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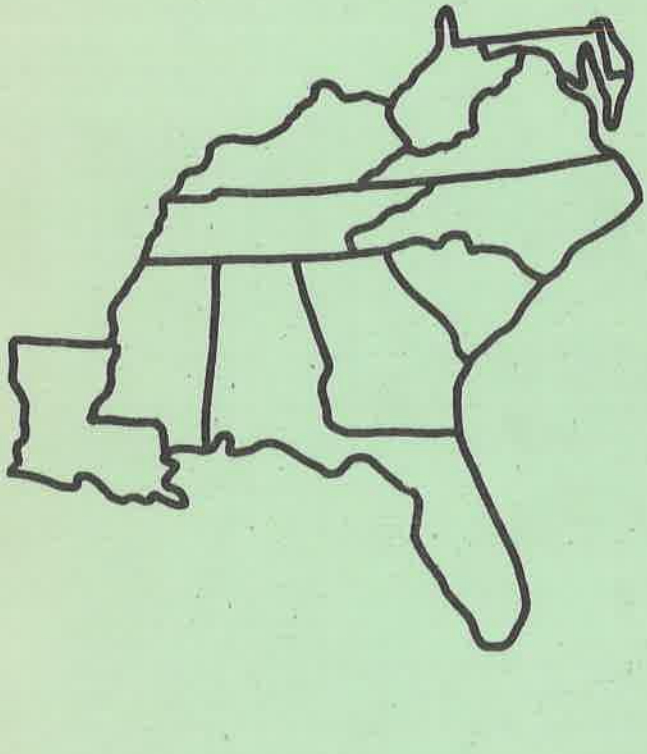

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SOUTHEASTERN GEOLOGY

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A BIOSTRATIGRAPHIC EVALUATION OF THE SNOW HILL MEMBER, UPPER CRETACEOUS OF NORTH CAROLINA

by

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and
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ABSTRACT

Strata adjacent to the Black Creek-Peedee boundary were studied to determine the relationship of the Snow Hill "member" to these two units. Sediments from the type locality of the Snow Hill "member" of the Black Creek formation were compared with equivalent strata along the Cape Fear River, N. C. Fossil criteria indicate that the strata at both localities are upper Taylor in age with the exception of a Navarro bed at Scuffleton, N. C. Sedimentary and faunal data were compared with published data on Recent sedimentary environments. The upper Black Creek shale is of marine deltaic origin whereas the lower Peedee sandstone is of near shore marine origin. The type Snow Hill was deposited in an open lagoonal environment.

Outcropping Snow Hill sediments are not sufficiently distinct lithologically from the rest of the Peedee formation to warrant a separate name. The "Snow Hill' might be considered a member of the Peedee

formation, though we believe the small difference in lithology observed in outcrops does not warrant this. If future work from subsurface data should reveal that a member category is useful it should be justified on a lithologic basis and not on fauna.

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Statement of the Problem

Outcropping Cretaceous formations of the North Carolina Coastal Plain consist, in ascending order, of the Cape Fear, Middendorf, Black Creek and Peedee formations. The Black Creek formation is presently divided into two members - the lower Bladen member and the upper Snow Hill member. All the formations are considered Upper Cretaceous except possibly the Cape Fear formation (Heron, 1958, p. 123).

The purpose of this investigation is the study of the "Snow Hill member" and its relation to the upper layers of the Black Creek formation and the basal layers of the overlying Peedee formation. During the course of this investigation, it became apparent that the "Snow Hill member" is lithologically more closely related to the overlying Peedee strata. It also became apparent that the "Snow Hill member" might not be a lithostratigraphic unit. This would be true if the "member" were a faunal assemblage-zone rather than a lithologically distinct subdivision.

A second purpose is the identification of the environment of deposition and the determination of the probable physical properties of the environments and their effect on the fauna. This subject has been largely neglected in the past for the lack of data necessary to delineate paleoenvironments.

Localities

The Cretaceous formations of North Carolina crop out mainly where

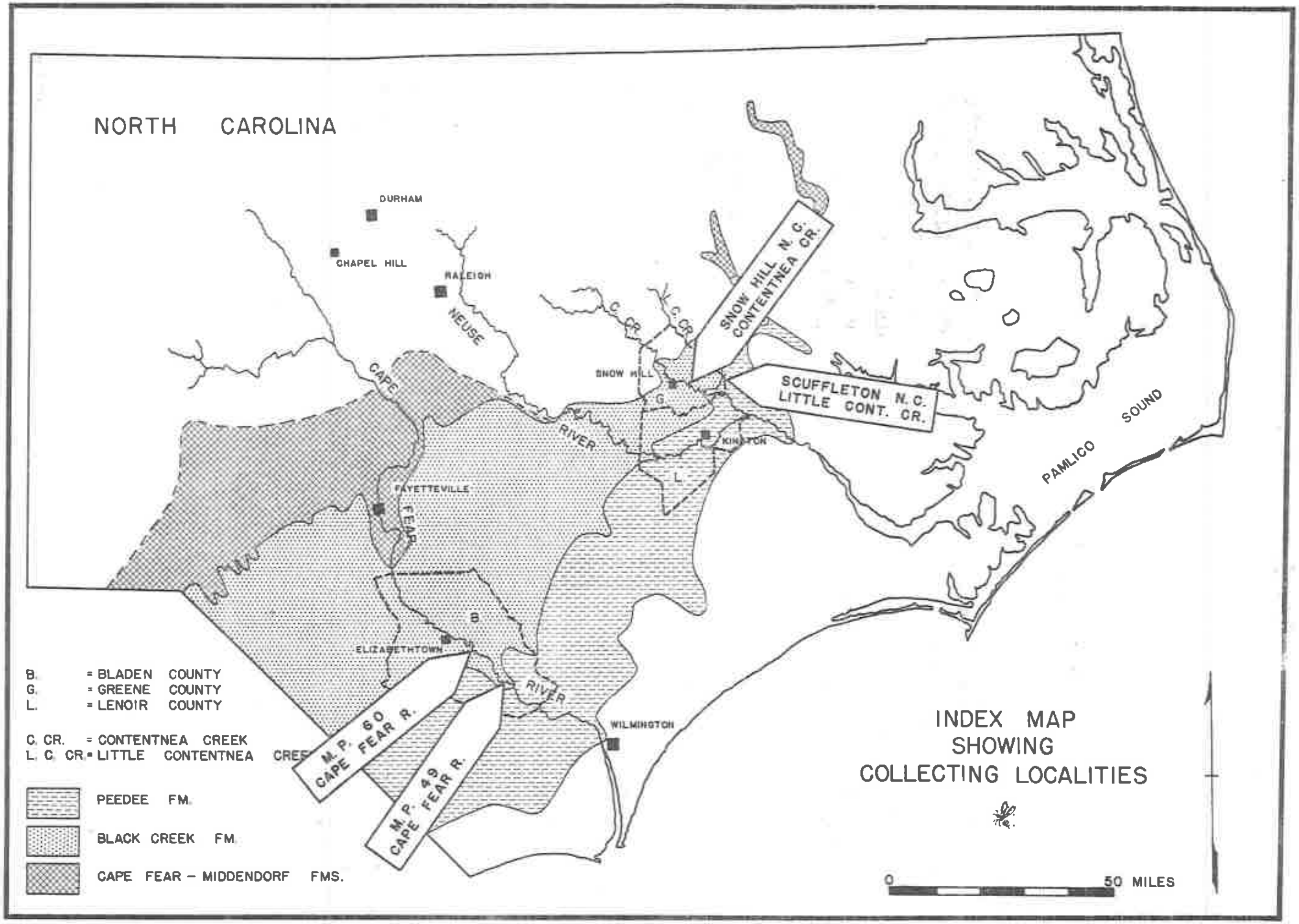

Figure 1. Index map of study areas.

streams have sufficiently dissected the surficial Pleistocene (?) veneer which covers most of the Coastal Plain. Consequently, studies of Coastal Plain strata are largely restricted to the banks of those streams.

This study was made in two areas: (1) the type locality of the "Snow Hill member" which includes outcrops along Contentnea Creek near Snow Hill, North Carolina, and (2) outcrops along the Cape Fear River (Figure 1).

The Cape Fear River area was deemed especially good for comparison with the Contentnea Creek area because as Stephenson (1923, p. 2) said:

> "The best continuous series of Cretaceous exposures is furnished by the bluffs of the Cape Fear River and its tributaries, the strata appearing at intervals all the way from the Fall Line to Wilmington, a distance of over 100 miles. The Cape Fear region furnishes not only the widest area of Cretaceous strata in the Carolinas, but also the widest area at right angles to the Fall Line in the Coastal Plain region east of the Mississippi River."

Including the type locality of the "Snow Hill member" at Snow Hill, Greene County, North Carolina, the Contentnea Creek area is defined for purposes of this study as the outcrops along Contentnea Creek from the bridge at Snow Hill downstream 7.1 miles (approximately 3.2 airline miles - Figure 2) and an outcrop on a tributary of Little Contentnea Creek. The Little Contentnea Creek outcrop is on a tributary of that creek 0.7 miles north of Scuffleton, North Carolina, along North Carolina route 102 on the farm of E. H. Rogers (Figure 3).

The Cape Fear River area consists of an outcrop on the right bank at Milepost 60 known as Walker's Bluff (Figure 4) and exposures at Donohue's Creek Landing in the immediate vicinity of Milepost 49 on the right bank near the northwestern corner of Oakland plantation (Figure 5).

Fossil bearing outcrops were located at the top of the Black Creek formation and at the base of the Peedee formation in each of the two areas. The Black Creek and Peedee exposures in either area are several miles apart when viewed on a map; however, because of the extreme low angle of dip, they are separated by only a few feet stratigraphically.

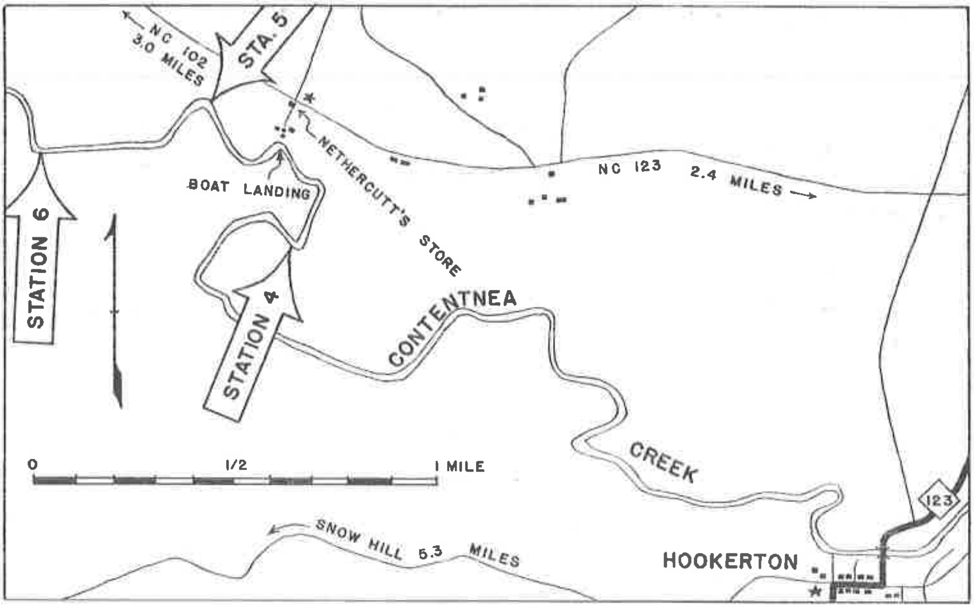

Figure 2. Location map of the Contentnea Creek outcrops.

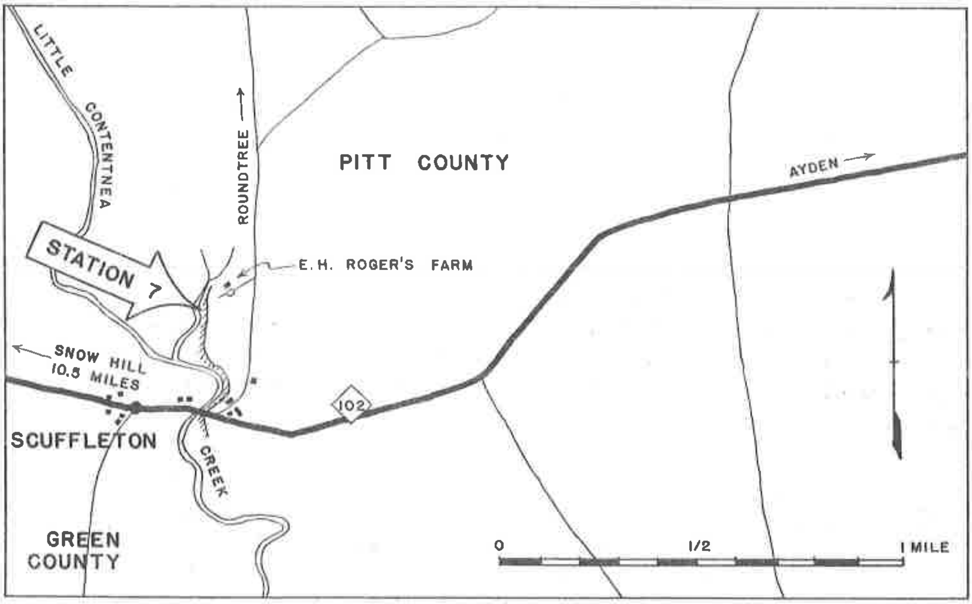

Figure 3. Location map of the Little Contentnea Creek Outcrop.

Previous Investigations

The Black Creek formation was named by Sloan in 1907 for beds exposed along the Black Creek in Florence and Darlington Counties, South Carolina. Stephenson later in the same year (Stephenson, 1907, p. 95) applied the name Bladen formation to equivalent rocks in North Carolina, but in 1912 (Clark, et al., 1912, p. 111) he recognized the priority of Sloan's nomenclature and dropped "Bladen" from the literature. In 1923 Stephenson (1923, p. 1) termed the upper portion of the formation the "Snow Hill calcareous member". The lower Black Creek, for the lack of another name, has since been called the "lower unnamed member". Heron (1958, p. 86) proposes using the name "Bladen member" for the portion of the Black Creek formation below the "Snow Hill member".

The "Snow Hill marl member" was separated from the rest of the Black Creek by Stephenson mainly because of the presence of invertebrate fossils. Stephenson (1923, p. 10) stated:

> "On account of the numerous localities in the transitional beds which have yielded invertebrate fossils, it is necessary for convenience of reference to apply a name to this part of the Black Creek formation.
>
> The name Snow Hill calcareous member is therefore proposed for the upper 100 to 200 feet of the formation which consists of lenses and layers of invertebrate-bearing sands and clays deposited in deeper marine waters interstratified with typical laminated strata more or less glauconitic."

Dorf (1952, p. 2184) subdivides the lower member of the Black Creek formation in South Carolina into two parts, a lower Middendorf member and an upper unnamed member. In North Carolina he recognizes only the two established members, the unnamed (Bladen) and the Snow Hill. Middendorf beds had previously been undifferentiated from the Tuscaloosa formation of Cooke (1936) and Stephenson (1942).

Heron (1958) presents cogent evidence for assigning the sediments below the Black Creek formation to two separate units. The bottom unit is the Cape Fear formation which is exposed only in North Carolina. The overlying unit is the Middendorf formation which is exposed in both Carolinas and which resembles basal Black Creek in many

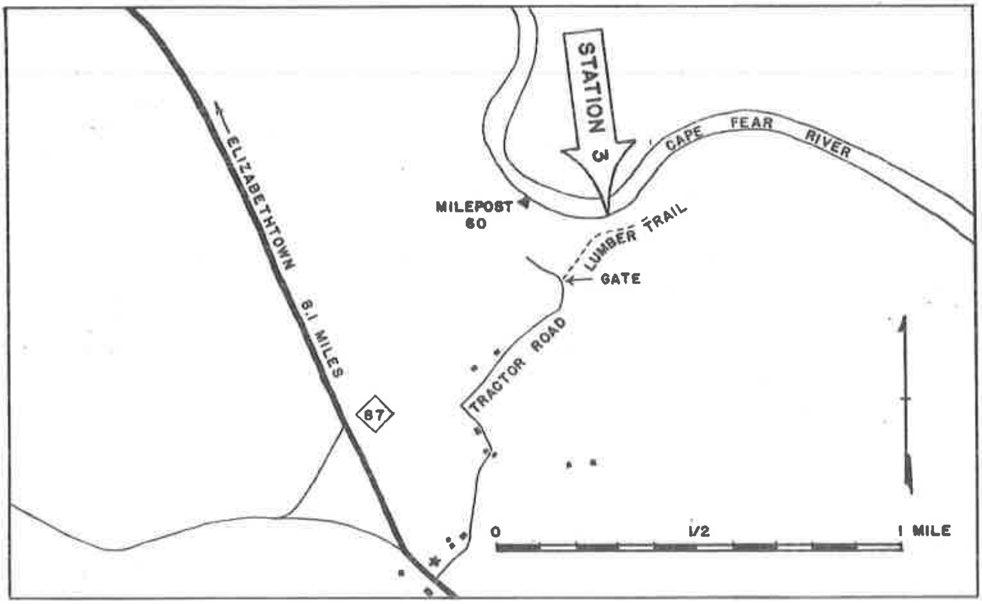

Figure 4. Location map of the Milepost 60 outcrop (Walker's Bluff).

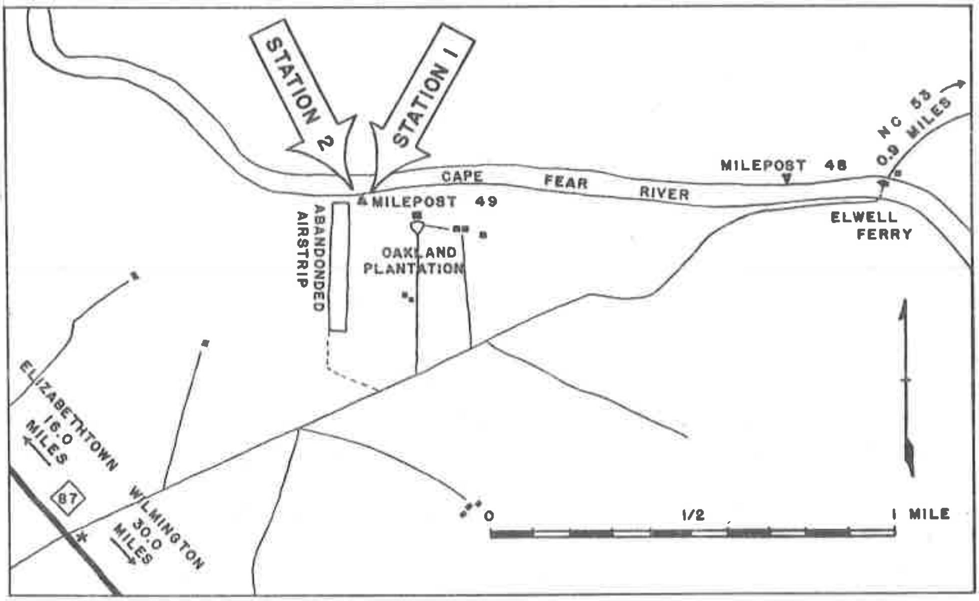

Figure 5. Location map of the milepost 49 outcrops (Donohue's Creek Landing).

places.

Dorf's and Heron's Middendorf beds are identical in South Carolina except that Heron places the Middendorf as a separate formation much as Cooke had done in 1926 (Cooke, 1926, p. 138).

Ruffin (1843) described and named the Peedee formation which overlies the Black Creek formation in North and South Carolina. Exposures along the Peedee River in Marion, Florence and Georgetown Counties, South Carolina, form the type locality for this stratigraphic unit.

Other workers who have contributed to the knowledge of the Black Creek and Peedee formations include Charles Lyell (1845) who made several fossil collections, T. A. Conrad (1871) who described 39 new species from the Snow Hill, North Carolina, locality (U.S.G.S. coll 5348) and W. C. Kerr (1875) who described outcrops and fauna from the same locality.

E. W. Berry (1914) published on the paleobotany and correlation of the two formations, Esther Greene (1937) wrote a thesis on the Foraminifera and Louise Berryhill (1948) studied the stratigraphy and Foraminifera of the Hatteras Light Well # 1.

H. G. Richards (1950) published a resumé of the geology of the North Carolina Coastal Plain, Walter Spangler (1950) published on the subsurface geology, M. C. Powers (1951) studied the outcropping Black Creek formation along the Cape Fear River and P. M. Brown (1957) reported on the Ostracoda. LeGrand and Brown (1955) prepared a field guide to coastal plain outcrops.

The best bibliographies have been compiled by Stephenson (1912), Richards (1950), and Brown (1957).

Acknowledgements

The authors are indebted to R. L. Ingram for suggestions concerning sedimentation and to W. A. White for the use of his aerial photograph indices and for ideas concerning geomorphology of the Contentnea Creek area. J. St. Jean examined the Foraminifera and offered many helpful suggestions on the manuscript. M. R. Carriker of the U. S. Fish and Wildlife Service Laboratory of Oxford, Maryland,

offered valuable suggestions on ecology and habitat and on the manuscript. J. Alan Ballard, Charles Copeland, Howell Deberry, Robert Edwards, F. Allan Hills and James Shockley assisted in the field. Invaluable aid was afforded by local people in the form of information, use of flatboats, shelter and hospitality.

STRATIGRAPHY

Procedures

Two methods were used in the description of the Black Creek and Peedee stratigraphy: (1) field description of the outcrops and (2) coarse-fraction studies of selected samples.

For field description the outcrops were measured with a 100 foot tape measure from the water level to the top of the outcrop. All measurements were made when the water was at a seasonal low. Texture and composition of the rocks were recorded from visual inspection with the aid of a hand lens of ten diameter magnification. At several places smooth clean-cup surfaces were prepared with a military entrenching tool to study sedimentary structures such as wavemarks, bedding characteristics and distribution of lignite fragments. Samples were collected in cloth bags for laboratory studies and photographs were taken of several aspects of each exposure.

For purposes of this report the following four degrees of induration are recognized: (1) nonindurated; hand samples do not maintain a definite shape, (2) poorly indurated; hand samples maintain a definite shape, but may be crushed in the hand; (3) indurated; hand samples maintain a definite shape, and cannot be crushed in the hand, and (4) well indurated; hand samples when ruptured break across the grains and matrix alike.

The terms designating thickness of strata are (R. L. Ingram, 1954, p. 938):

Less than 0.3 cm.	thin-laminated
0.3-1.0 cm.	thick-laminated

1.0-3.0 cm.	very thin-bedded
3.0-10.0 cm.	thin-bedded
10.0-30.0 cm.	medium-bedded
30.0-100.0 cm.	thick-bedded
100.0- cm. and thicker	very thick-bedded

Color names used are from the color chips published by the Rock Color Chart Committee of the National Research Council (1948).

The sediment samples were analyzed by a method called "coarse-fraction analysis," shown by Shepard and Moore (1954, p. 1792 and 1955, p. 1500) to be one of the most valuable for characterizing Recent environments along the central Texas coast. The binocular microscope is used to estimate the volume percentages of significant constituents in each of the Wentworth size classes larger than 1/16 millimeter. Constituents considered important in the central Texas coast area include: echinoids, Foraminifera, glauconite, ostracods, shells, plants including fibers (collectively called "wood"), and terrigenous minerals (land-derived mineral particles such as quartz, feldspar and ferromagnesians). All of these constituents are found in the Cretaceous sediments.

In addition to the usual method of making a coarse-fraction study, the different types of terrigenous minerals were determined. This information along with the particle distribution data from the coarse-fraction study provided the data for giving a specific rock name to the sediments.

Sandstone names used in this report are binomial (Figures 6 and 7 and based on the nomenclature of Shepard (1954, p. 155) and Pettijohn (1957, p. 291). The binomial nomenclature uses Shepard's grain size and Pettijohn's mineral composition terms with the pattern-(grain size):(Mineral composition). Since Pettijohn's nomenclature incorporates both a maturity index (feldspar/rock fragments ratio or the quartz plus chert/feldspar plus rock fragments ratio) and a fluidity index (sand detritus/interstitial detrital matrix), this method of naming sediments is descriptive and, to some degree, genetic.

Pettijohn's terminology does not allow for sandstones composed of 15% or more detrital matrix, the remaining percentage of which is predominantly quartz sand fragments. We would add to his terminology and call a sandstone with less than 25% labile fragments and 15% or more detrital matrix a quartzwacke.

To illustrate the binomial classification, a rock with 17% detrital matrix, 12% labile fragments, and 71% quartz and/or chert fragments depending on its grain size analysis could be called a (silty sandstone): (quartzwacke).

<table>
<tr><td colspan="2">CEMENT OR MATRIX</td><td colspan="2">DETRITAL MATRIX OVER 15 %
CHEMICAL CEMENT ABSENT</td><td colspan="4">DETRITAL MATRIX UNDER 15 %
VOIDS EMPTY OR FILLED WITH CHEMICAL CEMENT</td></tr>
<tr><td rowspan="5">SAND OR DETRITAL FRACTION</td><td rowspan="2">FELDSPAR EXCEEDS ROCK FRAGMENTS</td><td rowspan="4">QUARTZWACKES</td><td>FELDSPATHIC GRAYWACKE</td><td colspan="2">ARKOSIC SANDSTONES</td><td rowspan="4">ORTHOQUARTZITES</td><td rowspan="2">CHERT < 5 %</td></tr>
<tr><td rowspan="2">GRAYWACKES</td><td>ARKOSE</td><td>SUBARKOSE OR FELDSPATHIC SANDSTONE</td></tr>
<tr><td rowspan="2">ROCK FRAGMENTS EXCEED FELDSPAR</td><td colspan="2">LITHIC SANDSTONES</td><td rowspan="2">CHERT > 5 %</td></tr>
<tr><td>LITHIC GRAYWACKE</td><td>SUBGRAYWACKE</td><td>PROTOQUARTZITES</td></tr>
<tr><td>QUARTZ CONTENT</td><td>>60 %
<85 %</td><td><60 %</td><td><75 %</td><td>>75 % <95 %</td><td colspan="2">>95 %</td></tr>
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Figure 6. Mineral composition nomenclature for sandstones (modified from Pettijohn, 1957, p. 291).

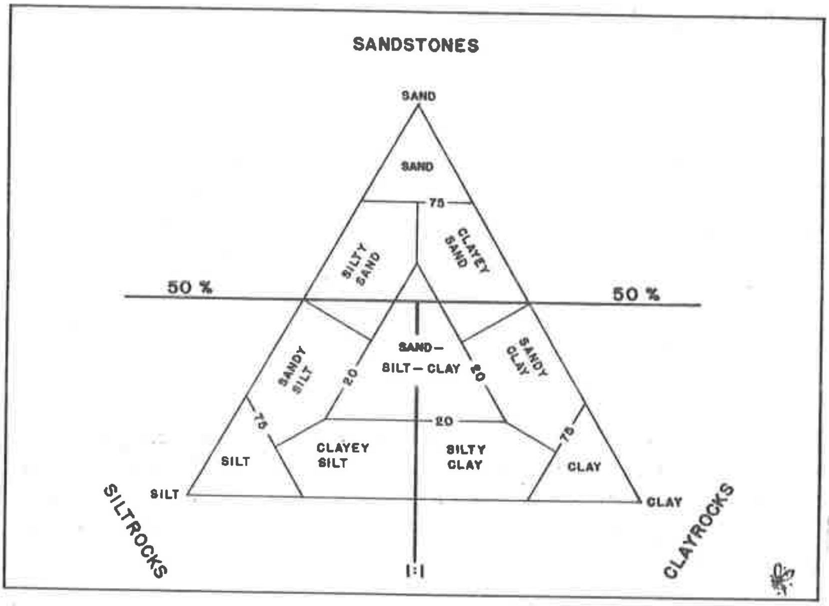


Figure 7. Grain size nomenclature for sandstone and mudrocks (combination of Ingram, 1953, and Shepard, 1954).

The nomenclature of Ingram (1953) is followed for sediments in which more than 50% of the detrital fragments are of a size less than 1/16 millimeter.

Definitions of Lithostratigraphic Units

The definitions presented below are compiled largely from the literature and are not the result of any work done in this study. They are offered only to show how authors have understood the formations for many years and later in this report they will be reviewed in light of new information derived from this study.

Black Creek Formation

The lithology of the exposed Black Creek formation is unmistakable in North Carolina. The rocks are poorly indurated, laminated, ferriferous and/or carbonaceous silt and clay shales intimately associated with lenses of sand. The sand strata vary from laminated to thick-bedded. Thick-bedded strata are rare. Sand predominates in some places, silt and clay at others (Powers, 1951, p. 77); usually the laminations are prevalent. Many outcrops are marked by cross-stratification of large proportions. The shales are dark gray to black in color giving most exposures a characteristic dark appearance. The sands vary from dark to light gray, occasionally light yellow and exceptionally approach white. Fine flakes of mica are common.

Lignitized, finely divided plant fragments occur as thin seams throughout the formation. The amount and size of lignite particles increases up-dip (down-section) until, in the basal beds, pieces are found in size from twigs, branches, and trunks as long as 30 or more feet. At Goldsboro, North Carolina, a tree stump has been uncovered in place with its roots extending into the sediments. Much of the lignite in the basal beds is found in various stages of replacement by silica making petrified wood common in certain localities.

Iron sulphide is an important constituent of the formation (Stephenson, 1923, p. 9), and, like lignite, becomes more important down-section. At a locality on Highway 87, 15 miles southeast of Fayetteville, North Carolina, marcasite concretions weighing up to 20 pounds have been found. Small particles of amber less than one-half inch have been found in many localities associated with the lignite.

Shark teeth and fragments of dinosaur and other bone are reported from several localities in the Black Creek formation, but invertebrate macrofossils are rare.

The base of the Black Creek formation is marked by a distinct unconformity. As yet no stratigraphic break has been reported between the Black Creek and Peedee formations except at one locality in the eastern part of Florence County, South Carolina (Stephenson, 1923, p. 8).

Stephenson (1923, p. 10) suggests that the Black Creek shale could be as much as 600 feet thick. More recently, Powers (1951, p. 74) gives an estimate of 215 feet.

Exposures are found in northern Pitt, northern Greene, Wayne, southern Cumberland, Bladen and Robeson Counties, North Carolina, and Dillon, Darlington, Marion, Florence, Marlboro and Chesterfield Counties, South Carolina. The belt of outcrop in North Carolina is approximately 40 miles wide, cropping out from Milepost 49 to Milepost 100, along the Cape Fear River. Narrowing northeastward the belt is only about 8 miles wide on the Tar River, beyond which outcrops are not found.

Snow Hill Member

Stephenson (1923, p. 9) defines the "Snow Hill member" as the upper part of the Black Creek formation where the laminated sands and clays become interstratified with layers or lenses of more or less calcareous greensand and marine clay, some of which contain an abundant marine fauna. Rocks bearing "Snow Hill" fauna are found at Snow Hill, Green County, North Carolina; numerous localities on the Black River, Sampson County, North Carolina, Pitt County, North Carolina; and at Hodge's old mill site in Marion County, South Carolina. In the laminated strata, Stephenson says, the thin sand partings and layers are also noticeably glauconitic in places. The thickness of this unit is reported as 100 to 200 feet.

Little additional information is available concerning the lithology of the "Snow Hill member" because most writers have referred to Stephenson's description. P. M. Brown, (1957, p. 4), however, apparently following Stephenson to some degree, has this slightly different view of the "member":

> "In surface exposures the Snow Hill marl member consists of black to gray laminated sandy clay and interbedded sand, with varying amounts of fine-grained glauconite, marcasite aggregates and black lignitized wood fragments. Most of the macrofossils consist of poorly preserved casts and molds, no calcareous shell material remaining. Locally, however, calcareous shell material has geen preserved in a sandy clay matrix, and forms drab-gray marl which reflects varying degrees of induration."

At two outcrops in the type area near Snow Hill, North Carolina, Stephenson (1923, p. 15) describes the Snow Hill lithology as"dark green compact, argillaceous, micaceous, glauconitic sand." No reference is made to laminations or other sedimentary structures except concretionary masses (1 to 2 feet in diameter) which have been witnessed in both the Black Creek and Peedee formations.

As nearly as it is possible to tell from the literature, the "Snow Hill member" is supposed to crop out from Snow Hill, North Carolina, downstream along the Contentnea Creek to about 2 miles below Hookerton, North Carolina. The outcrop width is about 7 miles, over a distance along the creek of about 14 miles.

Peedee Formation

Stephenson characterizes the Peedee formation (1923, p. 12) as chiefly a compact dark-green or gray, finely micaceous, more or less glauconitic and argillaceous sand, most layers of which are in some degree calcareous and some of which are sufficiently calcareous to form impure limestones, and interstratified layers of dark marine clay. Irregular concretionary masses of impure calcium carbonate occur in places either scattered randomly through the sand or arranged in layers parallel to the bedding, producing nodular bands along the river bluffs: concretions 4 or 5 feet in their longest diameter have been observed. The Peedee formation contains fossils, principally mollusks, scattered irregularly throughout the rocks and in layers 1 to 3 feet in thickness. Shark teeth are fairly common whereas fragments of bone occur only rarely. Foraminifera and Ostracoda are common at most localities.

In North Carolina the formation rests conformably on the Black Creek formation, striking roughly NE-SW. In the Cape Fear River region, Stephenson (1923, p. 13) suggests that the dip is 20 to 24 feet per mile. Thickness figures for Peedee rocks vary from 720 to 886 feet in wells (Stephenson, 1923, p. 13).

Outcrops may be found in a belt parallel to the Black Creek formation. As with that formation, the widest belt of outcrop is found along the Cape Fear River, North Carolina (about 34 miles). The belt extends from Greenville, in Pitt County, North Carolina, southwest to where it disappears beneath the overlapping Eocene sediments between the Peedee and Santee Rivers, South Carolina. Counties in which outcrops have been observed are Pitt, Greene, Lenoir, Duplin, Pender, Bladen, New Hanover, Columbus, and Brunswick, North Carolina and Horry, Marion, Florence, and Georgetown, South Carolina.

Description of Outcrops

In the following descriptions the positions from which the sediment samples were taken are indicated in the figures and in the text. The samples were numbered and a prefix assigned the number to indicate which area the sample came from. The prefix CCA means Contentnea Creek area and the prefix CFA means Cape Fear River area. These numbers will appear several times in other sections of the report.

Cape Fear River Area

Station 1:

Immediately downstream from milepost 49 on the left bank:

Bed #	Thickness in feet	
	Unit	Cum.
3. Sandstone, moderate yellowish brown to grayish		

Bed #		Thickness in feet	
		Unit	Cum.
	brown, massive, poorly indurated; with some clay and silt. Post-Cretaceous	20.0	28.8
	Unconformity		
2.	Sandstone, grayish brown, fresh surface pale yellowish orange; pitted, massive, calcareous, fossiliferous and indurated, with some lignite fragments. SAMPLE CFA1 Basal Peedee formation .	6.5	8.8
	Unconformity (?)		
1.	Shale, grayish black arenaceous, laminated to thin-bedded and poorly indurated Black Creek formation	2.3	2.3

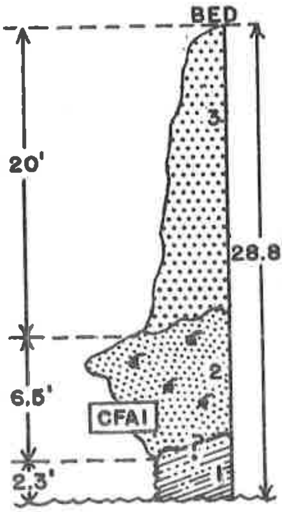


Figure 8. Stratigraphic section at Station 1.

The anomalous dip of the exposed portion of the lower two layers indicates that they compose a slump block. Overhanging trees and dense vegetation nearly obscure the outcrop. The exposure is separated from the next described exposure by a small intermittent stream. Figure 8 illustrates the outcrop.

Station 2:

Milepost 49, left bank:

Bed #		Thickness in feet	
		Unit	Cum.
4.	Sand, light brown to dark yellowish orange; nonindurated, massive, containing disseminated no-		

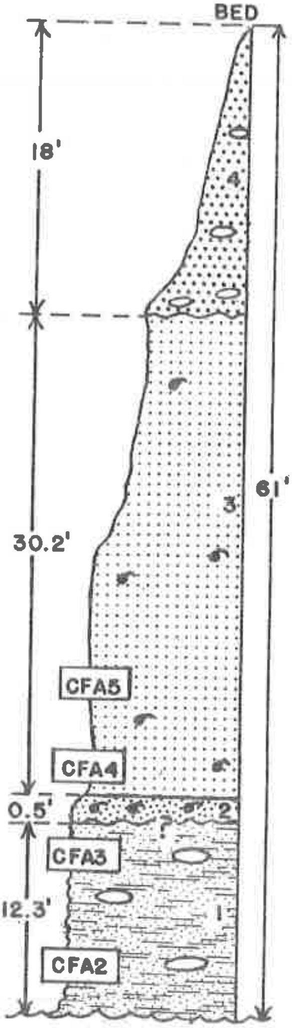


Figure 9. Stratigraphic section at Station 2.

Bed #		Thickness in feet	
		Unit	Cum.
	dular ferric iron oxide. Numerous small sandy clay shards give the sand a flaky appearance. Post-Cretaceous	18.0	61.0
	Unconformity		
3.	Sandstone, dark gray, fine, massive, micaceous, silty, clayey and poorly indurated. SAMPLE CFA5 Peedee formation	30.2	43.0
2.	Sandstone, dark yellowish orange to grayish orange, poorly indurated to indurated and fossiliferous. SAMPLE CFA4 Basal Peedee formation .	0.5	12.8
	Unconformity (?)		
1.	Shale, dark gray to grayish olive green, micaceous, poorly indurated, thick-laminated and silty, with sparce elliptical lime nodules up to 10'' long. Weathered surface shows moderate yellow green to moderate yellow stains between the laminae. SAMPLES CFA2 AND CFA3. Black Creek formation. .	12.3	12.3

The outcrop is well exposed; clear of trees and other vegetation. Bed 2, in which a small dinosaur femur was found, pinches out from the downstream extremity of the outcrop toward the middle. The layer is distinctive for the manner in which the sand is mechanically bound together by encrusting Bryozoa. The face of bed 3 is a smooth vertical surface. Beds 1, 2, and 3 contain Foraminifera. Beds 2 and 3 have been previously assigned to the "Snow Hill member", but for reasons given later they are here placed in the Peedee formation. Figures 9 and 10 illustrate the outcrop.

Figure 10. Cretaceous outcrop at Milepost 49, Cape Fear River, North Carolina. The ledge is cut on the Peedee, Black Creek contact. Bryozoa encrusted dinosaur femur found at base of Peedee formation here.

Station 3:

Lower bend of Walker's Bluff, left bank, Milepost 60:

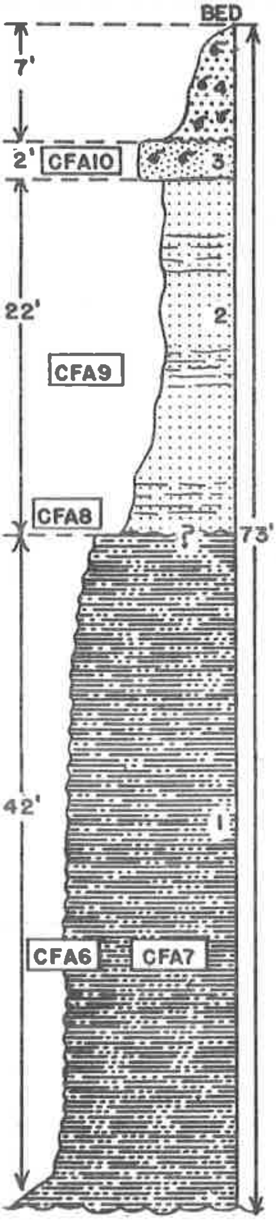


Figure 11. Stratigraphic section at Station 3.

Bed #		Thickness in feet	
		Unit	Cum.
4.	Sandstone, grayish orange to very pale orange, nonindurated, massive, clayey and coquinoid. Waccamaw formation (?)	7.0	73.0
	Unconformity		
3.	Sandstone, dark yellowish brown, indurated, cemented with calcium carbonate and containing numerous invertebrate fossil casts and molds. SAMPLE CFA10 Basal Peedee formation . . .	2.0	66.0
2.	Sand, greenish gray, massive, nonindurated, medium to coarse grained, with abundant black sand fragments, and a few scattered pebbles. Some horizontal clayey, silty layers, 6-8 inches thick, are cross-laminated with an apparent dip of 10-20 degrees SE. SAMPLES CFA8 AND CFA9. Basal Peedee formation . . .	22.0	64.0
	Unconformity (?)		
1.	Clayshale, greenish black to dark greenish gray, poorly indurated with interbedded sand. Sand beds average 3-6 inches in thickness while the shale laminae average from 1/4-1/2 inches thick. The shale laminae are in groups interlayered with thin sand lenses about 1/16-1/2 inches thick. Mica		

Bed #		Thickness in feet	
		Unit	Cum.
	is abundant. The upper surface of many of the sand layers is current rippled with an apparent eastern paleocurrent direction. Overlying the rippled sands are clay layers which have areas of dark material in the ripple troughs. SAMPLES CFA6 AND CFA7 Black Creek formation	42.0	42.0

This outcrop is nearly vertical and is one of a series of outcrops forming Walker's Bluff. The larger part of Walker's Bluff is covered by slump and a dense growth of trees and underbrush. Bed 3 has previously been assigned to the "Snow Hill member", but it is here placed in the Peedee formation for reasons to follow. Figures 11 and 12 illustrate the outcrop.

Figure 12. Cretaceous outcrop at Walker's Bluff, Milepost 60, Cape Fear River, North Carolina. The contact between the Black Creek formation and the overlying Peedee formation can be seen at the bend in the rope. The man standing at the top of the cliff gives the scale.

Contentnea Creek Area

Station 4:

Downstream 7.1 miles from the Snow Hill, North Carolina, bridge:

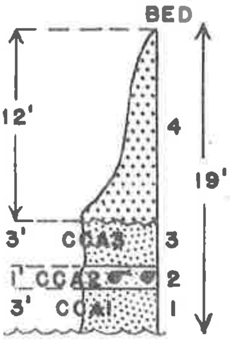


Figure 13. Stratigraphic section at station 4.

Bed #	Thickness in feet Unit	Cum.
4. Sand, massive, nonindurated, very pale orange, silty, and slightly gravelly. Post-Cretaceous	12.0	19.0
Unconformity		
3. Sandstone, massive, poorly indurated, greenish black, very fine, a few irregular laminations near the top. Scattered fragments of lignite occur near the top. SAMPLE CCA3 Peedee formation	3.0	7.0
2. Sandstone, very fine grained massive, poorly indurated, dark greenish gray, with scattered lignite fragments and many unbroken pelecypod and gastropod fossils. SAMPLE CCA2 Peedee formation	1.0	4.0
1. Sandstone, poorly indurated, greenish black, and very fine grained SAMPLE CCA1 Peedee formation	3.0	3.0

Beds 1, 2, and 3 are distinguished by only a slight difference in lithology. They are of similar composition except that the fossil zone has a little more clay and is somewhat lighter in color. The weathered surface of the three lower beds developes a slick grayish brown film which hides the presence of fossils or any lithologic difference. These beds have been previously placed in the "Snow Hill member", but are here placed in the Peedee formation for reasons to follow.

Station 5:

Downstream 6.4 miles from the Snow Hill, North Carolina, bridge:

Bed #	Thickness in feet Unit	Cum.
2. Sand, gravelly, nonindurated and white. Post-Cretaceous	10.0	11.7
Unconformity (?)		
1. Sandstone, dark gray, poorly indurated and very fine grained. SAMPLE CCA4. Peedee formation	1.7	1.7

Bed 1 forms a bench. Similar benches are found at the waterline all along the Contentnea Creek between Snow Hill and Hookerton, North Carolina. Bed 1 has been previously placed in the "Snow Hill member", but is here placed in the Peedee formation for reasons to follow

Station 6:

A low bluff 50-60 yards long, 5.9 miles downstream from the bridge at Snow Hill, North Carolina:

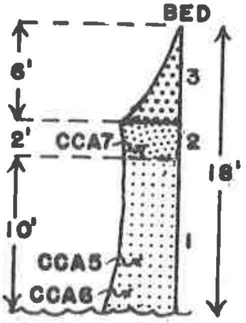


Figure 14. Stratigraphic section at Station 6.

Bed #	Thickness in feet Unit	Cum.
3. Sand, medium grained, pale yellowish orange to very pale orange, massive and nonindurated. Post-Cretaceous	6.0	18.0
Unconformity (?)		
2. Sandstone, fine grained, grayish olive to dark yellowish green, and poorly indurated. The layer is a lense varying from 1-3 feet thick. SAMPLE CCA7 (at the upstream end of the bluff). Peedee formation	2.0	12.0

Bed #		Thickness in feet	
		Unit	Cum.
1.	Sandstone, fine grained, dark gray, massive, micaceous, poorly indurated and silty. The rock surface is marked near the waterline with pits about 1 or 2 inches in diameter SAMPLE CCA5 (At the downstream end of the bluff). SAMPLE CCA6 (at the upstream end of the bluff). Peedee formation	10.0	10.0

The bluff is on the right side of the stream. The surface of the rock, as at other localities, forms a slick grayish brown film which hides the character of the rocks. Similar outcrops are found at fairly frequent intervals (best seen during low water) upstream to the Snow Hill, North Carolina, bridge. Molds (largely pelecypods) can be found at several exposures. One or two outcrops contain a few poorly preserved shells which are difficult to remove because of their friability. Beds 1 and 2 have been previously assigned to the "Snow Hill member", but are here placed with the Peedee formation for reasons to follow. Figures 14 and 15 illustrate the outcrops.

Figure 15. Cretaceous outcrop 5.9 miles downstream from Snow Hill, North Carolina, overlain by Post-Cretaceous sediments. Only Cretaceous sediments appear in the photograph.

Station 7:

Right bank on a tributary of the Little Contentnea Creek, 0.7 miles north of Scuffleton, North Carolina, along N. C. route 102 on the farm of E. H. Rogers:

Bed #		Thickness in feet	
		Unit	Cum.
4.	Sand, medium grained grayish orange, massive nonindurated, largely covered with thin soil and vegetation. Post-Cretaceous	18.0	23.0
	Unconformity		
3.	Sandstone, fine to medium grained, greenish gray, poorly indurated, clayey and silty. This bed is structureless and has a mottled appearance. SAMPLE CCA10 Peedee formation	2.0	5.0
2.	Sandstone, fine to medium grained, greenish gray, irregularly indurated. *Exogyra cancellata* are abundant and occur in cemented masses along with other fossils. SAMPLE CCA9 Peedee formation	2.0	3.0
1.	Sandstone, fine grained, dark greenish gray to greenish black, poorly indurated, micaceous, clayey and silty. SAMPLE CCA8 Peedee formation	1.0	1.0

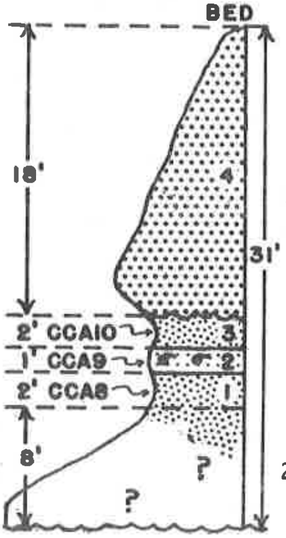


Figure 16. Stratigraphic section at Station 7.

The rocks below bed 1 are covered with slump and vegetation. Bed 1 closely resembles the sediments on Contentnea Creek between Snow Hill and Hookerton, North Carolina, except for being coarser grained and containing abundant Foraminifera. Figure 16 illustrates the outcrop.

Coarse-Fraction Study

The following data (Figures 17 and 18) are listed by stations from Station 1 to Station 7. The coarse-fraction results are illustrated in the form of pie diagrams to show the volume percentage of important constituents and histograms to show the weight percentage of size classes represented in a sample. Accompanying the description of each sample is the rock name derived in the manner previously explained. Heretofore, no parametric sedimentary classification has been applied to Upper Cretaceous rocks of North Carolina other than inclusive terms such as sandstone, shale and similar terminology with associated lists of dominant accessory minerals.

Sample CFA7 (Figure 17) is from a sand stratum taken from the Black Creek formation at Milepost 60 (Cape Fear River Area) while sample CFA9 (Figure 18) is a portion of a clay lamina taken from the overlying Peedee formation also at Milepost 60. These two samples are not representative of the rock units within which they were contained.

Sample CFA1 (Figure 8) because of the amount of cementation by calcium carbonate and solution of the macrofossils, could not properly be analyzed with the coarse-fraction method and does not also appear on Figure 17. All of the Foraminifera, macrofossils, and some of the clay would be destroyed in the course of reducing the sample to analyzable insoluble residue.

The bed from which sample CFA1 was taken does not appear upstream at Station 2, but further upstream immediately beyond Station 2 it again appears and continues for a few hundred yards.

Ten miles up river at Milepost 60, Station 3 (Figure 11), the cemented bed (Powers, 1951, p. 64) can be found high up on the side of the bluff. Sample CFA10 was taken from the bed for the fossils it contained, but like sample CFA1 it did not undergo a coarse-fraction analysis and does not appear on Figure 17. Using the cemented beds around Milepost 49 and its updip equivalent at Milepost 60, a dip of 7 feet per mile southeast can be arrived at which agrees favorably with Powers' figure (Powers, 1951, p. 73).

The cemented bed at Station 1 and the cemented bed upstream from Station 2 are at the same stratigraphic level as sample CFA4 (Figure 9) at Station 2. Remarks concerning the sedimentary environment of sample CFA4 are pertinent to the two adjacent cemented beds.

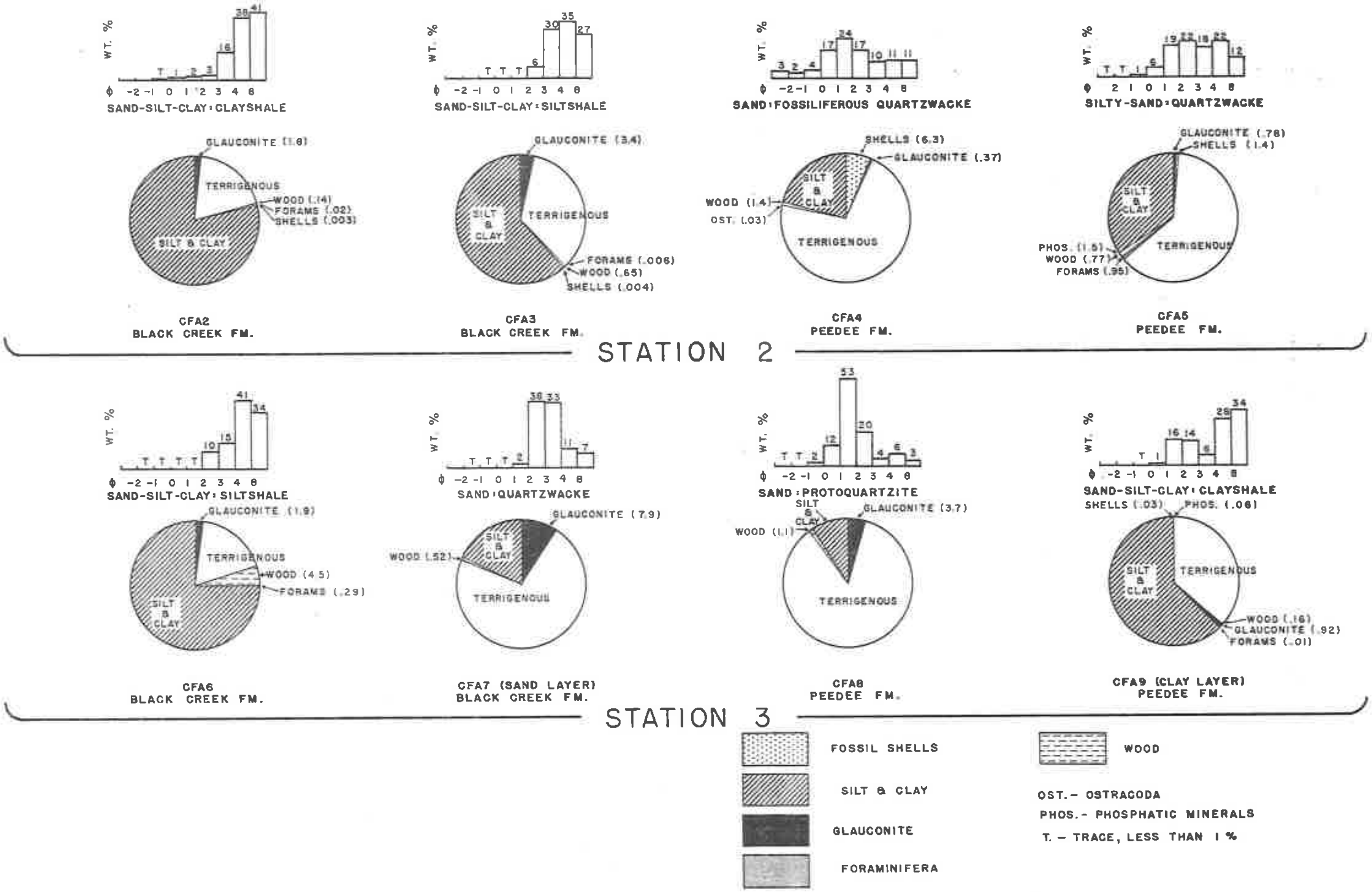


Figure 17. Coarse-fraction study of samples from Cretaceous rocks in the Cape Fear River Area.

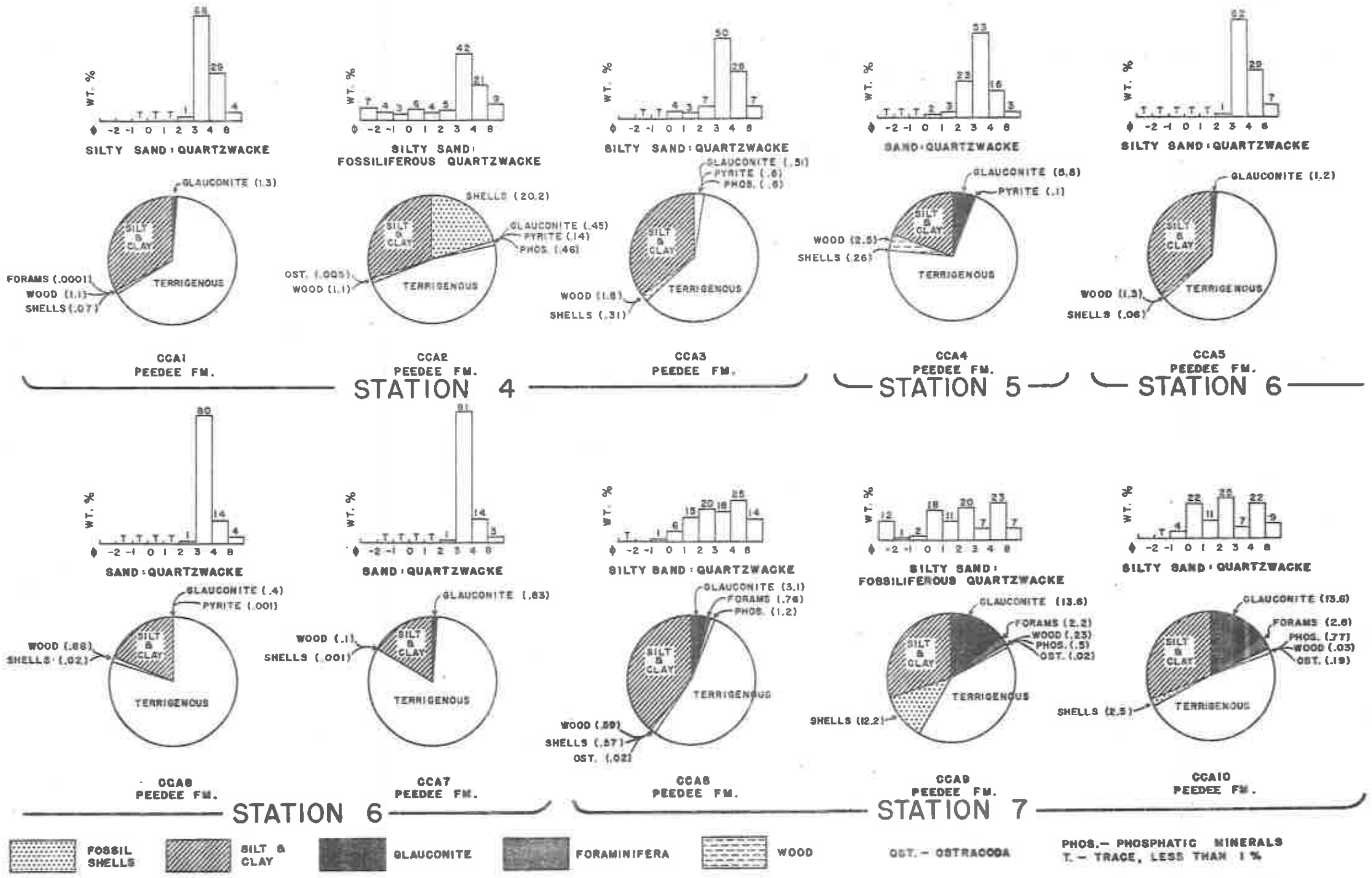


Figure 18. Coarse-fraction study of samples from Cretaceous rocks in the Contentnea Creek Area.

Powers (1951, p. 63) has analyzed the peculiarly cemented layers at Station 1 and above Station 2 and he offers this description:

> "Salt and pepper, sorted, angular to rounded, massive, medium-grained, well-indurated, calcareous, quartz sandstone. This bed is very fossiliferous."

Inspection under a binocular microscope shows that the "salt and pepper" effect is due to a large percentage of medium-grained glauconite with a lesser amount of magnetite, amphiboles or pyroxenes, olivine (?), and other dark minerals among the quartz grains.

Three miles downstream from Snow Hill, North Carolina, there is a distinctive outcrop from which sample CCA11 was taken. It is important to note the presence of this outcrop in the midst of the "Snow Hill member" type section, because the occurrence of Nonionella sp., cf N. wilcoxensis Cushman and Ponton, 1932, Rotalia globosa (van Voorthuyan), 1950 (=Streblus becarrii globosus van Voorthuyan, 1950), and a new species of Elphidium, E. limatulum, Copeland, 1961, suggest a Miocene age for the outcrop and certainly rule out a Cretaceous age. More important, the lithology of the outcrop closely resembles the lithology of the Cretaceous rocks in the area and may have been deposited in a similar environment. The sediment is 73% sand, 23% silt, and 4% clay. It is characterized by 69% quartz sand, 98% of which falls in the 1/8-1/16 mm. size class, and 3% muscovite mica. The following components were each found in amounts less than 1% by volume; glauconite, phosphatics, Foraminifera, wood, and shells. This rock is slightly indurated largely by compaction, is gray in color on a fresh surface, and is a (silty sand); (quartzwacke).

Special Features of the Samples

CFA1: Lignite in chunks up to 2 inches long imbedded in carbonate cement.

CFA2: Glauconite resembles tests of Foraminifera (Mo 1/8-1/16 mm.), most of the organic matter as lignite (Mo 1/4-1/8 mm).

CFA3: Glauconite occurring largely as pellets and apparently in various stages of development from muscovite (Mo 1/8 - 1/16 mm.), wood is lignite twigs, leaf fragments, stems, etc. (Mo 1/8-1/16 mm.), trace of limonite and resin, 5% mica.

CFA4: Dark heavy minerals present (Mo 1-1/2 mm.), one fish vertebra, 1% mica.

CFA5: Foraminifera in the 1/2-1/4 mm. class. Considerably worn, less than 1% mica.

CFA6: Leaf fragments present (Mo 1/4-1/8 mm.), glauconite as pellets (Mo 1/8-1/16 mm.), a shell fragment in the 1-2 mm. class. Foraminifera present but rare (Mo 1/8-1/16 mm.), 1% mica.

CFA7: Unusually large amount of glauconite (Mo 1/2-1/4 mm.), 2% mica.

CFA8: Fine-grained aggregate present (Mo 1/2-1/4 mm.), mica absent.

CFA9: 2% mica.

CFA10: Lignite in chunks up to 2 inches long.

CCA1: Glauconite rare but much of the mica (chiefly muscovite) seems to be in early alteration stages to glauconite, 4% mica.

CCA2: Portions of insect abdomens in the 1-1/2 mm. class, less than 1% mica.

CCA3: 2% mica.

CCA4: Muscovite seemingly in alteration stages to glauconite, fecal pellets in the 1/4-1/8 mm. class, less than 1% mica.

CCA5: Fecal pellets present in the 1/8-1/16 mm. class, 3% mica.

CCA6: 1% mica.

CCA7: 3% mica.

CCA8: Trace of resin in the 1/2-1/4 mm. class, 2% mica.

CCA9: 2% lime cemented aggregate (Mo greater than 4 mm.), less than 1% mica.

CCA10: Echinoderm spines in the 1/4-1/16 mm. classes, mica absent.

CCA11: 3% mica.

PALEONTOLOGY

Procedures

Foraminifera

Volume percentage of Foraminifera in each of the samples was estimated in the coarse-fraction study. From the data on size distribution also derived in the coarse-fraction study, a second set of samples was weighed out so that after washing in a Curtin sediment washer, 50 grams of the sand fraction were retained on the screen. The 50 gram sand aliquotes were dried in a 100 degree centigrade oven and while still warm the Foraminifera were floated with carbon tetrachloride. A 50 gram sand aliquote was used in order to insure the recovery of at least some Foraminifera if they were present. After the Foraminifera had been floated out of the sand, they were transferred from the filter paper on which they were recovered to a picking tray. Several hundred specimens were picked at random from each residual sample, were separated into species groups, were identified, and were counted in order to determine the relative abundance. The residual samples were also carefully searched for species that had escaped the random picking. This accounts in part for the logarithmic nature of the abundance scale listed below. Some samples contained so few Foraminifera that the total number present did not exceed 100 and some samples did not contain Foraminifera.

The following scale was used to express the relative abundance of Foraminifera. The scale was established after studying all of the samples. It is not quantitative. It may be well to look at the per-

Very abundant	AA	more than 20
Abundant	A	11-20
Common	C	6-10
Rare	R	3-5
Very rare	RR	1-2

centages of Foraminifera listed in the coarse-fraction study (Figs. 17, 18) when referring to the abundance estimates given below. For instance, Foraminifera may be rare in an outcrop, but of those recovered a particular species may be very abundant.

An attempt was made to identify all of the Cretaceous Foraminifera recovered with the result that about 80 species were identified by C. E. Brett. However, for purposes of this paper only certain species are listed - those that are either abundant, very abundant, or occur in more than one outcrop. The identification of these were verified by Joseph St. Jean.

Macrofossils

A large number of macrofossils were collected at Stations 1, 2, 3, 4, and 7 (No macrofossils were found at Stations 5 and 6). Because of the variable number of fossils available at each station and of the difficulty in recovering identifiable specimens from Stations 1, 3, and 4, abundance estimates are the opinion of the authors and hold only for the outcrop for which the estimate is made.

Because of the induration of the fossil beds at Stations 1 and 3, the only identifiable specimens obtained were those that appeared on freshly broken surfaces. Very few could actually be removed from the rock.

Fossils at Station 4 were so friable and crumbley that only a few heavy shelled specimens of Trigonia bartrami could be collected in field. Specimens from this outcrop were recovered by collecting large sediment blocks and allowing the blocks to dry well in the laboratory. The dried blocks were broken into workable chunks and carefully washed over a 1.41 mm. screen. The sediment slaked away more rapidly than did the calcareous shell material (probably because the shell material did not absorb the water as rapidly as did the sediment) and a few identifiable specimens could thus be obtained. In spite of all precautions, however, most of the fossils were destroyed by the wash water. Abundance of the more common and readily identifiable species was determined by noting relative numbers that appeared momentarily before they slaked away during the washing process. No actual count was possible. Approximately 50-75 pounds of sediment were processed.

The specimens from Station 7 were largely covered and filled in with cemented sand. Because the cementation occurred predominently around the fossils it would appear that the cementing material was derived from solution of the fossil shell material.

A special procedure was used to clean the fossils from Station 7 where a small amount of clay material exists in the cement. By boiling the fossils in a strong solution of Calgon, portions of the cemented material were sufficiently loosened to be removed with a chisel, a stiff scrub brush, and a stiff tooth brush.

Fossil Occurrences

Beds which contain fossils are listed below by station. Many beds listed in the stratigraphic section of this paper are not mentioned below. If so, it may be assumed that no fossils were found in those beds. There are three columns in each of the following lists. The first column gives the name of the species, the second column, the relative abundance and the third column the time range. Only the range of a fossil as it is related to the *Exogyra ponderosa* and *Exogyra costata* zones is considered. These two zones encompass all outcropping Upper Cretaceous rocks in North Carolina which are known to contain animal fossils. Figure 19 shows the vertical range of the zones. (See Figure 20 for stratigraphic relationships).

Faunal Zone	American Standard Section	European Type Section	North Carolina Section	
Exogyra costata	Navarro Group	Maestrichtian	Peedee fm.	
Exogyra ponderosa zone	Taylor Marl	Campanian	Black Creek fm.	Snow Hill member
	Uppermost Austin Chalk	Santonian (?)		Bladen member

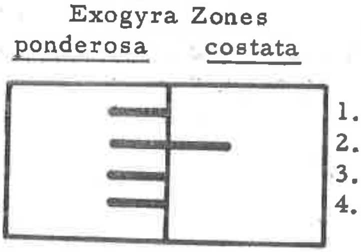
Figure 19. Range of the *Exogyra ponderosa* and *Exogyra Costata* assemblage-zones.

Station 1

Bed 2, Basal Peedee fm. (="Snow Hill mbr."), CFA1**

Macrofossils

1.	*Cardium donohuense**	AA
2.	*Arca (Barbatia) bladenensis*	A
3.	*Arca (Barbatia) carolinensis**	A
4.	*Anomia lintea donohuense**	C

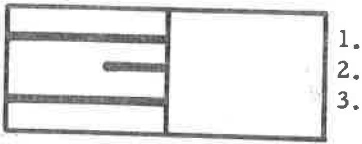


Station 2

Bed 1, Upper Black Creek fm., CFA2, CFA3

Foraminifera

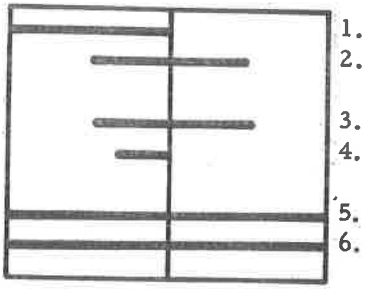
1.	*Cibicides subcarinatus*	A
2.	*Anomalina henbesti*	C
3.	*Robulus pseudosecans*	RR



Bed 2, Basal Peedee fm., CFA4, CFA5

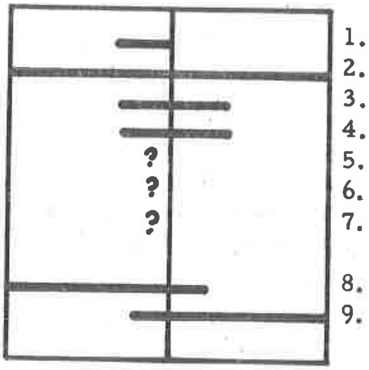
Foraminifera

1.	*Cibicides subcarinatus*	AA
2.	*Clavulinoides trilatera*	AA
3.	*Globulina sp.*, cf. *G. lacrima subspherica*	A
4.	*Anomalina henbesti*	C
5.	*Globigerinella sp.*, cf. *G. aspera*	C
6.	*Globigerina cretacea*	R

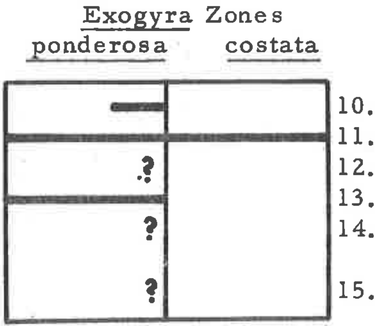


Macrofossils

1.	*Ostrea blackensis*	AA
2.	*Anomia argentaria*	A
3.	*Exogyra costata spinosa*	A
4.	*Ostrea pratti*	A
5.	Boring Pelecypods	C
6.	*Cliona sp.*	C
7.	Encrusting Bryozoa	C
8.	*Exogyra ponderosa erraticostata*	C
9.	*Ostrea falcata*	C



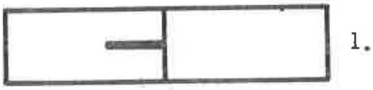
10.	Anomia lintea donohuense*	R
11.	Ostrea plumosa	R
12.	Serpula sp.	R
13.	Anomia olmstedi	RR
14.	Dinosaur bones, femur and tarsal	RR
15.	Gryphaea sp. (type A)	RR



Immediately upstream from Station 2
Basal Peedee fm. (="Snow Hill mbr.")

Macrofossils

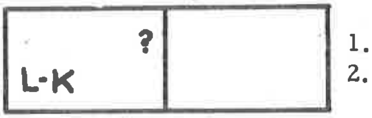
1.	Cardium donohuense*	AA



Station 3
Bed 1, Upper Black Creek fm., CFA6

Foraminifera

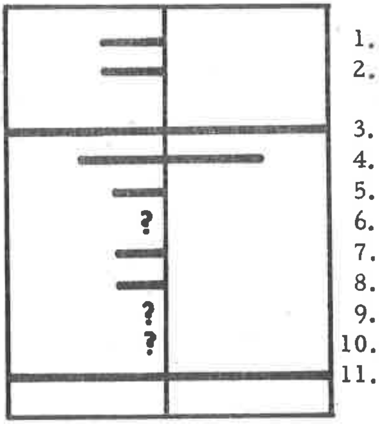
1.	?. Psammosphaera sp.	A
2.	Discorbis sp., cf. D minima	R



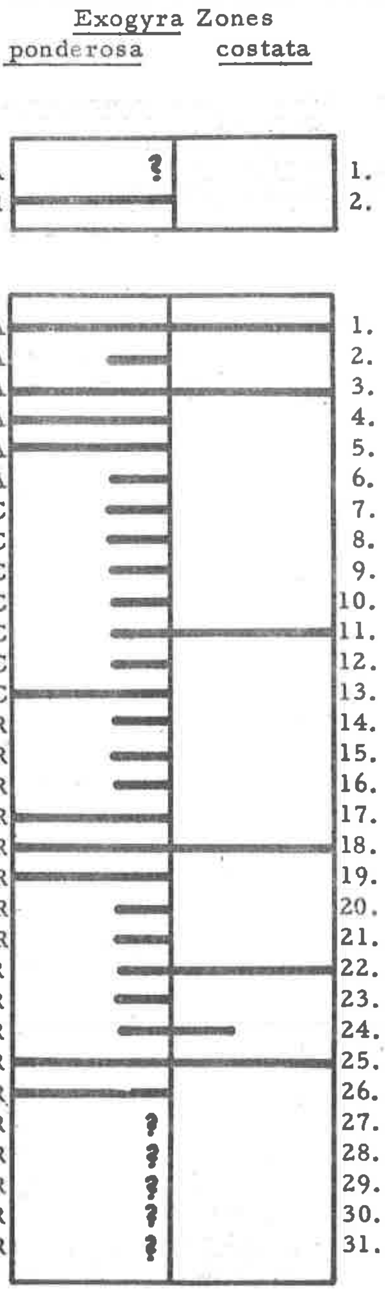
Bed 3, Basal Peedee fm. (="Snow Hill mbr.") CFA10

Macrofossils

1.	Ostrea blackensis	AA
2.	Cardium sp., cf. C. donohuense*	A
3.	Anomia argentaria	C
4.	Arca (Barbatia) bladenensis	C
5.	Ataphrus kerri*	C
6.	Serpula sp.	C
7.	Anomia lintea donohuense*	RR
8.	Crassatellites conradi	RR
9.	Inoceramus sp.	RR
10.	Pugnellus sp.	RR
11.	Turritella sp., cf. T. trilira	RR



Station 4
Bed 2, Basal Peedee fm. (="Snow Hill mbr."), CCA2



Foraminifera

1.	? Psammosphaera sp.	AA
2.	Robulus pseudosecans	RR

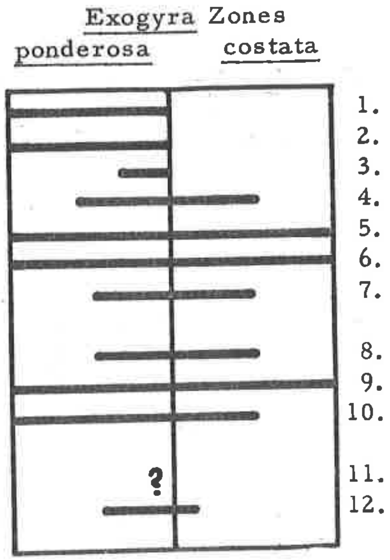
Macrofossils

1.	Cyprimeria depressa	AA
2.	Lucina parva	AA
3.	Anomia argrentaria	A
4.	Anomia olmstedi	A
5.	Corbula oxynema	A
6.	Pholadidea fragilis*	A
7.	Trigonia bartrami	C
8.	Cyprimeria gabbi	C
9.	Turritella quadrilira	C
10.	Corbula bisulcata	C
11.	Ostrea falcata	C
12.	Cardium vaughani	C
13.	Exogyra ponderosa	C
14.	Aphrodina regia	R
15.	Ataphrus kerri*	R
16.	Trigonarca elongata	R
17.	Turritella kerrensis*	R
18.	Veniella conradi	R
19.	Striarca perovalis*	R
20.	Legumen carolinense	R
21.	Nucula stantoni	RR
22.	Ostrea tecticosta	RR
23.	Arca sp., cf. A. carolinensis*	RR
24.	Exogyra costata spinosa	RR
25.	Ostrea plumosa	RR
26.	Crassatellites conradi	RR
27.	Bryozoa	RR
28.	Vertebrate fragments	RR
29.	Hamulus sp.	RR
30.	Seminola sp.	RR
31.	Gryphaea sp. (type B.)	RR

Station 7

Bed 1, Basal Peedee fm., CGA8

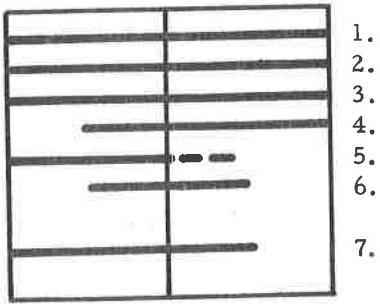
Foraminifera



1.	Cibicides subcarinatus	AA
2.	Robulus pseudosecans	AA
3.	Anomalina henbesti	A
4.	Clavulinoides trilatera	A
5.	Globigerinella sp., cf. G. aspera	A
6.	Nodosaria affinis	A
7.	Globulina sp., cf. G. lacrima subspherica	A
8.	Anomalinoides pinguis	C
9.	Globigerina cretacea	C
10.	Globotruncana sp., cf. G. austinensis	C
11.	? Psammosphaera sp.	R
12.	Robulus sp., cf. R. pondi	R

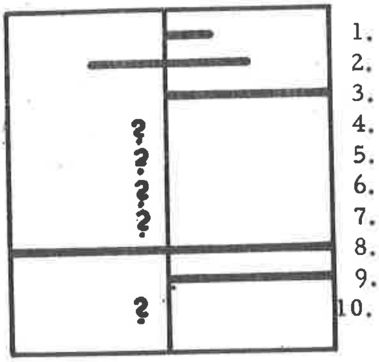
Bed 2, Peedee fm., CCA9

Foraminifera



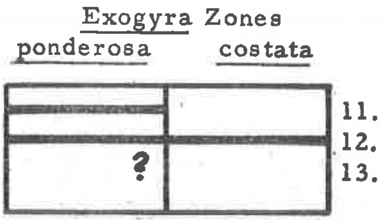
1.	Globigerina sp., cf. G. rugosa	AA
2.	Globigerinella sp., cf. G. aspera	AA
3.	Globigerina cretacea	A
4.	Gümbelina globulosa	A
5.	Gümbelina striata	A
6.	Globulina sp., cf. G. lacrima subspherica	A
7.	Globotruncana sp., cf. G. austinensis	C

Macrofossils



1.	Exogyra cancellata	AA
2.	Exogyra costata spinosa	C
3.	Pecten mississippiensis	C
4.	Cliona sp.	C
5.	Gryphaea sp. (type C)	R
6.	Pecten sp.	R
7.	Gryphaea sp. (type A)	RR
8.	Ostrea plumosa	RR
9.	Belemnitella americana	RR
10.	Turritella sp.	RR

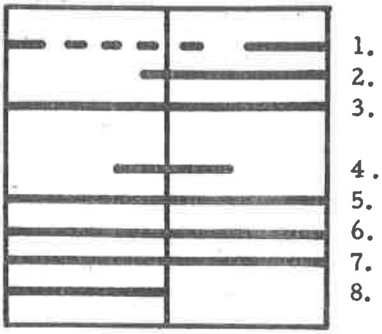
11. *Lima kerri* RR
12. *Anomia argentaria* RR
13. Fish vertebrae RR



Bed 3, Peedee fm., CCA10

Foraminifera

1. *Gümbelitria cretacea*, cf. *G. cretacea albertensis* AA
2. *Dorothia glabrata* A
3. *Globigerinella sp.*, cf. *G. aspera* A
4. *Globulina sp.*, cf. *G. lacrima subspherica* A
5. *Dorothia sp.*, cf. *D. bulleta* C
6. *Globigerina cretacea* C
7. *Globigerina sp.*, cf. *G. rugosa* C
8. *Textularia subconica* R



* Species not found outside of the North Carolina province and generally occurring in only 1 or 2 localities.

** Sample number.

In all, 53 kinds of macrofossils, including 38 pelecypods, 7 gastropods, 2 annelids, 1 cephalopod, and representatives from the phyla Porifera, Bryozoa, and Chordata, were collected and identified.

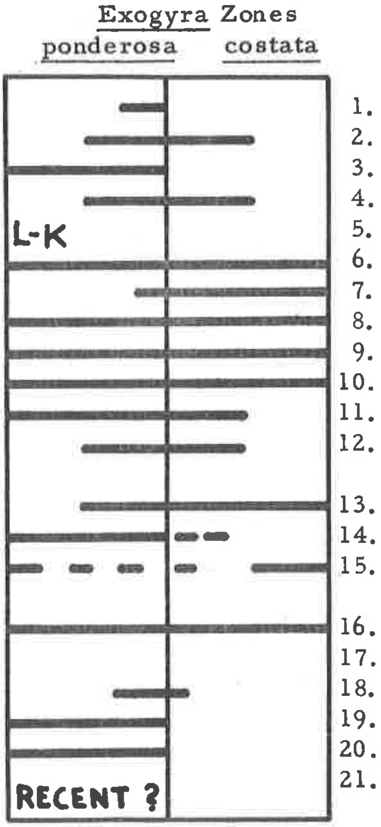
Approximately 80 kinds of Foraminifera were collected and identified, 21 of which appear in this paper. Only the Foraminifera which were abundant or appeared in more than one outcrop were used. The list below gives an alphabetical arrangement of all the fossil animals identified for this study. The range is noted as related to the *Exogyra ponderosa* and *Exogyra costata* zones. Each specimen is numbered consecutively without regard to the taxonomic position in the order in which they appear on Plates 1 through 9.

Faunal List

Phylum Protozoa

Class Sarcodina

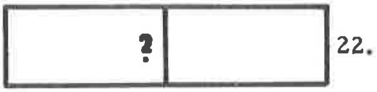
Order Foraminifera



1. *Anomalina henbesti*
2. *Anomalinoides pinguis*
3. *Cibicides subcarinatus*
4. *Clavulinoides trilatera*
5. *Discorbis sp.*, cf. *D. minima*
6. *Dorothia sp.*, cf. *D. bulleta*
7. *Dorothia glabrata*
8. *Globigerina cretacea*
9. *Globigerina sp.*, cf. *G. rugosa*
10. *Globigerinella sp.*, cf. *G. aspera*
11. *Globotruncana sp.*, cf. *G. austinensis*
12. *Globulina sp.*, cf. *G. lacrima subspherica*
13. *Gümbelina globulosa*
14. *Gümbelina striata*
15. *Gümbelitria cretacea*, cf. *G. cretacea albertensis*
16. *Nodosaria affinis*
17. ? *Psammosphaera sp.*
18. *Robulus sp.*, cf. *R. pondi*
19. *Robulus pseudosecans*
20. *Textularia subconica*
21. *Elphidium frizzelli*

Phylum Porifera

22. *Cliona sp.*



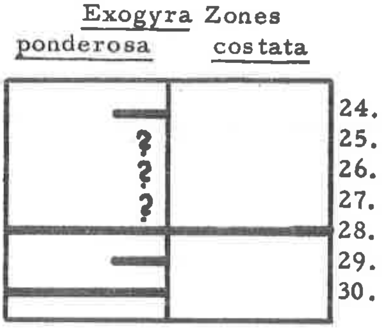
Phylum Bryozoa

23. Encrusting Bryozoa

Phylum Mollusca

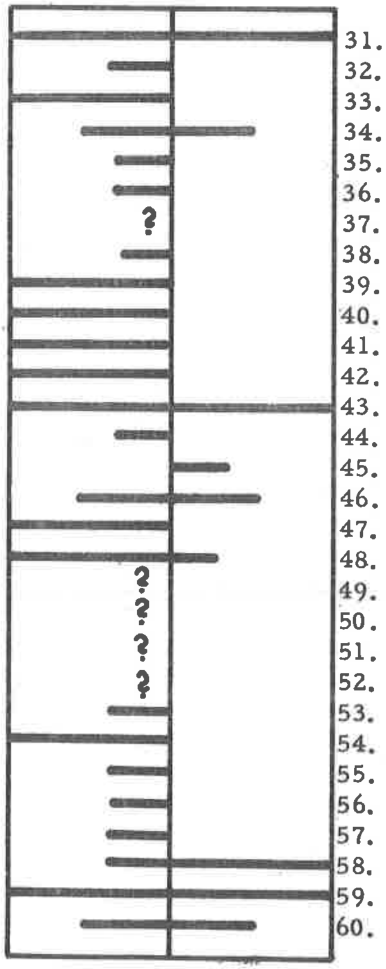
Class Gastropoda

24. *Ataphrus kerri**
25. *Pugnellus sp.*
26. *Seminola sp.*
27. *Turritella sp.*
28. *Turritella sp.*, cf. *T. trilira*
29. *Turritella quadrilira*
30. *Turritella kerrensis**

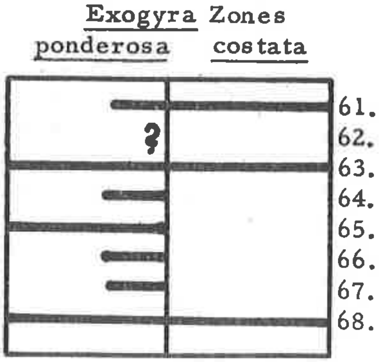


Class Pelecypoda

31. *Anomia argentaria*
32. *Anomia lintea donohuensis**
33. *Anomia olmstedi*
34. *Arca (Barbatia) bladenensis*
35. *Arca (Barbatia) carolinensis**
36. *Aphrodina regia*
37. Boring pelecypods
38. *Cardium donohuense**
39. *Cardium vaughani*
40. *Corbula bisulcata*
41. *Corbula oxynema*
42. *Crassatellites conradi*
43. *Cyprimeria depressa*
44. *Cyprimeria gabbi*
45. *Exogyra cancellata*
46. *Exogyra costata spinosa*
47. *Exogyra ponderosa*
48. *Exogyra ponderosa erraticostata*
49. *Gryphaea sp.* (type A)
50. *Gryphaea sp.* (type B)
51. *Gryphaea sp.* (type C)
52. *Inoceramus sp.*
53. *Lucina parva*
54. *Lima kerri*
55. *Legumen carolinense*
56. *Nucula stantoni*
57. *Ostrea blackensis*
58. *Ostrea falcata*
59. *Ostrea plumosa*
60. *Ostrea pratti*

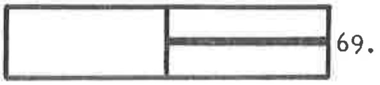


61. *Ostrea tecticosta*
62. *Pecten sp.*
63. *Pecten mississippiensis*
64. *Pholadidea fragilis**
65. *Striarca perovalis**
66. *Trigonarca elongata*
67. *Trigonia bartrami*
68. *Veniella conradi*



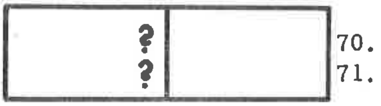
Class Cephalopoda

69. *Belemnitella americana*



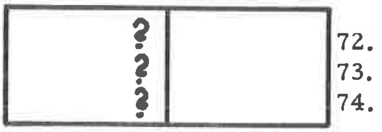
Phylum Annelida

70. *Hamulus sp.*
71. *Serpula sp.*



Phylum Chordata

72. Dinosaur bones
73. Fish vertebrae
74. Shark teeth



*Species not found outside of the North Carolina province and generally occurring in only 1 or 2 localities.

Correlation

The bulk of the fossil evidence listed above, tempered by the stratigraphic situation (see Figure 20) strongly suggests that all of the Cretaceous beds at Stations 1, 2 (along with beds just upstream from Station 2), and 3 were deposited during upper Taylor time and are equivalent to the upper Taylor rocks of Texas. This is important because the rocks at these three localities include lithologies representative of both the Black Creek and Peedee formations.

At Stations 4, 5, and 6 the evidence suggests that these beds were also deposited during upper Taylor time. Although no animal fossils were found at Stations 5 and 6, stratigraphic evidence indicates that the beds at the two Stations were deposited at the same time as beds at Station 4.

A greater range of time is indicated at Station 7 (see Figure 21) than at any other of the seven stations. Bed 1 is upper Taylor in age. Bed 2 is lower Navarro (Exogyra cancellata subzone), and Bed 3 is equivalent to the upper Navarro.

PALEOECOLOGY

A number of generalizations are made here concerning the ecologic situation of the several faunas encountered. This is by no means a thorough consideration of ecologic relationships, since in most cases a complete ecological framework does not exist in fossil faunas. Relationships of purely zoological interest are also omitted.

Characteristics of the Fauna

None of the species studied range into Recent time; however, there are several genera which are found in modern marine waters. The genera which range into the Recent are listed below with notes as to their habitat and occurrence.

Macrofauna

Anomia: marine epifauna, attaches by a calcified byssus to other shells and hard surfaces often clumped locally in large numbers, associated with the intertidal or nearshore subtidal zones.

Arca: marine epifauna, attaches to rocks and shells, associated with the intertidal zone often being found under rocks at low tide.

Cardium: marine infauna, near offshore in shallow water, associated with the breaker zone and deeper.

Cliona: marine epifauna, associated with the intertidal zone and near offshore. Permeates the shells of mollusca with canals (a boring sponge).

Corbula: marine shallow infauna, in sand, predominantly shallow water to 50 fathoms.

Crassatellites (=Crassatella): marine shallow infauna, in sand, common just offshore, habitat probably from beach to 60 fathoms.

Lucina: marine shallow infauna, in sandy mud, commonly from beach or just offshore to 50 fathoms.

Lima: marine epifauna, largely tropical, shallow water associated with the intertial zone, common under rocks at low tide.

Nucula: marine shallow infauna, common just offshore in mud, mostly shallow water, but also to 500 fathoms.

Ostrea: marine epifauna, common in intertidal zone and just offshore attaches to shells, rocks and other hard surfaces.

Pholadidea: marine epifauna, commensal on pelecypods (boring pelecypod).

Serpula: marine epifauna, common in areas of current and plentiful suspended food.

Turritella: marine infauna, mostly just offshore but also 1-100 fathoms.

Foraminifera

Anomalina: marine benthic, mostly shallow water, but occurs at depths to 2200 fathoms, not usually abundant in Recent seas. Rotaloid calcareous test.

Cibicides: marine benthic, found mostly on the open shelf, shallow water to 3000 fathoms, usually 5-500 fathoms, greatest abundance in depths of 50 fathoms and less. Rotaloid calcareous test.

Clavulinoides (?): marine benthic, 50-3000 fathoms, mostly 400-500 fathoms. Arenaceous test. (This genus may be Clavulina of some authors - the depth and occurrence data is from the genus Clavulina).

Discorbis: marine benthic, mostly shallow water, some to 1300 fathoms, commonly 15-50 fathoms. Rotaloid calcareous test.

Globigerina: marine pelagic - some benthic, most abundant in warm waters.

Globulina: marine benthic, mostly shallow water but occurs to 1500 fathoms, seldom abundant in Recent seas.

Nodosaria: marine benthic, mostly shallow warm water but occurs to 2000 fathoms, many species with a depth limit of 25 fathoms.

Robulus: marine benthic, seldom abundant in Recent seas; however, widespread. When abundant probably indicative of depth less than 200 fathoms. Depth ranges from 0 to 600 fathoms, most abundant 30-200 fathoms. Planispiral calcareous test.

Textularia: marine benthic, occurs in both shallow and deep water, most commonly 15-100 fathoms in warm water. Arenaceous test.

The following genera of Foraminifera are extinct; however, habitat and occurence have been postulated (Galloway, 1933).

Dorothia: marine benthic, shallow water. Arenaceous test.

Globotruncana: marine pelagic, warm shallow water.

Gümbelina: marine pelagic, found in shallow to deep water sediments.

Gümbelitria: marine pelagic, warm water.

The information concerning the habitat and occurence of the above genera was compiled from: Abbott (1954), Parker (1956), Shepard (1956), and Shepard and Moore (1955) for the macrofauna and Galloway (1933), Phleger (1955), Phleger and Parker (1951), Shepard (1956), and Shepard and Moore (1955) for the Foraminifera.

Black Creek Formation

Station 1

The Black Creek formation at Station 1 does not contain macrofossils. This is the result of an unfavorable environment and not the result of destruction of fossils after deposition, because there are a number of fairly well preserved Foraminifera occurring in the sediment. Foraminifera are present but not abundant.

Station 2

Here the Black Creek formation is again devoid of macrofossils for reasons explained above. Foraminifera are not abundant and only a few species are present. All of the Foraminifera have rotaloid and planispiral calcareous tests and all are benthic. A Cibicides subcarinatus community characterizes the fauna from this outcrop.

Station 3

Macrofossils have not been collected from this locality and it is again assumed that the original environment was not conducive for establishment by invertebrates except Foraminifera. Although Foraminifera do occur at Station 3, they are more rare than at Station 2. The preservation is such that few specimens can be positively identified.

There are objects in this outcrop varying in diameter around a mode of 0.3 millimeters. The objects are arenaceous, irregular, hollow spheres composed of quartz, glauconite and mica grains, loosely cemented with calcareous cement and lined with an inner calcareous layer. No aperture is apparent on any of the spheres. Because of the above characteristics and because the objects occur in various lithologies (silt-shale, this station - see Figure 17, sample CFA6; very fine silty sand, Station 4 - see Figure 18, samples CCA1, CCA2; fine silty sand, Station 7 - see Figure 18, sample CCA8) there can be little doubt that they are organic in nature, and so similar in overall architecture to arenaceous Foraminifera that they are here referred questionably to the genus Psammosphaera. The reason for questionable generic assignment is because they differ in lacking evidence of an internal chitinous layer and in being composed of a mixture of some coarse and predominantly fine clastic fragments. Unlike most species of Psammosphaera there is little selectivity of mineral composition.

The Foraminifera other than ? Psammosphaera are rotaloid and calcareous. A ? Psammosphaera community characterizes the fauna at Station 3.

Peedee Formation

Station 1

The Peedee fauna at Station 1 is composed of only a few species (4 were identified), but a large number of individuals. All of the individuals are epifauna which are usually attached to a hard substrate by a byssus. No Foraminifera were collected from this outcrop because of the solution and recementation of calcium carbonate. The fauna at this locality is characterized by a *Cardium donohuense* community.

Station 2

Could the basal Peedee here have been observed as it was during deposition, it might well have been called an oyster reef. The macrofossils are abundant and further, there are a large number of species (at least 15, representing a fraction of the number of species that must have lived in this environment). Succession by sessile organisms must have been near climax because many of the shells and several sand clumps are bound together by encrusting Bryozoa. An anomalous dinosaur femur found in these beds is encrusted with Bryozoa and valves of *Ostrea* and *Exogyra*. *Anomia* is the only byssal form present. There is a normal mixture of epifauna and infauna as might be expected in such a reef deposit where some current is usually present. Epifauna dominates with *Ostrea blackensis*, *Ostrea pratti*, and *Anomia argentaria* characterizing the macrofauna community.

Foraminifera are abundant, more so than in the underlying Black Creek formation. Surprisingly, those Foraminifera that are abundant in Black Creek are the most abundant species in the Peedee formation with 2 additions, *Clavulinoides trilatera* and *Globulina* sp., cf. *G. lacrima subspherica*. *Cibicides subcarinatus* and *Clavulinoides trilatera* characterize the foraminiferal community. Most of the Foraminifera are rotaloid, calcareous benthic forms, while benthic arenaceous species are also prominent. A few pelagic forms are present.

Station 3

The community at Station 3 is similar to that at Station 1 with the exception that there are more species at Station 3. This is perhaps due to better preservation at Station 3, but since the preservation at

Station 3 and Station 1 appear to be similar, the difference is probably due to a shoreward (up dip) difference in environment at Station 3. The difference results (at Station 3) in a greater diversity of pelecypods (most of which are attached epifauna), a greater number of gastropods (most of which are infauna), and the appearance of a large number of Serpula - a form dwelling in slow currents. This community approaches a reefal nature and is characterized by Ostrea blackensis and Cardium donohuense. Foraminifera if present were not preserved because of the high degree of solution and recalcification within the sediment.

Station 4

(Formerly Snow Hill Member)

The macrofauna at Station 4 is exceptional because of the large volume of fossils and the large number of species preserved. As mentioned before, the fossils are poorly preserved, although it is possible to recover a surprising number of species. At least 33 species of invertebrates were recovered. The community is dominated by pelecypods which in this case, unlike the communities previously considered, are predominantly shallow infauna. Cyprimeria depressa, the most abundant species, and Lucina parva characterize the community. Trigonia bartrami, although represented by a smaller number of preserved individuals, because of their large size, may have had a standing crop biomass equal to or greater than either of the other two characteristic species, therefore equally as important to the community. Infaunal gastropods are numerous, especially Turritella quadrilira.

Foraminifera are rare. Only one specimen of Robulus pseudosecans and several ? Psammosphaera sp. identical to those mentioned from Station 3 were recovered. ?Psammosphaera sp. at these two localities may indicate synchroneity.

Stations 5 and 6

(Formerly Snow Hill Member)

The rocks at Stations 5 and 6 are essentially identical. There are no Foraminifera and no macrofossils present. This situation may be due to failure of the fossils to be preserved (see comments under Environment of Deposition - Station 4). The wood in the sediments (leaves, seeds, twigs, etc.) is well preserved and the sediments themselves are otherwise unaltered.

Station 7

Station 7 has a succession of Peedee sediments which represent a greater span of time then the sediments of the previously mentioned localities; therefore, the communities will be discussed by bed in ascending order.

(Bed 1)

No macrofossils were found in Bed 1. Foraminifera are abundant, comprising as much as 1% of the total volume of the sand fraction. The community contains a striking diversity of species being almost wholly dominated by benthic, rotaloid, calcareous individuals with only a small percentage of benthic arenaceous forms and pelagic specimens. Clavulinoides trilatera was the most prominent arenaceous Foraminifera because of its large size. The community is characterized by Cibicides subcarinatus, Robulus pseudosecans, and Anomalina henbesti. A few ?Psammosphaera sp. are present.

(Bed 2)

Bed 2 contains a distinctive macrofossil assemblage in that almost all of the specimens recovered were Exogyra cancellata valves which characterize this community. Nearly 100 right valves were collected from an estimated half cubic yard of material with a lesser number of left valves. Very characteristic but of less importance to the community is Exogyra costata spinosa and Pecten mississippiensis. Also important is the presence of Cliona sp. in a fairly large per cent of the right valves of Exogyra.

Bed 2 contains a larger volume of Foraminifera than Bed 1, estimated to be about 2% of the total volume of the sand fraction. Although pelagic Foraminifera are more abundant than the benthic types, benthic Foraminifera are present even though none have been listed in the paper. Globigerina sp., cf. G. rugosa and Globigerinella sp., cf. G. aspera characterize the Foraminifera community. This bed contains a transition from benthic to pelagic species.

(Bed 3)

In Bed 3 there is a further change from benthic to pelagic species to the point of near exclusion of the benthic and rotaloid forms. About 3% of the sand fraction is Foraminifera showing an increase in volume over beds 1 and 2. The most striking aspect of this Foraminifera community is the exceedingly large number of the small *Gümbelitria cretacea*, cf. *G. cretacea albertensis*. Even though this is the smallest Foraminifera collected, its standing crop biomass must have approximated a third of the total volume of Foraminifera. Seemingly anomalous is the presence of a large number of benthic arenaceous forams such as *Dorothia glabrata*, *Dorothia sp.*, cf. *D. bulleta* and *Textularia subconica* in the planktonic community while other benthic forms are absent.

Bed 3 does not contain macrofauna.

CONCLUSIONS

Time of Deposition

It has already been concluded that the time of deposition of all the Cretaceous sediments studied with the exception of beds 2 and 3 at Station 7 (Little Contentnea Creek) was during upper Taylor time. However, more refined time relationships can be established between some of the various stratigraphic units. Frequent reference to Figure 20 will facilitate the reading of this section.

Along the Cape Fear River outcrops, beds 1 and 2 at Stations 1 and 2 (Milepost 49) are of upper Taylor age, as is bed 3 at Station 3 (Walker's Bluff).

Bed 2 at Milepost 49 and bed 3 at Walker's Bluff possess fossil faunas that are very similar, their lithologies are similar, and their projected dips coincide. It is concluded that these "two" beds are actually parts of the same lithostratigraphic unit and were deposited at the same time. Furthermore, the foraminiferal data from bed 2, Milepost 49, suggest that this bed was deposited at the same time as bed 1 at Station 7, Scuffleton, North Carolina.

The only data that associate bed 2 at Station 4 with the time of deposition of any other outcrop is the presence of ?*Psammosphaera* sp. in some abundance in the bed and in bed 1 at Milepost 60 (Station 3), Cape Fear River.

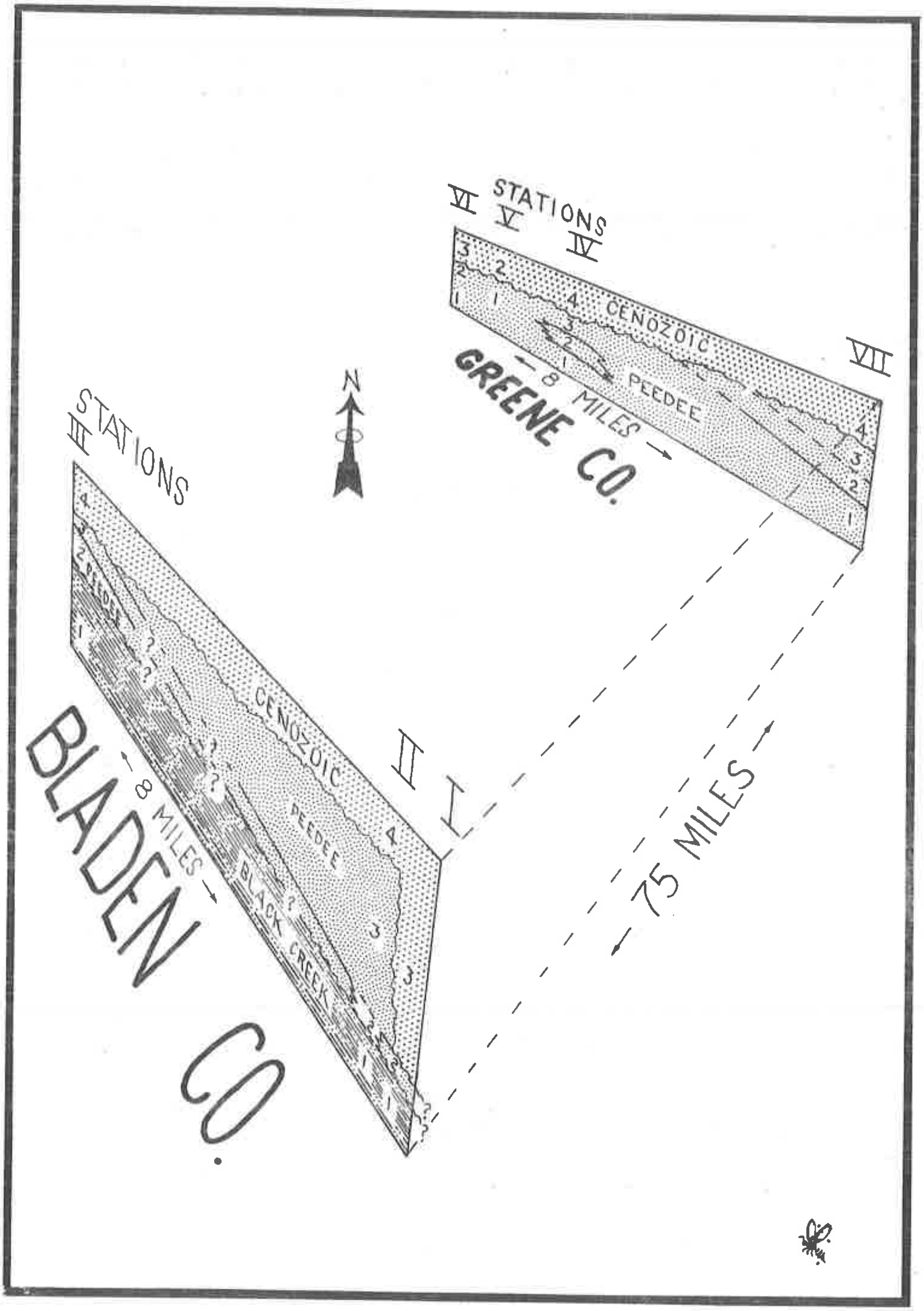


Figure 20. Cross-sections of the Cape Fear River (Bladen Co.) and Contentnea Creek (Greene Co.) Areas (not to scale).

Evidence that bed 1 at Station 7 is younger than bed 2 at Station 4 lies in the fact the bed 1, Station 7, is approximately 8 miles down dip from bed 2, Station 4, yet topographic maps with a contour interval of 10 feet indicate that both beds are at about the same elevation - 20-30 feet above mean sea level. With allowance for a dip of only 3 feet per mile (estimate - about half of the known dip of the Cape Fear River outcrops), bed 1, Station 7, would be approximately 24 feet higher stratigraphically than bed 2, Station 4.

Even more convincing evidence is the presence of a lithology identical to that at bed 3, Station 4, cropping out in the stream bed of Little Contentnea Creek just a few yards down stream from Station 7 toward the bridge at Scuffleton. The outcrop in the stream bed is about 5-10 feet below the outcrop at Station 7. The principle lithologic difference between bed 3, Station 4, and bed 1, Station 7, is that the latter is somewhat coarser and not as well sorted. In other aspects they are similar.

Time and Lithologic Relationships

In the past the Peedee and Black Creek formations have been identified in the field largely by their characteristic lithologies except when fossils were present. Then the fossil evidence was given greater weight in identifying the lithologic unit. For instance, at Milepost 49, Cape Fear River, Bed 1 definitely has the Black Creek shale lithology. The overlying beds form a massive sandstone which has many lithologic affinities to the Peedee formation. Still the sandstone beds have been called "Snow Hill" by some authors in spite of the fact that they in no way resemble the Black Creek formation. In the absence of fossils any observer would be forced to agree that the sandstone beds at Milepost 49 are part of the Peedee formation.

At several outcrops along the Cape Fear River from Milepost 49 to Milepost 60 an indurated calcareous sandstone bed identical to Bed 2, Station 1, can be found overlying the typical Black Creek beds with an unconformity between. This bed is a sandstone and not a shale, yet it has been placed in the Black Creek formation because it contains "Snow Hill" fossils.

It becomes increasingly apparent that along the Cape Fear River from Milepost 49 to Milepost 60 there are definitely two distinct lithologies representing two distinct formations, the Black Creek formation, which is a silt or clay shale and the Peedee formation, which is a quartzwacke. Here, both units were deposited during upper Taylor time, the time of deposition for the "Snow Hill member".

The situation as it exists on the Cape Fear River, disregarding any breaks in deposition, may be as shown in Figure 21. Upstream and updip from Elizabethtown the Black Creek formation was, without doubt, deposited during Taylor time represented by the *Exogyra ponderosa* zone (or older near the base), downstream and downdip from Milepost 60 to at least Milepost 49, both the Black Creek and Peedee formations were also deposited during Taylor time. Downstream from Milepost 49 only Peedee lithology is encountered, all of which was probably deposited during Navarro time represented by the *Exogyra costata* zone.

In the subsurface toward the present ocean, the *Exogyra ponderosa* zone representing Taylor time probably falls entirely within the Peedee formation (Figure 21). Further, the basal Peedee rocks could be as old as Austin time if rock and assemblage zone dips continue to diverge eastward.

Conversely, if the Upper Cretaceous beds that have been eroded away were restored, the Black Creek formation in the updip direction could have been deposited at least in part during Navarro time.

The stratigraphic situation along the Cape Fear River indicates an onlap condition during Upper Cretaceous time with an encroachment of the ocean onto a gently sloping coastal plain. Further evidence for an onlap condition is presented below in the conclusions concerning environment of deposition.

It is easy to imagine Black Creek rocks and Peedee rocks being deposited at the same time if we consider the present Carolina coast. Marine sands analogous to the Peedee formation are now being deposited offshore. Shoreward the typical marine sands change into the delta, river, and marsh sediments analogous to the Black Creek formation - both types of sediments being deposited at the same time. If in the course of time our present ocean slowly encroached onto the present coastal plain, the "Black Creek" type sediments would be deposited further inland and would be younger. The "Peedee" type sediments would be deposited further inland on top of the "Black Creek" type sediments previously deposited giving a condition very reminiscent of the Upper Cretaceous stratigraphy along the Cape Fear River.

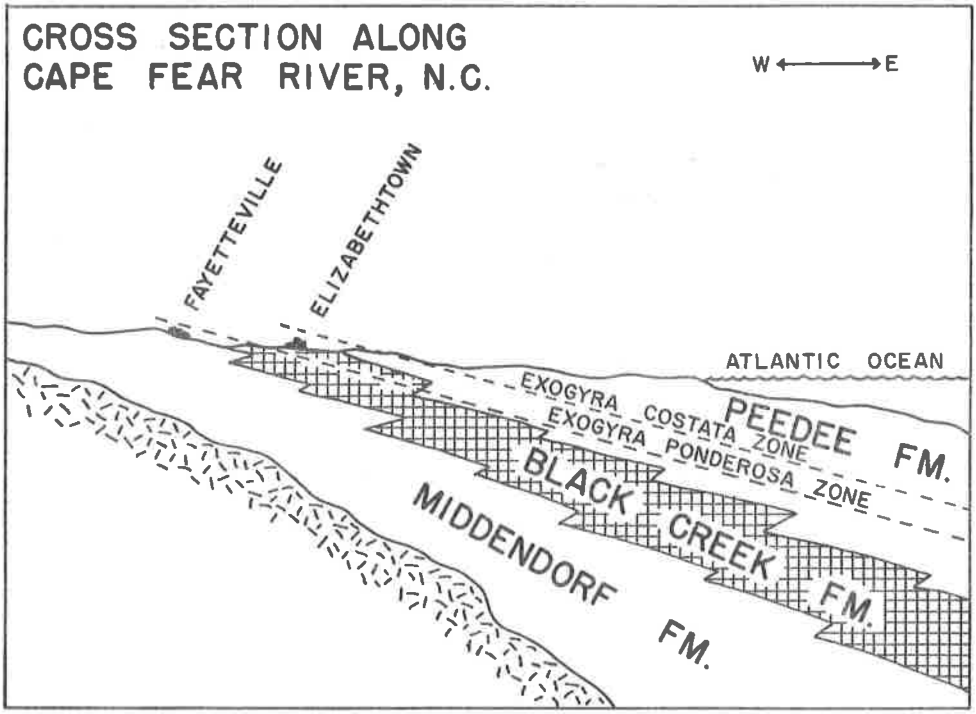


Figure 21. Generalized cross-section along the Cape Fear River with time of deposition indicated by assemblage-zones.

In the Contentnea Creek Area there are no shales typical of the Black Creek formation. All of the rocks at all stations are (sand or silty sand):(quartzwacke). There is a difference, however, between the sandstones at Stations 4, 5, and 6 and Station 7. The sandstones at Stations 4, 5, and 6 are finer grained and better sorted than the sandstones at Station 7. The rocks at Stations 4, 5, and 6 are type "Snow Hill" rocks as this is the locality designated the type area for the "Snow Hill member" by Stephenson (1923, p. 10). The "Snow Hill member" is supposed to be a part of the Black Creek formation, yet it can be seen from coarse-fraction data (Figures 17 and 18) and from Figure 22 that the "Snow Hill" rocks are more closely related to the Peedee formation than to the Black Creek formation.

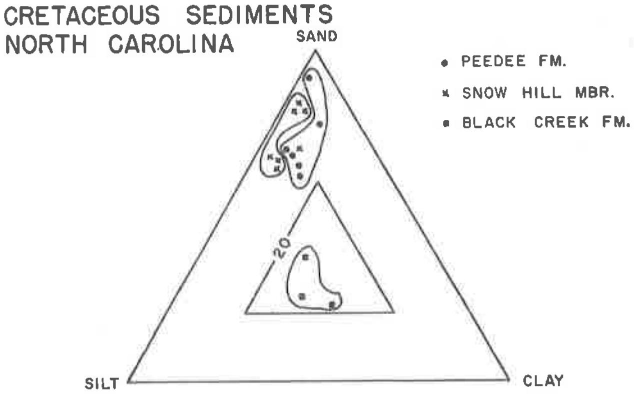


Figure 22. Triangle diagram showing distribution of sand, silt, and clay in the Black Creek and Peedee formations and in sediments from the type area of the "Snow Hill member".

It has been accepted for some time (Cohee, 1956, p. 2004) that formations and members be designated on the basis of lithologic characteristics and not on the basis of enclosed fossils unless they are important lithologic constituents. Since (1) the sediments of the "Snow Hill member" more closely resemble Peedee sediments than Black Creek sediments, (2) fossils are not important lithologic constituents (indeed they are rare, see Figure 18, samples CCA1-7) and (3) as originally defined by Stephenson (1923, p. 8)

> "The line of division between the two formations (Black Creek and Peedee) has been drawn at the top of the transition beds carrying the Snow Hill fauna, or at the point where the materials become finally of a true marine character."

at least the upper boundary of the "member" is an assemblage-zone boundary (Hedberg, 1957, p. 1881) and not a lithostratigraphic boundary, it is here proposed that the term "Snow Hill calcareous member" be abandoned and that the sediments at Snow Hill, North Carolina, be included as part of the Peedee formation (basal) as well as other similar unlaminated sediments from other localities heretofore designated "Snow Hill calcareous member". Assignment of the strata which have been designated as "Snow Hill member" to the Black Creek formation is not warranted. The lithology is close, though admittedly not identical, to that of the Peedee formation. The "Snow Hill" might be considered a member of the Peedee formation, though we believe the small difference in lithology observed in outcrops does not warrant this. If future work from subsurface data should reveal that a member category is useful, it should be justified on a lithologic basis and not on fauna. The term Black Creek formation should connote dark gray to black laminated shales with intercalated layers of clean sand as originally intended and the term should not be confused by lumping-in a number of extraneous associated overlying lithologies merely because they contain fossils from the Exogyra ponderosa zone (Taylor time).

Environment of Deposition

One of the best ways to characterize Recent sediments is with the coarse-fraction method (Shepard, 1954). Two areas in North America have been thoroughly described in this manner. Shepard and Moore (1955) have studied the sedimentary environments in the Central Texas Coast area and Shepard (1956) has done a sufficiently complete description of the East Mississippi Delta area. Fortunately the faunas from these two areas have also been well characterized by Parker (1956), Phleger (1951 and 1955), Shepard and Moore (1955) and Shepard (1956). The conclusions to follow are the result of a comparison of a composite of information available from the northern Gulf of Mexico region with the Cretaceous fauna and sediments from North Carolina.

There are no Recent species that occur in the Cretaceous sediments; however, there are a large proportion of Recent genera (21 of 69 identified) that occur in the Cretaceous rocks. It is here assumed that genera are sufficient for general comparisons in order to help characterize the physical environments in which the Cretaceous animals lived and in which the Cretaceous sediments were deposited.

In the following discussions the water depths existing at the time of deposition of the Cretaceous sediments are estimated through analogy with the Recent sediments in the area of the Mississippi Delta. Depositional depths of the Recent sediments there have been studied by

Shepard and Moore (1955) and by Shepard (1956).

It will be convenient to refer to Figure 20 while reading this section in order to keep stratigraphic relationships in mind.

Station 1

Bed 1, Black Creek fm., no sample. Same as Bed 1, Station 2.

Bed 2, Basal Peedee fm. "Snow Hill mbr.", Sample CFA1. The presence of the genera *Anomia*, *Arca*, and *Cardium* in this bed suggest that the sediment was deposited in shallow sea water. Infauna are absent indicating that the environment of the substrate was too rigorous for the survival of most infaunal forms. The sand is fine to medium in size and is fairly well rounded. All of these data tend to support the thesis that the sediment was deposited just off shore, perhaps as much as 1 mile, in the breaker zone and in water less than 20 feet deep. According to Shepard and Moore's classification (1955, p. 1503, 1535) the situation would best compare to a subaqueous extension of the "gulf beach" environment.

Station 2

Bed 1, Black Creek fm., Samples CFA2 and CFA3. The two samples from this bed were essentially alike, containing an abundance of mica (3-5%), considerable glauconite (2-5%) and a large amount of clay and silt. The most important aspect of this bed is the presence of distinct lamination and bedding indicating that the sediments were controlled by a fluctuating aqueous aggradation agent during deposition and that the beds were not disturbed by marine infauna during deposition. The absence of fossils and the undisturbed lamination indicates that no marine macroinfauna lived in this environment. There is a significant amount of organic matter present and a few Foraminifera. The coarse-fraction study best agrees with Shepard and Moore's (1955, p. 1502, 1531) "bays near rivers" environment. There are, however, two anomalies: 1) the large percentage of silt and 2) Foraminifera which are not distinct for low salinities. Low salinity Foraminifera are generally arenaceous (Phleger, 1955, p. 723 and Shepard, 1956, p. 2572-2573). It seems unlikely that the sediments were from a delta formed in a lagoon. The delta environments in the East Mississippi Delta offer better material for comparison. Shepard (1956, p. 2601-2602) states that lamination (of the type found at Bed 1) is found in the Mississippi Delta in river channels, on the platforms outside the distributaries and in the interdistributary bays. The high percentage of mica and the low percentage of Foraminifera suggests that the sediments in Bed 1 were deposited very close to a delta distributary perhaps on a platform outside a distributary. The Foraminifera are normally scarce in this environment but when they are found they are not of the arenaceous type typical of the marsh and bay environment. Although the Cretaceous percentage of glauconite is much higher than that for the platform areas of the Mississippi Delta, the difference can be explained by a slower rate of detrital accumulation in the Cretaceous sediments (Cloud, 1955, p. 490). Shepard (1955, p. 1493) indicates that the rate of deposition in the Mississippi Delta is rapid. Also, the low figure for the Cretaceous wood can be explained by a slower rate of deposition, in that organic material which is covered at a slow rate is decomposed more completely by bacteria and, therefore its chances of survival would be less than in an environment of more rapid deposition.

The depth of water in which Bed 1 was deposited is estimated at about 10-20 feet (the depth at which most of the Mississippi Delta platform environments are found).

Bed 2, Basal Peedee fm. "Snow Hill mbr.", Sample CFA4. The Recent sedimentary environment which is most comparable to the environment responsible for Bed 2 is found in Breton Sound (East Missisippi Delta region) in the "inlet" environment just behind Breton Island (Shepard, 1956, p. 2554-2582). Bed 2 was not deposited directly in an inlet where strong currents could sweep it with every wind and tide, but off to the side where enough protection was afforded to foster the large Ostrea population so evident in this Cretaceous rock. Factors which point to such an environment are: (1) about 10% silt and 10% clay, (2) approximately 80% coarse-fraction with a modal sand class of medium sand (1/2-1/4 mm.), (3) a large percent of shells (6% is estimated, but this is probably a low figure), (4) 1-10% wood (5) less than 0.5% glauconite, (6) less than 1% Foraminifera, (7) less than 1% mica, (8) Foraminifera of type usually found in a shallow sound with fresh water influence - benthic calcareous rotaloid and planispiral tests and a large fraction of benthic arenaceous types, (9) non-laminated sediments, (10) annelids common to shallow sounds and current water, (11) Bryozoa common to shallow water in the presence of some current, (12) presence of Cliona and boring pelecypods both of which are common in the intertidal or subtidal regions of sounds where some current is present. A few pelagic Foraminifera are present in this Cretaceous bed, but they were perhaps blown in or carried in by the tide from the near by open ocean.

Of interest is the presence of a dinosaur femur that must have come from a carcass which had been carried to the Cretaceous sound and subsequently lodged against the barrier. The bone was partially encased by fossils of sessile organisms (Bryozoa, Ostrea and others).

The water in which this bed was deposited must not have been over 10 feet deep and was probably less.

Bed 3, Peedee fm., Sample CFA5. The outstanding characteristics of this bed are (1) 60% sand with a fine sand modal class (1/4-1/8 mm.), (2) 22% silt, (3) 12% clay, (4) around 1% wood, (5) less than 1% mica, (6) about 1% Foraminifera which are shallow water, slightly subsaline types containing a large volume of benthic rotaloid and arenaceous tests, (7) more than 1% shells, and (8) around 1% glauconite.

The macrofauna present consisted largely of Exogyra costata spinosa and Ostrea falcata, forms which do not have modern counterparts.

The best published comparable environment available is again in the East Mississippi Delta region in the "open lagoonal inlet" environment southwest of Breton Island (Shepard, 1956, p. 2551 and Parker, 1956, p. 312). The sediments from the Recent environment and from Bed 3 compare closely. Bed 3 seems to indicate a deepening of the water over that indicated for Bed 2 yet there is still an association with some type of barrier or reef and with an environment which has a considerable amount of current. It is believed that Bed 3 was deposited a short distance seaward from a barrier ridge in an inlet with a depth of approximately 20-30 feet.

Station 3

Bed 1, Black Creek fm., Samples CFA6 and CFA7. As in Bed 1, Station 2, the presence of distinct lamination, high percentage of wood, the near absence of macrofossils (a few shell fragments occur), and the rarity of Foraminifera suggests an environment closely associated with a delta. The principal difference between this bed and Bed 1, Station 2, is the presence of much thicker quartz sand layers between the clay layers (Sample CFA7) and greater volume of wood. The coarse-fraction study from one of the sand layers (Figure 17, p. 77, Sample CFA7) indicates a volume of glauconite as high as 8%. There is the possibility that the glauconite estimated for Sample CFA6 (2%) came largely from the sand layers which were taken with the shales. Nevertheless glauconite was observed in the shales. The sand layers appear to be material that was washed into the environment in which the shales were being deposited. Comparing the coarse-fraction data with that from the Gulf Coast, it is probable that Bed 1 falls into the category of "delta front platform" sediments (Shepard, 1956, p. 2551-2581) much like those that occur directly in front of the mouths of Pass a Loutre and Southeast Pass (Mississippi Delta distributaries). The absence of most Foraminifera except a few abraded benthic rotaloids and the presence of the arenaceous ?Psammosphaera sp. lends some credence to this contention. This sediment was probably deposited in water less than 10 feet in depth.

Bed 2, Basal Peedee fm., - "Snow Hill mbr.", Sample CFA8, Bed 2 sediments closely resemble sediments from an area east of the Mississippi Delta which is designated as the "reworked Mississippi delta" area (Shepard, 1956, p. 2551-2581) and is characterized by a paucity of shells, Foraminifera, wood, and mica. A high concentration of glauconite suggests that if this sediment were deposited in an area of reworking as supposed, then the ancient environment was stable for a longer period of time than the comparable environment east of the Mississippi Delta. One of the more noticeable aspects of this deposit is the concentration of sand in the medium sand class of (1/2-1/4 millimeters).

The nearest comparable environment in the Central Texas Coast area is the "gulf beaches" environment (Shepard and Moore, 1955, p. 1535). The correlation is poor compared to that between the "reworked Mississippi delta" environment and Bed 2.

Sample CFA9 is from a small set of shaley cross-bedding within Bed 2. The primary purpose for taking this sample was to search for Foraminifera. Fine-grained sediments more often contain Foraminifera than coarser grained sediments. Two Elphidium frizzelli specimens were taken from the clay, but since the overlying Bed 3 is definitely Cretaceous it is assumed that the Recent foraminiferan is a contaminant from fossiliferous, Tertiary, Bed 4 overlying Bed 3. Bed 2 was probably deposited in water shallower than 60 feet.

Bed 3, Basal Peedee fm. - "Snow Hill mbr.", Sample CFA10. Because of the degree of induration, Bed 3, like Bed 2, Station 1, could not be studied by the coarse-fraction method. The nature of the Cretaceous fauna as described above, however, suggests an environment comparable to Parker's "upper sound" environment (Parker, 1956, p. 326). The small amount of glauconite noticeable in hand samples is compatable with the assumption of the environment.

Coincidental evidence that tends to substantiate the hypothesis that Bed 3 is an "upper sound" deposit lies in the down dip analysis of this bed. At Station 1 a subaqueous beach environment was postulated. At Station 2 the presence of an island barrier was suggested and it would seem to be more than coincidence that the fauna would indicate an "upper sound" environment for this bed.

Since most sound (lagoon) environments are shallow (less than 10 feet), an average depth of 5 or 6 feet is proposed for the depth of water in which Bed 3 was deposited.

Station 4

Bed 1, Basal Peedee fm. - "Snow Hill mbr.", Sample CCA1. There are several Recent environments which have sediments that are comparable to the sediments of this bed. Some of them are: Shepard and Moore's "nearshore gulf" environment (Shepard and Moore, 1955, p. 1537) on the Texas coast, Shepard's "open lagoon" environment (Shepard, 1956, p. 2551) in Breton Sound and Shepard's "open lagoonal inlet" environment (Shepard, 1956, p. 2551) southeast of Breton Island. There are, however, exceptional features which makes comparison with the Recent environments difficult.

Bed 1 is exceptional for its high percentage of sand with a high concentration in the 1/8-1/16 mm. sand class. It contains a considerable amount of mica, glauconite, and wood. Also distinctive is the absence of macrofauna and Foraminifera except for a few arenaceous ?Psammosphaera sp. The high percentage of wood and glauconite excludes the sediment from the "nearshore gulf" environment. It seems doubtful that Bed 1 is comparable with the "inlet" environment because Shepard makes note of the absence of glauconite in the "inlet" environments near the Mississippi Delta. The "open lagoon" environment is most satisfactory for comparison to Bed 1 in all respects except that the percentage of carbonate in Breton Sound is much higher than in Bed 1. Variation in carbonate may not be important because at several localities along Contentnea Creek there are a large number of pelecypod molds indicating removal of the carbonate by ground water. Carbonate is virtually absent in almost all of the rocks along Contentnea Creek. Assuming that the carbonate content was at one time higher in Bed 1, the "open lagoon" environment best suits the characteristics of the sediments. Bed 1 was probably deposited in less than 10 feet of water.

Bed 2, Basal Peedee fm. - "Snow Hill mbr.", Sample CCA2. The characteristics of Bed 2 are essentially the same as Bed 1 except that Bed 2 is lower in glauconite and mica and contains about 20% shell material. The diversity of species, the fact that most of the genera would be expected in relatively quiet waters with some current action, the lack of calcareous Foraminifera and the presence of ?Psammosphaera sp. support the thesis for an "open lagoon" environment. One well preserved calcareous Foraminifera (Robulus pseudosecans) was found. It is probable that an inlet was in the near proximity at the time Bed 2 was deposited. Bed 2 was, like Bed 1, probably deposited in less than 10 feet of water.

Bed 3, Basal Peedee fm. - "Snow Hill mbr.", Sample CCA3. Bed 3 is in all respects essentially like Bed 1 and therefore was probably deposited in an "open lagoonal environment" with a water depth of less than 10 feet. Bed 3 also contains the supposed arenaceous foraminiferan.

Station 5

Bed 1, Basal Peedee fm. - "Snow Hill mbr.", Sample CCA4. Bed 1 is identical to Beds 2 and 3 at Station 4 with the same suggestion that the bed was deposited in an "open lagoonal environment".

Station 6

Bed 1, Bed 2, Basal Peedee fm. - "Snow Hill mbr.", Samples CCA5 and CCA6 (Bed 1); Sample CCA7 (Bed 2). Beds 1 and 2 at this station are essentially identical to Bed 1, Station 5, and Beds 1 and 3, Station 4. Bed 2 of this station is somewhat different in that it contains considerable less wood and has a greenish tinge. There is the possibility that some of the woody material in Bed 2 was lost as the result of leaching since Sample CCA7 came from near the top of the outcrop.

Station 7

Bed 1, Peedee fm., Sample CCA8. The sedimentary characteristics of Bed 1 compare favorably to a mixture between Shepard's "open lagoonal inlet" environment and his "reworked Mississippi delta" environment (Shepard, 1956, p. 2551). These environments are found on the ocean side of the Breton Island barrier east of the Mississippi Delta. The principal characteristics which suggest this environment are the high percentage of wood, the large amount of glauconite, the absence of macrofossils, and the occurrence of a fairly small amount of Foraminifera. Most of these characteristics are associated with the "open lagoonal inlet" environment, but an exceptionally large per cent of sand which has a mode of 1/4-1/8 mm. indicates at least some degree of reworking as is associated with the "reworked Mississippi delta" environment.

Although there is a small volume of Foraminifera present, the fact that there is a great variety of species, and that the species are representative of both the "lagoonal" and "open shelf" environments suggests that the sample represents an ecotonal habitat as might be expected in a nearshore region near an open lagoon inlet. A large percentage of the Foraminifera recovered from Bed 1 are calcareous rotaloid benthic forms indicative of open lagoonal environments of near normal marine salinity. Mixed in with the lagoonal faunas is a good representation of pelagic Foraminifera and other species indicative of shelf environments.

The depth of water in which Bed 1 was deposited is probably in the proximity of 20 feet.

Bed 2, Peedee fm., Sample CCA9. Bed 2 differs from Bed 1 in the higher volume of glauconite (14%), the increase in percent of shells, an increase in volume of Foraminifera and a decrease in wood and mica. This bed shows a transition in the Foraminifera from benthic to pelagic forms. Although benthic types are present, the volume of pelagic types is much greater. The macrofauna is distinctive because of the abundance of one species, Exogyra cancellata. The condition of Exogyra indicates that they have not under gone much transportation; however, they occur in random orientation within the outcrop suggesting that the fauna is not a biocoenosis.

There are no environments in the northern Gulf coast which resemble the environment of deposition of Bed 2, as shown by the characteristics just listed as well as the high percentage of sand with a mode in the 1-1/2 mm. class. The high percentage of glauconite, coarse sand and Foraminifera, the near exclusion of mica and wood, and the presence of macrofauna which have obviously been moved about, indicate continuous reworking for a fairly long period of time. Reworking suggests that the depth of water was probably not over thirty feet, the maximum depth of effective wave base (Shepard, 1948, p. 47). However, the large percentage of benthic Foraminifera in Bed 2 may have been, in part, carried out to the Bed 2 deposit from farther inshore. It is here believed Bed 2 represents a sediment which was deposited in an area of sedimentary bypass of finer grained materials. The combination of factors: (1) preponderance of pelagic Foraminifera and glauconite and (2) evidence of reworking over a long period of time in water 30 feet deep or less suggests that the Cretaceous coast in upper Taylor and Navarro time had a gradient similar to our present neritic floor.

Bed 3, Peedee fm., Sample CCA10. Although, as in Bed 2, there are no environments in the northern Gulf coast which produce sediments similar to the sediments of Bed 3, Bed 3 is related environmentally to Beds 1 and 2. Bed 3 represents a continuous change from shallow to deeper shelf sediments ascending the outcrop at Station 7. The slight increase in glauconite, absence of mica, decrease and near absence of wood, decrease in volume of shells (the shells are all fragments in 1/4-1/8 mm. class) and increase in volume of Foraminifera point to somewhat deeper water farther from shore than the sediments from Bed 2. The high concentration of glauconite and Foraminifera in a bed one foot thick and concentration of terrigenous sand in the 1-1/2 mm. class suggests, as in bed 2, slow deposition, reworking and sedimentary by-passing. The large number of pelagic species of Foraminifera imply that the sediment was deposited in normal marine water at a distance from the shore. Shepard and Moore (1955, p. 1539) report that on the northern shelf of the Gulf of Mexico beyond a depth of about 120 feet there is a very marked increase in the percentage of planktonic Foraminifera to the near exclusion of benthic forms. If we assume that the gradient of the Cretaceous neritic shelf was similar to the present North Carolina neritic shelf then the sediments of Bed 3 were deposited perhaps 15 to 20 miles from shore. The reworked nature of the sediments and the high concentration of Foraminifera and glauconite can be accounted for by the factor of time coupled with the fact that vigorous wave action occasionally reaches depths of 200 feet (Shepard, 1948, p. 47). If the accumulation of terrigenous minerals on the shelf was very slow then glauconite and Foraminifera could have concentrated to the degree reported.

Resumé of Beds 1, 2, and 3. Beds 1, 2, and 3 at Station 7, showing a progressive change from shallow near shore sediments to deeper shelf sediments indicate an onlap condition. Since the outcrop is only a few feet thick and the fossils indicate that the outcrop was deposited during upper Taylor and much of Navarro time, the onlap must have been slow.

All of the three beds show evidence of continual reworking indicating that the water was shallow throughout the period of deposition. Bed 2 contains *Exogyra cancellata* largely permeated with *Cliona* borings which also suggests shallow water. Further, *E. cancellata* had been broken along the ventral edge while living (large scars occur on the shells where the mantle healed the broken edge and continued to deposit shell), indicating that the force of wave action may have been at least occasionally strong enough to uproot the *Exogyra* and cause them to collide and that the *E. cancellata* lived in a shallow shelf environment perhaps in the lower breaker zone. The *E. cancellata* may have been broken by predation, but there is no evidence of preditors capable of such force having been present.

The principal characteristic of this outcrop is the progressive change from bottom to top through the three beds as follows: (1) decrease in mica, (2) decrease in wood, (3) increase in glauconite, (4) increase in volume of Foraminifera, (5) decrease in benthic Foraminifera and (6) increase in pelagic Foraminifera.

Geologic History

Probably throughout Upper Cretaceous time the North Carolina coast had a shallow marine shelf with a low gradient. The present dip of the outcropping sediments (allowing for some post depositional compaction) along with the characteristics of the sediments and faunas suggest an average gradient of perhaps 3 feet per mile.

Upper Cretaceous time was tectonically fairly uneventful in North Carolina. The oldest important physiographic feature is the possible occurrence of a delta in the general region of the Cape Fear arch, represented by the Black Creek formation. Downstream below Elizabethtown, North Carolina, the Black Creek shales are marine, containing a few Foraminifera and considerable glauconite. Upstream toward Fayetteville the rocks become more and more terrestial, containing no fauna, no glauconite, and much woody material and pyrite suggesting stagnant swamp conditions. In the Contentnea Creek area, northeast of the Black Creek sediments at Milepost 49, Cape Fear River, the rocks of similar age suggest that the supposed delta was flanked by an open lagoon perhaps similar to Breton Sound in the Gulf of Mexico. The delta apparently had been forming and moving inland since Lower Taylor time. However, in the Cape Fear River area, the presence of a possible unconformity and a sudden change in lithology from shale to sandstone suggests a period in upper Taylor time when the delta was exposed to subaerial erosion. To the northeast in the Contentnea Creek area, no interruption of deposition is evident. Directly after the period of erosion, the sea apparently encroached onto the land with some accelaeratin covering the delta with typical open lagoonal and shallow shelf deposits represented by the Peedee formation in the Cape Fear River area. In the Contentnea Creek area the open lagoonal environments continued to persist as they had during the formation of the Black Creek Delta. Encroachment by the sea continued well into Navarro time as indicated by the Peedee sediments at Scuffleton, North Carolina. There is no evidence in either the Cape Fear River area or the Contentnea Creek area whether an offlap occurred in Cretaceous time. Nearly all the sediments of Navarro age have been eroded away except those at Scuffleton.

The Carolina coast during Upper Cretaceous time may have resembled to some extent the present coast line except that the barriers were largely submerged and the inlets were much wider allowing the ocean greater access to the lagoons. The exceptional feature, of course, is the delta.

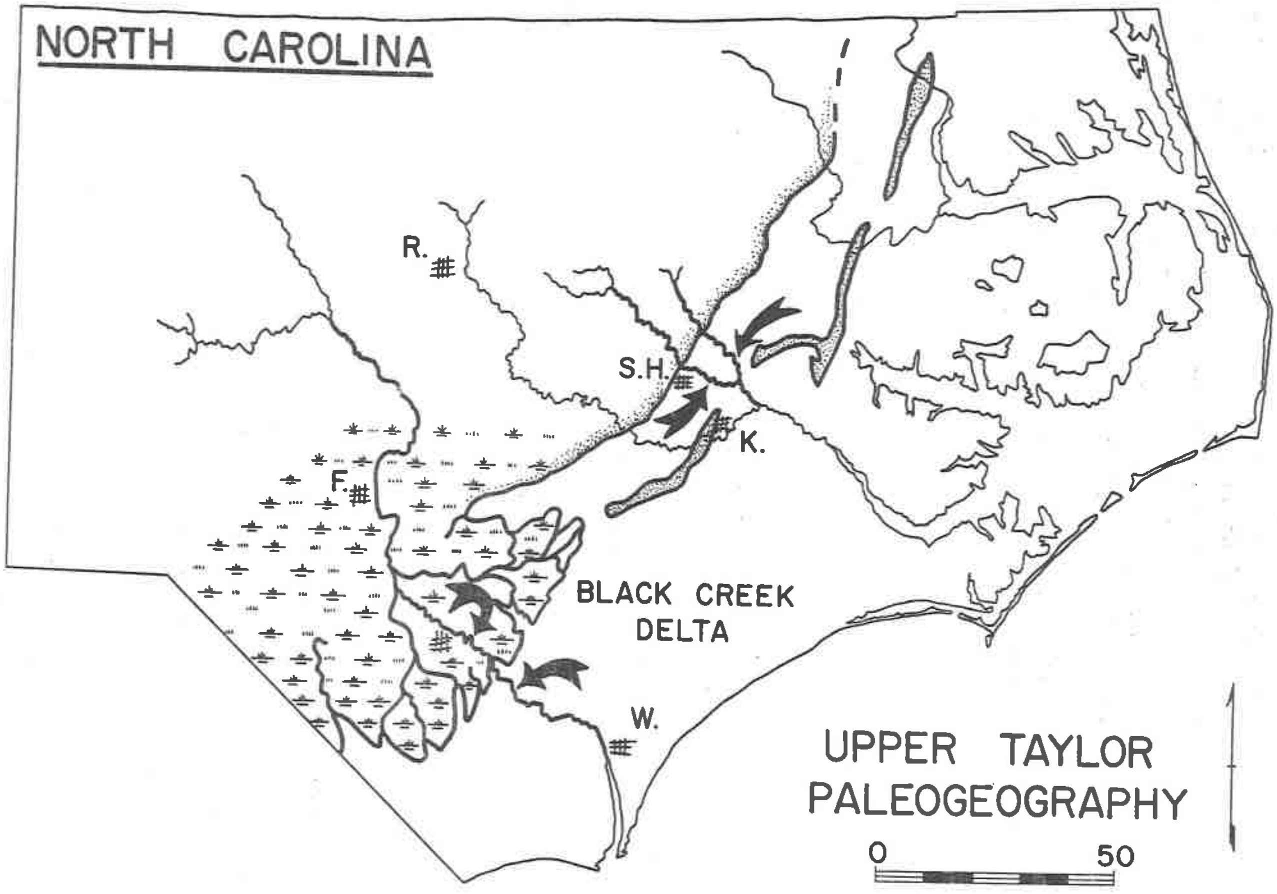


Figure 23. Upper Taylor paleogeography.

According to Urey (1951, p. 412) the average temperature of the Upper Cretaceous sea on the North Carolina shelf was 59 degrees Fahrenheit. His contention finds support in this study by the absence of corals, rudistids, and other tropical forms including tropical Foraminifera, and the paucity and diminution in size of *Exogyra ponderosa*. *E. ponderosa* is a tropical invertebrate closely associated environmentally with rudistid reefs (Jourdy, 1924, p. 32-38, 97).

It must not be assumed that the lagoonal environments were usually at a temperature near 59 degrees since because of their shallowness and restriction from the sea, slight as it may have been they would normally be colder in the winter and warmer in the summer than the ocean water.

Summary

Sediment samples and fossil fauna were collected from selected outcrops in the Upper Cretaceous Peedee and Black Creek formations from Milepost 49 to Milepost 60 (Walker's Bluff) on the Cape Fear River and from the town of Snow Hill, North Carolina, to a point 7.1 miles downstream along the Contentnea Creek. The purpose of the project was to study the Snow Hill member of the Black Creek formation in more detail than has been done in the past. In addition it was hoped that more light could be shed on the environments in which the Upper Cretaceous marine sediments were deposited.

The outcrops were described in detail in the field. Both Black Creek and Peedee lithologies were found in the Cape Fear River area on bluffs ranging from 5-70 feet in height. Two of the best exposures of Upper Cretaceous rocks showing both the Black Creek and Peedee formations are at Milepost 49 and Milepost 60. At Milepost 49 there is a strong suggestion of an unconformity at the contact between the two formations.

It was discovered that the base of the Peedee formation in the Cape Fear River area is marked by a distinctive indurated calcareous sandstone, which contains many specimens of *Cardium*, *Arca*, and *Anomia*. The indurated sandstone averages about a foot or two in thickness and occurs along the Cape Fear River from Milepost 49 to Milepost 60 anywhere the top of the Black Creek formation is exposed. At Milepost 60 the bed is high up on the side of a 70 foot bluff known as Walker's Bluff. Using this bed as a key bed a dip of 6-7 feet per mile can be arrived at for the Cretaceous rocks of the area.

In the Contentnea Creek area no Black Creek rocks were found, although the area studied included the type locality of the Snow Hill member of the Black Creek formation. Numerous "Snow Hill" outcrops were found along the Contentnea Creek below Snow Hill, North Carolina, but all of the rocks are a dark gray massive very fine sandstone. Shales are not present.

The sediment samples brought back to the laboratory were studied by the coarse-fraction method developed by Shepard and Moore (1954). This analysis revealed that the Black Creek formation is a (sand-silt-clay):(siltshale) while the Peedee formation, both in the Cape Fear River area and the Contentnea Creek area is a (silty sand):(quartzwacke).

During the coarse-fraction study the Foraminifera were used with the fossil macrofauna to determine the relative ages of the beds in the area studied and their ecology. It was found that all of the rocks in both areas are upper Taylor in age with the exception of one outcrop at Scuffleton, North Carolina, in which the top 2 of 3 beds are Navarro in age.

The macrofauna, Foraminifera and sediments were used to determine the environments in which the Black Creek and Peedee sediments were deposited. Determination of environments was made largely by comparing published data derived from Recent sediments and fauna in the northern Gulf of Mexico. It was determined that the Black Creek formation in the Cape Fear River area was deposited in a delta type of environment.

The basal Peedee formation was deposited in an open lagoonal environment partially at the same time as the Black Creek delta was formed. Following a period of onlap most of the subsequent Peedee sediments were deposited on a shallow shelf of low gradient (perhaps 3-6 feet per mile).

Careful scrutiny of the rocks at the type locality of the "Snow Hill calcareous member of the Black Creek formation", showed the "Snow Hill" rocks are consanguineous with the Peedee formation in the areas studied, both being (silty sand):(quartzwacke) and both being deposited in similar environments at least in the basal portion. The "Snow Hill" sediments are, without doubt, transitional between the Black Creek and Peedee formations as Stephenson said. But the rocks at the type locality of the "Snow Hill member" are lithologically and environmentally like the basal Peedee rocks. Since the "member", as originally defined, is in realty a biostratigraphic unit rather than a lithostratigraphic unit (really a part of the Exogyra ponderosa assemblage-zone and without member status) the name "Snow Hill member" should be dropped and the strata included within the Peedee formation. It should be recognized that lithostratigraphic and biostratigraphic units are separate entities even though they frequently coincide and, also, that fossils cannot be used to define a formation or member unless they are in themselves a significant lithologic constituent. Index fossils and guide fossils are often helpful in identifying lithostratigraphic units, but their use is at the same time dangerous if sufficient caution is not exercised because fossils are not necessarily restricted to one lithology as is so well illustrated in the areas of this study.

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EXPLANATION OF PLATES

Plate 1

Figure	Page
1. Anomia henbesti Plummer, 1936 . . . . A, ventral view; b, peripheral view; c, dorsal view; Black Creek formation (Exogyra ponderosa zone), Station 2, Bed 1, Milepost 49, Cape Fear River, N.C.; hypotype; U. N.C. cat. n. 3373. X 79.	89

Figure Page

2. *Anomalinoides pinguis* (Jennings), 1936 89
A, ventral view; b, peripheral view; c, dorsal view; Basal Peedee formation (*Exogyra ponderosa* zone), Station 7, Bed 1, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3374. X 79.

3. *Cibicides subcarinatus* Cushman and Deadrick, 1944 . . 89
A, ventral view; b, peripheral view; c, dorsal view; Black Creek formation (*Exogyra ponderosa* zone), Station 2, Bed 1, Milepost 49, Cape Fear River, N. C.; hypotype; U.N.C. cat. n. 3375. X 79.

4. *Clavulinoides trilatera* (Cushman), 1926 89
A, side view, the initial chambers are missing; b, apertural view; Peedee formation (*Exogyra ponderosa* zone), Station 2, Bed 3, Milepost 49, Cape Fear River, N. C.; hypotype; U. N. C. cat. n. 3376. X 52.

5. *Discorbis sp.*, cf. *D. minima* Vieaux, 1941 89
Ventral view; the specimen was poorly preserved and partially filled with limonite; other specimens in the outcrop were also poorly preserved and difficult to identify; Black Creek formation (Lower *Exogyra ponderosa* zone), Station 3, Bed 1, Cape Fear River, N. C.; hypotype; U. N. C. cat. n. 3377. X 79.

6. *Dorothia sp.*, cf. *D. bulleta* (Carsey), 1926 89
A, side view; b, apertural view; Peedee formation (*Exogyra costata* zone), Station 7, Bed 3, Scuffleton, N. C.; hypotype; U. N. C. cat. n. 3378. X 79.

7. *Dorothia glabrata* Cushman, 1933 89
Side view; terminal chamber is broken, the large dark grains are glauconite; Peedee formation (*Exogrya costata* zone), Station 7, Bed 3, Scuffleton, N. C.; hypotype; U. N. C. cat. n. 3379. X 52.

8. *Globigerina cretacea* d'Orbigny, 1840 89
A, ventral view; b, peripheral view; c, dorsal view; Peedee formation (Exogyra costata zone), Station 7, Bed 3, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3380. X 79.

9. *Globigerina sp.*, cf. *G. rugosa* Plummer, 1927. 89
A, ventral view; b, peripheral view; c, dorsal view;

Figure Page

this and other specimens resembles *G. rugosa* Plummer in all respects, especially in having the umbilical covering and coarse spinosity, except that rugae are insignificant or absent; Peedee formation (*Exogyra costata* zone), Station 7, Bed 3, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3381. X 79.

Plate 2

1. *Globigerinella sp.*, cf. *G. aspera* (Ehrenberg), 1854 . . 89
A, peripheral view; b, side view; this specimen not like Ehrenberg but identical to Cushman, 1955, plate 34, Figure 10; some of the specimens collected may be *G. messinae* Bronniman, 1952; Peedee formation (*Exogyra costata* zone), Station 7, Bed 3, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3382. X 79.

2. *Globotruncana sp.*, cf. *G. austinensis* Gondolphi, 1955 . . 89
A, ventral view; b, peripheral view; c, dorsal view; this specimen differs from *G. austinensis* in having more inflated chambers on the dorsal side and a convex rather than concave ventral side in back profile; Basal Peedee formation (*Exogyra ponderosa* zone), Station 7, Bed 1, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3383. X 79.

3. Globulina sp. [(= *G. lacrima subspherica* of Cushman, 1946, p. 96, plate 40) (=*G. fistulosa* Bullard, 1953, distinguished by fistulose apertures which do not have specific significance) 89
A, side view; b, apertural view; c, side view of another specimen with fistulose apertures; Cushman's specimen is not conspecific with the type of *G. lacrima subspherica* (Berthelin), 1880; a and b, Basal Peedee formation (*Exogyra ponderosa* zone), Station 7, Bed 1, Scuffleton, N. C.; c, Peedee formation (*Exogyra costata* zone), Station 7, Bed 3, Scuffleton, N.C.; hypotypes; U.N.C. cat. n. 3384. X 79.

4. *Gümbelina globulosa* (Ehrenberg), 1854 89
A, side view; b, apertural view; c, top view; Peedee formation (*Exogyra costata* zone), Station 7, Bed 2, Scuffleton, N.C.; hypotype; U.N.C. cat. n. 3385. X 79.

Figure Page

5. *Gümbelina striata* (Ehrenberg) 1854 89

A, side view; b, top view; Peedee formation (*Exogyra costata* zone), Station 7, Bed 2, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3386. X 79.

6. *Gümbelitria cretacea*, cf. *G. cretacea albertensis* Stelck and Wall, 1954 89

A, side view; b, top view; Peedee formation (*Exogyra ponderosa* zone), Station 7, Bed 3, Scuffleton, N. C.; hypotype; U. N. C. cat. n. 3387. X 79.

7. *Nodosaria affinis* Reuss, 1845 89

A, side view; b, apertural view; Basal Peedee formation (*Exogyra ponderosa* zone), Station 7, Bed 1, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3388. X 52.

8. ? *Psammosphaera sp*. 89

Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N.C.; hypotype; U.N.C. cat. n. 3389. X 79.

Plate 3

1. *Robulus sp.*, cf. *R. pondi* Cushman, 1941 89

A, side view; b, apertural view; this specimen is like Cushman, 1946, Plate 17, Figure 5, but not like the type; the North Carolina species is more limbate with fewer chambers; Basal Peedee formation (*Exogyra ponderosa* zone), Station 7, Bed 2, Scuffleton, N. C.; hypotype; U. N. C. cat. n. 3390. X 52.

2. *Robulus pseudosecans* Cushman, 1944 89

A, side view; b, apertural view; Peedee formation (*Exogyra ponderosa* zone), Station 2, Bed 3, Milepost 49, Cape Fear River, N. C.; hypotype; U.N.C. cat. n. 3391. X 52.

3. *Textularia subconica* Franke, 1932 89

A, side view; b, top view; Peedee formation (*Exogyra costata* zone), Station 7, Bed 3, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3392. X 79.

4. *Elphidium frizzelli* Miller, 1953 89

A, side view; b, apertural view; *E. frizzelli* is reported only from the Recent, but it was found near shore at Wilmington, N. C., where Cretaceous and Tertiary sediments contribute to near shore deposits

Figure Page

and it is a surface contaminant from the overlying Tertiary in the Cretaceous outcrop on which it was found; Basal Peedee formation (*Exogyra ponderosa* zone), Station 3, Bed 2, Milepost 60, Cape Fear River, N. C.; hypotype; U.N.C. cat. n. 3393. X 79.

Plate 4

1. *Cliona sp.* 89
Borings in a valve of *Gryphaea*; Peedee formation (*Exogyra costata* zone), Station 7, Bed 2, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3319. X 2.6.

2. Encrusting Bryozoa 89
A, a colony encrusting a clump of sand; b, enlargement of a portion of a; Basal Peedee formation (*Exogyra ponderosa* zone), Station 2, Bed 2, Milepost 49, Cape Fear River, N. C.; U. N. C. cat. n. 3320. 2a, X .88; 2b, X 8.8.

3. *Ataphrus kerri* Gabb, 1876 90
A, side view; b, bottom view; Basal Peedee formation (*Exogyra ponderosa* zone), Station 3, Bed 3, Milepost 60, Cape Fear River, N. C.; hypotype; U.N.C. cat. n. 3321. X 1.8.

4. *Pugnellus sp.* 90
Side view of an imperfect cast (natural replica) in calcareous sandstone; Basal Peedee formation (*Exogyra ponderosa* zone), Station 3, Bed 3, Milepost 60, Cape Fear River, N. C.; hypotype; U.N.C. cat. n. 3322. X .58.

5. *Seminola sp.* 90
Side view, basal whorl only; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; . hypotype; U.N.C. cat. n. 3323. X 1.8.

6. *Turritella sp.* 90
Incomplete internal mold composed of a phosphate mineral; Peedee formation (*Exogyra costata* zone), Station 7, Bed 2, Scuffleton, N. C.; hypotype; U. N. C. cat. n. 3324. X .88.)

Figure Page

7. *Turritella sp.*, cf. *T. trilira* Conrad, 1860 90
Poorly preserved incomplete case (natural replica) Basal Peedee formation (*Exogyra ponderosa* zone), Station 3, Bed 3, Milepost 60, Cape Fear River, N. C.; hypotype; U.N.C. cat. n. 3325. X .88.

8. *Turritella quadrilira* Johnson, 1898 90
Side view of a single whorl; Vasal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; hypotype; U.N.C. cat. n. 3326. X .88.

9. *Turritella kerrensis* Stephenson, 1923 90
Side view of an incomplete specimen; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.;hypotype; U.N.C. cat. n. 3327. X .88.

10. *Anomia argentaria* Morton, 1833 90
A, interior of left valve; b, exterior of same valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 2, Bed 2, Milepost 49, Cape Fear River, N. C.; hypotype; U. N. C. cat. n. 3328. X .88.

11. *Anomia lintea donohuensis* Stephenson, 1923 90
Broken exterior of left valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 2, Bed 2, Cape Fear River, N. C.; topotype; U.N.C. n. 3329. X .88.

12. *Anomia olmstedi* Stephenson, 1923 90
Exterior of left valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; topotype; U.N.C. cat. n. 3330. X .88.

13. *Arca (Barbatia) bladenensis* Stephenson, 1923 90
A, dorsal view of an internal cast, right valve; b, squeeze of an external mold, right valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 1, Bed 2, Milepost 49, Cape Fear River, N. C.; hypotype; U.N.C. cat. n. 3331. a, X .88; b, X 1.8.

14. *Arca (Barbatia) carolinensis* (Conrad), 1875 90
A, exterior of right valve; b, interior of same valve; c, squeeze of an external mold, left valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; topotype; U.N. C. cat. n. 3332. X .88.

Figure   Page

15. *Aphrodina regia* Conrad, 1875 90
Portion of the hinge line in the umbonal region, right valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; topotype; U. N. C. cat. n. 3333. X .88.

16. Boring pelecypods 90
Borings typical of certain pelecypods none of which were found for identification; Basal Peedee formation (*Exogyra ponderosa* zone), Station 2, Bed 2, Milepost 49, Cape Fear River, N. C.; U. N. C. cat. n. 3334. X 2. 6.

Plate 5

1. *Cardium donohuense* Stephenson, 1923 90
A, external mold of a portion of a valve; b, squeeze of a; c, squeeze of an external mold of another incomplete specimen; Basal Peedee formation (*Exogyra ponderosa* zone), immediately upstream from Station 2, Milepost 49, Cape Fear River, N. C.; U. N. C. cat. n. 3335. X .88.

2. *Cardium vaughani* Stephenson, ... 90
A, exterior of left valve; b, interior of same valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; topotype; U. N. C. cat. n. 3335. X .88.

3. *Corbula bisulcata* Conrad, 1875 90
A, exterior of left valve; b, interior of same valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; topotype; U. N. C. cat. n. 3337. X .88.

4. *Corbula oxynema* Conrad, 1875 90
Exterior of a right valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; topotype; U. N. C. cat. n. 3338. X .88.

5. *Crassatellites conradi* (Whitfield), 1886 90
A, exterior of left valve; b, interior of same valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; hypotype; U. N. C. cat. n. 3339. X .88.

Figure Page

6\. *Cyprimeria depressa* Conrad, 1875. 90

A, exterior of left valve; b, interior of same valve Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; hypotype; U.N.C. cat. n. 3340. X .88.

7\. *Cyprimeria gabbi* Stephenson, 1923. 90

A, exterior of incomplete left valve; b, interior of same valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; topotype; U.N.C. cat. n. 3341. X .88.

8\. *Exogyra cancellata* Stephenson, 1914 90

Exterior of left valve; Peedee formation (*Exogyra costata* zone), Station 7, Bed 2, Scuffleton, N. C.; hypotype; U. N. C. cat. n. 3342. X .58.

9\. *Exogyra costata spinosa* Stephenson, 1923. 90

Exterior of left valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 2, Bed 2, Milepost 49, Cape Fear River, N. C.; topotype; U.N.C. cat. n. 3343. X .88.

Plate 6

1\. *Exogyra costata spinosa* Stephenson, 1923 90

A, exterior of right valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 2, Bed 2, Milepost 49, Cape Fear River, N. C.; topotype; b, exterior of left valve; c, exterior and interior of two attached left valves; Peedee formation (*Exogyra costata* zone), Station 7, Bed 2, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3344. X .88.

2\. *Exogyra ponderosa* Roemer, 1849. 90

A, exterior of whole left valve; b, exterior of incomplete left valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; hypotype; U.N.C. cat. n. 3345. X .88.

3\. *Exogyra ponderosa erraticostata* Stephenson, 1914. . . 90

A, exterior of nearly perfect left valve; b, exterior of right valve which matches "a"; Basal Peedee formation (*Exogyra ponderosa* zone), Station 2, Bed 2, Milepost 49, Cape Fear River, N. C. hypotype; U. N. C. cat. n. 3346. X .58.

Figure Page

4. *Gryphaea sp.* Type A. 90
A, exterior of left valve; b, interior of same valve; Peedee formation (*Exogyra costata* zone), Station 7, Bed 2, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3347. X .58.

Plate 7

1. *Gryphaea sp.* Type B. 90
A, exterior of left valve; b, interior of same valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; hypotype; U.N.C. cat. n. 3348. X .58.

2. *Gryphaea sp.* Type C. 90
A, exterior of left valve; b, interior of same valve; Peedee formation (*Exogyra costata* zone), Station 7, Bed 2, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3349. X .58.

3. *Inoceramus sp.* 90
Incomplete cast (natural replica) Basal Peedee formation (*Exogyra ponderosa* zone), Station 3, Bed 3, Milepost 60, Cape Fear River, N. C.; hypotype; U. N. C. cat. n. 3350. X .88.

4. *Lucina parva* Stephenson, 1923 90
A, exterior of left valve; b, interior of same valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; topotype; U.N.C. cat. n. 3351. X .88.

5. *Lima kerri* Stephenson, 1923 90
Incomplete exterior of right valve cemented against the exterior of an Exogyra cancellata left valve; Peedee formation (*Exogyra costata* zone), Station 7, Bed 2, Scuffleton, N. C.; topotype; U.N.C. cat. n. 3352. X .88.

6. *Legumen carolinense* (Conrad), 1875 90
A, exterior of left valve; b, interior of same valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; topotype; U. N. C. cat. n. 3353. X .58.

7. *Nucula stantoni* Stephenson, 1923 90
Portion of left valve showing details of the hinge line; Basal Peedee formation (*Exogyra ponderosa* zone),

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Station 4, Bed 2, Snow Hill, N. C.; topotype; U.N.C. cat. n. 3354. X .88.

8. *Ostrea blackensis* Stephenson, 1923 90
A, exterior of right valve; b, interior of same valve; Basal Peedee formation (*Exogyra ponderosa* zone), Milepost 49, Cape Fear River, N. C.; hypotype; U.N.C. cat. n. 3355. X .88.

9. *Ostrea falcata* Morton, 1827 90
Exterior of left valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 2, Bed 2, Milepost 49, Cape Fear River, N. C.; hypotype; U.N.C. cat. n. 3356. X .88.

10. *Ostrea plumosa* Morton, 1833 90
A, exterior of right valve; b, interior of same valve; Peedee formation (*Exogyra costata* zone), Station 7, Bed 2, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3357. X .88.

11. *Ostrea tecticosta* Gabb, 1860 91
A, exterior of left valve; b, interior of same valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; hypotype; U.N.C. cat. n. 3358. X .88.

Plate 8

1. *Ostrea pratti* Stephenson, 1923 90
A, exterior of left valve; b, interior of right valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 2, Bed 2, Milepost 49, Cape Fear River, N. C.; hypotype; U.N.C. cat. n. 3359. X .58.

2. *Pecten sp.* 91
Interior of left valve half covered by rock; Peedee formation (*Exogyra costata* zone), Station 7, Bed 2, Scuffleton, N. C.; U.N.C. cat. n. 3360. X .88.

3. *Pecten mississippiensis* Conrad, 1860. 91
Interior of valve; Peedee formation (*Exogyra costata* zone), Station 7, Bed 2, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3361. X .88.

Figure Page

4. *Pholadidea fragilis* Stephenson, 1923 91
Boring in an unidentified valve some of which contain both valves of *P. fragilis*; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; topotype; U.N.C. cat. n. 3362. X .88.

5. *Striarca perovalis* (Conrad), 1872 91
A, exterior of right valve partially covered with sand - exterior sculpture has been lost; b, interior of same valve partially filled with sand; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; topotype; U.N.C. cat. n. 3363. X .88.

6. *Trigonarca elongata* Stephenson, 1923 91
A, exterior of left valve; b, interior of same valve partially filled with sand; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; hypotype; U.N.C. cat. n. 3364. X .88.

7. *Trigonia bartrami* Stephenson, 1923. 91
A, exterior of right valve; b, interior of same valve; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C. X .58.

Plate 9

1. *Veniella conradi* (Morton), 1833 91
A, exterior of a fragment of a left valve; b, exterior of a left valve; c, interior of "b" partially filled with sand; Basal Peedee formation (*Exogyra ponderosa* zone), Station 4, Bed 2, Snow Hill, N. C.; hypotypes; U.N.C. cat. n. 3366. X .88.

2. *Belemitella americana* (Morton), 1828. 91
Side view of an incomplete guard; Peedee formation (*Exogyra costata* zone), Station 7, Bed 2, Scuffleton, N. C.; hypotype; U.N.C. cat. n. 3367. X .88.

3. *Hamulus sp.* 91
A and b, side views of fragments of the worm tubes; Basal Peedee formation (*Exogyra pon-*

Figure Page

derosa zone), Station 4, Bed 2, Snow Hill, N. C.; *hypotype*; U.N.C. cat. n. 3368. X .88.

4. *Serpula sp.* 91
Internal mold of a worm tube; Basal Peedee formation (*Exogyra ponderosa* zone), Station 3, Bed 3, Milepost 60, Cape Fear River, N. C.; hypotype; U.N.C. cat. n. 3369. X .88.

5. Dinosaur bone 91
A, side of a tarsal replaced by limonite; b, top of "a"; Basal Peedee formation (*Exogyra ponderosa* zone), Station 2, Bed 2, Milepost 49, Cape Fear River, N. C.; hypotype; U.N.C. cat. n. 3370. X .88.

6. Fish vertebra 91
Side view of a vertebra; Basal Peedee formation (*Exogyra ponderosa* zone), Station 2, Bed 2, Milepost 49, Cape Fear River, N. C.; hypotype; U.N.C. cat. n. 3371. X .88.

7. Shark teeth 91
Teeth of at least two different kinds of shark; Basal Peedee formation (*Exogyra ponderosa* zone), Station 2, Bed 2, Cape Fear River, *N.C.*; hypotype; U.N.C. cat. n. 3372. X .88.