CAROLINA GEOLOGICAL SOCIETY

GUIDEBOOK

FOR THE

SOUTH CAROLINA COASTAL PLAIN FIELD TRIP

NOVEMBER 16-17, 1957

By
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U.S. Geological Survey

Prepared in cooperation with the South Carolina State Planning Board

NOVEMBER 1957

Retyped and formatted from the original. Some very light editing. October 1999

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GUIDEBOOK FOR THE SOUTH CAROLINA COASTAL PLAIN FIELD TRIP

NOVEMBER 16-17, 1957 [1]

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1. Publication authorized by the Director, U.S. Geological Survey

INTRODUCTION

The annual field trip taken by the Carolina Geological Society is designed to acquaint members with interesting and noteworthy features concerning the geology of the two Carolinas. Some members have requested that a trip, organized by the Ground Water Branch of the U.S. Geological Survey, be held in the Coastal Plain of South Carolina. This trip was arranged to fulfill that request.

Since 1946, ground- water investigations have been carried out intermittently by the U.S. Geological Survey within the State, in cooperation with the South Carolina State Development Board (formerly the South Carolina Research and Development Board). During the course of these activities, the writer has had opportunity to study some of the surface and subsurface geology of the area. However, this trip is not intended to be an all- inclusive or detailed account of the Coastal Plain geology. Limitation of time and other factors prohibit more than a general survey of some of the more important sections of the stratigraphic column. The stratigraphic nomenclature and age designations used in this report do not necessarily follow the usage of the U.S. Geological Survey.

Good outcrops of the sedimentary formations are scarce, owing to the covering mantle of material of Pleistocene to Recent age and the generally low relief of the area. But it is hoped that the locations selected will afford an accurate representation of a greater part of the stratigraphic column.

Some localities show only beds of one formation, whereas others have two or more and thereby indicate the nature of the formational contact.

Early investigators and travelers from the late 18th century to the present time have reported on the geology of the South Carolina Coastal Plain. Many of their works are referred to in the text and identified in the list of references.

DESCRIPTION OF FORMATIONS

The sedimentary formations of the Coastal Plain range in age from Late Cretaceous to Recent. They consist, for the most part, of unconsolidated sand, clay, gravel, marl, and limestone which have been deposited on a surface of granite, schist, and gneiss similar to and a continuation of the rocks underlying the adjoining Piedmont province. Some coquinas have been silicified to form so-called buhrstones and some clays hardened into siltstones. The phosphate rock occurring in the southern part of the Coastal Plain is, in some places, very hard and forms a caprock overlying the permeable limestone.

The distribution of geologic formations on the Coastal Plain is indicated on figure 1. The boundaries are generalized and are not to be interpreted rigorously. The sedimentary beds form wedges which dip and thicken gently to the south and southeast. They crop out at the surface in almost parallel belts that extend across the Coastal Plain from southwest to northeast.

The effect of topography is reflected in the greater intricacy of contact pattern in the areas contiguous to the Fall Line, contrasted with the simpler pattern in downdip areas leveled by Pleistocene marine inundations.

Such factors as weathering and the thin mantle of Pleistocene cover complicate the mapping of formational boundaries in the Coastal Plain, making it rather difficult in many parts of the area.

Upper Cretaceous Series

At the present time, all deposits of the Cretaceous system in South Carolina are considered Upper Cretaceous. Sloan (1904) considered the basal beds Lower Cretaceous. Sloan (1904) considered the basal beds Lower Cretaceous, as did Stephenson (personal communication) in North Carolina because of their similarity to Lower Cretaceous beds in the Middle Atlantic states.

The Upper Cretaceous deposits are divided into three formations, the Tuscaloosa at the base, overlain successively by the Black Creek and Peedee formations. Erosional unconformities separate each of the three formations.

Tuscaloosa Formation

The Tuscaloosa formation is the oldest recognized deposit of Late Cretaceous age in the State. In 1887 Smith and Johnson named this formation from the city, county, and river of that name in Alabama. Later, the name was extended

Table 1: Description of geologic formations in South Carolina and their correlation with the Gulf and Middle Atlantic equivalents.

System	Series	Group	Gulf Coast	South Carolina	Middle Atlantic Coast	Description of formation in South Carolina
Quaternary	Recent					Light-gray and tan fine to coarse lenticular sand and interbedded clay of marine and continental origin.
	Pleistocene		Beaumont clay Lissie sand	Pamlico Talbot Penhaloway Wicomico Coharie Hazelhurst	Pamlico Talbot Penhaloway Wicomico Coharie Hazelhurst	Light-gray, tan, orange, red, and black clay interbedded with sand and gravel. Deposits form a thin cover over greater portion of Coastal Plain.
Tertiary	Pliocene		Willis (?) sand and Goliad sand	Waccamaw	Brandywine (?) Waccamaw	Blue-gray to yellow and brown sandy shell marl.
	Miocene	Lagarto (?) clay	Duplin marl	Yorktown		Buff sandy, friable shell marl occurring in isolated patches in lower half of Coastal Plain
		Oakville ss	Hawthorn ----------?-------- Tampa (?) limestone[1]	St. Marys Choptank Calvert		Hard, brittle shale resembling silicified fuller's earth, with fine sandy phosphatic marl.
		Catahoula ss				White sandy phosphatic, fossiliferous limestone with molds and fragments of macro-shells.
	Oligocene		Vicksburg or Upper Suwanee	Flint River	?	Broken lumps of yellow vitreous chert in reddish-yellow sand. Chert is sparingly fossiliferous.
			Red Bluff	Cooper Marl	?	Light-brown to grayish-green marl, phosphatic.
	Eocene	Jackson	Jackson	Barnwell / Cooper	Piney Point	Light-brown to grayish-green phosphatic marl is characteristic of the Cooper. The Barnwell consists typically of deep-red to brown fine to coarse massive red sandy clay and clayey sand. Probably represents a residuum derived from solution of a sandy limestone.
		Claiborne	Cockfield or Gosport	Castle Hayne Limestone	Nanjemoy	Buff-gray tough or crumbly fossiliferous limestone underlain by soft fine-grained granular limestone. Fore-reef type of deposition.
			Cook Mountain	McBean/Santee		The McBean formation consists of fine- to medium-grained massive green-yellow and red quartz sand, green glauconitic marl, silicified beds of coquina, and clayey sand interbedded with red, brown, ochre, and yellow clay laminae. Littoral to neritic environment gradational with some estuarine or continental. The Santee limestone is a nearly pure white to creamy yellow fossiliferous and partly glauconitic limestone containing numerous Bryozoa. Fore-reef type of depositional environment.
			Zilpha clay Winona	Warley Hill marl		Fine green to yellow glauconitic sand overlain by yellow to reddish-yellow sandy clay.
			Tallahatta	Congaree		Well to poorly sorted sand, fuller's earth, brittle siltstone, and light-gray to green shale alternating with thin bedded fine-grained siltstone.
		Wilcox	Hatchetigbee to Nanafalia	Black Mingo	Aquia	Partly indurated fine white to yellow sand and sugary sandstone or bioclastic limestone. Cement is white and calcareous to siliceous. Underlain by gay to black laminated shales containing numerous macro-shells in some areas.
	Paleocene		Wills Point Kinkaid	? Unnamed - may be in part Black Mingo Peedee	Brightseat	Black to gray laminated clay interbedded with fine white sand and in some areas containing many shells.
Cretaceous	Upper Cretaceous	Navarro	Kemp clay to Naylandville marl		Monmouth	Dark-green to gray micaceous, glauconitic, argillaceous sand interbedded with impure limestone and massive dark clays. Deposited under open marine conditions -- probably at depths of not less than 100 fathoms.
		Taylor	Taylor group	Black Creek / Snow Hill Marl Member	Matawan group	Light-gray and dark clays interbedded with greensand and marine clay. Transition zone between the deeper marine Peedee formation and the more shallow marine Black Creek deposits.
		Austin	Austin	Black Creek / Unnamed member	Magothy	Dark-gray to black laminated lignitic clays interbedded with white to gray phosphatic, glauconitic sand. Deposited in shallow marine, estuarine, and paludal environment.
			Eagle Ford shale	Eagle Ford shale[1] ?	?	Gray, buff, and red arkosic crossbedded sand and gravel, interbedded with lenses of white and purple clay and kaolin. Mixed continental and marine environment characterized by fluvial, deltaic, and littoral deposits.
		Woodbine	Woodbine sand	Tuscaloosa	Raritan	

[1] Recognized only in the subsurface.

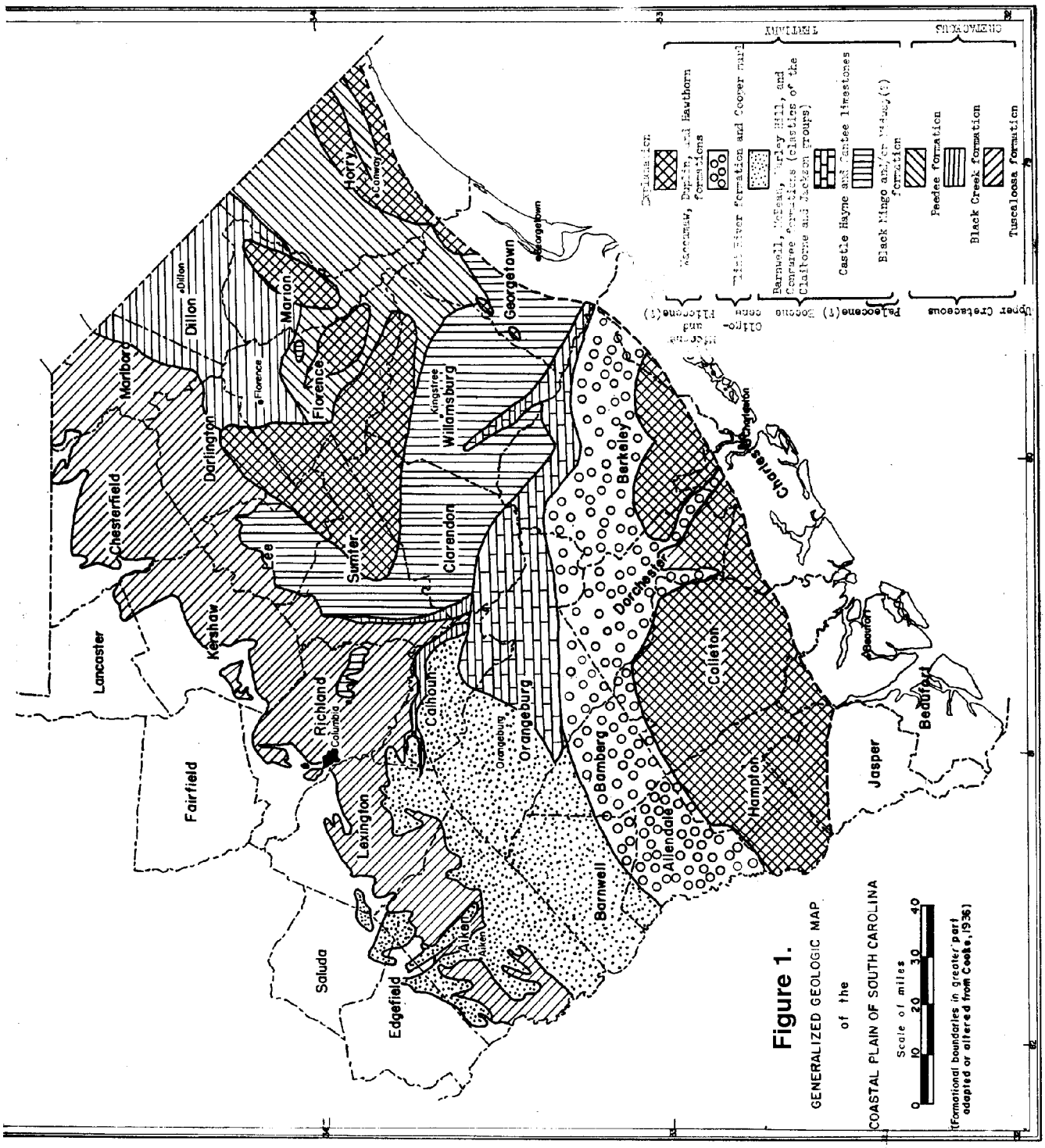


Figure 1.
GENERALIZED GEOLOGIC MAP
of the
COASTAL PLAIN OF SOUTH CAROLINA
Scale of miles
0 10 20 30 40
(Formational boundaries in greater part adapted or altered from Cooke, 1936)
Explanation
Upper Cretaceous
Tuscaloosa formation
Black Creek formation
Peedee formation
Paleocene(?) and Eocene(?)
Black Mingo and/or Williamsburg(?) formation
Castle Hayne and Santee limestones
Barnwell, McBean, Irley Hill, and Congaree formations (clastics of the Claiborne and Jackson groups)
Tallahatta formation and Cooper marl
Oligocene
Miocene and Pliocene(?)
Duplin, and Hawthorn formations
Horry
Marion
Dillon
Marlboro
Chesterfield
Darlington
Florence
Lancaster
Kershaw
Lee
Sumter
Clarendon
Williamsburg
Georgetown
Berkeley
Charleston
Dorchester
Colleton
Beaufort
Jasper
Hampton
Allendale
Bamberg
Barnwell
Orangeburg
Calhoun
Richland
Lexington
Fairfield
Saluda
Edgefield
Aiken

into Georgia by Spencer (1890). In 1936, Cooke correlated Sloan's Hamburg and Middendorf beds (1904, 1908) of South Carolina with the Tuscaloosa of Georgia. From the Middendorf locality in Chesterfield County, Berry (1914) lists 41 plant species, 23 of which occur in the Raritan and Magothy formations of New Jersey and Maryland and the Tuscaloosa formation of Alabama.

On the basis of re-analysis of the flora at Middendorf, Dorf (1952) placed 25 species in common with the Black Creek of North Carolina; 26 with the Tuscaloosa of Alabama; 24 with Magothy of Virginia; 14 with the Eutaw of Alabama, and 4 with the Woodbine formation of Texas. He concluded that the plant-bearing beds of the Middendorf locality were age equivalents to the plant-bearing lower part of the undifferentiated Black Creek formation of North Carolina.

The Tuscaloosa formation in South Carolina consists typically of light-gray, white, or buff-colored arkosic sand and grave interbedded with white, pink, brown, or purple clay. The formation is broken by many local unconformities. Voidal iron-oxide concretions, festoon crossbedding, and graded bedding are characteristic structural features. The Tuscaloosa crops out in a belt gradually widening from 10 to 40 miles, extending in a northeasterly direction from Aiken County to Marlboro County. In updip areas the top of the formation dips 15 to 20 feet per mile, although across the full length of the Coastal Plain the degree of dip increases to approximately 30 feet per mile. The thickness ranges from a featheredge at the Fall Line to more than 800 feet in the south coastal area. In its outcrop area, the Tuscaloosa contains lenticular deposits of kaolin, which, in some localities, are commercially minable--- principally in Aiken County.

Except for the occurrence noted by Siple, Brown, and LeGrand (1956) in an outcrop of questionable Tuscaloosa age near Cheraw, Chesterfield County, there has been no recorded faunal evidence in the outcropping beds of the Tuscaloosa in the Atlantic Coastal Plain. Mrs. E.R. Applin (personal communication) reports that fauna similar to that reported at Cheraw were found in the USGS Boykin no.2, a borehole drilled through the Tuscaloosa formation near its outcrop area in western Alabama.

The authenticity of the use of the name Tuscaloosa has been open to some question in this area. Berry (1914) considered the beds in the Middendorf area as an arkosic member of the Black Creek formation. Eargle (1955) considers that the Tuscaloosa thins out to 30 feet or less as it crosses Georgia in the northeastern direction, and that most of the deposits in east Georgia mapped as Tuscaloosa represent beds of Selma age. Considered to be mostly nonmarine, the formation does evidence facies changes both along the strike and down the dip. Thus, it is possible that the sand and clay identified as the Tuscaloosa formation in Kershaw and Chesterfield Counties become the marine or near-marine deposits of the Black Creek formation downdip. Similarly, the sand and clay of Aiken and lower Lexington Counties have a marked lithologic resemblance to the post-Tuscaloosa beds of southwestern Georgia. However, until more substantial evidence is obtained and a more suitable name applied, the name Tuscaloosa is herewith used in reference to typical lithology in this State.

The Tuscaloosa formation is one of the most permeable units in the stratigraphic column and provides large yields (up to 2,000 gallons per minute) to individual wells. The chemical quality of the water moving through the formation is very good for most purposes.

Black Creek Formation

The name "Black Creek shale" was used by Sloan (1907) to describe beds exposed along Black Creek in Florence and Darlington Counties and at various points along the Pee Dee River

The formation consists principally of very dark gray to black laminated clay and white to tan micaceous sand. The sands are to some degree phosphatic and glauconitic and the entire formation contains a considerable amount of carbonaceous material which includes nodules of pyrite and marcasite.

The Black Creek crops out in an arcuate belt extending from the central to the northeastern part of the Coastal Plain, from Lexington County on the southwest to Dillon County on the northeast. The formation has an average dip of about 23 feet per mile to the south-southeast. Its thickness in wells near the coast approximates 600 feet.

The upper part of the Black Creek formation, containing a prolific and characteristic marine macrofauna, was designated the Snow Hill member by Stephenson (1923).

The lower part of the Black Creek formation, in contrast to the Snow Hill, is only sparsely fossiliferous. Stephenson identified only three molluscan species from the basal beds of the Black Creek, whereas he described 140 species fro the Snow Hill marl member. In the area considered the type locality, eastern Darlington County, the only fossil remains consist of plant species, 15 of which are listed by Berry (1914).

The Snow Hill marl member compromises the upper part of the *Exogyra ponderosa* zone of the Atlantic and Gulf Coastal Plains, as indicated by Stephenson (1923). It is considered correlative with beds of Taylor age in this area. The lower part of the Black creek is thus correlative with the early Taylor to late Austin (Eutaw?). From a depth of 1800 feet in a well on Sullivan's Island, Stephenson (personal communication) obtained a specimen he identified as *Ostrea elegantula* Newberry. This species has a very narrow vertical range, restricted to the lower Blufftown in Alabama. This would indicate that the Austin occurs at a depth of 1800 feet or less at Charleston, and lends additional credence to the possibility that outcropping beds of Eutaw age occur in the Pee Dee River valley. (See description of Mars Bluff local-

ity.)

Peedee Formation

The youngest and uppermost Cretaceous unit in South Carolina is the Peedee formation. It was first described by Ruffin (1843) when he applied the name "Peedee bed." Later, Sloan (1908) used the term "Burches Ferry phase" when describing the formation but also used the name "Pee Dee phase" to deposits of Miocene age.

The Peedee formation consists of greenish-gray glauconitic sand interbedded with sandy marl and thick black clays. Outcrop areas are restricted to those along streams and the Intercoastal Canal. In interstream areas the younger strata of Tertiary or Pleistocene age form a concealing cover. Florence, Horry, Georgetown, and Williamsburg Counties contain almost all the known outcrop areas, the best of which are along the Pee Dee River between Burches Ferry and Yauhannah Ferry. Additional outcrop areas are located on Jeffreys Creek, the Lynches River, Black Mingo Creek, the Black River, the Waccamaw River, and the Intercoastal Canal. Owing to the structural influence of the Great Carolina arch, the Peedee formation has a gentle slope to the southeast in the area near the North Carolina- South Carolina State line but dips to the south in the lower parts of the South Carolina coastal areas. The latter might be due in part to other structural features, such as a basin in the area of the Savannah River or the Santee River.

The most conspicuous Upper Cretaceous fossil is *Exogyra costata*, present in the upper beds. The characteristic species, *Exogyra cancellata*, present in the basal beds of the formation in North Carolina is reportedly missing in South Carolina.

The sandy parts of Peedee formation are utilized as major aquifers over a large part of the Coastal Plain, principally north and east of the Santee River. The permeability of these sands in not very high, and as a result, the water levels have been lowered substantially in local areas of heavy pumping. The water is generally of good quality, although it is high in fluoride in the coastal areas.

Tertiary System

Paleocene (?) Series, Midway (?) Formation

Eocene Series, Wilcox (?) Group, Black Mingo Formation

The basal formation of the Tertiary system recognized in South Carolina is the Black Mingo formation of the Wilcox group, equivalent to the Aquia formation of the Middle Atlantic States and the Tuscahoma and Nanafalia formations of the Gulf Coast. Sloan (1908) adopted the name "Black Mingo shales" after Black Mingo Creek to describe the laminated sandy shale cropping out between the mouth of the creek and Rhems. Cooke (1936) used the name to apply to all Eocene strata older than the McBean formation. His correlation of the Black Mingo formation with the Wilcox group was based primarily on the presence of *Ostrea arrosis* Aldrich (restricted to the Nanafalia formation in Alabama) and *Turritella mortoni* Conrad, a species abundant in both the Nanafalia and the Tuscahoma of Alabama. However, Bowles (1939, p. 271) later identified one of the latter species as a subspecies, *T. mortoni mediavia* Bowles, which occurs in the Midway group in Alabama.

Cooke and MacNeil (1952, p.21) subsequently indicated that much of what had been mapped by Cooke (1936, pl. 2) as the Black Mingo in Richland, Lee, Sumter, Clarendon, and Williamsburg Counties should be considered as either Congaree or Midway. Lithologically, the basal clays are similar to those of the Midway of the Gulf Coast, and the upper sand member presumably could be either Wilcox or Claiborne in age. The Foraminifera obtained to date from outcrop areas of the Black Mingo have not indicated decisively whether the material is Wilcox or Midway. Localities included below contained species identified by S.M. Herrick as *Anomalina umbonifera* (Schwager), which could be of either age although Herrick thinks it is more probably Wilcox. Foraminifera of Paleocene age have been identified in the subsurface in wells to the south and east of the outcrop area. Thus, definite separation of the formation is not feasible at the present time but the evidence appears to indicate that it contains deposits of at least two ages (Midway and Wilcox) and probably three (Midway, Wilcox, and Claiborne). There is also some indication that beds in the west-central part of the Coastal Plain, previously mapped as Black Mingo, actually represent the Black Creek formation of Early Cretaceous age. MacNeil (1952, p. 21) regards the reverse to be applicable in eastern Sumter County--- that is, that the beds mapped by Cooke as Black Creek represent Black Mingo.

The lack of a definite age classification of the dark shales included in this group makes it considerably difficult to identify or contour the top of the Upper Cretaceous beds from well cuttings, owing to the similarity in lithology between the basal Tertiary clays and the Upper Cretaceous clays.

Claiborne Group

Congaree Formation

The name Congaree was first used by Sloan (1908, p. 455) as his Congaree phase, which included the shale, sand, and buhrstone underlying the Warley Hill phase and overlying the Black Mingo phase. Exposures along the western scarp of the Congaree River were regarded as typical. In Georgia, Veatch and Stephenson (1911, pp. 238, 267) described the Congaree clay as the basal member of the McBean formation, the oldest Claiborne unit recognized at that time. Cooke and Shearer (1918) reduced the Congaree to the rank of member and transferred it to the Barnwell formation, of Jackson age. That part of the Congaree containing

thin- bedded or laminated sand and clay was later restored by Cooke (1943, p. 61) to the McBean formation. Cooke (1936, p. 42) indicated that fossils obtained from Sloan's Congaree phase in South Carolina showed it to be in part the Black Mingo formation (of Wilcox age) and in part the McBean formation (of Claiborne age).

The Congaree was raised to formational rank by Cooke and MacNeil (1952, p. 22) and indicated to be equivalent to the Tallahatta formation of Alabama, Georgia, and Mississippi. A new type locality was described as the outcrop on State Highway 33, half a mile east of Creston, Calhoun County. The unit consists of well- to poorly sorted sand, fuller's earth, brittle siltstone, and light-gray to green shale, alternating with thin-bedded fine-grained sandstone. The unit contains two guide fossils, *Anadontia*? *augustana* Gardner and *Ostrea johnsoni* Aldrich.

Other exposures of the Congaree formation have been reported at Salley (Cooke, 1936, p. 59) and 2 miles south of Gaston (Sloan, 1908, p. 344). As a result of surface mapping in Aiken County, the writer discovered another occurrence of what he considers the Congaree formation at Upper Three Runs, approximately 2.5 miles south of State Highway 781. Scattered outliers of the Congaree formation were buried by younger rocks, and subsequent erosion has converted them into inliers on the present topographic surface. The Congaree formation is not considered an important aquifer because of its limited areal extent, low permeability, and thinness.

Warley Hill Formation

The Warley Hill formation was first described by Sloan (1908, p. 458) and was considered by Cooke (1936, p. 55) to be equivalent, in part, to the McBean formation. Cooke and MacNeil (1952, p. 23) restricted the unit to include the dominantly glauconitic beds that intervene between the Congaree formation and the *Ostrea sellaformis* zone, or restricted McBean formation. The type locality was selected as the exposure on an abandoned road west of State Highway 267 and south of Warley Creek, 3 miles north-northwest of Lone Star in Calhoun County. Here the section consists of a lower bed of fine green to yellow glauconitic sand containing *Venericardia* sp. and other fossils and overlain by a yellow sandy clay grading into reddish-yellow massive argillaceous sand containing many small grains of glauconite.

Sloan described occurrences of the Warley Hill marl at Cave Hall and Poplar Creek in Calhoun County. At Cave Hall he obtained specimens of *Ostrea lisbonensis* Harris, a characteristic fossil of the lower part of the Winona formation of Mississippi. The marl at both localities was overlain by the Santee limestone.

As defined by Cooke and MacNeil (1952, p.23), the Warley Hill formation occurs at only three localities. With such a limited areal extent it may be questionable whether such a unit should have been designated a formation. However, additional occurrences have been recognized in the surface and subsurface of the area southwest of the Congaree River. The writer recently found species of *Ostrea lisbonensis* Harris and *Ostrea smithvillensis* Harris in the central part of Williamsburg County. This would apparently extend the formation to that area also. When a more complete description of these occurrences has been made, possibly the formational rank will appear more justifiable.

The formation has only minor significance as an aquifer for the same reasons as pertain to the Congaree formation.

McBean Formation

The McBean formation was named originally by Veatch and Stephenson (1911, p. 237) for its occurrence near the town of McBean, Ga., and from McBean Creek, a tributary of the Savannah River. Subsequently, the use of the name in Georgia was restricted (Cooke and Shearer, 1918) to the deposits of Claiborne age in the Savannah River basin. In South Carolina Cooke (1936, p. 55) included part of Tuomey's (1848) Buhrstone formation and Sloan's (1908) Warley Hill marl within the McBean formation. Cooke and MacNeil (1952, p.24) used the name in a restricted sense to represent only the Cook Mountain equivalent, the *Ostrea sellaformis* zone of the Lisbon formation.

The formation in South Carolina consists of fine- to medium-grained massive greenish-yellow and red quartz sand, green glauconitic marl, and clayey sand interbedded with red, brown, ochre, and yellow clay laminae. The massive sand contains local aggregations of silicified shells, many of which are contemporaneous with similar fossils in the Lisbon and Cook Mountain formations of Mississippi. Local lenses of siltstone or sandstone contain the index pelecypod *Pteropsis lapidosa* Conrad.

Santee Limestone

The Santee limestone is a nearly pure white to creamy yellow, fossiliferous and partly glauconitic limestone containing numerous Bryozoa. Because the white limestone of the Santee formation was so unlike other known Eocene deposits, early investigators considered it Upper Cretaceous in age. However, after Charles Lyell (1845) examined the rocks in 1842, he described them as belonging in the Eocene. Sloan (1908) used the name "Santee marl" in a restricted sense and introduced the name "Mount Hope marl" for the typical exposures of the Santee marl described by earlier investigators. Cooke (1936) originally placed the Santee, along with the Cooper marl, in the Jackson group of the Eocene series, but later Cooke and MacNeil (1952) decided that the Santee was equivalent to the Cooke Mountain formation (upper middle Claiborne) on the basis of the included *Ostrea sellaformis* Conrad and *Chlamys wautubbeana* (Dall), species restricted elsewhere to the middle Claiborne. It thus represents an offshore facies of the restricted McBean formation.

The most fossiliferous natural exposures of the Santee formation occur along or near the Santee River. The type

exposure is usually considered to be that at Eutaw Springs in Orangeburg County, 3 ½ miles east-northeast of Eutawville. A good collecting site may be found on the spoil bank of the New Santee-Cooper Diversion Canal near Eadytown.

The Santee limestone is a moderately good aquifer, providing sufficient amounts of water for domestic use and some industrial use. The water is hard.

Castle Hayne Limestone

The Castle Hayne limestone was named by Miller (1910, 1912) from the town in New Hanover County, N.C. Referred to the upper Eocene by Miller, it was correlated with the Jackson group by Kellum (1926) and Richards (1950). Canu and Bassler (1920) specified the age of a large fauna of Bryozoa from the Wilmington area as "middle Jacksonian."

Because many of the species used by Kellum to correlate the Castle Hayne with the Jackson group were later found to have a greater stratigraphic range and because some species such as *Crassatella alta* Conrad are confined to the Gosport sand, Cooke and MacNeil (1952, p. 25) restricted the Castle Hayne to the late Claiborne, equivalent to the Gosport sand of Alabama.

In South Carolina surficial exposures of the Castle Hayne were recognized by Cooke and MacNeil (1952) only in artificial excavations such as the quarry of the Carolina Cement & Lime Co., 2 miles north of Harleyville, Dorchester County. At this locality, Cooke and MacNeil measured a 46-foot section of the formation at the bottom of the pit, where it consisted of a buff-gray tough to hard, crumbly fossiliferous limestone overlying a gray soft fine-grained granular limestone. The presence of the ostracod *Haplocytheridea montgomeryensis* (Howe and Chambers) at the surface near Santee Falls might indicate that this limestone is also Castle Hayne.

The full extent of the formation and its downdip extension are as yet undetermined. Recent studies by the writer in Beaufort and Jasper Counties appear to confirm the presence of the unit along the coast at comparatively shallow depths.

The evaluation of the Castle Hayne as an aquifer will depend on the extent to which some of the limestones, formerly called the Cooper marl, may now be classified as Gosport in age. Some of the Foraminifera in the lower Jacks or Ocala unit in southern Beaufort County are closely similar to species of Gosport age found in adjacent wells to the north. The inferences are that much of what was formerly considered Santee limestone or Cooper marl, may actually be the Castle Hayne limestone.

Jackson Group

Barnwell Formation

The name Barnwell was affixed by Sloan (1908, p. 454) to the lower unit of his "Buhrston" in western South Carolina, characteristically developed in Barnwell County. Cooke (1936, p. 89) considered part of Sloan's "Barnwell phase" to be Claiborne in age but defined the Barnwell formation as "an Eocene formation composed chiefly of sand that overlies unconformably the McBean formation." He considered it a shoreward facies of the Santee limestone and Cooper marl, in the Jackson group. Cooke and MacNeil (1952) revised the dating of the Santee and the Cooper and considered some beds mapped as Barnwell to be either middle Claiborne or middle Miocene in age. Thus they regarded only a small part of the supposed Barnwell to be representative of the Jackson in the outcrop areas, but considered it possible that the Ocala limestone was present under cover as the offshore representative of the Barnwell formation.

In South Carolina the Barnwell consists typically of fine to coarse red massive sandy clay and clayey sand. Mottled gray or greenish-gray sandy clay also is present in lesser amounts. The characteristic color is a deep red and sandy clay is exposed in vertical cliffs similar to loess deposits. Ferruginous sandstone layers 1 inch to 3 feet in thickness occur locally. The appearance and lithology of the Barnwell formation suggest that it represents a residuum of sandy limestone strata from which most, if not all, the calcareous material has been removed by solution.

In Aiken and Lexington Counties (Siple, 1957, p. 30) the Barnwell has overlapped or transgressed northwestward over the rocks of Claiborne age, the Tuscaloosa formation, and the crystalline rocks of the Piedmont. The thickness of the formation is about 10 feet in the extreme northern part of Aiken County and increases downdip to about 90 feet in the northern part of Allendale County.

Fossils are rare in the Barnwell formation, although some cherty layers have yielded fragments of Mollusca and Bryozoa. At Shell Bluff in Burke County, Ga., a 30-foot shell bed containing *Ostrea gigantissima* Finch crops out along the west side of the Savannah River. This reportedly forms the basal unit of the Jackson group. Quantities of the same species were recovered in n excavation 2 miles southeast of Ellenton in Barnwell County, S.C., and additional specimens were obtained from the east bank of Lower Three Runs Creek in the Allendale quadrangle.

The Barnwell formation is significant as an aquifer only in that it supplies fairly ample amounts of water for domestic use.

Oligocene Series

Cooper Marl

The first use of the name Cooper has been attributed to several investigators, but Stephenson (1914) used the name to describe a foraminiferal marl outcropping in the vicinity of Charleston, to which he referred as "either uppermost Eocene or Oligocene." Cooke (1936, p. 82) applied the name Cooper marl to exposures along the Cooper River, Goose Creek, the Ashley River, and the Edisto River and considered the unit as late Eocene in age.

On the basis of the macrofossil *Chlamys cocoana* (Dall) and the microfossil *Bolivinella rugosa* Howe, both considered Red Bluff (early Oligocene) fossils, Cooke and MacNeil (1952, p. 27) placed the Cooper marl back in the Oligocene series.

The Cooper marl is a finely granular olive-drab to brownish marl containing glauconite and Foraminifera and characterized by phosphatic nodules in the lower part. Generally not very great, the maximum thickness is thought to be less than 200 feet.

The formation has only minor significance as an aquifer in South Carolina, and in fact is more important in its capacity as an aquiclude (confining bed).

Flint River Formation

The Flint River formation of late Oligocene age was described by Cooke (1936, p. 98) as being typically developed along the Flint River near Bainbridge, Ga., whence it extends northeastward across Georgia into South Carolina where it occurs only in a narrow strip bordering the Savannah River in Allendale County. Scanty exposures consist of yellow vitreous chert in reddish-yellow sand. The chert has very few fossils, most of which are unrecognizable.

The unit has very little significance as an aquifer.

Miocene Series

Tampa (?) Limestone

The first use of the name "Tampa formation" is credited to L.C. Johnson (1888, p. 235). Used subsequently as a group and later restricted to a limestone formation in the vicinity of Tampa, Fla., Vernon (1942) revised the original term, Tampa formation, to include "all sediments lying above the Suwanee limestone and below the Alum Bluff group." Later, Vernon, Puri, and Calver (1956, p.13) divided the Miocene series into three time-rock units, the oldest of which was the Tampa stage. Downdip the Tampa consists of sand, silt, marl, limestone, and fuller's earth. The type area is near Tampa Bay.

Cooke (1943, p. 87) describes the Tampa in the outcrop area of Georgia, and Herrick (in Herrick and Wait, 1955, p. 7) tentatively identifies as Tampa the dense sandy and coarsely phosphatic material at depths of 110 to 140 feet in the Savannah area. The writer likewise has made a tentative correlation, mostly on the basis of lithology, of analogous subsurface sections in the adjacent area of Jasper and Beaufort counties, S.C. Herrick (1955) found poorly preserved Foraminifera belonging to the genera *Textularia, Quinqueloculina,* and *Discorbis* in a test well on Hilton Head Island, Beaufort County, S.C., and considered the fossils representative of early Miocene or Tampa age.

That the formation has been recognized only in the subsurface and is not very thick in the areas where it has been recognized limits its importance as an aquifer in South Carolina.

Hawthorn formation

The name Hawthorn was taken from the town of Hawthorn in Alachua County, Fla. (Dall, 1892). In South Carolina, Cooke (1936, p. 101) included the Combahee shale, the Parachucla marl, the Parachucla shale and marl part of the Ashley marl, the Edisto marl, and the Salkehatchie phase of Sloan (1908) within the Hawthorn formation.

The Hawthorn is characterized by sandy phosphatic marl or soft limestone and hard brittle shale resembling silicified fuller's earth. Formerly recognized only in the lower part of the Coastal Plain, it has subsequently been extended (Siple, 1957, p.33) to cover the high interstream areas of the inner Coastal Plain. In its updip facies the unit exhibits a characteristic mottling of deep purple, pink, and gray in the sandy clays and gravels. Small white flecks of kaolinitic material are commonly disseminated in the clayey sands, giving them a milky appearance. From a featheredge in the updip areas the formation thickens coastward apparently reaching a maximum in Hampton County, and then thins toward the coast where it has been completely eroded away in places.

The Hawthorn formation is not considered to be very fossiliferous. The most common species that have been collected in areas along the Savannah River include *Ostrea normalis* Dall, *Pecten acanikos* Gardner, *Carolia foridana* Dall, and *Mytilus conradinus* d'Orbigny. These species and others collected from the same area are considered Chipola (middle Miocene) in age.

The Hawthorn, because of its low permeability, does not rate as an important aquifer in South Carolina, although it does provide sufficient water for domestic and limited industrial use.

Cooke (1936, p.115) used the name "Raysor marl" for deposits of Miocene age alder than the Duplin and equivalent to the middle part of the Yorktown formation of Virginia and North Carolina. However, these beds were very thin (3 ½ feet) and occurred at only one small exposure near Raysor Bridge on the Edisto River. The name was later abandoned and the unit transferred to the Dublin formation by Cooke (1945, p. 182).

Duplin Formation

The Duplin formation is the youngest deposit of Miocene age in South Carolina. The use of the name "Duplin" apparently originated with Dall (1896, p. 40), who referred to a fossil from the Duplin formation exposed in Natural Well, 2 miles southwest of Magnolia in Duplin County, N.C. He later correlated the beds with the late Miocene. The Duplin in South Carolina is considered to be equivalent to the upper Yorktown of Virginia and the *Cancellaria* biofacies within the Choctawhatchee stage of Florida. A remnant of the lower *Ecphora* facies (equivalent to lower Yorktown) may be represented by the unit formerly called the Raysor marl, inasmuch as it contains an older

fauna than the Duplin.

The Duplin formation consists of a buff sandy friable shell marl, generally less than 50 feet thick in South Carolina. It occurs as isolated patches of various sizes, the largest of which includes the area between Sumter, Darlington, Hemingway, and Mullins. In the writer's opinion, a large part of the Miocene deposits in the State have not been mapped as such; in other words, both the continental phase (Hawthorn formation) and the marine (Duplin formation) extend more broadly than has been commonly recognized. From both faunal and geomorphic criteria there is fairly definite evidence to indicate that the Duplin formation exists along with or in place of the Waccamaw formation in areas extending from the North Carolina line down to Beaufort County near the Georgia State line.

Because of its limited thickness and permeability, the Duplin formation is not a major aquifer in this State. It is used as a source for domestic use by rural residents in the counties indicated above.

Pliocene Series

Waccamaw Formation

From the name "Waccamaw beds," adopted by Dall (1892), the name "Waccamaw formation" has come into general use in describing the marine Pliocene deposits of North and South Carolina. The formation consists of blue-gray to yellow and brown sandy shell marl. Its distribution throughout the State is not well known but from recognized occurrences it is thought to extend in a belt parallel to the coast from the North Carolina boundary through Horry County and part of Georgetown County. Its total thickness does not exceed 35 feet. Smaller areas have been recognized in Berkeley County near the Cooper River and Goose Creek and in parts of Charleston County. Characteristic Pliocene mollusks include *Pecten ernestsmithi* Tucker, *Pecten eboreaus senescens* Dall, *Scaphella floridana* (Heilprin), and *Encope macrophora* (Ravenel).

Cooke noted that the fossil assemblage collected from the exposure of this bed on the southeast side of Goose Creek, Berkely County, contained species that were either uppermost Miocene or Pliocene but could not be pinned down more conclusively as to age. Mainly on the basis of *Encope macrophora*, the unit was tentatively referred to the Pliocene. Thus, although the exact age of the Waccamaw could be either latest Miocene or Pliocene, it is herewith included in the Pliocene until more conclusive evidence is found to the contrary. The presence of unconformable contacts with underlying and overlying units in this State and in other coastal States, plus the presence of restricted Pliocene macrofossils, are regarded as supporting criteria for a Pliocene age. However, the writer identified specimens of *Andara lienosa* (Say) Mansfield from the formation in northern Horry County. Mansfield reported this species from the Choctawhatchee stage (upper Miocene) of Florida, whereas in North and South Carolina it has been described from both Miocene and Pliocene formations.

From the Bears Bluff locality in Horry County, S.M. Herrick (personal communication) identified the following Foraminifera and classified them as probably upper Miocene:

Cibicides cf. C. *americanus* (Cushman)
Cancris sagr D'Orbigny
Cibicides pseudoungerianus (Cushman)
Cibicides concentricus (Cushman)
Cibicides lobatulus (Walker and Jacob)
Nonion advenum (Cushman)
Nonion grateloupi D'Orbigny
Discorbis vilardeboana D'Orbigny
Textularia cf. *T. gramen* D'Orbigny
Cibicides americanus (Cushman)
Textularia candeiana D'Orbigny
Asterigerina miocenica Cushman and Ponton

Contemporaneous with marine deposits was accumulation of various continental deposits on the land. These include fulfill and deltaic deposits of sand and gravel referred to on the Gulf Coast as the Citronelle formation. Equivalent beds in South Carolina have not been mapped as Citronelle but have been so regarded by several geologists. Many of the so-called "high-level gravels" are in this category; heavy concentrations are noted in the basins of the Pee Dee, Wateree, and Savannah Rivers.

Pleistocene Series

Cooke (1936, p. 130) originally identified with seven separate marine terraces which, with their respective shoreline altitudes, were the Brandywine, 270 feet; Coharie, 215 feet; Sunderland, 170 feet; Wicomico, 100 feet; Penholoway, 70 feet; Talbot, 42 feet; and Pamlico 25 feet. This terrace chronology designates the highest as the oldest and the lowest as the youngest. It presumes the terraces to have been formed as a result of a series of sea-level oscillations during glacial and interglacial stages, the terrace being formed during the interglacial stage. Flint (1940) questioned the marine origin of the higher terraces but agreed that the lower scarps and terraces along the Atlantic seaboard from southern Virginia to Florida were of marine origin. Flint identified seaward-facing scarps for the recognition of marine shores and mapped remnants from the James River in Virginia to lower South Carolina. He recognized two such scarps in this area: the Suffolk scarp, have a toe at an altitude of 20 to 30 feet, and the Surry scarp, having a toe at an altitude of 20 to 30 feet, and the Surry scarp, having a toe at 90 to 100 feet. In Georgia and Florida, however, he recognized Trail Ridge at altitudes of 180 to 240 feet as a marine feature. Cooke (1945, p. 248) added the possibility of an eighth terrace, the Silver Bluff (?), at an altitude of 5 feet. MacNeil (1950, p.96) cor-

roborated the existence of this terrace along with the 25-foot, 70-foot, and 100-foot, but considered the 42-foot terrace to be obscure in Georgia and Florida. The highest recognizable marine shoreline according to MacNeil was the Okefenokee (questionably equivalent to the Sunderland) at an altitude of 150 feet. Subsequently, Cooke (1954, p. 203) recognized an Okefenokee shoreline at an altitude of 145 feet and revived the name Hazelhurst to replace Brandywine as the 270-foot terrace.

The Pleistocene formations in South Carolina consist mostly of sand, clay, and gravel. In general, the younger formations contain material less coarse than the older. The colors range from dark blue to gray, pink, yellow, and red. The thickness of each is generally less than 25 feet and not more than 50 feet. A considerable number of macrofossils have been identified from the Pamlico formation but none from older Pleistocene formations, except for the possibility indicated by Richards (1943) that mollusks from the Santee-Cooper area might represent the Penholoway formation of Cooke or be contemporaneous with the formation of the Surry scarp of Flint.

Most observers agree that the data available are inconclusive with respect to the delineation and origin of the higher terraces, and Taber (1954) includes all the post-Pliocene in one blanket Pleistocene deposit which he believes overlapped the present Fall Line and extended into the Piedmont. As is invariably pointed out, much study remains to be done before a complete understanding Pliocene and Pleistocene stratigraphy is reached.

STRUCTURE

Considered en masse, the formations of the Coastal Plain may be classified as having a monoclinal or aclinal structure; they rest on rocks of a much older crystalline complex. The unconsolidated rocks occur as wedges of sand, clay, marl, and limestone which, from a featheredge at the Fall Line, thicken coastward to approximately 10,000 feet in North Carolina and more than 3,500 feet in South Carolina. In general, the strike is northeast-southwest and the dip is to the southeast or south.

Underlying the unconsolidated sediments are "crystalline" rocks consisting of granite, gneiss, schist, and a series of volcanics. Fault troughs or grabens were formed in these pre-Mesozoic rocks during Triassic time, into which were deposited ferruginous and carbonaceous sands and clays. These sediments were subsequently injected by diabase dikes and sills.

Figure 2 shows the configuration of the pre-Cretaceous surface as interpreted from geophysical and well data (water wells and oil tests), together with the data on basement-rock altitudes contained in earlier publications. This contoured surface is essentially the basement surface, except that it includes elevations on top of the buried Triassic rocks, which are "bedrock" so far as the Coastal Plain sediments are concerned.

Three-point calculations of the strike and dip of the basement rock in the western Coastal Plain (Siple, 1957) indicate that the average in the western Coastal Plain (Siple, 1957) indicate that the average strike of the basement rocks in this area is approximately N. 66 E. and the average dip of their surface is 36 feet per mile to the southeast. Similar calculations on basement altitudes in adjacent areas indicate that these figures can be applied generally to the area southwest of the Pee Dee River. Northeast of the Pee Dee, the structure of the Great Carolina ridge (described below) makes a considerable change in the direction of strike and degree of dip.

In adjoining States the structure of the buried basement rocks has been described in several reports, the latest of which includes those of Eargle (1955) in Georgia and Spangler (1950 and Berry 1948) in North Carolina. In Georgia, Eargle determined that the strike of the basement rocks swings gradually form N. 77 E. in the western part to N. 55 E. in the eastern part. He gives a dip of 55 to 60 feet per mile in the Chattahoochee River region and 70 to 80 feet per mile in the central region, the dips being more gentle dips farther to the east. In North Carolina, Spangler (1950, p. 132) determined the average slope of the crystalline floor to the 2,500-foot subsea contour to be 35 feet per mile, but from the 2,500- to the 5,500-foot contour the dip increased to more than 100 feet per mile. Berry (1948) reported the steeper slope to be from 122 to 124 feet per mile. Spangler's basement map shows the steep slope (about 117 feet per mile) between the 2,500 and 5,500 subsea contour, followed by a gentler slope (about 99 feet per mile) between the 5,500- and 10,000-foot subsea contours. At the North Carolina-South Carolina line the dip of the basement surface is indicated as about 14 feet per mile. Richards' map (1945, p. 952) shows basement dip of approximately 16 feet per mile in the same area and a maximum dip of 38 feet per mile in the southern part of the Coastal Plain.

In the northeastern part of the Coastal Plain the most prominent structural feature is the Great Carolina ridge or Cape Fear arch. This ridge is a broad anticlinal arch whose axis is roughly parallel to the Cape Fear River in North Carolina. Spangler (1950, p. 132) describes it as a wide nose plunging southeast at approximately 15 feet per mile.

On the basis of magnetometer surveys in this area, MacCarthy (1936) obtained supporting evidence of a northwest-southeast structural uplift. Seismic-refraction traverses made by Bonini (1955, p. 1533) confirmed the attitude of the basement ridge, and those of Hersey and others (1955, p. 1573) demonstrated the extension of the Cape Fear arch out under the continental shelf. Offshore reverse seismic-refraction profiles conducted by Meyer (1955, p. 1579) between the 10- and 20- fathom lines off the North Carolina- South Carolina coast included six profiles near the Cape Fear structural

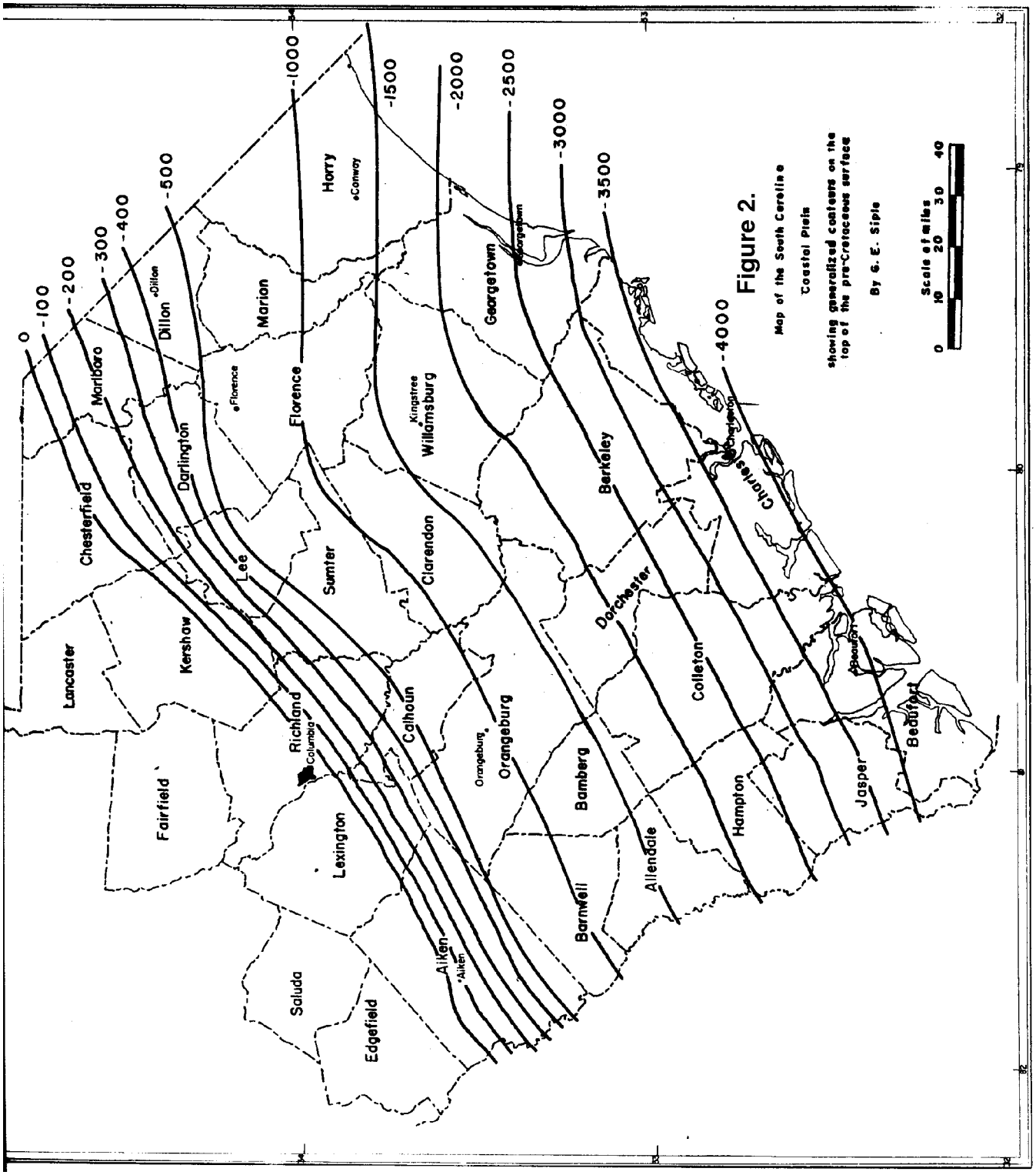


Figure 2.
Map of the South Carolina Coastal Plain
showing generalized contours on the top of the pre-Cretaceous surface
By G. E. Siple
Scale of miles
0 10 20 30 40
0
-100
-200
-300
-400
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
Chesterfield
Marlboro
Dillon
Darlington
Marion
Florence
Harry
Georgetown
Kingstree
Williamsburg
Berkeley
Charleston
Lee
Sumter
Clarendon
Dorchester
Colleton
Beaufort
Jasper
Hampton
Allendale
Barnwell
Aiken
Bamberg
Orangeburg
Calhoun
Richland
Columbia
Lexington
Fairfield
Kershaw
Lancaster
Saluda
Edgefield

axis. This, as Meyer described it, "constitutes a prominent basement ridge rising from about -4,000 feet off of Charleston to –2,000 feet off Cape Fear and falling away to the north to about –10,000 feet at Cape Hatteras. The ridge strikes approximately perpendicular to the general coast line."

The true relationship between structure and stratigraphic sequence in the vicinity of the arch, as indicated by LeGrand (1955), is not a simple one.

Stephenson, in 1912, noted the absence of Lower Cretaceous beds representing the Patuxent formation (equivalent in part to the Tuscaloosa formation), in a deep well in the Wilmington area and inferred that this was an indication of a land barrier of some kind in this region. Later, Stephens (1923, p. 5) offered three hypotheses to explain the absence of the "Lower Cretaceous" beds in the Wilmington area. They were (1) that a land barrier existed in the Wilmington area during Early Cretaceous time, (2) that Lower Cretaceous beds were removed by erosion before the beginning of Upper Cretaceous deposition, and (3) that the formation (Patuxent) thins toward the southeast and pinches out entirely between the underlying basement rocks and the overlying Upper Cretaceous deposits before the coast is reached.

Stephenson considered the basal sedimentary formation, the Patuxent, to be of Early Cretaceous age. This formation was subsequently considered equivalent to the Tuscaloosa formation in the lower part of North Carolina. In South Carolina Cooke (1926) included the Middendorf formation in the Tuscaloosa formation. Stephenson had considered the Middendorf to be equivalent to parts of the Black Creek formation in North Carolina. Thus, to Stephenson, the presence in the subsurface of beds of Middendorf lithology would be indicative of his Upper Cretaceous--- that is his Black Creek formation, whereas in more recent stratigraphic interpretations this lithologic sequence would be considered characteristic of the Tuscaloosa formation.

On the basis of structure, lithology, and possibly paleontology, there is considerable evidence to indicate the presence of buried pre-Taylor to pre-Austin (or Eutaw to Eagle Ford equivalents) on the southern flank of the Carolina Arch. However, there is also the possibility, as indicated by Stephenson, that beds of Tuscaloosa age may pinch out between outcrop areas and the coastal areas or that the deposits considered as Tuscaloosa in the outcrop represent the continental facies of a unit of which the Black Creek formation is the downdip equivalent.

The extent to which the stratigrahic sequence in the vicinity of the arch might have been affected by Triassic beds or terrain has not been determined. In a magnetic reconnaissance of the Coastal Plain, MacCarthy (1936, p. 405) traced a Triassic basin (previously identified only from a well log) northeast and southwest from Florence. As a consequence of recent ground-water studies, the first cored interval of buried Triassic rocks in the South Carolina Coastal Plain was obtained from a test well near Florence. The cored sample was subsequently thin sectioned and examined by Charles Milton, U.S. Geological Survey (written communication, 1955). He identified the rock as an olivine diabase, consisting of fresh diopsidic pyroxene, olivine (somewhat serpentinized), calcic plagioclase, and ilmenite-magnetite. Thus, the presence of Triassic ridges during Late Cretaceous or early Tertiary time could be responsible for the absence of one or more units of the sedimentary section.

The formation of the Cape Fear arch or uplift was accompanied by downwarping on the flanks. Cooke (1936, p. 158) believed that the downwarping occurred during late Eocene time, causing the Jackson sea to transgress beyond the limit of older Eocene and Upper Cretaceous formations and to flood the border of the Piedmont. This was followed by a Miocene transgression which left thin patches of nearly horizontal marine formations, subsequently reduced by erosion to separated remnants.

Other dates suggested for the arch range from Early Cretaceous to the close of early Miocene. Some (Siple, 1947; Eardley, 1951) have suggested that uplift and erosion may have occurred during more than one stage. Sloan (1908, p. 455) postulated a Cretaceous capped ridge, the "Carolinian ridge," extending southeasterly from Florence to Georgetown, which was never extensively submerged until near the close of the Miocene.

Supporting evidence for the existence of a basinal structural on the west side of the arch is found in the contoured pre-Cretaceous surface and such additional criteria as, for example, the discordant dips of the Cretaceous strata in the area extending from the western part of Sumter County to the central or eastern part of the county.

Major irregularities of the basement surface, such as block faulting and resultant fault troughs (other than those of the Triassic), have been suggested as specific structural features in the vicinity of the Cape Fear arch. However, the seismic and well data available at the present time do not corroborate such large-scale features under the South Carolina Coastal Plain.

The existence of medips, or basement rock, similar to that found at the Fountain, N.C., has never been confirmed in South Carolina. Inliers, or "windows," of basement rock have been observed in stream valleys contiguous to the Fall Line, where the basement rock has been exposed owing to the erosion of overlying Coastal Plain sediments.

Structural features of the basement rocks exclusive of the Great Carolina arch include (1) a suggested basinal structure in the vicinity of the Savannah River valley and (2) a basin in the Beaufort area which may not be connected with the Savannah basin.

The dips of the Coastal Plain strata, ranging from 33 feet per mile to less than 10 feet per mile, are slightly greater than the drainage gradient. The dips of beds in the southern half of the Coastal Plain are generally to the southeast, whereas

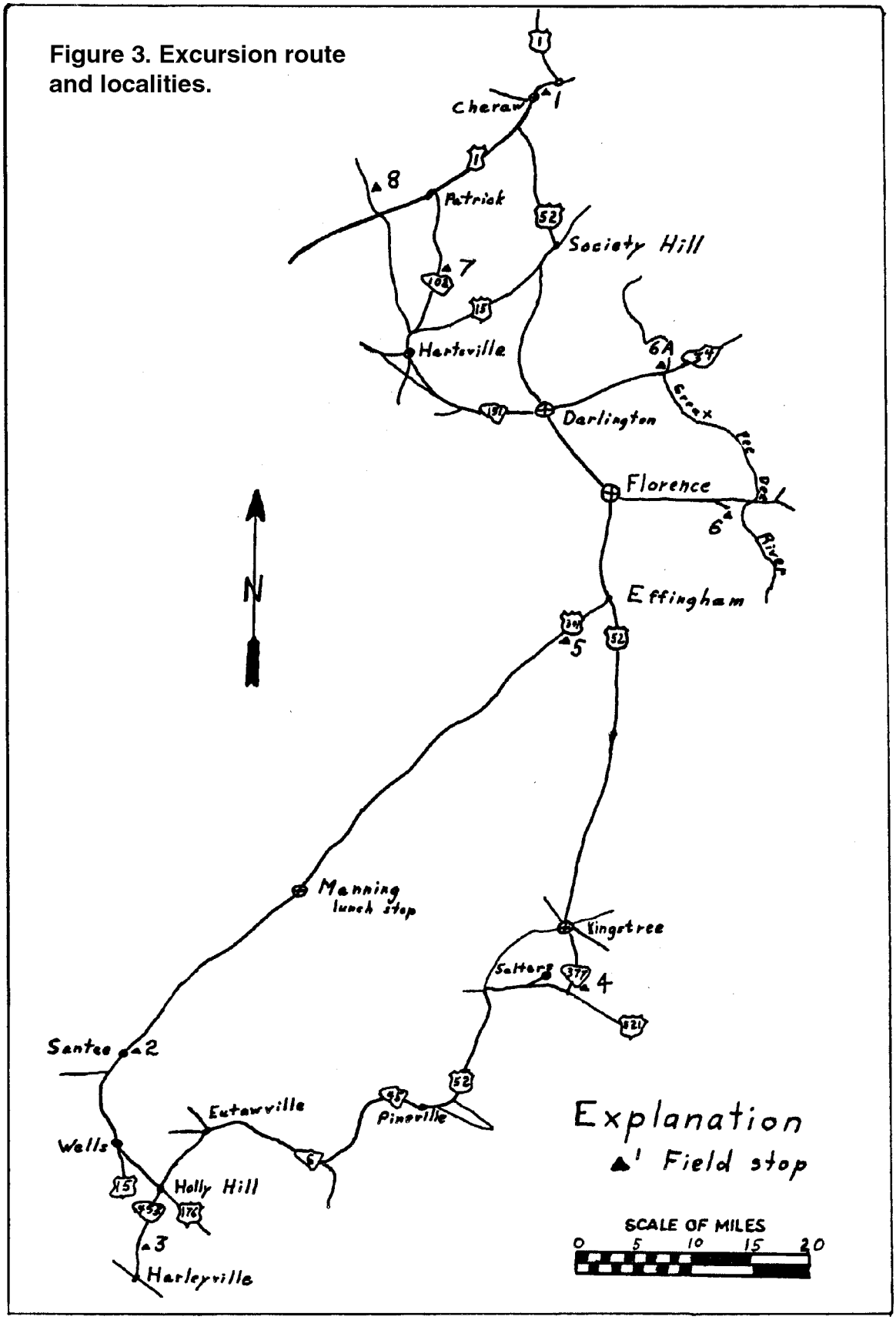


Figure 3. Excursion route and localities.

those in the north or northeastern part dip to the south, or even southwest in the vicinity of the Carolina arch.

Fairly extensive overlap of the Cretaceous beds by the Tertiary sediments is particulary characteristic of the area between the Congaree and Savannah Rivers. There is some indication that Tertiary sediments were once extensively developed in the area between the Congaree and Pee Dee Rivers, but the most of them have been removed b subsequent erosion.

Faulting in the unconsolidated sediments, though not identified specifically or known to extend over large areas, is fairly certain to have taken place in some areas. Neither lateral nor vertical displacement is likely to have been large. Nevertheless, older residents of the State who remember the Charleston earthquake describe such phenomena as sand boiling up through cracks in the surface soil during and after the first shock. Therefore, it is not improbable that many fractures do exist in the sediments and that there has been displacement along some. The fairly common occurrence of clay dikes in certain younger strata might be associated with structural disturbances (Siple, 1954). Apparent lateral discordance of the strata in the Jasper-Beaufort County area may have been caused by faulting.

ROAD LOG

Assembling point: 8:30 a.m. – On U.S. Highway 1, near west end of bridge over the Pee Dee River at Cheraw, S.C. Please have a full tank of gas.

Mileage

0.0 Stop 1. Cheraw, S.C. Proceed southwest on US01 through Cheraw.

2.0 Junction of US-1 and SC-9. Proceed south (left) on US-1.

4.3 Junction of US-1 and US-52. Proceed southeast (left) on US-52.

15.3 Society Hill- Junction of US-52 and US-15. Proceed southwest (right) on US-52

17.3 Junction of US-52 and US-15 on south side of Society Hill. Proceed south (left) on US-52.

31.3 Darlington- Continue on US –52

41.3 Florence- Junction of US- 301 and US- 52. Continue south on US-52 and US- 301 (straight ahead).

48.3 Effingham- Junction of US- 301 and US- 52. Proceed southwest (right) on US- 301.

61.7 Olanta – Continue southwest on US- 301.

85.7 Manning- Lunch stop. Variety of restaurants and lunch stands along US-301. Please reassemble promptly. Reassembling Point: Manning City limit on south side of town – US-301. Continue trip proceeding southwest on US-301.

95.8 Junction of US- 15 and US- 301 in Summerton. Proceed southwest (left) on US- 15.

103.2 Lake Marion.

106.9 **Stop 2.** Southwest end of bridge over Lake Marion. Turn off highway to the right and park cars on old road.

108.9 Junction of US-15 and US-301. Continue south on US-15 (left).

116.9 Wells- Junction of US- 15 and SC- 176. Proceed southwest (left) on SC- 176.

120.9 Holly Hill- Junction of SC-176 and SC-453. Proceed south (right) on SC-453.

127.3 **Stop 3.** Carolina Giant Cement Company. Please reassemble promptly in order to complete the remainder of the trip and arrive back in Florence on time.

133.7 Return to Holly Hill via SC- 453. Continue north on SC- 453 to Eutawville.

140.7 Junction of SC-453 with SC-6 and SC- 45. Turn east (right) on SC- 45.

151.7 Junction of SC-6 and SC- 45. Turn northeast (left) on SC-45 to Pineville.

163.5 Pineville- Junction of SC-45 and SC-6. Take left on SC-6.

166.0 Junction of SC-6 and US-52. Proceed north (left) on US-52.

170.0 Santee River

176.6 Junction of US-52 and US-521. Turn east (right) on US- 521.

183.6 Junction of US- 521 and SC- 377. Turn north (left).

183.9 **Stop 4.** Lower Bridge. Continue north on SC- 377.

190.3 Junction of SC- 377 and SC- 175 in Kingstree. Turn left to junction of SC- 175 and US- 52 in Kingstree. Turn north (right) on US- 52.

228.3 Return to Florence on US- 52 (end of first day's trip).

Sunday – 8:30 a.m.

Assemble on US-52 and US-301 in front of Garden Gate Cafeteria, Florence. Head South.

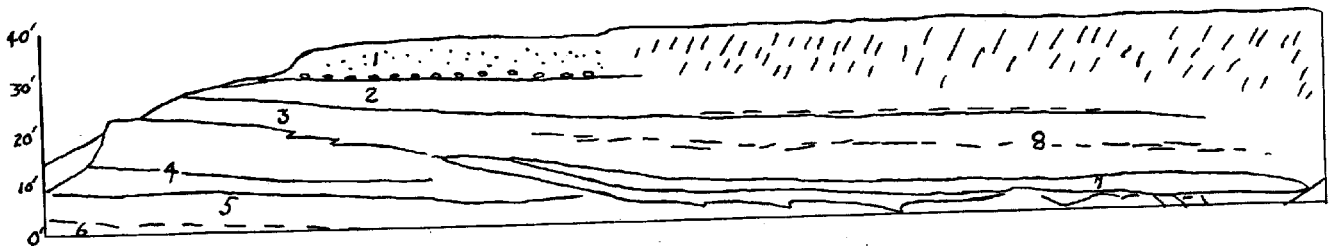
Mileage

0.0 Junction of US- 76 and US-301 and US-52 in Florence. Proceed south.

9.4 Effingham. Turn southwest (right) on US- 301.

11.8 Elim at Sinclair Station- Turn south (left) on unpaved road.

12.1 **Stop 5.** Continue around circle on unpaved road



Stop 1: Sketch of outcrop on east side of Cheraw (after Heron).

back to

12.5Highway 301. Turn right and return to Florence.

24.6Junction of US- 76 with US-301 and 52 in Florence. Turn east (right) on US- 301.

34.1Junction of US- 301 with abandoned road, US- 76. Turn right (southeast).

36.1**Stop 6.** Mars Bluff locality. Return to Florence on US- 301 to

47.6Junction of US-301 and US-52 in Florence. Turn north (right) on US-52. Proceed to

57.6Darlington. Turn left on SC-151.

68.1Junction of SC-151 and Alt- SC- 151. Keep to right on Alt- 151.

72.1Hartsville- Take US-15 north (right).

74.4Junction of US- 15 and SC- 102. Turn north (left) on SC-102.

79.9Note the change in topography from a level plain to a dissected upland of rolling hills, representing the outcrop area of the Tuscaloosa formation.

80.7**Stop 7.** Continue north on SC-102.

87.4Patrick – Junction of US-1 and SC-102. Turn southwest (left) on US-1.

92.5Junction of US-1 and SC-29. Turn north (right) on SC- 29.Signpost reads "Sugar Loaf Mountain."

93.1**Stop 8.** Middendorf locality (McKennon on map).

End of Trip.

DESCRIPTION OF LOCALITIES

Stop 1 – Cheraw, Chesterfield County – Tuscaloosa formation

In a borrow pit on the west side of the flood- plain of the Pee Dee River, approximately 300 feet south of U.S. Highway 1, beds assumed to be of Tuscaloosa age, are exposed between the highway and the Seaboard Air Line Railroad. The locality lies well within the outcrop area of the Tuscaloosa formation as mapped by Cooke (1936) but some of the beds have a striking similarity to those characteristic of the Eutaw or Black Creek formations. Form bed 7 Siple, Brown and LeGrand (1956) collected what may be the first recognized microfauna from outcropping basal Cretaceous strata, east of the Mississippi. The faunal assemblage consisted of depauperate arenaceous forams including: *Eouvigennia* sp., *Pseudovigerina* sp., *Globigerina* sps., *Proteonina* sp., *Pelosina* sp., *Stilostonella* sp., and *Globulina* (?) sp. Although the fauna were not diagnostic, they appeared to be older than foraminifera found by Brown in the subsurface Austin beds of North Carolina. The host bed is a dark- gray carbonaceous clay containing large fragments of lignite and fairly numerous nodules or concretions composed of approximately equal parts of quartz grains and marcasite.

The following abbreviated section is taken fro Duncan Heron (personal communication):

1. Reddish- brown medium sand – "terrace" deposit. Cobble conglomerate at base.
2. Pale orange silty clay – fine sand with strong red mottling.
3. Pale orange coarse to medium sand. Upper portion indurated.
4. Partly mottled pale orange, yellow and red silty fine to very fine sand.
5. Light gray silty, very fine to fine sand.
6. Light gray silty medium sand.
7. Medium light gray silty clay. Upper foot or so bleached to a lighter gray. Lignitic twigs, small branches, leaf fragments, and sand size amber particles scattered throughout. Partings of very coarse sand and granule quartz occur in the clay. Pebble- size feldspar grains occur in some of the partings. Marcasite as coatings and irregular pods occur in association with some of the lignite. The clay fraction is mostly kaolinitic with a small percent of montmorillonite.
8. Pale orange, poorly sorted coarse sand with irregular induration. Similar to bed 4 except that it is coarser.

Stop 2 – Santee – Santee limestone

On the southwest shore of Lake Marion just east of the bridge crossing on highway US – 301, the Santee limestone crops out from the water's edge to approximately 4 feet

above water where it is overlain by 12 to 15 feet of fine to coarse red and tan mottled, crossbedded quartz sand and gravel. Considerable piping and caving effects are noticeable in the overburden in the area 1,000 feet east of the highway. From the locality the writer collected a good specimen of Ostrea sellaformis and several pelecypods. Other shells and shell fragments are present in the semi- indurated limestone. Vugs filled with iron- cemented sand are also found scattered throughout the limestone. The following foraminifera were obtained from this locality: (Identification by S.M. Herrick.)

Cibicides americanus (Cushman)
Cibicides ouchitaensis Howe and Wallace
Siphonia claibornensis Cushman and Thomas

Stop 3 – Quarry of the Carolina Giant Cement Corporation, Harleyville – Cooper marl and Castle Hayne limestone

The quarry of the Carolina Giant Cement Corporation, about 2 miles north of Harleyville, Dorchester County, contains the section given by Cooke and MacNeil (1952, p. 25) as representing the Cooper marl and the Castle Hayne limestone. Their section, described in 1951, was as follows:

Pleistocene	Feet
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
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

From bed 3 the following foraminifera were identified by S.M. Herrick:

Spiroplectammina mississippiensis (Cushman), var. *alabamensis* Cushman
Textularia recta Cushman
Textularia cf. *Hockleyensis* Cushman and Applin
Guttulina irregularis (D'Orbigny)
Globulina gibba D'Orbigny
Marginulina cocoaensis Cushman
Dentalina cocoaensis (Cushman)
Dentalina jacksonensis (Cushman and Applin)
Plectofrondicularia cf. *P. vaughani* Cushman
Bolivina jacksonensis Cushman and Applin
Uvigerina cocoaensis Cushman
Angulogerina cooperensis Cushman
Angulogerina ocalana Cushman
Trifarina bradyi Cushman, var. *Gyroidina sooldanii* D'Orbigny, var *Cibicides lobatulus* (Walker and Jacob)
Cibicides americanus (Cushman)
Planulina cocoaensis Cushman

Stop 4 – Lower Bridge – Black Mingo formation

The following section, described by Cooke (1936, p. 46) as representing the Black Mingo formation, crops out along the south bank of Black River at Lower Bridge, approximately 6.5 miles south of Kingstree at the crossing of State Highway 377:

Penholoway (?) formation (Pleistocene?):	Feet
3. Coarse orange- colored sand with pebbles and broken shells at base; extends downward over bed 2 to bed 1, the overlapping part crossbedded; to top of hill, about	6-20
Unconformity	
Black Mingo formation (Eocene):	
2. Very fine grained thin- bedded gray and red sand, weathering brick- red and yellow; appears to contain a little glauconite	0-13
1. Light- gray to dark slate-colored hard fuller's earth or shale; base concealed. A few loose slabs contain a 3-inch bed of silicified shells (not determinable). To low- water mark in Black River	15

Representative exposures of the Black Mingo formation, containing both type lithology and type fauna, are not easy to find. The typical section is best seen therefore in a combination of localities. The Lower Bridge locality, together with that along the left bank of the Black River at Upper Browns Ferry and at the junction of State Highways 37 and 17 in the northwestern part of Georgetown County, afford fairly good representation of the lithology. Faunal collections may be made along an unpaved county road, 1.1 mile east of Salters where a thin bed of fuller's earth is overlain by a coarse red sand containing the type species *Coelohelia wagneriana* Vaughan, *Haimesistraea conferta* Vaughan, and *Cucullaea transversa* Rogers. Excavations for irrigation ponds in the area between Salters and Kingstree have revealed more specimens of the above fauna and, in

addition, Ostrea arrosis Aldrich, another guide fossil of the Wilcox.

Alternate stop 4 – Irrigation pond southwest of Kingstree- Warley Hill formation (?)

Several irrigation ponds in the area southwest of Kingstree have been excavated in material considered to be Black Mingo. The pond of Mr. E.C. Baker, located 4 ½ miles southwest of Kingstree on U.S. Highway 52, was excavated in black and gray laminated clay and fine white sand. Coquina- like aggregations scattered throughout the unit contained gastropods very similar to those found at Salters, a Black Mingo locality.

Two irrigation ponds owned by Mr. Terrell Jacobs are located about 3 miles farther south and one mile west of the Baker pond. These ponds were excavated in a different type of rock and the spoil banks contain a dissimilar fauna from the first pond.

From the excavated material of one pond, the writer obtained several species tentatively identifies as *Ostrea lisbonensis* Harris and *Ostrea smithvillensis* Harris, both of which are typical of the lower Lisbon of Alabama and correlative with the Warly Hill marl in South Carolina. Additional megafossils from the locality include *Ostrea divaricata* Lea, identified by Dr. H.G. Richards. This specie is associated with slightly younger beds in the Gulf Coast and equivalent to McBean or Santee formations in South Carolina. The presence of these fossils at comparatively shallow depths would indicate that the Black Mingo was quite thin in the immediate area.

Stop 5 – Florence County – Peedee formation

Approximately 2.5 miles southwest of Effingham and 0.25 miles southeast of Elim, on U.S. Highway 301, the Peedee formation crops out on the north bank of Sparrow Swamp as it joins the Pee Dee River. The unit consists of dark gray to black clay or marl interbedded with white fine sand, in places indurated. Species of *Trigonia thoracia, Exogyra costata* and *Ostrea* sp. are quite common. At this point the formation occurs at an altitude of about 70 feet above msl (altimeter) which is nearly its highest point in this State. The following foraminifera obtained from the black clay were identified by S.M. Herrick as Navarro in age:

Robulus pseudo-secan Cushman (also found in Snow Hill of N.C.)
Gaudryina rudita Sandridge
Anomailna pseudopapillosa Carsey
Guembelina globulosa (Ehrenberg) Egger
Lexostomum plaitum (Carsey)
Gyroidina depress (Alth) Cushman
Nonionella cretacea Cushman
Planulina correcta (Carsey) Cushman
Bulimina reussi Morrow, var. *navarroensis* Cushman and Parker
Vaginulina navarroana Cushman
Cibicides harperi (Sandridge) Cushman
Anomalina nelsoni W.Berry

From Cooke's locality 38, 1 ½ miles upstream from this site, the following additional species were identified: (by Herrick)

Robulus munsteri (Roemer) Cushman
Haplophragmoides excavata Cushman and Water

Stop 6 – Mars Bluff – Black Creek formation

This locality, described by Sloan (1908) and Cooke (1936), is on the right bank of the Pee Dee River, approximately 12 miles east of Florence and on the old U.S. Highway 76. The section, as given by Cooke, shows a 17- foot bed of yellow to bluish sandy clay (Wicomico formation-Pleistocene) overlying 52 feet of the Black Creek formation. The Black Creek formation consists from top to bottom of 10 feet of fine yellow sand, 4 feet of dark gray to black clay, 11 feet of fine buff, pink and gray crossbedded sand and a basal 27 feet of dark gray to black clay interbedded with fine yellow sand, which is indurated in part, and contains silicified shells. From a nearby outcrop of the same bed the author collected specimens of *Nuclana* sp., *Isocardia* sp. *Striarca* sp., *Tellina* sp., *Ostrea blackensis* Stephenson, *Anomia olmsteadi* Stephenson? and fish vertebra. This suite compares favorably with the fauna of the Snow Hill member of the Black Creek formation, although the lithology of the materials exposed here, and the structure, suggest the possibility that these beds are older than Snow Hill, possibly equivalent to the Blufftown formation or to the Tombigbee sand of the Eutaw formation. Stephenson (1923, p 43) indicates that *Anomia olmsteadi* Stephenson, *Arca* (*Barbatia*) *lintea* (Conrad), and *Cymbophora trigonali* Stephenson, all present at this locality, range elsewhere into the lower part of the *Exogyra ponderosa* zone. The species, *Anomia olmsteadi* Stephenson and *Cymbophora trigonalis* Stephenson (questionably), range into the basal beds of the Eutaw formation in the Chattahoochee region. Microfauna obtained from this outcrop have been rather sparse.

Alternate stop 6- Mechanicsville- Black Creek and Tuscaloosa formations.

Where State Highway 34 descends to the swamp of the Pee Dee River, 1 mile northeast of Mechanicsville, and 8 miles northeast of Darlington, the Black Creek and Tuscaloosa formations are exposed. The following section of this locality is taken from Cooke (1936, p.27):

Bed No.		Feet
3.	Sunderland formation (Pleistocene): Coarse pebbly compact sand at base, passing upward into finer sand laminated with clay; reddish-yellow to red and gray; to top of hill, about	35

Unconformity

2. Black Creek formation (Upper Cretaceous): Dark brown to black sandy clay 30
1. Tuscaloosa formation (Upper Cretaceous): Coarse light gray argillaceous sand 15

Stop 7 – State Highway 102, Darlington County

An excellent outcrop of the bedded white clays of the Tuscaloosa formation occurs on State Highway 102, Darlington County, 0.3 mile south of the Chesterfield County line.

A generalized section obtained recently by the writer is as follows:

Bed No.	Feet
4. Fine white to tan quartz sand containing gray clay nodules and lenses. Shows leaching effect near surface	6
3. Coarse red, brown, and tan, micaceous quartz sand	1
2. Cherry red and white mottled clay	6
1. Light gray laminated, micaceous, fine quartz sand, compact and indurated. Brecciation of bedding in north end.	

The Tuscaloosa at this locality exhibits lithology similar to that occurring in several areas along U.S. Highway 1 from Aiken County to Chesterfield County. Perhaps the most continuous bed of the Tuscaloosa formation, the red and gray mottled clay, is included here.

Stop 8 – Middendorf – Tuscaloosa formation

The railroad cut on the Seaboard Air Line Railway, at the crossing of the Hartsville- Ruby Road, 2 miles northeast of Middendorf, Chesterfield County, was designated by Sloan (1904) as the type locality of the Middendorf formation. He considered these beds to be of Lower Cretaceous age. On the basis of fossil plants, Berry (1914) transferred the Middendorf beds to the Upper Cretaceous as the Middendorf arkose member of the Black Creek formation. In 1936 Cooke, on the basis of previous correlation, substituted the name "Tuscaloosa formation" for "Middendorf formation" in describing the beds at this locality. Tan and gray to pink arkosic sands with lenses of light-colored clay are characteristic. According to Cooke, there was a 4-foot lens of clay containing many well-preserved leaf impressions, extending from a point near the bridge westward about 100 feet. Eastward from the bridge the clay grades into tough gray argillaceous sand.

From a reanalysis of the floras at Middendorf, Dorf (1952) concluded that the plant- bearing Middendorf beds were equivalent in age to the plant- bearing lower part of the undifferentiated Black Creek formation of North Carolina.

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