

## DEPOSITS OF CLAIBORNE AND JACKSON AGE IN GEORGIA.

By CHARLES WYTHE COOKE and HAROLD KURTZ SHEARER.

### INTRODUCTION.

In 1911 the Geological Survey of Georgia published as Bulletin 26 a "Preliminary report on the geology of the Coastal Plain of Georgia," by Otto Veatch and Lloyd William Stephenson, prepared in cooperation with the United States Geological Survey under the supervision of T. Wayland Vaughan, geologist in charge of Coastal Plain investigations, who contributed the determinations of the invertebrate fossils of the Tertiary and Quaternary formations. Although this report constituted a decided advance in our knowledge of the geology of the Coastal Plain of Georgia, it was admittedly of reconnaissance character, and corrections and additions to it were to be expected. During the last few years field work has been prosecuted vigorously in the Coastal Plain of Georgia, and the additional information thus accumulated throws light upon certain problems of stratigraphy left unsolved by Veatch and Stephenson and alters considerably some of their correlations. The object of the present paper is to present the new evidence regarding the age and correlation of the Eocene formations of Georgia and to revise in accordance with present knowledge the descriptions of the deposits of Claiborne and Jackson age.

### SUMMARY OF EOCENE AND LOWER OLIGOCENE FORMATIONS AS KNOWN TO 1911.

The chapters on the Eocene and lower Oligocene formations in the Coastal Plain report will be briefly summarized. Veatch and Stephenson recognized the following formations:

Lower Oligocene:

Vicksburg formation.

Eocene:

Jackson formation.

Claiborne group.

Barnwell sand.

McBean formation.

Congaree clay member (at base).

Wilcox formation.

Midway formation.

The Midway and Wilcox formations are confined to the region west of Perry, Houston County. East of Perry both formations are overlapped by younger strata.

The McBean formation of Veatch and Stephenson consists mainly of clays in the nature of fuller's earth, of marls, sandy limestones, and calcareous glauconitic sands. An extensive marine fauna containing many characteristic lower Claiborne mollusks occurs in the marls on McBean Creek, Burke County, and also in the lower part of Shell Bluff on Savannah River. A series of fuller's earth grading into calcareous clay which is exposed at short intervals from Grovetown, Columbia County, southwestward along the Fall Line to Bibb and Twiggs counties, was correlated on lithologic grounds with Sloan's Congaree "phase" of the South Carolina Eocene and designated the "Congaree clay member of the McBean formation."

The Barnwell sand, correlated with Sloan's Barnwell "phase" in South Carolina, consists largely of unconsolidated red and varicolored sands, with some indurated beds of gray sandstone and lumps of silicified limestone or flint. They stated that it overlies directly the McBean formation and is in contact with both the marls and the "Congaree" clay member of that formation, but the nature of the contact had not been satisfactorily determined. In places the Barnwell overlaps the McBean formation and rests directly upon the Lower Cretaceous. It carries a marine fauna which contains a number of species in common with the Gosport sand of Alabama (upper Claiborne) and was correlated with that formation.

The Jackson formation as originally mapped by Veatch and Stephenson included a small patch on Chattahoochee River, a small outlier on the Cretaceous at Rich Hill, Crawford County, and a long, narrow area running from a point about 8 miles southwest of Sandersville to a point 6 miles east of Montezuma. On

the map accompanying the report on the ground waters of the Coastal Plain of Georgia by the same authors<sup>1</sup> this area was extended into southwestern Sumter County.

The Vicksburg formation of Veatch and Stephenson included besides strata of true Vicksburg age the great mass of limestone underlying the lower drainage basin of Flint and Chattahoochee rivers and forming the northern extension of the Ocala limestone of Florida.

#### RECENT INVESTIGATIONS AND THE INCEPTION OF THE PRESENT WORK.

The recent discovery that the Ocala limestone is of Jackson age<sup>2</sup> has largely increased the known areal extent of the deposits of that age, at the expense of the Vicksburg formation. The area of deposits of Jackson age has been further extended by Brantly,<sup>3</sup> to include most of those parts of Wilkinson and Twiggs counties formerly mapped as Claiborne. Brantly also expressed the opinion that the "Congaree" clay of previous reports seems to be the continuation of the Jackson limestone and fuller's earth of Houston County.<sup>4</sup> The same opinion concerning the stratigraphic relations of the "Congaree" clay was reached by H. K. Shearer, assistant State geologist, in the course of field investigations of the fuller's earth deposits of Georgia,<sup>5</sup> but as the published correlation of the "Congaree" clay with the Claiborne group seemed to be supported by as good paleontologic evidence as the correlation of the limestone with the Jackson, he was uncertain to which epoch the fuller's earth deposits properly belong.

At the request of Prof. S. W. McCallie, State geologist of Georgia, C. Wythe Cooke was assigned by the United States Geological Survey to accompany Mr. Shearer over the field, with the object of reconciling the discrepancies between the apparent stratigraphic relations of the deposits in eastern and central Georgia as determined by Messrs. Brantly and Shearer and

the ages indicated by previously published lists of fossils.

Field work was done by the writers jointly from March 20 to April 19, 1916, and during that time all the most significant known exposures of Eocene strata in the region between Flint and Savannah rivers were visited and collections of fossils were made wherever possible.

The succeeding fortnight was spent by Mr. Cooke in visiting the type localities of the South Carolinian Eocene for the purpose of determining the propriety of applying the names Congaree and Barnwell to geologic formations in Georgia. Mr. Shearer subsequently examined the Claiborne deposits in Georgia west of Flint River. The results of Mr. Cooke's previous (1914) studies of the Ocala limestone are also incorporated in this paper.

The writers are indebted to Prof. E. W. Berry, of Johns Hopkins University, and to Dr. R. S. Bassler, of the National Museum, for reports on the plant remains and Bryozoa, respectively, and to Dr. Joseph A. Cushman for identifications of the Foraminifera. The other fossils collected in the course of this investigation have been identified by Mr. Cooke, who has also had the privilege of examining the collections in the National Museum upon which were based the correlations published in the preliminary report on the geology of the Coastal Plain of Georgia. The present paper was prepared under the direction of T. Wayland Vaughan, geologist in charge of Coastal Plain investigations of the United States Geological Survey, who has given it continuous personal attention and has made a number of suggestions that have been adopted by the writers.

#### CRITICAL SECTIONS AND EOCENE FAUNAS OF EASTERN GEORGIA.

##### DRY BRANCH.

In the vicinity of Dry Branch, Twiggs County, are good exposures of Eocene beds which were referred to the Claiborne group by Veatch and Stephenson, on the basis of Vaughan's identifications of the fossils, but which later discoveries have shown to be of Jackson age. The following section is typical. The formation names used are those adopted in this report.

<sup>1</sup> U. S. Geol. Survey Water-Supply Paper 341, pl. 3, 1915.

<sup>2</sup> Cooke, C. W., The age of the Ocala limestone: U. S. Geol. Survey Prof. Paper 95, pp. 107-117, 1915.

<sup>3</sup> Brantly, J. E., Report on the limestones and marls of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 21, 1916.

<sup>4</sup> Idem, p. 8.

<sup>5</sup> Since the completion of this manuscript Shearer's report on the bauxite and fuller's earth of the Coastal Plain of Georgia has been published as Bulletin 31 of the Georgia Geological Survey. He has adopted the correlations proposed here.



Section at the mines of the Georgia Kaolin Co., 2 miles east of Dry Branch.

|   |        |
|---|--------|
| Vicksburg or Barnwell formation:  | Feet.  |
| 7. Red sand, capping hill, about.....   | 80     |
| Barnwell formation (Twiggs clay member):  |        |
| 6. Greenish-gray fuller's earth (buff when dry).....  | 30-40± |
| Ocala limestone (Tivola tongue):  |        |
| 5. Impure white argillaceous limestone, grading into fuller's earth. Pinches out toward the north and northwest and is absent in the northwestern part of the quarry. Contains many Bryozoa. Separated from the underlying bed by a somewhat irregular contact..... | 0-5    |
| Barnwell formation (lower part):  |        |
| 4. Yellow sand with black carbonaceous stains. Contains a few large bones of <i>Basilosaurus cetoides</i> (Owen) <sup>1</sup> .....   | 1-2½   |
| 3. Yellow to red sand, medium coarse, irregularly bedded.....   | 12     |
| 2. Gray sandstone with calcareous cement, loaded with casts of mollusks. Pinches out at north end of quarry, where the kaolin is overlain by glauconitic sand..   | 0-2    |
| Unconformity.   |        |
| Lower Cretaceous:   |        |
| 1. White kaolin.....  | 15-20  |

The fossils collected from the basal Eocene at this locality are listed below.

Station 7691. Pit of Georgia Kaolin Co., 2 miles east of Dry Branch, Ga. Bed 2 of section. Basal sandstone immediately overlying the Lower Cretaceous. Cooke and Shearer, collectors, 1916.

*Levifusus trabeatus* (Conrad)?  
*Levifusus* sp.  
*Ficus filius* (Meyer).  
*Turritella* sp.  
*Mesalia vetusta* (Conrad).  
*Calyptraea* sp.  
*Nucula magnifica* Conrad.  
*Leda* cf. *L. mater* Meyer.  
*Leda* cf. *L. plicata* (Lea).  
*Leda regina-jacksonis* Harris?  
*Glycymeris staminea* (Conrad)?  
*Glycymeris* sp.  
*Barbatia cuculoides* (Conrad).  
*Ostrea trigonalis* Conrad.  
*Ostrea* sp.  
*Pteria limula* (Conrad)?  
*Panope porrectoides* (Aldrich).  
*Corbula oniscus* Conrad var.  
*Corbula densata* Conrad.  
*Phacoides* (Miltha) *pandatus* (Conrad).  
*Phacoides alveatus* (Conrad) var.  
*Phacoides* (Here) sp.  
*Tellina*, 2 sp.  
*Macoma* sp.  
*Metis* sp.  
*Tagelus* sp.  
*Meretrix securiformis* (Conrad)?  
*Protocardia nicolleti* (Conrad).

<sup>1</sup> Identified by C. W. Gilmore.

Many of the mollusks in this list occur in both Claiborne and Jackson deposits, but *Ficus filius*, *Leda mater*, *Leda regina-jacksonis*, *Ostrea trigonalis*, *Meretrix securiformis*, and *Protocardia nicolleti* are particularly characteristic of the Jackson and are rare or unknown in older beds. *Mesalia vetusta*, which had been previously thought to be confined to the upper Claiborne (Gosport greensand horizon), has recently been found at the base of the Jackson formation at Sims, Yazoo County, Miss.

*Basilosaurus cetoides*, the zeuglodon, which occurs in bed 4, is so far as known confined to the Jackson, and in most places is most abundant near the top.

According to R. S. Bassler, the Bryozoa in bed 5 constitute a fauna peculiar to the middle Jackson. The same fauna occurs at Rich Hill, Crawford County, and numerous other localities in central Georgia and will be referred to for convenience as the Rich Hill facies of the Jackson fauna.

The fuller's earth of bed 6, a greenish hackly clay of low specific gravity, resembles the beds exposed at numerous localities in central and eastern Georgia and referred by Veatch and Stephenson to the "Congaree" clay member of the McBean formation.

The red sand at the top of the section was correlated by Veatch and Stephenson with the Barnwell sand, and the underlying beds were placed doubtfully with the McBean formation.<sup>2</sup>

Certain problems in stratigraphy, which the authors cited were unable to explain under the supposition that the strata near Dry Branch are of Claiborne age, vanish immediately when it is discovered that the deposits are of Jackson age. For instance, they say:<sup>3</sup>

According to Dr. Vaughan the evidence of the fossils shows that Jackson strata occur near the mines of the Georgia Kaolin Co., 2 miles southeast of Dry Branch. There is an exposure of 15 feet of soft white argillaceous marl in a small ravine one-half mile southeast of the clay-working plant, which contains Bryozoa and other fossils and is similar lithologically to the marl at Rich Hill. It lies 10 to 15 feet above the white clay beds of the Cretaceous and is overlain by 125 feet of bluish or drab laminated sandy clay and red sand, the clay containing thin slabs of quartzite or sandstone. In this vicinity Claiborne fossiliferous strata occur at both higher and lower levels than this marl, and the presence of Jackson beds in this

<sup>2</sup> Veatch, Otto, and Stephenson, L. W., *Geology of the Coastal Plain of Georgia*: Georgia Geol. Survey Bull. 26, p. 256, 1911.

<sup>3</sup> *Ibid.*, p. 304.

position implies either a deep erosion unconformity between the two formations or a flexure. Exposures in this vicinity, so far as they have been examined, afforded no evidence of an unconformity or of any faulting or folding of the beds. Further detailed field work is necessary to solve this problem of stratigraphy.

The problem has been solved by the discovery that the beds higher and lower than the marl are Jackson and not Claiborne.

#### SOUTH OF PERRY.

Other localities which presented difficulties to Veatch and Stephenson are Mossy Hill and Ross Hill, in Houston County. These hills are a few miles apart on the escarpment south of Mill and Flat creeks, which extends north-eastward, approximately parallel to the general strike of the formations of the Coastal Plain in this part of the State. Ross Hill is crossed on the road from Perry to Elko, 3 miles south of Perry, and Mossy Hill lies on the National Highway (the road from Perry to Henderson) about 5.7 miles southwest of Perry.

The entire section at Ross Hill, with the exception of 10 feet at the top, was referred by Veatch and Stephenson to the Jackson formation, and this correlation was supported by lists of fossils identified by Vaughan. The following section measured by the writers is in essential agreement with that of Veatch and Stephenson.<sup>1</sup> The base of the section is 25 feet above Mill Creek.

#### Section on Perry-Elko road at Ross Hill.

|   |       |
|---|-------|
| Oligocene (?):  | Feet. |
| Vicksburg formation (?):  |       |
| 7. Concealed to edge of plowed field on top of hill, which rises a few feet higher. The surface is strewn with lumps of sparingly fossiliferous chert.....                      | 15    |
| Eocene (all of Jackson age):  |       |
| Barnwell formation:   |       |
| 6. Soft cream-colored to yellow sandy limestone with casts of fossils. <i>Lunularia distans</i> , <i>Endopachys</i> , <i>Calyptraea</i> , <i>Leda</i> , and <i>Pecten</i> ..... | 4±    |
| 5. Light-colored limestone at base; upper part concealed but with debris of soft limestone with <i>Periarchus pileus-sinensis</i> and Bryozoa.....                              | 15    |
| 4. Hackly cream-colored calcareous clay (fuller's earth) with lime concretions.   | 24    |
| Ocala limestone (Tivola tongue):  |       |
| 3. Cream-colored limestone, soft when fresh, with a hard ledge at bottom. Has been quarried in part. Contains <i>Pecten perplanus</i> and many Bryozoa..                        | 7½    |

#### Section on Perry-Elko road at Ross Hill—Continued.

|   |       |
|---|-------|
| Eocene (all of Jackson age)—Continued.  | Feet. |
| Ocala limestone (Tivola tongue)—Continued.  |       |
| 2. Soft greenish-yellow limestone, speckled with glauconite and with locally indurated nodules or ledges. Very argillaceous toward the top and contains numerous soft, irregular lime concretions. Bryozoa..... | 7½    |
| 1. Pale cream-colored soft limestone, replete with Bryozoa (Rich Hill facies of Jackson fauna). Hard ledges near the top. Contains also <i>Periarchus pileus-sinensis</i> . Exposed east of the road.....       | 38    |

The following section was measured in a gully on Ross Hill about 300 yards west of the Perry-Elko road. The top of the hill here is probably 40 feet or more higher than at the road. The base of the section is by barometer 40 feet above the bridge over Mill Creek.

#### Section on Ross Hill 300 yards west of Perry-Elko road.

|   |       |
|---|-------|
| Oligocene (?):  | Feet. |
| Vicksburg formation (?):  |       |
| 14. Red sand with "buckshot" ferruginous lumps. Fragments of fossiliferous chert on top.....  | 30    |
| Eocene:   |       |
| Barnwell formation (Twiggs clay member):  |       |
| 13. Glauconitic clay and fuller's earth, poorly exposed.....  | 15±   |
| 12. Glauconitic grains in a matrix of yellowish, calcareous clay. <i>Pecten</i> sp., etc.....   | 2½±   |
| 11. Gray hackly clay (fuller's earth); upper 2 feet containing lenses or nodules of glauconitic material resembling bed 12.....   | 7½±   |
| 10. Lens or nodule of greenish-gray limestone with casts of <i>Corbula</i> , probably <i>C. wailesiana</i> .....  | 1     |
| 9. Fuller's earth.....  | 4     |
| 8. Limestone.....   | 1     |
| 7. Calcareous fuller's earth.....   | 15    |
| 6. Continuous ledge of gray limestone with poorly preserved mollusks.....   | ½     |
| 5. Calcareous fuller's earth containing soft, white chalk nodules.....  | 3½    |
| 4. Hard light-gray limestone, softer at bottom. Contains some Bryozoa, <i>Flabellum</i> , <i>Turritella carinata</i> , <i>Mesalia vetusta</i> , <i>Pecten</i> , <i>Meretrix</i> , and <i>Periarchus pileus-sinensis</i> ..... | 3     |
| 3. Hackly cream-colored calcareous clay (fuller's earth). The base of this bed is the same as the base of bed 4 of preceding section.....   | 35    |
| Ocala limestone (Tivola tongue):  |       |
| 2. Soft argillaceous limestone loaded with Bryozoa (Rich Hill facies of Jackson fauna). Contains also <i>Ostrea trigonalis</i> and <i>Pecten perplanus</i> .....  | 7     |
| 1. Hard and soft ledges of limestone with Bryozoa, <i>Pecten perplanus</i> , and <i>Periarchus pileus-sinensis</i> very abundant.   | 17    |

<sup>1</sup> Op. cit., p. 301.



Bed 4 is particularly significant in that it shows the presence of *Turritella carinata* and *Mesalia vetusta*, which were considered by Vaughan to be diagnostic upper Claiborne fossils, well above the base of the deposits of Jackson age.

The geologic conditions at Mossy Hill appear to be similar to those at Ross Hill, but the exposures are less complete. The following section, exposed in and near an old quarry about 100 yards east of the National Highway, extends from a gully below the quarry to a level bench on the road.

*Section at Mossy Hill.*

Oligocene, Vicksburg formation:

13. Red argillaceous sand with chert fragments, commencing at a level bench on the National Highway and capping the upland area to the south ..... 30

Eocene: Barnwell formation (Twiggs clay member):

12. Mostly concealed, but interbedded fuller's earth and bryozoan limestone are exposed in a gully east of the road a few feet below the bench. .... 25
11. Yellow to green, partly indurated glauconitic marl. .... 5
10. Calcareous clay resembling fuller's earth, with a locally indurated stratum at top. .... 5½
9. Impure yellowish limestone with casts of fossils. .... 2½
8. Concealed. .... 6
7. Clay or fuller's earth with chalk concretions. .... 2
6. Concealed. .... 14
5. Calcareous fuller's earth, exposed on road-side. .... 3
4. Hard limestone. .... ½
3. Calcareous fuller's earth. .... 2½
2. Argillaceous fossiliferous limestone with hard ledges; quarried. .... 11
1. Gray calcareous clay with lime nodules below, grading upward into fuller's earth with lime nodules; exposed in gully below quarry. .... 21

From bed 2 the following species were obtained:

Station 7682. Quarry on Mossy Hill. Cooke and Shearer, collectors, 1916:

- Endopachys* sp.  
*Lunularia distans* (Lonsdale).  
*Turritella carinata* Lea.  
*Mesalia vetusta* (Conrad).  
*Leda* cf. *L. plicata* (Lea).  
*Glycymeris* sp.  
*Pecten perplanus* Morton.  
*Phacoides alveatus* (Conrad).  
*Miltha claibornensis* (Conrad).  
*Dentalium* sp.

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The stratum immediately below the bed from which these species were collected contains Bryozoa which R. S. Bassler refers to the horizon of the deposits of Jackson age at Baldock, S. C. The stratum in the quarry from which the fossils were collected seems to be identical with bed 4 of the section on Ross Hill west of the Perry-Elko road. Not only are the species, so far as they can be identified, the same, but the rocks in which they are embedded look alike, and the sections both above and below the fossiliferous zone are similar. Moreover, the topographic relations of the two localities are such as to indicate that the beds at both are at the same horizon, provided, of course, that there are no structural disturbances, of which there is no evidence.

In the Coastal Plain report<sup>1</sup> the lower part of the section at Mossy Hill was referred to the Claiborne group on the basis of collections of fossils made by T. W. Vaughan and S. W. McCallie. The species collected by Vaughan at Mossy Hill are listed as follows:

- Flabellum cuneiforme* Lonsdale.  
*Turbinolia pharetra* Lea.  
*Endopachys machurii* (Lea).  
 \**Turritella carinata* Lea.  
 \**Mesalia vetusta* (Conrad).  
*Calyptraea aperta* (Solander).  
*Dentalium thalloides* Conrad.  
*Nucula ovula* Lea.  
*Leda* sp.  
*Leda* sp.  
*Glycymeris idoneus* (Conrad)?  
 \**Phacoides alveatus* (Conrad).  
*Venericardia*, 2 or 3 sp.  
*Cytherea* sp.  
*Crassatellites* sp.  
*Corbula oniscus* Conrad or *wailesiana* Harris.  
*Corbula densata* Conrad?

Geologic horizon, Claiborne. Species marked \* are not known from the Jackson.

It will be noted that the only species checked as not known from the Jackson are *Turritella carinata*, *Mesalia vetusta*, and *Phacoides alveatus*. The first and second have since been found in the beds of Jackson age at Ross Hill, and the second and third at the mine of the Georgia Kaolin Co. One of the undetermined species of *Leda* listed occurs also at the latter place.

<sup>1</sup> Veatch, Otto, and Stephenson, L. W., op. cit., pp. 258-260.

The fossils collected by McCallie are listed as follows:

- Turbinolia pharetra Lea.
- Flabellum cuneiforme Lonsdale.
- Plejona petrosa (Conrad).
- \*Turritella carinata Lea.
- Mesalia vetusta (Conrad).
- Dentalium thalloides Conrad.
- Nucula ovula Lea.
- Leda.
- \*Glycymeris trigonella (Conrad).
- Pteria sp.
- \*Phacoides alveatus (Conrad).
- \*Phacoides aff. P. claibornensis (Conrad).
- Venericardia planicosta Lamarck.
- \*Venericardia alticostata (Conrad).
- Cytherea sp.
- \*Crassatellites protexus (Conrad).
- \*Corbula oniscus Conrad.
- \*Pteropsis lapidosa (Conrad).

Species marked \* are not known from beds above the Claiborne. *Pteropsis lapidosa* is characteristic of the lower Claiborne.

This does indeed look like a Claiborne fauna, and with the data then available Vaughan was perfectly justified in referring these fossils to the Claiborne group; but, as we shall see later, nearly all the species checked have since been found associated with Jackson fossils. The exception to these is *Pteropsis lapidosa*, which elsewhere seems to be confined to the lower Claiborne. As this collection of fossils apparently is not now in the National Museum, the identifications of the species could not be checked nor could the matrix be examined to ascertain whether there had been accidental mixture of specimens from different localities.

There is some uncertainty as to the locality at which the fossils ascribed to Mossy Hill were obtained. According to Veatch and Stephenson,<sup>1</sup> Mossy Hill is on the Perry-Elko road 4½ miles south of Perry, a location corresponding nearly with that of Ross Hill. However, as there seems to be little doubt that the horizon is the same as that from which the writers obtained *Turritella carinata* and *Mesalia vetusta*, the exact locality is of no particular importance.

#### VICINITY OF GIBSON.

A collection made by the writers from sandstone ledges exposed on the hillside east of Rocky Comfort Creek, on the Brassell property, 2 miles northeast of Gibson, Glascock

County, shows the presence in Georgia of a fauna not previously recognized east of Arkansas. The fossils are preserved in the form of hollow molds or siliceous pseudomorphs, some of which have weathered out of the sandy matrix. The rock, which is an indurated facies of the basal sand bed of the Eocene that is of widespread distribution in this part of the State, is exposed to a thickness of 3 or 4 feet but probably extends somewhat deeper. It lies not far above the Cretaceous, but the contact is not exposed here. The fossils collected are enumerated in the accompanying list, in which the initials C and J signify that the species so marked occur elsewhere in Claiborne and Jackson deposits, respectively.

Station 7710. Brassell property, 2 miles northeast of Gibson, Glascock County. Cooke and Shearer collectors, 1916.

- CJ Flabellum cuneiforme Lonsdale.
- J Astrhelia burnsi Vaughan?
- CJ Cancellaria gemmata Conrad.
- Olivella sp.
- CJ Marginella semen Lea?
- Psilocochlis mcalliei (Dall).
- CJ Lapparia pactilis (Conrad).
- CJ Plejona petrosa (Conrad).
- J Levifusus branneri Harris.
- CJ Levifusus trabeatus (Conrad).
- CJ Mazzalina inaurata (Conrad) var.
- Fusinus aff. F. bellus (Conrad).
- J Murex marksi Harris.
- CJ Pseudoliva vetusta (Conrad).
- CJ Calyptraphorus velatus (Conrad).
- Cerithium sp.
- J Ficus filius (Meyer).
- CJ Turritella carinata Lea.
- CJ Mesalia vetusta (Conrad).
- CJ Natica minima Lea.
- J Natica permunda Conrad?
- Dentalium sp.
- J Leda regina-jacksonis Harris.
- CJ Leda multilineata Conrad?
- CJ Glycymeris staminea (Conrad)
- CJ Pteria limula (Conrad).
- Crenella sp.
- Pecten n. sp.
- CJ Corbula densata Conrad.
- CJ Phacoides (Miltha) claibornensis (Conrad).
- Phacoides sp.
- CJ Crassatellites protexus (Conrad) var.
- Crassatellites n. sp?
- CJ Macrocallista perovata (Conrad)?
- CJ Venericardia planicosta (Lamarck).
- C Venericardia alticostata Conrad var.

To this list should be added the following, which were obtained with other fossils from the same horizon at station 7711, on the east

<sup>1</sup> Op. cit., p. 258.



side of Deep Creek,  $3\frac{1}{2}$  miles northeast of Gibson and about  $1\frac{1}{2}$  miles from the Brassell locality:

- J Turritella clevelandia* Harris.  
*Leda plicata* (Lea) var.  
*Trinacria?* sp.  
*J Corbula waillesiana* Dall.

The section there is as follows:

Section on roadside east of Deep Creek,  $3\frac{1}{2}$  miles northeast of Gibson.

|  |       |
|--|-------|
| Eocene (Barnwell formation):   | Feet. |
| 7. Mottled red or orange-colored sand.....                                   | 50 ±  |
| 6. Fuller's earth with sand laminae.....                                     | 11    |
| 5. Unconsolidated sand similar to No. 4.....                                 | 5     |
| 4. White or gray fossiliferous sandstone like that on Brassell property..... | 6     |
| 3. Gray clayey sand.....   | 4     |
| 2. Concealed.....  | 10    |
| Cretaceous:  |       |
| 1. Kaolin and white sand.....  | 15    |

This fauna, which occurs within 15 feet of the Eocene-Cretaceous unconformity, bears a remarkably close resemblance to that occurring at White Bluff and Crowleys Ridge, Ark., which was formerly referred to the Claiborne group but is now correlated with the lower Jackson.<sup>1</sup> It is rather surprising to encounter such species as *Levifusus branneri*, *Murex marksi*, and *Turritella clevelandia*, which are typical of the Jackson deposits in Arkansas, so far east of their previously known range; but their presence, as well as the general aspect of the fauna, is good evidence that the beds containing them occupy approximately the same stratigraphic position. The presence of *Astrhelia burnsi*, *Ficus filius*, *Natica permynda*, *Leda regina-jacksonis*, and *Corbula waillesiana* affords strong additional evidence that the deposits are of Jackson age.

It will be noted that this list, which is much more comprehensive than any previously compiled from this region, contains nearly all the species that were considered by Vaughan to be diagnostic of the upper Claiborne. There are, in addition, a few species that are abundant at this horizon in Georgia but have not yet been found elsewhere. Among these may be mentioned *Psilocochlis mcalliei* and an undescribed species of *Pecten* which has hitherto been confused with *Pecten wilcoxii* and *P. waktubbeanus*.

Fossils representing this same horizon and embedded in a similar matrix of gray sandstone

which were collected by McCallie on the English plantation,  $1\frac{1}{2}$  miles north of Gibson, were referred by Veatch and Stephenson<sup>2</sup> to the McBean formation. The revised list follows:

Station 3943. English plantation,  $1\frac{1}{2}$  miles north of Gibson. S. W. McCallie, collector, 1904.

- Flabellum cuneiforme* Lonsdale.  
*Endopachys maclurii* (Lea).  
*Mazzalina inaurata* (Conrad).  
*Plejona petrosa* (Conrad).  
*Turritella clevelandia* Harris.  
*Turritella* sp.  
*Pecten* n. sp.  
*Pteria limula* (Conrad)?  
*Panope* sp.  
*Phacoides* (Miltha) *claibornensis* (Conrad).  
*Venericardia alticostata* Conrad var.

The same fauna has been recognized at several localities between Glascock and Bibb counties and is usually found in more or less indurated gray sandstone resembling that near Gibson. All these exposures were referred by Veatch and Stephenson to the Claiborne group—some to the McBean formation, others to the Barnwell sand.

#### BROWNS MOUNTAIN AND VICINITY.

At Browns Mountain, Bibb County, 9 miles southeast of Macon, the strata were referred to the Barnwell sand.<sup>3</sup>

At this locality the main exposures consist of about 20 feet of hard gray sandstone, part of which appears to grade into sandy limestone. It contains fossils that are locally abundant but are not very well preserved. Above the sandstone are poor exposures of bryozoan limestone with *Pecten perplanus?* Beneath the sandstone are incomplete exposures of fuller's earth and sand.

The relations are more evident on a hill on the Marion road, four-tenths of a mile southwest of Bond's store, where the following section was observed:

Section on Marion road 9 miles southeast of Macon.

|   |       |
|---|-------|
| Eocene:   | Feet. |
| 6. Hard sandstone and quartzite, to top of hill...  | 7     |
| 5. Mottled plastic clay.....  | 3     |
| 4. Red sand.....  | 4     |
| 3. Soft fossiliferous sandstone.....  | 0-4   |
| 2. Basal conglomerate; white kaolin pebbles in cross-bedded sand. Contact with Cretaceous not precisely located because of lithologic similarity..... | 55    |
| Cretaceous:   |       |
| 1. Coarse white kaolinic sand to stream level....   | 65    |

<sup>1</sup> Stephenson, L. W., and Crider, A. F., Geology and ground waters of northeastern Arkansas: U. S. Geol. Survey Water-Supply Paper 399, pp. 73-84, 1916.

<sup>2</sup> Op. cit., p. 273.

<sup>3</sup> Idem, pp. 258-260.

Stratum 3 of the section consists of a discontinuous ledge of sandstone which in places is reduced to lumps embedded in incoherent sand. It contains casts of mollusks, including *Pecten* n. sp. Bed 6 is also unequally indurated but is more persistent than bed 3. It carries *Periarchus pileus-sinensis* and other fossils. Beds 3 to 6 are equivalent to the hard rock on Browns Mountain, half a mile away.

The following lists enumerate the species collected in this vicinity:

Station 7695. Hilltop on Macon-Marion road four-tenths of a mile southwest of Bond's store, Bibb County.

C. Wythe Cooke, collector, 1916.

*Nucula ovula* Lea?

*Leda regina-jacksonis* Harris?

*Glycymeris* sp.

*Pecten* n. sp.

*Cytherea* sp.

*Periarchus pileus-sinensis* (Ravenel)?

Station 7696. Browns Mountain, near Bond's store, 9 miles southeast of Macon. C. Wythe Cooke, collector, 1916.

*Flabellum cuneiforme* Lonsdale.

*Lunularia* sp.

*Turritella* sp.

*Mesalia vetusta* (Conrad).

*Calyptrea* sp.

*Nucula spheniopsis* Conrad.

*Leda mater* Meyer.

*Pecten* n. sp.

*Pecten perplanus* Morton? (cast of interior).

*Diplodonta* sp.

*Phacoides* (Miltha) *claibornensis* (Conrad).

*Protocardia* sp.

*Crassatellites* sp.

Station 3993. Browns Mountain. S. W. McCallie, collector, 1909.<sup>1</sup>

*Flabellum cuneiforme* Lonsdale.

*Endopachys maclurii* (Lea).

*Periarchus pileus-sinensis* (Ravenel).

*Calyptrophorus velatus* Conrad.

*Turritella carinata* Lea.

*Mesalia vetusta* (Conrad).

*Calyptrea aperta* (Solander).

*Nucula magnifica* Conrad?

*Pteria* sp.

*Pecten* n. sp.

*Crassatellites protexus* (Conrad) var.

*Astarte tellinoides* Conrad?

*Venericardia alticostata* Conrad var.

*Phacoides* (Here) *hamatus* Dall.

*Phacoides alveatus* (Conrad).

*Protocardia nicolleti* (Conrad).

*Pitaria perovata* (Conrad).

*Cytherea* sp.

*Psammobia* sp.

*Panope porrectoides* (Aldrich).

*Corbula oniscus* Conrad.

<sup>1</sup> Veatch, Otto, and Stephenson, L. W., op. cit., p. 295. Identified by T. W. Vaughan; list revised by C. W. Cooke.

#### LITTLE KEG CREEK.

A large collection of fossils that is especially interesting because it shows the intimate relationships of the Claiborne and Jackson faunas was obtained on the east side of Little Keg Creek, 7 miles north-northwest of Sandersville. Without the knowledge of the extended range of certain species acquired since the publication of the report on the Coastal Plain of Georgia, this assemblage of forms would have been unhesitatingly referred to the upper Claiborne. As it stands, the numerical proportions of Claiborne and Jackson species recognized are practically the same, and the discovery of one or two additional species might turn the scale to one side or the other. When the numerical evidence is inconclusive in determining the age of a fauna, the philosophic course appears to be to attribute greater significance to the initial appearance of new forms than to the survival of old species. According to this reasoning the fauna at Keg Creek is lower Jacksonian, and it is so considered in this report. Moreover, this correlation is in accordance with that deduced from other stratigraphic criteria.

Section on east side of Little Keg Creek, Washington County, 7 miles north-northwest of Sandersville.

Eocene: Feet.

- |   |     |
|---|-----|
| 4. Coarse red sand with a few small quartz pebbles; 40 feet above the base is a 10-foot bed of white sand and yellow and white clay.. | 100 |
| 3. Greenish plastic clay.....   | 6½  |
| 2. Coarse red sand grading into overlying bed. Fossils very abundant but restricted to 6 inches at bottom.....                        | 1½  |

Unconformity (altitude 360 feet above sea level).

Cretaceous:

- |   |    |
|---|----|
| 1. White sand with lenses of kaolin, to level of creek..... | 60 |
|---|----|

The fossils in the following list were collected from the base of bed 2, which is a local pocket filling a hollow in the Cretaceous surface.

Station 7707. Roadside east of Little Keg Creek, 7 miles north-northwest of Sandersville. Immediately above the Cretaceous. Cooke and Shearer, collectors, 1916:

CJ *Flabellum cuneiforme* Lonsdale.

J *Astrhelia burnsi* Vaughan.

*Astrhelia* sp.

*Volvula* sp.

CJ *Actaeon idoneus* Conrad.

*Actaeon* sp.

*Terebra* sp.

C *Cochlespirella nana* (Lea)?

*Turritidae*, 3 sp.



## Station 7707—Continued.

- CJ *Conus sauridens* Conrad.
- CJ *Cancellaria gemmata* Conrad.  
    *Cancellaria*, 2 sp.  
    *Olivella* sp.
- C *Ancillina scamba* (Conrad).
- CJ *Marginella semen* Lea.  
    *Conomitra* sp.
- J *Psilocochlis mcalliei* (Dall).  
    *Caricella* n. sp.
- CJ *Plejona petrosa* (Conrad).
- CJ *Lapparia pactilis* (Conrad).  
    *Fusinus* sp.  
    *Clavilithes* sp.
- CJ *Levifusus trabeatus* (Conrad)?  
    C *Phos sagenus* (Conrad).
- C *Terebrifusus amoenus* (Conrad).
- J *Ficus filius* (Meyer).
- CJ *Calyptrophorus velatus* (Conrad).  
    *Cerithiopsis* sp.
- CJ *Turritella carinata* Lea.
- CJ *Mesalia vetusta* (Conrad).  
    *Epitonium* sp.  
    *Turbonilla* sp.
- J *Sinistrella americana* (Aldrich)?  
    *Calyptraea* sp.
- CJ *Lunatia minima* (Lea).  
    *Neverita* sp.
- CJ *Dentalium* sp.
- CJ *Nucula magnifica* Conrad?
- CJ *Nucula ovula* Lea.
- CJ *Leda multilineata* Conrad.
- CJ *Glycymeris staminea* (Conrad).  
    *Glycymeris* sp.
- C *Crenella isocardioides* (Lea).
- CJ *Corbula oniscus* Conrad.
- CJ *Corbula densata* Conrad.
- C *Corbula alabamensis* Lea.
- C *Corbula fossata* var. *extenuata* Dall.
- CJ *Pitaria perovata* (Conrad).
- CJ *Pitaria mortoni* (Conrad).
- CJ *Miltha pandata* (Conrad)?
- CJ *Lucina subvexa* Conrad?
- CJ *Phacoides alveatus* (Conrad)?  
    *Astarte* cf. *A. tellinoides* (Conrad).
- CJ *Crassatellites protectus* (Conrad) var.  
    J *Crassatellites* n. sp.?
- J *Protocardia nicolleti* (Conrad).
- CJ *Venericardia planicosta* (Lamarck).
- J *Venericardia* sp. (small).
- CJ *Venericardia alticostata* Conrad var.

Sufficient evidence has been advanced in the preceding pages to show, first, that certain strata referred by Veatch and Stephenson to the McBean formation overlie limestones that are definitely of Jackson age and, second, that the fauna of the Barnwell formation appears to be more closely related to Jackson than to Claiborne faunas and that the fossiliferous beds at some places lie directly upon Lower Cretaceous strata.

Below is given a systematic outline of the stratigraphy of the deposits of Claiborne and Jackson age as it is interpreted in the light of the new evidence.

## STRATIGRAPHY OF DEPOSITS OF CLAIBORNE AND JACKSON AGE IN GEORGIA.

## DEPOSITS OF CLAIBORNE AGE.

## FORMATIONS INCLUDED.

The Claiborne group receives its name from Claiborne Landing, Alabama River, Ala., the site of a town formerly of considerable importance but now almost deserted. In the type region the group is divided into three formations, the lowest being the Tallahatta buhrstone, the middle the Lisbon formation, and the upper the Gosport sand. The correlations between Alabama and Georgia are not precise enough to justify the use of any of these formation names in Georgia.

According to the interpretation of Veatch and Stephenson, nearly all the deposits of Eocene age in Georgia were included in the Claiborne group, and their map shows Claiborne formations extending across the entire width of the State. They recognized two formations within the group—a lower, the McBean formation with the so-called Congaree clay member, and an upper, the Barnwell sand. The recent detailed field studies of Shearer and Brantly have shown that the so-called "Congaree clay member of the McBean formation" properly constitutes part of the Barnwell formation, and studies of the fossils by Cooke, as set forth in the preceding part of this paper, have shown that the residue of their McBean formation in central Georgia also belongs to the Barnwell. The paleontologic evidence also indicates that the Barnwell formation is of Jackson rather than of upper Claiborne age, as previously supposed, and this conclusion is corroborated by diastrophic and other stratigraphic criteria.

As restricted by the elimination of the Barnwell formation and parts of the McBean formation the outcropping strata of Claiborne age in Georgia are confined to two separate areas—a small irregular area in the valleys of McBean Creek and Savannah River, in the extreme eastern part of the State, and a long, narrow strip in western Georgia, extending from Chattahoochee River eastward to a point

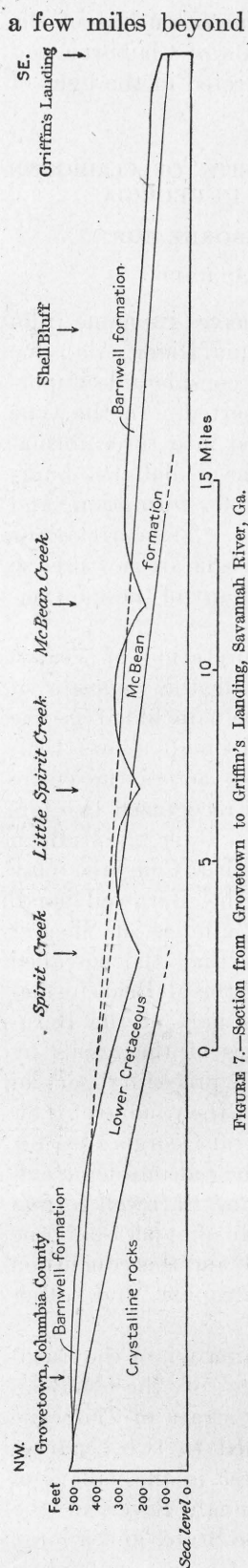


FIGURE 7.—Section from Grovetown to Griffin's Landing, Savannah River, Ga.

a few miles beyond Flint River. In the intermediate region the Claiborne deposits are overlapped by strata of Jackson age. The beds of Claiborne age in the Savannah area retain the name McBean formation, but those in the Chattahoochee-Flint River area, which were included by Veatch and Stephenson in the McBean formation and Barnwell sand, will be designated in this report undifferentiated Claiborne. The areal distribution is shown on the geologic map (Pl. VII).

#### MCBEAN FORMATION.

##### NAME.

The McBean formation was named by Veatch and Stephenson<sup>1</sup> from the town of McBean, in Richmond County, Ga., and from McBean Creek, which forms the boundary between Richmond and Burke counties.

##### STRATIGRAPHIC RELATIONS.

The McBean formation rests unconformably upon the Lower Cretaceous strata and is overlain by the Barnwell formation. The contact with the Barnwell is obscure, but it appears probable that there exists at least local unconformity between the two formations.

In the Savannah area the Claiborne strata have been overlapped by the Barnwell formation, though probably not so much as farther west,

but the valley of Savannah River has been incised so deeply that the overlapping portion of the Barnwell formation has been cut away along the river far enough to expose the McBean in its proper position above the Cretaceous. (See section, fig. 7.)

#### LITHOLOGIC CHARACTER AND THICKNESS.

The McBean formation consists chiefly of gray marl or sandy limestone and yellow sand with a little lignitic matter and greenish clay. The greatest thickness thus far observed at one locality is not more than 80 feet, and the total stratigraphic thickness along the outcrop in Georgia probably does not greatly exceed 100 feet.

#### PALEONTOLOGIC CHARACTER.

A large collection of well-preserved shells, chiefly mollusks, was obtained by Earle Sloan on the south side of McBean Creek near the Augusta-Waynesboro road. On the basis of these shells, Vaughan<sup>2</sup> correlates the strata with the Lisbon formation of Alabama and Mississippi, the St. Maurice formation of Louisiana, and the Cook Mountain formation of Texas. The same fauna has been found at several localities in Aiken and Orangeburg counties, S. C. The following list of species from Sloan's Scarp, McBean Creek, is quoted from the report on the Coastal Plain:<sup>3</sup>

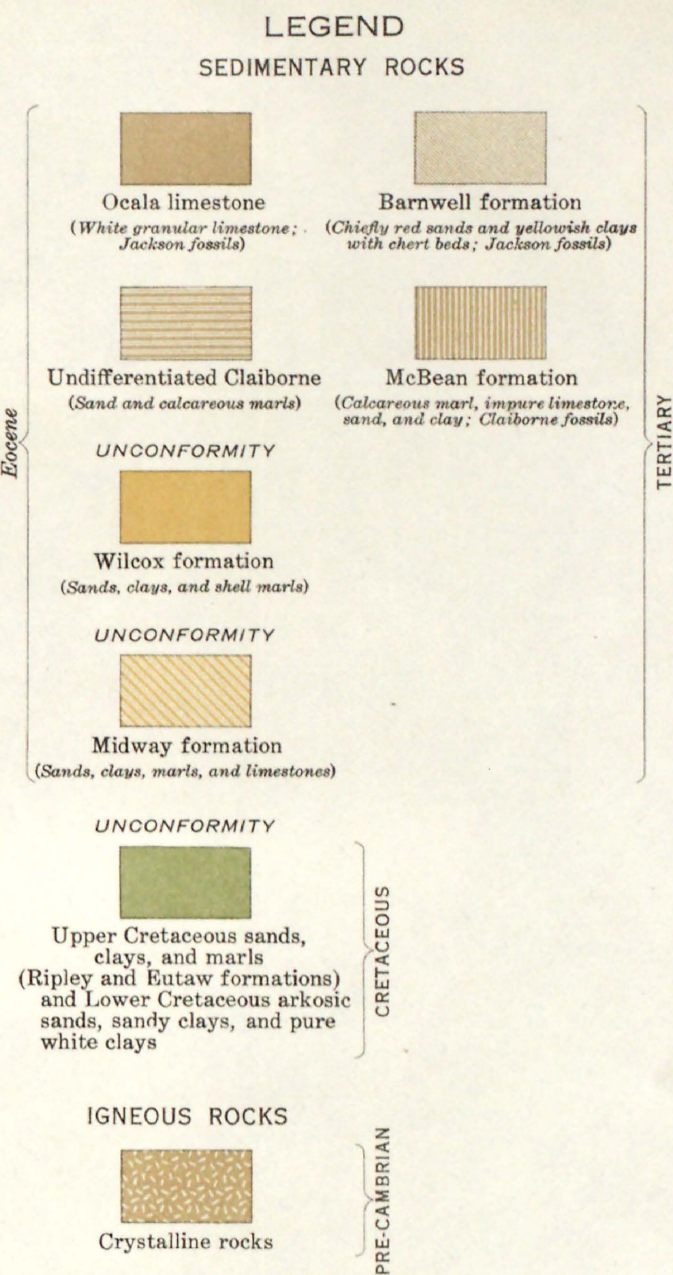
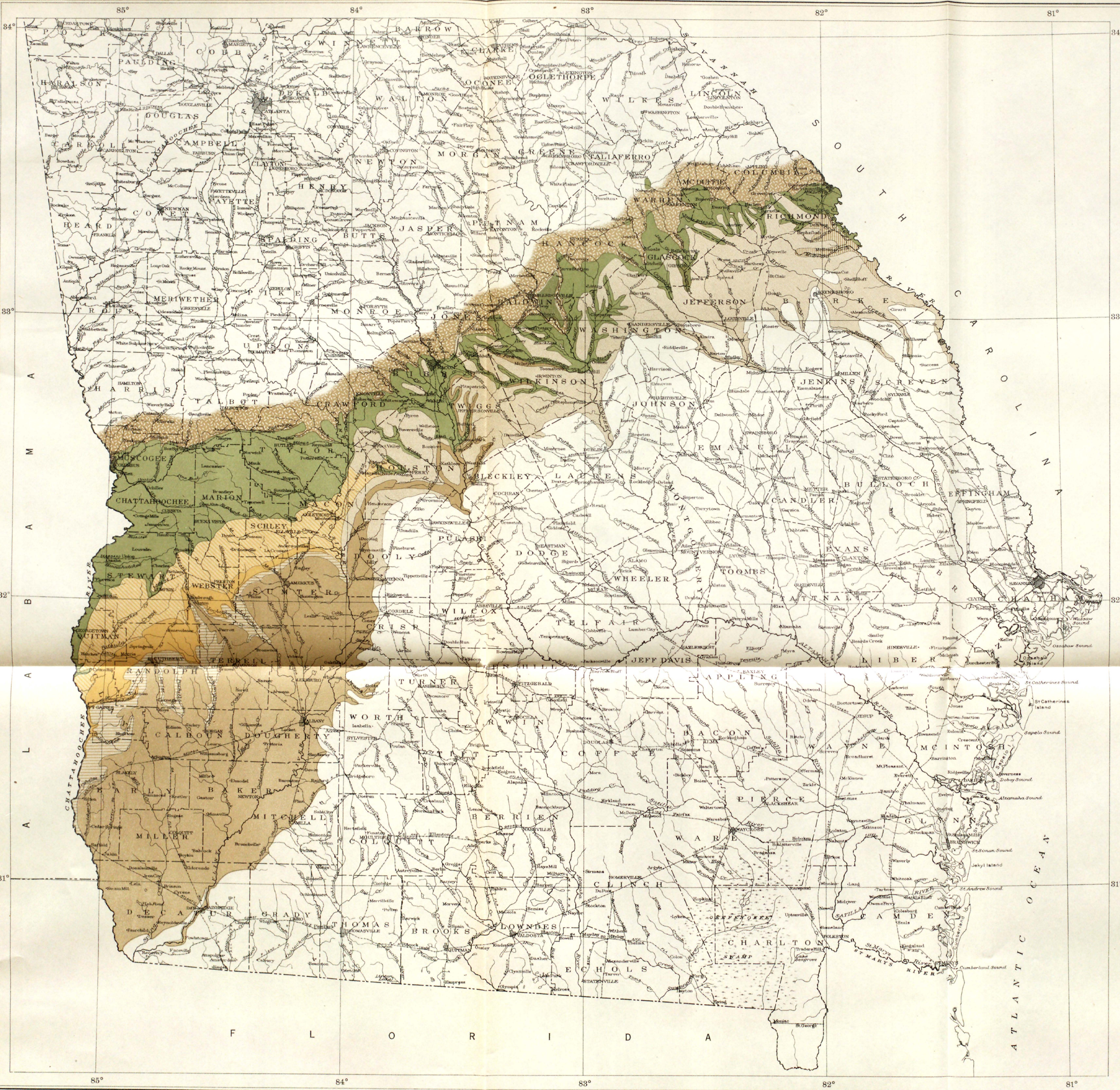
- Endopachys maclurii* (Lea).
- Ringicula buplicata* (Lea).
- Conus sauridens* Conrad.
- Pleurotoma kelloggi* Gabb.
- Pleurotoma texacoma* Harris.
- Pleurotoma terebriformis* Meyer.
- Pleurotoma childreni* Lea.
- Pleurotoma lesueuri* Lea.
- Pleurotoma nodocarinata* Gabb.
- Pleurotoma* aff. *P. rugosa* Lea.
- Amblyacrum stantoni* Vaughan.
- Amblyacrum huppertzi* var. *penrosei* Harris?
- Mangelia infans* Meyer.
- Marginella columba* Lea.
- Marginella semen* Lea.
- Caricella demissa* var. *texana* Gabb.
- Caricella* aff. *C. pyruloides* (Conrad).
- Clavelithes humerosus* Conrad.
- Fusus bellus* Conrad.
- Fusus mortoni* Lea.
- Lirofusus thoracicus* (Conrad).
- Typhis gracilis* Conrad.
- Pyrula* (*Fusocula*) *texana* Harris.
- Leiorhynchus prorutus* Conrad.
- Laevibuccinum prorsum* Conrad.
- Mitrella mississippiensis* Meyer and Aldrich.

<sup>1</sup> Op. cit., p. 237.

<sup>2</sup> Idem, p. 240.

<sup>3</sup> Idem, pp. 239-240.







*Phos sagemum* (Conrad).  
*Buccinanops altile* (Conrad).  
*Pseudoliva vetusta* (Conrad)  
*Lacinia alveata* Conrad.  
*Turritella nasuta* Gabb.  
*Turritella nasuta* var. *houstonia* Harris.  
*Turritella arenicola* Conrad.  
*Turritella carinata* Lea.  
*Mesalia claibornensis* (Conrad).  
*Tuba antiquata* Conrad.  
*Amalthea pygmaea* (Lea).  
*Calyptraea aperta* (Solander).  
*Crepidula lirata* Conrad.  
*Lunatia eminula* (Conrad).  
*Natica semilunata* Lea.  
*Sigaretus declivis* Conrad.  
*Solarium elaboratum* Conrad (young).  
*Solariorbis depressa* (Lea) var.  
*Dentalium annulatum* Meyer.  
*Nucula ovula* Lea.  
*Nucula magnifica* Conrad.  
*Leda media* Lea.  
*Yoldia psammotaea* Dall.  
*Arca rhomboidella* Lea.  
*Ostrea sellaeformis* Conrad.  
*Pecten wahtubbeanus* Dall.  
*Crassatellites protectus* (Conrad).  
*Venericardia* sp. (also at Lisbon, Ala.).  
*Venericardia alticostata* (Conrad).  
*Venericardia planicosta* Lamarck.  
*Phacoides papyraceus* (Lea).  
*Bornia prima* (Aldrich).  
*Cytherea discoidalis* Conrad.  
*Metis raveneli* (Conrad).  
*Tellina mooreana* Gabb.  
*Pteropsis lapidosa* Conrad.  
*Corbula alabamiensis* Lea.  
*Corbula densata* Conrad.  
*Corbula fossata* var. *extenuata* Dall.

#### AREAL DISTRIBUTION, PHYSIOGRAPHIC EXPRESSION AND STRUCTURE.

So far as known, exposures of the McBean formation in Georgia are confined to Richmond and Burke counties, forming a narrow strip along Savannah River north of Griffin's Landing, 16 miles below Shell Bluff, and covering the southern half of Richmond County in and north of the valley of McBean Creek. In general, the formation is too thickly covered by younger strata to have exerted much influence on the topography, but along the streams in the southern part of the area the harder ledges of limestone form prominent bluffs. No irregularities have been detected in the structure of the McBean formation. The upper surface of the formation slopes evenly seaward at the rate of about 10 feet to the mile, and the underlying beds evidently have a slightly steeper dip.

#### UNDIFFERENTIATED CLAIBORNE DEPOSITS.

The Claiborne deposits in western Georgia are best exposed in the bluff on Chattahoochee River at Fort Gaines and in the Danville Ferry bluff on Flint River, 16½ miles east of Americus. In the intermediate region the formation is thin and poorly exposed. Along Chattahoochee River Langdon<sup>1</sup> distinguished a lower "buhrstone" and an upper calcareous member of the Claiborne, but the division has not been recognized farther east.

Between Flint and Chattahoochee rivers the Claiborne rests upon the Wilcox formation, from which it is separated by an erosion unconformity, which has been observed at Fort Gaines and at Cuthbert. The Claiborne deposits are overlain unconformably by red argillaceous sand of undetermined age, which greatly resembles contiguous beds in the Claiborne and is with difficulty distinguished from them.

#### DEPOSITS OF JACKSON AGE.

##### FORMATIONS INCLUDED.

Two formations of Jackson age occur in Georgia—the Barnwell formation, including the Twiggs clay member, and the Ocala limestone, including the Tivola tongue. These are partly equivalent in age but are very different in lithology and present different faunal facies.

The Ocala limestone underlies a large part of Florida and southern Alabama and a considerable area in the southwestern part of Georgia. The Barnwell formation extends from Houston County, Ga., beyond Savannah River an unknown distance into South Carolina.

The Ocala limestone and the Barnwell formation interfinger and merge laterally into each other, but an arbitrary line drawn at the Dooly-Houston county line delimits fairly well the main bodies of the formations. However, the Twiggs clay member of the Barnwell formation extends southward a short distance into the Ocala area and a bed of bryozoan-bearing limestone, which will be referred to as the Tivola tongue of the Ocala limestone, projects as far north as Rich Hill, Crawford County, and forms an important horizon marker near the base of the Barnwell formation in Houston, Twiggs, and adjacent counties.

<sup>1</sup> Langdon, D. W., *Geology of the Coastal Plain of Alabama*, pp. 744-745, Alabama Geol. Survey, 1894.



## BARNWELL FORMATION.

## NAME.

Mr. Vaughan informs the present writers that he made a trip with Mr. Sloan into Barnwell County, S. C., for the special purpose of visiting the type locality of the Barnwell formation, and that he incorporated the results of observations made at that time in the following paragraph in the report by Veatch and Stephenson:<sup>1</sup>

Mr. Earle Sloan<sup>2</sup> has used the name Barnwell "buhr sands" or Barnwell "phase" for red ferruginous sands that immediately overlie the McBean formation as defined in this report. The type area of the Barnwell sand is in Barnwell County, S. C., where its stratigraphic position is as stated. Sloan, who has also studied the area in Georgia adjacent to Savannah River, states that the Barnwell "phase" is represented by the sands that overlie the fossiliferous marls of Shell Bluff. As there are sands of lower stratigraphic position but very similar in appearance to the Barnwell, Sloan, in several instances, confused the lower horizon with his Barnwell. A notable instance of this confusion is seen in his referring to the Barnwell the fossiliferous sands near Hixon's bridge on Tinker's Creek.<sup>3</sup> The horizon of the fossils of this exposure is far down in the McBean formation. However, it is evident that Sloan intended this name to apply to the red ferruginous sands of the upper horizon and not to those of the lower. He has orally given the information that he has found *Turritella carinata* Lea in the Barnwell sand in Barnwell County, S. C., and he is positive in his opinion that in the type area there is similarity in stratigraphic position and in both lithologic and faunal characters with the fossiliferous red ferruginous sands overlying the McBean formation in Burke County, Ga.

Although no specific locality is mentioned by Sloan in either of his papers cited as the type of his "Barnwell buhr sands," it is evident that he had in mind the higher horizon which "irregularly overlaps the upper margin of the Santee marls."<sup>4</sup>

The stratigraphic succession in western South Carolina, according to Vaughan,<sup>5</sup> is as follows:

At the base are silicified clays, fuller's earth, the Congaree shales of Sloan; these are overlain by glauconitic sandy marls, locally with silicified shells and buhr rock, and calcareous beds, the Cawcaw shales and marls of Sloan, which are equivalent to his Warley Hill marl, Santee marl, and Mount Hope marl of the Santee area and which are

succeeded by calcareous beds containing in their lower portion large numbers of *Ostrea georgiana*, these beds in turn being overlain by red sands, the typical Barnwell buhr sand of Sloan.

Inasmuch as the name Barnwell, as used by Veatch and Stephenson, was restricted to deposits composed almost entirely of sand, they employed the appropriate formational name Barnwell sand. For this is substituted, in the present paper, the name Barnwell formation, which is applied to a less homogeneous composite of materials, including, in addition to the Barnwell sand of Veatch and Stephenson, their so-called "Congaree" clay and the *Ostrea georgiana* zone of their McBean formation.

## TWIGGS CLAY MEMBER.

Extensive deposits of fuller's earth grading into calcareous clay of similar properties, which Veatch and Stephenson regarded as forming part of the McBean formation and which they designated the "Congaree clay member of the McBean formation," have been found to occupy a much higher stratigraphic position than the Congaree shales of Sloan in South Carolina, with which they were correlated but which underlie the South Carolina equivalents of the McBean formation, and to be of Jackson age. These deposits are characteristically developed in Twiggs County, and for that reason they are here named Twiggs clay member. Exposures near Pikes Peak station, on the Macon, Dublin & Savannah Railroad, are regarded as typical. The Twiggs clay is treated here as a member of the Barnwell formation.

## STRATIGRAPHIC RELATIONS.

In the Mississippi embayment, according to Berry,<sup>6</sup> the last third of Claiborne time was marked by a greater or less emergence of land, which was followed at the beginning of Jackson time by a pronounced transgression of the sea. Similar conditions appear to have prevailed in Georgia east of Flint River. The recession during late Claiborne time in Georgia is more or less conjectural, but the theory of transgression in Jackson time is supported by unequivocal evidence. The Jackson sea crept far inland up the drowned valleys of the old Claiborne land area, across the beveled edges of the lower Eocene and Cretaceous strata,

<sup>1</sup> Geology of the Coastal Plain of Georgia, p. 285, 1911.

<sup>2</sup> Handbook of South Carolina, pp. 86, 90, Columbia, S. C., Dept. Agr., Commerce, and Immigration, 1917; Catalogue of the mineral localities of South Carolina, pp. 449, 460, South Carolina Geol. Survey, 1908.

<sup>3</sup> Catalogue of the mineral localities of South Carolina, p. 268, 460.

<sup>4</sup> Handbook of South Carolina, p. 90.

<sup>5</sup> Index to the stratigraphy of North America: U. S. Geol. Survey Prof. Paper 71, p. 737, 1912.

<sup>6</sup> Berry, E. W., Erosion intervals in the Eocene of the Mississippi embayment: U. S. Geol. Survey Prof. Paper 95, p. 82, 1915.

until its waves beat in places upon the crystalline rocks of the Piedmont. The transgression of the sea that took place during Barnwell time appears to have been followed, in eastern Georgia, at least, by a slight emergence of the land which thrust back the Vicksburg shore line. At a subsequent period, perhaps during the Miocene epoch, the sea again advanced but did not attain its former maximum extent.

becomes calcareous and merges into limestones of the Ocala, and in the east, where it merges into marl and oyster-shell beds of the Barnwell formation. Along the northern margin of the outcrops the clay member is overlain with slight unconformity by red sands that apparently belong also to the Barnwell formation. This unconformity is exposed at Pikes Peak and Grovetown, but it evidently represents a withdrawal of the sea for only a short distance and

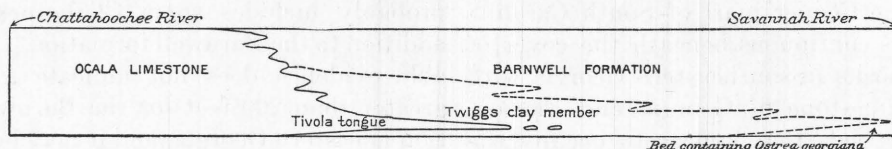


FIGURE 8.—Diagram showing the relations between the Ocala limestone and the Barnwell formation.

The Barnwell formation rests with at least local unconformity upon the McBean formation or, where that is absent, unconformably upon older strata. The relations of the Barnwell formation to the overlying strata are less obvious. On account of the similarity in appearance of much of the Barnwell to younger deposits of various ages, it is in many places difficult to distinguish between them or to be certain of the identity of the overlying formation.

The Twiggs clay member occupies a position at the base and near the landward margin of the Barnwell formation. Although the conditions of deposition were such that the fuller's earth and clays of similar character occur as lenses and discontinuous beds, exposures are

for a short period of time, because farther south the clay member is conformable with the remainder of the Barnwell formation. In the regions north and also east of Wilkinson County, where the Ocala limestone is absent, the clay rests directly upon the surface of the Lower Cretaceous or is separated from it by only a thin bed of sand; at a few places lobes of the clay member overlap the Cretaceous beds entirely and rest upon the crystalline rocks of the Piedmont area. The most notable of these overlaps are at Roberts and Grovetown.

The Barnwell formation appears to have been laid down at nearly the same time as the Ocala limestone but in a part of the sea supplied more abundantly with sand and mud, and

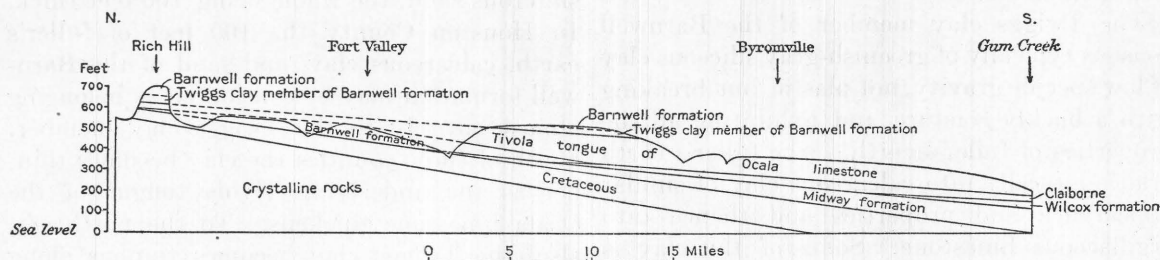


FIGURE 9.—Section from Rich Hill, Crawford County, to the mouth of Gum Creek, Crisp County, Ga.

abundant in a belt extending from Dooley County to Columbia County, more than halfway across the State. The mode of origin of the Twiggs clay and the agencies that produced its peculiar physical properties are not clearly understood, but its situation indicates that it may have been formed in long, narrow lagoons or bays to which coarse sediments had only occasional access but which appear to have had free communication with the open sea in the southwest, where the clay

the lateral transition from the siliceous sediments of the Barnwell to the limestones of the Ocala is gradual. The Tivola tongue of the Ocala limestone, which intrudes far into the main area of the Barnwell, represents a temporary invasion of the calcareous phase of deposition beyond its usual limits. The supposed relations between the Barnwell formation and the Ocala limestone are shown in the accompanying diagram (fig. 8) and section (fig. 9).



At the base of the Barnwell formation along Savannah River is a bed of impure limestone or marl that contains large numbers of shells of *Ostrea georgiana* Conrad, a huge oyster, some specimens of which attained a length of nearly 2 feet. This species appears in eastern Georgia to be restricted to the lower part of the Barnwell formation. The *Ostrea georgiana* zone has been traced for miles into South Carolina, and it seems probable that this zone represents a tongue of the Cooper marl of South Carolina and that it is continuous beneath the cover of younger deposits in southeastern Georgia with the Ocala limestone of Georgia and Florida. Local oyster beds that appear to occupy the same stratigraphic position as the bed on Savannah River have been seen as far west as Danville.

#### LITHOLOGIC CHARACTER.

The greater part of the Barnwell formation is sandy, comprising widespread deposits of coarse brilliant-red sand which appears to derive its color from weathered glauconite, together with locally indurated beds of gray sandstone which in places approaches quartzite in texture, and basal conglomerates resembling the gravels of the Pleistocene terraces. The sand in many localities incloses masses of flint, many of which are fossiliferous and appear to represent the silicified remnants of limestone lenses. Some of the flint is in scattered lumps, but most of it is restricted to well-defined zones.

The Twiggs clay member of the Barnwell consists typically of greenish-gray siliceous clay of low specific gravity, not plastic but breaking with a hackly fracture and exhibiting all the properties of fuller's earth. The fuller's earth grades laterally into calcareous clay of similar appearance and properties and thence into argillaceous limestone. Some of the clay is free from grit, but most of it is interbedded with thin layers of sand.

At places where the fuller's earth was not deposited and north of the limit of clay deposition beds of yellowish-green glauconitic sand extend to the base of the Barnwell formation. Near the base of the formation are local beds of lignite, shaly aluminous sandstone, quartzite, and completely silicified sandy limestone.

#### THICKNESS.

In eastern Georgia the thickness of the Barnwell formation has not been accurately deter-

mined, because the contact with the overlying formations is uncertain. In the Shell Bluff section 65 feet belong to this formation. At Louisville, which is about 10 miles from the Cretaceous-Barnwell contact, 100 feet of beds referred to the Barnwell formation are exposed from Rocky Comfort Creek up to the level of the town. In a deep well near Louisville the top of the Cretaceous is thought to have been reached at a depth of about 350 feet,<sup>1</sup> but this thickness probably includes some Claiborne strata in addition to the Barnwell formation. The available evidence does not indicate a thickness greater than 200 feet for the Barnwell formation in eastern Georgia, and it may be considerably less.

In Twiggs County the beds referred to the Barnwell formation extend from the surface of the Lower Cretaceous in the Dry Branch kaolin mines, at an altitude of 400 feet above sea level, to the tops of the higher hills in the vicinity of Pikes Peak, at an altitude of 625 feet. The formation is little more than 200 feet thick.

In Houston County, as the Tivola tongue of the Ocala limestone thickens the Barnwell formation becomes thinner, and only about 100 feet of the Ross Hill section may be referred to it.

The Twiggs clay member attains its maximum thickness near Pikes Peak in Twiggs County, where fuller's earth occurs at two distinct horizons separated by a bed of greenish fossiliferous sand, the whole being 100 feet thick. In Houston County the 100 feet of fuller's earth, calcareous clay, and sand of the Barnwell formation may be considered as belonging almost entirely to the Twiggs clay member. South of these counties the clay becomes thinner as the underlying Tivola tongue of the Ocala limestone thickens. To the northeast, also, the Twiggs clay becomes thinner along the strike, and at few places in Jefferson and Columbia counties is it as thick as 20 feet.

#### PALEONTOLOGIC CHARACTER.

The fauna of the Barnwell formation has already been discussed at some length (pp. 42-49). In general terms, it is an assemblage of shallow-water or littoral species which inherited many elements from the preceding upper Claiborne or Gosport fauna but which includes a number of species not known from older deposits.

<sup>1</sup> McCallie, S. W., A preliminary report on the underground waters of Georgia: Georgia Geol. Survey Bull. 15, p. 129, 1908.

The Mollusca constitute the dominant element, being represented by numerous genera and species. Bryozoa are abundant in what may be regarded as transition beds between the Barnwell and laterally adjacent formations but are scarce in more typical deposits. Corals are represented by a few very prolific species, and echinoderms by *Periarchus pileus-sinensis* and *Mortonella quinquefaria*. The most significant vertebrate thus far discovered is the huge zeuglodon *Basilosaurus cetoides*, which is particularly valuable as a guide fossil.

The Twiggs clay member of the Barnwell formation has yielded a small flora which assists in correlating isolated exposures of the formation with one another but which presents inconclusive evidence for determining the age of the deposits because the floras of the upper Claiborne and lower Jackson are very similar. As originally described by Berry,<sup>1</sup> the flora included only 17 species of plants, all of them new, but recent collections have increased the total to 26, and most of them have since been discovered elsewhere. The following list with comments has been furnished by Prof. Berry:

*Flora of the Twiggs clay member of the Barnwell formation.*

|   | Wilcox group. | Yegua formation. | Lisbon formation. | Gosport sand. | Jackson formation. |
|---|---------------|------------------|-------------------|---------------|--------------------|
| <i>Acrostichum georgianum</i> .....           | .....         | .....            | ×                 | ×             | .....              |
| <i>Arundo pseudogoepperti</i> .....           | .....         | ×                | ×                 | ×             | ×                  |
| <i>Carpolithus najasoides</i> .....           | .....         | .....            | .....             | .....         | .....              |
| <i>Castanea claibornensis</i> .....           | .....         | .....            | .....             | .....         | .....              |
| <i>Cassia georgiana</i> .....                 | .....         | .....            | .....             | .....         | .....              |
| <i>Conocarpus eocenica</i> .....              | .....         | .....            | .....             | ×             | ×                  |
| <i>Cupanites nigricans</i> <sup>a</sup> ..... | .....         | .....            | .....             | .....         | .....              |
| <i>Cinnamomum augustum</i> .....              | .....         | .....            | ×                 | .....         | .....              |
| <i>Dodonaea viscosoides</i> .....             | .....         | ×                | ×                 | .....         | ×                  |
| <i>Ficus claibornensis</i> .....              | .....         | .....            | .....             | .....         | .....              |
| <i>Ficus newtonensis</i> .....                | .....         | .....            | ×                 | .....         | .....              |
| <i>Malapoenna</i> sp.....                     | .....         | .....            | .....             | .....         | .....              |
| <i>Mimosites georgianus</i> .....             | .....         | ×                | ×                 | .....         | .....              |
| <i>Momisia americana</i> .....                | .....         | ×                | .....             | .....         | .....              |
| <i>Pestalozzites minor</i> .....              | .....         | .....            | .....             | .....         | .....              |
| <i>Pisonia claibornensis</i> .....            | .....         | ×                | .....             | .....         | .....              |
| <i>Pistia claibornensis</i> .....             | .....         | .....            | .....             | .....         | .....              |
| <i>Pteris inquirenda</i> .....                | .....         | .....            | ×                 | .....         | .....              |
| <i>Potamogeton megaphyllus</i> .....          | .....         | .....            | .....             | .....         | .....              |
| <i>Rhizophora eocenica</i> .....              | .....         | .....            | .....             | .....         | .....              |
| <i>Sapindus georgiana</i> .....               | .....         | ×                | ×                 | .....         | .....              |
| <i>Sophora claiborneana</i> .....             | .....         | .....            | ×                 | .....         | ×                  |
| <i>Sophora wilcoxiana</i> .....               | ×             | ×                | .....             | .....         | .....              |
| <i>Sphaerites claibornensis</i> .....         | .....         | .....            | .....             | .....         | .....              |
| <i>Terminalia phaeocarpoides</i> .....        | .....         | .....            | .....             | .....         | ×                  |
| <i>Thrinax eocenica</i> .....                 | .....         | ×                | ×                 | .....         | .....              |

<sup>a</sup> Green River formation of Wyoming.

To summarize this list, it may be noted that of the 26 species found in Georgia 1 comes up from the Wilcox, 3 occur in the St. Maurice, 8 occur in the Yegua, 10 in the Lisbon, and 3 in the Gosport, making 13 of the 26 that occur in known Claiborne. One additional species occurs in the Green River of Wyoming.

Six of the Georgia species occur in the Jackson. Although the Twiggs clay flora is thus apparently more like the Claiborne flora of other areas than it is like the Jackson, two features make this similarity more apparent than real. One is the fact that the continental deposits in Texas referred to the Yegua, in which several of the Georgia species reappear, are believed by me to be of Jackson age. The second modifying factor is that the bulk of the known Claiborne flora is found in the upper Claiborne and that this upper Claiborne flora is but slightly modified in passing over into the Jackson.

It should not be overlooked that 10 species, or 38 per cent of the total number, have not yet been found elsewhere and that subsequent collecting may change the relative proportions of Claiborne and Jackson species. The 26 species of plants known to science out of the hundreds that must have existed at the same time form so insignificant a part of the flora that they ought not to be considered as necessarily representative of the whole. Moreover, as pointed out by Ulrich,<sup>2</sup> paleobotanists are prone to place disputed formations lower in the time scale than is indicated by the marine invertebrates, because the plants attain their greatest development during the emergent interval preceding the introduction of the new marine fauna.

#### AREAL DISTRIBUTION.

The Barnwell formation extends in a broad belt from Savannah River nearly to Flint River, but in the western half of this belt, the area lying west of Oconee River, the formation is intermediate in character between the typical Barnwell and the Ocala limestone, merging into the Ocala toward the south, or seaward, and toward the southwest. In the description by counties the southwestern boundary of the formation is arbitrarily placed at the Houston-Dooly county line, although the Twiggs clay member and perhaps also some of the overlying red sands extend for some distance south of this line, and a wedge of bryozoan-bearing limestone (the Tivola tongue of the Ocala limestone) projects into the Barnwell formation in Houston, Twiggs, and adjacent counties, and

<sup>1</sup> Berry, E. W., The Upper Cretaceous and Eocene floras of South Carolina and Georgia: U. S. Geol. Survey Prof. Paper 84, p. 129, 1914.

<sup>2</sup> Ulrich, E. O., Correlation by displacements of the strand line and the function and proper use of fossils in correlation: Geol. Soc. America Bull., vol. 27, p. 465, 1916.



forms an important horizon marker near the base of the formation. (See map, Pl. VII, and section, fig. 8.)

The Barnwell formation occupies considerable areas in Burke, Richmond, Jefferson, Glascock, Washington, Wilkinson, Twiggs, and Houston counties and smaller parts of adjacent counties. The northern boundary is very irregular, the plain forming the surface of the formation having been deeply dissected by streams that have cut their valleys down into the Cretaceous strata, leaving promontories and erosional outliers of the Barnwell in the inter-stream areas. The southern boundary is likewise irregular, but in reverse order, having long salients extending down the river valleys.

The Twiggs clay member in eastern Georgia is confined chiefly to the northern edge of the area occupied by the Barnwell formation, but toward the west its outcrop widens until it practically coincides with that of the formation as a whole. It is characteristically developed near Grovetown, Columbia County, and outcrops have been noted at short intervals from that locality to Rich Hill, in Crawford County.

#### PHYSIOGRAPHIC EXPRESSION.

The unconsolidated sands of the Barnwell formation have yielded readily to erosional agencies and, especially along the fall line, have been deeply trenched. The harder sandstones have resisted better and in a few places, as at Browns Mountain, form hills of considerable height. In most places the Twiggs clay member is overlain by beds of sand, but where not so protected it shows a tendency to form barren "washes" or grassy slopes.

#### STRUCTURE.

The Barnwell formation strikes approximately northeastward.

From exposures along the Macon-Perry road (National Highway) in Houston County the slope of the Cretaceous surface is estimated at more than 12 feet but not more than 20 feet to the mile. The dip of the Barnwell formation is a little less than that of the surface upon which it lies and is probably about 10 feet to the mile.

In Twiggs County the slope of the upland plain is 9 feet to the mile measured parallel to the Macon, Dublin & Savannah Railroad from

Pikes Peak to Danville (southeast). The dip of the Barnwell formation, which is a little steeper than the slope of the plain, is probably between 10 and 15 feet to the mile.

In the eastern part of the State the upper surface of the Lower Cretaceous beds is very irregular, and the dip can not be stated with certainty. The base of the Barnwell formation in this region slopes from 500 feet above sea level at Grovetown to 80 feet at Griffin's Landing, a fall of 420 feet in 36 miles, or a little more than 11 feet to the mile toward the southeast.

Except for the slight tilt toward the southeast the beds of the Barnwell formation are practically undisturbed. The only indication of later movements detected is a local anticline, cut through by the railroad at Pikes Peak, in which the limbs dip 4° SE. and 3° NW.

#### OCALA LIMESTONE.

##### NAME.

In 1892 Dall<sup>1</sup> applied the name Ocala to limestone deposits exposed in the vicinity of Ocala, Marion County, Fla., and some years later the same author described a number of species of mollusks from the Ocala limestone and published a partial list of the species found in it.<sup>2</sup> This fauna was first recognized in Georgia by Vaughan,<sup>3</sup> who correlated the outcrops of limestone in Flint River near Bainbridge with the Ocala "zone," and the name Ocala limestone was recently employed by Cooke<sup>4</sup> in referring to the same deposits.

The Ocala limestone as defined in this report includes the greater part of the Vicksburg formation of Veatch and Stephenson<sup>5</sup> as well as most of the Jackson formation of the same authors. The Tivola tongue of the Ocala limestone is typically exposed at the quarry of the Planters Limestone Co., 2 miles south of Tivola. (See p. 76.)

<sup>1</sup> Dall, W. H., Correlation papers—Neocene: U. S. Geol. Survey Bull. 84, p. 103, 1892.

<sup>2</sup> Dall, W. H., Contributions to the Tertiary fauna of Florida, pt. 6: Wagner Inst. Trans., vol. 3, pp. 1219-1654, 1903.

<sup>3</sup> Vaughan, T. W., A Tertiary coral reef near Bainbridge, Ga.: Science, new ser., vol. 12, p. 873, 1900; The Eocene and lower Oligocene coral faunas of the United States: U. S. Geol. Survey Mon. 39, p. 31, 1900.

<sup>4</sup> Cooke, C. W., The age of the Ocala limestone: U. S. Geol. Survey Prof. Paper 95, p. 110, 1915; The stratigraphic position and faunal associates of the orbitoid Foraminifera of the genus *Orthophragmina* from Georgia and Florida: U. S. Geol. Survey Prof. Paper 108, pp. 109-113, 1917 (Prof. Paper 108-G).

<sup>5</sup> Veatch, Otto, and Stephenson, L. W., op. cit., pp. 296-362.

## STRATIGRAPHIC RELATIONS.

The relations of the Ocala limestone to both the underlying and the overlying formations are imperfectly known. At its northeastern limits the formation overlaps upon older strata (see fig. 8, p. 53), and similar conditions may prevail toward the west, but whether the overlap extends all the way to Chattahoochee River is uncertain. At any rate, the Claiborne deposits are not completely overlapped in the west, as in central Georgia.

The Ocala limestone is overlain by the Vicksburg formation, but the Vicksburg has been eroded so much that its original relations to the Ocala are very obscure. Where the two formations have been observed in contact no evidence of physical break in sedimentation between them has been detected. In the vicinity of Bainbridge the upper surface of the Ocala is exceedingly irregular, having suffered considerably from degradational agencies, but how much this unevenness is due to solution and disintegration of comparatively recent date or to what extent it antedates the deposition of the overlying beds is at present unknown. The Vicksburg in this region is apparently represented mostly by scattered lumps of residual flint, the main overlying formation belonging to the Apalachicola group. The following note is introduced through the courtesy of Messrs. Vaughan and Bassler:

In 1915 Vaughan<sup>1</sup> pointed out that a species of coral referred to by him as *Orbicella cellulosa* (Duncan) is common to Vicksburg deposits at Vicksburg, Miss., to the basal Chattahoochee at Bainbridge, Ga., to the Tampa formation at Tampa, Fla., and to the Antigua formation of Antigua. Recent unpublished results obtained by Vaughan from his studies of the corals and associated organisms in the base of the Chattahoochee formation and in the Antigua formation of Antigua indicate that these deposits are of middle Oligocene age and that they are stratigraphically only a little above the upper Vicksburgian Byram calcareous marl<sup>2</sup> of Mississippi. Bassler has identified Bryozoa characteristic of the Marianna limestone (middle Vicksburgian) in chert found associated with the coralliferous chert in the vicinity of Bainbridge but not in the same chert masses as the corals. As the Bryozoa and the corals have not been found together, they seem to represent different horizons. A considerable number of mollusks occurring also at Vicksburg have been listed from these beds by Dall,<sup>3</sup> but a critical comparison of the faunas has not been attempted.

<sup>1</sup> Carnegie Inst. Washington Year Book 13, p. 360, 1915.

<sup>2</sup> Defined by C. Wythe Cooke in Correlation of the deposits of Jackson and Vicksburg ages in Mississippi and Alabama: Washington Acad. Sci. Jour., vol. 8, pp. 186-198, 1918.

<sup>3</sup> 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. 488-489, 1916.

The Ocala limestone appears to have been deposited almost contemporaneously with the Barnwell formation, with which it is interbedded in the transition area. The Tivola tongue, which extends for many miles into the area occupied by the Barnwell, lies beneath the larger mass of that formation, but in most places is underlain by thin sandy beds that are classed with the Barnwell.

## LITHOLOGIC CHARACTER.

The Ocala limestone consists chiefly of soft white or cream-colored limestone that in places is composed almost entirely of the remains of Foraminifera and Bryozoa. The lower portion is more arenaceous and in places approaches sandstone in composition. In the transition area at the northeastern extremity of the formation the Ocala becomes highly argillaceous and merges into the Twiggs clay member of the Barnwell formation.

On exposed surfaces at many localities the pores of the soft limestone have been filled up by infiltration of calcium carbonate, which has "case hardened" the outer layers of the rock into hard semicrystalline limestone. That processes of silicification have been active in certain regions is shown by large masses of white flint or silicified limestone that are strewn over the surface or embedded in residual sand, but such action has by no means been confined to the Ocala limestone, as it has attacked the Vicksburg and Chattahoochee limestones as well.

## THICKNESS.

Reliable data concerning the thickness of the Ocala limestone are lacking. In a well at Albany<sup>4</sup> the drill is believed to have entered the Claiborne at a depth of about 280 feet, and the total thickness of the Ocala in this vicinity probably does not greatly exceed 300 feet. At Bainbridge the drill penetrated 750 feet of limestone, but how much of this is of Jackson age is unknown. The Tivola tongue in few places exceeds 40 feet in thickness and is commonly much thinner.

## PALEONTOLOGIC CHARACTER.

The Ocala limestone contains a large and characteristic bryozoan fauna, of which about 90 species have been found in Georgia.<sup>5</sup>

<sup>4</sup> Georgia Geol. Survey Bull. 26, pp. 317-318, 1911.

<sup>5</sup> Canu, Ferdinand, and Bassler, R. S., manuscript list.



Foraminifera are exceedingly abundant and in places constitute a large part of the rock, but lists are not yet available. The orbitoid Foraminifera are abundant, being represented by several species of *Orthophragmina*, both smooth and stellately marked, and also by species of *Lepidocyclus*. Species of both genera have been erroneously referred to *Orbitoides mantelli*, which is the type species of the genus *Lepidocyclus* and appears to be peculiar to the horizon of the Vicksburg represented by the Marianna limestone. *Operculina* is common in the middle or lower part of the formation.

Echinodermata attained during Ocala time a greater development than during any other part of the Tertiary period in the Atlantic and Gulf Coastal Plain area. These forms appear to be very much restricted in vertical range, and it seems probable that more detailed work will result in the discrimination of several zones by means of them. *Periarchus pileus-sinensis* appears to be restricted to the Tivola horizon; other species, which occur higher in the formation, are *Cidaris georgiana*, *Laganum? crustuloides*, *Schizaster floridanus*, *Macropneustes mortoni*, *Cassidulus (Rhynchopygus) depressus*, *Cassidulus (Pygorhynchus) conradi*, *Cassidulus (Pygorhynchus) georgiensis*, *Eupatagus carolinensis*, *Oliogopygus haldermani*, and *Agassizella conradi*.

A rather extensive molluscan fauna is contained in the Ocala limestone, but comparatively few forms have been preserved well enough for determination. A noteworthy exception to this is found in the pectens, which occur in great abundance and are beautifully preserved. *Pecten perplanus*, a typically Jackson species, is present, together with several closely related species or varieties. *Amusium ocalanum*, originally described from Florida, is widely distributed in Georgia.

#### AREAL DISTRIBUTION.

The Ocala limestone occurs at or near the surface over a broad belt lying chiefly in the drainage basins of Chattahoochee and Flint rivers. (See geologic map, Pl. VII.) The belt crosses Chattahoochee River between Saffold and a point about 4 miles above the mouth of Flint River, an airline distance of nearly 30 miles; thence it extends northeastward to the Dooley-Houston county line, but at that ex-

tremity the Ocala is interbedded with or transitional to the Barnwell formation. Northeast of this line the lower portion of the formation, the Tivola tongue, extends into the Barnwell area through Houston, Twiggs, and Bleckley counties, and parts of Wilkinson and Crawford counties. Throughout much of its areal extent the formation is concealed from view by a thin cover of younger strata, mainly sands, but it is exposed along watercourses, and its presence in the interstream areas is indicated by lime sinks and flint boulders.

#### PHYSIOGRAPHIC EXPRESSION.

The ready solubility of the Ocala limestone has assisted in the degradation of its surface. In the region lying between Flint and Chattahoochee rivers underground solution has been extensive, and the plain is dotted with lime sinks and ponds, ranging from shallow saucer-shaped circular depressions to sinks of considerable size. The region is a flat low-lying plain, in marked contrast to the high sandy plateau upheld by the Alum Bluff formation east of Flint River. Small surface streams are not abundant, much of the drainage going through subterranean channels.

In the northeastern part of the area occupied by the Ocala limestone, solution appears to have played a part in the formation of topographic forms subordinate to that of mechanical agencies. The harder limestone ledges have resisted erosion better than the clay deposits with which they are interbedded, with the result that the limestone stands out in steep slopes or bluffs.

#### STRUCTURE.

The Ocala limestone has not been studied in sufficient detail to permit accurate determination of its structure, and the scarcity of recognized horizon markers makes such determination difficult. The formation as a whole appears to be inclined very gently seaward at the rate of probably 10 feet to the mile. Gentle flexures may exist, but none have been detected.

#### ECONOMIC GEOLOGY.

The greater part of the workable limestones and marl deposits of the Coastal Plain of Georgia pertain to the Ocala limestone. These have been treated in detail by Brantly.<sup>1</sup>

<sup>1</sup> Brantly, J. E., Georgia Geol. Survey Bull. 21, 1916.

## SUMMARY.

The differences between the interpretation of the stratigraphy of Georgia here offered and that of Veatch and Stephenson may be briefly summarized as follows:

The deposits of Claiborne age, which they mapped as extending uninterruptedly across the entire width of the State, have been restricted to two areas, one along Savannah River and McBean Creek and the other between Flint and Chattahoochee rivers. The deposits of Claiborne age in the east retain the name McBean formation, but those in the west are called undifferentiated Claiborne.

The Barnwell sand, which they regarded as of upper Claiborne age, is raised in the time scale and placed in the Jackson epoch with the name altered to Barnwell formation. The so-called "Congaree clay member of the McBean formation" is placed bodily in the Barnwell formation and, together with calcareous clays which were already correlated with the Jackson formation, is renamed Twiggs clay member, the name Congaree being inappropriate because the clay is now known to be much younger than the typical Congaree shales of Sloan. Those parts of their McBean formation left after the elimination of the undifferentiated Claiborne and the typical McBean formation are here included in the Barnwell formation.

The littoral facies of the Barnwell fauna bears an exceedingly close relationship to the littoral fauna of the Gosport sand of Alabama but is transitional between that fauna and typical Jackson faunas and contains enough distinctive species to justify the reference of it to the Jackson epoch. The discovery of evidence of an extensive transgression of the sea upon the old land surface at the beginning of Barnwell time corroborates the reference of the formation to the beginning of a new stage rather than to the closing period of an old.

The greater portion of the Vicksburg formation of Veatch and Stephenson is transferred to the Jackson epoch, under the name Ocala limestone, and the Jackson formation of their usage is divided between the Ocala limestone and the Barnwell formation. The residue of the Vicksburg formation is left untouched for the present.

## LOCAL DETAILS.

## McBEAN FORMATION.

*McBean.*—Several sections along the south side of McBean Creek, southeast of McBean station, are given by Vaughan,<sup>1</sup> and localities farther upstream are described by Brantly.<sup>2</sup> These descriptions show that the McBean formation is variable within short distances. East of the Central of Georgia Railway the formation consists largely of sand, clay, and lignitic material, with marl only near the base of the section. West of the railway the marl beds become much thicker, reaching a thickness of over 50 feet, all above creek level, on the Newton Palmer property. The two following sections are typical of the beds east and west of the railway:

*Section on Newton Palmer property, McBean Creek, on west side of Central of Georgia Railway.*

[Measured by J. E. Brantly, op. cit., p. 46.]

|  |       |
|--|-------|
| Barnwell formation (?)   | Feet. |
| 6. Concealed interval; sandy soil on top of hill..                           | 34    |
| McBean formation:  |       |
| 5. Soft white argillaceous "rotten" limestone....                            | 7     |
| 4. Medium hard highly fossiliferous limestone; fossils poorly preserved..... | 2     |
| 3. Soft, "rotten" to consolidated cream-colored argillaceous limestone.....  | 45    |
| 2. Blue glauconitic clay like fuller's earth.....                            | 6     |
| 1. Hard arenaceous fossiliferous limestone.....                              | 2     |
| Creek bed.   |       |
|  | 96    |

*Section in gully on south side of McBean Creek, a quarter of a mile east of the bridge on the Augusta-Savannah public road.*

[Measured by C. W. Cooke.]

|   |       |
|---|-------|
| Barnwell formation (?)  | Feet. |
| 6. Brilliant red massive argillaceous sand, very coarse in lower portion.....   | 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    |
|   | 92    |

<sup>1</sup> Veatch, Otto, and Stephenson, L. W., op. cit., p. 242.

<sup>2</sup> Brantly, J. E., Report on the limestones and marls of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 21, pp. 44-50, 1916.



In the bottom of the gully at the second locality were found a few fragments of fossiliferous chert that were probably derived from the red sand, bed 6 of the section. The relations of the upper bed to bed 5 are somewhat obscure, but it seems probable that there is an erosional unconformity between them.

On the Waynesboro road, at the foot of the hill leading down to McBean Creek, a few fragments of shells were seen in yellow sand, apparently bed 3 of the preceding section. The shells are not disseminated throughout the sand but are segregated into small patches of shell marl. This is probably the horizon from which Sloan obtained the large collection of fossils listed on pages 50-51.

*Silver Bluff.*—The southernmost exposure of the Lower Cretaceous beds and the best section of the lower part of the McBean formation is seen at Silver Bluff, 27 miles by river below Augusta and 12 miles above Shell Bluff.

*Section at Silver Bluff, Savannah River.*

[Described by H. K. Shearer. Measured at west end of bluff on South Carolina side.]

| Recent:  | Feet. |
|--|-------|
| 8. Soil; gray sandy loam.....  | 2     |
| Eocene—McBean formation:   |       |
| 7. Coarse mottled argillaceous sand.....   | 6     |
| 6. Lenticular mass of crumbly, sandy iron-stained clay, somewhat like fuller's earth. Maximum thickness..... | 6     |
| 5. Coarse red and yellow cross-bedded sand....   | 10    |
| 4. Layer of sand cemented by limonite.....   | 1     |
| Unconformity.  |       |
| Lower Cretaceous:  |       |
| 3. Laminated yellow and brown sandy clay, maximum.....   | 2     |
| 2. Blue highly plastic clay free from grit.....  | 2.5   |
| 1. Yellow-gray arenaceous clay.....  | 2.5   |
|  | 31.1  |

The strata classed as Lower Cretaceous were slightly folded prior to the deposition of the overlying material, but there is no evidence elsewhere of any considerable disturbance of the beds. The beds above the unconformity are believed to lie at the same horizon or a little lower than the marl beds of Claiborne age at Shell Bluff, but as they were deposited very near the shore line they contain no calcareous material. If the correlation of these beds is correct, the Cretaceous surface dips beneath the river level near the mouth of McBean Creek.

*Shell Bluff.*—Shell Bluff, on Savannah River, 163 miles from the mouth of the river, is one of the classic localities in the study of the geology of the Coastal Plain of Georgia and South Carolina and has been described by many geologists during the last century. The 140 to 150 feet of beds exposed there have previously been correlated with various formations from the Claiborne to the Vicksburg. In the report on the geology of the Coastal Plain of Georgia the whole series was referred to the Claiborne group, and the line of division between the McBean formation and the Barnwell sand was placed at the top of the *Ostrea georgiana* zone. However, Vaughan<sup>1</sup> says in that report:

The McBean formation includes two paleontologic horizons. The lower one \* \* \* is especially characterized by *Pleurotoma nodocarinata* Gabb, *Turritella nasuta* Gabb, *Turritella nasuta* var. *houstonia* Harris, *Ostrea sellaeformis* Conrad, *Pteropsis lapidosa* Conrad, and *Corbula fossata* Meyer and Aldrich.

A higher horizon is represented especially well along Savannah River, between Shell Bluff, upstream, and Griffin's Landing, downstream. Along this stretch of the river a prominent ledge, largely composed of *Ostrea georgiana* Conrad, forms the top of the McBean formation. Although this formation could be subdivided along Savannah River, it was found impracticable to extend the subdivision westward, for which reason the *Ostrea georgiana* bed is considered as constituting its upper portion.

The red sand overlying the *Ostrea georgiana* zone was called the Barnwell sand, which was then supposed to be of Claiborne age. Since the publication of the Coastal Plain report, however, R. S. Bassler<sup>2</sup> has identified Bryozoa characteristic of the Jackson deposits from the *Ostrea georgiana* zone, and careful stratigraphic work has resulted in the recognition of this horizon in the Barnwell formation at numerous localities in central Georgia.

The following generalized section at Shell Bluff is made up from the writers' notes and from sections previously published.<sup>3</sup> The *Ostrea georgiana* zone occurs only downstream from the boat landing, but the underlying beds are exposed in the steep part of the bluff above the landing.

<sup>1</sup> Georgia Geol. Survey Bull. 26, p. 240, 1911.

<sup>2</sup> Oral communication.

<sup>3</sup> For more detailed sections see Sloan, Earle, Catalogue of the mineral localities of South Carolina: South Carolina Geol. Survey, 4th ser., Bull. 2, pp. 271-272, 1908. Veatch, Otto, and Stephenson, L. W., Georgia Geol. Survey Bull. 26, pp. 243-247, 1911. Brantly, J. E., Georgia Geol. Survey Bull. 21, p. 51, 1916.

*Generalized section at Shell Bluff.*

## Barnwell formation:

Feet.

7. Apparently all red argillaceous sand to level of upland plain. The surface of the plain is covered by several feet of loose gray sand, but clayey sand for road building is obtained from shallow trenches along the roads. . . . . 35
6. *Ostrea georgiana* zone. The base of the oyster bed is 80 feet above zero water level in the river, and although exposures are not continuous, oysters are found up to 110 feet above water level. The oyster ledge at the base of the zone contains very large shells in a matrix of yellowish sand. Above this is a bed of calcareous conglomerate containing quartz pebbles. Above the conglomerate bed the oysters are in a matrix of yellowish marl or hard calcareous clay, having some of the characteristics of fuller's earth. The matrix of the oyster shells contains Bryozoa of the Rich Hill facies of the Jackson fauna. . . . . 30

## McBean formation:

5. Concealed interval between the upper and lower bluffs. Covered by talus from the *Ostrea georgiana* zone and other overlying formations but probably is a bed of sand. . . . . 10
4. Moderately hard to hard light-colored marl, with few fossils. . . . . 9
3. Ledge of hard brown coquina-like rock, with numerous hollow casts of fossils. . . . . 6
2. White to purplish sandy limestone, made up largely of fossils. This is the most important fossiliferous stratum of the McBean formation, and Vaughan collected from it a total of 35 species. 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. A number of analyses show calcium carbonate content ranging from 50 to 90 per cent, but the actual local variation is even greater, for there are thin ledges of comparatively pure limestone and other beds of slightly calcareous sand and clay. The color, as a whole, appears light gray, but individual beds have various shades of white, yellow, buff, gray, and greenish yellow. This bed is exposed as an almost vertical cliff, rising from water level, in which the harder layers form projecting ledges. . . . . 50

The 99-foot bench mark of the United States Army Engineers is situated near the base of the bluff, and low-water level in the river is reported to be 87 feet above sea level. The preceding section starts approximately 90 feet above sea level and extends to an altitude of 235 feet, with the base of the Barnwell at 170 feet.

On Savannah River downstream from Shell Bluff marl of the McBean formation is exposed

at Demerie's Ferry, Hancock Landing, Utley Point, and Blue Bluff and finally passes beneath water level at Griffin's Landing, where it is overlain unconformably by the *Ostrea georgiana* zone and calcareous fuller's earth.

## UNDIFFERENTIATED CLAIBORNE DEPOSITS.

*Fort Gaines.*—A complete section of the Wilcox and Claiborne formations is exposed in a high bluff along the Georgia side of Chattahoochee River at Fort Gaines and in the slopes from the terrace on which the town is built up to the level of the upland plain. The sections given below show the character of the Claiborne in this vicinity.

*Section along road leading east from the Raymur Hotel, Fort Gaines.*

[Thicknesses approximate. Measured by L. W. Stephenson,<sup>1</sup> with comments by H. K. Shearer.]

| Age unknown:   | Feet. |
|--|-------|
| 8. Coarse red ferruginous pebbly sand. (Similar material extends down the hill for some distance, probably creep.) Thickness to top of hill, half a mile from the hotel. . . . .     | 50    |
| Eocene: Undifferentiated Claiborne:  |       |
| 7. Greenish sandy clays and argillaceous sands, more or less weathered and mottled. . . . .  | 40    |
| 6. Compact fine greenish-gray sandstone, with fossil prints (fossils collected). . . . .   | 3     |
| 5. Pale-green fine loose sand. . . . .   | 3     |
| 4. Compact fine greenish-gray sandstone, with fossil prints (fossils collected). . . . .   | 3     |
| 3. Light-green compact, finely arenaceous clay. A part of the bed is indurated, breaks with hackly fracture, and resembles the silicified fuller's earth of eastern Georgia. . . . . | 7     |
| 2. Fine green sandstone. . . . .   | 3     |
| 1. Greenish clays and sands, more or less weathered and mottled. . . . .   | 65    |
|  | 175   |

The following fossil mollusks from beds 4 and 6 were identified by T. W. Vaughan:

Plejona sp.  
 Turritella sp.  
 Leda pharcida Dall?  
 Venericardia planicosta Lamarck.  
 Miltha claibornensis (Conrad).  
 Cytherea sp.  
 Solen lisbonensis Aldrich?

The preceding section starts at an altitude of 225 feet above sea level, 15 feet below the level of the business section of Fort Gaines, which is on the second (upper) river terrace. The following section is exposed in the bluff a quarter of a mile below the wagon bridge and

<sup>1</sup> Georgia Geol. Survey Bull. 26, p. 263, 1911.



has its top at the edge of the terrace, at an altitude of 215 feet above sea level.

*Section of bluff at Fort Gaines.*

[Measured by Otto Veatch; descriptions revised by H. K. Shearer.]

Pleistocene:

- |  |             |
|--|-------------|
| 9. Coarse red sand with pebbles in the lower half; caps the bluff..... | Feet.<br>15 |
|--|-------------|

Eocene:

Undifferentiated Claiborne:

- |   |       |
|---|-------|
| 8. Drab fine-grained laminated clay with sand partings; has the appearance of fuller's earth but is not nearly so light and porous as the Twiggs clay, of Jackson age, and apparently has a more kaolinic base..... | 8     |
| 7. Yellow and grayish glauconitic sand. Locally it is oxidized and contains limonite-cemented crusts.....   | 10-12 |
| 6. Clay and sand, in part calcareous; consists of drab carbonaceous clay at base, sand in middle, and very sandy shell marl at the top.....   | 20    |
| 5. Indurated clay layer or drab claystone; contains fossils and is similar lithologically to the claystone east of the town of Fort Gaines. (See preceding section).....  | 2-2.5 |
| 4. Grayish argillaceous sand.....   | 6     |
| 3. Yellowish and gray quartz sand; contains calcareous sand nodules; small pebbles noted at the base; fossils <i>Xenophora</i> , <i>Venericardia planicosta</i> .....   | 2-2.5 |

Unconformity (?).

Wilcox formation:

- |  |    |
|--|----|
| 2. Clay, in part carbonaceous; calcareous, and lignitic sand, etc..... | 39 |
|--|----|

Unconformity.

Midway formation:

- |                                   |    |
|-----------------------------------|----|
| 1. Impure limestone, maximum..... | 20 |
|-----------------------------------|----|

124

In this section the Claiborne beds occupy the interval from 150 to 200 feet above sea level, and in the preceding section they extend from 225 to 350 feet, indicating a total thickness of 200 feet, only 25 feet of which is concealed. The top of the Claiborne has not been accurately located at this place, but on the Edison road, half a mile southeast of Fort Gaines, the Claiborne is overlain unconformably by sand interbedded with purple and white mottled plastic clay at an altitude of 355 feet above sea level.

The Claiborne strata are exceedingly variable in composition in the vicinity of Fort Gaines, and their lithologic appearance at the town is completely unlike that a mile away. This

difference is shown at a locality on the Lower River Road, three-quarters of a mile south of Fort Gaines, where there is an exposure of 85 feet of drab clay which is in part massive and sandy, in part interlaminated with sand, and is not fossiliferous. The clay crops out between 180 and 265 feet above sea level and is thought to be of Claiborne age.

*Cuthbert.*—In the cuts on the Central of Georgia Railway west of Cuthbert two unconformities, believed to mark the top and bottom of the Claiborne, are exposed. The lower unconformity, at an altitude of 410 feet above sea level, is seen near the 121-mile post, 3 miles west of Cuthbert.

*Section 3 miles west of Cuthbert, near 121-mile post, Central of Georgia Railway.*

Undifferentiated Claiborne:

- |  |             |
|--|-------------|
| 5. Dark-red argillaceous sand with a few clay laminae..... | Feet.<br>14 |
| 4. Fine gravel.....  | 1           |

Unconformity.

Wilcox formation:

- |   |    |
|---|----|
| 3. Light-colored argillaceous sand, with laminae and beds 2 or 3 feet thick of clay like fuller's earth.....                  | 10 |
| 2. Red argillaceous sand, with clay laminae.....  | 30 |
| 1. Blue and gray banded clay, with some sand laminae, dense, approaching kaolin rather than fuller's earth in properties..... | 30 |

85

A second unconformity is exposed 1 mile farther east, in the cut near the 120-mile post, at an altitude of 460 feet.

*Section 2 miles west of Cuthbert, near 120-mile post, Central of Georgia Railway.*

Oligocene: Undifferentiated Vicksburg:

- |  |     |
|--|-----|
| 2. Yellow plastic clay, partly laminated but with bedding much distorted by slump. Distributed through the clay are boulders and irregular masses of chert, containing fossils, most of which are undeterminable, but the Vicksburg species <i>Pecten poulsoni</i> was recognized..... | 10+ |
|--|-----|

Unconformity. (The unconformity is very irregular within a vertical range of 5 feet and is marked locally by a layer of ferruginous sandstone 1 to 2 inches thick, or by a thin band of carbonaceous sand or clay.)

Eocene: Undifferentiated Claiborne:

- |   |    |
|---|----|
| 1. Brown to yellow and red sand, a glauconitic sand more or less weathered, with local masses cemented by limonite..... | 5+ |
|---|----|

Exposures between the two cuts show that the entire 50 feet of beds of the Claiborne consist of red sand, with only a few laminae of clay.

## BARNWELL FORMATION.

## BURKE COUNTY.

The Barnwell formation in Burke County consists of calcareous clay and shell marl overlain by red sand containing ledges of fossiliferous chert. The *Ostrea georgiana* zone, which is characteristically developed at Shell Bluff (see pp. 60-61) and other localities on Savannah River, has been recognized also at several places in the interior. At Keys Mill, on Brushy Creek, in the northwest corner of Burke County, 3 miles northwest of St. Clair, a bed of *Ostrea georgiana* similar to that at Shell Bluff and apparently occurring at the same stratigraphic horizon is exposed in an excavation near the mill dam. The section at this locality follows.

## Section at Keys Mill.

| Barnwell formation:  | Feet. |
|--|-------|
| 5. Red argillaceous sand containing laminae of yellow plastic clay near the base and quartz gravel beds and a few fragments of chert near the top.....   | 40    |
| 4. Coarse yellow sand, carbonaceous at the base..  | 10    |
| 3. Pale-green, somewhat calcareous hackly clay or fuller's earth containing thin beds and irregular pockets of sand. The contact with the oyster bed is sharp.....   | 8     |
| 2. Large shells of <i>Ostrea georgiana</i> in a matrix of hard white limestone with patches of greenish clay. A few incrusting Bryozoa were found; other fossils are present but not determinable. Similar material is reported to extend to a depth of 70 feet. Thickness seen..... | 7     |
| 1. Concealed interval to level of the mill pond (altitude 300 (?) feet above sea level).....   | 5     |
|  | 70    |

Outcrops of chert beds are abundant throughout Burke County. They range in altitude from about 300 feet above sea level in the northern part of the county, where they are found near the hilltops, to 200 feet or less in the stream beds of the southern part. Nearly all the chert appears to lie at practically the same horizon (near the top of the Barnwell) and may be residual from one thin but persistent bed of limestone.

The thickest and most extensive exposures are in bluffs along Rocky Creek (altitude about 280 feet above sea level) near the Louisville road, 3.3 miles southwest of Waynesboro. The slope up to 20 feet above water level in Rocky Creek is covered with great blocks of soft and

porous to dense and vitreous red flint containing numerous poorly preserved fossils (*Turritella*, *Periarchus*, etc.). The bed is at least 15 feet thick.

Other notable outcrops of chert were found at the following localities: Waynesboro-Millen road 1 mile south of Waynesboro, altitude 260 feet above sea level; Waynesboro-St. Clair road 10 miles west of Waynesboro, altitude 335 feet, ledge 5 feet thick; Waynesboro-Hephzibah road 3.1 miles northwest of Waynesboro, altitude 285 feet, 1 foot of vitreous chert overlying 5 feet of porous chert; Girard-Millhaven road 2.1 miles southeast of Girard, altitude 220 (?) feet; Girard-Millhaven road 7.3 miles southeast of Girard, altitude 220 (?) feet, fragments of white vitreous flint.

Chert beds exposed at Johnsons Landing and Stony Bluff on Savannah River in or opposite Screven County, along the lower course of Brier Creek below Girard, and at the former site of Millhaven on Beaverdam Creek were mapped as Vicksburg in the Coastal Plain report but without very strong paleontologic evidence. Vaughan<sup>1</sup> later suggested that the rock at Johnsons Landing may be of Jackson age and stated that it contains *Pecten perplanus*, which is now considered diagnostic of the Jackson.

Recent investigations indicate that the main chert beds at all the localities cited are probably at the same geologic horizon as those exposed throughout Burke and Jefferson counties—that is, near the top of the Barnwell formation—but chert of later age may be present at some of them. The upper surface of the Barnwell therefore dips below water level in Savannah River between Stony Bluff and the mouth of Brier Creek, in Screven County.

## RICHMOND COUNTY.

The Barnwell formation caps the hills north of McBean Creek, where it overlies the McBean formation, but in the absence of characteristic beds it is almost impossible to distinguish one formation from the other. In the vicinity of Bath and in the western part of the county the Barnwell contains at its base beds of indurated fuller's earth which directly overlie the Cretaceous. A long, narrow area of Barnwell beds caps the ridge between Butler and Spirit creeks

<sup>1</sup> U. S. Geol. Survey Prof. Paper 71, p. 739, 1912.



and extends northwestward into Columbia County, where it overlaps the Lower Cretaceous beds to the edge of the crystalline area. As fossils are very rare in all the formations of Richmond County, the mapping of the contacts must depend largely on lithology and topography.

A good section of the lower beds of the Barnwell formation is exposed near a spring on the north slope of Mount Enon, an isolated remnant of the original plain, near the Dean's Bridge road, 14 miles southwest of Augusta and about 3 miles northeast of Bath.

*Section on north slope of Mount Enon.*

| Eocene:  | Feet. |
|--|-------|
| Barnwell formation:  |       |
| 8. Apparently all red sand to top of hill. Near the top are fragments of dense banded cherty sandstone.....  | 60    |
| Twiggs clay member:  |       |
| 7. Soft white fuller's earth; as the top of the bed is not exposed, the thickness may be greater than indicated.....   | 3     |
| 6. Argillaceous sandstone with abundant but poorly preserved fossils and rounded quartz pebbles an inch in maximum diameter.....   | 1     |
| 5. Coarse yellow sand.....   | 11    |
| 4. Light-drab claystone, with angular and conchoidal fracture on weathering. Has a high $\text{SiO}_2\text{-Al}_2\text{O}_3$ ratio and is a silicified fuller's earth, exactly like that at Hatcher's Mill and at Wrens, Jefferson County..... | 11    |
| 3. Gray plastic clay.....  | 1     |
| Unconformity.  |       |
| Lower Cretaceous:  |       |
| 2. Indurated sandy kaolin, or flint clay.  | 10    |
| 1. Kaolinic sand, etc., not measured.  | —     |
|  | 97    |

The altitude of the top of the hill is about 400 feet.

At Bath about 25 feet of indurated fuller's earth is exposed in the slope above the spring and bath house on the Walker property, and the bed is seen at several other places in the vicinity, but at Hepzibah, 6 miles farther east, the fuller's earth beds are absent. In the pit of the Albion Kaolin Co. the Cretaceous kaolin is overlain by 100 feet of red and yellow argillaceous sand without any conspicuous clay beds.

COLUMBIA COUNTY.

The only Eocene deposits of Columbia County are several lobes that extend into the southern part of the county near Grovetown, Forrest, and Harlem, but some of the exposures

are very interesting and important. The McBean formation is absent, and probably it never extended so far north. The calcareous beds found in the Barnwell farther south and west are here lacking, and the formation consists of beds of fuller's earth, clay shale, or lignite, lying directly above the Lower Cretaceous and overlain by red sand. An unconformity between the clay member and the red sand was noted at several places and may be of general occurrence throughout the county, and there are indications of local unconformities within the red sand. As the beds are all of shallow-water origin, these unconformities may have been produced by very slight oscillations in the level of the land or by currents.

*Phinizy Gully.*—The relations of the Barnwell strata to the Lower Cretaceous are well shown in a gully in the abandoned Augusta-Wrightsboro public road, 1 mile northeast of Grovetown, on the Phinizy property. This locality is especially interesting because it furnished a large collection of Eocene plants, described by Berry,<sup>1</sup> and because the unconformity between the Cretaceous and the Eocene is so well exposed here.

*Section of Phinizy Gully, 1 mile northeast of Grovetown.*

| Eocene:   | Feet. |
|---|-------|
| Barnwell formation:   |       |
| 6. Yellow to red argillaceous sand, coarse and pebbly near base. Caps hill to east of gully, to an altitude of 540 feet.....  | 50+   |
| 5. Laminated plastic greenish clay....  | 0-3   |
| 4. Conglomerate of varicolored kaolin pellets in red sand. Contains some fragments of lignitized wood.....  | 0-2   |
| Unconformity (?)  |       |
| Twiggs clay member:   |       |
| 3. Laminated shaly fuller's earth, containing leaf impressions. The bedding dips west at a smaller angle than the unconformity below. Pinches out toward the east.....                    | 0-6   |
| Lower Cretaceous:   |       |
| 2. Silicified white sandy kaolin or flint clay; has been described as "argillaceous sandstone." The bedding dips 10° E.; the unconformity above dips 15° W. in the head of the gully..... | 12    |
| 1. Soft plastic white kaolin, interbedded with white and yellow sand, with some kaolin conglomerate near the bottom of the exposure..   | 12    |

<sup>1</sup> Berry, E. W., U. S. Geol. Survey Prof. Paper 84, pp. 130-131, 1914.

*Grovetown.*—Fuller's earth exposed in the railroad cut at Grovetown station extends 4 feet above track level and is overlain unconformably by red sand. The large cut south of the station shows 20 feet of cross-bedded red and white sand, overlying the fuller's earth. The altitude of the station is 495 feet above sea level, and the highest exposure of fuller's earth is at 500 feet.

Fuller's earth was formerly mined on the Fiske property, about a quarter of a mile east of the station. When visited in 1916 the pit was filled with water, but according to the section given by Veatch and Stephenson<sup>1</sup> it penetrated 10 to 12 feet of fuller's earth, which lay immediately above white clay of Lower Cretaceous age. The earth was not a commercial success for bleaching, probably because it contains a considerable amount of pyrite, which readily becomes oxidized to iron sulphate and sulphurous acid after drying.

From this pit were obtained collections of fossil plants, which have been studied and described by Berry.<sup>2</sup>

A well at Usry Bros.' gin, near Grovetown station, penetrated 12 feet of fuller's earth that is very massive and thick bedded and is cut by several systems of widely spaced joints. It is dark gray when fresh and wet but becomes almost white on drying and weathering. It contains flakes of mica, small crystals of pyrite, and fragments of carbonized wood and stems.

*Chapman lignite mine.*—About 3 miles south of Grovetown a bed of lignite and lignitic clay occupies the horizon of the Twiggs clay. This material was formerly mined by W. C. Chapman for use as a fertilizer filler, but it was sufficiently carbonaceous to be used as fuel under the boiler at the grinding plant.

*Section in lignite pit 3 miles south of Grovetown.*

| Barnwell formation:   | Feet. |
|---|-------|
| 13. Gray or brownish incoherent sand, capping the hill.....                                       | 3-4   |
| 12. Coarse red argillaceous sand, with a bed of fine gravel at the base.....                      | 10    |
| Apparent unconformity.  |       |
| 11. White, yellow, and red laminated plastic clay.....  | 1-4   |
| 10. Coarse angular yellow quartz sand; contains limonite fragments and in places fine gravel..... | 15    |

<sup>1</sup> Op. cit., p. 269.

<sup>2</sup> Berry, E. W., op. cit., pp. 129-163.

Barnwell formation—Continued.

|  | Feet. |
|--|-------|
| 9. Varicolored cross-bedded sand and fine gravel, with some layers of white plastic clay a few inches thick..... | 35    |
| 8. White to buff or pink plastic clay, filling depressions in the surface of the lignite.....                    | 0-1   |
| Unconformity.  |       |
| Twiggs clay member:  |       |
| 7. Black lignite.....  | 2-4   |
| 6. Gray plastic clay.....  | 1     |
| 5. Black lignite.....  | 1     |
| 4. Gray clay, extremely plastic.....   | 1     |
| 3. Black lignite, containing large fragments of carbonized wood.....   | 1     |
| 2. Light-brown plastic lignitic clay.....  | 1.5   |
| 1. Dark-brown clayey lignite.....  | 1.5   |
|  | 75±   |

JEFFERSON COUNTY.

Nearly the whole of Jefferson County is underlain by the Barnwell formation, and its outcrop covers all of the county except a part near the northern boundary, where several streams have cut their valleys down into the Lower Cretaceous beds, and the area south of Louisville, where the hills are capped by beds of Miocene (Alum Bluff) age or younger.

The Twiggs clay member is thin but fairly persistent and appears in a line of exposures of fuller's earth across the northern part of the county. In general, the fuller's earth of this county contains less iron and is whiter than the deposits farther west. Some of it is soft and very light and porous, but farther east a larger proportion has become indurated into rather hard rock by the deposition of silica in the pores. Some of the silicified fuller's earth resembles the indurated Cretaceous kaolins found in the same area but may be distinguished from them on analysis by its much higher ratio of silica to alumina. Southward from the northern border of the Barnwell formation the earth grades into calcareous clay, marl, and oyster-shell beds, which have few of the characteristics of a true fuller's earth.

The upper part of the Barnwell formation is made up of a considerable but unmeasured thickness of red sand containing thin beds of plastic clay, locally indurated layers of fossiliferous or barren sandstone and thin beds of fossiliferous flint residual from original lenses of impure limestone.

*Louisville.*—One of the best sections of the upper part of the Barnwell formation is ex-



posed in a gully on the east slope of Rocky Comfort Creek, about 300 yards above the wagon bridge three-quarters of a mile west of Louisville.

*Section three-quarters of a mile west of Louisville.*

| Barnwell formation:  | 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   |

As the red sand bed, No. 8, continues to the level of Louisville Court House (315 feet above sea level), the total thickness is 100 feet.

A bed of *Ostrea georgiana* shells in a matrix of calcareous clay resembling fuller's earth is exposed at low water in the south bank of Ogeechee River, 200 yards upstream from Cowart's Bridge, 2.6 miles south of Louisville. The bed is entirely similar to those at Danville, Twiggs County, and at Shell Bluff. Its altitude is a few feet below the base of the section on Rocky Comfort Creek.

At Warren's Mill, on Big Creek 3 miles east-northeast of Louisville, a bed of rock containing *Ostrea georgiana* was excavated for use in building a dam. There are no natural exposures of the oyster bed, but above water level in the creek (altitude 245 feet above sea level) is exposed 3 feet of blue calcareous fuller's earth, which dries and weathers white. This grades upward, by interbedding, into yellow argillaceous sand containing laminae of fuller's earth and fragments of oyster shells.

*Old Town.*—At Old Town Plantation, 8.4 miles by road southeast of Louisville, a bed of rotten fossiliferous chert in the red sand is exposed on the slopes up to 20 feet above the level of a small creek (altitude between 220 and 250 feet). Collections of fossils made by S. W. McCallie, Earle Sloan, and T. W. Vaughan were identified by Vaughan, who supplied the fol-

lowing list of fossils for the Coastal Plain report:<sup>1</sup>

Mortonia sp.  
 Caricella pyruloides Conrad.  
 Turritella carinata Lea.  
 Mesalia vetusta (Conrad).  
 Calyptraea aperta (Solander).  
 Glycymeris staminea (Conrad).  
 Glycymeris idonea (Conrad).  
 Glycymeris n. sp.  
 Crassatellites protectus var. lepidus Dall.  
 Crassatellites n. sp.  
 Venericardia alticostata Conrad.  
 Cytherea perovata Conrad.  
 Spisula praetenuis (Conrad).  
 Corbula densata Conrad.  
 Lunulites distans Lonsdale.

More recent collections furnished the species in the following list:

Station 7428. Old Town road, east side of Boiling Spring Creek. J. E. Brantly, collector, 1915.

Mortonella quinquefaria (Say)?  
 Plejona petrosa (Conrad)?  
 Turritella carinata Lea.  
 Mesalia vetusta (Conrad).  
 Glycymeris staminea (Conrad).  
 Venus? sp.  
 Cytherea perovata Conrad.  
 Crassatellites protectus (Conrad) var.  
 Protocardia sp.  
 Diplodonta aff. D. unguina (Conrad), very close to species in basal Jackson at Sims, Miss.

*Wrens.*—Fuller's earth is exposed at a number of localities in the vicinity of Wrens and has been cut by many wells in and around the village. The earth is almost white, nonplastic, and noncalcareous and shows various degrees of induration. A section is exposed on the north slope of Brushy Creek, on the Louisville road 1 mile south of Wrens.

*Section 1 mile south of Wrens.*

| Barnwell formation:   | Feet. |
|---|-------|
| 4. Yellow sand with interlaminated clay, conformable with the underlying fuller's earth.....  | 20    |
| Twiggs clay member:   |       |
| 3. Slightly indurated fuller's earth, porous, laminated, greenish when wet but becoming pure white on drying. Contains laminae and beds of greenish sand as much as several feet thick..... | 20    |
| 2. Light-greenish argillaceous sand, slightly indurated.....  | 5     |
| 1. Concealed interval from creek level.....   | 5     |
|   | 50    |

<sup>1</sup> Georgia Geol. Survey Bull. 26, p. 292, 1911.

The section extends from 360 to 410 feet above sea level, and 410 feet is also the altitude of Wrens station.

Indurated fuller's earth unconformably overlies the Cretaceous at an altitude of 325 feet above sea level at Hatcher's Mill, on Reedy Creek 5.2 miles north of Wrens; and at Patterson's Bridge, on Brier Creek 7.7 miles northeast of Wrens, is an exposure of sandy laminated fuller's earth, a part of which is indurated and resembles that at Hatcher's Mill.

#### GLASCOCK COUNTY.

The unconformity separating the Lower Cretaceous from the Barnwell formation is plainly shown on the Gibson-Mitchell road at Jumping Gully Creek, 2 miles west of Gibson. The section at this locality was given by Veatch and Stephenson<sup>1</sup> and need not be repeated here. All the strata above the Cretaceous-Eocene unconformity, which lies at an altitude of 410 feet, should be referred to the Barnwell formation.

An interesting section, which shows the variability of the basal beds of the Barnwell, is exposed in the pits of the Harbison & Walker Refractories Co., east of milepost 48 on the Augusta Southern Railroad, 2 miles east of Gibson. The pits are in the eastern escarpment of Rocky Comfort Creek.

#### *Section in fire-clay mine 2 miles east of Gibson.*

##### Eocene:

##### Barnwell formation:

- |  |     |
|--|-----|
| 4. Yellowish sand with few pebbles.....  | 7   |
| 3. Conglomerate of yellow sand and pebbles; where bed 2 is absent, this bed rests directly upon the Cretaceous....   | 0-6 |
| 2. Gray to yellow indurated laminated clay or shale, with leaf impressions; at the base is a patch of impure lignite which grades upward into the gray plastic clay; fills erosion hollows in the surface of the Cretaceous..... | 0-4 |

Unconformity (altitude 340 feet above sea level).

##### Lower Cretaceous:

- |  |       |
|--|-------|
| 1. Gray fire clay and indurated kaolin, not very hard but extremely brittle..... | 10-15 |
|--|-------|

On the Gibson-Warrenton road 1.4 miles north of Gibson is exposed a section of the entire Cretaceous and lower part of the Eocene. There are no fossil-bearing beds, but the section is typical of deposition near the shore line.

#### *Section at Rocky Comfort Creek 1.4 miles north of Gibson.*

##### Eocene:

##### Barnwell formation:

- |  |       |
|--|-------|
|  | Feet. |
| 9. Massive red sand to top of hill.....  | 45    |
| 8. Interbedded red sand and red and gray plastic clay.....                         | 10    |
| 7. Mottled argillaceous sand, without kaolin fragments.....                        | 20    |
| 6. Mottled argillaceous sand, with small angular fragments of indurated kaolin.... | 7     |
| 5. Fine gravel, with angular fragments of indurated kaolin.....                    | 1     |
| 4. Limonite-cemented sandstone.....  | 1     |

##### Unconformity.

##### Lower Cretaceous:

- |   |    |
|---|----|
| 3. Yellow, white, and mottled kaolinic sand | 5  |
| 2. Concealed interval.....                  | 50 |

##### Pre-Cambrian (?):

- |                 |             |
|-----------------|-------------|
| 1. Granite..... | 20          |
|                 | <hr/> 158.1 |

The altitude of this section is 355 to 515 feet above sea level, and the Cretaceous beds occupy only the interval from 375 to 430 feet. The granite mass outcropping to 20 feet above the level of the creek is probably a hill or monadnock in the pre-Cretaceous surface, as no more igneous rock is seen for some miles farther north.

Other localities in Glascock County, with the fossils obtained at them, have been discussed on pages 46-47.

#### WASHINGTON COUNTY.

The Barnwell formation is present throughout a large part of Washington County. The bed within the formation most easily recognized by its lithology is the fuller's earth of the Twiggs clay member, which, although discontinuous and variable in thickness, can be traced by a line of outcrops from Oconee across the county to Chalker. The beds underlying the fuller's earth average about 50 feet in thickness and consist chiefly of calcareous clay and sand, with locally indurated beds of quartzite containing a characteristic lower Jackson fauna. Above the Twiggs clay member is red sand, with lenses of impure limestone containing *Mortonella quinquefaria* (Say), which probably represent the chert zones of Jefferson and Burke counties. The exposures of limestone extend from Wring Jaw Landing, on Oconee River a short distance south of the Washington County line, to Sunhill, passing between Sandersville and Tennille, and outliers of the same

<sup>1</sup> Op. cit., p. 273.



rock are thought to occur  $2\frac{1}{2}$  miles south of Warthen, but details are not available.

*Buffalo Creek.*—The Barnwell formation is well exposed in the steep escarpment east of Buffalo Creek, and sections have been measured along the roads east of Sheppard's Bridge, which is 3 miles north of the mouth of the creek and east of Turnpike Bridge, 5 miles farther north.

*Section along road east of Sheppard's Bridge,  $1\frac{1}{2}$  miles north of Oconee.*

Eocene:

Barnwell formation: Feet.

9. Red sand with plastic clay, laminated toward base..... 70

Twiggs clay member:

8. Plastic laminated yellowish-green clay..... 12  
7. Light-yellow nonplastic porous fuller's earth..... 5  
6. Gray plastic clay, more or less sandy..... 14  
5. Massive gray argillaceous sand, with casts of fossils, *Pecten perplanus*, *Panope*, *Glycymeris*.....  $6\frac{1}{2}$   
4. Interbedded sand and fuller's earth.....  $7\frac{1}{2}$   
3. Gray, very plastic sandy clay, becoming more sandy toward the top. The upper portion contains *Flabellum* and other poorly preserved fossils..... 27  
2. Gray sand, mottled with red; at base contains quartz pebbles as much as  $1\frac{1}{2}$  inches long; clay laminae near the top..... 6

Lower Cretaceous:

1. Cross-bedded kaolinic sand from level of Buffalo Creek. This may include the basal beds of the Eocene, as the contact has not been exactly determined..... 70

218

The altitude of the base of bed 2 of the preceding section is about 285 feet above sea level.

*Section along road east of Turnpike Bridge.*

Eocene:

Barnwell formation: Feet.

9. Red sand..... 35

Twiggs clay member:

8. Greenish plastic laminated sandy clay..... 10  
7. Fuller's earth. The exposures are not quite continuous, and there may be interbedded sandy strata in the covered intervals. All the earth in sight, however, appears to be of sufficient purity for use as a bleaching earth. It is light greenish yellow, fine grained, nonplastic, noncalcareous, and somewhat iron stained on account of its proximity to the surface but contains very little sand... 40

Eocene—Continued.

Barnwell formation—Continued.

Feet.

Twiggs clay member—Continued.

6. Covered interval. Beds probably of same character as the next underlying stratum. A spring emerges near the top of the interval..... 20  
5. Dark-gray sandy clay..... 5  
4. Greenish, slightly plastic clay, resembling fuller's earth in appearance, containing considerable sand and a few fossils..... 25  
3. Sandy and calcareous clay, containing *Flabellum*..... 3  
2. Gray sandy clay at base, grading upward into blue or greenish, very plastic gumbo or pipe clay..... 12

Unconformity (altitude 300 feet above sea level).

Lower Cretaceous:

1. Light-colored sand containing lenses of white kaolin, from level of Buffalo Creek..... 70  
220

*Sandersville.*—Near the Little Keg Creek bridge, 7.2 miles by road northwest of Sandersville and 8 miles in an air line northeast of Turnpike Bridge (see section and discussion, p. 48), the fuller's-earth bed is not present, but it comes in again farther south and is exposed where the same road crosses Rocky Branch, 3.2 miles by road northwest of Sandersville.

*Section along public road south of Rocky Branch, 3.2 miles northwest of Sandersville.*

Barnwell formation:

Feet.

6. Massive red sand to top of hill..... 90  
5. Gray and yellow argillaceous sand..... 12

Twiggs clay member:

4. Greenish fuller's earth, containing a few laminae of sand..... 10  
3. Red sand with laminae and thin beds of greenish fuller's earth..... 10  
2. Gray and greenish clay, becoming sandy and fossiliferous toward the top..... 7  
1. Concealed interval from level of Rocky Branch..... 5

134

As the base of this section is at an altitude of 330 feet, it can not be far above the top of the Cretaceous.

Limestone referred to the upper part of the Barnwell formation is exposed at the spring and lime sink at the head of Limestone Creek, 1 mile south of the courthouse at Sandersville. The topographic relations of the exposures are well shown in the sketch map by Brantly.<sup>1</sup> The section is as follows:

<sup>1</sup> Brantly, J. E., Limestones and marls of the Coastal Plain of Georgia. Georgia Geol. Survey Bull. 21, p. 59, 1916.

## Section 1 mile south of Sandersville.

| Barnwell formation:  | Feet. |
|--|-------|
| 6. Red sand to top of hill.....  | 10±   |
| 5. Coarse gray sandstone, irregularly indurated and terminating laterally in red sand.....   | 6     |
| 4. Gray sand, oxidized red and yellow, exposed along road.....   | 15    |
| 3. Light-gray chalky limestone; contains <i>Mortonella quinquefaria</i> (Say) in abundance and casts of other fossils; <i>Ostrea georgiana</i> is reported here. <sup>1</sup> Exposed in sink..... | 12    |
| 2. Gray, very sandy limestone with obscure fossils.....  | 5±    |
| 1. Bright-blue incoherent sand, apparently grading laterally into gray sandy limestone. Exposed in stream below sink.....  | 2     |

The altitude of the base of the exposure is 400 feet, which must be approximately 100 feet above the top of the Cretaceous and stratigraphically higher than the calcareous fuller's earth and limestone beds found in a well near Limestone Church, 3 miles down the creek. The yellowish and mottled sands that cap the hills within a mile south of this exposure probably belong to the Alum Bluff formation, which overlaps the beds of Vicksburg age.

*Sunhill.*—Limestone of the same horizon as that exposed at Sandersville was formerly used in the manufacture of lime at Sunhill. The old kiln and quarry are on the south slope of Williamson's Swamp Creek, an eighth of a mile southeast of the station. Brantly<sup>2</sup> gives the following section:

## Section in old quarry at Sunhill.

|  | Feet. |
|--|-------|
| 5. Red argillaceous sand.....                              | 10    |
| 4. Medium-grained white sand grading into yellow sand..... | 5     |
| 3. White calcareous clay.....                              | 2     |
| 2. Arenaceous limestone or calcareous sandstone.....       | 3     |
| 1. Hard white compact, partly crystalline limestone.....   | 9     |
|  | 29    |

As the altitude of the base of this section is 355 feet above sea level and as the normal dip of the beds is about 10 feet to the mile toward the southeast, the limestone must lie at about the same horizon as that at Sandersville.

Specimens of *Mortonella quinquefaria* (Say) in a matrix of limestone like that near Sandersville and Sunhill, collected by S. W. McCallie on the T. W. Smith farm, 2¼ miles south of Warthen (U. S. G. S. station 3953), indicate

the presence of outliers of this bed several miles north of the exposures described.

*Warthen.*—A good exposure of the Twiggs clay member of the Barnwell formation is found on the property of A. J. Irwin, 3 miles south of Warthen and 6 miles north of Sandersville, at the head of a branch of Little Keg Creek.

## Section on Irwin property, 3 miles south of Warthen.

| Barnwell formation:   | Feet. |
|---|-------|
| 5. Massive red sand. This bed overlies the clay with a sharp contact, showing no sign of gradation, which may represent a local unconformity..... | 40    |
| Twiggs clay member:   |       |
| 4. Greenish plastic clay and indurated sandy clay.....  | 2     |
| 3. Good fuller's earth, brownish gray when dry, laminated, brittle, and free from grit.....   | 8     |
| 2. Plastic greenish clay, with a tendency to crumble on drying.....   | 15    |
| 1. Greenish sandy, nonplastic clay resembling fuller's earth, containing thin beds of sand and plastic clay.....                                  | 20    |
|   | 85    |

This section extends from 365 to 450 feet above sea level, with the top of the clay member at 410 feet. The normal dip of the beds would carry the clay well below the limestone exposures at Sandersville and Sunhill.

On the property of John and George Powell, about 1 mile north of the locality on the Irwin property just described, are outcrops of a bed of white to dark-brown cherty sandstone containing small masses and veinlets of iridescent opal, some of which are said to be large enough to cut as gems. Much fragmental material from this bed is scattered in the vicinity of the outcrops. The chert contains silicified fragments of echinoids, but determinable fossils are rare.

The stratigraphic position of this chert bed is very near the base of the Barnwell. Beds of chert and sandstone at the base of the Barnwell are more extensively developed and more fossiliferous farther northeast, in the vicinity of Chalker and Gibson.

*Chalker.*—Near milepost 65 on the Augusta Southern Railroad, 1¼ miles southwest of Chalker, a lens of sandy kaolin of Lower Cretaceous age (used in the manufacture of common pottery) is overlain unconformably by 6 feet of bedded yellow to white clayey sand of

<sup>1</sup> Veatch, Otto, and Stephenson, L. W., Georgia Geol. Survey Bull. 26, p. 253, 1911.

<sup>2</sup> Op. cit., p. 61.



Eocene age. A quarter of a mile southwest of the pottery pit about 10 feet of indurated fuller's earth is exposed above the railroad level, overlain by a thin bed of quartzite, and below the railroad level and just above the Cretaceous is a bed of hard fossiliferous sandstone. The following species were obtained at this locality:

Station 7708. Base of Barnwell formation, Augusta Southern Railroad,  $1\frac{1}{2}$  miles southwest of Chalker, Washington County, Ga., Cooke and Shearer, collectors, 1916.

*Mesalia vetusta* Conrad.  
*Turritella carinata* Lea.  
*Cerithium* sp.  
*Glycymeris staminea* (Conrad).  
*Mytilus texanus* (Gabb).  
*Corbula alabamiensis* Lea.  
*Meretrix* sp.  
*Venericardia* sp.

To these should be added *Flabellum cuneiforme* Lonsdale, *Barbatia cuculoides* (Conrad), and *Ostrea georgiana* Conrad? (identified by T. W. Vaughan<sup>1</sup>); which were collected by S. W. McCallie at the same locality (station 3945).

One mile south of Chalker, where the road to Sandersville ascends from the Ogeechee Valley to the upland plain, a section is exposed which carries no fossiliferous beds but shows well the character of the Barnwell formation.

Section along Sandersville road 1 mile south of Chalker.

#### Eocene:

| Barnwell formation:   | Feet. |
|---|-------|
| 10. Massive red and mottled sand to top of hill.....  | 30    |
| 9. Red sand with laminae of white and bright-purple clay. This coloring is characteristic of the Alum Bluff formation in the southern part of the State, but it is unlikely that that formation extends so far north..... | 17    |
| 8. Yellow and mottled sand.....   | 16    |
| Twiggs clay member:   |       |
| 7. Greenish laminated fuller's earth, stained and somewhat plastic on account of weathering.....  | 11    |
| 6. Coarse yellow sand.....  | 11    |
| 5. Greenish laminated fuller's earth, free from sand.....   | 1     |
| 4. Concealed interval.....  | 10    |
| 3. Fuller's earth containing a little sand..  | 4     |
| 2. Sand with laminae of fuller's earth..  | 4     |

#### Lower Cretaceous:

|  |     |
|--|-----|
| 1. White sand with kaolin lenses; to level of Chalker station..... | 55  |
|  | 159 |

The Cretaceous surface in this area, as well as in the counties farther east, is much more irregular than to the west, showing a drop of no less than 50 feet between this exposure (altitude about 385 feet) and the vicinity of the sandstone exposures not more than a mile away.

#### WILKINSON COUNTY.

The upland areas of Wilkinson County are underlain by beds of Jackson age, but Oconee River and Commissioners and Big Sandy creeks have cut their valleys down into the Lower Cretaceous strata. The Barnwell strata cover the southern part of the county and form a narrow lobe along the ridge between Big Sandy and Commissioners creeks and an elongated erosional outlier between Commissioners Creek and Oconee River. Both of the latter areas extend beyond the northern boundary of the county. Chert of Vicksburg age is found along the southern county line, and it is possible, as in Twiggs County, that a part of the red sand farther north belongs to that formation.

A gradual change in the character of the deposits of Jackson age from west to east is noticeable in the area between Ocmulgee and Oconee rivers. The Tivola tongue of the Ocala limestone is nearly 50 feet thick along the Ocmulgee, in Twiggs and Houston counties, but it pinches out before reaching the Oconee. In Wilkinson County it is thin and very impure and is absent at many localities. The largest exposure is on the property of the General Bauxite Corporation near Toombsboro, but the bed there carries only about 50 per cent of calcium carbonate, the remainder being sand and clay. The limestone that is exposed on Oconee River at Wring Jaw Landing, Johnson County,<sup>2</sup> is correlated not with the bryozoan-bearing limestone of the southwestern part of the State but with the limestone beds at a higher Jackson horizon which are exposed near Sandersville. (See pp. 68-69.)

In Wilkinson County the Twiggs clay member is less persistent and less pure than in Twiggs County, and the material is generally too sandy or calcareous to serve as a commercial fuller's earth. Locally both limestone and fuller's earth are absent, and the Barnwell formation consists entirely of red sand with a few thin beds of plastic clay or gumbo.

<sup>1</sup> Georgia Geol. Survey Bull. 26, p. 276, 1911.

<sup>2</sup> Veatch, Otto, and Stephenson, L. W., op. cit., p. 305.

*Gordon.*—A section typical of the beds in the northern part of the county is exposed in a pit of the Savannah Kaolin Co., 1 mile south of Gordon.

*Section in pit of Savannah Kaolin Co.*

| Eocene:   | Feet |
|---|------|
| Barnwell formation (upper part):  |      |
| 5. Red and mottled argillaceous sand to the top of the hill.....                            | 60   |
| Twiggs clay member:   |      |
| 4. Greenish-yellow fuller's earth, containing chalk nodules and a few fossils.....          | 10   |
| Ocala limestone (Tivola tongue):  |      |
| 3. Sandy limestone, with <i>Pecten perplanus</i> and abundant bryozoa.....                  | 4    |
| Barnwell formation (basal part):  |      |
| 2. Argillaceous glauconitic sand filling erosion depressions in the Cretaceous surface..... | 0-2  |
| Unconformity.   |      |
| Lower Cretaceous:   |      |
| 1. Massive white kaolin.....  | 30   |
|   | 106  |

Bed 3 of this section represents the tip of the Tivola tongue of the Ocala limestone.

*Big Sandy Valley.*—In the exposures along the Valley of Big Sandy Creek the Tivola tongue of limestone is generally absent or is represented by local beds of fossiliferous chert, but the fuller's earth bed is well developed. A typical section is exposed along the public road on the southwest side of Big Sandy Creek near Sand Bed Bridge, 3 miles south of Irwinton.

*Section near Sand Bed Bridge, on southwest side of Big Sandy Creek.*

| Eocene:  | Feet. |
|--|-------|
| Barnwell formation:  |       |
| 6. Red, yellow, and mottled argillaceous sand, containing some thin beds of plastic clay.....  | 40    |
| Twiggs clay member:  |       |
| 5. Thin bed of sticky yellowish clay, not well exposed.....  | 5?    |
| 4. Fuller's earth, containing a few partings of yellow sand not over 1 inch thick, but the greater part of the interval is thick-bedded light-colored earth..... | 25    |
| 3. Very plastic bluish clay; several feet exposed, but the top and bottom of the bed are concealed.....  | 5?    |
| 2. At bottom red sand with laminae of clay resembling fuller's earth; above, mottled red and bluish clayey sand.....   | 25    |
| Unconformity.  |       |
| Lower Cretaceous:  |       |
| 1. Massive white kaolin.....   | 15    |
|  | 115   |

*Toomsboro.*—In the immediate vicinity of Toomsboro no limestone nor fuller's earth is exposed and the Barnwell seems to consist entirely of red sand, but the missing beds crop out on the property of the General Bauxite Corporation, 3 miles west of the station. No complete section is exposed. The following section is made up from aneroid readings taken at widely separated outcrops:

*Section on property of the General Bauxite Corporation, 3 miles west of Toomsboro.*

| Eocene:   | Altitude in feet. |
|---|-------------------|
| Barnwell formation:   |                   |
| 5. Red sands capping hills.   |                   |
| Twiggs clay member:   |                   |
| 4. Calcareous fuller's earth.....   | 300               |
| Ocala limestone (Tivola tongue):  |                   |
| 3. Hard and soft yellow impure limestone (50 per cent CaCO <sub>3</sub> ), containing <i>Pecten perplanus</i> , <i>Periarchus pileus-sinensis</i> , and Bryozoa of the Rich Hill facies of the Jackson fauna..... | 270-290           |
| Unconformity.....   | 250               |
| Lower Cretaceous:   |                   |
| 2. Bauxite lenses.  |                   |
| 1. Kaolin and kaolinic sands.   |                   |

BALDWIN COUNTY.

So far as known, only one lobe of the Barnwell formation enters Baldwin County. The Barnwell material forms the overburden at the fire-clay pits of the Stevens Bros. Co., at Stevens Pottery; and in one of these pits the section given below was measured.

*Section in clay pit, Stevens Pottery.*

| Eocene:   | Feet. |
|---|-------|
| Barnwell formation (Twiggs clay member):  |       |
| 5. Soil, consisting of weathered fuller's earth mixed with red sand.....  | 3     |
| 4. Fuller's earth, sandy, iron-stained, of higher specific gravity than commercially valuable earth of Twiggs County but very similar to the latter in appearance and composition; contains casts of fossils..... | 12    |
| 3. Blue argillaceous marl; Bryozoa very abundant in lower part; Mollusca more abundant toward top.....  | 10    |
| 2. Light-green glauconitic clayey sand filling minor irregularities in the Cretaceous surface; contains a few Bryozoa.....  | 0-2   |
| Lower Cretaceous:   |       |
| 1. Massive kaolin, locally sandy or bauxitic, used as fire clay.....  | 20    |
|   | 47    |



Station 7755. Bed 3 of section at Stevens Pottery, Central of Georgia Railway, Baldwin County, Ga. C. Wythe Cooke, collector, 1916.

Bryozoa (Rich Hill facies of Jackson fauna).  
 Turritella cf. *T. arenicola* var. *branneri* Harris.  
 Calyptraea sp.  
 Nucula ovula Lea.  
 Yoldia sp.  
 Leda cf. *L. coelata* Conrad.  
 Leda albirupina Harris?  
 Panope oblongata (Conrad)?  
 Pecten perplanus Morton?  
 Pseudamusium sp.  
 Corbula oniscus var. (probably) *wailesiana* Dall.  
 Phacoides (Miltha) *claibornensis* Conrad.  
 Tellina sp.  
 Tagelus? sp.  
 Cytherea discoidalis Conrad? (also at Roberts).  
 Venericardia planicosta (Lamarck).  
 Venericardia sp.

#### JONES COUNTY.

Several small isolated areas of beds of Jackson age extend into the southern part of Jones County, locally overlapping the Lower Cretaceous deposits and resting upon the crystalline basement rocks.

Interesting exposures of fossiliferous beds occur in the cuts of the Georgia Railroad, near Roberts, 9.4 miles by rail northeast of Macon. The best section is shown in the cut 1 mile northeast of the station, near the overhead crossing of the Central of Georgia Railway.

*Section in cut 1 mile northeast of Roberts.<sup>1</sup>*

Eocene:

Barnwell formation:

6. Loose red sand, containing a few scattered quartz pebbles; no fossils observed..... 10

Twiggs clay member:

5. Greenish and drab laminated sandy clay (fuller's earth), porous and of low, specific gravity..... 12

4. Laminated sandy clay containing white chalk nodules and casts of fossils. The upper 2 feet of the bed is very fossiliferous. This bed is a typical calcareous fuller's earth..... 8

3. Bluish fossiliferous mud or marl..... 8

Crystalline basement:

2. Concealed a few feet..... ?

1. Crystalline igneous rock.

The igneous rock does not appear in this cut but crops out in the next cut, a quarter of a mile farther northeast, where it is overlain by red sand. The highest altitude reached by the crystalline rock in this cut is 590 feet; the base of bed 3 in the section is 595 feet above sea level.

The amount of overlap of the Barnwell beds on the crystalline rock at this point is not great, for in a cut less than a mile south of Roberts the red sand of Jackson age unconformably overlies gray micaceous kaolinic sand of the Cretaceous.

Bed 3 closely resembles the corresponding stratum (No. 3) in the section at Stevens Pottery, and the sections are similar in other respects.

The exposures near Roberts were first studied by Harris,<sup>2</sup> who referred the strata to the upper Wilcox ("Lignitic"). Preliminary study of collections of fossils made by McCallie, Sloan, and Vaughan led Vaughan<sup>3</sup> to the conclusion that the beds are of lower Claiborne age. It appears, however, that the determinations of the most critical species were based on very imperfect material, and the correctness of some of them is open to question. The list of species as here revised contains a number of species in common with the lower Jackson fauna of Arkansas and bears a close resemblance to that of the species occurring in the lower part of the Barnwell formation near Gibson. This opinion of the age is in accordance with the lithologic and structural evidence, which shows that these beds are of the same age as the fuller's earth and bryozoan-bearing limestone of Twiggs County. The revised list of species follows:

*Fossils from cut on Georgia Railroad 1 mile east of Roberts, Jones County.*

[Identified by T. W. Vaughan; list revised by C. W. Czoike.]

|  | Collected by— |                    |
|--|---------------|--------------------|
|  | McCallie.     | Sloan and Vaughan. |
| Endopachys maclurii (Lea).....             | ×             | ×                  |
| Cylichna sp. ....                          | ×             | ×                  |
| Plejona petrosa (Conrad).....              | ×             | ×                  |
| Clavelithes sp. ....                       | ×             | ×                  |
| Mazzalina sp. ....                         | ×             | ×                  |
| Levifusus branneri Harris?.....            | ×             | ×                  |
| Pseudoliva vetusta (Conrad).....           | ×             | ×                  |
| Turritella apita De Greg. ....             | ×             | ×                  |
| Turritella sp. ....                        | ×             | ×                  |
| Turritella carinata Lea?.....              | ×             | ×                  |
| Turritella arenicola Conrad.....           | ×             | ×                  |
| Natica sp. ....                            | ×             | ×                  |
| Calyptraea aperta (Solander).....          | ×             | ×                  |
| Adeorbis sp. ....                          | ×             | ×                  |
| Nucula ovula Lea.....                      | ×             | ×                  |
| Yoldia aff. <i>Y. psammotaea</i> Dall..... | ×             | ×                  |
| Leda albirupina Harris.....                | ×             | ×                  |
| Leda sp. ....                              | ×             | ×                  |
| Trigonarca sp. ....                        | ×             | ×                  |

<sup>2</sup> Harris, G. D., Eocene outcrops in central Georgia: Bull. Am. Paleontology, vol. 4, p. 4, 1902.

<sup>3</sup> Georgia Geol. Survey Bull. 26, p. 282, 1911.

<sup>1</sup> Adapted from Veatch, Otto, and Stephenson, L. W., op. cit., p. 280.

*Fossils from cut on Georgia Railroad 1 mile east of Roberts, Jones County—Continued.*

|   | Collected by— |                    |
|---|---------------|--------------------|
|   | McCallie.     | Sloan and Vaughan. |
| Glycymeris sp.                                    |               | ×                  |
| Glycymeris trigonella (Conrad)?                   | ×             | ×                  |
| Ostrea alabamensis Lea                            |               | ×                  |
| Pteria limula (Conrad)                            |               | ×                  |
| Pecten n. sp.                                     |               | ×                  |
| Pecten (Pseudamusium) scintillatus Conrad         | ×             |                    |
| Modiolus alabamensis Aldrich                      | ×             |                    |
| Periploma sp.                                     |               | ×                  |
| Venericardia planicosta (Lamarck)                 | ×             | ×                  |
| Protocardia, probably P. nicolleti (Conrad)       |               | ×                  |
| Phacoides (Miltha) claibornensis (Conrad)         | ×             | ×                  |
| Cytherea sp.                                      |               | ×                  |
| Cytherea discoidalis Conrad?                      |               | ×                  |
| Psammobia sp.                                     | ×             |                    |
| Spisula parilis (Conrad) or S. fune-rata (Conrad) |               | ×                  |
| Corbula oniscus Conrad                            | ×             | ×                  |
| Corbula alabamensis Lea                           | ×             | ×                  |

## TWIGGS COUNTY.

*Vicinity of Pikes Peak.*—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 thinner as the underlying limestone thickens and the clay 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.

*Section in fuller's-earth mine of the General Reduction Co. half a mile northwest of Pikes Peak.*

|   |       |
|---|-------|
| Barnwell formation (?)  | Feet. |
| 8. Massive dark-red sand  | 17    |
| 7. Fine quartz gravel, indistinctly bedded  | 10    |
| 6. Varicolored sands with thin layers and fragments of sticky plastic "gumbo" clay. Some layers of the sand are slightly indurated.   | 8     |
| Unconformity (?)  |       |
| Twiggs clay member:   |       |
| 5. Light-colored fuller's earth. The lower portion is thin bedded, with fine sandy partings stained by oxides of iron and manganese. Toward the top the earth becomes more massive, and the beds are several feet thick between partings. The whole mass of fuller's earth is cut by joints in various directions, and iron and manganese stains are found along the joint planes. Some of the joints and partings are slickensided, showing that slight movements, probably caused by shrinkage, have occurred. This bed, which is uniform in texture and composition and is very light and porous, constitutes the commercially valuable fuller's earth   | 17    |
| 4. Dark-colored fuller's earth, almost black when wet but becoming light gray on drying. The dark color is probably due to organic matter. The clay contains visible crystals of pyrite and gives off a strong odor of sulphur dioxide when dried at 100° C. It also contains scattered concretions of hard siliceous material. The black layer thins to the north and west—that is, the slope of its upper surface follows the slope of the hill. The line of contact with the light-colored earth is sharp and even, but there is no visible change in texture, and the contact was observed to cut obliquely across the sand partings (bedding planes). It is evident that the light earth has been derived from the dark variety by leaching and oxidation of pyrite and carbonaceous matter. | 5     |
| 3. Yellow-drab fuller's earth. The lower part of the bed is mottled and banded with grains and layers of dark-colored oxides of iron and manganese.   | 1     |
| 2. Greenish-yellow sand containing some poorly preserved fossils. This bed is shown in borings in the floor of the mine and in wells near the mill.   | 50    |
| 1. Light-yellow fuller's earth, penetrated in wells near the mill.  | ?     |



The irregularity of the upper surface of the fuller's-earth bed indicates an unconformity between beds 5 and 6, and an unconformity at the same horizon is seen between the red sand and the fuller's earth in the railroad cut at Pikes Peak station. In the absence of paleontologic evidence it can not be certainly stated whether this unconformity is within the Barnwell or whether it separates the Barnwell formation from the Vicksburg formation.

On the property of J. D. Crump, which adjoins that of the General Reduction Co. on the northwest, and on the Lowe Wall property, 1 mile farther south, 12 feet of limestone containing Bryozoa (Rich Hill facies of Jackson fauna), *Periarchus pileus-sinensis*, and *Pecten perplanus* occurs at an altitude a little more than 100 feet lower than the top of the fuller's earth in the section just given (which is 585 feet above sea level). The limestone is underlain by tenacious yellow sand.

*Gallemore.*—A fossiliferous marl, consisting of fine quartz sand in a matrix of clay and calcium carbonate, is exposed in the bed of Turkey Creek (altitude, 380 feet above sea level) at Gallemore, or Willis, 4 miles northeast of Danville. That this marl is a shoal-water deposit of Jackson age is shown by the species in the following list:

Station 7699. Boulders below mill at Gallemore, Twiggs County, Ga. C. Wythe Cooke, collector, 1916.

- Plejona petrosa* (Conrad).
- Mesalia vetusta* (Conrad).
- Nucula* sp.
- Leda coelata* (Conrad)?
- Glycymeris staminea* (Conrad)?
- Corbula oniscus* Conrad.
- Spisula parilis* Conrad?
- Panope* sp.
- Meretrix* sp.
- Phacoides* (Miltha) *claibornensis* (Conrad).
- Phacoides* (Miltha) *pandatus* (Conrad)?
- Phacoides* (Here) *alveatus* (Conrad).
- Venericardia planicosta* (Lamarck).

All these species are represented by casts and molds. The following additional species, identified by T. W. Vaughan, were cited from this locality by Veatch and Stephenson:<sup>1</sup> *Calyptraea aperta* (Solander), *Turritella carinata* Lea, and *Diplodonta unguolina* (Conrad)?

*Section along public road east from Gallemore.*

|  |       |
|--|-------|
| Oligocene (?): Vicksburg formation (?)                                       | Feet. |
| 7. Red argillaceous sand   | 60    |
| 6. Basal conglomerate of red sand containing limestone and quartzite pebbles | 1     |

Unconformity (?).

Eocene: Barnwell formation:

|  |    |
|--|----|
| 5. Red sand  | 10 |
| 4. Plastic "gumbo" clay                            | 2  |
| 3. Red sand  | 10 |
| 2. Concealed interval from creek to railroad level | 15 |
| 1. Marl exposures in creek bed (station 7699)      | ?  |
|  | 98 |

The unconformity between beds 5 and 6 may be the same as that seen at Pikes Peak.

*Turkey Creek.*—Beside the tracks of the Macon, Dublin & Savannah Railroad just south of Turkey Creek, 1½ miles northwest of Danville, hackly yellow fuller's earth, somewhat calcareous and containing several thin ledges of hard argillaceous limestone near the top, rises 10 or 15 feet above the swamp level. At the top (altitude about 380 feet) is a stratum of sandy calcareous clay loaded with shells of *Ostrea georgiana* associated with impressions of other mollusks, including a large *Mytilus*?

Sections near Dry Branch have been described on pages 42–44 and need not be repeated here.

#### BIBB COUNTY.

An area underlain by the Barnwell formation extends into the southern part of Bibb County near Dry Branch and includes the localities at Browns Mountain and Bond's store which have already been described (pp. 47–48).

About 1½ miles south of Bond's store, on the John Tharpe estate near the boundary between Twiggs and Bibb counties, the fuller's-earth beds become very prominent but the bryozoan-bearing limestone and sandstone are absent. The section is well exposed in gullies above and below the level of the Macon-Marion road.

*Section on the John Tharpe estate, Macon-Marion road 10 miles southeast of Macon.*

Eocene:

|  |       |
|--|-------|
| Barnwell formation:  | Feet. |
| 4. Red sand, probably extending to top of hill, 75 feet in all. Thickness seen   | 55    |
| Twiggs clay member:  |       |
| 3. Gray hackly fuller's earth, more or less sandy throughout but especially so at top and bottom. <i>Crassatellites</i> and fossil plants (station 7694) found 20 feet below top | 80    |
| 2. Yellow sand to level of road  | 20    |

Unconformity.

Lower Cretaceous:

- 1. White plastic kaolin and kaolinic sand ?

<sup>1</sup> Op. cit., p. 256.



Prof. E. W. Berry has kindly furnished the following annotated list of plants collected by the writers at this locality:

Station 7694. Tharpe estate, 10 miles southeast of Macon.  
*Acrostichum georgianum* Berry (common; new to locality).  
*Dodonaea viscosoides* Berry (common).  
*Ficus claibornensis* Berry (common).  
*Pteris inquirenda* Berry (new to locality; also at Newton, Miss.).  
*Pisonia claibornensis* Berry.  
*Rhizophora eocenica* Berry.  
*Myrica nigricans* Lesquereux (new to locality; also Green River formation of Wyoming. Referred by me to *Cupanites*).  
*Potamogeton* sp. (new).  
*Carpolithus najasoides* Berry, n. sp. (seed).

The following additional species were collected by Prof. Berry at the same locality:<sup>1</sup>

*Arundo pseudogoepperti* Berry.  
*Conocarpus eocenica* Berry?  
*Malapoenna* sp.  
*Mimosites georgiana* Berry.  
*Sphaerites claibornensis* Berry.

South and west of Macon there are several isolated exposures of red sand with thin beds of plastic clay unconformably overlying the light-colored sands and clays of the Upper and Lower Cretaceous and resembling the Barnwell deposits of northern Houston County.

#### BLECKLEY COUNTY.

As the outcrops of the Barnwell beds in Bibb County are typical of near-shore deposition, those of the northern part of Bleckley County are typical of the deeper-water deposits now found near the southern limit of exposure of deposits of Jackson age. The deposits of Jackson age in this county are almost entirely calcareous, consisting of blue clay of the fuller's-earth type, sandy marl, and bryozoan-bearing limestone, overlain by red sand which belongs largely to the Vicksburg formation.

*Ainslie*.—An excellent exposure of the Tivola tongue of the Ocala limestone occurs on the east side of Shellstone Creek 1½ miles east of Ainslie. The following section is adapted from that given by Brantly:<sup>2</sup>

<sup>1</sup> Berry, E. W., The Upper Cretaceous and Eocene floras of South Carolina and Georgia: U. S. Geol. Survey Prof. Paper 84, p. 131, 1914.

<sup>2</sup> Brantly, J. E., Georgia Geol. Survey Bull. 21, p. 21, 1916.

*Section on Weatherly place, on east side of Shellstone Creek, 1½ miles east of Ainslie.*

|  |    |       |
|--|----|-------|
| Residual Oligocene or Eocene:  |    |       |
| Vicksburg or Barnwell formation:   |    | Feet. |
| 6. Red argillaceous sand to top of escarpment. No sharp line of contact between this and the underlying bed..... | 40 |       |
| Eocene:  |    |       |
| Barnwell formation (Twiggs clay member):   |    |       |
| 5. Cream-colored fuller's earth (weathered), with some sand.....   | 20 |       |
| Ocala limestone (Tivola tongue):   |    |       |
| 4. Hard pinkish, partly crystalline limestone.   | 1  |       |
| 3. Medium hard white, highly fossiliferous limestone.....  | 5  |       |
| 2. Soft white porous, friable, highly fossiliferous limestone.....   | 15 |       |
| 1. Creek bottom land.....  | 3  |       |
|  | 84 |       |

The following fossils from the Weatherly place were identified by C. W. Cooke:

Upper 1 foot of bed 3:

*Periarchus* sp.  
*Semele?* sp.

Lower 1 foot of bed 3:

*Lunulites* sp.  
*Flabellum wailesii* Conrad?  
*Endopachys maclurii* (Lea)?  
*Dentalium* sp.  
*Leda multilineata* Conrad.  
*Panope* sp.  
*Crassatellites* sp.

Bed 2:

Bryozoa (Rich Hill facies of Jackson fauna).  
*Periarchus pileus-sinensis* (Ravenel)?  
*Pecten perplanus* Morton.

*Deese property*.—Limestone and calcareous fuller's-earth beds of Jackson age are well exposed on the property of J. T. Deese on the southeast side of Shellstone Creek, 10 miles north of Cochran. The beds show local variations, but the following section, measured in a gully near the Deese residence, may be taken as typical.

*Section on Deese property, near Shellstone Creek.*

|   |    |       |
|---|----|-------|
| Oligocene or Eocene:  |    |       |
| Vicksburg or Barnwell formation:  |    | Feet. |
| 9. Red sand with chert ledges, to the flat summit of the hill.....                                      | 50 |       |
| Eocene:   |    |       |
| Barnwell formation (Twiggs clay member):  |    |       |
| 8. Blue calcareous fuller's earth, thin bedded, fossiliferous, more sandy than the underlying beds..... | 3  |       |



## Eocene—Continued.

| Barnwell formation—Continued.  |  | Feet.     |
|--|--|-----------|
| 7. Thin bed of hard impure fossiliferous limestone, probably.....  |  | 2         |
| 6. Blue calcareous fuller's earth weathered to light yellowish gray at the surface.....  |  | 20        |
| 5. Blue calcareous fuller's earth, containing harder and more calcareous layers.....   |  | 10        |
| 4. Blue calcareous fuller's earth, almost free from sand and grit.....   |  | 20        |
| 3. Concealed interval.....   |  | 10        |
| 2. Interbedded hard massive blue argillaceous limestone and blue calcareous fuller's earth. (These are varying phases of the same formation, the hardness depending on the percentage of calcium carbonate)..... |  | 5         |
| 1. Rotten fossiliferous limestone.....   |  | 5         |
|  |  | <hr/> 125 |

The base of this section (altitude, about 300 feet above sea level) is about 10 feet higher than the top of the Tivola tongue of the Ocala limestone exposed in the escarpment of Shellstone Creek  $1\frac{1}{2}$  miles northwest of the Deese residence and is stratigraphically above it.

## HOUSTON COUNTY.

The deposits of Jackson age present considerable diversity in Houston County. The Tivola tongue of the Ocala limestone enters the county from the south, with a thickness estimated by Brantly<sup>1</sup> at 45 feet. Its outcrop forms a narrow belt across the south-central part of the county to Grovania, and the principal exposures are in the steep escarpments along the south side of Indian Creek and its tributaries. From Grovania the limestone outcrop swings northward along the Georgia Southern & Florida Railway to Bonaire and occupies an area more than 10 miles wide between the railway and Ocmulgee River.

The Tivola tongue appears to be absent north of Perry, but it has probably been removed from that area by erosion, for outliers of the bed occur farther north at Rich Hill, Crawford County.

The Tivola tongue of the Ocala limestone is overlain by the Twiggs clay member of the Barnwell formation, which in this county consists principally of calcareous cream-colored clay resembling fuller's earth, forms the upper slopes of the Indian Creek escarpment and of other hills, and attains a thickness of about 100 feet.

<sup>1</sup> Brantly, J. E., op. cit., p. 82.

North of Perry red sand extends above the Cretaceous-Eocene unconformity to a maximum thickness of 50 feet. This bed probably corresponds in stratigraphic position with the yellow unconsolidated sands underlying the Tivola tongue of the Ocala limestone but may belong to the Midway formation.

Sections at Ross Hill and Mossy Hill, near Perry, are discussed on pages 44-46.

In the quarry of the Planters Limestone Co., near the crossing of the Georgia Southern & Florida Railway and the Perry-Fitzgerald branch of the Dixie Highway, 2 miles south of Tivola station, the following section is exposed:

Section in Planters Limestone Co.'s quarry, 2 miles south of Tivola.

## Eocene:

| Barnwell formation (Twiggs clay member):   |  | Feet.    |
|--|--|----------|
| 2. Calcareous cream-colored clay resembling fuller's earth, grading downward into argillaceous marl. This material starts at the top of the hill southeast of the quarry and is exposed in bare washes on the slope. There are conspicuous harder and more calcareous ledges 20 and 22 feet above the base of the member. The marl at the base contains numerous Bryozoa, with <i>Ostrea trigonalis</i> and <i>Pecten perplanus</i> , but the upper fuller's-earth beds are not fossiliferous..... |  | 33       |
| Ocala limestone (Tivola tongue):   |  |          |
| 1. Soft to medium-hard light cream-colored to white porous bryozoan limestone, exposed from the lowest point in the quarry to the top of the working face.....   |  | 39       |
|  |  | <hr/> 72 |

In a gully along the railroad siding near the quarry and probably not more than 5 feet below the bottom of the pit, there is an exposure of 7 feet of medium-grained yellow sand. The top of the Cretaceous can not lie far below.

The following fossils were obtained from bed 1 of the section:

Station 7689. Quarry 2 miles south of Tivola. Cooke and Shearer, collectors.

- Orthophragmina, stellately marked species.
- Lepidocyclina sp.
- Bryozoa (Rich Hill fauna).
- Periarchus pileus-sinensis (Ravenel).
- Cypraea fenestralis Conrad?
- Mesalia? sp.
- Ostrea sp.
- Pecten perplanus Morton.
- Panope sp.
- Protocardia nicolleti (Conrad)?



## CRAWFORD COUNTY.

The interesting occurrence of strata of Jackson age at Rich Hill, 6 miles east of Roberta, has been well described by Veatch and Stephenson.<sup>1</sup> The variability of the strata, indicating deposition near the shore, is illustrated by the following additional sections described by Shearer:

*Section in a gully on the north side of Rich Hill.*

Eocene:

Barnwell formation:

Feet.

4. Dark-red argillaceous sand, with thin beds of plastic clay near the base..... 30

Twiggs clay member:

3. Fuller's-earth horizon. At the base the clay is greenish, coarse grained, and fossiliferous; at the top, massive, rather plastic, and stained by iron deposited from percolating water..... 25
2. Unconsolidated yellow sand, grading upward into fossiliferous yellow sandy clay, which here represents the Tivola tongue of the Ocala limestone..... 10-

Unconformity.

Lower Cretaceous:

1. Kaolinic sand with a lens of massive kaolin at the top..... 100+

165

*Section in a gully on the south side of Rich Hill.*

Eocene:

Barnwell formation (upper part):

Feet.

8. Dark-red argillaceous sand, with thin beds of plastic clay near the base..... 40

Twiggs clay member:

7. Fuller's-earth horizon. The clay is light greenish yellow in color, very slightly calcareous at the top but becoming more so toward the base..... 10

Ocala limestone (Tivola tongue):

6. Hard massive argillaceous limestone..... 3
5. Soft massive argillaceous limestone, with few if any fossils..... 7
4. Bryozoan limestone of varying hardness. This is the bed from which the fossils listed below were collected..... 10

3. Sandy marl (gradational phase).... ½

Barnwell formation (basal part):

2. Unconsolidated light-yellow sand... 25

Unconformity.

Lower Cretaceous:

1. Kaolinic sand with lenses of massive kaolin..... 100+

195+

The fossils from Rich Hill, listed by T. W. Vaughan in the Coastal Plain report,<sup>2</sup> are as follows:

Periarchus pileus-sinensis (Ravenel).

Plejona sp.

Calyptraea aperta (Solander).

Ostrea georgiana Conrad.

Pecten perplanus Morton.

Pecten (probably *P. nuperus* Conrad), young and poor specimen.

Venericardia sp.

Lucina sp., found also 5½ miles south of Perry.

Panope sp.

The calcareous beds of the preceding sections are of undoubted Jackson age, and the Bryozoa of the Rich Hill facies of the Jackson fauna, as identified by R. S. Bassler, form valuable horizon markers.

The unconformity on the south side of the hill is 25 feet lower than that on the north side, showing an erosion depression in the Cretaceous surface, and in this depression the sand and limestone beds representing the Ocala are much thicker than over the old hilltops. The base of the deposits of Jackson age here is considerably higher than at any point in Houston or Twiggs counties, but the exact altitude is not known. The altitude of the top of the hill is probably about 700 feet.

## OCALA LIMESTONE.

## AREA NORTH OF DOOLY COUNTY.

The local details of the Ocala limestone in the area north of Dooly County have been given in the preceding discussion of the Barnwell formation and will not be repeated here. The type locality of the Tivola tongue of the Ocala limestone is described on page 76.

## DOOLY COUNTY.

The Twiggs clay member of the Barnwell formation extends southward from Houston County into Dooly County but becomes increasingly calcareous and merges into the Ocala limestone. The Tivola tongue of the Ocala limestone is well developed in Dooly County and has been seen at a number of natural exposures.

On the J. M. Carter property, 1½ miles south-east of Lilly, 20 feet or more of soft white limestone composed largely of Bryozoa but containing also *Pecten perplanus* and *Periarchus*

<sup>1</sup> Op. cit., pp. 299-300.<sup>2</sup> Georgia Geol. Survey Bull. 26, p. 300, 1911.



*pileus-sinensis* is exposed. Brantly<sup>1</sup> reports 20 feet of limestone overlain by 17 feet of calcareous fuller's earth on the L. Frieden property, 9 miles east of Montezuma.

#### EXPOSURES ON AND NEAR FLINT RIVER.

Strata of Jackson age first appear in the banks of Flint River about 3½ miles above the crossing of the Seaboard Air Line Railway west of Cordele. From this point exposures occur at short intervals to Fort Scott, about 11 miles above the confluence of Flint and Chattahoochee rivers. As most of the exposures show little diversity, detailed discussion here will be restricted to those which have furnished the best collections of fossils or which are otherwise of interest.

The lithologic variation in the Ocala limestone, as displayed along Flint River, is slight. In the upper reaches of the river the rock, which presumably constitutes the lower portion of the formation, is prevailingly finer grained and less harsh in texture than that farther south, where tests of Foraminifera and Bryozoa compose a large proportion of the limestone.

*Above Albany.*—The following fossils were obtained from the Ocala limestone on Flint River 3 miles above the Seaboard Air Line Railway bridge:

Station 7106. Flint River at mouth of Spring Creek, Sumter County. Brantly and Cooke, collectors, 1914.

Orbitoid Foraminifera.  
Flabellum wailesi (Conrad)?  
Schizaster floridanus Clark?  
Turritella sp.  
Nucula sp.  
Pecten perplanus Morton.  
Crustacean.

The Ocala limestone exposed at this locality consists of about 14 feet of white or cream-colored limestone in thin beds, alternating in degree of hardness and containing a little glauconite. Analysis of the rock shows 85.8 per cent calcium carbonate.<sup>2</sup>

A quarter of a mile below this point the following fossils were obtained:

Station 7107. West bank of Flint River a quarter of a mile below the mouth of Spring Creek. Brantly and Cooke, collectors.

Orbitoid Foraminifera.  
Bryozoa.  
Periarchus, probably *P. pileus-sinensis* (Ravenel).  
Mitra? sp.  
Pecten perplanus Morton.  
Amusium ocalanum (Dall).

The last two species named were found also at the railroad bridge below Spring Creek (station 7108).

At a small quarry on the Averitt property, 300 or 400 yards southwest of the corner of lots 7 and 26, half a mile east of Huguenen Ferry and 1 mile south of Daphne station, Crisp County (station 7237), the rock is a soft white limestone containing *Orthophragmina flintensis* Cushman, numerous Bryozoa, and an undetermined pecten, probably *Amusium ocalanum* (Dall). An analysis of the limestone from this locality given by Brantly<sup>3</sup> shows 85 per cent calcium carbonate. Better exposures of this rock occur in a sink about 300 yards east of the quarry, where 23 feet of soft argillaceous white limestone containing small specks of glauconite is overlain by 18 feet of reddish sandy loam. The course of an underground stream that flows through this sink can be traced northwestward by means of long, narrow slot-shaped sinks which expose it at intervals to Gum Creek.

The following section, which was measured by J. E. Brantly and C. Wythe Cooke on the east bank of Flint River 1 mile above the mouth of Cedar Creek, Crisp County, is quoted with a few minor changes from Brantly's report on the limestones and marls of Georgia.<sup>4</sup>

#### Section of Limestone Bluff on Armstrong place.

|  | Ft. in. |
|--|---------|
| Pleistocene:   |         |
| 11. Sands and gravel.....  | 7 0     |
| Ocala limestone:   |         |
| 10. Mostly concealed, but with several small exposures of soft white, finely granular limestone and hard, partly crystalline light-gray limestone. Bryozoa, <i>Pecten</i> , etc..... | 8 0     |
| 9. Hard, very light gray crystalline limestone.....  | 3       |
| 8. Alternating 6 to 10 inch layers of soft and slightly harder white, finely granular limestone.....   | 1 6     |
| 7. Hard, very light gray crystalline limestone.....  | 3       |
| 6. Alternating 6 to 10 inch layers of soft and slightly harder white, finely granular limestone.....   | 7 6     |
| 5. Medium-hard white, partly crystalline limestone.....  | 4 0     |
| 4. Soft white limestone.....   | 4 0     |
| 3. Hard white limestone containing Bryozoa; forms a projecting ledge.....  | 4 0     |
| 2. Soft light-gray limestone, with specks of glauconite and a few nodules of chert...  | 8 0     |

<sup>1</sup> Brantly, J. E., op. cit., p. 112.

<sup>2</sup> Idem, p. 120.

<sup>3</sup> Idem, p. 158.

<sup>4</sup> Idem, p. 159.



## Ocala limestone—Continued.

1. Hard white, partly crystalline limestone, irregularly weathered, to water's edge at 2-foot stage. Contains (station 7110) *Lunularia distans* and other Bryozoa, *Flabellum*, *Nucula*, *Glycymeris*, *Pecten*, *Amusium ocalanum*, and *Crassatellites*.. 2 6

On the east bank of Flint River at the bend to the west 6 miles below Burke Ferry and about 6 miles above the bridge of the Georgia Southwestern & Gulf Railway, near Warwick, Worth County (station 7115), the material exposed consists of white compact limestone rising 5 feet above water level and overlain by flint boulders, sand, and gravel. *Orthophragmina flintensis* Cushman and *Operculina* sp. were collected here.

The section at a bluff on the west bank of Flint River about 1½ miles above the bridge of the Georgia Southwestern & Gulf Railway is as follows:

## Section in bluff on west bank of Flint River.

|   | Feet. |
|---|-------|
| 3. Covered slope to top of hill.....  | 22    |
| Ocala limestone:  |       |
| 2. Hard ledges of compact white semicrystalline limestone (station 7117).....   | 3     |
| 1. Compact white limestone, mostly soft but with harder places. Contains (station 7116) <i>Orthophragmina flintensis</i> and <i>Laganum? crustuloides</i> (Morton)? To water level at 4-foot stage..... | 20    |

From bed 2 (station 7117) were collected the following:

## Foraminifera:

*Orthophragmina flintensis* Cushman.

## Bryozoa:

Several species.

## Echinodermata:

*Laganum? crustuloides* (Morton)?

## Mollusca:

*Ostrea* sp.

*Pecten perplanus* Morton.

*Pecten suwaneensis* Dall.

On the east bank of Flint River in Worth County near the Dougherty County line, about 16 miles above Albany (station 7119), the rock consists of 5 feet of limestone, the upper part white, lower part gray, overlain by flint fragments. It contains *Orthophragmina flintensis* Cushman, *Operculina* sp., and *Pecten suwaneensis* Dall. On the east bank of Flint River in Dougherty County, about 8 miles above Albany, at the mouth of a small creek (station 7235), the following fossils were obtained from soft white limestone, 8 feet in

exposed thickness, containing concretionary masses of hard limestone:

## Bryozoa.

*Laganum? crustuloides* (Morton).

*Schizaster floridanus* Clark?

*Macropneustes mortoni* (Conrad)?

*Ostrea* sp.

*Pecten perplanus* Morton.

*Pecten suwaneensis* Dall.

*Vicinity of Albany.*—The following section was observed in the bank of Kinchafoonee Creek at the power plant 2 miles north of Albany:

## Section on Kinchafoonee Creek 2 miles north of Albany.

|   | Feet. |
|---|-------|
| 4. River sands.....   | 15    |
| Ocala limestone:  |       |
| 3. Hard pink or yellow limestone with <i>Cidaris georgiana</i> and <i>Amusium ocalanum</i> .....  | 2½    |
| 2. Hard pinkish limestone with Bryozoa, echinoids, and <i>Amusium ocalanum</i> .....  | 2½    |
| 1. White, cream-colored, or yellow granular limestone with <i>Amusium ocalanum</i> and casts of corals. To water level in Kinchafoonee Creek..... | 5     |

Above bed 3 there is reported to be 5 feet of limestone which was inaccessible at the time this section was measured. Other sections at this locality that do not differ materially from this have been recorded by Veatch and Stephenson<sup>1</sup> and by Brantly.<sup>2</sup>

The fossils in the following list were collected from loose blocks on the dump heap below the dam at the power plant:

Station 7121. Excavation below dam at power plant on Kinchafoonee Creek 2 miles north of Albany, Ga. Cooke and Brantly, collectors, 1914.

## Foraminifera:

*Operculina* sp.

## Echinodermata:

*Cidaris georgiana* Twitchell.

*Cassidulus* (*Rhynchopygus*) *depressus* Twitchell?

*Cassidulus* (*Pygorhynchus*) *conradi* (Conrad).

*Eupatagus carolinensis* Clark?

*Linthia wilmingtensis* Clark?

*Macropneustes mortoni* (Conrad).

## Mollusca:

*Eucymba ocalana* Dall.

*Cypraea fenestralis* Conrad.

*Ostrea* sp.

*Gryphaeostrea* sp.

*Pecten perplanus* Morton, varieties.

*Amusium ocalanum* Dall.

*Mya?* sp.

<sup>1</sup> Veatch, Otto, and Stephenson, L. W., op. cit., p. 316.

<sup>2</sup> Brantly, J. E., op. cit., p. 135.

*Between Albany and Red Bluff.*—The following fossils were found in white, gray, or cream-colored limestone extending about 2 feet above water level.

Station 7125. West bank of Flint River in Baker County about 3 miles below Dewberry Ferry (Baconton Landing) and about 13 miles above Newton. Brantly and Cooke, collectors, 1914.

Flabellum sp.  
Cypraea fenestralis Conrad.  
Cerithium sp.  
Turritella sp.  
Calyptraea sp.  
Glycymeris sp.  
Pecten perplanus Morton.  
Pecten indecicus Dall.  
Amusium ocalanum (Dall)?  
Spondylus sp.  
Plicatula, Ocala sp.  
Venericardia sp.

The following species were collected from lumps of hard limestone excavated from the channel:

Station 7126. East bank of Flint River at Dry Bread Shoals, Mitchell County,  $8\frac{1}{2}$  or 9 miles below Newton.

Foraminifera:

Orthophragmina mariannensis var. papillata Cushman.  
Orthophragmina georgiana Cushman.

Anthozoa:

Trochoseris n. sp.

Echinodermata:

Cidaris georgiana Twitchell.  
Laganum? crustuloides (Morton)?  
Oligopygus haldermani (Conrad).

Mollusca:

Mitra sp.  
Chama sp.  
Limopsis sp.  
Barbatia sp.  
Ostrea trigonalis Conrad.  
Amusium ocalanum (Dall).  
Pecten perplanus Morton.  
Spondylus sp.  
Plicatula, Ocala sp.  
Mya? sp.  
Venericardia vicksburgiana Dall.  
Venericardia sp.  
Crassatellites sp.

Station 7127. Loose blocks excavated from the channel of Flint River, a quarter of a mile below Norman's Ferry, Mitchell County, midway between Newton and Bainbridge. Cooke and Brantly, collectors, 1914.

Lepidocyclus sp. and other Foraminifera.  
Lunularia sp. and other Bryozoa.  
Cidaris georgiana Twitchell.  
Oligopygus haldermani (Conrad).  
Laganum sp.  
Cypraea sp.

Station 7127—Continued.

Xenophora sp.  
Glycymeris sp.  
Barbatia sp.  
Amusium ocalanum (Dall) var.  
Spondylus sp.  
Lima halensis Dall.  
Plicatula, Ocala sp.  
Chama sp.  
Crassatellites sp.  
Venericardia sp.  
Mya? sp.

On the east bank of Flint River in Decatur County, 1 mile below Windell's Landing and about 15 miles above Bainbridge (station 7129), *Orthophragmina mariannensis* var. *papillata* Cushman and an undetermined species of *Pecten* were found in 5 feet of irregularly weathered pinkish limestone.

*Vicinity of Bainbridge.*—The Ocala limestone is the oldest formation in the vicinity of Bainbridge, and all its exposures appear to represent a single horizon. It is a soft, coarsely granular limestone varying in color from white to yellow and composed largely of tests of Foraminifera and Bryozoa, which on exposed surfaces have become firmly cemented or "case-hardened" into a brittle, semicrystalline limestone, but which when freshly exposed are only slightly coherent. The rock appears to lie very nearly horizontal, but the upper surface is exceedingly irregular and jagged, with pinnacles extending in places to 20 feet above water level. The irregularity is due in part to erosion prior to the deposition of the overlying materials and in part to subsequent solution. The Ocala is overlain unconformably by a complex series of red and variegated sands and carbonaceous clays containing chert fragments with impressions and siliceous pseudomorphs of mollusks and corals of lower Oligocene age. The Ocala itself appears to have been subjected to the silicifying agencies to a lesser extent, for chert fragments carrying Ocala fossils are only occasionally found. The accidental inclusion of some of these in the collections of the coralliferous chert has unfortunately been interpreted as a mingling of the Ocala and Chattahoochee faunas.<sup>1</sup>

The following species have been identified from localities near Bainbridge:

<sup>1</sup> Dall, W. H., A contribution to the invertebrate fauna of the Oligocene beds of Flint River, Ga.: U. S. Nat. Mus. Proc., vol. 51, p. 488, 1916.



Station 7099. East bank of Flint River half a mile above Red Bluff. C. Wythe Cooke, collector.

Foraminifera:

*Orthophragmina georgiana* Cushman.

Bryozoa:

Many species.

Echinodermata:

*Oligopygus haldermani* (Conrad).

*Agassizia conradi* (Bouvé)?

Stations 3387, 6159, 7098. Red Bluff, Flint River, 7 miles above Bainbridge. Vaughan, Stephenson, and Cooke, collectors.

Foraminifera:

*Orthophragmina americana* Cushman.

*Orthophragmina mariannensis* Cushman.

*Orthophragmina georgiana* Cushman.

*Orthophragmina vauhani* Cushman.

Bryozoa:

Many species.

Echinodermata:

*Oligopygus haldermani* (Conrad).

*Laganum? crustuloides* (Morton)?

*Cassidulus* (*Pygorhynchus*) *georgiensis* Twitchell.

*Agassizia conradi* (Bouvé).

Mollusca:

*Pecten perplanus* Morton.

*Pecten indecisus* Dall.

*Pecten suwaneënsis* Dall.

*Amusium ocalanum* (Dall).

Station 7097. Bluff on east side of Flint River near old factory three-quarters of a mile north of the Atlantic Coast Line Railway station at Bainbridge. Vaughan, Cooke, and Mansfield, collectors.

Foraminifera:

*Orthophragmina georgiana* Cushman.

*Lepidocyclus* sp. and many others.

Station 7097—Continued.

Bryozoa:

About 34 species, most of them new.

Echinodermata:

*Cidaris georgiana* Twitchell.

*Cassidulus* (*Pygorhynchus*) *conradi* (Conrad).

*Oligopygus haldermani* (Conrad).

*Agassizia conradi* (Bouvé).

*Eupatagus carolinensis* Clark?

Mollusca:

*Ostrea*, 2 sp.

*Pecten perplanus* Morton.

*Amusium ocalanum* (Dall).

*Plicatula*, *Ocala* sp.

*Cardium* sp.

Stations 3293, 6171. Bainbridge. A. H. Brooks and L. W. Stephenson, collectors.

*Lepidocyclus* sp. and other Foraminifera.

Bryozoa, many species.

*Cidaris georgiana* Twitchell.

*Cassidulus* (*Pygorhynchus*) *georgiensis* Twitchell.

*Oligopygus haldermani* (Conrad).

*Ostrea trigonalis* Conrad.

*Pecten perplanus* Morton.

*Amusium ocalanum* (Dall).

EXPOSURES WEST OF FLINT RIVER.

For local details of the Ocala limestone west of Flint River, the reader is referred to the county descriptions in Brantly's report on the limestones and marls of the Coastal Plain of Georgia.<sup>1</sup>

<sup>1</sup> Brantly, J. E., Georgia Geol. Survey Bull. 21, 1916.