TULANE STUDIES IN GEOLOGY AND PALEONTOLOGY

Volume 21, Number 2 July 20, 1988

AGE AND STRATIGRAPHIC CORRELATION OF THE RAYSOR FORMATION, LATE PLIOCENE, SOUTH CAROLINA

LAUCK W. WARD

U. S. GEOLOGICAL SURVEY
RESTON, VIRGINIA

AND

PAUL F. HUDDLESTUN

GEORGIA GEOLOGIC SURVEY
ATLANTA, GEORGIA

CONTENTS

I. ABSTRACT

Mollusks and foraminifers from the type section of the Raysor Formation in the Coastal Plain of South Carolina were obtained from collections in the National Museum of Natural History, Smithsonian Institution, Washington, D.C., and the Charleston Museum, Charleston, South Carolina. Analysis of the molluscan taxa shows the unit to be correlative with the Rushmere and Morgarts Beach Members of the Yorktown Formation in Virginia and North Carolina. Planktic foraminifers in the Raysor indicate an equivalency with Blow's (1969) Zone N20 [= Berggren, *et al.* (1983) Zone PL3]; this equivalency would suggest that the unit is lower upper Pliocene. The Raysor was deposited on a shallow shelf in a setting that was temperate at first, but which quickly warmed to subtropical.

II. INTRODUCTION

The Raysor Formation, a lithic unit in the Upper Tertiary of South Carolina, has been correlated with various beds of the Yorktown and former Duplin formations in Virginia, North Carolina, and South Carolina (Cooke, 1936; Blackwelder and Ward, 1979; Campbell *et al.*, 1975). The Duplin is now incorporated in the Raysor and Yorktown formations (Blackwelder and Ward, 1979). Some uncertainty exists concerning the exact stratigraphic placement of the Raysor because of the presence of temperate molluscan taxa that give it a lower Yorktown character, even though the preponderance of species present indicates correlation with the upper Yorktown. Collections of mollusks from the original Raysors Bridge locality (chosen by Cooke, 1936, p. 116, to be the type section, see figure 1) were obtained from the Char-

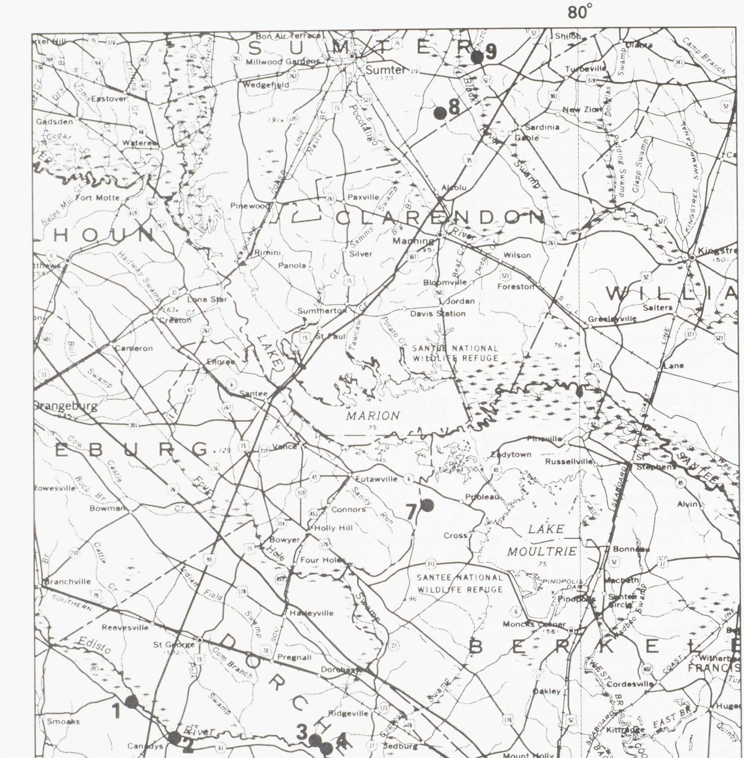

Figure 1. Index map of South Carolina showing the following localities referred to in the text. (1) Raysors Bridge, (2) Canadys Bridge, (3) mouth of Four Hole Swamp, (4) Neostratotype section of the Raysor Formation, (5) Givhans Ferry, (6) Goose Creek, (7) Martin Marietta, Berkeley Quarry, (8) Tearcoat Branch, (9) "Muldrow Place" of Gardner and Aldrich (1919).

leston Museum, Charleston, South Carolina, and the National Museum of Natural History, Smithsonian Institution, Washington, D.C. Some of the specimens retained enough matrix for a foraminiferal analysis.

III. HISTORY OF THE TERM RAYSOR FORMATION

Cooke (1936, p. 115) proposed the term "Raysor marl" for "deposits of upper Miocene age older than the Duplin marl in South Carolina." Thus, the formation name was based on a perceived difference in age and not based on lithic characteristics. Cooke (1936, p. 116) based his description on that of Sloan (1908, p. 280-281) and added no information on the outcrop on the Edisto River, "one-fourth of a mile below [Raysors] Bridge on west side, 8 miles S. 25° W. of St. Georges," Colleton County, South Carolina (fig. 1). Records of the mollusk collections in the National Museum of Natural History indicate that Earle Sloan and Frank Burns, an assistant to W. H. Dall (U. S. Geological Survey), visited the Raysors Bridge locality in 1904 (USGS Tertiary loc. 3991). Burns made another very small collection in 1904 at the confluence of Four Hole Swamp with the Edisto River, Dorchester County, S.C. (USGS Tertiary loc. 3989; fig. 1). Sloan made a larger collection in 1909, and sent specimens from that collection to the U. S. National Museum (USGS 5295). The bulk of the 1909 collection is retained in the Charleston Museum, where most of Sloan's collections are kept (Blackwelder, 1967).

The Raysors Bridge exposure has not been relocated since the Sloan collection in 1909. Sloan (1908, p. 280-281) described a section at that locality (his loc. no. 366). Cooke (1936, p. 116) repeated the section with some modifications as follows:

	Feet
Wicomico formation (Pleistocene):	
5. Mottled clay and sand	15
4. Dun-colored clay in layers, horizontally interstratified with thin seams of sand	11
3. Coarse sand on the much-eroded surface of the Raysor marl	3
Raysor marl (upper Miocene)	
2. Marl consisting of shells in a dark-blue soft matrix; contains 80.82 percent of calcium carbonate	3¼
Cooper marl (Eocene):	
1. Harsh, hard glauconitic marl similar to marl at Stokes Bridge	2

Attempts by the authors to find the original locality have failed. Possibly the locality can only be seen at extremely low water or, it may be slumped and overgrown. In 1975 Ward drilled an auger hole just south of the Route 15 bridge over the Edisto River at Canadys, Colleton County (fig. 1, loc. 2). He pentrated 13.5 feet (4.1 m) of fine, shelly, calcareous sand similar to that described by Sloan.

Cooke (1936) and Blackwelder and Ward (1979) recognized the "middle Yorktown" (of Mansfield, 1928, 1944) equivalency of the Raysor collections at the National Museum (USNM 5295, USNM 3991). Blackwelder and Ward (1979) further recognized that, in its type area, the Raysor was highly calcareous and was relatively lacking in clastic material. They suggested, therefore, that the name Raysor Marl (emended to Raysor Formation) be retained as a unit of formational rank and a facies equivalent of the shelly quartzose sands of the Yorktown Formation (fig. 2). The Yorktown, in its strict lithic sense, extends from Virginia across North Carolina and into South Carolina. In Virginia and North Carolina, the unit was deposited as a series of shelly sands and silty sands across the entire basin. In South Carolina, these clastic deposits became thinner southward, and were deposited only very near shore. Seaward in the basin, calcarenitic material dominates and replaces the clastic component. This predominatly calcareous facies is called the Raysor Formation.

Because the original type section could not be located, Blackwelder and Ward (1979, p. 39) selected a neostratotype section for the Raysor Formation on the left bank of the Edisto River, 0.68 miles (1.1 km) upriver of the Route 61 bridge, Dorchester County, S.C. (fig. 1, loc. 4).

IV. PREVIOUS CORRELATION OF THE RAYSOR FORMATION

Tuomey and Holmes (1855) did not study the beds near Raysors Bridge but discussed equivalent beds at Givhans Ferry

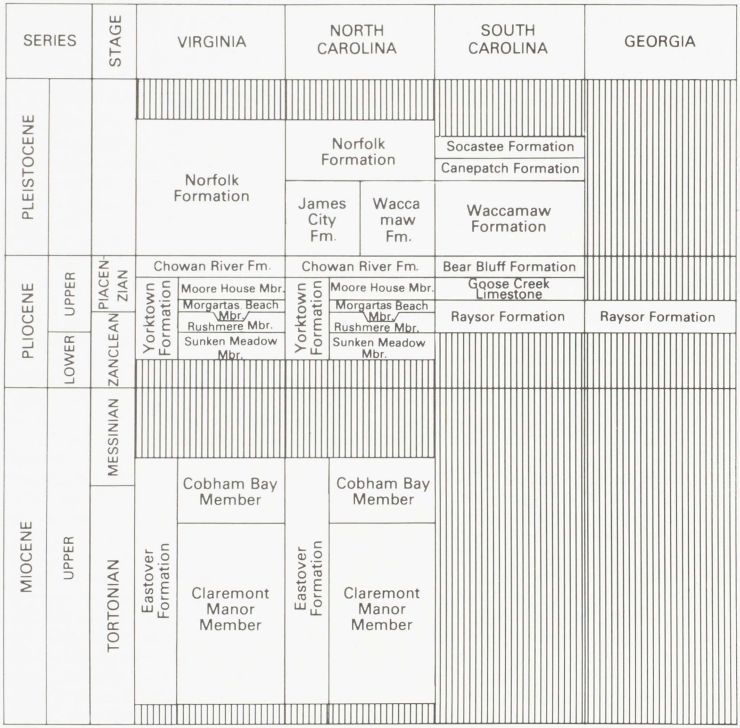

Figure 2. Correlation chart showing Neogene units from Virginia to Georgia.

(fig. 1, loc. 5). They concluded that those beds were of Pliocene age. Sloan (1908, p. 281) reported that the shelly marl below Raysors Bridge was of Miocene age. Sloan, who was not a paleontologist, may have been given this information by Frank Burns, (USGS), who helped him make his first collections in 1904 (USGS coll. no. 3991). Mansfield (1935), in a correlation chart, indicated that the bed at Raysors Bridge was equivalent to this "Zone 1" of the Yorktown Formation in Virginia and placed it in the lower upper Miocene. Cooke (1936, p. 115-117), referring to the lists of mollusks identified by W. C. Mansfield (USGS) from the Sloan collections, concluded that the Raysor deposits were of "upper Miocene age" and "older than the Duplin marl in South Carolina." Cooke further stated that the Raysor was believed to be "equivalent to a middle part of the Yorktown formation of Virginia and North Carolina and to the *Ecphora* zone of the Choctawhatchee Formation of Florida." Cooke's (1936, p. 100) correlation chart, however, showed that the Raysor was the equivalent of the lower and middle Yorktown Formation. Mansfield (1944) placed the Raysor in the lower Yorktown (his "Zone 1"), even though his zonal indi-

cator "*Pecten clintonius*" is not present in the unit. The Yorktown and its equivalents have been included in the Miocene, but Hazel (1971, p. 8) concluded that beds from the *Ecphora* zone at Alum Bluff, Florida, were in part early Pliocene and suggested that the "upper Miocene-lower Pliocene boundary in the Atlantic and Gulf Coastal Plain eventually will be revised further downward to include in the Pliocene more of the deposits that have been traditionally assigned to the upper Miocene." Hazel (1977, 1983) subsequenty placed all of the Yorktown, as applied in the strict sense by Ward and Blackwelder, 1980, and its equivalents in the Pliocene. The Raysor, therefore, has since been considered to be Pliocene (Blackwelder and Ward, 1979; Cronin, 1981; Cronin, *et al.*, 1984).

The correlation of the Raysor with specific units of the Yorktown Formation has been ambiguous. Campbell *et al.*, (1975) suggested that the "Raysors Bridge Member" (his term) was equivalent to Zone 1 of the Yorktown Formation (of Mansfield, 1928, 1935, 1944) but stated that the data were not conclusive. Blackwelder and Ward (1979) indicated a middle Yorktown equivalency based on the presence of the following mollusks (USGS loc. no. 5295):

Fissuridea redimicula (Say, 1824)
(=*Diodora redimicula* in Table 1)
Glycymeris subovata (Say, 1824)
Crassatella undulata Say, 1824
Anadara lienosa (Say, 1832)

This correlation would mean equivalency with the Rushmere and Morgarts Beach Members of the Yorktown Formation of Ward and Blackwelder (1980). Cronin (1981, p. 817) stated that the planktic foraminifers in the Raysor Formation "indicate the probable time-equivalence of this ostracode zone with the *Pterygocythereis inexpectata* and lower part of the *Orionina vaughani* ostracode Assemblage Zones of the Yorktown Formation of Virginia." These zones were established by Hazel (1971) and are equivalent to the lower (Zone 1 of Mansfield 1928, 1944) and upper (Zone 2 of Mansfield) parts of the formation. Hazel (1983) and Cronin *et al.* (1984) reiterated this placement. Because of the ambiguity in correlating the Raysor, the present study was initiated. All known collections from the original Raysors Bridge locality made by Sloan and(or) Burns were examined, and these collections then were compared with others made in South Caroina, North Carolina, and Virginia.

V. STUDY MATERIAL

The principal components of this study are three USGS collections in the National Museum of Natural History, Washington, D.C., and one collection in the Charleston Museum, Charleston, S.C., which contain a total of 492 mollusk specimens. These collections were made by Earle Sloan and Frank Burns in 1904 and by Sloan in 1909. The USGS collections 5295 and 3991 are listed as being from Raysors Bridge but clearly come from the locality described by Sloan (1908, p. 280-281) "one-fourth of a mile below [Raysors] Bridge on [the] west side," Colleton County, South Carolina. Sloan's collection in the Charleston Museum also lists Raysors Bridge as the locality but his locality number (S.C. Survey no. 366) is the same locality as the one described in 1908 (p. 280). Another sample was located that contained the single oyster species *Ostrea locklini*. The occurrence of that species in the sample suggests the presence of the same bed (Raysor Formation) at least as far downriver as the mouth of Four Hole Swamp, which is located approximately one mile (1.85 km) upriver from the neostratotype section chosen for the Raysor by Blackwelder and Ward (1979).

Taxa from each of the four collections are listed in Table 1. The number of specimens and their condition, if less than satisfactory, also are given. Comments on selected specimens are included. Several specimens in the collections are of unknown origin because the specimens are associated with lithologies different from the bulk of the material. These specimens are noted in the Appendix.

In addition to the Sloan Raysor material, Ward's collections of mollusks from the Martin Marietta Quarry in Berkeley County (fig. 1, loc. 7) and Tearcoat Branch, Sumter County (fig. 1, loc. 8) were studied and compared with Sloan's material as was the Gardner and Aldrich (1919) collection from the "Muldrow Place" (fig. 1, loc. 9). The close similarity of the assemblages

Taxa from Raysors Bridge	MIOCENE		PLIOCENE						ADDITIONAL SOUTH CAROLINA LOCALITIES		
	MIDDLE	UPPER	LOWER	UPPER							
	ST. MARYS	EASTOVER	YORKTOWN				CHOWAN RIVER	JAMES CITY	MARTIN MARIETTA — CROSS QUARRY	TEARCOAT BRANCH	MULDROW PLACE
			SUNKEN MEADOW	RUSHMERE	MORGARTS BEACH	MOORE HOUSE					
GASTROPODA											
Diodora redimicula (Say)				•		•			•	•	•
Turritella sp. new				•					•		
Polinices duplicatus (Say)	•										
Petaloconchus sculpturata H.C. Lea				•		•				•	•
SCAPHOPODA											
Dentalium attenuatum Say	•							•	•	•	•
Cadulus thallus (Conrad)	•						?		•	•	•
BIVALVIA											
Nucula proxima Say	•								•	•	•
Nucula taphria	•									•	•
Yoldia laevis (Say)	•										•
Nuculana sp. near *N. concentrica* (Say)	•								•		
Nuculana sp.				•							
Anadara lienosa (Say)				•		•			•	•	•
Glycymeris subovata tuomeyi Dall				•		•				•	•
Carolinapecten eboreus (Conrad)				•							•
"Leptopecten" irremotis Olsson and Harbison				•							
Amusium mortoni (Ravenel)				•					•		
Chesapecten sp. nearest *C. jeffersonius* (Say)			?	?							
Chesapecten septenarius (Say)				•							
Chesapecten madisonius (Say)				•					•		
Pteria sp.				•					•		
Plicatula marginata Say				•					•	•	•
Ostrea locklini Gardner				•							
Ostrea raveneliana Tuomey and Holmes				•					•	•	•
Lucinoma contracta (Say)	•										
Lucinisca cribrarius (Say)				•		•			•	•	•
Parvilucina multilineata (Tuomey and Holmes)				•					•	•	•
Callucina keenae Chavan				•					•	•	•
Divaricella quadrisulcata (d'Orbigny)			•							•	•
Diplodonta sp.											
Diplodonta yorkensis Dall				•		•				•	•
Pseudochama corticosa (Conrad)				•		•					
Echinochama arcinella (Linné)									•		
Aligena aequata Conrad				•		•					•
Caraditanera arata (Conrad)				•						•	•
Cyclocardia granulata (Say)	•								•	•	•
Astrate concentrica Conrad				•					•	•	•
Astarte floridana Dall											
Astarte sp.									•		
"Crassatella" gibbesii (Tuomey and Holmes)									•		
Marvacrassatella undulatus (Say)				•		•			•	•	•
"Cardium" sp.				•		•					
Tellina declivis Conrad			•			•			•		
Tellina aequistriata (Say)				•		•				•	•
Semele subovata (Say)				•		•			•	•	
Semele sp.		•				•					
Glossus fraterna (Say)			•			•					
Dosinia acetabulum (Conrad)	•					•			•		
Pitar sayana (Conrad)	•					•			•	•	•
Linophora sp. prob. *L. athleta* (Conrad)				•		•			•	•	•
Caryocorbula inaequalis (Say)	•					•			•		•
Caryocorbula sp.											
Varicorbula sp.											
Hiatella arctica (Linné)	•									•	•
Kuphus fistula (H.C. Lea)			•			•					
Pandora arenosa Conrad	•									•	•

Table 1. Composite list of taxa from 4 collections from the Raysor Formation in its type area. Distribution of the taxa in the Miocene and Pliocene is plotted.

suggest that the beds at those localities are Raysor equivalents.

Comments on collection from USGS locality 5295. Mansfield studied this collection and Cooke (1936, p. 116-117) published a list of its taxa with Mansfield's comments. That list is as follows:

Paracyathus vaughani Gane; identified by T. W. Vaughan
Epitonium sp.
Turritella variabilis Conrad
Cadulus thallus (Conrad)
Nucula proxima Say

Leda trochilia Dall (like form in *Ecphora* zone of Choctawhatchee Formation)
Yoldia tarphaeia Dall (like form in *Ecphora* zone of Choctawhatchee Formation)
Glycymeris subovata (Say) var.
Arca (Scapharca) lienosa (Say)
Ostrea sp.
Ostrea disparilis Conrad
Pecten jeffersonius Say
Pecten jeffersonius var. aff. *P. jeffersonius edgecombensis* Conrad
Plicatula marginata Say
Crassatellites gibbesii Tuomey and Holmes
Crassatellites undulatus cyclopterus Dall
Astarte concentrica var. *bella* Conrad
Astarte floridana Dall *(Ecphora* zone)
Cardita (Carditamera) arata (Conrad)
Venericardia granulata Say
Chama corticosa Conrad
Echinochama arcinella (Linnaeus)
Phacoides cribrarius (Say)
Phacoides contractus (Say)
Phacoides crenulatus Conrad
Phacoides radians (Conrad)
Diplodonta nucleiformis (Wagner)
Diplodonta yorkensis Dall?
Divaricella quadrisulcata D'Obigny
Aligena aequata (Conrad)
Cardium sp.
Isocardia fraterna Say, grading toward *I. carolina* Dall
Chione latilirata athleta Conrad
Tellina (Merisca) aequistriata Say
Tellina (Angulus) declivis Conrad
Semele subovata (Say) var.
Corbula inaequalis Say
Corbula, group of *C. chipolana* Dall
Saxicava sp.
Teredo calamus H. C. Lea

The specimen of *Paracyathus vaughani* Gane is now missing from the collection but several specimens are still present in the Sloan collection in the Charleston Museum. We have made several revisions in the taxonomic listings, but overall the lists are very similar (see Appendix). Several taxa that Cooke (1936) listed were not present in either USGS collection 5295 or 3991. Either these forms were put in the National Museum of Natural History (USNM) set and were lost, or were included in the list because they were in the Sloan collection in Charleston. Two of these taxa are "*Pecten jeffersonius* Say" and "*Pecten jeffersonius* var. aff. *P. jeffersonius edgecombensis* Conrad," as Cooke (1936, p. 116) listed.

Comments on collection from USGS locality 3991. This collection was described as coming from "1 mile below Raysor Bridge, on road from St. George station to courthouse, Earle Sloan and Frank Burns, collectors." We think that this is the same locality as USGS 5295. The collection made in 1904 is small, and its unique components probably prompted the later more extensive collections in 1909 (USGS, coll. no. 5295 and Sloan coll. no. 366 at the Charleston Museum).

Comments on collection from USGS locality 3989. This collection consists of two specimens of *Ostrea locklini* Gardner. A note in the specimen tray stated that the taxon is the same as that collected at Raysors Bridge, but the note appears to have been added later.

Comments on Sloan collection from locality 366 in Charleston Museum. Blackwelder (1967) first listed taxa from this collection. Blackwelder used the names that were written on the museum labels and made no attempt to update the taxonomic determinations. This collection is the most extensive in terms of numbers of individual specimens (308), but it contains only a few more species than the USGS 3991, 3989, and 5295 collections. The numerous specimens, however, did provide additional information on the assemblage. Furthermore, several specimens in this collection retained the original sediment in which they were deposited. This sediment was processed for foraminifers. The numbers assigned to the various taxa refer to the boxes in which they were packed in the Charleston Museum. The boxes commonly contained several specimens and, in some, many specimens.

VI. MOLLUSCAN ANALYSIS

As can be seen from Table 1, mollusks are common to abundant in the thin Pliocene bed below Raysors Bridge. Many are well preserved, and others appear water-worn. Specific comments on the various specimens in the collections are made in the Appendix. Table 1 shows the presence of only one species that is confined to beds older than the upper Pliocene Rushmere Member of the Yorktown

Formation – *Chesapecten jeffersonius* (Say, 1824) or a species closely related. *Chesapecten jeffersonius* occurs only in the lower Pliocene Sunken Meadow Member of the Yorktown Formation in Virginia, and an unconformity between that unit and the Rushmere Member represents a diastem of at least 0.5 million years. The *Chesapecten* lineage is so well represented in the Chesapeake Group of Virginia and Maryland that it is certain that faunal turnovers are due to speciation and not solely the result of migration of taxa or environmental shifts. Such speciation is evident in the *C. jeffersonius*, *C. madisonius*, and *C. septenarius* stock. *Chesapecten jeffersonius* is characterized by few and heavy ribs, finely scaled, which are square in outline at youth and become more rounded with age. In the lowest part of the Rushmere Member, two new forms appear which have affinities with *C. jeffersonius*, namely *C. madisonius* and *C. septenarius*. The earliest forms of *C. madisonius* have a few more ribs than *C. jeffersonius*, but the valves of *C. madisonius* are less inflated, and the ribs are more rounded and somewhat more coarsely scaled. *Chesapecten septenarius*, however, has fewer ribs than typical *C. jeffersonius*. In addition, *C. septenarius* has finely scaled ribs that are square in outline from juvenile to adult. Although the geographic ranges of *C. madisonius* and *C. septenarius* overlap, *C. madisonius* is common only in the upper Yorktown Formation of late Pliocene age north of the Neuse River and it is scarce to absent south of that area. *Chesapecten septenarius* is present, but never abundant, in stratigraphic equivalents of the Rushmere and Morgarts Beach members from Virginia to Florida. It appears to have been common in the type section of the Raysor and is also common at the Martin Marietta Berkeley Quarry in the Raysor Formation.

Although having several distinctly subtropical to tropical elements, the Raysor assemblage at the type locality is clearly most closely allied with the temperate fauna in the Salisbury Embayment (area of the Coastal Plain that includes parts of New Jersey, Maryland, and Virginia, and all of Delaware) to the north. An examina-

PLATE 1

1. *Diodora redimicula* (Say, 1824)
   Apical view of broken specimen in the Sloan Collection (box 1) at Charleston Museum, Charleston, S.C.; length 44.7 mm, height 19.3 mm.
2. *Turritella* sp.
   Apertural view of an incomplete specimen (USNM 405347) from USGS collection no. 3991 in the U. S. National Museum, Washington, D.C.; height 49.0 mm.
3. *Turritella* sp.
   Apertural view of an incomplete specimen (USNM 405348) from USGS collection no. 3991 in the U. S. National Museum, Washington, D.C.; height 28.4 mm.
4. *Glycymeris subovata tuomeyi* Dall, 1898
   Exterior view of an incomplete left valve (USNM 405349) from USGS collection no. 5295 in the U. S. National Museum, Washington, D.C.; length 53.5 mm, height 76.8 mm.
5. *Anadara lienosa* (Say, 1832)
   Exterior view of an incomplete left valve (USNM 405350) from USGS collection no. 5295 in the U. S. National Museum; Washington, D.C.; length 72.7 mm, height 46.8 mm.
6. *Ostrea locklini* Gardner, 1945
   Exterior of a left valve (USNM 405351) from USGS collection no. 5295 in the U. S. National Museum, Washington, D.C.; length 41.8 mm, height 34.5 mm.
7. *Ostrea raveneliana* Tuomey and Holmes, 1855
   Exterior of a left valve (USNM 405352) from USGS collection no. 5295 in the U.S. National Museum, Washington, D.C.; length 90.2 mm, height 96.1 mm.
8. *Pseudochama corticosa* (Conrad, 1833)
   Exterior and interior of a right valve of a specimen in the Sloan Collection (box 43) at Charleston Museum, Charleston, S.C.; length 54.1 mm, height 56.5 mm.

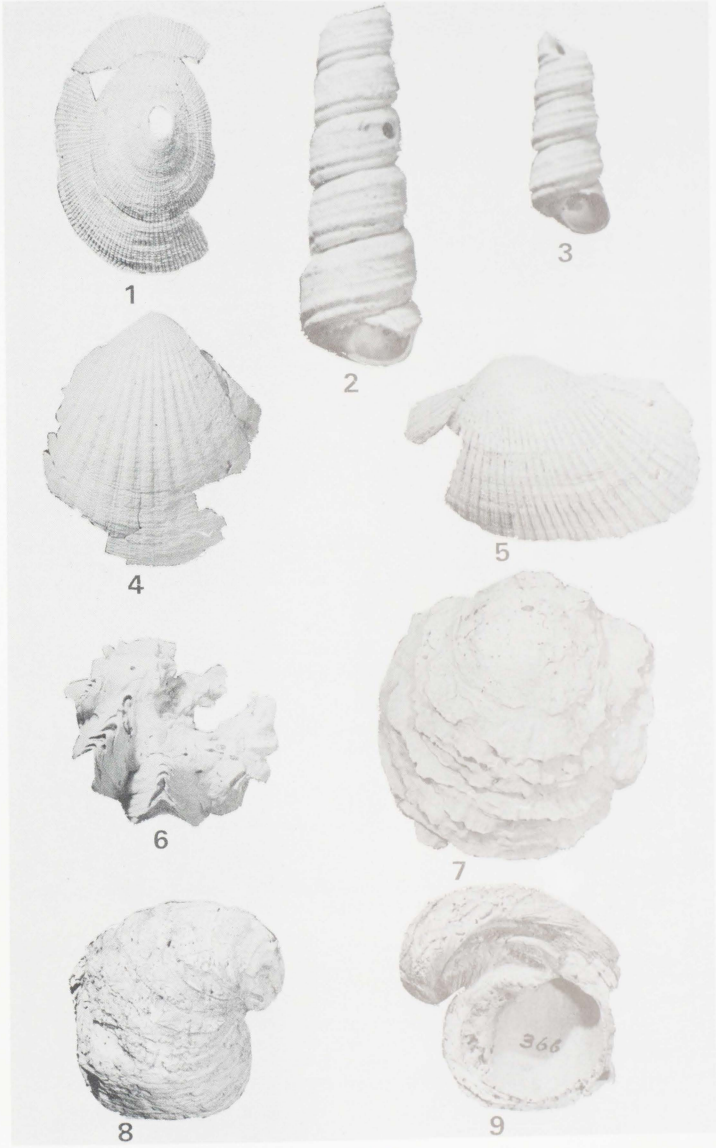

PLATE 1

tion of the assemblage as listed in Table 1 make this alliance clear, but the origin of the temperate condition is unclear. Perhaps a near-shore cool current brought temperate taxa far south of their normal range, or maybe the initial transgressive seas that invaded the area south of the Cape Fear Arch were temperate in nature. Whatever the reason, the temperate condition was succeeded by a more subtropical to tropical marine environment indicated by a principally carbonate substrate and a more diverse molluscan assemblage.

There are several possible explanations for the presence of a species in the upper Pliocene beds in South Carolina which is morphologically similar, if not identical to, *C. jeffersonius*. *Chesapecten jeffersonius* appears to have proliferated in a cool-temperate setting in the Yorktown (Sunken Meadows Member) sea and it may have survived the low sea-level cooling event, which is marked by an unconformity between the Sunken Meadows and Rushmere Members. If *C. jeffersonius* survived that regression, it may have been extant long enough to accompany the next transgression into the Charleston Embayment.

Another possibility is that an equivalent of the Sunken Meadows Member was deposited in South Carolina but later was largely removed by erosion. This possibility is plausible, as evidenced by the large shark teeth of *Procarcharodon megalodon* (Charlesworth), which are found as lag deposits over much of the South Carolina Coastal Plan. *Procarcharodon megalodon* was common in the Sunken Meadow Member and its equivalents in Virginia and North Carolina, but there is no record of the taxon in any younger units except as reworked phosphatized basal lag. Clearly an older unit, either Miocene or early Pliocene, was deposited over much of the South Carolina Coastal Plain, and this unit has been largely removed by erosion. The specimens of *Chesapecten jeffersonius* and also *Glossus fraterna* may represent a residuum of an older unit, but their good preservation makes this doubtful. Both taxa were abundant in the lower Pliocene, Sunken Meadow Member in Virginia and North Carolina, but *G. fraterna* is present also in the upper Pliocene Rushmere and Moore House Members of the Yorktown. *Glossus* has an aragonitic shell and is much less likely to survive reworking than the

PLATE 2

1. *Chesapecten madisonius* (Say, 1824)
   Exterior of a right valve in the Sloan Collection (box 18) at Charleston Museum, Charleston, S.C.; length 121.3 mm, height 119.4 mm. Specimen has fewer ribs than typical *C. madisonius* (Say, 1824).
2. *Chesapecten* sp. aff. *C. jeffersonius* (Say, 1824)
   Exterior of a left valve in the Sloan Collection (box 17) at Charleston Museum, Charleston, S.C.; length 86.9 mm, height 84.9 mm.

3, 4. *Chesapecten septenarius* (Say, 1824)
   3. Exterior of a right valve in the Sloan Collection (box 18) at Charleston Museum, Charleston, S.C.; length 77.2 mm, height 77 mm.
   4. Exterior of a right valve from the Sloan collection (box 19); length 136.4 mm, height 129.6 mm.

5. *Chesapecten madisonius* (Say, 1824)
   Exterior of a left valve in the Sloan Collection (box 19) at Charleston Museum, Charleston, S.C.; length 145.2 mm, height 149.5 mm.
6. *Carolinapecten eboreus* (Conrad, 1833)
   Exterior of a right valve in the Sloan Collection (box 16) at Charleston Museum, Charleston, S.C.; length 46.2 mm, height 43.2 mm.
7. *Lucinisca cribrarius* (Say, 1824)
   Exterior of a left valve (USNM 405353) from USGS collection no. 5295 in the U. S. National Museum, Washington, D.C.; length 8.7 mm, height 8.2 mm.
8. *Plicatula marginata* Say, 1824
   Exterior of a left valve (USNM 405354) from USGS collection no. 5295 in the U.S. National Museum, Washington, D.C.; length 17.5 mm, height 19.0 mm.

PLATE 2

calcitic pectinids. Our conclusion is that *C. jeffersonius* and other temperate forms accompanied the earliest transgression of the Raysor sea and that the taxon was soon replaced by the more subtropical to tropical species *C. septenarius*. The early temperate setting produced a mixed environment where Chesapeake mollusks occurred together with their subtropical counterparts. This early cool-water event clearly influenced the molluscan assemblage in the Jackson Bluff Formation at Alum Bluff, Florida, where a Chesapeake assemblage dominates and has an admixture of subtropical taxa.

Despite the anomalous occurrence of what appears to be a species closely related to *Chesapecten jeffersonius*, the remainder of the assemblage has a strong affinity with that of the upper Pliocene Rushmere, Morgarts Beach, and Moore House Members of the Yorktown. The following taxa are restricted to the upper Pliocene:

Turritella sp. new
Glycymeris subovata tuomeyi Dall, 1898
Chesapecten septenarius (Say, 1824)
Chesapecten madisonius (Say, 1824)
Carolinapecten eboreus (Conrad, 1833)
Astarte concentrica Conrad, 1834
Marvacrassatella undulatus (Say, 1824)
Lirophora sp. probably *L. athleta* (Conrad, 1863)

Chesapecten septenarius (Say, 1824) is not known in units above the Rushmere Member. The co-occurrence of *C. septenarius*, *C.* sp. aff. *jeffersonius*, *C. madisonius*, and an early form of *C. madisonius* that has fewer ribs than typical suggests that the Raysor is correlative with the Rushmere Member of the Yorktown. In the Moore House Member, *C. septenarius* has not been found. As seen in Table 1, most of the taxa appear first in the Rushmere Member of the Yorktown Formation or its stratigraphic equivalents in North Carolina and South Carolina. The preponderance of molluscan data, then, suggests that the Raysor Formation was deposited during a marine transgression in the late Pliocene. This transgression may have slightly preceded that in the Albemarle (area of the Coastal Plain that includes the northeastern part of North Carolina and the extreme southeastern part of Virginia) and Salisbury Embayments, but for the most part, the transgression coincides with the depositional event associated with the upper

PLATE 3

1. *Marvacrassatella undulata* Say, 1824
   Exterior of a right valve in the Sloan Collection (box 37) at Charleston Museum, Charleston, S.C.; length 106.1 mm, height 71.8 mm.
2. *"Crassatella" gibbesii* Tuomey and Holmes, 1856
   Exterior of a right valve in the Sloan Collection (box 35) at Charleston Museum, Charleston, S.C.; length 30.5 mm, height 22.4 mm.
3. *Astarte floridana* Dall, 1903
   Exterior of a left valve in the Sloan Collection (box 34) at Charleston Museum, Charleston, S.C.; length 26.9 mm, height 22.7 mm.
4. *Astarte concentrica* Conrad, 1834
   Exterior of a right valve (USNM 405355) from USGS collection no. 5295 in the U. S. National Museum, Washington, D.C.; length 18.6 mm, height 16.1 mm.
5. *Astarte* sp.
   Exterior of a left valve (USNM 405356) from USGS collection no. 5295 in the U.S. National Museum, Washington, D.C.; length 17.2 mm, height 10.6 mm.
6. *Lirophora athleta* (Conrad, 1863)
   Exterior of a left valve (USNM 405357) from USGS collection no. 5295 in the U.S. National Museum, Washington, D.C.; length 18.2 mm, height 14.0 mm.
7. *Glossus fraterna* (Say, 1824)
   Exterior of a left valve (USNM 405358) from USGS collection no. 3991 in the U.S. National Museum, Washington, D.C.; length 81.0 mm, height 71.9 mm.
8. *Cyclocardia granulata* (Say, 1824)
   Exterior of a left valve (USNM 408007) from USGS collection no. 5295 in the U. S. National Museum, Washington, D.C.; length 16.9 mm, height 17.0 mm.

PLATE 3

Yorktown or Rushmere and Morgarts Beach Members of the Yorktown. The Rushmere and Morgarts Beach Members are lithofacies of the same transgressive event. Because of the substrate conditions produced by the coarser basal transgressive shelly sands of the Rushmere, that bed contains a substantially different assemblage than the much more clayey, silty Morgarts Beach Member. In areas in Virginia and North Carolina, where local structural conditions or high areas resulted in similar substrates throughout the sequence, the members are not differentiated, and their assemblages are very similar. In those areas, the Yorktown is referred to as the Rushmere-Morgarts Beach undifferentiated.

The Raysor is probably not correlated with the highest member of the Yorktown, the Moore House Member. The Moore House overlies the Morgarts Beach unconformably and records a separate transgressive event that followed a brief regression. The unit is much less extensive than the Rushmere-Morgarts Beach transgressive event and occupies only about one-fifth of that basin in Virginia. In North Carolina, the Moore House is known only in the subsurface in the area of the Lee Creek Mine, at Aurora, where it is only 10 feet (3 m) thick. Elsewhere in North Carolina, the uppermost Pliocene Chowan River Formation and its equivalent south of the Cape Fear Arch, the Bear Bluff Formation, directly overlie the Rushmere-Morgarts Beach sequence or its undifferentiated equivalents.

VII. FORAMINIFERAL ANALYSIS

The planktic foraminiferal analysis was made on specimens obtained from matrix inside the paired valves of some of the Raysor Formation mollusks. Diverse assemblages were obtained from the matrix associated with *Marvacrassatella undulata* and *Ostrea raveneliana* in Boxes 28 and 38 from the Sloan collection at the Charleston Museum. In addition, a sample from Blackwelder and Ward's (1979) neostratotype for the Raysor was examined for planktic foraminifers. The following taxa were found in the three samples:

Sloan locality 366 - Box 28, in Charleston Museum; matrix from *Marvacrassatella undulata*.

Neogloboquadrina acostaensis (Blow, 1959)
Neogloboquadrina humerosa (Takayangi and Saito, 1962)
Globigerinoides obliquus Bolli, 1957
Globigerinoides ruber (d'Orbigny, 1839)
Globigerinoides quadrilobatus (d'Orbigny, 1846)
Globigerinoides saculifer (Brady, 1877)
Globigerinoides altispira (Cushman and Jarvis, 1936)
Sphaeroidinellopsis seminulina (Schwager, 1866)
Globigerina apertura Cushman, 1918
Globigerina sp.
Orbulina universa d'Orbigny, 1839

Sloan locality 366 - Box 38, in Charleston Museum; matrix from *Ostrea raveneliana*.

Neogloboquadrina acostaensis (Blow, 1959)
Neogloboquadrina humerosa (Takayangi and Saito, 1962)
Globigerinoides obliquus Bolli, 1957
Globigerinoides ruber (d'Orbigny, 1839)
Globigerinoides quadrilobatus (d'Orbigny, 1846)
Globigerinoides saculifer (Brady, 1877)
Globoquadrina altispira (Cushman and Jarvis, 1936)
Sphaeroidinellopsis seminulina (Schwager, 1866)
Globigerina apertura Cushman, 1918
Globigerina sp.
Orbulina universa d'Orbigny, 1839
Globorotalia menardii (d'Orbigny, 1826) right-coiled.
Globorotalia crassula Cushman and Stewart, 1930
Globorotalia punctulata (d'Orbigny, 1826)

Neostratotype of the Raysor Formation of Blackwelder and Ward (1979).

Neogloboquadrina acostaensis (Blow, 1959)
Neogloboquadrina humerosa (Takayangi and Saito, 1962)
Globigerinoides obliquus Bolli, 1957
Globigerinoides ruber (d'Orbigny, 1839)
Globigerinoides quadrilobatus (d'Orbigny, 1846)
Globigerinoides saculifer (Brady, 1877)
Sphaeroidinellopsis seminulina (Schwager, 1866)
Orbulina universa d'Orbigny, 1839
Globorotalia menardii (d'Orbigny, 1826) right-coiled.

In spite of the small volume of the samples, an abundant foraminiferal fauna is present, which includes a relatively large and well-preserved planktic assemblage. Analysis of the planktic assemblage suggests that the Raysor is not lower Pliocene but is upper Pliocene. It is the equivalent of zone N20 Blow (1969) and PL 3 of Berggren *et al.* (1983). The composition of the assemblage also suggests subtropical, open marine, shallow shelf conditions.

VIII. SUMMARY

An analysis of molluscan and planktic foraminiferal assemblages from the Raysor Formation in South Carolina indicates that this unit is of late Pliocene age and is stratigraphically equivalent to the Rushmere and Morgarts Beach Members of the Yorktown Formation in Virginia and northeastern North Carolina and the Yorktown Formation (undifferentiated) of southeastern North Carolina and South Carolina. The unit is also correlative with the Jackson Bluff Formation in western Florida. Planktic foraminifers suggest correlation with Blow's (1969) Zone N20 and Berggren's (1983) Zone PL3. This assignment places the Raysor Formation in the lower part of the upper Pliocene. The formation represents a shallow, open shelf, subtropical to tropical environment where calcarenitic sediments were deposited. The Raysor is a facies equivalent of the shelly, quartzose sands of the Yorktown Formation in northeastern South Carolina and southeastern North Carolina. In those areas, the Yorktown cannot be differentiated into the Rushmere and Morgarts Beach Members as it can in northeast North Carolina and Virginia.

IX. ACKNOWLEDGMENTS

The authors wish to thank Albert E. Sanders of the Charleston Museum, Charleston, S.C., for making available Sloan's extensive mollusk collection from the Raysors Bridge locality. The authors also thank Thomas R. Waller and Warren Blow of the National Museum of Natural History for making the Sloan Raysor Museum collections available to us. We express our appreciation to L. D. Campbell (University of South Carolina, Spartenburg, South Carolina), T. R. Waller (National Museum of Natural History), R. Z. Poore and R. E. Weems (both of the U. S. Geological Survey, Reston, Virginia) for offering suggestions on the manuscript.

X. REFERENCES CITED

BERGGREN, W. A., M. P. AUBRY, N. HAMILTON, 1983, Neogene magnetobiostratigraphy of DSDP Site 516 (Rio Grande Rise, South Atlantic), *in* P. BARKER, D. JOHNSON, *et al.* (eds.): Initial reports of the Deep Sea Drilling Project, v. 72, p. 675-706.

BLACKWELDER, B. W., 1967, Invertebrate fossil collections at the Charleston Museum: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 11, no. 1, p. 5-19.

BLACKWELDER, B. W., and L. W. WARD, 1979, Stratigraphic revision of the Pliocene deposits of North and South Carolina: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 23, no. 1, p. 33-49.

BLOW, W. H., 1969, Late middle Eocene to Recent planktonic foraminiferal biostratigraphy, *in* R. BRONNIMANN and H. H. RENZ (eds.): Proceedings of the First International Conference on Planktonic Microfossils, Geneva, 1967, Volume I. Leiden, E. J. Brill, p. 199-421.

CAMPBELL, L., S. CAMPBELL, D. CALQUHOUN, and J. ERNISSE, 1975, Plio-Pleistocene faunas of the Central Carolina Coastal Plain: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 19, no. 3, p. 49-124. [Published in March, 1976]

COOKE, C. W., 1936, Geology of the Coastal Plain of South Carolina: U. S. Geol. Survey, Bull. 867, p. 1-196.

CRONIN, T. M., 1981, Rates and possible causes of neotectonic vertical crustal movements of the emerged southeastern United States Atlantic Coastal Plain: Geol. Soc. Amer., Bull., Pt. 1, v. 92, p. 812-833.

CRONIN, T. M., L. M. BYBELL, R. Z. POORE, B. W. BLACKWELDER, J. C. LIDDICOAT, and J. E. HAZEL, 1984, Age and correlation of emerged Pliocene and Pleistocene deposits, U. S. Atlantic Coastal Plain: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 47, p. 21-51.

GARDNER, J. A., and T. H. ALDRICH, 1919, Mollusca from the upper Miocene of South Carolina with descriptions of new species: Proc. Acad. Nat. Sci. Philadelphia, 1919, p. 17-53.

HAZEL, J. E., 1971, Ostracode biostratigraphy of the Yorktown Formation (upper Miocene

and lower Pliocene) of Virginia and North Carolina: U. S. Geol. Survey, Prof. Paper 704, p. 1-13.

HAZEL, J. E., 1977, Distribution of some biostratigraphically diagnostic ostracodes in the Pliocene and lower Pleistocene of Virginia and northern North Carolina: U. S. Geol. Survey, Jour. Research, v. 5, no. 3, p. 373-388.

HAZEL, J. E, 1983, Age and correlation of the Yorktown (Pliocene) and Croatan (Pliocene and Pleistocene) Formations at the Lee Creek Mine: Smithsonian Cont. Paleobiology, no. 53, p. 81-199, pls. 1-38.

MANSFIELD, W. C., 1928, New fossil mollusks from the Miocene of Virginia and North Carolina, with a brief outline of the divisions of the Chesapeake Groups: Proc. U. S. National Museum, v. 74, art. 14, p. 1-11. [issued Jan. 14, 1929]

MANSFIELD, W. C., 1935, New Miocene gastropods and scaphopods from Alaqua Creek Valley, Florida: Florida Geological Survey, Bulletin 12, p. 1-64, 5 pls.

MANSFIELD, W. C., 1944, Stratigraphy of the Miocene of Virginia and the Miocene and Pliocene of North Carolina, *in* J. A. GARDNER, 1944, Mollusca from the Miocene and lower Pliocene of Virginia and North Carolina: U. S. Geol. Survey, Prof. Paper 199-A, p. 1-18.

SLOAN, EARLE, 1908, Catalogue of the mineral localities of South Carolina: South Carolina Geological Survey, ser. IV, Bulletin no. 2, p. 1-505.

TUOMEY, M., and F. S. HOLMES, 1855, Fossils of South Carolina, no. 1. John Russell, Charleston, S.C., p. 1-8.

WARD, L. W., and B. W. BLACKWELDER, 1980, Stratigraphic revision of upper Miocene and lower Pliocene beds of the Chesapeake Group, Middle Atlantic Coastal Plain: U. S. Geol. Survey, Bull. 1482-D, p. 1-61, pl. 1-5.

XI. APPENDIX

Localty 5295. Raysors Bridge, Edisto River, Colleton County, South Carolina, Earle Sloan collector, 1909. Collection in the National Museum of Natural History.

Epitonium sp. 1 specimen
Petaloconchus sculpturata H. C. Lea 1 specimen
Kuphus fistula (H. C. Lea) 1 specimen
Turritella sp. 7 specimens
Diodora redimicula (Say) 1 specimen
Dentalium attenuatum Say 6 specimens
Cadulus thallus (Conrad) 3 specimens
Nucula taphria Dall 1 specimen
Yoldia sp. 2 specimens
Nuculana sp. new? 3 specimens
Anadara lienosa (Say) 1 specimen (pl. 1, fig. 5)
Glycymeris subovata tuomeyi Dall 1 specimen (pl. 1, fig. 4) Hazel's (1983, p. 95) ostracode sample came from this specimen
Ostrea raveneliana Tuomey and Holmes 1 specimen (pl. 1, fig. 7)
Ostrea locklini Gardner 6 specimens (pl. 1, fig. 6)
Plicatula marginata Say 1 specimen (pl. 2, fig. 8)
"*Leptopecten*" *irremotis* Olsson and Harbison 1 specimen
Amusium mortoni (Ravenel) 1 fragment
Pteria sp. 1 fragment
Pandora arenosa Conrad 2 specimens
Lucinoma contracta (Say) 1 fragment
Carditamera arata (Conrad) 1 fragment
Cyclocardia granulata (Say) 2 specimens (pl. 3, fig. 8)
Pseudochama corticosa (Conrad) 2 specimens
Echinochama arcinella (Linné) 1 fragment
Lucinisca cribrarius (Say) 53 specimens
Parvilucina multilineata (Tuomey and Holmes) 9 specimens
Callucina keenae Chavan 2 specimens
Dosinia acetabulum? (Conrad) 1 fragment - poor condition
Diplodonta sp. 1 specimen
Diplodonta yorkensis Dall 2 specimens
Aligena aequata (Conrad) 1 specimen
"*Cardium*" sp. prob. "*C.*" *acutilaqueatum* (Conrad) 1 fragment
Glossus fraterna (Say) 2 specimens
Astarte sp. 2 specimens (pl. 3, fig. 5)
Astarte floridana Dall 2 specimens
Astarte concentrica Conrad 1 specimen (pl. 3, fig. 4)
Pitar sayana (Conrad) 1 specimen
Marvacrassatella undulata (Say) 2 specimens
Lirophora sp. prob. *L. athleta* (Conrad) 3 specimens (pl. 3, fig. 6)
Tellina aequistriata (Say) 1 specimen
Tellina declivis Conrad 2 specimens
Semele subovata (Say) 2 specimens
Semele sp.? 1 specimen
Corbula sp.? 1 specimen
Varicorbula sp.? 1 specimen
Corbula inaequalis Say 11 specimens
Hiatella arctica (Linné) 1 specimen
Divaricella quadrisulcata (d'Orbigny) 3 fragments
"*Crassatella*" *gibbesii* (Tuomey and Holmes) 2 young, fragments

Locality 3991. Raysors Bridge, Edisto River, Colleton County, S.C., Sloan and Burns collectors, 1904. Collection in the National Museum of Natural History.

Turritella sp. 6 incomplete specimens (pl.

1, figs. 2, 3)
Dentalium attenuatum Say 1 specimen
Ostrea raveneliana Tuomey and Holmes 8 specimens
Anadara lienosa (Say) 1 internal mold
Marvacrassatella undulata (Say) 3 specimens
Glossus fraterna (Say) 7 specimens (pl. 3, fig. 7)
Astarte floridana Dall 1 specimen
Lirophora sp. prob. *L. athleta* (Conrad) 1 specimen
Panopea goldfussii Wagner 1 specimen

Locality 3989. Mouth of Four Hole Swamp, Edisto River, Dorchester County S.C., Burns collector, 1904. Collection in the National Museum of Natural History.

Ostrea locklini Gardner 2 specimens

Locality 366. Raysors Bridge, Edisto River, Colleton County, S.C., Earle Sloan collector, 1909. Collection in the Charleston Museum.

Diodora redimicula (Say) 1 specimen
Turritella sp. 18 specimens; similar to sp. in Rushmere Member
Petaloconchus sp. 1 incomplete specimen
Polinices duplicatus (Say) 1 specimen
Dentalium attenuatum Say 8 entire specimens, 25 fragments
Cadulus thallus (Conrad) 3 entire specimens, 6 fragments
Nucula proxima Say 2 specimens
Nuculana sp. near *N. concentrica* (Say) 15 specimens
Nuculana sp. 4 specimens
Yoldia laevis Say 5 specimens
Anadara sp. 1 specimen filled with matrix not like other specimens, probably not from Raysors Bridge, no Sloan label
Carolinapecten eboreus Conrad 1 specimen, fewer and stronger ribs than typical
Chesapecten sp., very close to *C. jeffersonius* (Say) 2 specimens (pl. 2, fig. 2)
Chesapecten septenarius (Say) 9 specimens (pl. 2, figs. 1, 3, 4)
Chesapecten madisonius (Say) 1 specimen (pl. 2, fig. 5)
Chesapecten sp. 1 specimen, immature
Amusium mortoni (Ravenel) 1 fragment
Ostrea raveneliana Tuomey and Holmes 15 specimens including adults and juveniles; matrix removed from one double-valve for foraminifers.
Ostrea locklini Gardner 1 specimen
Astarte concentrica Conrad 1 specimen
Astarte floridana Dall 2 specimens (pl. 3, fig. 3)
"*Crassatella*" *gibbesii* (Tuomey and Holmes) 2 immature specimens (pl. 3, fig. 2)
Marvacrassatella undulatus (Say) 9 specimens including adults and immature
Cyclocardia granulata (Say) 3 specimens
Pseudochama corticosa (Conrad) 3 specimens (pl. 1, figs. 8, 9)
Chama sp. 2 very young, worn
Lucinisca cribrarius (Say) 112 specimens
Parvilucina multilineatus (Tuomey and Holmes) 35 specimens
Callucina keenae Chavan 2 specimens
Phacoides sp. 2 immature specimens
Divaricella quadrisulcata (d'Orbigny) 2 specimens, 1 fragment
Glossus fraterna (Say) 3 specimens
Dosinia acetabulum? (Conrad) 1 broken, worn specimen
Pitar sayana (Conrad) 3 immature specimens
Lirophora sp. prob. *L. athleta* (Conrad) 7 specimens
Tellina declivis Conrad 2 specimens
Semele subovata (Say) 2 specimens
Semele sp. prob. *S. subovata* (Say) 2 worn specimens
Caryocorbula inaequalis (Say) 13 specimens
Kuphus fistula (H. C. Lea) 3 specimens
Pandora arenosa Conrad 1 specimen
Balanus sp. 4 fragments