Tertiary Stratigraphy of South Carolina

GEOLOGICAL SURVEY PROFESSIONAL PAPER 243–B

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By C. WYTHE COOKE *and* F. STEARNS MACNEIL

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY, 1952, PAGES 19–29

GEOLOGICAL SURVEY PROFESSIONAL PAPER 243–B

A revised classification of Tertiary formations of the Coastal Plain, based mainly on new stratigraphic and paleontologic information

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1952

UNITED STATES DEPARTMENT OF THE INTERIOR

Oscar L. Chapman, *Secretary*

GEOLOGICAL SURVEY

W. E. Wrather, *Director*

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 15 cents (paper cover)

CONTENTS

ILLUSTRATION

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TERTIARY STRATIGRAPHY OF SOUTH CAROLINA

By C. Wythe Cooke and F. Stearns MacNeil

ABSTRACT

The following changes in the current classification of the Tertiary formations of South Carolina are proposed: The Black Mingo formation, mainly of Wilcox age, may include some Paleocene deposits. The McBean formation, heretofore including all the deposits of known Claiborne age in South Carolina, is restricted to the *Ostrea sellaeformis* zone, of late middle Claiborne age, and the names Congaree formation (equivalent to the Tallahatta formation) and Warley Hill marl (equivalent to the Winona formation) are revived for deposits of early Claiborne and early middle Claiborne age. A large part of the deposits mapped as Barnwell formation (of Jackson age) proves to be Congaree. The Santee limestone, heretofore supposed to be of early Jackson age, represents the *Ostrea sellaeformis* zone and seems to be an offshore facies of the restricted McBean formation. The Castle Hayne limestone, heretofore known only in North Carolina and referred to the middle Jackson, occurs under cover in South Carolina. Its fauna shows it to be equivalent to the Gosport sand, of late Claiborne age. The Cooper marl, currently referred to the late Eocene (Jackson), is reassigned to the early Oligocene? on the basis of its mollusks, foraminifers, and cetaceans. A gravelly facies of the Miocene Hawthorn formation similar to that in Georgia is recognized for the first time in South Carolina, where the formation had previously been recognized only by its offshore facies.

INTRODUCTION

The Coastal Plain of South Carolina has received somewhat less attention than that of the neighboring State of Georgia, and in comparison with the Coastal Plain of the Gulf States, which in recent years have been the center of extensive oil exploration, little is known. Since the days of Lyell only three general accounts of the stratigraphy of the Coastal Plain of South Carolina have been published, one by Tuomey in 1848, one by Sloan in 1908, and the most recent by Cooke in 1936 as Bulletin 867 of the United States Geological Survey.

The present paper presents a revised classification of the Tertiary formations of South Carolina, and indicates some of the changes necessary on the existing geologic map of the State. However, the greater part of the information on which this revision is based comes from entirely new exposures and new collections of fossils, and even the interpretation of the molluscan faunas is based on revised knowledge of the range of species.

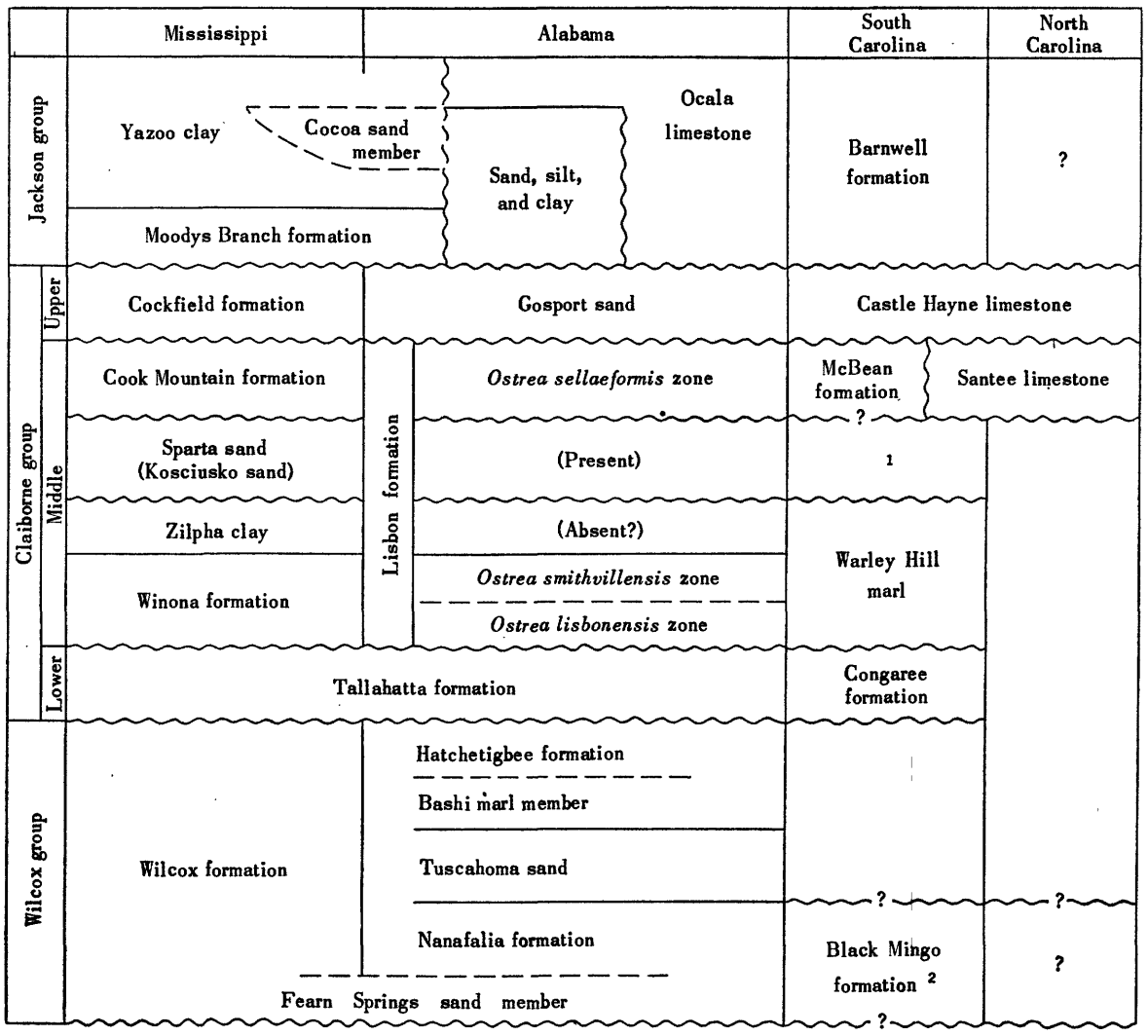
Travel in the Coastal Plain is now much easier and faster than it was before 1936. Many new roads and bridges have been built, and places formerly inaccessible are now within easy reach. The spoil bank of the Santee-Cooper Diversion Canal, cut about 1940, has brought to the surface an abundance of fossils of the Santee limestone, including species that had not been collected since the 1830's, when the original Santee Canal was dug. The associated fauna of the more characteristic of these species is now known for the first time. New pits sunk in the flat, featureless Pleistocene plain yield unsuspected evidence as to the age of the underlying limestones.

Since 1935 MacNeil has been making stratigraphic studies on the Tertiary formations of Mississippi, Alabama, Georgia, and Florida. These have resulted in more accurate information as to the geologic ranges of fossils, and familiarity with the stratigraphy of the formations containing them. Using this information he was able, during a three-week reconnaissance during 1950, presumably preliminary to the preparation of a new geologic map of the Tertiary formations of South Carolina, to make closer correlations with the type sections in Mississippi and Alabama than had been possible in 1936. The writers made two short trips to South Carolina together in May and June of 1951.

PALEOCENE (?) AND EOCENE SERIES

The name Paleocene series was not adopted by the U. S. Geological Survey until after the publication of Cooke's 1936 paper. The deposits in the southeastern States now referred to the Paleocene form the Midway group, which had previously been treated as the oldest division of the Eocene series. Since the removal of the Midway group to the Paleocene, the Eocene series in the Southern States has included only three groups—the Wilcox, Claiborne, and Jackson, represented in South Carolina, though the group names have not been applied there. In addition there is somewhat meager evidence to indicate that the lowest of the units here recognized may include beds of both Paleocene and early Eocene (Wilcox) age.

The only known representative of the Wilcox group in South Carolina is the Black Mingo formation. There is some evidence that the beds now included in the Black Mingo may be in part of Paleocene age, but the evidence is inconclusive. The Claiborne group is more fully



1 Nonfossiliferous, nonglauconitic limestone at Cave Hall may be of this age.

2 May include some Paleocene.

FIGURE 2.—Correlation of Tertiary formations of South Carolina.

represented. As here revised it includes the Congaree formation of early Claiborne age, the Warley Hill marl (both included in the McBean in Bulletin 867, Cooke, 1936), the restricted McBean formation and its offshore equivalent the Santee limestone of middle Claiborne age, and the Castle Hayne limestone, as here restricted, of late Claiborne age. The Jackson group is represented by sandy limestone and perhaps down dip by a less sandy facies. At the present, outcrop beds of Jackson age are almost completely reduced to oxidized sandy residues. The name Barnwell formation was applied to leached residues of the sandy limestone and no type locality was ever designated. It now appears that actually the railroad cut at Barnwell was made in a part of the Miocene Hawthorne formation, although many geologists must have regarded it as typical Barnwell. Residues of limestone of Jackson age certainly are present elsewhere in Barnwell County beneath the Hawthorne cover, and there is no reason why the name Barnwell cannot be applied to the unleached Jackson beds farther down the dip even though its type area falls entirely within the area of solution.

The relationships of the Eocene formations in the Carolinas to one another and to the generalized standard section in Georgia and Alabama are indicated in the correlation chart (fig. 2).

DEPOSITS OF WILCOX AGE

The Black Mingo formation was referred to as being of Wilcox age (Cooke, 1936) primarily because of the presence of *Ostrea arrosis* Aldrich. Although this oyster was stated by Aldrich to be from the Nanafalia

formation, and has since been found to be restricted to it, in the correlation table (p. 40) the Black Mingo was placed opposite the Tuscahoma sand of Alabama because of the occurrence in both of *Turritella mortoni* Conrad, a species now known to be abundant in both the Nanafalia and the Tuscahoma. Mapped with this oyster-bearing bed were underlying siliceous clay-shales and an overlying massive red sand now known to be of early Claiborne age. A revised map would show the Black Mingo to be confined to a much smaller area, chiefly along valley floors. Beds mapped by Cooke (1936, pl. 2) as Black Creek (Cretaceous) formation in western Sumter County are now regarded by MacNeil as Black Mingo as here restricted to the siliceous clay-shale and oyster-bearing bed, whereas the overlying more widely distributed sands in Richland, Lee, Sumter, Clarendon, and Williamsburg Counties that were mapped as Black Mingo are now placed by him in the Congaree formation, of early Claiborne age.

Among fossils collected by Cooke in 1922 on the River Road 3½ miles west of Pinewood, Sumter County (U.S.G.S. collection 10401) and referred to the Black Mingo formation (Cooke, 1936) is a *Turritella* he identified as *Turritella mortoni* Conrad, a species typically of early Wilcox age. Later Bowles (1939, p. 271) identified it as a new subspecies, *T. mortoni mediavia* Bowles, which occurs typically in the lower part of the Midway group at Prairie Creek, Alabama. He found this same subspecies also in U.S.G.S. collection 10403, from the Kingstree road east of Deep Creek, 5 miles east of Manning, Clarendon County. On the basis of this subspecies, Bowles was of the opinion that the Black Mingo is of Midway age, and not Wilcox, to which Cooke had tentatively referred it.

The section at Warley Hill includes in the lower part (bed 3, p. 23) 8 feet of clay or shale overlain by a quartzitic sand containing an oyster resembling *Ostrea crenulimarginata* Gabb, a species found at many localities in the Midway group in Alabama and western Georgia. Cooke (1936) included these beds in the McBean formation but they are now recognized as belonging to the Black Mingo formation. *Ostrea crenulimarginata* is related to the Wilcox oyster *O. arrosis*, but the material at hand more closely resembles the Midway species.

The Black Mingo formation as mapped by Cooke (1936, pl. 2) is now known to have included some beds of early Claiborne age, and (even as here restricted) may include beds of both early Eocene and Paleocene ages. However, further subdivision of the Black Mingo is deferred until more definite evidence of Paleocene age is produced. If the lower shales of the Black Mingo should prove to be of Paleocene age, one of Sloan's names (1907, 1908), Rhems shale or Lang Syne shale, may be available.

DEPOSITS OF CLAIBORNE AGE

All the then-known deposits of Claiborne age were included by Cooke (1936) in one formation, the McBean. This was the original usage in Georgia, where, according to Veatch and Stephenson (1911, p. 237), the McBean "formation is equal to the Tallahatta buhrstone plus the Lisbon formation of Alabama, and the top of it may include the base of the Gosport greensand of the Alabama section." The Claiborne group throughout the States from Alabama to Texas has been divided into well-defined formations, each characterized by its distinctive fossils, and it now seems desirable to divide the McBean of Cooke (1936) along similar lines into three formations. Names proposed by Sloan in 1907 and 1908 are already available. For the lowest beds of Claiborne age, equivalent to the Tallahatta formation, Sloan's name (1908, p. 455) Congaree is revived. For the intermediate beds, equivalent to the Winona formation of Mississippi, Sloan's name (1908, p. 457) Warley Hill is revived. The name McBean formation is retained, in a restricted sense, for the zone represented by the type locality of that formation. This zone, the *Ostrea sellaeformis*, is equivalent to the Cook Mountain formation of Texas and Mississippi, the upper part of the middle Claiborne.

MacNeil concluded in 1950, on the basis of field profiles and a restudy of its molluscan fauna, that the Santee limestone, long supposed to be of early Jackson age, represents the *Ostrea sellaeformis* zone of the Claiborne group, equivalent to the restricted McBean formation, of which it is an offshore facies.

Another astonishing result of the present investigations is the discovery of the Castle Hayne limestone in South Carolina. That formation (typically developed in North Carolina, where it was called a marl) had been considered to be equivalent to the Santee limestone and to be of Jackson age. As here restricted, it is younger than the Santee and is of late Claiborne age, equivalent to the Gosport sand of Alabama and the Avon Park limestone of Florida.

CONGAREE FORMATION

Though Sloan's "Congaree phase" (1908, p. 455) was vaguely defined, he evidently intended to include in it clay, sand, and buhrstone of early Claiborne age. Veatch and Stephenson (1911, pp. 238, 267) accepted Congaree in this sense for use in Georgia and described the Congaree clay as the basal member of the McBean formation, the oldest formation of Claiborne age known to them there. How much of their Congaree is really

Claiborne, however, is still uncertain; some deposits referred to it, notably the thick bed of fuller's earth at Pike's Peak, in Twiggs County, Georgia, are now believed to be of Jackson age because of their supposed equivalence to similar clay in Houston County, Ga., that lies above fossiliferous Jackson limestone. Cooke and Shearer (1918) supposed that all their Congaree clay member was of Jackson age and transferred it to the Barnwell formation under the name Twiggs clay member. Later Cooke (1943, p. 61) restored that facies consisting of thin-bedded or laminated sand and clay to the McBean formation but did not have an opportunity to revise his map, which had been published in 1939.

It now appears that the deposits of Claiborne and Jackson age have never been properly delimited in either eastern Georgia or South Carolina. Though Veatch and Stephenson (1911) mapped too much Claiborne in Georgia, both Cooke (1939; 1943, pl. 1) and MacNeil (1947) showed too little. Cooke's map of South Carolina (1936, pl. 2) included beds of Claiborne age in the supposed Jackson south of the Congaree River, but north of that river the lower Claiborne was mapped as Black Mingo formation (Wilcox). After studying the section of Claiborne age of South Carolina and its fauna, MacNeil is of the opinion that a large part of the deposits in eastern Georgia mapped as Barnwell is of Claiborne age. This would include several of the better-known fossil localities, such as Little Keg Creek (Cooke and Shearer, 1918, p. 48; Cooke, 1943, p. 55) and much of the Twiggs clay member of the Barnwell formation of eastern Georgia.

The Congaree is now deemed of formational rank because it is equivalent to the Tallahatta formation of Mississippi and Alabama, which presumably is separated from younger deposits by an erosion interval. The name Congaree formation rather than Congaree clay or shale is preferred because much sand as well as clay and shale are included.

Sloan specified no single locality as the type of his Congaree "shale," "sands," or "buhrstone." The name is evidently taken from the Congaree River, and it has been suggested (Cooke, 1936, p. 59) that Sloan's locality 505 on the Elmore Williams' place at the head of First Creek, a tributary of the Congaree River, be regarded as typical. This locality is difficult to find without a guide. However, ledges of similar rock are exposed on the road south of Bull Swamp Creek 2¼ miles west-northwest of Swansea and also at a waterfall north of the east-west county road about 2¼ miles west by north of Swansea.

A Tallahatta-like facies of the Congaree formation is well exposed in a cut on State Highway 33 half a mile east of Creston, Calhoun County, and west of Halfway Swamp; and for all practical purposes this can be regarded as a typical exposure. The section is as follows:

Section in road cut west of Halfway Swamp 0.5 mile east of Creston

	Feet
Warley Hill marl.	
4. Coarse weathered sand	5
3. Rusty highly glauconitic sand	2
Unconformity?	
Congaree formation.	
2. Alternating fine rusty unconsolidated sand and shale; borings in top	5
1. Light-gray shale alternating with thin-bedded fine-grained sandstone, most beds less than 3 inches thick. Contains *Anodontia? augustana* Gardner. This bed closely resembles a facies of the Tallahatta formation. About	16

The materials of the Congaree formation strongly resemble those of the Tallahatta formation. Both contain hard, brittle siltstone, which is the dominant component of the Tallahatta near the Mississippi-Alabama line. Well-sorted and poorly sorted sand are common to both formations. Brittle clay or fuller's earth is a conspicuous feature of the Congaree in the Congaree Valley, although the larger clay masses are local lenses. In Aiken and Lexington Counties coarse to fine gravelly sand makes up the greater part of the formation. The Congaree formation in this area resembles the coarser facies of the Tallahatta in northern Mississippi.

Several species of mollusks characteristic of the Tallahatta occur also in South Carolina, and are restricted there to the Congaree formation. The recently described guide mollusk *Anodontia? augustana* Gardner (1951, p. 9) was recorded by Gardner (1951, p. 10) from U.S.G.S. collection 7728, bed 8 of the section at Warley Hill (p. 23) and from a road cut on the south side of Halfway Swamp about 2½ miles northwest of Creston, Calhoun County. In Alabama this species occurs only in the Tallahatta formation. *Ostrea johnsoni* Aldrich, a species now known to be confined to the Tallahatta, has been found near Salley (Cooke, 1936, p. 59) and 2 miles south of Gaston (Cooke, 1936, p. 60). An oyster found in bed 2 of the section at Lang Syne (Cooke, 1936, p. 69) and reported as *Ostrea divaricata* Lea seems to be an undescribed species, related to *O. perplicata* Dall, which occurs also in the Tallahatta.

Hard sandstone and sand exposed in Aiken and Lexington Counties supposed by Cooke (1936) to be referable to the Barnwell sand prove on further study to be of Congaree age. The most important of such outcrops are Calico Spring (locality 185, p. 93), Decaradeaux place (locality 189, p. 94), and Bethel church

(locality 190, p. 95). The last two localities have yielded recognizable fossils formerly interpreted as of Jackson age. Two corals, however, *Endopachys maclurii* (Lea) and *Platytrochus stokesi* (Lea), found elsewhere only in beds of Claiborne age, occur at both places. Fossils, including *Turritella mcbeanensis* Bowles, were recently found by D. H. Eargle and B. F. Buie in a tough siliceous clay near the mine of the Monetta Clay Company along Highway 39 about 1½ miles northwest of New Holland Crossroads, Aiken County. This locality lies well within an area mapped as Cretaceous by Cooke in 1936.

One of the striking features of the basal part of the Claiborne is the occurrence of boulders of pisolitic clay, mainly bauxitic. These boulders of pisolitic clay have been found by MacNeil to be common in eastern Georgia and as far east as Calhoun County, S. C., where they occur sporadically in a coarse sandy bed at the base of the Congaree formation and rest directly on dark shale of the Black Mingo formation. The occurrence of these boulders of pisolitic clay at the base of the beds of Claiborne age agrees with what is now known of the age of the period of bauxitization throughout the southeastern States. Bauxite is known to have been formed from clays both of Cretaceous and of early Wilcox ages. All these clays are believed to have been bauxitized during early Wilcox time. The occurrence of these reworked boulders of bauxite and pisolitic clay in deposits of the next great transgressive period—the Claiborne—is entirely consistent with the current dating of the bauxite.

WARLEY HILL MARL

The "Warley Hill phase," described by Sloan (1908, p. 458), was included in the McBean formation by Cooke in 1936. The name is here revived in a restricted sense to include the dominantly glauconitic beds that intervene between the Congaree formation and the *Ostrea sellaeformis* zone, or restricted McBean.

The following section at Warley Hill is modified from Cooke (1936, p. 71). It is proposed to restrict the term Warley Hill marl to beds 9 and 10. This locality, regarded as the type exposure of the formation, is on an abandoned road west of State Highway 267 and south of Warley Creek 3 miles north-northwest of Lone Star, Calhoun County, within the Elloree quadrangle.

Section at Warley Hill

	Feet
Middle Eocene.	
Warley Hill marl (middle Claiborne).	
10. Yellow sandy clay at base, passing into reddish-yellow massive argillaceous sand containing many small grains of glauconite	16
Middle Eocene—Continued	
Warley Hill marl (middle Claiborne)—Continued	
9. Fine green to yellow glauconitic sand containing *Venericardia* sp. and other fossils. In sharp contact with the bed below	6
Congaree formation (lower Claiborne).	
8. Greenish and yellow to gray brittle, nonplastic clay resembling fuller's earth; a few casts of mollusks, including *Anodontia? augustana* Gardner	14
7. Sparsely glauconitic light-weight gray to yellow marl; a few casts of mollusks	2¼
6. Greenish-gray glauconitic sand with some clay at top; scattered pebbles 0.5 inch in diameter along base	1
Paleocene(?) and lower Eocene.	
Black Mingo formation.	
5. Flaky brown nonplastic clay	1
4. Slightly coherent fine yellow or red sand, a decomposed sandstone, where fresh containing *Ostrea crenulimarginata* Gabb?	2
3. Compact, brittle blue-gray shale or clay (fuller's earth); lower part with slaty cleavage, upper part more massive and with conchoidal or hackly fracture	8
2. Fine gray to yellow sand mingled with black carbonaceous, sandy clay; a 6-inch indurated ledge at top	2½
1. Concealed to level of Warley Creek	14

According to Sloan (1908, p. 302) the top of the Warley Hill marl was exposed at Cave Hall and at Whaley's mill on Poplar Creek, both now in Calhoun County. At both localities it consisted of harsh, gray-green glauconitic marl. Sloan obtained well-preserved specimens of *Ostrea lisbonensis* Harris (reported as *O. sellaeformis*), a reliable and characteristic fossil of the lower part of the Winona formation of Mississippi and of the basal glauconitic marl of the Lisbon formation of Alabama, at Cave Hall. At both places, he says, the Warley Hill is overlain by the Santee limestone. The contact at Cave Hall seems to be unconformable, for Sloan describes it as undulating, and he reports rounded lumps of the Warley Hill marl in the base of the Santee limestone.

Cave Hall is a deep ravine containing a flowing stream about 0.4 mile long entering Lake Marion 0.8 mile south of the embayed mouth of Halfway Swamp and 4.5 miles north-northeast of Elloree. Hard white limestone, presumably the lower part of the Santee limestone, though no fossils were found in it, is still exposed at the head of the ravine, but the Warley Hill marl there, which Sloan reports as rising 3 feet above the base line of the ravine, may now be covered by backwater from the lake.

McBEAN FORMATION

As originally defined by Veatch and Stephenson (1911, p. 237), the McBean formation of eastern Geor-

gia was equivalent to the combined Tallahatta formation and Lisbon formation of the Alabama section. The McBean is here restricted to include only the Cook Mountain equivalent, the *Ostrea sellaeformis* zone, of the Lisbon formation. This is represented at McBean, Georgia, and in South Carolina by white sandy marl and massive yellow or red sand, which appears to be at least partly residual from sandy marl. At Shell Bluff, on the Georgia side of Savannah River, a bed of nearly 80 feet of sandy marl and limestone includes a 6-foot bed carrying large *Ostrea sellaeformis* (Cooke, 1943, p. 57).

The massive sand contains local patches of silicified shells, many species of which occur also in the Lisbon formation and in the Cook Mountain formation of Mississippi. Fossils from several such patches in Orangeburg County are listed in Bulletin 867, notably Caw Caw Swamp (p. 63), Pooser's Hill (p. 64), and Orangeburg (p. 65).

A conspicuous component of the McBean formation in South Carolina is a very light weight sandstone or siltsone that appears to be a marl from which all the lime has been leached. This rock commonly contains *Pteropsis lapidosa* Conrad, a thin-shelled pelecypod with concentric undulations that seems to be confined to the McBean.

SANTEE LIMESTONE

The "Santee beds" were first correlated with the Jackson "stage" by Dall (1898, p. 342), though he says: "Tuomey included Claibornian as well as Jacksonian marls in his series. The term as adopted here refers to the upper green marls from which *Zeuglodon* has been obtained." Dall may have had in mind the Cooper marl rather than the Santee limestone as those formations are now divided, though no true zeuglodonts are known from the Cooper. The "*Zeuglodon*" of Tuomey was a primitive toothed whale. It was found in the Cooper. The only zeuglodontid from South Carolina, *Dorudon serratus* Gibbes, probably was found either in the Santee limestone or in the Castle Hayne limestone.

The Jackson age of the Santee limestone was accepted by Canu and Bassler (1920), who referred the large fauna of Bryozoa at Eutaw Springs and Leneudes Ferry to the "middle Jacksonian." They listed a total of 130 species from the two places. Eighty-one of these species are reported also from Wilmington, N. C., and 58 from the Ocala limestone in Georgia. The Bryozoa from Wilmington, N. C., are for the most part from the Castle Hayne limestone, though some may have come from the Santee limestone, which underlies it there. It is not surprising that the faunas of the Santee, Castle Hayne, and Ocala limestones are somewhat similar, for these three formations represent similar facies. The Santee and Castle Hayne faunas were not recognized as of Claiborne age because no similar bryozoan-bearing limestone facies occurs in the Claiborne west of the Carolinas.

The most conclusive paleontologic evidence for the middle Claiborne age of the Santee limestone is the presence in it of well-developed specimens of *Ostrea sellaeformis* Conrad. According to Stenzel (1949) this species is restricted to beds of middle Claiborne age, i. e., of the age of the Cook Mountain formation of Texas. This agrees with MacNeil's observations in Mississippi, Alabama, and Georgia, where shells of *O. sellaeformis* have not been found in beds younger than Cook Mountain except as badly worn and obviously reworked specimens.

The middle Claiborne age of the Santee limestone is indicated also by the occurrence in it of *Chlamys wautubbeana* (Dall), a species elsewhere restricted (so far as is known) to that horizon, and by several unnamed species that seem to have the same range.

The commonly accepted type exposure of the Santee limestone is Eutaw Springs, in Orangeburg County, 3½ miles east-northeast of Eutawville. Backwater from Lake Marion has partly inundated the old exposure, but some limestone still stands above the level of the reservoir. Among species recently taken are *Ostrea sellaeformis* and *Eurhodia raveneli* (Twitchell).

The best collecting from the Santee limestone is at the spoil bank of the New Santee-Cooper Diversion Canal near Eadytown, at the crossing of Route 45. Caution should be used in interpreting the collections, for perhaps the Castle Hayne limestone overlies the Santee limestone in that region. The Santee fauna from this locality has been studied by Harbison (1944). The following species were collected by the present writers near Route 45 in 1950 and 1951:

Fossils from the Santee-Cooper Diversion Canal

Mollusca:

Turritella sp. aff. *T. wechesensis* Bowles
Cypraea sp.
Conus sp.
Ostrea sellaeformis Conrad.
O. carolinensis Conrad
O. n. sp. aff. *O. podagrina* Dall
Chlamys wautabbeana (Dall)
C. n. sp. aff. *C. membranosa* (Morton)
C. sp. aff. *C. clarkeana* (Aldrich)
Plicatula filamentosa Conrad.
Spondylus sp.
Venericardia sp. aff. *V. alticostata* (Conrad)
Crassatatella n. sp. aff. *C. texana* (Heilprin) but with an obtuse posterior ridge
Lirodiscus santeensis Harbison
Pitar (*Costacallista*) sp.
Solen sp. cf. *S. lisbonensis* Aldrich

Echinoidea:
Cidaris sp.
Coelopleurus infulatus (Morton)
Protoscutella conradi (Cotteau)
Cassidulus gregoryi (Twitchell)?
Eurhodia raveneli (Twitchell)

Besides the species listed above, all of which are believed to have been derived from the Santee limestone, one specimen of *Ostrea trigonalis* Conrad was found. This probably came from a higher horizon, for there are blocks of a harder limestone that apparently does not contain *O. sellaeformis.*

CASTLE HAYNE LIMESTONE

The Castle Hayne limestone, heretofore known only from North Carolina, was named by Miller (1910, 1912) from a town in New Hanover County, N. C. The formation has since been described by Kellum (1926) and by Richards (1950). It was referred to the upper Eocene by Miller, and subsequent writers have correlated it with the Jackson group. Canu and Bassler (1920), who described a large fauna of Bryozoa from Wilmington, specified the age as "middle Jacksonian."

The echinoids, mollusks, and branchiopods from the Castle Hayne limestone were studied by Kellum (1926). Their evidence seemed to confirm the Jackson age, though Kellum says that "The poor state of preservation of most of the fossils, together with the relatively large number of new forms and the long range of some of the species, greatly limits their value in correlation." With the greater knowledge of the range of some species since acquired, it seems evident that most of the fossils attributed by Kellum to the Castle Hayne are somewhat older than he supposed, and that the Castle Hayne as here restricted is of late Claiborne age, equivalent to the Gosport sand of Alabama as now restricted.[1] Among the species supposed to indicate the Jackson age were *Periarchus lyelli* (Conrad), *Ostrea georgiana* Conrad (=*O. gigantissima* Finch), *Ostrea trigonalis* Conrad, *Chlamys deshayesii* (Lea) and *Crassatella alta* Conrad. Of these only *Ostrea gigantissima* is now regarded as exclusively Jackson, and Kellum reports it only from Pollocksville, where its only associate is *Ostrea trigonalis*, also commonly Jackson. The specimens identified as *Chlamys deshayesii* apparently represent a different, probably ancestral species. The other fossils occur also in the restricted Gosport sand. and *Crassatella alta* seems to be confined to it.

[1] In 1939 Cooke supposed that the Gosport sand was of basal Jackson age, part of his evidence being the occurrence in it of *Periarchus lyelli* (Conrad) and *Ostrea trigonalis* Conrad, species then considered as good indicators of Jackson age. The base of the Jackson at Claiborne, Alabama, is now drawn below the *Chlamys deshayesii* (Lea) bed, which was originally included as the top bed in the "Claiborne sand" (Gosport sand).

The fossils from Wilmington, Castle Hayne, and several other places listed by Kellum (1926, p. 11) include a few species that indicate the presence of middle Claiborne beds as well as the Castle Hayne limestone. Among these species are *Eurhodia raveneli* (Twitchell), probably *Hemipatagus subrostratus* Clark, and *Ostrea sellaeformis* Conrad. The middle Claiborne beds evidently include the coarse phosphatic basal conglomerate that lies on the Cretaceous at Wilmington and Castle Hayne and probably also several feet of limestone coquina that overlies the conglomerate. The name Santee limestone might appropriately be extended to these beds. The following section near Wilmington is based on a description and a diagram in the field notes of L. W. Stephenson, 1909. The locality is no longer accessible. The age assignments are by the present writers. The thicknesses are all approximate.

Section in the county rock quarry near Wilmington

	Feet
Pleistocene?	
7. Fine to medium-grained loose yellow sand. About	8
Miocene	
Duplin marl?	
6. Thin remnants of a sandy shell bed	0–1
Eocene	
Castle Hayne limestone	
5. Irregular masses of hard, massive limestone penetrated by solution channels; highly fossiliferous, containing abundant *Terebratula, Periarchus lyelli,* several other species of echinoids, many bryozoans	10–12
4. Very soft granular limestone with an abundance of bryozoans, *Terebratula.* The upper surface is uneven	2–4
Santee limestone?	
3. Hard bluish limestone with small dark phosphatic specks. Evidently formed as a coquina, as cross-bedding is evident in places	2
2. Stratified and cross-bedded coquina limestone, partly indurated; ledge at base similar to overlying bed. Contains bryozoans, small pelecypods, and other fossils	8
1. Phosphatic conglomerate consisting of dark-green nodules in a matrix of gray calcareous sand, all very hard	3

In South Carolina the Castle Hayne limestone has been recognized only in artificial exposures. The deep pit of the Carolina Cement & Lime Company 2 miles north of Harleyville, Dorchester County, when examined in June 1951, showed the following sequence:

Section at the Carolina Cement & Lime Company

	Feet
Pleistocene	
Wicomico formation?	
7. Dirty, clayey, sandy soil	3
6. Mottled gray and red clay, weathered at top	3
5. Subangular gravel containing pebbles as much as ¾ inch in diameter at base	5

	Feet
Unconformity	
Miocene?	
4. Fine angular yellow sand containing black grains and some glauconite	8
Oligocene (?)	
Cooper marl.	
3. Pale greenish-gray granular marl, glauconitic throughout and containing phosphatic nodules at the base; Foraminifera and *Chlamys cocoana* (Dall) abundant	3–8
Unconformity	
Eocene	
Castle Hayne limestone.	
2. Buff-gray, tough to hard, crumbly limestone; *Chlamys cookei* (Kellum) throughout; *Chlamys* n. sp. and *Glycymeris staminea* Conrad in upper part; *Chlamys* n. sp. aff. *C. deshayesii* (Lea), *Ostrea trigonalis* Conrad, and *Periarchus lyelli* (Conrad) in lower part	18
1. Gray soft, fine-grained, granular limestone to bottom of pit; *Chlamys cookei* and *Periarchus lyelli*	28

In addition to the species listed in the section, which were all found in place, the following species were collected from loose blocks of limestone, which apparently came from bed 2: *Endopachys* sp., *Turritella* sp. cf. *T. arenicola* Conrad, *Miltha* sp. aff. *M. claibornensis* Conrad, *Crassatella alta* Conrad, *Lucina* sp. cf. *L. pandata* Conrad, a large *Fusinus?*, a *Cardium*, and a *Panope*.

Of the identified species in beds 1 and 2 all but *Glycymeris staminea* are listed by Kellum from the Castle Hayne limestone in North Carolina, and that species is a Gosport form.

A sample from the lower part of bed 2 yielded the following species of Foraminifera:

Foraminifera from the Castle Hayne limestone at the Carolina Cement & Lime Company pit

(Identified by M. R. Todd)

Spiroplectammina wilcoxensis Cushman and Ponton?
Textularia recta Cushman
Globulina sp.
Entosolenia sp.
Bolivina sp.
Reussella sp.
Angulogerina byramensis (Cushman) var.
Valvulineria n. sp. (cf. *V. crassisepta* Keijzer)
Gyroidina soldanii octocamerata Cushman and G. D. Hanna
Eponides sp. 1
E. sp. 2
Alabamina wilcoxensis Toulmin
Cibicides danvillensis Howe and Wallace
C. lobatulus (Walker and Jacob)
C. plano-convexus Cushman and Todd

A rock pit in Orangeburg County nearly 3 miles north of the cement plant also entered the Castle Hayne limestone, and is apparently bed 1 of the above section. The pit, which is now full of water, is about half a mile west of Four Holes Station and 3 miles south-southwest of Holly Hill. *Periarchus lyelli* and *Chlamys cookei* were found there.

DEPOSITS OF JACKSON AGE

The formations of Jackson age listed by Cooke in 1936 included the Santee limestone, the Cooper marl, and the Barnwell sand. It has been shown that the Santee limestone is of middle Claiborne age, some beds mapped as Barnwell are of early Claiborne (Congaree) age, and others are of middle Miocene (Hawthorn) age. The Cooper marl is probably of early Oligocene (Red Bluff) age. A small part of the supposed Barnwell remains as the only true representative of the Jackson among the outcropping formations. It is possible, however, that the Ocala limestone or its equivalent is present under cover as the offshore representative of the Barnwell. This is suggested by the occurrence of *Ostrea podagrina* Dall, an Ocala species, at Givhans Bridge (Cooke, 1936, p. 86).

BARNWELL FORMATION

On the Savannah River at Shell Bluff, in Burke County, Georgia, and extending downstream to Griffins Landing, the Barnwell formation consists chiefly of a 30-foot bed of large shells of *Ostrea gigantissima* Finch embedded in pebbly sand and yellowish marl or hard calcareous clay containing Bryozoa (Cooke and Shearer, 1918, p. 61). A few occurrences of this oyster bed have been noted in South Carolina. Sloan (1908, p. 268) reported it along Lower Three Runs on the farm of J. W. Ussery, which is probably a mile or more below the Allendale-Barnwell County line. A well at Baldock passed through an oyster bed, perhaps of this same species, about 30 feet below the level of Miller Creek at Baldock (Cooke, 1936, p. 89). However, this oyster bed may have been composed of *Ostrea sellaeformis* and hence may be part of the underlying McBean formation.

A small outcrop of cream-colored very sandy, calcareous marl in the bed of Miller Creek at an old dam below the water tank at Baldock is probably Barnwell, though it was referred to the Cooper marl by Cooke (1936, p. 88). Such a marl would leach to a massive red sand considered characteristic of the Barnwell, and very common in Burke County, Georgia, notably around Louisville. Canu and Bassler (1920) list 38 species of Bryozoa from this marl at Baldock. None of these species are restricted elsewhere to the Santee limestone, though nine ranged from a higher horizon down to it. One is known only from the Castle Hayne at Wilmington, and 21 species occur there. Nine are restricted to

the Ocala limestone, and 27 are listed from it. Seven were found only at Baldock. The evidence of the Bryozoa indicates that the marl at Baldock is of late Eocene (Ocala) age.

The marl at Baldock is very rich in Foraminifera. The following species have been identified:

Foraminifera from Eocene marl at Baldock

(Identified by M. R. Todd)

Spiroplectammina mississippiensis alabamensis (Cushman)
Textularia adalta Cushman
T. subhauerii Cushman
Gaudryina sp.
Massilina decorata Cushman
Robulus sp.
Planularia georgiana Cushman and Herrick
Nodosaria latejugata carolinensis Cushman
Lagena costata (Williamson)
Guttulina byramensis Cushman
Globulina gibba punctata d'Orbigny
G. sp.
Sigmorphina jacksonensis (Cushman)
S. sp. cf. *S. undulosa* (Terquem)
S. sp.
Polymorphina advena Cushman
Nonion inexcavatum (Cushman and Applin)
Entosolenia orbignyana flintii (Cushman)
Bolivina gardnerae Cushman
B. mississippiensis Cushman
B. mornhinvegi Cushman
Reussella eocena (Cushman)
R. sp.
Uvigerina sp. cf. *U. cookei* Cushman
Angulogerina byramensis (Cushman)
Discorbis assulata Cushman
D. subaraucana Cushman="*D. georgiana* Cushman and Herrick"
Valvulineria texana Cushman and Ellisor
Gyroidina sp.
Eponides sp.
Siphonina jacksonensis Cushman and Applin
Amphistegina sp. cf. *A. alabamensis* Applin and Jordan
Alabamina sp.
Globigerina sp.
G. sp.
Hantkenina alabamensis Cushman (=*H. longispina* of Cushman and Herrick)
Anomalina sp.
Cibicides sp. cf. *C. americanus* (Cushman)
C. danvillensis Howe and Wallace
C. lobatulus (Walker and Jacob)
C. mississippiensis (Cushman)
C. plano-convexus Cushman and Todd

According to Miss Todd the following species are not known from beds younger than Eocene: *Nodosaria latejugata carolinensis*, *Nonion inexcavatum*, *Reussella eocena*, and *Cibicides danvillensis*.

OLIGOCENE SERIES

When Cooke's report was written the only known representative of the Oligocene series in South Carolina was the Flint River formation, which is represented by residual blocks of fossiliferous chert, of late Oligocene age. It now appears that the Cooper marl, then supposed to be late Eocene in age, is really one stage younger, early Oligocene(?), and is equivalent to the Red Bluff formation of Alabama and Mississippi. Oligocene limestone in Screven County, Georgia, and residual cherts derived from it found along the Savannah River are still believed to be of late Oligocene age.

COOPER MARL

The Cooper marl has been shifted back and forth between the Eocene and the Oligocene. Tuomey (1848) and Holmes (1870) called it Eocene, but Dall (1898) referred it to the lower Oligocene, which then included the Ocala limestone. Stephenson (1914) and Rogers (1914) classified the Cooper as uppermost Eocene or Oligocene. Stephenson (1914, p. 85) cited the supposed occurrence in it of *Basilosaurus* as indicating its Eocene age. This occurrence presumably referred to the so-called *Zeuglodon*, which Tuomey (1848, p. 166) mentioned as having been found in the long, low bluff extending from Greer's Landing to Middleton Place on the Ashley River. This specimen has since been identified as *Agorophius pygmaeus* (Müller), an archaic toothed whale. Other related forms in the Cooper marl are *Xenorophus sloanii* Kellogg, from Woodstock, and possibly *Archaeodelphis patrius* Allen. According to Dr. Remington Kellogg (oral communication), these are the most primitive representatives of the toothed whales, and as none have been found elsewhere in known Eocene deposits, he thinks they are early Oligocene. Higher zones contain less primitive forms.

A more specific indication of early Oligocene age is *Chlamys cocoana* (Dall). The type of this little pecten was supposed to have been found in beds of Jackson age near old Cocoa Post Office, Choctaw, County, Alabama, but it bears the same station number as Red Bluff (early Oligocene) fossils from that vicinity and it is similar to them in color, differing in appearance and state of preservation from shells of known Jackson age. *Chlamys cocoana* is abundant in the Cooper marl at the Carolina Cement & Lime Company pit (see section, p. 26).

The Foraminifera from the Cooper marl at the cement plant were studied by M. R. Todd, who reported that the fauna appears to be of Red Bluff age. This age is suggested primarily by the occurrence of *Bolivinella rugosa* Howe, a Red Bluff species. *Bolivinella* is not known from beds older than Oligocene. The list of species follows:

Foraminifera from the Cooper marl (bed 3) at the Carolina Cement & Lime Company

(Identified by M. R. Todd)

Spiroplectammina mississippiensis (Cushman)
S. mississippiensis alabamensis (Cushman)
Robulus sp.
Marginulina cocoaensis Cushman
M. sp.
Dentalina sp.
Lagena costata (Williamson)
Guttulina byramensis (Cushman)
Globulina gibba d'Orbigny
Nonion affine (Reuss)
Bolivinella rugosa Howe
Bulimina ovata d'Orbigny
Bolivina byramensis Cushman
B. costifera Cushman
B. gardnerae Cushman
B. sp.
Loxostomum sp.
Bifarina vicksburgensis (Cushman)
Uvigerina yazooensis Cushman
Angulogerina byramensis (Cushman)
A. byramensis (Cushman) var.
Ellipsonodosaria cocoaensis (Cushman)
Discorbis arcuato-costata Cushman
D. subaraucana Cushman
D. sp.
Gyroidina byramensis Cushman and Todd?
G. sp.
Eponides sp.
Siphonina sp.
Cancris sp.
Globigerina sp.
Cibicides sp. cf. *C. choctawensis* Cushman and McGlamery
C. lobatulus Walker and Jacob
C. mississippiensis (Cushman)
C. pseudoungerianus (Cushman)
Stichocibicides n. sp.
Dyocibicides sp.

A well-marked erosional contact of the Cooper marl on the Castle Hayne limestone at the cement plant is additional evidence of a time break, though it does not rule out the possibility that the Cooper is Jackson.

MIOCENE SERIES

HAWTHORN FORMATION

A thin series of sandy clay and gravelly sand beds similar to and presumably originally continuous with the Hawthorn formation of Georgia emerges from beneath cover at the northern margin of the coastal terraces and overlaps older formations. This facies of the supposed Hawthorn is quite different from the offshore facies, known only from well cuttings and a very few outcrops in Hampton and Colleton Counties, on the basis of which the Hawthorn was first recognized in South Carolina.

Detailed mapping will be required to determine the extent of the Hawthorn formation in South Carolina and to distinguish it from similar facies of the Eocene and Cretaceous formations. The formation can generally be recognized by a characteristic mottling of pink or yellow and gray, though these colors are by no means confined to it. An outcrop that can be referred to the Hawthorn with some assurance is in the cut of the Atlantic Coast Line Railroad that extends 1 mile east from the station at Barnwell. Cooke (1936, p. 91) referred this cut to the Barnwell sand, though it was not considered typical of that formation. Cuts along a new spur line extending northwestward from Dunbarton show excellent exposures of the Hawthorn formation.

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