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FLORIDA GEOLOGICAL SURVEY

Herman Gunter, Director

REPORT OF INVESTIGATIONS NO. 16

MISCELLANEOUS STUDIES

TALLAHASSEE, FLORIDA

1958

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LETTER OF TRANSMITTAL

Florida Geological Survey

Tallahassee

December 5, 1957

Mr. Ernest Mitts, *Director*
Florida State Board of Conservation
Tallahassee, Florida

Dear Mr. Mitts:

I am forwarding to you a report entitled, MISCELLANEOUS STUDIES, which includes the following papers: "Geology of the Area in and Around the Jim Woodruff Reservoir" by Charles W. Hendry, Jr. and J. William Yon, Jr.; "Phosphate Concentrations near Bird Rookeries in South Florida" by Dr. Ernest H. Lund, Department of Geology, Florida State University; and "An Analysis of Ochlockonee River Channel Sediments" by Dr. Ernest H. Lund, Associate Professor and Patrick C. Haley, Graduate Assistant, Department of Geology, Florida State University.

These three papers contribute to our knowledge of the geology and economic resources of Florida and are being published as Report of Investigations No. 16.

Respectfully submitted,
Herman Gunter, *Director*

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GEOLOGY OF THE AREA IN AND AROUND THE JIM WOODRUFF RESERVOIR

By

Charles W. Hendry, Jr.

and

J. William Yon, Jr.

Florida Geological Survey

Tallahassee, Florida

1958

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ACKNOWLEDGMENTS

Dr. Robert O. Vernon, Assistant Director, Florida Geological Survey, assisted the writers many times in the field investigation and offered many helpful suggestions during the preparation of this report.

Staff members of the Florida Geological Survey offered assistance and advice during the course of the study. Special recognition is given to Mrs. Ruth Shuler and Miss Betty Youngblood for the time they spent typing and editing the report. Assistance was given by Mr. Kenneth Highsmith who helped in the preparation of the illustrations and maps.

Appreciation is expressed to the staff of the Resident Engineer's office, U. S. Army Corps of Engineers, Chattahoochee, Florida, for making available maps and elevations of the Jim Woodruff reservoir area.

Citizens of Jackson and Gadsden counties, Florida, and Seminole and Decatur counties, Georgia, were very cooperative and helpful.

Part I

GEOLOGY OF THE AREA IN AND AROUND THE JIM WOODRUFF RESERVOIR

INTRODUCTION

PURPOSE AND SCOPE OF STUDY

In December 1953 Vernon, Hendry, and Yon[1] made a study of the outcropping Tertiary sediments along the lower portions of the Chattahoochee and Flint rivers in the area of the Jim Woodruff reservoir. This investigation was conducted prior to the conclusion of the Jim Woodruff Dam project. The completion of this dam has created a 37,000-acre lake which has masked from future investigations much of those sediments that were previously exposed in the area. This study along the rivers brought to light inconsistencies in the present concept of the geology of this area and the writers thought it wise to undertake a more thorough investigation of the surface geology.

The data collected through the study of surface exposures were supplemented by examination of cuttings from three oil test wells and six water supply wells that were drilled in the area and samples from three core holes which were obtained from the field office of the U. S. Army Corps of Engineers, Chattahoochee, Florida. The absence of samples from a sufficient number of wells to give a good coverage influenced the writers to put down 17 auger holes in locations where little or no subsurface information was available.

This report presents the results of the studies on the geology in and around the Jim Woodruff reservoir that have been conducted intermittently since December 1953.

LOCATION

The area of this investigation is located in southwest Georgia, Decatur and Seminole counties, and in the adjoining portions of Jackson and Gadsden counties, Florida. It is roughly rectangular in shape, bounded by 30°40′ and 31°00′ north latitude and 84°30′ and 85°00′ west longitude. The east-west dimension is approximately 30 miles, and the north-south dimension is approximately 20 miles (fig. 1). The investigation was confined principally to the area between and around the Chattahoochee and Flint rivers.

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[1] Dr. R. O. Vernon, Assistant Director, C. W. Hendry, Jr. and J. W. Yon, Jr., Geologists, Florida Geological Survey.

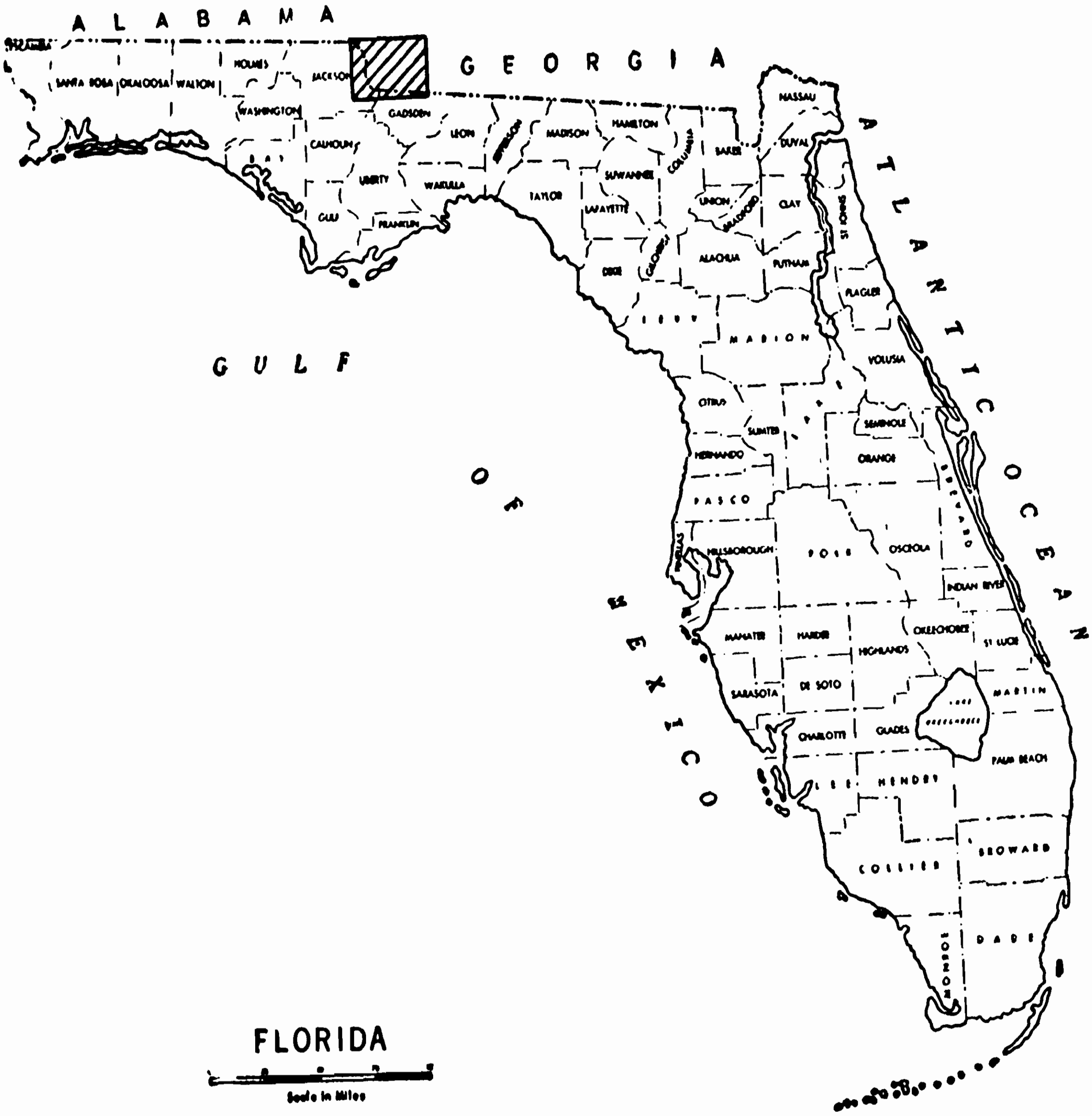

Figure 1. Map showing location of the area in and around the Jim Woodruff reservoir.

THE JIM WOODRUFF LOCK AND DAM

For nearly half a century Mr. Jim Woodruff, Sr., of Columbus, Georgia, sought development of the Apalachicola, Chattahoochee, and Flint rivers for navigation. In tribute to Mr. Woodruff's persistence, the first of the projects in the plan for improving these rivers was named the Jim Woodruff Lock and Dam. This project was authorized as a part of the River and Harbor Act of July 24, 1946, and was dedicated in 1957.

The dam is located northwest of Chattahoochee, Florida about 300 yards below the point where the Chattahoochee and Flint rivers unite to form the Apalachicola River. The normal level of the water in the reservoir is at an elevation of 77 feet with the tailwater at 44 feet.

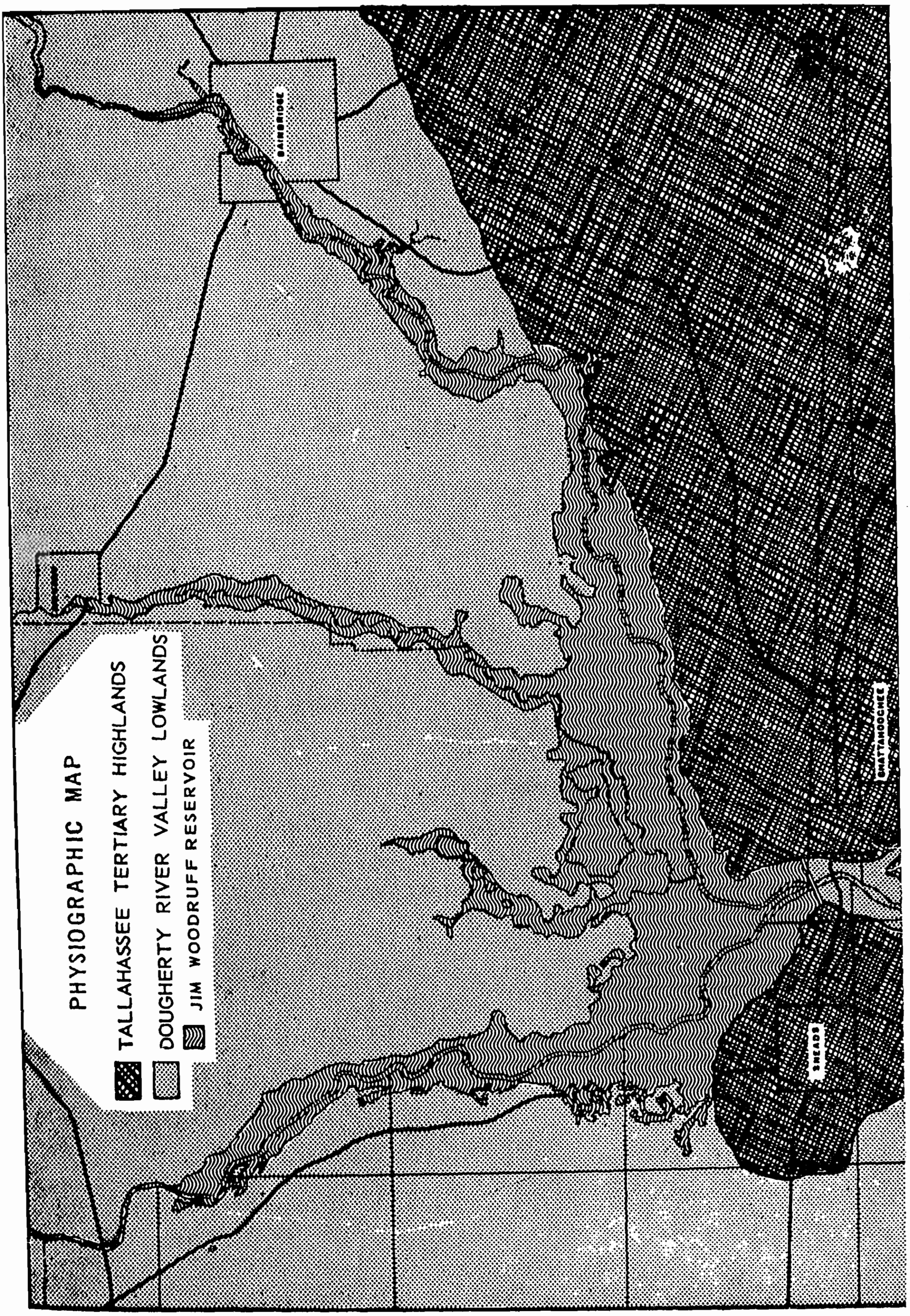

Figure 2. Physiographic map of area in and around the Jim Woodruff reservoir.

This dam provides channels, nine feet deep and 100 feet wide, in the Chattahoochee River to Columbia, Alabama, and in the Flint River to Bainbridge, Georgia. In addition to this navigational facility, the dam, having a shoreline of 243 miles, provides an area for recreational activities such as boating, camping, fishing, picnicking, and sightseeing (U.S.C.E. Pamphlet, 1953).

PHYSIOGRAPHY

INTRODUCTION

The sediments studied in this investigation lie within the East Gulf Coastal Plain, a subunit of the Coastal Plain Province (Fenneman 1938, p. 65-68). The recognizable physiographic subdivisions of this area were mapped as: (1) the Tallahassee Tertiary Highlands, and (2) the Dougherty River Valley Lowlands (fig. 2).

On the basis of origin, Vernon (1951, p. 16), subdivided the physiography of Florida into two general groups, each of which is subdivided into two units. These are the *Delta Plain Highlands,* the *Tertiary Highlands,* the *Terraced Coastal Lowlands,* and the *River Valley Lowlands.* He defined his highlands as sediments formed either as a part of a high-level, widespread, aggradational delta plain or of Tertiary land masses rising above this plain, and his lowlands as being formed by marine erosion and deposition along coastlines and by alluviation and stream erosion along stream valleys. Vernon proposed that where these subdivisions are mapped, local names may be appropriately applied.

TALLAHASSEE TERTIARY HIGHLANDS

The topography and composition of the Tallahassee Tertiary Highlands is considerably different from that of the surrounding terrain. The area abruptly rises 200 to 250 feet above the adjacent lowlands and the excellent soils developed on the highlands support lush, natural vegetation and give rise to many prosperous farms.

The Tallahassee Tertiary Highlands are characterized by erosional-remnant hills with relief up to 250 feet, except in the northwestern part of Gadsden County and in the adjoining southwestern portion of Decatur County, Georgia, where the highest hills are comparatively flat-topped with elevations slightly exceeding 300 feet. Because of the flat crests, remnant drainages and depositional sequences, these hills are interpreted as remnants of the original depositional surface of the Hawthorn delta. To the west, south and east of this flat-topped section, the cycle of erosion is more advanced, having reduced the highlands to a lower, more dissected topography. The highlands are composed of sands and clays of the Hawthorn formation with impure limestone of the Chattahoochee formation cropping out along the bluffs of the major streams, in road cuts, in small stream valleys, and in sinks that penetrate through the Hawthorn.

Descriptions of portions of the Tallahassee Tertiary Highlands area are numerous in the literature. Not until Cooke (1939, p. 14-21) divided the State into five physiographic divisions, was most of this highlands area grouped together and named.

Cooke (1939, p. 20) applied the name Tallahassee Hills to an area, approximately 25 by 100 miles, delineated by the Georgia-Florida state line on the north, the coastal lowlands on the south, and the Withlacoochee and Apalachicola rivers, respectively, on the east and west. He described the area as being characterized by long gentle slopes with rounded summits, the highest part of which is believed to be a plain with a maximum elevation of about 300 feet in the vicinity of northwestern Gadsden County. Cooke stated the geologic composition of these "hills" was impure limestone of the "Tampa limestone" overlain by the sands and clays of the Hawthorn formation. Later (1945, p. 9-10), he assigned the red surface sands to the Citronelle formation and the underlying sandy clays and clays to the Hawthorn formation.

Vernon considered that his definition of Tertiary highlands included Cooke's Tallahassee Hills, which he thought to be a general term and proposed the local name Tallahassee Tertiary Highlands, as more appropriate. The writers, conforming to Vernon's "locality-origin" terminology, have adopted the term Tallahassee Tertiary Highlands to include Cooke's Tallahassee Hills as bounded on the south and east, but extended on the west into Jackson County, Florida, and north into Decatur County, Georgia, where it is bounded by an escarpment facing the Dougherty River Valley Lowlands.

That part of the Tallahassee Tertiary Highlands in southeastern Jackson County, Florida, has been disjoined from the eastern part by the Apalachicola River. Previous investigators have found little dispute in assigning the sandy limestones underlying this highlands area to the lower Miocene; however, the capping clastics west of the Apalachicola River in Jackson County have been disassociated from the similar Miocene deposits on the eastern side of the river and generally assigned to the Pleistocene series in previous literature. The writers find no material lithologic differences in the clastics of these two areas and therefore include these western hills in their Tallahassee Tertiary Highlands. Also, it is the impression of the writers that the northern limits of the highlands should exceed Cooke's political boundary limit, the Gadsden-Decatur county line (Florida-Georgia state line), and be extended to the northward-facing escarpment overlooking the Flint River valley, a part of the Dougherty River Valley Lowlands.

DOUGHERTY RIVER VALLEY LOWLANDS

The Dougherty River Valley Lowlands is the largest physiographic unit in the area, consisting of sediments at relatively low elevations which occur north and west of the Tallahassee Tertiary Highlands. In

1911, Veatch (p. 30-31) applied the name Dougherty Plain to the lowlands of southwestern Georgia. In 1938, Fenneman (p. 76-77) expanded the term to include that portion of Florida which was later called the Marianna Lowlands by Cooke (1939), p. 18-19). Moore (1955, p. 6-8), using Vernon's terminology based on origin, called Cooke's Marianna Lowlands the Marianna River Valley Lowlands. Since the largest portion of the lowlands of this report is a part of Veatch's Dougherty Plain, the writers have used the term Dougherty River Valley Lowlands for this geomorphic unit.

The area assigned to the lowlands includes the flood plains and terraces of the present Apalachicola, Chattahoochee and Flint rivers, and also the topographically low area in Jackson County which is probably the result of ancestral streams of the Choctawhatchee and Chattahoochee river systems. Moore (1955, p. 7) briefly discusses the agencies forming these lowlands.

This westward extension has been traced through Jackson County into Holmes County by Moore (1955, p. 8, 13, 14) to where it joins the flood plains of the Choctawhatchee and Holmes rivers (Vernon 1942, p. 5-6) in Holmes and Washington counties. The sediments are clastics ranging in size from clays to large silicified boulders measuring up to 15 feet across (see Flood Plain, p. 13).

MAJOR STREAMS

There are portions of three major streams flowing within the area of this investigation. Two of these streams, the Chattahoochee and the Flint rivers, originate from outside the area, having their headwaters in the piedmont of northern Georgia. The third major stream, the Apalachicola River, has its headwaters within the area of this investigation, being formed by the confluence of the Chattahoochee and Flint rivers.

The channel banks of the Chattahoochee and Flint rivers are exceptionally steep for rivers as old and as well established as they appear to be, when compared to streams elsewhere in Panhandle Florida.

Northward in Georgia and Alabama, tributary streams join the Chattahoochee with valley floors standing much higher and out of adjustment at their point of confluence with the Chattahoochee. This evidence would indicate rejuvenation of the Flint and Chattahoochee system in the late Pleistocene or Recent.

Chattahoochee River

The Chattahoochee River flows southward near the western edge of the area. This stream is heavily laden with suspended sediment, as is evidenced by its turbidity and red color. It is an active river with a gradient of about 0.65 foot per mile in the lower 26 miles. Only at locality 34 do silicified boulders constrict the channel, a marked contrast to the Flint River channel, which is strewn with boulders and obstructed by boulder bars that create a definite hazard to river travel, especially during periods of low water.

Flint River

The Flint River flows southward along the eastern boundary of the area and is deflected westward by the high scarp along the north edge of the Tallahassee Tertiary Highlands. In contrast to the Chattahoochee River it carries much less load in suspension. This is readily noticeable at their confluence where, for some distance down the Apalachicola River, the discharge from each river is easily distinguishable by the color.

The Flint River has a gradient of approximately 0.55 foot per mile for the lower 26 miles. Rapids and islands of boulders or bedrock of silicified limestone of Eocene and Oligocene age are not uncommon in the area from locality 52 (Lamberts Island) to the northern limit of the area.

Apalachicola River

The Apalachicola River, formed by the union of the Chattahoochee and Flint rivers about one mile northwest of the town of Chattahoochee, Gadsden County, Florida, flows southward and empties into the Gulf of Mexico at Apalachicola, Florida. Only about five miles of this river lies within the area covered by this report. However, the writers feel it has played an important part in the evolution of the present landforms, and is, therefore, discussed more fully under stream capture.

Flood Plain

The deposits comprising the flood plains of the Chattahoochee and Flint rivers range in thickness from a thin veneer to over 80 feet. Near the Alabama state line, ledges of bedrock visible at stages of low water underlie 20 or 30 feet of flood-plain sediment which was deposited in a more shallow part of the valley. Two auger holes located about one mile west of the right bank of the Chattahoochee River (see auger hole localities AS-242[2] and AS-244) penetrated 80 feet of sand and pea-size gravel with small amounts of clay without reaching bedrock. At auger hole locality AS-243, a depth of 71 feet was reached before bed-

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[2] Florida Geological Survey auger sample numbers.

rock was encountered. This alluvium was deposited in deep abandoned channels probably formed in an older Chattahoochee system which were cut during a preceding interglacial period and subsequently filled.

The flood plain along the left bank of the lower section of the Chattahoochee River merges with that of the Flint River, giving a broad relatively low area between the two rivers in this region. Within this broad low area, auger holes AS-246, AS-247 and AS-249 did not penetrate bedrock at depths of 73.5, 67.5 and 73.5 feet, respectively; whereas, bedrock was reached in holes AS-248, AS-250 and AS-251 at depths of 63, 26 and 70 feet. This varying thickness of alluvium points up the highly eroded surface of the bedrock.

Natural Levees

Natural levees are present along the Apalachicola, Chattahoochee and Flint rivers. These natural levees are formed during flood stages of the rivers. As the high water rises above the confines of the channels and flows onto the flood plain, its velocity is sharply decreased and the increased load, transported by the higher velocity, is largely deposited immediately adjacent to the streams. At the time the field work was done, the flood plains of the Chattahoochee and Flint rivers had been cleared as part of the project of preparing the reservoir. The removal of trees and brush had exposed the levees over a wide vista and they were easily identified. Toward the upper limits of the reservoir, where the levees stand higher than the cleared, adjacent part of the flood plain, they are marked by elongated wooded islands and strips.

Rim Swamps

Natural levees, normally the highest part of any flood plain, slope gently toward the base of the valley walls, and low marginal areas are present along the base of the escarpment rising above the flood plain. During the wet season, when the ground-water level rises high enough, these low marginal areas become swampy and are termed rim swamps. As the local irregularities (basins) in the rim swamp area become full to overflowing, the drainage collects in a stream, called a rim swamp stream, which forms along the base of the valley wall (Russell 1938, p. 72-73).

Rim swamps are common along the flood plains of the streams within the area. Vernon (1942, p. 8) described rim swamp streams along the marginal valleys of the Choctawhatchee River in central Holmes County; however, rim swamp streams are not sharply delineated in the reservoir area.

Terraces, deposited as flood plains, have these same aggradational features. The higher terraces, having been subjected to erosion for a longer time, have fewer, if any, recognizable aggradational patterns preserved; whereas, the younger terraces still possess excellent examples. On the lower terraces, the marginal areas are marked by sinkhole alignment.

Tributary Streams

In the area of this investigation, the Flint River has five tributaries only one of which could be considered a major tributary. The major tributary, Spring Creek, originates about 10 miles southeast of Fort Gaines, Georgia, and flows southward to its junction with the Flint River. It is a very sluggish stream in its lower reaches, the channel being drowned and in many stretches unidentifiable through swamp vegetation. The stream carries almost no sediment, but is darkly colored by organic acids. It is locally reported that this stream is partially spring fed. The mouth of Spring Creek is obscured by cypress trees, giving the appearance of a drowned swampy area along the Flint River.

Butlers, Sanborn and Fourmile creeks, and Big Slough, are the four principal small tributary streams of the Flint River. All of these streams are located along the left side of the Flint, and contrary to the small tributaries of the lower Chattahoochee River, they are in adjustment at their point of confluence with the Flint. They drain relatively small areas, having an average length of only a few miles.

Butlers and Sanborn creeks originate in the Tallahassee Tertiary Highlands of southern Decatur County, Georgia. They flow northward and join the Flint River at the base of the northward facing highlands escarpment. Fourmile Creek and Big Slough originate in the Dougherty River Valley Lowlands and trend in a westerly direction, uniting with the Flint near the town of Bainbridge, Decatur County, Georgia.

The small segment of the Apalachicola River covered in this report has only one tributary. This is Mosquito Creek which drains the area northeast, east, and south of the town of Chattahoochee and enters the Apalachicola in the southern part of the area of this investigation.

There are no principal tributaries of the Chattahoochee River below the Alabama-Florida state line; however, mention has been made above of the tributaries of the Chattahoochee just north of this area.

Stream Terraces

The first published account of stream terraces in Florida was by Vernon (1942, p. 9-15). He reported four definite levels above the present flood plains of all the major streams in Holmes and Washington counties, Florida. Prior to Vernon's work on stream terraces in West Florida, H. N. Fisk (1938, 1939, 1940) reported on the occurrences of stream terraces in Louisiana. The reader is referred to these two workers' reports for a discussion on the origin and description of stream terraces.

Jim Woodruff Reservoir Area: The writers found four areally defined levels associated with stream-cut scarps bordering the Chattahoochee and Flint rivers. These four fluvial surfaces occur above the modern flood plain at heights of 10, 40, 60 and 90 feet. To substantiate the number of existing terraces and their heights above the flood plain the writers compiled, normal to the river axis, many land-surface profiles using U. S. Geological Survey topographic quadrangles and aneroid elevations taken in the field. Figure 3 represents a reconstructed composite of the terrace surfaces associated with the Chattahoochee and Flint rivers.

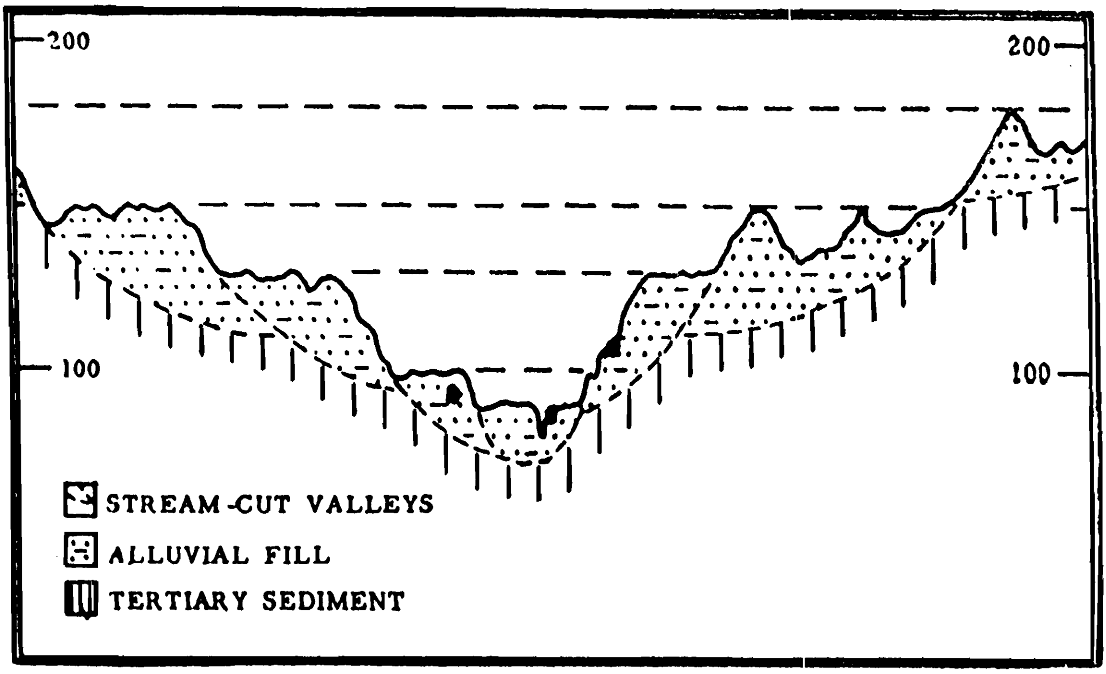


Figure 3. Generalized and diagrammatic profile across the Chattahoochee River Valley in Jackson County, Florida and Seminole County, Georgia.

Two terrace surfaces above the flood plain of the Flint River consistently show up in profiles drawn across the valley. These fluvial surfaces occur at 10 and 40 feet. Between these two levels there occur several levels at varying altitudes that may be traced only for short distances. They very probably are attributable to erosion and perhaps to rejuvenation of the river by stream capture.

Erosion and probably stream course change have so altered the land surface in this area that the highest terrace is not as well preserved in Jackson County, Florida, as it is in Seminole County, Georgia. Only sparsely scattered hilltops in the northern part of Jackson County reach this level, whereas in Seminole County the average elevation exceeds 160 feet with some hills reaching 180 feet. As this is the only level that doesn't fit into the system described by Vernon (1942) there is a possibility that the few remaining hilltops that mark this level were once higher and are now uniformly eroded to 90-100 feet above the modern flood plain.

The 60-foot level is extensively developed in central and northern Jackson County, but it is less distinguishable in Georgia because of the shorter areal distance between the lower terraces and the 90-foot level.

The 40-foot level is conspicuously developed along both the Chattahoochee and Flint rivers. In addition to the many flats which represent this terrace surface there are also many hilltops at this altitude that help substantiate the level.

In the vicinity of the juncture of the Chattahoochee and Flint rivers the 10-foot terrace is broadly developed but now flooded by the Jim Woodruff reservoir. Upstream this terrace narrows considerably, rarely exceeding two miles in width.

The stream terraces are very poorly defined or absent along the left side of the Flint River from Southlands Ferry to the dam. The presence of the steeply sloping, high Tertiary escarpment immediately to the left of the river makes identification of terrace levels impossible.

That section of the Apalachicola River covered in this report is bounded on each side by fairly high Miocene hills. There are no hilltops or extended flats that correspond to the levels described above that occur above the modern flood plain. The presence of only a recent flood plain indicated that the river did not occupy this course during the time the terraces were being formed (see Stream Capture).

STREAM CAPTURE

Paralleling the western edge of the Tallahassee Tertiary Highlands in Jackson County, Florida, is a broad, terraced, shallow valley which is characteristic of a flood plain commensurate with a system comparable to the Chattahoochee and Flint rivers. The western side of this valley is bounded by high Pleistocene clastic sediments. The valley trends in a north-south direction and merges at its southern end with the lowlands associated with the present Apalachicola River flood plain in the vicinity of northern Calhoun County. Its northern limit joins the lowlands associated with the Chattahoochee River lowlands, now inundated by the Jim Woodruff reservoir.

There are no perennial streams in the valley at the present time, but small tributaries of the Apalachicola River are present at its southern extremity. Most of the valley is drained by sinks and during periods of heavy rainfall and high water-table level the many ponds and swampy areas are connected by intermittent streams.

Moore (1955, p. 13) reports a buried stream channel in north central Jackson County that extends in a north-northeast direction into Alabama towards the Chattahoochee River. Along the right side of the Chattahoochee River, the depth to bedrock, as determined by auger holes, would indicate that formerly the Chattahoochee was several miles to the west of its present course. The writers believe that this river flowed through the remnant valley described above. If this is true, the Flint River would have extended beyond its present entry into the highlands to a point of juncture with the Chattahoochee several miles north or northwest of the town of Sneads (fig. 4-1).

Four and one-half miles north of the Jim Woodruff Dam the direction of the southward trending Chattahoochee River veers sharply to the left for approximately one mile and then again southward (right) to where it joins the Flint River. The axis of this jog in the river is in perfect alignment with the Flint River where it flows along the base of the high escarpment which marks the northern limits of the Tallahassee Tertiary Highlands. Because the location of this jog is not controlled by the high Miocene hills and because there is an exact alignment with the Flint River channel, it is possible that the jog may represent a portion of a former extension of the Flint River which drained to the west.

The geomorphic conditions that exist in the Chattahoochee-Sneads area at the present time strongly suggest the possibility of stream capture in the late Pleistocene or early Recent time. The relationship of the Apalachicola River with the Flint and Chattahoochee rivers indicates that the Apalachicola has advanced its headwaters northward into the high Miocene sediments and diverted the Chattahoochee and Flint rivers (fig. 4-2).

The Apalachicola, because of its steeper gradient along the southwestern edge of the Tallahassee Tertiary Highlands, cut back through these highlands into the drainage area of the Flint and Chattahoochee rivers. This stream capture caused a change in the direction of flow of these rivers at the point of capture (fig. 4-2).

The Flint River diverted by the captor stream, the Apalachicola River, now turns sharply at the point of capture, exhibiting a well-defined elbow of capture. The increased volume of the Apalachicola River after the capture of the Flint River allowed rejuvenation to enlarge the valley through the Tallahassee Tertiary Highlands.

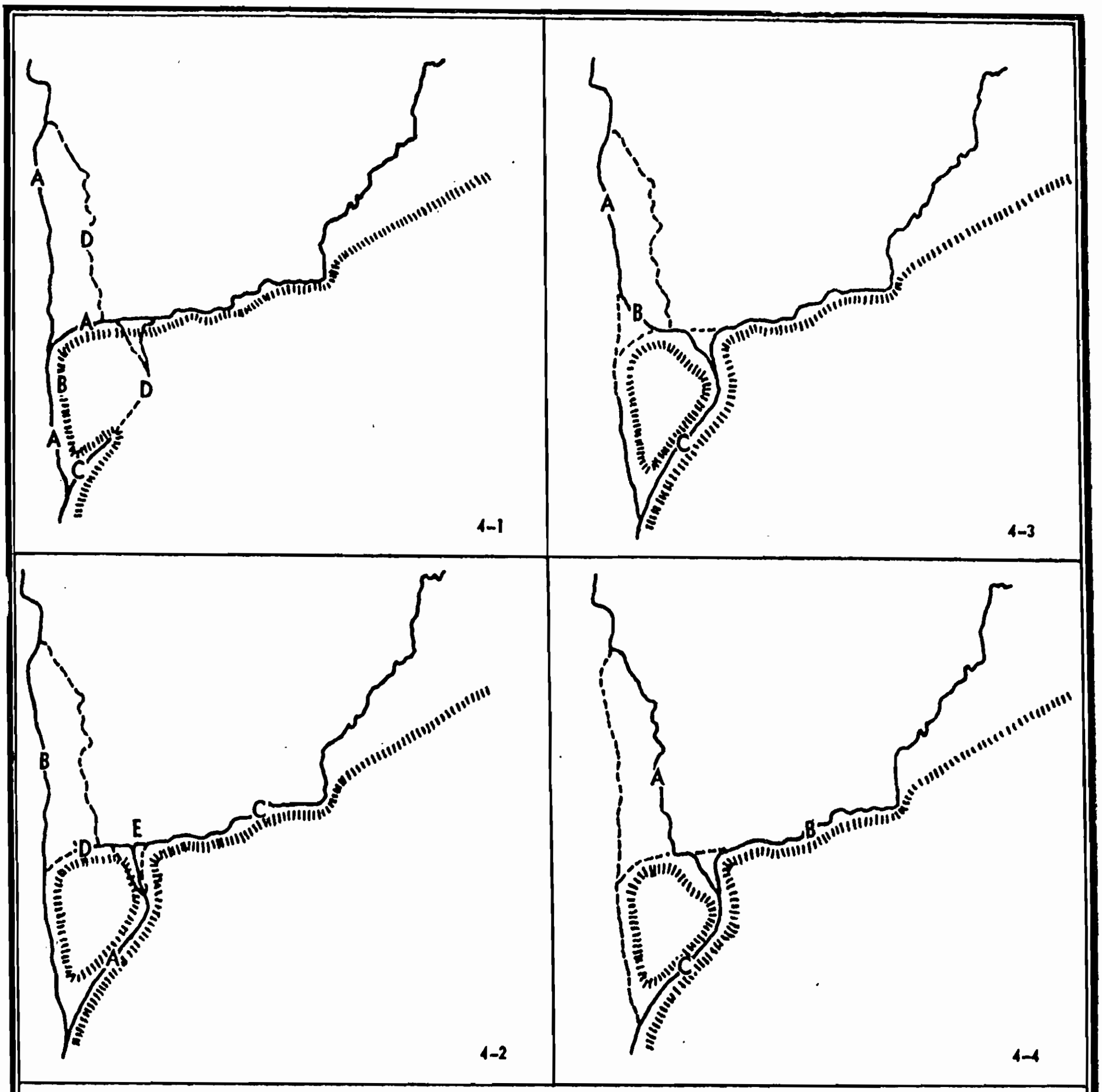


Figure 4. Four diagrammatic panels illustrating progressive stages in the stream capture of the Chattahoochee and Flint rivers by the Apalachicola River.

4-1. Hypothetical courses of the Chattahoochee and Flint rivers (A) which flowed around the Tallahassee Tertiary Highlands, the northern and western limit of which is shown by the hachured line (B). At this stage the Apalachicola River (C) was a small tributary to the Chattahoochee River and had just begun to cut headward into the highlands. The dashed line (D) represents the most recent courses of the three rivers.

4-2. The Apalachicola River (A), still tributary to the Chattahoochee River (B), has cut headward through the Tallahassee Tertiary Highlands and captured the Flint River (C). The captured stream (C) has been diverted by the captor stream (A) and now turns sharply at the point of capture (E), exhibiting a well-defined elbow of capture. The beheaded portion of the Flint River (D) has turned back into the captor stream, and thus has been transformed into an inverted stream.

4-3. The Chattahoochee River (A) has been diverted by the enlarged inverted stream (B). The combined flows of the Chattahoochee and Flint rivers rapidly enlarged the youthful valley of the Apalachicola River (C).

4-4. This panel illustrates the positions of the Chattahoochee (A), Flint (B), and Apalachicola (C) rivers just prior to the erection of the Jim Woodruff Dam. The dashed lines represent the former courses of the Chattahoochee and Flint rivers.

The Chattahoochee River, having lost most of its volume after the capture of the Flint, became a misfit stream. Probably the smaller tributaries, below the old point of juncture with the Flint River, built alluvial fans on the valley floor because the Chattahoochee could no longer transport the customary load. Lakes and marshes probably formed, and, subsequently, the development of sinks along this valley captured what surface drainage remained.

The writers believe that in the region south and southwest of the Tallahassee Tertiary Highlands the Apalachicola River now occupies or is closely associated with the former Chattahoochee River valley. The development of sinks along the valley to the west of Sneads has captured the surface drainage along this valley and the deposition of clastic sediments derived from the greatly dissected highlands on each side of the valley has caused the Chattahoochee to be deflected to the point of confluence with the Flint and Apalachicola rivers.

STRUCTURE

CHATTAHOOCHEE ANTICLINE

The largest geological structure occupying the region in southwestern Georgia, southeastern Alabama, and the adjoining portion of Florida is the Chattahoochee anticline. This broad flexure was first suggested and named by Veatch (1911, p. 62-64). He observed local disturbances of Cretaceous and Eocene beds along the Chattahoochee River and noticed inequalities in the drainage divides of the Chattahoochee and Flint rivers. Veatch reasoned that the shorter tributary streams of the much larger Chattahoochee River were developed along the crest of an anticline, whereas the longer tributaries of the Flint flowed down the eastern flank of the anticline. His interpretation of the somewhat parallel courses of the rivers was that the Chattahoochee flowed southward along the crest of the anticline and that the Flint flowed down the trough of a broad syncline complementary to this anticline.

Veatch noted that the much greater depth of the Chattahoochee valley and steepness of the channel walls indicated a greater magnitude of earth movement along the Chattahoochee than along the other rivers in the region.

A press release issued by the Federal Survey in 1917 stated that the available evidence was not adequate to substantiate this anticline.

Prettyman and Cave (1923, p. 107-111) did not believe that the geological evidence indicated crustal folding of the magnitude implied by Veatch in his description of the Chattahoochee anticline. In their opinion, it pointed only to gentle regional Pleistocene or later movement with some local reversals in dips.

Stephenson (1928, p. 295) in a description of local flexures in the coastal plain monocline, agreed that an anticline in this area existed, and dated (1928a, p. 892) the movement that caused this crustal disturbance as late Tertiary or early Quaternary.

In 1929 George I. Adams (p. 201-202) published a report on his investigation of the streams of the coastal plain of Alabama in which he stated he had examined the area of the Chattahoochee anticline and did not believe the geological facts supported the existence of this anticline.

Postley (1938, p. 809-810) presented a paper on the oil and gas possibilities in the Atlantic Coastal Plain and included the Chattahoochee anticline in his discussion on structure.

Leet (1940, p. 875) recognized the existence of the Chattahoochee anticline and described it as a broad upwarp with its axis trending along the Georgia-Alabama state line.

Cooke (1943, p. 4-5) explained the difference of the greater number of exposed geological formations along the Chattahoochee River as compared to the Ocmulgee and Savannah rivers as the result of progressive overlay which indicated a progressive uplift of that part of the coastal plain of Georgia.

An upwarp in the vicinity of Jackson County, Florida, was one of several structural features in the subsurface of Florida and southern Georgia described by Applin and Applin (1944, p. 1727).

The first deviation from the term Chattahoochee as a place-name for the uplift seems to have been made by Pressler (1947, p. 1852, fig. 1). He made no mention nor included any discussion of the upwarp in the text of his article; however, he did use the name Decatur Arch for the area of the uplift on the text figure which accompanied his article.

Applin (1951, p. 407) and Gunter (1953, p. 42, 48) continued the use of the term Decatur Arch.

Jordan (1954) recognized the priority of the term Chattahoochee and applied it in a discussion of the structure of the area. Toulmin (1955, p. 209-210) used the term Chattahoochee anticline in preference to Decatur Arch.

LINEAR TRENDS

Vernon (1951, p. 47) first recognized large scale fracturing in the subsurface of Florida and mapped these fractures from their physiographic expressions as shown on mosaics of aerial photographs. In Citrus and Levy counties the regional fractures parallel the axis of the Ocala uplift with a northwest-southeast trend. This system of fracturing is crossed by a secondary system which trends in a northeast-southwest direction. Vernon reports that stream patterns commonly parallel these two systems of fracturing.

Rectangular stream patterns have been reported in Jackson County by Moore (1955, p. 15-16). He stated that this pattern observed along the Chipola River and Dry Creek suggests a control by fracturing. He reports a similar pattern in west central Jackson County of the creeks that flow on alluvium 30 to 100 feet thick.

Examination of large scale prints made from aerial photographs of the Jim Woodruff Dam area shows a linear relationship existing among certain portions of the courses of the Flint and Chattahoochee rivers (fig. 5). The scarcity of well and core hole samples prevented the preparation of detailed geologic sections; the identification of fracturing

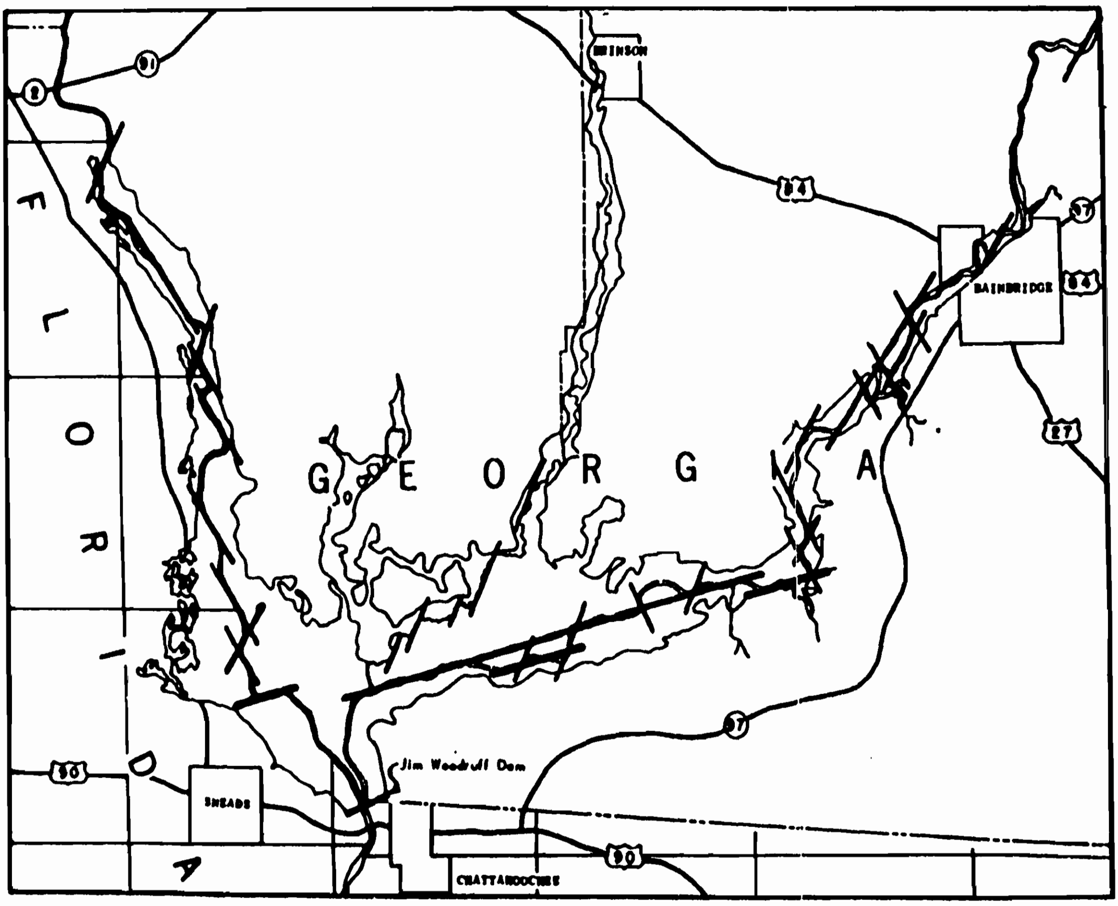


Figure 5. Map showing linear trends along the Chattahoochee and Flint rivers.

in relation to such linear trends, without the aid of detailed geologic sections, was impossible. However, the linear trends are closely similar to trends associated with fracturing reported by Vernon and Moore. There is a possibility that fracturing has resulted from the Chattahoochee anticline, and that the linear trends in the Chattahoochee and Flint rivers may be the result of fractures in the bedrock that extend through the alluvium.

STRATIGRAPHY

INTRODUCTION

The surface formations in the area of the Jim Woodruff Dam reservoir range in age from upper Eocene through Recent. The bedrock is composed of the Crystal River formation, Jackson Stage, in the northern part; the Oligocene, Suwannee limestone, in the central section; and the Chattahoochee facies, Tampa Stage, in the southern part. The clastics that mantle the bedrock in the northern and central parts are of Pleistocene and Recent age and the clastic Hawthorn formation of the Alum Bluff Stage, overlies the bedrock in the southern part of the area.

TERTIARY SYSTEM

EOCENE SERIES

JACKSON STAGE

OCALA GROUP

CRYSTAL RIVER FORMATION

Historical: The early history of the terms upper Eocene, Jackson group and "Ocala limestone," has been adequately discussed by Vernon (1942, p. 40-41) and Cooke (1945, p. 53). The Applins (1944, p. 1683-84) separated the Ocala limestone in peninsular Florida into an upper and lower member. Vernon (1951, p. 111-112) divided the Ocala limestone into two formations, the "Ocala limestone" (restricted) for the upper portion and the Moodys Branch formation for the lower portion. He further subdivided the Moodys Branch formation into a lower Inglis member and an upper Williston member.

Puri (1953, p. 130; 1957, p. 31) proposed the term Crystal River formation to replace the term "Ocala limestone" (restricted) of Vernon. He abandoned the name Moodys Branch formation of Vernon and raised the Williston and Inglis members of the Moodys Branch to formational rank.

Distribution: The oldest rocks cropping out in the area of this investigation are those of the Crystal River formation (fig. 6). The formation is exposed along the banks of the Chattahoochee and Flint rivers from the northern boundary of the area to about the center of this region where it dips under younger sediments. Completely silicified limestone, occurring as boulders and possibly pinnacles throughout the northern two-thirds of the area, contain Ocala fossils and, although the boulders are incorporated in clastics ranging in age from Pleistocene to Recent, they were probably derived from a former greater areal extension of the Crystal River formation.

Lithology: The Crystal River formation is predominantly a white to cream, soft to hard, porous to dense, crystalline, marine, generally friable, coquinoid limestone composed chiefly of foraminifers, bryozoans and mollusks. The formation has been locally replaced by silica to form a white to reddish-brown, hard, moldic (porous) crystalline to occasionally chalky, fossiliferous mass of chert with occasional zones of dense chert. During silicification the tests of the smaller microfauna were almost entirely destroyed and those retained are rarely identifiable. The larger microfossils are generally retained as molds and casts, and can usually be identified generically, but seldom specifically.

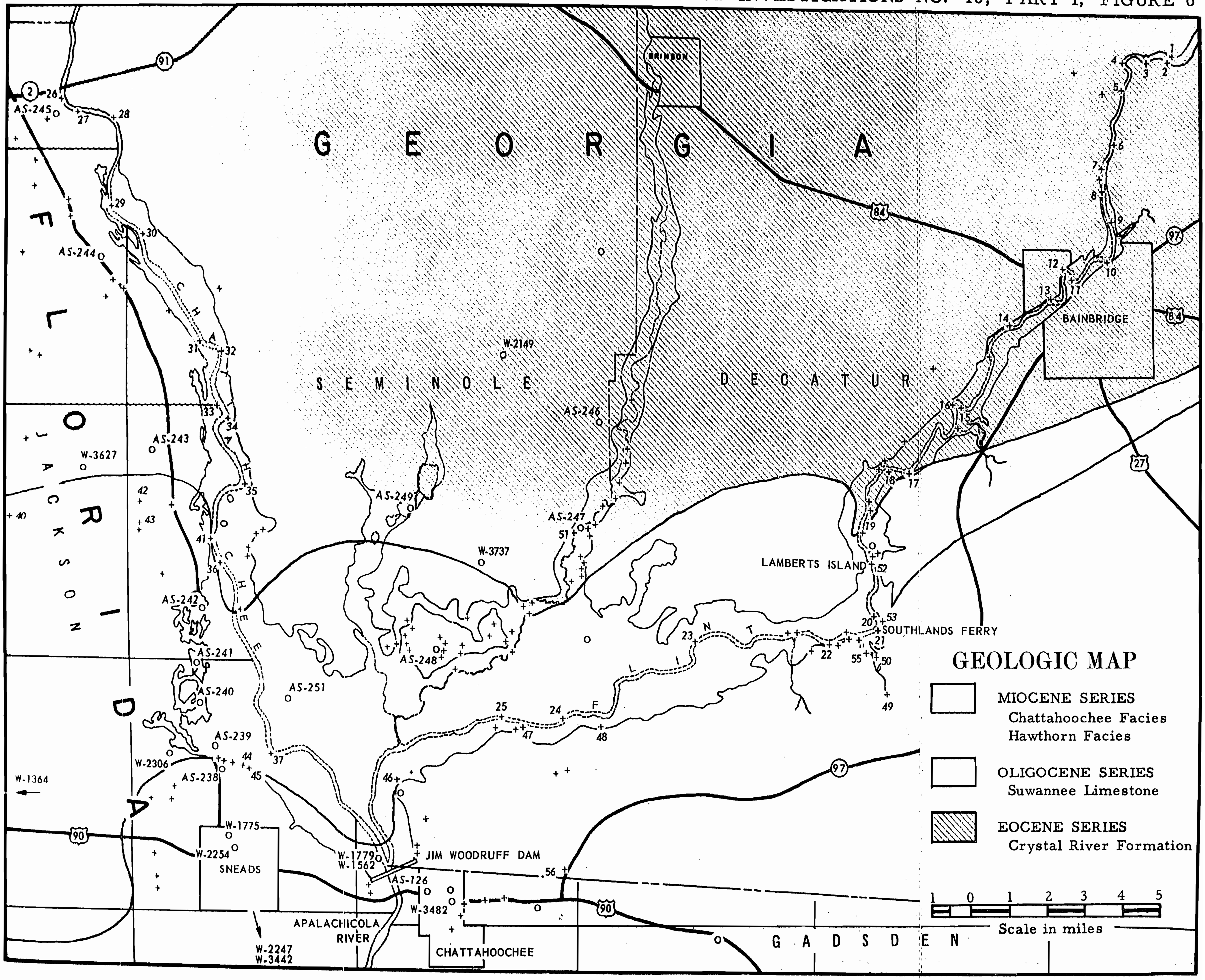
Thickness and Structure: The complete thickness of the Crystal River formation is not exposed in the area of this investigation. However, in Jackson County, Florida, Puri (personal communication, 1955) reports the Crystal River formation to be about 300 feet thick.

The top of the Crystal River formation as determined from exposures and well cuttings in Decatur County, Georgia, and in extreme eastern and southeastern Jackson County, Florida, indicates that the Crystal River dips south-southeast at approximately 17 feet per mile.

Stratigraphic Relationship: In the northern half of the area, the Crystal River formation is overlain unconformably by Pleistocene to Recent clastics which contain silicified limestone rubble derived from upper Eocene limestones. The elevation of the top of this formation is very irregular due to solution and sinkhole activity. In the southern portion of the area, the Crystal River formation is unconformably overlain by the Oligocene, Suwannee limestone.

Geologic Exposures: Decatur County, Georgia. The best exposures of the Crystal River formation along the Flint River are found from Bainbridge northward to High Bluff, about seven miles above Bainbridge. The thickest section is found at High Bluff where 17 feet are exposed (see Flint River traverse locality 4, p. 37, this report for description).

Seminole County, Georgia. The best and thickest exposure of the Crystal River formation on the Chattahoochee River is found at a bluff


GEORGIA
FLORIDA
JACKSON
SEMINOLE
DECATUR
GADSDEN
BRINSON
BAINBRIDGE
LAMBERTS ISLAND
SOUTHLANDS FERRY
JIM WOODRUFF DAM
SNEADS
CHATTAHOOCHEE
APALACHICOLA RIVER
CHATTAHOOCHEE
FLINT
91
2
84
97
27
90
AS-245
AS-244
AS-243
AS-242
AS-241
AS-240
AS-239
AS-238
AS-246
AS-247
AS-248
AS-249
AS-251
AS-126
W-2149
W-3627
W-3737
W-2306
W-1364
W-1775
W-2254
W-1779
W-1562
W-3482
W-2247
W-3442
GEOLOGIC MAP
MIOCENE SERIES
Chattahoochee Facies
Hawthorn Facies
OLIGOCENE SERIES
Suwannee Limestone
EOCENE SERIES
Crystal River Formation
1 0 1 2 3 4 5
Scale in miles

on the left bank of the river about 15 miles above the Jim Woodruff Dam, where 15 feet are exposed (see Chattahoochee River traverse locality 32, p. 42, this report for description).

In the J. R. Sealy, Seminole Naval Stores Company well no. 1 (W-3737[3]), Land Lot 142, Land District 21, bedrock was encountered at 40 feet. These sediments represent the Crystal River formation and have yielded *Asterocyclina* species.

Based on the presence of *Operculinoides ocalanus,* the top of the Crystal River formation was identified at a depth of 60 to 70 feet in the Mont Warren, Grady Bell well no. 1A (W-2149), located 560 feet north of the south line and 660 feet east of the west line of Land Lot 61, Land District 27.

Decatur and Seminole counties, Georgia. Nowhere between the Flint and the Chattahoochee rivers in Decatur and Seminole counties, did the writers find an outcrop of the Crystal River formation. However, large chert masses scattered throughout this area may possibly represent eroded pinnacles of this formation (see post-Miocene section of this report), but are more probably chert boulders derived by solution from limestone of the Crystal River formation and incorporated in later sediments.

Jackson County, Florida. Some of the silicified boulders found in the northeastern portion of Jackson County, were identified as upper Eocene in age. However, in most cases, the fossil component of the rock was not identifiable because of the poor state of preservation; therefore, the age of the rock was not positively established.

Ten feet of Crystal River formation, overlain by five feet of Oligocene limestone, is exposed in a sink in the south central part of sec. 14, T. 5 N., R. 9 W. (locality 38). An oil well test (W-3627) in the SE¼ NE¼ sec. 11, T. 5 N., R. 8 W., penetrated, at a depth of 25 feet, limestone of the Crystal River formation immediately beneath the clastic overburden.

OLIGOCENE SERIES

SUWANNEE LIMESTONE

Historical: Florida Geological Survey bulletins 21 and 29 are cited as references for excellent historical reviews of the use of the term "Suwannee limestone."

Distribution: The Suwannee limestone underlies the southern half of the area. Locality 53 represents the only Suwannee limestone outcrop found and, for this reason, the Suwannee was primarily mapped on the

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[3] Florida Geological Survey well sample number.

basis of subsurface information (fig. 6). The dip, as determined in wells, was projected to intersect the ground surface and provide a means of delimiting the formational boundary.

Lithology: The Suwannee limestone is a white to cream, granular, crystalline, soft to hard, porous, frequently dolomitic, fossiliferous limestone. Locally, the fossils are poorly preserved and are difficult to identify. The formation has been eroded and segments of it remain as completely silicified limestone boulders incorporated in terrace material (p. 36).

Thickness and Structure: A water well (W-3442) drilled in southeastern Jackson County, Florida, in the SW¼ sec. 12, T. 3 N., R. 7 W., penetrated 120 feet of sediment that were assigned to the Suwannee limestone. In the area above the confluence of the Chattahoochee and Flint rivers, the top of the formation, as penetrated in auger holes, is very irregular (fig. 7). These auger holes did not pass through the complete thickness of the Suwannee. The top has been eroded in this area and it is believed the thickness is probably somewhat less than 120 feet.

The dip of the Suwannee limestone in the area of the Jim Woodruff Dam reservoir trends south-southeast at approximately 25 feet per mile.

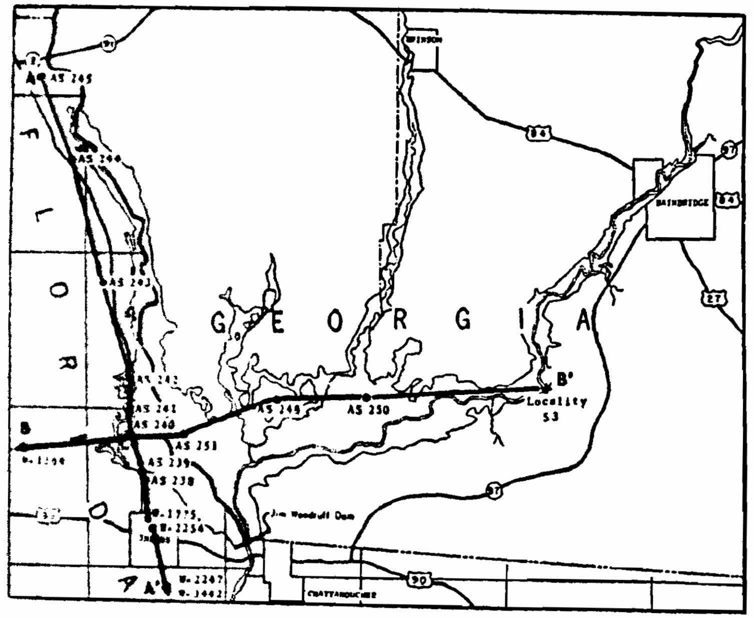
Stratigraphic Relationship: The Suwannee limestone lies unconformably upon the Crystal River formation, and unconformably below the younger Chattahoochee facies, or below younger clastics, where the Chattahoochee has been removed by erosion. In the central portion of the area the Suwannee is overlain unconformably by Pleistocene to Recent river alluvium.

Geologic Exposures: Decatur County, Georgia. Twenty-three feet of Suwannee limestone are exposed in the bank and in a gully on the slope of the escarpment on the left side of the Flint River at Southlands Ferry (locality 53).

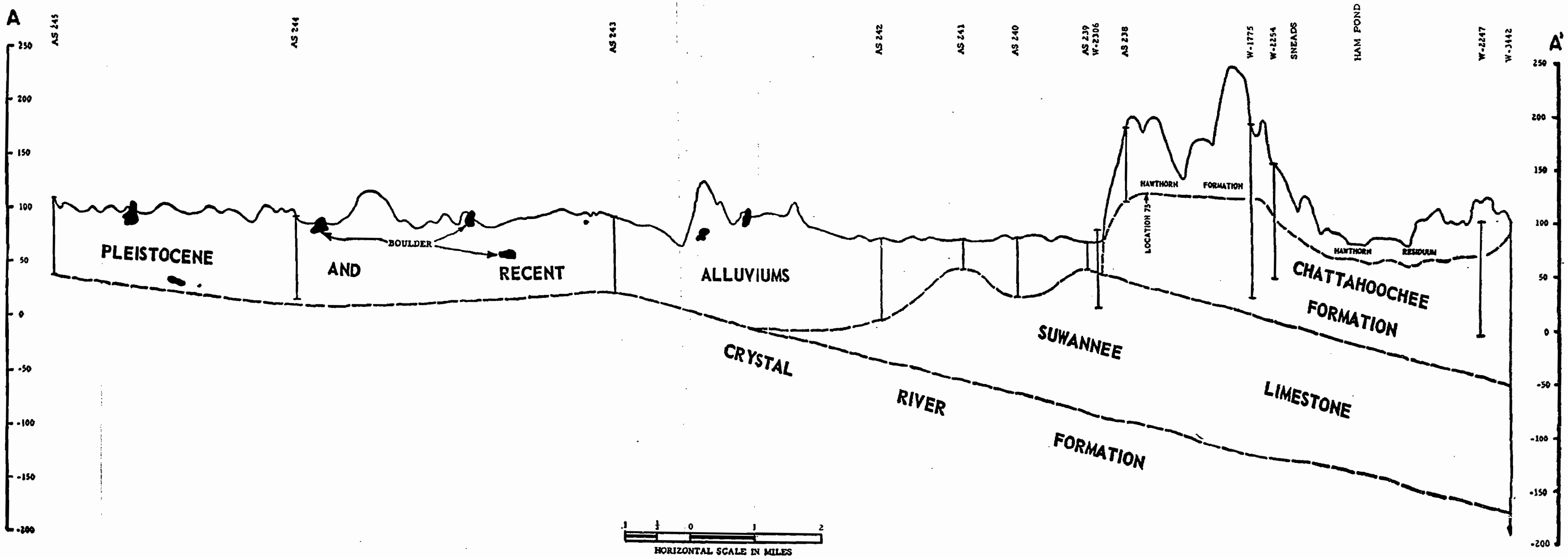
On the right bank of the Flint River at Lamberts Island, silicified limestone boulders of Suwannee age were found incorporated in Pleistocene to Recent sediments.

Seminole County, Georgia. Along the right bank of Spring Creek at locality 51, about two and one-half miles due south of Reynoldsville, silicified limestone boulders, Suwannee age, were found embedded in Pleistocene to Recent sediments.

About one mile east of the left bank of the Chattahoochee River and four miles northwest of the Jim Woodruff Dam, a depth of 70 feet (+8′) was reached with an auger (AS-251) without penetrating bedrock. However, rock fragments, probably from a weathered limestone surface, were



LOCATION MAP



EXPLANATION

Section A-A' drawn approximately parallel to dip of Tertiary strata.

Section B-B' drawn approximately parallel to strike of Tertiary strata.

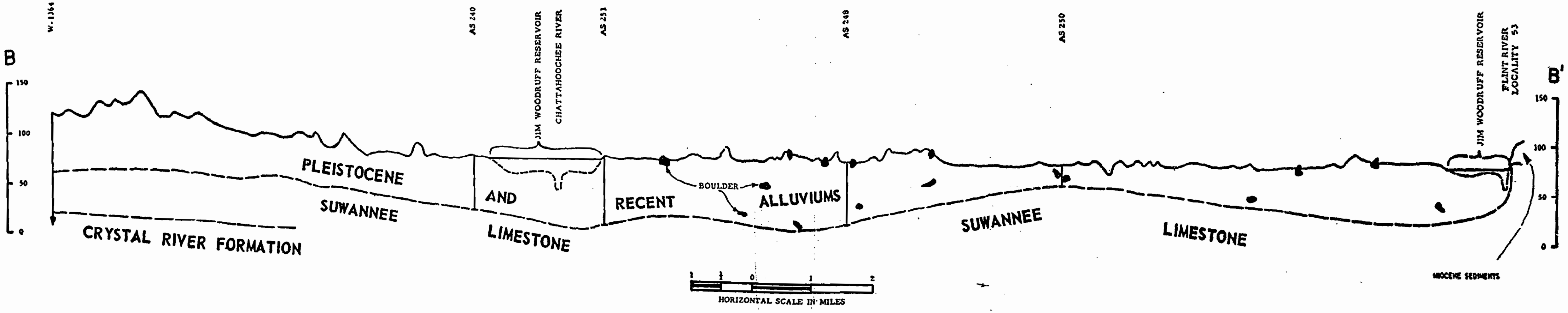


Figure 7. Geologic sections drawn north to south and west to east in area of Jim Woodruff reservoir.

found in the samples which were identified as Suwannee limestone in age by the presence of *Rotalia mexicana.*

Jackson County, Florida. At localities 39, 40, 41, 42 and 43, silicified boulders were identified as Suwannee in age.

Gadsden County, Florida. The section described below was measured in the powerhouse coffer dam excavation at the Jim Woodruff Dam site (locality 54). The top of the section is at an elevation of +12 feet. Between the top of this section and the bottom of the section measured on the west side of the Apalachicola River there are 62.6 feet of section that are covered.

Bed	Description	Thickness (feet)
Miocene Series Tampa Stage—Chattahoochee facies		
5	Limestone, white to light cream, crystalline calcite, soft, chalky, argillaceous, dendritic manganese in fractures. The middle two feet of the bed are hard and the bottom two feet are very argillaceous and soft	6.0
4	Limestone, light buff, chalky to very finely crystalline, hard to soft, argillaceous, dense, slightly dolomitic, dendritic manganese in fractures in the rock. Some isolated flakes of mica	4.0
Oligocene Series Suwannee limestone—elevation +2 feet		
3	Limestone, light buff, cryptocrystalline to very finely crystalline, with more crystalline calcite than bed 2, hard, dendritic manganese, dolomitic moldic porosity in part, dense in part. *Kuphus incrassatus.* Upper two feet of bed has small pea-size voids filled with soft green clay	5.0
2	Limestone, cream to light buff, very finely crystalline with some voids filled with crystalline calcite, dense, hard, dolomitic, fossiliferous. *Kuphus incrassatus*	4.0
1	Limestone, cream to light buff, finely crystalline, porous, hard, dolomitic, fossiliferous, but microfossils indistinct. *Kuphus incrassatus*	2.0
Total thickness		21.0

Base of section elevation —9 feet.

Near the contact the Chattahoochee is brecciated with masses of clay and angular dolomitic boulders incorporated together. Some of these basal boulders appear to have haloes of clay which grade into the Suwannee limestone and may represent alteration of the limestone to clay. At the top of the Suwannee limestone and extending into the

Chattahoochee formation are green clay deposits occurring as lenses, irregular masses, and vertical pipe fills. This green clay is not useful for widespread correlation as its vertical distribution in the base of the Tampa is perhaps as great as 30 feet, while its horizontal distribution is sometimes only a few feet.

MIOCENE SERIES

TAMPA STAGE

CHATTAHOOCHEE FACIES

Historical: Puri (1953a, p. 17) revised the terminology of the Miocene sediments in Panhandle Florida and included under his term Tampa Stage those sediments previously assigned to the Tampa formation. For a historical review of the Tampa formation the reader is referred to Florida Geological Survey Bulletin 21, pages 67-68.

Puri recognized two distinct lithofacies within the Tampa Stage, the downdip calcareous facies, called the St. Marks, and the updip silty and clayey facies, for which he revived the term Chattahoochee. The writers found no sediments within the area of this study that could be assigned to the St. Marks facies; therefore, only those sediments of the Chattahoochee facies are discussed.

Distribution: The Chattahoochee facies forms a part of the Tallahassee Tertiary Highlands in the southern part of the area of this investigation and underlies the clastics of the Hawthorn formation (fig. 6). The formation is exposed on the slopes of the bluffs trending along the Chattahoochee, Flint and Apalachicola rivers, in valleys cut by tributaries of the Flint River, and in sinkholes and road cuts.

Lithology: The Chattahoochee facies consists chiefly of lenses of clay within a white to cream, very silty to sandy, chalky to crystalline, soft to hard limestone, containing molluscan casts, several species of Foraminifera and a burrowing mollusk similar to *Kuphus incrassatus* Gabb, but generally smaller. Locally, at the base of the formation, is found a tan, brown and cream, finely sucrosic, hard, sometimes argillaceous and silty to sandy, usually dense, partially moldic dolomite. At localities 44, 45, 47 and 55 the formation is a cream, slightly hard, sandy, chalky, porous, finely crystalline, angular to slightly rounded limestone pebbles in a cream, slightly hard, finely crystalline, very microfossiliferous limestone. These two limestones exhibit the appearance of an intraformational conglomerate or, according to Tanner (1956, p. 309-311), a beach rock, which appears to represent only transgressive-regressive phases of the Tampa Stage.

Thickness: The top of the Chattahoochee facies, determined by the study of water well cuttings and outcrop samples, was found to be eroded and irregular in elevation. This erosional surface accounts for the variable thickness of the formation.

The thickness of the Chattahoochee sediments in well no. W-2254, located in the SE¼ SE¼ sec. 28, T. 4 N., R. 7 W., Jackson County, is 30 feet. The excavation and escarpment at the Jim Woodruff Dam exposed approximately 160 feet of Chattahoochee sediments. The top of the Chattahoochee facies was encountered at an elevation of 192 feet in an auger hole (AS-126) drilled on the east side of the town of Chattahoochee, Gadsden County, Florida, in the SW¼ NE¼ sec. 33, T. 4 N., R. 6 W. This is the highest known point for the top of the formation in the area. One-half mile south of this auger hole in the city of Chattahoochee well (W-3482), located in the SW¼ SE¼ sec. 33, T. 4 N., R. 6 W., the bottom of the Chattahoochee facies occurs at an elevation of –35 feet. The cumulative thickness, 227 feet, between the top and bottom of these two wells may more nearly represent the true thickness of the Chattahoochee facies in this area.

Stratigraphic Relationship: The Chattahoochee facies was observed to lie unconformably upon the Suwannee limestone in an excavation pit at the site of the Jim Woodruff Dam powerhouse. Chattahoochee and Suwannee sediments were observed in a gully near Southlands Ferry (locality 53), but the contact between the two formations was obscured in 22 feet of the section that was covered by slumped sediments.

Lithologic homogeneity of limestone beds 1 through 14, exposed at the Jim Woodruff Dam section, influenced Puri (1953a, p. 20) to place the upper limit of the Chattahoochee facies at the top of bed 14. He also mentioned the possibility that the rubble bed (bed 7), may represent a continental phase of the Alum Bluff Stage, probably the Chipola facies. Later, on the basis of the well-developed unconformable contact between beds 6 and 7, Puri and Vernon (1956, p. 56) placed the boundary between the Chattahoochee and the Hawthorn facies at the top of bed 6.

In this report, the boundary between the Chattahoochee and Hawthorn sediments is moved back to the top of bed 14. Recognizing that this boundary may only represent a lithologic and not a time break, this procedure is followed because:

1. Sediments represented by beds 1 through 14 are similar limestones.
2. There is difficulty in establishing which of the several rubble beds occurring in the section represent a major unconformity.
3. The rubble beds are not recognizable in well sections.
4. Rubble beds were not observed at other outcrops of the Chattahoochee facies within the limits of this report.

Geologic Exposures: Decatur County, Georgia. Fifty-two feet of Chattahoochee sediments were found along an abandoned road on the northeast-southwest trending escarpment on the left side of the Flint River about eight and one-half miles by river above the Jim Woodruff Dam (locality 48).

The following section was measured on the right bank of Sanborn Creek, approximately one mile upstream from its junction with the Flint River (locality 50):

Bed	Description	Thickness (feet)
Miocene Series		
Tampa Stage—Chattahoochee facies		
5	Limestone, buff, soft but tough, argillaceous, silty, moldic. This bed is exposed in a road 30 feet from creek bank	1.0
4	Limestone, cream to tan, nodular, conglomeratic, very weathered material, seemingly composed of chert boulders, indurated, and green clay nodules	4.0
3	Very light olive green and cream to tan, silty to finely sandy, argillaceous material, containing thin laminae running irregularly through the bed. Probably originally horizontal with slumping, causing distortion	3.0
2	Limestone, gray to cream, hard, cryptocrystalline, questionably silty, containing sparsely distributed coarse quartz sand	1.5
1	Cream to tan, silty to finely sandy, argillaceous, calcareous material, weathered surface soft, nonweathered surface hard	3.0
Total exposed		12.5

Jackson County, Florida. The following descriptions are of samples taken from ledges of rock cropping out on the slope of the escarpment in the SW¼ sec. 15, T. 4 N., R. 7 W. (locality 44):

Sample No.	Description	Elevation (feet)
Miocene Series		
Tampa Stage—Chattahoochee facies		
2	Limestone, white to cream, soft, porous, argillaceous, silty to finely sandy, chalky, with veinlets of crystalline calcite	124
3	Limestone, very light cream, slightly hard, porous, argillaceous, silty to finely sandy, chalky to very finely crystalline, microfossiliferous. *Archaias floridanus*, *Sorites* sp., Miliolids	116
4	Same as limestone above	113
5	Limestone, light cream, slightly hard, porous, silty to finely sandy, chalky to finely crystalline, with green nodules of clay that appear to be weathered from microfossils	110
6	Limestone, cream, slightly hard, sandy, porous, chalky to finely crystalline, occurring as angular to slightly rounded pebbles in a cream, slightly hard, finely crystalline, very microfossiliferous,	

Sample No.	Description	Elevation (feet)
	porous, limestone. The rock displays the appearance of an intraformational conglomerate or beach rock	100.5
7	Limestone, light cream, slightly hard, porous, silty to finely sandy, moldic; this sample was taken from a boulder which had probably moved down from above	100
8	Same as sample 6	89
9	Limestone, cream, hard, porous, finely sandy, finely crystalline, microfossiliferous	83
10	Same as sample 9	65

The thickest exposure of Chattahoochee sediments in the area of this study is found in the following combined geologic sections in Decatur County, Georgia, and Jackson County, Florida:

The Decatur County part is located on the access road to the earth dike of the Jim Woodruff Dam, directly below the U. S. Engineers office on the east side of the Apalachicola River. Measured in February, 1953, by Robert O. Vernon, C. W. Hendry, Jr., Harbans S. Puri, and J. William Yon, Jr.

Bed	Description	Thickness (feet)
Miocene Series		
Alum Bluff Stage—Hawthorn facies (deltaic)		
21	Quartz sand; red, yellow and white, fine to coarse-grained, poorly developed, graded bedding. Contains more quartz gravel at the base than at the top. Topped by about five feet of deep red soil profile which contains polished sandy, limonitic nodules, some of which occur along a definite zone	16.0
20	Quartz sand; mottled, light gray, purple and yellow, fine to medium-grained, very argillaceous	6.5
19	Covered	29.0
Alum Bluff Stage—Hawthorn facies (marine)		
18	Marl; variegated, cream and light gray. Contains fine-grained quartz sand, abundant Pecten and oyster shells within the bed	1.0
17	Quartz sand; tan to light brownish-gray, medium to fine-grained, argillaceous and becomes more argillaceous toward the top	8.1
16	Clay; dark greenish-gray, blocky, silty and contains fine-grained quartz sand	3.0
15	Siltstone; light greenish-gray, which contains bright, waxy, clay nodules and hard, brown, crystalline, dolomitic limestone. Oyster reef development within the bed	4.5
Section discontinuous—beds 14 to 1 measured about 40 yards to the west.		
Tampa Stage—Chattahoochee facies		
14	Limestone; tan, dolomitic, hard, cryptocrystalline, thinly bedded, pasty	6.0

Bed	Description	Thickness (feet)
13	Limestone; thinly bedded and interbedded with green, calcareous, silty clay	0.5
12	Limestone; light brownish-gray to cream, dolomitic, soft, tough, blocky, and contains quartz sand	1.5
11	Limestone; rubble of white, dolomitic, hard, pasty, with irregular lenses of fossils within the bed. Top of bed has irregular surface along which light green, crystalline calcite has been developed (Diastem?)	2.5
10	Limestone; light brownish-gray to cream, dolomitic, soft, tough, blocky and contains quartz sand	4.5
9	Limestone; rubble of white, hard, pasty, with irregular lenses of fossils within the bed. Top of bed has irregular surface along which light green crystalline calcite has been developed. Bed lies irregularly upon bed 8 (Diastem?)	2.5
8	Limestone; light cream to white, soft, tough, pasty, and contains quartz sand; within the bed are irregular tunnels filled with calcareous, harder, green sand and clay. Contains irregular lenses and nodules of the above sand and clay. Lenses and nodules of crystalline calcite are present. Occurring at the top of the bed is a layer of medium gray crystalline calcite about eight inches thick. The Gastropod *Ampulella* is found within the bed (Diastem?)	4.2
7	Limestone; rubble of white, dolomitic, hard, pasty, slightly fossiliferous, somewhat nodular, intermixed with sand and nodules of limestone. Possible Chipola equivalent	2.8
NOTE:	At the base of bed 7 and the top of bed 6 the contact between the beds is wavy. There is a one-inch calcite enrichment which may indicate that bed 7 overlies bed 6 unconformably. The Gastropod *Ampulella*? was found along the contact between beds 7 and 8.	
6	Limestone; white, pasty, silty, blocky, spherical weathering. Top four inches harder	0.8
5	Clay; light greenish-gray, containing thin seams and partings of sand and silt. Also contains limestone nodules appearing to be fossiliferous	0.8
4	Limestone; very light brownish-gray, dolomitic, hard, and tough where exposed. Contains numerous mollusk molds. Upper two and one-half feet contain greenish-gray silt and light green clay nodules which are fossiliferous. Weathers slightly harder than bed 3	8.1
3	Limestone; cream to white, soft, pasty. Contains quartz sand. Numerous molds of *Turritella* sp. and other mollusks, *Sorites* sp., and *Archaias* sp., are present in the bed. Blebs of green clay are disseminated throughout	2.0
2	Limestone; white to cream, dolomitic, pasty	0.1
1	Clay; light brownish-gray, silty, calcareous, blebs of green clay disseminated throughout. Gradually becomes more calcareous	

Bed	Description	Thickness (feet)
	and approaches a hard white marl near the top	13.6
Total exposed		119.2

The base of bed 1 is at an elevation of 108.85 feet.

The Jackson County part is located west of Apalachicola River Bridge on access road at the end of Victory Bridge NE¼ sec. 31, T. 4 N., R. 6 W. The top of bed 7 is at an elevation of 118.0 feet. Elevation at the top of spillway is 84.4 feet.

Bed	Description	Thickness (feet)
Tampa Stage—Chattahoochee facies		
7	Clay; blocky, waxy, greenish-gray	2.0
6	Limestone; cream to white, pasty, soft but tough, sandy, dolomitic, containing irregular bodies of light green, calcitic sand and a very indurated ledge in the center	11.0
5	Clay; light tan, very slightly calcareous, blocky and grades upward to a medium brownish-gray sandy, blocky clay	2.5
4	Limestone; light tan to cream, soft but tough, dolomitic, very fossiliferous, containing irregularities of gray silt and clay. Abundant specimens of regular and irregular echinoids. *Ampulella* and other mollusks within the bed. Irregular concretions of sandy brown limestone are also present	4.0
3	Limestone; light gray, tan to cream, soft but tough, pasty, dolomitic, containing greenish clay-filled borings and green irregular masses of crystalline calcite	5.0
2	Clay; mottled, light greenish-gray to tan, very sandy, blocky, containing dugong bones and irregular lenses of hard, apparently crystalline clay	4.0
1	Limestone; light brownish-gray, soft but tough, pasty, honeycombed, sandy, dolomitic, containing nodules, lenses, thin beds and irregular veins of light gray to greenish waxy, silty, blocky, clay. *Kuphus* sp. found in both the clay and limestone. The bed is more nodular, less honeycombed and with fewer definitely clay lenses near the top. This bed was apparently deposited as a beach-rock rubble. There are remains of numerous boring mollusks that lived in coral head of *Siderastraea* sp. although there are few well-preserved heads of the coral. *Ampulella* sp. is found throughout the bed. Five feet exposed here and an additional 9.9 feet is present on the lake side of the dam	14.9
Total exposed—east and west sections		162.6

At the time the powerhouse coffer dam excavation was open there were exposed ten feet of Chattahoochee facies unconformably overlying 11 feet of Suwannee limestone (see geologic section under Suwannee limestone, locality 54).

ALUM BLUFF STAGE

HAWTHORN FACIES

Historical: The reader is referred to page 144 of the Florida Geological Survey Bulletin 29, for a historical review of the term Hawthorn. Puri (1953a, p. 21) described the Hawthorn in the Florida Panhandle as a lithofacies of the Alum Bluff Stage.

Distribution: The Hawthorn formation is present in the entire southern portion of the area of this investigation (fig. 6). The eastern and southern limits of the Hawthorn exceed those of this report. The most northern extension of the Hawthorn sediments ends at the escarpment facing the left bank of the Flint River in Decatur County, Georgia, and its western limit is marked by the termination of the Tallahassee Tertiary Highlands in Jackson County, Florida.

Lithology: The Hawthorn formation is a highly varied assemblage of lenticular sand and clay beds that have only slight lateral persistence. The Hawthorn sediments consist of sorted to nonsorted, coarse to fine-grained, argillaceous, quartz sand, and rust-brown, gray-green, cream, red and tan arenaceous clays, some of which are calcareous and contain pelecypod shells. Irregularly distributed throughout these sediments are small phosphorite grains of varying colors.

Thickness: The Hawthorn formation in the area of this investigation has a variable thickness. In the area surrounding Sneads, Jackson County, Florida, and at Chattahoochee, Gadsden County, Florida, the Hawthorn formation is represented by approximately 70 feet of sediments. At locality 56 near Georgia State Highway 97, southward to the intersection of U.S. Highway 90, the writers measured 135 feet of Hawthorn deposits. Near Faceville, Decatur County, Georgia, at locality 49, 48 feet of sediments were assigned to the Hawthorn formation. Sixty-eight feet of Hawthorn sediments are exposed at the Jim Woodruff Dam section described on page 31.

Stratigraphic Relationship: The contact of the Hawthorn with the underlying Chattahoochee facies is unconformable.

Geologic Exposures: The Hawthorn formation mantles almost the entire area mapped as the Tallahassee Tertiary Highlands. Geologic sections of formations can be seen in many places in the area along the west-facing escarpment of the Flint and Apalachicola rivers, and around Chattahoochee, Gadsden County, and Sneads, Jackson County, Florida.

POST-MIOCENE STRATIGRAPHY

SILICIFIED LIMESTONE

Historical: Cooke (1929, p. 67) extended the name "Glendon limestone" from Alabama to Florida to include limestone of Oligocene age and what he felt were equivalent fossiliferous chert beds. Later, Cooke (1935, p. 1170-71) proposed the name Flint River formation for the fossiliferous chert beds in Florida, Georgia and southeastern Alabama, and continued the name "Glendon" for Oligocene limestones. Both the Glendon and Flint River formations were tentatively correlated with the Chickasawhay limestone of Mississippi. Vernon (1942, p. 130-133) presented evidence that these silicified boulders were enclosed in Pleistocene alluvium. They represent silicified portions of Oligocene and Eocene formations released during periods of valley cutting and incorporated in alluvium during later intervals of valley fill. Vernon did not recognize Cooke's "Glendon limestone" or "Flint River formation" in the counties west of the dam site. Cooke (1945, p. 104-107) again referred the boulders to formational rank and extended the Flint River formation to include beds of similar lithology in Florida, and mapped the formation from Walton County, Florida, eastward to the Chattahoochee River and across Georgia to Allendale, South Carolina.

MacNeil (1946, p. 64) stated that for the most part the materials in the Flint River formation are of Miocene age which became intermixed with limestone residue upon slumping into sinks during the process of solution. He established the age of the chert in Georgia as middle and upper Oligocene. Where the "Ocala limestone" has been dissolved, the residuum of the Oligocene and "Ocala" cannot be separated (MacNeil, 1946, p. 64). MacNeil (1946, p. 64) further states that, "In view of these findings, and because it is not the policy of the U. S. Geological Survey to apply formation names to residuum, the name Flint River has been abandoned and the heterogeneous beds to which it was applied are designated the residuum of the Jackson, Oligocene, and Miocene, undifferentiated."

Present Concept: In the area of this study Cooke's "Flint River formation," is a heterogeneous mass of silicified limestone boulders of upper Oligocene and possibly upper Eocene age. The boulders are embedded in Pleistocene to Recent sands and clays and as Vernon and MacNeil have stated should not be considered a single unit of deposition as previously supposed by Cooke (1935, p. 1170-71). Seventeen auger holes were drilled to determine if these boulders, some of which are 18 feet in diameter, were actually outcrops or merely boulders occurring at irregular horizons and haphazardly throughout a clastic matrix. The evidence obtained from these holes show that the boulders indiscriminately lie 26 to 78 feet above bedrock (fig. 7).

These silicified deposits represent the remnants of a higher limestone surface which probably became incorporated in the alluvium during valley cutting and filling by the present major streams or their ancestral equivalents.

The boulders occur most frequently along the Chattahoochee and Flint rivers and Spring Creek. Recent degrading by the streams have cut through the alluvium and have exposed the silicified limestone boulders and concentrated them by downstream sapping and accumulations in boulder bars at obstructions in the channel and along the inside of bends in the streams, where velocity is least.

Geologic Exposures: Decatur County, Georgia. On the right bank of the Flint River at Lamberts Island, silicified limestone boulders of Suwannee age were found incorporated in Pleistocene to Recent sediments.

Seminole County, Georgia. Along the right bank of Spring Creek at locality 51, about two and one-half miles due south of Reynoldsville, Seminole County, Georgia, silicified limestone boulders, Suwannee age, were found embedded in Pleistocene to Recent sediments.

Jackson County, Florida. At localities 39, 40, 41, 42 and 43, in Jackson County, Florida, silicified boulders occurring in Pleistocene to Recent sediments, were identified as Suwannee age.

GEOLOGIC EXPOSURES ALONG CHATTAHOOCHEE AND FLINT RIVERS

Traverse of a portion of the Flint River beginning at High Bluff, approximately seven miles upstream from Bainbridge, Georgia, and extending to the junction with the Chattahoochee River, approximately one mile north of Chattahoochee, Florida:

December 1-2, 1953
R. O. Vernon, C. W. Hendry, Jr. and J. W. Yon, Jr.

Bed	Description	Thickness (feet)
Locality 1		
Oligocene? and upper Eocene		
Suwannee limestone? and Crystal River formation		
	Silicified limestone boulders, approximately 12x20 feet, apparently not in place and restricting the channel in part.	

Bed	Description	Thickness (feet)
Locality 2		
Upper Eocene-Crystal River formation		
	Limestone, cream to tan, fragmental, granular, marine, porous, soft, coquinoid. Very cavernous with horsebone weathering and a tendency to laminate	10.0
Locality 3		
Post-Eocene		
2	Sand, varicolored, medium to coarse-grained and contains clay lenses, quartz gravel, silicified limestone boulders and a calcareous, clayey, sandstone which contains numerous molds of mollusks and nodules of a more calcareous material	10.0
Upper Eocene-Crystal River formation		
1	Limestone as found at locality 2	15.5
Total exposed		25.5
Locality 4		
Post-Eocene		
7	Sandy soil zone, tan to brown, weathered	4.0
6	Clay, variegated, gray, tan, red, white, blocky, sandy, and has a tendency to laminate	7.8
5	Sand, variegated, gray, tan, red, white, blocky, clayey, very fine-grained, and contains lenses of blocky clay of overlying bed 6	13.7
4	Slump	17.2
3	Clay, light gray, very sandy, blocky	11.4
2	Covered	9.4
Upper Eocene-Crystal River formation		
1	Limestone as found at locality 2	17.0
Total exposed		80.5
Locality 5		
Upper Eocene-Crystal River formation		
	Pinnacles of limestone protruding through tan, fine-grained, sandy alluvium	10.0-12.0
	Also ledges of limestone overlain by alluvium. Scattered boulders of silicified limestone, approximately 6x8 feet. Further downstream these boulders become more abundant in the river bed.	
Locality 6		
Post-Eocene (flood-plain alluvium)		
4	Sand, dark gray, with a thin sandy soil zone	0.5
3	Sand, yellow to orange, very fine-grained, slightly clayey	4.0
2	Bed 3 grades downward into seven feet of thinly bedded, orange, fine-grained sand, increasing in coarseness toward the base and merges with a one to three foot zone of thinly bedded, fine to coarse-grained sand containing numerous quartz pebbles and large silicified boulders of Crystal River age. Very irregular contact with bed below	1.0-7.0

Bed	Description	Thickness (feet)
1	Siltstone, light gray, very clayey, very sandy	9.6
Total exposed		15.1-21.1

Between localities 6 and 7 is flood-plain alluvium composed of fine-grained, light yellow sand with scattered silicified limestone boulders.

Bed	Description	Thickness (feet)
Locality 7		
Post-Eocene		
2	Sand, orange, fine-grained	8.0-14.0
1	Siltstone, light gray, very sandy, very clayey. Very irregular contact with bed above	3.0-3.5
Total exposed		11.0-17.5

Just downstream from locality 7 are scattered boulders of silicified limestone, 6 to 8 feet in diameter in river bed.

Bed	Description	Thickness (feet)
Locality 8		
Post-Eocene		
	Clay, gray, with incorporated silicified limestone boulders, 3x4 feet, lying on gray, sandy clay or siltstone	5.0
Locality 9		
Post-Eocene (flood-plain alluvium)		
2	Sand, poorly sorted, crossbedded, fine to coarse-grained, but generally coarsest at base	14.0
1	Clay, light gray, blocky, slightly silty.	
Locality 10		
Post-Eocene (flood-plain alluvium)		
3	Sand, fine to coarse-grained, crossbedded and reworked clayey alluvium	10.0
2	Clay, very silty and sandy, blocky, grading laterally into clay, variegated, sandy, weathered and mottled	9.8
Upper Eocene-Crystal River formation		
1	Limestone, tan, fragmental, granular, marine, hard, fossiliferous. Crystalline on exposed surfaces and occurring as pinnacles protruding through bed 2	7.8
Total exposed		27.6

Just downstream from locality 10 is crossbedded, sandy alluvium overlain by five feet of sandy, silty clay.

Locality 11

Silty clay overlaying gray clay and through which protrudes several pinnacles of limestone (upper Eocene?). Several large, 6x8 feet, boulders in river bed.

Locality 12

Upper Eocene-Crystal River formation

Limestone, tan to brown, fragmental, marine, very porous, soft,

Bed	Description	Thickness (feet)
	loose, coquinoid. Abundant large foraminifers and *Amusium* sp.	8.0
Locality 13		
	Limestone, recrystallized	4.5
Just downstream from locality 13 are large boulders of recrystallized and silicified limestone incorporated in very loamy flood-plain deposits.		
Locality 14		
Post-Eocene (flood-plain alluvium)		
2	Sand, fine to coarse-grained, crossbedded, slightly clayey, with a gravel and boulder bed at base	12.0
1	Clay, gray, silty	10.0
Total exposed		22.0
Locality 15		
9	Soil zone	0.67
8	Sand, yellow, fine-grained, oxidized and leached	1.0
7	Sand, red, very fine-grained, slightly clayey, oxidized, but not leached	0.75
6	Sand, dark brownish-gray, slightly clayey, very fine-grained and contains a four-inch freshwater clam bed	1.5
5	Sand, brown, very fine-grained, slightly clayey	1.0
4	Covered	2.0
3	Sand, tan, fine-grained, slightly clayey, crossed by laminae of deep reddish-brown, very fine-grained moderately clayey sand	3.0
2	Covered	2.0
1	Sand, mottled tan, gray, brown, fine-grained, very clayey and contains two eight-inch grit beds in the middle grading downward into a more clayey material with similar characteristics to top of bed	8.5
Total exposed		21.42
Locality 16		
Post-Eocene (flood-plain alluvium)		
3	Clay, loamy, blocky, very sandy	8.0
2	Sand, light brown, slightly clayey, fine to coarse-grained, crossbedded and contains pea-size gravel and boulders of silicified limestone (see basal bed)	4.0
1	Clay, bluish-gray, blocky, silty grading laterally into light grayish-green, very clayey silt. Where the bluish-gray clay forms a ledge there is a cascade of boulders of quartz up to one foot in diameter and silicified limestone of Crystal River, Suwannee and possibly Tampa age lying on the ledge and having fallen from the light brown silty sand of bed 2	6.0
Total exposed		18.0

One-quarter mile downstream from locality 16 are low islands of silicified limestone. River banks composed of eight feet of loams.

Bed	Description	Thickness (feet)
Further below locality 16—		
	Silt, greenish-gray, above which thick limonite has developed containing numerous silicified boulders and overlain by 12 feet of sandy alluvium.	
Locality 17		
	Silicified boulders forming a jetty extending into river channel and protecting the left bank.	
Locality 18		
Post-Eocene (flood-plain alluvium)		
2	Sand, red, crossbedded, fine to coarse-grained, poorly sorted with abundant boulders in base	10.0-14.0
1	Clay, gray	3.0- 5.0
Total exposed		13.0-19.0
Locality 19		
Post-Eocene		
	Clay, gray. Collected to check fossil content. Contained one small *Cardium* sp.	
Locality 20		
Post-Eocene (flood-plain alluvium)		
2	Sand	12.0
1	Clay. Very irregular contact between these two beds along which are numerous limonite pebbles	8.0
Total exposed		20.0
Locality 21 (Southlands Ferry)		
Oligocene Series—Suwannee limestone		
	Limestone, cream to tan, hard, crystalline, weathers cavernous. Crops out at base of Hawthorn hill	8.0
Locality 22		
Oligocene Series—Suwannee limestone		
	Limestone, cream to gray, hard, dense, finely crystalline, brecciated texture and contains very rare fossils. This limestone exposed in temporary road cut made by bulldozer part way up hill	5.0
	Covered	17.0
	This limestone exposed at small spring at base of hill	3.0
Total exposed		25.0
Locality 23		
Post-Eocene (flood-plain alluvium)		
2	Sand, reddish-brown, fine to very coarse-grained, crossbedded with irregular lenses of grit and pea-size gravel covering pinnacles of greenish-gray, massive sand	21.4

Bed	Description	Thickness (feet)
1	Sand, light greenish-gray, massive, slightly clayey, micaceous, jointed northeast-southwest	5.8
Total exposed		27.2

Locality 24
Oligocene Series–Suwannee limestone

Hill of limestone similar to lithology at locality 22.

Locality 25
Oligocene Series–Suwannee limestone

On right bank of river, several boulders of tan to cream, fragmental, marine limestone containing numerous echinoid fragments and specimens of *Lepidocyclina, Sorites,* and *Camerina.* Boulders are apparently dislodged by machinery used in clearing Jim Woodruff reservoir area.

Traverse of a portion of the Chattahoochee River beginning at Florida Highway 2 – Georgia Highway 91 Bridge, and extending to the junction with the Flint River, approximately one mile north of Chattahoochee, Florida:

December 2-3, 1953

Locality 26
Post-Eocene

	Sandy alluvium	10.0
	Clay, light greenish-gray, and purple, sandy, overlain by boulders of limonite and silicified limestone	5.0
Total exposed		15.0

Locality 27
Upper Eocene-Crystal River formation

	Limestone, white to cream, fragmental, marine, porous, soft but tough, very finely crystalline, coquinoid and contains numerous mollusks mostly as molds. *Olygopygus* abundant	6.8

Locality 28

Two feet of limestone as at locality 27 cropping out overlain by thin bed of limonite.

Two-thirds mile below locality 28, four feet of limestone as at locality 27.

Locality 29
Upper Eocene-Crystal River formation

2	Limestone, cream, granular, marine, dense, hard, cryptocrystalline to very finely crystalline and weathers extremely cavernous and marked by a white, speckled, chalky, nodular material, which may represent calcite dust from fossils	3.0
1	Limestone, tan, fragmental, marine, soft, coquinoid. *Olygopygus* sp.	0.5
Total exposed		3.5

Bed	Description	Thickness (feet)
Locality 30		
Upper Eocene-Crystal River formation		
4	Limestone, cream, fragmental, granular, marine, soft, weathering hard, miliolid bed contains numerous Lepidocyclinas and *Amusium ocalanum*	1.9
3	Limestone of above bed and weathered into hard ledge containing *Olygopygus* sp.	1.6
2	Limestone of bed 3, but very soft, cream to tan, very porous and extremely microfossiliferous	1.5
1	Limestone, cream, fragmental, marine, very hard, weathers cavernous and contains specks of chalky nodules representing calcite dust from weathered fossils. This bed similar to limestone at locality 29	4.0
Total exposed		9.0
Locality 31		
Upper Eocene-Crystal River formation		
	Limestone, white to cream, marine, dense, moldic porosity, cryptocrystalline to very finely crystalline, hard, microfossiliferous. Weathers cavernous and locally altered to green clay	5.5
Locality 32		
Upper Eocene-Crystal River formation		
2	Limestone, tan, fragmental, marine, coquinoid, contains abundant Lepidocyclinas, Camerinas, *Olygopygus* sp., small foraminifers, mollusks, and echinoids, weathers red	3.0
1	Limestone, cream to tan, fragmental, hard, coquinoid, contains small to large chalky nodules which are apparently calcite dust derived from weathered fossils. This type of limestone is apparently a subsequent product of the coquinoid limestone of bed 2 and the bed when traced laterally to a fresh exposure is the same as bed 2	12.0
Total exposed		15.0

Upstream and adjacent to above described limestone are 10 feet of extremely variable, massive, highly colored, purple, red, brown, gray, sandy clay and fine sand overlain by 10 feet of sandy alluvium. This area appears to be disturbed.

Bed	Description	Thickness (feet)
Locality 33		
Post-Eocene		
	Clay as described at locality 32.	
Locality 34		
Upper Eocene-Crystal River formation		
	Limestone, cream, marine, dense, hard, tough, fossiliferous. Weathers cavernous and microcoquinoid in places	5.6

One hundred yards downstream from locality 34, mottled clay as at locality 32, and limestone as at locality 34. Large limonite boulders 12 to 15 inches in diameter.

Bed	Description	Thickness (feet)
Scattered large boulders of limestone as bed 1, locality 32, and with fossiliferous, porous zones throughout. Boulders appear to have recrystallized and almost prohibit navigation because of abundance.		
Locality 35		
Post-Eocene		
3	Sandy alluvium	12.0-13.0
2	Sand and clay, variegated light greenish-gray, purple, red	9.0
1	Limestone, coquinoid, badly weathered and covered by considerable amount of limonite	5.0
Total exposed		26.0-27.0
Just downstream from locality 35 are five feet of limonite.		
Locality 36		
Upper Eocene-Crystal River formation		
	Limestone, white to cream, fragmental, marine, very finely crystalline, soft, weathers cavernous	2.0
Locality 37		
Upper Eocene-Crystal River formation		
	Limestone, cream to tan, fragmental, marine, very fossiliferous—composed largely of molds of mollusks and merges laterally with light gray mottled reddish-brown sandy clays. Limestone composed of boulders and possible pinnacles.	

INSOLUBLE RESIDUE STUDY

INTRODUCTION

Lithologic examination of the cuttings and core samples of carbonate rocks from wells in and near the area of this investigation indicated that the lower part of the Chattahoochee facies and the upper part of the Suwannee limestone have undergone secondary crystallization, thereby destroying the characteristic lithologic appearance of the respective formations and the diagnostic fossil content of the rock. The lack of these criteria for differentiating between the formations makes it extremely difficult to determine the contact between these two units.

Because the identifying paleontologic and lithologic characteristics had been destroyed, the writers felt that the determination of insoluble residues might assist in stratigraphic correlation. Three U. S. Corps of Engineers core holes and 43 outcrop samples were selected to be used in the experimental work. The three core holes, W-1562, W-1775 and W-1779, are located in Jackson County, Florida, and range in depth from 126 feet to 164 feet. The outcrop samples were collected at six discontinuous exposures along the east-west trending bluff, marking the northern limit of the Tallahassee Tertiary Highlands at localities 45 and 54, Jackson County, Florida, and localities 21, 46, 47 and 55, Decatur County, Georgia (fig. 6).

PROCEDURE

Twenty-five gram portions were used from each outcrop sample and from intervals of approximately two feet from the cores. These samples were digested in dilute hydrochloric acid at room temperature. The insoluble residues were filtered, thoroughly washed with water, dried, and weighed.

The clay content of the insoluble residue was removed by flocculation. The silt and sand-size material from two U.S. Corps of Engineers core holes (W-1775 and W-1779) was treated with bromoform to separate the heavy minerals from the quartz and mica. The writers felt that because W-1775 and W-1779 were close together, they would depict any similarities or dissimilarities and W-1562 would be used only to verify or disprove any zonational sequences that might show up.

A binocular microscope was used in the examination of the nonheavy minerals and a standard petrographic microscope was used for the mineralogic determination of the heavy minerals. The close proximity of W-1775 and W-1779 influenced the writers to use only these two for preliminary comparison.

INSOLUBLE RESIDUE

ARENACEOUS MATERIAL

Quartz sand was present as a part of the insoluble residue in all of the outcrop samples and in all of the core samples of W-1775, and in the upper 85 and 87 feet of W-1779 and W-1562 respectively.

The detrital quartz grains ranged in size from silt to medium sand with traces of coarse sand. Except for a few variations, the shape of the detrital quartz grains was angular to subangular. Frosting of the grains was absent or very slight in all of the samples examined.

SECONDARY SILICA

Silt-size to very fine sand-size aggregates of crystalline secondary silica were found to exist in the lower 48 feet of W-1775, and also in the lower 39 feet of W-1562.

SILICEOUS OOLITES

Texturally the oolites ranged from fine to medium sand-size, and occurred either singularly or in clusters of three or more.

MUSCOVITE

Fine to very fine sand-size muscovite was present as a part of all samples examined for insoluble material.

HEAVY MINERALS

The most common heavy minerals that existed as part of the residue were:

1. Tourmaline
2. Garnet
3. Kyanite
4. Zircon
5. Rutile
6. Monazite
7. Staurolite
8. Ilmenite
9. ?Hematite
10. Leucoxene

CONCLUSION

This investigation has shown that insoluble residues do exist in the sediments examined. Some of these insoluble constituents are useful in establishing local correlation zones. In the following discussion the overall value of the insoluble residues and insoluble residue zones is analyzed in relation to their value for establishing the Miocene-Oligocene boundary.

To help in visualizing graphically the range of the insolubles, the percentages of the insoluble residues of the core holes were calculated and plotted as the abscissa and the corresponding depths of the residue samples as the ordinate (fig. 8). The conclusion reached from this part of the experiment was that the upper part of the Chattahoochee formation has zones which are high in insoluble material, but percentages of insoluble residues gave no clue to the contact between the Chattahoochee facies and the Suwannee limestone.

The Suwannee limestone sometimes contains detrital sands and a detailed study was made of the detrital quartz grains to determine if the characteristics of the quartz sand revealed any differences which could be used in establishing the boundary between the Suwannee limestone and the Chattahoochee facies. All of the quartz sand present was angular to subangular and usually clear. The grain size ranged from silt to medium sand, with traces of coarse sand. The results of the examination of the detrital quartz grains indicated that if any apparent differences existed, they were insignificant and could not be used in determining the Miocene and Oligocene contact.

The aggregates of secondary crystalline quartz found in W-1562 and W-1779 occurred in a very badly leached foraminiferal coquina, some

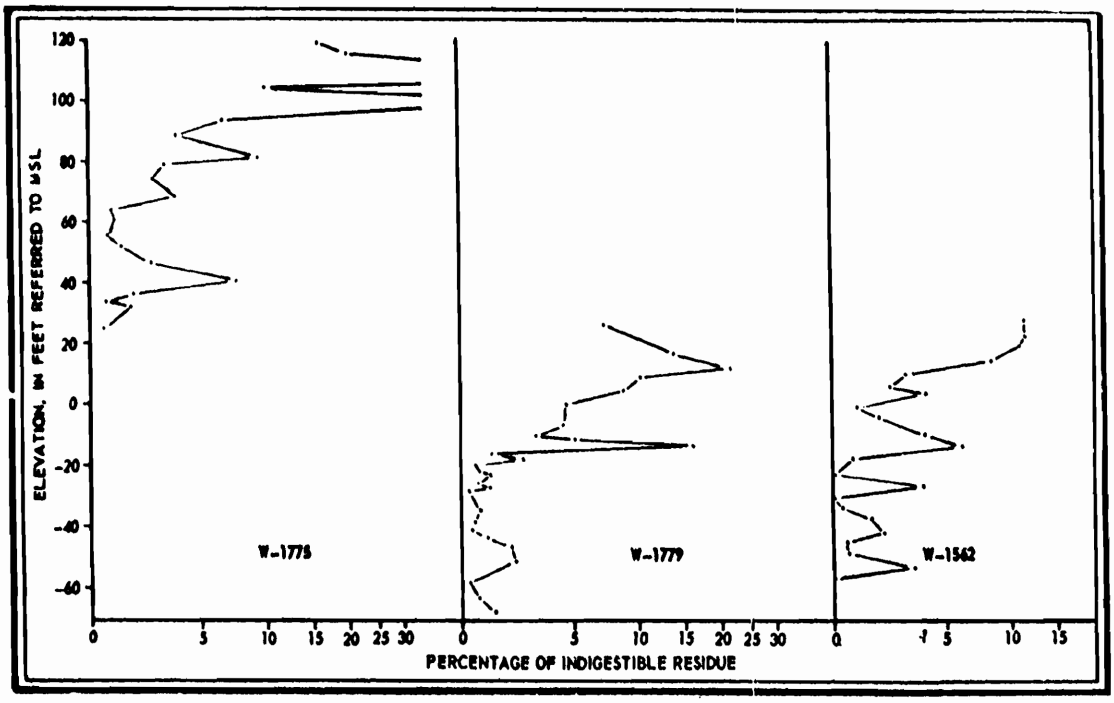


Figure 8. Diagrammatic representation of insoluble residue from three sampled wells. Percentages shown refer to insoluble residues.

of which were identified as Oligocene forms. By determining the elevation of the crystalline quartz, it was found that in both core holes, the elevations of the aggregates were practically the same. In the opinion of the writers, this zone is not the top of the Suwannee sediments even though the fossils indicate that it is Oligocene in age, but only a probable correlative zone within the Suwannee limestone.

The siliceous oolites proved to be of no help in separating the Chattahoochee and Suwannee formations because of their occurrence at irregular depths in only one well, W-1562, and because of their spasmodic appearance in the outcrop formations of locality 47.

The quantity of the mica was in most cases very small and not a useful criterion for establishing the bottom of the Chattahoochee facies and the top of the Suwannee limestone.

Heavy minerals from the core samples of W-1775 and W-1779 were mounted and identified. After computing and plotting the frequency percentages of the individual mineral species against the respective depths at which they occurred, no trends or suites appeared to be present which could be used in determining the contact between the Chattahoochee and the Suwannee formations.

LOCALITIES

Listed below are the locations of all outcrops, well and auger hole samples used in the preparation of this report. All locations of outcrop samples are listed chronologically; references to locations contained in the text are indicated by the index number which precedes each entry. Florida Geological Survey accession numbers precede all well and auger hole locations.

OUTCROP SAMPLES

1. Crystal River formation. Right bank of Flint River, approximately one mile upstream from locality 4, Decatur County, Georgia.
2. Crystal River formation. Left bank of Flint River, 50 yards downstream from locality 1, Decatur County, Georgia.
3. Post-Eocene. Left bank of Flint River, approximately one-half mile upstream from locality 4, Decatur County, Georgia.
4. Post-Eocene. Right bank of Flint River (High Bluff), center of L. L. 263, L. D. 15, Decatur County, Georgia.
5. Crystal River formation. Right bank of Flint River, SW¼ L. L. 264, L. D. 15, Decatur County, Georgia.
6. Post-Eocene. Left bank of Flint River, SE¼ L. L. 214, L. D. 15, Decatur County, Georgia.
7. Post-Eocene. Right bank of Flint River, W½ L. L. 291, L. D. 15, Decatur County, Georgia.
8. Post-Eocene. Right bank of Flint River, NW¼ L. L. 292, L. D. 15, Decatur County, Georgia.
9. Post-Eocene. Left bank of Flint River, SE¼ L. L. 217, L. D. 15, Decatur County, Georgia.
10. Crystal River formation. Left bank of Flint River, NW¼ L. L. 219, L. D. 15, Decatur County, Georgia.
11. Crystal River formation. Left bank of Flint River, NW¼ L. L. 223, L. D. 15, Decatur County, Georgia.
12. Crystal River formation. Right bank of Flint River, NE¼ L. L. 331, L. D. 15, Decatur County, Georgia.
13. Crystal River formation. Right bank of Flint River, NE¼ L. L. 332, L. D. 15, Decatur County, Georgia.
14. Post-Eocene. Right bank of Flint River, SE¼ L. L. 373, L. D. 15, Decatur County, Georgia.
15. Post-Eocene. Left bank of Flint River, SE¼ L. L. 359, L. D. 20, Decatur County, Georgia.
16. Post-Eocene. Right bank of Flint River, SW¼ L. L. 394, L. D. 20, Decatur County, Georgia.
17. Suwannee? limestone. Left bank of Flint River, SE¼ L. L. 250, L. D. 21, Decatur County, Georgia.
18. Post-Eocene. Left bank of Flint River, SW¼ L. L. 250, L. D. 21, Decatur County, Georgia.
19. Post-Eocene. Left bank of Flint River, NE¼ L. L. 257, L. D. 21, Decatur County, Georgia.

20. Post-Eocene. Right bank of Flint River, SW¼ L. L. 262, L. D. 21, Decatur County, Georgia.
21. Oligocene. Left bank of Flint River, SW¼ L. L. 262, L. D. 21, Decatur County, Georgia.
22. Oligocene. Left bank of Flint River, NE¼ L. L. 267, L. D. 21, Decatur County, Georgia.
23. Post-Eocene. Right bank of Flint River, SE¼ L. L. 203, L. D. 21, Decatur County, Georgia.
24. Oligocene. Left bank of Flint River, NE¼ L. L. 301, L. D. 21, Decatur County, Georgia.
25. Oligocene. Right bank of Flint River, SW¼ L. L. 240, L. D. 21, Decatur County, Georgia.
26. Post-Eocene. Right bank of Chattahoochee River, SW¼ sec. 26, T. 7 N., R. 8 W., Jackson County, Florida.
27. Crystal River formation. Right bank of Chattahoochee River, SE¼ sec. 26, T. 7 N., R. 8 W., Jackson County, Florida.
28. Crystal River formation. Left bank of Chattahoochee River, SE¼ L. L. 332, L. D. 14, Seminole County, Georgia.
29. Crystal River formation. Left bank of Chattahoochee River, NE¼ L. L. 328, L. D. 14, Seminole County, Georgia.
30. Crystal River formation. Left bank of Chattahoochee River, SW¼ L. L. 326, L. D. 14, Seminole County, Georgia.
31. Crystal River formation. Right bank of Chattahoochee River, SW¼ sec. 28, T. 6 N., R. 7 W., Jackson County, Florida.
32. Crystal River formation. Left bank of Chattahoochee River, NW¼ L. L. 242, L. D. 14, Seminole County, Georgia.
33. Post-Eocene. Right bank of Chattahoochee River, NW¼ sec. 4, T. 5 N., R. 7 W., Jackson County, Florida.
34. Crystal River formation. Left bank of Chattahoochee River, SE¼ L. L. 244, L. D. 14, Seminole County, Georgia.
35. Post-Eocene. Left bank of Chattahoochee River, NW¼ L. L. 196, L. D. 14, Seminole County, Georgia.
36. Crystal River formation. Right bank of Chattahoochee River, SE¼ sec. 21, T. 5 N., R. 7 W., Jackson County, Florida.
37. Crystal River formation. Right bank of Chatthoochee River, SE¼ sec. 10, T. 4 N., R. 7 W., Jackson County, Florida.
38. Suwannee limestone. Small sink in south central part of sec. 14, T. 5 N., R. 9 W., Jackson County, Florida.
39. Suwannee limestone. Residual boulder in small depression in SE¼ sec. 14, T. 5 N., R. 9 W., Jackson County, Florida.
40. Suwannee limestone. Pinnacles and/or boulders cropping out in edge of field, SW¼ sec. 15, T. 5 N., R. 8 W., Jackson County, Florida.
41. Suwannee limestone. Pinnacles and/or boulders exposed in side of hill on right bank of Chattahoochee River, NW¼ sec. 21, T. 5 N., R. 7 W., Jackson County, Florida.
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43. Suwannee limestone. Residual boulders scattered around rim of depression, SE corner, SW¼ sec. 18, T. 5 N., R. 7 W., Jackson County, Florida.

44. Chattahoochee facies. Ledges of rock exposed along bluff, SE corner, NE¼ sec. 16, T. 4 N., R. 7 W., Jackson County, Florida.
45. Chattahoochee facies. Residual boulders and ledges of rock exposed along bluff, SW¼ sec. 15, T. 4 N., R. 7 W., Jackson County, Florida.
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49. Chattahoochee facies. Exposed along both banks of small creek, SE¼ L. L. 284, L. D. 21, Decatur County, Georgia.
50. Chattahoochee facies. Exposed along right bank of Sanborn Creek, SE corner SW¼ L. L. 265, L. D. 21, Decatur County, Georgia.
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52. Suwannee limestone. Exposed along right bank of Flint River and on island in river, SW¼ L. L. 258, L. D. 21, Decatur County, Georgia.
53. Suwannee limestone overlain by Chattahoochee facies in small gully along left bank of Flint River, SW¼ L. L. 262, L. D. 21, Decatur County, Georgia.
54. Suwannee limestone overlain by Chattahoochee facies in powerhouse excavation, Jim Woodruff dam, SW¼ sec. 29, T. 4 N., R. 6 W., Gadsden County, Florida.
55. Chattahoochee facies. Exposed along left bank of Sanborn Creek, SW¼ L. L. 265, L. D. 21, Decatur County, Georgia.
56. Hawthorn facies. Exposed along road cut on Florida 269A-Georgia 97, L. L. 429, L. D. 21, Decatur County, Georgia, Gadsden County, Florida.

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AS-126	SW¼ NE¼ sec. 33, T. 4 N., R. 6 W., Gadsden County, Florida.
AS-238	SW¼ sec. 16, T. 4 N., R. 7 W., Jackson County, Florida.
AS-239	SW¼ sec. 9, T. 4 N., R. 7 W., Jackson County, Florida.
AS-240	SE corner sec. 5, T. 4 N., R. 7 W., Jackson County, Florida.
AS-241	NW¼ sec. 5, T. 4 N., R. 7 W., Jackson County, Florida.
AS-242	SE¼ sec. 29, T. 5 N., R. 7 W., Jackson County, Florida.
AS-243	NE¼ sec. 7, T. 5 N., R. 7 W., Jackson County, Florida.
AS-244	NW corner NE¼ SW¼ sec. 13, T. 6 N., R. 8 W., Jackson County, Florida.
AS-245	NE¼ NE¼ sec. 34, T. 7 N., R. 8 W., Jackson County, Florida.
AS-246	SE¼ L. L. 11, L. D. 21, Seminole County, Georgia.
AS-247	NW¼ L. L. 130, L. D. 21, Seminole County, Georgia.
AS-248	SW¼ L. L. 212, L. D. 21, Seminole County, Georgia.
AS-249	NE¼ L. L. 101, L. D. 21, Seminole County, Georgia.
AS-250	SW¼ L. L. 206, L. D. 21, Decatur County, Georgia.
AS-251	NW¼ L. L. 118, L. D. 14, Seminole County, Georgia.

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W-1364	NE¼ SW¼ sec. 8, T. 4 N., R. 8 W., Jackson County, Florida.
W-1562	SE¼ SW¼ sec. 30, T. 4 N., R. 6 W., Jackson County, Florida.
W-1775	SE¼ SE¼ NE¼ sec. 28, T. 4 N., R. 7 W., Jackson County, Florida.

W-1779	SE¼ SW¼ sec. 30, T. 4 N., R. 6 W., Jackson County, Florida.
W-2149	L. L. 61, L. D. 27, Seminole County, Georgia.
W-2247	NW¼ NE¼ sec. 12, T. 3 N., R. 7 W., Jackson County, Florida.
W-2254	SE¼ SE¼ sec. 28, T. 4 N., R. 7 W., Jackson County, Florida.
W-2306	SE¼ sec. 17, T. 4 N., R. 7 W., Jackson County, Florida.
W-3442	SW¼ sec. 12, T. 3 N., R. 7 W., Jackson County, Florida.
W-3482	SW¼ SE¼ sec. 33, T. 4 N., R. 6 W., Gadsden County, Florida.
W-3627	SE¼ NE¼ sec. 11, T. 5 N., R. 8 W., Jackson County, Florida.
W-3737	L. L. 142, L. D. 21, Seminole County, Georgia.

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Part II

PHOSPHATE CONCENTRATIONS NEAR BIRD ROOKERIES IN SOUTH FLORIDA

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PHOSPHATE CONCENTRATIONS NEAR BIRD ROOKERIES IN SOUTH FLORIDA

ABSTRACT

Sediments collected from the vicinity of four bird rookeries along the coast of southwest Florida were analyzed for their P_2O_5 content to determine the effect of a colony of large birds on the concentration of phosphate in the sediments near the rookeries. Samples were also taken from localities away from areas of dense bird population for comparison. In three of the sample rookery localities the amount of P_2O_5 was not significantly higher than in other nearby areas. In the fourth, the Cuthbert Lake rookery, dried sediments contain up to 24.55 percent P_2O_5. Samples of material near the edges of Cuthbert Lake contain less than one percent down to a trace. The comparison indicates that the bird colony has appreciably increased the phosphate content of the sedimentary material in the near vicinity of the rookery, but the effects are very local.

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INTRODUCTION

The numerous guano deposits on islands off the coast of South America, in the south and mid-Pacific, and in a number of other places demonstrate the ability of a large bird population to concentrate large amounts of phosphate in comparatively small areas. The Guanape Islands, latitude 8°34′S, longitude 78°56′W, off the coast of Peru, had a total estimated reserve of 1,300,000 tons of guano with P_2O_5 content of 12.75 percent (Hutchinson, p. 30). This quantity of guano had accumulated principally on two islands, North Island which is 1050 meters long and 700 meters wide and South Island which is 690 meters long and 570 meters wide.

A number of Pacific atolls have larger deposits of phosphate related to a more remote period of bird activity. Ocean Island and Nauru afford good examples of this type. Both of these islands are in the equatorial Pacific and lie within 1°S of the equator and between longitude 176°E and longitude 170°E. Neither has a guano-producing bird population at the present time. Ocean Island which is 2780 meters long and 2200 meters wide had an initial reserve estimated by Ellis (Hutchinson, p. 217) at 20,000,000 tons. Three analyses of this phosphate give a mean P_2O_5 content of 40.51 percent. Nauru, 6 kilometers long and 4.7 kilometers wide had an even larger reserve estimated by the British Phosphate Commissioners at 87,500,000 tons, with a mean P_2O_5 content of about 39 percent. Much of the phosphate of Ocean and Nauru islands consists of phosphatized coral rock and limestone debris.

Though limestone is the most favorable rock for phosphate replacement, there are numerous examples of other rock types that have been phosphatized. Echel and Milton (1953, p. 437-446) describe a deposit of phosphate which they believe was formed by the influence of guano on felsite. Chemical analyses by Teall (Hutchinson, p. 198) of trachyte from Clipperton Island in the East Pacific show replacement by phosphate with a highly altered specimen of the rock containing 38.5 percent P_2O_5. Basalt on Necker Island, one of the Hawaiian Leeward Islands, is considerably replaced by phosphate according to Elscher (Hutchinson, p. 203). None of the deposits of phosphate resulting from replacement of rocks other than limestone appears to be commercially important.

The present study is concerned with the influence of a large bird population on the phosphate content of sediments adjacent to the areas of bird concentration. Bird rookeries and roosts on small mangrove islands along the southwest coast of Florida are suitable for this sort of study, because there is a periodic removal of the bird droppings by rain and high tides. Accumulations such as those found on the many guano islands are not possible, and the material becomes available for distribution by wave and current action. The amount of droppings is large and highly localized in most cases, for as many as 80,000 large wading and swimming birds may be concentrated on a mangrove key no larger than five or six acres. Mills (1944) estimates that about 50 tons are added to the waters of Tampa Bay every 24 hours by the several rookeries and roosts located there.

Sampling was done with a cylindrical scoop of about one-quart capacity mounted on a stem of one-half inch pipe. This method of sampling recovered only surficial material, and all samples were taken where the water was less than 10 feet deep. Where sampling was done in the vicinity of a mangrove key, samples were taken at the edge of the

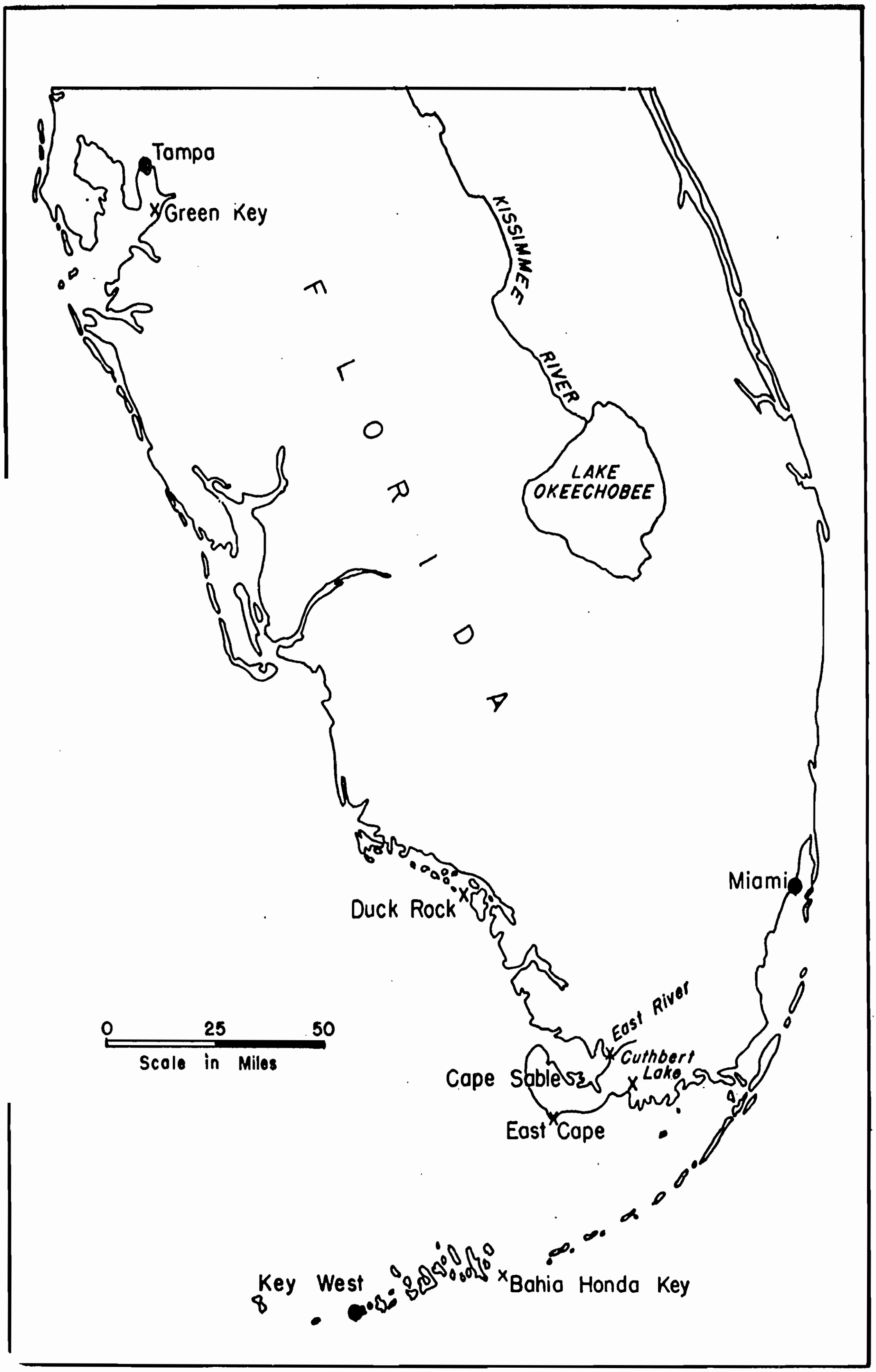

Figure 1. Index map of sampled localities.

mangrove and outward at predetermined intervals of 15 feet up to 300 feet. Lines of samples were taken in all directions from the key. At the East River (fig. 1) locality samples were taken from the channels between the mangrove islands. As a basis for comparison some samples were taken from a short distance above and below the rookery.

SAMPLED LOCALITIES

GREEN KEY ROOKERY

Green Key (fig. 1) is a mangrove island of about six acres located about 10 miles south of Tampa on the east side of Tampa Bay. The island has been the site of a bird rookery since about 1921 and has been under the protection of the Audubon Society since 1934. It is mainly a nesting place for herons, ibis, pelicans, and cormorants and is used by a small number of birds as a roost after the nesting period. According to Mills the population of the colony has grown from 700 to 50,000 under the Audubon Society's protection.

The sediment in the vicinity of Green Key is predominantly quartz sand with varying amounts of silt and clay-size material. The amount of fine material diminishes away from the island. Six samples (table 1) have P_2O_5 content, based on dry sample, ranging from 0.18 percent to 0.46 percent. The maximum value is less than the average of 40 samples more or less evenly spaced over Tampa Bay. According to Gould (personal communication) the P_2O_5 content of these 40 samples ranges from 0.06 percent to 6.24 percent and averages 0.55 percent. Two samples from near the mouth of Alafia River, about 4 miles north of Green Key, have P_2O_5 contents of 0.30 percent and 0.93 percent. This locality of high phosphorus concentration is probably affected considerably by the Alafia River which flows through one of the principal phosphate areas of the State. This river has a high phosphorus content and samples of its water analyzed by Odum (1953, p. 12) contained up to 3.55 ppm total phosphorus. The organic and particulate fractions of the river's phosphorus are less susceptible to removal from the water by plant activity than the dissolved phosphorus, and are more subject to settling out and becoming part of the sediment. The proximity of Green Key and the mouth of the Alafia River suggests that the phosphorus in the sediment around Green Key has been contributed in its major part by the river, with the bird colony perhaps contributing a small amount.

DUCK ROCK

Duck Rock (fig. 1), one of the Ten Thousand Islands, is a mangrove key of about five acres located about 10 miles south of the town of Everglades. The substratum of this island is oyster shell and coquina, and apparently it once stood above high tides, for ducks are said to have nested there prior to 1910. Establishment of mangrove made roosting possible, and it is now principally a roost for an estimated 75,000 to 80,000 white ibis and numerous brown pelicans, cormorants, egrets and other herons, and frigate birds. A number of birds including the egrets, Louisiana heron, brown pelican, and double-crested cormorant nest there. It has been under the protection of the Audubon Society for over 20 years.

Duck Rock is on the outer edge of the Ten Thousand Islands chain and its exposed southwest side shows considerable effects of storm-wave erosion. The sediment on the southwest side is mainly quartz sand, and that on the sheltered northeast side is a mixture of calcareous mud and sand. Bottom conditions permit the growth of organisms, and a number of live mollusks were picked up in the samples.

Eight samples (table 2, nos. 7-14) from the vicinity of Duck Rock have P_2O_5 content ranging from a trace to 0.29 percent based on dry samples. For comparative purposes three samples (table 2, no. 15-17) were taken from the vicinity of another key[1] located about a mile north of Duck Rock. This key is not known to have been a center of bird population. Three samples from this locality show respectively a trace, 0.20 percent, and 0.41 percent. The 0.41 percent noticeably exceeds the highest value obtained in the Duck Rock samples. These data suggest that the bird colony has had little influence on the phosphorus content in the sediments at Duck Rock.

EAST RIVER ROOKERY

East River (fig. 1), flowing sluggishly toward Whitewater Bay from the east, is characterized by a network of channels separated by numerous small mangrove islands. A number of these islands form the nesting site of some 20,000 or more wood and white ibis, American egret, cormorant, anhinga and snowy egret.

The mangrove of the East River area grows on a substratum of peat about 1½ to 2 feet thick. The peat lies on a layer of soft calcareous mud, referred to in this paper as marl, of about the same thickness, and below the marl is hard Miami limestone.

Samples taken from near the center of the channels at a number of points consist of mixtures of marl with abundant mollusk shells and peat. The high loss on ignition, up to nearly 20 percent, reflects the amount of peat in the samples. The sediment smells very strongly of hydrogen sulphide which may account for the fact that no live mollusks

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[1] Designated Bennett Key for purpose of this paper.

were found in it. Four samples (table 3) from this locality have P_2O_5 contents that range from a trace to 0.24 percent.

CUTHBERT LAKE ROOKERY

Cuthbert Lake Rookery (fig. 1) is on a small mangrove key about 500 feet long by 300 feet wide near the middle of Cuthbert Lake. This lake, which is about two miles long by one mile wide, is one of a large number of shallow brackish-water lakes located at the southern edge of the Florida mainland within a few miles of Florida Bay. The mangrove of Cuthbert Key grows on a substratum of peat which is three feet thick at the center of the island. This is underlain by a 14-inch layer of marl very similar to that under the peat at East River. The bedrock is Miami limestone.

The rookery is populated predominantly by wood ibis which, according to Moore (1953, p. 181-188), make up about nine-tenths of the total. American egrets, cormorants, anhinga, and snowy egret constitute the remainder. The total population varies between 2000 and 5000. A plume hunter named Cuthbert discovered the rookery in 1890, but no one has any idea how long the rookery had been in use prior to that. Bird protection laws passed by the State Legislature in 1901 virtually stopped the slaughter of birds for their plumes. In 1902 Guy M. Bradley, who was a few years later shot by a plume hunter, was employed by the National Audubon Society to protect the rookery. It remained under the protection of the Audubon Society until the establishment of the Everglades National Park.

Over most of its area the Cuthbert Lake bottom is on Miami limestone. The limestone has a solution pitted surface, and in many of the depressions there is an accumulation of shells, limestone fragments and other debris. The limestone is covered by marl only around the margins of the rookery key and around the fringes of the lake. The marl is thinner away from the edge of the mangrove and usually extends less than 100 feet out into the lake. This condition suggests that erosion instead of sedimentation is noneffective in the main body of the lake. In some of the small embayments, however, there is an accumulation up to two feet thick of a gelatinous sort of material. It is largely organic, for the analysis (table 4, no. 40) shows nearly 42 percent ignition loss.

Although in the vicinity of the rookery key there is essentially no deposition, there is some precipitation of phosphate. In addition to peat and marl, samples from this locality contain small concretion-like particles of phosphatic material. A sample submitted to J. B. Cathcart and analyzed by George Ashby of the U. S. Geological Survey showed apatite as the major mineral phase. Fluor-apatite is indicated by its fluorine content. The particles range in size from less than one mm. to about two cm. They accumulate in limestone solution pits beyond the edge of the marl and on the island's beach which is exposed at low tide. None of this material was found in the peat and marl samples taken near the middle of the island. Samples of sediment from the edges of Cuthbert Lake and from nearby West Lake and Long Lake contain none, although the sediment is otherwise similar to that near the rookery key. The localization of phosphatic material in the vicinity of the rookery indicates that the bird colony plays an important part in its accumulation.

Eleven samples (table 4, no. 22-32) collected at a distance of 20 feet to 70 feet from the edge of the mangrove on the rookery key contain varying amounts of peat, marl with shell fragments, fragments of bedrock, and phosphatic particles. The P_2O_5 contents of these samples range from 0.48 percent to 7.92 percent with an average of 4.10 percent. The amount of phosphorus varies with the quantity of the phosphatic particles in the sample. A sample from the island's beach (table 4, no. 33), consisting almost entirely of ground-up peat and phosphate particles, has 24.55 percent P_2O_5 based on dry sample. This sample has a 25.50 percent loss on ignition, and when the P_2O_5 percentage is based on ash, the value is 33.77 percent.

Some indication of replacement of the marl substratum by phosphate is given by a comparison of its P_2O_5 content with that of marl from other localities. A single sample of marl (table 4, no. 35) from near the middle of the island contains 0.85 percent P_2O_5. Four marl samples (table 5, no. 41-44), two each from nearby Long Lake and West Lake contain P_2O_5 ranging from a trace to 0.39 percent, one from near the beach at East Cape (table 5, no. 45) 0.18 percent and a sample of marl dredged up for fill on Bahia Honda Key (table 5, no. 46) has only a trace. There is further indication of replacement in the shell material located near the island. An analysis of oyster shell (table 4, no. 34) picked from the samples and washed clean of marl and other material shows 0.50 percent P_2O_5. Analyses of pelecypod shells by Clarke and Wheeler (1922) show $Ca_3P_2O_8$ ranging from a trace to only 0.07 percent.

There is a distinct difference in the amount of phosphorus in the sediment around the edge of the lake and the amount in the sediment from the near vicinity of the rookery. Four samples of marl (table 4, no. 36-39) from widely separated points near the lake's edge contain P_2O_5 ranging from a trace to 0.18 percent. A fifth sample (table 4, no. 40), consisting of a somewhat gelatinous organic material and whose analysis shows 41.85 ignition loss, contains 0.27 percent P_2O_5.

SUMMARY AND CONCLUSIONS

The lack of significant concentration of P_2O_5 in the Green Key, Duck Rock, and East River localities is probably due to several factors. The bird colonies may be too recent to have had much effect, currents may carry the material away and distribute it sparsely, or plant life may take up the soluble phosphorus before it has a chance to precipitate.

At Cuthbert Lake conditions have favored accumulation of phosphorus in the near vicinity of the rookery key. A large colony of birds has occupied the key for a long time providing an adequate source of phosphorus. Currents in the lakes are not as strong as in the other sampled localities, so the phosphorus has a better chance to accumulate.

Without a specific study of the flora of the water in the different localities, it is not possible to evaluate the effects plant life had in removing phosphorus from solution. Much algae had been growing around the rookery key in Cuthbert Lake, but when sampling was done in August, the algae was dead and largely disintegrated. A high H_2S content in the samples may have had some inhibiting effect on plant life, especially on forms near the bottom. In any case there was phosphorus in excess of that needed by plants and part of the excess was precipitated as apatite in small concretion-like particles.

The relatively high concentration of phosphorus in the sediments at the Cuthbert Lake rookery and the low concentration in other parts of this lake and in nearby lakes indicates that the bird colony has been a major factor in its accumulation.

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TABLE 1. ANALYSES OF SAMPLES FROM GREEN KEY VICINITY

Sample	P_20_5 based on air dried sample	*P_20_5 based on ash	Moisture	Ignition loss	Ash (650° C)
1	0.43	0.45	1.08	3.99	94.93
2	0.46	0.47	1.13	3.72	95.15
3	0.30	0.31	0.63	2.37	97.00
4	0.18	0.18	0.30	1.37	98.33
5	0.30	0.33	0.45	7.42	92.13
6	0.20	0.20	0.48	1.67	97.85

1 40 feet east of Green Key
2 200 feet east of Green Key
3 500 feet east of Green Key
4 40 feet south of Green Key
5 200 feet south of Green Key
6 500 feet south of Green Key

*Calculated by Author

TABLE 2. ANALYSES OF SAMPLES FROM DUCK ROCK VICINITY

Sample	P_20_5 based on air dried sample	*P_20_5 based on ash	Moisture	Ignition loss	Ash (650° C)
7	0.29	0.34	2.65	14.40	82.95
8	0.24	0.29	2.85	18.80	78.35
9	0.19	0.23	3.58	17.04	79.38
10	0.20	0.25	1.95	17.07	80.98
11	0.19	0.22	2.90	14.40	82.70
12	0.21	0.25	4.80	15.75	79.45
13	0.18	0.20	0.70	8.10	91.20
14	Trace	Trace	0.23	6.89	92.88
15	Trace	Trace	0.60	10.47	88.93
16	0.41	0.49	3.60	14.17	82.23
17	0.20	0.22	1.95	7.92	90.13

7 At north edge of Duck Rock
8 40 feet north of Duck Rock
9 100 feet north of Duck Rock
10 200 feet north of Duck Rock
11 500 feet north of Duck Rock
12 100 feet east of Duck Rock
13 150 feet south of Duck Rock
14 150 feet west of Duck Rock
15 40 feet north of Bennett Key
16 100 feet north of Bennett Key
17 100 feet west of Bennett Key

*Calculated by Author

TABLE 3. ANALYSES OF SAMPLES FROM EAST RIVER

Sample	P_2O_5 based on air dried sample	*P_2O_5 based on ash	Moisture	Ignition loss	Ash (650° C)
18	0.24	0.29	4.33	17.22	78.45
19	0.10	0.12	2.45	16.52	81.03
20	Trace	Trace	3.30	17.45	79.25
21	0.11	0.13	5.65	19.87	74.48

18 Channel sample from upper edge of rookery
19 Channel sample from middle of rookery
20 Channel sample from lower edge of rookery
21 Channel sample from below rookery

*Calculated by Author

TABLE 4. ANALYSES OF SAMPLES FROM CUTHBERT LAKE

Sample	P_2O_5 based on air dried sample	*P_2O_5 based on ash	Moisture	Ignition loss	Ash (650° C)
22	6.49	8.18	4.73	19.72	75.55
23	2.22	2.87	4.25	21.80	73.95
24	2.52	5.36	10.75	47.30	41.95
25	6.21	8.05	4.25	21.87	73.88
26	4.68	5.95	5.28	20.27	74.45
27	3.45	4.55	5.83	22.79	71.38
28	5.99	7.75	4.38	21.64	73.98
29	0.48	0.68	6.20	27.75	66.05
30	7.92	10.53	7.15	23.05	69.80
31	1.66	2.10	3.55	20.40	76.05
32	3.43	4.17	2.90	17.15	79.95
33	24.55	33.77	6.60	25.50	67.90
34	0.50	0.54	0.65	6.50	92.85
35	0.85	1.06	2.43	19.24	78.33
36	0.18	0.20	1.63	10.04	88.33
37	0.15	0.17	0.60	11.67	87.73
38	Trace	Trace	8.30	14.20	77.50
39	Trace	Trace	2.85	12.92	83.23
40	0.27	0.49	6.70	41.85	51.45

22 20 feet north of Cuthbert Key
23 40 feet north of Cuthbert Key
24 60 feet north of Cuthbert Key
25 40 feet northeast of Cuthbert Key
26 40 feet east of Cuthbert Key
27 40 feet southeast of Cuthbert Key
28 40 feet south of Cuthbert Key
29 30 feet southwest of Cuthbert Key
30 70 feet southwest of Cuthbert Key
31 70 feet west of Cuthbert Key
32 40 feet northwest of Cuthbert Key
33 Beach material from Cuthbert Rookery
34 Oyster shell from vicinity of Cuthbert Rookery
35 Marl from middle of Cuthbert Rookery
36 Southwest margin of lake, northwest of Cuthbert Creek
37 At north edge of lake
38 At southeast margin of lake
39 At southwest margin of lake, east of Cuthbert Creek
40 Southwest margin of lake at Cuthbert Creek

TABLE 5. SAMPLES FROM MISCELLANEOUS LOCALITIES

Sample	P_2O_5 based on air dried sample	*P_2O_5 based on ash	Moisture	Ignition loss	Ash (650° C)
41	0.18	0.23	1.70	18.65	79.65
42	Trace	Trace	2.05	23.05	74.90
43	0.34	0.43	2.20	21.10	76.70
44	0.39	0.51	3.48	21.67	74.85
45	0.18	0.24	1.95	22.65	75.40
46	Trace	Trace	3.40	11.07	85.53

41	East end of West Lake, 200 yards west of small island
42	Northwest corner of West Lake, near the channel opening
43	East end of Long Lake
44	West end of Long Lake
45	Marl from near beach at East Cape
46	Dredgings from Bahia Honda Key

*Calculated by Author

Part III

AN ANALYSIS OF OCHLOCKONEE RIVER CHANNEL SEDIMENTS

By

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Part III

AN ANALYSIS OF OCHLOCKONEE RIVER CHANNEL SEDIMENTS

ABSTRACT

Channel sediments from the Ochlockonee River between Ochlockonee Bay and the dam at Lake Talquin, Florida, were examined to determine sedimentary parameters and heavy-mineral content. Most samples show a unimodal grain-size distribution. There is considerable fluctuation in the median diameter and mean grain size, but there is a noticeable tendency for these values to decrease downstream. Total heavy-mineral content ranges from about 0.05 per cent to 0.46 per cent with magnetite-ilmenite the most abundant and rutile second in abundance.

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PURPOSE OF INVESTIGATION

The objectives of this study were to learn something of the physical characteristics of the Ochlockonee River channel sediments between Ochlockonee Bay and Lake Talquin and to determine the heavy-mineral content of these sediments.

METHOD OF SAMPLING

Samples were collected from the river channel at two-mile intervals, beginning at the entrance of the river into Ochlockonee Bay. A coring tube 2 inches in diameter and 18 inches long attached to a stem made up of 2½-foot sections was lowered into the water and forced into the channel deposits. The depth of penetration into the sediment was to the full length of the coring tube where the thickness of the sediment layer permitted. In a few places compaction of the material in the tube allowed a penetration in excess of 18 inches. Water depths ranged from 1 foot to 21 feet.

MECHANICAL ANALYSIS OF SEDIMENTS

A representative 100-gram portion of each sample was separated through a battery of 26 Tyler screens, the finest with an opening of .043 mm. and the coarsest with an opening of 6.680 mm. The data were plotted in histograms and cumulative frequency curves, and from these graphs the sedimentary parameters of table 1 were derived.

TABLE 1. SEDIMENTARY PARAMETERS*

Sample Number	Q_1	Median	Q_3	Mean	S_0
1	.115	.149	.184	.156	1.26
2	.126	.204	.315	.165	1.58
3	.173	.228	.320	.247	1.36
4	.202	.254	.340	.294	1.30
5	.200	.260	.284	.246	1.19
6	.238	.286	.336	.287	1.19
7	.305	.369	.470	.438	1.24
8	.160	.196	.250	.203	1.25
9	.268	.352	.520	.430	1.39
10	.390	.484	.680	.534	1.32
11	.350	.410	.530	.461	1.23
12	.360	.498	.568	.521	1.25
13	.360	.460	.625	.553	1.31
14	.260	.350	.480	.401	1.35
15	.269	.318	.395	.360	1.21
16	.430	.723	1.050	.767	1.56
17	.225	.298	.410	.365	1.35
18	.324	.470	.700	.546	1.47
19	.154	.220	.290	.256	1.37
20	.375	.477	.610	.519	1.27
21	.315	.385	.495	.429	1.25
22	.600	.790	1.120	.937	1.36
23	.215	.295	.410	.358	1.38
24	.335	.422	.570	.490	1.30
25	.590	.775	1.050	.871	1.33
26	.370	.530	.748	.607	1.42
27	.295	.437	.700	.550	1.54
28	.426	.610	.830	.675	1.39
29	.370	.508	.700	.590	1.37
30	.254	.441	.680	.605	1.63
31	.345	.475	.712	.587	1.43
32	.250	.430	.985	.849	1.98
Averages		.409		.478	1.36

* All figures except S_0 are expressed in mm.

With few exceptions the Ochlockonee channel deposits have a unimodal grain-size distribution and are very well sorted. The least well-sorted sample, with a sorting coefficient of 1.98, was taken just below the Lake Talquin Dam. Sorting coefficient values range from 1.98 to 1.19.

The median diameters range from 0.14 mm. to 0.790 mm. with considerable fluctuation from one locality to the next but with a noticeable decrease downstream. Sample number 1, taken at the river's mouth, has the lowest value. The mean grain sizes range from 0.156 mm. to 0.937 mm., and there is a fluctuation that almost parallels that of the median grain sizes. Like the median diameter, the mean grain size tends to decrease downstream.

TABLE 2. PERCENTAGE OF TOTAL HEAVY MINERALS IN EACH SAMPLE

Sample Number	Percent of Heavies
1	0.46
2	0.12
3	0.06
4	0.05
5	0.13
6	0.10
7	0.10
8	0.25
9	0.10
10	0.05
11	0.08
12	0.09
13	0.07
14	0.11
15	0.16
16	0.21
17	0.22
18	0.25
19	0.24
20	0.10
21	0.14
22	0.11
23	0.24
24	0.24
25	0.05
26	0.12
27	0.12
28	0.10
29	0.20
30	0.16
31	0.16
32	0.38

HEAVY MINERAL ANALYSIS

The heavy minerals were separated from the sands by allowing a 20-gram portion of each sample to settle in bromoform for a period of 30 minutes with agitation every five minutes. A representative part of each heavy fraction was mounted in balsam and a grain count was made using a mechanical stage on a petrographic microscope.

The amount of heavy minerals (table 2) in the Ochlockonee channel deposits is small, ranging from 0.05 percent to 0.46 percent. The opaque minerals, chiefly ilmenite but with some magnetite, are the most abundant (table 3). They make up from 10 percent to 34 percent of the total heavies, and the average for the 32 samples is about 22 percent. Rutile is the second most abundant, ranging from about 8 percent to 26 percent and averaging about 20 percent. Other minerals in decreasing order of abundance are kyanite, zircon, tourmaline, hornblende, leucoxene, sillimanite, staurolite, garnet and epidote.

TABLE 3. RELATIVE ABUNDANCE OF HEAVY MINERALS IN ALL SAMPLES

	Average Percent	Percent Range
Magnetite-ilmenite	22.4	10-34
Rutile	19.8	8-26
Kyanite	16.9	9-29
Zircon	12.8	5-25
Tourmaline	11.1	1-27
Hornblende	7.0	0-20
Leucoxene	5.3	1-21
Sillimanite	1.9	0-6
Staurolite	1.3	0-11
Garnet	0.8	0-5
Epidote	0.7	0-4

A study[1] by Alfred Larsen and Steve Revell of the heavy-mineral content of the Pleistocene terrace sands east of the Ochlockonee River shows a close similarity in the heavy-mineral suites of the terrace deposits and the river deposits. A notable difference is in the high percentage of hornblende in some of the river material and its scarcity in the terrace material. No monazite was noted in the river material, but in some of the terrace localities monazite makes up to 10 percent of the total heavy-mineral content.

Close similarity in the heavy minerals of the river deposits and the adjacent terrace deposits indicates that a major source of the river's

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[1] For Master's degree at Florida State University.

present bed load is the terrace material. Since the construction of the Talquin dam, the upstream sources of material have been cut off. The load below the dam is now obtained mainly by reworking of the flood plain and through contributions of Pleistocene terrace material from tributary streams and by slumping of this material along the banks of the Ochlockonee River. The limestone bedrock over which the river flows probably contributes a very small amount of clastic material to the bed load.