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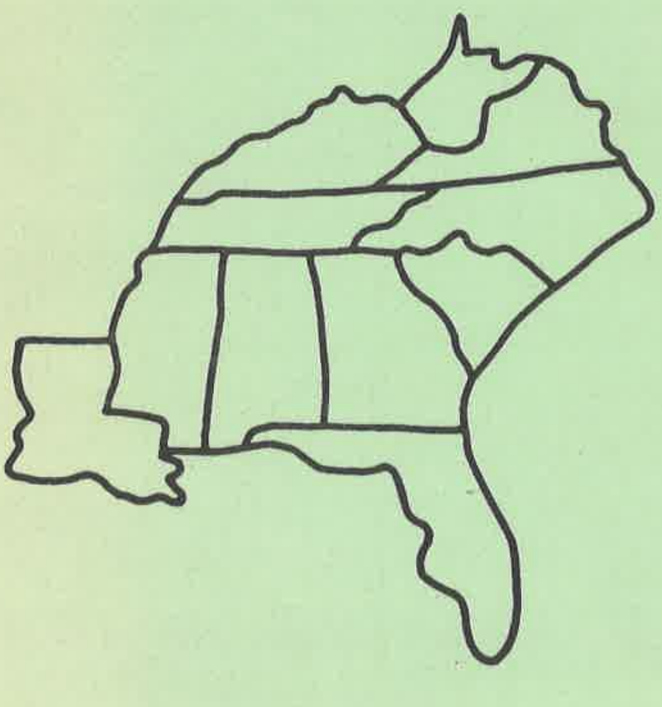

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SOUTHEASTERN GEOLOGY

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SEDIMENTS OF THE CHATTAHOOCHEE RIVER GEORGIA-ALABAMA

By

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ABSTRACT

Several bed load samples were collected along the Chattahoochee River, Georgia-Alabama, from near the headwaters and thence southward to the Florida state line. These samples were analyzed by means of mechanical and mineralogical methods to determine the general character of the river sediments. Results of this study indicate that the average grain diameter decreases downstream, that the sorting improves downstream, and that the river sands are generally unimodal. The heavy minerals in order of abundance are hornblende, epidote, magnetite-ilmenite, kyanite, garnet, staurolite, leucoxene, and tourmaline. Minor constituents are sillimanite, zircon, rutile, and monazite. The perceptible removal of unstable heavy minerals and the relative increase of the more stable varieties downstream suggest a dominance of chemical alteration over attrition during transport.

INTRODUCTION

The Chattahoochee River and its tributaries comprise a major drainage system located in the states of Georgia, Alabama, and Florida. The river rises in northeast Georgia and flows southwest to Troup County, where it swings south and forms the southern extension of the Georgia-Alabama state line. After joining the Flint River near the Georgia-Florida boundary, the river continues south as the Apalachicola River to the city of Apalachicola, Florida, where it empties into the Gulf of Mexico.

At its headwaters the Chattahoochee is a swift mountain stream. It increases rapidly in size as it flows across the Piedmont of north Georgia, and throughout a 120 mile segment of its course is a subsequent stream controlled by the presence of the Brevard Schist. Southward from Columbus, Georgia, the Chattahoochee flows over Cretaceous clastics and successively younger sediments of Tertiary age.

ACKNOWLEDGEMENTS

The authors are indebted to S. S. Winters and W. F. Tanner of the Florida State University for their suggestions and criticisms.

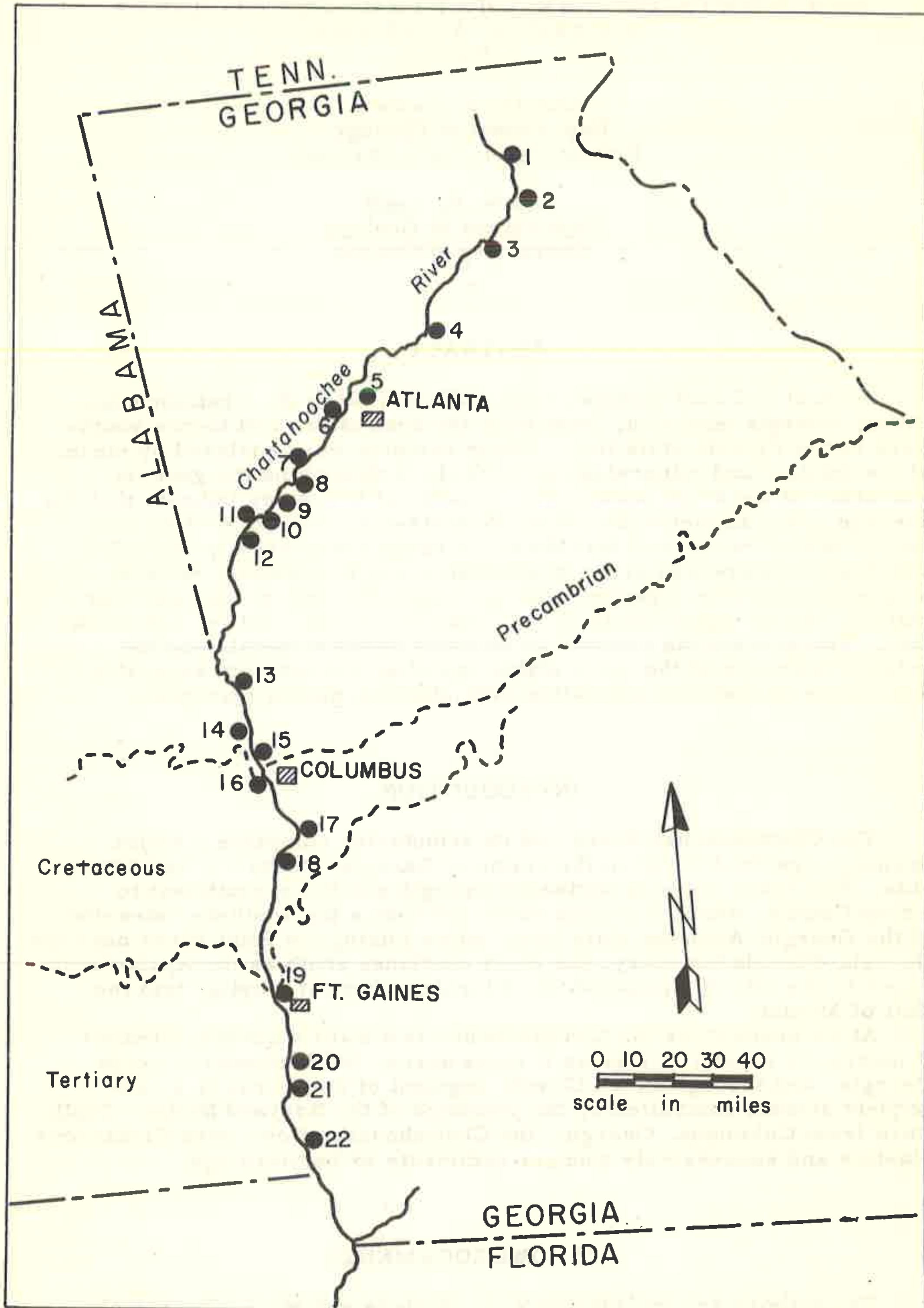

FIGURE I. Index to Sampled Localities

PROCEDURE

A series of bed load samples were obtained from the Chattahoochee River in order to determine the general character of its sediments. The samples were collected at intervals from near the headwaters southward to the Florida state line (Fig. 1). Four samples were also collected from the following tributaries: Nancy Creek (#5), Cedar Creek (#10), Pearson Creek (#13), and an unnamed tributary (#15) above the Bartlett's Ferry Dam. To insure some uniformity in sample collection, all samples were taken on the inside of river bends near the water line to a depth of 6 inches.

In the laboratory each sample was reduced to 100 grams in a Jones-Type splitter and separated into size fractions according to the Udden-Wentworth grade scale with a set of six wire mesh screens with mean diameter openings of 2 mm, 1 mm, 1/2 mm, 1/4 mm, 1/8 mm, and 1/16 mm. The weighed size fractions were used in computing the median diameter, the arithmetic mean diameter, and sorting coefficient for each sample. Heavy minerals were removed from the samples by means of bromoform, and those contained in the size range 1/2 mm - 1/8 mm were identified and counted with the aid of a petrographic microscope equipped with a mechanical stage.

MECHANICAL ANALYSIS

Sediments of the Chattahoochee are generally well sorted and unimodal, whereas tributary sediments tend to be coarser and bimodal as shown by representative histograms in Figure 2. No pronounced trends were detected in the mechanical analysis of the samples, although when divided into upstream and downstream groups* a slight trend downstream toward improved sorting and decreased grain size is evident (Table 1).

Figure 3 shows the downstream trend of the mode, or most "popular" grade size for each sample. A distinct increase in the grain size of the mode occurs south of the contact between the igneo-metamorphic complex of the Georgia Piedmont and Upper Cretaceous clastics. This suggests that tributaries draining Cretaceous and Tertiary areas south of the Piedmont are contributing significant amounts of relatively coarse sand to the main stream. Sidwell (1939) also noted a similar change in coarseness of South Canadian River sediments in New Mexico and Texas.

HEAVY MINERALS

The heavy mineral assemblage transported by the Chattahoochee River is principally a metamorphic suite reflecting its source in the Georgia Piedmont. The most abundant heavy minerals for all samples are green and blue-green hornblende (28%), epidote (19%), magnetite-ilmenite* (14. 4%), and kyanite (14. 1%). Also present in significant amounts are

*Columbus, Georgia, separates upstream from downstream samples.

*These two minerals were counted together.

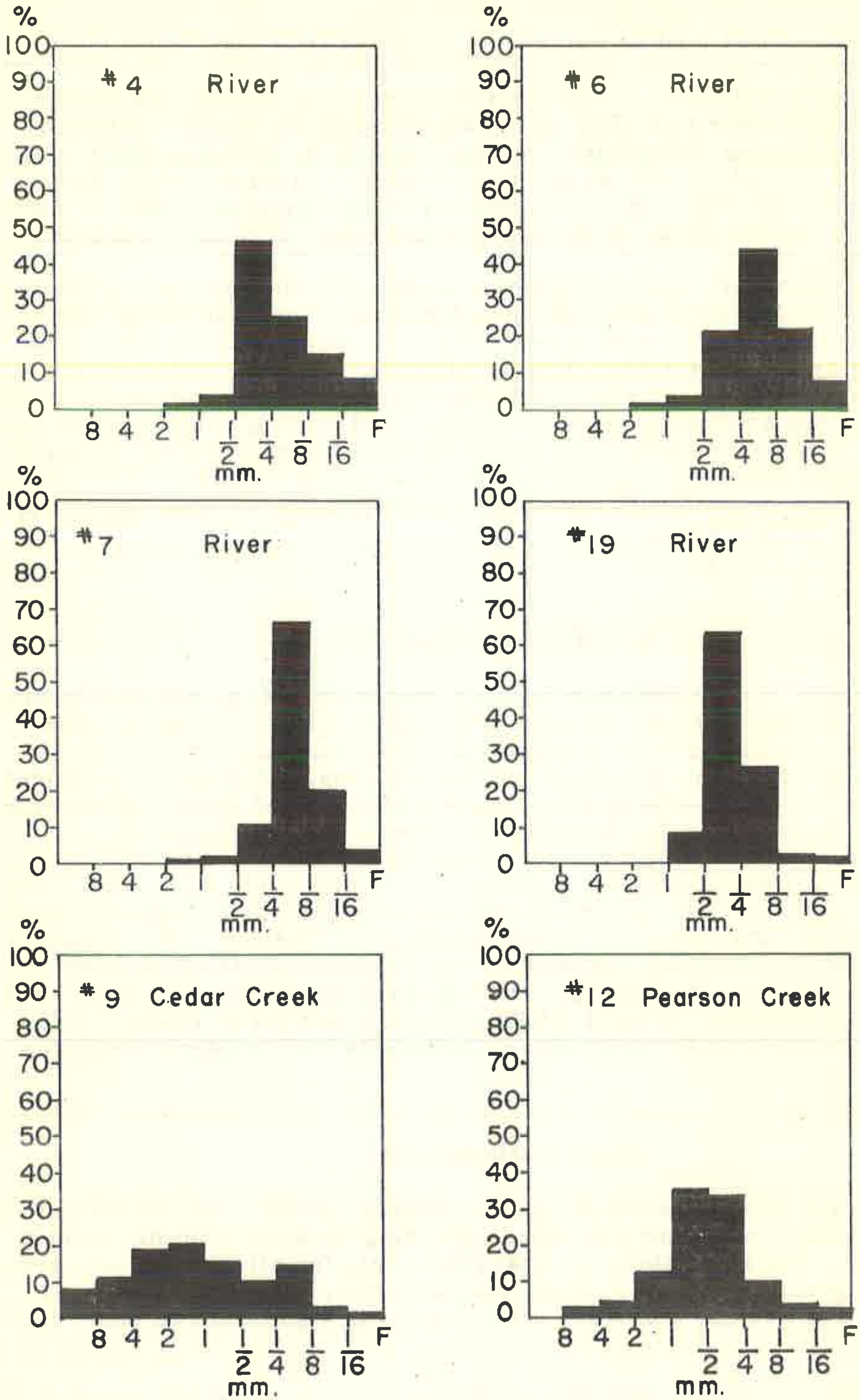

FIGURE 2. Representative Histograms of River and Tributary Samples.

	Median Diameter	Arithmetic Mean	Sorting Coefficient
Upstream Average	0. 46 mm	1. 17 mm	1. 57
Dowstream Average	0. 19 mm	0. 23 mm	1. 27
Tributary Average	0. 58 mm	1. 07 mm	1. 94

Table 1. Averaged sedimentary parameters.

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pink garnet (5. 5%), staurolite (5%), leucoxene (4%), and brown tourmaline (3. 7%). Minor constituents in order of decreasing occurrence are sillimanite, zircon, rutile, and monazite. The total heavy mineral crop of the samples averages less than 2% by weight. The bulk of each sample consists of quartz, and lesser amounts of biotite and muscovite.

Although the heavy mineral suite found in the Chattahoochee River sediments typifies the dominantly metamorphic province through which it flows in its upper reaches, there is no change in the assemblage that would serve to demark the transition from Piedmont to Coastal Plain. Stow (1939) and Berry et al (1955) have noted distinct mineralogical changes in sediments transported by rivers from one lithologic province to another. In this study, however, no pronounced changes are evident. This would appear to confirm the fact that Coastal Plain sediments were derived from the Piedmont. Heavy mineral species found in tributary samples were similar to those of the main stream.

The averaged percentages of individual mineral species from three selected points in the Chattahoochee River are presented in Table 2. The minerals are arranged in order of persistance and illustrate the relative amount of change taking place progressively downstream for each mineral species. Monazite and rutile are notably stable minerals and show the greatest relative increase downstream. Hornblende, epidote, and sillimanite are generally considered to be unstable minerals, and these show the greatest loss downstream. The position of tourmaline and zircon is anomalously lower than usual in this "stability series." Garnet shows a considerable decrease downstream, indicating a stability little better than that of sillimanite. Dryden and Dryden (1946) in their study of the comparative rates of weathering of common heavy minerals in situ found garnet to be the least resistant to chemical alteration, although most investigators list garnet as highly stable. Allen (1948) has pointed out that resistance of minerals to weathering depends upon the variety in question. Thus, iron-aluminum garnet (almandine) is more susceptible to alteration than other types of garnet (Dana, 1895; Bayley, 1925).

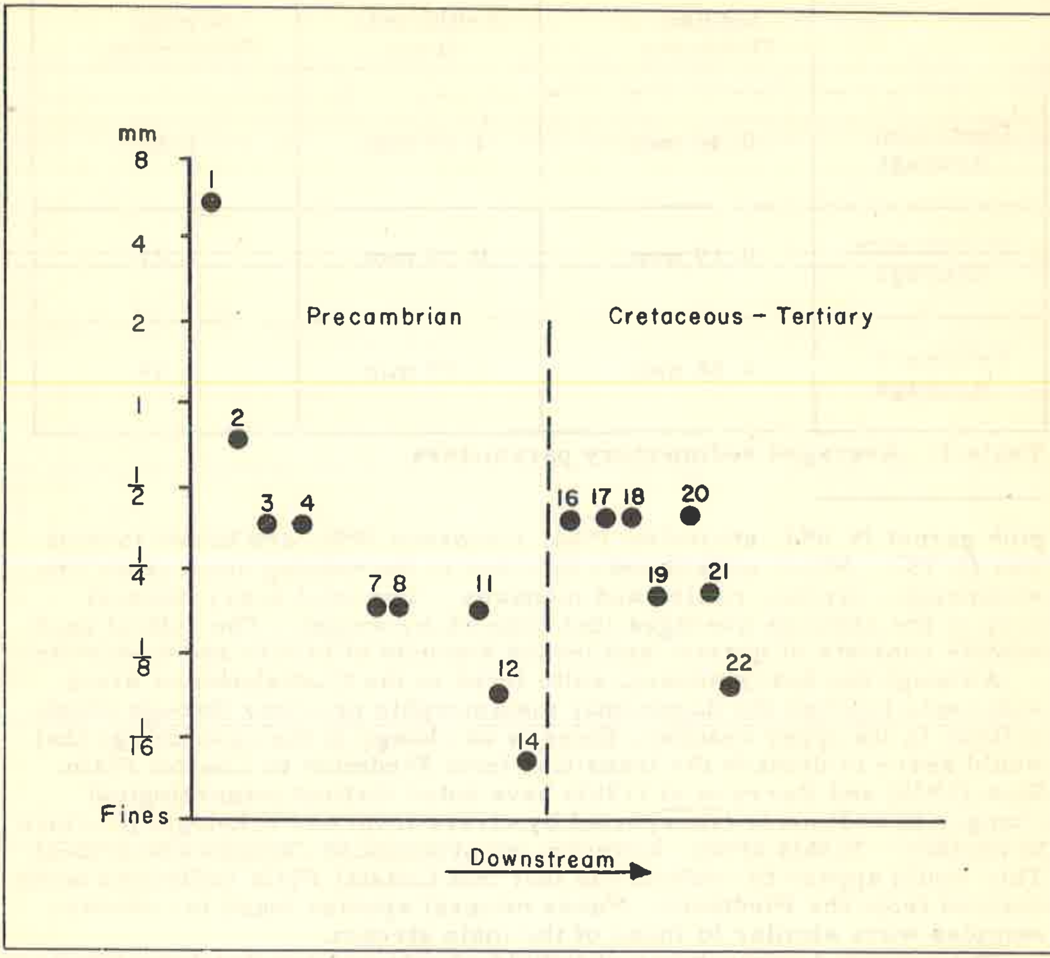

FIGURE 3. Trend of the Mode of River Samples

With the exception of garnet, tourmaline, and zircon the order of persistance of Chattahoochee heavy minerals conforms generally to orders of persistance established by other authors such as Pettijohn (1941). This suggests that the heavy mineral suite of the Chattahoochee is affected more by chemical attack than by attrition during transport.

CONCLUSIONS

The writers consider this study a cursory investigation. The tentative conclusions regarding Chattahoochee River bed load sediments are as follows:

1. The average grain diameter decreases downstream.
2. Sorting of the bed load improves downstream.
3. Changes in lithology over which the Chattahoochee flows appear to be reflected in the increase of grain

Mineral	Columbus	Ft. Gaines	Florida State Line
Monazite	0. 1	0. 4	0. 9
Rutile	0. 7	2. 2	3. 1
Leucoxene	2. 9	5. 0	10. 5
Magnetite-Ilmenite	12. 3	18. 4	17. 6
Staurolite	3. 6	4. 1	5. 2
Kyanite	12. 7	13. 4	15. 1
Tourmaline	3. 5	3. 3	3. 5
Zircon	2. 3	2. 3	2. 0
Epidote	18. 0	15. 0	14. 4
Hornblende	33. 9	31. 8	23. 7
Garnet	8. 1	1. 6	2. 5
Sillimanite	3. 5	1. 3	1. 1
		downstream →	

Table 2. Stability order and relative change downstream of heavy minerals.

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size of the mode but not by changes in the heavy mineral suite.

4. Chattahoochee River sands are generally unimodal.

5. Unstable heavy minerals are perceptibly removed with distance transported while the percentage of stable varieties remains the same or increases relative to the total heavy mineral assemblage.

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THE TIVOLA MEMBER OF THE OCALA LIMESTONE OF GEORGIA

By

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ABSTRACT

The Tivola Limestone Member of the Ocala Limestone consists of soft, fossiliferous, white to cream-colored limestone, with sand in its lower portion. The Tivola Member underlies the Twiggs Clay Member of the Barnwell Formation at most localities. However, the Twiggs Clay Member overlaps the Tivola Member in a southwestward direction as shown by several well exposed outcrops in east-central Georgia. The Tivola Member is a northeastward trending tongue of the Ocala Limestone which represents a short-lived northeastward transgression of the Ocala sea across a deltaic complex consisting of the contemporaneous Barnwell Formation and its several members.

INTRODUCTION

The use of the term Tivola as a stratigraphic name is attributed to Cooke and Shearer (1918, p. 51). They described a soft, cream to white, extremely fossiliferous limestone as the northeastward extension of the Ocala Limestone in central Georgia, and named the unit the Tivola tongue of the Ocala Limestone: the type locality is at the village of Tivola, one mile north of Clinchfield, Houston County, Georgia.

The Ocala Limestone trends north-northeastward from Florida into southwestern Georgia. Typical exposures consist of white to cream-colored to pink, partly crystalline, pure limestone. Prior to the present work, the northern boundary of the Ocala Limestone was arbitrarily placed at the Dooly-Houston County line, where a definite change in the character of the limestone occurs. From Houston County northeastward the formation is composed of a very soft, extremely fossiliferous, "spongy" mass of limestone that has a few silicified layers interspersed through the section. The "spongy" nature of the rock is due to the presence of great numbers of intertwined bryozoan zoaria, which make it extremely porous.

In a few localities the Tivola Limestone has at its base up to eight feet of massive, soft, fine-grained, tan to buff, calcareous quartz sand, containing abundant shark teeth. Where exposed, this lower sandy section lies with distinct disconformity on white to pink kaolin, or orange red sand of the Tuscaloosa Formation of Upper Cretaceous age.

During the present investigation the outcrop area of the Tivola Limestone was extended twenty-five miles southwest of the arbitrarily placed boundary of the Ocala Limestone at the Dooly-Houston County line. In a road cut at the junction of Georgia Highway 49 and the county road to New Era, 3. 9 miles north of Americus, Sumter County, seven feet of basal Tivola sand were found to contain fossils of Jackson Age. The

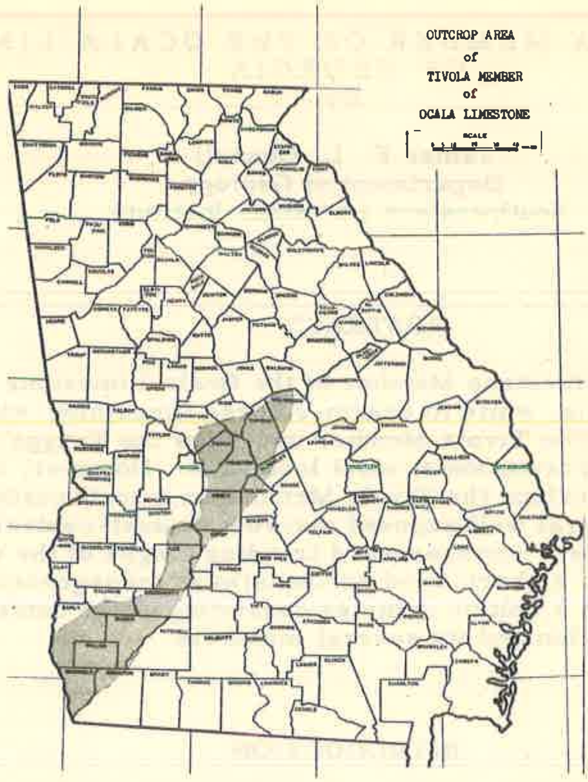

Figure 1

Tivola is here overlain by three feet of yellow to red-streaked, fine-grained quartz sand assigned to the Flint River (Oligocene) Formation.

The Tivola is typically exposed in working and abandoned quarries; it is of exceedingly high quality for cement manufacture. In some areas, however, where it is associated with the Twiggs Clay and the Tuscaloosa Formation, the Tivola is stripped off in order that rich deposits of fullers earth (Twiggs Clay) and Tuscaloosa kaolin may be worked. In a number of other localities, however, the Twiggs Clay overlies the Tivola Limestone, the former unit having overlapped the Tivola Limestone southwestwardly.

The thickest sections of Tivola Limestone occur in Crawford, Houston, Pulaski, Bleckley, Twiggs, and Wilkinson counties. In all localities studied the Tivola consists of white to cream-colored, very soft to hard, in places silicified, extremely fossiliferous limestone. Traced northeastward from Dooly County it forms (with the Twiggs Clay) a prominent west-facing escarpment, which extends to the vicinity of Gordon, northern Wilkinson County. Beyond the latter locality the Tivola appears to pinch out completely. One mile south of Gordon the Tivola Limestone with its shark tooth-bearing sand section lies with distinct disconformity on Tuscaloosa kaolin, and is in turn overlain by the Twiggs clay member. In the kaolin quarry of the General Refractories Company, 5. 7 miles northeast of Gordon, and 1 1/2 miles southeast of Stevens Pottery, southwestern Baldwin County, the Tivola is absent; the Tuscaloosa here is overlain with distinct disconformity by the Twiggs Clay Member of the Barnwell Formation.

The designation, Tivola Member of the Ocala Limestone, was adopted by the writer (Connell, 1958) after it was recognized that the lithologic character of the unit is quite distinct from the Ocala Formation. The Ocala wherever encountered in fresh exposures, exhibits a pure white to cream-colored, fine-textured, "grainy" appearance, the grains being mostly partly crystalline calcite. In one locality the rock consists of about fifty percent each of calcite crystals and quartz grains. The Ocala is more massively bedded and contains more and thicker beds of silicified or "case-hardened" limestone, especially in the Dougherty Solution Plain, where dissolved silica from the overlying Flint River Chert has percolated downward into the limy Ocala section. Fresh exposures of the Tivola Member consist of much softer, crumbly limestone, except for a few thin layers of partly silicified material. The rock is white to flesh-colored and averages from 85 to 90 percent pure calcium carbonate. The Tivola contains by far the most abundant fossil remains, the rock in many places being a solidly packed mass of typical shallow water forms ranging from protozoans to arthropods.

The Ocala Limestone and its Tivola Member represent nearshore-marine deposits laid down adjacent to a large deltaic mass collectively called the Barnwell Formation. These two adjacent complexes constitute the Jackson Group of Georgia, which is correlated with the Bartonian and most of the Ludian subseries or stages of the European Eocene. The Barnwell was named for the type locality at Barnwell, South Carolina. The formation crops out in a southwesterly direction across the Savannah River into east-central Georgia, where its red sands and clays underlie the Louisville Plateau ("Red Hills District"). In east-central and central Georgia the Barnwell becomes differentiated into several lithologies, on the basis of which the following member have been erected:

Barnwell Formation	Roberta Sand Member Upper Sand Member Sandersville Limestone Member Irwinton Sand Member Twiggs Clay Member Channel Sands

The Tivola Member of the Ocala Limestone merges from southwest to northeast with the Twiggs Clay Member of the Barnwell Formation. This condition is evident as far south as the vicinity of Dooling, Dooly County, where the two members are present along Georgia Highway 90. Farther to the southwest, the limy portion of the Tivola is missing, and the Twiggs clay lies on the lower sandy portion of the Tivola. It can be demonstrated that the Twiggs and Tivola members are contemporaneous deposits, exhibiting a definite interfingering with each other at many localities. Northeast and southwest of the critical intertonguing area the two members overlap each other for long distances. In those areas immediately adjacent to the Fall Zone, the Twiggs Clay Member overlaps the Tivola completely, coming to rest on either the eroded surface of the Tuscaloosa (Upper Cretaceous), or the crystalline rocks of the Piedmont.

LITHOLOGIC DESCRIPTIONS

Crawford County

An interesting exposure of a practically complete section of the Jackson Group occurs at Rich Hill, an imposing topographic feature located south of Georgia Highway 42, six miles east of Roberta. This exposure is unique in that it is situated at least thirty miles from the nearest outcrop of Jackson rocks, and constitutes the westernmost locality where rocks of that age occur. The area between Rich Hill in Crawford County and Clinchfield in Houston County seems to have been completely denuded of all Jackson strata, with the possible exception of about six feet of red argillaceous sand at Powersville, Peach County, which may be all that remains of the Barnwell Formation. Rocks that are exposed in the area between Rich Hill and Clinchfield include sands and kaolin deposits assigned to the Tuscaloosa Formation, and erratic exposures of sand and clay which may represent the Gosport, Lisbon, and Tallahatta Formations of Claiborne Age. None of the latter units has been found in association with the Jackson strata.

In the deep gully on the south side of Rich Hill, the following section occurs at an elevation of 518 feet:

	Feet
Eocene:	
Barnwell Formation:	
Roberta Sand Member:	
8. Deeply eroded, dark red to yellow-stained, fine to medium-grained, argillaceous quartz sand, with thin beds of plastic, greenish-gray clay near the base	40
Twiggs Clay Member:	
7. Light-green to yellow, blocky, hackly, plastic, fullers earth type clay	10
Ocala Limestone:	
Tivola Member:	
6. Massive, soft to medium hard, white, nodular, argillaceous, fossiliferous limestone .	3
5. Grayish-green, hackly, fullers earth type clay	3
4. White, soft to medium hard, nodular, fossiliferous limestone	3
3. Soft, yellowish to cream-colored, arenaceous, fossiliferous limestone. Molds and casts of pelecypods and gastropods prolific. Echinoids (<u>Periarchus</u>) abundant	5

Feet

2. Massive, unconsolidated, light yellow to tan, calcareous quartz sand, with hard ledges of fossiliferous limestone grading downward into top of bed. Shark teeth abundant throughout sand 8

Unconformity:

Upper Cretaceous:

Tuscaloosa Formation:

1. Massive kaolinic sand at base, ranging from fine to coarse-grained, white quartz sand, and massively-bedded, pure white kaolin to bottom of gully 100

Houston County

Outcrops of the Tivola Member along with several members of the Barnwell Formation occur in the prominent northeast-southwest trending escarpment which crosses Houston County. Most of the exposures occur in abandoned and active quarries and in road cuts, especially along U. S. Highway 341 (Georgia Highway 7) southeast of Perry. In most of these localities the dominant lithology is the typical white to cream-colored, very soft limestone of the Tivola Member.

In an abandoned quarry at Ross Hill, three miles south of Perry, on both sides of the Perry to Elko road, along the south slope of Flat Creek, the following section is exposed at an elevation of 366 feet:

Oligocene: Feet

Flint River Formation:

7. Thin layer of wooded soil, strewn with lumps of pink to red sparsely fossiliferous chert 2

Eocene:

Barnwell Formation:

Twiggs Clay Member:

6. Soft, gray, hackly, sandy, red-stained clay merging upward with bed No. 7 2

5. Reddish, sandy, weathered limestone containing molds of fossils 4

4. Hackly, cream-colored to green, calcareous fullers earth type clay containing limy nodules 4

Ocala Limestone: **Feet**

Tivola Member:

3. Soft, cream-colored to white, fossiliferous limestone, with a thin silicified layer at the base 7

2. Soft, yellow, fossiliferous limestone, with locally indurated nodules and ledges. Also contains soft, irregular limestone concretions 7

1. Pale, cream-colored, soft limestone, with abundant bryozoans, Pecten, Chlamys, and echinoids (Periarchus). Weathered ledges of silicified limestone near top of bed 20

In the main working quarry of the Penn-Dixie Cement Company at Clinchfield, six miles southeast of Perry, the following section occurs in the west-facing escarpment on the north side of U. S. Highway 341 at an elevation of 350 feet:

Barnwell Formation: **Feet**

Twiggs Clay Member:

5. Massive, cream-colored to greenish, blocky, hackly, plastic clay, with stringers and nodules of white chalky limestone. This bed grades upward into brilliant to dark red, argillaceous quartz sand to top of quarry which represents a remnant of the Roberta sand member of the Barnwell Formation 20

Ocala Limestone:

Tivola Member:

4. Massive, soft to hard, white to cream-colored, fossiliferous limestone forming floor of upper quarry face 7

3. Cream-colored to grayish-green, hackly, plastic, fullers earth type clay, grading downward into limestone 3

2. Massive, soft to very hard, white to cream-colored "bryozoan" limestone 4

1. Massive, white to yellowish, soft to medium hard, highly fossiliferous limestone to floor of quarry 40

Pulaski County

Up to six feet of mixed Tivola Limestone and Twiggs Clay occur along U. S. Highway 341 between the Houston-Pulaski County line and the county seat at Hawkinsville. Most of the Eocene section is covered by red sand and chips of Flint River (Oligocene) Chert or by Recent deposits. Cooke (1943, page 73) reports a few exposures of Tivola Limestone along the Ocmulgee River. If present, the limestone is well covered by Recent alluvium and vegetation.

In a road cut 2.7 miles north of Hawkinsville and 1/4 mile east of a prominent bluff on the east bank of the Ocmulgee River, immediately south of the Henry Wilcox property, the following section is exposed on the east side of the road at an elevation of 250 feet:

	Feet
Eocene:	
Ocala Limestone:	
Tivola Member:	
3. Soft to medium hard, white to red-stained, argillaceous, fossiliferous limestone. The lower two feet consist of a hard massive yellow layer of arenaceous limestone	25
Unconformity:	
Barnwell Formation:	
Twiggs Clay Member:	
2. Green to reddish-brown, hackly, blocky, fullers earth type clay	1-3
1. Unconsolidated, white to gray, fine-grained quartz sand with red surface stain to level of road	5

Bleckley County

In an abandoned limestone quarry on the Weatherly Farms property, one and one-half miles east of Ainslie on the east bank of Shellstone Creek, seventy-one feet of section is exposed in a west-facing escarpment, that crosses the northwest part of Bleckley County. This locality is located 5.5 miles west of U. S. Highway 129 (Cochrane Short Route or Georgia Highway 87), and 5.5 miles northwest of Cochran, the county seat.

The following section is exposed at an elevation of 335 feet:

	Feet
Eocene:	
Barnwell Formation:	
Irwinton Sand Member:	

	Feet
5. Massively bedded, orange-red to dark red, quartz sand to top of surrounding hills	30

Twiggs Clay Member:

4. Cream-colored to greenish-gray, weathered fullers earth type clay, with local sandy ledges. This bed grades upward into bed No. 5	15

Ocala Limestone:

Tivola Member:

3. Soft to medium hard, well-pitted, white to cream-colored, fossiliferous limestone . . .	10
2. Soft, white to yellow, very porous, friable, highly fossiliferous limestone (Periarchus remains are the dominant fossils)	13

Recent:

1. Creek bottom land	3

Twiggs County

Several excellent outcrops of the Tivola Member and other units of the Jackson Group occur in Twiggs County: In the southeastern part of the County, 5 miles southeast of Jeffersonville, in the creek bank at the old county bridge across Turkey Creek; in a road cut 100 feet west of the bridge at old Gallemore Mill, 4 miles northeast of Danville, and one mile east of U. S. Highway 80; and at Dry Branch in northwesternmost Twiggs County.

Two miles east of Dry Branch, south of U. S. Highway 80, the following practically complete section of the Jackson Group is exposed in the quarry of the Georgia Kaolin Company at an elevation of 585 feet:

Eocene:

Barnwell Formation:

Irwinton Sand Member:

	Feet
7. Unconsolidated to partly indurated, fine-grained, white to dark red quartz sand with clay partings to the top of the quarry . .	65

Twiggs Clay Member:

6. Massive, blocky, hackly, greenish-gray plastic fullers earth type clay	15

Ocala Limestone: **Feet**

Tivola Member :

5. Massive, white, argillaceous, fossiliferous limestone, grading upward into fullers earth 3

4. Yellow to brown, unconsolidated to partly indurated fine-grained, calcareous quartz sand, with abundant molds and casts of pelecypods and gastropods 8

3. Hard, massive, white, partly crystalline limestone, forming a persistent ledge around the quarry face 2

2. Unconsolidated to partly indurated, light brown to yellow, calcareous quartz sand, with abundant molds and casts of gastropods and pelecypods, and shark teeth 8

Unconformity:

Upper Cretaceous:

Tuscaloosa Formation:

1. Massive, pure white kaolin to level of pond on quarry floor 2

Wilkinson County

Beds of Jackson Age crop out essentially in the southern and southeastern parts of Wilkinson County. Farther north these beds cap the higher northwest-southeastward trending "Red Hills," which owe their origin and relief to such deep-cutting streams as Commissioners, Slash, Black, and Big Sandy Creeks. These streams have removed most of the Jackson deposits in the northern part of the county, exposing the deeply-eroded clays, sands, and gravels of the underlying Tuscaloosa Formation. The Tivola Member is exposed in very few outcrops, occurring only in creek bottoms and in a few road cuts. The most extensive section of this unit occurs in the quarry of the Southern Clays Company one mile south of Gordon and one mile east of Georgia Highway 18. The elevation here is 347 feet above sea level.

Eocene: **Feet**

Barnwell Formation:

Irwinton Sand Member:

5. Massive, dark red to mottled yellow, fine-grained quartz sand to top of surrounding hills 60

Twiggs Clay Member:	Feet
4. Greenish-yellow, blocky, hackly plastic, fullers earth type clay, containing white chalky nodules at the base	10
Ocala Limestone:	
Tivola Member:	
3. Massively-bedded, sandy, white to cream-colored limestone, with abun- bryozoans and molds and casts of pelecypods and gastropods. This bed is essentially a friable limestone, but it contains several hard coquinoid layers that contain fossils occurring as molds and casts	10
2. Massive, fine to medium-grained, light yellow to tan, argillaceous, glauconitic, quartz sand, containing shark teeth, and filling depressions on the eroded Cretaceous surface	2
Unconformity:	
Upper Cretaceous:	
Tuscaloosa Formation:	
1. Massive, pure white kaolin to the floor of the quarry	30

Other outcrops containing Jackson units in Wilkinson County were once exposed at McIntyre, three miles north of Irwinton on Georgia Highway 29, and at Ivey, one mile northeast of Gordon on Georgia Highway 243. The Barnwell units, as well as a thin section of the Tivola Member, have either been removed to expose the underlying kaolin deposits, or have been covered by an overburden of waste material from the kaolin mills. Within a distance of 5.7 miles northeast of Gordon, the Tivola Member must pinch out. In the preceding section described from the quarry of the Southern Clays Company, the Tivola is twelve feet thick. The formerly exposed section at Ivey which was observed by the writer was less than half that thickness. In the quarry of the General Refractories Company one and one-half miles southeast of Stevens Pottery, southern Baldwin County, and one-half mile east of Georgia Highway 243, the Tivola is absent. The Twiggs Clay here overlies the Tuscaloosa kaolin with distinct disconformity. The Twiggs Clay at this locality contains a prolific fauna of molluscan remains, such as is found in the Tivola Member to the south. This fossiliferous condition of the Twiggs Clay exists in only one other locality, a railroad cut one mile northeast of Postell (formerly Roberts) at the underpass of the Central of Georgia Railroad in southern Jones County. All other exposures of the Twiggs Clay were found to be barren of fossils.

The lithology and fauna of the Tivola Member of the Ocala Limestone suggest deposition in a near-shore environment. Bryozoan, pelecypod, gastropod, and echinoid remains are very abundant throughout most localities studied; this suggests warm, clear waters adjacent to a strand line. The presence of the Tivola Member as far north as northern Wilkinson County suggests a temporary transgression of the Tivola sea across the Barnwell delta. A corresponding regression in Late Tivola time is demonstrated by a southwestward encroachment of the delta during Twiggs time, as far as the vicinity of Americus, Sumter County. Between these two movements of the strand line, the edge of the delta and the marine environment were essentially stable, as evidenced by the notable intertonguing of the two units in central Georgia.

PALEONTOLOGY

Most of the fossil remains occurring in the Tivola Member are preserved as molds and casts. A few forms including Pecten, Chlamys, Periarchus, Ostrea, and the bryozoan remains still retain the original shell material. The majority of the forms in the following list have been previously recorded from rocks of Upper Jackson age in the Carolinas, Florida, Alabama, Mississippi, and Louisiana. A few, however, have been reported from the Lower Jackson Moodys Branch Formation of Florida, Alabama, Mississippi, and Louisiana.

Harris (1951) reports forty-seven species of pelecypods from the Ocala Limestone and its Tivola Member. During the present investigation, sixty-six species distributed through nineteen families have been recorded. Of this number, there are two new species. A more comprehensive report on the paleontology of the Tivola Member will appear in a subsequent paper.

Following is a list of faunas occurring at the seven localities discussed in this report:

Protozoa:

Lepidocyclina georgiana? Cushman

Coelenterata:

Flabellum cuneiforme Lonsdale

Echinodermata:

Cassidulus ericsoni Fischer
Eupatagus (Plagiobrissus) ocalanus? Cooke
Periarchus lyelli (Conrad)
P. Pileus-sinensis (Ravenel)
Peronella cubae Weisbord
Rumphia archerensis (Twitchell)

Bryozoa:

Beisselina trulla Canu and Bassler
Filisparsa ingens Canu and Bassler
Hincksina jacksonica Canu and Bassler
Holoporella damicornis Canu and Bassler

Hornera polyporoides Canu and Bassler
Lunulites distans Lonsdale
Membraniporidra porrecta Canu and Bassler
M. spissimuralis Canu and Bassler
Parleiosoecia jacksonica Canu and Bassler
Rectonychocella semiluna Canu and Bassler
Schismopora globosa Canu and Bassler
Schizopodrella linea Lonsdale
S. viminea Lonsdale
Spiropora majuscula Canu and Bassler
Steganoporella jacksonica Canu and Bassler
Stomatopora cornu Canu and Bassler
Tretonea levis Canu and Bassler

Mollusca:

Pelecypoda:

Amusium ocalanum Dall
Astarte triangulata Meyer
A. triangulatoides Harris
Atrina jacksoniana Dall
Cardium sp.
Chlamys spillmani (Gabb)
C. spillmani var. clinchfieldensis Harris
Crassatella eutawacolens (Harris)
Corbula wailesiana Harris
Gastrochaena mississippiensis Harris
Glycymeris sp. cf. G. anteparailis Kellum
G. idonea (Conrad)
Gryphaeostrea vomer var. plicatella (Morton)
Lirodiscus jacksonensis (Meyer)
Lucina (Plastomiltha) gaufia Harris
Macrocallista annexa (Conrad)
Meretrix ovata var. pyga Conrad
Miltha ocalana Dall
Ostrea georgiana? Conrad
O. trigonalis Conrad
O. sp.
Panope elongata (Conrad)
Pecten choctavensis Aldrich
P. perplanus Morton
P. wautubbeanus Dall
Pitar sp. cf. P. cornelli Harris
P. sp. cf. P. nuttali Conrad
P. trigoniata (Lea)
Protocardia (Nemocardium) nicolletti (Conrad)
Pteria limula var. vanwinkleae Harris
Spisula praetenuis Conrad
Spondylus hollisteri? Harris
Venericardia (Venericor) planicosta var. ocalaedes Harris
"Venus" jacksonensis Meyer

Gastropoda:

Acteon? idoneus? Conrad
Calyptraea aperta (Solander)
Pseudocrommium brucei Palmer
Turritella arenicola (Conrad)
Turritella sp.

Arthropoda:

Crustacea:

Callianassa inglisestris Roberts

Chordata:

Chondrichthyes:

Aetobatis irregularis Agassiz
Galeocerdo alabamensis Leriche
Lamna obliqua Agassiz
Myliobatis sp.
Odontaspis macrota Agassiz
Odontaspis sp.
Oxyrhina hastalis Agassiz
O. nova Winkler
O. praecursor var. *americanus* Leriche
Sphyrna gilmorei Leriche

Osteichthyes:

Pristis? aquitanicus? Delfortrie
Fish vertebrae (gen. and sp. indet.)

Many of the above-listed species are abundant in the Caste Hayne Limestone of North Carolina (Kellum, 1926) and the Santee Limestone of South Carolina (Cooke, 1936). The western equivalents of the Tivola Member include the upper part of the Ocala Limestone of eastern and central Alabama, and the Cocoa Sand, Pachuta Clay, and the Shubuta Clay Members of the Yazoo Formation of western Alabama and Mississippi. The Danville Landing Beds, which are included in the uppermost Yazoo of Louisiana by some workers, and as a separate unit of uppermost Eocene Age by others, contain many of the species common to the Tivola Limestone Member of Georgia.

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LIMESTONES EXPOSED IN THE LOWER WITHLACOOCHEE VALLEY OF GEORGIA

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ABSTRACT

At least two limestones, the Suwannee and Tampa, of Oligocene and Miocene ages, respectively, are exposed along the Withlacoochee River and in nearby sink holes in Brooks and Lowndes Counties, Georgia. The Suwannee Limestone is a relatively pure, white calcareous formation almost unchertified and unfossiliferous in the area investigated. The overlying Tampa Limestone is separated from the Suwannee by a yellowish colored phosphatic, silicious layer a few feet thick. The Tampa is an impure limestone commonly having angillaceous and cherty facies. Its upper levels are thoroughly brecciated and silicified, and locally phosphatic. It is commonly separated from the overlying mottled Hawthorne Formation (Miocene) by a white sand layer of variable thickness mixed with fullers earth and/or kaolin. Except for local undulations and slumps, the beds dip slightly to the south.

INTRODUCTION

In 1958, the writers investigated the Withlacoochee Valley south of the bridge at U. S. Highway 84, Georgia. The river in the area covered marks the boundary between Brooks and Lowndes Counties. It was slightly above mean low-water mark at the time; there may be a few more exposures at low water than are shown (Fig. 1). Numerous scattered sink-holes and other depressions occur in this vicinity, in some of which limestone outcrops.

STRATIGRAPHY AND LITHOLOGY

The geologic map of Georgia (1939) shows one limestone, the Suwannee (Oligocene) (Table I), extending northward from the Florida border through that part of the Withlacoochee Valley examined by the writers. Two main limestones are exposed in the valley. These rocks constitute separate formations, based upon data presented below, which tentatively can be correlated with the Suwannee and the Tampa. This differs from past interpretations in which the Tampa was omitted (Geol. Map Ga.).

Suwannee. The Suwanne Limestone, named by Cooke and Mansfield (1943), is a yellow-colored, hard, crystalline limestone that is much

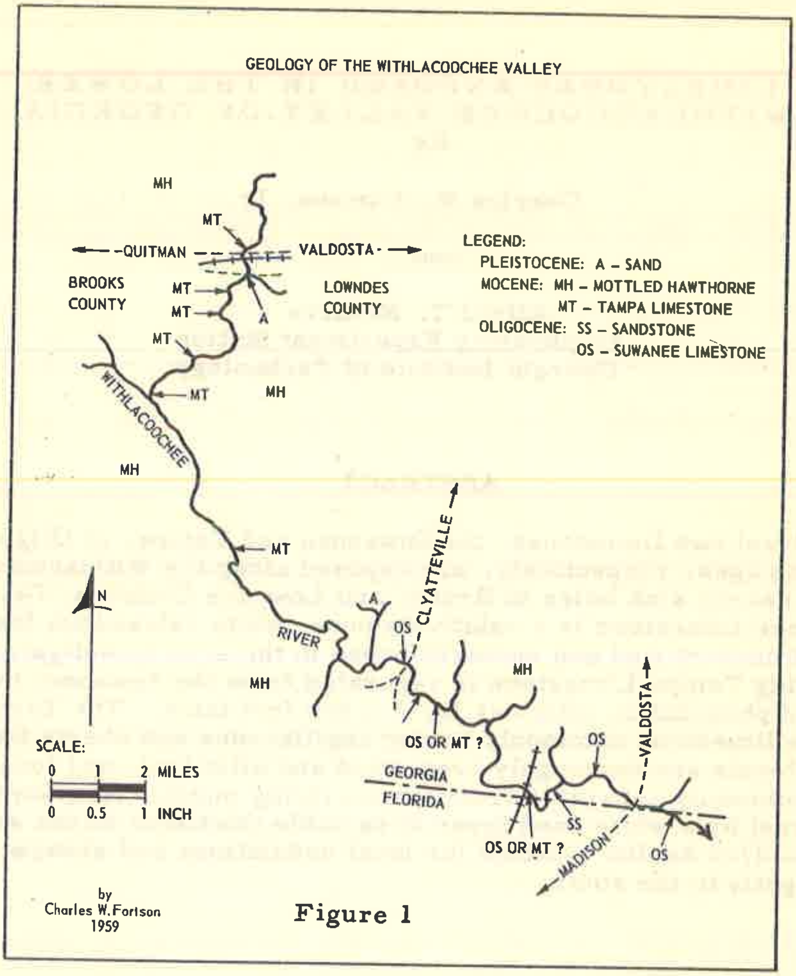

Figure 1

purer than the overlying Tampa Limestone; it is exposed in bluffs up to 20' high, especially along the outsides of meanders. Quantitative analyses show that the unit contains a low percentage of magnesium (Table I). No chertified or brecciated zones were seen. The only fossils are molds of pelecypods and were not identified. The age of the Suwannee is based upon its stratigraphic position.

As implied by Cooke (1943) and Brantley (1917) from paleontological evidence, the Suwannee may be equivalent in age to the Flint River Formation exposed farther west. MacNeil (1950), however, does not distinguish the Flint River Formation as a separate unit. Although local undulations occur, in general the Suwanne dips slightly to the south. As can be seen from Fig. 1, what the writers recognize as the Suwannee extends up the Withlacoochee to about a mile south of the Clyatteville-road bridge. It appears that local undulations allow certain layers of Tampa to extend below this place. In some exposures, notably just below the railroad trestle at the Georgia-Florida state line, outcrops are insufficient to determine if the limestone exposed is a relatively pure facies of the Tampa or the cream-colored Suwannee.

Transition. Some half mile below the treste is a thin, silicified, argillaceous-sandstone layer thought to mark the hiatus between the Suwannee and the Tampa. This layer is probably a residuum of leached Tampa or Suwannee limestone.

Table I

Quantitative Chemical Analyses

Suwannee Limestone
(East of Georgia Highway 31 bridge over
Withlacoochee River)

Compounds	Samples Numbers 23	28	33	38	43	48
Moisture, 100° C	0.00	0.01	0.16	0.00	0.00	0.00
Ignition loss	42.78	43.60	42.68	42.68	42.49	42.51
Lime (CaO)	53.72	43.69	42.68	42.68	42.49	42.51
Magnesia (MgO)	0.66	5.19	0.72	1.11	2.77	4.06
Alumina and iron oxide	1.26	1.54	1.76	1.26	1.40	1.74
Silica	1.56	1.17	1.78	1.69	1.61	1.74
Undetermined	0.02	0.40	1.78	0.38	0.11	0.00
TOTALS	100.00	100.00	100.22	100.00	100.20	100.11
Calcium Carbonate	95.83	85.67	91.63	94.38	97.92	97.84
Magnesium carbonate	1.38	10.86	4.05	2.32	0.79	0.49
TOTAL CARBONATE	97.21	96.53	96.68	96.70	96.71	98.33

*Laboratory samples 7209-7213

Source: Georgia Department of Mines, Mining and Geology; courtesy of William L. Goodloe, Valdosta, Georgia, to whom it was supplied 4 April, 1947.

Tampa. What the writers consider to be the overlying Tampa in this valley is a highly silicified, impure limestone that is brecciated in many places. It extends up the Withlacoochee past the Quitman-Valdosta Highway (U. S. 84). (Fig. 1). The unit is thought to be of Tampa age because of its stratigraphic position. The brecciated zones are composed of angular fragments between one-fourth and one-half of an inch in maximum dimension; they are thoroughly silicified and partly phosphatic. Much of the unit probably went through stages of leaching and collapse, followed by ground-water silicification. After subsequent subsidence and diagenesis, some of the silica reverted to milky quartz. The thickness is uncertain.

Hawthorn. The overlying Hawthorn (Miocene) Formation appears to be locally reworked. Its basal member, called the Chipola Formation by McNeil (1947, 1950), is a fuller's earth-bearing sand of variable thickness. The remainder of the Hawthorn Formation may be further divided into other horizons which are fairly consistent in this area (Table II).

Table II

Stratigraphic Column

Series	Formation	Member and Lithology	Thick (feet)
		Ferruginous sandstone	
		Gray sand	
		Red or yellow-brown clay	4
		Limonitic pellets	1.5
	Hawthorn Mottled	Mottled clay and fuller's earth	70
Miocene		Yellow clay	4
		White or gray sand, containing fuller's earth bodies	50
	Tampa Limestone		30-120
Oligocene	Suwannee Limestone		75+

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CLAY DISPERSAL STUDY OF A RED SILTSTONE

By

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ABSTRACT

As a result of experimentation it was found that the best dispersing reagent for a poorly indurated, arenaceous, argillaceous siltstone was sodium hexametaphosphate (Calgon) in a de-ionized water solution. The greatest clay yield was attained using a Calgon solution of not less than 0. 2 normal.

The best shaking time for complete dispersal was found to be no more than 12 hours.

INTRODUCTION

A series of laboratory tests were made in an end-over-end shaker to determine the most favorable dispersing reagent, the proper normality of the dispersing reagent, and the most favorable shaking time for a sediment that is to be subjected to sedimentary analysis. The results are compared with Tyner's (1939) results.

ACKNOWLEDGMENT

The writer appreciates the advice and help given by Roy L. Ingram.

SAMPLE AND LOCATION

The sample used for this experiment was a light brown (5YR6/4), arenaceous, argillaceous, poorly indurated siltstone. The sample contained 10. 18% sand, 17. 82% clay and 70. 88% silt. It was collected well below the soil profile in the fresh rock of the undifferentiated Triassic sediments in the Durham basin. The sample was collected six feet above the road grade in a shallow road cut along the Mt. Moriah Church Road. The locality is 1. 3 miles north of the intersection of the Mt. Moriah Church Road with the Durham Road (U. S. 15) east of Chapel Hill in Orange County, North Carolina.

METHODS

The sample was air dried and the larger lumps were broken with the fingers. Twenty-gram samples were used throughout the experimentation. Duplicate 20-gram samples were prepared and subjected to identical procedure in order to determine how much variation in results could occur. The samples were carefully quartered, then dispersed and agitated in an end-over-end shaker as described by Hussy (1951, p. 224). In each agitation a 150 ml. solution of dispersing reagent and water was shaken with 20 grams of sample in 600 ml. shaker tubes. The normality here discussed is the normality of the 150 ml. solution of de-ionized water and reagent.

After shaking was completed the plus 1/16 mm. fraction was split from the sample by sieving, and saved for further optical study. The remaining silt and clay fractions were split by centrifugation. Previously prepared charts calculated for the centrifuge were used for the silt-clay split. These charts showed the r. p. m., time, and temperature that were necessary to settle the silt while leaving the clay in suspension.

Prior to centrifugation, tests were conducted comparing centrifuge clay yield on known samples with clay yield from the same samples but using standard pipette analysis. The slight error incurred by using the centrifuge as compared to the pipette method was not enough to justify using the time-consuming pipette method.

An aliquot of the silt and clay fraction was dried (42°C) and weighed since the percent clay yield of the entire sample determines the degree of dispersal attained by the reagent used. The dispersing reagent weight remaining in the silt and clay fractions was subtracted from the sample weight. This was easily determined since the reagent dry weight per ml. of solution was known. The silt and clay fractions were saved for further optical study.

RESULTS

Reagent

For dispersal of samples similar to those under consideration, Tyner (1939) suggests the following reagents:

A. 0. 033 normal sodium hexametaphosphate solution
B. 0. 03 sodium hydroxide solution

He also found that eight hours of shaking time will bring about complete dispersal and that shaking for 12 to 16 hours produced little increase in clay yield.

In the present study, Tyner's above suggestions were followed with the exceptions that additional reagents were used and a longer period of time was allowed for shaking.

The additional reagents tested were sodium carbonate, sodium hydroxide, de-ionized water, and tap water. The 20-hour shaking period was chosen to insure complete dispersal of the clay fraction.

As can be seen in figure 1, sodium hexametaphosphate gave the highest clay yield, followed by sodium carbonate, sodium hydroxide, de-ionized water, and tap water.

Normality

Since the reagent giving the highest clay yield was found to be Calgon, five different normalities of this reagent were prepared in order to

Reagent	Normality[1]	Shaking Time (Hours)	Clay Yield %
Sodium Hexametaphosphate (Calgon)	0.033	20	14.25
Sodium Carbonate	0.020	20	14.0
Sodium Hydroxide	0.030	20	12.72
De-ionized water	-	20	12.72
Tap water	-	20	12.45

[1]Normality of 150 ml. solution containing sample.

Fig. 1. Clay yield by various reagents.

determine the concentration of Calgon which would give the highest clay yield. Tyner (1939) suggests a Calgon normality between .020 and .047, and chose .033 for his experimentation. A somewhat broader range of normality was chosen for this report, specifically, 0.0024, 0.0050, 0.020, 0.033, and 0.200. The samples were shaken for 20 hours with each of the above Calgon normalities to allow for complete dispersal. The greatest clay yield was attained using 0.20 normal Calgon solution (fig. 2).

Reagent	Normality	Shaking Time (Hours)	Clay Yield %
Sodium Hexametaphosphate (Calgon)	0.0024	20	13.53
Sodium Hexametaphosphate (Calgon)	0.0050	20	13.59
Sodium Hexametaphosphate (Calgon)	0.020	20	13.80
Sodium Hexametaphosphate (Calgon)	0.033	20	14.25
Sodium Hexametaphosphate (Calgon)	0.200	20	20.43

Fig. 2. Sodium hexametaphosphate (Calgon) normalities compared with clay yield.

It is indeed possible that the maximum yield was attained between 0.033 and 0.20 normal, and it is also possible that a still greater clay yield may be attained by using a normality greater than 0.20. Nevertheless, until more experimentation is completed it appears that nothing less than 0.20 normal Calgon solution should be used for dispersal of siltstones such as these under consideration.

Shaking Time

Having established the type reagent which would give most complete dispersal and the proper concentration of the reagent giving the greatest dispersal, the length of shaking needed to completely disperse the clay fraction was determined.

As stated before, Tyner (1939) found that eight hours of shaking time brought about complete dispersal. He used Calgon having a normality between 0. 020 and 0. 047. In the current study, 0. 20 normal Calgon was used for dispersal in the end-over-end shaker. Eight samples were shaken for eight progressively greater intervals of time (fig. 3).

Hours	Clay Yield-%
2	10. 14
4	12. 33
6	13. 56
8	15. 75
12	17. 82
16	17. 94
18	19. 26
20	20. 43

Fig. 3. Clay yield at timed intervals using Calgon for dispersal.

Maximum dispersal, as shown by figure 3 and 4, occurred at 20 hours; however, as will be seen, a sample such as this arenaceous, argillaceous siltstone should not be shaken using this procedure for as long as 20 hours. As can be seen in figure 4, the increase in clay steadily rose between two hours and twelve hours. Thereafter the clay yield showed little increase until 16 hours was reached. Between 16 and 20 hours the clay yield resumed about the same rate of increase as in the 2 to 12 hour interim.

After each time interval the sample was inspected with the microscope to determine if the silt fraction or the sand fraction showed any increase in roundness. Any increase in roundness would effectively produce more clay size material. The visible particles of sand and silt showed little or no rounding at the end of 12 hours of shaking. Whereas by the end of 16 hours of shaking the visible particles had been abraded from the original subangular state to the subrounded state. At the end of 20 hours of shaking, the particles were rounded. Thus it may be assumed that after shaking this type of material for 12 hours, any additional shaking will manufacture clay size material, thus effectively increasing the clay yield.

CONCLUSION

It is shown that a particular arenaceous, argillaceous siltstone when dispersed in an end-over-end shaker gives greatest clay yield using not less than a 0. 20 normal sodium hexametaphosphate solution (commercial Calgon). A shaking time of 12 hours is recommended when using this end-over-end shaker as described by Hussy (1951, p. 224). The normality of the Calgon and sample solution giving the greatest clay yield is higher than that suggested by Tyner (1939).

Calgon, sodium carbonate, sodium hydroxide, de-ionized tap water, and tap water were tested as a dispersing reagent; Calgon was found to be the best. Five different normalities of Calgon were used to determine the best concentration for the highest clay yield. The highest concentration used, 0. 20 normal, gave the highest yield. It is suggested that higher concentrations be tried.

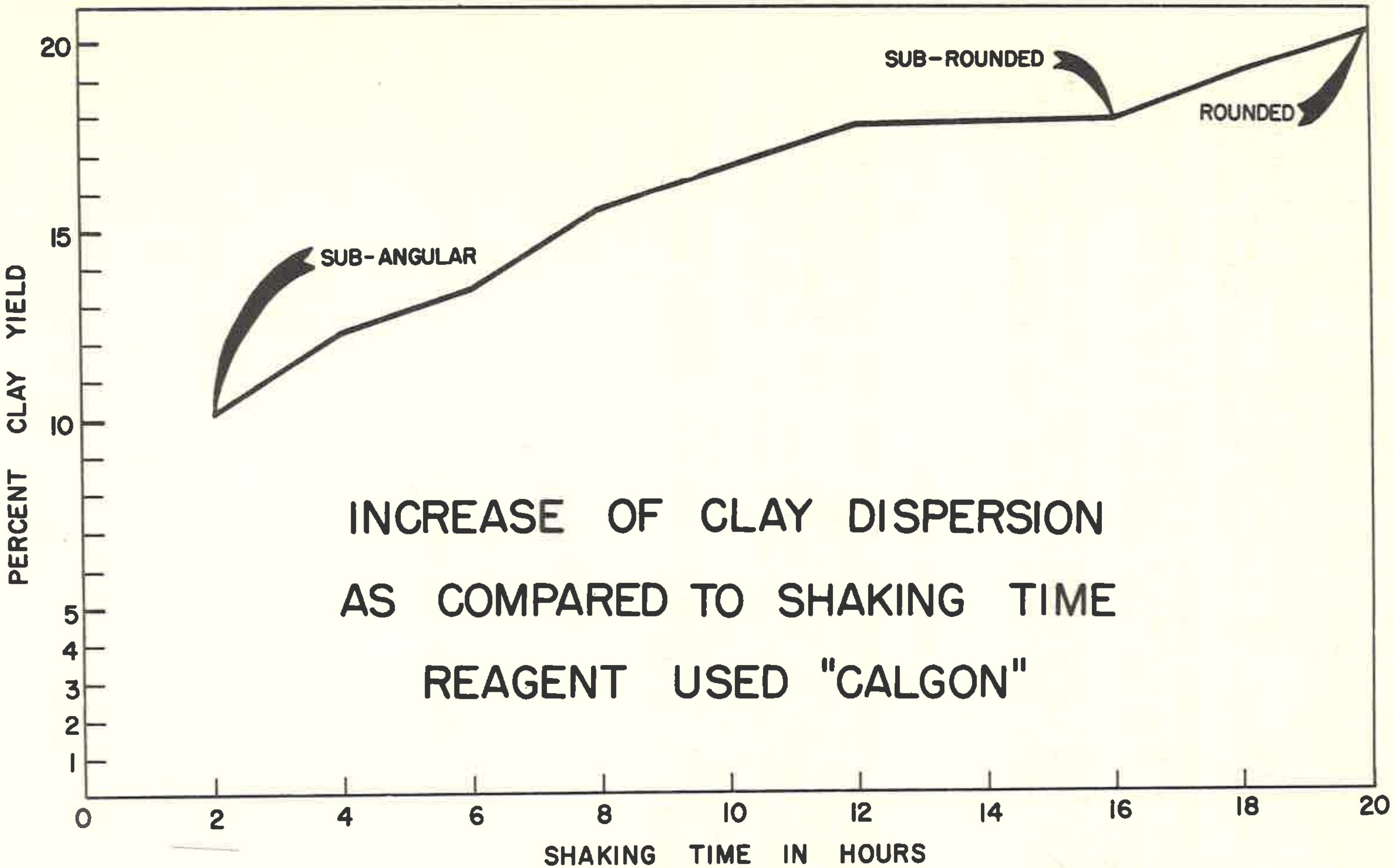
SUB-ANGULAR
SUB-ROUNDED
ROUNDED
INCREASE OF CLAY DISPERSION
AS COMPARED TO SHAKING TIME
REAGENT USED "CALGON"
PERCENT CLAY YIELD
20
15
10
5
4
3
2
1
0
2
4
6
8
10
12
14
16
18
20
SHAKING TIME IN HOURS

FIG. 4

Concentrations higher than 0.030 normal of each of the dispersing reagents other than Calgon were not prepared and compared with Calgon, since it was found that nearly equal normalities of Calgon and these other reagents showed Calgon to give the most complete dispersal. It is suggested that a comparison be made of higher normalities of those other reagents with Calgon in order to determine if these reagents will give dispersals comparable to that of Calgon, though the Calgon has a lower normality.

It was found that when dispersing samples for mechanical analysis, if the 12 hour shaking period is exceeded, the sand and silt fractions of the sample will become more rounded and the clay fraction percentage will increase.

Duplicate samples were prepared and subjected to identical procedure throughout the experiment in order to determine if there would be any variation in results. The results were the same in each case.

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