DPST-81-141-16

**GEOLOGY AND MINERAL RESOURCES OF
THE FLORENCE, BEAUFORT, ROCKY MOUNT,
AND NORFOLK 1° X 2° NTMS QUADRANGLES**

**NATIONAL URANIUM RESOURCE
EVALUATION PROGRAM**

MASTER

W. BURLEIGH HARRIS

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Savannah River Laboratory
Aiken, SC 29808**

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Prepared for the U. S. Department of Energy
Grand Junction Office, Colorado

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W. BURLEIGH HARRIS

Approved by

**C. E. Coffey, Research Manager
Analytical Development Division**

Publication Date: August 1982

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SUMMARY GEOLOGY OF THE
FLORENCE, BEAUFORT, ROCKY MOUNT, AND
NORFOLK 1° x 2° NTMS QUADRANGLES

BY

W. Burleigh Harris
Department of Earth Sciences
University of North Carolina at Wilmington
Wilmington, NC

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ABSTRACT

This document provides geologic and mineral resources data for previously-issued Savannah River Laboratory hydrogeochemical and stream sediment reports of the Beaufort, Florence, Norfolk, and Rocky Mount 1° x 2° National Topographic Map Series quadrangles in the southeastern United States.

This report is issued in draft form, without detailed technical and copy editing. This was done to make the report available to the public before the end of the National Uranium Resource Evaluation program.

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INTRODUCTION

The National Uranium Resource Evaluation (NURE) was established to evaluate uranium resources in the United States and to identify areas favorable for uranium exploration. The Grand Junction Office of the Department of Energy (DOE) was responsible for administering the program. The Savannah River Laboratory (SRL) was responsible for hydrogeochemical and stream sediment reconnaissance (HSSR) of 3.9 million square kilometers (1.5 million square miles) in 37 eastern and western states.

This document provides reports on the geology and mineral resources of the Beaufort, Florence, Norfolk, and Rocky Mount 1° x 2° National Topographic Map Series quadrangles in the southeastern United States. The individual reports were prepared for SRL by Dr. W. Burleigh Harris, University of North Carolina at Wilmington, in 1978 and 1979. There is often duplication of information among the reports.

The purpose of these reports is to provide background geologic and mineral resources information to aid in the interpretation of NURE geochemical reconnaissance data. All reports are accompanied by geologic and mineral locality maps.

NURE hydrogeochemical and stream sediment reconnaissance data for three of these quadrangles have been issued previously. They are listed in the references.

REFERENCES

SRL-146, SRL-NURE Data Reports, E. I. du Pont de Nemours & Co., Savannah River Laboratory, Aiken, S.C.

<u>NTMS 1° x 2° Quadrangle</u>	<u>SRL Doc. No.</u>	<u>DOE-GJO Doc. No.*</u>
Beaufort	DPST-80-146-22	GJBX-17(81)
Norfolk and southern Eastville	DPST-81-146-10	GJBX-283(81)
Rocky Mount-Manteo	DPST-80-146-21	GJBX-16(81)

*DOE-GJO reports are available on microfiche from the Grand Junction Office. Inquiries about orders should be sent to: Bendix Field Engineering Corporation, Technical Library, P. O. Box 1569, Grand Junction, CO 81502-1569, telephone (303)242-8621.

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GEOLOGY AND MINERAL RESOURCES OF THE
FLORENCE
1° x 2° NTMS QUADRANGLE

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LOCATION AND PHYSICAL GEOGRAPHY

The Florence 1° x 2° NTMS quadrangle covers about 20,000 square kilometers in North and South Carolina and includes the Coastal Plain Physiographic Province and a small part of the Piedmont Physiographic Province. Elevations range from about 160 m in the extreme northwestern part of the quadrangle to about sea level in the eastern part of the quadrangle. Rainfall averages about 108 cm per year. Temperatures are moderate, averaging about 27 °C in July and 6.6 °C in January (Florence). Dense vegetation, the existence of a thin veneer of surficial sand, and a deeply weathered soil profile make geologic mapping difficult.

In the Florence quadrangle, the Atlantic Coastal Plain is physiographically divisible into three distinct parts. The upper Coastal Plain extends from the fall line to the Orangeburg scarp at an approximate elevation of +75 m. The middle Coastal Plain extends from the Orangeburg scarp (+75 m) to the Surry scarp at about +33 m. The lower Coastal Plain extends from the Surry scarp (+33 m) to the coastal margin. "Geomorphically these three regions are characterized by differing combinations of primary depositional topography (beach ridges, etc.) and subsequent erosion (scarps, etc.)" Colquhoun (1974).

A vast system of creeks and rivers of two major types drains the quadrangle. Heading in the Piedmont, the Cape Fear River and the Pee Dee and Lynches Rivers drain the northern and southern part of the quadrangle, respectively. Heading in the Coastal Plain, the Little Pee Dee - Lumber and Waccamaw Rivers drain the central part of the quadrangle. Interstream areas are gently rolling, with steepest topography usually adjacent to the major drainage systems.

STRATIGRAPHY

Piedmont

Carolina Slate Belt Rocks

In the extreme northwest part of the quadrangle, Carolina Slate Belt rocks occur in stream and river valleys. They consist of a volcanic-sedimentary sequence overlying what is often referred to as the Charlotte Belt. The lower part of the Carolina Slate Belt consists of mafic volcanic and sedimentary rocks, including fine- to coarse-grained amphibolite, hornblende schist, hornblende gneiss, actinolite schist, and chlorite schist; some diorite, metagabbro, and biotite gneiss occur. Overlying these materials are felsic pyroclastic and volcanoclastic rocks. The uppermost of the Carolina Slate Belt are grey and greenish-gray argillite, slates, and graywacke. Regionally these rocks are in the greenschist facies of metamorphism.

Lilesville Granite

The Lilesville Granite crops out in the northwest part of the quadrangle and is a sheet- or tongue-shaped concordant mass of compositionally zoned adamellite, granodiorite, and tonalite. It is characterized by a porphyritic rapakivi texture with a medium- to coarse-grained matrix of plagioclase, quartz, and biotite. The pluton,

which is surrounded by a contact aureole of metasedimentary schist and mica gneiss, contains numerous xenoliths throughout, but they are most abundant near contacts with country rocks. The Lilesville pluton has Rb-Sr isochron age of 332 ± 12 m.y. (Fullagar, 1974, personal communication).

Triassic Undifferentiated

Two small parts of the Wadesboro Basin are present in the extreme northwest corner of the quadrangle. The Triassic sedimentary rocks strike N 33° and dip about 20° toward the southeast. The sediments consist mainly of sandstone, siltstone, and lesser volumes of conglomerate and clay. The sandstones are arkosic wackes and feldspathic wackes. Generally, arkosic wacke occurs along the eastern margin and the interior of the Wadesboro Basin while feldspathic wacke occurs throughout the basin. Conglomerates and fanglomerates are limited to the structurally splintered western border; they are lacking along the eastern border. These rocks are considered to be of late Triassic to early Jurassic age.

Diabase

Several northwest-trending Mesozoic diabase dikes occur in the extreme northwest part of the quadrangle. The dikes range in thickness from less than 1 m to about 340 m, with a median width of about 15 m. Most of the dikes in this swarm are olivine normative and olivine-modal tholeiitic diabases. The dikes are considered to be earliest Jurassic in age (P. A. Thayer, 1978, personal communication).

Coastal Plain

Cape Fear Formation

The term Cape Fear was originally applied by Stephenson (1907) to exposures on the Cape Fear River below Fayetteville, North Carolina and to those on the Neuse and Tar Rivers and Contentnea Creek. Abandoned from usage by Cooke (1936), the name was re-introduced by Heron (1958) for the easily distinguished beds in the Cape Fear valley south of Fayetteville. Swift and Heron (1969) formally proposed that the name be reaccepted for the basal Cretaceous beds of the Cape Fear River valley. The Cape Fear Formation rests on crystalline basement and is unconformably overlain by the Middendorf or Black Creek formations.

The Cape Fear Formation is a sandstone (quartz to feldspathic wacke) with intercalated layers of mudstone and is estimated to be 15-70 m thick along the Cape Fear River. The sandstones usually have quartz pebbles or intraformational conglomerate at their base and a matrix principally of montmorillonitic kaolinite or kaolinitic montmorillonite clay.

The most characteristic feature of the Cape Fear Formation is the very thick-bedded stratification expressed as alternating layers of sandstone and mudstone. Most sandstone layers are from 1 to 5 m; mudstone layers seldom exceed 1.5 m. Many sand layers are massive;

however, cross-bedding may be seen at some localities. Cape Fear strata have characteristics that point to deposition by fluvio-marine turbidity currents in estuaries along an embayed coast (Heron and others, 1968). The Cape Fear Formation is essentially nonfossiliferous, with minor amounts of lignite, twigs and branches, and insect parts (?). Although Swift and Heron (1969) originally favored a Lower Cretaceous age for the Cape Fear Formation, more recent work suggest that it is Upper Cretaceous (Heron, 1978, personal communication).

Middendorf Formation

The name Middendorf was first used by Sloan (1904) in South Carolina for sands and kaolinitic clays. Although abandoned by Cooke (1936) in favor of the term Tuscaloosa, Heron (1958) favored a formational rank for the unit. Swift and Heron (1969) formally proposed that the Middendorf Formation be recognized for beds between the "Hamburg" (Cape Fear Formation) and the overlying Black Creek Formation. Although Sloan (1904) did not designate a type section, the railroad cut on the Seaboard Railroad 3.2 km east of Middendorf (Chesterfield County, S. C.) is generally accepted as the type section. The Middendorf Formation disconformably overlies the Cape Fear Formation and is gradational with the overlying Black Creek Formation. Locally, Cenozoic sediments ranging in age from Eocene to Recent overlie the Middendorf Formation.

The Middendorf Formation is a fluvial unit that crops out in the upper Coastal Plain from just north of Darlington, South Carolina to just south of Fayetteville, North Carolina; it is generally above the Orangeburg scarp. The Middendorf probably does not exceed 70 m in thickness (Swift and Heron, 1969). It is composed of argillaceous sand with lenses of mudstone and discontinuous conglomerate. Loose to poorly indurated, generally cross-bedded quartz wackes with basal conglomerate are the main sediment type, and kaolinitic clay is the dominant matrix component (Heron and Wheeler, 1964). Because fossil leaves, clay, pebbles, channeling, local disconformities, point bar, and channel fill deposits can be identified, the formation is believed to be of fluvial origin (Heron, 1958).

The Middendorf Formation contains a well known and abundant flora (Berry, 1914; Dorf, 1952) and is considered Coniacian and Santonian in age.

Black Creek Formation

The Black Creek Formation is a transitional unit between the Middendorf Formation and the marine Peedee Formation. The formation was named by Sloan (1907) for exposures along Black Creek in Florence and Darlington counties, South Carolina. The Black Creek outcrop belt is principally restricted to the areas between the Orangeburg and Surry scarps. The formation has an estimated average thickness of 100 m, but may reach greater than 200 m near the coast in the subsurface (Benson, 1968).

The Black Creek Formation conformably overlies and interfingers with

the Middendorf Formation (Swift and Heron, 1969) and is characterized by laminated dark gray clay intercalated with gray to yellow-orange sand that is often cross-bedded. The claystones of the Black Creek form the bulk of the formation (Heron and Wheeler, 1964). The formation contains abundant lignitized wood and less abundant sulfide aggregates. A complex of unusual stratification give the formation a striking appearance. Generally, the formation is easily recognized by the alternation of sand and mud strata. The sediments represent deposition in estuarine, lagoonal and littoral environments (Benson, 1968).

The Black Creek contains a flora of Austin and Taylor age (Dorf, 1952) that is essentially synchronous with plant mega-fossils from the Middendorf Formation (Berry, 1914; Dorf, 1952). Wolfe (1976) found palynomorph assemblages in the upper part of the Black Creek that are assignable to his CA-3 to CA-5 zones. These zones range from lower to upper Campanian (Taylor).

Peedee Formation

Edmund Ruffin named the Peedee Formation in 1843; Sloan (1908) designated the type locality as Burches Ferry, 16 km south of the U.S. Route 301 bridge over the Pee Dee River. Although the Peedee Formation disconformably overlies the Black Creek Formation (Benson, 1968), recent workers suggest that the Black Creek-Peedee Formations represent a conformable, transgressive sequence with an interfingering formational contact (Woole and Colquhoun, 1977). The Peedee Formation crops out along the Cape Fear and the Pee Dee Rivers in the eastern part of the Florence Quadrangle. The unit has a thickness ranging from a feather edge in the west to a maximum of 260 m east in the subsurface.

The Peedee Formation is a neritic, dark micaceous, argillaceous sand characterized by an abundant molluscan fauna (Stephenson, 1923). Although the unit is generally considered highly glauconitic, glauconite usually forms less than 1 percent of the sands.

Swift (1964) undertook the most extensive study of the Peedee Formation and concluded that it was deposited on an open shelf where extensive reworking by infauna occurred. He divided the Peedee into two depositional units: an inner shelf suite composed of sand and muddy sand representing the lower Peedee and an outer shelf suite composed principally of calcareous muddy sand and sandy mud representing the upper Peedee. Swift (1964) also recognized several lenses of biomicrite and biomicrudite.

At the top of the Peedee Formation, a carbonate called the Rocky Point Member occurs. The Rocky Point occurs north of the Cape Fear arch in eastern Brunswick and New Hanover Counties, and interfingers with the Peedee Formation. The upper surface of the unit forms the Cretaceous-Tertiary boundary and is an irregular disconformity. It is marked by solution cavities, generally coated with phosphate and minor glauconite. The Rocky Point Member ranges in thickness to a maximum of 27 m in southern New Hanover County and represents nearshore deposition in a marine environment of normal salinity.

The Peedee Formation is Campanian and Maestrichtian; the Rocky Point has been dated radiometrically with glauconites at 68.1 ± 1 m.y. (Harris, 1976).

Black Mingo Formation

The Black Mingo Formation was first recognized by Sloan (1907) in exposures along the Black River from Brewington Lake, Clarendon County, S. C. to the mouth of Black Mingo Creek, Georgetown County, S. C., Cooke (1936). It referred to all Eocene strata older than the McBean Formation (middle Eocene) as the Black Mingo Formation. The Black Mingo only crops out in the southwest part of the Florence quadrangle at one locality. Its thickness is unknown.

The Black Mingo Formation consists of quartz sand, commonly glauconitic, thin layers of gray to light green silty clay, and dark-gray opal mudstone. Downdip, well-indurated light gray fossiliferous limestone is present. The lithology and fauna indicate that the updip facies of the Black Mingo was deposited in estuarine, tidal flat, and littoral environments. In the lower Coastal Plain, the glauconitic sands and fossiliferous limestone suggest a normal shallow shelf environment.

Cooke (1936) assigned the Black Mingo Formation to the lower Eocene on the basis of mollusks. Cooke and MacNeil (1952) suggested the unit may include beds of Paleocene and early Eocene age. Most recent workers believe that the Black Mingo is a time-transgressive unit with its basal part Paleocene and its upper part lower Eocene (Colquhoun and others, 1969).

Castle Hayne Limestone

The Castle Hayne Limestone was named by Miller (1912) for "exposures in the vicinity of the town of Castle Hayne." The type section was designated the Martin-Marietta quarry, located approximately 4.5 km northeast of Castle Hayne, North Carolina by Baum and others (1978a). The Castle Hayne Limestone has a maximum thickness of 11 m and is present in outcrop only in Duplin County and in the subsurface of the extreme eastern part of Brunswick County. The Castle Hayne Limestone consists of two facies, each characterized by bryozoans and sponges. In New Hanover County, portions of the section are partially to completely dolomitized.

The Castle Hayne Limestone has a well-documented and characteristic fauna. Although Brown and others (1972) consider the unit Claiborne in age, most workers (Canu and Bassler, 1920; Kellum, 1925; Cooke, 1959; and Harris, 1978a) consider the unit latestmost Eocene or Jacksonian in age.

Unnamed Oligocene

Although rocks of Oligocene age have not been mapped in the Florence quadrangle, a small exposure of possible Oligocene, which crops out along Royal Oak Swamp, Brunswick County, North Carolina, suggests that Oligocene may underlie the extreme southeastern corner of the quadrangle. Brown and others (1972) map Oligocene in this area of Brunswick County.

Duplin Formation

The Duplin Formation was first referred to as the Duplin "marl" by Cooke (1936). DuBar (1971) proposed the name Duplin Formation be formally accepted for the unit. An exposure at Natural Well, near Magnolia, Duplin County, North Carolina has generally been accepted as the type section. The Duplin Formation occurs throughout the quadrangle as isolated patches (outliers) overlying a dissected Cretaceous or Paleogene surface. However, southward in Darlington, Florence, and Lee Counties, South Carolina, fossiliferous Duplin sands form a thin, nearly continuous layer 3 to 6 m in thickness.

The Duplin is characteristically sandy limestone; silty, nearly pure soft limestone; and calcareous silty sand. Well preserved fossils of foraminiferas, ostracods, and mollusks are common. Subarkosic and quartzose sands and clays which form interfluvial surfaces between the Mechanicsville and Surry scarps are correlated with the Duplin Formation by DuBar and others (1974a). These beds, which appear gradational with the underlying Duplin, are informally referred to as the "Marietta unit." Because these beds have been considered by most workers as surficial, they are not mapped as a distinct formation on the geologic map. The maximum thickness of the Marietta is 20 m.

The Duplin Formation is generally regarded as late Miocene (Cooke, 1936; Richards, 1950; and Copeland, 1964); however, recent work by duBar and others (1974a) suggests that this unit is Pliocene in age.

Bear Bluff Formation

The name Bear Bluff Formation was proposed by DuBar and others (1974a) for a sequence of calcareous sandstone, sandy limestone, subarkosic sand, and calcareous silt that occurs east of the Surry Scarp. The type section is located on the east bank of the Waccamaw River at Bear Bluff, approximately 3 km east of Conway, Horry County, South Carolina.

The Bear Bluff Formation occurs in the subsurface from southeastern North Carolina to the Santee River of South Carolina. The maximum thickness is unknown, but where the unit occurs in lows on the underlying Peedee and Duplin Formations, its thickness commonly exceeds 30 m. The Bear Bluff Formation is either late Pliocene or early Pleistocene (DuBar and others, 1974a). Because it is often impossible to distinguish Bear Bluff sediments from the overlying Waccamaw Formation, it is included with the Waccamaw on the geologic map.

Waccamaw Formation

The Waccamaw Formation was named by Dall and Harris (1892) for fossiliferous marine deposits exposed along the banks of the Waccamaw River in Horry County, South Carolina. The Waccamaw occurs as outliers in the outer Coastal Plain from the Cape Fear River southward to the vicinity of Charleston, South Carolina. The thickness of the Waccamaw varies from a feather edge to a maximum of about 16 m in the subsurface (Howard, 1974). The Waccamaw Formation consists of poorly sorted to moderately well-sorted, semi-indurated, fine to coarse sand. Carbonate content is mostly in the form of fossil shells. Unweathered sediments

are light blue; weathered sediments are yellowish brown to deep reddish brown. In some areas, these deposits grade upward to generally unfossiliferous sediments. Locally, a thin unit of quartz and phosphate pebbles and coarse sand forms the base of the Waccamaw. Waccamaw fauna are well-preserved and abundant, and they indicate brackish-water and shallow marine shelf.

The Waccamaw Formation age has been disputed by numerous workers. Most early workers considered the Waccamaw to be Pliocene; however, recent work by DuBar and others (1974a) and Zullo and Harris (1978) suggests a Pleistocene age.

Canepatch Formation

The name Canepatch Formation was proposed by DuBar and others (1974a) for complex deposits of sand, clay, silt, and peat exposed along the Intracoastal Waterway in Horry County, S.C. The type section is located on the south bank of the waterway near Canepatch Swamp, approximately 10.4 km northeast of Myrtle Beach. The unit only occurs in the extreme southeast corner of the Florence quadrangle, along the west bank of the Cape Fear River. The formation reaches a maximum thickness of about 23 m, but averages only about 10 m. Dominant lithologies are: cross-bedded, humate impregnated sand; fossiliferous clayey sand; blue fossiliferous sandy clay; dark brown sand and clayey sand and peaty clay; and beach rock (coquina).

The Canepatch Formation contains an abundant and well-described fauna (DuBar and others 1974a) that suggests an interglacial origin for the formation. Radiocarbon dates of cypress wood, the coral Septastrea crassa, and the pelecypod Mercenaria campehiensis, from Horry County by the radiocarbon method and obtained an age of 31,810 $\pm$ 785 years.

Post-Canepatch Units

Modern floodplain and Pleistocene fluvial terrace deposits occur along Lynches, Pee Dee, Little Pee Dee, Lumber, Waccamaw, and Cape Fear Rivers. These units are herein grouped together because of their similarity in lithology and origin and their geographical position along the major drainage systems. These sediments are principally humate-rich sand, sandy silt, and silty clay. Their thickness is highly variable, ranging from about 6 to 20 m. On the basis of their stratigraphic position, these units range from Holocene for the modern floodplain deposits to medial-late Pleistocene for the oldest terrace deposits.

Surficial Deposits

The Coastal Plain in the Florence quadrangle is covered by a thin veneer of sand and clay that almost everywhere conceals the older formations. Above the Orangeburg scarp, the surface is covered by fluvial and rare eolian sediments classed as high-level gravels, sands, and clays. These high-level surficial deposits have variously been called the Citronelle Formation in the area of the Pee Dee River and Pinehurst Formation in the Sandhills area of North Carolina and are considered Miocene. The Citronelle has a maximum thickness of 33 m (Doering, 1960); the Pinehurst at the type section in Moore County, approximately 2 km southeast of West End, is 7 m thick (Bartlett, 1967).

Between the Orangeburg and Surry scarps (middle Coastal Plain), three prominent terraces are present: Coharie (+75 m); Sunderland (+52 m); and Okefenokee (+41 m). These plains dip gently oceanward and include primary depositional topography that can be identified as alluvial fans or deltas, and minor landforms such as offshore bars, beach ridges, and meander scars. Terrace sediments in the middle Coastal Plain vary in type and thickness and are considered late Miocene in age.

The lower Coastal Plain (below the Surry scarp) exhibits the effects chiefly of depositional topography, although continental and marine landforms are present. Six terraces have been recognized: the Wicomico, Penholway, Talbot, Pamlico, Princess Anne, and Silver Bluff. Sediments underlying these terraces are variable in type and thickness.

STRUCTURAL GEOLOGY

The Cape Fear arch in southern North Carolina is the principal structural feature of the Atlantic Coastal Plain Province. It is southeast-plunging basement high extending from the fall line along the Cape Fear River to about Cape Fear. Its axial trace marks the main area of Cretaceous outcrops in North and South Carolina.

Movement of the arch may have occurred as early as Albian or post-Albian pre-Cenomanian time; however, it was local in nature, because Tuscaloosa (Middendorf and Cape Fear) sediments on the arch near the fall line do not show thinning (Bonini and Woolard, 1960). Recurrent movement of the arch has probably occurred during most of the Cenozoic Era (Harris and others, 1979a). Some recent workers have suggested the Cape Fear arch has periodically been active as recent as 75,000 years ago (Zullo and Harris, 1979). There are no other structures in the quadrangle.

MINERAL RESOURCES

There are no reported occurrences of metallic minerals, mica, pegmatites, or massive sulfides in the quadrangle. There are commercial deposits of non-metallic resources including sand and gravel, stone, and clay.

Sand, gravel, and crushed stone

Sand, gravel, and stone (granite) are mined commercially in Anson, Buncombe, Cumberland, Harnett, and Moore Counties, North Carolina, and Chesterfield, Dillon, Darlington, Florence, and Marlboro Counties, South Carolina. Most produced sand is used in building and construction work. Gravel and crushed stone are used in building, paving, and railroad ballast.

Clay

Clay is quarried in Darlington, Marlboro, and Marion Counties, South Carolina from Pleistocene(?) terrace deposits along the Pee Dee River and its tributaries. This material is used to manufacture brick and drain tile.

Others

Phosphate and glauconite occurrences in the quadrangle are discussed because they contain traces of uranium and thorium.

Glauconite is a finely-divided micaceous dioctahedral clay mineral rich in iron and potassium and similar to illite. It commonly occurs in concentrations of 20-30% in some zones within the Peedee, Black Mingo, and Castle Hayne Formations. In addition, it also occurs as a precipitate mixed with phosphate on many Coastal Plain disconformities. Yasyrev (1966) demonstrated that glauconites average 400 ppm thorium and 10 ppm uranium. Therefore, concentration of these two elements may occur under proper conditions of diagenesis.

Although phosphates are not mined in the quadrangle, Texas Gulf Sulphur Company operates a large mine in Beaufort County, N.C. Because trace amounts of uranium have been found uniformly distributed with the phosphate grains at this deposit, undiscovered phosphate deposits in the Florence quadrangle may be enriched in uranium and thorium. Phosphate deposits have been described in South Carolina by Rogers (1914) and Watkins (1937), and in the Charleston area by Malde (1959). The generalized geology of the quadrangle is shown on Plate 1.

GEOLOGIC LITERATURE FOR THE FLORENCE AREA

Previous Studies

Recent geologic mapping of the Florence quadrangle is sparse (Figure 1). Only the northwest part of the quadrangle has been mapped since 1958; most previous studies have only concentrated on local problems of stratigraphy, paleontology, or petrology. Heron (1958) examined and mapped Cretaceous sediments in the upper Coastal Plain between Lynches River, S. C., and Neuse River, N. C., Jorgenson (1969), Cooley (1970), Waskom (1970), and Monrad (1972) examined various parts of the western part of the quadrangle (Figure 1). The Coastal Plain in North Carolina below the Orangeburg scarp has been mapped by Stephenson (1923) and Clark and others (1912), and the subsurface by Brown and others (1972). These reports are the only studies that attempt to delineate the surface and subsurface distribution of sediments and rocks in North Carolina as part of the quadrangle. Baum (1977) mapped the Tertiary units in North Carolina east of the quadrangle.

In South Carolina, only the works of Cooke (1936) and DuBar and others (1974a) have delineated the spatial distribution of the surface formations in the quadrangle. Recent surficial deposits have been described by Colquhoun (1974) south of the Cape Fear River. Concentrated studies of specific units have been made by: Swift (1964) - Peedee Formation; Benson (1968) - Black Creek Formation; Ibrahim (1973) - Middendorf; Harris (1975) - Rocky Point Member of Peedee Formation; and Upchurch (1973) Castle Hayne Limestone.

Current Research

The Geology and Mineral Resources Section (GMRS) of the North Carolina

Department of Natural and Economic Resources has initiated a program to produce reconnaissance geologic maps for the entire state. The state has been divided into 17 multi-county planning regions that will be covered by the maps. The GMRS plans to have open-file reports on the Coastal Plain by 1981. Mapping has not yet been started.

Three graduate students at the University of North Carolina at Chapel Hill are currently working on masters' theses of parts of the Florence quadrangle. Roger Shew (under the direction of Roy L. Ingram) is mapping along the Cape Fear River from just south of Fayetteville to Elizabethtown. He is also examining recent sediments in the river. Suellen Cape (under the direction of Walter H. Wheeler) is examining the Citronelle Formation in the inner Coastal Plain from south of Fayetteville to the South Carolina border. Edward Custer (under the direction of Roy L. Ingram) is examining the subsurface distribution environments of the Cretaceous formations in the region of Cape Fear arch.

Duncan Heron, at Duke University, is in the beginning stages of examining the subsurface distribution of the Cretaceous formations along the Cape Fear River. During 1978 he plans to profile the river between Fayetteville and Wilmington.

Donald Colquhoun, University of South Carolina, and several students have been actively examining the Cretaceous geology of Marlboro, Dillon, Marion, and Horry Counties, South Carolina.

James Owens and Blake Blackwelder of the U.S. Geological Survey have been mapping in the Cape Fear - Pee Dee Rivers region.

Thomas Worsley and two graduate students at Ohio University are examining nanofossils in the Pee Dee Formation and most Tertiary units in North Carolina.

Victor Zullo and W. Burleigh Harris, at the University of North Carolina at Wilmington, are examining the Pliocene and Pleistocene stratigraphy and paleontology of North and South Carolina.

There are no other current concentrated efforts to map the Florence quadrangle.

GEOLOGIC HISTORY

The Coastal Plain Physiographic Province extends along the Atlantic Coast from southern Florida to the Grand Banks of Newfoundland. The sediments and sedimentary rocks form a wedge-shaped mass that thickens from a feather edge along the fall line to a maximum along the coast. These sediments and rocks rest unconformably on a Paleozoic and Precambrian basement of igneous and metamorphic rocks. In the western part of the Florence quadrangle, Coastal Plain strata onlap the Carolina Slate Belt. Although the strata range in age from Jurassic(?) to Holocene, only Upper Cretaceous through Holocene sediments and rocks occur in the Coastal Plain part of the quadrangle.

During early Late Cretaceous time, a transgression of the ocean onto the Piedmont surface established a time-transgressive stratigraphic sequence dominantly representative of three depositional environments: the Cape Fear-Middendorf Formations - fluvial, fluvio-marine; the Black Creek Formation - estuarine, lagoonal, and littoral; and the Peedee Formation - open marine shelf. Although local disconformities exist between the Cape Fear and Middendorf and the Black Creek and Peedee Formations, formational boundaries are generally intertonguing and suggest the absence of major tectonic or eustatic changes in sea level.

During latest Cretaceous, uplift of the Cape Fear arch established a near shore regressive sequence in the dominantly transgressive regime of the Peedee Formation. This initiated deposition of the shallow marine Rocky Point Member of the Peedee Formation along the Cape Fear arch and north of it. The close of the Mesozoic is marked by regression of the sea and probably uplift of the Cape Fear arch. The arch appears to have remained high during the entirety of Paleocene deposition, as Paleocene sediments only occur south and north of the arch axis.

The Castle Hayne Limestone represents a major transgression of the sea over Mesozoic and Paleocene sediments and rocks. The Castle Hayne was deposited during the temporal transgression during the middle and late Eocene. In New Hanover County, N.C., the presence of dolomitized sediments in the Castle Hayne, which are thought to have originated through diagenetic dolomitization, suggest that the Cape Fear arch was active and a positive element. Subsequently, during late Eocene, the Castle Hayne deposition, the sea withdrew from the Coastal Plain and the Cape Fear arch emerged.

A major transgression occurred during the late Miocene or early Pliocene(?) when the Duplin Formation was deposited seaward of the Orangeburg scarp while high-level gravels were deposited west of the scarp. The Duplin transgression resulted in deposition of strata on a dissected surface of late Cretaceous to Paleocene strata. Regression of the Duplin sea may have been a direct result of polar ice cap advance (DuBar and others, 1974a) or tectonism (Zullo and Harris, 1979).

The next major transgression occurred during the late Pliocene-early Pleistocene and resulted in the occupation of the Mechanicsville scarp and deposition of the Marietta-Bear Bluff Formations. Marine Bear Bluff sediments extend landward to the Surry scarp; the "Marietta" sands occur between the Surry and Mechanicsville scarps and are considered to be equivalent to the Bear Bluff Formation. The Bear Bluff sea reached a maximum elevation of about 36.5 m.

Prior to Waccamaw submergence, the Duplin, Marietta, and Bear Bluff formations were subjected to a significant period of erosion. During the Pleistocene, the Waccamaw sea rose to a maximum level of about 30 m, occupying the Surry scarp.

The Bear Bluff and Waccamaw seas never transgressed north of Cape Fear River, and are therefore restricted to the area south of the Cape

Fear River and a narrow zone along the North Carolina coast. Withdrawal of the Waccamaw sea from the Coastal Plain was followed by the less extensive Canepatch transgression that occupied part of the unelevated outer Coastal Plain. This transgression probably occurred during the Sangamon stage. The Canepatch sea withdrew at the end of the Sangamon (75,000 years ago) and was followed by uplift along the Cape Fear River. This resulted in elevation of the area southwest of the Cape Fear River and formation of terrace deposits along the Pee Dee, Little Pee Dee - Lumber, and Waccamaw Rivers.

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GEOLOGY AND MINERAL RESOURCES OF THE
BEAUFORT
1° x 2° NTMS QUADRANGLE

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LOCATION AND PHYSICAL GEOGRAPHY

The Beaufort 1° x 2° NTMS quadrangle covers about 20,000 sq km in North Carolina, of which about 9,500 sq km are land area and 10,500 sq km are ocean. The land part of the quadrangle is located entirely in the Atlantic Coastal Plain Province. Elevations range from greater than 30 m in the extreme northwestern part to sea level in the eastern part of the quadrangle. Rainfall averages 132 cm per year in Wilmington, the largest city. Temperatures are moderate, with the normal 26.44 °C in July and 7.28 °C in January. Dense vegetation, low relief and the existence of a thin veneer of surficial sand, and a deeply weathered soil profile make geologic mapping difficult.

The quadrangle is physically divisible into two distinct parts. The middle Coastal Plain extends from the Coats (Orangeburg) scarp (75 m) to the Surry scarp (33 m). The lower Coastal Plain extends from the Surry scarp to the coastal margin. Although the Surry scarp (33 m) is commonly shown about 70 km inland paralleling the coastline between Cape Lookout and Cape Fear (Daniels, and others, 1972), Zullo and Harris (1978) suggested that the Surry scarp extended south from about Pink Hill (Lenoir County) to about the New River at Jacksonville and turned southwest to join the Hanover scarp. The middle and lower Coastal Plains are characterized by differing combinations of primary depositional features and subsequent erosion features.

A vast system of creeks and rivers of two major types drains the quadrangle. Heading in the Piedmont are the Cape Fear and Neuse Rivers, which drain the southern and northern part of the quadrangle, respectively. Heading in the Coastal Plain and draining the central part of the quadrangle are the Northeast Cape Fear, New, and Whiteoak Rivers. The quadrangle is gently rolling to flat with steepest topography usually adjacent to major drainage systems.

STRATIGRAPHY

CRETACEOUS

Peedee Formation

The Peedee Formation was named by Ruffin in 1843; Sloan (1908) designated the type locality as Burches Ferry, 16 km south of the U.S. Route 301 bridge over the Peedee River, Florence County, South Carolina. The Peedee Formation represents the oldest strata present in the Beaufort quadrangle. It crops out along the Northeast Cape Fear River in the western part of New Hanover, Pender, and Duplin Counties, and is present in the subsurface of the eastern part of the quadrangle. The unit reaches its maximum thickness of greater than 100 m in the subsurface of New Hanover and eastern Onslow Counties.

The Peedee Formation is a massive neritic, dark micaceous, argillaceous sand characterized by an abundant molluscan fauna (Stephenson, 1923). Glauconite forms a minor constituent of the unit.

Swift (1964) undertook the most extensive study of the Peedee Formation and concluded that it was deposited on an open shelf where extensive reworking by infauna occurred. He divided the Peedee into two depositional units, an inner shelf suite composed of sand and muddy sand representing the lower Peedee and an outer shelf suite composed principally of calcareous muddy sand and sandy mud representing the upper Peedee. Swift (1964) also recognized several lenses of biomicrite and biomicrudite. On the basis of mega- and microfauna the Peedee Formation is Campanian to Maestrichtian (Upper Cretaceous).

Rocky Point Member

The top of the Peedee Formation north of the Cape Fear arch is characterized by a carbonate called the Rocky Point Member. Although it occurs in eastern Brunswick, New Hanover, eastern Pender, and southern Onslow Counties, it crops out only in northern New Hanover County along the northeast Cape Fear River. The unit occurs directly below the Mesozoic-Cenozoic boundary to the west and interfingers and underlies typical Peedee lithology to the east. The Rocky Point Member consists of four principal lithologies: lower quartz arenite; upper sandy, pelecypod biosparrudite; sandy, pelecypod biosparite, and sandy biosparite. These last three lithologies form lateral, time-equivalent facies. The Rocky Point Member represents deposition in a nearshore marine environment of normal salinity. It ranges in thickness to a maximum of 27 m in the subsurface of southern New Hanover County.

The Rocky Point Member contains an Upper Cretaceous megafauna and a Campanian and Maestrichtian foraminifera microfauna. Most microfauna are restricted to the Maestrichtian stage. Glauconites from the Rocky Point Member and stratigraphically equivalent Peedee sediments have been dated by the Rb-Sr isochron method at 68.1 ± 1 m.y. by Harris (1976).

TERTIARY

Beaufort Formation

The Beaufort Formation only occurs in the subsurface of the quadrangle; however, because it may be present in outcrop it is discussed. The Paleocene Beaufort Formation was unrecognized in outcrop when Brown (1958) named the unit from a well drilled at Chocawinity (Beaufort County), North Carolina. The Beaufort Formation includes mudstone that intergrades with chert, mudstone-chert intercalated with sandstone (Jericho Run Member), glauconitic sand, and phosphatic conglomerate (Brown and others, 1977). Mudstone and siliceous mudstone showing significant quantities of disordered cristobalite and opal are the dominant rock type and characterize the lower Beaufort Formation. Unconsolidated, sandy, foraminiferal-glauconitic sediments alternating with thinner, slightly glauconitic, foraminiferal biomicrosparites characterize the upper Beaufort Formation. The unit obtains a maximum thickness in the subsurface of approximately 46 m in eastern Carteret County (Brown and others, 1972).

The siliceous mudstone and basal phosphate-pebble conglomerate of the lower Beaufort (Danian) were deposited in the inner neritic environment

(Carlson, 1976). Thanetian sediments were deposited in a normal marine environment that ranged from inner to middle neritic.

Based on the planktic foraminifera, the siliceous mudstone belongs to Berggrens' (1972) P1 zone which is early Danian. Planktic foraminifera from the upper unconsolidated glauconitic sediments belong to Berggrens' (1972) P4 zone which is Thanetian. In addition, Rb-Sr glauconite ages of 55.7 and 57.8 M.Y. from these sediments support a Thanetian age for the upper glauconitic sand (Harris and Baum, 1977).

Castle Hayne Limestone

The Castle Hayne Limestone was named by Miller (1912) for "exposures in the vicinity of the town of Castle Hayne." The type section was designated the Martin Marietta quarry, located approximately 6 km northeast of Castle Hayne, North Carolina was designated the type section by Ward and others (1978). The Castle Hayne Limestone is present in outcrop in western New Hanover, central and northern Pender, northwestern Onslow, and eastern Duplin Counties. In Duplin County, it occurs only as outliers. The unit is also present in the subsurface of New Hanover, Pender, Onslow, Jones, Craven, and Carteret Counties.

The Castle Hayne Limestone has a maximum outcrop thickness of 11 m and subsurface thickness in eastern Carteret County of about 250 m. It is divided by Baum and others (1978a) into three lithofacies: lower phosphate pebble conglomerate, middle bryozoan biosparrudite, and upper bryozoan biomicrudite. In New Hanover County, parts of the formation are partially to completely dolomitized (Baum and others, 1978b) and contain abundant sponges (Upchurch, 1973).

The Castle Hayne Limestone contains an abundance of stenohaline fauna typical of a warm temperate to tropical marine environment; therefore it was deposited in an open environment of normal salinity. Based on the assemblages of bryozoans, mollusks, crinoids, and other faunal elements, Baum (1977) suggested that the bryozoan biomicrudite facies was deposited in water depths of 30-50 m. As the bryozoan biosparrudite facies occurs updip and shoreward, Baum (1977) suggested that it was deposited in water depths less than 30 m.

The Castle Hayne Limestone has a well-documented and characteristic fauna, although Brown and others (1972) and Baum and others (1978a; 1979b) consider the unit Claibornian, Canu and Bassler (1920), Kellum (1925), Cooke (1959), and Harris and others (1979b) consider the unit late Eocene or Jacksonian. The Castle Hayne Limestone probably transgresses the Claibornian and Jacksonian. Harris and others (1979b) determined a late Jacksonian age (34.8 ± 1 m.y.) for the bryozoan biomicrudite lithofacies at the Martin Marietta quarry, based on Rb-Sr dates of glauconite.

New Bern Formation

The New Bern Formation was named for a predominantly sandy, pelecypod-mold biomicrosparrudite that disconformably overlies the Castle Hayne Limestone in the Martin Marietta quarry at New Bern,

Craven County, North Carolina by Baum and others (1978a). This same unit is considered by Ward and others (1978) as the Spring Garden Member of the Castle Hayne Limestone. The New Bern Formation crops out only in the northern part of the quadrangle in Jones County but probably occurs in the subsurface of eastern Onslow and Jones Counties and in Carteret and Craven Counties. At the type section, the New Bern Formation is about 9 m thick and consists of three lithologies: lower calcareous quartz arenite; sandy, fine, pelecypod-mold biomicroparrudite; and sandy, medium to coarse, pelecypod-mold biomicroparrudite.

The New Bern Formation was deposited in a transgressive depositional system ranging from intertidal in the lower part through a sandy, continental shelf at depths of 7-40 m in the upper part. The fauna suggest a warm temperate marine environment.

Because diagnostic fossils do not occur in the New Bern Formation, and because the formation is disconformably overlain by the Oligocene Trent Formation, the New Bern is assigned a latest Jacksonian age.

Trent Formation

The type section of the Trent Formation was designated the Trent River from New Bern to Trenton (Miller, 1912); however, because the section contains two distinct formations, Baum and others (1978a) restricted the Trent Formation to the outcrops occurring along the river from New Bern to within 0.7 km of Pollocksville (Jones County). Ward and others (1978) named this same unit the River Bend Formation and designated the series of limestones that occur 0.3 km above Rhems Landing at River Bend Estates along the Trent River, Craven County, North Carolina, the type section. The Trent Formation disconformably overlies the New Bern Formation.

The Trent Formation is confined to the areas between the Neuse and New Rivers and crops out only in a narrow northeast trending belt in central Onslow and eastern Jones Counties. It probably occurs in the subsurface of eastern Onslow, Jones, and Carteret Counties.

The Trent Formation consists of three lithologies: lower, sandy, echinoid biosparite; sandy, pelecypod-mold biomicrudite; and barnacle, pelecypod-mold biosparrudite. The formation has an approximate thickness of 9-10 m along the Trent River, Craven County.

The Trent Formation represents a transgressive-regressive sequence that was deposited in a warm-temperature marine environment. The basal part was deposited in the intertidal zone, the middle on a sandy, continental shelf at depths of 7-40 m. The upper part was deposited during regression of the seas, in a shallow marine environment. Because of the concurrence of Oligocene to recent mollusks and Eocene to Oligocene barnacles, the Trent Formation is considered Oligocene age (Baum and others, 1978a).

Belgrade and Silverdale Formations

The basal 7.5 m of the Martin Marietta quarry located south of the Whiteoak River in the town of Belgrade, Onslow County, was designated the type section of the Belgrade Formation by Baum and others (1978a). Ward and others (1978) regard this lower section the upper part of their Oligocene River Bend Formation. The two principal lithologies of the Belgrade Formation are lower unconsolidated quartz arenite about 2.5 m thick, grading upward into 5.5 m of sandy, pelecypod-mold biomicrudite. Disconformably overlying the Belgrade Formation are channel sands containing Crassostrea gigantissima and an abundant molluscan fauna which grade upward into clay. These lithologies are approximately 2 m thick and are regarded by Baum and others (1978a; 1979b) as equivalent to their Silverdale Formation. Ward and others (1978) consider this section the Haywood Landing Member of their Belgrade Formation, and consider the member as a contemporaneous facies of the Crassostrea beds.

The quarry located just east of the city of Silverdale, Onslow County, was designated by Baum and others (1978a) the type section of the Silverdale Formation. The Silverdale consists of two lithologies: a basal 0.8 m dense, sandy, pelecypod-mold biomicrudite which grades upward into 2.4 m of an unconsolidated, sandy, pelecypod biomicrudite.

The Belgrade and Silverdale Formations disconformably overlie the Trent Formation and occur in eastern Pender, eastern Onslow, eastern Craven, and Carteret Counties. They do not crop out naturally, and exposures are apparently restricted to active quarries. The Belgrade and Silverdale Formations represent depositions on a sandy, continental shelf in normal marine waters. Parts of the Silverdale Formation (Crassostrea beds) suggest lagoonal brackish water environments.

The Silverdale Formation has a well documented Miocene age (Kellum, 1925, 1926; Richards, 1948; Vokes, 1967, 1970). Because barnacles that occur in the Silverdale Formation are conspecific with barnacles found in the Belgrade Formation, the Belgrade and Silverdale Formations probably represent two laterally equivalent depositional facies. Therefore, the Belgrade and Silverdale Formations are considered Miocene in age (Baum and others, 1978a).

Pungo River Formation

Kimrey (1964) proposed the name Pungo River Formation for middle Miocene phosphatic sediments first described by Brown (1958) in the subsurface of Beaufort County. A core hole located at 76°34'59"W, 35°35'58"N, Beaufort County, was chosen as the type section. The Pungo River Formation occurs as an outlier in Carteret County and in the subsurface of Pamlico and Carteret Counties.

The chief lithologies of the Pungo River Formation are light-green diatomaceous clay and fine- to medium-grained quartz sand containing varying amounts of greenish-brown clay and light- to dark-brown collophane. Light olive-green dolomite and dolomitic limestone, white to light gray molluscan limestone, calcareous clay, shell hash, and

chalk are less abundant constituents. In the Beaufort quadrangle, the Pungo River Formation reaches a maximum thickness of about 45 m in the subsurface of eastern Carteret County.

The Pungo River Formation was deposited in an open marine, normal salinity, shallow shelf environment with water temperatures cool to cool-temperate. Gibson (1967) concluded that most of the unit was deposited in water 100-200 m deep.

The Pungo River Formation is considered correlative with the middle Miocene Calvert Formation of Maryland on the basis of benthic foraminifera (Brown, 1958). Gibson (1967) also concluded the formation was middle Miocene on the basis of mollusks and benthic foraminifera.

Duplin and Yorktown Formations

The Duplin Formation was first referred to formally in North Carolina by Miller (1912). Although he stated that the Yorktown and the Duplin Formations occupied the same stratigraphic position, because of differences in the fauna they should not be referred to as a single formation. Although the type section was not designated, the exposure at Natural Well, approximately 3 km southwest of Magnolia, Duplin County, is regarded the type section.

The Duplin Formation occurs as isolated outliers in New Hanover, Pender, Duplin, and Onslow Counties. It overlies a dissected Cretaceous, Eocene, and Miocene surface.

The Duplin Formation consists of fine quartz sand and bluish-green argillaceous sand with abundant mollusks. The mollusks are well worn and broken as well as unworn and whole. South of the Cape Fear River, the Duplin Formation is characteristically a sandy limestone; silty, nearly pure soft limestone; and calcareous silty sand.

The Yorktown Formation was named by Clark and Miller (1906) for exposures of fossiliferous sand and clay on the York River at Yorktown, Virginia. The Yorktown Formation is characterized by its abundant and varied fauna and has been divided into four members in the Virginia Coastal Plain by Blackwelder and Ward (1976). Although these members can be traced into northeastern North Carolina to the Neuse River, they have not been mapped. South of the Neuse River, the discontinuous nature of Yorktown beds precludes their recognition.

In the northern part of the Beaufort quadrangle, the Yorktown Formation consists of bluish to greenish gray, clayey quartz sand and interbedded clay and sandy clay beds that contain an abundant fauna. Because of the lithological similarity of the Duplin Formation to the Yorktown Formation, and because the Duplin Formation is the same age as the Yorktown Formation, Blackwelder and Ward (1979) proposed that the term Duplin Formation be abandoned and that the beds formally assigned to it be called Yorktown. The thickness of the Duplin and Yorktown Formations probably is about 2-3 m in outcrop and 45 m in the subsurface of eastern Carteret County.

The Duplin and Yorktown Formations represent deposition in a warm-temperate climatic zone. Specific environments are shallow marine bars, lagoons, and a sandy, continental shelf in water depth 23 to 46 m.

The Duplin and Yorktown Formations have traditionally been regarded as late Miocene (Cooke, 1936; Richards, 1950; and Copeland, 1964); however, recent work by DuBar and others (1974a, b), and Blackwelder and Ward (1979) suggests that the Duplin and Yorktown Formations are Pliocene.

Waccamaw and James City Formations

The Waccamaw Formation was named by Dall and Harris (1892) for fossiliferous marine deposits exposed along the banks of the Waccamaw River in Horry County, South Carolina. It occurs in a nearly continuous outcrop belt in the outer Coastal Plain from Brunswick to Carteret Counties (east of the Hanover and Surry scarps). The Waccamaw Formation ranges up to 15 m in thickness in the subsurface.

The Waccamaw consists of poorly to moderately well sorted, semi-indurated, fine to coarse fossiliferous sand. Unweathered sediments are light blue; weathered sediments are yellowish brown to deep reddish brown. In some areas these deposits grade into generally unfossiliferous sediments. Locally, a thin unit consisting of quartz and phosphate pebbles and coarse sand forms the base of the Waccamaw.

The formation contains an abundant molluscan fauna that probably exceeds 500 species (Campbell and others, 1975). The abundant, well-preserved Waccamaw fauna are indicative of a warm-temperate brackish-water and a shallow marine shelf environment.

Numerous workers have disputed the age of the Waccamaw Formation. Most early workers considered the unit Pliocene; however, DuBar and others (1974a) Zullo and Harris (1978) suggest an early Pleistocene age for the unit. Campbell and others (1975) favored a late Pliocene age based on correlation with the radiometrically dated Caloosahatchee Formation of south Florida.

Fossiliferous marine sediments at the same stratigraphic horizon that occur north of New River and east of the Hanover scarp are referred to as the James City Formation. The James City Formation was described by DuBar and Solliday (1963) from strata exposed along the banks of the Neuse River estuary near the town of James City, Craven County, North Carolina. It includes part of the Croatan Formation of previous workers. The fauna of the James City Formation is correlated with that of the Waccamaw Formation; therefore, the two units are considered equivalent.

The James City Formation consists of slightly to moderately indurated, very fine quartz sand, silt, and clay. An abundant, well preserved molluscan fauna is usually present; however, in places all carbonate has been dissolved and fossil molds are present.

Because the Waccamaw and James City formations occupy the same stratigraphic interval, and are of similar lithology, they are grouped together on the geologic map.

Canepatch and Flanner Beach Formations

The Canepatch Formation was proposed by DuBar and others (1974a) for complex deposits of sand, clay, silt, and peat exposed along the Intracoastal Waterway in Horry County, South Carolina. This unit only occurs in the extreme southern part of the quadrangle along the Cape Fear River and Intracoastal Waterway. The formation reaches a maximum thickness of about 23 m, but averages only about 10 m.

The Canepatch Formation consists of the following dominant lithologies: cross-bedded, humate impregnated sand; fossiliferous clayey sand; blue fossiliferous sandy clay; dark brown sand; and clayey sand and peaty clay. Beach rock coquina is also common. The Canepatch Formation contains an abundant and well-described fauna (DuBar and others, 1974a) that suggest an interglacial origin for the formation.

Radiocarbon dated cypress wood, the coral Septastrea crassa, and the pelecypod Mercenaria campechensis from the Canepatch Formation yielded ages greater than 35,000 years for the unit (DuBar and others, 1974a). Zullo and Harris (1978) dated a Mercenaria campechensis from the type Canepatch and obtained a radiocarbon age of $31,810 \pm 785$ years. A Mercenaria campechensis specimen from equivalent material at Burnett, New Hanover County, yielded a radiocarbon age of $39,040 \pm 1800$ years.

The Flanner Beach Formation was first described by DuBar and Solliday (1963) from exposures along the Neuse River at Flanner Beach, Craven County. It here includes the Newport sand, Arapahoe sand, Minnesott sand, and Beard Creek member of Mixon and Pilkey (1976). The Flanner Beach Formation consists of slightly indurated very fine to fine sand with minor medium to coarse sand and some silt and clay. The upper part of the unit is characterized by cross-stratification. Calcium carbonate comprises 20 percent or more of some lithologies and is mainly in the form of pelecypods and gastropods. The maximum thickness of the Flanner Beach Formation is 10 m.

Flanner Beach sediments represent deposition in a barrier-island, lagoonal complex. Therefore, fauna and sediments represent brackish to normal marine waters. The Flanner Beach Formation is considered medial Pleistocene and equivalent to the Canepatch Formation of the southern part of North Carolina.

Because the Canepatch and Flanner Beach Formations and the Waccamaw and James City Formations represent a short span of geologic time and are lithologically similar and have not been separated throughout most of the area, they are grouped together as Q-T on the geologic map.

Undifferentiated Late Pleistocene and Holocene Sediments

Undifferentiated late Pleistocene sediments include the Core Creek sand, the Atlantic sand, Cedar Island sand, North Bay sand, Bogue sand, and Beaufort sand of Mixon and Pilkey (1976). Also included in this category are the Socastee Formation of DuBar and others (1974a) which is restricted to the area south of the Cape Fear River and the "Cherry Point unit" of DuBar and others (1974b), which is restricted to the area of the Neuse River.

The sediments occur east of the Suffolk or Bogue scarps. They consist dominantly of silty and clayey fossiliferous sand, very pale gray to light greenish-gray, fine to medium nonfossiliferous quartz sand, and associated silty and clayey sands which vary in thickness.

Holocene sediments include beach and dune sand and fossiliferous sand, soft silty and clayey mud, and peat that occur along the barrier islands and the sounds. They are not differentiated from late Pleistocene sediments.

Surficial Deposits

The middle and lower Coastal Plain in the quadrangle is covered by a thin veneer of gravel, sand, silt, and clay that almost everywhere conceals the older formations. The middle Coastal Plain includes the area between the Coats (Orangeburg) scarp and the Surry scarp, and consists of three seaward sloping terrace plains separated by the Wilson Mills scarp (65.5 m) and the Kenly scarp (45 m). These three plains, which form the bulk of the surficial deposits of the middle Coastal Plain, are: the Brandywine, Coharie, and Sunderland Formations of Stephenson (1912) and Cooke and others (1943) and morphostratigraphic units (msu) of Daniels and others (1972). They disconformably overlie Cretaceous to Miocene units and are variable in thickness and composition and are unfossiliferous. In general, they consist of lower coarse sand and gravel which grade upward into clay, silt, and fine sand in any combination. Kaolinite is the dominant clay-size constituent. The sediments of the middle Coastal Plain display cross-bedding and channeling in the lower part and represent a fluvial origin. They are considered Pliocene to early Pleistocene age.

The lower Coastal Plain occurs east of the Surry scarp. It is a stepped sequence of seaward sloping terrace plains similar to the middle Coastal Plain. The Walterboro (14 m) and Suffolk (6 m) scarps separate the seaward sloping terrace plains into three units: the Wicomico msu, the Talbot msu, and the Suffolk msu. Sediments in the lower Coastal Plain are principally marine and show the effects of a depositional topography. Sediments underlying these terrace plains are variable in type and thickness and are considered mid to late Pleistocene.

STRUCTURAL GEOLOGY

The Cape Fear arch in southern North Carolina is the principal structural feature of the Atlantic Coastal Plain Province. It has been referred to as a southeast plunging basement high extending from the fall line along the Cape Fear River to about Cape Fear. Harris and others (1979a) suggest that the Cape Fear arch is a northwest-trending basement fault that has experienced periodic differential movement since the early Late Cretaceous and may have moved as recently as 75,000 years ago.

Harris and others (1979a) also suggest the presence of a fault, parallel to the Cape Fear fault, that coincides with Whiteoak River (Onslow-Carteret County line). This fault was also active during the early Late Cretaceous and periodically has experienced movement as recently as the Pleistocene. In addition, a northeast-trending fault

parallel to the coast has been suggested as passing through Cove City, Craven County. This basement rooted feature has been called the "Carolina fault". No other structures are known in the Beaufort quadrangle.

MINERAL RESOURCES

There are no reported occurrences of uranium, niobium, tin, beryllium, lithium, tungsten, vanadium, thorium, zircon, or rare earth minerals in the quadrangle. In addition, there are no igneous intrusions of pegmatites or massive sulfides in the area. There are commercial deposits of nonmetallic mineral resources, including sand and gravel and limestone currently being mined.

Limestone

Major commercial operations mine limestone at Castle Hayne in New Hanover County and at Belgrade in Onslow County. Minor operations for limestone occur at Maple Hill, Pender County, and at Silverdale in Onslow County.

Sand and Gravel

Sand and gravel are locally mined throughout the quadrangle.

Others

Although no other commercial operations are active in the quadrangle, the widespread occurrence of glauconite and phosphate in Coastal Plain sediments and the potential associations of uranium or thorium or both with these minerals necessitates their discussion.

Glauconite occurs in concentrations of up to 30% in some zones of the Peedee Formation, Beaufort Formation, and Castle Hayne Limestone. In addition, glauconite mixed with phosphate coats many disconformities. Because Yasyrev (1966) demonstrated that glauconites average 400 ppm thorium and 10 ppm uranium, proper conditions of diagenesis may result in enrichment of uranium or thorium in associated sediments.

Scattered concentrations of phosphate occur in the Peedee Formation, the Beaufort Formation, the Castle Hayne Limestone, and the Pungo River Formation. Because of sufficient concentration in the Pungo River Formation, they are mined by Texas Gulf Sulphur at Aurora in Beaufort County (Rocky Mount quadrangle). Uranium is produced as a byproduct of phosphate mining in Florida, so there is the potential for commercial accumulation of uranium and thorium in North Carolina Coastal Plain. However, no concentrated zones of phosphatic minerals have been noted in the Beaufort quadrangle.

The generalized geology of the quadrangle is shown in Plate 2.

GEOLOGIC LITERATURE FOR THE BEAUFORT QUADRANGLE

Previous Studies

Detailed geologic mapping in the Beaufort quadrangle is sparse (Figure 2); only Mixon and Pilkey (1976) have mapped in detail the surface distribution of the sediments, but their study was confined to the area east of 77°W longitude. Fallaw (1963) mapped the distribution of rocks in the Rocky Point quadrangle and the adjacent coastal area.

Regional geologic mapping of the North Carolina Coastal Plain was completed by Stephenson (1923) for the Cretaceous and by Clark and others (1912) for the Tertiary. Brown and others (1972) reported on the subsurface distribution of Cretaceous and Tertiary sediments from New York to North Carolina. Baum and others (1978a) and Ward and others (1978) revised the stratigraphy of the Eocene to Miocene of the North Carolina Coastal Plain. The generalized areal distribution of the Tertiary section was shown by Baum and others (1978a). These reports represent the only major studies that attempt to delineate the surface and subsurface distribution of sediments and rocks in the quadrangle.

Recent concentrated studies on specific units have been made on the Peedee Formation by Brett (1961), Swift (1964), and Curran (1968); the Rocky Point Member by Cunliffe (1968) and Harris (1978b); the Beaufort Formation by Carlson (1976), Harris and Baum (1977), and Brown and others (1977); the Castle Hayne Limestone by Upchurch (1973) and Baum (1977); the Trent Formation by Baum (1977); and Belgrade and Silverdale formations by Baum and others (1978a). The Pungo River Formation has been studied by Miller (1971) and Holland (1974); the Yorktown-Duplin Formations by Howard (1966), Blackwelder (1971) and Blackwelder and Ward (1979); the Waccamaw and James City Formations by Howard (1966), DuBar and Solliday (1963), Woodas (1965), DuBar and others (1974a), Campbell and others (1975), and Zullo and Harris (1978); and the Canepatch and Flanner Beach Formations by DuBar and Solliday (1963) and DuBar and others (1974b).

Current Research

The Geology and Mineral Resources Section (GMRS) of the North Carolina Department of Natural and Economic Resources has initiated a program to produce reconnaissance geologic maps for the entire state. The state has been divided into 17 multi-county planning regions that the maps will cover. The GMRS plans to have open-file reports on the Coastal Plain by 1981. Mapping in the Coastal Plain has not been started.

Two graduate students at the University of North Carolina at Chapel Hill are currently working on doctoral dissertations that relate to the geology of the Beaufort quadrangle. Lee Otte (under the direction of Daniel A. Textoris) is studying the Castle Hayne Limestone in Duplin County; Edward Custer (under the direction of Roy L. Ingram) is examining the subsurface distribution and depositional environments of the Cretaceous formations in the Cape Fear arch region. In addition, Roy L. Ingram, the University of North Carolina at Chapel Hill, is under contract from the North Carolina Energy Institute to assess the peat resources of North

Carolina. His group has actively been examining peat deposits in the Beaufort quadrangle.

Lauck Ward and Blake Blackwelder of the U.S. Geological Survey have been studying the Tertiary units in the quadrangle.

Thomas Worsley and two graduate students (Joe Finneran and D. Sekel) at Ohio University are examining nannofossils in the Peedee Formation and the Tertiary units of North Carolina. Kevin Turco has recently completed a master's thesis at Ohio University on Tertiary nannofossils in the North Carolina Coastal Plain.

Philip M. Brown of the U.S. Geological Survey, Raleigh, North Carolina, and W. Burleigh Harris, University of North Carolina at Wilmington, have recently taken seven shallow cores from locations in Brunswick, New Hanover, and Pender Counties and are studying the Upper Cretaceous and Tertiary sections. In addition, Victor Zullo and W. Burleigh Harris, University of North Carolina at Wilmington, are examining the Tertiary and Quaternary stratigraphy and paleontology of the North Carolina Coastal Plain.

GEOLOGIC HISTORY

The Coastal Plain Physiographic Province extends along the Atlantic Coast from southern Florida to the Grand Banks of Newfoundland. The sediments and sedimentary rocks generally form a wedge-shaped mass that thickens from a featheredge along the fall line to a maximum along the coastal margin. However, the recent recognition that a basement rooted tectonic framework has affected Coastal Plain deposition suggests that local variations in sediment thickness and lithology occur. Coastal Plain sediments and rocks rest unconformably on a Paleozoic and Precambrian basement of igneous and metamorphic rock or early Mesozoic sedimentary rock. Upper Cretaceous through Holocene sediments and sedimentary rocks occur in the Beaufort quadrangle.

During early Late Cretaceous time, a transgression of the ocean on to the Piedmont surface established a time-transgressive stratigraphic sequence: the Cape Fear and Middendorf Formations - fluvial, fluviomarine; the Black Creek Formation - estuarine, lagoonal, and littoral; and the Peedee Formation - open marine shelf. Although local disconformities exist between the Cape Fear and Middendorf, and the Black Creek and Peedee Formations, formational boundaries are generally of an intertonguing nature and suggest the absence of major eustatic changes in sea level or tectonism.

During latest Cretaceous, uplift of the Cape Fear arch established a nearshore regressive sequence in the dominantly transgressive regime of the Peedee Formation. This started deposition of the shallow marine Rocky Point Member of the Peedee Formation north of and along the Cape Fear arch. The close of the Mesozoic is marked by regression of the sea and probably uplift of the Cape Fear arch. The arch appears to have remained high during the entirety of Paleocene deposition, as Paleocene sediments are restricted to the area north of the arch axis.

The Castle Hayne Limestone represents a major transgression of the sea over Cretaceous and Paleocene sediments and rocks. The Castle Hayne was deposited during a temporal transgression during the middle and late Eocene. In New Hanover County, the presence of dolomitized sediments in the Castle Hayne, which are thought to have originated through diagenetic dolomitization, suggest that the Cape Fear arch was active and a positive element. Subsequently, during late Eocene, the Castle Hayne sea transgressed across the arch and deposited late Eocene sediments. As the sea withdrew from the Coastal Plain after Castle Hayne deposition, the Cape Fear arch emerged, and uplift and erosion of the area south of the Neuse fault resulted in deposition of the New Bern Formation north of the Neuse fault as a regressive (?) pulse during latest Eocene.

During the Oligocene, the sea transgressed the entire area north of the Cape Fear arch and deposited the shallow marine Trent Formation. The Trent Formation displays lithofacies indicative of transgression and regression. The extensive eustatic sea level drop in the mid-Oligocene suggest that Trent deposition occurred during the early to middle Oligocene.

The Belgrade and Silverdale Formations were deposited during the early Miocene as the sea transgressed the area from the east. The coastal area was not tectonically active during the early Miocene.

During the middle Miocene, the sea transgressed from the east and deposited the Pungo River Formation in the area north of the Neuse fault. This restriction of the Pungo River Formation suggests that the Neuse fault was active during the middle Miocene. The seas retreated from the Coastal Plain during the late Miocene.

A major transgression occurred during the late Miocene (?) or early Pliocene when the Yorktown and Duplin Formations were deposited seaward of the Coats (Orangeburg) scarp. The Yorktown-Duplin transgression resulted in deposition of strata on a late Cretaceous to Paleocene dissected surface. Regression of this early Pliocene sea may have been the direct result of polar ice cap advance (DuBar and others 1974a) or tectonism (Zullo and Harris, 1979). The present distribution of the Yorktown and Duplin Formations suggest elevation of the area between the Cape Fear and Neuse Faults after regression of the sea.

During the Pleistocene, the Waccamaw-James City rose to a maximum level of about 30 m, occupying the Surry scarp. Therefore, Waccamaw and James City sediments are restricted to the area south of the Cape Fear River, to a narrow zone along the coast east of the Hanover scarp, and (in the north) east of the Surry scarp. Withdrawal of the Waccamaw-James City seas from the Coastal Plain was followed by the less extensive Canepatch-Flanner Beach transgression that occupied part of the unelevated outer Coastal Plain and reoccupied the Hanover scarp. This transgression occurred during the late Pleistocene. Undifferentiated late Pleistocene sediments were deposited east of the Suffolk and Boque scarps during the latest high stand of sea level.

GEOLOGY AND MINERAL RESOURCES OF THE
ROCKY MOUNT
1° x 2° NTMS QUADRANGLE

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LOCATION AND PHYSICAL GEOGRAPHY

The Rocky Mount quadrangle covers about 20,000 sq km in North Carolina in the Atlantic Coastal Plain Province; however, Piedmont rocks of the Eastern Slate Belt are present in the extreme northwest part. Elevations range from greater than 65 m in the extreme northwest to sea level in the eastern part of the quadrangle. Temperatures are moderate, with the normal 25.7°C in July and 5.8°C in January. Dense vegetation, low relief, the existence of a thin veneer of surficial sand, and a deeply weathered soil profile make geologic mapping difficult.

The Atlantic Coastal Plain is physiographically divisible into two distinct parts in the Rocky Mount quadrangle. The middle Coastal Plain extends from the Coasts scarp (Orangeburg) at an approximate altitude of 33 m. The lower Coastal Plain extends from the Surry scarp to the coastal margin. The middle and lower Coastal Plains are characterized by differences between primary depositional features and subsequent erosional features.

A well-integrated system of creeks and rivers drains the quadrangle. The major rivers are the Neuse, Tar, and Roanoke, which head in the Piedmont. The Northeast Cape Fear, Trent, Pungo, and Alligator rivers head in the Coastal Plain and are minor drainage systems. The quadrangle is gently rolling to flat with steepest topography usually adjacent to major drainage systems.

STRATIGRAPHY

PIEDMONT

Eastern Slate Belt Rocks

Eastern Slate Belt Rocks occur in the extreme northwest part of the quadrangle. They consist of a sequence of low rank metavolcanic-sedimentary rocks that may reach a thickness of over 600 m. These low rank rocks include mainly sericite-chlorite phyllite, slate, argillite, metagraywacke, quartzite, greenstone, and comparable metafelsites (Parker, 1968) and are regionally in the greenschist facies of metamorphism.

Granite Plutons

Granitic plutons are exposed west of Rocky Mount and northwest and southwest of Wilson along the larger streams. The plutons are variable in crystal size and biotite content. Coarse-grained red microcline granite with little plagioclase and biotite is the common type.

COASTAL PLAIN

Middendorf Formation

The name Middendorf was first applied by Sloan (1904) in South Carolina for sand and kaolinitic clay. Although abandoned in favor of the term Tuscaloosa (Cooke, 1936), Swift and Heron (1969) formally proposed that the Middendorf Formation be recognized for beds between the "Hamburg" (Cape Fear Formation) and the overlying Black Creek Formation. The railroad cut on the Seaboard Railroad 3.2 km east of Middendorf (Chesterfield County, S.C.) is generally accepted as the type section. The Middendorf disconformably overlies the Cape Fear Formation, Triassic basin sediments, and crystalline rocks of the Piedmont.

The Middendorf Formation is a fluvial unit that crops out principally in the upper Coastal Plain above the Coasts (Orangeburg) scarp south of Fayetteville, N.C. However, limited exposures are present in the area of Goldsboro and along the Roanoke and Tar Rivers. It is composed of argillaceous and micaceous sand with lenses of white to gray mudstone and discontinuous conglomerate. Cross-bedded quartz wacke with basal conglomerate is the main sediment type with kaolinite the dominant matrix component (Heron and Wheeler, 1964). Fossil leaves, clay pebbles, channeling, local disconformities, point bar and channel fill deposits suggest the unit is fluvial in origin (Heron, 1958). The Middendorf Formation, which probably does not exceed 70 m in thickness (Swift and Heron, 1969), contains a well known and abundant flora (Berry, 1914; Dorf, 1952) and is considered Coniacian and Santonian in age.

Black Creek Formation

The Black Creek Formation is transitional between the fluvial Middendorf Formation and the marine Peedee Formation. It was named by Sloan (1907) for exposures along Black Creek, Florence and Darlington Counties, S.C. In the Rocky Mount quadrangle, the Black Creek Formation crops out south of the Pamlico and Tar Rivers west of Kinston, N. C.

The Black Creek Formation is characterized by laminated dark gray clay intercalated with gray to yellow-orange sand that is often crossbedded. Claystone forms the bulk of the formation (Heron and Wheeler, 1964). Also abundant lignitized wood and less abundant sulfide aggregates are present. Black Creek sediments represent deposition in estuarine, lagoonal and littoral environments (Benson, 1968). The formation has an estimated average thickness of 100 m but may reach greater than 200 m near the coast in the subsurface (Benson, 1968).

The Black Creek Formation contains a flora of Austin and Taylor age (Dorf, 1952) that is essentially synchronous with plant mega-fossils from the Middendorf Formation (Berry, 1914; Dorf, 1952). Wolfe (1976) assigned the upper part of the Black Creek Formation to his CA-3 to CA-5 palynomorph assemblage zones which range from lower to upper Campanian (Taylor).

Peedee Formation

The Peedee Formation was named by Ruffin in 1843; Sloan (1908) designated the type locality as Burches Ferry, 16 km south of the U.S. Route 301 bridge over the Pee Dee River, Florence County, S.C. The Peedee Formation crops out south of the Pamlico and Tar Rivers in a broad outcrop belt with Kinston in the center.

The Peedee Formation is a neritic, dark micaceous, argillaceous sand characterized by an abundant molluscan fauna (Stephenson, 1923). Near the base, the mollusks are concentrated and form a distinctive lithic unit that was designated the "Snow Hill Member" and placed in the Black Creek Formation by Stephenson (1923). However, Brett and Wheeler (1961) proposed the abandonment of the name and assigned the beds to the basal Peedee. The Peedee Formation has a thickness ranging from a feather edge in the west to a maximum of greater than 100 m in the subsurface of eastern Pamlico County (Brown and others, 1972).

Swift (1964) concluded that the Peedee Formation was deposited on an open shelf and divided the Peedee into two depositional units: an inner shelf suite composed of sand and muddy sand, representing the lower Peedee, and an outer shelf suite composed principally of calcareous muddy sand and sandy mud, representing the upper Peedee.

The Peedee Formation is Campanian and Maestrichtian; the upper part has been dated with Rb-Sr glauconite ages at 68.1 m.y. (Harris, 1976).

Beaufort Formation

Brown (1959) named the Beaufort Formation from a well drilled at Chocowinity (Beaufort County), N.C.; subsequently, the unit was recognized in outcrop in the area around Kinston, principally along Moseley Creek and the Neuse River.

The Beaufort Formation consists of two members: the lower Jericho Run Member consists of mudstone with intercalations of chert and sandstone; the upper unnamed member consists of unconsolidated, sandy, foraminiferal glauconitic sediments alternating with thinner, slightly glauconitic, foraminiferal biomicrosparites. The unit probably does not exceed 5 m in surface exposures; however, it attains a thickness of approximately 46 m in the subsurface of eastern Carteret County (Brown and others, 1972).

The siliceous mudstone and basal phosphate-pebble conglomerate of the lower Beaufort were deposited in the inner neritic environment (Carlson, 1976). The unnamed sediments were deposited in a normal marine environment that ranged from inner to middle neritic.

Based on planktic foraminifera, the siliceous mudstone is early Danian in age and belongs to Berggrens' (1972) P1 zone. Planktic foraminifera from the upper unconsolidated glauconitic sediments are Thanetian and belong to Berggrens' (1972) P4 zone. Rubidium-strontium glauconite ages of 55.7 m.y. and 57.8 m.y. from the P4 zone suggest a Thanetian age for the unnamed member (Harris and Baum, 1977).

Castle Hayne Limestone

The Castle Hayne Limestone was named by Miller (1912) for "exposures in the vicinity of the town of Castle Hayne." The type section was concurrently designated the Martin-Marietta quarry, 4.5 northeast of Castle Hayne, by Baum and others (1978a), and the Ideal Cement Co. quarry, 6 km northeast of Castle Hayne, by Ward and others (1978). The Castle Hayne Limestone forms a continuous outcrop belt south of the Pamlico River between Kinston and New Bern. It also occurs as scattered outliers west of the outcrop belt in Jones, Lenoir, Wayne, Pitt, and Greene counties.

The Castle Hayne Limestone consists of three lithofacies (Baum and others, 1978a): lower phosphate pebble conglomerate, middle bryozoan biosparrudite, and upper bryozoan biomicrudite. Dolomitization occurs in some parts of the unit (Baum and others, 1978a). The unit has a maximum outcrop thickness of about 5 m and subsurface thickness of about 250 m in eastern Carteret County.

The abundance of stenohaline fauna in the Castle Hayne Limestone is indicative of a warm temperate to tropical marine environment. Based on the assemblages of bryozoans, mollusks, crinoids, and other less abundant faunal elements, Baum (1977) suggested that the bryozoan biomicrudite was deposited in waters 30-50 m deep and the bryozoan biosparrudite in waters less than 30 m deep.

The Castle Hayne Limestone is considered by Brown and others (1972), Baum and others (1978a), and Baum and others (1979a) as Claibornian (middle Eocene); however, Canu and Bassler (1920), Kellum (1925), Cooke (1959) and Harris and others (1979b) consider the unit Jacksonian (late Eocene). Harris and others (1979b) determined a 34.8 ± 1 m.y. Rb-Sr isochron age on glauconites for the bryozoan biomicrudite facies. The Castle Hayne Limestone probably represents deposition during the Claibornian and Jacksonian.

New Bern Formation

The New Bern Formation is a sandy, pelecypod-mold biomicrosparrudite that disconformably overlies the Castle Hayne Limestone. The unit was first named by Baum and others (1978a) for exposures at the Martin-Marietta quarry located at New Bern. The formation crops out only in the southern part of the Rocky Mount quadrangle in Jones County and along the Neuse River. At the type section, the New Bern Formation is about 9 m thick and consists of lower calcareous quartz arenite and sandy, fine pelecypod-mold biomicrosparrudite.

The New Bern Formation was deposited in a transgressive depositional system ranging from intertidal in the lower part through a sandy, continental shelf at depths of 7-40 m in the upper part. The fauna suggest a warm temperate marine environment. Because of the lack of diagnostic fossils in the New Bern Formation, and because the formation is disconformably overlain by the Oligocene Trent Formation, the New Bern is assigned a latest Jacksonian age.

Trent Formation

The type section of the Trent Formation was designated the Trent River from New Bern to Trenton by Miller (1912); however, because the section contains two distinct formations, Baum and others (1978a) restricted the Trent Formation to the outcrops occurring along the river from New Bern to within 0.7 km of Pollocksville (Jones County). Ward and others (1978) named these same exposures the River Bend Formation. The Trent Formation disconformably overlies the New Bern Formation and crops out in a narrow belt along the Trent and Neuse Rivers in Jones and Craven Counties.

Three lithofacies characterize the Trent Formation: lower sandy, echinoid biosparite; sandy pelecypod-mold biomicrudite; and barnacle, pelecypod-mold biosparrudite. The formation has an approximate thickness of 9-10 m along the Trent River, Craven County.

The Trent Formation represents a transgressive-regressive sequence that was deposited in a warm temperate marine environment. The basal part was deposited in the intertidal zone, the middle on a sandy, continental shelf at depths of 7-40 m, and the upper part in a shallow marine regressive sea. Because of the concurrence of Oligocene to Recent mollusks and Eocene to Oligocene barnacles, the Trent Formation is considered Oligocene age (Baum and others, 1978a).

Belgrade and Silverdale Formations

The basal 7.5 m of the Martin-Marietta quarry located south of the White Oak River in the town of Belgrade, Onslow County, was designated the type section of the Belgrade Formation by Baum and others (1978a). Ward and others (1978) regard this section the upper part of their River Bend Formation (Oligocene). The Belgrade Formation consists of lower unconsolidated quartz arenite that grades upward into sandy, pelecypod-mold biomicrudite.

The quarry located just east of the city of Silverdale, Onslow County, was designated the type section of the Silverdale Formation. It consists of a basal dense, sandy, pelecypod-mold biomicrudite that grades upward into an unconsolidated, sandy, pelecypod biomicrudite. Discontinuous channel sands containing Crassostrea gigantissima and an abundant molluscan fauna that grade upward into clay in Jones and Craven Counties are considered part of the Silverdale Formation.

The Belgrade and Silverdale Formations disconformably overlie the Trent Formation and occur only in Jones County. Exposures are restricted to river and stream banks and open pits. Faunal constituents of the two formations suggest deposition on a sandy, continental shelf in lagoonal, brackish water environments.

The Silverdale Formation has a well documented Miocene fauna (Kellum, 1925; 1926; Richards, 1948; Vokes, 1967; 1970). Because of barnacles found in the Belgrade Formation, the two units are considered equivalent in age. Therefore, the Belgrade and Silverdale Formations are considered Miocene age (Baum and others, 1978a).

Pungo River Formation

Although the Pungo River Formation does not crop out in the Rocky Mount quadrangle, it occurs in the subsurface and is mined for its phosphate. Kimrey (1964) proposed the name Pungo River Formation for middle Miocene phosphatic sediments described by Brown (1958) from the subsurface of Beaufort County. A core hole located at 76°34'59"W, 35°35'58"N, Beaufort County, was chosen as the type section.

The chief lithologies of the Pungo River Formation are light-green diatomaceous clay and fine to medium grained quartz sand containing varying amount of greenish-brown clay and light to dark brown collophane. Light olive-green dolomite and dolomitic limestone, white to light gray molluscan limestone, calcareous clay, shell hash, and chalk are less abundant constituents. The unit reaches a maximum thickness of about 45 m in the subsurface of eastern Carteret County.

The Pungo River Formation was deposited in an open marine, normal salinity, shallow shelf environment with water temperatures cool to cool-temperate. Gibson (1967) concluded that most of the unit was deposited in water 100-200 m deep.

The Pungo River Formation is considered correlative with the middle Miocene Calvert Formation of Maryland on the basis of benthic foraminifera (Brown, 1958; Gibson, 1967). Gibson (1967) also concluded from mollusks that the formation was middle Miocene.

Yorktown Formation

The Yorktown Formation was named by Clark and Miller (1906) for exposures of fossiliferous sand and clay on the York River at Yorktown, Virginia. It is characterized by an abundant and varied fauna and has been divided into four members in the Virginia Coastal Plain by Blackwelder and Ward (1976). These members have not been traced and mapped in northeastern North Carolina. Therefore, on the geologic map, all members are grouped as the Yorktown Formation.

The Yorktown Formation represents one of the most extensive transgressions in the Rocky Mount quadrangle. Consequently, the unit occurs as a continuous covering over most of the western half of the quadrangle. In addition, it occurs as outliers on pre-Miocene units (Piedmont to Coastal Plain). The lithology of the formation ranges from gray to blue shell marl, molluscan limestone, fine to coarse sand, and massive clay with interbedded micaceous sand. The thickness of the Yorktown Formation in outcrop probably does not exceed 6 m; in the subsurface it reaches a thickness of greater than 120 m just north of Lake Mattamuskeet (Hyde County).

The Yorktown Formation represents deposition in a warm temperate climatic zone. Specific environments are: shallow marine shelf; open bay, sound, or lagoon; and low salinity bay or estuary. The depth of deposition was probably less than 30 m (Bailey, 1970).

Traditionally, the Yorktown Formation has been considered late Miocene (Cooke, 1936; Richards, 1950; and Copeland, 1964). However, recent work by DuBar and others (1974a), Baum and Wheeler (1977), and Blackwelder and Ward (1979) suggests the formation is Pliocene.

James City Formation

The James City Formation was described by DuBar and Solliday (1936) from strata exposed along the banks of the Neuse River estuary near the town of James City, Craven County, N.C. It includes part of the Croatan Formation of previous workers and the Small sequence of Daniels and others (1972). The fauna of the James City Formation is correlated with that of the Waccamaw Formation; therefore, the two units are considered equivalent. The James City Formation only occurs disconformably on top of the Yorktown Formation, along the Neuse River south of New Bern (Craven County).

The James City Formation consists of slightly to moderately indurated, very fine quartz sand, silt, and clay. An abundant, well preserved molluscan fauna is usually present; however, in places all carbonate has dissolved and fossil molds are present. The maximum thickness of the unit probably does not exceed 15 m, although in outcrop no more than 3 m are present.

Molluscan assemblages from the unit suggest its deposition in a semirestricted environment such as an embayment similar to modern Pamlico Sound. Water depth during deposition probably did not exceed 7-8 m (DuBar and others, 1974b). Recent workers suggest that the James City Formation is early Pleistocene in age, based on its correlation with the Waccamaw Formation to the south.

Flanner Beach Formation

The Flanner Beach Formation was first described by DuBar and Solliday (1963) along the Neuse River at Flanner Beach, Craven County, N. C. Here it includes the Newport sand, Arapahoe sand, Minnesott sand, and Beard Creek member of Nixon and Pilkey (1976). The Flanner Beach Formation covers most of the eastern part of the Rocky Mount quadrangle.

The Flanner Beach Formation consists of some silt and clay and slightly indurated, very fine to fine sand with minor medium to coarse sand. The upper part of the unit is characterized by cross-stratification. Calcium carbonate comprises 20 percent or more of some lithologies and is mainly in the form of mollusks. The unit has a maximum thickness of about 10 m.

Sediments mapped as the Flanner Beach Formation represent deposition in a barrier-island, lagoonal complex; therefore, fauna and sediments represent brackish to normal marine waters. The Flanner Beach Formation is considered medial Pleistocene and equivalent to the Canepatch Formation of the southern part of North Carolina.

Undifferentiated Late Pleistocene and Holocene Sediments

Undifferentiated late Pleistocene sediments include the Core Creek sand, the Atlantic sand, Cedar Island sand, North Bay sand, Bogue sand, and Beaufort sand of Mixon and Pilkey (1976). Also included in this category is the "Cherry Point unit" of DuBar and others (1974b), which is restricted to the area of the Neuse River.

These sediments occur east of the Suffolk or Bogue scarps. They consist dominantly of silty and clayey fossiliferous sand, very pale gray to light greenish-gray, fine to medium nonfossiliferous quartz sand, and associated silty and clayey sands which vary in thickness.

Holocene sediments include beach and dune sand and fossiliferous sand and soft silty and clayey mud and peat that occur along the barrier islands and the sounds. They are not differentiated from late Pleistocene sediments.

Surficial Deposits

The middle and lower Coastal Plain in the Rocky Mount quadrangle is covered by a thin veneer of gravel, sand, silt, and clay that almost everywhere conceals the older formations. The middle Coastal Plain includes the area between the Coats (Orangeburg) scarp and the Surry scarp, and consists of three seaward sloping terrace plains separated by the Wilson Mills scarp (65.5 m) and the Kenly scarp (45 m). These three plains, which form the bulk of the surficial deposits of the middle Coastal Plain, are: the Brandywine, Coharie, and Sunderland formations of Stephenson (1912) and Cooke and others (1943) and morphostratigraphic units (msu) of Daniels and others (1972). They disconformably overlie Piedmont crystalline rocks and Cretaceous to Miocene units of the Coastal Plain. They are variable in thickness and composition and are unfossiliferous. In general, they consist of lower coarse sand and gravel which grade upward into clay, silt, and fine sand in any combination. Kaolinite is the dominant clay-size constituent. The sediments of the middle Coastal Plain display cross-bedding and channeling in the lower part and represent a fluvial origin. They are considered Pliocene to early Pleistocene age.

The lower Coastal Plain occurs east of the Surry scarp. It is a stepped sequence of seaward sloping terrace plains similar to the middle Coastal Plain. The Waltersboro (14 m) and Suffolk (6 m) scarps separate the seaward sloping terrace plains into the Pamlico Formation of Clark and others (1912) or the Wicomico msu, the Talbot msu, and the Suffolk msu of Daniels and others (1972). Sediments in the lower Coastal Plain are principally marine and show the effects of a depositional topography. Sediments underlying these terrace plains are variable in type and thickness and are considered mid to late Pleistocene.

STRUCTURAL GEOLOGY

Coastal Plain strata in the Rocky Mount quadrangle occur as a seaward-thickening and dipping monoclinial wedge. This uniform dip to the east at a rate of 6-10 m/km is disrupted only in the area of Kinston (Leonir County) where the Graingers Wrench zone affects the overlying Cretaceous, Paleocene, and Eocene strata and by the Neuse fault along the Neuse River.

The Graingers Wrench zone is a northeast trending structural mosaic of horsts, grabens, and half grabens. These en echelon faults overlie a buried Triassic basin and have experienced Paleocene and post-Paleocene movements (Harris and others, 1979a). The Neuse fault trends northwest-southeast from about Smithfield, Johnston County, to Bogue Inlet, the Onslow-Carteret County line. The fault is probably part of a series of basement faults that occur between the Neuse and New Rivers. Movement along the Neuse fault has occurred periodically from Lower Cretaceous through the Quaternary.

Harris and others (1979a) have also suggested the presence of a basement rooted northeast-trending fault (Carolina fault), parallel to the Graingers Wrench zone and passing through Cove City, Craven County. Times of movement of the Carolina fault have not been determined. No other structures occur in the quadrangle.

MINERAL RESOURCES

There are no reported occurrences of uranium, niobium, tin, beryllium, lithium, tungsten, vanadium, thorium, zircon, or rare earth minerals in the quadrangle. In addition, there are no reported igneous intrusions of pegmatites or massive sulfides in the area. There are commercial deposits of non-metallic mineral resources, including sand, gravel, stone, and phosphate currently being mined in the area. These locations are shown on the geologic map.

Sand, Gravel, and Crushed Stone

Major commercial operations mine sand, gravel, and stone throughout the quadrangle. Stone for crushing is mined at New Bern (Craven County), at Fountain (Pitt County), Elm City (Wilson County), and Rocky Mount (Edgecomb County). In addition, there are minor operations at Kinston (Lenoir County), and Windsor (Bertie County).

Phosphate

A major accumulation of phosphate underlies seven or eight counties, including Beaufort County, in the Aurora Area. This deposit, which may be one of the largest in the world, yields about 2-3 million tons of phosphate per year for Texasgulf, Inc. The phosphate occurs in the middle Miocene Pungo River Formation. Uranium is currently produced in Florida as a byproduct of phosphate production, and because phosphate at the Texasgulf, Inc. quarry may contain up to 50 ppm uranium, a major source of uranium is present in the Coastal Plain part of the Rocky Mount quadrangle.

Others

Although no other commercial operations are active in the quadrangle, the widespread occurrence of glauconite and phosphate in Coastal Plain sediments and the potential associations of uranium or thorium or both with these minerals necessitates their discussion.

Glauconite occurs in concentrations of up to 30% in some zones of the Peedee Formation, Beaufort Formation, and Castle Hayne Limestone. In addition, glauconite mixed with phosphate coats many disconformities. Because Yasyrev (1966) demonstrated that glauconites average 400 ppm thorium and 10 ppm uranium, proper conditions of diagenesis may result in enrichment of uranium or thorium in associated sediments.

In addition to the major occurrence of phosphate in the Pungo River Formation, scattered concentrations of phosphate occur in the Peedee Formation, the Beaufort Formation, and the Castle Hayne Limestone. However, no concentrated zones of phosphate minerals have been noted in the quadrangle.

The generalized geology of the quadrangle is shown in Plate 3.

GEOLOGIC LITERATURE FOR THE ROCKY MOUNT QUADRANGLE

Previous Studies

Detailed geologic mapping in the Rocky Mount quadrangle is sparse (Figure 3). Mixon and Pilkey (1976) have mapped in detail parts of the quadrangle; however, their work is confined to the lower 2.5 minutes east of 77°W longitude. Parker (1968) mapped the area north of 35°15'N latitude and west of 77°30'W longitude.

Regional geologic mapping of the North Carolina Coastal Plain was completed by Stephenson (1923) for the Cretaceous and by Clark and others (1912) for the Tertiary. Brown and others (1972) reported on the subsurface distribution of Cretaceous and Tertiary sediments from New York to North Carolina. Baum and others (1978a) and Ward and others (1978) revised the stratigraphy for the Eocene to Miocene of the North Carolina Coastal Plain. Baum and others (1978a) showed the generalized areal distribution of the Tertiary units for the southern part of the quadrangle.

Groundwater studies of the general geology of the quadrangle include: LeGrand (1960) on the Wilmington area; Pusey (1960) on the Goldsboro area; Nelson (1964) on the Swanquarter area; Sumison (1970) on the Greenville area; and Mundorff (1946) on the Halifax area. These studies do not show in detail the surface distribution of units.

Concentrated studies on specific units have been made on the Middendorf Formation by Ibrahim (1973); the Black Creek Formation by Benson (1968); the Peedee Formation by Brett (1961) and Swift (1964); the Beaufort Formation by Carlson (1976), Harris and Baum (1977), and

Brown and others (1977); the Castle Hayne Limestone by Baum (1977); the New Bern Formation by Baum (1977) and Thayer and Textoris (1972, 1977); the Trent Formation by Baum (1977); and the Belgrade and Silverdale Formations by Baum and others (1978a). The Pungo River Formation has been studied by Gibson (1967), Miller (1971), and Holland (1974); the Yorktown Formation by Bailey (1970, 1973) and Blackwelder and Ward (1979); the James City Formation by DuBar and Solliday (1963), Daniels and others (1972, DuBar and others (1974b); and the Flanner Beach Formation by DuBar and Solliday (1963) and DuBar and others (1974b). In addition, Fallaw and Wheeler (1969) examined marine fossiliferous Pleistocene deposits in southeastern North Carolina. The undifferentiated Late Pleistocene and Holocene sediments and surficial sediments have been studied by Mixon and Pilkey (1976) and have been synthesized by Daniels and others (1972).

Current Research

The Geology and Mineral Resources Section (GMRS) of the North Carolina Department of Natural and Economic Resources has initiated a program to produce reconnaissance geologic maps for the entire state. The state has been divided into 17 multi-county planning regions that will be covered by the maps. The GMRS plans to have open-file reports on the Coastal Plain by 1981. Mapping in the Coastal Plain has not yet been started.

Current work in the Rocky Mount quadrangle is in progress by Roy L. Ingram at the University of North Carolina at Chapel Hill (peat resources), Thomas Worsley at Ohio University (nannofossil biostratigraphy), Duncan Heron at Duke University (origin and evolution of Core Banks), Philip Brown of the U.S. Geological Survey in Raleigh (core holes in the New Bern area), and Stanley Riggs at East Carolina University (phosphate origin and occurrence and uranium resources).

GEOLOGIC HISTORY

The Coastal Plain Physiographic Province extends along the Atlantic Coast from southern Florida to the Grand Banks of Newfoundland. The sediments and sedimentary rocks generally form a wedge-shaped mass that thickens from a featheredge along the fall line to a maximum along the coastal margin. However, the recent recognition that a basement-rooted tectonic framework has affected Coastal Plain deposition suggests that local variations in sediment thickness and lithology occur. Coastal Plain sediments and rocks rest unconformably on a Paleozoic and Precambrian basement of igneous and metamorphic rock or early Mesozoic sedimentary rock. Precambrian (?) to early Paleozoic Piedmont rocks and Upper Cretaceous through Holocene sediments and sedimentary rocks occur in the Rocky Mount quadrangle.

During early Upper Cretaceous time a transgression of the ocean onto the Piedmont surface established a time-transgressive stratigraphic sequence in the Rocky Mount quadrangle: Middendorf Formation - fluvial, fluviomarine; the Black Creek Formation - estuarine, lagoonal and littoral; and the Pee Dee Formation - open marine shelf. Although local

disconformities occur between the units, formational boundaries are generally of an intertonguing nature and suggest the absence of major eustatic changes in sea level or tectonism during the Upper Cretaceous. The close of the Mesozoic is marked by regression of the sea as a result of eustatic sea level drop and uplift of the Cape Fear region to the south.

During the Paleocene, eustatic sea level rise coupled with movement along Graingers Wrench zone and Neuse fault(?) created a depositional basin for Danian and Thanetian sediments. Lithofacies distribution suggests that Graingers Wrench zone was active during Paleocene deposition. The end of the Paleocene is marked by a major regression and withdrawal of the sea from the Coastal Plain.

The Castle Hayne Limestone represents the next major transgression of the sea over Cretaceous and Paleocene sediments and rocks. The Castle Hayne was deposited during a temporal transgression during the middle to late Eocene. This transgression covered most of the North Carolina Coastal Plain. As the sea withdrew from the Coastal Plain after Castle Hayne deposition, uplift and erosion of the area south of the Neuse fault resulted in deposition of the New Bern Formation north of Neuse fault as a regressive (?) pulse during latest Eocene.

During the Oligocene, the sea transgressed the entire North Carolina Coastal Plain and deposited the shallow marine Trent Formation. The Trent Formation displays lithofacies indicative of transgression and regression. The extensive eustatic drop of sea level during the middle Oligocene suggests that Trent deposition occurred during early to middle Oligocene.

The Belgrade and Silverdale Formations were deposited during the lower Miocene as the sea transgressed the area from the east. The coastal area was not tectonically active during the lower Miocene.

During the middle Miocene, the sea transgressed from the east and deposited the Pungo River Formation in the area north of the Neuse fault. This restriction of the Pungo River Formation suggests that Neuse fault was active during the middle Miocene. The seas retreated from the Coastal Plain during the late Miocene.

A major transgression occurred during the late Miocene(?) or early Pliocene when the Yorktown was deposited seaward of the Coats (Orangeburg) scarp. The Yorktown transgression resulted in deposition of strata on a dissected surface of Precambrian(?) to Paleocene strata. Regression of this early Pliocene sea may have been a direct result of polar ice cap advance (DuBar and others, 1974a) or tectonism (Zullo and Harris, 1979). The present distribution of the Yorktown Formation suggests that downdropping of the area north of the Neuse fault resulted in preservation of Yorktown sediments.

During the Pleistocene, the James City sea rose to a maximum level of 20 to 30 m, occupying the Hazleton or Surry scarp(?). Therefore, James City sediments are restricted to a narrow zone along the coast, southeast of Hanover scarp and east of Surry scarp(?). Withdrawal of the James City sea from the Coastal Plain was followed by the less extensive Flanners Beach transgression that occupied part of the unelevated outer Coastal Plain. Maximum submergence was about 15 m. This transgression occurred during the late Pleistocene. Undifferentiated late Pleistocene sediments were deposited east of Suffolk and Bogue scarps during the latest high stand of sea level.

GEOLOGY AND MINERAL RESOURCES OF THE
NORFOLK
1° x 2° NTMS QUADRANGLE

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LOCATION AND PHYSICAL GEOGRAPHY

The Norfolk 1° x 2° NTMS quadrangle covers about 20,000 sq km in the North Carolina and Virginia Atlantic Coastal Plain and Piedmont provinces. Elevations range from greater than 130 m in the western part (Piedmont) to sea level in the eastern part. Rainfall averages 114.07 cm/year in Norfolk, the largest city, and temperatures are moderate, with the normal 23.11°C in July and 2.39°C in January. Dense vegetation, low relief, the existence of a thin veneer of surficial sand and gravel and a deeply weathered soil profile make geologic mapping difficult.

The Atlantic Coastal Plain, which comprises the principal part of the quadrangle, is physiographically divisible into two distinct parts. The Suffolk scarp, at an elevation of about 7 m, separates the inner Coastal Plain (west to the fall line) from the outer Coastal Plain (east to the coastal margin). The inner and outer Coastal Plain are characterized by differences between primary depositional features and subsequent erosional features. In general, the inner Coastal Plain is characterized by elevations of 7 to 53 m and relief of 7 to 15 m whereas the outer Coastal Plain is characterized by elevations below 8 m and relief locally to 7 m. Broad, flat undissected areas, pocosins, form poorly drained areas between major streams in both parts of the Coastal Plain.

A fairly well integrated system of creeks and rivers drains the quadrangle. The major rivers are the Roanoke, Chowan, and James, which head in the Piedmont, and the Perquimans, Little, Pasquotank, North Landing, Elizabeth, and Nansemond, which head in the Coastal Plain. The Dismal Swamp occupies an area of approximately 5700 sq km east of the Suffolk scarp and centered on the Virginia-North Carolina border.

STRATIGRAPHY

PIEDMONT

Eastern Slate Belt Rocks

Eastern Slate Belt rocks (Pzfvs) occur in the west part of the quadrangle. They consist of a sequence of low-rank metavolcanic-sedimentary rocks that may reach a thickness of over 6000 m. The principal rock types are sericite-chlorite phyllite, slate, argillite, metagraywacke, quartzite, greenstone, and comparable metafelsites (Parker, 1968). These rocks are regionally in the greenschist facies of metamorphism.

Raleigh Belt Rocks

Rocks of the Raleigh Belt (Pzmgn) occur in the western part of the quadrangle west of Eastern Slate Belt. The rocks of the Raleigh belt are high-rank metamorphics that include biotite-muscovite gneiss and schist, commonly with interbeds of hornblende gneiss. They belong to the upper greenschist and amphibolite facies, having almandine and associated minerals. The boundary between the Raleigh Belt and the Eastern Slate Belt separates rocks containing almandine and other high temperature minerals from rocks that contain chlorite, epidote, and biotite.

Granite Plutons

Granitic plutons are exposed south and east of Roanoke Rapids, N. C., and south and north of Emporia, Virginia, in river valleys where Coastal Plain materials have been removed by fluvial erosion. In addition, major granitic plutons occur west of Roanoke Rapids and east and west of Lawrenceville, Virginia. These plutons are variable in crystal size and mineral content, but generally consist of microcline, biotite granite, and chloritic granodiorite. In Virginia they are referred to as the Petersburg Granite. In North Carolina, the plutons are commonly coarse-grained red microcline granite with little plagioclase and biotite.

Basic Rocks

A body of basic rock extends northwest from Emporia, Virginia, exposed in river valleys and continuing into the Piedmont. The rock types are amphibole chlorite schist, chloritic hornblende gneiss, and some amphibolite, chloritic diorite, and hornblende diorite.

COASTAL PLAIN

Potomac Group

The basal unit of the Virginia Coastal Plain, the Potomac Group, overlies nonconformably a highly eroded and saprolitized Precambrian and early Paleozoic basement of igneous and metamorphic rocks (Piedmont). The Potomac Group was originally defined by McGee (1885) as the sediments between the Triassic redbeds (Newark formation) and the Cretaceous greensands of New Jersey. Clark and Bibbins (1897) divided the Potomac Group into four formations: Patuxent, Arundel, Patapsco, and Raritan. The oldest sediments overlying the Piedmont in the Norfolk quadrangle are the Patuxent Formation and occur along the Nottoway River in Sussex County, Virginia.

The Potomac Group in the southern Virginia Coastal Plain consists of an alternating sequence of very light gray to white, medium to very coarse feldspathic sand, conglomerate, and silty to sandy clay with abrupt vertical and lateral variations. Common sedimentary structures are cross-beds and graded bedding. Lignitized wood and well-preserved microflora are abundant in the clay- and silt-sized sediments. The Potomac Group is a wedge-shaped body that ranges in thickness from a feather edge on the west to almost 550 m in the subsurface at Norfolk.

The Potomac Group was deposited in a complex fluvial and deltaic environment (Glaser, 1969) and can be compared with modern alluvial valley fill of the Mississippi River. Specific environments are floodplain, channel, bank, and swamp. The Potomac Group is considered of Early Cretaceous age, based on pollen from sediments exposed in the Hopewell area, and is assigned to pollen zone I (Barremian to Aptian) to zone II-B (lower to middle Albian) (Dischinger, 1979).

Aquia Formation

The Aquia Formation rests unconformably on an eroded Potomac Group surface. It was named from exposures along Aquia Creek, Stafford County, Virginia by Clark (1895).

The Aquia Formation consists of massive green to black, very fine to fine, well-sorted sand. It is usually glauconitic, with the glauconite principally concentrated in burrows. It is generally less than 10 m thick in outcrop; however, it exceeds 30 m in the subsurface east of the outcrop belt. Gradational to the Aquia Formation is the Marlboro Clay, which is a massive gray to red clay. As the upper surface of the Marlboro Clay is a distinct unconformity, it is part of the underlying Aquia Formation.

The Aquia Formation contains an abundant marine invertebrate fauna dominated by a molluscan assemblage. However, fishes and reptiles are also present. The Aquia formation was deposited in relatively quiet and probably deep open marine water. The Marlboro Clay was deposited in a brackish water estuarine environment.

Calcareous nannofossils from the Aquia Formation indicate that the unit is uppermost Paleocene (T. R. Worsley, personal communication) and assignable to Zone NP 9. Sporomorph assemblages from the Marlboro Clay suggest that it is either latest Paleocene or earliest Eocene in age (Gibson and others, in press).

St. Marys Formation

The St. Marys Formation was established by Shattuck (1902) from exposures in St. Marys County, Maryland. Sediments originally referred to as the St. Marys south of the James River in Virginia have been referred to as the Claremont or Cobham Formations (Blackwelder and Ward, 1976). Because no recent work has identified which unit (Claremont or Cobham) represents the St. Marys Formation of southern Virginia, both units are discussed.

The Claremont Formation is named for exposures in the vicinity of Claremont on the right bank of the James River, Surry County, Virginia. The Claremont Formation characteristically consists of gray, fine clayey sand or sandy clay. Glauconite is common in the sand fraction. The thickness of the Claremont in the type area is about 8 m.

The Claremont Formation contains a molluscan assemblage, which suggests deposition of the unit in a full marine to nearshore marine environment. The unit is considered early late Miocene, based on superposition and K-Ar radiometric dates of the underlying Cobham Formation.

The Cobham Formation is named for exposures at Cobham Wharf on the James River, Surry County, Virginia. The unit disconformably overlies the Claremont Formation and is unconformably overlain by the Yorktown Formation.

The Cobham Formation consists of fairly well sorted mixtures of fine to medium shell and sand. Generally, the Cobham consists of well-sorted, clayey sand and sandy clay in the central and northern parts of the depositional area, whereas the beds are poorly sorted around the periphery of the basin. In the type area, the Cobham Formation is approximately 5 m thick.

The Cobham Formation, which contains an abundant molluscan assemblage, is considered middle late Miocene on the basis of a K-Ar glauconite age of 8.7 ± 0.4 m.y. and on the basis of molluscan correlation with the Miocene of Florida. The diverse molluscan assemblage suggests deposition in a nearshore to full marine environment.

Yorktown Formation

The Yorktown Formation was named by Clark and Miller (1906) for exposures of fossiliferous sand and clay on the York River at Yorktown, Virginia. Blackwelder and Ward (1976) divided the Yorktown into four members from study of exposures in Virginia; however, they have not been traced or mapped into northeastern North Carolina. Consequently, the Yorktown Formation is not subdivided for purposes of this report or on the accompanying geologic map.

The Yorktown Formation represents one of the most extensive transgressions in the Norfolk quadrangle. The unit, therefore, occurs over most of the inner Coastal Plain between the fall line and Suffolk scarp. Several incised rivers in the outer Coastal Plain also expose the Yorktown Formation, and it also occurs as outliers along the fall line in the Virginia Piedmont. The lithology of the formation ranges from gray- to blue-colored shell marl, molluscan limestone, fine to coarse sand, and massive clay with interbedded micaceous sand. In the type area the thickness of the Yorktown Formation is about 17 m; in the subsurface of eastern North Carolina it reaches a thickness of greater than 120 m.

The Yorktown Formation represents deposition in a warm temperate climatic zone. Specific environments are: shallow marine shelf, open bay, sound, or lagoon; and low salinity bay or estuary. The depth of deposition was probably less than 30 m (Bailey, 1970).

Traditionally, the Yorktown Formation has been considered late Miocene (Cooke, 1936; Richards, 1950; and Copeland, 1964). However, DuBar and others (1974a), Baum and Wheeler (1977), and Blackwelder and Ward (1979) suggest the formation is Pliocene.

Undifferentiated Late Pliocene, Pleistocene and Holocene Sediments

Late Pliocene to Pleistocene sediments occur west of the Suffolk scarp in Virginia and include the Sedley Formation, Bacons Castle Formation, the "Moorings Unit," and Windsor Formation.

The Sedley Formation, which unconformably overlies the Yorktown Formation, was named by Moore (1956) and consists of sandy silt and fine sand with thin layers of silty clay. Near major streams it coarsens to clayey, fine to medium sand with organic matter, and it also coarsens distinctly westward. The Sedley Formation occurs principally west of the Suffolk scarp; however, within 2 km east of the scarp, it is present as thin, isolated remnants in the subsurface. The thickness of the Sedley ranges from less than a meter just east of the Suffolk scarp to more than 9 m west of the scarp; it averages about 4 m in thickness.

The Sedley Formation contains a few marine fossils and therefore its origin is partly marine. Thicker, coarser, and organic-rich parts of the Sedley suggest a fluvial-estuarine origin. The stratigraphic position and the fossils of the unit suggest a Pliocene or early Pleistocene age for the unit.

The Bacons Castle Formation was named by Coch (1968) and is composed of clayey sand, silty sand, pebble gravel, and cobble gravel. It is present on the surface and in the subsurface only west of the Suffolk scarp where it unconformably overlies the Yorktown and Sedley Formations. The maximum thickness of the Bacons Castle is less than 9 m; it thickens toward major streams.

The complex intertonguing of facies, the lack of fossils, oxidation, eastward-dipping cross laminae, westward coarsening, and thickening near present major streams suggest a fluvial environment of deposition for the unit (Oaks and Coch, 1973). The age of the Bacons Castle is uncertain; however, a probably Pliocene or Pleistocene age is indicated by the stratigraphic position of the unit.

The "Moorings Unit" was introduced informally by Oaks and Coch (1973) for a linear body of fine sand along the Surry scarp that interfingers westward with a thin clayey silt. The sand has a thickness up to almost 10 m and is unfossiliferous, fine, and slightly silty. The clayey silt ranges in thickness from less than 2 m to greater than 6 m. Barrier and lagoonal environments of deposition for the sand and silt of the "Moorings Unit" are indicated. Stratigraphic position suggests that the "Moorings Unit" is Pleistocene.

The Windsor Formation was proposed by Coch (1968) for the silty sand that occurs east of the Surry scarp. It unconformably overlies the "Moorings Unit" along the Surry scarp and unconformably overlies the Bacons Castle, Sedley, and Yorktown Formations between the Surry and Suffolk scarps. The unit does not occur east of the Suffolk scarp. The maximum thickness of the formation is about 10 m. The unit consists of lower light-gray, medium to coarse, unfossiliferous sand and gravel which grades upward into unfossiliferous, thick-bedded clayey sand, silty sand, and silty clay. On the basis of the good sorting and rounding of the sediment, coarse grain size, its unoxidized color, westward limit at the Surry scarp, and the probable beach ridges along the Surry scarp, a nearshore-marine environment of deposition for the lower member is suggested. A lagoonal environment of deposition is

inferred from the flat depositional morphology, the blanket-like distribution, fine grain size, unoxidized aspect, and lack of sediment structures for the upper part of the Windsor Formation. A middle Pleistocene age is assigned to the Windsor Formation (Oaks and Coch, 1973).

The Great Bridge, Norfolk, Kempsville, Londonbridge, and Sand Bridge Formations are principally restricted to the area east of the Suffolk scarp.

The Great Bridge Formation, named by Oaks and Coch (1963) and modified by Oaks (1965), occurs only in the subsurface east of Suffolk scarp. It consists of lower sand and gravel and an overlying clay and sand that unconformably overlies the Yorktown Formation. The lower lithology ranges up to almost 8 m in thickness and the upper lithology to almost 17 m. Deposition of the Great Bridge Formation in a fresh-water estuarine environment is indicated by the occurrence of peat in the lower part and the clayey silt of the upper part. A late Pleistocene age is assigned to the Great Bridge Formation.

The Norfolk Formation was named by Clark and Miller (1906) for exposures in Norfolk County, Virginia. The unit unconformably overlies the Yorktown, Sedley, Bacons Castle, Windsor, and Great Bridge Formations. It is mainly present east of the Suffolk scarp; however, it occurs west of the scarp in the Great Dismal Swamp. The maximum thickness of the Norfolk Formation is about 15 m. The formation has a lower member composed of bluish-gray, fine to very coarse quartz sand with minor gravel; it reaches almost 3 m in thickness. The member occurs throughout the entire area where the Norfolk Formation is present east of the Suffolk scarp. An upper member, divisible into eight mappable units designated by the dominant lithologic aspect (Coch, 1968), forms the major part of the formation. The maximum thickness of the Norfolk Formation is about 15 m.

The Norfolk Formation was deposited in a shallow-marine environment east of the Suffolk scarp, whereas Norfolk sediments west of Suffolk scarp were deposited in fluvial and estuarine systems and include the following specific environments: open bay, lagoonal, marsh to tidal flat. The Norfolk Formation is late Pleistocene age. Uranium ages of corals indicate an age of about 70,000 years. The Norfolk Formation occupies the same position as the Flanner Beach Formation in the Neuse River area of North Carolina.

The Kempsville and Londonbridge Formations were named by Oaks and Coch (1963) and are used for linear sand or gravel bodies that overlie the Norfolk Formation in the Hickory scarp and Oceana ridge, respectively. The Kempsville Formation reaches a thickness of about 5 m and probably represents deposition in beach, dune, and marsh environments. The Kempsville Formation is late Pleistocene age based on the presence of Pleistocene fossils and on a ^{14}C age greater than 40,000 years b. p. determined from a piece of driftwood collected from the type section. The Londonbridge Formation, in addition to containing sand and gravel, also contains a clay-silt facies that interfingers in the subsurface with the sand.

The Londonbridge Formation formed in a barrier island-open lagoon complex as indicated by the sand-gravel lithology and the clay-silt lithology. A very late Pleistocene age for the Londonbridge Formation is suggested by its stratigraphic position.

The Sand Bridge Formation was named by Oaks and Coch (1963) for a terrigenous sequence of quartz sand, clayey sand, silty sand, and silty clay that occurs on the surface east of Suffolk scarp. The formation reaches a maximum thickness of about 11 m. Characteristic lithologies and sedimentary structures, morphology, and stratigraphic patterns suggest a barrier-lagoonal environment of deposition within the following specific environments: lagoon, eolian, open-marine, and shoal. The Sand Bridge Formation is of late Pleistocene pre-Holocene age.

Holocene sediments include beach, dune, barrier, backbarrier, and fossiliferous sand, soft silty and clayey mud, and peat that occur along the barrier islands and the sounds. They are not differentiated from late Pleistocene sands.

Surficial Deposits

In the North Carolina part of the quadrangle, post-Yorktown sediments have not been studied and separated into formations. They are, therefore, referred to as surficial deposits and consist of a thin veneer of gravel, sand, silt, and clay that almost everywhere conceals the older formations. In Virginia they have been studied and partially mapped; therefore, they were identified and discussed under undifferentiated Pliocene, Pleistocene, and Holocene sediments above.

STRUCTURAL GEOLOGY

Coastal Plain strata in the quadrangle occur as a seaward-thickening monoclinical wedge that dips to the east at a rate of 6-10 m/km. Two major structural features involving the basement in or adjacent to the quadrangle are recognized: the Hatteras embayment in northeastern North Carolina and the Norfolk arch (Ft. Monroe high) in southeastern Virginia. The Hatteras embayment represents a major area of sedimentary thickening between the Cape Fear arch to the south and the Ft. Monroe high in Virginia. Jurassic(?) age sediments in the Esso #1 Hatteras well drilled at Cape Hatteras indicates that the area has actively received sediment since the Jurassic. The Ft. Monroe high is an east-west-trending structure that extends through Norfolk, Virginia. It has affected Late Cretaceous and Tertiary deposition (Teifke, 1973). Additional structural features that have affected Coastal Plain sediments in the Norfolk quadrangle include two minor north-south-trending faults that involve Eocene and Miocene strata just west of Norfolk (Cedarstrom, 1945). No other structures occur in the quadrangle.

MINERAL RESOURCES

There are no reported occurrences of uranium, niobium, tin, beryllium, lithium, tungsten, vanadium, thorium, zircon, or rare earth minerals in the quadrangle. In addition, there are no reported igneous intrusions of pegmatites or massive sulfides in the area. There are commercial deposits of non-metallic mineral resources including sand, gravel, stone, clay, and lime currently being mined in the area. These locations are shown on the geologic map (Plate 4).

Sand, Gravel, and Crushed Stone

Sand and stone for crushing are mined in major commercial operations throughout the quadrangle. In North Carolina, sand and gravel are mined at Garysburg (Northampton County). In Virginia, sand and gravel are mined near Stoney Creek and Gray (Sussex County), near Adams Grove and Boykins Courtland (Southampton County), Benns Church and Wills Corner (Isle of Wight County), Sandy Bottom and Suffolk (Nansemond County), and at several different localities in Chesapeake (Virginia Beach).

Stone for crushing is mined in North Carolina at Weldon (Northampton County) and in Virginia near Rawlings and Lawrenceville (Brunswick County) and near Skippers (Greensville County).

Clay

Clay is mined at Lawrenceville and Pleasant Shade in the Virginia part of the quadrangle for use in brick manufacture in Lawrenceville.

GEOLOGIC LITERATURE FOR THE NORFOLK QUADRANGLE

Previous Studies

Recent geologic mapping of the Norfolk quadrangle is sparse (Figure 4). No recent geologic maps have been made of the North Carolina part of the quadrangle, and only the eastern part in Virginia has received recent study. Detailed Geologic mapping in Virginia includes the work of Coch (1968, 1971) on the Benns Church, Smithfield, Windsor, Chuckatuck, Newport News South and Bowers Hill quadrangles, Oaks (1965) on the Kempsville, Princess Anne, Suffolk, Lake Drummond NW, Deep Creek, Fentress, Pleasant Ridge, Corapeake, Lake Drummond, Lake Drummond SE, Moyock, and Creeds quadrangles, and Barker and Bjorken (1978) on the Norfolk North quadrangle.

Regional geologic mapping of the North Carolina Coastal Plain was completed by Stephenson (1923) for the Cretaceous and by Clark and others (1912) for the Tertiary. Rogers (1884) reported on the geology of the Virginias, and Clark and Miller (1906, 1912) reported on the geology and physiography of the Coastal Plain of Virginia. Brown and others (1972) reported on the subsurface distribution of Cretaceous and Tertiary sediments from New York to North Carolina. In Virginia, Oaks and Coch

(1973) reported on the Post-Miocene stratigraphy and morphology of the southeastern part of the quadrangle, Teifke (1973) reported on the stratigraphy of the Lower Cretaceous through Miocene, and Onuschak (1973) on Pleistocene-Holocene environmental geology.

Other studies that have included the Norfolk quadrangle in Virginia include Wentworth (1930) on the sand gravel resources of the Virginia Coastal Plain; Cederstrom (1945) on the structural geology; Gooch and others (1960) on sources of aggregate used in highway construction; Le Van and Pharr (1963) on a magnetic survey; McLean (1966) on Miocene and Pleistocene foraminifera and ostracoda; Blackwelder and Ward (1976) on the Chesapeake Group; and Johnson (1977) on bouguer gravity.

Current Research

The Geology and Mineral Resources Section (GMRS) of the North Carolina Department of Natural and Economic Resources has divided the state into 17 multi-county planning regions that will be covered by the geologic maps. The GMRS plans to have open-file reports on the Coastal Plain by 1981.

Current work in the quadrangle is in progress in the Piedmont of North Carolina by State University. The Coastal Plain area of the North Carolina part of the quadrangle is currently being studied by Stanley R. Riggs and Scott W. Snyder of East Carolina University. The Coastal Plain area of the Virginia part of the quadrangle is currently being studied by Wayne Newell and Lauck W. Ward of the U.S. Geological Survey and Gerald H. Johnson of the College of William and Mary.

GEOLOGIC HISTORY

The Coastal Plain Physiographic Province extends along the Atlantic Coast from southern Florida to the Grand Banks of Newfoundland. The sediments and sedimentary rocks generally form a wedge-shaped mass that thickens from a featheredge along the fall line to a maximum along the coastal margin. However, the recent recognition that a basement-rooted tectonic framework has affected Coastal Plain deposition suggests that local variations in sediment thickness and lithology occur. Coastal Plain sediments and rocks rest unconformably on a Paleozoic and Precambrian basement of igneous and metamorphic rock or early Mesozoic sedimentary rock. Precambrian(?) to early Paleozoic Piedmont rocks and Lower Cretaceous through Holocene sediments and sedimentary rocks occur in the quadrangle.

The oldest Coastal Plain sediments in the quadrangle consist of complex fluvial-deltaic sand and conglomerate referred to the Potomac Group. This group, which represents the lower unit of a nonmarine succession, filled pre-existing basement lows north and south of the Fort Monroe high and generally displays thickening toward the east.

Tiefke (1973) has mapped the distribution of the Potomac Group in the subsurface. The Arundel, Patapsco, and Raritan formations (Teifke's transitional beds) were deposited north and south of the Fort Monroe high in the Salisbury and Hatteras embayments, respectively. These transitional beds represent the final stage of a long period of terrigenous clastic sedimentation and basin filling. The transitional beds are intermediate in composition and texture between the underlying Patuxent Formation and the overlying Mattaponi Formation, and the lower contact is presumed to be one of unconformity. The transitional beds may conformably transgress the Cretaceous-Tertiary boundary.

The Paleocene Aquia Formation disconformably overlies the Potomac Group and represents the first extensive marine transgression of the Paleogene. The top of the unit, which is marked by a distinctive clay known as the Marlboro Clay, represents a major regression that may transgress the Paleocene-Eocene boundary. The Marlboro Clay underlies the Eocene Nanjemoy Formation in the subsurface of the northern part of the quadrangle.

Upper Eocene to Miocene time is marked by a major marine transgression that resulted in deposition of the Calvert Formation over most of the Coastal Plain of Virginia. Although the Calvert Formation is not exposed in outcrop, it has been mapped in the subsurface of the quadrangle by Tiefke (1973). During the late Miocene, the St. Marys Formation was deposited over most of the Coastal Plain in a full marine to nearshore marine environment.

During the Pliocene, one of the most extensive marine transgressions of the Tertiary occurred and is represented by the Yorktown Formation. The unit, which crops out over much of the inner Coastal Plain between the fall line and the Surry scarp represents deposition in a warm climatic zone in shallow marine shelf to estuary or bay environments.

During the late Pliocene, Pleistocene, and Holocene, sediments of various depositional environments were deposited unconformably on the Yorktown Formation. During the late Pliocene-early Pleistocene, sea level rose to a maximum of about 23 m and deposited the marginal marine, fluvial-estuarine Sedley Formation over most of the Coastal Plain of the quadrangle. Although the unit was deposited west of the Suffolk scarp to near the fall line, it is preserved principally as erosional remnants east of the scarp. As sea level fell, the Bacons Castle Formation was deposited west of the Suffolk scarp. Although the boundary between the underlying Yorktown and Sedley Formations and the overlying Bacons Castle Formation is unconformable, the fluvial nature of the Bacons Castle and its restriction to the Coastal Plain west of the Suffolk scarp suggests that the unit was deposited during regression of an early Pleistocene sea.

During the middle Pleistocene, sea level rose to the Surry scarp and deposited the transgressive Windsor Formation disconformably on the "Moorings Unit", Bacons Castle, Sedley, and Yorktown Formations. As probable beach ridges occur along the Surry scarp, the westward limit of the Windsor Formation is depositional and reflects the height to which sea level rose.

During the late Pleistocene, sea level rose to the Suffolk scarp and deposited the Great Bridge, Norfolk, Kempville, Londonbridge, and Sand Bridge Formations disconformably on middle Pleistocene to Pliocene units. Where the Suffolk scarp was breached, sediments assigned to the Norfolk Formation were deposited west of the scarp in the Great Dismal Swamp.

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Figure 1. Sources of data for the generalized geologic map of the Florence quadrangle.

Figure 2. Sources of data for the generalized geologic map of the Beaufort quadrangle.

Figure 3 - Sources of data for the generalized geologic map of the Rocky Mount quadrangle.

Figure 4. Sources of data for the generalized geologic map of the Norfolk quadrangle.

PLATE 1

GENERALIZED GEOLOGIC MAP OF THE FLORENCE QUADRANGLE, NORTH CAROLINA and SOUTH CAROLINA

EXPLANATION

Coastal Plain

QUATERNARY	HOLOCENE	Qal - Recent floodplain and terrace sediments
	PLEISTOCENE	Tcp - Conepatch Formation
	PLEISTOCENE PLIOCENE	Tw, Tbb - Waccamaw and Bear Bluff Formations
TERTIARY	MIOCENE	Tdp - Duplin Formation
	OLIGOCENE	Tun - Unnamed Oligocene
	Eocene	Tch - Castle Hayne Limestone
	PALEOCENE	Tbm - Black Mingo Formation

CRETACEOUS		Kpd - Pee Dee Formation
		Kbc - Black Creek Formation
		Kmd - Middendorf Formation
		Kcf - Cape Fear Formation

Piedmont

TRIASSIC	Rd	-Diabase Dikes
	Ru	-undifferentiated

PALEOZOIC	gr	-granite
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LOWER PALEOZOIC or PRECAMBRIAN	Carolina Slate Belt Rocks	
	Psb	- bedded argillites, felsic volcanics, mica gneiss, mica schist, and gabbro

SYMBOLS

	well defined contact
	approximate contact
	inferred or concealed contact

REGIONAL GEOLOGIC DIVISIONS

CREDITS
COMPILER: W. Burleigh Harris
This map is generalized and slightly
modified from the sources listed in
Figure 1 of text. It shows principal
geologic features on a regional scale.

GENERALIZED GEOLOGIC MAP OF THE BEAUFORT QUADRANGLE

INDEX		
RALEIGH	ROCKY MOUNT	MANTEO
FLORENCE	BEAUFORT	
GEORGETOWN

BEAUFORT, N. C.
 CREDITS 7600
 COMPILER: W. BURLEIGH HARRIS
 This map is generalized and slightly modified from the sources listed in Figure 2 of text. It shows principal geologic features on a regional scale.

PLATE 2

EXPLANATION

- Qun UNDIFFERENTIATED LATE PLEISTOCENE AND HOLOCENE (includes Core Creek Sand, Atlantic, Cedar Island and North Bay Sands, Bogue Sand, and Beaufort Sand)
- Q-T CANEPATCH - FLANNER BEACH FORMATIONS (includes Newport Sand, Arapahoe Sand, Minnesota Sand, and Beard Creek Member)
- Q-T WACCAMAW - JAMES CITY FORMATIONS
- Ty
Td YORKTOWN - DUPLIN FORMATIONS
- Tpr PUNGO RIVER FORMATION
- Tbs BELGRADE AND SILVERDALE FORMATIONS
- Ti TRENT FORMATION
- Tnb NEW BERN FORMATION
- Tch CASTLE HAYNE LIMESTONE
- Kpd PEEDEE FORMATION (includes Rocky Point Member)

SYMBOLS

CONTACT.....
 APPROXIMATE CONTACT.....

QUATERNARY
 TERTIARY
 CRETACEOUS

GENERALIZED GEOLOGIC MAP OF THE ROCKY MOUNT QUADRANGLE

PLATE 3

EXPLANATION COASTAL PLAIN

Qun	UNDIFFERENTIATED LATE PLEISTOCENE AND HOLOCENE (INCLUDES CORE CREEK SAND, ATLANTIC, CEDAR ISLAND AND NORTH BAY SANDS, BOGUE SAND AND BEAUFORT SAND)	HOLOCENE
Q-T	JAMES CITY AND FLANNER BEACH FORMATIONS (INCLUDES NEWPORT SAND, ARAPAHOE SAND, MINNESOTA SAND AND BEARD CREEK MEMBER)	PLEISTOCENE
Ty	YORKTOWN FORMATION	MIOCENE-PLIOCENE
Tbs	BELGRADE AND SILVERDALE FORMATIONS	MIOCENE-PLIOCENE
Tt	TRENT FORMATION	OLIGOCENE
Tnb	NEW BERN FORMATION	OLIGOCENE
Tch	CASTLE HAYNE LIMESTONE	EDCENE
Tbt	BEAUFORT FORMATION	PALEOCENE
Kpd	PEEDEE FORMATION	UPPER CRETACEOUS
Kbc	BLACK CREEK FORMATION	UPPER CRETACEOUS
Km	MIDDENDORF FORMATION	UPPER CRETACEOUS

PIEDMONT

fvs	EASTERN SLATE BELT ROCKS
gn	GRANITE

SYMBOLS

Contact
Approximate Contact
Quarry

SCALE 1:250,000

INDEX

Greensboro	Norfolk	Eastville
Raleigh	Rocky Mount	Manteo
Florence	Beaufort

CREDITS
COMPILER: W. BURLEIGH HARRIS
This map is generalized and slightly modified from the sources listed in Figure 3 of text. It shows principal geologic features on a regional scale.

GENERALIZED GEOLOGIC MAP
OF THE
NORFOLK QUADRANGLE

PLATE 4

EXPLANATION

COASTAL PLAIN

- Qun
- UNDIFFERENTIATED LATE PLIOCENE, PLEISTOCENE AND HOLOCENE SEDIMENTS (INCLUDES THE SEDLEY FORMATION, BACONS CASTLE FORMATION, THE "MOORINGS UNIT," WINDSOR FORMATION, GREAT BRIDGE FORMATION, NORFOLK FORMATION, KEMPVILLE FORMATION, LONDONBRIDGE FORMATION, AND SAND BRIDGE FORMATION IN VIRGINIA)
- Ty
- YORKTOWN FORMATION
- Ts
- ST. MARYS FORMATION (INCLUDES CLARMONT AND COBHAM FORMATIONS)
- Ta
- AQUIA FORMATION
- Kpg
- POTOMAC GROUP
- PIEDMONT
- fvs
- EASTERN SLATE BELT ROCKS
- mgn
- RALEIGH BELT ROCKS
- hgb
- BASIC ROCKS
- gn
- GRANITE PLUTONS
- SYMBOLS
- Contact
- Approximate Contact
- Quarry
- CRETACEOUS
- TERTIARY
- QUATERNARY

INDEX

Greensboro	Norfolk	Eastville
Raleigh	Rocky Mount	Manteo
Florence	Beaufort

CREDITS
COMPILER: W. BURLEIGH HARRIS
This map is generalized and slightly modified from the sources listed in Figure 4 of text. It shows principal geologic features on a regional scale.