The background of the cover is a detailed, light-colored photograph of numerous fossilized trilobites. The trilobites are shown from various angles, highlighting their segmented bodies, heads with prominent eyes, and three distinct parts: the cephalon, thorax, and pygidium. The fossils are set against a dark, textured matrix.

**Geology and Paleontology  
of the  
Lee Creek Mine, North Carolina, II**

**CLAYTON E. RAY  
EDITOR**

SMITHSONIAN CONTRIBUTIONS TO PALEOBIOLOGY • NUMBER 61

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Geology and Paleontology  
of the  
Lee Creek Mine, North Carolina, II

*Clayton E. Ray*

EDITOR



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## ABSTRACT

Ray, Clayton E., editor. Geology and Paleontology of the Lee Creek Mine, North Carolina, II. *Smithsonian Contributions to Paleobiology*, number 61, 283 pages, 80 plates, 49 figures, 21 tables, 1987.—Volume I of this projected series of three volumes included the prologue to the series, a biography of Remington Kellogg, and 13 papers on geology and paleontology other than Mollusca and Vertebrata (except otoliths). It was published in 1983 as *Smithsonian Contributions to Paleobiology* number 53. The present volume consists of a foreword and five chapters devoted to molluscan paleontology. The foreword recounts the earliest scientific publication of New World fossils, all mollusks, and reproduces Martin Lister's illustrations of them. William M. Furnish and Brian F. Glenister record the nautilid genus *Aturia* from the Pungo River Formation and discuss its occurrence elsewhere. Druid Wilson describes a new pycnodont oyster from the Pungo River Formation and lists the Cenozoic pycnodonts from the Atlantic and Gulf Coastal Plain; he also summarizes the stratigraphic and geographic occurrences of the subgenera of *Ecphora*, *Ecphora* and *Stenomphalus*, naming a new species of each from the Pungo River Formation, and a new species of the former from the St. Marys Formation of Maryland. Thomas G. Gibson clarifies the relationships and stratigraphic utility of 17 taxa (including one new species from the Pungo River Formation) of pectinid bivalves on the basis of biometric study of large samples from lower Miocene to lower Pleistocene beds in and near the mine. Lauck W. Ward and Blake W. Blackwelder describe a molluscan fauna of 194 species, including 30 new species and 3 new subspecies, from the Chowan River (upper Pliocene) and James City (lower Pleistocene) formations, and conclude that the fauna reflects a subtropical thermal regime and that it was deposited under open marine conditions at depths not exceeding 25 meters.

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Dedicated to  
Remington Kellogg  
1892-1969





# Geology and Paleontology of the Lee Creek Mine, North Carolina, II

## Foreword

*Clayton E. Ray*

Foreword . . . front matter likely to be of interest but not necessarily essential for the understanding of the text of a book and commonly written by someone other than the author[s] of the text.

WEBSTER'S THIRD NEW  
INTERNATIONAL  
DICTIONARY, 1964.

The first of three proposed volumes on the "Geology and Paleontology of the Lee Creek Mine, North Carolina," has now been published (Ray, 1983). This, the second, volume is devoted exclusively to the Mollusca. Truly comprehensive coverage of this most conspicuous component of the Lee Creek macrofauna justifiably could have occupied at least twice the space. Faunal studies of the mollusks of the Pungo River and Yorktown formations comparable in scope to those of the James City and Chowan River formations (Ward and Blackwelder, this volume) remain as prime desiderata. A mollusk-rich, late Pleistocene bed of regional significance became well exposed by mining too late for inclusion in this volume. Detailed studies as dictated by abundance and state of knowledge of given taxonomic groups, exemplified by the chapters on *Aturia* (Furnish and Glenister, this volume), pycnodonts and ecphoras (Wilson, this volume), and pectens (Gibson, this volume), would be equally well warranted for numerous additional taxa.

The rich shell beds of the middle Atlantic Coastal Plain were of practical interest from the early days of British settlement, as a source of lime for mortar (Ray, 1983:4). Later, in the nineteenth century, these "shell marls" were used extensively to improve the agricultural lands of the coastal plain (see, for example, Olmsted, 1827; Croom,

1835; Emmons, 1858; Mitchell, 1981; Allmendinger, 1985).

Mollusks from the Yorktown Formation of Virginia were the first fossils of any kind from the Western Hemisphere to receive scientific attention and to be illustrated in publication, both nearly 300 years ago. The centerpiece of this story is the classical monument of malacology, Martin Lister's *Historiae Conchyliorum*, parts of which were published for the first time at least from 1685 to 1692, if not to 1697, and probably posthumously, as late as 1770. Some aspects of the paleontological part of the story have been presented by subsequent authors, but as yet not both completely and correctly. The problems stem primarily from Lister's confusing practices in the printing, distributing, and publishing of his great work, a subject of research in itself beyond our scope here, to which a good introduction may be gained from Wilkins (1957), Sawyer (1962), and Keynes (1981). It is unlikely that any two copies of the work as prepared during Lister's lifetime are identical; plates were repeatedly modified as successive "proofs" were printed and variously distributed; some plate numbers were omitted and others duplicated; in no case is it correct to cite 1685 as date of publication in connection with North American fossils.

That Lister's 1000-plus plates include representation of some North American fossil shells was recognized nearly 200 years ago by Lightfoot (1786:162), who listed as number 3516 in his catalogue for auction of the Portland

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Museum “a very curious and rare species of *Buccinum* in a fossil state, having four high sharp ridges, from *Maryland*, very rare—Lister, 1059.2.” However, his observation seems to have had no impact on contemporary or later authors. Other early authors apparently did not recognize as a fossil the specimen represented by Lister (e.g., Schröter, 1783:361; Dillwyn, 1823:48), and Dillwyn referred it to the living species *Buccinum scala*, regarded as a junior synonym of the Indo-Pacific *Thais* (*Trochia*) *cingulata* by Dodge (1956:235–237), and earlier by Tryon (1880:170), who also noted that “the normal development of ribs strikingly resembles the fossil *Rapana* (*Ecphora*) *quadricostata*, Say, of the United States.”

For practical purposes recognition of the significance of Lister’s plates for North American paleontology came when Say (1824:134) ascribed a shell illustrated by Lister to his own new species, *Pecten jeffersonius*, based on material then thought to have come from Maryland, but later recognized as coming from Virginia (Gardner, 1943:38, 1948:201; Ward and Blackwelder, 1975:3–4; Wilson, this volume, p. 21). Harris (1937:443) apparently was the first to consider without question that three North American fossils were so represented, as reflected in the following statement: “We have often wondered by what home-returning sailor, specimens of *Ecphora quadricostata*, *Pecten jeffersonius*, and *Venus tridacnoides* were brought from our colonial shores . . . and published in . . . Lister’s *Historiae Conchyliorum*.”

Lister’s figure of the snail, *Ecphora*, has been widely regarded as the first published (supposedly in 1685) of a North American fossil, but the year and priority are certainly wrong and the specific identification as *E. quadricostata* is questionable. Lister’s figure is reproduced here (Figure 1F) along with photographs of specimens of *E. quadricostata* from the Lee Creek Mine (Figure 1A–E). Say (1824:128) had speculated upon the similarity between his new species, *Fusus 4-costatus*, and that figured by Lister, but rejected their identity because Lister’s specimen seemed to lack an umbilicus. Conrad (1864:211) however, regarded Lister’s figure as representing a rare variety of the species, as he had himself found one specimen without umbilicus. Recent efforts to locate Conrad’s specimen in the collections of the Academy of Natural Sciences of Philadelphia have not as yet been successful (Carol Jones, pers. comm.). The specific identification might be resolved if the original specimen could be found. Shattuck (1904:xxxiv) simply asserted that “in 1685, Martin Lister published a figure of *Ecphora quadricostata*. This was the first American fossil to be figured, and the original came from the Miocene of Maryland.” Martin (1904:207, pl. 52: fig. 3) cited Lister in his synonymy of *E. quadricostata* and reproduced Lister’s figure. Vokes (1957:30, pl. 25: fig. 1) followed these authors and reproduced the figure again. Ward and Blackwelder (1975:3) were the first to point out that none of Lister’s illustrations of the three North American mollusks was

published as early as 1685, and that both *Chesapecten jeffersonius* and *Mercenaria tridacnoides* preceded *Ecphora*. However, their assertion that the figure of *Ecphora* was published in 1692 seems not to be demonstrable. Available evidence indicates that it was first published in the Huddesford (1770) edition of Lister (Wilkins, 1957:204; Wilson, this volume; Robert Cross, British Museum (Natural History), pers. comm.).

Conrad (1840:46; in Dall, 1893:68) agreed with Say’s (1824) identification of Lister’s scallop as *Pecten jeffersonius*, but regarded the peculiarities of the shell margin as resulting from attachment of barnacles, rather than from abnormality in growth as implied by Say. Ward and Blackwelder (1975, pl. 1) and Blackwelder and Ward (1976, frontispiece) reproduced Lister’s figure of *Chesapecten jeffersonius*, which they regarded, correctly it seems, as indeed the first illustrated (and described, though not formally) North American fossil. *C. jeffersonius* is unique among the three in that it has descriptive text both on the original plate (Figure 2 here) and in annotations written by Lister and published by Huddesford (1770), all reproduced in full (and that on the plate translated) by Ward and Blackwelder (1975:15).

Conrad (1838:10; in Dall, 1893:28) apparently was the first to recognize among Lister’s plates the third example of a North American fossil, the clam *Venus tridacnoides*, an identification accepted also by Gardner (1943:132). Wilson (1983:485) has traced the nomenclatural history of this taxon, which should now be known as *Mercenaria corrugata*. Lister’s figures are reproduced here as Figure 3.

These North American fossils probably came into Lister’s hands through much more purposive acts than a sailor’s curio-collecting. Ewan and Ewan (1970:312) made a strong circumstantial case for their having been received from John Banister, who certainly sent specimens to Lister and others, and who lived and collected on the Virginia coastal plain from 1678 to 1692. Banister’s untimely death foreclosed any possibility of completing his planned natural history of Virginia, which undoubtedly would have provided a more nearly adequate record of his extensive contributions, including those in paleontology. The two bivalves illustrated by Lister, now assigned to species of the Yorktown Formation, in all probability were collected by Banister. The *Ecphora* seems less certain in that its specific identity is questionable; it appeared only in one of the last supplemental plates, at least some years after Banister’s death, and it is labeled in the figure as “a Marilandia.” According to Druid Wilson (pers. comm.) extreme variants of *Ecphora* are to be expected in the pre-Yorktown Miocene and in Maryland, but not in the Yorktown Formation and not in Virginia. The illustrated specimen well might have been obtained by Hugh Jones who served in the ministry in Maryland from 1696 through 1701, during most of that time in Christ Church Parish, Calvert County (Ewan and Ewan, 1970:111; Frick et al., in press; Reveal, 1984). He

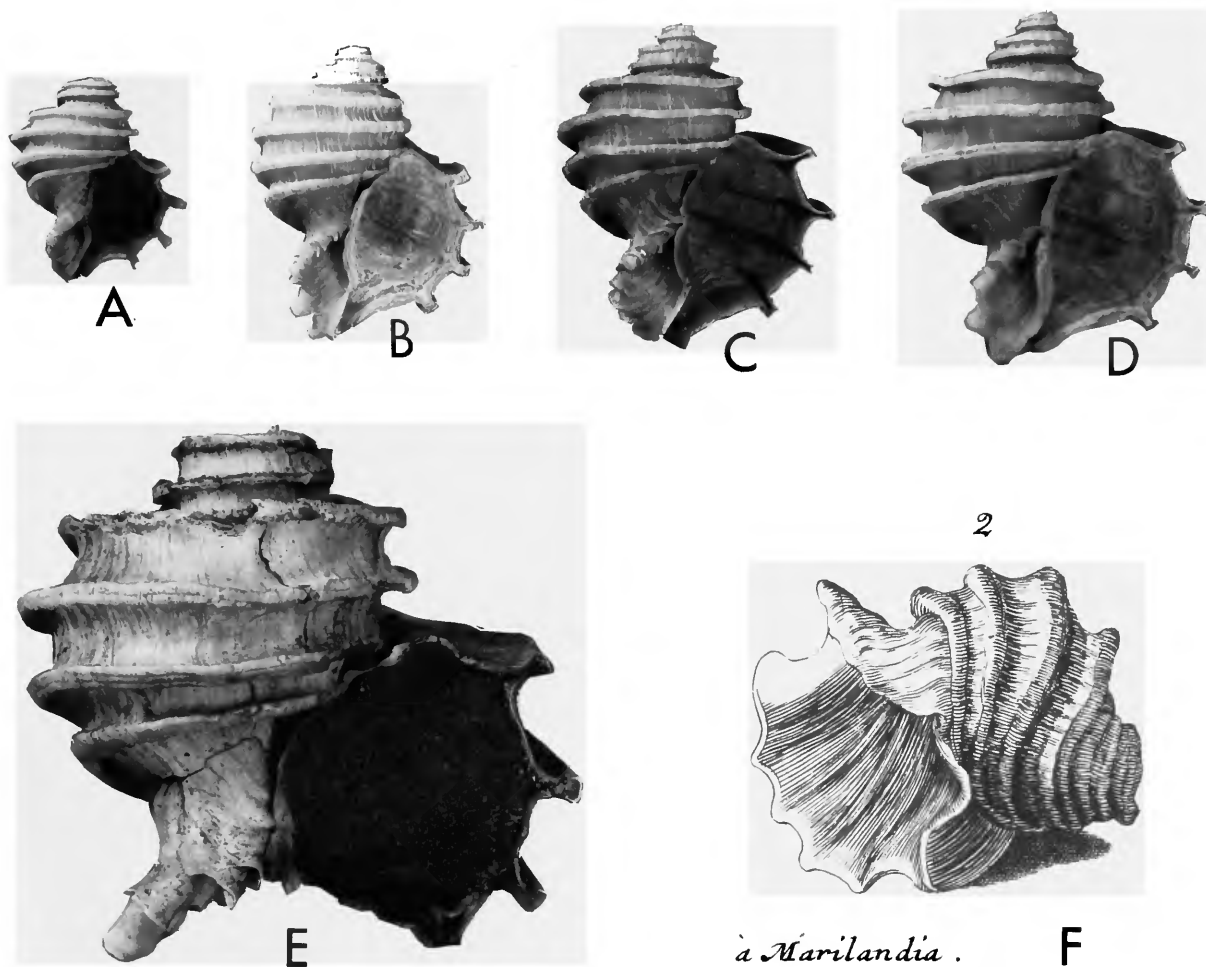


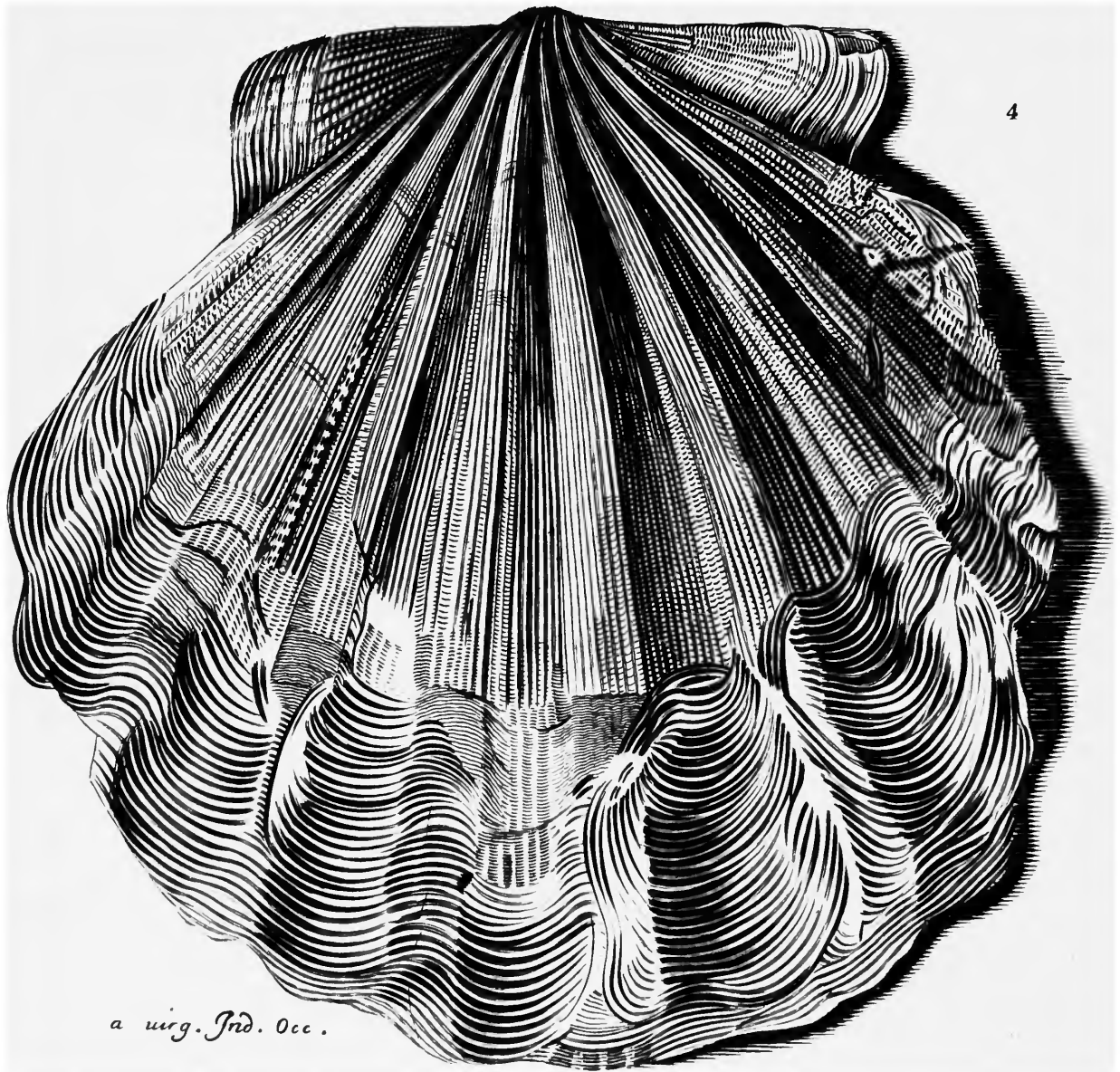
FIGURE 1.—*Ecphoras* from the Atlantic Coastal Plain: A–E, *Ecphora quadricostata*, Yorktown Formation, Lee Creek Mine, North Carolina, approximately  $\times 1$  (A, USNM 371353, and B, USNM 371352, collected by Druid Wilson from spoil heaps; C, USNM 371354, and D, USNM 371355, collected by Jack H. McLellan from spoil heaps. E, USNM 371351, collected by Peter J. Harmatuk in place in basal bed of Yorktown Formation). F, *Ecphora* sp., collector and formation unknown; from Maryland according to original figure caption (first published in, and reproduced at approximately original size from, Lister, Huddesford edition, 1770, pl. 1059: fig. 2).

was described in 1699 by the British naturalist James Petiver as “a very curious Person in all parts of Natural History; particularly in Fossils; some of which he hath sent me from Maryland . . .” (Dandy, 1958:142). These may in part have been among the fossils sent in 1697 to England by Jones, apparently intended for Edward Lhwyd, but diverted to other hands, probably including those of Petiver and John Woodward (Frick et al., in press). Woodward “evidently” lent fossils to Lister for illustration (Keynes, 1981:31). Petiver’s friend, Dr. David Krieg, would seem to have been yet another possible source of the *Ecphora*, as he collected in Maryland in 1698, at least informally under the aegis of the Temple Coffee House Botany Club, which included

Sloane and Lister, and later apparently prepared some of Lister’s plates for engraving (Frick et al., in press).

It seems not at all improbable that some or all of these historic fossils may yet be rediscovered, although thus far none of Lister’s specimens has been identified positively in the Ashmolean Museum at Oxford (MacGregor, 1983; confirmed by H.P. Powell, Oxford University, pers. comm.). Lister of course used other collections extensively, including those of the Dutchess of Portland and Sir Hans Sloane, including ultimately that of Petiver. Wilkins (1953) did not record the American fossils among Listerian shells recognized in the Sloane Collection, but it is not clear that he searched the paleontological holdings. However, a recent

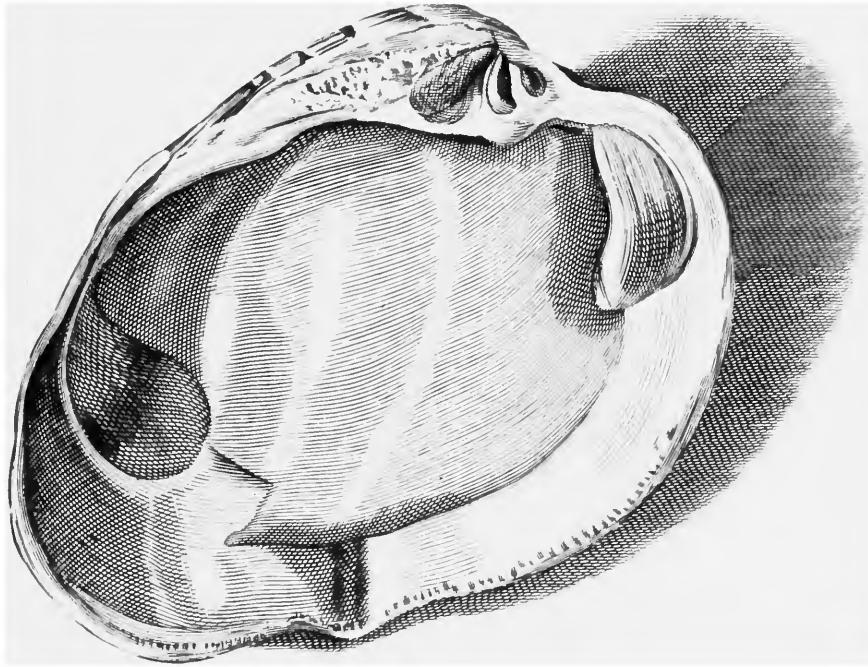
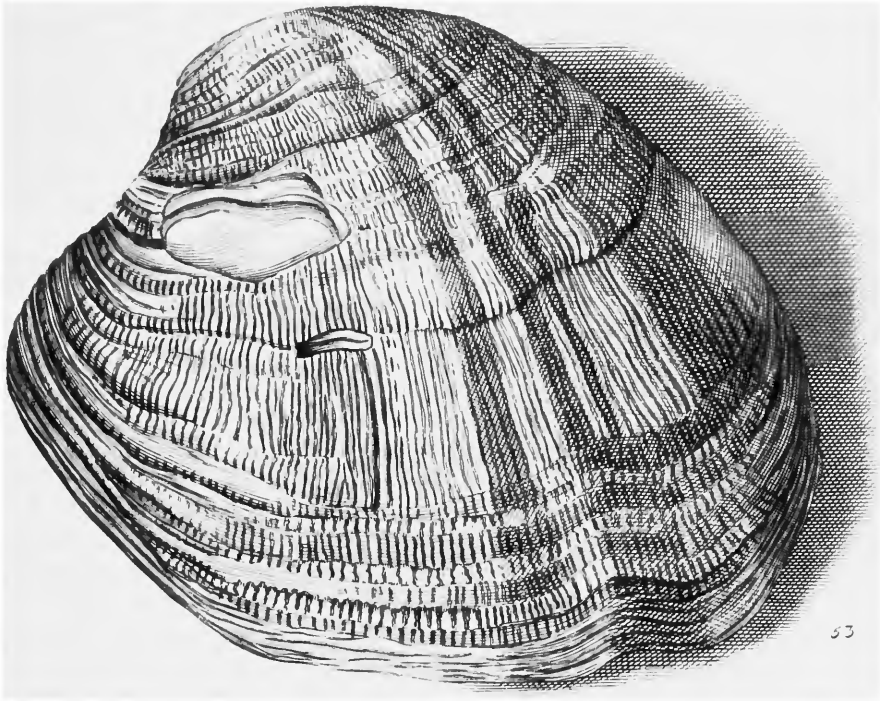
4. pecten omnium longè maximus, minus cauus, octo uel decem, ad summum, stryis donatus;  
item huic canaliculi profundi.



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FIGURE 2.—*Chesapeakepecten jeffersonius* (Say, 1824), right valve (thought to have been collected by John Banister from the Yorktown Formation of Virginia; first published in Lister, 1687, pl. 167; reproduced at approximately original size from Huddesford edition, 1770).





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FIGURE 3.—*Mercenaria corrugata* (Lamarck, 1818), left valve in external (above) and internal (below) aspects (thought to have been collected by John Banister from the Yorktown Formation of Virginia; first published in Lister, 1688, pl. 499; reproduced at approximately 0.8 original size from Huddesford edition, 1770).

search of both the modern and fossil collections of the British Museum (Natural History) did not yield Lister's *Ecphora* (John Cooper, British Museum (Natural History), pers. comm.) Interestingly Wilkins (1953:14) did note that "the last five plates [1055–1059] seem to have been drawn by different artists [the identity of Lister's artists and engravers is a special problem, discussed at length by Keynes, 1981:25–35], most of the specimens being from collections other than those connected with the present account." The appearance of *Ecphora* in one of those plates suggests a history for it later than and separate from that for *Chesapecten* and *Mercenaria*. Could it be the very specimen listed by Lightfoot? The specimens scarcely can be recovered through further speculation from this side of the Atlantic, but might be pursued fruitfully in England and possibly on the Continent.

Meanwhile, because Lister's figures are the starting point in the study of mollusks of the Chesapeake series, and because the figures are available together in no single, recent, widely distributed publication, it seems that the present volume is a suitable place for their reproduction. Accordingly, they are presented here in Figures 1–3, with data as presently understood in the respective captions. All of the figures and their plate numbers are taken from the Huddesford edition (1770), specifically from the copy in the library of the Division of Mollusks, National Museum of Natural History, Smithsonian Institution.

Of course Lister's work was pre-Linnaean, and however interesting antiquarianly, had only limited relevance to North American paleontology, except as a harbinger of things to come. The superabundance of well-preserved mollusks in the deposits of the Atlantic Coastal Plain inevitably resulted in intensive and extensive research as the sciences of malacology and paleontology developed. Following close upon the pioneering work by Say (1819–1824; see Summers, 1982), Conrad began his sustained and voluminous flow of publications extending at least from 1830 to 1877 (see Dall, 1893, especially pages v–xiv, for proof that Conrad was a worthy successor to Lister in the arena of idiosyncratic publication). The modern era of basic descriptive and increasingly synthetic taxonomic work spans ap-

proximately a century, and this long and strong tradition continues vigorously, as evidenced in the chapters by contributors to this volume, where citations to many of the writings of their predecessors may be found. The existence and progressive improvement and expansion of a broad and deep database of this kind are the indispensable prerequisites to addressing questions of a more theoretical or abstract nature, as exemplified by Blackwelder (1981), Stanley and Campbell (1981), Miyazaki and Mickevich (1982), and Kelley (1983).

General acknowledgments relating to the Lee Creek project may be found in Ray (1983:9–11). With regard to this foreword, I wish to thank Joseph Ewan for reading and improving the manuscript; James L. Reveal for information on Hugh Jones; Carol Jones for trying to find specimens at the Academy of Natural Sciences of Philadelphia alluded to by Timothy Conrad; Stephen Keynes for responding to my letter to his father, the late Sir Geoffrey Keynes; John Cooper and H.P. Powell for information about collections at the British Museum (Natural History) and Oxford, respectively; Robert Cross and associates at the British Museum (Natural History) for looking into publication dates of Lister; the late Joseph Rosewater for access to *Historiae Conchyliorum* and other rare molluscan literature; Victor E. Krantz for photographs; Lawrence B. Isham, for preparing the figures as a "rush" job on the last afternoon of his last day before retirement, after more than 30 years at the Smithsonian Institution; and Mary Parrish for modification of Figures 1 and 3.

Finally, it should go without saying, but must not, that I have no credentials in malacology; even these historical notes are derivative. Any slight augmentation of my minimal layman's knowledge of the subject is to be attributed primarily to the authors of the chapters in this volume, to whom I am deeply indebted, both for specific assistance to me and for fortitude and patience in seeing this volume to completion. The preceding unquestionably fulfills every criterion of a foreword, with one debatable exception. If indeed it is "likely to be of interest," that results in significant part from Druid Wilson's influence.

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# Miocene Cephalopods from North Carolina

*William M. Furnish and Brian F. Glenister*

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## ABSTRACT

Specimens representing the nautilid genus *Aturia* have been recovered during phosphate mining operations in North Carolina. This material consists of a few fragmentary internal molds too incomplete for specific determination. Such fossils are rare elsewhere, but comparable occurrences have been recorded throughout the world.

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## Introduction

Predecessors of living externally shelled cephalopods, represented by *Nautilus*, are not known from Neogene strata. *Aturia* is a bizarre related form in a nautilid lineage that originated about 50 million years ago in the Paleocene and became extinct during the Miocene. In a comprehensive survey, Stenzel (1940:734) was able to find only two references involving Miocene specimens from the entire Atlantic and Gulf Coasts. Miller (1947:110) was able to add but one occurrence, from Florida. These records included a total of only three specimens, one never studied in detail. In such a light, new discoveries from North Carolina seem worth recording. Congeneric specimens of Miocene age have been found in the Caribbean region and the Pacific Coast of the United States, and *Aturia* is known to have a world-wide distribution in contemporaneous strata. Nevertheless, Neogene occurrences are so rare that many records are based upon single specimens found in association with an abundance of other shells. Still, there is no indication of any geographic restriction, such as that now in effect for *Nautilus*, which is limited essentially to Melanesia and nearby areas of the southwest Pacific. Although more nearly characteristic of low latitudes, *Aturia* has been found at 60 degrees north and 55 degrees south. Similarly, there are no clear cases of endemism in fossil species and sexual dimorphism has not been demonstrated.

ACKNOWLEDGMENTS.—The *Aturia* from the Lee Creek

Mine were secured and made available for study by Jack H. McLellan and William D. Bennett of Texasgulf Inc. One of the specimens, found by P.J. Harmatuk, was forwarded by Clayton E. Ray, Smithsonian Institution. Their assistance is appreciated.

## Superfamily NAUTILACEAE De Blainville, 1825

There are fairly distinct lineages of nautilids in the late Mesozoic and Tertiary (Kummel, 1964; Shimanskii, 1962, 1975; Wiedmann, 1960). Representatives of the Hercoglossidae Spath, 1927, most common in the Paleogene, are relatively unspecialized; there are no fundamental differences between them and some Paleozoic forms. By contrast, those in the Aturiidae differ markedly as far as suture and siphuncle are concerned. Complex sutures are known in unrelated Mesozoic forms; for example, *Pseudonautilus* Meek, 1876, [= *Permoceras* Miller and Collinson, 1953]. The aturiid dorsal siphuncle, more nearly unique for coiled shells, is developed comparably only in a couple of Paleozoic ammonoid superfamilies.

## Family ATURIIDAE Chapman, 1857

The well-known aturiid phylogeny may be almost as simple as it appears. Ancestral *Aturoidea* Vredenburg (1925:9) has been found widely distributed in strata of Paleogene age, characteristically Paleocene and lower Eocene. An even simpler relative occurring in early Paleocene type Danian of Faxe, Denmark, should be included in the family. *Danaturoidea* Rosenkranz, 1960, has been proposed with *Nautilus fricator* Beck, 1836, as type-species. This taxon is a rare associate of *Hercoglossa danica* (Schlothheim, 1820), and was well illustrated by Ravn (1902, pl. 5: figs. 1,2,4). A prominent narrowly rounded ventrolateral lobe and dorsal lobe anticipate these developments in *Aturoidea*. The dorsal position of the siphuncle is also indicative of relationship.

A modern concept of typical *Aturia* is based upon Miocene material from southwestern France (Jung, 1966) and Italy (Sturani, 1958, 1959). Well preserved larger shells can be distinguished taxonomically; but most named species are based upon vagaries of preservation, size, or geography.

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Some apparently reached a size of a half-meter in diameter, without appreciable mature modifications. As a rule, Eocene forms have symmetry in the ventrolateral lobe reversed from that in the Miocene. The apex of the lobe is directed away from the periphery in younger representatives. All differences are marginally apparent and gradational, so there is little practical basis for the several subgenera that have been proposed. No aturiid can be regarded as an index fossil, except in a general sense.

### Genus *Aturia* Bronn, 1838

TYPE-SPECIES.—*Nautilus aturi* Basterot, 1825; subsequent designation.

Discoidal and thinly discoidal shells are included in the genus *Aturia*. Surface of test nearly smooth, with fine growth lines forming a rounded hyponomic sinus. Umbilicus closed by callous within the first volution of the conch. Camerae normally short, with base of the angular ventrolateral lobe in contact with preceding suture. Siphuncle is relatively large and invaginated within the narrow dorsal lobe.

#### *Aturia* sp.

Four specimens representing a species of *Aturia* have been recovered from the Pungo River Formation at Texasgulf's Lee Creek Mine, near Aurora in the Pamlico area of coastal North Carolina. All specimens are deposited in the collections of the National Museum of Natural History, Smithsonian Institution. These fossils are probably not a measure of abundance, in comparison to other known localities, but rather an evidence of diligent search in an extensive exposure. Cephalopod shells are relatively large and distinctive in appearance. All of these have a restored diameter of some 100 to 150 mm, normal for the genus. Only one was secured in a larger portion of matrix, and this specimen is a mere fragment of five camerae, suggesting that the shells suffered deterioration in a zone of moderately high energy. The other specimens consist of shorter segments fragmented during excavation and picked up as free specimens (Figure 1). One has a sedimentary interface, representing a chamber only partially filled with fine silt. In all cases, the original aragonitic test has been dissolved away subsequent

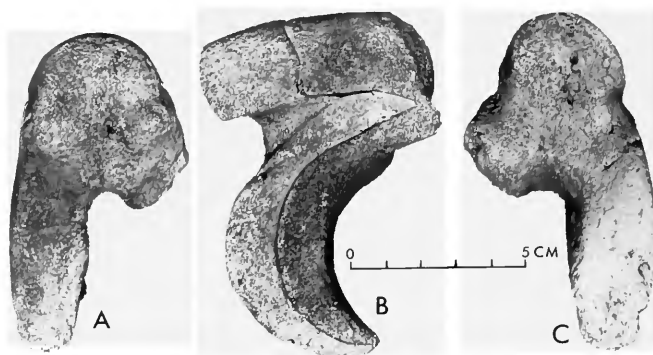


FIGURE 1.—*Aturia* sp. from units 4–5 in the Pungo River Formation (Miocene) at the Texasgulf Inc Lee Creek Mine, near Aurora, Beaufort County, North Carolina: A, septal view; B, lateral view; C, apertural view. This specimen is the best and largest of the cephalopods found at the locality; the complete whorl would have been slightly greater than 150 mm in diameter and about 65 mm in width. A body chamber would add an additional 100 mm of diameter. There were probably about four volutions of the complete conch. Specimen deposited in collections of the National Museum of Natural History.

to deposition. Collectively, the four specimens give a satisfactory view of the taxon represented. Measurements and conch features are indicative of an advanced representative of the genus such as *A. aturi*. Some details cannot be observed.

REMARKS.—There are no particular conclusions to be drawn from the occurrence of the North Carolina *Aturia*, and the locality has not been examined personally. These specimens are preserved as internal molds with granular phosphate disseminated throughout the matrix. Other occurrences of the genus are considered to be normal shallow marine, most commonly detrital carbonates. Living habits of these cephalopods were probably similar to modern forms, *Nautilus*, that is, nektons inhabiting ocean margins of a few hundred feet depth or less. No particular advantage is known for the dorsal siphuncle; cameral fluid could still have been exchanged through the connecting rings. Presumably these animals were reasonably strong swimmers and empty tests were subject to postmortem drift. The conch of all such nautilids was capable of withstanding severe changes in hydrostatic pressure, but suffered breakage from predators or in zones of agitation.

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# A New Pycnodont Oyster from the Pungo River Formation, and an Annotated List of the Cenozoic Pycnodonts of the Atlantic and Gulf Coastal Plain

Druid Wilson

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## ABSTRACT

*Pycnodonte (Gigantostrea) leeana*, new species, is described, and the Coastal Plain pycnodont oysters are listed with geologic and geographic ranges.

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## Introduction

The oysters with vesicular shell structure now commonly referred to as pycnodonts (Pycnodontinae) have been distinguished lately from other suprageneric taxa in the Ostreacea. The need for discrimination has been well demonstrated by the work of Ranson (1939–1941) and of Stenzel, culminating in Stenzel (1971).

Although its systematic significance may have been overlooked, vesicularity in American fossil oysters had been noted by Whitfield (1894:29) in the Miocene *Ostrea percrassa* Conrad and earlier Lamarck's *Gryphaea vesicularis* was commonly used as a name for Cretaceous and Paleocene pycnodonts, particularly in New Jersey. The vermiculate character of the chomata (denticles) is equal in importance and usually more easily observed. Gardner (1916:572) used *Pycnodonte* Fischer de Waldheim as a subgenus of *Gryphaea* for the species *vesicularis* Lamarck, which she regarded as the prior name for *radiata* Fischer de Waldheim, the type-species of *Pycnodonte*. No notice was taken of the vesicular shell structure but the vermiculate form of the denticles was described. According to Stenzel (1971:1105) prismatic shell layers are absent except in the genus *Neopycnodonte*.

Fossil pycnodonts are presently unknown in the Coastal Plain after Yorktown time, but they can be expected. *Ostrea thomasi* McLean (1941:7, pls. 3, 4) described from the western Atlantic is obviously a pycnodont. Its vesicular shell structure is well illustrated. It is a homonym of *O. thomasi*

“Conrad” Glenn (1904:380), and according to Abbott (1954:374) it is a synonym of the pycnodont *Ostrea hyotis* L. (as recognized by Ranson (1949:451)), which is a common Recent Indo-Pacific species. Ranson reported *O. hyotis* from numerous Atlantic localities. The species has not been reported in any of the standard works on Atlantic or Caribbean faunas except by Abbott (1954, 1974). Recently, Harry (1985:130) has renamed *O. thomasi* McLean as *Parahyotissa mcgintyi* and made it the type of his new genus *Parahyotissa*. Harry (1985:132–133) also reported *Neopycnodonte cochlear* (Poli) in the western Atlantic and Gulf of Mexico.

The purpose here is to describe new species of *Pycnodonte (Gigantostrea)* from the middle Miocene Pungo River Formation. Palmer and Brann (1965:149) introduced the use of *Gigantostrea* Sacco for some Coastal Plain pycnodonts. The figure of the type of the type-species of *Pycnodonte* Fischer de Waldheim, 1835 (*P. radiata* Fischer de Waldheim) is so different from that of *Gigantostrea* Sacco (*G. gigantea* (Solander) as figured by Stenzel (1971, fig. J81, 1, 2) that I am unable to follow Stenzel (1971:1107) in synonymizing *Gigantostrea* under *Pycnodonte (Pycnodonte)*.

ACKNOWLEDGMENTS.—Thanks are extended to Robert H. McKinney and Haruo E. Mochizuki of the U.S. Geological Survey for photography and prints; and to Barbara A. Bedette of the U.S. Geological Survey for preparation of the plates.

## *Pycnodonte (Gigantostrea) leeana*, new species

FIGURES 1–5

DESCRIPTION.—Shell large, subcircular, not excessively thickened for the size. More or less equivalved, left valve of holotype slightly larger. Convexity irregular, more pronounced anteriorly; left valve of the holotype the more convex; left valve, the larger figured paratype, irregularly flattened. Exterior concentric sculpture of irregular lamellae and occasional concentric welts; radial sculpture of faint interrupted lines and undulations. Resilifer small and high.

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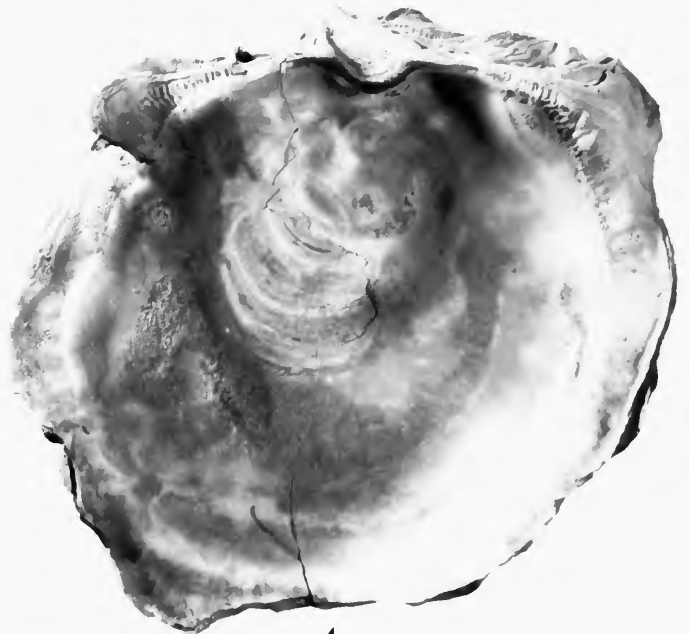
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4

FIGURES 1-4.—*Pycnodonte (Gigantostrea) leana*, new species, holotype, USNM 647680, height 87 mm, length 102 mm, thickness 34.4 mm: 1-2, right valve; 3-4, left valve.



FIGURE 5.—*Pycnodonte (Gigantostrea) leana*, new species, left valve, paratype, USNM 647681, height 155 mm, length 140 mm.

Adductor scar ovate and above midpoint. Chomata vermiculate and prominent.

**HOLOTYPE.**—USNM 647680 (both valves), height 87 mm, length 102 mm, thickness 34.4 mm (Figures 1–4); paratype: USNM 647681 (left valve), height 155 mm, length 140 mm (Figure 5).

All specimens are float with matrix like sediments of the Pungo River Formation.

Woodring (1982:607) considered an unnamed species from the Gatun Formation (middle Miocene) of Panama to be similar to or the same as *P. leana*.

Specimens from a float locality in Charlotte County in southern Florida collected by Muriel Hunter are very close to *P. (G.) leana*. They may be from Hunter's (1968:443) Bayshore Clay member of the Tamiami Formation said to have been named from an underwater exposure. Float

specimens of species of mollusks collected in the same general area have been identified by Hunter as species now known to belong to faunal assemblages of the Eastover Formation of Virginia. The Eastover fauna is older than Yorktown but not as old as Pungo River. At any rate the Charlotte County occurrence is the last known *Gigantostrea* in the Coastal Plain.

#### Annotated List of Pycnodonts of the Atlantic and Gulf Coastal Plain

There are 12 named, valid species and four unnamed species of pycnodont oysters in the Cenozoic of the Coastal Plain. Other names are synonyms, and still others are expedient uses of non-Coastal Plain species names. Palmer and Brann (1965) has been an indispensable source of

information, and the same Paleocene and Eocene species have been well figured by Toulmin (1977). Ranson (1941[1939–1941]:63–64) apparently was first to recognize several of the Coastal Plain species as pycnodonts. It is not known why Ranson (1941[1939–1941]:64) considered *O. vomer* Morton and *O. thirsae* Gabb to be pycnodonts. These species are currently allocated respectively to the genera *Gryphaeostrea* and *Odontogryphaea*, neither of which is classified as pycnodont by Stenzel (1971). Original descriptions, synonymies, and diagnoses of generic-group names are presented in detail in Stenzel (1971:1105–1114) and need not be repeated here. The Coastal Plain species are subsumed under the generic-group names listed below.

#### GENERIC-GROUP NAMES

##### *Pycnodonte* (*Phygraea*) Vyalov (1936:19)

Type: *Pycnodonte* (*Phygraea*) *pseudovesicularis* (Gümbel, 1861). According to Stenzel (1971:1107), this is the prior name for the originally designated type, *Phygraea frauscheri* Vyalov (= *Ostrea escheri* Frauscher, 1886, non Mayer-Eymar, 1876). Cretaceous-Miocene according to Stenzel (1971:1107).

##### *Pycnodonte* (*Gigantostrea*) Sacco (1897:14)

Type: *Gigantostrea gigantea* (Solander), by original designation. Lower Eocene-Miocene in the Coastal Plain.

##### *Neopycnodonte* (*Neopycnodonte*) Stenzel (1971:1109)

Type: *Neopycnodonte cochlear* (Poli), by original designation. Eocene-Recent.

##### *Neopycnodonte* (*Costellata*) Garcia and Levy (1983:283, pl. 1: figs. 1–5)

No type designated, but proposed to receive specimens from the late Tertiary of Argentina identified as *Ostrea alvarezii* d'Orbigny, 1832. The taxon may be represented by an unnamed species in the Yorktown Formation of Virginia.

##### *Hyotissa* Stenzel (1971:1107)

Type: *Hyotissa hyotis* (L.), by original designation. Upper Cretaceous-Recent, according to Stenzel.

#### SPECIFIC-GROUP NAMES

Specific names that have been applied to pycnodonts of the Coastal Plain are here listed alphabetically, with commentary. Those believed to represent valid Cenozoic species are preceded by an asterisk (\*).

##### *alabamiensis* (Lea), *Pycnodonte*

Lea, 1833:91. Ward et al. (1979:29, 31) have used Lea's name for an Eocene species from South Carolina. I have not seen Lea's holotype (monotype), but the original figure (Lea, 1833, pl. 3: fig. 71) exhibiting nonvermiculate chomata, and Harris' description (1919:8) of the type as "thin and pearly," and Palmer and Brann's syn-

onymy (1965:111) seem to preclude use of the name and classification as a pycnodont. Stenzel, et al. (1957:97) have used the name as a *Crassoostrea*. Presumably the South Carolina specimens are pycnodonts.

##### *antiguensis* Brown, *Ostrea*

Brown, 1913:603, 614, pl. 19: fig. 7, pl. 20: figs. 1, 5, 6.

See new species, *Hyotissa* (Subgenus?)

##### \* *bryani* (Gabb), *Pycnodonte* (*Phygraea*)

Gabb, 1877:321. Paleocene (Vincentown Fm)-middle Eocene (Manasquan Fm and Shark River Fm), New Jersey. According to Palmer and Brann (1965:230) *precedens* and *glandiformis*, both of Whitfield (1885), are synonyms. *P. bryani* and *P. glandiformis* were recognized as pycnodonts by Ranson (1941[1939–1941]:63).

##### \* *dissimularis* (Weller), *Pycnodonte* (*Phygraea*)

Weller, 1907:453, pl. 46: figs. 2, 3. Paleocene, New Jersey (Hornerstown Fm) and North Carolina (Beaufort Fm) (Wilson et al., 1972:129). Earlier writers on the New Jersey fauna used *vesicularis* Lamarck as a name for this species and Clark and Martin's figures (1901, pl. 50: figs. 6, 6a) of *vesicularis* from Maryland are the same.

##### *glandiformis* Whitfield, *Ostrea*

Whitfield, 1885:205, pl. 27: figs. 1–5. See *bryani* (Gabb).

##### \* *haitensis* (Sowerby), *Hyotissa*

Sowerby, 1850:53. Early Miocene (Chipola Fm, Florida)-late Miocene or Pliocene (Yorktown). Woodring (1982:607–610) detailed the occurrences in Tropical America and Florida. Specimens from Black Rock, Cape Fear River, North Carolina, occur with a Yorktown assemblage.

According to Olsson and Petit (1964:531) both *tamiensis* and *monroensis* of Mansfield (1932) are synonyms. They have also placed *Ostrea meridionalis* Heilprin in the synonymy of *haitensis*. *O. meridionalis* was described from the Caloosahatchee River as a part of the Caloosahatchee (Pliocene) fauna (Heilprin, 1886–1887:31, 100, 103). Dall (1898:686) placed *meridionalis* in the synonymy of *O. sculpturata* Conrad, a moderately large plicate nonpycnodont oyster. I have examined the better preserved specimen of Heilprin's two figured syntypes of *Ostrea meridionalis*; it exhibits the vesicular shell structure of pycnodonts in one small worn area of the exterior. This left valve (Heilprin, 1886 [1886–1887], pl. 14, fig. 35a) called holotype by Olsson and Harbison (1953:51, pl. 4, figs. 3, 3a) is here designated lectotype. This is in accord with Recommendation 74A of the 1985 International Code of Zoological Nomenclature (third edition). Richards (1968:65) has cited the well-preserved syntype as "type." Heilprin's specimen undoubtedly came from a facies of the Tamiame Fm, which underlies the Caloosahatchee Fm along the Caloosahatchee River. The fauna of this facies includes *Echphora quadricostata* (Say), *Ostrea compressirostra* Say (*O. disparilis* Conrad of authors), and *Discinisca lugubris* (Conrad), all species characteristic of beds of Yorktown age.

Although *Hyotissa haitensis* has the greatest range in time of any Coastal Plain pycnodont, it is stratigraphically useful. It is not known to occur in strata of an age later than Yorktown time, i.e., the Pinecrest Fm of southern Florida and the Jackson Bluff Fm of western Florida.

In an involved use of the names *Ostrea tamiamiensis* Mansfield and *O. tamiamiensis monroensis* Mansfield, Epert (1966:58–59) has overlooked the fact that beds of both Tamiami and Chipola ages are present in the Sarasota area. This is reflected in his faunal lists, which are biostratigraphic faunal mixtures, treated as faunal assemblages. *Hyotissa haitensis* occurs in beds of both ages.

\* *leana*, *Pycnodonte* (*Gigantostrea*), new species

See page 13.

\* *ludoviciana* (Harris), *Hyotissa* (Subgenus?)

Harris, 1919:14, pl. 10: figs. 1–10. The range may be middle Eocene (Claiborne) of Louisiana only: Palmer and Brann (1965:26) have queried the Jackson Eocene occurrence given by Harris (1946, pl. 2: fig. 7). Discrimination of the *vicksburgensis-mortoni-ludoviciana* species complex is so difficult that ranges cannot be accepted as final until the complex has been studied carefully. Ward et al. (1979:29) have listed *ludoviciana* (as *Pycnodonte*) from the middle Eocene Santee Limestone of South Carolina. Previous workers (Gabb, 1861; Harbison, 1944) have reported *mortoni* from the Santee (see *mortoni* Gabb).

*meridionalis* Heilprin, *Ostrea*

Heilprin, 1886[1886–1887]:100, pl. 14: fig. 35. See *haitensis* (Sowerby).

*monroensis* Mansfield, *Ostrea tamiamiensis*

Mansfield, 1932:46, pl. 14: fig. 2, pl. 15: figs. 1–4. See *haitensis* (Sowerby).

\* *mortoni* (Gabb), *Hyotissa* (Subgenus?)

Gabb, 1861:329. This name was proposed by Gabb for specimens from the Eocene of South Carolina and from Alabama; he also referred to a specimen figured by Morton (1834, pl. 19: fig. 10) as *Ostrea*, “var. from Alab.” This specimen was regarded as “Gabb’s type” by Harris (1946, pl. 1: fig. 15) and Palmer and Brann (1965:27), but Richards (1968:67) has considered the “types” to be from South Carolina. The Alabama occurrence is listed as “Eocene probably upper” by Palmer and Brann. If the species occurs in South Carolina, it is probably in the middle Eocene Santee Limestone. In the absence of specimens or figures of specimens from South Carolina, it is not possible to make decisions. Harbison’s figured fragment (1944, pl. 3: fig. 5) is too poor to be definitive. The species was recognized as a pycnodont by Ranson (1941[1939–1941]:64).

*panda* Morton, *Ostrea*

Morton, 1834:51, pl. 3: fig. 6, pl. 19: fig. 10. According to Palmer and Brann (1965:26) this name has been used for specimens of *Hyotissa* (Subgenus?) *mortoni* (Gabb). It is a valid Cretaceous species.

*pandaeformis* Gabb, *Ostrea*

Gabb, 1861:328. See *trigonalis* (Conrad).

\* *paroxis* (Dockery), *Hyotissa*?

Dockery, 1982:53, pl. 17: fig. 13, pl. 59: fig. 10, pl. 60: figs. 1–3. Oligocene Vicksburg group of Mississippi. Dockery has documented the source of the name as Leseur’s unpublished manuscript. The description and type material are Dockery’s. The pycnodont characters have been described by Harry and Dockery (1983:9). A species of pycnodont common in the Oligocene of the Superior Stone Co. quarry, New Bern, North Carolina, probably belongs to this species.

\* *percrassa* (Conrad), *Hyotissa*

Conrad, 1840:50, pl. 25: fig. 1. Middle Miocene, Maryland (Calvert Fm) and New Jersey (Kirkwood Fm). Palmer and Brann (1965:149) have noted Dall’s misuse (1898:683) of the name for Eocene oysters. The vesicular structure of the species was noted as early as 1894 by Whitfield (1894:29). Ranson (1941[1939–1941]:64) recognized it as a pycnodont.

\* *podagrina* (Dall), *Hyotissa*

Dall, 1896:22; 1898, pl. 30: figs. 5, 6. Upper Eocene (“Ocala Fm”), Florida. Palmer and Brann (1965:236) have documented the Eocene as determined by Foraminifera associated with the type-specimen; and that the “Oligocene” of Dall (1898, pl. 30: figs. 5, 6) and the Miocene (“Chipola Formation”) of Gardner (1926:42, pl. 10: figs. 5, 6) are erroneously applied to the type-specimen. Recognized as a pycnodont by Ranson (1941[1939–1941]:64). See new species, *Hyotissa* (Subgenus?), for records of erroneous usages.

*precedens* Whitfield, *Gryphaea bryani*, var.

Whitfield, 1885:194, pl. 26: figs. 7, 8. See *bryani* (Gabb).

*queteleti* Nyst, *Ostrea*

See new species, *Pycnodonte* (*Phygraea*). I have had no success in finding the original reference of “*Ostrea queteleti* Nyst 1853” of authors, a European species.

\* *sylvaerupis* (Harris), *Pycnodonte* (*Gigantostrea*)

Harris, 1897:230, pls. 4, 5, pl. 6: figs. 3, 3a, 4. Lower Eocene (Sabine), Alabama and Louisiana, according to Palmer and Brann (1965:149).

*tamiamiensis* Mansfield, *Ostrea*

Mansfield, 1932:46, pl. 14: figs. 1, 3. See *haitensis* (Sowerby).

\* *trigonalis* (Conrad), *Pycnodonte* (*Gigantostrea*)

Conrad, 1854:289, pl. 14: fig. 10 (reprinted 1939:359, pl. 23: fig. 10). Upper Eocene (Jackson), Mississippi and Alabama. Jackson age established by Harris (1946:21–24). Perhaps no pycnodont species name has been so widely used and misused. Glenn (1904:381, pl. 101, figs. 1a, 1b) used the name for a form of *percrassa*. Lately Harry and Dockery (1983:9) have extended the range downward into “the Gosport Sand of the upper Claiborne Group,” by reidentifying forms earlier figured by Dockery (1977:118, pl. 22: figs. 6a, 6b, 7) as a “variation” of *P. trigonalis*. Kellum (1926:17) and Cooke and MacNeil

(1952:25) used the name for a nonpyncnodont species from a bed at Pollocksville, North Carolina, now known to be Oligocene in age. According to Palmer and Brann (1965:149) *pandaeformis* (Gabb, 1861) and *tuomeyi* (Conrad, 1865) are synonyms of *trigonalis*. Cooke's *trigonalis* (1926, pl. 96: fig. 3) apparently is *P. podagrina* (Dall). Palmer and Brann (1965:150) have documented the misuse of the name for Miocene species by various authors. *P. trigonalis* was recognized as a pyncnodont by Ranson (1941[1939–1941]:64).

*tuomeyi* Conrad, *Ostrea*

Conrad, 1865:184. See *trigonalis* (Conrad).

*vesicularis* Lamarck, *Gryphaea*

Lamarck, 1806:160. See *dissimularis* (Weller).

\**vicksburgensis* (Conrad), *Hyothissa* (Subgenus?)

Conrad, 1847:296. Palmer and Brann (1965:27) have characterized as "*vicksburgensis* variations" published Eocene occurrences of this species, thus effectively limiting the name to Oligocene occurrences. The species has been reported in the Oligocene of Alabama, Arkansas, Georgia, and Louisiana, as well as its type occurrence at Vicksburg, Mississippi; also Oligocene of Mexico (Gardner, 1945:83). The species was recognized as a pyncnodont by Ranson (1941[1939–1941]:64).

#### UNNAMED SPECIES

new species, *Hyothissa* (Subgenus?)

Lower Miocene (Edisto Fm), Edisto River, South Carolina. Sloan's (1908:470–472) "Edisto Phase" [not "Marl"]

has been resurrected by Ward et al. (1979:26) as the Edisto Formation. Sloan (1908:471) noted this species as "*Ostrea haitiensis*"; Cooke (1936:86) and later Cooke and MacNeil (1952:26) called it *podagrina*. MacNeil (in Malde, 1959:26, 27) referred to it as *Ostrea* sp. aff.? *O. antiguensis* Brown, saying that it belonged to the *pandapodagrina-vicksburgensis* group. This is not the same as the small or poorly preserved specimens identified by Mansfield (1937:204) as *Ostrea* aff. *O. antiguensis* from the Oligocene of Florida nor as *Ostrea* sp. cf. *O. antiguensis* from the Oligocene of Mississippi (Mansfield 1940:187).

new species, *Neopyncnodonte*

Lower Eocene (Tusahoma Formation), Marengo County, Alabama (USGS 15194 and 15478). Identified by Harold Harry.

new species, *Neopyncnodonte* (*Costellata*)

An undescribed species in the Yorktown Formation of Virginia and at Lee Creek, North Carolina, apparently belongs to *Costellata* Garcia and Levy, described from the late Tertiary of Argentina. This new species may or may not be the same as the *Pyncnodonte* sp. figured by Ward and Blackwelder (1980, pl. 4: figs. 3, 4) and Blackwelder (1981, pl. 1: fig. 8).

new species, *Pyncnodonte* (*Phygraea*)

Oligocene (Cooper Marl), South Carolina. Identified as "*O. n. sp. aff. O. queteleti* Nyst" by MacNeil (in Malde, 1959:15, 20) a pyncnodont widespread in the Oligocene of Europe. This is the last occurrence in the Coastal Plain of the lineage of species with incised radiate lines on the right valve.

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# Species of *Ecphora*, Including the Subgenus *Stenomphalus*, in the Pungo River Formation

Druid Wilson

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## ABSTRACT

Published references to the genus *Ecphora* and the subgenus *Stenomphalus* and their species are summarized, including American and European stratigraphic and geographic occurrences. *Ecphora* "quadricostata" of the Maryland St. Marys Miocene is here named *Ecphora* (*Ecphora*) *gardnerae* and two other new species, *Ecphora* (*Ecphora*) *pamlico* and *Ecphora* (*Stenomphalus*) *aurora* are described from the Middle Miocene Pungo River Formation. *E. (S.) aurora* is noted in both America and Europe.

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## Introduction

Specimens of the species of the gastropod genus *Ecphora* have long engaged the interest of naturalists and collectors alike. In areas where they are available ecphoras are second only to shark teeth as fossils of interest to the public. Perhaps no American fossil has been so widely illustrated, particularly copies of *Ecphora* "quadricostata" figured by Martin in the *Maryland Geological Survey Miocene* volume in 1904. It has been claimed that *Ecphora quadricostata* was the first American fossil to be illustrated (Shattuck, 1904:xxxiv; Vokes, 1957:30; Raup, 1961:606). As pointed out by Harris (1937:443) and also noted by Ward and Blackwelder (1975:3), three extinct Tertiary species, *Chesapecten jeffersonius*, *Mercenaria "tridacnoides"*, and the *Ecphora* are all illustrated in Lister's *Historiae Conchyliorum*. The various parts of Lister's two editions of his work were published between 1685 and 1697 and the Huddesford edition in 1770. According to the findings of Engelmann (1846:461) and Wilkins (1957:203–204), no claim to priority can be made for Lister's figure of *Ecphora*; the plate on which it appears was not published until 1770 in the Huddesford edition. One hesitates, but the figure representing *Chesapecten jeffersonius*, published in the first edition of Lister in

liber III in 1687 (pl. 167), apparently is first; a close second is *Mercenaria "tridacnoides"* in the appendix to liber III (Lister, 1688, pl. 499).

Discovery in North America of specimens of new species of *Ecphora* (*Ecphora*), and of *Ecphora* (*Stenomphalus*) (until now known only in the Miocene of Europe), are of great interest, and their probable relationships with European species are also possibly of great significance.

Three species of *Ecphora* occur in the Pungo River Formation: *Ecphora* (*Ecphora*) *tricostata* Martin, and the two new species, *Ecphora* (*Ecphora*) *pamlico* and *Ecphora* (*Stenomphalus*) *aurora*. Only *Ecphora tricostata* has been collected in place, as reported by Gibson (1967:639, fig. 4). Nevertheless, the matrix associated with the specimens indicates that each species occurs in a separate bed. According to Gibson, *E. tricostata* occurs in unit 7 at the top of the Pungo River Formation. Gibson (pers. com.) considers that the matrix of limestone with considerable phosphate grains associated with a float specimen of *E. tricostata* may indicate that it came from as low as unit 5. He believes that the small pebble-sized phosphate in the matrix associated with specimens of *Ecphora pamlico* is characteristic of beds lower than unit 5, but not as low in the section as the thoroughly phosphatized matrix of the specimens of *Ecphora* (*Stenomphalus*) *aurora*. *E. (S.) aurora* may also occur in the Burdigalian and Helvetian Miocene in France. I believe that Cossmann and Peyrot (1924:534–536, pl. 14: fig. 47, pl. 15: fig. 19) have misidentified this species as *Ecphora moulinsii* (Brochon, 1849:117–128, figs. 1, 2), a strikingly different species named from type Burdigalian at Léognan, France. It is interesting that *Ecphora* (*Ecphora*) *jauberti* (Gratoloup, 1840, pl. 1: figs. 3, 4), a very rare European species related to *E. (E.) pamlico*, occurs in the Tortonian Miocene of Saubrigues, France, according to Cossmann and Peyrot (1924:534). If this is so, then *E. (E.) jauberti* occurs later than *E. (S.) aurora* in France, just as the closely related *E. (E.) pamlico* apparently does at Lee Creek. No particular significance can be placed on these possible temporal-stratigraphic relationships until *pamlico* and *aurora* are collected in place in America and the rare *jauberti* is recollected in France. Cossmann and Peyrot (1924:534–535) reported

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that the type specimen of *E. jauberti* (Grateloup) is lost and no other specimens have been collected.

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### Genus *Ecphora* Conrad, 1843

*Ecphora* Conrad, 1843:310.

TYPE-SPECIES.—*Fusus 4-costatus* Say (1824:127, pl. 7: fig. 5); by monotypy. Say's protograph is of the species found in the Yorktown Formation of Virginia. Sohl (1964:173) characterized the genus *Ecphora* as

small to moderately large subfusiform shells and a moderately low spire. Whorls strongly shouldered, with strong spiral carinations over periphery; basal constriction strong. Whorls may be loosely attached. Aperture ovate, produced to a narrow, generally elongate and curving siphonal canal terminating in a moderately strong notch; outer lip crenulate; inner lip moderately thick, free or partly attached over parietal surface. Umbilicus broad, open, deep, and margined by a serrate strong carina.

Shells of *Ecphora* consist of two layers; a thick outer translucent brown layer and a thinner light-colored inner layer, which is sometimes leached away. Zalman Altschuler (pers. com.) of the U.S. Geological Survey has determined by x-ray identification that the outer layer of specimens of *E. quadricostata* and *E. gardnerae* is almost entirely calcite and the inner layer entirely aragonite. Aragonite, being less stable, is often leached away, as in the numerous specimens of *Ecphora quadricostata* from the Yorktown Formation at Lee Creek.

*Ecphora tricostata* Martin (1904:209, pl. 52: figs. 5, 6) occurs in the Miocene Calvert Formation (rarely in the Choptank) in Maryland and in the Pungo River Formation in North Carolina.

Some species not originally referred to the genus *Ecphora* are here included in it and some initially called *Ecphora* are here excluded from it.

*Rapana tampaensis* Dall (1890 [1890–1903]:153; 1915:78, pl. 13: fig. 8), first referred to *Ecphora* by Cossman (1903:65), is from the Tampa Formation of Florida. The species also occurs in the "Silverdale" beds (USGS 23108) of North Carolina. These beds are approximately of the same age. Current research in micro- and macro-paleontology of the Silverdale fauna indicates that it may be late Oligocene in age rather than early Miocene. The

fragmentary specimen from these beds identified by Richards (1943:524, pl. 85: fig. 16) as *E. quadricostata*, is apparently the same as an undescribed species from Silverdale in the U.S. National Museum collection (USGS 21943).

The specimen (USNM 112520) from Church Hill, Maryland (Calvert Formation) figured by Dall (1892 [1890–1903] pl. 20: fig. 14) as *Rapana tampaensis* Dall, var.? and referred to as *Ecphora tampaensis* by Martin (1904:211, pl. 52: fig. 9) followed by Grabau and Shimer (1909:787, fig. 1152a) was later named *Rapana ecclesiastica* by Dall (1915:78). Martin had noted that "*Fasciolaria* (*Lyrosoma*) *sulcosa*" of Whitfield (1894, pl. 17: figs. 9, 10; not Conrad (1830:220, pl. 9: fig. 8) was related; subsequently Richards and Harbison (1942:211) synonymized Whitfield's species with *ecclesiastica*. I am indebted to the late W.P. Woodring for pointing out (pers. com.) that *ecclesiastica* should be referred to the genus *Tritonopsis* Conrad (1865:20) found in the late Eocene of Panama (Woodring, 1973:477, pl. 70: figs. 26, 27) and the Oligocene of Mississippi.

Sohl (1964:173) has outlined the problem of considering *Ecphora proquadricostata* Wade, a Cretaceous species, as the earliest known *Ecphora*. Zalman Altschuler (pers. com.) has determined that the entire shell of *E. proquadricostata* is aragonitic. This fact strengthens my opinion that there is no direct genetic connection with the known later species, though as pointed out by Sohl, the Cretaceous species is morphologically like *Ecphora*. I believe that the earliest undoubted ecphoras are in the Oligocene both in Europe and in North America. *Ecphora koeneni* G6rges (1952:6, pl. 2: fig. 11a, b) judging from the figure, is an *Ecphora*, sensu stricto. It is from the Oligocene of North Germany. The poorly preserved impression identified by Dall (1894:301) as "*Ecphora quadricostata*" from the "land phosphate" rock of South Carolina, is undoubtedly of the genus *Ecphora*. An examination of the associated specimens and Dall's list of species indicates that they come from the Oligocene Cooper Marl.

### *Ecphora* (*Ecphora*) *gardnerae*, new species

FIGURE 1A,B

*Ecphora quadricostata*.—Martin 1904:207, pl. 52: fig. 1.

It is now known that most if not all of the fossils described by Say in 1824 came from Virginia rather than Maryland, contrary to Say's title "An Account of Some of the Fossil Shells of Maryland." According to Gardner (1948:201), "Mansfield believed from internal evidence that they came not from Maryland but from Virginia" and Dall (1892 [1890–1903]:351) had earlier doubted the provenience of a Say species. Ward and Blackwelder (1975:9, 16) have shown that the common pecten of the Maryland Miocene is not *Pecten madisonius* Say as formerly universally used, but that the name in fact belongs to a Yorktown species of



FIGURE 1.—*Ecphora (Ecphora) gardnerae*, new species, holotype, USNM 647519, height about 120 mm; A, apertural view; B, dorsal view.

Virginia. This confusion of locality undoubtedly initiated the chain of coincidence that resulted in the common *Ecphora* of the St. Marys Miocene of Maryland masquerading under the name "*Ecphora quadricostata*," which properly belongs to the Yorktown species of Virginia. This St. Marys Miocene species is here named *Ecphora (Ecphora) gardnerae*, new species. In *Ecphora gardnerae* the four prominent spiral ribs become stronger with maturity, in contrast to the ribs in *E. quadricostata*, which become weaker with age. The holotype of *Ecphora gardnerae* (USNM 647519) is the specimen figured by Martin.

Probably because the name *Ecphora quadricostata* had been preempted for the Maryland St. Marys species, the name *Ecphora umbilicata* (Wagner) has had some usage as the name for the Yorktown species. "*Fusus umbilicata* Wagner" Dall (1898 [1897]:9, pl. 2: fig. 2) is a synonym of *Ecphora quadricostata* Say, as very early recognized by Cossmann (1898:110), as well as a homonym of *Fusus umbilicata* Smith (1839:98, pl. 1: fig. 2). It has also been used by Martin (1904:209, pl. 52: fig. 4) for a Choptank Miocene species of Maryland, which apparently needs a name. Mansfield (1930:71) recognized that the Choptank species was not the same as *F. umbilicata* Wagner (i.e., *E. quadricostata*). Dall (1898:8) related the circumstances concerning "Wagner's plates" and reference to them in Bronn's Index (1848:517, 1849:455). Brochon's repeated reference (1849:119, 124, 127) to "*Fusus quadricostatus* Wagner" (with no mention of Say) establishes their circulation, but their subsequent treatment by Martin (1904:209) and by Mansfield (1930:70) as validly published is not justified. In any case, a date earlier than 1839 would have to be proved because of the prior use of the name by Smith. These bits of information indicate probable correspondence between Brochon and Wagner and perhaps realization by Wagner that his figure represented Say's species *quadricostatus*. Brochon (1849:128) does establish that "le *Fusus* de Wagner provient des couches pliocenes de Virginie," a fact apparently not known to Dall. Another nominal species, *Ecphora parvicostata* Pilsbry (1911:438, fig. 1), with only "Maryland" for locality, is apparently nothing more than an extreme variation of *E. quadricostata* and must have come from Virginia.

A large well-preserved specimen (USNM 106919) of *Ecphora* in the National Museum of Natural History supposedly from Florida was identified by Dall as *Ecphora quadricostata*. Because it was repeatedly mentioned by Dall and undoubtedly had an early influence on his thinking concerning the age of the beds from which it was supposed to have come, it seems desirable to document and dispose of the specimen. It had come to the National Museum from R.E.C. Stearns, who was on an expedition to Florida in 1869. Dall (1885:82) first reported the specimen as found at Tampa "on the long rocky point"; later he (1887:166) identified the locality as Ballast Point, and later still (1890:8, 125) as "Long Key . . . containing no solid rock of any sort." At this time Dall seems to have had some reservations probably due to the discrepancies. Although he still considered the specimen as possibly from the siliceous bed, he recognized that the specimen was not silicified. Dall and Harris (1892:125) referred it to a "later horizon" and Dall's final notice (1903 [1890–1903]:1596) in his "List of Species of the Floridian Miocene" repeated this pronouncement. A critical examination of the specimen and comparison with specimens from the St. Marys River leads to the conclusion that it is a specimen of *Ecphora gardnerae* from the St. Marys Miocene of Maryland. Stearns (1869:466–467) did not

mention the find in his account of his stay on Long Key or any other locality. His wide interests and knowledge of mollusks is so well demonstrated that it seems unlikely that a find so unusual would have gone unrecorded. There seems to be no satisfactory accounting for this confusion. Eppert's reference (1966:49, 58) to "*Ecphora quadricostata umbilicata*" is a lapsus and undoubtedly concerns Stearns' specimen.

### *Ecphora (Ecphora) pamlico*, new species

PLATE 1: FIGURES 1, 2

Shells moderately large with angle-sided whorls; three prominent spiral thin flange-like costae at the whorl angles. Secondary sculpture of many spiral bands between costae; bands becoming obsolete or nearly so on the flattened shoulder; posterior interspace between the costae wider than anterior interspace. Aperture ovate; anteriorly produced into a very narrow, broadly curved canal. Umbilicus large, rounded and bordered by a regularly and weakly stepped (or serrated) carina.

Most specimens are both distorted and defective; neither spires nor canals are complete in any specimen. The holotype is the only undistorted large specimen (Plate 1: figure 2).

MEASUREMENTS.—Holotype, height about 65 mm, width about 65 mm; aperture of holotype not exposed; figured paratype, height about 58 mm, width about 44 mm.

*Ecphora (E.) pamlico* is represented by 25 specimens; all are caught up in a phosphatized matrix with dark phosphate pebbles throughout. A small slab collected by Royal Mapes contains nine specimens. No specimen has been collected in place, but the associated matrix is considered by Gibson (pers. com.) to indicate beds lower than unit 5 of the Pungo River Formation.

REMARKS.—*Ecphora (E.) pamlico* is related to a large undescribed species of *Ecphora* in the National Museum of Natural History from zone 10 of the Calvert Formation of Maryland, collected by the late Sydney F. and Doris Blake. It is also related to *E. (E.) jauberti* (Gratoloup) (Plate 1: figures 3, 4) found in the Tortonian of Saubrigues, France.

TYPES.—Holotype USNM 647668; figured paratype USNM 647671, unfigured paratypes USNM 647669-647670, 647672-647679.

OCCURRENCE.—Known only from the Pungo River Formation at Lee Creek, North Carolina.

### Subgenus *Stenomphalus* Sandberger, 1861

Subgenus *Stenomphalus* Sandberger, 1861:222.

The type-species by subsequent designation (Dall, 1890: 124) is *Fusus cancellatus* Thomä (= *Ecphora (Stenomphalus) caerulea ornata* Bucher). The nomenclatorial imperatives

and the interspecific relationship are derived from the work of Zilch (1983:93–101, pl. 10), who has recently published the results of his studies of the species group to which the type-species belongs. *Fusus cancellatus* Thomä (1845:162, pl. 4: fig. 8) is four times preoccupied; first by Sowerby (1826:45). Braun's later, undescribed substitute name (1851:1131), listed thus "*Fusus brevis* A. Braun (*F. cancellatus* Thomae a.o.a. O.S. 162)," valid only by the included reference to Thomä's species, is preoccupied by *Fusus brevis* Brown (1827, pl. 48: fig. 34). The earliest described species name in the group is *Buccinum caeruleum* Römer-Büchner (1827:18, pl. 1: figs. 1–3) published in a work so rare that it was not recorded in the famed Index Animalium of Sherborn. A copy of Römer-Büchner's work could not be located in the United States, and I have seen only a xerox of the pertinent part. A species named by Bucher (1913:93, 96, pl. 1: figs. 8–10) *Stenomphalus cancellatus ornatus* is from the type-locality of *F. cancellatus*. Since Wenz's (1932) resurrection of Römer-Büchner's species name and revision of the nomenclature, *S. caeruleus ornatus* Bucher has been maintained as the valid name for the type-species of *Stenomphalus* Sandberger. Presumably the species is quite variable; Thomä's type figures (1845, pl. 4: figs. 8a, 8b) show obvious differences from the somewhat larger specimens figured by Sandberger (1860, pl. 17: figs. 7, 7a, 7b). Sandberger's figures have been considered as representing the typical form by Boettger (1883:218). Both Thomä and Sandberger reported the species as abundant at Hochheim, the type-locality. Thirteen specimens in the U.S. National Museum collections from three localities (Hochheim, Florsheim, and "Flonheim u. Alzey," including seven from the type-locality (Hochheim), are more nearly like Thomä's figures in size and outline, but some of them exhibit the broader spiral bands of Sandberger's figures. According to Zilch (1983) the type-locality is in the early Miocene "Cerithien-Schichten" of the Mainz Basin, Germany.

The shells of the species of the subgenus *Stenomphalus* are characterized by a reduction in the strength of the spiral sculpture and a much less prominent umbilicus. The species are generally smaller than species of the typical subgenus.

### *Ecphora (Stenomphalus) aurora*, new species

PLATE 2: FIGURES 1–5

?*Rapana (Ecphora) Moulinsii* (Brochon).—Cossmann and Peyrot, 1924:534, pl. 14: fig. 47; pl. 15: fig. 19?

Shell moderately large for the subgenus, pyriform with rounded whorls bearing three primary low but prominent spiral bands, which in turn bear secondary bifid spiral bands; the anterior primary band hardly set off from the anterior secondary bifid spiral bands of the anterior of the body whorl; shoulder flattened and sunken below edge of posterior primary band. Broadly ovate aperture anteriorly pro-

duced into a slightly curved siphonal canal. Umbilicus anteriorly produced and bordered by a rudely stepped carina.

All large well-preserved specimens of *E. (S.) aurora* are somewhat distorted; the strong step-like feature of the outer lip just below the shoulder on the figure of the holotype (Plate 2: figure 1) is a result of distortion. The umbilical region of the paratype (Plate 2: figure 5) is the least distorted of any specimen.

MEASUREMENTS.—Holotype, height 80 mm, width 55 mm; illustrated paratype, height 44.5 mm, width 30.5 mm.

SPECIMENS EXAMINED.—*Echphora (S.) aurora* is represented by 95 specimens including many fairly well-preserved specimens and some steinkerns. They all have a completely phosphatized matrix that Gibson (pers. com.) regards as occurring lower in the Pungo River Formation than the matrix associated with *E. (E.) pamlico*, new species.

TYPES.—Holotype, USNM 647654 (Plate 2: figures 1–3); illustrated paratype, USNM 647656 (Plate 2: figures 4, 5); other paratypes, USNM 647655, 647657–647667.

OCCURRENCE.—Pungo River Formation, Lee Creek, North Carolina, and Saucats (Peloua), France.

REMARKS.—*Echphora (S.) aurora* is not related to any American species, but it seems to be the same as the species figured by Cossmann and Peyrot (1924) from France as *Rapana (Echphora) moulinsii* (Brochon); particularly their figured specimen from the Burdigalian at Saucats (Peloua) (Plate 2: figure 7). Brochon's species (1849:117–128, figs. 1, 2) was described from the type Burdigalian at Léognan (Coquillat) and the original figures copied here (Plate 1: figures 5, 6) are strikingly different from the figures of Cossmann and Peyrot. Cossmann and Peyrot (1924:536) suggested that the specimen from the Helvetian at Salles

figured by them may be reworked; if this is true, both species are confined to the Burdigalian.

### Stratigraphic Order of the American Species of *Echphora*

*E. quadricostata* (Say): Yorktown Formation and equivalents. Virginia to Florida; traditional late Miocene of the Coastal Plain; currently regarded as Pliocene by many micropaleontologists.

*E. gardnerae*, new species: St. Marys Miocene of Maryland and Eastover Formation, late Miocene, of Virginia. (See Ward and Blackwelder, 1980:19, 28; pl. 1: fig. 2).

*E. "umbilicata"* of Martin: Choptank Miocene of Maryland.

*E. tricostata* Martin: Choptank and Calvert Miocene of Maryland and upper part of Pungo River Formation (unit 7) in North Carolina. My report (see Espenshade and Spencer, 1963, table 10) of *Echphora* cf. *E. tricostata* in a drill hole sample from central north Florida, said to be of middle(?) Miocene age, is based on fragmentary material. However, both the "cf." of the species and the query of the age should be removed.

*E. pamlico*, new species: Pungo River Formation of North Carolina, but apparently below the occurrence of *E. tricostata*.

*E. aurora*, new species: Lower part of the Pungo River Formation of North Carolina.

*E. tampaensis* (Dall): Tampa Limestone of Florida, "Silverdale beds" of North Carolina (USGS 23108); early Miocene or late Oligocene.

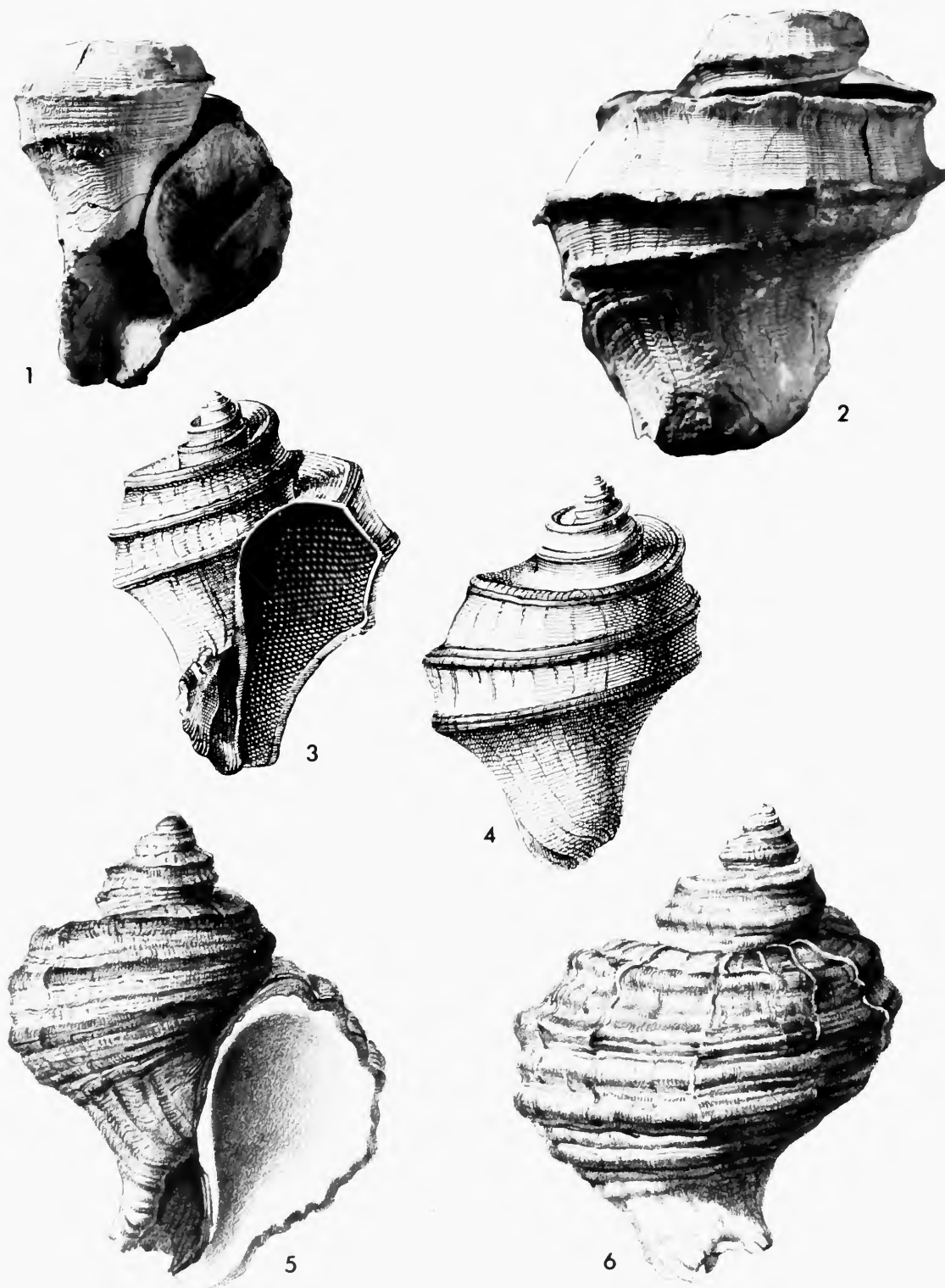
*E. "quadricostata"* of Dall: Cooper Formation Oligocene of South Carolina.

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## PLATE I

- 1, 2. *Eophora (Eophora) pamlico*, new species: 1, paratype, USNM 647671, apertural view, height about 58 mm; 2, holotype, USNM 647668, dorsal view, height about 65 mm.
- 3, 4. *Eophora (Eophora) jauberti* (Grateloup), Saubrigues, France, Tortonian Miocene (after Grateloup, 1840): 3, apertural view; 4, dorsal view.
- 5, 6. *Eophora (Stenomphalus) mouhinsi* (Brochon), Léognan, France, type Burdigalian Miocene (after Brochon, 1849): 5, apertural view; 6, dorsal view.





## PLATE 2

- 1-5. *Ephora (Stenomphalus) aurora*, new species: 1-3, holotype, USNM 647654, height 80 mm; 4, 5, paratype, USNM 647656, height 44.5 mm: 1, apertural view; 2, dorsal view; 3, apical view; 4, apertural view; 5, dorsal view.
- 6, 7. *?Rapana (Ephora) moultinsii* sensu Cossmann and Pevrot: 6, Salles, France, Helvetian Miocene; 7, Saucats (Peloua), France, Burdigalian, Miocene (after Cossmann and Pevrot, 1924): 6, apertural view; 7, dorsal view.



# Miocene and Pliocene Pectinidae (Bivalvia) from the Lee Creek Mine and Adjacent Areas

Thomas G. Gibson

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## ABSTRACT

Seventeen taxa of Pectinidae (Bivalvia) from lower Miocene to lower Pleistocene strata in the Lee Creek Mine, North Carolina, and surrounding region were studied biometrically. The study of large population samples clarifies the relationships of the taxa and their biostratigraphic utility. Because of widespread geographic distribution of the species into various environmental conditions and relatively short time ranges, the pectens make ideal index species for the outcropping strata. The co-existence of planktonic Foraminifera with the pectinids in some of the strata allows correlation with European stages.

Characters found to be most important for discrimination at the subspecific and specific levels include the byssal notch, shape of the resilial insertion, size and shape of the auricles, number and shape of the plicae, and convexity of the valves.

One new species, *Pecten mcclellani*, is described from the upper lower Miocene part of the Pungo River Formation exposed at the Lee Creek Mine. It is demonstrated that *Chlamys decemnaria* (Conrad) from the Pliocene should include *C. virginianus* (Conrad). A probable intermediate form between *Placopecten clintonius* of early Pliocene age and the living *P. magellanicus* is illustrated and described. Other rearrangements at the subspecific level are made.

Lectotypes are selected for *Pecten yorkensis* Conrad, 1867, *Pecten eboreus darlingtonensis* Dall, 1898, *Pecten eboreus urbannaensis* Mansfield, 1929, *Pecten (Chlamys) eboreus bertienensis* Mansfield, 1937, and *Amusium precursor* Dall, 1898.

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## Introduction

The Pectinidae (Bivalvia) are one of the most abundant and useful groups of mollusks for stratigraphic control of the Cenozoic strata in the Atlantic Coastal Plain. This study examines the known stratigraphic ranges and paleogeographic limits of the species found in the sequence of strata ranging from lower Miocene to lower Pleistocene at the Lee Creek Mine, North Carolina, and, also, species from surrounding areas. The ranges are correlated, whenever

possible, with the currently used stages of Europe and radiometric time scales by means of correlations based on planktonic Foraminifera.

Detailed quantitative morphologic studies were made on 17 taxa, employing large population samples of most species. These studies allowed the establishment of morphologic characters that both characterize the taxa and allow their differentiation. The characters found to be of most importance are those of the byssal notch, size and shape of the auricles, convexity of the valves, shape of the resilial insertion, number and shape of the plicae, and in some instances the overall shape of the valves.

In most localities the large number of pecten valves reflects their true abundance in relation to the remainder of the molluscan fauna; but, in some, the relative abundance of pectens is in part a reflection of diagenetic processes. The pectens, along with the oysters and barnacles, have a large amount of calcite in the shell structure and resist diagenetic processes more strongly than aragonitic-shelled organisms. In many highly permeable coarse-grained sediments, particularly those with large amounts of fragmented shell materials resulting from turbulent conditions during deposition, the pectens, oysters, and barnacle plates are the major recognizable fossil remains. This type of preservation is found in the uppermost bed of the Pungo River Formation in the Lee Creek Mine (unit 7 of Gibson, 1967) where a shell hash is composed almost entirely of barnacle plates and bryozoan tests with lesser numbers of pectens and scattered *Echphora*. A similar preservation of calcitic specimens is found in the limey indurated layers, units 4–6 of Gibson (1967), in which other molluscan species are represented by internal molds. In the lower phosphatic sand units of the Pungo River Formation, however, even the pectens have been removed by diagenetic processes, and the only specimens recovered are internal molds of *Pecten humphreysii*, along with internal molds of other mollusks.

Many of the pectens have a wide geographic range in deposits of the Atlantic Coastal Plain. *Pecten humphreysii* probably has the widest distribution, from New Jersey southward through Maryland, Virginia, and North Carolina into Florida. Other species range from Maryland or Virginia

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southward into Florida, even into south-central Florida. The pectens must have fairly broad environmental tolerances as the same species are found with changing assemblages of other molluscan species.

Another characteristic of pectens in the later Cenozoic of the Atlantic Coastal Plain is their limited stratigraphic ranges. Most species are restricted to a single formation, and some have an even shorter range. The pectens are not alone in this rather rapid vertical change, with other molluscan groups such as *Astarte* and *Crassatella* showing change also; but the pectens are the most conspicuous group.

As a result of their abundance, their widespread geographic occurrence, and their restricted stratigraphic occurrence, the pectens are probably the most important biostratigraphic guide to the later Cenozoic deposits. The abundant benthic foraminiferal species tend to have longer ranges than the pectens. This is particularly true in the Pliocene and Pleistocene strata where essentially all the common species range into the Recent. Some of the rarer species have more restricted ranges, but are not as desirable for correlation because of their scarcity. The planktonic foraminiferal species are too rare in almost all of the strata to be highly useful in correlation within the region.

It is the aim of this paper to give a better understanding of the morphologic variation found within the various species of pectens that occur in the Pungo River and Yorktown formations in the Lee Creek Mine and their closely related species, both by quantitative methods and illustration of the variations.

#### PREVIOUS WORK

The fossiliferous bluffs along Chesapeake Bay and its tributaries long have been famous collecting sites for Tertiary fossils. The first illustrated fossil invertebrate from North America was probably from the Atlantic Coastal Plain deposits of the Chesapeake group. A pecten, later to be named *Pecten jeffersonius*, was illustrated by Lister in 1887 (see Ward and Blackwelder, 1975:3, 15, pl. 1; Wilson, p. 21 herein). The pectens were among the earliest species described because of their large size and great abundance in the strata of Maryland, Virginia, and North Carolina. Say (1824) described three of the most common and important species of pectens, *Pecten jeffersonius*, *P. madisonius*, and *P. clintonius*, naming them after famous Americans of that time. The type suites of these species were deposited in the British Museum, and type specimens were recently selected and illustrated by Ward and Blackwelder (1975).

Most of the early descriptions of the marine mollusks from the Atlantic Coastal Plain Cenozoic deposits were made by Timothy Abbott Conrad. Conrad made far-ranging collecting trips and published numerous papers from the 1830s to the 1870s describing the faunas. *Pecten hum-*

*phreysii* (Conrad, 1842:194), *Argopecten eboreus* (Conrad, 1833:341), and *Chlamys decemnaria* (Conrad, 1834:151), three species found in the Lee Creek Mine and treated in this paper, were named by Conrad. A listing of Conrad's type specimens at the Academy of Natural Sciences of Philadelphia and a bibliography are given in Moore (1962), with some additional information on type specimens in Richards (1968).

The molluscan faunas of South Carolina were treated by Tuomey and Holmes, the initial part of which (1855) included many of the pectens found in the Yorktown strata of the Lee Creek Mine. Emmons (1858) discussed and described many of the vertebrate and invertebrate groups from the Miocene (now recognized as Pliocene) deposits of eastern North Carolina, including the pectens and named one new species. Various groups of mollusks from areas of the Atlantic Coastal Plain as widely separated as New Jersey and Florida were treated by Angelo Heilprin. One of Heilprin's publications (1881) was concerned solely with the Tertiary pectens found east of the Mississippi River, and this paper touches on most of the pectens found in the Lee Creek Mine.

The first comprehensive study of the pectens of the later Cenozoic was made by Dall (1898). In addition to describing species of pectens characteristic of the Florida Tertiary, Dall treated many species from North Carolina, Virginia, and Maryland.

The Maryland Geological Survey's volume on the Miocene deposits of that state (Clark, 1904, with parts prepared by various authors) is an amazingly complete study of the fauna of the Chesapeake group. The pectens are included in the section on the Pelecypoda by Glenn (1904) for that volume. Later, a study of the Coastal Plain of Virginia was published (Clark and Miller, 1912) and also one of the Coastal Plain of North Carolina (Clark et al., 1912). These latter two volumes deal with the stratigraphy of the Miocene and Pliocene deposits, but the invertebrate faunas are presented only in the form of lists and charts.

Several publications by Axel Olsson, particularly those dealing with the molluscan species from the Yorktown Formation in Virginia (Olsson, 1914, 1917), added new information on the pectens and knowledge of the general age and faunal relationships of the strata. Helen Tucker-Rowland (1934, 1936a, 1936b, 1938) covered most of the species of pectens from the Cenozoic deposits of Eastern North America, both reviewing older species and describing new taxa. During the same period, W.C. Mansfield worked on the Miocene and Pliocene deposits in North Carolina and Virginia and described several new species and subspecies of pectens (Mansfield, 1929b, 1936, 1937). The information obtained from the biostratigraphic distribution of the pectens was of great importance in his development of a zonal concept for the Miocene and Pliocene strata of Virginia and North Carolina (cf. Mansfield, 1929a, 1944).

Pectens from the older Miocene strata in Maryland, particularly the Calvert and Choptank formations, were re-described by Lois Schoonover (1941). Julia Gardner's (1944, 1948) descriptions of the molluscan fauna from the Miocene and Pliocene strata of North Carolina and Virginia illustrate many of the molluscan species, including many of the important species of pectens. Although this work does not include all the molluscan species found in the Yorktown strata in Virginia and North Carolina, it is by far the most extensive study to date.

Richards (1950) presented collecting localities, a partial faunal list, and illustrations of some of the more common species of mollusks, including pectens, from the coastal plain of North Carolina. Mongin (1959), in her comparison of molluscan species from the Miocene and Pliocene of North America with those of Europe, discussed various species of pectens that are found in the Lee Creek Mine.

A comprehensive study of the evolution of the *Argopecten gibbus* group from Cenozoic strata of eastern North America, based upon the multivariate study of population morphology through time, was made by Waller (1969).

Recently Ward and Blackwelder (1975) separated Atlantic Coastal Plain species formerly assigned to *Lyropecten*, an endemic Pacific Coast genus, into their new genus *Chesapecten*. Several of the species found in the Lee Creek Mine belong in *Chesapecten*: *C. coccymelus*, *C. nefrens*, *C. jeffersonius*, and *C. madisonius*. They also refigured some of the Say (1824) types from the British Museum and renamed some of the species of pectens because of nomenclatorial problems.

#### COLLECTING TECHNIQUES

In the early stages of mining operations by Texasgulf Inc. at Lee Creek (Figure 1), a small test pit several hundred yards in length and width was opened in an area subsequently mined out and now reclaimed. The pit was dug by a floating dredge that, with the help of other pumps, lowered the water level in the pit as it dug. The dredge frequently needed maintenance or underwent repairs and thus ceased pumping water out of the test pit. Even though other pumps continued working, with the dredge not working, water level rose in the pit by as much as 30 feet (9 m). The rising water level cleaned the near-vertical sides of the pit, and resumption of pumping by the dredge permitted detailed inspection of the stratigraphic units in the walls. The newly cleaned and emerged walls were examined for fossils, and careful stratigraphic collections were made.

The author spent numerous days collecting during the winter of 1963–1964, and the stratigraphic information gained forms the basis of the placement of lithologies into the sequence presented in Figure 2.

The lithologies vary among the different parts of both the Pungo River and Yorktown formations. The Pungo



FIGURE 1.—Location of major localities and formational units discussed in text: 1 = Kirkwood Formation in vicinity of Salem and Jericho, New Jersey; 2 = Calvert, Choptank, and St. Marys formations at Calvert Cliffs, Maryland; 3 = Yorktown Formation along Chowan River, North Carolina, 4 = Lee Creek Mine, North Carolina; 5 = Waccamaw Formation in southern North Carolina and northern South Carolina; 6 = Torreya, Chipola, Oak Grove, and Jackson Bluff formations in northwestern Florida; 7 = Caloosahatchee Formation in southern Florida.

River Formation has phosphatic sands composed of primary grains of phosphate (oval in shape, light to medium brown in color generally) in the lower and middle parts, with some dolomitic and diatomaceous layers; upwards the phosphatic sands begin to interbed with limy layers, causing the resulting limestones to contain abundant phosphate grains; the uppermost beds consist of limestones having abundant molds of mollusks and few phosphatic grains giving way upward to loosely consolidated bioclastic debris, which does not contain any appreciable amount of phosphatic material.

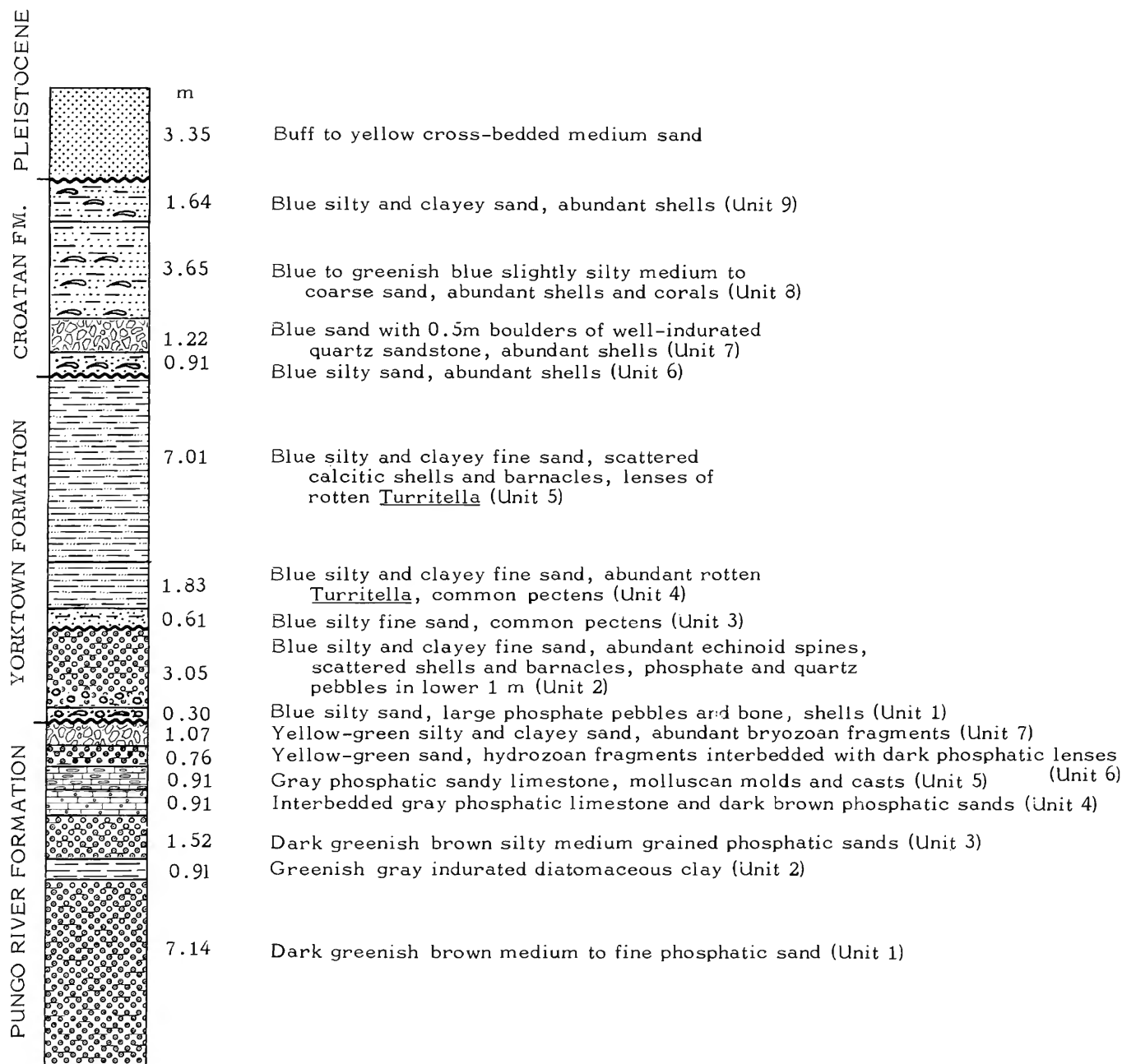


FIGURE 2.—Section of Miocene and younger strata exposed in the northwest wall of the test pit, Lee Creek Mine.

The lower units of the Yorktown Formation are bluish clays and sands containing large amounts of secondary phosphatic material (irregularly shaped, black in color), which rapidly decreases in size above the base; overlying this is a sequence with abundant echinoid spines in a fine quartz sandy matrix, the abundance of spines sometimes giving a fibrous appearance; the next sequence upward has large numbers of *Turritella*, which generally have been

diagenetically altered to a chalky and partially dissolved appearance, and near the top the beds are partially indurated because of the local redeposition of the carbonate from the shells.

With the beginning of mining operations several years later, vast amounts of the Pungo River and Yorktown formations were exposed in the spoil piles derived from the dry stripping operations. Because of the large size of the

drag-line bucket (72 cubic yards; 55 cubic meters) and the careful stripping of the layers, material from the same stratigraphic intervals tends to be localized on the spoil piles. The localized material can be placed within the stratigraphic sequence by comparison of the lithologies and faunas with the known distribution in the outcrop sequence in the walls of the test pit, and thus into the distinctive unit sequence of Gibson (1967). Although some of the measured and illustrated specimens were collected in place from the walls of the test pit or large mining pit, most specimens are from the spoil piles; the great amount of areal exposure of the units uncovered many well-preserved specimens from a relatively narrow and known stratigraphic interval.

#### CORRELATION

Most of the species identified to date from exposures of the Pungo River Formation in the Lee Creek Mine also are found in the Calvert Formation of Maryland and Virginia. Three species, *Chesapecten coccymelus*, *Ostrea percrassa*, and *Ecphora tricostata* are restricted elsewhere to the Calvert Formation in Maryland and Virginia and the coeval Kirkwood Formation in New Jersey. *Chesapecten nefrens* from the uppermost part of the Pungo River Formation in the mine is restricted to the upper part of the Calvert Formation and the Choptank Formation in Maryland and northern Virginia. The other species of mollusks reported to date from the Pungo River Formation include *Pecten mcllellani*, new species, and two new species of *Ecphora*: *E. pamlico* (p. 24) and *E. aurora* (p. 24), which in North America are restricted to the Lee Creek exposure of the Pungo River Formation.

The three species restricted to the Calvert Formation and the one species that ranges from the Calvert into the Choptank Formation permit correlation of the Pungo River Formation in North Carolina with the Calvert Formation in Maryland. The similarity of the span of time represented in the two formations is unknown at present, but evidence to date from the pectens suggests that they have a similar time span. The Calvert Formation in Maryland consists of 16 beds (zones 1–16 of Shattuck, 1904). *Pecten humphreysii* is known from beds 1–10, the lower and middle part of the Calvert. *Chesapecten nefrens* occurs in bed 14 and ranges upward into the Choptank Formation. The specimens from the Lee Creek Mine are from the uppermost beds of the Pungo River Formation. Thus the superposition of the two species in the Pungo River Formation at the Lee Creek Mine is the same as in the Calvert, with an indicator of bed 10 or older strata (*Pecten humphreysii*) being overlain by an indicator of bed 14 or younger (*Chesapecten nefrens*). The considerable thickness of strata below the occurrences of *Pecten humphreysii* in the upper middle part of the Pungo River Formation may correspond to the time represented by the strata below bed 10 of the Calvert Formation in

Maryland. The types of lithologies are different, phosphatic sands in the Pungo River Formation and clayey sands and diatomaceous clays in the Calvert Formation, but a similar time span for the two formations rather than just a slight overlap of part of one formation with a part of the other is indicated. Gibson (1983a:38, 63; 1983b:359) has found younger parts of the Pungo River Formation to the north and east of the section in the mine, and these strata appear to be younger in age than any part of the Calvert Formation so far dated.

The age significance of the planktonic Foraminifera of the Pungo River Formation was discussed by Gibson (1967; 1983b). The assemblages from the Pungo River Formation on which ages were obtained occur in the upper part of the formation. These assemblages are referable to zones N8 or possibly early N9 in the Neogene planktonic scale (Blow, 1969:229, 230), which is presently accepted as approximating the early to middle Miocene transition (Blow, 1969:203, 265ff; Berggren and Van Couvering, 1974:202, 271ff). The foraminiferal assemblages in the lower and middle parts of the formation are too poorly preserved to be identifiable. A similar assemblage referable to zone N8 or N9 also is found in bed 10 of the Calvert Formation in Maryland (see Gibson 1983b:360), and thus these two parts of the two formations have a similar age, approximating the early to middle Miocene boundary.

The time ranges of *Chesapecten coccymelus* and *C. nefrens* thus seem to be similar in the different geographic areas. *Pecten humphreysii* also appears to have a similar range in North Carolina, Virginia, Maryland, and New Jersey, occurring in what are considered to be generally time-equivalent strata (Gibson, 1967:636; 1983a:38). Banks and Hunter (1973) reported this species from the Torreya Formation in Florida, and some of their specimens are illustrated in the present paper (Plate 4: figures 4–6). (The Torreya Formation of Banks and Hunter (1973) is herein adopted for U.S. Geological Survey usage.) The strata in which they occur, however, are tentatively assigned by them to the planktonic foraminiferal zones N5 and N6, considerably older than the present ages known for the strata bearing *P. humphreysii* in the Lee Creek Mine and northward (N8 and N9). The age of the Torreya Formation may be refined upward, but if not, it will mark a significantly older occurrence of *P. humphreysii* in Florida than presently known in the North Carolina–Maryland area. Another possibility is that the lower part of the Calvert and Pungo River formations, which are not dated by planktonic Foraminifera because of lack of specimens and/or poor preservation, could be of an age older than N8, thus similar to the Torreya.

The upper part of the Yorktown Formation in Virginia and North Carolina has been correlated with the Duplin Formation of the southern part of North Carolina and adjacent Georgia (Mansfield, 1944, table 1). The *Ecphora*

and *Cancellaria* zones of the Choctawhatchee Formation in Florida were correlated with the Yorktown Formation by Mansfield (1944, table 1). The Choctawhatchee Formation has been reinstated, redefined, and stratigraphically restricted to include only the lower part of former usage by the U.S. Geological Survey; its upper part, the *Ecphora* and *Cancellaria* zones, is now placed in the Jackson Bluff Formation of Puri and Vernon (1964). A number of pectens restricted to the Yorktown Formation in Virginia and North Carolina are also found in the Jackson Bluff Formation. They include *Chesapecten jeffersonius*, *Argopecten eboreus watsonensis*, and *A. comparilis*. These species support the correlation of these formations.

Mansfield (1936, 1944) divided the Yorktown Formation in Virginia and North Carolina into two zones. Zone 1 or the *Pecten clintonius* zone is overlain by zone 2 or the *Turritella alticostata* zone, which is composed of three sets of beds. Units 1 and probably all of 2 of the Yorktown Formation in the Lee Creek Mine of Gibson (1967; see also Figure 2) belong to Mansfield's zone 1, and the overlying units 3 to 5 belong to zone 2.

Planktonic Foraminifera from zone 1 of the Yorktown in the northern part of North Carolina and in the Lee Creek Mine are of an early Pliocene age, planktonic zone N19/N20 (Gibson, 1983b:363). Mansfield's zone 2 belongs to younger parts of zone N19/N20 and probably extends into zone N21 (late Pliocene).

The upper part of the fossiliferous strata in the Lee Creek Mine, termed the upper shell bed (units 8 and 9 of Gibson, 1967) was included in the Yorktown Formation by Gibson (1967) because it appeared to be the youngest part of the depositional cycle of later Cenozoic strata in eastern North Carolina. Other strata of a similar age are found at Mt. Gould Landing along the Chowan River in northeastern North Carolina (Figure 1), and these were also placed in the upper part of the Yorktown Formation by Mansfield (1944) (although given a younger age than the classic Yorktown by Hazel, 1971). The upper shell bed (units 8 and 9) and the underlying boulder bed and fossiliferous bed (units 6 and 7 of Gibson, see Figure 2) appear to be part of a sequence that is separated from the rest of the Yorktown by an unconformity. The age of these strata is younger than that of the typical Yorktown beds in most of North Carolina. These units are probably time-equivalents of the Croatan Formation, the type area of which is slightly south of the Lee Creek Mine, and the Waccamaw Formation, which is exposed in southern North Carolina and northern South Carolina (Figure 1). As the lithology is similar to that of the Croatan Formation, which is probably in the same depositional basin (Gibson, 1983a:74; 1983b:364), the upper part of the fossiliferous strata in the mine, units 6-9, is assigned to the Croatan Formation. The James City Formation of DuBar and Solliday (1963) is considered to be synonymous

with the Croatan Formation (Hazel, 1983:84-85).

The upper part of the Croatan Formation is correlated with the Waccamaw Formation, and both formations are considered time-equivalents of the Caloosahatchee Formation in Florida. There are seven species of pectens in common between the Waccamaw and Caloosahatchee formations: *Pecten brouweri*, *P. raveneli*, *Argopecten eboreus*, *A. vicenarius*, *Straliopecten ernestsmithi*, *Leptopecten leonensis*, and *Amusium mortoni*. Two of these species are restricted to the Waccamaw and Caloosahatchee formations, *Straliopecten ernestsmithi* and *Pecten brouweri*, and support the correlation of the two units. The planktonic Foraminifera support a correlation with the early Pleistocene zone N22 for part, at least, of the Waccamaw and Croatan formations, with a probable late Pliocene age or zone N21 for the remainder (see Gibson, 1983b:364).

#### BIOSTRATIGRAPHY OF THE PECTINIDAE

The pectens, as already noted, are ideal guide fossils to the upper Cenozoic deposits of the Atlantic Coastal Plain. Species range zones often coincide with formational boundaries, which is not surprising as the formations characteristically used in the Atlantic Coastal Plain are in most instances biostratigraphic rather than lithostratigraphic units. Thus, the pectens are one of the most prominent markers of the biostratigraphic "formations." In addition, changes in the assemblage, either at the specific or subspecific level, sometimes allow further biostratigraphic subdivision within a formation.

The following sequence of pectens may be used to subdivide the strata of the Chesapeake group, starting from the basal unit, the Calvert Formation (Figure 3).

*Pecten humphreysii* and *Chesapecten coccymelus* are restricted to the lower and middle part of the Calvert Formation in Maryland, occurring from bed 1 to bed 10, and to the Pungo River Formation in North Carolina. The upper part of the Calvert Formation and the overlying Choptank Formation are characterized by the occurrence of *Chesapecten nefrens*, which also occurs in the uppermost part of the Pungo River Formation in North Carolina. The St. Marys Formation in Maryland is characterized by *Chesapecten santamaria*, with a change in the species morphology upward through the beds. Strata of the Maryland St. Marys and Choptank formations are not known south of northern Virginia (Gibson, 1970). The St. Marys Formation in Virginia (considered the basal part of the Yorktown Formation, Gibson, 1971) is marked by the occurrence of *Chesapecten middlesexensis* throughout the formation, although with a series of morphologic variations, and in its upper part by *Argopecten eboreus urbannaensis* and *Placopecten clintonius rappahannockensis*. Both *Chesapecten santamaria* and *C. middlesexensis* show considerable variation throughout their



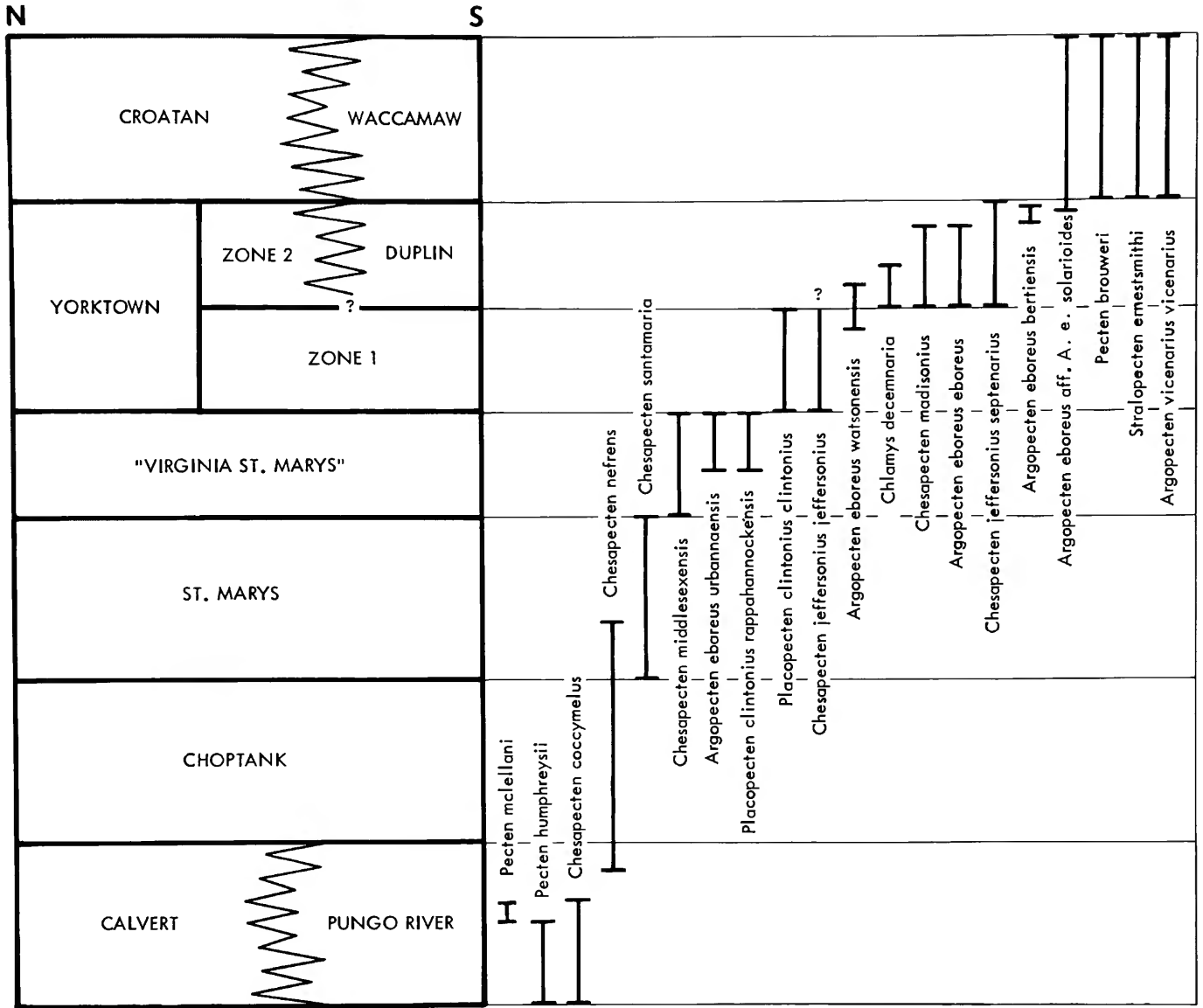


FIGURE 3.—Range chart of the common late Cenozoic pecten species occurring in the formations of the central Atlantic Coastal Plain.

chronologic range, and further subdivision of the strata may be possible.

The lower beds of the Yorktown belonging to zone 1 of Mansfield, are characterized by the occurrence of *Placopecten clintonius clintonius* along with the first appearance of *Chesapeake jeffersonius jeffersonius*.

In the middle part of the Yorktown Formation, the lower part of Mansfield's zone 2, the *Chesapeake* stock changes to *C. jeffersonius septenarius* and *C. madisonius*. Other subspecies of *Argopecten eboreus* become diagnostic, such as *A. eboreus watsonensis* in the lower middle part, giving rise to *A. eboreus eboreus* in the middle part. *Chlamys decemmaria* is

also an important index to this part of the section.

The upper part of the Yorktown Formation is characterized by some of the more advanced forms of *Argopecten eboreus eboreus*, *A. eboreus bertiensis* in a few localities along with *A. eboreus* aff. *A. eboreus solaroides*, advanced forms of *Chesapeake madisonius*, along with a very few advanced specimens of *C. jeffersonius septenarius*.

The younger Croatan and Waccamaw formations contain new groups such as *Pecten brouweri*, *Stralopecten ernestsmitthi*, *Argopecten vicenarius*, along with the abundant specimens of the various subdivisions of *A. eboreus solaroides*.

Other species of pectens are found in the strata of the

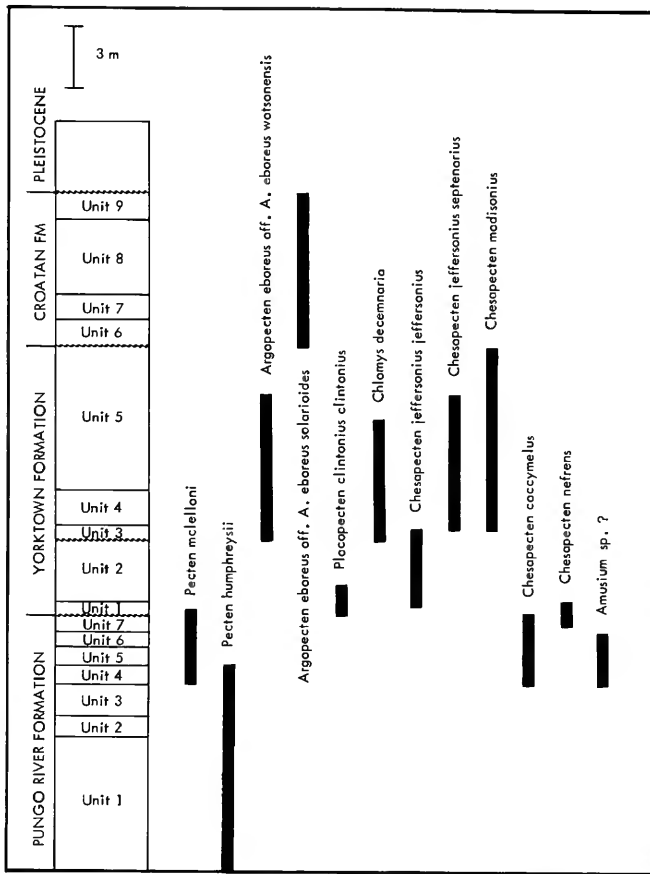


FIGURE 4.—Distribution of species of pectens in the test pit strata of the Lee Creek Mine.

Chesapeake group; however, they are either rare or their range is uncertain at the present time. Distribution of species in the Lee Creek Mine is given in Figure 4.

#### PHYLOGENY OF THE PECTENS

Although Dall (1898) and subsequent workers mentioned relationships among the various groups of pectens, Mansfield (1936) developed the first extensive phylogenies of the late Tertiary pectens of the Atlantic and Gulf Coastal plains. Modifications have been made in some of the lineages, but in large part Mansfield's phylogenies still are generally accepted. Waller's (1969) detailed phylogeny of the *Argopecten gibbus* stock, however, involved changes from that of Mansfield.

In the present paper, the species stocks and their inferred phylogenies are given, when possible, in the discussion of the individual species and also summarized in Figure 5. Phylogenies have been proposed, either in Mansfield (1936) or herein, for the *Chesapeake* group, the *Argopecten eboreus* stock, the *Placopecten* group, and the probable *Pecten mcllellani* lineage. Phylogenies have not been developed for *Chla-*

*mys decemmaria* and *Amusium*, the other two groups found in the Lee Creek Mine.

Although phylogenies have been developed for late Tertiary pectens, little has been determined concerning the origin of the groups. The absence of information is due both to the lack of strata of immediately preceding age (upper Eocene, Oligocene, and lower Miocene strata are poorly represented in the central and northern Atlantic Coastal Plain) and also to the lack of knowledge of the faunas existing in older strata. The pectens found in strata of late Eocene and Oligocene age are quite different from those found in the lowermost Miocene deposits of the Calvert and Pungo River formations.

The earliest recognized representatives of the *Chesapeake* stock appear in the Calvert Formation in Maryland and Virginia. If the ancestral forms were confined to the central and northern parts of the Atlantic Coastal Plain because of environmental restrictions, determining them will be difficult because strata of Oligocene and early Miocene age crop out in only one place in this area. In North Carolina, Oligocene and possibly lower Miocene strata are present, but forms ancestral to the Miocene pectens have not been reported. It may be necessary to look to other areas, possibly Florida, to find the ancestral forms that later moved northward into this area.

Therefore, at the present time, while phylogenies have been proposed for most groups, early Tertiary ancestral groups remain unrecognized.

#### BIOGEOGRAPHY AND PALEOCLIMATE

For many years, probably since Dall (1904), the environment during deposition of the lower Miocene deposits of Florida (of Dall, now in part Pliocene) was considered to be very warm, followed by progressive cooling. After the early Miocene, cooling presumably would lead to the southward migration of the faunas found in the Chesapeake area, possibly resulting in a mixing of the more northern species with the indigenous Florida assemblages. A result of this faunal migration would be strong provincialism in the northern earlier Miocene faunas, such as those of the Calvert compared to those of the Chipola or Oak Grove formations of Florida in contrast to the more widespread distribution of the faunas in the later deposits considered Pliocene in this volume.

The faunal provincialism between the Chipola (lower Miocene) and/or Oak Grove (middle Miocene) formations of Florida and the more northern Calvert Formation is well marked by the distribution of the mollusks in the two areas. The exact correlation of these units is uncertain at this time, because some authors regard the Chipola as being slightly older than the Calvert, and the Oak Grove Formation as being more or less equivalent to the Calvert (Mansfield, 1944). Correlations place the Hawthorn Formation in Flor-

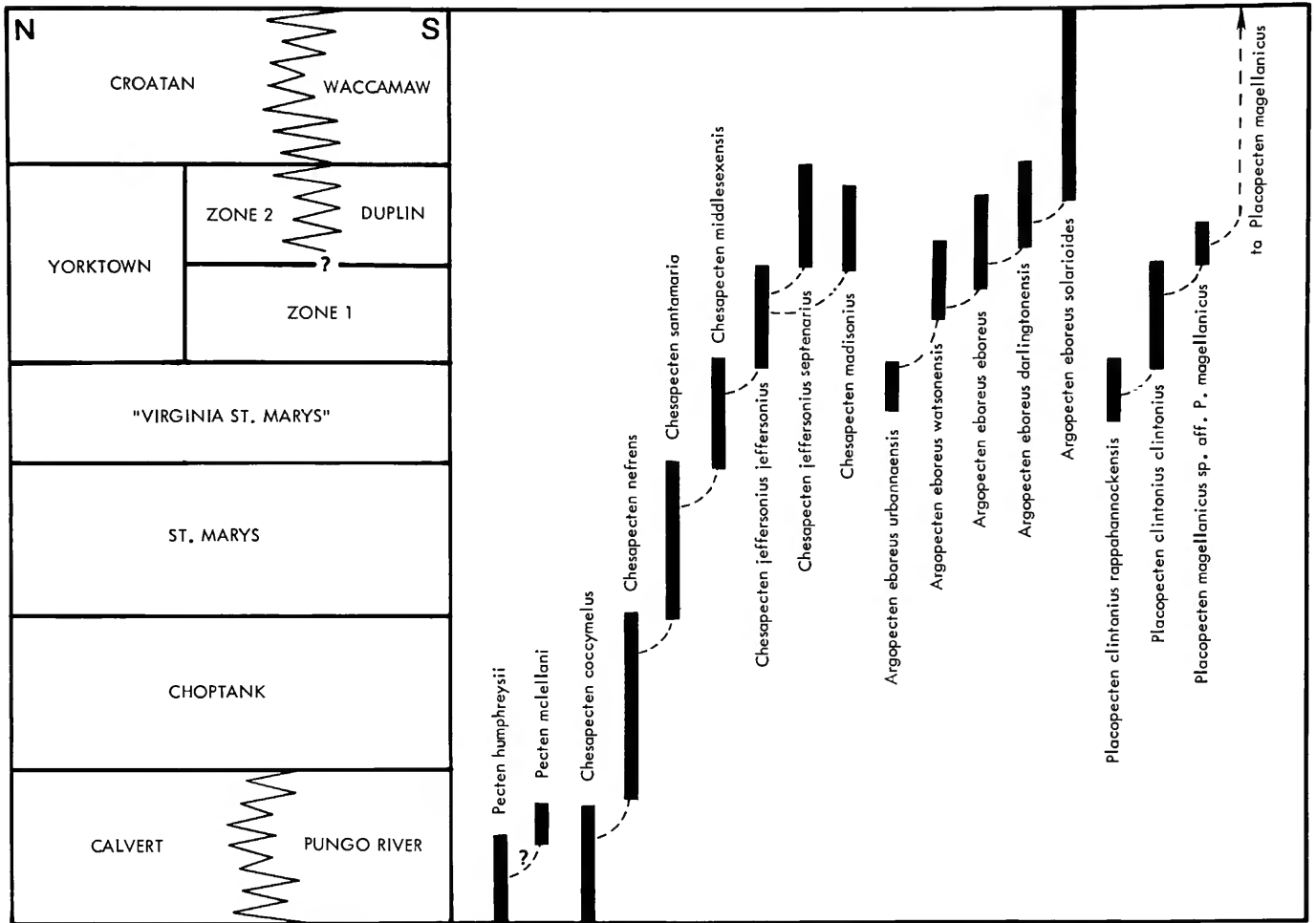


FIGURE 5.—Phylogeny of some pecten species occurring in Miocene through lower Pleistocene strata in the Atlantic Coastal Plain. The placement of the boundary between zone 1 and zone 2 of the Yorktown Formation is uncertain, as is the relationship between *Pecten humphreysii* and *P. mcllellani*.

ida and southern Georgia as at least in part equivalent in age to the Calvert (Gibson, 1967), a correlation given some additional support by the newly noted occurrence in both formations of *Chlamys nematopleura* Gardner (Druid Wilson, pers. comm., 1976). The Hawthorn appears to be at least in part of the same age as the Chipola (Gibson, 1967).

A search of the literature and the USNM collections was made to determine correlation of the pecten assemblages between the various Neogene formations in Florida, North Carolina, and Maryland.

The following six species of pectens have been reported from the Chipola Formation (Dall, 1898:720, 729, 733, 740, 755; Gardner, 1926:44, 46, 47, 50; Tucker-Rowland, 1936a:478, 1936b:1007, 1938:11, 58): *Pecten burnsii* Dall, 1898, *Chlamys acanikos* Gardner, 1926, *C. alumensis* (Dall, 1898), "*Chlamys*" *chipolana* (Dall, 1898), *Nodipecten condylomatus* (Dall, 1898), and *Amusium precursor* Dall, 1898.

Four species of pectens are reported from the Oak Grove

Formation, including one species that also occurs in the Chipola Formation (Dall, 1898:775, 729; Gardner, 1926:45, 46, 49, 50; Tucker-Rowland, 1938:12, 13, 70): *Chesapeake sayanus* (Dall, 1898), *Nodipecten condylomatus* (Dall, 1898), *Pseudamusium diktuotum* Gardner, 1926, and *Pseudamusium* sp. of Gardner, 1926.

Five species of pectens are found in the Calvert Formation (Dall, 1898:720, 741, 753; Glenn, 1904:372, 373, 374; Schoonover, 1941:188, 201; Tucker-Rowland, 1936a:478, 1936b:1007, 1938:68; Ward and Blackwelder, 1975:8, 9): *Pecten humphreysii* Conrad, 1842, *Chlamys nematopleura* Gardner, 1936, *Chesapeake coccymelus* (Dall, 1898), *C. nefrens* Ward and Blackwelder, 1975, and *Pseudamusium cerinus* (Conrad, 1869).

The Pungo River Formation, from the only known outcrop in the Lee Creek Mine, also contains five species of pectens (Gibson, 1967:636, and this paper): *Pecten mcllellani*, new species, *P. humphreysii* Conrad, 1842, *Chesapeake coc-*

*cymelus* (Dall, 1898), *C. nefrens* Ward and Blackwelder, 1975, and *Amusium* sp.

There are no species in common between the Chipola or Oak Grove formations in Florida and the Pungo River Formation in North Carolina or the Calvert Formation in Virginia and Maryland. The complete difference in assemblages supports the inference of a high degree of provincialism in Calvert–Chipola–Oak Grove time. The Chipola Formation is considered to be of very warm water origin with a number of tropical elements in the molluscan fauna. The Calvert Formation is of a cooler environment; just how much cooler is a matter of some controversy. Gibson (1962) considered the foraminiferal fauna of the Calvert Formation to be of a temperate nature, probably similar to the conditions presently existing off the Maryland coast today. The basis for this conclusion was that, of the 41 species of Foraminifera found in the formation, 7 are living species characteristic of temperate waters, while none of the living species are of exclusively warm water distribution (restricted to areas south of Cape Hatteras). However, F.C. Whitmore (pers. com., 1974) considers the Calvert Formation to represent a warm to possibly subtropical environment based upon the vertebrates, including crocodiles and otoliths.

Whatever the climatic conditions may have been, there were considerable differences between Florida and the Chesapeake Bay area, which resulted in the provincialism of the pectens and other molluscan and foraminiferal groups. The difference between the pectens of the Calvert and Pungo River formations and those of the Chipola and Oak Grove formations in Florida indicates that the main provincial barrier was south of central North Carolina. This supports the similar conclusion of Gibson (1967), based upon the benthic and planktonic Foraminifera, that the main provincial boundary was to the south of the Lee Creek Mine.

Later, in the Miocene and Pliocene (i.e., Yorktown), according to Dall (1904), a southward migration of the species from the Chesapeake area took place, leading to the presence of cooler water species in the Florida area. This hydroclimatic change would lead to a lesser amount of provincialism, and this change is reflected in the pecten assemblages.

Nine species of pectens from the Yorktown Formation have been reported in the literature or are in the USNM collections of the National Museum of Natural History (Dall, 1898:722, 725, 730, 741, 749, 750, 757; Gardner, 1944:30, 31, 32, 34, 36, 37, 39; Mansfield, 1936:178–180; Tucker-Rowland, 1936a:480, 1936b:1008, 1009; 1938:15, 19, 33, 38, 40, 52, 59; Waller, 1969:52, 59; Ward and Blackwelder, 1975:13): *Pecten smithi* Olsson, 1914, *Chlamys decemnaria* (Conrad, 1834), *C. rogersii* (Conrad, 1834), *Argopecten eboreus* (Conrad, 1833), *A. comparilis* (Tuomey and Holmes, 1857), *Placopecten clintonius* (Say, 1824), *Chesapecten jeffersonius* (Say, 1824), *Leptopecten* sp., and *Amusium mortoni* (Ravenel, 1844).

The following seven species of pectens have been reported in the *Ecphora* and *Cancellaria* facies of the Jackson Bluff Formation of Florida; only these two facies are considered coeval with the Yorktown Formation (Gardner, 1944:34, 36, 37, 39; Mansfield, 1932:56–65; Tucker-Rowland, 1936a:480, 481, 482, 1938:33, 40, 59; Waller, 1969:52, 59): *Pecten ochlockoneensis* Mansfield, 1932, *Flabellipecten macdonaldi* (Olsson, 1922), *Argopecten eboreus* (Conrad, 1833), *A. comparilis* (Tuomey and Holmes, 1857), *Chesapecten jeffersonius* (Say, 1824), *Leptopecten leonensis* (Mansfield, 1932), and *Amusium mortoni* (Ravenel, 1844).

Four of these species are found in both the Yorktown and Jackson Bluff formations. They are *Argopecten eboreus*, *A. comparilis*, *Chesapecten jeffersonius*, and *Amusium mortoni*. This is in marked contrast to the Calvert and Chipola formations of early and middle Miocene ages, during which time there were no species in common between the two areas.

It is important to determine whether this overlap is the result of a southward migration of the Chesapeake area pectens into Florida, as postulated by Dall (1904), and thus a cooling trend, or a northward migration of species from Florida, indicating a warming trend through the Coastal Plain as postulated by Gibson (1967) and Hazel (1971). The geologic record is reasonably good between the Calvert to Yorktown ages in the Chesapeake area and the Chipola to Jackson Bluff ages in Florida. An examination of the origins of the four common species suggests that there was movement both ways.

The earliest recognized members of the *Chesapecten* stock are *C. coccymelus* in the Calvert and Pungo River formations of late early to early middle Miocene age and *C. sayanus* in the Oak Grove Formation of early middle Miocene age (Huddlestun, 1976). Correlations would suggest that the northern occurrences are slightly older. Although *C. jeffersonius* is found both in the Chesapeake area and Florida, the development of *C. middlesexensis* from which it came is mainly or solely in the Chesapeake area and would seem to indicate a southward migration of this species group into Florida.

Although the early members of the *Argopecten gibbus* stock are characteristic of the Florida area, it appears that the earliest recognized member of the *A. eboreus* lineage within that stock, *A. eboreus urbannaensis*, is found in the Chesapeake area (Waller, 1969). The later development of *A. eboreus* would indicate a southward movement of the stock and diversification into a number of forms. If *A. eboreus urbannaensis* belongs to a separate lineage from the other forms placed in *A. eboreus*, then the earliest member of the *A. eboreus* stock would be *A. eboreus watsonensis*, which appeared at approximately the same time both in Virginia and Florida from southern ancestry.

*Argopecten comparilis* is a phyletic descendant of *A. chotawhatcheensis* (Mansfield) according to Waller (1969:27). The latter species is found only in Florida, and thus the

immediately following *A. comparilis*, which is found at approximately the same time in both Florida and Virginia—North Carolina, would have southern ancestry.

*Amusium mortoni* presents a complex problem in terms of occurrences. Although specimens of *A. mortoni* have been reported from pre-Yorktown beds in the Chesapeake area (Dall, 1898:757; Gardner, 1944:39), Mansfield (1932:65) restricts the species to Yorktown-Jackson Bluff and younger strata, correctly crediting the older reported occurrences of misreading of localities (see discussion under *Amusium* sp.). Mansfield (1936:180) lists *A. mortoni* as occurring only in the younger part of the Yorktown, while occurring in the slightly older *Eophora* zone of the Jackson Bluff Formation. If this correlation is valid, *A. mortoni* first appeared in Florida and moved into the Chesapeake area later in Yorktown time. Huddleston (1976), however, reported the Jackson Bluff to be of late Zanclean age; if so, this age would place it very close to the age of the Yorktown strata in which it occurs, indicating a similar time of origin in the two areas.

Therefore, of the four groups, one, *Chesapeecten jeffersonius*, is a southward migrant; one, *Argopecten eboreus*, a probable southward migrant; one, *A. comparilis*, a probable northward migrant; and one, *Amusium mortoni*, a possible northward migrant. Thus, in the pectens, the similarity in the fauna is due to a two way movement between Florida and the Chesapeake area. The movement may have been facilitated by the change in the paleoclimate during Yorktown time. The Chesapeake area during early Yorktown time is postulated as being cool with a warming trend upward through Yorktown time (Gibson, 1967; Hazel, 1971), which could have been a cause of decrease in provincialism during this time interval.

The Waccamaw Formation in North and South Carolina and the Caloosahatchee Formation in Florida are here considered coeval units. All reports of occurrences of pectens from the literature and from the USNM collections were noted in order to compare the degree of similarity between the two areas.

The Waccamaw Formation, including Croatan Formation at the Lee Creek Mine, contains 11 species of pectens (Ward and Blackwelder, this volume; Dall, 1898:721, 751; Gardner, 1944:31, 34, 36, 39; Mansfield, 1936:181–183; Tucker-Rowland, 1936a:484, 1938:24, 27, 50, 59; Waller, 1969:49, 51, 59): *Pecten brouweri* Tucker, 1934, *P. hemicyclius* Ravenel, 1834, "*Pecten*" *holmesii* Dall, 1898, *Euvola raveneli* (Dall, 1898), *Argopecten anteamplicostatus* (Mansfield, 1936), *A. eboreus* (Conrad, 1833), *A. vicenarius* (Conrad, 1843), *Stralopecten ernestsmiti* (Tucker, 1931), *Leptopecten leonensis* (Mansfield, 1932), *Leptopecten auroraensis* Ward and Blackwelder, this volume, and *Amusium mortoni* (Ravenel, 1844).

The Caloosahatchee Formation contains 13 reported species of pectens (Dall, 1898:721, 728, 731, 742, 757; DuBar, 1958:158–161; Gardner, 1944:30, 31, 36, 39; Mansfield,

1936:181–183; Olsson and Harbison, 1953:53–56; Tucker-Rowland, 1936a:483, 1936b:1010, 1938:25, 27, 28, 34, 39, 59; Waller, 1969:50, 51, 59): *Pecten brouweri* Tucker, 1934, *P. exasperatus* (Sowerby, 1843), *Euvola raveneli* (Dall, 1898), *Argopecten anteamplicostatus* (Mansfield, 1936), *A. eboreus* (Conrad, 1833), *A. vicenarius* (Conrad, 1843), *Chlamys harrisii* (Dall, 1898), *Stralopecten ernestsmiti* (Tucker, 1931), *S. caloosensis* (Dall, 1898), *Leptopecten leonensis* (Mansfield, 1932), *L. wendelli* (Tucker, 1934), *Nodipecten nodosus* (Linnaeus, 1758), and *Amusium mortoni* (Ravenel, 1844).

Of the 11 species of pectens reported from the Waccamaw Formation and its equivalent in North Carolina, the Croatan Formation, three species are restricted in their known distribution to the Waccamaw. They are *Pecten hemicyclius*, "*Pecten*" *holmesii*, and *Leptopecten auroraensis*. All of the remaining eight species are found also in the Caloosahatchee Formation, making a remarkable similarity between the two areas, and indicating very little provincialism in the pectinids at this time along the Atlantic Coast between Florida and North Carolina.

Thus from the middle Miocene to the early Pleistocene there is an increasing number of species in common between the North Carolina–Maryland and Florida areas. What this means with regard to temperature relationships is somewhat conjectural, but it would appear that the strong provincialism between the Chipola and Oak Grove formations with a generally subtropical nature and the Calvert would mark the Calvert as cooler; whether this would be warm temperate or cool temperate for the Calvert is unsettled at present. The decreasing provincialism higher in the column, with the Waccamaw fauna having most of its pecten species in common with the Caloosahatchee while the latter still retains a subtropical character, suggests a considerable warming of the North Carolina area.

#### DIVERSIFICATION OF THE PECTINIDS

The faunal list of pectens from each of the formations gives information on the diversity of one group of mollusks between the more southerly and more northerly parts of the Coastal Plain strata.

The surprising observation is that although the Chipola Formation is considered to have been deposited in considerably warmer environmental conditions, the number of species of pectens is just one greater than is found in the Pungo River or Calvert formations 500 miles (805 km) to the north. The Oak Grove Formation, which is also considered coeval with the Pungo River–Calvert strata, has one less species than the formations found farther north. Many complex factors are involved in a list of species from a formation, such as the geographic area covered, the availability of outcrops, the variety of facies, and the amount of collecting, study, and publication. With the present information, however, the common biological phenomenon of

increasing numbers of species with decreasing latitude is not observed in the pectens of the Chipola–Oak Grove, Calvert–Pungo River interval.

A similar paradoxical situation exists in the Yorktown–Jackson Bluff time interval. The Yorktown Formation in the more northerly area contains nine species of pectens, whereas the equivalent *Ephora* and *Cancellaria* facies of the Jackson Bluff Formation in Florida contain only seven species. However, during deposition of the uppermost Pliocene and lower Pleistocene strata the general biologic pattern of more species in the more southerly areas is marginally present, as 13 species of pectens are found in the Caloosahatchee Formation in Florida, whereas only 11 species are found in the Waccamaw–Croatan formations in North and South Carolina.

An interesting point is the increasing diversity of the species of pectens with time. Considering the known outcrops of the formations, it is probable that similar numbers of facies are represented at the different time intervals and have been more or less equally studied. Yet, the oldest Miocene assemblages consist of four to six species, increasing from seven to nine during Yorktown–Jackson Bluff time, and from 11 to 13 during Waccamaw–Caloosahatchee time. It is doubtful that these increases are a result of the temperature–diversity relationship, as the Chipola is thought to be as warm as any of the later formations. Increase in diversity upward through the section appears to reflect an increasing diversification of the pectens as a group.

#### MORPHOMETRY

The morphometry of the species of pectens found in the Lee Creek Mine was studied by the use of all suitable valves. In some species the population sample amounts to 10 or fewer specimens, but in others as many as 90 specimens are available. Approximately 20 morphological characters were measured on each valve, although the number is variable among species because some lack certain characters, such as plicae.

The measuring devices and methods employed in this study are similar to those used by Waller (1969). The measurements of the exterior of the valve, except for convexity, were determined by placing the specimen on graph paper. The convexity of the valves was measured on a glass plate with the use of a large vernier caliper. The widths of the plicae and of the areas between the plicae were taken by vernier calipers, either internally or externally in various species. The number of plicae was counted on the basis that the outermost plica must be reflected on the interior of the valve and be bounded externally on the disk–flank side by a distinct groove. The measurements of the resilial insertion and resilifer were taken through the ocular micrometer of the microscope.

MEASUREMENTS AND ABBREVIATIONS.—A selection of

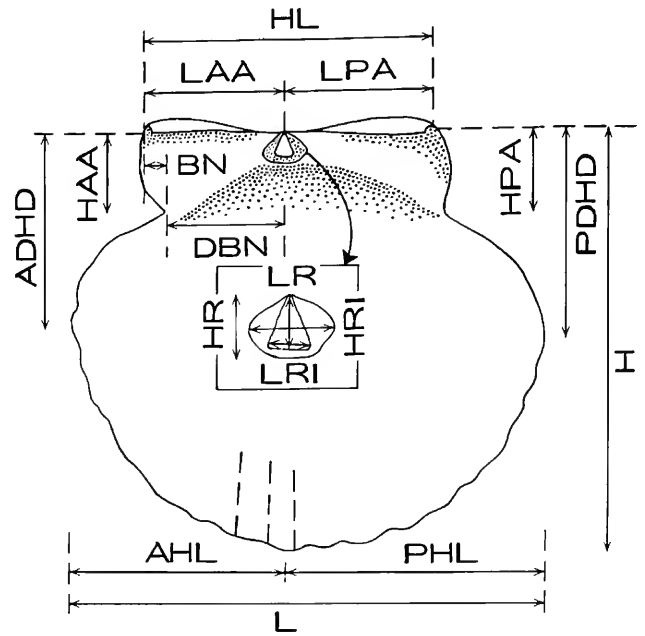


FIGURE 6.—Diagram of measurements for pectens. (See below for explanation of symbols.)

specimens of graduated size is presented at the end of the discussion of each species. The arbitrary selection of specimens was made on the basis of the most nearly complete set of measurements possible on three or four different sized specimens. These data are presented for the Lee Creek specimens, as well as for comparative material of the same or related taxa from the USNM collections. Complete data on the population samples are available from the Department of Paleobiology, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560. The variates measured and their appropriate abbreviations are as follows (see also Figure 6):

ADHD	Anterior dorsal half-diameter of disk
AHL	Anterior half-diameter of disk
BN	Depth of byssal notch
CON	Convexity
DBN	Distance from origin of growth to inner part of byssal notch
H	Height of disk (linear)
HAA	Height of anterior auricle
HL	Total length of hinge line
HP	Height of plicae
HPA	Height of posterior auricle
HR	Height of resilifer
HRI	Height of resilial insertion
L	Length of disk
LAA	Length of anterior auricle
LPA	Length of posterior auricle
LR	Length of resilifer
LRI	Length of resilial insertion
NP	Number of plicae
NRIB	Number of ribs
PDHD	Posterior dorsal half-diameter of disk
PHL	Posterior half-diameter of disk

V	Valve, left (S) or right (D)
W1	Width of interspaces between plicae
WP	Width of plicae

**IMPORTANT CHARACTERS.**—A small number of characters were found important in characterizing and discriminating various species of pectens from the Miocene and Pliocene strata in the Lee Creek Mine and environs. Although internal characteristics were found to be important by Waller (1969), the musculature was not used in the present study because of the difficulty in obtaining a large enough population sample having these characters preserved. In some species, the interior, and to a lesser extent the exterior, is covered with an indurated matrix, which requires considerable time for each specimen to be cleaned by air abrasive methods. Also the air abrasion process erodes enough of the weakly preserved muscle scars to make accurate measurement of them difficult. In other groups that do not have the indurated matrix, the state of preservation on the interior is not sufficient to allow careful study of the muscle scar locations. The general morphological characteristics of the valve do yield important characterizations and distinctions in all cases. In the *Placopecten* stock, attachment scars in the form of the resilial insertion are used as an important differentiating characteristic.

The valve shape among most pectens is similar, and in only two groups in this study could species be differentiated on the basis of valve shape. One is the *Placopecten* group, where the sample of *P. clintonius clintonius* from the Lee Creek Mine has an oblique valve outline compared to the Holocene sample of *P. magellanicus*. The other is in the *Chesapecten* group where *C. nefrens* differs from *C. coccymelus* by having a longer valve in relation to the height.

The convexity of the valves varies greatly from genus to genus, but also varies within a species group as shown in the *Pecten humphreysii* group (Figure 10) and the *Argopecten eboreus* stock (Figure 14).

The byssal notch is important as it may closely reflect anatomical changes. The byssal notch varies phylogenetically within the *Chesapecten* stock; the early members, such as *C. coccymelus* and *C. nefrens*, have deep byssal notches; the next number, *C. santamaria*, has a notch of moderate depth; the following species, *C. middlesexensis*, has a slightly shallower notch; and the youngest members, *C. jeffersonius* and *C. madisonius*, have very shallow notches. This character also varies within other species groups or genera as shown in *Pecten humphreysii* and allies (Figure 9) and the *Argopecten eboreus* stock (Figure 13).

The height and length of the auricles is a variable character within a species group, as shown in *Placopecten clintonius* (Figure 20).

The plicae are among the most striking features in many pecten groups, particularly in the *Chesapecten* group, where they are strongly developed. The number of plicae is a valid and useful characteristic. This chapter is especially useful in

the *Chesapecten* lineage (Figure 23) and to a somewhat lesser degree in the *Argopecten eboreus* stock, with its many subspecies (Figure 11).

Other aspects of ornamentation are also important in the pectens studied herein. These include significant differences in the number of costae on the plicae in the *Chesapecten* group. The number of costae varies from 1 to 4 in *C. coccymelus* to as many as 20 in *C. jeffersonius* and *C. madisonius*. There also is a significant difference in the number of costae on the auricles with the number varying from as few as 6 in *C. coccymelus* to as many as 25 to 30 in *C. jeffersonius* and *C. madisonius*.

The arrangement of the internal lirae, which are characteristic of *Amusium*, appears to be diagnostic of several species. This character should be useful in specific identification as most of the specimens of *Amusium* are fragmentary. In *Amusium* the lirae vary from closely spaced pairs with wider areas between pairs to essentially widely and uniformly spaced lirae.

#### ACKNOWLEDGMENTS

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### Family PECTINIDAE Rafinesque, 1815

#### Genus *Pecten* Muller, 1776

#### *Pecten mcllellani*, new species

PLATES 1, 2, 13: FIGURE 2

**DESCRIPTION.**—*Shell Outline:* Shell medium to large in size, with specimens having heights of 80 to 100 mm common in the population sample, and reaching a maximum height of 130 mm; slightly longer than high, with a maximum length of slightly greater than 120 mm; right valve low to moderately convex with a maximum convexity of 17 mm; left valve flat to slightly convex with a maximum convexity of 9 mm; outline of disk equilateral, with almost identical anterior and posterior half-diameters.

*Auricles and Outer Ligament:* Right anterior auricle with a slightly convex surface; dorsal margin slightly dorsal to groove of outer ligament and folded; byssal notch very shallow with broad apex; byssal fasciole poorly developed; ctenolium observable on right valves. Left anterior auricle

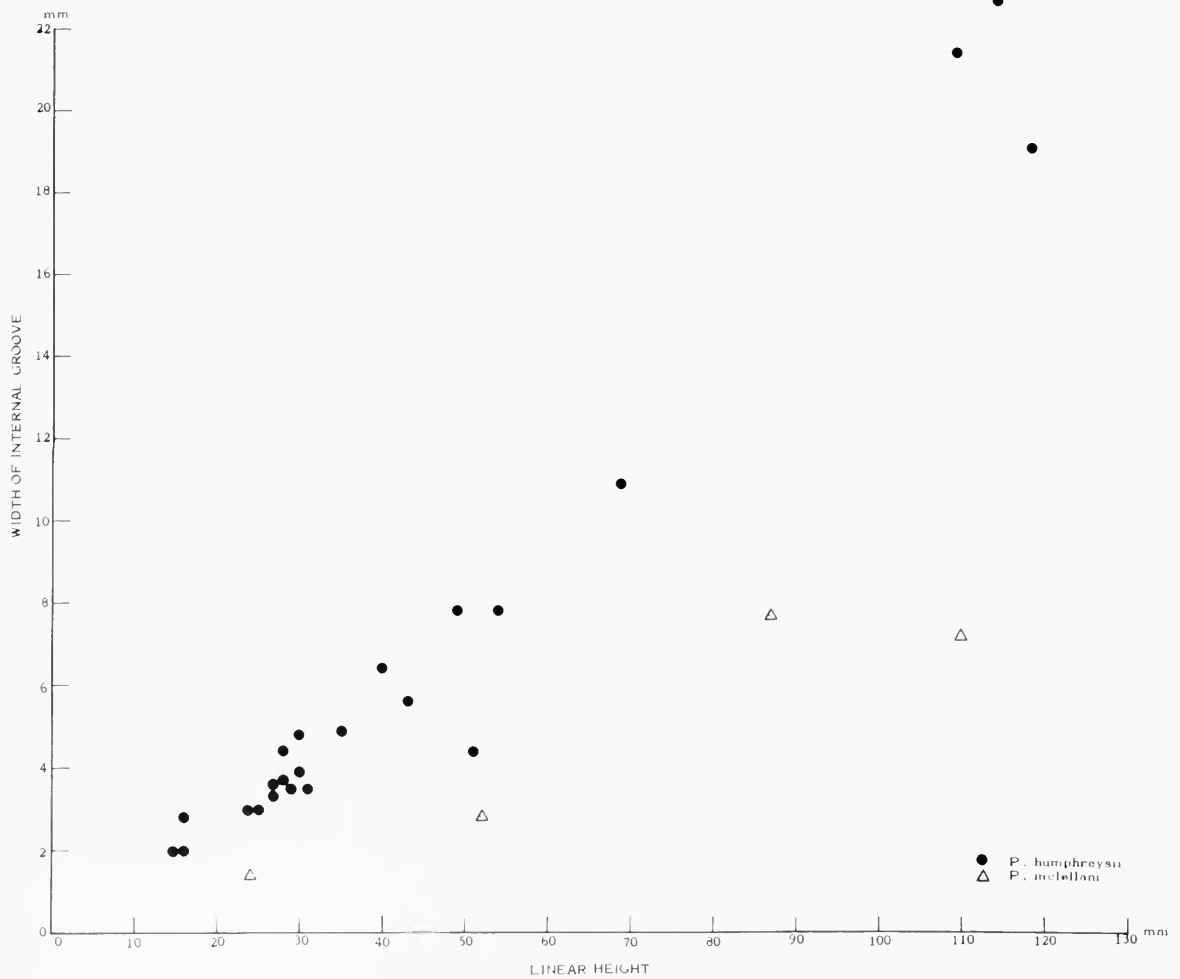
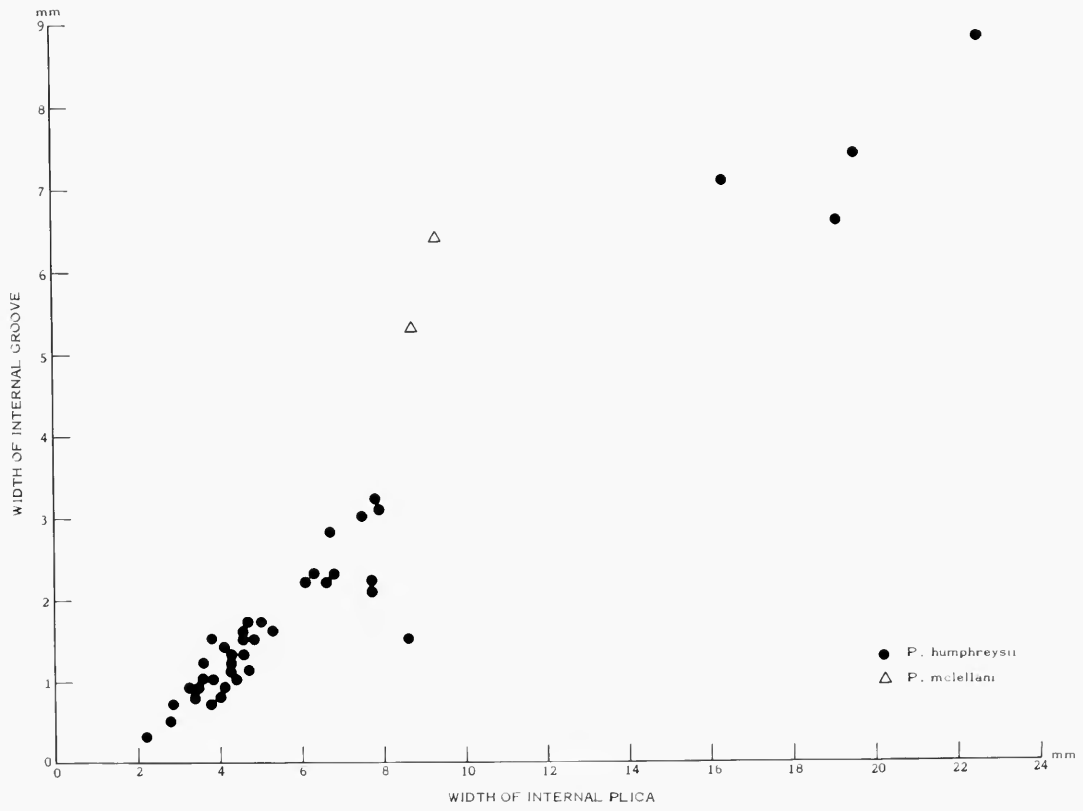


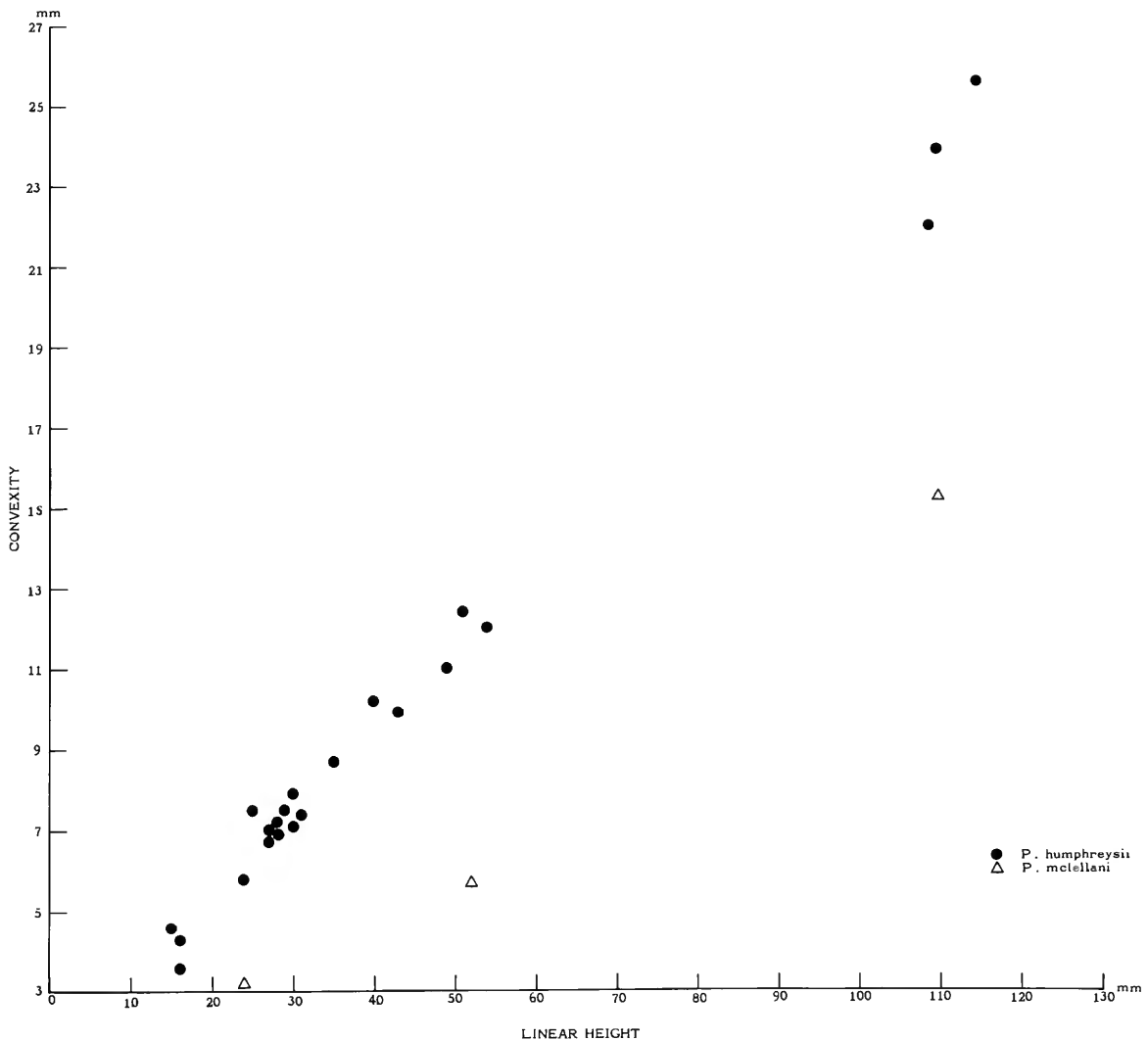
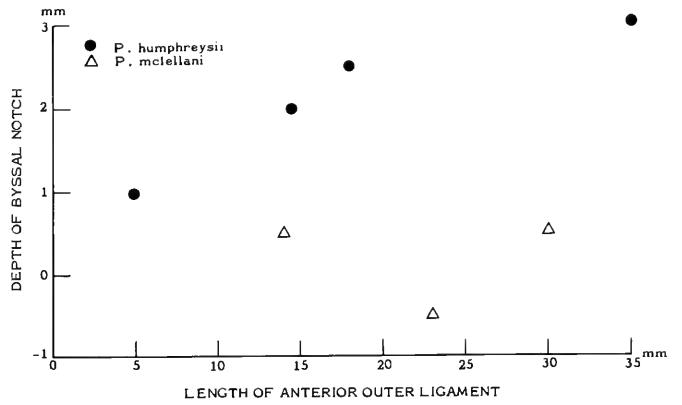


FIGURE 7 (top left).—Bivariate scatter diagram showing the difference in the width of the internal plica and groove between samples of *Pecten humphreysii* (Calvert Formation, Maryland) and *P. mclellani* (Pungo River Formation, North Carolina).

FIGURE 8 (bottom left).—Bivariate scatter diagram showing the difference in the width of the internal groove compared to the height of the valve among samples of *Pecten humphreysii* (Calvert Formation, Maryland) and *P. mclellani* (Pungo River Formation, North Carolina).

FIGURE 9 (right).—Bivariate scatter diagram showing the deeper byssal notch in relation to the length of the anterior outer ligament in a sample of *Pecten humphreysii* (Calvert Formation, Maryland) compared to *P. mclellani* (Pungo River Formation, North Carolina).

FIGURE 10 (below).—Bivariate scatter diagram showing the greater convexity of the right valves compared to the height of the valve in a sample of *Pecten humphreysii* (Calvert Formation, Maryland) compared to *P. mclellani* (Pungo River Formation, North Carolina).



with surface nearly planar to slightly convex; dorsal margin slightly folded and nearly coincident with trace of outer ligament; free margin slightly rounded with shallow byssal sinus having a rounded apex. Posterior auricles similar in size to anterior; dorsal margin slightly dorsal to groove of outer ligament and folded; free margin slightly convex, especially near dorsal margin. Posterior and anterior outer ligaments generally about equal in length.

*Exterior Shell Surface:* Both valves with about 12 plicae; in early growth stages plicae defined from interspaces by low, moderately rounded sides until shell heights of approximately 50 mm are reached, thereafter plicae becoming less strongly defined from interspaces with very broad, low sides, until becoming obscure at margins of large valves; no secondary radial ornamentation on plicae or interspaces; concentric lamellae well developed on left valves, less so on right valves being primarily preserved on the disk flanks. Anterior and posterior auricles have approximately 8 radial costae, moderately developed on the initial 10 mm of the auricle, becoming obsolete beyond this point; concentric lamellae well developed on auricles. Disk flanks of right valves have 4 moderately developed radial costae on initial 15 mm along with moderately developed concentric lamellae; left valves have smooth disk flanks except for well-developed concentric lamellae.

*Interior Features:* Resilial insertions slightly less than 1½ times as high as long, orientation ranging from perpendicular to hinge line to slightly sloping either anteriorly or posteriorly; single, strongly developed auricular denticle both anteriorly and posteriorly; additional one or two costae found within the interior plicae.

**DISCUSSION.**—The only closely related species in the Miocene strata of the Atlantic Coastal Plain is *Pecten humphreysii* Conrad, which is found in slightly lower beds of the Pungo River Formation in the Lee Creek Mine and in the Calvert Formation in northernmost Virginia, Maryland, and New Jersey. *Pecten mclellani* is distinguished from this species by the ornamentation, position of the byssal notch relative to the end of anterior outer ligament, and convexity of the right valve.

The number of plicae in *P. mclellani* is greater, ranging from 10 to 13 in number, while *P. humphreysii* has from 8 to 10 (7 or 8 broad and prominent ones and two lateral ones quite reduced in size, which are more prominent on the interior of the valve). *Pecten humphreysii* has much wider plicae on the right valve, with relatively narrower interspaces and, correspondingly on the left valve, has relatively narrow plicae with wide interspaces. The plicae on both valves are quite pronounced with vertical sides in some specimens. *P. mclellani* has considerably narrower plicae on the right valve with the interspaces more nearly approaching equal width with the plicae; on the left valve correspondingly are wider plicae than in *P. humphreysii* with narrower interspaces. The plicae are very slightly raised in comparison with *P. humphreysii* and do not have the vertical sides

common in the latter. Figures 7 and 8 show the significantly greater width of the plicae on the right valves of *P. humphreysii*. (The measurements are taken internally as the sharpness of the plicae is increased on the interior, giving more accurate measurements.)

Although the byssal notch is shallow in both species, the position of the notch in relation to the anterior end of the outer ligament is different between the two species (Figure 9). In *P. humphreysii* the posterior end of the byssal notch is 1 to 3 mm posterior to the anteriormost point of the outer ligament. In *P. mclellani* the posterior end of the byssal notch is from 0.5 mm posterior to almost 1 mm anterior to the anteriormost end of the outer ligament.

The right valves of *P. humphreysii* have considerably greater convexity compared to those of *P. mclellani* as shown in Figure 10.

As *P. humphreysii* is found in beds of the Pungo River Formation, below those in which *P. mclellani* occurs, and as the two species have similar morphology, it is considered likely that *P. humphreysii* is ancestral to *P. mclellani*. One important phylogenetic change between the two species is a decrease in the strength and width of the plicae in the descendant species. Mature specimens of *P. humphreysii* do show a decrease in the strength of the plicae in the later stages of the valve to a height and sharpness similar to that found in the early stages of *P. mclellani*.

There is a general similarity in the shell shape, ornamentation, both internal and external, and byssal characters between *P. mclellani* and the later occurring *Pecten holmesii* Dall from the Waccamaw Formation in South Carolina. No related species of an intermediate age is known, and the similarity may not reflect any relationship. An increase in convexity of the right valve of *P. mclellani*, however, along with a further reduction in the largely obscure plicae would give a form similar to that of *P. holmesii*.

*Pecten ochlockoneensis* Mansfield from the Choctawhatchee Formation in Florida and *P. smithi* Olsson from the Yorktown Formation in Virginia differ from *P. mclellani* in having many more plicae on both valves and in being much smaller in size. In addition, *P. ochlockoneensis* has a more convex right valve. These two species are most similar to *P. mclellani*, but are doubtfully congeneric.

**NAME.**—The species is named in honor of Mr. Jack McLellan of Texasgulf Inc., who collected and donated many specimens of pectens and other invertebrates from the Lee Creek Mine.

**TYPES.**—Holotype: right valve, USNM 218830. Figured paratypes: right valve, USNM 218828; right valve, USNM 218829; left valve, USNM 218831; left valve, USNM 218865; unfigured paratypes, USNM 218933, 362976, 362977, 362978, and 362979.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE.**—The only known occurrence of this species is in the upper part of the Pungo River Formation of early middle Miocene age in the Lee Creek Mine in North Carolina. Well-preserved speci-

TABLE 1.—Measurements (in mm) of a representative sample of *Pecten mclellani*, new species.

Character	USNM 218828 (D)	USNM 218830 (D)	USNM 362976 (D)
H	52.0	110.0	87.0
AHL	28.5	64.0	—
PHL	27.5	63.0	49.0
L	56	127	—
ADHD	27	50	—
PDHD	28	55	42
CON	7.5	17.0	—
HAA	9.0	18.5	15.0
HPA	11.0	18.0	14.0
LAA	14	30	23
LPA	12.0	26.0	19.0
HL	26.0	56	41
DBN	13.5	29.5	23.5
BN	0.5	0.5	−0.5
WP	2.8	7.2	7.7
WI	3.3	6.4	4.6
NRIB	12	13	13

mens are found in the upper 6-12 feet (1.8–3.7 m) (units 4–7 of Gibson, 1967) of the Pungo River Formation, some being found just an inch (2.5 cm) below the contact with the overlying Yorktown. This mine contains the only known outcrop of this formation in North Carolina, the formation being limited to the subsurface except for this artificial exposure. Strata of this age containing calcareous fossils do not naturally crop out south of north central Virginia.

**MEASURED MATERIAL.**—Total specimens measured include: 3 right valves and 1 left valve from USGS 25743 and 3 right valves and 1 left valve from USGS 25757. A population sample from the Pungo River Formation at Lee Creek Mine, USGS 25743 and 25757, consisting of 8 specimens, 6 right valves and 2 left valves, was measured. Measurements of a representative sample of 3 specimens are given in Table 1 (USNM 218830, holotype, and USNM 218828, both from USGS 25743; USNM 362976 from USGS 25757).

### *Pecten humphreysii humphreysii* Conrad

PLATE 3: FIGURES 2–7; PLATES 4, 5: FIGURES 1, 2, 4; PLATE 6:  
FIGURES 5, 7

*Pecten humphreysii* Conrad, 1842:194, pl. 2: fig. 2.—Mongin, 1959:297-299, pl. 25: figs. 1a-b.

*Vola humphreysi* (Conrad).—Whitfield, 1894:32-34, pl. 4: figs. 6-9.

*Pecten (Pecten) humphreysii* Conrad.—Glenn, 1904:372, pl. 98: figs. 10-12—Schoonover, 1941:188-190, pl. 20: figs. 1-2.

*Pecten (Pecten) humphreysi* Conrad.—Tucker, 1936a:478-479, pl. 3: fig. 3; pl. 4: fig. 10.

**DESCRIPTION.**—*Shell Outline:* Shell medium to large in size, reaching a maximum height of 115 mm; slightly longer than high, with a maximum length of 127 mm; length to

width ratio increases slightly with ontogeny; right valve moderately convex with maximum convexity of 26 mm; left valve planar to slightly convex in a few specimens; outline of disk equilateral with almost identical anterior and posterior half-diameters. Moderately developed disk gape both anteriorly and posteriorly, amounting to approximately a 4 to 5 mm gape in shells slightly greater than 100 mm in height.

*Auricles and Outer Ligament:* Right anterior auricle with strongly convex surface, being raised as much as 6 mm above the plane of commissure in large valves; dorsal margin slightly dorsal to groove of outer ligament and slightly to moderately folded, increasing in degree toward anterior part; byssal notch very shallow with broad, rounded apex; byssal fasciole poorly developed; ctenolium of 3 teeth occasionally observed in very young stages. Left anterior auricle with strongly concave surface; dorsal margin slightly folded and nearly coincident with trace of outer ligament; free margin rounded with shallow byssal sinus having a rounded apex. Posterior auricles similar in size to anterior; surface planar to slightly convex; dorsal margin slightly dorsal to groove of outer ligament and slightly to moderately folded; free margin straight to slightly convex. Posterior and anterior outer ligaments generally about equal in length. Auricular gape relatively large both anteriorly and posteriorly, reaching 4 mm in the largest specimens.

*Exterior Shell Surface:* Both valves with about 8 to 9 plicae. Right valves have broad plicae with relatively narrow interspaces, with ratio of width of plicae to width of interspaces of 20–30 to 1; in early growth plicae sharply defined from interspaces with sides of plicae at angle of about 60 degrees to surface of valve; in later stages plicae of large valves greater than 88 mm height, sides of plicae make low angles of about 20 degrees to valve surface, giving low and poorly defined plicae at the valve margins. Left valves have narrow plicae with wide interspaces; plicae are sharply defined from interspaces in early stages, becoming less sharply defined at shell heights of about 80 mm. Secondary radial ornamentation of 4 to 10 costae of varying strengths and widths on plicae of right valves; plicae on left valves rarely have 2 radial costae; no radial ornamentation in interspaces of either valve. Concentric lamellae moderately developed on right valves, both in interspaces and on plicae; lamellae more strongly developed on interspaces and plicae of left valves. Anterior and posterior auricles of right valves have 8 to 14 radial costae, which vary in strength and spacing and become obsolete about 25 mm from origin of growth; both auricles of left valves have fewer costae, about 6 to 8, which have a more regular development but also become obsolete about 25 mm from the origin of growth; concentric lamellae well developed on all auricles. Disk flanks of right valves have 5 to 8 moderately developed radial costae, which become obscure towards ventral margins, and well-developed concentric lamellae; disk flanks of left valves have 3 to 5 weakly developed radial costae, which become obscure

towards ventral margins, and well-developed concentric lamellae.

*Interior Features:* Resilial insertion elongated perpendicular to hinge line, being about twice as high as long; single auricular denticle strongly developed both anteriorly and posteriorly; single weakly developed costae within the interior plicae.

**DISCUSSION.**—As mentioned under *P. mclellani*, *P. humphreysii* differs from the former by having fewer plicae on the right valve, which are wider and much more pronounced, fewer, much narrower, and more pronounced plicae on the left valve, a deeper byssal notch, and a considerably greater convexity of the right valve as shown in Figure 10. The surface of the right anterior auricle in *P. humphreysii* is also more strongly convex. In addition, secondary radial ornamentation of costae on the plicae and auricles of the right valve is better developed in *P. humphreysii*, both in coarseness and extent (Plate 3: figures 1, 2, 4). The costae on the valves of *P. humphreysii* are variable in development; but the absence of costae on the plicae of right valves in many larger specimens is probably a result of wear.

Typical specimens of *P. humphreysii* with approximately 8 or 9 broad, pronounced plicae are confined to the phosphatic and dolomitic layers in the lower and middle part of the Pungo River section and to the lowermost part of the overlying interbedded phosphatic sand and limestone sequence. On the other hand, *P. mclellani* is found only in the upper sequence. Only one specimen of *P. humphreysii* was obtained from possibly the upper part of the Pungo River section, that being a young individual found as float (Plate 3: Figure 5). The vertical change suggests that either there

is (1) an evolutionary development during this interval from *P. humphreysii* to *P. mclellani* or (2) the environmental changes between the beds are reflected in the occurrences of the two species.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE.**—This subspecies is doubtfully present in the uppermost 3-6 feet (0.9-1.8 m) (units 6 and 7 of Gibson, 1967) of the Pungo River Formation in the Lee Creek Mine, being represented by a single well-preserved individual not collected in place, but possibly from unit 6 or 7 because of color and preservation. In the lower part of the interbedded limestone and phosphatic sand horizon (unit 4), however, specimens become more common and are quite common as molds and casts in the phosphatic intervals below this (units 1-3). Many of the phosphatic molds and casts are found in ore piles derived from the more phosphatic beds that are void of original calcareous material.

This subspecies is found also in the lower and middle parts of the Calvert Formation in Maryland, being moderately common in bed 10 and lower beds. The typical form and an additional subspecies, *P. humphreysii woolmani* Heilprin, have been described from outcrops of the Kirkwood Formation and subsurface Miocene in New Jersey (Richards and Harbison, 1942:186). An examination of the material in the USNM collections of the National Museum of Natural History would place all specimens from New Jersey into *P. humphreysii woolmani*.

Banks and Hunter (1973:359) report *P. humphreysii* from the Torreya Formation of early Miocene age from the northwestern part of Florida. Hunter kindly sent specimens for examination, and three are illustrated in Plate 4: figures 4-6. The fragments of the left valves agree closely with

TABLE 2.—Measurements (in mm) of a representative sample of *Pecten humphreysii humphreysii*.

Character	USNM 218838		USNM 362980 (D)	USNM 362981 (D)	USNM 362982 (D)	USNM 362983 (S)	USNM 362984 (S)	USNM 362985 (S)
	(D)	(S)						
H	115.0	112.5	69.0	51.0	29.0	49.0	66.0	33.0
AHL	66	62	36	29	15	25	35	16
PHL	61.0	61.0	40.0	27.0	15.5	27.0	34.0	17.0
L	127.0	123.0	76.0	56.0	30.5	52.0	69.0	33.0
ADHD	55	54	37	28	17	24		17
PDHD	60	55	36	28	16	24	—	16
CON	25.6	—	—	12.4	7.5	—		—
HAA	21.0	21.0	16.0	11.0	6.5	13.0	16.0	8.0
HPA	24	22	16	13	7	12	15	8
LAA	35.0	32.5	—	18.0	10.0	15.0		8.0
LPA	31.0	32.5	21.0	16.0	—	15.0		10.0
HL	66	65	—	34	—	30		18
DBN	32.0	—	22.5	15.5	8.0	—		—
BN	3.0	—	—	2.5	2.0	—		—
WP	9.1	22.5	0.9	4.4	3.5	3.0	3.1	1.5
WI	22.7	8.8	4.9	3.6	2.3	7.5	7.9	8.6
NRIB	10	9	10	10	8	9	10	7

specimens of *P. humphreysii humphreysii* from Maryland as does the largest right valve (Plate 4: figure 4). The other two right valves are of immature individuals and have more sharply raised plicae with essentially vertical sides. A pronounced development of the plicae in the early stages with a general rounding of the edges of the plicae during ontogeny is commonly found in larger specimens of *P. humphreysii humphreysii* from Maryland, and the Florida specimens are placed in this subspecies.

The occurrence in Florida of *P. humphreysii* is by far the farthest southern limit for this species. According to Banks and Hunter (1973) the Torreya Formation is found in the Gulf trough opening through the southeast Georgia embayment into the Atlantic Ocean. This opening would give a fairly direct migration route between the area of the Torreya Formation in Florida and areas farther north along the Atlantic Coast, such as the Lee Creek Mine in North Carolina and Maryland.

The Torreya Formation is placed in the N5 or N6 planktonic zones of early Miocene age by Banks and Hunter (1973). Bed 10 of the Calvert Formation at Plum Point, Maryland, and the upper part of the Pungo River Formation in the Lee Creek Mine are placed in planktonic zones N8 or N9 by Gibson (1967; 1983b:360), making the Florida specimens the oldest known of this species along the Atlantic and Gulf Coast.

Grant and Gale (1931:222) and Fleming (1957:16) suggested that the *Pecten humphreysii* group migrated, probably during the Miocene or Pliocene from Maryland via California to Japan where it persists as *Pecten albicans* Schroter.

**MEASURED MATERIAL.**—A population sample from the Calvert Formation at the Basford Farm, USGS localities 23565 and 25744, and Howard Post Office, USGS locality 10278, consisting of 66 specimens, 24 right valves and 42 left valves, was measured. Measurements (in mm) of a representative sample of 8 specimens are given in Table 2 (USNM 218838 is from USGS locality 23565, USNM 362980 through 362985 are from USGS locality 25744).

### *Pecten humphreysii woolmani* Heilprin

PLATE 3: FIGURE 1, PLATE 5: FIGURE 3, PLATE 6: FIGURES 1-4, 6,  
PLATE 17: FIGURE 2

*Pecten Humphreysii* var. *Woolmani* Heilprin, 1888:405.

*Pecten (Pecten) humphreysii woolmani* Heilprin.—Tucker, 1936a:479-480, pl. 4: fig. 11.

*Pecten humphreysii woolmani* Heilprin.—Richards and Harbison, 1942:186, pl. 8: figs. 12-13, pl. 9: fig. 2.

**DESCRIPTION.**—Except for a few almost complete valves of immature individuals, the samples are composed of fragmented specimens and a complete description and biometric studies are not possible.

**Shell Outline:** Shell medium to large in size, with fragments suggesting valve heights of greater than 100 mm; right valves moderately to strongly convex; left valve planar; outline of disk equilateral.

**Auricles and Outer Ligament:** Right anterior auricle with essentially planar surface; dorsal margin slightly dorsal to groove of outer ligament and folded; byssal notch shallow with broad, subrounded to angular apex; byssal fasciole poorly developed. Left anterior auricle with slight to moderately concave surface; dorsal margin nearly coincident with trace of outer ligament and slightly folded; free margin slightly rounded with shallow byssal sinus having a subrounded apex. Posterior auricles similar in size to anterior; surfaces planar; dorsal margins nearly coincident with trace of outer ligament and folded; free margins planar and slightly rounded. Posterior and anterior outer ligaments generally about equal in length.

**Exterior Shell Surface:** Both valves with 7 or 8 plicae. Right valves have broad plicae with relatively narrow interspaces, with ratio of width of plicae to width of interspaces of 2.5-3 to 1; in early growth stages plicae sharply defined with vertical to overhanging sides; in later stages plicae still have almost vertical sides. Left valves have narrow plicae with wide interspaces; plicae have sharply defined sides throughout growth, although becoming less so in later stages. Secondary radial ornamentation of 10 to 15 costae of relatively uniform development on plicae of right valves; plicae on left valves lack costae; occasional radial costae on interspaces of right valve (Plate 6: figure 1). Concentric lamellae moderately developed on right valves, both in interspaces and on plicae; lamellae more strongly developed on interspaces and plicae of left valves. Anterior and posterior auricles of right valves have about 12 to 18 weak radial costae, which become obsolete about 30 mm from origin of growth; auricles of left valves have fewer costae, about 8 to 10, weakly developed, which quickly become obsolete; concentric lamellae well developed on all auricles. Disk flanks of right valves have numerous fine radial costae, which become weaker anteriorly, but persist; as many as 25 costae on the posterior flank and about 10 slightly coarser costae on the anterior flank; both flanks have moderately developed concentric lamellae; left valves have about 5 fine costae on each flank and well-developed concentric lamellae.

**Interior Features:** Resilial insertion elongated perpendicular to hinge line, being about twice as high as long; single auricular denticle, moderately developed both anteriorly and posteriorly.

**DISCUSSION.**—Specimens of *P. humphreysii* occurring in New Jersey were separated by Heilprin (1888:405) as "a variety or subspecies" on the basis of having greater height of the auricles, having a more distinct quadrangulation of the plicae on the convex valve, and having more prominent striations on the plicae. Whitfield (1894:33) did not believe

the auricular characters differed between the two forms, but he did not have a complete valve from New Jersey to examine. Whitfield mentioned a considerably larger size for the New Jersey specimens, up to approximately 5 inches (12.7 cm) (based upon projections from incomplete valves), but specimens of such size from Maryland are in the USNM collections at the National Museum of Natural History.

Tucker (1936a, pl. 4: fig. 11) figured a specimen she took as the neoholotype of *P. humphreysii woolmani*. It is a partial left valve and, along with relatively pronounced plicae, has a slight sulcus developed on the summit of the plicae. This sulcus was not observed on plicae on left valves of the numerous specimens in the USNM collections.

An examination of the specimens of *P. humphreysii woolmani* in the USNM collections, which number more than 50 fragmented valves, shows the prominent quadrangulation of the plicae mentioned by Heilprin (1888:405) to be a consistent feature of the right valves. Compared with the great majority of specimens from Maryland, the plicae on the right valves of the specimens from New Jersey are much more sharply delineated from the interspaces, having essentially vertical to overhanging sides on the plicae compared to sloping sides in the majority of the specimens from Maryland (Plate 3: figure 1). The specimens from New Jersey also have more sharply defined and higher plicae on the left valves. Other differences between the two subspecies include the following: *Pecten humphreysii woolmani* has a more convex right valve as deduced from the fragments of larger valves; is lacking the convexity of the right anterior auricle; generally has one or two fewer plicae, which are slightly broader; has weaker auricular denticles; and has more numerous radial costae developed on the plicae, auricles, and disk flanks in addition to the presence of an occasional costae in the interspaces.

Within a single population sample of *P. humphreysii humphreysii* from Maryland, a few valves fall within the range of ornamentation found in the specimens from New Jersey. They show a tendency toward quadrangulation of the plicae and development of more costae, but do not reach the development of the typical specimens. The geographic separation of the areas of the two morphotypes, with probably 90 percent of the population sample in each area being composed of one form, suggests that they are valid geographic subspecies with some mixing in the area of overlap.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE.**—This subspecies has been recorded only from the Kirkwood Formation of New Jersey, which is considered equivalent to the Calvert Formation in Maryland.

**MEASURED MATERIAL.**—Total specimens measured include 2 left valves (USNM 218847 and USNM 362986) from USGS locality 2106, Kirkwood Formation, marl beds near Jericho, Cumberland Company, New Jersey. Their measurements are given in Table 3.

TABLE 3.—Measurements (in mm) of a representative sample of *Pecten humphreysii woolmani*.

Character	USNM 218847 (S)	USNM 362986 (S)
H	33	26
AHL	16	13
PHL	16	12
L	32	25
HAA	9.5	7.0
HPA	9.0	7.0
LAA		8
LPA		7
HL		15
DBN		—
BN		—
ADHD		—
PDHD	—	—
CON	—	—
WP	4.8	3.8
WI	1.3	1.0
NRIB	7	8

### Genus *Argopecten* Monterosato, 1889

#### *Argopecten eboreus* (Conrad)

*Pecten eboreus* Conrad, 1833:341.

*Pecten* (*Plagiocentrum*) *eboreus* Conrad.—Dall, 1898:749 [in part].

*Chlamys* (*Plagiocentrum*) *eboreus* (Conrad).—Tucker-Rowland, 1938:40–41, pl. 3, fig. 12.

*Chlamys* (*Aequipecten*) *eborea* (Conrad)—Gardner, 1944:36–37, pl. 7: figs. 1, 5, 6, 8 [in part].

*Argopecten eboreus* (Conrad).—Waller, 1969:59–61, pl. 5: fig. 14.

**DISCUSSION.**—This species is very common in the later Cenozoic strata of the Atlantic Coastal Plain. Its oldest occurrence is in the basal Yorktown Formation (= "Virginia St. Marys" beds of Mansfield) of late Miocene age in Virginia, and it ranges into strata of Pleistocene age in Florida (Waller, 1969:60). Many morphologic variations are present, and these have been made into a number of subspecific taxa. Some of the subspecific characters are found only in a single group, but generally there is a complex mixture of the morphologic characters with some of the diagnostic subspecific characters being found in varying combinations. The morphologic variation in this complex of subspecies led Gardner (1944:36) and Waller (1969:60) to place all the forms into a single species group without trying to apply the subspecific names.

The earliest subspecies, *A. eboreus urbannaensis* (Mansfield), from the lowermost part of the Yorktown Formation in Virginia, is readily separable on morphologic criteria; but in the middle and upper parts of the Yorktown Formation a group of names is available. These include *A. eboreus eboreus* (Conrad, 1833), originally described from the Yorktown Formation at Suffolk, Virginia, *A. eboreus*

*darlingtonensis* (Dall, 1898), described from the Duplin Marl near Darlington, South Carolina, *A. eboreus watsonensis* (Mansfield, 1936), described from the *Echphora* zone of the Jackson Bluff Formation in Florida, *A. eboreus solariooides* (Heilprin, 1887), from the Caloosahatchee Marl of Florida, *A. eboreus bertiensis* (Mansfield, 1937), from the upper Yorktown beds at Mt. Gould Landing in North Carolina, and *A. eboreus senescens* (Dall, 1898), described from the Waccamaw Formation in South Carolina.

*Argopecten e. darlingtonensis* (Dall) was characterized by radial threads towards the margin of the disk (plate 9: figure 1), along with 21 to 24 well-marked, angular plicae. However, in comparing the suite of type material of *A. e. darlingtonensis* with population samples from Suffolk, Virginia, the type area for *A. e. eboreus*, the specimens from the Suffolk area also have marginal threads on many specimens along with a similar number and character of the plicae. On these characteristics and a general overall morphologic similarity, it would seem that these two subspecies, at least from their type areas, are synonymous. A variety of forms are labeled *A. e. darlingtonensis* in the USNM collections, and some of these undoubtedly belong to other members of the *A. eboreus* complex. Mansfield (1936:184) placed *A. e. darlingtonensis* in the phylogenetic development of *A. eboreus* as a time equivalent subspecies to *A. eboreus eboreus*, and leading to *A. e. solariooides*, but it is uncertain what specimens he was considering. The specimen illustrated by Mansfield (1932, pl. 12: fig. 1) as *A. e. darlingtonensis* from the Pliocene of Florida appears to be related to *A. e. solariooides*. It would be difficult, however, to place this specimen within the variation found in the type suite and other samples from South Carolina.

*A. eboreus watsonensis* (Mansfield) was distinguished by having 18, nearly flat, nearly smooth plicae. Specimens belonging to this general morphologic type were reported by Mansfield (1936) to occur in strata of Pliocene age in Florida and also in Mansfield's zone 1 of the Yorktown Formation in Virginia and North Carolina, and this morphologic group could be identified in the present study.

*A. eboreus bertiensis* (Mansfield) differs in having a very convex left valve, and having an incised groove on the plicae of both valves. In an examination of the type suite and topotype material, the high convexity of the left valve is a constant characteristic, but the incised groove, although found on many, is not present on all the specimens. This subspecies has been found up to now only at the type locality and at Colerain Landing, a short distance farther north on the Chowan River.

*A. eboreus solariooides* (Heilprin) was characterized as having right valves with approximately 20 broad, squarish plicae with narrow interspaces bearing radial striae. The number of striae vary in number from one to two in samples from different localities. Although striae occur in the inter-

spaces on the right valve, they are most commonly found on the left valve. The squareness of the plicae varies from very square to moderately rounded in samples from southern Florida, although the form with squared plicae is the dominant one. This subspecies is found in the Caloosahatchee Formation in Florida, and also probably occurs in the Waccamaw Formation in North and South Carolina.

*A. eboreus senescens* (Dall) was distinguished on the basis on having about 23 plicae, which become obscure in the later ontogenetic stages. This subspecies has been reported from the Waccamaw Formation in North and South Carolina.

*Pecten yorkensis* was described by Conrad (1867) from the Yorktown Formation at Yorktown, Virginia. A single left valve (ANSP 38007) labeled *Pecten yorkensis* is in the collections at the Academy of Natural Sciences at Philadelphia and is chosen as the lectotype (Plate 9: figure 5). This specimen closely matches the dimensions and number of plicae given in the original description. Although some workers (e.g., Mansfield, 1936:179, Tucker-Rowland, 1938:38) have considered *P. yorkensis* to be a valid subspecies of *Argopecten eboreus*, this specimen appears to fall within the range of variation of *A. e. eboreus*.

There is considerable variation within the population samples of *A. eboreus*. Some populations include diagnostic characteristics of several subspecies within a single sample. The complex morphologic intergradation in the *A. eboreus* group needs a similar treatment to that given the *A. gibbus* stock by Waller (1969). However, a stratigraphic succession among some subspecies can be recognized. The earliest subspecies, *A. e. urbannaensis*, is easily differentiated (there is some question whether this is the basal stock or even a member of *A. eboreus*). This subspecies occurs in the basal part of the Yorktown Formation in Virginia (includes the upper part of the "Virginia St. Marys" beds of Mansfield). Occurring above this stratigraphically in the beds of zone 1 of the Yorktown of Mansfield (1944) are the forms referred to here as *A. eboreus* aff. *A. e. watsonensis*. In the overlying zone 2 of the Yorktown Formation is typical *A. e. eboreus*, which also would include at present *A. e. darlingtonensis* and *A. e. yorkensis*. Stratigraphically above, at least in the upper beds of the Yorktown Formation along the Chowan River in North Carolina, is *A. e. bertiensis*. This subspecies occurs in the lowest beds exposed at Mt. Gould Landing; but the strata 10 feet (3 m) higher in the section, which would be the uppermost part of the Yorktown Formation, have forms closely approaching *A. e. solariooides*, along with an occasional *A. e. bertiensis*. The highest group in the sequence is *A. e. solariooides*, which occurs in the Waccamaw Formation in North and South Carolina and the Caloosahatchee Formation in Florida, containing in a few places a component of *A. e. senescens* as a part of the population structure.

General characteristics noted during study and measure-

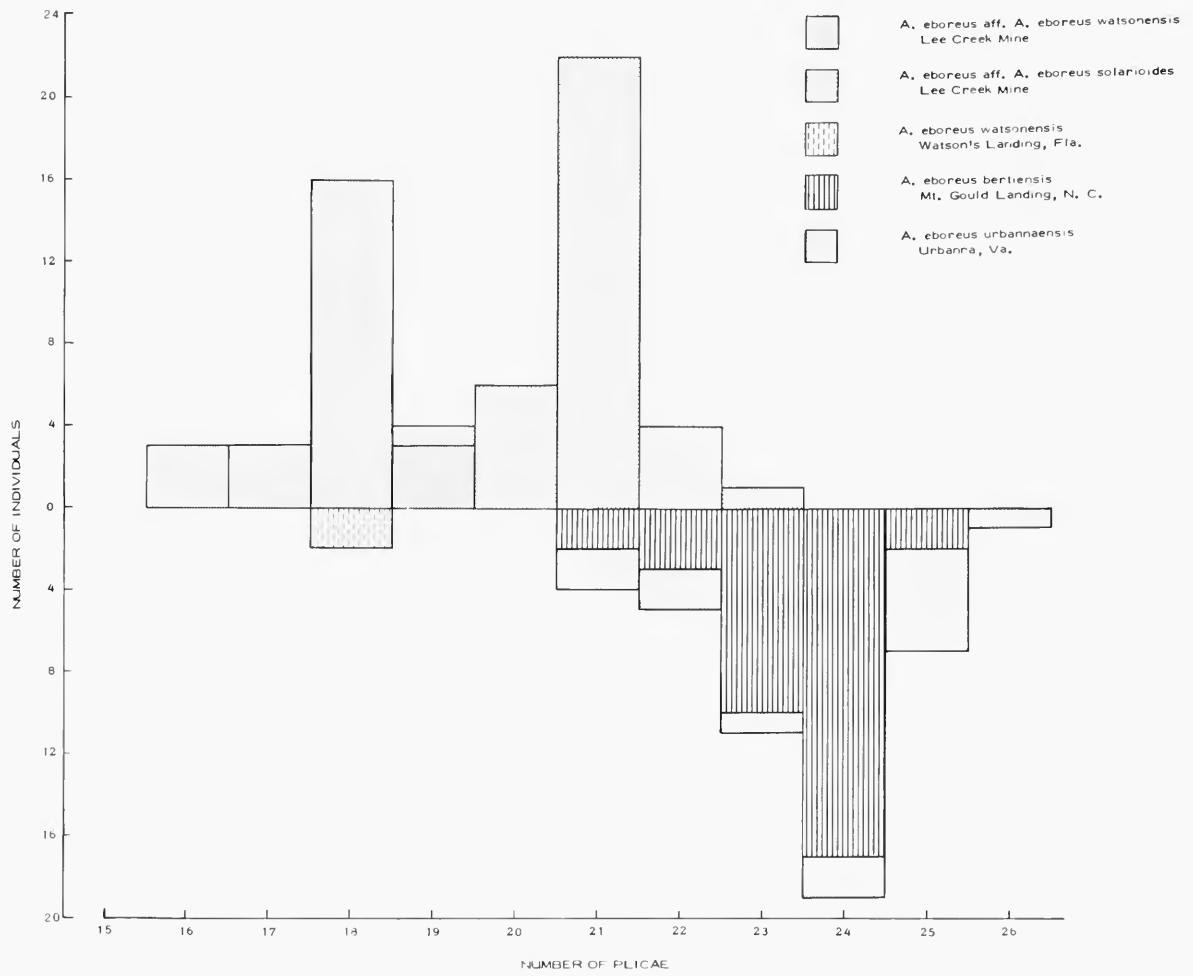


FIGURE 11.—Double-sided bar graph of the number of plicae in five subgroupings of *Argopecten eboreus*.

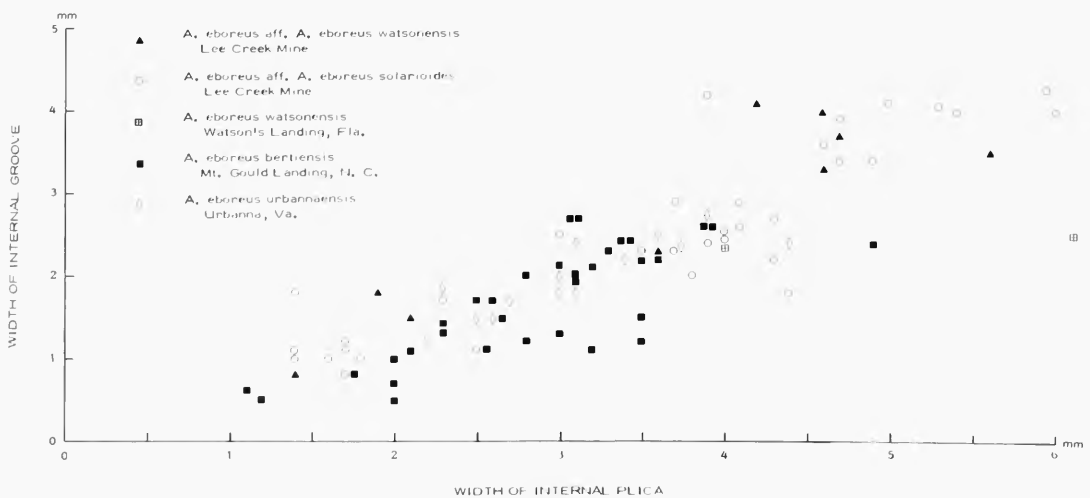


FIGURE 12.—Bivariate scatter diagram showing the general similarity of the width of the internal plica and groove in various subgroupings of *Argopecten eboreus*.



ment of the *A. eboreus* complex include the following: All forms have a slightly longer posterior half diameter than anterior. The convexity of the left valve is more variable within the species complex than that of the right valve, but the left valve is always more convex than the right. The number of plicae varies from about 16 to 25 (Figure 11), but the width of the internal plicae is always greater than the width of the adjacent groove. Moreover, regardless of the number of plicae and grooves, the ratio of the width of the internal plicae to the width of the internal groove is essentially constant between forms (Figure 12), indicating a

preferred ratio, which may reflect the strongest way of constructing the shell. The depth of the byssal notch becomes shallower through the stratigraphic sequence described above of *A. e. urbannaensis* to *A. e. solarioides* (Figure 13), except for the reversal in the sample of *A. e. aff. A. e. solarioides* from the Lee Creek Mine.

LECTOTYPES.—In addition to the lectotype designated for *Argopecten eboreus yorkensis*, ANSP 38007, left valve, Yorktown Formation, Yorktown, Virginia, lectotypes also are selected for 3 additional taxa.

A lectotype is selected for *A. eboreus darlingtonensis*: right

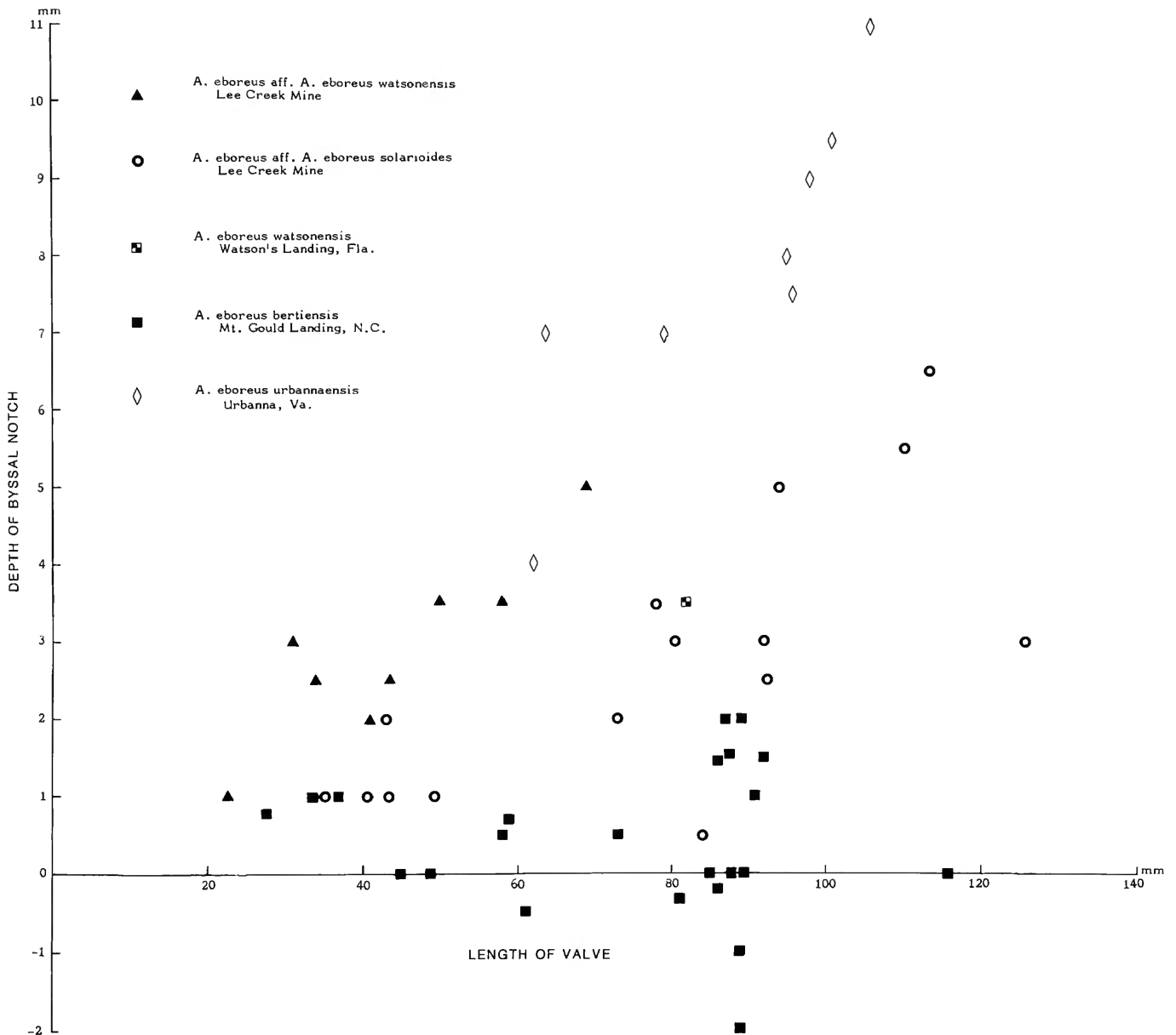


FIGURE 13.—Bivariate scatter diagram showing the differences in the depth of the byssal notch in relation to the length of the valve in various subgroupings of *Argopecten eboreus*.

valve, USNM 145432, from the Duplin Formation at USGS 2025 (Plate 9: figure 1). This is part of the type material, and is one of the cotypes selected by Tucker-Rowland (1938:42). The other cotype, a left valve, becomes a lectoparatype, USNM 218934. An additional lectoparatype is illustrated (Plate 9: figure 4).

A lectotype is selected for *A. eboreus urbannaensis*: right valve, USNM 370829, from the basal Yorktown ("Virginia St. Marys" bed) at USGS 3915 (Plate 11: figures 1, 3). This valve is one of the cotypes. The other cotype, a left valve, USNM 218862 (Plate 11: figure 4), becomes a lectoparatype.

A lectotype is selected for *A. eboreus bertiensis*: right valve, USNM 496224, from the Yorktown Formation at USGS 11999. This valve is one of the cotypes (Mansfield, 1937, fig. 1). The other cotype, a left valve, USNM 218935, becomes a lectoparatype.

*Argopecten eboreus* aff. *A. eboreus watsonensis*  
(Mansfield), new combination

PLATES 7, 8, PLATE 10: FIGURE 4

*Pecten* (*Chlamys*) *eboreus watsonensis* Mansfield, 1936:188.

**DESCRIPTION.**—*Shell Outline:* Shell of medium size, attaining height of 80 mm; left valve of low to moderate convexity and only slightly more convex than right valve. Outline of disk equilateral; disk flanks very low. Disk gapes narrow.

*Auricles and Outer Ligament:* Right anterior auricle with almost planar to slightly convex surface; dorsal margin slightly dorsal to groove of outer ligament, sharply folded and thickened; folding of dorsal margin increases in amount away from origin of growth; byssal notch moderately shallow, with angular to rounded apex; byssal fasciole moderately broad and slightly arched adjacent to suture and planar away from suture; ctenolium of 3 teeth in specimens up to 60 mm height, occasionally 1 tooth visible in specimens up to 80 mm height. Left anterior auricle with moderately concave surface; dorsal margin flat and nearly coincident with trace of outer ligament; free margin slightly rounded with shallow byssal sinus having a rounded apex. Posterior auricles similar in size to anterior; right posterior has planar to slightly convex surface with dorsal margin dorsal to groove of outer ligament and folded more strongly away from origin of growth; left posterior auricle has concave surface with dorsal margin nearly coincident with trace of outer ligament. Posterior and anterior ligaments generally about equal in length.

*Exterior Shell Surface:* Number of plicae on valves varies from 16 to 19, with 18 being most common; plicae are low in early growth stages but sides are relatively steep, with plicae remaining low in later stages but sides becoming

rounded; plicae wider than interspaces. Occasionally 3 or 4 costae on the plicae and 1 or 2 in the interspaces, but most specimens smooth. Concentric lamellae weakly developed on interspaces and plicae of both valves. Right anterior auricle has about 5 costae of moderate strength, left anterior about 8; both posterior auricles have about 10 weakly developed costae; concentric lamellae moderately developed on auricles. Disk flanks have moderately developed concentric lamellae and occasionally 2 or 3 weak costae.

*Interior Features:* Resilial insertion about as long as high, orientation ranging from perpendicular to slightly posterior slant; single, weakly developed auricular denticle both anteriorly and posteriorly.

**DISCUSSION.**—Mansfield (1936:188) characterized *A. eboreus watsonensis* as having "18 nearly flat, nearly smooth, moderately narrow ribs separated by spaces about as wide as ribs" and differing from *A. e. eboreus* "in having 5 to 8 fewer, more widely spaced ribs."

The specimens from Lee Creek resemble the specimens of *A. e. watsonensis* from Florida in having the same number of plicae, a similar development of the plicae into more squared profile in the higher, float specimens, and in having the same width of the internal plicae and grooves. They differ in having a less convex right valve and a slightly deeper byssal notch. Thus, for now, they will be treated as having affinities to the Florida subspecies as they are generally similar in morphologic characteristics and occur in a similar stratigraphic interval. The specimens collected at Lee Creek support Mansfield's statement (1936:184) that there is an additional form of *A. eboreus* between *A. e. urbannaensis* from the lowermost part of the Yorktown Formation ("Virginia St. Marys" beds of Mansfield) and the typical *A. e. eboreus* of the younger Yorktown around Suffolk, Virginia.

The specimens from the Lee Creek Mine have 16 to 19 plicae, with most having 18 (Figure 11). Development of the plicae ranges from relatively low and rounded, particularly in the specimens collected in place in unit 3 of the Yorktown (Plate 7: figures 1, 4), to moderately high and squared, most common in the float specimens, which come from higher units, probably units 4 and 5 (Plate 7: figure 2). The left valve has an approximately median convexity for the *A. eboreus* group, being more convex than *A. e. urbannaensis* and most convex in *A. e. solarioides*, but less convex than *A. e. bertiensis* (Figure 14). The right valve is moderately convex, being approximately the same as *A. e. urbannaensis* and *A. e. solarioides* and more convex than *A. e. bertiensis*. The result for the two valves is that the left valve is only slightly more convex than the right, the closest to equal convexity of any sample of *A. eboreus* herein studied. The type specimen of *A. e. watsonensis* and other specimens from Florida differ from the North Carolina specimens in having a considerably more convex right valve.

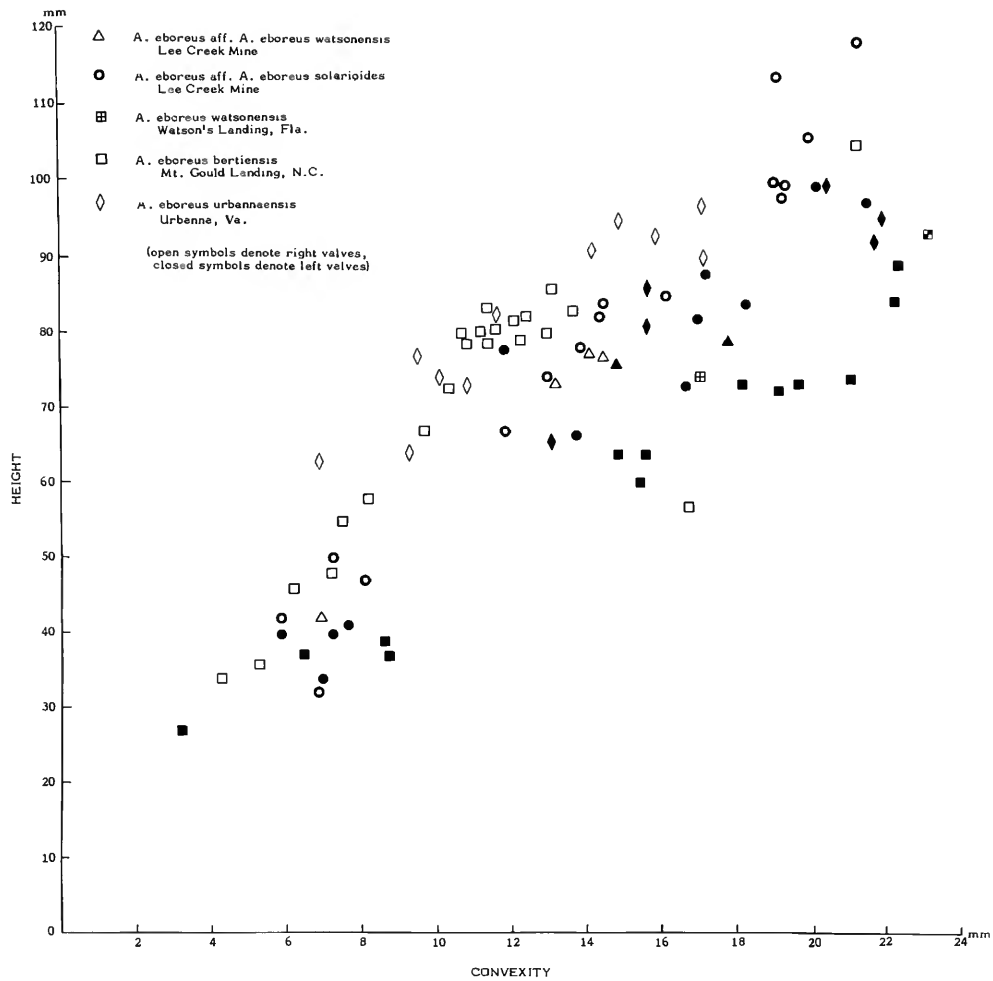


FIGURE 14.—Bivariate scatter diagram showing the differences in convexity of the left and right valves among the various subgroupings of *Argopecten eboreus*.

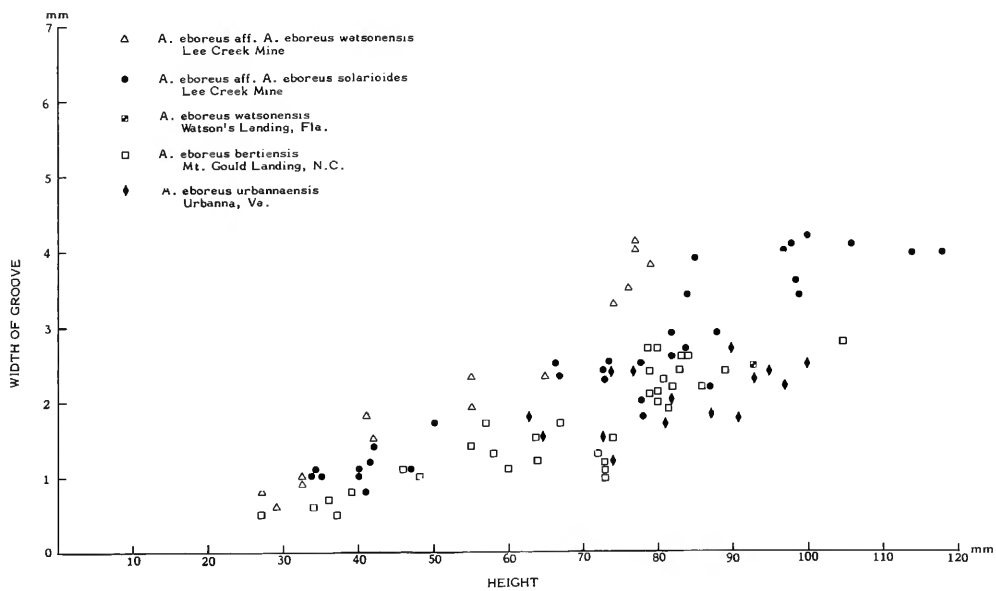


FIGURE 15.—Bivariate scatter diagram showing the differences in the width of the internal groove in relation to the height of the valve in various subgroupings of *Argopecten eboreus*.

In the Lee Creek specimens the width of the internal plicae is greater than the width of the internal groove (Figure 12). The width of the internal groove compared to the height of the valve is markedly different between the Lee Creek specimens and those from Florida (Figure 15). The Lee Creek specimens have approximately the same length of the anterior and posterior auricles, but the height of the posterior auricles is greater than that of the anterior auricles.

The specimens from the Lee Creek Mine can be differentiated from the stratigraphically lower *A. e. urbannaensis* by a shallower byssal notch (Figure 13), fewer but better developed plicae (Figure 5), wider internal grooves (Figure 15), a relatively shorter anterior auricle and lower posterior auricle, and a greater convexity of the right valve (Figure 14).

**STRATIGRAPHIC AND GEOGRAPHIC RANGE.**—Specimens of *A. eboreus* aff. *A. eboreus watsonensis* were collected in place in unit 3 of the Yorktown Formation in the Lee Creek Mine, and in spoil material having an indurated matrix, which places the specimens as coming from units 4 and 5 of the Yorktown Formation. Units 3–5 of the Yorktown Formation in the Lee Creek Mine belong to the lowest part of Mansfield's zone 2 of the Yorktown.

*A. eboreus watsonensis* was described by Mansfield (1936:188) from the *Echphora* zone of the Jackson Bluff Formation in Florida, and was also listed from several localities in zone 1 of the Yorktown Formation in Virginia. MacNeil (in Bergendahl, 1956:76) listed specimens from the Tamiami Formation in central Florida as having affinities to *A. eboreus watsonensis*, and additional closely related specimens exist in the USNM collections. These specimens are not typical *A. eboreus watsonensis*, but are closer to this subspecies than to any other in the *A. eboreus* stock. The age relationship of *A. eboreus watsonensis* and those specimens having affinities with it is relatively close according to our current understanding of regional stratigraphy. They occur in the *Echphora* zone, upper lower and lower middle parts of the Yorktown, and Tamiami formations. Except for *A. eboreus urbannaensis*, this group is the earliest member of *A. eboreus* and looks like an ancestral form for the later subspecies.

**MEASURED MATERIAL.**—Total specimens measured of *Argopecten eboreus* aff. *A. eboreus watsonensis* include 6 right valves and 3 left valves from USGS 25746 and 7 right valves and 9 left valves from USGS 25338. A population sample from the Lee Creek Mine, North Carolina, Yorktown Formation, USGS 25746 (in situ), and USGS 25338 (spoil bank), consisting of 13 right valves and 12 left valves, was measured. Measurements of a representative sample of 7 valves are given in Table 4. The measurements for the holotype of *Argopecten eboreus watsonensis*, USNM 371139, from USGS 10962, Choctawatchee Marl, Watsons Landing, Liberty County, Florida, are given in Table 5.

Total specimens measured of *Argopecten eboreus urban-*

*naensis* include 1 right valve and 5 left valves (USNM 218862, 370829, 362991) from USGS 3915 and 11 right valves and 1 left valve (USNM 362990) from USGS 23468. The specimens from USGS 3915 are from the lowermost part of the Yorktown Formation (= "Virginia St. Marys" beds of Mansfield) on the river front at Urbanna, Middlesex County, Virginia. Those from USGS 23468 are float from the beach of the Rappahannock River from Urbanna to the fish cannery. Measurements from a representative sample of 4 valves are given in Table 6.

Total specimens measured of *Argopecten eboreus bertiensis* include 3 right valves and 4 left valves (USNM 218933, 496224, 362992) from USGS 11999 and 20 right valves and 9 left valves (USNM 362993–362995) from USGS 25758. Those from USGS 11999 are from the Yorktown Formation on the right bank of the Chowan River 0.75 mile (1.2 km) below Mt. Gould Landing, North Carolina. Those from USGS 25758 are from the Yorktown Formation in a bluff on the west side of the Chowan River approximately 0.5 mile (0.8 km) below Mt. Gould Landing. Measurements from a representative sample of 6 valves are given in Table 7.

***Argopecten eboreus* aff. *A. eboreus solarioides* (Heilprin),  
new combination**

PLATE 9: FIGURES 2, 3; PLATE 10: FIGURES 1–3; PLATE 11: FIGURES 2, 5;  
PLATE 17: FIGURES 4, 5

*Pecten solarioides* Heilprin, 1887:99.

**DESCRIPTION.**—*Shell Outline:* Shell of medium to large size, reaching maximum height of 118 mm; valves slightly longer than high with a maximum length of 125 mm. Right valve of low to moderate convexity, with a maximum convexity of 22 mm; left valve only slightly more convex than right. Outline of disk approximately equilateral, but slightly extended posteriorly in most specimens; disk flanks very low. Disk gapes moderately broad, reaching 3 mm in larger specimens.

*Auricles and Outer Ligament:* Right anterior auricle with planar to slightly concave surface; dorsal margin slightly dorsal to groove of outer ligament, sharply folded and thickened; folding and thickening of dorsal margin increase away from origin of growth; byssal notch moderately shallow, with rounded to subangular apex; byssal fasciole moderately broad and slightly convex; ctenolium of 1 or 2 teeth common in smaller specimens, occasionally 1 tooth visible in specimens up to 80 mm in height. Left anterior auricle with moderately concave surface; dorsal margin flat and nearly coincident with trace of outer ligament; free margin slightly rounded with shallow byssal sinus having a rounded apex. Posterior auricles similar in size to anterior; posterior slightly higher than anterior; right posterior has planar to slightly convex surface with dorsal margin dorsal to groove of outer ligament and folded more strongly away from

TABLE 4.—Measurements (in mm) of a representative sample of *Argopecten eboreus* aff. *A. eboreus watsonensis*.

Character	USNM 218853		USNM 218854 (D)	USNM 218856 (S)	USNM 362987 (D)	USNM 362988 (D)	USNM 362989 (S)
	(D)	(S)					
H	55.0	55.0	77.0	79.0	41.0	22.5	27.0
AHL	29.0	28.0	42.0	40.0	20.0	11.5	13.0
PHL	29	30	44	42	21	12	14
L	58.0	58.0	86.0	82.0	41.0	23.5	27.0
ADHD	29	27	37	42	22	12	14
PDHD	31	30	44	42	24	12	14
CON	—	—	14.5	15.8	—	5.0	5.6
HAA	10.0	11.0	14.0	14.0	8.0	4.5	5.5
HPA	12.0	12.0	17.0	16.0	9.5	6.0	6.5
LAA	18.5	18.0	—	23.0	12.0	7.0	8.0
LPA	18	18	25	24	11	7	8
HL	36.5	36.0	—	47.0	23.0	14.0	16.0
DBN	15	—	—	—	10	6	—
BN	3.5	—	—	—	2.0	1.0	—
WP	2.8	3.2	4.6	4.7	1.9	—	1.4
WI	2.3	1.9	4.0	3.8	1.8	—	0.8
NRIB	18	18	17	17	16	18	18

TABLE 5.—Measurements (in mm) of the holotype of *A. eboreus watsonensis*.

Character	USNM 371139 (D)	Character	USNM 371139 (D)
H	74	HPA	16
AHL	40	LAA	25.5
PHL	42	LPA	25.5
L	82	HL	51
ADHD	33	DBN	22
PDHD	39	BN	3.5
CON	15.3	WP	4.2
HAA	12	WI	4
		NRIB	18

TABLE 6.—Measurements (in mm) of a representative sample of *Argopecten eboreus urbannaensis*.

Character	USNM 218862 (S)	USNM 362990 (D)	USNM 362991 (S)	USNM 370829 (D)
H	100	64	66	97
AHL	51	30	32	49
PHL	53	34	38	57
L	104	64	70	106
ADHD	50	—	35	49
PDHD	53	—	36	50
CON	20.3	9.3	13.1	17.1
HAA	22	12	15	18
HPA	23	15	13	23
LAA	35	23	18	39
LPA	33	19	14	34
HL	68	42	32	73
DBN	—	16	—	28
BN	—	7	—	11
WP	3.6	2.6	3.3	3.4
WI	2.5	1.5	1.4	2.2
NRIB	21	21	22	25

TABLE 7.—Measurements (in mm) of a representative sample of *Argopecten eboreus bertiensis*.

Character	USNM 218933 (S)	USNM 362992 (S)	USNM 362993 (D)	USNM 362994 (D)	USNM 362995 (S)	USNM 496224 (D)
H	89	60	57	34	39	81
AHL	46	29	29	16	19	42
PHL	52	35	32	18	20	45
L	98	64	61	34	39	87
ADHD	41	32	27	16	20	38
PDHD	45	30	28	18	20	45
CON	22.3	14.5	16.8	4.3	8.7	11.6
HAA	18.0	12.5	9.0	6.0	8.0	14.0
HPA	16	10	10	8	8	16
LAA	25.0	14.0	13.0	8.5	9.0	24.0
LPA	24	13	12	8	8	21
HL	49.0	27.0	25.0	16.5	17.0	45.0
DBN	—	—	13.5	7.5	—	22.5
BN	—	—	-0.5	—	—	1.5
WR	4.8	2.5	2.5	1.1	1.7	3.3
WG	2.4	1.1	1.7	0.6	0.8	2.3
NRIB	23	23	22	24	24	24

origin of growth; left posterior auricle has slightly concave surface with dorsal margin coincident with trace of outer ligament. Posterior and anterior ligaments about equal in length. Moderate auricular gape both anteriorly and posteriorly.

*Exterior Shell Surface:* Number of plicae on valves varies from 19 to 23, with 21 being most common; plicae are relatively sharply defined by steep sides in early growth stages and either remain so throughout or become broadly rounded and lower in later stages; width of plicae on right valves varies from about twice as wide as interspaces to approximately equal width. Right valves of forms with wider, squared plicae occasionally have 1 or 2 weak costae

on the plicae, but have moderately developed costae in the interspaces, consisting of 1 in the interspaces of the central part of the valve and 1 (or sometimes 2) in the interspaces toward the anterior and posterior margins; the anterior auricles have about 10 moderate to weak costae, and the posterior, 10 to 12; concentric lamellae fair to poorly developed, mostly confined to interspaces. Left valve of forms with squared plicae does not have costae on the plicae, but usually have 1 well-developed median costa in the interspaces throughout the valve; the anterior auricles have 7 costae and the posterior 8 or 9; concentric lamellae well developed on interspaces and auricles. Right valves of forms with narrower, rounded plicae have 2 to 4 weakly developed costae on the plicae and none in the interspaces; the anterior auricles have 4 to 6 weak costae and the posterior about 9; concentric lamellae well developed in interspaces and auricles and also commonly on plicae. Left valves of forms with rounded plicae occasionally have 1 or 2 weak costae on the plicae and commonly have 1 and rarely 2 weak costae in the interspaces; anterior and posterior auricles have about 9 costae; concentric lamellae well developed on plicae, interspaces, and auricles. Disk flanks of all valves have well-developed concentric lamellae and 2 to 4 weak costae.

*Interior Features:* Resilial insertion about as long as high, oriented perpendicular to hinge line except for slight posterior slant in some left valves; single, weak to moderate auricular denticle both anteriorly and posteriorly.

**DISCUSSION.**—The population sample from the Lee Creek Mine differs from samples of *A. eboreus solarioides* from the Caloosahatchee Formation of Florida by having a much greater percentage of specimens with rounded rather than squared plicae, and by having a median costa in the interareas on both the right and left valves instead of just the left valve. There is a complex of forms in *A. e. solarioides*, and this form certainly belongs to the lineage.

The specimens from the upper shell bed (units 8 and 9) in the Yorktown Formation in the Lee Creek Mine differ considerably from the specimens of *A. eboreus* aff. *A. eboreus watsonensis*, which occur in the lower and middle part of the formation. The specimens from the upper bed are larger in size, ranging to a height of 118 mm compared to 79 mm for the largest specimen in the lower beds; the number of plicae is greater, ranging from 19 to 23 with a mean of 21 compared to 16 to 19 for the lower specimens (Figure 11), the byssal notch is shallower (Figure 13), and the width of the internal groove is narrower (Figure 15). The shape of the plicae in the sample from the upper bed varies from individuals with broad and raised plicae with a square outline (Plate 11: figure 5), characteristic of *A. e. solarioides* to those with relatively low and rounded plicae, which become poorly developed in the later portions of the valve (Plate 9: figures 2, 3), similar to *A. e. senescens*, which was described from the Waccamaw Formation in South Carolina.

The majority of specimens from the Croatan Formation at Lee Creek were collected in place over the thickness of this unit in the pit. They are grouped as a single population sample with a few float specimens undoubtedly from the same interval. The variation in characteristics of the plicae into several groupings could indicate a mixing of assemblages of slightly different ages or environmental tolerances within the Croatan Formation. However, there does not seem to be any significant amount of time represented in the upper shell bed in the area of collection and there is only a slight change upward in the environment of deposition. The preservation of the two extreme kinds is similar, and it is thought that they represent one variable population. Supporting this interpretation is the fact that samples of *A. e. solarioides* from the Caloosahatchee Formation in Florida are dominated by specimens with squarish plicae, but there is considerable variation toward rounded plicae in some specimens. It appears that the populations of *A. eboreus* at the time of deposition of the Caloosahatchee Formation and the upper bed at Lee Creek had a considerable range of ornamentation. The two end groups seem to be present in both areas, with a considerable proportion of forms with obsolete plicae in the Lee Creek beds of the Croatan Formation and the Waccamaw Formation in South Carolina and fewer in Florida. A careful study of samples from both areas is needed to determine whether there is sufficient difference in population structure to warrant recognition of two subspecies, but samples of this type are not available at the present time. Overall, the Croatan sample from Lee Creek is similar to *A. e. solarioides* in most characteristics, and it is considered to have closest affinities to this group.

The Lee Creek specimens have radial costae in the interspaces, a characteristic of *A. e. solarioides*. The interspace ornamentation dominantly consists of a single costa, developed over most or all of the disk, and is found on both the left and right valves. In some specimens the costae are only developed in the lateral interspaces, and in a few specimens the left valve has two costae in the lateral interspaces, a characteristic of the specimens found in the Caloosahatchee Formation in Florida. The convexity of the left valve in the Lee Creek specimens is moderate among the *A. eboreus* group as a whole, with the right valve having a moderately high convexity (Figure 14). The left valve is more convex than the right, but this sample has the second closest similarity in convexity between the two valves. The byssal notch is moderately shallow, being less than in *A. e. watsonensis* and *A. e. urbannaensis*, but slightly deeper than *A. e. bertiensis* (Figure 13).

**STRATIGRAPHIC AND GEOGRAPHIC RANGE.**—This group is found in the Croatan Formation in the Lee Creek Mine, and also in the uppermost part of the "Yorktown" at Mt. Gould Landing along the Chowan River, North Carolina.

**MEASURED MATERIAL.**—Total specimens measured of

TABLE 8.—Measurements (in mm) of a representative sample of *Argopecten eboreus* aff. *A. eboreus solarioides*.

Character	USNM 362996		USNM 362997		USNM 362998	
	(S)	(D)	(S)	(D)	(S)	(D)
H	99.0	100.0	73.0	73.5	40.0	40.0
AHL	51.0	53.0	38.0	39.0	19.5	20.0
PHL	58.0	58.0	41.0	41.5	21.0	20.5
L	109.0	111.0	79.0	80.5	40.5	40.5
ADHD	49	48	39	37	20	21
PDHD	53	52	39	39	21	—
CON	20.2	17.1	16.7	13.1	7.2	5.9
HAA	21.0	18.0	15.0	14.5	8.5	7.5
HPA	20.0	22.0	16.0	16.0	9.0	9.5
LAA	—	—	23.0	24.0	11.0	11.5
LPA	34.0	35.0	23.0	24.0	11.0	11.5
HL	—	—	46.0	48.0	22.0	22.5
DBN	—	—	—	21	—	10
BN	—	—	—	3.0	—	1.5
WP	4.7	3.9	3.9	3.0	2.8	1.7
WI	3.4	4.2	2.4	2.5	1.0	1.1
NRIB	21	21	21	21	21	21

*Argopecten eboreus* aff. *A. e. solarioides* include 4 right valves and 3 left valves from USGS 25339 and 19 right valves and 7 left valves (USNM 362996–362998) from USGS 25364. Those from USGS 25339 are from spoil piles and those from USGS 25364 from the upper shell bed, both at the Lee Creek Mine. Measurements from a representative sample of 6 valves are given in Table 8.

### Genus *Placopecten* Verrill, 1897

#### *Placopecten clintonius clintonius* (Say), new combination

PLATE 12: FIGURES 2, 4, PLATE 14: FIGURES 1, 2, 5–7; PLATE 15:  
FIGURES 1, 4

*Pecten clintonius* Say, 1824:135, pl. 9: fig. 2.

*Pecten (Placopecten) clintonius* Say.—Dall, 1898:725.

*Chlamys (Placopecten) clintonius* (Say).—Tucker-Rowland, 1938:52-53, pl. 1: fig. 11.

*Chlamys (Placopecten) clintonia* (Say).—Gardner, 1944:37, pl. 6: figs. 1, 4.—Mongin, 1959:299, pl. 25: figs. 2a-d.

**DESCRIPTION.**—*Shell Outline:* Shell large in size, with specimens having heights greater than 100 mm common, and reaching a maximum height of at least 130 mm; length of shell similar to height; left valve more convex than right; left valve moderately convex, reaching 25 mm in larger specimens; right valve low to moderately convex, reaching 14 mm; outline of disk moderately oblique posteriorly; moderate disk gape anteriorly and posteriorly, reaching 3 mm.

*Auricles and Outer Ligament:* Right anterior auricle with a planar to slightly concave surface; dorsal margin nearly coincident with trace of outer ligament and slightly folded; byssal notch very shallow with broad, rounded apex; byssal fasciole poorly developed; no ctenolium observed. Left anterior auricle with a planar to slightly concave surface; dorsal margin flat and nearly coincident with trace of outer ligament; free margin slightly rounded to straight with very shallow byssal sinus having a rounded apex. Posterior auricles similar in size to anterior; surfaces planar to slightly concave; dorsal margins nearly coincident with groove of outer ligament. Posterior and anterior outer ligaments generally about equal in length.

*Exterior Shell Surface:* Both valves with numerous radial costae, numbering about 9 to 10 per centimeter at heights of 100 mm; costae with steeply curved sides and rounded summits; costae narrower than interspaces; interspaces broadly U-shaped; on left valves additional costae during ontogeny added by intercalation; on right valves additional costae added both by intercalation and bifurcation; concentric lamellae poorly developed and usually worn; surface of well-preserved valves covered by small elongated pustules, which in some specimens become suggestive of *camptonectes* microsculpture. Auricles have 10 to 12 costae with additional ones added by intercalation; concentric lamellae weakly developed.

*Interior Features:* Resilial insertion slightly less than 1½ times higher than long; orientation ranging from essentially perpendicular to hinge line in most right valves to a generally slightly posterior slope in most left valves; single, moderately developed auricular denticle, both anteriorly and posteriorly.

**DISCUSSION.**—*Placopecten clintonius*, a Miocene species, was considered to be the ancestor of the living scallop, *P. magellanicus*, by Dall (1898:726) and Gardner (1944:37) because of the close morphologic similarity. The absence of any intermediate forms between these two species is probably due to the absence of fossiliferous cool water deposits of latest Miocene and Pliocene age in the Atlantic Coastal Plain. Beds of this age in the Lee Creek Mine and surrounding areas of North Carolina and southeastern Virginia are of a considerably warmer character (Gibson, 1967; Hazel, 1971), which would seem to exclude the *P. clintonius* stock on environmental grounds. *P. clintonius* is not found south of central North Carolina (the Lee Creek Mine) in the Miocene, and specimens of the presumed living descendant, *P. magellanicus*, have their southern boundary in the Atlantic Ocean approximately at Cape Hatteras, North Carolina. Fossiliferous cool-water deposits of latest Miocene and Pliocene age are not found on land in the more northern Atlantic Coastal Plain, but undoubtedly occur on the northern continental shelf and there should contain the intermediate forms.

Dall (1898:726) mentioned the difficulties in separating

the two species, and used the following criteria:

The latter [*P. magellanicus*] can, however, be at once discriminated from the fossil by the shorter hinge-line, higher auricles, much narrower resiliary pit, and usually, the smaller and less central adductor scar of the recent shell. . . . As a rule the radiating threads in the fossils are markedly coarser than those of the living species.

The ornamentation, as represented by the radial costae, is generally considerably coarser in *P. clintonius*, as mentioned by Dall (1898:726). Specimens of *P. magellanicus* have finer costae ranging from 10 to 16 per centimeter at 100 mm height. However, the more southern forms of *P. magellanicus* have sufficiently coarse costae to overlap with some of the more finely costate *P. clintonius*. It appears that some *P. clintonius* have coarser ornamentation than any *P. magellanicus*, and many *P. magellanicus* have finer ornamentation than any *P. clintonius*, but there is overlap in the middle of the sculptural range.

A population study of the two species was made by comparing *P. clintonius clintonius* from the Lee Creek Mine (from spoil bank material derived from the lower two feet (61 cm) of the Yorktown Formation) with living *P. magellanicus* taken on the Atlantic shelf east southeast of Long Island at 67 fathoms (USFC Sta. 2244). The comparison involved those characters used by Dall and subsequent authors as diagnostic between the two species, and some additional ones.

As mentioned by Dall (1898:726), Tucker-Rowland (1938:53), and Mongin (1959:299), the resiliifer is considerably broader in *P. clintonius* than in *P. magellanicus*. The gently sloping sides of the resiliifer in many specimens make it difficult to obtain an accurate measurement. Because of the possibility that the size and shape of the resilium is not always closely correlated with the resiliifer, measurements were made on both for comparative purposes. The ratio of length to height of the resiliial insertion differs between the two species, with *P. clintonius* having a considerably broader resiliial insertion (Figure 16), supporting the views of Dall, Tucker-Rowland, and Mongin. The resiliifer also varies between the two species, with *P. clintonius* again having a broader one. While the correlation between height and length of the resiliifer is lower than that of the resiliial insertion, probably reflecting in large part the difficulty of accurately measuring the resiliifer because of the gently sloping sides, this character could be used in species where the resiliial insertion is not readily preservable.

Valves of *P. clintonius clintonius* from the Lee Creek beds are posteriorly oblique in shape, whereas valves of *P. magellanicus* are very slightly, if at all, oblique. This difference is noted by comparing the anterior and posterior half-lengths of the valves of the two species. As indicated in Figure 17, *P. clintonius clintonius* has a considerably larger posterior half-length, whereas *P. magellanicus* has nearly equal posterior and anterior half-lengths. Other specimens of *P. clintonius clintonius* from various localities in Virginia do

not exhibit as marked an obliquity of the valves.

Several of the other characters mentioned by Dall and others as distinguishing the two species were also studied. Dall (1898:726) and Tucker-Rowland (1938:53) mention that a distinguishing character of *P. magellanicus* is the shorter hinge line as compared to *P. clintonius clintonius*. In the populations studied, no difference in length of the hinge line can be seen between the two species (Figure 18). If anything, the larger specimens of *P. magellanicus* have a generally longer hinge line rather than shorter.

Another differentiating character mentioned by Dall (1898:726) is that the auricles are higher in *P. magellanicus*. No significant difference was noted in this study (Figure 19). Nevertheless the general trend is toward a slightly higher posterior auricle in *P. clintonius clintonius* rather than otherwise.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE.**—This species occurs in abundance in the lower 2 to 3 feet (0.6 to 0.9 m) of the Yorktown Formation in the Lee Creek Mine. Mansfield (1929b:1) used this species to name his lowest zone of the Yorktown Formation in Virginia, calling it zone 1 or *Pecten clintonius* zone. *P. clintonius clintonius* is restricted to this zone, and is an excellent guide fossil in North Carolina and Virginia. Another subspecies, *P. clintonius rappahannockensis* (Mansfield) is found in the beds immediately underlying Mansfield's zone 1 of the "Yorktown" in North Carolina, and a slight distance below in several localities in Virginia. These beds were placed in the "Virginia St. Marys" beds by Mansfield (1944) but were included in the Yorktown Formation by Gibson (1971).

**MEASURED MATERIAL.**—Total specimens measured of *Placopecten clintonius clintonius* include 35 right valves and 27 left valves from USGS 25338, (USNM 362999–36300), and 4 right valves and 7 left valves from USGS 25339 (USNM 363001–363003). Both collections are from spoil banks of the Yorktown Formation, Lee Creek Mine, North Carolina, and include a total population sample of 39 right valves and 34 left valves. Measurements of a representative sample of 8 valves are given in Table 9.

***Placopecten clintonius rappahannockensis* (Mansfield),  
new combination**

PLATE 18

*Pecten* (*Glymys*) *clintonius rappahannockensis* Mansfield, 1936:186–187, pl. 22: figs. 1–3.

*Glymys* (*Placopecten*) *clintonius rappahannockensis* (Mansfield).—Tucker-Rowland, 1938:53–54, pl. 3: fig. 6, pl. 4: fig. 1.

**DESCRIPTION.**—*Shell Outline:* Shell large in size, reaching heights of 130 mm; length of shell is similar to or slightly greater than the height; left valve more convex than right; left valve moderately convex, reaching 19 mm in larger specimens; right valve of low convexity, reaching 13 mm in



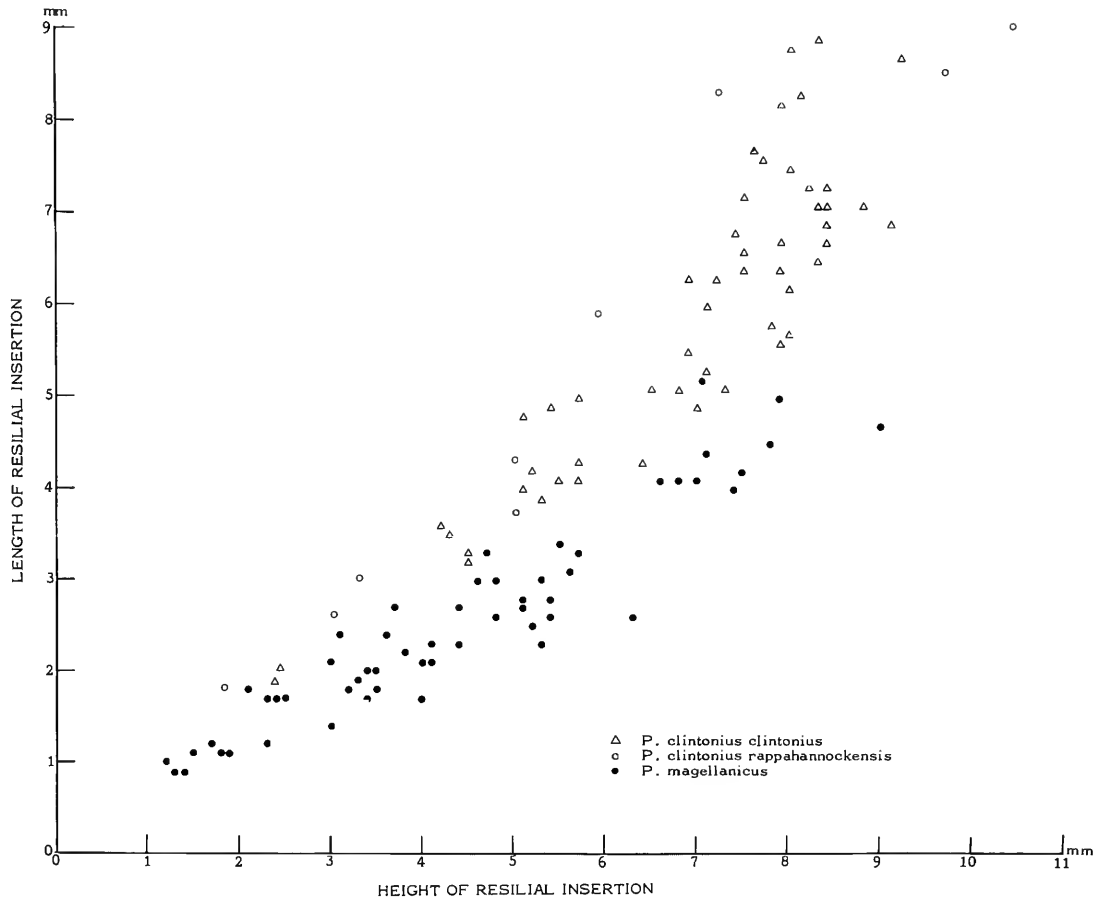


FIGURE 16.—Bivariate scatter diagram showing the differences in the size of the resilial insertion among samples of subspecies of *Placopecten clintonius* (Yorktown Formation, North Carolina) and *P. magellanicus* (Holocene, New England shelf).

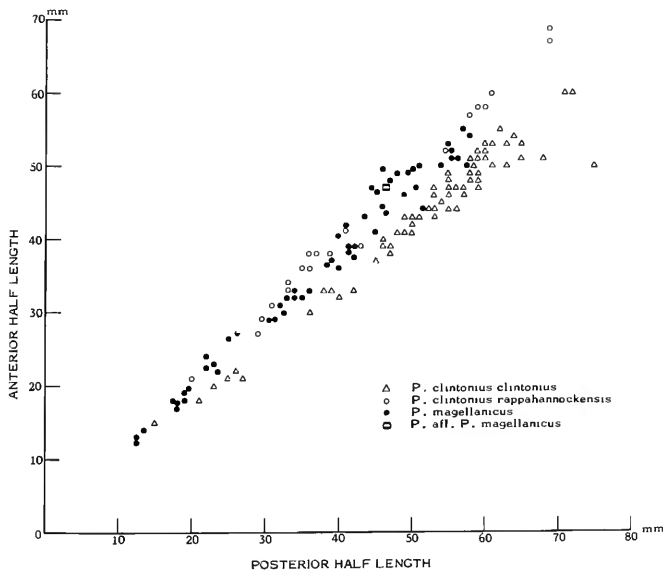


FIGURE 17.—Bivariate scatter diagram showing the difference in the shape of the valve among various subgroupings of *Placopecten*.

TABLE 9.—Measurements (in mm) of a representative sample of *Placopecten clintonius clintonius*.

Character	USNM 362999		USNM 363000		USNM 363001		USNM 363002	USNM 363003
	(S)	(D)	(S)	(D)	(S)	(D)	(S)	(D)
H	68.0	70.0	112.0	109.0	90.0	89.0	46.5	48.0
AHL	33	33	51	52	41	38	21	22
PHL	39	38	65	60	49	47	25	26
L	72.0	71.0	116.0	112.0	87.5	85.0	46.0	48.5
ADHD	32	33	51	44	39	37	20	22
PDHD	37	39	53	55	43	45	22	24
CON	10.2	7.0	21.0	14.2	12.8	9.1	6.0	5.1
HAA	11.5	11.0	17.0	16.0	15.0	14.5	9.5	8.0
HPA	10.0	12.0	14.0	17.0	15.0	16.0	8.5	9.5
LAA	13.0	13.2	22.0	23.5	16.0	—	10.0	9.0
LPA	14.0	13.5	21.3	19.0	15.0	15.5	9.5	10.0
HL	26.0	26.5	42.0	42.0	30.0	33.0	18.0	19.5
DBN		14.7	—	24.4	—	19.0	—	10.2
BN		—1.5	—	—0.9	—	—	—	—1.2
HR	5.01	5.62	9.17	9.94	6.68	7.02	2.60	—
LR	4.43	4.94	8.10	8.50	6.71	6.89	2.85	—
HR1	4.47	4.45	8.39	8.34	6.36	6.35	2.42	2.46
LRI	3.20	3.30	6.74	6.47	4.29	4.32	1.89	2.01

larger specimens; outline of disk equilateral with essentially identical anterior and posterior half-diameters; disk gape moderately broad anteriorly and posteriorly.

*Auricles and Outer Ligament:* Right anterior auricle with a planar to slightly concave surface; dorsal margin nearly coincident with trace of outer ligament and slightly folded; byssal notch very shallow with broadly rounded apex; byssal fasciole poorly developed; no ctenolium observed. Left anterior auricle with a planar to slightly convex surface; dorsal margin nearly coincident with trace of outer ligament and slightly folded; free margin slightly rounded to straight with a very shallow byssal sinus having a rounded apex. Posterior auricles similar in height to anterior and have essentially planar surfaces. Anterior outer ligament longer than posterior. Moderate auricular gape.

*Exterior Shell Surface:* Both valves with numerous radial costae, numbering about 11 to 15 per centimeter at height of 100 mm; costae low, with steep sides and flat, broad summits; costae equal in width to slightly narrower than interspace; interspaces broadly U-shaped; on left valves additional costae during ontogeny added by intercalation and bifurcation; on right valves additional costae added largely by bifurcation; concentric lamellae poorly developed and usually worn. Auricles have 5 to 10 weakly developed costae; concentric lamellae poorly developed.

*Interior Features:* Resilial insertion slightly higher than long; orientation generally with a slight posterior slant in both valves; single, moderately developed auricular denticle both anteriorly and posteriorly.

**DISCUSSION.**—This subspecies differs from *P. clintonius clintonius* in characteristics of the radial ornamentation. The costae in *P. clintonius rappahannockensis* are more numerous, numbering from 11 to 15 per centimeter, are lower and wider with broadly rounded to flattened summits, and the interspaces are relatively narrow and shallow. In comparison, the costae on *P. clintonius clintonius* range from approximately 5 to 10 per centimeter, are higher and narrower with subangular to rounded summits, and the interspaces are relatively deep and broad.

As mentioned by Mansfield (1936:187), the hinge line of *P. clintonius rappahannockensis* is longer, although this is mostly characteristic of immature specimens (Figure 18). The height of the auricles in the two subspecies is similar (Figure 19), but *P. clintonius rappahannockensis* has a longer anterior auricle in relation to shell length (Figure 20) and a longer anterior auricle than posterior. *P. clintonius clintonius* has auricles approximately equal in length.

The valves of *P. clintonius rappahannockensis* are essentially equilateral, and differ from the Lee Creek sample of *P. clintonius clintonius* in which the valves are sharply not equilateral (Figure 17). Other population samples of *P. clintonius clintonius* from Virginia, however, more closely approach being equilateral. The resilial insertion has a relatively great length in both subspecies of *P. clintonius*

compared to *P. magellanicus* (Figure 16).

Emmons (1858:280) named *Pecten princepoides* from the Miocene strata along the Meherrin River near Murfreesboro, North Carolina. From the type figure and subsequent collecting in the type area, it is clear that this taxon belongs to *Placopecten clintonius* as Dall (1898:726) noted. Of which subspecies it is a synonym is a more difficult problem as both subspecies are found in this area, in places within a foot of each other stratigraphically. The type figure (Emmons, 1858, fig. 198) seems to be of a finely striate form like *P. clintonius rappahannockensis*, but the description (Emmons, 1858:280) mentions that the radiating striae are "coarse," which would seem better to fit *P. clintonius clintonius*. The description also mentions that the ears are unequal, which would be indicative of *P. clintonius rappahannockensis*, as would be the size which has a length of 5¼ inches (13.3 cm). A final determination will have to be made from whatever type material can be found.

**STRATIGRAPHIC AND GEOGRAPHICAL RANGE.**—This subspecies occurs in the upper part of the "Virginia St. Marys" beds of Mansfield (1944:6), also called zone 2 or *Crassatellites meridionalis* zone. These strata were reassigned by Gibson (1971) to the lowermost part of the Yorktown Formation as the initial part of the Yorktown depositional cycle in the Virginia–northern North Carolina area. The subspecies is found in beds of this age along the Rappahannock and James rivers in Virginia and the Meherrin River in northernmost North Carolina, and occurs immediately or closely below the strata of Mansfield's zone 1 of the "Yorktown," the *P. clintonius clintonius* zone.

**MEASURED MATERIAL.**—Total specimens measured of *Placopecten clintonius rappahannockensis* include 5 right valves and 4 left valves (USNM 218878, 218879, 363004) from USGS 3924, one right valve from USGS 8179, and 5 right valves and 4 left valves (USNM 363005–363007) from USGS 25747. All are from the lowermost part of the Yorktown Formation: USGS 3924 from bluff at "Jones Point" on the Rappahannock River about 21 km north of Urbana, Virginia; USGS 8179 from the beach about 0.8 km downstream from "Jones Point"; USGS 25747 from bluff on Meherrin River 4.8 km above Highway 158 bridge. Measurements from a representative sample of 9 valves are given in Table 10.

*Placopecten* sp. aff. *P. magellanicus* (Gmelin),  
new combination

PLATE 16: FIGURE 1, PLATE 17: FIGURE 3

*Ostrea magellanica* Gmelin, 1791:3317.

**DESCRIPTION.**—*Shell Outline:* Shell medium in size, height of 88 mm; length slightly longer than height; right valve with low convexity of 9 mm; outline of disk essentially equilateral with a slightly longer posterior half-length.

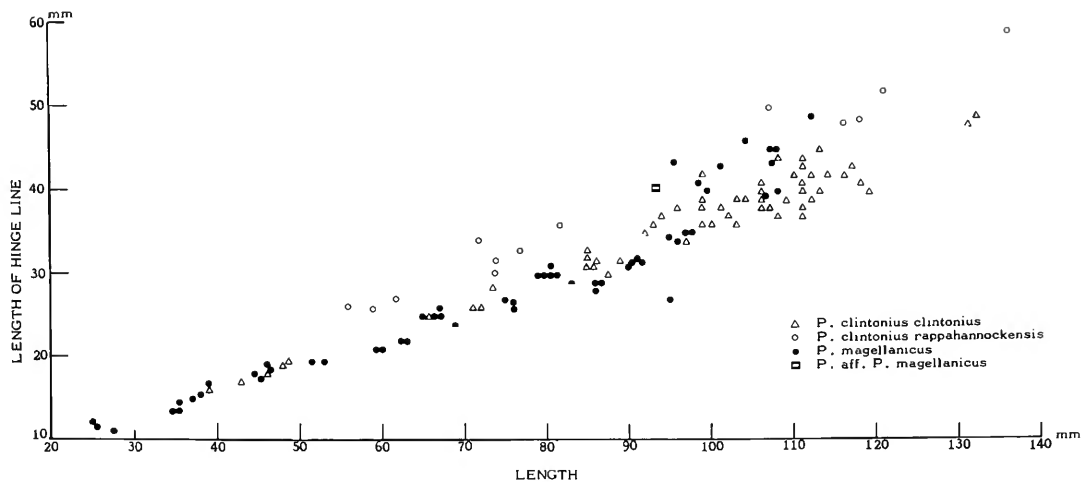


FIGURE 18.—Bivariate scatter diagram showing the similarity in the length of the hinge line among various subgroupings of *Placopecten*.

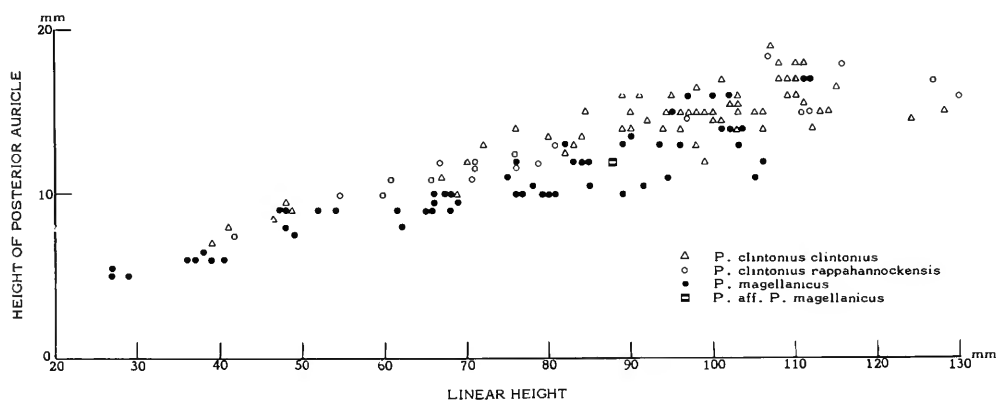


FIGURE 19.—Bivariate scatter diagram showing variation in the height of the posterior auricle in various subgroupings of *Placopecten*.

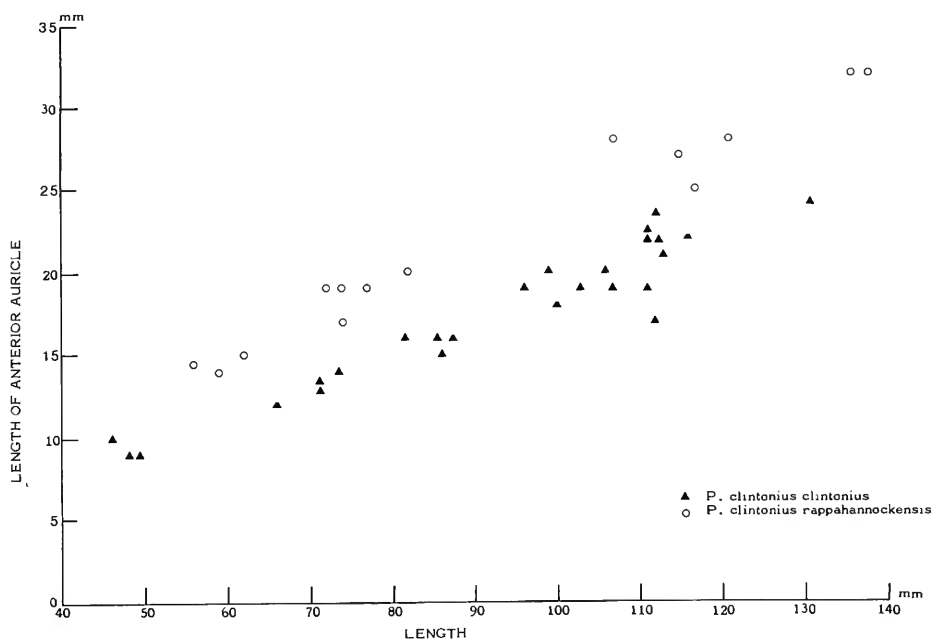


FIGURE 20.—Bivariate scatter diagram showing the greater length of the anterior auricle in a sample of *Placopecten clintonius rappahannockensis* (basal Yorktown Formation, Virginia and North Carolina) compared to a sample of *P. clintonius clintonius* (Yorktown Formation, North Carolina).

TABLE 10.—Measurements (in mm) of a representative sample of  
*Placopecten clintonius rappahannockensis*.

Character	USNM 218878		USNM 218879		USNM 363004 (D)	USNM 363005 (D)	USNM 363006 (S)	USNM 363007	
	(S)	(D)	(S)	(D)				(S)	(D)
H	66	67	112	107	76	55	42	130	127
AHL	34	33	58	57	37	27	21	67	69
PHL	33	33	59	58	37	29	20	69	69
L	67	66	117	115	74	56	41	136	138
ADHD	30	32	—	54	36	—	21	55	50
PDHD	32	32	53	52	35	28	21	58	54
CON	8.5	7.1	17.9	12.1	8.5	6.0	5.1	17.4	11.5
HAA	12.0	12.0	17.0	17.5	13.0	11.0	9.5	18.0	16.5
HPA	11.0	12.0	15.0	18.5	12.0	10.0	7.5	16.0	17.0
LAA	—	—	25.0	27.0	19.0	14.5	—	32.0	32.0
LPA	—	13.0	23.5	21.0	13.5	11.5	9.0	27.0	—
HL	—	—	48.5	48.0	32.5	26.0	—	59.0	—
DBN	—	18	—	28	20	14	—	—	34
BN	—	—	—	-1.0	-1.0	0.5	—	—	-2.0
HR	4.1	5.0	7.2	8.6	6.5	4.0	2.5	—	—
LR	5.7	4.3	10.3	9.0	6.8	3.6	3.2	—	—
HRI	—	5.0	7.2	—	5.9	3.0	1.8	9.7	10.4
LRI	—	3.7	8.3	—	5.9	2.6	1.8	8.5	9.0

*Auricles and Outer Ligament:* Right anterior auricle with a planar surface; dorsal margin nearly coincident with trace of outer ligament and slightly folded; byssal notch very shallow with broadly rounded apex; byssal fasciole poorly developed; no ctenolium observed. Right posterior auricle with planar surface; dorsal margin nearly coincident with trace of outer ligament and folded; free margin slightly curved. Posterior auricle similar in height to anterior. Anterior outer ligament longer than posterior.

*Exterior Shell Surface:* Right valve with numerous radial costae, about 16 to 18 per centimeter; costae are low and broad, with gently sloping sides; costae wider than interspaces; interspaces shallow and narrow; concentric lamellae poorly developed. Auricles with about 10 weakly developed costae; concentric lamellae moderately developed.

*Interior Features:* Resilial insertion about as long as high, oriented perpendicular to hinge line; single, moderately developed auricular denticle both anteriorly and posteriorly.

**DISCUSSION.**—*Placopecten clintonius* from the Yorktown Formation of the Atlantic Coastal Plain has been considered the ancestral form of the living *P. magellanicus* of the North Atlantic Ocean (Dall, 1898:726). However, no forms transitional in morphology or age between the two species have been found in the younger Cenozoic strata of the Atlantic Coastal Plain. A single right valve found in the Lee Creek Mine appears to be an intermediate form between the two species in that lineage. The specimen was collected by Jack McLellan from spoil banks in the Lee Creek Mine. It was determined to be from the Yorktown Formation on the basis of the type of sediment adhering to small cracks in the

shell; but the crucial information as to the exact stratigraphic occurrence in the Yorktown Formation is lacking. The cementation of part of an echinoid test onto the shell is a strong indication that the specimen came from unit 2 of Gibson (1967). From a phylogenetic viewpoint, the specimen should come from somewhere above the basal beds of the Yorktown, which contain the supposed ancestor, typical *P. clintonius*, and if it is from unit 2 this would be true. Because there is only the one specimen, and particularly because the precise stratigraphic position is uncertain, the specimen will not be placed more definitely taxonomically until additional valves with stratigraphic information are found. The specimen has closer proximity to *P. magellanicus* morphologically, although it is presumably very close to *P. clintonius* stratigraphically.

The shape of the single right valve of *Placopecten* sp. aff. *P. magellanicus* is similar to that of the modern *P. magellanicus* in being equilateral with a fairly equal anterior and posterior half-length (Figure 17). This contrasts with the moderately oblique shape of the disk in a population of *P. clintonius clintonius* from the Lee Creek Mine.

The ornamentation on the disk of *Placopecten* sp. aff. *P. magellanicus* consists of very fine radial costae. The strength of the costae is considerably less than that found in *P. clintonius*, especially in the population from the mine, which has moderate to coarse radial ornamentation. The single specimen from the mine has costae that fall about midway in the range of variability of *P. magellanicus*, not being as sharply defined as in the coarser forms, but not being so flat as to be essentially smooth as in the more finely ornamented examples.

The auricles of *Placopecten* sp. aff. *P. magellanicus* are different from those of both *P. clintonius* and *P. magellanicus*, although they are more similar to the latter. In comparison to *P. clintonius clintonius*, the auricles in the single specimen of *Placopecten* sp. aff. *P. magellanicus* have considerably finer costae. The posterior auricle has an essentially straight free margin perpendicular to hinge line, whereas in *P. clintonius* this margin has a strong posterior slant away from the hinge line. In the specimen of *Placopecten* sp. aff. *P. magellanicus* the anterior end of the anterior outer ligament is about the same distance from the origin of growth as is the innermost part of the byssal notch. In *P. clintonius* the byssal notch is more anterior than the anteriormost end of the ligament. The hinge line of *Placopecten* sp. aff. *P. magellanicus* is longer than most specimens of *P. clintonius clintonius* (Figure 18). Although there are close similarities in most characteristics of the auricles between the population of *P. magellanicus* and the specimen of *Placopecten* sp. aff. *P. magellanicus* (Figure 19), the latter has longer auricles than most specimens of *P. magellanicus*. (See Plate 16: figures 1 and 2 where the similar-sized valve of *P. magellanicus* has considerably shorter auricles.)

The resilial insertion of *Placopecten* sp. aff. *P. magellanicus* is relatively long in relation to its height, being similar to the shape of *P. clintonius* but significantly wider than that of *P. magellanicus*. No absolute measurements are given for the resilial insertion, as it is fractured and separated.

*Placopecten* sp. aff. *P. magellanicus* is close to *P. magellanicus* in many characteristics, and appears to be well along in the phylogenetic sequence from *P. clintonius clintonius* to that species. Unfortunately, without knowing how far above the basal Yorktown beds (containing *P. clintonius clintonius*) the specimen occurred, the rapidity of this transition cannot be determined. As mentioned, the nature of the small amount of sediment in crevices on the specimen and the echinoid fragment cemented to the shell suggest that the specimen came from the upper lower part of the Yorktown or lower middle part of the Yorktown (upper part of unit 2 to lower part of unit 5, most probably unit 2), indicating a rapid phylogenetic change. The possibility that the single specimen is an extreme variant within the population of *P.*

*clintonius clintonius* cannot be dismissed entirely, but as little variation toward this form is observed in the hundreds of valves examined from the Lee Creek Mine and other sections in the Atlantic Coastal Plain, it seems unlikely.

MEASURED MATERIAL.—The measurements of the specimen of *Placopecten* sp. aff. *P. magellanicus*, USNM 218873, from USGS 25743; spoil piles, Lee Creek Mine, North Carolina, are given in Table 11.

## Genus *Chlamys* Röding, 1798

### *Chlamys decemnaria* (Conrad)

PLATE 15: FIGURES 2, 3, 5-7, PLATE 16: FIGURES 3-5; PLATES 19, 20

*Pecten decemnarius* Conrad, 1834:151; 1840:49, pl. 24: fig. 2.

*Pecten virginianus* Conrad, 1840:46, pl. 21: fig. 10.

*Pecten dispalatus* Conrad, 1845:74, pl. 42: fig. 3.

*Pecten (Placopecten) virginianus* Conrad.—Dall, 1898:727.

*Pecten (Chlamys) decemnarius* Conrad.—Dall, 1898:741.

*Chlamys (Placopecten) virginianum* (Conrad).—Tucker, 1934:617.

*Chlamys (Chlamys) decemnarius* (Conrad).—Rowland, 1936b:1009, pl. 8: figs. 5-6.

*Chlamys (Placopecten) virginianus* (Conrad).—Tucker-Rowland, 1938:55-56, pl. 4: fig. 22, pl. 5: fig. 14.

*Chlamys decemnaria* (Conrad).—Gardner, 1944:31-32, pl. 5: figs. 1-2, 6, 7.

*Chlamys (Placopecten) virginiana* (Conrad).—Gardner, 1944:38-39, pl. 4: fig. 3.

DESCRIPTION.—*Shell Outline*: Shell of medium size, attaining height of 78 mm; both valves of low to moderate convexity, with left valve of equal to slightly greater convexity than right. Outline of disk equilateral; height of valve similar to length; disk flanks low. Narrow disk gape anteriorly, none posteriorly.

*Auricles and Outer Ligament*: Right anterior auricle with planar surface; dorsal margin slightly dorsal to groove of outer ligament and strongly folded; byssal notch moderately deep with broadly to moderately rounded apex; byssal fasciole moderately broad and planar; ctenolium with 3 to 4 teeth well developed throughout. Left anterior auricle with planar surface; dorsal margin flat and coincident with trace of outer ligament; free margin straight and essentially 90 degrees to hinge line. Posterior auricles much smaller than anterior; surfaces planar; free margin straight, slanted posteriorly. Anterior outer ligament almost twice as long as posterior.

*Exterior Shell Surface*: Radial ornamentation on right valve less strongly developed than on left valve; radial ornamentation varies greatly in development; disk ornamentation ranges from very low, broad costae separated by narrow grooves, numbering about 16 to 18 costae per centimeter, to strongly developed plicae, numbering 10 to 12 per disk; costae increase in number by bifurcation, may be unequal strength. Right valves have plicae broader than interspaces; plicae vary in development from low with broadly rounded sides to low with almost vertical sides;

TABLE 11.—Measurements (in mm) of the specimen of *Placopecten* sp. aff. *P. magellanicus*.

Character	USNM 218873 (D)	Character	USNM 218873 (D)
H	88	HPA	12.0
AHL	47	LAA	21.0
PHL	46.5	LPA	18.5
L	93.5	HL	39.5
ADHD	36	DBN	21.0
PDHD	41	BN	0
CON	9.1	WP	—
HAA	12.5	WI	—

interspaces contain 3 costae. Left valves have narrow plicae with interspaces 3 to 4 times as wide; plicae vary in shape from very low and rounded to moderately high and sharply defined; costae not present on the plicae; as many as 12 costae in the interspaces. Concentric lamellae developed only on strongly plicate right valves, but strongly developed on all plicate left valves. Right anterior auricles have 6 to 8 costae, low, rounded, and broad with narrow grooves; right posterior have 6 to 20 low and narrow costae, more weakly developed than on anterior; auricles on left valve have 10 to 20 costae, with generally more on the anterior than posterior; there is no increase in strength of the costae on the auricles with increasing strength of the costae and plicae on the disk. Concentric lamellae poorly to moderately developed on auricles of right valves, more strongly developed on auricles of left valves.

*Interior Features:* Resilial insertion about  $1\frac{1}{2}$  times as high as long, oriented perpendicular to hinge line; single, weakly developed auricular denticle both anteriorly and posteriorly.

**DISCUSSION.**—Samples of more than 300 specimens of *Pecten decemnarius* and *Pecten virginianus* from the Lee Creek Mine show the complete intergradation of these previously separated species. These two forms are only moderately common in most localities and, although people have noted the co-occurrence and similarities between them, heretofore they have not been considered as belonging to a single variable species. For example, Mansfield (1936:178) noted that "*Pecten decemnarius* Conrad and *Pecten virginianus* Conrad are closely related and usually occur together." In the same paper, Mansfield considered both species questionably to have evolved from *Placopecten clintonius*. A population sample was composed of specimens occurring together on the spoil piles in a similar matrix, coming from the indurated silty sand in the lower part of unit 5. *Chlamys decemnaria* and rotten specimens of *Turritella* are about the only fossils present.

The presence of articulated specimens in the Lee Creek material shows the variation in the strength of the ornamentation on the two valves of an individual specimen. Regardless of whether the general development of the ornamentation is strong or weak, the right valve has considerably weaker development than the left (Plate 15: figures 2, 3, 6, 7; Plate 16: figures 4, 5). Within the large sample, it is possible to demonstrate an intergrading sequence of ornamentation from fine radial costae to coarse plications with coarse concentric lamellae (Plates 19, 20). On the right valves (Plate 19) the ornamentation exhibits wide variation, ranging from fine costae (figure 1) to moderate costae on a slightly undulating surface marked by more conspicuous grooves (figure 2), to moderately coarse costae with the undulations and grooves developing into plicae (figures 3-5), and then to increasingly better developed plicae with coarser costae (figures 6-13). Coarse concentric lamellae

occur commonly in the coarser stages of the plicae (figures 10, 13). A similar increase in the development of the plicae and other ornamentation is observable on the left valves (Plate 20). Because the costae and/or plicae are coarser on the left valve than on the right, specimens with a finely costate right valve usually have moderately strongly sculptured left valves. Therefore, finely sculptured left valves are not common, but do occur (figure 2). The costae increase in coarseness (figure 3), and then valves occur with raised areas or plicae composed of two or three costae formed by bifurcation of an earlier raised single one (figure 5). The plicae become stronger, and along with them the intervening costae (figures 6, 7), with the development commonly of coarse concentric lamellae as on the right valve (figure 8). The extreme stage consists of three to five strong plicae along with a number of weaker plicae in varying stages of development, reflecting the coarsening of the costae between the plicae, commonly those formed by bifurcation from the original strong one (figure 9). In this variation, i.e., *Pecten dispalatus* Conrad, both the stronger and weaker plicae have coarse concentric lamellae.

Although the ornamentation is intergradational between the two nominal species, a check of other possibly significant morphological characters was made to see if they also showed overlap. Specimens were divided into three groups on the basis of the strength of the ornamentation. These groups included the following three forms: (1) those with fine to moderate costae, without plicae, i.e., typical *Pecten virginianus*; (2) those with moderately developed costae and the incipient to moderate appearance of plicae, i.e., *Pecten decemnarius*; and (3) those forms with well-developed plicae and moderate to coarse costae along with concentric lamellae, i.e., typical *Pecten decemnarius*.

A comparison among the three morphologic groups was made on the basis of external shell morphology, including features of the disk, auricles, and byssal notch. None of the comparisons indicates any difference among the three groups. Whether the characters used have a very high correlation (Figure 21) or only a moderate correlation (Figure 22), the three groups show no significant differences. Characteristics of the byssal notch, which have proven important in other species and genera, show that although the relatively deep byssal notch is a variable character within each group, it is similar among the three groups (Figure 22). The considerably greater length of the anterior auricle in comparison to the posterior auricle also is consistent among the three groups (Figure 21). Because of the indurated matrix on the specimens, only external characters were used.

The absence of significant differences in any of the studied characters among the three groups reinforces the conclusion that the range in ornamentation is just a variable characteristic of a single species. This wide range of ornamentation is greater than in most species of pectens. As

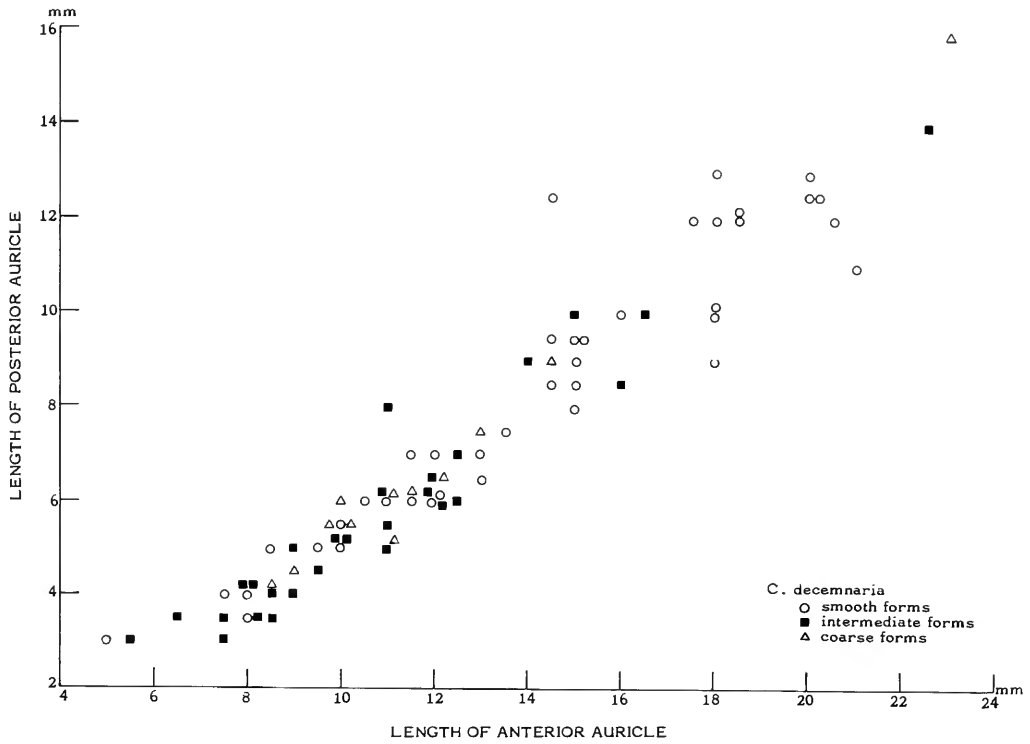


FIGURE 21.—Bivariate scatter diagram showing similarity in length of the auricles in different forms of *Chlamys decemnaria* from a sample in the Yorktown Formation in the Lee Creek Mine.

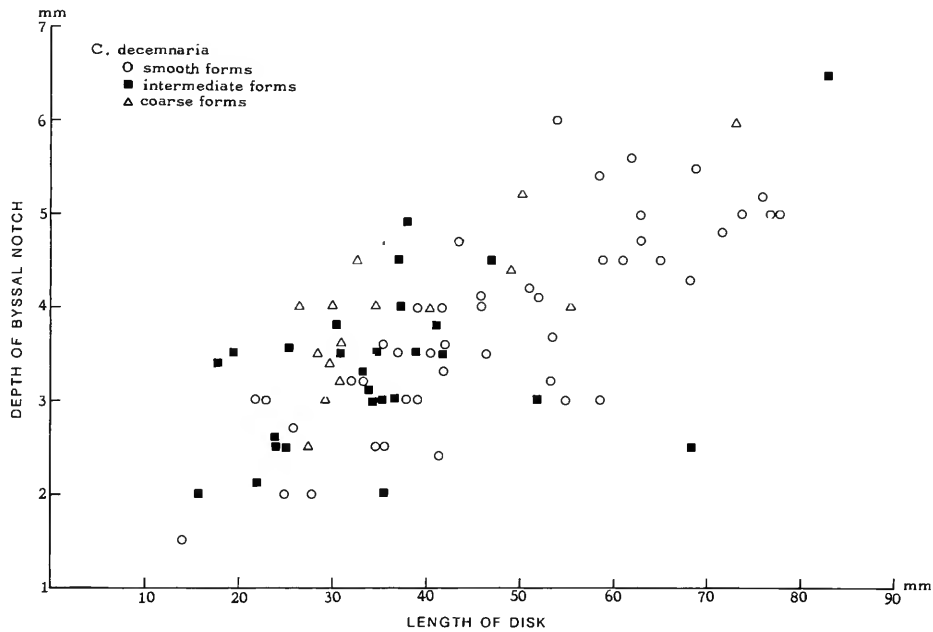


FIGURE 22.—Bivariate scatter diagram showing similarity in depth of the byssal notch in different forms of *Chlamys decemnaria* from a sample in the Yorktown Formation in the Lee Creek Mine.

both the finer and more coarsely ornamented forms are generally found in most localities, it appears that the wide range of ornamentation is a common genetic characteristic throughout the time range of the species. It also appears that as far as can be determined no phylogenetic or geographic trends toward finer or coarser plicae are present in the North Carolina–Virginia area.

A wide variety of species have been placed in *Chlamys*, including the more recent placements of "*Pecten*" *decemnarius*. Although the ornament pattern in "*Pecten*" *decemnarius* is within the range of the type-species of *Chlamys* and other closely related species, it differs in not having the elongated shape of the disk characteristic of *Chlamys islandicus*, the type-species. Until a thorough reclassification of the Pectinidae is available, "*Pecten*" *decemnarius* is placed in the genus *Chlamys*. "*Pecten*" *virginianus* generally has been placed in the then subgenus *Placopecten* (Dall, 1898:727; Tucker-Rowland, 1934:617; 1938:55; Gardner, 1944:38), although these workers noted that "*Pecten*" *virginianus* and *Placopecten clintonius* differ by the former having a much deeper byssal notch and a strongly developed ctenolium. These two species were placed in the then subgenus *Placopecten* because of a general similarity in the shape and convexity of the two valves and their fine radial ornamentation. Differences in the byssal notch, however, and the intergradation with coarser radial ornamentation including plicae in the "*P.*" *virginianus* and "*P.*" *decemnarius* suite, make this placement questionable. The transition between "*P.*" *virginianus* (usually placed in the subgenus *Placopecten*) and "*P.*" *decemnarius* (usually placed in the subgenus *Chlamys*) does indicate that there may be a close relationship between the two groups, here regarded as genera.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE.**—This species occurs in units 3 to 5 of Gibson (1967) in the Yorktown Formation at the Lee Creek Mine and is fairly common in this interval. The species previously has been reported in the Yorktown Formation from the Pamunkey River in Virginia southward to Greenville, North Carolina (Gardner, 1944:32). Dall (1898:741) also reported it from the Ashley River phosphate rock in South Carolina, but the specimen is only a small fragment of an external mold and cannot be placed with certainty. This species usually occurs stratigraphically closely above the range of *Placopecten clintonius*, which is the common guide species to the lower part of zone 1 of Mansfield (1944). *Chlamys decemnaria* is recorded by Mansfield (1936:178) in the lower part of his zone 2, but he considered its occurrence doubtful in zone 1. It is possible that some of the occurrences of this species, such as the lower part of the range in the Lee Creek Mine, should be placed in the upper part of zone 1 of the Yorktown, but the sparsity of the associated fauna limits this determination. As of this time, therefore, the known range of the species is the lower part of Mansfield's zone 2 of the Yorktown Formation.

**MEASURED MATERIAL.**—Total specimens measured of

TABLE 12.—Measurements (in mm) of a representative sample of smooth forms of *Chlamys decemnaria*.

Character	USNM 363008 (D)	USNM 363009 (D)	USNM 363010 (D)	USNM 363011 (D)
H	23.5	73.0	38.0	58.5
AHL	12	39	18	31
PHL	10.0	38.5	17.5	28.5
L	22.0	77.5	35.5	59.5
ADHD	12	35	20	30
PDHD	12	34	20	32
CON	3.6	10.6	4.6	9.2
HAA	4.5	11.0	6.5	10.0
HPA	5.5	11.5	7.0	11.0
LAA	8	20	10	17
LPA	3.5	13.0	5.5	11.0
HL	11.5	33.0	15.5	28.0
DBN	5.0	15.0	7.0	12.5
BN	3.0	5.0	3.0	4.5

TABLE 13.—Measurements (in mm) of a representative sample of intermediate forms of *Chlamys decemnaria*.

Character	USNM 363012 (D)	USNM 363013 (D)	USNM 363014 (D)
H	50	38	23
AHL	26	18	11
PHL	26.0	17.5	11.0
L	52.0	35.5	22.0
ADHD	24	20	11
PDHD	26	20	12
CON	5.9	5.3	3.3
HAA	8.5	7.0	3.8
HPA	8	8	5
LAA	14.0	9.0	6.5
LPA	9.0	5.0	3.5
HL	23	14	10
DBN	11.0	7.0	4.4
BN	3.0	2.0	2.1

TABLE 14.—Measurements (in mm) of a representative sample of coarse forms of *Chlamys decemnaria*.

Character	USNM 218890 (D)	USNM 363015 (D)	USNM 363016 (D)
H	58.0	41.5	28.0
AHL	28	22	14
PHL	27.5	19.0	12.5
L	55.5	41.0	26.5
ADHD	28	20	15
PDHD	28	20	15
CON	8.3	7.0	4.6
HAA	10.5	7.5	5.5
HPA	11.5	9.0	6.0
LAA	15	13	10
LPA	10.0	7.5	5.5
HL	25.0	20.5	15.5
DBN	11	9	6
BN	4	4	4



*Chlamys decemnaria* include 88 right valves (USNM 218890, 363008–363016) from USGS 25338, spoil banks of the Yorktown Formation, Lee Creek Mine, North Carolina. Measurements from representative samples showing radial ornamentation relatively smooth (4 valves), intermediate (3 valves), and coarse (3 valves) are given in Tables 12–14.

## Genus *Chesapecten* Ward and Blackwelder, 1975

### *Chesapecten jeffersonius jeffersonius* (Say)

PLATE 21: FIGURES 1–6, PLATE 22: FIGURES 4–6, PLATE 23:  
FIGURES 4, 5

*Pecten jeffersonius* Say, 1824:133, pl. 9: fig. 1.

*Pecten (Chlamys) jeffersonius* Say.—Mansfield, 1936:174–175, 178–179, 184–185.

*Chlamys (Lyropecten) jeffersonius* (Say).—Tucker-Rowland, 1938:19–20, pl. 1: figs. 3–4, pl. 5: figs. 19–20.

*Chlamys (Lyropecten) jeffersonia* (Say).—Gardner, 1944:32–34, pl. 4: fig. 2.

*Chlamys jeffersonia* (Say).—Mongin, 1959:307–308, pl. 27: fig. 3.

*Chesapecten jeffersonius* (Say).—Ward and Blackwelder, 1975:13–15, pl. 1, pl. 2: figs. 1–3, pl. 5: figs. 3–7, pl. 7: figs. 3, 10.

**DESCRIPTION.**—*Shell Outline:* Shell large, attaining height of 152 mm; both valves of moderate convexity, with left valve more convex than right; convexity reaching 37 mm in left valves and 32 mm in right. Outline of disk almost equilateral with slight posterior obliqueness; shells slightly longer than high, more pronounced in larger specimens. Moderate disk gape anteriorly and posteriorly, reaching 5 mm in larger specimens.

*Auricles and Outer Ligament:* Right anterior auricle with planar surface; dorsal margin slightly dorsal to groove of outer ligament and slightly folded; byssal notch shallow with broad, subangular apex; byssal fasciole poorly developed; ctenolium with 3 or 4 teeth well developed in specimens up to 80 mm height, absent in larger individuals. Left anterior auricle with concave surface; dorsal margin flat and coincident with trace of outer ligament; free margin slightly curved with a broad, shallow byssal sinus. Posterior auricles similar in size to anterior, except posterior are slightly higher; surfaces planar to slightly concave; free margins nearly straight and perpendicular to hinge line. Anterior and posterior outer ligaments about equal in length.

*Exterior Shell Surface:* Valves with 8 to 12 large plicae; in early stages of growth plicae have vertical sides and are sharply defined from interspaces; in later stages plicae become more rounded and sides have about a 45 degree slope; plicae slightly wider than interspaces. Radial costae strongly developed on shell with a scabrous appearance where crossed by concentric lamellae; costae number as many as 20 on the plicae, with up to 5 on the sides of the plicae, and as many as 18 in the interspaces; costae of varying strengths but generally uniform. Concentric lamellae well developed over the valves. Auricles have about 25 costae of about equal strength with well-developed concentric lamellae giv-

ing a scabrous appearance. Disk flanks steep and covered with numerous costae.

*Inferior Features:* Resilial insertion about twice as high as long; oriented with a slight to moderate posterior slope; single auricular denticle of weak to moderate development both anteriorly and posteriorly.

**DISCUSSION.**—This species is one of the most abundant mollusks in the lower part of the Yorktown Formation in the Lee Creek Mine. The *Chesapecten* group exhibits a great amount of morphologic change during its phylogeny, making it valuable for biostratigraphy, and *C. jeffersonius* has several forms that are distinctive for the lower and middle parts of the Yorktown Formation. The morphologic trends within the *C. jeffersonius* lineage are being studied by the author from carefully sampled sections of the Yorktown Formation in Virginia, particularly along the James River, and in North Carolina, where population samples collected in 1 foot (0.3 m) vertical intervals are available. Because of the phylogenetic changes in this lineage and the lack of detailed stratigraphic sampling information for the Lee Creek specimens, the three common taxa of the *C. jeffersonius* species group are compared only in general subspecific or specific terms. Detailed subspecific phylogenetic trends between populations will be discernible in the precisely collected sections.

Although both valves are convex, the left valve is more convex than the right with a ratio of convexity of 0.77 to 0.83 between the valves in mature specimens and an even greater left convexity in younger individuals with ratios as low as 0.63. The strong developed plicae are broadly rounded in the stratigraphically earlier forms of this subspecies, but become more squared with flattened tops and nearly vertical sides in the higher parts of zone 1 where *C. jeffersonius septenarius* develops from it. In the population sample of *C. jeffersonius jeffersonius* from the pit, the number of plicae varies from 8 to 12 (Figure 23) with a mean of 10.1 for a sample of 139 valves.

Some individuals in populations of *C. jeffersonius jeffersonius* from the upper part of Mansfield's zone 1 exhibit characteristics transitional to those found in *C. jeffersonius septenarius*, which is the prevalent form in the lower part of zone 2 of Mansfield. Samples of *C. jeffersonius jeffersonius* are characterized by a greater number of plicae, with a mean of 10.1 versus 6.9 for *C. jeffersonius septenarius* in the Lee Creek samples, but there is some overlap between the two subspecies (Figure 23). Typical members of *C. jeffersonius jeffersonius* have plicae rounded in cross-section, lacking the flattened tops and square sides characteristic of *C. jeffersonius septenarius* (Plate 22: figures 3, 4), although there is gradation between the two forms in the youngest members of *C. jeffersonius jeffersonius*. The plicae in *C. jeffersonius jeffersonius* are actually broader than those of *C. jeffersonius septenarius*, probably due to the vertical sides in the latter form. In *C. jeffersonius jeffersonius* the plicae are lower in relation to the width (Figure 24). The height of

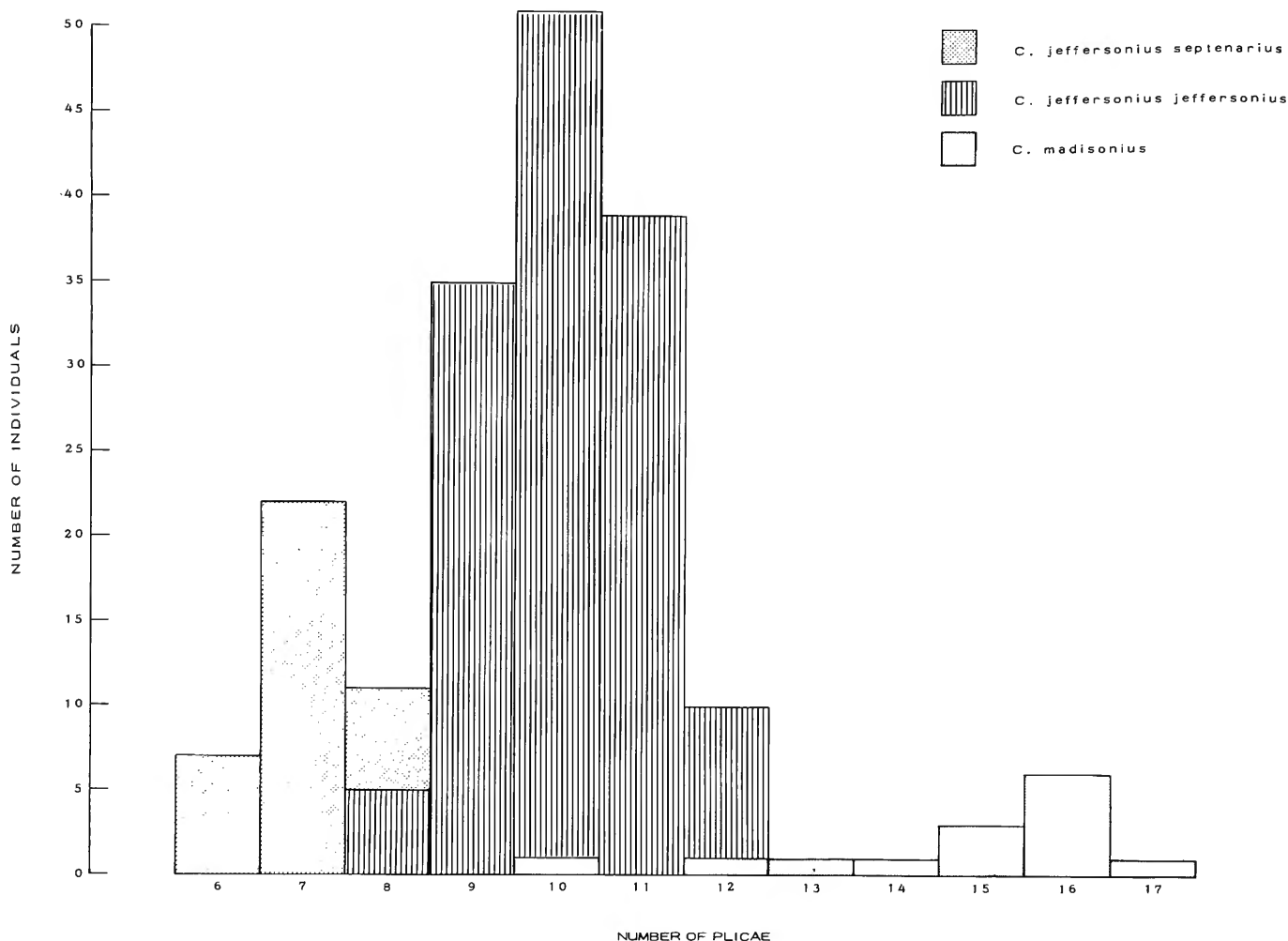


FIGURE 23.—Histogram of the number of plicae in various subgroupings of *Chesapecten* from the Yorktown Formation in the Lee Creek Mine.

the plicae in relation to width becomes proportionally less in the larger, older individuals. The scabrous nature of the costae is less developed in *C. jeffersonius jeffersonius*. The convexity of the valve is slightly less in both the right and left valves of *C. jeffersonius jeffersonius*, but this appears to be primarily a result of greater height of the plicae in *C. jeffersonius septenarius* rather than to a basically more convex shape of the valve.

In other shell characters, such as length of hinge line, size of auricles, and shape of disk, no differences could be noted between the two subspecies. *C. jeffersonius septenarius* tends to have a deeper byssal notch with increasing size, but larger populations of both subspecies with an intact byssal notch will be necessary to confirm this.

Because of the general similarity of morphology between the two subspecies, except for characteristics of the plicae, and because even in the plicae there is transition between the two groups in the upper part of zone 1 of Mansfield,

the two groups are considered chronologic subspecies rather than separate species.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE.**—In the Lee Creek Mine, specimens occur commonly in units 1 to 3 of the Yorktown Formation of Gibson (1967); specimens in unit 3 are transitional to *C. jeffersonius septenarius*. This subspecies has been reported from Mansfield's zones 1 and 2 of the Yorktown Formation in Virginia and North Carolina. It is likely that most or all of the occurrences in zone 2 should be referred to *C. jeffersonius septenarius* and that *C. jeffersonius jeffersonius* is characteristic of zone 1 only. In addition, the subspecies is found in roughly time-equivalent Pliocene strata southward through South Carolina and Georgia into Florida.

**MEASURED MATERIAL.**—Total specimens measured of *Chesapecten jeffersonius jeffersonius* include 27 right valves and 19 left valves (USNM 363017, 363019–363021) from USGS 25338 and 1 right valve and 1 left valve (USNM

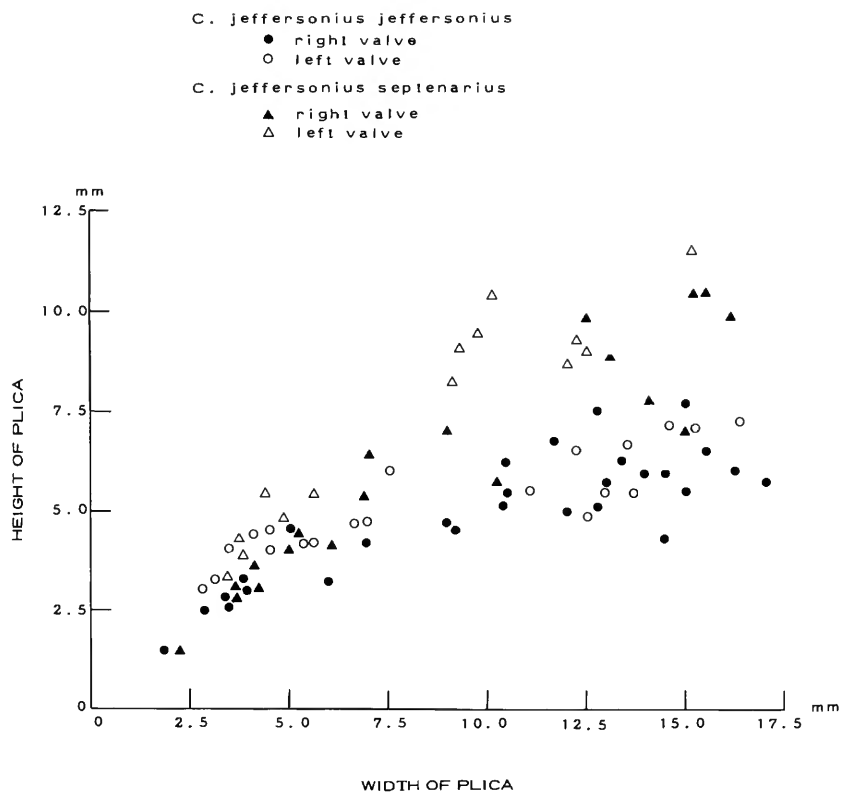


FIGURE 24.—Bivariate scatter diagram showing the greater height of the plica in relation to the width in *Chesapecten jeffersonius septenarius* than in *C. jeffersonius jeffersonius* from the Yorktown Formation in the Lee Creek Mine.

TABLE 15.—Measurements (in mm) of a representative sample of *Chesapecten jeffersonius jeffersonius*.

Character	USNM	USNM		USNM	USNM	USNM
	363017	363018	363018	363019	363020	363021
	(D)	(S)	(D)	(S)	(S)	(D)
H	86	123	123	75	27	29
AHL	46.0	63.0	64.0	38.0	12.0	14.5
PHL	50.0	67.0	67.0	40.0	13.0	14.5
L	96	130	131	78	25	29
ADHD	39	60	60	35	16	16
PDHD	40	65	62	37	16	18
CON	16.4	27.4	21.6	16.7	8.1	5.6
HAA	15.0	23.0	20.0	15.0	7.5	5.5
HPA	16.0	29.0	28.0	15.0	7.0	7.5
LAA	25	31	33	20	8	9
LPA	25	32	31	19	8	8
HL	50	63	64	39	16	17
DBN	22.0	—	32.0	—	—	6.5
BN	3.0	—	1.0	—	—	2.5
WP	10.6	12.2	14.4	6.9	3.2	3.4
WI	5.8	10.5	9.5	5.6	3.0	1.8
HR	5.4	6.4	6.0	4.7	3.2	2.8
NRIB	10	9	9	11	8	10

363018) from USGS 25339. Both USGS collections are from spoil banks of Yorktown Formation in the Lee Creek Mine, North Carolina. Measurements (in mm) from a representative sample of 6 valves are given in Table 15.

*Chesapecten jeffersonius septenarius* (Say)

PLATE 21: FIGURES 7, 8; PLATE 22: FIGURES 2, 3; PLATE 23: FIGURES 1–3, 6, 7; PLATE 24: FIGURES 1, 2; PLATE 25: FIGURE 5; PLATE 26: FIGURE 2

*Pecten septenarius* Say, 1824:136, pl. 9: fig. 3.  
*Pecten Jeffersonius* var. *septenarius* Say.—Dall, 1898:722.  
*Pecten (Chlamys) jeffersonius septenarius* Say.—Mansfield, 1936:174–175, 179, 184–185.  
*Chlamys (Lyropecten) jeffersonius septenarius* (Say).—Tucker-Rowland, 1938:20–21, pl. 3: fig. 15.  
*Chesapecten septenarius* (Say).—Ward and Blackwelder, 1975:15–16, pl. 6:figs. 5–7, pl. 7: figs. 2, 9.

DESCRIPTION.—*Shell Outline*: Shell large, attaining height of 132 mm; both valves convex, with left valve moderately convex and right valve of low convexity. Outline of disk almost equilateral with slight posterior obliqueness;

shells slightly longer than high, more pronounced in larger specimens. No disk gape.

**Auricles and Outer Ligament:** Right anterior auricle with planar surface; dorsal margin nearly coincident with groove of outer ligament and slightly folded; byssal notch of moderate depth with subangular apex; byssal fasciole poorly developed; ctenolium with 3 or 4 teeth well developed in specimens up to 75 mm height, absent in larger individuals. Left anterior auricle with concave surface; dorsal margin flat and coincident with trace of outer ligament; free margin curved with a moderately broad and shallow byssal sinus. Posterior auricles similar in size to anterior; surfaces planar to slightly concave; free margins curves. Anterior and posterior outer ligaments about equal in length. Moderate auricular gape anteriorly and posteriorly.

**Exterior Shell Surface:** Valves with 6 to 8 large plicae; in early growth stages plicae have vertical sides and a flat summit with an overhanging edge; in later stages plicae lose the overhanging edge and may retain vertical sides or become slightly sloping; plicae slightly wider than interspaces. Radial costae are strongly developed on shell and have a scabrous appearance where crossed by the concentric lamellae; costae number as many as 20 on the summit of the plicae, up to 9 on the sides of the plicae, and as many as 15 in the interspaces; costae are of varying strengths and additional ones come in by intercalation. Concentric lamellae well developed over the valves. Auricles have about 25 costae of about equal strength; well-developed concentric lamellae give a scabrous appearance. Disk flanks steep and covered with fine costae.

**Interior Features:** Resilial insertion about 1½ to 2 times as high as long; oriented with a slight posterior slope; single weakly developed auricular denticle both anteriorly and posteriorly.

**DISCUSSION.**—A gradational change in the characteristics of *C. jeffersonius* occurs vertically through the Yorktown Formation. In the uppermost part of Mansfield's zone 1, the population samples contain some individuals with fewer plicae that have square sides and are moderately high in the early ontogenetic stages. In the lower part of zone 2 these characteristics are well developed throughout the ontogeny of most individuals and dominate the populations. The populations in zone 2 are considered a chronologic subspecies, *C. jeffersonius septenarius*, in which the gradational change from its predecessor, *C. jeffersonius jeffersonius*, takes place during the upper part of zone 1. *Chesapecten jeffersonius septenarius* is very similar to its ancestral form in most characteristics, but it is decidedly different in the characters of the plicae. The younger subspecies has fewer plicae, ranging from 6 to 8 with a mean of 6.9 (Figure 23) for the Lee Creek sample compared to a range of 8 to 12 with a mean of 10.1 for the sample of *C. jeffersonius jeffersonius* from the Lee Creek Mine. In addition, the plicae in *C.*

*jeffersonius septenarius* are higher in relation to the width (Figure 24), and have a squared cross-sectional profile with flattened summits and vertical sides. In the early and middle stages of ontogeny the plicae exhibit an overhang at the edge (Plate 22: figure 3), although the plicae become more rounded in later growth stages. Other morphologic differences are the presence in *C. jeffersonius septenarius* of a more strongly developed scabrous ornamentation, a deeper byssal notch and sinus, and the thickening of the early part of the interior of the shell by additional shell layers. The shell thickening is similar to that found in *C. madisonius*, but it does not reach the thickness found in later forms of *C. madisonius*.

An additional subspecies from the Yorktown Formation, *C. jeffersonius palmyrensis*, was described by Mansfield (1936) from Palmyra Bluff on the Roanoke River in North Carolina, a locality he placed in the lower part of his zone 2. The holotype is the only known complete specimen in the USNM collections. It was characterized by Mansfield as having four high, very broad plicae with flattened summits. The plicae have overhanging edges in the umbonal area. Although Mansfield mentioned only four plicae, there is a small plica on each margin of the holotype, which is reflected on the interior of the shell, giving a count of six plicae by the writer's method. Fragments of valves having similarly large plicae have been found at several localities in the Yorktown Formation in North Carolina. Because of the absence of adequate samples, it is uncertain whether the holotype is an extreme variant of *C. jeffersonius septenarius*.

TABLE 16.—Measurements (in mm) of a representative sample of *Chesapecten jeffersonius septenarius*.

Character	USNM 218910		USNM 218915	USNM 363022	USNM 363023	USNM 363024
	(S)	(D)	(D)	(S)	(D)	(S)
H	73	73	104	132	35	31
AHL	38.0	37.0	53.0	60.0	15.5	14.0
PHL	40.0	41.0	61.0	78.0	18.0	15.5
L	78.0	48.0	114.0	138.0	33.5	29.5
ADHD	36	40	52	60	18	19
PDHD	40	44	56	72	22	18
CON	21.6	15.5	28.3	38.1	7.2	7.9
HAA	18.0	15.5	20.5	30.0	7.0	9.0
HPA	18	18	21	27	7	8
LAA	24.0	25.0	—	33.0	10.5	9.0
LPA	23	23	33	38	10	9
HL	47.0	48.0	—	71.0	20.5	18.0
DBN	—	17	29	—	7	—
BN	—	8.0	—	—	3.5	—
WP	10.1	13.1	16.1	15.1	5.2	3.8
WI	12.0	8.8	14.5	14.2	3.9	3.9
HR	10.4	8.8	9.9	11.5	4.4	4.3
NRIB	6	7	7	7	7	7

or subspecifically distinct. For the present it is retained as a separate taxon.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE**—In the Lee Creek Mine, specimens occur fairly commonly in units 3 to 5 of the Yorktown Formation of Gibson (1967). Specimens of this subspecies are common in the lower part of Mansfield's zone 2 of the Yorktown Formation but become rare in the upper part of the zone. The subspecies is found in the Yorktown Formation from the York River in Virginia southward to the Lee Creek Mine in North Carolina.

**MEASURED MATERIAL**—Total specimens measured of *Chesapecten jeffersonius septenarius* include 20 right valves and 15 left valves (USNM 218910, 218915, 363022–363024) from USGS 25338, collected from spoil banks of the Yorktown Formation in the Lee Creek Mine, North Carolina. Measurements (in mm) from a representative sample of 6 valves are given in Table 16.

### *Chesapecten madisonius* (Say)

PLATE 22: FIGURE 1; PLATE 24: FIGURES 3–5; PLATE 25: FIGURES 1–4, 6;  
PLATE 26: FIGURES 1, 3–5

*Pecten Madisonius* Say, 1824:134 [not *Pecten madisonius* of authors subsequent to Say].

*Pecten Edgecombensis* Conrad, 1862:291.

*Pecten jeffersonius edgecombensis* Conrad.—Mansfield, 1936:174–175, 179, 184–185.

*Chlamys (Lyropecten) jeffersonius edgecombensis* (Conrad).—Tucker-Rowland, 1938:15–16, pl. 2: fig. 5, pl. 4: fig. 6.

*Chesapecten madisonius* (Say).—Ward and Blackwelder, 1975:16–18, pl. 6: figs. 1–4; pl. 7: figs. 1, 7, 8.

**DESCRIPTION**—*Shell Outline*: Shell of large size, attaining height of 133 mm; both valves of low to moderate convexity, with left valve more convex than right; convexity reaches 27 mm in left valves and 23 in right. Outline of disk equilateral; shells slightly longer than high, more pronounced in larger specimens. No disk gape.

*Auricles and Outer Ligament*: Right anterior auricle with planar surface; dorsal margin nearly coincident with groove of outer ligament and slightly folded; byssal notch of moderate depth with subangular apex; byssal fasciole poorly developed; ctenolium with 3 or 4 teeth well developed in specimens up to height of 65 mm, absent in larger individuals. Left anterior auricle with concave surface; dorsal margin flat and coincident with trace of outer ligament; free margin curved with a broad and moderately shallow byssal sinus. Posterior auricles similar in size to anterior; surfaces planar to slightly concave; free margins straight and perpendicular to hinge line. Anterior and posterior outer ligaments about equal in length. Moderate auricular gape anteriorly and posteriorly.

*Exterior Shell Surface*: Valves with 10 to 17 plicae; in early growth plicae have vertical sides with a flat summit;

in later growth stages plicae have rounded summits and sloping sides; plicae wider than interspaces. Radial costae well developed on shell and have a scabrous appearance where crossed by the concentric lamellae; costae number as many as 10 on the summit of the plicae, up to 4 on the sides of the plicae, and as many as 7 in the interareas; costae are of varying strengths and additional ones come in by intercalation. Concentric lamellae well developed over the valves. Auricles have as many as 30 costae of about equal strength; well-developed concentric lamellae give a scabrous appearance. Disk flanks steep on left valves, moderately sloping on right, covered with costae.

*Interior Features*: Resilial insertion about 1½ times as high as long; oriented with a slight posterior slope; single weakly developed auricular denticle, both anteriorly and posteriorly.

**DISCUSSION**.—Ward and Blackwelder (1975) reinstated the name *C. madisonius* Say on the basis of this name having been applied to a different species than what they determined to be the type lot in the Academy of Natural Sciences of Philadelphia.

As Mansfield (1936:184) indicated, *C. madisonius* (= *C. edgecombensis* of authors subsequent to Say) is part of the *C. jeffersonius* lineage and appears at approximately the same time as *C. jeffersonius septenarius*. The appearance of the two taxa indicates a splitting of the *C. jeffersonius* stock according to Mansfield's (1936) phylogeny. Although populations of *C. jeffersonius septenarius* are characterized by fewer plicae compared to the present *C. jeffersonius jeffersonius* stock, populations of *C. madisonius* have a greater number of plicae. *C. madisonius* from the Lee Creek Mine have from 10 to 17 plicae with a mean of 14.8 compared to 10.1 for *C. jeffersonius jeffersonius* (Figure 23). Stratigraphically younger populations of *C. madisonius* from other localities have a higher mean number. The plicae in *C. madisonius* are considerably lower than in subspecies of *C. jeffersonius*, and they are rounded in cross-section (Plate 22: figures 1–4) in contrast to the squared plicae in the time-equivalent populations of *C. jeffersonius*.

The anterior and posterior auricles of *Chesapecten madisonius* are essentially equal in height on each valve in contrast to the right valve of both subspecies of *C. jeffersonius* in which the posterior auricle is higher than the anterior one. The depth of the byssal notch is comparable to *C. jeffersonius*, but it is most similar to the population of *C. jeffersonius septenarius*, which has a slightly deeper notch. *C. madisonius* is also similar to *C. jeffersonius septenarius* in the thickening of the shell by the addition of calcite to the inside of the valve. In *C. madisonius* the thickness becomes greater in the later forms and is considerably thicker than found in the other forms of the lineage. Although the convexity of the valves is similar between *C. madisonius* and *C. jeffersonius jeffersonius*, it is consistently less in the former than in the

time equivalent populations of *C. jeffersonius septenarius*. The right valve of *C. madisonius* is comparatively less convex than the left in relation to *C. jeffersonius*.

The scabrous ornamentation is not as strongly developed in this species as it is in *C. jeffersonius*. The early and middle ontogenetic stages of *C. madisonius* have only three costae on the summits of the plicae (Plate 24: figure 5), and are probably the source of reports of *C. madisonius* (= *C. nefrens* of Ward and Blackwelder) from the Yorktown Formation. The increased number of costae on the plicae during ontogeny arise by intercalation. The lesser number of costae in *C. madisonius* mainly is a reflection of the greater number of plicae, and thus narrower width of each plica.

In most characteristics the population of *C. madisonius* from the Lee Creek Mine is of an early to middle stage of development, not the latest, of the *C. madisonius* lineage.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE.**—In the Lee Creek Mine, this species is found in units 3 to 5 of the Yorktown Formation of Gibson (1967), where it is moderately common. The species occurs in Mansfield's zone 2 of the Yorktown Formation from the York River in Virginia southward to the Lee Creek Mine in North Carolina. It is a useful guide fossil to zone 2.

**MEASURED MATERIAL.**—Total specimens measured of *Chesapecten madisonius* include 7 right valves and 7 left valves (USNM, 218908, 218916, 218919, 363025) from USGS 25338, collected from spoil banks of Yorktown Formation in the Lee Creek Mine, North Carolina. Measurements from a representative sample of 6 valves are given in Table 17.

### *Chesapecten coccymelus* (Dall)

PLATES 27–30

*Pecten* (*Chlamys*) *coccymelus* Dall, 1898:741–742, pl. 34: fig. 1.—Glenn, 1904:374–375, pl. 99: fig. 3.

*Chlamys* (*Chlamys*) *coccymelus* (Dall).—Rowland, 1936b:1007–1008, pl. 8: figs. 3–4.

*Chlamys* (*Lyropecten*) *madisonius bassleri* Tucker-Rowland, 1938:13–14, pl. 5: fig. 1.

*Chesapecten coccymelus* (Dall).—Ward and Blackwelder, 1975:8–9, pl. 3: figs. 1, 2, pl. 7: figs. 14, 15.

**DESCRIPTION.**—*Shell Outline:* Shell of medium size, attaining height of 58 mm; both valves of moderate convexity, with left valve more convex than right. Outline of disk equilateral; smaller valves slightly higher than long, larger valves of equal height and length; slight disk gape anteriorly and posteriorly.

*Auricles and Outer Ligament:* Right anterior auricle with planar surface; dorsal margin slightly dorsal to groove of outer ligament and strongly folded; byssal notch deep with an anuglar apex with a 60 to 90 degree angle; byssal fasciole broad, arched near disk, concave away; ctenolium with 4 or 5 teeth well developed throughout all growth stages. Left anterior auricle with concave surface; dorsal margin flat and coincident with trace of outer ligament; free margin slightly curved with a shallow byssal sinus. Posterior auricles much smaller than anterior; surfaces planar to slightly concave; free margins nearly straight, with posterior slope. Anterior outer ligament about 1½ to 2 times as long as posterior.

*Exterior Shell Surface:* Valves with 17 to 19 prominent plicae; plicae have vertical to steeply sloping sides throughout the valve; plicae slightly wider than interspaces. Radial costae strongly developed on shell, with coarsely scabrous appearance where crossed by the concentric lamellae; costae vary in number from 1 to 4 on the summits of the plicae with 3 being the most common; early ontogenetic stages may have only 1 costa on each plica, with the 2 lateral ones being added later; the median costae on the plicae are stronger in development than the lateral ones; the sides of the plicae have 1 to 3 finely scabrous plicae; the interspaces commonly have 3 scabrous plicae with the central one being considerably stronger; all costae have strongly projecting spines, which may be recurved toward the umbo. Right anterior auricle has 6 coarse costae and may have 1 or 2 weakly developed ones intercalated between the more ventral strong ones; well developed but weakly spinose lamellae; other auricles with 8 to 15 fine costae, strongly spinose. Disk flanks on right valves have moderate slope, and have several fine costae; left valves have steep disk flanks with 5 or 6 scabrous costae.

*Interior Features:* Resilial insertion somewhat higher than long; oriented with a slight to moderate posterior slope; single auricular denticle weakly developed both anteriorly and posteriorly.

TABLE 17.—Measurements (in mm) of a representative sample of *Chesapecten madisonius*.

Character	USNM 218908 (D)	USNM 218916		USNM 218919		USNM 363025 (S)
		(S)	(D)	(D)	(S)	
H	130	66	64	82	83	133
AHL	66	32	31	45	41	68
PHL	74	35	35	42	44	70
L	140	67	66	87	85	138
ADHD	62	33	31	44	38	62
PDHD	74	36	33	43	46	68
CON	22.8	13.0	8.4		–	26.3
HAA	23	16	13	16	17	27
HPA	27	15	14	17	18	32
LAA	40	21	21	28	24	37
LPA	38	18	18	23	24	55
HL	78	39	39	51	48	72
DBN	34	–	15	20		
BN	6		6	8		
WP	8.9	3.9	3.8	–		8.6
WI	6.2	2.4	3.2	–		5.3
HR	4.6	2.9	2.7	3.1		4.4
NRIB	15	16	16	16	15	16

DISCUSSION.—A number of workers, including Tucker-Rowland (1938), Schoonover (1941), and Mongin (1959) have separated the populations of *Pecten madisonius* (= *C. coccymelus*) that occur in the Calvert and Choptank formations in Maryland into two groups, primarily on the basis of shell size and ornamentation. These consist of a group of small, thin-valved specimens with rows of distally concave spines found in the middle part of the Calvert Formation (bed 10 at Plum Point), and a second group of considerably larger, thicker-valved specimens with considerably less scaly ornamentation, which occur in the upper part of the Calvert and the overlying Choptank Formation. Schoonover (1941) and Mongin (1959) did not propose new names for these groups, although they noted the differences between them. Tucker-Rowland (1938:11) did use *Chlamys* (*Lyropecten*) *madisonius acanikos* (Gardner), a form originally described from the Miocene deposits in Florida, for part of the group found in the Calvert Formation at Plum Point. She (Tucker-Rowland, 1938:13) also named a new subspecies, *Chlamys* (*Lyropecten*) *madisonius bassleri*, for part of the complex group found in the Calvert Formation. *Chlamys coccymelus* was considered to be a rare, but close relative of the other forms found in bed 10.

Ward and Blackwelder (1975) proposed that the specimens within the populations from bed 10 of the Calvert Formation had a continuous range from forms carrying three rows of distally concave spines to the forms of *Chesapecten coccymelus*, which is an end member carrying only one row. This would include most of the bed 10 forms in the senior name, *C. coccymelus*. My examination of population samples taken from bed 10 at two localities near Plum Point supports this treatment. The type specimen of *C. coccymelus* (Plate 29: figure 5) is a relatively small left valve, 30 mm high, which has only one row of spines on the plicae. It has a row of moderate spines in the interspaces and one or more rows of smaller spines. The more common forms of small *Chesapecten* found in bed 10 have three rows of spines on the plicae, although the three rows usually are not equal, the central row being larger than the two lateral ones. The two lateral rows of spines are added at some distance from the origin of growth and become progressively stronger in development (Plate 30: figures 2–4). The place of insertion of the two lateral rows may be within a few millimeters of the origin of growth or as much as 20 mm below the point. In smaller individuals single rows of spines on the plicae are common. The development of a single row of spine is predominantly confined to the left valves. The type specimen of *C. coccymelus* is a left valve, which would contribute to the extreme form of ornamentation. Most right valves have three rows of spines but a few have four rows (Plate 28: figure 3). Another variation in the ornamentation is the common appearance on a single individual at a similar growth stage of plicae bearing three rows of spines and plicae having just a single row (Plate 30: figure 3).

*Chlamys* (*Lyropecten*) *madisonius bassleri* Tucker-Rowland,

1938, is one of the ornamental variations of *Chesapecten coccymelus* found in bed 10 at Plum Point. The holotype of *C. m. bassleri* (Plate 29: figures 1–3) has a median row of large spines surrounded by two lateral rows of smaller spines on the more ventral part of the valve, but the early part of the valve up to a distance of approximately 17 mm from the origin of growth has the single row of spines characteristic of *C. coccymelus*. This specimen also illustrates the variation found in the rows of spines in the interspaces; some interspaces have one dominant row of spines, while other interspaces have two or three essentially equally developed rows of spines.

The specimens found in the upper part of the Pungo River Formation in the Lee Creek Mine include three complete right valves and fragments of other specimens. These specimens from the Pungo River Formation compare well with the population samples from bed 10 of the Calvert Formation at Plum Point, Maryland. A population study was made involving 17 morphologic characters, and the Lee Creek specimens fall well within the range of variation of the population sample from the Calvert Formation in all characters. The depth of the byssal notch is one of the more important characteristics distinguishing *C. coccymelus* from the stratigraphically younger species of *Chesapecten*. Comparison of the specimens from the Pungo River Formation in North Carolina and the Calvert Formation in Maryland indicates no difference in this character (Figure 25). Other characteristics exhibit a similar pattern. The specimens from the Pungo River Formation in North Carolina have a consistency in the ornamentation, with three well-developed rows of spines on the plicae of the right valve (with a fourth being found on the largest valves) and a dominant row of spines in the middle of the interspaces. The samples from the Pungo River Formation does not contain all of the variation in ornamentation found in the samples from the Calvert, such as single rows of spines on the plicae, but this could be due to the relatively small number of specimens recovered.

STRATIGRAPHIC AND GEOGRAPHIC RANGE.—This species is found in the upper 6 to 12 feet (1.8 to 3.7 m) of the Pungo River Formation in the Lee Creek Mine. It is fairly common in the bryozoan shell hash zone that comprises the uppermost 2 to 3 feet (0.6 to 0.9 m) in the test pit (unit 7 of Gibson, 1967), and also in the limey and indurated intervals in the underlying interbedded limestone and phosphatic sand units (units 4 to 6). This species previously has been reported from the middle and lower parts of the Calvert Formation, occurring in bed 10 (Ward and Blackwelder, 1975:9) and possibly as far down in the Calvert as bed 2 (Schoonover, 1941:196, reported as *Chlamys madisonius*). It is a reliable index to the Calvert Formation and serves a similar function in the Pungo River Formation in North Carolina.

MEASURED MATERIAL—Total specimens measured of *Chesapecten coccymelus* include 3 right valves (USNM

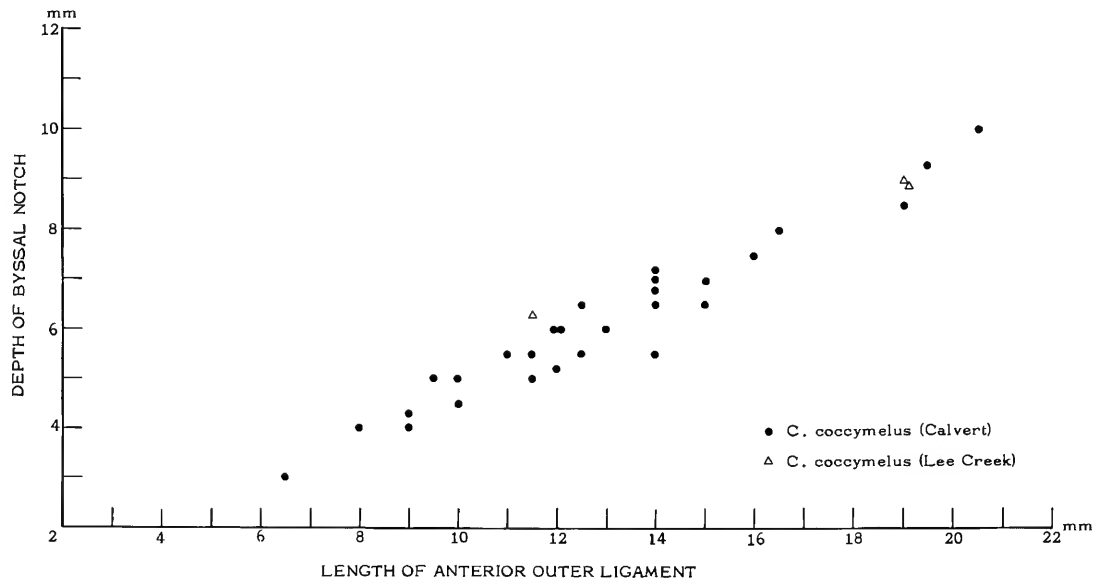


FIGURE 25.—Bivariate scatter diagram showing similarity of depth of the byssal notch between samples of *Chesapecten coccyamelus* from the Calvert Formation, Maryland, and from the Pungo River Formation in the Lee Creek Mine.

TABLE 18.—Measurements (in mm) of a representative sample of *Chesapecten coccyamelus*.

Character	USNM 218922 (D)	USNM 218924 (D)	USNM 218925 (D)	USNM 363026 (D)	USNM 363027 (D)	USNM 363028 (D)	USNM 363029 (D)
H	54.0	52.3	58.0	34.5	46.0	31.0	18.0
AHL	27.5	—	27.0	16.0	22.0	15.0	8.0
PHL	29	—	30	18	24	15	8
L	56.5	53.6	57.0	34.0	46.0	30.0	16.0
ADHD	29	—	31	18	23	22	10
PDHD	29	—	29	17	26	22	11
CON	11.5	8.0	9.4	5.2	8.3	5.3	3.2
HAA	9.0	9.2	10.0	5.5	8.5	6.0	3.5
HPA	13.5	14.0	12.0	8.0	10.5	7.0	5.0
LAA	19.0	19.0	20.5	11.5	16.5	11.5	6.5
LPA	—	—	—	9.0	10.0	7.0	3.5
HL	—	—	—	20.5	26.5	18.5	10.0
DBN	10.0	10.0	10.5	5.2	8.5	6.0	3.5
BN	9.0	9.0	10.0	6.3	8.0	5.5	3.0
WP	2.8	—	2.6	1.2	2.3	1.1	—
WI	3.3	—	3.6	1.8	3.1	1.7	—
NRIB	19	19	17	18	17	19	18

218922, 218924, 363026) from USGS 25338, 13 right valves from USGS 25344, and 19 right valves (USNM 218925, 363027–363029) from USGS 25345. Those from USGS 25338 are from spoil banks of the Pungo River Formation at the Lee Creek Mine, North Carolina; those from USGS 25344 are from the Calvert Formation, 1.5 miles south of Plum Point, Maryland; those from USGS 25345 are from the Calvert Formation at Camp Roosevelt,

Maryland. Measurements from a representative sample of 7 valves are given in Table 18.

### *Chesapecten nefrens* Ward and Blackwelder

PLATE 31: FIGURE 7

*Pecten Madisonius*.—Conrad, 1840:48, pl. 24: fig. 1 [not *Pecten madisonius* Say, 1824].

*Pecten (Chlamys) madisonius*.—Glenn, 1904:377, pl. 100: fig. 1.—Mansfield, 1936:174–177, 184.

*Chlamys (Lyropecten) madisonia*.—Tucker-Rowland, 1938:9–11, pl. 1: figs. 1–2.—Gardner, 1944:32, pl. 4: fig. 5, pl. 9: fig. 7.

*Chlamys (Lyropecten) madisonius*.—Schoonover, 1941:192–201, pl. 21: figs. 1–3, pl. 22: fig. 4, pl. 23: fig. 3.

*Chlamys madisonia*.—Mongin, 1959:309–314, pl. 26: figs. 1a–b.

*Chesapecten nefrens* Ward and Blackwelder, 1975:9–10, pl. 2: figs. 4–6, pl. 3: figs. 4–7, pl. 4: figs. 1–2, pl. 7: figs. 6, 13.

**DESCRIPTION.**—*Shell Outline:* Shell large, with height of 95 mm; right valve of moderate convexity. Outline of disk equilateral; valve longer than high.

*Auricles and Outer Ligament:* Right anterior auricle with planar surface; dorsal margin slightly dorsal to groove of outer ligament and strongly folded; byssal notch deep with angular apex with an 80 degree angle; byssal fasciole broad, arched near disk, planar away; ctenolium with 4 teeth well developed in adult form. Right posterior auricle with planar surface; dorsal margin slightly dorsal to groove of outer ligament; free margin straight, sloping posteriorly. Anterior outer ligament about 1½ times as long as posterior.

*Exterior Shell Surface:* Valve with 19 plicae; plicae of moderate height with steep sides; plicae wider than inter-



spaces. Radial costae strongly developed on shell and have a coarsely scabrous appearance where crossed by the concentric lamellae; 3 costae on the summits of the plicae, the 2 lateral ones being weaker in the early stages and of equal strength in the later; interspaces have 3 costae, with the central one being considerably coarser than the lateral ones; costae have moderately projecting spines or scabrous appearance. Right anterior auricle has 7 moderately coarse costae with low scabrous ornamentation; right posterior auricle has 12 fine costae with scabrous nature. Disk flanks of moderate slope and having several costae.

*Interior Features:* Resilial insertion somewhat higher than long, oriented approximately perpendicular to the hinge line; single auricular denticle weakly developed both anteriorly and posteriorly.

**DISCUSSION.**—The single specimen found in the Lee Creek Mine is probably typical of the stratigraphically earlier members of *C. nefrens*. *C. nefrens* differs from *C. coccy-melus* in being larger in size, having a greater length in relation to height of the disk, in having a longer posterior auricle in relation to the anterior, in having low scabrous costae on the plicae rather than rows of highly recurved spines, and in having a lower and less pronounced plicae.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE.**—One specimen was collected from the uppermost bed of the Pungo River Formation in the Lee Creek Mine (unit 7 of Gibson, 1967). Schoonover (1941) and Ward and Blackwelder (1975) give the stratigraphic occurrence of this species as from bed 14 of the Calvert Formation to bed 19 of the Choptank Formation in Maryland. In the Calvert Cliffs section in Maryland, *C. coccy-melus* occurs in bed 10 (Ward and Blackwelder, 1975:9) and probably below bed 10 (Schoonover, 1941:196, reported as *Chlamys madisonius*). However, both species are found within the upper bed in the Lee Creek Mine, although only *C. coccy-melus* has been found below the upper bed.

**MEASURED MATERIAL.**—Measurements of a single specimen of *Chesapecten nefrens* (USNM 218932) from USGS 25749, Pungo River Formation at the Lee Creek Mine, North Carolina, are given in Table 19.

TABLE 19.—Measurements (in mm) of a specimen of *Chesapecten nefrens*.

Character	USNM 218932 (D)	Character	USNM 218932 (D)
H	95	HPA	17
AHL	54	LAA	29
PHL	53	LPA	
L	107	HL	
CON	17.6	DBN	16
HAA	13	BN	13
		NRIB	19

## Genus *Amusium* Röding, 1798

### *Amusium* sp.

PLATE 31: FIGURES 3, 4

**DISCUSSION.**—The material from the upper part of the Pungo River Formation in the Lee Creek Mine consists of three fragments, each several inches in length. The Lee Creek fragments differ in several characteristics from *Amusium mortoni* (Ravenel), the common species of *Amusium* occurring in the Pliocene and Pleistocene deposits from Virginia to Mexico (Gardner, 1944:39). Although the specimens from the Pungo River Formation have approximately the same moderate convexity of the valve and slight concentric corrugation on the exterior of the valve without radial ornamentation, they are considerably thicker in shell cross-section and have widely separated paired lirae internally (Plate 31: figure 3). This is in contrast to the thin shell and the closely spaced double lirae found in *A. mortoni* (Plate 31: figure 1). The fragments do not allow comparison of other morphologic features. As *A. mortoni* has consistently thin valves and equidistant spacing of interior lirae over its wide geographic and stratigraphic range, it appears that the Lee Creek specimens belong to a different and probably new species. Glenn's (1904:373) report of specimens of *A. mortoni* from the St. Marys Formation in Maryland is in error, apparently as a result of misreading the labels (USGS 2831 and 2835 were read as 2331 and 2325); the specimens in question actually come from the upper part of the Yorktown Formation near Suffolk, Virginia, in line with other reports of the age of the species. Thus, the Lee Creek material is considerably older in age than the reported range of *A. mortoni*.

*Amusium precursor* (Dall, 1898) occurs in the Miocene Chipola Formation in Florida, a unit close in age to the Pungo River Formation (Gibson, 1967:643; Akers, 1972:9). Thus, *A. precursor* is of a generally comparable age to the specimens found in the Lee Creek Mine, but differs in having uniformly closely spaced internal lirae and finely impressed radial lines on the exterior.

As Dall (1898) did not select a holotype or illustrate any specimens of *A. precursor*, a lectotype is here selected and a lectoparatype illustrated (Plate 31: figures 5, 6). The lectotype is an articulated specimen, USNM 647532, from USGS 2213 in the Chipola Formation, one mile (1.6 km) below Bailey's Ferry, Chipola River, Florida. A number of problems are encountered in the selection of the lectotype. Among localities mentioned by Dall (1898:755) in his description of the species are Alum Bluff, from which no material could be found in the museum collections, and others along the Chipola River. Gardner (1926:50) and other writers have taken USGS 2212 (Chipola Formation at Ten Mile Creek) as the type locality, possibly because the

label in the museum collections says "type locality" compared with "cotype locality" for USGS 2213; however, this entry of unknown origin has no standing. In the USNM catalogue for the lots from these localities, the number of specimens listed is fewer than are now in the type lots, indicating that specimens were added to the type lots, whether before or after Dall described this species is not known. The only specimen that can be identified unequivocally with Dall's original material is the largest specimen from USGS 2213, which agrees with measurements given in the original description. Therefore this specimen is picked as the lectotype. All the material in the lots from USGS 2212, 2213, and 2564 will be considered lectoparatypes as there is no feasible way to determine if, or which, specimens may have been added to the type lots, and all the material appears to be conspecific. A lectoparatype is illustrated (Plate 31: figures 5, 6) to show the interior lirae, as the lectotype is an indurated double valve, the interior of which cannot be observed.

Most recovered fossil specimens of *Amusium* are fragmentary and do not show many of the shell characteristics, such as byssal notch and auricles. From the present observations it appears that the internal lirae are distinct specific characters. The three species examined here illustrate differences in internal lirae (Plate 31: figures 1, 3, 6). The paired lirae in specimens from the Lee Creek Mine are separated by wide interspaces, varying from 9 to 10 mm between pairs and also have a wide distance of 7 to 8 mm between lirae of a pair. The lirae in *A. precursor* do not appear in pairs, but as closely spaced independent ones, varying in spacing from 1 to slightly over 2 mm within a single specimen. The lirae in *A. murtoni* occur in pairs, with a very close spacing of 0.2 to 0.5 mm between the lirae within a pair, and with a relatively wide spacing of 3.5 to 5.0 mm between the pairs in the illustrated specimen (Plate 31: figures 1, 2) with a height of 73 mm. Thus it appears that the characteristics of the internal lirae are of considerable help in defining the species, particularly because of the fragmentary nature of most specimens.

**STRATIGRAPHIC AND GEOGRAPHIC RANGE.**—The only known specimens of this possibly new *Amusium* sp. occur in the limy interbedded layers (units 4–6 of Gibson, 1967) in the upper part of the Pungo River Formation in the Lee Creek Mine.

### List of Localities

#### USGS LOCALITIES

- 2025 Darlington County, South Carolina: Shell Branch, 1 mile (1.6 km) east of Darlington Court House. Frank Burns, collector, 1886. Duplin Formation.
- 2106 Cumberland County, New Jersey: marl beds near Jericho. Frank Burns, collector, 1887. Kirkwood Formation.

- 2212 Calhoun County, Florida: Ten Mile Creek, 1 mile (1.6 km) west of Bailey's Ferry on the Chipola River. Frank Burns, collector, 1889. Chipola Formation.
- 2213 Calhoun County, Florida: Chipola River, 1 mile (1.6 km) below Bailey's Ferry. Frank Burns, collector, 1889. Chipola Formation.
- 2447c Calvert County, Maryland: Blakes Cliffs, about 3 miles (4.8 km) north of Plum Point wharf. Burns and Harris, collectors, May 1892. Calvert Formation.
- 2452 James City County, Virginia: "Grove Wharf" on James River, 9 miles (14.5 km) west of Yorktown and 9 miles (14.5 km) south of Williamsburg. Frank Burns, collector, 1892. Yorktown Formation.
- 2564 Calhoun County, Florida: McClelland Farm, 1 mile (1.6 km) below Bailey's Ferry, Chipola River. Frank Burns, collector, 1889. Chipola Formation.
- 3915 Middlesex County, Virginia: river front at Urbanna, between mouth of creek and wharf of Weems Line of steamers on Rappahannock River. Frank Burns, collector, 1903. Lowermost part of Yorktown Formation (= "Virginia St. Marys" beds of Mansfield).
- 3924 Essex County, Virginia: right bank of Rappahannock River at a very high bluff locally known as "Jones Point," 1 mile (1.6 km) north or up the river from "Bay Port" wharf, about 13 miles (21 km) north of Urbanna. Frank Burns, collector, 1903. Lowermost part of Yorktown Formation (= "Virginia St. Marys" beds of Mansfield).
- 8179 Essex County, Virginia: right bank of Rappahannock River about 0.5 mile (0.8 km) downstream from Jones Pt. or 0.5 mile (0.8 km) northeastward from Butylo. W.J. Lee, collector, 1918. Most of this material was picked up from beach, not obtained in place in bank. Lowermost part of Yorktown Formation (= "Virginia St. Marys" beds of Mansfield).
- 10278 Anne Arundel County, Maryland: Howard Post Office. John Shepherd, collector, 1922. Calvert Formation.
- 10962 Liberty County, Florida: cut in road leading to Watsons Landing. W.C. Mansfield and E.C. Bracewell, collectors, 1925. Choctawhatchee Marl.
- 11999 Bertie County, North Carolina: right bank of Chowan River, 0.75 mile (1.2 km) below Mt. Gould Landing, from bed exposed from beach to 10 feet (3 m) above river beach. W.C. Mansfield, collector, 1929. Yorktown Formation.
- 23468 Middlesex County, Virginia: collected along beach of Rappahannock River from Urbanna to fish

- cannery. T.G. Gibson, D. Wilson, and R. Brody, collectors, 1963. Float material mixed with Holocene material, but most is Miocene, which has weathered from bluffs.
- 23565 Anne Arundel County, Maryland: Paul Basford Farm, on north side of Maryland Highway 424, about 1.2 miles (1.9 km) SE of Davidsonville. D. Wilson and H. Vokes, collectors, ca. 1958. Calvert Formation.
- 25338 Beaufort County, North Carolina: Lee Creek Mine, near Aurora. Spoil banks, west of access road to central part of pit. T. Gibson, collector, August 1972. Pungo River and Yorktown formations.
- 25339 Beaufort County, North Carolina: Lee Creek Mine, near Aurora. Float from spoil piles. D. Wilson and others, collectors, 1969–1973. Pungo River and Yorktown formations.
- 25344 Calvert County, Maryland: 1.5 miles (2.4 km) south of Plum Point. Charles Buddenhagen, collector, 1965. Calvert Formation, bed 10.
- 25345 Calvert County, Maryland: 0.5 miles (0.8 km) below Camp Roosevelt. Thor Hansen, collector, 1969. Calvert Formation, bed 10.
- 25364 Beaufort County, North Carolina: Lee Creek Mine, on the right bank of the Pamlico River, 5.5 miles (8.8 km) north of Aurora; section on northwest wall of main pit, in 5 foot (1.5 m) thick bed of gray sand, 16 feet (4.9 m) below the top of the pit. L.W. Ward and others, collectors, February 1972. Yorktown Formation, upper shell bed.
- 25743 Beaufort County, North Carolina: Lee Creek Mine. Jack McLellan, collector, 1970s. Spoil piles. Pungo River and Yorktown formations.
- 25744 Anne Arundel County, Maryland: Paul Basford Farm, on north side of Maryland Highway 424, about 1.2 miles (1.9 km) SE of Davidsonville; in small stream gully NW of tobacco barn. T. Gibson and others, collectors, July, 1968. Calvert Formation.
- 25745 Wakulla County, Florida: Taff Pit, south of Crawfordville. Muriel Hunter, collector, ca. 1970. Torreya Formation.
- 25746 Beaufort County, North Carolina: Lee Creek Mine, near Aurora, from northwest wall of test pit, 2 foot (0.6 m) bed of blue sand, 11 feet (3.4 m) above base of Yorktown Formation, underlain by channeled surface. T. Gibson, collector, January 1964. Yorktown Formation (unit 3 of Gibson, 1967).
- 25747 Northampton County, North Carolina: bluff on right bank of Meherrin River about 3 miles (4.8 km) above the Highway 258 Bridge; sample taken in interval of blue clayey sand, 1 to 5 feet (0.3 to 1.5 m) above water level. T. Gibson and D. Wilson, collectors, May 1963. Lowermost part of Yorktown Formation.
- 25748 Beaufort County, North Carolina: shell fragments from limey layers, spoil piles, Lee Creek Mine, near Aurora. Jack McLellan, collector, April 1974. Pungo River Formation.
- 25749 Beaufort County, North Carolina: Lee Creek Mine, near Aurora. Jack McLellan, collector, April 1974. Uppermost part of Pungo River Formation.
- 25757 Beaufort County, North Carolina: Lee Creek Mine, near Aurora, Lot 211. Jack McLellan, collector, 1970s. Upper calcareous layers of Pungo River Formation.
- 25758 Bertie County, North Carolina: bluff on west side of Chowan River, about 0.5 mile (0.8 km) below Mt. Gould Landing, at W.H. Fowler place (old Steele place), 3–5 feet (0.19–1.5 m) above beach. T. Gibson and D. Wilson, collectors, 1963. Yorktown Formation.

## USFC STATION

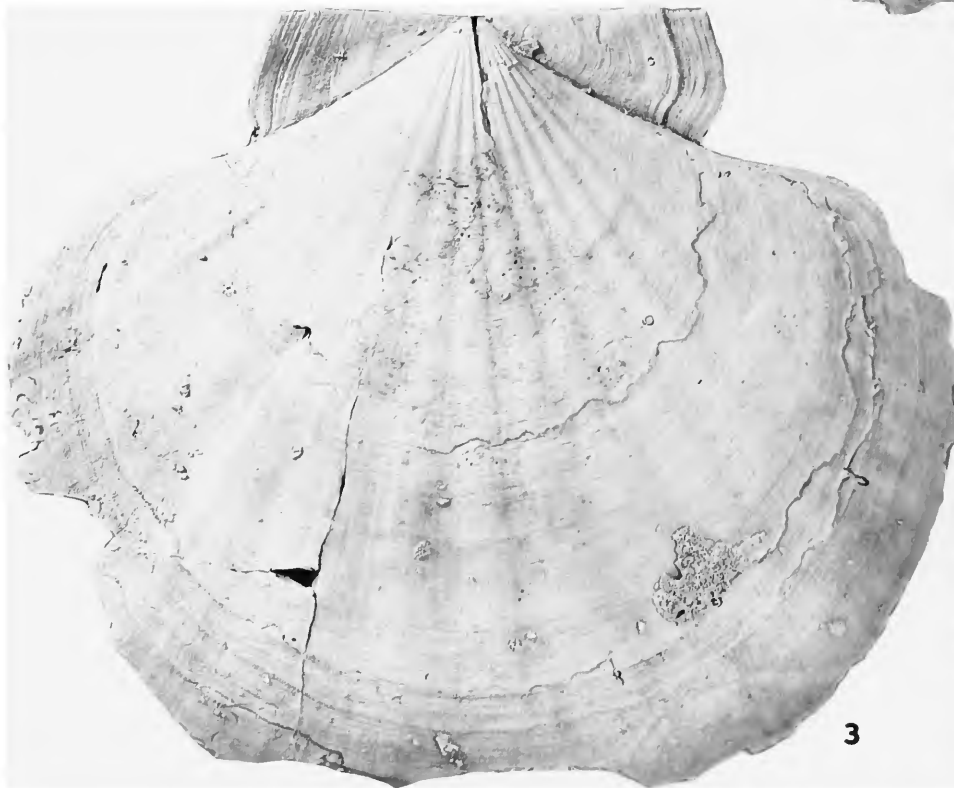
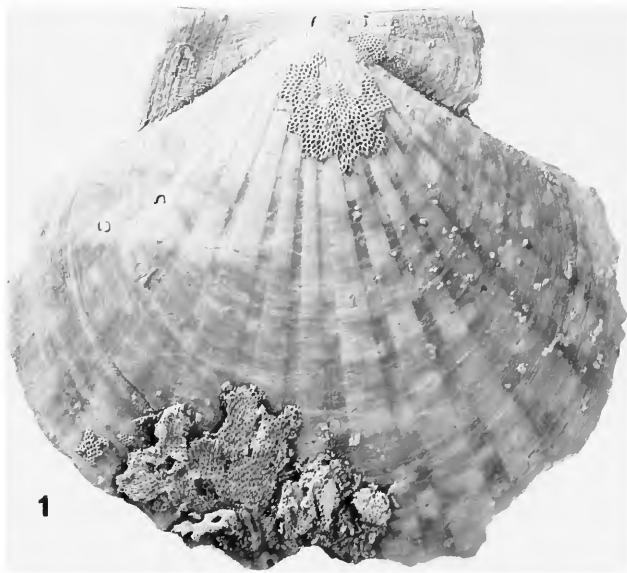
- 2244 Western North Atlantic Ocean, SE of Long Island, U.S.A., 40°05'15" N, 70°23'00" W, 67 fathoms (121 m), green mud and sand, bottom temperature, 52.9°

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## PLATE 1

*Pecten mclellani*, new species, Pungo River Formation,  
Lee Creek Mine, USGS 25743

1. Paratype, USNM 218828, external view of right valve,  $\times 1.5$ .
2. Paratype, USNM 218829, external view of right valve,  $\times 1$ .
3. Holotype, USNM 218830, external view of right valve,  $\times 1$ .

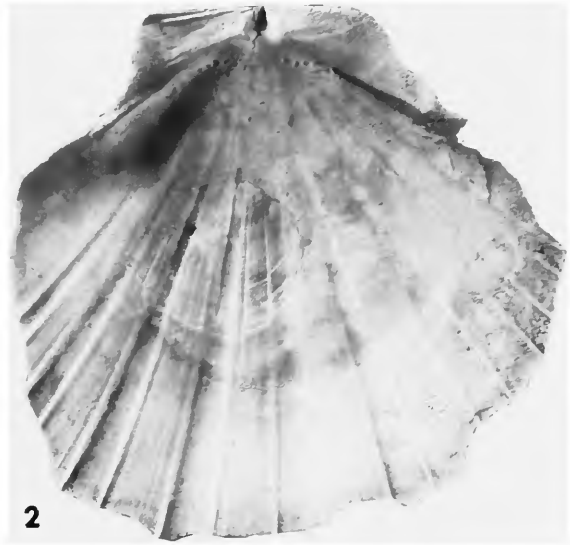


PLATE 2

*Pecten mclellani*, new species, Pungo River Formation,  
Lee Creek Mine, USGS 25743

- 1, 2. Paratype, USNM 218831, external and internal views of left valve,  $\times 1$ .
3. Holotype, USNM 218830, internal view of right valve,  $\times 1$ .



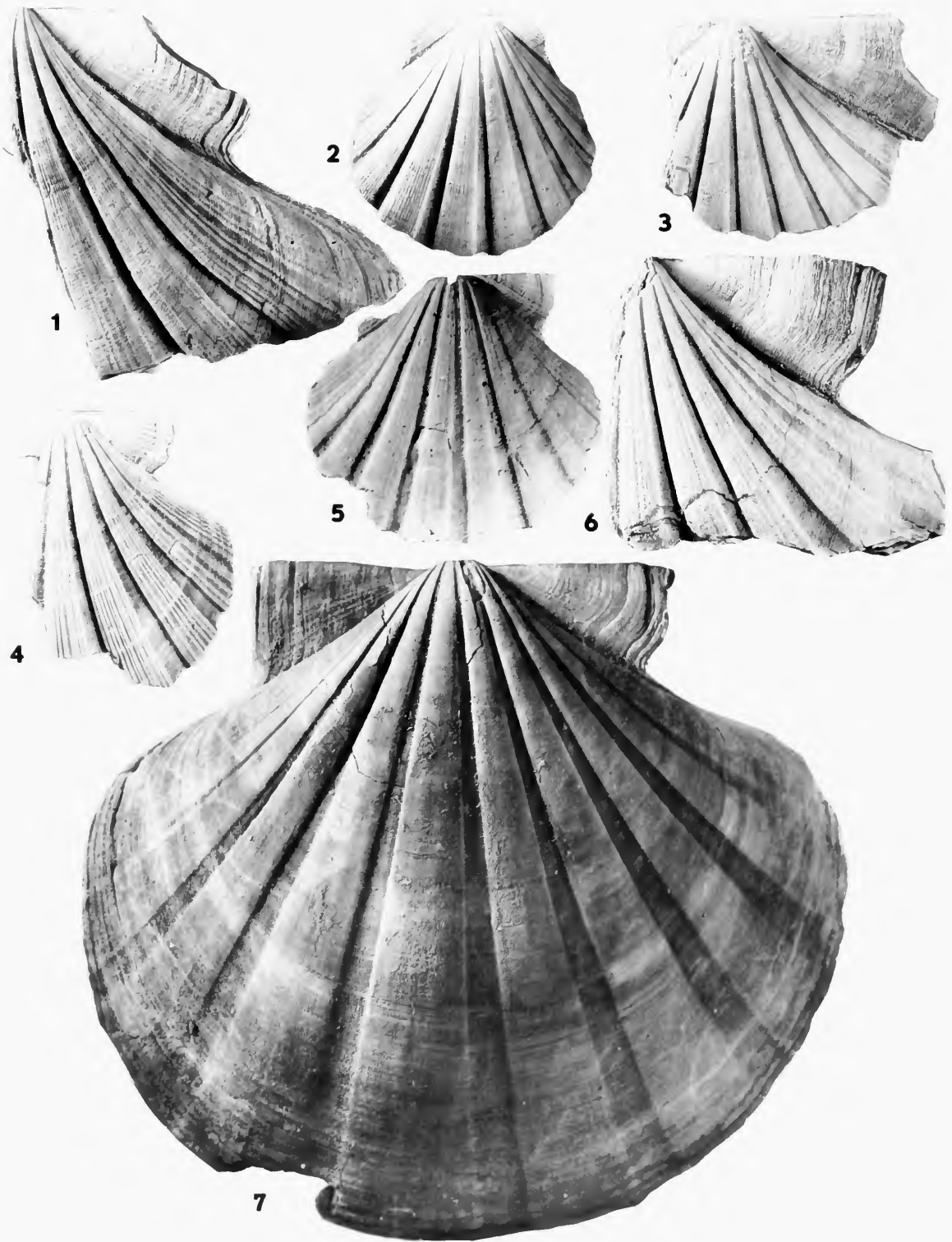


PLATE 3

1. *Pecten humphreysi woolmani* Heilprin, Kirkwood Formation, Jericho, New Jersey, USNM 218832, USGS 2106, external view of partial right valve,  $\times 1$ .
- 2, 4, 7. *Pecten humphreysi humphreysi* Conrad, Calvert Formation, Davidsonville, Maryland: 2, USNM 218833, USGS 23565, external view of right valve,  $\times 1$ ; 4, USNM 218835, USGS 25744, external view of partial right valve,  $\times 1$ ; 7, USNM 218838, USGS 23565, external view of right valve,  $\times 1$ .
- 3, 5, 6. *Pecten humphreysi humphreysi* Conrad, Pungo River Formation, Lee Creek Mine: 3, USNM 218834, USGS 25339, external view of partial right valve,  $\times 1$ ; 5, USNM 218836, USGS 25743, external view of right valve,  $\times 2$ ; 6, USNM 218837, USGS 25339, external view of partial right valve,  $\times 1$ .



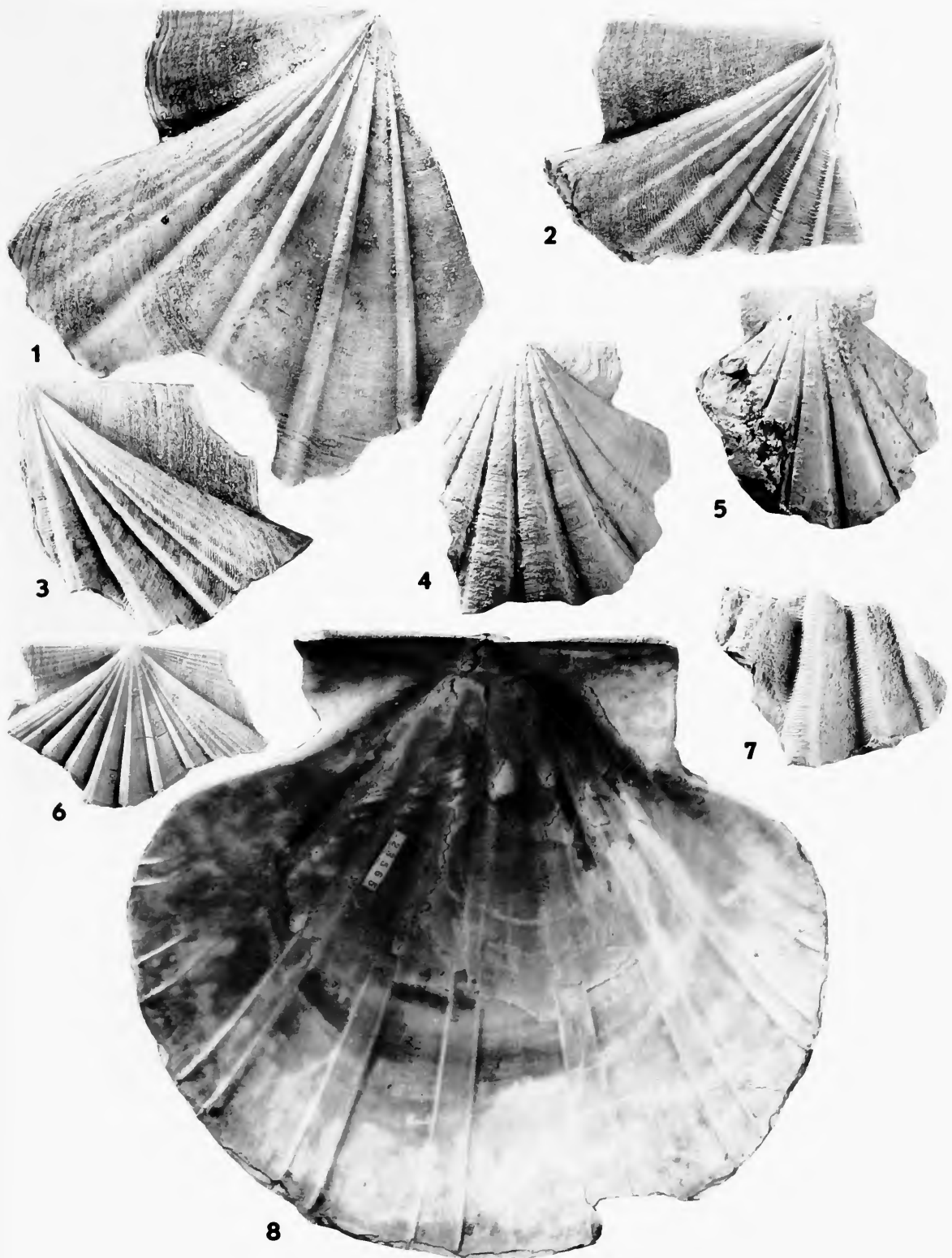
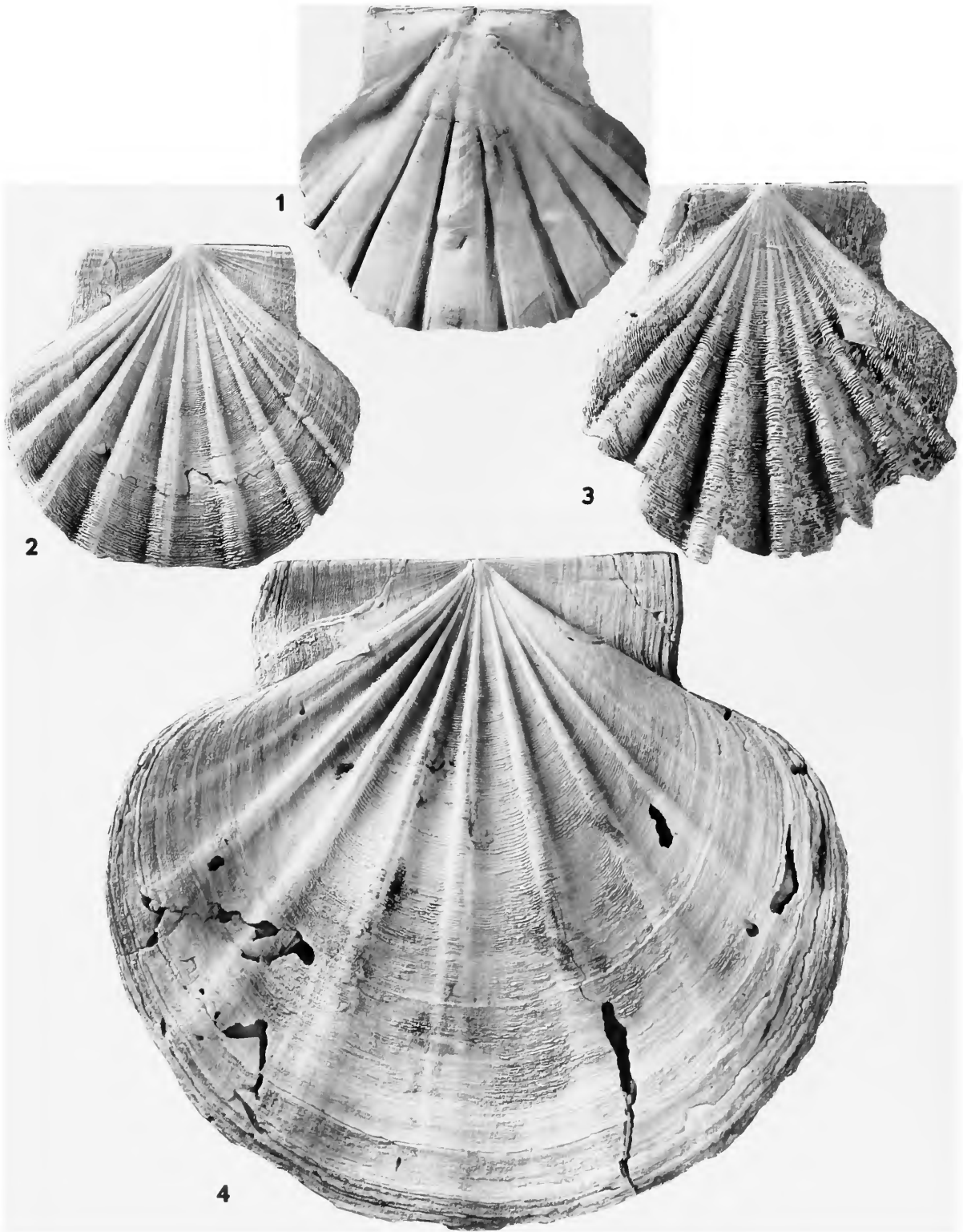


PLATE 4

- 1-3, 7. *Pecten humphreysii humphreysii* Conrad, Pungo River Formation, Lee Creek Mine, external view of partial left valve: 1, USNM 218839, USGS 25339,  $\times 1$ ; 2, USNM 218840, USGS 25339,  $\times 1$ ; 3, USNM 218841, USGS 25339,  $\times 1$ ; 7, USNM 218845, USGS 25339,  $\times 1$ .
- 4-6. *Pecten humphreysii humphreysii* Conrad, Torreya Formation, Crawfordville, Florida, USGS 25745: 4, USNM 218842, external view of partial right valve,  $\times 1$ ; 5, USNM 218843, external view of partial right valve,  $\times 1.5$ ; 6, USNM 218844, external view of partial left valve,  $\times 1$ . (From Banks and Hunter, 1973.)
8. *Pecten humphreysii humphreysii* Conrad, Calvert Formation, Davidsonville, Maryland, USNM 218838, USGS 23565, internal view of right valve,  $\times 1$ .



## PLATE 5

- 1, 2, 4. *Pecten humphreysii humphreysii* Conrad, Calvert Formation, Davidsonville, Maryland, left valve: 1, USNM 218846, USGS 25744, external view,  $\times 1.5$ ; 2, USNM 218846, USGS 25744, internal view,  $\times 1.5$ ; 4, USNM 218838, USGS 23565, external view,  $\times 1$ .
3. *Pecten humphreysii woolmani* Heilprin, Kirkwood Formation, Jericho, New Jersey, USNM 218847, USGS 2106, external view of left valve,  $\times 2$  (see also, Whitfield, 1894, pl. 4: fig. 7).

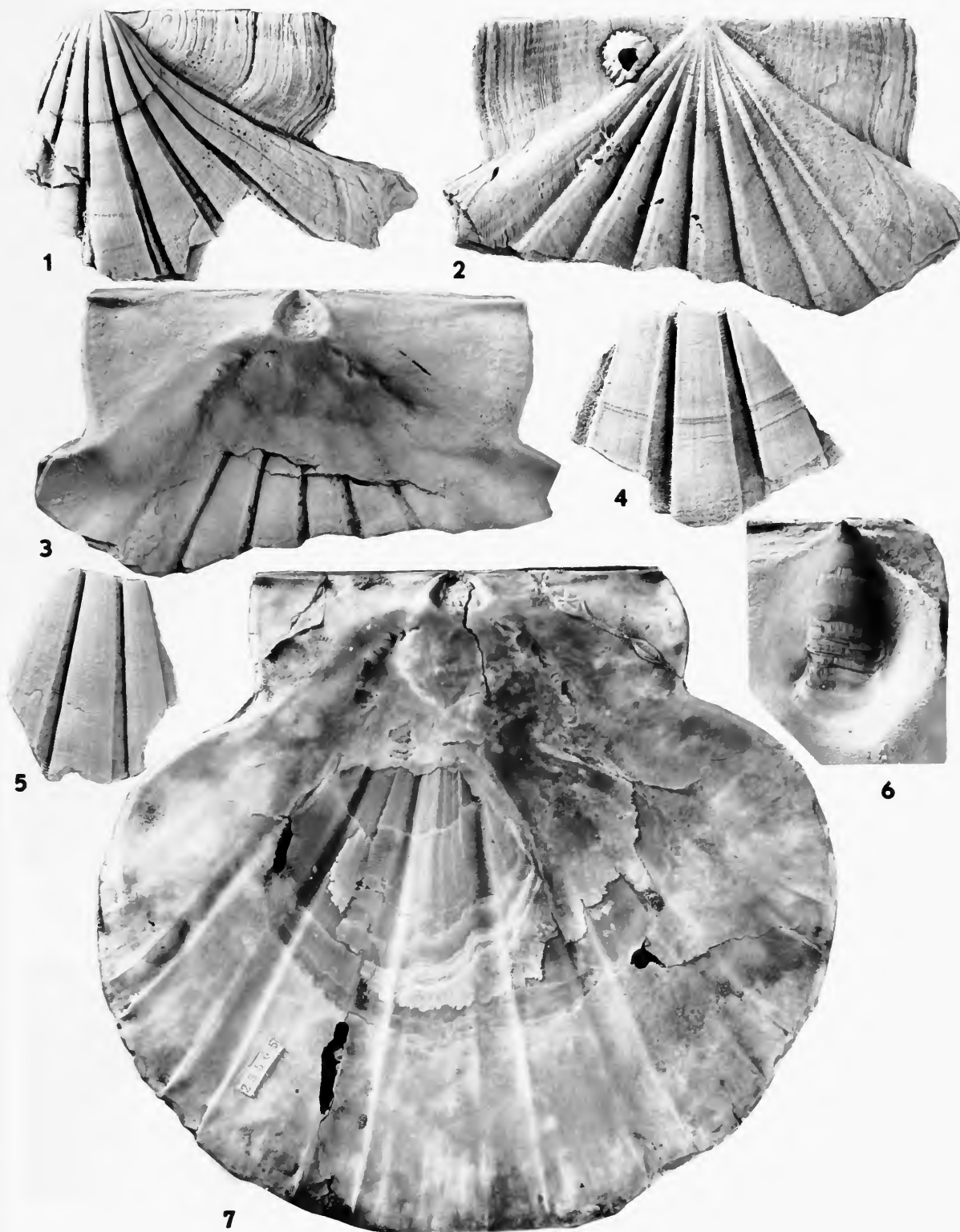
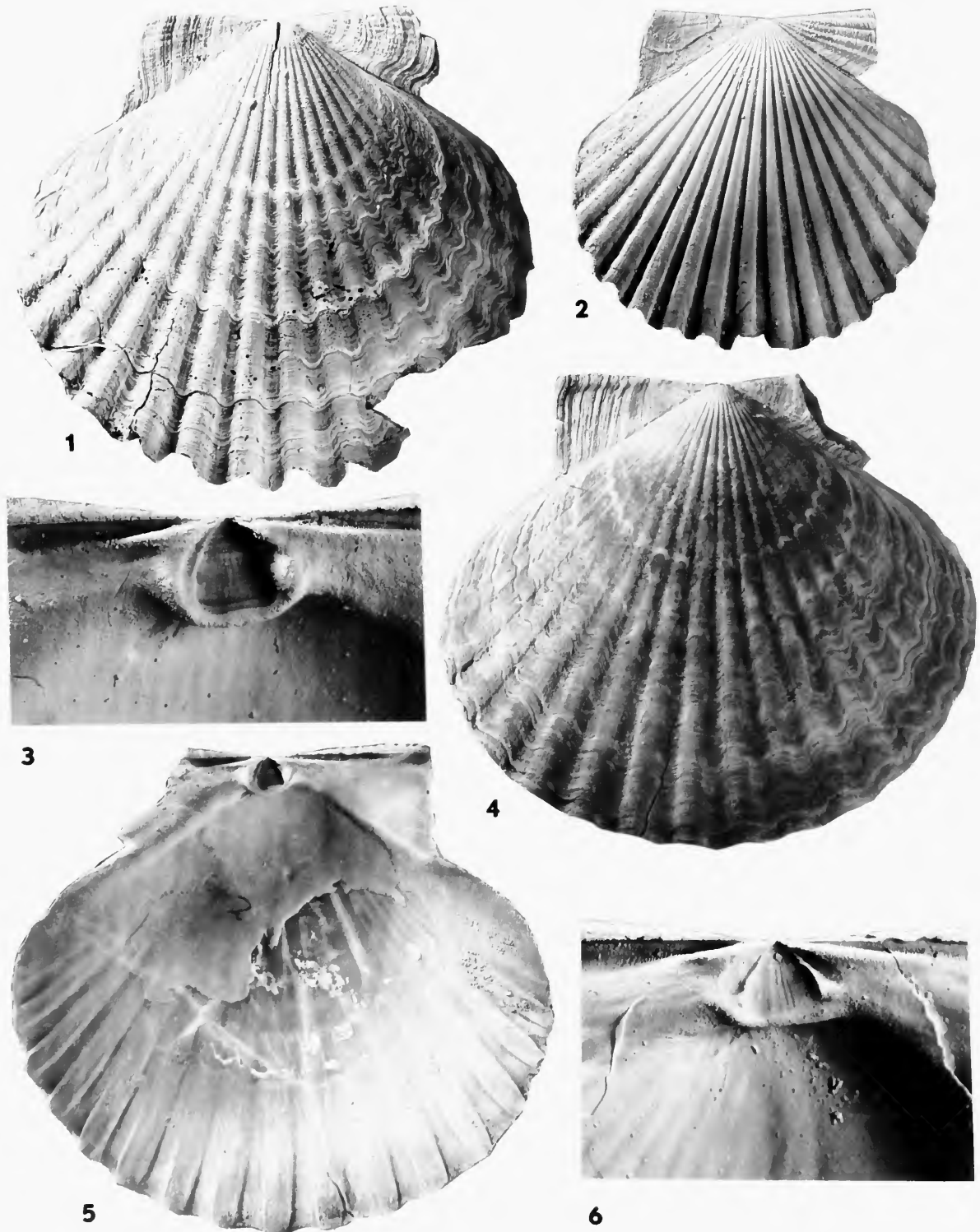


PLATE 6

- 1-4, 6. *Pecten humphreysii woolmani* Heilprin, Kirkwood Formation, Jericho, New Jersey, USGS 2106; 1, USNM 218848, external view of right valve,  $\times 1$ ; 2, 3, USNM 218849, external and internal views of left valve,  $\times 1$  (see also Whitfield, 1894, pl. 4: figs. 8,9); 4, USNM 218850, external view of partial right valve,  $\times 1$ ; 6, USNM 218848, resilial insertion of right valve,  $\times 3$ .
5. *Pecten humphreysii humphreysii* Conrad, Pungo River Formation, Lee Creek Mine, USNM 218851, USGS 25339, external view of partial right valve,  $\times 1$ .
7. *Pecten humphreysii humphreysii* Conrad, Calvert Formation, Davidsonville, Maryland, USNM 218838, USGS 23565, internal view of left valve,  $\times 1$ .



## PLATE 7

*Argopecten eboreus* aff. *A. eboreus watsonensis* (Mansfield),  
Yorktown Formation, Lee Creek Mine

1. USNM 218852, USGS 25746, external view of right valve,  $\times 1$ .
2. USNM 218853, USGS 25338, external view of right valve,  $\times 1$ .
- 3-5. USNM 218854, USGS 25746, right valve: 3, resial insertion,  $\times 3$ ; 4, external view,  $\times 1$ ; 5, internal view,  $\times 1$ .
6. USNM 218855, USGS 25746, right valve, resial insertion,  $\times 3$ .

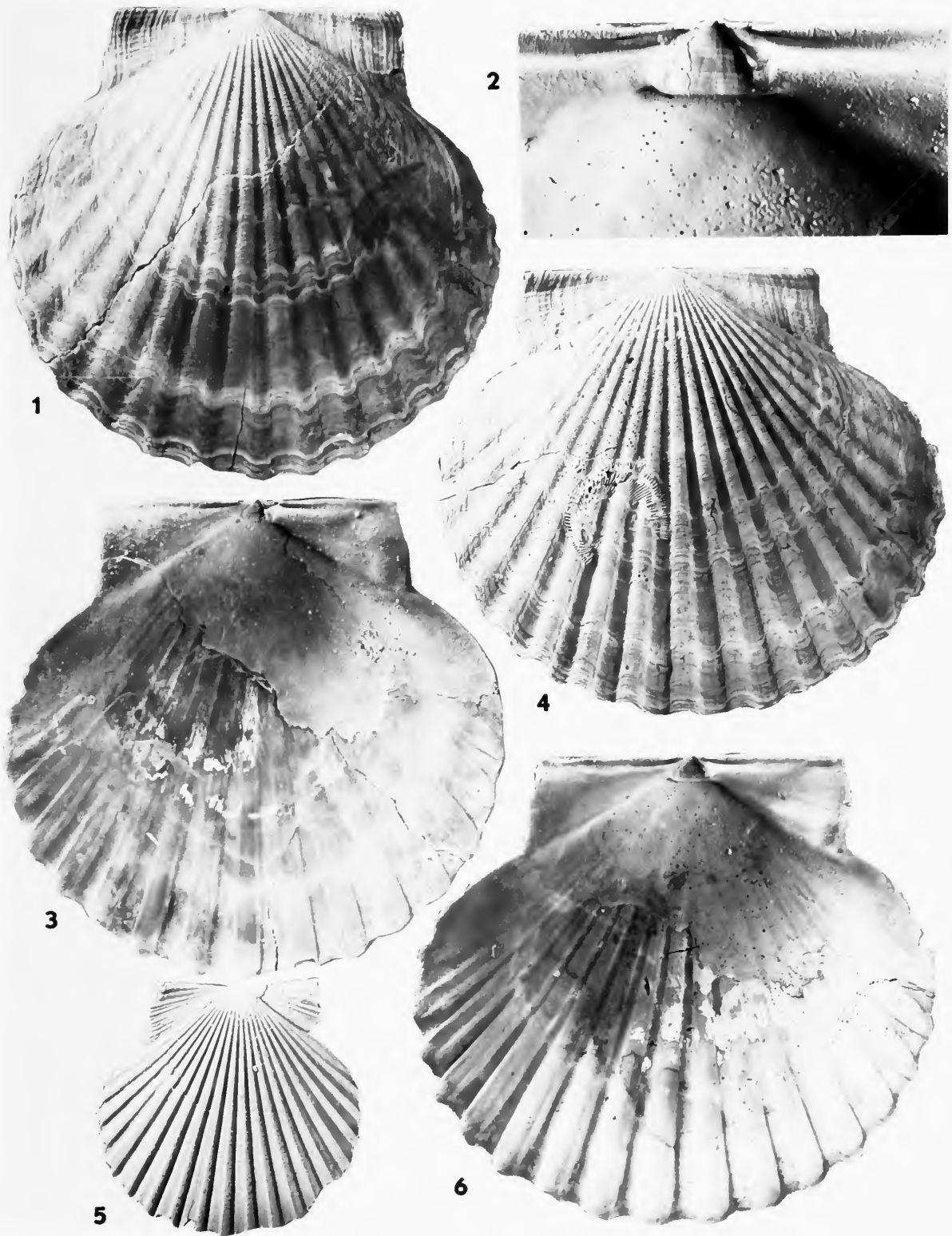
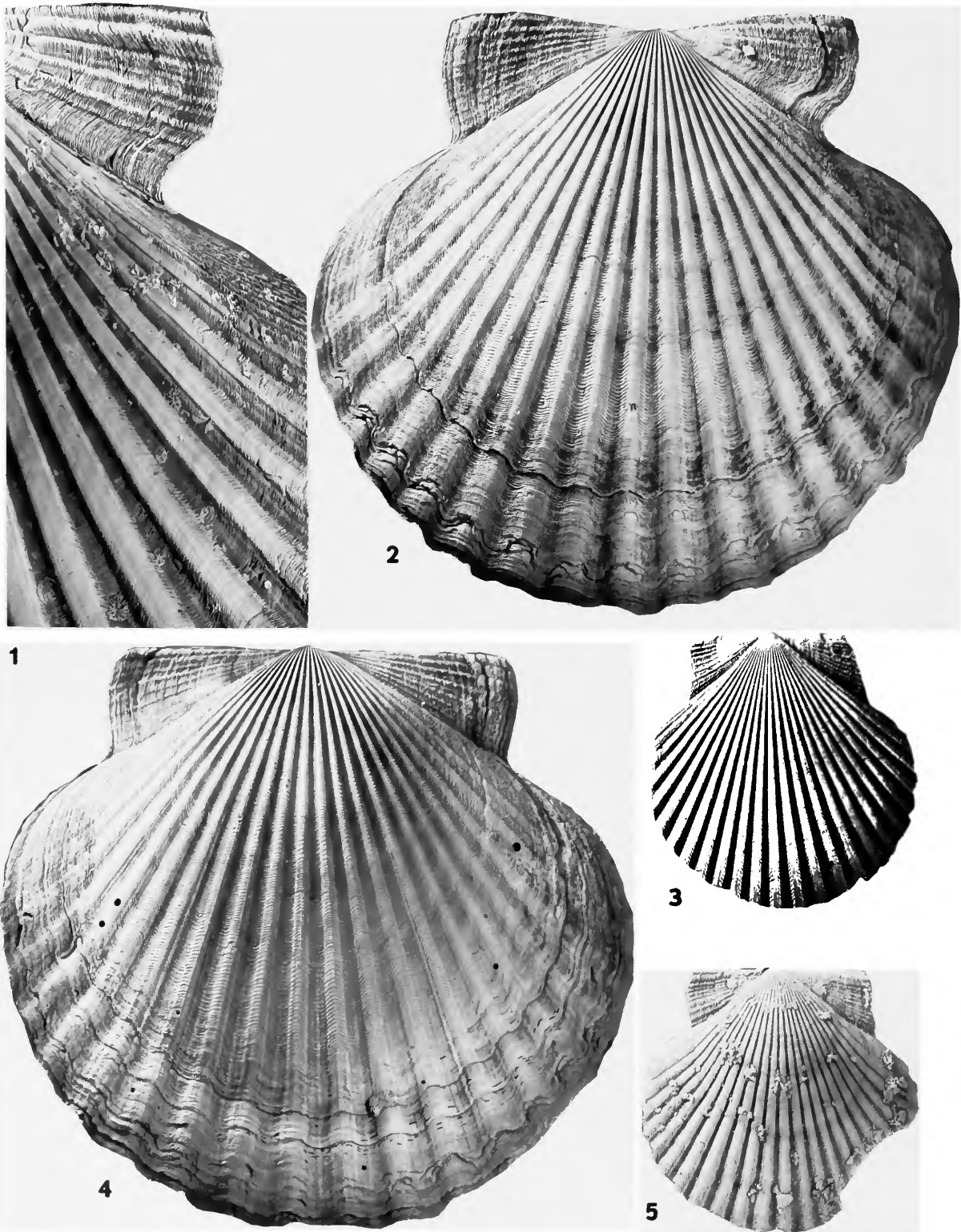


PLATE 8

*Argopecten eboreus* aff. *A. eboreus watsonensis* (Mansfield),  
Yorktown Formation, Lee Creek Mine, USGS 25746

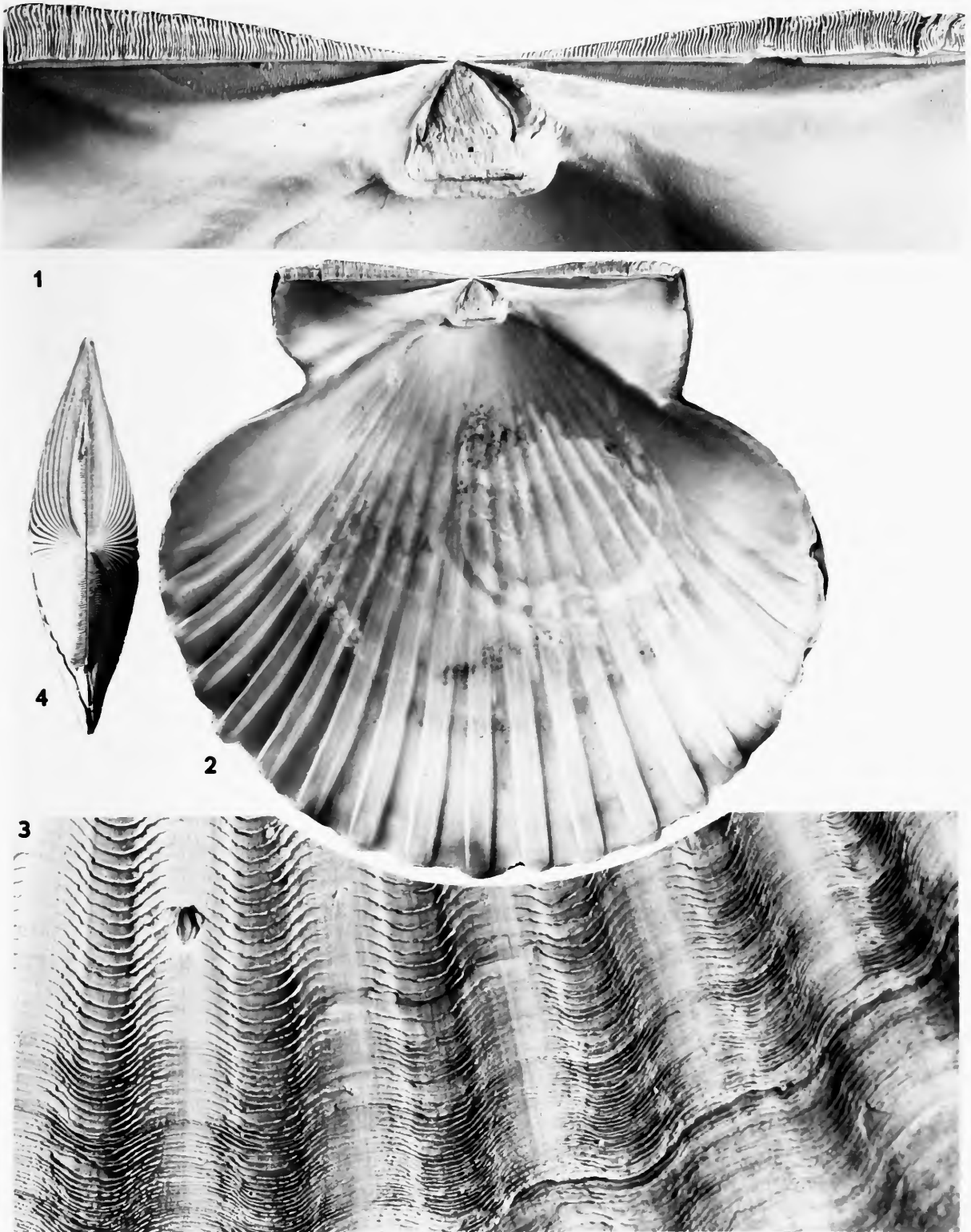
- 1, 3. USNM 218856, left valve: 1, external view  $\times 1$ ; 3, internal view,  $\times 1$ .  
2, 4, 6. USNM 218857, left valve: 2, resial insertion,  $\times 3$ ; 4, external view,  $\times 1$ ; 6, internal view,  $\times 1$ .  
5. USNM 218858, external view of right valve,  $\times 1$ .





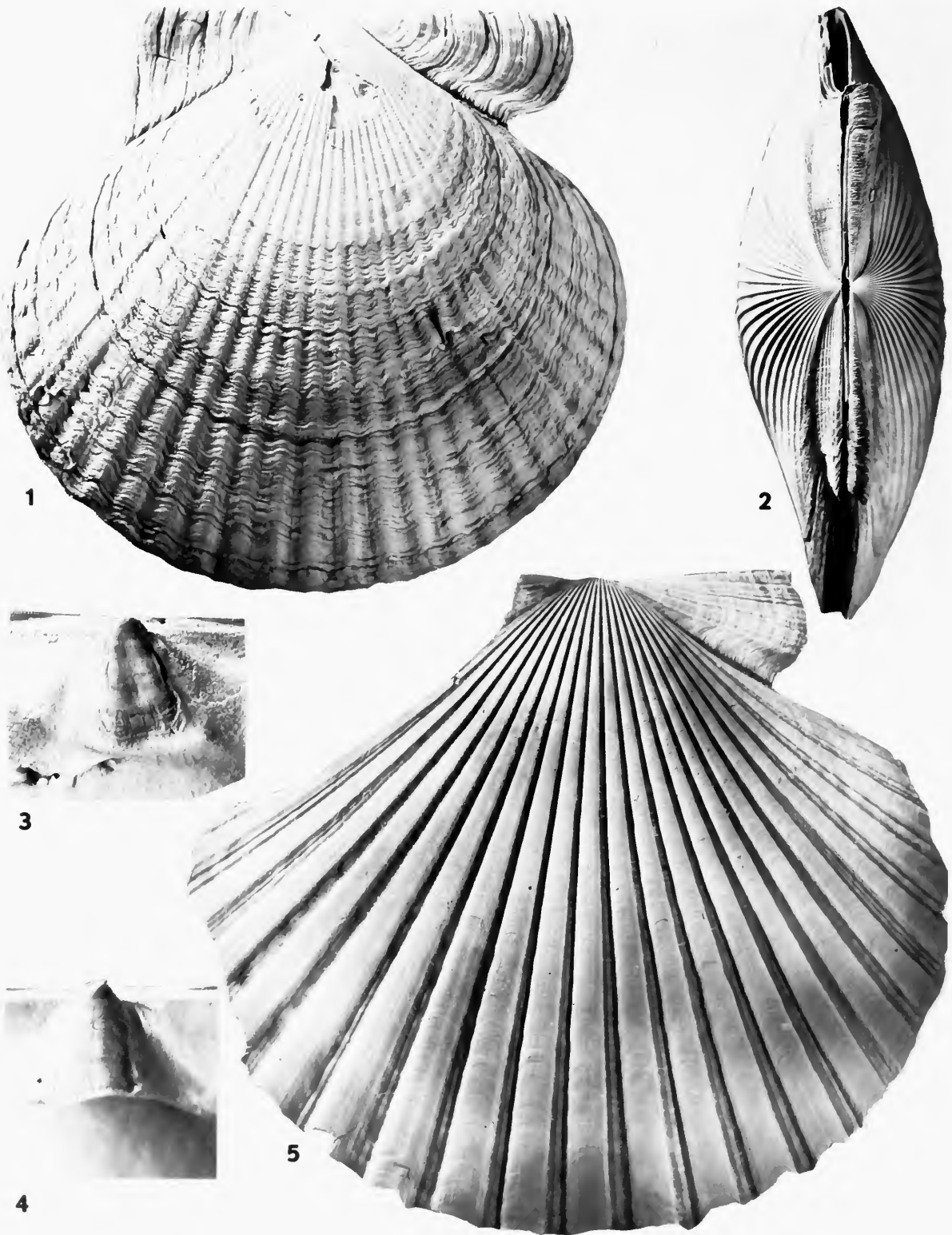
## PLATE 9

- 1, 4. *Argopecten eboreus darlingtonensis* (Dall), Duplin Formation, Darlington, South Carolina, USGS 2025: 1, lectotype, USNM 145432, external view of anterior portion of right valve,  $\times 2$ ; 4, lectoparatype, USNM 218859, external view of left valve,  $\times 1$ .
- 2, 3. *Argopecten eboreus* aff. *A. eboreus solariooides* (Heilprin), Yorktown Formation, Lee Creek Mine, USNM 218860, USGS 25339: 2, external view of right valve,  $\times 1$ ; 3, external view of left valve,  $\times 1$ .
5. *Argopecten eboreus yorkensis* (Conrad), Yorktown Formation, Yorktown, Virginia, lectotype, ANSP 38007, external view of left valve,  $\times 1$ .



## PLATE 10

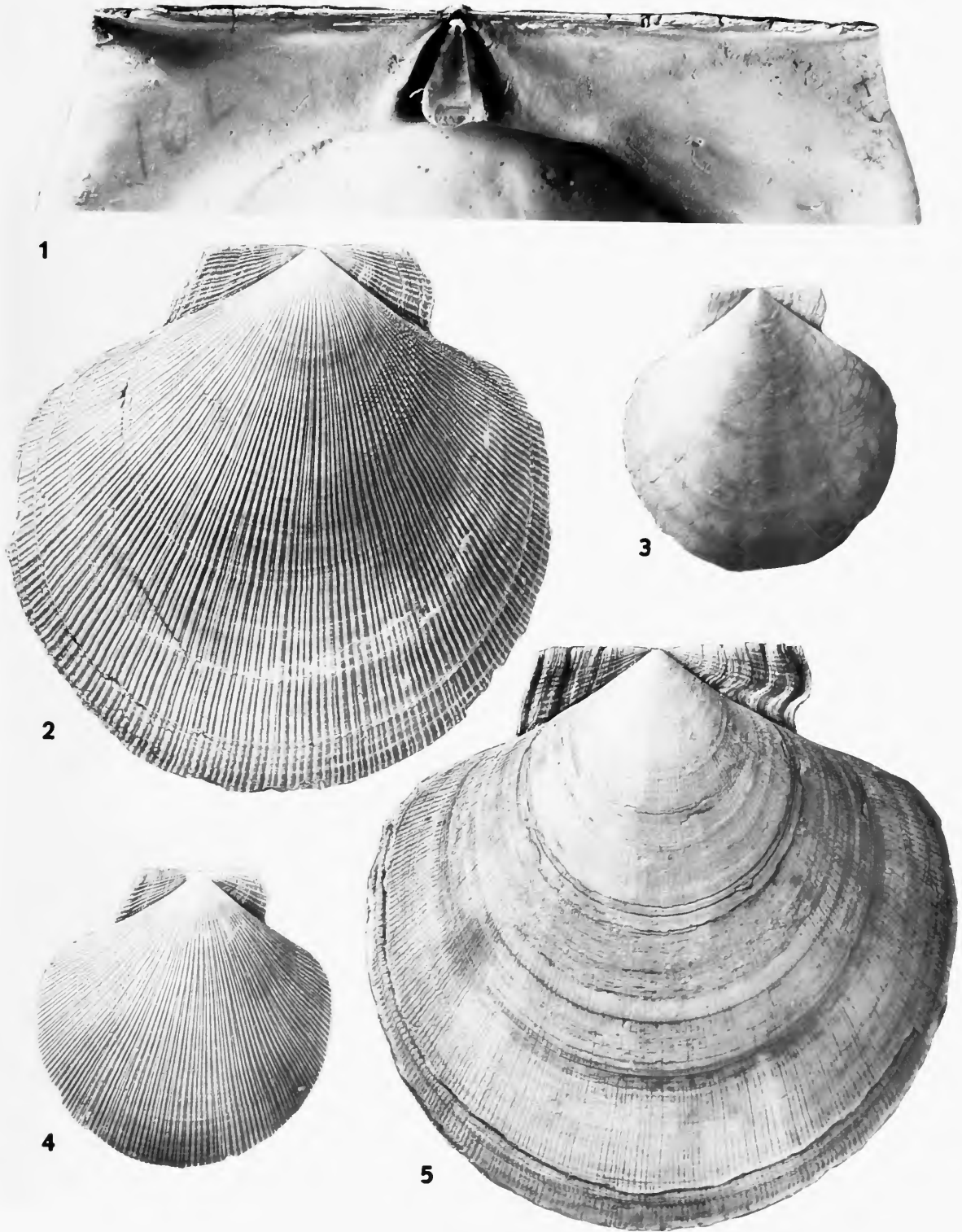
- 1-3. *Argopecten eboreus* aff. *A. eboreus solarioides* (Heilprin), Yorktown Formation, Lee Creek Mine, USNM 218860, USGS 25339, right valve: 1, resilial insertion,  $\times 3$ ; 2, internal view,  $\times 1$ ; 3, external view of anterior ventral part,  $\times 4$ .
4. *Argopecten eboreus* aff. *A. eboreus watsonensis* (Mansfield), Yorktown Formation, Lee Creek Mine, USNM 218861, USGS 25338, dorsal view of articulated specimen,  $\times 1$ .



## PLATE 11

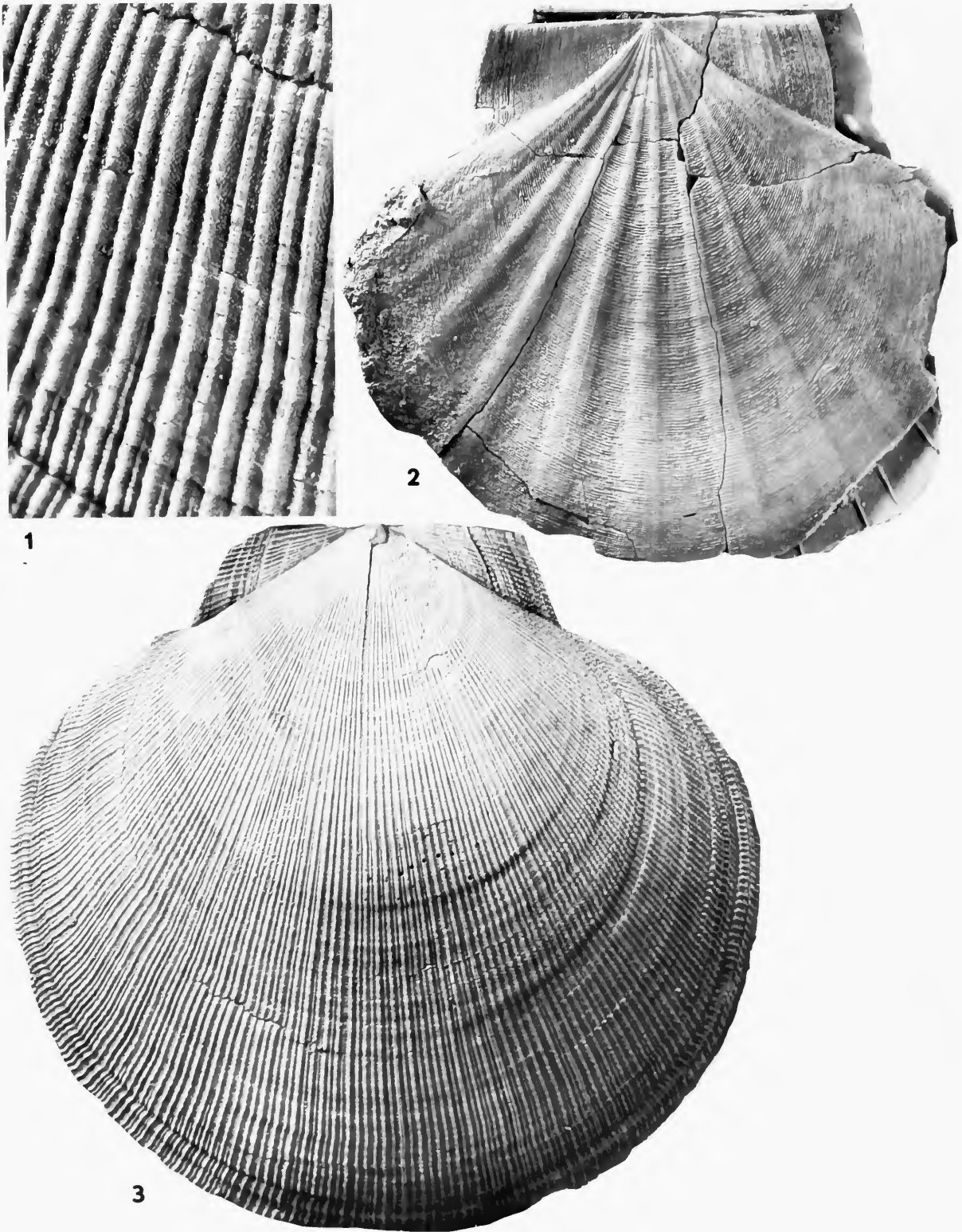
- 1, 3, 4. *Argopecten eboreus urbannaensis* (Mansfield), "Virginia St. Marys" beds, Urbanna, Virginia, USGS 3915: 1, lectotype, USNM 370829, external view of right valve,  $\times 1$ ; 3, lectotype, USNM 370829, resilial insertion,  $\times 3$ ; 4, lectoparatype, USNM 218862, resilial insertion of left valve,  $\times 3$ .
- 2, 5. *Argopecten eboreus* aff. *A. eboreus solarioides* (Heilprin), Yorktown Formation, Lee Creek Mine: 2, USNM 218860, USGS 25339, dorsal view of articulated specimen,  $\times 1$ ; 5, USNM 203904, USGS 25364, external view of right valve,  $\times 1$ .





## PLATE 12

- 1, 3, 5. *Placopecten magellanicus* (Gmelin), Recent, south of Long Island, 67 fathoms, USFC 2244: 1, USNM 703766-16L, resilium,  $\times 3$ ; 3, USNM 703766-21R, external view of right valve,  $\times 1$ ; 5, USNM 703766-16R, external view of right valve,  $\times 1$ .
- 2, 4. *Placopecten clintonius clintonius* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338, external view of right valve: 2, USNM 218863,  $\times 1$ ; 4, USNM 218864,  $\times 1$ .



## PLATE 13

- 1, 3. *Placopecten clintonius clintonius* (Say) (= *P. clintonius donaldi* (Tucker-Rowland)), Yorktown Formation, Grove Wharf, Virginia, holotype of *P. c. donaldi*, USNM 114996, USGS 2452: 1, external ornamentation on anterior ventral part of valve,  $\times 3$ ; 3, external view of left valve,  $\times 1$ .
2. *Pecten mclellani*, new species, Pungo River Formation, Lee Creek Mine, paratype, USNM 218865, USGS 25743, external view of left valve,  $\times 1$ .

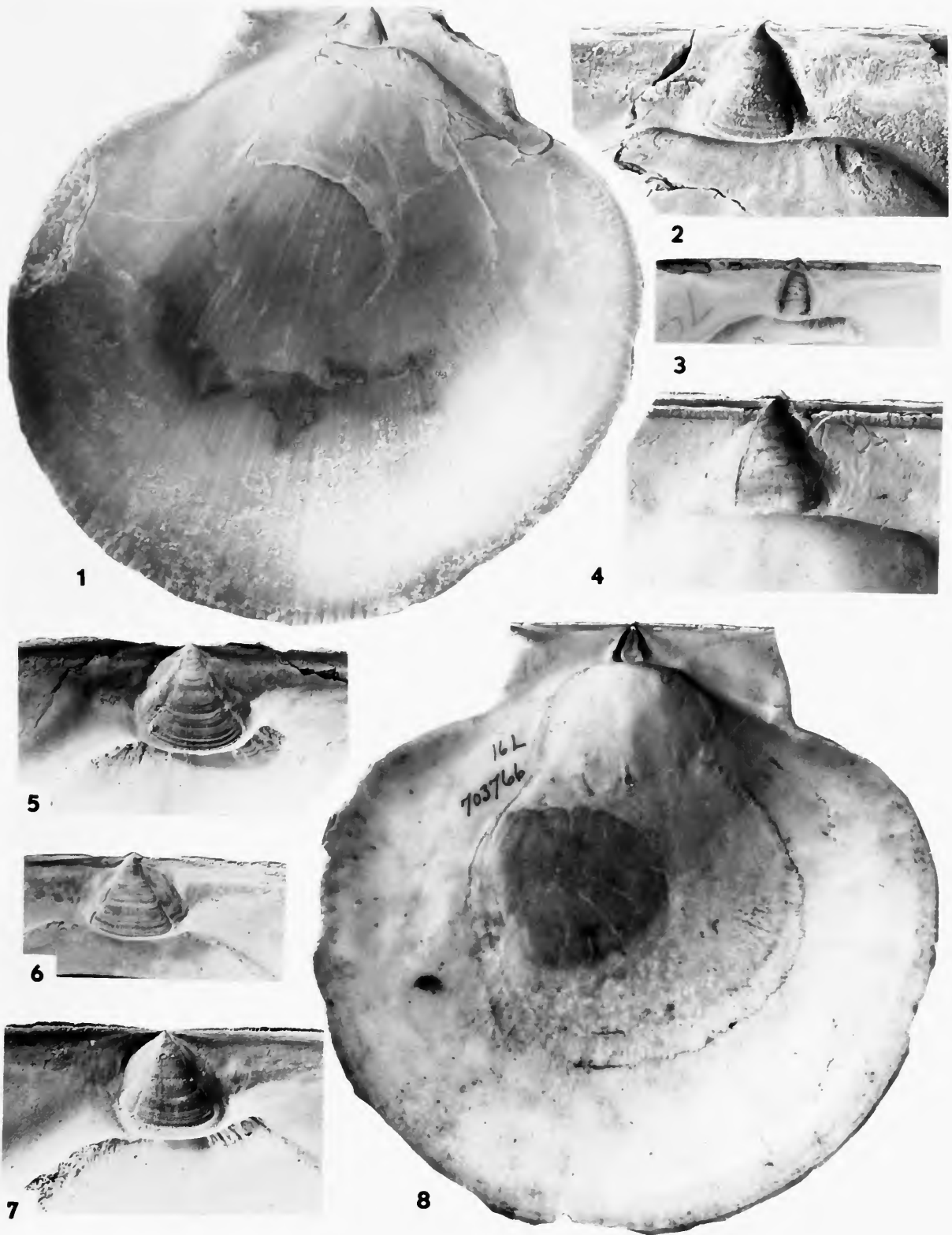


PLATE 14

- 1, 2, 5-7. *Placopecten clintonius clintonius* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338: 1, USNM 218866, internal view of left valve,  $\times 1$ ; 2, USNM 218866, resiliar insertion of left valve,  $\times 3$ ; 5, USNM 218867, resiliar insertion of right valve,  $\times 3$ ; 6, USNM 218868, resiliar insertion of left valve,  $\times 3$ ; 7, USNM 218869, resiliar insertion of right valve,  $\times 3$ .
- 3, 4, 8. *Placopecten magellanicus* (Gmelin), Recent, south of Long Island, 67 fathoms, USFC 2244, left valve: 3, USNM 703766-25L, resiliar insertion,  $\times 3$ ; 4, USNM 703766-9L, resiliar insertion,  $\times 3$ ; 8, USNM 703766-16L, internal view,  $\times 1$ .

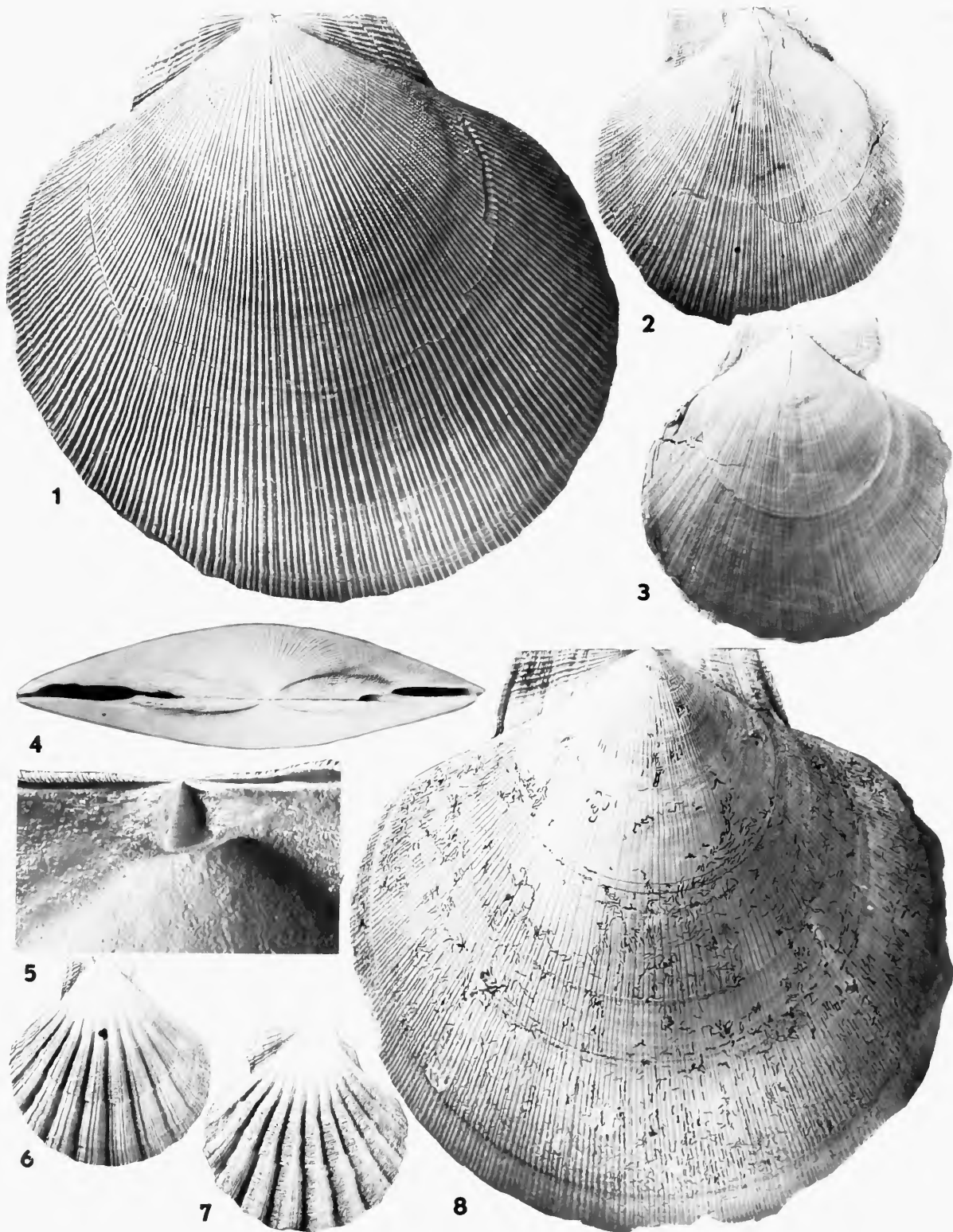


PLATE 15

- 1, 4. *Placopecten clintonus clintonus* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338: 1, USNM 218866, external view of left valve,  $\times 1$ ; 4, USNM 218863, dorsal view of articulated specimen,  $\times 1$ .
- 2, 3, 5-7. *Chlamys decemmaria* (Conrad), Yorktown Formation, Lee Creek Mine, USGS 25338: 2, USNM 218870, external view of left valve of articulated specimen,  $\times 1$ ; 3, USNM 218870, external view of right valve of articulated specimen,  $\times 1$ ; 5, USNM 218871, resilial insertion of right valve,  $\times 3$ ; 6, USNM 218872, external view of right valve,  $\times 1$ ; 7, USNM 218872, external view of left valve,  $\times 1$ .
8. *Placopecten magellanicus* (Gmelin), Recent, south of Long Island, 67 fathoms, USNM 703766-16L, USFC 2241, external view of left valve,  $\times 1$ .



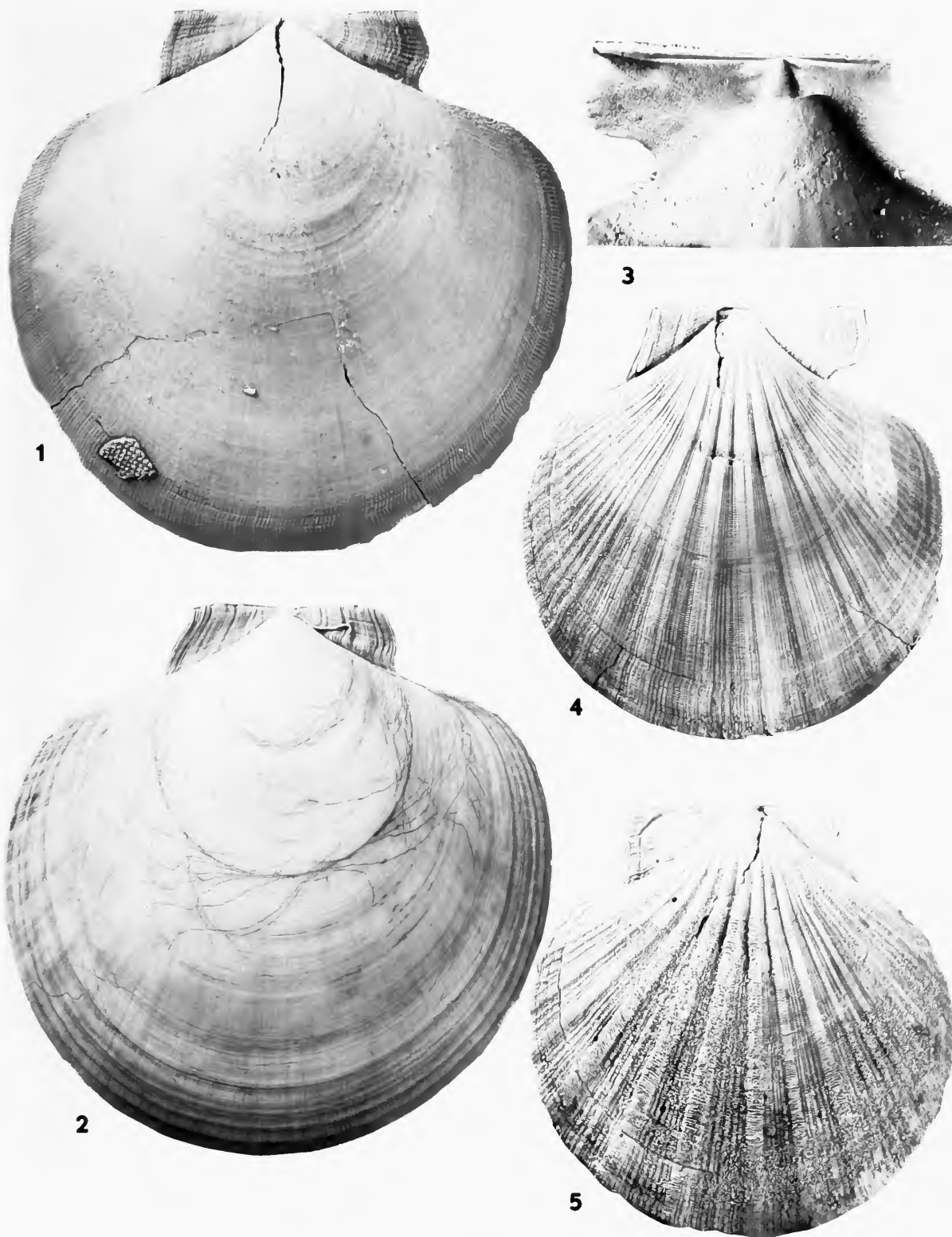


PLATE 16

1. *Placopecten* sp. aff. *P. magellanicus* (Gmelin), Yorktown Formation, Lee Creek Mine, USNM 218873, USGS 25743, external view of right valve,  $\times 1$ .
2. *Placopecten magellanicus* (Gmelin), Recent, south of Long Island, 67 fathoms, USNM 703766-18R, USFC 2244, external view of right valve,  $\times 1$ .
- 3-5. *Chlamys decemnaria* (Conrad), Yorktown Formation, Lee Creek Mine, USGS 25338: 3, USNM 218874, resilial insertion of right valve,  $\times 2$ ; 4, USNM 218875, external view of right valve of articulated specimen,  $\times 1$ ; 5, USNM 218875, external view of left valve of articulated specimen,  $\times 1$ .

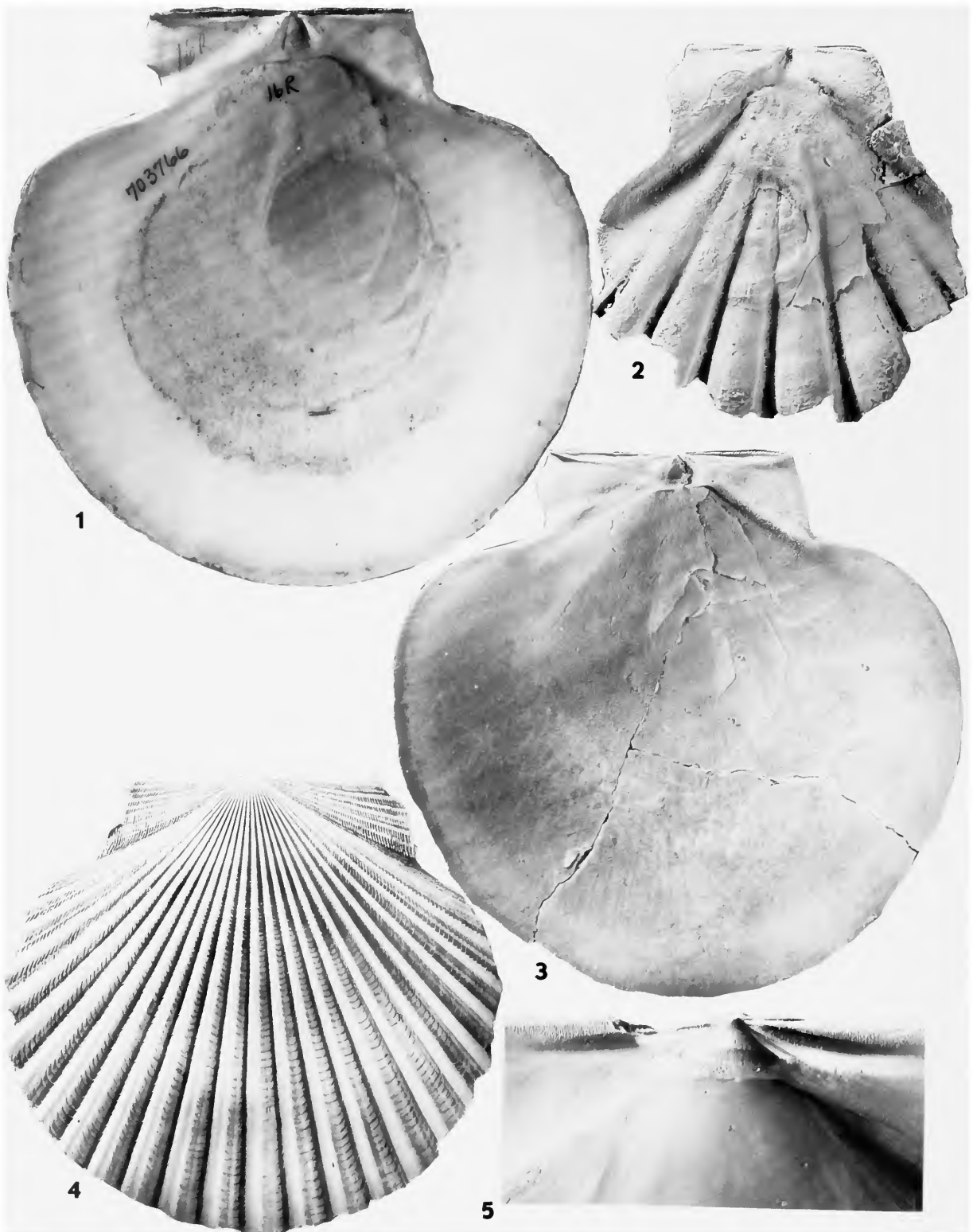
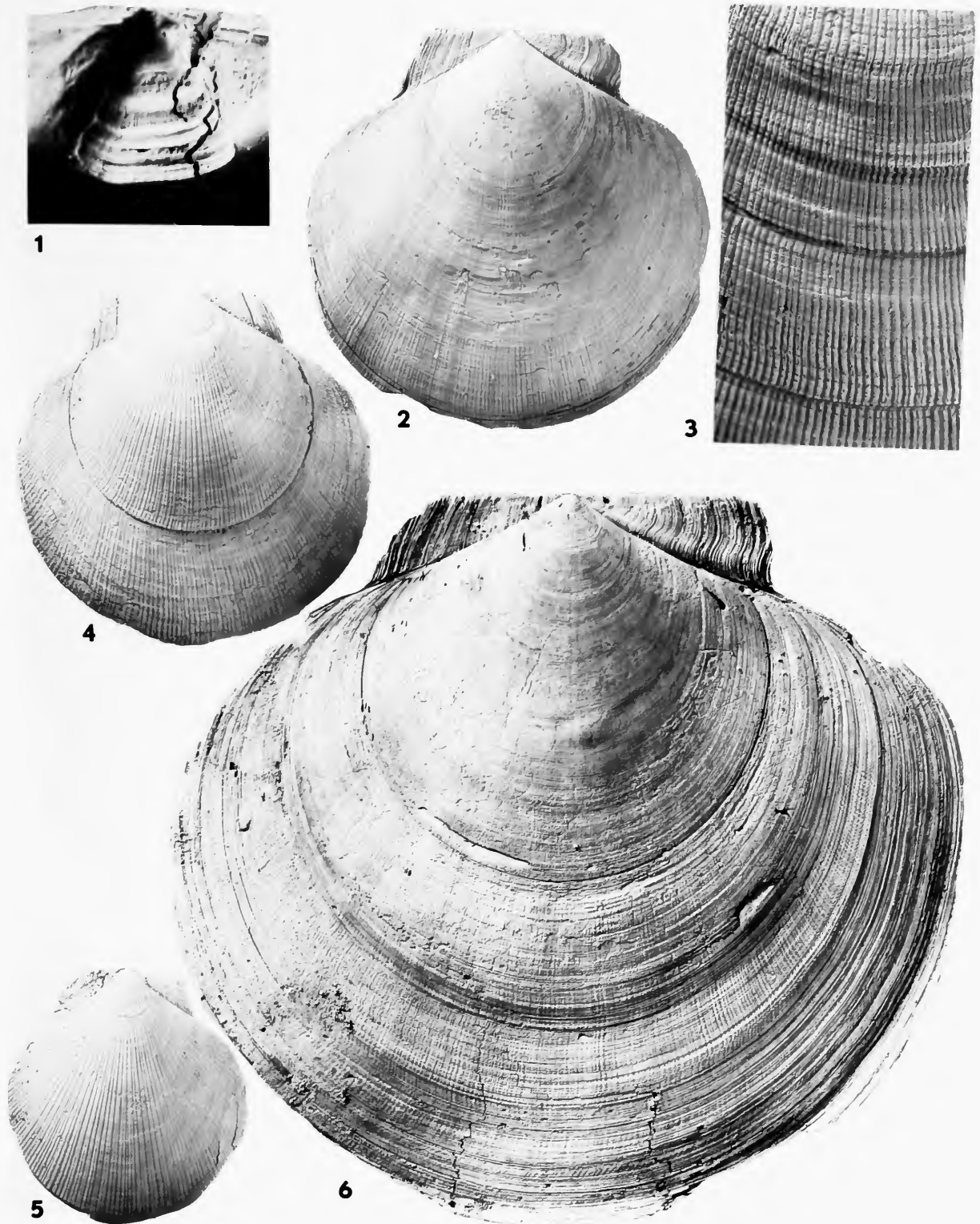


PLATE 17

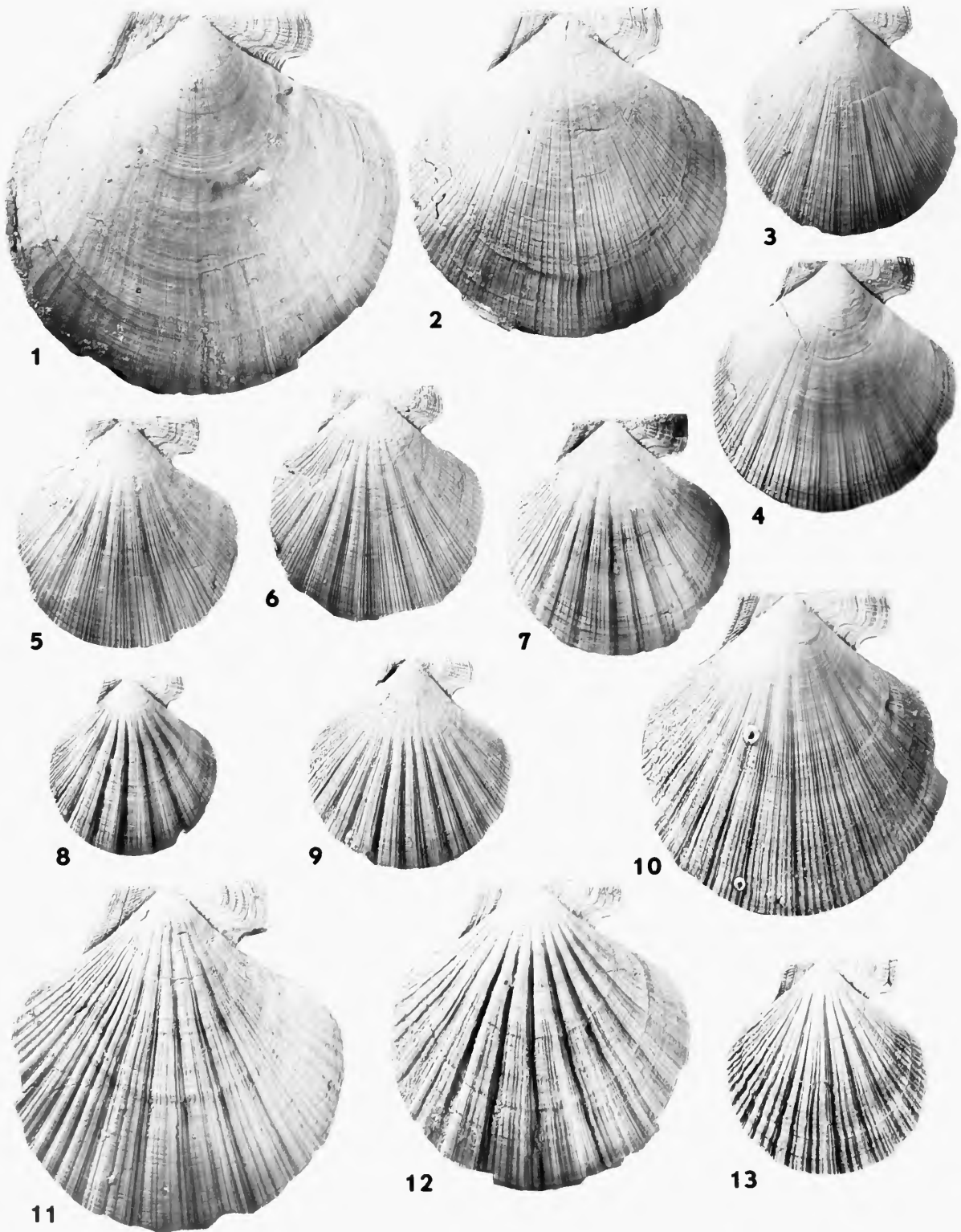
1. *Placopecten magellanicus* (Gmelin), Recent, south of Long Island, 67 fathoms, USNM 703766-16R, USFC 2244, internal view of right valve,  $\times 1$ .
2. *Pecten humphreysii woolmani* Heilprin, Kirkwood Formation, Jericho, New Jersey, USNM 218847, USGS 2106, internal view of left valve,  $\times 2$  (see also Whitfield, 1894, pl. 4: fig. 7).
3. *Placopecten* sp. aff. *P. magellanicus* (Gmelin), Yorktown Formation, Lee Creek Mine, USNM 218873, USGS 25743, internal view of right valve,  $\times 1$ .
- 4, 5. *Argopecten eboreus* aff. *A. eboreus solarioides* (Heilprin), Yorktown Formation (upper shell bed), Lee Creek Mine, USNM 218876, USGS 25364: 4, external view of left valve,  $\times 1$ ; 5, resilial insertion,  $\times 3$ .



## PLATE 18

*Placopecten clintonus rappahannockensis* (Mansfield)

- 1, 4-6. "Virginia St. Marys" beds, Murfreesboro, North Carolina, USGS 25747: 1, USNM 218877, resilial insertion of right valve,  $\times 3$ ; 4, USNM 218880, external view of left valve,  $\times 1$ ; 5, USNM 218881, external view of left valve,  $\times 1$ ; 6, USNM 218877, external view of right valve,  $\times 1$ .
- 2, 3. "Virginia St. Marys" beds, Jones Point, Virginia, USGS 3924: 2, lectoparatype, USNM 218878, external view of right valve,  $\times 1$ ; 3, lectoparatype, USNM 218879, anterior ventral area of exterior of left valve,  $\times 3$ .



## PLATE 19

*Chlamys decemnaria* (Conrad), Yorktown Formation,  
Lee Creek Mine, USGS 25338

1-13. External view of right valve,  $\times 1$ : 1, USNM 218871; 2, USNM 218882; 3, USNM 218883; 4, USNM 218884; 5, USNM 218885; 6, USNM 218886; 7, USNM 218887; 8, USNM 218888; 9, USNM 218889; 10, USNM 218874; 11, USNM 218890; 12, USNM 218891; 13, USNM 218892.



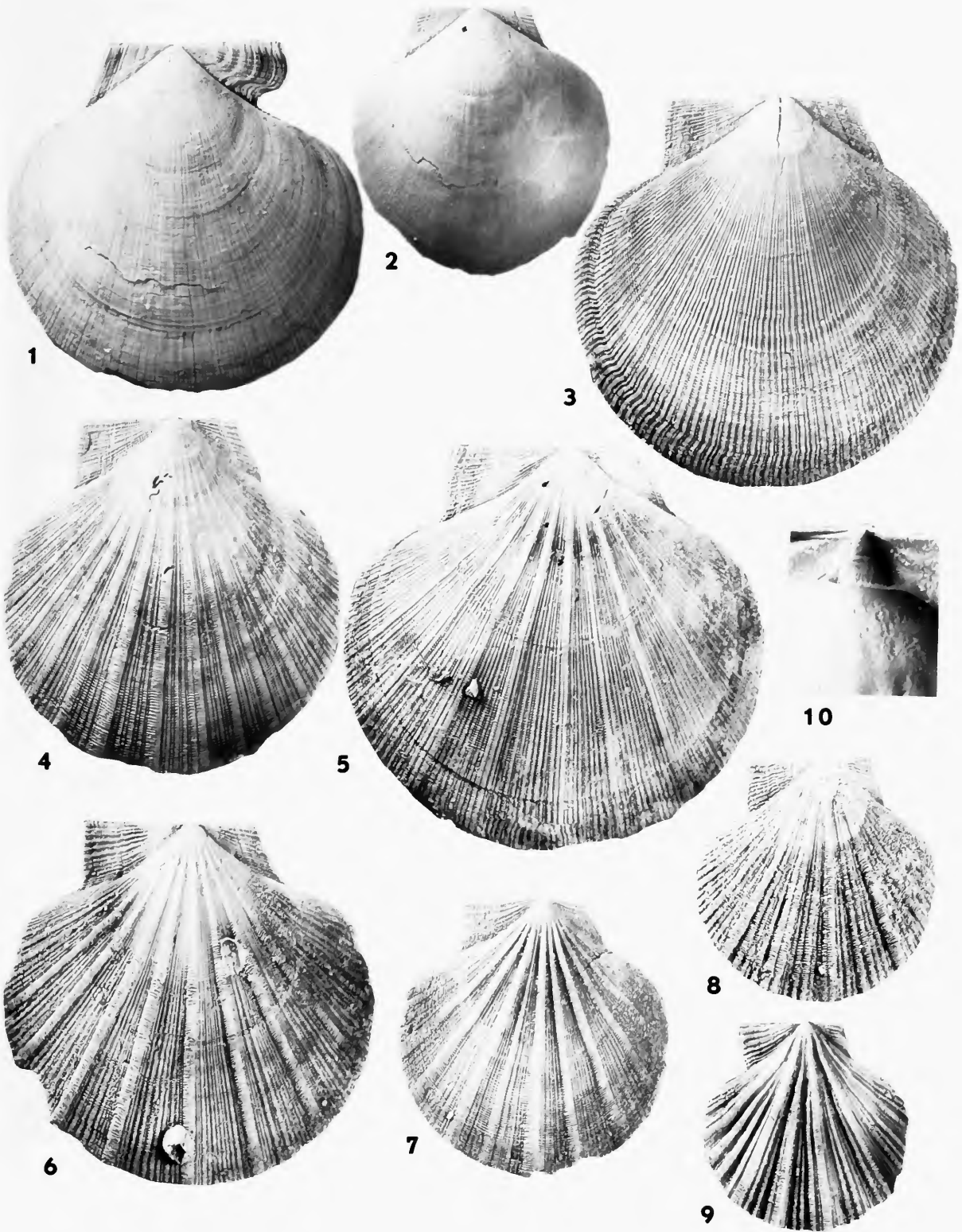


PLATE 20

1. *Chlamys decemnaria* (Conrad) (= *Pecten virginianus* (Conrad), Yorktown Formation, City Point, Virginia, holotype, ANSP 1620, external view of right valve,  $\times 1$ .
- 2-9. *Chlamys decemnaria* (Conrad), Yorktown Formation, Lee Creek Mine, USGS 25338, external view of left valve,  $\times 1$ ; 2, USNM 218893; 3, USNM 218894; 4, USNM 218895; 5, USNM 218896; 6, USNM 218897; 7, USNM 218898; 8, USNM 218899; 9, USNM 218900.
10. *Chlamys decemnaria* (Conrad), Yorktown Formation, Lee Creek Mine, USNM 218897, USGS 25338, resilial insertion of left valve,  $\times 3$ .

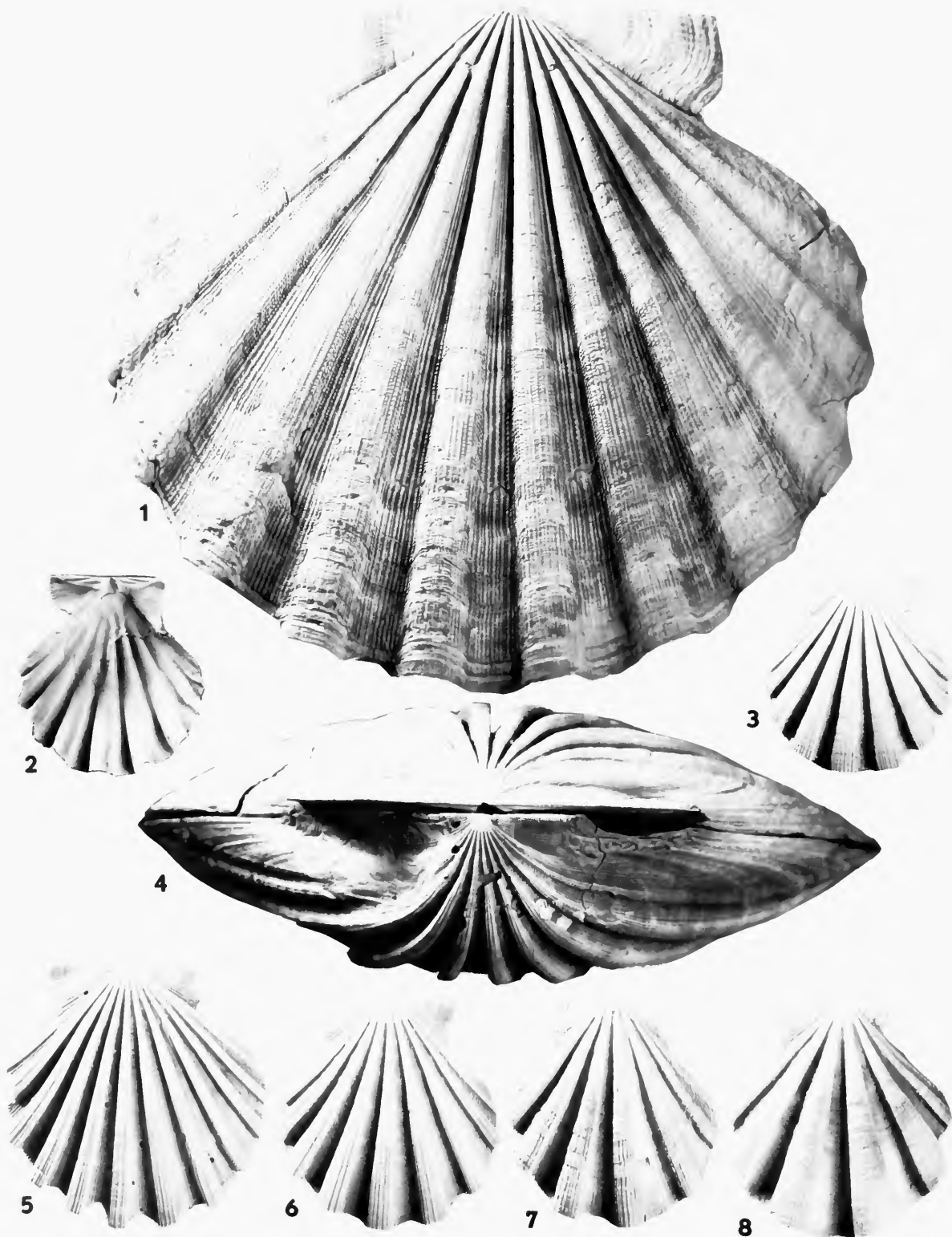


PLATE 21

*Chesapecten jeffersonius jeffersonius* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338

1, 3. External view of right valve,  $\times 1$ ; 1, USNM 218901; 3, USNM 218902.

2. USNM 218902, internal view of right valve,  $\times 1$ .

4. USNM 218903, dorsal view of articulated specimen,  $\times 1$ .

5, 6. External view of left valve,  $\times 1$ ; 5, USNM 218904; 6, USNM 218905.

*Chesapecten jeffersonius septenarius* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338

7, 8. External view of left valve,  $\times 1$ ; 7, USNM 218906; 8, USNM 218907.

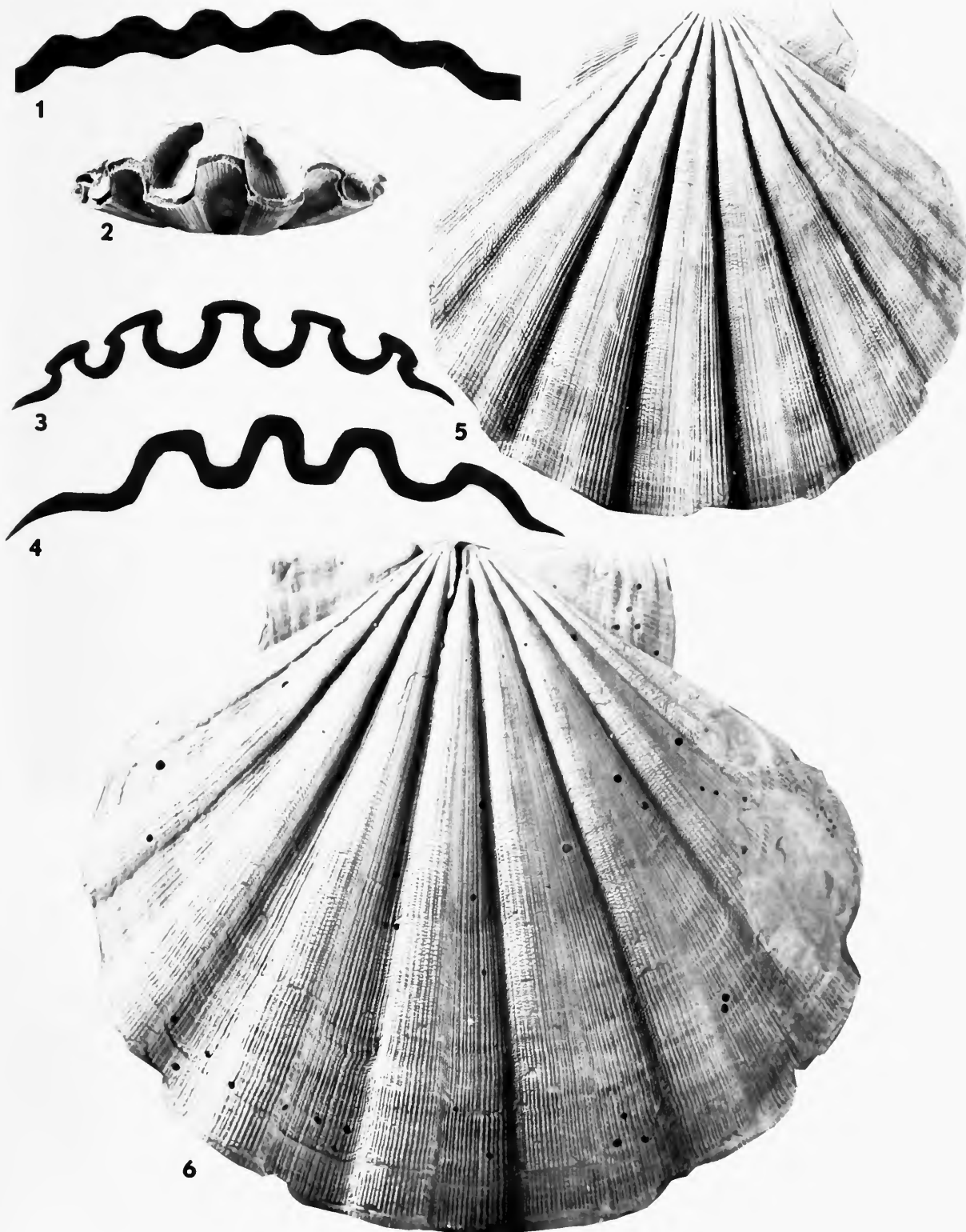
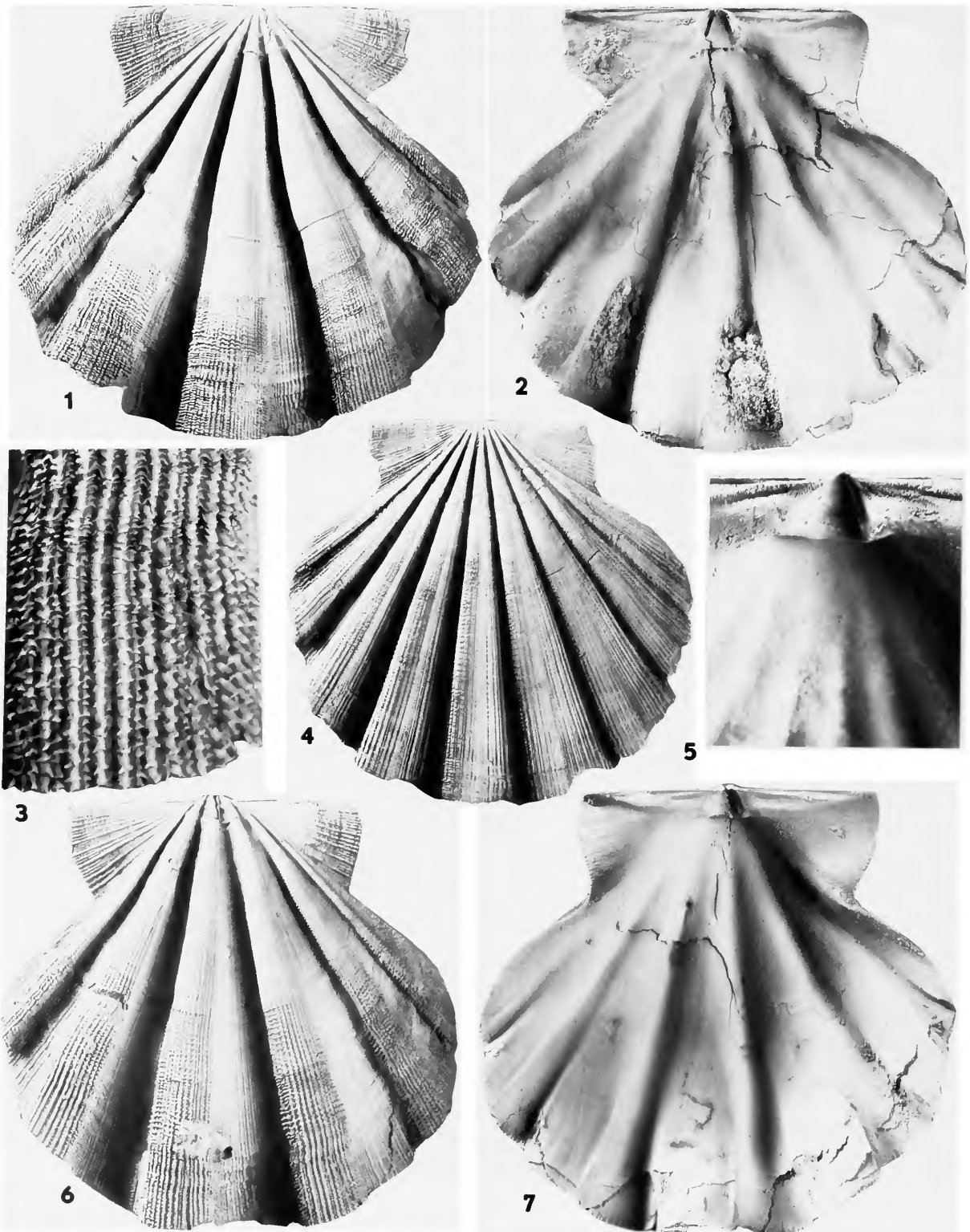


PLATE 22

1. *Chesapeake madisonius* (Say), Yorktown Formation, Lee Creek Mine, USNM 218908, USGS 25338, cross-section of right valve, about midway dorsoventrally,  $\times 1$ .
- 2, 3. *Chesapeake jeffersonius septenarius* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338: 2, USNM 218909, ventral view of articulated specimen,  $\times 1$ ; 3, USNM 218910, cross-section of left valve, about midway dorsoventrally,  $\times 1$ .
- 4-6. *Chesapeake jeffersonius jeffersonius* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338: 4, USNM 218901, cross-section of right valve, about midway dorsoventrally,  $\times 1$ ; 5, USNM 218911, external view of right valve,  $\times 1$ ; 6, USNM 218912, external view of left valve,  $\times 1$ .



## PLATE 23

1-3, 6, 7. *Chesapecten jeffersonius septenarius* (Say), Yorktown Formation, Lee Creek Mine, USNM 218910, USGS 25338: 1, external view of right valve,  $\times 1$ ; 2, internal view of right valve,  $\times 1$ ; 3, rib at ventral margin of left valve,  $\times 3$ ; 6, external view of left valve,  $\times 1$ ; 7, internal view of left valve,  $\times 1$ .

4, 5. *Chesapecten jeffersonius jeffersonius* (Say), Yorktown Formation, Lee Creek Mine, USNM 218913, USGS 25338: 4, external view of left valve,  $\times 1$ ; 5, resiliol insertion of left valve,  $\times 3$ .



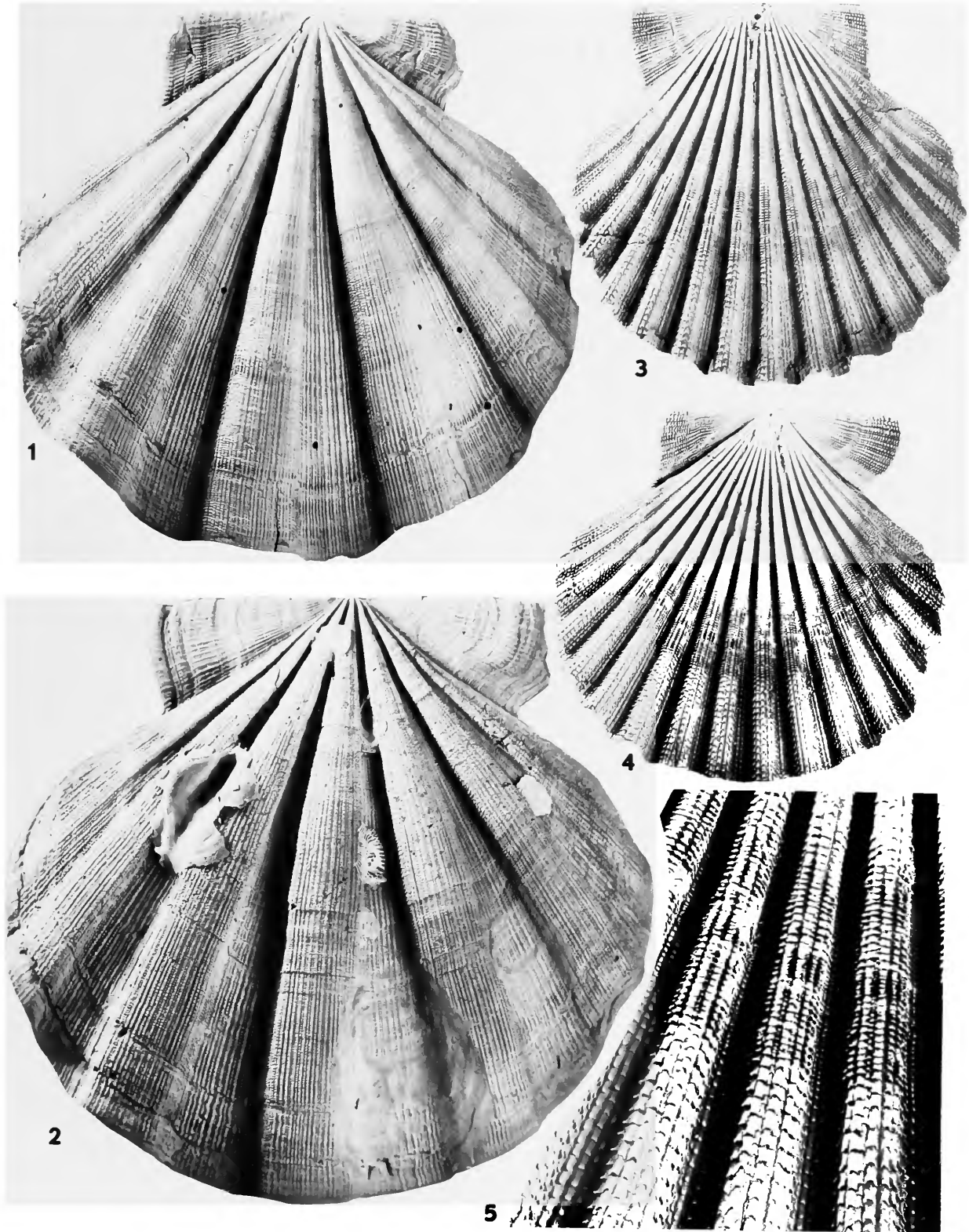


PLATE 24

- 1, 2. *Chesapecten jeffersonius septenarius* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338, external view of right valve,  $\times 1$ ; 1, USNM 218914; 2, USNM 218915.
- 3-5. *Chesapecten madisonius* (Say), Yorktown Formation, Lee Creek Mine, USNM 218916, USGS 25338: 3, external view of left valve,  $\times 1$ ; 4, external view of right valve,  $\times 1$ ; 5, ribs on posterior-ventral portion,  $\times 3$ .

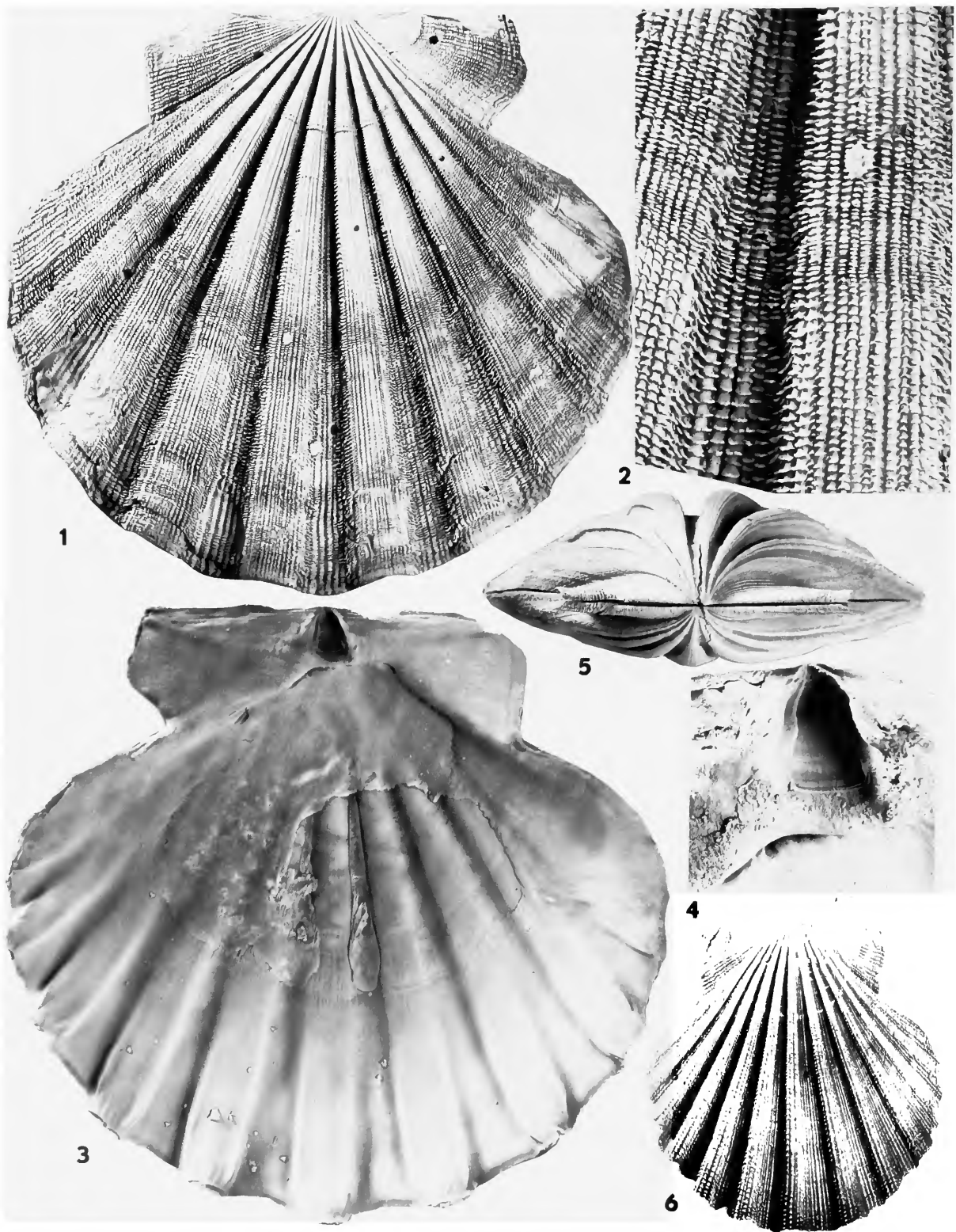


PLATE 25

- 1-4. *Chesapecten madisonius* (Say), Yorktown Formation, Lee Creek Mine, USNM 218917, USGS 25338, right valve: 1, external view,  $\times 1$ ; 2, ornamentation,  $\times 3$ ; 3, internal view,  $\times 1$ ; 4, resillial insertion,  $\times 3$ .
5. *Chesapecten jeffersonius septenarius* (Say), Yorktown Formation, Lee Creek Mine, USNM 218910, USGS 25338, dorsal view of articulated specimen,  $\times 1$ .
6. *Chesapecten madisonius* (Say), Yorktown Formation, Lee Creek Mine, USNM 218918, USGS 25338, external view of left valve,  $\times 1$ .

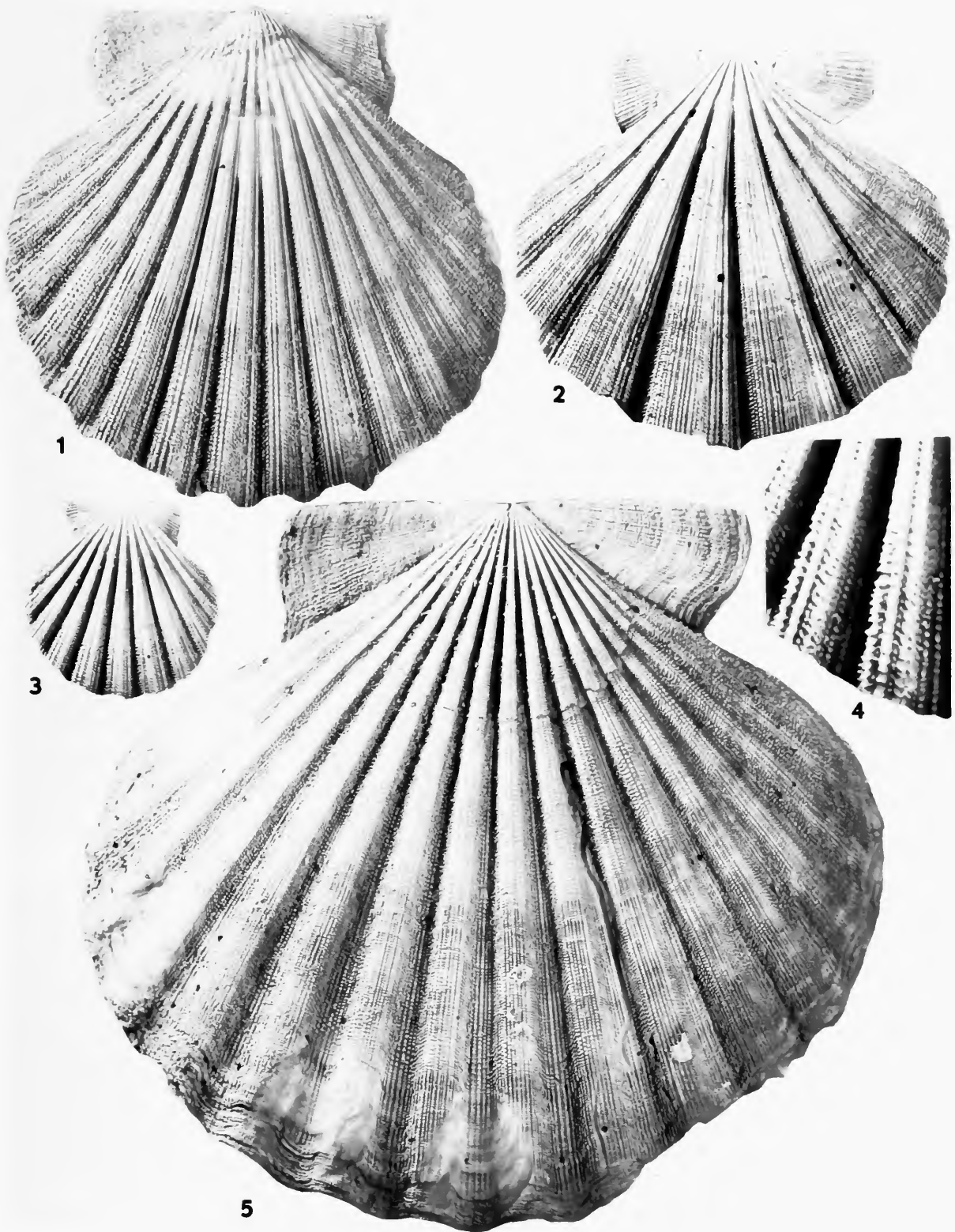
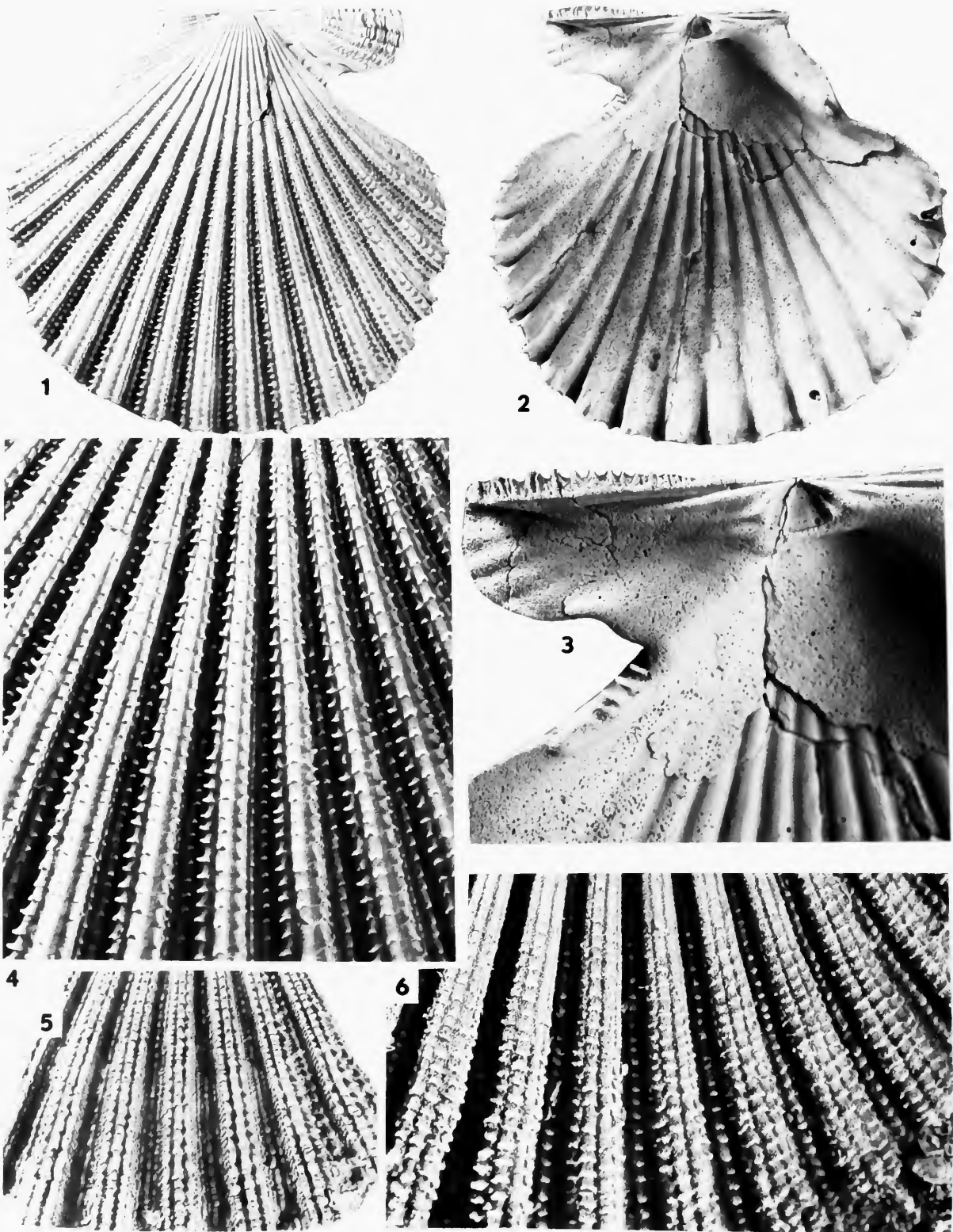


PLATE 26

- 1, 3-5. *Chesapecten madisonius* (Sav), Yorktown Formation, Lee Creek Mine, USGS 25338: 1, USNM 218919, external view of left valve,  $\times 1$ ; 3, USNM 218920, external view of left valve,  $\times 1$ ; 4, USNM 218920, anteroventral ribs,  $\times 3$ ; 5, USNM 218908, external view of right valve,  $\times 1$ .
2. *Chesapecten jeffersonius septenarius* (Sav), Yorktown Formation, Lee Creek Mine, USNM 218921, USGS 25338, external view of right valve,  $\times 1$ .

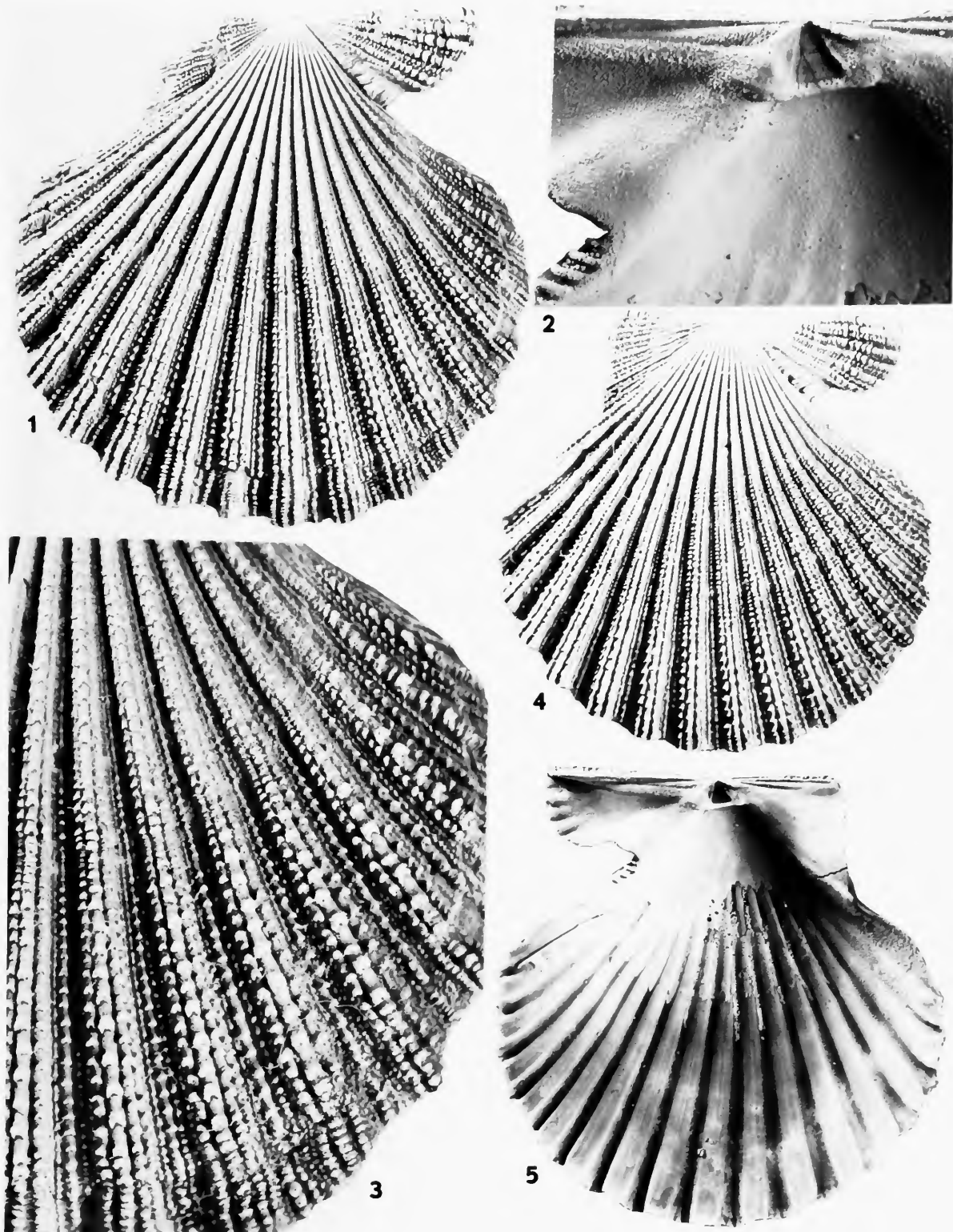


## PLATE 27

*Chesapeake coccymelus* (Dall), Pungo River Formation,  
Lee Creek Mine, USGS 25338

- 1-4. USNM 218922, right valve: 1, external view,  $\times 1.4$ ; 2, internal view,  $\times 1.4$ ; 3, resilial insertion and ctenuolium,  $\times 3$ ; 4, ribs in mid-part of right valve,  $\times 3$ .  
 5. USNM 218923, external view of partial valve,  $\times 1.3$ .  
 6. USNM 218924, ribs in anteroventral portion of right valve,  $\times 3$ .

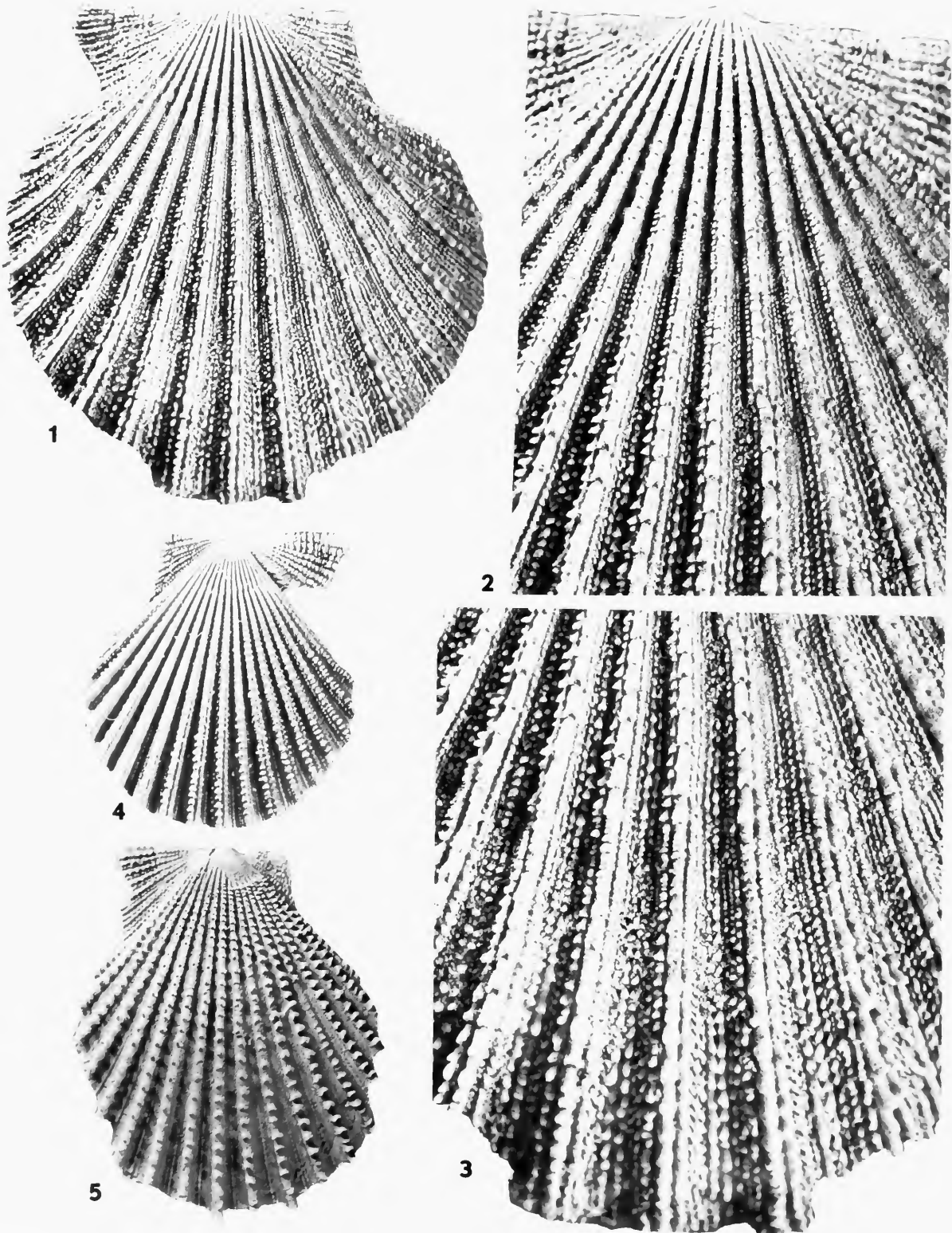




## PLATE 28

*Chesapeake coccymelus* (Dall), Calvert Formation,  
Plum Point, Maryland, USGS 25345

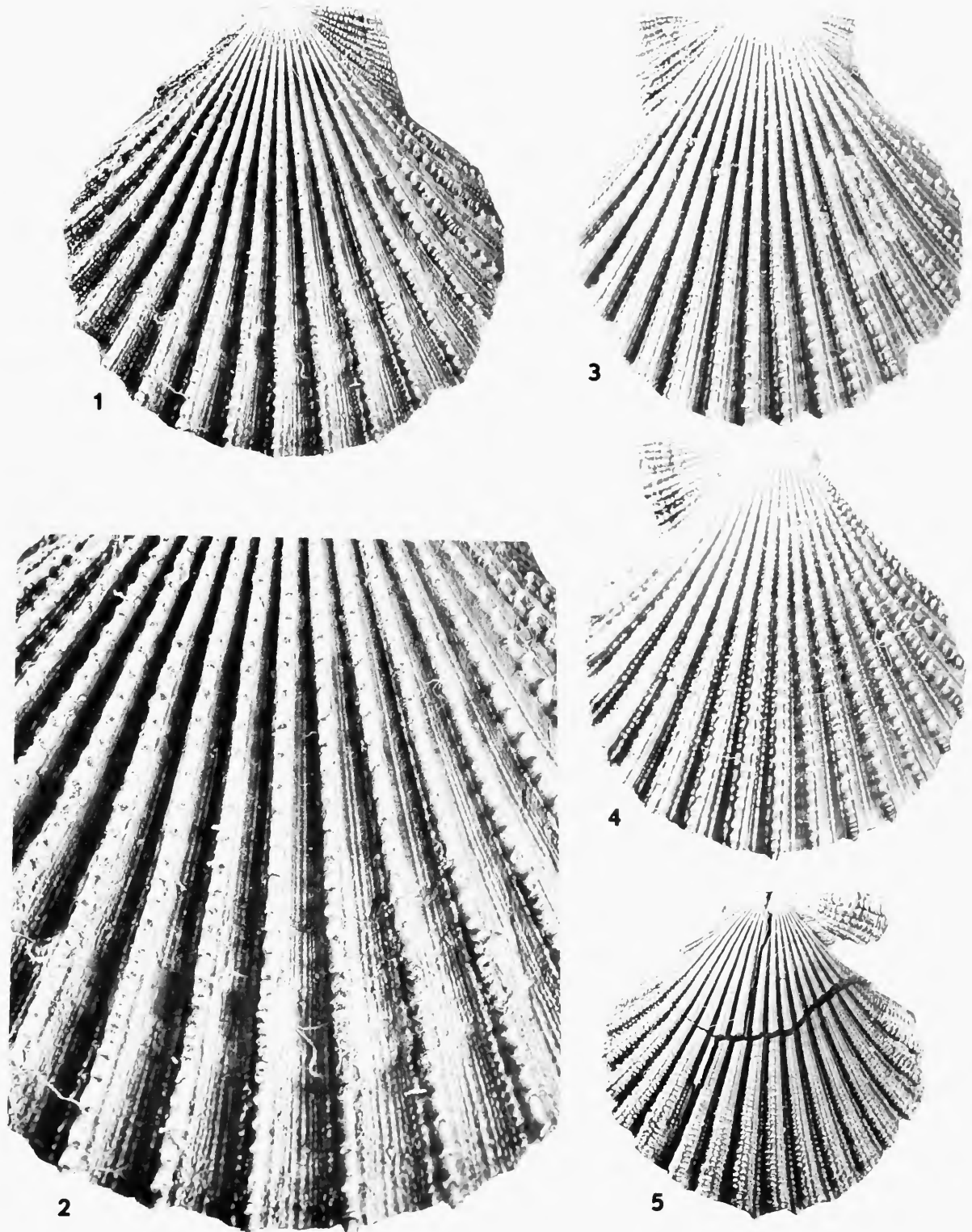
- 1, 3. USNM 218925, right valve: 1, external view,  $\times 1.5$ ; 3, ribs of anteroventral portion,  $\times 3$ .  
2, 4, 5. USNM 218926, right valve: 2, resial insertion and ctenolium,  $\times 4$ ; 4, external view,  $\times 1.5$ ; 5, internal view,  $\times 1.5$ .



## PLATE 29

*Chesapecten coccyneus* (Dall), Calvert Formation, Plum Point, Maryland

- 1-3. (= *Chlamys* (*Lyropecten*) *madisonius bassleri* Tucker-Rowland), holotype, USNM 145919, USGS 2447c,  
 left valve: 1, external view,  $\times 1.5$ ; 2, dorsal portion,  $\times 3$ ; 3, ventral portion,  $\times 3$ .  
 4. USNM 218927, USGS 24345, external view of right valve,  $\times 2$ .  
 5. Holotype, USNM 87754, external view of left valve,  $\times 2$ .



## PLATE 30

- 1-4. *Chesapecten coccymelus* (Dall), Calvert Formation, Plum Point, Maryland, left valve: 1, Maryland Geological Survey No. 1921, external view,  $\times 1.5$ ; 2, Maryland Geological Survey No. 1921, ventral portion,  $\times 3$ ; 3, USNM 218928, USGS 25345, external view,  $\times 2$ ; 4, USNM 218929, USGS 25345, external view,  $\times 2$ .
5. *Chesapecten coccymelus* (Dall), Pungo River Formation, Lee Creek Mine, USNM 218924, USGS 25338, external view of right valve,  $\times 1$ .

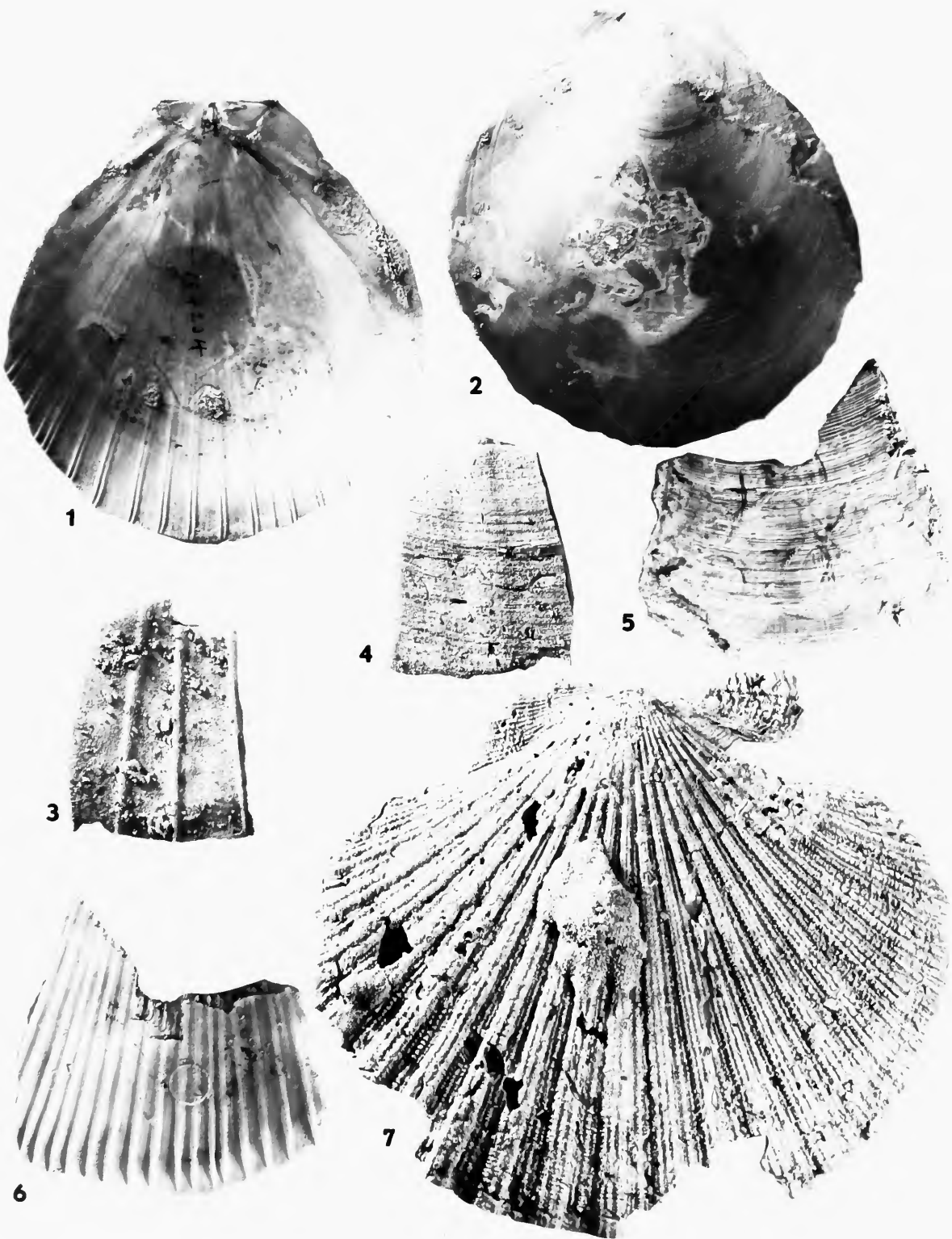


PLATE 31

- 1, 2. *Amustum mortoni* (Ravenel), Caloosahatchee Formation, Shell Creek, Florida, USNM 154204, left valve: 1, internal view,  $\times 1$ ; 2, external view,  $\times 1$ .
- 3, 4. *Amustum* sp., Pungo River Formation, Lee Creek Mine, USNM 218930, USGS 25748, fragment of valve: 3, internal view,  $\times 1$ ; 4, external view,  $\times 1$ .
- 5, 6. *Amustum precursor* (Dall), Chipola Formation, Baileys Ferry, Florida, USNM 218931, USGS 2212, fragment of valve: 5, external view,  $\times 1$ ; 6, internal view,  $\times 1$ .
7. *Chesapecten nefrens* Ward and Blackwelder, Pungo River Formation, Lee Creek Mine, USNM 218932, USGS 25749, external view of right valve,  $\times 1$ .

# Late Pliocene and Early Pleistocene Mollusca from the James City and Chowan River Formations at the Lee Creek Mine

Lauck W. Ward and Blake W. Blackwelder

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## ABSTRACT

A molluscan fauna consisting of 194 species is described from the Chowan River (upper Pliocene) and James City (lower Pleistocene) formations at the Lee Creek Mine, Aurora, North Carolina. These two formations are as much as 7 m thick in the mine and unconformably overlie strata that correlate with the Yorktown Formation in its type area. The Chowan River and James City formations are separated by an unconformity. The mollusks of the Chowan River Formation are assigned to the *Glycymeris hummi*-*Turritella perexilis* assemblage-zone and the mollusks in the overlying James City Formation are assigned to the *Marvacrassatella kauffmani*-*Astarte berryi* assemblage-zone. Although mollusks in these zones lived in a subtropical thermal regime, they include some warm-temperate species not found in contemporaneous deposits farther south. The units represented by these assemblage zones were deposited mostly under open marine conditions at a maximum depth of about 25 m. The *Marvacrassatella kauffmani*-*Astarte berryi* assemblage at Lee Creek lived in association with an offshore bar system, which has some large unidirectional current-bedded shelly sands. Although more than 65 percent of the species in the assemblages are now extinct, the composition and diversity of the mollusks in the different beds is very similar to that of the *Argopecten gibbus* community presently living off the North Carolina coast.

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## Introduction

Open-pit mining for phosphate by Texasgulf Inc. at Lee Creek, near Aurora, Beaufort County, North Carolina (Figure 1), has provided excellent exposures of the Pungo River Formation (lower and middle Miocene), the Yorktown Formation (lower Pliocene), the Chowan River Formation (upper Pliocene), and the James City Formation (lower Pleistocene). The James City Formation at the mine is very

macrofossiliferous and represents about the northernmost known locality for such richly fossiliferous lower Pleistocene beds. Because of the paleogeographic importance of this locality, the molluscan fauna of the Chowan River and James City formations is documented in formal systematics in this paper, and the stratigraphy, biostratigraphy, and paleoecology of the beds is discussed.

Collections at the pit were made on 14 and 15 February 1972 with Druid Wilson, Thor Hansen, and Gordon Lawrence. Additional collecting was done on 25 and 26 April 1972, 14 June 1972, and on 4 May 1973. Other localities of similar age have also been studied and collections made between the Neuse River and the Chowan River, North Carolina. This paper was submitted to the volume editor on 3 March 1975. Some updating of the paper has been done since that time but not all recent references have been included.

ACKNOWLEDGMENTS.—Texasgulf Inc. generously provided access to the phosphate pit. Collection of mollusks was aided by Jack McLellan, then of Texasgulf, now Austin, Texas, by G.B. Lawrence, Richmond, Virginia, and by Thor Hansen, University of Texas at Austin. Lyle Campbell, University of South Carolina at Spartanburg, and Druid Wilson, National Museum of Natural History, provided assistance in various parts of this project. Joseph E. Hazel, then U.S. Geological Survey, Reston, and Norman F. Sohl, U.S. Geological Survey, Washington, made substantial contributions to the content of this paper. Walter R. Brown and Mary J. Mann, National Museum of Natural History, took the SEM photographs. Several other photographs were taken by Robert H. McKinney and Haruo E. Mochizuki, U.S. Geological Survey, Washington. Jules R. DuBar, then Morehead State University, and Thomas R. Waller and F.A. Ruhoff, National Museum of Natural History, provided advice and assistance during the study.

## Stratigraphic Setting

GENERAL.—Approximately 21 m of beds thought to be of Pliocene and early Pleistocene age (Hazel, 1971a:10;

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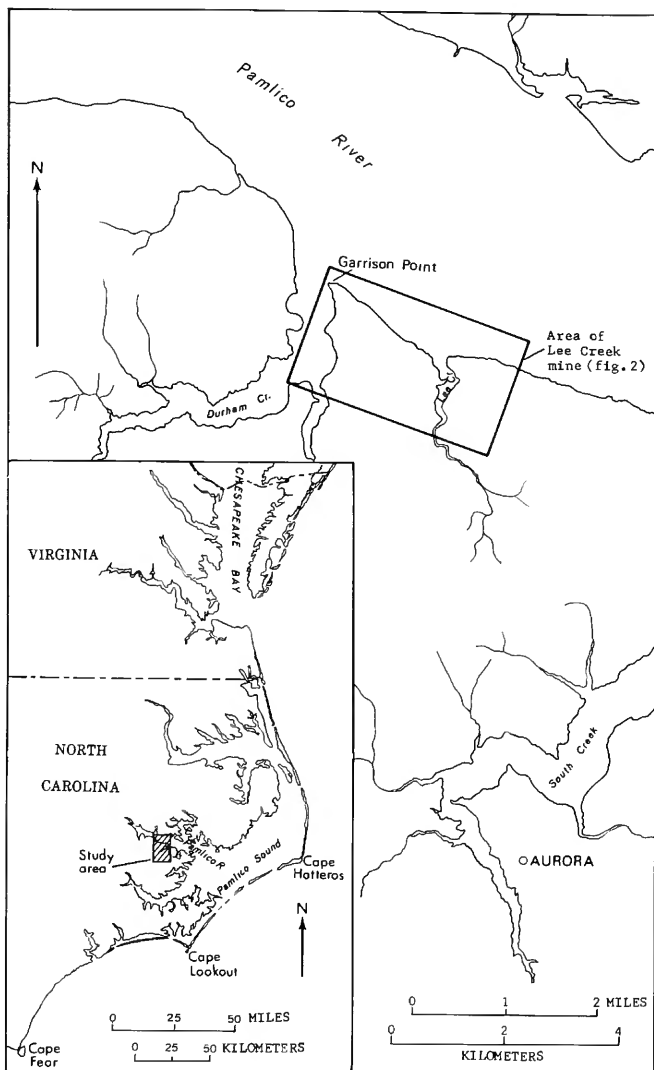


FIGURE 1.—Location of the Lee Creek Mine on the Pamlico River, North Carolina. The corner inset shows the study area on a regional map.

Akers, 1972:134) unconformably overlie the Pungo River Formation (lower and middle Miocene) at the mine (Gibson, 1967:634). The lower 14 m belong to the Yorktown Formation and consist of sparsely macrofossiliferous (except for certain beds in the lower 3 m) sandy clays and clayey sands. These beds are unconformably overlain by 7 m of richly macrofossiliferous upper Pliocene and lower Pleistocene sands and clayey sands. These 7 m of section are the basis of this study. On the basis of mollusks, ostracodes, and foraminifers, the beds assigned to the Yorktown Formation at the mine can be correlated with the Yorktown Formation in its type area. The Chowan River Formation is separated from the Yorktown by a regionally significant unconformity and represents a separate important geologic event.

**CHOWAN RIVER FORMATION.**—Deposits along the Chowan River, northeastern North Carolina, have long been

assigned to the uppermost part of the Yorktown Formation (Clark et al., 1912; Mansfield, 1944). More recently, Hazel (1971a; 1977) recognized that the Chowan River beds are younger than most Yorktown beds in the type area at Yorktown, Virginia. Ward and Blackwelder (1980) redefined the Yorktown Formation and recognized that the "Chowan River beds" unconformably overlie the Yorktown Formation. Blackwelder (1981) named the Chowan River Formation for the "Chowan River beds" and correlated the formation with the Bear Bluff Formation in South Carolina. Bailey (1977) discussed molluscan biofacies in these deposits.

In Virginia, Oaks et al. (1974) discussed a barrier and lagoonal deposit, informally termed the "Moorings unit," which formed when sea level was at 36–37 m (120–125 ft). They indicated that substantial erosion followed the deposition of the "Moorings unit." Oaks and DuBar (1974) correlated the Bear Bluff Formation of South Carolina with the "Moorings unit." "Moorings" apparently represents the shoreline deposits of the Chowan River Formation.

**JAMES CITY FORMATION.**—To the south of the Chowan River area, Mansfield (1943) considered the "Croatan Sand" on the lower Neuse River stratigraphically higher than the "Chowan River beds." DuBar and Solliday (1963:214) proposed that the name "Croatan Formation" be abandoned because it had been used for two very different and unrelated lithic units. They named these units the James City Formation (now known to be of early Pleistocene age) and Flanner Beach Formation (of late Pleistocene age). Prior to the DuBar and Solliday (1963) paper, Mansfield (1936:668) suggested that the Croatan be restricted to the older of the two deposits. These attempts to restrict the use of the term "Croatan" to the older beds have not been based on lithic criteria. Mansfield suggested that the beds at James City *might* be considered the type section. However, this locality below James City was not even mentioned by Dall, whose type sections were rather remote from James City and adjacent New Bern. Dall (1892:209) had proposed the name "Croatan beds" for units along the Neuse River at Slocum's Creek and at Mallison's. The Slocum's Creek locality was stated to be "fifteen miles [24.13 km] below New Bern" and the Mallison's locality "thirteen miles [20.91 km] below New Bern." At these localities, late Pleistocene age material is prominent and early Pleistocene age beds are poorly exposed. For these reasons Blackwelder (1981) recommended that the term Croatan be abandoned.

The Windsor Formation in Virginia was named by Coch (1968) for beach, nearshore, and lagoonal coarse sands, pebble gravel, and silty clay and sands that formed when sea level stood at 24.4–30.2 m (80–100 ft). Coch's Windsor is correlated with the Waccamaw Formation by Oaks and DuBar (1974:73) and is found to the east of the Surry Scarp in Virginia. The Windsor represents marginal marine deposits correlative with the James City Formation. Black-

welder (1981) discussed the distribution of the James City Formation and its relationship to the Chowan River Formation.

The James City Formation has also been correlated with the Waccamaw Formation in North and South Carolina and with the upper part of the Caloosahatchee Formation in Florida on the basis of the fossils (DuBar, Solliday, and Howard, 1974). Five He/U dates on corals from the Caloosahatchee Formation in the type area range from 1.78 to 1.98 million years (m.y.) with an average of 1.84 m.y. (Bender, 1973). A sample from beds, which have been assigned to the Caloosahatchee Formation at St. Petersburg, Florida, was dated by Bender at 2.53 m.y. The Pliocene-Pleistocene boundary is placed at about 1.8 m.y. (Berggren and Van Couvering, 1974). The Chowan River Formation (unit B at Lee Creek, see below) may be approximately equivalent to the lower part of the Caloosahatchee at St. Petersburg (upper Pliocene) and the James City Formation at Lee Creek may be the equivalent of the type Caloosahatchee (lower Pleistocene).

**STRATIGRAPHY OF THE CHOWAN RIVER AND JAMES CITY FORMATIONS AT THE LEE CREEK MINE.**—Figure 1 shows the location of the mine on the Pamlico River. The mine

area is large, and the walls of the pit as they existed in April of 1972 are shown in Figure 2. The original shoreline of the Pamlico River at Lee Creek has been changed. In Figure 2, the original location of Lee Creek and the old Pamlico River shoreline are represented by a thin dashed line, and a solid line represents the new shoreline. The location of the walls of the phosphate pit is shown by a heavy dashed line. The locations of six measured sections made in the pit are indicated by numbered circles. The section studied by Gibson (1967) was from a test pit between our first and second sections and in the area of the old Lee Creek channel.

A fence diagram of the measured sections indicated in Figure 2 is shown in Figure 3. Sea level is approximately 4.5 m below the land surface. Unit A (Yorktown Formation) is an olive-gray clayey fine sand containing abundant microfossils, a lithology that typifies much of the Yorktown from this unit down to the top of the Pungo River Formation at the pit (~14 m). This 14 m section contains beds that belong to the *Pterygocythereis inexpectata* and *Orionina vaughani* assemblage-zones of Hazel (1971a). Unit A is separated from unit B (Chowan River Formation) by an unconformity. Unit B is an olive-gray coarse sand, bedded, burrowed,

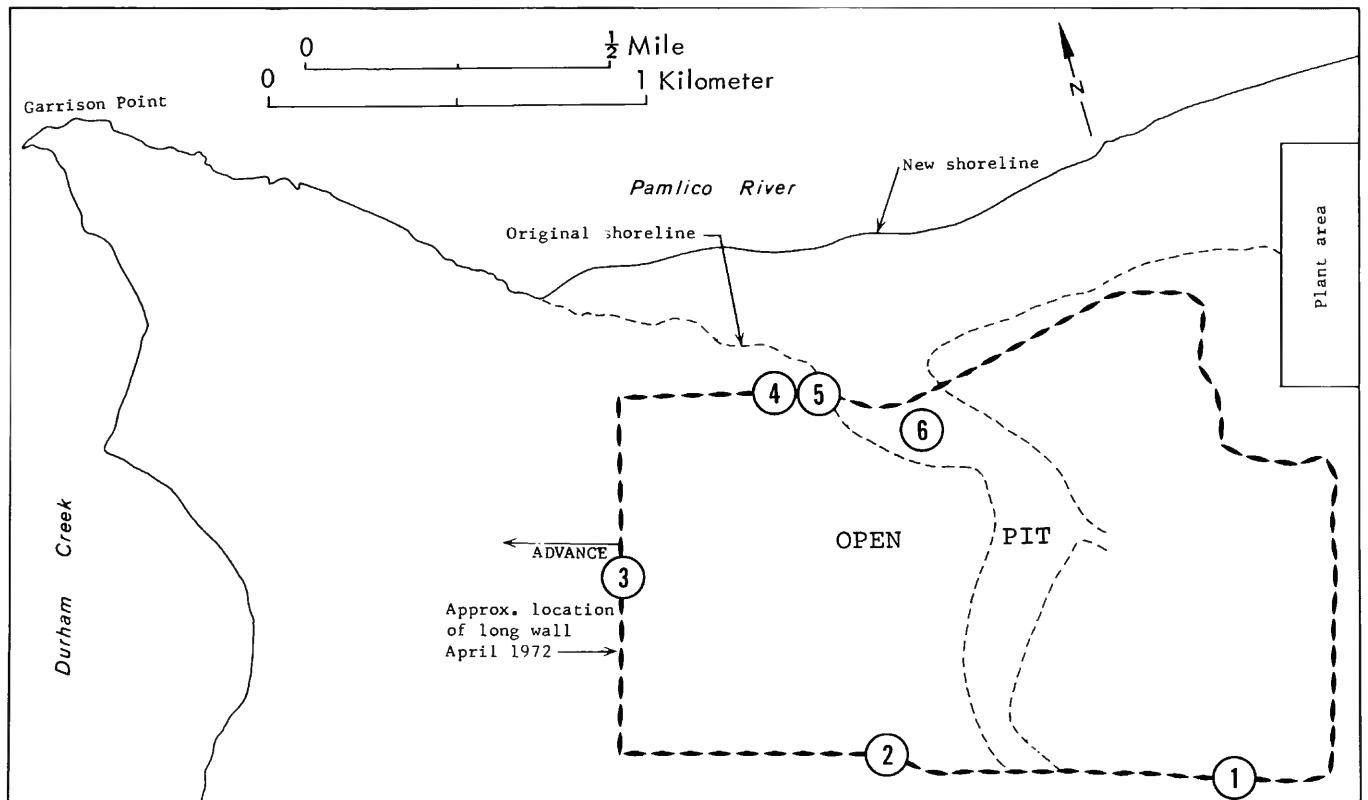


FIGURE 2.—Original location of Lee Creek and of the old Pamlico River shoreline in relation to the walls of the Lee Creek Mine. Location of the measured sections in the walls of the mine is indicated by numbered circles.

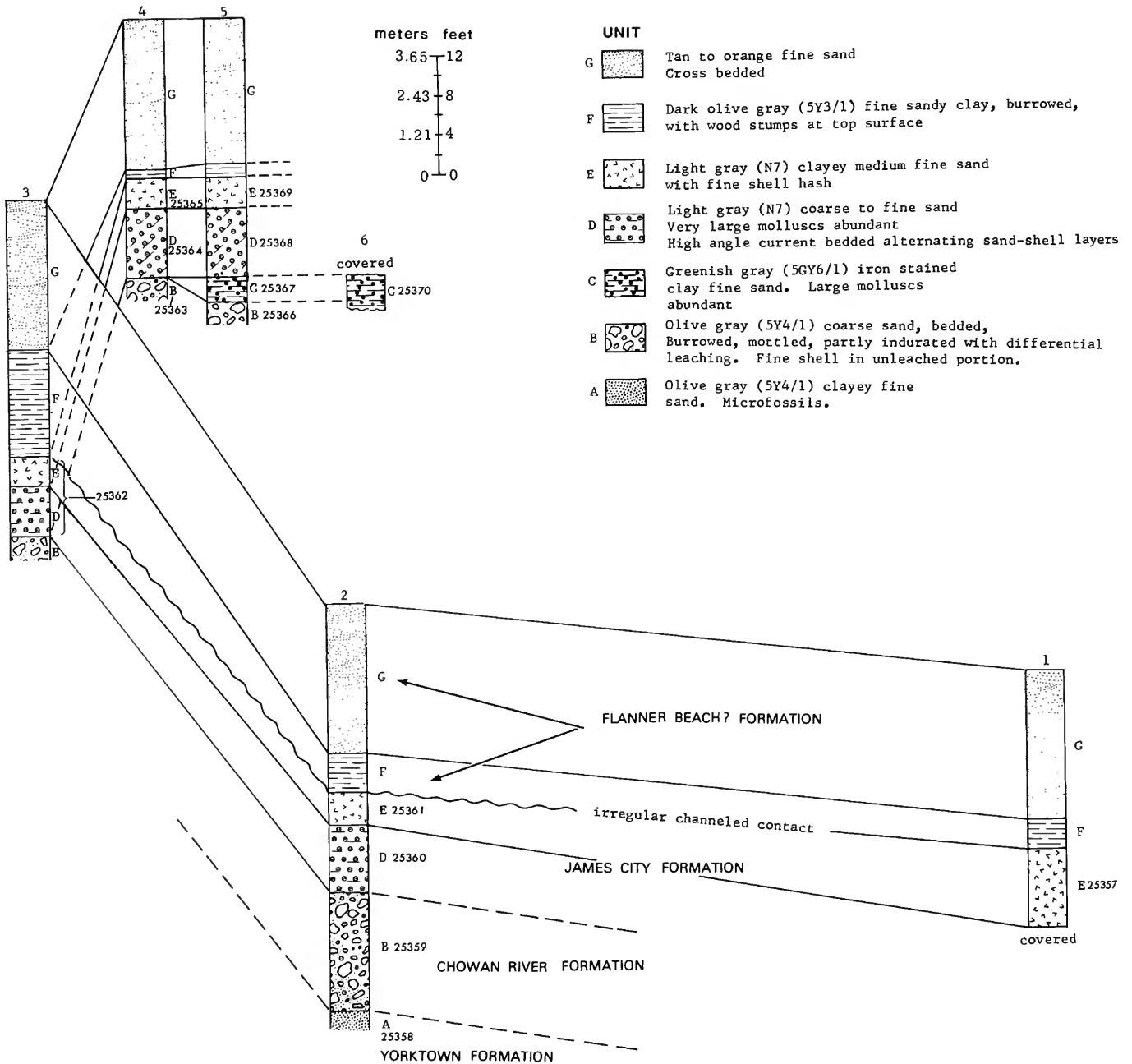


FIGURE 3.—Fence diagram of measured sections. Locations of measured sections are shown in Figure 2. U.S. Geological Survey numbers are given for the particular units from which samples of mollusks were taken.

mottled, and partly leached. Many small-shelled mollusk species are found in the unleached parts.

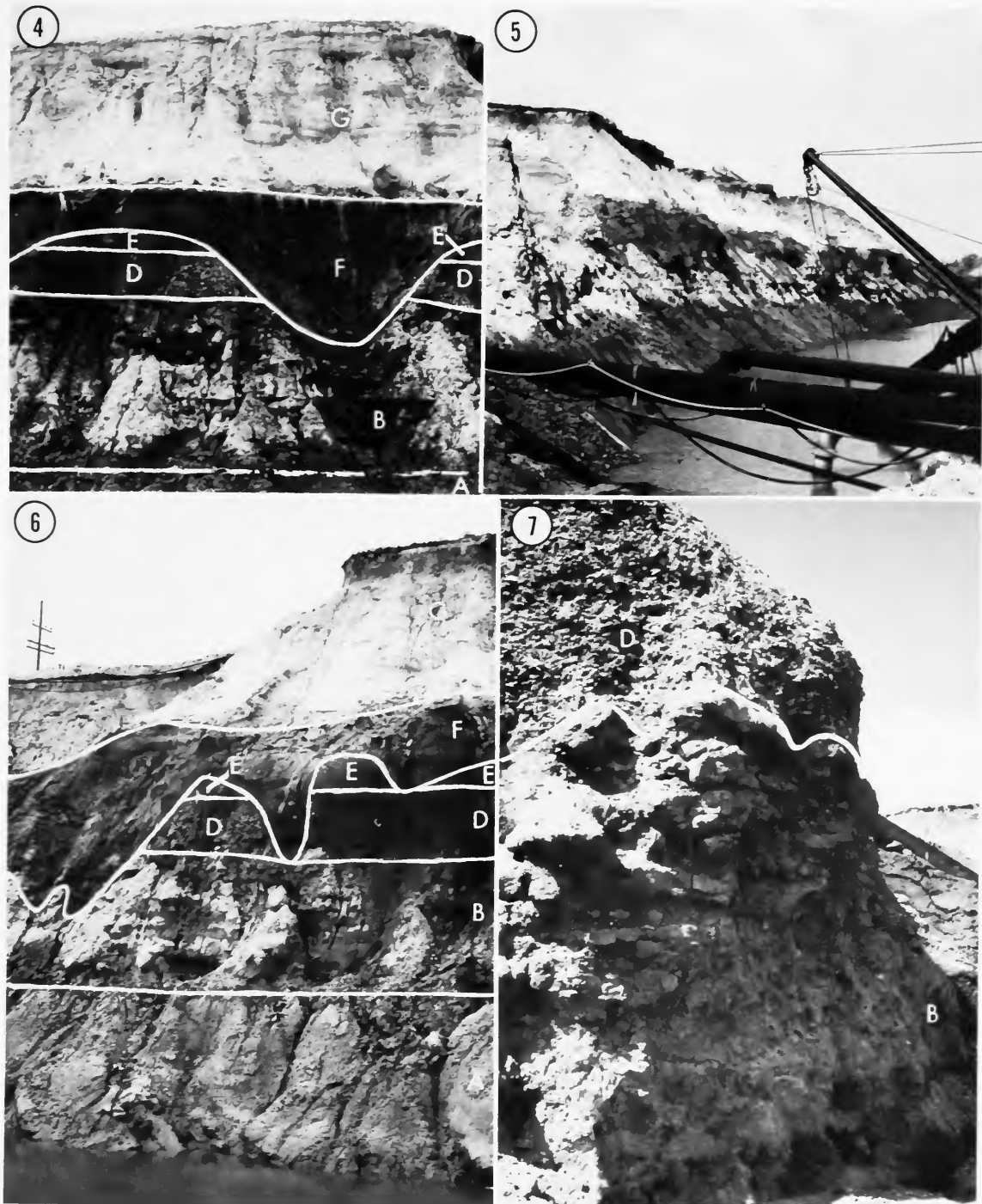
Unit B is overlain by units C–E, assigned to the James City Formation. In the northern part of the pit a greenish gray iron-stained clayey fine sand containing abundant large mollusks (unit C) fills an extensive cut in the top of unit B.

Over these units, a light gray sand was deposited (unit D), which varies from fine to coarse and contains extremely

abundant mollusks. On the north wall of the pit, this unit was deposited as unidirectional high-angle current-bedded, very shelly sand containing occasional pockets of almost pure shell and other pockets of pure sand. Elsewhere in the pit, this unit is horizontally bedded.

Unit D is succeeded by a light gray, horizontally bedded, clayey, medium fine sand containing abundant small shells (unit E). On the south wall, unit E has been extensively





FIGURES 4-7.—The south wall of the pit showing unit A, succeeded by the ledgy indurated sandstone (unit B), followed by very shelly units D and E. The channels cut into shell beds, and the fillings by unit F are visible. The light sands at the top of the section are unit G. Figure 4 shows a channel cutting into shell beds D and E, and the sharp contact between beds F and G. Figure 5 is a view of this south wall looking to the west and showing continuous indurated ledges in unit B. Figure 6 is a closer view of this wall showing the unconformable contact between unit E and unit F and the sharp unconformable contact between bed F and bed G. Stumps and logs are found along the contact of F and G. Figure 7 is a close-up of the indurated sand unit (unit B) and clearly shows the small shell in the unleached and unindurated part of the unit. The shell bed (unit D) containing abundant mollusks can be seen overlying this unit.



FIGURE 8.—West wall of the pit showing the thinning of unit F to the north-northeast (channeled out by river system?). To the left of center in the photograph, the channel cuts down to unit B; units D and E have been completely removed. Below the working ledge of the pit are the fine, clayey sands of the Yorktown Formation.

channeled, and a dark olive-gray fine burrowed sandy clay of the Flanner Beach(?) Formation (unit F) has been deposited over the unit and in the channels. Unit F thins considerably in the north-northeast part of the pit.

Over unit F, a crossbedded tan-orange fine sand of the Flanner Beach(?) Formation (unit G) was deposited with in-place tree stumps and wood at the contact between the two units. Figures 4 through 11 show the nature of the units.

No calcareous fossil remains have been found in deposits above unit E, and these beds are tentatively referred to the Flanner Beach(?) of late Pleistocene age. On the basis of their sedimentologic characteristics, these beds probably represent back barrier and estuarine deposition.

### Biostratigraphy

**RANGE ZONES AND CONCURRENT RANGE ZONES.**—Range zones and concurrent range zones of mollusks may be most useful in correlation with beds at Lee Creek. Figure 12 is a biostratigraphic chart of the upper Pliocene shell beds at Lee Creek and other associated deposits in North Carolina and Virginia. Ranges of common, stratigraphically important taxa are indicated, and the assemblage zones are shown.

Some mollusks such as *Chesapecten madisonius* (Say, 1824) and *Mulinia congesta* (Conrad, 1833) do not range into beds younger than zone 2 of the Yorktown Formation (Mansfield, 1943) or the equivalent Raysor Formation. In contrast to these species, *Glycymeris hummi*, new species, continued into slightly higher stratigraphic units (Chowan River Formation) and consequently is a useful indicator in these higher beds. A large number of species found in the upper

units do not range downward into the older Yorktown beds, and a few of these, such as *Turritella perexilis* Conrad, *Marvacrassatella kauffmani*, new species, and *Crucibulum lawrencei*, new species, are indicated in Figure 11.

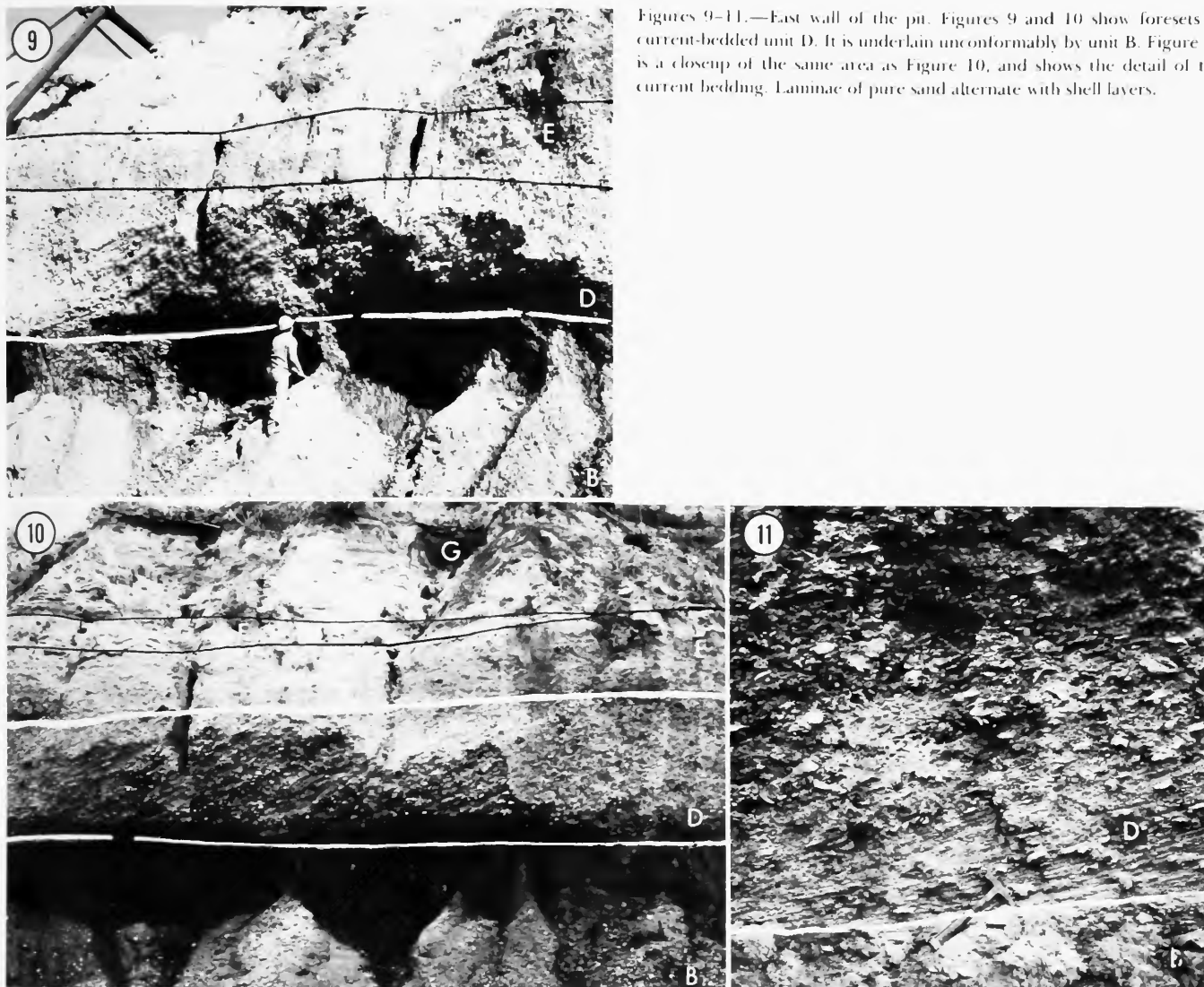
As shown in Figure 12, the deposits of zone 2 of the Yorktown Formation (Mansfield, 1944) are older than deposits belonging in the *Puriana mesacostalis* Zone of Hazel (1971a). The Yorktown, Chowan River, and James City formations in North Carolina were deposited under similar climatic conditions, and about 40 percent of the species are common to the three formations.

The lower beds of the Chowan River Formation at Colerain Landing on the Chowan River, North Carolina, contain a considerably different assemblage from that of the typical Yorktown, and common Yorktown indicator species are generally absent. These beds at Colerain Landing are thought to be slightly older than the Chowan River assemblage at Lee Creek, which has a similar molluscan composition but which also contains some apparently younger elements (such as, *Turritella perexilis*) not found at Colerain Landing. Also, *Glycymeris hummi* is common at Colerain Landing but is very rare in the Chowan River assemblage at Lee Creek and is not found at all in the James City Formation. We believe that the Chowan River Formation at Lee Creek represents approximately the highest known stratigraphic occurrence of this species and that the species became extinct before the deposition of the James City Formation.

**ASSEMBLAGE ZONES.**—Hazel (1971a) has recognized the upper shell beds at Lee Creek to be part of his *Puriana mesacostalis* assemblage-zone. We tentatively recognize two mollusk zones within this ostracode assemblage zone. The lower unit is termed the *Glycymeris hummi*-*Turritella perexilis* assemblage-zone, and the upper unit is termed the *Marvacrassatella kauffmani*-*Astarte berryi* assemblage-zone. These two assemblage-zones are separated by an unconformity thought to represent a brief regression (Figure 12) at the Pliocene-Pleistocene boundary.

The *Glycymeris hummi*-*Turritella perexilis* assemblage-zone represents the lower shell bed and is the indurated sandstone bed of Gibson (1967). This induration is believed to be the result of carbonate solution and reprecipitation within this unit caused by a regression and subsequent exposure of this unit to ground water. Mollusks in this assemblage zone at Lee Creek are generally small and lived in a relatively coarse sand. The sediment may have been mobile at this time because of current action, thus accounting for a lack of larger mollusks. This assemblage zone essentially corresponds to the Chowan River Formation and is believed to be intermediate in age between zone 2 of the Yorktown Formation (Mansfield, 1944) and deposits of the Waccamaw Formation (Figure 12).

At the Lee Creek Mine, the Chowan River and James City molluscan assemblages are very similar to that of the



Figures 9-11.—East wall of the pit. Figures 9 and 10 show foresets of current-bedded unit D. It is underlain unconformably by unit B. Figure 11 is a closeup of the same area as Figure 10, and shows the detail of the current bedding. Laminae of pure sand alternate with shell layers.

Waccamaw Formation (more than 55 percent of the species are in common). Especially high similarities between the assemblages are found where the environment of deposition appears to have been a moderate-energy type of deposit. We believe that the mollusks from the Waccamaw Formation reported from Wilmington by Mansfield (1936a) may represent such a deposit.

Since the deposition of these beds at Lee Creek in late Pliocene and early Pleistocene time, there has been a 65 percent extinction of the species involved. About 35 percent of these species at Lee Creek have no close Holocene representative in the present Atlantic shelf communities. Much of the extinction probably is due to the stress placed upon shelf communities and their component species by climatic and eustatic changes during the Pleistocene.

All the shell beds above the indurated sandstone of the

Chowan River Formation have been placed within the *Marvacrassatella kauffmani*-*Astarte berryi* assemblage-zone. Mollusks of this zone at Lee Creek consist of abundant large species associated with an offshore bar system and also other species in higher beds, which lived during the shallowing conditions that succeeded this bar system. *Marvacrassatella kauffmani* and *Astarte berryi* are both northern species, believed to be typical of this latitude in early Pleistocene time. Both species are representatives of lineages that thrived in the more northern early Pliocene basin in Virginia, and these species represent less thermophilic forms than other similar forms living at the same time to the south in the Waccamaw Sea. For example, *Marvacrassatella* is generally replaced by an entirely different southern group (the *Eucrassatella speciosa* group) in beds of the Waccamaw Formation. Stratigraphically, it should be noted that *Marva-*

STRATIGRAPHIC RANGE OF KEY SPECIES, SUBGENERA AND GENERA

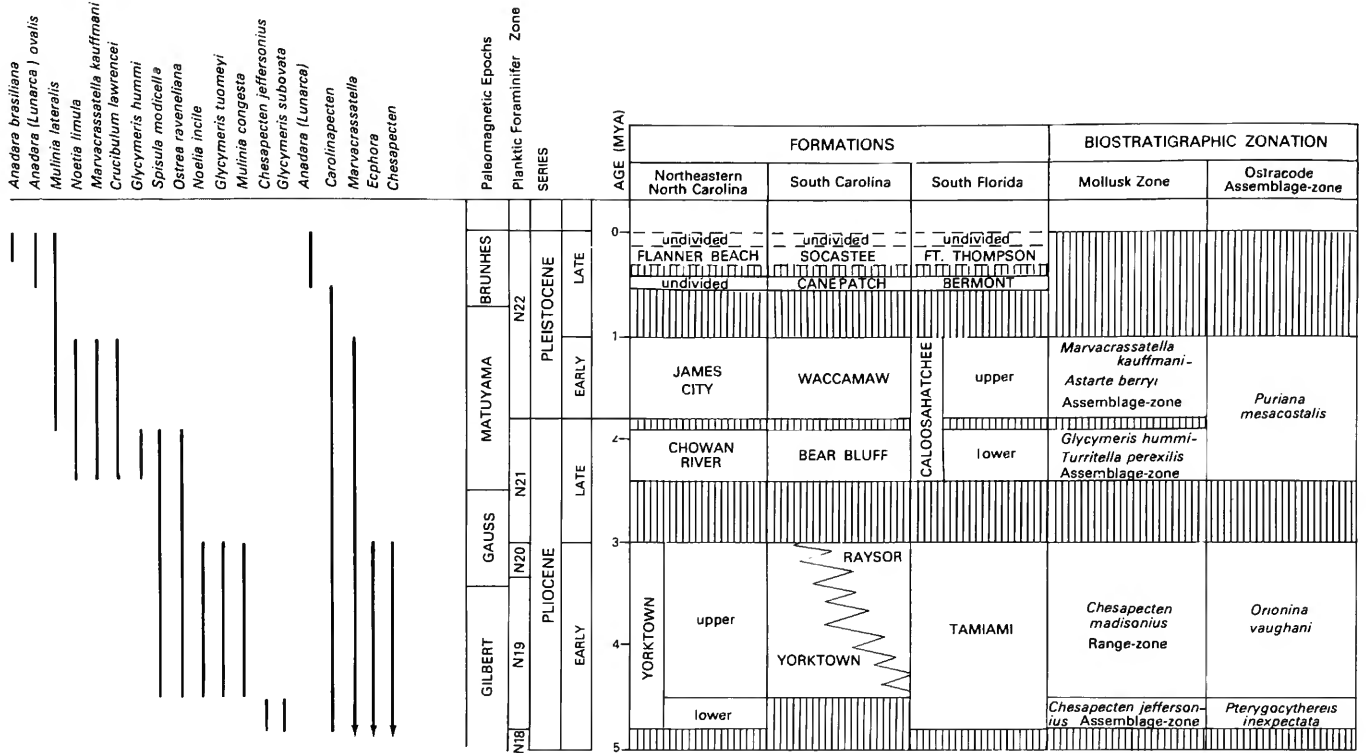


FIGURE 12.—Biostratigraphic correlation of the Yorktown, Chowan River, and James City formations at Lee Creek. Stratigraphic positions of other associated deposits in South Carolina and Florida are indicated. The stratigraphic range of some important taxa is also shown.

*crassatella kauffmani* succeeds *Marvacrassatella undulata*, which is found in zone 2 of the Yorktown. For this reason, *M. kauffmani* is a guide to the upper Pliocene in this part of the Coastal Plain. *Marvacrassatella kauffmani* and *Astarte berryi* both occur in the *Glycymeris hummi* and *Turritella perexilis* assemblage-zone, but *G. hummi* does not range into this younger assemblage. Both of these assemblage-zones may be important in recognizing subsurface units in this part of North Carolina.

**Paleoenvironmental Reconstruction**

FAUNAL COMPARISON OF UNITS B THROUGH E.—The stratigraphic occurrence of different species of mollusks is documented in Table 1. Occurrences are shown by an "X" and the sections and units refer to those on the fence diagram (Figure 3). To facilitate quick reference between Table 1 and the systematic section, the list is alphabetized by genus and secondarily by species. Table 1 shows that many species range through the whole section in different parts of the pit. This distribution of the species reflects the fact that these shell beds were deposited under essentially similar hydrographic conditions on the shallow shelf at a water depth of at least 15 m, most of the beds probably

being at a depth of 20 m or slightly greater (see "*Argopecten gibbus* Community," p. 124). The most important species having a limited range (because of evolution or extinction) within these beds is *Glycymeris hummi* (p. 138).

Table 1 has some bias, in that the mollusks contained in the units of section 5 were studied in more detail than were those of other sections. Other sections were examined for composition and relative abundance of species, but samples were never entirely picked or sorted. For this reason, data from section 5 are more nearly complete than those from the other sections. Because of the small number of samples involved and because of this bias in examination, multivariate methods were not used to analyze the data. The arrangement by stratigraphic unit of samples in Table 1 permits an easy visual analysis of the stratigraphic occurrence of species. Abundances of species are probably more diagnostic of the different stratigraphic units, but abundances change in the same unit in different sections of the pit because topographic and hydrographic conditions were not everywhere the same during deposition. The spatial arrangement of certain species abundances is given in Figure 13 and in a later section on the chronology of events. Individual species abundances are mentioned in the systematic section. Because of the close similarity in species com-

TABLE 1.—Species occurrences in measured sections of the Chowan River (unit B) and James City (units C, D, E) formations at Lee Creek Mine (sections designated by number, units by letter, x = present, dash = not found, \* = collected as float from USGS 25339)

Species	B			C		D				E				
	2	4	5	5	6	2	3	4	5	1	2	3	4	5
Class PELECYPODA														
<i>Abra aequalis</i> (Say)	X	-	X	X	-	-	-	X	X	X	-	-	X	X
<i>Aligena striata</i> Lea	-	-	X	X	-	-	-	-	-	X	-	-	-	-
<i>Anadara aequicostata</i> (Conrad)	X	X	X	X	X	X	X	X	X	-	X	X	X	X
<i>Anisodonta carolina</i> Dall	X	-	X	-	X	X	-	-	-	-	-	-	-	-
<i>Anomia simplex</i> d'Orbigny	-	-	X	X	-	-	X	X	X	X	-	X	-	-
<i>Argopecten vicenarius vicenarius</i> (Conrad)	-	-	-	-	-	X	-	X	-	-	-	-	-	X
<i>Astarte berryi</i> Gardner	-	X	X	X	X	X	X	X	X	-	-	X	-	X
<i>Astarte concentrica</i> Conrad	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Bellucina waccamawensis</i> (Dall)	-	-	-	-	-	X	-	-	-	X	X	-	X	X
<i>Bornia triangula</i> Dall	-	-	X	X	-	-	-	-	X	-	-	-	-	X
<i>Brachidontes</i> sp.	-	-	-	X	-	-	-	-	-	-	-	-	-	X
<i>Callucina kenae</i> (Chavan)	-	-	-	-	-	-	-	X	-	-	-	-	-	-
<i>Carditamera arata</i> (Conrad)	-	-	X	X	X	-	X	X	X	X	X	X	-	X
<i>Carolinapecten eboreus</i> (Conrad)	-	-	X	X	X	X	X	X	X	-	X	X	X	X
<i>Caryocorbula auroraensis</i> , new name	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Caryocorbula contracta</i> (Say)	-	-	X	X	-	-	-	X	-	-	-	-	-	X
<i>Cavilinga trisulcata</i> (Conrad)	-	-	X	X	-	X	-	-	X	X	X	-	-	X
<i>Chama gardnerae</i> Olsson and Harbison	-	-	-	X	-	-	-	-	X	X	-	-	X	X
<i>Chione cribraria</i> (Conrad)*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Chione grus</i> (Holmes)	-	-	-	-	-	-	-	-	-	X	X	-	-	-
<i>Cochlodesma emmonsii</i> , new species	-	X	-	-	-	-	-	-	-	X	-	-	-	-
<i>Conradostrea lawrencei</i> , new species	X	X	X	-	X	X	-	X	X	X	X	-	X	-
<i>Corbicula densata</i> (Conrad)	-	-	-	-	-	-	X	X	-	-	-	-	X	X
<i>Crassinella dupliniana</i> (Dall)	X	X	X	X	-	-	X	X	-	-	-	X	X	-
<i>Crassinella johnsoni</i> , new species	-	-	X	X	-	-	X	-	-	-	-	X	-	-
<i>Crassinella lunulata</i> (Conrad)	X	X	X	X	X	X	-	X	X	X	X	-	X	X
<i>Grassostea virginica auroraensis</i> new subspecies	-	-	-	X	-	X	-	X	X	-	-	-	-	-
<i>Crenella decussata</i> (Montagu)	X	X	X	X	-	-	X	-	X	-	X	-	-	-
<i>Cumingia tellionoides</i> (Conrad)	-	-	X	X	-	-	X	-	X	X	-	X	X	X
<i>Cylocardia</i> sp. cf. <i>C. granulata</i> (Say)	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Crytopleura</i> sp.	-	-	X	-	-	-	-	-	-	-	-	-	-	X
<i>Dinocardium robustum hazeli</i> new subspecies	-	-	-	-	-	-	-	X	-	-	-	-	-	-
<i>Diplodonta acclinis</i> (Conrad)	X	X	X	X	X	-	X	X	X	-	-	X	-	-
<i>Diplodonta berryi</i> McGavock	-	-	-	-	X	-	X	-	-	X	-	X	-	X
<i>Divalinga</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Donax fossor</i> Say	-	X	X	X	-	-	-	-	-	-	-	-	-	X
<i>Dosinia</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Ensis directus</i> (Conrad)	X	X	X	X	-	-	X	X	X	X	-	X	X	X
<i>Ensitellops elongata</i> Olsson and Harbison	-	-	X	X	-	-	-	-	X	-	-	-	-	-
<i>Erycinella ovalis</i> Conrad	-	-	X	-	-	-	-	-	-	-	-	-	-	-
<i>Gastrochaena hians</i> (Gmelin)	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Gemma magna majorina</i> Gardner	-	-	-	X	-	-	-	X	X	X	-	-	X	X
<i>Glycymeris americana</i> (Defrance)	X	X	X	-	X	-	X	X	X	-	-	X	X	X
<i>Glycymeris arata</i> (Conrad)	-	-	X	X	-	-	X	X	X	-	-	X	X	X
<i>Glycymeris hummi</i> , new species	-	-	X	-	-	-	-	-	-	-	-	-	-	-
<i>Glycymeris sloani</i> , new species	X	X	X	X	X	-	-	X	X	-	-	-	X	X
<i>Gouldia metastriatum</i> (Conrad)	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Laevicardium sublineatum</i> (Conrad)	-	X	-	X	-	-	-	X	-	X	-	-	-	-
<i>Leptopecten? auroraensis</i> , new species	X	-	X	X	X	X	-	-	-	X	X	-	-	X
<i>Lithophaga yorkensis</i> Olsson	-	-	-	-	-	-	-	-	-	-	-	-	-	X
<i>Macoma holmsii</i> Dall	-	-	-	-	-	X	-	-	-	-	-	-	-	-
<i>Macrocallista greeni</i> , new species	-	-	X	X	X	-	X	-	X	-	-	X	-	X
<i>Marvocrassatella kauffmani</i> , new species	-	-	-	X	X	X	X	X	X	-	-	X	X	X
<i>Mercenaria mercenaria</i> (Linnaeus)	-	-	-	-	-	-	-	X	-	-	-	-	-	-
<i>Mercenaria permagna</i> (Conrad)	-	-	X	X	X	X	X	X	X	X	-	X	X	X
<i>Modiolus</i> sp. cf. <i>M. modiolus</i> (Linnaeus)	X	-	X	-	X	-	X	X	X	X	-	X	X	X
<i>Mulinia lateralis</i> (Say)	-	-	-	-	-	-	-	X	X	-	X	-	-	X
<i>Musculus lateralis</i> (Say)	-	-	-	X	-	-	-	-	-	-	-	-	-	-
<i>Mya arenaria</i> Linnaeus	-	-	-	-	-	-	-	X	X	-	-	-	X	-
<i>Mysella baufortensis</i> , new species	-	-	-	X	-	-	-	-	-	-	-	-	-	-
<i>Mytilus</i> sp.	-	-	X	-	-	-	-	-	-	-	-	-	-	-
<i>Noetia limula</i> (Conrad)	-	-	X	-	X	X	X	X	X	X	-	X	-	X
<i>Nucula pilkeyi</i> , new species	-	-	-	-	-	-	-	-	X	-	-	-	-	-
<i>Nucula proxima</i> Say	X	X	X	X	X	X	X	-	X	X	X	X	X	X
<i>Nucula taphria</i> Dall	-	-	X	X	-	-	X	-	-	-	X	-	-	-

TABLE I.—Continued.

Species	B			C		D				E				
	2	4	5	5	6	2	3	4	5	1	2	3	4	5
<i>Nuculana acuta</i> (Conrad)	X	X	X	X		-	X	X	X	X	-	X	X	X
<i>Pandora tuomeyi</i> Gardner and Aldrich		X	X	X		-		X	X		-	-	-	X
<i>Panopea floridana</i> Heilprin	-	-	-	-		-	X	-			-	X	-	
<i>Paramya subovata</i> (Conrad)	X	-	X	X		-	X	-	X		-	X	-	
<i>Parvilucina multilinea</i> (Tuomey and Holmes)	-	-	X	X		-		X	X		-	-	-	X
<i>Petricola pectorosa</i> (Conrad)	-	-	-	X		-	-	-			-	-	-	-
<i>Petricola pholadiformis</i> Lamarck*	-	-	-	-		-	-	-			-	-	-	-
<i>Phlyctiderma heroni</i> , new species	-	-	-	X		-	-	-			-	-	-	-
<i>Pitar chioneformis</i> (Gardner)	-	-	X	X	X	-		X	-	X	-	-	-	X
<i>Pleuromeris auroraensis</i> , new species	X	X	X	X	-	X	X	X	-	-	-	X	-	X
<i>Pleuromeris decemcostata</i> Conrad	X	X	X	X	X	X		X	X		-	-	X	X
<i>Plicatula marginata</i> Say	X	X	X	-	-	X	X	X	X	X	X	X	X	X
<i>Pododesmus fragosus</i> (Conrad)	-	-	-	-	-	-	X	-	-		-	X	X	-
<i>Pteromeris perplana</i> (Conrad)	X		X	X	X	-	X	X	X		-	X	-	X
<i>Quadrilatera adamsi</i> (Dall)	-		-	-	-	-	-	-	-		-	-	-	X
<i>Raeta plicatella</i> (Lamarck)	-	X	X	X	-		-	X	-		-	-	-	
<i>Rangia clathrodonta</i> (Conrad)	-		-	-	-	-		X	-		-	-	-	
<i>Semele bellastrata</i> (Conrad)	X	X	-	-	X	X	X				-	X	-	
<i>Sphenia dubia</i> (Lea)	-		-	-	-	-	-	-			-	-	-	X
<i>Spisula similis</i> (Say)	-		X	X	-	X	X	X	X		X	-	X	
<i>Spisula solidissima</i> (Dillwyn)	-		-	-	-	-	-	X	-		-	-	-	
<i>Sportella waccamawensis</i> Gardner	-		-	-	-	-	-	-			-	-	-	
<i>Stewartia anodonta floridana</i> (Conrad)	-		-	-	X			X	X		-	X	X	
<i>Tagelus plebeius carolinensis</i> (Conrad)	-		-	-	-	X	-	-	-		-	-	X	
<i>Tellina agilis</i> Stimpson	X		X	X	X	X	X	X	X		X	X	X	
<i>Thracia brioni</i> , new species	X		X	X	-		-	-	-		-	-	-	-
<i>Transennella stimpsoni</i> Dall	X		X	X	-	X	X	-	X		-	X	-	
<i>Verticordia emmonsii</i> Conrad	-		X		-		-	-			-	-	-	
<i>Verticordia lockei</i> , new species	-		-	X	-		-		X		-	-	-	
Class SCAPHOPODA														
<i>Cadulus quadridentatus</i> (Dall)	-		X		-		-	-			-	-	-	
Class GASTROPODA														
<i>Acetocina candei</i> (d'Orbigny)	-		X	X	-	X	-	X	X	X	-	-	X	X
<i>Aesopus gardnerae</i> , new species	-		X	X	-		-	-	X		-	-	-	X
<i>Aesopus ithitoma</i> (Dall)	-		-	-	-		-	-	X		-	-	-	
<i>Aesopus stearnsii</i> (Tryon)	-		X	X	-		-	X	X		-	-	-	
<i>Anachis milleri</i> Gardner	-		X	X	-	X		X	X		-	-	-	X
<i>Arene pergemma</i> (Gardner)	X	X	X	X	-		-	X	X		-	-	-	X
<i>Balcis beaufortensis</i> , new species	-		-	X	-		-	-	-		-	-	-	
<i>Balcis biconica</i> (Gardner)	-		X										X	
<i>Balcis eborea</i> (Conrad)	-			X										
<i>Balcis?</i> sp.	-		-	X	-				X		-	-	-	-
<i>Billium podagrinum</i> Dall	-		-	X	-	X	-	X	X		-	-	X	-
<i>Brachycthara reidenbachi</i> , new species	-		-	-	-		-	X	X		-	-	-	X
<i>Busycon adversarius</i> Conrad see 1329	-		X	X	-	X	X	X	X		-	-	X	-
<i>Busycon carica</i> (Gmelin)	-		-	-	-		X	X	-		-	X	-	
<i>Busycon concinnum</i> Conrad	-		-	-	X		-	X	-		-	-	-	
<i>Busycon spiratus pyruloides</i> (Say)	-		-	-	X	X		X	-		-	-	-	
<i>Caecum beaufortensis</i> , new species	-		-	X	-		-	-	-		-	-	-	
<i>Caecum flemingi</i> Gardner and Aldrich	-		X	X		-		X	X		-	-	X	X
<i>Caecum imbricatum</i> Carpenter	-		X	X		-	X	X	X		-	X	X	
<i>Caecum pulchellum</i> Stimpson	-	X	X			-		X	X		-	-	X	X
<i>Calliostoma philanthropum pontoni</i> Mansfield	-		-	-	X	X		X	-	X		-	X	-
<i>Calyptrea centralis</i> (Conrad)	-		X	-	-	-	-	-	X		-	-	-	-
<i>Chrysallida auroraensis</i> , new species	-		-	-	-	-	-	-	-		X	-	-	-
<i>Chrysallida beaufortensis</i> , new species	-		-	-	-	-	-	-	-		-	-	-	X
<i>Conus adversarius</i> Conrad	-		-	-	-	-	X	X	-		-	X	-	-
<i>Crepidula aculeata</i> (Gmelin)	-		X	X		-	X	X	X	X	-	X	X	X
<i>Crepidula fornicata</i> (Linnaeus)	-		X	X	X		X	-	X		-	X	X	X
<i>Crepidula plana</i> Say	-		X	X		-	X	-	-		-	X	-	-
<i>Crucibulum lawrencei</i> , new species	-		X	X		X	X	X	-		-	X	X	-
<i>Cyclostremiscus obliquestriatus</i> (Lea)	-		X	X		-	-	X	-		-	-	-	X
<i>Cymatosyrinx lunata</i> (Lea)	-		X	X		-	-	-	X		-	-	-	
<i>Dentimargo polypira?</i> (Olsson and Harbison)	-	X	X	X		X	X	X	X		-	X	-	X





positions of different units, the assemblages are considered together in some of the comparisons to follow. It should be remembered that the number of species in units B and E is slightly less than that of other units, but that most of these species are also shared by other units and that the units all represent similar or related shelf environments.

**DEPOSITIONAL PHASES.**—The upper shell beds at Lee Creek are interpreted as representing three distinct depositional phases (Figure 13). The first phase (bottom) consists of a transgression and the deposition of unit B (Chowan River Formation, a shallow-shelf coarse-bedded sand deposit) over the fine clayey sands of unit A. Unit B, which contains the *Glycymeris hummi*-*Turritella perexilis* assemblage-zone, has subsequently been differentially leached during subaerial exposure.

The second phase resulted in deposition of the James City Formation as an offshore bar system, which formed at Lee Creek following a new transgression. Unit C represents a shallower part of this depositional system, possibly deposited in scoured-out parts of unit B. Unit C is followed by deposition of higher energy fine-to-coarse shelly sands (unit D) which, in the north wall of the pit, are unidirectionally current bedded (Figure 13 and Figures 9–11).

In the last phase of deposition (Figure 13), finer grained sediments containing abundant small shells (unit E) were deposited in a lower energy, slightly shallower environment. Possibly an offshore barrier had built up and prevented scouring, except in certain places, such as topographic highs on the old bar deposits.

**COMPARISON OF FAUNA OF BEDS B THROUGH E WITH *ARGOPECTEN GIBBUS* COMMUNITY.**—The composition and diversity of the Chowan River and James City Lee Creek molluscan assemblages are (with the exception of the highest shell bed, unit E) quite similar to those of the subtropical *Argopecten gibbus* community reported by Porter and Wolfe (1971) living today off the North Carolina coast south of Hatteras in about 20 to 40 meters of water. This *Argopecten* community has about 82 species of pelecypods (compared with 95 for Lee Creek), 2 scaphopods (1 at Lee Creek), and 94 gastropods (98 at Lee Creek). Shallower water assemblages usually have fewer species. For example, the number of species listed by Bird (1970) for shallow-marine and estuarine benthic molluscan communities from Beaufort, North Carolina, is small (57 pelecypods and 48 gastropods). Parker (1959) listed only 68 pelecypods and 53 gastropods from the bays and lagoons of the Rockport, Texas, region and the Laguna Madre. Not only do these shallow-water communities have fewer species, but the apportionment of species among the different molluscan families is quite different from that of the Lee Creek assemblages. Table 2 is a comparison of the number of species in each family from Lee Creek assemblages and the number of species in the same families represented in the Holocene *Argopecten gibbus* community. The number of species be-

longing to each of the families is quite similar for each of the two groups (some of the small gastropods, such as the Vitrinellidae and Caecidae, are missing from the lists of Porter and Wolfe (1971:93) because of sampling techniques). The similarity of the composition of these two assemblages is very close, considering that almost 65 percent of the species at Lee Creek are extinct. Comparison of the families shows that the general faunal composition has remained the same (proportions of predators, scavengers, and different types of filter feeders).

Despite the high percentage of extinct species at Lee Creek, many generic and specific faunal similarities can be seen between the *Argopecten* community and the Lee Creek beds. Porter and Wolfe (1971) note the common presence of *Crepidula aculeata*, *Crepidula fornicata*, *Fasciolaria*, *Oliva*, *Prunum*, *Conus*, *Anadara*, *Pecten*, *Eucrassatella*, *Laevicardium*, *Chione*, and *Macrocallista* in the *Argopecten* community. Also, one part of the *Argopecten* community is surrounded by large heads of lobe star coral *Solenastrea hyades* (Dana). In parts of our beds, *Argopecten* is common, although not abundant. Many of our species are found in close association with *Solenastrea* at Lee Creek. Considering the number of extinct species and the species replacement in the communities since the late Pliocene, there is a close relationship between the Lee Creek upper Pliocene–lower Pleistocene assemblages and the Holocene *Argopecten* community.

The beds associated with the bar assemblage are thought to be the result of particularly rapid deposition. Circulation and nutrient supply to the area apparently provided ideal conditions for high productivity, resulting in the great diversity of species and individuals. Similar areas of high productivity have been observed by the authors on the present-day continental shelf on shallow bars several miles offshore from Myrtle Beach, South Carolina.

**CORBICULA-RANGIA PROBLEM.**—When the James City assemblages are examined in detail, several important features are seen. Two genera, *Corbicula* and *Rangia*, are present; these are not normally associated with Holocene marine deposits. The species at Lee Creek are the bivalves *Rangia clathrodonta* (Conrad) and *Corbicula densata* (Conrad). In other Pliocene and lower Pleistocene deposits in the Coastal Plain, both of these species are commonly found in shallow marine deposits. They are definitely more abundant in shallower water marine fossil deposits than in more offshore deposits. At Lee Creek, specimens of *Corbicula* range from a few millimeters to more than 50 mm in length. Many specimens are paired and unworn. Specimens that reach adulthood in the freshwater environment often have umbos corroded by fresh water, a feature not observed on Lee Creek specimens. Individuals from low salinity environments may have been transported as larvae and may have established themselves on the offshore bar system and grown to adulthood in the marine environment. Holocene

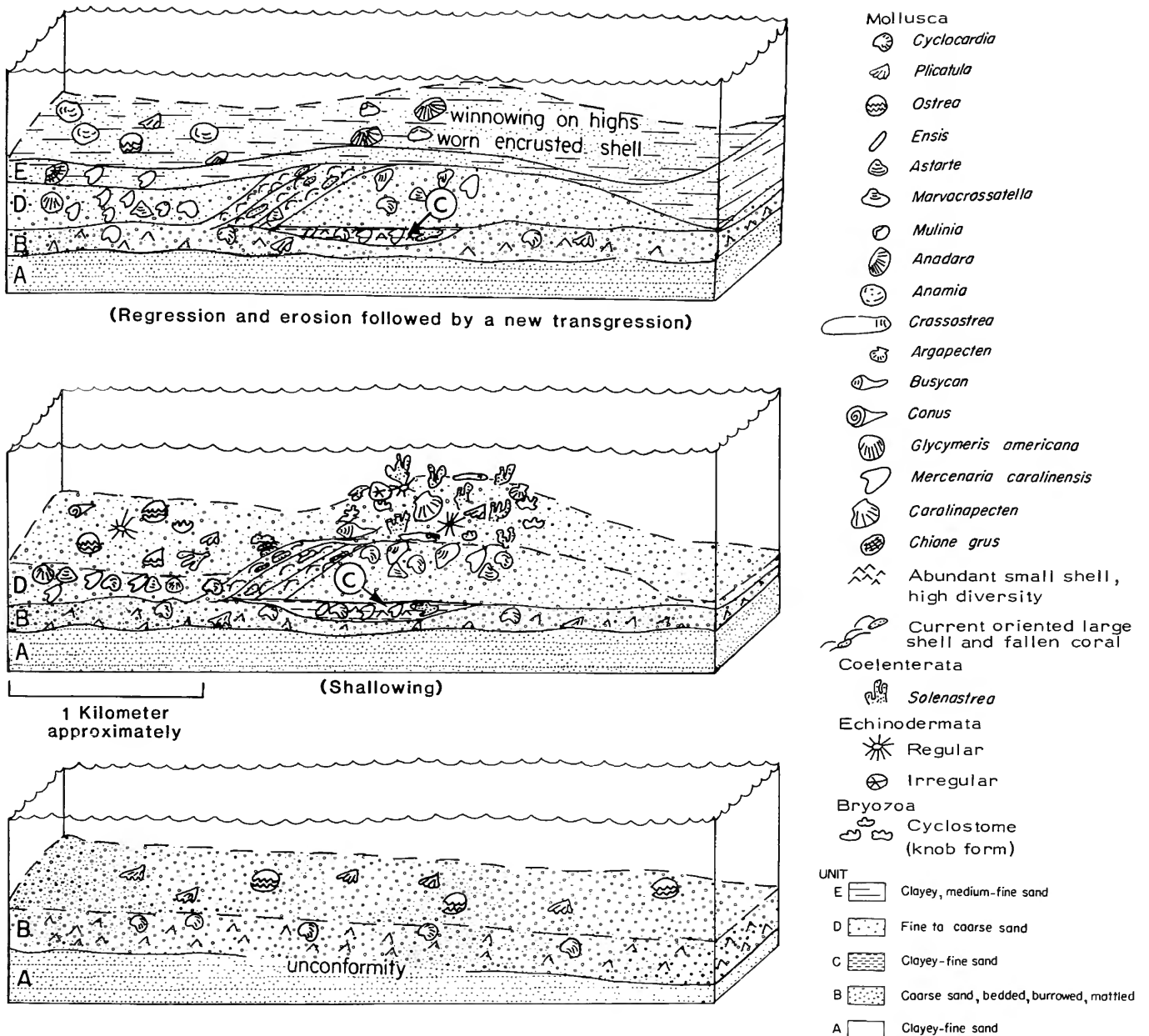


FIGURE 13.—Depositional phases of the Chowan River and James City Formations at Lee Creek shown by schematic block diagrams. Major macrofaunal elements are shown on each of the block diagrams, and different sediment types for each of the units are indicated. These units correspond with those shown in Figure 3. *Bottom*: deposition of unit B (Chowan River Formation) over an unconformable surface of the Yorktown Formation. *Middle*: A brief regression and erosion preceded deposition of the lower bed of the James City Formation (C). A bar complex formed in the area after the deposition of unit C. This bar complex supported a diverse molluscan assemblage. *Top*: A slight shallowing caused a change in the nature of deposition in the area, and a less diverse assemblage lived in the finer sediments deposited at this time (unit E).

representatives of *Corbicula* and *Rangia* have not retained the euryhaline range of the Pliocene and early Pleistocene forms, and consequently, only on the very rarest occasion are these ever seen in a shallow marine environment and

only then by transport from another environment. Both *Rangia* and *Corbicula*, we feel, indicate proximity of land, and their presence in the beds at Lee Creek marks the approximate limit of their range into such marine units.

TABLE 2.—Comparison of the numbers of species/subspecies per family in the Chowan River and James City molluscan assemblages at Lee Creek Mine with those of the *Argopecten gibbus* community reported by Porter and Wolfe, 1971 (families listed in phylogenetic order; see Checklist, p. 129)

Family	Lee Creek Mine	<i>A. gibbus</i> community	Family	Lee Creek Mine	<i>A. gibbus</i> community
Class PELECYPODA			Class SCAPHOPODA		
Nuculidae	3	1	Siphonodentaliidae	1	1
Nuculanidae	1	0	Class GASTROPODA		
Arcidae	2	5	Fissurellidae	3	1
Noetiidae	1	1	Trochidae	1	3
Glycymerididae	4	2	Liothiidae	1	0
Mytilidae	6	8	Littorinidae	1	0
Pectinidae	3	4	Rissoidae	1	0
Plicatulidae	1	1	Vitrinellidae	6	0
Anomiidae	2	3	Tornidae	2	0
Ostreidae	2	3	Caecidae	4	0
Lucinidae	6	2	Turritellidae	2	1
Ungulinidae	3	2	Vermicularidae	1	1
Chamidae	1	4	Vermetidae	1	0
Lasacidae	2	0	Cerithiidae	2	0
Leptonidae	1	0	Triphoridae	1	0
Sportellidae	3	0	Epitoniidae	6	2
Carditidae	5	0	Melanellidae	5	2
Condylocardiidae	1	0	Crepidulidae	5	5
Astartidae	2	0	Eratoidae	1	0
Crassatellidae	4	1	Naticidae	3	7
Cardiidae	2	6	Muricidae	6	6
Mactridae	5	2	Columbellidae	7	6
Cultellidae	1	0	Nassariidae	5	2
Tellinidae	2	6	Melongenidae	4	4
Donacidae	1	0	Fasciolaridae	3	3
Semelidae	3	3	Olividae	2	3
Solecurtidae	1	2	Mitridae	1	0
Corbiculidae	1	0	Volutidae	1	1
Veneridae	10	7	Cancellariidae	1	1
Perticolidae	2	1	Marginellidae	4	5
Myidae	3	1	Conidae	1	2
Corbulidae	2	3	Terebridae	2	2
Gastrochaenidae	1	2	Turridae	5	4
Hiatellidae	1	2	Pyramidellidae	8	2
Pholadidae	1	1	Ringiculidae	1	0
Pandoridae	1	1	Acteocinidae	1	2
Periplomatidae	1	0			
Thraciidae	1	1			
Verticordiidae	2	0			

*Crassostrea*, generally associated with bays and lagoonal deposits in the Holocene, is abundant in certain units at Lee Creek. Studies of the Holocene range of this species have shown that it can survive in the marine environment (Wells and Gray, 1960), and Stenzel (1971:1039) noted that larvae and young adults tolerate 10–40 parts per thousand and may grow in hyperhaline conditions. Specimens of *Crassostrea* at Lee Creek have a peculiar lamellate growth structure rarely approached by Holocene representatives living in bays and estuaries. Such a growth structure may repre-

sent an open-shelf growth habit. The Lee Creek specimens of *Crassostrea* were adapted to conditions on the inner part of a very broad shelf platform. During late Pliocene and early Pleistocene deposition at Lee Creek, the shelf was at least twice as wide as it is now in the Raleigh Bay area. On such a broad shallow platform, inner-shelf conditions may have been much more influenced by periodic coastal runoff and dilutions. These conditions would explain the association of *Crassostrea* with other species at Lee Creek, which are of an open-marine nature (see herein). Many of the

typical very shallow (less than 10 m) marine mollusks (e.g., *Donax*, *Terebra*, *Ervilia*) are either rare or lacking at Lee Creek.

**THERMAL REGIME.**—The thermal regime represented by the upper shell beds at Lee Creek is different from that existing off the coast at the same latitude today. The subtropical faunal provinces and equivalent climatic zones in this region off the southeastern United States are: Virginian-mild temperate, Carolinian-subtropical, Caribbean-tropical. At present there is no warm-temperate faunal province in this region and the boundary of the Virginian and Carolinian provinces is located at Cape Hatteras (latitude 35° 15' N) (Valentine, 1971:17). This sharp boundary exists because of the convergence of isotherms here. The latitude of the Lee Creek locality is approximately 35° 20' N, and the assemblages may have lived south of such a sharp thermal boundary. Almost without exception, living species found in the Lee Creek beds have a subtropical range on the Atlantic continental shelf today. Cape Hatteras today occupies a unique position in that the shelf is extremely narrow at this particular latitude, and hence the barrier has much more influence upon current patterns than any of the other capes along the coast. When the Cape Hatteras area was submerged, currents could flow more directly northward, as is shown in Figure 14. The present-day Gulf Stream trends in the same general direction north of Hatteras, but here the trend of the continental margin changes to a more westerly direction away from the Gulf Stream axis, as shown by the 200-m depth contour. This change in the continental margin makes Virginia more remote from the Gulf Stream influence. The removal of Cape Hatteras as a barrier to coastal currents would permit the Gulf Stream to influence the marine environments much farther north than at present (Figure 14), as suggested by the arrows of generalized shelf currents (bottom drift) during Pliocene and early Pleistocene time. Current directions are modified from positions of present shelf currents shown by Bumpus and Lauzier (1965) and Bumpus (1973) and are only meant to suggest (in this paper) generalized directions of bottom drift.

A second factor influencing the composition of the Lee Creek molluscan assemblages is the postulated presence of a warm-temperate province to the north in late Pliocene time, whereas today a mild-temperate climatic zone is found off Virginia. Prior to the deposition of these assemblages at Lee Creek, the Yorktown Sea occupied a large basin in Virginia (Figure 14). Mollusks common to these Yorktown beds, especially to the upper part of the Yorktown, include a large number of taxa that are not found in mild-temperate waters but which are warmer water forms including species of *Conus* (sinistral), *Amusium*, *Glycymeris americana*, two species of *Fasciolaria*, *Sconsia*, *Chione* sp. cf. *C. intapupurea*, *Chama congregata*, *Cancellaria*, *Trigonostoma*, and *Anadara lienosa*. Also, a large number of subtropical taxa in the

contemporaneous Yorktown Formation to the south are not commonly found in the Virginia Yorktown, including the taxa: *Cypraea*, *Murex*, 5 species of *Fasciolaria*, *Trachycardium*, sinistral *Busycon*, *Turbo*, *Mitra*, *Echinochama*, *Eucrasatella?*, and *Codakia*. For these reasons we believe that the Yorktown Formation, especially the upper part, is representative of a warm-temperate climatic zone. Although this Yorktown basin apparently closed (nondepositional area) when the Yorktown Sea retreated, warm-temperate marine conditions apparently continued to prevail at these latitudes during the deposition of the assemblages at Lee Creek. As many species are not restricted to a single thermal province, a few representatives of such a warm-temperate environment (*Astarte berryi* and *Marvacrassatella kauffmani*) are present at Lee Creek. The presence of these warm-temperate species suggests that the Lee Creek deposits may be near to the northernmost part of the subtropical thermal regime.

Paleotemperatures for these assemblages at Lee Creek are difficult to calculate because of lack of knowledge concerning the details of distribution of present-day mollusks on the continental shelf. Temperatures at Lee Creek may have a seasonal range similar to that found on the North Carolina shelf in Onslow Bay at depths of about 20 m. *Solenastrea*, a coral common at Lee Creek, was reported by Macintyre and Pilkey (1969) in Onslow Bay at this depth in bottom temperatures ranging from 10.6° to about 27° C. More normal temperature ranges for this area may be from 15° to 27° C (Walford and Wicklund, 1968). Similar paleoclimatic observations for these units were made by Hazel (1971b) on the basis of the ostracodes, although he indicated that the winter temperature may have been somewhat warmer than 15° C.

#### Chronology of Late Pliocene and Early Pleistocene Events at the Lee Creek Mine

**CHOWAN RIVER FORMATION.**—A transgressive shallow-water coarse marine sand containing abundant small mollusks (unit B) was deposited over finer grained sediments of the Yorktown Formation (unit A) which, here, lack abundant well-preserved macrofossils. This coarse marine sand contains a diverse assemblage (in terms of number of species), which is typical of the modern east coast shallow shelf (about 20 m or slightly greater). The most conspicuous members of this assemblage are *Cyclocardia* and *Plicatula* (Figure 13). Unit B has been differentially leached and indurated by groundwater flow and the resultant reprecipitation of carbonate. Apparently leaching took place during a brief period of emergence before deposition of succeeding units.

**JAMES CITY FORMATION.**—In the northern area of the pit, a coarse shelly sand (unit C) was deposited where part of unit B had been eroded. The most conspicuous species here is *Mercenaria permagna*, which is found in living posi-

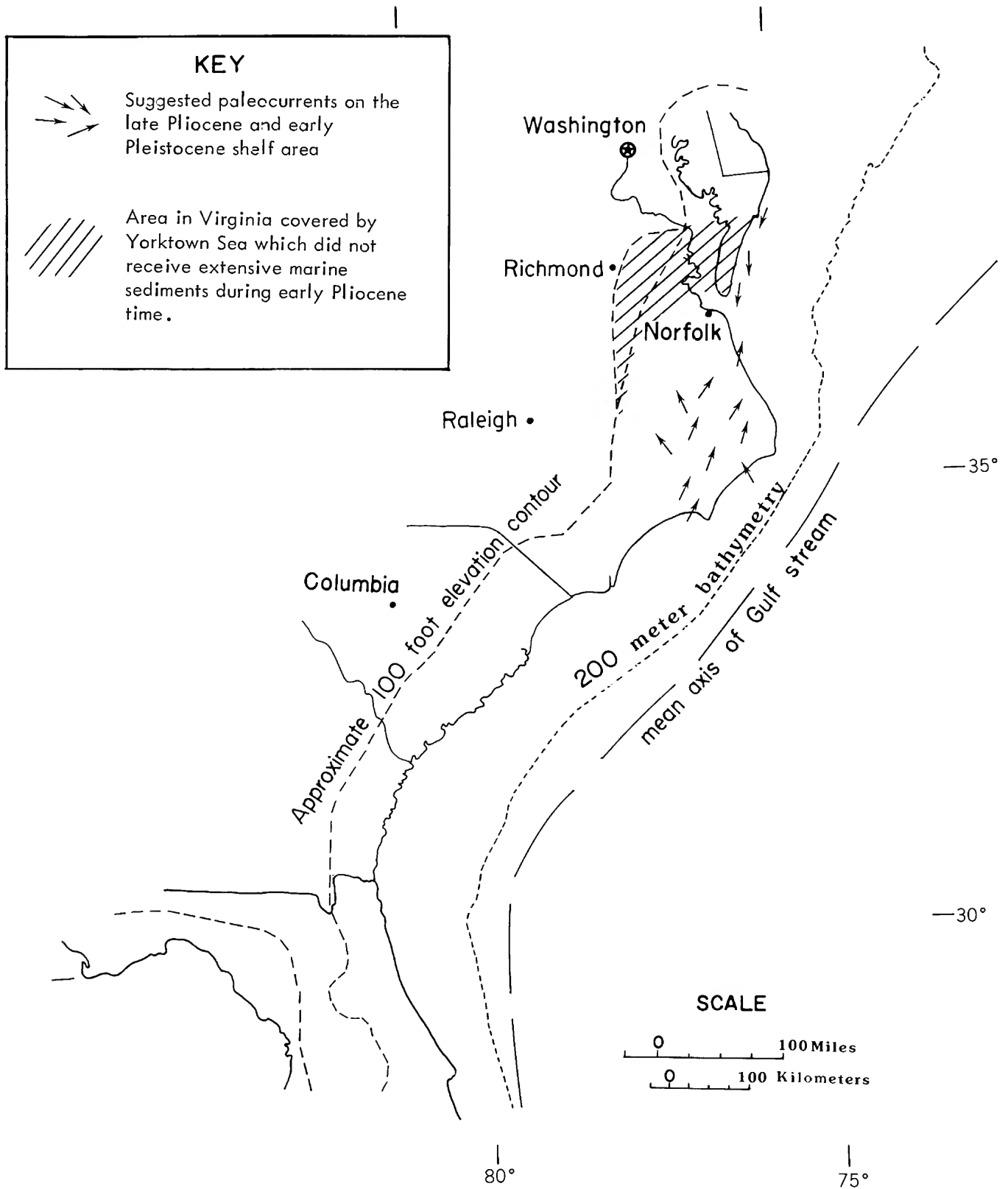


FIGURE 14.—Paleocurrent map for Lee Creek area in late Pliocene and early Pleistocene time, showing present-day mean axis of the Gulf Stream (Arx, Bumpus, and Richardson, 1955), 200 m bathymetry, and approximate 100 foot (30.5 m) elevation contour.

tion. In addition, this assemblage contains many specimens of *Ensis*, *Conradostrea*, *Cyclocardia* and a fairly high number of small molluscan species, the abundance being fairly evenly distributed among taxa. This assemblage is interpreted as being a shallow-shelf assemblage (about 15 to 20 m in depth). It is succeeded by sediments deposited as part of an offshore bar system (unit D).

The main part of the bar could not be seen in the present exposures and must be east of our measured sections in the north wall. The north wall deposits at our sections consist of unidirectional steeply dipping current-bedded coarse sands that resulted from bar migration, especially storm-caused bar migration to the southwest. The height of these current-bedded sands is about 6 feet (1.8 m), and the angle of dip is approximately 34°. The current-bedded sands contain abundant large mollusks, large coral pieces (*Solenastrea*), regular and irregular echinoid remains, and knobs of cyclostomatous bryozoans. The diversity of the mollusks is high in terms of numbers of species. In these current-bedded sands are occasional lenses of almost pure shell hash, whereas elsewhere there are pockets of almost pure sand. The coral pieces found in these beds are very large (more than 0.3 m in height) and have a palmate growth pattern.

The construction and influence of another seaward barrier, probably in response to a slight lowering of the sea level, resulted in the deposition of unit E, a shallow-shelf clayey sand. Rapid deposition of well-preserved shells took place in topographically lower areas (section 1 of Figure 2) whereas in the higher areas (top of old bar deposits), such as the beds in section 5, winnowing and reworking resulted in the deposition of worn and encrusted shell, much of which is blackened and possibly recycled. At section 1, where well-preserved material accumulated, *Mercenaria per magna* is abundant, as are *Chione grus*, *Plicatula marginata*, and *Anomia simplex*. At section 5, there is worn and reworked shell material; *Mulinia lateralis* and *Anadara sequicostata* are the most common species.

### Systematic Checklist

The following hierarchic classification is used in this report:

Phylum MOLLUSCA  
 Class PELECYPODA  
 Subclass PALAEOXODONTA  
 Order NUCULOIDA  
 Superfamily NUCULACEA  
 Family NUCULIDAE  
 Genus *Nucula* Lamarck, 1799  
*Nucula proxima* Say  
*Nucula taphria* Dall  
*Nucula pilkeyi*, new species  
 Superfamily NUCULANACEA  
 Family NUCULANIDAE  
 Genus *Nuculana* Link, 1807  
*Nuculana acuta* (Conrad)

Subclass PTERIOMORPHA  
 Order ARCOIDA  
 Superfamily ARCACEA  
 Family ARCIDAE  
 Genus *Anadara* Gray, 1847  
*Anadara aequicostata* (Conrad), new combination  
 Genus *Quadrilatera* Deshayes, 1860  
*Quadrilatera adamsi* (Dall), new combination  
 Family NOETIIDAE  
 Genus *Noetia* Gray, 1857  
*Noetia limula* (Conrad)  
 Superfamily LIMOPSACEA  
 Family GLYCYMERIDIDAE  
 Genus *Glycymeris* da Costa, 1778  
*Glycymeris americana* (DeFrance)  
*Glycymeris arata* (Conrad)  
*Glycymeris hummi*, new species  
*Glycymeris sloani*, new species  
*Glycymeris* sp.  
 Order MYTILOIDA  
 Superfamily MYTILACEA  
 Family MYTILIDAE  
 Genus *Brachidontes* Swainson, 1840  
*Brachidontes* sp.  
 Genus *Mytilus* Linnaeus, 1758  
*Mytilus* sp. aff. *M. edulis* Linnaeus  
 Genus *Crenella* Brown, 1827  
*Crenella decussata* (Montagu)  
 Genus *Musculus* Röding, 1798  
*Musculus lateralis* (Say)  
 Genus *Modiolus* Lamarck, 1799  
*Modiolus* sp. cf. *M. modiolus* (Linnaeus)  
 Genus *Lithophaga* Röding, 1798  
*Lithophaga yorkensis* Olsson  
 Order PTERIOIDA  
 Suborder PTERIINA  
 Superfamily PECTINACEA  
 Family PECTINIDAE  
 Genus *Leptopecten* Verrill, 1897  
*Leptopecten? auroraensis*, new species  
 Genus *Carolinapecten*, new genus  
*Carolinapecten eboreus* (Conrad), new combination  
 Genus *Argopecten* Monterosato, 1889  
*Argopecten vicenarius vicenarius* (Conrad)  
 Family PLICATULIDAE  
 Genus *Plicatula* Lamarck, 1801  
*Plicatula marginata* Say  
 Superfamily ANOMIACEA  
 Family ANOMIIDAE  
 Genus *Anomia* Linnaeus, 1758  
*Anomia simplex* d'Orbigny  
 Genus *Pododesmus* Philippi, 1837  
*Pododesmus fragosus* (Conrad), new combination  
 Suborder OSTREINA  
 Superfamily OSTREACEA  
 Family OSTREIDAE  
 Genus *Crassostrea* Sacco, 1897  
*Crassostrea virginica auroraensis*, new subspecies  
 Genus *Conradostrea*, new genus  
*Conradostrea lawrencei*, new species  
 Subclass HETERODONTA  
 Order VENEROIDA  
 Superfamily LUCINACEA  
 Family LUCINIDAE  
 Genus *Stewartia* Olsson and Harbison, 1953  
*Stewartia anodonta floridana* (Conrad), new combination

- Genus *Parvilucina* Dall, 1901  
*Parvilucina multilinea* (Tuomey and Holmes)
- Genus *Bellucina* Dall, 1901  
*Bellucina waccamawensis* (Dall), new combination
- Genus *Cavilinga* Chavan, 1937  
*Cavilinga trisulcata* (Conrad), new combination
- Genus *Callucina* Dall, 1901  
*Callucina keena* (Chavan)
- Genus *Divalinga* Chavan, 1951  
*Divalinga* sp.
- Family UNGULINIDAE
- Genus *Diplodonta* Bronn, 1831  
*Diplodonta acclinis* (Conrad)  
*Diplodonta berryi* McGavock
- Genus *Phlyctiderma* Dall, 1899  
*Phlyctiderma heroni*, new species
- Superfamily CHAMACEA
- Family CHAMIDAE
- Genus *Chama* Linnaeus, 1758  
*Chama gardnerae* Olsson and Harbison
- Family LASAEIDAE
- Genus *Aligena* Lea, 1843  
*Aligena striata* Lea
- Genus *Bornia* Philippi, 1836  
*Bornia triangula* Dall
- Family LEPTONIDAE
- Genus *Mysella* Angas, 1877  
*Mysella beaufortensis*, new species
- Superfamily CYAMIACEA
- Family SPORTELLIDAE
- Genus *Anisodonta* Deshayes, 1858  
*Anisodonta carolina* Dall
- Genus *Sportella* Deshayes, 1858  
*Sportella waccamawensis* Gardner
- Genus *Ensitellops* Olsson and Harbison, 1953  
*Ensitellops elongata* Olsson and Harbison
- Superfamily CARDITACEA
- Family CARDITIDAE
- Genus *Carditamera* Conrad, 1838  
*Carditamera arata* (Conrad)
- Genus *Pleuromeris* Conrad, 1867  
*Pleuromeris auroraensis*, new species  
*Pleuromeris decemcostata* Conrad
- Genus *Pteromeris* Conrad, 1862  
*Pteromeris perplana* (Conrad)
- Genus *Cyclocardia* Conrad, 1867  
*Cyclocardia* sp. cf. *C. granulata* (Say)
- Family CONDYLOCARDIIDAE
- Genus *Erycinella* Conrad, 1845  
*Erycinella ovalis* Conrad
- Superfamily CRASSATELLACEA
- Family ASTARTIDAE
- Genus *Astarte* J. Sowerby, 1816  
*Astarte berryi* Gardner  
*Astarte concentrica* Conrad
- Family CRASSATELLIDAE
- Genus *Marvacrassatella*, new genus  
*Marvacrassatella kauffmani*, new species
- Genus *Crassinella* Guppy, 1874  
*Crassinella dupliniana* (Dall)  
*Crassinella lunulata* (Conrad)  
*Crassinella johnsoni*, new species
- Superfamily CARDIACEA
- Family CARDIIDAE
- Genus *Laevicardium* Swainson, 1840  
*Laevicardium sublineatum* (Conrad)
- Genus *Dinocardium* Dall, 1900  
*Dinocardium robustum hazeli*, new subspecies
- Superfamily MACTRACEA
- Family MACTRIDAE
- Genus *Mulinia* Gray, 1837  
*Mulinia lateralis* (Say)
- Genus *Rangia* Desmoulins, 1832  
*Rangia clathrodonta* (Conrad)
- Genus *Spisula* Gray, 1837  
*Spisula similis* (Say)  
*Spisula solidissima* (Dillwyn)
- Genus *Raeta* Gray, 1853  
*Raeta plicatella* (Lamarck)
- Superfamily SOLENACEA
- Family CULTELLIDAE
- Genus *Ensis* Schumacher, 1817  
*Ensis directus* (Conrad)
- Superfamily TELLINACEA
- Family TELLINIDAE
- Genus *Tellina* Linnaeus, 1758  
*Tellina agilis* Stimpson
- Genus *Macoma* Leach, 1819  
*Macoma holmesii* Dall
- Family DONACIDAE
- Genus *Donax* Linnaeus, 1758  
*Donax fossor* Say
- Family SEMELIDAE
- Genus *Semele* Schumacher, 1817  
*Semele bellastrata* (Conrad)
- Genus *Abra* Lamarck, 1818  
*Abra aequalis* (Say)
- Genus *Cumingia* Sowerby, 1833  
*Cumingia tellinoides* (Conrad)
- Family SOLECURTIDAE
- Genus *Tagelus* Gray, 1847  
*Tagelus plebeius carolinensis* (Conrad)
- Superfamily CORBICULACEA
- Family CORBICULIDAE
- Genus *Corbicula* Mergel von Mühlfeld, 1811  
*Corbicula densata* (Conrad)
- Superfamily VENERACEA
- Family VENERIDAE
- Genus *Gouldia* C. B. Adams, 1847  
*Gouldia metastratum* (Conrad)
- Genus *Transennella* Dall, 1883  
*Transennella stimpsoni* Dall
- Genus *Pitar* Römer, 1857  
*Pitar chioneformis* (Gardner), new combination
- Genus *Macrocallista* Meek, 1876  
*Macrocallista greeni*, new species
- Genus *Dosinia* Scopoli, 1777  
*Dosinia* sp.
- Genus *Gemma* Deshayes, 1853  
*Gemma magna majorina* Gardner
- Genus *Chione* Megerle von Mühlfeld, 1811  
*Chione grus* (Holmes)  
*Chione cribraria* (Conrad)
- Genus *Mercenaria* Schumacher, 1817  
*Mercenaria permagna* (Conrad), new combination  
*Mercenaria mercenaria* (Linnaeus)
- Family PETRICOLIDAE
- Genus *Petricola* Lamarck, 1801  
*Petricola pectorosa* (Conrad)  
*Petricola pholadiformis* Lamarck
- Order MYOIDA
- Suborder MYINA



- Superfamily MYACEA  
 Family MYIDAE  
 Genus *Mya* Linnaeus, 1758  
*Mya arenaria* Linnaeus  
 Genus *Paramya* Conrad, 1861  
*Paramya subovata* (Conrad)  
 Genus *Sphenia* Turton, 1822  
*Sphenia dubia* (Lea)  
 Family CORBULIDAE  
 Genus *Caryocorbula* Gardner, 1926  
*Caryocorbula auroraensis*, new name  
*Caryocorbula contracta* (Say), new combination  
 Superfamily GASTROCHAENACEA  
 Family GASTROCHAENIDAE  
 Genus *Gastrochaena* Spengler, 1783  
*Gastrochaena hians* (Gmelin)  
 Superfamily HIATELLACEA  
 Family HIATELLIDAE  
 Genus *Panopea* Ménard, 1807  
*Panopea floridana* Heilprin  
 Suborder PHOLADINA  
 Superfamily PHOLADACEA  
 Family PHOLADIDAE  
 Genus *Cyrtopleura* Tryon, 1862  
*Cyrtopleura* sp.  
 Subclass ANOMALODESMATA  
 Order PHOLADOMYOIDA  
 Superfamily PANDORACEA  
 Family PANDORIDAE  
 Genus *Pandora* Bruguière, 1797  
*Pandora tuomeyi* Gardner and Aldrich  
 Family PERIPLOMATIDAE  
 Genus *Cochlodesma* Couthouy, 1839  
*Cochlodesma emmonsii*, new species  
 Family THRACIIDAE  
 Genus *Thracia* Sowerby, 1823  
*Thracia brioni*, new species  
 Order SEPTIBRANCHOIDA  
 Superfamily POROMYACEA  
 Family VERTICORDIIDAE  
 Genus *Verticordia* Sowerby, 1844  
*Verticordia emmonsii* Conrad  
*Verticordia lockei*, new species  
 Class SCAPHOPODA  
 Family SIPHONODONTALIIDAE  
 Genus *Cadulus* Philippi, 1844  
*Cadulus quadridentatus* (Dall)  
 Class GASTROPODA  
 Subclass PROSOBRANCHIA  
 Order ARCHAEOGASTROPODA  
 Superfamily FISSURELLACEA  
 Family FISSURELLIDAE  
 Genus *Diodora* Gray, 1821  
*Diodora nucula* (Dall)  
*Diodora auroraensis*, new species  
*Diodora pamlicoensis*, new species  
 Superfamily TROCHACEA  
 Family TROCHIDAE  
 Genus *Calliostoma* Swainson, 1840  
*Calliostoma philanthropum pontoni* Mansfield  
 Family LIOTIIDAE  
 Genus *Arene* H. and A. Adams, 1854  
*Arene pergemma* (Gardner), new combination  
 Superfamily LITTORINACEA  
 Family LITTORINIDAE  
 Genus *Littorina* Férussac, 1822  
*Littorina carolinensis* Conrad  
 Superfamily RISSOACEA  
 Family RISSOIDAE  
 Genus *Rissoa* Fréminville, 1814  
*Rissoa geraea* Dall  
 Family VITRINELLIDAE  
 Genus *Teinostoma* A. Adams, 1851  
*Teinostoma goniogyrus* Pilsbry and McGinty  
*Teinostoma smirkon* Gardner  
*Teinostoma beaufortensis*, new species  
*Teinostoma tectispira* Pilsbry  
 Genus *Cyclostremiscus* Pilsbry and Olsson, 1945  
*Cyclostremiscus obliquistriatus* (Lea)  
 Genus *Didianema* Woodring, 1928  
*Didianema carolinae* Gardner  
 Superfamily TORNACEA  
 Family TORNIDAE  
 Genus *Macromphalina* Cossmann, 1888  
*Macromphalina pierrot* Gardner  
*Macromphalina hanseni*, new species  
 Family CAECIDAE  
 Genus *Caecum* Fleming, 1813  
*Caecum beaufortensis*, new species  
*Caecum pulchellum* Stimpson  
*Caecum imbricatum* Carpenter  
*Caecum flemingi* Gardner and Aldrich  
 Superfamily CERITHIACEA  
 Family TURRITELLIDAE  
 Genus *Turritella* Lamarck, 1799  
*Turritella beaufortensis*, new species  
*Turritella perexilis* Conrad  
 Family VERMICULARIDAE  
 Genus *Vermicularia* Lamarck, 1799  
*Vermicularia spirata* (Philippi)  
 Family VERMETIDAE  
 Genus *Serpulorbis* Sassi, 1827  
*Serpulorbis granifera* (Say), new combination  
 Family CERITHIIDAE  
 Genus *Bittium* Gray, 1847  
*Bittium podagrinum* Dall  
 Genus *Seila* A. Adams, 1861  
*Seila adamsii* (Lea)  
 Family TRIPHORIDAE  
 Genus *Triphora* Blainville, 1828  
*Triphora dupliniana* (Olsson)  
 Order PTENOGLOSSA  
 Superfamily EPITONIACEA  
 Family EPITONIIDAE  
 Genus *Epitonium* Röding, 1798  
*Epitonium leai*, new species  
*Epitonium sohli*, new species  
*Epitonium* sp. cf. *E. foliaceicostum* (d'Orbigny)  
*Epitonium carolinae* Gardner  
*Epitonium rupicolum* (Kurtz)  
*Epitonium fractum* Dall  
 Suborder GYMNOGLOSSA  
 Family MELANELLIDAE  
 Genus *Balcis* Gray, 1847  
*Balcis?* sp.  
*Balcis beaufortensis*, new species  
*Balcis biconica* (Gardner), new combination  
*Balcis eborea* (Conrad), new combination  
 Genus *Eulima* Risso, 1826  
*Eulima juncea* (Gardner), new combination  
 Superfamily CREPIDULACEA  
 Family CREPIDULIDAE

- Genus *Crucibulum* Schumacher, 1817  
*Crucibulum lawrencei*, new species
- Genus *Calyptraea* Lamarck, 1799  
*Calyptraea centralis* (Conrad)
- Genus *Crepidula* Lamarck, 1799  
*Crepidula aculeata* (Gmelin)  
*Crepidula fornicata* (Linnaeus)  
*Crepidula plana* Say
- Superfamily CYPRAEACEA
- Family ERATOIDAE  
Genus *Trivia* Broderip, 1837  
*Trivia floridana* Olsson and Harbison
- Superfamily NATICACEA
- Family NATICIDAE  
Genus *Polinices* Montfort, 1810  
*Polinices duplicata* (Say)  
Genus *Lunatia* Gray, 1847  
*Lunatia heros* (Say)  
Genus *Tectonatica* Sacco, 1890  
*Tectonatica pusilla* (Say)
- Superfamily MURICACEA
- Family MURICIDAE  
Genus *Murexiella* Clench and Pérez Farfante, 1945  
*Murexiella macgintyi* (M. Smith), new combination  
Genus *Urosalpinx* Stimpson, 1865  
*Urosalpinx* sp. cf. *U. perrugata* (Conrad)  
*Urosalpinx stimpsoni* Gardner  
*Urosalpinx suffolkensis* Gardner  
Genus *Pterorhynchus* Conrad, 1862  
*Pterorhynchus conradi* (Dall), new combination  
Genus *Eupleura* H. and A. Adams, 1853  
*Eupleura caudata* (Say)
- Superfamily BUCCINACEA
- Family COLUMBELLIDAE  
GENUS *Mitrella* Risso, 1826  
*Mitrella gardnerae ecarinata* (Olsson and Harbison), new combination  
*Mitrella gardnerae gardnerae* (Olsson and Harbison), new combination  
*Mitrella vaccamawensis* Gardner  
Genus *Anachis* H. and A. Adams, 1853  
*Anachis milleri* Gardner  
Genus *Aesopus* Gould, 1860  
*Aesopus gardnerae*, new species  
*Aesopus ithitoma* (Dall)  
*Aesopus stearnsii* (Tryon)
- Family NASSARIIDAE  
Genus *Nassarius* Dumeril, 1806  
*Nassarius chowanensis* (Gardner), new combination  
*Nassarius cornelliana* (Olsson)  
*Nassarius granifera* (Conrad), new combination  
*Nassarius schizopyga?* (Dall), new combination  
*Nassarius scalaspira?* (Conrad), new combination
- Family MELONGENIDAE  
Genus *Busycon* Röding, 1798  
*Busycon spiratus pyruloides* (Say)  
*Busycon adversarius* Conrad  
*Busycon carica* (Gmelin)  
*Busycon concinnum* Conrad
- Family FASCIOLARIIDAE  
Genus *Fasciolaria* Lamarck, 1799  
*Fasciolaria cronlyensis* Gardner  
*Fasciolaria beaufortensis*, new species  
Genus *Heilprinia* Grabau, 1904  
*Heilprinia caloosaensis malcolmi*, new subspecies
- Superfamily VOLUTACEA
- Family OLIVIDAE  
Genus *Oliva* Bruguière, 1789  
*Oliva carolinensis* (Conrad)  
Genus *Olivella* Swainson, 1831  
*Olivella mutica* (Say)
- Family MITRIDAE  
Genus *Vexillum* Röding, 1798  
*Vexillum wandoense* (Holmes)
- Family VOLUTIDAE  
Genus *Volutifusus* Conrad, 1863  
*Volutifusus typus* Conrad
- Family CANCELLARIIDAE  
Genus *Trigonostoma* Blainville, 1827  
*Trigonostoma* sp.
- Family MARGINELLIDAE  
Genus *Granulina* Jousseaume, 1888  
*Granulina ovuliformis* (d'Orbigny)  
Genus *Prunum* Hermannsen, 1852  
*Prunum limatulum* (Conrad), new combination  
Genus *Dentimargo* Cossmann, 1899  
*Dentimargo polyspira?* (Olsson and Harbison), new combination  
Genus *Volvarina* Hinds, 1844  
*Volvarina avena* (Kiener), new combination
- Family CONIDAE  
Genus *Conus* Linnaeus, 1758  
*Conus adversarius* Conrad
- Family TEREBRIDAE  
Genus *Strioterebrum* Sacco, 1891  
*Strioterebrum* sp. cf. *S. petiti* Olsson  
*Strioterebrum* sp.
- Family TURRIDAE  
Genus *Cymatosyrinx* Dall, 1889  
*Cymatosyrinx lunata* (Lea)  
Genus *Sedilia* Fargo, 1953  
*Sedilia* sp. aff. *S. sedilia* (Dall)  
Genus *Vitricythara* Fargo, 1953  
*Vitricythara micromeris* (Dall)  
Genus *Glabrocythara* Fargo, 1953  
*Glabrocythara* sp.  
Genus *Brachyocythara* Woodring, 1928  
*Brachyocythara reidenbachi*, new species
- Subclass EUTHYNEURA
- Order PYRAMIDELLOIDA
- Superfamily PYRAMIDELLACEA
- Family PYRAMIDELLIDAE  
Genus *Odostomia* Fleming, 1813  
*Odostomia simplex* (Lea), new combination  
*Odostomia turbinatus* (Lea), new combination  
Genus *Chrysallida* Carpenter, 1856  
*Chrysallida beaufortensis*, new species  
*Chrysallida auroraensis*, new species  
Genus *Orinella* Dall and Bartsch, 1904  
*Orinella beaufortensis*, new species  
Genus *Pyrgiscus* Philippi, 1841  
*Pyrgiscus daedaleum* (Lea)  
*Pyrgiscus* sp.  
Genus *Turbonilla* Risso, 1826  
*Turbonilla abrupta* Bush
- Family RINGICULIDAE  
Genus *Ringicula* Deshayes, 1838  
*Ringicula semistriata* d'Orbigny
- Order CEPHALASPIDEA
- Superfamily ACTEONIDAE
- Family ACTEONINIDAE  
Genus *Acteocina* Gray, 1847  
*Acteocina candei* (d'Orbigny)

### Systematic Paleontology

All molluscan species found in the Chowan River and James City beds at Lee Creek are illustrated, with the exception of *Divaricella* sp. and *Dosinia* sp., which were found in a very fragmentary condition.

In the "Discussion" section under each species, references are made to Gardner (1944, 1948) and to Olsson and Harbison (1953). These works represent the most up-to-date monographic treatments of the Pliocene and Pleistocene molluscan assemblages in the Atlantic Coastal Plain and Florida. Gardner discussed only a part of the species contained in the formations with which she was concerned. The biostratigraphy was not known in detail at this time, and consequently Gardner's discussion of the stratigraphic range of different species was generalized. Olsson and Harbison (1953), Pilsbry (1953), Fargo (1953), and Bartsch (1955) discussed the "Pliocene" deposits of North St. Petersburg, Florida. The assemblage at St. Petersburg, collected by Olsson and Harbison (1953), is said to come from the Caloosahatchee Formation, but apparently specimens were not collected in place, and the biostratigraphic treatment is abbreviated. Specimens from overlying Pleistocene deposits at St. Petersburg apparently were collected and not differentiated from Caloosahatchee-age specimens. At least some of the units at St. Petersburg may represent the oldest beds of the Caloosahatchee Formation or beds of an older formation, as some of the species recorded by Olsson and Harbison are known only from older deposits (species such as *Hemimetis magnoliana* (Dall, 1900)). The Caloosahatchee Formation in Florida has been correlated with the Waccamaw Formation in the Carolinas by several workers.

References in the systematic section to species occurrences in the Yorktown Formation refer only to beds that correlate with type Yorktown.

Information has been included on the type locality of most of the species listed. The author of each species is referenced, and certain additional references are included. Extensive comparison with other species in related stratigraphic units is beyond the intended scope of this paper. USGS (U.S. Geological Survey) locality numbers are listed for the illustrated specimens, and these numbers are indicated for the fence diagram (Figure 2). USNM (former United States National Museum, now National Museum of Natural History) numbers have been given to all illustrated specimens. It should be noted that this is a later USNM series and the Museum is now duplicating the number series originally used for mollusks. SEM notation refers to the scanning electron microscope pictures. Some shells were opaqued by carbon-ink for photography. A few notations concerning the dates of certain taxonomic papers should be made:

The date (1791) of the publication of *Systema Naturae*, volume 6, by Gmelin is in doubt. A letter to Dall from C. W. Stiles in the copy of Gmelin's work at the National

Museum states that the data given in the Leipzig edition of Gmelin's work is 1789, but on page 3056 of this work (N. 19) the article cited "Braun" was not printed until 1792. Stiles concluded that 1792 is therefore the earliest possible date for volume 6. Kohn (1966:74) stated that he accepts the collation given by Hopkinson (1907:1035) in which the date of Part 6 containing *Conus* is stated to be 1791 and is supported by the Catalogue of the Library of the British Museum (Natural History) (II (1910): 1128). Until further, conclusive evidence concerning the date[s] of publication of this volume, we accept the date used by most authors (1791).

Professor Booth read a communication by H.C. Lea, which was published in 1843(b). The publication date of this paper is not later than 3 October 1843 (copy donated to the Philadelphia Academy of Natural Sciences Library) nor earlier than the death of Nicollet (11 September 1843), which is reported on page 164 in the same publication of Lea (1843b). The date of publication of this paper is important in that it bears on the status of the genus *Aligena*; the following description is found on page 163 of Lea (1843b):

Genus *Aligena* (Nobis): Descr. Gen. Testâ aequivalvi, subaequilateralis, posticè et anticè clausâ: cardine dente cardinali uno, sulco sub natibus longo, minimè profound. *A. striata*, *A. laevis*.

A second publication (Lea, 1843a), which may predate the above paper, contains an almost identical description for *Aligena* and, in addition, described *Aligena striata* and *Aligena laevis* (p. 3). On this paper is the notation that it was received by the library at the Philadelphia Academy on 19 October 1843. In 1845 there appeared a quarto excerpt that was identical with the final publication in volume 9 of the *Transactions of the American Philosophical Society*, except that it had a pagination of its own. Volume 9, in which the article made its final appearance, was published in 1846 (Martin, 1904:170-171).

The dates of both of H.C. Lea's papers predate that of Conrad's publication (1843a), in which he described *Amphidesma aequata*. According to Nolan (1913:ix), the *Proceedings of the Academy of Natural Sciences of Philadelphia* (numbers 30 and 31) which contain Conrad's paper were not presented until 17 November 1843, at an Academy meeting. For this reason *Aligena striata* Lea predates *Amphidesma aequata* Conrad. Dall (1900:1175) selected *Aligena striata* Lea as the type species of *Aligena*. However, Dall also synonymized *Aligena striata* with *Aligena aequata* (Conrad, 1843a), because he believed the date of Lea's publication to be 1845. Chavan (1969:522-525) did not recognize these earlier descriptions by Lea and followed Dall. *Aligena* Lea in fact dates from 1843 (October); the type species is *Aligena striata* Lea, 1843 (October).

Websters Biographical Dictionary gives the dates for H. C. Lea as 1825 to 1909, which means that H.C. Lea was only 18 years old when he first published. His father, Isaac Lea, who was an authority on freshwater mollusks and described more than 1800 species of mollusks, fossil and

Holocene, was probably helpful in these early publications.

It is not generally recognized that Tuomey and Holmes' publication of *Pleiocene Fossils of South-Carolina* originally came out in parts. Pages 1–30 were published in 1855 and pages 31–152 were published in 1856. This information is verified by notices in the *American Journal of Sciences and Arts* (Anonymous, 1855a, 1855b, 1856), and pages of the different parts are penciled in a copy of *Pleiocene Fossils of South-Carolina* at the Smithsonian. Holmes later published *Post-Pleiocene Fossils of South Carolina* in several parts. Although the various parts have been found with title pages removed and placed at the back, it is possible to ascertain the original location of the title pages by reading the print that has rubbed off on the back of each title page. Numbers 1–5 were published in 1858 (pages 1–64). Numbers 6 and 7 were published in 1859 (pages 65–98). The remainder of the volumes by Holmes is on vertebrates and was written by Joseph Leidy (parts 8–10, pages 99–114?, 1859; parts 11–12, pages 115–118, 1860; parts 13–15, pages 119–122, 1860).

In 1873, Conrad published an appendix as a separate, and later in 1875, this appendix was published as part of Kerr's report on the geology of North Carolina (see Conrad, 1875). This earlier date of publication of the species is not usually recognized.

Part 1 of Gardner's *Mollusca from the Miocene and Lower Pliocene of Virginia and North Carolina* is ordinarily cited as published in 1943, as indicated on its title page. However, the contents page for the complete volume, published in 1948, indicates that part 1 was published in January 1944.

### Genus *Nucula* Lamarck, 1799

#### *Nucula proxima* Say

PLATE 1: FIGURES 7, 8

*Nucula proxima* Say, 1822:270.—Dall, 1898:574.—Gardner, 1944:19–20 [in part].

DISCUSSION.—*Nucula proxima* Say is a small, distinctive protobranch bivalve, which was described from the Holocene of the Atlantic Coast of the southern United States. The specific name has been misapplied subsequently to include some other species found in the Calvert Formation of Maryland and in other younger Coastal Plain deposits. Dall (1898:574–475) mistakenly attributed the type locality of the species *Nucula obliqua* (Say, 1820) to the Miocene of Petersburg, Virginia. Dall (1898), Gardner (1944):19–21, and Bird (1965:19–20) synonymized *Nucula obliqua* Say (1820:40 [not Lamarck, 1818]) with *Nucula proxima* Say (1822). The specimens that Say examined in 1820 apparently came from the Calvert Formation at Upper Marlboro, Maryland (Say, 1820:38–40). Specimens that we examined from the Calvert Formation appear to be different from specimens of *Nucula proxima* in shape, shell thickness, size,

and nature of growth. Specimens from the Calvert Formation that are nearest in shape to *N. proxima* differ in being small and in having a sharper posterior. Say's description of *Nucula obliqua* is rather generalized, and it is not possible to ascertain which of the Calvert Formation species he had in his possession. Say's type specimen of *N. proxima* is apparently lost.

Gardner (1944:19) gave the original description of *Nucula obliqua* as the original description of *Nucula proxima*, and the type locality of *Nucula obliqua* as the type locality of *Nucula proxima*. Say's (1822:270) original description is included below in order to clarify any confusion as to the original species description:

Shell subtriangular, oblique, concentrically wrinkled, and longitudinally marked with numerous, hardly perceptible striae; posterior margin very short and very obtusely rounded, a submarginal impressed line; anterior margin very oblique, and but slightly arquated; umbo placed far back; within perlaceous, polished, edge strongly crenated; teeth of the hinge robust, the posterior series very distinct and regular.

Say (1822:270) also stated that *Nucula proxima* very much resembles *Nucula nucleus* (Lamarck, 1799) but is proportionally wider, and the posterior series of teeth is more regular and distinct.

Hampson (1971) designated a neotype for *Nucula proxima*. The selected specimen is from off Beaufort, North Carolina, at a depth of 40 m. The specimen is delicate, thin, small, and not typical of most of the nearshore specimens found along the Atlantic Coast. Say (1822:270) described the specimen in front of him as being three-tenths of an inch long by less than two-fifths of an inch high (8.5 by 10.0 mm). Hampson's neotype is much smaller (4.1 mm long by 4.3 mm high).

Hampson (1971:336–337, fig. 2) discussed internal anatomy of this species and referred to sketches in his figure 2. These drawings are intended to indicate that the intestine is longer and more compressed dorsally and the palp proboscides proportionally smaller in *Nucula proxima* than in *Nucula annulata* Hampson, 1971. It is also intended to show that the tentacles of *N. annulata* are more ventral, the labial palps proportionally larger, the coiling of the intestine looser, and the stomach larger than in *N. proxima*. However, the drawn specimen of *Nucula proxima* is shown as having a strongly retracted foot, whereas the figured specimen of *N. annulata* has an extended foot, and it would appear that the anatomical differences are more likely attributable to the position in death than to basic morphologic differences.

Although Hampson stated (1971:334) that the neoholotype selected is from South Carolina, the longitude and latitude given (76°07.0'W and 34°28.5'N) indicate that the coast off North Carolina is the proper locality, agreeing with Hampson's statement (1971:336).

Hampson's neoholotype for *Nucula proxima* is apparently not figured in his publication. Figure numbers for this species given in his systematic section do not always relate to existing figures.

Morphologic variation in *Nucula proxima* has been described by Dall (1898:574–575). He stated that a geographical series of this species shows that the northern specimens are almost smoothly truncate behind, the escutcheon is not impressed to any marked degree, and there is no angle at the margin below the escutcheon. Dall stated that the specimens from the southern coast, whence Say's type was derived, have a thinner shell and an impressed escutcheon, the middle of which pouts more or less strongly; the valve-margin below the escutcheon has a projecting angle; the shell is somewhat compressed and has a paler and more delicate epidermis.

Gardner (1944:20) noted that the contour characteristic of the northern inhabitants among the Holocene species is, in the fossil representatives, limited for the most part to what are considered in this paper to be Pliocene beds in southern North Carolina (Yorktown and Waccamaw formations). Gardner stated that the characters given by Dall for the northern form (variety *truncula*) (i.e., outline, convexity, escutcheon characters) have proved in the material under investigation to bear no constant relation to one another. In other words, her North Carolina Pliocene material is not really equivalent morphologically to Dall's northern form, except in certain aspects of shape.

Gardner (1944:19–20) recorded this species from a large number of localities in Virginia and North Carolina. Olsson and Harbison (1953:27) recorded it as represented in the St. Petersburg, Florida, collection (Caloosahatchee Formation).

FIGURED SPECIMEN.—USNM 203877 from USGS 25366.

OCCURRENCE.—This species is abundant at section 5 in units B–E. It is also found at sections 2 (B, D, E), 3 (D, E), 4 (B, E), and 6 (C).

TYPE LOCALITY.—Say's type locality is the "southern coast" of the United States (Holocene).

### *Nucula taphria* Dall

PLATE 1: FIGURES 1, 2

*Nucula taphria* Dall, 1898:576, pl. 32: fig. 14.

Not *Nucula taphria*—Glenn, 1904:400, pl. 108: figs. 9, 10, 11.

DISCUSSION.—Specimens from the listed Lee Creek units correspond well with Dall's figured specimen. Glenn's specimens from the Maryland Miocene are heavier, with a larger, heavier hinge platform and with a usually less elongate outline. This species was not discussed by Gardner (1944) or by Olsson and Harbison (1953). The *Nucula taphria* lineage goes back at least to Calvert-age (early middle Miocene), but *Nucula taphria* sensu stricto apparently is confined to upper Yorktown beds and younger. This species is found along the James River near Smithfield and in the bar complex at Chuckatuck, Virginia (late Yorktown-age).

FIGURED SPECIMEN.—USNM 203878 from USGS 25366.

OCCURRENCE.—This species is rare at sections 3 (D, E) and 5 (B, C).

TYPE LOCALITY.—Miocene of Magnolia and the Natural Well, Duplin County, North Carolina; collected by Burns (Yorktown Formation).

### *Nucula pilkeyi*, new species

PLATE 1: FIGURES 9, 10

DIAGNOSIS.—Valves obliquely subtriangular and rounded in outline, exterior smoothish with concentric growth lines over the surface giving very subdued sculpture, growth lines occurring at irregular intervals; anterodorsal and posterodorsal slopes gently convex in profile; hinge plate broad with heavy taxodont dentition, inner margin of shell finely crenulate.

DISCUSSION.—This is the only specimen of this species found at Lee Creek. No intermediate forms between this species and *Nucula proxima* have been observed. *Nucula pilkeyi* is distinguished from *Nucula proxima* by its rounder outline, and its heavier dentition and a broader hinge platform.

Our specimen from Lee Creek agrees with that figured by Abbott (1974:410, species 4791) as *Nucula aegeensis* Jeffreys, 1879. Abbott stated that the range of this species is from North Carolina to the West Indies and Brazil. Abbott's specimen from the Holocene may be the same species as ours, but he gave no locality data for the figured specimen. The specimen he figured is probably not *Nucula aegeensis*. *Nucula aegeensis* was named by Forbes (1844:192) from "Macri (180 f., Crete (119f.))" and thus is a deep-water Aegean species. Jeffreys (1879) did not describe the species and cited Forbes when referring to this species.

FIGURED SPECIMEN.—Holotype, USNM 203879 from USGS 25368, length 5.7 mm.

OCCURRENCE.—A single valve is recorded from section 5, unit D.

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25368, Section 5, unit D.

### Genus *Nuculana* Link, 1807

#### *Nuculana acuta* (Conrad)

PLATE 1: FIGURES 3–6

*Nucula acuta* Conrad, 1832a:32, pl. 5: fig. 1.—Conrad, 1845:57, pl. 30: fig. 2.

*Nuculana acuta* (Conrad).—Mansfield, 1944:9, 12.

DISCUSSION.—Our figured specimens agree quite well with material believed to be Conrad's type material. Plate 1 illustrates some of the variation in external sculpture.

A suite of specimens usually shows continual variation in

coarseness of exterior sculpture ranging from very pronounced concentric ridges to only slightly expressed concentric ridges. Dall (1898:592–593) noted extreme variation in this species at a single locality or bed, especially with respect to exterior sculpture. Parker (1956:329, 347, pls. 2, 7) indicated that there are two distinct forms of *Nuculana acuta*. His figured nearshore form has pronounced concentric ridges, a highly convex shell, and a fairly elongate outline. His offshore form has a more subdued concentric exterior sculpture with relatively more numerous ridges, and, compared with the nearshore form, it is higher in proportion to its length and is not as sharply pointed or as pronounced posteriorly.

Lee Creek specimens have a similar shape to the offshore form of Parker, but a sculpture more nearly like that of the nearshore form. Much of the variation in this species may be in response to local conditions. Some of the exterior sculptural variation in this species is shown in Plate 1: figures 3, 5.

Bird (1965:21) noted that the forms observed by Parker were not definitely discernible in samples of the Virginia and North Carolina Pliocene. His figured specimen from the James City Formation at James City, North Carolina, resembles Parker's onshore form, with pronounced concentric ridges, although these ridges are more numerous than on the form figured by Parker.

FIGURED SPECIMENS.—USNM 203880 from USGS 25368 (Plate 1: figures 3, 4) USNM 203881 from USGS 25368 (Plate 1: figures 5, 6).

OCCURRENCE.—This species is found at sections 1 (E), 2 (B), 3 (D, E), 4 (B, D, E), and 5 (B, C, D, E).

TYPE LOCALITY.—Unknown; specimens obtained from "a fossil deposit of so recent a character, that the species, with one or two exceptions, are such as occur very commonly upon the coasts of the middle and southern states" (Conrad, 1832a:32).

### Genus *Anadara* Gray, 1847

#### *Anadara aequicostata* (Conrad), new combination

PLATE 1: FIGURES 11, 12, PLATE 2: FIGURES 1, 2

*Arca aequicostata* Conrad, 1845:61, pl. 2: figs. 1, 2, pl. 31: fig. 6.

*Arca lineolata* Conrad, 1845:61, pl. 32: fig. 3.

*Arca plicatura* Conrad, 1845:62, pl. 32: fig. 4.

*Arca brevidesma* Conrad, 1845:62, pl. 32: fig. 5.

*Arca subsinuata* Conrad, 1845:62, pl. 32: fig. 6.

*Anadara* (*Anadara*) *plicatura* (Conrad).—Olsson and Harbison, 1953:39, pl. 3: fig. 9.

DISCUSSION.—Conrad applied several specific names to this variable species. The first-mentioned name in his 1845 publication that is referable to this species is *Arca aequico-*

*stata*; this name should have priority over other names found later in the same publication. Although Olsson and Harbison (1953:39) recognized that these names should be synonymized, they did not select the first names found in the publication. They wrongly list *Anadara plicatura* as being mentioned on page 61 in Conrad (1845), whereas this specimen is listed on page 62. *Arca buccula* Conrad (1845:60, pl. 31: fig. 4) is so small and worn that we cannot be certain of the specific group to which it actually belongs. Contrary to Bird's opinion (1965:31), *Anadara aequicostata* does differ from *Anadara transversa* (Say, 1822) and has the beaks more posteriorly positioned, a generally larger shell, and a tendency to be less elongate. The posterodorsal shoulder is often lower in *A. transversa*, and although some individuals of the two species are very similar to one another, specimens on the whole are easily separable. Some of the variation typical of this species is shown in Plates 1 and 2. Differences in elongation are common.

FIGURED SPECIMENS.—USNM 203883 from USGS 25364 (Plate 2: figures 1, 2) and USNM 203882 from USGS 25364 (Plate 1: figures 11, 12).

OCCURRENCE.—This species is abundant at section 5, units D, E and is common at section 5, units B, C. It also occurs in sections 2 (B, D, E), 3 (D, E), 4 (B, D, E), and 6 (C).

TYPE LOCALITY.—Neuse River below New Bern, North Carolina (specimens were probably collected in the James City Formation).

### Genus *Quadrilatera* Deshayes, 1860

TYPE.—*Quadrilatera solida* (Sowerby, 1833:18), a valid eastern Pacific species living from Baja California to Peru; selected herein.

DISCUSSION.—Deshayes (1860:866) divided the arcids into seven groups, of which the sixth group was described as follows:

Les *Quadrilatera* qui, independamment d'un ligament mince étendu sur toute la surface cardinale, ont une fossette superficielle dans laquelle cet organe est plus concentré: l'*Arca solida* et l'*Arca sculptilis* vivants peuvent servir de type à ce group.

The designation is a proper Latin designation and is adequate for a publication of that period. Deshayes (1860:898) also referred to the group in the vernacular as "Les Quadrilatères."

This genus is distinguished from *Striarca* Conrad, 1862, in that it has a short ligament confined to a shallow triangular resilifer below the beaks.

The selection of the first-mentioned species in the description given by Deshayes (1860) as the type-species of this genus means that *Arcopsis* will fall into synonymy with this genus.

***Quadrilatera adamsi* (Dall), new combination**

PLATE 2: FIGURES 5, 6

*Arca caelata* Conrad, 1845:61, pl. 32: fig. 2 [not *Arca coelata* Reeve, 1844].  
*Arca adamsi* [Shuttleworth].—Dall, 1886:243 [Shuttleworth apparently never published on this species; Dall published from a museum label].  
*Fossularca (Fossularca) adamsi* (Dall).—Olsson and Harbison, 1953:36.

DISCUSSION.—Although Conrad has priority and the spelling is not that of Reeve (1844), nomenclatorial rules dictate that Conrad's name is invalid because the name differs from Reeve's only by the use of *ae* and *oe* and hence must be regarded as a junior homonym. This species is not discussed by Gardner (1943). Olsson and Harbison (1953) noted that a somewhat similar species is found on the Pacific Coast ("*Arcopsis*" *pusilla* (Sowerby)). Olsson and Harbison (1953:36) stated that "*A. adamsi*" has considerable abundance at St. Petersburg, Florida. Bird (1965:25, 26) recorded this species from Old Dock, Acme, and Walkers Bluff (all North Carolina localities of Waccamaw-age).

FIGURED SPECIMEN.—USNM 203885 from USGS 25368.

OCCURRENCE.—This species is found at section 5, unit E (rare).

TYPE LOCALITY.—Wilmington, North Carolina, Mr. Hodge, collector. Probably lower Pleistocene.

**Genus *Noetia* Gray, 1857*****Noetia limula* (Conrad)**

PLATE 2: FIGURES 3, 4

*Arca limula* Conrad, 1832b:15, pl. 1: fig. 1.  
*Noetia (Fontia) Limula* (Conrad).—Bird, 1965:36, pl. 3: fig. 1a, c.

DISCUSSION.—This species was not discussed by Gardner (1944) or Olsson and Harbison (1953). Olsson and Harbison (1953:42) recorded only *Noetia ponderosa macneili* Olsson and Harbison from St. Petersburg. This taxon is not found in beds as old as the Caloosahatchee. The geologically younger *N. ponderosa* group is quite distinct from the *N. limula*–*N. platyura*–*N. carolinensis* group in that its outline is more quadrate with the beaks centrally placed and with higher umbones.

Compared with *Noetia platura* (Dall, 1898), *Noetia limula* is less sharply truncate posteriorly, is more elongate, and has a slight ventral depression. *Noetia carolinensis* (Conrad, 1863) differs from *N. limula* by having more posteriorly located beaks and a less constant ventral depression. Bird (1965:36) recorded *N. limula* from Town Creek and from James City (both North Carolina Waccamaw-age localities). This species does not appear in the Yorktown Formation (restricted sense).

FIGURED SPECIMEN.—USNM 203884 from USGS 25364.

OCCURRENCE.—This species is common at section 5 unit E and rare in section 5 units B and D. It occurs in 1 (E), 2 (D), 3 (D, E), 4 (D), and 6 (C).

TYPE LOCALITY.—[Neuse River below] New Bern, North Carolina (probably collected from the James City Formation).

**Genus *Glycymeris* da Costa, 1778*****Glycymeris americana* (Defrance)**

PLATE 2: FIGURES 7, 8

*Pectunculus americanus* Defrance, 1826:225.

DISCUSSION.—Dall (1898:609) listed synonyms of *Glycymeris americana* Defrance. Olsson and Harbison (1953:29) noted that this species occurs sparingly in the Caloosahatchee beds at LaBelle, and elsewhere, but not in the beds at St. Petersburg.

Bird (1965:40–41) stated that there are two intergrading subsets of this species. One subset is subcircular, while the other subset is subovate and produced posteriorly. The subcircular subset is like the specimens in Holocene collections at the National Museum of Natural History. We have not observed the two subsets coexisting at any one locality. At Lee Creek, the subcircular subset is found, whereas at Calabash, North Carolina, Waccamaw beds contain the subovate subset.

FIGURED SPECIMEN.—USNM 203886 from USGS 25364.

OCCURRENCE.—This species is abundant at section 5 unit D and is common in units B and E at this section. It also occurs in sections 2 (B), 3 (D, E), 4 (B, D, E), and 6 (C).

TYPE LOCALITY.—"On la trouve à la Caroline du Nord" [probably North Carolina] (DeFrance, 1826:225).

***Glycymeris arata* (Conrad)**

PLATE 3: FIGURES 3–5

*Glycymeris (Tuceta) arata* (Conrad).—Olsson and Harbison 1953:31, pl. 1: figs. 6, 6a.

*Pectunculus aratus* Conrad, 1841:346.—Conrad, 1845:62, pl. 34: fig. 2.

DISCUSSION.—Olsson and Harbison (1953:31) stated:

*G. arata* was placed in the synonymy of *G. pectinata* (Gmelin), a recent species, by Dall, Gardner, and Mansfield, but the fossil has typically a smaller, heavier and more trigonal shaped shell with fewer ribs spaced apart by intervals as wide as the ribs themselves, while in *pectinata* the ribs are numerous, rounded, and close set, separated by grooved lines.

This species is not found in the Yorktown Formation (restricted sense).



**FIGURED SPECIMENS.**—USNM 203887 from USGS 25367 (Plate 3: figure 3), and USNM 203888 from USGS 25366 (Plate 3: figures 4, 5). Figure 3 shows an unusually large specimen while figures 4 and 5 show a more normal specimen.

**OCCURRENCE.**—This species is common in section 5 units D and E and is rare at this section in units B and C. It is recorded from sections 3 (D, E) and 4 (D, E).

**TYPE LOCALITY.**—Wilmington, North Carolina (probably Waccamaw Formation).

### *Glycymeris hummi*, new species

PLATE 4: FIGURES 12, 13

**DIAGNOSIS.**—Shell of moderate size, up to approximately 60 mm in length, relatively thick and moderately convex, with pointed low beaks, subrounded in outline but tending to be somewhat produced anteriorly; sculpture of gently arched low ribs with very narrow interspaces, ribs range from about 26 to 30 in number; ribs indistinct on the lateral slopes and on the ventral margins of larger specimens; transverse, very fine closely spaced concentric elevated threads over the entire exterior; cardinal area large and with about 5 or 6 concentric chevron grooves; teeth large, 5 or 6 to a side in large specimens, the line of teeth gently arched and broadly separated by hinge and ligament area; basal inner margin of shell with about 10 flutings that vary from weakly to strongly expressed. Anterior and posterior muscle scars strongly raised and distinct, elongated; interior of shell with many thin radial impressed lines.

**DISCUSSION.**—*Glycymeris hummi* differs from *Glycymeris tuomeyi* (Dall, 1898) (*subovata* of most authors) in being more produced anteriorly, the ribs narrower and less pronounced, the dentition generally heavier, less regular, and with fewer teeth. *Glycymeris tuomeyi* also tends to have the ribs separated by well-defined interspaces, while the ribs in *hummi* are separated only by a narrow groove. The dorsal and ventral shoulders bordering the ligamental area in *hummi* are dorsally arched, while in *tuomeyi* they tend to be straight. The ligamental area in *hummi* also tends to be much longer than that of *tuomeyi*.

*Glycymeris subovata*, which is confined to the lower part of the Yorktown Formation, differs from *G. hummi* in that it has many teeth (approximately 11 in average-sized, 60 mm long, specimens); the ligamental area is relatively small, and the ribs are quite broad and tend to be V-shaped.

This species is named for Edward Humm, the father of Kathryn Humm Karlson, Paleontology and Stratigraphy Branch, United States Geological Survey.

At Lee Creek only one small valve was found in the lowest unit of section 5(B) that may be this species. The species is not found in the Waccamaw Formation to the south. The appearance of a single valve in our lowest stratigraphic unit

may represent approximately the highest stratigraphic appearance of the taxon.

**FIGURED SPECIMENS.**—Holotype, USNM 204136 from USGS 26123, length 65.3 mm, height 58.3 mm, width 15.2 mm (Plate 4: figures 12, 13).

**OCCURRENCE.**—At Lee Creek a specimen that may be this species came from section 5, unit B (Plate 3: figures 1, 2).

**TYPE LOCALITY.**—Right bank of Chowan River, 0.25 miles (0.40 km) down river from Colerain Beach, Bertie County, North Carolina, at mean high tide level (unmapped quadrangle); Chowan River Formation (upper Pliocene).

### *Glycymeris sloani*, new species

PLATE 3: FIGURES 6, 7

**DIAGNOSIS.**—Shell, small, rounded-triangular, solid, moderately convex with pointed small low beaks and a flattened lunule area. Sculpture of raised ribs with narrow interspaces; anterior and posterior ribs on the lateral slopes broad and indistinct, on the middle of the shell are about 9 to 11 well-defined ribs; transverse, very fine, regularly spaced, concentric, elevated lines over entire exterior; cardinal area small and short, with three or four concentric chevron grooves; teeth small, six or seven on each side, the line arched and uninterrupted; anterior margin straight, base rounded, posterior slightly arcuate; basal inner margins with about 10 flutings.

**DISCUSSION.**—*Glycymeris sloani* is distinguished from *Glycymeris duplinensis* (Dall, 1898:613) by the lack of bifurcations on the radial ribs, and from *Glycymeris arata* by its triangular shell shape, its compressed hinge area, and its straighter anterior and posterior margins.

The illustrated specimen (holotype) is typical of the species in size, shape, and sculpture. This species has been named in honor of Earle Sloan, former state geologist of South Carolina.

**FIGURED SPECIMEN.**—Holotype, USNM 203889 from USGS 25367, length 6.6 mm.

**OCCURRENCE.**—This species is abundant at section 5, units B, C, D, and E. It is recorded from sections 2 (B), 4 (B, D, E), and 6 (C).

**TYPE LOCALITY.**—Lee Creek Mine, Beaufort County, North Carolina, USGS 25367, section 5, unit C.

### *Glycymeris* sp.

PLATE 3: FIGURES 1, 2

**DISCUSSION.**—The single specimen found at Lee Creek is a juvenile. It seems more rounded than is typical of the ribbed glycymerids. Further it has more ribs than typical *Glycymeris hummi*, new species.

FIGURED SPECIMEN.—USNM 203890 from USGS 25366.

**Genus *Brachidontes* Swainson, 1840**

***Brachidontes* sp.**

PLATE 4: FIGURE 9

DISCUSSION.—All specimens found at Lee Creek are small, usually about 5 mm long. The shell is moderately heavy. The specimens are somewhat similar to *Brachiodontes venustus* Olsson and Harbison (1953), although the posterodorsal margin is less flared in our specimens, and the valves are quite heavy.

FIGURED SPECIMEN.—USNM 203892 from USGS 25367.

OCCURRENCE.—This species is rare at section 5, units C and E.

**Genus *Mytilus* Linnaeus, 1758**

***Mytilus* sp. aff. *M. edulis* Linnaeus**

PLATE 4: FIGURES 1, 2

DISCUSSION.—The specimens collected at Lee Creek are all fragmentary. The specimens are rather heavy, and the pieces of specimens collected resemble some Holocene specimens of the morphologically variable *Mytilus edulis* Linnaeus, 1758.

FIGURED SPECIMEN.—USNM 203891 from USGS 25366.

OCCURRENCE.—This species is found only at section 5, unit B (rare).

TYPE LOCALITY.—The type locality of *Mytilus edulis* Linnaeus (1758:705, n. 215) is “in O[ceano] Europaeo, Indico, & M. Balthico.” [Probably eastern Atlantic, West? Indies, and Baltic Sea].

**Genus *Crenella* Brown, 1827**

***Crenella decussata* (Montagu)**

PLATE 4: FIGURES 3–6

*Mytilus decussatus* Montagu, 1808:69.

*Crenella decussata*.—Brown, 1827, pl. 31: figs. 12–14.

DISCUSSION.—Brown (1827, pl. 31: figs. 12–14) figured this species and assigned it to a new genus, *Crenella*. *Crenella precursor* Gardner (1944) may belong to this species, which has quite variable morphology. Our figured specimens from Lee Creek illustrate some of the variation in ribbing, exterior sculpture, and shell outline. Such variation is common

in Holocene collections of this species at the National Museum of Natural History.

*Crenella divaricata* (d'Orbigny), which is recorded by Olsson and Harbison (1953:63) from the beds at St. Petersburg, Florida, and by DuBar (1958:162) from the Caloosahatchee Formation in Florida, is a living species and has a heavier dentition, and a deeper, more elongate shell.

FIGURED SPECIMENS.—USNM 203893 from USGS 25367 (Plate 4: figures 3, 4) SEM photograph, and USNM 203894 from USGS 25366 (Plate 4: figures 5, 6).

OCCURRENCE.—This species is rare at section 5, units B, C, and D. It is found at sections 2 (B, E) and 3 (D).

TYPE LOCALITY.—Scottish Coast (Holocene).

**Genus *Musculus* Röding, 1798**

***Musculus lateralis* (Say)**

PLATE 4: FIGURES 7, 8

*Mytilus lateralis* Say, 1822:264.

DISCUSSION.—This species is rare in the Atlantic Coastal Plain Cenozoic. It was not recorded by Gardner (1944), DuBar (1958), or Olsson and Harbison (1953). Richards (1962:57) noted its occurrence in the Pleistocene of Simmons Bluff, South Carolina. Only a single valve was collected at Lee Creek.

FIGURED SPECIMEN.—USNM 203895 from USGS 25367.

OCCURRENCE.—The only valve collected is from section 5, unit C.

TYPE LOCALITY.—“Inhabits the southern coast” (Holocene).

**Genus *Modiolus* Lamarck, 1799**

***Modiolus* sp. cf. *M. modiolus* (Linnaeus)**

PLATE 4: FIGURES 10, 11

DISCUSSION.—Only fragments of shells were recovered. These fragments are morphologically similar to *Modiolus modiolus* (Linnaeus, 1758). *Modiolus modiolus* (Linnaeus) was not recorded by Gardner (1944) or by Olsson and Harbison (1953).

FIGURED SPECIMEN.—USNM 203986 from USGS 25364.

OCCURRENCE.—This species is common at section 5, unit D, and rare at this section in units B and E. It also occurs at sections 1 (E), 2 (B), 3 (D, E), 4 (D, E), and 6 (C).

TYPE LOCALITY.—Type locality of *Modiolus modiolus* (Linnaeus, 1758:706, no. 217): “in M. Mediterraneo” [Mediterranean].

**Genus *Lithophaga* Röding, 1798*****Lithophaga yorkensis* Olsson**

PLATE 5: FIGURES 1–3

*Lithophaga yorkensis* Olsson, 1914:51–52, pl. 2: figs. 5, 6, 10.

DISCUSSION.—Olsson (1914) recognized this species as that figured but not named by Conrad (1875, pl. 3, fig. 11).

Plate 5: figure 1 shows the specimen as found in *Mercenaria* valve which is encrusted with Bryozoa and heavily bored. Such bored *Mercenaria* valves are common in section 5, unit E.

This species was not recorded by Olsson and Harbison (1953) or by Gardner (1944).

FIGURED SPECIMEN.—USNM 203897 from USGS 25369.

OCCURRENCE.—This species is recorded only from section 5, unit E.

TYPE LOCALITY.—Yorktown, Virginia (Yorktown Formation).

**Genus *Leptopecten* Verrill, 1897*****Leptopecten? auroraensis*, new species**

PLATE 5: FIGURES 4–6

DIAGNOSIS.—Shell small, about 13 mm long, left valve only slightly convex, right valve quite convex, outline of disk slightly produced posteriorly. Byssal notch deep, ctenolium present, resilial insertion located anteriorly and in line with anterodorsal margin of disk. Resilial insertion of about equal length and height. Interior calcification in right valve heavy and obscuring fluting of the ribs. Auricular denticles and cardinal crura prominent. About 15 major plicae in right valve with very small ribs in interspaces (small ribs arising about 5 mm from the beak). Major plicae in right valve and sharply arched to narrowly rectangular, with spaces between major plicae about twice the width of the plicae; faint trace of concentric lamellae in interspaces.

Left valve with about 5 high, prominent ribs having sharply arched summits, and with 2 lower, broader, flat-topped ribs between each of the 5 prominent ribs. A single faint fold occasionally occurs between ribs. Concentric lamellae cover parts of the high ribs and the auricles.

DISCUSSION.—*Leptopecten leonensis* (Mansfield, 1932:58, type locality *Ephora* Zone at Jackson Bluff, Florida) differs from *L. auroraensis* in that it has stronger auricular denticles, fewer ribs (10 as opposed to about 14 in *L. auroraensis*), which are covered by raised concentric lamellae and are almost V-shaped in cross-section. The cross-section of ribs of *L. auroraensis* is quite rounded in the right valve. The left valve of *L. leonensis* lacks the square-shaped, very flattened ribs seen between the V-shaped ribs of *L. auroraensis*.

All the ribs of the type specimen of *L. leonensis* (a left valve) are V-shaped with one small V-shaped rib between each major rib while *L. auroraensis* has 2 flat ribs between each major rib. Also *L. auroraensis* has almost twice as many plicae on the auricles as does *L. leonensis*.

Specimens from the Tamiami Formation are probably *Leptopecten wendelli* (Tucker, 1934). Tucker's (1934:612) type locality is Fort Denaud where there is a good deal of spoil material from both the Tamiami Formation and from the Caloosahatchee Formation. *Leptopecten* is rare in the Caloosahatchee Formation, and Tucker's specimens apparently came from the Tamiami Formation. *Leptopecten wendelli olgensis* (Mansfield, 1939) is also probably from the Tamiami Formation and so too is *Leptopecten irremotis* (Olsson and Harbison, 1953) (See page 133 concerning collections used in Olsson and Harbison, 1953). *Leptopecten wendelli* is believed to be a senior synonym of *L. leonensis*. In addition, *L. wendelli olgensis* probably represents only a variation within this species. Specimens of *L. wendelli* from Punta Gorda (Tamiami Formation, Florida, Cenozoic, USGS 22454) are almost twice the size of *L. auroraensis*. Similar-sized right valves of *L. wendelli* are very close morphologically to *L. auroraensis*, but the right valves have only half the convexity of Lee Creek specimens, and the auricular denticles are smaller than those in Lee Creek specimens. Tucker (1936, pl. 4, fig. 9) illustrated a specimen from Walkers Bluff, but it is only a left valve, and convexity measurements are not given for this specimen.

*Leptopecten* sp. (unnamed) from the Chipola Formation at Ten Mile Creek, Florida (1 mile (1.6 km) west of Baileys Ferry), is an early representative of this group and is small (approximately 8.0 mm in height). The ribs tend to be about equal in size, except for minor alternation of rib size, and ribs on both valves are high and sharply arched. Concentric lamellae cover the exterior of both valves. The outline of the disk is produced posteriorly, and the auricles are similar to those of later members of this group.

The Holocene species *Leptopecten bavayi* (Dautzenberg, 1900) from the West Indies has more numerous ribs in the right valve than does *L. auroraensis*. *Leptopecten bavayi* also has less tendency to alternate rib size (i.e., it has more uniform ribbing). Both valves of this Holocene species have one small rib between major ribs. The left valve of *L. auroraensis* has only a trace of these small ribs, the disk is less rounded in outline (the angle from the beak to the edges of the disk is lower), and the interior shows heavier calcification and a larger resilial insertion area. The right valve of *L. auroraensis* has stronger auricular denticles and is slightly more convex than *L. bavayi*. The entire surface of *L. bavayi* is covered by concentric lamellae.

The type species of *Leptopecten* is a West Coast species with a strongly inclined shape and as far as we know it does not alternate rib sizes. Atlantic species assigned to *Leptopecten* have probably been separate long enough and show

enough difference to be considered a separate genus.

**FIGURED SPECIMENS.**—Holotype, USNM 203898, USGS 25357 (Plate 5: figure 4). Paratype, USNM 203899, USGS 25357 (Plate 5: figures 5, 6).

**OCCURRENCE.**—This species is rare at section 5 units B, C, and E. It occurs in 1 (E), 2 (B, D, E), and 6 (C).

**TYPE LOCALITY.**—Clewiston, Florida (Caloosahatchee Formation).

### Genus *Carolinapecten*, new genus

**TYPE.**—*Carolinapecten eboreus* (Conrad, 1833), Pliocene, upper Yorktown beds at Suffolk, Virginia, on the Nansemond River; designated herewith.

**DIAGNOSIS.**—Shells usually large, commonly 80 mm and as much as 150 mm in height; valves thin and of low convexity, shells ranging from distinctly left-convex to slightly right-convex; outline of disk equilateral; disk flanks low and curved in plane perpendicular to commissure and to disk flanks. Disk gapes broad. Auricles about equal in length; anterior auricle with shallow byssal notch, ctenolium absent in individuals larger than about 60 mm in height; auricles of right valve with dorsal margins extending dorsally from outer ligament in distinct folds increasing in amplitude distally, giving dorsal margins a shallow V-shape appearance in plane of commissure; auricles of right valve with free margins forming acute angles at juncture with outer ligament. Ornament of approximately 20 to 25 low radial plicae and of concentric lamellae, the latter better developed in interspaces; radial costae never common on disk and arising distally in interspaces or at sides of plicae or rarely on crests of plicae. Plicae reflected over almost entire interior of valves with sharp, approximately squared margins. Adductor scar large and only faintly expressed as a thin layer of aragonite. Auricular denticles absent to moderately strong; cardinal crura low. Ventral margin of shell with interspaces projecting ventrally to form interdigitation with opposing ribs.

**DISCUSSION.**—The genus *Carolinapecten* (type species, *Carolinapecten eboreus* (Conrad)) is proposed for an important group of eastern North American Pectinidae. *Carolinapecten* species are distinguished by their large size (adults often 80 to 150 mm in height), the thin valves of low convexity, ranging from left-convex to slightly right-convex, ornament of approximately 20 to 25 low radial plicae, cardinal crura low, byssal notch shallow, and large specimens lacking ctenolium. Disk flanks are low and poorly demarcated, the free margins of the posterior auricles are convex in the plane of commissure with the posterior sinus obscure or absent.

The *eboreus* group was recognized by Waller (1969:59–61) as a separate species-group on morphologic grounds and as a separate lineage. Waller stated that this group forms a discrete taxonomic unit separate from all other

related groups. Although he treated the group as consisting of a single essentially monotypic species, he recognized that with further work the group could probably be subdivided into different taxa. Waller indicated that the *eboreus* group arose when the subspecies *eboreus urbannaensis* appeared as a splitting from the main *Argopecten gibbus* species-group. Although Waller retained the *eboreus* species-group within the genus *Argopecten*, we believe that the *eboreus* group is sufficiently distinct with respect to morphology and evolution to merit generic rank. Given present evidence, we are not at all certain as to the origin of the group; in particular, we are not convinced that the lineage is closely related evolutionarily to the *Argopecten gibbus* species-group. The earliest known specimens of the *eboreus* group are quite distinct (upper Miocene Eastover Formation of Ward and Blackwelder, 1980). A small unnamed pecten in the Choptank Formation of Maryland may possibly be near to the origin of the group and is related to the genus *Chesapecten* Ward and Blackwelder, 1975.

Species belonging in the genus *Carolinapecten* have previously been referred to *Pecten*, *Chlamys*, *Plagioctenium*, *Lyropecten*, *Aequipecten*, and *Argopecten*. *Argopecten* is a senior synonym of *Plagioctenium* (Waller, 1969:32–36). *Lyropecten* of Conrad, 1863, is an eastern Pacific genus with prominent, strong ribs, large cardinal crura, and a large byssal notch. *Aequipecten* Fischer, 1886, is an eastern Atlantic genus with species having anterior auricles longer than posterior, and the plicate disk covered with dense scabrous radial costae. *Argopecten* (type species, *Pecten circularis* Sowerby, 1835) differs substantially from *Carolinapecten* in being smaller in size (usually less than 70 mm high); having disk flanks steep; plicae high and rectangular in cross-section; byssal notch deep; and with quite convex valves.

### *Carolinapecten eboreus* (Conrad), new combination

PLATES 6, 7: FIGURES 9–11

- Pecten eboreus* Conrad, 1833:341; 1840a:48, pl. 23: fig. 2, pl. 24: fig. 3.—Tuomey and Holmes, 1855:28, pl. 11: figs. 1–5.  
*Pecten* (*Plagioctenium*) *eboreus* Conrad.—Dall, 1898:749 [in part].  
*Chlamys* (*Plagioctenium*) *eboreus eboreus* (Conrad).—Mansfield, 1932:60, pl. 12: fig. 11.  
*Pecten* (*Chlamys*) *eboreus eboreus* Conrad.—Mansfield, 1936b:174, 180, 181, 184.  
*Pecten* (*Chlamys*) *gladensis* Mansfield, 1936b:188, pl. 23: fig. 4.  
*Chlamys* (*Plagioctenium*) *eboreus* (Conrad).—Tucker-Rowland, 1938:40–41, pl. 3: fig. 12.  
*Chlamys* (*Lyropecten*) *planicosta* Gardner, 1944:34, pl. 9: fig. 1  
*Chlamys* (*Aequipecten*) *eborea* (Conrad).—Gardner, 1944:36–37, pl. 7: fig. 1, 5, 6, 8 [in part].  
*Argopecten eboreus* (Conrad).—Waller, 1969:59–61, pl. 5: fig. 14.

**DISCUSSION.**—The type specimen(s) are apparently lost. Richards (1968) did not record the type specimens as being at the Philadelphia Academy. Moore (1962:57) recorded the specimens as missing from the Academy. Conrad's type

locality for this species is Suffolk, Virginia. We have selected a specimen from this locality to be the neoholotype (USNM 204134). This articulated specimen was collected from the right bank of the Nansemond River at Suffolk, Suffolk 7.5' quadrangle, Virginia, from the cliffs exactly 0.5 miles (0.8 km) east of the crossing of Route 460 over the river. The sample was collected from 6 feet (1.8 m) above the beach in a fine sand of the upper part of the Yorktown Formation (presumably the same age beds in Conrad's sampled units). The dimensions of the neoholotype are 53.8 mm (height), 56.2 mm (length), 9.4 mm (convexity of left valve), and 7.8 mm (convexity of right valve). The right valve has 22 ribs. Conrad's original description of this species as being thin-shelled, about 22 ribs, rounded, little elevated and smooth with a flatter right valve, closely coincides with the selected neotype and with other specimens collected from this locality. Conrad mentioned that his specimen is 2 inches (5.0 cm) long, which is slightly more than 50 mm and close to the size of the selected neotype. Many of the best-preserved specimens from this locality are of this small size, and the larger specimens common at other localities are rare in these beds at Suffolk.

The various subspecies and species that we have synonymized and that were synonymized by Waller (1969) are apparently geographic variants or local ecologic variants. The specimens of this species at the type locality differ from those at Lee Creek in being smaller, with more numerous, narrow ribs which have more highly crenulated, microscopic growth striae and less tendency to form riblets in the interspaces. Thirty-eight topotypes (USNM 204135), whose measurements are given below, are deposited with the neotype at the National Museum of Natural History, Smithsonian Institution.

MEASURED MATERIAL.—Measurements (in mm) of 38 topotypes (USNM 204135) from Suffolk, Virginia, are given below:

Length	Height	Convexity
LEFT VALVES		
89.7	79.4	14.8
86.1	78.6	17.3
74.0	68.6	12.5
54.8	51.3	10.0
48.0	43.8	9.5
36.8	35.0	7.2
45.6	43.0	—
42.5	39.7	13.7
61.6	56.7	14.2
48.0	46.9	9.7
53.6	50.4	10.1
56.8	54.6	9.5
43.6	41.0	—
45.5	42.2	7.4
34.3	33.2	6.6

39.0	36.5	6.8
45.5	42.7	7.8
44.9	42.8	8.5
45.1	42.0	8.4
37.5	35.6	7.5

#### RIGHT VALVES

65.8	59.5	7.4
63.4	59.5	8.1
61.6	56.7	7.8
59.3	54.5	8.6
56.0	52.0	7.2
55.0	51.9	8.2
51.1	48.4	7.0
45.1	41.2	7.1
45.0	40.9	6.1
45.0	42.4	7.3
44.1	40.9	6.5
43.7	40.0	5.5
42.3	39.1	6.0
40.5	41.1	4.8
40.3	37.5	5.5
33.0	31.3	4.5
29.7	28.0	4.5
28.7	27.0	3.5

FIGURED SPECIMENS.—USNM 203901 from USGS 25364 (Plate 6: figure 1), USNM 203902 from USGS 25362 (Plate 6: figures 2, 3), USNM 203903 from USGS 25360 (Plate 6: figures 4–6), USNM 203904 from USGS 25364 (Plate 6: figure 7), and USNM 203905 from USGS 25364 (Plate 6: figures 8, 9). Neoholotype, USNM 204134 from USGS 25724A (Plate 7: figures 9–11).

OCCURRENCE.—This species is common at section 5, units B, C, D, and E. It also occurs at sections 2 (D, E), 3 (D, E), 4 (D, E), 6 (C).

TYPE LOCALITY.—Suffolk, Virginia (Yorktown Formation).

### Genus *Argopecten* Monterosato, 1889

#### *Argopecten vicenarius vicenarius* (Conrad)

PLATE 5: FIGURES 7–9

*Pecten vicenarius* Conrad, 1843a:306.

*Argopecten vicenarius vicenarius* (Conrad).—Waller, 1969:49–50, pl. 6: figs. 5–14.

DISCUSSION.—Waller (1969:49) noted that *Argopecten vicenarius vicenarius* differs from *Argopecten gibbus* (Linnaeus, 1758), its Pleistocene and Holocene descendant, in having steeper disk flanks, which are generally noncostate, a more strongly left-convex shell with wider disk gapes, larger auricular denticles, and a ctenolium that is commonly retained into maturity. Waller presumed that the ecological requirements of *Argopecten vicenarius vicenarius* were the

same as living *Argopecten gibbus* because of morphological similarity and because of the existence in other areas of apparently well-differentiated bay scallops that were probably contemporaneous with *Argopecten vicenarius vicenarius*. Waller (1969:49) stated that these requirements include open, relatively warm marine waters of shallow to moderate depths (5–200 fathoms). This is independently substantiated by the paleoecological studies of Dubar and Howard (1963) dealing with the type Waccamaw outcrops on the Waccamaw River, Horry County, South Carolina, where *A. vicenarius*, although not abundant, is the most common scallop present. DuBar and Howard (1963:27) concluded that “essentially all of the type Waccamaw Formation was deposited in an open, unrestricted ocean on the inner shelf (2–12 fathoms) or the shallow part of the intermediate shelf (12–35 fathoms).”

FIGURED SPECIMEN.—USNM 203900 from USGS 25364.

OCCURRENCE.—This species is found at sections 2 (D), 4 (D), and 5 (E).

TYPE LOCALITY.—Wilmington, North Carolina (probably Waccamaw Formation), Mr. Hodge, collector. Waller (1969) designated a right valve, syntype of Conrad, ANSP 31416, as the lectotype.

### Genus *Plicatula* Lamarck, 1801

#### *Plicatula marginata* Say

PLATE 7: FIGURES 3–5

*Plicatula marginata* Say, 1824:136–137, pl. 9: fig. 4.

DISCUSSION.—Most specimens of *Plicatula marginata* Say at Lee Creek have 3 to 6 large sharp plications or ribs, some of which become spiniferous toward the ventral margin. These specimens have a dark-colored marginal band on the shell interior, which is formed by the outer shell layer projecting beyond inner shell layers. Olsson and Harbison (1953:58) mentioned that their specimens lack this dark band. This species is abundant in the Yorktown and Waccamaw formations. Gardner (1944:40) provided a long list of localities where this species may be found. The Holocene species *Plicatula gibbosa* Lamarck, 1801, usually has 5 to 9 radial ribs and is common in shelf deposits where the bottom is gravelly or shelly.

FIGURED SPECIMENS.—USNM 203906 from USGS 25368 (Plate 7: figures 3, 4), USNM 203907 from USGS 25368 (Plate 7, figure 5).

OCCURRENCE.—This species is common at section 5, units B and D. It is also found at sections 1 (E), 2 (B, D, E), 3 (D, E), 4 (B, D, E), and 5 (E).

TYPE LOCALITY.—Incorrectly attributed to “Maryland” (type specimens were not collected in Maryland but from

the York and James rivers, Yorktown Formation, in Virginia (Ward and Blackwelder, 1975:3)).

### Genus *Anomia* Linnaeus, 1758

#### *Anomia simplex* d’Orbigny

PLATE 7: FIGURES 6–8

*Anomya simplex* d’Orbigny, 1842, pl. 28: figs. 31–33.

*Anomia eohippium* Conrad, 1845:75, pl. 43: fig. 4 [not of Linnaeus].

DISCUSSION.—Olsson and Harbison (1953:61) included in their generic description an excellent discussion of shell morphology. We have illustrated some of the internal features of this species. Our specimens from Lee Creek appear identical with Holocene specimens. Olsson and Harbison (1953:61) recorded this species from St. Petersburg, Florida, Caloosahatchee beds. Dall (1898:784) included a fuller synonymy of this species. It should be noted that many of the synonymies included by Dall in his papers in the *Transactions of the Wagner Free Institute of Science* apparently were aided by a card catalog prepared by Deshayes.

FIGURED SPECIMEN.—USNM 203908 from USGS 25362.

OCCURRENCE.—This species is rare at section 5 (B, C, D) and is also found at sections 1 (E), 3 (D, E), and 4 (D).

TYPE LOCALITY.—The type specimens apparently came from Martinique and Cuba (Holocene).

### Genus *Pododesmus* Philippi, 1837

#### *Pododesmus fragosus* (Conrad), new combination

PLATE 7: FIGURES 1, 2

*Placunomia fragosa* Conrad, 1875:19.

*Ostrea waccamawensis* Gardner, 1944:41, pl. 3: fig. 17.

*Pododesmus waccamawensis* (Gardner).—Olsson and Petit, 1964:530–531, pl. 77: fig. 2–2c.

DISCUSSION.—Although Conrad did not figure this species, his description (1875) is complete enough to indicate this species. Gardner (1944:41) did not recognize her specimen as a *Pododesmus* because of oyster growths on the inside of the valve in her specimen (oysters are visible protruding from the margin of the shell in her plate 3: figure 14). Gardner found this species only at Cronly, Columbus County, North Carolina (Waccamaw Formation). Druid Wilson (pers. comm.) first recognized this as Conrad’s species.

FIGURED SPECIMEN.—USNM 203909 from USGS 25362.

OCCURRENCE.—This species is found at sections 3 (D, E) and 4 (E).

TYPE LOCALITY.—Twenty miles (32 km) north of Wil-

ington on the Cape Fear River (probably Waccamaw Formation, lower Pleistocene).

### Genus *Crassostrea* Sacco, 1897

#### *Crassostrea virginica auroraensis*, new subspecies

PLATE 8: FIGURES 1–4

**DESCRIPTION.**—Shell large (up to 180 mm in height or more), elongate and highly variable in outline, lower valve convex, upper valve flat to convex, exterior sculpture of many prominent concentric lamellae, shell extremely thick. Small attachment area on left valve. Interior of shell smooth and lacking marginal denticles; adductor muscle scar of moderate size, semilunate, and deeply impressed. Ligamental area very large and elongate, and may be straight, coiled, or rotated.

**DIAGNOSIS.**—Large, platy, lamellar, thickened shell, deeply impressed muscle scars, lacking chomata.

**DISCUSSION.**—*Crassostrea virginica auroraensis* appears to be close morphologically to *C. virginica virginica* (Gmelin, 1791) but differs in having a thickened, lamellar shell. This subspecies of *Crassostrea virginica* was apparently able to thrive in near normal marine salinities. *Crassostrea virginica auroraensis* also occurs in the Waccamaw Formation along the Intracoastal Waterway in South Carolina.

**FIGURED SPECIMENS.**—USNM 203910 from USGS 25364 (Plate 8: figure 1), USNM 203912 from USGS 25364 (Plate 8: figure 2). Holotype, USNM 203911 from USGS 25364 (Plate 8: figures 3, 4).

**OCCURRENCE.**—This subspecies is found at sections 2 (D), 4 (D), and 5 (C, D).

**TYPE-LOCALITY.**—Lee Creek Mine, Beaufort County, North Carolina, USGS 25364, section 4, unit D.

### Genus *Conradostrea*, new genus

**TYPE SPECIES.**—*Conradostrea lawrencei*, new species.

**DIAGNOSIS.**—This genus is characterized by its large size, its prominent exterior folds, a large sublunate adductor muscle scar, and strong chomata along the antero- and posterodorsal margins.

**DESCRIPTION.**—Shells usually large, commonly 90 mm or more in height, oval to triangular in outline, lower valve convex, upper valve flat or of irregular low convexity, exterior sculpture of approximately 7 to 10 prominent irregular radial folds, which may split or rotate slightly. Interior of shell smooth and not reflecting exterior folds except at margins of shell, adductor muscle scar large and sublunate, chomata strong and present in small and large specimens along the antero- and posterodorsal margins, ligament area broad but small and triangular in shape.

**DISCUSSION.**—The members of this genus are discussed in the section describing the type species.

### *Conradostrea lawrencei*, new species

PLATE 8: FIGURES 5, 6; PLATE 9: FIGURES 1, 2

Not *Ostrea meridionalis* Heilprin, 1886:100.—Heilprin, 1887:100, pl. 14: figs. 35, 35a (= *Hyotissa haitensis* (Sowerby, 1850)).

**DESCRIPTION.**—Shell of moderate size (to 90 mm in height or more), oval to triangular in outline, lower valve convex, upper valve flat or of irregular low convexity, exterior sculpture of approximately 7 to 10 prominent irregular radial folds, which may split or may rotate slightly. Attachment area on the left valves ranging from an obtuse angle (often about 150°) to almost a right angle with direction of later shell growth.

Interior of shell smooth and not reflecting exterior folds except at margins of shell; adductor muscle scar large and sublunate, chomata strong and present in small and large specimens along the antero- and posterodorsal margins; ligamental area broad but small (usually much less in height than one-fourth the total height of the shell) and triangular in shape with tendency to rotate slightly.

**DIAGNOSIS.**—Shell of moderate size with 4 to 11 strong irregular radial folds over entire exterior of valves, lower valve convex, upper valve flat or of low convexity, interior smooth and not reflecting exterior fold except along margins, chomata present.

**DISCUSSION.**—*Conradostrea lawrencei* has often been identified as *Ostrea meridionalis* Heilprin (1886:100; 1887:100, pl. 14: figs. 35, 35a). Olsson and Harbison (1953:51, pl. 4: figs. 3, 3a) refigured one of Heilprin's specimens and termed it the holotype, although such designation is improper. This refigured specimen was reported to be in the Wagner Free Institute in Philadelphia (Olsson and Harbison, 1953:51). Heilprin's statements that the adults are massive and ponderous and that the hinge area is sometimes nearly one-half the length of the shell and that the ponderous proportions of the shell surpass *Ostrea percrassa* (a Miocene pycnodont oyster) indicate that he was describing a pycnodont oyster (probably from the Tamiami Formation) (see Olsson and Petit, 1964:531).

Our figures show some of the sculptural variation in Lee Creek individuals. A few specimens at Lee Creek do resemble *Ostrea sculpturata* Conrad (1840b). Generally these two species are quite distinct, and comparative measurements are provided below in the measurement section. In comparison to *Conradostrea lawrencei*, *C. sculpturata* is smaller, with thinner valves, particularly the right valve, with less pronounced and fewer plications, with a narrower ligamental area, and with generally narrower proportions along the dorsal half of the shell.



Conrad's type specimen of *Ostrea sculpturata* Conrad (1840a:50-51, pl. 25: fig. 3) is the same specimen (viewed from the other valve) that Conrad figured as *Ostrea virginiana* var. Conrad (1832b:28, pl. 14: fig. 2) and listed as being from Suffolk, Virginia. Conrad (1840a:50-51) referred this same specimen to the James River, near Smithfield, Virginia. Conrad's first given locality is probably the correct one for this specimen. In his later years, Conrad tended to make mistakes more frequently. Regardless of the exact type locality, both localities are late Yorktown in age.

MEASURED MATERIAL.—Measurements (in mm) of *Conradostrea lawrencei*, new species, from Lee Creek Mine are as follows:

Height	Length	Convexity	No. of plicae
RIGHT VALVES			
83.4	75.3	25.5	9
82.7	65.3	16.5	11
71.0	49.2	13.3	8
62.1	50.0	10.8	7
61.3	43.7	10.6	6
56.5	47.4	13.1	5
56.3	51.8	18.1	7
53.4	35.5	10.7	6
51.7	43.7	13.2	5
49.2	32.8	93.	4
LEFT VALVES			
75.3	55.2	28.6	6
70.3	53.5	22.5	9
67.4	56.4	24.4	5
65.4	55.1	22.5	7
62.7	56.1	18.7	6
59.7	47.3	18.3	5
59.6	48.5	15.5	8
59.1	48.5	16.7	5
55.4	43.3	20.6	8
54.8	44.8	15.1	11
51.4	47.5	17.4	5
47.5	36.0	10.5	7
43.5	39.1	12.4	9

Measurements (in mm) of *Conradostrea sculpturata* (Conrad), from Brant's Pit, Virginia are as follows:

Height	Length	Convexity	No. of plicae
RIGHT VALVES			
42.8	37.2	5.4	7
LEFT VALVES			
64.7	50.0	21.3	7
61.0	47.8	15.4	7
59.1	57.0	17.3	7
58.9	41.9	14.4	6

51.3	41.7	14.5	5
49.8	43.8	13.7	10

Measurements (in mm) of *Conradostrea sculpturata* (Conrad) from Petersburg, Virginia, are as follows:

Height	Length	Convexity	No. of plicae
RIGHT VALVES			
56.7	39.9	6.2	6
46.8	35.3	4.9	4
43.5	32.5	7.8	2
42.0	30.9	7.0	7
39.6	34.0	3.9	4
38.7	30.4	5.4	5
35.4	28.5	6.2	6
LEFT VALVES			
51.5	36.2	13.9	8
48.7	37.4	7.8	6
46.7	30.3	9.4	5
44.8	37.4	14.5	6
42.7	34.0	7.8	6

FIGURED SPECIMENS.—Holotype, USNM 203913 from USGS 25364 (Plate 8: figures 5, 6). USNM 204127 from USGS 25364 (Plate 9: figures 1, 2).

OCCURRENCE.—This species is found at sections 1 (E), 2 (B, D, E), 4 (B, D, E), 5 (B, D), and 6 (C).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25364, section 4, unit D.

**Genus *Stewartia* Olsson and Harbison, 1953**

***Stewartia anodonta floridana* (Conrad), new combination**

PLATE 9: FIGURES 7, 8

*Lucina floridana* Conrad, 1833:344-345.

DISCUSSION.—The more pronounced beak (deeper lunule) of this subspecies differentiates it from *Stewartia anodonta anodonta* (Say, 1824). Olsson and Harbison (1953:83, pl. 12: figs. 5, 5a) provided a figure of Conrad's type specimen of *Stewartia anodonta floridana* and stated that *Stewartia anodonta intermixta* (Olsson and Harbison, 1953) differs from typical *S. anodonta floridana* by its more strongly descending sides and more deeply immersed lunule. Dall (1903:1379) stated that he had seen no fossil specimens that he considered to be *S. floridana*. Not recorded from St. Petersburg, Florida, by Olsson and Harbison (1953). Not recorded by Gardner (1944).

FIGURED SPECIMEN.—USNM 203914 from USGS 25364.

OCCURRENCE.—This species is rare at section 5, unit D, and is also recorded from sections 3 (D, E), 4 (D, E), and 6 (C).

TYPE LOCALITY.—Florida, Holocene, “found near Pensacola by Dr. Hutchins, who sent it to Dr. S. G. Morton.” The length of the type specimen is described as 1 inch (2.5 cm).

### Genus *Parvilucina* Dall, 1901

#### *Parvilucina multilineata* (Tuomey and Holmes)

PLATE 9: FIGURES 3–6

*Lucina multilineata* “Conrad.”—Tuomey and Holmes, 1856:61, pl. 18: figs. 16, 17.

*Phacoides* (*Parvilucina*) *multilineatus* Tuomey and Holmes.—Dall, 1903:1384.—Gardner, 1943:78–79, pl. 13: figs. 34–37.—Olsson and Harbison, 1953:86–87.

*Parvilucina multilineata*.—Abbott, 1974:459, fig. 5290.

DISCUSSION.—Gardner noted that Tuomey and Holmes identified their species with *L. multilineata* of Conrad. Conrad’s form was not named “*multilineata*” but “*multistriata*.” Contrary to Gardner (1943:79), Conrad’s specimen should not be relegated to subspecific rank under *P. trisulcatus*, as the dentition is distinctly different, as is the exterior sculpture and shape of the two species. *Parvilucina multilineata* does differ from *Parvilucina multistriata* (Conrad, 1843a:307, from Wilmington, North Carolina; 1845:71, pl. 40: fig. 6) in its larger size, its heavier shell, more subdued sculpture, and less dorsoventral elongation.

Gardner (1943:78–79) noted that this species is abundant in the *Cancellaria* zone and is present in the *Arca* zone of the Florida Choctawhatchee Formation. She lists other localities, particularly North Carolina and South Carolina localities of the Yorktown and Waccamaw formations. She noted it in the Holocene. Olsson and Harbison (1953:86–87) recorded this as common in St. Petersburg beds.

FIGURED SPECIMENS.—USNM 203915 from USGS 25368 (Plate 9: figures 3, 4) and USNM 203916 from USGS 25368 (Plate 9: figures 5, 6).

OCCURRENCE.—At section 5, this species is rare in unit B, common in C and D, and abundant in unit E. It is also found in section 4 (D).

TYPE LOCALITY.—Waccamaw, South Carolina (Waccamaw Formation).

### Genus *Bellucina* Dall, 1901

#### *Bellucina waccamawensis* (Dall), new combination

PLATE 10: FIGURES 1–4

*Lucina costata* Dall, 1892:210 [not *Lucina costata* Tuomey and Holmes, 1855].

*Phacoides* (*Bellucina*) *waccamawensis* Dall, 1903:1386, pl. 52: fig. 2.—Olsson and Harbison, 1953:87.

DISCUSSION.—This species was not recorded by Gardner (1943). Olsson and Harbison (1953) reported it as common at St. Petersburg, Florida.

FIGURED SPECIMENS.—USNM 203917 from USGS 25360 (Plate 10: figures 1, 2), and USNM 203918 from USGS 25369 (Plate 10: figures 3, 4).

OCCURRENCE.—This species is rare at section 5, unit E. It is also recorded from sections 1 (E), 2 (D, E), and 4 (E).

ORIGINAL LOCALITIES.—Pliocene [lower Pleistocene] of the Waccamaw district at Tilly’s Lake, South Carolina, collected by Johnson; and of the marls of the Caloosahatchee and Shell Creek, Florida, collected by Dall and Burns. (Locality of Dall’s figured specimen is Tilly’s Lake, South Carolina).

### Genus *Cavilinga* Chavan, 1937

#### *Cavilinga trisulcata* (Conrad), new combination

PLATE 10: FIGURES 7, 8

*Lucina trisulcata* Conrad, 1841:346.

DISCUSSION.—This species ranges from the upper Yorktown into early Pleistocene-age beds. It is distinctive from the Holocene and late Pleistocene species *C. blanda* (Dall, 1901), contrary to McLean’s (1951:64) opinion. The lunule of *C. blanda* is less excavated, the shell is more dorsoventrally elongated, and the hinge is weaker than in *Cavilinga trisulcata*. Much of the variation in morphology within *Cavilinga trisulcata* can be related to local ecologic conditions. This species is common in the Yorktown, Waccamaw, and Caloosahatchee formations of the Atlantic Coast.

Olsson and Harbison (1953:85) listed “Conrad, 1841,” as the original reference to this species. However, this reference is dated 1843 (Conrad, 1843b) and is a reprint of the 1841 *American Journal of Science* article. As the original reference to *Callucina radians* (Conrad), Olsson and Harbison cited this same reference, but incorrectly indicated the date 1840; this is also incorrect as the original reference.

FIGURED SPECIMEN.—USNM 203920 from USGS 25368.

OCCURRENCE.—This species is found at section 5 where it is rare in units B, C, and D and is common in unit E. It is also found at 1 (E) and 2 (D, E).

TYPE LOCALITY.—Natural Well, North Carolina (Yorktown Formation).

### Genus *Callucina* Dall, 1901

#### *Callucina keenae* (Chavan)

PLATE 10: FIGURES 5, 6

*Lucina radians* Conrad, 1841:347 [not Bory De St. Vincent, 1824] [see *Cavilinga trisulcata* regarding original Conrad reference].  
*Callilucina* [sic] *keenae* Chavan, 1971:N1215.

DISCUSSION.—The illustrated specimen is the only one found in the collections at Lee Creek. Druid Wilson (1974,

pers. comm.) first mentioned that this species had been described in an appendix to the Treatise. The generic name is misspelled in the Treatise. *Callucina keenae* (Chavan) is the type species of the genus.

FIGURED SPECIMEN.—USNM 203919 from USGS 25364.

OCCURRENCE.—This species is rare at Lee Creek and is recorded only from section 4, unit D.

TYPE LOCALITY.—“Recent at Mobile Point, Alabama, and occurs near Newbern, North Carolina” (Conrad, 1841:347).

### Genus *Divalinga* Chavan, 1951

*Divaricella* of authors, fide Keen, 1958:100 [not of Von Martens, 1880].

#### *Divalinga* sp.

DISCUSSION.—Only fragments of a species belonging to this genus were found. Olsson and Harbison (1953:89–90) recorded *Divaricella compsa* Dall (1903) from St. Petersburg and Fort Thompson, Florida, and stated that this species differs from *D. quadrisulcata* d'Orbigny by its smaller size and finer, more uniform sculpture. The genus was not recorded by Gardner (1944).

OCCURRENCE.—This species is recorded only from section 5, unit E.

### Genus *Diplodonta* Bronn, 1831

#### *Diplodonta acclinis* (Conrad)

PLATE 11: FIGURES 1–3

*Lucina acclinis* Conrad, 1832b:21, pl. 6: fig. 2.

DISCUSSION.—This species was not recorded by Olsson and Harbison (1953) or by Gardner (1944).

FIGURED SPECIMEN.—USNM 203924 from USGS 25366.

OCCURRENCE.—This species is rare at section 5, units B, C, D, and is recorded from sections 2 (B), 3 (D, E), 4 (D), and 6 (C).

TYPE LOCALITY.—Yorktown, Virginia, in “commi-nuted” bed.

#### *Diplodonta berryi* McGavock

PLATE 11: FIGURES 7–10

*Diplodonta berryi* McGavock, 1944:2, figs. 3–6.

FIGURED SPECIMEN.—USNM 203925 from USGS 25370.

OCCURRENCE.—This species is rare at sections 1 (E), 3 (D, E), 5 (E), and 6 (C).

TYPE LOCALITY.—“High and undercut bluff of York River below Yorktown” (McGavock, 1944:2).

### Genus *Phlyctiderma* Dall, 1899

#### *Phlyctiderma heroni*, new species

PLATE 10: FIGURES 9–12; PLATE 11: FIGURES 4–6

DIAGNOSIS.—Shell of medium size, moderately thin-shelled, globose (both valves of about equally strong convexity), rounded, posteriorly enlarged, lunule minute, externally pustulose, ligament long, in groove, resilium narrow, hinge with bifid 2 and 3b, and oblique 3a, 4b, AIII, posterior muscle scars broad.

DISCUSSION.—No species similar to this has been described from the Pliocene of North Carolina. This species is fairly rare at Lee Creek.

FIGURED SPECIMENS.—Holotype, USNM 203921 from USGS 25367, length 12.1 mm (Plate 10: figures 9, 12). USNM 203922 from USGS 25367 (Plate 10: figure 10, Plate 11: figure 5), USNM 203923 from USGS 25367 (Plate 10: figure 11, Plate 11: figures 4, 6).

OCCURRENCE.—This species is rare at section 5, unit C.

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25367, section 5, unit C.

### Genus *Chama* Linnaeus, 1758

#### *Chama gardnerae* Olsson and Harbison

PLATE 12: FIGURES 1–3

*Chama gardnerae* Olsson and Harbison, 1953:76–77, pl. 7: figs. 7, 7a, 7b.

DISCUSSION.—Olsson and Harbison (1953) stated that the figure and description of *Chama striata* as given by Emmons are wholly inadequate for a certain identification and proposed that the species identified by Dall, Mansfield, and Gardner as *Chama striata* Emmons be called *Chama gardnerae*. Nicol (1953:706) had previously renamed *C. striata*, which is preoccupied, *Chama emmonsi*.

Compared with *C. congregata*, *Chama gardnerae* is smaller and more compressed and has a medial depression that is diagnostic. Also, the lamellae of the left valve are fewer and stronger, and the right valve is flatter, and the radial sculpture more delicate except for an occasional strongly developed spine (Gardner, 1944:88).

FIGURED SPECIMENS.—USNM 203926 from USGS 25367 (Plate 12: figures 1, 3), and USNM 203927 from USGS 25367 (Plate 12: figure 2).

OCCURRENCE.—This species is found at section 5, where it is rare in units C and D, and abundant in unit E. It is also recorded from sections 1 (E) and 4 (E).

TYPE LOCALITY.—St. Petersburg, Florida (Caloosahatchee Formation).

### Genus *Aligena* Lea, 1843

#### *Aligena striata* Lea

PLATE 12: FIGURES 9, 10

*Aligena striata* Lea, 1843b:163.

DISCUSSION.—There has been some confusion as to the date of publication of the above paper by H.C. Lea. The following statements have been imparted by Druid Wilson (pers. commun. 1974). The publication date of the above paper of Lea is prior to 19 October 1843, when it was received by the library of the Academy of Natural Sciences of Philadelphia [date noted on paper]. *Aligena striata* is the first described species under *Aligena* in this paper. Contrary to Chavan (1969:N523), *Aligena striata* Lea, 1843, is a valid name and has priority as the type species of this genus [see p. 20]. See Abbott (1974), not Chavan (1969), for characteristics of this genus.

This species was not recorded by Gardner (1944) and the genus was not listed by Olsson and Harbison (1953).

FIGURED SPECIMEN.—USNM 203929 from USGS 25367.

OCCURRENCE.—This species is found at section 5, where it is rare in units B and C. It is also found in section 1 (E).

TYPE LOCALITY.—Petersburg, Virginia (Yorktown Formation).

### Genus *Bornia* Philippi, 1836

#### *Bornia triangula* Dall

PLATE 12: FIGURES 4–6

*Bornia triangula* Dall, 1900:1151 [*Kellia triangula* H.C. Lea, label in collection of Academy of Natural Sciences of Philadelphia, never published].—Gardner, 1944:82–83, pl. 14: figs. 2, 3, 4, 5, 10.

DISCUSSION.—Olsson and Harbison (1953:92–93) recorded *Bornia* cf. *triangula* Dall (fragmentary specimens only) from St. Petersburg. Gardner (1944:83) recorded this species from Yorktown localities in Virginia, from the “Duplin” and Waccamaw formations in North Carolina, and from the Caloosahatchee Formation in Florida.

FIGURED SPECIMENS.—USNM 203931 from USGS 25366 (Plate 12: figures 4, 6) and USNM 203932 from USGS 25366 (Plate 12: figure 5).

OCCURRENCE.—This species is found at section 5, where it is common in units B and C, and rare in units D and E.

TYPE LOCALITY.—Petersburg, Virginia (Dall, 1900:1151) (Yorktown Formation).

### Genus *Mysella* Angas, 1877

#### *Mysella beaufortensis*, new species

PLATE 12: FIGURES 7, 8

DIAGNOSIS.—Shell small, thin, oval, not equilateral with beaks about two-thirds of the distance back toward the posterior margin, the exterior surface with many small growth lines, ends rounded, beaks fairly low, hinge with small lamellar teeth, resiliary notch small, ventral margin rather straight.

DISCUSSION.—This species is close in morphology to *Mysella bladenensis* Gardner, 1943, but differs in its straighter ventral margin, in being less contracted posteriorly, and in having a more evenly anterodorsally sloping ventral margin. The species is distinct from any other species of this genus.

FIGURED SPECIMEN.—Holotype, USNM 203930 from USGS 25367, length 5.7 mm.

OCCURRENCE.—This species is recorded from section 5, unit C.

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25367, section 5, unit C.

### Genus *Anisodonta* Deshayes, 1858

#### *Anisodonta carolina* Dall

PLATE 13: FIGURES 1–4

*Anisodonta* (*Fulcrella*) (*elliptica* Récluz? var.) *carolina* Dall, 1900:1133, pl. 45: fig. 20.

DISCUSSION.—Olsson and Harbison (1953) and Gardner (1944) did not record this species.

FIGURED SPECIMENS.—USNM 203933 from USGS 25366 (Plate 13: figures 1, 2), USNM 203934, USGS 25366 (Plate 13: figures 3, 4).

OCCURRENCE.—This species is rare at sections 2 (B, D), 5 (B), and 6 (C).

TYPE LOCALITY.—“Miocene” of Duplin County, North Carolina at the Natural Well, Burns, collector (Yorktown Formation).

### Genus *Sportella* Deshayes, 1858

#### *Sportella waccamawensis* Gardner

PLATE 12: FIGURES 11, 12

*Sportella waccamawensis* Gardner, 1943:85, pl. 14: figs. 21, 22.

DISCUSSION.—Gardner stated that this species has been recorded only from the Waccamaw Formation and listed Neills Eddy Landing as another locality besides the type locality. *Sportella waccamawensis* differs from all its conge-

ners by the configuration of the anterior part of the shell, outlined by the slightly excavated dorsal margin, the horizontal ventral margin, and the lateral margin truncated at right angles to the base (Gardner, 1944:85).

Specimens from Lee Creek are close morphologically to the type specimen. This species was not recorded by Olsson and Harbison (1953).

FIGURED SPECIMEN.—USNM 203928 from USGS 25367.

OCCURRENCE.—This species is rare at sections 1 (E), 4 (D), and 5 (B, C, E).

TYPE LOCALITY.—Walkers Bluff on the Cape Fear River, Bladen County, North Carolina (Waccamaw Formation).

### Genus *Ensitellops* Olsson and Harbison, 1953

#### *Ensitellops elongata* Olsson and Harbison

PLATE 13: FIGURES 5, 6

*Ensitellops elongata* Olsson and Harbison, 1953:95, pl. 8: figs. 7, 7A.

FIGURED SPECIMEN.—USNM 203935 from USGS 25367.

OCCURRENCE.—This species is rare at section 5 (B, C, D).

TYPE LOCALITY.—St. Petersburg, Florida (Caloosahatchee Formation).

### Genus *Carditamera* Conrad, 1838

#### *Carditamera arata* (Conrad)

PLATE 14: FIGURES 1–3

*Cypricardia arata* Conrad, 1832b:20, pl. 5: fig. 1.

*Cardita* (*Carditamera*) *arata* (Conrad).—Olsson and Harbison, 1953:74–75.

DISCUSSION.—Olsson and Harbison (1953:74–75) recorded this species from the Caloosahatchee Formation, St. Petersburg, Florida. They also noted that these specimens are somewhat shorter and heavier than *C. arata*, but are closer to this species than to *C. floridana* Conrad, 1838, of the Holocene. Abbott (1954:378) recorded *C. floridana* from the southern half of Florida and Mexico (Holocene distribution). Gardner (1944:69) noted that *Carditamera arata* occurs in the *Cancellaria* zone of the Choctawhatchee Formation. *Carditamera arata verdevilla* Gardner, 1944, intergrades with normal *C. arata* at the same locality and apparently represents a local variant in the morphology of the species.

A member of this genus is present in the lower part of the Choptank Formation in Maryland. The next represent-

ative of this species in the Chesapeake group does not appear until middle Yorktown time.

FIGURED SPECIMENS.—USNM 203936 from USGS 25364 (Plate 14: figures 1, 2), and USNM 203937 from USGS 25364 (Plate 14: figure 3).

OCCURRENCE.—This species is found at section 5 where it is rare at units B, C, and E, and common at D. It is also found at sections 1 (E), 2 (E), 3 (D, E), 4 (D), and 6 (C).

ORIGINAL LOCALITIES.—New Bern, North Carolina, Mr. Nuttall (first locality in Conrad's (1832b) list of occurrences) (James City Formation); James River near Smithfield and Yorktown, Virginia; Easton, Maryland; Cumberland County, New Jersey.

### Genus *Pleuromeris* Conrad, 1867

#### *Pleuromeris auroraensis*, new species

PLATE 13: FIGURES 7–10

DIAGNOSIS.—Shell small, rounded-trigonal, subequilateral, moderately convex, anterior end shorter, posterodorsal margin obliquely truncate and merging inferiorly into the rounded lateral margin. Umbones subcentral or slightly anterior, the apices acute and feebly prosogyrate. Lunule minute, lanceolate. Exterior sculpture of low radiating smooth costae, averaging about 12 in number and separated by grooves or very narrow interspaces. Ligament external, opisthodontic. Dentition of right valve reduced to a single cardinal with anterior cardinal strong and prominent, triangular, the apex of the triangle directly beneath the apices of the umbones; anterior lateral socket short, double; posterior lateral tooth very low and inconspicuous; two cardinals in the left valve, of which the anterior is shorter and stouter, divergent on each side of the large subumbonal socket. Anterior left lateral short, posterior lateral socket shallow. Adductor impressions usually obscure. Pallial line simple. Inner margins denticulated in harmony with external fluting.

DISCUSSION.—*Pleuromeris auroraensis* differs from *Pleuromeris tridentata* (Say, 1826) and *Pleuromeris decemcostata* Conrad, 1867, in the smaller size of the individuals (largest individuals about 6 mm long), the lack of concentric sculpture, the narrowness of the interspaces between costae, and the very reduced expression of the costae. It is distinct from any known species.

FIGURED SPECIMENS.—USNM 203941 from USGS 25367 (Plate 13: figures 7, 8). Holotype, length 4.6 mm, USNM 203942 from USGS 25367 (Plate 13: figures 9, 10).

OCCURRENCE.—This species is found at section 5, where it is common in unit B and rare in units C and E. It is recorded from sections 2 (B, D), 3 (D, E) and 4 (B, D).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25367, section 5, unit C.

***Pleuromeris decemcostata* Conrad**

PLATE 13: FIGURES 11, 12

*Pleuromeris decemcostata* Conrad, 1867:12.*Glans (Pleuromeris) tridentata decemcostata* (Conrad).—Gardner, 1943:71, pl. 13: figs. 1–4.

DISCUSSION.—Gardner (1943:71) recorded this species from both the *Ecphora* and the *Cancellaria* zones of the Choctawhatchee Formation. She also recorded it from Duplin and Waccamaw localities in North Carolina, and she noted it from the Caloosahatchee Formation in Florida. She stated that it is Holocene off the coast of Florida in shallow water. Olsson and Harbison (1953:73) recorded only the species *Pleuromeris tridentata* (Say, 1826) from St. Petersburg, Florida, and noted that the specimens have strong (about 15) coarsely noded ribs. *Pleuromeris tridentata* differs from *P. decemcostata* in having more ribs (approximately 15 as opposed to 13 in *P. decemcostata*), which are lower and have less pronounced concentric lirae.

FIGURED SPECIMEN.—USNM 203940 from USGS 25368.

OCCURRENCE.—This species is abundant at section 5 units B, C, D, and E. It is found at sections 2 (B, D), 4 (B, D, E), and 6 (C).

TYPE LOCALITY.—No locality given.

**Genus *Pteromeris* Conrad, 1862*****Pteromeris perplana* (Conrad)**

PLATE 14: FIGURES 8–11

*Cardita perplana* Conrad, 1841:347, pl. 2: fig. 16.*Glans (Pteromeris) perplana* (Conrad).—Gardner, 1944:72, pl. 13: figs. 6–9.*Pteromeris perplana* (Conrad).—Abbott, 1974:477.

DISCUSSION.—Gardner (1944:72) stated that this species varies in convexity and outline from relatively high and less compressed forms, which are isolated under the subspecies *abbreviata* (Conrad, 1841), to broader individuals in which the cavity is scarcely thicker than the outer shell covering. In the Waccamaw, she noted that the species attains its maximum size and compression. She recorded the species from the Yorktown Formation, the “Duplin” Formation, the Waccamaw Formation, the Caloosahatchee Formation, and the Holocene.

Olsson and Harbison (1953:74) recorded *Cardita (Pteromeris) abbreviata* Conrad from the beds at St. Petersburg, Florida.

FIGURED SPECIMENS.—USNM 203943 from USGS 25368 (Plate 14: figures 8, 10), USNM 203944 from USGS 25368 (Plate 14: figure 9), and USNM 203945 from USGS 25368 (Plate 14: figure 11). The figured specimens show some of the variation in shape and surface sculpture seen in this species at Lee Creek.

OCCURRENCE.—At section 5, this species is rare in units B, D, and E, and common in unit C. It is also found at sections 2 (B), 3 (D, E), 4 (D), and 6 (C).

TYPE LOCALITY.—Natural Well, Duplin County, North Carolina (Yorktown Formation).

**Genus *Cyclocardia* Conrad, 1867*****Cyclocardia* sp. cf. *C. granulata* (Say), new combination**

PLATE 14: FIGURES 4–7

*Venericardia granulata* Say, 1824:142, pl. 12: fig. 1.*Venericardia (Cyclocardia) granulata*.—Dall, 1903:1431.

DISCUSSION.—*Cyclocardia granulata* was not discussed by Gardner (1944) or by Olsson and Harbison (1953). Examination of the original type material indicates that the specimens came from zone 1 Yorktown Formation (Mansfield, 1944:12). The forms at Lee Creek may well deserve another specific or subspecific status, but this should be done as a part of a detailed study of this lineage because many of the differences are very subtle.

FIGURED SPECIMENS.—USNM 203938 from USGS 25364 (Plate 14: figures 4, 5) and USNM 203939 from USGS 25364 (Plate 14: figures 6, 7). The figured specimens show some of the variation in outline and surface sculpture.

OCCURRENCE.—In section 5, this species is abundant in units B, D, and E, and rare in unit C. It is also recorded from sections 1 (E), 2 (B, D, E), 3 (D, E), 4 (B, D, E) and 6 (C).

TYPE LOCALITY.—Incorrectly attributed to “Maryland” (type specimens were not collected in Maryland but from the York and James rivers, Yorktown Formation, in Virginia (Ward and Blackwelder, 1975:3)).

**Genus *Erycinella* Conrad, 1845*****Erycinella ovalis* Conrad**

PLATE 15: FIGURES 5, 6

*Erycinella ovalis* Conrad, 1845:74, pl. 42: fig. 5.—Gardner, 1944:73–74, pl. 14: fig. 46.

DISCUSSION.—Gardner (1944:74) stated that this species is the only representative of this minute but well-characterized genus in the east coast Miocene [and Yorktown-age beds] and is abundant only along the York River and in the environs of Suffolk. She listed it from Colerain Landing in North Carolina. This genus was not recorded by Olsson and Harbison (1953).

FIGURED SPECIMEN.—USNM 203946 from USGS 25366, SEM photographs.

OCCURRENCE.—This species is rare and recorded only from section 5, unit B.

TYPE LOCALITY.—Yorktown, Virginia (Yorktown Formation).

Genus *Astarte* J. Sowerby, 1816*Astarte berryi* Gardner

PLATE 16: FIGURES 1, 2

*Astarte berryi* Gardner, 1944:56, pl. 12: figs. 23, 24.

DISCUSSION.—Olsson and Harbison (1953) did not record this species. Gardner (1944:56) recorded it from Colerain Landing and Chocowinity, North Carolina, and from north of Suffolk, Virginia.

FIGURED SPECIMEN.—USNM 203947 from USGS 25364.

OCCURRENCE.—At section 5, this species is common in units B, C, and D and rare in unit E. It occurs at sections 2 (D), 3 (D, E), 4 (B, D), and 6 (C).

TYPE LOCALITY.—2½ miles (4 km) northwest of Chocowinity, Beaufort County, North Carolina (Chowan Formation).

*Astarte concentrica* Conrad

PLATE 16: FIGURES 3–5

*Astarte concentrica* Conrad, 1834:133; 1840:44, pl. 21: fig. 6.*Astarte* (*Ashtarotha*) *concentrica* Conrad.—Gardner, 1943:59–60, pl. 12: figs. 32–34, 40.*Astarte* (*Ashtarotha*) *concentrica conradi* Gardner, 1944:60, pl. 12: figs. 37, 41.

DISCUSSION.—Gardner (1944:60) recorded this species from the Yorktown Formation in Virginia and North Carolina and from the "Duplin" and Waccamaw formations in North Carolina and South Carolina. Gardner's subspecific name is preoccupied and in any case her subspecies represents only a minor local variation within this species. This species was not recorded by Olsson and Harbison (1953).

FIGURED SPECIMENS.—USNM 203948 from USGS 25364 (Plate 16: figures 3, 4), and USNM 203949 from USGS 25364 (Plate 16: figure 5).

OCCURRENCE.—At section 5, this species is common in units B, C, D, and E. It also occurs in sections 1 (E), 2 (B, D, E), 3 (D, E), 4 (B, D, E), and 6 (C).

TYPE LOCALITY.—Yorktown, Virginia (Yorktown Formation).

Genus *Marvacrassatella*, new genus

TYPE SPECIES.—*Marvacrassatella kauffmani*, new species.

DIAGNOSIS.—This genus is characterized by its large size, valves often 100 mm long or longer, by the flat, thin nepionic shells, which are subtrapezoidal in outline, by the strong concentric undulations on the nepionic shell, which diminish and disappear during later shell growth, and by the orthogyrous beaks.

DESCRIPTION.—Valves large, often more than 100 mm long, subtrapezoidal to transversely subtrigonal in outline,

of low convexity, orthogyrous beaks sometimes rotated by later growth to appear very slightly prosogyrous; posteriorly elongated; early growth until about 20 mm long characterized by very flat, very thin valves, which are quite trapezoidal and elongate (height to length ratio about 0.8) and marked by concentric undulations, which vary from closely spaced to fairly broad. When valves are more than about 25 mm long, the undulations rapidly diminish and then disappear altogether, the remainder of the exterior being marked only by slightly incised irregular growth lines. Hinge area is thick and heavy in adults, muscle scars are large and impressed, inner margins of valve are smooth. Valves thickened with calcium carbonate deposits under the hinge area. Cardinals strong, posterior ones straight and in front of a large pit, which extends downward to the lower margin of the plate, laterals large, anterior pedal retractor muscle insertion located on the inner part of the lateral hinge process.

DISCUSSION.—*Marvacrassatella* is a common and widespread genus throughout the beds of the Chesapeake group in Maryland and Virginia. In Maryland, the first member of this lineage is known from zone 10 of the Calvert Formation (*Crassatellites melinus* (Conrad, 1832)). *Marvacrassatella turgidulus* (Conrad, 1843) is abundant in the Choptank Formation in zones 16, 17, 18. In zone 19 of the Choptank Formation, *Marvacrassatella marylandicus* (Conrad, 1832) is found in abundance. These Calvert and Choptank species represent a more elongate group within *Marvacrassatella* and are succeeded by a group that has a higher outline and includes several species (*M. surryensis* (Mansfield, 1928), *M. urbannaensis* (Mansfield, 1928), *M. undulatus* (Say, 1824)) found in beds of the Eastover Formation of Ward and Blackwelder (1980) and in beds of the Yorktown Formation. The highest recorded occurrence of this genus in the Atlantic Coastal Plain is in the James City Formation at Lee Creek where *M. kauffmani* is abundant.

*Eucrassatella? speciosa* (A. Adams, 1852), the common Holocene species on the Atlantic shelf south of Hatteras represents a separate, subtropical lineage that has been geographically separate from *Marvacrassatella* at least since middle Yorktown time. The elimination of a warm-temperate province in Pleistocene time may have caused the extinction of *Marvacrassatella*.

*Eucrassatella? antillarum* (Reeve, 1842) is a West Indian Holocene species that has the beaks slightly inclined posteriorly and has a sharp posterior sulcus with a very attenuated posterior and a sharply curving ventral margin, somewhat similar to a *Pandora* outline. Two apparently authentic Holocene specimens are in Smithsonian USNM collections (USNM 127021 and 425765). *Eucrassatella? digueti* (Lamy, 1917) is a Pacific cognate of this species.

COMPARISON.—*Marvacrassatella* differs from *Eucrassatella* Iredale, 1924, an Australian genus, in being much less convex, especially the nepionic part of the shell, in having a much more elongate rectangular shell as opposed to the



rather rounded juvenile outline of species of *Eucrassatella*. The beaks of *Eucrassatella* are located more anteriorly than the beaks of *Marvacrassatella*. *Marvacrassatella* has much heavier carbonate deposits under the hinge area, and the anterior pedal retractor muscle insertion is more central and less high on the lateral process. *Marvacrassatella* has orthogyrous beaks and smooth margins. *Crassatella* Lamarck, 1799, has prosogyrous beaks and crenulate valve margins.

*Marvacrassatella* is named for the widespread occurrence of this species in the Miocene, Pliocene, and lower Pleistocene beds in Maryland and Virginia.

***Marvacrassatella kauffmani*, new species**

PLATE 15: FIGURES 1-4

**DIAGNOSIS.**—Shell large, solid, elongate-subtrigonal, valves subequal; anterior end rounded; posterior end truncate, subrostrate, and longer than anterior; beaks high, full, flattened at apex; nepionic shell flattish with many low, concentric close-set waves that terminate at sulcus. Remainder of shell smoothish but covered with fine to occasionally pronounced irregular concentric threading; hinge normal; laminar grooves and adductor scars deep; internal margin of valves smooth.

**DISCUSSION.**—Mansfield (1928:8-9) described two species that are very similar to our species and must be closely related. These species along with *M. kauffmani* are morphologically variable with respect to external shape, proportions of teeth arrangements, and in hinge structure. They are similar in nature of hingement and in exterior sculpture, starting with an undulant nepionic sculpture and having a smoothish surface over the remainder of the shell interrupted only by fine growth lines.

*Marvacrassatella surryensis* (Mansfield, 1928) from "zone 2 St. Marys Formation" of Virginia (actually the beds collected from are the lower part of the Eastover Formation, Ward and Blackwelder, 1980) differs from *M. kauffmani* in having moderately strong concentric undulations on the exterior of the nepionic shell (about 10 undulations), which extend for only about 10 mm from the beak toward the ventral margin, as opposed to 18 or more undulations in *M. kauffmani*, which extend for a distance of usually at least 14 mm. Also *M. surryensis* is generally shorter, smaller, and more triangular than *M. kauffmani*.

*Marvacrassatella urbannaensis* (Mansfield, 1928) from the upper part of the Eastover Formation tends to be shorter than *M. kauffmani* and has larger concentric undulations on the nepionic shell; these undulations extend only for a distance of 7 to 9 mm from the beak toward the ventral margin.

*Marvacrassatella meridionalis* (Dall, 1900) from Alum Bluff, Florida, differs from *M. kauffmani* in having a smaller

shell with a narrower rostrate posterior and with fairly large and broadly separated undulations on the nepionic shell.

**FIGURED SPECIMEN.**—Holotype, length 89.1 mm, USNM 203950 from USGS 25362.

**OCCURRENCE.**—This species is rare at section 5, units C, D, and E and is found at 2 (D), 3 (D, E), 4 (D, E), and 6 (C).

**TYPE LOCALITY.**—Lee Creek Mine, Beaufort County, North Carolina, USGS 25362, section 3, unit D.

**MEASURED MATERIAL.**—Measurements (in mm) of the holotype\* (USNM 203950, paired valves) and 8 paratypes from Lee Creek Mine, North Carolina, Chowan River Formation, late Pliocene, USGS 25362 (section 3, unit D), are given below:

Length	Height	Convexity
RIGHT VALVES		
89.1*	64.6*	17.5*
107.8	76.0	22.8
101.7	67.5	20.7
106.0	75.1	20.4
99.2	67.0	18.3
72.4	52.5	13.9
106.9	74.0	20.9
LEFT VALVES		
110.1	78.8	21.1
81.2	55.4	14.9

**Genus *Crassinella* Guppy, 1874**

***Crassinella dupliniana* (Dall)**

PLATE 16: FIGURES 9, 10

*Crassatellites* (*Crassinella*) *duplinianus* Dall, 1903:1478, pl. 50: figs. 5, 6.  
*Crassinella dupliniana* (Dall).—Gardner, 1944:64, pl. 13: figs. 10, 11.

**DISCUSSION.**—Dall's type specimen is apparently lost. His original figure is poor, and the specimens in his original lot of material from Natural Well are variable. We consider our figured specimens typical of this species.

Gardner (1944:64) recorded this species from several localities of the "Duplin" and Waccamaw formations in North Carolina. Mansfield (1932:83) reported this species from the *Cancellaria* zone of the Choctawhatchee Formation of Florida. This species was not recorded by Olsson and Harbison (1953).

**FIGURED SPECIMEN.**—USNM 203951 from USGS 25366 (Plate 16: figure 9), and USNM 203952 from USGS 25366 (Plate 16: figure 10).

**OCCURRENCE.**—This species is rare at section 5, units B and C. It occurs at 2 (B), 3 (D, E), and 4 (B, D, E).

**TYPE LOCALITY.**—Natural Well, Duplin County, North Carolina (Yorktown Formation).

*Crassinella lunulata* (Conrad)

PLATE 16: FIGURES 6–8

*Astarte lunulata* Conrad, 1834:133; 1840a:44, pl. 21: fig. 8.*Crassinella lunulata* (Conrad).—Gardner, 1944:62–63, pl. 19: fig. 30.

DISCUSSION.—Olsson and Harbison (1953:72) recorded this species from St. Petersburg. Gardner (1944:62–63) reported a widespread distribution for the species.

FIGURED SPECIMENS.—USNM 203953 from USGS 25367 (Plate 16: figures 6, 7), and USNM 204133 from USGS 25367 (Plate 16: figure 8).

OCCURRENCE.—This species is abundant at section 5, units B, C, D, and E. It is recorded from sections 1 (E), 2 (B, D, E), 4 (B, D, E), and 6 (C).

TYPE LOCALITY.—Suffolk, Virginia (Yorktown Formation).

*Crassinella johnsoni*, new species

PLATE 17: FIGURES 1, 2

DIAGNOSIS.—Shell small (usually 2.0 to 3.0 mm long), trigonal, thin, dorsal slopes moderately steep and subequilateral, the posterior slope very slightly convex, the anterior slope rather straight, the angle at the beak formed by the dorsal margins is approximately 100°, basal margin arcuate and anterior- and posteriormost outline of shell quite rounded, umbones opisthogyrate, approximately central, lunule and escutcheon sublinear, coextensive with the dorsal margin, surface sculpture of about same size and evenly spaced low concentric folds, about 4 folds per millimeter, surface microsculpture of very fine, anteriorly-posteriorly elongated hexagonal, honeycomb-like ridges arranged in tightly packed rows over the entire exterior surface; dentition normal for genus, resilial pit narrow, dorsal margins modified as laterals, pallial line simple, inner margins simple.

DISCUSSION.—*Crassinella lunulata* (Conrad, 1834), although variable morphologically, differs from *C. johnsoni* in having the exterior concentric folds often forming sharp elevated lamellae, in often being quite unequilateral, with the anterior margin frequently more produced than the posterior margin, and in having a more pointed and less rounded beak. Also *C. johnsoni* has a less variable morphology. *Crassinella acuta* (Dall, 1903) has a proportionally longer posterodorsal area and is narrower and higher.

This species is named in honor of Henry S. Johnson, Jr.

FIGURED SPECIMENS.—USNM 203956 from USGS 25362 (Plate 17: figure 1, SEM photograph), USNM 203955 from USGS 25367, holotype, length 2.2 mm, (Plate 17: figure 2, SEM photograph).

OCCURRENCE.—This species is rare at sections 3 (D, E) and 5 (B, C).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25367, section 5, unit C.

Genus *Laevicardium* Swainson, 1840*Laevicardium sublineatum* (Conrad)

PLATE 17: FIGURES 3, 4

*Cardium sublineatum* Conrad, 1841:347, pl. 2:fig. 13.*Laevicardium sublineatum* (Conrad).—Gardner, 1944:94, pl. 15: figs. 11, 12, 15, 16.

DISCUSSION.—Gardner (1944:94) recorded this species from localities in Virginia and North Carolina, including Chuckatuck and Suffolk, Virginia; Edenhous, North Carolina; and several localities of the Waccamaw and "Duplin" formations in North Carolina. This species was not reported by Olsson and Harbison (1953).

FIGURED SPECIMEN.—USNM 203957 from USGS 25364.

OCCURRENCE.—This species is rare at sections 1 (E), 4 (B, D), and 5 (C).

TYPE LOCALITY.—Wilmington, North Carolina (Waccamaw Formation).

Genus *Dinocardium* Dall, 1900*Dinocardium robustum hazeli*, new subspecies

PLATE 17: FIGURES 5, 6

DIAGNOSIS.—Shell large, 126.7 mm in height, obliquely subquadrate in outline, inflated, with 33 prominent, rounded, radial ribs; ribs crossed by concentric thin raised threads that are concave anteriorly on each rib in harmony with configuration of the anterior margin. Umbo wide, ending at the hinge margin in a small inrolled beak facing anteriorly, hinge normal with an external ligament, large hook-shaped cardinal teeth and strong equidistantly placed lateral teeth almost in line with the cardinal teeth, giving the hinge area a very square shape, interior margins of shell deeply fluted by the ends of the ribs except on the posterior side.

DISCUSSION.—This type of *Dinocardium* differs from *Dinocardium robustum robustum* (Lightfoot, 1786) in possessing abnormally strong teeth, a very squared off hinge area, and more ribs than are common in specimens currently living off the Atlantic Coast. In outline, this subspecies resembles the specimen figured by Tuomey and Holmes (1856, pl. 19: fig. 1) but has fewer ribs.

FIGURED SPECIMEN.—Holotype, length 128.6 mm, USNM 203958 from USGS 25364.

OCCURRENCE.—The only specimen of this new subspecies came from section 4, unit D.

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25364, section 4, unit D.

### Genus *Mulinia* Gray, 1837

#### *Mulinia lateralis* (Say)

PLATE 17: FIGURES 7–9

*Maetra lateralis* Say, 1822:309.

*Mulinia lateralis* (Say).—Olsson and Harbison, 1953:141 [incorrectly cite Say as 1821].

DISCUSSION.—*Mulina lateralis* is apparently part of the *Mulinia congesta* lineage. *Mulinia congesta* (Conrad, 1833) first appears in upper Yorktown strata and is widespread in deposits of this age in the Atlantic Coastal Plain. *Mulinia congesta* is distinguished from the later *Mulinia lateralis* by its heavier shell, its heavier hinge structure, more ovate and more equilateral shell. *Mulinia lateralis* first appears in James City time. Although Olsson and Harbison (1953:140–141) recorded both *M. lateralis* and *M. congesta*, it is doubtful that these two species came from the same bed. Apparently all the collections used by Olsson and Harbison were float, and the specimens of *Mulinia lateralis* may well have come from overlying Pleistocene beds at the St. Petersburg pit.

FIGURED SPECIMENS.—USNM 203959 from USGS 25368 (Plate 17: figure 7) and USNM 203960 from USGS 25368 (Plate 17, figures 8, 9).

OCCURRENCE.—This species is common at section 5 (D, E) and is also found at sections 2 (E) and 4 (D).

TYPE LOCALITY.—“Inhabits the coast of the United States” (Say, 1822:309).

### Genus *Rangia* Desmoulins, 1832

#### *Rangia clathrodonta* (Conrad)

PLATE 19: FIGURES 4, 5

*Maetra clathrodonta* Conrad, 1833:340.

*Rangia (Perissodon) clathrodonta* (Conrad).—Conrad, 1863a:573.

DISCUSSION.—Large articulated specimens of this species are found at Lee Creek. This species was not discussed by Gardner (1944) and was not recorded by Olsson and Harbison (1953), who noted only the presence of *Rangia nasuta* (Dall, 1894). Dall's type specimen of *R. nasuta* was found in salt water at Port Lavaca, Mitchell County, Texas, (Dall, 1894:98–99). Olsson and Harbison (1953:142–143) noted that their fossils from along the Caloosahatchee are beautifully preserved, the surface polished, with no signs of umbonal corrosion, an indication of a more marine environment. *Rangia nasuta* apparently existed at the same time as *Rangia clathrodonta*, a less elongate species. Specimens of

*Rangia* at Lee Creek are paired and many are well preserved.

FIGURED SPECIMEN.—USNM 203961 from USGS 25364.

OCCURRENCE.—This species is rare at section 4, unit D.

TYPE LOCALITY.—Yorktown, Virginia.

### Genus *Spisula* Gray, 1837

#### *Spisula similis* (Say)

PLATE 18: FIGURES 3–8

*Maetra similis* Say, 1822:309.

*Spisula (Hemimaetra) similis* (Say).—Gardner, 1944:111–112, pl. 22: figures 6, 7.

DISCUSSION.—Adults of this species are rare in the units sampled, although small individuals are rather common. Gardner (1944:112–113) noted the finding of indubitable specimens of *Spisula similis* in the “Duplin” Formation of Robeson County, North Carolina. This genus was not recorded by Olsson and Harbison (1953).

FIGURED SPECIMENS.—USNM 203962 from USGS 25368 (Plate 18: figures 3, 4), USNM 203963 from USGS 25364 (Plate 18: figures 5, 6), and USNM 203964 from USGS 25364 (Plate 18: figures 7, 8).

OCCURRENCE.—This species is recorded from sections 1 (E), 3 (D, E), and 4 (D). It is common in section 5, units B, C, and D and rare in unit E.

TYPE LOCALITY.—“Inhabits the coast of the United States” (Say, 1822:309).

#### *Spisula solidissima* (Dillwyn)

PLATE 18: FIGURES 1, 2

*Maetra solidissima* Dillwyn, 1817:140.

*Spisula solidissima* (Dillwyn).—Abbot, 1974:489.

DISCUSSION.—This species was not recorded by Gardner (1944) or by Olsson and Harbison (1953).

FIGURED SPECIMEN.—USNM 203965 from USGS 25364.

OCCURRENCE.—This species is recorded from section 4, unit D.

TYPE LOCALITY.—“Inhabits the coasts of North America” (Dillwyn, 1817:140).

### Genus *Raeta* Gray, 1853

#### *Raeta plicatella* (Lamarck)

PLATE 19: FIGURES 1–3

*Lutraria plicatella* Lamarck, 1818:470.

*Lutraria canaliculata* Say, 1822:310.

*Raeta plicatella* (Lamarck).—Olsson and Petit, 1964:533–534.

DISCUSSION.—Olsson and Harbison (1953:143) recorded a single poorly preserved specimen from St. Petersburg, Florida, and mentioned that this appears to be the first record of the species from beds older than Pleistocene. However, their material from St. Petersburg is a mixture of Pliocene and Pleistocene.

FIGURED SPECIMEN.—USNM 203966 from USGS 25363.

OCCURRENCE.—This species is rare at sections 4 (B, D) and 5 (B, C).

TYPE LOCALITY.—“Habite . . . Probablement l’Océan indien. Mus. n.” (probably West Indies) (Lamarck, 1818:470).

### Genus *Ensis* Schumacher, 1817

#### *Ensis directus* (Conrad)

PLATE 19: FIGURES 6, 7

*Solen directus* Conrad, 1844:325.

*Ensis directus* (Conrad).—Abbott, 1974:494, fig. 5627.

DISCUSSION.—The genus was not recorded by Olsson and Harbison (1953) or by Gardner (1944).

FIGURED SPECIMEN.—USNM 203967 from USGS 25364.

OCCURRENCE.—This species is common in section 5, units B, C, and E and rare in unit D. It occurs in sections 1 (E), 2 (B), 3 (D, E), and 4 (B, D, E).

TYPE LOCALITY.—Neuse River below New Bern, North Carolina (James City Formation?).

### Genus *Tellina* Linnaeus, 1758

#### *Tellina agilis* Stimpson

PLATE 19: FIGURES 8–10

*Tellina agilis* Stimpson, 1858:125.

DISCUSSION.—This species was not recorded by Olsson and Harbison (1953) or by Gardner (1944). In certain features, the specimens at Lee Creek are similar to *Tellina tenella* Verrill, 1874, in that the ventral margin is quite rounded and the posterior is blunt. However, specimens lack a rather concave anterior dorsal margin.

FIGURED SPECIMENS.—USNM 203968 from USGS 25367 (Plate 19: figure 8), USNM 203969 from USGS 25367 (Plate 19: figure 9), and USNM 203970 from USGS 25367 (Plate 19: figure 10).

OCCURRENCE.—This species is abundant at section 5, units B, C, D, and E. It is also recorded from sections 1 (E), 2 (B, D), 3 (D, E), 4 (D, E), and 6 (C).

TYPE LOCALITY.—Stimpson (1858) proposed that the name *T. agilis* replace the preoccupied name of *T. tenera*

Say, 1822. Say’s (1822:303) locality for this species is Great Egg Harbor, New Jersey (Holocene).

### Genus *Macoma* Leach, 1819

#### *Macoma holmesii* Dall

PLATE 20: FIGURES 1–4

*Macoma* (*Psammacoma*?) *holmesii* Dall, 1900:1054, pl. 47: fig. 4.

DISCUSSION.—This species was not recorded by Gardner (1944) or by Olsson and Harbison (1953).

FIGURED SPECIMENS.—USNM 203971 from USGS 25648 (Plate 20: figures 1, 2), and USNM 203972 from USGS 25648 (Plate 20: figures 3, 4).

OCCURRENCE.—This species is found at section 2 (D) at Lee Creek Mine.

TYPE LOCALITY.—“Miocene of the Natural Well, Duplin County, North Carolina; Burns” (Dall, 1900:1054) (Yorktown Formation).

### Genus *Donax* Linnaeus, 1758

#### *Donax fossor* Say

PLATE 20: FIGURES 7, 8

*Donax fossor* Say, 1822:306.—Gardner, 1944:106–107, pl. 23: figs. 1, 2, 10, 11.—Olsson and Harbison, 1953:138–139.

FIGURED SPECIMEN.—USNM 203973 from USGS 25369.

OCCURRENCE.—This species is rare at sections 4, unit B, and 5, units B, C, and E.

TYPE LOCALITY.—“Inhabits the coasts of New Jersey and Maryland” (Say, 1822:306). (Holocene).

### Genus *Semele* Schumacher, 1817

#### *Semele bellastrata* (Conrad)

PLATE 20: FIGURES 5, 6

*Amphidesma bellastrata* Conrad, 1837:239, pl. 20: fig. 4

*Semele bellastrata* (Conrad).—Gardner, 1944:102, pl. 17: figs. 27, 28, 32, 33.—Olsson and Harbison, 1953:133–134.

FIGURED SPECIMEN.—USNM 203974 from USGS 25360.

OCCURRENCE.—This species is recorded from sections 2 (B, D), 3 (D, E), 4 (B), and 6 (C).

TYPE LOCALITY.—“Inhabits Mobile Point, Alabama, occurs sparingly in the newer Pliocene marl, near New Bern, North Carolina” (Conrad, 1837:239).

**Genus *Abra* Lamarck, 1818*****Abra aequalis* (Say)**

PLATE 20: FIGURES 9–11

*Amphidesma aequalis* Say, 1822:307; 1830, unnumbered page facing pl. 28, pl. 28: unnumbered lateral figures.

*Abra aequalis* (Say).—Gardner, 1944:104, pl. 17: figs. 12–15.—Olsson and Harbison, 1953:135, pl. 14: fig. 5 [fig. 5 mislabeled "*Tellina* (*Acorylus*) *suberis* Dall"].

*Tellina* (*Acorylus*) *suberis* Dall.—Keen, 1969, fig. E104–7b [only].

DISCUSSION.—This species was recorded by Gardner (1944:104) from Suffolk, Virginia, many localities in the North Carolina Yorktown Formation, the "Duplin" Formation, and the Waccamaw Formation. She also lists it from the Choctawhatchee Formation in Florida and from the Holocene, usually in shallow water. Keen (1969) uncritically copied the erroneously labelled figure of a specimen of *Abra aequalis* of Olsson and Harbison (1953, pl. 14: fig. 5).

FIGURED SPECIMENS.—USNM 203975 from USGS 25369 (Plate 20: figure 9), and USNM 203976 from USGS 25369 (Plate 20: figures 10, 11).

OCCURRENCE.—This species is common in section 5, units B, D, E and rare in unit C. It is recorded at sections 1 (E), 2 (B), and 4 (D, E).

TYPE LOCALITY.—"Inhabits the southern coast" (Say, 1822:307) (Holocene).

**Genus *Cumingia* Sowerby, 1833*****Cumingia tellinoides* (Conrad)**

PLATE 21: FIGURES 1–6

*Mactra tellinoides* Conrad, 1831:258, pl. 11: figs. 2, 3.

*Cumingia tellinoides* (Conrad).—Conrad, 1838:28, pl. 15: fig. 4.

DISCUSSION.—The species was not recorded by Olsson and Harbison (1953) or by Gardner (1944). Olsson and Harbison (1953:136) recorded *Cumingia amydra* Olsson and Harbison, 1953, which differs from *C. tellinoides* by being more rounded, undistorted, and with closer, more regular sculpture.

FIGURED SPECIMENS.—USNM 203977 from USGS 25369 (Plate 21: figures 1, 3, 5), and USNM 203978 from USGS 25369 (Plate 21: figures 2, 4, 6).

OCCURRENCE.—This species is common in section 5, unit C and rare in units B, D, and E. It is recorded from 1 (E), 3 (D, E), and 4 (E).

TYPE LOCALITY.—"Inhabits the northern coast" (Conrad, 1831:258) (Holocene).

**Genus *Tagelus* Gray, 1847*****Tagelus plebeius carolinensis* (Conrad), new combination**

PLATE 21: FIGURES 10, 11

*Siliquaria carolinensis* Conrad, 1863a:571.

*Tagelus gibbus carolinensis* (Conrad).—Gardner, 1944:108, pl. 22: fig. 5.

DISCUSSION.—Gardner (1944:108) listed this species only from the type locality. Olsson and Harbison (1953:138) recorded only the species *Tagelus divisus* (Spengler, 1794). This form is shorter and stouter and with a shorter pallial sinus than that possessed by *Tagelus plebeius* (Lightfoot, 1786) (as noted by Dall, 1900:593). *Tagelus gibbus* (Spengler, 1794) is a synonym of *T. plebeius*.

FIGURED SPECIMENS.—USNM 203979 from USGS 25360.

OCCURRENCE.—This taxon is rare at sections 2 (D) and 4 (E).

TYPE LOCALITY.—Wilmington, New Hanover County, North Carolina (Waccamaw Formation).

**Genus *Corbicula* Mergle von Mühlfeld, 1811*****Corbicula densata* (Conrad)**

PLATE 21: FIGURES 7–9

*Cyrena densata* Conrad, 1844:324; 1845:68, pl. 39: fig. 2.

*Corbicula densata* (Conrad).—Gardner, 1944:65, pl. 15: figs. 3, 4, 7, 8.

DISCUSSION.—Gardner (1944:65) noted that this species is the only representative of this genus in the east coast Tertiary. Holocene species are confined exclusively to rivers and lakes of the Eastern Hemisphere. This species is recorded from the Yorktown and the Waccamaw formations in North Carolina. It was not recorded by Olsson and Harbison (1953).

Specimens of this species at Lee Creek are well preserved and often found articulated. Since early Pleistocene time, this group has drastically changed its geographic range.

FIGURED SPECIMEN.—USNM 203980 from USGS 25364.

OCCURRENCE.—This species is common at section 5, units D and E. It is recorded at section 4, units D and E.

TYPE LOCALITY.—"Locality, vicinity of Petersburg, Virginia; Mr. Tuomey; rare." (Conrad, 1844:324).

**Genus *Gouldia* C.B. Adams, 1847*****Gouldia metastriatum* (Conrad)**

PLATE 22: FIGURES 4–5

*Cytherea metastrata* Conrad, 1838:14, pl. 8: fig. 5.

*Gouldia metastriatum* (Conrad).—Olsson and Harbison, 1953:118, pl. 13: fig. 11.

**DISCUSSION.**—This species was not discussed by Gardner (1944). Olsson and Harbison (1953:118) recorded a smaller and less convex species, *Gouldia floridana* Olsson and Harbison, 1953. Olsson and Harbison (1953, pl. 13: fig. 8) figured *Gouldia cerina* C.B. Adams, *G. floridana*, and *G. metastriatum* (Conrad's type specimen).

**FIGURED SPECIMEN.**—USNM 203981 from USGS 25368.

**OCCURRENCE.**—This species is abundant at section 5, units B, C, D, and E. It is recorded from 1 (E), 2 (B, D, E), 3 (D, E), 4 (B, D, E), and 6 (C).

**TYPE LOCALITY.**—“Suffolk, Virginia . . . occurs . . . near New Bern, North Carolina and recent Gulf of Mexico near Mobile Point” (Conrad, 1838:14).

### Genus *Transennella* Dall, 1883

#### *Transennella stimpsoni* Dall

PLATE 22: FIGURES 1–3

*Transennella stimpsoni* Dall, 1902:367, 369.

**DISCUSSION.**—This species is not recorded by Gardner (1944) or by Olsson and Harbison (1953).

**FIGURED SPECIMENS.**—USNM 203982 from USGS 25367 (Plate 22: figures 1, 2), and USNM 203983 from USGS 25367 (Plate 22: figure 3).

**OCCURRENCE.**—This species is abundant at section 5, units B, C, and D. It occurs also at sections 2 (B, D) and 3 (D, E).

**TYPE LOCALITY.**—Egmont Key, Florida (Holocene).

### Genus *Pitar* Römer, 1857

#### *Pitar chioneformis* (Gardner), new combination

PLATE 22: FIGURES 6–8

*Callocardia* (*Agriopoma*) *chioneformis* Gardner, 1944:126, pl. 19: figs. 7, 8.

**DISCUSSION.**—This species was not recorded by Olsson and Harbison (1953). Gardner (1944:126–127) recorded it only from the Waccamaw Formation at Wilmington, North Carolina. The lunule of this species is wider and less elongate than that of *Pitar sayana* (Conrad, 1833), and the concentric wrinkling of the external surface is somewhat stronger.

**FIGURED SPECIMENS.**—USNM 203984 from USGS 25370 (Plate 22: figure 6), and USNM 203985 from USGS 25370 (Plate 22: figures 7, 8; specimen shows extensive boring by Bryozoa).

**OCCURRENCE.**—This species is rare at section 5, units B, C, and E. Also, it is recorded at 1 (E), 4 (D), and 6 (C).

**TYPE LOCALITY.**—Wilmington, North Carolina (Waccamaw Formation).

### Genus *Macrocallista* Meek, 1876

#### *Macrocallista greeni*, new species

PLATE 23: FIGURES 1, 2

*Macrocallista reposta* (Conrad).—Gardner, 1944:123 [in part].

**DIAGNOSIS.**—Shell thin, not thickened within, elongate-ovate in outline, sharply rounded anteriorly and posteriorly, moderately larger in size (more than 70 mm), and of low convexity. Exterior porcellanous, smooth, faint growth lines evident over entire surface. Central part of shell below umbo is a very convex area of shell and is bordered by a distinctive flattish part between this convex area and the sharply terminate slightly arched posterodorsal margin. Ventral margin gently curved. Pallial sinus impressed, broad, broadly rounded, directed horizontally. Anterior laterals and three cardinals present in each valve, posterior cardinals slender and elongated.

**DISCUSSION.**—The posteroventrally directed flattish area on the exterior of the shell is a distinctive feature of this species. The highly convex area in the central part of the valve is a unique feature of this species. *Macrocallista reposta* (Conrad, 1834), named from Suffolk, Virginia, is a species with a much more rounded, less elongate outline. *Macrocallista nimbosa* (Solander) is a Holocene species with a much more produced posterior, a much less convex shell, and the ventral margin is somewhat straighter than that of *M. greeni*. In similar-sized specimens, those of *M. nimbosa* have much weaker dentition. Specimens from Walker's Bluff, which have been recorded as *M. reposta*, are *M. greeni* (see Gardner, 1944:123). This species is named in honor of John B. Green, Jr.

**FIGURED SPECIMEN.**—Holotype, UNSM 203986 from USGS 25362.

**OCCURRENCE.**—This species is rare at section 5, units B, C, D, and E. It occurs at sections 3 (D, E) and 6 (C).

**TYPE LOCALITY.**—Lee Creek Mine, Beaufort County, North Carolina, USGS 25362, section 3, unit D.

### Genus *Dosinia* Scopoli, 1777

#### *Dosinia* sp.

**DISCUSSION.**—Only small fragments of a species belonging to this genus were recovered.

**OCCURRENCE.**—This taxon is found only rarely at section 5, unit E.

**Genus *Gemma* Deshayes, 1853*****Gemma magna majorina* Gardner**

PLATE 22: FIGURES 9, 10

*Gemma magna majorina* Gardner, 1944:136–137, pl. 19: figs. 19, 27.

DISCUSSION.—Gardner (1944:137) noted that this subspecies is larger than *Gemma magna*, sensu stricto, and more compressed, less trigonal, with more rounded margins, a relatively thinner shell, and a less robust hinge. She recorded it from several localities including one that is ½ to ¾ mi (0.8 to 1.20 km) above Edenhouse on the Chowan River, North Carolina.

Olsson and Harbison (1953:119) recorded only *Gemma magna floridana* Olsson and Harbison, 1953, which they said differs in being smaller and more equilateral than *Gemma magna* Dall (1903), the type locality of which is Natural Well, North Carolina.

FIGURED SPECIMEN.—USNM 203987 from USGS 25368.

OCCURRENCE.—This taxon is abundant at section 5, units D and E, and rare in unit C. It is also recorded from sections 1 (E) and 4 (D, E).

TYPE LOCALITY.—1 mile (1.6 km) east of Lizzie Greene County, North Carolina (Yorktown Formation).

**Genus *Chione* Megerle von Mühlfeld, 1811*****Chione grus* (Holmes)**

PLATE 23: FIGURES 3–5

*Tapes grus* Holmes, 1858:37, pl. 7: fig. 5.*Chione* (*Chione*) *grus* (Holmes).—Gardner, 1944:128, pl. 19: figs. 12, 13, 20, 21.*Chione* (*Timoclea*) *grus* (Holmes).—Olsson and Harbison, 1953:113.

FIGURED SPECIMENS.—USNM 203988 from USGS 25357 (Plate 23: figures 3, 4) and USNM 203989 from USGS 25357 (Plate 23: figure 5).

OCCURRENCE.—This species is rare at sections 1 (E) and 2 (E).

TYPE LOCALITY.—Simmons Bluff, South Carolina (Pleistocene).

***Chione cribraria* (Conrad)**

PLATE 23: FIGURES 7, 8

*Venus cribraria* Conrad, 1843a:310–311.*Chione cribraria* (Conrad).—Dall, 1903:1292.

DISCUSSION.—Only one specimen was found in our collections. It differs from late Pliocene specimens collected at Wilmington, North Carolina, in having a straighter posterodorsal margin, a less robust hinge area, and in being more

pointed posteriorly. No specimens of this species were observed in collections from the Croatan Formation immediately below New Bern, North Carolina.

Gardner (1944:128) recorded *C. cribraria* from Yorktown localities in Virginia and North Carolina, from the “Duplin” and Waccamaw formations in North Carolina, and from the Waccamaw Formation South Carolina. Gardner stated that *cribraria* is heavier than *C. cortinaria* (Rogers), a Yorktown species in which the crenulations of the inner margins of the valves are finer and shallower. *C. cortinaria* also has concentric lamellae more crowded, less strongly fluted transversely, and free edges more strongly recurved and dorsally appressed. *Chione morsitans* (Olsson and Harbison, 1953:112) is a larger, heavier species than *cribraria*. The Holocene species *Chione intapupurea* (Conrad, 1849), which lives from North Carolina to Texas, West Indies, and Brazil, is more ventrally produced in outline than *cribraria*.

FIGURED SPECIMEN.—USNM 204130 from USGS 25648.

OCCURRENCE.—Recorded from float.

TYPE LOCALITY.—“Wilmington, N. C.; Neuse River below New Bern, N. C.” (Conrad, 1843a:311).

**Genus *Mercenaria* Schumacher, 1817*****Mercenaria permagna* (Conrad), new combination**

PLATE 24: FIGURES 2–5

*Venus permagna* Conrad, 1838:8–9; 1844:324–325.*Mercenaria carolinensis* Conrad, 1873:20.*Venus* (*Mercenaria*) *campechiensis carolinensis* Conrad.—Gardner, 1944:132, pl. 20: figs. 1, 2.

DISCUSSION.—This species is not recorded by Olsson and Harbison (1953). Gardner (1944) recorded *M. carolinensis* from several North Carolina Waccamaw localities. Mansfield (1932:132) reported *M. carolinensis* from the *Cancelaria* zone of the Choctawhatchee Formation.

*Mercenaria rileyi* (Conrad, 1838) was named for specimens in the upper part of the Yorktown Formation at Yorktown, Virginia (the lower part lacks this form). The type specimens are small and ovate. This particularly small ovate morphologic form is restricted to the sandier part of the formation. Where the sediment becomes clayey, the specimens are very large; we think that these larger specimens are probably the same species living in a more favorable environment.

Gardner (1944) stated that by a decrease in size, weight, relative altitude, and prominence of the umbones, *M. carolinensis* merges gradually into *Mercenaria rileyi*, its probable ancestor.

FIGURED SPECIMENS.—USNM 203990 from USGS 25367 (Plate 24: figures 2, 3, 5), and USNM 203991 from USGS 25367 (Plate 24: figure 4).

OCCURRENCE.—This species is common at section 5, units



C and D, and rare in units B and E. It also occurs in sections 1 (E), 2 (D), 3 (D, E), 4 (D, E), and 6 (C).

TYPE LOCALITY.—New Bern, North Carolina (probably James City Formation).

***Mercenaria mercenaria* (Linnaeus)**

PLATE 23: FIGURE 6; PLATE 24: FIGURE 1

*Venus mercenaria* Linnaeus, 1758:686, no. 99.

*Mercenaria mercenaria*.—Schumacher, 1817:135.

DISCUSSION.—Gardner (1944:130) discussed only a subspecies, which she recorded from Yorktown (Virginia) and from Claremont Wharf (upper bed, Virginia), and from the Pleistocene and Holocene. Olsson and Harbison (1953:108) recorded a possible subspecies of *M. mercenaria* from St. Petersburg, Florida; their material is represented only by juveniles.

FIGURED SPECIMEN.—USNM 203992, USGS 25364.

OCCURRENCE.—This species is recorded from section 4, unit D.

TYPE LOCALITY.—Coast of Delaware (as amended by Dodge, 1942:97–98) (Holocene).

**Genus *Petricola* Lamarck, 1801**

***Petricola pectorosa* (Conrad), new combination**

PLATE 25: FIGURES 1–3

*Saxicava pectorosa* Conrad, 1834:130.

DISCUSSION.—This species was not recorded by Gardner (1944) or by Olsson and Harbison (1953).

FIGURED SPECIMENS.—USNM 203993 from USGS 25367 (Plate 25: figures 1, 3) and USNM 203994 from USGS 25367 (Plate 25: figure 2).

OCCURRENCE.—This species is rare at section 5, unit C.

TYPE LOCALITY.—Suffolk, Virginia (Yorktown Formation).

***Petricola pholadiformis* Lamarck**

PLATE 24: FIGURES 6, 7

*Petricola pholadiformis* Lamarck, 1818:505.

*Petricola* (*Petricolaria*) *pholadiformis* Lamarck.—Gardner, 1944:117–118.

DISCUSSION.—This species was not recorded by Olsson and Harbison (1953). Gardner (1944) recorded this species from several localities of the Waccamaw Formation in North Carolina, from the Yorktown Formation at Yorktown, Virginia, and from the Pleistocene and Holocene.

FIGURED SPECIMEN.—USNM 204131 from USGS 25648.

OCCURRENCE.—Recorded as float.

TYPE LOCALITY.—None given with original description.

**Genus *Mya* Linnaeus, 1758**

***Mya arenaria* Linnaeus**

PLATE 25: FIGURES 4, 5

*Mya arenaria* Linnaeus, 1758:670, no. 17.—Gardner, 1944:138–139, pl. 22: fig. 8.

*Mya* (*Arenomya*) *arenaria* Linnaeus.—MacNeil, 1965:33–35, pl. 5: figs. 2–12; pl. 6: figs. 1–15, 17, 18.

DISCUSSION.—Gardner (1944) recorded this species from the Yorktown Formation at Yorktown, from a few localities of the Waccamaw Formation in North Carolina, and from the Pleistocene and Holocene. Olsson and Harbison (1953) did not record this species.

FIGURED SPECIMEN.—USNM 203995 from USGS 25364.

OCCURRENCE.—This species is rare at sections 4 (D, E) and 5 (D).

TYPE LOCALITY.—“In O. Europae septentrionalis sub arena” (Linnaeus, 1758:670) (northern Europe).

**Genus *Paramya* Conrad, 1863**

***Paramya subovata* (Conrad)**

PLATE 25: FIGURES 6–8

*Myalina subovata* Conrad, 1845:65, pl. 36: fig. 4.

*Paramya* (*Myalina*) *subovata* (Conrad).—Conrad, 1863a:572.

DISCUSSION.—This genus was recorded neither by Olsson and Harbison (1953) nor by Gardner (1944). This lineage could probably be subdivided. The group ranges from Calvert-age to the Holocene. This lineage can be best treated in a separate study.

FIGURED SPECIMENS.—USNM 203996 from USGS 25367 (Plate 25: figures 6, 7) and USNM 203997 from USGS 25367 (Plate 25: figure 8).

OCCURRENCE.—This species is commonly found at section 5, unit C and rarely in units B and D. It is also recorded at sections 2 (B) and 3 (D, E).

TYPE LOCALITY.—“Virginia, I know not the particular locality” (Conrad, 1845:65).

**Genus *Sphenia* Turton, 1822**

***Sphenia dubia* (Lea)**

PLATE 26: FIGURES 1, 2

*Panopaea dubia* Lea, 1843a:2.

*Sphenia dubia* (Lea).—Glenn, 1904:283, pl. 68: figs. 3–6.

DISCUSSION.—The type specimen of this species is from the Yorktown Formation at Petersburg, Virginia. Individuals of this species have not been observed in USNM collections from this locality. We do not have the type specimen, and the original figure of the specimen is poor.

Glenn (1904:283–284, pl. 68: figs. 3–6) figured another species than Lea's (Glenn's material was from the much older Choptank Formation of Maryland). Compared with Glenn's material, our specimens have a much more ventrally directed spoon as opposed to the inwardly directed spoon of the Choptank specimens. Our spoon is smooth and regular, whereas the Choptank one has a prominence on one-half of the spoon. In addition, the exterior sculpture on the Lee Creek specimens is much more pronounced. This genus was not recorded by Gardner (1944).

Olsson and Harbison (1953:150) recorded *Sphenia attenuata* Dall (1898:860, pl. 35: fig. 9, type locality, Pliocene of the Caloosahatchee River, Florida) from St. Petersburg, Florida. This species is very different from the one at Lee Creek in that it has a very attenuated posterior end that terminates with a rounded outline. In addition, our species is proportionally longer anteriorly.

FIGURED SPECIMEN.—USNM 203998 from USGS 25369.

OCCURRENCE.—This species is found at section 5, unit E.

TYPE LOCALITY.—Petersburg, Virginia (Yorktown Formation).

### Genus *Caryocorbula* Gardner, 1926

#### *Caryocorbula auroraensis*, new name

PLATE 26: FIGURES 7, 8; PLATE 27: FIGURES 1–3

*Corbula* (*Caryocorbula*) *conradi* Gardner, 1944:139–140, pl. 23: figs. 27–28 [not *Corbula conradi* Dall, 1898:842].

DISCUSSION.—Specimens from Lee Creek that apparently belong to this species are quite variable with respect to shape and to sculpture of the exterior. In this respect, the members of this species show variation seen in the Holocene species *Caryocorbula dietziana* C.B. Adams, which is also a large and heavy-valved species. *Caryocorbula conradi retusa* (Gardner) probably does not merit subspecific differentiation, and the differences in exterior sculpture of her species and subspecies (Gardner, 1944, pl. 23: figures 27–28, 33–34) are considered by us to be typical variation within this species. Our figures of this species illustrate some of the variations in external sculpture and shell outline that may be seen in the specimens from Lee Creek. The various forms are all connected by a gradational series of specimens. This species was not recorded by Olsson and Harbison (1953).

FIGURED SPECIMENS.—USNM 204001 from USGS 25368 (Plate 26: figures 7, 8), USNM 204002 from USGS 25368 (Plate 27: figures 1, 2), and USNM 204003 from

USGS 25368 (Plate 27: figure 3).

OCCURRENCE.—This species is common at section 5, unit E, and rare in units B, C, and D. It also occurs in sections 1 (E), 2 (B, D, E), 3 (D, E), 4 (B, D, E), and 6 (C).

TYPE LOCALITY.—15½ miles (25 km) above Bells Bridge on the Tar River, Edgecombe County, North Carolina (Yorktown Formation) (Gardner, 1944:139–140).

### *Caryocorbula contracta* (Say), new combination

PLATE 26: FIGURES 3–6

*Corbula contracta* Say, 1822:312.

DISCUSSION.—This species is characterized by its rather distinctively compressed shape and rather fine growth lines, which are expressed in a fairly similar manner in different individuals. This constancy of shell outline and nature of exterior sculpture can also be seen in Holocene specimens in the USNM collections of this species. This species was not discussed by Olsson and Harbison (1953) or by Gardner (1944).

FIGURED SPECIMENS.—USNM 203999 from USGS 25366 (Plate 26: figures 3, 6) and USNM 204000 from USGS 25366 (Plate 26: figures 4, 5).

OCCURRENCE.—This species is abundant at section 5 (B, C, D, E).

TYPE LOCALITY.—“Inhabits the coasts of Georgia and East Florida” (Say, 1822:312) (Holocene).

### Genus *Gastrochaena* Spengler, 1783

#### *Gastrochaena hians* (Gmelin)

PLATE 27: FIGURES 4–6

*Pholas hians* Gmelin, 1791:3217.

*Gastrochaena hians* (Gmelin).—Abbott, 1974:540, fig. 6015.

*Gastrochaena cuneiformis* Spengler.—Dall, 1898:825.—Olsson and Harbison, 1953:151.

DISCUSSION.—This species was not recorded by Gardner (1944). Abbott (1954:460) stated that this species had erroneously been called *G. cuneiformis* Spengler, 1788, an Indo-Pacific species.

FIGURED SPECIMEN.—USNM 204004 from USGS 25369.

OCCURRENCE.—This species occurs in section 5, unit E.

TYPE LOCALITY.—“Habitat ad insulas Americae mediae oppositas” (Gmelin, 1791:3217) (Caribbean area).

### Genus *Panopea* Ménéard, 1807

#### *Panopea floridana* Heilprin

PLATE 28: FIGURES 1, 2

*Panopaea floridana* Heilprin, 1886:91; 1887:91, pl. 10: fig. 21.

*Panopaea navicula* Heilprin, 1886:91–92; 1887:91–92, pl. 10: fig. 22.

*Panopaea menardi* Heilprin, 1886:90–91; 1887:90–91, pl. 9: fig. 19 [not *Panopaea menardi* of Deshayes].  
*Panopaea floridana* Heilprin.—Olsson and Harbison, 1953:151 [emendation].

DISCUSSION.—This species was not discussed by Gardner (1944). Dall (1898:831) discussed the different names used by Heilprin.

FIGURED SPECIMEN.—USNM 204005 from USGS 25362.

OCCURRENCE.—This species occurs in section 3, units D and E.

TYPE LOCALITY.—None given (probably Caloosahatchee Marl, Florida).

### Genus *Cyrtopleura* Tryon, 1862

#### *Cyrtopleura* sp.

PLATE 27: FIGURE 9

DISCUSSION.—Only a few fragments of this species were obtained, and these were not considered sufficient for specific determination.

FIGURED SPECIMEN.—USNM 204006 from USGS 25339.

OCCURRENCE.—This species is recorded from section 5, units B and E.

### Genus *Pandora* Bruguière, 1797

#### *Pandora tuomeyi* Gardner and Aldrich

PLATE 27: FIGURES 7, 8

*Pandora (Clidiophora) tuomeyi* Gardner and Aldrich, 1919:45, pl. 4: figs. 8, 10, 13.—Gardner, 1944:48–49, pl. 10: fig. 27, pl. 11: figs. 9, 10.

DISCUSSION.—Our figured specimen is worn and not well preserved. It differs from the type specimen of this species in being more elongate and in having a straighter dorsal margin. Our specimen may be intermediate between *Pandora tuomeyi* and *Pandora trilineata* Say, 1822. Our specimen is not as elongate as *P. trilineata* and has a slightly different outline.

Gardner (1944:49) recorded this species from Suffolk, Virginia, from Tar Ferry, North Carolina, from Walkers Bluff, North Carolina and from the “Duplin” Formation in South Carolina. Olsson and Harbison (1953:65) recorded only *Pandora* sp. cf. *P. crassidens* Conrad, 1838. Gardner (1944:50) indicated that she might consider *tuomeyi* to be a subspecies of *P. crassidens*. *Pandora crassidens* Conrad (1838:2; type locality James River near Smithfield, Virginia, Yorktown Formation) is a distinctly separate species from *P. tuomeyi*, as it is much larger and less elongate. Gardner’s figures (1944, pl. 10: figs. 17, 18) of *Pandora crassidens* are not of this species, because Glenn (1904:357) incorrectly identified this species as *P. tuomeyi* from the St. Marys Formation of Maryland, and Gardner used Glenn’s figures.

FIGURED SPECIMEN.—USNM 204007 from USGS 25367.

OCCURRENCE.—This species is rare at sections 4 (B, D) and 5 (B, C, D, E).

TYPE LOCALITY.—Walkers Bluff on the Cape Fear River, Bladen County, North Carolina (Waccamaw Formation).

### Genus *Cochlodesma* Couthouy, 1839

#### *Cochlodesma emmonsii*, new species

PLATE 28: FIGURES 3–6

DIAGNOSIS.—Oval but with anterior end somewhat compressed, fragile, smooth exterior, umbones opisthogyrate, hinge edentulous; chondrophore large, directed ventrally, chondrophore buttressed anteriorly, inequivalve, the right valve being somewhat flat, the left valve quite inflated, pallial sinus broad, shallow.

DISCUSSION.—This species differs from *Cochlodesma leanum* (Conrad) in nature of outline and in having a very inflated left valve.

FIGURED SPECIMEN.—USNM 204008 from USGS 25363 (Plate 28: figures 3, 4) and USNM 204009 from USGS 25363, holotype, length 27.0 mm (Plate 28: figures 5, 6).

OCCURRENCE.—This species is recorded from sections 1 (E) and 4 (B).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25363, section 4, unit B.

### Genus *Thracia* Sowerby, 1823

#### *Thracia brioni*, new species

PLATE 29: FIGURES 7–10

*Thracia transversa* Lea.—Gardner, 1944:43–44, pl. 10: figs. 8, 9 [in part].

DIAGNOSIS.—Shell small (usually 9 mm or less in length), moderately convex, umbones situated at the posterior third of the specimen, posterior rather squarely truncate, anterior rounded, anterodorsal margin rather straight and of low slope. Posterodorsal margin sloping very steeply and much shorter than anterodorsal. Exterior sculpture of regular, low, closely spaced concentric ridges with very narrow interspaces, prominent sulcus on the posterior. Interior of shell with impressed radiating channels, which cross the pallial sinus. Muscle scars impressed, ligament short and marginal, hinge edentulous.

DISCUSSION.—This genus was not recorded by Olsson and Harbison (1953). Richards (1968:91) indicated that Lea’s type specimen of *Thracia transversa* at the Philadelphia Academy is numbered ANSP 1585. Gardner (1944:43–44, pl. 10: figs. 5, 10) figured this numbered specimen but failed to mention this as the type specimen of *Thracia transversa* (Lea, 1843). Two of Gardner’s other figures (1944, pl. 10: figs. 8, 9) agree well with our specimens and

(based on Gardner's figure) differ from that of Lea's species in outline. Lea's species is much less elongate and much less produced posteriorly, and the dorsal margin slopes away from the umbo at steeper angles. In addition, the specimen of Lea has a process (lacking in our specimens) projecting anteriorly from the hinge area.

**FIGURED SPECIMENS.**—USNM 204010 from USGS 25367 (Plate 29: figures 7, 8) and holotype, USNM 204011 from USGS 25366 (Plate 29: figures 9, 10).

**OCCURRENCE.**—This species is rare at sections 2 (B) and 5 (B, C).

**TYPE LOCALITY.**—Lee Creek Mine, Beaufort County, North Carolina, USGS 25366, section 5, unit B.

## Genus *Verticordia* Sowerby, 1844

### *Verticordia emmonsii* Conrad

PLATE 29: FIGURES 1, 2

*Verticordia Emmonsii* Conrad, 1863c:289.

Not *Verticordia (Trigonalina) Emmonsii*.—Dall, 1903:1512–1513.

Not *Verticordia (Trigonalina) emmonsii*.—Gardner, 1944:50–51, pl. 10: fig. 14.

**DISCUSSION.**—Conrad named this species from a figured but unnamed specimen of Emmons (1858:286, fig. 206). It can be seen from Emmons' figure that Dall's description and Gardner's figured specimen are clearly of a different species. Emmons' figure has about 6 anterior ribs, whereas Dall described 9 anterior ribs. Our single specimen of this species agrees quite well with the figure of Emmons' and also shows the coarse granulation arranged in radial lines, which is evident on the figure of Emmons. *Verticordia emmonsii* is a much narrower, more elevated species than that indicated by Dall and by Gardner. Olsson and Harbison (1953:68) recorded this species but cited Dall and Gardner, and they did not provide a figure of their own. Because they cited Gardner's figure specifically, we assume that the specimen they have is *Verticordia lockei* Blackwelder and Ward, new species.

**FIGURED SPECIMEN.**—USNM 204014 from USGS 25366.

**OCCURRENCE.**—This species is rare at section 5, unit B.

**TYPE LOCALITY.**—North Carolina.

### *Verticordia lockei*, new species

PLATE 29: FIGURES 3–6

*Verticordia (Trigonalina) Emmonsii* Conrad.—Dall, 1903:1512–1513.

*Verticordia (Trigonalina) emmonsii*.—Gardner, 1944:50–51, pl. 10: fig. 14.

**DIAGNOSIS.**—From Gardner (1944:51):

Shell nacreous, small, compressed, subcircular, inequilateral. Umbones subcentral, the apices acute and prosogyrate. Margin directly in front of umbones deeply excavated by false lunule. Escutcheon absent. Anterior

end somewhat expanded. Posterior margin a parabolic curve from the umbones to the arcuate base. External sculpture conspicuous; nine subequal, strongly elevated, linear lirae radiating from the umbones to the anterior hemicycle in gentle curves, convex posteriorly; interradials no wider than the radials anteriorly, broadening to more than double their width toward the medial portion of the valve; a single isolated radial more feeble than any of those in front of it a little less than halfway between the median vertical and posterior margin; posterior submarginal radial of normal strength. Entire external surface covered with microscopic radial granulation; incrementals sometimes discernible on the summits of the costae. Ligament deeply inset, continued to the apices of the umbones. Right subumbonal cardinal moderately stout, tubercular; posterior dorsal margin sulcated almost to the base to receive the elongated lateral of the left valve; lunular margin of left valve thickened to function as a denticle; no left cardinal developed. Adductor impressions small. Pallial line conspicuously distant from margin; sinus very shallow. Margin strongly denticulated by external costae.

**DISCUSSION.**—Gardner's description is used here because it is excellent and complete. Gardner's figured specimen is much better preserved than our figured specimens. There is some question as to the exact locality for Gardner's specimen. For this reason we designate our specimen (USNM 204013) as the holotype. Our other specimen (Plate 29: figures 3, 4) we also refer to this species, although it has 11 anterior ribs. We lack enough material to be certain of the degree of external sculptural variation to be expected in this species.

See the discussion under *Verticordia emmonsii* Conrad as to why the specimens referred to *V. emmonsii* by Dall and by Gardner are not Conrad's species. Also in that discussion, we indicated that the specimens referred by Olsson and Harbison (1953:58) to *V. emmonsii* probably actually represent *V. lockei*.

**FIGURED SPECIMEN.**—(Plate 29: figures 3, 4) USNM 204012 from USGS 25368, and USNM 204013 from USGS 25367, holotype, length 6.8 mm (Plate 29: figures 5, 6).

**OCCURRENCE.**—This species is rare at section 5 (C, D).

**TYPE LOCALITY.**—Lee Creek Mine, Beaufort County, North Carolina, USGS 25367, section 5, unit C.

## Genus *Cadulus* Philippi, 1844

### *Cadulus quadridentatus* (Dall)

PLATE 29: FIGURES 11, 12

*Siphonodentalium quadridentatum* Dall, 1881:36.

*Cadulus incisus* Bush, 1885:471, pl. 45: fig. 20.

*Cadulus quadridentatus* (Dall).—Dall, 1889:428, pl. 27: fig. 5.

*Cadulus (Polyschides) quadridentatus* (Dall).—Olsson and Harbison, 1953:156–157.

**DISCUSSION.**—This genus was not recorded by Gardner (1948).

**FIGURED SPECIMENS.**—USNM 204015 from USGS 25366 (Plate 29: figure 11, SEM photograph) and USNM 204016 from USGS 25366 (Plate 29: figure 12, SEM seamed composite photograph).

OCCURRENCE.—This species is rare at section 5, unit B.  
 TYPE LOCALITY.—West Coast of Florida (Holocene).

### Genus *Diodora* Gray, 1821

#### *Diodora nucula* (Dall)

PLATE 30: FIGURES 1–3

*Fissuridea nucula* Dall, 1892:426, pl. 19: figs. 9, 12.

*Diodora nucula* (Dall).—Olsson and Harbison, 1953:359, pl. 63: figs. 9, 9a.

DISCUSSION.—This species was not recorded by Gardner (1948). Olsson and Harbison (1953) noted that this species is common at St. Petersburg.

FIGURED SPECIMENS.—USNM 204017 from USGS 25368 (Plate 30: figures 1, 2), and USNM 204018 from USGS 25368 (Plate 30: figure 3).

OCCURRENCE.—This species is rare at section 5, units B, C, and D, and is also recorded from sections 1 (E), 2 (B), 3 (D, E), and 4 (B).

TYPE LOCALITY.—“Newer Miocene of Duplin County, North Carolina, near the Natural Well, Burns; Pliocene of the Caloosahatchie, Dall” (Dall, 1892:426).

#### *Diodora auroraensis*, new species

PLATE 30: FIGURES 4, 5

DIAGNOSIS.—Shell medium sized, moderately elevated, egg-shaped in basal outline and tapering anteriorly with very slight concavities in middle part of lateral sides, foramen small and keyhole shaped, located anteriorly; sculpture of coarse radials with strong rounded ribs alternating with similar but less pronounced ribs and crossed by regularly spaced but well-separated elevated concentric threads, which form small beads and frills at intersections. Interior smooth, the margin arched laterally and denticulated in harmony with the radials, foramen callus spade-shaped, slightly indented behind. Shell shorter and more narrow in front of foramen than behind. Sculpture consists of 38 strong radials with smaller radials in between primary ones.

DISCUSSION.—This new species is distinctive and unlike any described species from the Coastal Plain.

FIGURED SPECIMEN.—USNM 204019 from USGS 25362, holotype, length 25.3 mm, width 17.0 mm, height 9.9 mm.

OCCURRENCE.—This species is recorded from sections 3 (D, E) and 4 (D).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25362, section 3, unit D.

#### *Diodora pamlicoensis*, new species

PLATE 30: FIGURES 6, 7

DIAGNOSIS.—Shell medium sized, elevated, egg-shaped in basal outline and tapering anteriorly; radial sculpture

with subequal rounded ribs (interspaces simple grooves) crossed by closely spaced, strong concentric threads giving the entire surface a finely sculptured, beaded appearance (about 20 radial ribs per centimeter); foramen semioval, small; interior smooth, the margin flat and finely denticulate, foramen callus spade-shaped and indented behind; shell shorter and more narrow in front of foramen than behind. Anterior and lateral slopes approximately uniform; posterior slope slightly convex.

DISCUSSION.—This species resembles *Fissuridea carolinensis* (Conrad, 1873) (Conrad, 1875:22, pl. 4: fig. 1), but the description given does not agree with our species. Conrad's specimen has compressed sides, and 39 prominent flat-sided ribs.

FIGURED SPECIMEN.—USNM 204020 from USGS 25362, holotype, length 30.2 mm, width 20.3 mm, height 9.1 mm.

OCCURRENCE.—This species is recorded from section 3 (D, E).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25362, section 3, unit D.

### Genus *Calliostoma* Swainson, 1840

#### *Calliostoma philanthropum pontoni* Mansfield

PLATE 30: FIGURES 8, 9

*Calliostoma philanthropum pontoni* Mansfield, 1930:129–130, pl. 19: figs. 7, 10.

DISCUSSION.—Gardner (1948:184) mentioned the *Calliostoma philanthropum* group as being distinct from *C. cheopsi* Gardner, 1948, by virtue of the posterior suture being overhung by the beaded peripheral keel of the preceding whorl. Gardner included a figure of Mansfield's holotype in her plate 26, figure 15. This species was not recorded by Olsson and Harbison (1953).

FIGURED SPECIMEN.—USNM 204021 from USGS 25370.

OCCURRENCE.—This species is rare at sections 3 (D, E), 5 (C, D), and 6 (C).

TYPE LOCALITY.—Harveys Creek, 0.5 mile (0.8 km) above abandoned mill, Leon County, Florida (Choctawhatchee Formation).

### Genus *Arene* H. and A. Adams, 1854

#### *Arene pergemma* (Gardner), new combination

PLATE 31: FIGURES 1–4

*Liotia* (*Arene*) *pergemma* Gardner, 1948:190, pl. 28: figs. 31, 36, 37, 40, 41.

DISCUSSION.—Olsson and Harbison (1953:348) noted that *Arene* is a distinct genus from *Liotia* Gray, 1847. Olsson and Harbison (1953:348–349) recorded *Arene tricarinata*

(Stearns, 1872) from their St. Petersburg, Florida, assemblages and recognized that this name is possibly a senior synonym of *Trochus gemma* Tuomey and Holmes (1856:118) (also see Warmke and Abbott, 1961:45–46). Gardner (1948:190–191) stated that *Liotia (Arene) pergemma* is separated from the coexistent *L. (Arene) gemma* by its larger size, more depressed, right-angled, discoidal outline, the more heavily annulated spirals, and the deeper sutural channel. The entire surface of this species is covered by delicate microscopic axial threads.

**FIGURED SPECIMENS.**—USNM 204022 from USGS 25366 (Plate 31: figures 1–3) and USNM 204023 from USGS 25366 (Plate 31 figure 4).

**OCCURRENCE.**—This species is abundant in section 5, units B, C, and D and is rare in unit E. It is also recorded from 2 (B), and 4 (B, D).

**TYPE LOCALITY.**—Cronly, Columbus County, North Carolina (Waccamaw Formation).

### Genus *Littorina* Férussac, 1822

#### *Littorina carolinensis* Conrad

PLATE 31: FIGURE 6

*Littorina carolinensis* Conrad, 1863a:567; 1875:23, pl. 4: fig. 11.

*Littorina carolinensis* var.—Conrad, 1875:23, pl. 4: fig. 10.

**DISCUSSION.**—*Littorina carolinensis* Conrad is more slender and higher spired than *Littorina irrorata* (Say, 1822). Following Gardner (1948:191–192, pl. 24: fig. 16), Olsson and Harbison (1953:328) put *L. carolinensis* in synonymy with *L. irrorata*, but we do not believe the population morphologic variation to be that great. *Littorina irrorata* lives between high and low tides and periodically is transported on plant debris out to open marine deposits.

**FIGURED SPECIMEN.**—USNM 204024 from USGS 25368.

**OCCURRENCE.**—This species is rare in section 5, unit D.

**TYPE LOCALITY.**—No locality given (placed under Miocene section in Conrad, 1875:23).

### Genus *Rissoa* Fréminville, 1814

#### *Rissoa geraea* Dall

PLATE 31: FIGURE 5

*Rissoa (Onoba) geraea* Dall, 1892:340, pl. 21: fig. 13a.

*Rissoa geraea* Dall.—Gardner, 1948:192, pl. 29: fig. 21.

**DISCUSSION.**—This genus is not recorded from the Atlantic Coast Holocene. Gardner (1948:192) noted that this genus has been reported from the Pliocene and Pleistocene of northern Italy. It is still living in the Mediterranean and Adriatic seas. This genus was not recorded by Olsson and

Harbison (1953). Gardner (1948) recorded this species from Neills Eddy Landing, North Carolina (Waccamaw Formation), the only other locality noted in addition to the type locality.

**FIGURED SPECIMEN.**—USNM 204025 from USGS 25367 (SEM photograph).

**OCCURRENCE.**—This species is rare in section 5, unit C.

**TYPE LOCALITY.**—Mrs. Purdys marl bed, Cape Fear River, North Carolina (Waccamaw Formation).

### Genus *Teinostoma* A. Adams, 1851

#### *Teinostoma goniogyrus* Pilsbry and McGinty

PLATE 31: FIGURES 7–9

*Rotella carinata* Lea, 1843a:10; 1846:263, pl. 36: fig. 78 [Petersburg, Va.] [not *Rotella carinata* d'Orbigny, 1842:62].

*Teinostoma carinatum* (Lea).—Mansfield, 1930:134, pl. 20: figs. 10–12?—Gardner, 1948:188, pl. 25: figs. 35, 36, 39.

*Teinostoma goniogyrus* Pilsbry and McGinty, 1945:3, pl. 1: fig. 8.

**DISCUSSION.**—*Teinostoma goniogyrus* is distinct from other species of *Teinostoma* found at Lee Creek in that it possesses a distinct keel on the periphery of the shell. Gardner (1948) figured a specimen from Suffolk, Virginia. Mansfield (1930:134) recorded this species from the *Ecphora* zone of the Choctawhatchee Formation of Florida. Pilsbry (1953:414–415) noted that although Mansfield (1930) distinguished between *T. carinatum* and *T. lenticulare* (Lea, 1843) in his text, Mansfield's figures of *T. carinatum* look more like *T. lenticulare*, a less depressed shell with the columella not distinctly marked off from the umbilical callus.

**FIGURED SPECIMEN.**—USNM 204026 from USGS 25359.

**OCCURRENCE.**—This species is recorded from section 2 (B).

**TYPE LOCALITY.**—Off Destin, Florida, in 18 to 20 fathoms (Holocene).

#### *Teinostoma smirkon* Gardner

PLATE 32: FIGURES 4–6

*Teinostoma smirkon* Gardner, 1948:187–188, pl. 25: figs. 18–20.

**DISCUSSION.**—This species is distinct from other species of *Teinostoma* found at Lee Creek in that it possesses axial ribs on the sides of the whorls. These ribs are best seen in Plate 32: figure 4 (apertural view).

Gardner (1948) recorded this species only from the type locality. This species was not recorded by Pilsbry (1953).

**FIGURED SPECIMEN.**—USNM 204028 from USGS 25367 (SEM photographs).

**OCCURRENCE.**—This species is rare in section 5, units B, C.

**TYPE LOCALITY.**—Neills Eddy Landing, Cape Fear River, 3 miles (4.8 km) north of Cronly, Columbus County, North Carolina (Waccamaw Formation).

***Teinostoma beaufortensis*, new species**

PLATE 32: FIGURES 1–3

**DIAGNOSIS.**—Shell of average size, low spired, whorls approximately three, rapidly increasing in size so that the earlier are partly concealed by later whorls; earlier whorls slightly elevated above the plane of coiling so as to be only slightly visible from the aperture view; whorls convex and rounded, suture closely appressed, periphery of final whorl broadly rounded, umbilicus partly covered by lip.

**DISCUSSION.**—The major difference covered between *Teinostoma beaufortensis* and *T. tectispira* Pilsbry, 1953, is in the more rounded aperture in *T. beaufortensis* and in the more elevated spire in *T. beaufortensis*.

**FIGURED SPECIMEN.**—USNM 204027 from USGS 25367, holotype, maximum diameter 1.6 mm (SEM photographs).

**OCCURRENCE.**—This species is rare in sections 4 (B) and 5 (C).

**TYPE LOCALITY.**—Lee Creek Mine, Beaufort County, North Carolina, USGS 25367, section 5, unit C.

***Teinostoma tectispira* Pilsbry**

PLATE 32: FIGURES 7–9

*Teinostoma tectispira* Pilsbry, 1953:417–418, pl. 50: figs. 6–6c.

**DISCUSSION.**—Pilsbry (1953) noted that in this species the last whorl is more depressed, the aperture more oblique, and the basal callus larger than in *T. umbilicatum* or *T. cryptospira*. Our figured specimen has a little rounder aperture than that figured by Pilsbry, but this may be due to age differences within the different specimens, the larger specimens having a more angular appearance.

**FIGURED SPECIMEN.**—USNM 204029 from USGS 25367 (SEM photographs).

**OCCURRENCE.**—This species is rare in section 5, units C and E.

**TYPE LOCALITY.**—St. Petersburg, Florida (Caloosahatchee Formation).

**Genus *Cyclostremiscus* Pilsbry and Olsson, 1945**

***Cyclostremiscus obliquistriatus* (Lea)**

PLATE 33: FIGURES 1–3

*Delphinula obliquè-striata* Lea, 1843a:9; 1846:261, pl. 36: fig. 72.

*Cyclostremiscus obliquè-striatus* (Lea).—Gardner 1948:189, pl. 25: figs. 31, 32.

**DISCUSSION.**—Gardner (1948, pl. 25: figs. 31, 32) figured the holotype (Acad. Nat. Sci. Phila. 1541). This species was not recorded from St. Petersburg, Florida, in Pilsbry (1953) although some species of this genus are listed as being found there. Gardner (1948:189) stated that the type locality is the sole known locality of this species occurrence. Our specimens differ from the type specimen in that there are relatively fewer axial ribs on our specimens and the umbilicus is smaller, tending to conceal earlier whorls.

**FIGURED SPECIMEN.**—USNM 204030 from USGS 25367 (SEM photographs).

**OCCURRENCE.**—This species is rare in section 5, unit B, and common in units C and E. It is also recorded from section 4 (D).

**TYPE LOCALITY.**—Petersburg, Dinwiddie County, Virginia (Yorktown Formation).

**Genus *Didianema* Woodring, 1928**

***Didianema carolinae* Gardner**

PLATE 33: FIGURES 4–6

*Didianema? carolinae* Gardner, 1948:191, pl. 25: figs. 15–17.

**DISCUSSION.**—The SEM photographs on Plate 33 illustrate quite clearly the characteristics of this genus. The genotype is *Didianema tytha* Woodring (1928:447) from Bowden, Jamaica. Pilsbry (1953:436–437) stated:

According to Dr. Gardner (1948), the genotype of *Didianema* has a beaded umbilical callus, but this was not mentioned by Dr. Woodring or shown in his figures (which are too small to show the characters beyond general form). The species in the southeastern United States referred to this genus do not have "two spiral threads emerging from the umbilical opening . . . at outer edge of umbilicus," but the umbilical funnel is bounded by a single carina or a strong angulation. The type of *Didianema* was described as polished and smooth except for growth lines. All of the Floridan species seen are dull and show sculpture, though sometimes worn smooth.

These various discrepancies account for the introduction of the subgenus *Diagonaulus* Pilsbry and McGinty (1945:12: Type *D. pauli* Pils. and McG., Recent, N. W. Florida). This subgenus probably includes all of the continental Miocene and Pliocene species mentioned below.

We believe that Gardner's type specimen originally had low irregular axial sculpture, but that this has worn off and possibly was not expressed as much in her specimen originally. Our specimens are less high-spined than Gardner's specimen. *Didianema duplinensis* (Dall) differs in having a very strong umbilical keel and a higher spire with flatter sides to the whorls.

Pilsbry (1953:437–438) recorded a new species and a new subspecies of *Didianema duplinensis* (Dall) from the beds at St. Petersburg, Florida. The illustrations are such that one would need the specimens for accurate evaluation of these species.



FIGURED SPECIMEN.—USNM 204031 from USGS 25366, SEM photographs.

OCCURRENCE.—This species is rare in section 5, units B and C, and common in unit D. It is also recorded from section 4 (B, D).

TYPE LOCALITY.—Walkers Bluff, Cape Fear River, Bladen County, North Carolina (Waccamaw Formation).

### Genus *Macromphalina* Cossmann, 1888

#### *Macromphalina pierrot* Gardner

PLATE 34: FIGURES 4–6

*Macromphalina pierrot* Gardner, 1948:195, pl. 25: figs. 41–43.—Pilsbry, 1953:435–436, pl. 52: figs. 6, 6a, 6b.

DISCUSSION.—Our specimen differs from Gardner's type in that it has more coarse spiral sculpture. Pilsbry (1953) recorded this species from St. Petersburg, Florida, and noted that except for the smaller size of the specimens, there was no material difference between the type and these specimens. Pilsbry (1953) also noted that species of this genus are now living off east Florida and that they are prolific in the Panamic marine fauna. From the figures presented by Gardner, her *Macromphalina pierrot* and her *Macromphalina* sp. (Gardner, 1948:195, pl. 25: figs. 9–11) differ very little. Gardner also stated that *Macromphalina pierrot* is known only from the type locality.

FIGURED SPECIMEN.—USNM 204033 from USGS 25357 (SEM photographs).

OCCURRENCE.—This species is rare in section 1 (E).

TYPE LOCALITY.—Neills Eddy Landing, Cape Fear River, 3 miles (4.8 km) north of Cronly, Columbus County, North Carolina (Waccamaw Formation).

#### *Macromphalina hanseni*, new species

PLATE 34: FIGURES 1–3

DIAGNOSIS.—Shell minute, protoconch of 1½ minute, highly polished naticoid whorls, the first turn half-bulbous, whorls rounded, rapidly increasing in diameter. Surface crowded by linear spiral cords that are irregular in expression and of differing thickness, some cords appear to be paired and divided only by a groove, whorl surface having annular folds that decrease in strength toward the umbilicus. Sutures deeply impressed and channeled near the aperture.

DISCUSSION.—*Macromphalina hanseni* differs from *M. pierrot* Gardner, 1948, in having a more distinctly annulated sculpture, less concealed early coiling, a lower axis of coiling, and a less widely expanding outer periphery. In *M. hanseni*, the umbilicus shows more of the earlier whorls, and the aperture does not cover much of the base of the shell.

FIGURED SPECIMEN.—USNM 204032, USGS 25367,

holotype, maximum diameter 1.4 mm (SEM photographs).

OCCURRENCE.—This species is rare at section 5 (C).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25367, section 5, unit C.

### Genus *Caecum* Fleming, 1813

#### *Caecum beaufortensis*, new species

PLATE 35: FIGURE 9

DIAGNOSIS.—Shell gently and evenly arcuate, only very slightly larger at the anterior end than the posterior end, surface smooth except for microscopically fine incremental striae. Plug mammillate. Anterior aperture oblique to the horizontal axis, apertural ring represented as a few slightly raised and closely spaced annular threads.

DISCUSSION.—*Caecum glabrum* Montagu (Gardner, 1948:203, pl. 28: fig. 19) is a species with a mammillate plug that was reported from the Yorktown Formation by Meyer (Gardner, 1948, did not verify this report). *Caecum glabrum* (as figured in Gardner) differs from *C. beaufortensis* in that it tapers more abruptly and is much more arched.

*Caecum johnsoni* Winkley, 1908, may be this species, but as his specimen was not figured and as we can find no comparative material in Holocene collections of the National Museum from near his type locality (Woods Hole, Massachusetts, on gravel, 2–3 fathoms), we have named the Lee Creek species.

FIGURED SPECIMEN.—USNM 204034 from USGS 25367, holotype, height 3.3 mm (SEM photograph).

OCCURRENCE.—This species is rare at section 5 (C).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25367, section 5, unit C.

#### *Caecum pulchellum* Stimpson

PLATE 35: FIGURE 10

*Caecum pulchellum* Stimpson, 1851:36–37, pl. 2: fig. 3.

*Caecum annulatum* Emmons, 1858:274, fig. 190.

*Caecum regulare* Carpenter, 1858:428.—Mansfield, 1930:102, pl. 14: fig. 5.—Gardner, 1948:203, pl. 28: fig. 18.

*Caecum* (*Caecum*) *regulare* Carpenter.—Olsson and Harbison, 1953:317, pl. 45: figs. 2, 2a, 2b, 2c.

DISCUSSION.—*Caecum pulchellum* Stimpson was originally described from New Bedford Harbor, Massachusetts, and Stimpson (1851, pl. 2: fig. 3) figured a specimen that is much more constricted posteriorly than any fossils from the southeastern United States or specimens from the Holocene off the southeastern coast. No specimens from as far north as Stimpson's specimens were found in the USNM collections. It may be that his figure is poor and that his specimen actually is conspecific with that figured as *C. regulare* Carpenter. Abbott (1974:91) indicated that this is the case, and

he listed *C. pulchellum* as ranging from New Hampshire to Brazil.

Although Meyer (1888) listed *Caecum trachea* Montagu, 1803, as a senior synonym of *C. pulchellum* Stimpson, it is difficult to tell what his specimen is really like, as his figure is poor and his locality is Milton in Devonshire, England. It should be noted that *C. annulatum* Emmons, 1858, is preoccupied by *Brochus annulatus* T. Brown, 1827.

Our figured specimen shows rather smooth annulations. Many specimens do have more pronounced annulations.

Gardner (1948) recorded this species from Rock Landing on the Neuse River (Yorktown Formation) and from the Waccamaw Formation at Neills Eddy Landing. These specimens appear to be identical with specimens from the Holocene.

FIGURED SPECIMEN.—USNM 204035 from USGS 25367 (SEM photograph).

OCCURRENCE.—This species is common at sections 4 (B, D, E) and 5 (B, C, D, E).

TYPE LOCALITY.—Laminarian zone in the New Bedford Harbor, Massachusetts (Holocene).

### *Caecum imbricatum* Carpenter

PLATE 35: FIGURE 11

*Caecum imbricatum* Carpenter, 1858:422–423.

*Caecum cooperi* S. Smith.—Dall, 1892:299 [in part].—Gardner, 1948:204, pl. 28: figs. 20, 29.

*Caecum (Elephantanellum) imbricatum* Carpenter.—Olsson and Harbison, 1953:318, pl. 45: figs. 4, 4a, 4b.

DISCUSSION.—Olsson and Harbison (1953:319) noted that this species has usually been identified as *C. cooperi* S. Smith, described from the colder waters of Vineyard Sound, Massachusetts. The figure of *cooperi* is that of a short shell with numerous longitudinal ribs; the concentric annulations are predominantly at one end. Olsson and Harbison recorded *C. imbricatum* from St. Petersburg, Florida. Gardner's figured specimen is from the Waccamaw Formation at Neills Eddy Landing, Cape Fear River. Mansfield (1930:101, pl. 14: fig. 7) recorded this species from Florida. In so far as we can tell, this species in the late Pliocene–early Pleistocene does not differ from the Holocene specimens.

FIGURED SPECIMEN.—USNM 204036 from USGS 25367 (SEM photograph).

OCCURRENCE.—This species is common in section 5, units B, C, and D, and is also found at sections 3 (D, E) and 4 (D, E).

TYPE LOCALITY.—West Indies (Holocene).

### *Caecum flemingi* Gardner and Aldrich

PLATE 35: FIGURE 12

*Caecum flemingi* Gardner and Aldrich, 1919:40–41, pl. 4.—Gardner, 1948:203, pl. 28: fig. 26.

DISCUSSION.—This species was not recorded by Olsson and Harbison (1953). Gardner (1948) recorded this species from Neills Eddy Landing (Waccamaw Formation) North Carolina, and from the “Duplin” Marl at Muldrow Place, South Carolina.

FIGURED SPECIMEN.—USNM 204037 from USGS 25367 (SEM photograph).

OCCURRENCE.—This species is common in section 5, units B, C, and D and is rare in unit E. It is also recorded from section 4 (D, E).

TYPE LOCALITY.—Neills Eddy Landing, Cape Fear River, Columbus County, North Carolina (Waccamaw Formation).

## Genus *Turritella* Lamarck, 1799

### *Turritella beaufortensis*, new species

PLATE 35: FIGURES 1, 2

DIAGNOSIS.—Shell a uniformly tapering pyramid, volutions approximately 9, apical angle about 20° to 22°, axial sculpture absent or as incremental wrinkles, spiral sculpture fairly constant for the species. Whorls flat sided with two primary spiral striae, each bordering a very deeply impressed suture with about three to six small spiral striae in depression between the two primaries. Aperture square-shaped, columella simple, parietal wall glazed.

DISCUSSION.—*Turritella carolinensis* Conrad (1873:22) differs in being straight sided with 11 even spiral lines and also has a very large quadrate aperture. *Turritella beaufortensis* has a wider apical angle than *T. alumensis* Mansfield, 1930.

FIGURED SPECIMENS.—USNM 204038 from USGS 25370, holotype, height 29.0 mm (Plate 35: figure 1), and USNM 204039 from USGS 25366 (Plate 35: figure 2).

OCCURRENCE.—This species is common in section 5, unit B, and rare in unit C. It is also recorded from section 6 (C).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25370, section 6, unit C.

### *Turritella perexilis* Conrad

PLATE 35: FIGURES 3, 4

*Turritella perexilis* Conrad, 1873, pl. 4: fig. 9, pl. 22.

*Turritella subannulata* Heilprin, 1886:89; 1887:89, pl. 8: fig. 17.

*Turritella (Eichwaldiella) subannulata* Heilprin.—Olsson and Harbison, 1953:312, pl. 44: fig. 8.

DISCUSSION.—This species is quite common at Lee Creek, North Carolina. It was figured by Conrad in the Kerr Report. It is quite distinctive from most other species of *Turritella* in that it has a slight axial component to its sculpture resulting in nodes that are crossed by the spiral lines. Although the whorls are basically rounded (Plate 35:

figure 3), some variation to more straight sided may also be seen (Plate 35: figure 4).

It should be noted that *T. perexilis* replaces *Turritella subannulata* (of authors). The morphology of the specimens from Lee Creek is probably not typical of this species as a whole, and the morphologic forms observed in the Waccamaw Formation may be more typical. In the Waccamaw Formation at Lake Waccamaw and at Neills Eddy Landing (Cape Fear River), some specimens are close morphologically to the Lee Creek specimens, whereas others have certain very strong spiral threads that give an almost nodose appearance to individuals with strong axial folds. In addition to specimens that resemble the Lee Creek specimens quite closely, there are, in the Caloosahatchee Formation, a large number of individuals that are highly ornamented and similar to the Waccamaw ones, but often these specimens lack the numerous spiral threads between the major raised spiral threads (a feature found in most Waccamaw and Lee Creek specimens).

On the bases of Holocene USNM collections, *Turritella acropora* Dall, 1889, apparently shows much less variation throughout its geographic range than many of the fossil specimens from one horizon and one locality. Most of the raised spiral threads of *T. acropora* are equal-sized, interspaces are only about half the width of the spiral threads, the spiral threads are very numerous (Lee Creek specimens have only about two-thirds the number of raised spiral threads per whorl as does *T. acropora*), and axial ribbing is often faint to absent. Early in the growth of *T. acropora*, one central spiral thread dominates, from which the sides of the whorl slope rather directly downward to the sutures, thus giving the sides a low V-shaped profile. In contrast to *T. acropora*, specimens of *T. perexilis* from Lee Creek have only about two-thirds the number of raised spiral threads per whorl, the interspaces between these spiral threads are about as wide as the spiral threads themselves, and usually several spiral threads are much more prominent than others.

**FIGURED SPECIMENS.**—USNM 204040 from USGS 25366 (Plate 35: figure 3) and USNM 204041 from USGS 25366 (Plate 35: figure 4).

**OCCURRENCE.**—This species is common in section 5, units B and D, and is rare in units C and E. It is also recorded from sections 2 (B), 3 (D, E), 4 (B, D), and 6 (C).

**TYPE LOCALITY.**—Wilmington, North Carolina (Waccamaw Formation).

### Genus *Vermicularia* Lamarck, 1799

#### *Vermicularia spirata* (Philippi)

PLATE 35: FIGURES 6–8

*Vermetus spiratus* Philippi, 1836(1):224; 1836(2), pl. 7: figs. 1a,b,c.  
*Vermicularia spirata* (Philippi).—Gardner, 1948:202–203, pl. 24: fig. 5.—  
Olsson and Harbison, 1953:306–307.

**DISCUSSION.**—Our specimens start out with postnuclear whorls having three spiral ridges, the lowest ridge nearly coincident with the suture and the middle ridge prominent and midway between sutures. Our specimen differs from that figured by Gardner (1948), which has three more equally prominent ridges.

**FIGURED SPECIMENS.**—USNM 204128 from USGS 25366 (Plate 35: figure 6) and USNM 204042 from USGS 25370 (Plate 35: figures 7, 8).

**OCCURRENCE.**—This species is rare at sections 3 (D, E), 4 (B, D), and 5 (B, D, E).

**TYPE LOCALITY.**—“Habitat in Indian Occidentali ad Havanam” (Philippi, 1836:224).

### Genus *Serpulorbis* Sassi, 1827

#### *Serpulorbis granifera* (Say), new combination

PLATE 35: FIGURE 5

*Serpula granifera* Say, 1824:154, pl. 8: fig. 4.  
*Lemintina granifera* (Say).—Gardner, 1948:201.

**DISCUSSION.**—Warmke and Abbott (1961:66–67) recognized that the genus *Lemintina* Risso, 1826, is evidently based upon a worm and not a mollusk.

**FIGURED SPECIMEN.**—USNM 204043 from USGS 25364.

**OCCURRENCE.**—This species is found in sections 3 (D, E), 4 (B, D, E), and 5 (B, C, D, E).

**TYPE LOCALITY.**—Not Maryland as was stated by Say (1824:124) but probably Virginia, Yorktown Formation [see Ward and Blackwelder, 1975].

### Genus *Bittium* Gray, 1847

#### *Bittium podagrimum* Dall

PLATE 36: FIGURE 7

*Bittium podagrimum* Dall, 1892:274, pl. 21: fig. 12.  
*Bittium (Bittiolium) podagrimum* Dall.—Olsson and Harbison, 1953:290, pl. 48: fig. 10.

**DISCUSSION.**—This genus was not recorded by Gardner (1948). Olsson and Harbison (1953) recorded this species as common at St. Petersburg.

**FIGURED SPECIMEN.**—USNM 204044 from USGS 25368 (SEM photograph).

**OCCURRENCE.**—This species is rare in section 5, unit C, and common in unit D. It is also recorded from sections 2 (D) and 4 (D, E).

**TYPE LOCALITY.**—“Pliocene of the Caloosahatchee and Shell Creek, Florida, Dall and Wilcox” (Dall, 1892:274).

Genus *Seila* A. Adams, 1861*Seila adamsii* (Lea)

PLATE 36: FIGURES 2, 3

*Cerithium Adamsii* Lea, 1843a:162.*Seila adamsii* (Lea).—Olsson and Harbison, 1953:302.

DISCUSSION.—This species was not recorded by Gardner (1948). Olsson and Harbison (1953) recorded this species from St. Petersburg and from Shell Creek, Florida. Olsson and Harbison discussed the differences between Holocene and fossil specimens. Specimens from Lee Creek were missing the protoconch. Lea's figure of *Seila clavulus* is of an extremely slender specimen.

FIGURED SPECIMENS.—USNM 204045 from USGS 25368 (Plate 36: figure 2) and USNM 204046 from USGS 25368 (Plate 36: figure 3).

OCCURRENCE.—This species is rare in section 5, unit B, and common in units C, D, and E. It is also recorded from sections 2 (D, E), 4 (B, D), and 6 (C).

TYPE LOCALITY.—Petersburg, Virginia (Yorktown Formation).

Genus *Triphora* Blainville, 1828*Triphora dupliniana* (Olsson)

PLATE 36: FIGURES 5, 6

*Triphoris dupliniana* Olsson, 1916:18, pl. 3: fig. 8.*Triphora dupliniana* (Olsson).—Gardner, 1948:205, pl. 27: fig. 3.*Triphora* (*Cosmotriphora*) *dupliniana* (Olsson).—Olsson and Harbison, 1953:295, pl. 43: fig. 2.

DISCUSSION.—Although our specimens are all small, they appear to belong to this species. Our specimens show the distinct excavated sutures of *Triphora dupliniana*. *Triphora bolax* (Olsson and Harbison, 1953) differs in that the sutures are indistinct or are not visible. Gardner (1948:205) recorded this species from Natural Well, North Carolina (Yorktown Formation), and from the James River north of Smithfield, Virginia (fide Olsson), in the Yorktown Formation. Olsson and Harbison (1953) recorded this species from St. Petersburg, Florida.

FIGURED SPECIMENS.—USNM 204047 from USGS 25368 (Plate 36: figure 5) and USNM 204048 from USGS 25368 (Plate 36: figure 6).

OCCURRENCE.—This species is common in section 5, unit D, and rare in unit C. It is also recorded from section 4 (D).

TYPE LOCALITY.—Natural Well, North Carolina (Yorktown Formation); James River, north of Smithfield, Virginia (Yorktown Formation).

Genus *Epitonium* Röding, 1798*Epitonium leai*, new species

PLATE 36: FIGURE 1

DIAGNOSIS.—Shell conical, thin, apex broken, about 8 whorls, axial costae thin and high, axial costae of one whorl join that of the next; whorls rounded and sutures impressed, between axials there are about 8 faint spiral threads, which become indistinct in later whorls that appear to have quite smooth spaces between the axials. Aperture round, anterior part broken. No basal cord.

DISCUSSION.—This species resembles *E. microstoma* (Lea, 1843) but lacks the basal cord, and the varices are thicker and do not extend out as far from the body whorl.

FIGURED SPECIMEN.—USNM 204049 from USGS 25366, holotype, height 8.1 mm.

OCCURRENCE.—This species is rare at section 5 (B, E).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25366, section 5, unit B.

*Epitonium sohli*, new species

PLATE 36: FIGURE 10

DIAGNOSIS.—Shell of medium size, moderately broad, whorls of conch about 7. Axial costae blunt and reflected, progressively larger, and with growth lines expressed on costae, axials spaced equidistantly and usually in harmony with earlier costae on previous whorl, 8 costae on last whorl. Spiral sculpture of revolving threads, about 13 on later whorls and approximately equidistantly spaced. Aperture round and not patulous.

DISCUSSION.—This species differs from *Epitonium can-deanum* (d'Orbigny, 1842) (= *E. antillarum* (DeBoury, 1909:258)) in being stouter and in having more strongly reflected varices. *Epitonium novangliae* (Couthouy, 1838) is close morphologically to *sohli* but is more highly spired with more numerous axial costae.

FIGURED SPECIMEN.—USNM 204052 from USGS 25366, holotype, height 5.3 mm (SEM photograph with seam).

OCCURRENCE.—This species is rare at section 5 (B).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25366, section 5, unit B.

*Epitonium* sp. cf. *E. foliaceicostum* (d'Orbigny)

PLATE 36: FIGURE 11

*Epitonium* cf. *foliaceicostum* (d'Orbigny).—Olsson and Harbison, 1953:336, pl. 58: fig. 2.

DISCUSSION.—Our figured specimen is quite small (height 6.4 mm). It corresponds well to that figured by Olsson and Harbison (1953) in morphologic detail, and any differences

may be due to their figured specimen having been a larger individual. This species was not recorded by Gardner (1948).

FIGURED SPECIMEN.—USNM 204053 from USGS 25369 (SEM photograph with seam).

OCCURRENCE.—This species is rare at section 5 (E).

***Epitonium carolinae* Gardner**

PLATE 36: FIGURES 8, 9

*Epitonium (Hyaloscala) carolinae* Gardner, 1948:205–206, pl. 28: fig. 50.

DISCUSSION.—This species was not recorded by Olsson and Harbison (1953). Gardner (1948) recorded this species only from the type locality. Our specimens are very small, and they differ slightly from Gardner's specimen in having slightly lower axial sculpture.

FIGURED SPECIMENS.—USNM 204050 from USGS 25368 (Plate 36: figure 8) and USNM 204051 from USGS 25366 (Plate 36: figure 9).

OCCURRENCE.—This species is rare at section 5 (B, D).

TYPE LOCALITY.—Natural Well, 2 miles (3.2 km) southwest of Magnolia, Duplin County, North Carolina (Yorktown Formation).

***Epitonium rupicolium* (Kurtz)**

PLATE 36: FIGURES 12, 13

*Scalaria rupicolium* Kurtz, 1860:7.

*Clathrus (Pictoscala) rupicolium* (Kurtz).—Olsson and Harbison, 1953:338, pl. 58: fig. 4.

*Scalaria lineata* Say, 1822:242 [not *Epitonium lineatum* Röding, 1798].

DISCUSSION.—Our figured specimen is small but otherwise agrees quite well with that figured by Olsson and Harbison (1953). Our specimens are more obese than *Epitonium pratti* (Gardner, 1948) and possess occasionally thickened varices.

FIGURED SPECIMEN.—USNM 204054 from USGS 25368.

OCCURRENCE.—This species is rare at section 5 (D, E).

TYPE LOCALITY.—“In the crevices of stones, Fort Johnson, South Carolina” (Kurtz, 1860:7) (Holocene).

***Epitonium fractum* Dall**

PLATE 36: FIGURE 14

*Epitonium fractum* Dall, 1927:60.

DISCUSSION.—This species was not recorded by Gardner (1948) or by Olsson and Harbison (1953).

FIGURED SPECIMEN.—USNM 204132 from USGS 25339.

OCCURRENCE.—This species is rare at section 5 (C).

TYPE LOCALITY.—USGS 108015, off Fernandina, Florida, in 294 fm (Holocene).

**Genus *Balcis* Gray, 1847**

***Balcis?* sp.**

PLATE 36: FIGURE 4

DISCUSSION.—Our figured specimen is small and the aperture is broken. Our specimen is less slender than specimens of *Balcis conoidea* (Kurtz and Stimpson, 1851).

FIGURED SPECIMEN.—USNM 204055 from USGS 25367.

OCCURRENCE.—This species is rare in section 5 (C, D).

***Balcis beaufortensis*, new species**

PLATE 37: FIGURE 1

DIAGNOSIS.—Shell of moderate size, stout of genus, conic in outline, body whorl a little more than half the total altitude, whorls very gently curved, regularly increasing in size, 7 in number including the protoconchal turns, body whorl broadly rounded, sutures distinct and even faintly impressed, nuclear turns minute, not more than 2 in number, differentiated by their convexity. External surface polished, devoid of sculpture, aperture holostomous, subovate in outline and acutely angulated posteriorly. Inner lip fused with parietal callous.

DISCUSSION.—*Balcis beaufortensis* is of similar dimensions to *B. magnoliana* (Gardner and Aldrich, 1919), but it has only half the number of whorls for a similar-sized specimen, each whorl of *B. beaufortensis* being a little broader, the sides a little more convex, and the aperture more elongate.

FIGURED SPECIMEN.—USNM 204056 from USGS 25367, holotype, height 4.5 mm (SEM photograph).

OCCURRENCE.—This species is rare in section 5 (C).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25367, section 5, unit C.

***Balcis biconica* (Gardner), new combination**

PLATE 37: FIGURE 2

*Strombiformis biconica* Gardner, 1948:210–211, pl. 27: figs. 9, 21.—Olsson and Harbison, 1953:330, pl. 59: fig. 6.

DISCUSSION.—Gardner (1948) recorded this species from the “Duplin” Marl at Natural Well, North Carolina, and from the Waccamaw Formation at Neills Eddy Landing, North Carolina. Olsson and Harbison (1953) recorded this species from St. Petersburg, Florida. This species is characterized by its angled periphery and depressed base.

FIGURED SPECIMEN.—USNM 204057 from USGS 25367 (SEM photograph).

OCCURRENCE.—This species is rare in section 5 (B, E).

TYPE LOCALITY.—Natural Well, Duplin County, North Carolina (Yorktown Formation).

***Balcis eborea* (Conrad), new combination**

PLATE 37: FIGURE 3

*Eulima eborea* Conrad, 1846a:20, pl. 1: fig. 21.

*Strombiformis* (*Polygireulima*) *eborea* (Conrad).—Gardner, 1948:212, pl. 27: fig. 6.

DISCUSSION.—This species was not recorded by Olsson and Harbison (1953). Gardner (1948) recorded this species from the Yorktown Formation at Suffolk, Virginia, from the Yorktown of Pitt County, Wilson County, and Bertie County (Edenhouse Point), North Carolina.

FIGURED SPECIMEN.—USNM 204058 from USGS 25367 (SEM photograph).

OCCURRENCE.—This species is rare in section 5 (C).

TYPE LOCALITY.—Suffolk, Virginia (Yorktown Formation).

**Genus *Eulima* Risso, 1826**

***Eulima juncea* (Gardner), new combination**

PLATE 37: FIGURE 4

*Strombiformis juncea* Gardner, 1948:210, pl. 27: fig. 10.

DISCUSSION.—This species was not recorded by Olsson and Harbison (1953). Gardner (1948) recorded this species from the type locality only. This species is distinguished by its slenderness and less numerous volutions. Our specimens show a slight reflection in the body whorl that is not apparent in the figure of the holotype.

FIGURED SPECIMEN.—USNM 204059 from USGS 25367 (SEM photograph).

OCCURRENCE.—This species is rare in section 5 (C).

TYPE LOCALITY.—Neills Eddy Landing, Cape Fear River, 3 miles (4.8 km) north of Cronly, Columbus County, North Carolina (Waccamaw Formation).

**Genus *Crucibulum* Schumacher, 1817**

***Crucibulum lawrencei*, new species**

PLATE 37: FIGURES 9–11

DIAGNOSIS.—Shell moderately large, fairly heavy, conical, the base irregularly subovate, variation in exterior outline common, and the right and/or left side may vary from quite convex to almost straight; apex slightly anterior and directed anteriorly, apex in line with the area of attachment of the inner cup; interior smooth, internal cup located

in the anterior half of the shell, internal cup two-thirds the height of shell, cup pyriform, posterior angle between cup wall and shell approximately 60°, anterior angle very small, left wall of shell forms almost one-third of the cup, cup suboval in outline with the posterior wall often straight to concave; sculpture of exterior variable and consisting of numerous slightly wavy, narrow, radial riblets, new radials do not arise very frequently among the riblets, new radials when added appear in the interspaces and at irregular intervals.

DISCUSSION.—The fine, numerous radial riblets on the exterior of this species are a diagnostic feature. Also the size and convexity of this species tend to set it apart from other species. The species is larger in size than *C. auricula* Gmelin, 1791.

FIGURED SPECIMEN.—USNM 204061 from USGS 25364, holotype, maximum diameter 52.8 mm, height 22.6 mm.

OCCURRENCE.—This species is common in section 5, unit B, and rare in unit C. It is also recorded from section 2 (D), 3 (D, E), and 4 (D, E).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25364, section 4, unit D.

**Genus *Calyptraea* Lamarck, 1799**

***Calyptraea centralis* (Conrad)**

PLATE 37: FIGURES 5, 6

*Infundibulum centralis* Conrad, 1841:348; 1845:80, pl. 45: fig. 5.

*Calyptraea centralis* (Conrad).—Dall, 1892:353.

DISCUSSION.—This species ranges from Pliocene to Holocene. Gardner (1948) did not record this species. Olsson and Harbison (1953:277) recorded this species from St. Petersburg, Florida.

FIGURED SPECIMEN.—USNM 204060 from USGS 25368.

OCCURRENCE.—This species is common in section 5, unit B, and rare in unit D.

TYPE LOCALITY.—Natural Well, Duplin County, North Carolina (Yorktown Formation).

**Genus *Crepidula* Lamarck, 1799**

***Crepidula aculeata* (Gmelin)**

PLATE 37: FIGURES 7, 8

*Patella aculeata* Gmelin, 1791:3693.

*Crepidula aculeata* (Gmelin).—Tryon, 1886:129, pl. 39: figs. 61–65.

*Crepidula* (*Bostrycapulus*) *aculeata* (Gmelin).—Olsson and Harbison, 1953:280.

DISCUSSION.—Olsson and Harbison (1953) stated that this species is common at St. Petersburg.

FIGURED SPECIMEN.—USNM 204062 from USGS 25362.

OCCURRENCE.—This species is common in section 5, units C and D, and rare in units B and E. It is also recorded from sections 1 (E), 3 (D, E), and 4 (D, E).

TYPE LOCALITY.—“Paulo rarior ad insulas Americae mediae obversas” (Gmelin, 1791:3693) (Caribbean area).

### *Crepidula fornicata* (Linnaeus)

PLATE 38: FIGURES 1, 2

*Patella fornicata* Linnaeus, 1758:781.

*Crepidula fornicata* (Linnaeus).—Say, 1822:225.

DISCUSSION.—This species was not discussed by Gardner (1948). Olsson and Harbison (1953:277) stated that this species has been reported from the Florida Pliocene but that it is not present at St. Petersburg. Specimens of this species at Lee Creek are larger than usual and are rather broadly arched.

FIGURED SPECIMEN.—USNM 204063 from USGS 25364.

OCCURRENCE.—This species is rare in section 5, unit B, common in unit C, and abundant in units D and E. It is also recorded from sections 3 (D, E), 4 (E), and 6 (C).

TYPE LOCALITY.—“Habitat ad Ilvam insulam” (Linnaeus, 1758:781) (probably the Island of Elba, near the coast of Italy).

### *Crepidula plana* Say

PLATE 38: FIGURES 5, 6

*Crepidula plana* Say, 1822:226.

*Crepidula (Ilanacua) plana* Say.—Olsson and Harbison, 1953:279.

DISCUSSION.—Gardner (1948) did not discuss this species. Olsson and Harbison (1953) recorded it as common at St. Petersburg, Florida. This species is quite variable in outline because of the nature of its life mode (sedentary, often in confined space).

FIGURED SPECIMEN.—USNM 204064 from USGS 25362.

OCCURRENCE.—This species is rare at sections 3 (D, E) and at 5 (B, C).

TYPE LOCALITY.—“Inhabits the coast of the United States” (Say, 1822:226) (Holocene).

## Genus *Trivia* Broderip, 1837

### *Trivia floridana* Olsson and Harbison

PLATE 38: FIGURES 3, 4

*Trivia floridana* Olsson and Harbison, 1953:265, pl. 60: figs. 2, 2a, 2b.

DISCUSSION.—This species is rare at Lee Creek. Olsson and Harbison (1953) recognized that the specimen identi-

fied and figured by Gardner (1948:214–215, pl. 29: figs. 8, 9) as *Trivia pediculus* (Linnaeus, 1758) was rather close to *Trivia floridana*. We believe *T. pediculus* to be the same as *T. floridana*. Gardner recorded this species from several Waccamaw Formation localities in North Carolina.

FIGURED SPECIMEN.—USNM 204065 from USGS 25339.

OCCURRENCE.—This species is rare at section 5 (C) and is also recorded as spoil.

TYPE LOCALITY.—St. Petersburg, Florida (Caloosahatchee Formation).

## Genus *Polinices* Montfort, 1810

### *Polinices duplicata* (Say)

PLATE 38: FIGURES 9–11

*Natica duplicata* Say, 1822:247.

*Polinices (Neverita) duplicatus* (Say).—Dall, 1892:368.—Olsson and Harbison, 1953:268–269, pl. 57: fig. 3.

DISCUSSION.—This species was not recorded by Gardner (1948). Olsson and Harbison (1953) recorded it from St. Petersburg, Florida. Olsson and Harbison discussed some of the shape variation in this species and differences between the Holocene and the fossil collections. The form at Lee Creek is the typical sandy substrate form with a rather low spire. It is identical with specimens in the Holocene USNM collections.

FIGURED SPECIMEN.—USNM 204067 from USGS 25364.

OCCURRENCE.—This species is rare at sections 2 (D, E), 3 (D, E), 4 (D), 5 (B, D), and 6 (C).

TYPE LOCALITY.—“Inhabits the coast of the United States” (Say, 1822:247) (Holocene).

## Genus *Lunatia* Gray, 1847

### *Lunatia heros* (Say)

PLATE 38: FIGURE 12

*Natica heros* Say, 1822:248

*Lunatia heros* (Say).—Abbott, 1974:155, fig. 1690.

DISCUSSION.—This species was not recorded by Gardner (1948) or by Olsson and Harbison (1953). Specimens from Lee Creek appear to be identical morphologically with specimens in the Holocene USNM collections.

FIGURED SPECIMEN.—USNM 204068 from USGS 25362.

OCCURRENCE.—This species is recorded from sections 2 (B), 3 (D, E), and 4 (D).

TYPE LOCALITY.—“Inhabits the coast of New Jersey” (Say, 1822:248)

**Genus *Tectonatica* Sacco, 1890*****Tectonatica pusilla* (Say)**

PLATE 38: FIGURES 7, 8

*Natica pusilla* Say, 1822:257.*Tectonatica pusilla* (Say).—Woodring, 1928:384, pl. 30: fig. 12.—Olsson and Harbison, 1953:269–270, pl. 57: figs. 4, 4a.

DISCUSSION.—This species was not recorded by Gardner (1948). Olsson and Harbison (1953) recorded it from St. Petersburg, Florida. This species is distinguished from juveniles of other members of the Naticidae by the nature of the umbilicus (Plate 38: figure 8) and by the thick nature of the shell.

FIGURED SPECIMEN.—USNM 204066 from USGS 25367.

OCCURRENCE.—This species is common in section 5, units B and D, and rare in units C and E.

TYPE LOCALITY.—“Inhabits the southern coast” (Say, 1822:257) (Holocene).

**Genus *Murexiella* Clench and Pérez Farfante, 1945*****Murexiella macgintyi* (M. Smith), new combination**

PLATE 39: FIGURES 3, 4

*Murex macgintyi* M. Smith, 1938:88, pl. 6: fig. 11.*Murex (Favaritia) macgintyi* Maxwell Smith.—Olsson and Harbison, 1953:246, pl. 36: fig. 5.

DISCUSSION.—Olsson and Harbison (1953) recorded this species from St. Petersburg, Florida. Gardner (1948) did not record it. The species also occurs in the Holocene off the southern coast of Florida and in the Bahamas. Only one specimen has been recorded from Lee Creek, North Carolina.

FIGURED SPECIMEN.—USNM 204069 from USGS 25362.

OCCURRENCE.—This species is recorded from section 3 (D, E).

TYPE LOCALITY.—Clewiston, Hendry County, Florida (Caloosahatchee Formation).

**Genus *Urosalpinx* Stimpson, 1865*****Urosalpinx* sp. cf. *U. perrugata* (Conrad)**

PLATE 39: FIGURES 1, 2

*Fusus perrugatus* Conrad, 1846b:397.*Urosalpinx perrugata* (Conrad).—Gardner, 1948:224–225, pl. 31: fig. 24.

DISCUSSION.—Specimens from Lee Creek differ from typical *Urosalpinx perrugata* in that they are much more elongate. Olsson and Harbison (1953:255, plate 37: fig. 7)

figured a Holocene specimen of this species, but they did not record it as present at St. Petersburg, Florida. Gardner (1948) recorded the species from several localities in North Carolina, although she queried these occurrences.

FIGURED SPECIMEN.—USNM 204072 from USGS 25366.

OCCURRENCE.—This species is rare in section 5, units B and C, and common in unit D, and is found at section 2 (D).

TYPE LOCALITY.—Manatee River, Florida (Holocene).

***Urosalpinx stimpsoni* Gardner**

PLATE 39: FIGURES 10, 11

*Urosalpinx stimpsoni* Gardner, 1948:224, pl. 31: figs. 13, 23.

DISCUSSION.—This species is quite large, attaining length of about 40 mm. Because of the nature of shell wear, specimens from Lee Creek often appear to have a somewhat subdued sculpture. Variation in number of axial ribs is common. This species was not recorded by Olsson and Harbison (1953). Gardner (1948) recorded it from localities in the Yorktown and Waccamaw formations of North Carolina.

FIGURED SPECIMEN.—USNM 204074 from USGS 25364.

OCCURRENCE.—This species is recorded from section 4 (D).

TYPE LOCALITY.—Neills Eddy Landing, Cape Fear River, 3 miles (4.8 km) north of Cronly, Columbus County, North Carolina (Waccamaw Formation).

***Urosalpinx suffolkensis* Gardner**

PLATE 39: FIGURES 5, 6

*Urosalpinx suffolkensis* Gardner, 1948:225, pl. 28: fig. 9.

DISCUSSION.—This species was not recorded by Olsson and Harbison (1953). Gardner (1948) listed it from several Yorktown Formation localities in Virginia and North Carolina, and also from the “Duplin” formation at Natural Well, North Carolina. This species is quite coarse with respect to the fine detail of the exterior sculpture and in form and sculpture resembles *Urosalpinx perrugata* (Conrad, 1846). However, the nature of the axial ribs and the height of the shell serves to differentiate *U. suffolkensis*.

FIGURED SPECIMEN.—USNM 204073 from USGS 25364.

OCCURRENCE.—This species is found at section 4 (D).

TYPE LOCALITY.—One mile (1.6 km) northeast of Suffolk, Nansemond County, Virginia (Yorktown Formation).



**Genus *Pterorhytis* Conrad, 1862*****Pterorhytis conradi* (Dall), new combination**

PLATE 39: FIGURES 7, 8

*Murex (Pterorhytis) conradi* Dall, 1890:143, pl. 12: fig. 11.*Pterorhytis (Neurorhytis) marshalli*.—Olsson and Petit, 1964:549–550, pl. 81: figs. 3, 3a [not Mansfield, 1930].

DISCUSSION.—The specimen figured by Dall (1890) is somewhat artistically tailored to a more regular, smooth-looking form, whereas in reality the sculpture is somewhat rougher and shaggier, and a good deal of the fine detail shown by Dall is obscure. Also this species is somewhat variable with respect to exterior sculpture and length-to-width proportions.

FIGURED SPECIMEN.—USNM 204070 from USGS 25360.

OCCURRENCE.—This species is found at section 2 (D).

TYPE LOCALITY.—The specimen figured by Dall (1890) is labeled in the USNM collections as coming from the St. Marys River, Maryland (St. Marys Formation). This specimen from Clark that Dall received was cataloged 3 June 1890 in the same lot with materials both from the St. Marys River, Maryland, and from Wilmington, North Carolina. By some accident, the *Pterorhytis* must have received the wrong label. We recommend that the type locality for this species be changed to Wilmington, North Carolina (lower Pleistocene beds), and that the St. Marys River, St. Marys Formation, locality be removed from the recorded occurrences of this species. Stratigraphically, the St. Marys Formation is too low for this form of *Pterorhytis*, and to our knowledge, extensive collections on the St. Marys River have never produced such a specimen.

**Genus *Eupleura* H. and A. Adams, 1853*****Eupleura caudata* (Say)**

PLATE 39: FIGURE 9

*Ranella caudata* Say, 1822:236.*Eupleura caudata* (Say).—Gardner, 1948:222, pl. 29: figs. 12, 13, 18, 19.—Olsson and Harbison, 1953:256–257, pl. 37: figs. 6, 6a, 6b.

DISCUSSION.—Gardner (1948) recorded this species from localities in Virginia and North Carolina. Olsson and Harbison (1953) recorded the species from St. Petersburg and from Fort Thompson, Florida. Only fragments of this species have been found at Lee Creek.

FIGURED SPECIMEN.—USNM 204071 from USGS 25367.

OCCURRENCE.—This species is rare at sections 5 (C, D, E).

TYPE LOCALITY.—“Inhabits the coast of the United States” (Say, 1822:236) (Holocene).

**Genus *Mitrella* Risso, 1826*****Mitrella gardnerae* (Olsson and Harbison), new combination**

PLATE 40: FIGURES 6, 7

*Anachis (Alia) gardnerae* Olsson and Harbison, 1953:236, pl. 38: figs. 6, 6a.

DISCUSSION.—This species differs from *Mitrella lunata* (Say, 1826) in being much stouter. Also *Mitrella gardnerae* is a very heavy shelled species. Our specimens from Lee Creek are generally heavier than that figured by Olsson and Harbison.

FIGURED SPECIMEN.—USNM 204078 from USGS 25366.

OCCURRENCE.—This species is common at section 5 (D, E).

TYPE LOCALITY.—St. Petersburg, Florida (Caloosahatchee Formation).

***Mitrella gardnerae ecarinata* (Olsson and Harbison), new combination**

PLATE 40: FIGURES 4, 5

*Anachis (Alia) gardnerae ecarinata* Olsson and Harbison, 1953:236–237, pl. 38: fig. 8.

DISCUSSION.—This subspecies is distinct from other subspecies in that it possesses an angulated body whorl.

FIGURED SPECIMEN.—USNM 204077 from USGS 25368.

OCCURRENCE.—This subspecies is recorded from section 5 (D).

TYPE LOCALITY.—St. Petersburg, Florida (Caloosahatchee Formation).

***Mitrella waccamawensis* Gardner**

PLATE 40: FIGURES 10, 11

*Mitrella waccamawensis* Gardner, 1948:226, pl. 30: fig. 16

DISCUSSION.—Gardner (1948) recorded this species only from the type locality. Our specimens are close in morphology to her figured specimen and are of similar size. This species was not recorded by Olsson and Harbison (1953).

FIGURED SPECIMEN.—USNM 204079 from USGS 25368.

OCCURRENCE.—This species is common in section 5, unit D, and rare in units C and E.

TYPE LOCALITY.—Neills Eddy Landing on the Cape Fear River, 3 miles (4.8 km) north of Cronly, Columbus County, North Carolina (Waccamaw Formation).

Genus *Anachis* H. and A. Adams, 1853*Anachis milleri* Gardner

PLATE 40: FIGURES 1-3

*Anachis (Costoanachis) milleri* Gardner, 1948:231, pl. 28: fig. 2.

DISCUSSION.—This species differs from *Anachis avara* (Say, 1822) in having a less angulated body whorl, in having more rounded whorls, and in being slightly stouter. Gardner (1948:231) stated that *A. milleri* differs from *A. avara* Say in having finer and more numerous costals that show no tendency to evanesce on any of the whorls of the spire or to become more prominent on the first half of the body turn. She listed occurrences in Virginia and North Carolina. This species was not recorded by Olsson and Harbison (1953).

FIGURED SPECIMENS.—USNM 204075 from USGS 25368 (Plate 40: figures 1, 3) and USNM 204076 from USGS 25366 (Plate 40: figure 2).

OCCURRENCE.—This species is rare in section 5, unit B, common in units C and E, and abundant in unit D. It is also recorded from 2 (D) and 4 (D).

TYPE LOCALITY.—Wilson, Wilson County, North Carolina (Yorktown Formation).

Genus *Aesopus* Gould, 1860*Aesopus gardnerae*, new species

PLATE 40: FIGURE 14

*Aesopus* sp.—Gardner, 1948:233, pl. 28: fig. 33.

DIAGNOSIS.—Shell small, stout, spirally sculptured, living body whorl longer than spire, consisting of 1½ nuclear and three postnuclear whorls, nuclear whorls large, smooth, moderately inflated, constricted at the suture, apical one bluntly rounded, postnuclear whorls enlarging and very rounded in outline. Suture grooved, not appressed. Sculpture of (on the penultimate whorl) 5 broad raised spiral lines separated by equally broad interspaces. The spiral lines extend forward to the end of the canal. Very fine numerous axial growth threads connect the spiral lines. Aperture elongate-subovate.

DISCUSSION.—Gardner (1948) figured but did not name this species. Her figured specimen is from Colerain Landing, Chowan River, North Carolina. This species is distinct from other species in that it has pronounced spiral lines connected by fine axial growth threads. The body whorls are also quite rounded compared with other species.

FIGURED SPECIMEN.—USNM 204082 from USGS 25367, holotype, height 3.8 mm (SEM photograph).

OCCURRENCE.—This species is rare in section 5, units B, C, and E, and common in unit D.

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25367, section 5, unit C.

*Aesopus ithitoma* (Dall)

PLATE 40: FIGURE 13

*Anachis ithitoma* Dall, 1890:136-137, pl. 12: fig. 6.*Aesopus (Ithiaesopus) ithitoma* (Dall)—Olsson and Harbison, 1953:241, pl. 38: figs. 5, 5a.

DISCUSSION.—This species was not recorded by Gardner (1948). Olsson and Harbison (1953) recorded it from St. Petersburg, Florida, and noted that Dall's type is an immature specimen. Our figured specimen is also not as large as that figured by Olsson and Harbison (1953). The sculpture of this species is of chiefly straight, rounded riblets, contrasting strongly with the chiefly spiral sculpture of *Aesopus gardnerae* Blackwelder and Ward, new species.

FIGURED SPECIMEN.—USNM 204081 from USGS 25368 (SEM photograph).

OCCURRENCE.—This species is rare in section 5 (D).

TYPE LOCALITY.—"Rare in the Caloosahatchie marl" (Dall, 1890:137) (Florida).

*Aesopus stearnsii* (Tryon)

PLATE 40: FIGURE 12

*Columbella (Seminella) stearnsii* Tryon, 1883:179, pl. 58: fig. 48.*Aesopus stearnsii* (Tryon)—Gardner, 1948:232, pl. 30: fig. 19.

DISCUSSION.—This small species possesses a distinctive cancellate surface sculpture. It was not recorded by Olsson and Harbison (1953). Gardner (1948) recorded this species from the "Duplin" Formation at Natural Well, North Carolina, and from the Waccamaw Formation at Neills Eddy Landing, North Carolina.

FIGURED SPECIMEN.—USNM 204080 from USGS 25368 (SEM photograph).

OCCURRENCE.—This species is rare in section 5, units B, C, and D. It is also recorded from section 4 (D).

TYPE LOCALITY.—"Habitat—West Coast of Florida, on shores of Tampa Bay" (Tryon, 1883:179).

Genus *Nassarius* Duméril, 1806*Nassarius chowanensis* (Gardner), new combination

PLATE 40: FIGURES 8, 9

*Uzita chowanensis* Gardner, 1948:249-250, pl. 30: figs. 9, 10, 12, 13.

DISCUSSION.—This species is distinguished by its elevated, multiwhorled spire and strong rounded axials overridden by sharp and evenly spaced spiral lirae (Gardner, 1948). Gardner listed its localities in Virginia and North Carolina,

but did not mention any localities of the Waccamaw Formation. This species was not recorded by Olsson and Harbison (1953).

FIGURED SPECIMEN.—USNM 204083 from USGS 25362.

OCCURRENCE.—This species is abundant in section 5, units B, and rare in units C and D. It is also recorded from sections 2 (D) and 3 (D).

TYPE LOCALITY.—Colerain Landing on the Chowan River, Bertie County, North Carolina (Chowan River Formation).

***Nassarius cornelliana* (Olsson), new combination**

PLATE 40: FIGURES 16, 17

*Nassa cornelliana* Olsson, 1914:45 [7], pl. 11 [4]: fig. 11.

*Uzita caloosaensis cornelliana* (Olsson).—Gardner, 1948:252, pl. 30: fig. 24.

DISCUSSION.—Gardner (1948) recorded this species from the Waccamaw Formation and the "Duplin" Formation in North Carolina. Olsson and Harbison (1953:222) recorded *Nassarius caloosaensis* (Dall, 1890), a shouldered species similar to *N. cornelliana*, from St. Petersburg, Florida. Our specimens differ slightly from that figured by Gardner (1948) in that the axial sculpture is more reduced and the incised spiral lines are more numerous.

This small species is quite distinct from other species in that the axial ribs are few and expressed as slightly raised parts of the shell. Our specimen has five fairly flat spiral cords on the body whorl.

FIGURED SPECIMEN.—USNM 204085 from USGS 25366.

OCCURRENCE.—This species is recorded from section 5 (B).

TYPE LOCALITY.—Currie, North Carolina (Yorktown Formation).

***Nassarius granifera* (Conrad),  
new combination**

PLATE 40: FIGURE 15

*Ptychosalpinx (Paranassa) granifera* Conrad, 1868:263, pl. 19: fig. 6.

*Ilyanassa granifera* (Conrad).—Gardner, 1948; pl. 31: fig. 10.

DISCUSSION.—This stout species is distinct in having about evenly sized and evenly spaced axial and spiral cords so that the entire exterior surface appears to have nodes approximately equally spaced.

Gardner (1948) recorded this species from localities in Virginia and North Carolina (not Waccamaw Formation localities) and Caloosahatchee at Nashua, Florida. This species was not recorded by Olsson and Harbison (1953).

FIGURED SPECIMEN.—USNM 204084 from USGS 25364.

OCCURRENCE.—This species is found at section 4 (D).

TYPE LOCALITY.—Virginia.

***Nassarius schizopyga?* (Dall),  
new combination**

PLATE 41: FIGURES 1–4

*Ilyanassa (porcina var.?) schizopyga* Dall, 1892:238.

*Ilyanassa schizopyga* Dall.—Gardner, 1948:246, pl. 31: fig. 4.

DISCUSSION.—Specimens of this species from Lee Creek show a high degree of morphologic variation. The exterior of the larger figured specimen has faint axial cords (Plate 41: figures 1, 2), whereas on the other specimen, these cords are much less in evidence, and spiral sculpture is more obvious (Plate 41: figures 3, 4).

This species was not recorded by Olsson and Harbison (1953). Gardner (1948) recorded this species from the "Duplin" and Waccamaw formations in North Carolina. Specimens from Lee Creek are questionably referred to this species.

FIGURED SPECIMENS.—USNM 204086 from USGS 25367 (Plate 41: figures 1, 2) and USNM 204087 from USGS 25339 (Plate 41: figures 3, 4).

OCCURRENCE.—This species is found at section 5 (C).

TYPE LOCALITY.—Mrs. Purdys marl bed on the Cape Fear River (Yorktown Formation).

***Nassarius scalaspira?* (Conrad),  
new combination**

PLATE 41: FIGURE 8

*Ptychosalpinx scalaspira* Conrad, 1868:263, pl. 19: fig. 4.

*Ilyanassa scalaspira* (Conrad).—Gardner, 1948:247–248, pl. 31: figs. 7, 8.

DISCUSSION.—A single specimen of this species was found at Lee Creek, and that was fragmentary, so the assignment is queried. The specimen agrees closely in morphology with specimens figured by Gardner (1948). The axial ribs are very heavy and are crossed by distinct spiral lines. Also the whorls are shouldered.

This species was not recorded by Olsson and Harbison (1953). Gardner recorded it from several localities in North Carolina and Virginia. Specimens from Lee Creek are questionably referred to this species.

FIGURED SPECIMEN.—USNM 204088 from USGS 25339.

OCCURRENCE.—Collected as spoil material.

TYPE LOCALITY.—Virginia.

**Genus *Busycon* Röding, 1798**

***Busycon spiratus pyruloides* (Say)**

PLATE 41: FIGURES 5, 6; PLATE 42: FIGURE 3

*Fulgur pyruloides* Say, 1822:237.

*Busycotyphus (Pyrofulgur) spiratus pyruloides* (Say).—Hollister, 1958:100–

102, pl. 15: figs. 10, 11; pl. 16: figs. 10, 14; pl. 17: fig. 8 [neotype designated].

*Busycon spiratum pyruloides* (Say).—Abbott, 1974:223, fig. 2451, pl. 6.

DISCUSSION.—Our figured specimen (Plate 41: figure 6) shows a pattern of small holes bored by Bryozoa. Such borings are common in many shells at Lee Creek. Plate 42: figure 3 shows a specimen in which the canal is less elevated, and we tentatively refer this specimen to this species.

This species was not recorded by Gardner (1948) or by Olsson and Harbison (1953). Hollister (1958:100) stated that this species is *Busycon pyrum* of authors (not of Dillwyn, 1817).

FIGURED SPECIMENS.—USNM 204089 from USGS 25371 (Plate 41: figures 5, 6) and USNM 204092 from USGS 25364 (Plate 42: figure 3).

OCCURRENCE.—This species is recorded from sections 2 (D), 4 (D), and 6 (C).

TYPE LOCALITY.—Neotype of Hollister was collected on Siesta Key, Sarasota, Manatee County, Florida (Holocene).

### *Busycon adversarius* Conrad

PLATE 41: FIGURE 7

*Busycon adversarium* Conrad, 1863a:560.

DISCUSSION.—Conrad introduced the name "*Busycon adversarium* C." in a list and indicated that this name takes the place of "*B. perversum* Tuomey and Holmes, (not Lam.,) Plioc. Foss, S. C. 145, 29, 3." Actually *B. perversum* is a species described by Linnaeus and not Lamarck, contrary to Conrad's reference. Also Gardner (1948:239 in text) gave an incorrect reference to *B. adversarius* when she stated that the species referred to was in Tuomey and Holmes, 1856, plate 29: figure 2, whereas the correct reference is plate 29: figure 3.

This species was not recorded by Olsson and Harbison (1953). Gardner (1948:239, pl. 35: figs. 1, 3) described a subspecies *Busycon perversum robesonense*, which is very different from "*B. perversum*" in that it has stronger spiral sculpture, the axials are more numerous and nodose rather than spiney.

FIGURED SPECIMEN.—USNM 204090 from USGS 25364.

OCCURRENCE.—This species is recorded from sections 2 (D), 3 (D, E), 4 (D), and 5 (B, C, D).

TYPE LOCALITY.—Pee Dee River, South Carolina.

### *Busycon carica* (Gmelin)

PLATE 42: FIGURES 1, 2

*Murex carica* Gmelin, 1791:3545, no. 67.

*Busycon* (*Busycon*) *aruanum*.—Hollister, 1958:70–78, pl. 8: figs. 1–3, 5–11; pl. 18: figs. 3, 5.

*Busycon carica* (Gmelin).—Abbott, 1974:222, fig. 2440.

Not *Murex aruanus* Linnaeus, 1758:753, no. 484.

DISCUSSION.—There is some controversy as to whether this species is *Murex aruanus* of Linnaeus or is *Murex carica* Gmelin. Linnaeus apparently had two species belonging to different genera when he was describing *aruanus*. The locality cited by Linnaeus (New Guinea) and the first figure cited are a species later called *Fusus probosidiferus* by Lamarck (Dodge, 1957:160–162). Gmelin (1791:3545), the first reviser of this composite species of Linnaeus, listed *aruanus* and *carica* separately as valid species, and in general the diagnoses are mutually exclusive (Dodge, 1957:160–162).

This species is not recorded by Olsson and Harbison (1953) or by Gardner (1948).

FIGURED SPECIMEN.—USNM 204091 from USGS 25364.

OCCURRENCE.—This species is recorded from sections 3 (D, E) and 4 (D).

TYPE LOCALITY.—None given.

### *Busycon concinnum* Conrad

PLATE 42: FIGURES 4, 5

*Busycon* (*Sycotypus*) *concinnum* Conrad, 1873:23.—Gardner, 1948:242–243, pl. 33: figs. 1, 3.

DISCUSSION.—This species was not recorded by Olsson and Harbison (1953). Gardner (1948) listed it from several Waccamaw Formation localities in North Carolina. The specimens from Lee Creek are very close morphologically to specimens in the Waccamaw Formation of southern North Carolina.

FIGURED SPECIMEN.—USNM 204093 from USGS 25370.

OCCURRENCE.—This species is recorded from sections 4 (D) and 6 (C).

TYPE LOCALITY.—Mr. King's marl pit, Sampson County, North Carolina.

### Genus *Fasciolaria* Lamarck, 1799

#### *Fasciolaria cronlyensis* Gardner

PLATE 43: FIGURES 1, 2

*Fasciolaria cronlyensis* Gardner, 1948:254, pl. 36: figs. 1, 2, 3, 6.

DISCUSSION.—The figured specimen is the only specimen found at Lee Creek and is the only reported occurrence outside of the type locality.

FIGURED SPECIMEN.—USNM 204094 from USGS 25364.

OCCURRENCE.—This species is recorded from section 4 (D).

TYPE LOCALITY.—Neills Eddy Landing, Columbus County, North Carolina (Waccamaw Formation).

***Fasciolaria beaufortensis*, new species**

PLATE 43: FIGURES 3-5

DIAGNOSIS.—Shell medium sized, fusiform, whorls convex, smooth except for faint, irregular growth lines, exterior spiral color bands in some specimens show about 4 thin bands on each whorl, nucleus slightly swollen, smaller than the succeeding whorls, smooth, subglobular, followed by a nearly smooth half-whorl, next half whorl with closely spaced annular folds with the interspaces and folds of about equal size, next whorl continues to have annular folds and these are crossed by 3 spiral bands, slightly incised, flat bottomed, and with the spacing between the anteriormost band and the middle band greater than that between the middle and posterior one; remaining whorls smooth with only a few faint spiral lines on the base, aperture subelliptical, prolonged forward into a moderately long anterior canal, not recurved at the end, with a small posterior canal in the upper lip junction, outer lip not thickened, lirate within, parietal wall with a thin glaze of callus, the columella somewhat thickened below and with two long oblique plaits. A spiral ridge emerges from the aperture below the suture and extends across the parietal wall to the margin of the callus.

DISCUSSION.—This species differs from the Holocene *Fasciolaria hunteri* G. Perry, 1811, and *F. tulipa* Linnaeus, 1758, in being less slender and in having ornamented early whorls.

FIGURED SPECIMENS.—USNM 204095 from USGS 25364 (Plate 43: figure 3) and USNM 204096 from USGS 25362, holotype, 82.0 mm (Plate 43: figures 4, 5).

OCCURRENCE.—This species is recorded from sections 3 (D, E) and 4 (D, E).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25362, section 3, unit D.

**Genus *Heilprinia* Grabau, 1904*****Heilprinia caloosaensis malcolmi*, new subspecies**

PLATE 43: FIGURES 6-8

DIAGNOSIS.—Shell fusiform, with a rounded body-whorl. Sculpture of axial ribs and slightly elevated spiral cords, the ribs tending to become reduced on later whorls. Sutures distinct, the adjacent area on the posterior part of each whorl wide, sloping, and appressed. Two nuclear whorls present with closely spaced axial ribs followed by about 6 postnuclear whorls which have about 4 to 5 spiral cords on the spire whorls (about 10 to 11 on the body whorl, cords also extending the length of the siphon) along with the rounded axial ribs. Whole surface of shell roughened by axial growth lines. Aperture ovate, siphonal canal nearly straight, very small posterior sinus present. Anterior end of aperture extremely narrowed and prolonged along the an-

terior canal. Inner lip with a shelf of callus, free-edged externally. Both inner and outer lip on the inner side.

DISCUSSION.—This subspecies differs from *Heilprinia caloosaensis* (Heilprin, 1887:68, pl. 1: fig. 1) in having much more rounded body whorls, less prominent spiral cords, and less prominent axial ribs. *Heilprinia caloosaensis florida* (Olsson and Harbison, 1953:219) differs in having a much more shouldered appearance with stronger axial ribs and a longer siphonal canal in proportion to the rest of the shell. Our subspecies differs from *Heilprinia caloosaensis carolinensis* (Dall, 1892:234) in having a smoother and more extended posterior area on each whorl.

FIGURED SPECIMENS.—USNM 204097 from USGS 25648, holotype, height 76.5 mm (Plate 43: figures 6, 8), USNM 204098 from USGS 25371 (Plate 43: figure 7).

OCCURRENCE.—This species is recorded as float.

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25638.

**Genus *Oliva* Bruguière, 1789*****Oliva carolinensis* (Conrad)**

PLATE 44: FIGURES 5, 6

*Dactylus Carolinensis* Conrad, 1863a:563; 1863b:584.

*Oliva carolinensis* (Conrad).—Olsson and Harbison, 1953:184.

DISCUSSION.—*Oliva sayana* is a morphologically variable species that is strongly influenced by the environment. Examination of some Holocene collections suggests that more highly spired forms may be associated with certain nearshore conditions and more lowly spired ones with deeper water. We believe the specimens at Lee Creek to represent the low-spired form of this species. The more highly spired form is figured by Olsson and Harbison (1953:184, pl. 29: figures 4, 4a). Richards (1968:112) suggested that the specimen figured by Olsson and Harbison (their pl. 29: fig 4) may be one of Conrad's type specimens (ANSP 14654). Conrad did not figure his specimen. This species was not recorded by Gardner (1948).

FIGURED SPECIMEN.—USNM 204099 from USGS 25371.

OCCURRENCE.—This species is recorded from section 5 (B).

TYPE LOCALITY.—"Dauphin County, North Carolina, Professor Mitchell" (Conrad, 1863a) (actually Duplin County; probably Yorktown Formation).

**Genus *Olivella* Swainson, 1831*****Olivella mutica* (Say)**

PLATE 44: FIGURE 7

*Oliva mutica* Say, 1822:228.

*Olivella (Dactylidia) mutica* (Say).—Olsson and Harbison, 1953:186, pl. 39: fig. 7.

DISCUSSION.—Specimens at Lee Creek are referred to this species. There is great morphologic variation in this group, and resolution of this variation needs to be done on the Holocene species. Olsson and Harbison (1953, pl. 39: fig. 7) recorded this species from St. Petersburg and from Fort Thompson, Florida. Their figured specimen is somewhat stouter than our specimens. Such differences may be only local differences. Say's type specimen is apparently lost. Gardner (1948) did not record this species.

FIGURED SPECIMEN.—USNM 204100 from USGS 25366.

OCCURRENCE.—This species is found at sections 2 (B, D), 3 (D, E), 4 (B, D), and 5 (B, C, D, E).

TYPE LOCALITY.—“Inhabits the southern shores. . .,” East Florida.

### Genus *Vexillum* Röding, 1798

#### *Vexillum wandoense* (Holmes)

PLATE 45: FIGURE 8

*Volutimitra wandoensis* Holmes, 1859:77, pl. 12: figs. 10, 10a.  
*Vexillum* (*Costellaria*) *wandoense* (Holmes).—Abbott, 1974:240.

DISCUSSION.—This species was not recorded by Gardner (1948) or by Olsson and Harbison (1953). The larger number of axial ribs and spiral cords distinguish this species from *Vexillum holmesii* (Dall, 1890).

FIGURED SPECIMEN.—USNM 204101 from USGS 25366.

OCCURRENCE.—This species is recorded from section 5 (B, C).

TYPE LOCALITY.—“Post-Pliocene marl of Wando River,” South Carolina (Holmes, 1859:77).

### Genus *Volutifusus* Conrad, 1863

#### *Volutifusus typus* Conrad

PLATE 44: FIGURES 1–3

*Volutifusus typus* Conrad, 1866:67, pl. 3: fig. 2.

DISCUSSION.—Conrad (1866) stated that this species has a columella with 2 distinct little prominent folds. The specimens at Lee Creek agree quite well with Conrad's figure and on the surface of all specimens, especially younger specimens, fine spiral threads may be seen (Plate 44: figure 1). Martin (1904:175) incorrectly referred the specimens in zone 17 of the Choptank Formation to this species. In the Eastover Formation, the specimens of this genus are more shouldered in the early whorls and have a more enameled exterior with no spiral lines showing. Also the columella is not as straight in these Miocene specimens. In the upper part of the Yorktown Formation (fragmentary shell beds) at 0.5 mile (0.8 km) above Morgarts Beach, Isle of Wight County, Virginia, a specimen was found which is heavily

glazed on the exterior of the shell, so much so as to obscure the early whorls. Also the columella is strongly curved, but the specimen is similar to the Lee Creek species in not being shouldered. This species was not recorded by Gardner (1948) or by Olsson and Harbison (1953).

The type species of *Volutifusus* is *V. mutabilis* (Conrad, 1834) from the St. Marys Formation, St. Marys River, Maryland.

FIGURED SPECIMENS.—USNM 204102 from USGS 25364 (Plate 44: figure 1) and USNM 204103 from USGS 25364 (Plate 44: figures 2, 3).

OCCURRENCE.—This species is found at sections 3 (D, E), 4 (D), and 6 (C).

TYPE LOCALITY.—North Carolina.

### Genus *Trigonostoma* Blainville, 1827

#### *Trigonostoma* sp.

PLATE 45: FIGURE 7

DISCUSSION.—Only one fragment of a specimen belonging to this genus was found.

FIGURED SPECIMEN.—USNM 204109 from USGS 25362.

OCCURRENCE.—This species is recorded from section 3 (D).

### Genus *Granulina* Jousseume, 1888

#### *Granulina ovuliformis* (d'Orbigny)

PLATE 44: FIGURE 4; PLATE 45: FIGURE 1

*Marginitella ovuliformis* d'Orbigny, 1842(2):101., pl. 20: figs. 33–35.

*Granulina ovuliformis* (d'Orbigny).—Abbott, 1974:254, fig. 2774.

*Marginitella* (*Gibberula*) *lachrimula* Gould, 1862:238.

*Cypraolina lachrimula* (Gould).—Gardner, 1948:263–264, pl. 38: figs 20, 21.—Olsson and Harbison, 1953:200.

DISCUSSION.—Olsson and Harbison (1953) recorded this species as abundant from St. Petersburg, Florida. Gardner (1948) recorded it from Suffolk, Virginia, from Hamilton Bluff on the Roanoke River, North Carolina, and from Wilson, Colerain Landing, and Natural Well, all in North Carolina.

FIGURED SPECIMENS.—USNM 204107 from USGS 25368 (Plate 44: figure 4) and USNM 204129 from USGS 25368 (Plate 45: figure 1). The specimen in figure 4 lacks part of the thin outer shell layer.

OCCURRENCE.—This species is common in section 5, units B and C, abundant in unit D, and rare in unit E. This species is also recorded from sections 3 (D, E) and 4 (D).

ORIGINAL LOCALITIES.—Martinique, Saint-Thomas, Guadeloupe (Holocene).

**Genus *Prunum* Herrmannsen, 1852*****Prunum limatulum* (Conrad), new combination**

PLATE 44: FIGURES 11-14

*Marginella limatula* Conrad, 1834:140.

DISCUSSION.—Plate 44: figure 11 shows some of the original color pattern of the shell, especially where some of the outer layer is missing. This species differs from *Prunum pardalis* (Dall, 1890) in being stouter and in having a lower spire. *Prunum eulima* (Dall, 1892) differs in being more slender than *Prunum limatulum*. This species was not recorded by Gardner (1948) or by Olsson and Harbison (1953).

FIGURED SPECIMENS.—USNM 204105 from USGS 25366 (Plate 44: figure 11) and USNM 204106 from USGS 25366 (Plate 44: figures 12-14).

OCCURRENCE.—This species is abundant in section 5, units B, C, and D, and is common in unit E. It is also recorded from sections 1 (E), 3 (D, E), 4 (B, D, E), and 6 (C).

TYPE LOCALITY.—Suffolk, Virginia.

**Genus *Dentimargo* Cossmann, 1899*****Dentimargo polyspira?* (Olsson and Harbison),  
new combination**

PLATE 44: FIGURES 8, 9

*Marginella (Eburnospira) polyspira* Olsson and Harbison, 1953:202, pl. 31: figs. 3, 3a, 3b.

DISCUSSION.—Specimens from Lee Creek are tentatively referred to this species. They differ from that figured by Olsson and Harbison (1953) in being smaller and in having a less widely flaring lip with a narrower outline. *Dentimargo aureocincta* (Stearns, 1872) is less elongate and the sutures are more impressed.

FIGURED SPECIMEN.—USNM 204104 from USGS 25367.

OCCURRENCE.—This species is common in section 5, units B, C, and D, and rare in unit E. It is also recorded from sections 2 (D), 3 (D, E), and 4 (B, D).

TYPE LOCALITY.—St. Petersburg, Florida (Caloosahatchee Formation).

**Genus *Volvarina* Hinds, 1844***Volvarina* Hinds fide Keen, 1971:635.***Volvarina avena* (Kiener), new combination**

PLATE 44: FIGURE 10

*Marginella avena* Kiener, 1834:17-18.

DISCUSSION.—The figured specimen is the only one found in the Lee Creek samples. This species was not recorded by Olsson and Harbison (1953) or by Gardner (1948). Our specimen is similar to that figured by Warmke and Abbott (1961:129, pl. 23H). Our specimen is a little less slender than that shown in their figure.

FIGURED SPECIMEN.—USNM 204108 from USGS 25366.

OCCURRENCE.—This species is rare at section 5, unit B.

TYPE LOCALITY.—“Habite les mers des Indes Occidentales” (Kiener, 1834:18) (West Indies).

**Genus *Conus* Linnaeus, 1758*****Conus adversarius* Conrad**

PLATE 45: FIGURES 2, 3

*Conus adversarius* Conrad, 1840b:388.

DISCUSSION.—This species was not recorded by Gardner (1948). Olsson and Harbison (1953:171, pl. 27: figs. 1, 1a) recorded *Conus adversarius tryoni* (Heilprin, 1886) from St. Petersburg, LaBelle, and Ortona Locks, Florida. The nominate subspecies is larger with strongly descending sutures.

FIGURED SPECIMEN.—USNM 204110 from USGS 25364.

OCCURRENCE.—This species is recorded from sections 3 (D, E) and 4 (D).

TYPE LOCALITY.—Duplin County, North Carolina (Yorktown Formation).

**Genus *Strioterebrum* Sacco, 1891*****Strioterebrum* sp. cf. *S. petiti* Olsson**

PLATE 45: FIGURE 12

DISCUSSION.—Although only a fragment, this specimen resembles *Strioterebrum petiti* Olsson, 1967. His specimen is from the Waccamaw Formation, Crescent Beach Airport, South Carolina.

FIGURED SPECIMEN.—USNM 204119 from USGS 25369.

OCCURRENCE.—This species is recorded from section 5 (E).

***Strioterebrum* sp.**

PLATE 45: FIGURE 11

DISCUSSION.—Although somewhat similar to the specimen from Lee Creek figured as *Strioterebrum* sp. cf. *S. petiti* Olsson (Plate 45: figure 12), this specimen differs in that it has fewer spiral cords that are bounded by more deeply impressed lines. Also, axial cords on this specimen are fewer. This is probably an undescribed species.

FIGURED SPECIMEN.—USNM 204118 from USGS 25366.

OCCURRENCE.—This species is recorded from section 5 (B).

### Genus *Cymatosyrinx* Dall, 1889

#### *Cymatosyrinx lunata* (Lea)

PLATE 45: FIGURES 4–6

*Pleurotoma lunatum* Lea, 1843a:11; 1846:269–270, pl. 37: 93.

DISCUSSION.—Collections of this species from a single horizon from various localities in the Coastal Plain show this to be a highly variable species. Variation in the expression of exterior sculpture (number of axial ribs and their strength) and variation in the ratio of height to length is common. This species was not recorded by Gardner (1948). Fargo (1953:369) recorded this species from St. Petersburg, Florida.

FIGURED SPECIMENS.—USNM 204111 from USGS 25367 (Plate 45: figures 4, 6) and USNM 204112 from USGS 25368 (Plate 45: figure 5).

OCCURRENCE.—This species is recorded from section 5 (B, C, D).

TYPE LOCALITY.—Petersburg, Virginia (Yorktown Formation.)

### Genus *Sedilia* Fargo, 1953

#### *Sedilia* sp. aff. *S. sedilia* (Dall)

PLATE 45: FIGURES 9, 10

*Sedilia* sp., near *Drillia sedilia* Dall.—Fargo, 1953:370, pl. 17: fig. 1.

DISCUSSION.—The type locality of *Sedilia sedilia* (Dall) is “Caloosahatchie beds, rare.” Specimens from Lee Creek correspond quite well to that figured by Fargo (1953, pl. 17) as *Sedilia* sp., near *Drillia sedilia* Dall. These specimens differ from *Sedilia sedilia* (Dall, 1890, pl. 2: fig. 1) in having much fewer axial ribs and weaker spiral cords.

FIGURED SPECIMEN.—USNM 204113 from USGS 25368.

OCCURRENCE.—This species is recorded from 5 (D).

### Genus *Vitricythara* Fargo, 1953

#### *Vitricythara micromeris* (Dall)

PLATE 46: FIGURE 4

*Cythara micromeris* Dall, 1903, pl. 60: fig. 16 [no text].

DISCUSSION.—Our sole specimen of this species from Lee Creek is small. We refer this specimen to *V. micromeris* (Dall)

although there are some differences in sculpture and our specimen is not as shouldered. This species was not recorded by Gardner (1948). Fargo (1953:396, pl. 21: fig. 2) recorded this species from St. Petersburg, Florida.

FIGURED SPECIMEN.—USNM 204117 from USGS 25368 (SEM photograph).

OCCURRENCE.—This species is recorded from section 5 (D).

TYPE LOCALITY.—Pliocene marl of Shell Creek, Florida.

### Genus *Glabrocythara* Fargo, 1953

#### *Glabrocythara* sp.

PLATE 46: FIGURES 3, 5

DISCUSSION.—Two worn specimens from Lee Creek are referred to this rare genus.

FIGURED SPECIMENS.—USNM 204115 from USGS 25368 (Plate 46: figure 3, SEM photograph) and USNM 204116 from USGS 25367 (questionably referred to this species) (Plate 46: figure 4).

OCCURRENCE.—This species is recorded from section 5 (C, D).

### Genus *Brachygythara* Woodring, 1928

#### *Brachygythara reidenbachi*, new species

PLATE 46: FIGURES 1, 2

DIAGNOSIS.—Shell small, slender, apex blunt, whorls angular at the periphery, constricted to the impressed sutures. Shoulders steeply sloping, about half the height of the whorls, the protoconch of 2 to 2½ volutions, blunt at apex, its tip minute, immersed, rapidly enlarging, the first volution smooth, the following with fairly strong and subequal spiral and axial threads. The conch is dominated by low, narrow, rounded, fairly widely spaced axial ribs, higher at the periphery, narrowing posteriorly, and more widely spaced on later whorls. The entire surface of the conch is covered with very fine and very closely spaced spiral cords, which are crossed by very fine, closely spaced axial cords of about the same size so that a fine-textured appearance is given to the entire surface. Aperture long and fairly narrow, almost half the total length of the shell, its width about one-third of its length, canal hardly differentiated, base slightly broken.

DISCUSSION.—This species differs from *Brachygythara galae dimonia* (Fargo, 1953) in having a much finer beaded surface sculpture, in having a shorter posterior slope on the whorls, and in having a slightly shorter aperture. Olsson's figure (1916:5, pl. 2: fig. 12) of *Mangilia smithfieldensis* Olsson, 1916, appears similar to this species, but his description is not complete enough to be definitive, his figured



specimen does not show any of the fine sculpture (largely because of the quality of the figure), and his specimen is almost twice as large as our specimens.

This species is named in honor of F.W. Reidenbach, a paleontologist who has given much encouragement and guidance to the junior author.

**FIGURED SPECIMEN.**—USNM 204114 from USGS 25369, holotype, height 3.6 mm (SEM photograph).

**OCCURRENCE.**—This species is recorded from sections 4 (D) and 5 (D, E).

**TYPE LOCALITY.**—Lee Creek Mine, Beaufort County, North Carolina, USGS 25369, section 5, unit E.

### Genus *Odostomia* Fleming, 1813

#### *Odostomia simplex* (Lea), new combination

PLATE 46: FIGURE 6

*Acteon simplex* Lea, 1843a:8; 1846:258. pl. 36: fig. 62.

**DISCUSSION.**—This species was not recorded by Gardner (1948) or by Olsson and Harbison (1953). *Odostomia laevigata* d'Orbigny, 1842, as illustrated by Warmke and Abbott (1961:147, pl. 26k), has more rounded whorls and more whorls in proportion to its size. *Odostomia canaliculata* C.B. Adams, 1850, as illustrated by Warmke and Abbott (1961:148, pl. 26l) has a more square aperture. We have compared our specimen with that of the type.

**FIGURED SPECIMEN.**—USNM 204118 from USGS 25369 (SEM photograph).

**OCCURRENCE.**—This species is recorded from section 5 (C, D).

**TYPE LOCALITY.**—Petersburg, Virginia (Yorktown Formation).

#### *Odostomia turbinatus* (Lea), new combination

PLATE 46: FIGURE 7

*Acteon turbinatus* Lea, 1843a:7; 1846:256, pl. 36: fig. 56.

**DISCUSSION.**—This species was not recorded by Gardner (1948) or by Olsson and Harbison (1953). *Odostomia turbinatus* has much more rapidly expanding whorls than any species illustrated by Warmke and Abbott (1961). We have compared our specimen with the type specimen.

**FIGURED SPECIMEN.**—USNM 204119 from USGS 25368 (SEM photograph).

**OCCURRENCE.**—This species is recorded from section 5 (D).

**TYPE LOCALITY.**—Petersburg, Virginia (Yorktown Formation).

### Genus *Chrysallida* Carpenter, 1856

#### *Chrysallida beaufortensis*, new species

PLATE 47: FIGURE 4

**DIAGNOSIS.**—Shell large, stout, early whorls decollated in all material, postnuclear whorls very slightly rounded and strongly squarely shouldered, spiral sculpture consists of four strong low cords. The first cord is at the summit. Cords separated by impressed lines. Juncture of axial ribs and spiral cords form small tubercles on all cords. Spaces enclosed by the axial ribs and spiral cords are deep round pits; suture constricted and rendered very conspicuous by the shouldered summit of the whorls. Aperture elongate oval, columella stout, vertical. Parietal wall glazed by thin callus. Outer lip gently curved and rendered wavy by the external spiral cords.

**DISCUSSION.**—This species differs from *Chrysallida seminuda* (C.B. Adams, 1839) in having a more elongate aperture and stronger axial sculpture. This species has a more rounded aperture, less strong spiral cords, and is less elongate than *Chrysallida stimpsoni* Bartsch, 1955.

**FIGURED SPECIMEN.**—USNM 204121 from USGS 25369, holotype, height 2.9 mm (SEM photograph).

**OCCURRENCE.**—This species is recorded from section 5 (E).

**TYPE LOCALITY.**—Lee Creek Mine, Beaufort County, North Carolina, USGS 25369, section 5, unit E.

#### *Chrysallida auroraensis*, new species

PLATE 47: FIGURE 8

**DIAGNOSIS.**—Shell elongate ovate, moderately large, axial ribs not stronger than spiral cords, particularly in later whorls, 4 spiral cords between the sutures of later whorls, suture deeply channeled, base umbilicated, basal spiral cords strong. Axial ribs only slightly expressed after the fourth whorl, aperture oval and somewhat angulated posteriorly, columella is slightly curved with the edges reflected and with a strong fold at its insertion. Outer lip is gently curved and rendered wavy by the external spiral cords.

**DISCUSSION.**—This species differs from *Chrysallida granulata* (H.C. Lea, 1843) in being less elongate and in having a heavier shell. Warmke and Abbott (1961:148, pl. 26f) recorded *Odostomia* (*Chrysallida*) *gemmulosa* (C.B. Adams, 1850) from the Holocene of the West Indies. It is much more elongate and more strongly sculptured than *C. auroraensis*. Recorded from the Holocene of the Atlantic Coast of the United States to the West Indies (Warmke and Abbott, 1961:148, pl. 26e) is *Odostomia* (*Chrysallida*) *seminuda* (C.B. Adams, 1839), which differs from *C. auroraensis* in having much more deeply channeled spiral lines and a less rounded base on the lower part of the body whorl.

FIGURED SPECIMEN.—USNM 204122 from USGS 25361, holotype, height 3.5 mm (SEM photograph).

OCCURRENCE.—This species is recorded from section 2 (E).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25361, section 2, unit E.

### Genus *Orinella* Dall and Bartsch, 1904

#### *Orinella beaufortensis*, new species

PLATE 46: FIGURE 8

DIAGNOSIS.—Shell elongate-conic, suture slightly impressed, whorls slightly rounded and periphery base rounded, narrowly umbilicated. Aperture broadly oval, columella with a single strong fold, which gives it a twisted appearance. Outer lip flaring.

DISCUSSION.—This species is shorter, broader, with a stronger fold on the columella and having a more flaring outer lip than *Orinella pliocena* Bartsch, 1955.

FIGURED SPECIMEN.—USNM 204120 from USGS 25368, holotype, height 2.7 mm (SEM photograph).

OCCURRENCE.—This species is recorded from section 5 (D).

TYPE LOCALITY.—Lee Creek Mine, Beaufort County, North Carolina, USGS 25368, section 5, unit D.

### Genus *Pyrgiscus* Philippi, 1841

#### *Pyrgiscus daedaleum* (Lea)

PLATE 47: FIGURE 6

*Cerithium daedaleum* Lea, 1843a:11; 1846:269, pl. 37: fig. 91.

DISCUSSION.—This species was not recorded by Gardner (1948) or by Bartsch (1955).

FIGURED SPECIMEN.—USNM 204124 from USGS 25366 (SEM photograph).

OCCURRENCE.—This species is recorded from section 5 (B).

TYPE LOCALITY.—Petersburg, Virginia (Yorktown Formation).

#### *Pyrgiscus* sp.

PLATE 47: FIGURE 7

DISCUSSION.—This *Pyrgiscus* specimen is similar to specimens of *Pyrgiscus daedaleum* (H. C. Lea) but differs in having a much more squarely shaped aperture. The figured specimen is somewhat worn.

FIGURED SPECIMEN.—USNM 204125 from USGS 25368.

OCCURRENCE.—This species is recorded from section 5 (B).

### Genus *Turbonilla* Risso, 1826

#### *Turbonilla abrupta* Bush

PLATE 47: FIGURE 5

*Turbonilla abrupta* Bush, 1899:168, pl. 8: fig. 4.

DISCUSSION.—This species was not recorded by Gardner (1948). It is listed by Warmke and Abbott (1961:149, pl. 26c) from the West Indies (Holocene).

FIGURED SPECIMEN.—USNM 204123 from USGS 25367 (SEM photograph).

OCCURRENCE.—This species is recorded from sections 2 (B), 3 (D), 4 (B), and 5 (B, C, D, E).

TYPE LOCALITY.—St. Thomas, West Indies (Holocene).

### Genus *Ringicula* Deshayes, 1838

#### *Ringicula semistriata* d'Orbigny

PLATE 47: FIGURES 1, 2

*Ringicula semi-striata* d'Orbigny, 1853, pl. 21: figs. 17, 19.

DISCUSSION.—The original figures of this species by d'Orbigny show a specimen with much more pronounced spiral lines on the interior canal. Warmke and Abbott (1961:141, pl. 29k) reported this species from the southeastern United States Holocene and from the West Indies. Their figure shows stronger tooth processes and a heavier outer lip, with a pronounced fold in the outer lip. Our figured specimen is somewhat worn, which may account for some differences in the finer details of sculpture.

This genus was not recorded by Gardner (1948). Olsson and Harbison (1953:166) recorded *Ringicula* (*Ringiculella*) *floridana* (Dall, 1889) from St Petersburg, Florida. This species differs from *R. semistriata* in having strong spiral grooving over the whole shell.

FIGURED SPECIMEN.—USNM 204126 from USGS 25369 (SEM photograph).

OCCURRENCE.—This species is found at section 5 (E).

TYPE LOCALITY.—“La hemos hallado en la arena traída de La Jamaica por M. de Candé” (d'Orbigny, 1842) (Jamaica).

### Genus *Acteocina* Gray, 1847

#### *Acteocina candei* (d'Orbigny)

PLATE 47: FIGURE 3

*Bulla candei* d'Orbigny, 1841(1):128, pl. 4bis: figs. 1, 4.

*Acteocina candei* (d'Orbigny).—Olsson and Harbison, 1953:160, pl. 25: figs. 7, 7a, 7b.

DISCUSSION.—This species shows considerable variation with regard to the height of the whorls and the flaring of the lip. Gardner (1948:278–279, pl. 38: figs. 5, 6) reported a subspecies *Acteocina canaliculata vaughani* Gardner, 1948, from Neills Eddy Landing, Waccamaw Formation, North Carolina. Olsson and Harbison (1953:159, 160) recorded *A. canaliculata* (Say, 1827) from Fort Thompson and *A. candei* (d'Orbigny, 1841) from St. Petersburg, Florida.

FIGURED SPECIMEN.—USNM 204127 from USGS

25367 (SEM photograph).

OCCURRENCE.—This species is found at sections 1 (E), 2 (D), 4 (D, E), and 5 (B, C, D, E).

ORIGINAL LOCALITIES. “Nous avons trouvé cette espèce dans le sable de Cuba rapporté par M. de la Sagra, et dans celui de la Guadeloupe, de Saint Thomas et de la Jamaïque, recueilli par M. Ferdinand de Candé” (d'Orbigny, 1842:129) (Cuba, Guadeloupe, Saint Thomas, and Jamaica).

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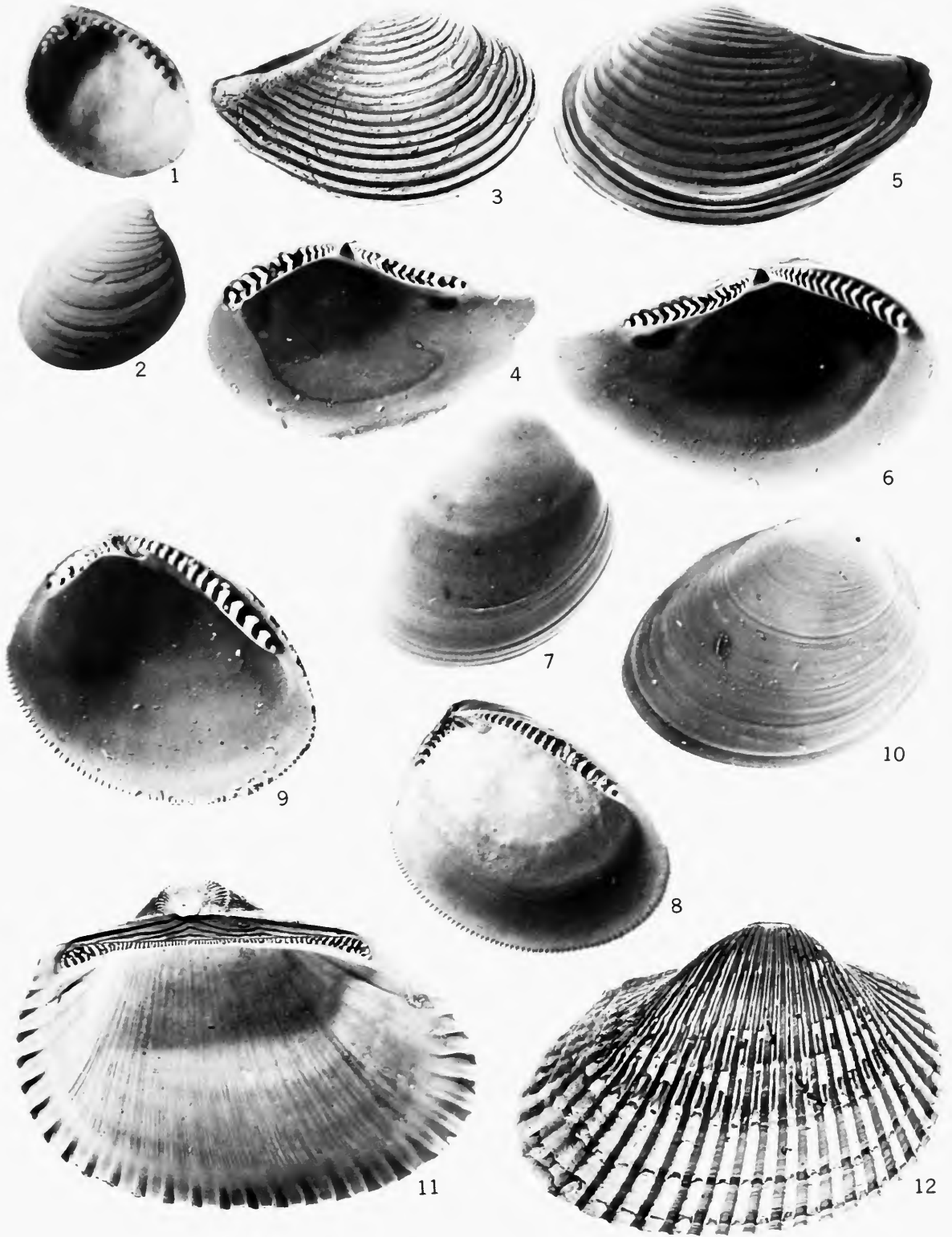
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## Plates



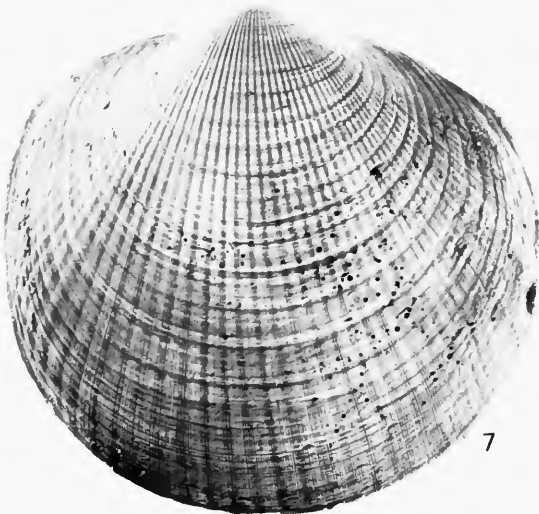
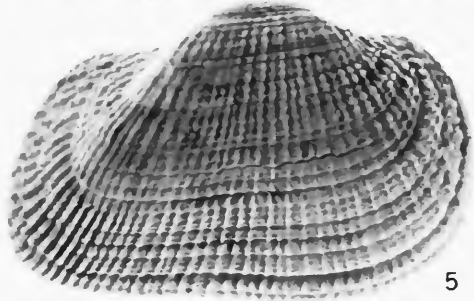
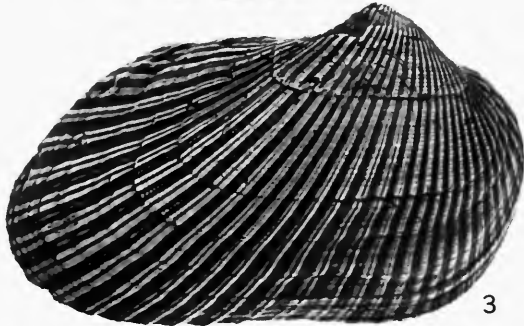
## PLATE 1

- 1, 2. *Nucula taphria* Dall, USNM 203878 from USGS 25366, right valve, length 2.3 mm: 1, interior view; 2, exterior view.
- 3, 4. *Nuculana acuta* (Conrad), USNM 203880 from USGS 25368, right valve, length 6.0 mm: 3, exterior view; 4, interior view.
- 5, 6. *Nuculana acuta* (Conrad), USNM 203881 from USGS 25368, left valve, length 8.2 mm: 5, exterior view; 6, interior view.
- 7, 8. *Nucula proxima* Say, USNM 203877 from USGS 25366, right valve, length 9.0 mm: 7, exterior view; 8, interior view.
- 9, 10. *Nucula pilkeyi*, new species, holotype, USNM 203879 from USGS 25368, right valve, length 5.7 mm: 9, interior view, 10, exterior view.
- 11, 12. *Anadara aequicostata* (Conrad), USNM 203882 from USGS 25364, right valve, length 50.4 mm: 11, interior view; 12, exterior view.



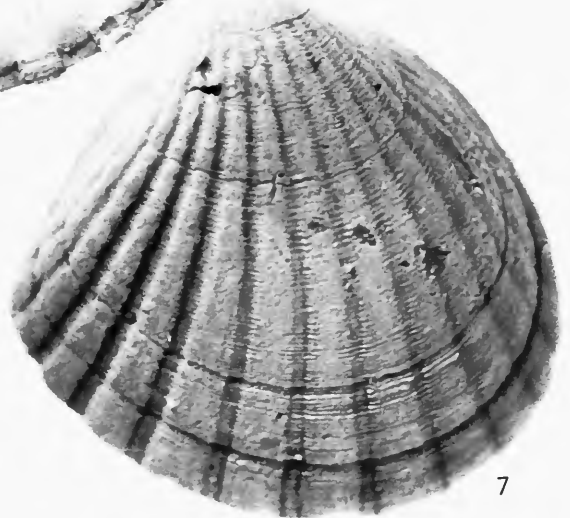
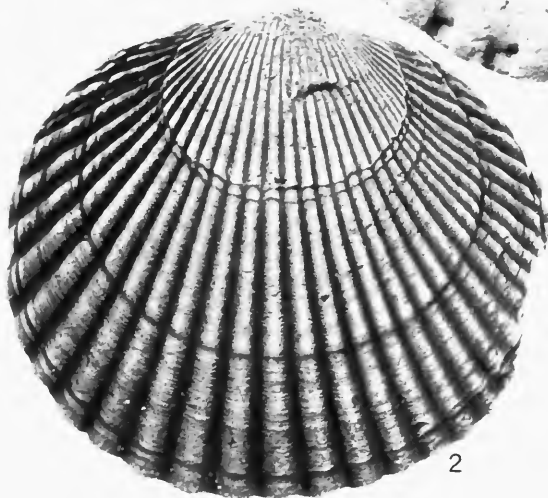
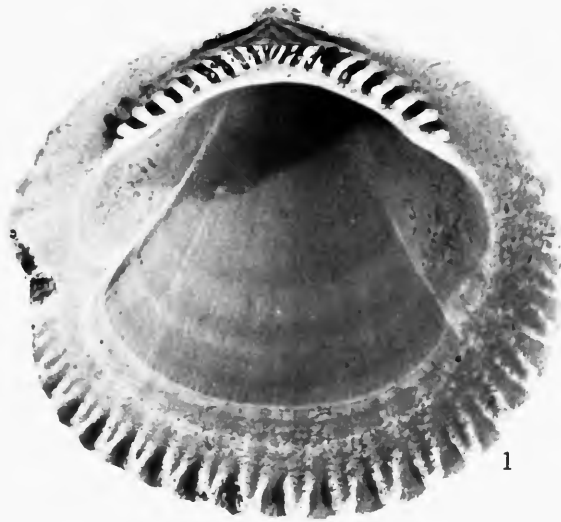
## PLATE 2

- 1, 2. *Anadara aequicostata* (Conrad), USNM 203883 from USGS 25364, right valve, length 37.5 mm: 1, exterior view; 2, interior view.
- 3, 4. *Noetia limula* (Conrad), USNM 203884 from USGS 25364, right valve, length 63.9 mm: 3, exterior view; 4, interior view.
- 5, 6. *Quadrilatera adamsi* (Dall), USNM 203885 from USGS 25368, right valve, length 13.2 mm: 5, exterior view; 6, interior view.
- 7, 8. *Glycymeris americana* (Defrance), USNM 203886 from USGS 25364, left valve, length 102.6 mm: 7, exterior view; 8, interior view.



## PLATE 3

- 1, 2. *Glycymeris* sp., USNM 203890 from USGS 25366, left valve, length 18.8 mm: 1, interior view; 2, exterior view.
3. *Glycymeris arata* (Conrad), USNM 203887 from USGS 25367, interior view of right valve, length 21.2 mm.
- 4, 5. *Glycymeris arata* (Conrad), USNM 203888 from USGS 25366, right valve, length 11.2 mm: 4, exterior view; 5, interior view.
- 6, 7. *Glycymeris slaani*, new species, holotype, USNM 203889 from USGS 25367, left valve, length 6.6 mm: 6, interior view; 7, exterior view.



## PLATE 4

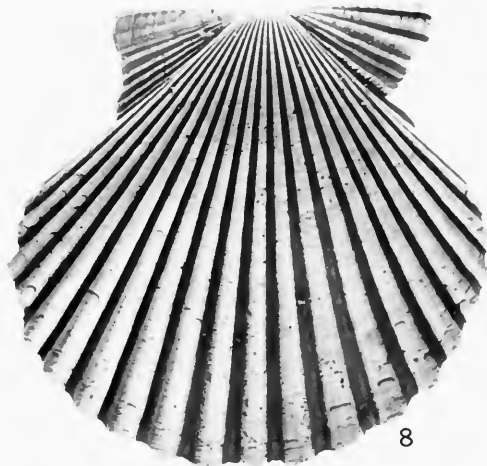
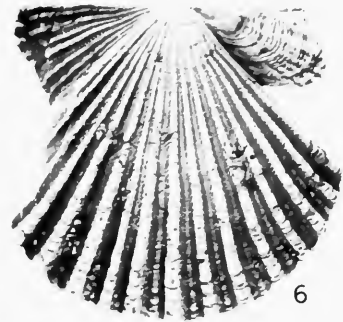
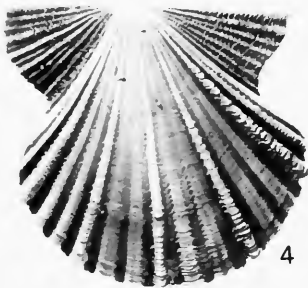
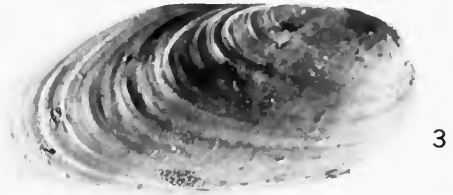
- 1, 2. *Mytilus* sp. aff. *M. edulis* Linnaeus, USNM 203891 from USGS 25366, left valve, length 9.7 mm: 1, exterior view; 2, interior view.
- 3, 4. *Crenella decussata* (Montagu), USNM 203893 from USGS 25367, right valve, length 3.1 mm: 3, exterior view; 4, interior view.
- 5, 6. *Crenella decussata* (Montagu), USNM 203894 from USGS 25366, right valve, length 3.1 mm: 5, exterior view; 6, interior view.
- 7, 8. *Musculus lateralis* (Say), USNM 203895 from USGS 25367, right valve, length 3.0 mm: 7, exterior view; 8, interior view.
9. *Brachidontes* sp., USNM 203892 from USGS 25367, exterior view of left valve, length 5.4 mm.
- 10, 11. *Modiolus* sp. cf. *M. modiolus* (Linnaeus), USNM 203896 from USGS 25364, right valve, length 52.2 mm: 10, interior view; 11, exterior view.
- 12, 13. *Glycymeris hummi*, new species, holotype, USNM 204136 from USGS 26123, left valve, length 65.1 mm: 12, interior view; 13, exterior view.





## PLATE 5

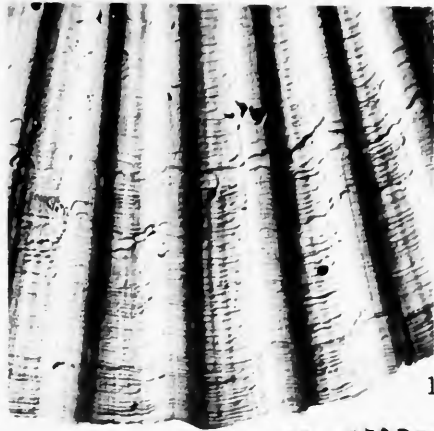
- 1–3. *Lithophaga yorkensis* Olsson, USNM 203897 from USGS 25369, length 9.6 mm: 1, articulated specimen in *Mercenaria* valve; 2, interior view of right valve; 3, exterior view of right valve.
4. *Leptopecten? auroraensis*, new species, holotype, USNM 203898 from USGS 25357, exterior view of left valve, length 11.7 mm.
- 5, 6. *Leptopecten? auroraensis*, new species, USNM 203899 from USGS 25357, right valve, length 13.4 mm: 5, interior view; 6, exterior view.
- 7–9. *Argopecten vicenarius vicenarius* (Conrad), USNM 203900 from USGS 25364, right valve, length 45.6 mm: 7, interior view; 8, exterior view; 9, anteroventral view.



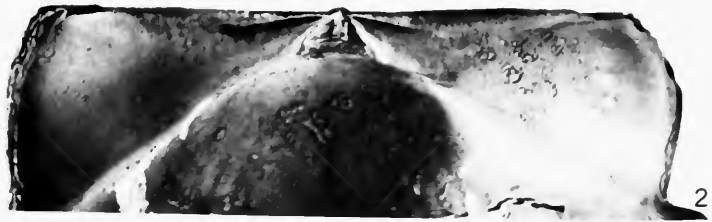
## PLATE 6

*Carolinapecten eboreus* (Conrad)

1. USNM 203901 from USGS 25364, exterior sculpture and ribbing on ventral margin of left valve, length of figured portion 40.6 mm.
- 2, 3. USNM 203902 from USGS 25362, interior hinge area and exterior dorsal margin of left hinge, length 67.2 mm.
- 4-6. USNM 203903 from USGS 25360, length of specimen 109.6 mm: 4, dorsal view of articulated specimen; 5, exterior view of right valve; 6, exterior view of left valve.
7. USNM 203904 from USGS 25364, exterior sculpture and ribbing on ventral margin of right valve, length of figured portion 44.0 mm.
- 8, 9. USNM 203905 from USGS 25364, right valve: 8, exterior dorsal margin; 9, interior hinge area, hinge length 65.7 mm.



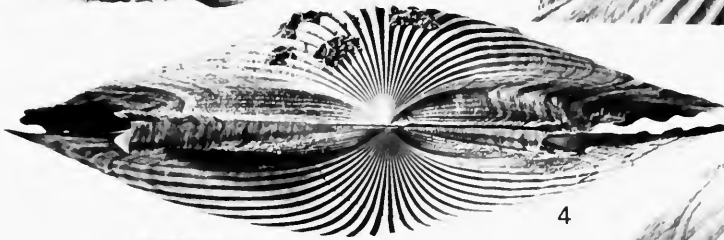
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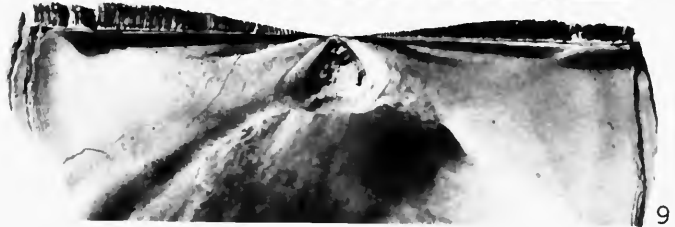
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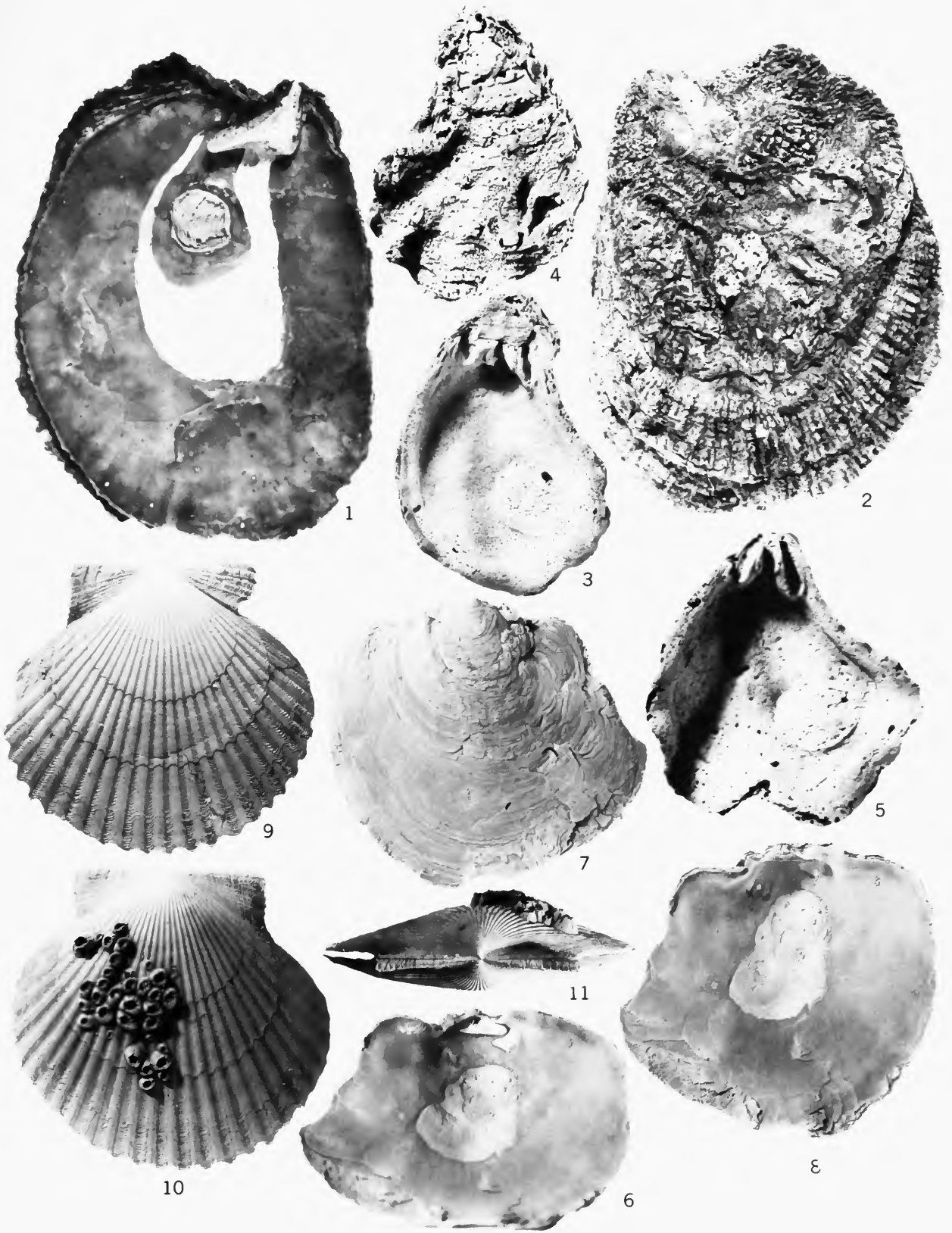
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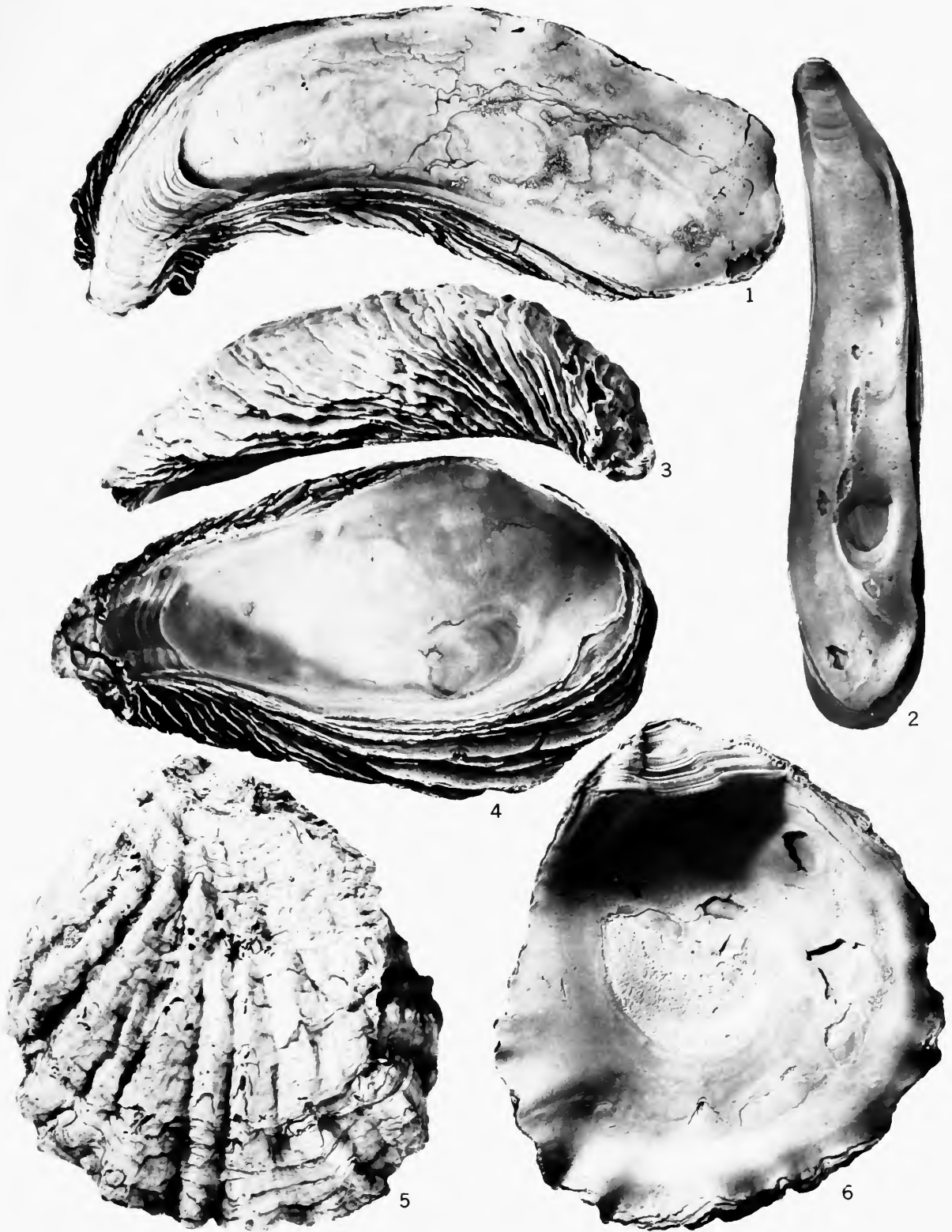
## PLATE 7

- 1, 2. *Pododesmus fragosus* (Conrad), USNM 203909 from USGS 25362, right valve, length 47.6 mm: 1, interior view; 2, exterior view.
- 3, 4. *Plicatula marginata* Say, USNM 203906 from USGS 25368, left valve, length 19.0 mm: 3, interior view; 4, exterior view.
5. *Plicatula marginata* Say, USNM 203907 from USGS 25368, interior view of left valve, length 17.1 mm.
- 6–8. *Anomia simplex* (d'Orbigny), USNM 203908 from USGS 25362, left valve, length 37.8 mm: 6, interior oblique-ventral view; 7, exterior view; 8, interior view.
- 9–11. *Carolinapecten eboreus* (Conrad), neoholotype, USNM 204134 from USGS 25724A, length of specimen 56.2 mm (right valve convexity 7.8 mm, left valve convexity 9.4 mm): 9, exterior view of right valve; 10, exterior view of left valve; 11, dorsal view of articulated valves.



## PLATE 8

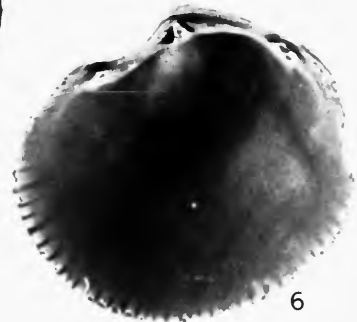
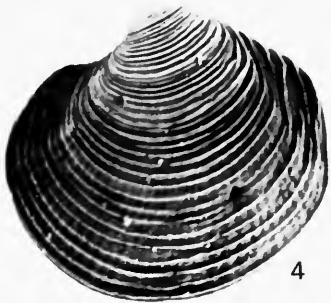
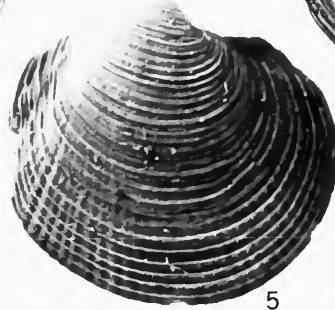
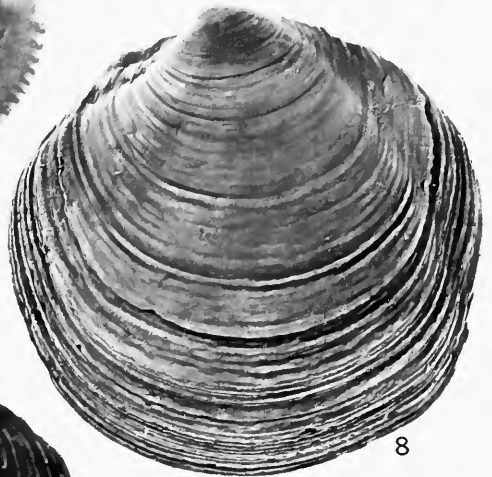
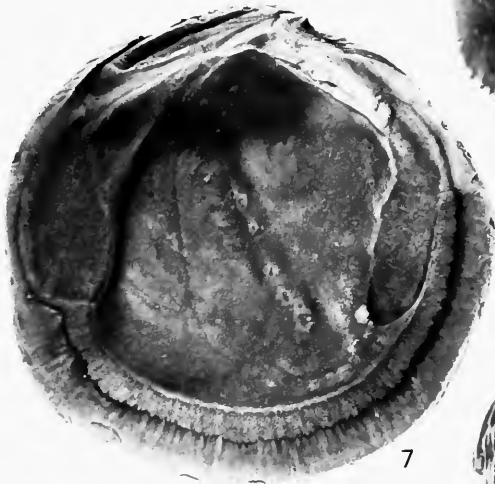
1. *Crassostrea virginica auroraensis*, new subspecies, USNM 203910 from USGS 25364, interior view of right valve, height 179.0 mm.
2. *Crassostrea virginica auroraensis*, new subspecies, USNM 203912 from USGS 25364, interior view of right valve, height 123.7 mm.
- 3, 4. *Crassostrea virginica auroraensis*, new subspecies, holotype, USNM 203911 from USGS 25364, left valve, height 117.6 mm: 3, anterior profile; 4, interior view.
- 5, 6. *Conradostrea lawrencei*, new species, holotype, USNM 203913 from USGS 25364, left valve, height 69.3 mm: 5, exterior view; 6, interior view.





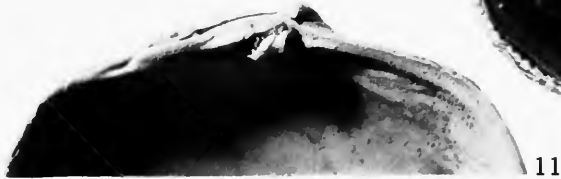
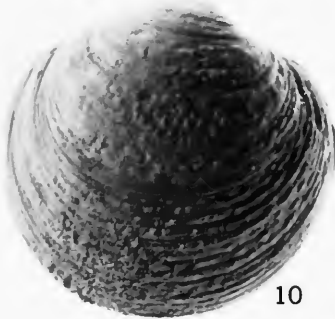
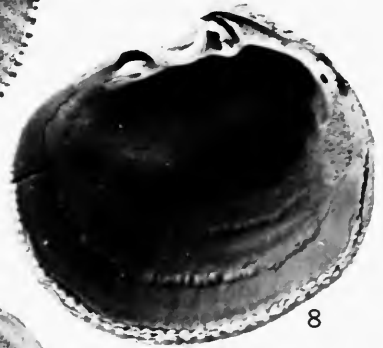
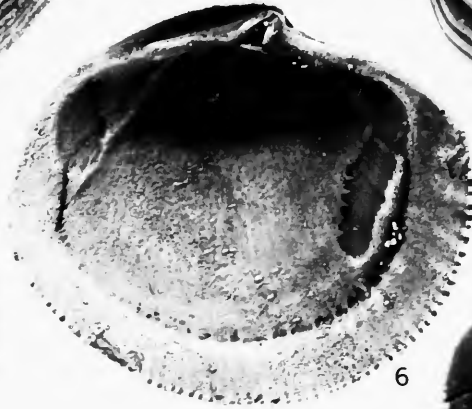
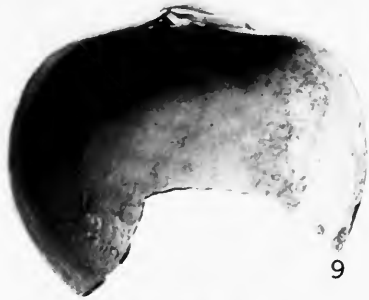
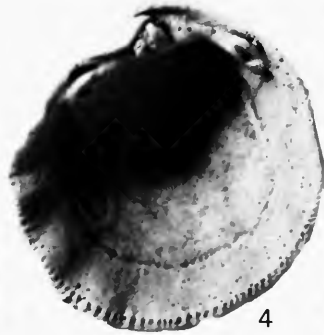
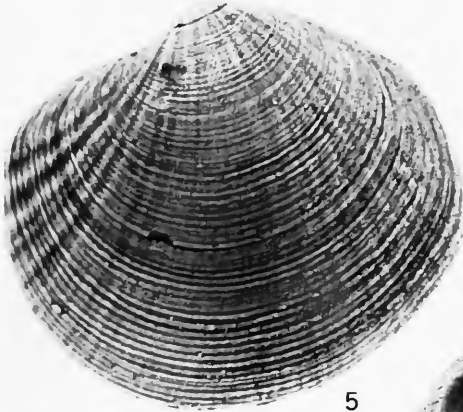
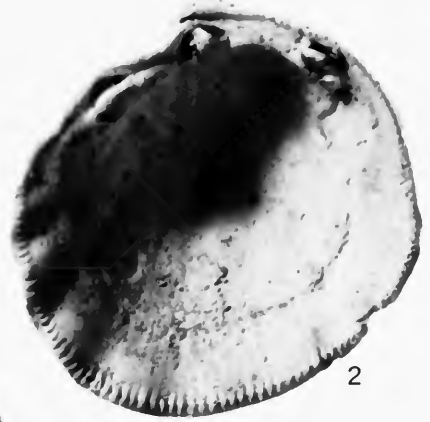
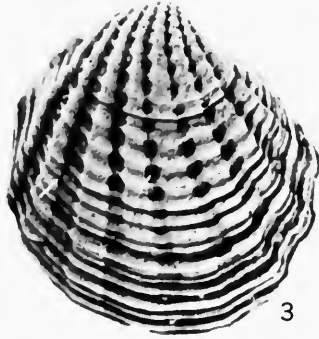
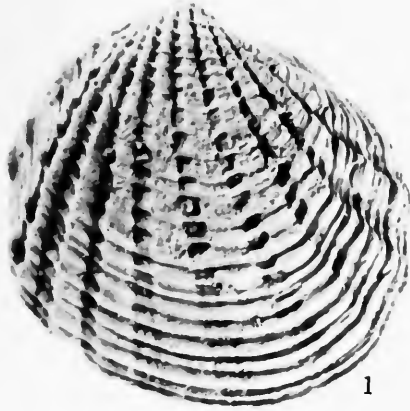
## PLATE 9

- 1, 2. *Conradostrea lawrencei*, new species, USNM 204127 from USGS 25364, right valve, height 90.0 mm: 1, interior view; 2, exterior view.
- 3, 4. *Parvilucina multilineata* (Tuomey and Holmes), USNM 203915 from USGS 25368, left valve, length 4.1 mm: 3, interior view; 4, exterior view.
- 5, 6. *Parvilucina multilineata* (Tuomey and Holmes), USNM 203916 from USGS 25368, right valve, length 4.4 mm: 5, exterior view; 6, interior view.
- 7, 8. *Stewartia anodonta floridana* (Conrad), USNM 203914 from USGS 25364, left valve, length 32.8 mm: 7, interior view; 8, exterior view.



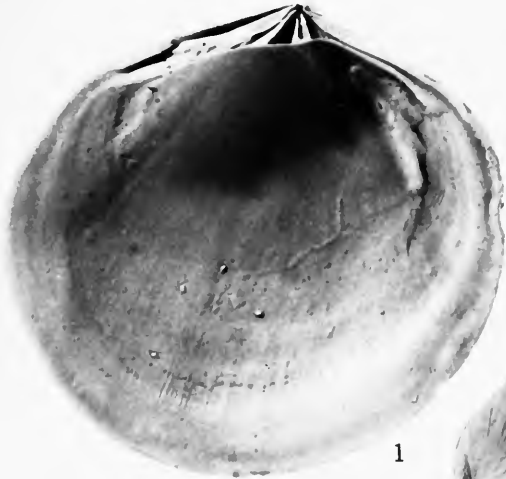
## PLATE 10

- 1, 2. *Bellucina waccamawensis* (Dall), USNM 203917 from USGS 25360, right valve, length 8.3 mm: 1, exterior view; 2, interior view.
- 3, 4. *Bellucina waccamawensis* (Dall), USNM 203918 from USGS 25369, right valve, length 6.3 mm: 3, exterior view; 4, interior view.
- 5, 6. *Callucina keenae* (Chavan), USNM 203919 from USGS 25364, left valve, length 14.1 mm: 5, exterior view; 6, interior view.
- 7, 8. *Cavilinga trisulcata* (Conrad), USNM 203920 from USGS 25368, right valve, length 5.2 mm: 7, exterior view; 8, interior view.
- 9, 12. *Phlyctiderma heroni*, new species, holotype, USNM 203921 from USGS 25367, right valve, length 12.1 mm: 9, interior view; 12, hinge view (length of hinge 11.4 mm).
10. *Phlyctiderma heroni*, new species, USNM 203922 from USGS 25367, exterior view of right valve, length 7.3 mm.
11. *Phlyctiderma heroni*, new species, USNM 203923 from USGS 25367, hinge view (length 10.0 mm) of left valve.



## PLATE 11

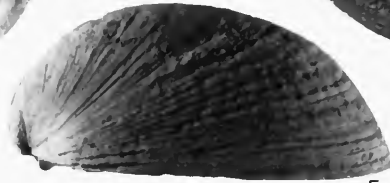
- 1-3. *Diplodonta acclinis* (Conrad), USNM 203924 from USGS 25366, length of articulated valves, length 17.3 mm: 1, interior view of left valve; 2, exterior view of left valve; 3, interior view of right valve.
- 4, 6. *Phlyctiderma heroni*, new species, USNM 203923 from USGS 25367, left valve, length 10.0 mm: 4, exterior view; 6, interior view.
5. *Phlyctiderma heroni*, new species, USNM 203922 from USGS 25367, profile of left valve from articulated specimen, height 7.1 mm.
- 7-10. *Diplodonta berryi* McGavock, USNM 203925 from USGS 25370, articulated specimen, length 17.9 mm: 7, interior view of left valve; 8, exterior view of left valve; 9, interior view of right valve; 10, exterior view of right valve.



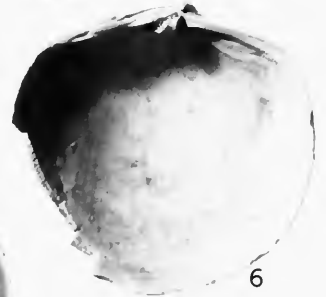
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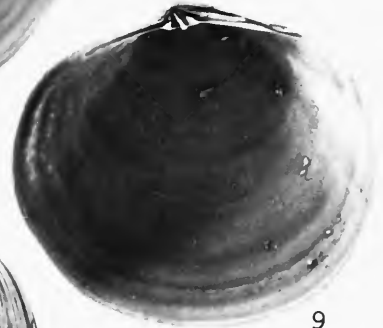
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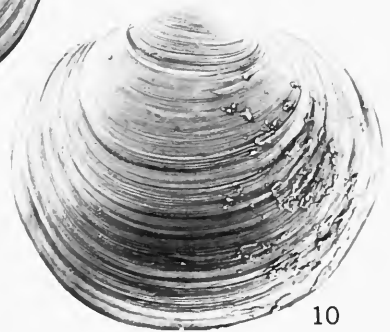
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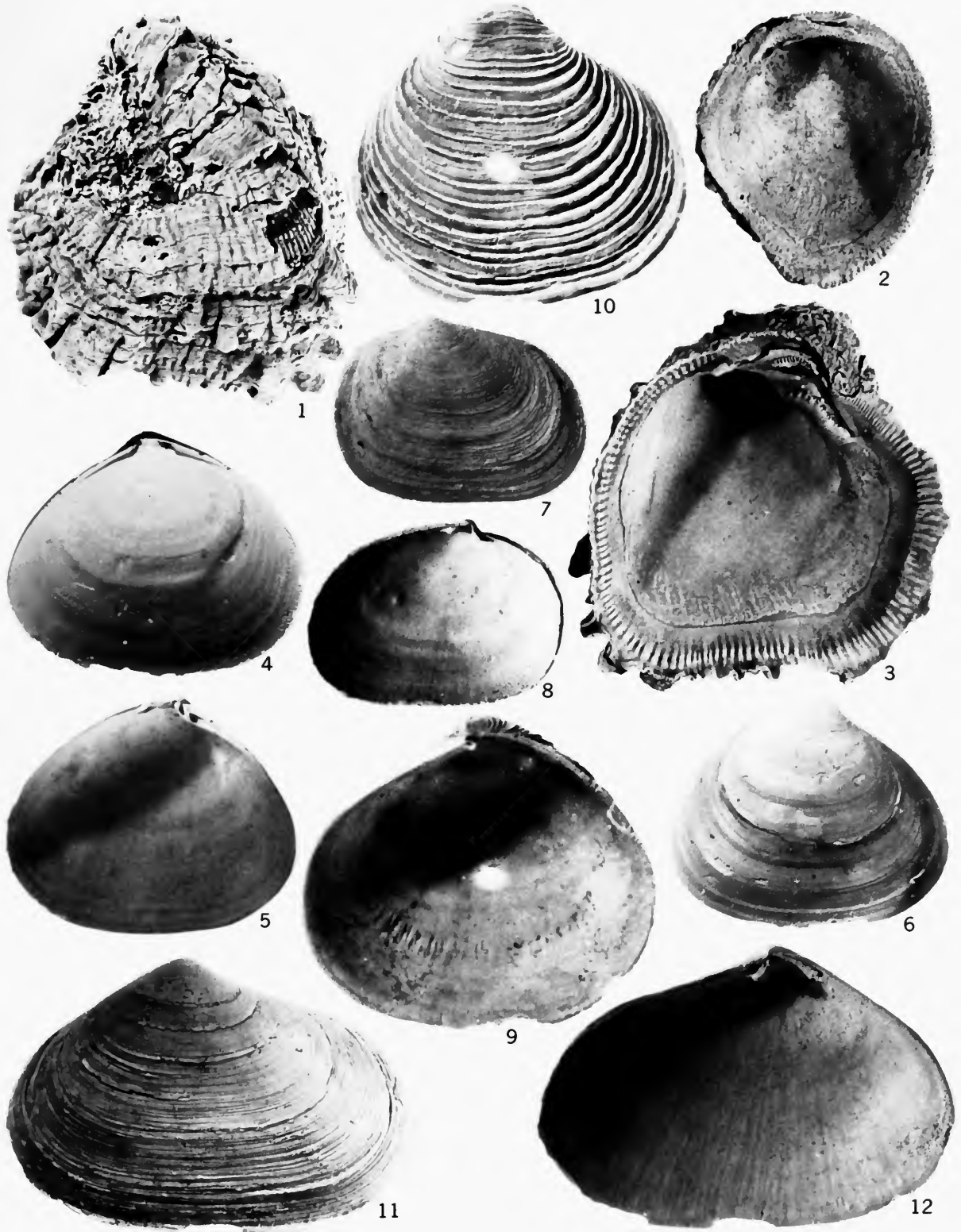
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## PLATE 12

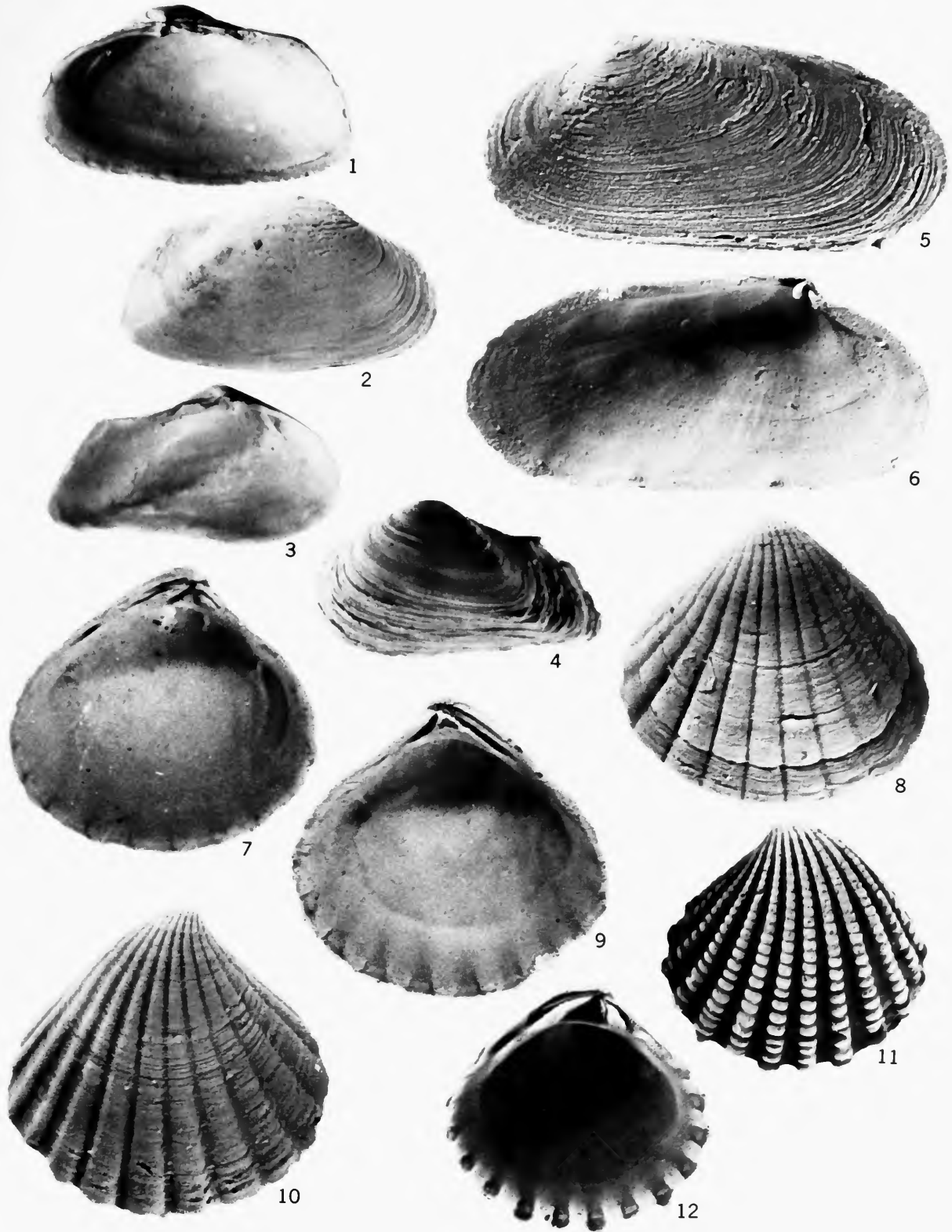
- 1, 3. *Chama gardnerae* Olsson and Harbison, USNM 203926 from USGS 25367, left valve, length 17.1 mm: 1, exterior view; 2, interior view.
2. *Chama gardnerae* Olsson and Harbison, USNM 203927 from USGS 25367, interior view of right valve, length 12.2 mm.
- 4, 6. *Bornia triangula* Dall, USNM 203931 from USGS 25366, right valve, length 8.5 mm: 4, interior view; 6, exterior view.
5. *Bornia triangula* Dall, USNM 203932 from USGS 25366, interior view of left valve, length 9.0 mm.
- 7, 8. *Mysella beaufortensis*, new species, holotype, USNM 203930 from USGS 25367, right valve: 7, exterior view; 8, interior view.
- 9, 10. *Aligena striata* Lea, USNM 203929 from USGS 25367, right valve, length 12.4 mm: 9, interior view; 10, exterior view.
- 11, 12. *Sportella waccamawensis* Gardner, USNM 203928 from USGS 25367, right valve, length 16.1 mm: 11, exterior view; 12, interior view.





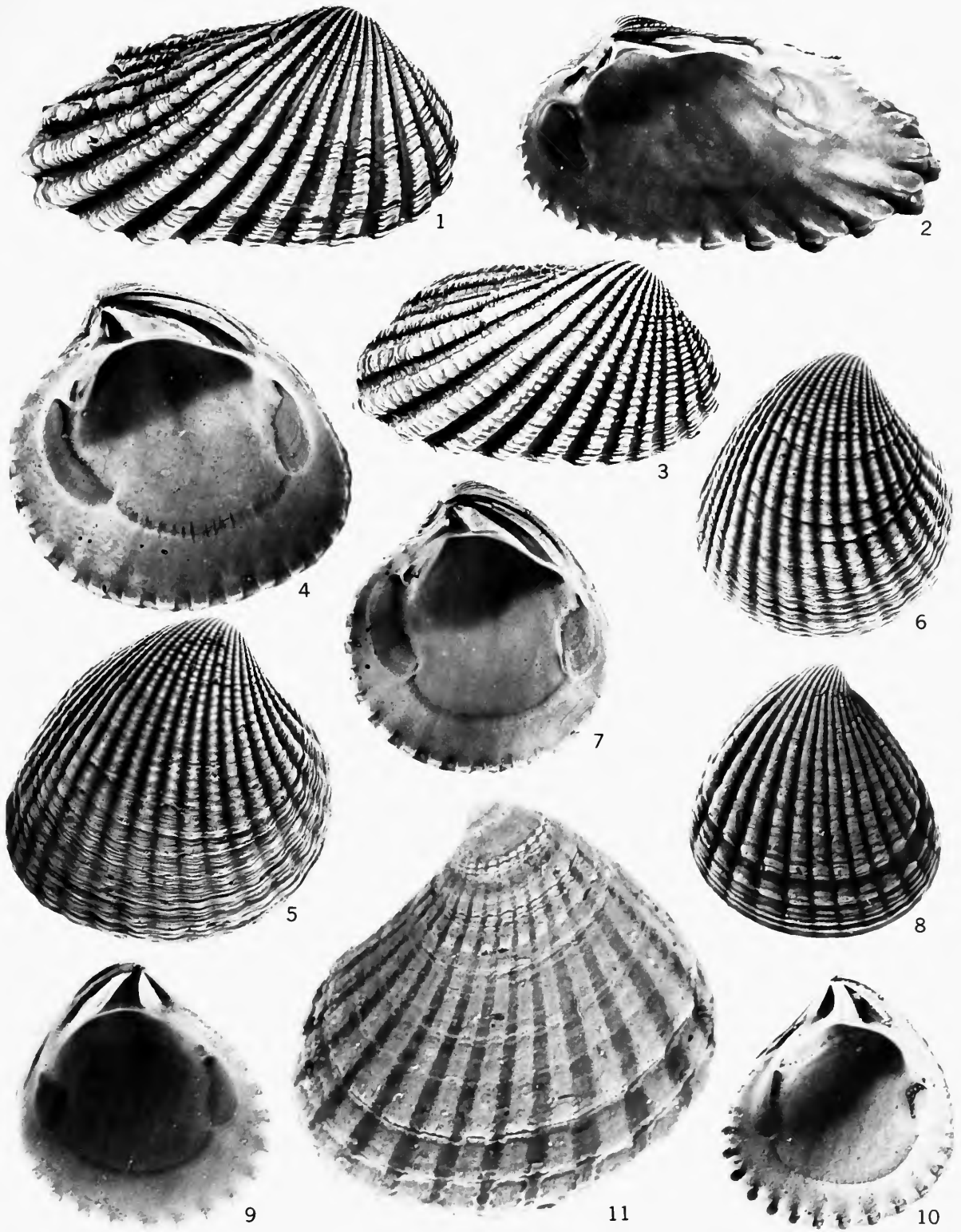
## PLATE 13

- 1, 2. *Anisodonta carolina* Dall, USNM 203933 from USGS 25366, right valve, length 6.3 mm: 1, interior view; 2, exterior view.
- 3, 4. *Anisodonta carolina* Dall, USNM 203934 from USGS 25366, left valve, length 6.0 mm: 3, interior view; 4, exterior view.
- 5, 6. *Ensitellops elongata* Olsson and Harbison, USNM 203935 from USGS 25367, left valve, length 9.0 mm: 5, exterior view; 6, interior view.
- 7, 8. *Pleuromeris auroraensis*, new species, USNM 203941 from USGS 25367, left valve, length 4.5 mm: 7, interior view; 8, exterior view.
- 9, 10. *Pleuromeris auroraensis*, new species, holotype, USNM 203942 from USGS 25367, right valve, length 4.6 mm: 9, interior view; 10, exterior view.
- 11, 12. *Pleuromeris decemcostata* Conrad, USNM 203940 from USGS 25368, left valve, length 5.8 mm: 11, exterior view; 12, interior view.



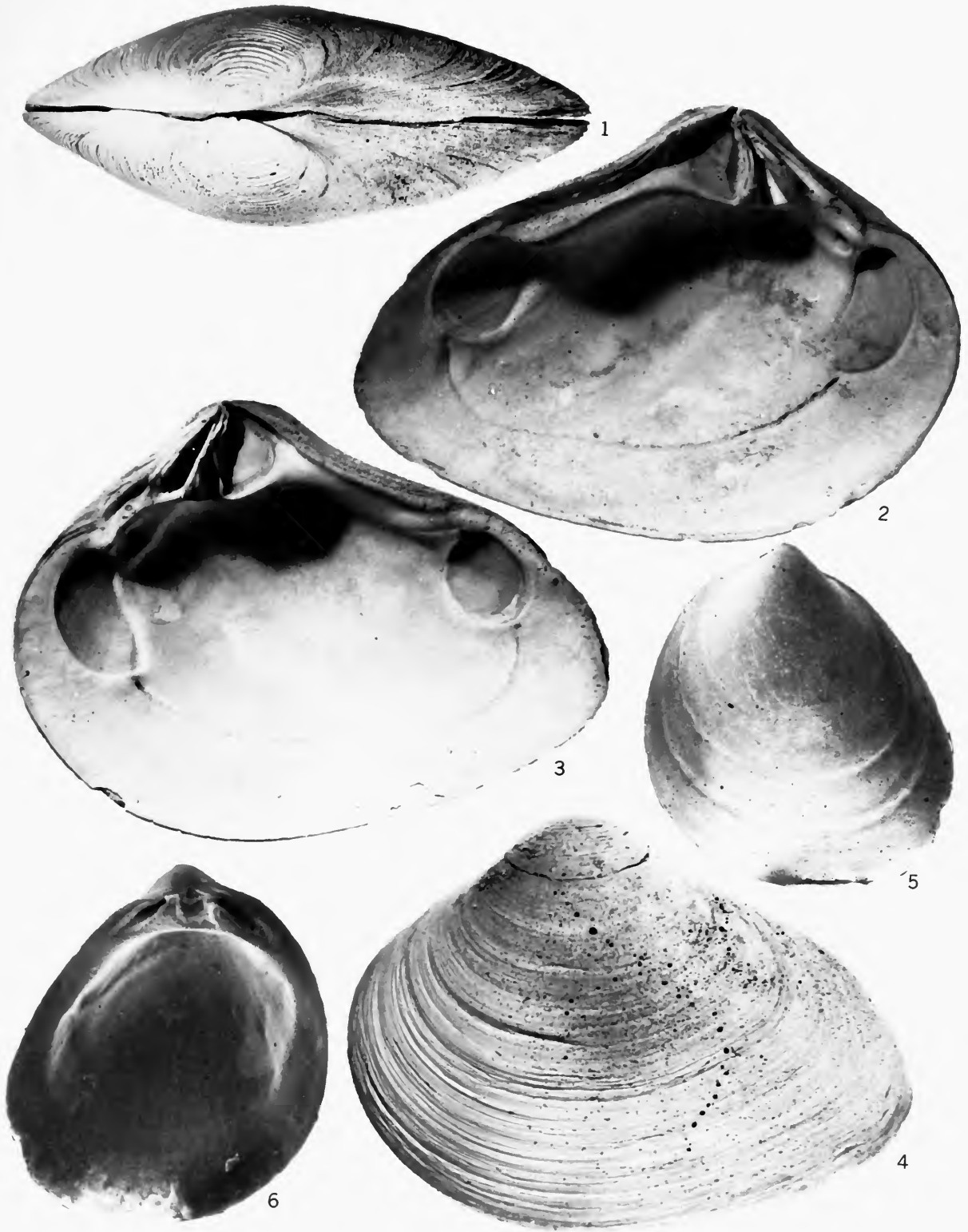
## PLATE 14

- 1, 2. *Carditamera arata* (Conrad), USNM 203936 from USGS 25364, right valve, length 43.1 mm: 1, exterior view; 2, interior view.
3. *Carditamera arata* (Conrad), USNM 203937 from USGS 25364, exterior of right valve, length 35.9 mm.
- 4, 5. *Cyclocardia* sp. cf. *C. granulata* (Say), USNM 203938 from USGS 25364, right valve, length 32.8 mm: 4, interior view; 5, exterior view.
- 6, 7. *Cyclocardia* sp. cf. *C. granulata* (Say), USNM 203939 from USGS 25364, right valve, length 26.4 mm: 6, exterior view; 7, interior view.
- 8, 10. *Pteromeris perplana* (Conrad), USNM 203943 from USGS 25368, right valve, length 4.2 mm: 8, exterior view; 10, interior view.
9. *Pteromeris perplana* (Conrad), USNM 203944 from USGS 25368, interior of left valve, length 4.5 mm.
11. *Pteromeris perplana* (Conrad), USNM 203945 from USGS 25368, exterior view of left valve, length 6.7 mm.



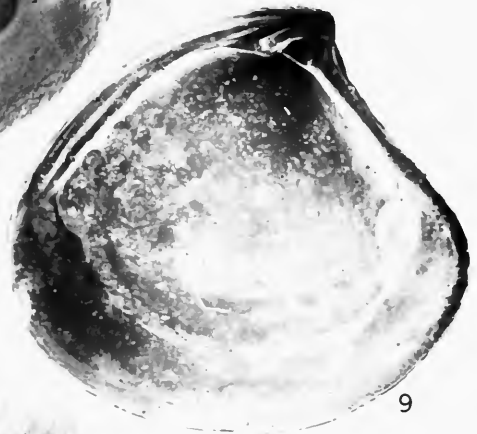
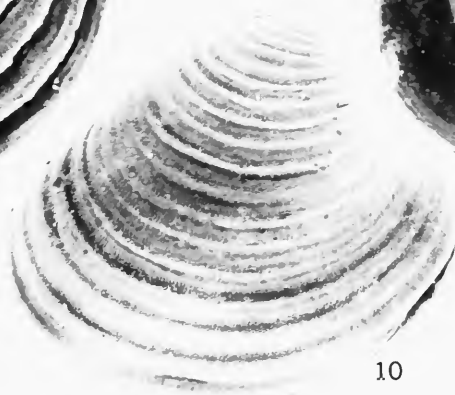
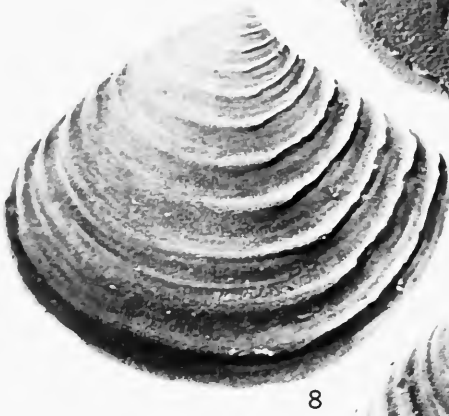
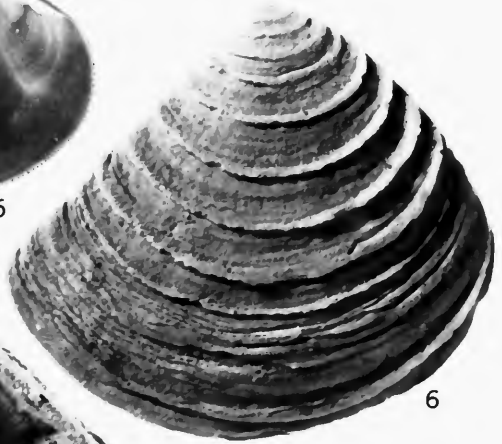
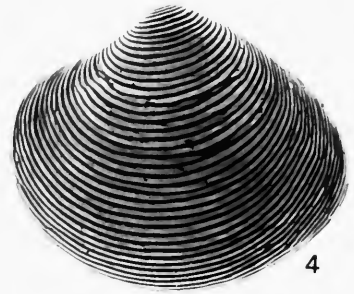
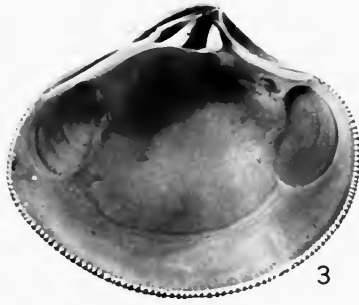
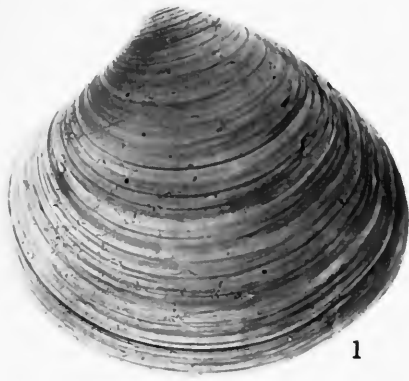
## PLATE 15

- 1-4. *Marvacrassatella kauffmani*, new species, holotype, USNM 203950 from USGS 25362, length 89.1 mm: 1, dorsal view of articulated specimen; 2, interior view of left valve; 3, interior view of right valve; 4, exterior view of left valve.
- 5, 6. *Erycinella ovalis* Conrad, USNM 203946 from USGS 25366, right valve, length 1.4 mm: 5, exterior view; 6, interior view.



## PLATE 16

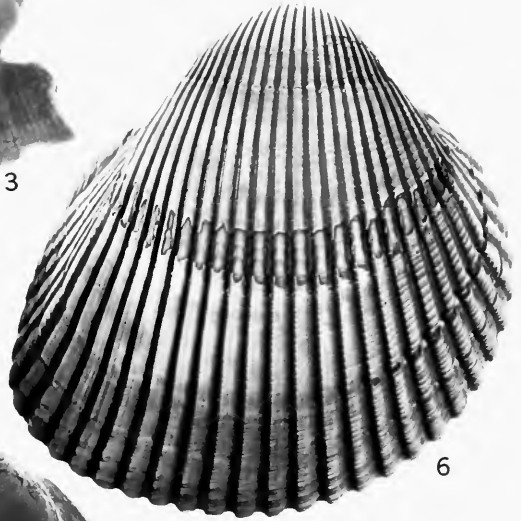
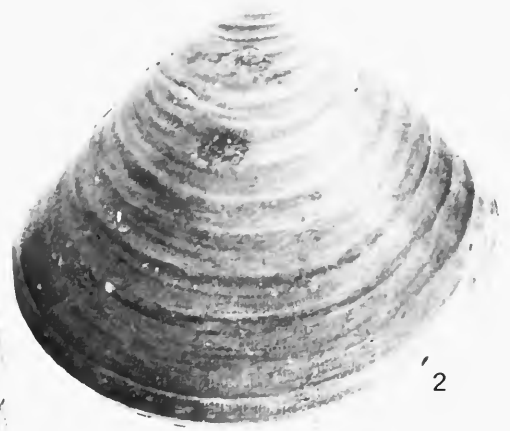
- 1, 2. *Astarte berryi* Gardner, USNM 203947 from USGS 25364, left valve, length 27.8 mm: 1, exterior view; 2, interior view.
- 3, 4. *Astarte concentrica* Conrad, USNM 203948 from USGS 25364, left valve, length 28.4 mm: 3, interior view; 4, exterior view.
5. *Astarte concentrica* Conrad, USNM 203949 from USGS 25364, interior view of right valve, length 26.2 mm.
- 6, 7. *Crassinella lunulata* (Conrad), USNM 203953 from USGS 25367, left valve, length 6.4 mm: 6, exterior view; 7, interior view.
8. *Crassinella lunulata* (Conrad), USNM 204133 from USGS 25367, exterior view of right valve, length 6.0 mm.
9. *Crassinella dupliniana* (Dall), USNM 203951 from USGS 25366, interior view of left valve, length 2.0 mm.
10. *Crassinella dupliniana* (Dall), USNM 203952 from USGS 25366, exterior view of right valve, length 2.3 mm.





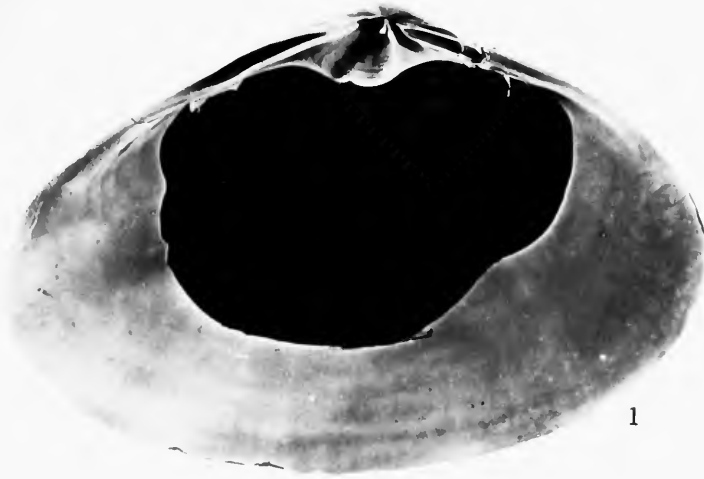
## PLATE 17

1. *Crassinella johnsoni*, new species, USNM 203956 from USGS 25362, interior view of left valve, length 2.2 mm.
2. *Crassinella johnsoni*, new species, USNM 203955 from USGS 25367, exterior view of right valve, length 2.2 mm.
- 3, 4. *Laevicardium sublineatum* (Conrad), USNM 203957 from USGS 25364, right valve, length 25.6 mm: 3, interior view; 4, exterior view.
- 5, 6. *Dinocardium robustum hazeli*, new subspecies, holotype, USNM 203958 from USGS 25364, right valve, length 128.6 mm: 5, interior view; 6, exterior view.
7. *Mulinia lateralis* (Say), USNM 203959 from USGS 25368, hinge view of right valve, length (of illustrated portion) 9.0 mm.
- 8, 9. *Mulinia lateralis* (Say), USNM 203960 from USGS 25368, left valve, length 11.9 mm: 8, interior view; 9, exterior view.



## PLATE 18

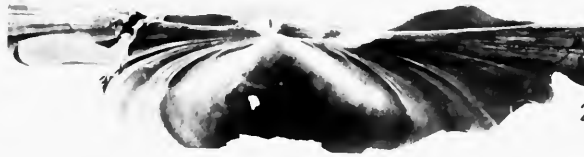
- 1, 2. *Spisula solidissima* (Dillwyn), USNM 203965 from USGS 25364, left valve, length 105.7 mm: 1, interior view; 2, hinge view.
- 3, 4. *Spisula similis* (Say), young specimen, USNM 203962 from USGS 25368, right valve, length 18.3 mm: 3, interior view; 4, exterior view.
- 5, 6. *Spisula similis* (Say), young specimen, USNM 203963 from USGS 25364, left valve, length 43.2 mm: 5, interior view; 6, exterior view.
- 7, 8. *Spisula similis* (Say), adult specimen, USNM 203964 from USGS 25364, left valve, length 64.3 mm: 7, interior view; 8, hinge view.



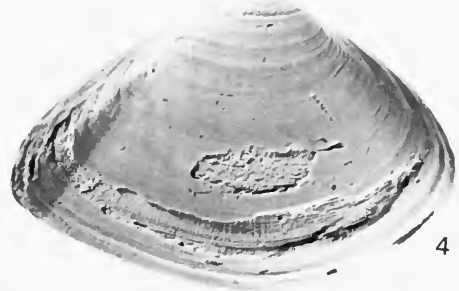
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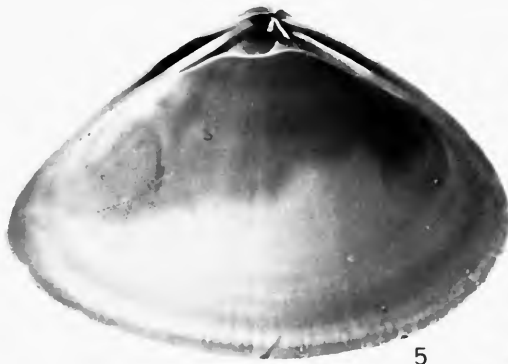
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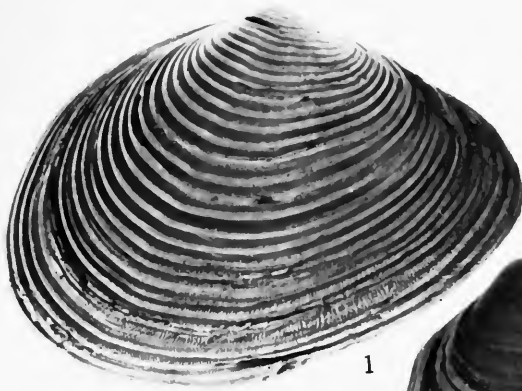
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## PLATE 19

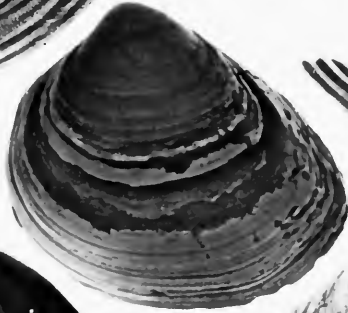
- 1–3. *Raeta plicatella* (Lamarck), USNM 203966 from USGS 25363, length 46.6 mm: 1, exterior view of right valve; 2, interior view of left valve; 3, interior view of right valve.
- 4, 5. *Rangia clathrodonta* (Conrad), USNM 203961 from USGS 25364, left valve, length 49.0 mm: 4, exterior view; 5, interior view.
- 6, 7. *Ensis directus* (Conrad), USNM 203967 from USGS 25364, right valve, length 72.3 mm: 6, interior view; 7, exterior view.
8. *Tellina agilis* Stimpson, USNM 203968 from USGS 25367, exterior view of right valve, length 10.5 mm.
9. *Tellina agilis* Stimpson, USNM 203969 from USGS 25367, interior view of right valve, length 8.6 mm.
10. *Tellina agilis* Stimpson, USNM 203970 from USGS 25367, interior view of left valve, length 10.8 mm.



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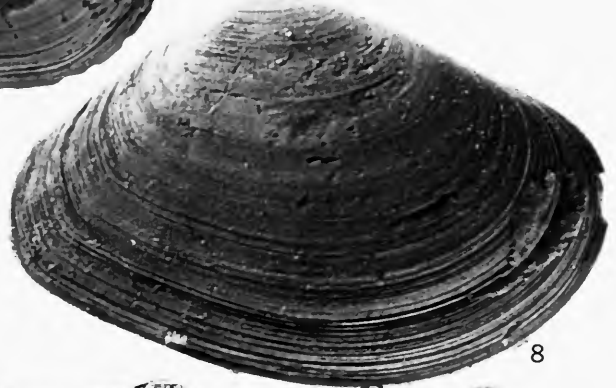
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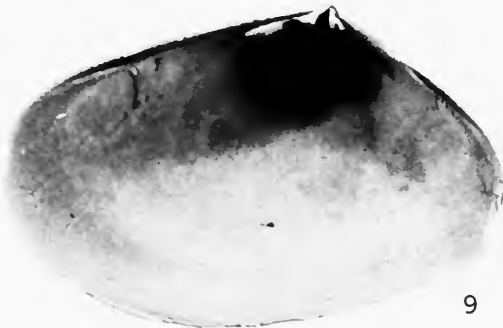
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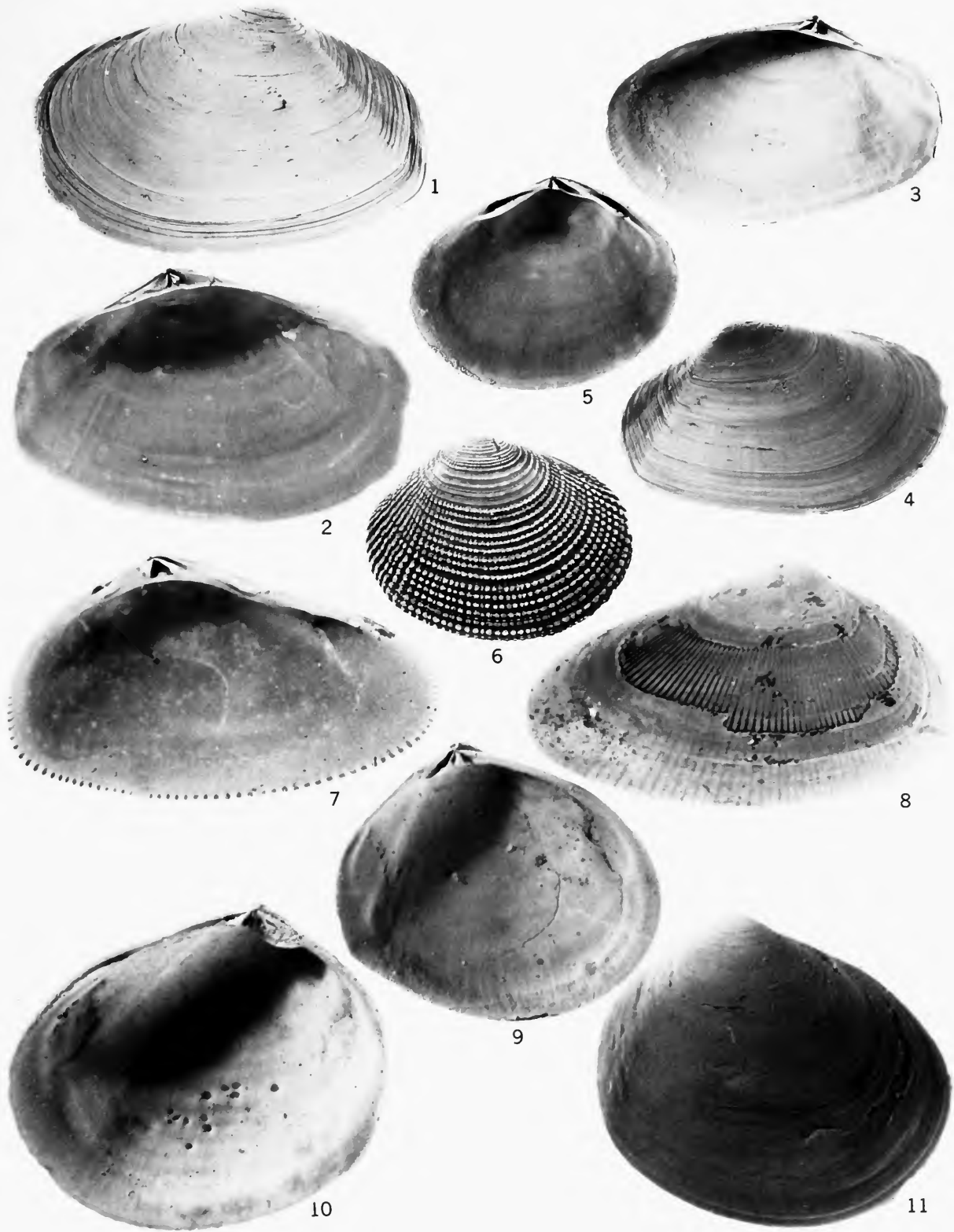
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## PLATE 20

- 1, 2. *Macoma holmesii* Dall, USNM 203971 from USGS 25648, left valve, length 40.7 mm: 1, exterior view; 2, interior view.
- 3, 4. *Macoma holmesii* Dall, USNM 203972 from USGS 25648, right valve, length 28.7 mm: 3, interior view; 4, exterior view.
- 5, 6. *Semele bellastriata* (Conrad), USNM 203974 from USGS 25360, right valve, length 16.4 mm: 5, interior view; 6, exterior view.
- 7, 8. *Donax fossor* Say, USNM 203973 from USGS 25369, left valve, length 8.7 mm: 7, interior view; 8, exterior view.
9. *Abra aequalis* (Say), USNM 203975 from USGS 25369, interior view of left valve, length 10.5 mm.
- 10, 11. *Abra aequalis* (Say), USNM 203976 from USGS 25369, right valve, length 12.0 mm: 10, interior view; 11, exterior view.





## PLATE 21

- 1, 3, 5. *Cumingia tellinoides* (Conrad), USNM 203977 from USGS 25369, left valve, length 13.2 mm: 1, exterior view; 3, interior view; 5, detail of hinge area.
- 2, 4, 6. *Cumingia tellinoides* (Conrad), USNM 203978 from USGS 25369, right valve, length 14.4 mm: 2, exterior view; 4, detail of hinge area; 6, interior view.
- 7–9. *Corbicula densata* (Conrad), USNM 203980 from USGS 25364, length of articulated valves 53.3 mm: 7, interior view of right valve; 8, exterior view of left valve; 9, interior view of left valve.
- 10, 11. *Tagelus plebeius carolinensis* (Conrad), USNM 203979 from USGS 25360, right valve, length 92.7 mm: 10, interior view; 11, exterior view.



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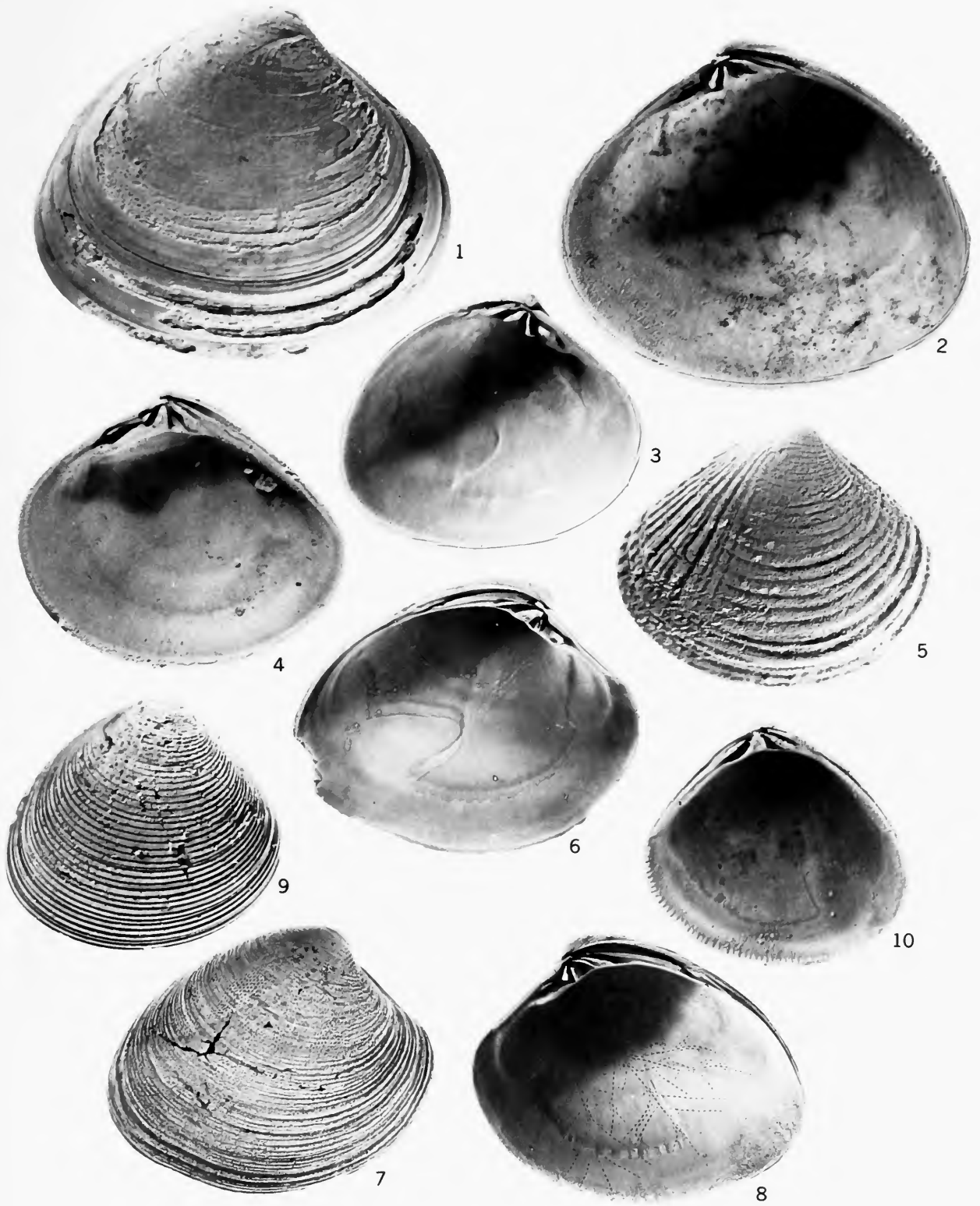
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## PLATE 22

- 1, 2. *Transennella stimpsoni* Dall, USNM 203982 from USGS 25367, right valve, length 9.6 mm: 1, exterior view; 2, interior view.
3. *Transennella stimpsoni* Dall, USNM 203983 from USGS 25367, interior view of left valve, length 7.3 mm.
- 4, 5. *Gouldia metastriatum* (Conrad), USNM 203981 from USGS 25368, right valve, length 10.0 mm: 4, interior view; 5, exterior view.
6. *Pitar chioneformis* (Gardner), USNM 203984 from USGS 25370, interior view of left valve, length 29.1 mm.
- 7, 8. *Pitar chioneformis* (Gardner), USNM 203985 from USGS 25370, right valve, length 28.5 mm: 7, exterior view; 8, interior view.
- 9, 10. *Gemma magna majorina* Gardner, USNM 203987 from USGS 25368, right valve, length 4.8 mm: 9, exterior view; 10, interior view.



## PLATE 23

- 1, 2. *Macrocallista greeni*, new species, holotype, USNM 203986 from USGS 25362, left valve, length 78.6 mm: 1, exterior view; 2, interior view.
- 3, 4. *Chione grus* (Holmes), USNM 203988 from USGS 25357, left valve, length 11.6 mm: 3, interior view; 4, exterior view.
5. *Chione grus* (Holmes), USNM 203989 from USGS 25357, interior view of right valve, length 10.7 mm.
6. *Mercenaria mercenaria* (Linnaeus), USNM 203992 from USGS 25364, interior view of right valve, length 58.0 mm.
- 7, 8. *Chione cribraria* (Conrad), USNM 204130 from USGS 25648, left valve, length 26.7 mm: 7, exterior view; 8, interior view.



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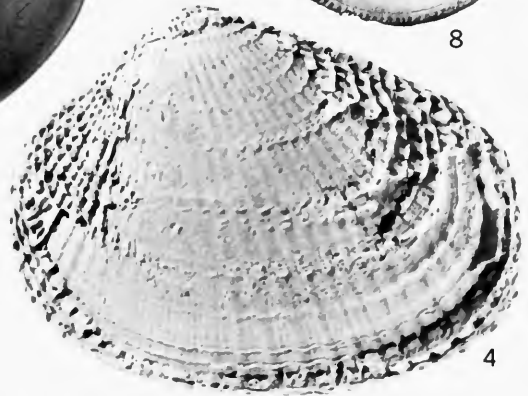
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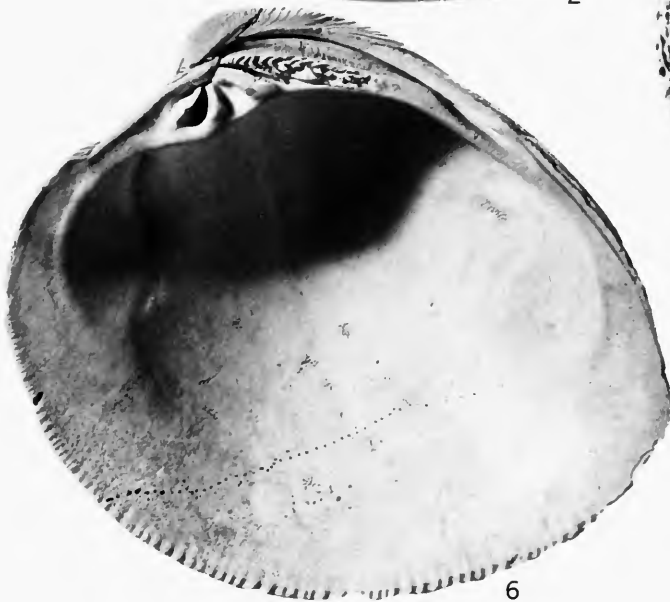
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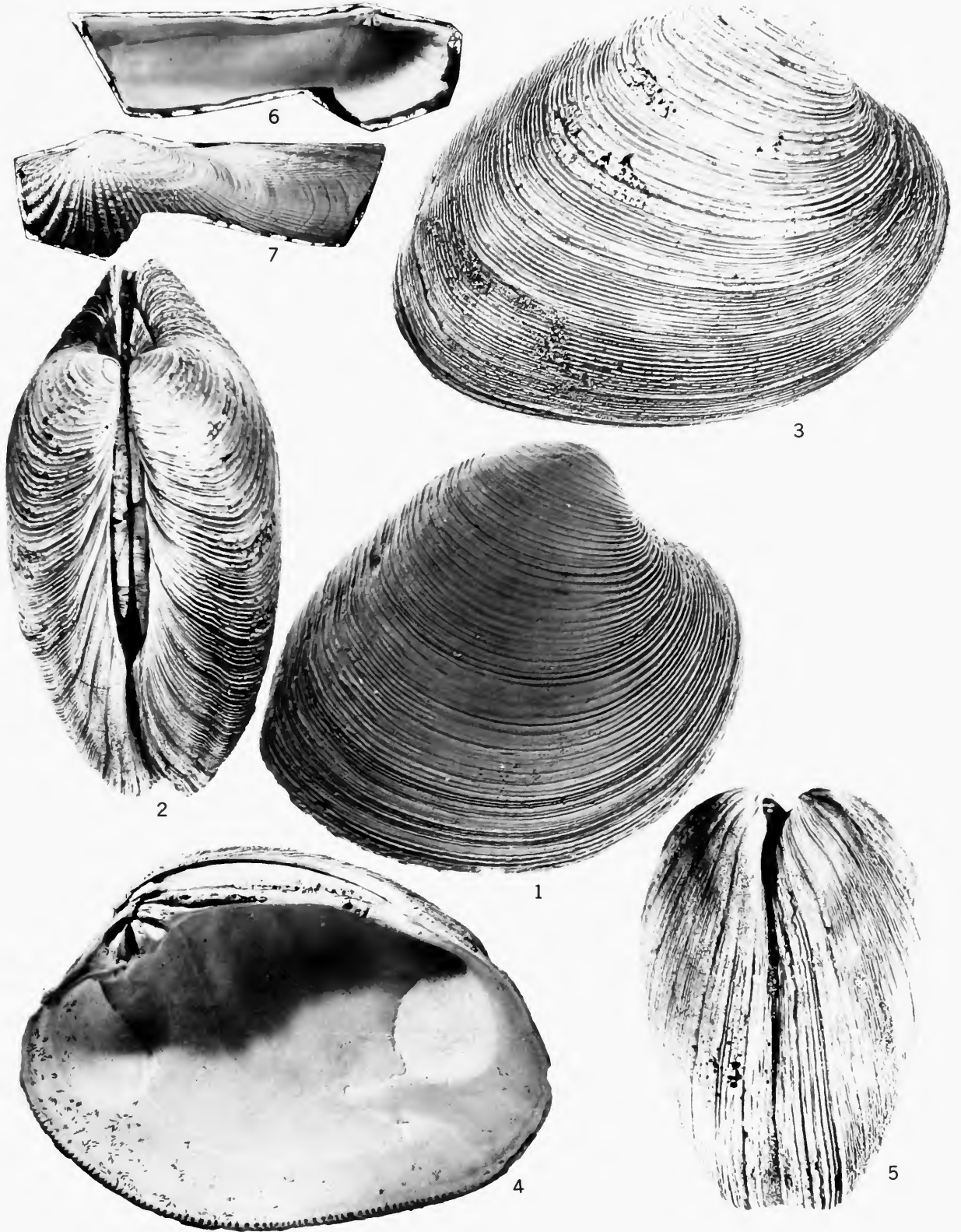
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## PLATE 24

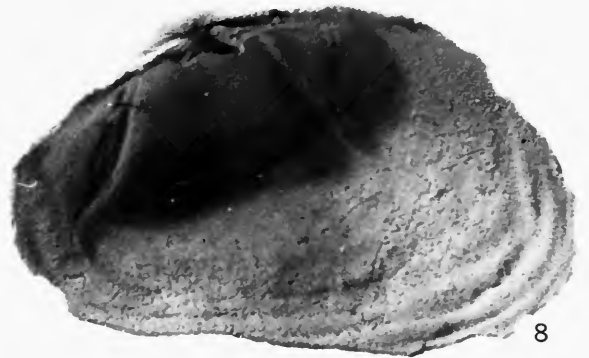
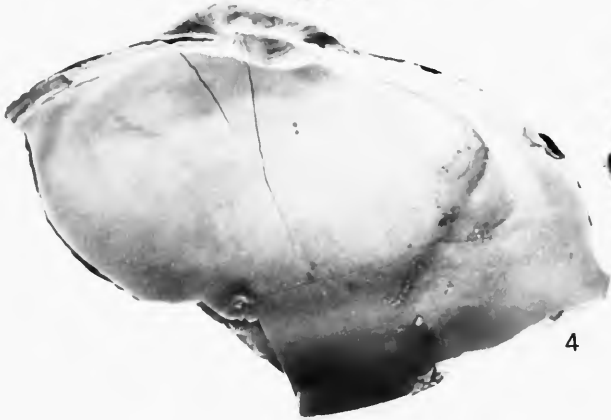
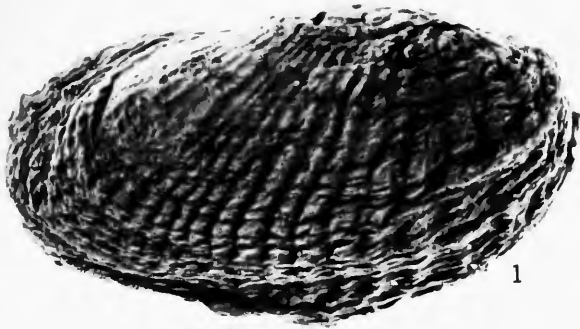
1. *Mercenaria mercenaria* (Linnaeus), USNM 203992 from USGS 25364, exterior view of right valve, length 58.0 mm.
- 2, 3, 5. *Mercenaria permagna* (Conrad), USNM 203990 from USGS 25367, articulated specimen, length 122.0 mm, height 90.3 mm: 2, dorsal view; 3, exterior view of right valve; 5, posterior view.
4. *Mercenaria permagna* (Conrad), USNM 203991 from USGS 25367, interior view of right valve, length 118.9 mm.
- 6, 7. *Petricola pholadiformis* Lamarck, USNM 204131 from USGS 25648, left valve, length 41.6 mm: 6, interior view; 7, exterior view.





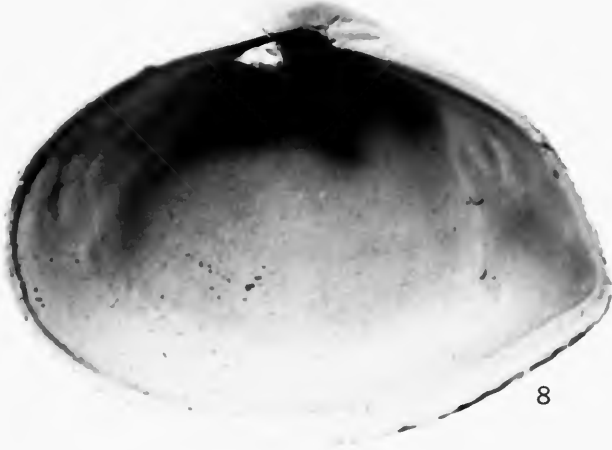
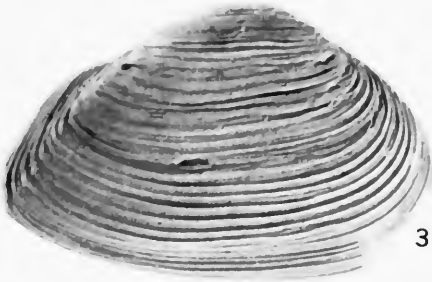
## PLATE 25

- 1, 3. *Petricola pectorosa* (Conrad), USNM 203993 from USGS 25367, right valve, length 18.0 mm: 1, exterior view; 3, interior view.
2. *Petricola pectorosa* (Conrad), USNM 203994 from USGS 25367, interior view of left valve, length 17.9 mm.
- 4, 5. *Mya arenaria* Linnaeus, USNM 203995 from USGS 25364, right valve, length 56.1 mm: 4, interior view; 5, exterior view.
- 6, 7. *Paramya subovata* (Conrad), USNM 203996 from USGS 25367, left valve, length 9.9 mm: 6, interior view; 7, exterior view.
8. *Paramya subovata* (Conrad), USNM 203997 from USGS 25367, interior of right valve, length 10.0 mm.



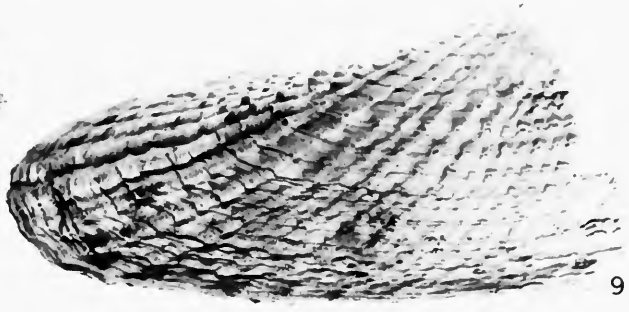
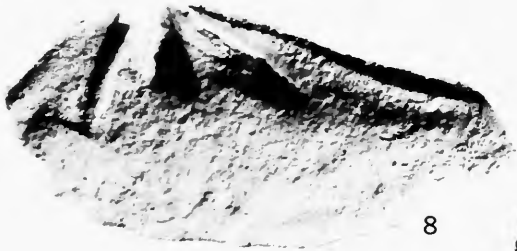
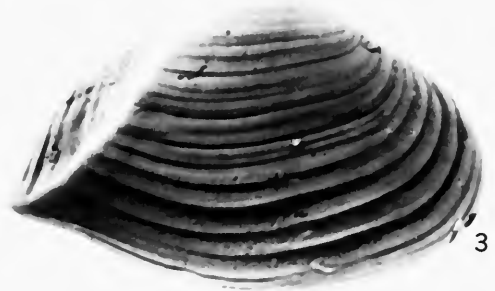
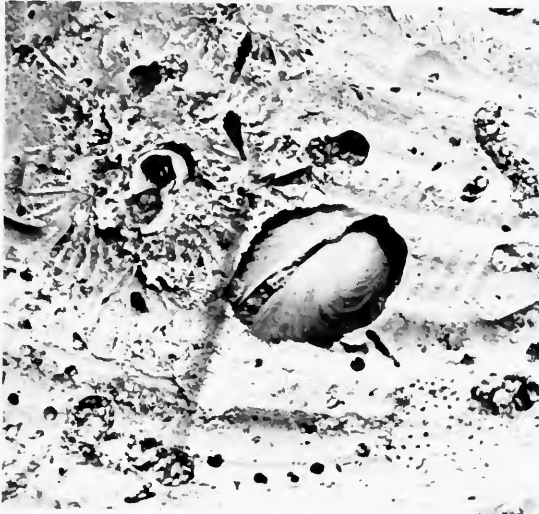
## PLATE 26

- 1, 2. *Sphenia dubia* (Lea), USNM 203998 from USGS 25369, left valve, length 7.8 mm: 1, exterior view; 2, interior view.
- 3, 6. *Caryocorbula contracta* (Say), USNM 203999 from USGS 25366, right valve, length 8.7 mm: 3, exterior view; 6, interior view.
- 4, 5. *Caryocorbula contracta* (Say), USNM 204000 from USGS 25366, left valve, length 9.2 mm: 4, exterior view; 5, interior view.
- 7, 8. *Caryocorbula auroraensis*, new name, USNM 204001 from USGS 25368, right valve, length 13.5 mm: 7, exterior view; 8, interior view.



## PLATE 27

- 1, 2. *Caryocorbula auroraensis*, new name, USNM 204002 from USGS 25368, left valve, length 7.4 mm: 1, exterior view; 2, interior view.
3. *Caryocorbula auroraensis*, new name, USNM 204003 from USGS 25368, exterior view of right valve, length 8.2 mm.
- 4-6. *Gastrochaena hians* (Gmelin), USNM 204004 from USGS 25369, length of specimen 4.6 mm: 4, specimen in valve of *Mercenaria carolinensis*; 5, interior view of right valve; 6, exterior view of right valve.
- 7, 8. *Pandora tuomeyi* Gardner and Aldrich, USNM 204007 from USGS 25367, right valve, length 14.3 mm: 7, exterior view; 8, interior view.
9. *Cyrtopleura* sp., USNM 204006 from USGS 25339, exterior view of right valve, length (broken) 71.0 mm.



## PLATE 28

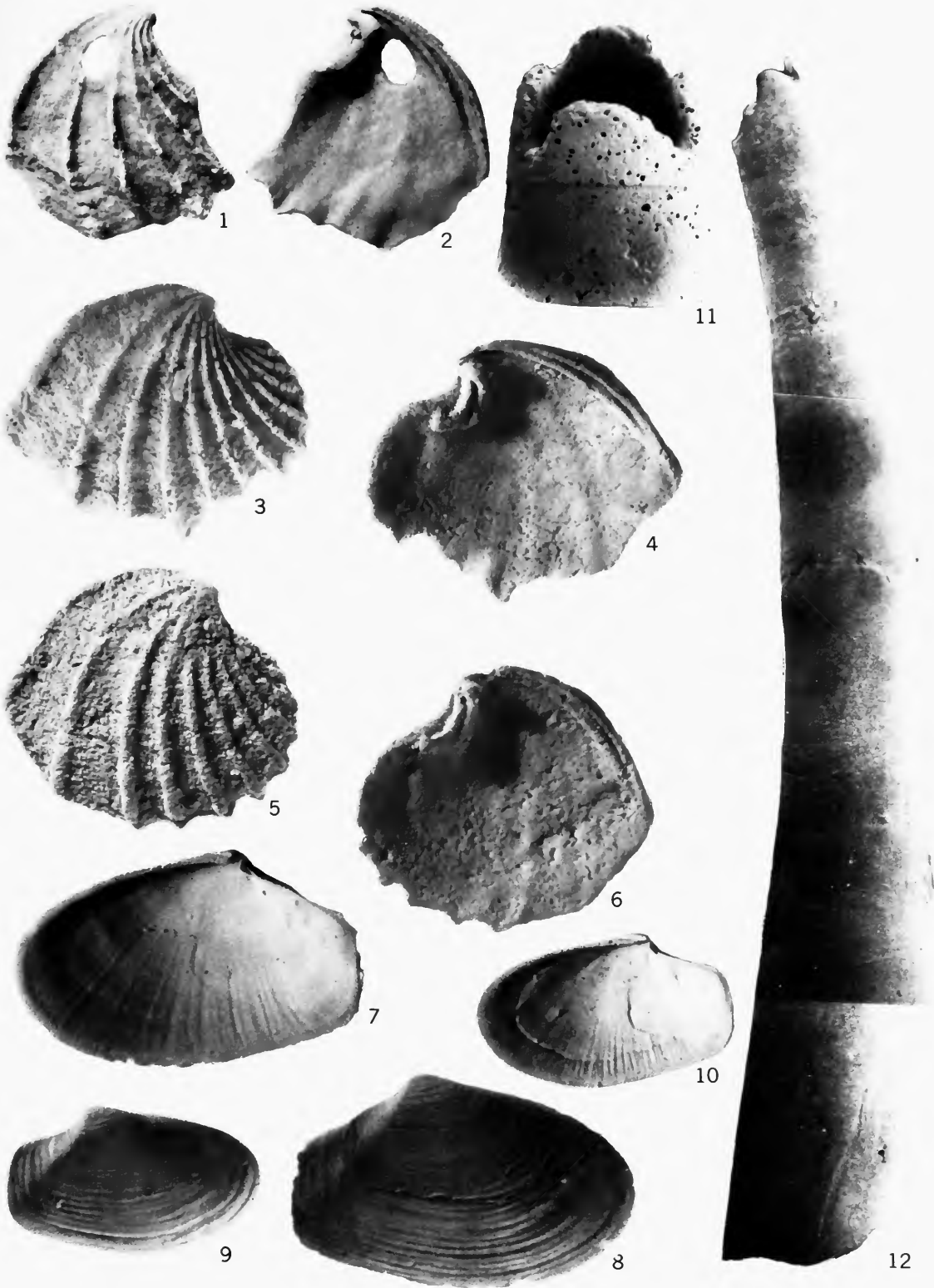
- 1, 2. *Panopea floridana* (Heilprin), USNM 204005 from USGS 25362, left valve, length 166.4 mm: 1, exterior view; 2, interior view.
- 3, 4. *Cochlodesma emmonsii*, new species, USNM 204008 from USGS 25363, right valve, length 27.4 mm: 3, exterior view; 4, interior view.
- 5, 6. *Cochlodesma emmonsii*, new species, USNM 204009 from USGS 25363, left valve, length 27.0 mm: 5, exterior view; 6, interior view.





## PLATE 29

- 1, 2. *Verticordia emmonsii* Conrad, USNM 204014 from USGS 25366, right valve, length 4.5 mm: 1, exterior view; 2, interior view.
- 3, 4. *Verticordia lockei*, new species, USNM 204012 from USGS 25368, right valve, length 6.7 mm: 3, exterior view; 4, interior view.
- 5, 6. *Verticordia lockei*, new species, holotype, USNM 204013 from USGS 25367, right valve, length 6.8 mm: 5, exterior view; 6, interior view.
- 7, 8. *Thracia brioni*, new species, USNM 204010 from USGS 25367, right valve, length 9.1 mm: 7, interior view; 8, exterior view.
- 9, 10. *Thracia brioni*, new species, holotype, USNM 204011 from USGS 25366, right valve, length 6.1 mm: 9, exterior view; 10, interior view.
11. *Cadulus quadridentatus* (Dall), USNM 204015 from USGS 25366, oblique view of apex of specimen, apical diameter 0.7 mm.
12. *Cadulus quadridentatus* (Dall), USNM 204016 from USGS 25366, lateral view of specimen, height 8.8 mm.

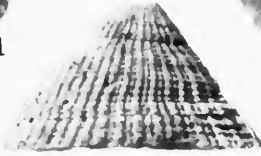


## PLATE 30

- 1, 2. *Diodora nucula* (Dall), USNM 204017 from USGS 25368, length 4.3 mm: 1, dorsal view; 2, ventral view.
3. *Diodora nucula* (Dall), USNM 204018 from USGS 25368, lateral view, height 2.3 mm.
- 4, 5. *Diodora auroraensis*, new species, holotype, USNM 204019 from USGS 25362, length 25.3 mm: 4, ventral view; 5, dorsal view.
- 6, 7. *Diodora pamlicoensis*, new species, holotype, USNM 204020 from USGS 25362, length 30.2: 6, ventral view; 7, dorsal view.
- 8, 9. *Calliostoma philanthropum pontoni* Mansfield, USNM 204021 from USGS 25370, height 22.1 mm, maximum diameter 19.6 mm: 8, apertural view; 9, umbilical view.



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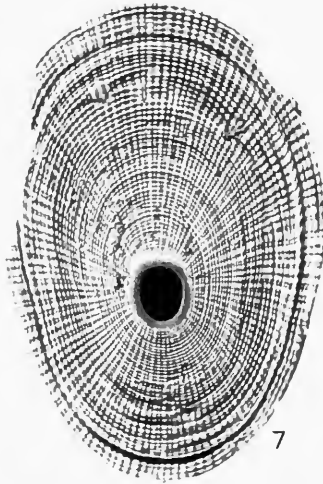
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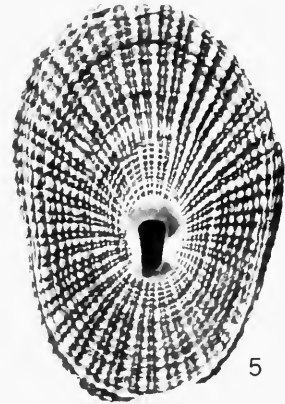
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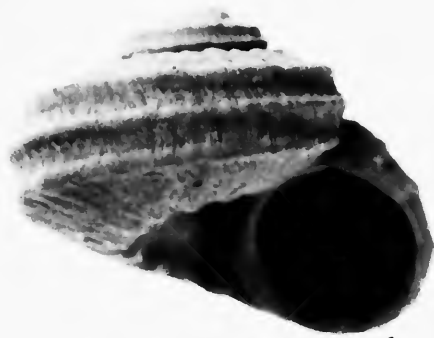
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## PLATE 31

- 1-3. *Arene pergemma* (Gardner), USNM 204022 from USGS 25366, height 3.9 mm, maximum diameter 5.1 mm: 1, apertural view; 2, umbilical view; 3, apical view.
4. *Arene pergemma* (Gardner), USNM 204023 from USGS 25366, apical view showing color pattern, maximum diameter 4.0 mm.
5. *Rissoa geraea* Dall, USNM 204025 from USGS 25367, apertural view, height 3.1 mm.
6. *Littorina carolinensis* Conrad, USNM 204024 from USGS 25368, apertural view, height 2.3 mm.
- 7-9. *Teinostoma goniogyrus* Pilsbry and McGinty, USNM 204026 from USGS 25359, maximum diameter 2.2 mm: 7, apical view; 8, apertural view; 9, umbilical view.



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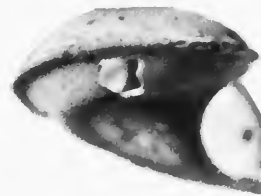
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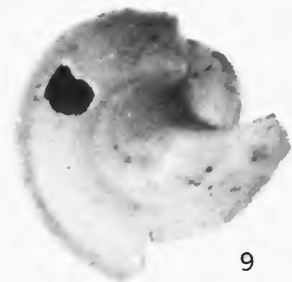
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## PLATE 32

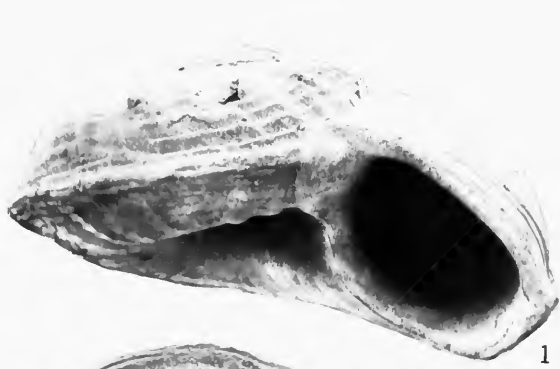
- 1-3. *Teinostoma beaufortensis*, new species, holotype, USNM 204027 from USGS 25367, maximum diameter 1.6 mm: 1, apertural view; 2, apical view; 3, umbilical view.
- 4-6. *Teinostoma smirkon* Gardner, USNM 204028 from USGS 25367, maximum diameter 1.5 mm: 4, apertural view; 5, apical view; 6, umbilical view.
- 7-9. *Teinostoma tectispira* Pilsbry, USNM 204029 from USGS 25367, maximum diameter 1.7 mm: 7, apertural view; 8, apical view; 9, umbilical view.





## PLATE 33

- 1-3. *Cyclostremiscus obliquistriatus* (Lea), USNM 204030 from USGS 25367, maximum diameter 2.6 mm: 1, apertural view; 2, apical view; 3, umbilical view.
- 4-6. *Didianema carolinae* (Gardner), USNM 204031 from USGS 25366, maximum diameter 1.4 mm: 4, apertural view; 5, umbilical view; 6, apical view.



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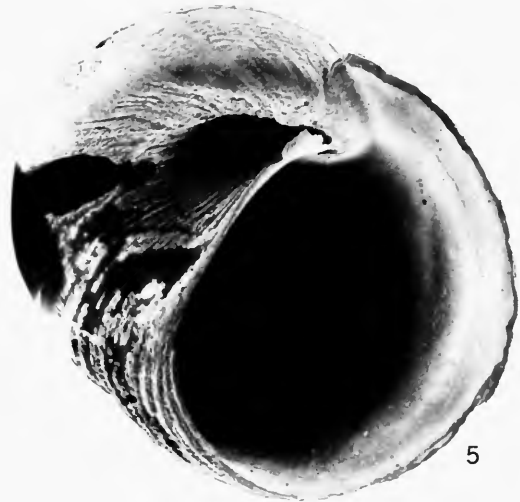
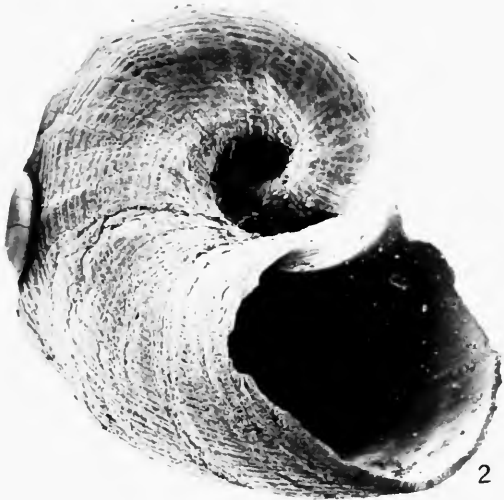
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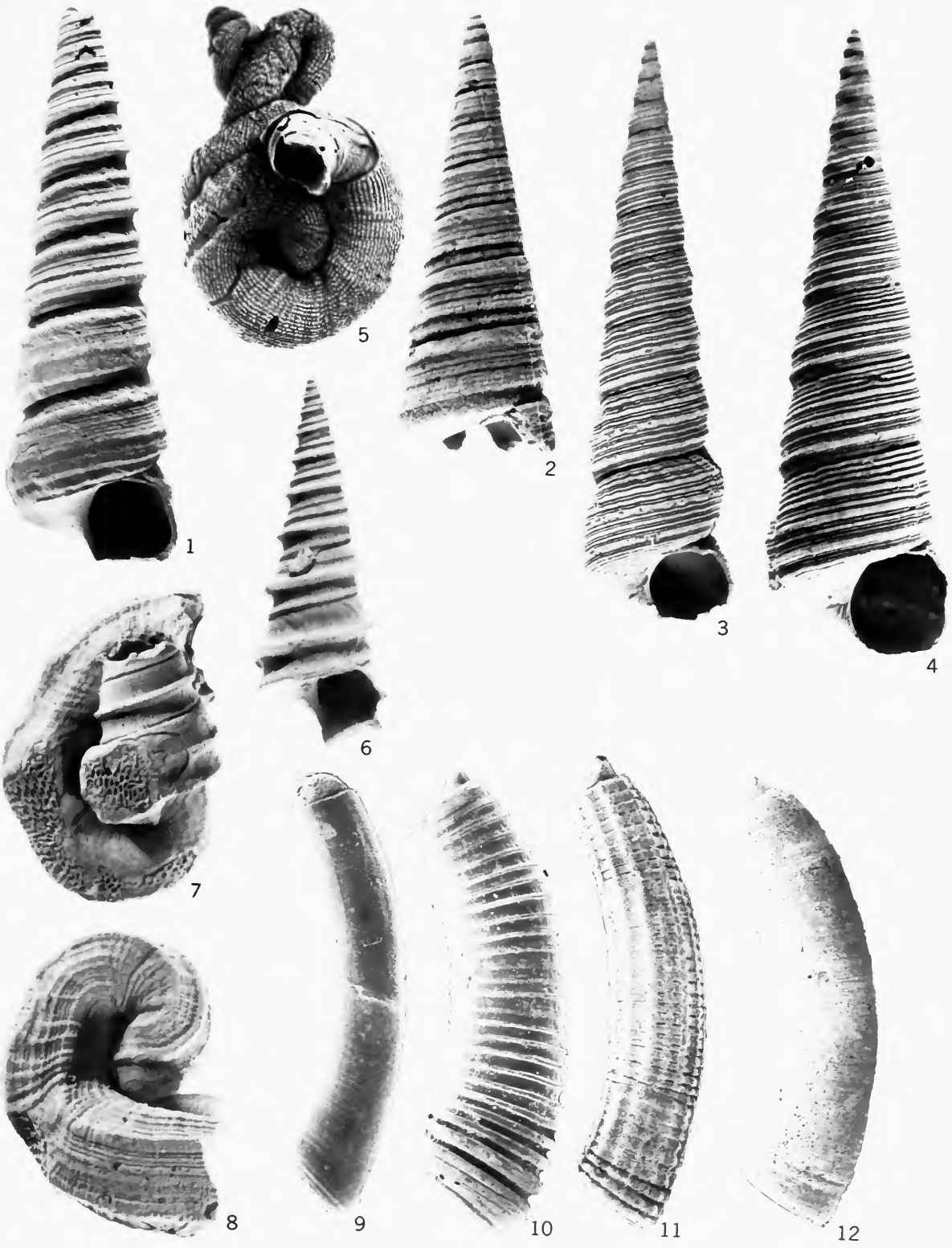
## PLATE 34

- 1–3. *Macromphalina hanseni*, new species, holotype, USNM 204032 from USGS 25367, maximum diameter 1.4 mm: 1, apical view; 2, umbilical view; 3, apertural view.
- 4–6. *Macromphalina pierrot* Gardner, USNM 204033 from USGS 25357, maximum diameter 2.2 mm: 4, apical view; 5, umbilical view; 6, apertural view.



## PLATE 35

1. *Turritella beaufortensis*, new species, holotype, USNM 204038 from USGS 25370, apertural view, height 29.0 mm.
2. *Turritella beaufortensis*, new species, USNM 204039 from USGS 25366, exterior sculpture, height 14.0 mm.
3. *Turritella perexilis* Conrad, USNM 204040 from USGS 25366, apertural view, height 25.3 mm.
4. *Turritella perexilis* Conrad, USNM 204041 from USGS 25366, apertural view, height 19.6 mm.
5. *Serpulorbis granifera* (Say), USNM 204043 from USGS 25364, length of specimen 34.0 mm.
6. *Vermicularia spirata* (Philippi), USNM 204128 from USGS 25366, apertural view, height 9.2 mm.
- 7, 8. *Vermicularia spirata* (Philippi), USNM 204042 from USGS 25370, lateral views, height (of figure 7) 10.7 mm.
9. *Caecum beaufortensis*, new species, holotype, USNM 204034 from USGS 25367, height 3.3 mm.
10. *Caecum pulchellum* Stimpson, USNM 204035 from USGS 25367, height 2.6 mm.
11. *Caecum imbricatum* Carpenter, USNM 204036 from USGS 25367, height 4.3 mm.
12. *Caecum flemingi* Gardner and Aldrich, USNM 204037 from USGS 25367, height 4.7 mm.



## PLATE 36

1. *Epitonium leai*, new species, holotype, USNM 204049 from USGS 25366, apertural view, height 8.1 mm.
2. *Seila adamsii* (Lea), USNM 204045 from USGS 25368, apertural view, height 9.8 mm.
3. *Seila adamsii* (Lea), USNM 204046 from USGS 25368, apertural view, height 7.8 mm.
4. *Balcis?* sp., USNM 204055 from USGS 25367, apertural view, height 3.7 mm.
5. *Triphora dupliniana* (Olsson), USNM 204047 from USGS 25368, apertural view, height 2.4 mm.
6. *Triphora dupliniana* (Olsson), USNM 204048 from USGS 25368, apertural view, height 3.3 mm.
7. *Bitium podagrinum* Dall, USNM 204044 from USGS 25368, apertural view, height 3.2 mm.
8. *Epitonium carolinae* Gardner, USNM 204050 from USGS 25368, apertural view, height 5.1 mm.
9. *Epitonium carolinae* Gardner, USNM 204051 from USGS 25366, apertural view, height 5.5 mm.
10. *Epitonium sohli*, new species, holotype, USNM 204052 from USGS 25366, apertural view, height 5.3 mm.
11. *Epitonium* sp. cf. *E. foliaceicostum* (d'Orbigny), USNM 204053 from USGS 25369, apertural view, height 6.4 mm.
- 12, 13. *Epitonium rupicolum* (Kurtz), USNM 204054 from USGS 25368, height 7.3 mm: 12, abapertural view; 13, apertural view.
14. *Epitonium fractum* Dall, USNM 204132 from USGS 25339, apertural view, height 14.6 mm.





## PLATE 37

1. *Balcis beaufortensis*, new species, holotype, USNM 204056 from USGS 25367, apertural view, height 4.5 mm.
2. *Balcis biconica* (Gardner), new combination, USNM 204057 from USGS 25367, apertural view, height 5.0 mm.
3. *Balcis eborea* (Conrad), new combination, USNM 204058 from USGS 25367, apertural view, height 5.2 mm.
4. *Fulima juncea* (Gardner), new combination, USNM 204059 from USGS 25367, apertural view, height 4.7 mm.
- 5, 6. *Calyptraea centralis* (Conrad), USNM 204060 from USGS 25368, maximum diameter 4.4 mm: 5, ventral view; 6, dorsal view.
- 7, 8. *Crepidula aculeata* (Gmelin), USNM 204062 from USGS 25362, length 27.8 mm: 7, ventral view; 8, dorsal view.
- 9–11. *Crucibulum lawrencei*, new species, holotype, USNM 204061 from USGS 25364, maximum diameter 52.8 mm: 9, dorsal view; 10, ventral view; 11, lateral view.



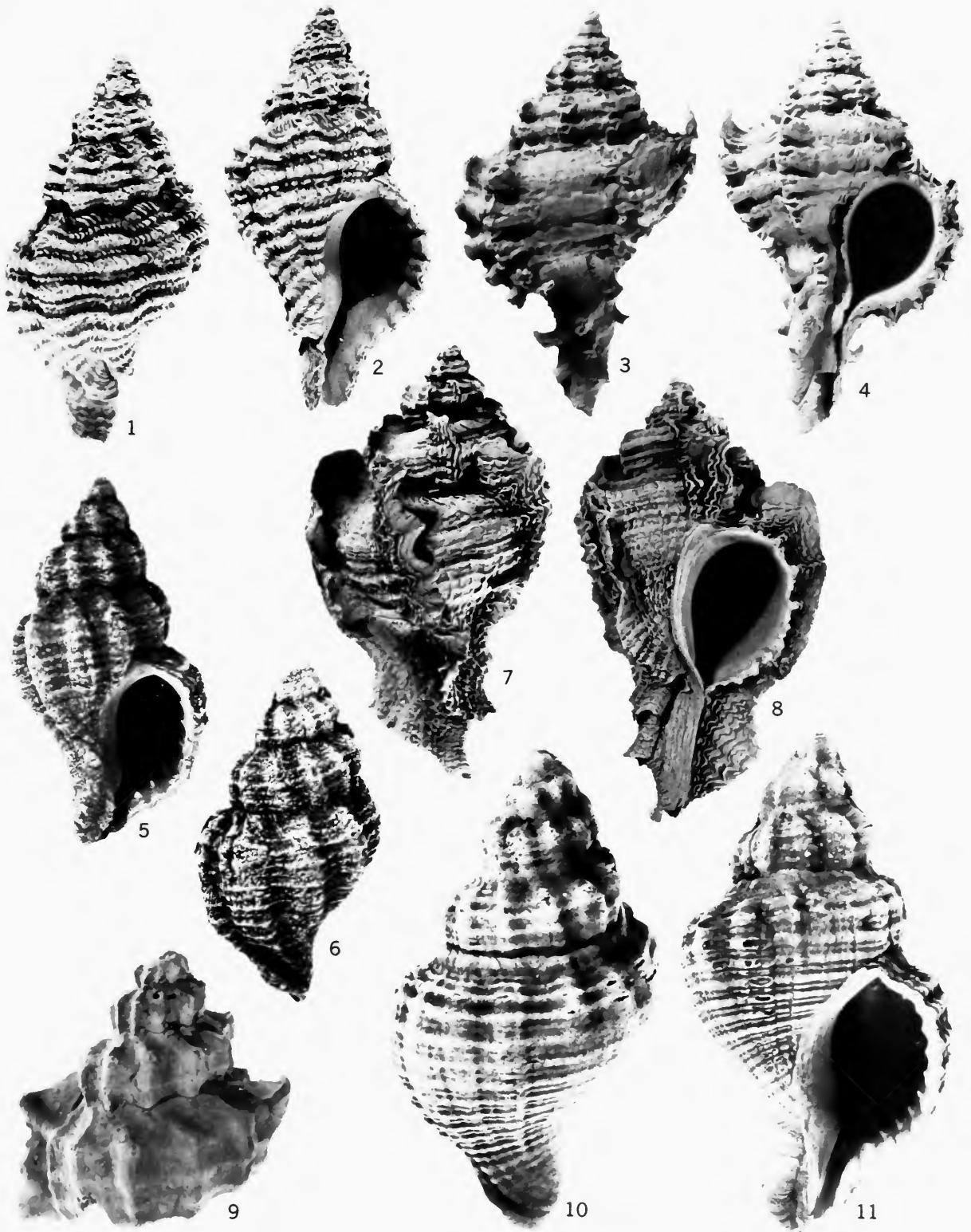
## PLATE 38

- 1, 2. *Crepidula fornicata* (Linnaeus), USNM 204063 from USGS 25364, length 29.1 mm: 1, ventral view; 2, dorsal view.
- 3, 4. *Trivia floridana* Olsson and Harbison, USNM 204065 from USGS 25339, length 15.5 mm: 3, apertural view; 4, abapertural view.
- 5, 6. *Crepidula plana* Say, USNM 204064 from USGS 25362, length 31.3 mm: 5, dorsal view; 6, ventral view.
- 7, 8. *Tectonatica pusilla* (Say), USNM 204066 from USGS 25367, height 6.7 mm: 7, abapertural view; 8, apertural view.
- 9–11. *Polinices duplicata* (Say), USNM 204067 from USGS 25364, height 27.7 mm: 9, apical view; 10, umbilical view; 11, apertural view.
12. *Lunatia heros* (Say), USNM 204068 from USGS 25362, apertural view, height 22.8 mm.



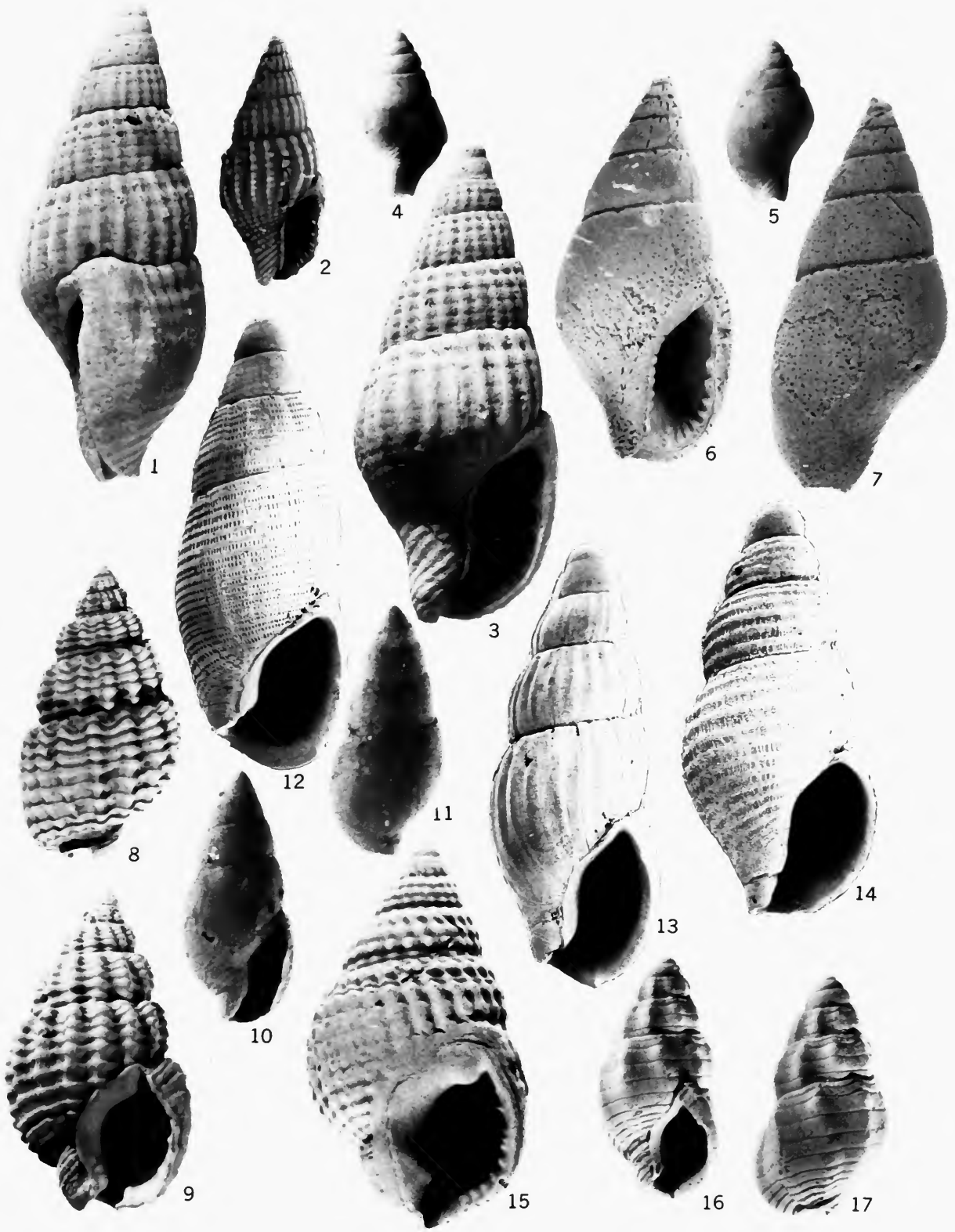
## PLATE 39

- 1, 2. *Urosalpinx* sp. cf. *U. perrugata* (Conrad), USNM 204072 from USGS 25366, height 13.0 mm: 1, abapertural view; 2, apertural view.
- 3, 4. *Murexiella macgintyi* (M. Smith), USNM 204069 from USGS 25362, height 14.8 mm: 3, abapertural view; 4, apertural view.
- 5, 6. *Urosalpinx suffolkensis* Gardner, USNM 204073 from USGS 25364, height 28.5 mm: 5, apertural view; 6, abapertural view.
- 7, 8. *Pterorhytis conradi* (Dall), USNM 204070 from USGS 25360, height 35.8 mm: 7, abapertural view; 8, apertural view.
9. *Eupleura caudata* (Say), USNM 204071 from USGS 25367, abapertural view, height (of broken specimen) 13.8 mm.
- 10, 11. *Urosalpinx stimpsoni* Gardner, USNM 204074 from USGS 25364, height 29.7 mm: 10, abapertural view; 11 apertural view.



## PLATE 40

- 1–3. *Anachis milleri* Gardner, USNM 204075 from USGS 25368, height 11.9 mm: 1, profile view; 3, apertural view.
2. *Anachis milleri* Gardner, USNM 204076 from USGS 25366, apertural view, height 14.7 mm.
- 4, 5. *Mitrella gardnerae ecarinata* (Olsson and Harbison), USNM 204077 from USGS 25368, height 2.5 mm: 4, apertural view; 5, abapertural view.
- 6, 7. *Mitrella gardnerae* (Olsson and Harbison), USNM 204078 from USGS 25366, height 12.9 mm: 6, apertural view; 7, abapertural view.
- 8, 9. *Nassarius chowanensis* (Gardner), USNM 204083 from USGS 25362, height 9.8 mm: 8, abapertural view; 9, apertural view.
- 10, 11. *Mitrella waccamawensis* Gardner, USNM 204079 from USGS 25368, height 3.4 mm: 10, apertural view; 11, abapertural view.
12. *Aesopus stearnsii* (Tryon), USNM 204080 from USGS 25368, apertural view, height 4.0 mm.
13. *Aesopus ithitoma* (Dall), USNM 204081 from USGS 25368, apertural view, height 3.7 mm.
14. *Aesopus gardnerae*, new species, holotype, USNM 204082 from USGS 25367, apertural view, height 3.8 mm.
15. *Nassarius granifera* (Conrad), USNM 204084 from USGS 25364, apertural view, 17.2 mm.
- 16, 17. *Nassarius cornelliana* (Olsson), USNM 204085 from USGS 25366, height 4.6 mm: 16, apertural view; 17, abapertural view.





## PLATE 41

- 1, 2. *Nassarius schizopyga?* (Dall), USNM 204086 from USGS 25367, height 26.0 mm: 1, apertural view; 2, abapertural view.
- 3, 4. *Nassarius schizopyga?* (Dall), USNM 204087 from USGS 25339, height 20.5 mm: 3, apertural view; 4, abapertural view.
- 5, 6. *Busycon spiratus pyruloides* (Say), USNM 204089 from USGS 25371, height 20.5 mm: 5, abapertural view; 6, apertural view.
7. *Busycon adversarius* Conrad, USNM 204090 from USGS 25364, apertural view, height 187.3 mm.
8. *Nassarius scalaspira?* (Conrad), USNM 204088 from USGS 25339, apertural view of broken specimen, height 21.2 mm.



## PLATE 42

- 1, 2. *Busycon carica* (Gmelin), USNM 204091 from USGS 25364, height 193.1 mm: 1, apertural view; 2, abapertural view.
3. *Busycon spiratus pyruloides* (Say), USNM 204092 from USGS 25364, abapertural view of broken specimen, height 96.3 mm.
- 4, 5. *Busycon concinnum* Conrad, USNM 204093 from USGS 25370, height 69.2 mm: 4, apertural view; 5, abapertural view.



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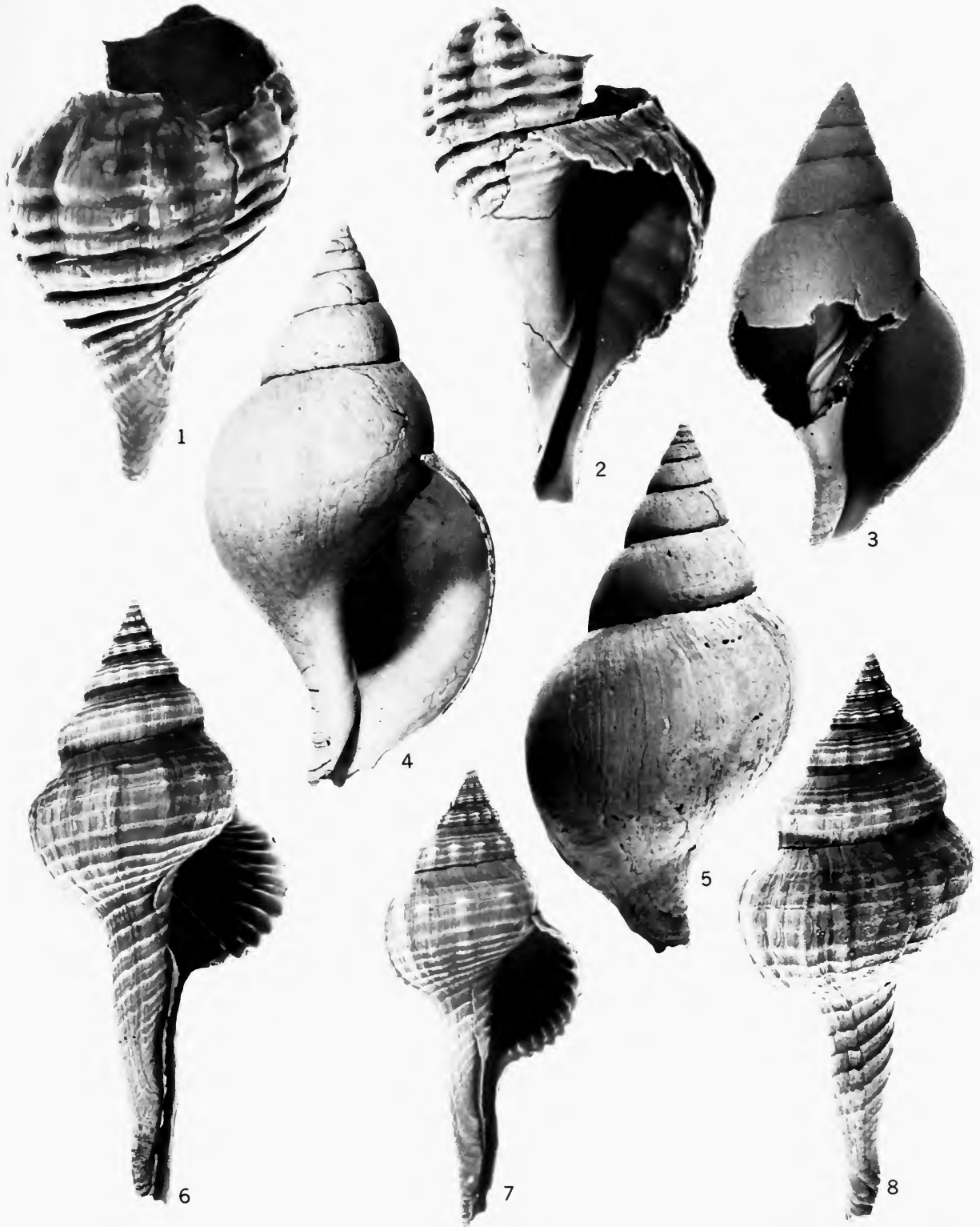
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## PLATE 43

- 1, 2. *Fasciolaria cronlyensis* Gardner, USNM 204094 from USGS 25364, height 60.2 mm: 1, abapertural view; 2, apertural view.
3. *Fasciolaria beaufortensis*, new species, USNM 204095 from USGS 25364, apertural view, height 98.8 mm.
- 4, 5. *Fasciolaria beaufortensis*, new species, holotype, USNM 204096 from USGS 25362, height 82.0 mm: 4, apertural view; 5, abapertural view.
- 6, 8. *Heilprinia caloosaensis malcolmi*, new subspecies, holotype, USNM 204097 from USGS 25648, height 76.5 mm: 6, apertural view; 8, abapertural view.
7. *Heilprinia caloosaensis malcolmi*, new subspecies, USNM 204098 from USGS 25371, apertural view, height 48.6 mm.



## PLATE 44

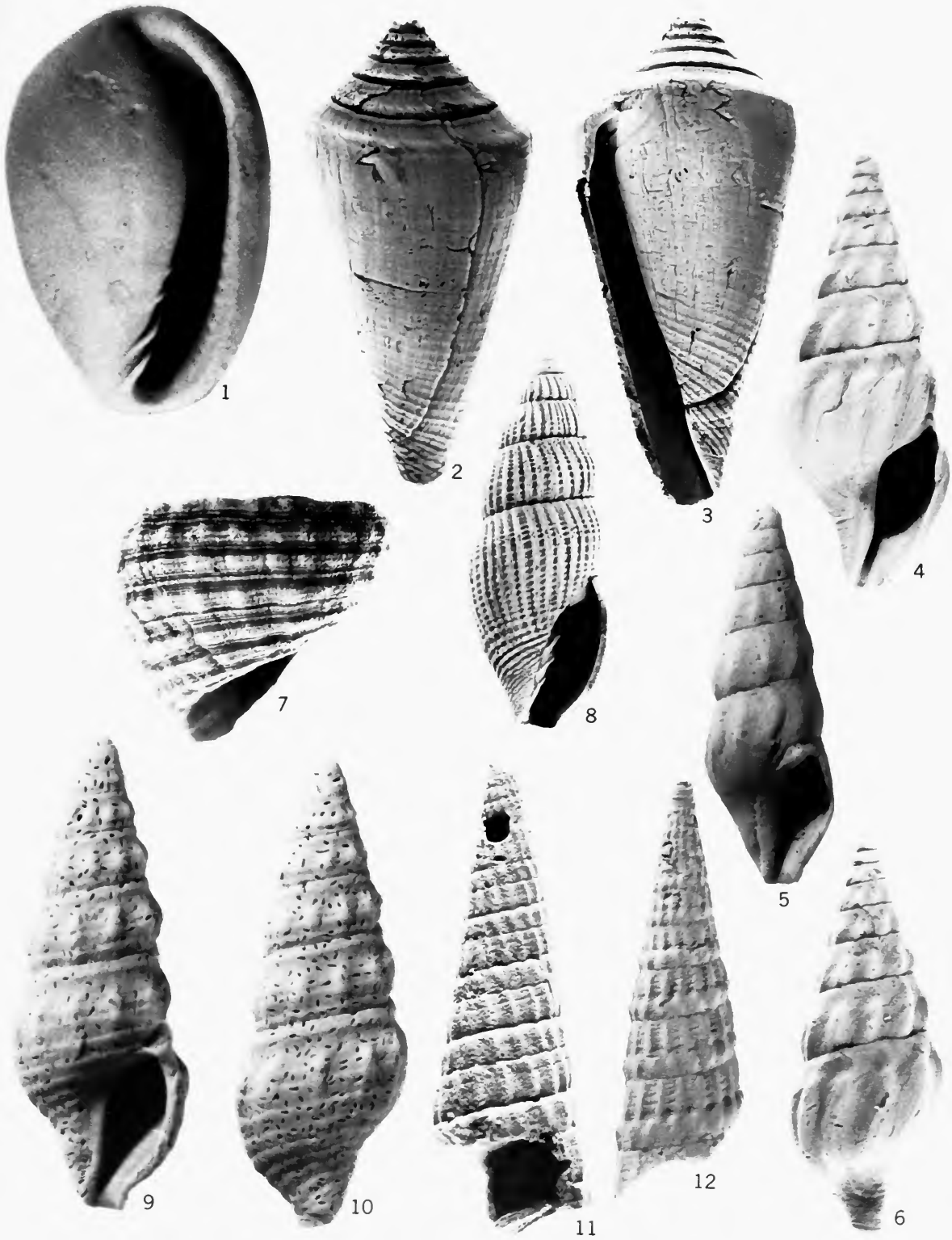
1. *Volutifusus typus* Conrad, USNM 204102 from USGS 25364, apertural view, height 91.5 mm.
- 2, 3. *Volutifusus typus* Conrad, USNM 204103 from USGS 25364, height 153.0 mm: 2, abapertural view; 3, apertural view.
4. *Granulina ovuliformis* (d'Orbigny) USNM 204107 from USGS 25368, abapertural view, height 4.4 mm.
- 5, 6. *Oliva carolinensis* (Conrad), USNM 204099 from USGS 25371, height 41.7 mm: 5, abapertural view; 6, apertural view.
7. *Olivella mutica* (Say), USNM 204100 from USGS 25366, apertural view, height 15.1 mm.
- 8, 9. *Dentimargo polyspira?* (Olsson and Harbison), USNM 204104 from USGS 25367, height 4.3 mm: 8, apertural view; 9, abapertural view.
10. *Volvarina avena* (Kiener), USNM 204108 from USGS 25366, apertural view, height 7.3 mm.
11. *Prunum limatulum* (Conrad), USNM 204105 from USGS 25366, abapertural view showing color pattern beneath exterior shell layer, height 11.0 mm.
- 12–14. *Prunum limatulum* (Conrad), USNM 204106 from USGS 25366, height 10.5 mm: 12, abapertural view; 13, profile of aperture; 14, apertural view.





## PLATE 45

1. *Granulina ovuliformis* (d'Orbigny), USNM 204129 from USGS 25368, apertural view, height 4.0 mm.
- 2, 3. *Conus adversarius* Conrad, USNM 204110 from USGS 25364, height 64.7 mm: 2, abapertural view; 3, apertural view.
- 4, 6. *Cymatosyrinx lunata* (Lea), USNM 204111 from USGS 25367, height 12.6 mm: 4, apertural view (lacks part of the thin outer shell layer); 6, abapertural view.
5. *Cymatosyrinx lunata* (Lea), USNM 204112 from USGS 25368, apertural view, height 7.6 mm.
7. *Trigonostoma* sp., USNM 204109 from USGS 25362, abapertural view, height of broken specimen 18.1 mm.
8. *Vexillum wandoense* (Holmes), USNM 204101 from USGS 25366, apertural view, height 6.8 mm.
- 9, 10. *Sedilia* sp. aff. *S. sedilia* (Dall), USNM 204113 from USGS 25368, height 9.4 mm: 9, apertural view; 10, abapertural view.
11. *Strioterebrum* sp., USNM 204118 from USGS 25366, apertural view, height 14.7 mm.
12. *Strioterebrum* sp. cf. *S. petiti* Olsson, USNM 204119 from USGS 25369, view of broken specimen, height 12.6 mm.



## PLATE 46

- 1, 2. *Brachycthara reidenbachi*, new species, holotype, USNM 204114 from USGS 25369, height 3.6 mm:  
1, apertural view; 2, profile of aperture.
3. *Glabrocythara* sp., USNM 204115 from USGS 25368, apertural view, height 5.5 mm.
4. *Vitricythara micromeris* (Dall), USNM 204117 from USGS 25368, apertural view, height 2.3 mm.
5. *Glabrocythara* sp., USNM 204116 from USGS 25367, apertural view, height 5.9 mm.
6. *Odostomia simplex* (Lea), USNM 204118 from USGS 25369, apertural view, height 1.5 mm.
7. *Odostomia turbinatus* (Lea), USNM 204119 from USGS 25368, apertural view, height 1.6 mm.
8. *Orinella beaufortensis*, new species, holotype, USNM 204120 from USGS 25368, apertural view, height 2.7 mm.



## PLATE 47

- 1, 2. *Ringicula semistriata* d'Orbigny, USNM 204126 from USGS 25369, height 2.0 mm: 1, apertural view; 2, profile of aperture.
3. *Acteocina candei* (d'Orbigny), USNM 204127 from USGS 25367, apertural view, height 4.0 mm.
4. *Chrysallida beaufortensis*, new species, USNM 204121 from USGS 25369, apertural view, height 2.9 mm.
5. *Turbonilla abrupta* Bush, USNM 204123 from USGS 25367, apertural view, height 4.9 mm.
6. *Pyrgiscus daedaleum* (Lea), USNM 204124 from USGS 25366, apertural view, height 3.4 mm.
7. *Pyrgiscus* sp., USNM 204125 from USGS 25368, apertural view, height 3.8 mm.
8. *Chrysallida auroraensis*, new species, holotype, USNM 204122 from USGS 25361, apertural view, height 3.5 mm.











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