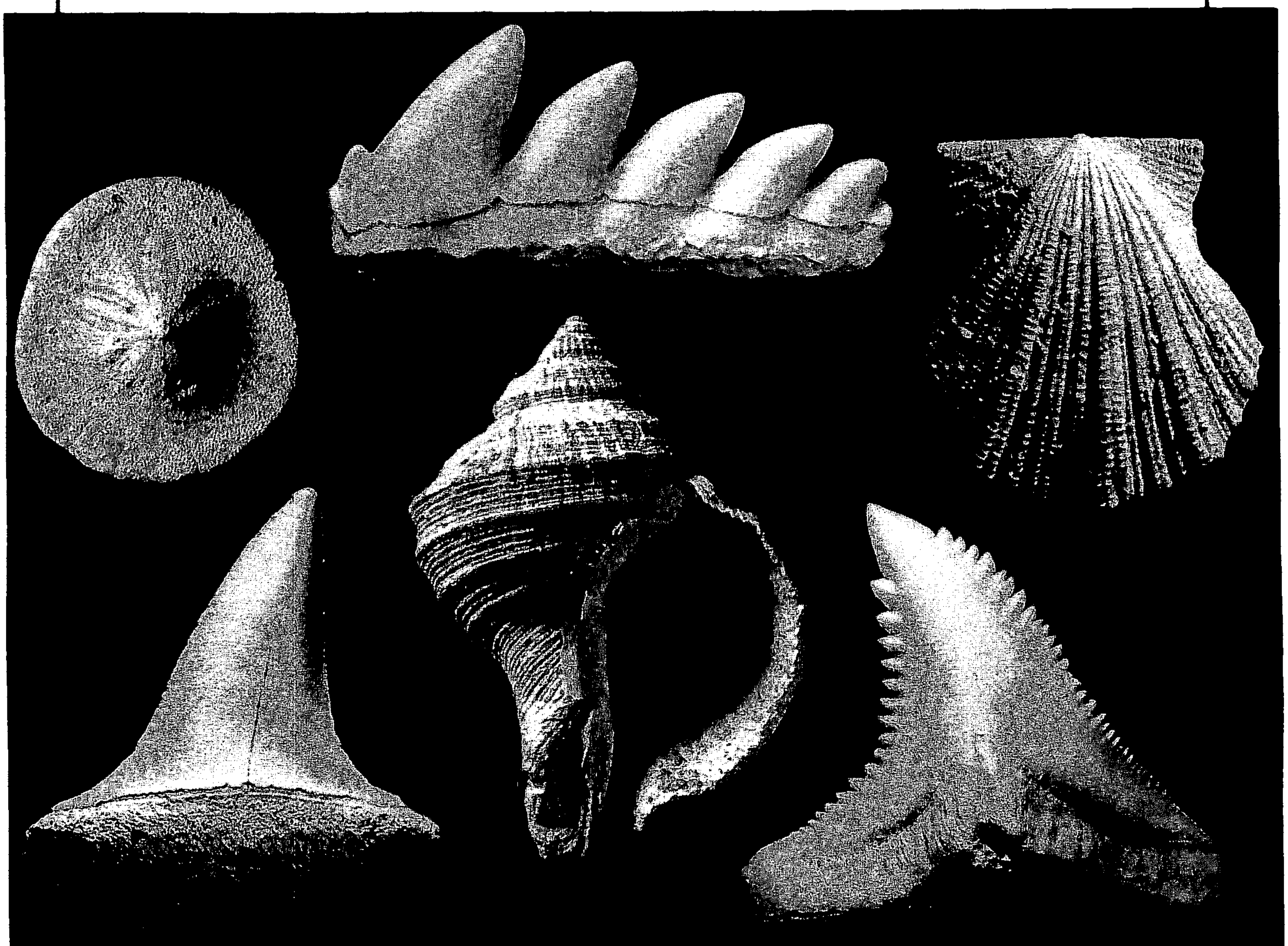
FOSSIL COLLECTING IN NORTH CAROLINA

Bulletin 89



DEPARTMENT OF ENVIRONMENT, HEALTH, AND NATURAL RESOURCES
DIVISION OF LAND RESOURCES
RALEIGH, 1988
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DEDICATION

This publication is dedicated to Robert Jerry Britt, Jr. (1962-1987), a native of Fayetteville, N.C., whose exceptional character, intellect, and passion for fossil collecting will long be remembered by his Tarheel friends and colleagues.

COVER ILLUSTRATIONS

Top left. *Periarchus lyelli* (Conrad), 1834a, UNC 7611, Eocene Castle Hayne Formation at the Martin Marietta Ideal Quarry, northeast of Castle Hayne, New Hanover County, N.C. 32 mm in height.

Top center. *Notorhynchus* aff. *N. serratissimus* (Agassiz), 1844, UNC 8467, Cooper Marl, upper bed, Giant Portland Quarry, Harleyville, South Carolina. 19.8 mm in length. Similar fossils occur in the River Bend Formation of North Carolina.

Top right. *Pecten trentensis* Harris, 1919b, UNC 12536d, Oligocene River Bend Formation, N.C. Department of Transportation Quarry, northeast of Pollocksville, Jones County, N.C. 21.2 mm in height.

Bottom left. *Oxyrhina praecursor* (Leriche), 1905, UNC 8429, Upper Eocene Cross Member of the Santee Limestone, Giant Portland Quarry, Harleyville, South Carolina. 25.1 mm in height. This species also occurs in the Eocene Castle Hayne Formation of North Carolina.

Bottom center. *Rapana gilletti* Richards, 1943, UNC 12526a, Late Oligocene or Early Miocene, Haywood Landing Member of the Belgrade Formation, Haywood Landing (Locality 20). 35 mm in height.

Bottom right. *Hemipristis serra* Agassiz, 1843, UNC 14231, North Carolina, probably from the Miocene Pungo River Formation. 25.5 mm in height.

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The section conducts a number of basic and applied research projects in environmental resource planning, mineral resource exploration, mineral statistics, and systematic geologic mapping. Services constitute a major portion of the Section's activities and include identifying rock and mineral samples submitted by the citizens of the state and providing consulting services and specially prepared reports to other agencies that require geological information.

The Geological Survey Section publishes results of research in a series of Bulletins, Economic Papers, Information Circulars, Education Series, Geologic Maps, and Special Publications. For a complete list of publications or more information about the Section please write: Geological Survey Section, P.O. Box 27687, Raleigh, NC 27611

Jeffrey C. Reid
Chief Geologist

FOSSIL COLLECTING IN NORTH CAROLINA

by

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INTRODUCTION

Fossil collecting is enjoyed by a large number of amateur and professional paleontologists in North Carolina. The popularity of this pursuit reflects the aesthetic and scientific value of fossils, plus the fact that eastern North Carolina has some of the richest fossil localities in eastern North America. A few of these localities are unique for their faunal diversity and quality of fossil preservation. Hundreds of species of fossil plants, sea shells, bones and teeth ranging from a few thousands to hundreds of millions of years old can be collected from eastern North Carolina's river banks, rock quarries, and other geological exposures. This publication provides information on where to find fossils and how to collect and identify them.

The thirty-four fossil localities described in this publication were chosen for their ease of access, abundance and diversity of fossils, and historical and geological significance. Many of the sites are readily accessible on foot, and only a few require access by boat or permission to collect. The locality descriptions contain important information on accessibility and guidelines for collecting, as well as summaries of geology and paleontology. The selected fossil localities are restricted to eastern North Carolina (see back cover). The rocks comprising the mountains of western North Carolina generally lack fossils, or their fossils are poorly preserved and difficult to collect.

Fossil displays and museums in North Carolina are also listed here, and a glossary defines terms which may be unfamiliar to non-geologists. A few of North Carolina's more familiar invertebrate, vertebrate and plant fossils are illustrated in the accompanying figures.

FOSSILS AND FOSSILIZATION

Once considered to be magical objects fallen from the sky or grown in rocks by virtue of a mysterious "plastic" force, fossils still capture our imagination as windows on the distant past. Fossils provide the physical evidence for the fact of biological evolution. They are studied by paleontologists and evolutionary biologists to test theories of how evolution works, and to suggest new evolutionary mechanisms and pathways.

Fossils are remains, impressions or traces of animals or plants of former geologic ages. They are generally the hard parts or imprints of organisms from prehistoric times, such as shells, bones, teeth, petrified wood, impressions of plants, or tracks and trails. Fossils rarely include an organism's soft parts, although virtually entire animal fossils are known from Siberia, where wooly mammoths have remained permanently frozen since the last Ice Age. Sometimes, arrowheads, stone tools, and even pottery shards are mistakenly called fossils. Even though they may date from prehistoric times, these works of man are properly called **artifacts**, and their study lies in the domain of **archeology** rather than **paleontology**.

Fossilization usually begins when the hard parts of an organism become buried in mud or sand deposited in a river, lake or ocean. These hard parts may remain unaltered for millions of years, even after the surrounding sediments have been heated and compressed to form shale, limestone, or sandstone. More commonly, however, they become altered through contact with groundwater. Percolating groundwater may cause fossils to lose their original color and luster, become stained with minerals, or even dissolve and become replaced with minerals such as calcite, pyrite, or quartz.

Fossil tree trunks and branches may become petrified through the filling of their pore spaces with minerals in a process called **permineralization**. Some of North Carolina's fossil wood is so thoroughly permineralized that it can be cut with a rock saw and polished to show its cellular structure. Other kinds of petrified wood are replaced with silica so that sections reveal little of their original internal structure. Rarely, fossil wood may remain virtually unchanged for millions of years. The banks of the Neuse River near Goldsboro are famous for their Cretaceous tree trunks and branches which, despite their great age, are still unpetrified. This wood is now **lignitized** (darkened through slight carbonization) but virtually undeformed, and it may be carved with a pocket knife or even burned in a wood stove. The latter experiment is not recommended, as the burning wood gives off sulfur fumes! Some of North Carolina's Triassic plant fossils, which are even older, are likewise unmineralized, but they are strongly compressed and altered to thin, carbonaceous films.

Fossil shells, bones and teeth are sometimes preserved virtually unaltered in ancient rocks. However, some of these animal fossils are more susceptible to destruction than others. Bones and teeth, which consist of calcium phosphate, are extremely durable and resistant to corrosion by groundwater. One commonly finds well preserved fossil bones and teeth in rocks where most seashells have been completely dissolved. Fossil shark teeth are so durable they are frequently redeposited from older into younger geological strata. However, redeposited fossil teeth can generally be identified by their water-worn, abraded edges.

Fossil shells are generally more susceptible than bones and teeth to destruction by groundwater. Shells generally consist of calcite or aragonite, the two common forms of calcium carbonate. Calcitic shells are more resistant to dissolution than aragonitic ones. Thus, the calcitic shells of oysters, scallops, sea urchins, and barnacles may remain well preserved in rocks which contain dissolved shells of originally aragonitic bivalves, gastropods, and cephalopods. It is rare to find aragonitic fossils in rocks over 25 million years old in North Carolina, but one commonly finds well preserved calcitic fossils in rocks over 65 million years old (Plate 2, Figures 7-12).

Many of the older fossil shells in North Carolina have been entirely dissolved by groundwater, leaving only **molds** (impressions of surfaces) or **casts** (mineral or sediment replicas of the original shell). Fossil molds may be internal or external. Internal molds are impressions of inner surfaces, whereas external molds are impressions of outer surfaces. Latex rubber casts can be made from natural molds to reveal the original shape of the fossil (Plate 6, Figures 44-49; Plate 8, Figures 59, 61, 64). Some internal molds completely fill the inside of a bivalve or gastropod shell. These three-dimensional internal molds are called **steinkerns** (German for "rock core"), and they often reveal features that are helpful for identification.

Fossil casts are rarer than fossil molds in North Carolina. However, natural casts of molluscan shells occur in the Eocene Castle Hayne Formation, where bivalve and gastropod mollusks are sometimes replaced by coarsely crystalline calcite. The calcitic casts may weather from their enclosing rock, revealing nearly perfect, three-dimensional replicas or **pseudomorphs** (Plate 4, Figures 24-25, 28-29).

FINDING AND COLLECTING FOSSILS

Naturally occurring fossiliferous outcrops are present throughout the Coastal Plain of eastern North Carolina, and they are also present, but much rarer, in the eastern Piedmont. Fossiliferous sediments may be exposed in gully and stream banks where erosion has removed the sands, silts, and clays deposited during the past several thousand years (i.e., the "undivided surficial deposits" in the geologic column on the inside of the back cover of this publication). Other fossiliferous exposures are produced by construction and quarry operations. However, anyone who has collected fossils for even a short period of time has come to learn that not all of these exposures contain fossils.

Fossiliferous outcrops along river and creek banks tend to persist for many years because flowing water clears away slumped sediment and often cuts into new fossil beds. Streams may even wash fossils free of their sediment or rock matrix and concentrate them at the base of outcrops. North Carolina's beaches contain some fossils mixed with modern shells. These redeposited fossils are sometimes discolored, so they are usually easy to distinguish from modern shells. However, appearances may be deceiving. At Flanner Beach, south of New Bern (Locality 10), Pleistocene shells of the bivalve *Rangia cuneata* are difficult to distinguish from modern shells of the same species, which live in the Neuse River.

Commercial quarries provide some of the richest fossil collecting localities in North Carolina. Unfortunately, many of these quarries are closed to collectors. The Boren Clay Products quarry near the town of Gulf (Locality 6) is one of the more famous Triassic plant localities in eastern North America. In recent years, this quarry has remained open to collectors requesting permission. Another richly fossiliferous quarry is the Texasgulf, Inc., phosphate mine near Aurora. This pit contains fossil shells, bones and teeth of a great diversity of animals, including mollusks, sharks, turtles, alligators, whales, porpoises, and land mammals. This quarry is generally closed to collectors, but collecting trips to this locality may be arranged through Raleigh's Museum of Natural History. Information about these trips may be obtained from the Curator of Extension Programs, North Carolina Museum of Natural History, P. O. Box 27647, Raleigh, North Carolina, 27611, telephone: (919) 733-7450. Quarry owners or operators should always be contacted in advance to determine if the site is still open to collectors, and to obtain permission to collect.

Once you have found a fossil locality, collecting the fossils may be easy or difficult, depending on the nature of the sediments or rocks, the type of fossilization, and the kinds of fossils you wish to collect. Large shells, shark teeth, and bone fragments are generally easily collected. However, rare fossils, such as mammal teeth, may require sifting large volumes of sediment. Many collectors prefer to gather both larger and smaller fossils. The smaller fossils are best obtained by sieving bulk sediment samples.

Handy tools for collecting fossils include a pick for digging unconsolidated sediment and, for harder rocks, a hammer and chisel. A small pick-axe is more useful than a hammer and chisel for most Pliocene and Pleistocene localities in eastern North Carolina, where fossils are generally contained in sands and clays.

Fragile fossils are best wrapped individually and carried home on trays, rather than packing them into large bags. If collecting bags must be used, the more delicate fossils should be packed on top and surrounded with tissue paper or with layers of fine sediment for protection. Fragile fossils should not be washed in the field, because their adhering sediment can help prevent breakage during transport.

Cleaning fossils may be accomplished with the aid of discarded dental tools (available at many dentists' offices), an old toothbrush, and water for rinsing. Faded color patterns in some fossil shells can sometimes be enhanced by soaking the shells overnight in chlorine bleach, rinsing and drying them, and then illuminating them with ultraviolet light. Relict color patterns are sometimes important for fossil identification.

The scientific value of fossils is greatly enhanced by detailed information about their locality of collection and geologic horizon. Even when sampling apparently uniform outcrops, one should note the distance up or down section from a reference point such as normal water level or the base of the outcrop. This information can be important for determining the fossil's geologic formation and age. Paleontologists commonly sketch and photograph fossiliferous outcrops and gather sediment or rock samples to document the geologic horizon.

A common mistake among beginning fossil collectors is to assume that apparently uniform sediment or rock type at a fossil locality indicates a single geologic age. The danger of this assumption is shown at Locality 18B, where the basal part of the outcrop contains Miocene and Pliocene fossils in adjacent beds consisting of lithologically similar silty sands (Text-figure 18.2).

Geographic documentation of fossil localities is facilitated by using large scale county road maps and U.S. Geological Survey topographic or geologic maps. U.S.G.S. topographic maps were used to illustrate the location of the fossil localities described in this report. Questions concerning U.S.G.S. map availability may be directed to the National Cartographic Information Center, 536 National Center, 12201 Sunrise Valley Drive, Reston, Virginia, 22092, telephone: (703) 860-6336. Maps may be ordered from this Virginia office or purchased at local bookshops, outdoor sport and recreation shops, map companies, and blueprinters, who maintain selected inventories at their own prices.

Fossil collectors should respect the rights of property owners and preserve the aesthetic quality of collecting sites. One should always request permission to cross or collect on private property. Most land owners will oblige fossil collectors who request permission. Fossil collectors should also leave localities free of discarded collecting bags, boxes, and other trash. These practices will help insure that North Carolina's fossil localities remain open to future students and collectors.

Surface collecting of fossils is permitted in National Forest Lands, provided excavations are not made (e.g., in Croatan National Forest, Localities 10 and 20). None of the localities described below are in state parks, but it may be noted that state regulations prohibit collecting fossils in state parks.

IDENTIFYING FOSSILS

General books on fossil identification: A variety of fossil identification books may be purchased in museums and book stores. Among the more recently published titles are *The Audubon Society Field Guide to North American Fossils* (Thompson, 1982) and *The Fossil Collector's Handbook* (MacDonald, 1983). Although helpful for illustrating representatives of the major groups of fossil animals and plants, these works contain only a small portion of the thousands of fossil species known from North Carolina. Shimer and Shrock's (1944) *Index Fossils of North America* illustrates over two thousand fossil genera, but even it lacks many of North Carolina's more common fossils. One must be cautious in using older works for fossil identification, because many of their generic and species names have subsequently been revised.

The illustrations in the present publication show only a few of the more common or distinctive North Carolina fossils. Many additional figures would be required to show all of the fossils you are likely to find on a single collecting trip to any one of the fossil localities described here. Additional illustrations of North Carolina fossils may be found in the references listed at the end of this publication.

Invertebrate fossils: Invertebrate animals constitute the most abundant fossils in eastern North Carolina. They include the nearly ubiquitous bivalve and gastropod mollusks as well as sponges, corals, brachiopods, bryozoans, crabs, insects, sea urchins, sand dollars, and many other animal groups lacking backbones. Discussions of the anatomy, evolution and ecology of the major groups of fossil invertebrates may be found in many introductory biology and paleontology texts.

The *Treatise on Invertebrate Paleontology* (Raymond C. Moore, editor) is a valuable reference for taxonomic studies of invertebrate fossils. It outlines the generic and higher level classifications of most invertebrates, and it explains and illustrates the criteria used for their identification. The *Treatise* does not, however, contain illustrations of all invertebrate fossils you are likely to find. This work is used primarily to document definitions and the current taxonomic status of generic names, and to list their type species. These are important aspects of taxonomy because many generic names are no longer in use, or their applications have changed since they were originally defined. The *Treatise* documents most of these changes, and indicates which generic names are validly defined and available for use according to the rules of the International Code of Zoological Nomenclature (1985).

The *Treatise* volume planned for higher gastropods was never published. For taxonomic discussion of mesogastropods and neogastropods, the reader may consult Wenz (1938-1944) and Zilch (1959-1960) (both in German) or recent shell books such as Abbott's (1974) *American Seashells*.

Vertebrate fossils: Many of the common vertebrate fossils in North Carolina are illustrated by Case (1967, 1973, 1979, 1980, 1981), Thomas (1968), and Ellis (1975).

Kurtén and Anderson's (1980) *Pleistocene Mammals of North America* contains many useful illustrations of fossil mammal bones and teeth, plus summaries of the distribution of mammal fossils in the stratigraphic record. Savage and Russell's (1983) *Mammalian Paleofaunas of the World* reviews Cenozoic land mammal ages and provides extensive lists of mammal fossils arranged by age and geographic location. For fossil turtle bones, which are fairly common in North Carolina, the most useful reference is Hay's (1908) *Fossil Turtles of North America.*

For help in identifying rarer vertebrate fossils and for revising older taxonomic lists, one may consult Hay's (1902, 1929-1930) *Bibliography and Catalogue of the Fossil Vertebrata of North America*, Hay's (1923) work on the Pleistocene of North America, or the *Bibliography of Fossil Vertebrates* published annually by the Society of Vertebrate Paleontology. These works contain taxonomic information summarized from thousands of references, most of which are available only in larger university and museum libraries.

Plant fossils: Stewart's (1983) paleobotany text provides a useful overview of the evolution of plants and the criteria for their identification. Fossil plants are sometimes difficult to identify from hand specimens of leaves, stems or wood alone. Their identification commonly requires rarely preserved sporangia, flowers or fruits, or examination of microscopic cellular structures. Identification of ferns, cycads, and cycadeoids may require entire compound leaves, rather than fragments, because of variations in their structure. Features useful for the identification of fern, cycad and cycadeoid species include leaf venation pattern, position and angle of attachment of the leaflets, and shape and attachment of the leaflet bases. Fossil wood can sometimes be identified to genus, but fossil logs are commonly inadequate, in the absence of additional parts of the plant, for species-level identification.

The Triassic sediments of North Carolina contain one of the richest fossil floras in North America, including ferns, horsetails, cycads, cycadeoids, and conifers. Plate 1, Figures 2-4, illustrate three of the more common Triassic plants present at the Boren Clay Products Quarry in Chatham County (Locality 6). Additional species from this locality are illustrated by Hope and Patterson (1969, 1970) and Gensel (1986).

GEOLOGIC TIME

It may seem incredible that some of North Carolina's fossils are about 620 million years old. But these vast stretches of time are a reality. Various methods of dating the earth tell us that life began at least 3.3 billion years ago; that the first organisms with shells evolved about 600 million years ago; and that our genus, *Homo*, evolved from our primate ancestors sometime within the last several million years.

Fossils constitute the most important source of information for determining the relative geologic ages of sedimentary rocks, such as sandstones, limestones and shales. This aspect of geology is essential for exploring for fossil fuels as well as for reconstructing earth history. The geologic ages indicated by fossils are "relative" as opposed to "absolute". An **absolute age** is the time of formation of a rock in thousands or millions of years. Absolute ages are generally based on radiometric techniques which analyze ratios of radioactive atoms and their decay products. **Relative ages** are the times of formation of rocks relative to one another, without reference to number of years.

Fossils may be used as chronometers of relative age because animals and plants follow definable sequences of evolutionary change. Virtually any fossil group can be used to determine relative age, including corals, mollusks, sea urchins, barnacles, vertebrates, and even plant spores and pollen. However, minute marine fossils such as Foraminifera and coccolithophores, and terrestrial plant fossils such as spores and pollen are especially useful for establishing relative ages. These and other **microfossils** have been used to construct a global zonation of the rock record for the past several hundred million years of earth history.

Paleontologists have been working for many years to refine their fossil zonation of the earth's layered rocks, or stratigraphic record. At the same time, geochronologists have been correlating these fossil zones with absolute ages to produce a global geologic time scale. Given this framework, it is possible to estimate the absolute age of most fossiliferous rocks in eastern North Carolina without resorting to radiometric age dating. The more precise estimates of geologic age generally come from rocks with diverse assemblages of planktonic (free floating) marine microfossils. Microfossils are usually better preserved in fine-grained rocks such as mudstones and shales. River and lake sediments are commonly more difficult to age, but fine-grained river and lake sediments may contain spore and pollen fossils which permit correlation with the geologic time scale.

As shown in the idealized geologic column on the inside back cover of this publication, the fossil record of North Carolina represents the Proterozoic and Phanerozoic **Eons**, the Paleozoic, Mesozoic and Cenozoic **Eras**, and the Eocambrian, Cambrian, Triassic, Cretaceous, Paleogene, Neogene and Quaternary **Periods.** Eons, eras, periods, and their subdivisions are known as geologic time units. The geologic periods are subdivided into smaller units of geologic time known as **epochs**, as shown for the Paleogene, Neogene, and Quaternary Periods on the geologic column.

THE STRATIGRAPHIC RECORD

The stratigraphic record indicates that the shoreline of North Carolina has migrated back and forth several times during the past several million years. The shoreline moves very slowly in response to world-wide changes in sea level, and in response to upward or downward movements of the continental margins. Fluctuations in world-wide sea level may be caused by heat-related thinning or thickening of the sea floor near ocean spreading ridges, or freezing and melting of continental glaciers and polar ice caps. Cycles of continental and polar glaciation can account for a sea level drop of about 360 feet or a rise of about 200 feet relative to present sea level. Although glacial sea level changes are relatively minor, they may produce numerous cycles of deposition during short intervals of geologic time, i.e., over tens of thousands of years. Hundreds of feet of additional sea level change may be caused by long term cycles of sea floor thickening or thinning, and elevation or subsidence of the continental margins. At various times in the past, these factors have caused oceanic flooding of much of North America.

With each advance and retreat of the sea, new layers of sediment were added to or removed from North Carolina's Coastal Plain. These cycles of deposition left a patchwork of evidence that can be used by geologists to reconstruct earth history. The study of these rock sequences constitutes the science of **stratigraphy**.

Lithostratigraphic units are bodies of strata defined by their lithic (rock) characteristics and stratigraphic position, independently of the identity of their fossils. **Formations**, the fundamental lithostratigraphic units, are bodies of rock that are mappable at the earth's surface or traceable in the subsurface. Sequences of formations may comprise larger units known as **groups**, or formations may be divided into members, which have lithic or positional features distinguishing them from adjacent parts of a formation. **Members** are defined independently of the identity of their fossils but, unlike formations, members are not necessarily mappable at the earth's surface or traceable in the subsurface.

Lithostratigraphy is used in conjunction with biostratigraphy to interpret the origins of sediments and to map ancient basins of deposition. **Biostratigraphy** is the branch of stratigraphy which describes and names fossils, and analyzes them to determine their age and environmental significance. Biostratigraphers utilize fossils to correlate sedimentary packages with the geologic time scale. Biostratigraphic units are defined by the identity of their fossils. These include interval zones, assemblage zones, and abundance zones. An **interval zone** is a body of strata between the lowest or highest occurrences of one or two fossils. For example, the *Periarchus lyelli* interval zone corresponds with the lowest and highest stratigraphic positions of this fossil echinoid. An **assemblage zone** is similar to an interval zone, but it is defined by the co-occurrence of several fossils. An **abundance zone** is the interval of maximum abundance of a fossil. The abundance zone of a species is almost always smaller than its entire stratigraphic range.

The accompanying idealized **geologic column** (inside of back cover) summarizes the fossiliferous rocks and sediments of North Carolina. The Cambrian Chilhowee Group is restricted to the western part of North Carolina, but all other units are found in the central and eastern parts of the state. The Miocene Pungo River Formation has no natural exposures; it is known only from the subsurface and from quarry exposures in the Texasgulf phosphate mine near Aurora.

The spaces between some of the formations on the idealized geologic column indicate episodes of non-deposition or erosion, called unconformities and disconformities. **Unconformities** may represent greater amounts of "missing time" than disconformities. Widespread, long-term, unconformities may be associated with angular truncation of older formations, solution holes or sinks, buried soil horizons, root casts, and accumulations of pebbles, bones and teeth. Two unconformities in North Carolina's eastern Piedmont and Coastal Plain are particularly noteworthy. One occurs between the time of deposition of the Carolina Slate Belt and the Triassic basin sediments, and represents over 300 million years of "missing" earth history, including most of the Paleozoic Era. The second occurs between the time of deposition of the Triassic basin sediments and the Cretaceous Cape Fear Formation, and represents the entire Jurassic Period and part of the Cretaceous Period. **Disconformities** are indicated in the geologic column by smaller spaces between formation names or within formations, e.g., between the River Bend and Belgrade Formations, and within the River Bend Formation.

Most of the formations described below are listed on the *Geologic Map of North Carolina* (North Carolina Geological Survey, 1985). However, the following formation names are not listed on the state geologic map, and they are not currently used by the North Carolina Geological Survey: Eastover Formation, Bear Bluff Formation, Chowan River Formation, James City Formation, Canepatch Formation, and Flanner Beach Formation. The Yorktown and Waccamaw Formations appear on the state geologic map, but their areas on the current *Geologic Map of North Carolina* include more than one formation, as defined by many geologists currently working in the middle Atlantic Coastal Plain.

Some differences in stratigraphic nomenclature between the *Geologic Map of North Carolina* and the present publication reflect differing viewpoints regarding the identification and mapping of formations outside their type areas.

Geologists generally agree that formations should be defined in their type areas by lithologic criteria alone, independently of the identity of their fossils. However, geologists sometimes differ on whether formations should be mapped outside their type areas solely on the basis of lithology, or whether such mapping may incorporate paleontological evidence of regional unconformities. In the latter approach, fossils are not used to identify formations, but they are used to help locate and identify regional unconformities which may punctuate otherwise apparently uniform stratigraphic sequences. This paleontological approach, which is followed in the present work, can contribute significantly to interpretations of geologic history and the evolution of life.

STRATIGRAPHIC REVIEW OF NORTH CAROLINA FOSSILS

EOCAMBRIAN FOSSILS:

The oldest fossils in North Carolina are few in number and generally difficult to find. They occur in **Eocambrian** (about 620 million years old) portions of the Carolina Slate Belt. The Eocambrian is the youngest period of the Precambrian Era. The Carolina Slate Belt extends from southernmost Virginia to Georgia. Slate Belt rocks consist of sands, muds, and volcanic and plutonic rocks which have been compressed and heated to form slates, argillites, metatuffs, and other metamorphic rocks. Eocambrian fossils in North Carolina consist primarily of burrows and body impressions of marine invertebrates.

One Precambrian fossil locality in northern Durham county contains traces of an Eocambrian, or possibly older, worm-like organism called *Vermiforma antiqua*. An Eocambrian locality in Stanly County has yielded impressions of another animal, called *Pteridinium carolinaense* (Plate 1, Figure 1). This fossil may be related to modern, feather-shaped soft corals commonly known as "sea pens". *Pteridinium* represents one of the world's oldest relatively large fossil animals. More recent finds in this part of North Carolina include imprints of additional animals plus diverse animal trails and burrows (Gibson, 1987).

CAMBRIAN FOSSILS:

The Paleozoic fossils of North Carolina are extremely rare, and are presently known only from the Cambrian Period. Lower Cambrian burrow traces called *Skolithos* occur in quartzites on the summit of Bald Knob and on the slopes of Linville Mountain, west of Hickory and northeast of Asheville (Bryant and Reed, 1970). These simple, vertical burrows were made by marine worms or representatives of the invertebrate phylum Phoronida. The Cambrian Rome Formation and Shady Dolomite of the Blue Ridge Belt may also be locally fossiliferous. Exposures of the Shady Dolomite in Southern Virginia contain small, conical fossils of uncertain affinities known as *Salterella conulata* (see Byrd, Weinberg and Yochelson, 1973). However, these fossils have not yet been found in North Carolina. Most of the Paleozoic rocks in western North Carolina are either igneous rocks, which have crystallized from **magmas**, or metamorphic rocks, which have been too thoroughly altered by heat and compression to retain identifiable fossils.

Cambrian and younger Paleozoic fossils may occur in the Carolina Slate Belt in central North Carolina, but none have yet been discovered. A Slate Belt locality in South Carolina has yielded Middle Cambrian trilobites, and radiometric dating indicates that rocks of similar age are exposed in neighboring North Carolina.

The next youngest fossils in North Carolina are younger than these Eocambrian and Cambrian fossils by over 300 million years, and are Late Triassic in age.

TRIASSIC FOSSILS:

Late Triassic fossils in North Carolina are found primarily in the eastern Piedmont near its border with the Coastal Plain. These fossils were deposited in a series of linear, northeast-southwest trending basins. Each basin consists of a faulted portion of the earth's crust which subsided as North America drifted away from Africa, thereby creating the Atlantic Ocean. For several million years, lakes, deltas and swamps formed in these basins, and their sediments received the remains of a variety of animals and plants. These Late Triassic fossils date from near the beginning of the age of dinosaurs, about 210 million years ago.

Fossils in North Carolina's Triassic basins include insects, freshwater arthropods, fishes (e.g., *Cionychthys*, *Synorithchys*, and *Diplurus*), amphibians (e.g., *Eupelor* and *Dictyocephalus*), phytosaur reptiles, mammal-like reptiles (e.g., *Dromatherium*, *Microconodon*, and *Placerias*), dinosaurs (rare footprints, bones and teeth, including *Zatomus* and other forms), and a long-necked reptile called *Tanytrachelos* (see Emmons, 1856, 1860; Baird and Patterson, 1968; Patterson, 1969; Gore, 1986). One recently discovered *Tanytrachelos* skeleton is nearly complete, and includes black and silvery impressions of its skin (Olsen et al., 1978; Olsen, 1979). The insects comprise the only large fauna of their age and taxonomic composition in North America. These include aquatic and forest insects such as water bugs, crane flies, March flies, and beetles (Olsen et al., 1978; Olsen, 1979; Robbins, 1982).

The Triassic sediments of North Carolina also contain one of the best known Triassic floras in North America. Emmons (1856, 1857) published the first accounts of these plants, and Fontaine (1883, 1900) and Ward (1900) reviewed these fossils, making a few revisions and new identifications.

The opening of the Boren Clay Products Quarry (Locality 6) near Gulf during the 1960's resulted in new fossil discoveries and significant contributions to our understanding of plant evolution. The plant fossils consist of sphenophytes (horsetails), pteridophytes (ferns and their allies), and gymnosperms (cycads, cycadeoids, and conifers). Notably absent are the angiosperms, or flowering plants, which had not yet evolved.

CRETACEOUS FOSSILS:

Late Cretaceous fossils are widespread, locally abundant, and commonly well preserved in North Carolina's Coastal Plain. Most Late Cretaceous fossil localities occur along the banks of major rivers such as the Neuse and Cape Fear, where erosion provides continually renewed exposures. Fossil plants and animals have been collected from these localities since the late 18th Century. The botanist William Bartram (1791) described fossiliferous exposures along the Cape Fear River at Ashwood, near Elizabethtown. The Cretaceous sediments here contain abundant fossil shells, shark teeth, and plants. Several years later, Denison Olmsted (1827), the first state geologist of North Carolina, mentioned a concentration of fossil wood along the Neuse River near Goldsboro.

The Cretaceous sediments of North Carolina consist of the Cape Fear, Middendorf, Black Creek, and Peedee Formations, in order of decreasing age (see idealized geologic column). The most diverse and abundant fossils are found in the Black Creek and Peedee Formations.

Cape Fear Formation: The Cape Fear Formation consists of sandstones, mudstones and clays, which commonly form continuous beds. The continuity of these beds, as well as their clay mineralogy, suggest marine, estuarine, and lagoonal environments (Heron, Swift and Dill, 1968). The Cape Fear Formation is exposed near the western margin of the Coastal Plain near Fayetteville, south of Smithfield, and southeast of Halifax. The Cape Fear Formation is unconformably overlain by the Middendorf and Black Creek Formations, except where these formations have been removed by erosion (Conley, 1962).

For most fossil collectors, the Cape Fear Formation is relatively unproductive. Plant microfossils known as palynomorphs (pollen) are the only fossils presently known from this unit (Christopher, Owens and Sohl, 1978).

Middendorf Formation: The Middendorf Formation consists of gray to orange sand, sandstone, and mudstone with clay balls and concretions. This formation is more commonly cross-bedded than the Cape Fear Formation. Plant microfossils indicate the Middendorf Formation is at least locally younger than the Cape Fear Formation. These two units may be separated by a regional unconformity. The Middendorf Formation comprises much of the western Coastal Plain in southern North Carolina, where it consists primarily of river deposits.

In addition to plant microfossils, the Middendorf Formation contains silicified wood and fossil leaves. One noteworthy Middendorf plant fossil locality occurs in a clay bed near Spout Springs, Harnett County. Additional information on the stratigraphy and fossils of the Middendorf Formation may be found in works by Hattner and Wise (1980) and Christopher (1982).

Black Creek Formation: The Black Creek Formation interfingers with and overlies the Middendorf Formation. Black Creek sediments comprise much of the southern half of North Carolina's Coastal Plain east of the exposures of the Middendorf Formation. Black Creek sediments were deposited primarily in nearshore, restricted marine environments, including tidal flats, tidal channels, estuaries, and shallow marine bays. The gray to black, thinly bedded clays of the Black Creek Formation contain "stringers" of fine sand that often grade abruptly into thick lenses of cross-bedded sand.

The basal Black Creek Formation generally lacks marine fossils, but its upper part contains abundant remains of marine invertebrates and vertebrates. Arthropod (crab or shrimp) burrows are common near the top of the unit. These and "shipworm" borings in fossil wood indicate nearshore marine environments. Some shelly sands toward the top of this unit contain diverse and well preserved molluscan shells.

Vertebrate fossils in the Black Creek Formation occur primarily as isolated teeth and bone fragments. These represent sharks and bony fish, aquatic turtles, crocodiles, marine lizards, and rare dinosaurs. Dinosaur fossils were first described from the Black Creek Formation by Cope (1869). Subsequently, four major dinosaur groups have been found here: three upright (bipedal) forms and a large, four-footed form. One bipedal dinosaur, *Dryptosaurus* or *Albertosaurus*, resembled the famous *Tyrannosaurus* of the western United States. A second bipedal dinosaur, *Ornithomimus*, had an ostrich-like neck, toothless mouth, and powerful hind limbs. The third bipedal dinosaur, *Kritosaurus* or *Hadrosaurus*, may have been one of the largest duckbill dinosaurs, measuring over thirty feet in length (Baird and Horner, 1979). The fourth dinosaur, *Hypsibema*, was a huge vegetarian resembling the familiar long-necked, long-tailed *Apatosaurus* (= "*Brontosaurus*"). Many of these vertebrate fossils were collected from exposures of the Black Creek Formation at Phoebus Landing, southeast of Elizabethtown near Milepost 68 on the Cape Fear River (Richards, 1950).

Lignitized wood, leaves, and amber are locally abundant in the Black Creek Formation (Stephenson, 1912, 1923). Well preserved Cretaceous tree trunks occur in this formation along the banks of the Neuse River, where they have been described as fossil "logjams" (Berry, 1950). Were it not for their dark color, slight compaction, and local petrifaction, some of these logs would be indistinguishable from modern water-logged wood. Black Creek fossil plants include ferns, cycads, conifers, and many early angiosperms, including relatives of oaks, figs, willows, magnolias, persimmons, and eucalyptus. About 40 fossil plant species were found in a single clay bed in the Black Creek Formation near Courthouse Landing (Milepost 77) on the Cape Fear River (Berry, 1907a,b; Stephenson, 1912).

Peedee Formation: The Peedee Formation is exposed east of the Black Creek Formation in North Carolina's southeastern Coastal Plain. It consists of greenish-gray to black, massive (non-bedded) sand, clayey sand, and clay, with clayey or sandy limestones and concretions. The contact between the Black Creek Formation and the overlying Peedee Formation has been interpreted as gradational by some workers (e.g., Stephenson, 1923) and as disconformable or unconformable by others (e.g., Brett and Wheeler, 1961). Work by Sohl and Christopher (1983) suggests that, along the Cape Fear River, this contact is marked by a local disconformity. The Peedee Formation was deposited primarily in open marine environments.

The Peedee Formation is commonly fossiliferous, but its aragonitic shells are mostly dissolved, leaving only calcitic shells of belemnoid cephalopods, oysters, phosphatic bones and teeth, and a few plant fossils. The invertebrate fossils include diverse bivalves, gastropods, scaphopods, cephalopods, and echinoderms. Fossil zonation of the Peedee Formation along the Cape Fear River is discussed by Sohl and Christopher (1983). This formation includes several paleontological zones defined by the extinct oysters *Exogyra ponderosa*, *Exogyra cancellata* and *Exogyra costata costata*. The first of these three species is illustrated in Plate 2, Figures 10 and 11. These oyster zones comprise useful biostratigraphic markers for correlation throughout much of the Atlantic and Gulf Coastal Plains of southeastern North America. Shark teeth from the Peedee Formation have been described and illustrated by Case (1979).

The upper part of the Peedee Formation near Wilmington consists of quartz sandstone and fossiliferous, sandy, moldic limestone. This unit was originally named the Rocky Point Member by Wheeler and Curran (1974). However, the name "Rocky Point" was previously used for other Cretaceous strata, so Ward and Blackwelder (1978) proposed the replacement name "Scotts Hill Member". The fossils of the Scotts Hill Member were deposited in shallow marine settings where currents winnowed away the finer sediment, leaving concentrated shell beds. This unit contains a variety of fossil bivalves, gastropods, and echinoids, plus crustacean (crab) burrows (Cunliffe, 1968; Wheeler and Curran, 1974; Curran, 1986) (Plate 2, Figure 12).

PALEOCENE FOSSILS:

The Paleocene Beaufort Formation is exposed along Mosley Creek near the Lenoir-Craven County line, between Kinston and Fort Barnwell, and at other localities near Kinston in Lenoir County (Brown and Miller, 1986). The green-gray sands and silty clays of the Beaufort Formation are locally fossiliferous. Marine invertebrates include the brachiopod *Oleneothyris harlani* (Plate 3, Figure 13), the oyster *Pycnodonte (Phygraea) dissimilaris*, and the nautiloid cephalopod *Eutrephoceras sloani* (see Wilson, 1972, 1987a, and Bailey, 1976). The current *Geologic Map of North Carolina* shows an area of Paleocene sediments southeast of Burgaw in Pender County, but larger Paleocene fossils are yet unknown from this part of North Carolina.

EOCENE FOSSILS:

Castle Hayne Formation: The Eocene Castle Hayne Formation has many richly fossiliferous exposures at natural outcrops and in quarries in southeastern North Carolina. This unit is exposed primarily from Brunswick County northward to Jones and Pitt Counties. However, isolated Eocene "outliers" occur farther west in Wake, Johnston, Harnett, and Moore Counties. The Eocene outliers near Raleigh and Fayetteville contain molluscan fossils which indicate that the Eocene sea extended at least that far inland (Richards, 1950; Parker, 1949; Cabe, 1984).

Charles Lyell, the famous British geologist and originator of the term "Eocene", was the first to describe fossils from the Castle Hayne Formation (Lyell, 1842). Hundreds of additional Castle Hayne fossils were described by paleontologists during the 19th and 20th centuries. Many of these early descriptions were based on specimens collected from the French Brothers' quarries at old Rocky Point (subsequently called Lanes Ferry) on the Northeast Cape Fear River, three miles east of Rocky Point Station, Pender County. Similar Eocene exposures can now be seen in quarries near Rocky Point and Castle Hayne, just north of Wilmington.

The Castle Hayne Formation contains some of the world's most diverse assemblages of Eocene bryozoans, echinoids, and sponges. The bryozoans were described by Canu and Bassler (1920), and the echinoids and sponges were studied by Kier (1980) and by Rigby (1981) and Finks (1986), respectively. Finks (1986) indicated this is the only major early Cenozoic sponge fauna known from the Western Hemisphere. Calcitic brachiopods, scallops, and oysters are also well represented here. Aragonitic mollusks were also deposited in these beds, but their shells are now dissolved, leaving only molds and rare casts (Plate 4, Figures 24-25, 28-29).

Vertebrate fossils are also well represented in the Castle Hayne Formation, e.g., crushing plates and stingers of the ray *Myliobatis*, (Plate 5, Figures 32-33), and teeth of the sharks *Procarcharodon auriculatus* and *Lamna lerichei* (Plate 5, Figures 36, 38). Turtle bones, fish spines and whale teeth also occur here (Plate 5, Figures 34-35, 39-40). Plant fossils are rare in this formation, but plants fragments have been found with marine bivalves and gastropods in some of the Eocene outliers in the western Coastal Plain (Parker, 1979).

OLIGOCENE AND EARLY MIOCENE FOSSILS:

Oligocene and early Miocene strata in North Carolina are represented by the River Bend and Belgrade Formations. The River Bend Formation consists of moldic limestones and interbedded calcareous sands and sandstones. This formation crops out along the Trent River in Jones County southwest of New Bern, and along the New River near Jacksonville and Richlands, Onslow County (Ward, 1977, Ward et al., 1978). The River Bend Formation may contain two distinct depositional sequences, one early or middle Oligocene, the other late Oligocene (Zarra, 1983; Fletcher, 1987). The overlying Belgrade Formation consists of sand and clayey sand with well preserved aragonitic shells. The Belgrade Formation is exposed in Jones County along the White Oak River, and in quarries in Onslow County near Belgrade and Silverdale. Microfossil evidence suggests that the Belgrade Formation was deposited during late Oligocene and/or early Miocene time (Zarra, 1983; Russell, 1987).

The River Bend Formation is partly equivalent to the Trent Formation of Miller (1910, 1912), Kellum (1926), and Baum, Harris and Zullo (1978). The name "Trent Formation" was rejected by Ward et al. (1978) because of confusion in its application.

River Bend Formation: The basal part of the River Bend Formation consists of barnacle and echinoid plate "hashes" and nearly pure, moldic limestones with minor quartz sand, grading upward into sandier limestones. The upper part of this formation is sandier, consisting of sandy limestones, quartz sands, and sandstones. The River Bend Formation contains a diverse molluscan fauna which is, unfortunately, difficult to analyze because of its largely moldic nature. However, it contains some well preserved calcitic oysters (probably *Hyotissa*? *paroxis*, according to Wilson, 1987a, p. 17) and scallops (e.g., *Pecten trentensis* and *Pecten* cf. *P. biformis*), plus molds of the bivalves *Mercenaria gardnerae*, "*Dinocardium*" *belgradensis*, *Modiolus stuckeyi*, *Ventricolaria judithae*, *Anomia onslowensis*, and *Panopea* sp.; molds of the snails *Turritella* aff. *T. bowenae*, *Galeodaria* cf. *G. shubutensis gardnerae*, *Apiocypraea* aff. *A. humbergi*, and *Calyptraea aperta;* and plates of the barnacle *Lophobalanus kellumi* [Plate 6; see also Kellum (1926), Richards (1948), and Zullo (1984)].

Belgrade Formation: The Belgrade Formation, as defined by Ward et al. (1978), unconformably overlies the River Bend Formation. This unit includes the Haywood Landing and Pollocksville Members. The Haywood Landing Member is a shelly, gray to brown, clayey sand with local lenses of sandy, moldic limestone. The Pollocksville Member is a locally indurated, light brown to orange sand. The Belgrade Formation corresponds with the Silverdale Formation of Baum, Harris, and Zullo (1978).

Fossil preservation is excellent in the Haywood Landing Member. This unit contains abundant fossil mollusks, including the bivalves *Astarte onslowensis*, *Macrocallista minuscula*, and *Donax idoneus*; the gastropods *Ecphora tampaensis* (see Wilson, 1987b, p. 25), *Cymatophos* sp., *Apporhais* sp., *Rapana gilletti*, *Turritella bowenae*; *Turritella* aff. *T. bowenae*, *Turritella tampae*, *Turritella tampae* form "pagodaeformis", plus scores of additional species (Plate 7). Mollusks from quarry exposures of the Haywood Landing Member near Silverdale, Onslow County, have been described by Kellum (1926), Richards (1943) and Heaslip (1968). Barnacles from this unit include *Concavus belgradensis*, *Lophobalanus baumi*, and *Balanus*? *silverdalensis* (see Zullo, 1984). Near its type locality on the White Oak river, the Haywood Landing Member contains over 75 species of small to medium-size fossil bivalves and gastropods (Locality 20). Large *Crassostrea* also occur here, but not in the high concentrations characteristic of the Pollocksville Member.

The Pollocksville Member is densely packed with shells of a large species of oyster that includes varieties similar to *Crassostrea gigantissima* (Finch) (a late Eocene species from Georgia), and three late Oligocene or early Miocene species from the southeastern United States: *C. blanpiedi* (Howe) (from Mississippi), *C. vaughani* (Dall) (from Florida), and *C. normalis* (Dall) (from Florida). The Pollocksville species is more variable in shape than *C. gigantissima*, but it includes relatively narrower shells than the other three species. In addition to straight, narrow shells, the Pollocksville species includes straight to curved, broad shells, up to two feet in length, plus oval shells that may be as almost as thick as they are long. The beaks (umbones) are also variable, pointing forward, backward, or nearly vertical (Lawrence, 1966). The Pollocksville Member also contains plates of the barnacles *Lophobalanus baumi* and *Concavus crassostricola* (see Zullo, 1984), plus bryozoans, worm tubes, Foraminifera, and, in the oyster shells, borings made by lithophaginid bivalves and clionid sponges.

MIOCENE FOSSILS:

North Carolina's Miocene fossils occur in the Pungo River and Eastover Formations. The Pungo River Formation is early to middle Miocene, whereas the Eastover Formation is late Miocene.

Pungo River Formation: The Pungo River Formation is an economically important phosphatic unit which extends in the subsurface from near Norfolk, Virginia, to the continental shelf off southeastern North Carolina (Riggs et al., 1982). The dolomitic sands and limestones in this formation represent predominantly warm temperate, open marine environments.

There are no natural exposures of the Pungo River Formation in North Carolina. However, its fossils may be collected from spoil piles in the Texasgulf phosphate mine near Aurora in Beaufort County. The base of this unit consists of greenish-gray dolomitic sands which contain the bivalves *Pecten trentensis*, *Pecten humphreysii*, and *Venus* aff. *V. langdoni*; the gastropods*Calyptraea aperta*, *Ecphora (Stenomphalus) aurora*, and probably also *Ecphora (Ecphora) pamlico*, and teeth of the whale *Squalodon atlanticus* (Plate 8, Figures 59-61; see also Wilson, 1987b, and Gibson, 1987). The upper part of this formation includes richly fossiliferous limestones containing the bivalves *Lucinoma contracta*, *Chesapecten coccymelus*, *Chesapecten nefrens*, *Pecten mclellani*, *Pecten humphreysii*, *Hyotissa percrassa*, and *Pycnodonte leeana*; the gastropod *Ecphora (Ecphora) tricostata*, the nautiloid cephalopod *Aturia*, the barnacles *Balanus imitator* and *Fistulobalanus klemmi*, and hydrozoan corals (Plate 8, Figures 62-66; see also Zullo, 1984; Wilson, 1987b, Gibson, 1987, and Furnish and Glenister, 1987,). Pungo River fossils also include shark teeth such as *Procarcharodon* aff. *P. auriculatus* (Plate 8, Figure 65).

Eastover Formation: The Eastover Formation of North Carolina and Virginia consists of a greenish-gray to light-brown, fine-grained, well sorted, shelly sand with massive shell beds (Ward and Blackwelder, 1980). In northeastern North Carolina, the upper or Cobham Bay Member is exposed along the Meherrin River near Murfreesboro. Fossils from this unit may be collected at Locality 18B. Here the upper Eastover sediments resemble the overlying Sunken Meadow Member of the Yorktown Formation. However, these two units may be separated by an unconformity (see discussion of Locality 18B).

The Eastover Formation contains abundant fossil scallops, oysters, and many other bivalve and gastropod mollusks, as well as shark teeth and whale bones. Distinctive fossils in this formation include the large, saucer-shaped scallop *Placopecten princepoides*, originally described from exposures along the Meherrin River by Emmons (1858). Emmons' species is synonymous with *Placopecten clintonius rappahannockensis* (Mansfield), 1936, recently illustrated by Gibson (1987). *Placopecten princepoides* has finer ribbing than *Placopecten clintonius*, which occurs in the overlying Yorktown Formation (Plate 10, Figure 77). Also common here are the bivalves *Chesapecten middlesexensis*, *Glossus fraterna*, *Ostrea compressirostra*, and the thick, pearly-shelled *Isognomon (Hippochaeta)* sp.

PLIOCENE FOSSILS:

The Pliocene sediments of North Carolina have traditionally been mapped as Yorktown Formation north of the Neuse River, and Duplin Formation south of the Neuse River. This practice is still favored by some Coastal Plain geologists (e.g., Bailey, 1987). However, some geologists now recognize the Yorktown Formation as extending from Virginia to South Carolina, if not farther south, and they regard the "Duplin Formation" as a complex of southern Yorktown facies (see discussion by Blackwelder and Ward, 1979). Certain parts of the Duplin Formation are less glauconitic and contain more uniformly coarse-grained sediments than parts of the northern Yorktown Formation, but both units are lithologically variable, and some of their beds are lithologically indistinguishable in the field.

Yorktown Formation: Near its type area in Virginia, the Yorktown Formation consists of clayey, silty, fine sands and sandy silts, with molluscan shells common at most localities. Exposures of the Yorktown Formation commonly weather from bluish-green to light brown, yellow, and yellow-orange, and they may be locally cemented with calcium carbonate. The Yorktown Formation in northern North Carolina represents a variety of nearshore to offshore marine depositional environments.

The Yorktown Formation south of the Neuse River, or the Duplin Formation of some workers, includes estuarine, deltaic, lagoonal, and offshore marine depositional environments (DuBar et al., 1974). These southern Yorktown-age sediments have traditionally been differentiated from the northern Yorktown Formation primarily on the basis of geography and faunal content, rather than lithology. Their contained fauna, here called the Duplin fauna, is climatically distinct and taxonomically more diverse than the northern Yorktown fauna.

The Yorktown fauna of Virginia and northern North Carolina contains diverse fossil mollusks and vertebrates. Northern Yorktown mollusks constitute the *Astarte stephensoni* assemblage, a warm temperate, open marine to nearshore marine fossil association (Blackwelder and Ward, 1979). Vertebrate fossils, especially shark teeth and whale bones, are locally abundant in this northern Yorktown fauna. The Yorktown Formation at the Texasgulf phosphate mine near Aurora contains fossils of the canid *Osteoborus* cf. *O. dudleyi*, the horse *Nannipus* cf. *ingenuus*, the protoceratid (extinct cloven hoof animal) *Synthetoceras* sp., the camel relative *Hemiauchenia*, a deer, a relative of the pronghorn, and a long-jawed mastodon (extinct relative of the elephant) (Tedford and Hunter, 1984).

South of the Neuse River, the Duplin fauna of the Yorktown Formation contains warmer water, tropical to subtropical fossil assemblages. The molluscan fossils here comprise the *Dosinia elegans* assemblage of Blackwelder and Ward (1979). Also present in this unit are numerous fossil vertebrates, including sharks, whales, and many reptiles and terrestrial mammals.

The Yorktown-Duplin molluscan faunas of North Carolina are known for their high diversity, as illustrated in works by Emmons (1858), Conrad (1875), Dall (1903), Gardner and Aldrich (1919), Mansfield (1928), Gardner (1943, 1948), Richards (1950), Bird (1965), Ward (1975), and many others. Interestingly, many of these species became extinct immediately following Yorktown-Duplin time. Increased instability of marine climates, brought on by climatic cooling and closure of the Isthmus of Panama, may have caused, or at least contributed to, a regional extinction of many Atlantic Coastal Plain mollusks during late Pliocene and early Pleistocene time. As many as 65% of the Yorktown-Duplin bivalve species, and possibly comparable numbers of gastropods, were then eliminated from the southeastern United States (Stanley, 1986). Taxa becoming extinct at this time include the gastropods *Turritella alticostata* and *Busycon incile*, plus the bivalves *Mulinia congesta*, *Astarte undulata* and *Marvacrassatella undulata*. Several genera also became extinct after Yorktown-Duplin time, most notably the gastropod *Ecphora* (Plate 9, Figure 70) and the bivalves *Planicardium* and *Chesapecten* (Plate 10, Figure 76).

Chowan River Formation: The Chowan River Formation is a richly fossiliferous, clayey to sandy unit overlying the Yorktown Formation near the Chowan River in Bertie County, and near the Tar River in Pit County. The Chowan River Formation is equivalent to the lower part of the "Croatan Formation" of some workers (see Blackwelder, 1981b, and Hazel, 1983). The Chowan River Formation represents warm-temperate to subtropical shallow marine, estuarine and nearshore environments (Bailey, 1977, 1987; Bailey and Tedesco, 1986; Blackwelder, 1981b; Ward and Blackwelder, 1987). Ward and Blackwelder (1987) recently assigned the molluscan fauna of the Chowan River Formation to the *Glycymeris hummi* - *Turritella perexilis* assemblage-zone. Their work contains illustrations of many mollusks found in this formation.

Blackwelder (1981b) divided the Chowan River Formation into two members. The basal, Edenhouse Member is a fossiliferous, shelly, silty sand. The overlying Colerain Beach Member consists of sparsely fossiliferous, cross-bedded sand, silt and clay, with large arthropod (crab or shrimp) burrows. The lower member contains abundant branches of the coral *Septastrea crassa*, plus abundant bivalve and gastropod mollusks. At Colerain Beach (Locality 2), fossils in the Colerain Beach Member are concentrated in lenses containing the estuarine bivalves *Rangia* and *Corbicula*, plus brackish water ostracode arthropods (Blackwelder, 1981b).

Bear Bluff Formation: The Bear Bluff Formation consists of sandy limestones, calcareous sandstones, clayey sands, and calcareous silts. This unit is exposed only in southeastern North Carolina and northeastern South Carolina (DuBar, 1968; 1969, 1971; DuBar et al., 1974). The Bear Bluff and Chowan River Formations are similar in age. Both units contain the bivalves *Noetia carolinensis* and *Glycymeris hummi*, and the gastropod *Turritella perexilis*, but they lack typical Yorktown mollusks such as *Chesapecten*, *Glossus*, and *Ecphora* (Blackwelder and Ward, 1979; Blackwelder, 1981b). However, the Bear Bluff Formation contains abundant shells of the oyster *Ostrea raveneliana*, suggesting that parts of this unit may be slightly older than the Chowan River Formation (Blackwelder and Ward, 1979).

Near Elizabethtown (Locality 5), Bear Bluff marine shells and vertebrate bones and teeth are mixed with Cretaceous vertebrates reworked from the underlying Black Creek Formation. Bear Bluff fossils may also be collected from exposures on the north shore of Lake Waccamaw in Columbus County (Locality 8). Here an unconformity separates this unit from the overlying Waccamaw Formation (DuBar, 1971, p. 59). Aragonitic Bear Bluff fossils are dissolved at this locality, but calcitic valves of the scallop *Carolinapecten eboreus* and the oyster *Ostrea raveneliana* are well preserved and fairly common.

LATE PLIOCENE AND EARLY PLEISTOCENE FOSSILS:

North Carolina's late Pliocene and early Pleistocene sediments comprise the James City and Waccamaw Formations. These units are exposed in east-central and southeastern North Carolina, respectively.

James City Formation: The James City Formation was named by DuBar and Solliday (1963, p. 228) for shelly clays and sands along the Neuse River just south of James City. This formation was deposited north of the Cape Fear River, primarily between the New River in the south and the Pamlico River in the north. The James City Formation corresponds with the upper part of the Croatan Formation of some workers (see discussion by DuBar and Solliday, 1963).

The James City Formation contains a large number of marine mollusks. The fossils in the type area suggest a bay environment similar to modern Pamlico Sound (DuBar and Howard, 1969; Howard, 1974), whereas those from the Texasgulf phosphate mine near Aurora are indicative of shallow shelf, open marine, subtropical to warm temperate environments (Ward and Blackwelder, 1987). Fossils may be collected from the James City Formation at James City, Craven County, and southward about four miles along the banks of the Neuse River Estuary (DuBar and Solliday, 1963) (Locality 9, below). The James City Formation at the Texasgulf phosphate mine comprises the upper part of the "Croatan Formation" described by Hazel (1983, his Units 6-

7) (see also Ward and Blackwelder, 1987). The molluscan fauna of the James City Formation was recently assigned to the *Marvacrassatella kauffmani - Astarte berryi* assemblage-zone by Ward and Blackwelder (1987). Their work contains illustrations of many mollusks found in this formation.

Some of the vertebrate fossils reported by Croom (1835), Conrad (1835, 1842), Harlan (1842), Cope (1875), and Hay (1923) from the old Lucas Benners Estate on the east bank of Beard Creek, southeast of New Bern, may have come from the James City Formation (DuBar, Solliday and Howard, 1974, p. 119). Other vertebrates from this locality may have come from younger Pleistocene sediments. Some vertebrate fossils from the Texasgulf phosphate mine at Aurora may likewise have come from exposures of the James City Formation. The Pliocene and Pleistocene vertebrate fossils from the old Benners pits and the Texasgulf mine include shark teeth, bony fishes, turtles, alligators, snakes, manatees, whales, walruses, seals, mammoths, mastodons, deer, horses, and birds (Hay, 1923; Boreske et al., 1972; Ray et al., 1981).

Waccamaw Formation: The Waccamaw Formation commonly consists of shelly, fine- to medium-grained quartz sand, but it may include other lithologies as well. This unit extends from northeastern South Carolina northward to the Cape Fear River (DuBar et al., 1974; Blackwelder, 1979). Waccamaw fossils indicate subtropical to warm temperate, open marine and bay environments (Gibson, 1962; Howard, 1974).

Fossils from the Waccamaw Formation were described by Miller (1912), Gardner (1943, 1948), and Richards (1950), among others. At Walker's Bluff on the Cape Fear River, the Waccamaw Formation contains mollusks, corals, bryozoans, barnacles, echinoids, and shark teeth. Faunal lists for the type Waccamaw Formation in South Carolina and for its informal lower member in North and South Carolina are provided by DuBar et al. (1974, 1980). Waccamaw sediments contain the scallop *Carolinapecten eboreus* and the bivalves *Mulinia lateralis* and *Noetia limula*, plus the gastropod *Turritella perexilis*. Conspicuous for their absence are the bivalves *Glycymeris hummi*, which became extinct after Chowan River-Bear Bluff time, and *Spisula modicella*, which became extinct after Yorktown time. The Waccamaw and James City formations contain the latest occurrences in North Carolina of the bivalves *Noetia limula*, *Pododesmus frugosus*, and *Marvacrassatella* (Blackwelder, 1981a). The bivalve subgenus *Anadara (Lunarca)* had not yet appeared in the Atlantic Coastal Plain during Waccamaw time (Blackwelder, 1979).

LATE PLEISTOCENE FOSSILS:

The Late Pleistocene sediments of North Carolina comprise the Flanner Beach Formation, exposed primarily along the banks of the Neuse River estuary, and the Canepatch Formation, exposed locally from the Cape Fear River southward to the Santee River, South Carolina. These formations represent unconformity-bounded sedimentary sequences consisting primarily of clays, silts, and sands with some peat and lignitized wood (DuBar and Solliday, 1963; DuBar et al., 1974). The Flanner Beach Formation corresponds in part with the Pamlico and Croatan Formations of some workers. The Flanner Beach and Canepatch Formations are represented as undivided surficial deposits on the *Geologic Map of North Carolina* (North Carolina Geological Survey, 1985).

Canepatch Formation: The Canepatch Formation represents marsh, swamp, cypress grove, high salinity bay, barrier sand, lagoonal, estuarine, mud flat, and open marine environments. This formation includes, in part, the "Pamlico Formation" of previous workers. Typical fossils include the bivalves *Anadara ovalis, Chama gardnerae, Cyrtopleura costata, Dinocardium robustum, Dosinia elegans, Mulinia lateralis,* and *Rangia cuneata*; the gastropods *Busycon carica, Busycon contrarium, Polinices duplicata,* and *Turritella subannulata*; the echinoids *Encope emarginata* and *Mellita quinquesperforata*; and the branching coral *Septastrea crassa* (DuBar et al., 1974). A few terrestrial mammal fossils have also been found in this formation.

Flanner Beach Formation: The Flanner Beach Formation was deposited in a narrow coastal zone in the vicinity of the Neuse River Estuary. This unit represents cypress grove, estuarine, and nearshore marine depositional environments. Fossiliferous exposures of the Flanner Beach Formation are accessible at its type locality, Flanner Beach, Craven County, and along the shores of the Neuse River Estuary from the Trent River to the Cherry Point Marine Station (DuBar et al., 1974). Some of these Neuse River localities also expose the underlying early Pleistocene James City Formation.

Common Flanner Beach mollusks include the bivalves *Mulinia lateralis, Rangia cuneata, Dinocardium robustum* and *Cyrtopleura costata*. Some mollusks reported from the Flanner Beach Formation have been reworked from the underlying James City Formation (DuBar and Solliday, 1963).

Molluscan fossils in the Canepatch and Flanner Beach Formations have a distinctly modern aspect (DuBar et al., 1974). Following Flanner Beach and Canepatch time, only a few mollusks became extinct, notably the bivalves *Carditamera (Carditamera) arata, Cyclocardia (Cyclocardia) granulata, Chama gardnerae,* and the coral *Septastrea crassa* (DuBar et al., 1974).

SELECTED FOSSIL LOCALITIES

Most fossil localities described below were selected for their accessibility and for their diversity and abundance of fossils. A few are not abundantly fossiliferous, but they are included to provide broad geographic and stratigraphic coverage.

The following fossil localities are listed alphabetically by county. Their general locations are shown on the back cover of this publication. Additional locality information appears on the topographic maps in the text-figures and in the locality descriptions. "SR" is used here as an abbreviation for "State Road".

State regulations prohibit collecting fossils in state parks. Fossils may be collected in National Forest Lands, providing excavations are not made, e.g., at Flanner Beach (Locality 10) and Haywood Landing (Locality 20). Property owners should always be contacted to obtain permission to collect fossils on private lands.

BEAUFORT COUNTY
1. Terra Ceia.

Age and Formation: Pleistocene Flanner Beach (?) Formation.

Location: This fossiliferous outcrop is under a bridge which crosses a drainage canal east of Terra Ceia. To reach the bridge, travel on SR 1612 1.5 mile east of the intersection of SR 1612 and SR 1619 at Terra Ceia. Turn right (south) on SR 1616, and travel 0.15 mile to the bridge. Pantego 7.5 minute quadrangle.

Access: This locality may be easily reached on foot.

Fossils: Abundant and moderately diverse Pleistocene fossils occur in a two-feet-thick exposure of light brown to brown, clayey sand, underlain by three feet of bluish gray, clayey sand. Fossils are more abundant in the upper part of the exposure, and include numerous mollusks (Richards, 1966), e.g., the bivalves *Mulinia lateralis, Noetia ponderosa, Anadara transversa, Nuculana acuta, Crassostrea virginica, Phacoides crenella, Divaricella quadrisulcata, Mercenaria mercenaria, Tellina agilis, Abra angulata, Corbula contracta, Ensis directus, Spisula solidissima, Rangia cuneata, Mya arenaria*, and *Cyrtopleura costata*, and the snails *Turbonilla* sp., *Crepidula fornicata, Crepidula plana, Eupleura caudata, Urosalpinx cinerea, Nassarius obsoletus, Nassarius trivittatus, Nassarius acutus, Busycon canaliculatum, Busycon carica, Polinices duplicata, Prunum roscidum, Olivella mutica, Terebra dislocata*, and *Retusa canaliculata*. The main shell bed here grades laterally into an oyster bed.

Richards (1966) identified this exposure as "Pamlico" Sangamon Pleistocene age. Gibson (1983, p. 76) indicated the Terra Ceia beds are approximately equivalent in age to the Chowan River Formation and strata near James City on the Neuse River (= Flanner Beach or James City Formation?). Of the mollusks identified by Richards (1966), *Noetia ponderosa, Busycon canaliculatum* and *Urosalpinx cinerea* are typical of Blackwelder's (1981b) molluscan zones M1 or M2. This suggests correlation with the Flanner Beach or Canepatch Formations, i.e., strata younger than the James City and Chowan River Formations.

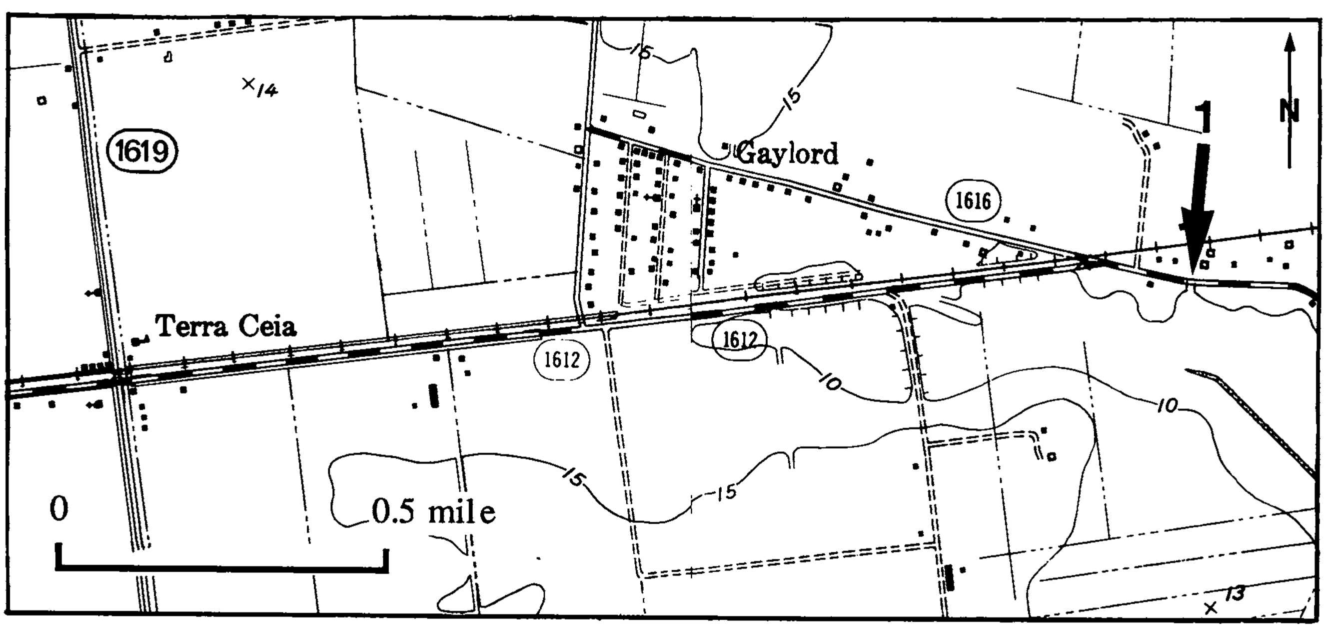

Figure 1. Locality 1. Terra Ceia. Pantego 7.5 minute quadrangle.

BERTIE COUNTY
2. Colerain Beach.

Age and Formation: Late Pliocene Chowan River Formation.

Location: Fossils may be collected from the bluffs on the west bank of the Chowan River, 0.1 to 0.5 mile downstream (south) from Colerain Beach, 1.0 mile east of Colerain. Colerain and Valhalla 7.5 minute quadrangles.

Access: This locality may be visited by boat or on foot. A N.C. Wildlife Commission boat access is at Edenhouse on the north side of the U.S. Highway 17 bridge, about 11 miles downstream (south) from Colerain Beach. The site may be reached on foot from the landing at Colerain, but this requires permission of the property owner. Requests for permission to collect should be directed, in writing, to the President of the Colerain Beach and Boat Club, Colerain, N.C., 27924. The requests should include your telephone number and anticipated date of arrival.

Fossils: The bluffs expose 14 to 20 feet of the fossiliferous late Pliocene Chowan River Formation, overlain by Pleistocene unfossiliferous sands and silty sands. The lower bed here, the Edenhouse Member of the Chowan River Formation, consists of a poorly sorted, shelly, slightly glauconitic, phosphatic, silty, fine- to medium-grained, light olive-brown to blue-green quartz sand, grading upward to a slightly shelly, somewhat glauconitic, fine- to medium-grained yellow quartz sand. Common fossils from this member include the bivalves *Glycymeris americana*, *Glycymeris hummi*, *Noetia carolinensis*, *Carolinapecten eboreus*, *Ostrea sculpturata*, *Mercenaria permagna*, *Astarte* sp., *Abra* sp., *Corbula* sp., *Parvilucina* sp., and *Cyclocardia granulata*; plus *Busycon*, *Nassarius*, *Polinices*, and many other gastropods; the sand dollar *Mellita* sp.; and the branching coral *Septastrea crassa*. *Ostrea raveneliana* and *Ecphora* sp. have been collected here, but these may have been reworked from the underlying Yorktown Formation.

The overlying Colerain Beach Member of the Chowan River Formation is separated from the lower member by a limonitic sand. This upper member contains lenses of yellowish gray, shelly, fine sand plus laminated clay, silt and fine sand with limonite tubes. Its fossils include the estuarine bivalves *Rangia clathrodonta* and *Corbicula densata* plus *Mercenaria* and *Glycymeris* (see Blackwelder, 1981b).

The fossiliferous sediments exposed here were correlated with the Yorktown Formation by most stratigraphers and paleontologists prior to 1981. As shown by Blackwelder (1981b) and others, however, these strata are younger than the type Yorktown Formation of Virginia. The upper member of the Yorktown Formation in North Carolina, the Morgarts Beach Member, underlies the Chowan River Formation at this locality. This member of the Yorktown Formation is exposed along the west bank of the Chowan River a few miles north of Colerain Beach (R. Bailey, personal communication, 1986).

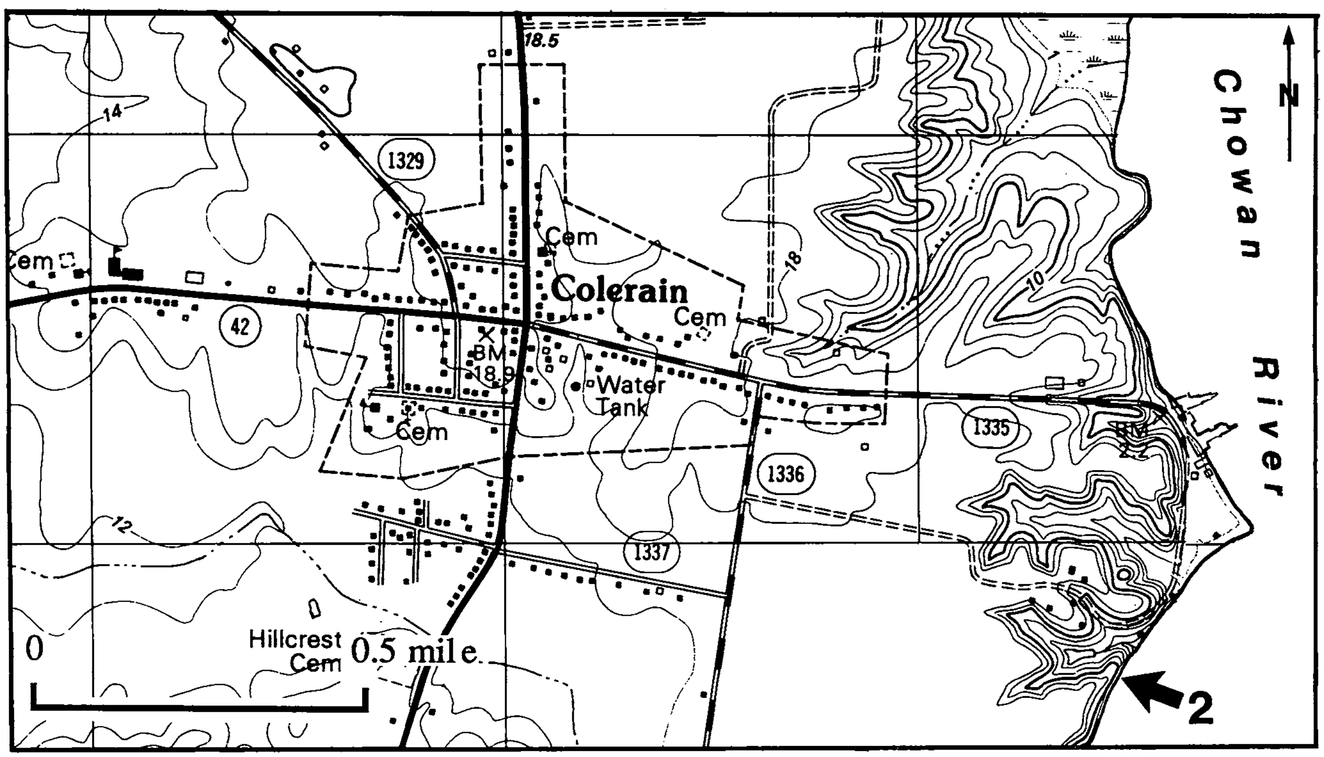

Figure 2. Locality 2. Colerain Beach. Colerain and Valhalla 7.5 minute quadrangles.

3. Mount Gould Landing.

Age and Formation: Late Pliocene Chowan River Formation.

Location: Fossils may be collected from the bluffs on the west bank of the Chowan River, 0.1 mile north of Mount Gould Landing, and 0.3 mile south of Mount Gould Landing. Mount Gould Landing is 1 mile east-northeast of Mount Gould on SR 1354. Valhalla 7.5 minute quadrangle.

Access: Access by boat is recommended for these exposures. There is a N.C. Wildlife Commission boat access at Edenhouse on the north side of the U.S. Highway 17 bridge, about 6 miles downstream from Mount Gould Landing. There is also a boat landing at Colerain, upstream from Mount Gould Landing, but this requires permission of the property owner.

Fossils: This locality contains abundant molluscan fossils in a 9-feet-thick exposure of the Chowan River Formation just above the water level. These include the bivalves *Glycymeris americana*, rare *Glycymeris subovata*, common *Glycymeris hummi*, *Astarte concentrica*, *Carditamera arata*, *Ostrea sculpturata*, plus numerous gastropods and the branching coral *Septastrea crassa*.

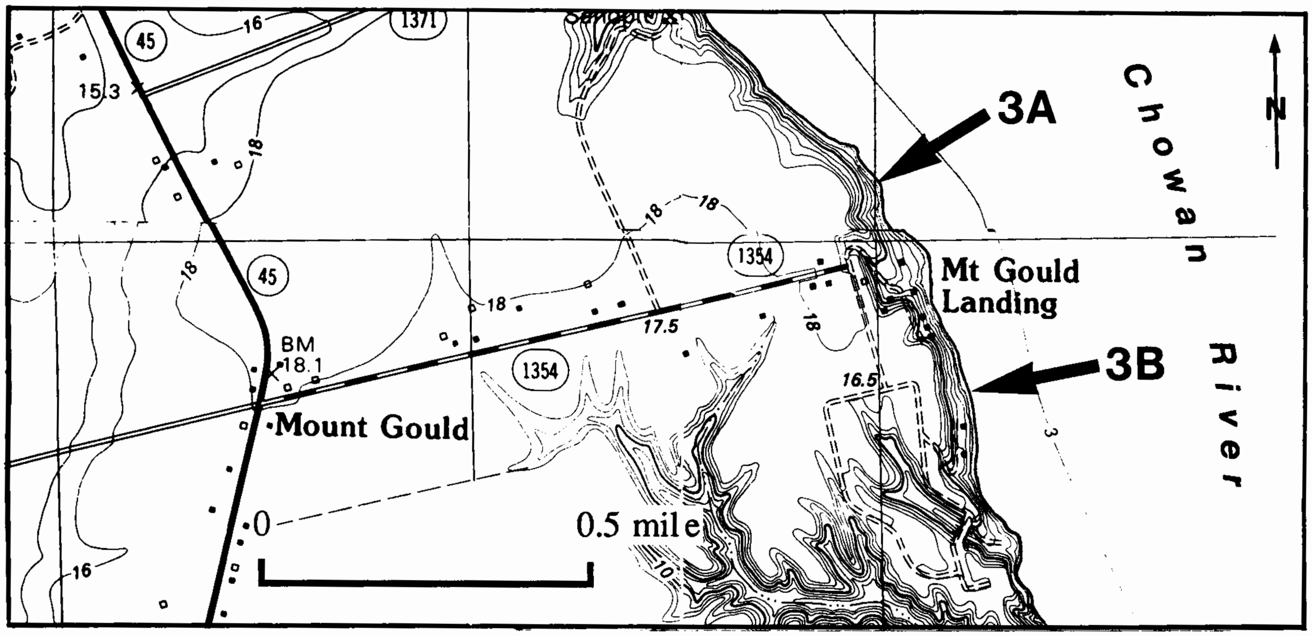

Figure 3.1. Locality 3. Mount Gould Landing. Valhalla 7.5 minute quadrangle.

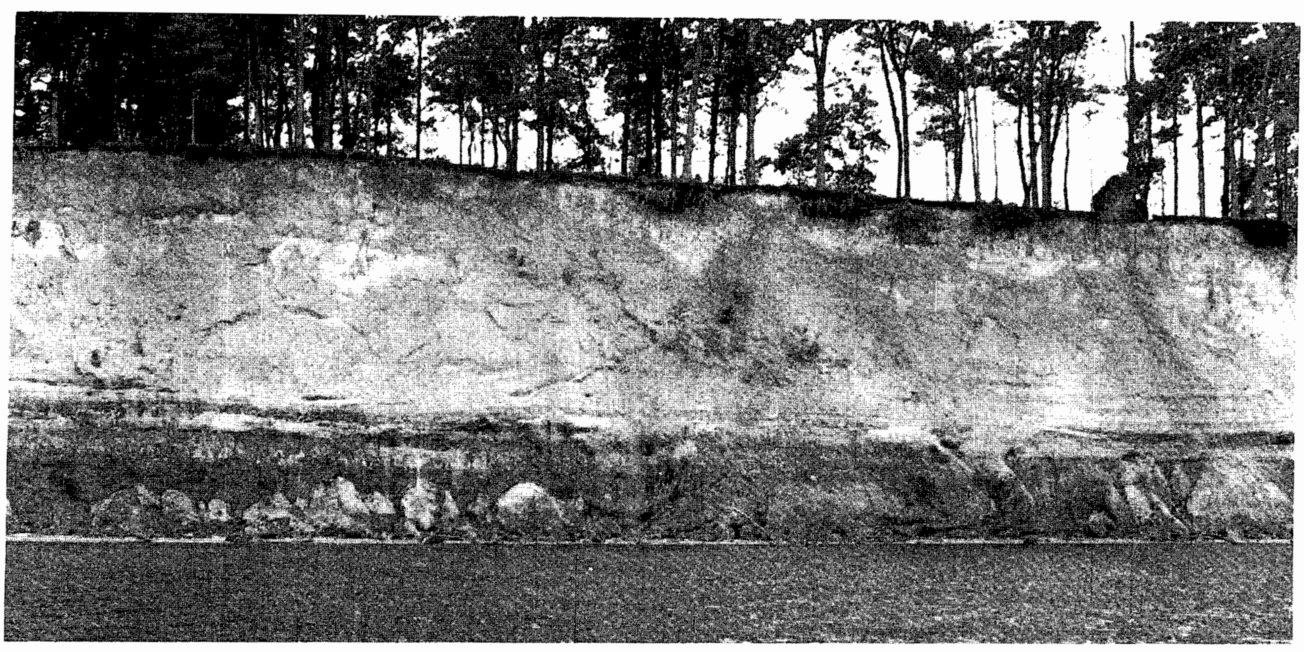

Figure 3.2. Chowan River Formation and surficial deposits exposed at Mount Gould Landing.

BLADEN COUNTY
4. Black Rock Landing.

Age and Formation: Late Cretaceous Peedee Formation, Eocene Castle Hayne Formation, undifferentiated Pliocene or Pleistocene sediments.

Access: This locality may be reached on foot using a path on the south bank of the river. The locality is best visited during low water.

Location: Fossils are exposed on the south bank of the Cape Fear River at Black Rock Landing, at the N.C. Highway 11 bridge over the Cape Fear River, just northwest of the Bladen/Columbus County line. Bolton 15 minute quadrangle.

Fossils: This locality exposes the Peedee Formation, a small section of the overlying Eocene Castle Hayne Formation, and overlying undifferentiated Pliocene or Pleistocene sediments. The Peedee Formation contains two zones: the lower zone consists of dark blue-black to black, micaceous, clayey, fossiliferous sand. The upper zone consists of several feet of blue-black to black, micaceous sandy clay. The Peedee Formation contains the oysters *Exogyra cancellata*, *Exogyra costata*, *Exogyra costata* variety "spinosa", and *Pycnodonte vesicularis*; the bivalves *Anomia argentaria*, *Veniella conradi*, and *Pachycardium spillmani*; several gastropods, including *Anchura*, *Gyrodes*, and *Rostellites*; the calcitic cigar-shaped skeleton of the extinct squid-like *Belemnitella americana*; and rare reptile teeth (Stephenson, 1912, 1923). This exposure also contains teeth of the shark *Squalicorax pristodontus*.

The upper part of the bluff at this locality is heavily vegetated. At one time, it exposed three feet of the Eocene Castle Hayne Formation, containing fossil scallops and bryozoans. In recent years, however, this Eocene exposure has been covered by vegetation.

The Cretaceous and Eocene beds in this area are overlain by about 25 feet of surficial deposits (Miller, 1912, p. 192). Gardner (1943) indicated the presence of Waccamaw Formation here, citing occurrences of the scallops *Carolinapecten eboreus* and *Amusium mortoni*. However, both species are known to range through the Waccamaw, Bear Bluff and Yorktown Formations, as these units are presently defined. Fossiliferous Pliocene or Pleistocene sediments were not differentiable at this locality in 1986, when the field work for this publication was conducted.

The Peedee and Castle Hayne Formations here are indicative of the contrasting sediment types deposited in North Carolina during Late Cretaceous and Eocene time. North Carolina's Late Cretaceous sediments consist largely of sands, silts and clays shed from the area of the original Appalachian Mountains, i.e., from the Piedmont area of modern North Carolina. By Eocene time, the Piedmont may have been largely flattened by erosion, thereby reducing its supply of sediment washed into the sea. With this reduced sediment supply, calcium carbonate-secreting organisms such as calcareous algae and corals thrived in North Carolina's coastal waters. Their skeletons, plus the skeletons of many other carbonate-secreting organisms, were eventually transformed into the Castle Hayne Limestone.

The Peedee and Castle Hayne Formations represent two of the most profound inundations of North America during the past 200 million years. During Late Cretaceous time, the Atlantic Ocean reached as far west as Raleigh. Also, the Gulf of Mexico covered all of the southern states and much of the American Midwest, joining with the eastern Pacific Ocean in northwest North America. The Eocene sea was less extensive, but in North Carolina it deposited fossil shells almost as far west as the Late Cretaceous sea.

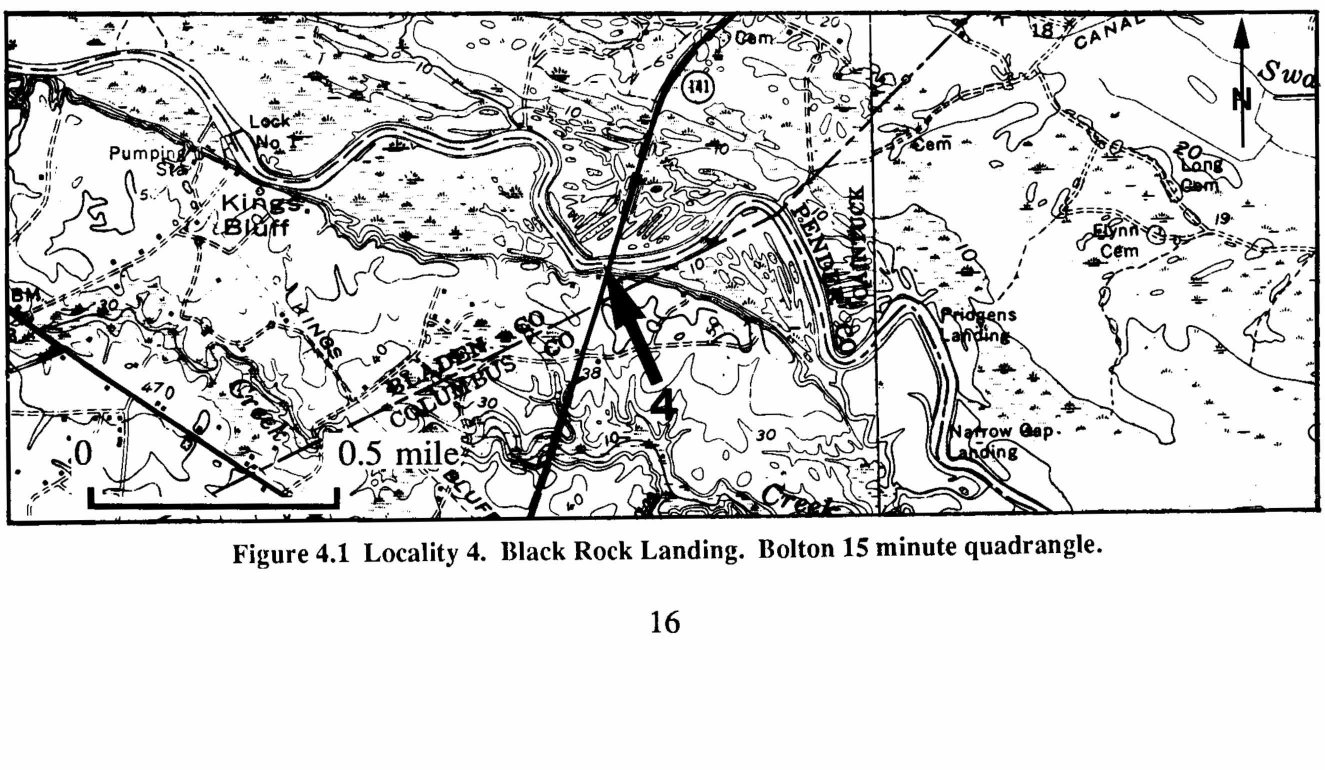

Figure 4.1 Locality 4. Black Rock Landing. Bolton 15 minute quadrangle.

Figure 4.2. Exposure of the Peedee Formation at Black Rock Landing.

5. Elizabethtown.

Age and Formation: Late Cretaceous Black Creek Formation; Pliocene Bear Bluff Formation.

Location: Fossils are exposed along the sides of trenches dug for a sanitary landfill about 300 feet east of U.S. Highway 701, 1.5 miles south southwest of the intersection of U.S. Highway 701 with N.C. Highway 87 in Elizabethtown. From the gate at the entrance to the sanitary landfill, proceed on the dirt road past the office to the trenches and spoil piles. The gate is open 9:00 a.m. to 5:00 p.m. Monday through Friday, and Saturday from 9:00 a.m. to 12:00 p.m. Elizabethtown 15 minute quadrangle.

Access: This locality is readily accessible on foot.

Fossils: Fossils are abundant in the spoil piles and in the walls of the sanitary landfill trenches. Most of these fossils come from the bluish-gray to grayish-brown clayey sands which comprise the trench walls. About 1.5 feet of the Cretaceous Black Creek Formation are exposed in the northern part of the trenches, where it consists of a laminated, micaceous, blue-gray clayey sand with carbonized impressions of plants. In the overlying Bear Bluff Formation, the basal 1.5 feet consists of blue-gray, pebbly, clayey sand with lignitized wood and phosphatic sand and pebbles, plus bone fragments and shark teeth reworked from the underlying Cretaceous sediments. This basal Bear Bluff bed contains shells of the bivalves *Nucula proxima*, *Mulinia congesta*, and *Ensis directus*. This is overlain by about 9 feet of bluish-gray, clayey, quartz sand with four faunal zones, from base to top: 1. a 3-feet-thick bed containing the bivalves *Mercenaria permagna*, *Mulinia congesta*, *Noetia carolinensis*, and *Ensis directus*; 2. a 1-foot-thick bed with abundant shells of the oyster *Ostrea sculpturata*, 3. a 1-foot-thick bed with abundant branching corals (*Septastrea crassa*), the bivalves *Mercenaria permagna*, *Noetia carolinensis*, and *Carditamera arata*, and the gastropod *Busycon concinnum*; and 4. a 4-feet-thick, very clayey sand with the bivalves *Glycymeris hummi*, *Glycymeris tuomeyi* (much rarer than *Glycymeris hummi*), *Ensis directus*, *Raeta undulata*, *Dosinia acetabulum*, *Carolinapecten eboreus*, *Noetia carolinensis*, *Mercenaria permagna*, and *Cyrtopleura* aff. *C. arcuata*, and the gastropods *Busycon maximum*, *Busycon concinnum*, and *Polinices duplicata*. This last bed is unconformably overlain by surficial clays, sands and gravels. Molluscan fossils from the Bear Bluff Formation at this locality also include *Pitar chioneformis*, *Stewartia anodonta*, *Corbicula densata*, *Plicatula marginata*, and *Conus adversarius*.

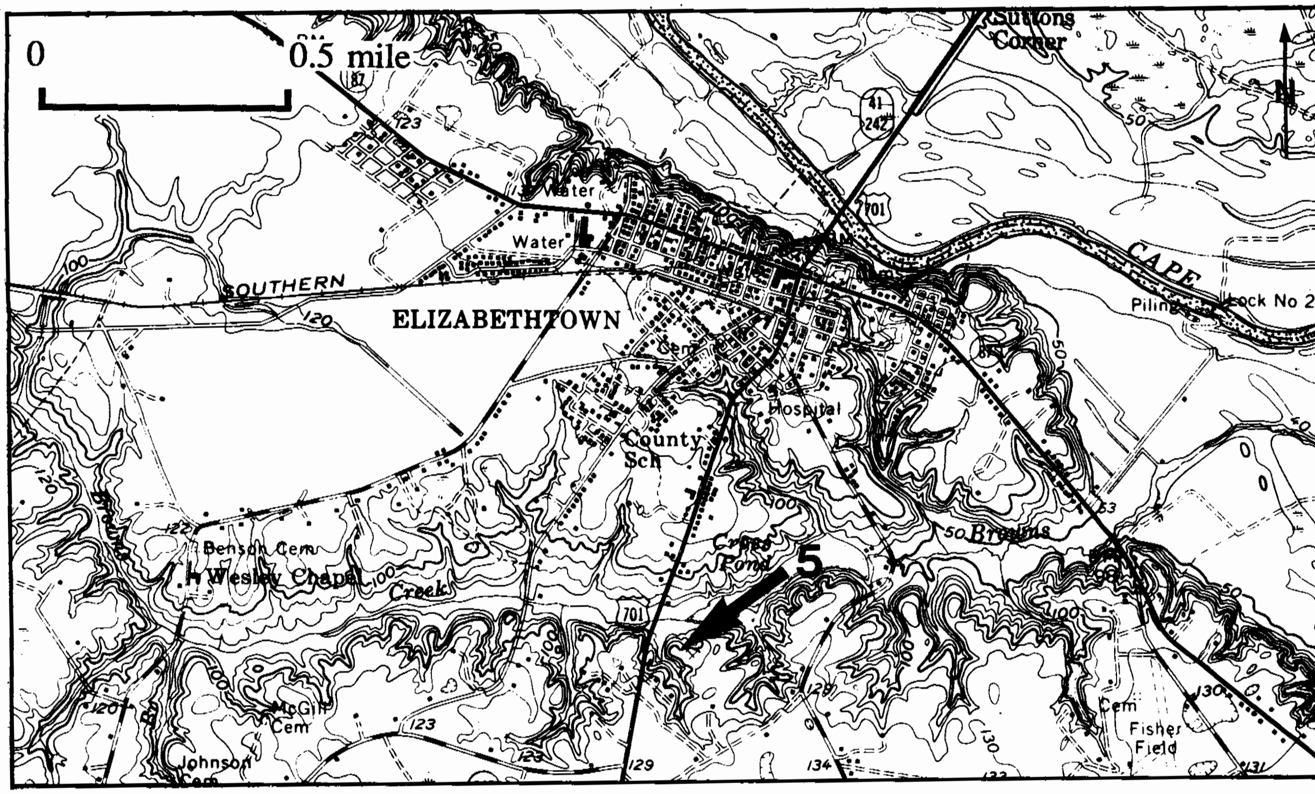

Figure 5.1. Locality 5. Elizabethtown. Elizabethtown 15 minute quadrangle.

Fossil teeth and bones of mammals and reptiles are abundant on the spoil piles near the landfill trenches. These vertebrate fossils are best collected just after the piles have been washed by rain. Vertebrate fossils collected from these sediments include Pliocene sharks, rays, whales, tortoises, and crocodiles, plus Cretaceous reptile and shark teeth reworked from the underlying Black Creek Formation.

Figure 5.2. Bear Bluff Formation and surficial deposits in the sanitary landfill at Elizabethtown.

CHATHAM COUNTY
6. Boren Clay Products Quarry.

Age and Formation: Late Triassic Pekin Formation.

Location: From the intersection of U.S. Highway 421 and SR 2140 (= Gulf Road) just west of the small community of Gulf (there are two such intersections west of Gulf; choose the northernmost of these two), travel 0.6 mile northwest on U.S. Highway 421 to SR 2139, near the entrance to the Boren Clay Products Quarry. Turn right on SR 2139 and take an immediate right into the quarry via a gravel access road. Proceed 0.3 mile into the quarry. The fossiliferous exposures are in the northwest corner of the quarry on the east side of the gravel access road. Goldston 7.5 minute quadrangle.

Access: Permission is required to enter the quarry. This may be requested by contacting the Boren Clay Products Company office in Goldston, North Carolina. Their telephone number is: (919) 898-4301. A vehicle may be driven into the quarry, but this is advisable only under dry conditions.

Fossils: Fossil plants are locally abundant in the Triassic Pekin Formation within the light brown to yellowish-gray siltstones exposed near the northwest quarry wall. The darker red and brown siltstones which comprise most of the quarry are less fossiliferous. The carbonaceous plant compressions and impressions are best collected by parting the siltstones with a hammer and chisel. Common plant fossils in this quarry are illustrated in Plate 1, Figures 2-4. These include a variety of ferns, cycads, cycadeoids, and conifers.

Also present here are stems and leaves of the horsetail *Neocalamites*. This fossil is interesting for its large size. It was probably several feet tall, much larger than North Carolina's modern horsetail *Equisetum*, but similar in this regard to some modern tropical horsetails. The ferns of the Pekin Formation generally occur as parts of compound leaves, but some large leaves and stems have been found here (Hope and Patterson, 1969; Delevoryas, 1970; Hope, 1975; Gensel, 1986).

In addition to plant fossils, this locality contains fossil fish scales, freshwater arthropods, and rare bones and teeth of amphibians, therapsids (mammal-like reptiles), phytosaurs (crocodile-like reptiles), and rare dinosaur teeth.

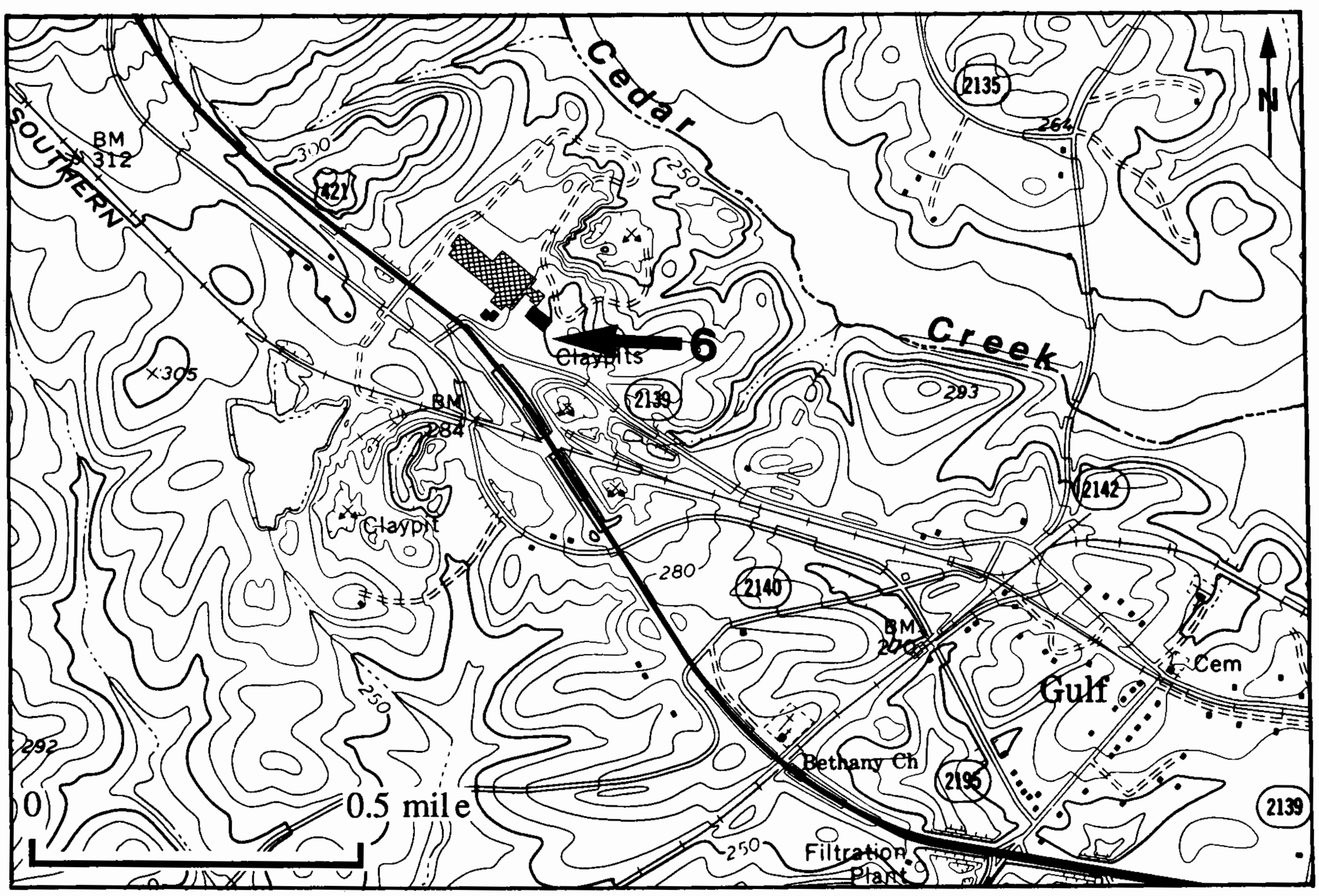

Figure 6. Locality 6. Boren Clay Products Quarry. Goldston 7.5 minute quadrangle.

COLUMBUS COUNTY
7. Old Dock.

Age and Formation: Pliocene Bear Bluff Formation, Plio-Pleistocene Waccamaw Formation.

Location: Fossils may be collected from the spoil piles around the perimeter of this abandoned state quarry, now water-filled, 2.3 miles northwest of Old Dock. The pit is located 300 feet north of N.C. Highway 130, 0.6 mile northwest of the intersection of N.C. Highway 130 with SR 1001. Old Dock 7.5 minute quadrangle.

Access: This locality is readily accessible on foot. However, access is no longer available to the quarry walls, which are now under water. Fossil collecting is better at this locality following a hard rain, which cleans the sediment from the fossils and exposes them on the surfaces of the spoil piles.

Fossils: The fossils come predominantly from the medium to coarse-grained, blue-gray, clayey sand of the Waccamaw Formation. DuBar (1971, p. 41) suggested the Waccamaw Formation here is underlain by the Pliocene Bear Bluff Formation and, below this, the Cretaceous Peedee Formation. Specimens of the bivalves *Chesapecten madisonius* and *Mercenaria corrugata* form "rileyi" collected here indicate the presence of some fossils reworked from the Yorktown Formation. Common Waccamaw and Bear Bluff fossils here include the bivalves *Glycymeris americana* and *Chione cancellata*, plus the gastropods *Conus floridanus* and *Oliva sayana*, and the branching coral *Septastrea crassa*.

This is the type locality of *Panopea dockensis* Olsson and Petit, a large, broadly gaping, smooth, bivalve shell also known as a "geoduck". This common name derives from the Chinook Indian name for the Pacific Coast edible clam *Panopea generosa*. Although not extinct in the Western Atlantic today, "geoducks" are seldom collected in this ocean because they live in deep burrows in offshore shelfal, muddy and sandy environments.

DuBar (1971) has provided an extensive faunal list for this quarry (his fossil locality WA70), which includes the microfossil groups Foraminifera and Ostracoda, plus many bivalves and gastropods not listed here.

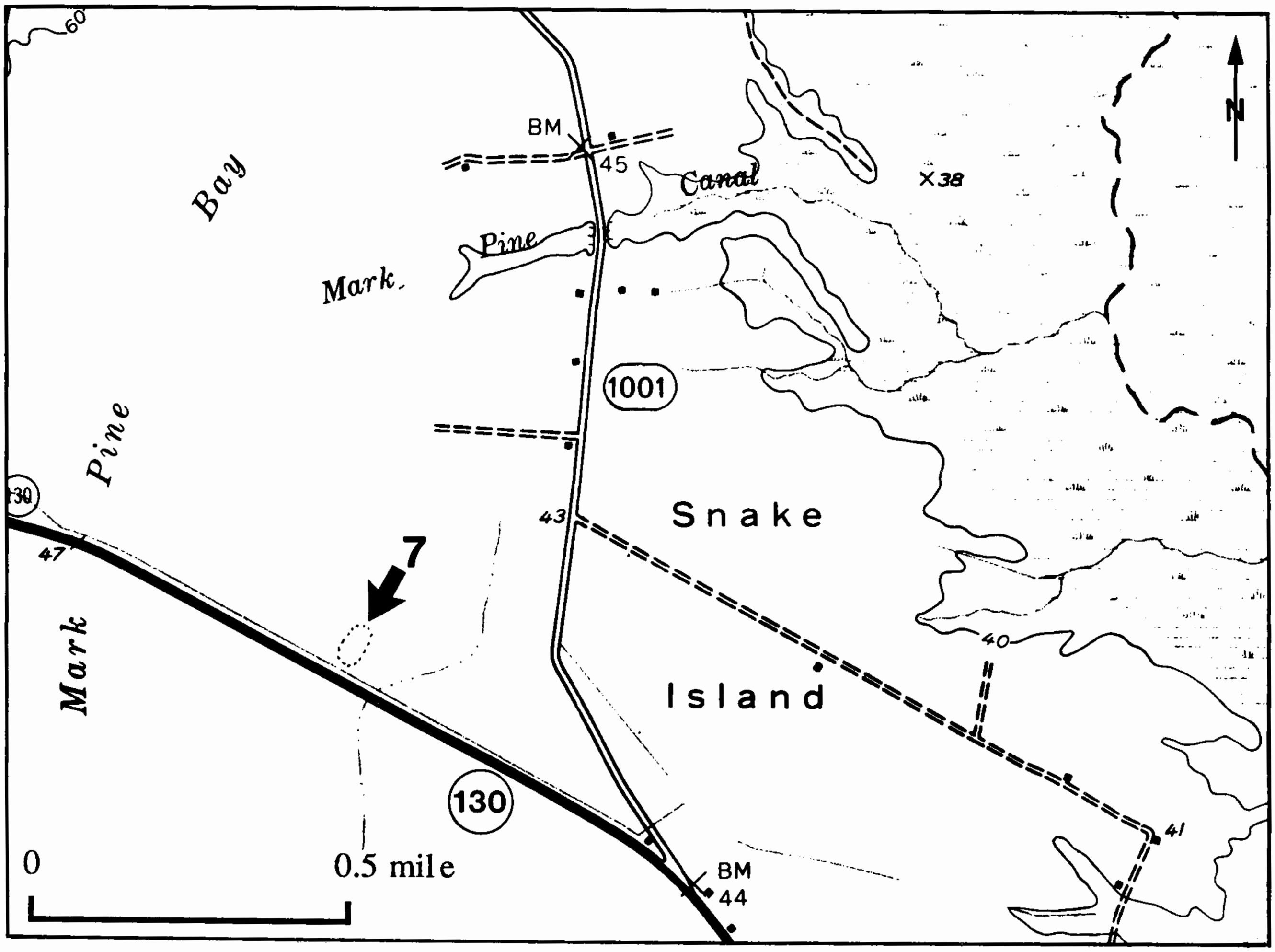

Figure 7.1. Locality 7. Old Dock. Old Dock 7.5 minute quadrangle.

Figure 7.2. Abandoned quarry near Old Dock, Locality 7, surrounded by fossiliferous spoil piles.

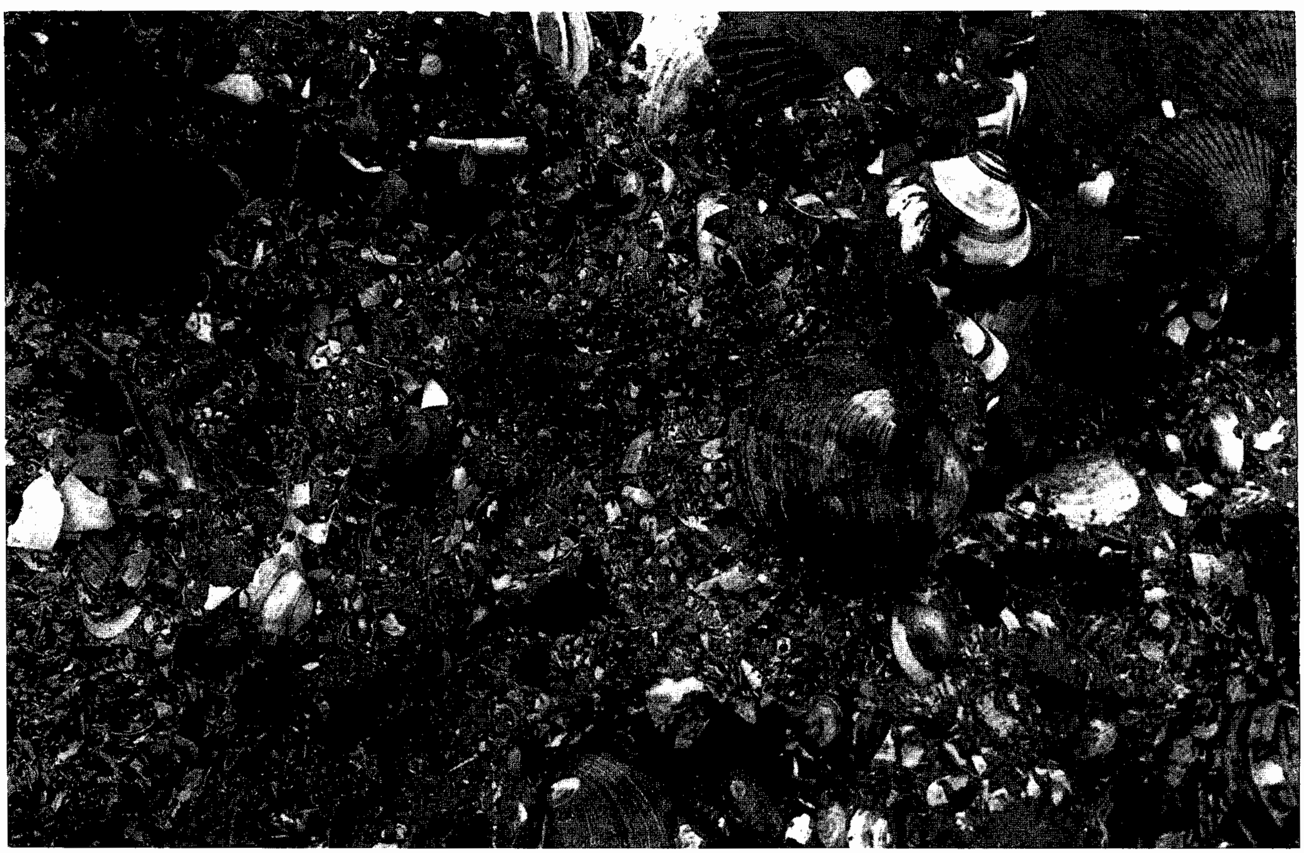

Figure 7.3. Fossils from the Bear Bluff and Waccamaw Formations in the spoil piles near Old Dock.

8. Lake Waccamaw.

Age and Formation: Pliocene Bear Bluff Formation, Plio-Pleistocene Waccamaw Formation.

Location: Fossils are exposed along the north shore of Lake Waccamaw directly across N.C. Highway 214 from the Lake Waccamaw Methodist Church, 1.3 miles west of the intersection of N.C. Highway 214 with SR 1942. Collecting west of this access point is strictly forbidden; this area is a Natural Heritage site. Whiteville 15 minute quadrangle.

Access: This locality may be easily reached on foot.

Fossils: Bear Bluff Formation fossils can be collected from the basal 4 feet of this exposure. The overlying 2 feet are assigned to the Waccamaw Formation. The Bear Bluff Formation is a light-brown, sandy, molluscan-mold limestone with largely dissolved shells. The Waccamaw Formation is a fossiliferous, yellow-orange sand with well preserved molluscan shells.

Fossil mollusks from this locality have been listed by Gardner (1943) and DuBar (1971). Fossils here include the bivalves *Glycymeris americana*, *Abra aequalis*, *Cyrtopleura arcuata*, *Mya arenaria*, and *Mercenaria corrugata* form "rileyi" (= probably *Mercenaria permagna*), and the gastropod *Turritella perexilis*.

Figure 8.1. Exposure of the Waccamaw (above arrow) and Bear Bluff (below arrow) Formations at Locality 8.

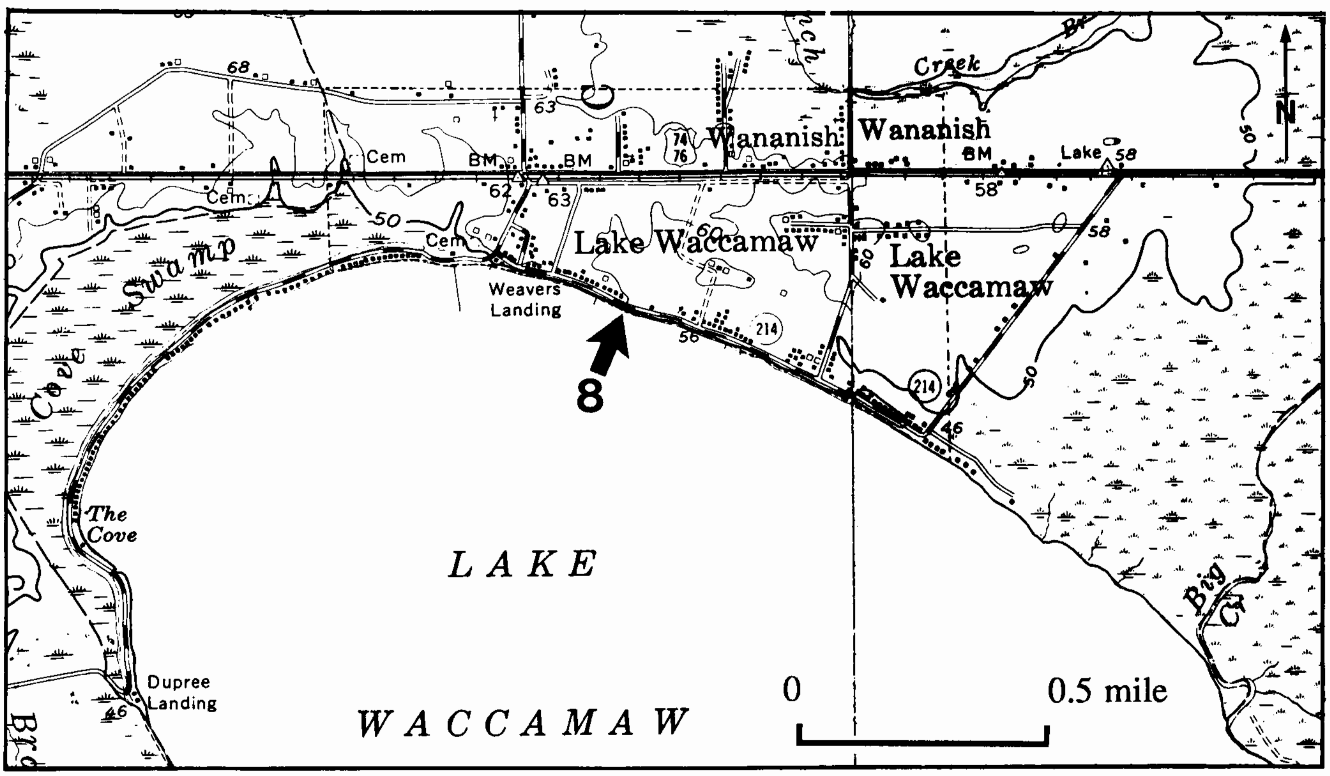

Figure 8.2. Locality 8. Lake Waccamaw. Whiteville 15 minute quadrangle.

CRAVEN COUNTY
9. Brinson Memorial School, James City.

Age and Formation: Plio-Pleistocene James City Formation.

Location: Fossils are exposed on the southwest bank of the Neuse River behind Brinson Memorial School, 3.0 miles southeast of New Bern, 1.5 miles south of James City off U.S. Highway 70. From Highway 70 turn northeast onto SR 1124 (East Grantham Road) at the sign for Brinson Memorial School. Proceed one long block to the end of the street and turn left onto SR 1113 (Cherry Point Road). Proceed one short block to SR 1125 (Neuse Forest Road) and turn right. Follow SR 1125 0.2 mile to the edge of the grassy field on the south side of SR 1125. Cross the field to reach the river. New Bern 7.5 minute quadrangle.

Access: This locality is readily accessible on foot. The fossils are exposed only at low tide.

Fossils: Fossils occur at the base of the river bank in 3 feet of grayish-blue, silty clay. Sandy clay balls are common in the upper part of the exposure. Overlying the clay, in the bluffs farther from the river, are 9 to 15 feet of surficial Pleistocene deposits consisting of unfossiliferous white to orange sands.

The river banks in this area expose the Plio-Pleistocene James City Formation from James City to about 4 miles south of James City. The bivalves *Mercenaria permagna*, *Mulinia lateralis*, *Panopea floridana*, *Noetia limula*, and *Anadara lienosa*, the gastropods *Polinices duplicata* and *Crepidula fornicata*, and the branching coral *Septastrea crassa* are common here.

This is the type area of *Mercenaria permagna*, the type specimens of which may have come from the James City Formation. This species resembles *Mercenaria corrugata* (form "rileyi") of the Pliocene Yorktown Formation, except that *permagna* has a relatively higher shell and more prominent umbones (beaks) (see Ward and Blackwelder, 1987, p. 158).

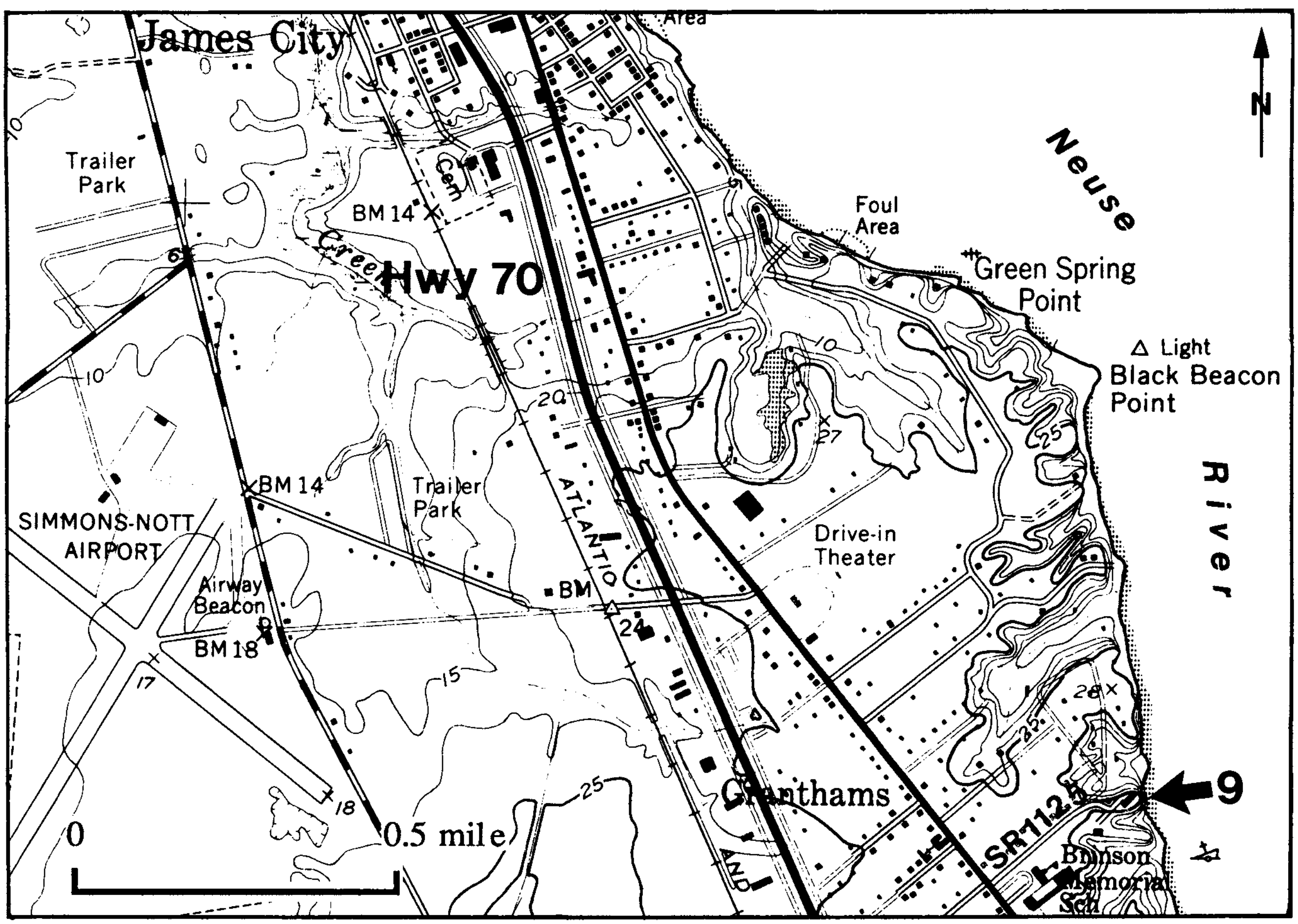

Figure 9.1. Locality 9. Brinson Memorial School. New Bern 7.5 minute quadrangle.

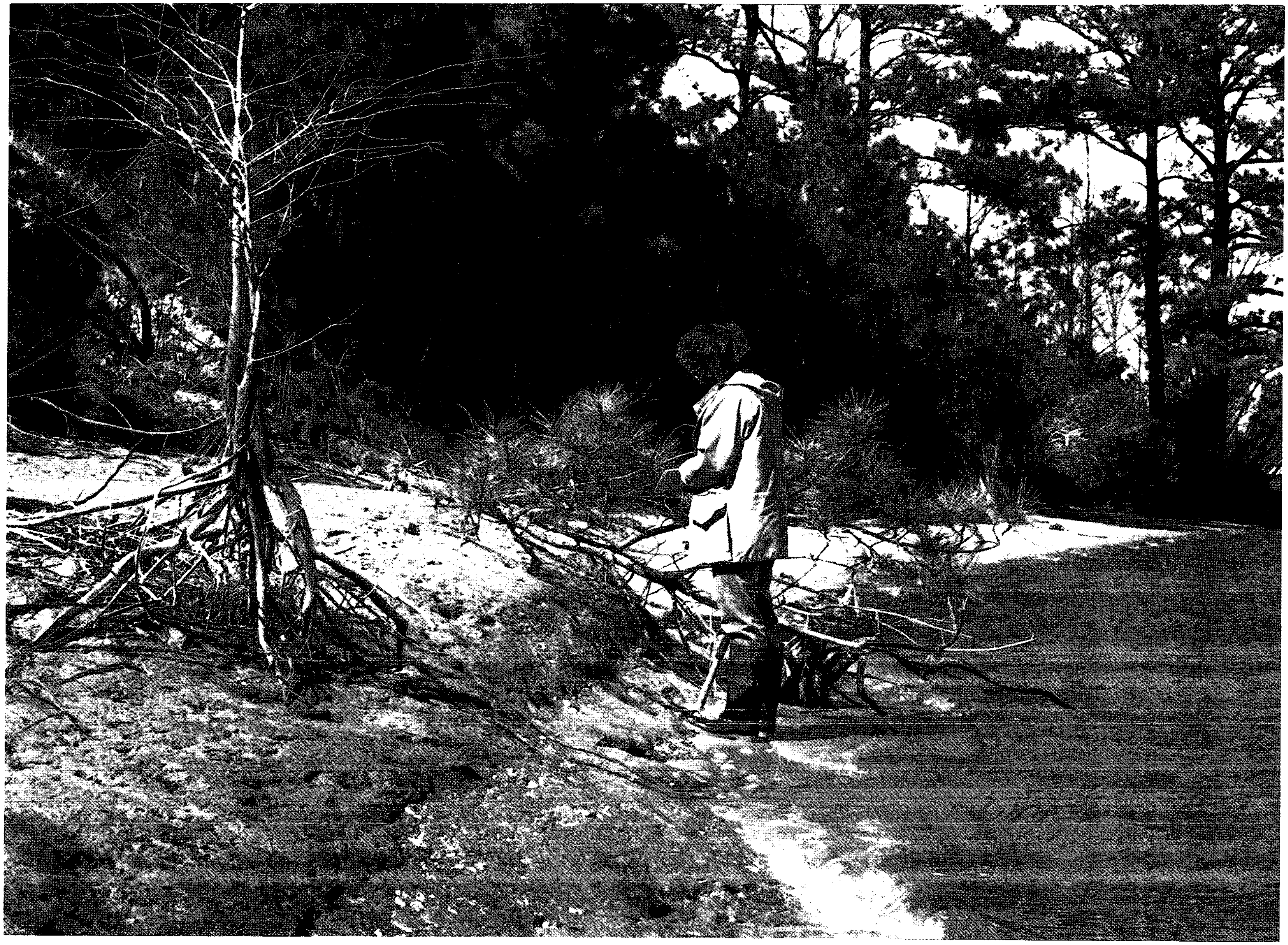

Figure 9.2. James City Formation exposed along the Neuse River near Brinson Memorial School.

10. Flanner Beach.

Age and Formation: Pleistocene Flanner Beach Formation.

Location: Fossils are exposed at the Croatan National Forest Recreation Area at Flanner Beach, on the south bank of the Neuse River. The recreation area is at the end of the Flanner Beach access road (SR 1107), which intersects US Highway 70 about 0.5 mile south of Croatan. Havelock 7.5 minute quadrangle.

Access: This locality is readily accessible on foot. Surface collecting is permitted here, but digging for fossils is not permitted on this and other National Forest Lands.

Fossils: Exposures of the Flanner Beach Formation in the River banks consist mostly of olive-brown and bluish-gray clayey silt. These are overlain by surficial, unfossiliferous, orange sands, silts and clays. The Flanner Beach Formation contains many small bivalves, especially *Mulinia lateralis*, *Nucula proxima*, *Nuculana acuta*, and *Yoldia limatula*, plus the larger bivalves *Dinocardium robustum* , *Lunarca ovalis*, *Noetia ponderosa*, *Argopecten irradians*, *Crassostrea virginica*, *Mercenaria mercenaria*, *Anadara transversa*, *Ensis directus*, and *Raeta plicatella*; the gastropods *Busycon canaliculatum*, *Busycon carica*, *Polinices duplicata*, *Oliva sayana*, and *Eupleura caudata*; and some reworked, older shells from the underlying James City Formation (not exposed here). The estuarine bivalve *Rangia cuneata* occurs here as both fossils in the Flanner Beach Formation and as living specimens in knee-deep water just offshore from the beach.

Low water sometimes exposes a basal non-marine, dark, pre-Flanner Beach clay with lignitized cypress stumps up to 6 feet in diameter near this locality (Mansfield, 1928).

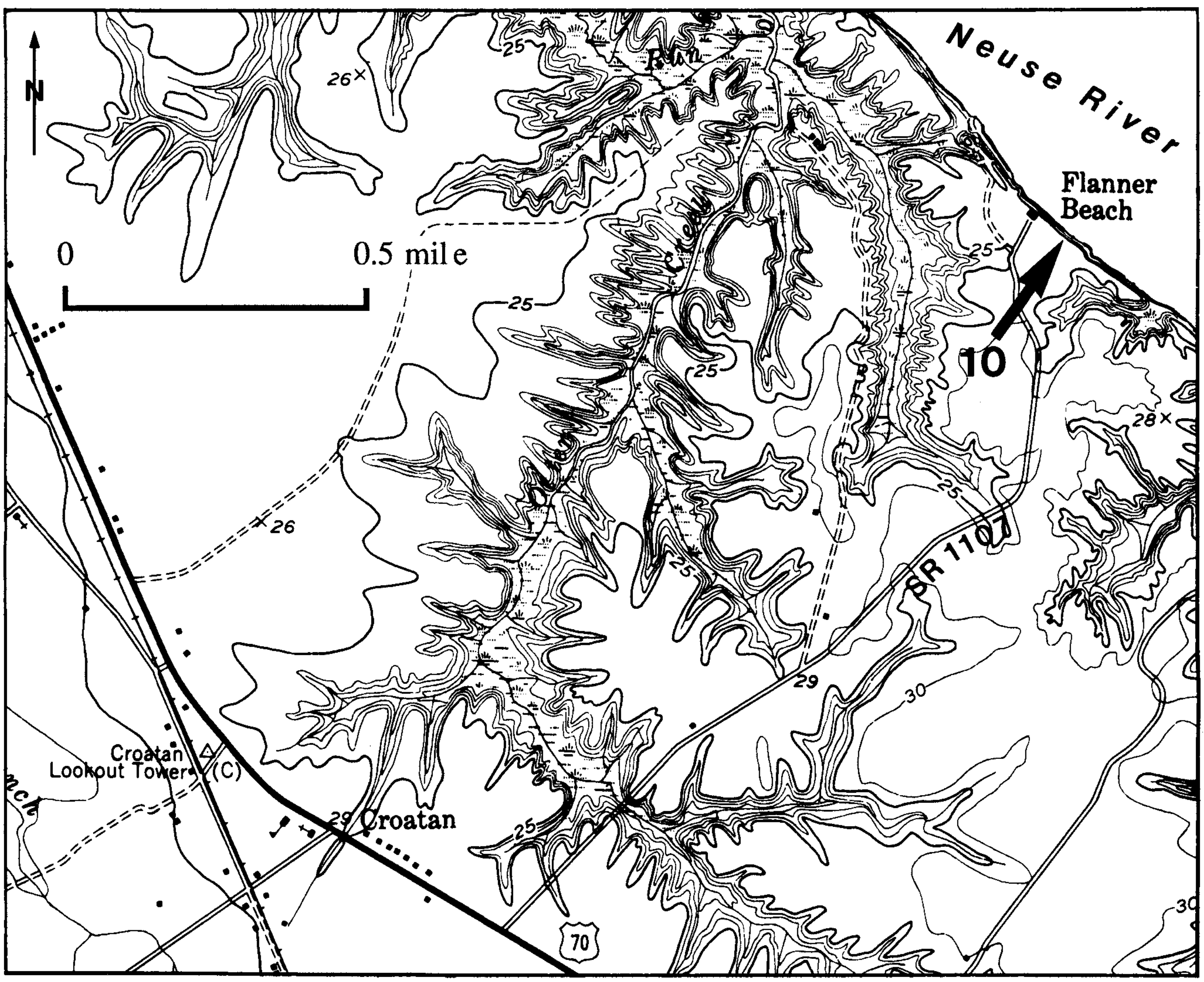

Figure 10. Locality 10. Flanner Beach. Havelock 7.5 minute quadrangle.

11. Shell Landing.

Age and Formation: Eocene Castle Hayne Formation.

Location: Fossils may be collected east of the boat ramp on the south side of Turkey Quarter Creek at its confluence with the Neuse River. Collecting is strictly forbidden within 600 feet to the west of the boat ramp; this area is a Natural Heritage site. Fossils can be collected to the west of this restricted zone, preferably along water level. To reach Shell Landing, travel 2.2 miles northwest of Jasper on N.C. Highway 55 to SR 1445. Turn right (east) onto SR 1445 and travel 1.4 miles to the boat ramp. Jasper 7.5 minute quadrangle.

Access: The boat ramp is privately owned, and a small fee is charged for its use. Collect only from boats; landowners have requested that private property not be crossed.

Fossils: Eocene fossils may be collected from the Castle Hayne Formation near the boat ramp at Shell Landing (= Rock Landing in the older literature). The lower part of this exposure consists of about 8 feet of sparsely fossiliferous, light yellowish-gray carbonate sand with the echinoid *Scutella*. The upper part of the exposure consists of about 3 feet of light gray to grayish-orange, sandy, phosphatic, molluscan mold limestone with a fine-grained matrix. The moldic fossils here are commonly stained with iron oxide. Some of the mollusks may be silicified (see Figure 15 of Ward and Blackwelder, 1980a). Ward (1977, p. 158) collected the following mollusks from the upper part of the Castle Hayne Formation here: the bivalves *Crassatella alta*, *Macrocallista neusensis* [= *Macrocallista perovata*], *Pecten* sp. cf. P. *biddleana*, *Pycnodonte* sp., and the gastropod *Fusinus abruptus*.

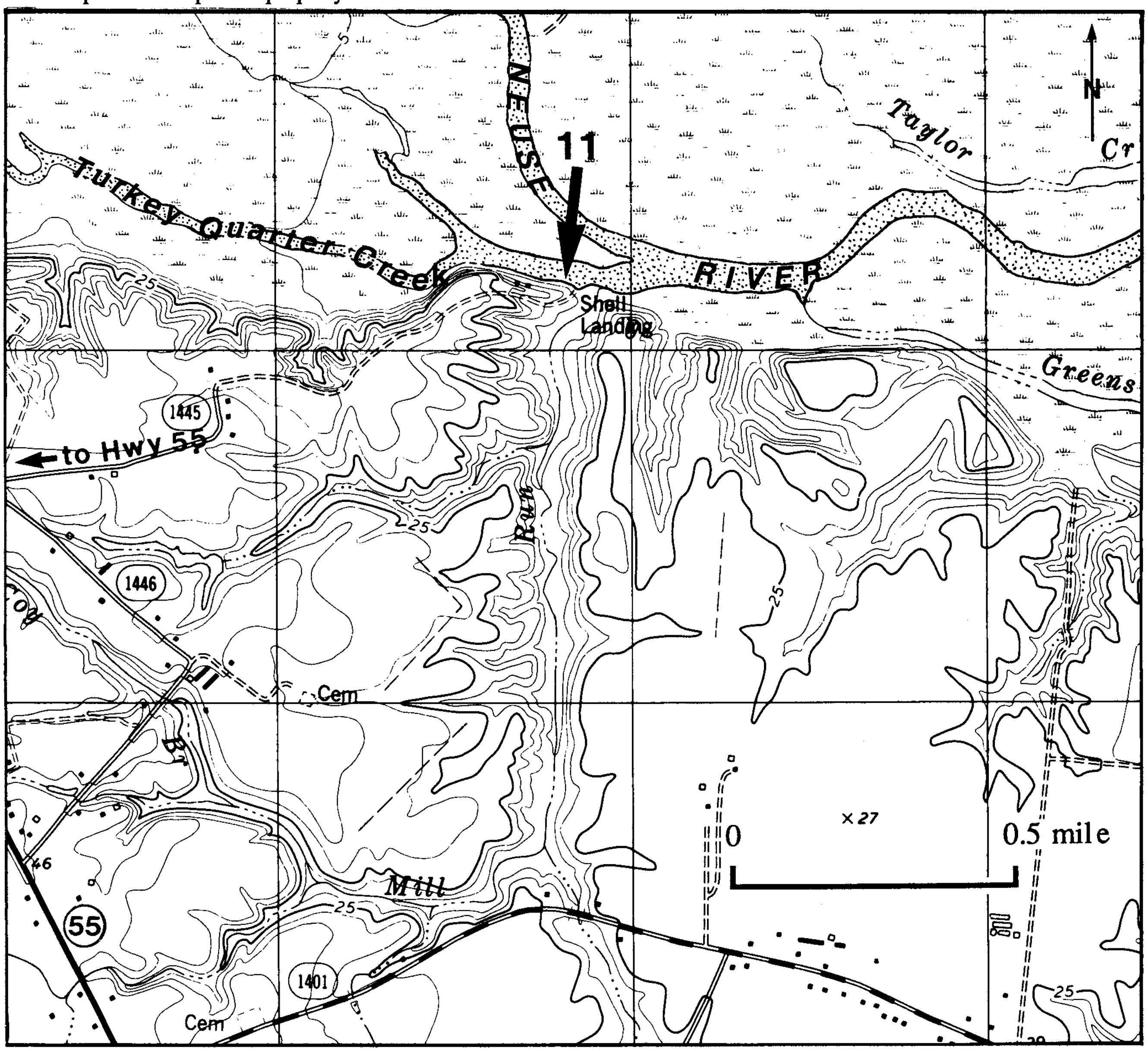

Figure 11. Locality 11. Shell Landing. Jasper 7.5 minute quadrangle.

CUMBERLAND COUNTY
12. Willis Creek.

Age and Formation: Late Cretaceous Black Creek Formation.

Location: Fossils may be collected from the bluff on the south side of Willis Creek just west of the N.C. Highway 87 bridge. The bridge is located between Fayetteville and Tarheel, 0.9 mile north of the sign for the Cumberland/ Bladen County line. The bridge is also 8.1 miles south of the intersection of Interstate Highway 95 with N.C. Highway 87. St. Pauls 15 minute quadrangle.

Fossils: Lignitized wood, seeds, and leaves, and silicified logs occur here in the Black Creek Formation on the banks of Willis Creek. This exposure contains two zones, with fossils concentrated in the lower zone. The lower zone consists of five feet of white, feldspathic, micaceous, medium to coarse sand and gravel with lignite fragments scattered throughout or locally concentrated in discontinuous thin layers. An 8-inch-thick bed of concentrated lignite occurs 1.5 feet above the base of the exposure; its position on the outcrop face is marked by yellow sulfur deposits. The upper zone consists of about 6 feet of grayish-black clay with fine, micaceous sand partings and thin lenses of light brown, coarse sand.

Figure 12.1 Exposure of the Black Creek Formation along Willis Creek, Locality 12.

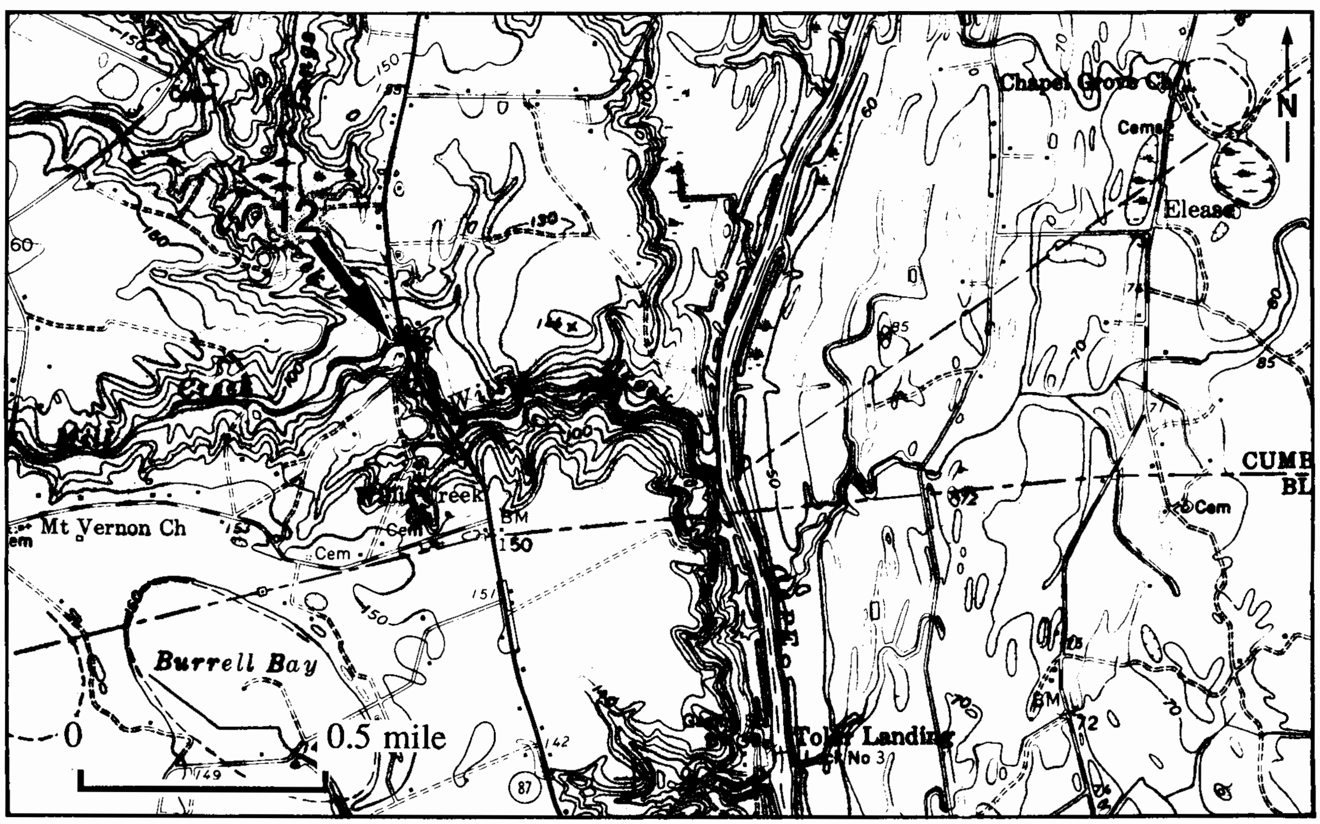

Figure 12.2. Locality 12. Willis Creek. St. Pauls 15 minute quadrangle.

DUPLIN COUNTY
13. Chinquapin Bridge.

Age and Formation: Late Cretaceous Peedee Formation, Eocene Castle Hayne Formation.

Location: Fossils may be collected from the east bank of the Northeast Cape Fear River at the N.C. Highway 41-50 bridge, 1.3 miles west of Chinquapin. Chinquapin 7.5 minute quadrangle.

Access: This locality is best visited by boat. There is a dirt access ramp (in rather poor condition) on the west bank of the river across from the outcrop.

Fossils: Fossils occur primarily as molds in the Eocene Castle Hayne Formation, which forms a 3-feet-thick ledge jutting out toward the river. The exposure is a light brown and cream-colored sandy limestone and calcareous sandstone. Kellum (1926) reported the scallop *Pecten cookei* from this exposure. The Peedee Formation is intermittently exposed in a ledge 6 to 12 inches below normal water level on the east bank of the river, where its sediments consist of greenish-gray, glauconitic, calcareous siltstones and sandy limestones. The Peedee fossils consist primarily of molds of molluscan shells.

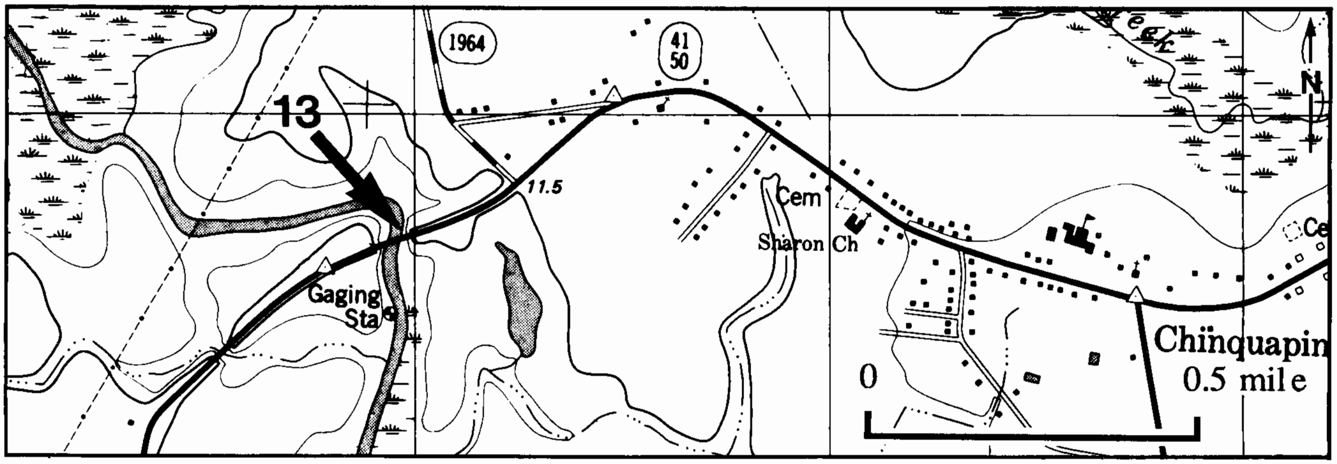

Figure 13.1. Locality 13. Chinquapin Bridge. Chinquapin 7.5 minute quadrangle.

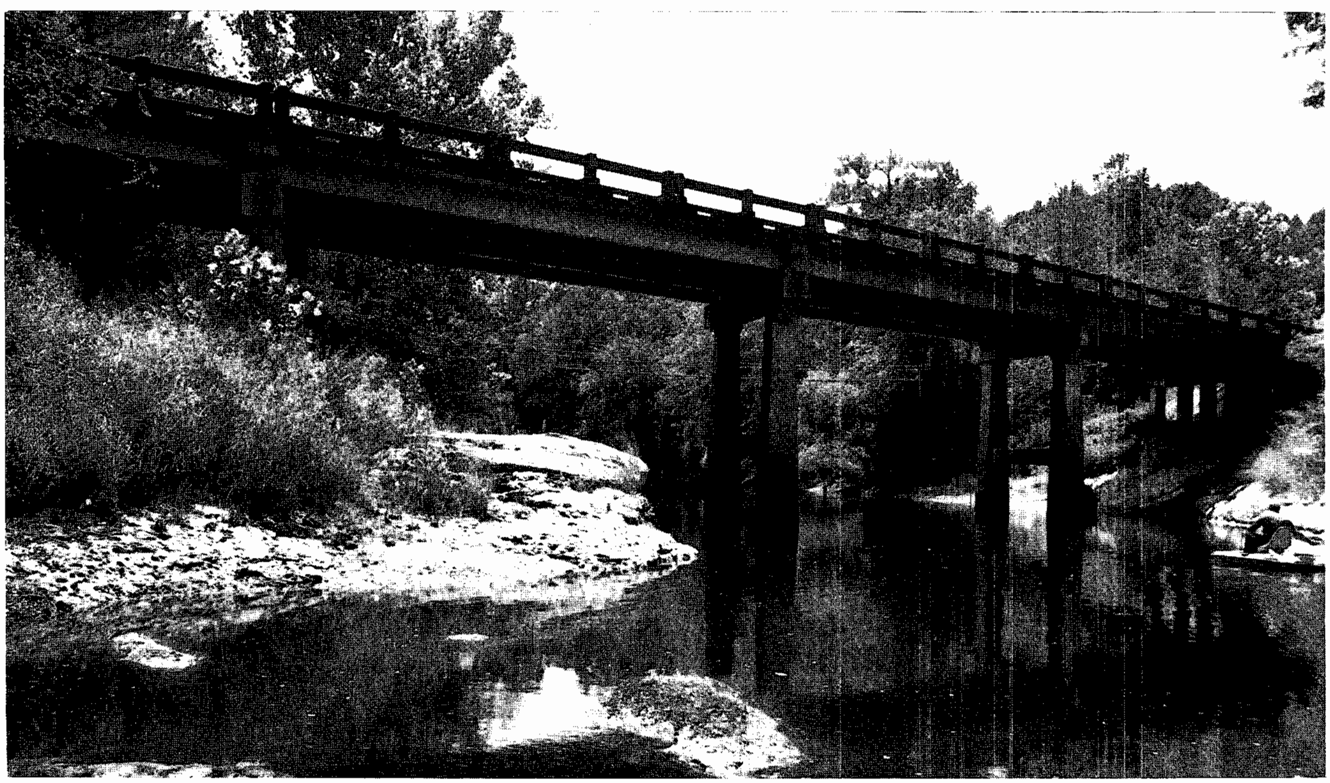

Figure 13.2. Castle Hayne Formation exposed along the Northeast Cape Fear River at Chinquapin Bridge.

14. Natural Well.

Age and Formation: Eocene Castle Hayne Formation, Pliocene Yorktown Formation (= Duplin Formation).

Location: Fossils are exposed on the rim of a sink hole about 450 yards southeast of the house of Mr. Albert Matthews, on the south side of SR 1003, approximately 0.8 miles southwest of the intersection of SR 1003 with State Road 1104, west of Magnolia. Warsaw South 7.5 minute quadrangle.

Access: Access to this locality requires the permission of the landowner.

Fossils: The 3-feet-thick exposure of the Yorktown Formation (= Duplin Formation) near the top of this sinkhole consists of shelly, yellowish-brown to bluish, clayey sand. This is the unofficial type locality and type section of the Duplin Formation. As originally defined, the "Duplin marl" included these Pliocene sediments and the underlying Eocene sediments. Later workers restricted the Duplin Formation to the Pliocene part of this section. The Eocene Castle Hayne Formation here consists of 18 feet of soft to indurated, cream-colored, fossiliferous limestone.

The Yorktown (= Duplin) Formation contains diverse fossil bivalves, gastropods, scaphopods, and the brachiopod *Discinisca lugubris*. This fauna is characterized by warm water taxa such as the cowry *Siphocypraea (Siphocypraea) carolinensis* (Figure 71 of Plate 9) and the bivalve *Placunanomia plicata*. Also found in this Pliocene bed are the scallops *Chesapecten septenarius* and *Chesapecten madisonius*, the bivalves *Mercenaria corrugata* and *Mulinia congesta*, and the oyster *Ostrea sculpturata* (see Blackwelder and Ward, 1979). The Castle Hayne Formation here contains a few shark teeth, coral molds, scattered oysters, and burrow structures.

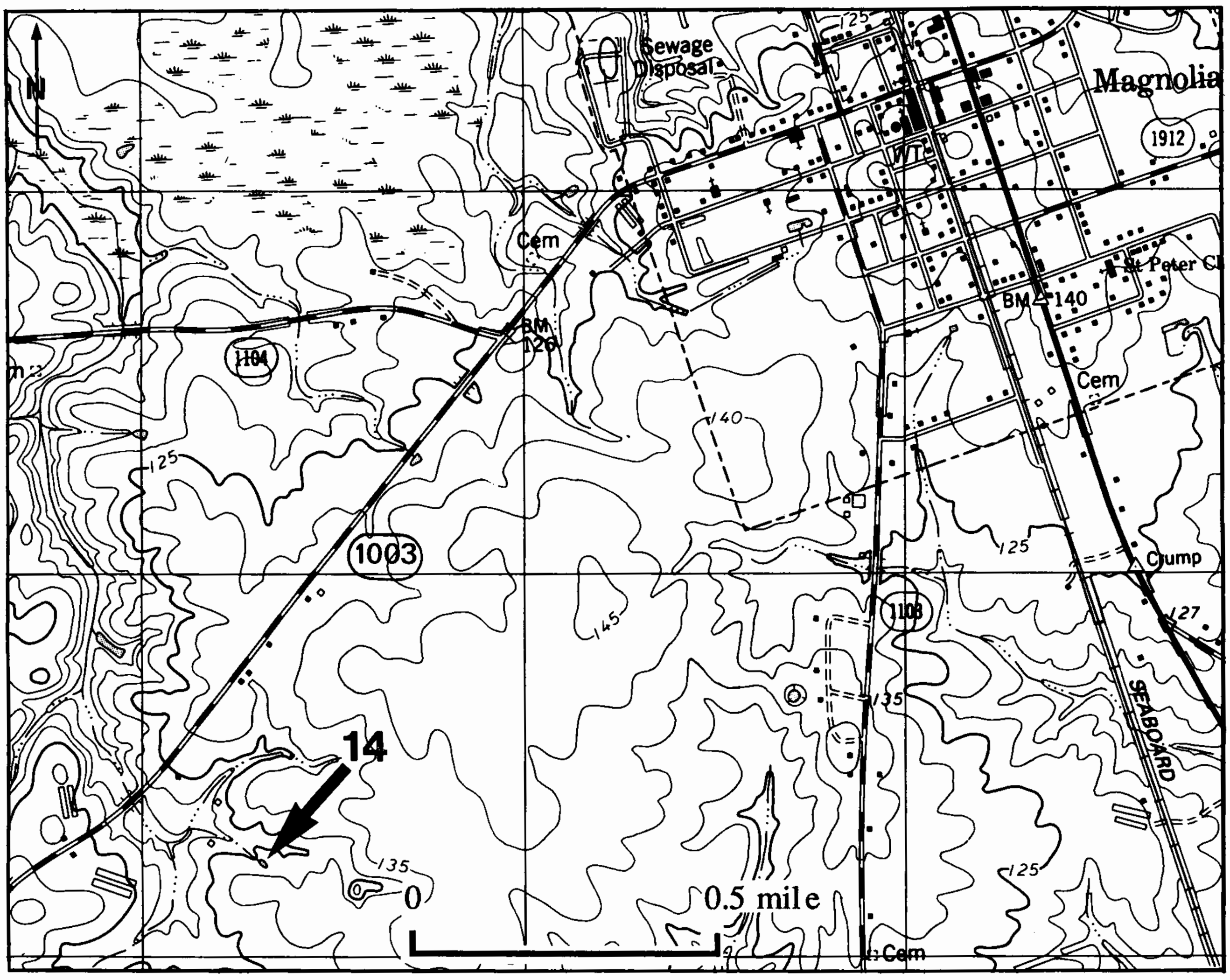

Figure 14.1 Locality 14. Natural Well. Warsaw South 7.5 minute quadrangle.

Figure 14.2. Natural Well. Unofficial type exposure of the Duplin Formation (= southern Yorktown Formation, between the arrows), plus overlying surficial deposits and the underlying Castle Hayne Formation, in a sink hole on the farm of Mr. Albert Matthews. The Duplin Formation is about 2 feet thick in this photograph. William Dall's (1895, p. 40) "Duplin marl" included both the present Duplin Formation and the underlying exposed Castle Hayne Formation. This shell bed has yielded well over two hundred species of fossil mollusks, including bivalves, gastropods, and scaphopods, plus brachiopods (e.g., *Discinisca lugubris*), barnacles, echinoid spines, and corals. This "Duplin fauna" is taxonomically richer than the northern Yorktown Formation of North Carolina north of the Neuse River. Many of the fossil mollusks found in this bed suffered extinction later during the Pliocene and early Pleistocene Epochs.

EDGECOMBE COUNTY
15. Old Sparta.

Age and Formation: Late Cretaceous Cape Fear Formation, Pliocene Yorktown Formation.

Location: Fossils are exposed on the west bank of Tar River, 0.4 mile downstream (southeast) from the N.C. Highway 42 bridge. This bridge is located on N.C. Highway 42 between the towns of Crisp and Conetoe. Old Sparta 7.5 minute quadrangle.

Access: This locality is best reached by boat. There is a boat ramp on the east side of the N.C. Highway 42 bridge over the Tar River.

Fossils: This bluff on the Tar River exposes about 20 feet of the Late Cretaceous Cape Fear Formation, overlain by about 18 feet of the Pliocene Yorktown Formation. The Cape Fear Formation consists of 12 feet of unfossiliferous, yellowish-brown, slightly micaceous, coarse-grained sand, overlain by 8 feet of gray, clayey, coarse-grained sand. Cobbles and phosphatic pebbles are concentrated along the unconformity separating the Cape Fear Formation from the overlying Yorktown Formation.

The Yorktown Formation consists of about 6 feet of brownish-gray to olive-gray, fine to medium-grained, fossiliferous sand, overlain by about 6.5 feet of brownish-gray to greenish-gray, medium-grained, abundantly fossiliferous sand, in turn overlain by 5.5 feet of poorly fossiliferous, thinly laminated clay. Bailey's (1973) faunal list for the Yorktown Formation at this locality includes a variety of scallops, oysters, and other bivalve and gastropod mollusks.

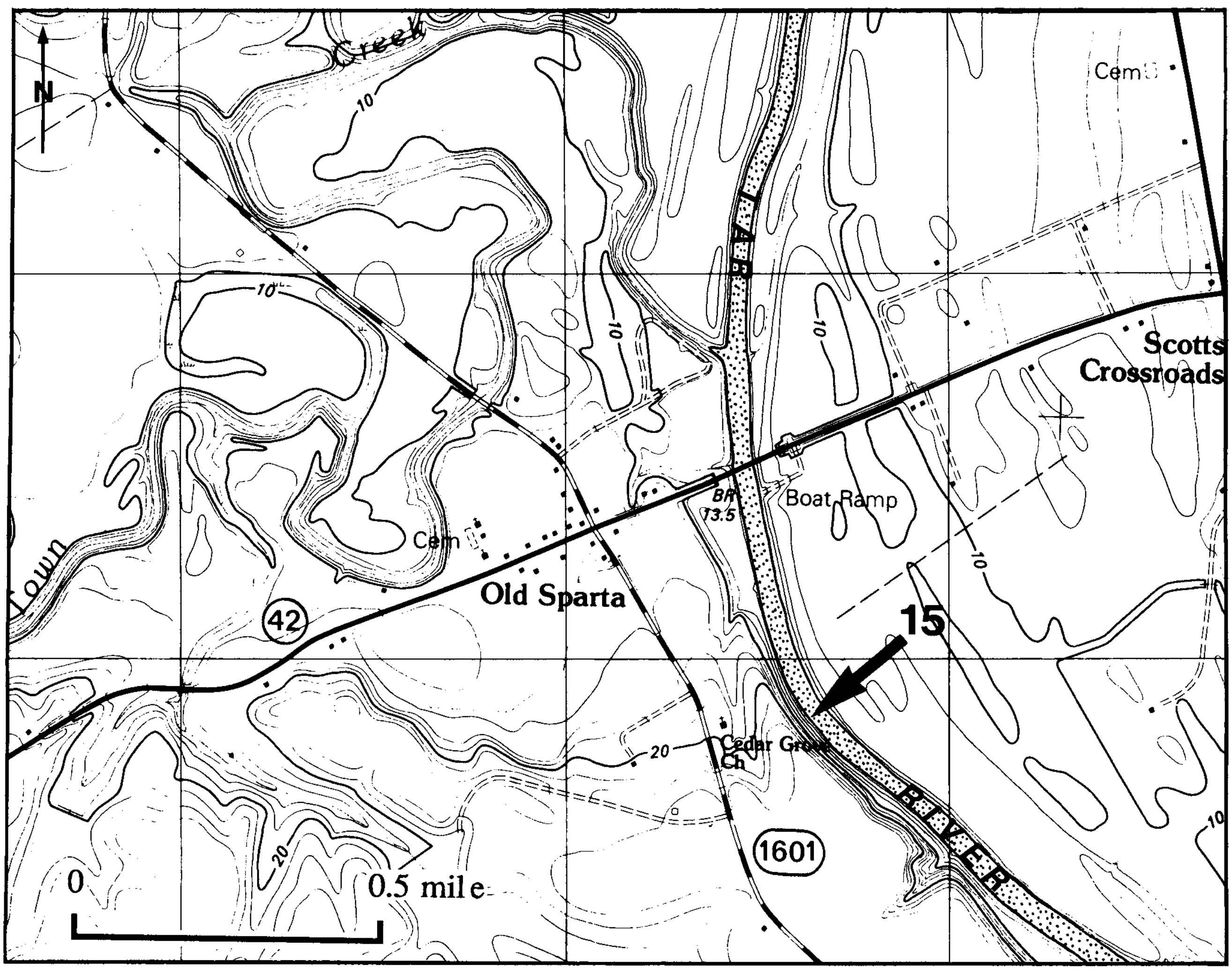

Figure 15. Locality 15. Old Sparta. Old Sparta 7.5 minute quadrangle.

16. Fishing Creek.

Age and Formation: Pliocene Yorktown Formation.

Location: Two fossiliferous exposures, 16A and 16B, occur on the west bank of Fishing Creek near the N.C. Highway 97 bridge about 8 miles north of Tarboro. Locality 16A is 70 yards north of the bridge; Locality 16B, is is 100 yards south of the bridge. Draughn 7.5 minute quadrangle.

Access: This locality may be easily reached on foot.

Fossils: Fossil mollusks are scattered throughout the 3- to 6-feet-thick exposure of the Yorktown Formation here. The Yorktown Formation consists of bluish-gray to yellowish-gray clayey sand. This is overlain by slumped, heavily vegetated, unfossiliferous gravelly sands. Many of the fossils at this locality are well preserved, but some occur as external and internal molds. Fossils include the bivalves *Chesapecten jeffersonius*, *Mercenaria corrugata*, *Ostrea sculpturata*, and the large mussel *Modiolus* sp., plus the gastropods *Busycon* and *Turritella*.

Two geologists working in North Carolina during the early to middle 19th century, Samuel Mitchill (ca. 1818) and Ebenezer Emmons (ca. 1852), reported diggings near Fishing Creek, about four miles from "Tarborough", turning up abundant fossil shells and partial whale skeletons. Their finds almost certainly came from the Yorktown Formation, and some of their fossils may have come from the present exposures.

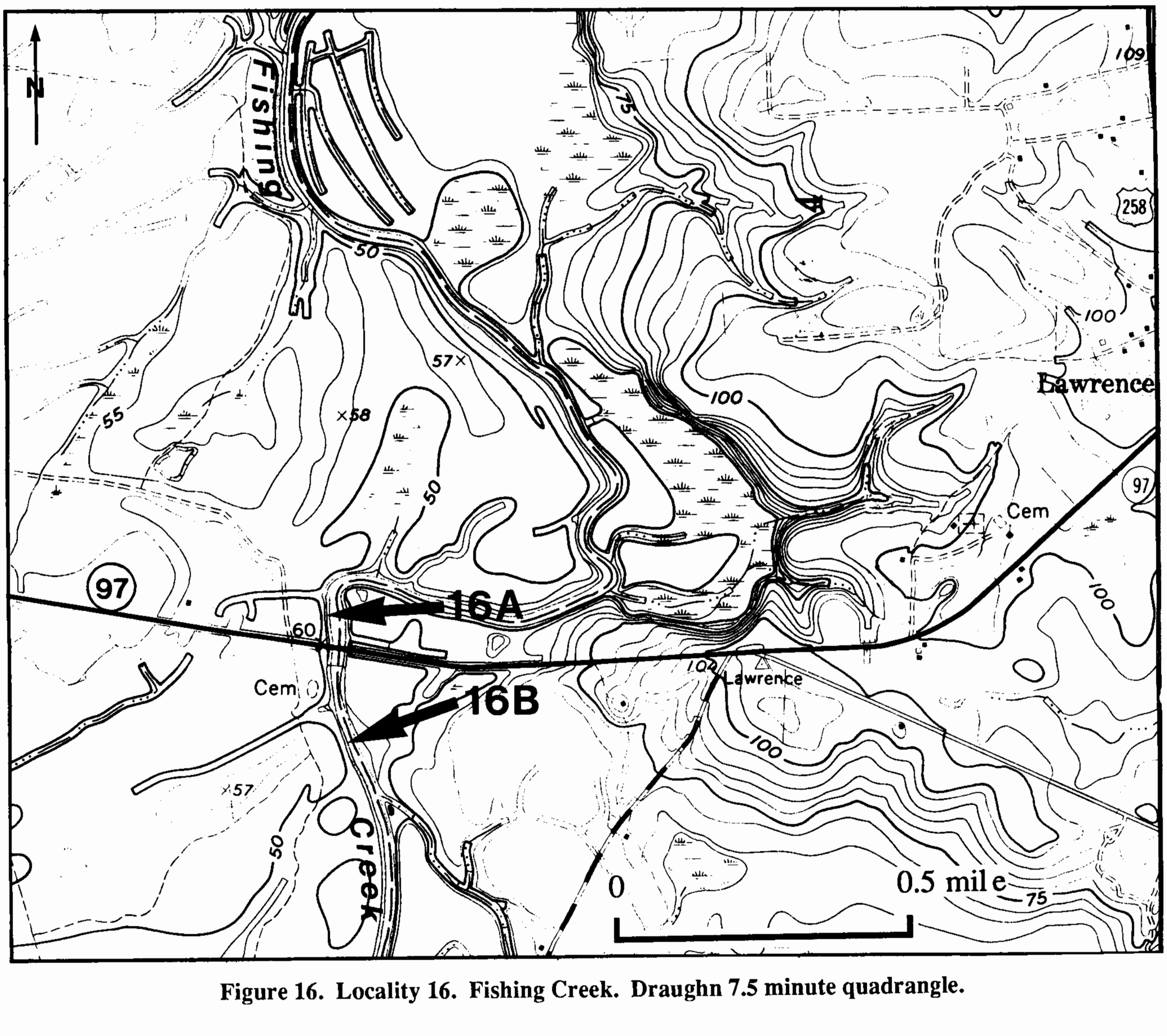

Figure 16. Locality 16. Fishing Creek. Draughn 7.5 minute quadrangle.

HALIFAX COUNTY
17. Quankey Creek.

Age and Formation: Pliocene Yorktown Formation.

Location: Fossils are exposed southwest of Halifax in a gully which intersects the south bank of Quankey Creek about 50 yards west of the Seaboard Coast Line Railroad tracks, 0.1 mile west of the U.S. Highway 301 bridge over Quankey Creek. This bridge is located 0.2 mile north of the intersection of U.S. Highway 301 and N.C. Highway 561. The fossils are exposed in the gully at the base of a bluff on the south side of the creek immediately northeast of a cemetery. Halifax 7.5 minute quadrangle.

Access: This locality is accessible by walking west (upstream) from the railroad bridge, following the south bank of the creek to the first gully. Access by the road leading to the cemetery near this locality is not permitted by the land owner.

Fossils: This locality exposes the Yorktown Formation which, with great unconformity, overlies Paleozoic or Precambrian granite and metamorphic rocks. Fossils are abundant in the basal Yorktown Formation, which consists of 3 feet of greenish-gray silt and sand with phosphatic and quartzite pebbles. This is overlain by about 18 feet of unfossiliferous, massive, cliff-forming, green to blue-green clay, sand and clayey sand, which is in turn overlain by 2 feet of irregularly bedded, light green to gray, unfossiliferous clay and silt.

Fossils here include the bivalves *Astarte stephensoni*, *Astarte roanokensis*, *Marvacrassatella undulata*, *Mulinia congesta*, *Dosinia acetabulum*, *Pitar sayana*, *Thracia conradi*, *Ostrea raveneliana*, and *Ostrea sculpturata*, plus many other molluscan species. The faunal list for this locality provided by Miller (1912, p. 207) is extensive, but requires some taxonomic revision. The fragile shells exposed here may be cleaned by drying and then rinsing away their sediment matrix with warm water.

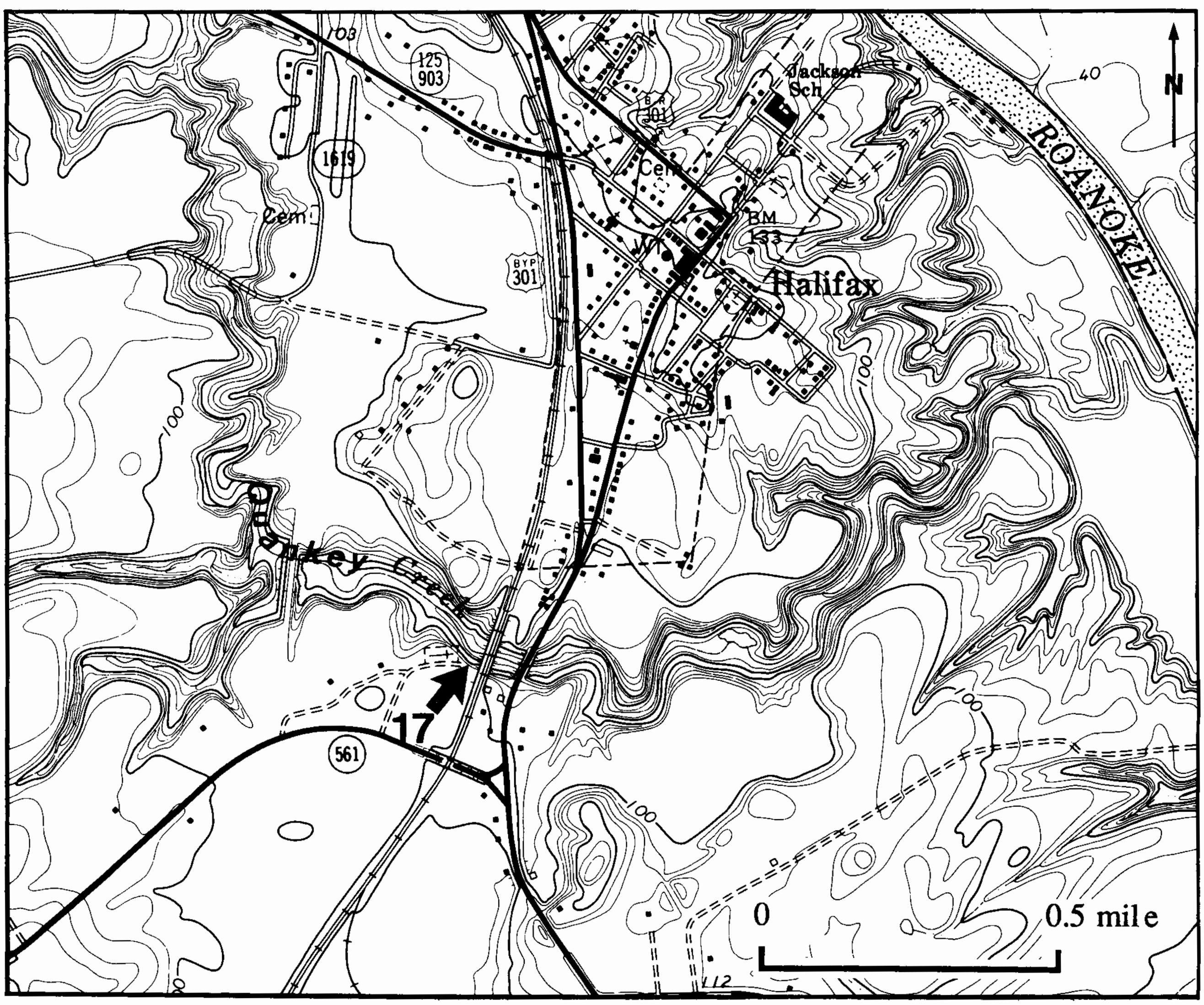

Figure 17. Locality 17. Quankey Creek. Halifax 7.5 minute quadrangle.

HERTFORD COUNTY
18. Meherrin River, Murfreesboro.

Age and Formation: Late Miocene Eastover Formation, Pliocene Yorktown Formation.

Location: Three fossil localities, 18A, 18B and 18C, are included here, all located on the Murfreesboro 7.5 minute topographic quadrangle in the vicinity of Murfreesboro.

Locality 18A is 20 to 100 yards west of the U.S. Highway 258 bridge on the south bank of the Meherrin River. Here the Sunken Meadow, Rushmere, and Morgarts Beach Members of the Yorktown Formation are exposed near the water level and along a gully perpendicular to the river bank.

Locality 18B is a magnificent exposure of the Cobham Bay Member of the Eastover Formation and the overlying Sunken Meadow, Rushmere, and Morgarts Beach Members of the Yorktown Formation, in a bluff 1.2 to 1.6 miles north by northwest of locality 18A, on the south bank of the Meherrin River.

Locality 18C exposes the Sunken Meadow, Rushmere and Morgarts Beach Members of the Yorktown Formation at Maddry's Bluff, about 1 mile downstream from the Highway 258 bridge over the Meherrin River.

Access: Locality 18A can be easily reached on foot from Highway 258 on the south side of the bridge over the Meherrin River. Localities 18B and 18C are best visited by boat. There is a N.C. Wildlife Commission boat ramp on the east side of Highway 258 just downriver from the north end of the bridge over the Meherrin River.

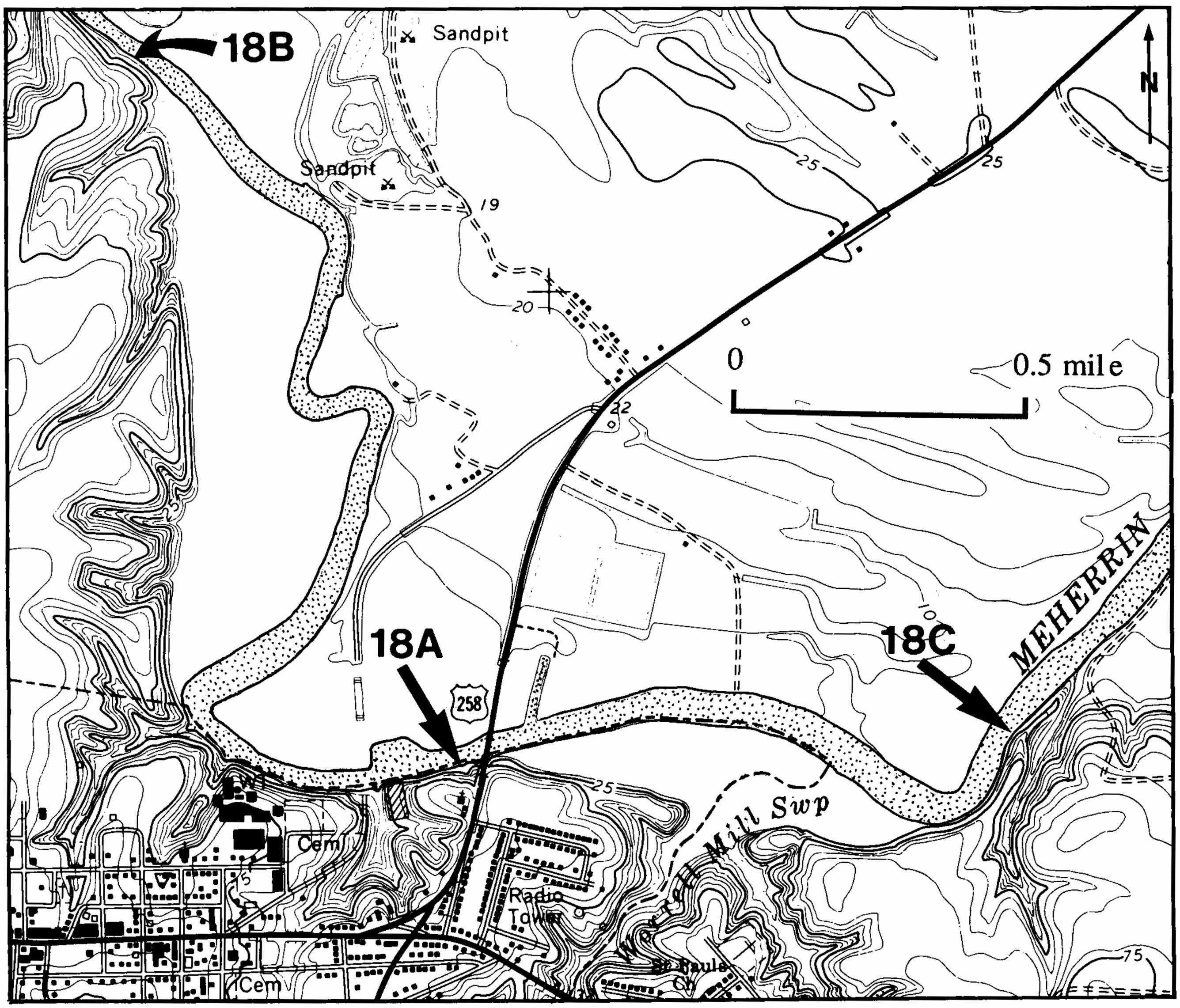

Figure 18.1. Localities 18A,B,C. Murfreesboro 7.5 minute quadrangle.

Fossils: At Locality 18B, the Cobham Bay Member of the Eastover Formation is exposed at normal water level, where it consists of a medium-grained, greenish to bluish-gray, phosphatic, silty sand. It contains the bivalves *Isognomon* sp., "*Dinocardium*" sp., *Glossus* sp., *Placopecten princepoides*, and *Chesapecten middlesexensis*, plus the gastropods *Ecphora* and *Calliostoma.*

Bailey (1987) placed the Eastover-Yorktown contact at locality 18B at the top of a 2- to 8-inch-thick bed containing "*Dinocardium*" sp. and *Placopecten princepoides* (this thin bed overlies a layer of densely packed *Isognomon* shells), and below a thin lag of sparse, reworked *Isognomon* sp., *Placopecten princepoides*, whale bones, phosphate pebbles, and shark teeth (see thick arrow in Text-Figure 18.2). Although appropriate as a lithologic boundary between these two formations, it may be noted that this does not correspond with the lowest occurrence of *Placopecten clintonius* in this section. This species occurs in the upper part of the "*Dinocardium*" and *Placopecten princepoides* bed, just below the disconformity between the Eastover and Yorktown Formations (see thin arrow in Text-Figure 18.2).

At Locality 18B, the basal Yorktown Formation (the Sunken Meadow Member) is lithologically similar to the upper Eastover Formation (Text-figure 18.2). Both units consist of greenish to bluish-gray, medium-grained, phosphatic, silty sand. However, the Sunken Meadow Member contains abundant *Placopecten clintonius* and only isolated, reworked shells of *Isognomon* sp. and *Placopecten princepoides.* The Sunken Meadow Member also contains the bivalves *Glossus, Cyclocardia*, "*Dinocardium*", *Chesapecten jeffersonius*, and forms transitional between the latter species and *Chesapecten middlesexensis.*

At Localities 18A and 18C, the base of the outcrop consists of the Sunken Meadow Member of the Yorktown Formation. At Locality 18A, the basal one foot of the Sunken Meadow Member is unweathered and greenish- to bluish-gray, but the overlying 8 feet of this member are weathered and light yellow to yellow-brown. The upper part of the Sunken Meadow Member is more fossiliferous than its lower part, and it contains abundant *Placopecten clintonius*, *Glossus* sp., *Glycymeris tuomeyi, Chesapecten jeffersonius, Ostrea disparilis, Lucinoma contracta, Astarte hertfordensis, Astarte undulata deltoidea*, and *Cyclocardia granulata.*

At localities 18A, 18B and 18C the next highest part of the Yorktown Formation, the Rushmere Member, consists of about 5 feet of bluish-green, clayey, silty, slightly phosphatic and glauconitic, shelly sand that weathers to a light grayish-orange. This unit is richly fossiliferous, containing the bivalves *Chesapecten septenarius, Chesapecten madisonius, Mercenaria corrugata* forms "tridacnoides" and "corrugata", the oyster *Ostrea raveneliana*, abundant representatives of *Astarte* and *Marvacrassatella*, and the gastropods *Turritella alticostata, Crepidula aculeata*, and *Fissuridea redimicula. Chesapecten jeffersonius* also occurs here, but it may be reworked from the underlying Sunken Meadow Member. The contact between the Rushmere and Sunken Meadow Members appears to be gradational, but it is locally marked by a zone of phosphatic sand and whale bones, suggesting a break in deposition (Bailey, 1987).

At localities 18A, 18B and 18C, the uppermost Yorktown Formation is represented by the Morgarts Beach Member. This consists of over 25 feet of light olive-gray, silty to sandy clay with lenses of gray to orange silt plus gray, silty clay. Limonite concretions and iron-oxide-stained molluscan molds are common in these beds. The fresh outcrop commonly appears massive, but weathered surfaces reveal distinct, horizontal bedding. The Morgarts Beach Member contains locally abundant *Mulinia congesta, Yoldia laevis*, and *Nucula proxima,* with less common *Carolinapecten eboreus, Panopea reflexa.*, and *Modiolus* sp. This unit also contains isolated corals (*Septastrea crassa*) and large, encrusting barnacles attached to the fossil shells.

Figure 18.2. Cliff-face exposure along the Meherrin River showing the contact between the Eastover Formation (below thick arrow) and the Sunken Meadow Member of the Yorktown Formation (above thick arrow) at Locality 18B. The thin arrow shows the lowest occurrence of *Placopecten clintonius.* The base of the section contains a bed of thick, pearly *Isognomon* shells in the Eastover Formation.

JONES COUNTY
19. Pollocksville.

Age and Formation: Oligocene River Bend Formation, Late Oligocene or early Miocene Pollocksville Member of the Belgrade Formation.

Location: This area contains two fossil localities, both of which are located on the Pollocksville 7.5 minute quadrangle. At Locality 19A, the Pollocksville Member of the Belgrade Formation is exposed on the north bank of the Trent River at the site of a former Atlantic Coast Line railroad bridge, about 100 yards east of the U.S. Highway 17 bridge over the Trent River, immediately north of Pollocksville. The bank is 20 to 25 feet high and extends for about 100 yards along the north bank of the river. The exposures are clearly visible from the Highway 17 bridge over the Trent River.

At locality 19B, the River Bend Formation is exposed along the south and southeast banks of the Trent River 0.4 to 0.5 mile downstream (east) from Pollocksville.

Access: Localities 19A and 19B are readily accessible by boat. There is a boat ramp in Pollocksville which may be reached by a dirt road located about 50 feet south of the Trent River, on the east side of U.S. Highway 17. This is the first dirt road south of the bridge. This road parallels the river for about 150 feet, then curves left (north) toward the river.

Fossils: At Locality 19A, large oysters (*Crassostrea* sp.) and plates of the barnacle *Lophobalanus baumi* and *Concavus crassostricola* occur in the light yellow-brown, slightly clayey, non-indurated sands of the Pollocksville Member of the Belgrade Formation. These are accompanied by polydorid worm tubes, boring sponges, echinoid spines, and rare bivalves of the genus *Nuculana*. At Locality 19B, the River Bend Formation downstream from Pollocksville contains barnacles, scallops (e.g., *Pecten trentensis*) and a few gastropods (e.g., *Calyptraea aperta*).

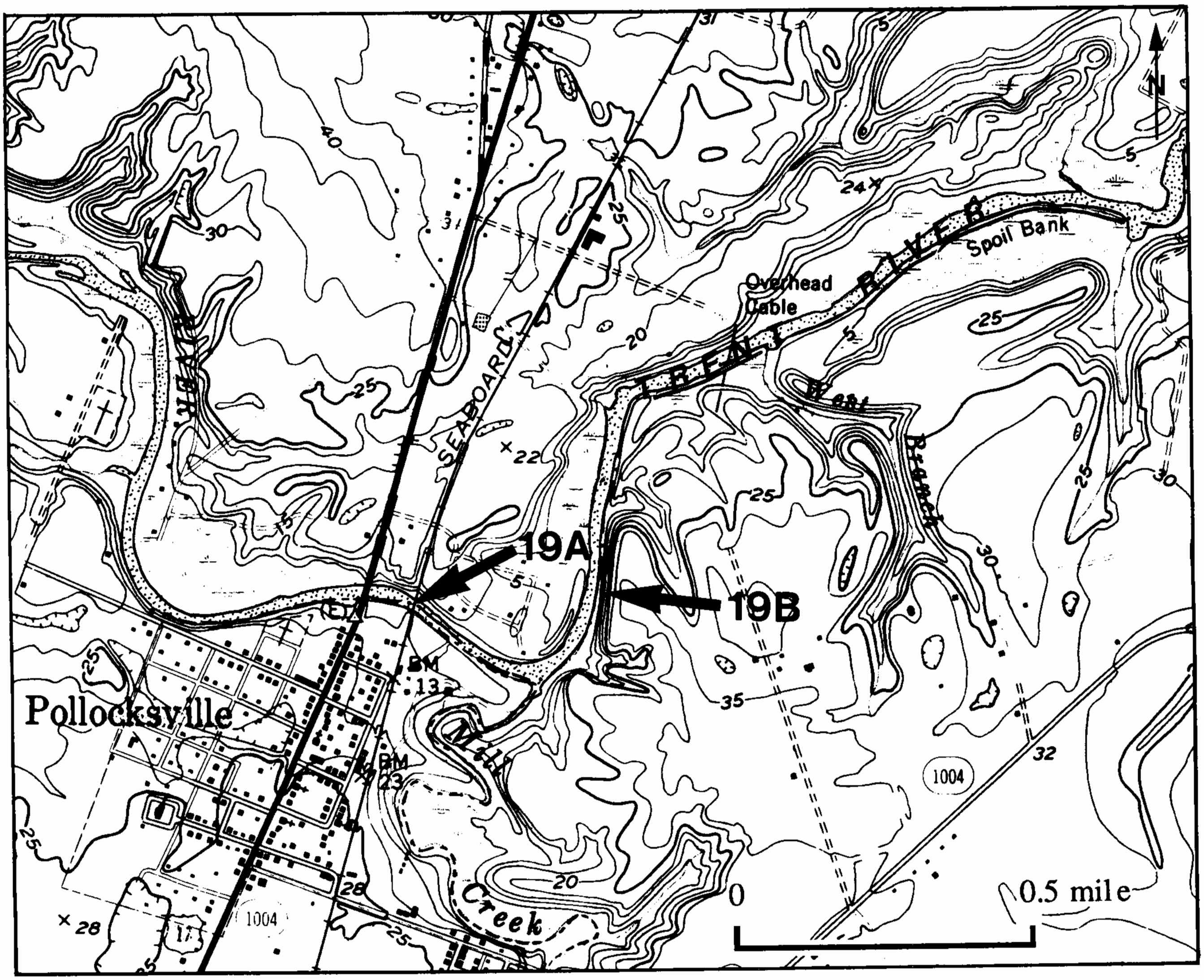

Figure 19. Localities 19A,B. Pollocksville. Pollocksville 7.5 minute quadrangle.

20. Haywood Landing.

Age and Formation: Late Oligocene to early Miocene Haywood Landing Member of the Belgrade Formation. This is the type locality of the Haywood Landing Member defined by Ward, Lawrence, and Blackwelder (1978).

Location: To reach Haywood Landing, travel 7.0 miles southeast of Maysville on N.C. Highway 58, then turn right (southeast) onto Croatan National Forest Road. This narrow gravel road is marked on the southwest side of N.C. Highway 58 by a small sign erected by the N.C. Wildlife Commission. There is a church on the northeast side of N.C. Highway 58 just a few tens of yards southeast of this small sign. After turning onto Croatan National Forest Road, proceed southwest on the gravel road for 0.05 mile, then turn right (west) and continue 1.8 miles to a "T" intersection. Turn right and proceed 0.4 miles to the boat ramp at Haywood Landing. Stella 7.5 minute quadrangle.

There are two fossiliferous exposures at this locality. Locality 20A occurs in the east bank of the Whiteoak River, about 25 yards southwest of the boat ramp. There is a short trail leading to this exposure from the picnic table area. Fossil shells, including abundant *Stewartia anodonta*, may be collected on the exposed surface of this bank.

Locality 20B is located in a small gully on the edge of the swamp immediately north of the access road to the boat ramp. Shells may be collected in abundance from the sediment exposed in this gully. Smaller gastropod shells are especially diverse here.

Access: These two exposures are readily accessible on foot. Only surface collecting is permitted here; digging is not allowed on National Forest lands.

Fossils: The fossils exposed at localities 20A and 20B are mostly small bivalves and gastropods, but these are abundant and diverse. The more common species include the bivalves *Stewartia anodonta* (=*Phacoides nocariensis* of Kellum, 1926), *Glyptoactis* (*Glyptoactis*) *nodifera*, *Anadara silverdalensis*, *Donax idoneus*, *Cyclocardia* sp., and *Crassostrea* sp., plus the gastropods *Polinices duplicata*, *Cymatophos* sp., *Rapana vaughani*, and *Rapana gilletti*. Small shark teeth are fairly common here, as well as crushing plates from the ray *Myliobatis*.

Localities 20A and 20B contain the best preserved fossil mollusks for their age along the Atlantic Coast of North America. When these animals were alive, the Western Atlantic was undergoing major changes in both its chemistry and patterns of shallow-shelf sedimentation. Prior to this time, during the Oligocene Epoch, the Atlantic Ocean was relatively low in nutrients, and its sediments deposited in North Carolina were typically rich in calcium carbonate (limestone). After Haywood Landing time, limestone deposition became less common in North Carolina. Additionally, especially during the lower Miocene, nutrient levels increased significantly in the Western Atlantic from Virginia to Florida, resulting in the formation of extensive phosphate deposits, e.g., in the lower to middle Miocene Pungo River Formation. These oceanographic changes were accompanied by the extinction of many reef-building corals in the tropical Western Atlantic, and a simultaneous evolutionary radiation of bivalve and gastropod mollusks.

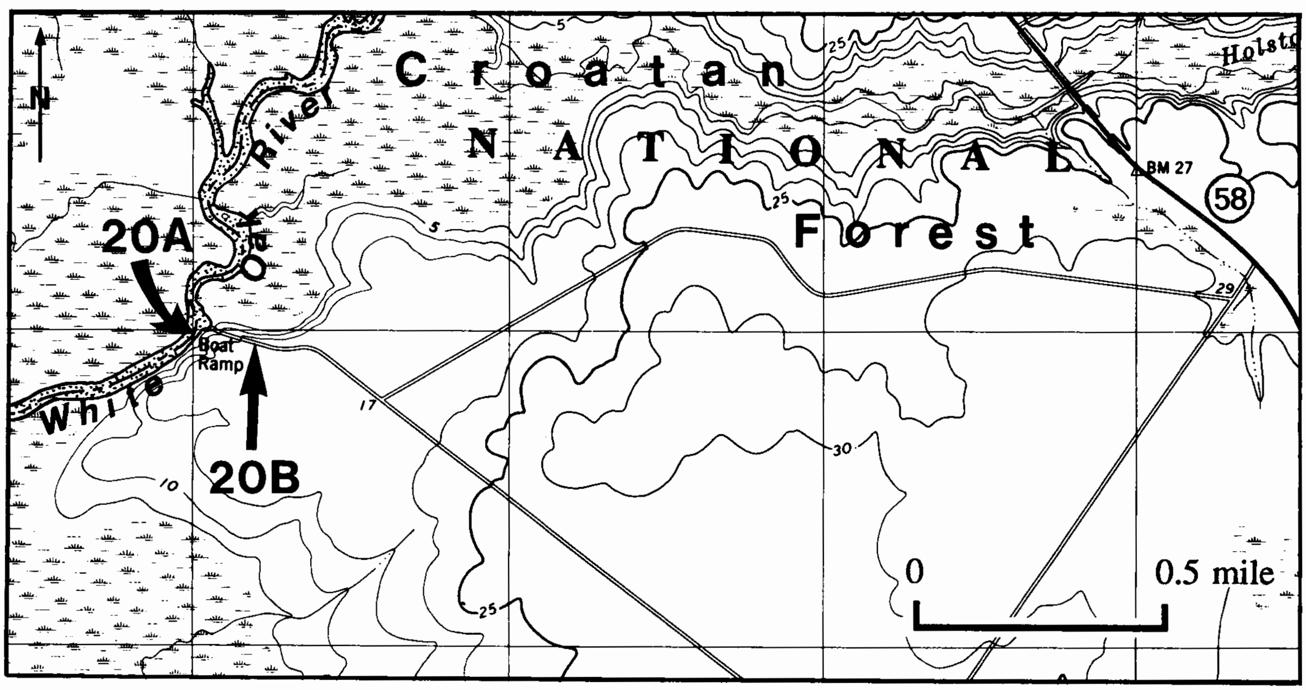

Figure 20. Localities 20A,B. Haywood Landing. Stella 7.5 minute quadrangle.

LENOIR COUNTY
21. Mosley Creek.

Age and Formation: Paleocene Beaufort Formation, Eocene Castle Hayne Formation.

Location: Fossils are exposed along the banks of Mosley Creek northeast of Kinston, upstream and downstream from the N.C. Highway 55 Bridge over Mosley Creek. To reach the bridge, start at the intersection of N.C. Highway 11 with N.C. Highway 58 in Kinston, and proceed northeast on N.C. Highway 11 for 3.6 miles. Turn right (east) onto N.C. Highway 55, and continue 4.5 miles to the bridge over Mosley Creek. Grifton 7.5 minute quadrangle.

Fossils: Fossils are common but not diverse in the Beaufort Formation at this locality. This consists of about 6 feet of olive-gray, glauconitic, soft to moderately hard, clayey sandstone. The fossils are scattered throughout the formation, but they weather out and concentrate in the creek bed. The more common Paleocene fossils include the oysters *Pycnodonte dissimilaris* and *Ostrea* sp., and the brachiopod *Oleneothyris harlani.* The nautiloid cephalopod *Eutrephoceras sloani* has also been found here (Bailey, 1976).

The Eocene Castle Hayne Formation, which overlies the Beaufort Formation in this area, contains the echinoids *Maretia subrostrata, Protoscutella mississippiensis rosehillensis*, and *Santeelampas oviformis* (see Kier, 1980).

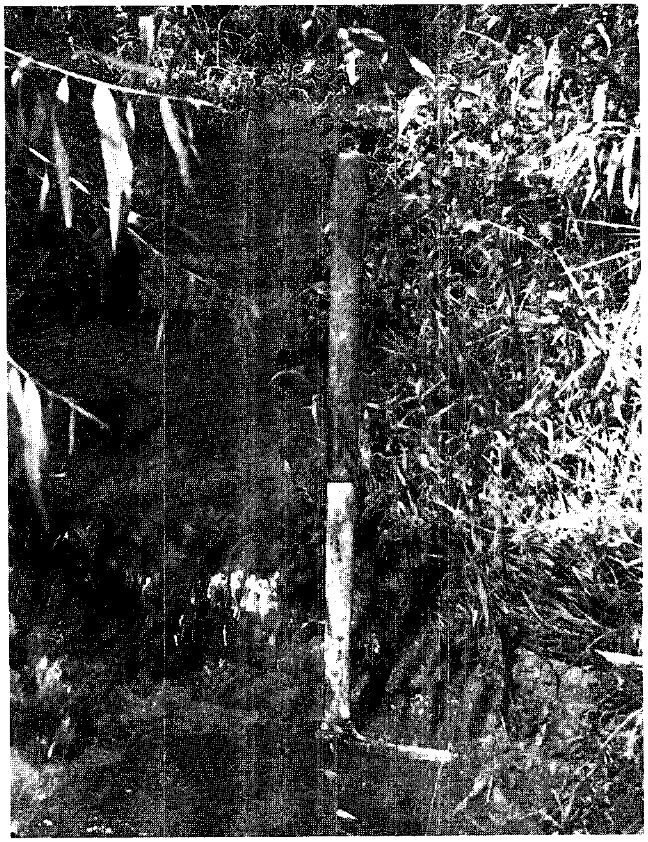

Figure 21.1 Exposure of the Beaufort Formation along Mosley Creek, Locality 21.

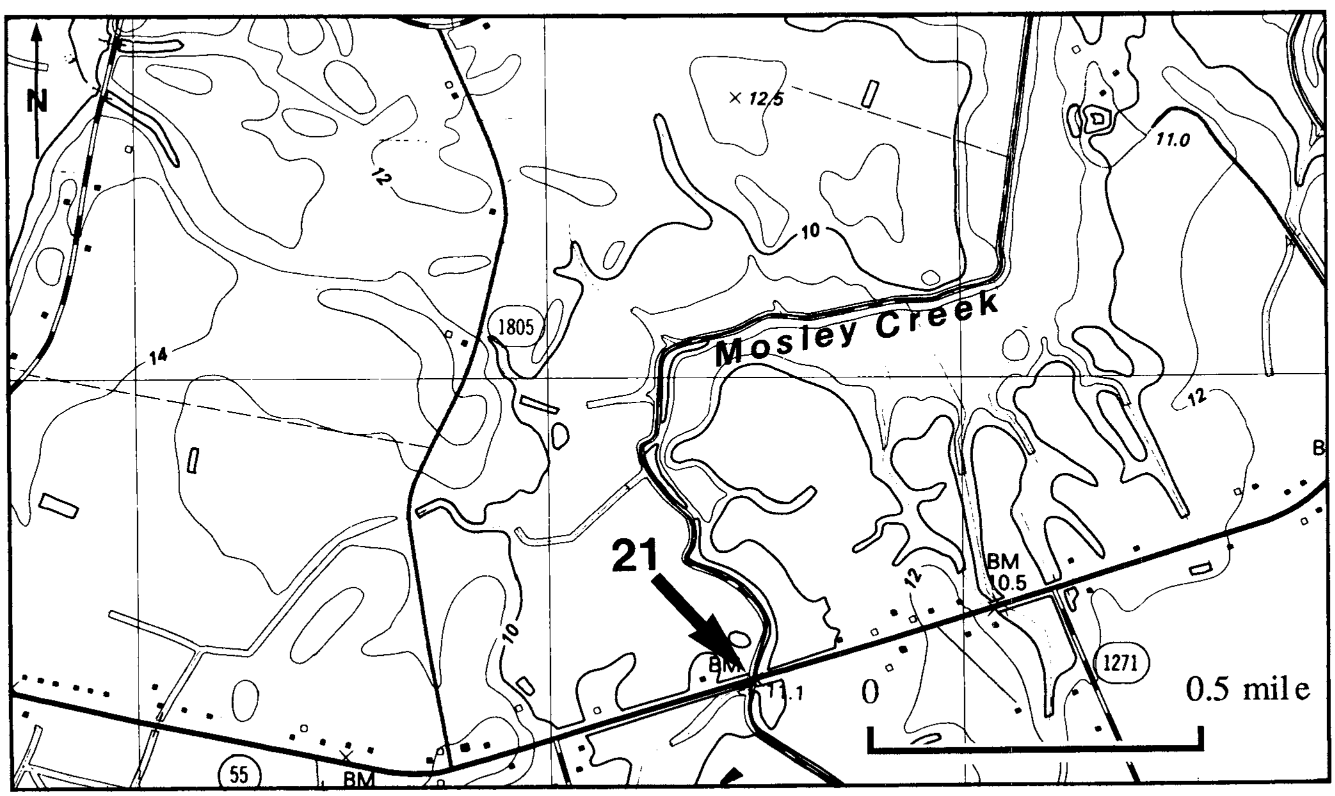

Figure 21.2. Locality 21. Mosley Creek. Grifton 7.5 minute quadrangle.

22. Whitleys Creek Landing.

Age and Formation: Late Cretaceous Black Creek Formation.

Location: Fossils are exposed on the south bank of the Neuse River about 100 yards east (downstream) from Whitleys Creek Landing on the Neuse River. To reach Whitleys Creek Landing, start at the intersection of N.C. Highway 55 and U.S. Highway 258 southwest of Kinston, and proceed west on N.C. Highway 55 to Jacksons Cross-roads. Continue west on N.C. Highway 55 for 2.15 miles to a narrow, dirt road on the right (north) side of N.C. Highway 55. (This dirt road can also be reached by traveling east of

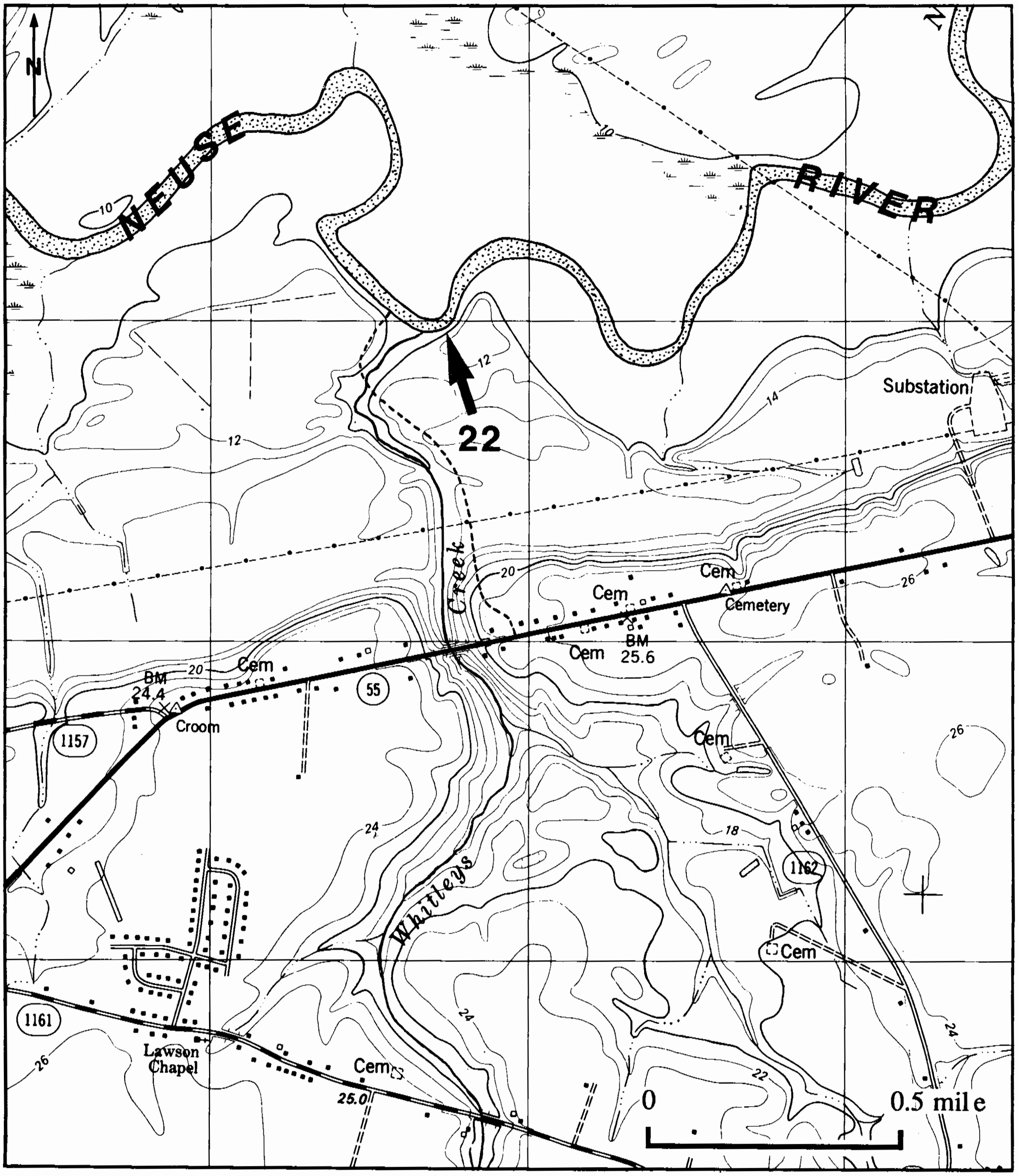

Figure 22.1. Locality 22. Whitleys Creek Landing. Deep Run 7.5 minute quadrangle.

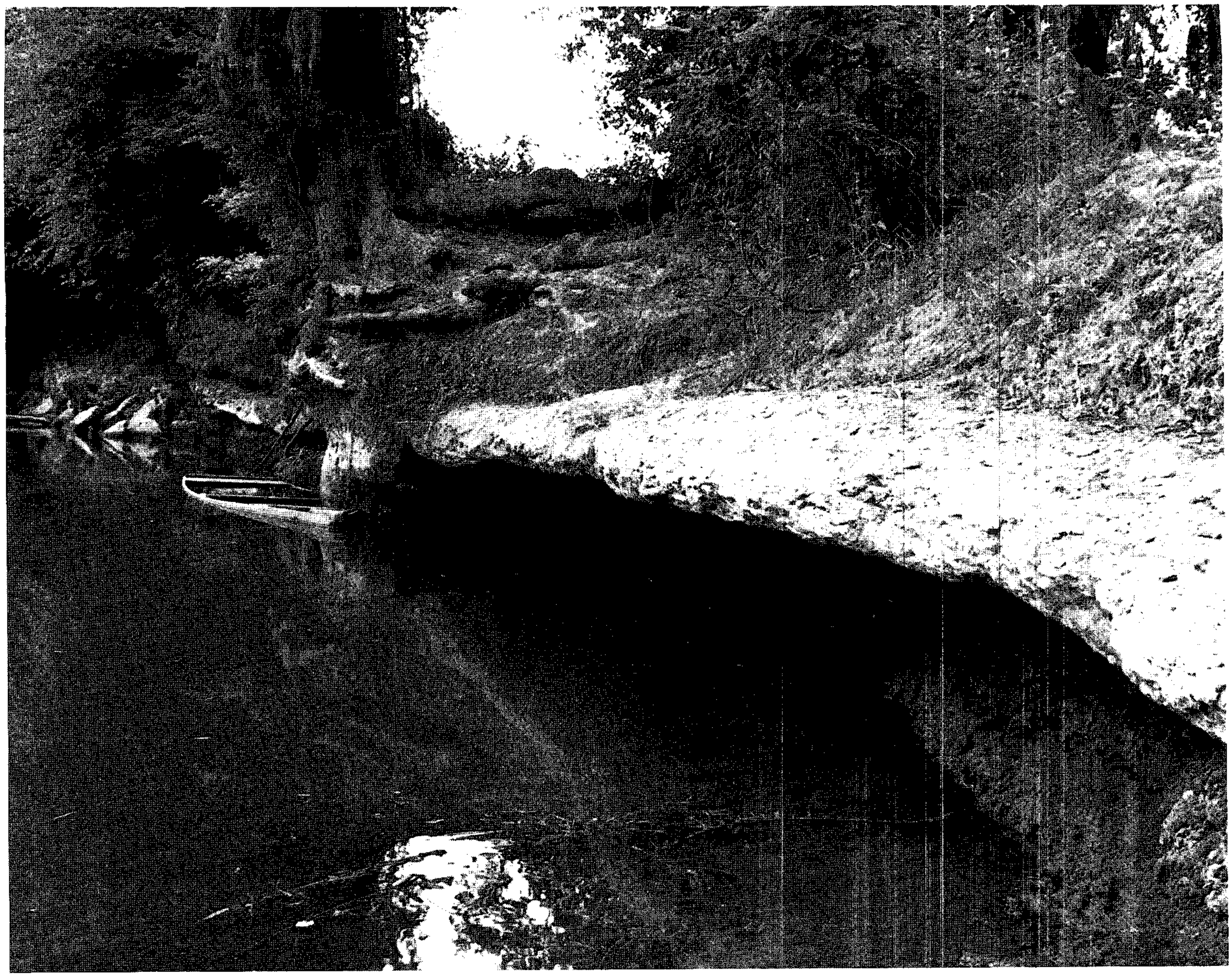

Figure 22.2. Exposure of the Black Creek Formation near Whitleys Creek Landing on the Neuse River.

Seven Springs on N.C. Highway 55 to Sandy Bottom, and then proceeding 1.2 miles farther east on N.C. Highway 55 to the dirt road). This dirt road is located immediately east of the intersection of N.C. Highway 55 with Whitleys Creek. From the intersection of the dirt road with N.C. Highway 55, proceed north 0.65 miles to Whitleys Creek Landing. Deep Run 7.5 minute quadrangle.

Access: Permission is required to use the dirt access road to Whitleys Creek Landing. However, this locality can also be visited by boat. The nearest public boat access is a N.C. Wildlife Commission access ramp on the east side of the Neuse river near the U.S. Highway 70 by-pass bridge in Kinston. Whitleys Creek Landing is about 8 miles upstream (west) from this boat access, and is located at milepost 60 on the Neuse River.

Fossils: The Black Creek Formation here consists of a 3-feet-thick exposure of fossiliferous, dark greenish-gray, micaceous, glauconitic, mottled tannish-orange, clayey sand, overlain by 1.5 to 4 feet of very fossiliferous, pale yellowish-brown, glauconitic, sandy limestone. The limestone forms a ledge along the south bank of the river. The upper part of the bank is now slumped, but Stephenson (1923) reported about 6 to 9 feet of Pleistocene gravel, sand and clay overlying the Black Creek Formation here.

Cretaceous fossils from this locality were listed by Stephenson (1912, p. 137; 1923, p. 18). Although generally moldic, some of the fossil mollusks preserve their original aragonite. However, these shells are generally fragile and difficult to collect without breaking. Calcitic oysters, such as *Flemingostrea subspatulata*, *Ostrea plumosa* and *Exogyra costata*, are often well preserved and easy to collect.

NEW HANOVER COUNTY
23. Northeast Cape Fear River, Wilmington.

Age and Formation: Late Cretaceous Peedee Formation.

Location: From the intersection of U.S. Highway 117 and 6th Street in Wilmington, proceed north on 6th Street 0.2 mile to the railroad tracks, then turn left (west) onto the dirt road (Seaboard Coast Line maintenance road). You will reach this dirt road before crossing the railroad tracks. Follow the dirt road for 500 feet to the Northeast Cape Fear River. Fossils are exposed on the east bank of the Northeast Cape Fear River immediately north of the Seaboard Coast Line Railroad Bridge. Castle Hayne 7.5 minute quadrangle.

Access: The accessibility of the outcrop changes with the water level, which varies as much as 6 feet with the tide. During low water, when the river level is 14 feet below the railroad trestle bridge, a 6-feet-thick section of the Cretaceous Peedee Formation is exposed.

Fossils: Fossil mollusks such as the oyster *Exogyra costata* are scattered throughout this exposure of the Upper Cretaceous Peedee Formation, which consists of greenish-gray, clayey sand with indurated nodules of calcareous sandstone.

Figure 23.1 Exposure of the Peedee Formation along the Northeast Cape Fear River, Locality 23.

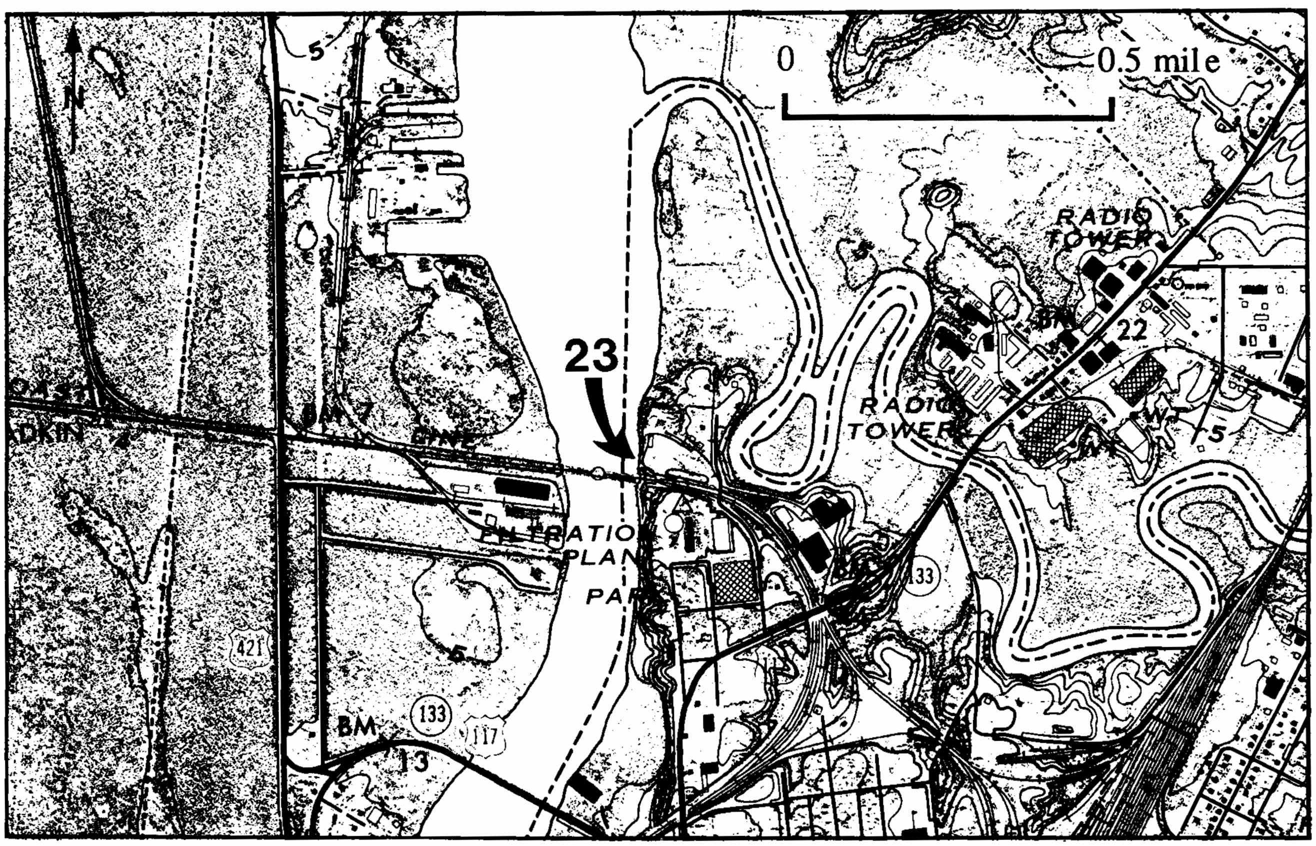

Figure 23.2. Locality 23. Northeast Cape Fear River. Castle Hayne 7.5 minute quadrangle.

24. Snow's Cut.

Age and Formation: Late Pleistocene Canepatch (?) Formation.

Location: Fossils are exposed on both sides of Snow's Cut in outcrops 0.4 mile west of the U. S. Highway 421 bridge north of Carolina Beach. The exposure on the north side of the cut contains the most abundant and least fragmented fossils. This north exposure may be reached from a path that turns south off SR 1100, 0.3 mile west of its intersection with State Road 1576. To reach State Road 1576, turn west off U.S. Highway 421 onto River Road, 0.1 mile north of the canal, then take an immediate left onto SR 1576. Carolina Beach 7.5 minute quadrangle.

Fossils may be seen, but not collected, from another exposure of this formation along the beach near Fort Fisher (Figure 24.1; not shown in Figure 24.2). Fort Fisher is located at the southern end of U.S. Highway 421, just south of Snow's Cut.

Fossils: The late Pleistocene sediments at Snow's Cut are tentatively correlated with the Canepatch Formation. They consist of a yellowish-orange to grayish-orange, sandy coquina, containing primarily weakly cemented to well indurated, abraded, locally cross-bedded, transported shell debris. Fossils include the bivalves *Rangia cuneata*, *Mulinia lateralis*, *Mercenaria mercenaria*, *Noetia ponderosa*, *Crassostrea virginica*, *Donax variabilis*, *Tagelus plebeius*, and *Lunarca ovalis*, plus the gastropods *Nassarius obsoleta* and *Nassarius trivittatus*.

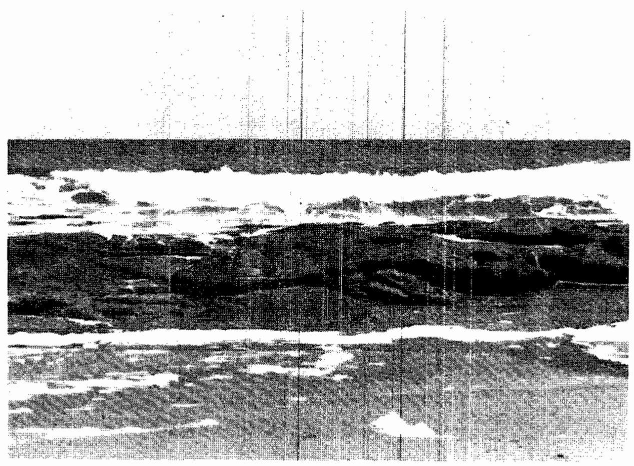

Figure 24.1. Rocky exposures of late Pleistocene sediments on the beach at Fort Fisher, south of Snow's Cut (not shown in Figure 24.2).

These same species are contained in the rocks exposed on the beach at Fort Fisher. However, the Fort Fisher fossils should not be collected, as they are part of a protected N.C. Natural Heritage Site.

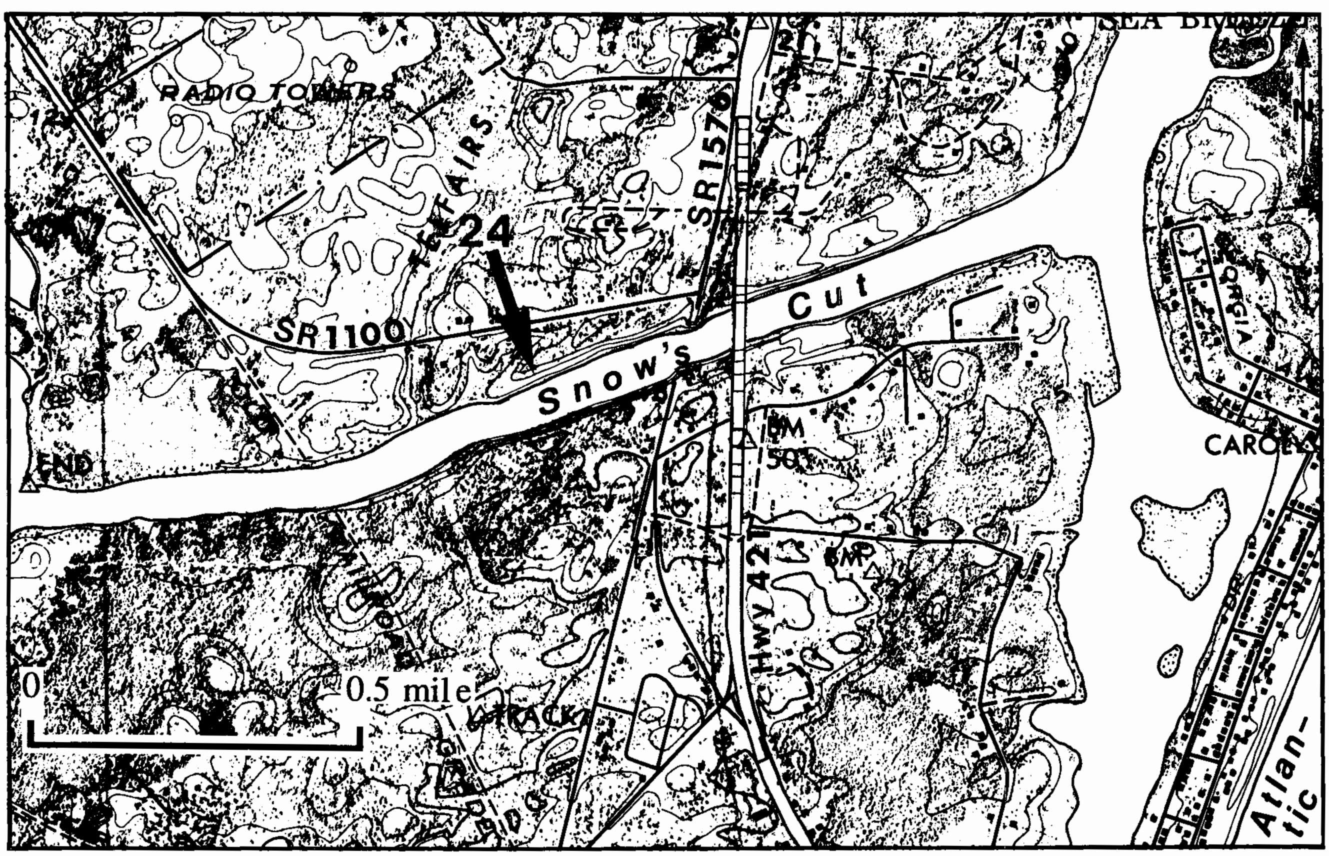

Figure 24.2. Locality 24. Snow's Cut. Carolina Beach 7.5 minute quadrangle.

NORTHAMPTON COUNTY
25. Kirbys Creek.

Age and Formation: Pliocene Yorktown Formation.

Location: Travel 4.3 miles east on U.S. Highway 158 from its intersection with N.C. Highway 35 in Conway; turn left (north) onto SR 1364 and travel 2 miles; turn left onto SR 1362 and travel 0.3 mile to the bridge over Kirbys Creek (the former site of Watson's Mill). Fossiliferous exposures are on the east bank of the creek under the bridge, and downstream about 75 yards. Conway 7.5 minute quadrangle.

Access: This locality is readily accessible on foot. In the older literature, this locality was referred to as Watson's Mill.

Fossils: The Rushmere Member of the Yorktown Formation is exposed under the bridge, where it consists of about 3 feet of dark greenish-gray, fine-grained, clayey sand, which weathers to an orange-brown color. Common fossils here include the scallops *Chesapecten jeffersonius*, *Chesapecten madisonius*, *Placopecten clintonius*, *Mercenaria corrugata* form "rileyi", *Astarte hertfordensis meherrinensis*, *Caryocorbula conradi*, and *Thracia conradi*. Some of these fossils (e.g., *Chesapecten jeffersonius*) may be reworked from the underlying Sunken Meadow Member of the Yorktown Formation. The Sunken Meadow Member is not exposed at the bridge, but it is exposed at normal water level about 100 yards downstream from the bridge.

A low bluff on the east side of the creek, about 50 yards downstream (north) of the bridge, exposes about ten feet of the Morgarts Beach Member of the Yorktown Formation. This member consists of clayey, silty sand capped by a thin, calcareous siltstone. The silty sand here contains local concentrations of the bivalves *Mulinia congesta* and *Yoldia laevis*. The overlying calcareous siltstone contains abundant *Mulinia congesta* and a few *Chesapecten madisonius*. The underlying Rushmere Member is here covered by slumped Morgarts Beach sediments.

Figure 25.1. Exposure of the Yorktown Formation along Kirbys Creek, Locality 25.

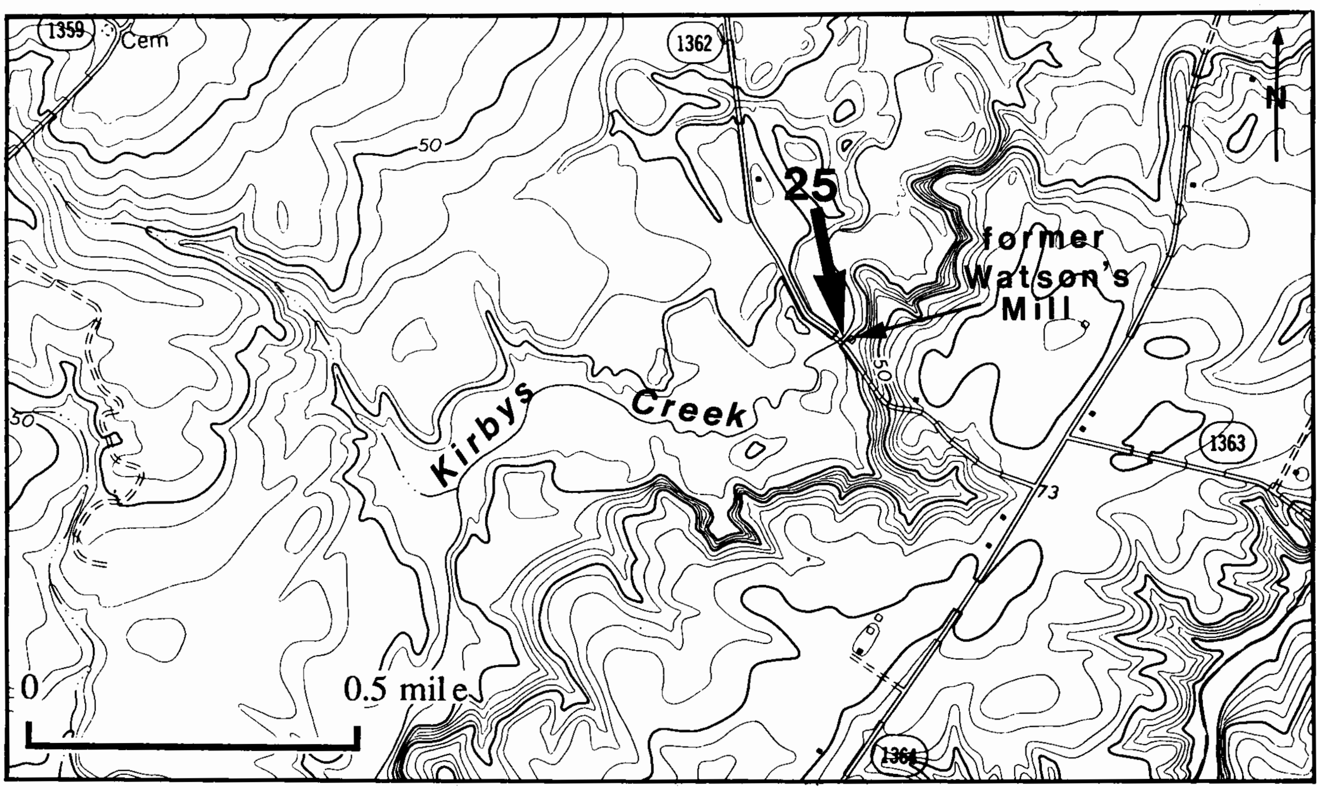

Figure 25.2. Locality 25. Kirbys Creek. Conway 7.5 minute quadrangle.

PENDER COUNTY
26. Lanier and Holly Creek Pits.

Age and Formation: Eocene Castle Hayne Formation.

Location: Fossils are exposed in two adjacent marl pits (Localities 26A and 26B) southeast of Maple Hill. From the intersection of SR 1532 with N.C. Highway 50, proceed southwest 0.4 mile along SR 1532 to the dirt road at the cemetery. Turn south (left) onto the dirt road and drive 0.3 mile to the first pit on the right (west) side of the road. This is the Lanier pit (locality 26A). Proceed another 0.2 mile to the Holly Creek pit, which is at the end of the road (locality 26B). This second pit is operated by Mr. Esley Jones. Maple Hill and Maple Hill SW 7.5 minute quadrangles.

Access: This locality is readily accessible on foot.

Fossils: These pits expose several feet of the Comfort Member of the Castle Hayne Formation, overlain by surficial orange and light-brown, unfossiliferous, silty sands. Fossils reported from these pits include barnacles, calcareous sponges, the brachiopods *Plicatoria wilmingtonensis*, *Tanyoscapha glabra*, *Tanyoscapha sigmanae*, *Terebratulina* cf. *T. lachryma*, and *Rhynchonella salpinx*; the bryozoans *Centronea micropora*, *Lunulites oblongus*, *Antropora octonaria*, *Hornera*, and *Schizoporella*; the cephalopods *Aturia alabamensis*, *Eutrephoceras carolinensis* and *Belosepia* sp.; the corals *Endopachys*, *Balanophyllia*, and *Flabellum*; carapaces and claws of the crab *Ranina (Lophoranina)* cf. *R. (L.) georgiana*; abundant scallop shells; molds of other bivalve and gastropod mollusks; and a great diversity of echinoids, including *Echinolampas appendiculata*, *Periarchus lyelli*, *Echinocyamus parvus*, *Echinocyamus bisexus*, *Unifascia carolinensis*, *Dixieus* cf. *D. dixie*, *Linthia hanoverensis*, *Linthia wilmingtonensis*, *Cidaris pratti*, *Maretia subrostrata*, and *Agassizia wilmingtonica wilmingtonica* (see Kier, 1980).

Eocene vertebrate fossils are likewise abundant and diverse. They include teeth of the sharks *Lamna* cf. *twiggensis*, *Odontaspis* cf. *O. cuspidata*, *Odontaspis* cf. *O. acutissima*, *Galeorhinus huberensis*, and *Procarcharodon auriculatus*, as well as mouth plates from the ray *Myliobatis*, and spines from the bony fish *Cylindracanthus*.

These exposures of the Eocene Castle Hayne Limestone represent tropical, carbonate (limestone) environments comparable to the modern Bahamas Banks. The bryozoan and sponge fossils collected from these pits are famous for their diversity and distinctive taxonomic composition.

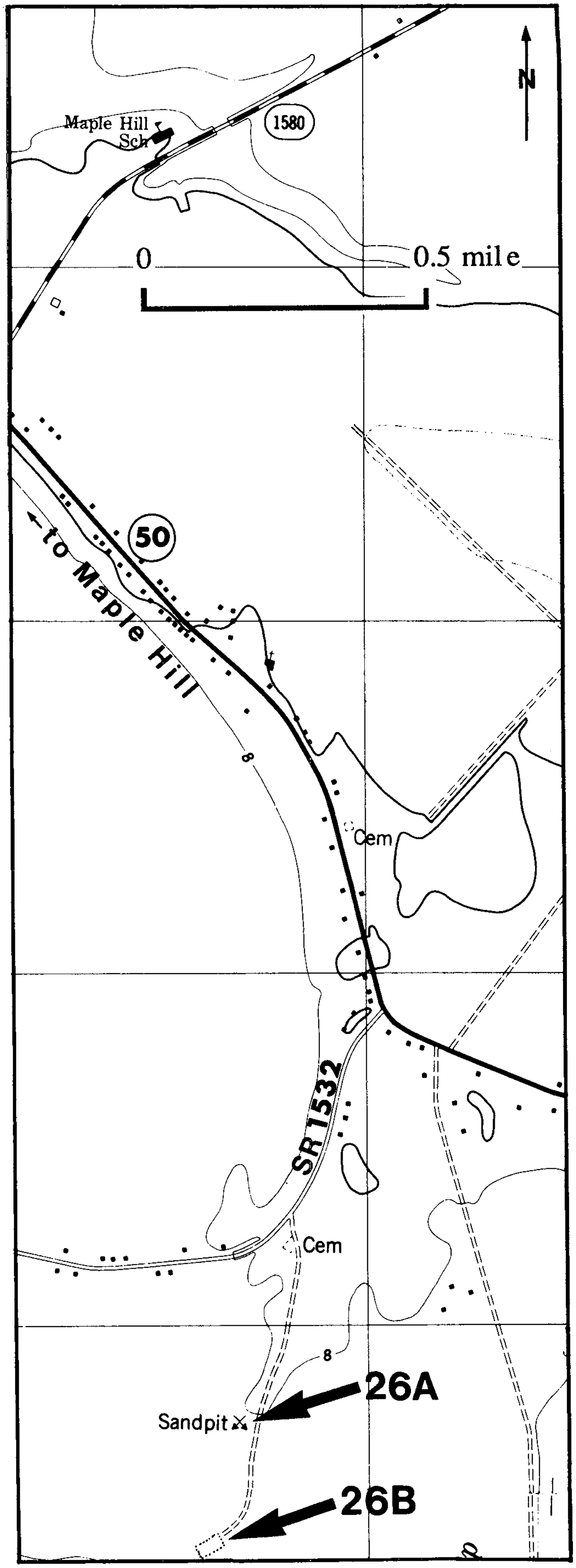

Figure 26. Localities 26A,B. Lanier (26A) and Holly Creek (26B) Pits, Maple Hill and Maple Hill SW 7.5 minute quadrangles.

PITT COUNTY
27. Blue Banks Landing.

Age and Formation: Late Cretaceous Black Creek Formation.

Location: Fossils are exposed on the southwest bank of the Tar River, 4.0 miles northwest of Greenville. The nearest N.C. Wildlife Commission boat access is near Falkland, on SR 1400 about one mile east of the intersection of SR 1400 with N.C. Highway 43. The boat access is approximately four miles upstream (northwest) from Blue Banks Landing. Greenville NW 7.5 minute quadrangle.

Access: This locality is best visited by boat.

Fossils: The lower 6.5 feet of these bluffs are covered with slumped sediments. Above this, the Black Creek Formation consists of 3 feet of dark-green, fossiliferous, glauconitic, micaceous, sandy calcareous clay, overlain by 4 feet of fissile, dark green to black, micaceous sandy clay with fine lignite fragments. These beds are in turn overlain by 9 feet of massive, dark-green, glauconitic, micaceous, clayey sand. These Black Creek sediments are overlain by about 30 feet of orange and light brown, unfossiliferous surficial sands and clays.

The Black Creek Formation here contains a diverse fauna described by Stephenson (1912, p. 143; 1923), including the oyster *Exogyra ponderosa*.

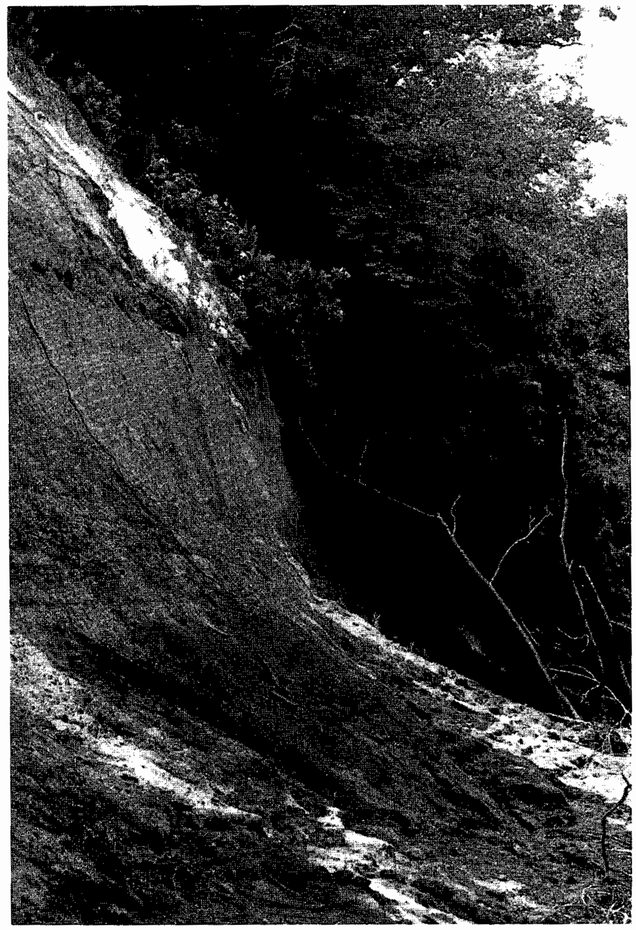

Figure 27.1. Exposure of the Black Creek Formation and overlying surficial deposits at Locality 27.

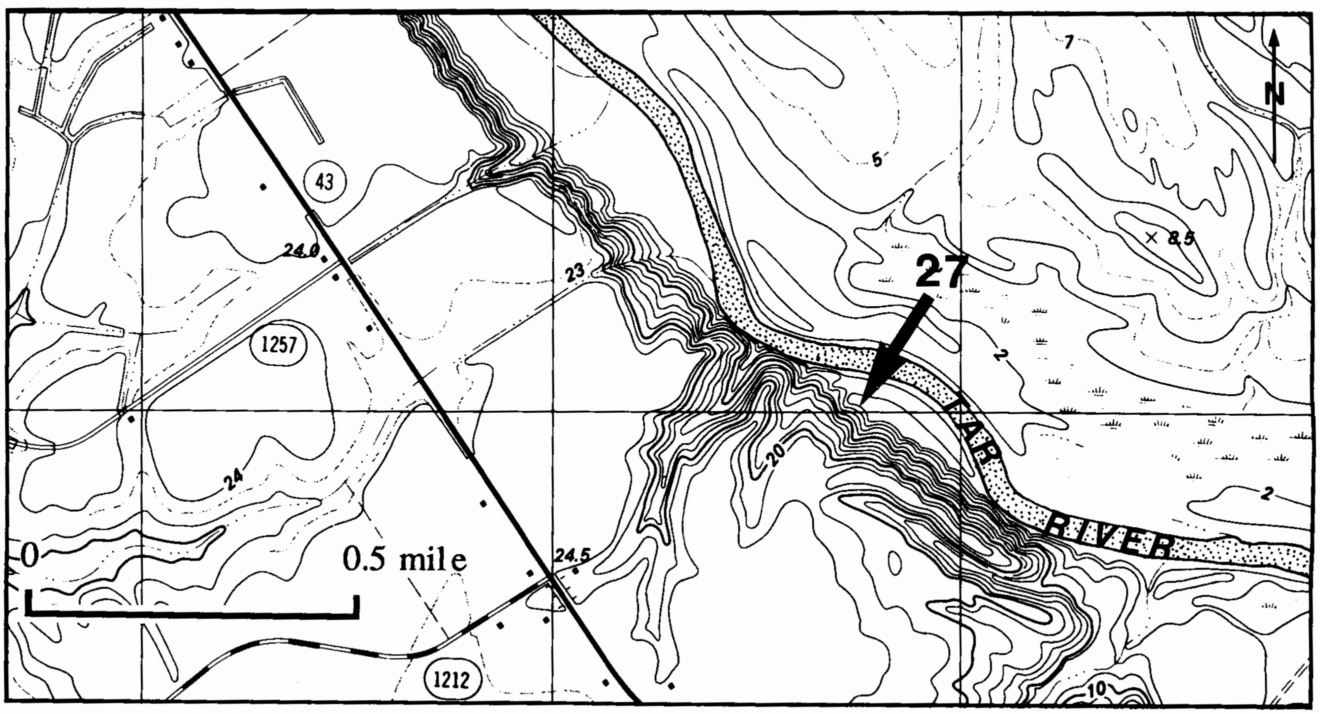

Figure 27.2. Locality 27. Blue Banks Landing. Greenville NW 7.5 minute quadrangle.

28. Grimesland.

Age and Formation: Pliocene Yorktown Formation (?), late Pliocene Chowan River Formation.

Location: Fossils are exposed on the south bank of the Tar River immediately downstream from the bridge on SR 1565. This bridge is located 1.2 miles northeast of the intersection of SR 1565 with N.C. Highway 33 in Grimesland. Grimesland 7.5 quadrangle.

Access: This locality is best visited by boat. There is a boat ramp on the southeast side of the bridge. At low water, fossils may be collected by wading near the river bank. However, extreme caution is advised in doing so. The river here is two to three feet deep near its bank at low water, and it has a firm, sandy bottom, but the water depth and current may vary considerably.

Fossils: The fossiliferous exposure here is about 9 feet thick, and it contains abundant molluscan fossils concentrated in two beds. The lower bed, exposed at and just above normal water level, consists of three feet of dark greenish-gray, silty clay. This contains abundant fossil bivalves (*Ostrea raveneliana*, *Carolinapecten eboreus*, *Dosinia acetabulum*, and *Mercenaria* sp.), a few gastropods (e.g., *Busycon maximum* and *Turritella* aff. *T. beaufortensis*), large barnacles, and isolated fragments of branching and encrusting corals (mostly *Septastrea crassa*). This basal shell bed grades upward into about six feet of yellowish-brown, clayey silt and silty clay which becomes more fossiliferous near its top. The upper shell bed contains *Turritella beaufortensis*, and it has a few *Mercenaria* sp. identical to those in the underlying bed. The *Mercenaria* in these two beds include forms similar to *Mercenaria corrugata* form "rileyi", plus greatly thickened forms which lack the marginal undulations of *M. corrugata* form "tridacnoides".

The lower of these two shell beds is tentatively correlated with the Yorktown Formation. *Dosinia acetabulum* is common in this lower shell bed and in the Yorktown Formation, but it is less common in the overlying Chowan River Formation in northern North Carolina (L.W. Ward, personal communication). The presence of *Turritella beaufortensis* and the paucity of *Dosinia acetabulum* in the upper shell bed is compatible with its correlation with the Chowan River Formation. More detailed lithostratigraphic and biostratigraphic analyses will be required to verify the age and lithostratigraphic correlation of the basal part of this exposure.

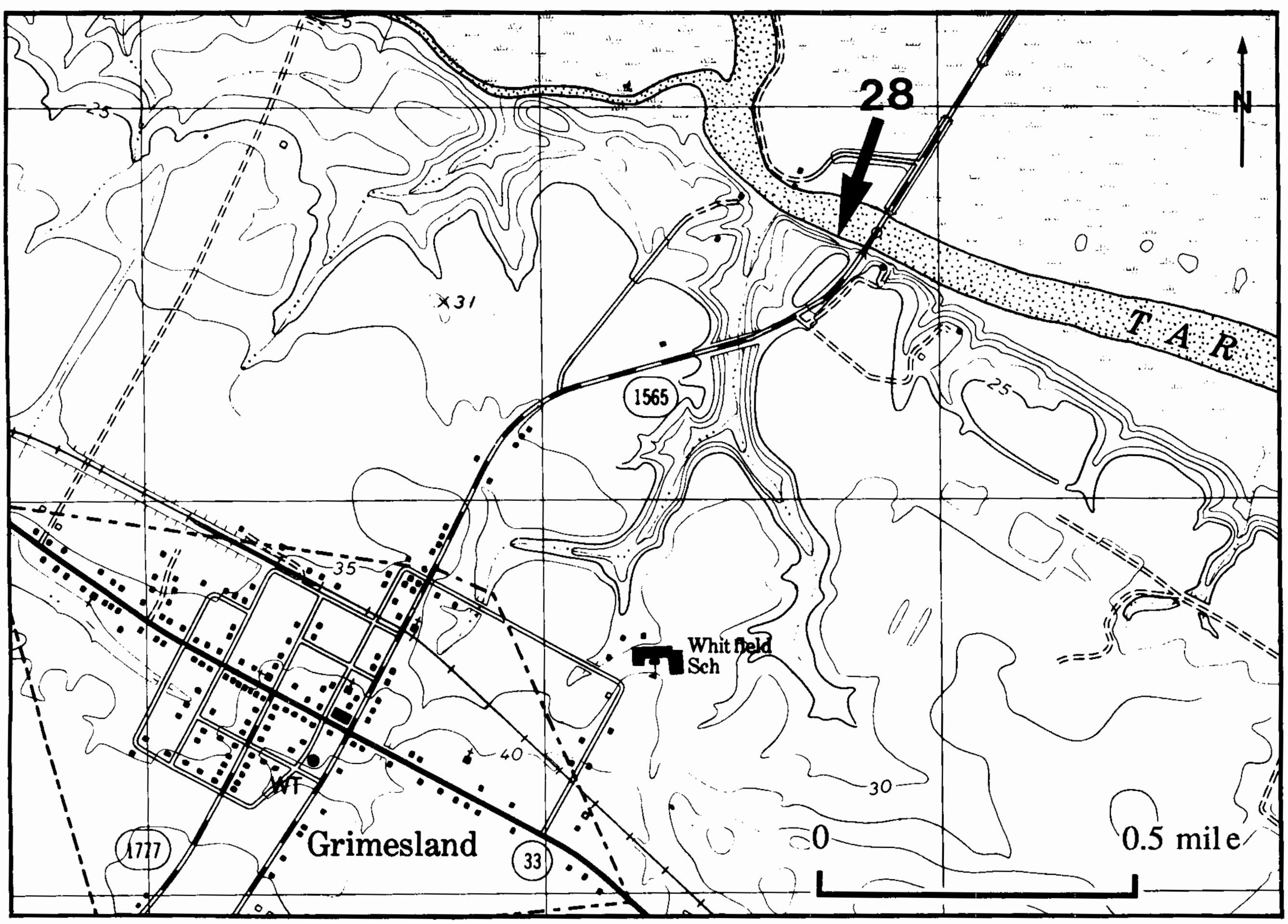

Figure 28. Locality 28. Grimesland. Grimesland 7.5 minute quadrangle.

29. Greens Mill Run, Greenville.

Age and Formation: Pliocene Yorktown Formation, late Pliocene Chowan River (?) Formation.

Location: Fossils are exposed along both banks and the bed of Greens Mill Run at the bridge immediately south of the intersection of Rock Spring Road with 10th Street (U.S. Highway 264 Business) in Greenville. Greenville 7.5 minute quadrangle.

Fossils: This exposure consists of three beds. The basal bed is about 2 feet thick and consists of dark greenish-gray, silty, sandy, phosphatic clay, with a few small pebbles. Fossils are abundant, well preserved, and easy to collect from this bed, including the bivalves *Carolinapecten eboreus*, *Cyclocardia granulata*, *Mercenaria* sp., *Dosinia acetabulum*, *Pitar chioneformis*, *Panopea reflexa*, *Lucinoma contracta*, rare *Glycymeris subovata*, rare *Glycymeris tuomeyi*, and *Thracia conradi*; the gastropods *Calliostoma* sp., *Fusinus burnsii*, *Turritella beaufortensis*, and *Cymatosyrinx* sp.; and the branching coral *Septastrea crassa*. *Ecphora quadricostata* and *Chesapecten jeffersonius* have been collected from this basal bed, but they are rare and fragmentary, and they may have been reworked from older strata. If these two fossils are not reworked, their presence and the abundance of *Dosinia acetabulum* and *Panopea reflexa* suggest correlation with the Yorktown Formation.

The basal bed grades upward into 3 feet of dark greenish-gray, silty, sandy clay which is slightly sandier and less phosphatic than the lower bed. Fossils in this middle bed are mostly dissolved, but they represent some of the same taxa seen in the lower bed. This middle bed is overlain by about 8 inches of weathered, irregularly bedded, yellow-orange, medium- to coarse-grained sand and yellowish-gray clayey sand, with moldic fossils of *Carolinapecten eboreus*, *Mercenaria* sp., *Nuculana* sp., and other mollusks. Age-diagnostic fossils have not yet been recovered from these two upper beds. They may correlate with the Yorktown Formation, or possibly with a younger unit, such as the Chowan River Formation.

Figure 29.1. Exposure of the Yorktown Formation (with abundant shells) and overlying Chowan River (?) Formation along Greens Mill Run, Locality 29.

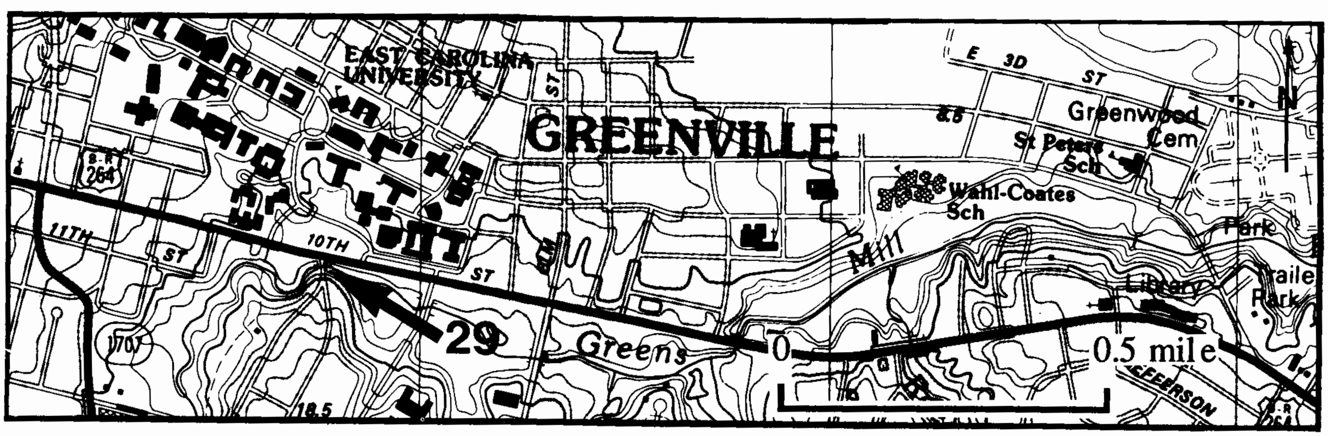

Figure 29.2. Locality 29. Greens Mill Run, Greenville. Greenville 7.5 minute quadrangle.

30. Scuffleton.

Age and Formation: Late Cretaceous Peedee Formation.

Location: Fossils are exposed on the east bank of Little Contentnea Creek, about 70 yards north of the N.C. Highway 903 bridge over Little Contentnea Creek, 0.2 mile east of the intersection of SR 1004 and SR 1110 in Scuffleton. Ayden 7.5 minute quadrangle.

Fossils: The Peedee Formation along the creek bank consists of four beds. The lowest bed consists of 2 feet of glauconitic, light olive-gray, indurated calcareous sandstone with scattered oysters (*Exogyra cancellata* and *Flemingostrea subspatulata*). The second bed consists of 8 feet of dark olive-brown, micaceous, sandy clay that becomes sandier toward its base, and contains shell fragments, shark teeth, and lignitized wood. The third bed is a 1-foot-thick layer with abundant *Exogyra costata*, phosphate pebbles, and rare fossil belemnites. The fourth bed is a fossiliferous, light olive-gray calcareous sand which is locally indurated. The uppermost 6 feet of the bank is covered by vegetation.

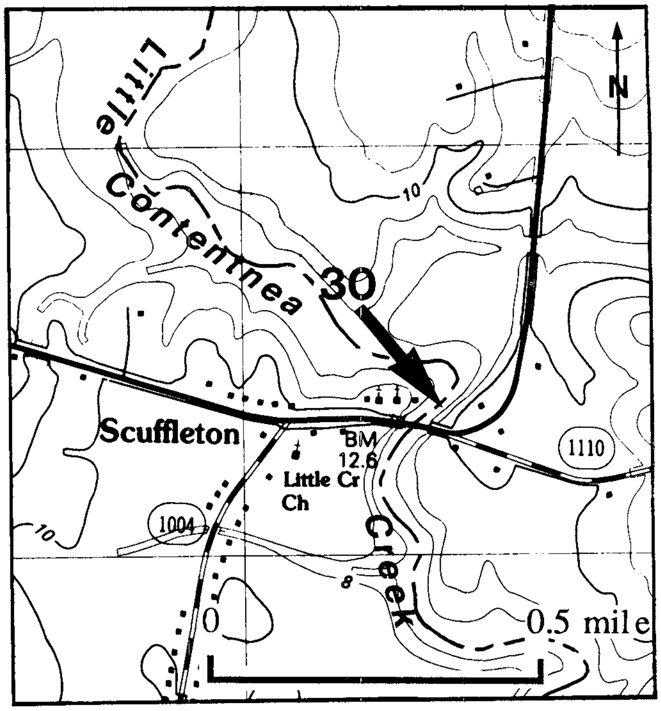

Figure 30.1. Locality 30. Scuffleton. Ayden 7.5 minute quadrangle.

Figure 30.2. Exposure of the Peedee Formation along Little Contentnea Creek near Scuffleton.

ROBESON COUNTY
31. Lumber River near Lumberton.

Age and Formation: Pliocene Duplin fauna of the Yorktown Formation.

Location: Fossils are exposed on the east bank of the Lumber River south-southeast of Lumberton. The outcrop is 0.25 mile upriver from the North Carolina Wildlife Commission boat access along N.C. Highway 72 (old U.S. Highway 74). The outcrop is also 0.75 mile south of the intersection of N.C. Highway 72 and N.C. Highway 211 in Lumberton. The site can be easily reached by walking 50 yards west of N.C. Highway 72 along a dirt road where the power lines cross this highway, 0.2 mile northeast of the N.C. Highway 72 bridge over the Lumber River. There are two exposures separated by about 20 yards along the river bank. Bladenboro 15 minute quadrangle.

Fossils: Abundant and diverse mollusks can be collected from the Yorktown Formation (also called the Duplin Formation here), which consists of about 15 feet of bluish-gray to yellow and reddish-brown shelly quartz sand. The section contains a basal oyster-rich bed, a middle bed with abundant and diverse open marine mollusks and a few estuarine mollusks (e.g., *Rangia clathrodonta*), and an upper bed with mostly fragmented shells. Common fossils include the bivalves *Plicatula marginata, Lirophora latilirata, Eucrassatella speciosa, Mercenaria corrugata* form "rileyi", *Ostrea sculpturata, Glycymeris hummi, Glycymeris tuomeyi, Mulinia congesta, Divaricella quadrisulcata, Carolinapecten eboreus, Astarte concentrica, Panopea reflexa, Anadara transversa, Anadara plicatura, Noetia carolinensis,* and *Rangia clathrodonta,* plus the gastropods *Crucibulum scutellatum, Conus adversarius, Conus presozoni, Nassarius scalaspirus, Nassarius harpuloides, Natica canrena plicatella, Polinices duplicata, Siphocypraea (Siphocypraea) carolinensis, Busycon maximum, Busycon incile* and *Fasciolaria sparrowi acuta.*

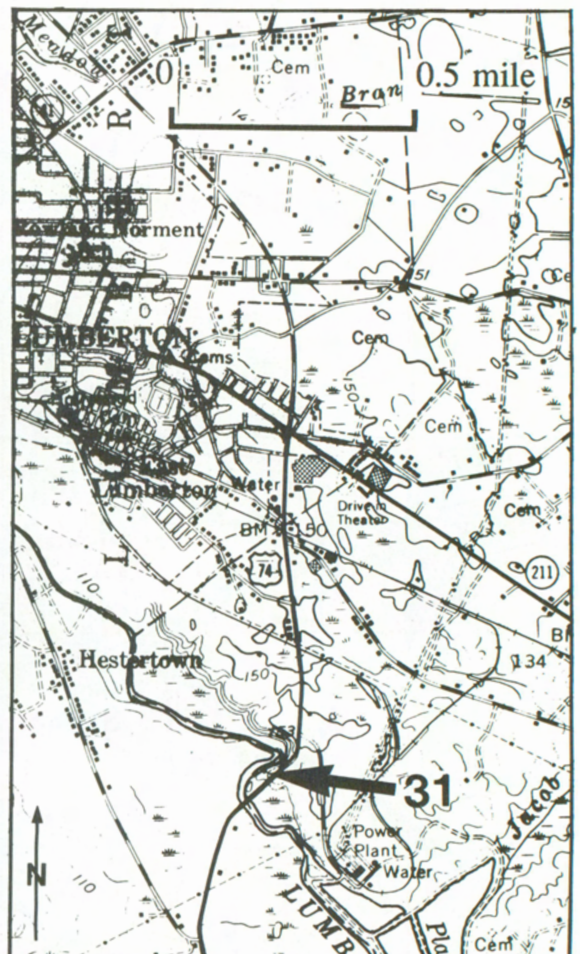

Figure 31.1 (above): Locality 31, Lumber River, Bladenboro 15 minute quadrangle. Figure 31.2 (left): Will Carter excavating shells from the Yorktown Formation at Locality 31.

WAYNE COUNTY

32. Auger Hole Landing.

Age and Formation: Late Cretaceous Black Creek Formation.

Location: Fossils are exposed on the north side of the Neuse River at Milepost 73. The outcrop occurs at a sharp bend in the river, 0.9 miles east northeast of Seven Springs, 1.2 - 1.4 miles downstream from the boat access in Seven Springs. The outcrop starts on the north (left) bank about 100 feet upstream from the power lines crossing the river, and continues downstream for 0.2 miles. Seven Springs 7.5 minute quadrangle.

Access: This locality is best visited by boat. There is a N.C. Wildlife Commission boat access on the south side of the Neuse River immediately east of the SR 1731 bridge in Seven Springs.

Fossils: Fossils may be collected from 6- to 12-feet-thick river bank exposures of the Upper Cretaceous Black Creek Formation. At very low water, three horizons are exposed: a basal sandy shell bed, a middle indurated calcareous sandstone with diverse mollusks, including ammonite cephalopods, and an upper greenish-gray, clayey, glauconitic sand. Shells are concentrated near the base of the upper bed at the top of the indurated sandstone. In the upper bed, the fossils form a shell hash a few inches thick. Lignitized wood occurs throughout the exposure. Fish vertebrae and shark teeth are also found here, e.g., *Lamna texana*, *Otodus appendiculatus* and *Galeocerdo falcatus*.

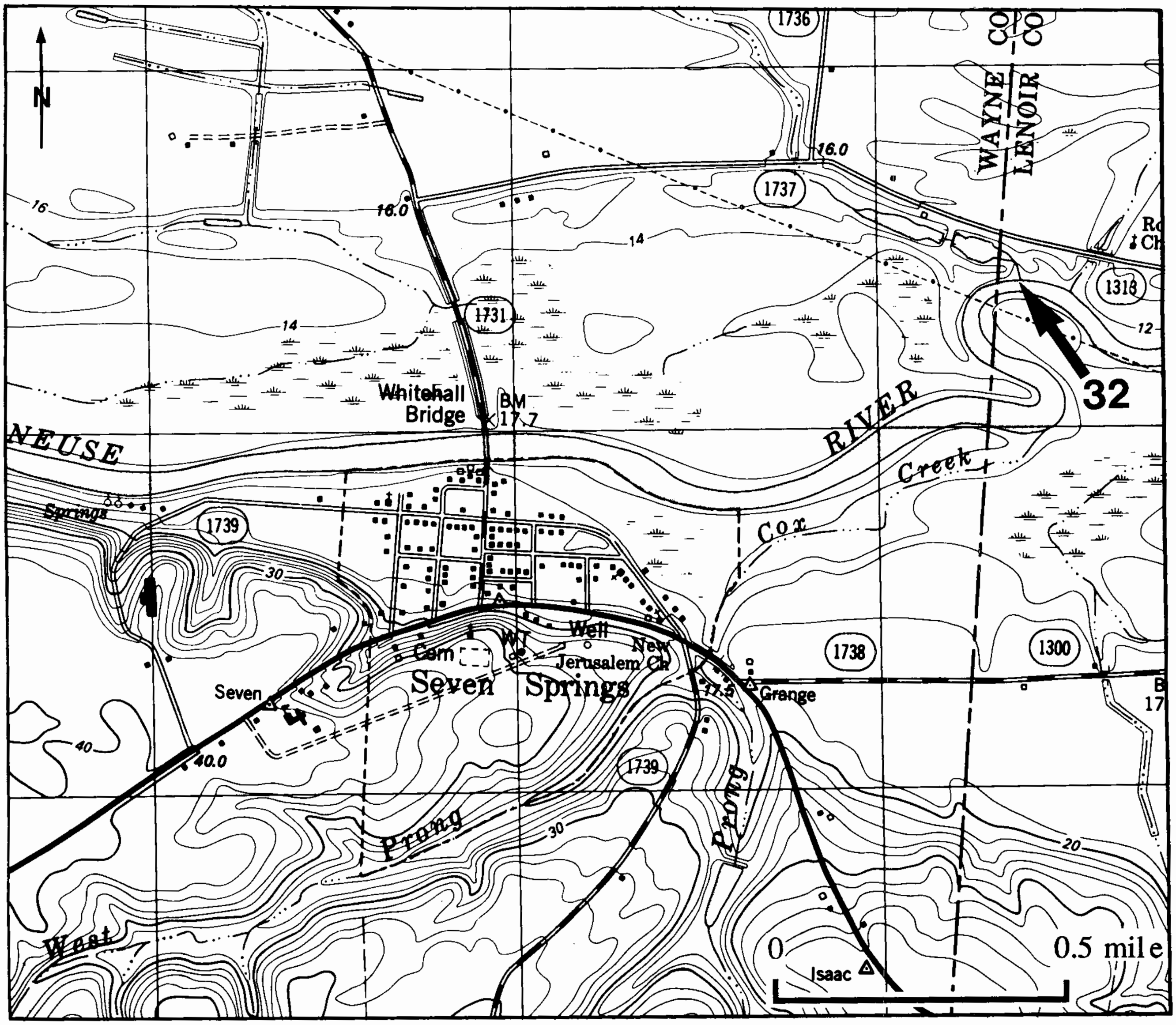

Figure 32.1. Locality 32. Auger Hole Landing. Seven Springs 7.5 minute quadrangle.

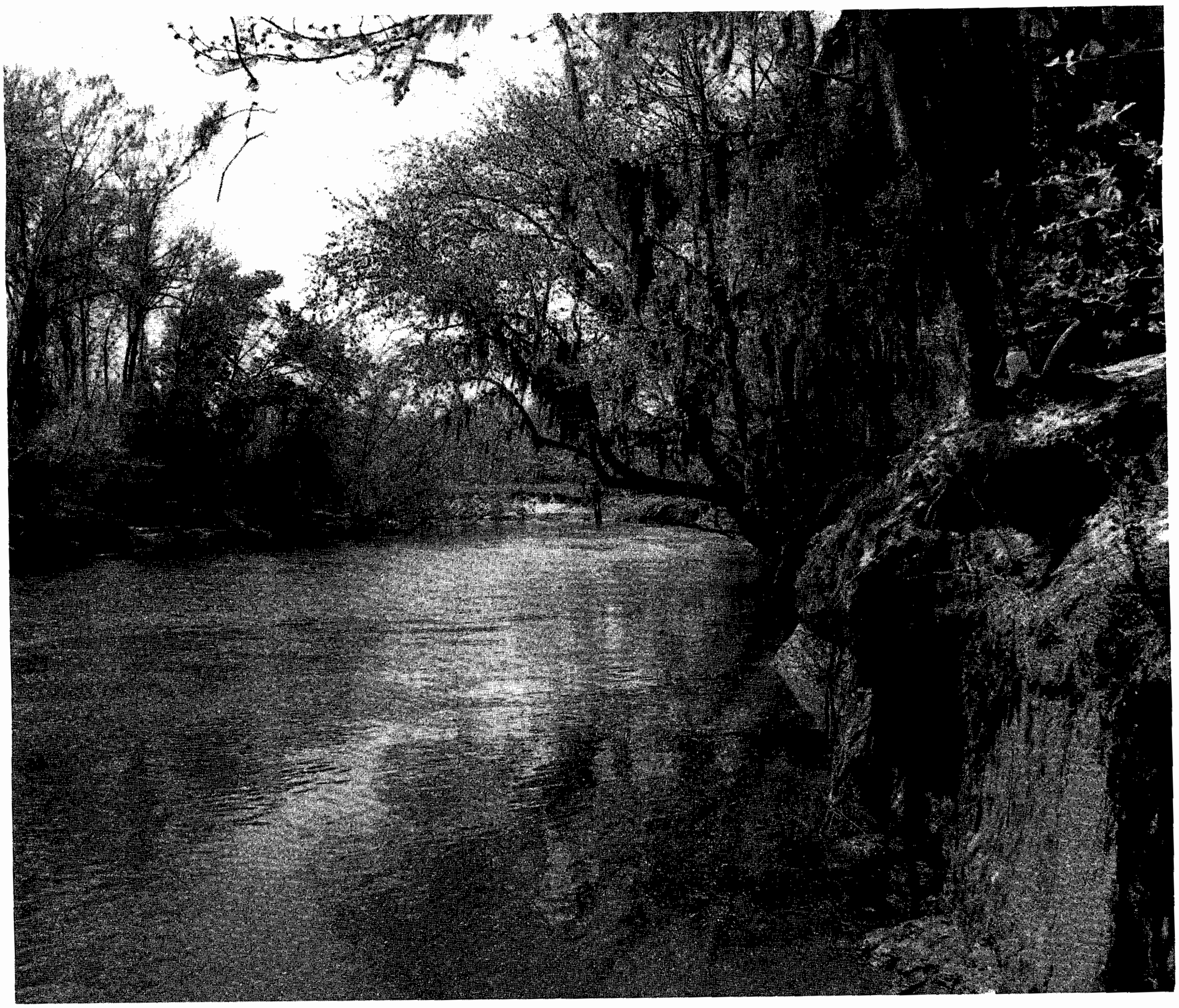

Figure 32.2. Exposure of the Black Creek Formation at Auger Hole Landing on the Neuse River.

33. Highway 111 Bridge, Neuse River.

Age and Formation: Eocene Castle Hayne Formation.

Location: This locality consists of two separate sites, Localities 33A and 33B. Locality 33A is located at the mouth and along the banks of a small tributary creek on the south bank of the Neuse River, 60 yards upstream (west) of the N.C. Highway 111 bridge over the Neuse River, 5.5 miles south of the intersection of N.C. Highway 111 with U.S. Highway 70 in Goldsboro. Locality 33B is located 1.3 miles upstream (west) of the Route 111 Bridge on the south bank of the Neuse River. Southeast Goldsboro 7.5 minute quadrangle.

Access: Localities 33A and 33B are best visited by boat. The direct path from Highway 111 to locality 33A crosses private property, and the adjacent river bank is steep and overgrown with dense vegetation. Although there is no boat ramp at this locality, a small boat may be put in on the north side of the river east of the bridge.

Fossils: Locality 33A exposes 4 feet of cream-colored, phosphatic, largely fragmental, calcareous, locally indurated sand in the basal part of the Castle Hayne Formation. This overlies the Cretaceous Black Creek Formation, and is separated from it by a bed of phosphatic cobbles and pebbles that have been bored by mollusks. Fossils in the Castle Hayne Formation include encrusting bryozoans, echinoid fragments, mollusks and vertebrates. Kellum (1926, p. 11) listed the oyster *Pycnodonte trigonalis* and the scallop *Chlamys cookei* from this locality. Also present are *Ostrea* sp., juvenile *Cubitostrea* sp., borings by lithophaginid bivalves, teeth of the sharks *Isurus oxyrhinchus* and *Odontaspis* sp., bone fragments, and crocodile teeth. These sediments also contain a few moldic fossils of bivalve and gastropod mollusks.

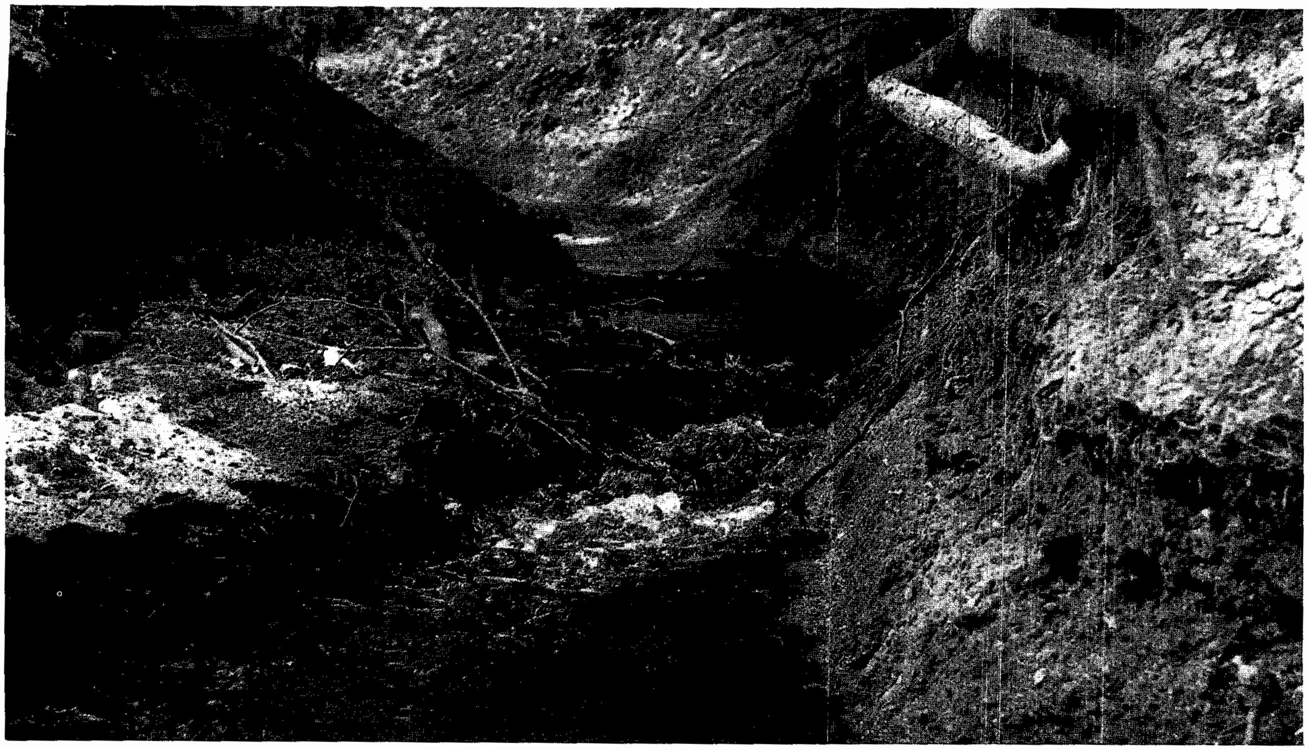

Figure 33.1. Castle Hayne Formation exposed near the Highway 111 Bridge, Neuse River (Locality 33A).

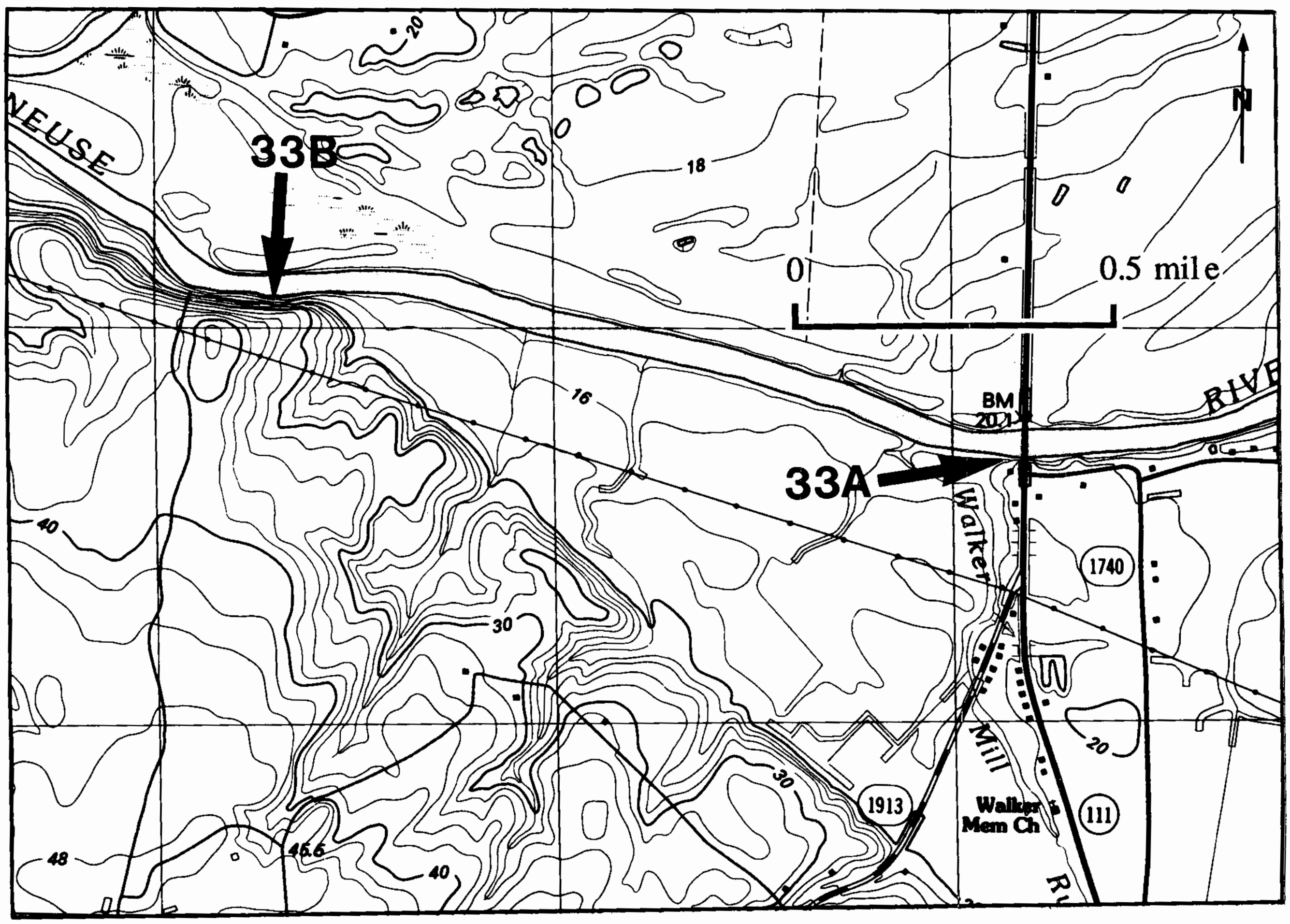

Figure 33.2. Localities 33A,B. Highway 111 Bridge over the Neuse River. SE Goldsboro 7.5 minute quadrangle.

34. Neuse River Cutoff.

Age and Formation: Late Cretaceous Black Creek Formation.

Location: Fossils are exposed on both banks and along the bed of the Neuse River Cutoff southwest of Goldsboro. The outcrops occur upstream and downstream from the SR 1222 bridge over the Neuse River Cut-off. The bridge is reached by taking the first westerly turn off U.S. Highway 117 Bypass south of the Neuse River Cutoff. This turn is located at a traffic light. After turning west, proceed 0.1 mile to the traffic island and turn right (to the north) onto SR 1247. Follow SR 1247 for 0.5 mile and turn right onto SR 1222. Proceed on SR 1222 for several hundred yards to the bridge. Southwest Goldsboro 7.5 minute quadrangle.

Access: This locality is readily accessible on foot, but is best visited during very low water.

Fossils: Fossil wood and rare amber may be collected from the Cretaceous Black Creek Formation. Much of the fossil wood occurs as lignite, but some is permineralized with silica and coated with small crystals of quartz and pyrite or marcasite. The lower part of the Black Creek Formation consists of 1.5 feet of medium-gray, coarse, feldspathic sand, which forms a ledge extending from the bank toward the river. This is overlain by thinly interbedded, dark-gray clays and orange and yellow, fine- to coarse-grained sands. Cross-bedding and pyritized burrows occur near the base of the interbedded sequence. The Black Creek Formation is overlain by about 0.5 foot of surficial gravel grading upward into 9 feet of medium to coarse-grained yellow and orange sand.

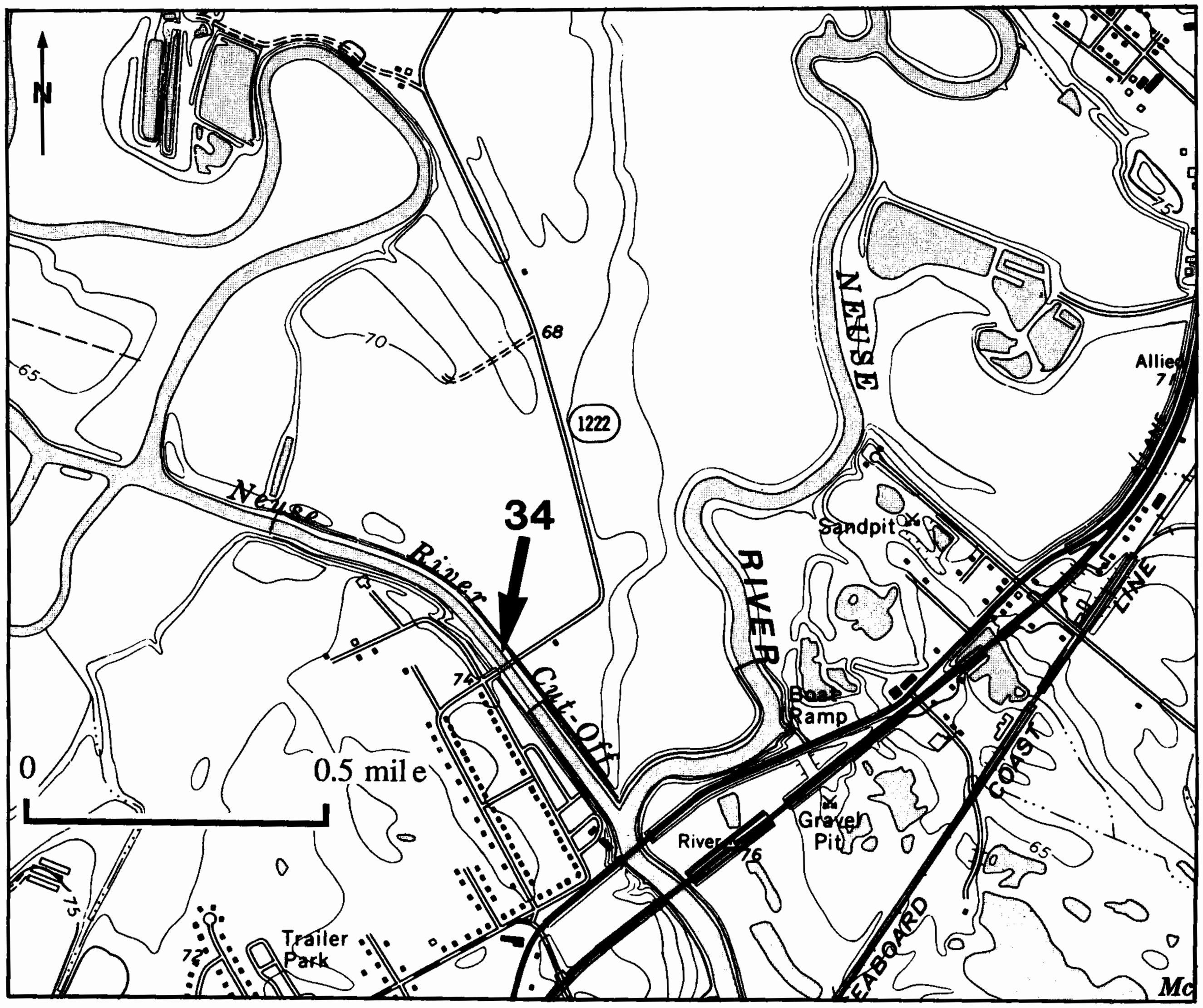

Figure 34.1. Locality 34. Neuse River Cutoff. Southwest Goldsboro 7.5 minute quadrangle.

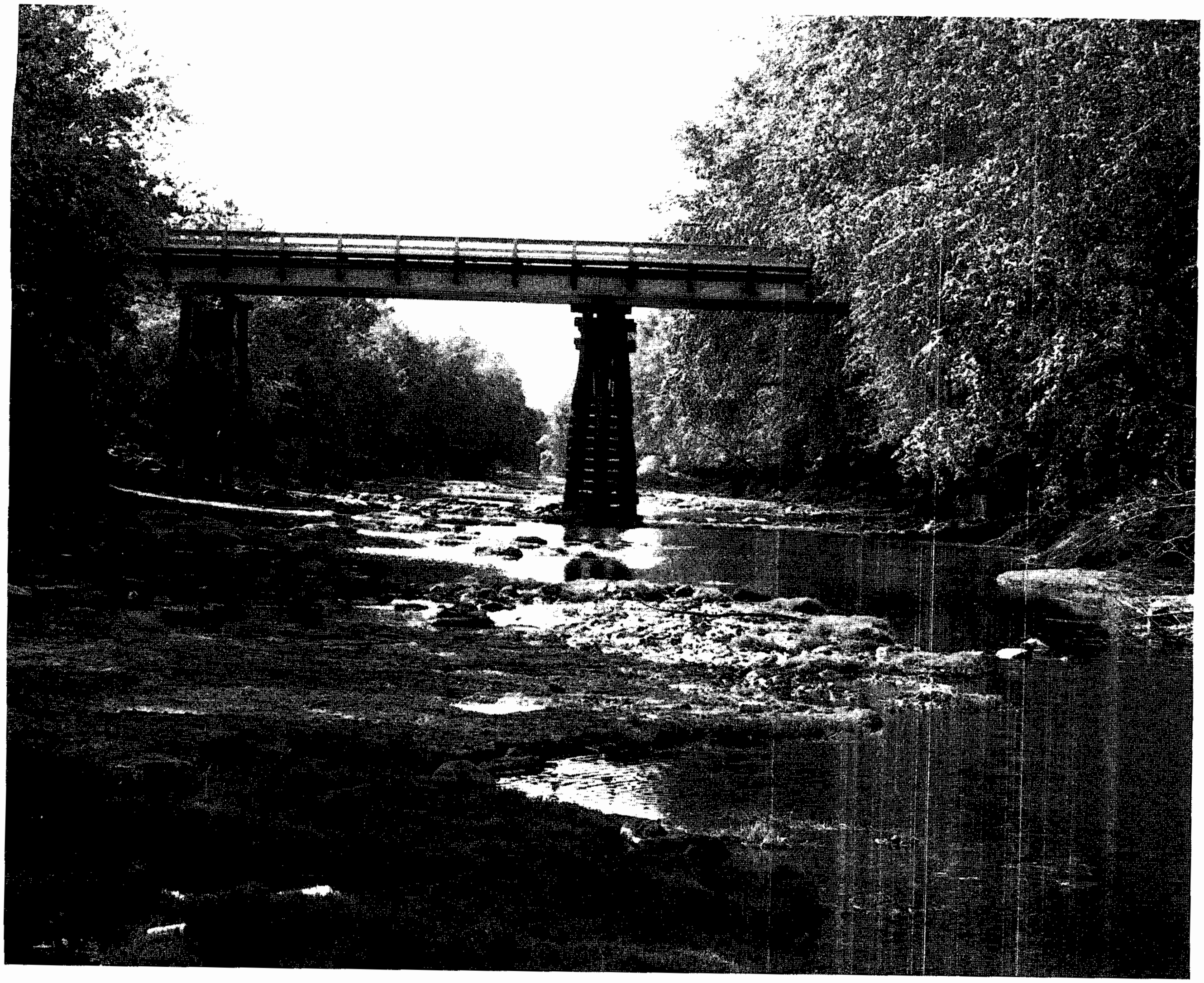

Figure 34.2. Exposure of the Black Creek Formation along the Neuse River Cutoff, Locality 34.

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REPOSITORY OF FIGURED SPECIMENS

With the exception of the Eocene fossils in Figures 24, 25 and 31 of Plate 4 (deposited in the Department of Geology at the University of North Carolina at Wilmington), and the *Astarte* illustrated in Plate 7, Figure 53 (deposited at the United States National Museum, Washington, D.C.), the fossils illustrated in this publication are deposited in the type collections of the Department of Geology, University of North Carolina, Chapel Hill. Specimens indicated in the figure explanations as new species will, upon formal description and publication, be deposited in the type collections of the Department of Paleobiology, United States National Museum of Natural History, Washington, D.C.

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FOSSIL COLLECTIONS AND DISPLAYS

North Carolina fossils are displayed in a number of museums and universities throughout the state. These displays are often accompanied by valuable research collections. Some research collections, such as those at the Natural History Museum at Raleigh, represent over a century of fossil collecting. A few of North Carolina's fossil collections and displays are listed below.

1. Beaufort County. Aurora Fossil Museum, P.O. Box 373, Aurora, North Carolina, 27806, (919) 322-4238. Summer hours: 9 a.m. to 5 p.m., Tuesday through Saturday. The museum is open by appointment only during the Fall, Winter and Spring. Admission is free. Most of the fossils come from Beaufort County, and are of Eocene through Pleistocene age. The exhibits include murals depicting marine life through the ages, accompanied by actual fossils of the animals portrayed. The museum also contains artifacts representing North Carolina's Indian heritage.

2. Carteret County. North Carolina Maritime Museum, 315 Front Street, Beaufort, North Carolina, 28516, (919) 728-7317. The museum is open Monday through Friday 9 a.m. to 5 p.m., Saturday 10 a.m. to 5 p.m., and Sunday 2 p.m. to 5 p.m. Admission is free. The museum contains collections of North Carolina Coastal Plain fossils and recent shells. A diagram depicts ancient shorelines at intervals spanning the last 135 million years. The Museum sponsors field trips to the Texasgulf phosphate mine in Aurora several times each year. A calendar of scheduled events may be obtained upon request.

3. Durham County. North Carolina Museum of Life and Science, 433 Murray Avenue, Durham, North Carolina, 27704, (919) 477-0431. During the Spring and Summer the museum is open Monday through Saturday, 10 a.m. to 6 p.m. During the Fall and Winter it is open Monday through Saturday, 10 a.m. to 5 p.m., and Sunday, 1 p.m. to 5 p.m. An admission fee is charged for older children and adults. The museum depicts life through time in a series of murals accompanied by fossils from each period. A special exhibit shows North Carolina fossils. A short, wooded path around the museum has life-size reconstructions of prehistoric amphibians and reptiles, including several large dinosaurs and a pterosaur.

4. Gaston County. Schiele Museum of Natural History and Planetarium, Inc., 1500 East Garrison Boulevard, Gastonia, North Carolina, 28503, (704) 864-3962 or 865-6131. Open Tuesday through Friday, 9 a.m. - 5 p.m.; Saturday and Sunday 2 p.m. - 5 p.m. Admission is free to the general public, but a small fee is requested of organized groups from outside Gaston County. Fossil collections, primarily from the Carolinas, are available for viewing by appointment only. Some fossil collecting trips are open to the public.

5. Guilford County. Natural Science Center of Greensboro, 4301 Lawndale Drive, Greensboro, North Carolina, 27420, (919) 288-3769. The Natural Science Center is open Monday through Saturday, 9 a.m. to 5 p.m., and Sunday 1 p.m. to 5 p.m. An admission fee is charged. Life-size reconstructions of dinosaurs may be seen in the geology gallery. Also exhibited are North American and European fossils of all ages. Special exhibits include marine invertebrates, a display of crinoid ("sea lily") root systems, fossil plants, and fossils from the Texasgulf phosphate mine at Aurora.

6. Harnett County. Campbell University, Buies Creek, North Carolina, 27506, (919) 893-4111. Dr. R. C. Hope has an extensive research collection of Triassic plants, many of which are described in Hope and Patterson (1969). This publication may be purchased from the North Carolina Geological Survey in Raleigh. Arrangements to examine the collection should be made through the geology department.

7. Mecklenburg County. University of North Carolina at Charlotte, North Carolina, 28223, (919) 597-2293. The Department of Geography and Earth Sciences houses a teaching collection of fossil invertebrates from North Carolina. Arrangements to examine the collection may be made through this department.

8. New Hanover County. University of North Carolina at Wilmington, 28403, (919) 395-3000. The Geology and Marine Sciences building displays a small sampling of North Carolina Coastal Plain fossils. These may be viewed from 9 a.m. to 5 p.m., Monday through Friday. The Geology department has an invertebrate fossil collection, especially from the Eocene of North Carolina. It also has an excellent research collection of fossil barnacles.

9. Orange County. University of North Carolina, Chapel Hill, 27514, Department of Geology, Mitchell Hall, (919) 966-4516. The geology department houses a large research collection of Coastal Plain mollusks from many localities throughout the southeastern United States. For information, call the Geology Department general office.

10. Pitt County. East Carolina University, Greenville, North Carolina, 27834, (919) 757-6360. A fossil collection is displayed on the third floor of the Graham Building. This building is open from 9 a.m. to 5 p.m., Monday through Friday. The Geology Department has a teaching collection with many Coastal Plain fossils, including extensive microfossil research collections. Arrangements to examine the research collections can be made through the geology department.

11. Wake County. North Carolina Museum of Natural History, 102 North Salisbury Street, Raleigh, North Carolina, 27611, (919) 733-7450. Open Monday through Saturday, 9 a.m. to 5 p.m., and Sunday 1 p.m. to 5 p.m. Admission is free. A variety of fossils are on display, including life-size reproductions of *Tyrannosaurus*, a saber-tooth cat, and horned camel skulls. A wall-sized reconstruction of an outcrop at the Texasgulf quarry at Aurora is of special interest. The museum contains research collections of North Carolina Coastal Plain invertebrates and vertebrates, including a few type specimens of mollusks described by Horace Richards (1943) from the Belgrade Formation near Silverdale.

GLOSSARY

A

absolute age — The age in years, commonly based on radiometric dating techniques.

abundance zone — A body of strata representing the maximum abundance or frequency of occurrence of a taxon, but not necessarily its total stratigraphic range. Also called an "acme zone".

amber — Fossil tree resin or sap, especially from conifers.

angiosperm — A flowering plant.

aragonite — Calcium carbonate in its orthorhombic crystal form.

archeology — The study of human cultures through the recovery and analysis of artifacts.

arthropod — Any member of the Phylum Arthropoda, characterized by a jointed exoskeleton, e.g., crabs, lobsters, and insects.

artifact — A prehistoric or historic object created by man.

assemblage zone — A biostratigraphic unit defined and identified by a group of associated fossil taxa rather than by a single taxon.

B

basin — A low geographic area in which sediments may accumulate.

belemnite — Any member of the extinct Order Belemnitida of the molluscan Class Cephalopoda, characterized by cigar-shaped, calcitic fossils.

biostratigraphy — Stratigraphy based on the paleontological aspects of rocks.

biostratigraphic unit — A rock unit characterized by its fossil content.

bituminous — Containing bitumen, or a variety of natural complex hydrocarbons.

bivalve — Any member of the Class Bivalvia in the Phylum Mollusca, possessing two hinged, calcareous shells.

bone bed — A sedimentary layer rich in fossil bones and teeth.

brachiopod — Any member of the Phylum Brachiopoda, commonly known as the lamp shells, which possess two calcareous shells which are symmetrical when cut by a vertical plane across the shells.

brackish — Having a salinity intermediate between normal seawater and normal freshwater.

bryozoan — Any member of the Phylum Bryozoa, commonly known as the moss animals.

C

calcareous — Made of or containing calcium, usually calcite or aragonite.

calcite — Calcium carbonate in its hexagonal crystalline form.

Cambrian — The oldest period of the Paleozoic Era, lasting from 570 to 500 million years ago.

carbonization — A process of fossilization in which animal or plant remains are compacted and reduced to an outline or film of carbon.

cast — A replica of the internal or external features of a fossil, produced by the filling in of a cavity (mold) left by the dissolution of the original hard parts.

Cenozoic — The youngest and present geologic era, which started about 65 million years ago.

cephalopod — Any member of the Class Cephalopoda in the Phylum Mollusca, possessing a well developed head and tentacles; living forms include the octopus, squid and the pearly nautilus.

Coastal Plain — The generally flat land area between the ocean and the hills of the Piedmont, blanketed by Mesozoic and Cenozoic sediments.

coccolithophore — Any of several microscopic, single-celled, mostly marine, planktonic algae which produce calcareous skeletal platelets called coccoliths.

coccoliths — The platelets of a coccolithophore.

coquina — A sedimentary rock composed almost entirely of cemented mollusk shells and other invertebrate fragments.

concretion — A hard, compact mass of mineral matter, usually spherical to disk-shaped, formed by the precipitation of mineral matter around a nucleus, or center, such as a leaf or other decaying tissue.

conglomerate — A sedimentary rock consisting of rounded, waterworn fragments of rock or pebbles cemented together by another mineral substance.

conifer — Any of several cone-bearing trees, commonly known as the pines and firs.

continental shelf — The gently sloping, shallowly submerged marginal zone of the continents extending from the shore to an abrupt increase in bottom inclination.

correlate — To show correspondence in character or stratigraphic position between formations or fossil faunas from different areas.

Cretaceous — The third and youngest of the three Mesozoic periods, lasting from approximately 141 to 66.4 million years ago.

crinoid — Any member of the Class Crinoidea of the Phylum Echinodermata, usually characterized by a cup-shaped body attached to a multi-segmented stalk.

cross-bedded — Having sedimentary layers inclined at an angle to the main planes of stratification.

cycad — Any member of the plant order Cycadales, having a thick, unbranching, columnar trunk and a crown of large, leathery leaves.

cycadeoid — Any member of the gymnosperm plant group Bennettitales.

D

deltaic — Pertaining to a delta.

diatomaceous — Composed of diatoms, microscopic single-celled plants which secrete a siliceous test.

dinosaur — Any member of the extinct reptile orders Saurischia and Ornithischia.

disconformity — The surface of a division between parallel rock strata, indicating interruption of sedimentation.

duckbill — Any of several semi-aquatic dinosaurs of the Suborder Ornithopoda in the Order Ornithischia, characterized by a broad duck-like mouth with numerous rows of small, grinding teeth.

E

echinoderm — Any member of the Phylum Echinodermata, characterized by marine animals possessing a calcitic endoskeleton and, usually, a covering of numerous spines; e.g., starfish, sea urchins, sand dollars and crinoids.

echinoid — Any member of the Class Echinoidea of the Phylum Echinodermata; e.g., sea urchins and sand dollars.

Eocambrian — The geologic period immediately preceding the Cambrian, dating from about 650 to 570 million years ago.

Eocene — An epoch of the Paleogene Period, lasting approximately from 57.8 to 36.6 million years ago.

eon — The largest geologic time unit, consisting of eras and their subordinate time units.

epoch — A geologic time unit of intermediate rank between periods and ages.

era — A geologic time unit of rank between eon and period.

estuarine — Pertaining to an estuary, where fresh water comes into contact with seawater.

F

facies — The aspect, appearance and characteristics of a rock unit, usually reflecting the conditions of its origin; the environment in which a rock was formed.

fauna — A general term for an assemblage of animals.

feldspar — Any of a group of abundant, rock-forming minerals occurring principally in igneous and metamorphic rocks, and consisting of silicates of aluminum with potassium, sodium, calcium, and, rarely, barium.

feldspathic — Containing feldspar.

fissile — Able to be broken into sheets.

flora — A general term for an assemblage of plants.

Foraminifera —Certain small, often microscopic, single-celled organisms of the Phylum Protozoa.

formation — A basic stratigraphic unit consisting of a distinct, usually tabular body of rock that is mappable at the earth's surface or traceable in the subsurface.

fossil — Any remain, impression, or trace of a plant or animal from a former geologic age.

fossilization — Any of several processes by which plant and animal remains are buried and preserved, either whole, in part, or by traces of animal activity.

friable — Able to be easily broken or crumbled.

G

gastropod — Any member of the molluscan class Gastropoda in the Phylum Mollusca, usually having a well developed head and a helically spiralled shell; a snail.

genera — Plural of "genus".

genus — The taxonomic level above species which contains either one species or several closely related species.

geochronologist — One who studies geochonology, i.e., time in relationship to the history of the Earth.

geologic column — The sequence of rocks in a designated part of the earth.

glauconitic — Containing the mineral glauconite, a green silicate mineral.

group — A lithostratigraphic unit consisting of a sequence of formations.

gymnosperm — a plant of the Class Gymnospermae, with seeds not enclosed within an ovary, including cycads, cycadeoids, ginkgoes and conifers.

H

hash — A sediment consisting of a mixture of fragments of animal hard parts, e.g., shells, barnacles, or echinoderm plates.

Holocene — The youngest and present epoch of the Quaternary period, beginning approximately 10,000 years ago.

horsetail — Any of various non-flowering plants of the genus *Equisetum*, having a jointed, hollow stem and narrow, sometimes much reduced leaves.

hydrozoan — Any member of the Class Hydrozoa of the Phylum Cnidaria, e.g., sea anemones and fire corals.

I

Ice Age — The Pleistocene Epoch, characterized by extensive continental and polar glaciation.

Igneous — Formed by solidification from a molten or partially molten state.

indurated — Hardened or consolidated by pressure, cementation and/or heat.

interval zone — An interval of strata between two distinctive biostratigraphic horizons.

invertebrate — An animal lacking a backbone or spinal column.

J

Jurassic — The middle period of the Mesozoic Era, lasting approximately from 195 to 141 million years ago.

L

laminated — In thin layers.

lens — A geological deposit bounded by converging surfaces, with at least one of them being curved, thick in the middle, and thinning out toward the edges.

lignite — An imperfectly formed coal, usually dark-brown and commonly having a woody texture; brown coal..

lignitize — To turn into lignite.

limestone — A sedimentary rock consisting predominantly of calcium carbonate, $CaCO_3$.

limonite — A yellow to brown, non-crystalline, hydrated iron oxide of varying composition.

lithic — Pertaining to rock.

lithification — The process of turning into rock.

lithofacies — A rock unit characterized by a given environment of deposition, as indicated by its lithic features.

lithology — The physical characteristics of a rock in terms of color, mineralogic composition, and grain size and shape.

lithostratigraphic unit — A body of strata defined solely on its lithic characteristics and stratigraphic position, independently of its fossil content and time of deposition.

lithostratigraphy — The study of the lithic characteristics and physical correlation of sequences of sedimentary rocks.

M

macrofossil — Any fossil clearly visible to the naked eye.

magma — Molten matter under the earth's crust, from which igneous rock is formed by cooling.

mammal-like reptile — Any member of the reptile subclass Synapsida, especially of the Order Therapsida, characterized by the possession of certain mammal-like features.

manatee — Any of several aquatic mammals of the Order Sirenia, characterized by a paddle-like tail and the absence of front teeth.

marcasite — An iron sulfide mineral with the same composition as pyrite (FeS_2) but having a different crystalline structure.

marl — A sedimentary rock consisting of a mixture of clay and calcium carbonate.

mastodon — An extinct elephant-like mammal of the Family Gomphotheriidae of the Order Proboscidea, characterized by molars with large, isolated cusps instead of fine ridges.

matrix — The finer-grained material which fills the interspaces between fossil skeletal material and the larger grains of a rocks.

member — A formal subdivision of a formation which possesses lithic or positional features distinguishing it from adjacent parts of the formation.

Mesozoic — The middle of three eras of the Phanerozoic Eon, lasting from about 230 to 65 million years ago.

metamorphic rock — a rock in which great heat or pressure has altered its original composition, structure, or texture.

micaceous — Containing any of the mica, or sheet silicate minerals.

microfossil -- A fossil that is too small to be readily seen with the naked eye.

Miocene — The older epoch of the Neogene Period, lasting from approximately 23.7 to 5.3 million years ago.

mold — An impression or cavity in a rock created by the decay or dissolution of a fossil.

moldic — Containing molds.

mollusk — Any member of the Phylum Mollusca, including the gastropods (snails), bivalves (clams, oysters and scallops), cephalopods (octopus, squid, belemnites, and the pearly *Nautilus*), scaphopods (tusk shells), chitons (coat-of-mail or butterfly shells), sea slugs, land snails, and monoplacophorans.

mosasaur — Any member of the Family Mosasauridae of the Suborder Lacertilia of the reptile Order Squamata; large marine lizards of the Cretaceous Period.

mud flat — A relatively level area of clay and fine silt along a shore or around an island, alternately covered and uncovered by the tide, or covered by shallow water; a muddy tidal flat.

mudstone — A clayey sedimentary rock of nearly uniform texture throughout, with little or no lamination.

N

nannofossil — A fossil smaller than a microfossil, i.e., commonly only a few tens of micrometers in diameter.

nautiloid — Any member of the Subclass Nautiloidea of the molluscan Class Cephalopoda, characterized by a straight, curved or coiled calcareous shell with straight or gently folded divisions between its shell chambers.

Neogene — The Period of the Cenozoic Era which includes the Miocene and Pliocene Epochs.

O

Oligocene — The youngest epoch of the Paleogene Period, lasting from approximately 36.6 to 23.7 million years ago. ago.

opal — A mineral, an amorphous form of silica, with some water of hydration, found in many varieties and colors, including a common form that is milky white.

outcrop — The part of a geologic formation which appears at the surface of the earth.

P

Paleocene — The oldest epoch of the Tertiary Period, lasting from approximately 66.4 to 57.4 million years ago.

Paleogene — The Cenozoic Period which includes the Paleocene, Eocene and Oligocene Epochs.

paleontology — The study of life existing in former geologic time.

Paleozoic — The first era of the Phanerozoic Eon, lasting from approximately 570 to 230 million years ago.

period -- A geologic time unit of rank between eras and epochs.

permineralization — A process of fossilization in which the porous hard parts of an animal are filled with mineral deposits.

petrifaction — the conversion of organic remains into stone or a stony substance.

Phanerozoic — The current eon which started approximately 570 million years ago, and consists of the Paleozoic, Mesozoic and Cenozoic Eras.

phosphatic — composed of or including apatite or other minerals containing phosphate (PO_4).

phyla — Plural of phylum.

phylum — The taxonomic rank between kingdom and class.

phytosaur — Any member of the reptile Suborder Phytosaria of the Order Thecodontia, resembling modern crocodiles but possessing nostrils near its eyes instead of at the end of its snout.

Piedmont — The low platform in the eastern United States extending eastward from the Appalachian and Blue ridge Mountains to the Coastal Plain, and northward from Alabama to New Jersey.

planktonic — Descriptive of organisms that float in a body of water.

Pleistocene — The older of two epochs of the Quaternary Period, lasting approximately from 1.6 million to 10,000 years ago.

Pliocene — The younger of the two epochs of the Neogene Period, lasting from approximately 5.3 to 1.8 million years ago.

plutonic — Of deep igneous or magmatic origin.

porous — Containing small holes.

Precambrian — All geologic time prior to the beginning of the Cambrian Period.

prehistoric — Pertaining to the time period before the advent of written records, generally considered to be older than 5000 years B.C.

pseudomorph — A natural cast in which the replacing material is a crystallized mineral, such as pyrite, calcite, or more commonly silica in the form of chalcedony.

pyrite — A mineral, iron sulfide, FeS_2, also called fool's gold, with the same composition as marcasite but with a different crystalline form.

Q

quartz — A hard, crystalline, vitreous mineral consisting of silicon dioxide, SiO_2.

quartzite — A granular metamorphic rock consisting essentially of quartz in interlocking grains.

quartzose — Containing quartz.

Quaternary — The third and present period of the Cenozoic Era, which began approximately 1.8 million years ago.

R

radiometric dating techniques — Any of several methods of determining the age of rocks or minerals by measuring the ratio of their radioactive atoms and their decay products.

regression — Seaward retreat of the shoreline through geologic time.

relative age — A geologic age based on relative position in a sequence of rock units, or based on presumed position in a phylogenetic sequence.

reworked — Sediments, fossils, rock fragments or other geologic materials that have been removed or displaced by natural processes from their initial resting place or place of origin.

S

sandstone — A sedimentary rock composed chiefly of sand-sized quartz grains cemented by calcium carbonate, silica, or other materials.

scaphopod — Any member of the Class Scaphopoda of the Phylum Mollusca, commonly known as the tusk shells, possessing a tapering, curved, tubular shell resembling an elephant tusk.

scarp — A cliff face produced by erosion or faulting.

sediment — Solid fragmental material such as sand, gravel and clay, plus other transported fragments that settle to the bottom of a body of water.

sedimentary rock — A rock formed from sediment.

sedimentary structure — A feature of a sedimentary rock which indicates some aspect of its deposition, such as layered bedding or cross-bedding.

sedimentation — The process of accumulation of sediment.

seed-fern — An extinct plant group superficially like modern ferns, but producing seeds.

shale — A fissile sedimentary rock composed of laminated layers of claylike, fine-grained sediments.

shelfal — Pertaining to the continental shelf.

silica — Silicon dioxide, SiO_2.

silicified — Cemented by or replaced with silica.

siltstone — A sedimentary rock composed of silt-sized sedimentary particles.

sink — A natural depression in a land surface communicating with a subterranean passage, generally occurring in limestone regions and formed by dissolution or by collapse of a cavern roof.

species — The fundamental category of taxonomy, ranking lower than a genus. In biology, a species consists of all populations of actually or potentially interbreeding individuals which, under, natural conditions, can produce fertile, viable offspring. In paleontology, the criterion of interbreeding is commonly evaluated through analysis of morphological discontinuity between fossil populations.

steinkern — An internal mold which fills the inside of a fossil shell.

strata — Plural of "stratum."

stratigraphy — The science of rock strata.

stratum — A layer of sedimentary rock, visually distinct from layers above and below it.

subgenus — A taxonomic rank below genus and above species.

surficial — Of, pertaining to, or occurring on the earth's surface.

T

taxa — Plural of taxon.

taxon — A group of organisms constituting one of the categories or formal units in taxonomic classification, especially genus or species.

taxonomy — The science of naming, describing, and classifying organisms; the arrangement of organisms into a hierarchy.

therapsid — Any member of the reptile Order Therapsida, or mammal-like reptiles.

tidal channel — A channel followed by tidal currents.

tidal flat — An extensive, almost horizontal, marshy or barren area of unconsolidated sand and mud, which is alternately covered and uncovered by the tide.

trace fossil — A fossil track, trail or burrow resulting from the activities of an animal.

transgression — Landward advance of the shore line through geologic time.

Triassic — The oldest period of the Mesozoic Era, lasting from approximately 230 to 195 million years ago.

tributary — A small side branch of a river.

trilobite — Any member of the extinct Class Trilobita of the Phylum Arthropoda.

U

unconformity — A surface of erosion or non-deposition in the sedimentary rock record.

V

venation — The pattern of veins in a leaf.

vertebrate — Any animal such as fishes, amphibians, reptiles, and mammals, having a backbone or spinal column.

PLATES

The "height" measurements given for the following specimens refer to the vertical extent of the specimen as measured from top to bottom in the plate, unless indicated otherwise. The abbreviation "UNC" indicates the University of North Carolina at Chapel Hill, Department of Geology, paleontological collection. The abbreviation "SR" stands for State Road.

Plate 1. Eocambrian and Triassic Fossils.

Eocambrian

Figure 1. *Pteridinium carolinaense* (St. Jean), 1973, holotype, UNC 3602, one of the most ancient large animal fossils, and possibly a representative of the sea pen group in the Phylum Cnidaria (i.e., corals and jellyfish). Eocambrian, Upper McManus Formation, at the bridge over Island Creek, SR 1115, Stanly County, N.C. The scale on the lower left is graduated in millimeters.

Triassic

Figure 2. *Pekinopteris auriculata* Hope and Patterson, 1970, UNC 14241, topotype, a fern from the Late Triassic Pekin Formation, Boren Clay Products Quarry (Locality 6). The scale shows 10 millimeters.

Figure 3. *Cynepteris* sp., UNC 14239, a fern from the Late Triassic Pekin Formation, Boren Clay Products Quarry (Locality 6). This compound leaf shows circular clusters of sporangia (spore bearing structures). The scale shows 5 millimeters.

Figure 4. *Zamites* sp., UNC 14240, a cycadeoid (group Bennettitales) from the Late Triassic Pekin Formation, Boren Clay Products Quarry (Locality 6). The scale shows 10 millimeters.

Plate 1

Plate 2. Cretaceous Fossils.

Figure 5. *Squalicorax kaupi* (Agassiz), 1843, UNC 14230, Late Cretaceous Black Creek Formation at Elizabethtown (Locality 5). The tooth is 12.5 mm long (from left to right in the figure).

Figure 6. *Squalicorax pristodontus* (Agassiz), 1843, UNC 9684c, a shark tooth redeposited from Cretaceous into Eocene sediments at the Fussel Quarry in Duplin County, N.C.. The tooth is 27 mm long (from left to right in the figure).

Figure 7. *Cubitostrea? tecticosta* (Gabb), 1860, UNC 8023, an oyster fron the Late Cretaceous Peedee Formation, Mosley Creek, 3 miles east of Grifton, N.C. 27 mm in height.

Figure 8. *Exogyra costata* Say, 1820, form "spinosa" of Stephenson (1914), UNC 8264, the left valve of an oyster from the Late Cretaceous Peedee Formation at Milepost 49, near Donohue Landing on the Cape Fear River, N.C. 58 mm in height.

Figure 9. *Flemingostrea pratti* (Stephenson), 1923, UNC 8269, a Late Cretaceous oyster from the Peedee Formation at Milepost 49, near Donohue Landing on the Cape Fear River, N.C. 12.2 cm in height.

Figures 10-11. *Exogyra ponderosa* Römer, 1849, UNC 3120, Late Cretaceous Black Creek Formation at Blue Banks Landing on the Tar River (Locality 28). 73 mm in height.

Figure 12. *Hardouinia mortonis* (Michelin), 1850, UNC 14232, a cassiduloid echinoid from the Late Cretaceous Scotts Hill Member of the Peedee Formation, Superior Stone Quarry, 3 miles east of Castle Hayne, N.C. 37 mm in height.

Plate 2

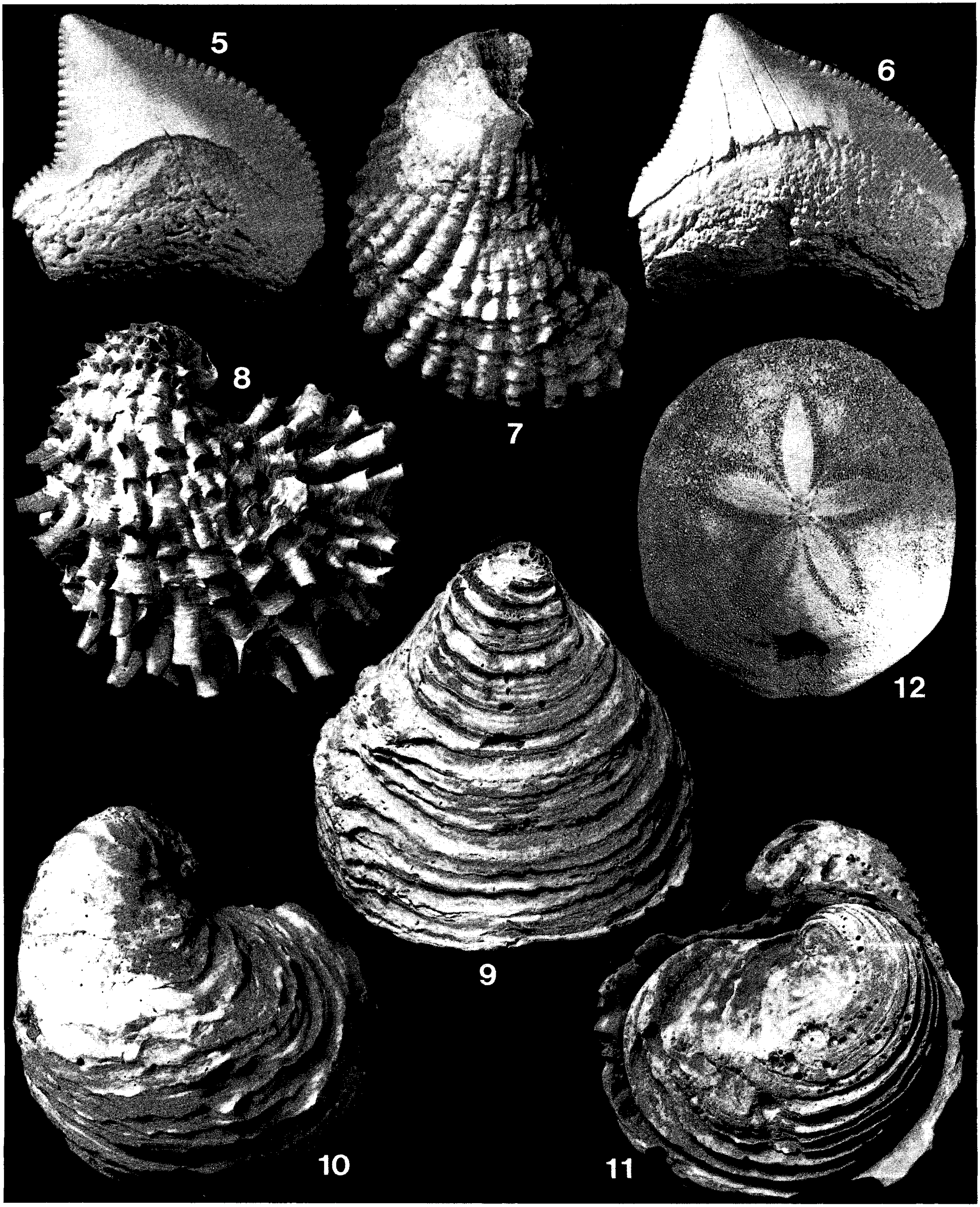


Plate 3. Paleocene and Eocene Fossils.

Paleocene

Figure 13. *Oleneothyris harlani* (Morton), 1828, UNC 1286, Paleocene Vincentown Formation, New Egypt, New Jersey. This brachiopod is 67 mm in height. This species also occurs in the Paleocene Beaufort Formation of North Carolina (Locality 21).

Eocene

Figures 14-15. *Euscalpellum carolinensis* Zullo and Baum, 1981, UNC 14233, Eocene Castle Hayne Formation, southeastern N.C. Figure 14 shows the inside and Figure 15 shows the outside of a carinal plate of this scalpellid barnacle. 39 mm in length.

Figures 16-17. *Periarchus lyelli* (Conrad),1834a, UNC 7611, Eocene Castle Hayne Formation at the Martin Marietta Ideal Quarry, northeast of Castle Hayne, New Hanover County, N.C. Figure 16 shows the upper surface of this clypeasteroid echinoid; Figure 17 shows the lower surface. 41.2 mm in height.

Figure 18. *Periarchus lyelli* (Conrad), 1834a, UNC 8428, Upper Eocene Cross Member of the Santee Formation, Giant Portland Quarry, Harleyville, S.C. This species is abundant in the Eocene Castle Hayne Formation of North Carolina. 71 mm in height.

Figures 19-20. *Plicatoria wilmingtonensis* (Lyell and Sowerby), 1845, UNC 10009, Eocene Castle Hayne Formation, Maple Hill, Lanier pit, N.C. (Locality 27). This brachiopod is 37 mm in height.

Figures 21-22. *Echinolampas appendiculata* Emmons, 1858, UNC 12631, Eocene, Castle Hayne Formation, New Bern, Craven County, N.C.. Figure 21 shows the upper surface and Figure 22 shows the lower surface of this echinoid. 36 mm in height.

Figure 23. *Ranina (Lophoranina)* cf. *L. georgiana* Rathbun, 1935, UNC 14145, Eocene Castle Hayne Formation, Maple Hill, N.C. (Locality 27). This partial crab carapace is 19.2 mm in height.

Plate 3

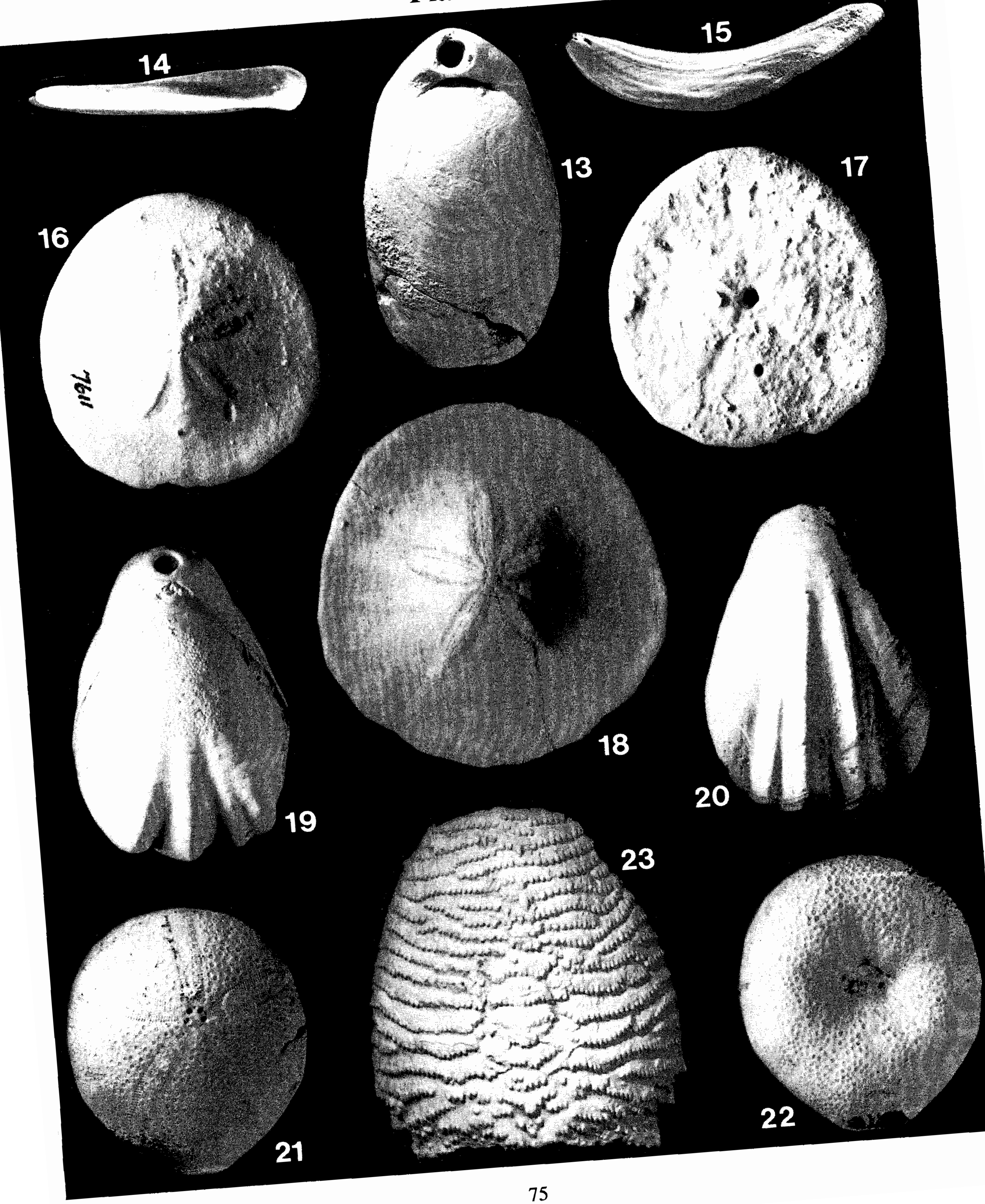


Plate 4. Eocene Fossils.

Figures 24-25. *Crassatella* aff. *C. texana* Heilprin, 1891, UNC 14246, Eocene, uppermost New Hanover Member of the Castle Hayne Formation, Martin Marietta Rocky Point Quarry, New Hanover Co., N.C. Calcitic pseudomorph, 34 mm in height. This species is closely related to the middle Eocene *C. texana*, but is larger and less elongate than the specimen of *C. texana* illustrated by Harris (1895, his Plate 2, Figure 1). It is also closely related to the Belgian middle Eocene *C. nystana* d'Orbigny (see Vincent, 1898), which is smaller and has a more central beak.

Figure 26. *Belemnosella*? sp., UNC 14146, internal cast of the phragmocone of a sepiid cephalopod, showing the position of the septae (horizontal indentations) and the ventral siphuncle (the central, vertical column). Eocene Castle Hayne Formation, Martin Marietta Ideal Quarry, northeast of Castle Hayne, New Hanover County, N.C. 34 mm in height.

Figure 27. *Pecten membranosus* Morton, 1834, UNC 7684, Eocene Castle Hayne Formation, Martin Marietta Ideal Quarry, northeast of Castle Hayne, New Hanover County, N.C. 29 mm in height.

Figures 28-29. *Callista (Callista) neusensis* (Harris), 1919a, UNC 14143, Eocene Spring Garden Member of the Castle Hayne Formation, Martin Marietta New Bern Quarry, New Bern, Craven County, N.C. Figure 28 shows a left valve. Figure 29 shows the umbonal region of two joined valves. Both figures are calcitic pseudomorphs. This species is similar to but has less projecting umbones than *Callista (Callista) perovata* (Conrad), 1833, from the Claibornian Eocene of Alabama. Figure 28 is 28 mm in height. Figure 29 is 40 mm in height.

Figure 30. *Centronea micropora* (Reuss) 1869, UNC 10012, Eocene Castle Hayne Formation, Maple Hill, Lanier pit (Locality 27). This colonial bryozoan is 32 mm in height.

Figure 31. *Spondylus lamellacea* Kellum, 1926, UNC 14244, left (upper) valve, Eocene Castle Hayne Formation at the Martin Marietta Ideal Quarry, northeast of Castle Hayne, New Hanover County, N.C. 67 mm in height. The lower valve of this species (not shown here) has prominent, sheet-like, concentric lamellae.

Plate 4

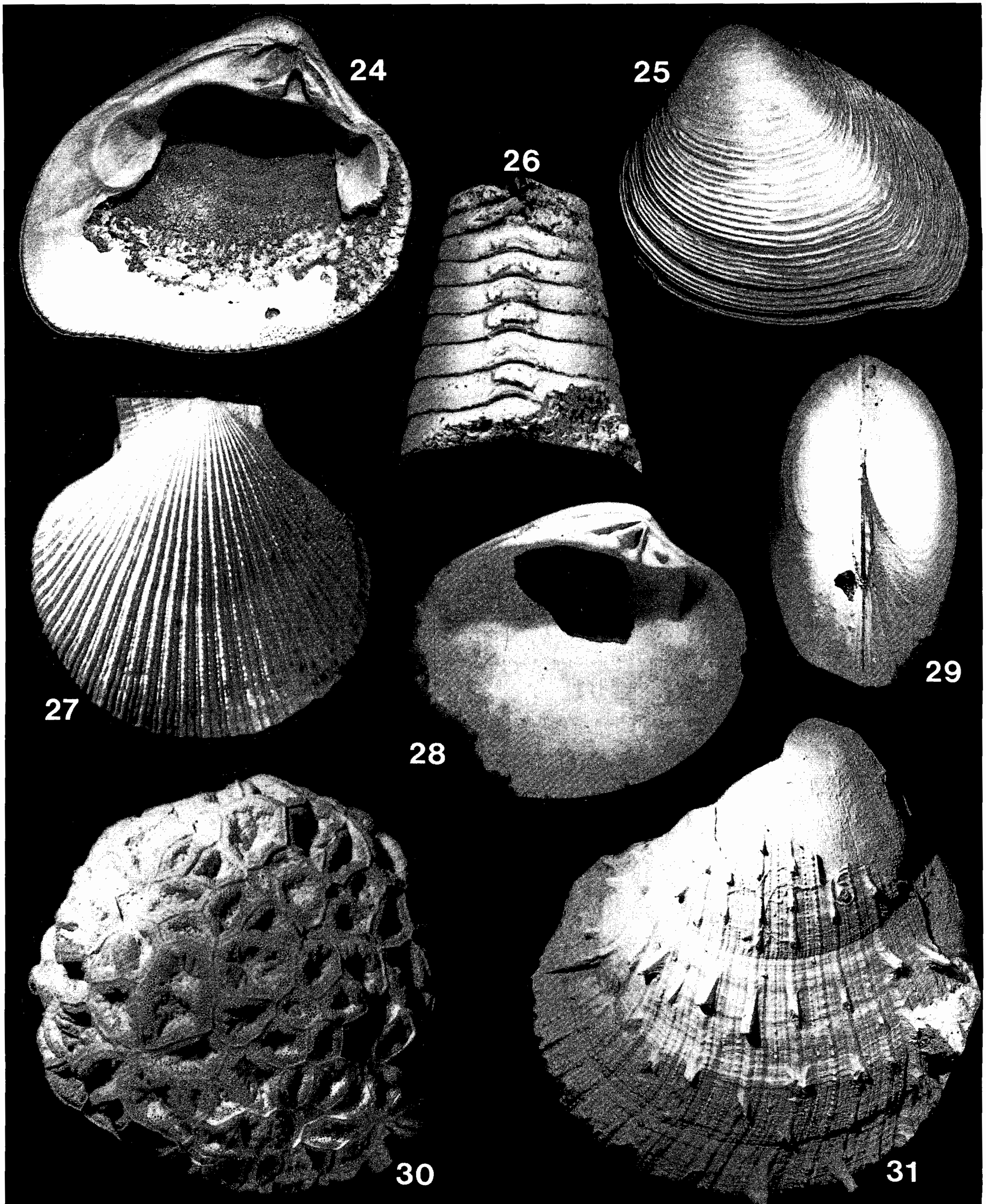


Plate 5. Cretaceous and Eocene Fossils.

Cretaceous

Figure 37. *Plicatolamna arcuata* (Woodward), 1894, UNC 14203, from Upper Cretaceous strata, reworked into the Eocene Castle Hayne Formation, Fussel Quarry, Duplin County, N.C. 19 mm in height.

Eocene

Figure 32. *Myliobatis* sp., UNC 14141, Eocene Castle Hayne Formation, Maple Hill, Lanier pit (Locality 27). Ventral (attached) view. This ray tooth plate is 19 mm in height.

Figure 33. *Myliobatis* sp., UNC 14166, Eocene Santee Formation, Santee Portland Cement Co. Quarry, Cross, S.C. This sting ray barb is 43 mm long. Similar fossils occur in the Eocene Castle Hayne Formation of North Carolina.

Figure 34. *Zygorhiza kochii* (Reichenbach), 1847, UNC 12634, Eocene Castle Hayne Formation, N.C. This tooth, from the back part of the jaw of a primitive whale, is 89 mm long. See also Figure 39.

Figure 35. *Cylindracanthus* sp., UNC 14142, Eocene Castle Hayne Formation, from the abandoned N.C. Lime Excavating Co. quarry, 4.5 miles west of Comfort, Jones Co., N.C. This bony spine belonged to a perciform fish. Length 8.8 cm.

Figure 36. *Procarcharodon auriculatus* (Blainville) 1818, UNC 11691, Eocene Spring Garden Member of the Castle Hayne Formation, Martin Marietta New Bern Quarry, New Bern, Craven County, N.C. 60 mm in height.

Figure 38. *Lamna lerichei* Casier, 1946, UNC 9674, Eocene Castle Hayne Formation, Fussel Quarry, Duplin County, N.C. 16.5 mm in height.

Figure 39. *Zygorhiza kochii* (Reichenbach), 1847, UNC 7692, Eocene Castle Hayne Formation at the Martin Marietta Ideal Quarry, northeast of Castle Hayne, New Hanover County, N.C. This tooth comes from the forward part of the jaw of this primitive whale. 67 mm in height. See also Figure 34.

Figure 40. Turtle bone, UNC 9661a, Eocene Castle Hayne Formation, Fussel Quarry, Duplin Co., N.C. The scale on the lower left is graduated in millimeters.

Plate 5

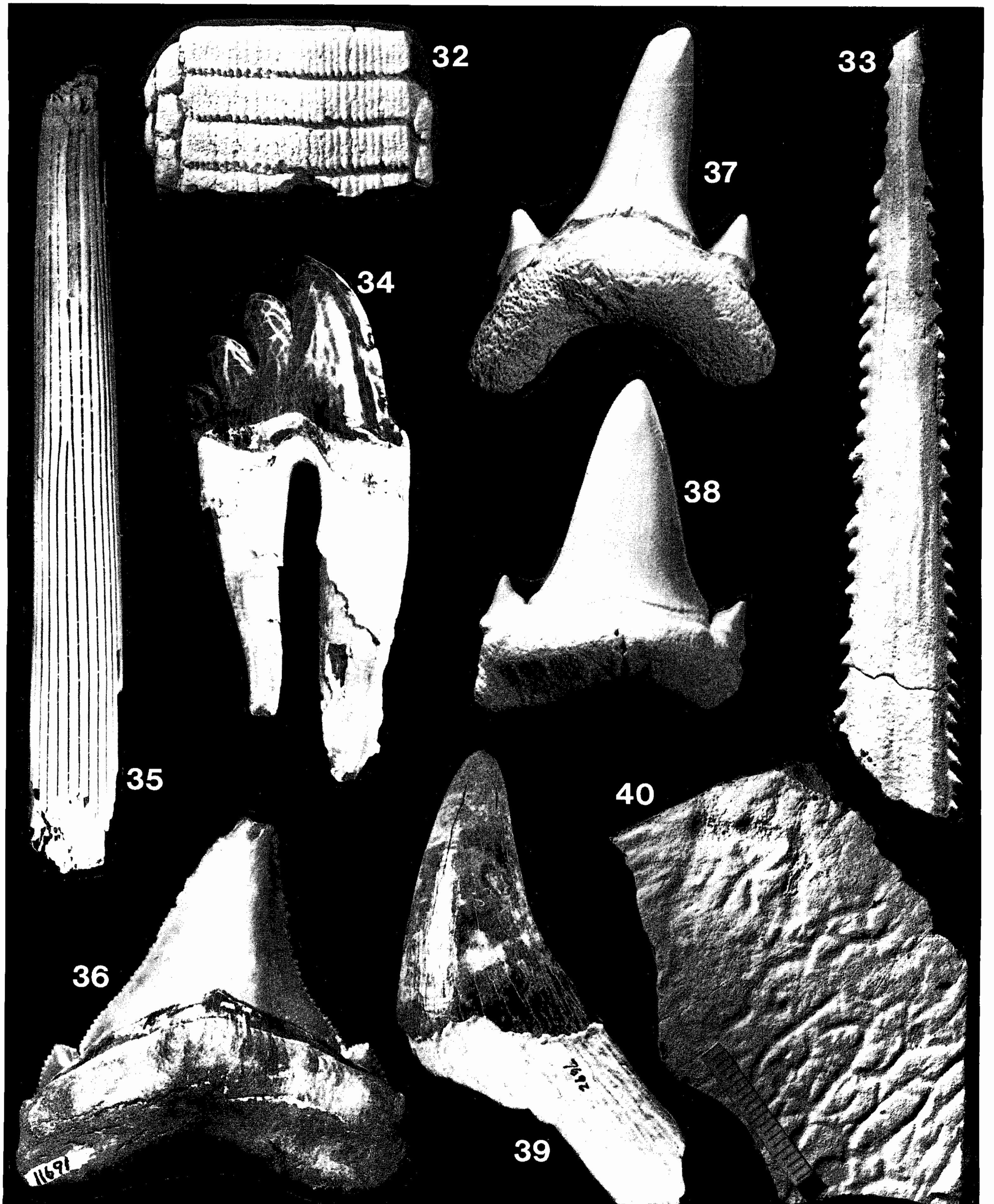


Plate 6. Oligocene Fossils.

Figure 41. *Pecten trentensis* Harris, 1919b, UNC 12536, Oligocene River Bend Formation, N.C. Department of Transportation Quarry, northeast of Pollocksville, Jones County, N.C. 18.9 mm in height.

Figure 42. *Pecten trentensis* Harris, 1919b, UNC 12536b, Oligocene River Bend Formation, N.C. Department of Transportation Quarry, northeast of Pollocksville, Jones County, N.C. 46 mm in height.

Figure 43. *Pecten* cf. *P. biformis* Conrad, 1843, UNC 12536a, Oligocene River Bend Formation, N.C. Department of Transportation Quarry, northeast of Pollocksville, Jones County, N.C. 33.4 mm in height. As in *P. biformis*, the juvenile part of this left valve is concave, whereas the adult shell margin is slightly convex. The primary and secondary ribbing resembles the left valve of *P. biformis* (see Tucker, 1936, his Plate 4, Figure 5). However, the present shell is thicker than *P. biformis*, which Tucker (1936, p. 477) described as translucent. The geologic age of Conrad's *P. biformis* is not well documented. Conrad (1843, p. 306) indicated his specimens came from Petersburg, Virginia, but in 1845 (p. 73 in Conrad, 1838-1861) he mentioned only the Pamunkey River, Virginia. While not mentioning Conrad's original locality designation, Tucker (1936) indicated the Pamunkey River as the type area. Fossiliferous Yorktown Formation is exposed both near Petersburg and along the Pamunkey River in Virginia. However, Pamunkey River exposures also include strata ranging in age from Paleocene to Miocene (Ward, 1984).

Figure 44. *Turritella* aff. *T. bowenae* Mansfield, 1937, UNC 14064b, (latex cast), Oligocene, lower River Bend Formation, Martin Marietta New Bern Quarry, New Bern, Craven County, N.C. 66.4 mm in height. This specimen differs from typical *T. bowenae* in replacing the second of two strong basal cords in *T. bowenae* (the one closer to the apex) with a double cord. This New Bern assemblage also includes typical *T. bowenae* (originally described from the Suwannee Limestone of Florida; see Plate 9, Figure 3 of Mansfield, 1937), and *Turritella* aff. *T. bowenae* of Mansfield (1940, Plate 27, Figure 52), originally described from the lower Chickasawhay Formation of Alabama. The New Bern specimens are closely related to *T. tampae* Heilprin, 1887, form "pagodaeformis" of Heilprin, 1887 (see Dall, 1892), but in "pagodaeformis" there are fewer spiral cords above the two strong basal cords, and one of these finer cords is clearly stronger than the others.

Figure 45. *Galeodaria* cf. *G. shubutensis gardnerae* MacNeil and Dockery, 1984, UNC 14004 (latex cast), Oligocene, lower River Bend Formation, Martin Marietta New Bern Quarry, New Bern, Craven County, N.C. 33.1 mm in height.

Figure 46. *Calyptraea (Trochita) aperta* (Solander), 1766, UNC 12428 (latex cast), Oligocene, upper River Bend Formation, Martin Marietta Belgrade Quarry, Onslow County, N.C. 32 mm in height.

Figure 47. *"Dinocardium" belgradensis* (Richards), 1948, UNC 12392a (latex cast), Oligocene, upper River Bend Formation, Martin Marietta Belgrade Quarry, Onslow County, N.C. 25 mm in height.

Figure 48. *Apiocypraea* aff. *A. humbergi* Janssen, 1978, UNC 13987 (latex cast), Oligocene, lower River Bend Formation, Martin Marietta New Bern Quarry, New Bern, Craven County, N.C. 29.1 mm in height. The lower River Bend Formation at this locality also contains a cowry similar to *Cypraeorbis ventripotens* (Cossmann), 1903, described by MacNeil and Dockery (1984, p. 98) from the upper Eocene and lower Oligocene of the Gulf Coast. The latter species includes "*Cypraea tumulus*" of Dall (1915) (not of Heilprin, 1887), from the upper Eocene of Louisiana and Mississippi, and from the late Oligocene or early Miocene Tampa Formation of Florida.

Figure 49. *Mercenaria gardnerae* (Kellum), 1926, UNC12368a (latex cast), Oligocene, upper River Bend Formation, Martin Marietta Belgrade Quarry, Onslow County, N.C. 44 mm in height.

Plate 6

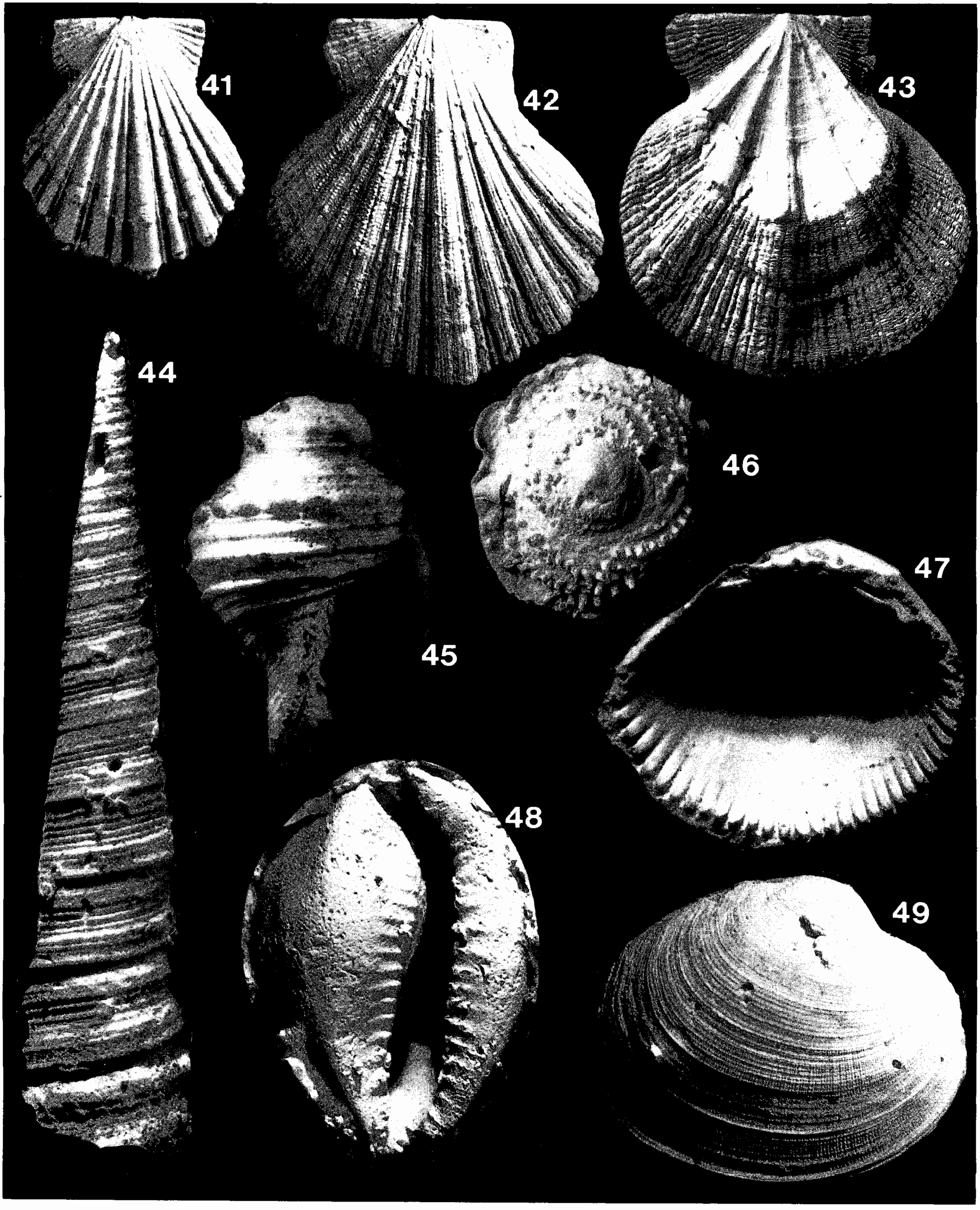


Plate 7. Late Oligocene or Early Miocene Fossils.

Figure 50. *Pecten* aff. *P. trentensis* Harris, 1919b, UNC 4838, late Oligocene or early Miocene, Haywood Landing Member of the Belgrade Formation, Silverdale, Onslow County, N.C. The ribs on this right valve are more uniformly bifid than typical *P. trentensis*. 68.5 mm in height.

Figure 51. *Rapana gilletti* Richards, 1943, UNC 12526a, late Oligocene or early Miocene, Haywood Landing Member of the Belgrade Formation, Haywood Landing (Locality 20). 35 mm in height.

Figure 52. *Cymatophos* n. sp. aff. *C. veatchi* (Olsson), 1922, UNC 12527c, late Oligocene or early Miocene, Haywood Landing Member of the Belgrade Formation, Haywood Landing (Locality 20). 39.6 mm in height. The closely related *Cymatophos veatchi* of the Miocene Gatun Formation of Costa Rica (which resembles *Cymatophos pilsbryi* Olsson, 1964, of the Miocene Angostura Formation of Ecuador) has prominent spiral cords on the adult whorls.

Figure 53. *Astarte onslowensis* Kellum, 1926, USNM 353244, Exterior and interior views of Kellum's type specimen, Late Oligocene or Early Miocene, Haywood Landing Member of the Belgrade Formation, Silverdale, Onslow Co., N.C. 10.5 mm in height.

Figure 54. *Aporrhais* n. sp., UNC 12529, Late Oligocene or Early Miocene, Haywood Landing Member of the Belgrade Formation, Haywood Landing (Locality 20). 22 mm in height. This is a very common gastropod at Haywood Landing, but it is generally found broken.

Figure 55. *Turritella* aff. *T. bowenae* Mansfield, 1937, UNC 12159, Late Oligocene or Early Miocene, Haywood Landing Member of the Belgrade Formation, Silverdale, Onslow County, N.C. 29.3 mm in height. Like the specimen in Figure 44, this one differs from typical *T. bowenae* in replacing the more posterior of two strong, basal cords with a weaker, double cord. The Haywood Landing Member at Silverdale also contains typical *T. tampae* Heilprin, 1887. *Turritella fuerta* Kellum, 1926, originally described from Silverdale, is probably a junior synonym of *T. tampae* Heilprin, 1887 (compare Dall's, 1892, Plate 17, Figure 8, with Kellum's, 1926, Plate 10, Figure 8).

Figure 56. *Turritella bowenae* Mansfield, 1937, UNC 12486, Late Oligocene or early Miocene Haywood Landing Member of the Belgrade Formation, Haywood Landing (Locality 20). 31.6 mm in height. This species differs from the closely related *T. tampae* Heilprin, 1887, form "pagodaeformis" of Heilprin, 1887 (see Dall, 1892) in having more numerous and more equally prominent spiral cords posterior to its two strong basal cords. The Haywood Landing Member at this locality also contains typical *T. tampae* and *T. tampae* form "pagodaeformis"

Figure 57. *Macrocallista minuscula* Kellum, 1926, UNC 12512, Late Oligocene or Early Miocene, Haywood Landing Member of the Belgrade Formation, Haywood Landing, N.C. (Locality 20). 67 mm in height. *Macrocallista waltonensis* Gardner (published September 20, 1926) is a junior synonym of Kellum's species, which was published by July 31, 1926 (the date of receipt of Kellum's publication at the U.S. Geological Survey Library in Reston, Virginia). *M. minuscula* resembles *M. acuminata* Dall, 1903, except that the former species is rarely, if ever, as pointed posteriorly as the specimen of *M. acuminata* illustrated by Dall (1903; his Plate 57, Figure 3).

Figure 58. *Donax idoneus* Conrad, 1872, UNC 12456, Late Oligocene or Early Miocene, Haywood Landing Member of the Belgrade Formation, Haywood Landing (Locality 20). Interior and exterior views of an exceptionally large left valve, 38 mm in height.

Plate 7

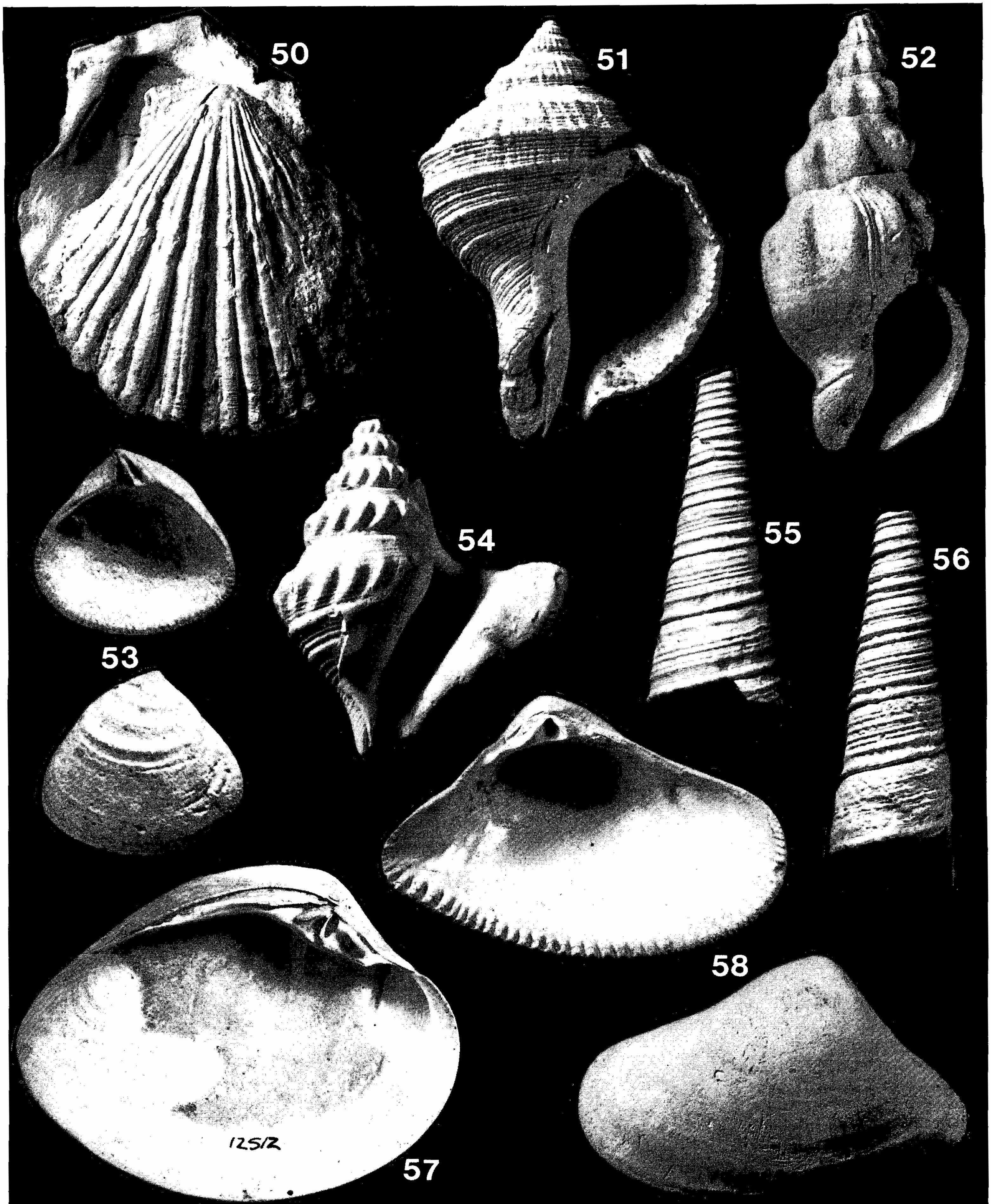


Plate 8. Early and Middle Miocene Fossils.

Figure 59. *Pecten trentensis* Harris, 1919b, UNC 12538 (latex cast), early Miocene, lower dolomitic, sandy portion of the Pungo River Formation at the Texasgulf phosphate mine near Aurora, N.C. 17.4 mm in height.

Figure 60. *Squalodon atlanticus* Leidy, 1856, UNC 14147, early Miocene, lower dolomitic, sandy portion of the Pungo River Formation at the Texasgulf phosphate mine near Aurora, N.C. This whale tooth is 50.1 mm in height.

Figure 61. *Venus* n. sp., aff. *Venus langdoni* Dall, 1903, UNC 12562 (latex cast), early Miocene, lower dolomitic, sandy portion of the Pungo River Formation at the Texasgulf Phosphate Mine near Aurora, N.C. 43.8 mm in height. This species resembles *V. langdoni* in its hinge dentition, non-cancellate ornament, and nearly smooth, strongly beveled escutcheon in the left valve, but it differs from *V. langdoni* in having slight corrugations on its concentric lamellae.

Figure 62. *Chesapecten coccymelus* (Dall), 1898, UNC 10376, middle Miocene, upper moldic limestone portion of the Pungo River Formation at the Texasgulf phosphate mine near Aurora, N.C. 34.7 mm in height.

Figure 63. *Ecphora tricostata* Martin, 1904, UNC 10398, middle Miocene, upper moldic limestone portion of the Pungo River Formation at the Texasgulf phosphate mine near Aurora, N.C. 23.4 mm in height.

Figure 64. *Lucinoma contracta* (Say), 1824, UNC 10392 (latex cast), middle Miocene, upper moldic limestone portion of the Pungo River Formation at the Texasgulf phosphate mine near Aurora, N.C. 32.7 mm in height.

Figure 65. *Procarcharodon* aff. *P. auriculatus* (Blainville), 1818, Texasgulf phosphate mine near Aurora, N.C., probably from the basal (Lower Miocene, Aquitanian or Burdigalian) part of the Pungo River Formation, or the underlying upper Oligocene or lower Miocene Belgrade Formation. 70.4 mm in height. This species is intermediate between *Procarcharodon auriculatus* (Figure 36) and *Procarcharodon megalodon* (Figure 69). It has accessory side cusps like *P. auriculatus*, but its apical portion is more expanded than typical *P. auriculatus*. This specimen is similar to the one which Weems (1984, his Plate 1, Figure J) identified from the Upper Oligocene or Lower Miocene of Virginia as *Procarcharodon angustidens* (Agassiz), 1843. Case (1981) regarded *P. angustidens* as a junior synonym of *P. auriculatus*.

Figure 66. *Hyotissa percrassa* (Conrad), 1840, UNC 12134a, middle Miocene, upper moldic limestone portion of the Pungo River Formation at the Texasgulf phosphate mine near Aurora, N.C. This pycnodont oyster is 76.9 mm in height.

Plate 8

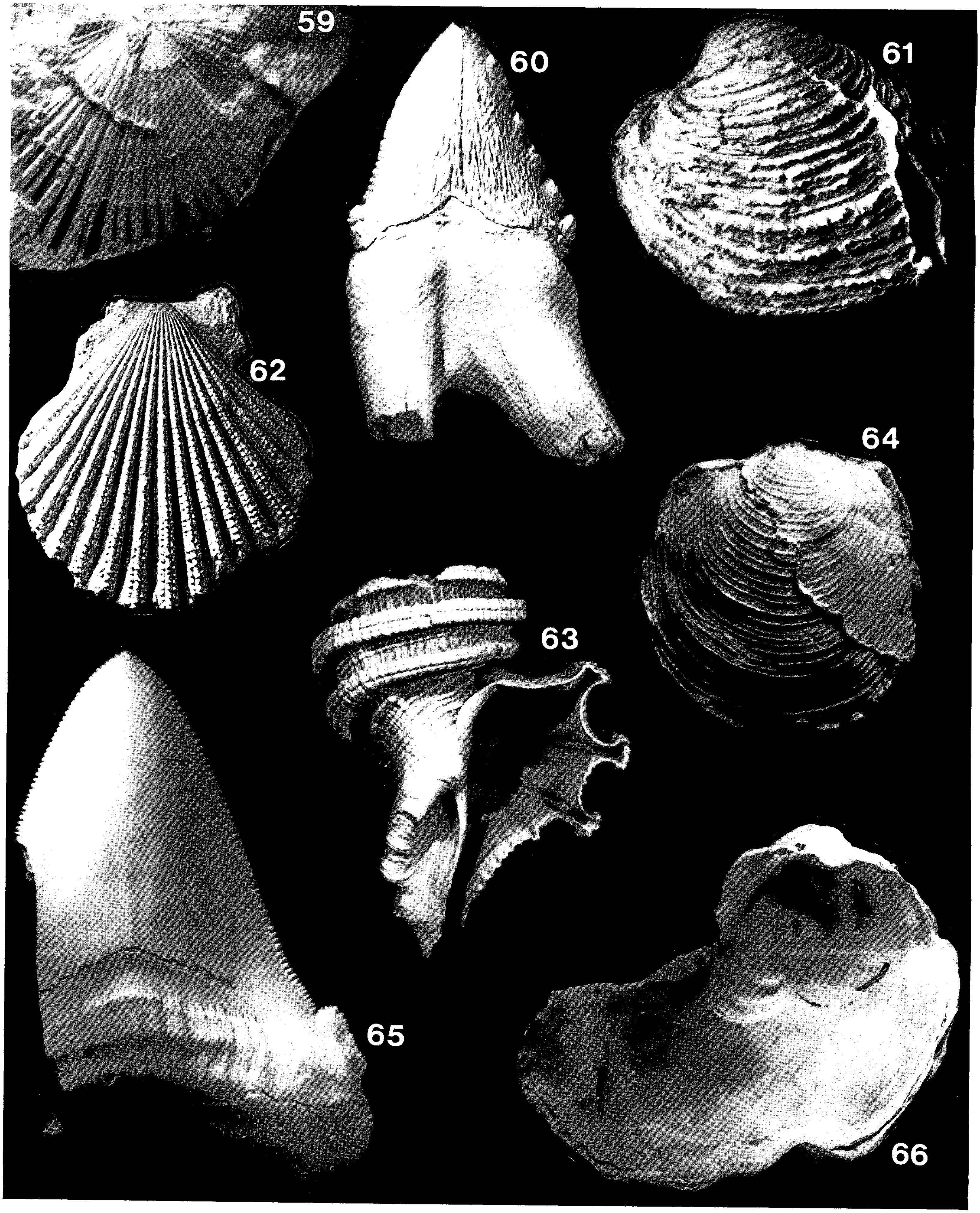


Plate 9. Miocene, Pliocene, and Pleistocene Fossils.

Miocene

Figure 67. *Parotodus benedeni* (LeHon), UNC 14170, a Miocene species reworked into the Pliocene, Duplin fauna of the Yorktown Formation at Tarheel, N.C. 39.4 mm in height.

Figure 69. *Procarcharodon megalodon* (Agassiz), 1837, UNC 14249, from spoil piles at the Texasgulf phosphate mine near Aurora, N.C., probably Miocene in age. 99 mm in height.

Pliocene

Figure 68. *Fusinus equalis* (Emmons), 1858, UNC 11353, Pliocene, Duplin fauna of the Yorktown Formation, Tarheel, N.C. 73.6 mm in height.

Figure 70. *Ecphora* n. sp. aff. *E. quadricostata* (Say), 1824, UNC 11752, Pliocene, Duplin fauna of the Yorktown Formation, Robeson farm, Tarheel, N.C. 64.6 mm in height.

Figure 71. *Siphocypraea* (*Siphocypraea*) *carolinensis* (Conrad), 1841, (= *Cypraea pilsbryi* Ingram, 1939), UNC 11357, Pliocene, Duplin fauna of the Yorktown Formation, Robeson farm, Tarheel, N.C. 31 mm in height.

Figure 72. *Fasciolaria elegans* Emmons, 1858, UNC 14229, Pliocene, Duplin fauna of the Yorktown Formation, Robeson farm, Tarheel, N.C. 89 mm in height.

Pliocene or Pleistocene

Figure 73. Turtle bone, UNC 14158, Pliocene or Pleistocene, Waccamaw Formation, Town Creek, south of Wiggins Crossroads, Edgecombe Co., N.C. The scale in this figure is graduated in millimeters.

Plate 9

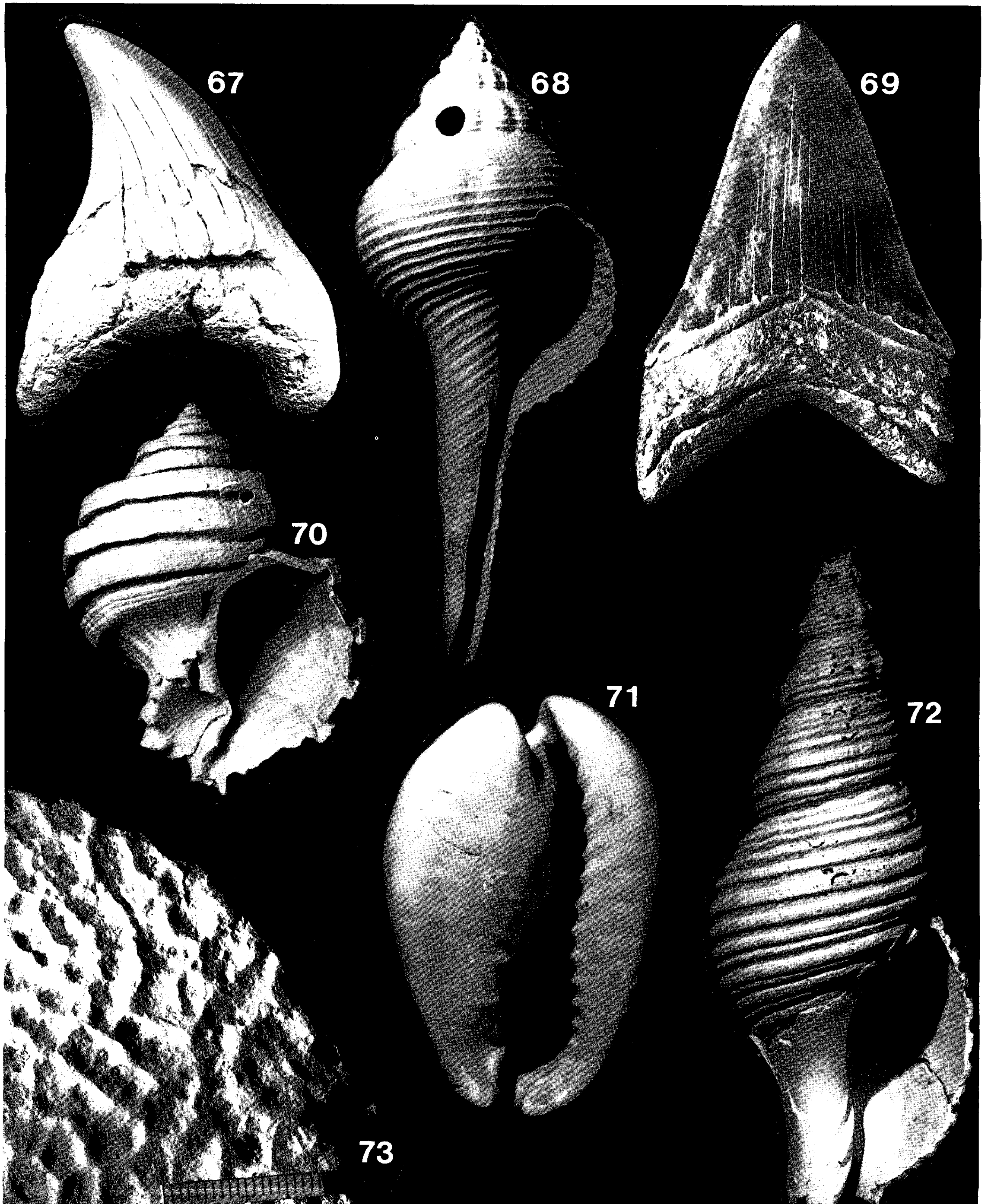


Plate 10. Pliocene Fossils.

Figure 74. *Chlamys* aff. *C. decemnaria* (Conrad), 1834b, UNC 12883, Pliocene, Sunken Meadow Member of the Yorktown Formation at Murfreesboro, N.C. (Locality 18A). 26.5 mm in height. This specimen is closely related to the form "dispalatus" of *Chlamys decemnaria* (originally published as *Pecten dispalatus* Conrad, 1845), as redescribed by Dall (1898, p. 741).

Figure 75. *Ostrea sculpturata* Conrad, 1840, UNC 11136, Pliocene, Yorktown Formation, Murfreesboro, N.C. 80 mm in height.

Figure 76. *Chesapecten septenarius* (Say), 1824, UNC 12586, Pliocene, Yorktown Formation, Texasgulf phosphate mine, near Aurora, N.C. 79 mm in height.

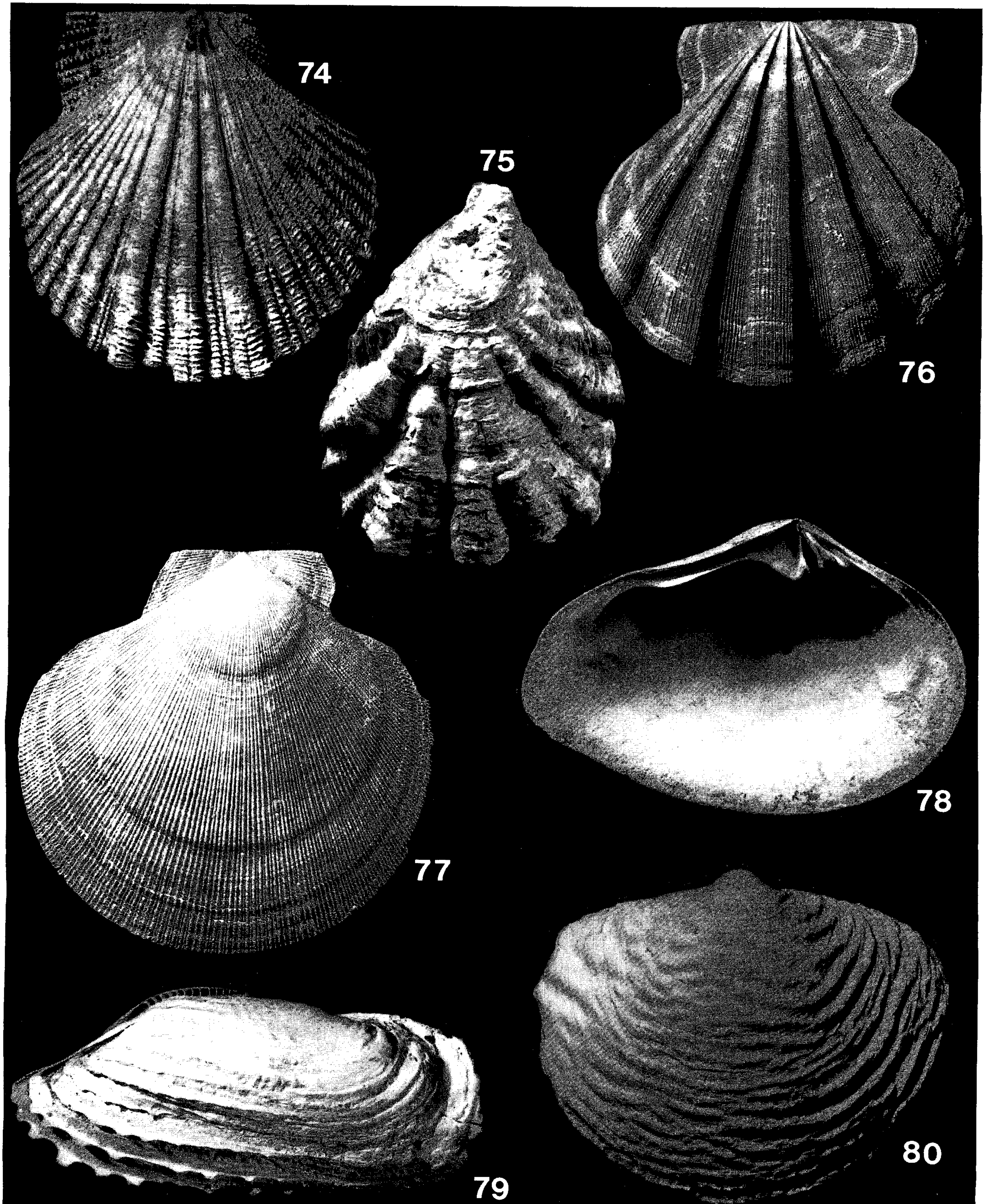
Figure 77. *Placopecten clintonius* (Say), 1824, UNC 11460, Pliocene Yorktown Formation on the Meherrin River, Murfreesboro, N.C. 11.1 cm in height.

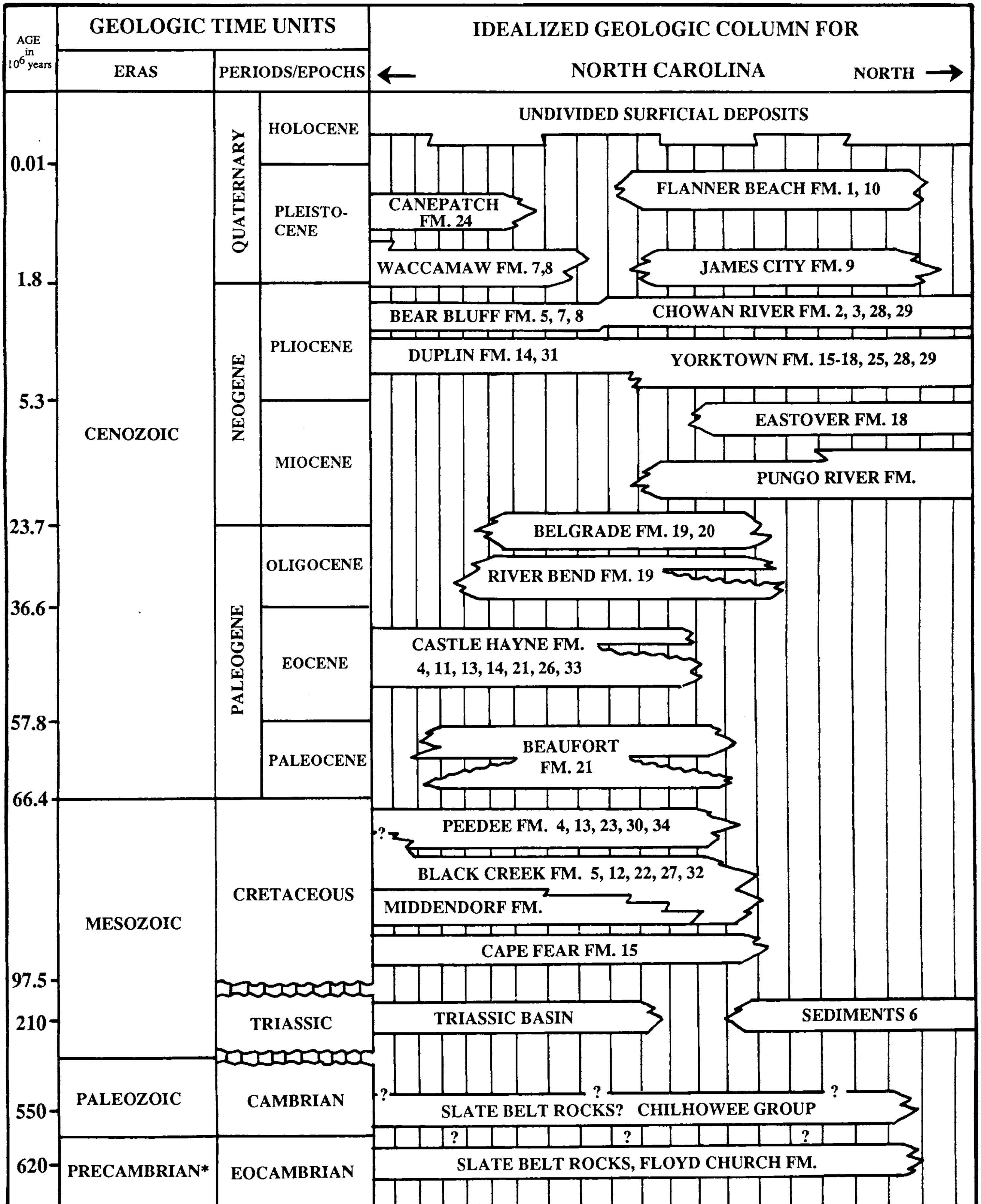
Figure 78. *Marvacrassatella undulata* (Say), 1824, UNC 9003, Pliocene, Zone 2 Yorktown Formation, A. B. Southall Pit, East side of Big Bethel Road (Virginia Road 600) about 0.1 mile south of Virginia Highway 134, Newport News North 7.5' quadrangle, Virginia. 57.1 mm in height.

Figure 79. *Pholas* aff. *P. memmingeri* Tuomey and Holmes, 1858 ("1856"), UNC 14144, Pliocene, Duplin fauna of the Yorktown Formation, basal clay in the gully between the Robeson and Mitchell farms, Tarheel, N.C. 30 mm in length. The Tarheel populations of this species are uniformly less than 45 mm in length, i.e., about one-half the size of the specimens illustrated by Tuomey and Holmes (1858) from the Pliocene of the Sumter District of South Carolina, and by Olsson and Petit (1964) from the Pliocene Pinecrest Member of the Tamiami Formation of Florida.

Figure 80. *Glycymeris americana* (Defrance), 1826, UNC 11292b, form "aberrans" of Nicol (1953), Pliocene, Duplin fauna of the Yorktown Formation, Tarheel, N. C. 32.5 mm in height.

Plate 10





The numbers following the formation names refer to fossil localities described in the text. "Fm." stands for "Formation". *The exposed Precambrian rocks in the Piedmont of North Carolina belong in the Proterozoic Eon. The Paleozoic, Mesozoic and Cenozoic Eras belong in the Phanerozoic Eon.

Fossil Collecting Localities in Eastern North Carolina