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

Thomas G. Gibson

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 mclellani*, 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 bertiensis* Mansfield, 1937, and *Amusium precursor* Dall, 1898.

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.

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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 *Ecphora*. 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 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 Greek 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 1687 (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 humphreysii* (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 redescribed 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

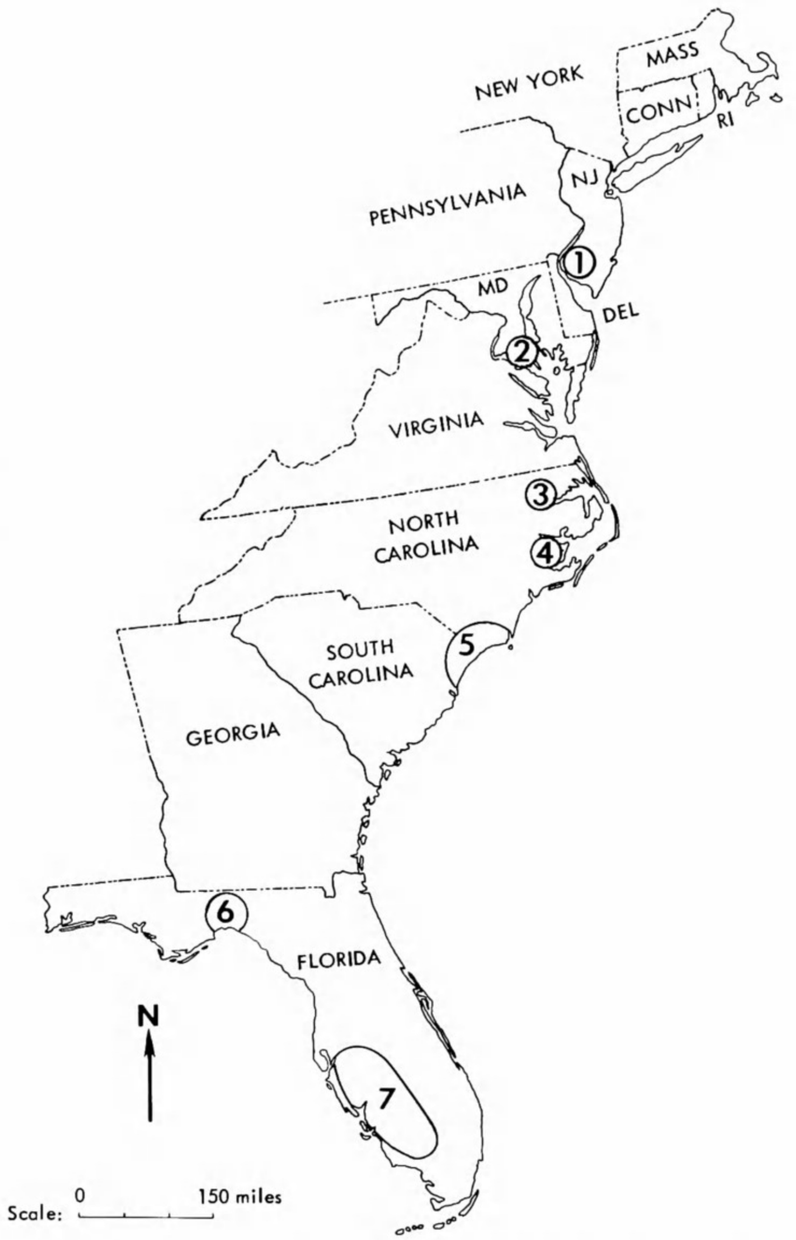

FIGURE 1.—Location of major localities and formational units discussed in text: 1 = Kirkwood Formation in vicinity of Salem and Jericho, New Jersey; 2 = Calvert, Choptank, and St. Marys formations at Calvert Cliffs, Maryland; 3 = Yorktown Formation along Chowan River, North Carolina, 4 = Lee Creek Mine, 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.

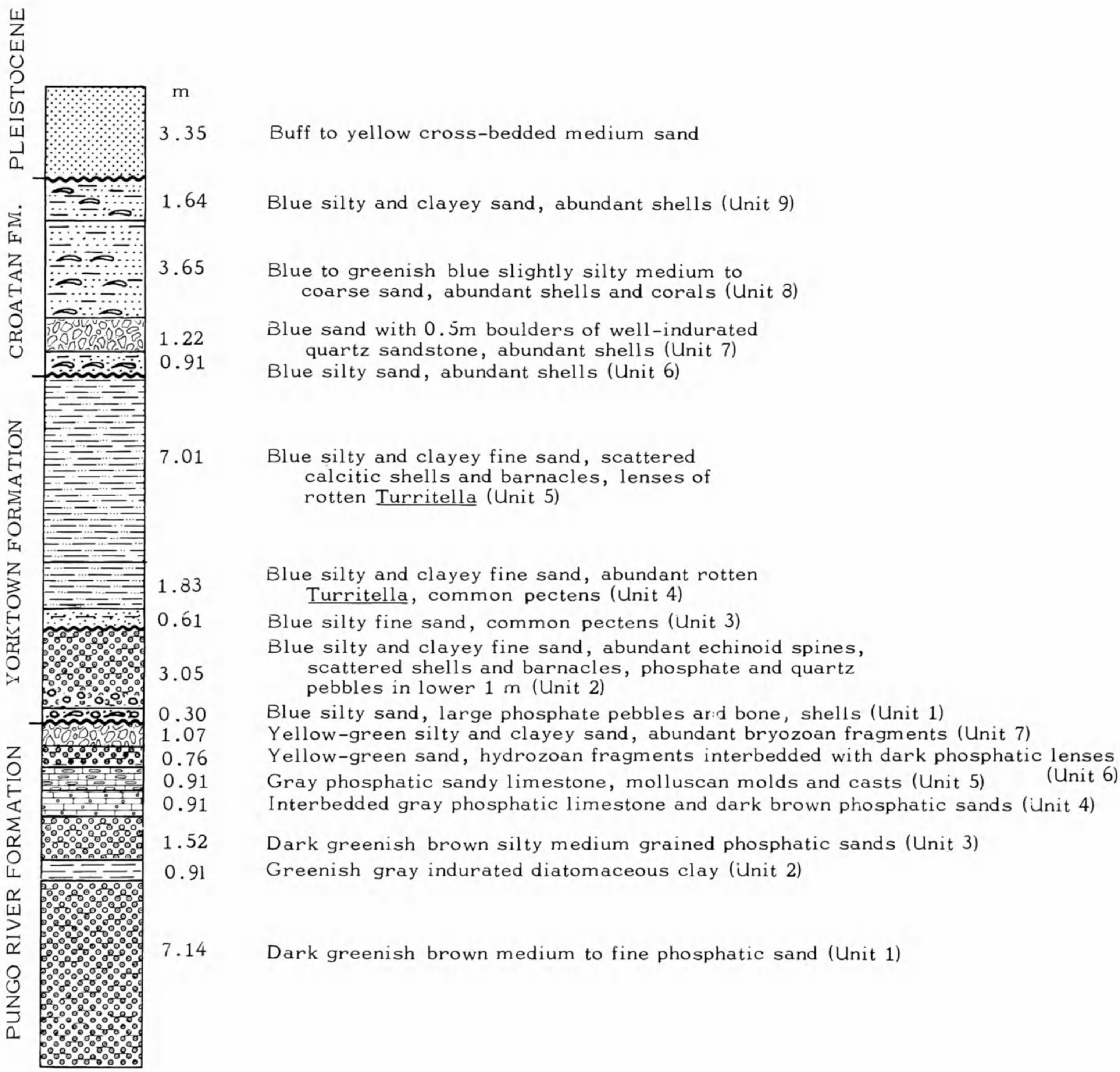

FIGURE 2.—Section of Miocene and younger strata exposed in the northwest wall of the test pit, Lee Creek Mine.

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 mclellani,* 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 hymphreysii*) 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*, *Stralopecten ernestsmithi*, *Leptopecten leonensis*, and *Amusium mortoni*. Two of these species are restricted to the Waccamaw and Caloosahatchee formations, *Stralopecten 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

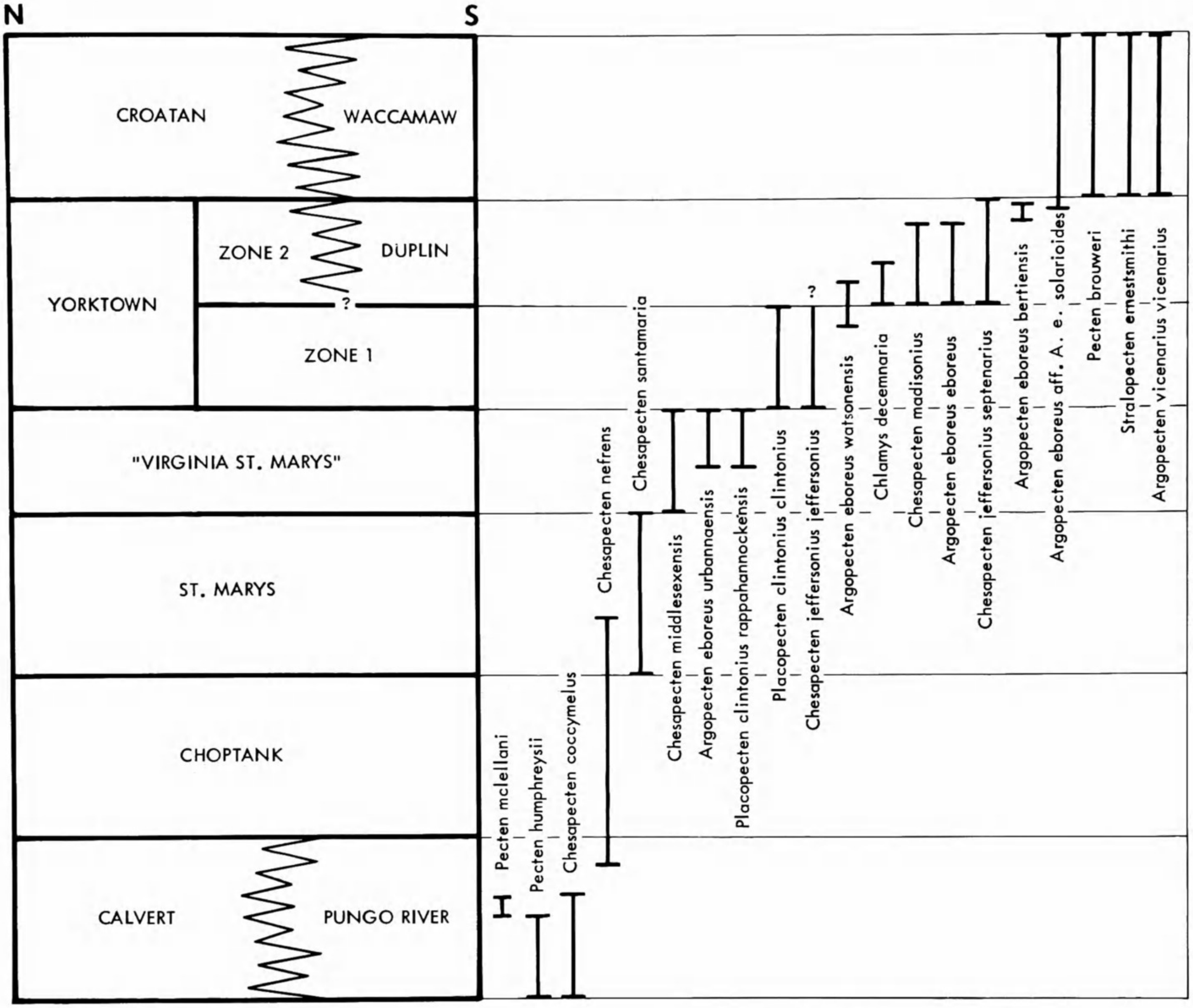

FIGURE 3.—Range chart of the common late Cenozoic pecten species occurring in the formations of the central Atlantic Coastal Plain.

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 *Chesapecten jeffersonius jeffersonius*.

In the middle part of the Yorktown Formation, the lower part of Mansfield's zone 2, the *Chesapecten* 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 decemnaria* 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 solarioides,* advanced forms of *Chesapecten 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 ernestsmithi, Argopecten vicenarius,* along with the abundant specimens of the various subdivisions of *A. eboreus solarioides.*

Other species of pectens are found in the strata of the

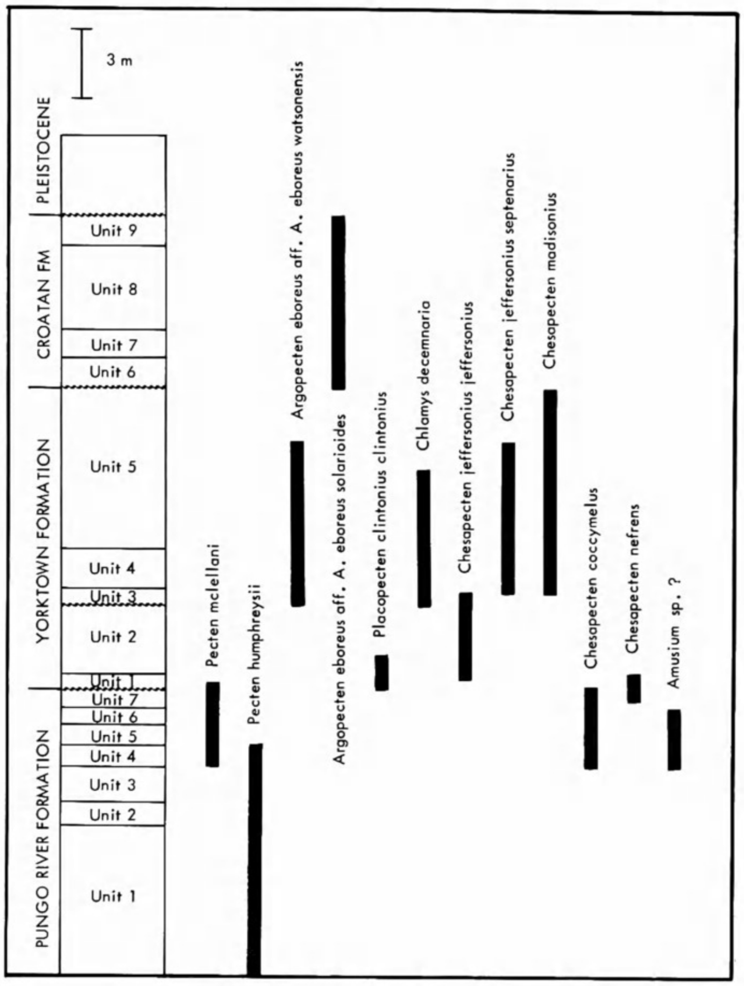

FIGURE 4.—Distribution of species of pectens in the test pit strata of the Lee Creek Mine.

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 *Chesapecten* group, the *Argopecten eboreus* stock, the *Placopecten* group, and the probable *Pecten mclellani* lineage. Phylogenies have not been developed for *Chlamys decemnaria* 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 *Chesapecten* 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-

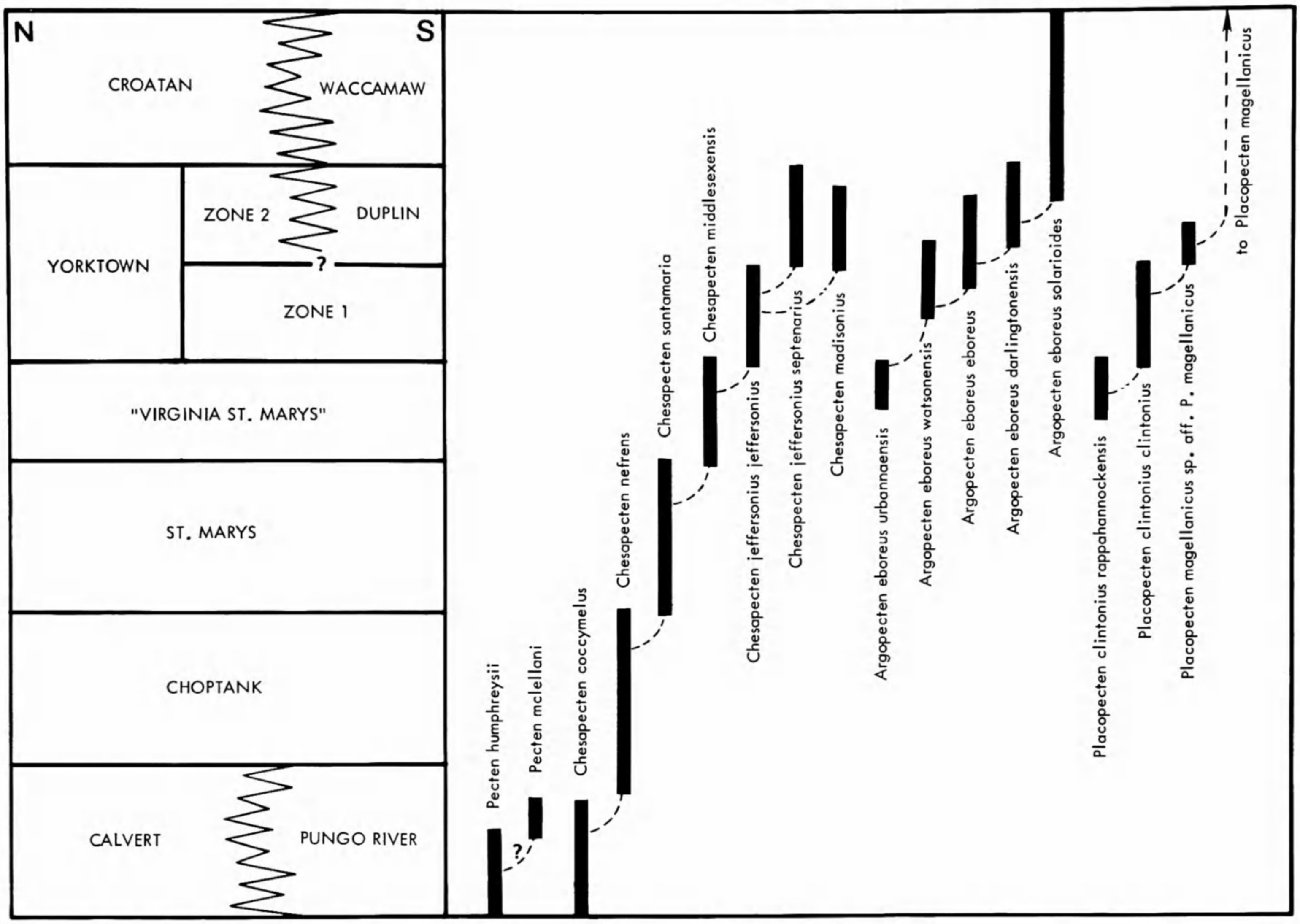

FIGURE 5.—Phylogeny of some pecten species occurring in Miocene through lower Pleistocene strata in the Atlantic Coastal Plain. The placement of the boundary between zone 1 and zone 2 of the Yorktown Formation is uncertain, as is the relationship between *Pecten humphreysii* and *P. mclellani.*

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): *Chesapecten 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, *Chesapecten 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 mclellani*, new species, *P. humphreysii* Conrad, 1842, *Chesapecten 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. choctawhatcheensis* (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 *Ecphora* 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. Huddlestun (1976), however, reported the Jackson Bluff to be of late Zanclian 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, *Chesapecten 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. hemicyclicus* Ravenel, 1834, "*Pecten*" holmesii Dall, 1898, *Euvola raveneli* (Dall, 1898). *Argopecten anteamplicostatus* (Mansfield, 1936), *A. eboreus* (Conrad, 1833), *A. vicenarius* (Conrad, 1843), *Stralopecten ernestsmithi* (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 ernestsmithi* (Tucker, 1931), *S. caloosaensis* (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 hemicyclicus, "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 *Ecphora* 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

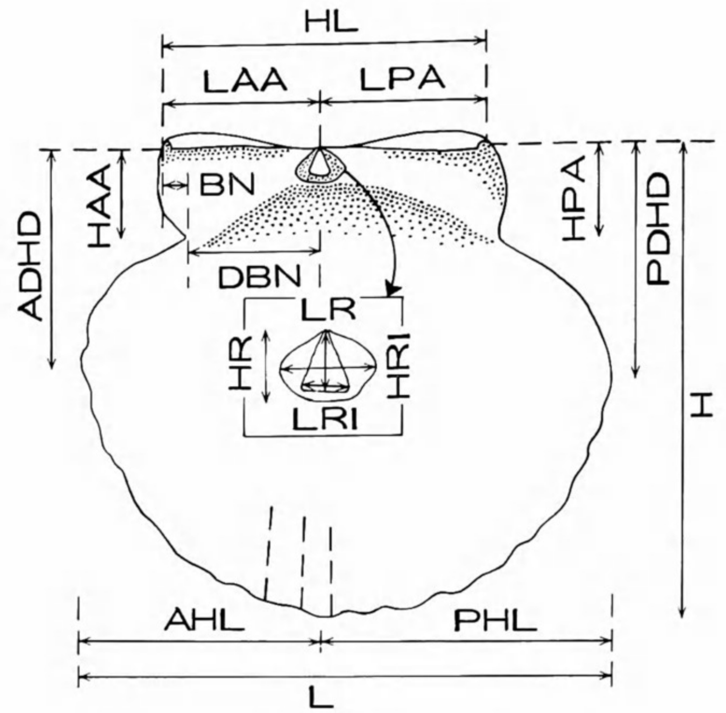

FIGURE 6.—Diagram of measurements for pectens. (See below for explanation of symbols.)

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)
WI 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

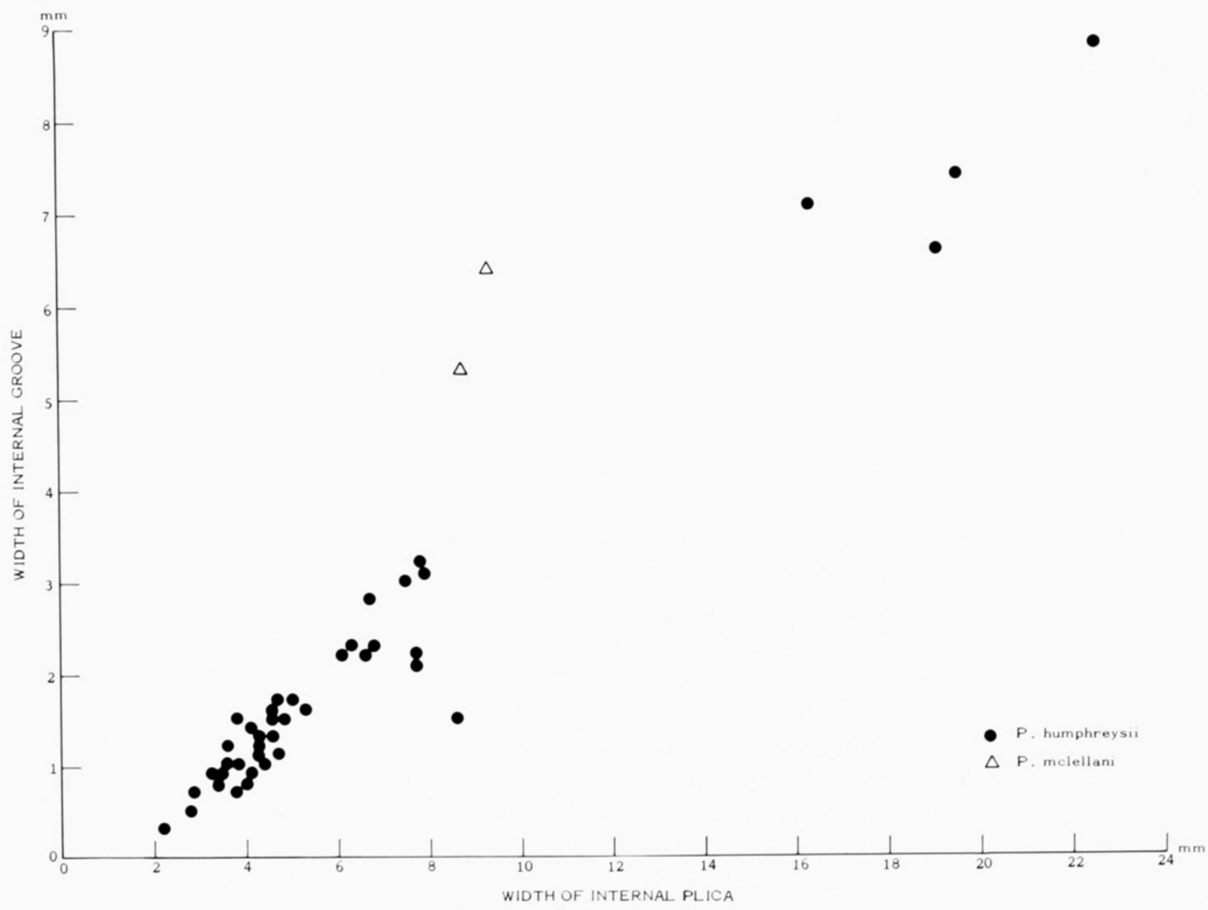
Genus *Pecten* Muller, 1776

Pecten mclellani, new species

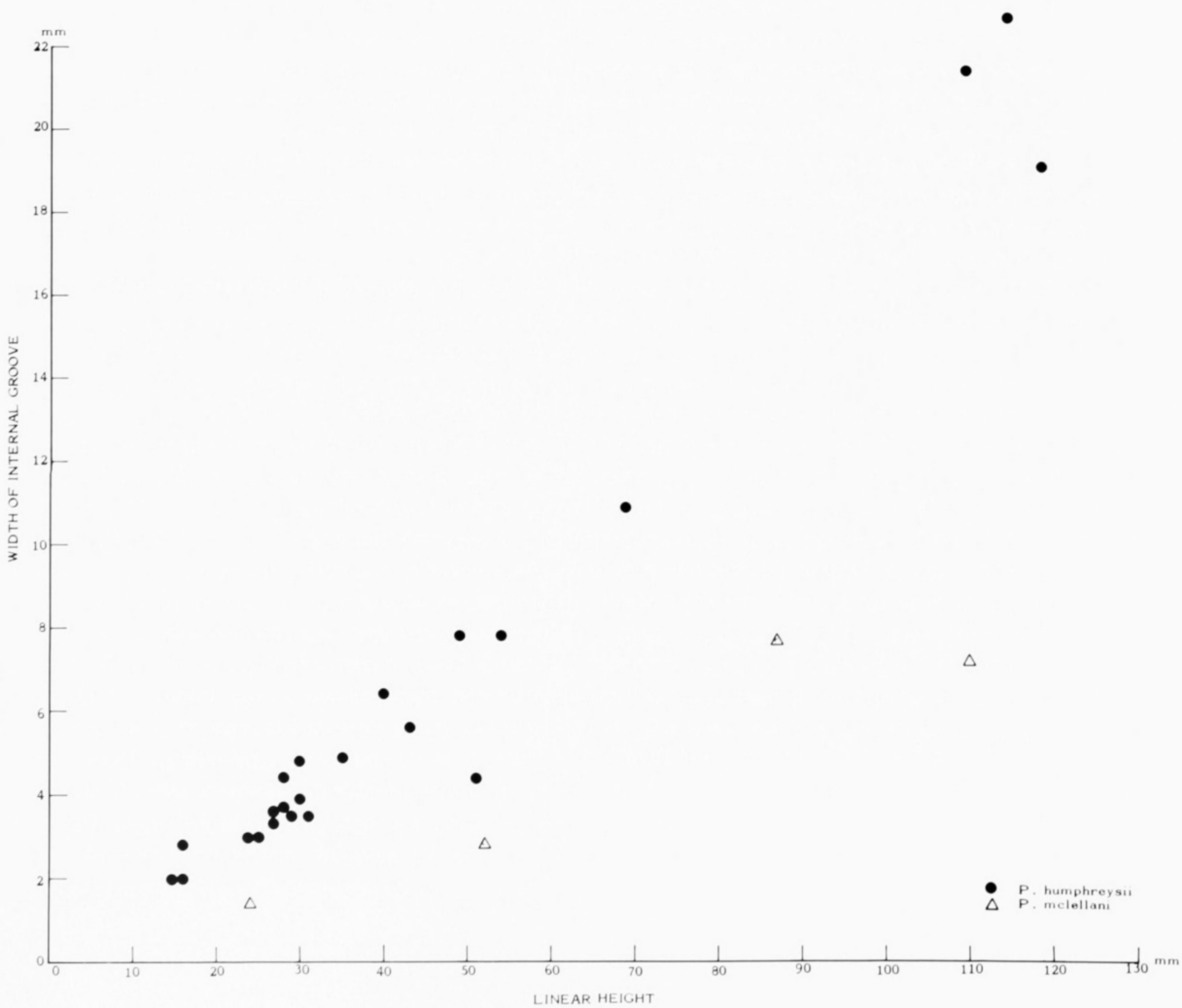
PLATES 1, 2, 13: FIGURE 2

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



mm
WIDTH OF INTERNAL GROOVE
WIDTH OF INTERNAL PLICA
P. humphreysii
P. mclellani



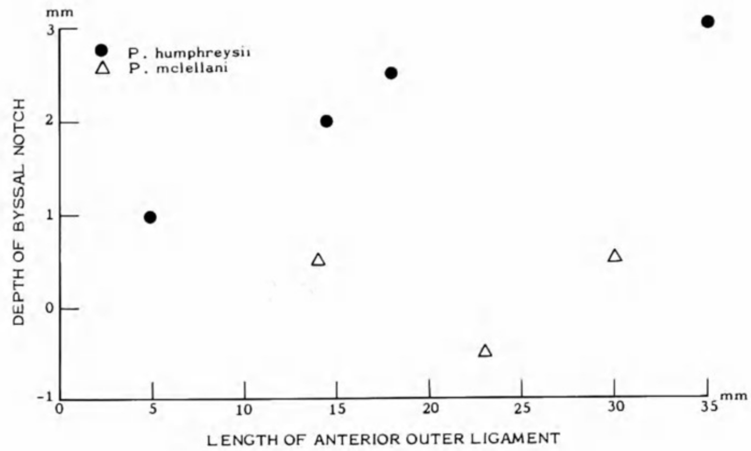
mm
WIDTH OF INTERNAL GROOVE
LINEAR HEIGHT
P. humphreysii
P. mclellani

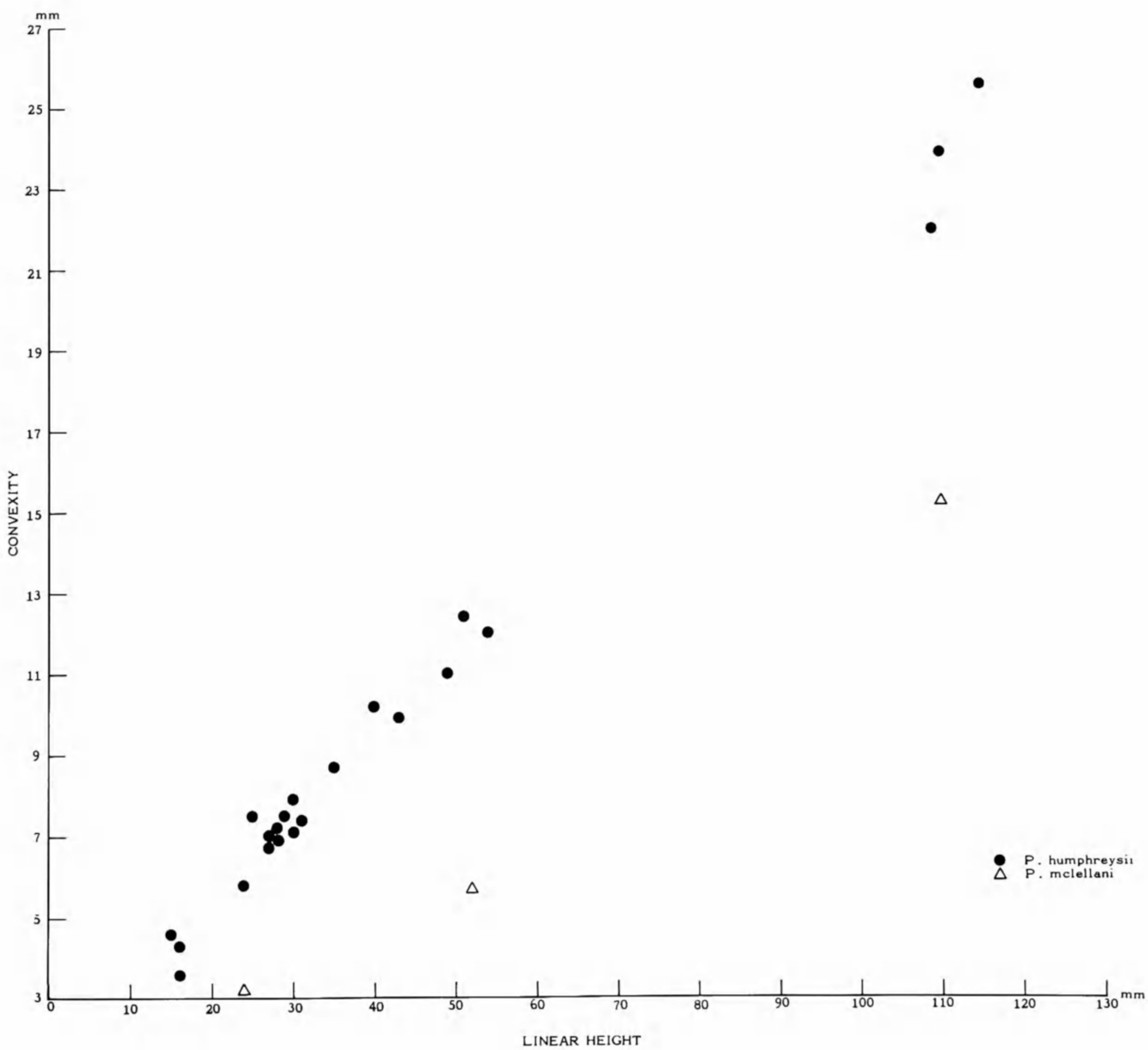
FIGURE 7 (top left).—Bivariate scatter diagram showing the difference in the width of the internal plica and groove between samples of *Pecten humphreysii* (Calvert Formation, Maryland) and *P. mclellani* (Pungo River Formation, North Carolina).

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	USNM 362981	USNM 362982	USNM 362983	USNM 362984	USNM 362985
	(D)	(S)	(D)	(D)	(D)	(S)	(S)	(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*) *humphreysi 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 (Plagioctenium) eboreus Conrad.—Dall, 1898:749 [in part].
Chlamys (Plagioctenium) 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 *Ecphora* zone of the Jackson Bluff Formation in Florida, *A. eboreus solarioides* (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. solarioides*, 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. solarioides*. 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 solarioides (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 interspaces 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. solarioides*, along with an occasional *A. e. bertiensis*. The highest group in the sequence is *A. e. solarioides*, 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-

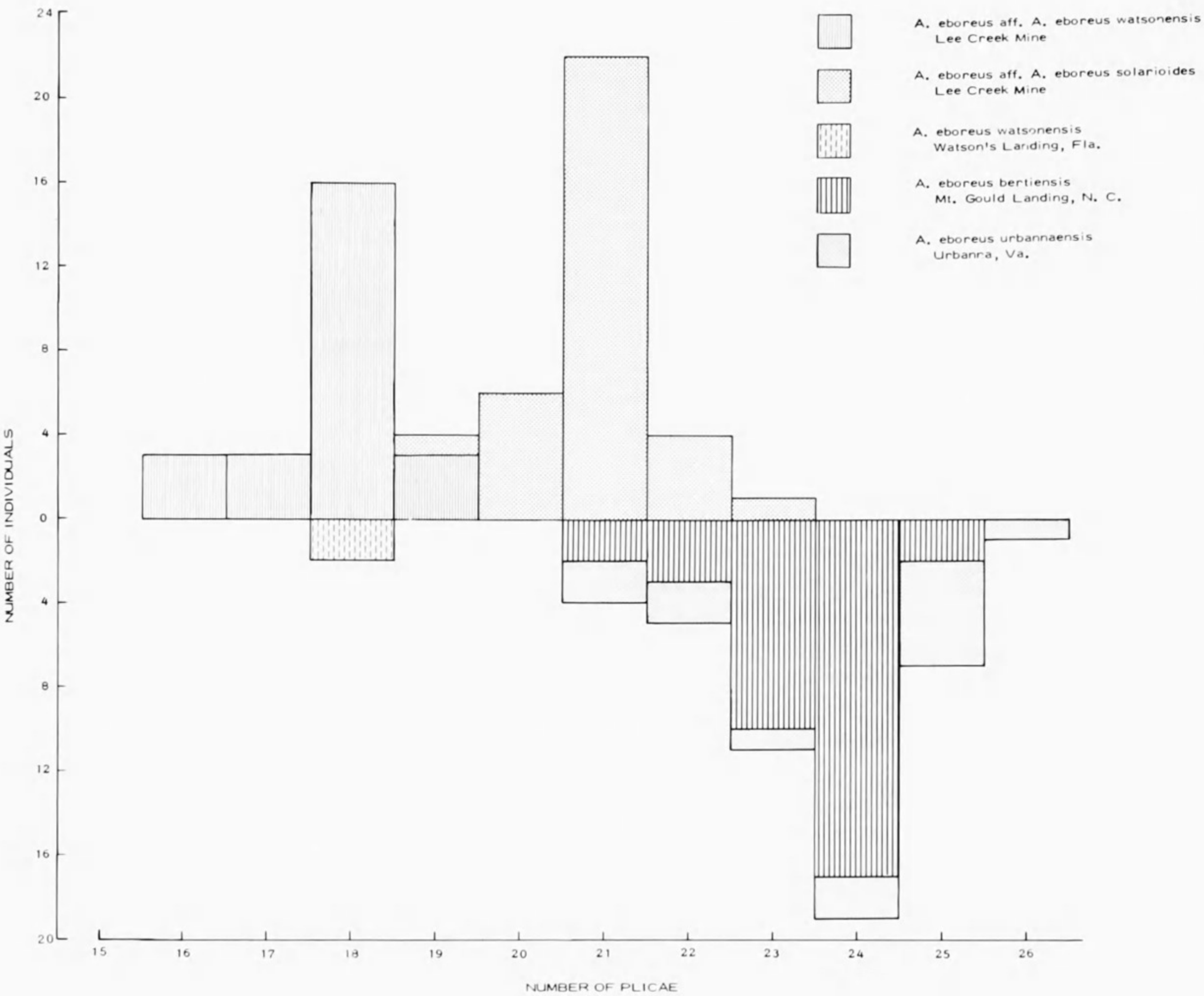


FIGURE 11.—Double-sided bar graph of the number of plicae in five subgroupings of *Argopecten eboreus*.

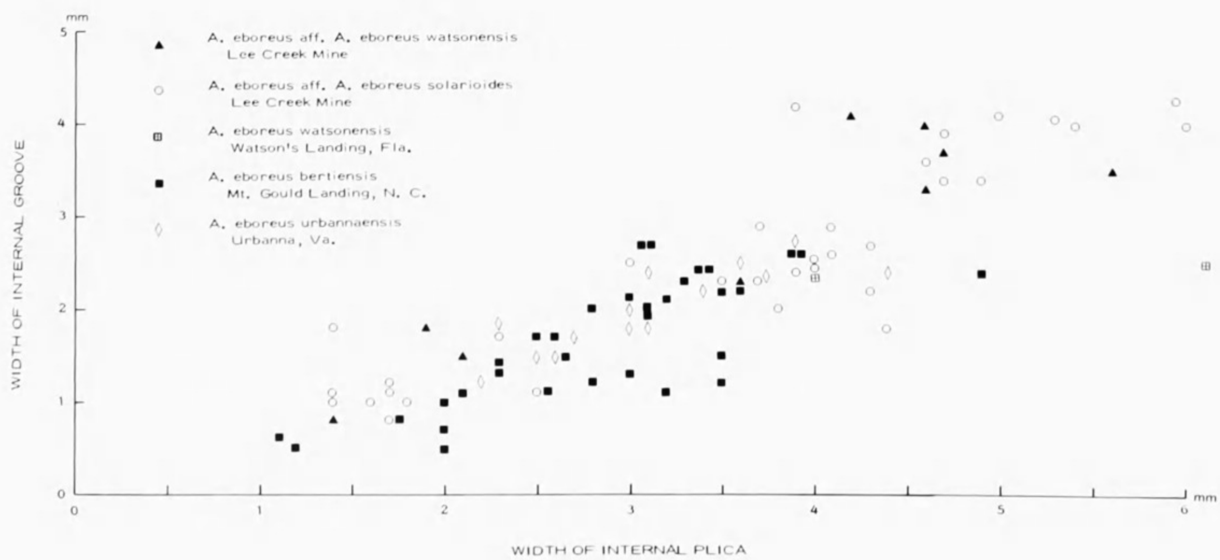


FIGURE 12.—Bivariate scatter diagram showing the general similarity of the width of the internal plica and groove in various subgroupings of *Argopecten eboreus*.

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

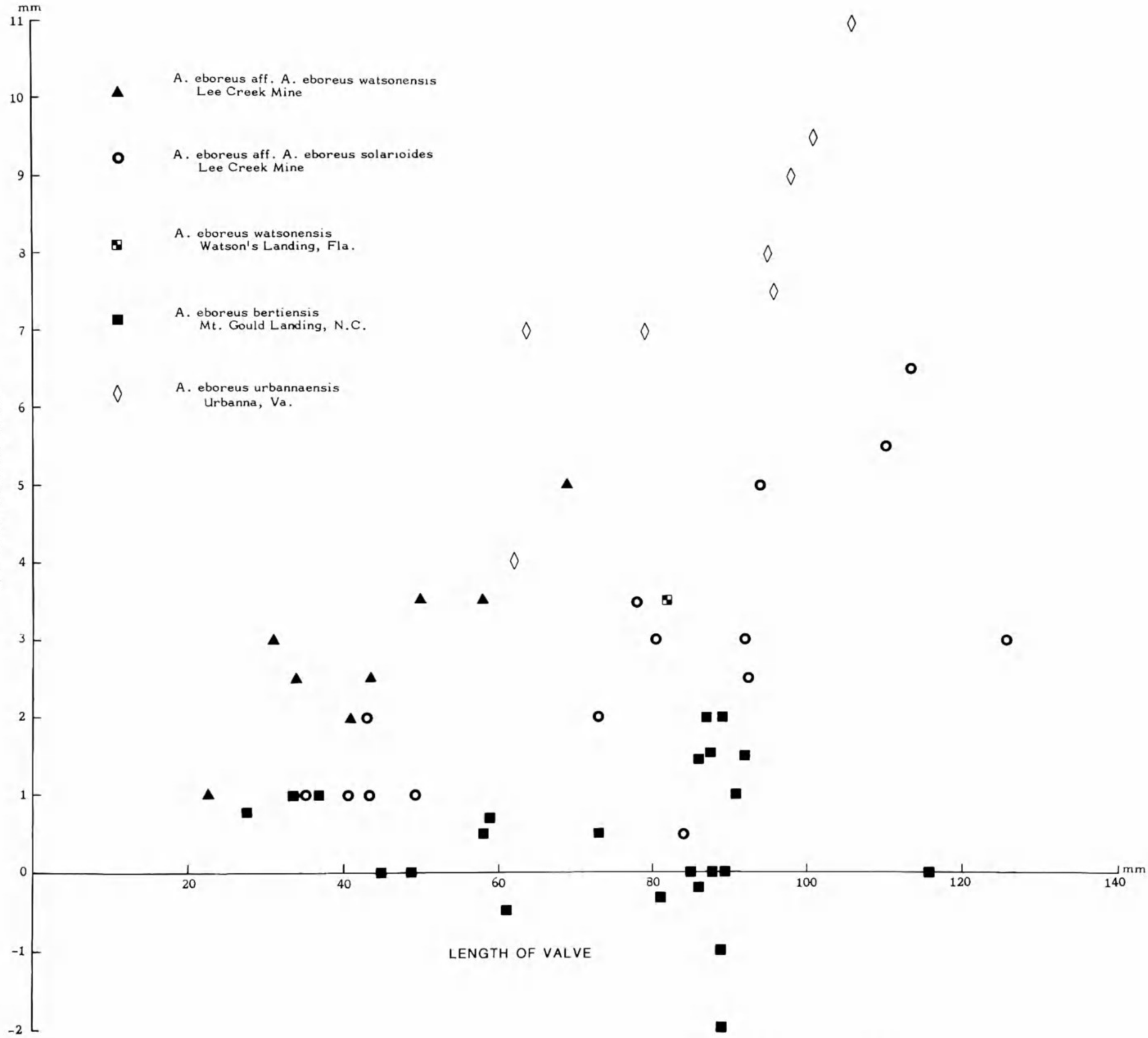


FIGURE 13.—Bivariate scatter diagram showing the differences in the depth of the byssal notch in relation to the length of the valve in various subgroupings of *Argopecten eboreus*.

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.

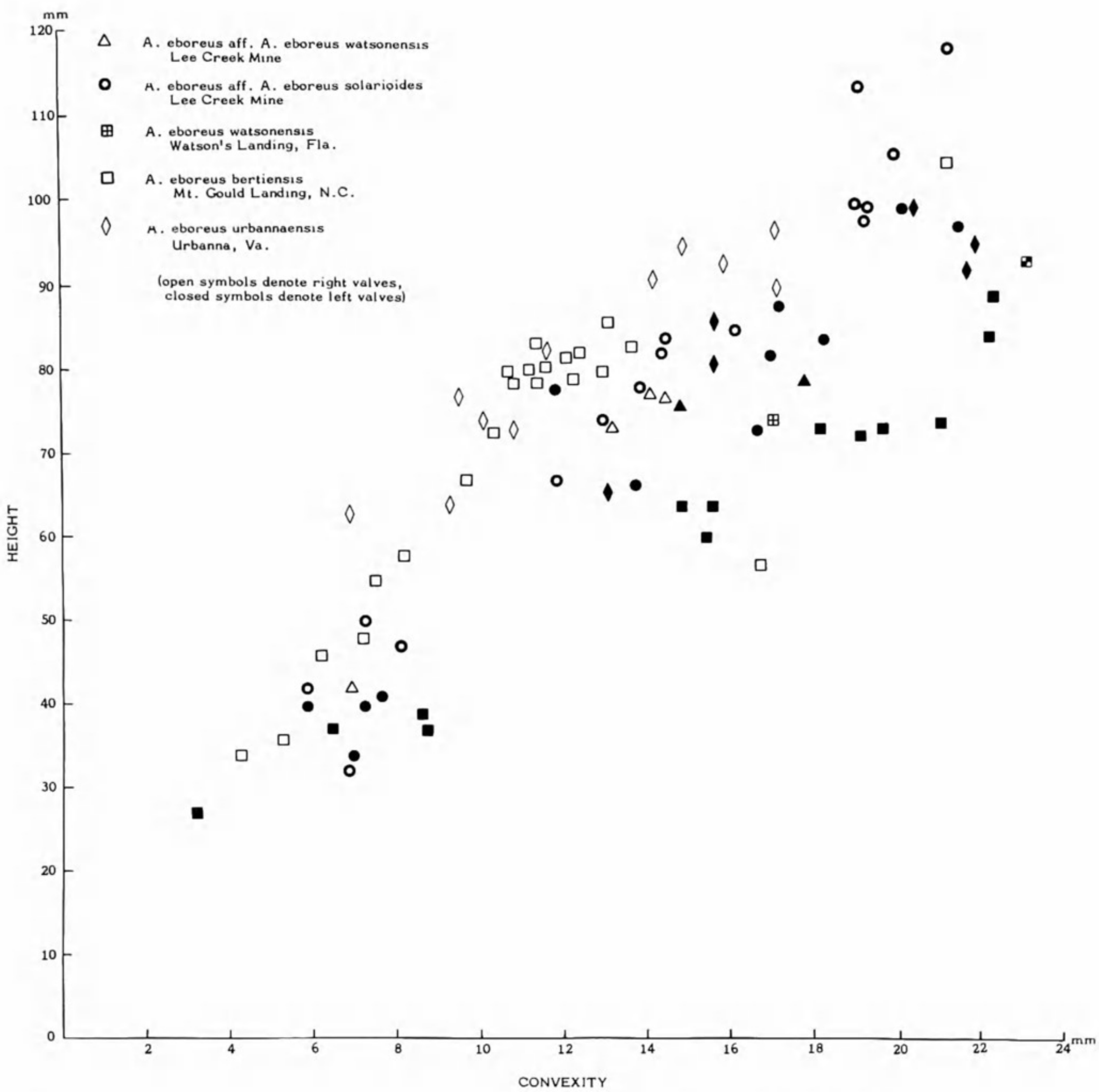


FIGURE 14.—Bivariate scatter diagram showing the differences in convexity of the left and right valves among the various subgroupings of *Argopecten eboreus.*

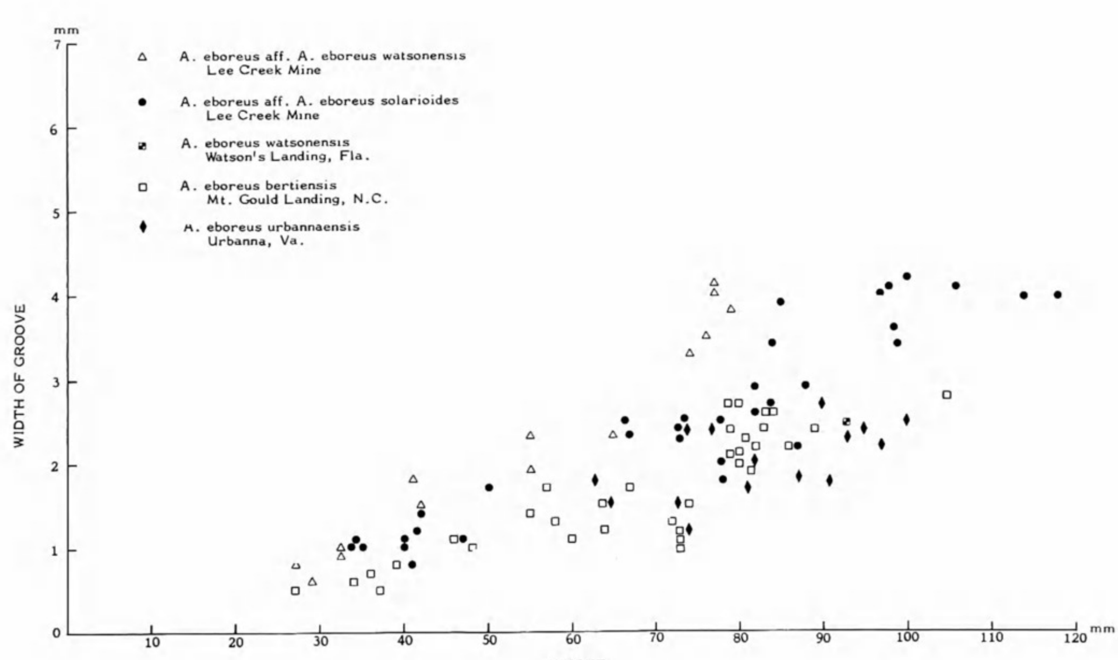


FIGURE 15.—Bivariate scatter diagram showing the differences in the width of the internal groove in relation to the height of the valve in various subgroupings of *Argopecten eboreus.*

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 *Ecphora* 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 *Ecphora* 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 urbannaensis* 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 (D)	USNM 218853 (S)	USNM 218854 (D)	USNM 218856 (S)	USNM 362987 (D)	USNM 362988 (D)	USNM 362989 (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 resilifer is considerably broader in *P. clintonius* than in *P. magellanicus*. The gently sloping sides of the resilifer 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 resilifer, measurements were made on both for comparative purposes. The ratio of length to height of the resilial insertion differs between the two species, with *P. clintonius* having a considerably broader resilial insertion (Figure 16), supporting the views of Dall, Tucker-Rowland, and Mongin. The resilifer also varies between the two species, with *P. clintonius* again having a broader one. While the correlation between height and length of the resilifer is lower than that of the resilial insertion, probably reflecting in large part the difficulty of accurately measuring the resilifer because of the gently sloping sides, this character could be used in species where the resilial 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 (Chlamys) clintonius rappahannockensis Mansfield, 1936:186–187, pl. 22: figs. 1-3.

Chlamys (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

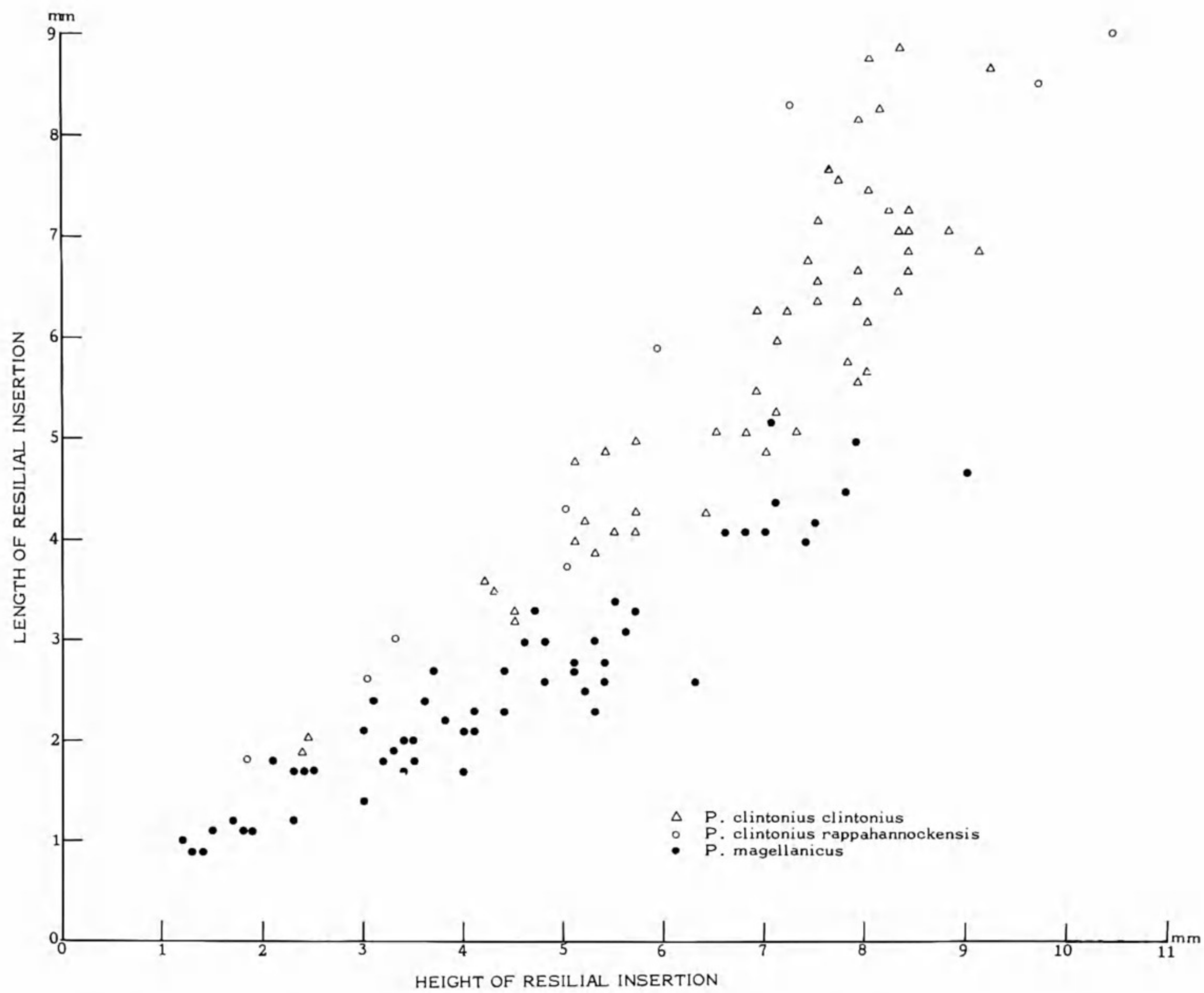


FIGURE 16.—Bivariate scatter diagram showing the differences in the size of the resilial insertion among samples of subspecies of *Placopecten clintonius* (Yorktown Formation, North Carolina) and *P. magellanicus* (Holocene, New England shelf).

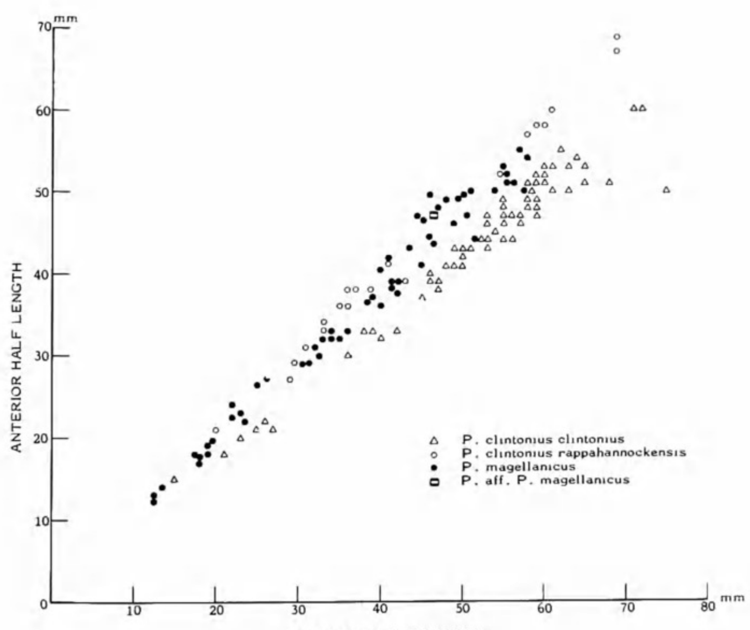


FIGURE 17.—Bivariate scatter diagram showing the difference in the shape of the valve among various subgroupings of *Placopecten*.

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

Character	USNM 362999 (S)	USNM 362999 (D)	USNM 363000 (S)	USNM 363000 (D)	USNM 363001 (S)	USNM 363001 (D)	USNM 363002 (S)	USNM 363003 (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	–
HRI	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.

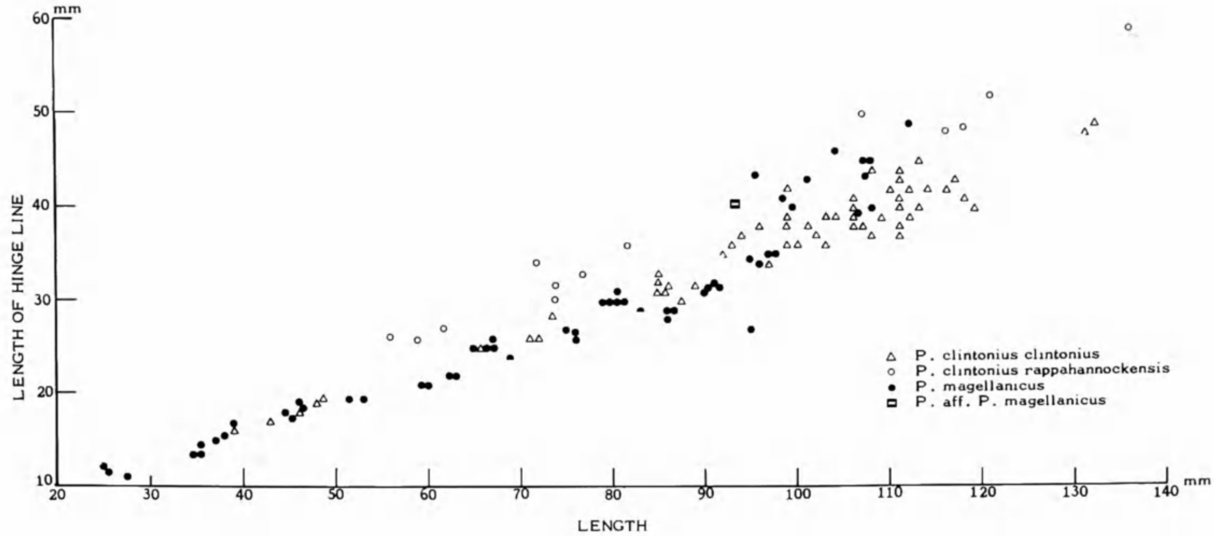


FIGURE 18.—Bivariate scatter diagram showing the similarity in the length of the hinge line among various subgroupings of *Placopecten*.

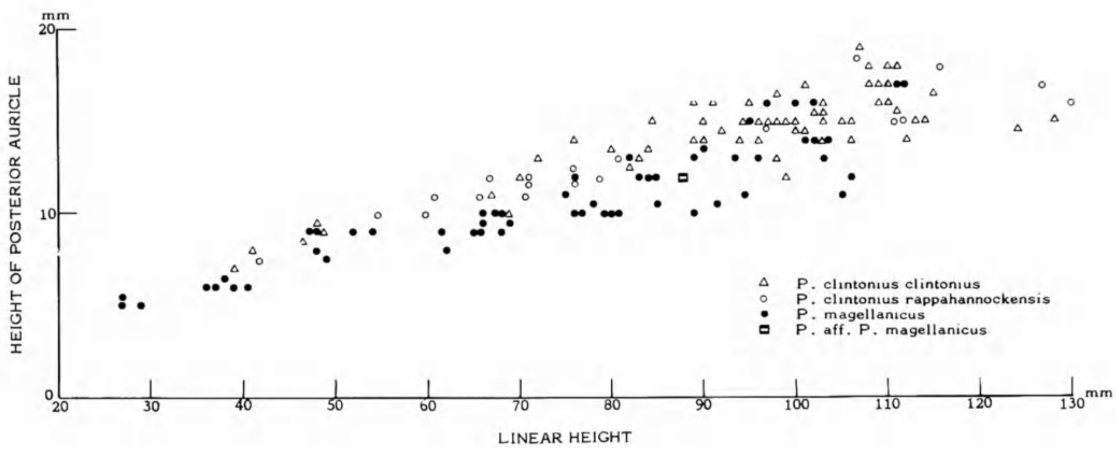


FIGURE 19.—Bivariate scatter diagram showing variation in the height of the posterior auricle in various subgroupings of *Placopecten*.

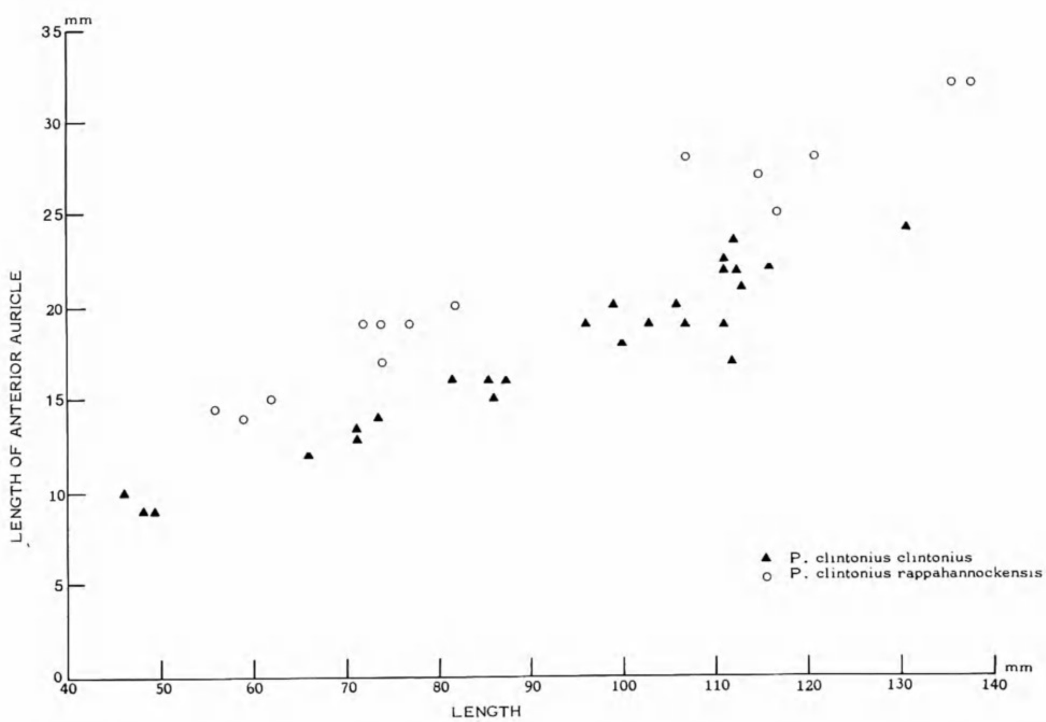


FIGURE 20.—Bivariate scatter diagram showing the greater length of the anterior auricle in a sample of *Placopecten clintonius rappahannockensis* (basal Yorktown Formation, Virginia and North Carolina) compared to a sample of *P. clintonius clintonius* (Yorktown Formation, North Carolina).

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

Character	USNM 218878		USNM 218879		USNM 363004	USNM 363005	USNM 363006	USNM 363007	
	(S)	(D)	(S)	(D)	(D)	(D)	(S)	(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 bysall 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.

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	–

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;

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 1½ 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

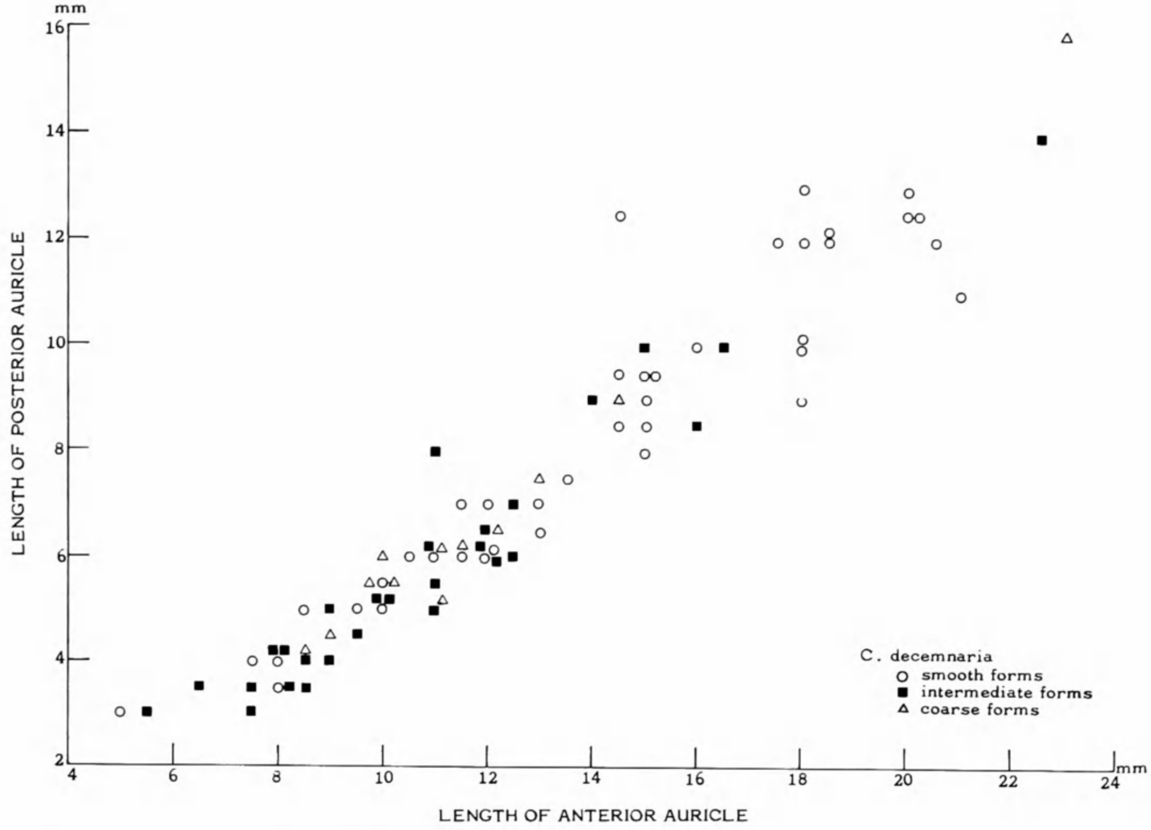


FIGURE 21.—Bivariate scatter diagram showing similarity in length of the auricles in different forms of *Chlamys decemnaria* from a sample in the Yorktown Formation in the Lee Creek Mine.

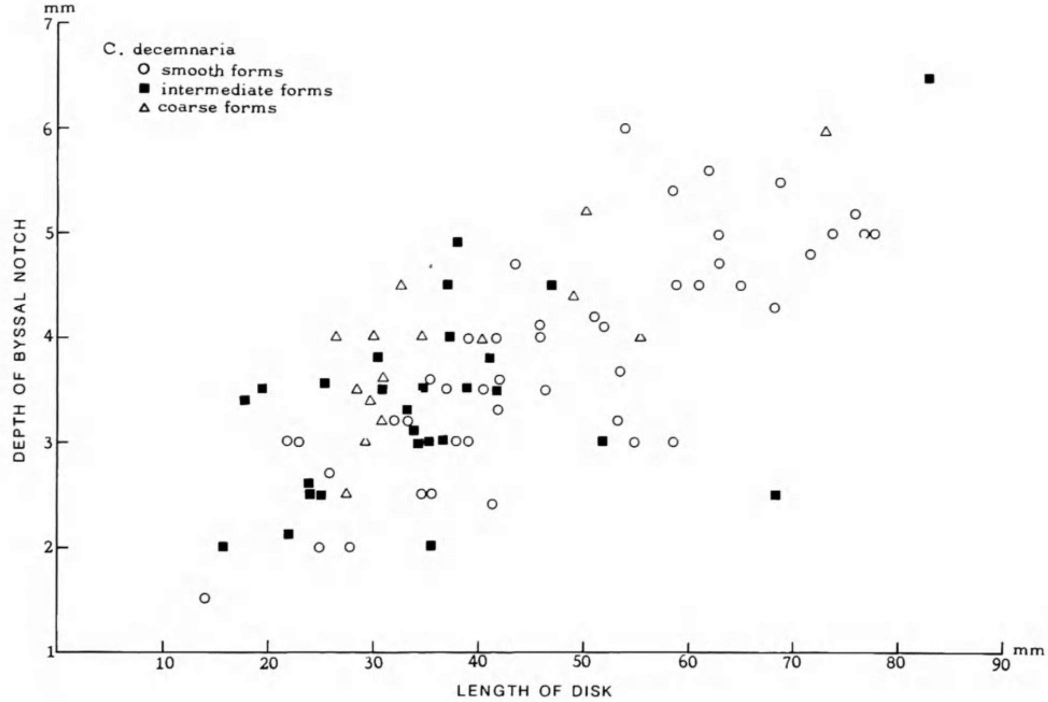


FIGURE 22.—Bivariate scatter diagram showing similarity in depth of the byssal notch in different forms of *Chlamys decemnaria* from a sample in the Yorktown Formation in the Lee Creek Mine.

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 giving 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

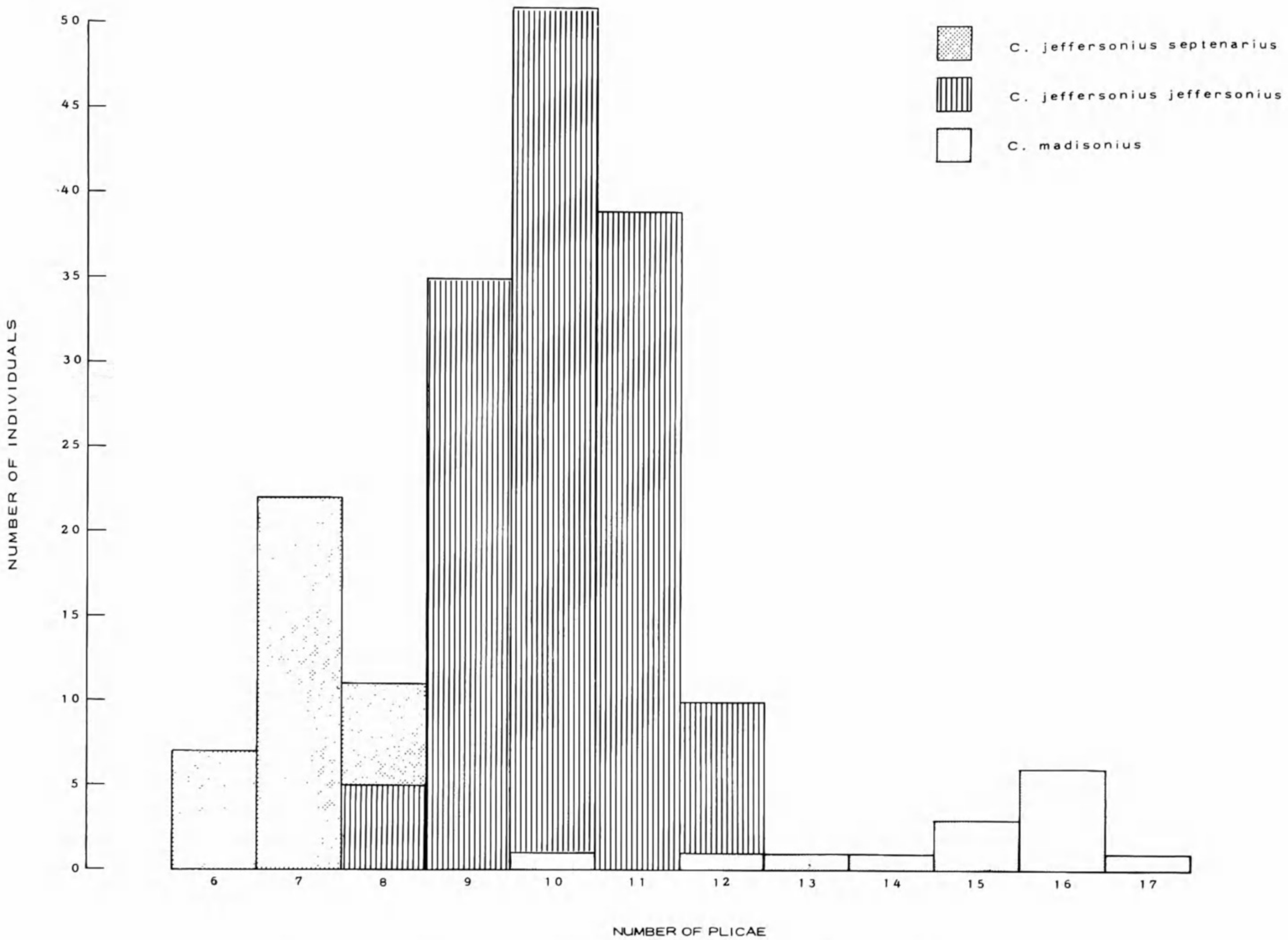


FIGURE 23.—Histogram of the number of plicae in various subgroupings of *Chesapecten* from the Yorktown Formation in the Lee Creek Mine.

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

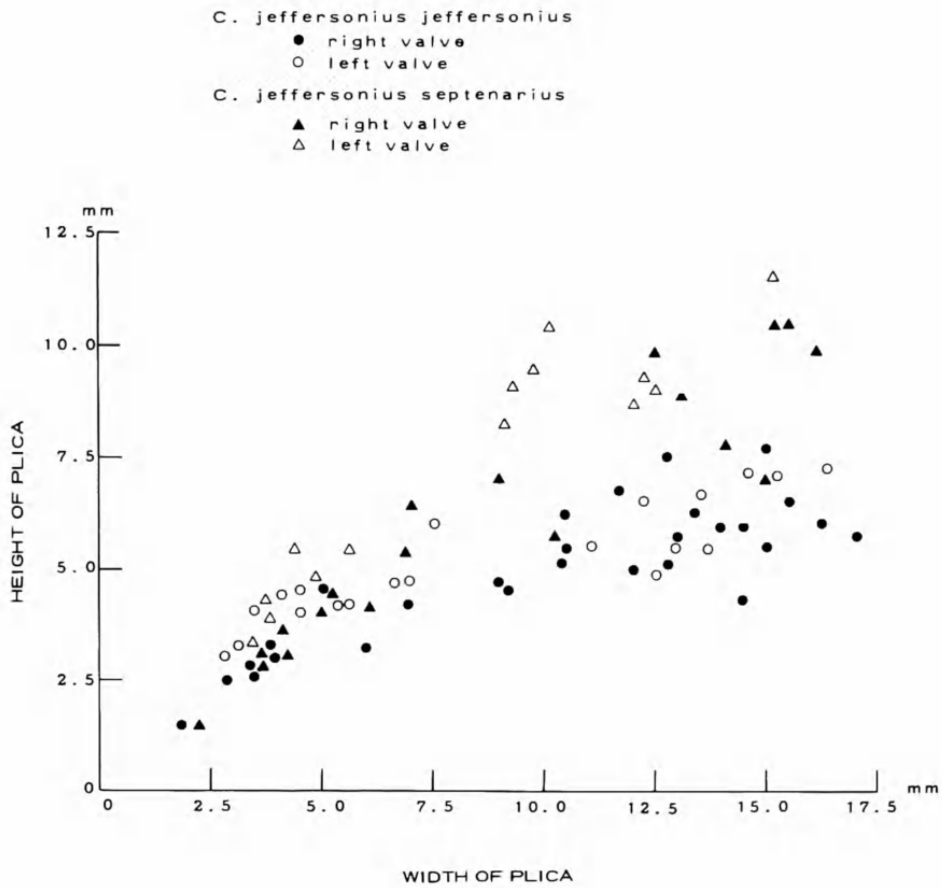


FIGURE 24.—Bivariate scatter diagram showing the greater height of the plica in relation to the width in *Chesapecten jeffersonius septenarius* than in *C. jeffersonius jeffersonius* from the Yorktown Formation in the Lee Creek Mine.

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

Character	USNM 363017	USNM 363018		USNM 363019	USNM 363020	USNM 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 value 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.

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

Character	USNM 218908	USNM 218916		USNM 218919		USNM 363025
	(D)	(S)	(D)	(D)	(S)	(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

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.

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 *Cheaspecten 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

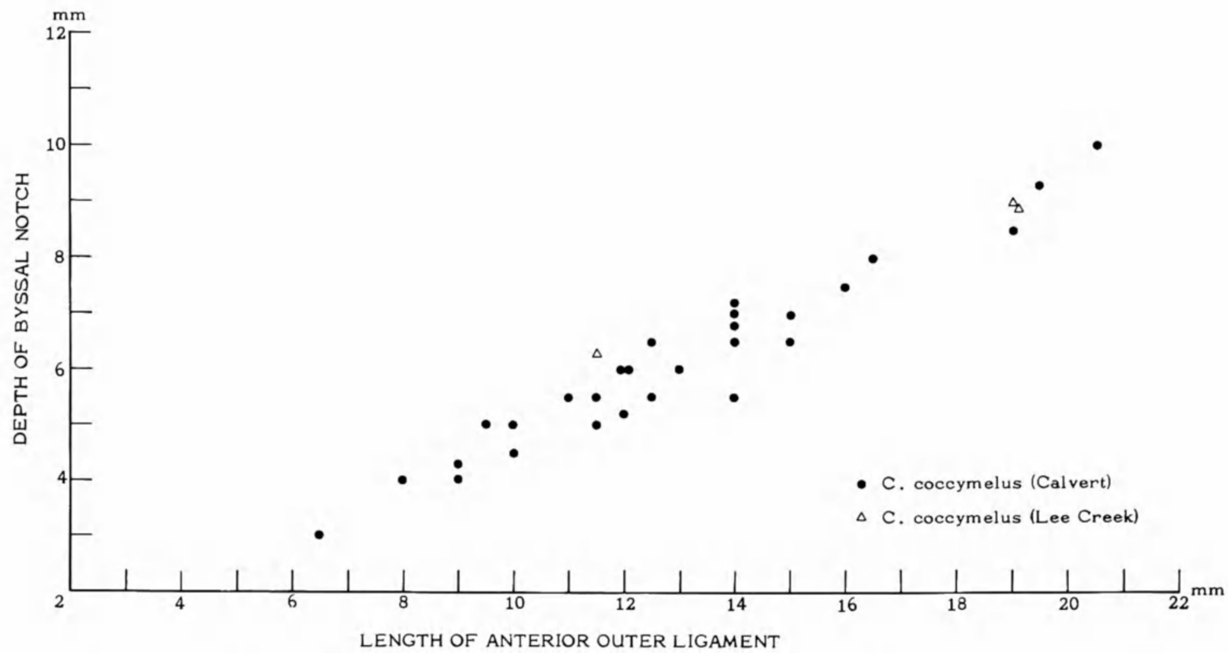


FIGURE 25.—Bivariate scatter diagram showing similarity of depth of the byssal notch between samples of *Chesapecten coccymelus* from the Calvert Formation, Maryland, and from the Pungo River Formation in the Lee Creek Mine.

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

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.
Chesapacten 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 interspaces. 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. coccymelus* 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. coccymelus* 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. coccymelus* 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. mortoni* 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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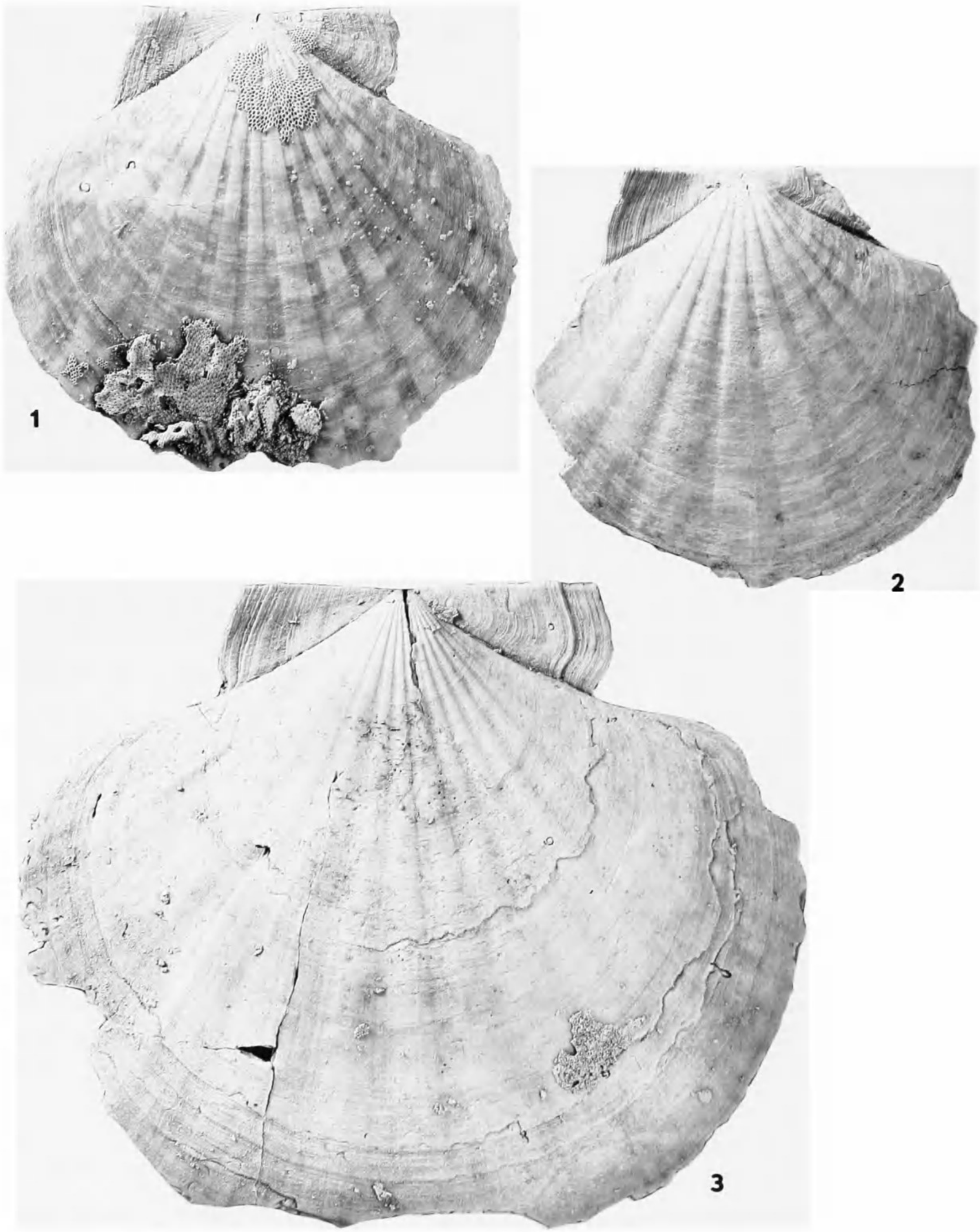

PLATE 1

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

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

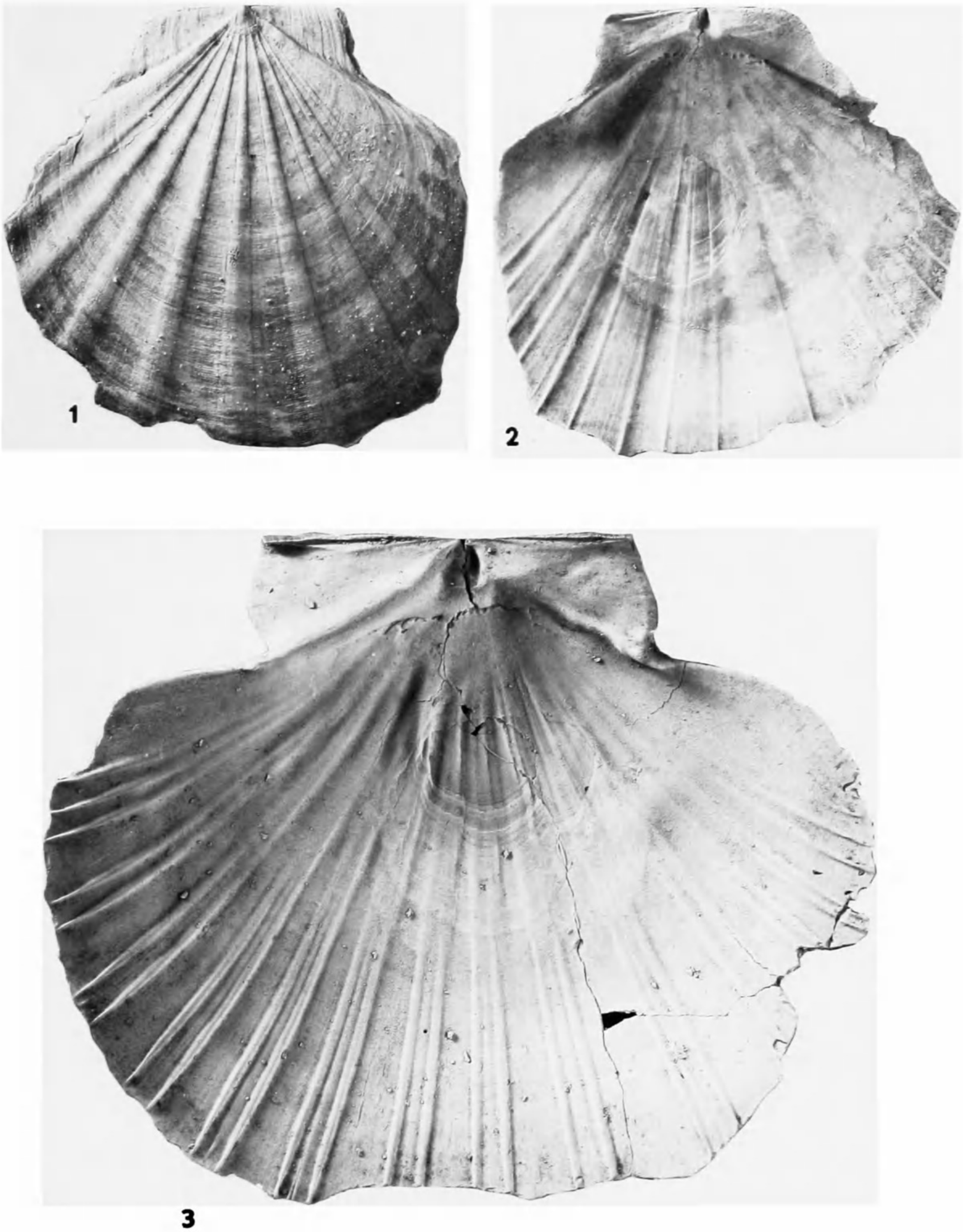

PLATE 2

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

1, 2. Paratype, USNM 218831, external and internal views of left valve, × 1.
3. Holotype, USNM 218830, internal view of right valve, × 1.

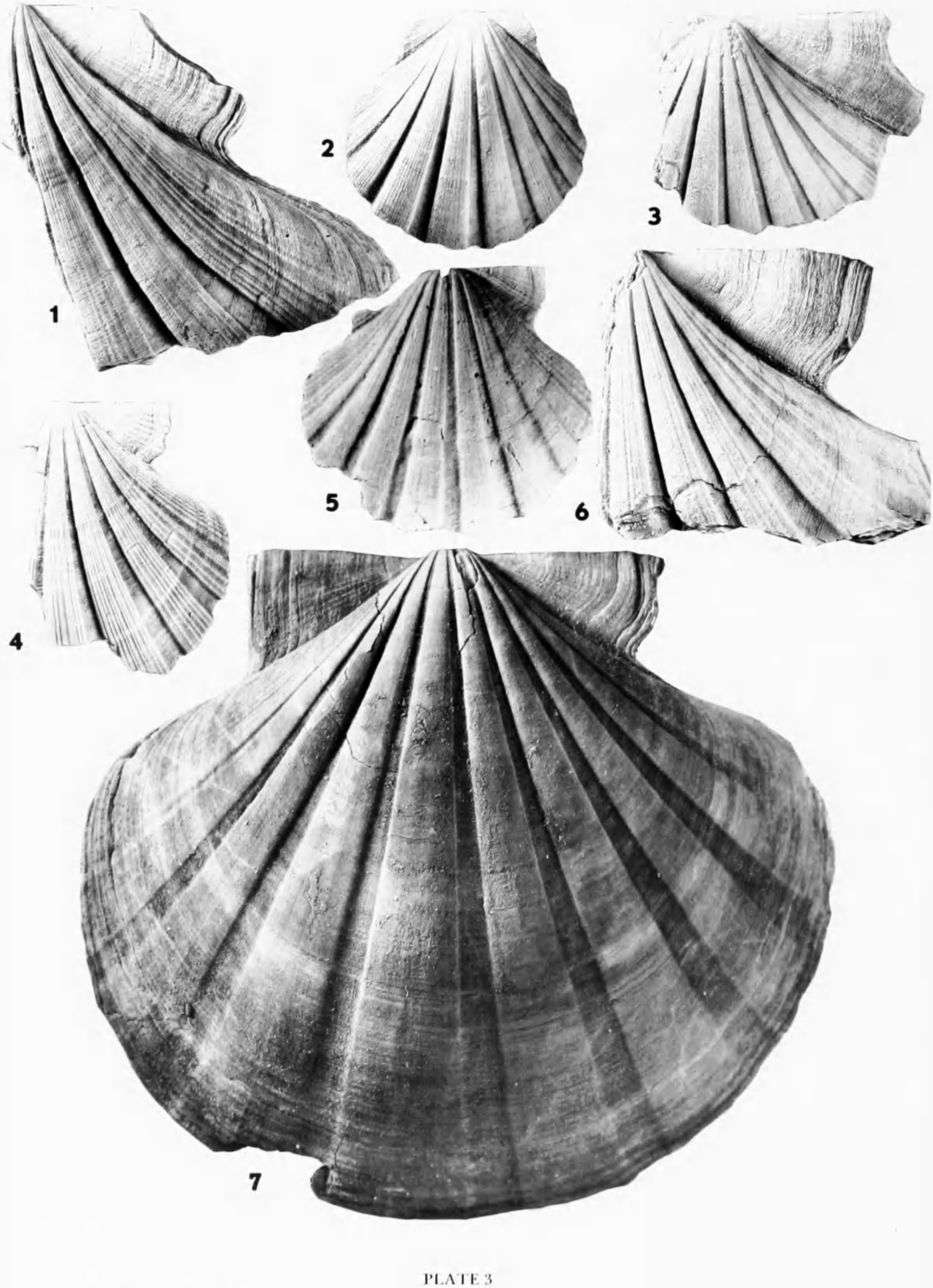

PLATE 3

1. *Pecten humphreysii woolmani* Heilprin, Kirkwood Formation, Jericho, New Jersey, USNM 218832, USGS 2106, external view of partial right valve, × 1.

2, 4, 7. *Pecten humphreysii humphreysii* Conrad, Calvert Formation, Davidsonville, Maryland: 2, USNM 218833, USGS 23565, external view of right valve, × 1; 4, USNM 218835, USGS 25744, external view of partial right valve, × 1; 7. USNM 218838, USGS 23565, external view of right valve, × 1.

3, 5, 6. *Pecten humphreysii humphreysii* Conrad, Pungo River Formation, Lee Creek Mine: 3, USNM 218834, USGS 25339, external view of partial right valve, × 1; 5, USNM 218836, USGS 25743, external view of right valve, × 2; 6, USNM 218837, USGS 25339, external view of partial right valve, × 1.

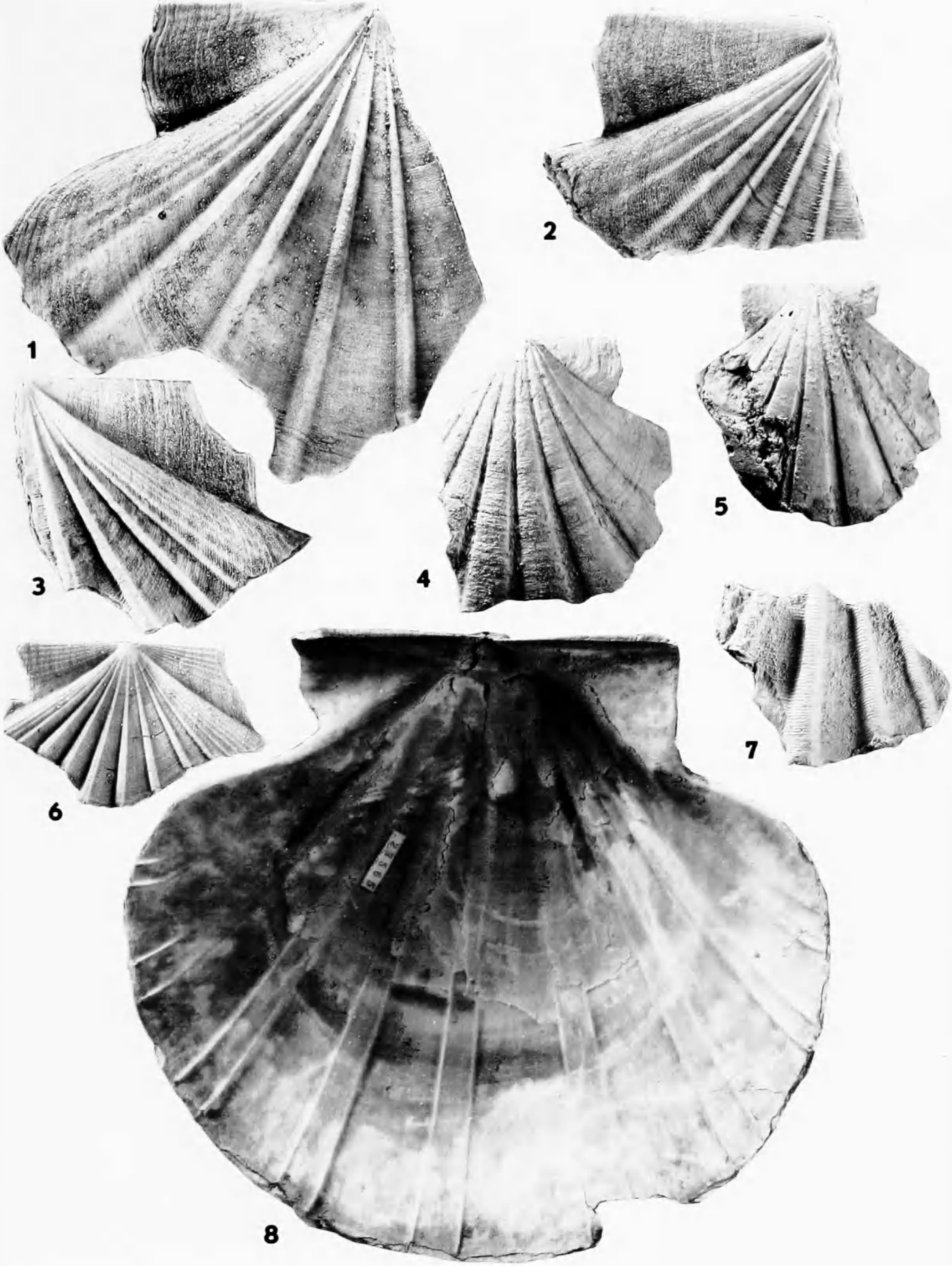

PLATE 4

1–3, 7. *Pecten humphreysii humphreysii* Conrad, Pungo River Formation, Lee Creek Mine, external view of partial left valve: 1, USNM 218839, USGS 25339, × 1; 2, USNM 218840, USGS 25339, × 1; 3, USNM 218841, USGS 25339, × 1; 7, USNM 218845, USGS 25339, × 1.

4–6. *Pecten humphreysii humphreysii* Conrad, Torreya Formation, Crawfordville, Florida, USGS 25745: 4, USNM 218842, external view of partial right valve, × 1; 5, USNM 218843, external view of partial right valve, × 1.5; 6, USNM 218844, external view of partial left valve, × 1. (From Banks and Hunter, 1973.)

8. *Pecten humphreysii humphreysii* Conrad, Calvert Formation, Davidsonville, Maryland, USNM 218838, USGS 23565, internal view of right valve, × 1.

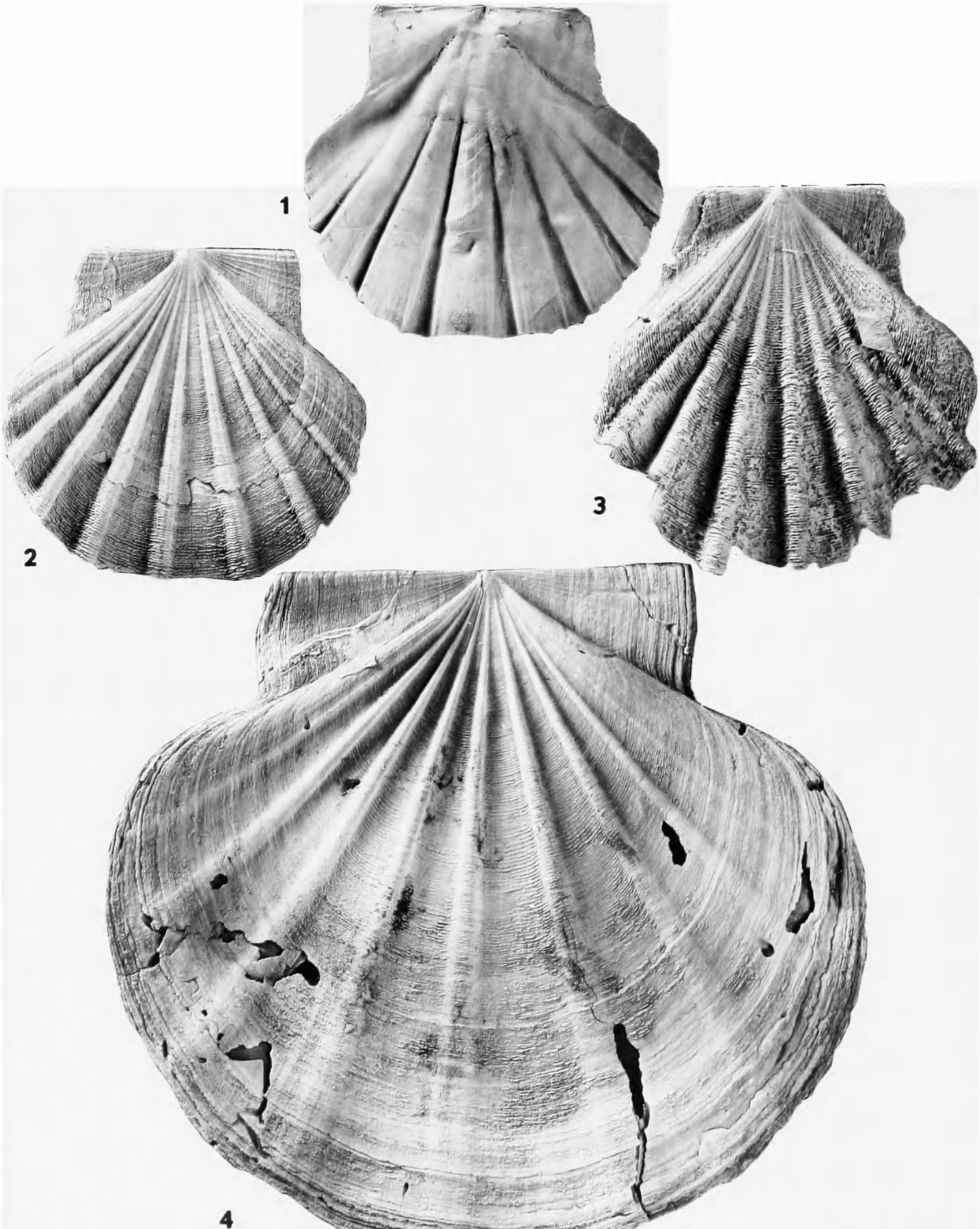

PLATE 5

1, 2, 4. *Pecten humphreysii humphreysii* Conrad, Calvert Formation, Davidsonville, Maryland, left valve: 1, USNM 218846, USGS 25744, external view, × 1.5; 2, USNM 218846, USGS 25744, internal view, × 1.5; 4, USNM 218838, USGS 23565, external view, × 1.

3. *Pecten humphreysii woolmani* Heilprin, Kirkwood Formation, Jericho, New Jersey, USNM 218847, USGS 2106, external view of left valve, × 2 (see also, Whitfield, 1894, pl. 4: fig. 7).

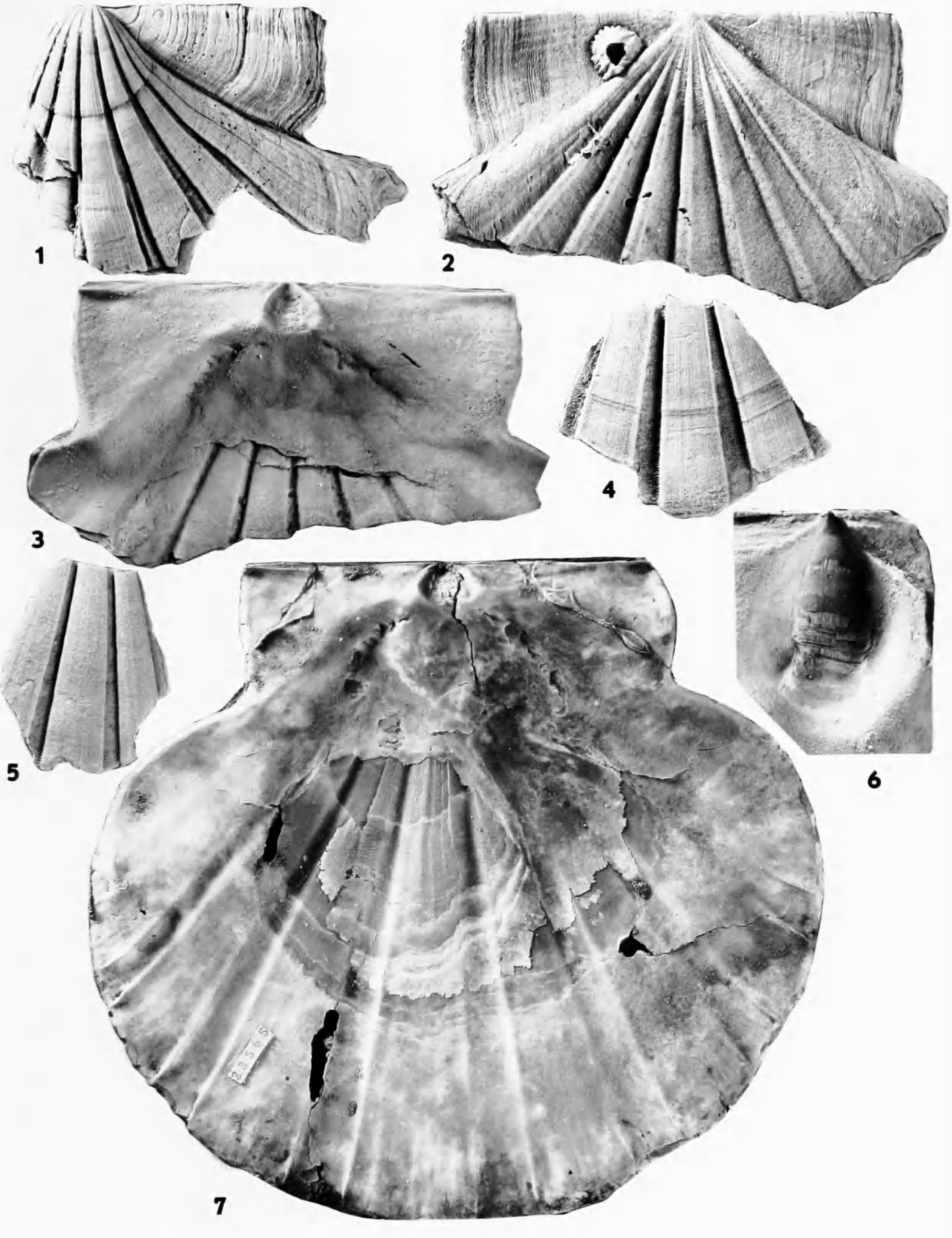

PLATE 6

1–4, 6. *Pecten humphreysii woolmani* Heilprin, Kirkwood Formation, Jericho, New Jersey, USGS 2106: 1, USNM 218848, external view of right valve, × 1; 2, 3, USNM 218849, external and internal views of left valve, × 1 (see also Whitfield, 1894, pl. 4: figs. 8,9); 4, USNM 218850, external view of partial right valve, × 1; 6, USNM 218848, resilial insertion of right valve, × 3.

5. *Pecten humphreysii humphreysii* Conrad, Pungo River Formation, Lee Creek Mine, USNM 218851, USGS 25339, external view of partial right valve, × 1.

7. *Pecten humphreysii humphreysii* Conrad, Calvert Formation, Davidsonville, Maryland, USNM 218838, USGS 23565, internal view of left valve, × 1.

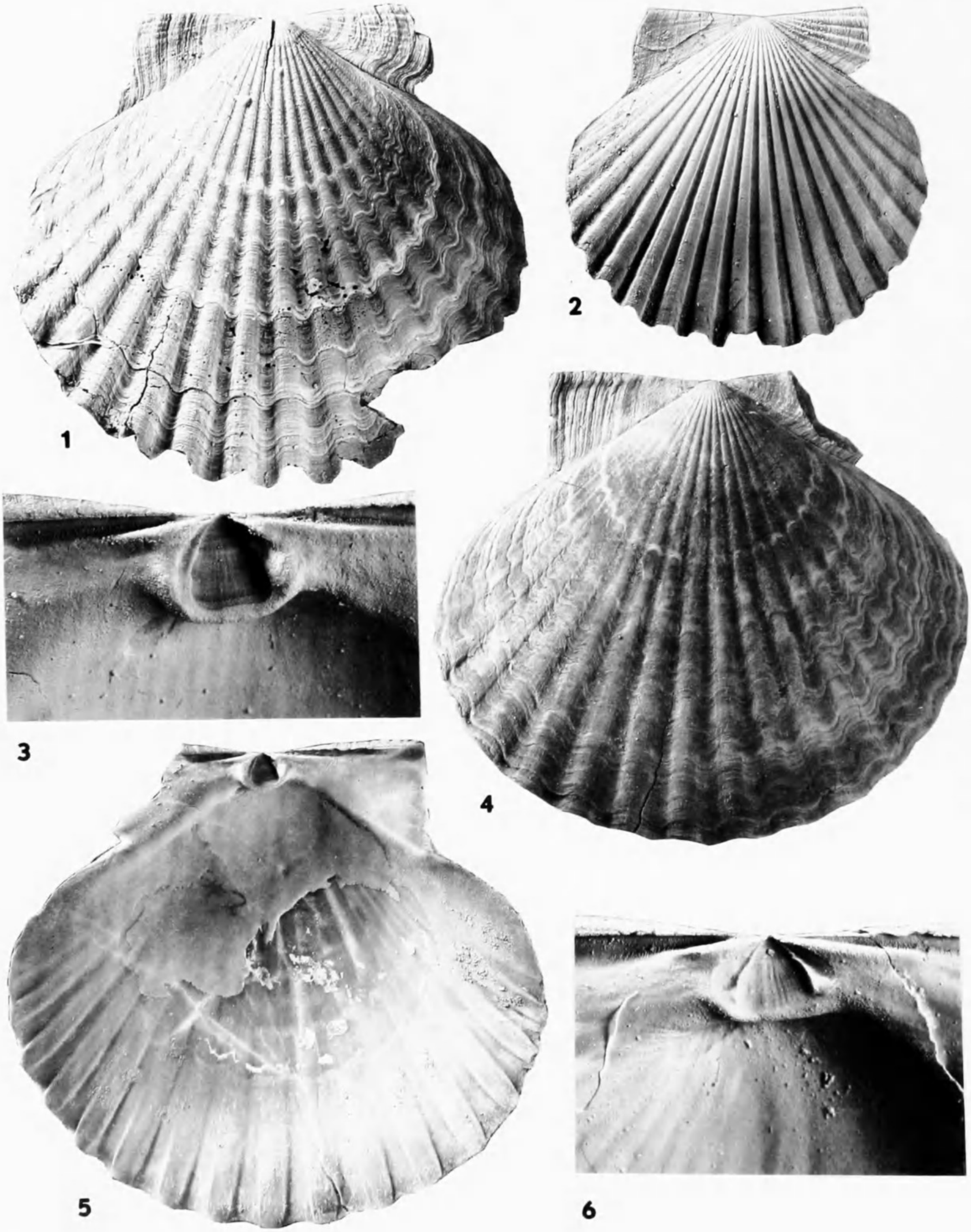

PLATE 7

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

1. USNM 218852, USGS 25746, external view of right valve, × 1.
2. USNM 218853, USGS 25338, external view of right valve, × 1.

3–5. USNM 218854, USGS 25746, right valve: 3, resilial insertion, × 3; 4, external view, × 1; 5, internal view, × 1.

6. USNM 218855, USGS 25746, right valve, resilial insertion, × 3.

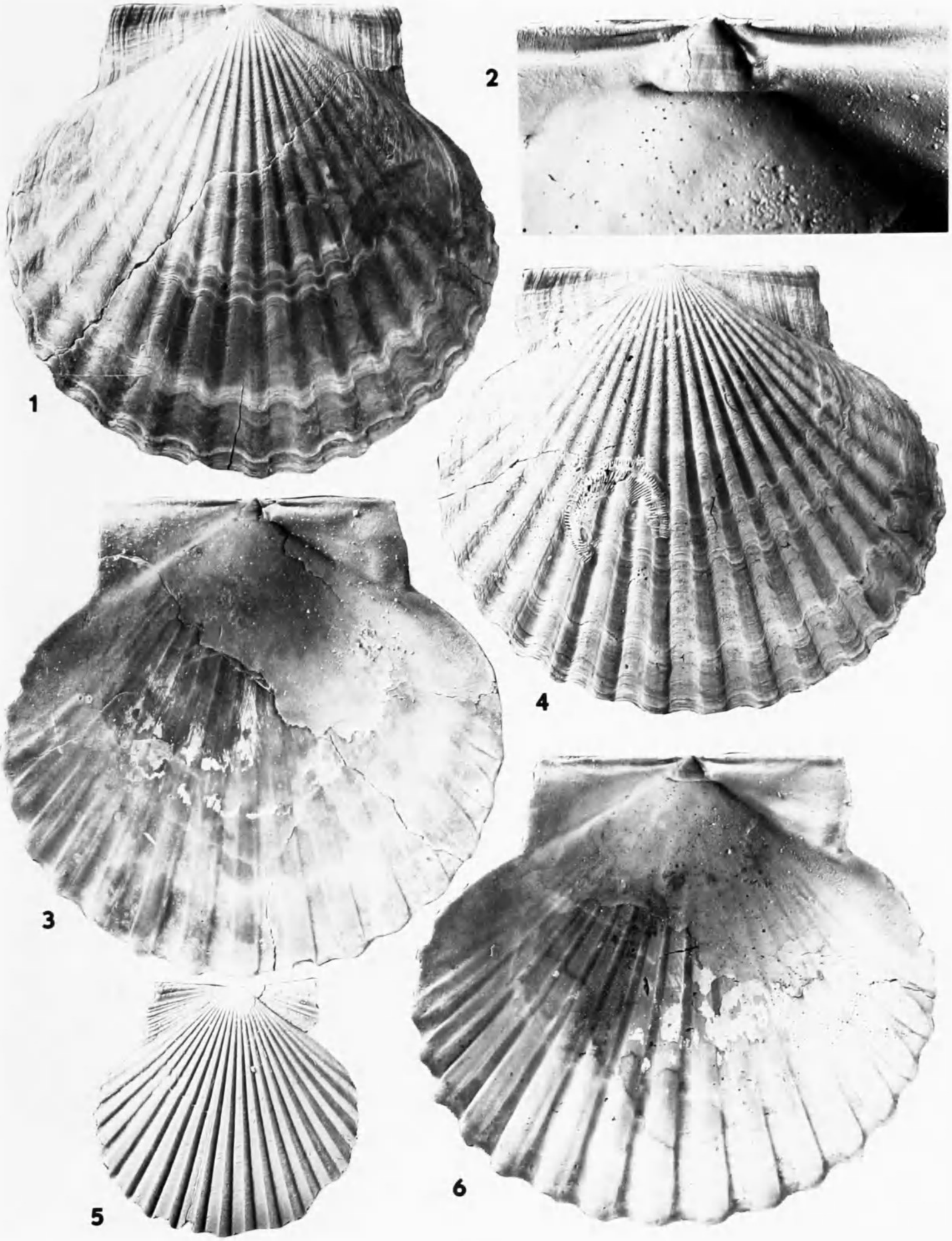

PLATE 8

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

1, 3. USNM 218856, left valve: 1, external view × 1; 3, internal view, × 1.
2, 4, 6. USNM 218857, left valve: 2, resilial insertion, × 3; 4, external view, × 1; 6, internal view, × 1.
5. USNM 218858, external view of right valve, × 1.

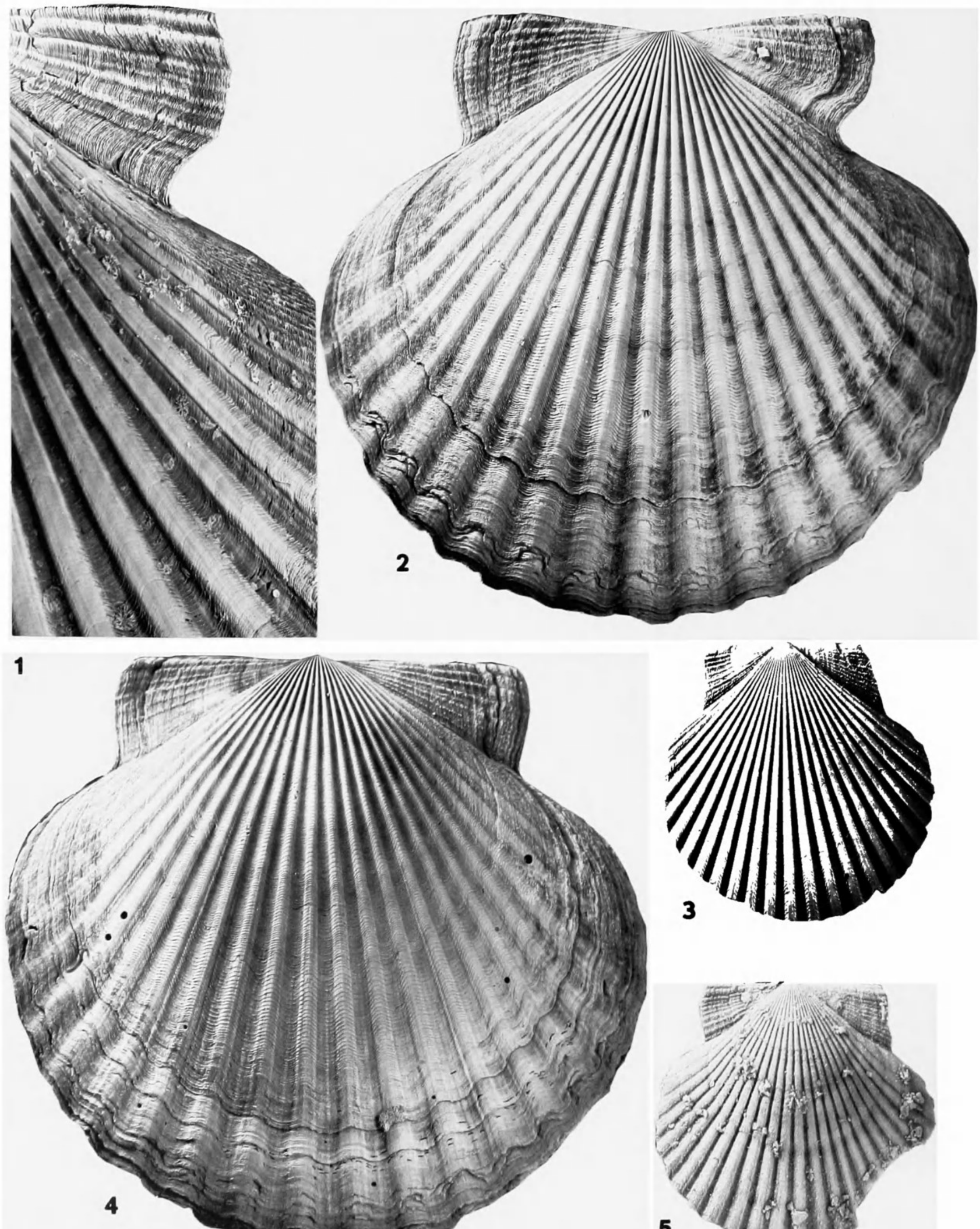

PLATE 9

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, × 2; 4, lectoparatype, USNM 218859, external view of left valve, × 1.

2, 3. *Argopecten eboreus* aff. *A. eboreus solarioides* (Heilprin), Yorktown Formation, Lee Creek Mine, USNM 218860, USGS 25339: 2, external view of right valve, × 1; 3, external view of left valve, × 1.

5. *Argopecten eboreus yorkensis* (Conrad), Yorktown Formation, Yorktown, Virginia, lectotype, ANSP 38007, external view of left valve, × 1.

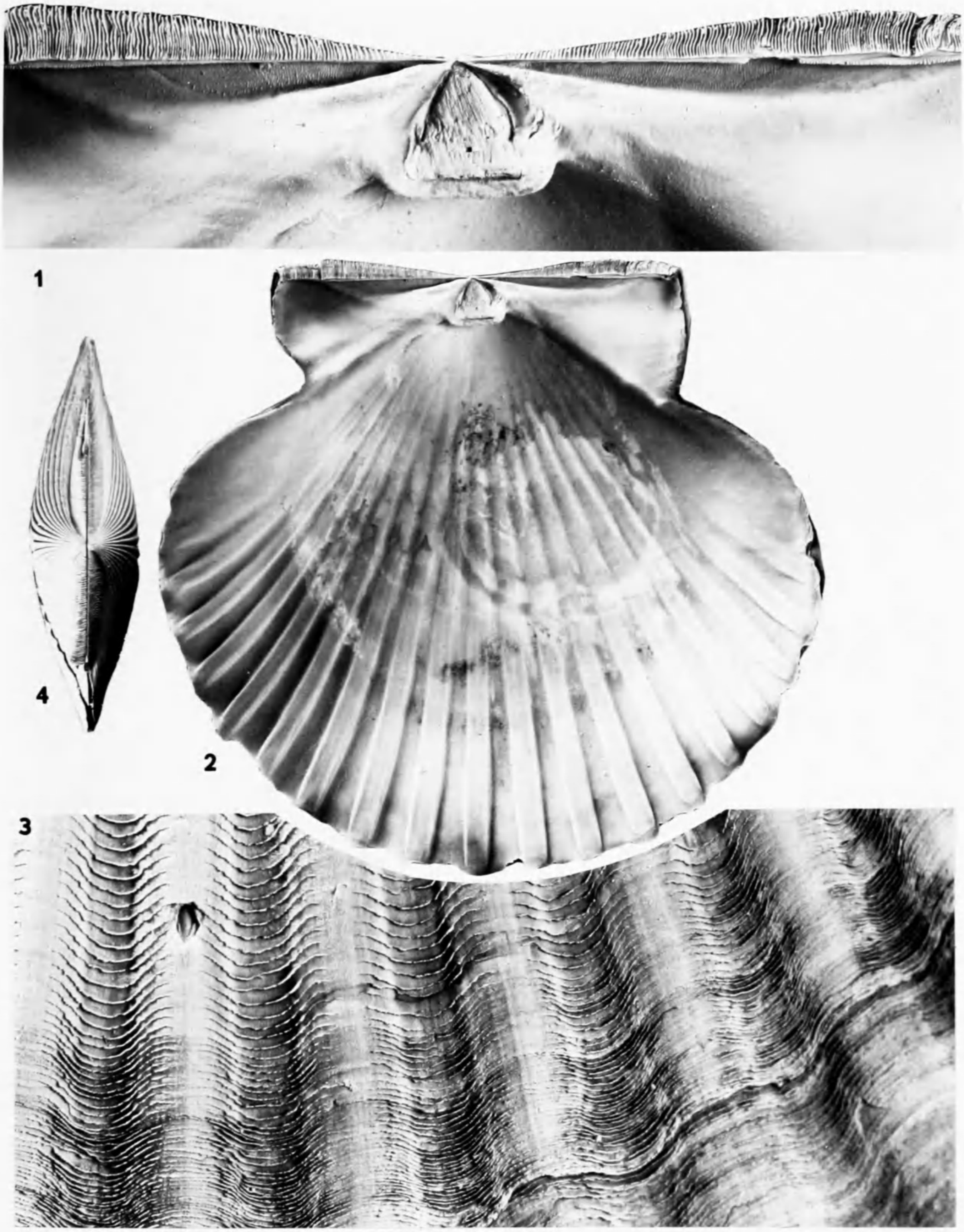

PLATE 10

1–3. *Argopecten eboreus* aff. *A. eboreus solarioides* (Heilprin), Yorktown Formation, Lee Creek Mine, USNM 218860, USGS 25339, right valve: 1, resilial insertion, × 3; 2, internal view, × 1; 3, external view of anterior ventral part, × 4.

4. *Argopecten eboreus* aff. *A. eboreus watsonensis* (Mansfield), Yorktown Formation, Lee Creek Mine, USNM 218861, USGS 25338, dorsal view of articulated specimen, × 1.

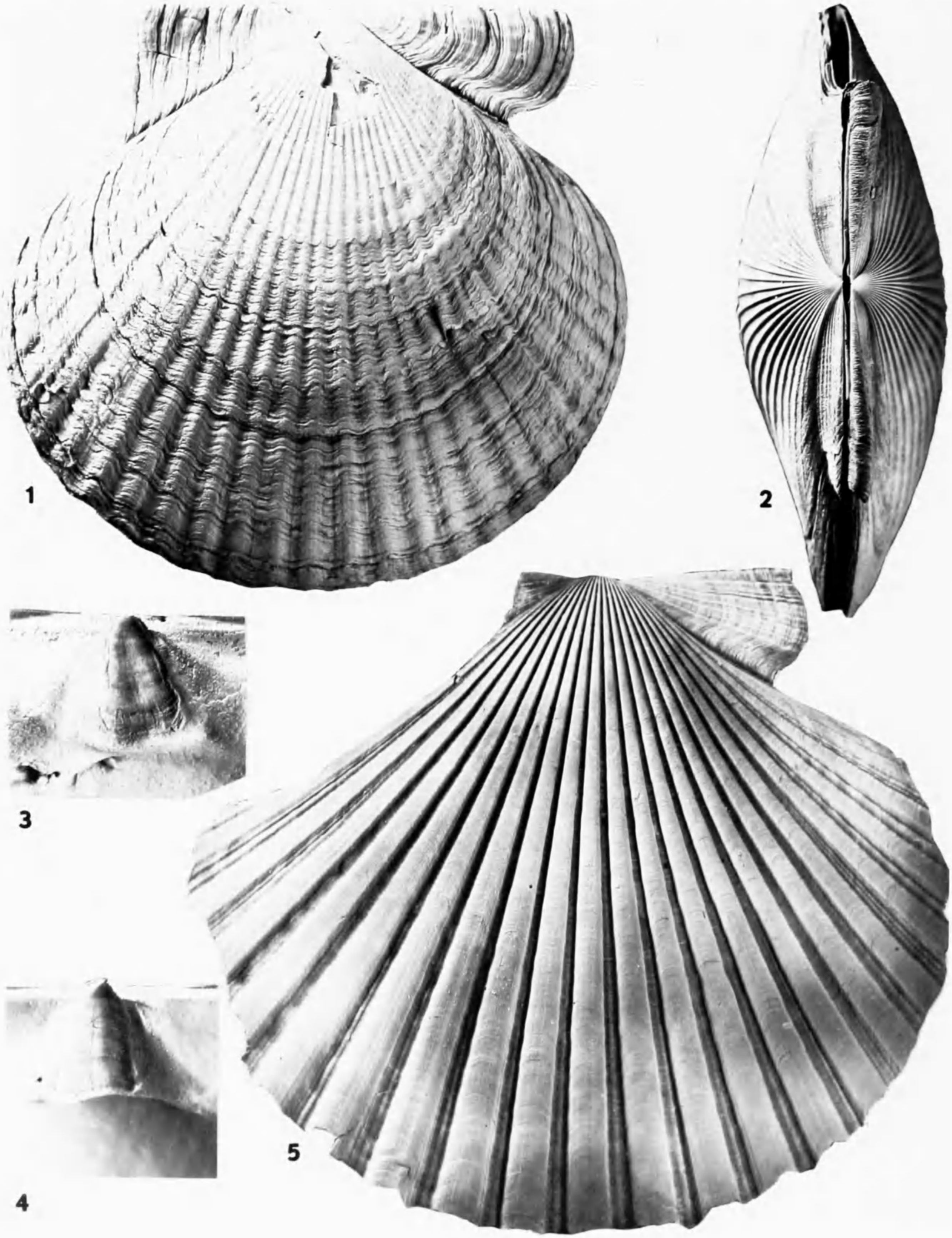

PLATE 11

1, 3, 4. *Argopecten eboreus urbannaensis* (Mansfield). "Virginia St. Marys" beds, Urbanna, Virginia, USGS 3915: 1, lectotype, USNM 370829, external view of right valve, × 1; 3, lectotype, USNM 370829, resilial insertion, × 3; 4, lectoparatype, USNM 218862, resilial insertion of left valve, × 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, × 1; 5, USNM 203904, USGS 25364, external view of right valve, × 1.

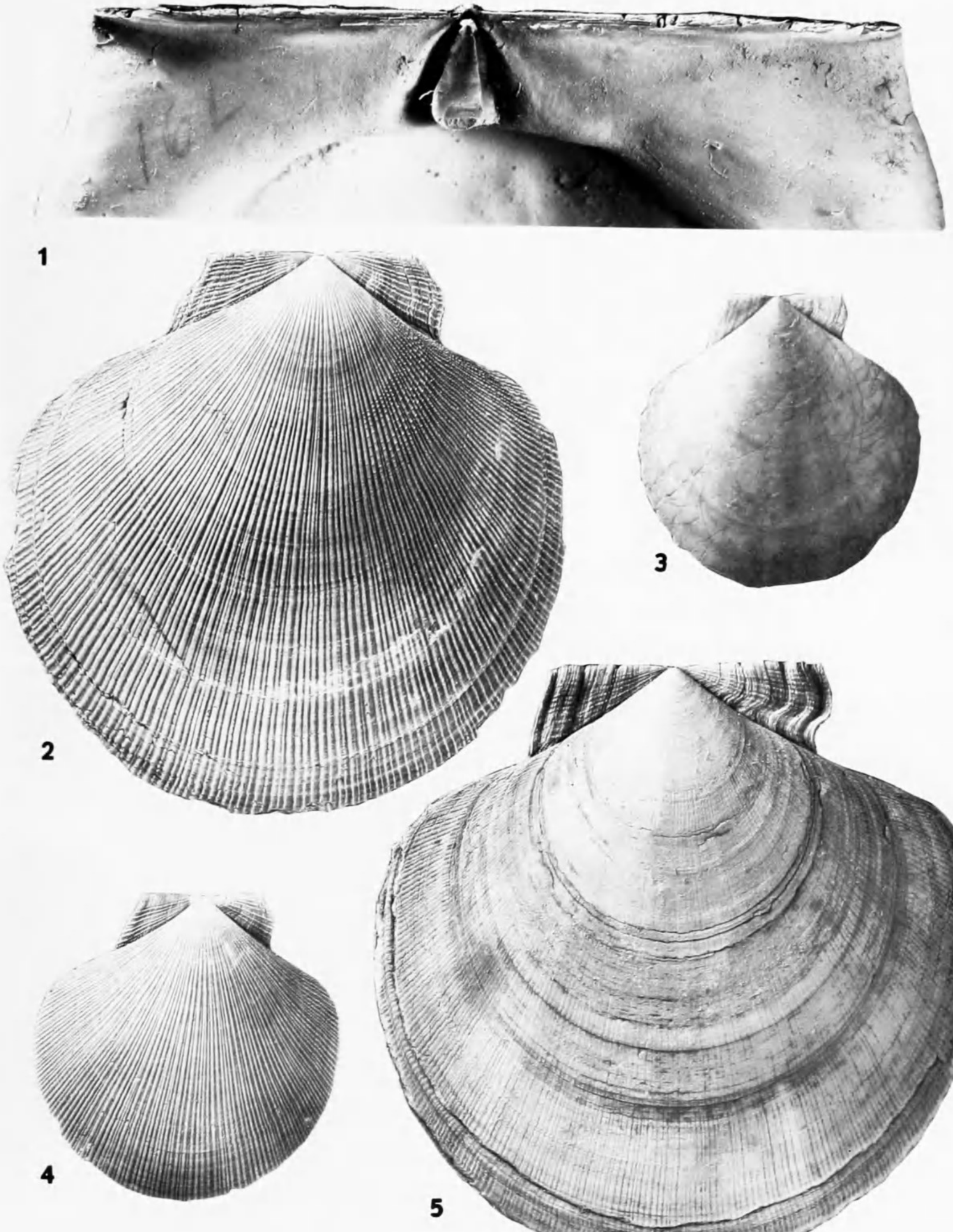

PLATE 12

1, 3, 5. *Placopecten magellanicus* (Gmelin), Recent, south of Long Island, 67 fathoms, USFC 2244: 1, USNM 703766-16L, resilium, × 3; 3, USNM 703766-21R, external view of right valve, × 1; 5, USNM 703766-16R, external view of right valve, × 1.

2, 4. *Placopecten clintonius clintonius* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338, external view of right valve: 2, USNM 218863, × 1; 4, USNM 218864, × 1.

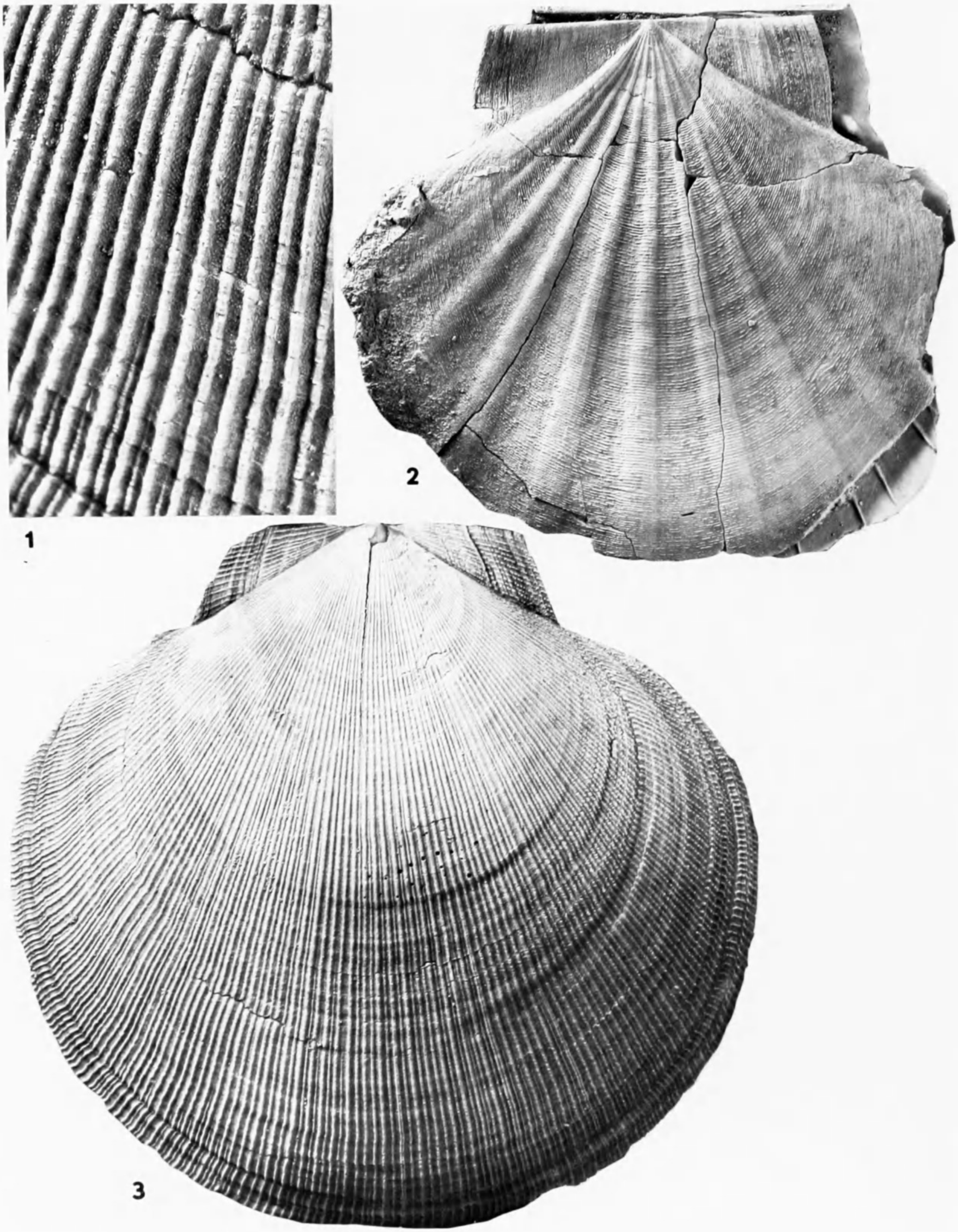

PLATE 13

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, × 3; 3, external view of left valve, × 1.

2. *Pecten mclellani*, new species, Pungo River Formation, Lee Creek Mine, paratype, USNM 218865, USGS 25743, external view of left valve, × 1.

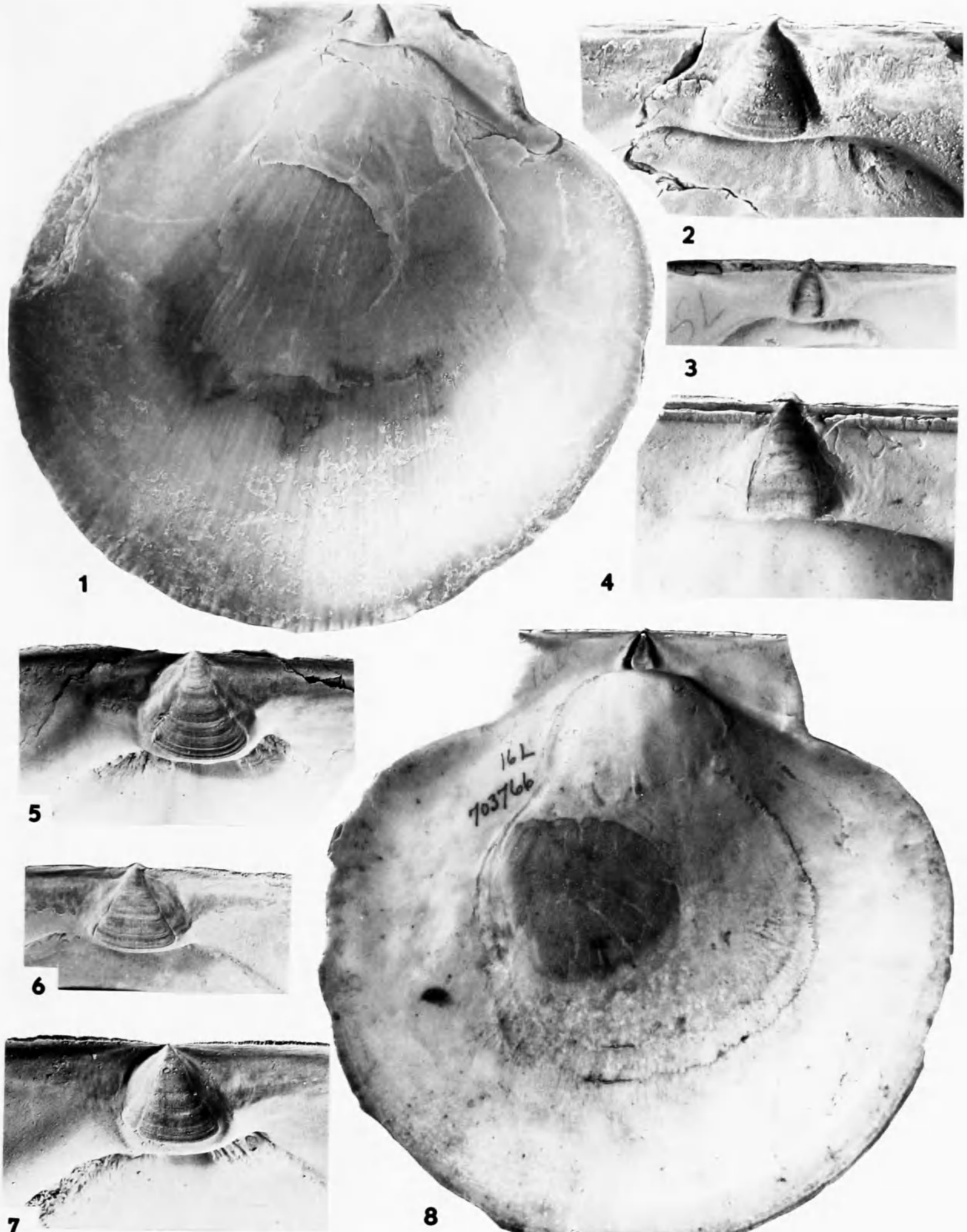

PLATE 14

1, 2, 5–7. *Placopecten clintonius clintonius* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338: 1, USNM 218866, internal view of left valve, × 1; 2, USNM 218866, resilial insertion of left valve, × 3; 5, USNM 218867, resilial insertion of right valve, × 3; 6, USNM 218868, resilial insertion of left valve, × 3; 7, USNM 218869, resilial insertion of right valve, × 3.

3, 4, 8. *Placopecten magellanicus* (Gmelin), Recent, south of Long Island, 67 fathoms, USFC 2244, left valve: 3, USNM 703766–25L, resilial insertion, × 3; 4, USNM 703766–9L, resilial insertion, × 3; 8, USNM 703766–16L, internal view, × 1.

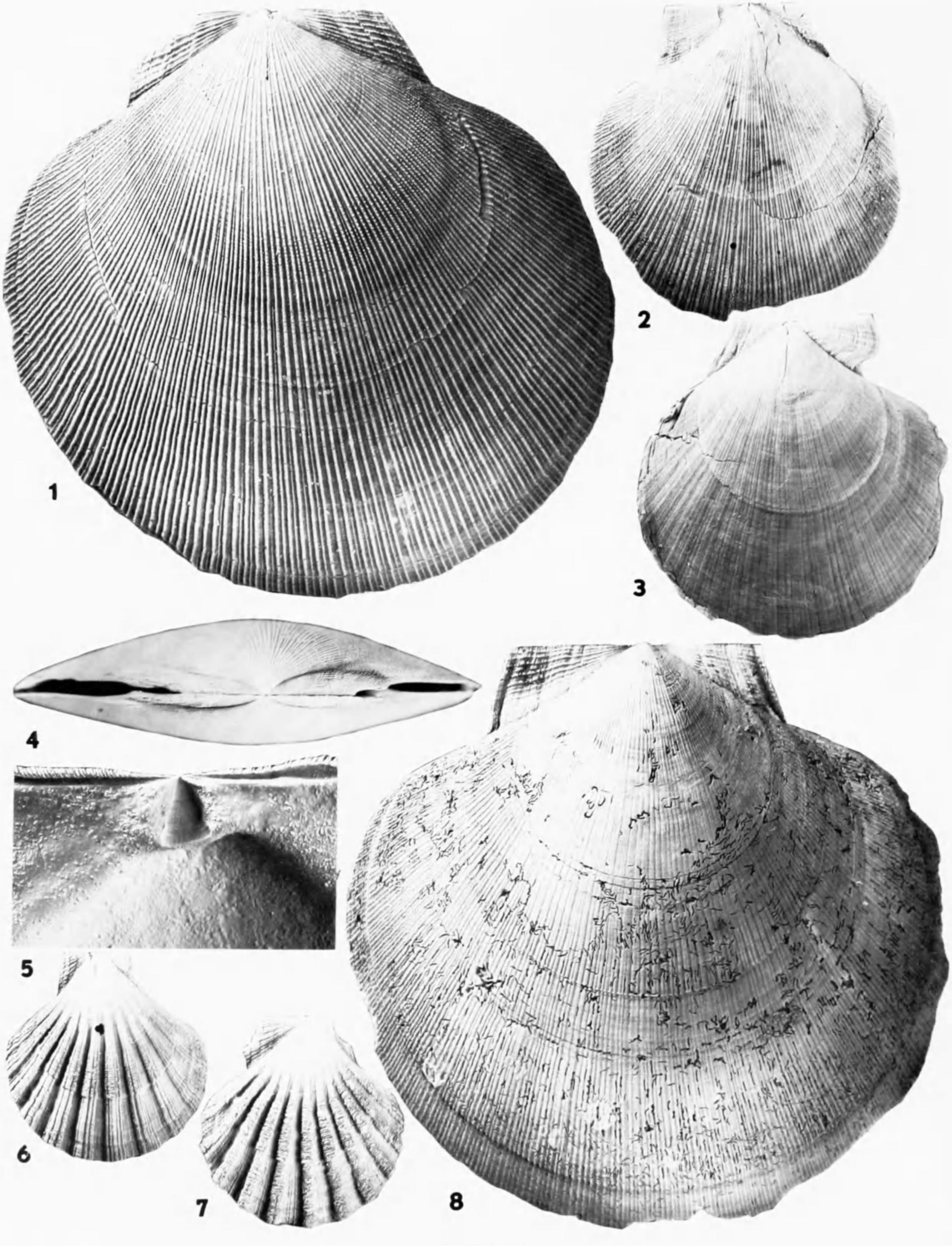

PLATE 15

1, 4. *Placopecten clintonius clintonius* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338: 1, USNM 218866, external view of left valve, × 1; 4, USNM 218863, dorsal view of articulated specimen, × 1.

2, 3, 5–7. *Chlamys decemnaria* (Conrad), Yorktown Formation, Lee Creek Mine, USGS 25338: 2, USNM 218870, external view of left valve of articulated specimen, × 1; 3, USNM 218870, external view of right valve of articulated specimen, × 1; 5, USNM 218871, resilial insertion of right valve, × 3; 6, USNM 218872, external view of right valve, × 1; 7, USNM 218872, external view of left valve, × 1.

8. *Placopecten magellanicus* (Gmelin), Recent, south of Long Island, 67 fathoms, USNM 703766–161L, USFC 2244, external view of left valve, × 1.

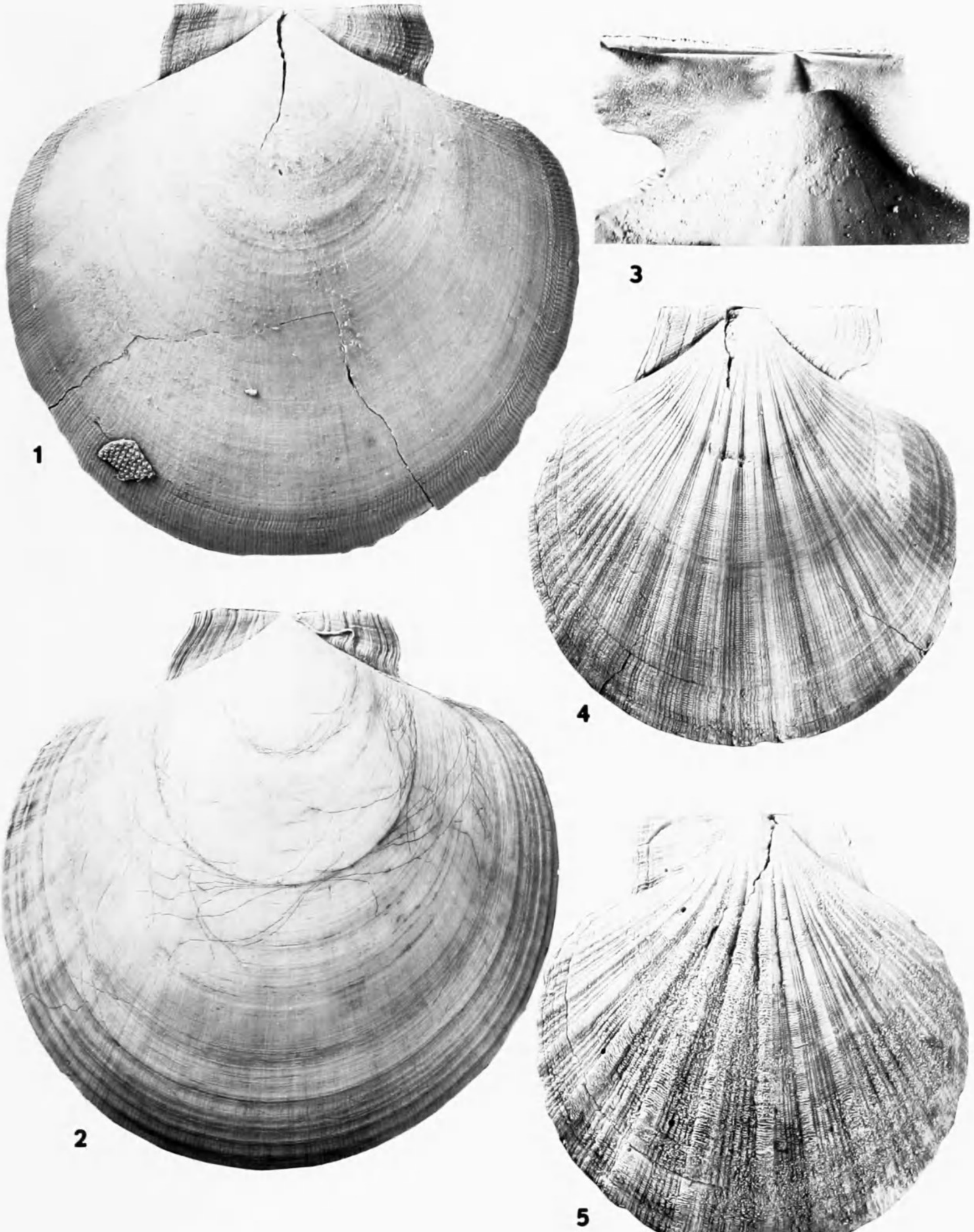

PLATE 16

1. *Placopecten* sp. aff. *P. magellanicus* (Gmelin), Yorktown Formation, Lee Creek Mine, USNM 218873, USGS 25743, external view of right valve, × 1.
2. *Placopecten magellanicus* (Gmelin), Recent, south of Long Island, 67 fathoms, USNM 703766–18R, USFC 2244, external view of right valve, × 1.

3–5. *Chlamys decemnaria* (Conrad), Yorktown Formation, Lee Creek Mine, USGS 25338: 3, USNM 218874, resilial insertion of right valve, × 2; 4, USNM 218875, external view of right valve of articulated specimen, × 1; 5, USNM 218875, external view of left valve of articulated specimen, × 1.

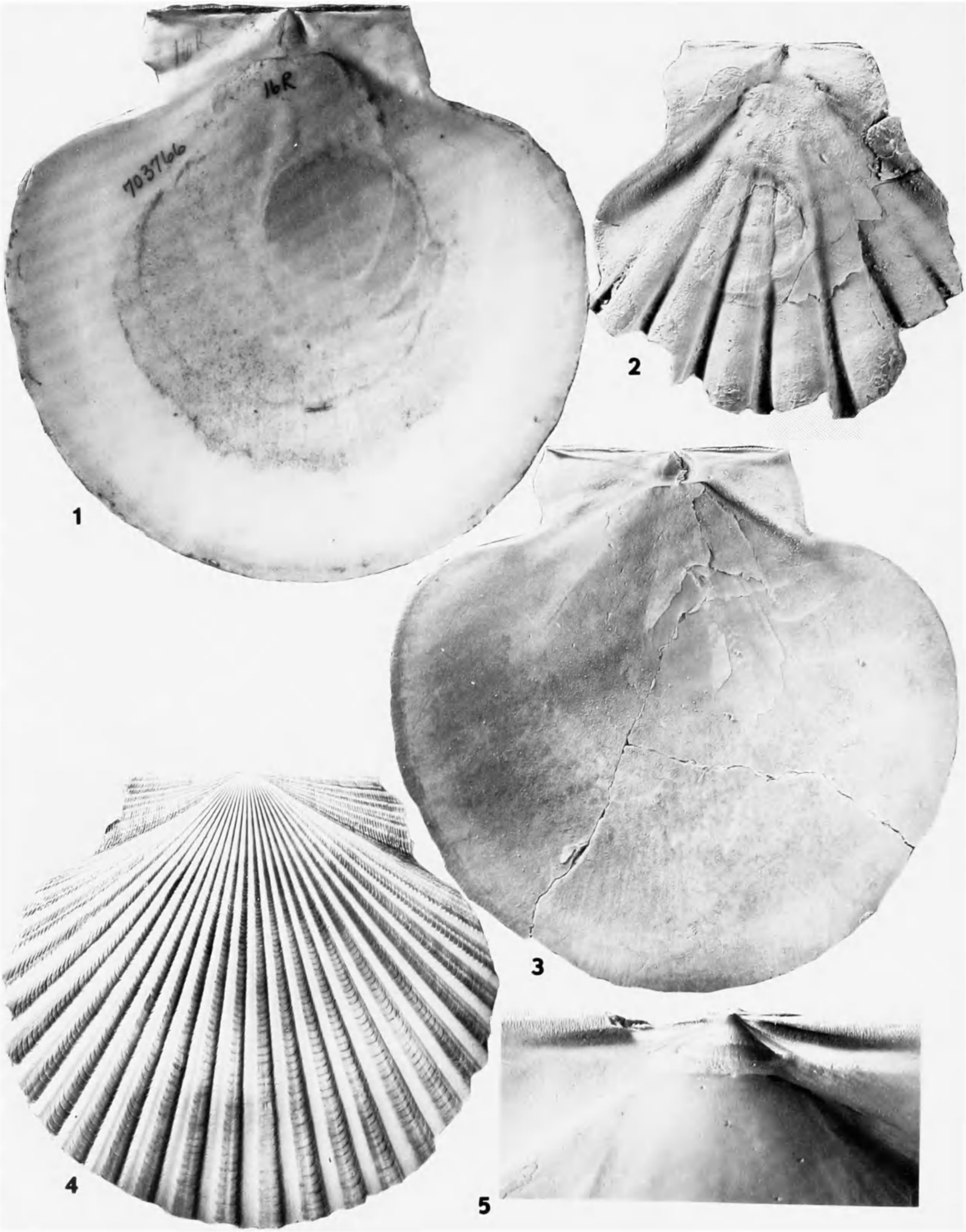

PLATE 17

1. *Placopecten magellanicus* (Gmelin), Recent, south of Long Island, 67 fathoms, USNM 703766-16R, USFC 2244, internal view of right valve, × 1.
2. *Pecten humphreysii woolmani* Heilprin, Kirkwood Formation, Jericho, New Jersey, USNM 218847, USGS 2106, internal view of left valve, × 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, × 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, × 1; 5, resilial insertion, × 3.

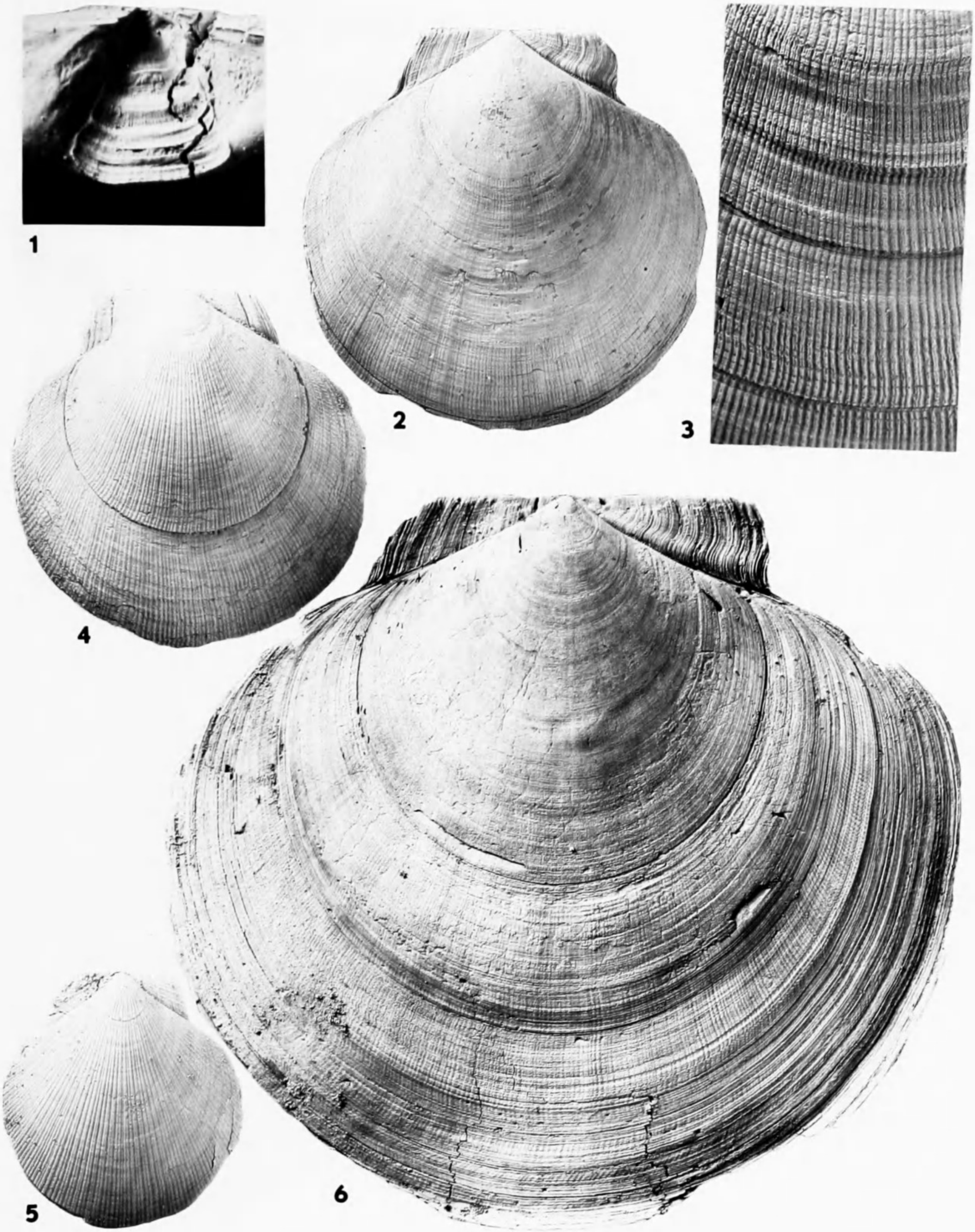

PLATE 18

Placopecten clintonius rappahannockensis (Mansfield)

1, 4–6. "Virginia St. Marys" beds, Murfreesboro, North Carolina, USGS 25747: 1, USNM 218877, resilial insertion of right valve, × 3; 4, USNM 218880, external view of left valve, × 1; 5, USNM 218881, external view of left valve, × 1; 6, USNM 218877, external view of right valve, × 1.

2, 3. "Virginia St. Marys" beds, Jones Point, Virginia, USGS 3924: 2, lectoparatype, USNM 218878, external view of right valve, × 1; 3, lectoparatype, USNM 218879, anterior ventral area of exterior of left valve, × 3.

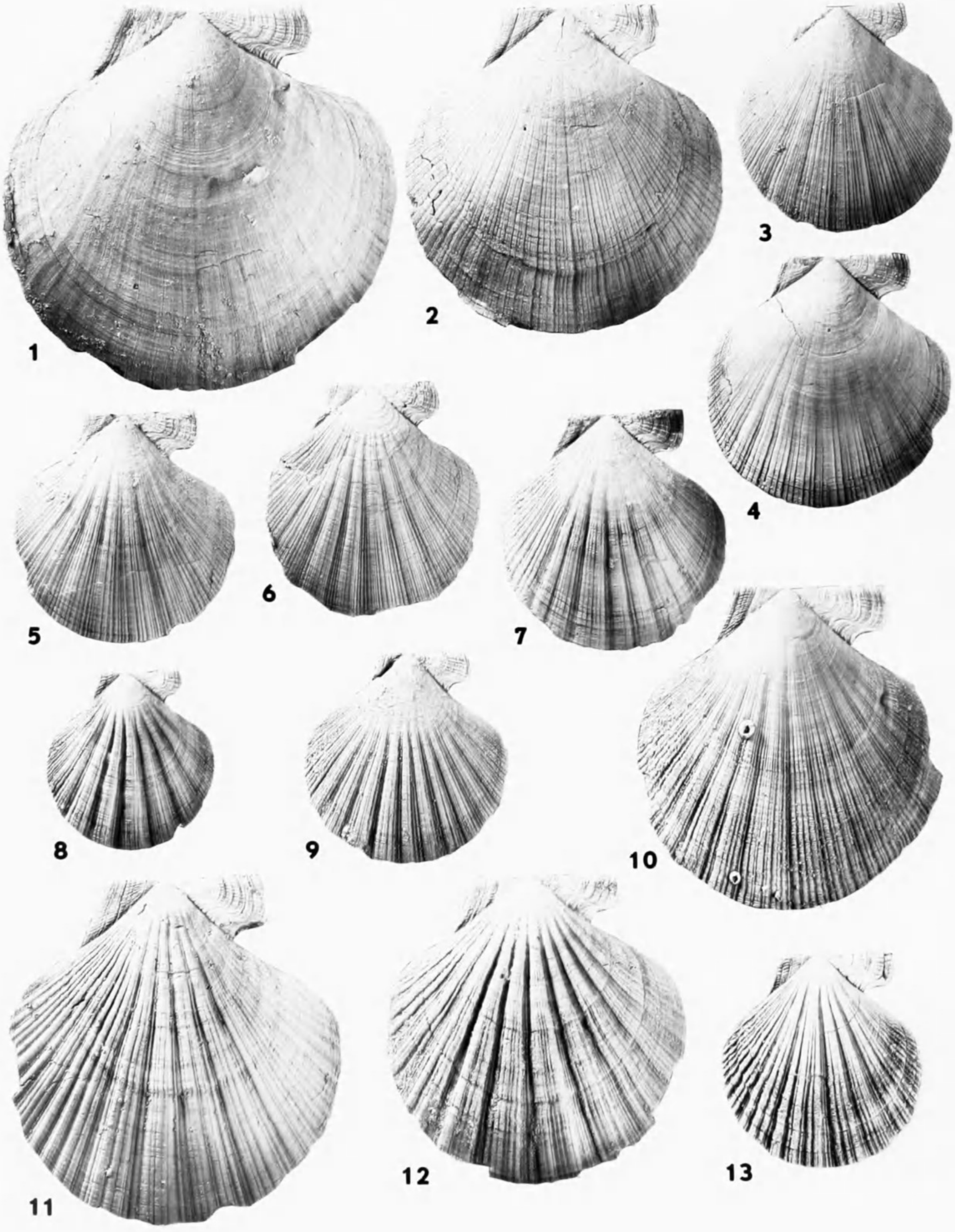

PLATE 19

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

1–13. External view of right valve, × 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.

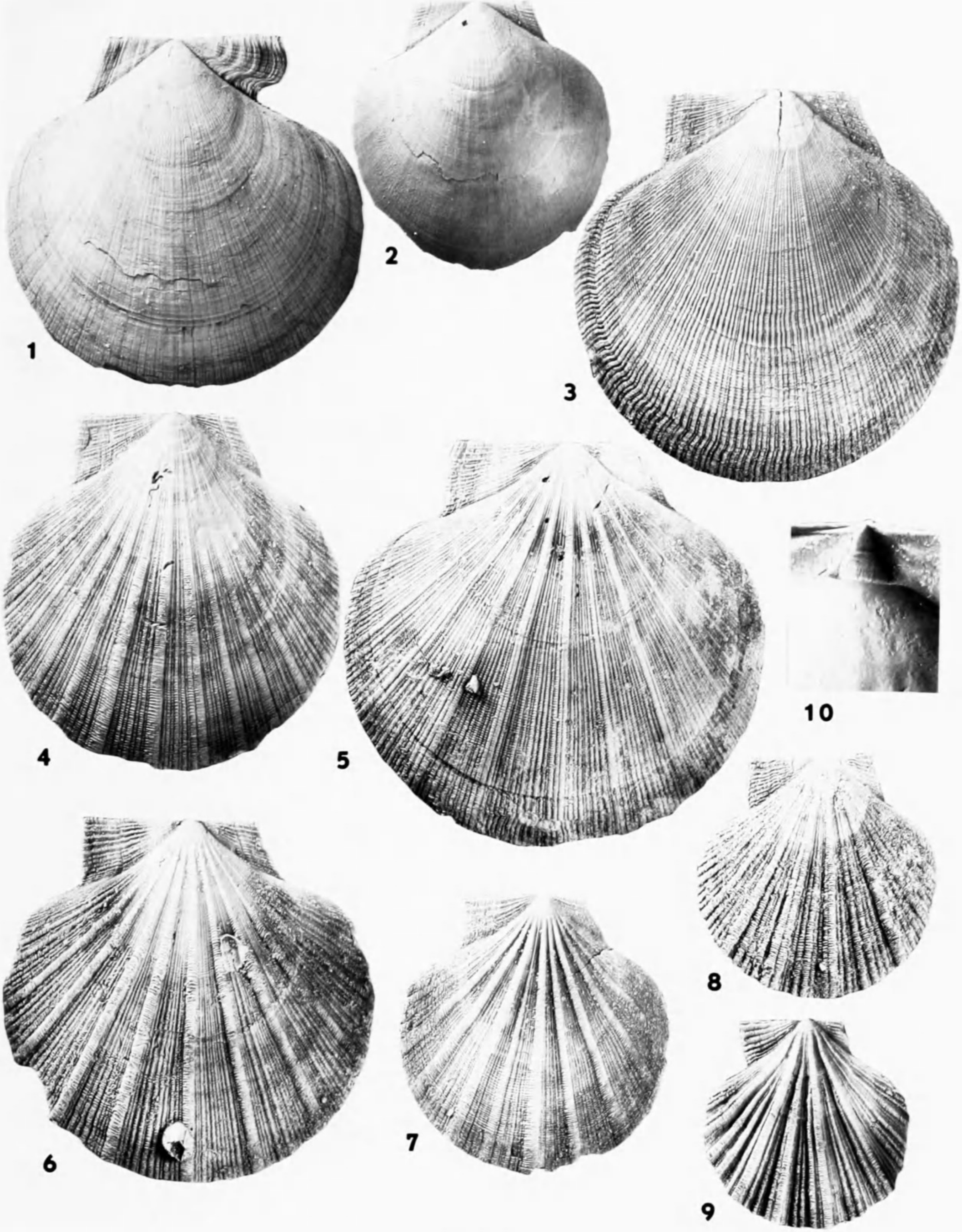

PLATE 20

1. *Chlamys decemnaria* (Conrad) (= *Pecten virginianus* (Conrad), Yorktown Formation, City Point, Virginia, holotype, ANSP 1620, external view of right valve, × 1.

2–9. *Chlamys decemnaria* (Conrad), Yorktown Formation, Lee Creek Mine, USGS 25338, external view of left valve, × 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, × 3.

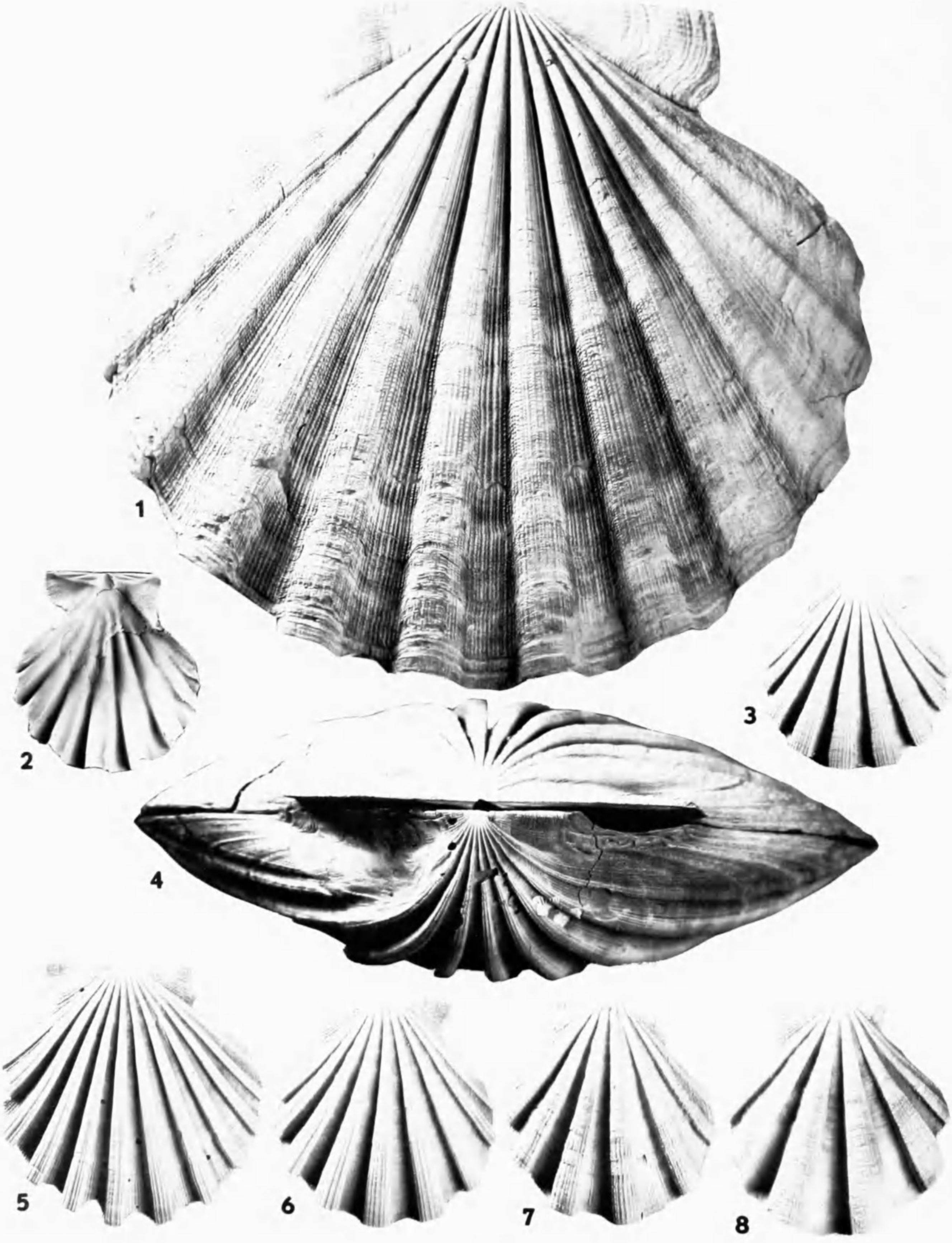

PLATE 21

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

1, 3. External view of right valve, × 1; 1, USNM 218901; 3, USNM 218902.
2. USNM 218902, internal view of right valve, × 1.
4. USNM 218903, dorsal view of articulated specimen, × 1.
5, 6. External view of left valve, × 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, × 1: 7, USNM 218906; 8, USNM 218907.

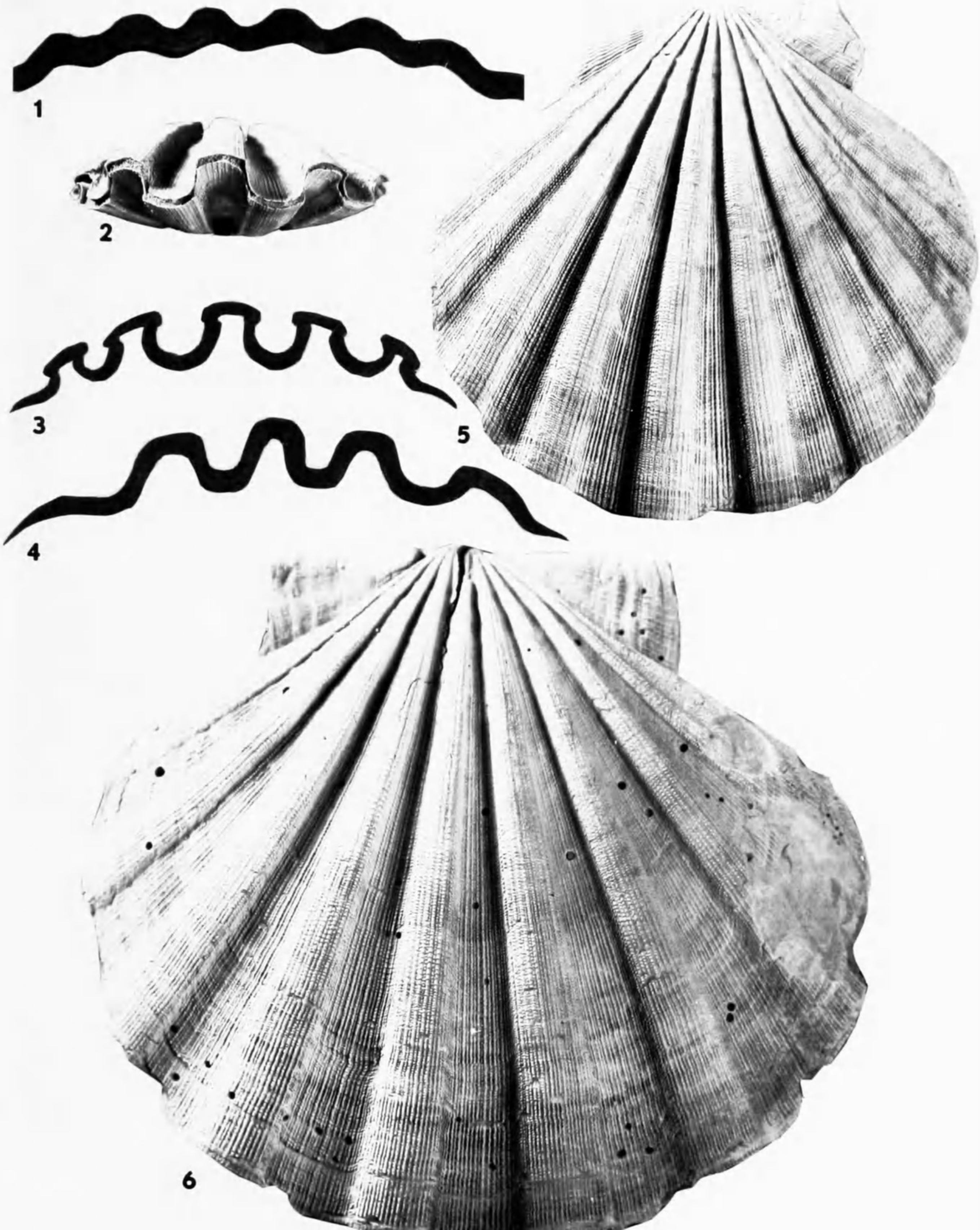

PLATE 22

1. *Chesapecten madisonius* (Say), Yorktown Formation, Lee Creek Mine, USNM 218908, USGS 25338, cross-section of right valve, about midway dorsoventrally, × 1.

2, 3. *Chesapecten jeffersonius septenarius* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338: 2, USNM 218909, ventral view of articulated specimen, × 1; 3, USNM 218910, cross-section of left valve, about midway dorsoventrally, × 1.

4–6. *Chesapecten jeffersonius jeffersonius* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338: 4, USNM 218901, cross-section of right valve, about midway dorsoventrally, × 1; 5, USNM 218911, external view of right valve, × 1; 6, USNM 218912, external view of left valve, × 1.

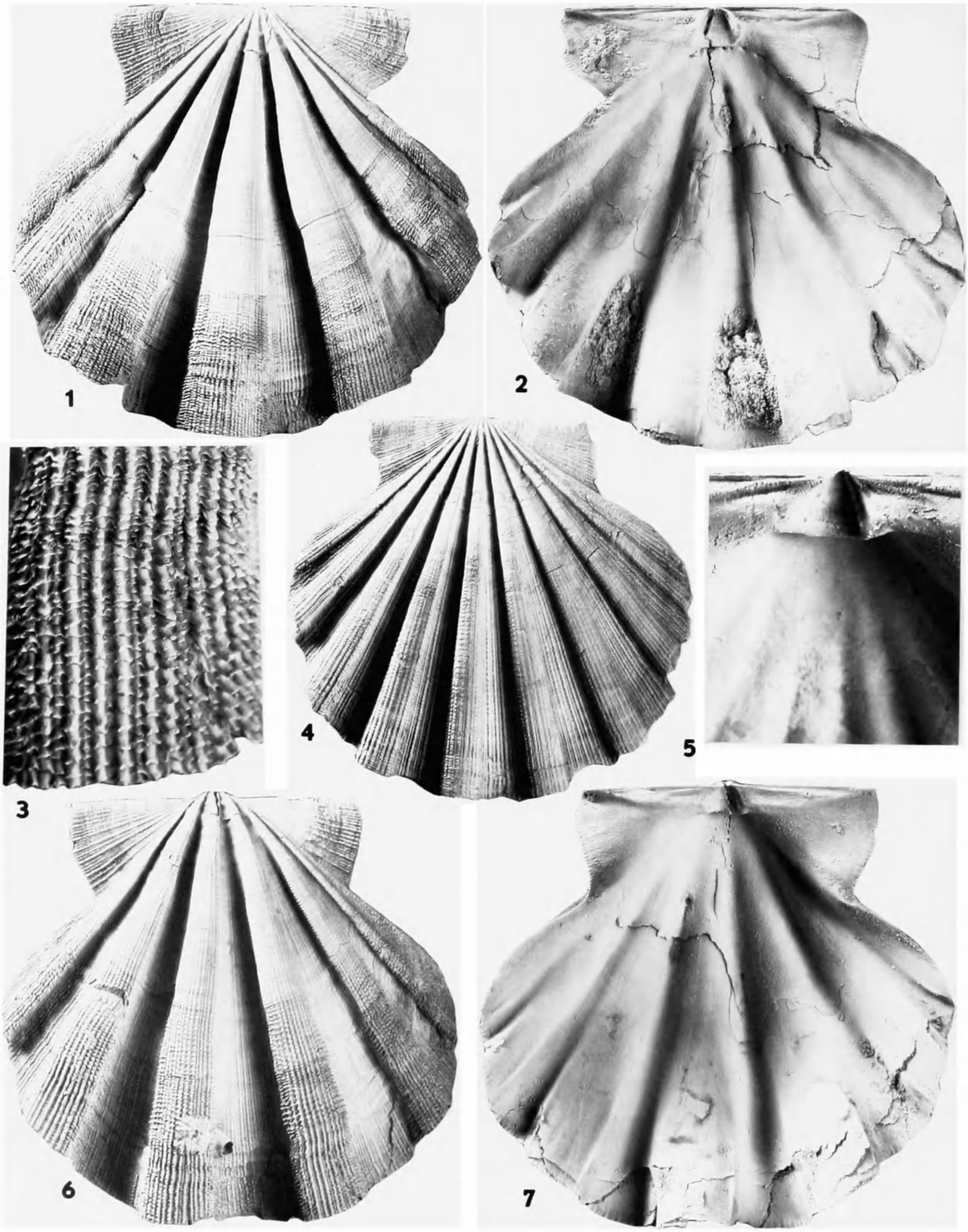

PLATE 23

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

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

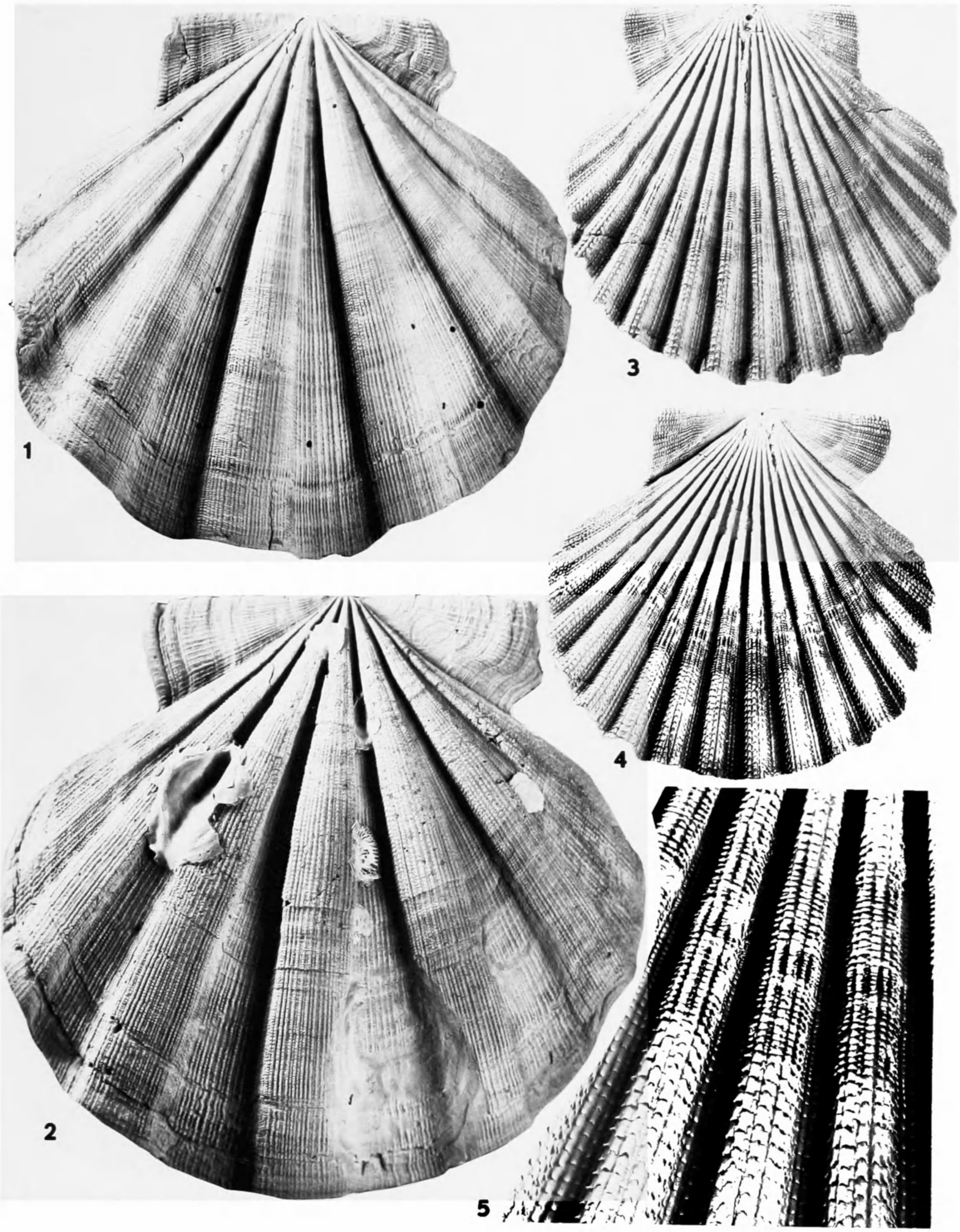

PLATE 24

1, 2. *Chesapecten jeffersonius septenarius* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338, external view of right valve, × 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, × 1; 4, external view of right valve, × 1; 5, ribs on posterior-ventral portion, × 3.

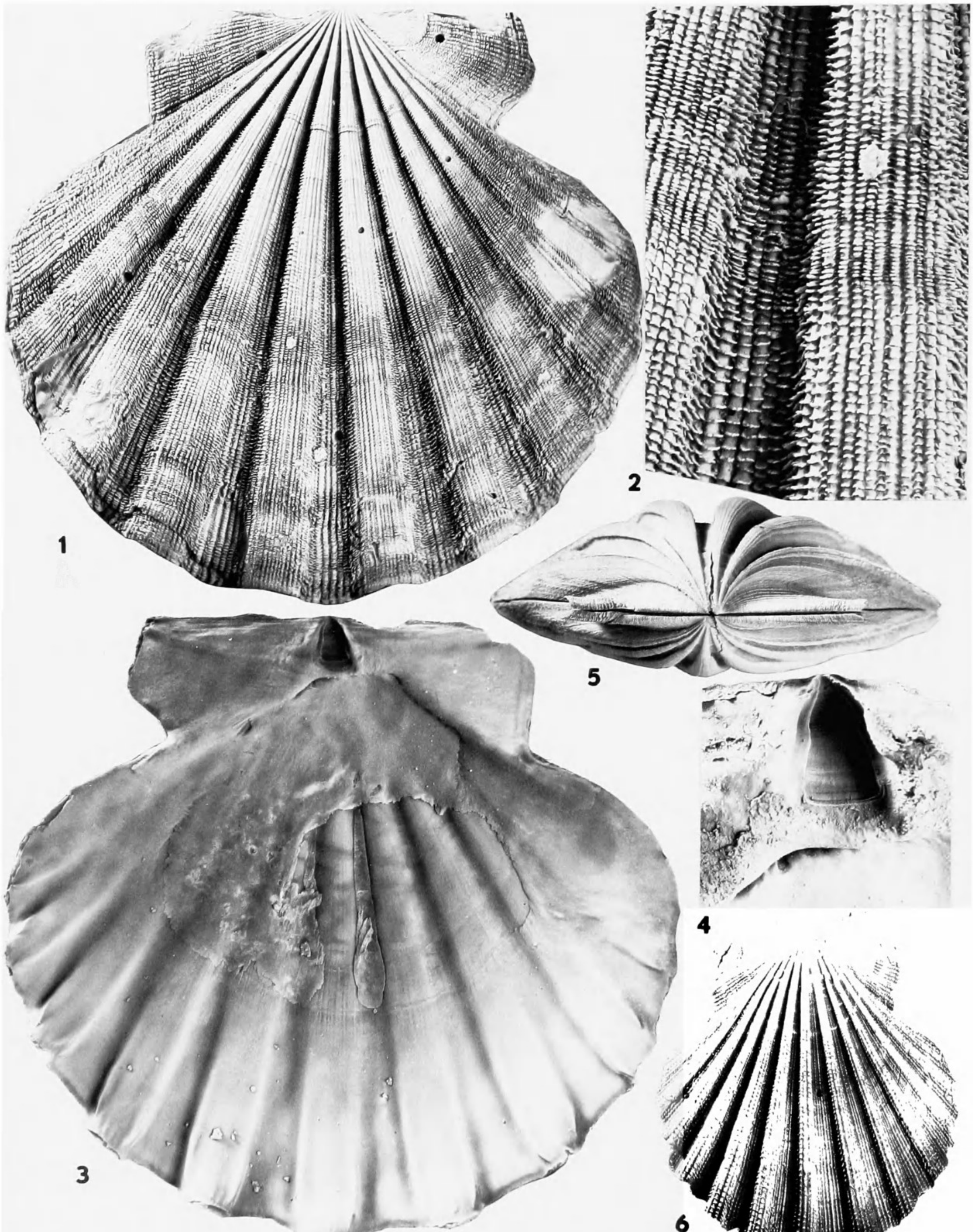

PLATE 25

1–4. *Chesapecten madisonius* (Say), Yorktown Formation, Lee Creek Mine, USNM 218917, USGS 25338, right valve: 1, external view, × 1; 2, ornamentation, × 3; 3, internal view, × 1; 4, resilial insertion, × 3.

5. *Chesapecten jeffersonius septenarius* (Say), Yorktown Formation, Lee Creek Mine, USNM 218910, USGS 25338, dorsal view of articulated specimen, × 1.

6. *Chesapecten madisonius* (Say), Yorktown Formation, Lee Creek Mine, USNM 218918, USGS 25338, external view of left valve, × 1.

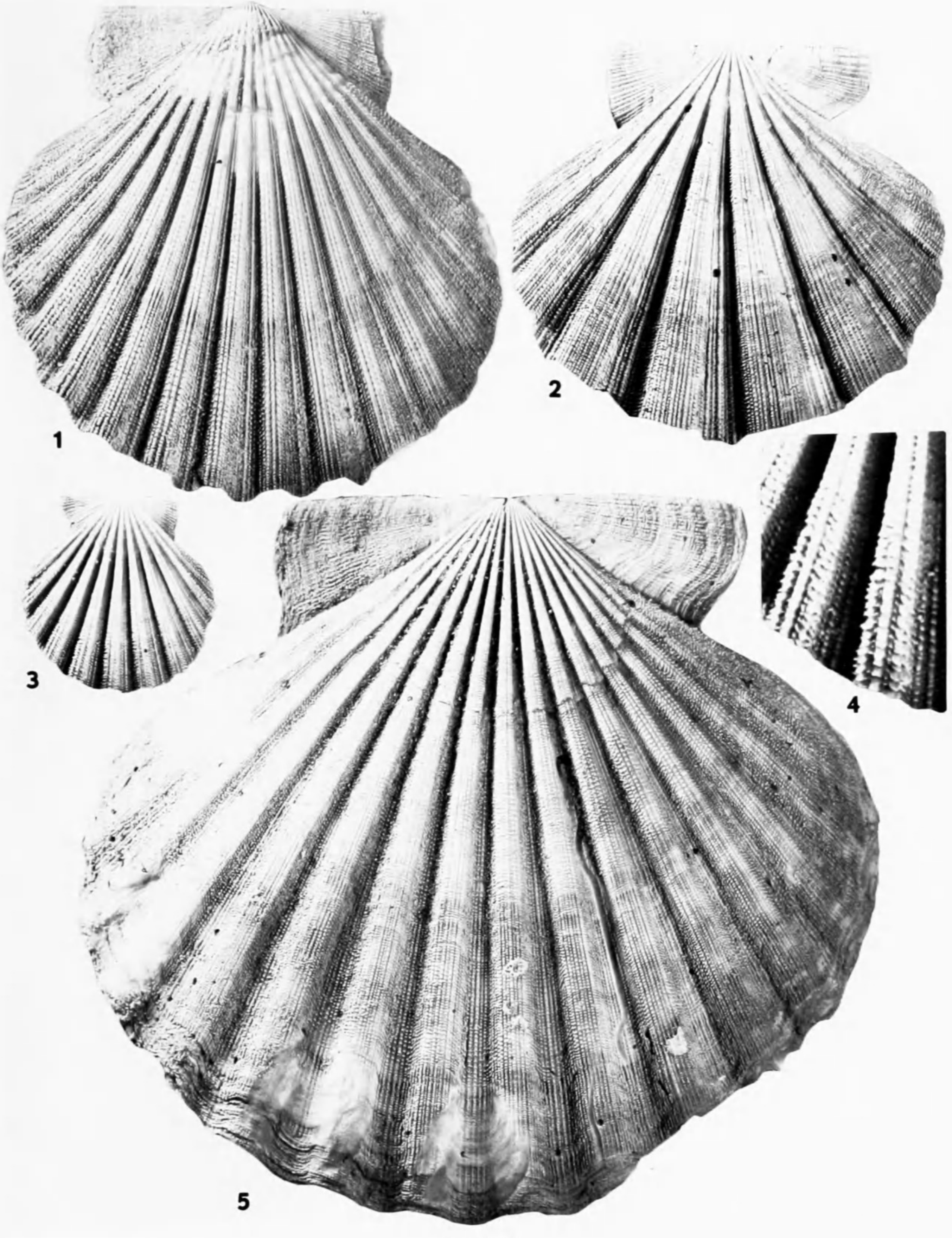

PLATE 26

1, 3–5. *Chesapecten madisonius* (Say), Yorktown Formation, Lee Creek Mine, USGS 25338: 1, USNM 218919, external view of left valve, × 1; 3, USNM 218920, external view of left valve, × 1; 4, USNM 218920, anteroventral ribs, × 3; 5, USNM 218908, external view of right valve, × 1.

2. *Chesapecten jeffersonius septenarius* (Say), Yorktown Formation, Lee Creek Mine, USNM 218921, USGS 25338, external view of right valve, × 1.

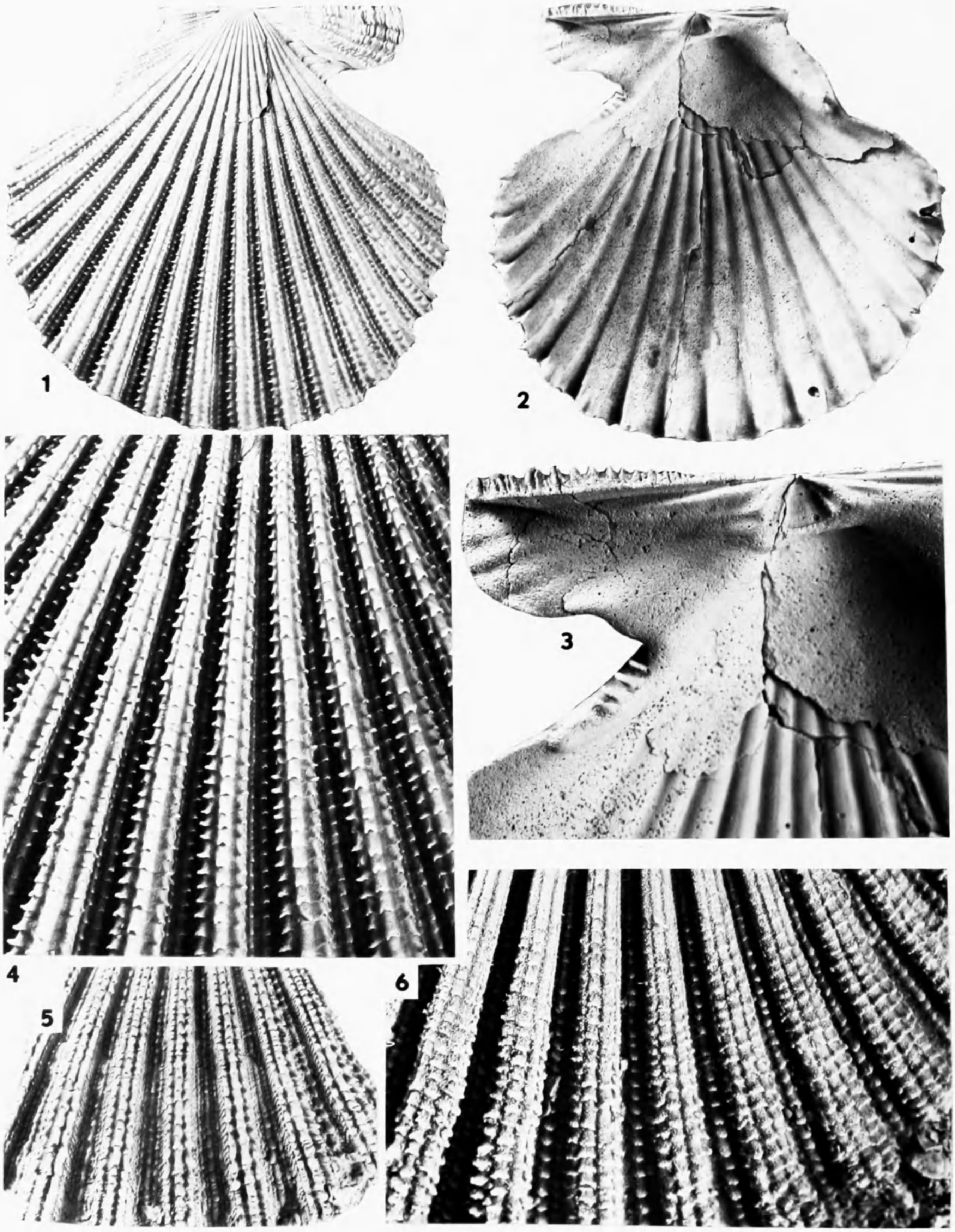

PLATE 27

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

1–4. USNM 218922, right valve: 1, external view, × 1.4; 2, internal view, × 1.4; 3, resilial insertion and ctenolium, × 3; 4, ribs in mid-part of right valve, × 3.

5. USNM 218923, external view of partial valve, × 1.3.

6. USNM 218924, ribs in anteroventral portion of right valve, × 3.

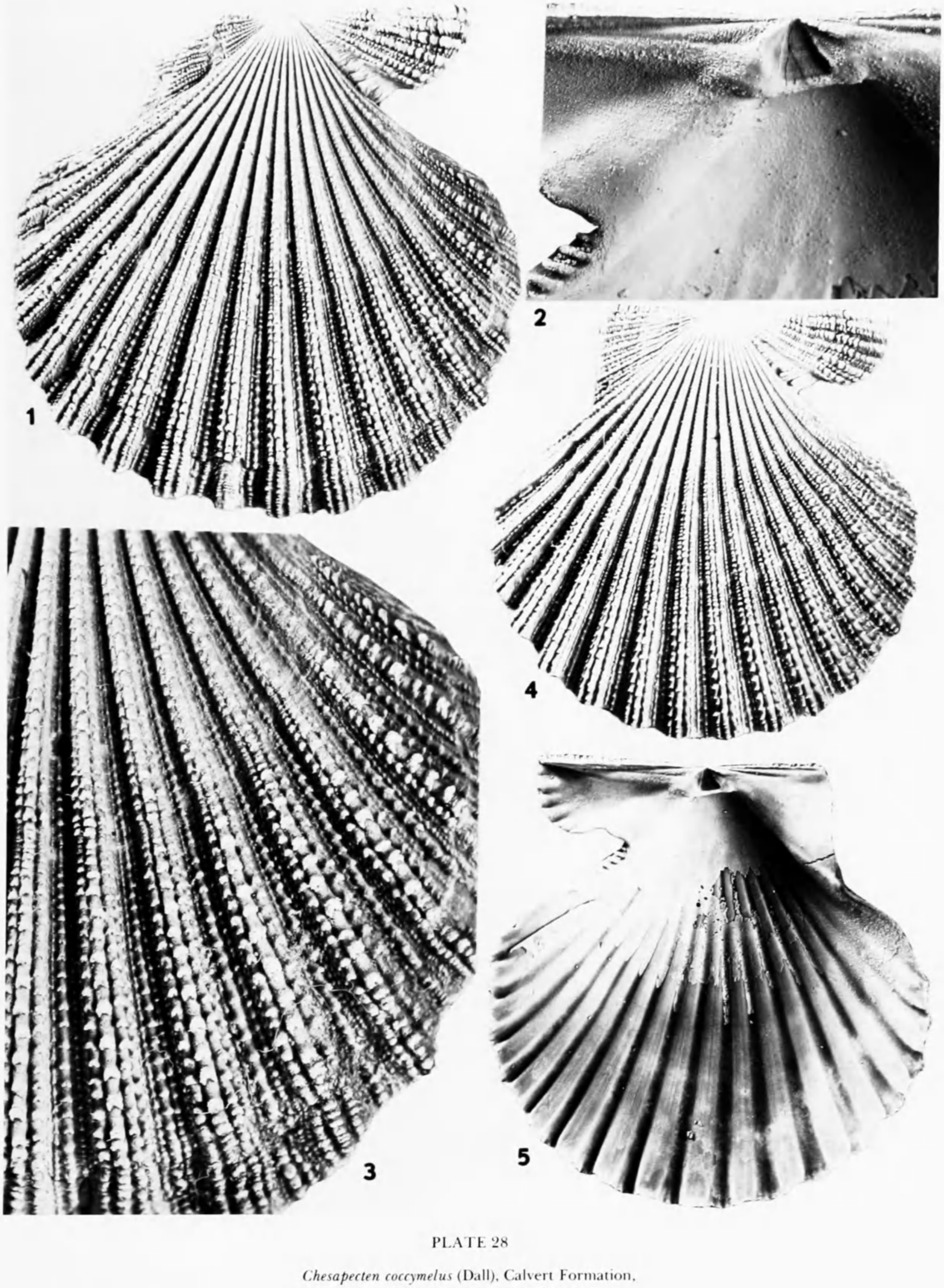

PLATE 28

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

1, 3. USNM 218925, right valve: 1, external view, × 1.5; 3, ribs of anteroventral portion, × 3.

2, 4, 5. USNM 218926, right valve: 2, resilial insertion and ctenolium, × 4; 4, external view, × 1.5; 5, internal view, × 1.5.

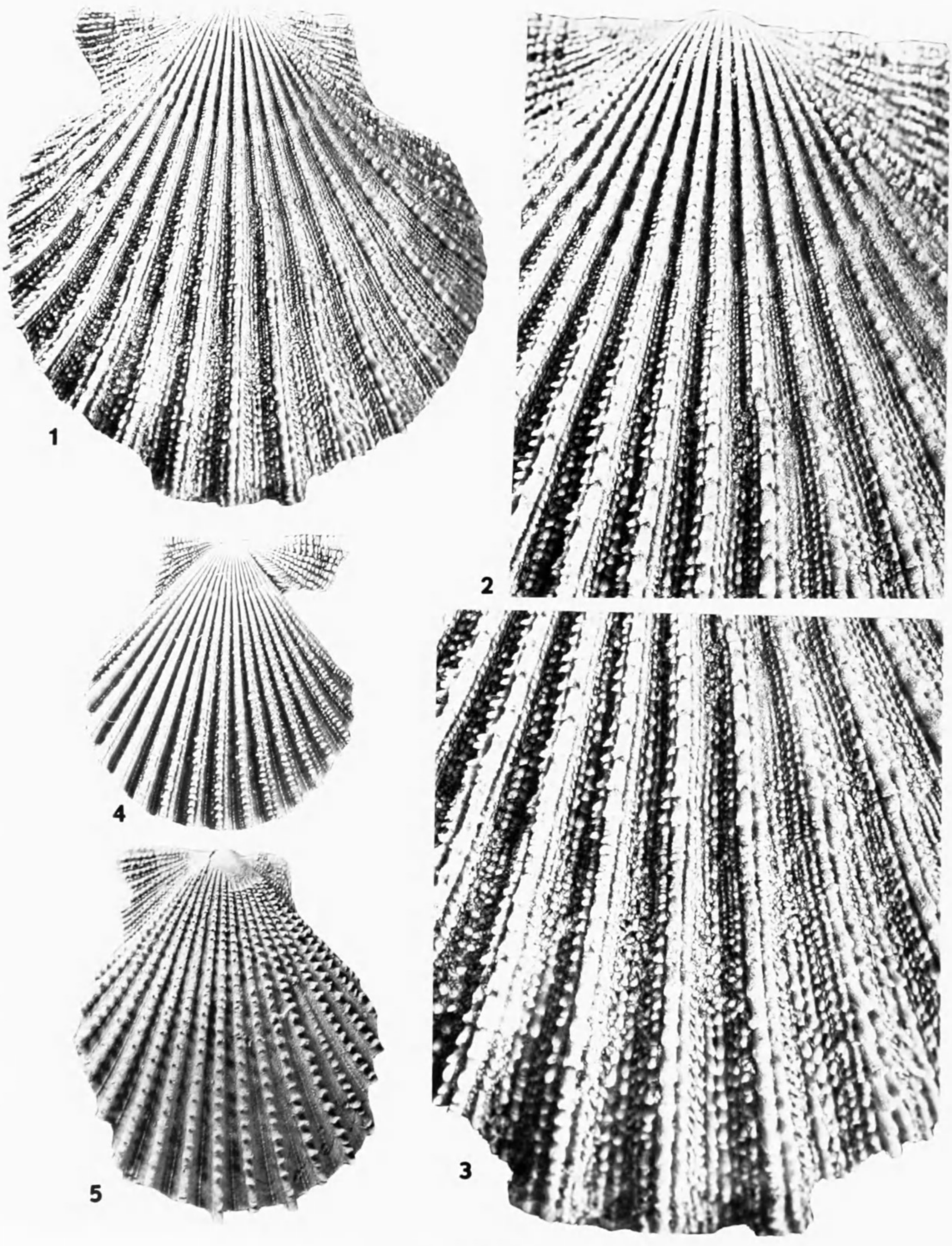

PLATE 29

Chesapecten coccymelus (Dall), Calvert Formation, Plum Point, Maryland

1–3. (= *Chlamys* (*Lyropecten*) *madisonius bassleri* Tucker-Rowland), holotype, USNM 145919, USGS 2447c, left valve: 1, external view, × 1.5; 2, dorsal portion, × 3; 3, ventral portion, × 3.

4. USNM 218927, USGS 24345, external view of right valve, × 2.

5. Holotype, USNM 87754, external view of left valve, × 2.

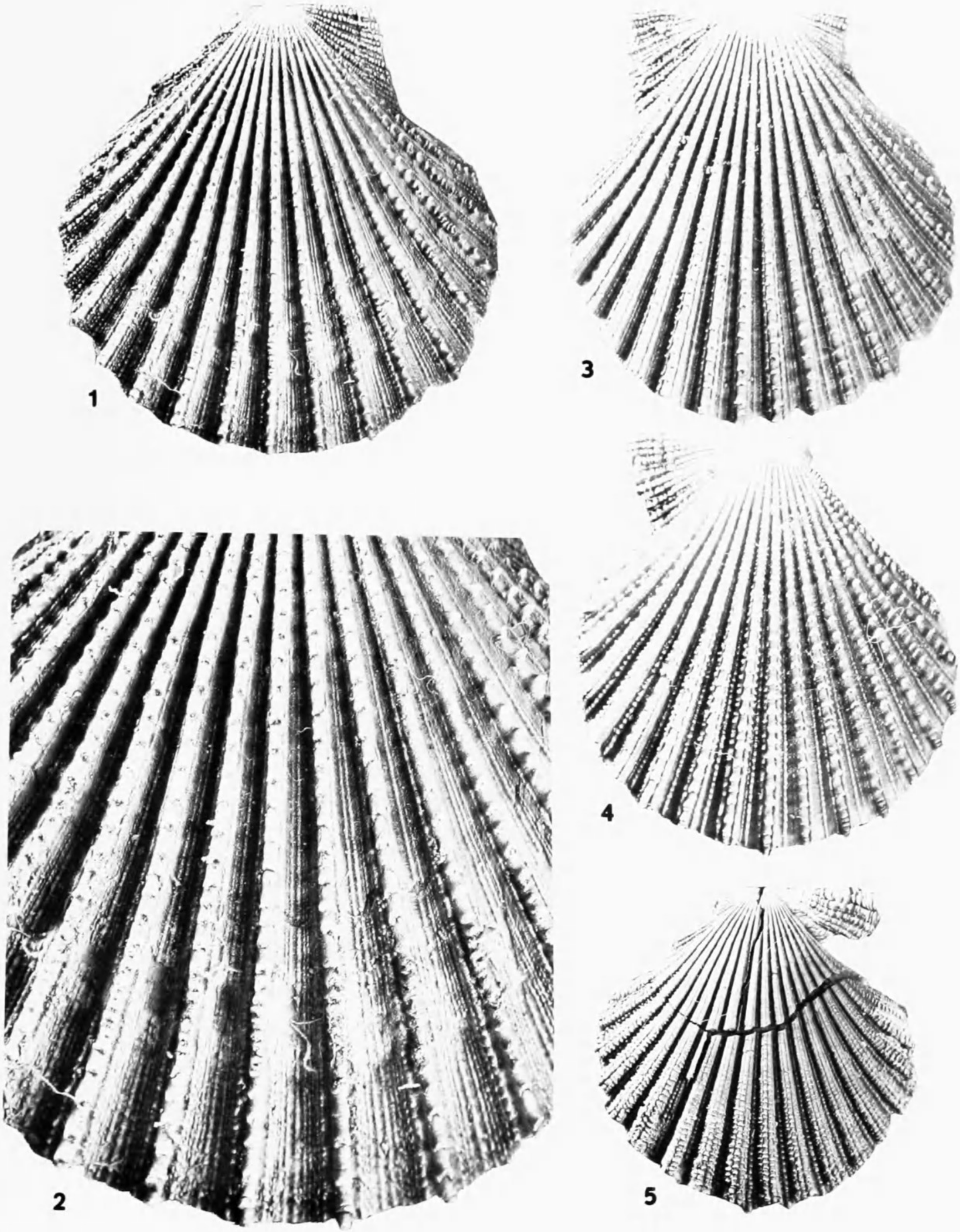

PLATE 30

1–4. *Chesapecten coccymelus* (Dall), Calvert Formation, Plum Point, Maryland, left valve: 1, Maryland Geological Survey No. 1921, external view, × 1.5; 2, Maryland Geological Survey No. 1921, ventral portion, × 3; 3, USNM 218928, USGS 25345, external view, × 2; 4, USNM 218929, USGS 25345, external view, × 2.

5. *Chesapecten coccymelus* (Dall), Pungo River Formation, Lee Creek Mine, USNM 218924, USGS 25338, external view of right valve, × 1.

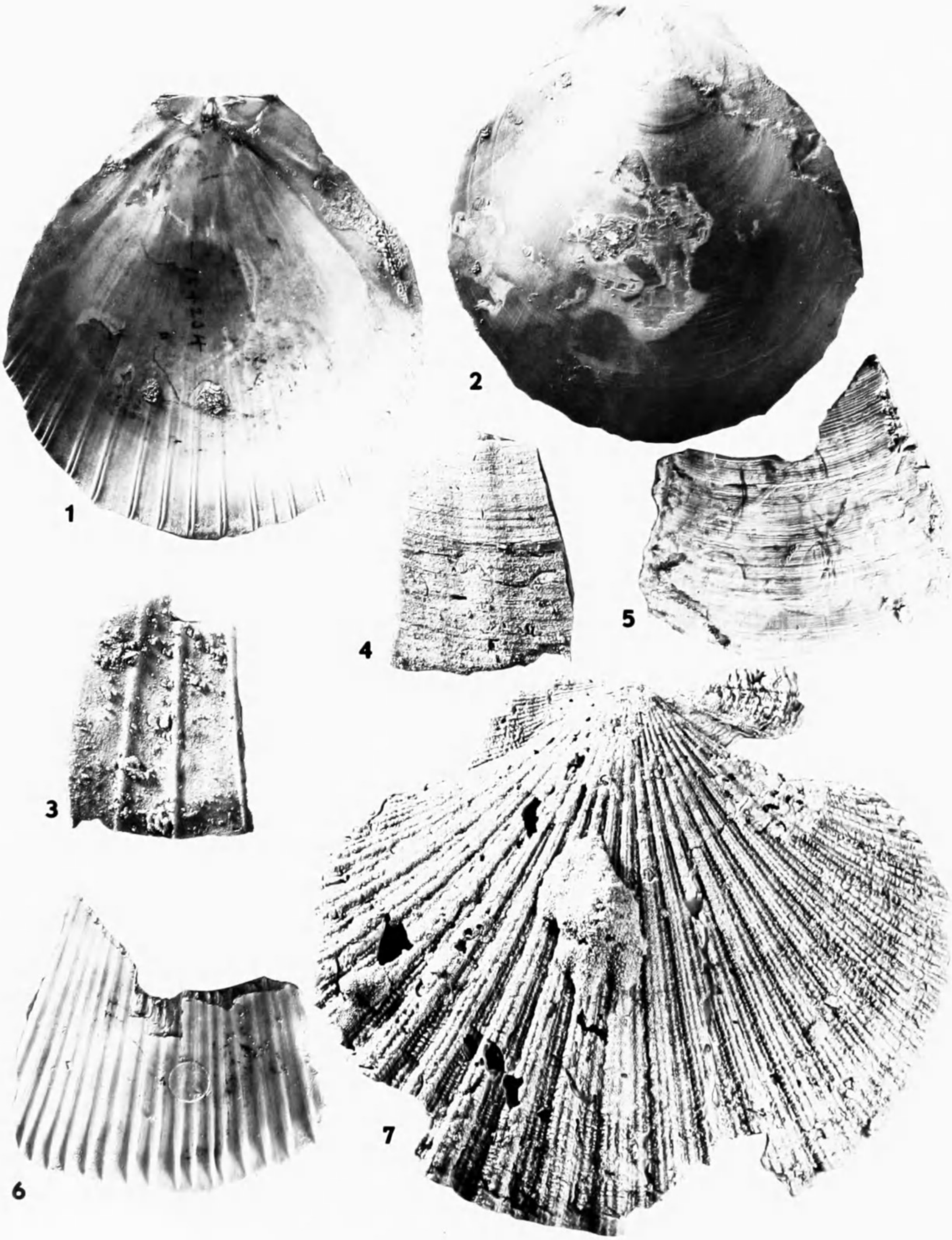

PLATE 31

1, 2. *Amusium mortoni* (Ravenel), Caloosahatchie Formation, Shell Creek, Florida, USNM 154204, left valve: 1, internal view, × 1; 2, external view, × 1.

3, 4. *Amusium* sp., Pungo River Formation, Lee Creek Mine, USNM 218930, USGS 25748, fragment of valve: 3, internal view, × 1; 4, external view, × 1.

5, 6. *Amusium precursor* (Dall), Chipola Formation, Baileys Ferry, Florida, USNM 218931, USGS 2212, fragment of valve: 5, external view, × 1; 6, internal view, × 1.

7. *Chesapecten nefrens* Ward and Blackwelder, Pungo River Formation, Lee Creek Mine, USNM 218932, USGS 25749, external view of right valve, × 1.