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GEOLOGY OF THE COASTAL PLAIN OF GEORGIA

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GEOLOGY OF THE COASTAL PLAIN OF GEORGIA

BY

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PREFACE

The manuscript of this report, which is the culmination of field and office studies carried on intermittently since 1914, partly in cooperation with the Geological Survey of Georgia, was completed early in 1938. It was prepared with the expectation that it would form part of a more comprehensive report on the geology of Georgia by several authors, which was intended to accompany a geologic map of the entire State on a scale of 1:500,000. However, this map without the text was published in 1939 by the Georgia Division of Mines, Mining and Geology. Part of this map is reproduced herein as plate 1 without revision.

Much of the mapping of the Coastal Plain was based on rapid reconnaissances carried on without adequate vertical and horizontal control and without satisfactory base maps. The resulting boundary lines therefore lack detail and are subject to modification. During 1941 and 1942 an intensive search for bauxite by several field parties of the Federal Geological Survey necessitated the remapping of parts of the Coastal Plain on a much larger scale and in great detail. This work is still in progress, and the final results are not yet available. Oral reports from the field geologists appear to indicate that part of the area east of Flint River that was mapped as the Clayton formation in 1938 may be the Barnwell formation, as it was colored on Cooke and Shearer's map in Professional Paper 120–C, published in 1918. This change seems very plausible, for it brings the upper Eocene outlier on Rich Hill, Crawford County, much closer to the main body of the upper Eocene deposits. This area is very difficult to map because it lacks distinctive beds. It also seems possible that part of the McBean formation as mapped may be basal upper Eocene instead of McBean, which is middle Eocene. With these possibilities in mind the writer has made a few changes in the text in an attempt to bring it as nearly up to date as is practicable without additional field work.

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GEOLOGY OF THE COASTAL PLAIN OF GEORGIA

By C. Wythe Cooke

ABSTRACT

The oldest known deposit on the crystalline basement of the Coastal Plain of Georgia is the Tuscaloosa formation, which is classified as early Upper Cretaceous because of its fossil leaves, which correlate it with the Woodbine sand of Texas. No marine fossils have been found in the Tuscaloosa formation in Georgia. It consists chiefly of coarse drab sand with intercalated lenses of white and purple clay. Its outcrop extends as a wide belt from Chattahoochee River to Savannah River, but east of the Ocmulgee its continuity is broken at several places by an overlap of the upper Eocene Barnwell formation.

The Upper Cretaceous series above the Tuscaloosa is divisible into five formations, which are exposed only west of Flint River. The marine Eutaw formation, which lies unconformably on the Tuscaloosa, is overlain on Chattahoochee River by sands and clays that form the basal part of the Blufftown formation.

The Blufftown is overlain unconformably by the Cusseta sand, which overlaps it and the Eutaw in Marion County and extends eastward on the Tuscaloosa as far as Peach County, where it is overlain by Eocene deposits.

Above the Cusseta lies more than 100 feet of dark-gray micaceous sand representing the Ripley formation, which includes the middle and lower parts of the *Exogyra costata* zone and contains an abundance of other marine shells. A more restricted zone (*Exogyra cancellata* zone) is included in the lower part of the *E. costata zone.* A greater thickness of the Ripley is exposed along the Chattahoochee than farther east.

The Providence sand lies unconformably on the Ripley. East of Flint River it is overlapped by Cenozoic deposits. The lower course of Pataula Creek is cut in gray fossiliferous sand alternating with ledges of coarse-grained sandstone, which seem to be an offshore facies of the Providence sand. The Providence is the youngest Cretaceous formation exposed in Georgia.

The Paleocene Clayton formation, of Midway age, lies unconformably on the Providence west of Flint River. East of the Flint the Clayton is probably overlapped by the Barnwell formation and by the McBean formation. The typical facies of the Clayton is white sandy limestone, which weathers to greenish clay and red sand.

The oldest Eocene deposit is the Wilcox formation, which is not subdivided in Georgia and is exposed only in the valleys of western Georgia. It is completely overlapped east of Muckalee Creek.

The McBean formation, which apparently represents the Tallahatta formation and the Lisbon formation of Alabama, extends completely across Georgia, but it is partly overlapped by younger formations.

The Ocala limestone, extensively developed in the southwest, and the Barnwell formation, in the northeast, meet and merge in Twiggs County. Both lie unconformably on the McBean formation and overlap it. Both are of Jackson age. The Barnwell represents a littoral facies of the Ocala. The Cooper marl, which contains upper Eocene Foraminifera, overlies the Barnwell near Millen and overlies the Ocala at Clinchfield. Only a few outcrops have been recognized.

No early Oligocene deposits are known in Georgia. The Flint River formation, formerly supposed to be a facies of the Glendon limestone, has been proved to be somewhat younger. It is correlated with the Chickasawhay marl of Mississippi. It overlaps the Eocene formations. East of Oconee River it is overlapped by the Hawthorn formation but reappears in the Savannah drainage basin. The Suwannee limestone, about the same age as the Flint River formation, projects a few miles up the valley of Withlacoochee River from Florida.

The Tampa limestone, of basal Miocene age, extends northward from Florida a few miles up the valleys of the Ochlockonee and the Flint and has been traced by means of residual chert along the foot of the Tifton Upland as far north as Sylvester. The Tampa is overlain by the Hawthorn formation, which occupies a band 80 miles wide trending northeastwardly across the State. There are few recognizable horizon markers in this enormous area. The Hawthorn consists mostly of lenses of sand and gravel but includes some marine marl beds and extensive deposits of fuller's earth. It overlaps the Tampa and Flint River formations onto the Barnwell.

The next younger formation is the Duplin marl, of upper Miocene age. The Duplin is known to crop out only in bluffs along Savannah River at and near Porters Landing and at Doctortown on the Altamaha.

The Marine Pliocene (?) is represented in Georgia only by approximately 20 feet of light-colored clay and impure limestone, the Charlton formation, which is exposed along St. Marys River and near the Satilla.

A broad belt adjoining the ocean is underlain by marine sand of Pleistocene age deposited by four repeated invasions of the sea and divided into seven formations. Remnants of the deposits of the earliest invasion (the Brandywine formation) have been recognized nearly 100 miles from the present coast at altitudes approximating 270 feet above sea level. Progressively younger and lower deposits are called the Coharie, Sunderland, Wicomico, Penholoway, Talbot, and Pamlico formations. Bones of mastodons and giant ground sloths have been found near Savannah and Brunswick.

The sea islands, chiefly of Pamlico age, and the tidal marshes, of recent origin, form a band 10 or 12 miles wide along the coast. The marshes extend 20 miles or more up all the estuaries.

A significant feature is the much more complete outcrop of the formations in the west than elsewhere. Near Chattahoochee River 11 formations are exposed between the Tuscaloosa and the Hawthorn formations. Near the Ocmulgee there are only 4, and along the Savannah there are only 3. This difference is the result of progressive overlap. It appears to indicate either an intermittent downwarp in the central and eastern parts of the State, which permitted the ocean to advance farther and farther inland, or an uplift in the west, which hastened the erosion of the littoral facies of the younger formations and exposed more and more of the underlying beds. That there may have been also slight uplift or at least flattening of the strata in the Chattahoochee region in line with the Ocala arch of Florida but separated from it by a structural "low" is suggested by the great width of the outcrop of the Ocala limestone in southwestern Georgia and by the considerable body of younger deposits between the two areas of Ocala outcrop.

GENERAL FEATURES OF THE COASTAL PLAIN

Extent.—The name Coastal Plain is applied to a region of plains and low hills that fringes North America from Massachusetts to Mexico and that is bounded on the inland border by regions of much older rocks. In the Atlantic States, including Georgia, the Coastal Plain adjoins the Piedmont province. In Alabama it cuts across the south end of the Appalachian Valley and Plateaus. It occupies more than half of Georgia. Its inland boundary forms a crooked line passing through Columbus, Macon, and Augusta and is marked by the inner boundary of the Tuscaloosa formation and the overlapping Barnwell formation (see geologic map, pl. 1).

Topographic divisions.—The Coastal Plain of Georgia has been divided into six topographic areas,[1] each of which differs from the others not only in topography but also in the kind of rocks by which it is underlain. In fact, these differences in lithologic composition, together with the differing periods of time during which the respective areas have been subject to erosion, are the fundamental factors that have produced the differences in topography. The divisions are as follows:

An area of hills and valleys corresponding approximately to the outcrop of the Upper Cretaceous sands and clays and extending across the State adjacent to the Piedmont is called the *Fall Line Hills* because all the streams entering it from the Piedmont have falls or rapids near the border, where they descend to the softer, more easily eroded rocks of the Coastal Plain. The *Fort Valley Plateau*, in Peach County and vicinity, is upheld by the firm red clayey sand of the Barnwell (Eocene) formation. The *Louisville Plateau*, which overlooks the Fall Line Hills east of Oconee River, is also underlain by Barnwell. The *Dougherty Plain*, most of which occupies the drainage basin of Flint River, owes its low, flat topography to the ready solubility of the Ocala limestone and the limy parts of the Flint River formation, most of which have been removed in solution. The more resistant and less soluble sand and gravel of the Hawthorn formation uphold the *Tifton Upland* above the Louisville Plateau and the Dougherty Plain, from which latter it is separated by a conspicuous scarp. It occupies a broad band crossing the middle part of the Coastal Plain. Between the Tifton Upland and the ocean lie seven *Coastal Terraces*, little-modified Pleistocene sea bottoms laid bare by the retreat of the sea to successively lower levels. Their flatness is due partly to the shortness of the time during which they have been exposed to erosion and partly to the scarcity of soluble rocks beneath them.

[1] Cooke, C. W., Physical geography of Georgia; the Coastal Plain: Georgia Geol. Survey Bull. 42, pp. 19–54, 1925.

Age, composition, and source of sediments beneath the Coastal Plain.—All the geologic formations in the Coastal Plain of Georgia are sedimentary deposits of Upper Cretaceous or Cenozoic age. No igneous intrusives or coarse volcanic ejecta have been found, but it is likely that there are beds derived from fine ash blown by the wind from volcanoes west or southwest of Georgia. Deposits of Lower Cretaceous age likewise appear to be wanting in Georgia, though they are well represented in the Coastal Plain from Virginia northward and in Arkansas and Texas. The absence of volcanic rocks and of early Cretaceous deposits may be explained by supposing that for a long time before the Upper Cretaceous epoch the present Coastal Plain of Georgia lay in the interior of a stable continental land mass in which volcanic activity was confined to the margins, and that the region remained volcanically inactive when it was invaded by a shallow sea in late Cretaceous and more recent times.

That the region has been repeatedly covered by the sea is proved by the occurrence of sea shells at many different stratigraphic levels. The marine beds are separated from one another by unconformities marking erosion intervals. The clastic deposits left by the invasions of the sea range in coarseness from gravel to clay. The ultimate source of most of them appears to be the crystalline rocks underlying the Piedmont province of Georgia and neighboring States, but the finer particles have doubtless been reworked time and again from one formation into a younger formation, just as today sand and mud washed from marine formations now above sea level are being distributed along the coast. Calcium carbonate is mingled in all proportions with the sand and clay, and there are extensive accumulations of nearly pure limestone.

Structure.—The structure of the Coastal Plain of Georgia is very simple. The region lacks large close folds, as well as faults of great displacement, but it contains a few small folds and faults in the western part. The regional dip is toward the south-southeast, or seaward, at a very gentle rate.

From a study of well logs and other data Prettyman and Cave[2] concluded that there is a gentle synclinal depression centering off the southern part of the coast of Georgia.[3] This basin appears to be merely the result of the regional dip opposed to the northeastward slope away from the Ocala arch of Florida. The northward slope from the Ocala arch accounts also for a slight sag in the Hawthorn formation along the Florida State line farther west.

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[2] Prettyman, T. M., and Cave, H. S., Petroleum and natural gas possibilities in Georgia: Georgia Geol. Survey Bull. 40, fig. 11 (p. 131) and map 2 (facing p. 134), 1923.

[3] The recent discovery that the basement rocks lie 4,347 feet below the surface at Offerman, Pierce County, appears to be confirmatory evidence.

A significant feature brought out by study of the geologic map (pl. 1) is the much more complete outcrop of formations in the west than elsewhere. Near Chattahoochee River 11 formations are exposed between the Tuscaloosa and Hawthorn formations, but near the Ocmulgee there are only four, and along the Savannah there are only three. This difference is not the result of a lithologic simplification but of progressive overlap. It appears to indicate a progressive uplift of the northwestern part of the Coastal Plain of Georgia, which hastened the erosion of the littoral facies of the younger formations and exposed more and more of the underlying beds. Further evidence of slight uplift or at least of flattening of the strata in the Chattahoochee region is suggested by the great width of the outcrop of the Ocala limestone there.

UPPER CRETACEOUS SERIES

GENERAL FEATURES

The deposits of Upper Cretaceous age in Georgia are divided in this report into six formations, named, in ascending order, the Tuscaloosa, the Eutaw, and the Blufftown formations, the Cusseta sand, the Ripley formation, and the Providence sand. The Tuscaloosa is composed of irregularly bedded lenses of sand, clay, and gravel. The Eutaw and the Blufftown contain much fine clayey gray to brown sand. The Cusseta consists chiefly of fine micaceous yellow sand and coarser buff-colored to pink cohesive sand. The most characteristic part of the Ripley is fine dark-gray to black sand with rows of calcareous concretions. The typical Providence contains lenses of white clay and cross-bedded white sand, but the formation merges seaward into evenly bedded fossiliferous gray sandstone. All six formations are believed to be chiefly marine, though the most characteristic parts of the Tuscaloosa, the Cusseta, and the Providence are littoral or even nonmarine facies without fossils. A few fossil plants have been found in the Tuscaloosa in Georgia, but no remains of animals. The seaward facies of the other five formations contain characteristic marine faunas.

The Upper Cretaceous deposits younger than the Tuscaloosa fall within two major and wide-ranging faunal zones: The *Exogyra ponderosa* zone, which includes the Eutaw and Blufftown formations and most of the Cusseta sand, and the *Exogyra costata* zone, which includes the uppermost part of the Cusseta sand, the Ripley formation and the Providence sand. The lower part of the Ripley contains also *Exogyra cancellata*, a guide fossil whose stratigraphic range is much more restricted than that of the other two species.

In the area of outcrop there is a stratigraphic break at the top and bottom of each of the six Upper Cretaceous formations, with the

possible exception of the contact between the Cusseta sand and the Ripley, whose mutual relations have not yet been satisfactorily determined. Evidence of unconformity is yielded not only by exposures of the actual contacts but also by the overlapping of one formation across another, as is shown on the geologic map (pl. 1). The overlapping of the Cusseta across the Blufftown and Eutaw to the Tuscaloosa, and the overlapping of the Paleocene Clayton formation across all the Upper Cretaceous formations younger than the Tuscaloosa are especially conspicuous.

The intervals of time represented by these stratigraphic breaks doubtless grow less as one travels seaward from the belts of outcrop of the formations, and some of the intervals are represented in other States by exposed beds. For instance, the interval between the Tuscaloosa and the Eutaw is supposed to be partly filled in Texas by the Eagle Ford shale and the lower part of the Austin chalk.

As is indicated in the diagram (fig. 1) most of the Upper Cretaceous formations of Georgia merge laterally into deposits of different facies. The Tuscaloosa, however, extends with little change from North Carolina to Tennessee. The Eutaw, which in Georgia is represented only by the upper (Tombigbee sand) member of the formation, differs somewhat from deposits of the same age in Alabama but retains the same name. The Blufftown formation, the Cusseta sand, and the Ripley formation of Georgia are equivalent to the Selma chalk of Alabama as recently restricted by Stephenson and Monroe,[4] and the Providence sand merges westward into the Prairie Bluff chalk, which formerly was included in the Selma. The chalky equivalent of the Ripley merges northwestward into sand, which extends northward from Noxubee County, Miss., to Tennessee and forms the typical part of the Ripley formation.

Stratigraphic studies made since the completion of Stephenson's preliminary report[5] have resulted in the following changes in classification: The supposed Lower Cretaceous deposits have been found to be of Upper Cretaceous age and placed in the Tuscaloosa formation. The Eutaw formation is restricted to the beds supposed in 1911 to be older than the Tombigbee sand member of the Eutaw but recently found to be equivalent to it. The beds classified in 1911 as Tombigbee sand member are here called Blufftown formation, a restoration of an older name. The Cusseta sand is removed from the Ripley formation, of which it was called a member, and is made an independent forma-

[4] Stephenson, L. W., and Monroe, W. H., Stratigraphy of Upper Cretaceous series in Mississippi and Alabama: Am. Assoc. Petroleum Geologists Bull., vol. 22, no. 12, pp. 1639–1657, 1938.

[5] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, pp. 66–215, 1911.

tion. The name Ripley formation is restricted to marine beds lying wholly within the lower part of the zone of *Exogyra costata* but more comprehensive than the zone of *E. cancellata*. The so-called Provi-

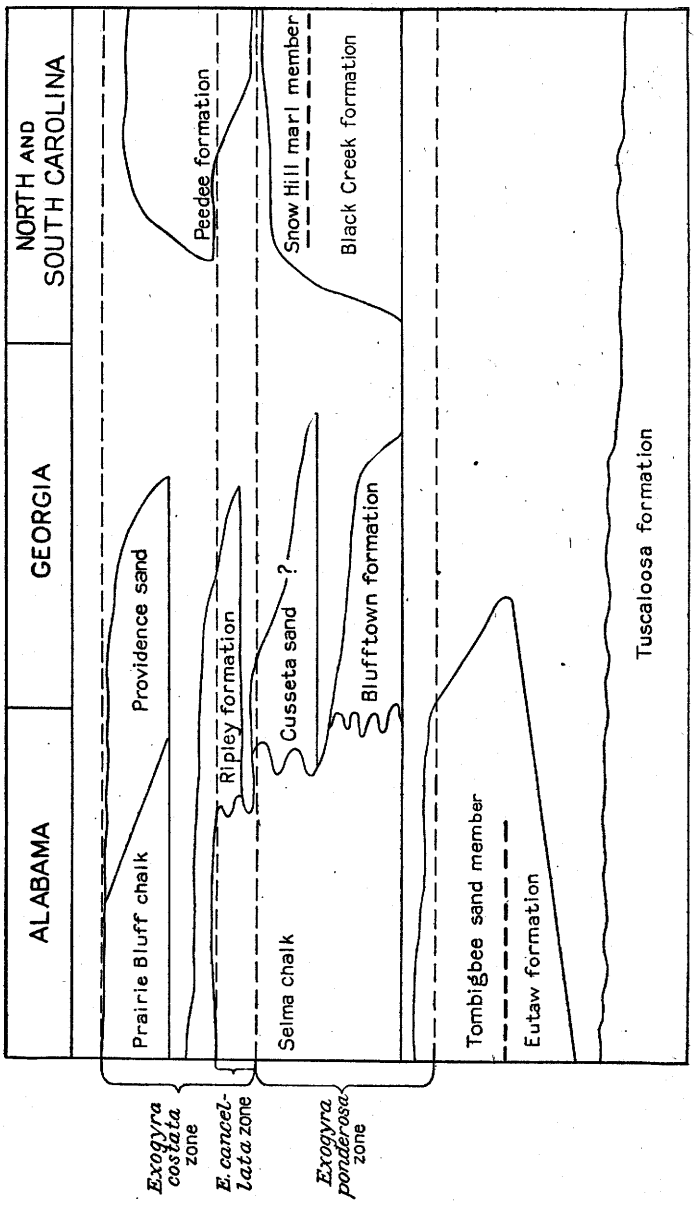

FIGURE 1.—Stratigraphic relations of Upper Cretaceous deposits in North Carolina, South Carolina, Georgia, and Alabama.

dence sand member of the Ripley is made an independent formation, to which are added the marine beds near the mouth of Pataula Creek, which likewise were included in the Ripley. Most of these changes

are the result of faunal studies by Dr. L. W. Stephenson,[6] to whom the writer is sincerely grateful for information and advice in the preparation of this report.

TUSCALOOSA FORMATION

GENERAL FEATURES

Name.—The Tuscaloosa formation, named in 1887 from a town in Alabama, was first recognized in Georgia in 1890 by Spencer, a former State geologist, who correlated it with the Potomac group of the Middle Atlantic region.[7] McGee, the same year, applied the name Potomac to the Tuscaloosa deposits near Macon and Columbus. Four years later, on the basis of plant remains studied by Fontaine and Ward, the Tuscaloosa formation of Alabama was correlated with the Amboy clay (Raritan formation) of New Jersey, which was then placed at the top of the Potomac group (Lower Cretaceous) but which is now generally accepted as of Upper Cretaceous age.[8] In 1910 Stephenson collected from the Tuscaloosa formation at Old Fort Decatur, Macon County, Ala., some poorly preserved leaves, which E. W. Berry provisionally identified as of Lower Cretaceous age although possibly not so old as the basal Potomac Patuxent formation of Maryland. For this and other reasons Stephenson supposed that the beds containing the leaves were older than the typical Tuscaloosa formation. He therefore classified as undifferentiated Lower Cretaceous the equivalent deposits in Georgia.[9] Later, Cooke reached the conclusion, based on the areal and stratigraphic relations, that the so-called Lower Cretaceous of Georgia east of Flint River is equivalent to what was then called the Middendorf arkose member of the Black Creek formation of South Carolina, of Upper Cretaceous age. With this in mind, Stephenson revisited Old Fort Decatur and collected more leaves, which Berry definitely identified as of Upper Cretaceous, Tuscaloosa age.[10] Accordingly, Cooke proposed to restore the name Tuscaloosa to the so-called Lower Cretaceous deposits of eastern Alabama and western Georgia and to call the deposits of eastern Georgia and South Carolina, which might not be exactly equivalent, by the name of Middendorf formation.[11] Further investigation removed his doubt as to the equivalence of the Tuscaloosa and the Middendorf, and in 1936

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[6] Stephenson, L. W., and Monroe, W. H., op. cit., pp. 1639–1657.

[7] Spencer, J. W. W., "Southern drift" and its agricultural relations: Georgia Agr. Exper. Sta. Bull. 6, pp. 90–94, 1890.

[8] Smith, E. A., Johnson, L. C., and Langdon, D. W., Report on the geology of the Coastal Plain of Alabama: Alabama Geol. Survey, pp. 255, 347, 1894.

[9] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 109–111.

[10] Berry, E. W., The age of the supposed Lower Cretaceous of Alabama: Washington Acad. Sci. Jour., vol. 13, pp. 433–435, 1923.

[11] Cooke, C. W., Correlation of the basal Cretaceous beds of the Southeastern States: U. S. Geol. Survey Prof. Paper 140, pp. 137–139, 1926.

he discarded the name Middendorf in favor of Tuscaloosa.[12] The name Tuscaloosa is now applied to basal Upper Cretaceous beds from North Carolina to Mississippi, and northward into Tennessee.

Distribution.—In Georgia the Tuscaloosa formation crops out as an irregular band bordering the Piedmont and extending entirely across the State but covered at several places by overlaps of younger deposits. There are also a number of outliers of the formation on the Piedmont.

Thickness and lithologic character.—The Tuscaloosa formation is generally less than 600 feet thick and is much less along Chattahoochee River.[13] In western Georgia it consists chiefly of buff or tawny arkosic sand made firm by an admixture of clay and lenses of sandy clay. Farther east lenses of light-colored clay are more abundant. Along the border of the Piedmont it contains a good deal of coarse gravel composed of angular quartz pebbles; farther away from the Piedmont it is generally finer. Most of the sand is massive or cross-bedded; very little, if any, is horizontally thin-bedded. Some of it is locally cemented into purplish sandstone. Thin-bedded or laminated clay is very rare, and dark clay is unusual.

Flora.—The only organic remains that have been found in the Tuscaloosa formation in Georgia are a few leaves. A larger flora has been discovered in South Carolina. Stephenson[14] cites E. W. Berry's identifications of the species in the following list, then believed to be basal Eutaw, but now known to be Tuscaloosa.

Plants from McBride ford, Upatoi Creek 4½ miles upstream from the Cusseta Road

Andromeda cretacea Lesq.?
Andromeda wardiana Lesq.
Androvettia elegans Berry.
Aralia eutawensis Berry.
Brachyphyllum macrocarpum Newberry
Cinnamomum newberryi Berry.
Cinnamamum heeri Lesq.
Eucalyptus angusta Valen.
Ficus ovatifolia Berry.
Juglans arctica Heer?
Magnolia boulayana Heer.
Magnolia capellinii Heer.
Manihotoides georgiana Berry.
Menispermites variabilis Berry.
Paliurus upatoiensis Berry.
Salix flexuosa Newberry.
Sequoia reichenbachi (Geinitz) Heer.
Tumion carolinianum Berry?
Zizyphus laurifolius Berry.

Stratigraphic relations.—The Tuscaloosa formation is separated from the underlying crystalline rocks by an unconformity that represents many eons of time. It is separated from the next younger formation by another break of much shorter duration. The unconformity at the top represents a longer time interval at the east end

[12] Cooke, C. W., Geology of the Coastal Plain of South Carolina: U. S. Geol. Survey Bull. 867, p. 17. 1936.
[13] Veatch, Otto, and Stephenson, L. W., op. cit., p. 77.
[14] Idem., p. 128.

of the State than at the west end, for progressively younger formations overlap the Tuscaloosa toward the east. This progressive overlap apparently records an intermittent down-tilting toward the east or an upwarp toward the west.

Economic significance.—Deposits of sand and gravel sufficiently extensive to be of local importance are widely distributed throughout the region underlain by the Tuscaloosa formation. The Tuscaloosa formation is the source of the valuable sedimentary kaolin deposits that are extensively mined in Twiggs, Wilkinson, Washington, Glascock, and Richmond Counties. One principal use of the kaolin is as a coating and filler in the manufacture of paper, rubber, and linoleum. It is also used in making whiteware and refractory products. Associated with these kaolins at places are deposits of bauxite, an ore of aluminum. The Tuscaloosa formation because of its porosity and the absence of readily soluble minerals, yields plentiful supplies of unusually pure water.

LOCAL OCCURRENCE

Muscogee County.—The Tuscaloosa formation is exposed at intervals along Chattahoochee River from Columbus to Broken Arrow Bend at Camp Benning, where it passes beneath water level. At Girard, Ala., across the river from Columbus, 3 feet of argillaceous, very arkosic light-gray friable sandstone is overlain by 9 feet of massive light-drab coarsely sandy clay.[15] West of the tracks of the Central of Georgia Railway at Girard somewhat higher beds are reported by Stephenson as follows:

Section at southern outskirts of Girard, Ala.

	Feet
Pleistocene? (or surface creep):	
6. Sandy and pebbly loam	2
Upper Cretaceous (Tuscaloosa formation):	
5. Reddish sandy loam grading down into harsh sandy clay, and this in turn into a slightly indurated arkosic, micaceous sand	25
4. Mottled purplish and gray harsh clay	3
3. Hard grayish to somewhat mottled sandy clay	6
2. Gray, in places iron-stained loose cross-bedded very arkosic and micaceous sand becoming very coarse and gravelly in lower 6 feet	16
1. Light greenish-drab clay	12

About 100 feet of Tuscaloosa formation crops out on the road west of Tiger Creek 5½ miles southeast of Columbus. It consists of alternating lenses of clay and coarse arkosic sand. Near the middle is a thick bed of white to purple clay, and near the base is gray sandy

[15] Veatch Otto, and Stephenson, L. W., op. cit., p. 78.

clay. Crusts of limonitic sandstone mark the contact with the overlying Tombigbee sand member of the Eutaw, which consists of about 20 feet of much finer micaceous light-gray to dark-gray sand flaked with gray clay in the upper part, which weathers orange-red.

Marion and Taylor Counties.—On the road (State Highway No. 41) from Buena Vista to Geneva 1 mile south of Juniper Creek, in Marion County, there is a 10-foot ledge of white to purple sandstone that probably lies somewhere in the lower part of the Tuscaloosa. Gullies at Mauk, in Taylor County, show white kaolin interbedded with coarse white, yellow, and reddish sand that apparently represents a younger part of the formation. These beds are overlain unconformably by red cross-bedded sand, which is probably of Cusseta age. Lenses of white and purple clay are conspicuous in the Tuscaloosa formation south of Butler.

Crawford County.—Gullies on the southern slope of Rich Hill, in Crawford County 4½ miles east-southeast of Knoxville, have cut through a capping of Eocene beds (Ocala limestone) into more than 100 feet of pure white clay and white cross-bedded micaceous, arkosic sand of the Tuscaloosa formation. White and purple clay and fine pale-drab sand are exposed along State Highway No. 7, 2 or 3 miles north-northwest of Zenith.

Houston County.—The following section on the highway from Macon to Fort Valley near the Peach-Houston County line was measured in 1930:

Section on State Highway No. 49, 1.6 miles south of Echeconnee Creek

	Feet
Barnwell formation (?) (Eocene):	
6. Coarse gray argillaceous sand weathering brick red. To top of hill	25
Tuscaloosa formation (?) (perhaps Providence sand) (Upper Cretaceous):	
5. Light-gray micaceous sandy clay interbedded with reddish sand	2
4. Coarse pink cross-bedded micaceous argillaceous sand	12
3. White micaceous sandy clay, sand predominating at bottom, clay at top	3½
2. White mealy sand	5½
1. Concealed	5

Farther down the gully, where it cuts across an abandoned road, the section is as follows:

Section of Tuscaloosa formation (?) below State Highway No. 49. 1.6 miles south of Echeconnee Creek

	Feet
5. Coarse reddish argillaceous sand at base, passing upward into fine white cross-bedded micaceous sand; mottled red and white above	
4. Finely banded white micaceous sandy clay	4½

Section of Tuscaloosa formation (?) below State Highway No. 49. 1.6 miles south of Echeconnee Creek—Continued

	Feet
3. Massive medium-coarse white sand, passing upward into highly micaceous bedded white sand at top	15
2. Very coarse sand and gravel containing enough clay to make it firm, and pellets of white clay	5
1. White kaolin	15

Bibbs and Twiggs Counties.—At Andrews Hill, in Bibb County 4½ miles northeast of Ocmulgee River at the Twiggs County line, the Barnwell formation is underlain by 50 feet or more of white to pink micaceous sand and coarse sand of Tuscaloosa age. The Barnwell is underlain by the Tuscaloosa also at Dry Branch, Twiggs County, where kaolin of the Tuscaloosa formation is mined, and at Stevens pottery, Baldwin County.

Wilkinson County.—In Wilkinson County, where kaolin has been mined since 1908, the Tuscaloosa contains both soft and hard varieties of kaolin, as well as bauxite and bauxitic clay, part of which hardens on exposure and is used locally for building chimneys. The lenses of clay are generally underlain by white cross-bedded micaceous sand and overlain unconformably by the Eocene McBean or Barnwell formations.

Washington County.—In Washington County the Tuscaloosa formation is exposed chiefly in the valleys of Oconee River, Buffalo Creek, and Ogeechee River, and is covered elsewhere by the McBean or Barnwell formations. It rises 60 feet above water level along Little Keg Creek, a tributary of Buffalo Creek, 7 miles north-northwest of Sandersville. Seventy feet of light-colored sand containing lenses of white kaolin underlies the Eocene east of Buffalo Creek on the road to Milledgeville 8 miles west of Sandersville. The unusually soft kaolin in the Deepstep section has been extensively mined.

Glascock County.—More than 20 feet of hard white sandy kaolin underlying more than 100 feet of Eocene beds is reported by Smith [16] at Tompkins Hill south of Joes Creek on the Edgehill road 4 miles south of Gibson, Glascock County. Deposits of flint kaolin have been mined for many years.

Richmond County.—The Tuscaloosa formation is exposed in the valley of Spirit Creek and other tributaries of Savannah River. It consists of fine to coarse argillaceous sand containing lenses of white clay. Kaolin has been mined for many years near Hephzibah. The following section in the face of a clay pit of the Albion Kaolin Co. on Grindstone Creek 1½ miles west of Hephzibah is reported by Smith: [17]

[16] Smith, R. W., Sedimentary kaolins of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 44, p. 343, 1929.

[17] Idem., p. 398.

Section in pit of the Albion Kaolin Co.

	Feet
Barnwell formation (Eocene):	
8. Coarse red sand	5–10
7. Hard very sandy mottled bright-red and buff clay	15–20
Tuscaloosa formation (Upper Cretaceous):	
6. White micaceous and kaolinic quartz sand; water bearing	12–15
5. Soft to semihard stained kaolin containing mica and fine grit; occasionally sold as sagger clay	0–12
4. Soft light cream-colored kaolin practically free from grit and with only occasional mica flakes; dries white and breaks with splintery fracture; mined and sold as No. 1 clay	6
3. Soft cream-colored kaolin with small darker-colored spots; slightly harder than bed above; contains almost no grit and very little mica except bottom foot or two, which is softer, contains more mica, and grades into bed below; mined and sold as No. 2 clay	8
2. Soft cream-colored sandy and micaceous kaolin; grades into bed below; not mined	6–8
1. Coarse white water-bearing sand	?
	52 to 69

Other parts of the pit show 10 to 12 feet of hard micaceous arkose, the coarser parts of which resemble granite. This kind of rock was formerly used for grindstones, whence the name of the creek.

EUTAW FORMATION

GENERAL FEATURES

Name.—The Eutaw formation was named from a town in Alabama. As herein described, the formation in Georgia is restricted to beds that Stephenson [18] formerly thought lay below the Tombigbee sand member, but he has since discovered that they are equivalent to it. The beds that he called Tombigbee sand member are herein called Blufftown formation.

Distribution.—The Eutaw formation extends eastward across Chattahoochee County into Marion County, where it is overlapped by the Cusseta sand. There are also several outliers in Muscogee County. Westward, it extends across Alabama to Mississippi and thence northward to Tennessee. The region underlain by the Eutaw formation in Georgia is hilly and deeply gullied. It includes very few flat places except the terraces bordering Chattahoochee River. Altitudes in it range from less than 180 feet to more than 500 feet above sea level.

[18] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, pp. 117–131, 1911.

Thickness and lithologic character.—The Eutaw formation is more than 100 feet thick. The base of the formation is a littoral deposit of coarse gray or iron-stained cross-bedded sand. The remainder consists chiefly of platy sandy clay and clayey sand. Fresh exposures are gray when damp and light-gray when dry. Weathered surfaces are rusty brown or chocolate-colored. Smooth, even surfaces are not rare in road cuts, but crumbly, hackly surfaces are more common. Concentric markings that resemble incipient concretions decorate some smooth cuts. Fresh exposures of the Eutaw are easily recognized; weathered surfaces differ from other Upper Cretaceous formations in their rusty-brown color. The most characteristic soil derived from the Eutaw is the Ruston sandy loam.

Fauna.—The Eutaw contains a moderate number of marine mollusks, which are preserved in part as shells and in part as molds. Among the more diagnostic species may be mentioned an undescribed *Pedalion?*, *Exogyra upatoiensis* Stephenson, *Ostrea cretacea* Morton, and *Anomia olmstedi* Stephenson. The first and the last two of these species range upward into somewhat younger beds.

Stratigraphic relations.—The Eutaw formation lies unconformably on the Tuscaloosa formation and is unconformably overlain by the Blufftown formation. It is unconformable with the still higher Cusseta sand, which overlaps across the Blufftown onto the Eutaw. The part of the formation exposed in Georgia represents only the upper part (Tombigbee sand member) of the Eutaw formation of Alabama and Mississippi.

Economic significance.—No particular use has been found for any part of the Eutaw formation, but the sand may be suitable for making concrete.

LOCAL OCCURRENCE

Muscogee County.—The character of the Eutaw formation away from the river is shown by the following section, which is adapted from Stephenson's report.[19]

Section along Cusseta Road 1½ to 2 miles southeast of Bull Creek, Muscogee County

	Feet
Eutaw formation (?):	
11. Red stratified argillaceous sand	10
10. Interstratified red sand and light harsh clay layers with a line of pebbles and cobbles along base	8
Eutaw formation:	
9. Fine light weathered argillaceous sand	6
8. Fine laminated sand and clay with brown iron crusts	7
7. Mottled marine sand and clay	10
6. Greenish-drab finely arenaceous marine clay	10

[19] Veatch, Otto, and Stephenson, L. W., op. cit., p. 124.

Section along Cusseta Road 1½ to 2 miles southeast of Bull Creek, Muscogee County—Continued

Eutaw formation—Continued.	Feet
5. Fine white marine sand more or less streaked with red and yellow due to weathering	10
4. Mottled argillaceous marine sand, much weathered	17
3. Greenish-gray argillaceous marine sand	27
2. Coarse crossbedded sand with kaolin grains and irregularly distributed clay balls	15
Unconformity.	
Tuscaloosa formation:	
1. Medium-coarse cross-bedded sand, arkosic in part	20

Stephenson [20] found poorly preserved prints of *Pedalion?* n. sp., *Cymbophora* sp., *Corbula oxynema* Conrad, and other mollusks in greenish-gray micaceous sand near the base of the Eutaw on the Steam Mill road east of Tiger Creek 7 miles east-southeast of Columbus.

Chattahoochee County.—There are excellent exposures of the Eutaw formation in the bluff of Upatoi Creek between the railroad bridge and the new location of the Cusseta road, where Stephenson measured the following section and collected fossils: [21]

Section on Upatoi Creek ¼ mile below the railway bridge 7 miles southeast of Columbus

Eutaw formation:	Feet
9. Brown unconsolidated marine sand	5
8. Greenish partially weathered irregularly foliated fine sand and clay	5
7. Fine-grained white sandstone	1
6. Greenish irregularly foliated fine sand and clay	2
5. Dark greenish-gray argillaceous sand	5
4. Fine-grained white sandstone	1½
3. Very fine grained dark greenish-gray clay with fine irregular dark clay foliations. Contains discontinuous nodular limestone layers and irregularly distributed lime concretions. Scattered fragments of lignite present in the materials. Fossiliferous	25
Unconformity (not clearly exposed).	
Tuscaloosa formation:	
2. Light-gray coarse cross-bedded more or less arkosic sand, partially streaked with yellow, with subordinate sandy clay layers	22
1. Concealed to water level	30

The collections of fossils from Upatoi Creek include *Pedalion?* sp., *Ostrea cretacea*, *Exogyra upatoiensis*, other unidentified mollusks, and shark teeth including *Lamna texana* and *Corax falcatus*.

[20] Veatch, Otto, and Stephenson, L. W., op. cit., p. 125.
[21] Veatch, Otto, and Stephenson, L. W., op. cit., p. 126.

The Eutaw formation is exposed on Ochillee Creek near Ochillee, where Veatch [22] reports the following section:

Section of Eutaw formation at Ochillee

	Feet
5. Brown or yellow unconsolidated sand (at top).	
4. Blue or black laminated sandy clay, "marl"	40
3. Sandstone	4
2. Dark-gray calcareous sandstone. In places the bed is composed almost entirely of shells	4
1. Black and gray micaceous, calcareous sand; contains poorly preserved shells and lignite	8

Stephenson [23] suggests that bed 4 of Veatch's section at Ochillee corresponds to the clay bed exposed on Chattahoochee River at Slick Bluff and other places along Euchee Rapids. He has identified the following species of fossil mollusks from the lower beds:

Fossil mollusks from Ochillee

Nucula sp.	Etea sp.
Protarca obliqua Stephenson?	Cyprimeria depressa Conrad?
Pedalion? sp.	Leptosolen biplicata Conrad.
Ostrea cretacea Morton.	Cymbophora sp.
Anomia olmstedi Stephenson.	Corbula oxynema Conrad.

The lower part of the Eutaw formation and its contact with the underlying Tuscaloosa formation is exposed at the foot of the high bluff on Chattahoochee River opposite Broken Arrow Bend at Fort Benning. The following section is adapted from Stephenson's report.[24]

Section at Broken Arrow Bend, 10½ miles below Columbus

	Feet
Eutaw formation:	
3. Slightly laminated gray calcareous, micaceous fossiliferous sand containing impure lime nodules in layers 2 to 3 feet apart	15
2. Coarse cross-bedded gray or iron-stained sand and black to gray laminated clay, in part reworked from underlying Tuscaloosa beds, containing pieces of petrified wood, large logs, and smaller pieces of lignite; fossil leaves were found in a lens of black clay 8 inches thick several feet above water level. Grades conformably into the overlying bed	2 to 13
Unconformity.	
Tuscaloosa formation:	
1. Characteristic gray sand and clay	0 to 5

[22] Veatch, Otto, Second report on the clay deposits of Georgia: Georgia Geol. Survey Bull. 18, p. 91, 1909.

[23] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 128–129.

[24] Idem., p. 118.

From bed 2, E. W. Berry has identified the following leaves:

Malopoenna horrellensis Berry.
Phragmites pratti Berry.
Salix eutawensis Berry.
S. flexuosa Newberry.
Sequoia reichenbachi (Geinitz) Heer.

Another exposure on the Alabama side of the river a short distance upstream shows 13 feet of dark-gray calcareous, micaceous fine sandy clay broken by several layers of nodular lime concretions in the upper 8 feet. This clay extends to the water level. Stephenson obtained the following species (tentatively identified) at this place:

Fossil mollusks and fish from Broken Arrow Bend

Pedalion? n. sp.
Ostrea cretacea Morton.
Exogyra upatoiensis Stephenson.
Pecten sp.
Anomia olmstedi Stephenson.
Cardium sp.
Cyprimeria sp.
Corbula oxynema Conrad.
Turritella sp.
Placenticeras sp. cf. P. guadalupae Roemer.
Lamna texana Roemer.
Otodus appendiculatus Agassiz.

The layers of lime concretions dip below water half a mile below Broken Arrow Bend and form the bed of the river at the head of Euchee rapids. At Burdock Landing, Ala., one-half to three-quarters of a mile below the head of the rapids, Stephenson [25] reports 12 to 30 feet of greenish somewhat laminated clay, with sandy partings, containing *Pedalion?* n. sp., *Ostrea cretacea* Morton?, *Pecten cliffwoodensis* Weller, *Anomia olmstedi* Stephenson, *Cyprimeria depressa* Conrad, *Legumen* sp., *Cymbophora* sp., *Corbula oxynema* Conrad, and other mollusks. Similar fossiliferous clay is exposed at Slick Bluff, half a mile below Burdock Landing. Stephenson also reports 25 feet of dark-gray laminated clay with seams and thin layers of white or yellow-stained sand and seams of finely comminuted lignitic matter on the Alabama side about 200 yards above the mouth of Euchee Creek.

BLUFFTOWN FORMATION

GENERAL FEATURES

Name and distribution.—The Blufftown marl was named in 1909 by Veatch,[26] who adopted the name of a small village (now abandoned), on a high bluff overlooking Chattahoochee River, in Stewart County, Ga. The formation is known in Georgia only in the northwestern part of Stewart County, in Chattahoochee County, and in Marion County, where it is overlapped by the Cusseta sand.

[25] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 119–120.
[26] Veatch, Otto, Second report on the clay deposits of Georgia: Georgia Geol. Survey Bull. 18, pp. 86, 88, 1909.

Thickness and lithologic character.—Veatch described the Blufftown marl as being composed of 200 feet of black lignitic clay, gray calcareous and argillaceous sand, and thin layers of calcareous rock. The term formation seems more appropriate than marl, which forms only a small part of the Blufftown as here interpreted. Veatch's section at old Blufftown, showing about 100 feet of material referable to the Blufftown marl, consists chiefly of gray calcareous sand (marl) with ledges of nodular limestone.

Fauna.—The Blufftown formation is abundantly fossiliferous. The type locality has yielded 66 species of mollusks and several other kinds of organisms. Some of these species occur also in the Tombigbee sand member of the Eutaw, but *Exogyra upatoiensis* Stephenson (the typical form) has not yet been found in it. The presence of *Exogyra ponderosa* shows that the Blufftown belongs well down in the Upper Cretaceous, and the formation contains several restricted species of mollusks that have not yet been described.

Stratigraphic relations.—Veatch classified the Blufftown as the lowest part of the Ripley formation, following Langdon's correlation [27] of the beds exposed along Chattahoochee River. Stephenson [28] recognized it as the upper part of the Eutaw formation and called it the Tombigbee sand, which is the youngest part of the Eutaw in western Alabama. He has since come to the conclusion that it is about the age of the Coffee sand, which overlies the Tombigbee in northern Mississippi and merges into the lower part of the Selma chalk in the intervening area.

The Blufftown formation is interpreted as resting unconformably upon the underlying Tombigbee sand, a relationship suggested by the coarse sand and sandstone at its base. It is overlain unconformably by the Cusseta sand, which overlaps it.

Economic significance.—The Blufftown formation appears to contain no important mineral deposits.

LOCAL OCCURRENCE

Chattahoochee County.—Rusty-gray micaceous clayey sand exposed to a thickness of 20 feet on the Cusseta road 5.7 miles southeast of Upatoi Creek contain impressions of shells. Gullies north of the road a mile farther east and 3.3 miles northwest of Cusseta show nearly 100 feet of alternating fine gray micaceous sand and clay.

The following section, which is adapted from Stephenson's report,[29] is exposed south of Sand Branch on the old Lumpkin trail on Fort

[27] Langdon, D. W., Variations in the Cretaceous and Tertiary strata of Alabama: Geol. Soc. America Bull., vol. 2, pp. 587–606, 1891.

[28] Veatch, Otto, and Stephenson, L. W. Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, p. 112, 1911.

[29] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 138–139.

Benning Military Reservation 2 miles east-northeast of Chimney Bluff. The dividing line between the Blufftown formation and the Cusseta sand is placed provisionally at the point indicated in the section, for the present writer has not examined the beds.

Section on the Lumpkin Trail south of Sand Branch

	Feet
Cusseta sand:	
12. Reddish, ferruginous massive medium-grained marine sand, partially indurated	5
11. Coarse reddish and yellowish loose sand	3
Blufftown formation:	
10. Fine micaceous unconsolidated sand, streaked with yellow and purple	20
9. Dark laminated finely micaceous clay	1
8. Fine micaceous greenish-gray argillaceous marine sand filled with soft molds of pelecypods, with some lenses of unfossiliferous gray sand and a thin layer of dark laminated clay 2 feet above base	10
7. Greenish-gray argillaceous sand with numerous small, short interlocking laminae of clay	6
6. Dark finely arenaceous thinly laminated clay	12
5. Greenish-gray argillaceous massive sand with numerous soft molds of fossils	5
4. Dark laminated micaceous clay interstratified with lenses and layers of light greenish-gray fine micaceous sand reaching a maximum thickness of 3 feet. Some fossil molds	17
3. Dark greenish-gray extremely micaceous sand with occasional calcareous concretions. Contains an abundance of decayed fossil shells	11
2. Similar to bed 2 but light greenish gray in color. Contains soft shells	10
1. Poorly exposed to base of hill but consists, for the most part, of greenish-gray massive nonfossiliferous marine sand	22

From beds 2 and 3 of the preceding section, Stephenson obtained the species (tentatively identified) in the following list:

Fossils from Lumpkin Trail south of Sand Branch (U. S. G. S. 6411)

Nucula sp., cf. N. stantoni Stephenson.	Cyprimeria depressa Conrad.
Exogyra ponderosa Roemer.	Cymbophora trigonalis Stephenson.
Trigonia sp.	Schizodesma appressa Gabb?
Anomia olmstedi Stephenson.	Corbula oxynema Conrad.
Veniella sp., cf. V. mullinensis Stephenson	Turritella quadrilira Johnson.

From 10 feet of dark-gray marine sand, with a layer of nodular lime concretions near the base, exposed in a cut of the Seaboard Railway 2½ miles northwest of Cusseta, Stephenson [30] reports the following species of mollusks (tentatively identified):

[30] Veatch, Otto, and Stephenson, L. W., op. cit., p. 140.

Fossils at milepost 16, Seaboard Railway (U. S. G. S. 5379)

Cucullaea sp.
Inoceramus, 2 sp.
Breviarca sp.
Exogyra ponderosa Roemer.
Exogyra ponderosa var, erraticostata Stephenson.
Pecten cliffwoodensis Weller.
Pecten bellisculptus (Conrad).
Anomia argentaria Morton.
Liopistha alternata Weller.
Veniella conradi Morton.
Etea sp.
Lucina glebula Conrad.
Cardium sp.
Cardium alabamense Gabb?
Cyprimeria depressa Conrad.
Aphrodina sp.
Corbula oxynema Conrad.
Turritella trilira Conrad.

From black clay exposed at the base of a railroad cut half a mile northwest of Cusseta, Stephenson obtained *Cymella bella* Conrad, *Schizodesma* cf. *S. appressa* Gabb, and molds of other fossils.

Between Euchee Creek and Chimney Bluff, Chattahoochee River passes over a considerable thickness of basal coarse pebbly ferruginous sandstone containing in places poorly preserved molds of fossils. Rocks of this kind were observed by Stephenson [31] along the left bank between the mouth of Euchee Creek and Chimney Bluff at Moore Rocks, Betons Rocks, and Codys Rock, 18, 19, and 20¼ miles, respectively, below Columbus. These coarse sandstones are interpreted as the basal beds of the Blufftown formation. Beds stratigraphically higher than these coarse, basal sandstones are exposed in the lower part of Chimney Bluff as described in the following section (measured in April 1938 by L. W. Stephenson and W. H. Monroe):

Section at Chimney Bluff, Chattahoochee County

Blufftown formation:	Feet
5. Dark laminated finely arenaceous clay	6
4. Dark-gray medium to coarse massive argillaceous sand with a few scattered lignite particles; quartz pebbles not larger than a pea are present in the lower 2 feet; fossils identified include *Inoceramus* sp., and *Cyprimeria depressa* Conrad	10
3. Almost white loose, fine to medium-grained cross-bedded micaceous sand, with scattered films of dark clay and some lignite seams; tubes of *Halymenites major* Lesquereux are common	16
2. Very dark laminated lignitic micaceous sand and clay, the lignite present chiefly in the form of partings of comminuted fragments	2
1. Gray to dark-gray micaceous sand with numerous laminae of dark clay; contains some irregularly scattered lignite fragments, and one log perforated with *Teredo* borings was observed	20+

At the Racepasses, 1½ miles below Chimney Bluff, 14 feet of dark greenish-gray compact sandy clay containing casts of *Pecten burling-*

[31] Veatch, Otto, and Stephenson, L. W., op. cit., p. 121.

tonesis and other shells overlies 12 feet of laminated, cross-bedded lignitic sand and clay like that in the lower part of Chimney Bluff.

At Big Bend, right bank, 2½ miles below Chimney Bluff, 12 to 15 feet of laminated clay and sand is overlain by a few feet of gray marine sand containing *Exogyra ponderosa*, *Anomia olmstedi*, *Etea carolinensis*, *Lucina glebula*, *Cyprimeria depressa*, and other fossils.[32]

A bluff at Planters Landing, half a mile below Big Bend and 25 miles below Columbus, shows 25 or 30 feet of dark-green finely arenaceous marine clay containing a conspicuous layer of *Exogyra ponderosa* 12 or 15 feet above water level.[33] Other fossils found at Planters Landing include *Hamulus major* Gabb, *Anomia argentaria* Morton, *Etea carolinensis* Conrad, *Lucina glebula* Conrad?, *Cardium* (*Granocardium*) *alabamense* Gabb?, *Cyprimeria depressa* Conrad, *Cymbophora lintea* (Conrad)?, *Corbula sp.* (large), and *Turritella quadrilira* Johnson.

Stewart County.—At Banks Landing, in Stewart County half a mile below Hichitee Creek, 25 or 30 feet of light-gray calcareous clay and glauconitic sand with calcareous concretionary ledges several feet apart contains the species (tentatively identified) in the following list:[34]

Species from Banks Landing

Serpula lineata (Weller).
Hamulus major Gabb.
Hamulus onyx Morton.
Nucula sp., cf. N. stantoni Stephenson.
Nucula sp.
Nuculana tarensis Stephenson?
Nuculana longifrons (Conrad).
Breviarca sp.
Breviarca sp., cf. B. umbonata Conrad.
Nemodon sp.
Gervilliopsis ensiformis (Conrad).
Pedalion? n. sp.
Inoceramus sp.
Ostrea cretacea Morton.
Ostrea plumosa Morton.
Ostrea whitei Stephenson.
Gryphaea sp.
Exogyra ponderosa Roemer.
Exogyra ponderosa var. erraticostata Stephenson.
Trigonia sp.
Pecten (Neithea) sp.
Pecten simplicius Conrad.
Pecten burlingtonensis Gabb.
Pecten sp.
Lima kerri Stephenson?
Anomia argentaria Morton.
Anomia olmstedi Stephenson.
Liopistha sp.
Veniella conradi (Morton).
Etea sp.
Crassatella sp.
Brachymeris carolinensis (Conrad).
Cardium dumosum Conrad.
Isocardia sp.
Cyprimeria depressa Conrad.
Aphrodina? sp.
Legumen aff. ellipticum Conrad.
Linearia metastriata Conrad?
Cymbophora sp.
Corbula crassiplica Gabb.
Corbula sp.
Dentalium n. sp.
Astralium? sp.
Polinices carolinensis (Conrad).
Turritella quadrilira Johnson.
Pterocerella sp.
Anchura sp.
Mortoniceras sp.

[32] Veatch, Otto, and Stephenson, L. W., op. cit., p. 132.
[33] Idem.
[34] Idem, p. 138.

At Blufftown, 6 miles above the railroad bridge near Omaha, both the Blufftown formation and the overlying Cusseta sand are exposed. The contrast in lithology and the presence of pebbles in the Cusseta suggests that the formations are unconformable. The following section, measured by aneroid, is adapted from Stephenson's report.[35] Measurements made with a hand level in 1938 by L. W. Stephenson and W. H. Monroe indicate that the base of the Cusseta lies at least 120 feet above water level.

Section on Chattahoochee River at Blufftown

	Feet
Cusseta sand:	
4. Red and yellow unconsolidated sand containing small pebbles and thin crusts of limonite	100
Unconformity, not clearly exposed.	
Blufftown formation:	
3. Gray calcareous marine sand containing *Ostrea plumosa*, *Anomia olmstedi*, and a young costate *Exogyra*	50+
2. Gray calcareous, glauconitic sand with nodular concretionary ledges several feet apart; about	35
1. Gray calcareous, finely sandy fossiliferous clay; about	10

Most of the fossils in the following list, which were tentatively identified by Stephenson, came from bed 1, but a few were found in bed 2.

Fossils from the Blufftown formation at Blufftown

Serpula lineata (Weller).
Hamulus major Gabb.
Nucula aff. N. percrassa Conrad.
Nucula aff. N. eufaulensis Gabb.
Nuculana pittensis (Stephenson).
Cucullaea carolinensis Gabb.
Trigonarca sp.
Breviarca umbonata Conrad.
Breviarca sp.
Nemodon n. sp.
Arca (Barbatia) lintea (Conrad)?
Glycymeris? sp.
Gervilliopsis ensiformis (Conrad)?
Pedalion? sp.
Inoceramus sp.
Pteria petrosa (Conrad).
Ostrea plumosa Morton.
Ostrea whitei Stephenson.
Gryphaea sp.
Exogyra ponderosa Roemer.
Trigonia sp.
Pecten burlingtonensis Gabb.
Pecten cliffwoodensis Weller.
Pecten bellisculptus (Conrad)?
Lima kerri Stephenson?
Anomia argentaria Morton.
Anomia olmstedi Stephenson.
Liopistha sp.
Veniella conradi (Morton).
Etea sp.
Vetericardia? sp.
Crassatella sp., cf. C. carolinensis Conrad
Crassatella hodgei Stephenson.
Brachymeris carolinensis (Conrad).
Lucina glebula Conrad.
Cardium dumosum Conrad.
Cardium sp.
Cardium spillmani Conrad.
Cardium, two sp.
Isocardia sp.
Cyprimeria depressa Conrad.
Aphrodina regia Conrad?
Aphrodina sp.?
Cyclothyris alta Conrad?
Legumen aff. L. ellipticum Conrad.
Linearia cf. L. carolinensis Conrad.
Linearia sp.
Leptosolen biplicatus Conrad.

[35] Veatch, Otto, and Stephenson, L. W., op. cit., p. 135.

Cymbophora appressa (Gabb).
Corbula crassiplica Gabb.
Corbula oxynema Conrad.
Corbula sp.
Dentalium sp.
Cadulus obnutus Conrad?
Capulus? sp.
Polinices carolinensis (Conrad).
Gyrodes sp.
Turritella quadrilira Johnson.
Turritella, two sp.
Pterocella sp.
Anchura?, two sp.
Eutrephoceras sp.
Placenticeras sp.
Scaphites? sp.
Claws of crabs.
Lamna texana Roemer.
Vertebrae of fishes.

Compact calcareous sand and clay with hard ledges 2 to 10 feet apart are said to crop out in the banks of Chattahoochee River at intervals to the bend about 2 miles below the Seaboard Railway bridge near Omaha.

The Blufftown formation is exposed in the base of the bluff at Florence. It consists of 6 to 10 feet of light-gray rather soft cross-bedded sand, with small pebbles and fragments of shells in some lenses, unconformably overlain by 30 feet of Cusseta sand (see sec. on p. 25). The unconformable upper surface of the Blufftown dips gently down stream at a rate that should carry it beneath low water level a few hundred yards farther downstream.

Marion County.—The unconformable contact of the Blufftown? and the Cusseta sand is exposed near the Marion-Chattahoochee County line on the old road from Glen Alta to Box Springs 2 miles north of the road from Columbus to Buena Vista. About 10 feet of fine gray to buff-colored micaceous sand containing thin beds of light-gray clay is stained with iron at the top, which is marked by a 2-inch ledge of ferruginous sandstone. The overlying Cusseta is coarse iron-stained sand containing a few small rounded quartz pebbles at the base. The contact is somewhat uneven.

Ten feet of fine micaceous gray to yellow marine sand streaked with clay unconformably underlying the Cusseta sand, on the road to Box Springs 7¾ miles northwest of Buena Vista, probable represents the Blufftown.

Prints of fossils were noted in 1936 in chocolate-colored clay and fine micaceous sand on the Geneva road 4½ miles north of Buena Vista. Correlation of this deposit with the Blufftown formation wants verification.

CUSSETA SAND

GENERAL FEATURES

The Cusseta sand was named in 1909 by Veatch [36] from the town of Cusseta, county seat of Chattahoochee County. Stephenson [37] accepted

[36] Veatch, Otto, Second report on the clay deposits of Georgia: Georgia Geol. Survey Bull. 18, pp. 82–90, 1909.

[37] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, p. 152, 1911.

the name but reduced the unit to the rank of member in the Ripley formation.

Distribution.—The Cusseta sand extends as a band of variable width from Chattahoochee River in Stewart County to Peach County, in which it is overlapped by the Clayton formation.

Thickness and lithologic character.—Veatch estimates the maximum thickness of the Cusseta sand as about 250 feet. The formation consists typically of loose yellowish sand. The lower part is generally cross-bedded, coarse, and pebbly. The upper part is finer and contains some clay. An offshore facies in the Chattahoochee Valley is finer, dark gray where unweathered, and contains fossils. Northeastward, along the strike, the Cusseta becomes coarser, and the parts that contain clay weather to a shade of red or pink resembling that of several Eocene formations but generally paler. Unconsolidated parts of the formation give rise to loose drab sandy soils.

Fauna.—Few fossils have been found in the typical, near-shore facies of the Cusseta, but the deeper-water, offshore facies exposed in bluffs on Chattahoochee River has yielded many species, chiefly mollusks. *Ostrea pratti* Stephenson, a large undescribed *Ostrea*, and *Trigonia bartrami* Stephenson seem to be restricted to this facies.

Stratigraphic relations.—The Cusseta lies unconformably on the Blufftown formation and overlaps across it and the Eutaw formation to the Tuscaloosa formation. It is overlain by the Ripley formation except at the eastern extremity of the belt of outcrop, where it is overlapped by the Paleocene Clayton formation. The relationship to the Ripley may be that of unconformity, but this has not been satisfactorily established.

Economic significance.—The Cusseta sand appears to have no commercial value except for use as an aggregate for concrete, but it holds stores of underground water.

LOCAL OCCURRENCE

Stewart County.—Stephenson [38] refers to the Cusseta the upper 100 feet of red and yellow unconsolidated sand containing small pebbles and thin limonite crusts poorly exposed on the upper slopes in the bluff on Chattahoochee River at Blufftown, 31¼ miles below Columbus. According to measurements made by L. W. Stephenson and W. H. Monroe in 1938 the base of the Cusseta lies 120+ feet above water level there.

At Florence the following section is exposed in a bluff extending for 400 or 500 feet along the left side of the river; the measurements were made in 1938 by Stephenson and Monroe at the upstream end of the bluff:

[38] Veatch, Otto, and Stephenson, L. W., op. cit., p. 135.

Section on Chattahoochee River at Florence

	Feet
Pleistocene terrace deposit:	
3. Sand and gravel	17
Cusseta sand:	
2. Dark massive highly micaceous, strong argillaceous sand (almost a sandy clay); two layers within 4 feet of the base contain discontinuous concretionary masses. A layer 6 inches to 1 foot thick at the immediate base contains more or less water-worn shells of *Ostrea pratti* Stephenson, *Ostrea* sp. (a large undescribed species), *Exogyra* sp., well rounded sandstone and phosphatic pebbles, and an occasional *Teredo*-bored log of lignitized wood	30
Unconformity.	
Blufftown formation:	
1. Light-gray, yellow, and brown rather soft cross-bedded sand, some layers containing small pebbles and fragments of shells, and local lignite seams. A network of *Halymenites major* Lesquereux was observed just below the Cusseta contact at one place	10

Stephenson has recorded the species listed below from the lower few feet of layer 2.

Fossils from Chattahoochee River at Florence (upper part of Exogyra ponderosa *zone)*

Hamulus onyx Morton.
Nucula sp.
Nuculana longifrons (Conrad)?
Trigonarca sp.
Arca (Barbatia) lintea (Conrad)?
Ostrea sp. (large).
Ostrea pratti Stephenson.
Exogyra ponderosa Roemer var. erraticostata Stephenson.
Trigonia bartrami Stephenson.
Anomia argentaria Morton.
Crassatella roodensis Stephenson.
Cardium vaughani Stephenson.
Cyprimeria depressa Conrad.
Aphrodina regia Conrad.
Cyclothyris alta Conrad.
Cymbophora trigonalis Stephenson?
Corbula oxynema Conrad.
Crocodilian teeth.
Lamna sp.

The Cusseta formation is exposed on both sides of the river near Woolridge Landing, Ala., 13½ miles above Eufaula. Beneath 40 feet of poorly exposed terrace sand and Cretaceous deposits, on the Alabama side just below the landing, Stephenson [39] records the following section and fossils:

Section of Cusseta sand on Chattahoochee River below Woolridge Landing

	Feet
4. Dark-gray argillaceous, finely micaceous, calcareous, glauconitic sand. One small specimen of *Exogyra* sp. with costae obtained near base	30

[39] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 157–158.

Section of Cusseta sand on Chattahooche River below Woolridge Landing—Con.

	Feet
3. Yellow rather loose sandy shell marl with some dark-drab clay laminae. Contains soft shells, including *Exogyra, Anomia, Cardium, Trigonia*, a large undescribed oyster, etc. Also shark teeth, crocodilian teeth and bones	20
2. Shell marl with gray sand matrix. Shells very soft. About 3 feet above base is a discontinuous layer of large massive oysters, some specimens of which have a measured length of 17.5 inches	6
1. Dark-gray micaceous, argillaceous marine sand	5

From bed 2, Stephenson obtained the following fossils (tentatively identified):

Fossils from Woolridge Landing (Exogyra ponderosa *zone*)

Serpula sp.
Hamulus? sp.
Nucula sp.
Cucullaea carolinensis (Gabb).
Trigonarca maconensis Conrad.
Breviarca sp.
Breviarca cf. B. congesta (Conrad).
Nemodon brevifrons Conrad.
Glycymeris sp.
Inoceramus sp.
Ostrea tecticosta Gabb.
Ostrea blackensis Stephenson.
Ostrea pratti Stephenson.
Ostrea sp. (very large).
Exogyra ponderosa Roemer var. erraticostata Stephenson.
Exogyra sp. (costate).
Trigonia bartrami Stephenson.
Pecten burlingtonensis Gabb?
Pecten cliffwoodensis Weller.
Plicatula sp.
Anomia lintea Conrad.
Veniella conradi (Morton).
Crassatella roodensis Stephenson.
Crassatella sp., cf. C. carolinensis Conrad.
Lucina glebula Conrad.
Cardium nixicollis Stephenson.
Isocardia cliffwoodensis Weller.
Cyprimeria depressa Conrad.
Aphrodina regia Conrad.
Cyclothyris alta Conrad.
Legumen aff. L. ellipticum Conrad.
Legumen carolinense (Conrad).
Cymbophora trigonalis Stephenson.
Corbula oxynema Conrad.
Gyrodes cf. G. supraplicatus (Conrad).
Pugnellus pauciplicatus Stephenson.
Lamna texana Roemer.
Corax falcatus Agassiz.
Otodus sp.
Ischyriza mira Leidy (identified by J. W. Gidley).
Thecachampsa rugosa Emmons (identified by C. W. Gilmore).
Polydectes biturgidus Cope (identified by C. W. Gilmore).

In Bulletin 26 are mentioned exposures of dark-gray massive argillaceous sand at Lower Roods Bend 1 mile below Woolridge Landing and at a broad bend 1½ miles above the Stewart-Quitman County line, both on the Georgia side of the river. These exposures represent the same zone as that at Woolridge Landing.

Chattahoochee County.—Railroad cuts west of Cusseta expose yellow Cusseta sand. The Lumpkin road at Cusseta cuts through it into the underlying hackly gray sandy clay of the Blufftown, which contains imprints of shells.

Cross-bedded yellow Cusseta sand containing angular pebbles smaller than half an inch in diameter unconformably overlies tough clayey gray to yellow sand of the Blufftown formation on the Lumpkin road 2.2 miles south of Cusseta. Similar basal Cusseta sand is exposed on both sides of Little Hichitee Creek about 1½ miles northwest of Renfroe.

Stephenson [40] describes a section of Cusseta sand in a cut of the Seaboard Railway at Manta, 5½ miles east of Cusseta, as follows:

Section at Manta

	Feet
Ripley formation:	
5. Weathered coarse red ferruginous compact massive sand	7
Cusseta sand:	
4. Laminated drab clay and red and gray micaceous sand	5
3. Gray medium to coarse micaceous sand with scattered drab clay balls, the whole mottled with purple	7
2. Laminated drab clay, streaked with yellow	4
1. Medium to very coarse gray sand tinted with pink and locally indurated to a purple ferruginous sandstone	11

Marion County.—Coarse iron-stained Cusseta sand containing a few small rounded quartz pebbles at the base unconformably overlies about 10 feet of fine gray to buff-colored micaceous sand (Blufftown?) containing thin beds of light-gray clay, on the old road from Glen Alta to Box Springs 2 miles north of the road from Columbus to Buena Vista.

The following section is exposed on the road to Box Springs 7¾ miles northwest of Buena Vista:

Section 7¾ miles northwest of Buena Vista

	Feet
Cusseta sand:	
5. Fine and coarse pebbly gray to yellow tough sand weathering brick red at top	20
4. Light-gray bedded clay	1½
3. Fine thin-bedded sand	2½
2. Coarse cross-bedded rusty sand containing a few small rounded quartz pebbles at the base	12
Unconformity.	
Blufftown formation (?):	
1. Fine micaceous gray to yellow marine sand streaked with clay	10

At Tazewell the Cusseta consists of brick-red pebbly sand. Cross-bedded ferruginous sand and ironstone is exposed at the mill on the Buena Vista road half a mile southwest of Tazewell.

Stephenson [41] described a section on the Buena Vista road near

[40] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 162–163.
[41] Veatch, Otto, and Stephenson, L. W., op. cit., p. 163.

Tazewell in which 50 feet of coarse light-colored cross-bedded arkosic Cusseta sand is overlain by 70 feet of brownish marine sand of Ripley age. The Cusseta is locally ferruginous and contains lenses of leaf-bearing black to white clay.

Taylor County.—A gully one-quarter of a mile northwest of the railroad station at Mauk shows white kaolin interbedded with white, yellow, and reddish coarse sand (Tuscaloosa formation) overlain unconformably by red cross-bedded Cusseta sand containing pellets of clay.

Coarse orange Cusseta sand unconformably overlies massive white clay of the Tuscaloosa formation a quarter of a mile north of Charing.

Macon County.—Stephenson [42] refers to the Cusseta more than 100 feet of coarse to fine more or less arkosic cross-bedded sand containing small clay balls and scattered lenses of light-drab clay exposed in the high scarp facing Flint River 5 or 6 miles west of Marshallville. A ledge of hard ironstone midway in the section is underlain by a layer of rolled clay balls.

RIPLEY FORMATION

GENERAL FEATURES

Name.—The Ripley formation takes its name from the town of Ripley, Miss. The deposits in Georgia that are called Ripley formation in this report are believed to be nearly equivalent to the typical Ripley of Mississippi, but they represent only part of what was included in the formation by Stephenson [43] in 1911. The details here presented are based chiefly on his descriptions.

Distribution.—The Ripley formation is crossed by Chattahoochee River between the mouth of Cowikee Creek, 6 or 7 miles above Eufaula, and a point above the mouth of Pataula Creek 10 miles or more below Eufaula. The formation has been traced to Flint River, in Macon County. East of Flint River it is overlapped by Paleocene beds (Clayton formation) and probably also by the Providence sand.

Thickness and lithologic character.—The Ripley consists of more than 100 feet of very dark gray to black fine micaceous sand interbedded with a few layers of nodular limestone a foot or more thick. The thickness in the Chattahoochee Valley is considerably greater than elsewhere and may reach 400 feet or more. Weathering causes the sand to become lighter in color and ultimately almost white. When so weathered the Ripley is difficult to distinguish from the older Cusseta sand or from the younger Providence sand.

Fauna.—Fossil shells are very common in the Ripley formation except where deep weathering has leached out all the lime and left

[42] Idem, p. 165.
[43] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 142–145.

only molds and impressions. Stephenson [44] has tentatively identified the species in the following list, in which those marked "B" range downward into the Blufftown formation. In the Chattahoochee region *Exogyra cancellata* is confined in its vertical range to the lower part of the Ripley, the thickness of the containing beds possibly not exceeding 50 feet.

Fossils in the Ripley formation on Chattahoochee River

Hardouinia porrecta (Clark).
Hardouinia subconica (Clark).
Hardouinia micrococcus (Gabb).
Hardouinia subquadrata (Conrad).
Hemiaster slocumi Lambert (=Hemiaster lacunosus Slocum).
Coptosoma? mortoni (de Loriol).
Serpula cretacea (Conrad).
Serpula barbata Morton.
Serpula sp.
B Hamulus onyx Morton.
Hamulus squamosus Gabb.
Nucula percrassa Conrad.
Nucula cuneifrons Conrad.
B Nucula eufaulensis Gabb.
Nuculana tarensis Stephenson?
Nuculana longifrons Conrad.
Cucullaea sp.
Cucullaea littlei Gabb.
Cucullaea antrosa Morton.
Nemodon eufaulensis Conrad.
Ostrea subspatulata Forbes.
B Ostrea plumosa Morton.
B Ostrea tecticosta Gabb.
Ostrea falcata Morton.
B Gryphaea mutabilis Morton.
Exogyra costata Say.
Exogyra cancellata Stephenson (restricted to lower part).
Trigonia sp.
Pecten (Neithea) sp.
Pecten sp.
B Pecten simplicius Conrad.
Pecten mississippiensis Conrad.
B Lima reticulata Forbes.
Lima acutilineata (Conrad).
Lima pelagica covensis Stephenson.
B Anomia argentaria Morton.
Anomia tellinoides Morton (restricted to lower part).
Paranomia scabra (Morton).
Pulvinites argentea Conrad (upper part).
Crenella serica Conrad.
Dreissensia tippana Conrad.
Pholadomya littlei Gabb.
Pholadomya sp.
Anatimya anteradiata Conrad.
B Cymella bella Conrad.
Liopistha protexta Conrad.
Cuspidaria sp.
B Veniella conradi (Morton).
Etea sp.
B Vetericardia? crenalirata (Conrad).
Crassatella pteropsis Conrad.
Crassatella eufaulensis Gabb.
Scambula perplana Conrad.
Tenea paralis Conrad.
Unicardium concentricum (Conrad).
Glycymeris sp.
B Gervilliopsis ensiformis (Conrad).
Panope sp.
Gastrochaena sp.
B Cardium eufaulense Conrad.
B Cardium spillmani Conrad.
Cardium kümmeli Weller.
Cardium tippanum Conrad.
B Cardium (Granocardium) alabamense (Gabb).
Cyprimeria depressa Conrad.
Aphrodina tippana Conrad.
Aenona eufaulensis Conrad.
B Legumen ellipticum Conrad.
B Linearia metastriata Conrad.
B Leptosolen biplicatus Conrad.
Cymbophora sp.
B Corbula crassiplica Gabb.
Dentalium ripleyanum Gabb.
B Cadulus obnutus (Conrad).

[44] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 210–211.

	Polinices rectilabrum (Conrad).	Volutomorpha cf. V. dumasensis Dall (restricted to upper part).
	Gyrodes alveatus Conrad.	Morea cf. M. marylandica Gardner.
	Turritella vertebroides Morton.	Ringicula pulchella Shumard.
B	Turritella trilira Conrad.	Cyclichna recta Morton.
	Pugnellus densatus Conrad.	Sphenodiscus pleurisepta (Conrad).
	"Chemnitzia" interrupta Conrad?	Nostoceras stantoni Hyatt?
	Sargana stantoni Weller.	

Of these species, *Exogyra cancellata* and *Anomia tellinoides* are restricted to the lower part of the Ripley formation (*Exogyra cancellata* zone). They are exceptionably valuable as index fossils because of their wide geographic range and narrow stratigraphic range.

Stratigraphic relations.—The Ripley formation rests upon the Cusseta sand, perhaps unconformably. It is overlain unconformably by the Providence sand except where that is overlapped by the Clayton formation.

Economic significance.—The Ripley formation has no present known commercial use, but the fossils in it are in some demand by collectors and museums. Some of the shell marls may have local potential value as fertilizers.

LOCAL OCCURRENCE

Chattahoochee River.—The exact location of the Cusseta-Ripley contact in the banks of Chattahoochee River has not been determined. It probably passes beneath water level not far upstream from the mouth of Cowikee Creek, a stream entering from the west about 6 miles (air line) upstream from Eufala, Barbour County, Ala.

On Cowikee Creek just above its mouth and in the right bank of the River just below the mouth of the Creek is exposed 40 feet of dark-gray compact argillaceous, micaceous marine sand, which Stephenson [45] has assigned to the Ripley formation. It contains *Ostrea plumosa*, *Ostrea subspatulata?*, *Cymella bella*, and a few other scattering mollusks; also a few poorly preserved fossil leaves.

From 15 to 20 feet of dark-gray compact calcareous sand exposed on the Alabama side opposite Burstahatchee Creek, 1½ miles farther downstream, Stephenson [46] lists the following species:

Echinoids and mollusks from Chattahoochee River 5½ miles above Eufaula (U. S. G. S. 853 and 6398)

Hemiaster sp.	Ostrea sp.
Inoceramus sp.	Gryphaea mutabilis Morton.
Ostrea plumosa Morton.	Exogyra costata Say.
Ostrea falcata Morton.	Pecten (Neithea) sp.
Ostrea subspatulata Forbes?	Anomia argentaria Morton.

[45] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, p. 172, 1911.

[46] Idem, p. 174, revised by L. W. Stephenson.

Paranomia scabra (Morton).	Epitonium sp.
Veniella conradi (Morton).	Turritella trilira Conrad.
Cardium sp.	Pyropsis sp.

Higher beds, exposed on the Georgia side at Stewarts Hill, which is just below the mouth of Burstahatchee Creek 4 miles north of Georgetown, are described by Stephenson,[47] from whose report the following section is adapted.

Section at Stewarts Hill

	Feet
Providence sand:	
11. Coarse red and yellow argillaceous sand, well exposed only in lower 5 feet; a layer of ironstone averaging 2 inches in thickness at the bottom	10
10. Fine laminated variegated argillaceous, micaceous sand merging downward into clay	10
9. Coarse gray and reddish argillaceous sand	5
8. Variegated finely sandy, micaceous laminated clay with pockets and small lenses of coarse sand and a layer of coarse ironstone at the bottom	4
7. Coarse yellow arkosic rather loose sand with a layer of ironstone at the bottom	9
6. Fine greenish-gray argillaceous, micaceous sand finely mottled with yellow	22
5. Finely laminated sand and clay with thin plates of ironstone	3
4. Fine gray micaceous sand delicately mottled with purple, red, and yellow, with coarse ironstone at the base	20
Unconformity?	
Ripley formation:	
3. Mottled fine gray micaceous sand	10
2. Gray micaceous sand and dark laminated micaceous clay, poorly exposed; about	30
1. Concealed, except masses of dark-gray marine sand and clay at base that have slipped from a higher level; about	125

The river bluff at Eufaula, Ala., exposes 80 feet of dark-gray to black more or less calcareous, micaceous, and glauconitic sand and clay. The continuity of the sand is broken every 5 or 10 feet by hard nodular calcareous ledges.

There are many exposures of fossiliferous Ripley on Chattahoochee River below Eufaula. The uppermost beds are exposed on the west bank near Alexanders Landing, 8 miles south of Eufaula, where Stephenson[48] reports 15 feet of dark-gray more or less clayey, very micaceous marine sand. This bed is overlain by 15 feet of coarse sandy limestone containing *Ostrea subspatulata* Forbes var. and the three echinoids *Hardouinia porrecta* (Clark), *H. subconica* (Clark), and *H. subquadrata* (Conrad).

[47] Veatch, Otto, and Stephenson, L. W., op. cit., p. 174.
[48] Veatch, Otto, and Stephenson, L. W., op. cit., p. 179.

The same kinds of oyster and echinoids and also *Cardium kümmeli* Weller have been found in 30 feet of similar rock interbedded with soft pockets and layers of sand in a bluff on the Georgia side 10 miles below Eufaula.

Quitman County.—In a gully on the road from Georgetown to Cuthbert 0.4 mile east of Pataula Creek, dark-gray highly fossiliferous sand was exposed in 1917 beneath coarse light-gray and white Providence sand and clay. Red-brown rusty sand (Clayton formation) unconformably caps the Providence. Fine gray sand west of a creek at Hatcher station likewise contains prints of many fossils. These fossiliferous Cretaceous beds may be a facies of the Providence sand.

Stephenson [49] reports 8 or 10 feet of dark-gray to black finely micaceous sand containing bits of lignite and many fossils at the bridge of the Central of Georgia Railway across Mercers Mill Creek half a mile south of Georgetown. This bed corresponds in stratigraphic position to the upper part of the exposure of Ripley at Eufaula. In a cut of the same railroad near milepost 139, 5 miles southeast of Eufaula, he found a somewhat higher horizon represented by *Crassatella pteropsis*, *Cardium kümmeli*, *C. eufaulense*, *C. tippanum*, and other fossils in light yellowish-gray coarse somewhat micaceous sand. Stephenson also found *Exogyra costata* and a few other fossils in dark-gray clay on the Georgetown road 6 miles south of Coffinton.

Stewart County.—Dark-gray sand with hard ledges about 100 feet below the Eufaula-Lumpkin road 1½ miles east of Coffinton, contains *Ostrea subspatulata*, *Exogyra costata*, *Anomia argentaria*, and *Baculites* sp.[50] Several other species occur in dark-gray micaceous, glauconitic sand below the Providence sand in a gully south of the Florence road near Providence, 8 miles west of Lumpkin.

The Ripley formation is exposed on the road to Cusseta (U S 27) south of Colochee Creek, 3¾ miles north of Lumpkin, where the following section was measured in 1936:

Section 3¾ miles north of Lumpkin

	Feet
Providence sand:	
4. Moderately fine cross-bedded pink argillaceous sand with streaks of white clay and lumps of clay at base	15
Unconformity.	
Ripley formation:	
3. Fine micaceous buff-colored marine sand	28
2. Fine very dark gray marine sand containing *Exogyra costata, Ostrea subspatulata, Anomia argentaria,* and other fossils; this bed lies stratigraphically above the *Exogyra cancellata* zone	33
1. Fine gray clayey sand containing small white concretions and *Anomia* sp	20

[49] Veatch, Otto, and Stephenson, L. W., op. cit., p. 181.
[50] Veatch, Otto, and Stephenson, L. W., op. cit., p. 186.

This exposure is a few hundred yards east of the place called Johnsons Hill by Stephenson,[51] who lists the following species from the *Exogyra cancellata* zone, which is exposed low on the slope:

Fossils at Johnsons Hill on the old road (abandoned) to Louvale, 4 miles north of Lumpkin

Ostrea tecticosta Gabb.
Ostrea plumosa Morton.
Ostrea falcata Morton.
Gryphaea mutabilis Morton.
Exogyra costata Say.
Exogyra cancellata Stephenson.
Trigonia thoracica Morton?
Pecten (Neithea) sp.
Lima reticulata Forbes.
Anomia argentaria Morton.
Anomia sp.
Paranomia scabra (Morton).
Pholadomya littlei Gabb.
Turritella trilira Conrad.

Chattachoochee County.—Fine gray sand peppered with small grains of glauconite and overlain by coarser pink massive Providence sand is cut into by the highway from Richland to Cusseta a quarter of a mile north of Renfroe. Farther down the hill (northward) the Ripley consists of gray micaceous, sandy fossiliferous clay. The same beds are exposed in cuts along the Seaboard Railway one-quarter of a mile to 1¼ miles north of Renfroe, from which Stephenson obtained the following species:

Fossils from railroad cuts north of Renfroe

Cucullaea sp.
Ostrea tecticosta Gabb.
Ostrea falcata Morton.
Ostrea plumosa Morton.
Gryphaea mutabilis Morton.
Gryphaea sp.
Exogyra costata Say.
Exogyra cancellata Stephenson.
Pecten (Neithea) sp.
Spondylus sp.
Lima reticulata Forbes.
Anomia argentaria Morton.
Paranomia scabra (Morton).
Paranomia n. sp.
Pholadomya littlei Gabb.
Ischyriza mira Leidy (identified by J. W. Gidley).

Marion and Schley Counties.—Stephenson [52] lists Ripley fossils from the Bivens plantation, on Dry Creek 3 miles west of Pineville, Marion County (*Exogyra cancellata*, etc.); from Laneyhassey Creek 4 miles south of Buena Vista; from a cut in the public road near the Central of Georgia Railway bridge over Kinchafoonee Creek 5 miles west-southwest of Buena Vista; and from Usrys mill, 7 miles north of Ellaville and half a mile east of Murray crossroads, in Schley County.

Macon County.—The Ripley is exposed beside the railroad track at Ideal and in a railroad cut 1⅛ miles north of Ideal. The following section at the latter place is adapted from Stephenson's report.[53]

[51] Veatch, Otto, and Stephenson, L. W., op. cit., p. 187.
[52] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 190–191.
[53] Veatch, Otto, and Stephenson, L. W., op. cit., p. 192.

Railroad cut 1⅛ miles north of Ideal

	Feet
Providence sand?:	
6. Loose yellow pebbly sand, probably creep	4
Ripley formation:	
5. Fine micaceous, argillaceous massive yellow marine sand	7
4. Laminated micaceous, sandy gray marine clay with fine sand partings	4
3. Fine yellow argillaceous marine sand with a crust of iron at the bottom	8
2. Dark-gray finely sandy and micaceous compact clay, weathering somewhat shaly; contains poor prints and molds of fossils	20
1. Dark-gray to yellow massive marine sand with numerous prints of fossils at the south end of the cut	4

From beds 1 and 2 of the preceding section Stephenson reports *Cucullaea* sp., *Crassatella pteropsis*, *Cardium spillmani*, *Cyprimeria depressa*, *C. densata?*, *Cymbophora lintea*, *Turritella trilira*, and other fossils.

Early in 1943 A. D. Zapp discovered an outcrop of the Ripley formation east of Flint River on State Highway 127, 5 miles S. 70° W. of Marshallville. This extends the Ripley about 6 miles farther toward the northeast than is shown on the geologic map. The Ripley consists of 12 feet of soft gray micaceous, argillaceous sand containing many soft prints of fossils, among which L. W. Stephenson recognized *Veniella conradi*, *Cyprimeria depressa*, *Etea?* sp., and *Turritella trilira*. The bottom of the bed lies about 15 feet above the normal water level in the river. The bed is overlain by coarse red sand and sandstone supposed to be Providence.

PROVIDENCE SAND

GENERAL FEATURES

Name.—The Providence sand was named and very briefly described as part of the Ripley formation by Veatch [54] in 1909. Two years later Stephenson [55] described it more fully as a member of the Ripley formation. It is here treated as an independent formation because the old Ripley has been found to be stratigraphically more complex than formerly supposed and has now been dismembered. The name of the new formation was taken from a settlement called Providence in Stewart County 7 miles west of Lumpkin.

Distribution.—The Providence sand has been mapped as far west as Crenshaw County, Ala. In Georgia it extends northeastward from

[54] Veatch, Otto, Georgia Geol. Survey Bull. 18, p. 86, 1909.

[55] Veatch, Otto, and Stephenson, L. W., Preliminary report on the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, pp. 152, 192–200, 1911.

Quitman County to the valley of Flint River north of Montezuma. Many of its exposures are in deep steep-walled gullies capped by firm red Paleocene sand (Clayton formation).

Thickness and lithologic character.—Veatch estimates the thickness of the Providence sand as 150 feet. The formation consists chiefly of white or light-colored generally cross-bedded micaceous sand and lenses of white or light-colored massive clay. It contrasts strikingly with the dark-gray to black evenly bedded sand in fresh exposures of the Ripley formation, which underlies it, but weathered and bleached exposures of the Ripley are difficult to distinguish from the Providence.

No fossils have been found in the typical part of the Providence sand, which evidently was deposited in very shallow water, for its cross-bedding and rolled clay balls bear witness to the work of waves and currents. Along Chattahoochee River and Pataula Creek, however, are exposures of a highly fossiliferous facies accumulated in deeper water farther offshore. This facies consists chiefly of fine gray sand alternating with ledges of hard calcareous sandstone.

Fauna.—The offshore facies of the Providence contains a large marine fauna, among which the Mollusca are dominant. Many of the species range downward through older beds, but the following appear to be restricted to the Providence or its equivalents: *Cossmannaster conoideus* (Clark), *Breviarca cuneata* (Gabb), *Trigonia angulicostata* Gabb, *Anomia ornata* Gabb, *Turritella* n. sp. (with two spiral ridges), *Pterocerella tippana* Conrad?, and *Sphenodiscus pleurisepta* (Conrad).

Stratigraphic relations.—The Providence sand is equivalent in age to the Prairie Bluff chalk of Alabama and Mississippi and to the Owl Creek formation of northern Mississippi. It lies unconformably on the Ripley formation, and transgresses across the upper part of the Ripley in its extension to the northeast in Georgia. The Providence is overlain unconformably by the Paleocene Clayton formation, which overlaps it east of Flint River.

Economic significance.—The Providence contains lenses of white clay or kaolin, some of which may be valuable, and much white sand. Its hard ledges on Pataula Creek make an excellent dam site.

LOCAL OCCURRENCE

Chattahoochee River.—Many years ago T. W. Stanton collected *Breviarca cuneata* and other species from beds above the Ripley formation and more than 30 feet above water level near Alexander Landing (U. S. G. S. locality 857), 8 miles below Eufaula. This is the point farthest upstream on the Chattahoochee at which Providence

fossils have been reported. The list of species is given by Stephenson.[56]

At the mouth of Pataula Creek, 12¼ miles below Eufaula (locality 855), Stanton collected the species shown in the following list, which has been revised by Stephenson:

Fossils from the mouth of Pataula Creek

Nucula aff. N. percrassa Conrad.
Nucula perequalis Conrad.
Nuculana longifrons (Conrad).
Nuculana sp.
Cucullaea littlei (Gabb).
Breviarca cuneata (Gabb).
Nemodon eufaulensis Conrad.
Glycymeris subaustralis (d'Orbigny).
Gervilliopsis ensiformis (Conrad).
Gryphaea mutabilis Morton?
Pecten simplicius Conrad.
Pecten sp.
Lima acutilineata (Conrad).
Lima reticulata Forbes.
Anomia argentaria Morton.
Anomia ornata Gabb.
Crenella serica Conrad.
Dreissensia tippana Conrad.
Pholadomya littlei Gabb.
Liopistha protexta Conrad.
Veniella conradi (Morton).
Vetericardia crenalirata (Conrad).
Crassatella pteropsis Conrad.
Crassatella vadosa Morton (variety?).
Tenea pinguis (Conrad)?
Unicardium concentricum (Conrad).
Cardium spillmani Conrad.
Cardium vadosa Conrad (variety).
Cyprimeria aff. C. alta Conrad.
Cyprimeria depressa Conrad.
Legumen ellipticum Conrad.
Aphrodina tippana Conrad.
Aenona eufaulensis Conrad.
Linearia metastriata Conrad.
Leptosolen biplicatus Conrad.
Corbula crassiplica Gabb.
Dentalium ripleyanum Gabb.
Polinices rectilabrum (Conrad).
Turritella sp. (with 2 lirae).
Sphenodiscus pleurisepta (Conrad).

Stanton obtained fossils also at locality 859, 1 mile below the mouth of Pataula Creek. Near this place Stephenson [57] reports the following section:

Section of Providence sand 1¼ miles below Pataula Creek

	Feet
3. Tree-covered slope probably in part Paleocene (Clayton)-----	50
2. Gray coarsely arenaceous clay with poor fossils, *Anomia argentaria* Morton recognized. Brownish band a few inches thick along the base----------	3
1. Gray marine sand alternating with numerous ledges of coarsely arenaceous limestone. Contains *Hardouinia subquadranta* (Conrad), *Exogyra costata* Say, *Cardium kümmeli* Weller, and undetermined gastropods, about--------	25

The Providence sand passes beneath water level somewhere between this place and Morris Landing, Ala., about 5 miles below the mouth of Pataula Creek.

[56] Veatch, Otto, and Stephenson, L. W., op. cit., p. 179.
[57] Veatch, Otto, and Stephenson, L. W., op. cit., p. 181

Pataula Creek.—From its mouth to the road from Georgetown to Fort Gaines, Pataula Creek is deeply entrenched in the offshore facies of the Providence sand, which forms vertical banks on both sides. The beds exposed near the highway bridge consist of about 15 feet of gray micaceous sand and ledges of hard coarse sandstone overlain by 4 feet of softer ferruginous sand. One or two zones bear large spherical concretions. An additional 15 feet of hard and soft ledges is exposed at the dam above the bridge. *Exogyra costata* is abundant. Many other species are represented chiefly by molds. At the Narrows, farther downstream, a hard bed of sandstone supports a picturesque waterfall. This place has yielded many fossils. The following section is adapted from Stephenson's report.[58]

Section of Providence sand at the Narrows, Pataula Creek

	Feet
2. Brownish weathered argillaceous marine sand	12
1. Dark greenish-gray massive micaceous argillaceous marine sand with indurated ledges 1 to 6 feet apart. A few specimens of *Exogyra costata* Say were observed, and near the base an abundance of soft shells	23

Coarse fossiliferous sandstone in the bed of Pataula Creek 2 miles north of Days crossroads and 4½ miles east of the Chattahoochee probably represents this same offshore facies.

Quitman County.—Buff-colored micaceous sand and clay, and also gravel containing well-rounded pebbles, were noted a mile and a half south of Hatcher and on the Cuthbert road 0.4 mile south of Pataula Creek, where it lies between the Ripley and Clayton formations. White micaceous Providence sand overlain by pebbly orange sand—probably Clayton formation—is exposed at Wire Bridge at the crossing of the Central of Georgia Railway and the Fort Gaines road 3½ miles southeast of Georgetown.

Stewart County.—The typical exposures of the Providence sand are in gullies near Providence Church (near Providence Post Office, abandoned), which is on the Florence road 7 miles west of Lumpkin. Stephenson's [59] amended section is as follows:

Section of Providence sand near Providence Church

	Feet
4. Irregularly bedded white, yellow, red, and purple fine- to medium-grained sand, somewhat argillaceous in places	120
3. Yellow argillaceous sand becoming more argillaceous toward base	10
2. Dark-gray thinly laminated finely arenaceous and micaceous clay. Contains some bits of lignite and small bits of amber	15

[58] Veatch, Otto, and Stephenson, L. W., op. cit., p. 185.
[59] Veatch, Otto, and Stephenson, L. W., op. cit., p. 194.

Section of Providence sand near Providence Church—Continued

	Feet
1. Dark greenish-gray micaceous, slightly argillaceous and glauconitic sand with numerous soft fossil molds in the upper part and with shells in the lower 2 or 3 feet	25

The lower fossiliferous part of this section may belong to the Ripley formation, but no certain evidence of an unconformity separating it from the overlying Providence sand was observed.

The Providence gullies, said to be the largest in the Southeast, owe their steepness to the fact that the sand exposed in them contains just enough cementing clay to permit it to stand with vertical walls beneath a protecting cover of more firmly bound sandy clay (Clayton formation).

The unconformable contact of cross-bedded light-colored micaceous Providence sand with dirty red coarse pebbly sand at the base of the Clayton formation is exposed at several places on the road to Cuthbert within 7 miles of Lumpkin.

The hill south of Vorus Bridge, 1½ to 1¾ miles south of Lumpkin, shows the following section:

Section 1½ miles south of Lumpkin

	Feet
Clayton formation (Paleocene):	
7. Greenish hackly clay containing irregular lumps of white and yellow chert; exposed on T-road at top of hill	6
6. Reddish sand, fine above, coarser and pebbly at the base, which is marked by a ledge of ferruginous sandstone	15
Unconformity.	
Providence sand (Upper Cretaceous):	
5. Light-gray to pink clayey sand, massive at top, cross-bedded in lower part, which contains small clay balls	14
4. Fine to coarse highly micaceous white sand; consolidated in lower part, upper part massive; top uneven	33
Ripley formation (Upper Cretaceous):	
3. Fine black micaceous sand weathering drab or yellowish; a ledge of limonite at the top	27
2. White to rusty ferruginous cross-bedded sand	16
1. Covered by loose sand to water in creek	15

On the Cusseta road about 3¾ miles north of Lumpkin, 15 feet of fine cross-bedded pink argillaceous Providence sand with streaks of white clay and lumps of clay at the base lies unconformably on the Ripley formation. A section at this place is recorded on page 32.

Marion County.—Thirty-five feet of white Providence sand is exposed in a gully at the northwest edge of Buena Vista, and white clay of Providence age underlies red Eocene sand a mile east of the railway station. White clay is more common in the Providence east of Buena Vista than in the region west and southwest of it.

Schley County.—On U. S. No. 19, 1.4 miles north of Ellaville, the Clayton formation is underlain by 15 feet of coarse Providence sand and gravel and white clay weathering bright pink. Coarse white Providence sand is exposed beneath white fossiliferous Clayton limestone on the road to Friendship near Muckalee Creek, 6¼ miles southwest of Ellaville.

PALEOCENE SERIES

GENERAL FEATURES

The designation "Paleocene series" has not previously been accepted in official reports on Georgia and adjacent States. The deposits now referred to it, the Midway group, have heretofore been included in the Eocene series, of which they formed the basal part. The justification for classifying the Paleocene as a series apart from the Eocene lies in its fauna, which is, perhaps, as individual as that of any other series of the Cenozoic era.

In Alabama the Paleocene series includes three or more formations called the Midway group, of which only the Clayton formation is represented in Georgia. The Paleocene is not known to be represented in South Carolina, though it is possible that the Black Mingo formation, which was classified as Wilcox (lower Eocene) in a previous report by Cooke,[60] may be Paleocene. If present in Florida, the Paleocene is deeply buried. (See correlation table, p. 40.)

CLAYTON FORMATION

GENERAL FEATURES

Name and distribution.—The Clayton formation is named from the town of Clayton, Ala., only 18 miles west of Georgetown, Ga., from which it extends northeastward in a band of variable width to Macon County, east of which it is probably overlapped.

Thickness.—The thickness of the Clayton formation has been estimated as 218 feet on Chattahoochee River [61] and 300 or 400 feet farther east.[62] Neither of these estimates has been checked by well records, and both may be excessive. Both were based on observed widths of outcrop and assumed rates of dip.

Lithologic character.—As typically exposed at Clayton, Ala., the Clayton formation includes two beds—an upper bed composed of 15 feet of brittle calcareous light-gray clay, and a lower one with 35

[60] Cooke, C. W., Geology of the Coastal Plain of South Carolina: U. S. Geol. Survey Bull. 867, pp. 41–54, 1936.

[61] Langdon, D. C., in Smith, E. A., Johnson, L. C., and Langdon, D. W., Report on the geology of the Coastal Plain of Alabama, p. 369, Alabama Geol. Survey, 1894.

[62] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, p. 218, 1911.

Cenozoic formations of Georgia and the adjacent States

	Alabama	Florida	Georgia	South Carolina
Recent		Marsh, beach, swamp, and alluvial deposits.		
Pleistocene		Erosion interval.		
		Melbourne bone bed.	Pamlico formation.	
		Erosion interval.		
	Undifferentiated.	Key Largo limestone. Miami oolite. Anastasia formation. (Contemporaneous.)	Talbot formation. Penholoway formation. Wicomico formation.	
		Erosion interval.		
		Sunderland formation. Coharie formation.		
		Erosion interval.		
		Brandywine formation.		
		Erosion interval.		
Pliocene		Erosion interval.		
	Citronelle formation.	Caloosahatchee formation.	Charlton formation.	Waccamaw formation.
Miocene		Erosion interval.		
	Undifferentiated.	Choctawhatchee formation. Shoal River formation. Oak Grove sand. Chipola formation.	Duplin marl.	Raysor marl.
			Hawthorn formation.	
	Catahoula sandstone.	Tampa limestone.		
Oligocene		Erosion interval.		
	Chickasawhay marl.	Flint River formation.	Suwannee limestone.	Flint River formation.
		Erosion interval?		
		Byram marl. Glendon limestone. Marianna limestone.		
		Erosion interval.		
	Red Bluff clay.			
Eocene		Erosion interval.		
	Yazoo clay. Moodys marl.	Ocala limestone.	Cooper marl. Barnwell formation. Santee limestone.	
		Erosion interval.		
	Lisbon formation. Tallahatta formation.		McBean formation.	
		Erosion interval.		
	Wilcox group.		Wilcox formation.	Black Mingo formation.
Paleocene		Erosion interval.		
	Naheola formation. Sucarnoochee clay. Clayton formation.		Clayton formation.	

feet of sandy white limestone containing *Ostrea crenulimarginata* and grading downward into coarse rusty-yellow sand and grading laterally into irregularly hardened calcareous sand. This bed rests unconformably on the Providence sand, of Upper Cretaceous age.

Scattered outcrops of Clayton limestone have been found as far east as Flint River at Montezuma, but at most exposures of the formation all the lime has been leached out. That the formation originally contained lime at these places is indicated by a few feet of crumpled greenish clay near its base that appears to be residual from limestone. Small rounded lumps of yellowish chert are commonly associated with this residual clay. Neither limestone nor chert of Midway age has been found east of Flint River. A few shallow depressions 2 or 3 miles northeast of Montezuma indicate that soluble beds once extended that far.

The most conspicuous constituent of the Clayton formation at the weathered outcrop is tough brick-red or maroon clayey sand, which contrasts strikingly with the light-colored unconsolidated Cretaceous sand and clay that underlie it. Because of its toughness this material resists erosion much more than the underlying beds and upholds level to rolling plateaus that terminate in steep-walled gullied escarpments. At many places the base of the formation is marked by an accumulation of brown iron ore.

Fauna.—The most widely distributed and most easily recognized fossil in the Clayton formation is the ribbed oyster *Ostrea crenulimarginata* Gabb. Other species are not abundant and are not commonly well preserved.

Stratigraphic relations.—The Clayton formation lies unconformably on the Providence sand. It is overlain unconformably by the Wilcox formation and by other formations that overlap the Wilcox. East of Macon County it passes beneath the Barnwell formation and probably does not reappear at the surface farther east in Georgia.

Economic significance.—The Clayton formation is associated with accumulations of bauxite, an ore of aluminum. The principal known deposits are in the vicinity of Andersonville. The formation also contains some fuller's earth. Some of the limestone in the formation is probably suitable for making agricultural lime. Parts of the limestone resemble travertine, which is used as a decorative stone.

LOCAL OCCURRENCE

Clay County.—On the Chattahoochee River the Clayton limestone is first exposed at a point on the Alabama side 7 miles above Fort Gaines, near Morris Landing, where Veatch and Stephenson [63] report

[63] Veatch, Otto, and Stephenson, L. W., op. cit., p. 220.

greenish calcareous sand containing *Turritella mortoni* and *Venericardia "planicosta."* They also report sandy limestone and calcareous sand at a point 5 miles above Fort Gaines. On the west side of the river about 100 yards above the old bridge at Fort Gaines, Clayton limestone extends 20 feet above low water. Its surface is pitted with large sinks filled with fine white micaceous sand of Nanafalia (Wilcox) age. On the Georgia side at the new bridge yellowish limestone containing echinoid spines and other obscure organisms rises 13 feet above the water.

About 22 feet of rather soft creamy-yellow limestone is exposed in the gorge of Cemocheechobee Creek at a mill 1 mile north of Fort Gaines.

Quitman County.—The former presence of limestone in Quitman County is indicated by residual lumps of chert on the Fort Gaines road about 3½ miles southeast of Georgetown. Chert occurs also about 4 miles east-northeast of Georgetown on the Lumpkin road. At milepost 139 on the Central of Georgia Railway near Hatcher, Veatch and Stephenson [64] found casts of *Venericardia "planicosta," V. smithii,* and other fossils in limonitic crusts near the base of the Eocene.

According to Veatch and Stephenson [65] there is an exposure of 20 feet of sandy limestone at the site of the old Redding mill and limekiln on the Griffith plantation 4 miles south of Hatcher. The rock contains *Ostrea crenulimarginata* and *O. pulaskensis?* and appears to be similar to that at Clayton, Ala.

Randolph County.—The Clayton formation appears to be somewhat thicker than elsewhere in the northwestern part of Randolph County. It is indicated by sinks, by yellow residual chert, and by outcrops. The most notable exposure is at Griers cave near the head of Punkin Creek 9 miles north of Cuthbert, where 50 feet of limestone is exposed almost continuously from a spring to the top of the hill near the cave. The lower part of the limestone is very sandy. It contains *Ostrea crenulimarginata* and *Venericardia* sp. Entrance to the cave is through a small circular hole near the top of the hill. The limestone near the spring has been quarried for use as an ornamental stone.

There is another exposure of limestone a mile farther south on the Cuthbert-Lumpkin road south of Little Punkin Creek near Punkin Creek Church.

Stewart County.—There are no known exposures of Clayton limestones in western Georgia north of Griers cave, but yellowish chert in greenish residual clay at a number of places in southern Stewart

[64] Veatch, Otto, and Stephenson, L. W., op. cit., p. 222.
[65] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 221–222.

County show that it once extended at least as far as Hodchodkee Creek. The basal Clayton formation in this region consists chiefly of coarse dirty red pebbly sand.

A gully heading northwest of the Lower Eufaula road 6 miles southwest of Lumpkin shows 10 feet or more of crumpled platy olive-green residual clay containing lumps of white chert. The upper part of the clay is micaceous and sandy. When dry it is light in weight and color and adheres to the tongue. A somewhat similar deposit crops out in a gully half a mile east of Hodchodkee Creek at Carter Bridge, about 5 miles southwest of Lumpkin. These beds seem to occupy about the same stratigraphic position as the 10 feet or more of light-gray brittle clay once mined for fuller's earth 5½ miles south of Lumpkin. This last-named deposit resembles the upper part of the Clayton formation at Clayton, Ala.

Webster County.—Veatch and Stephenson [66] report about 15 feet of hard grayish limestone or marlstone at Lime Spring, on the south side of Kinchafoonee Creek 2 miles southeast of Preston. The rock contains *Turritella humerosa*, *Mesalia alabamiensis*, *Ostrea pulaskensis?*, *Ostrea crenulimarginata*, and unidentified species of *Protocardia* and *Crassatellites*. *Ostrea crenulimarginata* was found also in similar marl in the bed of the creek at the old Harrell distillery, about 2 miles south of Preston.

At a point on the Weston road 1 mile south of Preston and at Bell's mill, 4½ miles northeast of Preston, Veatch and Stephenson [67] found thin fossiliferous flint beds, which they refer to the Midway (Clayton) although the beds contain *Ostrea thirsae*, a species more common in the Eocene Nanafalia formation.

Marion County.—In Marion County the Clayton formation consists chiefly of red pebbly sand and clay. *Ostrea crenulimarginata* occurs near the base of the formation in brick-red weathered clay west of the Preston road 4½ miles south of Buena Vista. At a point 1½ miles east of the Preston road and 6¼ miles south of Buena Vista white Cretaceous clay (Providence) is overlain by red clay containing Clayton chert and shells. Clayton chert occurs also 1 mile north-northeast of Putnam and 2½ miles (3 miles by road) northeast of Putnam. At this latter place it is associated with red pebbly sand containing two species of corals, *Turritella* sp., *Venericardia "planicosta,"* and *Crassatellites* sp. The pebbles are of quartz and are well rounded. The appearance of the deposit is very much like that of the Black Mingo formation of South Carolina, which also contains corals. The Clay-

[66] Veatch, Otto, and Stephenson, L. W., op. cit., p. 223.
[67] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 223–224.

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ton overlies light-colored clay of Providence age. Red pebbly sand 1 mile east of Doyle contains *Turritella* sp.

Schley County—Veatch and Stephenson [68] found 20 feet of highly siliceous, sparingly phosphatic limestone and clay containing siliceous nodules near the site of old Quebec, 8 miles southwest of Ellaville. The rock contains *Ostrea crenulimarginata*. They also report a thin bed of marl and a 4-foot bed of limestone at the head of a small branch 200 yards northwest of the cotton gin at Walls Crossing, 4½ miles northwest of Ellaville. At this place they collected *Turritella humerosa*, *Turritella alabamiensis*, *Ostrea crenulimarginata*, *Venericardia smithii*, and *Cytherea ripleyana*.

The following section was measured in 1930 on the roadside southwest of Muckalee Creek perhaps a mile north of the Sumter County line and 6 miles by road southwest of the railroad station at Ellaville.

Section on Muckalee Creek north of the Sumter County line

	Feet
Flint River formation (?) (Oligocene) (possibly McBean formation):	
7. Yellow to red argillaceous sand containing quartz pebbles up to 2 inches in diameter in the lower part. To top of hill	39
Clayton formation (Paleocene):	
6. Fine to coarse yellowish micaceous cross-bedded sand containing pellets of white clay. Large blocks of cream-colored limestone containing *Ostrea pulaskensis* in great numbers are level with the top of this bed beside the road	13
5. Greenish weathered clay, apparently residual from limestone, passing upward into greenish glauconitic marl	32
4. Dark-gray hackly clay; small oysters with nodules of white claystone in the upper part	10
3. Cream-colored limestone; *Venericardia "planicosta," Ostrea crenulimarginata, O. pulaskensis*, and other fossils	5
2. Coarse argillaceous sandstone; some glauconite; highly ferruginous in the upper part	11
1. Concealed, from Muckalee Creek	20

Poor exposures of a foot or more of white fossiliferous limestone of the Clayton formation overlying coarse white Providence sand were seen in 1936 west of Muckalee Creek on the road to Friendship 6¼ miles southwest of Ellaville.

In 1930 the section south of Beaver Run on the Butler road 2 miles north of Ellaville was as follows (later landslides have partly concealed it):

[68] Veatch, Otto, and Stephenson, L. W., op. cit., p. 224.

Section on the Butler road 2 miles north of Ellaville

	Feet
Flint River formation (Oligocene):	
5. Coarse dirty cross-bedded sand containing rolled lumps of light-gray clay, passing upward into massive brick-red coarse argillaceous sand, to top of hill. One fragment of rock containing *Glycymeris* in middle part	50
Clayton formation (Paleocene):	
4. Gray flaky clay, iron-stained at base, chert bed 3½ feet above base and fossiliferous chert 26 feet above base. Partly residual bauxitic clay at top	31
3. Iron-stained sand containing small oyster shells	8
Unconformity.	
Providence sand (Upper Cretaceous):	
2. Fine pale blue-gray sandy clay at base; blue-gray clay in middle; coarse gray clayey sand at top	16
1. Concealed to water level below mill dam on Beaver Run	40

Red-brown sand containing small oyster shells caps the hills half a mile and a mile and a quarter north of this place. Lumps of yellow chert were found on the first hill.

Sumter County.—In Sumter County gray to black hackly clay containing small, young oysters and lumps of irregular white chert of the Clayton formation occurs south of Sweetwater Creek about three-quarters of a mile south-southeast of Andersonville.

Macon County.—Black to light-gray clay exposed in a ditch at the south edge of Oglethorpe is overlain by terrace gravel. On the road to Butler 1 mile north of Oglethrope 5 feet of coarse yellow sand is overlain by 10 feet of flaky brown clay, the lower half of which is sandy and encrusted with limonite.

A foot of yellow to cream-colored limestone containing obscure fossils was exposed in 1914 in a gully one-half to three-quarters of a mile northwest of the Oglethorpe plantation house about 1¾ miles northwest of Oglethorpe. The limestone is underlain by drab clay and overlain by 7 feet of thin-bedded carbonaceous clay.

At the site of the old wagon bridge over Flint River 1 mile above Montezuma the Clayton formation includes an oyster reef crammed with shells of *Ostrea crenulimarginata.* The reef is underlain by brittle sandy clay. The natural section there is now partly covered by rubbish, but Veatch and Stephenson [69] record it as follows:

Section 1 mile northwest of Montezuma

Pleistocene (terrace deposit):
6. Red sand with a covering of brown incoherent superficial sand.

[69] Veatch, Otto, and Stephenson, L. W., op. cit., p. 225.

Section 1 mile northwest of Montezuma—Continued

	Feet
Age?:	
5. Laminated drab clay	15 to 20
Eocene (Midway formation [Paleocene (Clayton)]:	
4. Compact limestone, variable thickness; contains large oysters	2
3. Clay, marl, and limestone	8
2. Massive limestone layer; contains *O. crenulimarginata, Cardium, Crassatellites*	5
1. Bluish massive-bedded clay and coarse gritty argillaceous sand	15

Veatch and Stephenson[70] record the following section on the De Vaughn plantation, 2½ miles north of the preceding.

Section of the Clayton formation on the De Vaughan plantation

	Feet
5. Red argilaceous sand capping bluff.	
4. Clay with nodules of limestone, oyster shells abundant; the materials are weathered and not well exposed	8
3. Compact gray sandy limestone; fossils	3
2. Friable calcareous gray clayey sand	10
1. Sandy glauconitic limestone	20

Ostrea crenulimarginata occurs near the top of a 10- or 12-foot bed of dark clay containing dense gray calcereous concretions overlying 11½ feet of fossiliferous limestone at "Fern Bluff" on the west bank of the Flint River about a mile below the mouth of Camper Creek and above the cut-off above Sweetwater Creek. The fossils in the following list were obtained at this place.

Fossils from "Fern Bluff," 1 mile below Camper Creek (U. S. G. S. 7101)

[Identified by Julia Gardner]

Solitary coral.
Nuculanid ind.
Glycymeris? sp. ind.
Ostrea crenulimarginata Gabb.
Crassatellites n. sp.? cf. C. gabbi (Safford).
Venericardia (Venericor?) sp. ind.
Venericardia (Glyptoactis) sp. ind.
Solenid?
Callocardia sp. cf. C. ripleyana Gabb.
Callocardia sp. ind.
Protocardia sp. ind.
Turritella levicunea Harris.
Turritella sp. ind.
Pseudoliva scalina Harris, 1896, non Heilprin, 1880; cf. "Fulgur?" dallianum Harris.

A similar exposure on the right bank of Flint River several miles above "Fern Bluff," about a mile above Britts Ferry and below Lees Landing yielded the following species.

[70] Veatch, Otto, and Stephenson, L. W., op. cit., p. 225.

Fossils from Flint River below Lees Landing (U. S. G. S. 7100)

[Identified by Julia Gardner]

Saçella? sp. ind.
Cucullaea sp. ind.
Lithophaga n. sp.?
Ostrea crenulimarginata Gabb.
Crassatellites n. sp.? cf. C. gabbi (Safford).
Venericardia (Venericor) smithii Aldrich.
Venericardia (Glyptoactis) sp. ind.
Callocardia n. sp.?
Turritella sp. ind.

Fine dark-gray sand and clay and a layer of calcareous nodules, exposed 3½ miles east of Marshallville, are overlain by fine ferruginous sand, ledges of ironstone, and fine coarse red and white cross-bedded sand containing pellets of white clay. The dark sand and clay contain a few imprints of mollusks.

Veatch and Stephenson [71] report gray and black laminated sandy clay bearing *Venericardia "planicosta"* at Barrows mill, 4½ miles east of Marshallville.

EOCENE SERIES

GENERAL FEATURES

The Eocene series in the Southeastern States comprises three groups, which are also faunal divisions: Wilcox, Claiborne, and Jackson (the youngest). With these is usually included the Midway group, which is herein separated from the Eocene as an older, independent series, the Paleocene. There are representatives of all three divisions in the Coastal Plain of Georgia, but the sequence of none except perhaps the Jackson is complete. The Wilcox is not divided in Georgia, though it is a group of six formations in Alabama. The Claiborne group is represented in Georgia only by the McBean formation, which appears to be equivalent to the Tallahatta and Lisbon formations of Alabama. Deposits of Jackson age in Georgia include the Ocala limestone and the equivalent Barnwell formation, the latter with a Twiggs clay member and a Sandersville limestone member, and the overlying Cooper marl. The Ocala is typically developed in Florida; the type areas of the Barnwell and the Cooper are in South Carolina. The group itself is named from Jackson, Miss.

In the correlation table on page 40 each of the Eocene formations of Georgia is placed in its supposed stratigraphic position with respect to the formations of neighboring States.

[71] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 197, 217.

WILCOX FORMATION

GENERAL FEATURES

Name.—The name Wilcox, taken from Wilcox County, Ala., is applied in Alabama to a group of six formations—the Ackerman formation, at the base, the Nanafalia formation, the Salt Mountain limestone, the Tuscahoma sand, the Bashi formation, and the Hatchetigbee formation. The Ackerman does not extend into eastern Alabama and may properly belong to the Midway group rather than to the Wilcox.[72] The deposits of Wilcox age in Georgia have not been subdivided and are called the Wilcox formation, though the equivalents of the Nanafalia, the Tuscahoma, and the Bashi formations are known to be represented there.

Distribution.—The Wilcox formation is exposed in valleys and lowlands between Fort Gaines and Americus. It does not appear on the uplands because it is covered by the McBean formation and the Flint River formation, which overlap it and effectually cover it.

Thickness and lithologic character.—Veatch and Stephenson [73] estimate the thickness of the Wilcox formation as 150 to 200 feet. The formation consists chiefly of fine sand and gray laminated or hackly clay. The lower part, corresponding to the Nanafalia formation of Alabama, is generally coarser and includes some sandstone (pseudobuhrstone) containing angular lumps of hard clay.

Among the more characteristic fossils of the Wilcox formation that have been found in Georgia are *Ostrea thirsae*, which occurs in great abundance in the Nanafalia formation and which has been found near the base of the Wilcox at Fort Gaines; and *Ostrea compressirostra*, which occurs typically in the Aquia formation of Maryland and which has been reported also from Nanafalia, Ala. Other species are listed in descriptions of localities.

Stratigraphic relations.—The Wilcox formation lies unconformably on limestone of the Clayton formation and fills tubular sinkholes in it at Fort Gaines. The Wilcox is unconformably overlain by the McBean formation or by the Flint River formation, both of which overlap it. It is completely overlapped east of Flint River.

Economic significance.—No important mineral deposits have been found in the Wilcox formation.

LOCAL OCCURRENCE

Clay County.—The Wilcox formation crops out in the bluff of Chattahoochee River at Fort Gaines and occupies all the interval be-

[72] Cooke, C. W., Ackerman formation in Alabama: Am. Assoc. Petroleum Geologists Bull., vol. 17, pp. 192–195, 1933.

[73] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, p. 229, 1911.

tween the Clayton and the terrace gravel on which the town is built. In 1925, while the new highway bridge was under construction, a ledge of coarse calcareous sandstone containing well-preserved *Ostrea compressirostra* and casts of other shells was exposed near the top of the bluff. The ledge is underlain by softer sandstone and brittle sandy clay. *Ostrea thirsae* was found in abundance only a few feet above the Clayton between the new bridge and the old one, which was farther upstream. The exact place of these beds in the following section, which was measured in 1929, is uncertain.

Section on Chattahoochee River at the highway bridge at Fort Gaines

	Feet
Terrace deposit (Pleistocene):	
13. Coarse white to red sand and gravel	33
Unconformity.	
Wilcox formation (Eocene):	
12. Hackly bedded gray clay	8
11. Coarse reddish glauconitic sand and gravel, with irregular ferruginous crusts in upper part; to 5 feet above the floor of the bridge	13
10. Fine massive gray sand containing fossils and mica	10
9. Darker gray clayey sand	1½
8. Coarse loose gray dirty sand at base; slightly indurated in upper part, which contains many casts of mollusks	6½
7. Concealed or inaccessible	19
6. Coarse gray to yellow micaceous sand containing scattered angular lumps of hard gray claystone; comminuted plants	13
5. Irregularly laminated or flaky micaceous clay containing a few comminuted plants and having a hard ledge at top	6½
4. Massive hackly gray clay containing fossil mollusks	5½
3. Thin-bedded highly micaceous gray sand and clay merging into the overlying bed. Contains *Venericardia* and other mollusks	7
2. Mostly concealed	15
Unconformity.	
Clayton formation (Paleocene):	
1. Yellowish limestone containing echinoid spines and obscure fossils	13

The beds higher than about 60 feet above the river at Fort Gaines were referred to the McBean formation by Veatch and Stephenson because of the supposed presence in them of *Ostrea sellaeformis*, *O. georgiana*, and *Pecten deshayesii*, but the reference of these species to Fort Gaines may be due to an error in transcribing the lists. None of the collections of fossils from Fort Gaines in the United States National Museum include these species, but there are several specimens of *O. compressirostra* among them. My own observations confirm the

statements of Langdon [74] and Loughridge that *O. compressirostra*, a species characteristic of the Wilcox and not likely to be confused with *O. sellaeformis* or *O. georgiana*, occurs near the top of the bluff at Fort Gaines.

The following section was measured in 1917 on the left bank of the river at a bend 1¾ miles below Fort Gaines:

Section of the Wilcox formation on Chattahoochee River 1¾ miles below Fort Gaines

	Feet
3. Rough gray calcareous sandstone full of casts of mollusks and containing lumps of indurated clay	2
2. Yellowish-gray micaceous fossiliferous sand; a ledge of calcareous sandstone at base, round limestone concretions averaging 3 inches in diameter at 2 feet, and discontinuous ledges at 4 and 6 feet; oyster bed 9 feet above base, and clay beds at 4 and 7 feet	14
1. Lower 4 feet consisting of dark-gray micaceous, argillaceous sand containing comminuted plants and casts of mollusks; grading upward into less argillaceous sand with irregular shaly laminae at top; contains fragments of shells	9

A log of silicified wood was found loose at the river's edge.

Veatch and Stephenson [75] report 2 or 3 feet of glauconitic sandy shell marl of Wilcox age at the mouth of Flat Creek, 4½ miles south of Fort Gaines. They list *Cucullaea macrodonta*, *Ostrea compressirostra*, *O. sellaeformis*, *Chlamys greggi*, and *Pecten* sp. from this bed.

Early County.—Beds of Wilcox age underlie the McBean formation along the roadside south of Colomokee Creek about 6 miles south of Fort Gaines and 1½ miles east of the river. They are here tentatively correlated with the Nanafalia formation, though they may be equivalent to part of the Tuscahoma formation of Alabama. The section follows:

Section south of Colomokee Creek

	Feet
Flint River formation (Oligocene) or possibly Pleistocene deposits:	
8. Coarse brick-red sand containing large corroded pebbles in the lower part. To top of hill	50
McBean formation (Eocene):	
7. Red sand with scattering patches of fine gravel in the lower part; shell-bearing zone 80 feet above base; brick red above	100

[74] Langdon, D. W., The Tertiary and Cretaceous formations east of the Alabama River: Alabama Geol. Survey, Report on the geology of the Coastal Plain of Alabama, pp. 406, 419, 1894.

[75] Veatch, Otto, and Stephenson, L. W., op. cit., p. 233.

Section south of Colomokee Creek—Continued

Wilcox formation (Eocene):	Feet
6. Fine sticky yellowish sand	6
5. Massive, somewhat hackly gray clay	7½
4. Massive greenish-gray glauconitic sand becoming very fine and only sparingly glauconitic above	22
3. Chocolate-colored clay interbedded with gray micaceous, sparingly glaconitic sand; sand more abundant in the upper part	15
2. Concealed to floor of bridge	14
1. Dark-gray clay containing comminuted plants and a few spherical concretions. Exposed in the bed and banks of Colomokee Creek	8

Exposures of the Wilcox formation on the left bank of Chattahoochee River at Howards Bend, 12½ miles below Fort Gaines, were noted in 1917 as follows:

Section at Howards Bend

River deposit (Quaternary):	Feet
6. Fine yellow micaceous sand, about	15
Wilcox formation (Eocene):	
5. Light-gray slightly indurated sand loaded with *Ostrea compressirosta* and molds of other fossils (USGS 7985)	(?)
4. Blue-gray laminated sand with ferruginous laminae	5
3. Fine gray massive slightly coherent sand; a few shells at base	14
2. Hard uneven layer of blue-gray sand, probably calcareous	1
1. Fine dark-gray sand with shells. To water level	5

The beds in this vicinity are very nearly horizontal.

Randolph County—In Randolph County the exposures of Wilcox strata apparently represent the Tuscahoma sand. The following section was described in 1929:

Section east of Hog Creek 4 miles southwest of Cuthbert

Flint River formation (Oligocene):	Feet
7. Orange-red pebbly sand at base, pink and white to brick-red at top; small fragments of chert on top. About	35
McBean formation (Eocene):	
6. Flaky pale-green clay	6
5. White to orange pebbly sand	12
Wilcox formation (Eocene):	
4. Very fine rusty glauconitic sand with laminated clay in the lower part	16
3. Very fine gray-brown sand streaked with clay and containing rolled lumps of gray clay	9
2. Fine laminated gray sand and clay	10
1. Concealed to water level in Hog Creek	16

Fine gray to yellow slightly laminated sand resembling the Tuscahoma formation is exposed on both sides of the valley at Seely's mill, 3 miles northeast of Cuthbert. It is overlain unconformably by pebbly sand, apparently the McBean formation. About 20 feet of massive gray glauconitic sand occurs at Pitman mill, 6 miles northeast of Cuthbert.

A washed-out road a quarter of a mile west of Miller mill and 5½ miles north of Pachitla station cuts 17 feet of fine gray thin-bedded sand and clay appearing massive where water-worn but showing many rusty fissures on weathered surfaces. This bed is overlain by 43 feet of reddish-yellow glauconitic sand passing upward into gray thin-bedded sand and clay. Thirty feet of coarse red argillaceous sand streaked with clay, presumably McBean formation, caps the hill.

An unconformable contact of cross-bedded pebbly sand of the McBean formation and glauconitic sand of Wilcox age lies 21 feet above water level in Nochaway Creek 1 mile north-northwest of Crittenden mill and 3 miles north-northeast of Troutman, Stewart County. It is overlain by weathered yellow clay containing many fossil shells in a zone about 5 feet above the level of the spring. The following list of fossil mollusks indicates that the clay is of about the age of the Bashi formation of Alabama, that is, near the top of the Wilcox group.

Fossil mollusks from spring west of Georgia, Florida & Alabama Railway 1¼ miles northeast of Troutman, Stewart County, Ga. (U. S. G. S. 12097)

[Identified by Julia Gardner]

Nucula ovula Lea.
Indeterminate ark.
Modiolaria sp. ind. (juveniles).
Lirodiscus sp. ind. (juvenile).
Venericardia planicosta Lamarcks s. l.
Callocardia subimpressa Conrad.
Callocardia nuttaliopsis Helprin? (less inflated than usual form).
Corbula sp. ind. (juveniles).
Polinices harrisii Garner?
Ficopsis juvenis Whitfield?
Siphonalia subscalarina (Heilprin).
Cornulina armigera Conrad s. l.
Volutospina sp. cf. V. tuomeyi Conrad.
Levifusus pagodiformis (Heilprin).
"Surcula" sp. possibly n. sp.
Hemisurcula sp. cf. H. tombigbeensis Aldrich (juveniles).

Webster County.—Six feet of fine blue-gray micaceous sand is exposed near the foot of the hill west of Kinchafoonee Creek on the highway 2 miles northwest of the courthouse at Preston. It is overlain by about 20 feet of yellow cross-bedded sand containing small pebbles at the base. The upper bed is probably part of the McBean formation.

Sumter County.—South of Deer Creek 2½ miles east of Friendship, dark-gray massive clay and sandy "pseudobuhrstone" resembling the Nanafalia formation of Alabama are exposed in a roadside ditch. They contain small oysters and other mollusks.

Compact fine gray sand containing carbonaceous particles and *Leda* sp. in the upper part and glauconite and casts of pelecypods in the lower part was seen in 1923 on the road south of Magnolia Spring, 3 miles north of Plains. It is overlain by massive brick-red sand with pebbles at the base and lumps of fossiliferous chert of the Flint River formation on the surface.

Twenty feet of dark-gray sandy clay overlain by red sand of the Flint River formation is exposed south of Muckalee Creek near Myrtle Springs, 5 miles northwest of Americus.

At Copperas or Chambliss Bluff on the west bank of Flint River about 2 miles below the mouth of Hogcrawl Creek are clay and sand that were referred to the Midway formation by Veatch and Stephenson [76] but that may be of Wilcox or possibly Upper Cretacous age. The following section was measured in 1914:

Section at Copperas or Chambliss Bluff

	Feet
Terrace deposit (Pleistocene):	
6. Yellow sand, pebbles at base	21⅔
Wilcox formation(?) (Eocene):	
5. Medium-grained white sand	2
4. Irregularly bedded yellow sand and gray clay	5
3. Black carbonaceous clay	3⅓
2. Fine dark-gray carbonaceous and argillaceous sand and obscure plant remains	12
1. Stiff pale-blue clay weathering white; no sand. To water level	14

The dip of the contact of beds 1 and 2 in the direction S. 50° E. is 80 feet to the mile.

McBEAN FORMATION

GENERAL FEATURES

Name.—The McBean formation was named in 1911 by Veatch and Stephenson [77] from a village in Richmond County, Ga., and from McBean Creek, which forms the boundary between Richmond and Burke Counties. As originally described it included the †Congaree [78] clay member, most of which later proved to be younger than the McBean and which has been transferred to the Barnwell formation under the name Twiggs clay member. In 1918 Cooke and Shearer [79] restricted the name McBean formation to the deposits of lower Claiborne (Lisbon) age along Savannah River and its tributaries and

[76] Veatch, Otto, and Stephenson, L. W., op. cit., p. 226.

[77] Veatch, Otto, and Stephenson, L. W., op. cit., p. 237.

[78] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the Federal Geological Survey.

[79] Cooke, C. W., and Shearer, H. K., Deposits of Claiborne and Jackson age in Georgia: U. S. Geol. Survey Prof. Paper 120, pp. 41–81, 1918.

classified the Claiborne deposits in Georgia between Chattahoochee River and Flint River as "undifferentiated Claiborne." In the present report these deposits west of Flint River are mapped as McBean, though some of them may be somewhat older than the typical part of the formation.

Distribution.—The McBean formation does not make a continuous belt of outcrops across the State because it is overlapped by the Barnwell and the Flint River formations part of the way. These formations cap the divides between all the larger streams and thus cut the outcrop of the McBean into a series of disconnected areas in the bordering lowlands. As shown on the geologic map (pl. 1), these disconnected areas extend in a nearly straight band across Georgia from Savannah River below Spirit Creek to Chattahoochee River below Fort Gaines. However, some of the areas mapped as McBean may represent instead a basal upper Eocene deposit, not the McBean, which is middle Eocene. No exposures of the McBean have been recognized on Ocmulgee River or its tributaries; the formation appears to be completely overlapped there.

Thickness.—The thickness of the McBean formation appears to be fairly uniform across the State. Cooke and Shearer [80] estimate that its thickness in the vicinity of Savannah River does not greatly exceed 100 feet. This estimate is certainly not excessive and may be too low, but accurate measurements are not yet available.

Lithologic character.—The typical part of the formation, as exposed near McBean, consists chiefly of fine loose yellow sand containing a few discontinuous ledges of sandstone and patches of carbonaceous and calcareous matter. The sand merges downward into white, gray, or greenish marl containing *Ostrea sellaeformis* and other fossils. Sandy marlstone, fine sand, olive-green platy clay, and fuller's earth are the prevailing constituents elsewhere. In the region between Flint and Chattahoochee Rivers, loose light-colored sand is more conspicuous. At Fort Gaines greenish clay and buhrstone, apparently of lowest Claiborne (Tallahatta) age, make up the lower part of the formation. A littoral gravelly facies mapped as McBean can be distinguished from the Barnwell formation by its pebbles, which are subangular and dull, not well rounded, polished, and flattened like those of the Barnwell. This facies may be basal upper Eocene, not McBean.

Fauna.—Casts of shells are common in the marlstone near the base of the McBean formation but are rarer elsewhere. An exceptionally fine collection of well-preserved shells including many characteristic Lisbon species obtained by Earl Sloan from near the mouth of McBean Creek is now in the United States National Museum. The species are

[80] Cooke, C. W., and Shearer, H. K., op. cit., p. 50.

listed by Veatch and Stephenson [81] and by Cooke and Shearer.[82] Silicified shells collected and listed by Cooke and Shearer [83] from the east side of Little Keg Creek 7 miles north-northwest of Sandersville and supposed by them to be basal Barnwell may prove to be basal McBean or a basal upper Eocene formation older than the Barnwell. The collection (U. S. G. S. 7707) includes the following identified species:

Corals and mollusks from Little Keg Creek

Flabellum cuneiforme Lonsdale.
Astrohelia burnsi Vaughan.
Actaeon idoneus Conrad.
Cochlespirella nana (Lea)?
Conus sauridens Conrad.
Cancellaria gemmata Conrad.
Ancellina scamba (Conrad).
Marginella semen Lea.
Psilocochlis mccalliei (Dall).
Plejona petrosa (Conrad).
Lapparia pactilis (Conrad).
Levifusus trabeatus (Conrad)?
Phos sagenus (Conrad).
Terebrifusus amoenus (Conrad).
Ficus filius (Meyer).
Calyptraphorus velatus (Conrad).
Turritella carinata Lea.
Mesalia vetusta (Conrad).
Sinistrella americana (Aldrich)?
Lunatia minima (Lea).
Nucula magnifica Conrad?
Nucula ovula Lea.
Leda multilineata Conrad.
Glycymeris staminea (Conrad).
Crenella isocardioides (Lea).
Corbula oniscus Conrad.
Corbula densata Conrad.
Corbula alabamiensis Lea.
Corbula fossata extenuata Dall.
Pitaria perovata (Conrad).
Pitaria mortoni (Conrad).
Miltha pandata (Conrad)?
Lucina subvexa Conrad?
Phacoides alveatus (Conrad)?
Astarte sp. cf. A. tellinoides (Conrad).
Crassatella protexta Conrad var.
Crassatella n. sp.?
Protocardia nicolleti (Conrad).
Venericardia planicosta (Lamarck).
Venericardia alticostata Conrad var.

Stratigraphic relations.—In western Georgia the McBean formation lies unconformably on the Wilcox formation. Farther east it overlaps across the Wilcox to the Clayton formation, which it apparently reaches in northeastern Sumter County. East of the Ocmulgee it lies unconformably on the Tuscaloosa formation. It extends northeastward, under the same name, into South Carolina and is probably equivalent to the Nanjemoy formation of Virginia and Maryland. It also appears to be equivalent to the Lisbon formation and part, perhaps all, of the Tallahatta formation of Alabama and Mississippi, though those formations are thicker, and the Tallahatta contains more hard rock. The McBean is overlain unconformably by the Ocala limestone and the Barnwell formation, both of which overlap it, and by the Flint River formation, which overlaps the Ocala.

Economic significance.—The McBean formation as mapped in Wilkinson, Washington, Glascock, Jefferson, and Burke Counties contains

[81] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 239–240.
[82] Cooke, C. W., and Shearer, H. K., op. cit., pp. 50–51.
[83] Cooke, C. W., and Shearer, H. K. op. cit., 48–49.

beds of fuller's earth, which, though not so extensive as those of the Barnwell and Hawthorn formations, are being mined at several places. The widespread sand beds of the McBean doubtless yield water of good quality to shallow wells within the areas of outcrop and to wells deep enough to reach them in the region farther seaward.

LOCAL OCCURRENCE

Burke County.—The typical exposures of the McBean formation are on the south side of McBean Creek about a quarter of a mile below McBean. The beds are variable, but the following section, which was described in 1916, is more or less representative, though possibly beds 4 and 5 should be referred to the Barnwell formation.

Section in gully on south side of McBean Creek a quarter of a mile east of the highway bridge at McBean

	Feet
Barnwell formation:	
6. Brilliant red massive argillaceous sand, very coarse in lower part	20
McBean formation:	
5. Coarse incoherent yellow sand; at the top a locally indurated ledge of friable white sandstone, which elsewhere is represented by carbonaceous sand	30
4. Coarse quartz sand in a matrix of greenish-yellow clay	4
3. Fine yellow sand, incoherent at top, argillaceous below, with patches of calcareous and carbonaceous, almost lignitic material	5
2. Soft fine-grained sandy gray calcareous marl with a few fragments of shells and some hard nodules	3
1. Concealed interval to creek level, about	30

About 100 yards east of this gully the marl at the base of the section was exposed in 1916 to a thickness of 12 feet and contained *Ostrea sellaeformis*. An echinoid, apparently *Periarchus* sp., occurs also in the marl. When revisited in 1937, the marl was covered in the gully by an alluvial fan but was still exposed along the road nearby.

A much greater thickness of marl is exposed farther upstream. Brantly [84] reports the following section on the south side of the creek, above the Central of Georgia Railway:

Section of the McBean formation on the Newton Palmer property, McBean Creek, west of the Central of Georgia Railway

	Feet
5. Soft white argillaceous rotten limestone	7
4. Medium-hard highly fossiliferous limestone; fossils poorly preserved	2

[84] Brantly, J. E., A report on the limestones and marls of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 21, p. 46, 1916.

Section of the McBean formation on the Newton Palmer property, McBean Creek, west of the Central of Georgia Railway—Continued

	Feet
3. Soft, rotton to consolidated cream-colored argillaceous limestone	45
2. Blue glauconitic clay like fuller's earth	6
1. Hard arenaceous fossiliferous limestone. To creek bed	2

Brantly describes several deposits of similar limestone in neighboring parts of Burke County.

The lower part of Shell Bluff, a noted locality on Savannah River 40 miles below Augusta, is composed of marl and limestone of the McBean formation, as follows:[85]

Generalized section at Shell Bluff

	Feet
Barnwell formation:	
7. Red argillaceous sand to level of upland plain	35
6. Oyster bed (*Ostrea gigantissima* Finch); base 80 feet above zero water level	30
McBean formation:	
5. Concealed interval between the upper and lower bluffs. Covered by talus from the oyster bed and other overlying beds but probably a bed of sand	10
4. Moderately hard to hard light-colored marl, with few fossils	9
3. Ledge of hard brown coquinalike rock, with numerous hollow casts of fossils	6
2. White to purplish sandy limestone made up largely of fossils. Vaughan collected 35 species from it. It is characterized by large specimens of *Ostrea sellaeformis*	6
1. Sandy and argillaceous marl, not abundantly fossiliferous; in layers differing considerably in color, hardness, and chemical composition. Content of calcium carbonate ranges from less than 50 percent to more than 90 percent. The color as a whole appears light gray, but individual beds have various shades of white, yellow, buff, gray, and greenish yellow. Exposed as an almost vertical cliff, rising from water level, in which the harder layers form projecting ledges	50

On Savannah River downstream from Shell Bluff, marl of the McBean formation is exposed at Demeries Ferry, Hancock Landing, Utley Point, and Blue Bluff and finally passes beneath water level at Griffins Landing, where it is overlain unconformably by an oyster bed and calcareous clay.

At Keys water mill on Brushy Creek, 3 miles northwest of St. Clair, the following section is exposed:

[85] Cooke, C. W., and Shearer, H. K., op. cit., p. 61.

Section at Keys mill

	Feet
Barnwell formation:	
6. Coarse firm brick-red sand; many polished and flattened pebbles at base; about	25
McBean formation:	
5. Alternating thin-bedded flaky clay and loose red sand	3
4. Fine greenish-yellow sand with laminae of yellow flaky clay near top	18
3. Concealed	11
2. Hard greenish-gray marlstone composed chiefly of large oysters resembling *Ostrea gigantissima* Finch	4
1. Concealed to water level in mill pond	7

Jefferson County.—The basal part of the McBean formation unconformably overlain by the Barnwell is shown in the following section:

Section on Reedy Creek 2 miles north-northeast of Matthews

	Feet
Barnwell formation:	
3. Coarse shelly sand at base containing rounded and flattened pebbles	15
McBean formation:	
2. Large rounded pebbles at base overlain by greenish-yellow platy clay	23
Tuscaloosa formation:	
1. Coarse white cross-bedded sand with white cement. To water in Reedy Creek	11½

The McBean formation, here consisting of platy yellow-olive clay and fine red sand, rises 38 feet above Howard Branch on the road to Hobbs mill 4 miles north by west of Wrens. It is overlain unconformably by 61 feet of red sand of the Barnwell containing many flattened beach pebbles at the bottom.

Washington County.—A road cut 1 mile southwest of Chalker exposes 45 feet of the McBean formation. The upper 20 feet consist of fine mealy yellow sand streaked with gray clay. The sand is underlain by fuller's earth, which merges downward into fine greenish-gray sandy clay containing molds of *Flabellum*, *Pecten*, and many other mollusks. Nine feet above the base is a 4-inch bed of sandy claystone.

On the roadside approaching Keg Creek 6 miles west-northwest of Sandersville, brittle white kaolin of the Tuscaloosa formation is overlain by a 5-foot bed of greenish-gray clayey marl containing soft white concretions, Bryozoa, *Flabellum* sp., *Venericardia* sp., *Pecten* sp., and other mollusks. The marl is overlain by 10 feet of fuller's earth, which is calcareous at the base. Both the marl and the fuller's earth represent part of the McBean formation.

Pockets of coarse sand unconformably on the Tuscaloosa formation east of Little Keg Creek, 5 miles southwest of Warthen and 7 miles

northwest of Sandersville, yielded the silicified shells listed on page 55. The sand is overlain by 3 or 4 feet of greenish fuller's earth.

The McBean formation is exposed along the road east of Sheppards Bridge, 3 miles above the mouth of Buffalo Creek, where it lies between the Tuscaloosa and the Barnwell formations with a thickness of approximately 105 feet. At the base is a bed of fine sandy marl containing impressions of shells. Fuller's earth and sand with laminae of platy clay make up most of the remainder. The contact with the Tuscaloosa was only approximately located, but the contact with the Barnwell is a sharp, uneven line high on the hill. The Barnwell consists of massive red sand containing flat pebbles.

Wilkinson County.—Thin-bedded fine sand and fuller's earth of the McBean formation is overlain unconformably by the Barnwell formation, here consisting of gray sand containing patches of fuller's earth and many flat polished pebbles, a quarter of a mile southwest of the site of Kemp School, 5¾ miles southeast of Irwinton. The contact is exposed also three-quarters of a mile southwest of the school.

Sumter County.—Exposures at old Danville Ferry and Penny Bluff on Flint River were referred to the McBean formation by Veatch and Stephenson [86] on the basis of fossils identified by T. W. Vaughan. At old Danville Ferry *Ostrea sellaeformis*, commonly occurring in the Lisbon formation, is the most conspicuous fossil, and other Lisbon species are also present. Fragments of a *Periarchus*, possibly *P. lyelli*, suggest that the upper part of the section classed as McBean may be of Jackson age (basal Ocala limestone). Penny Bluff is described as 12 miles west of Vienna and about 1½ miles above old Danville Ferry.

The section at the upper end of Danville Bluff on the west bank of Flint River about 1 mile above the mouth of Pennahatchie Creek is as follows:

Section at Danville Bluff

	Feet
Terrace deposit (Pleistocene):	
5. Sand, to top of hill	35
McBean formation (Eocene):	
4. White friable fossiliferous sandstone	6
3. Hard gray coarse calcareous standstone containing poor fossils	2
2. Blue to gray calcareous sandy clay, micaceous at bottom, passing upward into very sandy clay marl containing comminuted shells; at top consists of coarse sandy slightly glauconitic marl with *Ostrea sellaeformis* abundant, *Pecten* sp., and *Lunularia* sp.; includes several thin beds of hard nodular claystone	18
1. Hard nodular highly fossiliferous calcareous gray sandstone, at water level	1

[86] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 260–261.

Friable gray to red sandstone containing obscure fossils and passing upward into fossiliferous thin-bedded to laminated clay, and then into massive red sand occurs north of a creek about 3 miles northwest of Murrays Ferry and about 1¼ miles west of Flint River.

Clay County.—The basal part of the McBean formation, presumably equivalent to the Tallahatta formation of Alabama, is exposed on the road to the reservoir on the eastern outskirts of Fort Gaines.

Section on the road to the reservoir at Fort Gaines

	Feet
Flint River formation (Oligocene) or possibly early Pleistocene or Pliocene terrace deposit:	
8. Tough red argillaceous sand containing many large deeply corroded pebbles. To top of hill at reservoir; base not certainly exposed; lower part may be creep	55
McBean formation (Eocene):	
7. Chiefly laminated greenish clay and sand and thin beds of fossiliferous sandstone	9
6. Alternating ledges of greenish clay and highly fossiliferous buhrstone; *Venericardia "planicosta"* and other fossils	25
5. Coarse reddish sand and fine gravel at base; hard ledge at top forming waterfall; pebbles ¾ inch long	9
Unconformity?	
Wilcox formation or basal McBean (Eocene):	
4. Greenish clay; to foot of waterfall below road	5
3. Fine somewhat clayey greenish-gray sand	10
2. Olive-drab clay	5
1. Fine gray sparingly glauconitic sand containing laminae of clay in the lower part	22

Chattahoochee River.—Along Chattahoochee River the McBean formation extends from near the mouth of Abbie Creek (in Alabama) to a point near Gordon, Ala. On the west bank three-quarters of a mile below Abbie Creek there is an exposure of 6 feet of blue to green granular glauconitic marl overlying 3 feet or more of coarse gray sparingly glauconitic sand containing shells. These beds probably do not lie stratigraphically far above the bed containing *Ostrea compressirostra* at Howards Bend and may, like it, be of Wilcox age. At Mercer Shoal, about half a mile below Columbia, alternating hard and soft beds of calcareous sandstone extend to a height of 25 feet above the river. The following section was measured in 1917:

Section of the McBean formation at Mercer Shoal

	Feet
6. Hard calcareous sandstone	3
5. Soft calcareous sandstone	6
4. Hard calcareous sandstone	3
3. Light-green somewhat indurated calcareous sandy clay	6
2. Sand and sandy clay grading upward into a hard ledge of clay-stone	3
1. Hard nodular ledges. To water level	3½

At Wilson Landing, 4 miles below Columbia, 10 feet of massive somewhat indurated argillaceous, glauconitic sand is overlain by 3 feet of hard thin-bedded sandstone. At Smith Bend, 3 miles farther downstream, 1 foot of green glauconitic clay weathering olive gray is overlain by 2 feet of lumpy green clay containing limestone nodules. Where the river swings toward the east in Smith Bend, the following section is exposed on the Alabama side:

Section of McBean formation in Smith Bend, Chattahoochee River

	Feet
4. Hard blue glauconitic sandy limestone weathering rough and cavernous	2
3. Greenish-yellow weathered argillaceous, glauconitic sand irregularly hardened	2
2. Hard rough ledge of bluish-gray sandy glauconitic limestone	2½
1. Green glauconitic, calcareous sand, somewhat hardened. To water level	3½

BARNWELL FORMATION

GENERAL FEATURES

Name.—The Barnwell sand, named by Sloan [87] in 1907 from Barnwell County, S. C., was defined in 1936 by Cooke [88] as "an Eocene formation composed chiefly of sand that overlies unconformably the McBean formation." The name had been used in that sense for deposits in Georgia by Veatch and Stephenson,[89] who, however, included the Barnwell sand with the McBean formation in the Claiborne group and excluded from the Barnwell certain deposits known to be of Jackson age. Cooke and Shearer [90] later discovered that many of the fossils on which Veatch and Stephenson based their correlation with the Claiborne occur also in deposits of Jackson age. They classified the Barnwell as of Jackson age and included in it part of Veatch and Stephenson's Jackson formation and all of the so-called Congaree clay member of the McBean formation, which latter member they renamed "Twiggs clay member of the Barnwell formation." Cooke and Shearer's usage is adopted in this report, except that part of the so-called Congaree clay is restored to the McBean formation. This part, however, may be an upper Eocene deposit intermediate between the Barnwell and the McBean.

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[87] Sloan, Earle, Catalogue of the mineral localities of South Carolina, p. 454, 1908; Handbook of South Carolina, p. 90, 1907.

[88] Cooke, C. W. Geology of the Coastal Plain of South Carolina: U. S. Geol. Survey Bull. 867, p. 89. 1936.

[89] Veatch, Otto, and Stephenson, L. W. Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, 1911.

[90] Cooke, C. W., and Shearer, H. K., Deposits of Claiborne and Jackson age in Georgia: U. S. Geol. Survey Prof. Paper 120, pp. 41–81, 1918.

The Twiggs clay member of the Barnwell takes its name from Twiggs County, Ga., in which it is typically developed at Pikes Peak station, on the Macon, Dublin & Savannah Railroad.

Limestone referred by Veatch and Stephenson [91] to the McBean formation and by Cooke and Shearer [92] to the upper part of the Barnwell is herein named the Sandersville limestone member of the Barnwell formation, after the town of Sandersville, near which it is typically exposed.

Distribution.—The Barnwell formation extends from western South Carolina through Georgia almost to Flint River. It underlies most of the Louisville Plateau and caps many of the Fall Line Hills. The width of the band of outcrop averages 30 or 40 miles, though it is narrowed in places by overlaps of the Hawthorn and Flint River formations and by projections of the Tuscaloosa and McBean formations down the valleys. The typical sandy facies is best developed in Burke and Jefferson Counties, the Sandersville limestone member in Washington County, and the Twiggs clay member in Twiggs County.

Thickness.—The thickness of the Barnwell formation is estimated [93] as less than 200 feet in eastern Georgia and somewhat more than 200 feet in Twiggs County, where the Twiggs clay member accounts for nearly half of it. The Twiggs clay member attains its greatest thickness at Pikes Peak, Twiggs County, where it is 100 feet thick. The thickness of the Sandersville limestone member probably does not much exceed 40 feet.

Lithologic character.—The typical part of the Barnwell consists of moderately fine to coarse tough argillaceous sand, which weathers to a brilliant shade of red. The color appears to be due to the oxidation of the small grains of glauconite that are disseminated through the sand. Local ledges of gray sandstone occur at some places, generally near the bottom of the formation. Except near the west end of its belt of outcrop, where the formation becomes more calcareous, the base of the Barnwell nearly everywhere contains flat polished beach pebbles, which aid in distinguishing it from the coarser facies of the McBean formation. Masses of flint are common at several zones within the Barnwell, particularly near the top, where they seem to have been derived from the Sandersville limestone member.

The Twiggs clay member consists typically of greenish-gray siliceous hackly brittle clay interbedded with thin layers of sand. Large deposits of it are utilized as fuller's earth. The member becomes calcareous toward the west and merges laterally into the Ocala lime-

[91] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 253–255.
[92] Cooke, C. W., and Shearer, H. K., op. cit., pp. 68–69.
[93] Cooke, C. W., and Shearer, H. K., op. cit., p. 54.

stone. The Sandersville limestone member is light gray and chalky. It becomes sandy toward the base.

Fauna.—The fauna of the Barnwell formation presents several different facies. Sandstone ledges at the base of the Barnwell near Rocky Comfort Creek in Glascock County recall the Jackson formation of Arkansas, with which they have in common *Levifusus branneri*, *Murex marksi*, and *Turritella clevelandia*. *Psilocochlis mccalliei*, a species known only from Georgia, and many other upper Eocene species occur also in this bed. The more calcareous basal beds in Bibb and Twiggs Counties include *Periarchus lyelli pileus-sinensis*, and *Pecten spillmani*, both abundant in the Ocala limestone, and many bryozoans. The Sandersville limestone member contains an abundance of *Periarchus quinquefarius* (Say), a species that seems to be restricted to beds of upper Barnwell age. *Ostrea gigantissima* Finch, commonly called *O. georgiana* Conrad, forms reefs at the bottom of the Barnwell on Savannah River and elsewhere. The species enumerated form only a small part of the total fauna of the Barnwell formation, but well-preserved shells are rather uncommon.

Stratigraphic relations.—The Barnwell formation lies unconformably on the McBean formation and overlaps beyond it across the Tuscaloosa formation to the crystalline rocks of the Piedmont. The unconformable contact of the Barnwell on the Tuscaloosa or the McBean is plainly visible in many valleys, and where direct evidence of unconformity is lacking flat polished pebbles in the lower part of the Barnwell suggest the traces of an advancing beach. Toward the southwest end of its area of outcrop the Barnwell merges laterally into the Ocala limestone, and similar mergence probably takes place under cover seaward. At most places, however, the Flint River formation or the Hawthorn formation overlaps beyond the seaward edge of the Barnwell formation and lies unconformably on it.

Economic significance.—The Twiggs clay member of the Barnwell formation contains large deposits of high-grade fuller's earth, which are extensively mined in Twiggs County. The limestone of the Sandersville member has been quarried in Washington County. The firm, clayey sand of the typical part makes good roads for light traffic. The fertile soils of the Louisville Plateau are derived in large part from the Barnwell formation.

LOCAL OCCURRENCE

Burke County.—The most conspicuous part of the Barnwell in Burke County is massive firm red sand, which forms the surface of a large part of the county. At the base of the formation along Savannah River is a bed of enormous oyster shells (*Ostrea gigantissima* Finch), the abundance of which suggested the name of Shell Bluff.

This bed was included by Veatch and Stephenson in the McBean formation, to which it may properly belong. None of the exposures recently examined are sufficiently clean to give clear evidence as to its true stratigraphic position. Cooke and Shearer [94] put it in the Barnwell because it includes a conglomeratic zone containing quartz pebbles and because the bed contains bryozoans like those in the Ocala limestone at Rich Hill.

Outcrops of chert beds are abundant in Burke County. They lie near the hilltops in the northern part and in the valleys in the southern part. The thickest and most extensive exposures are in bluffs along Rocky Creek near the Louisville road 5.3 miles west-southwest of Waynesboro, where the bed is at least 15 feet thick and contains *Turritella* sp., *Periarchus* sp., and other obscure fossils. This rock may represent a silicified facies of the Sandersville limestone member. At Hatchers mill, 3½ miles north of Alexander, the chert contains *Periarchus quinquefarious?* and a few mollusks.

Jefferson County.—One of the best sections of the Barnwell formation in Jefferson County is exposed in a gully on the east slope of Rocky Comfort Creek about 300 yards above the highway bridge three-quarters of a mile west of Louisville. It is recorded thus by Cooke and Shearer.[95]

Section of the Barnwell formation three-quarters of a mile west of Louisville

	Feet
8. Massive brilliant-red argillaceous sand	10+
7. Fine white silica or tripoli, probably a decomposed chert bed	1–2
6. Indurated yellow sand	6
5. Bluish and yellow mottled clay, laminated but rather plastic, intermediate in properties between fuller's earth and common pipe clay	3
4. Coarse gray sand with a little clay, partly concealed	14½
3. Gray sand and yellow clay, locally indurated	2
2. Concealed interval	15
1. Blue calcareous fossiliferous argillaceous sand, weathering yellow; from creek (215 feet above sea level)	5
	57½

A bed of *Ostrea gigantissima* shells in calcareous clay like that at Shell Bluff is exposed at low water in the south bank of Ogeechee River 200 yards above Cowarts Bridge, 2.6 miles south of Louisville. *O. gigantissima* was found also in an excavation at Warren's mill on Big Creek, 3 miles eastnortheast of Louisville.

Periarchus quinquefarius (Say), the characteristic species of the Sandersville limestone member, occurs in rotten sandy chert on the

[94] Cooke, C. W., and Shearer, H. K., op. cit., p. 61.
[95] Cooke, C. W., and Shearer, H. K., op. cit., p. 66.

road south of Mill Creek near Old Town, 8.4 miles southeast of Louisville (U. S. G. S. 5251). Vaughan [96] reports the following additional species from this place:

Fossils from Old Town

Caricella pyruloides Conrad.	Crassatella protexta lepida (Dall).
Turritella carinata Lea.	Crassatella n. sp.
Mesalia vetusta (Conrad).	Venericardia alticostata Conrad)
Calyptraea aperta (Solander).	Cytherea perovata Conrad.
Glycymeris staminea (Conrad).	Spisula praetenuis (Conrad).
Glycymeris idonea (Conrad).	Corbula densata Conrad.
Glycymeris n. sp.	Lunularia distans (Lonsdale).

In the vicinity of Williamson Swamp Creek below Davisboro, notably 2 miles west of Bartow and near Wadley, are a number of exposures of chert that may have been derived from the Sandersville limestone member. Large masses of silicified limestone south of Ogeechee River on the road to Wadley 3 miles west of Midville contain many obscure *Cerithium* or *Turritella*, and there are also interminable fossils in hard, partly silicified limestone in the old brick pits at Midville, Burke County.

Washington County.—The type locality of the Sandersville limestone member is at a sink and a spring west of the Tennille road 0.8 mile south of the courthouse at Sandersville, where the following section is exposed:

Section of the Sandersville limestone member of the Barnwell formation 1 mile south of Sandersville

	Feet
3. Light-gray chalky limestone; contains *Periarchus quinquefarius* in abundance and casts of other fossils. Exposed in sink	12
2. Very sandy gray limestone containing obscure fossils	5
1. Bright-blue incoherent sand, apparently grading laterally into gray sandy limestone. Exposed in stream below sink	2

In the quarry of the Atlantic Lime Rock Co., 1½ miles south of Sandersville, only 17 feet of cream-colored chalky limestone was exposed in 1930, but borings showed that the rock is about 40 feet thick. The limestone contains many *Periarchus quinquefarius*, bryozoans, fragments of oysters, and a few other mollusks.

Periarchus quinquefarius, obtained by S. W. McCallie between mileposts 138 and 139, on the Central of Georgia Railway about 3½ miles southwest of Tennille (U. S. G. S. 3959), probably came from this horizon. His section and a list of fossils is given by Veatch and Stephenson.[97] About 5 feet of yellowish sandy sparingly glauconitic

[96] Vaughan, T. W., in Veatch, Otto, and Stephenson, L. W., op. cit., p. 292.
[97] Veatch, Otto, and Stephenson, L. W., op. cit., p. 254.

marl exposed in a gully below the railroad track at the overpass of the Dublin road nearby closely resembles the lower bed at the sink a mile south of Sandersville. It contains *Crassatella alta*, *Periarchus* sp., and other fossils.

In an old quarry a quarter of a mile south of Sun Hill there is exposed about 6 feet of compact pale-greenish limestone containing nodules of hard crystalline limestone. The only fossil seen in it in 1922 was a small ribbed *Pecten*, but Veatch and Stephenson [98] report *Flabellum cuneiforme*, *Venericardia alticostata*, and other fossils. These species indicate its Eocene age. The sand nearby contains fragments of an oyster resembling *Ostrea gigantissima*.

Johnson County.—A bluff on Oconee River near Ringjaw Landing contains a few exposures of greenish-gray sandy fuller's earth, which is apparently somewhat calcareous. It includes hard lenses of marlstone containing unrecognizable fragments of a thin-margined *Periarchus* resembling *P. pileus-sinensis* and other fossils. Veatch and Stephenson [99] report *Flabellum cuneiforme*, *Platytrochus stokesi*, *Endopachys maclurii*, *Nucula ovula*, *Pecten "perplanus,"* *Ostrea trigonalis*, *Protocardia nicolleti*, *Lunularia distans*, and several unidentified species including an orbitoid foraminifer.

Wilkinson County.—The following section, typical of the beds in the northern part of Wilkinson County, is adapted from the report by Cooke and Shearer.[1]

Section in pit of Savannah Kaolin Co., 1 mile south of Gordon

	Feet
Eocene:	
Barnwell formation:	
5. Red and mottled argillaceous sand. To top of hill	60
4. (Twiggs clay member) Greenish-yellow fuller's earth containing chalk nodules and a few fossils	10
3. Sandy limestone, with *Pecten spillmani* and abundant Bryozoa	4
2. Argillaceous, glauconitic sand filling erosion depressions in the Cretaceous surface	0–2
Upper Cretaceous:	
Tuscaloosa formation:	
1. Massive white kaolin	30

In Wilkinson County the Twiggs clay member is generally too sandy or calcareous to serve as commercial fuller's earth, and it is not persistent. Where it is absent the Barnwell formation consists entirely of red sand and a few thin beds of plastic clay.

[98] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, p. 255, 1911.

[99] Veatch, Otto, and Stephenson, L. W., op. cit., p. 306.

[1] Cooke, C. W., and Shearer, H. K., Deposits of Claiborne and Jackson age in Georgia: U. S. Geol. Survey Prof. Paper 120, p. 71, 1918.

Baldwin County.—Fossils have been found in the base of the Barnwell formation at Stevens pottery, Baldwin County, where they overlie the Tuscaloosa formation, and in cuts of the Georgia Railroad near Roberts, Jones County, where the Barnwell overlaps beyond the Tuscaloosa onto the crystalline basement rocks. Sections at both these places and lists of the fossils are given by Cooke and Shearer.[2]

Twiggs County.—Cooke and Shearer[3] describe the deposits in the vicinity of Pikes Peak, Twiggs County, thus:

> The Twiggs clay member of the Barnwell attains its greatest thickness in Twiggs County, where, at Pikes Peak, it is mined for use as fuller's earth. The member changes considerably in character from north to south within the county. The best exposures in the northern part are on the property of the General Reduction Co., near Pikes Peak, where there are two well-defined beds of fuller's earth in an interval of about 100 feet. The lower bed is about 45 feet thick, the upper more than 20 feet, and the two are separated by a bed of greenish-yellow fossiliferous sand, which reaches a thickness of 30 feet. The earth in this vicinity is not calcareous except near the base, where it grades into limestone. Where leached and oxidized by surface water it has a pale-yellow to cream color and is extremely light and porous; but below the zone of oxidation it is usually dark gray and contains organic matter and pyrite. Farther south, in the neighborhood of Danville and Westlake, for instance, the fuller's earth bed becomes more and more calcareous. The calcareous clay is blue or gray when unoxidized but becomes cream-colored or yellow at the surface. As it is much less pervious than the noncalcareous variety farther north, the zone of oxidation in many parts of its outcrop extends less than an inch from the surface, whereas in the northern part of the county the material is oxidized to depths of many feet.

Bibb County.—There are several fossiliferous outliers of the Barnwell formation in Bibb County east of Ocmulgee River. At Browns Mountain, west of State Highway No. 87, 1½ miles from the Twiggs County line, about 20 feet of sparingly fossiliferous hard gray sandstone appears to merge into sandy limestone. Andrews Hill, 4½ miles from the Ocmulgee measured along the Twiggs County line, is capped by two massive ledges of greenish-gray sandstone separated by 7 feet of reddish sand containing zones of silicified shells. The upper ledge, about 5 feet thick, contains great numbers of *Periarchus lyelli pileus-sinensis.* Other species from this vicinity are listed by Cooke and Shearer.[4]

OCALA LIMESTONE

GENERAL FEATURES

Name.—The Ocala limestone, named from the town of Ocala, Fla., underlies several large areas in Florida and Alabama, one of which extends northeastward into Georgia as far as Wilkinson County.

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[2] Cooke, C. W., and Shearer, H. K., op. cit., pp. 71–72.
[3] Cooke, C. W., and Shearer, H. K., op. cit., p. 73.
[4] Cooke, C. W., and Shearer, H. K., op. cit., p. 48.

Most of the rocks in Georgia now known to be the Ocala limestone were classified by Veatch and Stephenson [5] as the Vicksburg formation, with which the Ocala limestone of Florida was then correlated. Other rocks now interpreted as part of the Ocala limestone were put by them into the Jackson formation, though the fact that the Ocala limestone of Florida is of Jackson age was not discovered until 4 years later.[6] The first application of the name Ocala to a formation in Georgia was that of Cooke,[7] who in 1915 described the occurrence of the Ocala limestone at Bainbridge. In 1918 Cooke and Shearer [8] formally described the Ocala limestone in Georgia.

Distribution.—The Ocala limestone lies near the surface in a belt—broad in the southwest, narrowing toward the northeast—that extends from Chattahoochee River to Twiggs County. Outcrops of unaltered limestone are most abundant along streams and rivers. The broad undulating plain between the Flint and the Chattahoochee contains some outcrops of silicified limestone, but in most of it the limestone is concealed by a thin cover of Pleistocene sand.

All the southeastern part of the State appears to be underlain at moderate depth by the Ocala limestone. At the Barbour Lathrop Plant Introduction Garden, 12½ miles southwest of the courthouse at Savannah, the top of the Ocala was struck at a depth of 398 feet. The log of a well at Waycross, recorded by McCallie in 1908,[9] indicates that the rock at a depth of 665 feet is the Ocala limestone but possibly not the top of it.

Thickness.—Well records indicate that at Albany the thickness of the Ocala limestone is somewhat more than 280 feet. The limestone may be thicker farther south.

Lithologic character.—The Ocala is predominantly white or cream-colored pure limestone, but the basal beds are commonly sandy and locally contain more sand than lime. At the northeast end of the outcrop it contains much clay and merges laterally into the Twiggs clay member of the Barnwell formation. Unaltered parts of the Ocala are soft and friable, but weathered outcrops generally show ledges of harder rock in which the pores have been filled with crystalline calcite.

Fauna.—Organic remains are notably abundant in the Ocala limestone. Bryozoans, foraminifers, and calcareous algae locally make up a large part of the rock. Mollusks are commonly represented only by

[5] Veatch, Otto, and Stephenson, L W., op. cit., pp. 306–324.

[6] Cooke, C. W., The age of the Ocala limestone: U. S. Geol. Survey Prof. Paper 95, pp. 107–117, 1915.

[7] Idem, p. 110.

[8] Cooke, C. W., and Shearer, H. K., Deposits of Claiborne and Jackson age in Georgia: U. S. Geol. Survey Prof. Paper 120, pp. 41–81, 1918.

[9] McCallie, S. W., A preliminary report on the underground waters of Georgia: Georgia Geol. Survey Bull. 15, pp. 181–183, 1908.

casts, except the scallops, the oysters, and an occasional *Spondylus*. Sea urchins are abundant and generally well preserved. Vertebrates are represented by teeth and vertebrae of fishes and by bones of three species of zeuglodont cetaceans.

Cushman [10] lists about 32 species of small foraminifers from the Ocala limestone in Georgia. This list does not include the Orbitoidae, of which the following species occur at the top of the formation near Bainbridge: *Lepidocyclina georgiana* Cushman, *Discocyclina flintensis* (Cushman), *Pseudophragmina floridana* (Cushman), *Asteriacites mariannensis* (Cushman) and its variety *papillata* (Cushman), *Discocyclina* (*Asterocyclina*) *georgiana* (Cushman), *Asteriacites americana* (Cushman) and *Asteriacites vaughani* (Cushman). With these are associated *Operculina ocalana* Cushman, and *Heterostegina ocalana* Cushman. Some, perhaps all, of these species are not confined to the topmost zone of the Ocala, for Vaughan [11] reports *Lepidocyclina georgiana* and *Discocyclina* (*Asterocyclina*) *georgiana* with *Operculina cookei* Cushman from the lower part of the formation at the Atlantic Coast Line Railway bridge over the Chattahoochee at Saffold.

The topmost 16 feet of the Ocala limestone (depths 398–414 feet) in the deep well at the Barbour Lathrop Plant Introduction Garden near Savannah contains [12] *Operculina ocalana* Cushman, *Heterostegina ocalana* Cushman, *Discocyclina* (*Discocyclina*) *citrensis* Vaughan, *D.* (*Asterocyclina*) *georgiana* (Cushman), a variety of the last-named species with projecting arms, *D.* (*A.*) *mariannensis* (Cushman), *D.* (*A.*) *mariannensis papillata* (Cushman), and an immature *Lepidocyclina* (*Lepidocyclina*) probably *L. ocalana* or *L. georgiana* Cushman.

Canu and Bassler [13] list about 132 species of Bryozoa from the Ocala limestone in Georgia, but many of them are long ranging.

Amusium ocalanum Dall is a common and characteristic mollusk of the Ocala limestone. With it is often *Pecten spillmani* Gabb, which has been incorrectly called *P. perplanus* Morton,[14] and several closely related species or varieties.

Periarchus lyelli (Conrad) and its conical variety *pileus-sinensis* (Ravenel) are the most common echinoids in the lower part of the Ocala limestone but appear not to occur in the upper part. Other

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[10] Cushman, J. A., Upper Eocene Foraminifera of the southeastern United States: U. S. Geol. Survey Prof. Paper 181, table 2 (facing p. 60), 1935. Collection 7719 from 5 miles north of Millen, referred by Cushman to the Ocala limestone, properly represents the Cooper marl.

[11] Vaughan, T. W., letter dated February 9, 1926.

[12] Identifications of T. W. Vaughan.

[13] Canu, Ferdinand, and Bassler, R. S., North American early Tertiary Bryozoa: U. S. Nat. Mus. Bull. 106, pp. 22–23, 1920.

[14] The name *Pecten perplanus* was applied by Morton to the flat valve of *P. poulsoni*, a Vicksburg species.

echinoids that have been found in Georgia are: *Cidaris* (*Phyllacanthus*) *mortoni* Conrad, *Fibularia vaughani* (Twitchell), *Oligopygus haldemani* (Conrad), *Amblypygus americanus* Desor, *Peronella crustuloides* (Morton), *Peronella cubae* Weisbord, *Peronella dalli* (Twitchell)?, *Cassidulus* (*Cassidulus*) *trojanus* Cooke, *C.* (*Paralampas*) *conradi* (Conrad), *C.* (*P.*) *lyelli* (Conrad), *Eurhodia patelliformis* (Bouvé), *Schizaster armiger* Clark, *Agassizia floridana* De Loriol, *Macropneustes mortoni* (Conrad), *Eupatagus* (*Plagiobrissus*) *dixie* Cooke, *E.* (*P.*) *curvus* Cooke, *E.* (*P.*) *ocalanus* Cooke, and *E.* (*Brissopatagus*) *georgianus* Cooke.

The three species of zeulodont cetaceans in the Ocala in Georgia have been identified by Kellogg[15] as *Basilosaurus cetoides* (Owen), *Zygorhiza kochii* (Hammerschmidt), and an archaeocete that may be *Pontogeneus brachyspondylus* (Müller). The first came from Houston County; the others were found on Flint River below the mouth of Cedar Creek, Crisp County.

Stratigraphic relations.—The Ocala limestone represents the deposits of an invading sea that transgressed beyond the shore line of the preceding epoch and laid its sediments unconformably on whatever older formations lay in its path. Remnants of the Ocala, isolated by erosion, lie on the Upper Cretaceous Tuscaloosa formation at Rich Hill, near Roberta. The Ocala sea extended even farther inland, upon the ancient rocks of the Piedmont, but its deposits seem to have been completely removed by erosion. Contemporaneous calcareous sediments, classified for convenience as part of the Barnwell formation, lie on the Piedmont rocks in Jones County.

In Twiggs County the Ocala limestone merges laterally into the Barnwell formation, which adjoins it on the northeast. Parts of the Barnwell in Twiggs, Macon, and Jones Counties might equally as well be classified as Ocala but are not included with it here for convenience in description and mapping. The Ocala limestone east of Flint River was named the Tivola tongue of the Ocala limestone by Cooke and Shearer.[16]

Near Ocmulgee River the Ocala limestone is overlain conformably by the Cooper marl. Farther south the Cooper is overlapped completely by the Flint River formation, which rests unconformably on the Ocala.

Economic significance.—Most of the unaltered Ocala is very pure limestone. It is generally too soft and crumbly to make satisfactory building stone, but it is used at Clinchfield, Houston County, for the manufacture of cement, and is quarried extensively for use as a road

[15] Kellogg, Remington, A review of the Archaeoceti, pp. 20, 105, 256, Washington, 1936.
[16] Cooke, C. W., and Shearer, H. K., op. cit., p. 51.

metal. At many natural exposures, however, all the lime originally in it has been replaced by silica, and the rock at the surface is flint. Many deep wells draw their water from the Ocala limestone, but the water yielded by them is hard and at some places is contaminated.

LOCAL OCCURRENCE

Chattahoochee River.—On Chattahoochee River the basal beds of the Ocala limestone are exposed at the bridge of the Atlantic Coast Line Railway at Saffold. The rock is hard gray to yellow-brown calcareous sandstone containing many large *Periarchus lyelli*, bryozoans, foraminifers, and other fossils. At the site of the old railroad bridge a quarter of a mile farther downstream, the rock is less sandy, and contains large oysters. At the crossing of the highway (US 84) from Bainbridge to Dothan, about a mile below the railroad bridge, the Ocala limestone rises 18 feet above water, and contains innumerable *Discocyclina* sp., large broad-hinged oysters, and *Crassatella alta.*

There are many other exposures of the Ocala limestone on Chattahoochee River. About 25 feet of hard, white limestone containing *Amusium ocalanum* and other fossils (U. S. G. S. 6765) was noted in 1913 on the Georgia side about a quarter of a mile below Bartons Landing, Fla., and similar rock rises about 5 feet above water at a place above Haywood Landing, and about 2 miles below Bartons. The top of Ocala apparently passes beneath water level in the neighborhood of Fairchild Landing, where the Flint River formation is exposed.

Spring Creek and its tributaries.—Many of the springs that give Spring Creek its name rise in the Ocala limestone. The rock is silicified at the highway bridge at Colquitt, where *Operculina* sp., *Lepidocylina* sp., and *Ostrea trigonalis* were recognized. Massive ledges of silicified limestone rise 23 feet above the creek near Pilgrims Rest Church, 6½ miles below Colquitt. Large oysters and orbitoid foraminifers occur in great masses of chert at an old grist mill on Aycock Creek at Twilight, 1½ miles northwest of Pilgrims Rest Church.

Brantly[17] reports exceptionally pure limestone (98.6 percent $CaCO_3$) on Spring Creek, 1½ miles above the trestle of the Central of Georgia Railway, 4 miles west-northwest of Arlington. The limestone rises 15 feet above the swamp level and is said to extend to a depth of at least 60 feet. He also noted[18] hard cream-colored

[17] Brantly, J. E., A report on the limestone and marls of the Coastal Plain of Georgia; Georgia Geol. Survey Bull. 21, p. 132, 1916.
[18] Idem, p. 173.

limestone rising 2 feet above water level in Watsons Spring, on the west side of Spring Creek, 3 miles below Brinson. The rock contains *Pecten* sp. and orbitoid foraminifers.

Flint River.—Flint River crosses the Ocala limestone between Pennahatchie Creek and Swift Creek. Below Swift Creek the river runs along the upper part of the formation to Blue Spring Creek, 3½ miles below Bainbridge, where the uneven top of the limestone is partly above and partly below water level. Forty feet of limestone in alternating hard and soft ledges is exposed on the east bank of the river at Limestone Bluff, a mile above the mouth of Cedar Creek. The lower part of the rock contains *Amusium ocalanum* and other fossils (U. S. G. S. 7110).

An exposure of 15 feet of limestone at the power plant at the mouth of Kinchafoonee Creek, 2 miles north of Albany, is notable for the number of echinoids that it contains. Among them are *Cidaris mortoni* Conrad, *Eurhodia patelliformis* (Bouvé), *Cassidulus conradi* (Conrad), *Eupatagus dixie* Cooke, *E. curvus Cooke*, *Macropneustes mortoni* (Conrad), and *Schizaster armiger* Clark. Among the mollusks are *Eucymba ocalana* Dall, *Cypraea fenestralis* Conrad, *Pecten spillmani* Gabb (varieties), *Amusium ocalanum* Dall, and *Vulsella ocalensis* MacNeil.

The topmost zone of the Ocala in Georgia is exposed on Flint River near Bainbridge at several places between Red Bluff, 6 miles above Bainbridge, and Blue Spring. It is white to cream-colored limestone composed chiefly of a loose or case-hardened mass of marine organisms of many kinds. Orbitoid foraminifers are very abundant. Echinoids are represented by *Cidaris mortoni* Conrad, *Peronella crustuloides* (Morton), *Oligopygus haldemani* (Conrad), *Eupatagus curvus* Cooke, *Eupatagus ocalanus* Cooke, *Agassizia floridana* De Loriol, and *Fibularia vaughani* (Twitchell). Mollusks include *Pecten spillmani* Gabb, *P. indecisus* Dall, *P. suwaneenis* Dall, *Amusium ocalanum* Dall, and others. This zone appears to be identical with that exposed on Chipola River at Marianna, Fla. In Georgia it is overlain unconformably by the Flint River formation; in Florida, by the Marianna limestone, of lower Vicksburg age.

Crawford County.—A notable outlier of the Ocala limestone lies on the Tuscaloosa formation on Rich Hill, 4½ miles east-southeast of the courthouse at Knoxville, Crawford County, and more than 20 miles from any other known exposure of the Ocala. It includes a littoral or near-shore facies similar to the Barnwell formation. The following section is adapted from one by Veatch and Stephenson:[19]

[19] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, p. 299, 1911.

Section at Rich Hill

	Feet
Ocala limestone (Eocene):	
13. Brilliant red sand capping the hill and forming "creep" on the upper slopes	30
12. Purplish and yellow sand containing thin clay laminae	12
11. Greenish laminated clay, thin lignitic partings	4
10. Plastic calcareous clay with fossils	½
9. Jointed drab laminated clay with sand partings	6
8. Fossiliferous nodular calcareous layer	1
7. Drab soft laminated clay with fossils; contains nodular calcareous layers	12
6. Limestone, generally soft and friable, but in places hard and compact; in places it is a bryozoan marl so soft that it can be scraped up with the hands. Contains *Periarchus lyelli pileus-sinensis, Pecten spillmani,* and other fossils. Fish teeth are abundant in places	20
5. Brown and yellow unconsolidated sand, which in places is replaced by limestone	12
Tuscaloosa formation (Upper Cretaceous):	
4. White micaceous clay; maximum	10
3. White cross-bedded clayey sand	10
2. White micaceous clay	3
1. Coarse white sand	10

Cooke and Shearer [20] give two additional sections at Rich Hill, which show the variability of the strata.

Houston County.—The Ocala limestone crops out along the northern face of the eastward-trending escarpment that passes 4 miles south of Perry. There are notable exposures on it near the roads from Perry to Henderson (US 41) and Elko. At Clinchfield, near the east end of the escarpment, about 40 feet of limestone is quarried for use in a cement mill. This rock contains *Asterocyclina* sp., *Periarchus lyelli pileus-sinensis, Pecten spillmani, Protocardia nicoletti,* and other fossils, including many bryozoans.

Pulaski County.—The Ocala limestone crops out on both sides of the valley of the Ocmulgee, but there are few exposures in the river banks. About 5 feet of soft, white, granular limestone exposed near water level at Hawkinsville and overlain by limestone of Vicksburg age may be Ocala, though it has been mapped as Cooper marl. Half a mile above the railroad bridge at Hawkinsville, soft, gray, highly calcareous marl containing *Flabellum* sp., *Spondylus* sp., shark teeth, and many bryozoans has been blasted from the channel. At High or Taylors Bluff, on the east side of the Ocmulgee, 3½ miles above Hawkinsville, there is 48 feet of soft gray, moderately argillaceous

[20] Cooke, C. W., and Shearer, H. K. Deposits of Claiborne and Jackson age in Georgia: U. S. Geol. Survey Prof. Paper 120, p. 77, 1918.

limestone, the lower 15 feet of which is very sandy. Veatch and Stephenson [21] found *Amusium ocalanum* 22 feet above the base of the bluff, and report *Flabellum cuneiforme*, *Sphenotrochus* sp., *Endopachys maclurei*, *Leda multilineata*, *Venericardia planicosta*, and *Lunularia* sp. from the lower 20 feet. According to Brantly,[22] the beds in the upper half of the exposure at Taylors Bluff crop out on the west bank at Colliers Bluff, a mile farther upstream, and in another bluff on the west side, 5½ miles above Hawkinsville.

Bleckley and Twiggs Counties.—Brantly mentions deposits of limestone of Jackson age (Ocala) at Ainsley station and other places in Bleckley County, and in Twiggs County.

COOPER MARL

GENERAL FEATURES

Name.—The name Cooper marl is derived from the Cooper River in South Carolina. The use of the name and the occurrence of the formation in South Carolina have been fully discussed by Cooke.[23] The formation has never before been recognized in Georgia. The soft, marly limestone near Millen that is here correlated with the Cooper was tentatively put in the Chattahoochee (Tampa, of present usage) formation by Veatch and Stephenson,[24] though they were very doubtful as to where it belongs. Other exposures they classified as Jackson formation, which appears to be its true equivalent.

Distribution.—Known exposures of the Cooper marl in Georgia are limited to areas in Jenkins County north of Millen, and in Bleckley, Pulaski, and Houston Counties. The formation is continuous under cover between these outcrops and the typical areas near Charleston, S. C.

Thickness.—The thickest exposure in South Carolina is 76 feet, but under cover it is about 100 feet thicker. Exposures in Georgia apparently do not much exceed 33 feet; the thickness under cover is unknown.

Lithologic character.—The formation consists of cream-colored to drab, finely granular, highly calcareous marl or soft limestone. It contains scattered grains of glauconite.

Fauna.—The most abundant organisms in the Cooper marl are the foraminifers. No orbitoids have been found in it, but 24 species of smaller foraminifers have been identified from one place (Spring Mill Branch). Sixteen species occur also in the Cooper marl in South

[21] Veatch, Otto, and Stephenson, L. W., op. cit., p. 305.
[22] Brantly, J. E., op. cit., p. 107.
[23] Cooke, C. K., Geology of the Coastal Plain of South Carolina: U. S. Geol. Survey Bull. 867, pp. 73–75, 82–89, 1936.
[24] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, p. 341, 1911.

Carolina, and all occur elsewhere in deposits of Jackson (upper Eocene) age. The formation includes also a good many bryozoans, but the species have not been identified. Among the mollusks found in Georgia are two or three species of *Pecten* and an *Epitonium*. The only echinoid yet found in the Cooper is *Periarchus kewi* Cooke.

Stratigraphic relations.—The Cooper marl overlies the Ocala limestone with apparent conformity. Its contact with the Barnwell formation has not been seen, but presumably it is younger than the Sandersville limestone member and perhaps conformable with it. In 1936 Cooke[25] suggested that the lower part of the Cooper might be equivalent to the upper part of the Barnwell, but it now seems more likely that the Cooper is younger than any part of the Barnwell. However, it would not be surprising if the littoral facies of the Cooper resembled the littoral facies of the Ocala, and both may be represented in the Barnwell. The Cooper is overlain unconformably by the Flint River formation. The hiatus between them represents all the early part of Oligocene time.

Economic significance.—The Cooper marl contains much lime and some potash. It is porous and friable. These qualities should make it valuable for use as a raw slow-acting fertilizer. It may contain some phosphate also, for in South Carolina it is phosphatic.

LOCAL OCCURRENCE

Jenkins County.—The presence of soluble rocks not far beneath the surface in an area north of Millen is indicated by many sinks. Magnolia Spring, 5½ miles north of Millen, issues from soft yellow marly limestone, which can be seen beneath the water. At the mouth of Spring Mill Branch, 4½ miles north-northwest of Millen, 4 or 5 feet of creamy-yellow soft finely granular limestone is exposed below the old Spring Mill dam. The rock contains a small delicately ribbed *Pecten*, a few bryozoans, and foraminifers. A collection made by Mr. Shearer and the writer (U. S. G. S. 7719) yielded the 24 species of foraminifers listed below.[26] Sixteen of these species occur in the Cooper marl in South Carolina.

Foraminifers from old Spring Mill

[Identified by Joseph A. Cushman]

Lenticulina convergens (Bornemann).
Saracenaria arcuata hantkeni Cushman.
Planularia truncana (Gümbel).
Marginula cocoaensis Cushman.
Dentalia cocoaensis (Cushman).
Dentalina cooperensis (Cushman).
Dentalina jacksonensis (Cushman and Applin).
Nodosaria latejugata Gümbel.

[25] Cooke, C. W., op. cit. (Bull. 867), pp. 82–83.

[26] Cushman, J. A., Upper Eocene Foraminifera of the southeastern United States: U. S. Geol. Survey Prof. Paper 181, table 2 (facing p. 60), 1935.

Nodosaria ewaldi Reuss?
Nodosaria fissicostata (Gümbel).
Lagena acuticosta Reuss.
Lagena costata (Williamson).
Guttulina irregularis (d'Orbigny).
Globulina gibba d'Orbigny.
Globulina münsteri (Reuss).
Pseudopolymorphina dumblei (Cushman and Applin).
Hantkenina alabamiensis Cushman.
Bolivina gardnerae Cushman.
Bolivina jacksonensis Cushman and Applin.
Uvigerina cookei Cushman.
Uvigerina jacksonensis Cushman.
Angulogerina ocalana Cushman.
Eponides jacksonensis Cushman and Applin.
Cibicides lobulatus (Walker and Jacob).

According to Veatch and Stephenson[27] rather hard white sandy fine-grained limestone, presumably the Cooper marl, containing a small *Pecten* and other fossils was dug from a well on the Alexander Murphy place, 9 miles northwest of Millen.

Houston County.—Above the Ocala limestone in the quarry at Clinchfield lies about 33 feet of creamy-yellow highly calcareous clay with ledges of limestone. It contains barnacle plates, a few bryozoans, and a poorly preserved *Pecten*. It appears to represent the Cooper marl. Similar clayey limestone crops out between the Ocala limestone and the Flint River formation at several places along the escarpment about 4 miles south of Perry.

United States Highway No. 341 (Perry to Hawkinsville) 4.2 miles southeast of Clinchfield cuts into about 6 feet of finely granular cream-colored soft limestone or marl tinged green by small grains of glauconite. This rock contains many small foraminifers, bryozoans, about three species of *Pecten*, an *Epitonium*, and *Periarchus kewi* Cooke. The marl is overlain by chert-bearing orange sand of the Flint River formation. Four feet more of marl is exposed at a culvert 100 yards away and 38 feet lower than the bottom of the Flint River formation. The marl appears to merge downward into fuller's earth at an exposure on the same road 0.2 mile farther northwest.

Pulaski County.—Soft marly limestone intervening between the Flint River formation at Hawkinsville and the supposed Ocala limestone at Taylors Bluff, which is on the east bank of Ocmulgee River 3 miles above Hawkinsville, is suspected to represent the Cooper marl, though it has not been examined since the formation in Georgia was first recognized. In 1915, compact soft marly limestone, greenish at the base, white above, rose vertically 11 feet above water in the bluff on Ocmulgee River below the highway bridge at Hawkinsville. It was overlain by a sloping bank of residual clay and decomposed chert derived from the Flint River formation. When revisited in 1937 the limestone appeared to be completely covered by waste from a sawmill. In 1922 piles of soft gray highly calcareous marl that had been blasted from the channel about half a mile above the railroad bridge con-

[27] Veatch, Otto, and Stephenson, L. W., op. cit., p. 341.

tained many corals (*Flabellum* sp.), bryozoans, shark teeth, and *Spondylus* sp. Another pile about a quarter of a mile below Taylors Bluff consisted chiefly of blue calcareous clay. Veatch and Stephenson [28] report *Amusium ocalanum*, a characteristic fossil of the Ocala limestone, from Taylors Bluff near the top of a 17-foot bed of fossiliferous limestone, which is overlain by 25 feet of massive soft argillaceous limestone, probably the Cooper marl.

OLIGOCENE SERIES

GENERAL FEATURES

The name Oligocene is applied to a series of deposits intermediate in age between the Eocene series below and the Miocene series above. There has been little disagreement as to the location of the lower boundary, but opinions differ as to where to place the boundary between the Oligocene and the Miocene. For some years the Tampa limestone and the Alum Bluff group (represented in Georgia by the Hawthorn formation) were classified as Oligocene, but since 1924 they have been referred by members of the United States Geological Survey to the Miocene. Some geologists prefer to draw the line still lower, but others would restore the Tampa and perhaps also the Alum Bluff to the Oligocene. At what location the boundary between the Oligocene and the Miocene is placed is not of much practical importance because it does not affect the correlation of individual formations with one another. In the present report the current usage of the United States Geological Survey is followed; that is, the boundary between the Oligocene and the Miocene is drawn at the base of the Tampa limestone. The formations recognized are named in the correlation table on page 40.

The Oligocene is most completely developed in Mississippi, where it includes the Vicksburg group. In Georgia the older formations of the series are absent, but the youngest horizon appears to be represented by the Flint River formation and the Suwannee limestone. The latter occupies only a very small area along Withlacoochee River, up which it extends from Florida, where it is an important formation.

FLINT RIVER FORMATION

GENERAL FEATURES

Name.—The name Flint River formation was proposed by Cooke [29] in 1935 for deposits in Georgia and southeastern Alabama that are typically exposed above the Ocala limestone along the Flint River

[28] Veatch, Otto, and Stephenson, L. W., op cit., p. 305.

[29] Cooke, C. W., Notes on the Vicksburg group: Am. Assoc. Petroleum Geologists Bull., vol. 19, pp. 1170–1171, 1935.

between Hales Landing and Red Bluff near Bainbridge. The typical outcrops were regarded as the lower part of the Chattahoochee formation by Veatch and Stephenson,[30] who, however, correctly placed other parts of the Flint River in the Vicksburg "formation." In 1923 Cooke [31] discovered that the fauna of the chert beds near Bainbridge is much more closely related to Vicksburg faunas than had been supposed. He correlated it with that of the Glendon limestone of western Alabama, which lies in the Vicksburg group between the Marianna limestone and the Byram marl. Later,[32] he was lead to doubt this correlation with the Glendon because the fauna of the Chickasawhay marl of Mississippi, which is younger than the Byram, was found to have much in common with that of the Antigua limestone of the British West Indies, which is correlated with the Flint River formation because of its similar foraminifers and corals.

Distribution.—The Flint River formation extends across Georgia from Chattahoochee River between Fort Gaines and the mouth of the Flint to Screven County. The band of outcrop between Seminole County and Dooly County is divided by a wide strip of the underlying limestone. Between Oconee River and the valley of the Savannah the formation is covered by an overlap of the Hawthorn formation and by Pleistocene terrace deposits.

The topography of the region where the Flint River formation lies at the surface is generally gently rolling. It is not so flat as that underlain by the Ocala limestone. The principal soils derived from the Flint River are the Greenville sandy loam and related types.

Thickness.—There are no reliable measurements of the thickness of the Flint River formation. About 70 feet of limestone referable to the Flint River was once exposed at Waterfall, a sink 11 miles north of Whigham. A well at the Barbour Lathrop Plant Introduction Garden, 12½ miles southwest of Savannah, passed through 148 feet (depths 250–398 feet) of limestone between the Hawthorn formation and the Ocala limestone. It is not known whether all of this represents the Flint River.

Lithologic character.—In its original condition the Flint River formation varied from pure homogeneous limestone to sandy and pebbly limestone, sand, and gravel. At most of the outcrops the limy part has been either dissolved out, leaving a crumpled mass of varigated residual clay, sand, and gravel, or completely silicified into chert. Unaltered limestone remains only where the rock has been protected by

[30] Veatch, Otto, and Stephenson, L. W., op. cit., p. 328–332.

[31] Cooke, C. W., The correlation of the Vicksburg group: U. S. Geol. Survey Prof. Paper 133, pp. 1–9, 1923.

[32] Cooke, C. W., Notes on the Vicksburg group: Am. Assoc. Petroleum Geologists Bull., vol. 19, pp. 1162–1172, 1935. See also Cooke, C. W., in Mansfield, W. C., Mollusks of the Chickasawhay marl: Jour. Paleontology, vol. 14, pp. 171–173, 1940.

a thick cover. Exposures of it are most common beyond the normal area of outcrops in sinks that penetrate to it through the overlying Hawthorn formation. This limestone, being farther from the original shore line of the Flint River sea, is less sandy than that farther inland.

The sandy and pebbly parts of the Flint River, which represent a littoral facies of the formation, occupy a large part of the area of outcrop; but chert lumps of varying sizes and abundance are widely distributed. Some of the chert contains large angular pebbles. It usually contains also molds of fossils, which, if identifiable, readily distinguish it from silicified Ocala limestone. The lumps derived from the Flint River are ordinarily smaller, less angular, and darker colored than those derived from the Ocala, a purer limestone. They are not likely to be mistaken for chert of Clayton or Tampa age, both of which formations yield chert that is yellower and more or less botryoidal.

Fauna.—The fauna of the Flint River formation near Bainbridge, the only part that has been critically studied, is a reef facies including many corals, calcareous algae, and reef-dwelling mollusks. The list of mollusks, as described by Dall [33] in 1916 and revised by Cooke [34] in 1923, includes 82 species, of which 10 species belong to the genus *Cerithium*. *Orthaulax hernandoensis* Mansfield is widely distributed in Georgia and Alabama, also in the Suwannee limestone of Florida. One of the most convenient of the mollusks for identifying the chert of the Flint River is *Glycymeris cookei* Dall, originally described from a place near Bainbridge but since found in the Flint River formation at many other places and also at Vicksburg, Miss. The orbitoid foraminifers *Lepidocyclina undosa* Cushman and *L. favosa*, Cushman, which are locally common in the Flint River, indicate a correlation with the Chickasawhay marl, the Antigua formation, and equivalent deposits in Mexico. The echinoids *Clypeaster rogersi* (Morton) and *Cassidulus gouldii* (Bouvé) are rather rare. The latter is very common in the Suwannee limestone in Florida. Critical study of the fauna of the Flint River formation as a whole may reveal the existence of more than one zone within it; but such incomplete studies as have been made suggest that the known local differences are the result of differences of facies rather than of time. The formation seems to be definitely of Oligocene age. It apparently ties in most closely with the youngest stage of the Oligocene, the Chickasawhay marl, whose fauna, however, is still very imperfectly known.

Stratigraphic relations.—The Flint River formation lies uncomformably on the Ocala limestone and overlaps across it and older

[33] Dall, W. H., A contribution to the invertebrate fauna of the Oligocene beds of Flint River, Ga.: U. S. Nat. Mus. Proc., vol. 51, pp. 487–524, pls. 83–88, 1916.

[34] Cooke, C. W., op. cit. (Prof. Paper 133), pp. 5–6.

Eocene formations to the Clayton. The hiatus between the Flint River and the Ocala apparently includes all the interval of time represented by the Byram marl and older Oligocene formations and perhaps also the Cooper marl. However, some of these formations may have been removed by erosion during a shorter interval. The formation appears to be nearly equivalent to the Suwannee limestone, of which it is probably the littoral facies, but possibly nowhere represents quite so long a period of deposition as the Suwannee. It is probably equivalent, or partly so, to the Chickasawhay marl of Mississippi and Alabama. Its relations to the overlying Tampa limestone are not known with certainty, but the writer suspects that there is a stratigraphic break between them. There must certainly be a break between the Flint River and the Hawthorn formation, which overlaps beyond the Tampa.

Economic significance.—Lumps of chert from the Flint River formation are used as a decorative stone in walls, in borders of flower beds, and to some extent in houses. The unaltered limestone is suitable for making lime, and the harder parts for use as building stone. The accessible limestone deposits have been described by Brantly.[35]

LOCAL OCCURRENCE

Seminole County.—On Chattahoochee River the Flint River formation is well exposed at Fairfield Landing, Seminole County, where large masses of porous and vitreous chert containing many *Lepidocyclina favosa?* are associated with residual gray sandy clay. It is overlain by pebble-bearing terrace sand.

Decatur County.—On Flint River the lowest known exposure of the Flint River formation is at Wyley Landing, which is on the south bank 3 miles above the mouth of Spring Creek. Near the water level is irregularly indurated white limestone containing many reef corals, *Lepidocyclina favosa?*, *Lima halensis*, and other fossils. The limestone, which varies in texture from loose and granular to hard, massive, and crystalline, is overlain by sticky greenish clay that is probably residual from it. Still higher is hard conglomeratic limestone supposed to be basal Tampa.

About 3 feet of hard crystalline limestone, presumably Flint River, was noted in 1914 at the lower end of Fort Scott Bluff, on the right bank of Flint River 1½ miles below Hutchensons Ferry. At Hutchensons Ferry, 7¼ miles east-northeast of the mouth of Spring Creek, huge lumps of chert of the Flint River formation rise almost 15 feet above water level. Five feet of hard pinkish-white limestone containing obscure corals crops out on the east bank 5¼ miles northeast

[35] Brantly, J. E., A report on the limestones and marls of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 21, 300 pp., map, 1916.

of Hutchensons Ferry. This place is 3 miles below Hales Landing. *Cassidulus gouldii* was noted in 1914 in large masses of chert 2 miles below Hales Landing.

At Hales Landing, 6¼ miles southwest of the highway bridge at Bainbridge, large blocks of chert contain many silicified fossils including, according to Vaughan,[36] about 21 species of corals. Corals are also present at Little Horseshoe Bend, Blue Spring, and Cherry Chute, 3 to 4 miles below Bainbridge.

At Red Bluff, on Flint River 6 miles north of Bainbridge, pinnacles of Ocala limestone, crested with limonite, rise 20 feet above the water. The Flint River formation, which overlies it unconformably, contains much gravel throughout. Much of it may have been originally calcareous sandstone—an algal reef—but all the lime has been leached out. The formation now consists of fine cohesive sand and gravel, in which are embedded lumps of fossiliferous chert. The colors are light yellows and grays.

Limestone from Cato Glenn's well, 5 miles southwest of Bainbridge, yielded the type of *Lepidocyclina chattahoocheensis* Cushman, which name has been put in the synonymy of *L. favosa* Cushman. This species is reported also in the Flint River at Red Bluff and at the old factory 1½ miles above Bainbridge.

Grady County.—The Flint River formation is reached in several deep sinks in the northwestern part of Grady County. Silicified limestone containing *Lepidocyclina favosa*, algae, and *Pecten* sp. is exposed in the sides of Bay Sink, 9 miles north by west of Whigham, and lumps of chert extend to the level of the upland, which is coated with loose gray sand. In 1914, 13½ feet of light gray to pinkish-yellow semicrystalline limestone containing *Pecten* sp. and *Lepidocyclina favosa?* was exposed in the bottom of Forest Falls (Lime Sink), 6½ miles north of Whigham. Its thickness as reported by Veatch and Stephenson [37] was 35 feet. As the sink has filled in considerably since then, this rock is no longer exposed. (See section on page 92.)

One hundred feet of limestone was exposed in 1914 in a sink called Waterfall on the I. E. Maloy property, 11 miles north of Whigham and about 3 miles northeast of Forest Falls. The upper 30 feet is more sandy than the lower part and probably represents the Tampa limestone. The lower part, which is nearly pure,[38] is Flint River, for it contains *Lepidocyclina favosa?*, *Orthaulax* sp., *Turritella* sp., *Cerithium silicifluvium*, and a coral (U. S. G. S. 7092 and 7136).

Mitchell County.—Large blocks of reef rock at Greenough are composed chiefly of calcareous algae but contain also a few large-calyced

[36] Vaughan, T. W., in Veatch, Otto, and Stephenson, L. W., op. cit., p. 332.
[37] Veatch, Otto, and Stephenson, L. W., op. cit., p. 335.
[38] Brantly, J. E., op. cit., pp. 182–185.

corals and many *Lepidocyclina favosa*. *Glycymeris cookei* and other fossils are in great blocks of chert at Niggerhead Bend on Flint River at the Mitchell-Dougherty County line. The chert weathers into reddish, yellowish, and purplish sandy clay like that near Bainbridge.

Worth County.—Hard white limestone of the Flint River formation containing many algae, *Lepidocyclina favosa*, and *Pecten* sp. is exposed in a cave at the bottom of a sink 50 feet north of the road from Bridgeboro to Albany a quarter of a mile or less east of the Dougherty-Worth County line and about three-quarters of a mile north of the corner of Dougherty and Mitchell Counties. The rock is silicified outside the cave but not within. About 15 feet of rock is visible from the surface.

Another sink about 50 feet north of the road 6.4 miles west of Isabella shows about 13 feet of silicified limestone. It contains foraminifers (probably *Lepidocyclina favosa*) and *Clypeaster cotteaui* Egozcue. The latter species, described from Cuba, has also been reported from Antigua and Jamaica.

On both sides of Jones Creek on the Albany road 1¼ miles southwest of Oakfield are large residual blocks of white chert from which the species in the following list were collected.[39]

Fossils from Jones Creek 1¼ miles southwest of Oakfield (U. S. G. S. 7118)

Lepidocyclina sp.
Conus cookei Dall.
Conus alveatus Conrad.
Lyria? sp.
Xancus wilsoni (Conrad).
Phalium caelatura (Conrad).
Murex sp.
Gypraea sp.
Cerithium mascotianum Dall?
Cerithium halense Dall.
Cerithium corallicolum Dall.
Cerithium cookei Dall.
Ampullina mississippiensis (Conrad).
Glycymeris mississippiensis (Conrad).
Arca sp. cf. A. subprotracta Heilprin.
Pecten n. sp.
Pecten n. sp.
Pecten anatipes Morton.
Pecten poulsoni Morton?
Spondylus filiaris Dall.
Lima halensis Dall.
Modiolus mississippiensis Conrad.
Macrocallista (Chionella) sobrina (Conrad).
Chione bainbridgensis Dall.
Phacoides (Miltha) sp.
Phacoides (Here) wacissanus Dall.
Cardium glebosum Conrad.
Cardium sp.
Crassatella sp.

Randolph County.—About 25 feet of Flint River formation is exposed at the underpass on the Central of Georgia Railway 2½ miles east of Cuthbert. It consists chiefly of broken sparingly fossiliferous chert, which appears to be disintegrating into coarse argillaceous sand. Where freshly disintegrated the color is light yellow to purple. Further weathering changes it to mottled orange and red.

Sumter County to Pulaski County.—There are many lumps of chert between Americus and Plains and between Hogcrawl Creek and

[39] Cooke, C. W., op. cit. (Prof. Paper 133), p. 8.

Hawkinsville. Above the supposed Cooper marl in the bank of Ocmulgee River at Hawkinsville is harder, more or less nodular limestone containing *Lepidocyclina favosa?* and *Clypeaster rogersi.* Limestone is continuously exposed on the west bank for 2 miles downstream. Limestone is also exposed on the first hill beyond the railroad trestle on the Fitzgerald road at the south edge of Hawkinsville. Woods Springs, 8 miles south of Hawkinsville, issues from beneath about 15 feet of yellowish chert.

Wilcox County.—Hard white limestone containing many calcareous algae, *Lepidocyclina* sp., and *Pecten* sp. is exposed at the edge of the Ocmulgee swamp opposite Wilcox's sawmill, about 3 miles below Abbeville. Similar rock extends to a height of 12 feet above water on the west bank of the river at Jordan Bluff, 4.9 miles by road below Abbeville. The lower part, which is hard and nodular, contains calcareous algae, *Lepidocyclina favosa?*, and *Glycymeris* sp. The upper part is softer but contains small hard nodules. It is overlain unconformably by greenish sandy clay of the Hawthorn formation. Loose lumps of white limestone containing *Lepidocyclina favosa?* were noted in a field south of a small branch east of the Fitzgerald road 1 mile south of Abbeville.

A series of sinks west of the Abbeville-Center School road 9 miles southwest of Abbeville and half a mile northeast of the Rochelle-Fitzgerald road at Center School exposes the Flint River formation. At the bottom of the deepest sink is hard white somewhat conglomeratic limestone containing many calcareous algae and several species of *Lepidocyclina*, many small foraminifers, *Pecten* sp., and *Cardium* sp. In a dry runway leading into the sink are discontinuous exposures of soft chalky white limestone containing *Cassidulus gouldii* and many loose silicified shells of *Ostrea vicksburgensis* and *Pecten* sp. (U. S. G. S. 10324). On the slopes above the sink are exposures of sandstone and chert of Hawthorn age.

Laurens County.—Large blocks of chert containing a thick species of *Lepidocyclina* and fossil mollusks underlies bright red sand on the road from Dublin to Montrose half a mile west of Turkey Creek. About 5 feet of friable fine-grained yellowish fossiliferous chert is exposed on the east side of Turkey Creek 1½ miles northeast of Dudley; it is overlain by brick-red sand.

Screven County.—Blue Spring, north of Beaverdam Creek 6 miles north-northeast of Sylvania, issues as a bold stream from soft white limestone. The same rock is exposed a quarter of a mile away in an old quarry on the H. T. Reddick property, south of Beaverdam Creek. Brantly [40] reports 16 feet of soft white limestone there. According to the owner, a drill hole at the foot of the outcrop and about 5 feet above

[40] Brantly, J. E., op. cit., p. 55.

the level of the creek went 20 feet into the limestone without reaching its bottom. This is the type locality of *Clypeaster jonesii* (Forbes), which apparently is a synonym of *C. rogersi* (Morton), and of *Cerithium georgianum* Lyell and Sowerby. The rock contains molds of many mollusks. The rock was named Jacksonboro limestone by Dall and Harris,[41] but that name has not come into general use.

There is another exposure of white compact fossiliferous limestone on the south side of Brier Creek half a mile below New Bridge, which is three-quarters of a mile below the mouth of Beaverdam Creek.

The so-called Jacksonboro limestone has been assigned to various ages ranging from Eocene to Miocene. It probably forms part of the Flint River formation.

Masses of brittle, vitreous chert rising 10 feet above Brier Creek on a stock farm west of Millhaven contain *Lepidocyclina* sp., *Pecten anatipes*, and a few other fossils. Similar rock is exposed on the Girard road 1½ miles north of Millhaven.

SUWANNEE LIMESTONE

GENERAL FEATURES

Name.—The name Suwannee limestone was proposed in 1936 by Cooke and Mansfield,[42] and the formation was further described in Mansfield's report on the fauna.[43] The rock included in it has previously been referred to the Vicksburg group, to the Hawthorn formation, or to the Tampa limestone.

Distribution.—The type area is along the Suwannee River above the bridge of the Seaboard Railway at Ellaville, Fla. From Ellaville the Suwannee limestone extends up the Withlacoochee River across the State line possibly as far as the highway bridge west of Ousley, Lowndes County, Ga. The formation doubtless underlies a much larger area in Georgia and may be continuous with the limestone of the Flint River formation.

Thickness.—Only 18 or 20 feet of Suwannee limestone is exposed in Georgia, but in Florida the formation is nearly 100 feet thick.

Lithologic character.—The typical Suwannee limestone varies from a friable mass of calcareous granules to hard resonant limestone. It is generally yellowish or cream in color. It is much purer than the Tampa limestone, which at most places contains much very fine sand, but it probably is not quite so pure as the Ocala limestone.

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[41] Dall, W. H., and Harris, G. D., Correlation papers; Neocene: U. S. Geol. Survey Bull. 84, p. 83, 1892.

[42] Cooke, C. W., and Mansfield, W. C., Suwannee limestone of Florida (abstract): Geol. Soc. America Proc. for 1935, pp. 71–72, 1936.

[43] Mansfield, W. C., Mollusks of the Tampa and Suwannee limestones of Florida: Florida Dept. Cons. Geol. Bull. 15, pp. 46–62, 1937.

Fauna.—Well-preserved fossils are not common in the Suwannee limestone because most of the shells have been dissolved and have left only molds. An exception is the echinoid *Cassidulus gouldii* (Bouvé), which occurs abundantly at many places in Florida. This species has been found also in the Flint River formation at widely scattered localities—in fact, the type came from the Flint River formation. Mansfield [44] lists only nine species of mollusks that are identical with or very closely related to species in the Flint River, but his distinctions of species are based on very minute differences. Among these species is *Orthaulax pugnax hernandoensis* (Mansfield). A significant species in the Suwannee is *Teredo incrassata* (Gabb), which appears to be identical with *T. circula* Aldrich, a species common in the Chickasawhay marl in Alabama and Mississippi. No specimens of *Lepidocyclina* or other orbitoid foraminifers have yet been found in the Suwannee limestone. The conical foraminifer *Coskinolina cookei* Moberg is abundant in the type area but possibly was reworked from older deposits.

Stratigraphic relations.—At Ellaville, Fla., the Suwannee limestone lies unconformably on a thin bed of limestone containing *Lepidocyclina supera* and many Vicksburg mollusks and therefore probably of Byram age. It probably overlaps the Byram onto the underlying Ocala limestone. From these relations and from the similarity of the faunas it seems probable that the Suwannee merges laterally into the Flint River formation, which appears to be its littoral equivalent. The Suwannee limestone may, however, include beds younger than any part of the Flint River formation now preserved. The Suwannee is overlain unconformably by the Hawthorn formation, which overlaps beyond its margin in Georgia. Farther south in Florida the Tampa limestone intervenes between the Suwannee and the Hawthorn.

Economic significance.—The Suwannee is a limestone of good quality, but too little exposed in Georgia for it to have much commercial importance.

LOCAL OCCURRENCE

Lowndes and Brooks Counties.—Limestone resembling the Suwannee but possibly of basal Hawthorn age extends up Withlacoochee River from the Florida line to the highway bridge west of Ousley, where Shearer [45] reports it at water level. The best exposure is at Horn Bridge, near the Florida line, where it rises 18 or 20 feet above the water. The lower part is hard, massive, dense pinkish limestone, somewhat conglomeratic above. The top is friable and nodular. The

[44] Mansfield, W. C., op. cit., pp. 49–50.

[45] Shearer, H. K., A report on the bauxite and fuller's earth of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 31, p. 282, 1917.

Suwannee is overlain by sand derived from the Hawthorn formation and containing great quantities of the coral *Siderastraea*.

Thomas County.—A well on the McKinnon property, on the Boston road 4¾ miles east of Thomasville, encountered hard white limestone at a depth of 50 to 55 feet. The rock contains several species of mollusks that occur elsewhere in either the Flint River formation or in the Suwannee limestone of Florida. The following species were identified by W. C. Mansfield.

Fossils from a well 4¾ miles east of Thomasville (U. S. G. S. 10393)

Lyria musicina dalli Mansfield.
Cerithium sp. cf. C. suwannensis Mansfield.
Orthaulax pugnax Heilprin var.?
Turritella sp. cf. T. halensis Dall.
Cassis sp. like one at Blue Spring, Decatur County.
Chlamys sp. cf. C. flintensis Mansfield.
Chlamys wannensis Mansfield.
Phacoides sp. cf. P. hillsboroensis Dall.
Cardium sp. cf. C. hernandoensis Mansfield.
Chione bainbridgensis Dall.
Teredo? incrassata (Gabb.)

MIOCENE SERIES

GENERAL FEATURES

The Miocene series, as here interpreted, includes three formations—the Tampa limestone at the base, the Hawthorn formation, and the Duplin marl. The Tampa and the Hawthorn, which appear to be conformable with one another, were at one time classified as Oligocene, but the arbitrary boundary between the Miocene and the Oligocene has since been shifted downward, without change of correlation of the formations involved, to the base of the Tampa. The Miocene formations in the adjoining States are named in the correlation table. (See p. 40.)

The Tampa extends from Florida only a short distance into Georgia. It may merge laterally into the basal part of the Hawthorn formation; or the basal Hawthorn, where the Tampa is wanting, may represent the deposits of a transgressing sea that extended beyond the Tampa shore line.

The Duplin marl once covered all the coastal region from North Carolina to Georgia, but it is now represented by only a few remnants, which lie unconformably on the Hawthorn and older formations and which are unconformably overlain by Pleistocene deposits.

TAMPA LIMESTONE

GENERAL FEATURES

Name.—The Tampa limestone, named from the city of Tampa, is best and most typically developed in west-central Florida. A sandy facies in northwestern Florida, formerly called the Chattahoochee

limestone, extends into southwestern Georgia. The formation in Georgia to which the name Tampa limestone is now applied is not, however, coextensive with the "Chattahoochee formation" of Veatch and Stephenson,[46] which includes also the typical part of the Flint River formation.

Distribution.—The sandy facies of the Tampa limestone is best exposed along and near Apalachicola River near River Junction and Chattahoochee, Fla. It extends into the southwestern part of Decatur County, Ga., from which it has been traced by means of its characteristic residual chert as far north as Sylvester. The formation also extends up Ochlockonee River for several miles beyond the Florida line.

Thickness.—The maximum thickness of the Tampa limestone in Georgia appears to be about 100 feet. The formation thins and pinches out or merges with the Hawthorn formation toward the east and northeast.

Lithologic character.—The Tampa limestone contains a good deal of very fine sand. Chemical analyses of the purer parts generally show more than 17 percent of silica. Other parts contain a much larger proportion of insolubles and grade laterally into sand or clay. Much of the limestone has a dull chalky appearance. One facies is conglomeratic or brecciated, as if the partly consolidated rock had been broken by violent waves and redeposited. A bed of this kind of rock appears to mark the base of the formation.

Fauna.—Nearly 300 species of mollusks, including 33 land and freshwater gastropods, are listed by Mansfield [47] from the Tampa limestone of Florida. The fauna includes also the echinoid *Lovenia depressa* (Clark), which occupies a bed near the base of the formation at Chattahoochee and therefore is likely to occur in nearby Georgia. A considerable coral fauna is reported from Tampa. The foraminifers have not been studied. Few fossils have been found in Georgia. From Wylie Landing on Flint River Mansfield [48] has identified *Bulimulus* sp., *Potamides campanulatus* Heilprin, *P. cornutus* Heilprin, *Cerithium* cf. *C. praecursor* (Heilprin), *Rapana vaughani* Mansfield, *Turritella* cf. *T. tampae* Dall, *Ampullina amphora* (Heilprin), *Barbatia* (*Acar*) cf. *B. domingensis* (Lamarck), *Ostrea* sp., *Crassatella deformis* Heilprin, and *Cyrena floridana* (Dall).

Stratigraphic relations.—The stratigraphic relations of the Tampa limestone are somewhat conjectural because of the scarcity and obscurity of critical exposures. The Tampa lies on the Flint River formation in Decatur County, and there probably is a hiatus between them.

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[46] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, pp. 324–342, 1911.

[47] Mansfield, W. C., op. cit., 334 pp., 21 pls., 2 tables.

[48] Mansfield, W. C., op. cit., p. 29.

It is overlain by the Hawthorn formation, whose similarity of composition suggests that the two are conformable. The Hawthorn appears to overlap the Tampa north of Sylvester and east of Grady County, but the apparent overlap may be due merely to a difference of facies, not of time.

Economic significance.—The hardness and composition of the Tampa limestone vary within such short distances, both vertically and horizontally, as to render it unsuitable for any use requiring large quantities of uniform material.

LOCAL OCCURRENCE

Decatur County.—At Wylie Landing on Flint River, 3 miles above the mouth of Spring Creek and 3½ miles north of the Florida line, very hard limestone conglomerate above the Flint River formation probably represents the base of the Tampa limestone. The Tampa contains large oysters and other obscure mollusks.

Near the Atlantic Coast Line Railway 1 mile west of Recovery, Decatur County, is a sink exposing sandy conglomeratic Tampa limestone. There is an exposure of similar limestone at a trestle 2 miles west of the station.

About 100 feet of Tampa limestone is exposed along Sanborn Creek, both above and below the bridge on the road from Bainbridge to Chattahoochee, Fla., 2 miles northwest of Faceville. The lower part is hard and somewhat resembles the conglomerate at Wylie Landing. Most of it is very sandy—more so than that of the Tampa limestone at Chattahoochee, Fla.

Fifty or sixty feet of limestone is visible at Powell limesink (Brushy Cave), 200 yards north of the Thomasville road, 2¼ miles north of Climax, and 8½ miles east of Bainbridge. The lower part of the pit, which is inaccessible without rope or ladder and artificial light, was not examined. The lower part of the accessible rock is hard nodular conglomeratic limestone containing a few obscure fossils, chiefly small foraminifers. It probably represents the base of the Tampa limestone. Limestone of the Flint River formation may be exposed below it.

Grady County.—A picturesque waterfall is upheld by sandy, cream-colored Tampa limestone at Forest Falls, 6½ miles north of Whigham, where 3 feet of hard conglomeratic limestone, presumably basal Tampa, is overlain by 27 feet of calcareous clay that grades into compact, cream-colored sandy limestone, the top of which forms the crest of the falls. Fossiliferous yellow or buff calcareous clay above the waterfall is conformable with the Tampa, and represents the Hawthorn formation. The sink has filled in considerably since the section on page 92 was measured. In 1930 the crest of the falls was only 13 feet above water level.

Soft, earthy Tampa limestone, containing hard, nodular lumps, overlies hard limestone of the Flint River formation at Waterfall, a sink on the L. E. Maloy property, 3 miles northeast of Forest Falls. The upper part of the Tampa contains some greenish clay and passes without break into sandy clay and fossiliferous marl of the Hawthorn formation. The Tampa is exposed also at Little Limesink, 5 miles north of Whigham,[49] and at the Blowing Cave, 11 miles north-northeast of Whigham.

About 200 feet of fine gray calcareous sand is exposed on the road east of Hadley Bridge on Ochlockonee River, 4½ miles above the Florida line in Grady County. It includes a hard ledge 6 feet higher than the floor of the bridge. Chert, apparently derived from the Tampa, was noted on the same road at Hadley Creek, 2 miles southeast of Hadley Bridge, and on roads crossing Bryants Mill Creek 2 and 4 miles west of the river. Hard very sandy limestone at the bottom of Ponto Spring in the northeast corner of Gadsden County, Fla., half a mile west of the road from Concord, Fla., and about 0.3 mile south of the Georgia line, is evidently Tampa. An oyster bed overlying it presumably marks the base of the Hawthorn formation.

Mitchell and Worth Counties.—No outcrops of unaltered Tampa limestone have been found in Mitchell or Worth Counties, but small irregular nodules of yellow chert that are probably derived from it crop out in many road cuts crossing a narrow belt that passes north-northeastwardly through points 2 miles northwest of Pelham, and 4 miles northwest of Sylvester.

HAWTHORN FORMATION

GENERAL FEATURES

Name.—The name Hawthorn, taken from a town in Alachua County, Fla., is here applied to a widespread geologic formation, to different parts of which Veatch and Stephenson [50] applied the names Alum Bluff formation, Marks Head marl, and †Altamaha (†Lafayette) formation (part). The name Alum Bluff is still used in Florida for a group of formations of which the Hawthorn is one. The †Marks Head marl was supposed to be younger than the Alum Bluff, but Gardner [51] discovered that its fauna is similar to that of the Chipola formation, which comprises the basal part of the Alum Bluff group in Florida, and is equivalent to the Hawthorn formation. The

[49] Brantly, J. E., A report on the limestones and marls of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 21, p. 187, 1916.

[50] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, pp. 342–366, 400–423, 1911.

[51] Gardner, Julia, The detection of the Chipola fauna in the Marks Head marl: Washington Acad. Sci. Jour., vol. 15, pp. 264–268, 1925.

†Altamaha grit, as originally defined by Dall and Harris,[52] evidently forms part of the unit here called Hawthorn formation, but Veatch and Stephenson included younger (Pleistocene) beds in it.

Distribution.—The Hawthorn formation underlies an enormous area that stretches from near Arcadia, Fla., to the vicinity of Charleston, S. C. In Georgia it lies near the surface throughout the Tifton Upland (wire-grass region) as well as the more fertile fields of Brooks and Thomas Counties. The west boundary south of Cordele lies along the slope leading down to the lower plains in the valley of the Flint. On the east the Hawthorn passes beneath the nearly horizontal coastal terrace deposits.

Thickness.—In spite of its great area of outcrop, the Hawthorn formation probably does not greatly exceed 300 feet in thickness. It is probably thickest near the Florida line, from which it extends northward in a thinning sheet.

Lithologic character.—Fine sandy phosphatic limestone forms an important part of the Hawthorn in Florida and South Carolina but is a less conspicuous component in Georgia. Dolomitic limestone containing as much as 35 percent of $MgCO_3$ lies near the base of the formation in the southern part of the State. The southern part also contains lenses of fuller's earth, which are especially thick in Decatur County. Gravel deposits, consisting chiefly of coarse angular pebbles, and sand locally cemented into hard sandstone are the main constituents of the Hawthorn in a large area and comprise the facies to which the name † Altamaha grit was originally applied. This sandy facies gives rise to the Tifton sandy loam and related soils, yellow to gray soils containing many small round hard ferruginous lumps that pack firmly under pressure into excellent natural roads. In the southern part of the State the soils are redder and are classified as Orangeburg sandy loam and related types. In this region road cuts show a peculiar mottling of red and gray; the red color is more brilliant in the upper more weathered part of the section.

Fauna.—The Hawthorn is not notable for its fossils. The greater part of the formation is unfossiliferous. The most common species that have been collected along Savannah River near Porters Landing are *Ostrea normalis* Dall, *Pecten acanikos* Gardner, *Carolia floridana* Dall, and *Mytilus conradinus* d'Orbigny. These and other species from that region are regarded as of Chipola age. Several exposures near Bainbridge have yielded mollusks that are regarded by Gardner[53] as of Oak Grove (middle Alum Bluff group) age. The

[52] Dall, W. H., and Harris, G. D., Correlation papers; Neocene: U. S. Geol. Survey Bull. 84, pp. 81–82, 1892.

[53] Gardner, Julia, The molluscan fauna of the Alum Bluff group of Florida: U. S. Geol. Survey Prof. Paper 142, p. 5, 1926.

fuller's earth and associated sand and clay of nearby Florida contain a small fauna of land vertebrates, which Simpson [54] correlates with the middle or lower Miocene. The species from Midway, Gadsden County, Fla., listed by him include two rodents, *Proheteromys magnus* and *P. floridanus*; two dogs, *Amphicyon pontoni* and a species of *Tomarctus* or *Cynodesmus*; three horses, *Archaeohippus* cf. *A. nanus*, *Merychippus gunteri*, and *Anchitherium clarencei*; a rhinoceros, *Aphelops?* sp.; an unidentified oreodont; two unidentified camels; and two deer, *Blastomeryx?* cf. *B. marshi* and *Dryomeryx?* cf. *D. americanus*.

Stratigraphic relations.—The Hawthorn is supposed to lie conformably on the Tampa limestone, but it overlaps beyond the Tampa on the Suwannee limestone, the Flint River formation, the Cooper marl, and the Barnwell formation. On all these formations, of course, it rests unconformably. It is overlain unconformably by the Duplin marl or the Charlton formation at a few places, but elsewhere it passes beneath Pleistocene terrace deposits.

Economic significance.—The most valuable product of the Hawthorn formation in Georgia is fuller's earth, which is extensively mined near Attapulgus, Decatur County, and has recently been mined near Ochlockonee, Thomas County. The Hawthorn is the source rock from which the phosphate deposits of Florida and South Carolina were derived. Phosphatic limestone is present in Georgia, too, but no residual accumulations large enough to be of commercial value have yet been discovered.[55]

LOCAL OCCURRENCE

Decatur County.—A cut on the highway half a mile to three-quarters of a mile east-southeast of Amsterdam, Decatur County, exposes the following section of the Hawthorn formation.

Section of the Hawthorn formation near Amsterdam

	Feet
6. Coarse orange clayey sand with pea-sized pebbles in the lower part. To top of hill at bend	15
5. White and purple hackly clay	3
4. Reddish-yellow current-bedded sandy clay streaked with white; many rolled clay balls in the lower part and at top	15
3. Thin-bedded white and red sandy clay	4
2. Fine white, yellow, and red sandy clay	15
1. Covered by weathered sand from creek to schoolhouse	25

The upper three beds in this section possibly are of early Pleistocene age.

[54] Simpson, G. G., Miocene land mammals from Florida: Florida Geol. Survey Bull. 10, p. 16, 1932.

[55] McCallie, S. W., A preliminary report on a part of the phosphates and marls of Georgia: Georgia Geol. Survey Bull. 5–A, 101 pp., 1896.

The upper part of the Hawthorn formation is poorly exposed at "Gastropod Gully" on the Bowers' property, 6 miles (air line) southeast of the highway bridge at Bainbridge, and 1½ miles north of the Atlantic Coast Line Railway at a point 5½ miles southwest of Climax. At this place lumps of brick-red or yellow fossiliferous sandstone lie loose on the surface or are embedded in residual red sand. The gully lies at an altitude of about 220–225 feet above sea level on the western slope of a hill that rises to an altitude of 268 feet. Fossils have also been found on Campbell Hill on Roseland plantation 1½ miles west of "Gastropod Gully," and on Sam Dixon's farm not far away.

Grady County.—Above the Tampa limestone at Forest Falls, 6½ miles north of Whigham, is very impure white to yellow apparently phosphatic limestone containing bones, corals, *Pecten acanikos*, and other obscure mollusks. The following section is adapted from two measured by Veatch and Stephenson [56] in 1908, since when the sink has filled in more than 50 feet.

Section at Forest Falls

	Feet
Hawthorn formation (Miocene):	
7. Red and yellow sand containing thin laminae of clay (possibly terrace deposit; Veatch and Stephenson report an unconformity at the base)	10–20
6. Greenish and gray sandy clay	15–20
5. Soft calcareous sandstone containing few fossils; argillaceous compact sand containing nodules of calcareous sand	8
4. Indurated buff and greenish argillaceous sand veined with calcite and containing minute calcite crystals and geodes; base at crest of falls	5
Tampa limestone (Miocene):	
3. Calcareous clay grading into compact argillaceous, sandy limestone	27
2. Hard limestone having the conglomeratic appearance of some of the rock at Faceville and Wylie Landing	3
Flint River formation (Oligocene):	
1. Very hard crystalline limestone, massive bedded. Parts of the bed are oölitic. Contains *Lepidocyclina favosa?*	35

Thomas County.—Large loose lumps of light-brownish limestone noted in 1917 near the top of a hill on the Monticello road 7 miles south of Thomasville probably came from the lower part of the Hawthorn formation. The rock varies from hard and dense to friable. Some of it is distinctly nodular or conglomeratic, with round or slightly angular inclusions of hard limestone. Some of the rock contains many

[56] Veatch, Otto, and Stephenson, L. W., op. cit., p. 335.

poorly preserved fossils, including a large ribbed *Pecten* (probably *P. acanikos*) and a small strongly carinate *Cardium*.

Chalky white limestone, containing many poorly preserved casts of mollusks and foraminifers identified by T. W. Vaughan as *Amphisorus duplex* (Carpenter), *Archaias* sp., and *Peneroplis* sp., crops out at Original Pond, 3 miles west of Metcalf, Thomas County. The species identified as *Amphisorus duplex* occurs also in the basal Hawthorn at Sopchoppy, Fla. According to Veatch and Stephenson [57] this rock is 15 feet thick and is underlain by 10 feet of harder brittle brecciated and vesicular limestone whose surface is rough and jagged. Similar rock is reported also on the McIntyre plantation, 5 miles west of Metcalf, where it is overlain by greenish clay and brown sand, and on the old Copeland plantation, 9 miles west of Metcalf. At all three of these places fragments of phosphatic sandstone are scattered through the soil.

Pinnacles of sandy limestone are still visible in the old phosphate prospect pits on the Thomasville highway (US 84) west of Aucilla Creek, 3 miles west of Boston. Veatch and Stephenson [58] report 5 or 6 feet of limestone also at a sink on the Mitchell plantation, half a mile north of the road and 6 miles west of Boston. A chemical analysis quoted by Brantly [59] shows that the limestone is highly magnesian.

The northeastern part of the county contains extensive deposits of fuller's earth. According to A. C. Munyan, a pit 1 mile west of Ochlockonee shows 10 feet of greenish-gray hackley fuller's earth overlain by about 15 feet of tan and gray coarse cross-bedded sand.

Brooks County.—At the Devils Hopper in Brooks County, about 2 miles northeast of Barwick, very sandy magnesian limestone is overlain by greenish-gray clayey sand. Brantly [59] describes the section as follows:

Section at Devil's Hopper

	Feet
8. Sandy loam	1
7. Bluish claylike fuller's earth (slightly arenaceous) with 6-inch bed of yellow sand about midway	15
6. Greenish argillaceous sand similar to that seen in Beasley limesink	10
5. Concealed (probably greenish arenaceous clay)	5
4. Hard cream-colored compact limestone; weathers to a brown arenaceous material	8
3. Soft white argillaceous limestone with black veinlets, probably manganese; weathers to yellowish argillaceous material	6

[57] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 336–337.
[58] Veatch, Otto, and Stephenson, L. W., op. cit., p. 338.
[59] Brantly, J. E., op. cit., pp. 192–193.

Section at Devil's Hopper—Continued

	Feet
2. Medium-hard light cream-colored argillaceous limestone; weathered product, deep cream-colored clay	3
1. Brownish compact hard limestone; similar to stone of bed 3 in Waterfalls sink; weathers to soft yellow arenaceous material; breaks easily	15

Lowndes County.—According to Shearer,[60] silicified fuller's earth of the Hawthorn formation is exposed in bluffs along Withlacoochee River from the railroad bridge near Ousley, Lowndes County, southward to Stony Lake and Knights Ferry. Near old Troupville, 4 miles west of Valdosta, a 7-foot bed of pisolitic claystone lies between beds of sandstone, the whole section totaling 15 feet.

Lumps of coarse sparingly phosphatic white-cemented sandstone embedded in loose rusty sand were noted in prospect pits north of the road and in a gully south of the road between Ocean Pond and Hammock Lake, 1.6 miles west of the railroad crossing west of Lake Park, and at several other places in southern Lowndes County. The surface materials in this region are the Hawthorn formation or residual from it; the lakes are the result of solution of the underlying Oligocene limestone.

Echols County.—Strongly cross-bedded coarse yellowish-gray pebbly sand containing clay matrix, phosphatic pebbles, and obscure impressions of mollusks rises about 4 or 5 feet above water in Alapaha River at Statenville, Echols County. Shearer[61] reports a few feet of sandy limestone overlain unconformably by sand, impure limestone, and fuller's earth, 2 and 2½ miles above Statenville. Brantly[62] describes 15 to 18 feet of hard dove-colored oölitic limestone on the Alapaha, 3½ miles below Statenville. His analysis shows that it is somewhat phosphatic and contains 30 percent of magnesium carbonate.

Suwannee River below Fargo, Clinch County, has cut through the cover of Pleistocene sand into phosphatic sand of the Hawthorn formation, which is exposed only at low water. Veatch and Stephenson[63] report exposures beneath the railroad bridge at Fargo; at Bony Bluff, 9 miles southwest of Fargo; and at Rocky Ford, 5 miles below Bony Bluff and half a mile above the State line. At Bony Bluff and Rocky Ford fossil bones are abundant, and there are also prints of shells.

Altamaha River.—An excellent exposure of the Hawthorn formation on Altamaha River at Grays Landing Bluff in Toombs County,

[60] Shearer, H. K., A report on the bauxite and fullers earth of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 31, p. 282, 1917.

[61] Idem., pp. 285–286.

[62] Brantly, J. E., A report on the limestones and marls of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 21 p. 205, 1916.

[63] Veatch, Otto, and Stephenson, L. W., op. cit., p. 355.

10 miles below the junction of the Ocmulgee and the Oconee, is described by Shearer [64] as follows:

Section of the Hawthorn formation at Grays Landing Bluff

	Feet
6. Greenish-gray feldspathic sandstone or grit	8
5. Greenish argillaceous sand, upper part containing more clay than the lower	15
4. Sand with laminae of claylike fuller's earth	5
3. Slightly indurated greenish sand	1
2. Fuller's earth containing much sand interlaminated and in irregular pockets	4
1. Laminated fuller's earth, pale greenish color when wet, dries white, contains only occasional pockets of sand. Exposed above water level	2

At the east end of the bluff, bed 6 reaches a thickness of 30 feet and is locally so coarse as to be almost a conglomerate. The fuller's earth of bed 1 is described as similar in appearance and composition to that of Decatur County. It may be thicker than 2 feet, for the river was 5 feet above its normal level when the section was measured.

Fuller's earth and greenish sandy clay are reported also at Red Bluff on the south side of Altamaha River below Manns Ferry.

Ledges of gray Hawthorn sandstone rise 41 feet above the zero mark on the Altamaha River gage at Belltona camp on the highway (U. S. No. 1) between Baxley and Lyons. At Lanes Bridge on the road (Georgia No. 64) from Baxley to Glennville the Hawthorn consists of about 85 feet of light greenish-gray, clayey sand partly indurated into soft sandstone. The lower part is finer grained than the upper and is without pebbles; the upper part contains many angular quartz pebbles. The top is more weathered and is mottled with red and orange. The Hawthorn is overlain by loose gray sand, probably residual from it. Tillmans Ferry, Tattnall County, which is cited by Dall and Harris [65] in the original description of the Altamaha grit, is probably somewhere near Lanes Bridge. The Hawthorn passes beneath water level below Doctortown, Wayne County, where Veatch and Stephenson report 7 feet of coarse bluish or greenish compact clayey sand.

Ocmulgee River.—House Creek Bluff on Ocmulgee River, 2 miles east of Bowen's mill, Wilcox County, one of the typical localities of the Altamaha grit, is compared by Dall and Harris [66] with the Hawthorn of Florida. Veatch and Stephenson [67] referred it to the Alum Bluff formation and described the beds as follows:

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[64] Shearer, H. K., op. cit., p. 287.
[65] Dall, W. H., and Harris, G. D., op. cit., p. 82.
[66] Dall, W. H., and Harris, G. D., op. cit., p. 81.
[67] Veatch, Otto, and Stephenson, L. W., up. cit., p. 357.

Section at House Creek Bluff, Ocmulgee River

	Feet
Terrace deposit (Pleistocene):	
8. Thin covering of gray sand.	
7. Mottled red and yellow sand or loam	30
Hawthorn formation (Miocene):	
6. Greenish fine-textured clay containing sand pockets and siliceous nodules	10
5. White calcareous sandstone	5
4. Bed of oyster shells in a calcareous sandy matrix	2½
3. Greenish clayey sand with calcareous concretions	3
2. Greenish laminated sandy clay	4
1. Gray compact sand	5

At Quinns Fractions, on Ocmulgee River 4 miles below Lumber City, Veatch and Stephenson [68] found a 1-foot bed of quartzite underlain by 15 feet of gray sand containing clay laminae and prints of fossils and underlain by 5 feet of greenish laminated clay with partings of sand. Similar greenish brittle quartzite occurs at Oaky Bluff, 2 miles above the junction with the Oconee, and on the Altamaha just above Nayles Ferry.

Oconee River.—On the Oconee they found 50 feet of gray aluminous sandstone on 15 feet of softer sandstone and claystone at Berry Hill Bluff, 55 miles above the mouth of the river. The rock varies from claystone to coarse, almost conglomeratic feldspathic sandstone containing disseminated greenish clay slightly cemented by silica. Similar rock appears at Joyces Bluff, 2 miles above the Seaboard Railway and at Stallings Bluff, 2 miles west of Mount Vernon.

Ogeechee River.—The only exposures of the Hawthorn formation on Ogeechee River mentioned by Veatch and Stephenson [69] are at a place 1 mile west of Rocky Ford, Screven County, where shaly clay and greenish-gray siliceous claystone rise 20 feet above the water, and at Indian Head, 3 miles west of Egypt, Effingham County, where 2½ feet of sandstone containing pockets of greenish silicified clay crops out in a slough on the property of Carl Higgins. The formation crops out also just below water level at a bluff 3½ miles northeast of Stilson, where fine gray sand contains prints of fossils, lumps of lignite, and calcareous concretions composed of radiating crystals. St. Peters Bluff, 2 miles north of Hubert, shows fine cream-colored sand containing a few prints of shells.

Savannah River.—There are many exposures of the Hawthorn formation in the bluffs that extend along Savannah River from a point about a mile above Hudsons Ferry, Screven County, to Ebenezer Landing, Effingham County. Some of them were referred to the Alum Bluff by Veatch and Stephenson, some to the Marks Head marl, which

[68] Veatch, Otto, and Stephenson, L. W., preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, p. 358, 1911.

[69] Veatch, Otto, and Stephenson, L. W., op. cit., p. 360.

they considered a younger formation, and others were classed as undifferentiated Miocene. Published and unpublished descriptions were assembled and revised by Cooke,[70] from whose report the following excerpts are quoted:

Section at a landing three-quarters of a mile below Hudsons Ferry Landing

	Feet
Wicomico (?) formation (Pleistocene):	
8. Loose gray sand	2
7. Mottled gray and red coarse clayey sand	10
6. Interstratified harsh sand and fine-grained waxy clay	10
5. Brown ocherous coarse sand; well-rounded pebbles at base	5
Hawthorn formation (lower Miocene):	
4. Compact ash-colored argillaceous sand	10
3. Drab, brown, or yellow sandy clay containing poorly preserved fossils; *Pecten "madisonius"* (perhaps *P. acanikos*)	2
2. Massive gray and brown phosphatic sand	25
1. Concealed by creep from upper part of bluff	20

Section at Porters Landing

	Feet
Sunderland (?) formation (Pleistocene ?):	
8. Clay and stratified sand of various colors and sizes of grain	64
Duplin marl (upper Miocene):	
7. Thin broken line of vertebrate fossils (shark teeth and dental plates of *Myliobatis*) and particles of phosphate rock.	
6. Hard yellow to gray marl forming a ledge; many fossils, including *Ecphora* sp., *Ostrea disparilis*, *Pecten eboreus*, and many *Anomia* sp	5.8
Hawthorn formation (lower Miocene):	
5. Yellow arenaceous material in which occur nodular masses composed of sand indurated by calcareous cement; at the bottom is an undulating ledge of indurated material similar to the concretions and containing *Ostrea normalis* Dall	27
4. Loose yellow sand containing many *Pecten acanikos* Gardner, also *Mytilus conradinus?* and *Balanus* sp	1.8
3. Drab shale with siliceous concretions	12
2. *Carolia floridana* bed, calcareous constituents largely leached; exposed at low water	0–5
1. Arenaceous laminated gray shale with sandy partings	0–8

The round concretions in the Hawthorn formation at Porters Landing are composed of radiating calcareous crystals.[71]

[70] Cooke, C. W., Geology of the Coastal Plain of South Carolina: U. S. Geol. Survey Bull. 867, pp. 104–109, 1936.

[71] Cooke, C. W., Radial calcite concretions in marine beds in Georgia: Washington Acad. Sci. Jour., vol. 21, p. 27, 1931.

Gardner [72] lists the following species from the †Marks Head marl (Hawthorn formation of present classification) from the vicinity of Porters Landing:

Fossils from Porters Landing

Turritella alcida bicarinata Gardner mss.	Phacoides (Parvilucina) trisulcatus Conrad?
Natica (Cryptonatica) sp., cf. N. (C.) platabasis Gardner mss.	Phacoides (Parvilucina) sp. cf. P. (P.) piluliformis Dall.
Calliostoma sp. ind. cm. C. aphelium Dall.	Phacoides (Here) sp. cf. P. (H.) para-whitfieldi Gardner.
Calliostoma sp.	Cardium sp. ind.
Scapharca staminata Dall?	Dosinia sp. cf. D. chipolana Dall.
Ostrea normalis Dall.	Macrocallista sp. ind.
Pecten acanikos Gardner.	Strigilla n. sp.
Carolia floridana Dall.	Donax n. sp.
Mytilus conradinus d'Orbigny?	Mactra sp. ind.
Astarte sp. ind.	Spisula n. sp.
Venericardia (Pteromeris) sp. ind. cf. V. (P.) perplana abbreviata Conrad?	Corbula n. sp.
	Balanus sp.

DUPLIN MARL

GENERAL FEATURES

Name and distribution.—The Duplin marl, named from a county in North Carolina, has been found in Georgia only in the bluffs along the Savannah near Porters Landing, and along the Altamaha near Doctortown.

Thickness.—According to Miller [73] the Duplin is about 100 feet thick in North Carolina, but this estimate may be excessive. The greatest thickness known in South Carolina is 41 feet, and the formation is generally much thinner there. At the few exposures in Georgia the formation is only 5 to 16 feet thick.

Lithologic character and fauna.—The Duplin marl consists characteristically of shells mixed with sand. Large collections of fossils have been made from it, particularly at the Natural Well in Duplin County, N. C., and at the Muldrow place in Sumter County, S. C. From the latter place Gardner and Aldrich [74] list 249 species of mollusks. Fewer fossils have been found in it in Georgia. Veatch and Stephenson [75] quote Vaughan's list of 49 mollusks (only 30 identi-

[72] Gardner, Julia, The detection of the Chipola fauna in the Marks Head marl: Washington Acad. Sci. Jour., vol. 15, p. 267, 1925.

[73] Miller, B. L., The Tertiary formations [of North Carolina]: North Carolina Geol. Survey, vol. 3, p. 239, 1912.

[74] Gardner, Julia, and Aldrich, T. H., Mollusca from the upper Miocene of South Carolina with descriptions of new species: Acad. Nat. Sci. Philadelphia. Proc., February 1919, pp. 17–53, 1919.

[75] Veatch and Stephenson, L. W., op cit., p. 368.

fied), and several other organisms from Porters Landing, most of which occur also at the Natural Well, though few of them are restricted to the Duplin marl.

Stratigraphic relations.—At all the known outcrops in Georgia the Duplin lies unconformably on the Hawthorn formation. The Duplin probably once extended as a continuous thin sheet across the coastal region of the Carolinas and Georgia. At its northeast end it merged into the upper part of the Yorktown formation, and at its south end into the upper part of the Choctawhatchee formation of Florida. The once-continuous sheet was later cut by erosion into patches of irregular size and shape. These patches of Duplin marl and the intervening areas of younger formations were later buried beneath deposits of Pleistocene age, which subsequent erosion has cut through in only a few places. For this reason outcrops of Duplin marl are few and far between.

Economic significance.—Because of the lime in its shells, the Duplin marl may be of local use as a slow-acting fertilizer. The marl could also be used to surface roads on which the traffic is light.

LOCAL OCCURRENCE

Savannah River.—At Porters Landing, Savannah River, the Duplin marl is only 5 or 6 feet thick. It is gray, highly calcareous, and contains many Pectens, oysters, and impressions of other shells. According to Veatch and Stephenson,[76] the sand in it is phosphatic. and include small well-rounded quartz pebbles at the base, which rests unconformably on the Hawthorn formation. The most conspicuous fossils are *Pecten eboreus* and *Anomia simplex.* The same writers note the Duplin marl 1½ miles below Porters Landing at Mount Pleasant Landing, where it is 7 feet thick, and three-quarters of a mile below Hudsons Ferry, Screven County, where it is 12 feet thick, and consists chiefly of sand.

Altamaha River.—On Altamaha River the Duplin is exposed at Doctortown, Wayne County, and at Buzzards Roost Bluff and Bugs Bluff, 2 and 2½ miles, respectively, above Doctortown. The following section is adapted from one by Veatch and Stephenson.[77]

Section at railroad bridge at Doctortown

Wicomico? formation (Pleistocene):	Feet
6. Yellow and mottled argillaceous sand	10
5. White and yellow cross-bedded sand containing thin layers of small quartz pebbles	10

[76] Veatch, Otto, and Stephenson, L. W., op. cit., p. 372.
[77] Veatch, Otto, and Stephenson, L. W., op. cit., p. 377.

Section at railroad bridge at Doctortown—Continued

	Feet
Duplin marl (Miocene):	
4. Red and yellow stratified sand, probably leached marl, containing thin clay laminae	10
3. Calcareous fossiliferous sand or sandy friable marl	1
2. Bluish sand containing *Pecten eboreus, Mactra congesta,* etc	4
Hawthorn formation (Miocene):	
1. Coarse bluish or greenish compact clayey sand. To water's edge	7

The following section, also, is based on one by Veatch and Stephenson.[78]

Section at Buzzards Roost Bluff

	Feet
Wicomico formation (Pleistocene):	
7. Gray sand	2
6. Mottled clayey sand	10
5. Coarse white cross-bedded sand, pebbly at the base	28
Duplin marl (Miocene):	
4. Yellow and white faintly laminated very sandy clay, pebbly in the upper part	5
3. Blue, almost black, silty clay	6
2. Shell and pebble conglomerate composed of well-rounded quartz pebbles, coarse sand, and shells, locally consolidated by calcium carbonate. Contains *Pecten eboreus, Mytilus conradinus,* and large fragments of water-worn silicified wood	1½
Hawthorn formation (Miocene):	
1. Bluish-gray massive compact clayey sand	10

PLIOCENE SERIES

GENERAL FEATURES

The Pliocene deposits of the eastern States fall into three main divisions—river and delta deposits, residual accumulations, and marine shell marls. The river and delta deposits include the Bryn Mawr gravel and related formations in the northeastern States, the Bone Valley gravel in Florida, and the Citronelle and related formations in the Gulf States. The Alachua formation of Florida is a residual accumulation, at least in part. The marine shell marls include the Caloosahatchee marl of Florida, the Charlton formation of Georgia and Florida, the Waccamaw formation of the Carolinas, and the Croatan sand of North Carolina.

On the evidence of the land animals in them, the Alachua and the Bone Valley are regarded as contemporaneous and are correlated with

[78] Veatch, Otto, and Stephenson, L. W., op. cit., p. 376.

the bone-bearing early Pliocene beds of the western States.[79] The Caloosahatchee, the Waccamaw, and the Croatan likewise appear to be contemporaneous, but their relative age with respect to the bone-bearing beds and to the unfossiliferous Citronelle and related formations is unknown.

The Charlton, which is the only formation of supposed Pliocene age that has been recognized in Georgia, probably is contemporaneous with the other marine deposits, but its fauna is much more meager than those of the Caloosahatchee and Waccamaw, and no extinct species have been recognized in it.

CHARLTON FORMATION

GENERAL FEATURES

Name and distribution.—The name Charlton formation was applied by Veatch and Stephenson[80] to deposits exposed in bluffs on the Florida side of St. Marys River opposite Charlton County, Ga., between Stokes Ferry and Orange Bluff. There are also a few exposures near Satilla River in Charlton and Brantley Counties. The formation is not shown on the geologic map because most of the known outcrops are in Florida, and because the formation is nearly everywhere covered by Pleistocene deposits.

Thickness.—The thickness of the Charlton exposed in most sections is less than 20 feet. It is not likely that the total thickness much exceeds 20 feet, for the beds are presumably nearly horizontal or dip seaward at a rate little greater than the gradient of the rivers. High dips noted by Veatch and Stephenson may be due to landslides.

Lithologic character and fauna.—The Charlton formation consists chiefly of light-colored calcareous clay and impure limestone. It contains ostracods, *Pecten gibbus*, and a few other mollusks, all of which have been identified as existing species. In spite of this fact, the formation is probably older than Pleistocene, for it is overlain by late Pleistocene formations and does not resemble any known early Pleistocene formation in the region. It was tentatively referred by Veatch and Stephenson to the Pliocene, which is probably its true age. A mixture of fresh and brackish-water species occurs in it on Satilla River. The Charlton is similar to the Buckingham limestone of southern Florida, which appears to be a facies of the Caloosahatchee marl.

Stratigraphic relations.—Although the base of the formation has not been seen, it can be inferred that the Charlton lies unconformably on

[79] Simpson, G. G., The extinct land mammals of Florida: Florida Geol. Survey 20th Ann. Rept., p. 248, 1929.

[80] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, p. 392, 1911.

the Hawthorn formation. It apparently represents the sediments of an embayment or estuary of the invading sea whose more open marine facies is represented by the Caloosahatchee marl of Florida and the Waccamaw formation of the Carolinas.

Economic significance.—The deposit appears to be of little value.

LOCAL OCCURRENCE

St. Marys River.—Veatch and Stephenson describe 12 sections of the Charlton formation on St. Marys River. At Stokes Ferry, which is on the road from St. George, Ga., to Macclenny, Fla., there is 4 or 5 feet of greenish or drab stiff, tenaceous clay containing calcareous concretions, phosphatic particles, and ostracods, underlain by 1 foot of fossiliferous limestone. At Hicks Bluff, which is probably 5 miles south of the bridge at St. George, they found 4 feet of greenish sticky sandy clay underlain by 4 feet of soft argillaceous limestone containing *Pecten gibbus*, *Phacoides multilineatus*, and *Laevicardium* sp. At Red Bluff, probably 1½ miles below the bridge at St. George, 7 feet of drab sandy clay is underlain by 1½ feet of sandy limestone containing *Leda acuta*, *Barbatia marylandica*, *Arca umbonata*, and species of *Pecten*, *Lithophaga*, and *Phacoides*. A similar section is recorded from Schoolhouse Bluff, about 5 miles below St. George, but the limestone there contains *Rangia cuneata*, small gastropods, and ostracods. An alternation of thin beds of limestone and calcareous clay totaling 15 feet in thickness was noted at Rand Landing, a mile farther downstream.

Other sections recorded by Veatch and Stephenson are at Clay Landing, 1½ miles northeast of Toledo, and at Nettles Landing, which is probably at the north end of the same bluff. The next exposure downstream is half a mile below Cow Ford and 9 miles south of Folkston, where a total of 4 feet of limestone and clay crops out. At Sawpit Landing, 2 miles by river above the ferry at Traders Hill, soft chalky limestone alternates with white calcareous clay containing *Leda acuta?*, *Pecten gibbus*, *Anomia simplex*, and other fossils. Clay and limestone alternate to a thickness of 15 feet at the railroad bridge south of Folkston, where Veatch and Stephenson obtained *Pecten gibbus*, *Anomia simplex*, and *Rangia cuneata*. White and greenish chalky clay rises 6½ feet above water at Chalk Bluff, 3 miles west of Kings Ferry, Fla., and there is 4½ feet of clayey limestone at Orange Bluff, 2 miles above Kings Ferry. At the latter place Veatch and Stephenson obtained *Leda acuta*, *Pecten gibbus*, *Phacoides multilineatus*, *Chione cancellata*, and *Mulinia lateralis*.

Satilla River.—Fossiliferous marl found by Veatch[81] near Satilla River on the land of W. M. Thrift, 6 miles east of Winokur, resembles

[81] Veatch, Otto, and Stephenson, L. W., op. cit., p. 392, footnote.

the Charlton formation. White marl described by Loughridge at Burnt Fort, at the head of tidewater on Satilla River 10½ miles northeast of Folkston, is tentatively referred to the Charlton formation by Veatch and Stephenson.[82]

A lump of marl from Satilla River 4 miles south of Atkinson, Brantley County, contained the fossils listed below—a mixture of freshwater and brackish-water species.[83]

Fossils from Satilla River 4 miles south of Atkinson

[Identified by T. H. Aldrich]

Rangia cuneata Gray.
Mulinia lateralis Say.
Mulinia congesta Conrad.
Dosinia sp.
Modiolaria sp.
Gemma purpurea H. C. Lea.
Neritina sp.
Neverita sp.
Potamides saltillensis Aldrich.
Potamides cancelloides Aldrich.
Paludestrina plana Aldrich.
Amnicola saltillensis Aldrich.
Amnicola georgiensis Aldrich.
Amnicola expansilabris Aldrich.
Planorbis antiquatus Aldrich.

PLEISTOCENE SERIES

GENERAL FEATURES

The Pleistocene epoch, which probably lasted a millon years or more, included long periods of time as different from one another as winter from summer, and in some respects having the characteristics of those seasons. Its most distinctive feature was the repeated accumulation, spread, and melting of continental ice sheets. At least five times ice sheets pushed southward into the United States from centers of accumulation in Canada, tarried a while, then slowly melted away. Such an ice sheet still covers much of Greenland. These glacial stages are believed to have consumed only a comparatively short part of the Pleistocene epoch. The intervening interglacial stages were of much longer duration.

Though the ice sheets stopped far north of Georgia, their influence was doubtless felt in the climate, which presumably was somewhat colder during the glacial stages than during the interglacial stages, and, more tangibly, in their control of sea level. So much water was locked up as ice on the land when the ice caps were large and so much water was released into the sea when they melted that the level of the sea must have been appreciably affected. It has been estimated that sea level during the climax of the last glaciation was 300 feet lower than now from this cause, and that there is still enough ice on the land to raise the level of the sea by 200 feet if it were all melted.[84] Though

[82] Veatch, Otto, and Stephenson, L. W., op. cit., pp. 380–381.

[83] Aldrich, T. H., Notes on some Pliocene fossils from Georgia, with descriptions of new species: Nautilus, vol. 24, pp. 131–132, 138–140, 1911.

[84] Antevs, Ernst, Am. Jour. Sci., 5th ser., vol. 17, p. 43, 1929.

these estimates may be excessive, the glacial stages must have been times of relatively low sea level; the interglacial, times of higher sea level.

Most of the Pleistocene deposits of Georgia are marine or estuarine. They make part of a wide-ranging series of thin sandy formations that accumulated on the bottom of the sea and in estuaries when the sea stood at various levels ranging from the present level up to about 270 feet higher. All the accessible deposits of this kind presumably represent interglacial stages; the marine accumulations of the glacial stages were presumably formed at lower levels and are now out at sea.

The division of the marine Pleistocene deposits into formations is based primarily on topography. Each formation is defined as the sum of the deposits that accumulated while the sea stood at a definite level. Its original landward margin, therefore, was the shore line at that level. Its upper surface was the corresponding sea bottom, now a marine terrace.

As the parts now exposed of the original surfaces (terraces) of the lower formations are much better preserved than those of the higher, and as they retain shore-line features that might have been obliterated if a rising sea had wiped across them, it is inferred that the formations corresponding to the lower shore lines are younger than the higher.

As the Pleistocene deposits of Georgia have not been noticeably warped or folded, the surface of each formation normally lies between definite altitudes—that of its original shore line and that of the shore line of the next lower terrace. Some beach ridges, dunes, and barrier islands, however, rise considerably higher than the shore line of the sea along which they were formed.

Deposits corresponding to eight Pleistocene stages of sea level have thus far been found in the southeastern States, and there may be others that have not yet been detected. Named in the order of decreasing ages, these formations and the approximate heights of their shore lines are as follows:

Brandywine, 270 feet.	Penholoway, 70 feet.
Coharie, 215 feet.	Talbot, 42 feet.
Sunderland, 170 feet.	Horry, sea level.
Wicomico, 100 feet.	Pamlico, 25 feet.

All these formations are represented in Georgia except the Horry clay, which is buried beneath estuarine parts of the Pamlico formation in South Carolina, where it is typically exposed at low tide in the Intracoastal Waterway Canal near Myrtle Beach.[85] The Horry

[85] Cooke, C. W., The Pleistocene Horry clay and Pamlico formation near Myrtle Beach S. C.; Washington Acad. Sci. Jour., vol. 27, pp. 1–5, 1937.

clay may be older than the horizon to which it has been assigned.

There appear to have been intervals of lower sea level and subaerial erosion before and after the deposition of the Brandywine formation, between the Sunderland and the Wicomico, between the Talbot and the Pamlico, and after the Pamlico. After Coharie time the sea probably dropped to the Sunderland level without an intermediate lower stage. The Wicomico, the Penholoway, and the Talbot likewise seem to form an uninterrupted sequence of steps.

That Pamlico time was followed by a lowering of the sea to a position at least 25 feet (possibly much more) below its present level is proved by shallow valleys and channels cut to that depth in the Pamlico terrace and now flooded and converted into estuaries. This post-Pamlico lowering of sea level appears to have been contemporaneous with the last (late Wisconsin) glaciation. The four other low-water stages—pre-Pamlico, pre-Wicomico, pre-Coharie, and pre-Brandywine—may likewise have been contemporaneous with extensive continental glaciation and may have been caused by glacial control of sea level.

It might be supposed that the difference in altitude between the shore lines of any two terraces is proportional to the relative amounts of ice remaining on the continents when the shore lines were being washed by the sea. But this does not necessarily follow, for all or part of the net lowering of 270 feet since Brandywine time may have been caused by intermittent downwarp of some distant part of the globe.

The nonmarine Pleistocene deposits of Georgia are to be looked for in bogs and river terraces. The larger rivers of the State came into existence before the beginning of the Pleistocene and have been continually eroding or aggrading their valleys. Their upper courses (above 270 feet) have been continuously normal rivers; their lower courses, with each fluctuation of sea level, were alternately flooded by the rising tidal waters and quickened by the fall of base level. The flood plains and terraces of the upper parts are the accumulations of normal rivers; the accumulations in the lower parts are a combination of estuarine and normal river deposits. A river terrace slopes downstream at a rate approximating the grade of the river. The shore line of an estuarine terrace is nearly horizontal, but the terrace itself retains the slope of the delta, tidal flat, or partly silted bottom in which the river entrenched itself as sea level fell.

Okefenokee Swamp and other upland bogs contain deposits of peat that are commonly regarded as of Recent origin. But a cooler climate than that of Georgia today is more favorable for the accumulation of peat. Therefore, it seems not improbable that the peat deposits of

Georgia were formed during the glacial stages, when the climate presumably was somewhat cooler than now, and that they are not now increasing. Proof of this supposition is lacking, but peat now below tide level in Blackwater River in western Florida contains fresh-water microscopic plants (diatoms) like those of much more northern latitudes.[86] Search should be made for diatoms in the peat deposits of Georgia.

BRANDYWINE FORMATION

GENERAL FEATURES

Name.—The Brandywine formation was named in 1915[87] from a place in Prince Georges County, Md. It was later restricted[88] to the deposits that accumulated in the sea and estuaries at a stage of sea level about 270 feet higher than the present. The formation in Georgia has never been formally described, but the older name Brandywine was substituted in 1931[89] for the name Hazelhurst terrace, which was described in 1925.[90]

Distribution.—The Brandywine sea probably extended across Georgia from Screven County to Thomas County, but much of its deposits have been removed by erosion. Recognition of them is made difficult by the lack of topographic maps except in the area east of longitude 82°, where the Brandywine formation is thoroughly dissected. The generalized boundaries shown on the geologic map (pl. 1) will be greatly modified by detailed mapping.

Thickness, lithologic character, and stratigraphic relations.—The Brandywine formation probably does not much exceed 50 feet in thickness. It consists chiefly of sand and gravel resembling the coarser unconsolidated parts of the Hawthorn formation, from which much of it appears to have been derived. No fossils have been found in it. It lies unconformably on the Hawthorn and possibly other formations. Any formations that may overlie it are presumably also unconformable, for the sea probably withdrew beyond the present seacoast at the end of Brandywine time.

Economic significance.—Some of the sand and gravel deposits in the Brandywine formation may be of value for structural work or as road metal.

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[86] Hanna, G. D., Diatoms of the Florida peat deposits: Florida Geol. Survey, 23d–24th Ann. Repts., pp. 68–96, pls. 1–11, 1933.

[87] Clark, W. B., The Brandywine formation of the Middle Atlantic Coastal Plain: Am. Jour. Sci., 4th ser., vol. 40, pp. 499, 505, 1915.

[88] Cooke, C. W., Seven coastal terraces in the Southeastern States: Washington Acad. Sci. Jour., vol. 21, p. 506, 1931.

[89] Idem, p. 506.

[90] Cooke, C. W., Physical geography of Georgia; the Coastal Plain: Georgia Geol. Survey Bull. 42, p. 29, 1925.

COHARIE FORMATION

GENERAL FEATURES

Name.—The Coharie formation was named in 1912 by Stephenson [91] from Great Coharie Creek in Sampson County, N. C. Cooke [92] more precisely defined it by reference to a shore line about 215 feet above sea level. The remnants of the original surface in Georgia were called the "Claxton terrace" [93] before their identity with the Coharie terrace was established.

Distribution.—Much more of the Coharie than of the Brandywine has been preserved, especially in the southern part of Georgia, where a broad stretch about 50 miles long has been cut through by only a few streams. Farther north the areas are smaller. The boundaries of the formation shown on the geologic map (pl. 1) are merely provisional because most of the Coharie areas are not included in topographic maps.

Thickness and lithologic character.—The Coharie formation consists chiefly of sand, some of which is as coarse as rice. Angular pebbles apparently derived from the Hawthorn occur in it at some places, and it contains also smooth flat beach pebbles of transparent quartz. Its thickness is doubtless variable, but probably does not much exceed 50 feet. No fossils have been found in it.

Stratigraphic relations.—If the Coharie anywhere lies on the Brandywine formation, the relations are probably unconformable, for the sea presumably retreated beyond the present coast line during the interval between Brandywine and Coharie time. At most places it lies unconformably on the Hawthorn formation. The inconspicuousness of the scarp separating the Coharie terrace from the next lower Sunderland terrace and the apparent straightness of the Sunderland shore line suggest that the Coharie was immediately succeeded by the Sunderland without an intermediate retreat of the sea beyond the Sunderland shore.

Economic significance.—Sand and gravel are the only deposits in the Coharie formation that are likely to be of commercial value.

SUNDERLAND FORMATION

GENERAL FEATURES

Name.—The Sunderland formation and the Sunderland terrace correspond approximately to the Okefenokee† formation and the

[91] Stephenson, L. W., The Coastal Plain of North Carolina; the Quarternary formations: North Carolina Geol. Survey, vol. 3, p. 273, 1912.

[92] Cooke, C. W., Correlation of coastal terraces: Jour. Geology, vol. 38, p. 582, 1930; Seven coastal terraces in the Southeastern States: Washington Acad. Sci. Jour., vol. 21, p. 506, 1931.

[93] Cooke, C. W., Physical geography of Georgia; the Coastal Plain: Georgia Geol. Survey Bull. 42, p. 29, 1925.

Okefenokee terrace of previous reports on Georgia.[94] The name Sunderland, proposed by Shattuck [95] for deposits in Maryland bounded by a shore line 170 feet above sea level, is the older.

Distribution.—The Sunderland formation underlies a great triangular area in the southeastern part of the State, including Okefenokee Swamp and smaller areas farther north, which were once continuous with the main area but have been separated from it by erosion. The eastern boundary of the main area is marked by Trail Ridge, an old sand spit and bar that extended northward in the Sunderland sea from an island in Clay County, Fla., to the present course of Satilla River. This ridge dams drainage from the west and is responsible for the existence of Okefenokee Swamp.

Thickness.—The Sunderland formation is thickest in Trail Ridge, which rises 60 feet above Okefenokee Swamp west of St. George, where it appears to have formed a low island. Elsewhere the ridge ranges from 20 to 30 feet in height and accumulated under water. The maximum thickness of the formation, including the Trail Ridge bar, is probably not more than 100 feet. Generally the formation is much thinner. Near Fargo it is so thin that the shallow valley of Suwannee River cuts through it into the Hawthorn formation.

Lithologic character and stratigraphic relations.—The Sunderland formation consists chiefly of fine white or light-gray sand. The lower part of the sand may be of Coharie age, but if so, it probably cannot be distinguished from the Sunderland formation, with which it presumably is conformable. In Okefenokee Swamp and other swamps the Sunderland is overlain by peat and by boggy material that has accumulated since the emergence that ended Sunderland time. During the epoch of low sea level that followed Sunderland time, erosion probably removed most of the deposits of Sunderland age from areas east of its present belt of outcrop. If any remain, they are not conformable with the younger terrace deposits that cover them.

Economic significance.—The fine sand of the Sunderland formation may be of commercial value. The peat deposits that overlie it in the Okefenokee Swamp and elsewhere do not properly form part of the formation. They may ultimately be utilized. Some of the alluvial brick clays near the Fall Line along the larger rivers may represent estuarine or fluviatile parts of the Sunderland formation.

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[94] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, 1911. Cooke, C. W., Physical geography of Georgia; the Coastal Plain: Georgia Geol. Survey Bull. 42, 1925.

[95] Shattuck, G. B,, The Pleistocene problem of the North Atlantic Coastal Plain: Johns Hopkins Univ. Circ. 20, p. 14, 1901; Am. Geologist, vol. 28, pp. 102–103, 1901.

WICOMICO FORMATION

GENERAL FEATURES

Name and distribution.—The Wicomico formation, named [96] from a river in Maryland, occurs in Georgia as patches bordering the east edge of the Sunderland formation. North of the Altamaha the west edge of the Wicomico is very sinuous, with reentrants penetrating into the areas of Sunderland; south of the Satilla it abuts against the foot of Trail Ridge and is straight. Its east edge is only slightly indented. The Wicomico formation appears to be absent from the area between Altamaha and Satilla Rivers.

Thickness and lithologic character.—Few details are available as to the thickness and composition of the Wicomico. The formation is probably very thin and presumably consists chiefly of sand, but finer sediments may have accumulated in the indentations along the coast. No fossils have been found in it.

Stratigraphic relations.—The Wicomico formation has been defined [97] as the marine and estuarine Pleistocene deposits that accumulated while the sea stood about 100 feet above its present level. This epoch has been tentatively identified as the early part of the Sangamon interglacial stage.[98] From the sinuosity of its shore line and from the occurrence of stumps of trees beneath it in North Carolina and in the District of Columbia, one can infer that the Wicomico formation was deposited unconformably on a land surface by an advancing sea. At the end of the Wicomico epoch, sea level fell about 30 feet and became stabilized at a height of about 70 feet above its present level during the Penholoway stage. The part of the sea bottom (Wicomico formation) exposed by this lowering of sea level has been above water and exposed to erosion ever since.

Economic significance.—The Wicomico formation may contain workable deposits of sand or gravel and probably brick clay.

PENHOLOWAY FORMATION

GENERAL FEATURES

Name.—The Penholoway terrace was named in 1925,[99] at which time an area extending from Hortense, Brantley County, northeastward to Penholoway Creek and Penholoway Swamp, in Wayne County, was designated as the type. The Penholoway formation was

[96] Shattuck, G. B., op. cit. (Am. Geologist), p. 103.

[97] Cooke, C. W., Correlation of coastal terraces: Jour. Geology, vol. 38, p. 582, 1930; Geology of the Coastal Plain of South Carolina: U. S. Geol. Survey Bull. 867, p. 143, 1936.

[98] Cooke, C. W., Tentative ages of Pleistocene shore lines: Washington Acad. Sci. Jour., vol. 25, pp. 331–333, 1935.

[99] Cooke, C. W., Physical geography of Georgia; the Coastal Plain: Georgia Geol. Survey Bull. 42, p. 24, 1925.

later defined as the deposits laid down in the seas and its estuaries when the ocean stood about 70 feet higher than its present level, which height seems to be that of the shore line corresponding to the typical Penholoway terrace.[1]

Distribution.—The Penholoway formation extends across Georgia from Effingham County south of Springfield to Charlton County near Folkston. The band is widest between Jesup and Nahunta, where it attains a maximum width of more than 20 miles.

Thickness.—The formation is probably very thin except where the accumulation of sand in bars, spits, and barrier islands increases its thickness by 20 feet or more. One such group of bars, whose higher parts protruded above water as low barrier islands, lies along the east edge of the typical area.

Lithologic character.—The Penholoway formation is probably composed almost entirely of fine quartz sand, but some clay may have been deposited behind the barrier islands or in estuaries. No fossils have been found in it.

Stratigraphic relations.—The Penholoway formation appears to have succeeded the Wicomico without stratigraphic break, the sea having withdrawn from a height of 100 to about 70 feet and become stationary there. The estuarine extensions of the Penholoway did not occupy freshly eroded valleys but merely filled shortened and narrowed remnants of the Wicomico estuaries. Similarly, at the end of the Penholoway epoch sea level dropped about 28 feet and came to rest about 42 feet above its present position. The Penholoway epoch has been tentatively correlated with the middle part of the Sangamon interglacial stage.

Economic significance.—Clay suitable for making bricks and tiles may occur in the Penholoway formation.

TALBOT FORMATION

GENERAL FEATURES

Name and distribution.—The Talbot formation takes its name from a county in Maryland. As originally defined[2] it included also the younger Pleistocene deposits that are now called Pamlico formation, which are separated from it by an interval of erosion. In Georgia the Talbot is most extensively developed in ancient estuaries, diminished remnants of the tidal areas of the preceding epoch, but between Hinesville and Savannah River lies a narrow band that seems to have been deposited in open sea water.

[1] Cooke, C. W., Geology of the Coastal Plain of South Carolina: U. S. Geol. Survey Bull. 867, p. 147, 1936.

[2] Shattuck, G. B., op. cit. (Am. Geologist), p. 104.

Thickness and lithologic character.—Little is known about the composition and thickness of the Talbot. Presumably the formation is thin and consists mainly of sand or sandy clay. No fossils have been reported from it though the shells herein mentioned in the description of the Pamlico may really be Talbot.

Stratigraphic relations.—The Talbot formation apparently marks the last epoch of a series of three characterized by successively lower stages of sea level. These three (Wicomico, Penholoway, and Talbot) have been tentatively correlated with the Sangamon interglacial stage. Sea level during Talbot time stood approximately 42 feet higher than now. At the end of Talbot time, probably during the early Wisconsin ("Iowan") glacial stage, it fell considerably lower than its present location, and the Talbot deposits were actively eroded.

Economic significance.—The only deposits of value to be looked for in the Talbot formation are sand, clay and probably shells. The clay may be suitable for making tile and bricks but not for porcelain, the shells for road metal.

PAMLICO FORMATION

GENERAL FEATURES

Name.—The Pamlico formation, named from Pamlico Sound in North Carolina,[3] is approximately equivalent to the †Satilla formation of Bulletin 26,[4] which was published before the name Pamlico appeared in print, though the manuscript of Bulletin 26 was transmitted for publication several months after that describing the Pamlico. The name Pamlico is preferred because it has gained wider acceptance.

Distribution.—The Pamlico formation occupies a belt that is 20 to 25 miles wide near the coast of Georgia, extending from tidewater to an abandoned shore line about 25 feet above sea level. The seaward boundary of the belt is very sinuous. The landward margin shows several broad arcs somewhat like those on the east coast of Florida and the Carolinas. Estuarine reentrants extend up all the principal valleys.

Thickness and lithologic character.—The thickness of the Pamlico formation probably does not greatly exceed 60 feet, which is its maximum known thickness in South Carolina, and at many places it is very much less. The formation consists chiefly of sand and clay.

Fauna.—It now seems probable that the most prolific Pleistocene shell beds of Florida, those of the Anastasia coquina and the Miami

[3] Stephenson, L. W., The Coastal Plain of North Carolina; Quaternary formations: North Carolina Geol. Survey, vol. 3, p. 286, 1912.

[4] Veatch, Otto, and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, p. 434, 1911.

oolite, are of Talbot age rather than Pamlico, as had been supposed,[5] and that the Pamlico formation, where present, consists chiefly of barren sand. The same may be true of many of the shell beds in the Carolinas, Virginia, Maryland, Delaware,[6] and along the Atlantic coast farther north.[7] There are fewer records from Georgia, though Bulletin 26[8] reports oyster shells at several widely scattered places. In 1936 the sea shells in the following list were dug from a depth of 8 to 10 feet below the surface on 36th Street between Harmon and Ott Streets at Savannah. It is not known from which formation they came.

Fossil sea shells at Savannah

[Identified by W. C. Mansfield]

Ilyanassa obsoleta Say.
Busycon caricum Gmelin.
Polinices duplicata Say.
Argina pexata Say.
Cunearca incongrua Say.
Ostrea virginica Gmelin.
Venus mercenaria Linnaeus.
Tagelus sp.
Mulinia lateralis Say.

Three feet of greenish clay containing fossil oysters and clams was exposed in 1938 in a 7-foot drainage ditch crossing De Renne Street 100 yards east of Bull Street, about 3 miles south of Savannah. The shells were most abundant about 150 feet east of De Renne Street.

Hodgson[9] reports fossil marine shells at Vernonburg, 9 miles south of Savannah, at a bluff on Skidaway Island, and in the Brunswick canal connecting Turtle River with the Altamaha.

Stratigraphic relations.—Pamlico time was preceded by a time of lower sea level, during which the Talbot sea bottom, on which the Pamlico formation rests, was exposed to the forces of subaerial erosion.[10] The intricacy of the present high-tide line shows that there was considerable erosion of the Pamlico before the sea advanced across it to its present position, and that the recent deposits lie uncomformably on it. Drowned channels in the coastal waters are further proof of recent submergence. The Pamlico epoch has been correlated with the "Peorian interglacial stage," which is now generally interpreted as the middle part of the Wisconsin glacial stage.

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[5] Cooke, C. W., and Mossom, Stuart, Geology of Florida: Florida Geol. Survey, 20th Ann. Rept., p. 199, 1929.

[6] Richards, H. G., Fauna of the Pleistocene Pamlico formation of the southern Atlantic Coastal Plain: Geol. Soc. America Bull., vol. 47, pp. 1611–1656, 1936.

[7] MacClintock, Paul, and Richards, H. G., Correlation of late Pleistocene marine and glacial deposits of New Jersey and New York: Geol. Soc. America Bull., vol. 47, pp. 289–338, 1936.

[8] Veatch, Otto, and Stephenson, L. W., op. cit., p. 437.

[9] Hodgson, W. B., Memoir on the *Megatherium* and other extinct gigantic quadrupeds of the coast of Georgia, with observations on its geologic features, p. 21, New York, 1846.

[10] Cooke, C. W., Tentative ages of Pleistocene shore lines: Washington Acad. Sci. Jour., vol. 25, p. 33, 1925.

Economic significance.—Some of the clay deposits in the Pamlico formation may be of value.

BONE BED

GENERAL FEATURES

On Skidaway Island, Chatham County, bones of the giant ground sloth, *Megatherium*, were found in 1823. The bed containing them was called the "inland swamp formation" by J. Hamilton Couper, whose description of the occurrence is included in a pamphlet by Hodgson [11] published in 1846.

Distribution.—Though reported at only a few places in Georgia, the bone bed is probably represented by many widely scattered patches, some of which may be concealed by Recent deposits. Besides Skidaway Island, the bed has been reported on the nearby mainland at Hainers Bridge and in Glynn County. It is probably equivalent to the Melbourne bone bed,[12] which has been thoroughly explored at several places in Florida.

Thickness and lithologic character.—Couper describes the "inland swamp formation" as follows:

> This formation consists, usually, of a surface stratum of loam 1 or 2 feet deep, resting on a compact clay destitute of vegetable matter. The stratum of clay varies in depth but is generally from 5 to 10 feet deep and is of various colors but is more commonly blue or yellow. It frequently contains beds of marl, calcareous and siliceous gravel, petrified wood, bog iron ore, and in most instances exhibits traces of lime and iron. In some localities it assumes the appearance of green marl and contains grains of protophosphate of iron. It rests, in every instance, at a greater or less depth on a sandy, newer Pliocene formation. No fossil shells have hitherto been noticed in it; but, as has been observed, all the fossil bones of the terrestrial Mammalia discovered on the seacoast of Georgia have been found at the *bottom* of it and *embedded* in it, but resting on the newer Pliocene sand.

Fauna.—Fossil bones dredged from the Brunswick Canal and probably from other places near Brunswick have been identified as representing the giant beaver, the Columbian elephant, the American mastodon, a buffalo, a deer, a tapir, three kinds of horses, ground sloths, crocodiles, and several kinds of fishes. The species found there have been listed by Hay [13] as follows:

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[11] Hodgson, W. B., Memoir on the *Megatherium* and other extinct gigantic quadrupeds of the coast of Georgia, with observations on its geologic features, 47 pp., 3 pls., New York, 1846.

[12] Cooke, C. W., and Mossom, Stuart, Geology of Florida: Florida Geol. Survey 20th Ann. Rept., pp. 218–226, 1929.

[13] Hay, O. P., The Pleistocene of North America and its vertebrated animals from the States east of the Mississippi River and from the Canadian Provinces east of longitude 95°: Carnegie Inst. Washington Pub. 322, p. 370, 1923.

Fossil vertebrates from near Brunswick

Castoroides ohioensis.
Elephas columbi.
Mammut americanum.
Bison sp. indet.
Cervus? sp. indet.
Tapirus haysii.
Equus complicatus.
E. leidyi.
E. littoralis.
Megatherium mirabile.
Mylodon harlani.
Chelonia (??) couperi.
Crocodylus (?) sp. indet.
Lamna sp. indet.
Galeocerdo sp. indet.
Carcharodon sp. indet.
Dasyatis sp. indet.

Several of these species and the box tortoise *Terrapene canaliculata* are listed by Hay from near Savannah.

The species thus far discovered in the bone bed represent only a small part of the contemporaneous fauna. They are merely accidental finds, not the result of systematic exploration. The probably contemporaneous Melbourne bone bed of Florida has yielded 66 spieces, including human remains.

Stratigraphic relations and origin.—The bone bed is said to fill hollows in the underlying shell bed, which may represent the Talbot formation. It is being eroded today, and Recent sediments are being deposited unconformably on it. The writer has not seen any fresh exposures of the bone bed in Georgia, but as it appears to be very much like the Melbourne bone bed, he offers the following hypothesis of its origin, based on his observations of the Melbourne bone bed.

During the latter part of the Pamlico epoch, while the sea still stood at the 25-foot level, a series of low barrier islands fringed the Atlantic coast and offered habitat to many living creatures. Between the islands and the mainland were tidal marshes, shallow lagoons, and deeper channels. From time to time, bones of land animals and teeth of sharks and other fishes were buried in the watercourses by sand blown from the islands or mud dropped by the turbid water of the Savannah, Ogeechee, and Altamaha Rivers. Accumulation of the bed ceased at the end of the Pamlico epoch, when sea level fell to the low level of the late Wisconsin glacial stage, and the bed was trenched by rapid streams. Melting of the Wisconsin ice sheet at the beginning of Recent time raised the level of the ocean and flooded the newly carved valleys and the older lagoons to the height of present sea level. If this interpretation is correct, the bone bed is of late Pamlico age or in terms of glacial chronology, it marks the end of the mid-Wisconsin ("Peorian") interglacial stage.

Economic significance.—So far as known the bone bed has no intrinsic value. The bones in it, however, have much scientific interest, and the skeletons, if complete enough for museum specimens, command a limited market.

LOCAL OCCURRENCE

Chatham County.—A bluff where the tidal currents of Burnside and Back Rivers scour against the shore of Skidaway Island, 4 miles south of the village of Isle of Hope, is the type locality of the bone bed. Here, according to Lyell[14]

no less than three skeletons of the huge *Megatherium* have been dug up, besides the remains of the *Mylodon, Elaphas primigenius, Mastodon giganteus,* and a species of the ox tribe. The bones occur in a dark, peaty soil of marsh mud, above which is a stratum three or four feet thick of sand charged with oxide of iron, and below them and beneath the sea level occurs sand containing a great number of marine fossil shells, all belonging to species which still inhabit the neighboring coast.

Similar conditions exist at Hayners Bridge, 2½ miles west of Isle of Hope, where *Mammut americanum* and *Mylodon harlani* were found below high tide level in White Bluff River overlying a shell bed.

Glynn County.—Most of the bones found near Brunswick were dug from a shallow canal connecting Brunswick with Darien. The occurrence is described by Couper[15] as follows:

The Brunswick Canal, from which the fossil terrestrial and marine bones and fossil marine shells were taken during the years 1838 and 1839, is intended, when finished, to connect the Alatamaha [Altamaha] and Turtle Rivers. It lies about 9 miles from the ocean and 2 from the eastern edge of the mainland, to which its general course is parallel, and is excavated, in part, through the sandy newer Pliocene which forms this part of the continent and, in part, through a narrow inland swamp, called the Six-mile. This swamp is connected by creeks with the Alatamaha and Turtle Rivers at its opposite ends, and at either extremity the sandy land closes in between the swamp and the rivers and leaves only small shallow channels for the discharge of its waters. It presents, therefore, the appearance of a small shallow lake, which has been gradually filled up by alluvial deposits to within a few feet of the surrounding sandy plain. This alluvium consists of a hard, compact clay, generally of a yellow color, much impregnated with iron, and contains thin strata of a soft chalky marl and numerous fragments of calcareous petrifactions of wood. It is covered by a thin stratum of vegetable and sandy loam and rests, at an average depth of 5 or 6 feet, on a yellow sand varying in coarseness but always of well-rounded grains. The surface of the swamp is about 11 feet at its ends and 16 in the centre above the line of high water at spring tides, and forms an inclined plane sloping off to the two rivers.

The fossil bones of the terrestrial Mammalia were discovered during the excavation of the canal at the southern end of the swamp at six different points, extending up it from its junction with the salt marsh to a distance of 3 miles. In every instance they were found at the bottom of the alluvial formation, between 4 and 6 feet below the surface, embedded in clay but resting on yellow sand. This yellow sand stratum is, at these points, about 5 feet above the line of high tides. Five feet below its surface, or at the height of high water, it changes from a yellow to a white color and assumes a quicksand character, which it retains for

[14] Lyell, Charles, A second visit to the United States of North America. vol. 1, pp. 313–314, 1855.

[15] Couper, J. H., in Hodgson, W. B., op. cit., pp. 38–40.

1 or 2 feet. It is then succeeded by a coarser and sharper sand with occasional thin strata of a foetid black mud. Marine fossil shells of the same species as those now existing along the adjoining coast are found in small masses in a slightly inclined or horizontal position scattered at intervals throughout the whole length of the canal and at depths extending from the surface of the sand to 5 feet below the line of high water—which is the greatest depth to which the excavation has extended.

The same species, particularly the *Mactra lateralis*, are generally found grouped together; and as several of them, such as the *Artemis concentrica* and *Tellina alternata*, are so perfect as still to retain their epidermis, it is obvious that they originally grew on or near to the spot in which they are now found.

The bones of the different species of Mammalia occurred together in groups, and in some cases the greater part of the bones of the same skeleton were found in immediate juxtaposition. They were generally unbroken when first uncovered but, being soft and tender, fell to pieces if roughly handled. Many of the specimens were quite perfect and beautifully fossilized, and in no instance, except when they had been washed out into a salt-water creek, was there any abrasion of the surface or incrustation of marine shells. These circumstances render it highly probable that the carcasses of the various animals were floated or fell into the then lake or stream and, sinking to the sandy bottom, were gradually covered to their present depth by the alluvial deposit from the water. All the bones of the terrestrial Mammalia were found at nearly the same depth below the surface resting on the same stratum of sand and embedded in the same alluvial formation.

RECENT SERIES

As has already been stated, the final epoch of the Pleistocene series was a glacial stage (late Wisconsin), during which the level of the sea was considerably lower than now and the shore lay some distance seaward from its present location. The space between the present high-tide line and the late Wisconsin seashore was then dry land crossed by extensions of all the present streams and further drained by a system of rapidly growing gullies and rivulets.

Just when the Pleistocene epoch ended and the Recent epoch began is perhaps debatable. A logical time would seem to be when the Wisconsin ice caps began to melt, the sea to rise, and a transgressing series of marine sediments to be deposited on the old land surface. Flooded by continual additions of glacial melt-water, the sea crept higher and higher, ponded the lower courses of all the streams, and converted their valleys into estuaries. Finally a period of approximate equilibrium between melting and freezing was reached, and the sea level became nearly stationary—a condition that appears to have persisted for some thousands of years.

During this comparatively short period of stability the streams have been filling up their estuaries with sand and mud, converting them into tidal marshes. The growth of aquatic plants has hastened this process by retarding the currents and by the accumulation of vegetable matter. Some of the shoals thus formed have been raised

above high tide by the addition of sediments deposited on them during floods.

The waves and winds have added to the accumulation of Recent deposits by distributing sand along the beaches, by raising it above water level, and by blowing it inland across preexisting lowlands. It thus happens that the Pleistocene core of the sea islands is covered by a veneer of wind-blown sand.

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