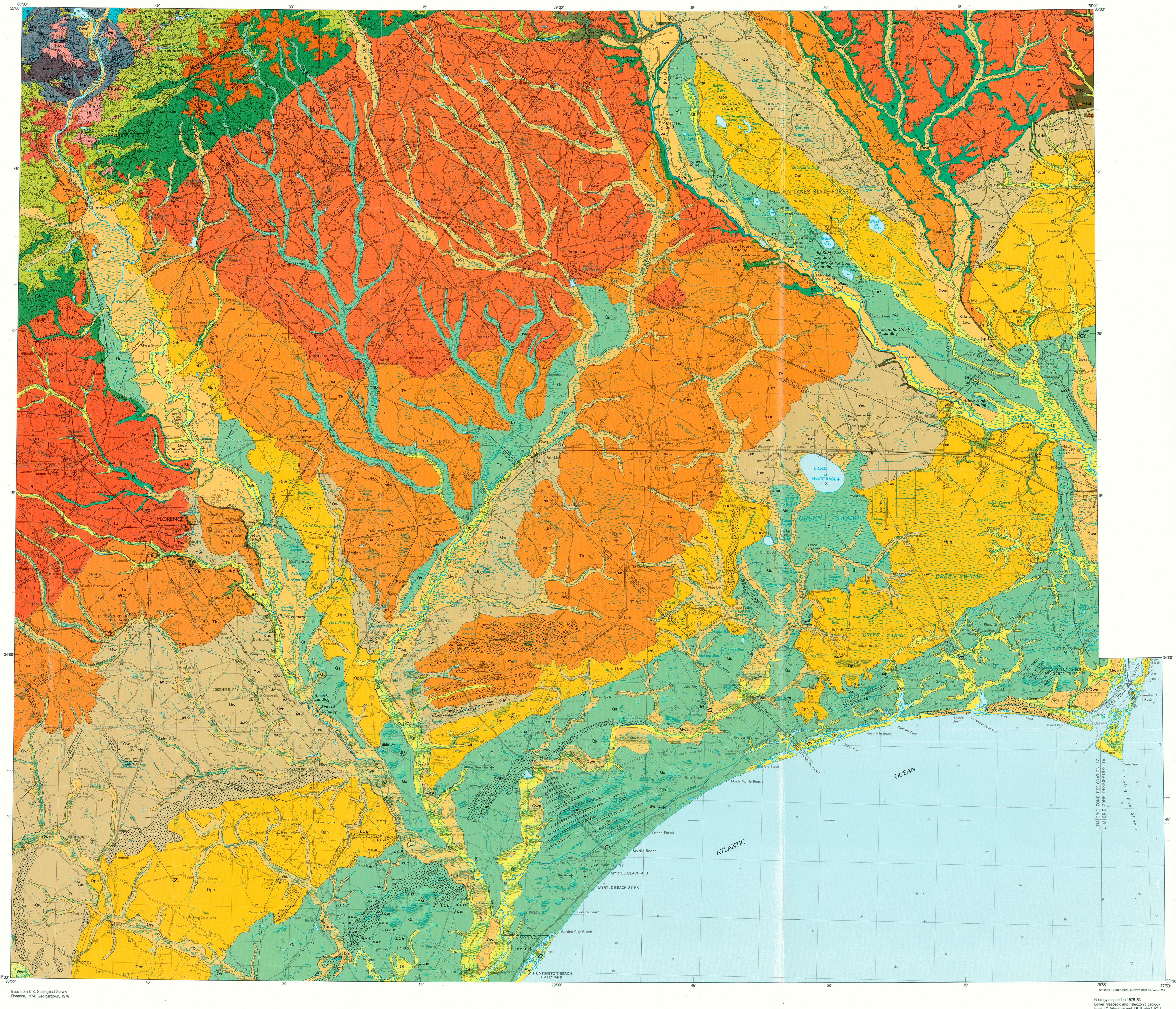


Base from U.S. Geological Survey
Florence, 1974; Georgetown, 1978

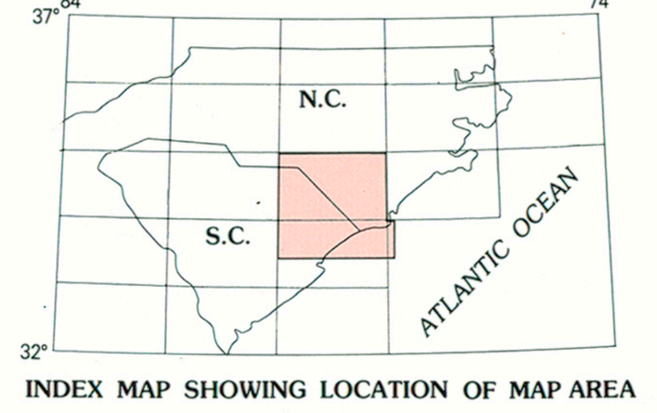
INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1990

Geology mapped in 1976–83
Lower Mesozoic and Paleozoic geology
from J.D. Waskom and J.R. Butler (1971)
and J.R. Burt (1981)

Manuscript approved for publication,
September 17, 1987.

Scale 1:250,000
5 0 5 10 15 20 Statute Miles
5 0 5 10 15 20 25 30 Kilometers

CONTOUR INTERVAL 50 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929



INDEX MAP SHOWING LOCATION OF MAP AREA

GEOLOGIC MAP OF THE CAPE FEAR REGION, FLORENCE 1° x 2° QUADRANGLE AND NORTHERN HALF OF THE GEORGETOWN 1° x 2° QUADRANGLE, NORTH CAROLINA AND SOUTH CAROLINA

By
James P. Owens
1989

CORRELATION OF MAP UNITS

Map unit	Epoch	Period	Era
Qh	Holocene	QUATERNARY	CENOZOIC
Qwa, Qs, Qcp, Qph, Qw	Pleistocene	QUATERNARY	CENOZOIC
Tb, Td	Pliocene	TERTIARY	CENOZOIC
Tug, Tph	Age uncertain	TERTIARY	CENOZOIC
Tch	Eocene	TERTIARY	CENOZOIC
Tbm	Paleocene	TERTIARY	CENOZOIC
Kpd, Kdc, Kb, Kth, Km, Kcf		CRETACEOUS	MESOZOIC
JTRu		JURASSIC TRIASSIC	MESOZOIC
Mg, Mgr, Mmg		MISSISSIPPIAN	PALEOZOIC
Ꞓar, Ꞓph		CAMBRIAN	PALEOZOIC

DESCRIPTION OF MAP UNITS

COASTAL PLAIN DEPOSITS

Qh **Holocene deposits**—Holocene sediments are confined to major drainageways and small valleys, which are too small to be mapped at a scale of 1:250,000. The Holocene alluvial valley deposits are particularly widespread in the lower reaches of the Cape Fear and Pee Dee Rivers, where they overlap the older sediments of the valley. In addition, small sand dunes are widespread on most flood plains. The Holocene sediments vary in thickness from a feather edge to 15 m.

The riverine sediments typically are interbedded dark clays and light sand, commonly containing a thin gravel layer at the base. Woody materials are common throughout, especially in the lower reaches of the larger river valleys. Large logs, for example, are particularly abundant in the lower Cape Fear River.

Clay beds in the Holocene sections are typically dark gray to dark green, peaty, and micaceous. Illite-smectite and, to a lesser degree, kaolinite are the major clay minerals. The sands are variable in composition, largely because of the mixing of reworked Coastal Plain sediments and much less weathered minerals from the crystalline rocks of the Piedmont. Quartz and feldspar are the major sand minerals. Feldspar tends to decrease rapidly downvalley from 25 percent at Elizabethtown, N.C., to 15 percent at Wilmington, N.C. (east of the map area).

Wood from the base of the unit at Wilmington has a radiocarbon age of 7,270 years B.P., whereas upriver at Elizabethtown, ages of 3,540 years were obtained. Wood collected from dunes yielded ages between 5,000 and 7,000 years B.P.

Qwa **Wando Formation (upper Pleistocene)**—This formation consists of sandy deposits that form a single barrier and a very large fluvial system. The Wando Formation was named by McCartan and others (1984) for deposits lying at a similar elevation in the Charleston, S.C., area.

The barrier facies of the Wando is restricted to a thin zone along the coast in the southeastern corner of the map. At Holden Beach, west of Southport, N.C., a single barrier abuts against the older Socastee Formation. The barrier at Holden Beach has altitudes near 6.1 to 7.6 m above m.s.l. (mean sea level).

Five miles to the northeast at Carolina Beach, a channel (Snows Cut) has been cut through a similar coastal barrier (surface altitude 8.6 m above m.s.l.). The lower part of this barrier contains massive to crudely bedded, very shelly strata. The shell beds are extensively bleached, and the surrounding sand is stained a deep orange to rust brown. The shell beds rest unconformably on an indurated, massive, very shelly unit (Waccamaw or Bear Bluff Formation). The upper part of the Snows Cut barrier consists of thick to thin, humate-cemented sands. Most of the sand beds are internally structureless. In the humate-free sand beds, clay lamellae are common. No trace fossils were found in the upper sands, probably because this part of the barrier was formed principally by coastal dunes. No samples of these Wando barriers were collected for mineralogic analyses.

A hole was drilled through another Wando barrier at Southport. The upper 7.6 m in this hole is basically a loose medium to coarse sand. The upper meter of this sand is stained dark brown by humate, whereas most of the rest is pale gray. At 7.6 m the loose sand overlies a pale-green-gray clayey silt. Small amounts of wood are scattered throughout this 1.5-m interval. Between 9.1 to 11.8 m there is an increase in dark-gray clay and large shells of the oyster (*Crassostrea virginica*) are abundant. These large shells are absent from 11.8 to 15.2 m; this interval is largely a medium-gray very clayey fine sand in which microfauna, mainly benthic foraminifera, are very common. From 15.2 to 16.8 m is a fine- to coarse-grained slightly clayey sand. No fossils were observed in this interval. This lower sand is the basal part of the Wando Formation at this site. The Wando at this site, therefore, represents a shoaling sequence: shelf at the base, backbarrier in the middle, and barrier at the top.

Quartz is the major mineral in the sands of the Wando Formation. Feldspar, mostly potassium feldspar, ranges from 1 to 6 percent of the sand fraction. The heavy minerals in the Wando are immature. Labile minerals, such as hornblende, epidote, and, to a lesser degree, garnet, are abundant within 1.5 m of the surface. This mineral distribution indicates a minimum depth of weathering in the Wando.

The fluvial facies of the Wando is widespread in the Pee Dee River valley and, to a lesser extent, in the Waccamaw and Cape Fear River valleys. The tops of the Wando terraces lie at altitudes ranging from 6.1 to 27.4 m above m.s.l. in the Cape Fear valley and from 3.0 to 33.5 m above m.s.l. in the Pee Dee valley. The elevation of the base of the terrace deposits is known only along the Cape Fear River, where the range is from 4.4 to 18.9 m above m.s.l. The upper surface of the Wando Formation is unique because original depositional features are intact. A ridge-and-swale (scrollwork) topography is common. No Carolina bays (surface depressions) have formed on this surface, and their absence distinguishes Wando terraces from the older, higher level terraces in the valleys.

The sands in the scrollwork terraces as a whole are characterized by a high feldspar concentrations (typically greater than 20 percent of the sand fraction). The feldspar is entirely potassium feldspar and is largely altered. The nonopaque heavy minerals are characterized by large concentrations of epidote and, to a lesser degree, hornblende. Like the feldspar, the hornblende is commonly altered to varying degrees.

Studies of weathering profiles on the scrollwork terraces, particularly those in the Pee Dee River valley, show little alteration in the primary clay minerals. The surficial weathering, therefore, is slight to practically negligible. In the upper meter, the only significant change appears to be the partial transformation of illite-smectite to vermiculite. Hornblende persists into this zone, although the percentage is small, as compared with the unweathered part of the terraces below.

The age of the Wando Formation, as determined by uranium-disequilibrium studies on corals from this unit in the Charleston area, is about 90,000 years (McCartan and others, 1982). The Wando is, therefore, late Pleistocene in age.

Qs **Socastee Formation (upper Pleistocene)**—The Socastee Formation, like the Wando, has both marine and nonmarine facies. The marine facies of the Socastee, however, is much more widespread than that of the Wando. In fact, the Socastee Formation is the major coastal Pleistocene unit in the Cape Fear region (see map).

DuBar (1971) and DuBar and others (1974 and 1980) used the name Socastee to include all the coastal units occurring up to altitudes of 6.7 m above sea level. However, this definition would include part of my Wando Formation. My comparison of the Socastee at its type locality on the lower Waccamaw River and of the beds mapped by DuBar and others as both Wando and Socastee along the Intracoastal Waterway at and near Myrtle Beach, S.C., indicates that they are really part of the same formation. Hence, the name Socastee is retained and redefined in this report.

The marine facies of the Socastee crops out from the coast to just south of Allen, S.C., a width of about 30 km. The surface in much of the area is characterized by a well-developed ridge-and-swale topography. The ridges, or barriers, are closely spaced, especially between Myrtle Beach and Conway. DuBar and others divided the Socastee barriers into two systems, the Conway and Jaluco. Both are considered the same age by DuBar and others and me. The Conway and Jaluco barriers are east of the Pee Dee River. A similar, but less widespread, ridge-and-swale topography occurs west of the Pee Dee, especially between Yauhannah and Allentown, S.C. This barrier sequence thins toward the southern border of the Georgetown quadrangle and apparently merges with the Bethera barriers mapped by McCartan and others (1984). These authors considered the Bethera to be older than the Conway and Jaluco barriers, but I disagree. The Socastee has a maximum surface altitude of 15.2 m in the north and 9.1 m in the south. The base of the formation is irregular, ranging from about 2 m below m.s.l. to, less commonly, 5 m above m.s.l. In its updip area, the Socastee has eroded older formations and forms a low scarp with a base near 14 m above m.s.l.. The scarp is developed best east of the Pee Dee River and indistinct west of the river. Elliptical bays, or depressions, are abundant on the sandy barrier facies. Some of these bays are large, up to 3 km long, and are oriented northeast-southwest.

The lithology of the Socastee was determined largely from the exceptional exposures along the Intracoastal Waterway. Here, cut banks as much as 10 m high occur at several localities between the U.S. Route 501 and State Route 9 bridges. The base of the Socastee is exposed at several localities and commonly consists of 0.3 to 1 m of reworked shells, fine gravel, coarse sand, and, occasionally, woody pieces. The rest of the formation consists of interbedded sands and clays. The clays are commonly very peaty and, in some areas, contain upright tree trunks. Both the sands and clays are locally fossiliferous. Bioherms of oysters (*Crassostrea virginica*) in growth position are present in some of the clays. In most cases, however, the shells in this formation are current oriented, which suggests water transport after deposition. The sands are commonly clayey and poorly sorted. The sands range from massive to well cross-stratified. Trace fossils, notably the *Callianassa* type of crab, are present, but uncommon in these sands. The fossils in the formation are the types commonly found in restricted relatively low salinity environments (*Rangia* sp.., *Crassostrea virginica, Tagelus plebieus, Mulinia lateralis, Nassarius obsoletus*, and *Merceneria merceneria*).

Mineralogic studies of the sands in the Socastee show that quartz is the major mineral, and feldspar, mostly potassium feldspar, is present in amounts less than 15 percent of the sand fraction. The heavy-mineral assemblages are relatively immature and contain significant concentrations of such labile constituents as hornblende and epidote. X-ray studies of the clay fraction from a profile through the sands indicate that surficial weathering, as indicated by a gibbsite-vermiculite-kaolinite mineral assemblage, occurs to depths of 1 to 3 m. This depth suggests only a moderate amount of weathering, but more weathering than in the Wando Formation. The clay minerals in the clay beds are mostly illite-smectite. Smaller amounts of kaolinite and illite are also present. The nonmarine or fluvial system is best developed in the Cape Fear River valley, although erosional remnants are present in the Pee Dee, Lumber, and Waccamaw River valleys. In the Cape Fear River valley, the top of the fluvial facies slopes seaward from 32 m above m.s.l. in the upper part of the valley to 11 m above m.s.l. in the lower part of the valley. The base of the fluvial facies slopes from 18.3 to 1.5 m above m.s.l. From the upper valley seaward, younger terrace deposits of the Wando Formation bevel the Socastee deposits. In the lower valley, the fluvial and backbarrier facies of the Socastee are interfingered. In general, the Socastee nonmarine sediments are mostly sand. Clays in beds are, for the most part, uncommon.

The sands of the Socastee Formation, whether in the fluvial, barrier, or backbarrier facies, has large concentrations of epidote and hornblende. The light minerals are characterized by high quartz and low (10 percent average or less) feldspar content.

The age of the Socastee is about 200,000 years (McCartan and others, 1982). This unit, therefore, is an upper Pleistocene deposit.

Qcp **Canepatch Formation (middle Pleistocene)**—This unit was originally named by DuBar (1971), who thought the Canepatch was a widespread unit that underlay the Conway and Jaluco barriers near Myrtle Beach, S.C. McCartan and others (1982) showed that this relationship was unlikely on the basis of field relationships and "absolute" age determinations on corals (uraninum-disequilibrium-series technique) and mollusks (amino-acid racemization analyses). Corals from one Canepatch locality (originally collected by J.P. Owens and L.A. Sirkin in 1979) were dated at about 450,000 years by Szabo (1985) and are considerably older than any corals contained within other exposures of DuBar's Canepatch. For this reason, the Canepatch is restricted to one subsurface shelf facies outcrop found along the Intracoastal Waterway at locality ***WA–20*** of DuBar (1971). The Canepatch has no known fluvial facies in this map area.

The Canepatch Formation at locality ***WA–20*** is a coarse shelly quartz sand about 4.5 m thick, which lies unconformably over the Waccamaw Formation. The basal Canepatch contains shells reworked from the Waccamaw. The upper boundary of the Canepatch is marked by a thin bed of fine gravel that grades up into the thinly bedded, very carbonaceous clay and sand beds of the backbarrier facies of the Socastee Formation.

The light-sand fraction of the Canepatch is mostly quartz. The feldspar content, however, increases rapidly upward through the section, and, near the top, feldspar is about 23 percent of the sand fraction. Immature mineral species of nonopaque heavy minerals follow the same trend by being common only near the top of the unit. Hornblende and epidote, the labile minerals, are present in small amounts in the base, but are very abundant at the top of the unit where they locally total nearly 70 percent of the assemblage.

Canepatch fossils are abundant and belong to the *Andara ovalis* (*A. brasiliana* and *A. ovalis*) mollusk subzone of Blackwelder (1981). In most classifications, this subzone is middle Pleistocene in age.

Qph **Penholoway Formation (Lower Pleistocene)**—The name Penholoway was used in South Carolina by Colquhoun (1974) to define a terrace that reached to 21 m above m.s.l. McCartan and others (1984) used the informal designation of lithostratigraphic unit Q5 for beds underlying this terrace in the Charleston area. The Penholoway is largely a barrier and backbarrier system, the top of which lies at altitudes between 15 and 21 m above m.s.l. The base of the Penholoway deposits ranges from 6 to 9 m above m.s.l. and commonly lies below the deposits of the older Waccamaw Formation.

The Penholoway barriers are typically smaller than those associated with the Waccamaw. The barriers west of the Pee Dee River include the Pleasant Hill barrier system and, southwest of Lake Waccamaw, the Nakina barrier system of DuBar (1971). The barrier sands are thin, typically about 3 to 4.5 m thick. The sand is mainly quartz and less than 10 percent feldspar. The heavy-mineral assemblages vary considerably, but typically have high concentrations of the more resistant minerals, such as staurolite, sillimanite, kyanite, zircon, tourmaline, and rutile.

Most of the Penholoway surface is underlain by the backbarrier facies. The backbarrier deposits are thicker than the barrier sands, some backbarrier deposits being as much as 15 m thick. The base of the backbarrier facies typically has a thin reworked sediment zone that consists of shells, wood, sparse shark's teeth, and other vertebrate remains. Most of the backbarrier sediments are interbedded clay, clayey sand, and sand. In the Green Swamp area in North Caroina, the barrier facies consists of thinly bedded sand and silty clay, which gradually thicken downdip. The beds downdip are mostly sand, but have fine gravel dispersed throughout. The sand in the backbarrier facies has more labile heavy minerals than sand in the barriers. Epidote and, to a lesser degree, hornblende are locally major constituents in the backbarrier beds. Light minerals are similar in both the backbarrier and barrier sands.

The fluvial facies of the Penholoway is widespread in the Cape Fear and Pee Dee River valleys. Along the Cape Fear River, the top of the fluvial facies slopes from nearly 40 to 15 m above m.s.l. In the upper part of the Cape Fear River valley, the Penholoway fluvial strata have been replaced by younger units. In the Pee Dee valley, the fluvial Penholoway slopes from about 41 m above m.s.l. in the upper valley to 12 m above m.s.l. in the lower valley. In general, the Penholoway fluvial facies seems to lie at slightly higher altitudes in the Cape Fear valley than in the Pee Dee valley. In both valleys, the fluvial facies are about 15 m thick. Most of the Penholoway fluvial facies in the Cape Fear valley is sand. In the Pee Dee valley, the few exposures of this facies become finer upward in the sequence. In the upper one-third of the Pee Dee valley, gravel and gravelly sand in the lower half of the fluvial facies grade into sand; sand grades upward into a clayey silt in the upper half of the facies. In the middle and lower one-third of the valley, the gravel content decreases, but the same clay-silt to sand relationship exists. In both areas, the upper clay-silt facies is about 3 to 4.5 m thick.

X-ray studies of the clay and silt indicate the clay is predominantly kaolinite plus lesser amounts of illite-smectite and even smaller amounts of vermiculite. The sand has large concentrations of the metamorphic minerals staurolite, sillimanite, and kyanite, as well as high concentrations of epidote. In the opaque fraction, ilmenite is the dominant mineral. In the light fraction, quartz is dominant, but feldspar is abundant (about 20 percent). Feldspar appears more abundant in the Pee Dee valley than in the Cape Fear valley.

Fossil assemblages in the Penholoway are sporadically distributed throughout the outcrop belt and are exposed in some of the deeper pits near the coast. Fossil analyses indicate the Penholoway is younger than the Waccamaw Formation, but is still presumed to be early Pleistocene (older than 760,000 years) (T.M. Cronin, written commun., 1985).

Qw **Waccamaw Formation (lower Pleistocene)**—The type locality of the Waccamaw Formation is a small fossil bed lying along the Waccamaw River near Conway, S.C. The history of the nomenclature pertaining to this formation is described by DuBar and others (1974). DuBar (1971) and DuBar and others (1974) expanded the definition of the Waccamaw Formation to include a related barrier facies. McCartan and others (1984) divided the Waccamaw of DuBar into the Penholoway (their lithostratigraphic unit Q5) and Waccamaw (their unit Q6) Formations, and this twofold separation is extended into the Cape Fear area.

In the coastal area, the Waccamaw is largely a barrier and backbarrier sequence that crops out at altitudes between 21 and 30 m above m.s.l. A shallow-shelf facies of the Waccamaw is exposed at depth along some of the larger rivers in the downdip area, such as along the Waccamaw River, along the Intracoastal Waterway near Myrtle Beach, and in large, now inactive pits near Little River and Calabash, N.C. A fluvial sequence is particularly widespread in the Cape Fear and Lumber River valleys.

The Waccamaw barriers are most abundant west of the Pee Dee River, where they reach altitudes near 27 m above m.s.l. (the Kingstree barrier of DuBar, 1971). Eastward, these barriers form a headland abutting against older units, and they include the Daisy strand and Nakina barrier of DuBar (1971). Northeast of the Cape Fear River, the barriers are small, but near Rose Hill, N.C., they reach the highest known level for the Waccamaw barrier system (30 m above m.s.l.).

The thickness of the barrier sands averages about 10.7 m near the Pee Dee River and about 6 m elsewhere along the outcrop belt. The barriers are commonly fine to coarse interbeds of poorly to well-sorted sands. The lower few meters are commonly reworked sediments from the underlying units. Where the barrier overlies the shelly facies of the Bear Bluff or Duplin Formations, the basal beds of the Waccamaw contain shells from those units. Elsewhere, few indigenous fossils are associated with the barrier sands except for some *Mulinia*-dominated assemblages (shallow-water facies) east of the Cape Fear River. Compositionally, the Waccamaw barrier sands are mostly quartz; feldspars are present only in the base of the barrier sands. Nonopaque heavy-mineral assemblages vary along outcrop, and the southwest barriers are characterized by large amounts of metamorphic minerals (staurolite, sillimanite, and kyanite). Locally epidote is a constituent. A maximum depth of 8 m of subaerial alteration was determined from weathering profiles on the barriers by using the vermiculite-kaolinite-gibbsite mineral assemblage.

The Waccamaw backbarrier facies occur in broad flat areas, but locally they may fill channels lower than the general level of most of the formation. The sediments of the backbarrier facies are more complex than those of the barrier facies. In general, the backbarrier facies are interbeds of clayey silts and clayey sands, which may have reworked shells at the base. The sands in both the backbarrier and barrier facies are similar. The clays in the backbarriers are principally illite-smectite and small amounts of kaolinite. Abundant organic matter and logs are locally characteristic of the backbarriers. A peaty facies is particularly abundant northeast of the Cape Fear River. The backbarrier facies, averaging about 6 m in thickness, are thinner than the barrier sands. However, these deposits can be up to 12 m thick.

The marine or shelf facies of the Waccamaw occurs only downdip beneath the younger Coastal Plain deposits. Downdip exposures of the Waccamaw near Little River and Calabash, N.C., reveal normal, open ocean faunas. The fossil assemblages in this unit are characterized by the following species: *Ostrea sculpturata, Noetia limula*, and *Mulinia lateralis*. On the basis of the macrofauna, Blackwelder (1981) believes that this unit was deposited during a subtropical interval of the Pleistocene. The microflora (pollen from one of the thickest organic-rich facies of this unit near Kingstree, S.C.) suggests that the climate during deposition was cooler in the lower part of the strata than in the warmer, subtropical, upper part.

The Waccamaw has a fluvial facies that is particularly widespread in the valleys of the Cape Fear and Lumber Rivers. There the Waccamaw riverine sediments form broad terraces that slope upvalley and reach altitudes over 42.7 m above m.s.l. at the northeast edge of the map. The riverine, or fluvial, facies of the Waccamaw were best studied in the Cape Fear River valley, where a broad terrace is assigned to this unit. The Cape Fear terrace ranges up to 13.7 m thick and is mostly sand. Small gravel, no larger than 2.5 cm in maximum dimension, is common in the basal part of the formation, especially in the upvalley areas. The surface of the terrace has abundant, small to large surface depressions, or Carolina bays.

Tb **Bear Bluff Formation (upper Pliocene)**—Originally, the Bear Bluff Formation was defined as those deposits lying immediately seaward of the Surry scarp (below 30.5 m above m.s.l. of DuBar (1971). Later, DuBar and others (1974) tentatively correlated the Bear Bluff with their Marietta unit, a widespread subarkosic to quartzose sand that occurs between the Surry scarp (30.5 m above m.s.l.) and the Mechanicsville scarp (40 m above m.s.l.). This correlation has been adopted with slight modifications in the Florence-Georgetown area. As mapped, the Bear Bluff includes all the barrier and backbarrier facies above 30.5 m in altitude between the Pee Dee and Cape Fear Rivers, and this includes the Horry and Rosindale barrier systems of DuBar and others (1974) as well. The Mechanicsville scarp, which marks the updip limit of the Bear Bluff, is intermittent and, for the most part, poorly defined between the Pee Dee and Cape Fear Rivers. West of the Pee Dee River, the scarp is very difficult to recognize. East of the Cape Fear River, most of the marginal marine facies of the formation were removed during the emplacement of the Waccamaw Formation.

The marine (shelf) facies of the Bear Bluff typically consists of a basal shelly horizon. The basal shelly beds locally occur in deep narrow trenches, particularly in the downdip areas. These entrenched shelly beds are commonly leached and recemented by calcite into hard masses. An excellent exposure of this leached shelly facies of the Bear Bluff is in a large quarry near Cedar Grove, S.C. Here, the channels, or trenches, extend down at least 12 m below m.s.l., and the leached shell horizons are as much as 25.6 m thick.

The calcite-rich shell beds become thinner updip, and the shells are dominantly calcitic. Although widespread, the shelly horizons are not ubiquitous in the base of the formation. Some of the larger (up to 3 m thick) shell concentrations of this calcite-rich shell layer are present in the vicinity of Elizabethtown, N.C. (including the commonly cited, so called "Waccamaw" exposures at Walkers Bluff), Marietta, N.C., and Sardis, S.C.

The shell beds in most areas grade up into thick beds of bluish-green to dark-gray, very clayey silt. These beds are largely known from subsurface sampling, but they are exposed in small outcrops in road cuts along U.S. Route 76 near Whiteville, N.C. The very clayey silts are complex intercalations of sand and silty clay beds, which commonly contain abundant carbonaceous matter and locally contain light-brown uncarbonized wood fragments. DuBar (1971) referred to these beds as the Chadbourn shoal, which he considered to be a deltaic deposit. However, DuBar and others (1974) later redefined these beds as backbarrier (lagoon and marsh) deposits. DuBar and others (1974, 1980) also recognized another delta, called the Olanta delta, near Kingstree, S.C., which they considered to be younger than the Chadbourn. I believe the two deposits are coeval and are part of the clayey silt facies of the Bear Bluff Formation.

X-ray studies of the clay fraction of the clayey silt facies show that illite-smectite is the major clay mineral and that kaolinite and illite are minor constituents. Studies show similar compositions for the heavy- and light-mineral fractions of the sands and the underlying shelly facies. The major heavy, resistant-to-weathering minerals include zircon, tourmaline, rutile, staurolite, sillimanite, and kyanite. The more labile epidote is abundant locally, and hornblende is common in some of the updip shelly beds. Both the clay minerals and the heavy-sand minerals indicate moderate sediment maturity. Feldspar comprises about 10 percent of the light-mineral fraction and also substantiates a moderate sediment maturity.

The barrier facies of the Bear Bluff is very thin and averages about 4.5 m in thickness. The barriers are poorly exposed for the most part, and their internal bedding characteristics are generally not known. However, in pits near Smithboro, S.C., laminated to thin-bedded, burrowed tidal-flat deposits overlie crossbedded sands of tidal-inlet deposits. The tidal-inlet deposits have abundant *Ophiomorpha* burrows. Sand minerals in the barriers are varied, largely because of deep postdepositional weathering. The less weathered deposits have a feldspar content of 15 to 35 percent; the lowest values are in the barriers, and the highest are in the fluvial facies of the formation. The opaque heavy minerals are dominated by the weathering products of ilmenite, pseudorutile, and leucoxene. The nonopaque heavy minerals are mostly zircon, tourmaline, rutile, staurolite, sillimanite, and kyanite. No hornblende, epidote, garnet, actinolite, or tremolite occurs in the deeply oxidized sands, but they do have particularly large concentrations of sillimanite.

The fluvial facies of the Bear Bluff can be traced updip in the Cape Fear and Pee Dee River valleys. The fluvial facies reach an altitude of about 40 m above m.s.l. in the Pee Dee valley, but are higher in the Cape Fear River valley where their updip limit lies north of the Florence quadrangle. The thickness of the fluvial facies is variable due to extensive dissection. In both the Pee Dee and Cape Fear River valleys, the fluvial facies is a maximum of about 13 m thick, and the surface has abundant, small to large Carolina bays. The fluvial facies in the Pee Dee River valley has a thick clay-silt cap overlying a very gravelly unit at Cheraw, S.C.; the gravel becomes sandier downvalley. No such clay-silt cap is present in the Cape Fear valley. The light-mineral assemblage of the sand in both valleys is mostly quartz and feldspar. The nonopaque heavy minerals are also similar and are relatively immature containing high concentrations of epidote. Monazite is notably abundant in the extreme updip areas near Cheraw, S.C.

Interfingering of the fluvial, barrier, and backbarrier facies of the Bear Bluff is evident from borings in the Pee Dee valley. Interfingering of the fluvial facies with fossiliferous marine (shelf) beds of the Bear Bluff shows that the ancestral Pee Dee and Cape Fear Rivers are at least as old as the Bear Bluff, which is late Pliocene in age (DuBar and others, 1980). A fossil suite collected from the Bear Bluff at Elizabethtown, N.C., has a relatively diverse assemblage that is similar to that of the Chowan River Formation (L.W. Ward, written commun., 1984). Of particular note in the megainvertebrate assemblage are *Noetia limula, Anadara improcera*, and *Ostrea sculpturata*. The ostracodes also suggest that the Bear Bluff is latest Pliocene (Cronin and others, 1984) and that it was deposited about 1.8 to 2.4 m.y. (million years) ago.

Td **Duplin Formation (lower Pliocene)**—DuBar and others (1974) restricted the Duplin Formation to the area between the Mechanicsville scarp (toe about 41 m above m.s.l.) and the Orangeburg scarp (toe between 55 and 67 m above m.s.l.). This definition has been applied in the Florence-Georgetown area, although the Orangeburg scarp is higher than perceived by DuBar and others; it ranges between 76 and 88 m above m.s.l. Blackwelder and Ward (1979) recommended that the name Yorktown rather than Duplin he used in North and South Carolina. However, until the area between southern Virginia (the type locality of the Yorktown) and Florence is mapped, the use of the name Yorktown seems premature, and the name Duplin is retained herein.

The Duplin Formation underlies a broad, highly dissected plain that slopes from nearly 88 m above m.s.l. near Silver Hill, N.C., to 30.5 m near Lumberton, N.C. The base of the unit near its updip limit is nearly 67 m above m.s.l., whereas at Lumberton, N.C., it is only 16.8 m above m.s.l. Carolina bays, some large, are very abundant on the Duplin sand plain. This presence of Carolina bays helps separate the Duplin from the adjacent older units along the Orangeburg scarp, where units are poorly exposed.

Near the Orangeburg scarp, the Duplin Formation is about 21.3 m thick, and basal beds of gravelly sand are typically about 3 to 4.5 m thick. These gravelly beds are capped locally by interbedded, thin, dark-gray clay and silt and light-yellow sand. Pollen studies indicate a Neogene age for these beds, and the abundance of dinoflagellates in the pollen samples indicates a strong marine influence during deposition. Farther downdip, calcareous fossils are present in the base of the formation. West of Florence, S.C., and near Lumberton, N.C., these fossil beds are 3 m or less in thickness, but they are sporadically distributed north of the Cape Fear River at Magnolia and near Clinton, N.C. Even farther downdip, the fossil beds thicken and are generally confined to channels cut into the underlying Cretaceous formations. The commonly cited fossil-rich localities at Davis and Bostick Landings (Cooke, 1936, for example) on the Pee Dee River are the best examples of the Duplin shelf facies. There, the Duplin consists of light-gray, fine calcarenite containing large pectinoid shells. These shell beds differ from those in the younger shelf beds of the Bear Bluff Formation in that fossil beds in the Bear Bluff still contain aragonite.

Although widespread in the upper part of the formation, the sands of the Duplin typically are poorly exposed. Several pits have been dug into the sandy facies in the extreme updip areas near Cash, S.C., on the west side of the Pee Dee River. The sands there have a large gravel component and are characterized by long, low-angle, deltaic crossbeds. However, some sand beds are burrowed extensively and indicate deposition in a nearshore environment. Near Mont Clare and in pits north of Florence, S.C., the formation consists of intensely burrowed, thin interbeds of clay and sand that suggest some tidal-flat deposition. The sands of the Duplin probably were deposited in a complex marginal marine environment where both marine and nonmarine sands were interfingered. In all the pits examined in this sand plain, only a few widely scattered *Ophiomorpha* were observed. Although some geologists favor a barrier origin for this unit, the preserved Duplin sands appear to be more of a shelf system without major barriers.

The sandy facies of the Duplin are very deeply weathered. X-ray studies of the clay-silt fraction of the sands indicate that kaolinite is the major clay mineral and that it is developed to a depth of 12 m. The local indicators of intense weathering, gibbsite and vermiculite, are well developed, but they are absent in most profiles. Apparently, the upper beds of the Duplin plain were stripped during the formation of the widespread Carolina bays.

The heavy minerals in the sandy facies have only the resistant zircon-tourmaline-rutile and staurolite-sillimanite-kyanite mineral suites. The distribution of sillimanite seems important because it is more abundant nearer the Pee Dee River than the Cape Fear River. The light-mineral fraction of the Duplin sands is almost all quartz. Feldspars, if originally present, probably were removed by intrastratal solution. The Duplin deposits are much more mature than those of the Bear Bluff, probably because the permeable sands of the Duplin allowed water to percolate through the formation, which destroyed the labile minerals.

The age of the Duplin Formation is early Pliocene (DuBar and others, 1980). Cronin and others (1984) specifically indicated that this unit was deposited about 2.8 to 3.6 m.y. ago. The megainvertebrate fauna includes *Ostrea raveneli, Noetia rigintinaria, Glycemeris subovata*, and *G. americana*, all of which characterize the Yorktown Formation in Virginia (L.W. Ward, written commun., 1984). Cronin and others (1981, 1984) put the Bear Bluff and Duplin in their *Paracytheridea mucra* zone, yet they assigned samples from Davis Landing and other Pee Dee River localities to their *Murrayina barclayi* zone (Bear Bluff). This is unlikely because the two formations are clearly separated in the field.

Tug **Upland gravels (lower Pliocene?)**—Upland gravels are found in small areas at altitudes between 92 and 152 m above m.s.l. in the northwest corner of the Florence quadrangle. The surface of the upland gravels decreases in altitude to the southeast, where the gravels appear to be truncated by the Orangeburg scarp. However, the area near their downdip limit is highly dissected, and it is possible that they extend below the scarp as a fluvial facies of the Duplin Formation.

The upland gravels are mined extensively for gravel and sand near Lilesville, N.C. In a typical exposure, the gravel beds are stratified horizontally. Crossbedded sand beds without gravel are present locally. The upland gravels are weathered deep red to a depth of 3 m and are a lighter red below.

The sand and gravel are primarily quartz. Heavy-mineral assemblages are typically mature (high in zircon, tourmaline, and rutile) and locally have high concentrations of monazite. Sillimanite persists throughout, although the amount varies greatly. Brown ilmenite (pseudorutile) is the major opaque mineral.

The age of the upland gravels is conjectural. The presence of sillimanite suggests a Tertiary age. If the upland gravels are a fluvial facies of the Duplin Formation, then they are early Pliocene in age.

Tph **"Pinehurst" Formation (lower Pliocene?)**—The uplands between 116 and 170 m above m.s.l. in the Hamlet-Raeford, N.C., area are capped by a widespread loose sand. Burt (1981) correlated this sand with the Pinehurst Formation of the Neuse River area to the northeast. After detailed examination, Daniels and others (1978) concluded that the Pinehurst was a widespread surficial unit of fluvial origin that overlay the Macks Formation of Daniels and others (1966), equivalent to lower Yorktown Formation, at altitudes greater than 85 m above m.s.l. in the Neuse River area.

The "Pinehurst" is typically a massive to very thick bedded, white, medium sand and some intermixed fine to coarse sand. Orange-to-brown, thin clay lamellae and small circular burrows are present in most outcrops. In a few places, buried soil horizons have been recognized. The total thickness of the "Pinehurst" is unknown, but it could be as much as 30 m. Cuts approximately 7 m high are present along the railroad near Hamlet, N.C., and in road cuts near McLeod Lake and east of Hamlet.

Quartz is the major light mineral in this unit. No feldspars were found in any of the analyzed samples. The nonopaque heavy-mineral assemblages are mature and are characterized by high zircon-tourmaline-rutile and moderate staurolite-sillimanite-kyanite concentrations. Monazite comprises almost 10 percent in most samples. Small amounts of sillimanite are present throughout. Except for sillimanite, the mineral assemblage is similar to that of the underlying Cretaceous units (Tar Heel and Middendorf Formations). Similarly, the opaque mineral assemblage is dominated by brown ilmenite (pseudorutile), which characterizes the older Cretaceous formations.

The age of the "Pinehurst" Formation in this area could not be determined directly. If the proposed equivalency with the Pinehurst of the Neuse River area is correct, this unit would be Pliocene in age (post-Macks Formation, equivalent to lower Yorktown Formation) (Daniels and others, 1978). The stratigraphic position of the "Pinehurst" in the Florence quadrangle suggests that it is older than the Orangeburg scarp and, therefore, pre-Duplin (Yorktown equivalent) in age; however, if this unit is partly eolian, a much younger age is possible.

Tch **Castle Hayne Limestone (middle Eocene)**—The Castle Hayne Limestone is normally a subsurface unit in this area, but it is exposed in two large quarries, one north and one south of Rose Hill, N.C. In both pits, the Castle Hayne occurs as filled channels cut deeply into the adjacent Cretaceous formations. The Castle Hayne here is largely a crossbedded calcirudite to calcarenite as much as 15 m thick. Although most of the formation is calcareous, fine-grained glauconite grains are common throughout. The heavy-mineral assemblage includes ilmenite and leucoxene as opaque minerals, as well as nonopaque zircon and staurolite, and accessory amounts of tourmaline, garnet, and kyanite.

The main outcrop belt of the Castle Hayne is near the coast. About 13 m of the calcirudite facies was penetrated beneath Pleistocene deposits in an auger hole north of Southport, N.C. Although the contact with the underlying Peedee Formation was not reached in this area, this contact was observed in large pits at Castle Hayne, N.C., just north of Wilmington; this contact is sharp and unconformable. The Paleocene Beaufort Formation is absent there, which indicates an overlap or unconformity between the Castle Hayne and Beaufort. The basal part of the Castle Hayne has up to 30 cm of an indurated basal conglomerate containing large black clasts of limestone and phosphate.

The age of the Castle Hayne Limestone is middle Eocene (Lutetian) (Ward and others, 1978); diagnostic fossils in this interval are *Cubitostrea sellaformis, Pecten membranous*, and *Pecten clarkeanus*.

Tbm **Black Mingo Formation (Paleocene)**—The Black Mingo Formation underlies most of the western part of the Georgetown quadrangle. Small outcrops are exposed only along the Black River near Rhems and Bryans Crossroads, S.C. The formation was studied most recently by Van Nieuwenhuise and Colquhoun (1982), who favored raising the unit to group rank and dividing it into three formations: Rhems, the Williamsburg, and an upper unnamed lower Eocene unit. The lower Eocene (Ypresian) unit later was defined and named the Fishburne Formation; it overlies the Black Mingo Formation (Gohn and others, 1983). Because of poor exposure, these units have been combined in this area, and the old name of Black Mingo has been retained.

About 34.4 m of Black Mingo and Pleistocene deposits was exposed recently in a diversion canal near St. Stephens, S.C. (R.E. Weems, written commun., 1984), just west of the mapped area. There, the Black Mingo resembles the Black Mingo described by Van Nieuwenhuise and Colquhoun (1982), except that more crossbedding is reported at St. Stephens.

An upper unit of the Black Mingo at St. Stephens consists of 23 m of intercalated, horizontally layered, thin, dark-gray clay beds and light-yellow sands. The lower part of this unit is shelly; most are oysters, broken shells, and some *Ophiomorpha*. At the base of this upper unit is a 0.6–m–thick coarse sand bed containing phosphate, quartz pebbles, and a few broken fossil shells and wood fragments. X-ray studies from this interval show that illite-smectite and cristobalite are the major clay-sized minerals. Nonopaque heavy minerals are characterized by zircon, tourmaline, rutile, staurolite, sillimanite, and kyanite. Garnet, however, is a major mineral in all samples. Most of the light minerals in this unit are quartz. Feldspar constitutes less than 5 percent of the sand fraction.

A lower unit at St. Stephens is about 5.5 m thick and consists of thick beds of sand in the upper part and massive black shale below. Indurated calcareous lenses up to 15 cm thick, as well as scattered fossils are present in the shale. The contact with the underlying Peedee Formation is sharp, but no coarse clasts occur along the boundary. The clay and sand mineralogy of this lower unit is similar to that of the upper unit.

The upper unit of the Black Mingo is Selandian (Thanetian) in age on the basis of an ostracode assemblage that includes *oprimocythere nanafaliana, Clithrocytheridea harrisi, Ouachitaia broussardi, Hermanites bassleri*, and others. The lower unit of the Black Mingo is Danian, as determined largely from the presence of the ostracodes *Opimocythere elonga, Haplocytheridea anteronoda, Loxoconcha atlantica, Acanthocythereis washingtonensis*, and *Cytheropteron walkeri*.

Kpd **Peedee Formation (upper Cretaceous)**—This formation is exposed in the banks cut along the Cape Fear and Pee Dee Rivers and their large tributaries. Most of the outcrops are small (5 m in thickness or less), but the length of exposure provides a good opportunity to examine much of the formation. The formation is best exposed along the Pee Dee River from near Burches Ferry to Hemingway, S.C., a distance of about 40 km. Most of the Peedee is a massive to thick-bedded, dark-gray to gray-green, slightly to very clayey, micaceous, calcareous, glauconitic quartz sand. These deposits are extensively bioturbated. Locally, thin (30–100 cm) ledges of impure limestone are present. Most of the glauconite-rich beds are massive, although some are crossbedded locally. The Peedee is abundantly fossiliferous and contains large macrofossils, notably *Exogyra costata* and *Belemnitella americana*, and a microfaunal suite, which belongs to the *Globotruncana ganserri* foraminifer zone (Sohl and Christopher, 1983).

The Peedee is separated from the underlying unit by a reworked zone containing abundant phosphatic pebbles and phosphatic organic remains (shells, for example). The best exposures of this contact are at Black Rock Landing on the Cape Fear River and at Burches Ferry on the Pee Dee River. The reworked bed varies in thickness, but locally is as much as 1 m thick. Sohl and Christopher (1983) included in the Peedee Formation the beds between Donoho Creek Landing and Black Rock Landing along the Cape Fear River. Owens and Gohn (1985) favored returning this unit to the Black Creek, and I have done the same.

The thickness of the Peedee is difficult to determine because the dip is very low (estimated to be 3 m per km) and variable throughout the region. The Peedee is at least 37.4 m thick as measured in the corehole (*MRN–78*) near Britton Neck (fig. 2). However, only the lower part of the formation is present at that locality.

The light-sand fraction of the Peedee is mostly quartz. Feldspars typically occur in amounts less than 10 percent. The nonopaque heavy-mineral assemblages are characterized by moderate concentrations of zircon, tourmaline, rutile, staurolite, and kyanite and an unusually high concentration of garnet. The clay minerals in the Peedee are principally illite-smectite, kaolinite, and illite.

The Peedee Formation in this area represents a complete sedimentary cycle if the Scotts Hill Member (Rocky Point Member of Wheeler and Curran, 1974) of the Peedee at Wilmington, N.C., is included. The Scotts Hill consists of interbedded quartz sands and massive limestone, which are interpreted as a nearshore deposit (barrier-backbarrier facies). The Peedee apparently represents a single marine transgressive-regressive sequence having deeper water facies at the base and shallower water facies at the top. N.F. Sohl (written commun., 1982) notes, however, that facies changes within the upper part of the Peedee suggest several episodes of deepening and shallowing and that this formation consists of several transgressive-regressive cycles rather than one.

The Peedee is middle to late Maestrichtian as determined from the foraminifer species *Globotruncana aegyptiaca, Rugoglobigerina macrocephala*, and *Heterohelix glabrans*, which are near the base of the unit at the Burches Ferry locality. Pollen from this interval indicates that this unit lies within the CA6/MA1 pollen zone (Sohl and Christopher, 1983) of middle to late Maestrichtian age. Finally, the abundant megainvertebrate fauna indicates that the Peedee falls within the *Exogyra costata* zone (Sohl and Christopher, 1983). The Peedee also contains *Haustator bilira*, which suggests a late Maestrichtian age.

BLACK CREEK GROUP

The long-established Black Creek Formation is characterized by intercalated thin beds of black clay and light-yellow sand at its type locality near Darlington, S.C., Sohl and Christopher (1983) studied the Black Creek Formation along the more or less continuous exposures on the Cape Fear River, and they found that the Black Creek spanned nearly all of the Campanian Stage, although several time gaps, some of significant length, occurred. Marine units of similar age north and south of the Cape Fear arch have at least two transgressive-regressive cycles (Owens and Gohn, 1985). Time breaks between these regionally recognized marine cycles appear to coincide with time breaks recognized in the Black Creek unconformities along the Cape Fear River. However, correlation of Black Creek lithofacies between the Cape Fear River and the Pee Dee River valley is difficult, primarily because the Black Creek is a complex deltaic deposit in which rapid vertical and lateral facies changes are common. Therefore, the Black Creek is redefined. In this framework, the Black Creek Formation is raised to group status and divided into three formations, the Donoho Creek, Bladen, and Tar Heel, that are bounded by regionally synchronous unconformities. The regional distribution of the three formations and their depositional relationships between Greenville, N.C., and Columbia, S.C., are shown in figure 3.

Kdc **Donoho Creek Formation (upper Cretaceous)**—The upper unit of the Black Creek Group is the newly named Donoho Creek Formation. Sohl and Christopher (1983) noted that, from Donoho Creek Landing to Browns Landing on the Cape Fear River, typical Black Creek beds (intercalated clays and sands) were overlain by a more massive, fossiliferous sand deposit. The base of this massive unit is marked by a thin zone of small reworked quartz and phosphate pebbles. This massive unit can be traced downstream to Black Rock Landing, where it is overlain by a second pebble bed at the base of the Peedee Formation. This lithologic association can be traced from the Cape Fear River northeastward into the Neuse River valley and its tributaries, a distance of about 100 km. Farther northeast, the Donoho Creek Formation is buried beneath Tertiary formations. Sohl and Christopher (1983) had assigned this unit to the basal part of the Peedee Formation. However, to the southwest in the Pee Dee River valley, this massive unit is not present. Instead, the stratigraphic interval between the unconformities at Browns Landing and Black Rock Landing has laminated to thinly bedded, intercalated sands and clays or thin crossbedded sands that are typical of the Black Creek. These deposits are best exposed at Mars Bluff and can be followed intermittently downstream from Mars Bluff to Burches Ferry, where they are overlain unconformably by the massive Peedee Formation. In the Pee Dee River valley, therefore, the Donoho Creek Formation has more lithic affinities to the Black Creek Formation than to the Peedee Formation. For this reason, the Donoho Creek Formation is included as the upper formation of the Black Creek Group.

The Donoho Creek deposits in the Cape Fear River valley are largely dark-gray, medium-grained sands. Large megainvertebrates are scattered throughout this unit. Much of the formation has a mottled appearance resulting from bioturbation. The nonopaque heavy minerals are dominated by the more resistant types: zircon, tourmaline, rutile, staurolite, and kyanite. Garnet, chloritoid, and, to a lesser extent, epidote and monazite are accessory minerals. Ilmenite is the major opaque mineral, followed by its weathering products, pseudorutile and leucoxene. Quartz is by far the major light mineral; feldspar is present in amounts less than 5 percent. X-ray studies show that illite-smectite is the major clay mineral, and kaolinite and illite are accessory minerals.

In the Pee Dee River valley, the Donoho Creek Formation has a variable lithology. At Mars Bluff near the base of the formation, well-sorted crossbedded beach sands interfinger with intercalated thin beds of dark clay and light sand, which represent the delta front. Downriver, the delta-front facies dominate, as can be seen at the top of the formation exposed at Burches Ferry. There, the beds are shelly and extensively burrowed. In the Britton Neck corehole about 24 km downvalley from Burches Ferry, the Donoho Creek lithology is the same as that exposed along the Cape Fear River.

The heavy-mineral fraction of the sand in the outcropping Pee Dee River beds is similar to that of the Cape Fear River deposits, but feldspar is much more abundant in the former, in some cases half of the light-mineral sand fraction. There is more kaolinite in the Pee Dee River facies than in the deposits in the Cape Fear River area. Similar sand and clay mineralogies are found in the top of the formation at Burches Ferry.

The Donoho Creek marine sequences are about 18 m thick in the corehole near Britton Neck (fig. 2). The delta-front and beach facies exposed in the river sections are at least this thick.

The fossils in the Donoho Creek Formation indicate that this unit represents the *Exogyra cancellata* zone of Sohl and Christopher (1983) and is essentially early Maestrichtian in age.

Kb **Bladen Formation (upper Cretaceous)**—The Bladen Formation as originally defined by Stephenson (1907) consisted of intercalated, thin, dark clays and light sands found along the Cape Fear River. The name was replaced by Black Creek when it was found this name had priority. The Bladen was later used as a member of the Black Creek Formation by Heron (1958). The name Bladen is raised here to formation rank, now that the Black Creek has been raised to group status. As defined in this report, the Bladen Formation consists of the intercalated sand-clay sequences that occur between Donoho Creek Landing on the south and Dawsons Landing on the north. This definition fits the description of Stephenson (1907) and applies to both the Cape Fear River and Pee Dee River valleys. The unit is about 44 m thick.

In the Cape Fear valley, the basal beds consist of thin intercalated sand and clay beds; woody fragments, some burrows, and coarse mica flakes are common. Near Little and Big Sugar Loaf Landings on the Cape Fear River, the thinly bedded facies change to thick, crossbedded sand and massive black clay beds. Large lignitic logs are present in the clay, and a few *Ophiomorpha* are present in the sand. The Bladen is best exposed farther downstream at Walkers Bluff. There, several facies show rapid vertical and horizontal changes. One of the more striking facies has finely bedded to laminated, horizontal intercalations of sand and clay. The sand here has a small, but persistent, concentration of glauconite. Scattered megainvertebrates are present, although not abundant. The Bladen here has extensive, small, short burrows. This laminated sequence is in sharp contact with an overlying, crossbedded, fine to coarse sand unit, which contains local concentrations of small pebbles, scattered fossils, and small burrows. The same lithic variability continues downstream to Donoho Creek Landing. Fossil beds are present at Deep Point and Donoho Creek Landing on the Cape Fear River at Fair Bluff, N.C., and along the Lumber River drainage at Hodges Mill near Mullin, S.C.

In the Pee Dee River valley, the Bladen is exposed intermittently from the bluff north of Florence to near Hurricane Branch and along Black Creek at Darlington. The same lithic variability noted in the Cape Fear valley is present here, except that there are no megainvertebrates, burrows, or glauconitic sand indicative of marine deposition. In the corehole near Britton Neck in the lower Pee Dee valley, the Bladen is characterized by abundant shelly layers (fig. 2). These beds are more marine than those of the upper Pee Dee valley and are more like the beds in the Cape Fear River valley.

In the Cape Fear valley, the sand is mostly quartz, but feldspar comprises up to 15 percent. The nonopaque heavy minerals are dominated by the resistant types: zircon, tourmaline, rutile, staurolite, and kyanite. Garnet is present locally in moderate amounts and epidote in lesser amounts. Chloritoid, monazite, and andalusite are accessory minerals. In general, chloritoid is less abundant in the Bladen than in the Donoho Creek Formation.

The age of the Bladen Formation is latest Campanian to earliest Maestrichtian or the uppermost part of the *Exogyra ponderosa* zone of Sohl and Christopher (1983). The Bladen Formation can be correlated with the Marshalltown-Wenonah-Mount Laurel marine cycle of New Jersey (Owens and Gohn, 1985).

Kth **Tar Heel Formation (upper Cretaceous)**—The basal unit of the Black Creek Group is the Tar Heel Formation. The Tar Heel beds, like the other units in this group, are characterized by rapid facies changes in the Cape Fear River valley. The best exposures of the Tar Heel occur in the type area between Tar Heel and Court House Landing on the Cape Fear River. The many facies within the Tar Heel include thin- to thick-bedded, black clays and thin to thick, light-colored sand beds. Carbonaceous matter ranges from finely dispersed grains through log-sized pieces. The sands are massive to crossbedded and are mostly very micaceous. No burrows were observed, although dinoflagellates suggesting some marine influence have been found in a few clay samples. The Tar Heel beds overlie the Cape Fear Formation with a sharp contact, which is exposed at several localities along the Cape Fear River, mainly between Cedar Creek and Lena, N.C. One interesting aspect is that there is no reworked material along the surface of the contact, even though a large time interval is represented by this unconformity. The upper contact with the Bladen Formation is not exposed in this area and is buried beneath the late Tertiary onlap between the Cape Fear River and the Pee Dee River valleys. The Bladen and Tar Heel Formations in this region are separated largely on the presence or absence of burrows and, less reliably, on the amount of sand, the Bladen being far more sandy.

However, in the Pee Dee valley, the Tar Heel beds are mainly sandy. Here, the unit consists of thick, red-to-white, typically crossbedded sands and white-to-black, thick-bedded clays. The well-laminated facies of the Cape Fear valley are not present in the Pee Dee region. The Tar Heel sands underlying the Sand Hills near Cash, S.C., commonly have been mapped as the Middendorf Formation. In general, however, the Tar Heel sands have fewer clay breccias, more burrow, and more mica than the Middendorf. The well-burrowed sands, suggesting some marine influence, of the Tar Heel are exposed in several road cuts west and north of Society Hill. The sand facies can be traced northeastward from the hills near Hamlet to Raeford, N.C., at the northern boundary of the map area. Downdip in the Britton Neck corehole, the sand facies of the Tar Heel changes facies to a largely shallow marine shelf-delta-front facies (fig. 2). In the Sand Hills area, the Tar Heel is at least 60 m thick. In the corehole near Britton Neck, the unit is 55 m thick.

A mature heavy-mineral assemblage of the sand is characterized by the more resistant minerals (zircon and others) and, locally, large concentrations of garnet. Much of the maturity of the sand, however, can be attributed to the deep weathering in the Sand Hills region. Probably because of this deep weathering, no feldspars were found in these weathered sands. Where fresh, the clay-mineral suites are mixtures of illite-smectite and kaolinite. Where weathered, kaolinite is the only major clay mineral.

As with the Donoho and Bladen Formations, the Tar Heel Formation tends to become more marine from the Pee Dee valley to the Cape Fear valley and toward the ocean. In the Pee Dee valley, the Tar Heel Formation appears to be a delta-plain deposit that has some shallow-shelf intrusions, whereas in the Cape Fear valley, the strata are more characteristic of a delta front. The most marine facies of this formation occurs in the subsurface at the Britton Neck corehole, where beds containing marine fossils and glauconite are intercalated with thin-bedded, clay-sand sequences (also delta-front deposits, but more marine than those in the Cape Fear valley).

The age of the Tar Heel Formation is early Campanian as determined by pollen (zones CA2 and CA3, R.A. Christopher, written commun., 1980) and by ostracodes (G.S. Gohn, oral commun., 1985) in the downdip beds at Britton Neck. These beds, therefore, correlate with the Merchantsville-Englishtown marine cycle in the Raritan embayment in New Jersey or the Blufftown marine cycle in Georgia (Owens and Gohn, 1985).

Km **Middendorf Formation (upper Cretaceous)**—The Middendorf Formation crops out over a large area in the northwest corner of the Florence quadrangle. Most outcrops are in pits, especially in the vicinity of Rockingham, N.C. Because of the nonindurated, sandy nature of the formation, natural exposures are few. Differentiation of the Middendorf from the overlying Tar Heel Formation is locally difficult, especially near Cheraw where the Middendorf has marine-influenced beds overlain by the marine facies of the Tar Heel Formation.

Most of the Middendorf consists of interbedded black-weathering to chocolate-brown or white clayey beds and clayey crossbedded micaceous sands. Commonly, the sands are stained extensively by iron oxides, which impart a mottled deep-red appearance, especially where the Middendorf sands occur near the surface. At Rockingham, N.C., the Middendorf lies within broad channels cut into the underlying saprolite. The channel fill typically consists of interbedded thick, white, clay-silt and clayey, coarse-grained, crossbedded sands. Small pebbles (0.6 cm in diameter) are abundant in the coarse-grained beds, and clasts are common.

The Middendorf ranges between 45 to 60 m in thickness in outcrop and is nearly 110 m thick in the Britton Neck corehole (fig. 2). The sands of the Middendorf are exclusively quartz. Heavy-mineral assemblages are mature and have high concentrations of the nonopaque resistant minerals such as zircon, tourmaline, rutile, staurolite, and kyanite. Monazite is locally abundant. Brown ilmenite and leucoxene are the major opaque minerals. The clay minerals in the Middendorf are mainly kaolinite, plus small amounts of illite and, in a few samples, small amounts of illite-smectite.

The Middendorf appears to be largely a deltaic deposit (mainly upper delta-plain facies in outcrop) that prograded into the Florence area from the west or northwest and overlapped the Cape Fear Formation. Some marginal-marine beds containing foraminifers occur at Cheraw, N.C. (Siple, 1959). In the Britton Neck corehole, the Middendorf is typically a lower delta-plain to perhaps delta-front deposit similar in many respects to the Black Creek lithology.

Age determination from the pollen and spore assemblage of the Middendorf indicates a Santonian age, zone V_c of the palynozonal age classification (R.A. Christopher, written commun., 1983).

Kcf **Cape Fear Formation (upper Cretaceous)**—The Cape Fear Formation crops out only in the Cape Fear River valley and its tributaries, mainly Rockfish Creek. The contact relationships between the Middendorf and Cape Fear were not observed in the map area. Regionally, however, the Cape Fear always underlies the Middendorf or younger units.

The Cape Fear is quite distinct from the Middendorf. Crossbedded sands, graded beds, and slump structures are common in the Cape Fear, but the crossbedded sands are on a much smaller scale than those in the Middendorf. The most distinct difference between the two formations is that the Cape Fear is semi-indurated due to the presence of small amounts of cristobalite. Locally, the sands are sufficiently indurated to form small waterfalls.

The clays in the Cape Fear are dominantly illite-smectite and kaolinite that contain small amounts of cristobalite; the Middendorf has little to no illite-smectite and cristobalite. Heavy-mineral suites are similar to those in the Middendorf, except that in the Cape Fear they contain much less monazite and more feldspar, although feldspar is usually less than 10 percent of the sand fraction.

The Cape Fear is about 10 m thick in the Florence quadrangle, but is considerably thicker north of Fayetteville where bluffs up to 30 m high are exposed. This unit is at least 61 m thick in the corehole near Britton Neck (fig. 2).

The age of the Cape Fear is Santonian, pollen zone V_a as determined on the basis of its microflora (Christopher and others, 1979). The Cape Fear appears to be a deltaic deposit (upper delta plain) similar to some of the Middendorf beds, but the Cape Fear delta system was deposited from the north and northeast.

CONSOLIDATED PIEDMONT ROCKS

JTRu **Jurassic and Triassic rocks, undivided**—The northwestern corner of the Florence quadrangle and a somewhat larger area east of the power plant on the Pee Dee River are underlain by Triassic sedimentary rocks cut by Jurassic diabase dikes of the Wadesboro basin. Exposures are present only in the extreme northwestern corner, and they are very poor to nonexistent. The distribution of Jurassic and Triassic rocks follows the map of Burt (1981).

East of the power plant on the Pee Dee River, small boulders of diabase float occur at the surface. Burt mapped Jurassic diabase dikes, but they are too small to show on this Florence-Georgetown map. Rock exposures in drainage ditches and small roadcuts north of the Florence quadrangle indicate that the Triassic section is a complex mixture of maroon shales, sandstones, and conglomerates.

The sandstones have a heavy-mineral assemblage similar to that found in the Cretaceous Middendorf and Cape Fear Formations; there is a high percentage of zircon, tourmaline, rutile, staurolite, kyanite, and monazite. In contrast to the Cretaceous units, the Triassic rocks have an abundance of magnetite in the opaque fraction. Peinemund (1955) also noted that abundant magnetite was characteristic of the Triassic sedimentary rocks in the Deep River basin farther to the north in North Carolina.

Mg **Gabbro (Mississippian)**—Unmetamorphosed, massive, dark-gray, coarse-grained gabbro that is composed chiefly of hornblende and lesser amounts of pyroxene, olivine, and plagioclase. Other minerals include sericite, epidote, calcite, pyrite, and leucoxene (Waskom and Butler, 1971).

This unit weathers to a thick, very dark maroon, silty clay; exposures of weathered gabbro occur along U.S. Route 74 west of Rockingham, N.C. Fresh rock is exposed only at a few places along the Pee Dee River near Rockingham.

Presumably this unit is the same age as the Lilesville Granite.

Mgr **Lilesville Granite of Waskom and Butler (1971) (Mississippian)**—This unit includes postmetamorphic, coarse-grained, porphyritic, granitic rocks. The Lilesville Granite of Waskom and Butler (1971) is zoned compositionally and consists of quartz monzonite, granodiorite, and quartz diorite, which are characterized by a porphyritic rapakivi texture in a matrix of plagioclase, quartz, and biotite. Fresh rock was observed only in quarries, the largest of which was actively operated 3.2 km west of Rockingham in 1983. The Lilesville Granite weathers to a light-brown to yellow-brown, clayey sand; most outcrops of this unit are saprolite. In a few areas, especially north of Lilesville, N.C., the granite surface has abundant, very large boulders.

The Lilesville Granite has been dated at 326±27 million years (Waskom and Butler, 1971).

Mmg **Mica gneiss and schist (Mississippian)**—This unit consists of gray, medium- to coarse-grained, well-foliated biotite gneiss and sericite schist (Waskom and Butler, 1971). The unit weathers similarly to the Lilesville Granite and is the same age.

Ꞓar **Argillite (Middle Cambrian)**—This argillite is light gray to bluish gray to brown, is in part well bedded, and consists mainly of clay- and silt-sized particles, which impart a prominent bedding plane of slatey cleavage to most outcrops. The argillite contains primarily quartz, plagioclase, sericite, rock fragments, and chlorite. Beds of mudstone, novaculite, sandstone, conglomerate, and felsic volcanic rock also are present; some rocks are tuffaceous (Waskom and Butler, 1971). The argillite weathers to a deep-red, micaceous to nonmicaceous clay-silt. Most outcrops of this unit are saprolite or clay.

Ꞓph **Phyllitic to schistose rocks (Middle Cambrian)**—These rocks are fine-grained, light-gray, silver-gray, greenish, and white phyllite and fine-grained schist that have a well-developed cleavage. The unit includes hornfels in metamorphic zones around intrusions, phyllite associated with pyrophyllite mineralization, sericite phyllite, and phyllite in what may be shear zones. Many small shear(?) zones were observed, but they could not be mapped at this scale. Principal minerals are sericite and muscovite; subordinate amounts of quartz, chlorite, feldspar, and hematite are present (Waskom and Butler, 1971). This unit weathers similarly to the argillite, except that it is even more micaceous. Fresh exposures occur along U.S. Route 220 on the north edge of Rockingham, N.C.

EXPLANATION OF MAP SYMBOLS

Contact

Barrier—Morphology intact

Multiple Barrier Complex

S.C. 39 — **Drill hole**—Number only, drilled by U.S. Geological Survey; *S.C., CW and H, MRN-78*, Britton Neck corehole, on Sheet 2.

• *WA-20* — Locality of Dubar (1971)

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