NEW MOLLUSCAN FAUNAS FROM THE EOCENE OF SOUTH CAROLINA

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CONTENTS

I. ABSTRACT

Over 80 Eocene molluscan species have been identified from the Southern Aggregates Orangeburg quarry near Cross, South Carolina, doubling the total reported fauna from the Santee Limestone. Use of latex peels and casts greatly facilitated the identification of leached aragonitic species. Some supposed endemics proved to be synonymous with Gulf Coast species. About 50% of the molluscan species collected at this quarry are also found in the Cook Mountain Formation and 35% are found in the Gosport Sand. The faunule from the nearby Martin Marietta Berkeley quarry is similar. The chronological ranges of some species found at these localities differ between South Carolina and the Gulf Coast. Some distinctive endemics are present, including a new genus, *Santeevoluta* (Volutidae), as well as taxa previously known solely from the Gulf Coast or Florida.

Younger deposits are present in the Giant Portland quarry, near Harleyville, South Carolina. Taxa include the new species *Batequeus ducenticostatus* (Pectinidae). Additional material from the Martin Marietta Georgetown and Southern Aggregates Jamestown quarries, near Jamestown, South Carolina, represents a deeper water facies of the Santee Limestone.

II. INTRODUCTION

Although the Eocene marine deposits in South Carolina have been known as long as those of the Gulf Coast, they have received much less study. This is partially because of nature of the deposits. Today the type locality of the Santee Limestone at Vance's Ferry is mostly under Lake Marion (Cooke and MacNeil, 1952). Current exposures are primarily in limestone quarries and, because of mining operations, accessibility is relatively ephemeral. Erosion, diagenesis, and poor preservation all have discouraged stratigraphic work in the Atlantic Coastal Plain (Owens, 1992).

The planktic foraminifera and nannofossils of the Eocene limestones of the Carolinas remain poorly known in comparison to those of the Gulf Coastal Plain. Foraminiferal and nannofossil correlations between these regions are currently inadequate and, in some instances, even contradictory (Laws, 1992). Likewise, molluscan biostratigraphic data for the Eocene limestones of the Carolinas, Georgia, and Florida remain sparse and are commonly limited to tentative identifications. In most cases, the synchronicity between ranges of potential index species in the Gulf and Atlantic Coastal Plains remains untested. Planktic microfossils are more accurate biostratigraphic markers than are the molluscs, being uninfluenced by substrate differences and less prone to regional diachronisms. However, microfossils tend to be poorly preserved in samples from the quarries, and cores are often difficult to correlate with quarry outcrops. Thus, macrofossils must be used for biostratigraphy of these beds until microfossil and macrofossil occurrences are better correlated.

The present study aims to provide more accurate and more complete taxonomic information on the molluscan faunas of the Eocene Santee and "Cross" formations of South Carolina in order to build a foundation for future, more detailed biostratigraphic comparisons. Preliminary assessments of biostratigraphic significance are offered for certain taxa and for molluscan faunas as a whole. Although limited by time averaging and incomplete knowledge of both species composition and biofacies controls, the present faunal comparisons provide a tentative basis for regional temporal correlation.

III. PREVIOUS WORK

Various workers have examined South Carolina Eocene faunas since their discovery about 1830. Lyell (1845) generally is considered the first to have recognized the Eocene age of the "white limestone of South Carolina." Conrad (1848a, 1848b) briefly described several mollusks from the collections of a Mr. Vanuxem from the "Orangeburg District," and this region has remained important for the Eocene of South Carolina. Tuomey (1848) and Sloan (1908) discussed these strata in their works on South Carolina geology. Harris *in* Van Winkle and Harris (1919) described some Eocene bivalves from the Santee Limestone. Cooke (1936) provided brief species lists for several Eocene localities in South Carolina, and Harbison (1944) reported 20 molluscan species from the Santee Limestone.

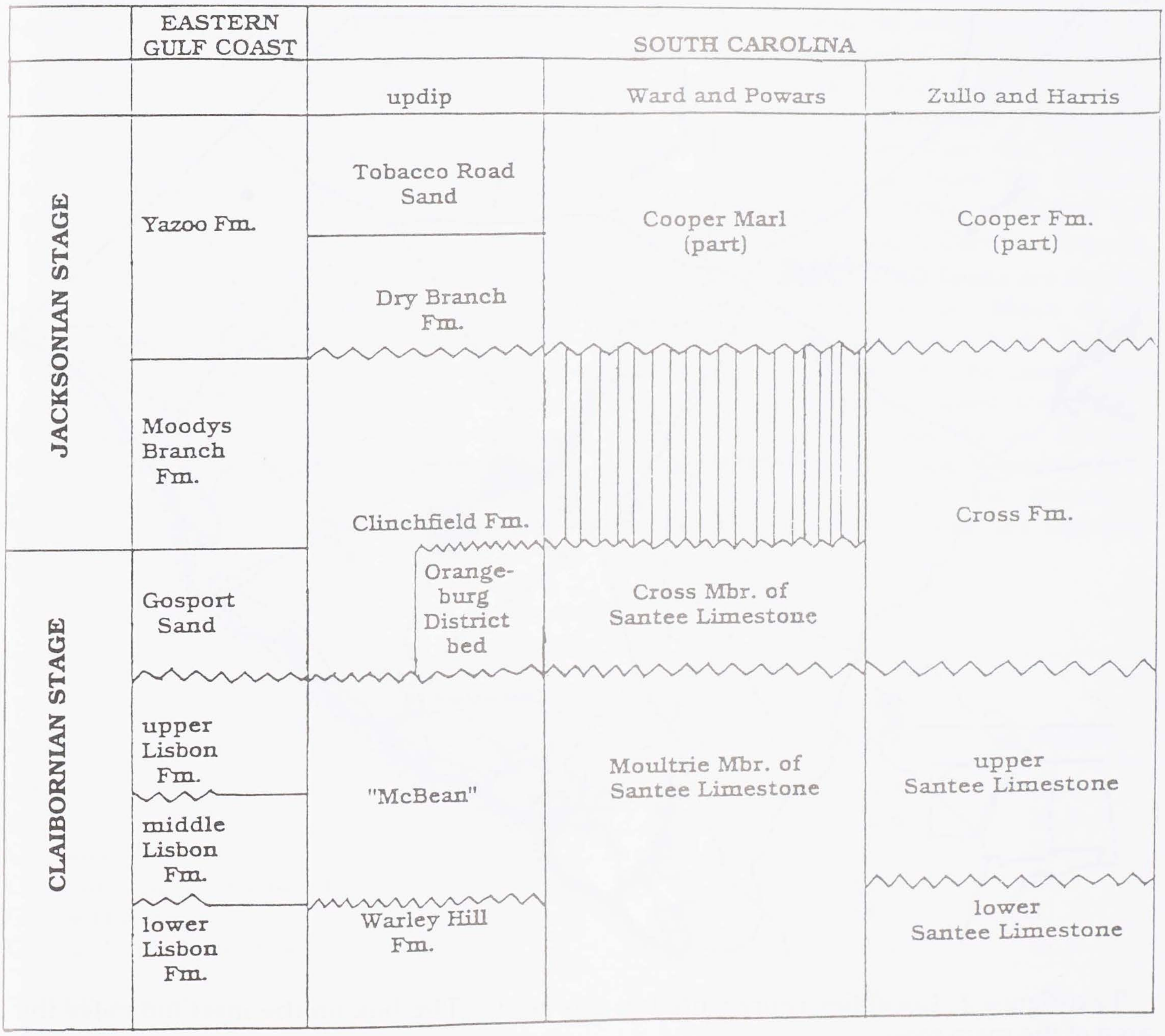
Cooke and MacNeil (1952) redefined the McBean Formation and Santee Limestone, restricting them to the *Cubitostrea sellaeformis* range zone (not a permissible method of defining lithostratigraphic units by current stratigraphic rules), redefined the Castle Hayne Limestone as a Gosport Sand equivalent, and applied the names Santee and Castle Hayne to beds in both North and South Carolina. Unlike Cooke and MacNeil, Pooser (1965) used lithologic definitions for the Eocene formations of South Carolina, in accord with modern stratigraphic rules. Palmer and Brann (1965-1966) noted 45 molluscan species recorded from the Santee Limestone.

Banks (1977) recognized several lithozones in the Santee Limestone and suggested that lower Lisbon Formation and Gosport Sand equivalent beds were present, but did not name them. A flurry of papers from 1978 to 1982 named several members and formations in the Middle Eocene to Lower Miocene of North and South Carolina (Baum, Harris, and Zullo, 1978, 1979a; Ward, Lawrence, and Blackwelder, 1978; Ward *et al.*, 1979; Baum *et al.*, 1979, 1980; Baum, 1980, 1981; Ward and Blackwelder, 1980; Powell and Baum, 1982). Although faunal lists are often supplied in these papers, they were intended for stratigraphic rather than taxonomic purposes. In the South Carolina Eocene, all of these papers use the name "Santee Limestone" for the hard, moldic Middle Eocene limestone in South Carolina. The softer, younger limestone in South Carolina, called "Castle Hayne" by Cooke and MacNeil (1952), is referred to as the Cross Member of the Santee Limestone or the Cross Formation, but this designation is not stratigraphically valid. The stratotype of the Cross Member is actually lithologically similar to the typical Santee Limestone (L.W. Ward, pers. comm.). Text-figure 1 summarizes current views of the Eocene stratigraphy of the limestones of South Carolina.

Although current workers seem to agree that the contact between the Santee Limestone and the "Cross Formation" is chronologically equivalent to the upper Lisbon Formation-Gosport Sand contact in Alabama, no consensus exists on the age of the basal Santee or youngest "Cross." Also, the confusion over definitions of stratigraphic units makes it difficult to determine how a given sample fits into any particular stratigraphic scheme. For example, because there are two slightly different uses of the name "Cross," one must establish the actual beds sampled before faunal lists from the "Cross Formation" can be interpreted. Most stratigraphic units in the region were defined in outcrop, whereas microfossils are often better preserved in cores, which must be correlated to the stratotypes. Thus, any stratigraphic chart of the Eocene of South Carolina must presently be considered tentative.

One particular difficulty in correlating these faunas has been the diachronous appearance of traditional index taxa in South Carolina and the Gulf. Dockery and Nystrom (1992a), in a study of the molluscan faunas of the upper Coastal Plain of South Carolina, noted the presence of Gosport Sand index species such as *Glyptoactis alticostata* and *Crassatella alta* in the Santee Limestone, along with the Cook Mountain Formation and upper Lisbon Formation index species *Cubitostrea sellaeformis*. They suggested that the warm current flowing through the Gulf Trough would have been an effective barrier to dispersal between the warm carbonate province of the southeastern states and the turbid clastic province of the Gulf Coast. Thus, *Glyptoactis alticostata* and *Crassatella alta* seem to have evolved in the carbonate province in the late Claibornian and invaded the clastic province only in the latest Claibornian.

In contrast to the 50 or so species reported in the literature from the Santee Limestone, this study has found over 80 molluscan species at the Southern Aggregates Orangeburg quarry alone and over 120 molluscan species from the Santee Limestone (excluding the "Cross" Member or Formation). Approximately half of the molluscan species in my collections from the Eocene of South Carolina have not been previously reported from the state. Also, some taxa previously described from



Text-figure 1. Eocene stratigraphy of South Carolina. Little consensus exists on nomenclature and correlation. Adapted from Zullo and Harris (1987, p. 197-214); Rossbach and Carter (1989, correlation chart); Ward and Powars (1991, p. 161-201); and Fallaw and Price (1992, p. B-II-1 – B-II-33). The quotation marks around "McBean" reflect doubts, raised by Fallaw and Price, about the use of this name. Also, the use of the name "Cross" is in doubt as the stratotype is part of the Santee Limestone (see text).

molds are junior synonyms, mostly of Gulf Coast species. Both the Santee and "Cross" faunas include undescribed species.

IV. LOCALITIES STUDIED

Specimens examined in this study were collected at six localities in south-central South Carolina (Text-figure 2), in Dorchester, Orangeburg, Berkeley, and Georgetown counties. The "McBean Formation" and Orangeburg District bed are updip (*i.e.*, west and slightly north) of the Santee Limestone localities. Some comparison material was obtained from "McBean Formation" deposits, including both the silicified shell-bearing Orangeburg District bed and a lower moldic limestone to calcareous marl bed, at the Dockery and Nystrom (1990, 1992a) locality N-25. The "Cross Formation" specimens are from the Giant Portland cement quarry (GP) between Holly Hill and Harleyville in Dorchester County. Santee Limestone material was obtained from the Southern Aggregates Orangeburg quarry (SAO) and the Martin Marietta Berkeley quarry (MMB), near the town of Cross, S.C.; and the Martin Marietta Georgetown quarry (MMG) and

Text-figure 2. Localities represented in this study. The box on the inset indicates the area of the main map.

A = Giant Portland Quarry
B = Southern Aggregates Orangeburg Quarry
C = Martin Marietta Berkeley Quarry
D = Martin Marietta Georgetown Quarry
E = Southern Aggregates Jamestown Quarry
F = Dockery and Nystrom locality N-25

the Southern Aggregates Jamestown quarry (SAJ), near Jamestown, S.C. All four quarries are mined for crushed stone. Specimens from the quarries were, of necessity, collected only from boulders and spoil. However, the abundance of *Cubitostrea sellaeformis* in the boulders at SAO and MMB establishes their general location in section.

The Santee Limestone is indurated and very moldic, with common glauconite. It is typically gray but may be white, often with orange iron stains. Aragonitic shells are leached, leaving well-preserved molds, whereas calcitic shells are preserved. Molds are frequently hard to identify, but liquid latex can be used to make casts that are more readily identified. Also, a mold in a large boulder may not be feasibly extracted with a chisel, and so a latex cast may be the only practical method of collecting some specimens.

The "Cross Formation" limestone is less indurated than the Santee Limestone. It also contains abundant molds and calcitic or phosphatic fossils. Unlike the Santee Limestone, it is consistently creamy white. With weathering, boulders often develop a thin, black coating. Probably because of its poor induration, the "Cross Formation" has fewer well-preserved molds than the Santee.

V. RESULTS

Due to wide variations in species diversity at each locality, percent overlap (# of species in common/# of species at the locality, essentially Simpson's Index 2 [Frederiksen, 1980]) was used to determine the best correlation. Table 1 shows the correlations for the primary localities in this study and for the Santee Limestone as a whole. Other faunas that show at least a 20% overlap with one or more of the studied South Carolina Eocene assemblages are included.

The well-collected molluscan faunas from the *Cubitostrea sellaeformis* zone of the Santee Limestone correlated best to faunas from the upper Claibornian Cook Mountain Formation. For SAO, the overlap with the Cook Mountain Formation fauna (50%) is greater than the overlap with published faunas from the Santee Limestone (maximum 27%), reflecting the poor knowledge of South Carolina faunas. The affinities of the MMB fauna are similar to those of the SAO fauna. [Much of the Gulf Coast range data come from Palmer and Brann (1965-1966). As the name "Lisbon Formation" is preoccupied, they referred records from the upper Lisbon Formation of Alabama to the Cook Mountain Formation. Therefore, the Cook Mountain and upper Lisbon formations are together in the table.]

TABLE 1
MAJOR CORRELATIONS–PERCENT OVERLAP

Locality	SAO	MMB	all Santee
SAO	100.0	95.8	98.4
MMB	38.3	100.0	39.3
Gosport Sand	40.0	33.3	39.3
Cook Mt., upper Lisbon Fms.	53.3	62.5	54.1
Castle Hayne Ls.	38.3	66.7	37.7
Orangeburg District bed	41.7	29.2	41.0
number of species	60	24	61

These figures do not include undescrbed species or taxa not yet identified to species.

All Santee = all Santee Limestone, *Cubitostrea sellaeformis* zone records from this study.

Gosport Sand, Cook Mountain Formation, and upper Lisbon Formation records from Palmer and Brann (1965, 1966) and Dockery (1980). Orangeburg District bed records from Dockery and Nystrom (1990, 1992a) and the present collections. Castle Hayne Limestone records from the present collections.

The faunas from MMG, SAJ, and GP are not adequately documented to draw firm conclusions about their overall affinities. Most species identified from MMG and SAJ are also known from SAO and MMB. However, patterns of abundance are different, with many rare or absent at the more inland localities (SAO and MMB) but common at MMG and SAJ. These species tend to be common in the Castle Hayne Limestone near Wilmington, N.C., equally distant from Eocene nearshore deposits. Probably, these species favored deeper water environments. The GP fauna seems distinct from the other South Carolina faunas. It correlates best with faunas from the lower Jacksonian Moodys Branch Formation (9 taxa identified to species, 4 also in Moodys Branch, 2 also in Gosport), but the low number of species limit the reliability of these conclusions.

The faunas of the Santee Limestone and the "Cross Formation" appear strongly influenced by the warm current flowing through the Gulf Trough (Popenoe *et al.*, 1987). In addition to producing a temperature gradient, the current would have provided a route of invasion for Tethyan taxa. The offshore carbonate environment of the Carolinas formed a distinct province from the Gulf Coast in the Eocene (B. Carter, 1987), though the clastic province of the inner Coastal Plain of South Carolina may have provided a bridge for Gulf Coast species to reach the carbonate province and vice versa.

VI. ACKNOWLEDGMENTS

I thank Wallace Fallaw for introducing me to the Eocene of South Carolina. The owners and operators of all the quarries were helpful in allowing me to collect at the various localities. David Dockery, Jerry Howe, Andrew Howard, Joseph Carter, Warren Blow, Elana Benamy, Gary Rosenberg, and Roger Portell provided access to collections. Many people have edited drafts of this paper, including David Grant, William Lammers, Victor Zullo, Lyle Campbell, Joseph Carter, David Dockery, Thomas Yancey, and Warren Allmon. David Dockery and Paul Nystrom provided information on and directions to the Orangeburg locality (N-25). Many of these individuals have also provided assistance in identification of various taxa. Joseph Carter, Thomas Rossbach, and Rebeccah Grey assisted with photography. Funds have been provided by the Southeastern Section of the Geological Society of America, the Undergraduate Science Research Program of the Merck Company Foundation, a National Science Foundation Fellowship, a Geological Society of America Research Grant, and a Martin Research Fellowship. Finally, I wish to thank my family, whose efforts in collecting, photography, editing, encouraging, and all other aspects made this study possible.

VII. SYSTEMATIC PALEONTOLOGY OF SELECTED TAXA

Over 350 species of mollusks are known from the Eocene of South Carolina, either from literature records or from my collections. Among these, this paper discusses several species that are inadequately described in literature. These include species with regional synonyms, frequently misidentified species, and forms with wider geographic or chronological ranges than previously thought. The synonymies include the original descriptions as well as references not found in Palmer and Brann (1965-1966).

A question mark in front of a species name indicates uncertainty in synonymizing the name with the species under discussion, whereas a question mark by an author's name indicates uncertainty of the validity of the record (usually species reported without figures or description). Personal observation of some collections has allowed me to assess some records such as the Sloan collections at the USNM, described by Vaughan (*in* Veatch and Stephenson, 1911); the Cooke collections at the USNM, cited in Cooke (1936) and Cooke and MacNeil (1952); the Santee-Cooper Canal collection of Richards at the ANSP described in Harbison (1944); and the Dockery and Nystrom Orangeburg area collections (cited in Dockery and Nystrom, 1990, 1992a, 1992b). Some of the Banks and Powell field collections are at the University of North Carolina-Chapel Hill. These were part of the material used to make the species lists in such works as Banks (1977), Baum (1980), Baum *et al.* (1980), Howe (1987), and Powell and Baum (1982); however, they did not indicate which specimen was the basis for which published record.

Phylum MOLLUSCA
Class BIVALVIA
Subclass PTERIOMORPHIA
Order PECTINOIDA
Superfamily PECTINOIDEA
Family PECTINIDAE
Genus CHLAMYS Röding, 1798

CHLAMYS (AEQUIPECTEN?) CACAWENSIS (Harris)

Plate 1, figure 1

Pecten cawcawensis HARRIS, 1919, Bulls. Amer. Paleontology, v. 6, p. 27, pl. 15, figs. 1-7.

Pecten (Chlamys) membranosus Morton. HARBISON, 1944, Acad. Nat. Sci. Phila., Not. Nat., no. 143, p. 3, pl. 1, fig. 5 [not *P. membranosus* Morton, 1833].

Chlamys cawcawensis (Harris). PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 81; TOULMIN, 1977, Geol. Survey Alabama, Monograph 13, p. 313, 354 [in part, not Jackson records]; ZULLO and HARRIS, 1987, Cushman Found. Foram. Research, Spec. Publ. 24, p. 207; DOCKERY and NYSTROM, 1990, Proc. Second Bald Head Island Conf. (conference version), p. 86; DOCKERY and NYSTROM, 1992a, *ibid.* (revised version), p. 95.

Not *Chlamys cawcawensis* (Harris). GLAWE, 1974, Georgia Geol. Survey Inform. Circ. 46, p. 8; TOULMIN, 1977, Geol. Survey Alabama, Monograph 13, p. 313, 354 [in part, Moodys Branch records], pl. 54, figs. 12, 13; BAUM, HARRIS, and ZULLO, 1979, *in* G.R. BAUM, W.B. HARRIS, and V.A. ZULLO (eds.), Structural and Stratigraphic Framework for the Coastal Plain of North Carolina, p. 9; BAUM *et al.*, 1979, *ibid.*, p. 89, 91; BAUM *et al.*, 1980, South Carolina Geology, v. 24, no. 1, p. 23; POWELL and BAUM, 1982, Geol. Soc. Amer., Bull., v. 93, p. 1101, 1105. See *Chlamys (Aequipecten)* n. sp.

Not *Chlamys* aff. *C. cawcawensis* (Harris). BAUM, HARRIS, and ZULLO, 1978, Southeastern Geol., v. 20, no. 1, p. 11; BAUM, HARRIS, and ZULLO, 1979, *in* G.R. BAUM, W.B. HARRIS, and V.A. ZULLO (eds.), Structural and Stratigraphic Framework for the Coastal Plain of North Carolina, p. 9; BAUM, HARRIS, and ZULLO, 1979, *ibid.*, p. 101; BAUM, 1981, Southeastern Geol., v. 22, no. 4, p. 181. See *Chlamys (Aequipecten)* n. sp.

Discussion: Baum *et al.* (1979, p. 89) listed *Chlamys cawcawensis* among "the faunal elements which have generated the greatest confusion" in the Eocene of the Carolinas. Harris (1919) obtained the syntypes of *C. cawcawensis* from the "McBean Formation" (probably not the silicified Orangeburg District Beds of Dockery and Nystrom, 1992a). However, these specimens are poorly preserved. Harris also figured a complete specimen from Alabama (1919, pl. 13, fig. 8) and suggested that it might be a variety of *C. cawcawensis*. Many later authors have used this specimen in their species concept (*e.g.*, Toulmin, 1977, whose specimens from the Moodys Branch Formation closely resemble this one). The Alabama specimen is not conspecific with the syntypes, having smooth, uniform primary ribs, whereas true *C. cawcawensis* has fine concentric sculpture on the primary ribs, which bifurcate irregularly.

The name has been widely misapplied to a younger species common at GP, as discussed below. Both species have narrow interspaces, although those of true *Chlamys cawcawensis* are wider than those of the undescribed species. My specimens of this taxon are from SAO, MMB, and a locality with silicified shell north of Orangeburg, S.C.

CHLAMYS (AEQUIPECTEN) sp.

Plate 1, figure 2

Chlamys n. sp. ZULLO and HARRIS, 1986, *in* D.A. TEXTORIS (ed.), SEPM Field Guidebook, Southeastern United States, p. 258, 261, 263, fig. 5G.

Chlamys (Aequipecten) n. sp. ZULLO and HARRIS, 1987, Cushman Found. Foram. Research, Spec. Publ. 24, p. 207, 209, 210.

Chlamys n. sp. aff. *C. deshayesii* (Lea). COOKE and MACNEIL, 1952, U.S. Geol. Survey, Prof. Paper 243-B, p. 26; POOSER, 1965, Univ. Kansas Paleont. Cont., Arthropoda, art. 8, p. 18.

Chlamys cawcawensis (Harris). BAUM, HARRIS, and ZULLO, 1979, *in* G.R. BAUM, W.B. HARRIS, and V.A. ZULLO (eds.), Structural and Stratigraphic Framework for the Coastal Plain of North Carolina, p. 9; BAUM *et al.*, 1979, *ibid.*, p. 89, 91; BAUM *et al.*, 1980, South Carolina Geology, v. 24, no. 1, p. 23; POWELL and BAUM, 1982, Geol. Soc. Amer., Bull., v. 93, p. 1101, 1105.

Chlamys aff. *C. cawcawensis* (Harris). BAUM, HARRIS, and ZULLO, 1978, Southeastern Geol., v. 20, no. 1, p. 11; BAUM, HARRIS, and ZULLO, 1979, *in* G.R. BAUM, W.B. HARRIS, and V.A. ZULLO (eds.), Structural and Stratigraphic Framework for the Coastal Plain of North Carolina, p. 9; BAUM, HARRIS, and ZULLO, 1979, *ibid.*, p. 101; BAUM, 1981, Southeastern Geol., v. 22, no. 4, p. 181.

Discussion: The "*Chlamys cawcawensis*" of the "Cross Formation" and upper Castle Hayne Limestone (New Bern or Spring Garden) is an unnamed species with wide, low, arched, regular ribs unlike the uneven, elevated, flat, bifurcating ribs of Harris's species (Zullo and Harris, 1987). The new species is moderately common at GP and is also present at various localities in North Carolina. It lacks the intercostal riblets of true *C. cawcawensis* and of the Gulf Coast taxon of Harris (1919, pl. 13, fig. 8) and Toulmin (1977, pl. 54, figs. 12, 13).

Powell and Baum (1982) cited *Chlamys cawcawensis* as an index fossil that indicates a Jacksonian age for the "Cross Formation." Baum, Harris, and Zullo (1978) recognized that the Jacksonian species were not *C. cawcawensis*, and referred to the species from the upper Castle Hayne as *Chlamys* aff. *C. cawcawensis*, but many subsequent publications missed the "aff."

CHLAMYS WAHTUBBEANA Dall
Plate 1, figures 3-7

Pecten (Chlamys) wahtubbeana DALL, 1898, Trans. Wagner Free Inst. Sci. Phila., v. 3, pt. 4, p. 736, pl. 34, fig. 9.

Pecten wahtubbeanus Dall. ?VAUGHAN *in* VEATCH and STEPHENSON, 1911, Georgia Geol. Soc., Bull. 26, p. 240 (very small juvenile).

Chlamys wautubbeana Dall. ?COOKE and MACNEIL, 1952, U.S. Geol. Survey, Prof. Paper 243-B, p. 24; ?POOSER, 1965, Univ. Kansas Paleont. Cont., Arthropoda, art. 8, p. 18; ?POWELL and BAUM, 1982, Geol. Soc. Amer., Bull., v. 93, p. 1100.

Chlamys wahtubbeana Dall. PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 88; TOULMIN, 1969, Trans. Gulf Coast Assoc. Geol. Soc., v. 19, p. 472; TOULMIN, 1977, Geol. Survey Alabama, Monograph 13, p. 245, 354, pl. 33, figs. 17, 18; DOCKERY, 1980, Mississippi Dept. Nat. Res., Bull. 122, p. 155, pl. 47, figs. 1, 2, 5; ZULLO and HARRIS, 1987, Cushman Found. Foram. Research, Spec. Publ. 24, p. 207.

Chlamys wautubbeanna [*sic*] (Dall). POWELL and BAUM, 1982, Geol. Soc. Amer., Bull., v. 93, p. 1105.

Pecten (wahtubbeanus var. ?*) Willcoxii* DALL, 1898, Trans. Wagner Free Inst. Sci. Phila., v. 3, pt. 4, p. 737, pl. 29, fig. 4.

Chlamys wahtubbeana willcoxi (Dall). PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 89.

Pecten biddleana KELLUM, 1926, U.S. Geol. Survey, Prof. Paper 143, p. 8, 11, 20, pl. 2, fig. 4; HARBISON, 1944, Acad. Nat. Sci. Phila., Not. Nat., no. 143, p. 3, pl. 1, fig. 5.

Chlamys biddleana (Kellum). PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 80.

?"*Pecten* sp. cf. *biddleana*?" Kellum. DUBAR *et al.*, 1980, *in* R.W. FREY (ed.), Excursions in Southeastern Geol., v. 1, p. 234; J. CARTER *et al.*, 1988, North Carolina Geol. Survey, Bull. 89, p. 26.

?*Chlamys membranosa* (Morton). WARD *et al.*, 1978, U.S. Geol. Survey, Bull. 1457-F, p. F9.

?*Pecten membranosus* Morton. RICHARDS, 1950, Amer. Philos. Soc., Trans., n. s., v. 40, pt. 1, p. 15, 18, fig. 63d (as *membrabosus* lapsus calami); WARD and BLACKWELDER, 1980, *in* R.W. FREY (ed.), Excursions in Southeastern Geol., v. 1, p. 202.

"*Pecten*" sp. WARD, 1985, U.S. Geol. Survey, Prof. Paper 1346, p. 49, pl. 6, fig. 3 [not figs. 1, 2].

Discussion: This species is especially common in the collections from MMB and SAO and previously has been reported from the Santee Limestone and "McBean Formation." The type locality is Wautub-

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PLATE 1

Measurements are greatest length (l), height (h), or diameter (d) of the specimen. Original dimensions of incomplete specimens were not reconstructed.

1. *Chlamys cawcawensis*, original shell, SAO; UNC 15231; 25.7 mm (h).
2. *Chlamys (Aequipecten)* sp. nov., original shell, GP; UNC 8458a; 39.2 mm (l).
3. *Chlamys wahtubbeana*, original shell, MMB; specimen lost; 23.3 mm (h).
4. *Chlamys wahtubbeana*, original shell, MMB; specimen lost; 22.7 mm (h).
5. *Chlamys wahtubbeana*, original shell, MMB; UNC 8350; 22.2 mm (w).
6. *Chlamys wahtubbeana*, original shell, MMB; UNC 8363; 27.1 mm (h).
7. *Chlamys wahtubbeana*, original shell, MMB; UNC 12267; 24.0 mm (h).
8. *Batequeus ducenticostatus*, paratype, original shell, GP; UNC 12248a; 38.7 mm (h).


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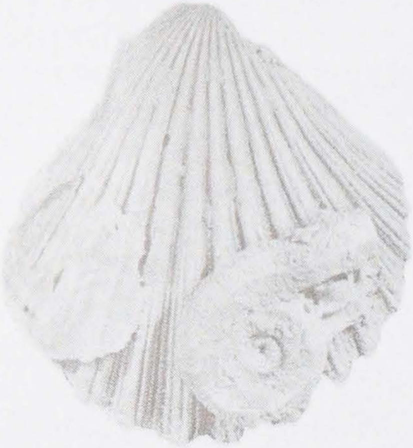
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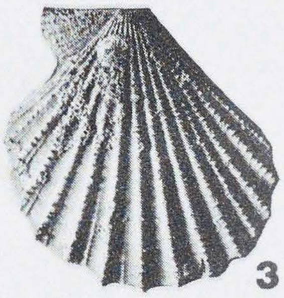
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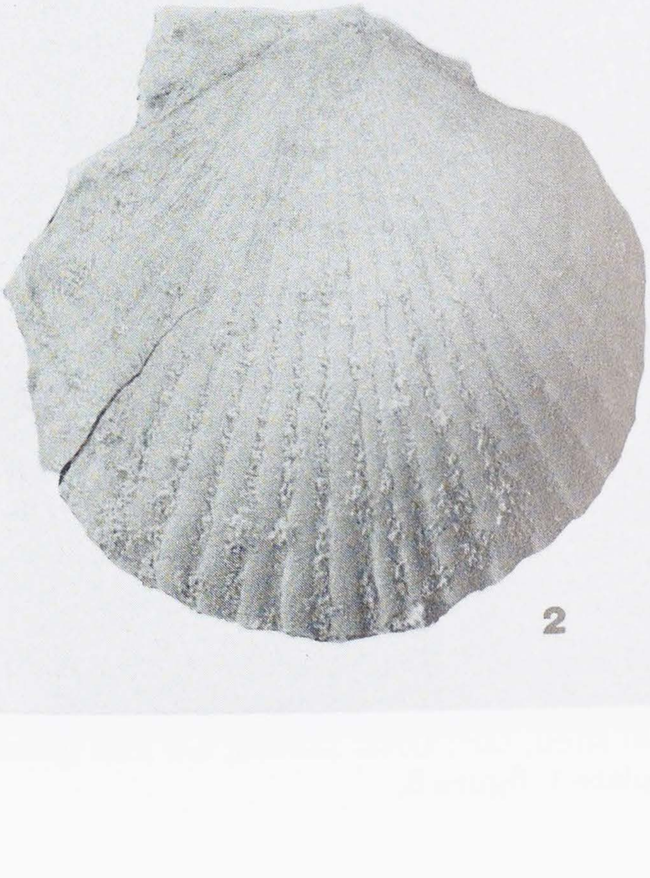
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PLATE 1

bee, Mississippi, but the original spelling of the species was with an 'h' due to the "bad orthography of the collector" according to Harris (1919, p. 21). Harris (*ibid.*) observed that "this species is extremely variable in appearance, even at the type locality." Right and left valves commonly show different sculpture, and the pattern of sculpture on a single valve may show considerable ontogenetic change.

The range of variation includes *Chlamys wahtubbeana willcoxi* (Dall, 1898) and *Chlamys biddleana* (Kellum, 1926). The type of *C. biddleana* is eroded, making it appear somewhat different from well-preserved specimens. Frequently, the ribs of *C. wahtubbeana* develop a tricarinate form, with concentric sculpture ranging from fine prickles to overlapping laminae exaggerated to the exclusion of other sculpture. Other specimens have reduced the ribs to threads.

All specimens observed in this study have about 15 ribs and are somewhat longer than wide. Various authors have reported forms with more or fewer ribs: *e.g.*, variety "*tirmus*" as used by Harris (1919) and Rowland (1936); "*Pecten*" sp. of Ward (1985, pl. 5, fig. 1); *C. gilbertharrisi* Tucker (1931) (a junior homonym; renamed *C. beverlyi* Tucker, 1934). Judging by the lack of variation in rib number seen in *C. wahtubbeana*, these probably represent distinct species.

Ward *et al.* (1978) and Ward and Blackwelder (1980) synonymized *C. wahtubbeana* with *C. membranosa* (Morton, 1833). As recognized by Cooper (1981, cited in Zullo and Harris, 1987), the latter is a distinct taxon common in the Santee and Castle Hayne Limestones. The type lot of *Chlamys membranosa* (Morton) consists of about a dozen specimens. They are all smaller, more circular in outline, and more convex than *C. wahtubbeana*, with numerous (about 40) fine, thread-like ribs. No designation of a lectotype has been found, but none are conspecific with *C. wahtubbeana*. I cannot tell which forms Ward *et al.* (1978) intended to synonymize.

Genus BATEQUEUS
Squires and Demetrion, 1990
BATEQUEUS DUCENTICOSTATUS sp. nov.
Plate 1, figure 8; Plate 2, figures 1, 2;
Plate 3, figures 1, 2

Chlamys n. sp. COOKE and MACNEIL, 1952, U.S. Geol. Survey, Prof. Paper 243-B, p. 26.

?*Chlamys cocoana* Dall. COOKE and MACNEIL, 1952, U.S. Geol. Survey, Prof. Paper 243-B, p. 26, 27; PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 82.

?*Pecten cocoanus* Dall. WARD *et al.*, 1979, South Carolina Geol. Notes, v. 23, p. 23, 32; WARD and BLACKWELDER, 1980, *in* R.W. FREY (ed.), Excursions in Southeastern Geol., v. 1, p. 196; DUBAR *et al.*, 1980, *ibid.*, v. 1, p. 236.

?*Chlamys* cf. *C. cocoana* (Dall). POWELL and BAUM, 1982, Geol. Soc. Amer., Bull., v. 93, p. 1105.

Description: Adult shell produced posteriorly, adult height slightly less than length (maximum 55 mm), juvenile taller than long. Anterior auricle with fine radial sculpture, concentric growth lines prominent near byssal notch; byssal notch shallow; dorsal margin straight or slightly concave; posterior auricle with very faint, fine radial sculpture, narrow and smaller than anterior auricle. Shell thin. Left valve sculpture of about 25 primary radial ribs, which may bifurcate; first intercalary ribs (secondary ribs) appear at about 5 to 6 mm below beak and become equal to the primary ribs in size (about 0.5 mm wide at ventral margin in adult), later intercalary ribs (tertiary ribs) remaining narrower (0.3 mm at ventral margin); almost no interspace in well-preserved areas; fine scales not aligned from rib to rib. Right valve sculpture similar; about 30 primary ribs, with a greater trend towards bifurcation than in left valve; additional intercalary ribs possible, becoming equal in width to tertiary ribs, producing a pattern of three smaller ribs between each pair of large ribs in the center of the ventral edge. Sculpture of both valves finer towards anterior and posterior margins; easily eroded to form smooth, threadlike ribs with interspaces narrower than the ribs.

Holotype: USNM 466955.

Paratypes: USNM 466956; UNC 12248a.

Type locality: Giant Portland cement quarry, north of Harleyville, South Carolina. All known specimens of this species are from this locality.

PLATE 2

1. *Batequeus ducenticostatus*, paratype, original shell, GP; UNC 12248a; 11.3 mm (auricle length). Detail of anterior auricle from specimen of plate 1, figure 8.
2. *Batequeus ducenticostatus*, paratype, original shell, GP; UNC 12248a; 5.0 mm (photo width). Detail of sculpture from specimen of plate 1, figure 8.

PLATE 2

Etymology: Adults have about 150 more ribs than any other Eocene scallop in the region; hence, "two hundred-ribbed" is a useful distinguishing feature.

Discussion: This species closely resembles *Batequeus mezquitalensis* Squires and Demetrion (1990), the type species of *Batequeus*. They are similar in size and shape, being slightly longer than high as adults. The valves in both species seem equally low-convex, but I do not have any articulated pairs of *B. ducenticostatus* for direct comparison. The byssal notch in both is small, but in *B. ducenticostatus* the anterior auricles are larger than the posterior ones, unlike *B. mezquitalensis*.

Both species have left valves with numerous very closely spaced riblets, though the scales are discontinuous and more widely spaced in *B. ducenticostatus*, as opposed to the "imbricated growth lines" of *B. mezquitalensis*. The right valve sculpture is more distinctive. Both have 25-30 primary ribs, but in *B. mezquitalensis* they are low, flat-topped, and can be grooved, unlike the fine, ungrooved, scaled riblets of *B. ducenticostatus*, which are similar to those of the left valve. Intercalary ribs are present on both valves of both species. In the largest specimens of *B. ducenticostatus*, three sets of intercalary ribs may be present, in addition to some bifurcation of primary ribs, producing a total of over 200 ribs ventrally. As noted by Squires and Demetrion (1990), *Batequeus* is assignable to the *Chlamys* group of Hertlein (1969). It seems closely related to the New Zealand genus *Serripecten*.

Batequeus ducenticostatus is distinct from all other known Eocene species from the eastern United States. The sculpture of the various forms in the type lot of *Chlamys membranosa* is finer but otherwise similar to that of *B. ducenticostatus*, but the latter attains a larger maximum size and differs greatly in shape. *Chlamys cocoana* (Dall, 1898) is similar in overall outline to *B. ducenticostatus*, but has wider, more irregular primary ribs and wider interspaces without the rapid development of intercalary ribs. Also, the type of *C. cocoana* is probably from the Oligocene (Cooke and MacNeil, 1952). Glawe (1974, pl. 2) figures what appear to be at least three species under this name, all of which have taller, wider primary ribs and less well-developed intercalary ribs than *B. ducenticostatus*. However, the form(s?) represented by his figures 1, 4, 7, and 8 are similar in shape of auricle and overall outline to *B. ducenticostatus*.

Records from the Cooper Formation of *Chlamys cocoana* (Ward *et al.*, 1979, p. 23; Ward and Blackwelder, 1980, p. 196; Cooke and MacNeil, 1952; Glawe, 1974) may represent true *C. cocoana* or *B. ducenticostatus* (in that case, the specimens probably were from the "Cross" and not the Cooper), or they may represent a new species.

Order OSTREOIDA
Superfamily PLICATULOIDEA
Family PLICATULIDAE
Genus PLICATULA Lamarck, 1801
PLICATULA FILAMENTOSA Conrad
Plate 3, figure 3

Plicatula filamentosa CONRAD, 1833, Fossil shells of the Tertiary formations of North America, v. 1, no. 3, p. 38; ?GARDNER *in* MILLER, 1912, North Carolina Geol. and Econ. Survey, Publ., v. 3, p. 188; KELLUM, 1926, U.S. Geol. Survey, Prof. Paper 143, p. 8, 11, 21, pl. 2, figs. 5, 6; ?RICHARDS, 1950, Amer. Philos. Soc., Trans., n. s., v. 40, pt. 1, p. 18; ?HARRIS, 1951, Bulls. Amer. Paleontology, v. 8, no. 138, p. 7, pl. 2, figs. 6-9; ?COOKE and MACNEIL, 1952, U.S. Geol. Survey, Prof. Paper 243-B, p. 24; PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 280; TOULMIN, 1977, Geol. Survey Alabama, Monograph 13, p. 260, pl. 40, figs. 10-11; ?BAUM, HARRIS, and ZULLO, 1979, *in* G.R. BAUM, W.B. HARRIS, and V.A. ZULLO (eds.), Structural and Stratigraphic Framework for the Coastal Plain of North Carolina, p. 108; ?BAUM *et al.*, 1980,

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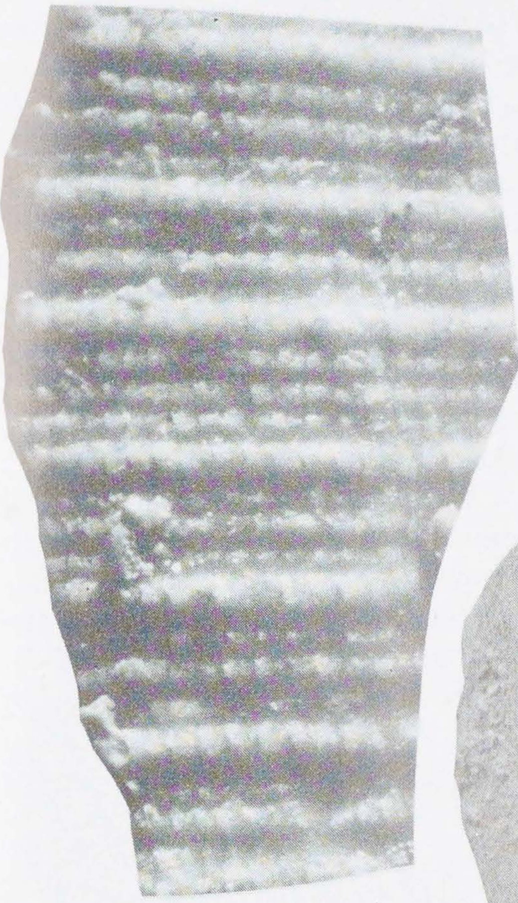
PLATE 3

1. *Batequeus ducenticostatus*, paratype, original shell, GP; UNC 12278b; 11.6 mm (photo width). Detail of right valve sculpture from the largest available specimen.
2. *Batequeus ducenticostatus*, holotype, original shell, GP; USNM 466955; 47.8 mm (l).
3. *Plicatula filamentosa*, latex cast, SAO; UNC 15444; 21.8 mm (h).
4. *Glyptoactis (Claibornicardia) alticostata*, latex cast, SAO; UNC 15449; 56.9 mm (l).



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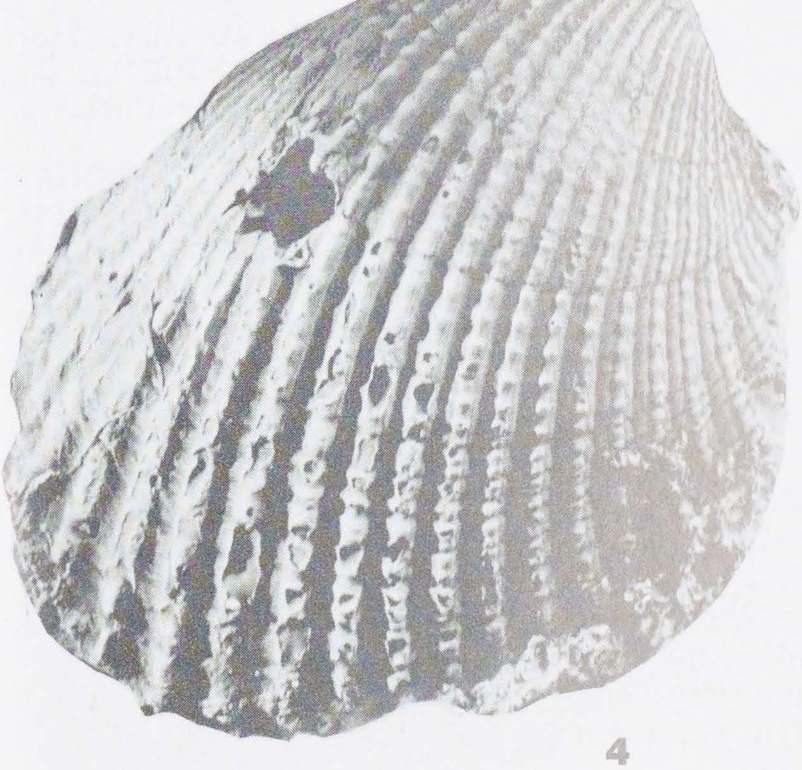

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PLATE 3

South Carolina Geology, v. 24, no. 1, p. 26; ?BAUM, 1980, Southeastern Geol., v. 21, no. 3, p. 195; DOCKERY, 1980, Mississippi Dept. Nat. Res., Bull. 122, p. 159, pl. 47, fig. 7 [as var.?]; ?POWELL and BAUM, 1982, Geol. Soc. Amer., Bull., v. 93, p. 1105; WARD, 1985, U.S. Geol. Survey, Prof. Paper 1346, p. 49, pl. 5, fig. 7.

Plicatula filementosa [*sic*] Conrad. RICHARDS, 1955b, Georgia Mineral Newsletter, v. 8, no. 4, p. 152, first pl., figs. 2, 3.

Plicatula spp. PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 281, 282 [in part?].

Plicatula gibbosa Lamarck. ?HOWE, 1987, Rocks and Minerals, July/August, p. 241 [not *P. gibbosa* Lamarck, 1801 (Recent)].

?*Plicatula* sp. aff. *P. filamentosa* Conrad. SQUIRES and DEMETRION, 1992, Contrib. Sci. Nat. Hist. Mus. Los Angeles Co., no. 434, p. 37, figs. 106, 107.

Plicatula filamentosa concentrica DALL, 1898, Trans. Wagner Free Inst. Sci. Phila., v. 3, pt. 4, p. 762; PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 281; DOCKERY, 1980, Mississippi Dept. Nat. Res., Bull. 122, p. 158, pl. 47, figs. 6, 8.

Plicatula filamentosa planata MEYER and ALDRICH, 1886, Cincinnati Soc. Nat. Hist., Jour., v. 9, no. 2, p. 45, pl. 2, fig. 20; PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 281; TOULMIN, 1977, Geol. Survey Alabama, Monograph 13, p. 260, pl. 40, fig. 12; DOCKERY, 1980, Mississippi Dept. Nat. Res., Bull. 122, p. 158, pl. 23, fig. 6, pl. 48, figs. 1-3.

Discussion: Kellum (1926) reported *Plicatula filamentosa* Conrad (1833) from the Castle Hayne Limestone. Palmer and Brann (1965) listed his record as an undescribed species, not the Claibornian *P. filamentosa*. Kellum's figured specimen and the Santee and Castle Hayne Limestone specimens in the present study are conspecific with *P. filamentosa*, most closely resembling the nominate form rather than *P. filamentosa concentrica* Dall, 1898, or *Plicatula filamentosa planata* Meyer and Aldrich, 1886. The latter two are reported to occur together (Palmer and Brann, 1965). Dall (1898) noted that *P. filamentosa concentrica* intergrades with *P. filamentosa* s.s., so these "subspecies" must be regarded as varieties.

The Early Eocene specimen from Baja California figured by Squires and Demetrion (1992) closely resembles figures of *P. filamentosa "concentrica"* in Harris (1919, pl. 12, fig. 10) and in Dockery (1980, pl. 47, figs. 6-8). Also within the range of *P. filamentosa* s.l. (as figured by Harris, 1919) are four specimens from the Ocala Group figured by Harris (1951). Two of these figures (Harris, 1951, pl. 2, figs. 6, 7) also appear in Richards (1955b, first pl., figs. 2-3). The epifaunal cemented growth form of this genus produces wide variations in shell morphology. This species is present at SAO, MMB, SAJ, and MMG.

Subclass HETEROCONCHIA
Order VENEROIDA
Superfamily CARDITOIDEA
Family CARDITIDAE
Genus GLYPTOACTIS Stewart, 1930

GLYPTOACTIS (CLAIBORNICARDIA) ALTICOSTATA (Conrad)

Plate 3, figure 4

Cardita alticostata CONRAD, 1833, Amer. Jour. Sci., 1st ser., v. 23, no. 2, p. 342; RICHARDS, 1968, Acad. Nat. Sci. Phila., Spec. Publ. 8, p. 31.

Venericardia alticostata (Conrad). ?VAUGHAN *in* VEATCH and STEPHENSON, 1911, Georgia Geol. Soc., Bull. 26, p. 240; ?RICHARDS, 1955, Georgia Mineral Newsletter, v. 8, no. 3, p. 113, 115, fig. 9; ?CHEETHAM, 1962, Micropaleontology, v. 8, no. 3, p. 323; TOULMIN, 1969, Trans. Gulf

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PLATE 4

1. *Crassatella eutawcolens*, paratype of *C. inglisia*, calcite cast, FGS loc. L-92; FGS I-7542; 24.1 mm (l).
2. *Crassatella eutawcolens*, latex cast, SAO; UNC 15441; 51.9 mm (l).
3. *Crassatella eutawcolens*, internal mold, SAO; UNC 15442; 42.7 mm (l).
4. *Crassatella texalta*, internal mold, SAO; UNC 15440; 96.4 mm (l).
5. *Crassatella alta*, internal mold, GP; UNC 15443; 107.1 mm (l).

Note: In the original figure of FGS I-7542 (Richards and Palmer, 1953, pl. 9, fig. 10), 20.3 mm and 24.1 mm are both listed as the height due to a typographical error. As it is longer than high and because length is consistently listed second, one can safely conclude that 24.1 mm is actually the length.

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PLATE 4

Coast Assoc. Geol. Soc., v. 19, p. 472, pl. 3, figs. 7, 8.

?*Venericardia* sp. aff. *V. alticostata* (Conrad). COOKE and MACNEIL, 1952, U.S. Geol. Survey, Prof. Paper 243-B, p. 24

Venericardia (Claibornicardia) alticostata (Conrad). STENZEL, KRAUSE, and TWINING, 1957, Univ. of Texas, Publ. 5704, p. 8, 104, pl. 13, figs. 1-9, pl. 14, fig. 5 (type of *Claibornicardia*); PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 321, pl. 2, figs. 10, 11; HEASLIP, 1968, Paleontographica Amer., v. 6, no. 39, p. 55 *et seq.*, pl. 26, figs. 6-11; TOULMIN, 1977, Geol. Survey Alabama, Monograph 13, p. 263, 356, pl. 41, figs. 8-10.

?*Venericardia* cf. *V. nasuta* Dall. POWELL and BAUM, 1982, Geol. Soc. Amer., Bull., v. 93, p. 1105.

Glyptoactis (Claibornicardia) alticostata (Conrad). CHAVAN, 1969, *in* R. C. MOORE (ed.), Treatise on Invertebrate Paleontology, Part N, Mollusca 6, v. 2. p. N557; NYSTROM, WILLOUGHBY, and DOCKERY, 1990, Proc. Second Bald Head Island Conf. (conference version), p. 54; DOCKERY and NYSTROM, 1990, *ibid.* (conference version), p. 82, 84, 86; NYSTROM, WILLOUGHBY, and DOCKERY, 1992, *ibid.* (revised version), p. 59; DOCKERY and NYSTROM, 1992, *ibid.* (revised version), p. 90, 92, 95.

Not *Venericardia alticostata* (Conrad). RICHARDS, 1955, Georgia Mineral Newsletter, v. 8, no. 3, p. 112.

(Additional synonyms in Heaslip, 1968)

Discussion: Glyptoactis (Claibornicardia) alticostata traditionally has been considered indicative of latest Claibornian age (correlating with the Gosport Sand). Before 1992, it was reported with adequate documentation only from the Gosport Sand (above the last regional occurrence of *Cubitostrea sellaeformis*) and from the Orangeburg District Beds of South Carolina. Its presence in these beds, along with the absence of *Cubitostrea sellaeformis*, are major reasons for the post-*C. sellaeformis* zone Gosport Sand equivalence proposed by Dockery and Nystrom (1992a, 1992b).

However, *G. alticostata* is also found in the Santee Limestone at MMB and SAO, along with *C. sellaeformis*. Both are abundant and are often found in the same boulder. Hence, at least one of these taxa had a longer chronological range in South Carolina than in the Gulf Coast. Because of the greater affinities of the Santee Limestone fauna to the *C. sellaeformis* zone beds of the Gulf Coast (upper Lisbon Formation, Cook Mountain Formation) than to the Gosport Sand, it is probably *G. alticostata* that appeared earlier in the Santee Limestone than in the Gulf, as suggested by Dockery and Nystrom (1992a, 1992b), and not a diachronous extinction of *C. sellaeformis*. *Glyptoactis alticostata* is, therefore, not a valid index species for uppermost Claibornian age in all deposits. As discussed above, Dockery and Nystrom (1992a) suggested that the boundary between carbonate and clastic environments acted as an environmental barrier to the spread of this species until the latest Claibornian. Specimens in this study came from MMB, SAO, MMG, SAJ, and Dockery and Nystrom (1992a) locality 25.

Vaughan (*in* Veatch and Stephenson, 1911) reported both *C. sellaeformis* (as *Ostrea*) and *G. alticostata* (as *Venericardia*) from the type locality of the "McBean Formation." However, the labeled specimens of both species from this collection are juveniles, which are difficult to identify. Richards (1955a) lists both species from the Wilcox Group in Georgia (middle Paleocene to lowermost Eocene), probably based on early records that lumped other taxa under these names. His report of *G. alticostata* in the Claibornian of Georgia is possible, but the figure (p. 115, fig. 9) is not clear and may be a comparison specimen from Alabama.

PLATE 5

1. *Crassatella alta*, latex cast, SAO; UNC 15456; 121.3 mm (l).
2. *Crassatella willcoxi*, holotype, internal mold and calcite cast, Wilmington, N.C.; ANSP 12463; 105 mm (l).
3. *Crassatella willcoxi*, holotype, internal mold, Wilmington, N.C.; ANSP 12463; 105 mm (l).
4. *Lirodiscus smithvillensis*, latex cast, SAO; UNC 15458; 17.5 mm (l).
5. *Chama monroensis*, latex cast, SAO; UNC 15459; 24.4 mm (d).
6. *Chama monroensis*, latex cast, SAO; UNC 15460; 37.1 mm (d).


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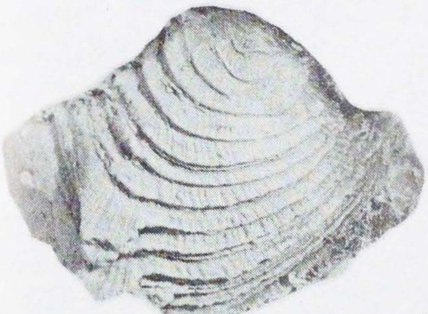
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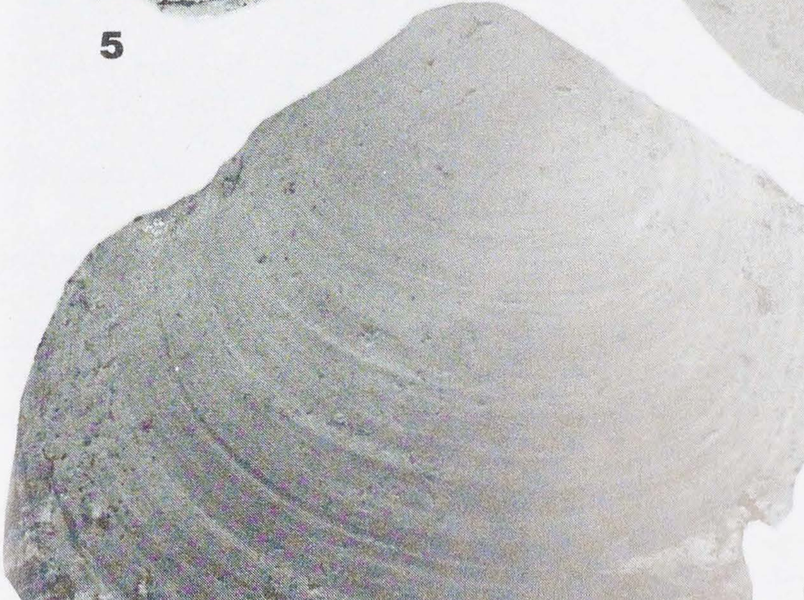
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PLATE 5

Superfamily CRASSATELLOIDEA
Family ASTARTIDAE
Genus LIRODISCUS Conrad, 1869
LIRODISCUS SMITHVILLENSIS (Harris)
Plate 5, figure 4

Astarte smithvillensis HARRIS, 1895, Acad. Nat. Sci. Phila., Proc., v. 47, p. 48, pl. 1, figs. 8, 8a, 9-9c.

Lirodiscus smithvillensis (Harris). HARRIS, 1919, Bulls. Amer. Paleontology, v. 6, p. 89, pl. 31, figs. 17-23; HARBISON, 1944, Acad. Nat. Sci. Phila., Not. Nat., no. 143, p. 4; PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 177.

Lirodiscus santeensis HARBISON, 1944, Acad. Nat. Sci. Phila., Not. Nat., no. 143, p. 4, pl. 2, fig. 3; ?COOKE and MACNEIL, 1952, U.S. Geol. Survey, Prof. Paper 243-B, p. 24; PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 177; RICHARDS, 1968, Acad. Nat. Sci. Phila., Spec. Publ. 8, p. 82.

?*Lirodiscus* sp. BAUM *et al.*, 1980, South Carolina Geology, v. 24, no. 1, p. 25; POWELL and BAUM, 1982, Geol. Soc. Amer., Bull., v. 93, p. 1105.

Lirodiscus (Lirodiscus) cf. *L. (L.) smithvillensis* (Harris). DOCKERY, 1980, Mississippi Dept. Nat. Res., Bull. 122, p. 174, pl. 50, figs. 2, 3.

Discussion: Comparison of latex casts from SAO with the original figure of *Lirodiscus santeensis* and with the original figure of *L. smithvillensis* shows that all three are conspecific. In the original description, Harris (1895) noted the variability of this species. The "larger size, the closer interspaces, the more rounded margin, and the wider diameter," cited by Harbison as distinguishing the two species, do not appear to be valid differences. Harbison's specimen is incomplete, so the roundness of the margin is indeterminate. Reconstructing the margin gives a diameter of 25 mm *versus* 17 mm for Harris's largest figured specimen. The interspaces also appear similar. Specimens in this study came from SAO.

Family CRASSATELLIDAE
Genus CRASSATELLA Lamarck, 1799
CRASSATELLA EUTAWCOLENS (Harris)
Plate 4, figures 1-3

?"*Crassatella*, agreeing with a cast from Eutaw" LYELL, 1845, Quart. Jour. Geol. Soc. London, Proc., v. 1, p. 431.

Crassatellites eutawcolens HARRIS *in* VAN WINKLE and HARRIS, 1919, Bulls. Amer. Paleontology, v. 8, p. 14, pl. 2, fig. 4.

Crassatellites species "a" KELLUM, 1926, U.S. Geol. Survey, Prof. Paper 143, p. 11, 22, pl. 3, fig. 1.

Crassatella sp. [second]. HARRIS, 1951, Bulls. Amer. Paleontology, v. 8, no. 138, p. 19 [in part], pl. 8, fig. 12; PALMER and BRANN, 1965, *ibid.*, v. 48, p. 107 [in part].

Crassatella eutawcolens (Harris). PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 100.

Crassatella inglisia RICHARDS *in* RICHARDS and PALMER, 1953, Florida Geol. Survey, Bull. 35, p. 46, pl. 9, figs. 9, 10; PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 101.

Crassatellites sp. ?BAUM *et al.*, 1980, South Carolina Geology, v. 24, no. 1, p. 25.

Crassatella aff. *C. texana* Heilprin. J. CARTER *et al.*, 1988, North Carolina Geol. Survey, Bull. 89, pl. 4, figs. 24, 25 [not *C. texana* Heilprin, 1891].

Not *Crassatellites* species "a" Kellum. HARBISON, 1944, Acad. Nat. Sci. Phila., Not. Nat., no. 143, p. 4, pl. 2, fig. 1.

"Crassatellinae" BAUM, 1980, Southeastern Geol., v. 21, no. 3, p. 195 [in part?].

Discussion: The distinctive, somewhat rectangular shape of *Crassatella eutawcolens* (Harris *in* Van Winkle and Harris, 1919) also characterizes *Crassatellites* sp. "a" of Kellum, both known only as internal molds. Harbison's (1944) *Crassatellites* sp. "a" is actually a lucine. Harris (1951, pl. 8, fig. 12) figured an internal mold of this species from the Ocala Limestone as the rhomboidal end of variation in a series of molds. In addition, molds found in this study show that this peculiar internal form has the exterior sculpture shown by *Cras-*

PLATE 6

1. *Clavilithes abruptus?*, internal mold, SAO; UNC 15470; 82.1 mm (h).
2. *Santeevoluta wilmingtonensis*, latex cast, SAO; UNC 15462; 149.5 mm (h).
3. *Hippochrenes fissura*, original shell, Calcaire Grossier, France; USNM 496700; 87.5 (h).
4. *Santeevoluta wilmingtonensis*, latex cast, SAO; UNC 15461; 34.8 mm (h) in photo, entire specimen 180.8 mm.

PLATE 6

satella inglisia Richards, 1953, which is based on calcite casts of the external form. J. Carter *et al.* (1988) figured a calcite cast of a left valve that replicates the external sculpture and much of the internal form precisely. Thus, *Crassatella eutawcolens* has been found in limestone deposits from North Carolina to Florida by several workers since Harris, but has gone largely unrecognized. This species is present at MMG, SAJ, and SAO.

The original figure of *Crassatella rhomboidea* (Conrad, 1846) suggests a broken mold of this species; however, the holotype is actually a complete internal mold of a distinct species with very low beaks.

CRASSATELLA TEXALTA Harris
Plate 4, figure 4

Crassatella texalta HARRIS, 1895, Acad. Nat. Sci. Phila., Proc., v. 47, p. 49, pl. 2, fig. 2; PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 104; TOULMIN, 1977, Geol. Survey Alabama, Monograph 13, p. 247, pl. 34, figs. 3, 4; DOCKERY, 1980, Mississippi Dept. Nat. Res., Bull. 122, p. 175, pl. 23, fig. 1, pl. 50, figs. 1, 4, pl. 51, figs. 1, 5-7.

Crassatella cf. *C. texalta* Harris. ?BAUM, HARRIS, and ZULLO, 1979, *in* G.R. BAUM, W.B. HARRIS, and V.A. ZULLO (eds.), Structural and Stratigraphic Framework for the Coastal Plain of North Carolina, p. 108; ?BAUM *et al.*, 1980, South Carolina Geology, v. 24, no. 1, p. 23, 25; ?POWELL and BAUM, 1982, Geol. Soc. Amer., Bull., v. 93, p. 1102, 1105.

Crassatellites alta (Conrad) KELLUM, 1926, U.S. Geol. Survey, Prof. Paper 143, p. 8, 11, 22 [in part?].

Discussion: Three species of very large crassatellids with roughly equal height and length are present in the Santee Limestone and "Cross Formation." *Crassatella texalta* Harris, 1895, is reported from various upper Claibornian (Cook Mountain Formation equivalent) localities. It is most easily distinguished from *Crassatella alta* Conrad, 1832 by the lack of concentric undulations in the umbonal area, which are present in *C. alta*. As noted by Harris (1919), *Crassatella willcoxi* (Brown and Pilsbry, 1912) continues this trend by having concentric undulations over the entire shell.

An external mold of *C. texalta* from the SAO quarry preserved the lack of umbonal sculpture. The lateral profiles of the three species and their pallial lines also differ. Harris (1919) further observed that *C. texalta* is more angular as an adult than is *C. alta*. The maximum known size of *C. texalta* is less than that of *C. alta*, but *C. willcoxi* reaches as large a size as *C. alta*. *Crassatella texalta* is present at SAO and MMB.

CRASSATELLA ALTA Conrad
Plate 4, figure 5; Plate 5, figure 1

Crassatella alta CONRAD, 1832, Fossil shells of the Tertiary formations of North America, v. 1, no. 2, p. 21, pl. 7; ?RICHARDS, 1950, Amer. Philos. Soc., Trans., n. s., v. 40, pt. 1, p. 18; COOKE and MACNEIL, 1952, U.S. Geol. Survey, Prof. Paper 243-B, p. 25 [in part?]; ?CHEETHAM, 1961, Jour. Paleontology, v. 35, no. 2, p. 395; PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 98; POOSER, 1965, Univ. Kansas Paleont. Cont., Arthropoda, art. 8, p. 18 [in part]; RICHARDS, 1968, Acad. Nat. Sci. Phila., Spec. Publ. 8, p. 31; TOULMIN, 1969, Trans. Gulf Coast Assoc. Geol. Soc., v. 19, p. 474, pl. 3, fig. 9; TOULMIN, 1977, Geol. Survey Alabama, Monograph 13, p. 246, pl. 34, figs. 7-9; ?BAUM, HARRIS, and ZULLO, 1979, *in* G.R. BAUM, W.B. HARRIS, and V.A. ZULLO (eds.), Structural and Stratigraphic Framework for the Coastal Plain of North Carolina, p. 11; ?BAUM *et al.*, 1979, *ibid.*, p. 89, 91; ?WARD *et al.*, 1979, South Carolina Geol. Notes, v. 23, p. 8, 12, 29, 31; ?WARD and BLACKWELDER, 1980, *in* R.W. FREY (ed.), Excursions in Southeast-

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PLATE 7

1. *Strombus alatus*, original shell, Recent, Florida; UNC 15464; 81.7 mm (h).
2. *Hystrivasum locklini*, original shell, APAC pit, Sarasota, Florida; UNC 15465; 100.5 mm (h).
3. *Scaphella trenholmi*, original shell, Pliocene, North Carolina; UNC 15466; 106.4 mm (h).
4. *Santeevoluta wilmingtonensis*, holotype, internal mold, Wilmington, N.C.; ANSP 13476; 113 mm (h).
5. *Santeevoluta wilmingtonensis, holotype*, internal mold, Wilmington, N.C.; ANSP 13476; 113 mm (h).

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PLATE 7

ern Geol., v. 1, p. 193, 202; ?DUBAR *et al.*, 1980, *ibid.*, v. 1, p. 234, 236; ?BAUM *et al.*, 1980, South Carolina Geology, v. 24, no. 1, p. 19, 23; ?HARRIS and ZULLO, 1980, Geol. Soc. Amer., Bull., v. 91, p. 589; ?POWELL and BAUM, 1982, *ibid.*, v. 93, p. 1101, 1105; ?J. CARTER *et al.*, 1988, North Carolina Geol. Survey, Bull. 89, p. 26; ?NYSTROM, WILLOUGHBY, and DOCKERY, 1990, Proc. Second Bald Head Island Conf. (conference version), p. 56; ?WARD and J. CARTER, 1992, *in* J.M. DENNISON and K.G. STEWART (eds.), Geologic Field Guides to North Carolina and Vicinity, Field Trip 8, p. 118, 123, 127; ?DOCKERY and NYSTROM, 1992, Proc. Second Bald Head Island Conf. (revised version), p. 93.

Crassatellites altus (Conrad). ?GARDNER *in* MILLER, 1912, North Carolina Geol. and Econ. Survey, Publ., v. 3, p. 188; ?CLARK, 1912, *ibid.*, v. 3, p. 316.

Crassatellites alta (Conrad). KELLUM, 1926, U.S. Geol. Survey, Prof. Paper 143, p. 8, 11, 22 [in part?]; ?RICHARDS, 1950, Amer. Philos. Soc., Trans., n. s., v. 40, pt. 1, p. 18.

Crassatella cf. *C. alta* (Conrad) ?BAUM, HARRIS, and ZULLO, 1978, Southeastern Geol., v. 20, no. 1, p. 11; ?BAUM, HARRIS, and ZULLO, 1979a, *in* G.R. BAUM, W.B. HARRIS, and V.A. ZULLO (eds.), Structural and Stratigraphic Framework for the Coastal Plain of North Carolina, p. 9; ?BAUM, HARRIS, and ZULLO, 1979, *ibid.*, p. 101; ?BAUM, 1980, Southeastern Geol., v. 21, no. 3, P. 195; ?BAUM, 1981, *ibid.*, v. 22, no. 4, p. 181.

Discussion: Crassatella alta, like *Glyptoactis alticostata*, is a traditional index species for the uppermost Claibornian that also occurs in older deposits in the Santee Limestone. Many stratigraphic works on the Santee and Castle Hayne limestones (Cooke and MacNeil, 1952; Pooser, 1965; Ward *et al.*, 1979; Baum *et al.*, 1980; Ward and Blackwelder, 1980; Powell and Baum, 1982) cite abundant *C. alta* as indicative of uppermost Claibornian age (Gosport Sand equivalent) deposits, now referred to the "Cross Formation" and the New Bern Formation or Spring Garden Member of the Castle Hayne Limestone. *Crassatella alta* was listed by Baum *et al.* (1979) as another taxon causing much biostratigraphic confusion in the Eocene of the Carolinas. In this study, *C. alta* was found in the "Cross Formation" at GP and the Santee Limestone at SAO. *Crassatella alta* and *C. texalta* are both found at SAO, and Dockery and Nystrom (1992a, 1992b) also reported *C. alta* from the Santee Limestone at MMB. The similarity of these two species makes careful identification necessary.

CRASSATELLA WILLCOXI
Brown and Pilsbry
Plate 5, figures 2, 3

Crassatellites willcoxi BROWN and PILSBRY, 1912, Acad. Nat. Sci. Phila., Proc., v. 64, p. 152, pl. 1, fig. 1; HARRIS, 1919, Bulls. Amer. Paleontology, v. 6, p. 104; RICHARDS, 1950, Amer. Philos. Soc., Trans., n. s., v. 40, pt. 1, p. 74, fig. 61a (as *wilcoxi* lapsus calami); RICHARDS, 1968, Acad. Nat. Sci. Phila., Spec. Publ. 8, p. 96.

Crassatella wilcoxi [sic] (Brown and Pilsbry). RICHARDS, 1950, Amer. Philos. Soc., Trans., n. s., v. 40, pt. 1, p. 18; PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 105.

?*Crassatellites* species "b" KELLUM, 1926, U.S. Geol. Survey, Prof. Paper 143, p. 11, 23, pl. 3, fig. 2; HARBISON, 1944, Acad. Nat. Sci. Phila., Not. Nat., no. 143, p. 4.

Crassatellites negreetensis HARRIS, 1919, Bulls. Amer. Paleontology, v. 6, p. 97 [in part?], ?pl. 33, figs. 6-8.

Crassatella negreetensis (Harris). PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 102 [in part?].

Discussion: The type of *Crassatella willcoxi* is an exceptionally good specimen for the Castle Hayne Limestone in that it preserves a complete internal mold with a partial cast of the external sculpture. *Crassatellites* species "b" of Kellum is probably the young of this species, but it could be *Crassatella texalta* or *C. alta*. In addition to

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PLATE 8

1. *Santeevoluta wilmingtonensis*, internal and external mold, SAO; UNC 15471; internal mold, 172 mm (h); external mold, 220 mm (h).
2. *Santeevoluta wilmingtonensis*, internal mold, MMB; UNC 8223; 166.1 mm (h).
3. *Santeevoluta wilmingtonensis*, composite latex casts, SAO; UNC 15454, UNC 15455. Apical portion: 110.0 mm (h), 132.1 mm (w); body whorl 119.5 mm (h).
4. *Santeevoluta wilmingtonensis*, latex cast, SAO; UNC 15463; 35.2 mm (h).

PLATE 8

its more extensive sculpture, *C. willcoxi* is more elongate as an adult than either of the other two species. *Crassatella negreetensis* (Harris, 1919) may be a junior synonym from the Gulf Coast. The specimens from Eutaw Springs, S.C., tentatively assigned to *C. negreetensis* by Harris (1919) and Palmer and Brann (1965) are probably *C. willcoxi*, even if the Gulf Coast form is validly distinct. This species is common at MMG and SAJ and rare at SAO. Its abundance at these two localities and near Wilmington, N.C., suggests that it favored deeper water than *C. texalta* or *C. alta*.

Superfamily CHAMOIDEA
Family CHAMIDAE
Genus CHAMA Linnaeus, 1758
CHAMA MONROENSIS Aldrich
Plate 5, figures 5, 6

Chama monroensis ALDRICH, 1903, Nautilus, v. 16, no. 9, p. 100, pl. 4, fig. 15; PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 79; DOCKERY, 1980, Mississippi Dept. Nat. Res., Bull. 122, p. 166, pl. 48, figs. 4, 5, 8.

Chama sp. "a" KELLUM, 1926, U.S. Geol. Survey, Prof. Paper 143, p. 11, 23, pl. 3, fig. 5; HARBISON, 1944, Acad. Nat. Sci. Phila., Not. Nat., no. 143, p. 5; PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 80; ?POWELL and BAUM, 1982, Geol. Soc. Amer., Bull., v. 93, p. 1105.

Chama richardsi HARBISON, 1944, Acad. Nat. Sci. Phila., Not. Nat., no. 143, p. 5, pl. 2, figs. 5, 6; PALMER and BRANN, 1965, Bulls. Amer. Paleontology, v. 48, p. 79; RICHARDS, 1968, Acad. Nat. Sci. Phila., Spec. Publ. 8, p. 81; POWELL and BAUM, 1982, Geol. Soc. Amer., Bull., v. 93, p. 1105.

Chama sp. BAUM *et al.*, 1980, South Carolina Geology, v. 24, no. 1, p. 25; BAUM, 1980, Southeastern Geol., v. 21, no. 3, p. 194.

Discussion: Chama richardsi is an internal mold of *Chama monroensis*, as shown by combinations of molds showing both sides of a single valve. Also, all external molds of *Chama* in the present collections from the Santee Limestone are assignable to *C. monroensis*. These external molds are similar in size to the "*C. richardsi*" internal molds. Harbison contrasted *C. richardsi* with *Chama* sp. "a" of Kellum. The posterior margin of Kellum's figured specimen is somewhat irregular, indicating that it is slightly incomplete. Harbison differentiated the two on the basis of the appearance of the posterior portion of the molds. No difference is evident between Kellum's and Harbison's specimens. This species is present at MMB and SAO.

Class GASTROPODA
Subclass PROSOBRANCHIA
Order MESOGASTROPODA
Superfamily TONNOIDEA
Family FICIDAE
Genus FICUS Röding, 1798
FICUS AFFINIS Van Winkle
Plate 9, figure 1

Ficus affinis VAN WINKLE *in* VAN WINKLE and HARRIS, 1919, Bulls. Amer. Paleontology, v. 8, p. 8, pl. 1, figs. 10, 10a; PALMER and BRANN, 1966, *ibid.*, v. 48, p. 680.

Not *Ficus* sp. PALMER and BRANN, 1966, Bulls. Amer. Paleontology, v. 48, p. 681.

Discussion: Ficus affinis was originally described from the bank of the James River, just below City Point in Virginia. It is also represented in the present collections from Dockery and Nystrom's locality 25 (silicified) and SAO. These finds are of stratigraphic significance, because they suggest that this species came from the upper Claibornian Piney Point Formation and not the upper Sabinian Nanjemoy Formation, to which Palmer and Brann (1966) referred the City Point locality. Because the Nanjemoy Formation was the main fossiliferous formation known from the Paleogene of Virginia at that time, the age assignment was reasonable. However, fossiliferous beds of the Piney Point Formation are now known to outcrop in this area (Ward, 1985), making it a likely source for this species. A previous report of *Ficus*

PLATE 9

1. *Ficus affinis*, latex cast, SAJ; UNC 15232; 18.8 mm (h).
2. *Voluticella levensis*, latex cast, SAO; UNC 15467; 23.9 mm (h).
3. *Voluticella levensis*, latex cast, SAO; UNC 15445; 47.5 mm (h).
4. *Voluticella levensis*, latex cast, SAO; UNC 15467; 23.9 mm (h).
5. *Conus smithvillensis* var., latex cast, SAO; UNC 15448; 27.6 mm (h).

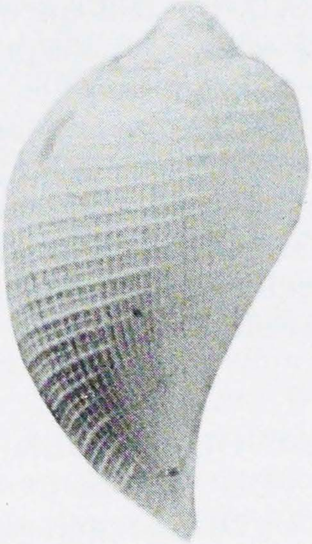

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PLATE 9

sp. from the Castle Hayne Limestone (a reassignment of *Cassis* ? sp. of Kellum, 1926) proves to be *Ficopsis penita* (Conrad, 1833).

Order NEOGASTROPODA
Superfamily BUCCINOIDEA
Family FASCIOLARIIDAE
Genus CLAVILITHES Swainson, 1840
?CLAVALITHES ABRUPTUS (Tuomey)
Plate 6, figure 1

?*Fusus abruptus* TUOMEY, 1853, Acad. Nat. Sci. Phila., Proc., v. 6, p. 193.

Fusinus abruptus (Tuomey). KELLUM, 1926, U.S. Geol. Survey, Prof. Paper 143, p. 8, 11, 29, pl. 6, fig. 1 [not fig. 6 as in PALMER and BRANN, 1966]; HARBISON, 1944, Acad. Nat. Sci. Phila., Not. Nat., no. 143, p. 6, pl. 4, fig. 1; ?RICHARDS, 1950, Amer. Philos. Soc., Trans., n. s., v. 40, pt. 1, p. 18; ?DUBAR *et al.*, 1980, *in* R.W. FREY (ed.), Excursions in Southeastern Geol., v. 1, p. 234, 236; ?POWELL and BAUM, 1982, Geol. Soc. Amer., Bull., v. 93, p. 1105; ?J. CARTER *et al.*, 1988, North Carolina Geol. Survey, Bull. 89, p. 26; ?WARD and J. CARTER, 1992, *in* J.M. DENNISON and K.G. STEWART (eds.), Geologic Field Guides to North Carolina and Vicinity, Field Trip 8, p. 123.

Fusinus sp. KELLUM, 1926, U.S. Geol. Survey, Prof. Paper 143, p. 11, 29, pl. 6, fig. 2; COOKE and MACNEIL, 1952, U.S. Geol. Survey, Prof. Paper 243-B, p. 26.

?Cf. *Clavilithes abruptus* (Tuomey). PALMER and BRANN, 1966, Bulls. Amer. Paleontology, v. 48, p. 583.

Discussion: Although Tuomey (1853) described *Fusus abruptus* rather briefly without a figure ("ovoid; whorls rounded, ventricose, the last one terminating abruptly in the canal. Dimen. Spiral angle 70°; ht. 6 in; br. 4 in."), it is frequently reported in the subsequent literature. Kellum (1926, p. 29) stated that, although the specimens he collected from the type locality suggested a smaller spire angle than Tuomey's estimate, they were fairly common and were "the only large *Fusus*-like forms" present. On these grounds, Kellum thought his species was probably what Tuomey had in mind, though he doubted that it could be definitively identified. Palmer and Brann (1966) tentatively assigned *Fusus abruptus* to *Clavilithes* and questioned other records, probably because of the inadequate original description and lack of a known type. The records after Tuomey are probably all assignable to *Clavilithes* spp. Kellum (1926) and Harbison (1944) had the same species, also present in the Banks and Powell collections and in my material from MMB and SAO, but it is uncertain if this is Tuomey's species, which is probably best regarded as a *nomen dubium*. Unfortunately, Harbison's figured specimen is probably lost. A note with the collections at the Academy of Natural Sciences at Philadelphia in Axel Olsson's handwriting states that it was removed for a temporary exhibit, which would have been about 1960.

Superfamily VOLUTOIDEA
Family VOLUTIDAE
Genus SANTEEVOLUTA gen. nov.

Description: Protoconch low for a volutid, domed, paucispiral; spire proportionally short, nodose, rapidly expanding; large (>250 mm maximum length); body whorl smooth below shoulder except for irregular growth lines, roughly conical; parietal callous present; four prominent columellar plaits; lip broad, flaring, recurved.

Type species: Vasum wilmingtonense Brown and Pilsbry, 1912.

Stratigraphic distribution: Castle Hayne Limestone, Santee Limestone.

Etymology: From the Santee Limestone, so that the genus and species names together give the known range of this taxon.

Discussion: Santeevoluta wilmingtonensis, the type species, was originally described as a *Vasum* (Brown and Pilsbry, 1912). Palmer and Brann (1966) questioned the generic assignment, and Vokes (1966) recognized that it was not a *Vasum* but rather a volutid. Lacking a suitable genus, she suggested that it was "a large *Fusimitra*" (Vokes, p. 5), now considered a subgenus of *Mitra* (Dockery, 1980). Species of *Fusimitra*, including the type [*M. (Fusimitra) millingtoni*], are proportionally much narrower than *S. wilmingtonensis*, and have a spire approximately equal in length to the body whorl, whereas the latter has a spire only about one-fourth as long as the body whorl and reaches a much greater size than any known *Fusimitra* (25 *versus* 15 cm).

The shell is too thin and the columellar folds are too strong for a *Vasum* or an *Eovasum*. The flaring lip has no parallel in the Vasidae. *Vasum haitense* (Sowerby, 1850), cited in the original description, has a broad shoulder not found in *Santeevoluta* and is, thus, proportionally broader. It also shows greater development of sculpture than *Santeevoluta*. *Eovasum* is smaller than *Santeevoluta*, with a row of nodes on the lower body whorl. Species of various strombid genera, including *Strombus* Linnaeus (1758), *Hippochrenes* Montfort (1810) (see plate 6, figure 3), and *Wateletia* Cossmann (1889), may possess a large, flaring lip somewhat similar to this species. The latter two genera, from the Paleogene of Europe, have elongated anterior canals and proportionally taller spires, over half as long as the body whorl (including canal), unlike *Santeevoluta*. *Wateletia geoffroyi* (Watelet, 1855) (the type species) also differs from *Santeevoluta* in having an apical flange extending from the flaring lip parallel to the spire and in having greater development of the parietal callus, which covers the entire apertural side. *Hippochrenes macroptera* (Lamarck, 1803), on the other hand, seems to lack any appreciable callus. Also, these strombid genera lack strong columellar folds. *Strombus*, like *Vasum*, has a much thicker shell as an adult than does *Santeevoluta*.

Broken specimens and molds of juveniles reveal that the early whorls resemble the volutid *Caricella*, the type species of which (*C. pyruloides*) is present in the Santee Limestone. The unusual shape of the body and extremely large size of *Santeevoluta* distinguish it, however. Plate 7 compares the holotype of *S. wilmingtonensis* with a strombid, a vasid, and a volutid. External molds reveal the presence of a large, recurved, flaring lip not found in any other volutid. Two Cenozoic Australian volutids, *Livonia hannafordi* (McCoy, 1866) and *Ericusa macroptera* (McCoy, 1866) have some development of the lip (Darragh, 1988), though not to the extent found in *Santeevoluta*. The protoconch of *Santeevoluta* is lower and more dome-shaped than that of *Ericusa* and quite unlike the globose, offset protoconch of *Livonia*. The whorl shape is also different from these genera, being more straight-sided in *Santeevoluta*. The spire of *Santeevoluta* is proportionally shorter than in these two genera.

Several genera of volutids (notably the bailers, *Melo* and *Cymbium*) have large apertures, but no other recorded volutid has the extreme development of a recurved, flaring lip shown by the external molds. The domed protoconch resembles that of *Caricella* but is more paucispiral. This unique combination of traits leads me to propose the new genus *Santeevoluta* with "*Vasum*" *wilmingtonense* as the type species.

SANTEEVOLUTA WILMINGTONENSIS
(Brown and Pilsbry)
Plate 6, figures 2, 4; Plate 7, figures 4, 5;
Plate 8, figures 1-4

Vasum wilmingtonense BROWN and PILSBRY, 1912, Acad. Nat. Sci. Phila., Proc., v. 64, p. 152, pl. 1, figs. 2, 3; KELLUM, 1926, U.S. Geol. Survey, Prof. Paper 143, p. 7, 8, 11, 30; PALMER and BRANN, 1966, Bulls. Amer. Paleontology, v. 48, p. 1013; VOKES, 1966, Tulane Stud. Geol., v. 5, no. 1, p. 5; RICHARDS, 1968, Acad. Nat. Sci. Phila., Spec. Publ. 8, p. 205.

Strombus sp. ?LYELL, 1845, Quart. Jour. Geol. Soc. London, Proc., v. 1, p. 431; ?GARDNER *in* MILLER, 1912, North Carolina Geol. and Econ. Survey, Publ., v. 3, p. 188; BANKS, 1977, South Carolina Geol. Notes, v. 21, no. 3, p. 142 [in part?]; ?BAUM, HARRIS, and ZULLO, 1979, *in* G.R. BAUM, W.B. HARRIS, and V.A. ZULLO (eds.), Structural and Stratigraphic Framework for the Coastal Plain of North Carolina, p. 108; BAUM *et al.*, 1980, South Carolina Geology, v. 24, no. 1, p. 25 [in part?]; BAUM, 1980, Southeastern Geol., v. 21, no. 3, p. 194 [in part?]; ?DUBAR *et al.*, 1980, *in* R.W. FREY (ed.), Excursions in Southeastern Geol., v. 1, p. 236; POWELL and BAUM, 1982, Geol. Soc. Amer., Bull., v. 93, p. 1106 [in part?]; HOWE, 1987, Rocks and Minerals, July/August, p. 241 [in part?].

?*Scaphella (Eucymba) ocalana* Dall. KELLUM, 1926, U.S. Geol. Survey, Prof. Paper 143, p. 8, 11, 31; [not *Eucymba ocalana* Dall, 1890, nor "*Eucymba ocalana*" of authors = *Eucymba* sp. of Palmer and Brann, 1966].

Volute species [not *Strombus*]. DOCKERY and NYSTROM, 1992, Proc. Second Bald Head Island Conf. (revised version), p. 93.

Discussion: Brown and Pilsbry (1912) described this unusual species from a large, incomplete internal mold from the Castle Hayne Limestone:

> "This form is represented by an internal cast wanting the apical whorls, apparently derived from a species shaped like *V. haitense*. The conic spire diverges at an angle of about 80°, the crown of each whorl being narrowly rounded. The last whorl is much less convex above, being somewhat flattened and sloping to the rounded shoulder. The periphery, viewed from above, is polygonal; the last three angles on the last half whorl are prominent, but several on the first half are barely

perceptible. Below the shoulder the sides taper to the narrow base, are a little swollen midway and contracted below the shoulder and near the base. Four deep furrows indicate as many stout columellar folds in the shell, the lowest one being somewhat smaller. The length of the cast is 113 mm and the greatest diameter 66 mm."

Kellum (1926) noted that the USNM collections contain many molds of this species and correctly assigned it to the Castle Hayne, which Brown and Pilsbry had questioned. Dockery and Nystrom (1992a) recognized that many records of *Strombus* sp. in faunal lists from the Santee Limestone actually represented a "large volute...common in the Martin Marietta Quarry" that "superficially resembles a large *Strombus*." Several specimens have been found in this study, including internal and external molds which, in combination, show the entire shell.

Santeevoluta wilmingtonensis is, as Dockery and Nystrom (1992a) presumed, chiefly responsible for the reports of *Strombus* sp. from the Santee and Castle Hayne Limestones. Specimens of *Santeevoluta* in the Powell collections at the University of North Carolina at Chapel Hill are labeled *Strombus* sp.; however, so are a few other taxa. *Santeevoluta wilmingtonensis* is present at SAO, MMB, and MMG as well as at various North Carolina quarries.

Kellum (1926) tentatively assigned an internal mold of a juvenile volutid less than 1 cm long to *Eucymba ocalana* Dall, 1890. The identity of *E. ocalana* is confused (Palmer and Brann, 1966). Kellum's specimen may be a very young *Santeevoluta wilmingtonensis*.

Genus VOLUTICELLA Palmer *in* Richards and Palmer, 1953

VOLUTICELLA LEVENSIS Palmer

Plate 9, figures 2-4

Voluticella levensis PALMER *in* RICHARDS and PALMER, 1953, Florida Geol. Survey, Bull. 35, p. 11, 37, pl. 5, figs. 4-8; PALMER and BRANN, 1966, Bulls. Amer. Paleontology, v. 48, p. 1017.

Discussion: With its pyriform shape and low spire, *Voluticella levensis* superficially resembles *Ficus*, but the sculpture of the former consists of perpendicular grooves instead of threads. Also, the multiple columellar folds show it to be a volutid rather than a ficid. All specimens from South Carolina are from SAO.

The presence of this supposed Ocala Limestone endemic in the Santee Limestone extends its stratigraphic range from the "Inglis Formation" (lower Ocala Limestone in current Florida usage) into the upper Claibornian of South Carolina. Although it is known only from the southeastern United States, Nicol (1991) considered *Voluticella* to have Tethyan affinities. Its presence in the Santee Limestone, along with other taxa of Tethyan affinities [such as *Nayadina (Exputens)* sp. and *Lyrischapa* sp.] suggests that the warm current flowing through the Gulf Trough provided a pathway for warm-water taxa to reach this region.

Superfamily CONOIDEA

Family CONIDAE

Genus CONUS Linnaeus, 1758

CONUS (LITHOCONUS) SMITHVILLENSIS var. Dockery

Plate 9, figure 5

?*Conus gyratus* MORTON, 1833, Amer. Jour. Sci., 1st ser., v. 24, p. 131, pl. 10, fig. 13; PALMER, 1937, Bulls. Amer. Paleontology, v. 7, no. 32, p. 465; PALMER and BRANN, 1965, *ibid.*, v. 48, p. 596; RICHARDS, 1968, Acad. Nat. Sci. Phila., Spec. Publ. 8, p. 140.

?*Conus* sp. BAUM *et al.*, 1980, South Carolina Geology, v. 24, no. 1, p. 25; POWELL and BAUM, 1982, Geol. Soc. Amer., Bull., v. 93, p. 1105.

Conus (Lithoconus) smithvillensis Harris var. DOCKERY, 1980, Mississippi Dept. Nat. Res., Bull. 122, p. 137, pl. 43, fig. 8.

Discussion: The most common *Conus* in the Santee Limestone has a nodose shoulder and a taller, more tabulate spire than the widespread *Conus (Lithoconus) sauridens* Conrad, 1833. It closely resembles the *C. (L.) smithvillensis* Harris var. of Dockery (1980), both differing from true *C. (L.) smithvillensis* in lacking the extremely tall spire as shown by Palmer's (1937) figured specimen and Harris's (1895) original figure. Further study may provide enough material to determine whether this variety intergrades with typical *C. smithvillensis*.

Harbison's description of *Conus cormacki* as having a nodose shoulder whorl suggests this species; however, it is actually a broken volutid. *Conus gyratus* Morton, 1833, based on an internal mold, closely resembles internal molds of *C.*

smithvillensis var. Because the holotype of *C. gyratus* was collected in South Carolina, it is probably a synonym of *C. smithvillensis* var. However, internal molds of many species of *Conus* do not seem distinctive. *Conus smithvillensis* var. is present at SAO and MMB.

VIII. SUMMARY

The *Cubitostrea sellaeformis*-zone Santee Limestone faunas of South Carolina appear, on the basis of their molluscan faunas, to be upper Claibornian, coeval with the Cook Mountain Formation of Texas, Louisiana, and Mississippi, the upper Lisbon Formation of Alabama, much of the Castle Hayne Limestone in North Carolina, and the Piney Point Formation of Virginia. The "Cross Formation" at the Giant Portland quarry probably includes both Gosport Sand and Moodys Branch Formation equivalent beds, but is inadequately documented.

Further study of the Eocene deposits of the Atlantic Coastal Plain is needed before reliable regional biostratigraphic markers can be identified. In particular, better understanding of macrofossil evolutionary lineages and more extensive microfossil data will provide improved correlations for the region.

IX. LITERATURE CITED

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X. APPENDIX: PRELIMINARY LIST OF MOLLUSCA FROM THE SANTEE LIMESTONE AND "CROSS" FORMATION

For locality information see Text-fig. 2. GP = Giant Portland Quarry; SAO = Southern Aggregates Orangeburg Quarry; MMB = Martin Marietta Berkeley Quarry; MMG = Martin Marietta Georgetown Quarry; SAJ = Southern Aggregates Jamestown Quarry.

Nucula sp	SAO
Nuculana trumani	SAO
Arcoperna sp.	SAO
Modiolus cawcawensis	SAO, MMG
Lithophaga sp. cf. *L. clairbornensis*	SAO
Barbatia (Plagiarca) rhomboidella	SAO
Barbatia sp.	SAO, MMB, MMG, SAJ
Pachecoa sp.	SAO
Glycymeris sp.	SAO
Glycymeris staminea	SAO, GP
Lima sp.	SAO, SAJ
Eburneopecten calvatus	SAO, MMB
Chlamys burlesonensis	SAO, MMB
Chlamys cawcawensis	SAO
Chlamys membranosa s.l.	SAO, MMB
Chlamys wahtubbeana s.l.	SAO, MMB
Chlamys (Aequipecten) sp.	GP
Chlamys spp.	MMG, SAJ, GP
Batequeus ducenticostatus	GP
Spondylus lamellacea	SAO, MMB
Pteria sp. indet.	SAO
Atrina sp.	SAO, MMG?
Nayadina (Exputens) sp.	MMG
Lopha ["Alectryonia"] ludoviciana	SAO, MMB
Cubitostrea sellaeformis	SAO, MMB
Pycnodonte trigonalis	GP
Pycnodonte sp.	SAJ
Plicatula filamentosa	SAO, MMB, MMG, SAJ
Diplodonta ungulina	SAO
Eophysema sp.	GP
Chama monroensis	SAO, MMB
Venericardia (Venericor) claiboplata	SAO, MMB
Venericardia (Rotundicardia) eutawcolens	SAO
Venericardia (Rotundicardia) rotunda	SAO
Glyptoactis (Claibornicardia) alticostata	SAO, MMB, MMG, SAJ
Glyptoactis (Claibornicardia) complexicosta	SAO, MMB
Pleuromeris parva	SAO
Lirodiscus smithvillensis	SAO
Lirodiscus (Crustuloides) sp.	SAO, MMG
Crassatella willcoxi	SAO, MMG, SAJ
Crassatella eutawcolens	SAO, MMG, SAJ?
Crassatella texalta	SAO, MMB
Crassatella alta	SAO, GP
Crassatella sp.	SAO
Agnocardia claibornensis	SAO
Spisula (Symmorphomactra) praetenuis	SAO
S. (Symmorphomactra) praetenuis australina	SAO
Spisula decisa palmaris	SAO
Gari eborea	SAO
Semele australina	SAO
Semele linosa	SAO, MMB
Eosolen sp.	SAO
Meiocardia carolinae	SAO, MMB
Callista aequora	SAO

Callista perovata	SAO
Callista perovata lisbonensis	SAO, GP?
Pitar poulsoni	SAO
Corbula (Caryocorbula) densata	GP
Caestocorbula wailesiana	GP
Gastrochaena sp.	MMB
Pholadomya harrisi	MMB
Pholadomya spp.	SAO, SAJ
Diodora tenebrosa antica	SAO
Puncturella (Altrix) altior	SAO, MMB
Turritella arenicola	SAO, GP
Turritella ghigna	SAO, MMB
Mesalia claibornensis	SAO
Mesalia sp.	MMG
Serpulorbis squamulosus	SAO
Cheilea sp.	SAO, MMB, MMG, SAJ
Calyptraea aperta	SAO
Cypraeorbis alabamensis	SAO
Xenophora sp.	SAO
"*Natica*" sp.	SAO, MMB
cf. *Sconsia* sp.	GP
Distorsio septemdentata	SAO
Ficus affinis	SAO, SAJ
Ficopsis penita	SAO, MMB
Ficopsis texana	SAO
Cirsotrema sp. cf. *C.(Coroniscala) spillmani*	MMB
Scalina sp.	GP
Pseudoliva vetusta	SAO
"*Clavilithes abruptus*" of Kellum, 1926	SAO, MMB
Clavilithes sp.	MMB
Mitra (Fusimitra) sp.	SAJ
Agaronia alabamensis	SAO, MMB
Voluticella levensis	SAO
Athleta? cormacki?	SAO
Caricella pyruloides	SAO
Caricella spp.	SAO
Santeevoluta wilmingtonensis	SAO, MMB, MMG
Lyrischapa sp.	MMG
Conus smithvillensis var.	SAO
"*Dentalium*" sp.	SAO
Eutrephoceras carolinense	SAO, MMB,MMG, SAJ
Aturia (Brazaturia) sp. cf. *A. laticlavia*	SAO
Aturia spp.	MMG, GP

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