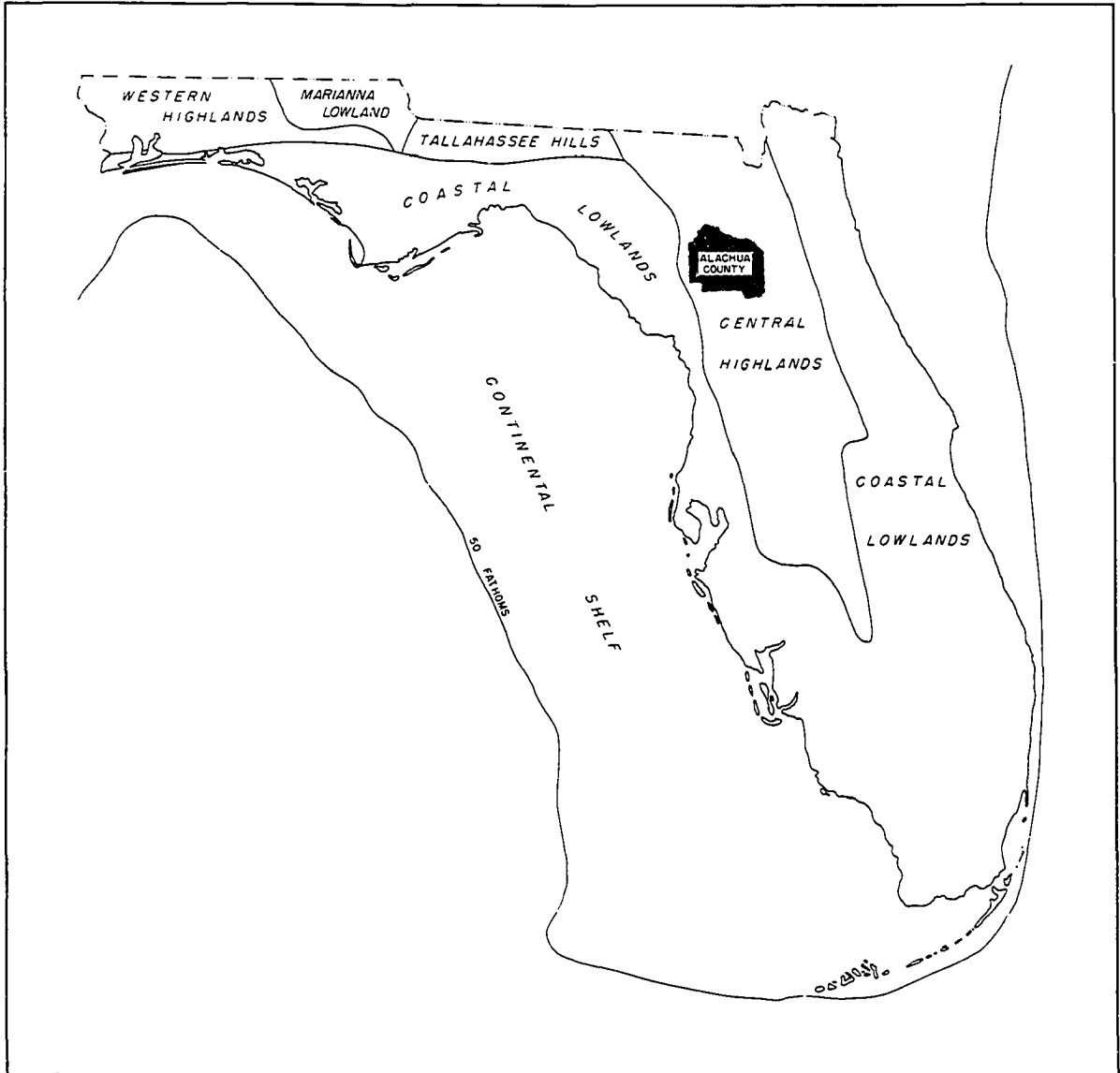


Figure 2. Location of Alachua County with respect to topographic divisions of Florida  
(After Cooke, 1939)

### Plateau Area

North of Gainesville and including much of the north-eastern part of Alachua County is a nearly level plateau-like area ranging in elevation from 150 to 200 feet above sea level (see figure 3). This plateau is characterized by its sameness, not by diversity. It is in this area that the pebble phosphate concentrations are found.

Loose sands at the surface are underlain by clayey sands and sandy clays of Pleistocene age throughout much of the region. Since these are relatively impermeable, surface stream drainage has developed radially outward in all directions from the plateau.

At some earlier stage in the physiographic development, the higher parts of the plateau probably constituted a natural divide between drainage to the Gulf of Mexico and that to the Atlantic Ocean. Some of the present drainage still reaches the Gulf of Mexico by way of the Santa Fe River which flows from Lake Santa Fe along the northern border of the County to the Suwannee River and thence to the Gulf. Newnans Lake, which today receives drainage from the plateau (see figure 3) is believed by Sellards (1910a, p. 66) to have formerly drained through Prairie Creek into Orange Lake, finally reaching the Atlantic Ocean by way of Orange Creek and the St. Johns River. Later, Prairie Creek was captured by the development of Paynes Prairie and Alachua Sink. Now, through

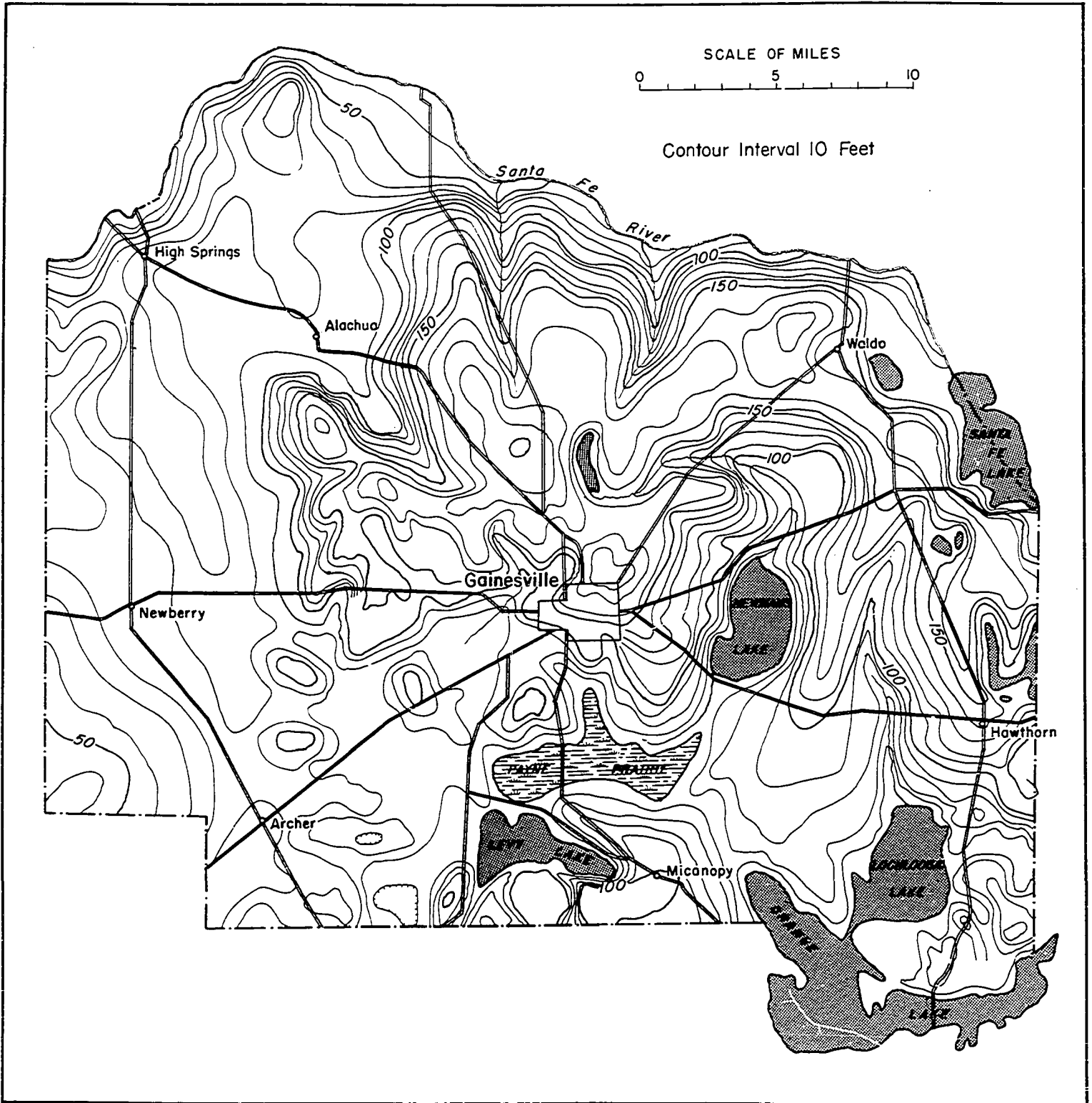


Figure 3. Generalized Topographic Map, Alachua County, Florida. (After U.S. Army Corps of Engineers)

a system of pumps and canals the drainage from Newnans Lake has been diverted from Paynes Prairie back into the drainage area of Orange Lake.

Many swampy areas containing peaty muck occur throughout the plateau. The depressions may have been formed by differential compaction of surficial Pleistocene sediments, or by solution of underlying calcareous rocks of the Hawthorne formation and the Ocala limestone. The importance of original irregularities in the Pleistocene sea floor can not be evaluated. The presence of the impermeable clays beneath the surface sands undoubtedly is responsible for the swampiness of any such depressions.

Only a few large sink holes have been developed in the plateau area. The most notable is the "Devil's Mill Hopper" which is a collapse sink approximately 125 feet deep resulting from solution in the underlying Ocala limestone. Sheet wash and springs leading into such sinks, along with occasional collapse and slumpage of material from the sides play a part in the lowering of the plateau surface. During a rainy spell in the winter of 1952-53 an estimated 20 tons of sediment slid from the sides to the bottom of the Mill Hopper sink. By now, most of the loose sediment has been washed down into the cavernous Ocala limestone. The role played by this type slumpage and wash during past destruction of the plateau is difficult to assess, but it must have been considerable.

The characteristic aerial view of the plateau surface with dense vegetation along streams appearing as dark, branching lines and with slight depressions containing peaty muck showing as dark patches is well shown in figure 4. Surface erosion, particularly along the margins and into the sinks, is important in the continuing destruction of the plateau. Nevertheless, as is suggested by the pattern of swampy depressions shown in figure 4, it must not be thought that the work of ground water is of no significance.

#### Western Plains Area

The western part of Alachua County is a plains area ranging in elevation from 50 to 80 feet above sea level throughout which the deeply pitted Ocala limestone is close to the surface (see figure 3). This region, which contains the hard-rock phosphate of the county, is an extension of the Williston Limestone Plain of Levy County named by Vernon (1951, p. 32). It has resulted from the breaching of the Ocala arch (see page 122 and figure 45).

The Ocala limestone in this area is covered by a thin veneer of loose sand. In places thin accumulations of clayey sand or sandy clay often considered as part of the Alachua formation occur between these loose surface sands and the limestone. Throughout much of the area loose sands, clayey sands and sandy clays fill the numerous



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Figure 4. Aerial photograph showing part of the plateau area of Alachua County. Note surface drainage and shallow depressions dominated by trees. The northern part of Newnans Lake is shown in the lower part of the picture.

solution features developed in the limestone and tend to mask the great irregularities in the limestone surface (see figure 5).

In no other part of the County is the solvent action of ground water more evident than in this plain. Aerial photographs show many solution depressions, some of which have slight to dominant elongations in northeast-southwest or northwest-southeast directions. These directions are believed to reflect control by the joint system of the Ocala limestone. A number of faintly developed ridges follow these same trends. A few caves in the Ocala limestone have been partly mapped in Alachua County and are noted to follow these same directions. Even the outlines of small shallow lakes frequently reflect this joint control. In a few cases, solution features seem to follow essentially north-south and east-west trends.

Sink holes from a few feet to more than 50 feet in depth can be found in almost any part of the plain. A group of trees in a field or pasture often indicates the presence of an open sink. Sink hole development no doubt started as soon as the Ocala limestone was raised from beneath the sea and still continues. Many old sinks have become filled with sediment due to subsequent marine submergences and rainwash. One exceptionally deep sink hole which has been filled with sediment is located on the farm



Figure 5. Smooth plain underlain by pitted and pinnacled surface of Ocala limestone. The limestone pinnacles are white and the clay and sand-filled pits are dark. Scale indicated by grass growing at the surface. Excavation on farm of Mr. Cummer in Section 35, T. 9 S., R. 17 E.

of Mr. Homer Gravely (SW $\frac{1}{4}$ , Section 1, T. 10 S., R. 17 E.). There a 10-inch irrigation well penetrated 268 feet of fill material. At the very bottom of the sink was 6 to 8 feet of muck. The surface elevation of the well is 92.69 feet above sea level. Ocala limestone is exposed at the surface in a sink hole only a few hundred feet from this well. In this sink hole the upper surface of the Ocala is approximately 15 feet lower than the top of the well. Several other sinks in the immediate area show Ocala at the surface.

Solution "pipes" (figure 6) are common throughout much of the area. These cylindrical features range from a few inches to a few feet in diameter and from a few feet to 75 feet in depth. Various origins have been proposed for these solution features. They range from ideas dealing with tap-root growth of trees to Vernon's recent idea of the solutional work of artesian water. Vernon (1951, p. 44) states, "Since artesian water is under pressure it tends to expand upward along joints and more soluble rock because of greater porosity toward the ground surface. The localization of this movement vertically may explain the formation of solution pipes and 'natural wells.'" Probably downward solution along joints and joint intersections is a sufficient explanation for the formation of many of the "pipes" in Alachua County.

In the southwestern part of the County (figure 7),



Figure 6. Three solution "pipes" aligned along a joint in the Ocala limestone are shown in the central part of the picture. On the far side of the one in the foreground (near the hammer) a seam of flint is marked by white bands on either side. That seam, which pinches out downward, runs through seven solution "pipes" uncovered along this joint. The picture was taken at the S. M. Wall quarry in Section 35, T. 9 S., R. 18 E., where the overburden was removed and the irregularities of the limestone smoothed out with bulldozers in preparation for quarrying. The solution "pipes" were mucked out.

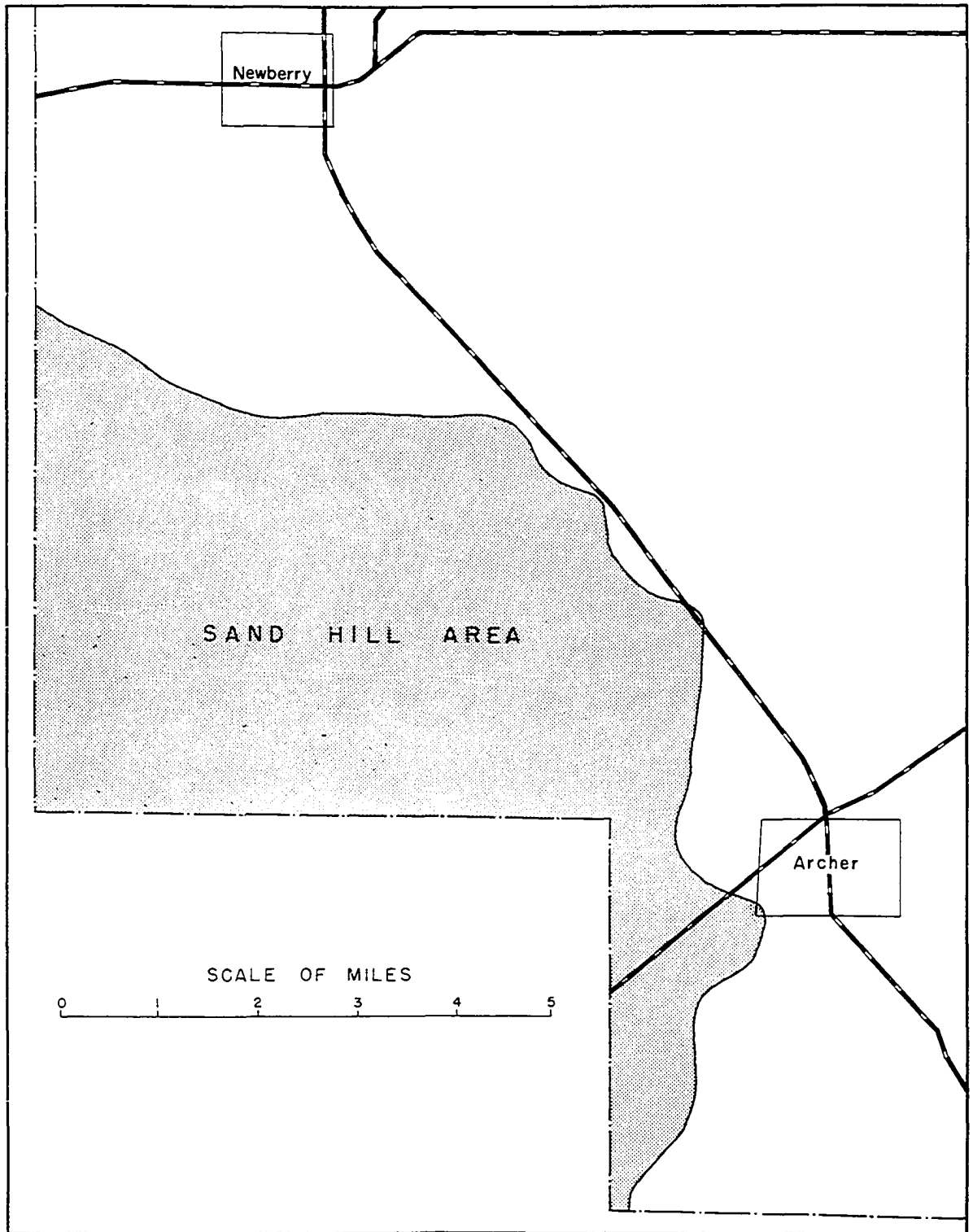


Figure 7. Location of sand-hill area in southwestern Alachua County.

this plain is covered by sand-hills and sand ridges. Some ridges of sand trend in a northeast-southwest direction, and others form arcs and irregular circles. These circular ridges seem associated with blow outs. The steepness of slopes and the trend of sand ridges suggest that the sand has been transported by winds from the southwest to the present site of deposition. The source of the sand probably was an area occupied by a Pleistocene sea not far to the west of the County. In figure 8, the region west of the railroad is typical of the sand-hill area.

Slumpage due to solution of the underlying Ocala limestone probably has played a part in the irregularities of the sand-hills, and solution along a northeast-southwest joint direction of the Ocala could have played a part in the trends of some of the sand ridges. More rapid solution in the Ocala limestone along a northeast-southwest joint direction would develop in the Ocala slight ridges and valleys which would follow this joint direction. Such ridges and valleys developed in areas after the overlying sands had become stabilized would tend to accentuate the northeast-southwest trend of sand ridges.

A westward-facing escarpment separates this plains area from the plateau region of the County. The question as to whether this feature is due to wave erosion or sub-aerial erosion of the Hawthorne formation is not settled.



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Figure 8. Aerial photograph of an area between the towns of Newberry and Archer. Most of the plains area to the left of the highway (State Road 45) is covered by hills and ridges of sand. The plains region to the right of the highway is devoid of such features. Note the tendency of some sand ridges to run in a northeast-southwest direction or to form irregular arcs.

A study of sections and a consideration of the probable development of the plains area of western Alachua County (see page 154) lends support to the belief that there, at least, the escarpment is the result of sub-aerial erosion of gently eastward or northeastward dipping Hawthorne beds. Also, it should be noted that frequently the plateau area gives way to the plains region through a series of hills and ridges which are erosional remnants of the plateau. These remnants are composed of Hawthorne sediments.

#### South-Central and Southeastern Area

The south-central and southeastern portions of Alachua County are characterized by shallow flat-bottomed lakes, level prairies, disappearing streams and erosional remnants of the plateau (see figure 3). This type of topography is visualized by Sellards as a transition stage in the reduction of the plateau area of the northeastern part of the county to the plains area of the western part.

The most fascinating topographic features are the flat-bottomed prairies and lakes of which Paynes Prairie, Levy Lake and Kanapaha Prairie are examples. Sellards (1910a, p. 52 and 67) suggested that the underground water table is the base to which the level bottoms have been eroded, and that Sanchez Prairie near Hague and Hogtown Prairie southwest of Gainesville represent varying degrees

in the development of large flat prairie areas.

The level bottoms of the prairies and shallow lakes in this part of Alachua County are noted from topographic maps to occur at elevations approximately 60 feet above sea level. The following three different types of flat-bottomed depressions, all of which appear to be associated with the ground water level, can be recognized.

(1) Erosional surfaces developed on the Ocala limestone.

In such cases the ground water level in the limestone seems to have determined this local base level. A thin layer of organic sediments cover these erosional plains formed by solution.

(2) Erosional surfaces developed on Hawthorne sediments.

Locally, erosional surfaces developed on Hawthorne sediments have undergone subsidence due to solution of underlying Ocala limestone and have formed lakes and marshes.

(3) Depositional surfaces.

Such surfaces have resulted from the filling of solution areas developed in the Ocala. Such solution depressions, some of which contained lakes at one time or another, have been filled by eroded Hawthorne and younger sediments transported to the low areas by rainwash and streams.

It is noted that the piezometric surface of the ground

water of the Eocene limestones roughly corresponds to the level of all the types of flat-bottomed depressions. It may be possible that in this part of Alachua County as the Ocala limestone is approached in the present erosion cycle, the piezometric surface of the ground water of the Eocene limestones is serving as a temporary base level to which high areas are being eroded and low areas are being filled. The following examples are listed and briefly discussed to show that there are differences in the various flat-bottomed depressions regardless of the fact that the surface elevations of the level bottoms are approximately the same.

Paynes Prairie, by far the largest of the prairies, has an east-west length of 8 miles and a north-south width varying from  $1\frac{1}{2}$  to 4 miles. Much of its 18,000 acres is excellent grazing land. Sellards pointed out that the flat floor of this prairie generally corresponds to the upper surface of the Ocala limestone and the ground water level of that limestone. Before a system of canals was constructed and huge diesel pumps installed, this area fluctuated between a flat-bottomed lake and a prairie as the ground water level changed or as Alachua Sink (the underground outlet) occasionally became plugged. The construction of canals throughout parts of the prairie shows that at least in the eastern portion the erosional plane developed on the Ocala limestone is almost at the surface, being covered by only a

small amount of sediment rich in organic material.

In Alachua County not all areas with flat bottoms surrounded by sloping land have Ocala limestone near the surface. Just south of the main part of the University of Florida is a prairie-like area which contains Lake Alice in its western end. Only recently the eastern part of this level depression was drilled in detail for foundation studies in connection with the construction of the new University of Florida Medical Center. In this drilling program, holes were spaced 100 feet apart on a square grid and drive samples or cores were taken every five feet. Casing was advanced with the holes. Thorough drilling of the eastern part of this level depression showed a very irregular surface of Ocala, with some drill holes going as deep as 200 feet and still not encountering the limestone, whereas other drill holes encountered the Ocala at depths as shallow as 17 feet. A check along the slight cliffs bordering the prairie-like area showed Ocala actually exposed above the level of the flat bottom in one locality.

A well drilled near the east end of Levy Lake reached Ocala limestone at a depth of 90 feet. Thus, the Ocala in that well is much lower than the surface of the adjacent flat-bottomed Levy Lake.

Some workers have attempted to correlate the surfaces of these level depressions and the elevations of surrounding

higher land with a Pleistocene sea invasion. One of the difficulties of relating the levels in this part of Alachua County to a Pleistocene marine invasion results from the fact that sloping land leads down from all directions to flat bottoms of prairies, and the elevations of the surrounding bluffs and slopes vary from place to place.

Filled sink holes in the Ocala limestone are numerous in this part of the County. A number of wells have been drilled in such sinks. One exceptionally deep, filled sink was penetrated during the latter part of June, 1955 by a water well drilled on the west side of the Archer Highway (SW $\frac{1}{4}$ , Section 14, T. 10 S., R. 10 E.) in the side yard of the home of Mr. J. P. Ahrano. The home site is on a slight rise with Ocala limestone outcropping in a number of places in the immediate area. This well which has a surface elevation of 85.18 feet above sea level penetrated 198 feet of fill material before encountering a brown sandy limestone of uncertain age.

In summary, in the south-central and southeastern parts of Alachua County the dominant land forms are flat-bottomed lakes, level prairies and erosional remnants of the plateau. This type of topography has resulted from the erosion of the plateau. The level bottoms of the prairies and shallow lakes appear to be related to the ground water level; the low areas caused by solution in the Ocala or

underlying limestones tend to be filled with sediments up to the ground water level and high areas tend to be eroded down to that level.

## STRATIGRAPHY AND LITHOLOGY

Details of the stratigraphy and lithology of certain post-Eocene formations in Alachua County are necessary for a better understanding of the mode of accumulation of the phosphate deposits of the area. As these phosphate deposits are believed to be a part of, or derived from the Hawthorne formation, a more thorough discussion of the Hawthorne is required than of other late Cenozoic formations. The formations to be discussed include:

- (a) the Suwannee limestone of Oligocene age.
- (b) the Hawthorne formation, largely of Middle Miocene age.
- (c) the Alachua formation consisting of terrestrial sediments of various ages collected in low places along the breached arch of the Ocala uplift.
- (d) post-Hawthorne sediments of the plateau area.

The Cenozoic formations of Florida according to Cooke (1945, p. 17) are listed in Table I. The general relationships of the late Cenozoic formations found in the plateau area of Alachua County are shown in figures 9 and 10.

TABLE I  
 GEOLOGIC FORMATIONS IN FLORIDA  
 (After Cooke) 1945

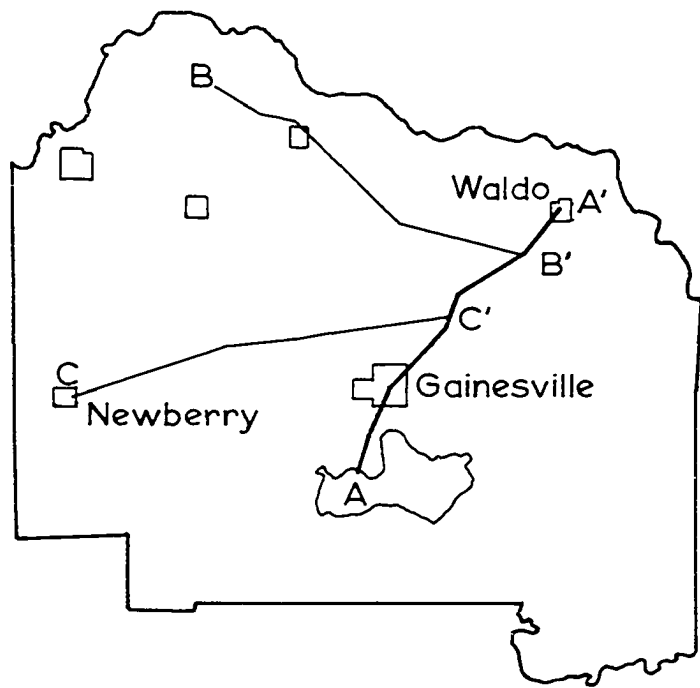
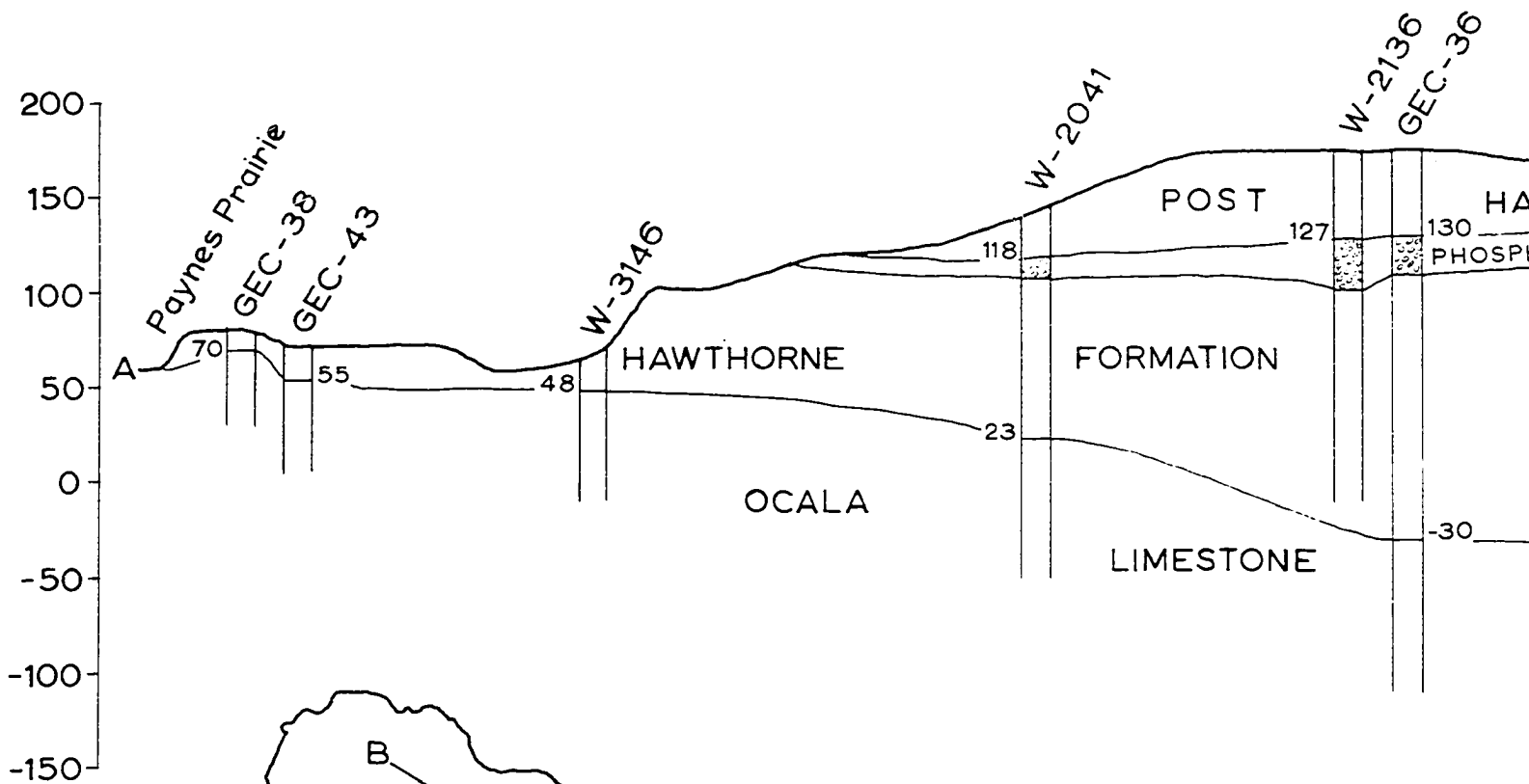
Quaternary System Pleistocene Series	Wisconsin Stage	Erosion interval. Lake Flirt marl (fresh-water, partly recent).  Pamlico sand (littoral, shore line at 25 feet).  Erosion interval.				
	Sangamon Stage	Talbot formation (littoral, shore line at 42 feet).  Penholoway formation (littoral, shore line at 70 feet).  Wicomico formation (littoral, shore line at 100 feet).	Anastasia formation (marine)	Miami oolite (marine)	Key Largo Limestone (marine)	Fort Thompson formation (marine and fresh-water)
	Illinoian Stage	Erosion interval. Fresh-water limestone in the Fort Thompson formation.				
	Yarmouth Stage	Sunderland formation (littoral, shore line at 170 feet).  Coharie formation (littoral, shore line at 215 feet).				
	Kansan Stage	Erosion interval. Fresh-water limestone in the Fort Thompson formation.				

TABLE I - continued

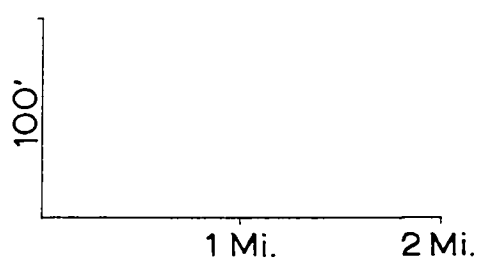
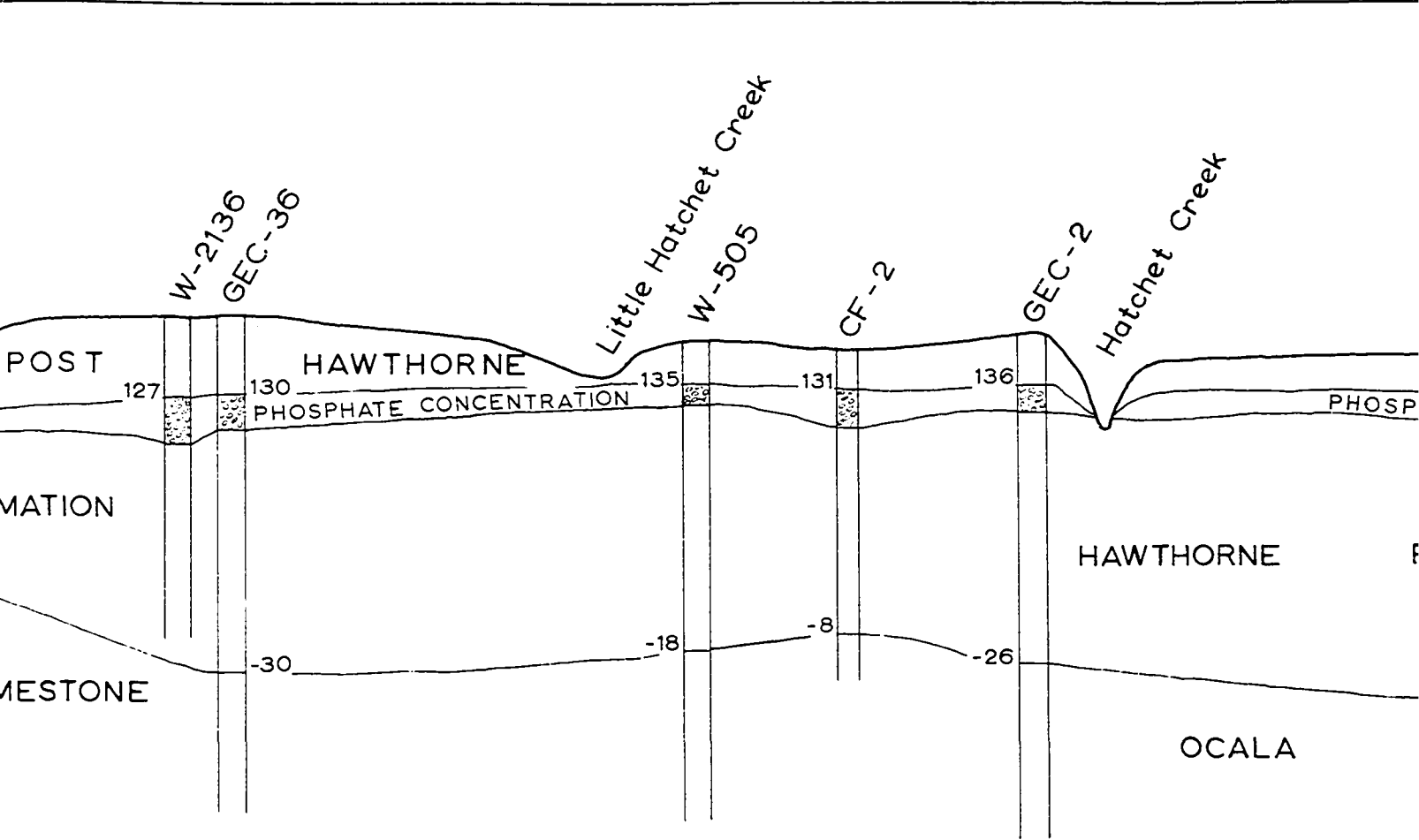
Quaternary System	Pleistocene Series	Aftonian Stage	Brandywine formation (littoral, shore line at 270 feet).	Fort Thompson Formation
	Nebraskan Stage		Erosion interval.	
Tertiary System	Pliocene Series	Contemporaneous	Deformation, tilting, and emergence. Alachua formation. (terrestrial of Hemphill age). Bone Valley formation. (estuarine, of Hemphill age). Buckingham marl. (marine). Caloosahatchee formation (marine). Charlton formation (estuarine). Citronelle formation (littoral). Tamiami formation (marine). Erosion interval	
	Miocene Series		Duplin marl (marine, of late Yorktown age). Erosion interval during early Yorktown time. Alum Bluff group: Shoal River formation (marine). Chipola formation (marine). Hawthorne formation (marine). Tampa limestone (marine, of Anguilla age).	
Oligocene Series			Erosion interval. Suwannee limestone (marine). Flint River formation (littoral, of Antigua age). Erosion interval Byram limestone (marine, of late Vicksburg age). Marianna limestone (marine, of early Vicksburg age). Erosion interval during Red Bluff time.	

TABLE I - continued

Tertiary System	Eocene Series	Ocala limestone (marine, of Jackson age). Erosion interval. Avon Park limestone (marine, of Claiborne age). Tallahassee limestone (marine, of Claiborne age). Lake City limestone (marine, of Claiborne age). Erosion interval. Oldsmar limestone (marine). Salt Mountain limestone (marine, of Wilcox age).
	Paleocene Series	Cedar Keys limestone (marine). Porters Creek formation (marine, of Midway age).



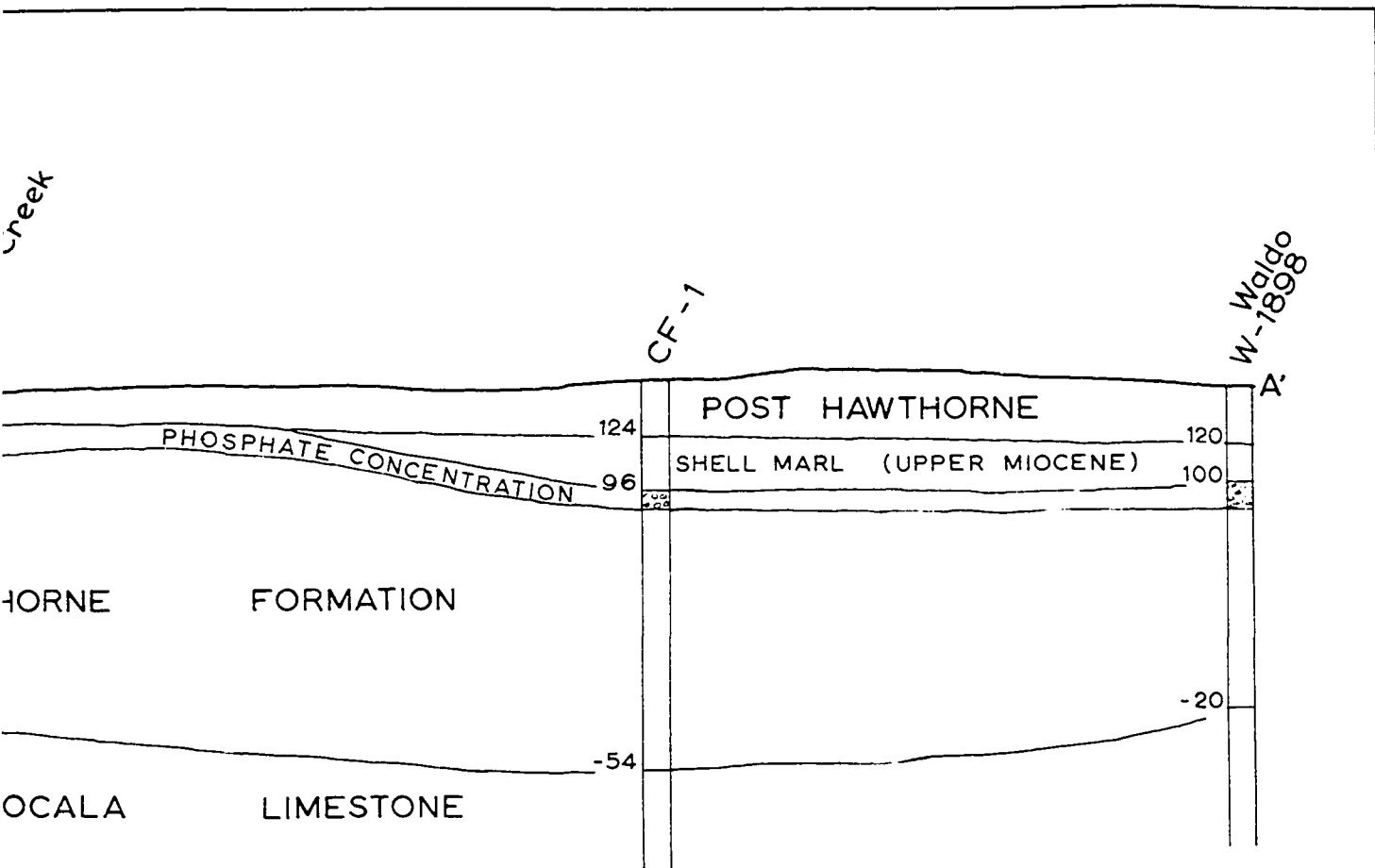
GENERAL  
FROM PA  
VERTICAL S



GENERALIZED CROSS SECTION  
FROM PAYNES PRAIRIE TO WALDO  
VERTICAL SCALE GREATLY EXAGGERATED

- WEL
- GEC
- GEC
- W-3
- W-2
- W-2
- GEC
- W-5
- CF-
- GEC
- CF-
- W-18

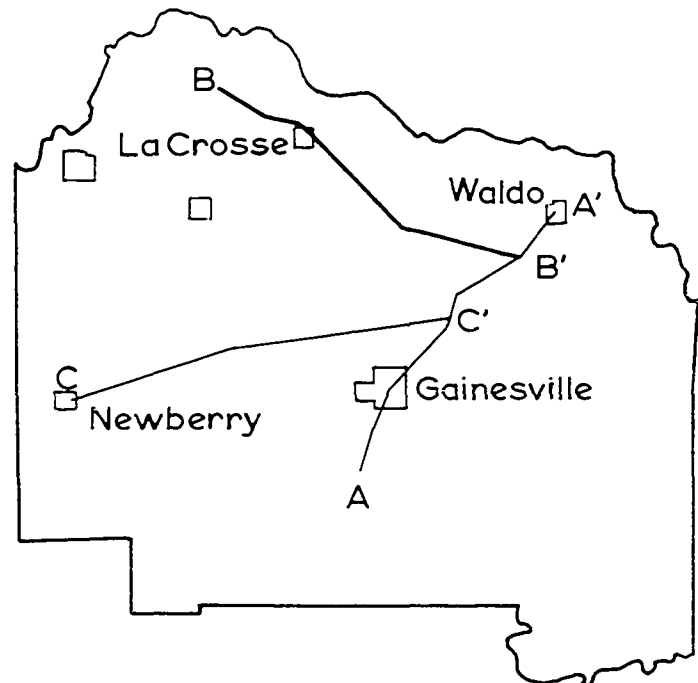
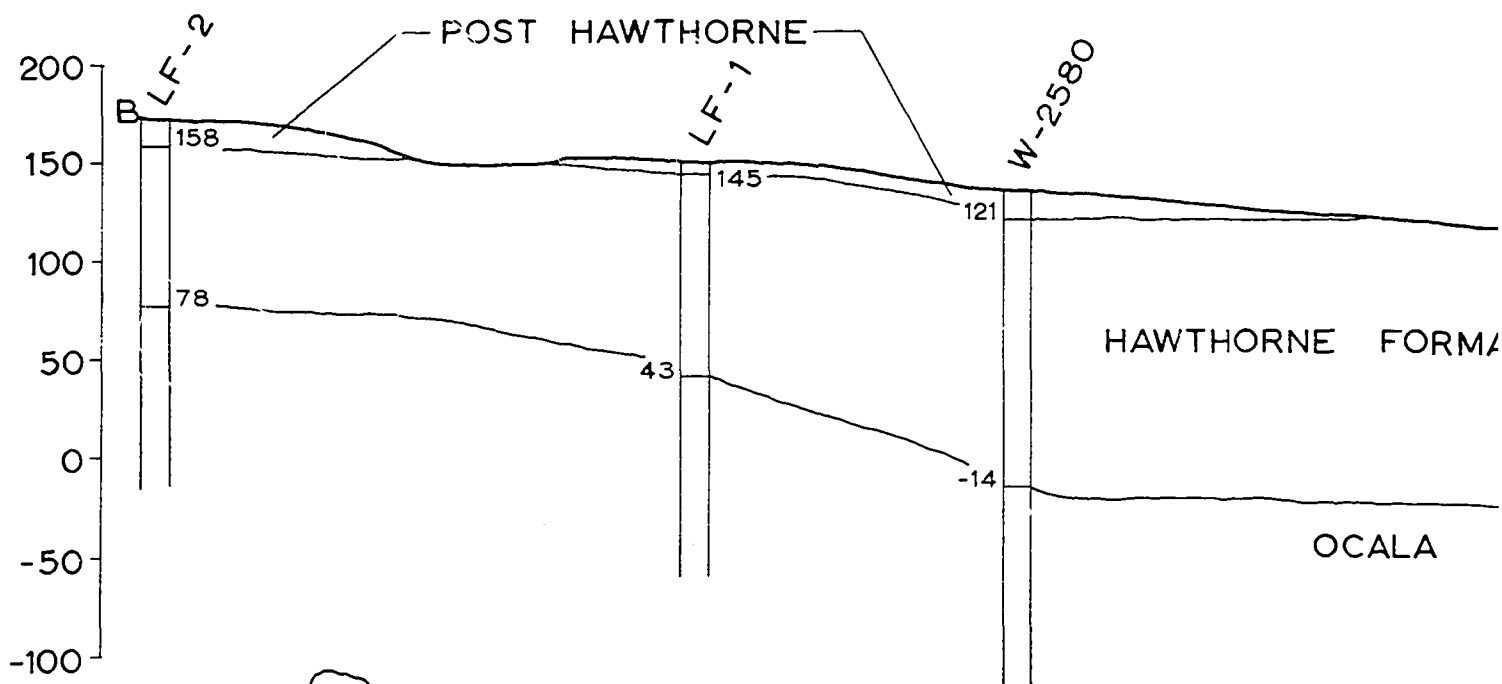
Figure 9.



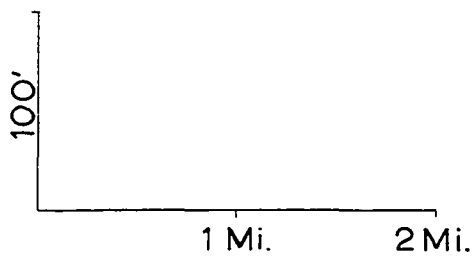
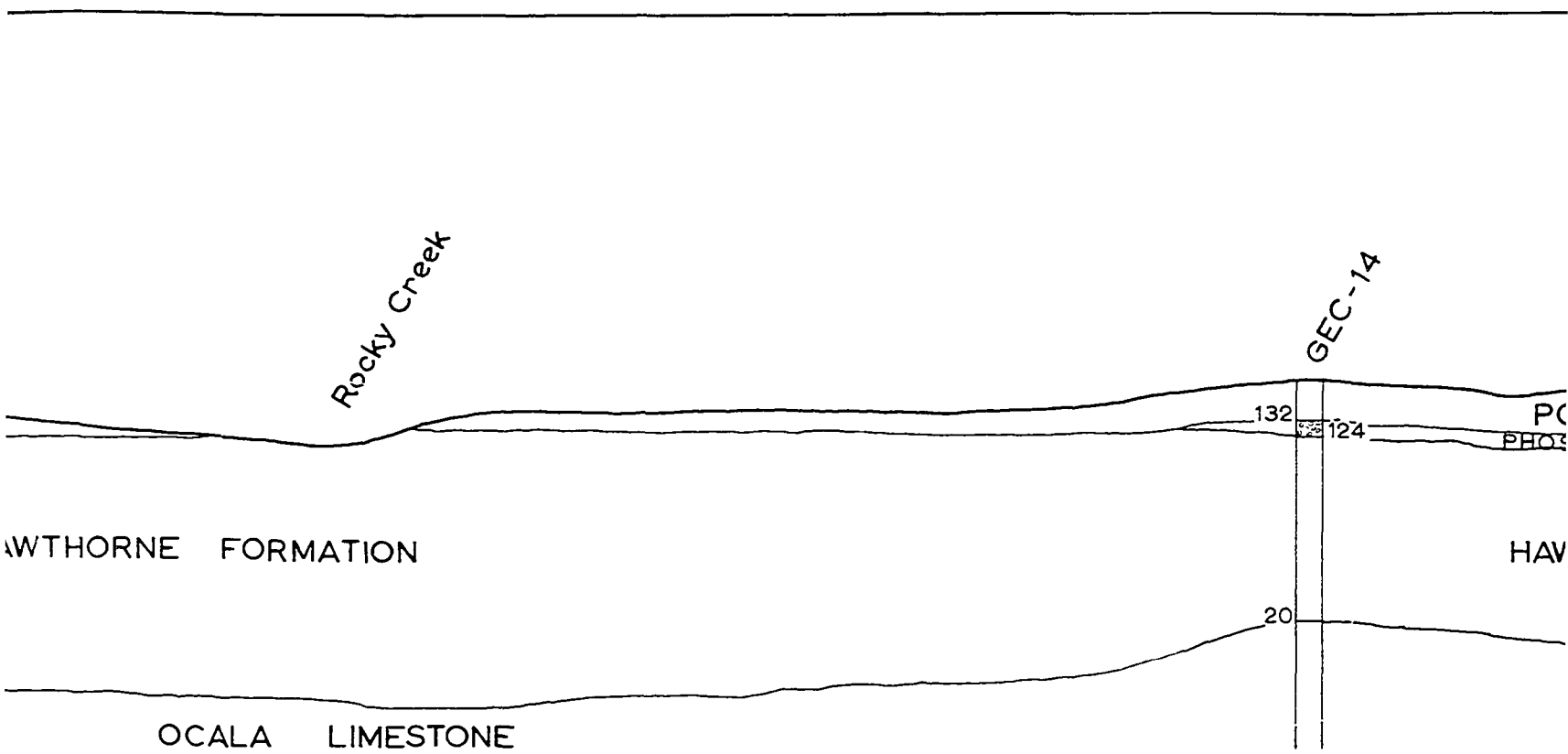
WELLS USED IN SECTION

- GEC-38- Home of Mr. Hume, Rocky Point Road
- GEC-43- Home of Mr. Buchholz, Rocky Point Road
- W-3146- Water well at Tom Sawyer Motel, Highway 441
- W-2041 - Black Laboratory well, Gainesville
- W-2136 - Well of R.T.Culpepper, Waldo Road
- GEC-36- Well at Cities Service Station, Waldo Road
- W-505 - Well near Municipal Airport, Waldo Road
- CF-2 - 20" well at Sperry Corporation, Waldo Road
- GEC-2 - Home of Mrs. Mize, Fairbanks
- CF-1 - Well in center of Sec. 33, Austin Cary Memorial Forest.
- W-1898 - Well in City of Waldo

Figure 9.



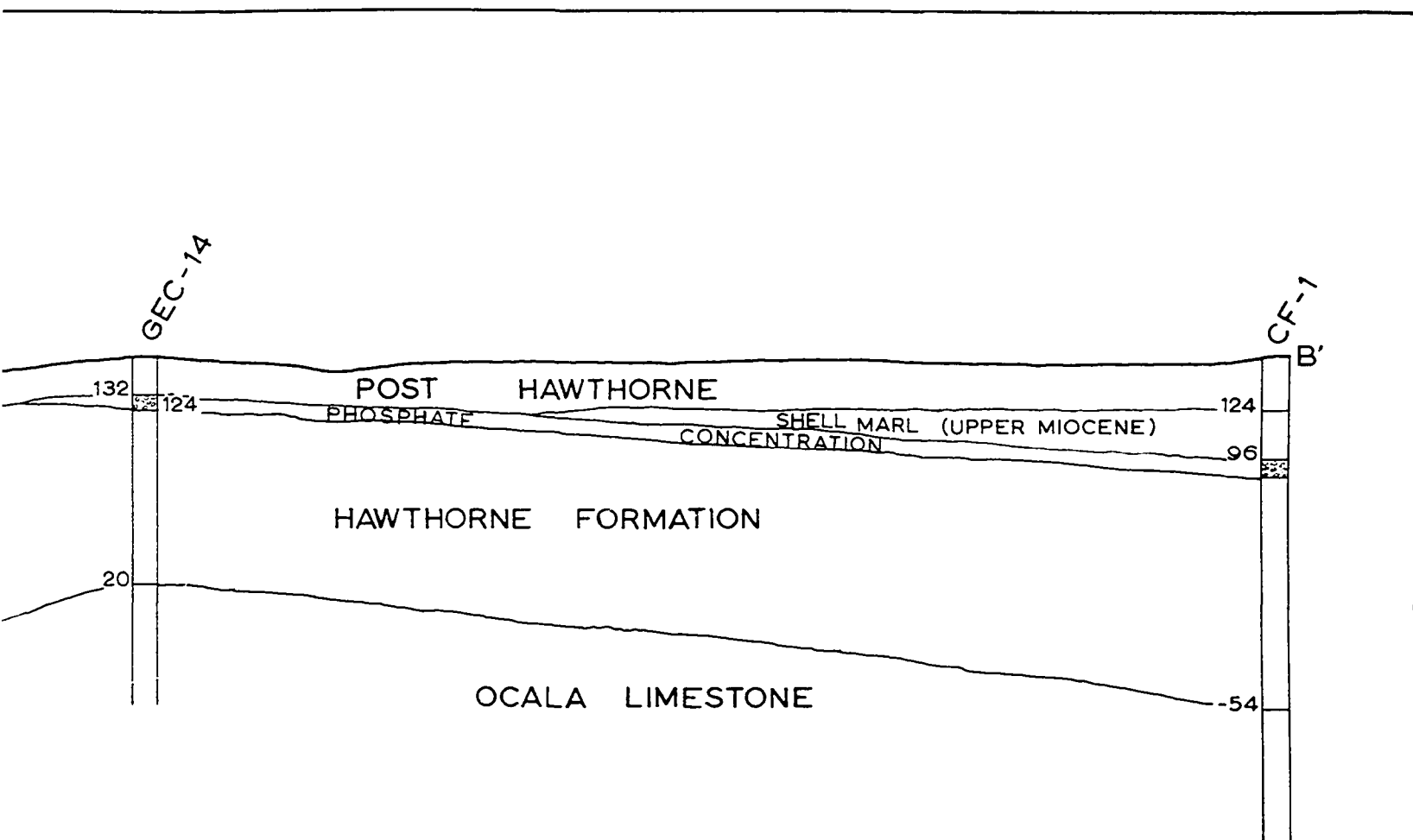
GENERALIZE  
 THE NORTHWEST  
 TO THE AUST  
 VERTICAL S



WELLS USED IN  
 LF - 2 - Field of  
 LF - 1 - Field of  
 W-2580- Well at  
 GEC-14 - Home of  
 CF - 1 - Well in

GENERALIZED CROSS SECTION FROM  
 NORTHWESTERN PART OF ALACHUA COUNTY  
 TO THE AUSTIN CARY MEMORIAL FOREST  
 VERTICAL SCALE GREATLY EXAGGERATED

Figure 1



WELLS USED IN SECTION

- LF - 2 - Field of Mr. Joe Imber (Sec.13, T7S, R18E)
- LF - 1 - Field of Mr. Lacy Doak (Sec.20, T7S, R19E)
- W-2580- Well at tower site (Sec. 22, T7S, R19E)
- GEC-14 - Home of Mr. Wilmer Thomas (Sec. 21, T8S, R20E)
- CF - 1 - Well in center of Sec.33, T8S, R21E, Austin Cary Memorial Forest

TY

Figure 10.

### Suwannee Limestone

Throughout parts of northwestern Alachua County, residual boulders of the Suwannee limestone are common. All of these are silicified and contain molds of Cassidulus gouldii (Bouvé), a Suwannee echinoid. The area containing the greatest number of these boulders is shown on Plate I, but residual boulders have been found in a few other areas. For example, just north of the town of Newberry, residual boulders of the limestone have been noted. Cooke (1945, p. 202) states that boulders of Suwannee limestone were encountered in the mining of hard-rock phosphate around the town of Newberry. Also, in the south-central part of the County in Section 30, T. 11 S., R. 19 E. many silicified boulders of the Suwannee limestone occur. In one field there is a pile with more than 50 boulders containing molds of Cassidulus gouldii (Bouvé)\*. These boulders had been cleared from surrounding fields to facilitate cultivation.

To what extent the Suwannee limestone once blanketed Alachua County is not known, but it certainly covered much of the western part. The nature of the contact between the Suwannee limestone and the underlying Ocala limestone can not be readily determined. With reference to exposures in other counties, Cooke (1945, p. 88) states that the

\*The identification of these fossils was verified by Dr. Harbans Puri.

Suwannee limestone lies unconformable on the Ocala, thus it is assumed that the contact between the Suwannee and Ocala limestones in Alachua County also is unconformable.

It is probable that the source of silica for the silicification of the limestone was a younger clay deposit which covered the Suwannee limestone at an earlier geologic time. This source may have been a part of the Hawthorne formation.

### Hawthorne Formation

#### General Features

Previous Usage.-- The name "Hawthorne beds" was applied by Dall and Harris in 1892 (p. 107) to phosphatic rocks being quarried near the town of Hawthorne in Alachua County. In referring to these phosphatic rocks, Dall stated "The latter at the time of my visit was being quarried and ground up as a fertilizer at Hawthorne, where the beds have a considerable thickness. For this reason I referred to these beds in my unpublished report as the 'Hawthorne beds.'"

At the time of Dall's visit, phosphatic rocks were being quarried near the town of Hawthorne in the old A. C. Simmons' pits. As these pits are the only ones from which phosphatic rock has been quarried and ground up as a fertilizer, they must be the ones referred to by Dall. The pits are located between the towns of Grove Park and Hawthorne, about  $1\frac{1}{2}$  miles south of State Road 20 in the

eastern part of Section 31, T. 10 S., R. 22 E. on land now owned by Mr. Roy Brown.

The reader is referred to the work of Cooke (1945, p. 144) for a summarized history of the use of the term "Hawthorne." In the latest work dealing with the Miocene of Florida, Puri (1953) states that the Hawthorne sediments east of the Apalachicola River constitute a lithofacies of the Alum Bluff Stage of post-Tampa and pre-Choctawhatchee age ("middle Miocene").

Types of Sediments.- The dominant sediments comprising the Hawthorne beds in Alachua County consist of clastic quartz sand, clay, carbonate, and pebbles and grains of phosphate.\* The proportions of these materials vary from bed to bed and, in cases, even within a few feet both horizontally and vertically in individual strata. The carbonate in some places is largely calcitic and in others dolomitic. In this report the sediments are termed clays, sands or limestones according to the dominant material composing the bed as apparent from hand specimens or with the use of a hand lens. For example, if a stratum is composed largely of calcium carbonate with numerous grains of quartz sand, the rock is called a sandy limestone. Occasionally, lenses of nearly pure clay or nearly pure sand are found. Individual beds and lenses vary in

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\*The phosphate in the pebbles and grains of phosphorite occurs as fluorapatites (Vernon, 1951, p. 20).

thickness from less than a foot to 30 feet. For typical lithology and stratification, see measured section of the Brooks Sink exposure, page 56.

In this study two types of materials are interpreted as Hawthorne sediments. One comprises the clays, sands and limestones of the main body of the Hawthorne and the other a concentration of phosphate pebbles and grains above this main body. Materials of both these types are present in Dall's type locality for the Hawthorne, and were referred to specifically by Dall.

Fauna and Age.- In Alachua County the main body of the Hawthorne formation is of marine origin and ranges in thickness from a few feet (where most of the formation has been eroded away) up to approximately 175 feet. It thickens in general to the northeast. The contemporaneous sediments in northwestern Florida were termed the "Alum Bluff group" by Cushman and Ponton (1932), Smith (1941), Vernon (1942) and Cooke (1945), and lie stratigraphically between the Tampa limestone (Lower Miocene) and Choctawhatchee formation (Late Middle Miocene and/or Upper Miocene).

Because no Tampa limestone has been identified in Alachua County and terrestrial vertebrate fossils of Lower Miocene age are known from the area, it seems probable that the region was land during Tampa or Lower Miocene time. With the advance of the Hawthorne sea, sediments of Middle

Miocene age were laid down. These sediments, which constitute the main body of the Hawthorne formation, are covered in Brooks Sink in Bradford County by a shell marl which has been dated on the basis of micro-fauna as of lower Choctawhatchee age.

The concentrations of pebbles and grains of phosphate at the top of the main body of the Hawthorne are believed to have accumulated under a marine environment during Hawthorne time, although some of these phosphatic sediments have been reworked in post-Hawthorne time by rainwash and streams. Because the concentrations are covered by sediments of Pleistocene age, it is very difficult to determine from drill hole samples those portions of the upper phosphate concentration which have been reworked.

The Hawthorne formation in Alachua County contains numerous molds and casts of marine fossils. Most of the fossils are so poorly preserved that in only very few cases is identification possible.

Lenses of silicified Ostrea normalis Dall, a characteristic fossil of the Hawthorne, are found in a number of exposures of Hawthorne sediments. The following locations of such lenses illustrate the wide occurrences of this fossil and may be located on Plate I.

- (a) In Gainesville on the south side of NW 23rd Road, approximately  $\frac{1}{2}$  mile west of the home of Mr. W. A. Shands. This is the only occurrence known in Alachua County in which the shells in the lens are composed of calcium carbonate. As many of the

fossils contain both valves together, it is assumed that they have not been transported far. Thus, the occurrences of such fossils in lenses in other localities, even though the shells might be silicified, are believed to represent primary deposition.

- (b) On the west side of State Road 241, 1.05 miles south of the Santa Fe River.
- (c) Along the south bank of the Santa Fe River, just west of a dirt road which leads to Brooker. The location is approximately in the NE $\frac{1}{4}$  of the SW $\frac{1}{4}$ , Section 14, T. 7 S., R. 19 E.
- (d) On the south side of State Road 236, 4 miles west of its intersection with State Road 241.
- (e) One mile south of the Newberry Highway along the north side of an east-west dirt road. The location is  $\frac{1}{4}$  mile west of the intersection of dirt roads which cross in the southeast corner of Section 6, T. 10 S., R. 19 E.
- (f) On the west side of the new truck cut-off southeast of Gainesville, about 1.2 miles northeast of the intersection of State Roads 329 and 25.

Silicified colonies of the coral Siderastraea sp. are common in many areas in the northwestern part of the County. Many masses of corals, some several feet in diameter, are found north of the town of Alachua, around the town of Traxler and especially in the area bounded by the Santa Fe River and State Roads 25, 236 and 241. These coral heads occur in the mantle and have not been found in place in Alachua County. Rare specimens have been found southeast of Gainesville on the farm of Mr; Hugh Simons.

Outcrops of the Hawthorne Formation.- As all of Alachua County is covered by sands of uncertain age, it

is almost impossible to find outcrops of the Hawthorne formation except in road cuts or sink holes. Outcrops of the Hawthorne are most numerous in the northwestern part of Alachua County and west, south and southeast of Gainesville.

In these areas, the Hawthorne formation consists primarily of clayey sands and sandy clays with occasional lenses of more pure clay, some of it of fuller's earth type. These sediments carry phosphate grains and pebbles which are dominantly white or gray, although shades of brown, black and orange are found. In the fresher clayey sands the white grains of phosphate frequently are soft and even pasty when wet.

In a number of instances, in water wells drilled in the above areas, a sandy limestone or a calcareous sandstone was encountered in the Hawthorne immediately above the Ocala limestone. A contact between it and the Ocala can be seen at the entrance to Warren's Cave (Section 14, T. 9 S., R. 18 E.). There it is only a few feet thick and contains poorly preserved impressions of marine invertebrate fossils and scattered grains and pebbles of phosphate. Besides carbonate, clastic quartz sand and phosphate grains and pebbles, thin sections of this rock show minor amounts of feldspar.

In Appendix "A" are listed five well logs to illustrate the nature of some of these Hawthorne sediments. During the drilling of the wells, samples were taken at

least every five feet, with the depths to the samples being measured. Nevertheless, as the wells were drilled with cable tool rigs, the degree of accuracy is limited.

Hawthorne Sediments North, Northeast, and East of Gainesville.- Exposures of the Hawthorne formation are rare north, northeast and east of Gainesville. Here, younger deposits of sand, clayey sands and sandy clays which range in thickness from 15 to 45 feet cover the Hawthorne formation.

Throughout much of this area the top strata of the Hawthorne consist of slight to heavy concentrations of grains and pebbles of phosphate mixed with sand and clay. Many of the pebbles appear to be detrital. The dominant colors of these pebbles and grains are black and brown although many other shades are present. Wells drilled through the Hawthorne often show several different zones in which phosphate grains and pebbles are concentrated. Limestone containing included quartz sand as well as grains and pebbles of phosphate is common in this area. Such limestone occurs as thin stringers, beds and lenses which range up to 30 feet in thickness.

These Hawthorne sediments in general differ from those found northwest, west and southeast of Gainesville in a number of ways including:

(a) the presence of an upper stratum which usually

contains common to abundant pebbles and grains of phosphate embedded in a matrix consisting of sand, clay and carbonate.

(b) the occurrence of a high percentage of detrital pebbles of phosphate.

(c) many more stringers, beds and lenses of limestone.

The four logs of Appendix "B" illustrate the types of Hawthorne sediments found throughout northeastern Alachua County.

Weathering.- Some of the fresh soft sandy clays and especially the clayey sands of the Hawthorne contain abundant soft white grains of phosphate mixed intimately with the sand and in the clay. It may be that as chemical weathering alters these clayey sands, a phosphatic clay develops due to chemical or physical reactions involving the soft phosphate grains and the clay. In cases the resulting phosphatic clay may act as a binding material for the sand grains, forming a sandstone.

Further weathering reduces this sandstone to sandstone pebbles which at times have a porous structure or are characterized by rounded openings, see Cooke (1945, p. 145). Cooke believes these openings are due to the weathering of phosphate grains and pebbles. One thin section of such a sandstone pebble is shown in figure 11.

Further weathering reduces these sandstone pebbles

to loose sand. Many of the Hawthorne clays, which when fresh are normally some shade of gray, are oxidized to yellowish and reddish colors during the weathering.



Figure 11. X 42. Photomicrograph of sandstone pebble collected along NW 23rd Road in Gainesville. This type of pebble commonly results from the weathering of soft clayey sand of the Hawthorne formation. The pebble is composed mainly of quartz sand with a minor amount of feldspar and phosphate embedded in phosphatic clay. Crossed nicols.

## Descriptions of Exposures and Borings

Simmons' Pit Locality.- As the area around the town of Hawthorne, especially at the old Simmons' pits, represents the type locality of Dall's "Hawthorne beds," the nature of those sediments was determined as accurately as possible. Through the courtesy of Mr. Roy Brown (the present owner of the land) and the American Metal Company, Limited, seven shallow holes were drilled by means of hand augers in and around the area of these old phosphate pits. Casing was advanced with the holes.

In these hand-augered holes it was found that 5 to 18 feet of overburden (consisting of loose sand grading down into clayey sand) covers 7 to 28 feet of Hawthorne sediments which contain abundant pebbles and grains of phosphate mixed with varying amounts of sand and clay. The strata containing heavy concentrations of phosphate pebbles and grains are underlain by a massive greenish to greenish gray clay. None of the borings reached the Ocala limestone. Figure 46 shows the location of these borings. A log of hole #1 is listed to indicate the stratigraphy of the sediments. The other six logs are given on pages 166-172. Analyses of the phosphate from these holes are listed with the logs.

### Log of Hole #1

#### Post-Hawthorne

0 to 1 foot	Dark brown, loose quartz sand and humus. Sand from fine to medium.
-------------	---

- 1 to 2 feet Whitish, loose to slightly clayey sand. Sand from fine to medium with a few coarse grains. Occasional porous pebbles up to 1" by 1½" composed of sand embedded in a phosphatic clay.
- 2 to 4½ feet Hardpan. Firm, brown to gray clayey sand containing fragments of sand-rock. Clay content and sand-rock fragments increase with depth. Sand-rock fragments consist of quartz sand cemented by a non-phosphatic clay. Clay is non-calcareous.
- 4½ to 7 feet Grayish to whitish sandy clay or clayey sand. Same as above except soft and no fragments of sand-rock.

Hawthorne

- 7 to 10 feet Grayish to buff clayey sand with abundant pebbles and grains of phosphate. Phosphate pebbles and grains dominantly white, but some brown.
- 10 to 14 feet Gray to buff clayey sand and sandy clay with a decrease in pebble size phosphate and a marked increase in grains of phosphate. From 10 to 11 feet a gradual decrease in pebble size phosphate. Grains of phosphate are white, gray, tan and brown.
- 14 to 20 feet Buff clayey sand with fewer but still common grains of brown, tan and amber phosphate. Bottom foot contains a few pebbles of brown and gray phosphate.
- 20 to 21 feet Sandy phosphatic clay with occasional grains of brown, amber and black phosphate.
- 21 to 30 feet Massive greenish to greenish gray clay with thin stringers consisting of a mixture of quartz sand and white phosphate grains. Embedded in the clay are numerous grains of soft white phosphate. At 30 feet the clay has the appearance of fullers earth and dries to a light gray or whitish color.

The summary of the hole is as follows:

0 to 7 feet	post-Hawthorne
7 to 30 feet	Hawthorne
T. D. - 30 feet	in Hawthorne

The sediments encountered in this boring and those of holes 2 through 5 (see pages 166-170) show that in the area of the Simmons' pits two distinctly different types of Hawthorne materials occur. At the top of the Hawthorne is a heavy concentration of pebbles and grains of phosphate which is entirely different from the underlying marine Hawthorne beds. It should be noted that Dall referred to both types of sediments in the area as "Hawthorne beds." These two different types of materials taken together constitute a mappable unit.

The log of hole #1 shows other interesting features. Porous pebbles consisting of quartz and embedded in phosphatic clay are present in the post-Hawthorne sands and clayey sands. Such pebbles are similar, if not identical, to pebbles resulting from the weathering of exposures of Hawthorne sediments today.

Pebble size phosphate is more highly concentrated in the top few feet of the phosphatic zone than elsewhere. This same condition has been found in numerous areas throughout the plateau of Alachua County.

In the bottom foot of the phosphate concentration (at a depth of 19 to 20 feet), pebbles of phosphate again

become common. Just beneath this slight increase in phosphate pebbles (at a depth of 20 to 21 feet) there occurs a phosphatic clay containing a few grains of brown, amber and black phosphate. Phosphatic clay of this same type is forming today from the weathering of the Hawthorne at some exposures. Beneath this 1-foot stratum is found massive greenish to greenish gray clay, which is sandy in places and includes numerous soft, white phosphate grains.

Throughout the area of the Simmons' Pits, the beds beneath the top phosphate concentration zone carry lenses of Ostrea normalis Dall. Dall (1892, p. 110) mentioned the occurrence of silicified shells of this oyster in the mud at the bottom of Magnesia Springs which is only a short distance from the old pits. The location of the springs is shown in figure 46. Many silicified specimens of this fossil can be found in Lochloosa Creek within a few hundred yards of the Springs.

Holes #6 and #7 (see pages 171 and 172) were drilled near Lochloosa Creek in an attempt to encounter a lens of undisturbed Ostrea normalis Dall. The sites for the borings were selected near the creek where it was believed that the top phosphate concentration zone had been stripped away by the stream. Such a location eliminated the necessity of hand augering through additional sediments. Hole #6 encountered these oysters although it can not be proved

that they represent an undisturbed lens.

Exposure South of Grove Park.- About 1 mile south of Grove Park in the eastern part of the SW $\frac{1}{4}$  of Section 25, T. 10 S., R. 21 E. about 1 $\frac{1}{2}$  feet of Hawthorne sediments similar to that quarried at the Simmons' pits are exposed in a road cut just west of a tributary of Lochloosa Creek. There the rock is composed of quartz sand and abundant grains and pebbles of whitish to tan phosphate embedded in phosphatic clay. Many of the phosphate grains are rounded to elliptical, and some show concentric structures in thin sections. Quartz sand is a common inclusion in many of the phosphate pebbles and grains (see figure 12). Thin sections show scattered grains of clastic feldspar including microcline in both the phosphatic clay and the phosphate pebbles. An analysis of the phosphate from this exposure is given on page 197.

Brooks Sink.- Brooks Sink, about  $\frac{1}{4}$  miles east of the town of Brooker in Bradford County and only a short distance north of Alachua County, furnishes the best exposures of the phosphatic Hawthorne. There, forty feet of such sediments are exposed and are overlain by forty feet of shell marl and covered slope. The sink, located in the NE $\frac{1}{4}$  of Section 14, T. 7 S., R. 21 E., is shown in figure 13. The following is a detailed section made at the sink.



Figure 12. X 26. Photomicrograph of a thin section made from the phosphatic sediments found outcropping about 1 mile south of Grove Park just west of a tributary of Lochloosa Creek (Section 31, T. 10 S., R. 22 E.). The elongated phosphate pebble shown in the left side of the pictures contains considerable clastic quartz sand. Other phosphate grains are scattered throughout the thin section. The cementing material is largely phosphatic clay. Top picture with plane polarized light; bottom picture with crossed nicols.



Figure 13, Brooks Sink, located about 4 miles east of Brooker in Bradford County. The best exposures of the phosphatic Hawthorne are found in this sink. These phosphatic beds are overlain by a shell marl of lower Choctawhatchee age.

Section at Brooks Sink

20. Covered interval ..... 15'
- Shell Marl (Upper Miocene)
19. Cream or light colored shell marl, bedding  
distinct, some cross bedding ..... 17'8"
- Sediments of Upper Miocene age (?) (Possibly Hawthorne  
sediments)
18. Loose shell fragments and particles of calcium  
carbonate with slight amount of quartz sand  
grading downward into fine sand and particles  
of calcium carbonate with numerous shiny black  
phosphate grains ..... 6'4"
17. Cream or light colored shell marl with  
scattered grains of small shiny black phosphate  
and quartz sand. Occurs as a ledge ..... 1'2"
- Hawthorne formation (Miocene)
16. Tan or buff mixture of carbonate and sand with  
common to abundant grains and pebbles of  
black and brown phosphate. Fossil impressions  
common. Occasional interior molds of large  
clams ..... 1'6"
15. Tan to buff, more or less sandy limestone  
with impressions of fossils and a few grains  
of black phosphate. Occurs as a ledge ..... 10"
14. Tan to buff mixture of carbonate and sand  
with common to abundant pebbles of brown  
phosphate. Thin zone of limestone pebbles  
near middle of bed. Limestone pebbles are  
sandy with many pebbles and grains of phosphate  
and abundant impressions of fossils, including  
gastropods ..... 1'
13. Sandy limestone with common pebbles of brown  
phosphate and impressions of fossils. Occurs  
as a poorly developed ledge ..... 6"
12. Tan to buff mixture of sand, clay and carbonate  
with a heavy concentration of pebbles and grains  
of brown and black phosphate. The materials near

- bottom of stratum contains more clay which weathers to an ochre or brown color. Numerous impressions and molds of fossils, mainly pelecypods...2'
11. Tan to buff mixture of sand, clay and carbonate with common brown and black phosphate grains. Impressions of fossil pelecypods .....5'
  10. Tan to buff sandy limestone with common grains of black and brown phosphate. Many fossil impressions, particularly big pelecypods. Occurs as a concretionary ledge ..... 1'6"
  9. Gray slightly calcareous to calcareous sandy clay with common grains of black and brown phosphate and numerous fossil impressions, mostly pelecypods. Weathers yellowish to tan ..... 4'8"
  8. Tan to buff sandy limestone with common small brown and black phosphate grains. Looks like a blue-gray sandy calcareous clay which has hardened. Occurs as a concretionary ledge ..... 1'
  7. Gray or blue-gray highly calcareous sandy clay with numerous small grains of shiny black and brown phosphate. Weathers tan or buff ..... 3'3"
  6. Concretionary ledge of gray or blue-gray, more or less sandy to sandy limestone, with included small black and brown phosphate grains and fossil impressions. Weathers tan to buff color ..... 7'5"
  5. Gray or blue-gray, sandy calcareous clay with numerous small black, brown and gray phosphate grains. Clay weathers tan or buff. Scattered through bed are occasional whitish, poorly preserved pelecypods..... 2'
  4. Layer of broken-up, mollusk-bored blue-gray limestone. Weathers tan to buff. Many whitish, poorly preserved fossil fragments intermingled with and on top of the fragments of limestone ..... 4"
  3. Tan or buff colored, highly calcareous sandy clay with a heavy concentration of pebbles and grains of phosphate and rounded and angular small blocks of clays. Pebbles of phosphate are brown, gray and white. Grains of phosphate are black, gray and brown ..... 1'11"

2. Cream or buff colored, more or less sandy to sandy limestone with occasional clusters of phosphate grains and pebbles. Bottom of bed has a wavy, very irregular surface and shows solution weathering. Occurs as a ledge ..... 1'10"
  1. Top one to two feet of stratum has the appearance of a "breccia" with whitish limestone fragments embedded in a matrix of phosphate pebbles and grains, sand and clay. "Breccia" grades downward into blue-gray, more or less calcareous to calcareous sandy clay with phosphate pebbles and grains. Clay weathers tan or buff. Near bottom of stratum, in places, are numerous fragments of poorly preserved white pelecypod shells ..... 5'10"
- Total depth to water 80' 9"

A small stream, entering from the southeast, offers the only entrance to the sink. That stream courses over two small waterfalls and then plunges 20 feet over bed 6 into a deep lake which occupies the bottom of the sink. Gullies cutting back from the sink expose whitish sands, red and yellow clayey sands or sandy clays and greenish clay. Some of these materials are lower in elevation than the shell marl of bed 19, but most certainly are younger in age. A few discoid quartz pebbles occur in the sands.

All of the beds exposed in the sink are essentially horizontal, can be traced completely around the sink and contain impressions of marine fossils. Cross bedding is conspicuous in the shell marl near the top of bed 19. The top of this shell marl has been identified as lower Choctawhatchee in age (see page 96). From the exposures

examined, the contact between the shell marl and the phosphatic sediments appeared to be gradational.

The color of the unweathered beds in the bottom of the sink (beds 1 through 9) is gray or blue-gray. These materials weather to a tan or buff color. It is probable that beds 10 through 16 were originally blue-gray or some other shade of gray. The shell marl is cream to light colored.

The grains and pebbles of phosphate occur disseminated throughout the sands, clays and carbonate and as concentrations in the form of lenses, irregular patches and as an abundant component of the matrix in the "breccia" near the top of bed 1 (see figures 14, 15 and 16). Beds 3 and 12 as well as the top two feet of bed 1 contain heavy concentrations of pebble phosphate. See page 199 for analyses of the phosphate in these three beds. In some instances there is no question but that some of the black phosphate pebbles weather to a brown color.

Bed 4 and the thin zone of limestone pebbles in bed 14 furnish interesting complications. Bed 4 is a thin broken-up, mollusk-bored, blue-gray limestone which weathers tan or buff. Some of the bore holes go inward from the top of the bed, and others start from the bottom (see figure 17). Bore holes, similar in shape and appearance to those of this limestone, occur in some of the clay of bed 1 and have been noted in manatee ribs.



Figure 14. Breccia zone in upper part of Bed 1, Brooks Sink. The area between the head of the hammer and the white limestone of Bed 2 has been cleaned to reveal the brecciation. This "breccia" can be traced completely around the sink.



Figure 15. A close-up picture of the "breccia" shown in figure 14.



Figure 16. Detail photo of a block of the "breccia" of figures 14 and 15. The white fragments of limestone are embedded in a matrix consisting of abundant pebbles and grains of phosphate, quartz sand and clay.

Even though the limestone of bed 4 is only a few inches thick, it maintains its stratigraphic position and can be traced around the sink. Immediately over the pieces of limestone and intermingled with them are abundant poorly preserved pelecypods. The top surface of this rock in a few places has a striated or grooved appearance (see figure 18). The origin of these striations is not understood, but they may be slip marks. In the weathering of this limestone, lines of discoloration develop which form concentric rings around the bore holes. Fragments of similar appearing limestones are found near the tops of several beds around the sink. Vernon (1951, p. 180) described fragments of a similar, if not identical, thin broken-up, mollusk-bored Hawthorne limestone.

The thin fragmented limestone in bed 14 is sandy, and includes many pebbles and grains of phosphate and fossil impressions. Some of the limestone pebbles seem case-hardened. Many pebbles scattered through Hawthorne beds look almost exactly like these impure limestone fragments.

Devil's Mill Hopper.- One of the best exposures of Hawthorne sediments in Alachua County occurs in the Devil's Mill Hopper, a sink located in Section 15, T. 9 S., R. 19 E. The following is a section made at the sink.



Figure 17. Fragmented, mollusk-bored, blue-gray limestone from bed 4 at Brooks Sink. In these rock fragments, borings are from all surfaces.

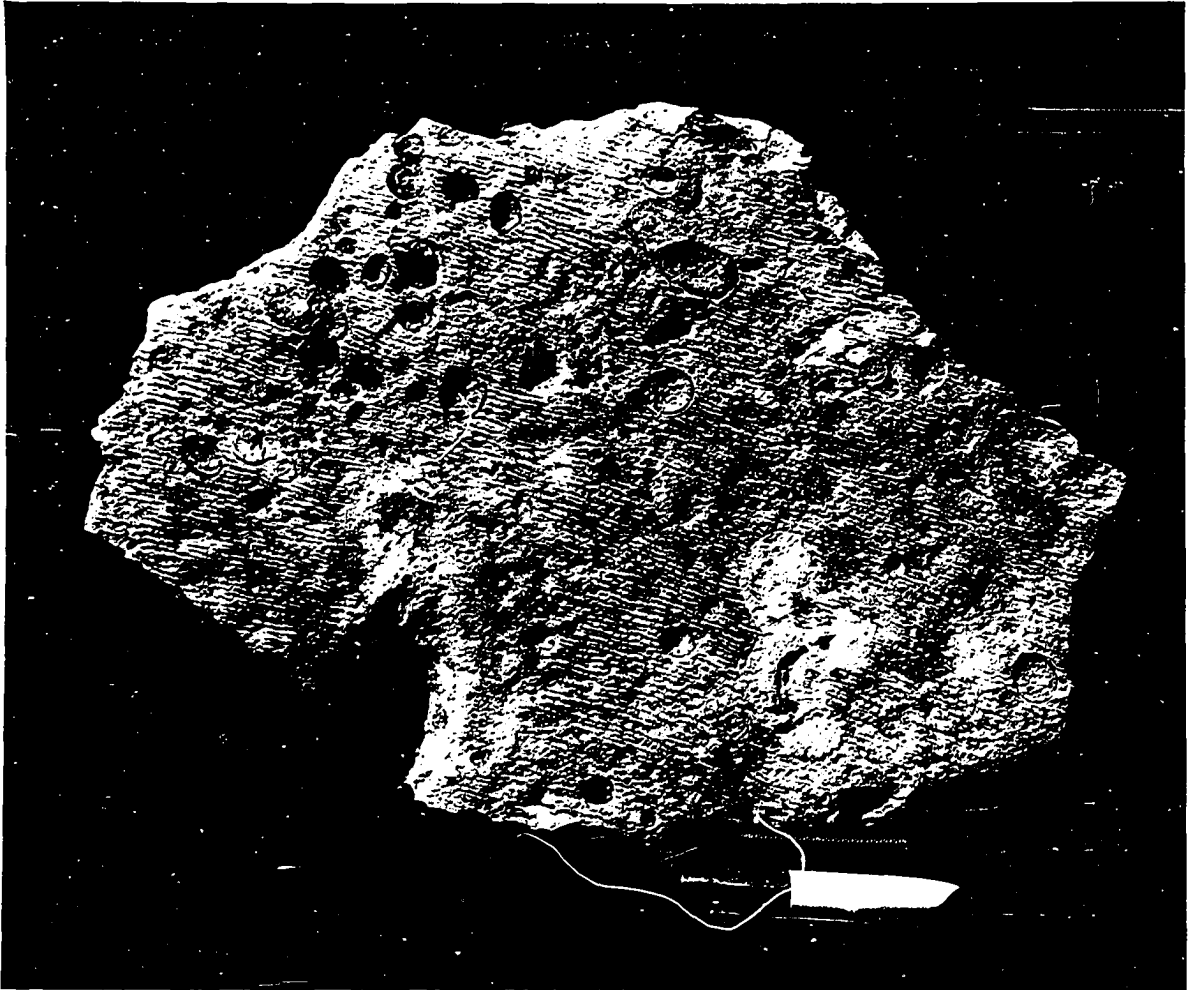


Figure 18. Striations on upper surface of a fragment of the blue-gray limestone from bed 4 at Brooks Sink. Note numerous mollusk borings. Bases of skeletons of barnacles are present on the surface in the lower right corner of the fragment. These barnacles could only have been present on a hard substratum. This suggests extremely slow deposition or an unconformity.

Section at Devil's Mill Hopper

11. Loose, gray to white sand .....	3'
Hawthorne	
10. Abundant pebbles and grains of phosphate in a matrix of sand and clay. See page 198 for an analysis of this phosphate .....	25'
9. Cream to yellow, calcareous sandstone or sandy limestone containing in places abundant molds and casts of marine pelecypods and gastropods. Phosphate pebbles and grains are common .....	30'
8. Whitish to gray, dense dolomitic limestone ...	3'
7. Mainly blocky clay of fuller's earth type. Toward top of bed, in places, a grayish to blue-gray sandy clay. Microscopic crystals of pyrite are common in the blue clay .....	30'
6. Limestone similar to bed 4 .....	2½'
5. Greenish gray to gray clay of fuller's earth type, similar to bed 3 .....	4½'
4. Sandy limestone containing many calcite fossil shells, angular blocks and rounded pebbles of fuller's earth clay, and phosphate pebbles and grains .....	1½'
3. Greenish gray to gray, blocky clay of fuller's earth type, with a few phosphate pebbles and rare impressions of marine fossils .....	18'
2. Dark colored, dense dolomitic limestone (partly silicified in places) with stringers of quartz sand. Grades down into a loosely cemented calcareous sandstone. Both dense limestone and sandstone contain included blocks of fuller's earth clay .....	2½'
1. White to gray sand, loose to slightly cemented, contains a few brown phosphate grains and pebbles. Rare shark's teeth .....	3'
Total depth	<u>123'</u>

The fuller's earth clay exposed in this sink is very fine grained and even textured. The dominant clay mineral is montmorillonite. A small piece of the clay, about the size of the head of a pin, when placed in immersion liquids and examined with a petrographic microscope reveals numerous included grains of fresh and angular orthoclase feldspar and quartz. Rare fragments of plagioclase, microcline and biotite are present.

The presence in clay of angular feldspar showing no evidences of decomposition or weathering imposes a problem. The following are possible sources for such feldspar in this clay:

- (1) The feldspar could have been brought down as clastic sediment from the Piedmont or Blue Ridge areas of Georgia and the Carolinas.
- (2) The minerals might be authigenic.
- (3) The clay could be volcanic in origin.

It seems unlikely that feldspars (not to mention biotite) freed by weathering in the Piedmont or Blue Ridge areas of Georgia or the Carolinas, could be transported at least 300 miles and probably much farther, finally to be deposited in the areas of Florida and yet show no signs of weathering or of abrasion. The angularity of the microscopic fragments might be explained by the cushioning effects of water, but the fragments should show signs of weathering.

Secondary growths of orthoclase and microcline on fragmental particles of these minerals are known to be authigenic in origin and in some cases euhedra appear to have formed without a seed. In studying thin sections of this clay, no criteria were found to indicate that the feldspars are authigenic. The particles appeared to be broken fragments of crystals and not the euhedra of authigenic crystals. No evidence of zonation suggestive of authigenic growths was detected though this is a feature not always present in crystals known to have formed within sediments. Biotite is not known to be authigenic, and occurrences of authigenic plagioclase are in question.

Several writers have indicated the possibility that such fuller's earth clay as that found in the Devil's Mill Hopper might be volcanic in origin. Mansfield (1940, p. 9) stated that "Recent field study by H. X. Bay, with laboratory investigations by P. G. Nutting, has brought to light evidence which may indicate that the major occurrences of naturally active clay in the Southeastern States have been derived directly from volcanic ash or indirectly from the same source through bentonites." C. S. Ross in describing similar clay collected from Citrus County, Florida, by R. O. Vernon (Vernon, 1951, p. 187) indicated that the clay had physical properties which suggested that it might be bentonitic. A thin section of fuller's earth clay collected in Marion

County, Florida, showed possible structures of glass shard relicts (Grim, 1933, p. 358). The derivation of fuller's earth clay such as that found in the Devil's Mill Hopper from volcanic ash would explain the presence of the angular, fresh feldspar.

The chemical composition of clay of fuller's earth type from other areas of Alachua County is noted to be similar to certain clays which without question have been derived from volcanic ash as indicated by the presence of glass shards or relict structures of such shards. The following examples (see Tables II and III) illustrate such similarities in chemical composition. The sample labeled "Newberry Highway" is from an exposure on the north side of the Newberry Highway, about  $5\frac{1}{2}$  miles west of Gainesville. The second sample was collected from NW 16th Avenue in Gainesville. These two analyses were furnished by Dr. W. C. Hackler of the University of Florida's Engineering and Industrial Experiment Station.

It is evident that the mineral and chemical composition of the fuller's earth clay is strikingly similar to that of unquestioned bentonites and meta-bentonites. Also, according to Bay and Ross similar clay has the physical properties expected from a clay of volcanic origin.

Although the stratification is persistent in the Devil's Mill Hopper, beds 2 through 8 vary lithologically. These variations are so peculiar that further comments seem pertinent.

TABLE II  
CHEMICAL ANALYSES OF CLAY OF FULLER'S EARTH  
TYPE FROM ALACHUA COUNTY

	Newberry Highway	16th Avenue
SiO <sub>2</sub>	51.31	59.85
Fe <sub>2</sub> O <sub>3</sub>	3.63	3.59
Al <sub>2</sub> O <sub>3</sub> (TiO <sub>2</sub> )	13.39	14.09
CaO	4.31	4.23
MgO	5.96	3.90
Na <sub>2</sub> O	0.11	
K <sub>2</sub> O	0.93	0.56
Moisture & Ignition Loss	20.17	13.60
Total	<hr/> 99.81	<hr/> 99.82

TABLE III

CHEMICAL ANALYSES OF MONTMORILLONITE DERIVED FROM BENTONITE AS INDICATED BY THE PRESENCE OF NUMEROUS GLASS SHARDS

(From Grim, 1933, p. 347)

	Conejos Quad., Colo.	Quilchena, B. C.
SiO <sub>2</sub>	54.46	56.20
Fe <sub>2</sub> O <sub>3</sub>	3.36	5.08
Al <sub>2</sub> O <sub>3</sub>	16.84	13.20
TiO <sub>2</sub>	0.80	
CaO	3.20	1.60
MgO	4.84	2.92
H <sub>2</sub> O- )		
) )	16.10	20.32
H <sub>2</sub> O+ )		
	<hr/>	<hr/>
Total	99.60	99.32

The clays of fuller's earth type in beds 3, 5 and 7 are in places silicified and in other places grade vertically and laterally into sandstones and limestones. When the clay dries it shrinks considerably, breaking up into small angular blocks (see figures 19 and 20). These figures show that this clay breaks with essentially a horizontal parting, which results from an original horizontal bedding. Probably through the aid of ground water, calcium carbonate is precipitated in cracks between the blocks of clay and at times quartz sand is brought in mechanically, resulting in an interlacing network of carbonate or cemented sand grains surrounding all of the blocks of clay. During weathering, some of these blocks of clay fall out displaying the network (see figure 21). Whether ground water could continue to carry parts of the clay away mechanically, depositing calcium carbonate from solution and bringing in quartz sand mechanically, or if in cases replacement involving calcite and the clay could take place, eventually resulting in a limestone or sandstone is not known (see figures 22 and 23). The possibility that unusual changes do take place has been mentioned by Vernon (1951, p. 187) and Calver (1952, p. 83), both of whom state that in cases some clay of this type appears to have formed by direct replacement of limestone.

Samples were collected from a zone of gradation between massive clay and limestone. Thin sections were



Photograph by R. L. Day

Figure 19. Fuller's earth clay showing partings developed on drying. When collected, the clay was damp and massive with no visible breaks. Specimen from bed 3 at the Devil's Mill Hopper.



Photograph by R. L. Day

Figure 20. Exposure of fuller's earth clay of bed 7 at the Devil's Mill Hopper illustrating blocks of clay which have developed from massive clay. Note the horizontal parting which resulted from an original horizontal bedding.



Photograph by R. L. Day

Figure 21. Fuller's earth clay of bed 7 at the Devil's Mill Hopper displaying network of calcite. The calcite with some included quartz sand has been deposited between blocks of the clay and is best shown where blocks of such clay have fallen out.



Figure 22. More advanced stage of box-work development than shown in figure 21. All of the clay blocks and remnant blocks of clay have a horizontal orientation. In this specimen collected from bed 3 at the Devil's Mill Hopper, calcium carbonate is more abundant than clay.

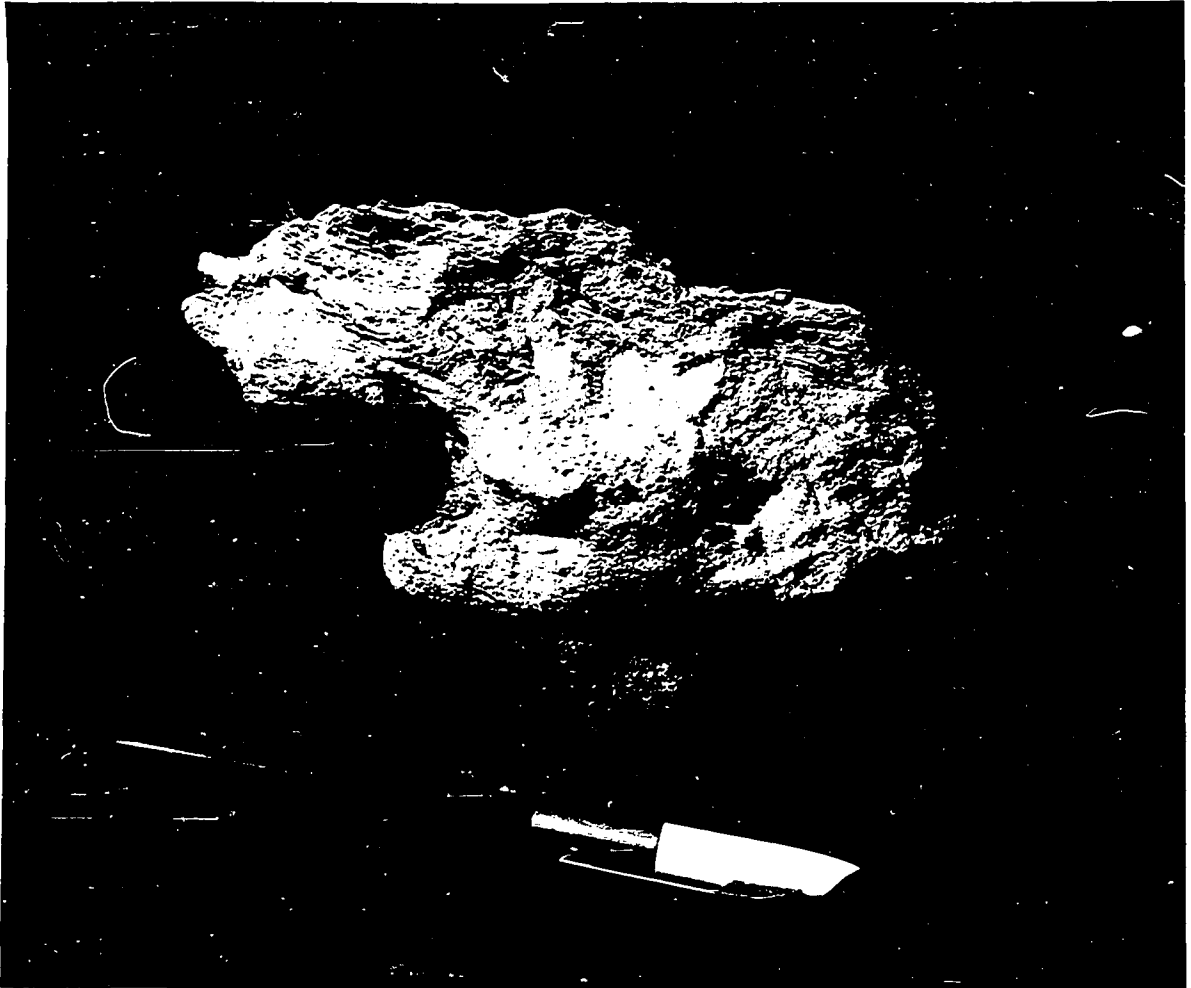
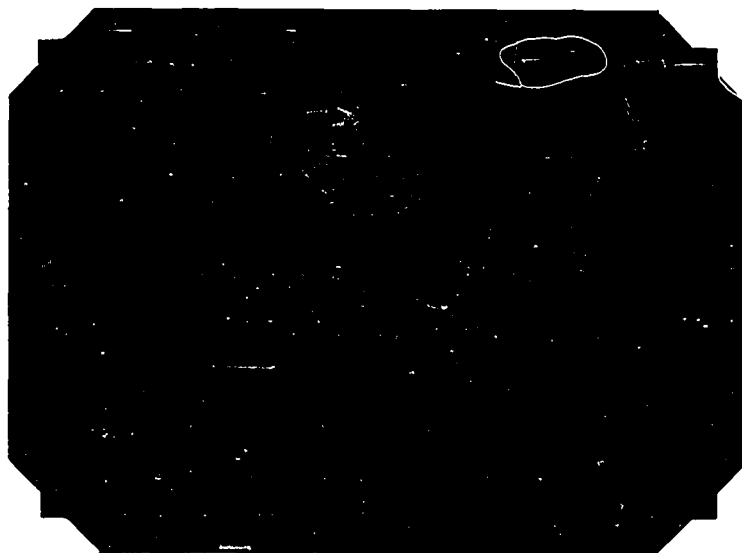
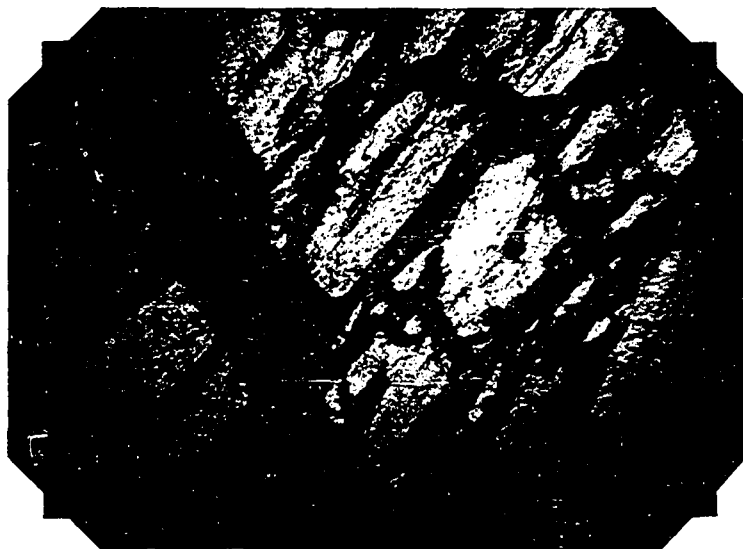


Figure 23. Specimen from bed 3 at Devil's Mill Hopper with calcium carbonate the dominant component. Numerous remnants of clay with essentially a horizontal orientation.

made of such material. All of the small blocks and relict blocks of clay visible in such thin sections have the same orientation, and the blocks appear to have been originally one mass of clay (see figure 24).

When the weathered surfaces, which show blocks of clay surrounded by films of carbonate or cemented quartz sand, are removed, the fresher material is noted to be blocky clay which is not characterized by the interlocking network. In places, these fresher clays contain stringers of carbonate or sand. Included in these fresher clays are nodules and concretions of dense dolomitic limestone (see figure 25) as much as 1 foot in diameter. Some of these enclose small blocks and relics of the fuller's earth clay. In all cases observed, these blocks of clay have a horizontal orientation and are more numerous and fresh near the outer edges of the dolomitic nodules. Relict blocks occur farther inside the boulders. It is believed that these boulders of dolomitic material are secondary in origin having in some way formed in the fuller's earth clay. Chemical analyses of the clay usually indicate a magnesium oxide content ranging from about 2 to 5 percent.

Occasional blocks and masses of clay having a horizontal orientation occur in the dense dolomitic material of bed 8 (see figure 26). The occurrence of these clay masses in the dolomite of bed 8 is not understood.



Photography by H. K. Brooks

Figure 24. X 26. Color microphotographs, made under crossed nicols with gypsum plate, showing clay remnants surrounded by calcium carbonate. Clay in top picture is bright yellow. In bottom photo, slide rotated 90 degrees from its position in top picture. Note that all clay fragments are oriented in the same direction. This thin-section suggests that the blocks and remnants of clay originally belonged to one mass of clay.



Figure 25. A nodule of dolomite which was embedded in the clay of bed 7 at the Devil's Mill Hopper. Note the blocky clay surrounding the whitish dolomite near the center of the specimen. Blocks and remnants of this clay are present in such dolomitic nodules and are more abundant near the edges of the dolomite. These included blocks of clay have a horizontal orientation as do the blocks of clay in which the dolomite is embedded.

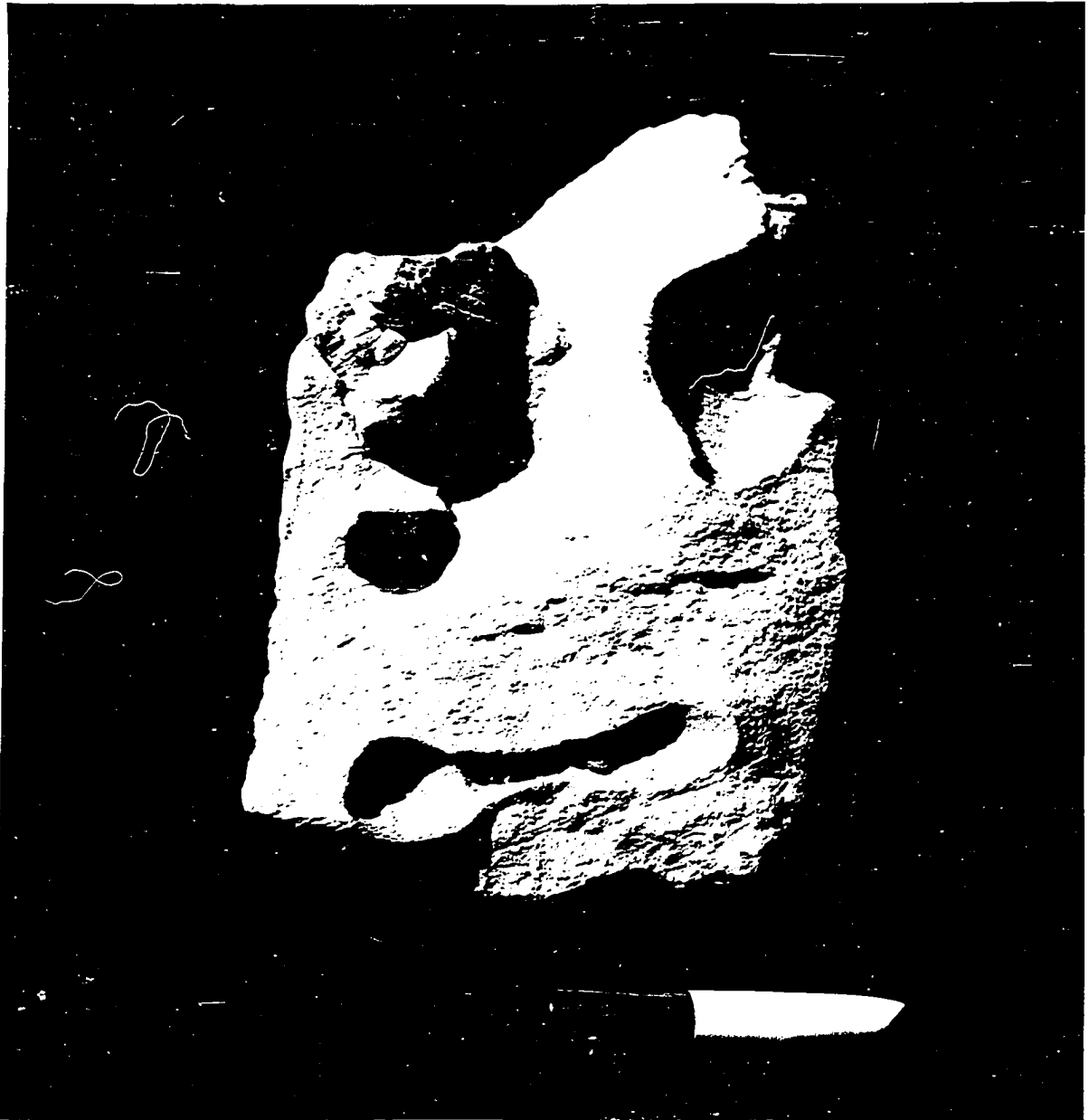
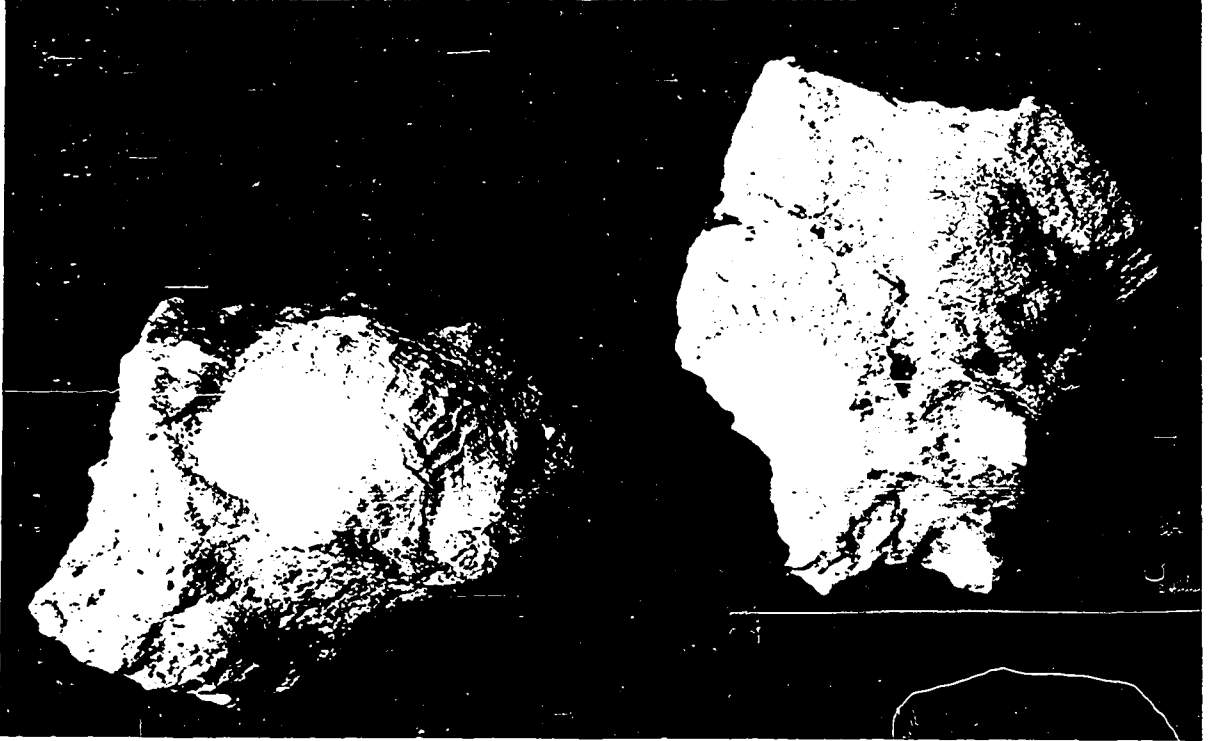


Figure 26. Dolomite from bed 8 at the Devil's Mill Hopper with included clay mass in upper left part of sample and openings from which clay masses have fallen. In places the 3 foot layer of dolomite from which this specimen was collected grades laterally and vertically into fuller's earth clay. The blocks of clay found in the dolomite have the same orientation as the blocks of clay into which the dolomite grades.

At the Devil's Mill Hopper, intercalated between beds 3, 5 and 7 (which are composed largely of fuller's earth clay), beds 4 and 6 are composed of materials having the appearance of intraformational breccias or conglomerates. These consist mainly of limestone containing angular blocks and rounded balls of the underlying fuller's earth clay as well as grains and pebbles of phosphate. The limestone contains calcite shells, which were identified by Dr. Harbans Puri as Pecten acanikos Gardner and Carolia floridana Dall (see figure 27). The angular blocks of fuller's earth clay occur in every conceivable orientation (see figure 28). It is believed that such a stratum is the result of the "churning up" of materials during a heavy storm.

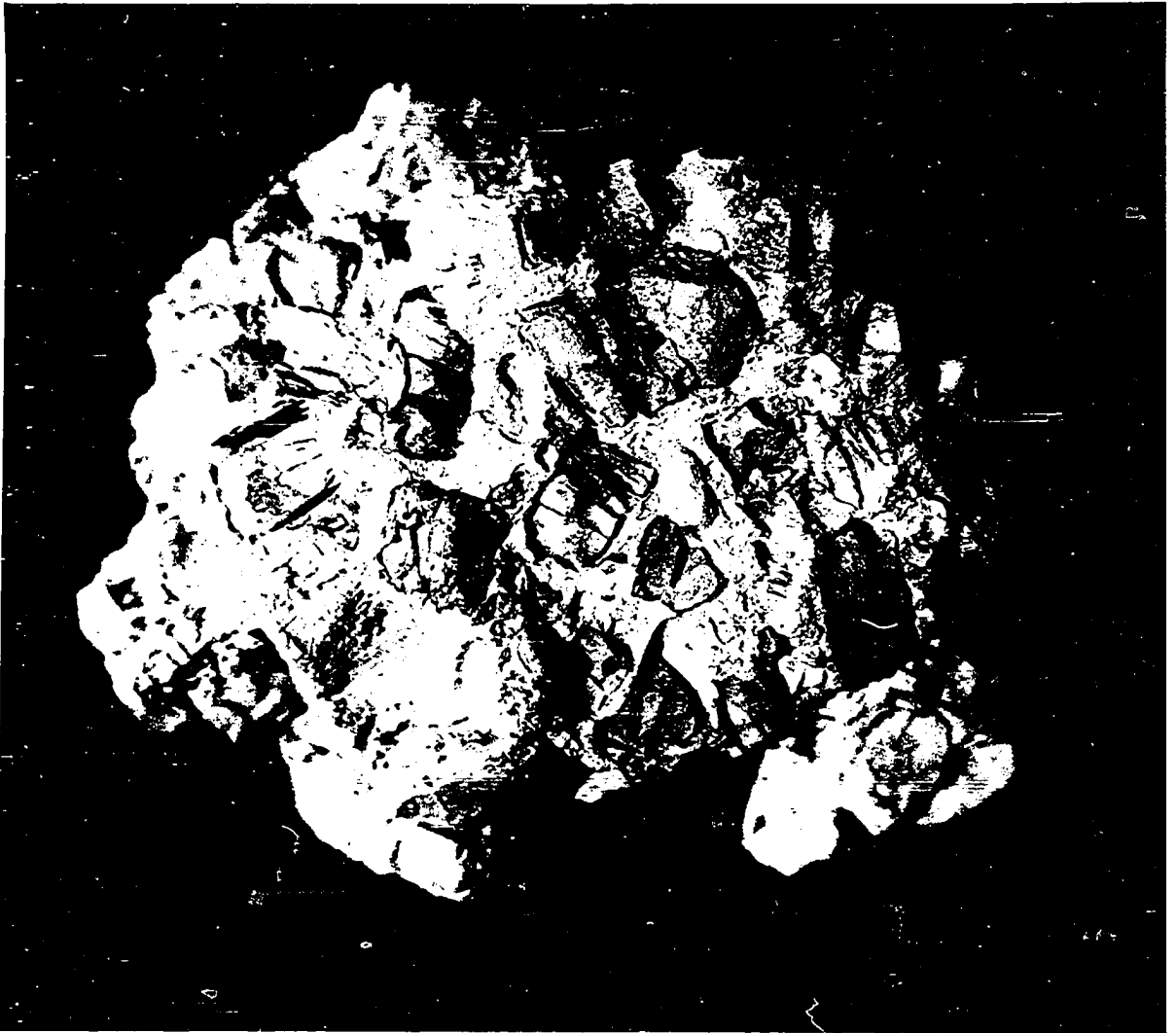
It can not be proved that blocks of fuller's earth clay could be washed around on the ocean floor by a storm without being destroyed, but it is known that the clay in the blocks is tenacious and can withstand considerable abrasive action. For example, in a number of areas where streams cut through fuller's earth clay, it has been noted that many blocks of clay have been rounded by the stream. Numerous rounded fuller's earth clay balls have been found in little pot holes beneath small waterfalls.

Another feature of interest concerning beds 4 and 6 is that their fossil shells are still composed of calcite, whereas in beds 3, 5 and 7 (those containing largely fuller's



Photograph by R. L. Day

Figure 27. Calcite fossils in limestone from bed 4 at the Devil's Mill Hopper. The fossil in the left of the picture is Carolia floridana Dall; that in the right is Pecten acanikos Gardner. Fossils identified by Dr. Harbans Puri.



Photograph by R. L. Day

Figure 28. Angular and rounded blocks of fuller's earth clay embedded in limestone of bed 4 at the Devil's Mill Hopper. Note that there is no definite orientation of the blocks of clay. The clay blocks have shrunk on drying leaving a space around each. This space in the picture appears as a black fringe around the blocks.

earth clay), all fossils, even though they are rare, occur as impressions or as silicified shells. It is believed that the fuller's earth clay is the source of the silica for the silicification of the fossil shells. As the fossil shells in beds 4 and 6 are embedded in limestone, those shells have not been affected as much by the silica from the clay and have not been silicified.

In these limestones of beds 4 and 6 there are many more pebbles and grains of phosphate than in the clays of beds 3, 5 and 7. In Alachua County wherever similar zones of limestone carry calcite fossils and angular blocks and rounded pebbles of underlying sediments, pebbles and grains of phosphate are more numerous than in the surrounding beds.

Thin sections of this limestone show included phosphate grains, clay pellets, orthoclase, plagioclase and microcline. No indications of replacement were seen. The feldspars appear to be clastic.

Exposures Southeast of Gainesville.- The construction of a new truck cut-off southeast of Gainesville between State Roads 339 and 24 during the spring and early summer of 1955 resulted in a few excellent exposures of the Hawthorne formation. As these exposures illustrate some of the features of Hawthorne sediments and because weathering changes their appearance considerably in a short time, a series of pictures was made of the materials as soon as entrance to the cuts was possible.

About 1.2 miles northeast of the intersection of State Roads 329 and 25 where the new cut-off cuts through Colclough Hill, a contact between the irregular erosion surface of the Ocala limestone and the Hawthorne formation can be seen on the west side of the highway (see figure 29). The Hawthorne consists of an impure dark brown clay which contains lenses of silicified Ostrea normalis Dall. The clay, which when unweathered is a light greenish to greenish gray color, contains a few shark teeth and manatee ribs.

Approximately .2 mile farther northeast along the cut-off for a distance of 500 feet, undisturbed exposures of Hawthorne sandstone, two filled sinks in this sandstone, and three clay lenses can be seen clearly. Figure 30 shows the northeast end of a clay lens, on the west side of the highway, which appears completely surrounded by clayey sands and loosely cemented sandstone. The clay lens is light green to greenish gray and weathers to a yellow or brown color. The clay is non-calcareous and contains only minor quartz sand although occasional sandy partings which contain quartz sand mixed with grains of soft white phosphate are present.

The clayey sand below the clay lens is soft and contains abundant grains of soft, white phosphate and some white to gray pebbles of phosphate. There are also a few balls of phosphatic clay.



Figure 29. Exposure in road cut southeast of Gainesville showing contact between the Hawthorne formation (dark) and the solution pitted Ocala limestone (light). An undisturbed lens of Ostrea normalis Dall (not visible in the picture) occurs in these Hawthorne sediments.



Figure 30. Part of a clay remnant (dark with slight gullying) exposed in road cut along the west side of the new truck cut-off southeast of Gainesville. The clay remnant appears to be completely surrounded by a whitish, slightly clayey sand (beneath the remnant) and loosely cemented sandstone (above the remnant). Field observations reveal many evidences of slumpage in the sandstone to the right (northeast) of the clay remnant.

A sandstone occurs above the clay lens. It is believed that this sandstone is nothing more than a soft clayey sand similar to that below the lens but which has hardened on weathering. In this sandstone a large part of the cementing material is a phosphatic clay.

Considerable evidence of slumpage, including slickensides in clay, distorted bedding and brecciation is noticeable in the sandstone just northeast of the clay lens. Joints have developed in the sandstone due to slumpage. About 75 feet northeast of the clay lens a filled sink in this sandstone can be seen clearly. The contact between the fill material and the sandstone is sharp and distinct as shown in figure 31. Much of the fill material may be weathered Hawthorne sediments and consists of a mixture of loose brown sand and clay with a few whitish to gray phosphate pebbles and occasional porous sandstone pebbles. The sandstone beneath the fill material is highly brecciated.

Approximately 60 feet still farther northeast another filled sink occurs in the sandstone on the opposite (east) side of the highway. This fill is shown in figure 32. Here a faint bedding is apparent in the sandstone, and due to slumpage distinctly dips down as the sink is approached from each direction. Figure 33 shows brecciation such as occurs in the sandstone beneath both filled sinks.



Figure 31. View perpendicular to a sloping surface showing sharp contact between Hawthorne sandstone (white material under the hammer) and the filling of a sink. Sink is result of solution of Ocala limestone below.



Figure 32. Section in road cut showing dark colluvium filling a shallow depression in white Hawthorne sandstone. The depression presumably was caused by sagging into a sink developed in the underlying Ocala limestone. East side of new truck cut-off southeast of Gainesville.



Figure 33. Looking vertically down at surface of brecciated sandstone below the filling of the sink shown in figure 32. This brecciation seemingly is a result of slumpage due to solution in underlying Ocala limestone.

Figure 34 shows the southwest end of the fill shown in figure 32. There, about 2 feet of loose whitish sand can be seen covering both the Hawthorne sandstone and the fill material. This loose sand is thought to be Pleistocene but might be of the same age as the fill material.

The following events are believed to form a part of the history of these exposures.

- (a) Marine Hawthorne sediments were laid down upon the highly weathered and solution-pitted surface of the Ocala limestone. The present clay masses such as seen in figure 30 are believed to represent parts of an earlier continuous clay stratum.
- (b) Continuing solution in the Ocala limestone resulted in small collapse sinks, which in the areas of the collapse carried the sandstone which was above the clay stratum to a lower position. Such collapse resulted in the distortion of the continuous clay stratum such as to give the present appearance of clay lenses.
- (c) This collapse presumably took place after the marine Hawthorne sediments had been uplifted and lithified sufficiently so that they became brecciated as they slumped into the sink.
- (d) The sinks, which developed in the sandstone as a result of solution in the Ocala, were filled by Hawthorne sediments slumped and washed in from the sides.



Figure 34. Loose, whitish surface sands (about 2 feet thick) covering Hawthorne sandstone (white and below arrow 1) and fill material (dark and between arrows 2 and 3). The fill material in this photo is the southwest end of the fill shown in figure 32.

- (e) After the sinks were filled, the sea covered the area and deposited the Pleistocene sands.

#### Correlation of Some Hawthorne Sediments

The phosphatic sediments in Brooks Sink can be correlated by means of well cuttings with sediments at the type locality of the Hawthorne formation around the town of Hawthorne. Such a correlation indicates that much sediment which has been considered as Hawthorne in the past actually is post-Hawthorne.

A water well (surface elevation 151.31 feet) drilled at the City Hall in the town of Hawthorne penetrated 125 feet of Hawthorne sediment. The following is a generalized summary of part of the well log.

0 to 40 feet	Post-Hawthorne. Mainly red and yellow sandy clay and clayey sand.
40 to 165 feet	Hawthorne. Similar to that exposed in Brooks Sink in Bradford County.
165 feet	Ocala limestone

The red and yellow sandy clays and clayey sands which cover the Hawthorne materials in this well and which often have been referred to as Hawthorne sediments are believed to be considerably younger than the Hawthorne. They are found outcropping throughout much of the northeastern part of Alachua County. These sandy clays and clayey sands are best exposed in an eastward-facing cut along the western side

of Highway 301 between Hawthorne and Orange Heights. They have been traced by outcrops (see figure 35) and by the cuttings from numerous wells to the CF-1 well (surface elevation 155.64 feet) drilled in the center of Section 33, T. 8 S., R. 21 E. in the Austin Cary Memorial Forest where 28 feet of shell marl occur between these overlying red and yellow sandy clays and clayey sands and the underlying Hawthorne. The following is a generalized summary of the post-Eocene materials penetrated by the well.

0 to 2 feet	Loose, tan sand.
2 to 32 feet	Mottled red and yellow clayey sand grading down into brownish to yellowish sandy clay. Colors result from weathering of a gray clay.
32 to 60 feet	White to cream to tan shell marl. Foraminifera abundant but too poorly preserved for identification.
60 to 210 feet	Hawthorne. Similar to that exposed in Brooks Sink.
210 feet	Ocala limestone.

The shell marl in the Austin Cary Memorial Forest well is similar in appearance and occupies the same stratigraphic position as the shell marl exposed in Brooks Sink in Bradford County. The shell marl at Brooks Sink has been dated by Puri on the bases of ostracods as lower Choctawhatchee age. In a personal letter dated May 3, 1955 Dr. Puri stated:

"I have examined the samples from the top of the shell bed, Brooks Sink, and they have yielded the following:

Microcythere stephensoni Puri (Alum Bluff and Choctawhatchee)

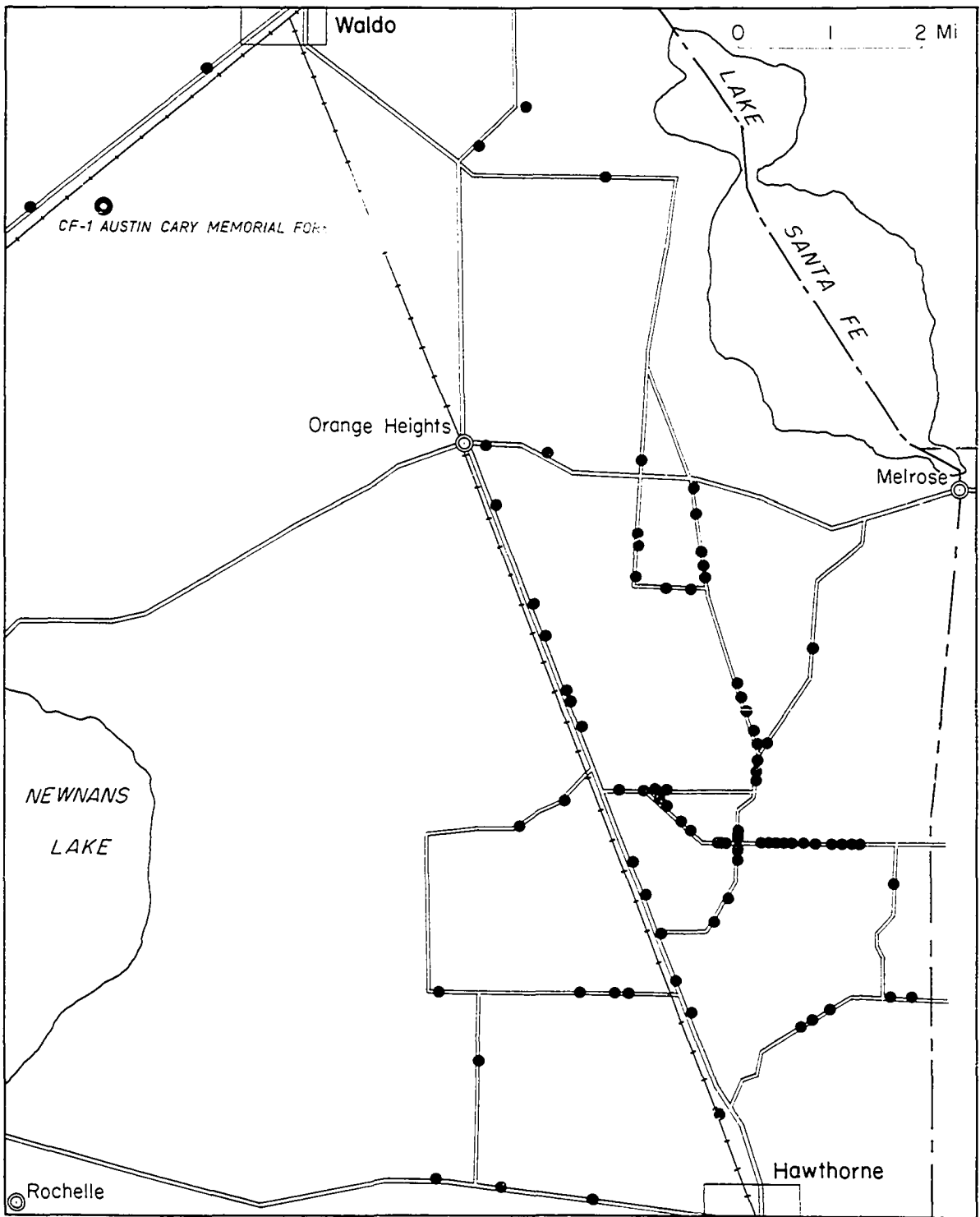


Figure 35. Outcrops of red and yellow clayey sands and sandy clays in northeastern Alachua County.

Cytheretta choctawhatcheensis Howe and Taylor  
(Chipola, Choctawhatchee)

Puriana rugipunctata Ulrich and Bassler (Shoal  
River, Choctawhatchee)

Anomocytheridea floridana Howe and Hough (Choctawhatchee)

Murrayina gunteri Howe and Chambers (Oak Grove,  
Choctawhatchee)

Xestoleberis choctawhatcheensis Puri (Choctawhatchee)

Loxoconcha cf. L. purisubrhomboidea Edwards  
(Choctawhatchee)

Haplocytheridea bassleri Stephenson (Alum Bluff,  
Choctawhatchee)

The Foraminifera from this bed are very badly leached and replaced by dolomite and I regret my inability to identify any of them. The ostracode fauna, however, is comparatively well preserved and the fauna associations are of lower Choctawhatchee age."

#### Summary of Hawthorne Formation

In summary, the main body of the Hawthorne is composed of sands, clays and limestones. It is marine in origin and Middle Miocene in age. The individual beds are highly variable in lithology both laterally and vertically. At the top of this main body is a concentration, ranging up to 40 feet in thickness, of pebbles and grains of phosphate embedded in a matrix composed of various combinations of clay, sand and carbonate. Dall, in his original description of the Hawthorne, included all of these materials in his "Hawthorne beds." Taken together they constitute a mappable unit even though the top phosphate concentration might locally include some

re-worked material of somewhat later age.

It should be emphasized that the red and yellow clayey sands and sandy clays found outcropping in the area of the town of Hawthorne and throughout northeastern Alachua County are not Hawthorne sediments. These materials apparently have been considered as a part of the Hawthorne formation by various workers in the past.

#### Alachua Formation

The name "Alachua clays" was applied in 1885 and published in 1892 by Dall (Dall and Harris, 1892, p. 127). The sediments usually called Alachua are found in the western part of the county in joints, sink holes and other low places in the Ocala limestone and generally are covered by sands which are believed to be Pleistocene. These sediments represent in part a residuum in situ of various post-Eocene sediments mixed with boulders of Ocala limestone, and in part materials transported by rainwash and streams to low areas such as sinks and shallow lake basins. This material is therefore terrestrial in origin having collected in low places along the breached arch of the Ocala uplift.

The so-called Alachua formation contains the hard-rock phosphate of Alachua County. Figure 36 shows the locations of old hard-rock phosphate pits in the County. Since the problem considered in this report is to determine whether

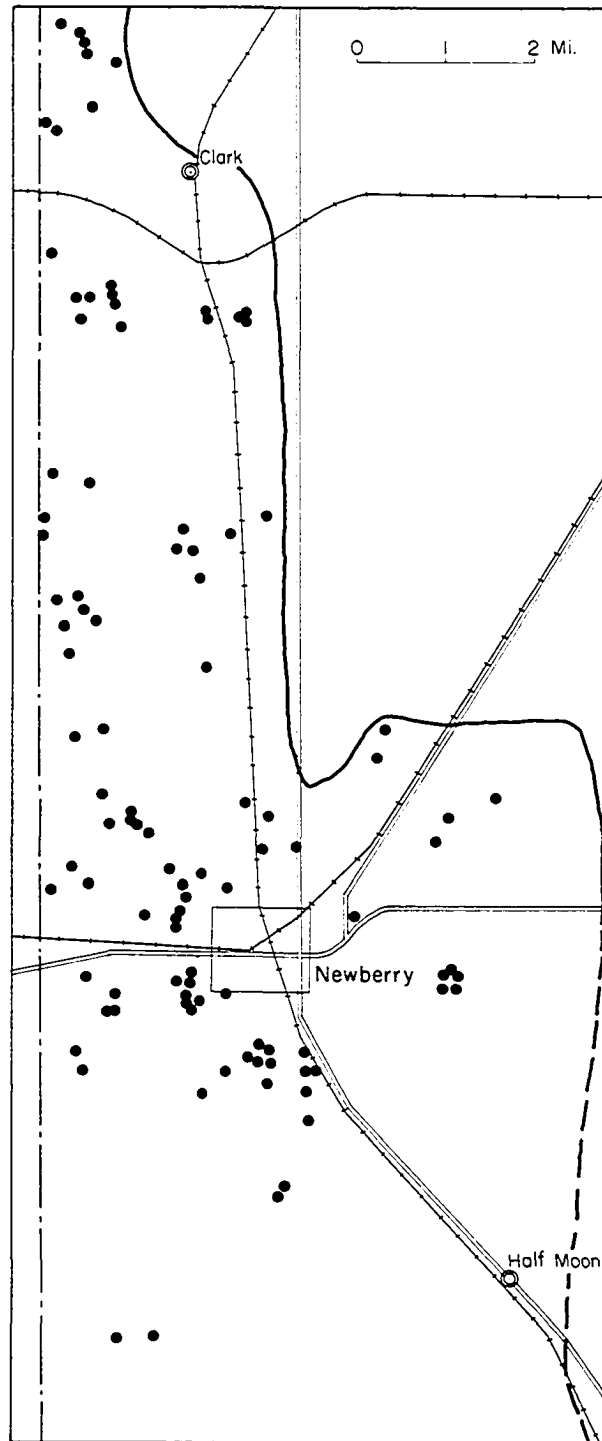


Figure 36. Location of abandoned **hard-rock** phosphate pits.

Hawthorne sediments could have served as a source for the phosphate of the hard-rock phosphate deposits within the county, no detailed study and description of the Alachua formation was undertaken. Besides, it is believed that descriptions of that part of the Alachua formation containing hard-rock phosphate made during the early 1900's when phosphate pits were being operated are more accurate than would be descriptions now made from the abandoned pits which are overgrown with vegetation and partly filled with trash and debris. The reader is referred to the work of Sellards (1913) and Matson (1915) for excellent discussions of the Alachua formation.

#### Types of Sediments

Sediments composing what has been called the Alachua formation in the county are largely combinations of sand, clay, silicified boulders of limestone of which most are Ocala, and plates, grains, pebbles and boulders of phosphate ranging up to masses several feet in diameter. Some of the clay in which boulders and plates of phosphate are embedded is phosphatic and constitutes the material called soft-rock phosphate.

#### Fauna and Age

The Alachua sediments contain bones of land vertebrates ranging in age from Lower Miocene to Pleistocene. A few

examples will demonstrate that they contain remains of animals of all these different ages.

A fauna, discussed by Simpson (1932), from the southwest side of pit number 2 (Section 31, T. 9 S., R. 17 E.) of the Franklin Phosphate Company near Newberry included the following fossils: Temnocyon? (dog), Parahippus or Archaeohippus (horse), Caeopus? or Diceratherium (rhino), Dinohyus which is probably a subgenus of Daeadon (early pig-like form), camelids (camels), and Blastomeryx? (deer). In a personal letter reviewing the Alachua fauna, Mr. H. H. Winters stated in regard to this locality: "Eliminating the questionable forms, the horse and pig are left. Both Parahippus and Archaeohippus range throughout the Miocene: Dinohyus hasn't been found later than early Miocene and in fact seems to be limited to that span of time. The questionable Temnocyon and the genus of rhino, whichever it is, point to a pre-Middle Miocene age." Field evidence is in accord with a possible early Miocene age for these land vertebrates. During early Miocene time (post-Suwannee and pre-Hawthorne) much of the Suwannee limestone was eroded from western Alachua County.

Many Pliocene and Pleistocene vertebrate land fossils have been reported from the Alachua formation in the County. Simpson (1930, p. 176) considers the following Pliocene vertebrates to be indigenous to the Alachua formation.

Hipparion ingenuum (horse)  
H. plicatile (horse)  
H. minor (horse)  
Teleoceras proterus (rhino)  
Aphelops longipes (rhino)  
Megatylopus? major (camel)  
Procamelus? minor (camel)  
P. minimus (camel)  
Serridentinus floridanus (mastodon)  
S. leidii (mastodon)

A number of occurrences of land vertebrates of Pleistocene age have been found in stream beds and in terrestrial deposits of sand and clay which occur as pockets and sinks in the Ocala limestone in the western and south-central parts of Alachua County. These deposits containing only Pleistocene fauna usually are covered by orange-tan clayey sand or a thin layer of loose whitish sand of probable marine origin. Brodkorb (unpublished report) has studied in detail one such occurrence (see Arredondo, page 105) and has given evidence, some of which is based on the nature of the associated bird fauna, that the vertebrates in that locality lived during a glacial stage and are embedded in fresh water clay. Such clay contains numerous remains of frogs and salamanders. It would seem that the methods of accumulation of such sediments are similar to those of typical Alachua

sediments.

From information supplied by Mr. Walter Auffenburg and Dr. Pierce Brodkorb, three Pleistocene occurrences were selected and the partial fauna of each is listed below. The lists as compiled by Dr. Brodkorb are:

1. Hornsby Spring Run in the extreme northwestern part of the County

Pleistocene Mammals

Tapirus vernoensis (Tapir)  
Mammut americanum (Mastodon)  
Mammuthus sp. (Elephant)

Pleistocene birds

Podilymbus podiceps (pied-billed Grebe)  
Anas platyrhynchos (Duck)  
A. rubripes (Duck)  
Aythya cf. marila (Duck)  
A. affinis (Duck)  
Lophodytes cucullatus (Duck)  
Aramus pictus (Rail)  
Rallus elegans (Rail)  
Gallinula chloropus (Coot)

2. Sand and clay occurring in solution depression in Ocala limestone. Exposed in quarry near Haile (Section 24, T. 9 S., R. 18 E.)

Pleistocene Mammals

Dasypus bellus (Armadillo)  
Holmesina septentrionalis (Armadillo)  
Aenocyon cf. ayersi (Wolf)  
Equus sp. (Horse)  
Platygonus sp. (peccary)  
Tapirus veroensis (Tapir)  
Smilodon sp. (sabertooth type)

Pleistocene Birds

\*\*Buteoninae indet. g. & sp. (Hawk)  
Colinus cf. virginianus (Bob-white)  
Meleagris gallopavo (Wild Turkey)  
\*\*Corvidae n.g., n. sp. (Crow)

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\* Amphibians and reptiles determined by Auffenburg; birds by Brodkorb; mammals by Guff, Bader, and Brodkorb.

\*\* Extinct Pleistocene species.

3. Clay in solution pits in Ocala limestone. Exposed in quarry northeast of Arredondo, approximately 6 miles southwest of Gainesville (NW $\frac{1}{4}$  of Section 22, T. 10 S., R. 19 E.)

Pleistocene Mammals

- Didelphis virginiana (Opposum)  
Scalopus aquaticus (Mole)  
Blarina cf. brevicauda (short-tailed Shrew)  
Myotis cf. austroriparius (Bat)  
\*Dasyops bellus (Armadillo)  
Sylvilagus floridanus (Cottontail Rabbit)  
Sciurus cf. carolinensis (Gray Squirrel)  
Geomys pinetis (Pocket Gopher)  
Peromyscus sp. (Mouse)  
Neotoma floridana (Wood Rat)  
\*Synaptomys australis (Lemming Mouse)  
Pitymys pinetorum (Pine Mouse)  
Neofiber allenti (Round-tailed Muskrat)  
Euarctos sp. (Bear)  
\*Tapirus cf. veroensis (Tapir)  
\*Equus sp. (Horse)  
\*Tanupolama cf. mirifica (Camel)  
Odocoileus virginianus (White-tailed Deer)  
Alligator mississippiensis (alligator)  
\*Testudo sellardsi (Large Tortoise)  
\*Terrapene canaliculata (Box Turtle)  
\*Pseudobranchius robustus (Salamander)  
Siren lacertina (mud-ell - a Salamander)  
Rana catesbiana (Bullfrog)  
Bufo americanus (Toad)  
Pseudemys cf. scripta (Pond Terrapin)

Pleistocene Birds

- Podilymbus podiceps (Pied-billed Grebe)  
Aythya collaris (Ring-necked Duck)  
Accipiter cooperii (Cooper's Hawk)  
Bonasa umbellus (Ruffed Grouse)  
\*Ectopistes migratorius (Passenger Pegeon; extinct within historical times)  
Aphelocoma coerulescens coerulescens (Scrub Jay)  
Lanius ludovicianus (Loggerhead shrike)  
Richmondena cardinalis (Cardinal)  
Pipilo erythrophthalmus (Spotted Towhee)  
Spizella passerina (Chipping Sparrow)  
S. pusilla (Field Sparrow)

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\* Extinct species

From the preceding discussion of fauna found in terrestrial deposits, it appears that the western part of the County was land, at least at times during Lower Miocene, Pliocene, parts of the Pleistocene, and Recent.

If all materials which represent residua formed at such times and which have accumulated along joints, in sinks and other low places in the Ocala limestone and if, in addition, sediments shifted by rainwash or streams into low areas of the Ocala during such intervals are classed as Alachua, the material loses time significance as a "formation." Materials being transported by rainwash and streams into shallow lakes, sink holes and other low areas of the Ocala today would fit the physical characteristics of the so-called Alachua, as would the mixtures of sand and clay containing bones of modern rabbits which are so abundant in some small solution pits in the Ocala. The difficulty can not be escaped by assigning to a named formation - the Alachua - only a portion of such sediments, for example that which contains hard-rock phosphate or that which contains only Pliocene terrestrial vertebrate fossils.

Some of these materials have definite characteristics. Those areas containing large quantities of hard-rock phosphate can be delimited. In a later section evidence will be given indicating that the Hawthorne formation covered the western part of Alachua County. It is reasonable to assume that

the phosphatic Hawthorne sediments served as a source for the phosphate now found in the hard-rock phosphate deposits. As the Hawthorne is Middle Miocene in age, phosphate which replaces the Ocala limestone or which is precipitated in openings in that limestone forming the hard-rock deposits would be post-Hawthorne in age. Such deposits normally are covered by sands believed to be Pleistocene. It is probable that most of such "Alachua sediments" containing hard-rock phosphate are post-Hawthorne and pre-Pleistocene in age (late Miocene or Pliocene). This does not preclude some of the limestone fragments now replaced by phosphate having accumulated in sinks prior to Hawthorne time, and being replaced by phosphate in post-Hawthorne time.

That part of the "Alachua formation" containing hard-rock phosphate is indicated on Plate I and for convenience is shown as probably late Miocene or Pliocene in age, though some parts of it must have been accumulated in sinks during the early Miocene before the Hawthorne sea covered the area.

#### Various Interpretations of Alachua Sediments

The terms "Alachua clays" and "Alachua formation" apparently have been applied to sediments of various types and ages. The situation can best be illustrated by the cross-section, Figure 37, considered in connection with quotations from previously published writings.

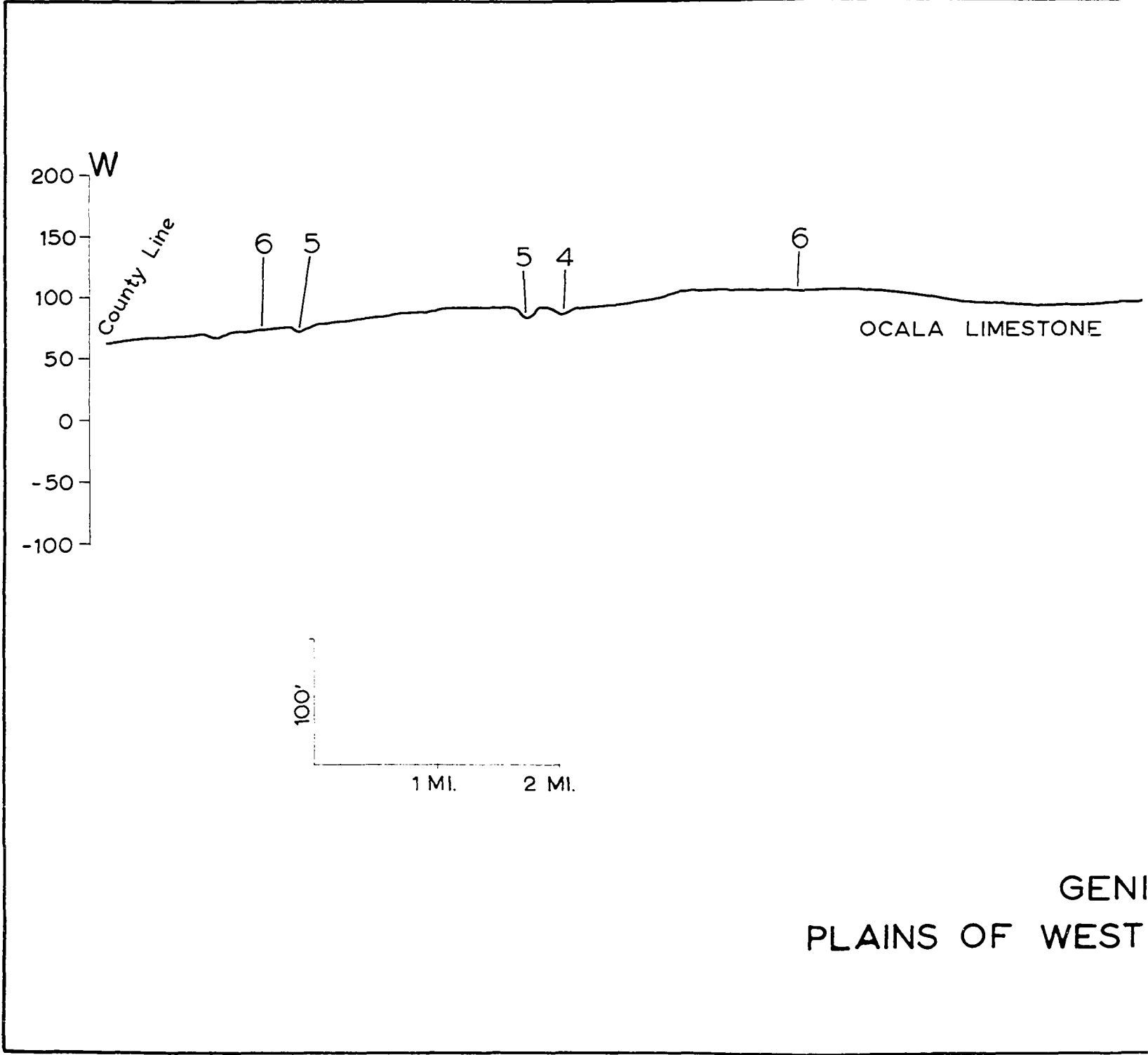
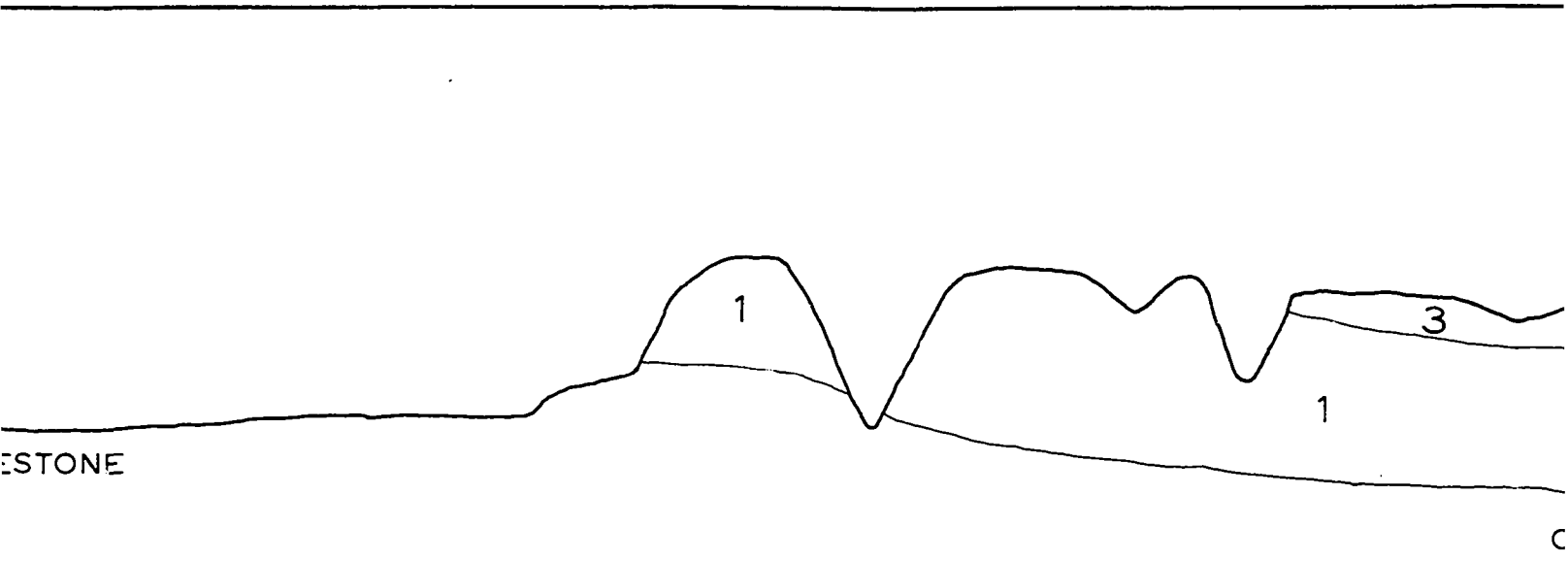
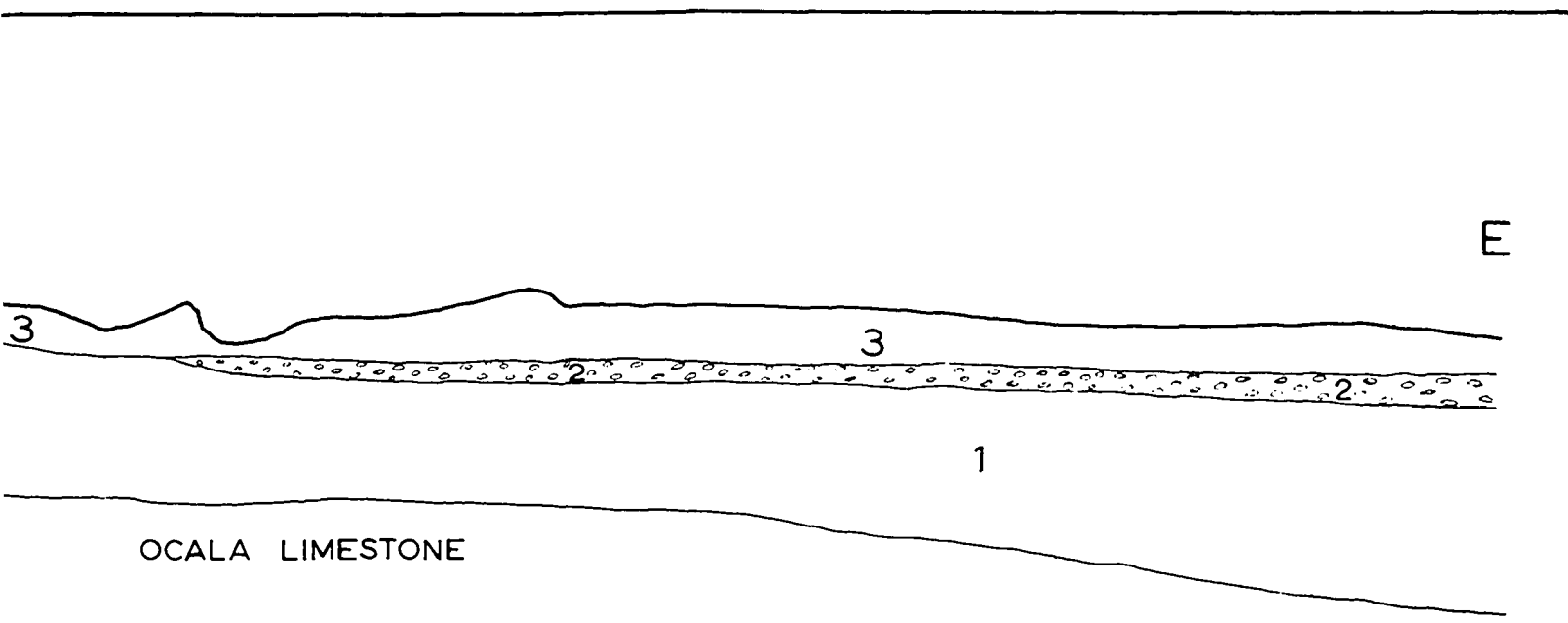


Figure 37.



GENERALIZED EAST-WEST CROSS SECTION THROUGH  
WESTERN ALACHUA COUNTY AND PART OF THE "PLATE  
VERTICAL SCALE GREATLY EXAGGERATED



1. Main body of the Hawthorne, marine, Middle Miocene.
2. Phosphate concentration at the top of the main body of the Hawthorne.
3. Post-Hawthorne sediments of "Plateau" area.
4. Combination of clays and sands containing bones of extinct mamalia, terrestrial; accumulated along joints, in sink holes and other low places of the Ocala limestone.
5. Mixture of clays and sands containing hard-rock phosphate, boulders of silicified limestone and in places bones of extinct mammalia; occurrences same as "4,"
6. Thin blanket of clays and sands covering large areas of Ocala. In much of area these clays and sands appear to be covered by younger sands.

OUGH  
 PLATEAU" AREA

Dall (1892, p. 127) described as his "Alachua clays" the "Clay containing bones of extinct mammalia," see "4" on figure 37. Dall further stated "These clays occur in sinks, gullies, and other depressions in the Miocene, Upper Eocene, and later rocks of Florida, especially on the western anticline in the higher portions of Alachua County, and along banks of many rivers and streams....The clays occur in patches, usually in depressions, but occasionally in short ridges whose lateral buttresses of limerock have disappeared through the dissolving agency of rainwater and carbon dioxide."

Dall's main localities of "Alachua clays" represent sediments accumulated in depressions of the Ocala limestone and would be illustrated by "4" on figure 37. Some of his other localities apparently do not represent such occurrences. His clays just west of Gainesville are for the most part Hawthorne sediments, "1" on figure 37. It is believed that his localities just north of Gainesville would correspond to "2" on the figure. Dall considered river pebble phosphate as "Alachua."

Sellards (1910b, p. 32) originally called sediments which occurred in sinks and low areas in underlying limestone and which contained hard-rock phosphate the "Dunnellon formation" from a locality near the town of Dunnellon in Marion County where such sediments occur. Similar sediments are represented on figure 37 as "5." Later Sellards

recognized that these sediments were the same as the clays containing extinct mammalia found in sink holes in the same general area (figure 37, occurrence "4"). Thus, Sellards concluded that the sediments of the hard-rock phosphate deposits were a part of the Alachua formation and recommended that the name "Dunnellon formation" be dropped.

Cooke (1945, p. 199) considers the Alachua formation as Middle Pliocene (Hemphill) in age and in giving his opinion of the formation, states "The Alachua is unique among geologic formations in Florida in that most of it was not deposited in water, either salt, or brackish, or fresh. The bulk of the Alachua is merely the collapse and compacted residue of the Hawthorne formation in situ together with accumulations in sinkholes and ponds. These latter accumulations contain the bones of Pliocene animals." Such sediments would be represented on figure 37 by "4," "5" and "6." Cooke states that the clays northwest of Gainesville are Alachua. Most clays northwest of Gainesville belong to the main body of the Hawthorne, contain lenses of undisturbed Ostrea normalis Dall and would be represented as "1" on the diagram.

Vernon (1951, p. 190) in his report on Citrus and Levy Counties used the term "Alachua formation" in reference to those counties to include "terrestrial deposits of diverse lithologic characteristics, but composed largely of clays,

fine sands and a basal rubble of phosphate rock, silicified wood, clay beds, and silicified Suwannee and Ocala limestone residuum. The sediments rest on a bed rock of limestone ranging in age from middle Eocene to Oligocene except in southern Citrus County, where they interfinger with, and, in part, lie upon the Hawthorn formation." Vernon (p. 195) further states "The formation is believed to be in part contemporaneous with the Hawthorn formation and in part of younger age. It was formed on uplands and as a rule overlies the Hawthorn formation, but in some wells occupies the same stratigraphic position of the Hawthorn." Vernon believed that the sediments of the Alachua formation accumulated during the Miocene and also perhaps during the period extending into the Pleistocene. He indicates that the formation may be largely Miocene in age with Pliocene and Pleistocene vertebrate land fossils representing contamination.

Vernon states that the Hawthorne formation never was deposited over the areas which contain hard-rock phosphate and in his figure 33 (1951, p. 180) indicates that the Hawthorne formation was not deposited over the western part of Alachua County. Thus, from Vernon's viewpoint, the sediments of the Alachua formation which contain hard-rock phosphate could not represent the collapse and compacted residue of the Hawthorne formation in situ. On pages 153-155 of this report, evidence is presented which indicates that the Hawthorne did cover all of Alachua County.

Vernon apparently considers phosphate concentrations at the top of the Hawthorne such as those north of Gainesville and throughout the northeastern part of Alachua County as Alachua. Such materials are labeled as "2" on figure 37 and in this report are considered as a part of the Hawthorne formation. Dall referred specifically to such a phosphate concentration as Hawthorne in the type area of the Hawthorne. This phosphate concentration at the top of the main body of the Hawthorne constitutes a mappable unit.

In review, it should be noted that Dall referred to the phosphate concentration at the top of the main body of the Hawthorne ("2" on the diagram) as part of his "Hawthorne beds." In citing occurrences to illustrate his "Alachua clays," it is believed that Dall indicated that this same type of concentration north of Gainesville was "Alachua." These statements concerning Dall should not be considered as criticism because it is clear that Dall mainly referred to sediments containing extinct mammalia occurring in sinks and other low areas of the Ocala limestone as his "Alachua clays." The quality of geological work performed in Florida by such men as Dall, Sellards and Matson has not been surpassed.

#### Post-Hawthorne Sediments of the Plateau Area

Throughout northeastern and east-central Alachua County there are many exposures of clayey sands and sandy clays (see figure 35) which commonly have a mottled red and yellow appearance but in cases are dominantly yellowish or

reddish in color. These colors are due to the weathering of gray clay. In places the sediments contain common to abundant elongated to discoid-shaped quartz pebbles. From one to five feet of loose surface sand of a white to tan color blankets these clayey sands and sandy clays (see figure 38).

The 1945 Geologic Map of Florida shows an area north of Gainesville covering at least 10 square miles which is mapped as thick sands of Pleistocene age. In drilling wells throughout this area, it is found that typically there is a cover of loose sand of variable thickness below which is sand with a clay binder between the grains, the clay content in general increasing with depth. Data gathered during this study indicates a strong possibility that, with the possible exception of the thin layer of loose surface sand, the sediments in the "thick" sand area north of Gainesville and the red and yellow clayey sands and sandy clays of northeastern and east-central Alachua County grade into each other.

Figure 39 shows 23 feet of sediment exposed in a canal just north of the Gainesville Airport. There, two or three feet of a phosphate concentration of the Hawthorne formation is overlaid unconformably by post-Hawthorne sediments. The post-Hawthorne sediments are mostly white to tan, loose to slightly indurated sand. In the lower part of

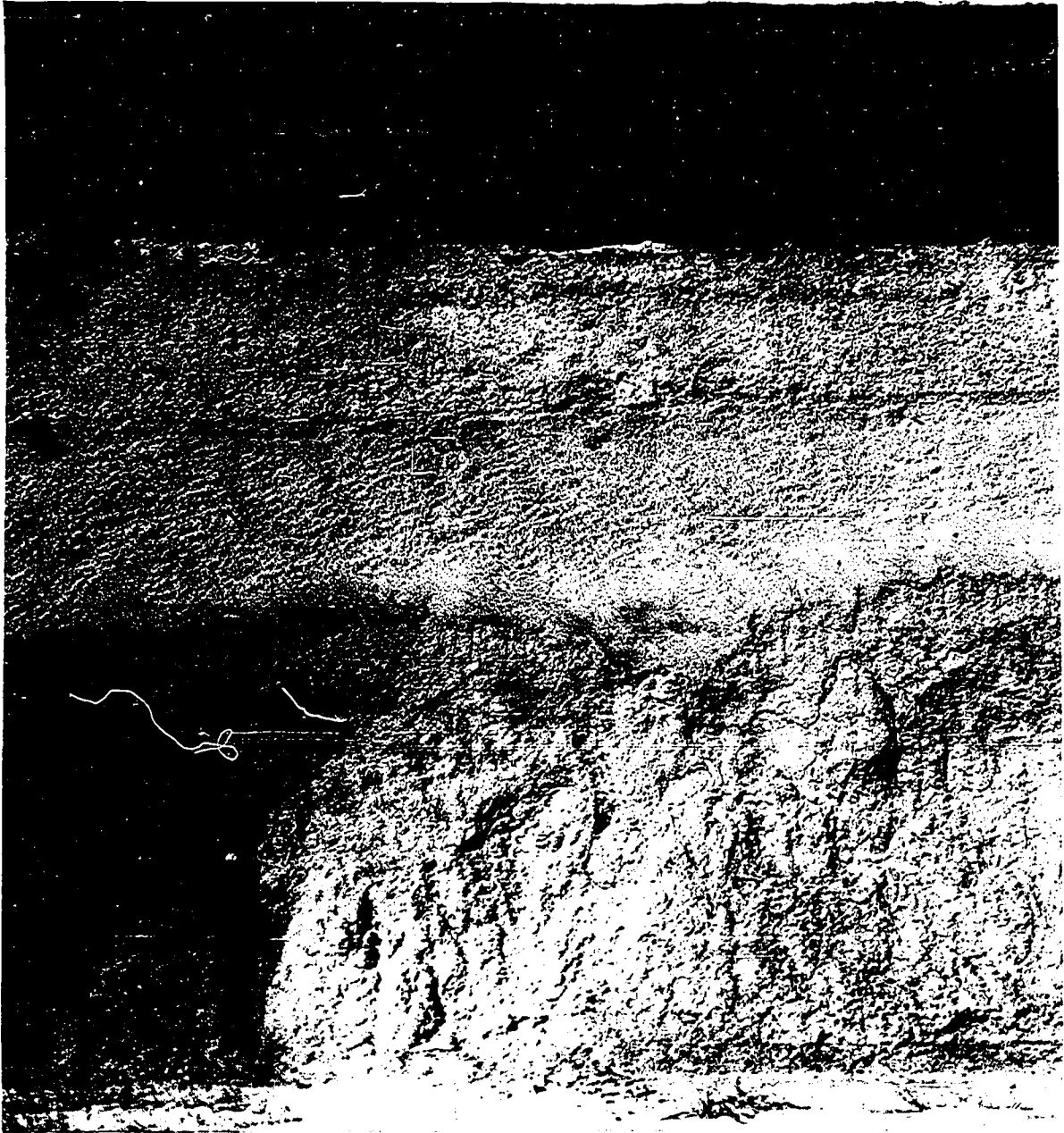


Figure 38. Exposure of post-Hawthorne sediments on west side of Highway 301, 1.85 miles south of Orange Heights, showing loose, whitish sand overlying clayey sand. The irregular contact, shown in the central part of the picture, has the appearance of an unconformity. It has not been determined whether two formations are represented or whether the loose sands have resulted from the downward migration of clay. The latter seems more probable. Such clayey sands often are various shades of red and yellow due to oxidation of iron compounds in the clay.



Figure 39. Post-Hawthorne sediments overlying unconformably a heavy concentration of pebbles and grains of phosphate of the upper Hawthorne. The top of the phosphate concentration in the lower part of the picture is indicated by the hammer. Blocks and slabs of clay occur in the lower parts of the post-Hawthorne sediments. Exposure along a canal dug in 1942 north of the Gainesville airport to direct one of the tributaries of Hatchet Creek around the landing strip.

these sands, blocks or slabs of gray clay occur, and discoid-shaped quartz pebbles are numerous. It may be that these slabs of clay represent a more continuous clay stratum which was broken up by waves and in places further deformed by the weight of the overlying sediments.

Along the same canal, not more than a few hundred feet from the section shown in the picture and at the same surface elevation, sediments beginning within a few feet of the surface have a mottled red and yellow appearance and look identical to the red and yellow sediments found in northeastern Alachua County. At the new Sperry plant just a few hundred yards north of this canal, mottled red and yellow clayey sand was encountered in drilling at a depth of seven feet. In drilling water wells in the "thick" sand area north of Gainesville, some holes penetrate as much as 25 or 30 feet of loose sand, whereas other holes nearby encounter the red and yellow sediments practically at the surface.

Those sediments north of Gainesville and throughout northeastern and east-central Alachua County range in thickness from a few feet to 45 feet and in general thicken toward the east and northeast and thin over Hawthorne sediments to the west. There is a marked unconformity between these sediments and the underlying material which usually is the Hawthorne formation but in a few places is the shell marl of

Choctawhatchee age.

There is no complete agreement as to the origin or age of these post-Hawthorne materials north of Gainesville and throughout northeastern and east-central Alachua County. Some workers have indicated the belief that some of the sediments are residual from the Hawthorne formation. Others have considered the red and yellow sandy clays and clayey sands as part of the Hawthorne formation of Middle Miocene age. These sediments, as previously mentioned under the discussion of Hawthorne materials (page 95), are stratigraphically younger than a shell marl which has been dated as lower Choctawhatchee and therefore post-Hawthorne. In areas where there is more or less of a concentration of quartz pebbles, the sediments have been called Citronelle of Pliocene age and considered to be a littoral deposit. Many workers consider the thick sands north of Gainesville as Pleistocene in age and of marine origin. However, F. Stearns MacNeil (1950, p. 99) states that there is no proof that the Pleistocene seas ever rose to elevations over 150 feet above present sea level and expressed his belief that terrace sands above that elevation are of sub-aerial origin.

These sediments north of Gainesville and throughout the northeastern part of Alachua County are considered in this report to be of marine origin. Overall, the materials appear too uniform in character to represent alluvial or

residual materials. Rare small, poorly preserved marine invertebrate fossils have been found in place in the thick sands along the canal north of the Gainesville airport. Dr. R. A. Edwards has accompanied the writer and verified the fact that the fossils occur in place. No reference has been found in the literature concerning any fossils from these thick sands. In a personal letter dated March 24, 1954 regarding these fossils, Dr. Harbans Puri stated that the fossils represent "a typical inner neritic molluscan fauna." Since it is believed that much of the "thick" sand north of Gainesville and the red and yellow sandy clays and clayey sands in northeastern and east-central Alachua County grade into each other, it is considered that these post-Hawthorne sediments all are marine in origin.

The age of these undifferentiated sediments constitutes a problem which can not be solved by a study of the sediments in Alachua County alone. Thus, no serious attempt was made to solve it. The materials are post-Choctawhatchee in age and are believed to be Pliocene or Pleistocene. A Pleistocene age is considered likely.

OUTLINE SUMMARY OF SOME IMPORTANT EVENTS IN  
THE POST-OCALA HISTORY OF ALACHUA COUNTY

1. All post-Ocala sediments in Alachua County lie unconformably over the Ocala limestone.
2. At least a part of western Alachua County was invaded by marine waters during Oligocene time resulting in the deposition of the Suwannee limestone. This is evidenced by hundreds of residual boulders of that limestone containing the characteristic fossil, Cassidulus gouldii (Bouvé). It is possible that Suwannee limestone is in place in a few small areas north of High Springs.
3. The presence of lower Miocene land vertebrate fossils from western Alachua County suggests that land area existed in or close to the County during lower Miocene.
4. With the possible exception of a few minor areas north of High Springs, Middle Miocene marine Hawthorne sediments were laid down directly on an irregular, solution pitted Ocala surface, the nature of which suggests that the Ocala was subjected to sub-aerial weathering and erosion before deposition of the Hawthorne beds. Lenses of undisturbed Ostrea normalis Dall have been observed in Hawthorne sediments directly over sink holes developed in the Ocala. If the sinks had developed after the Hawthorne was laid down, the beds of oysters should show the effects of slumpage. In western Alachua County a

number of such occurrences have been noted. This would indicate that between Suwannee time and Middle Miocene Hawthorne time, the Suwannee limestone was largely eroded away lending more evidence that part of the County was dry land during early Miocene.

5. Marine sediments of Choctawhatchee age (late Middle Miocene and/or Upper Miocene) were deposited in parts of northeastern Alachua County. There, during the drilling of water wells a shell marl has been encountered which has been correlated with a marl exposed in Brooks Sink in Bradford County. The shell marl in Brooks Sink has been dated on the basis of microfauna as early Choctawhatchee age.
6. The County was dry land probably during much of Pliocene time. Sediments carrying Pliocene terrestrial vertebrates have been found in a number of localities. For example, sands and clays occurring directly over Ocala limestone near Haile (Section 24, T. 9 S., R. 17 E.) were found by Auffenburg to contain Hipparion minor (small 3-toed horse), Pseudemys calacta (fresh water turtle) and a giant terrestrial tortoise.
7. During the Pleistocene the County was covered by marine waters at times and was dry land at other times. The "thick" sands north of Gainesville and the red and yellow sandy clays and clayey sands throughout northeastern and east-central Alachua County furnish an example which is believed to

represent marine Pleistocene sediments. Marine invertebrate fossils have been found in these sediments. Numerous deposits containing Pleistocene land vertebrate fossils have been located in the County.

## OCALA UPLIFT

According to Vernon (1951) the crest of the Ocala uplift runs in a northwest-southeast direction and is located in eastern Citrus and Levy Counties. Western Alachua County is located on the eastern flank of the major uplift. Vernon states "The Ocala uplift took place mainly in lower Miocene. However, some of the structural movements may have continued irregularly through later epochs."

It is believed that the major upwarplings which have affected Alachua County during post-Eocene time are associated with the Ocala uplift. The preceeding outline summary of some important events in the post-Ocala history of Alachua County indicates such upwarplings during lower Miocene with continuing periodic uplift during later Tertiary times.

## PHOSPHATE

### Introduction

In Alachua County pebbles\* and grains of phosphate occur disseminated through all the sediments of the Hawthorne formation (see logs in Appendix "A" and "B") and as concentrations in lenses and irregular bodies. In some individual beds the phosphate pebbles and grains, even though present throughout, are more abundant at the top or near the bottom.

In general, in the plateau area north of Gainesville (east of State Roads 23 and 329) and throughout the northeastern and east-central parts of Alachua County, slight to heavy concentrations of pebbles and grains of phosphate occur at the top of the Hawthorne formation. These phosphatic sediments are covered by loose sands, clayey sands and sandy clays of probable Pleistocene age which range in thickness up to 45 feet (see figures 9, 10 and 39). In this area the heaviest deposits of phosphate were found just north and northeast of Gainesville, around Waldo (beneath a shell marl), and south of the Hawthorne Highway between the towns of Grove Park and Hawthorne. Figure 40 shows the location of the phosphate area north and northeast of Gainesville as estimated from a study of well cuttings.

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\*Phosphate particles which pass the 20 mesh screen are termed grain size, flotation size or concentrates. Larger phosphate sediments are considered pebble size. This is in conformity with local terminology in the phosphate industry.

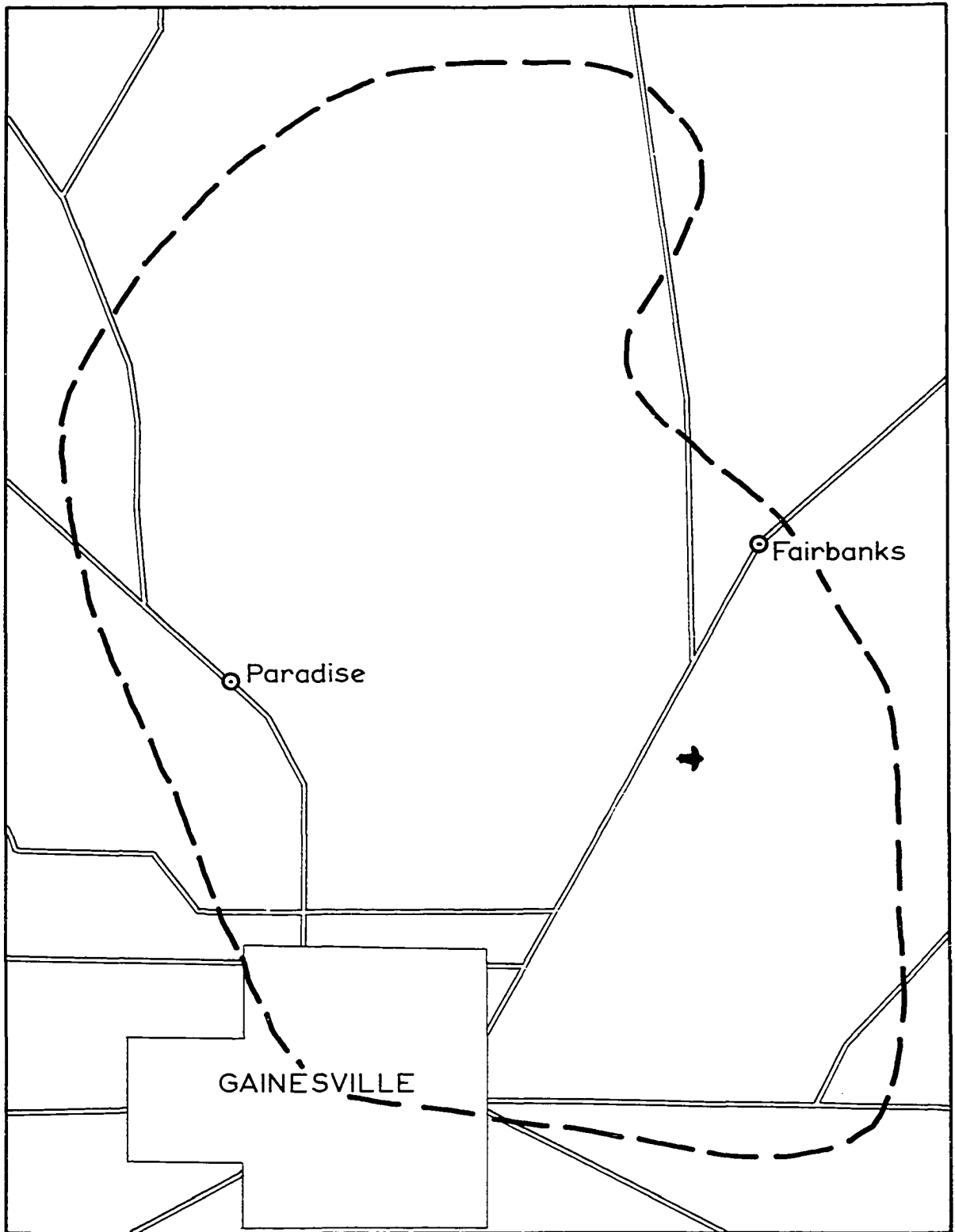


Figure 40. Location of area of heaviest phosphate concentration north and northeast of Gainesville.

This top zone of phosphatic sediments varies in thickness from a few feet to 30 or 40 feet and consists largely of pebbles and grains of phosphate embedded in materials ranging from almost pure sand, clay or carbonate to varying combinations of sand, clay and carbonate. The quantity of phosphate grains and pebbles ranges from slight amounts up to as much as 500 to 1000 tons per acre foot.

Numerous thin sections of phosphate pebbles and grains from Alachua County and from the commercial Bone Valley district of Polk and Hillsborough Counties in southern Florida have been examined. The major differences between the phosphatic sediments of the Hawthorne formation in Alachua County and those of the Bone Valley appear to be in the proportion of the types of phosphate grains and pebbles and in the degree of secondary leaching and enrichment. For example, there is a much higher percentage of phosphatized fragments of rather pure limestone in certain high-grade "properties" of the Bone Valley area than is found in the Hawthorne formation of Alachua County. Also, the materials in the Bone Valley district have been more highly leached. The phosphate of the commercial deposits of the Bone Valley formation has been identified as carbonate-fluorapatite\* by Z. S. Altschuler and E. A. Cisney (Cathcart, 1953). Because thin sections indicate

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\* Carbonate-fluorapatite is considered as a distinct mineral with both  $\text{CO}_2$  and F as integral parts of the mineral structure.

that the types of phosphate sediments found in the two areas are the same, it is assumed that the phosphate of Alachua County is carbonate-fluorapatite. Such phosphatic material often is termed "collophane" (Vernon, 1951, p. 201).

#### Phosphate Grains and Pebbles

The phosphate grains and pebbles in the Hawthorne formation are believed to have formed generally as discrete individual concretionary aggregates in a marine environment. The particles are white, black, brown, gray, tan, amber or orange in color. Thin sections of some of the grains and nodules show concentric zones. Others are uniform throughout. The zones in fresh particles are believed to be due to accretion during deposition (plate II, figure C), whereas some of those found in weathered surface exposures may have been produced secondarily during the weathering. Some particles contain non-concentric banding. The photographs in plate II show a few internal structures of individual phosphate grains. For convenience the following names are used to designate the different types of phosphate grains and pebbles.

#### Concretionary Oolites and Masses

Accretion was an important factor in the development of these phosphate grains and pebbles. The phosphatic materials of this type have incorporated clastic quartz,

orthoclase feldspar, microcline, smaller concretionary particles of phosphate, and organic matter. Other inclusions frequently found are diatoms, sponge spicules and unidentifiable fossil fragments (plate III, figures E and F, page 134). Biotite has been noted in a few phosphate particles. The percentages of impurities vary. Some grains and pebbles show only a few inclusions (plate II, figure C), whereas others contain abundant clastic material (plate II, figures A and B). Fossil fragments, noted in some of the concretionary oolites and nodules, were not observed to be present in the sediments surrounding such phosphate grains and pebbles. Figures 41 and 42 show photomicrographs of parts of phosphate pebbles.

#### Aggregated Masses

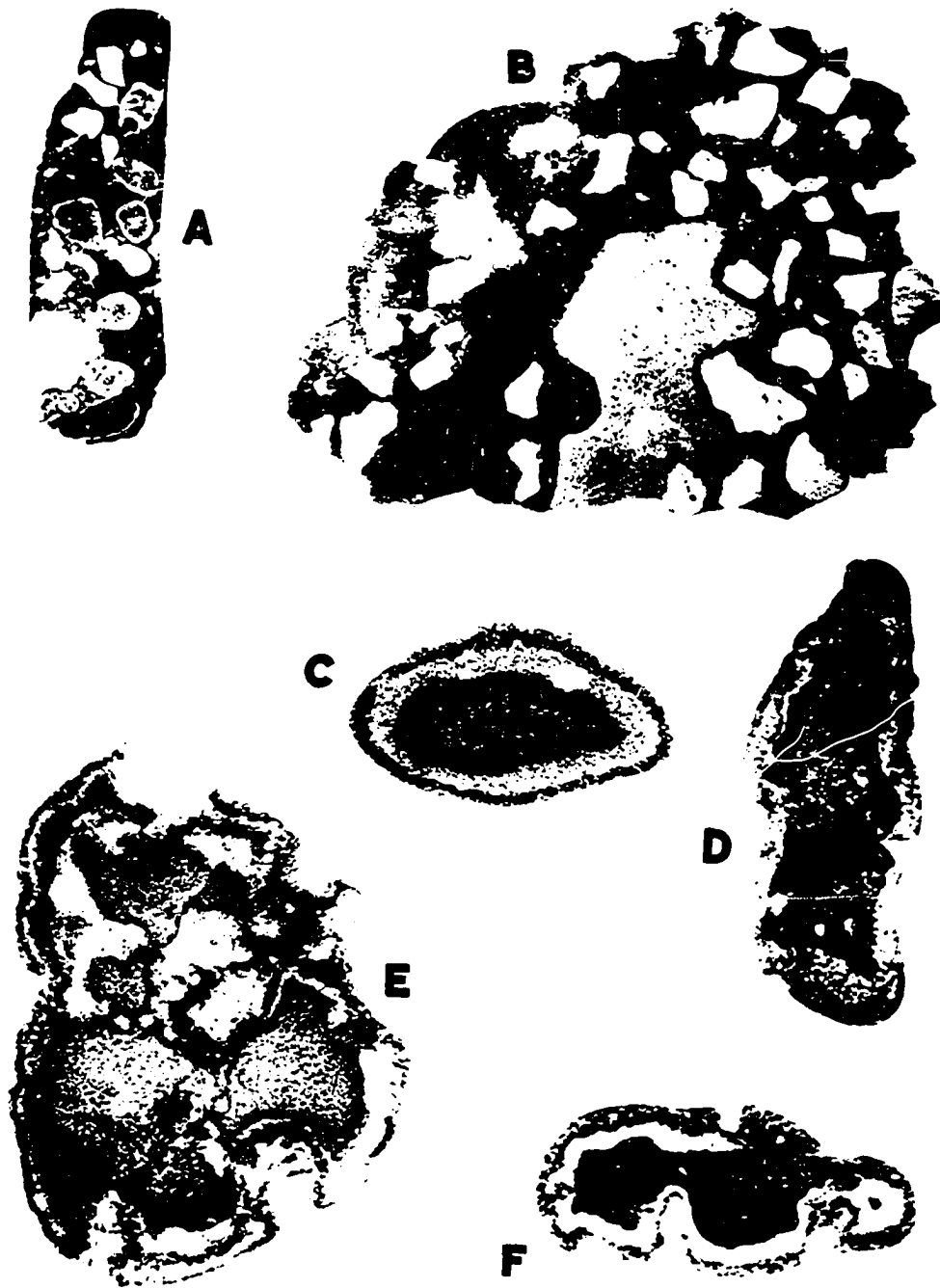
Many masses ranging in size from very small particles to pebbles show no plan of growth. These may represent aggregates of colloidal phosphate precipitated directly from sea water. Such materials may have been aggregated on the sea floor and at times apparently were rolled and washed around incorporating within the grains and pebbles various types and amounts of clastic sediments. White grains associated with more massive clays are discussed separately (page 139).

#### Steinkerns

A number of phosphate grains and pebbles were formed

PLATE II

	Page
A - Phosphate particle composed of numerous grains of quartz and phosphate (opposite the letter A and surrounded by white rings) cemented with phosphate .....	126
B - Phosphate grain consisting of abundant quartz and occasional phosphate particles embedded in phosphate. Note the whitish or grayish phosphate extending from the bottom of the particle and occupying its central part. The outline of this phosphatic material seems to have been controlled to some extent by the quartz and small phosphate grains .....	126
C,D,E and F - Phosphate grains showing internal structures. Specimen shown in figure C is typical of a concretionary oolite .....	126



Photography by H. K. Brooks and E. C. Pirkle

Photomicrographs of individual phosphate grains

Plane polarized light

X 32

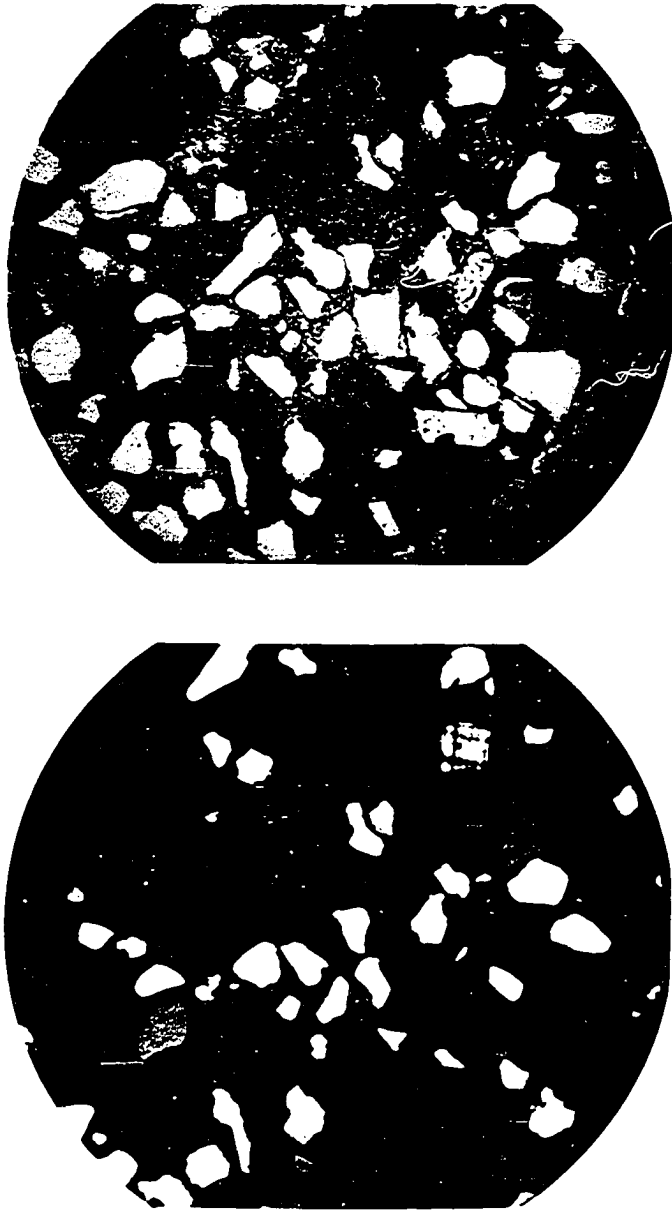


Figure 41. X 26. Photomicrographs of part of a brown phosphate pebble collected from the phosphate concentration at the top of the Hawthorne north of Gainesville. Note the high content of included quartz sand and feldspar, and also several small phosphate grains (show as a gray color in top photo) included in the large pebble. The top picture was made with plane polarized light; bottom under crossed nicols.



Figure 42. X 42. Photomicrograph of a corner of a phosphate pebble composed of quartz sand and phosphate grains cemented by phosphate. The pebble is from the heavy concentration of phosphatic sediments at the top of the Hawthorne on the property of Mr. Roy Brown (eastern part of Section 31, T. 10 S., R. 22 E.). Plane polarized light.

by deposition of phosphate in the interiors of mollusk shells, chambers of bryozoans (plate III, figure A and plate IV, figure A) and cavities of the skeletons of other invertebrate animals. Grains and pebbles formed by the filling of mollusk shells contain the same general types of inclusions listed for the concretionary oolites and nodules.

It appears that some of these steinkerns have resulted from replacement by phosphate of infiltrated clastic sediment comparable to the grains of glauconite found within shells in other deposits. Such grains of glauconite have been shown to be the result of diagenetic alteration.

#### Replacement of Skeletal Remains

Fragments of bryozoans, mollusk shells and the teeth and bones of animals have been replaced to varying degrees by phosphate. At times replacement of shell material started from the outside of shell fragments and proceeded into the shell (plate III, figures C and D and plate IV, figures C and D). In other cases phosphate was deposited within the interiors of shells as explained above for steinkerns, and replacement of the carbonate shell started from the inside.

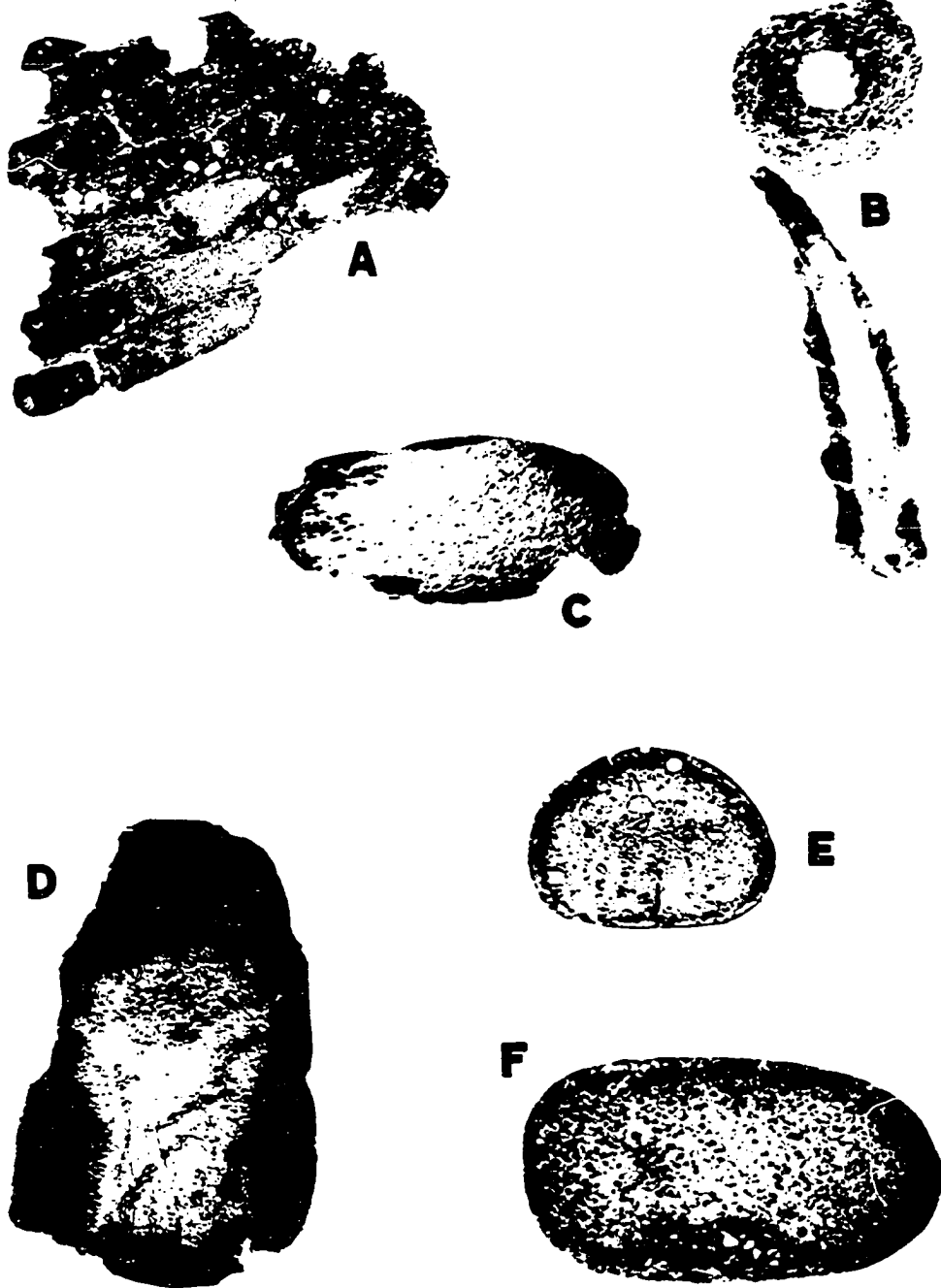
#### Replacement of Carbonate in Fragments of Shell Marls and Limestones

Some phosphatic particles were formed by replacement of shell material and the fine grained calcareous ground-mass in fragments of shell marls and limestones.

PLATE III

	Page
A - Phosphate grain resulting from the filling by phosphate of the zooecial chambers of a portion of a bryozoan colony .....	132
B - Spines. Circular fragment is cross section of an echinoid spine. Long particle represents a spine of an unidentified organism. Such spines often are converted to phosphatic sediments by replacement or open-space filling .....	132
C and D - Shell fragments of mollusks partly replaced by phosphate. Note that the replacement is from the outside of the particle inward .....	132
E and F - Phosphate grains containing minute fragments of clastic sediments. These grains contain parts of sponge spicules (long white particle in upper left margin of figure F) and diatoms and seem to have developed in areas characterized by fine sediments .....	127

PLATE III



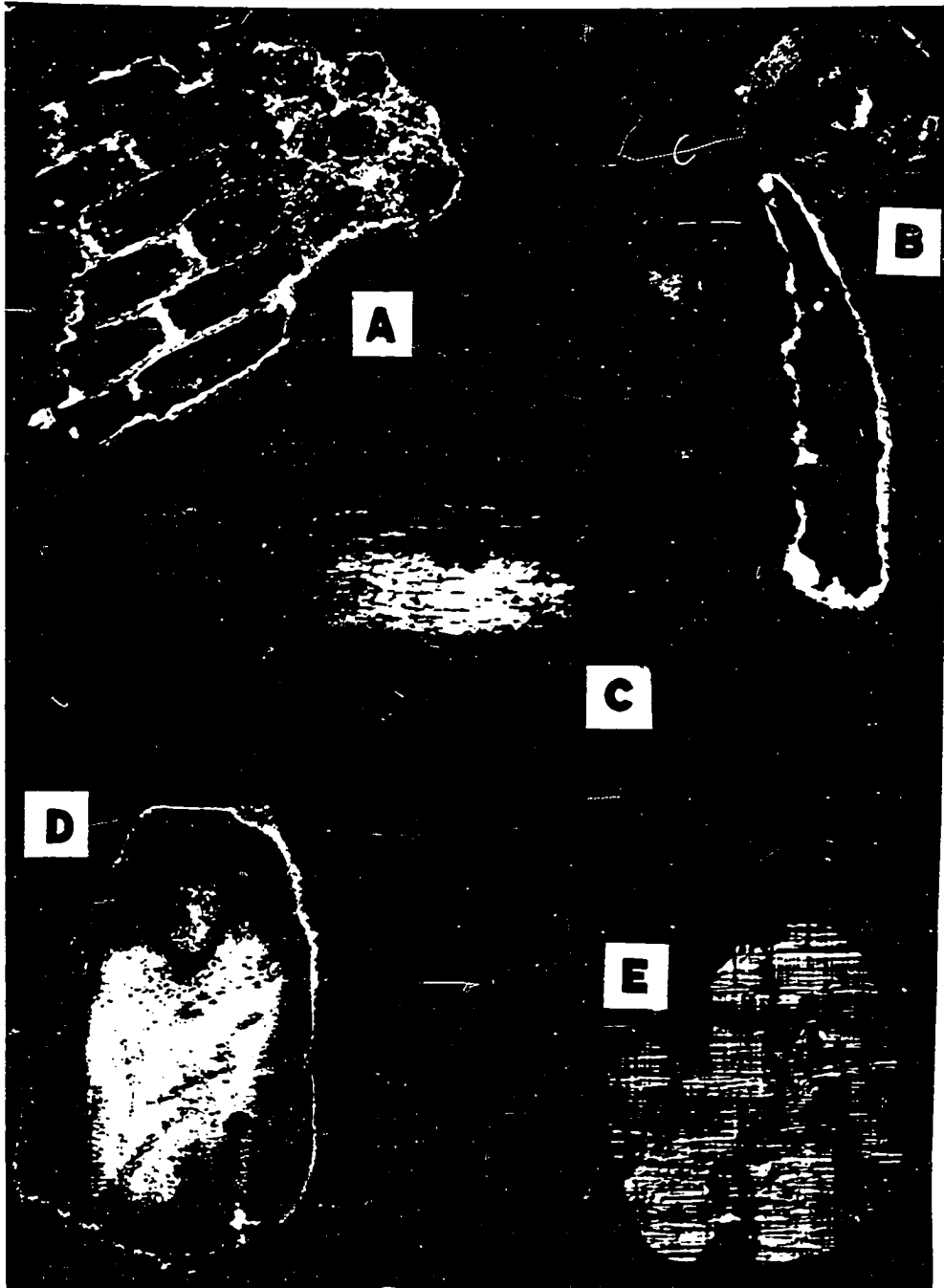
Photography by H. K. Brooks and E. C. Pirkle

Photomicrographs of individual phosphate grains  
Plane polarized light  
X 32

PLATE IV

	Page
A, B, C, and D - Photomicrographs taken under crossed nicols of grains labeled respectively on Plate III	
E - Microcline partly replaced by phosphate .....	137

PLATE IV



Photography by H. K. Brooks and E. C. Pirkle

Photomicrographs of individual phosphate particles  
Crossed nicols  
X 32

These particles retain the fragmental structure of the original limestone aggregate. The shell marls and impure limestones consisted originally of fine carbonate, fossils, shell fragments, quartz sand, clay and small concretionary oolites and masses of phosphate.

Phosphate particles resulting from replacement of carbonate in fragments of purer limestones contain less impurities such as quartz sand than the pebbles mentioned above. Mingled with phosphatic sediments are often found limestone fragments in which only a very small amount, if any, of the carbonate has been replaced by phosphate.

#### Phosphatic Clay Balls

Phosphatic clay balls have been noted in many areas of Hawthorne sediments. These normally contain only minor amounts of included material such as quartz sand. Such clay balls may represent, in cases, another form of "aggregated masses" formed on a sand free bottom.

#### Replacement of Feldspar and Quartz

Occasional grains show feldspar particles replaced by varying amounts of phosphate (plate IV, figure E). In rare cases there are suggestions that quartz grains may be partly replaced by phosphate (figure 43). Replacement such as this is usually attributed to syngenetic changes during diagenesis.

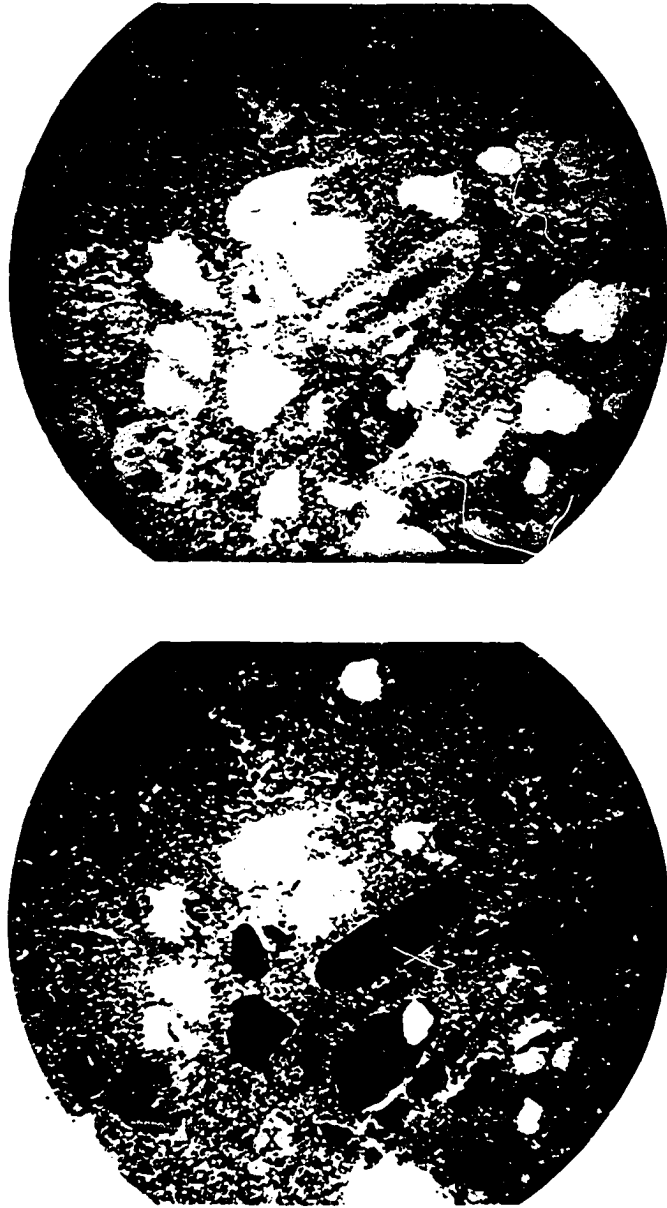


Figure 43. X 26. Photomicrographs of thin section showing phosphate grains, quartz and feldspar of the limestone of bed 6, Brooks Sink, Bradford County. The three grains marked "X" in the photograph are quartz grains which appear to be partly replaced by phosphate. Top photo in plane polarized light; bottom with crossed nicols.

Phosphate Particles in Main Body of Hawthorne Formation  
As Compared to Those in Top Concentration

In Alachua County the most noticeable difference between the pebbles of phosphate in the main body of the Hawthorne and those in the concentrated zone at the top is that the quantity of sand size clastic sediment within the individual phosphate pebbles is much greater in the top zone, resulting in a low-grade phosphate pebble. Many phosphatized fragments of impure limestones and shell marls are found in this upper zone of concentration, as for example, in the accumulation covering the main body of the Hawthorne at the Devil's Mill Hopper and in the area south of the Hawthorne Highway between the towns of Grove Park and Hawthorne. Such fragments are not characteristic of the main body of the Hawthorne formation in Alachua County. There, white, gray and tan grains and pebbles with only minor inclusions of clastic minerals are more characteristic.

In the main body of the Hawthorne white grains of phosphate are in places mixed with quartz sand and occur with the quartz sand as stringers in the massive clays or as individual beds or lenses between clay layers. Some of these beds or lenses are as much as 5 feet thick and may contain up to 30 or 40 percent white phosphate grains with the remainder of the lens or bed consisting of quartz sand with only minor amounts of clay.

These white phosphate grains are soft, even plastic when wet and have been found in all cases analyzed to be exceedingly high in phosphate content. For example, white, soft grains separated from an 18 pound sample collected from a clay exposure about  $5\frac{1}{2}$  miles west of Gainesville on the north side of the Newberry Highway had an average BPL content of 79.26 percent. The insoluble content was 4.00 percent of which 2.54 percent consisted of iron and aluminum oxides. White and gray pebbles from this same sample had an average BPL content of 72.04 percent with a content of insoluble material amounting to 10.51 percent of which 3.39 percent was iron and aluminum oxides. These analyses, furnished by the American Metal Company, Limited, were run by Thornton and Company of Tampa, Florida and signed by C. C. Thornton.

Thin sections (see figure 44) show no structures in the grains of white phosphate and very few inclusions of clastic minerals. During weathering those loose white grains which are associated with quartz sand at times appear to harden, in some cases apparently changing to a more brownish color.

This same type of soft phosphate grains often occurs disseminated through massive clay. It may be that during weathering, the white phosphate reacts chemically with the enclosing clay to form a phosphatic clay.

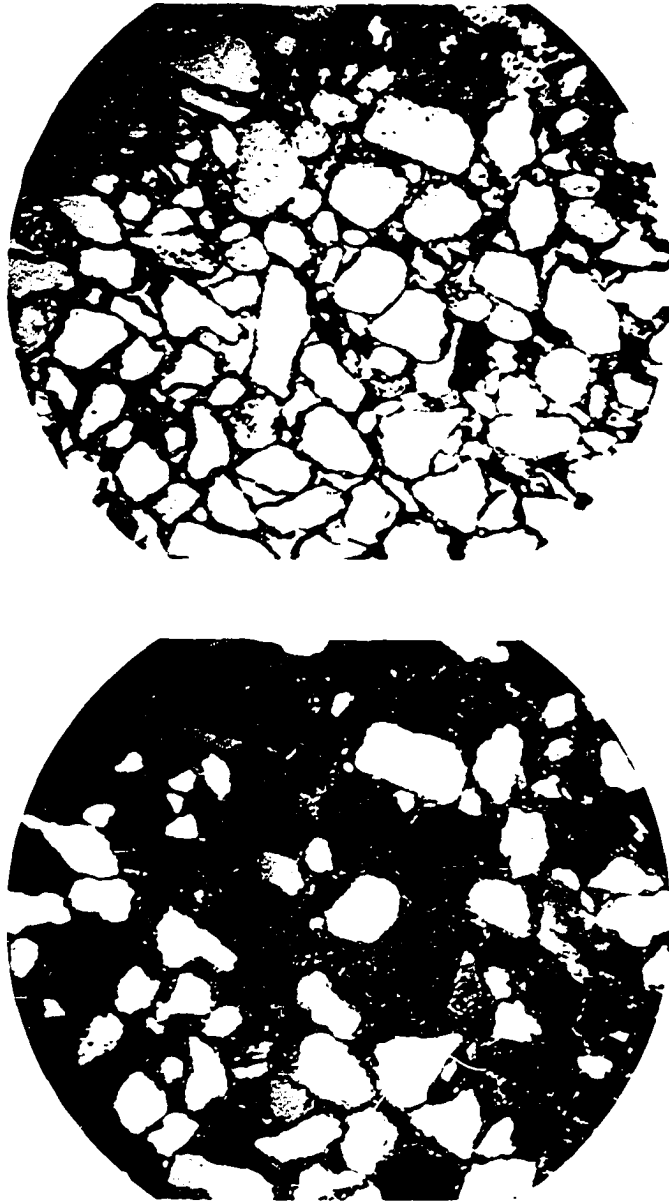


Figure 44. X 26. Thin section of a phosphatic sandstone collected at a clay exposure about  $5\frac{1}{2}$  miles west of Gainesville on the north side of the Newberry Highway. The rock consists largely of quartz and phosphate grains with minor amounts of clay, feldspar and biotite. The sediments occur as a lens about 5 feet thick. This lens is enclosed by massive clay. The phosphate grains are white and soft. Some of them have been compressed so as to fit tightly against other grains. Note there are only a very few inclusions of clastic materials in the phosphate grains. Phosphate of this type in all cases checked has been of high grade. Top photo with plane polarized light. Bottom picture with crossed nicols.

MODE OF ACCUMULATION OF THE PHOSPHATE CONCENTRATION  
AT THE TOP OF THE HAWTHORNE FORMATION IN THE  
PLATEAU AREA OF ALACHUA COUNTY

Introduction

Before discussing the possible mode of accumulation of the pebble phosphate in Alachua County, it is believed desirable to review the prevailing accepted hypotheses concerning the origin of the "land-pebble" phosphate deposits of the commercial Bone Valley formation of south Florida. Mention of these deposits is included because phosphate has been mined from that field since 1888, and these are the only land-pebble phosphate occurrences in Florida to have received detailed study. In the discussion which follows, these hypotheses for the mode of origin for the phosphate of the Bone Valley formation will be evaluated and tested with reference to the evidence indicating conditions of origin of the Alachua County deposits.

The Bone Valley formation occupies a large area in Polk, Hillsborough, Hardee and Manatee Counties and is considered Pliocene by most workers. It is overlain by Pleistocene sands ranging in thickness from a few feet up to 30 feet or more and rests on the Miocene Hawthorne formation. The phosphate deposits are composed of a mixture of quartz sand, clay, and phosphate pellets and nodules.

Cathcart (1953) in reviewing and summarizing ideas concerning the origin of the Bone Valley deposits indicates

two possible modes of origin:

1. A residuum of Miocene age (the residual hypothesis).
2. A reworked residuum of Pliocene or Quaternary age (the depositional hypothesis).

Cathcart (p. 86 and 87) states, "The residual hypothesis of origin of the phosphate deposits in its extreme form attempts to account for the entire sequence of unconsolidated material overlying the limestone of the Hawthorn in the land-pebble district as the relatively insoluble residue of the Hawthorn that has been concentrated in place by weathering."... "The depositional hypothesis was set forth in detail by Sellards (1915) and has been generally accepted. It postulates erosion of the limestone of the Hawthorn formation at the end of the Miocene time, deposition in Pliocene time of the lower unit of the Bone Valley formation in a shallow marine nearshore environment, the upper unit of the Bone Valley in a marine offshore environment, subsequent erosion, and finally, deposition in Pleistocene time of surficial terrace sands." After giving facts supporting both hypotheses, Cathcart concludes, "Evidence is lacking on which to establish either hypothesis as a fact at any specific place because many field relations are subject to two or more interpretations."

Most of the geologists who have studied the Bone Valley either believe those "land-pebble" phosphate deposits represent a residuum accumulated in place from the weathering of Hawthorne beds or assume the concentration represents such a residuum reworked by a Pliocene sea.

### Pebble Phosphate of Alachua County

The primary phosphate concentrations at the top of the Hawthorne formation in the plateau area of Alachua County are undoubtedly marine deposits which are, in part, lag concentrations that have been modified in places by subsequent weathering and erosion. These marine deposits are believed to have been formed in Hawthorne time, and the modifications by weathering, rainwash and streams have taken place intermittently since.

The original marine deposits probably developed in a shallow embayment, such as a gulf or estuary, which was not subjected to the full sweep of ocean waves but rather was characterized by variable tidal and storm-generated currents. There were no large areas free from the stirring effects of waves, so that complete winnowing out of fine sediments from coarser sediments occurred. Clay, sand, carbonate, and phosphate grains and pebbles mixed in all conceivable proportions would not be expected to accumulate above wave base along open coast lines subjected to the full sweep of ocean waves.

In the following discussion evidence which indicates that the phosphate concentrations at the top of the Hawthorne are of marine origin will be discussed. Following that discussion, examples will be given which suggest that the

original marine concentrations have been subsequently modified in places by such geologic processes and agents as weathering, rainwash and streams.

#### Data Which Suggests A Marine Origin for Phosphatic Sediments Concentrated at Top of Hawthorne

The following data favor or point to a marine origin for the phosphate concentrations in the upper part of the Hawthorne formation. No one criterion can be considered as definite proof of a marine origin, however, collectively these facts are rather conclusive.

1. There are many zones within the Hawthorne formation in which phosphate pebbles and grains are more abundant than in beds above and below. Some of these zones are undoubtedly marine, because they are lenses enclosed by marine fossiliferous strata.

Throughout the plateau area, lenses or beds ranging in thickness from a foot to more than 5 feet and consisting almost entirely of quartz sand and black or brown phosphate grains have been encountered in the Hawthorne formation<sup>in</sup>/water wells. In many instances these beds are the water-bearing strata. Locally, the sediments containing more than 50 percent phosphate grains, are exceedingly well sorted. Most certainly such well sorted concentrations of phosphate grains are of marine origin and probably represent

the prolonged winnowing action of waves.

Beds 4 and 6 at the Devil's Mill Hopper (see page 82) contain considerably more phosphate pebbles and grains than the enclosing strata. These two beds contain numerous angular and rounded blocks of the underlying fuller's earth clay (see figure 28) and are marine as indicated by numerous complete shells of marine invertebrate fossils included within the sediments. The presence of the blocks of fuller's earth clay indicates the probable "churning up" of beds by storm waves.

While exposures made during the construction of NW 23rd Road in Gainesville were still fresh, one bed was noted to contain a great many more phosphate pebbles and grains than the adjacent beds. The overlying bed is a sandy clay, while that beneath it is an impure limestone. Numerous fragments of the underlying limestone were found scattered throughout the phosphate bed.

The examples listed above cite sediments containing concentrations of phosphate pebbles and grains on a small scale. These concentrations are of marine origin and at least in the cases of beds 4 and 6 at the Devil's Mill Hopper and the concentration exposed on NW 23rd Road suggest the "churning up" of beds. Thus, it is conceivable that the same processes working over a much longer period of time and under the proper conditions of equilibrium could result in the heavy concentration of pebbles and grains

of phosphate at the top of the Hawthorne formation.

2. Impressions of complete shells of marine invertebrates have been found in the clay portion of the matrix in the top zone of phosphate concentration. It would be difficult to explain the occurrences of such fossils in clay if these materials represented a weathered product of Hawthorne beds developed in place.
3. The color of the clay in many parts of the phosphate concentration is some shade of gray. The color of unweathered clay in the Hawthorne proper often is also some shade of gray but weathers to a buff color or some tint of red or yellow. If the phosphate concentration represents a residual product of the Hawthorne formation accumulated in situ, the clays should be buff, red or yellow in color but not gray.
4. In some areas as much as 400 to 500 tons per acre-foot of phosphate pebbles and grains have been found embedded in a matrix consisting largely of carbonate with some quartz sand. It is difficult to conceive of such a soluble matrix if the product represents a residue from the surficial weathering of the Hawthorne beds.
5. Although it is not necessary in establishing a marine origin for the phosphate concentrations to prove that all phosphatized limestone fragments represent limestones broken up under a marine environment, the establishment

of the fact that limestones in the Hawthorne formation have been broken up by wave action eliminates the necessity of sub-aerial weathering to explain the presence of clastic limestone fragments.

In bed #14 at Brooks Sink is a thin zone of limestone pebbles (see page 63 ) containing fossil impressions, quartz sand, and small black phosphate pebbles and grains. All are well rounded and are largely ellipsoidal to spherical. This zone of limestone pebbles occurs in a marine bed composed mostly of quartz sand and carbonate with abundant impressions of marine fossils, and it is probable that the pebbles represent thin limestone beds which were broken up. The fragments were then rounded by wave action and redeposited. If their carbonate content was subsequently replaced by phosphate, the resulting pebbles would appear identical to many phosphate pebbles found in the Hawthorne formation in Alachua County, particularly in the concentration which occurs at its top.

Another example which suggests that limestone fragments have been rolled and subjected to wave action is furnished by the broken-up limestone of bed 4 at Brooks Sink (see page 59 ). Many pieces of that limestone have been bored by mollusks characteristic of shallow water marine environments. In individual fragments some of the bore holes start from the top of the limestone and others start from the bottom (see figure 17). The presence of mollusk

borings starting into the limestone fragments from all sides suggests that the fragments have been rolled about on the sea floor by waves. The occurrence of bases of barnacle shells on some pieces of the limestone indicates an environment of erosion, sedimentary by-passing, or slow deposition.

These examples are given to show that thin Hawthorne limestones were broken up and rounded under a marine condition. Thus, fragmented and rounded limestone particles are not evidence of sub-aerial conditions. This "proof" of terrestrial origin is therefore invalid. Quantities of such pebbles have accumulated under a marine environment at the top of the Hawthorne. Thus, it is not necessary to call on sub-aerial weathering of limestones and marls to account for phosphate pebbles and grains which represent phosphatized limestone and marl fragments.

6. Thin, typical Hawthorne limestones were encountered immediately over the phosphate horizon in a number of places in the county. Examples of such occurrences are the Wall well and the Conant well (see Appendix "B", pages 185 and 188). Such occurrences of thin Hawthorne limestones over the phosphate concentration could not be accounted for if the phosphate concentration is the result of sub-aerial weathering after the Hawthorne formation was deposited and raised above the sea. It must be assumed that these Hawthorne

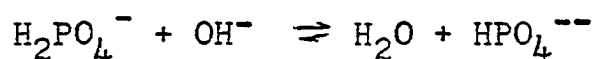
limestones at the top of the formation were laid down in the Hawthorne sea after the formation of the concentration.

#### Modifications by Weathering, Rainwash and Streams

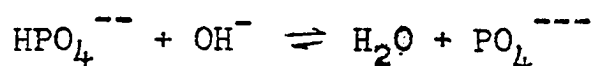
There can be little doubt but that in some places the original marine phosphate concentrations have been modified by weathering, rainwash and streams. In some areas 5 to 45 feet of sediment, believed to be Pleistocene in age, lie unconformably over the zone of phosphate concentration. No marine deposits of Pliocene age are known to occur in such areas. One must conclude that any Pliocene marine sediments laid down have since been eroded away or the region was land during that time. Because Pliocene fossils of land vertebrates have been found in sink holes like deposits developed on the Ocala limestone in western Alachua County, the Hawthorne formation in the plateau area of Alachua County probably was above sea level at least during part of this interim. Certainly, this region was land at intervals during the Pleistocene and is above sea level today.

While the plateau area was terrestrial during parts of Pliocene time and intermittently since, streams would develop. Stream action along with weathering and rainwash would modify the original marine phosphate accumulations. Oxidation is indicated by the buff, yellowish or reddish color of the clay in some parts of the phosphate concentration.

As a result of numerous chemical analyses, Dr. Howard Odum (1953) came to the conclusion that streams which cut the Hawthorne formation are acid and contain more phosphate in solution than spring waters issuing from limestones in the same area. The spring waters are basic. This suggests that phosphate taken into solution by acid surface waters is deposited from ground water under favorable environmental conditions such as might exist where the water becomes more alkaline due to contact with limestones or limestone particles. As the pH is increased from pH 6 to 9, for example, the concentration of the  $\text{HPO}_4^{--}$  ion is increased by the reaction



Above a pH of about 9.7 an appreciable concentration of the  $\text{PO}_4^{---}$  ion is formed by the reaction



Each of these ions form salts with calcium which are less soluble than the primary calcium phosphate,  $\text{Ca}(\text{H}_2\text{PO}_4)_2$ , and hence may be deposited under alkaline conditions. The overall effects in reference to the upper phosphate concentration zone would be leaching with enrichment of the original marine phosphatic deposits at depths below the action of the acid surface water. Enrichment (see pages 174 and 175) is more pronounced in the Bone Valley district (Cathcart, 1950) than in Alachua County.

Even though the upper surface of the phosphate

concentration is essentially a level surface over large areas, the bottom of the concentration is irregular. In places the concentration thickens so rapidly as to indicate the filling of old sinks. Although this sudden thickening of the phosphate concentration is not understood, the author would like to present an interpretation suggested by Dr. John L. Rich<sup>\*</sup> in oral discussion of the problem. If shallow sink holes developed in more calcareous Hawthorne sediments while the Hawthorne was above sea level, there would be a tendency for some of these sinks to become filled with weathered and eroded Hawthorne sediments due to rainwash and stream work. This would amount to reworking parts of the original marine phosphate concentration. Sinks developed previous to Pleistocene time would make the bottoms of the concentration irregular. Later erosion by an advancing Pleistocene sea, besides completing the filling of sinks, would tend to plane off and develop a more level top on the phosphate accumulation.

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\* Oral communication, January, 1956

THE HAWTHORNE AS A POSSIBLE SOURCE OF THE PHOSPHATE  
IN THE ALACHUA FORMATION

It is believed that the Hawthorne formation once covered the area of Alachua County in which hard-rock phosphate now is found and could have served as a source for that phosphate. Several lines of evidence lead to this conclusion.

1. In drilling a number of wells in western Alachua County materials were penetrated which are believed to represent Hawthorne sediments. One example is furnished by a water well completed July 7, 1955 at the home of Mr. Hooper Gravely (NE $\frac{1}{4}$ , SW $\frac{1}{4}$ , Section 2, T. 10 S., R. 17E.) about 1 $\frac{1}{2}$  miles east of Newberry. This well, with a surface elevation of 85.90 feet, is mentioned specifically because it is located in an area where hard-rock phosphates are known to occur in the Alachua formation. Also, the locality is west of pits from which hard-rock phosphate has been mined.

Ocala limestone was encountered in the well at a depth of 34 feet. In the interval between 5 and 20 feet, the sediments consisted mainly of clay ranging in color from a yellowish (ochre) tint to greenish gray. Embedded in the greenish gray clay were numerous soft, white phosphate grains. This clay with the included soft, white phosphate appears

identical to the clay encountered at a depth of 21-30 feet in hole #1 drilled on the property of Mr. Roy Brown in the type locality area of the Hawthorne formation. Clay of the same appearance with the included soft, white phosphate grains has been found in a number of other localities where undisturbed lenses of Ostrea normalis Dall are known to occur. An example of such an occurrence is furnished by exposures on the new truck cut-off southeast of Gainesville.

2. The physiographic relationships of the plateau to the plains (see figure 3) suggest that formations in the plateau at one time also covered the plain in western Alachua County. This plain has been developed as a result of the breaching of the Ocala uplift. The break between the plateau and the plain, which occupies the center of the arch, represents a retreating escarpment with occasional outliers on the plain.

As degradation proceeded after uplift, the overlying formations, mainly the Hawthorne, were weathered and eroded and the Ocala limestone approached. This initiated a stage of subsurface drainage and karst development at the center of the arch. Further development has resulted in subduing the karst relief and the development of a plain.

During the time of karst development, the areas surrounding sinks were more rapidly eroded, and the materials carried into the depressions.

Some of the ridges found along the boundary between the plain and the plateau show exposures containing the characteristic Hawthorne fossil, Ostrea normalis Dall. In one outlier, completely isolated from the "plateau", a lens of these fossils was located.

3. Cross sections constructed from the plateau area across the plains of Alachua County furnish strong evidence that the Hawthorne at one time covered a considerable area west of the present plateau. One such section is shown in figure 45.

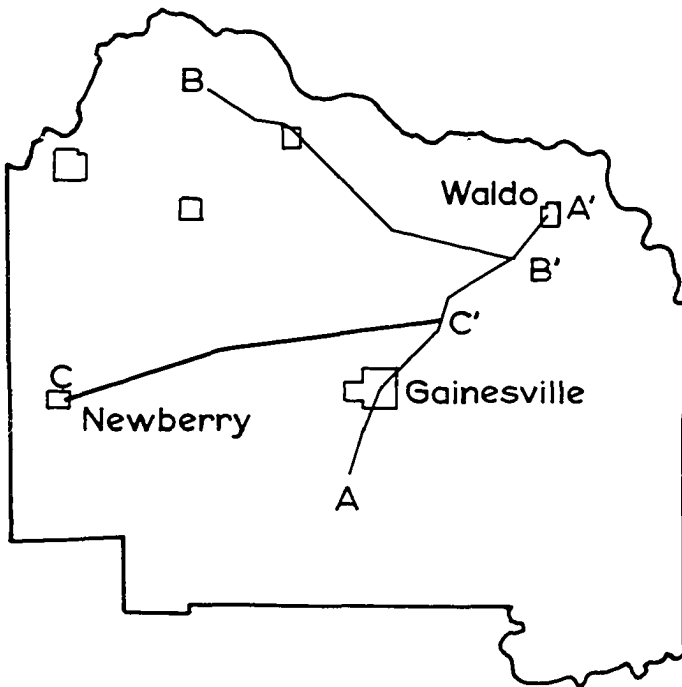
In summary, on the basis of information from drill hole cuttings in which sediments were encountered which appear identical to certain Hawthorne materials, from the physiographic relationships of the plateau to the plains, and from the study of cross sections, it is believed that the Hawthorne formation covered much or all of the plain in western Alachua County.

200  
150  
100  
50  
0  
-50  
-100

C Newberry

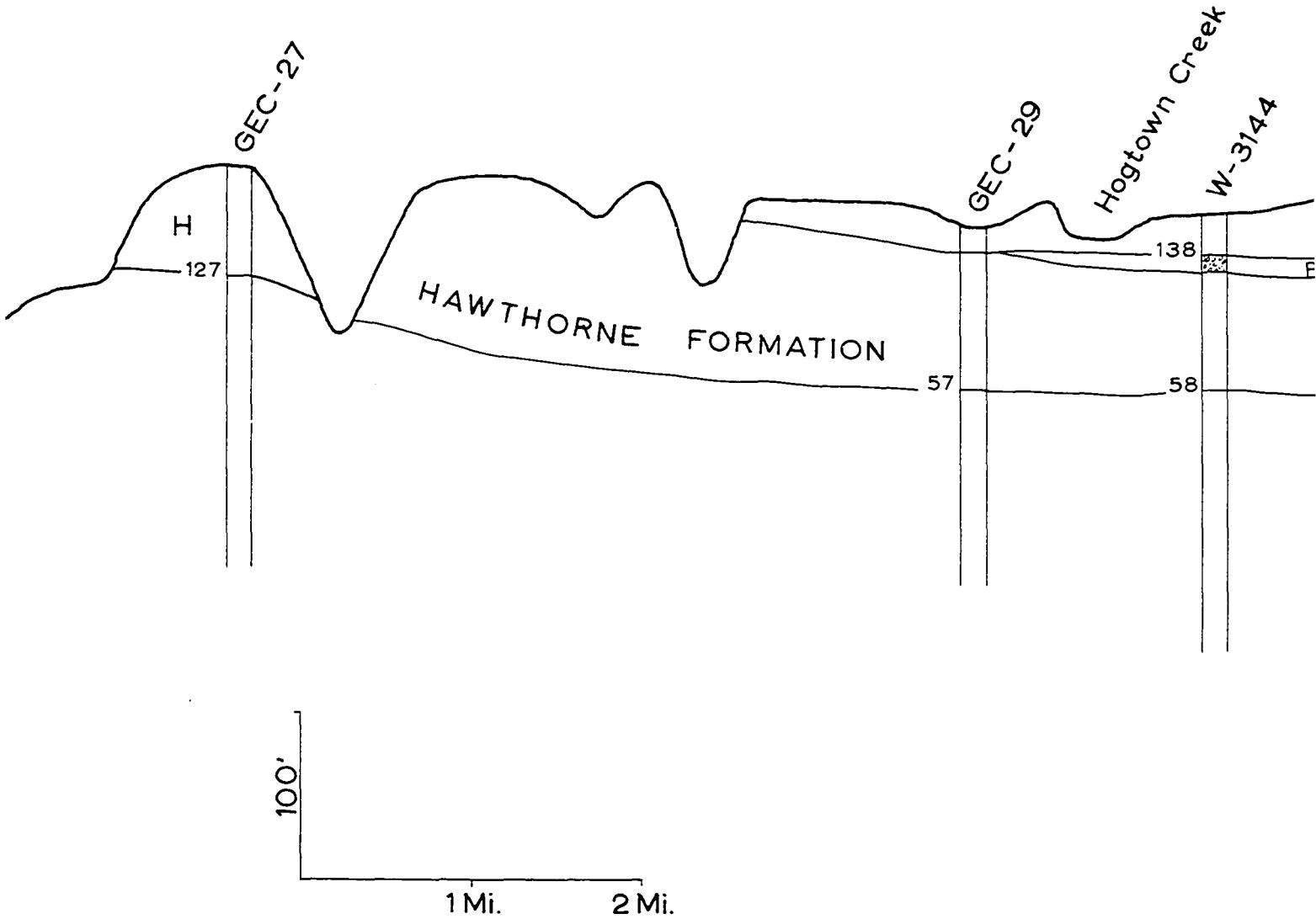
OCALA

LIMESTONE

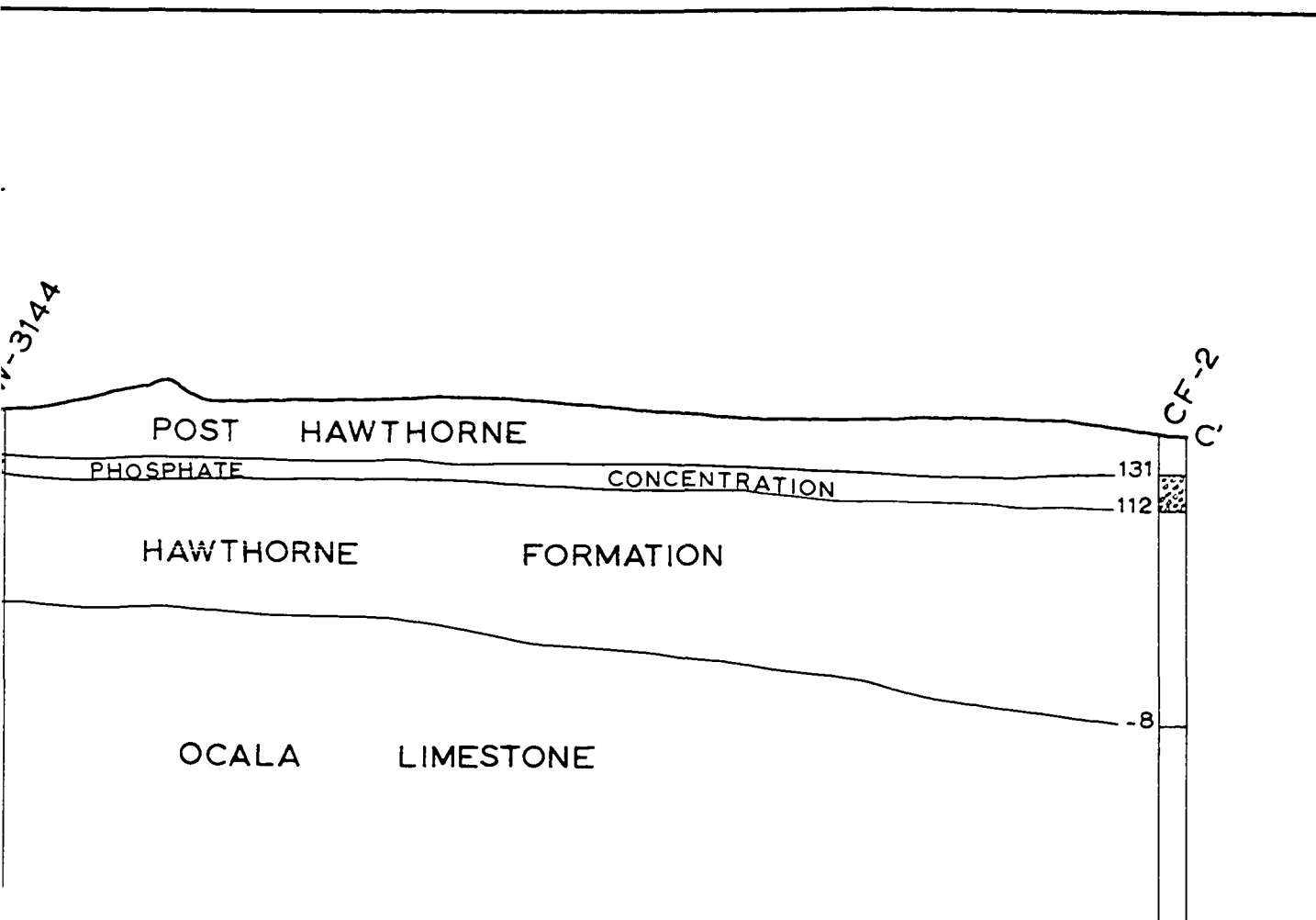


G  
FROM NEW  
JUST NO  
VER

Figure 45



GENERALIZED CROSS SECTION  
LEWBERRY TO THE SPERRY CORPORATION  
NORTH OF THE GAINESVILLE AIRPORT  
VERTICAL SCALE GREATLY EXAGGERATED



WELLS USED IN SECTION

GEC-27- Farm of Mr. George Fletcher, Sec. 25, T9S, R18E

GEC-29- Home of Mr. Ernest Ford, Glen Springs Road

W-3144- Sec. 23, T9S, R19E

CF - 2 - 20" well at Sperry Corporation, Waldo Road

ECONOMIC CONSIDERATION OF ALACHUA COUNTY  
PEBBLE PHOSPHATE

Introduction

Before discussing the economic possibilities of the pebble phosphate in Alachua County, a few problems and trends in the phosphate industry of Florida will be considered. Practically all of the phosphate produced in Florida comes from the Bone Valley field in Polk and Hillsborough Counties. Its average grade is approximately 74 percent BPL (Bone Phosphate of Lime).

About two-thirds of the agricultural phosphate needs of this country are met with normal superphosphate,  $\text{CaH}_4(\text{PO}_4)_2$  mixed with calcium sulfate, which is produced by treating finely ground phosphate rock with sulphuric acid. The general reaction may be indicated as follows:



Only one acidulation step is involved. Over 90 percent of the rock used in the manufacture of this fertilizer comes from Florida making that industry the big consumer of Florida phosphate rock. The south always has been the leading consuming area of this fertilizer.

During the earlier days in the history of the normal superphosphate industry, rock was mined in Florida and shipped by low-cost ocean transportation to manufacturing plants concentrated along the Eastern seaboard. Because

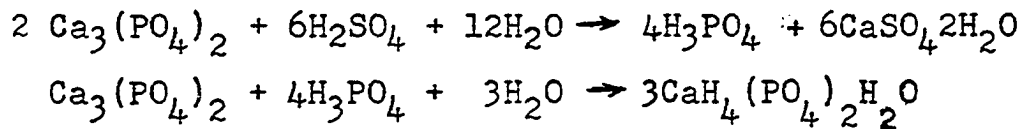
the farm market extends inland from such plants and the demand for fertilizers increased with progressive agricultural practices, plants have later been constructed in a number of states such as Ohio, Illinois, Kentucky and Tennessee. In the manufacture of normal superphosphate it is more economical, because of freight, handling and storage costs, to use phosphate rock with a BPL content of 75 percent or greater.

With the increase of fertilizer needs in the midwest, particularly after the development of hybrid corn, the need for a more concentrated fertilizer to help overcome the cost on long freight hauls became more acute. The triple superphosphate industry developed partly in response to this need. Triple superphosphate plants naturally were built near the source of the rock so that a concentrated product could be shipped.

Between 1948 and 1953 the amount of triple superphosphate produced in the United States doubled, and today this product supplies over 20 percent of the agricultural phosphate needs of the country. As most of the rock used in the manufacture of this product comes from Florida, the consumption of Florida phosphate rock for that use has been increasing greatly in the past few years. The higher concentration of phosphate in triple superphosphate results in savings on storage and shipping costs for the producer.

Also, the greater concentration of available plant food in this fertilizer furnishes definite advantages for some farming operations. Some high-analysis fertilizers, such as the popular 5-20-20, can not be made with normal superphosphate. Such a fertilizer requires triple superphosphate.

Two acidulation steps are used in the manufacture of triple superphosphate. In the first step sulphuric acid is added to phosphate rock to yield a weak phosphoric acid ( $\text{H}_3\text{PO}_4$ ). This, then, is generally concentrated by evaporation. In the second step, rock is treated with the concentrated phosphoric acid, resulting in triple superphosphate. The most important chemical changes are indicated by the following reactions.



The resulting product, triple superphosphate, contains almost three times the amount of available  $\text{P}_2\text{O}_5$  as normal superphosphate.

In the manufacture of triple superphosphate, low-grade phosphate rock (BPL approximately 68 percent) can be used economically in the first acidulation step. This step consumes about two-thirds of the phosphate rock needed in the production of that product. Although some companies still are using high-grade rock for both steps in the

manufacture of triple superphosphate, it should be noted that the Tennessee Corporation now is utilizing low-grade rock in its first acidulation step.

With most phosphate-rock-producers faced with depletion of their high-grade rock reserves within 20 years at the present rate of production, and with the rapid growth of industries such as triple super, electric furnace acid, and wet process acid capable of utilizing low-grade rock efficiently, it is believed that the average grade of phosphate rock produced in Florida will decrease steadily. As the high-grade land pebble phosphate is being depleted rapidly, it is certain that the phosphate-rock-producers will be faced in the future with the necessity of using lower grade rock if they continue to mine pebble phosphate in Florida.

#### Descriptions and Analyses of Borings on Roy Brown Property

It was decided to select one of the areas of phosphate concentration in Alachua County and test it by using the same methods of prospecting utilized in the commercial Bone Valley district. The area selected for this check was in the region of phosphate concentration south of the Hawthorne highway and between the towns of Grove Park and Hawthorne. This is Dall's type locality of the Hawthorne. The program was carried out through the courtesy of Mr. Roy Brown, the present owner of the property, and the drilling was done by

the American Metal Company, Limited. Seven holes were drilled by means of hand augers. Five of these borings were analyzed. For the location of the holes, see figure 46.

Holes 6 and 7 were drilled near Lochloosa Creek where that creek had cut through the phosphate concentration and into the main body of the Hawthorne formation. The purpose of these two borings was to attempt to encounter an undisturbed lens of Ostrea normalis Dall. It is possible that such a lens was penetrated by hole #6.

On the following pages are listed the logs of each hole. Laboratory analyses are given with each log. The following terms used with the logs are standard terminology in the commercial Bone Valley field and are used with the following meanings in reference to this drilling.

Overburden - Sediments overlying phosphate concentration.

Matrix - Sediments containing abundant phosphate particles. This term refers to the economic part of the phosphatic sediments in the Bone Valley district.

Bed Clay - Sediments (with high content of clay) underlying the heavy concentration of phosphate grains and pebbles.

The following abbreviations are used in the analyses data:

(7/16½) - Ratio of overburden to matrix. Seven feet of overburden to 16½ feet of matrix.

Plus 14 - Pebbles retained on 14 mesh screen.

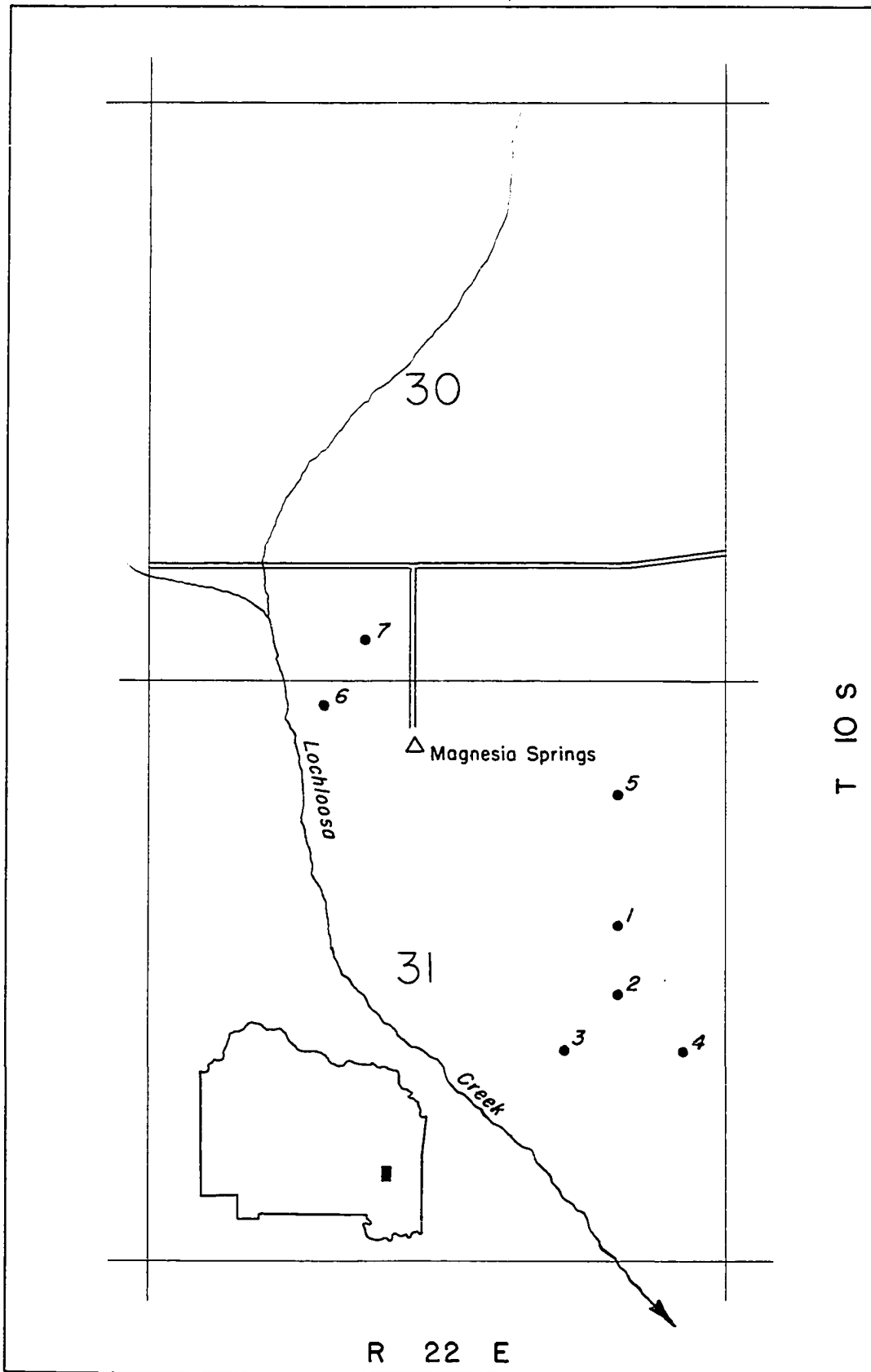


Figure 46. Location of borings on Roy Brown Property

14/20 - Pebbles which passed the 14 mesh screen and were retained on 20 mesh screen.

Conc. - Concentrates. Grains which are larger than 150 mesh and which passed 20 mesh screen. Flotation size sediments.

Product- Total product. Derived by adding all plus 14, 14/20 and concentrates.

T/A Ft.- Tons per acre foot.

T/A - Tons per acre.

BPL - Bone Phosphate of Lime,  $P_2O_5$  times 2.185.

Insol. - Insolubles in various mesh sizes.

Hole #1 - Roy Brown Property

Section 31, T. 10 S., R. 22 E. Log by: E. C. Pirkle  
See page 49 for a more complete log.

Overburden (Post-Hawthorne)

- 0 to 1 foot Dark brown, loose sand with admixed organic matter
- 1 to 2 feet Whitish, loose to slightly clayey sand. Occasional porous pebbles up to 1" by 1½".
- 2 to 4½ feet Hard pan. Firm, brown to gray clayey sand with fragments of sandrock.
- 4½ to 7 feet Grayish to whitish sandy clay or clayey sand.

Matrix\* (Hawthorne)

- 7 to 10 feet Grayish to buff clayey sand with abundant pebbles and grains of phosphate. Phosphate pebbles and grains are dominantly white, some brown.
- 10 to 14 feet Gray to buff clayey sand or sandy clay with a decrease in pebble size phosphate and an increase in grains of phosphate. Grains of phosphate are white, gray, tan and brown.
- 14 to 20 feet Buff clayey sand with a decrease, but still common grains of brown, tan and amber phosphate. Bottom foot contains pebbles of brown and gray phosphate.

Bed Clay (Hawthorne)

- 20 to 21 feet Sandy, phosphatic clay with occasional grains of brown, amber and black phosphate.
- 21 to 30 feet Massive greenish to greenish gray clay with thin stringers consisting of a mixture of quartz sand and white phosphate grains. Embedded in clay are grains of soft, white phosphate.

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\* The thickness of this unit does not correspond to that given with the analyses on the following page. The above log was made from samples collected every 6 inches and examined under a binocular microscope, whereas the samples analyzed were based upon units determined in the field.

Analyses of hole #1: Summary

Hole #	Fraction	Test Results		
		T/A	BPL	Insol.
#1 (7/16½)	plus 14	3381	58.5	16.86
	14/20	1037	60.1	15.09
	Conc.	4771	68.8	4.95
	Product	9189	64.0	10.48
	T/A Ft.	557		

Hole #2 - Roy Brown Property

Section 31, T. 10 S., R. 22 E.

Log by: C. O. Ensign

Overburden (Post-Hawthorne)

- 0 to 1 foot Black sandy top soil.
- 1 to 4 feet Large rocks. A cobble bed. The cobbles are very hard and show ferruginous seams. The surface appears porous.
- 4 to 4½ feet Light gray sand grading into a light sandy clay. This stratum contains some cobbles as above with size decreasing with depth.
- 4½ to 5½ feet Intercalated light gray and orange sandy clay containing a trace of white phosphate pebbles and some sandrock pebbles.
- 5½ to 7 feet Medium gray sandy clay containing sandrock pebbles and a trace of cream and white phosphate nodules.

Matrix (Hawthorne)

- 7 to 10 feet Medium gray sandy clay containing abundant brown and tan phosphate pebbles, but lean brown and tan concentrates.
- 10 to 15 feet Medium gray sandy clay containing abundant brown and tan small pebbles and abundant brown and tan concentrates.

Bed Clay (Hawthorne)

- 15 to 20 feet Pale yellow bed clay. Feels like talcum powder. Contains lean brown concentrates.

Analyses of hole #2: Summary

Hole #	Fraction	Test Results		
		T/A	BPL	Insol.
#2 (6/8)	plus 14	2704	58.6	15.66
	14/20	669	62.5	11.04
	Conc.	2413	69.2	3.14
	Product	5786	63.5	9.90
	T/A Ft.	723		

Hole #3 - Roy Brown Property

Section 31, T. 10 S., R. 22 E.

Log by: C. O. Ensign

Overburden (Post-Hawthorne)

- 0 to  $\frac{1}{2}$  foot Black sandy top soil.
- $\frac{1}{2}$  to 1 foot Medium gray sand.
- 1 to 3 feet Tan, water bearing sand, medium grained.
- 3 to  $11\frac{1}{2}$  feet Medium gray, water bearing sand containing a trace of white phosphate nodules; at 10 feet quartz sand becomes coarse grained.

Matrix (Hawthorne)

- $11\frac{1}{2}$  to 15 feet Medium gray sandy clay containing white phosphate granules and white and dark gray concentrates.
- 15 to 20 feet Whitish-gray sandy clay containing brown concentrates and lean soft white concentrates. This stratum is similar to bed clay in appearance.

Bed Clay (Hawthorne)

20 to  $21\frac{1}{2}$  feet Pale yellow calcareous bed clay.

Analyses of hole: Summary

Hole #	Fraction	Test Results		
		T/A	BPL	Insol.
#3 ( $11\frac{1}{2}/8\frac{1}{2}$ )	plus 14	1032	58.3	17.16
	14/20	565	58.7	17.07
	Conc.	2340	70.0	2.99
	Product	3937	65.3	8.72
	T/A Ft.	463		

Hole #4 - Roy Brown Property

Section 31, T. 10 S., R. 22 E.

Log by: E. C. Pirkle

Overburden (Post-Hawthorne)

- 0 to 1 foot Loose, gray, slightly clayey sand.
- 1 to 2½ feet Loose, whitish sand with clay content increasing with depth.
- 2½ to 4 feet Light gray, clayey sand.
- 4 to 5 feet Clayey sand containing pebbles of sandrock.
- 5 to 5½ feet Largely sandrock.

Matrix (Hawthorne)

- 5½ to 8½ feet White and gray pebbles and grains of phosphate in a clayey sand. Pebble size dominant. Color of clay changes with depth from gray to brown to gray.
- 8½ to 10½ feet Pebbles and grains of brown phosphate in a sandy greenish clay.
- 10½ to 14½ feet Abundant phosphate pebbles embedded in a grayish sandy clay or clayey sand. Brown concentrates.

Bed Clay (Hawthorne)

- 14½ to 17½ feet Pale yellow bed clay with occasional pebbles of brown phosphate.

Analyses of hole: Summary

Hole #	Fraction	Test Results		
		T/A	BPL	Insol.
#4 (5½/9)	plus 14	2882	59.2	15.90
	14/20	758	62.9	11.27
	Conc.	1477	69.6	3.08
	Product	5117	62.8	11.51
	T/A Ft.	569		

Hole #5 - Roy Brown Property

Section 31, T. 10 S., R. 22 E. Log by: Overburden - C. O. Ensign  
Matrix - E. C. Pirkle

Overburden (Post-Hawthorne)

0 to 1 foot Medium gray sand.  
1 to 5 feet Chocolate brown sand grading into cream sandy clay.  
5 to 7 feet Intercalated stiff gray and brown sandy clay.  
7 to 18 feet Stiff medium gray sandy clay with intercalated brown sandy clay laminae. At 9 feet sandrock pebbles appear. At 12 feet a trace of white phosphate appears.

Matrix (Hawthorne)

18 to 21½ feet A heavy gravel of phosphate pebbles with included quartz.  
21½ to 24½ feet Abundant phosphate in a light gray clayey sand. A decrease in pebble phosphate and an increase in brown concentrates.  
24½ to 33½ feet Fine brown phosphate grains and pebbles in a slightly clayey sand.

Bed Clay (Hawthorne)

33½ to 42½ feet Pale yellow bed clay. Becomes more gray with depth.

Analyses of hole: Summary

Hole #	Fraction	Test Results		
		T/A	BPL	Insol.
#5 (14/15½)	plus 14	4293	61.2	17.01
	14/20	1109	61.5	13.34
	Conc.	4651	70.2	2.63
	Product	10,053	65.4	9.95
	T/A Ft.	649		

Hole #6 - Roy Brown Property

Section 31, T. 10 S., R. 22 E.

Log by: C. O. Ensign

0 to 1 foot Black organic muck.

Hawthorne

1 to 5 feet Light olive gray clay, stiff. At 2½ feet whole silicified shells of Ostrea normalis Dall. The clay very stiff and sticky. At 4 feet soft white phosphate or limestone fragments appear, and copper green seams appear in clay.

5 to 7 feet Pale copper greenish-tan clay; very stiff. Trace of white limestone or phosphate fragments are evident. At 6 feet fragments of silicified oyster shells become abundant.

Bottomed at 7½ feet

No chemical analyses run on this hole.



## GENERALIZATIONS CONCERNING PEBBLE PHOSPHATE

A number of analyses of phosphate from Alachua County and three analyses from Brooks Sink in Bradford County are listed in Appendix "C." From those analyses, from the preceding data concerning phosphate on the property of Mr. Roy Brown and from a general knowledge of the geology of the county, it is believed that all of the phosphate in the zone of concentration at the top of the Hawthorne in the plateau area of Alachua County is low-grade, although in some areas there is a considerable tonnage of phosphate.

The low BPL content results in large part from the high percentage of included material within the pebble. Much of this material is quartz sand. It is entirely probable that no degree of leaching (a factor thought by Cathcart to be of importance in the development of high-grade phosphate in the Bone Valley district) would result in a high-grade deposit from such pebbles.

The nature of the original pebbles is one of the important factors in the development of high as compared to low-grade phosphate deposits. It seems that phosphate grains and pebbles formed in an environment favorable to the accumulation of more massive clays and more pure limestones contain less included clastic sediments in the sand size, thus resulting in a higher grade phosphate pebble or grain than one containing considerable included quartz.

If such pebbles and grains containing only a few inclusions could be concentrated later, a higher grade deposit would result than in the case where pebbles and grains with a high percentage of included quartz grains were concentrated.

Leaching, as shown by Cathcart (1950), is an important factor in high-grade land pebble deposits of the Bone Valley district. There the leached zone attests the work of this process. Yet, leaching alone does not explain the distribution of all high-grade pebble phosphate. Even within the Bone Valley area there are deposits of high-grade phosphate scattered through low-grade materials. If leaching were the only factor, there would appear to be a local control of some type.

General belief exists among some workers in the Bone Valley district that a limestone bed rock is favorable to high-grade phosphate deposits. Yet, there are properties in the Bone Valley where high-grade phosphate occurs above clays. Also, in some areas accumulations of phosphatic sediments over limestone bed rock are known to be low-grade. In Alachua County, phosphatic sediments enclosed by massive clays are known to be high-grade.

If both leaching and the types of phosphate pebbles are considered, the occurrence of high-grade as compared to low-grade "properties" might be more easily explained even within one district such as the Bone Valley. For example, if within an area pebbles and grains of phosphate which

contain only minor amounts of included sediments such as quartz sand and are concentrated, the deposit might be high-grade regardless of leaching and enrichment. If some of these types of phosphatic sediments are present in a deposit, along with numerous fragments of phosphatized limestone, the conditions for a high-grade "property" due to leaching and enrichment are especially favorable. Acid surface waters might leach phosphate from pebbles and grains above the water table and deposit the phosphate in voids or replace varying amounts of the remaining carbonate content of the limestone type pebbles below the water table.

Initially, leaching could result in higher grade pebbles above the water table by removing carbonate from phosphate particles. Continued solution above the water table will then leach considerable phosphate from the pebbles. Eventually a leached zone characterized by low-grade calcium aluminum phosphate results. Below the water table phosphate leached from the zone of aeration should be precipitated from ground water in response to the new environmental conditions. Some phosphate pebbles from certain high-grade properties of the Bone Valley area have been noted to contain openings partly filled with phosphate displaying a botryoidal structure. This is evidence of open-space filling. Also, below the water table the carbonate content of sediments might be replaced by phosphate. Thus, phosphate pebbles which represent limestone fragments replaced by

varying amounts of phosphate could be enriched by replacement of part of the remaining carbonate content of the nodules by phosphate.

Even though it may be possible that major changes in processing the phosphatic sediments may be developed in the future, at the present time the pebble phosphate in Alachua County is not of sufficiently high-grade to be mined. Nor is it believed that the mining will be economically feasible in the near future.

Though it is true that phosphate producers in the future must mine lower grade material, there is a great quantity of low-grade phosphate in the Bone Valley district. Pebble phosphate also is known from Hamilton, Bradford, Clay and other counties (Mansfield, 1942). The pebble phosphate at the top of the Hawthorne formation in the plateau area of Alachua County adds to the low-grade phosphate reserves of the State of Florida a minimum of between 30 and 50 million tons of phosphate particles which will average over 50 percent BPL.

## CONCLUSIONS

1. The pebble phosphate concentrations at the top of the Hawthorne formation in Alachua County are believed to represent original marine phosphate concentrations which in local areas have been modified by weathering, rainwash and stream action. The original deposit is thought to have been developed during Hawthorne time, and the modifications have been taking place intermittently since.
2. It is believed that the Hawthorne formation was deposited over western Alachua County where the Alachua formation is now found and thus could have been the source for the phosphate found in the hard-rock phosphate deposits of Alachua County.
3. Most of the pebble phosphate deposits in Alachua County are low-grade and are not considered as commercial at the present time. These deposits, however, add to the reserves of the State of Florida for future exploitation a considerable tonnage of low-grade phosphate which will average over 50 percent BPL.

APPENDIX "A"

Well Logs from Northwestern Alachua County  
and West and Southeast of Gainesville

1. Well located in Section 21, T. 7 S., R. 19 E. in field of Mr. Lacy Doak near Santa Fe. Surface elevation - 149.80 feet.

0 to 5 feet	Brown sand.
5 to 10 feet	Brown clayey sand with a few white phosphate grains.
10 to 55 feet	Yellowish to buff clayey sand and sandy clay with occasional whitish and brown phosphate grains.
55 to 65 feet	Grayish slightly clayey sand with common brownish and white phosphate grains.
65 to 80 feet	Buff colored clayey sand with small amount of white and gray grains of phosphate.
80 to 90 feet	Slightly clayey sand with common brown, tan and white phosphate grains.
90 to 107 feet	White limerock. No fossils noted. Sample from 90 to 95 feet contained a few included brown phosphate pebbles.
107 feet	Ocala limestone.
T. D. - 350 feet	in limestone.

Summary:

0 to 5 feet	Post-Hawthorne
5 to 107 feet	Hawthorne
107 to 350 feet	Eocene limestones

2. Buckley well located on the north side of the Newberry Highway at intersection of dirt road west of Fort Clarke (Four O'Clock) Church. SW $\frac{1}{4}$ , SE $\frac{1}{4}$ , Section 31, T. 9 S., R. 19 E. Surface elevation - 156.76 feet.

- 0 to 6 feet Loose tan sand, from fine to coarse. Predominantly fine.
- 6 to 15 feet Loose brown sand to slightly clayey sand. Sand mainly fine to medium but some coarse. Stringers of nearly pure dark gray, non-calcareous clay. Occasional white phosphate grains and pebbles.
- 15 to 40 feet Greenish, greenish gray to gray sandy clay and clayey sand. Sand from fine to coarse. Some clay shrinks on drying and does not effervesce. Fragments of oysters, probably Ostrea normalis Dall but no positive identification.
- 40 to 55 feet White slightly sandy clay, very light weight. Slightly calcareous. Sand is fine.
- 55 to 65 feet Same as 40 to 55 feet except now very calcareous. White slightly sandy very calcareous clay or white slightly sandy clayey carbonate.
- 65 to 73 feet Same as above except marked increase in sand. Light, white sandy very calcareous clay. Sand is fine. Occasional small pebbles of phosphate. Color changes to brownish just before contact or at contact with Ocala.
- 73 feet Ocala limestone.

T. D. - 150 feet in Eocene limestone.

Summary:

- |                |                  |
|----------------|------------------|
| 0 to 6 feet    | post-Hawthorne   |
| 6 to 73 feet   | Hawthorne        |
| 73 to 150 feet | Eocene limestone |

3. Well on farm of Mr. George Fletcher. Location is about  $1\frac{1}{2}$  miles north of Newberry Highway (approximately NW $\frac{1}{4}$ , Section 25, T. 9 S., R. 18 E.). Surface elevation - 192.20 feet.

0 to 12 feet	Tan to light brown clayey sand with rare small white grains of phosphate. Fresh clay, grayish in color.
12 to 30 feet	Sandy clay to clayey sand with color changing downward from orange-yellow to ochre to brown and then to light yellow. Colors due to weathering of grayish clay. From 25 to 30 feet increase in sand and common small white phosphate grains.
30 to 45 feet	Grayish sandy clay to clayey sand with common small white grains of phosphate grading down into massive gray clay of fuller's earth type.
45 to 65 feet	Ground up carbonate or very calcareous clay with much sand. Whitish to cream in color. Occasional grains of white phosphate.
65 feet	Ocala limestone.
T. D. - 264 feet in limestone.	

Summary:

0 to 65 feet	Hawthorne
65 to 264 feet	Eocene limestones

4. Well at residence of Mr. R. L. Black,  $\frac{1}{2}$  mile north of Gainesville Golf Course (Section 1, T. 10 S., R. 19 E). Surface elevation - 126.51 feet.

0 to 3 feet	Dark brown, iron stained quartz sand with admixed organic matter.
3 to 18 feet	Largely buff colored clayey sand. Common shiny, rounded grains of white and gray phosphate. Clay non-calcareous.
18 to 35 feet	Grayish sandy clay with common shiny rounded grains and small pebbles of white phosphate. Clay non-calcareous.
35 to 42 feet	Gray clayey sand with occasional grains and small shiny white pebbles of phosphate.
42 feet	Ocala limestone.
T. D. - 155 feet in limestone.	

Summary:

0 to 3 feet	post-Hawthorne
3 to 42 feet	Hawthorne
42 to 155 feet	Eocene limestone

5. Well southeast of Gainesville, off State Road 26. 2.1 miles east from intersection of State Roads 20 and 26. Turn south down dirt road for about .3 mile. Well on hill in yard of Mr. Courtney (Section 14, T. 10 S., R. 20 E.). Surface elevation - 155.93 feet.

0 to 2 feet	Loose tan sand.
2 to 22 feet	Cream colored sandy clay. Clay non-calcareous. Original clay was greenish gray. Rare grains and small pebbles of whitish phosphate.
22 to 31 feet	Gray sandy very calcareous clay. Sand decreases with depth. Quartz grains are coarse. Clay is very difficult to break when dry.
31 to 40 feet	Gray clay. Very little sand. Fuller's earth type. Cracks when dry. Light. Grades down into calcareous clay.
40 to 51 feet	White clay, very calcareous.
51 feet	Ocala limestone.
T. D. - 125 feet	in Eocene limestone.

Summary:

0 to 2 feet	post-Hawthorne
2 to 51 feet	Hawthorne
51 to 125 feet	Eocene limestone

## APPENDIX "B"

### Well Logs from North of Gainesville and Northeastern Alachua County

1. Well drilled at new chemical plant located just behind creosote plant on Glenn Springs Road north of Gainesville. Located in Section 26, T. 9 S., R. 20 E. Surface elevation - 177.15 feet.

0 to 28 feet	Cream, slightly clayey sand. Clay content increases with depth.
28 to 40 feet	Abundant grains and pebbles of black, brown and tan phosphate in a buff colored sandy calcareous clay. Fresh clay a light pastel blue color.
40 to 65 feet	Same as above except clay changes to a more grayish color and then to a good slate gray, with a decrease in pebble size phosphate. Clay is slightly calcareous.
65 to 79 feet	Massive gray calcareous clay with a marked decrease in pebble phosphate but still common grains of black and brown phosphate.
79 to 84 feet	Abundant grains of black phosphate in gray sandy calcareous clay.
84 to 102 feet	Sandrock. Mainly quartz sand with occasional small black, tan, white and amber phosphate grains cemented by gray calcareous clay or clayey carbonate. Some stringers of limerock. Clay content increases with depth.
102 to 105 feet	Massive blue green clay with sand partings.
105 to 113 feet	Sandrock. Largely sand grains cemented with a calcareous clay or clayey carbonate. Minor fine phosphate grains.
113 to 124 feet	Gray calcareous clay with stringers of limerock. In places clay is silicified.

124 to 128 feet	Gray calcareous clay with common grains of phosphate.
128 to 138 feet	Gray sandy calcareous clay. Clay is silicified in places.
138 to 144 feet	Cream to gray, very calcareous clay with tan and brown phosphate pebbles and minor black grains of phosphate. Limerock stringers.
144 feet	Ocala limestone.
T. D. - 199 feet in limestone.	

Summary:

0 to 28 feet	post-Hawthorne
28 to 144 feet	Hawthorne
144 to 199 feet	Eocene limestone

2. Well on farm of Mr. Sam Wall north of Gainesville.  
Approximately center Section 28, T. 9 S., R. 20 E.  
Surface elevation - 170.58 feet.

0 to 2 feet	Muck with included sand.
2 to 34 feet	Loose, brown to tan sand with clay content increasing with depth. Very little clay to 24 feet. Slight amount of clay at 25 feet. At 30 feet a greenish gray, non-calcareous sandy clay.
34 to 35 feet	Cream colored calcareous fossiliferous limestone with included clastic quartz sand and small shiny black phosphate grains. Fossils too poorly preserved to be identified but include pelecypods.
35 to 56 feet	Gray, clayey sandy carbonate or sandy very calcareous clay with abundant small shiny black and brown phosphate grains. Sand mainly fine.
56 to 77 feet	Calcareous sandy gray clay with abundant black shiny phosphate grains. Occasional lenses or stringers of white to cream limerock which has included phosphate grains, quartz sand and fossil impressions. Sediments yielded claw of crab.
77 to 87 feet	Clayey carbonate with small black phosphate grains and clastic quartz.
87 to 94 feet	Massive calcareous gray clay with marked decrease in phosphate content and practically no sand. Dries to whitish gray of some fuller's earth.
94 to 99 feet	Calcareous sandy gray clay or gray clayey carbonate with abundant fine black shiny phosphate grains. Some brown grains of phosphate.
99 to 104 feet	Whitish calcareous limerock with included fine to medium clastic quartz grains and shiny black phosphate grains. Drilled hard.

104 to 130 feet	Sand and sandrock. Sand loose to slightly cemented with clayey carbonate or calcareous clay. Occasional grains of black and whitish phosphate.
130 to 145 feet	Clayey sand to sandy clay. Clay calcareous. Sand fine to medium. Occasional grains of white to gray phosphate.
145 to 155 feet	Sandrock. Sand loosely cemented with carbonate. Occasional grains of white, gray and black phosphate.
155 to 165 feet	Calcareous bluish-gray sandy clay with occasional small white to gray phosphate grains and clay pellets. Sand from fine to coarse.
165 to 175 feet	Very calcareous light gray sandy clay. Sand is fine and decreases with depth. Thin lenses or stringers of dark greenish-gray massive clay with pyrite.
175 feet	Ocala limestone.
T. D. - 185 feet in limestone.	

Summary:

0 to 34 feet	post-Hawthorne
34 to 175 feet	Hawthorne
175 to 185 feet	Eocene limestone

3. Water well at home of Mr. Wilmer Thomas about  $1\frac{1}{2}$  miles south of State Road 340 (SE $\frac{1}{4}$ , NW $\frac{1}{4}$ , Section 21, T. 8 S., R. 20 E.). Surface elevation - 154.08 feet.

0 to 22 feet	Loose sand with clay content increasing with depth. Clay non-calcareous.
22 to 33 feet	Abundant grains of brown phosphate with minor pebble phosphate in a grayish sandy clay. Color of clay changes downward from grayish to buff or cream to a yellowish orange tint.
33 to 37 feet	Ochre to orange-yellow sticky sandy calcareous clay with a decrease in phosphate and sand.
37 to 55 feet	Tan to yellowish calcareous dense limestone; almost lithographic in places with pockets of clay. Top foot silicified. Limestone at places includes numerous phosphate pebbles and grains and quartz sand.
55 to 67 feet	Light gray to yellowish sandy calcareous clay to calcareous clayey sand.
67 to 95 feet	Mainly massive light bluish gray clay with occasional rather large phosphate pebbles. Thin stringers of limerock. Clay non-calcareous.
95 to 105 feet	Light gray slightly sandy calcareous clay. Cracks slightly on drying.
105 to 125 feet	Gray to whitish porous limerock. In places contains abundant brown pebbles of phosphate and quartz sand as inclusions.
125 to 134 feet	Mainly fine sand.
134 feet	Ocala limestone.
T. D. - 140 feet in limestone.	

Summary:

0 to 22 feet	post-Hawthorne
22 to 134 feet	Hawthorne
134 to 140 feet	Eocene limestone

4. Well at the home of Mrs. Conant near center SW $\frac{1}{4}$ , Section 21, T. 8 S., R. 22 E. between Hickory Pond and Little Santa Fe Lake. Surface elevation - 158.51 feet.
- |                 |   |
|-----------------|---|
| 0 to 2 feet     | Loose sand.   |
| 2 to 24 feet    | Mottled red and yellow sandy clay and clayey sand. Sand increases with depth and clay becomes grayer with depth. Sand not sorted and of all sizes, but mainly fine. Clay not calcareous and cracks on drying.   |
| 24 to 43 feet   | Slightly clayey sand at top grading down into loose sand and then into clayey sand. Sand largely fine from 24 to 35 feet. From 35 to 40 feet sand loose with abundant coarse grains. White mica present.  |
| 43 to 60 feet   | Light gray calcareous to slightly calcareous clayey sand or sandy clay with abundant pebbles of gray, white and brown phosphate and grains of white, gray and amber phosphate. Material capped by 6 inch bed of whitish limestone which has included quartz sand and phosphate grains.                                  |
| 60 to 70 feet   | Yellowish (ochre color) clayey to slightly clayey sand. Sand mainly fine to medium. Practically no effervescence.   |
| 70 to 75 feet   | Light weight, light gray sandy very calcic clay with occasional small black phosphate grains.   |
| 75 to 115 feet  | Mainly loose to slightly indurated sand. At 75 feet sand largely fine to medium. At 85 feet slight increase in clay content. From 90 to 105 feet sand mainly fine to medium with gray and white phosphate grains. At 110 feet sand fine with occasional grains of white, gray, amber, brown and black phosphate grains. |
| 115 to 120 feet | Gray sandy clay or clayey sand with common grains of small gray and white   |

phosphate. Clay only slightly calcareous. Sand mainly fine but some coarse.

- 120 to 135 feet Light weight, light gray calcareous sandy clay with occasional grains of gray and brown phosphate. Clay shrinks noticeably on drying.
- 135 to 141 feet White, platy calcareous limestone.
- 141 to 147 feet Sandy, very calcareous clay with abundant brown and occasional black phosphate grains.
- 147 to 167 feet Light gray calcareous clayey sand or sandy clay with abundant grains of brown and black phosphate. Thin limerock stringers with included quartz sand and phosphate grains.
- 167 feet Ocala limestone.

T. D. - 199 feet in limestone.

Summary:

0 to 43 feet post-Hawthorne  
43 to 167 feet Hawthorne  
167 to 199 feet Eocene limestone

APPENDIX "C"

PHOSPHATE ANALYSES

1. Sample taken just north of canal at Gainesville Air Port.  
 Hole drilled by hand auger.  
 Mechanical analyses made by Mr. James Cathcart.  
 Chemical analyses run by American Cyanamid Company.

OB - 23 feet  
 Strata - 6 $\frac{1}{2}$  feet (did not penetrate).

Screen Analyses

	Wt. (gms)	Wt. %	Wt. % Conc.	Wt. (gms) Conc.	Sand	Wt. % Conc.	Sand
+6	2180.7	28.4	----	} all phos.			----
6/12	1126.2	14.6	----				----
12/20	887.7	11.6	----				----
20/40	1199.1	15.6	10.8	832.2	366.9	69.4	30.6
40/50	403.3	5.3	2.7	240.7	162.6	51.0	49.0
50/70	403.9	5.3	1.8	134.9	269.0	33.4	66.6
70/100	156.4	2.0	0.4	28.9	127.2	18.5	81.5
100/140	87.1	1.1	0.2	12.8	74.3	14.7	85.3
140/200	27.8	0.4	0.07	4.8	23.0	17.3	82.7
-200	1220.7	15.9	----	some phosphate grains visible, about 15%			
	<u>7692.9</u>						

Tonnages (long tons) (115 pounds/cubic foot)

+6	4128	
6/12	2122	
12/20	<u>1686</u>	54.6% pebble
	7936	(Total pebble, tons per acre)
20/40	1570	
40/50	392	
50/70	262	
70/100	58	
100/140	29	
140/200	<u>10</u>	15.97% conc.
	2321	(Total concentrate, tons per acre)

Phos. = 70.5%; Sand = 13.6%; Slime = 15.9%

1. continued

<u>Description</u>	<u>B.P.L.</u>	<u>Insol.</u>
PEBBLE:		
Plus 6 Mesh -----	56.15	19.46
Minus 6 Plus 12 -----	59.89	14.62
Minus 12 Plus 20 -----	62.10	12.68
FEED:		
Minus 20 Plus 40 -----	57.14	19.52
Minus 40 Plus 50 -----	38.06	46.35
Minus 50 Plus 70 -----	25.00	64.28
Minus 200 Mesh -----	12.98	61.48
CONCENTRATE:		
Minus 20 Plus 40 -----	68.89	3.28
Minus 40 Plus 50 -----	69.35	2.51
Minus 50 Plus 70 -----	69.13	3.47
Minus 70 Plus 100 -----	65.16	9.10
Minus 100 Plus 140 -----	57.47	18.53
Minus 140 Plus 200 -----	47.81	31.64

2. NW $\frac{1}{4}$  of NW $\frac{1}{4}$  Section 13, T. 9 S., R. 20 E., Alachua County.  
 Hole drilled with rotary rig.  
 Log by Mr. James Cathcart.  
 Chemical analyses by American Cyanamid Company.

0 - 1'	Black sandy soil
1 - 3'	White, loose, medium to fine-grained sand.
3 - 10'	Brown, iron-stained sand, lighter with depth.
10 - 13'	White, loose sand.
13 - 20'	Clayey sand, with beds of grey sandy clay.
20 - 40'	Cream to white loose to slightly clayey sand; minor brown phosphate, becoming more abundant with depth.
40 - 60'	Greenish-grey clayey sand, grading to sandy clay at base. Abundant black phosphate. Hawthorne?

Sample A - 40' - 60'

<u>SAMPLE NO.</u>	<u>+20 MESH TPA</u>	<u>BPL PEB.</u>	<u>INSOL. PEB.</u>	<u>CORRECTED TPA FEED</u>	<u>BPL FEED</u>	<u>TPA CONC.</u>	<u>BPL CONC.</u>	<u>INSOL. CONC.</u>	<u>RATIO</u>
A	2,031	50.06	16.67	24,222	10.27	2,479	61.01	7.39	9.77

3. NE $\frac{1}{4}$  of NW $\frac{1}{4}$  Section 24, T. 9S., R. 20 E., Alachua County.  
 Hole drilled with rotary rig.  
 Log by Mr. James Cathcart.  
 Chemical analyses by American Cyanamid Company.
- 0 - 3' Black and brown, loose sand.
  - 3 - 6' White, loose sand.
  - 6 - 15' Light brown, iron-stained sand (hardpan) grading to tan, loose sand at base.
  - 15 - 33' Light grey, very slightly clayey sand.
  - 33 - 40' Light grey sandy clay to clayey sand, with abundant brown pebble phosphate.
  - 40 - 60' Light grey-green clay with abundant, black fine-grained phosphate.
  - 60 - 70' As above, but slightly stiffer.

T. D. 70 feet

Sample A - 33 - 40

Sample B - 40 - 60

Sample C - 60 - 70

<u>SAMPLE NO.</u>	<u>+20 MESH TPA</u>	<u>BPL PEB.</u>	<u>INSOL. PEB.</u>	<u>CORRECTED TPA FEED</u>	<u>BPL FEED</u>	<u>TPA CONC.</u>	<u>BPL CONC.</u>	<u>INSOL. CONC.</u>	<u>RATIO</u>
A	1,097 686	58.14 61.31	17.91 14.33	7,131	18.68	1,602	68.48	3.57	4.45
B	214 463	57.36 55.17	17.78 20.15	27,463	11.76)	:4,981	62.97	4.11	6.75
C	1,175 588 <u>4,223</u>	34.52 37.04 <u>48.78</u>	11.40 12.85 <u>15.05</u>	6,162 <u>40,756</u>	16.15) <u>13.63</u>	<u>6,583</u>	<u>64.31</u>	<u>3.98</u>	<u>6.19</u>

4. SW $\frac{1}{4}$  of SW $\frac{1}{4}$  Section 23, T. 9S., R. 20 E., Alachua County.  
 Hole drilled with rotary rig.  
 Log by Mr. James Cathcart.  
 Chemical analyses by American Cyanamid Company.

- 0 - 8' Gray, brown, and yellow loose sand.  
 8 - 12' Light brown, iron-stained sand (Hardpan).  
 12 - 18' Light grey, very slightly clayey sand.  
 18 - 25' Light buff, fine, loose sand, trace dark fine phosphate.  
 25 - 30' Light greenish-grey clayey sand, trace black-white phosphate.  
 30 - 37' Greenish-grey clayey sand, pebble and float phosphate, approximately 10%.  
 37 - 43' As above, pebble increasing.  
 43 - 53' As above, abundant coarse pebble.  
 53 - 60' As above, only trace pebble.

Sample A - 30 - 37'

B - 37 - 43'

C - 43 - 53'

<u>SAMPLE NO.</u>	<u>+20 MESH TPA</u>	<u>BPL PEB.</u>	<u>BPL PEB.</u>	<u>INSOL. PEB.</u>	<u>CORRECTED TPA FEED</u>	<u>BPL FEED</u>	<u>TPA CONC.</u>	<u>BPL CONC.</u>	<u>INSOL. CONC.</u>
A	1,193	55.80	16.95						
	677	51.98	15.26	7,801	10.07				
B	1,015	53.73	16.86						
	410	48.05	17.82	6,661					
C	1,745	54.60	17.21						
	463	51.87	16.61	8,371	9.53				

5. Center of the NE $\frac{1}{4}$  Section 34, T. 8 S., R. 20 E., Alachua County.

Hole drilled with rotary rig.

Log by Mr. James Cathcart.

Chemical analyses by American Cyanamid Company.

- 0 - 3 Sand, grey, loose
- 3 - 10 Clay, sandy, grey, with blue-green clay lenses?
- 10 - 24 Sand, clayey, white to grey (Kaolinitic?) lenses, darker and more clayey toward base.
- 24 - 44 Clay, sandy, ("salt and pepper") with black, mostly fine grained phosphate nodules - mines coarse.
- 44 - 58.5 Clay, dark grey, with black phosphate, decreasing toward base.

T. D. 58.5' in hard rock.

Sample A - 24' - 44'

B - 44' - 58.5'

<u>SAMPLE NO.</u>	<u>+20 MESH TPA</u>	<u>BPL PEB.</u>	<u>INSOL. PEB.</u>	<u>CORRECTED TPA FEED</u>	<u>BPL FEED</u>	<u>TPA CONC.</u>	<u>BPL CONC.</u>	<u>INSOL. CONC.</u>	<u>RATIO</u>
A	71	54.38	17.42						
	71	37.93	41.73	10,098	15.10	1,846	68.67	2.56	5.47
B	801	34.24	12.92						
	542	37.49	27.03	12,241	19.80	2,921	65.94	2.24	4.19
	<u>1,485</u>	<u>36.57</u>	<u>19.66</u>	<u>22,339</u>	<u>17.68</u>	<u>4,767</u>	<u>67.00</u>	<u>2.36</u>	<u>4.69</u>

6. SW $\frac{1}{4}$  of NW $\frac{1}{4}$  Section 18, T. 9 S., R. 20 E., Alachua County  
 Hole drilled with rotary rig.  
 Log by Mr. James Cathcart.  
 Chemical analyses by American Cyanamid Company.

- 0 - 1 Black soil.
- 1 - 3 Sand, clayey to loose, grey to tan.
- 3 - 18 Sand, clayey, grey.
- 18 - 24 Clay, sandy, light grey to white, abundant coarse and fine phosphate.
- 24 - 30 Clay, yellow-brown, sticky, abundant pebble phosphate.
- 30 - 45 Clay, khaki, sandy, flotation size phosphate.
- 45 - 60 Clay, buff to tan, bluish, with phosphate grains.

Sample A - 18' - 24'

B - 24' - 30'

C - 30' - 45'

D - 45' - 60'

<u>SAMPLE NO.</u>	<u>+20 MESH TPA</u>	<u>BPL PEB.</u>	<u>INSOL. PEB.</u>	<u>CORRECTED TPA FEED</u>	<u>BPL FEED</u>	<u>TPA CONC.</u>	<u>BPL CONC.</u>	<u>INSOL. CONC.</u>	<u>RATIO</u>
A	1,069	44.90	9.80						
	470	43.92	7.21	3,847	12.08	561	57.75	3.67	6.86
B	641	50.58	10.04						
	278	50.47	8.40	5,514	6.16				
C	196	47.20	16.47						
	142	41.52	23.83	9,617	9.68				
D	142	47.31	17.20						
	89	45.67	23.39	11,078	8.37				
	<u>3,027</u>	<u>46.59</u>	<u>11.16</u>	<u>30,056</u>	<u>8.86</u>	<u>2,952</u>	<u>62.58</u>	<u>4.68</u>	<u>10.18</u>

7. Analyses of a 13 pound sample collected at an exposure on south side of dirt road, just west of a tributary of Lochloosa Creek (section 25, T. 10 S., R. 21 E.), see page 53.

Analyses furnished by American Metal Company, Limited. Chemical analyses run by Thornton & Company of Tampa, Florida.

Weight of Matrix (wet) ----- 13.00 lbs.

Weight of  $-\frac{1}{2}$  plus 14 phosphate (dry) ----- 3.25 lbs.

	<u>Wet Screening</u> <u><math>-\frac{1}{2}</math> plus 14</u>	<u>FLOTATION-14 plus 150</u>		<u>HEADS</u>	<u>SLIME</u>
		<u>Concentrate</u>	<u>Tailings</u>		
Tons per Acre Foot	576	224	587	811	
Phosphoric Acid (P <sub>2</sub> O <sub>5</sub> )	24.32%	30.26%	3.20%	10.68%	19.30%
B. P. L.	53.14%	66.12%	7.00%	23.34%	42.17%
Iron & Alum. Oxides	6.41%	5.43%	----	----	
Insoluble	23.76%	4.00%	90.11%	66.30%	

FLOTATION FEED

Ratio: Dry feed to dry recovered phosphate, flotation -14 plus 150 3.62 to 1.

Composition: Dry Concentrate 27.62%  
Dry Tails 72.38%

8. Analyses of a 35 pound sample collected from bed 10 at the Devil's Mill Hopper, Alachua County, see page 66.

Data available through the courtesy of the American Metal Company, Limited.  
Chemical analyses run by Thornton & Company of Tampa, Florida.

Weight of Matrix (wet) ----- 35 pounds.

Weight of  $-\frac{1}{2}$  plus 14 phosphate (dry) ----- 8.62 pounds.

CERTIFICATE OF ANALYSIS  
(DRY BASIS)

	<u>Wet Screening</u> <u><math>-\frac{1}{2}</math> plus 14</u>	<u>FLOTATION-14 plus 150</u> <u>Concentrate</u>	<u>Tailings</u>	<u>HEADS</u>	<u>SLIME</u>
Tons per Acre Foot	543	182	666	848	
Phosphoric Acid (P <sub>2</sub> O <sub>5</sub> )	26.86%	31.06%	3.20%	9.19%	7.87%
B. P. L.	58.70%	67.86%	7.00%	20.07%	17.19%
Iron & Alum. Oxides	5.10%	4.72%			
Insoluble	14.62%	4.0%	88.08%	70.02%	

FLOTATION FEED

Ratio: Dry feed to dry recovered phosphate, flotation -14 plus 150 4.66 to 1.

Composition: Dry Concentrate 21.46%

Dry Tails 78.54%

9. Analyses of a 15 pound sample collected from near the bottom of bed 12 at Brooks Sink, Bradford County, see page 59. Although phosphate is abundant throughout bed 12, there is a heavier concentration near the bottom of the bed. Thus, the tons per acre foot figure in the following analyses would be high for the complete bed.

Data available through the courtesy of the American Metal Company, Limited.  
 Chemical analyses run by Thornton & Company of Tampa, Florida.

Weight of Matrix (wet) ----- 15 pounds  
 Weight of  $-\frac{1}{2}$  plus 14 phosphate (dry) ---- 5.88 pounds

CERTIFICATE OF ANALYSES  
 (DRY BASIS)

	<u>Wet Screening</u> <u><math>-\frac{1}{2}</math> plus 14</u>	<u>FLOTATION-14 plus 150</u> <u>Concentrate</u>	<u>Tailings</u>	<u>HEADS</u>
Tons per Acre Foot	707	181	325	506
Phosphoric Acid (P <sub>2</sub> O <sub>5</sub> )	27.58%	30.13%	3.20%	12.85%
B. P. L.	60.26%	65.83%	7.00%	28.07%
Iron & Alum. Oxides	1.91%	2.22%		
Insoluble	11.56%	4.00%	88.64%	58.31%

FLOTATION FEED

Ratio: Dry feed to dry recovered phosphate, flotation -14 plus 150 2.79 to 1.

Composition: Dry Concentrate 35.77%  
 Dry Tails 64.23%

10. Analyses of a 16 pound sample collected from bed 3 at Brooks Sink, Bradford County, see page 59. Near the top of this bed there are numerous pebbles of limestone. The inclusion of such limestone pebbles in the sample analyzed is a factor in the low BPL of the pebble fraction.

Weight of Matrix (wet) ----- 16.00 pounds

Weight of  $-\frac{1}{2}$  plus 14 phosphate (dry) ----- 3.75 pounds

CERTIFICATE OF ANALYSIS  
(DRY BASIS)

	<u>Wet Screening</u> <u><math>-\frac{1}{2}</math> plus 14</u>	<u>FLOTATION-14 plus 150</u> <u>Concentrate</u>	<u>Tailings</u>	<u>HEADS</u>
Tons per Acre Foot	399	108	322	430
Phosphoric Acid (P <sub>2</sub> O <sub>5</sub> )	21.81%	30.53%	3.20%	10.07%
B. P. L.	47.65%	66.71%	7.00%	22.01%
Iron & Alum. Oxides	2.13%	2.52%		
Insoluble	10.00%	4.00%	86.52%	65.77%

FLOTATION FEED

Ratio: Dry feed to dry recovered phosphate, flotation -14 plus 150 3.98 to 1.

Composition: Dry Concentrate 25.12%  
Dry Tails 74.88%

11. Analyses of a 10 pound sample collected from the top 2 feet of bed 1 at Brooks Sink in Bradford County, see page 59. This sample contained numerous limestone fragments as did sample number 10 on page 200.

Data available through the courtesy of the American Metal Company, Limited.  
 Chemical analyses run by Thornton & Company of Tampa, Florida.

Weight of Matrix (wet) ----- 10 pounds

Weight of  $-\frac{1}{2}$  plus 14 phosphate (dry)-- 3.00 pounds

CERTIFICATE OF ANALYSIS  
 (DRY BASIS)

	<u>Wet Screening</u> <u><math>-\frac{1}{2}</math> plus 14</u>	<u>FLOTATION-14 plus 150</u> <u>Concentrate</u>	<u>Tailings</u>	<u>HEADS</u>
Tons per Acre Foot	691	196	480	676
Phosphoric Acid (P <sub>2</sub> O <sub>5</sub> )	21.95%	30.15%	3.20%	11.03%
B. P. L.	47.96%	65.88%	7.00%	24.09%
Iron & Alum. Oxides	2.15%	2.75%		
Insoluble	8.56%	4.00%	86.25%	62.36%

FLOTATION FEED

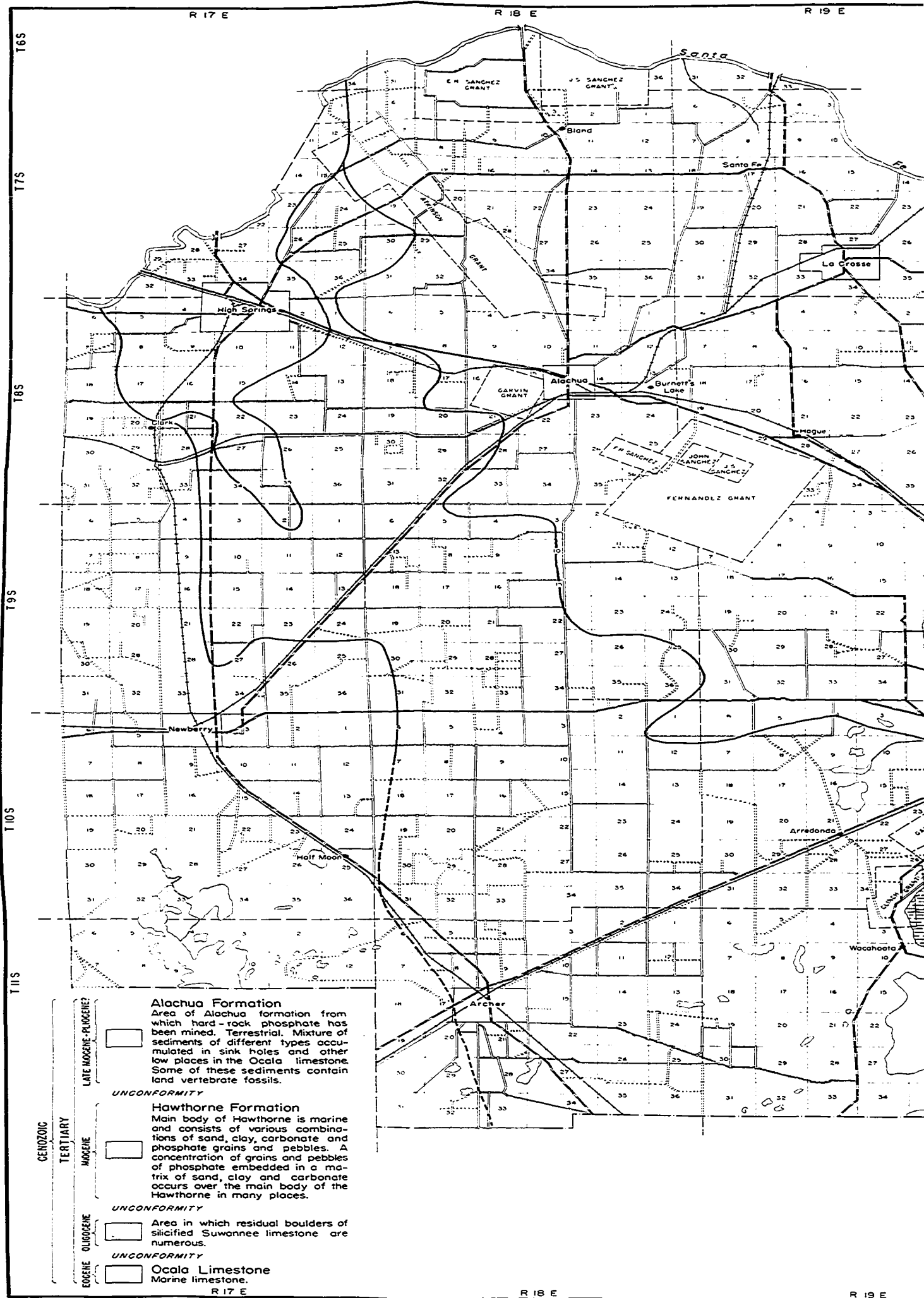
Ratio: Dry feed to dry recovered phosphate, flotation -14 plus 150 3.44 to 1.

Composition: Dry Concentrate 28.99%  
 Dry Tails 71.01%

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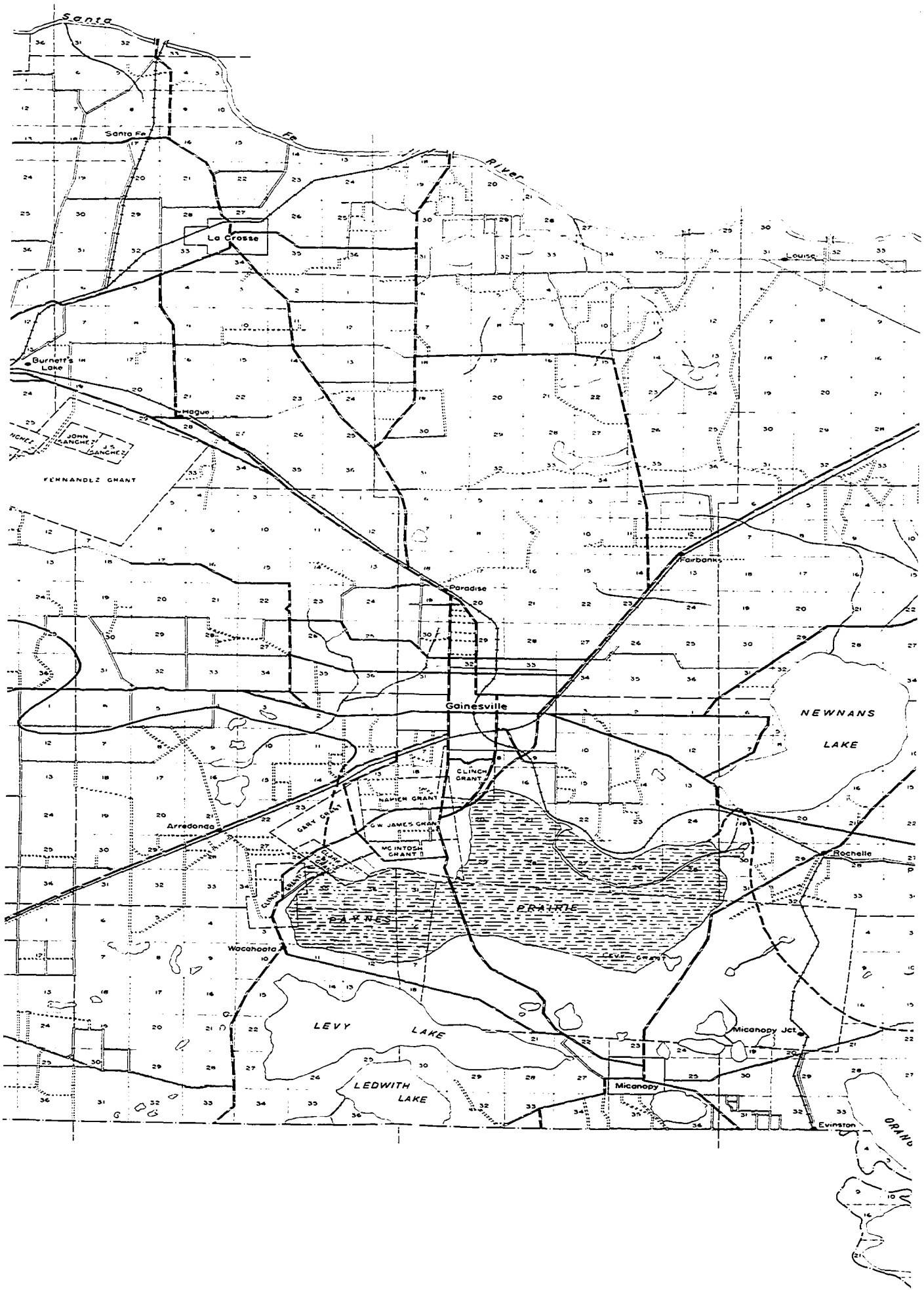


PLATE I  
 GEOLOGIC MAP OF CERTAIN  
 TERTIARY FORMATIONS IN  
 ALACHUA COUNTY, FLORIDA

Geology by E.C. Pirkle

Map shows the distribution of the tertiary formations discussed in the text as these formations would appear if younger sediments were removed. Base map taken from a map by Perry C. McGriff, Alachua County Surveyor.

