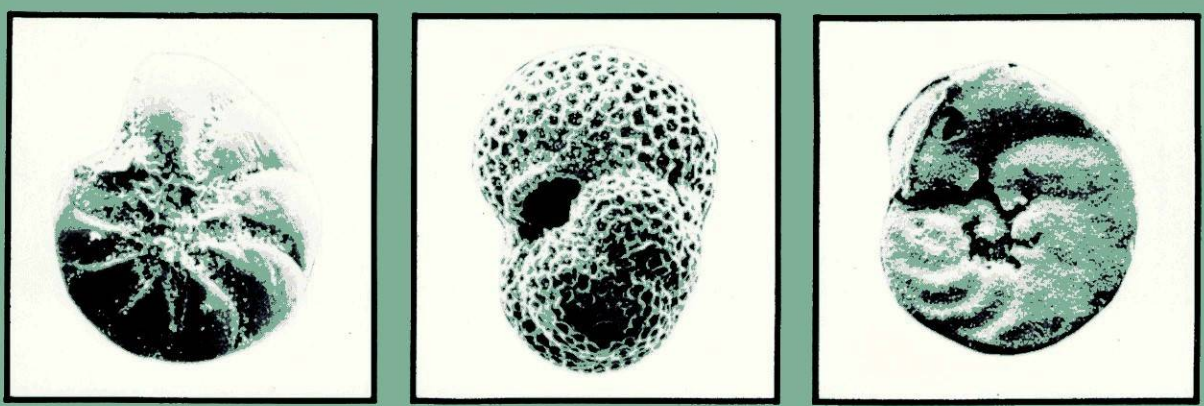
FORAMINIFERAL BIOSTRATIGRAPHY AND DEPOSITIONAL HISTORY OF THE MIDDLE EOCENE ROCKS OF THE COASTAL PLAIN OF NORTH CAROLINA

by

Garry D. Jones



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Foraminiferal Biostratigraphy and Depositional History of the Middle Eocene Rocks of the Coastal Plain of North Carolina

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ABSTRACT

Foraminifera identified from surface and shallow subsurface samples of the Coastal Plain of North Carolina indicate that the middle Eocene section is bounded above and below by unconformities; the section is underlain by Paleocene and older rocks and overlain by Oligocene and younger rocks. Contrary to earlier reports, upper Eocene rocks are not present in the study area. Planktic foraminifera indicate the middle Eocene section was deposited during the time represented by the *Morozovella lehneri* (P12) and *Orbulinoides beckmanni* (P13) Zones, 45-42 Ma. Four carbonate lithofacies comprise the middle Eocene section: (1) phosphate pebble lithocalcirudite (2) bryozoan-echinoid biocalcirudite (3) fine to coarse calcarenite (4) sandy, molluscan-mold biocalcirudite. The four lithofacies are approximately age-equivalent and seemingly interfinger; however, more microfossil data from cores are needed to accurately determine their specific temporal and spatial relationships.

Samples of the middle Eocene section are interpreted to belong to benthic foraminiferal biofacies representing inner shelf (0-15 meters water depth), middle shelf (15-50 meters), and outer shelf (50-100 meters) carbonate depositional environments. During middle Eocene time, these depositional environments comprised broad bands that paralleled the present-day shoreline which trends NE-SW. Perpendicular to this regional trend, a narrow band of inner shelf environments formed in Jones and Craven counties. These inner through outer shelf environments are correlated with the standard carbonate facies belts of Wilson (1975).

A structural model invoking differential movement of crustal blocks explains the spatial distribution of carbonate lithofacies comprising the middle Eocene section.

INTRODUCTION

It is difficult to correlate rocks of the Coastal Plain of North Carolina on the basis of their physical characteristics because of the paucity of outcrops and the abrupt facies changes they display. Because of these difficulties, there has been a tendency, historically, for reliance on biostratigraphic correlation. Most biostratigraphic correlations have involved comparison of benthic megafossils, particularly mollusks and bryozoans, with those of the standard Eocene Gulf Coast Stages: Wilcox (lower Eocene), Claiborne (middle Eocene), and Jackson (upper Eocene). The benthic fossils from Eocene rocks of the Coastal Plain of North Carolina have been studied for over 130 years yet the precise geologic ages and stratigraphic relationships of the lithofacies containing these fossils are still equivocal (e.g., Baum and others, 1978 vs. Ward and others, 1978).

Since the mid-1950's, fossil planktic organisms, particularly foraminifera and calcareous nannoplankton, have gained nearly universal acceptance as indices for dating Cenozoic rocks on an essentially worldwide basis. The underlying assumption of planktic biostratigraphy is that these types of fossils, because of their life mode, are a more reliable criterion for determining similar age than benthic fossils, which reflect identity of environment as much as identity of age. The application of planktic foraminiferal zonation to marine rocks (e.g., Loeblich and Tappan, 1957; Berggren, 1971; Mancini, 1979; Ingle, 1980) has shown that rock units were often miscorrelated in previous studies that relied on benthic fossils for biostratigraphic control.

Purpose and Scope

This study is a biostratigraphical analysis of the foraminifera contained in the middle Eocene rocks of the Coastal Plain of North Carolina. The boundaries of the middle Eocene section are delineated and correlated, from outcrop to shallow subsurface, solely on the basis of the foraminiferal content of the rocks. This study will -

1. demonstrate that the planktic foraminifera identified from the middle Eocene section correlate precisely with a worldwide zonation and that this age determination agrees well with determi-

nations based on other microfossil disciplines; and resolve the existing confusion surrounding the precise age of outcropping Eocene rocks in North Carolina.

2. propose a spatial and temporal depositional framework for the carbonate lithofacies comprising the middle Eocene section.

3. using statistical analysis of the foraminifera, characterize the bathymetry of the seafloor of North Carolina during deposition of the middle Eocene section.

4. propose a structural model invoking differential movement of crustal blocks to explain the thickness and distribution trends of middle Eocene carbonate lithofacies.

Study Area

Outcrop and near-surface deposits of middle Eocene rocks that are the focus of this study are located in two general areas (Fig. 1):

1. A linear belt that trends NE-SW. This belt is about 150 km (93 mi) long and averages about 25 km (15 mi) wide. Lower Eocene rocks are present in the subsurface eastward of this belt (Brown and others, 1972) but are not part of this study.

2. Scattered outliers that lie westward of the outcrop belt. Exact dimensions of outliers are only approximately known. Outliers are separated from the outcrop belt by pre-Eocene rocks (excluding late Cenozoic surficial deposits).

Previous Work

Charles Lyell, author of the term Eocene, first recognized rocks of that age in North Carolina and published descriptions of mollusks from Eocene limestones near Wilmington (Lyell, 1842, 1846). Since that time, numerous paleontologic-stratigraphic studies of Eocene age rocks in North Carolina have been conducted. Those undertaken during the latter half of the 19th century are summarized by Ward (1977).

The more important stratigraphic conclusions reached by various 20th century investigators of the State's Eocene age rocks are summarized in Fig. 2 (see also Ward, 1977, and Jones, 1982b). Since 1910, and as shown on Fig. 2, these rocks have been interpreted to occur in a wide variety of stratigraphic relationships and diverse names and ages have been applied to them. Furthermore, inspection of the literature suggests that many authors confused principles of rock correlation with those of time-stratigraphic correlation, and vice versa.

Depositional, environmental, and structural interpretations involving Eocene age rocks recognized in outcrop in North Carolina have been hampered in the past by the lack of precise age-dating of the rock mass itself as well as of its component parts.

Methods of Investigation

Samples analyzed for foraminifera are from three sources (Fig. 1 and sample register-appendix):

1. About 75 samples, each weighing several hundred grams, were collected from various outcrops along stream banks, in sinkholes, and in man-made exposures including roadcuts and quarries.

2. Samples spaced at 0.5 to 1.0 foot intervals were collected from thirteen cores provided by the USGS Water Resources Division, Raleigh, N.C.

3. Samples (cuttings) spaced at 10-foot intervals were collected from 12 wells also provided by the USGS.

The upper boundary of the middle Eocene section was determined by the highest occurrence of diagnostic middle Eocene planktic foraminifera identified in the core and well samples of this study. Mixed assemblages of Eocene and reworked (older) or downworked (younger) species were not a significant problem.

The lower boundary of the middle Eocene section was recognized in two ways:

1. Lack of benthic genera whose evolutionary appearance occurred during the Eocene, e.g., *Uvigerina, Cancris, Eponides,* and *Cassidulina* (Loeblich and Tappan, 1964).

2. Presence of Paleocene planktic foraminifera, e.g., *Morozovella aequa* (Cushman and Renz), *Planorotalites pseudomenardii* (Bolli) and *Subbotina triloculinoides* (Plummer), or the presence of Upper Cretaceous genera, e.g., *Heterohelix, Globotruncana,* and *Globigerinelloides.*

In some cores and wells, the Eocene boundaries delineated may not exactly coincide with the actual epochal boundaries because samples above or below the delineated boundaries lacked diagnostic foraminifera.

Standard washing and flotation techniques were used to extract and concentrate foraminifera from the samples. The number of non-floated foraminifera was not significant in any sample. Floated samples statistically analyzed for foraminifera were first split in a microsplitter until an aliquot with a workable number of specimens was obtained. All benthic and planktic specimens were picked from a gridded picking tray in conjunction with a random number table until 200-300 benthic specimens were counted. The following statistical information was determined:

i. Total benthic individuals in statistical count
ii. Total planktic individuals in statistical count

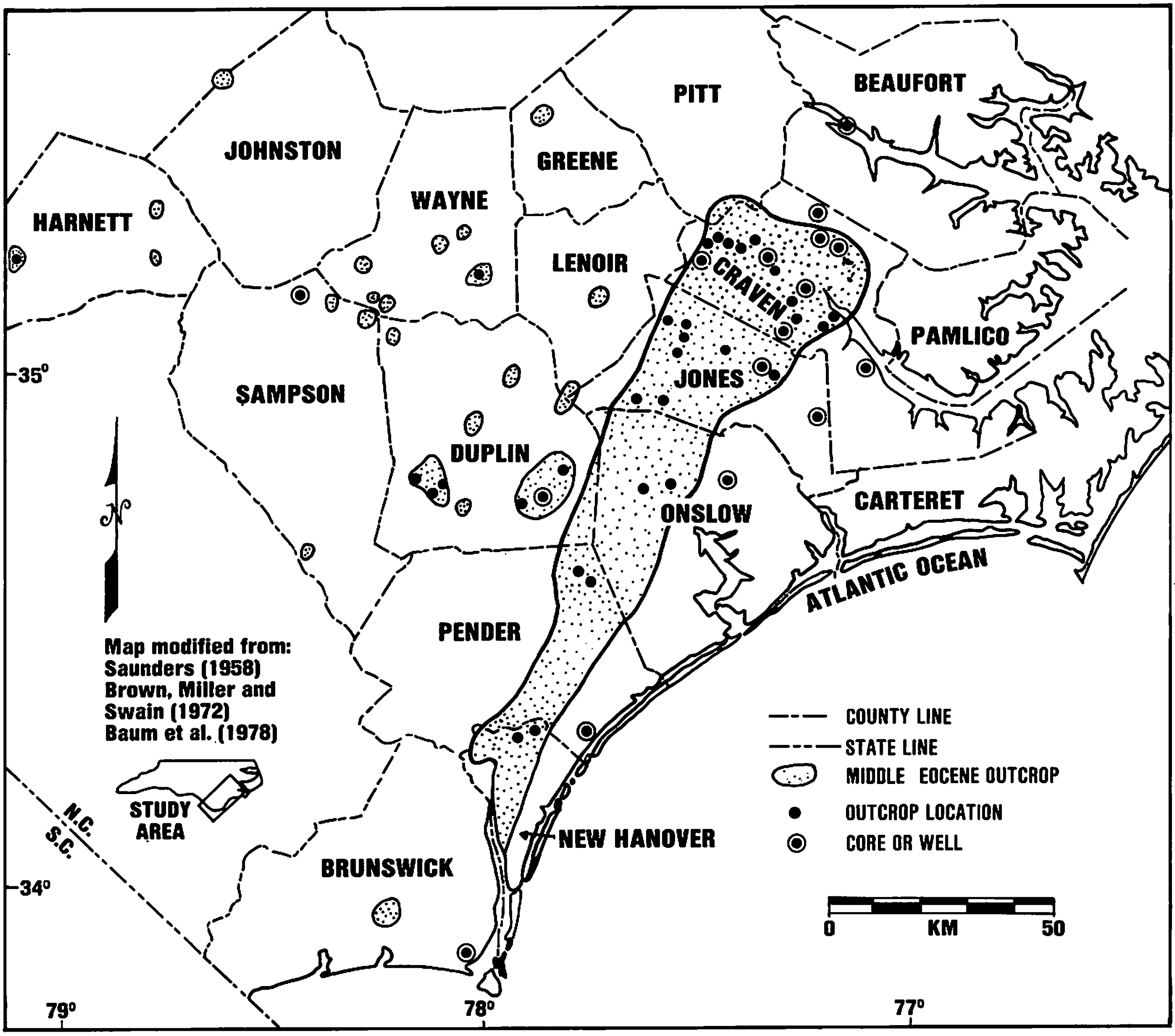


Figure 1 Map of study area and sample locations.

iii. Total individuals in statistical count

iv. Number of individuals per benthic species in statistical count

v. Common benthic species percent in statistical count

Common is defined as a species represented by five or more individuals in the count.

vi. Relative abundance of planktic species in planktic assemblage

Planktic foraminiferal species picked during the statistical count were related to a relative abundance scale as follows: abundant: 10 or more individuals; common: 5 to 10 individuals; rare: 1 to 5 individuals. After statistical counting, remaining foraminifera were perused for additional rare species, picked, and tabulated.

vii. Number of planktic species in planktic assemblage

This statistic equals the total number of planktic species identified in the statistical count and a perusal of remaining foraminifera.

viii. Percentage of planktic individuals

This statistic equals the total planktic individuals in statistical count divided by the total individuals in statistical count multiplied by one hundred.

ix. Shannon-Wiener information function (benthic diversity)

Benthic diversity equals $-\Sigma$ pi ln pi, where pi (proportion of the i^{th} species) equals the number of individuals per benthic species in statistical count divided by total benthic individuals in statistical count, and ln equals the natural logarithm. Benthic diversity equals the summation of the proportion of each species times the natural logarithm of that proportion for all species in the sample multiplied by -1.

Within each individual core and well, there was rarely more than one foraminiferal assemblage represented in the middle Eocene section. Samples chosen for statistical analysis were those with the best preserved and most abundant foraminifera. Thus, the sample chosen for statistical analysis is considered representative of the entire middle Eocene foraminiferal assemblage in that core or well. In a few cores and wells, the middle Eocene section consisted of two or more intervals in which samples belonged to distinctly different foraminiferal assemblages. In these cases, statistical analysis was performed on the sample in each distinct interval using the best-preserved and most abundant foraminifera.

Planktic foraminiferal species were recorded as present or absent in core and well samples.

A data matrix of the 73 Eocene samples versus presence or absence of 79 common benthic species was compiled and subjected to cluster analysis. Cluster analysis was performed on a Burroughs 7700 computer using a CANDE program written at the Computer Center, University College of London, England. The cluster program performed a Q-mode analysis, utilizing the Jaccard coefficient and unweighted pair group method (Mello and Buzas, 1968; Hazel, 1970).

The zonation applied to the planktic foraminifera identified from the Eocene section is that proposed for the Tertiary by Stainforth and others (1975) and updated by Hardenbol and Berggren (1978). This zonation is virtually identical to the zonation proposed by Bolli (1957, 1966) for the Eocene of Trinidad.

Specimens of foraminifera in each sample were related to the following subjective scale of preservation:

1. Poor preservation: Most tests broken or coated with secondary calcite resulting in mostly generic identifications only. Few specimens identifiable to species level.

2. Fair preservation: Most tests do not have ornamentation preserved; about half of specimens identifiable to species level.

3. Excellent preservation: Most tests have fine ornamentation preserved; majority of species identifiable to species level.

Acknowledgments

This report is based on a Ph.D dissertation submitted to the University of Delaware, Newark, in 1982. That study was done under the direction of Frederick M. Swain, who suggested the topic and whose guidance and encouragement are deeply appreciated.

Special thanks are due Philip M. Brown, North Carolina Geological Survey, who was invaluable in helping collect samples, discussing various aspects of the study, and overseeing publication of the manuscript.

Appreciation is also expressed to the following people for critically reviewing the manuscript: Kenneth Miller, Lamont-Doherty Geological Observatory; Richard Benson, Delaware Geological Survey; and James Miller, U.S. Geological Survey.

The following people helped with identification of foraminifera: William Berggren, Woods Hole Oceanographic Institute; Richard Cifelli, U.S. National Museum; D. Graham Jenkins, the Open University; Helen Tappan Loeblich, University of California at Los Angeles; and Richard Olsson, Rutgers University. Martin Buzas, U.S. National Museum; Stephen Culver, Old Dominion University; and Leonard Bates, Exxon U.S.A, kindly helped with the cluster analysis. Takako Nagase, University of Delaware, spent many hours taking the SEM photomicrographs. Chris Reis, Union Oil Company of California, patiently drafted the text-figures. Final decisions regarding taxonomy are the author's.

LITHOSTRATIGRAPHIC FRAMEWORK

Lithostratigraphically, the outcropping middle Eocene section analyzed in this study is essentially equivalent to the Castle Hayne Limestone as defined by Ward and others (1978) and the combined Castle Hayne and New Bern formations as defined by Baum and others (1978)(Figs. 2, 3). No attempt is made to advocate one previously published lithostratigraphic framework over another, nor are any lithostratigraphic correlations from outcrop to subsurface attempted. Instead, each sample collected in this study is related to one of the lithofacies defined in Fig. 3. In turn, each lithofacies is approximately related to the lithostratigraphic units of Ward and others (1978) and Baum and others (1978)(Fig. 3). For outcrop sections, cores, and wells of this study not previously described by Ward and others and/or Baum and others, the assignment of lithofacies type and relationship to the Eocene lithostratigraphic units of Ward and others and Baum and others represents the opinion of the writer.

RESULTS

Planktic Foraminiferal Biostratigraphy

Previously, the writer (Jones 1981, 1982a, b) assigned the middle Eocene section of the Coastal

Plain of North Carolina to the upper P11 and P12 zones (Fig. 4) and did not believe the middle Eocene section extended into zone P13 because of the presence of *Acarinina pentacamerata* (Subbotina) (last appearance datum-LAD-top P12 zone) and *Turborotalia cerroazulensis frontosa* (Subbotina) (LAD-top P12 zone). Also, Jones (op.cit.) believed the conferred identification of *Hantkenina longispina* Cushman in some sections indicated a possible need of revision for that species range. Newly established ranges for some diagnostic planktic foraminiferal species and new data for calcareous nannoplankton and dinoflaggelates (Berggren and Aubry, in press; Hazel and others, in press) substantiate Jones' basic age assignment (middle Eocene), but require that the middle Eocene section be assigned to the P12 and P13 zones.

Berggren and Aubry (in press) and Hazel and others (in press) report biostratigraphic and magnetobiochronologic evidence indicating that the middle Eocene section at the Martin Marietta Quarry, Castle Hayne (= type section of Castle Hayne Limestone as defined by Baum and others, 1978) is of latest Lutetian to lower Bartonian age (Fig. 4). At a maximum, planktic foraminiferal and calcareous nannoplankton data indicate correlation with zones P12-13 and NP15 (upper part) through NP16, respectively (Fig. 4). Extrapolated magnetobiostratigraphic data indicates that the middle Eocene section in this quarry, at a maximum, spans the interval between anomalies 20 and 18 (approximately 45-42 Ma, Ness and others, 1980). The combined dinoflagellate and molluscan assemblages suggest correlation with the uppermost Lisbon Formation of Alabama (Hazel and others, in press).

At this time, the writer considers that *Acarinina pentacamerata* (Subbotina) of earlier reports (Jones, 1981, 1982a, b) is not, in fact, that species and assigns this species to *A.* sp. aff. *A. pentacamerata.* Samples containing *Hantkenina longispina* Cushman are now thought to have zonal resolutions including the latest P12 and P13 zones (samples IC-2, New Hanover County; Newton Grove outlier, William and Mary Motel 13-27 ft., Sampson County; BEA-T-38 98-99 ft., Beaufort County; NR-2, Wayne County).[1] Samples containing *Turborotalia cerroazulensis frontosa* (Subbotina) without *H. longispina* Cushman (now considered suggestive of an age no younger than zone P12) and those containing both *H. longispina* and *T. cerroazulensis frontosa* (e.g., sample IC-2) are considered correlative with the uppermost P12 zone.

Figure 4 is a range chart that shows the key planktic species identified from the middle Eocene section and the planktic foraminiferal zonation utilized herein. Lists of planktic and benthic foraminifera, lithologic descriptions, and statistical data for each sample and biofacies may be found in North Carolina Geological Survey Open-File Report 83-1. Figures 5 and 6 give the planktic zonal resolutions and the lithofacies identified in outcrop, core, and well samples. (See Fig. 3 for description of lithofacies.) Planktic zonal resolution is defined as the smallest stratigraphic interval represented by the concurrent overlap of two or more planktic species ranges.

Information shown in Figs. 5 and 6 indicates that samples of the phosphate pebble lithocalcirudite lithofacies (lithofacies 1) did not yield suitably-preserved foraminifera that can be used to establish a zonal determination. The absence of whole specimens in material obtained from these samples was due to the difficulty of extracting individual tests from this hard, recrystallized rock. In the DUP-C1-80 core, Duplin County, a five-foot thick phosphate pebble-rich bed is assigned to lithofacies 1. Unlike lithofacies 1 in New Hanover County, the phosphate pebble bed present in DUP-C1-80 is not a basal conglomerate, but is intercalated with beds assigned to lithofacies 2 and 3. Lithofacies 2 and 3 in this core are correlative with zone P12. Thus, in at least the DUP-C1-80 core, lithofacies 1 is correlative with the P12 zone. Future thin-sectioning of samples from lithofacies 1 may permit identification of cross-sectioned foraminifera allowing direct rather than indirect zonal determination.

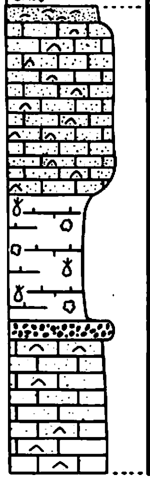
Samples of lithofacies 2, 3, and 4 yielded planktic foraminifera with excellent, excellent to fair, and poor preservation, respectively. All of the planktic species identified from the middle Eocene section are found in lithofacies 2 and 3 except *Tenuitella aculeata* (Jenkins), which is restricted to lithofacies 4. The following species are found in lithofacies 2 and 3 but not in lithofacies 4: *Pseudohastigerina sharkriverensis* Berggren and Olsson, *Acarinina bullbrooki* (Bolli), *Globigerinatheka mexicana mexicana* (Cushman), *G. mexicana barri* (Bronnimann), *"Guembelitria" columbiana* Howe, and *Hantkenina longispina* (Cushman.) Information shown in Figs. 5 and 6 indicates most samples representative of these lithofacies yield zonal resolutions consistent with the P12 and P13 zones; the remainder yield less specific resolutions.

In the writer's judgment, those samples less specific with respect to zonal resolution also were deposited during the time represented by the P12 and P13 zones for the following reasons:

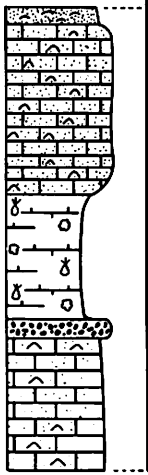
1. No sample has a zonal resolution restricted outside the P12 and P13 zones; i.e., these samples span a longer time range that encompasses zones P12 and P13.

[1]See sample register in appendix for location and lithologic, biostratigraphic, and paleobathymetric data of each sample.

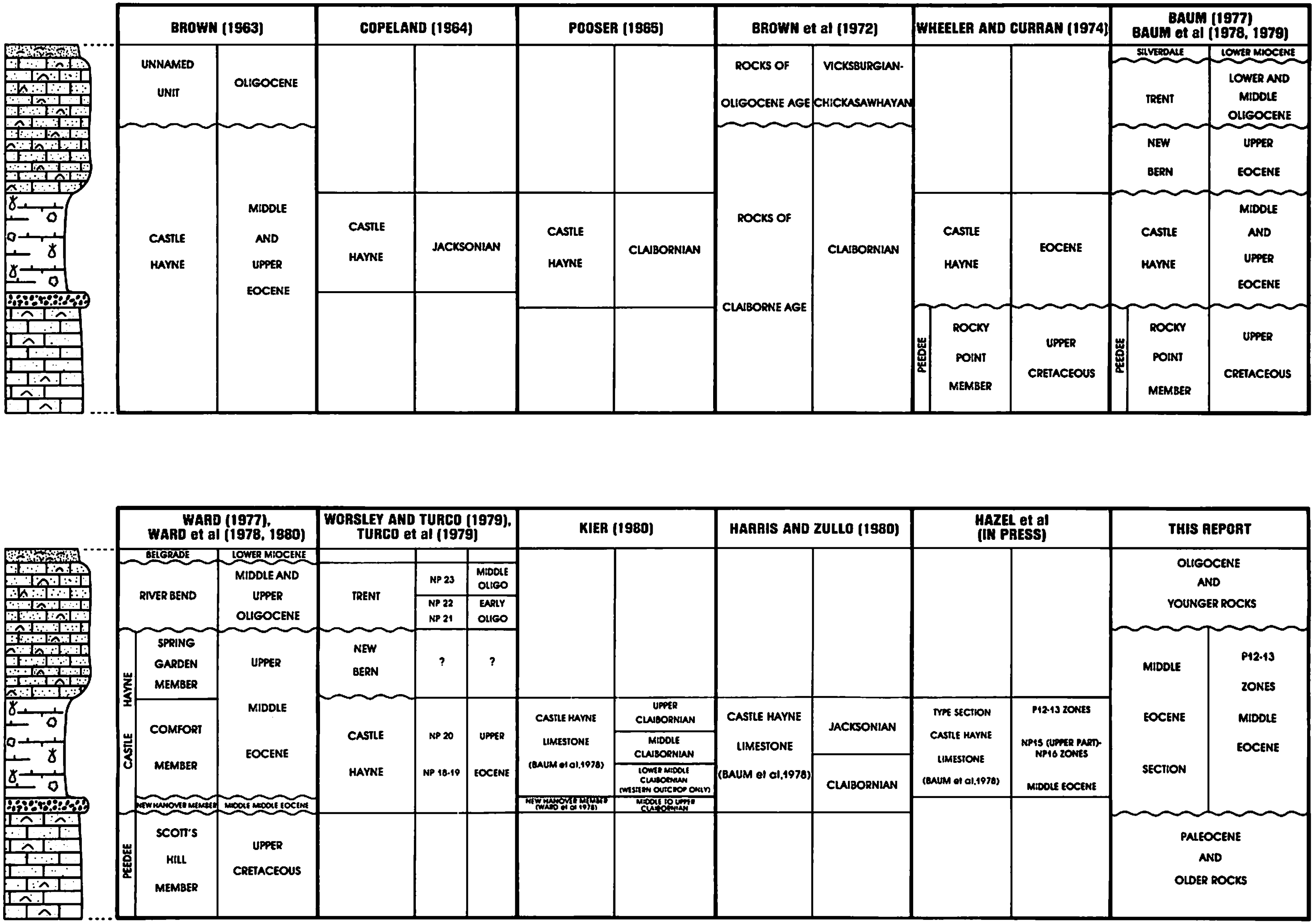
COMPOSITE SECTION OF CARBONATE ROCKS EXPOSED ON INNER COASTAL PLAIN OF N.C.



MILLER (1910, 1912)		VAUGHN (1918)		CANU AND BASSLER (1920)		KELLUM (1925, 1926)		CUSHMAN (1935)		HUDDLE (1940)	
TRENT FORMATION	UPPER CLAIBORNIAN	TRENT	UPPER EOCENE			TRENT	LOWER MIOCENE				
CASTLE HAYNE FORMATION	UPPER EOCENE	CASTLE HAYNE	UPPER EOCENE	CASTLE HAYNE	MIDDLE JACKSONIAN	CASTLE HAYNE	JACKSONIAN	CASTLE HAYNE	JACKSONIAN	CASTLE HAYNE	JACKSONIAN
TRENT FORMATION	UPPER CLAIBORNIAN										



COOKE, GARDNER, AND WOODRING (1943)		McLEAN (1947)		COOKE AND MACNEIL (1952)		LEGRAND AND BROWN (1955), BROWN (1955, 1958)		COOKE (1959)		LEGRAND (1960)	
		TRENT	LOWER MIOCENE			YORKTOWN OR CASTLE HAYNE	MIOCENE OR EOCENE				
		UNNAMED UNIT	OLIGOCENE				UPPER EOCENE				OLIGOCENE ? UPPER EOCENE
CASTLE HAYNE MARL	LOWER JACKSONIAN			CASTLE HAYNE	LATE CLAIBORNIAN	CASTLE HAYNE	MIDDLE EOCENE	CASTLE HAYNE	LATE EOCENE ? MIDDLE EOCENE	CASTLE HAYNE	MIDDLE EOCENE



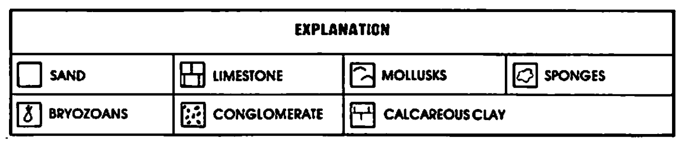


Figure 2 Historical development of stratigraphic nomenclature applied to carbonate rocks of Coastal Plain of North Carolina.

THIS STUDY (MODIFIED AFTER WARD et al., 1978)		WARD et al. (1978)			BAUM et al. (1978); Baum (1981)	
MIDDLE EOCENE SECTION	**LITHOFACIES 4** **SANDY, MOLLUSCAN-MOLD BIOCALCIRUDITE** Tan to Gray Color, Sandy, Hard, Permeable, Often Firmly Cemented with Silica, Bivalve Molds Abundant, Minor Phosphate, Irregularly Bedded.	CASTLE HAYNE LIMESTONE	SPRING GARDEN MEMBER	Sandy, Molluscan-Mold Biocalcirudite	NEW BERN FORMATION	Medium to Coarse, Pelecypod-Mold Biomicrosparrudite Fine, Pelecypod-Mold Biomicrosparrudite Calcareous Quartz Arenite
	LITHOFACIES 3 **FINE TO COARSE CALCARENITE** Hard, Compact, Few Megafossils, Locally a Calcareous Sandstone, Massively Bedded.		COMFORT MEMBER	Calcarenite and Bryozoan-Echinoid Biocalcirudite	CASTLE HAYNE LIMESTONE	Bryozoan Biomicrudite
	LITHOFACIES 2 **BRYOZOAN-ECHINOID BIOCALCIRUDITE** Gray to Cream Color, Soft and Friable, Locally Cemented, Abundant Megafossils, Quartz, Glauconite, Phosphate, Indistinctly Crossbedded in Places.					Bryozoan Biosparrudite
	LITHOFACIES 1 **PHOSPHATE PEBBLE LITHOCALCIRUDITE** Phosphate-Coated, Rounded, Cobble-to-Pebble- Size Clasts in a Cream-Colored Micrite Matrix, Hard, Well Cemented, Massively Bedded, "Fruitcake Rock". (Note: No Time Significance Implied by Superposition of Lithofacies. See Figure 7.)		NEW HANOVER MEMBER	Phosphate Pebble Lithocalcirudite		Phosphate Pebble Biomicrudite

Figure 3 Lithostratigraphic framework of lithofacies of the middle Eocene section defined in this study compared to schemes of other authors.

2. Most samples represent recrystallized, inner shelf deposits. Characteristically, these samples contain long-ranging species of *Subbotina*; deep-water, key marker species are absent or rare.
3. Most samples contain benthic foraminiferal assemblages that, elsewhere, are similar to assemblages assigned to the P12 and P13 zones, suggesting similarity of age.

In summary, information presented in Figs. 5 and 6 and other published data (Berggren and Aubry, in press; Hazel and others, in press) indicates that lithofacies comprising the middle Eocene section of the Coastal Plain of North Carolina are correlative with the *Morozovella lehneri* (P12) and *Orbulinoides beckmanni* (P13) Zones (45 - 42Ma, Lutetian/Bartonian). Unconformities of significant duration to be recorded by evolutionary changes in foraminifera were not recognized within this section.

Stratigraphic Relationship of Lithofacies

Recently published (Ward and others, 1978; Baum, 1981) and the writer's interpretations of the temporal and spatial relationships of lithofacies comprising the Eocene section are shown in Fig. 7. Previous authors proposed a superpositional relationship of Eocene lithofacies (Fig.7). Data presented below suggest the lithofacies, in fact, interfinger.

The near-equivalence in age of all samples obtained from the middle Eocene section suggests interfingering of the four lithofacies defined in Fig. 3. Confirmation of interfingering, however, requires direct observation of intercalation among the lithofacies in question:

1. A bed of lithofacies 1 is intercalated with lithofacies 2 and 3 in core DUP-C1-80, Duplin County. Lithofacies 1 was not observed interbedded with lithofacies 4.
2. Lithofacies 2 and 3 are intercalated at a number of localities (e.g., core CR-C3-79, Craven County).
3. Lithofacies 4 generally overlies lithofacies 2 and 3 in both surface and subsurface sections. However, at the Sallie Simmons outcrop, Jones County (samples SS-1 to SS-4), a five-foot bed of lithofacies 4 is intercalated with thicker beds of lithofacies 2.

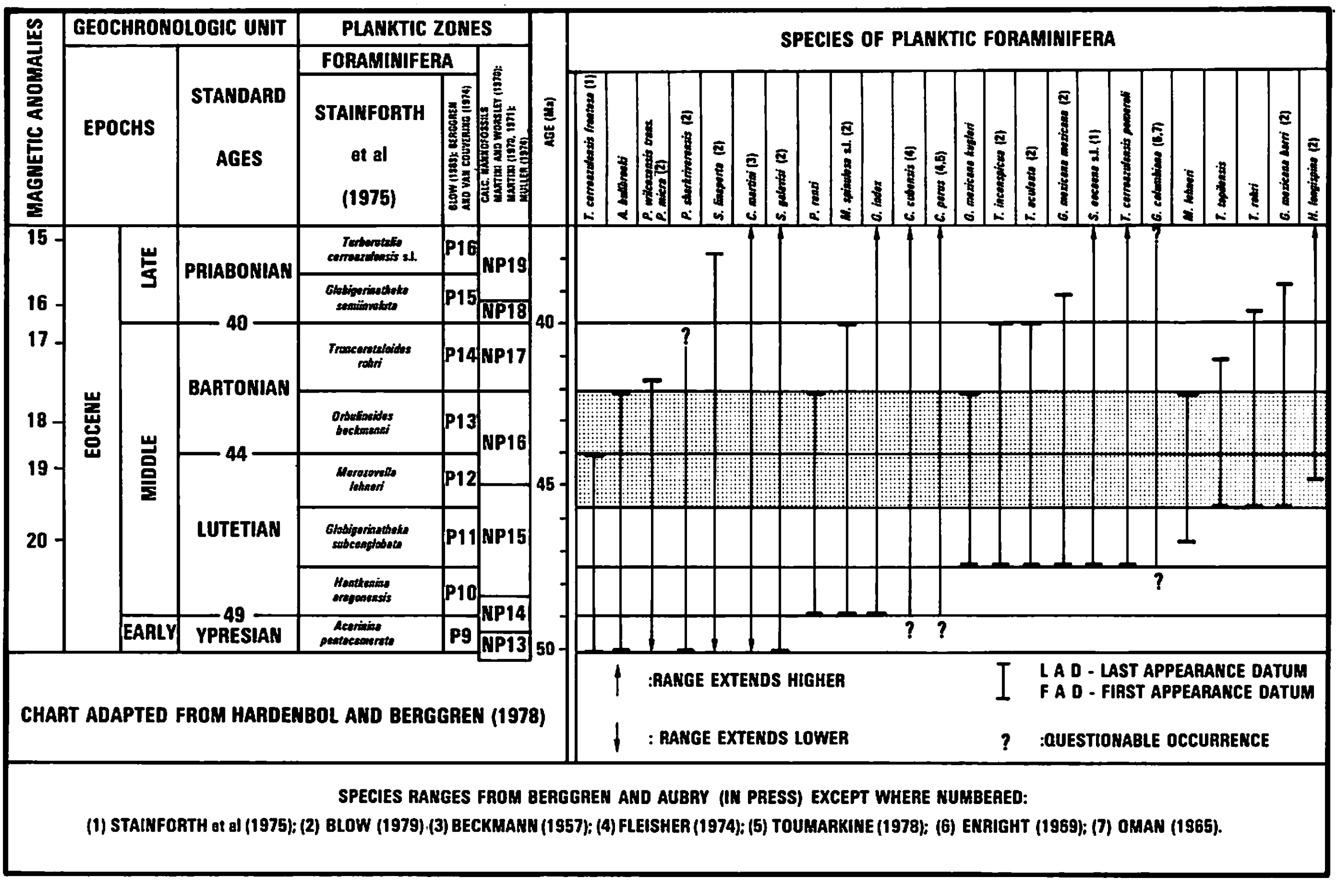


Figure 4 **Chart of worldwide ranges of key planktic foraminifera identified from middle Eocene section of Coastal Plain of North Carolina.**

Studies of more core samples, together with integrated planktic microfossil studies, are needed to conclusively demonstrate the stratigraphic positioning of these lithofacies.

The Bounding Unconformities

On the basis of the presence of the planktic foraminifera *Planorotalites pseudomenardii* (Bolli), *Subbotina triloculinoides* (Plummer), and *Morozovella velascoensis* (Cushman), the youngest rocks underlying the middle Eocene section in the study area are assigned to the *Planorotalites pseudomenardii* Zone, P4, of late Paleocene (Thanetian) age, 58-56 Ma (Hardenbol and Berggren, 1978). The middle Eocene section rests unconformably on rocks of Paleocene age at many localities; this contact is particularly well-displayed in cores from Jones, Pender and Craven counties. Elsewhere, as in the quarries of New Hanover County, the middle Eocene section lies unconformably on rocks of Cretaceous age. Thus, the minimum hiatus between the base of the middle Eocene section and underlying rocks in the study area is about 10.5 my (Hardenbol and Berggren, 1978). The lower unconformable surface of the middle Eocene section is often marked by relatively high glauconite and/or phosphate content.

The presence of the planktic foraminifera *Globigerina ciperoensis* Bolli, *Globigerina angulisuturalis* Bolli, and *Globigerina ampliapertura* Bolli places the oldest rocks overlying the middle Eocene section in the study area in the undifferentiated *Globigerina ampliapertura* (P20) and *Globigerina opima opima* (P21) Zones, of late Oligocene (Chattian) age, 32-24 Ma (Hardenbol and Berggren, 1978). Contrary to some previous reports upper Eocene rocks are not present in the study area. (See Discussion.) Berggren and Aubry (in press) identify the NP23 zone (= upper P19 to lower P21 zones) in rocks overlying the middle Eocene section in Craven County. Rocks of Oligocene age unconformably overlie the middle Eocene section, mainly in Craven and Jones counties. In other areas, Miocene and younger deposits unconformably overlie the middle Eocene section. Thus, the minimum hiatus between the top of the middle Eocene section and overlying rocks is about 10 my (Hardenbol and Berggren, 1978). The upper unconformable surface also is often marked by relatively high glauconite and/or phosphate content.

LITHOFACIES	NUMBER OF SAMPLES	ZONAL RESOLUTION
1	3	Age Not Determinable
2	3	Age Not Determinable
	6	P12
	13	P12-13
	3	P12-Middle P14
3	5	Age Not Determinable
	2	P12
	6	P12-13
	1	P11-Middle P14
	4	P12-Middle P14
	1	P11-Late Eocene
4	2	Age Not Determinable
	1	P12
	2	P12-13
	1	P11-P12
	1	P11-P13
	1	P11-P14

Figure 5 Planktic zonal resolutions of outcrop samples.

Foraminiferal Biofacies as Determined by Cluster Analysis

A binary (presence/absence) data matrix of benthic species versus sample is shown in Fig. 8. The dendrogram produced by Q-mode cluster analysis of this data matrix is shown in Fig. 9. The computer paired the two most similar samples (2 and 10) at the 0.80 correlation coefficient level and continued to do so until the final two samples (1 and 14) were paired at the 0.007 level. The dendrogram is divided into five clusters labeled foraminiferal biofacies A, B, C, D, and E. A foraminiferal biofacies is defined as an area that is segregated from other areas on the basis of species content. Each biofacies must be mappable (Mello and Buzas, 1968). Low correlation coefficients linking samples (e.g., biofacies D and E) indicate these last-clustered samples have low similarity. Four samples from biofacies E (PC-3, Pender County; DUP-C1-80 40 ft. 8 in., sample 17, Duplin County; and CHMM-Glauconite Layer, New Hanover County) and one sample from biofacies D (PEN-C2-79, Pender County) seemed "out-of-place" with respect to an initial, subjective grouping of samples. These "out-of place" samples are relocated in biofacies that contain samples with more similar foraminiferal assemblages (PC-3, PEN-C2-79, and CHMM-Glauconite Layer relocated into Biofacies B; sample 17 and DUP-C1-80 40 ft. 8 in. into Biofacies C).

Because all samples obtained from the middle Eocene section are approximately the same age, differences in biofacies probably can be attributed to ecological rather than age (evolutionary) differences. Water depth, and those properties that are dependent upon water depth, (e.g., pressure, light, temperature, etc.), are considered the main ecologic factors affecting the clustering of samples into biofacies.

Paleobathymetry of Foraminiferal Biofacies

Foraminifera have proven useful in interpreting the paleoecology of deposits in which they are preserved. Interpreting ancient environments using foraminifera rests on the principle of uniformitarianism, i.e., the foraminiferal species preserved in the rock record had distributional patterns and environmental adaptations similar to analogous (homeomorphic) species living in the modern ocean. In particular, relations such as foraminiferal trends in species diversity and abundance, planktic/benthic ratios, and species depth ranges (particularly upper depth limits) have been widely applied in interpreting the paleobathymetry of ancient deposits (Douglas, 1979).

The water depths of the five foraminiferal biofacies recognized in this study are interpreted by:

1. Comparing water depth trends of statistical parameters determined for present-day foraminifera with the same parameters determined for foraminifera from samples comprising the five middle Eocene biofacies (Fig. 10, Appendix B).
2. Comparing the diagnostic middle Eocene assemblage of benthic foraminifera comprising each biofacies with the water depth habitats determined for modern homeomorphic species (see Jones 1982b for further discussion).

Water depth trends of statistical data determined for modern and ancient foraminifera and the depth habitats of modern foraminiferal species and genera homeomorphic with middle Eocene species are summarized from Bandy (1960), Bandy and Arnal (1960), Betjement (1969), Biswas (1976), Boersma (1978), Buzas (1979), Culver and Buzas (1980, 1981), Douglas (1979), Eicher and Frush (1974), Gibson and Buzas (1973), Grimsdale and Morkhoven (1955), Kafescioglu (1971), Lipps (1979), McDougall (1980), Pflum and Frerichs

(1976), Phleger (1960), Poag (1972), Schnitker (1971), Sen Gupta and Kilbourne (1974, 1976), Sliter and Baker (1972), Stehli (1966), Stehli and Creath (1964), Todd (1979), Walton (1964), and Wilcoxon (1964).

i. Foraminiferal biofacies A and B

Biofacies A and B were deposited in water depths characteristic of an outer shelf environment (50-100m)(165-330ft)[2] as indicated by : (1) the relatively high mean percentage of planktic individuals, number of planktic species, and benthic diversity (Fig. 10), and (2) the common occurrence of *Uvigerina rippensis-gardnerae* species group, *Siphotextularia breviforma, Gaudryina* sp. aff. *G. pyramidata, Bulimina cooperensis, Globocassidulina subglobosa* and *Trifarina parvaspinata.*

ii. Forminiferal biofacies C

Biofacies C was deposited in water depths characteristic of a middle shelf environment (15-50m) (50-165 ft) as indicated by (1) the relatively moderate mean percentage of planktic individuals, number of planktic species, and benthic diversity (Fig. 10), and (2) the paucity of *U. rippensis-gardnerae* species group, *G. subglobosa, G.* sp. aff. *G. pyramidata, B. cooperensis;* lack of *S. breviforma* and *T. parvaspinata;* presence of common *Cancris involutus, Cribrononion advenum, Globulina gibba,* and *Nonion mauricensis.*

iii. Foraminiferal biofacies D and E

Biofacies D and E were deposited in water depths characteristic of an inner shelf environment (0-15m)(0-50ft) as indicated by (1) the relatively low mean percentage of planktic individuals, numbers of planktic species, and benthic diversity (Fig. 10), and (2) the presence of common *Buliminella elegantissima, Quinqueloculina* spp., *Asterigerina texana chattahoocheensis, Cribrononion advenum, Pararotalia* sp. A, *P.* sp. B, and numerous cibicidid species.

The distribution of benthic species within each foraminiferal biofacies may be found in North Carolina Geological Survey Open-File Report 83-1.

Paleobathymetric Map

A paleobathymetric map of the present Coastal Plain area of North Carolina at approximately the time represented by the upper boundary surface of the middle Eocene section is shown in Fig. 11. The map was constructed by contouring data derived from samples interpreted to have been deposited in similar water depths. Only data obtained from the uppermost samples of the middle Eocene section were used in this construction. If post-middle Eocene erosion is assumed to be negligible, and all lithofacies are considered approximately time-equivalent, the map can be considered as aproximating the configuration of the sea floor of North Carolina during the middle Eocene.

As shown in Fig. 11, water depths characteristic of inner, middle, and outer shelf environments occurred in arcuate bands that were oriented nearly parallel to the present-day shoreline which trends NE-SW. In contrast to this overall trend, an irregularly-shaped area in Jones and Craven counties characterized by water depths associated with inner shelf deposits was oriented perpendicular to the present-day shoreline. This area of inner shelf deposits was connected, by a narrow neck, to a broader band of inner shelf deposits to the west, abruptly descended to the south, to an area characterized by middle and outer shelf deposits, and gradually descended, in a northerly direction, to an area characterized by middle shelf deposits.

Carbonate Facies Belts

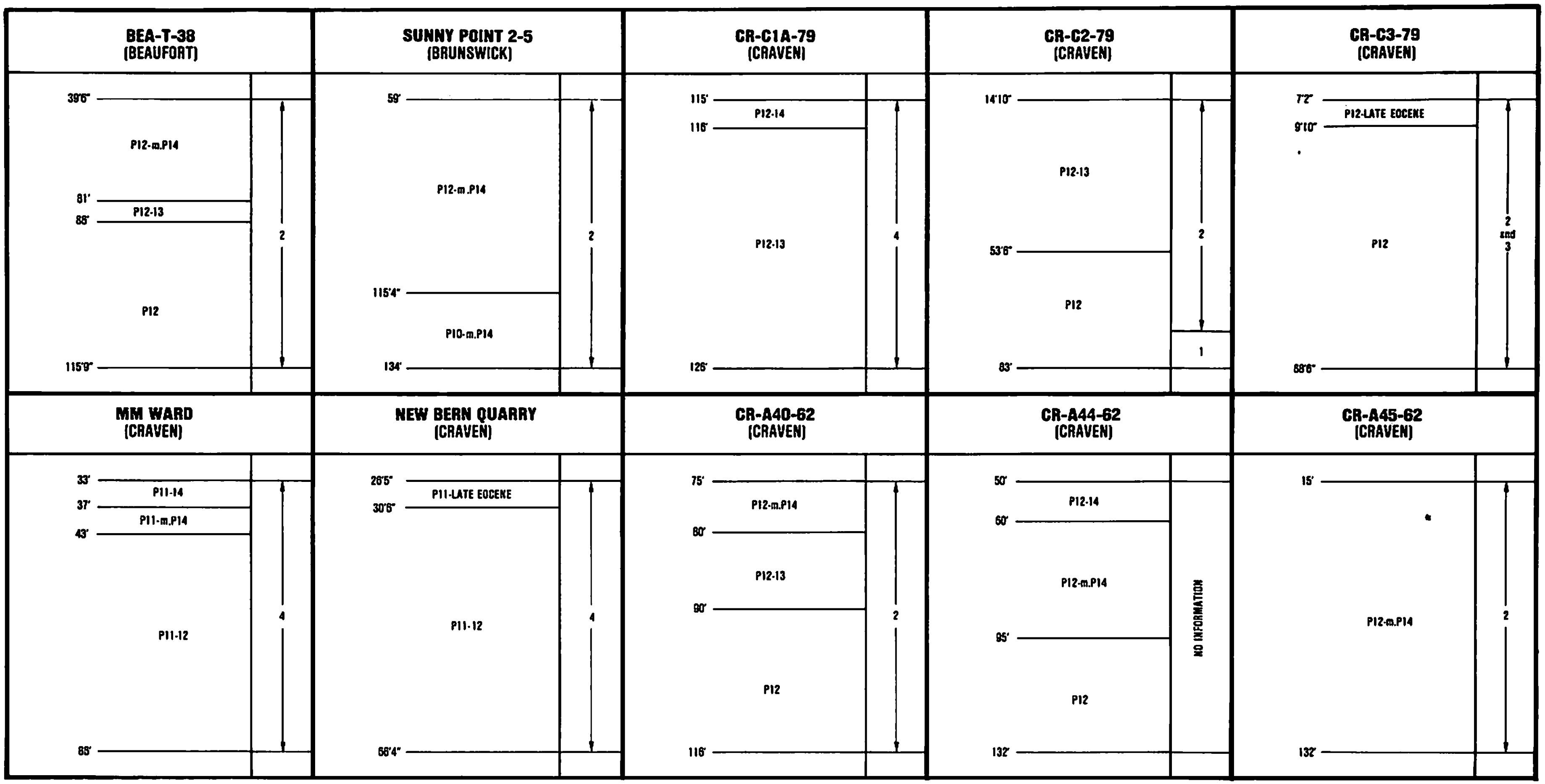
Wilson (1970, 1974, 1975) described a sequence of nine standard carbonate facies belts that he judged to occur commonly throughout the geologic record in a predictable sequence and in a variety of tectonic settings (Fig. 12). Wilson (1975) found the pattern to be persistent, so as to comprise essentially a single model for predicting the geographic distribution of carbonate rock types. In this report, correlation of inner through outer shelf depositional environments of the middle Eocene section in North Carolina with the facies belts of Wilson (1975) is based on comparison of rock type and relative geographic position along the facies belt profile.

Outer shelf deposits of the middle Eocene section consist largely of lithofacies 2. These deposits are equated with open sea, shelf deposits of facies belt 2 of Wilson (1975).

Middle shelf deposits of the middle Eocene section exclusive of Beaufort and Craven counties, consist largely of lithofacies 3. These deposits are equated with shelf deposits of facies belt 3 of Wilson (1975). Middle shelf deposits of Beaufort and Craven counties also consist largely of lithofacies 3. These deposits are equated with lagoonal deposits of facies belt 7 of Wilson (1975).

Inner shelf deposits of the middle Eocene section are present in two areas. A relatively-wide arcuate band of inner shelf deposits trends parallel to the present-day shoreline and lies to the west of middle shelf deposits (Fig. 11). These inner shelf deposits consist of lithofacies 3, and are equated

[2]The term *shelf* is equivalent to the neritic or sublittoral zone of many authors. Water depth boundaries of shelf environments (inner, middle, and outer) are modified to agree with the recognized bathymetry of the present-day continental shelf of North Carolina.


BEA-T-38
(BEAUFORT)
39'6"
P12-m.P14
81'
P12-13
88'
P12
115'9"
2
SUNNY POINT 2-5
(BRUNSWICK)
59'
P12-m.P14
115'4"
P10-m.P14
134'
2
CR-C1A-79
(CRAVEN)
115'
P12-14
116'
P12-13
126'
4
CR-C2-79
(CRAVEN)
14'10"
P12-13
53'6"
P12
83'
2
1
CR-C3-79
(CRAVEN)
7'2"
P12-LATE EOCENE
9'10"
P12
68'6"
2 and 3
MM WARD
(CRAVEN)
33'
P11-14
37'
P11-m.P14
43'
P11-12
85'
4
NEW BERN QUARRY
(CRAVEN)
26'5"
P11-LATE EOCENE
30'6"
P11-12
56'4"
4
CR-A40-62
(CRAVEN)
75'
P12-m.P14
80'
P12-13
90'
P12
116'
2
CR-A44-62
(CRAVEN)
50'
P12-14
60'
P12-m.P14
95'
P12
132'
NO INFORMATION
CR-A45-62
(CRAVEN)
15'
P12-m.P14
132'
2

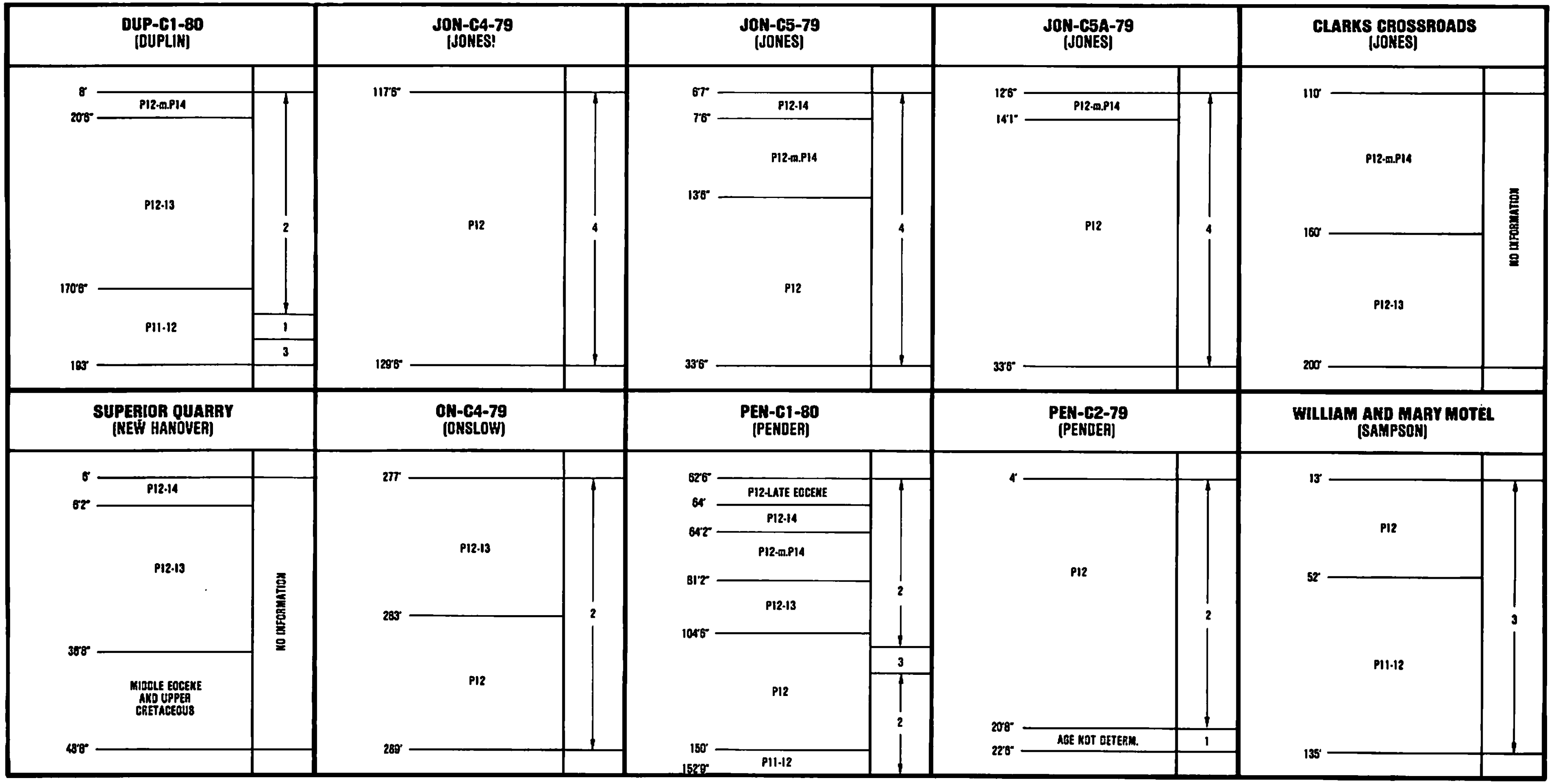


Figure 6 Planktic zonal resolutions of core and well samples from the middle Eocene section. Depths are in feet below land surface. Uppermost and lowermost depths define the upper and lower boundaries of the middle Eocene section as defined in this study. Numbers in right hand columns refer to lithofacies type (see Figure 3).

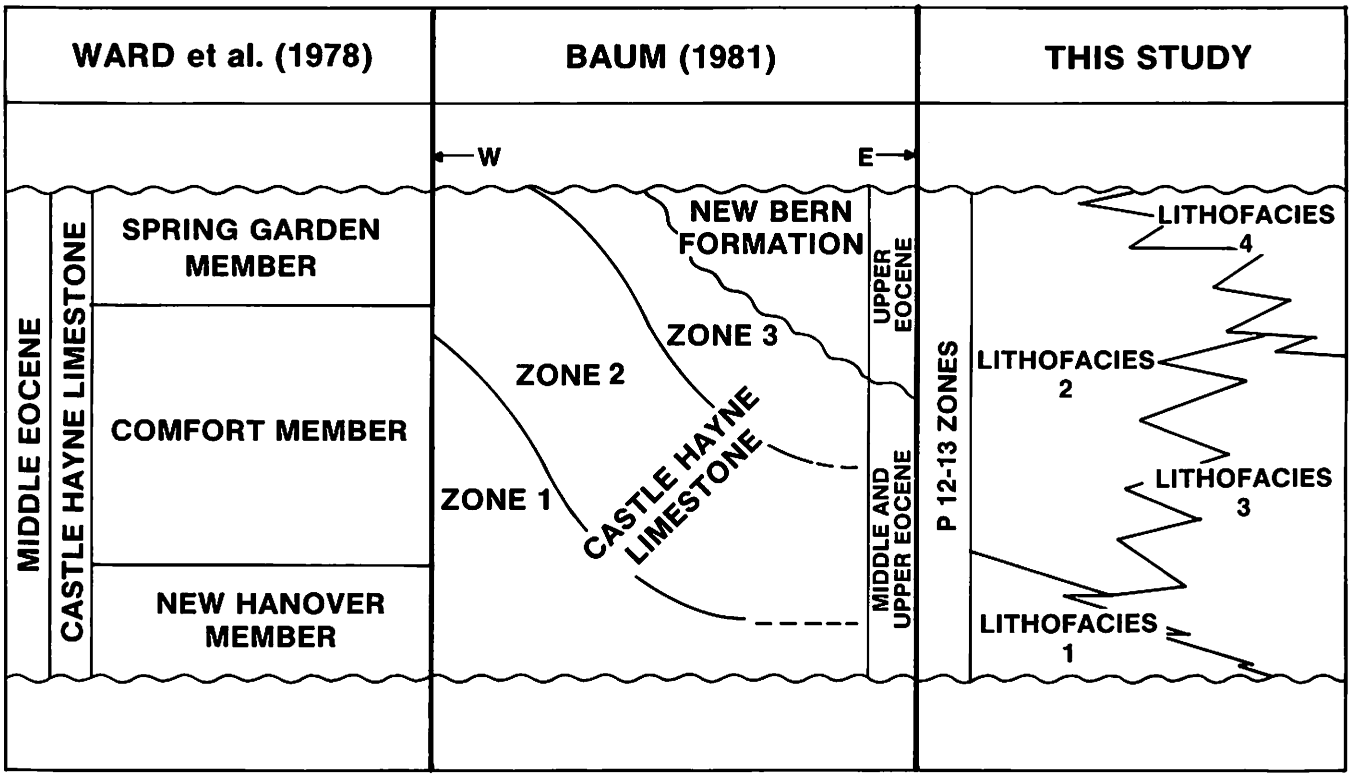


Figure 7 Postulated temporal and spatial relationships of middle Eocene section lithofacies defined in this study compared to schemes of other authors.

with a wide range of environments characterized by winnowed shelf edge sands and shelf, lagoon, restricted shelf, and tidal flat deposits of facies belts 6, 7, and 8 of Wilson (1975).

The other area characterized by inner shelf deposits contains lithofacies 4 and trends perpendicular to the present-day shoreline in Jones and Craven counties. These inner shelf deposits are equated with organic buildup deposits of facies belt 5 of Wilson (1975).

In Jones County, middle Eocene carbonate lithofacies equivalent to foreslope deposits of facies belt 4 have not been identified in those areas where they might be expected to occur in keeping with a transition between inner and outer shelf deposits (Fig. 11). Wilson (1975) noted that not all facies belts may be expected to develop in any one particular carbonate province. However, future drilling in Jones County may encounter middle Eocene rocks in the subsurface that represent facies belt 4.

Structural Control of Deposition

Anomalous changes in the thickness and distribution of time equivalent lithofacies (and interpreted depositional environments) of the middle Eocene section indicate that a depositional model invoking a seaward-dipping, monoclinal wedge (as is commonly considered to be the case), does not apply to this section. For example:

1. Outliers of the middle Eocene section in Sampson (William and Mary Motel well) and Duplin (Core DUP-C1-80) counties are considerably thicker (150-200ft) than deposits farther east in New Hanover County (e.g., Ideal Cement Company Quarry, 15-20 feet).
2. Interpreted inner shelf deposits in Jones and Craven counties trend perpendicular to the present-day shoreline (Fig. 11).
3. In Jones County, the rapid transition of outer shelf deposits (lower-energy, clay-rich lithofacies 2) to the anomalous inner shelf area (higher-energy, sand-rich lithofacies 4) is in a direction parallel to the present-day shoreline (Fig. 11). For further discussion see Jones (1982b).

Overall, the conclusion reached by recent investigators (e.g., Ferenczi, 1959; Brown and others, 1972, 1977; Harris, 1978; Baum and others, 1978, 1979; Harris and others, 1979; Jones 1981, 1982b) is that a style of deformation characterized by high-angle, block-faulting most readily explains the structural-sedimentary geometry observed for the study area. Brown and others (1972) considered the "basement" to be broken into fault-

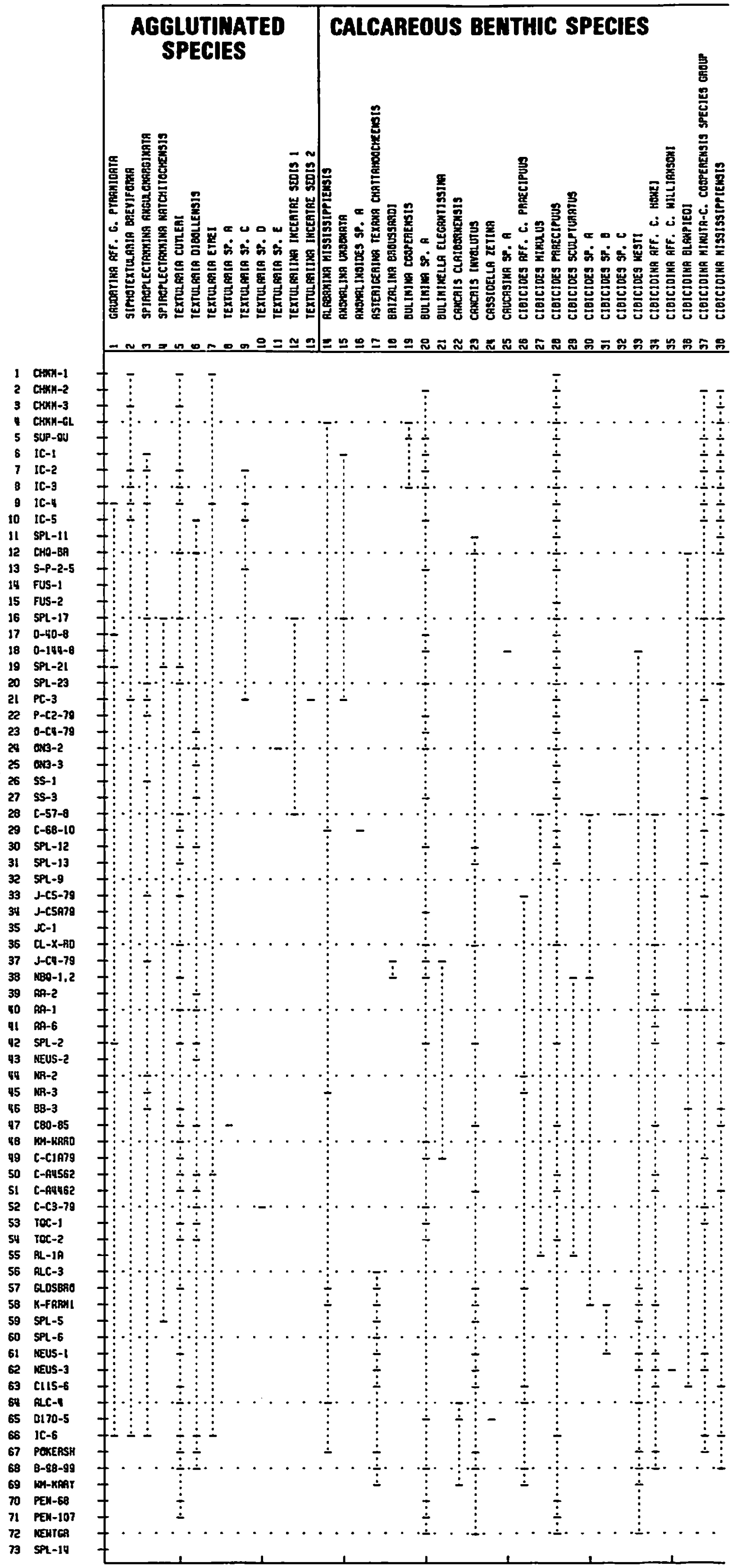


Figure 8 Foraminiferal data matrix: benthic marks indicate presence of species;

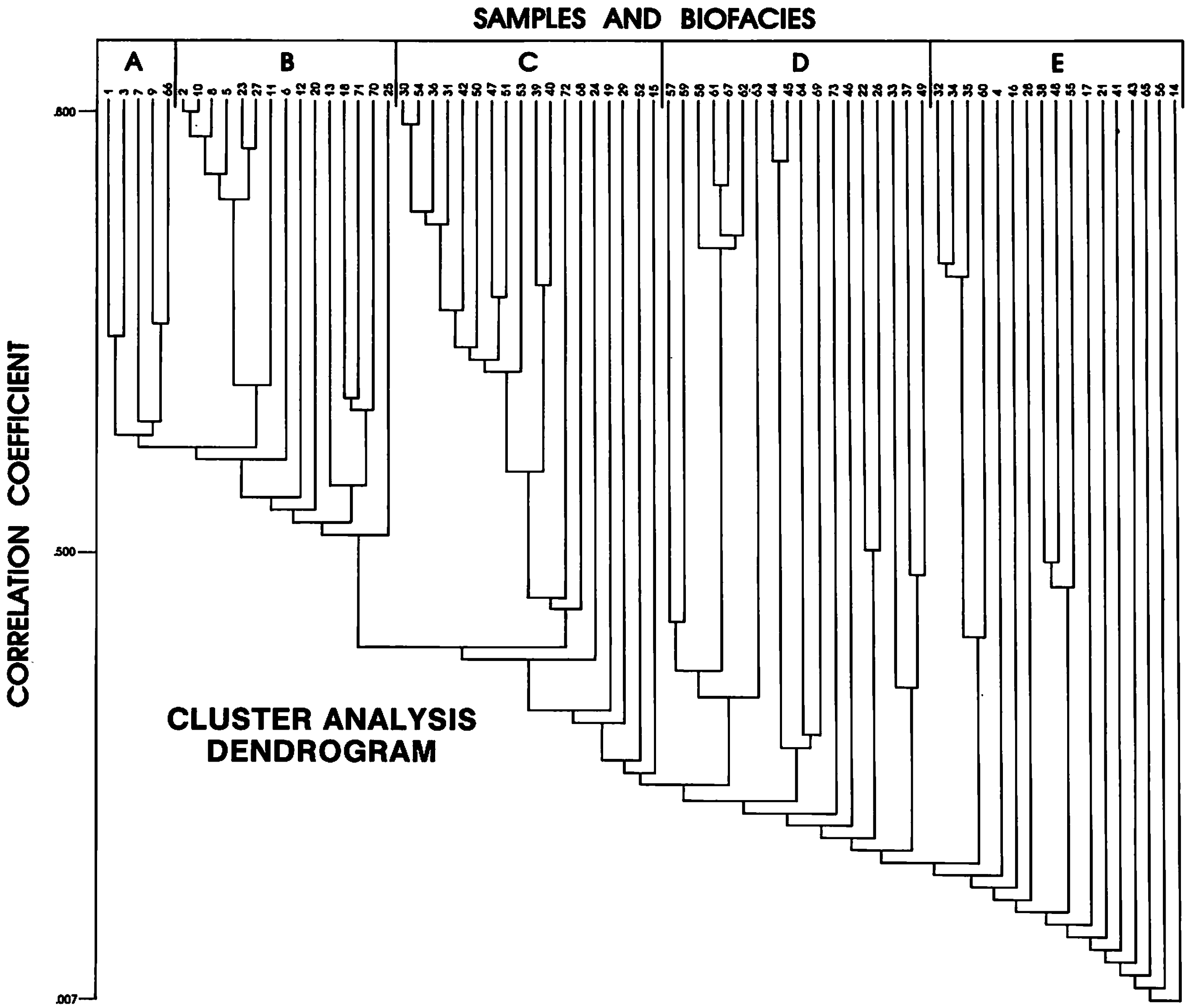


Figure 9 **Cluster analysis dendrogram of data matrix shown in Figure 8. Sample numbers correlate with those in Figure 8. Five clusters, defined herein as biofacies, are labeled A-E.**

bounded crustal blocks. As these crustal blocks changed position relative to each other, their motions were propagated upward through the sediment mass and were reflected at the surface as changes in the configuration of the sea-floor and in the alignments of its positive and negative areas. Because the relatively uplifted portions of crustal blocks acted as sediment sources, the resultant distribution of lithologic facies patterns and thickness trends are complex, and rapid changes may take place across fault lines or flexures.

The distribution of relatively thick middle Eocene sections that occur in outliers, particularly in Sampson and Duplin counties, indicates that these deposits accumulated in down-dropped half grabens and were largely protected from post-middle Eocene erosion and therefore preserved (Jones, 1982b). Post-middle Eocene uplift of crustal blocks located eastward of these outliers resulted in erosion of the middle Eocene section in these areas. This erosion explains the absence of Eocene deposits connecting outliers with the main outcrop belt located farther east (Fig. 1).

Otte (1979), however, ruled out faulting for the origin of a middle Eocene outlier in Duplin County. Based on data from wells drilled in the Atlantic Limestone Quarry (= samples ALC-1, 3, 4, this study) and from the quarry itself, Otte (1979) proposed that the outlier represents the sedimentaryfill of a pre-existing Eocene stream valley. Purportedly, as middle Eocene sea level rose, pre-existing stream valleys and interstream divides became inundated and the relic stream valleys

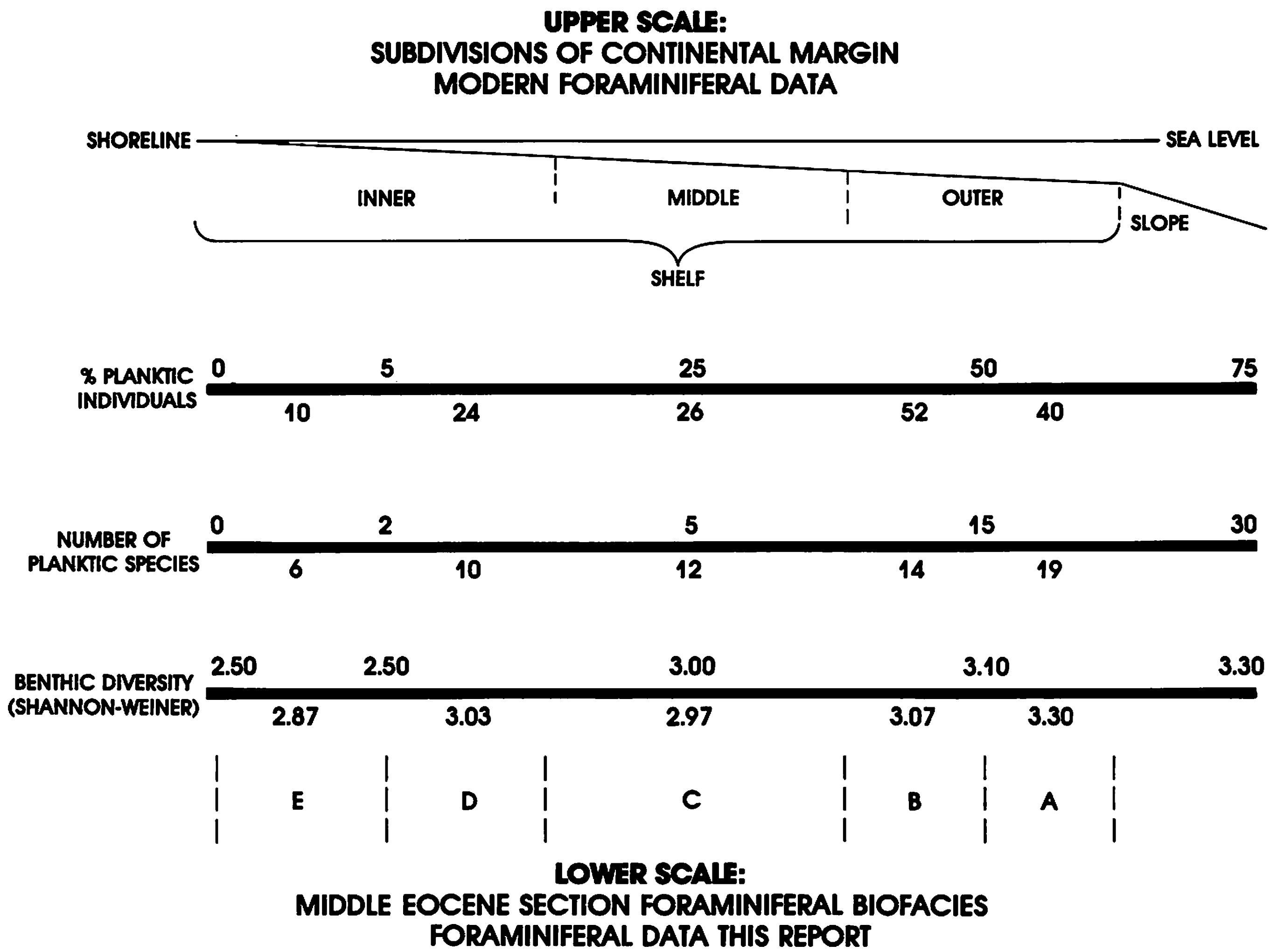


Figure 10 **Bathymetric trends of statistical data for modern foraminifera compared to trends of data for middle Eocene foraminifera comprising biofacies A-E. Data for middle Eocene biofacies represent the mean for all samples within each biofacies.**

became filled with marine sediment. According to Otte (1979), the thicker sediment accumulations in the pre-existing valleys would be more likely to be preserved than sediment on interstream divides.

Otte's (1979) main evidence supporting his scenario is the supposedly elongate shape of the depression filled by middle Eocene deposits. His data base, however, is extremely limited, covering only a fraction of the geographic area encompassing the known extent of the outlier. Furthermore, Otte's (1979) model fails to explain the absence of middle Eocene deposits between outliers and the main outcrop belt located farther east. If the outliers represent remnant sediment accumulation in pre-existing stream valleys, then presumably these rocks should continue farther to the east and link up with the main outcrop belt. Such is not the case: outliers are everywhere separated from the main outcrop belt by older rocks (excluding late Cenozoic surficial deposits). The block-faulting model described above more adequately explains the origin of middle Eocene outliers.

The presence of a middle Eocene inner shelf area in Jones and Craven counties, that, during time of deposition, trended perpendicular to the present-day coastline, is equated with organic buildup deposits of facies belt 5 of Wilson (1975). Wilson (1975) emphasized the sensitivity of carbonate production in facies belt 5 to any kind of pre-existing topographic high. He reported that carbonate accretion can be expected to occur along any sudden break, perhaps in response to drape on basement faults. Once initiated, growth is apt to be continuous and rapid. This break creates high wave energy and upwelling which in turn produce optimum growth conditions for an organic framework. Modern "reefs", for example, form best where a shelf break occurs (Wilson, 1975).

The rapid transition from outer shelf (lithofacies 2) to inner shelf (lithofacies 4) deposits in Jones County (Fig. 11) suggests that this inner shelf area was situated near wave base on the upthrown side of a fault-controlled shelf break. A postulated NE-SW trending fault would explain the occurence of

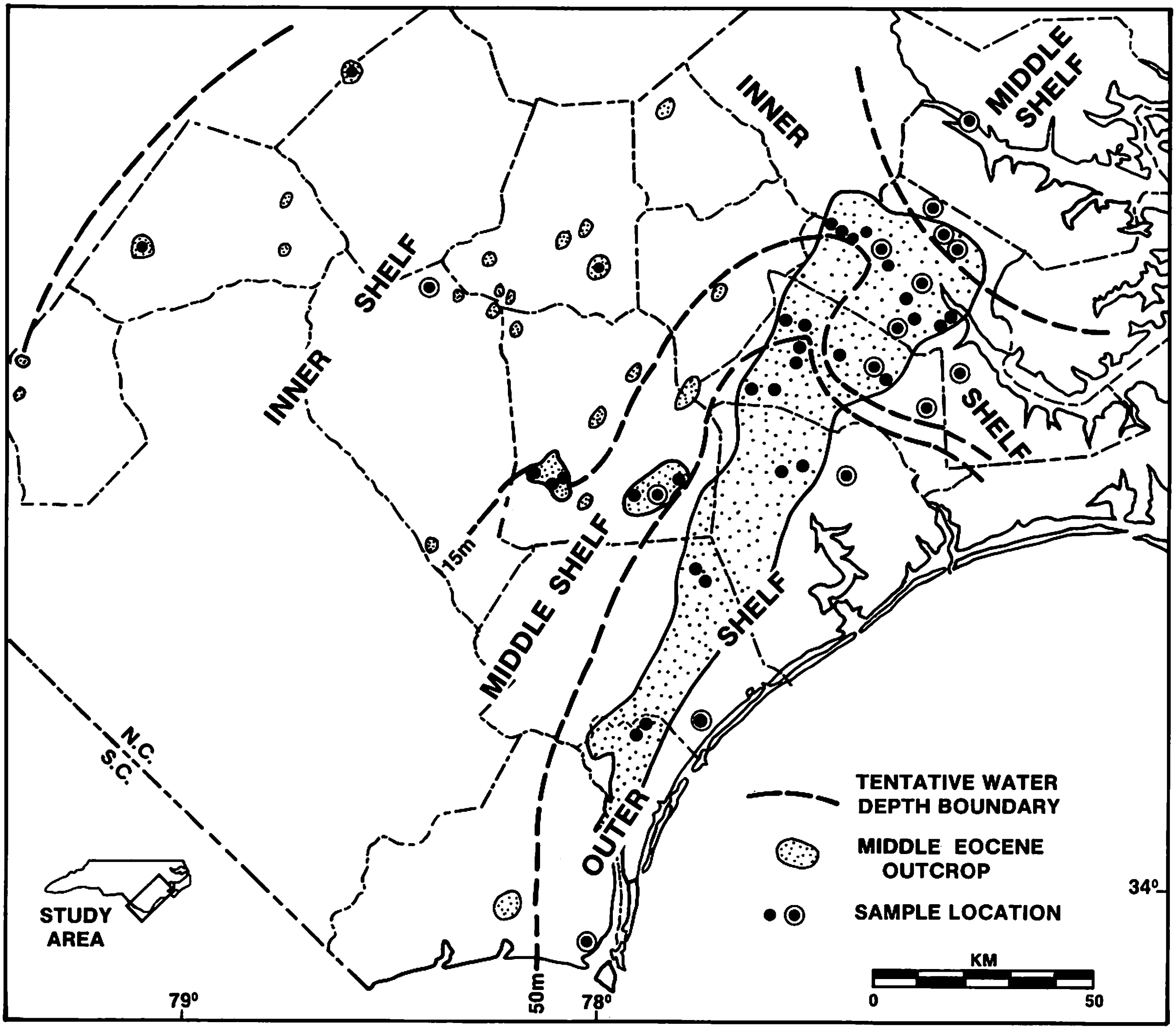


Figure 11 Bathymetric map of seafloor of coastal Plain of North Carolina near the end of deposition of the middle Eocene section. See text for full explanation.

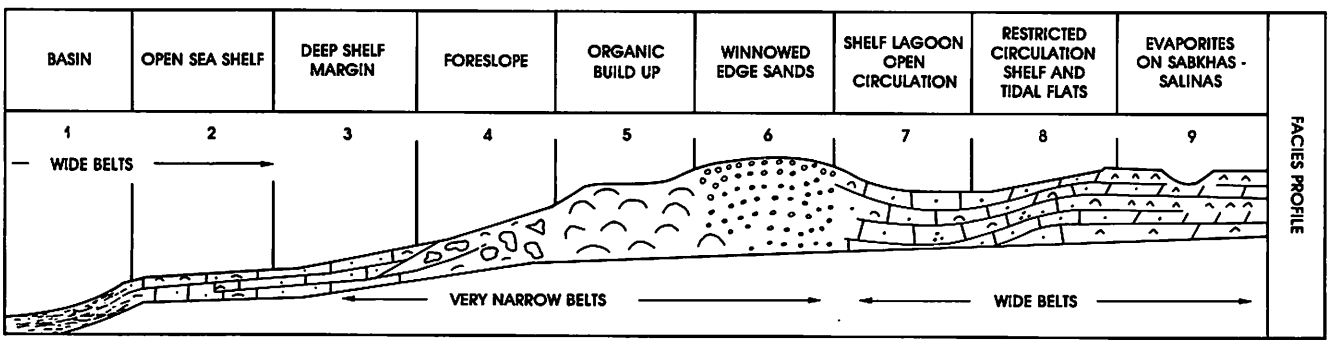


Figure 12 Profile of carbonate facies belts of Wilson (1975).

a rapid transition of lithofacies in the area and the anomalous perpendicular trend of these deposits relative to the present-day shoreline. The structural control of deposition of middle Eocene deposits of the Coastal Plain of North Carolina was more completely discussed in Jones (1982b).

DISCUSSION

Numerous recent articles (e.g., Baum, 1977, 1980, 1981; Baum, Harris, and Zullo, 1978, 1979; Baum, Collins, and others, 1980; Fullagar and others, 1980; Harris, 1982; Harris and Zullo, 1980, 1982; Harris, Zullo, and Baum 1979; Powell and Baum, 1982; Turco, Sekel, and Harris, 1979; Worsley and Turco, 1979; Zullo, 1979, 1980; Zullo and Baum, 1979, 1981) have reported an upper Eocene age (Jacksonian and/or Priabonian) for the upper Castle Hayne and/or New Bern formations (as defined by Baum and others, 1978; Fig. 3). As thoroughly discussed in this study and elsewhere (Ward and others, 1978; Jones, 1981, 1982 a, b; Berggren and Aubry, in press; Hazel and others, in press; Berggren and others, in press) molluscan, foraminiferal, calcareous nannoplankton, and dinoflagellate data clearly indicate the entire Castle Hayne Limestone (as defined by Baum and others, 1978) is of middle Eocene age. Similarly, planktic foraminiferal (this study) and molluscan (Ward and others, 1978) data indicate the New Bern Formation (as defined by Baum and others, 1978) is also of middle Eocene age.

The failure to recognize the middle Eocene age of these units has led to erroneous conclusions regarding, e.g., late Eocene chronology, eustatic changes in sea level, and the structural framework of the Coastal Plain of North Carolina:

1. Berggren and Aubry (in press) and Hazel and others (in press) provide strong evidence indicating that Harris and Zullo's (1980) and Fullagar and others (1980) Rb/Sr dates (34.8 ± 1 Ma) for the Castle Hayne Limestone (as defined by Baum and others, 1978) are from middle Eocene strata and do not provide age estimates of late Eocene chronology or the Eocene/Oligocene boundary.
2. Powell and Baum (1982) recognized upper Eocene global sequences of coastal onlap (Vail and others, 1977) in the middle Eocene section defined in this study.
3. Harris and others (1979) postulated the existence of an upper Eocene, fault-controlled basin to account for the deposition of the New Bern Formation (as defined by Baum and others, 1978; Fig. 3) and correlated the timing of movement along these faults with faults in South Carolina. As documented in this study, lithofacies 4 (= New Bern Formation) is middle Eocene in age and seemingly interfingers with other lithofacies characteristic of the middle Eocene section. Data contained herein indicate that lithofacies 4 was deposited as an organic buildup on the upthrown side of a crustal block (facies belt 5 of Wilson (1975)) in contrast with the downfaulted basin interpretation proposed by Harris and others (1979).

The above examples illustrate that future reports involving the structural-stratigraphic framework of the Eocene section must be cognizant of the fact that the age of the section is middle Eocene and that upper Eocene rocks are not present in the study area.

CONCLUSIONS

1. The middle Eocene section of the Coastal Plain of North Carolina is bounded above and below by unconformities; it is overlain by Oligocene and younger rocks and underlain by Paleocene and older rocks. Upper Eocene rocks are not present in the study area.
2. The middle Eocene section is correlative with the *Morozovella lehneri* (P12) and *Orbulinoides beckmanni* (P13) Zones, 45-42 Ma.
3. Lithofacies of the middle Eocene section are approximately age-equivalent and seemingly interfinger.
4. The middle Eocene sea floor of North Carolina was characterized by broad seaward-deepening bands of inner shelf (0 - 15 m water depth), middle shelf (15 - 50 m), and outer shelf (50 - 100 m) depositional environments that paralleled the present-day shoreline. A narrow band of inner shelf environments trended perpendicular to the regional trend in Jones and Craven counties.
5. The inner through outer shelf depositional environments relate to the standard facies belts of Wilson (1975) as follows:
   a. Inner shelf samples (exclusive of Jones and Craven counties) are platform edge winnowed sand, open shelf, lagoon, restricted shelf, and tidal flat deposits that correspond to Wilson's (1975) facies belts 6, 7, 8.
   b. Inner shelf samples of Jones and Craven counties are organic bank deposits that correspond to facies belt 5.
   c. Middle shelf samples (exclusive of Craven and Beaufort counties) correspond to facies belt 3.
   d. Middle shelf samples of Craven and Beaufort counties are lagoonal deposits that correspond to facies belt 7.
   e. Outer shelf samples are open sea deposits that correspond to facies belt 2.

6. Differential movement of fault-bounded crustal blocks controlled the thickness and distribution trends of carbonate lithofacies recognized in the middle Eocene section.

NOTE ON TAXONOMY

The total of 159 benthic and 30 planktic foraminiferal species identified from the middle Eocene section of this study are listed. Complete listing of synonymies is not attempted; instead, the original reference is given followed by, in most cases, one or more references that illustrate and/or describe the concept of the species as adopted by the writer. Complete taxonomic descriptions may be found in Jones (1982a).

The approach used for taxonomy of benthic foraminifera follows Loeblich and Tappan (1964). Benthic genera are listed alphabetically under the suborder headings Textulariina, Miliolina and Rotaliina. Species defined as common in one or more samples are noted by an asterisk; the remaining rare species are not noted by a symbol. Additional rare species identified but not listed and illustrated here are recorded in Jones (1982a).

The approach used for taxonomy of planktic foraminifera is adopted from the following authors: Bolli (1957, 1972), Berggren and others (1967), McGowran (1968), Cordey and others (1970), Toumarkine and Bolli (1970), Jenkins (1971), Fleisher (1974), Stainforth and others (1975), Berggren (1977), Blow (1979), and Benjamini (1980). Genera are listed alphabetically under the superfamily Globigerinacea.

A cf. (conferred) designation indicates the species in question was too poorly preserved or no type specimens or adequate illustrations were observed by the author for positive identification.

An aff. (affinities to) designation indicates the species in question is morphologically similar and probably phylogenetically related to the nominate species but possesses sufficient differences to be considered a separate form. Taxa unidentified to species level are informally described as species A, B, C, etc. Identification of foraminifera was aided by: the inspection of type specimens of the Cushman Collection, U.S. National Museum; the Copeland Collection, University of North Carolina, Chapel Hill; the collection of Rutgers University, New Brunswick; and specimens kindly sent to the author by D. G. Jenkins, Open University, Great Britain.

SYSTEMATIC PALEONTOLOGY

Order FORAMINIFERIDA

Suborder TEXTULARIINA
Genus GAUDRYINA

Gaudryina jacksonensis
Gaudryina jacksonensis Cushman, 1926
Plate 1, figures 24, 25

Gaudryina jacksonensis Cushman, 1926, p. 33, pl. 5, fig. 1.
Gaudryina jacksonensis Cushman, Bandy, 1949, p. 159, pl. 3, figs. 10a, b.

Gaudryina sp. aff. G. pyramidata
Cushman, 1946*
Plate 1, figures 13, 14

Diagnosis - Test pyramidal; peripheral margins angular in end view; test quadrate in section; surface coarsely-grained; sutures obscured; last two chambers inflated, rounded.

Remarks - Differs from true *G. pyramidata* in lacking raised sutures and more rounded edges, especially in last two chambers.

Genus SIPHOTEXTULARIA

Siphotextularia breviforma Copeland, 1964*
Plate 1, figures 16, 17

Siphotextularia breviforma Copeland, 1964, p. 300, pl. 23, figs. 4a, b.

Genus SPIROPLECTAMMINA

Spiroplectammina angulomarginata
Copeland 1964*
Plate 1 figures 1,2

Spiroplectammina angulomarginata Copeland, 1964, p. 300, p. 23, figs. 2a, b.

Spiroplectammina natchitochenis Howe, 1939*
Plate 1 figure 3

Spiroplectammina natchitochenis Howe, 1939, p. 31, pl. 1, figs. 6-7.
Spiroplectammina natchitochenis Howe, Copeland, 1964, p. 300, pl 23, figs. 3a, 3b.

Remarks - This species is difficult to separate from *Textularia cuyleri* Davis, 1941 s.l.; in adult tests *S. natchitochensis* is more elongate, larger, and has last two chambers more inflated than *T. cuyleri* Davis s.l.

Genus TEXTULARIA

Textularia adalta Cushman, 1926
Plate 1, figure 11

Textularia adalta Cushman, 1926, p. 29, pl. 4, figs 2a, b.
Textularia adalta Cushman, Bandy, 1949, p. 161, pl. 4, figs 13a, b; 14a, b.

Textularia cuyleri Davis, 1941 s.l.*
Plate 1 figure 4

Textularia cuyleri Davis, 1941, p. 147, pl. 24, figs. 3a-b, 4.
Textularia cuyleri Davis, Oman, 1965, p. 72, pl. 1, figs 2a, b.

Remarks - This species is difficult to separate from *Spiroplectammina natchitochensis* Howe; see that species for remarks. Copeland (1964) named *T. concisa* from the Castle Hayne Limestone, but it seems to be virtually indistinguishable from type specimens of *T. cuyleri*. *T. concisa* Copeland is placed here under the general morphotype of *T. cuyleri*, thus the s.l. designation.

Textularia dibollensis
Cushman and Applin, 1926*
Plate 1, figure 5

Textularia dibollensis Cushman and Applin, 1926, p. 165, pl. 6, figs 12-14.

Textularia eyrei Finlay, 1947*
Plate 1, figure 22

Textularia eyrei Finlay, 1947, p. 266, pl. 1, figs 13-17.
Textularia eyrei Finlay, Copeland, 1964, p. 300, pl. 23, figs 6a, b.

Textularia sp. A.*
Plate 1, figures 7,8

Diagnosis - Test elongate, large size; sharply acute peripheral margins, nonkeeled; surface coarse-grained; initial end somewhat compressed; sutures straight to slightly recurved downward at median line.

Remarks - Differs from *T. adalta* Cushman, 1926 in its acute periphery, more coarsely-grained test and less inflated and rounded final chambers.

Textularia sp. B.
Plate 1, figure 9

Diagnosis - Test elongate, gently tapered; surface extremely coarse-grained with large grains oriented at random on test surface

Remarks - No other *Textularia* species identified in this study is this coarsely-grained.

Textularia sp. C.*
Plate 1, figure 10

Diagnosis - Test smooth in appearance; fine-grained; gently tapered in side view; sutures straight, horizontal, depressed and distinct; chambers box-shaped with rounded peripheral margins; ovate to subquadrangular in section; last chamber slightly inflated.

Remarks - Differs from *T. claibornensis* Weinzierl and Applin, 1929, in being finer-grained, smaller-sized and with proportionately smaller final chambers.

Textularia sp. D.*
Plate 1, figures 19, 23

Diagnosis - Test small, triangular in side view, subcircular in section with one acute, pointed, peripheral margin; chambers rapidly increase in size; last chambers form a nearly horizontal line at upper surface, truncate; surface medium-grained.

Textularia sp. E.*
Plate 1, figure 15

Diagnosis - Initial end broadly rounded; peripheral margins acute but rounded; test gently tapered; ovate in section; sutures obscure; surface medium-grained.

Remarks - This species is found only in sample ON3-2, Onslow County. It is generally poorly preserved obscuring sutural characteristics. It is broadly similar to *T. dibollensis* Cushman and Applin, 1926, but narrower, with initial end less compressed.

Incertae sedis
Textulariina incertae sedis 1
Plate 1, figure 6

Diagnosis - Test sub-triangular in outline, stellate when viewed from apertural end, with 6 to 7 spine-like projections; initial end flattened, twisted 180° in lower one-fourth of test; following which chambers are inflated, biserial, enlarging gradually in size in remainder of test; peripheral margins with distinct, blunt, spine-like projections, opposite sides of test each with blunt projections forming two subparallel ridges that extend down to twisted portion; aperture a low slit at base of final chamber.

Textulariina incertae sedis 2
Plate 1, figure 20

Diagnosis - Similar to Textulariina incertae sedis 1 except test is more compressed axially and does not twist in lower portion; blunt, spine-like projections also not as well-developed.

Textulariina incertae sedis 3
Plate 1, figure 21

Diagnosis - Similar in overall morphology to Textulariina incertae sedis 2, differing in being more compressed axially and having a bluntly rounded initial end.

Suborder MILIOLINA
Genus QUINQUELOCULINA

Quinqueloculina sp. A.*
Plate 1, figures 12, 18

Diagnosis - Chambers distinctly separate due to dissolution?; sutures deep; last chamber arcuate, tube-shaped, extending over ends of previous chambers on both sides; surface smooth; aperture terminal, with no visible teeth.

Remarks - This species is often found disarticulated into separated chambers, apparently due to dissolution.

Quinqueloculina ? sp. B
Plate 1, figure 26

Diagnosis - Test broadly ovate; aperture a subcircular opening flush with end of last chamber; sutures generally obscure, chamber outlines barely visible.

Remarks - Owing to poor preservation it is difficult to tell if this form is truly *Quinqueloculina* or *Triloculina* sp.

Quinqueloculina sp. C.*
Plate 2, figure 1

Diagnosis - Test broadly ovate, somewhat compressed; surface smooth, commonly finely striate; shell wall fragile, pale pink; aperture terminal.

Suborder ROTALIINA
Genus ALABAMINA

Alabamina mississippiensis Todd, 1952*
Plate 15, figure 6, 7

Pulvinulinella obtusa Cushman and Todd, 1945b (not Burrows and Holland), p. 101, pl. 16, figs. 7, 8.
Alabamina mississippiensis Todd, 1952, p. 42, pl. 6, figs. 8a-c.
Alabamina mississippiensis Todd, Copeland, 1964, p. 308, pl. 31, figs. 1a-c.

Genus ANOMALINA

Anomalina umbonata Cushman, 1925d*
Plate 15, figures 14, 15

Anomalina umbonata Cushman, 1925d, p. 300, pl. 7, figs. 5, 6.
Anomalina umbonata Cushman, Copeland, 1964, p. 309, pl. 32, figs. 1a-c

Genus ANOMALINOIDES

Anomalinoides sp. A.*
Plate 16, figures 1, 2

Diagnosis - Test minute, planispiral, involute, compressed; periphery with broad, imperforate keel especially developed in early chambers; opposite sides distinctly different in ornamentation; one side smooth, opposite side covered with irregularly placed, large pores; aperture a low slit at base of apertural face, extending to both sides as slit at base of last 1 to 2 chambers.

Genus ASTACOLUS

Astacolus magnoliaensis Copeland, 1964
Plate 2, figure 17

Astacolus magnoliaensis Copeland, 1964, p. 301, pl. 24, figs. 1a, b.

Genus ASTERIGERINA

Asterigerina texana chattahoocheensis Oman, 1965*
Plate 6, figures 14, 15

Asterigerina texana chattahoocheensis, Oman, 1965, p. 78, pl. 4, figs. 7a-c.

Remarks - This species is very similar to Oman's (1965) subspecies except specimens from this study are more papillate on the ventral side.

Genus BRIZALINA

Brizalina broussardi (Howe and Roberts, *in* Howe, 1939)*
Plate 4, figure 19

Bolivina broussardi Howe and Roberts, Howe, 1939, p. 65, pl. 9, figs. 7, 8.

Brizalina striatellata (Cushman and Applin, 1926, emend. Bandy, 1949)
Plate 4, figure 20

Bolivina jacksonensis var. *striatella* Cushman and Applin, 1926, p. 167, pl. 7, figs. 5, 6.
Bolivina striatellata, Cushman and Applin, Bandy, 1949, p. 201, pl. 24, figs. 8a, b; 9a, b.

Genus BULIMINA

Bulimina cooperensis Cushman, 1933*
Plate 5, figure 3

Bulimina cooperensis Cushman, 1933, p. 12, pl. 1, figs. 32a, b.
Bulimina cooperensis Cushman, Cushman, 1935, p. 74, pl. 13, figs. 12-14.

Bulimina sp. A*
Plate 5, figure 1

Diagnosis - Test subglobular to slightly elongate; surface very smooth and shiny; chambers inflated, strongly overlapping; sutures flush; aperture a bulimine loop with lip on apertural face of last chamber.

Remarks - This species can be confused with *Globocassidulina subglobosa* (Brady, 1881) but differs in apertural characteristics, sutural patterns, and its smaller size.

Genus BULIMINELLA

Buliminella elegantissima (d'Orbigny, 1839)*
Plate 4, figure 18

Bulimina elegantissima d'Orbigny, 1839, p. 51, pl. 7, figs. 13-14.
Buliminella elegantissima (d'Orbigny), Howe and Wallace, 1932, p. 103, pl. 11, fig. 3.

Genus CANCRIS

Cancris claibornensis Howe, 1939*
Plate 6, figures 1, 2

Cancris claibornensis Howe, 1939, p. 78, pl. 10, figs. 20, 21.
Cancris claibornensis Howe, Bandy, 1949, p. 177, pl. 12, figs. 2a-c.

Cancris involutus Copeland, 1964*
Plate 6, figures 3, 4

Cancris involutus Copeland, 1964, p. 307, pl. 30, figs. 1a-c.

Genus CARPENTERIA

Carpenteria sp. A
Plate 14, figures 6-9

Diagnosis - Test large, attached; shape irregular and extremely variable, essentially plano-convex to concavo-convex; chambers coiled irregularly but generally in a trochospiral arrangement, commonly digitate, with great variation in degree of inflation, last chamber often greatly inflated relative to earlier chambers; sutures depressed; aperture a large, gaping, twisted opening on ventral side at base of last chamber near center of test, with thick lip on upper edge.

Genus CASSIDELLA

Cassidella zetina (Cole, 1929)*
Plate 14, figure 17

Virgulina mexicana Cole, 1927, p. 25, pl. 5, fig. 14 (not Cushman, 1922).
Virgulina zetina Cole, 1929 (new name).

Genus CASSIDULINA

Cassidulina armosa Bandy, 1949
Plate 14, figures 13-14

Cassidulina armosa Bandy, 1949, p. 205, pl. 26, figs. 12a, b.

Genus CAUCASINA

Caucasina sp. A.
Plate 5, figures 12, 13

Diagnosis - Test very small, elongate, subellipsoidal in shape; initial end bluntly rounded; chambers initially arranged triserially, rapidly becoming biserial, then uniserial at apertural end; sutures faintly depressed; aperture hood-like, with thickened rim on one side.

Genus CHILOSTOMELLA

Chilostomella cylindroides Reuss, 1851
Plate 15, figure 3

Chilostomella cylindroides Reuss, 1851, p. 80, pl. 6, fig. 43.

Genus CIBICIDES

Cibicides mimulus Bandy, 1949*
Plate 13, figures 7, 8

Cibicides mimulus Bandy, 1949, p. 191, pl. 19, figs. 1a-c.

Cibicides praecipuus Copeland, 1964*
Plate 13, figures 9-11

Cibicides praecipuus Copeland, 1964, p. 309, pl. 32, figs. 2a-c.
Cibicides praecipuus Copeland, Oman, 1965, p. 88, pl. 9, figs. 1a-c.

Remarks - This species is extremely variable morphologically, probably due to its attached mode of life, as discussed by Copeland (1964).

Cibicides sp. aff. C. praecipuus Copeland, 1964*
Plate 13, figures 12, 13

Diagnosis - Similar in most respects to true *C. praecipuus* except that dorsal side in *C.* sp. aff. *C. praecipuus* is slightly involute and the final chamber extends slightly backwards as a knob near the umbilicus.

Remarks - Youssefnia (1978) reported that the morphologic variability of *Cibicides* is horizontal or ecological, not stratigraphic or evolutionary, thus *C.* sp. aff. *C. praecipuus* may simply be a shallower-water form and true *C. praecipuus* a deeper-water form of the same species.

Cibicides sculpturatus Cushman and Cederstrom, 1945 (1949)*
Plate 13, figures 14, 15

Cibicides sculpturatus Cushman and Cederstrom, 1945 (1949), p. 41, pl. 6, figs. 5, 6.

Cibicides westi Howe, 1939*
Plate 13, figure 16; Plate 14, figure 1

Cibicides westi Howe, 1939, p. 88, pl. 13, figs. 20-22.
Cibicides westi Howe, Bandy, 1949, p. 193, pl. 20, figs. 7a-c.

Remarks - Differs from *Cibicidina blanpiedi* (Toulmin, 1941) in being evolute dorsally and unkeeled.

Cibicides sp. A.*
Plate 12, figures 15, 16

Diagnosis - Test very small, subcircular in outline, plano-convex; dorsal side flat; ventral side moderately convex, with clear umbonal plugs; ventral sutures curved, depressed; dorsal sutures faint; periphery acute, keeled; aperture a small arch at peripheral base of last chamber.

Cibicides sp. B.*
Plate 14, figures 2, 3

Diagnosis - Test plano-convex, higher than wide; periphery acute, keeled; dorsal side flat, sutures curved, commonly obscured; ventral chambers inflated, convex, sutures curved, depressed; aperture a low arch at peripheral base of final chamber.

Cibicides sp. C.*
Plate 14, figures 4, 5

Diagnosis - Test tiny, subcircular, plano-convex; periphery lobulate, with keel, acute; dorsal side flat with conspicuous coarse pores; sutures indistinct; ventral chambers inflated, convex, smooth, with clear umbo; sutures depressed, curved, limbate; aperture a low arch with lip at peripheral base of final chamber, extending dorsally as a slit along spiral suture of final 3 to 4 chambers.

Genus CIBICIDINA

Cibicidina blanpiedi (Toulmin, 1941)*
Plate 12, figures 7, 8

Cibicides blanpiedi Toulmin, 1941, p. 609, pl. 82, figs. 11-13.
Cibicidina blanpiedi (Toulmin), Copeland, 1964, p. 308, pl. 31, figs. 2a-c.

Cibicidina sp. aff. C. howei (Cushman and Todd, 1945a)*
Plate 12, figures 9, 10

Diagnosis - Test plano-convex, higher than wide; ventral side moderately convex, dorsal side flat; periphery subacute, with rounded keel; ventrally chambers are inflated, especially final chamber; ventral sutures slightly curved, depressed; dorsal sutures nearly straight, radial; aperture a slit under the inner margin of last two chambers.

Remarks - This species differs from true *C. howei* in being approximately twice as large and having less inflated final chamber.

Cibicidina minuta Copeland, 1964 - C. cooperensis (Cushman, 1933) species group
Plate 12, figures 11, 12

Cibicides cooperensis Cushman, 1933, p. 20, pl. 2, figs. 11a-c.
Cibicidina minuta Copeland, 1964, p. 308, pl. 31, figs. 4a-c.

Remarks - Copeland's (1964) type specimens of these species are virtually indistinguishable and observation of many specimens from this study has shown these two forms to be intergradational; thus, I combine the two species into one species group.

Cibicidina mississippiensis (Cushman, 1922a)*
Plate 12, figures 13, 14

Anomalina mississippiensis Cushman, 1922a, p. 98, pl. 21, figs. 6-8.
Cibicidina mississippiensis Cushman, Bandy, 1949, p. 183, pl. 15, figs. 7a-c.

Cibicidina praeconcentricus (Cushman, 1945)*
Plate 13, figures 1, 2

Cibicides praeconcentricus Cushman, 1945, p. 10, pl. 2, fig. 14.

Cibicidina sp. aff. C. williamsoni (Garrett, 1941)*
Plate 13, figures 3, 4

Cibicides williamsoni Garrett, 1941, p. 156, pl. 26, figs. 15a-c.
Cibicides williamsoni Garrett, Cushman and Renz, 1942, p. 14, pl. 3, fig. 12.

Remarks - This species differs from *C.* sp. aff. *C. howei* (Cushman and Todd, 1945a) in its more inflated final chamber and in possessing raised ventral sutures.

Cibicidina sp. A.*
Plate 13, figures 5, 6

Diagnosis - Test higher than wide, biconvex; umbilicus deep, open on dorsal side; sutures curved and distinctly raised on both sides; periphery acute with blunt keel; aperture extends from periphery dorsally as slit along base of last chamber, open to umbilicus.

Genus CIBICIDOIDES

Cibicidoides neelyi (Jennings, 1936)*
Plate 16, figures 3, 4

Cibicides neelyi Jennings, 1936, p. 39, pl. 5, figs. 4a-c.
Cibicides neelyi Jennings, Nogan, 1964, p. 47, pl. 7, figs. 16-18.

Cibicidoides truncatus (Bandy, 1949)*
Plate 16, figures 5, 6

Cibicides truncatus Bandy, 1949, p. 191, pl. 19, fig. 2.

Genus CRIBRONONION

Cribrononion advenum (Cushman, 1922b)*
Plate 7, figures 8, 9

Nonionina advena Cushman, 1922b, p. 139, pl. 32, fig. 8.
Nonion advenum Cushman, Cushman, 1935, p. 72, pl. 11, figs 1-4.
Nonion advena Cushman, Bandy, 1949, p. 173, pl. 10, figs. 8a, b.
Cribrononion preadvenum (Howe), Enright, 1969, pl. 2, fig. 9; pl. 4, fig. 2.

Cribrononion rolshauseni (Bandy, 1949)*
Plate 7, figures 10, 11a

Nonion rolshauseni Bandy, 1949, p. 74, pl. 11, fig. 3a, 3b.

Diagnosis - Test large, planispiral, subcircular in outline, biumbonate; edge broadly rounded; periphery smooth; umbilical region on both sides filled with large, clear umbonal plug; sutures curved, depressed, with tiny sutural bars; aperture a series of small pores at base of septal face.

Remarks - This species is found only in core NC-JON-C5A-79, Jones County, along with *C. advenum* with which it appears to be intergradational. It differs from *C. advenum* in being larger, possessing proportionately larger umbonal plugs, having less excavated sutures, and possessing small sutural bars.

Genus DENTALINA

Dentalina budensis Hantken, 1875
Plate 2, figure 12

Dentalina budensis Hantken, 1875, p. 34, pl. 3, fig. 12.
Dentalina budensis Hantken, Copeland, 1964, p. 301, pl. 24, fig. 6.

Dentalina jacksonensis
(Cushman and Applin, 1926)
Plate 2, figures 9, 10

Nodosaria jacksonensis Cushman and Applin, 1926, p. 170, pl. 7, figs. 14-16.
Dentalina jacksonensis (Cushman and Applin), Copeland, 1964, p. 301, pl. 24, fig. 7.

Dentalina nasuta Cushman, 1939
Plate 2, figure 11

Dentalina nasuta Cushman, 1939, p. 57, pl. 10, figs. 10, 11.
Dentalina nasuta Cushman, Bergquist, 1942, p. 129, pl. 5, fig. 9.

Dentalina soluta Reuss, 1851
Plate 2, figure 8

Dentalina soluta Reuss, 1851, p. 60, pl. 3, fig. 4.
Dentalina soluta Reuss, Bandy, 1949, p. 166, pl. 7, figs. 5a, b.

Remarks - Specimens identified in this study have 1 to 3 fewer chambers than type specimens in the USNM.

Dentalina vertebralis albatrossi (Cushman, 1923)
Plate 2, figure 14

Nodosaria vertebralis albatrossi Cushman, 1923, p. 87, pl. 15, fig. 1.
Dentalina cf. *D. vertebralis* (Batsch), Cushman, 1935, p. 19, pl. 8, figs. 13, 14.
Dentalina vertebralis albatrossi (Cushman), Bandy, 1949, p. 166, pl. 7, fig. 4.

Dentalina sp. A.
Plate 2, figure 15

Diagnosis - Test elongate, smooth, curved, banana-shaped in side view with initial and apertural ends pointed; sutures indistinct, not depressed; aperture slightly produced, radiate.

Genus EOEPONIDELLA

Eoeponidella hemisphaericus (Cushman, 1931)*
Plate 5, figures 14, 15

Discorbis hemisphaericus Cushman, 1931, p. 59, pl. 7, fig. 14.
Discorbis hemisphaericus Cushman, Bandy, 1949, p. 185, pl. 16, figs. 2a-c.

Genus EPISTOMINELLA

Epistominella sp. A*
Plate 15, figures 8, 9

Diagnosis - Test minute, biconvex, circular in outline; periphery sharply rounded; sutures radial on dorsal side, slightly curved and slightly depressed; sutures on ventral side radial, very slightly depressed, straight; aperture a slit at base of septal face extending up toward umbilicus on ventral side.

Genus EPONIDES

Eponides carolinensis Cushman, 1935
Plate 12, figures 1, 2

Eponides carolinensis Cushman, 1935, p. 78, pl. 17, figs. 7a-c.

Eponides cocoaensis Cushman, 1928*
Plate 12, figures 3, 4

Eponides cocoaensis Cushman, 1928, p. 73, pl. 10, figs. 2a-c.
Eponides cocoaensis Cushman, Copeland, 1964, p. 309, pl. 32, figs. 3a-c.

Eponides ouachitaensis Howe and Wallace, 1932
Plate 12, figures 5, 6

Eponides ouachitaensis Howe and Wallace, 1932, p. 69, pl. 13, fig. 8.

Genus FISSURINA

Fissurina howei (Cushman and Todd, 1945b)*
Plate 4, figure 14

Entosolenia howei Cushman and Todd, 1945b, p. 95, pl. 15, fig. 29.
Fissurina howei (Cushman and Todd), Copeland, 1964, p. 303, pl. 26, figs. 5a-c.

Fissurina sp. A
Plate 4, figure 15

Diagnosis - Test tiny, compressed, subrectangular in section, oval in side view; periphery bordered by large, flat-crested keel; aperture an elongate slit on plane of compression.

Fissurina sp. B*
Plate 4, figures 16, 17

Diagnosis - Test oval in side and apertural views; unornamented; with large, slit-like aperture in plane of compression.

Genus FLORILUS

Florilus spissa (Cushman, 1931)*
Plate 14, figures 20, 21

Nonionella hantkeni spissa Cushman, 1931, p. 58, pl. 7, figs. 13a-c.
Nonionella spissa Cushman, Copeland, 1964, p. 306, pl. 29, figs. 4a-c.

Genus FURSENKOINA

Fursenkoina sp. aff. F. dibollensis
(Cushman and Applin, 1926)
Plate 14, figure 16

Diagnosis - Test elongate, slender, compressed laterally, twisting about 45°; broadest near apertural end; chambers triserial in early portion, rapidly becoming biserial; edge rounded; sutures nearly flush, curved, and oblique; surface smooth; aperture an elongate slit extending up septal face.

Remarks - Specimens identified in this study are slightly more compressed, less twisted and sometimes do not display initial triserial chamber arrangement as in true *F. dibollensis*.

Genus GLOBOCASSIDULINA

Globocassidulina subglobosa (Brady, 1881)*
Plate 14, figure 12

Cassidulina subglobosa Brady, 1881, p. 60.
Cassidulina subglobosa Brady, Bandy, 1949, p. 205, pl. 26, figs. 7a, b.
Globocassidulina subglobosa (Brady), Oman, 1965, p. 87, pl. 9, figs. 8a, b.

Remarks - This form can be confused with *Bulimina* sp. *A* identified in this study; see that species for remarks.

Genus GLOBULINA

Globulina gibba (d'Orbigny, 1846) s.l.*
Plate 4, figures 4, 8

Polymorphina gibba d'Orbigny, 1846, p. 266.
Globulina gibba (d'Orbigny), Bergquist, 1942, p. 131, pl. 6, fig. 9.
Raphanulina gibba (d'Orbigny), Copeland, 1964, p. 305, pl. 28, figs. 1a-c.
Raphanulina subglobosa Copeland, 1964, p. 305, pl. 28, figs. 2a-c.

Remarks - There is great variation in size and shape of this species. Copeland's (1964) figured specimens of *Raphanulina gibba* and *R. subglobosa* (Copeland, 1964) are virtually identical except for sutural patterns. Hypotype specimens of *G. gibba* at the USNM include a wide range of variation which seemingly can explain *G. subglobosa* as being a morphological variant of *G. gibba*.

Genus GUTTULINA

Guttulina communis (d'Orbigny, 1846) s.l.*
Plate 4, figure 5

Polymorphina communis d'Orbigny, 1846, p. 266, pl. 12, figs. 1-4.
Guttulina communis (d'Orbigny), Copeland, 1964, p. 304, pl. 27, figs. 4a-c.

Remarks - Copeland's (1964) type specimens show wide variation in size and overall morphology as do the types at the USNM, hence I adopted an s.l. designation. This species differs from *Globulina gibba* (d'Orbigny, 1846) s.l. in possessing one flattened side as seen in apertural view.

Guttulina hantkeni Cushman and Ozawa, 1930
Plate 4, figure 9

Guttulina hantkeni Cushman and Ozawa, 1930, p. 33, pl. 15, figs. 4-6.
Guttulina hantkeni Cushman and Ozawa, Bandy, 1949, p. 173, pl. 10, figs. 1a, b.

Genus GYROIDINA

Gyroidina ? sp. A*
Plate 15, figures 10, 11

Diagnosis - Test loosely trochospiral, planoconvex in edge view, circular in outline, ventral side a high spire; dorsal side flat; sutures obscured; aperture a slit at base of septal face.

Remarks - This species was found only in a few samples of this study and specimens were poorly preserved. The overall morphology is suggestive of *Gyroidina*.

Genus GYROIDINOIDES

Gyroidinoides octocameratus
(Cushman and Hanna, 1927)*
Plate 15, figures 12, 13

Gyroidinoides soldanii var. *octocamerata* Cushman and Hanna, 1927, p. 223, pl. 14, figs 16-18.
Valvulineria danvillensis (Howe and Wallace), Copeland, 1964, p. 307, pl. 30, figs. 2a-c.

Genus KOLESNIKOVELLA

Kolesnikovella elongata (Halkyard, 1918)
Plate 5, figure 7

Tritaxia elongata Halkyard, 1918, p. 45, pl. 3, fig. 9.
Kolesnikovella elongata (Halkyard), Charletta, 1980, p. 78, pl. 3, fig. 7.

Genus LAGENA

Lagena altahumerifera Copeland, 1964*
Plate 2, figure 21

Lagena altahumerifera Copeland, 1964, p. 302, pl. 25, figs. 1a, b.

Lagena fenestrissima Howe and Ellis,
in Howe, 1939
Plate 2, figure 19

Lagena fenestrissima Howe and Ellis, Howe, 1939, p. 50, pl. 6, fig. 18.
Lagena fenestrissima Howe and Ellis, Copeland, 1964, p. 302, pl. 25, figs. 2a, b.

Lagena globosa (Montagu, 1803) s.l.*
Plate 2, figure 18

Vermiculum globosum Montagu, 1803, p. 523.
Lagena globosa (Montagu), Howe and Wallace, 1932, p. 93, pl. 6, figs. 15, 16.

Remarks - Virtually every globular-shaped, smooth *Lagena* imaginable has been placed under the name of *L. globosa* as recorded in USNM material, rendering the concept of this species nothing more than a morphotype; thus, I adopt the s.l. designation.

Lagena howei Bergquist, 1942
Plate 2, figure 5

Lagena sp. *C.* Howe and Wallace, 1932, p. 31, pl. 6, fig. 6, *fide* Bergquist, 1942.
Lagena howei Bergquist, 1942, p. 129, pl. 5, fig. 19.

Lagena laevis (Montagu, 1803)*
Plate 2, figure 23

Lagena laevis (Montagu), Copeland, 1964, p. 302, pl. 25, figs. 3a, b.

Lagena multicostata Copeland, 1964
Plate 2, figure 22

Lagena multicostata Copeland, 1964, p. 302, pl. 25, figs. 4a, b.

Lagena orbignyana semiconcentrica
Cushman, 1933
Plate 2, figure 3

Lagena orbignyana (Seguenza) var. *semiconcentrica* Cushman, 1933, p. 10, pl. 1, fig. 22.
Lagena orbignyana (Seguenza) var. *semiconcentrica* Cushman, Cushman, 1935, p. 70, pl. 9, fig. 9.

Lagena ouachitaensis Howe and Wallace, 1932
Plate 2, figure 20

Lagena ouachitaensis Howe and Wallace, 1932, p. 29, pl. 6, fig. 9
Lagena ouachitaensis Howe and Wallace, Copeland, 1964, p. 302, pl. 25, fig. 5.

Remarks - Copeland (1964) noted fine annulations on the apertural neck of this species; specimens from this study lack them.

Lagena protea Chaster, 1892
Plate 2, figure 2

Lagena protea Chaster, 1892, p. 62, pl. 1, fig. 14.

Lagena sulcata spirata Bandy, 1949
Plate 2, figure 4

Lagena sulcata Brady, 1884, p. 462, pl. 57, fig. 23.
Lagena sulcata spirata Bandy, 1949, p. 57, pl. 7, fig. 18.

Lagena sulcata spirata Bandy, Copeland, 1964, p. 302, pl. 25, figs. 7a, b.

Lagena torsicostata Copeland, 1964
Plate 2, figure 24

Lagena torsicostata Copeland, 1964, p. 303, pl. 26, figs. 1a, b.

Lagena wallacei Bandy, 1949
Plate 2, figure 25

Lagena sp. *B.* Howe and Wallace, 1932, p. 30, pl. 6, fig. 10 *fide* Bandy, 1949.
Lagena wallacei Bandy, 1949, p. 57, pl. 7, fig. 19.
Lagena wallacei Bandy, Copeland, 1964, p. 303, pl. 26, figs. 2a, 6.

Lagena sp. A.
Plate 3, figures 2, 2a

Diagnosis - Test subglobular with tapered cone-like apertural neck; surface ornamented with about 30 regularly spaced costae that merge into a circular ridge at base of test; costae continuous part way up apertural neck; aperture terminal, simple, round.

Lagena sp. B.
Plate 3, figures 1, 1a

Diagnosis - Test subpyriform, with about 13 thick, flat-crested costae that project as sharp spines from base of test and continue to base of apertural neck; neck smooth, gently tapered; aperture terminal, simple, round.

Genus LANKESTERINA

Lankesterina nuda (Howe and Roberts, *in* Howe, 1939
Plate 2, figure 26

Polymorphina advena nuda Howe and Roberts, Howe, 1939, p. 56, pl. 7, fig. 4.
Polymorphina nuda Howe and Roberts, Copeland, 1964, p. 304, pl. 27, figs. 1a, b.
Lankesterina nuda (Howe and Roberts), Oman, 1965, p. 74, pl. 2, fig. 5.

Genus LENTICULINA

Lenticulina alato-limbatus (Gümbel, 1868)
Plate 3, figure 3

Robulus alato-limbatus Gümbel, 1868, p. 641, pl. 2, figs. 70a, b.
Robulus alato-limbatus Gümbel, Cushman, 1935, p. 67, pl. 6, figs. 2a, b.

Lenticulina brantlyi (Garrett, 1941)
Plate 3, figure 9

Hemicristellaria brantlyi Garrett, 1941, p. 154, pl. 26, figs. 1a, b; 2, 4.

Lenticulina sp. cf. L. clericii (Fornasini, 1901)
Plate 3, figure 4

Cristellaria clericii Fornasini, 1901, p. 65, fig. 17.
Robulus clericii (Fornasini), Bergquist, 1942, p. 125, pl. 3, fig. 13.

Lenticulina sp. cf. L. convergens (Bornemann, 1855)
Plate 3, figure 5

Cristellaria convergens Bornemann, 1855, p. 327, pl. 13, figs. 16, 17.
Lenticulina convergens (Bornemann), Cushman, 1935, p. 67, pl. 6, figs. 4a, b.

Lenticulina deformis (Reuss, 1851)
Plate 3, figure 6

Robulus deformis Reuss, 1851, p. 70, pl. 4, fig. 30a, b.
Robulus deformis Reuss, Copeland, 1964, p. 303, pl. 26, figs. 3a, b.

Lenticulina jugosis (Cushman and Thomas, 1930)*
Plate 3, figure 8

Robulus jugosis Cushman and Thomas, 1930, p. 36, pl. 3, figs. 4a, b.
Robulus jugosis Cushman and Thomas, Bandy, 1949, p. 17, pl. 9, figs. 3a, b.

Remarks - Specimens from this study lack the beaded sutures reported by other authors and observed in some type specimens of the USNM.

Lenticulina sp. cf. L. mayi (Cushman and Parker, 1931)
Plate 3, figure 7

Robulus mayi Cushman and Parker, 1931, p. 2, pl. 1, figs. 3-5.
Robulus mayi Cushman and Parker, Bergquist, 1942, p. 125, pl. 3, fig. 2.

Lenticulina ovalis (Reuss, 1844)
Plate 3, figure 10

Cristellaria ovalis Reuss, 1844, p. 213
Robulus ovalis (Reuss), Copeland, 1964, p. 303, pl. 26, figs. 4a, b.

Lenticulina sp. cf. L propinquus (Hantken, 1875)
Plate 3, figure 11

Cristellaria propinquus Hantken, 1875, p. 45, pl. 5, fig. 4.
Robulus propinquus (Hantken), Cushman, 1935, p. 67, pl. 6, figs. 1a, b.

Genus LINGULINOPSIS

Lingulinopsis sp. A
Plate 4, figure 2

Diagnosis - Early portion of test coiled, becoming uniserial in later portion with strongly overlapping chambers; much compressed in early portion, less compressed in later portion; aperture a terminal, elongate slit in plane of compression.

Genus MARGINULINA

Marginulina moodysensis
Cushman and Todd, 1945b*
Plate 3, figure 14

Marginulina moodysensis Cushman and Todd, 1945b, p. 85, pl. 14, figs. 1, 2.
Marginulina moodysensis Cushman and Todd, Copeland, 1964, p. 301, pl. 24, fig. 3.

Remarks - This species differs from *M. winniana* Howe, 1939, in being less compressed and having more globular and more numerous chambers.

Marginulina triangularis danvillensis
Howe and Wallace, 1932
Plate 3, figure 15

Marginulina triangularis d'Orbigny var. *danvillensis* Howe and Wallace, 1932, p. 34, pl. 5, figs. 6a, b.
Marginulina triangularis d'Orbigny var. *danvillensis* Howe and Wallace, Bergquist, 1942, p. 125, pl. 3, figs. 15, 18.

Marginulina winniana Howe, 1939
Plate 3, figure 16

Marginulina winniana Howe, 1939, p. 43, pl. 6, figs. 8, 9.
Marginulina winniana Howe, Copeland, 1964, p. 301, pl. 24, fig. 4.

Remarks - This species is very similar in appearance to *M. moodysensis* Cushman and Todd, 1945; see that species for remarks.

Genus MELONIS

Melonis planatus (Cushman and Thomas, 1930)*
Plate 16, figures 7, 8

Nonion planatum Cushman and Thomas, 1930, p. 37, pl. 3, figs. 5a, b.
Nonion planatus Cushman and Thomas, Copeland, 1964, p. 306, pl. 29, figs. 2a, b.

Genus NODOSARELLA

Nodosarella silesica (Jedlitschka, 1930)*
Plate 14, figure 15

Ellipsonodosaria silesica Jedlitschka, 1930, p. 33, text-figs. 1a-c.
Ellipsonodosaria silesica Jedlitschka, Copeland, 1964, p. 311, pl. 34, fig. 5.

Genus NODOSARIA

Nodosaria latejugata Gümbel, 1868 (1870)
Plate 2, figure 7

Nodosaria latejugata Gümbel, 1868 (1870), pl. 1, fig. 32.
Nodosaria latejugata Gümbel, Bergquist, 1942, p. 127, pl. 4, figs. 12, 13.

Nodosaria longiscata d'Orbigny, 1846
Plate 2, figure 13

Nodosaria longiscata d'Orbigny, 1846, p. 32, pl. 1, figs. 10-12.
Nodosaria longiscata d'Orbigny, Bergquist, 1942, p. 127, pl. 4, fig. 26.

Nodosaria magnoliaensis Copeland, 1964
Plate 2, figure 6

Nodosaria magnoliaensis Copeland, 1964, p. 301, pl. 24, figs. 8a, b.

Nodosaria sp. aff. N. radicula Linnaeus,
1767 (1788)
Plate 2, figure 16

Diagnosis - Text composed of only two stout, compact, subequal, subglobular chambers; outline broadly rounded; suture depressed; aperture small, round, simple, terminal.

Remarks - Differs from true *N. radicula* in having fewer subequal chambers whereas in true *N. radicula* chambers increase in size. Specimens identified in this study are probably juveniles.

Genus NONION

Nonion mauricensis Howe and Ellis,
in Howe, 1939*
Plate 14, figures 18, 19

Nonion mauricensis Howe and Ellis, Howe, 1939, p. 57, pl. 8, figs. 1, 2.
Nonion mauricensis Howe and Ellis, Copeland, 1964, p. 306, pl. 29, figs. 1a, b.

Genus NONIONELLA

Nonionella jacksonensis Cushman, 1933
Plate 15, figures 1, 2

Nonionella jacksonensis Cushman, 1933, p. 10, pl. 1, figs. 23a-c.
Nonionella jacksonensis Cushman, Copeland, 1964, p. 306, pl. 29, figs. 3a-c

Genus OOLINA

Oolina morsei (Kline, 1943)*
Plate 4, figure 13

Entosolenia morseï Kline, 1943, p. 48, pl. 4, fig. 17.
Oolina morsei (Kline), Copeland, 1964, p. 301, pl. 24, figs. 5a, b.

Genus PARAROTALIA

Pararotalia ? sp. A*
Plate 7, figures 1-3

Diagnosis - Test large, varying from pseudoplanispiral to very low trochospiral; periphery strongly lobulate and broadly rounded; chambers subglobular, loosely appressed; umbilical area usually open, sometimes with plug; aperture umbilical-extraumbilical, commonly obscured.

Remarks - This species is restricted to samples NR-2 and NR-3, Wayne County, and is found poorly preserved; however, the overall test morphology, umbilical plug and apertural position suggest affinities with *Pararotalia.*

Pararotalia sp. B*
Plate 7, figures 4-7

Diagnosis - Test biconvex, very low trochospiral coil; chambers digitate, subglobular to subconical, dorsally chambers possess median, platelike ridge that may extend out as distinct spine at periphery; ventrally with distinct open umbilicus, in some specimens with umbonal plus preserved; aperture umbilical-extraumbilical, sometimes raised on septal face as isolated, oval opening bordered by lip.

Remarks - The development of medial ridges and spines is variable. This species can be confused with the smaller, planktic species *Testacarinata inconspicua* (Howe, 1939); see that species for remarks.

Genus PATELLINA

Patellina ? sp. A
Plate 6, figure 17

Diagnosis - Test conical, delicate; spiral side apparently evolute, umbilical side flat, apparently involute, aperture not visible.

Remarks - Specimens identified in this study are poorly preserved making generic assignment tentative.

Genus PLANULARIA

Planularia sp. cf. P. georgiana
Cushman and Herrick, 1945
Plate 3, figure 12

Planularia georgiana Cushman and Herrick, 1945, p. 57, pl. 9, figs. 2a, b.

Planularia ouachitaensis Howe and Wallace, 1932
Plate 3, figure 13

Planularia ouachitaensis Howe and Wallace, 1932, p. 87, pl. 3, figs. 7a, b.

Remarks - Type and other specimens identified in the USNM show great variation in elongation of test and overall outline.

Genus PLEUROSTOMELLA

Pleurostomella cubensis
Cushman and Bermudez, 1937
Plate 14, figure 10

Pleurostomella alazanensis cubensis Cushman and Bermudez, 1937, p. 17, pl. 1, figs. 64, 65.

Pleurostomella cubensis Cushman and Bermudez, Oman, 1965, p. 88, pl. 9, fig. 4.

Genus PSEUDONODOSARIA

Pseudonodosaria laevigata (d'Orbigny, 1846)
Plate 3, figure 18

Nodosaria laevigata d'Orbigny, 1846, p. 252, pl. 10, figs. 1-3.

Glandulina laevigata (d'Orbigny), Bandy, 1949, p. 164, pl. 6, figs. 13a, b.

Genus PULLENIA

Pullenia quinqueloba (Reuss, 1851)
Plate 15, figures 4, 5

Nonionina quinqueloba Reuss, 1851, p. 71, pl. 5, fig. 31.

Pullenia quinqueloba (Reuss), Bergquist, 1942, p. 137, pl. 9, fig. 8

Genus RAMULINA

Ramulina globulifera Brady, 1879
Plate 4, figure 12

Ramulina globulifera Brady, 1879, p. 272, pl. 8, figs. 32, 33.

Ramulina globulifera Brady, Copeland, 1964, p. 305, pl. 28, fig. 3.

Genus ROBERTINA

Robertina mcguirti Howe, 1939
Plate 16, figure 9

Robertina mcguirti Howe, 1939, p. 82, pl. 8, figs. 23, 24.

Robertina mcguirti Howe, Oman, 1965, p. 90, pl. 10, figs. 9a, b.

Genus ROSALINA

Rosalina assulata (Cushman, 1933)
Plate 5, figures 16, 17

Discorbis assulata Cushman, 1933, p. 15, pl. 2, figs. 2a-c

Discorbis assulata Cushman, Cushman, 1935, p. 78, pl. 17, figs. 1a-c.

Rosalina sp. aff. R. assulata (Cushman, 1933)
Plate 5, figures 18, 19

Diagnosis - Morphologically similar to *R. assulata* (Cushman, 1933) except periphery is more ragged, with carina extending as a pointed projection on final chamber; umbilicus much larger, more open; lip-like projections directed towards umbilical center; apertures located beneath lip-like projections.

Rosalina sp. aff. R. havanensis
(Cushman and Bermudez, 1937)
Plate 5, figures 20, 21

Diagnosis - Test biconvex, much compressed; periphery distinctly keeled; sutures limbate on dorsal side, strongly curved on ventral side with large umbilical flaps directed towards center of large open umbilicus; multiple apertures located beneath the umbilical flaps.

Remarks - This species is morphologically similar to true *R. havanensis* except specimens from this study possess a more open umbilicus, and slightly more inflated chambers.

Genus SARACENARIA

Saracenaria moresiana Howe and Wallace, 1932
Plate 4, figure 1

Saracenaria moresiana Howe and Wallace, 1932, p. 42, pl. 2, figs. 8a, b, c.
Saracenaria moresiana Howe and Wallace, Bergquist, 1942, p. 125, pl. 3, figs. 14a, b.

Saracenaria sp. A
Plate 4, figure 3

Diagnosis - Test elongate; two to three chambers make up the test; proloculus large, spherical; final chambers much inflated, tripyramidal, rounded; apertural face strongly convex, flared; aperture terminal, radiate.

Genus SIGMAVIRGULINA

Sigmavirgulina sp. aff. S. tortuosa (Brady, 1881)*
Plate 14, figure 11

Diagnosis - Test elongate, compressed, flattened; greatest breadth near apertural end; periphery acute with broad, flattened keel; chambers numerous, biserially arranged; lower one-third of test twisted about 90°; initial end bluntly rounded; coarsely perforate; last few chambers with retral processes; sutures depressed, curved downward; aperture an elongate slit on septal face bordered by faint lip.

Remarks - Differs from type specimens of true *S. tortuosa* in possessing more chambers, being more elongate, possessing retral processes and twisting in lower one-third of test whereas true *S. tortuosa* twists half-way up the test.

Genus SIGMOIDELLA

Sigmoidella plummerae
Cushman and Ozawa, 1930
Plate 4, figure 10

Sigmoidella plummerae Cushman and Ozawa, 1930, p. 142, pl. 39, figs. 3a, b.
Sigmoidella plummerae Cushman and Ozawa, Oman, 1965, p. 74, pl. 2, figs. 12a, b.

Genus SIGMOMORPHINA

Sigmomorphina sp. cf. S. pulchra Todd, 1952
Plate 4, figure 6

Sigmomorphina pulchra Todd, 1952, p. 20, pl, 3, fig. 13.
Sigmomorphina pulchra Todd, Copeland, 1964, p. 304, pl. 27, figs. 2a-c.

Remarks - Differs from *S. semitecta terquemiana* (Fornasini, 1900-1902) in being more elongate and more compressed, and in possessing a bluntly pointed initial end.

Sigmomorphina semitecta terquemiana
(Fornasini, 1900-1902)*
Plate 4, figures 7, 11

Polymorphina semitecta Reuss, 1844, p. 91, pl. 3, fig. 10.
Polymorphina amygdaloides Reuss, *terquemiana* Fornasini, 1900-1902, p. 72, fig. 25.

Remarks - The type specimens at the USNM are listed as *S. semitecta* var. *terquemiana* and not two separate species as Oman (1965) adopted. There is great variation in morphology among the types. This species is similar to S. cf. *S. pulchra* Todd, 1952; see that species for remarks.

Genus SIPHONINA

Siphonina danvillensis Howe and Wallace, 1932*
Plate 6, figures 12, 13

Siphonina danvillensis Howe and Wallace, 1932, p. 70, pl. 13, figs. 1a, b.
Siphonina danvillensis Howe and Wallace, Copeland, 1964, p. 310, pl. 33, figs. 1a-c.

Genus SIPHONODOSARIA

Siphonodosaria nuttali gracillima
(Cushman and Jarvis, 1934)
Plate 5, figure 2

Ellipsonodosaria nuttali gracillima Cushman and Jarvis, 1934, p. 72, pl. 10, fig. 7.
Siphonodosaria nuttali gracillima (Cushman and Jarvis), Copeland, 1964, p. 311, pl. 34, fig. 3.

Genus SPIRILLINA

Spirillina sp. A
Plate 6, figure 16

Diagnosis - Test planispiral, consisting of a spirally wound, undivided, tubular chamber following the proloculus; both sides concave; test wall fragile; aperture terminal, peripheral.

Genus TRIFARINA

Trifarina danvillensis (Howe and Wallace, 1932)*
Plate 5, figure 8

Angulogerina danvillensis Howe and Wallace, 1932, p. 56, pl. 12, fig. 2.
Angulogerina danvillensis Howe and Wallace, Bandy, 1949, p. 206, pl. 27, figs. 10a, b.

Trifarina parvaspinata (Copeland, 1964)*
Plate 5, figure 9
Angulogerina parvaspinata Copeland, 1964, p. 311, pl. 34, figs. 4a, b.

Trifarina wilcoxensis
(Cushman and Ponton, 1932)*
Plate 5, figure 10
Pseudouvigerina wilcoxensis Cushman and Ponton, 1932, p. 66, pl. 8, figs. 18a, b.
Trifarina wilcoxensis (Cushman and Ponton), Bandy, 1949, p. 207, pl. 27, figs. 11a, b.

Trifarina sp. A.*
Plate 5, figure 11
Diagnosis - Test elongate, triangular in section; surface very smooth; peripheral edges subacute, rounded; initial end pointed but rounded; aperture terminal, at end of short neck.

Genus UVIGERINA

Uvigerina cocoaensis Cushman, 1925e
Plate 5, figure 4
Uvigerina cocoaensis Cushman, 1925e, p. 68, pl. 10, fig. 12.
Uvigenina cocoaensis Cushman, Cushman, 1935, p. 76, pl. 15, figs. 11-13.

Uvigerina rippensis Cole, 1927 - U. gardnerae Cushman, 1935, species group*
Plate 5, figures 5, 6
Uvigerina rippensis Cole, 1927, p. 27, pl. 2, fig. 16.
Uvigerina gardnerae Cushman, 1935, p. 76, pl. 15, figs. 18, 19.
Uvigerina rippensis Cole - *U. gardnerae* Cushman species group, Charletta, 1980, p. 75, pl. 1, figs. 1-4.
Remarks - The concept of this species group follows Charletta (1980). Great variation in chamber arrangement and surface ornamentation occurs in specimens of this study.

Genus VAGINULINA

Vaginulina sp. A
Plate 3, figure 17
Diagnosis - Test elongate, rectilinear; chambers subglobular, inflated, subequant; inner peripheral margin nearly straight; outer peripheral margin lobulate; sutures straight, transverse, depressed; apertural neck short, oblique, aperture radiate.

Remarks - Differs from *V. legumen* (Linne) var. *elegans* d'Orbigny, 1846, in possessing subequant chambers and being rectilinear.

Genus VALVULINERIA

Valvulineria involuta
Cushman and Dusenbury, 1934
Plate 6, figures 5-7
Valvulineria involuta Cushman and Dusenbury, 1934, p. 63, pl. 8, fig. 12.
Valvulineria involuta Cushman and Dusenbury, McDougall, 1980, pl. 18, figs. 4, 7-11.
Remarks - The valvular flap is commonly not preserved.

Valvulineria texana Cushman and Ellisor, 1931*
Plate 6, figures 10, 11
Valvulineria texana Cushman and Ellisor, 1931, p. 56, pl. 7, figs. 9a-c.
Valvulineria texana Cushman and Ellisor, Copeland, 1964, p. 307, pl. 30, figs 4a-c.

Valvulineria sp. A.*
Plate 6, figures 8, 9
Diagnosis - Test trochospiral; dorsal side flattened; ventral side strongly convex, umbilicate; periphery broadly rounded, slightly lobulate; chambers closely appressed, increasing slowly in size, last chamber distinctly inflated; sutures radial on dorsal side, slightly curved, depressed slightly; aperture a low arch at base of apertural face extending from umbilicus to periphery under a thin valvular lip which partially covers umbilicus.
Remarks - Copeland (1964) misidentified this species as *Valvulineria (Gyroidinoides) octocamerata* (Cushman and Hanna, 1927). *Valvulinueria* sp. *A* differs from true *G. octocamerata* in being less convex ventrally, possessing an inflated, rounded final chamber and a larger valvular flap.

Genus WEBBINELLA

Webbinella sp. A
Plate 16, figures 11, 12
Diagnosis - Test attached, plano-convex, oval in outline, dorsal side strongly convex, with 2 or 3 poorly visible, strongly overlapping chambers arranged similar to a sigmoid series; sutures flush; ventral side flat, chambers barely visible; periphery sharp, keeled; no visible aperture.

Incertae sedis
Cibicidinae incertae sedis 1
Plate 16, figure 10
Diagnosis - Test large, discoidal, subcircular in outline, concavo-convex; periphery acute, not keeled; dorsal side slightly convex with chambers arranged in low trochospiral; ventral side convex, with about 4 or 5 large, peripheral chambers slightly inflated, curving inward and upward toward center of test creating a "hollowed-out" appearance; center portion with botryoidal ornamentation; no visible aperture.

Cibicidinae incertae sedis 2
Plate 16, figure 13

Diagnosis - Similar to Cibicidinae incertae sedis 1, but more circular in outline with chambers added in annular rings after early trochospiral portion.

SUPERFAMILY GLOBIGERINACEA

Genus ACARININA

Acarinina bullbrooki (Bolli, 1957)
Plate 7, figures 15-17

Globorotalia bullbrooki Bolli, 1957, p. 167-168, pl. 38, figs 4-6.
Globorotalia bullbrooki Bolli, Stainforth *et al.*, 1975, p. 174, fig. 40, no. 1a-c, 2a-c, 3-5.
Acarinina bullbrooki (Bolli), Benjamini, 1980, p. 338, pl. 2, figs. 11-14.

Acarinina sp. aff. A. pentacamerata (Subbotina, 1947)
Plate 7, figures 12-14

Globorotalia pentacamerata Subbotina, 1947, p. 128-129, pl. 7, figs 12-17, pl. 9, figs. 24-27.

Remarks - Juveniles of *A.* aff. *pentacamerata* are virtually indistinguishable from juvenile *Truncorotaloides rohri* and, in some cases, *T. topilensis.* The species differs from *A. pentacamerata* s.s. in being more tightly coiled and having 1 or 2 fewer chambers in the last whorl.

Acarinina sp. A
Plate 8, figures 1, 2

Diagnosis - This species tends to be small for the genus, consistently displaying four loosely-appressed, subglobose to subconical chambers in the last whorl; test coiled in a low trochospire; surface with numerous small pseudospines; aperture umbilical-extraumbilical.

Genus CASSIGERINELLA

Cassigerinella sp. aff. C. winniana (Howe, 1939)
Plate 11, figures 12-15, 15a

Cassigerinella winniana (Howe), Blow, 1979, pl. 246, figs. 8-10.

Remarks - Blow's (1979) figures of *C. winniana* are seemingly the same species found in this study; however, figures of the holotypes of *C. winniana* (figured in Steineck and Darrell, 1971) and the synonymous *C. eocaena* Cordey (1968) are significantly different from Blow's and this study's species of *Cassigerinella.* Thus, I define *Cassigerinella* sp. aff. *C. winniana,* that differs from *C. winniana* s.s. in its more well-developed initial planispiral coil and larger, more globular final chamber.

Genus CATAPSYDRAX

Catapsydrax perus (Todd, 1957)
Plate 9, figures 9, 10

Globigerina pera Todd, 1957, pl. 70, figs. 10, 11.
Catapsydrax perus (Todd), Fleisher, 1974, p. 1016, pl. 4, fig. 7.
Catapsydrax sp cf. *C. perus* (Todd), Benjamini, 1980, p. 342, pl. 4, figs. 14, 15

Genus CHILOGUEMBELINA

Chiloguembelina cubensis (Palmer, 1934)
Plate 11, figure 10

Gumbelina cubensis Palmer, 1934, p. 74, text-figs. 1-6.
Chiloguembelina cubensis (Palmer), Beckmann, 1957, p. 258, pl. 21, fig. 21a, b.
Chiloguembelina cubensis (Palmer), Fleisher, 1974, p. 1045, pl. 4, fig. 8.

Chiloguembelina martini (Pijpers, 1933)
Plate 11, figures 8, 9

Textularia martini Pijpers, 1933, p. 57, figs. 6-10.
Chiloguembelina martini (Pijpers), Beckmann, 1957, p. 89, text-figs. 14-18.

Remarks - This species is very similar in appearance to *C. mauriciana* (Howe and Roberts, *in* Howe, 1939), which, according to Oman (1965), may be a junior synonym of *C. martini.*

Genus GLOBIGERINATHEKA

Globigerinatheka index (Finlay) s.l.
Plate 11, figures 3, 4

Globigerinoides index Finlay, 1939, p. 125, pl. 14, figs. 85-88.
Globigerinatheka index s.l. (Finlay), Bolli, 1972, p. 117, text-figs. 67, 68.

Globigerinatheka mexicana barri (Bronnimann, 1952)
Plate 11, figures 5, 5a

Globigerinatheka barri Bronnimann, 1952, p. 27-28, fig. 1.
Globigerinatheka mexicana barri (Bronniman), Bolli, 1972, pl. 1, figs. 18-21; pl. 2, figs. 8-20; pl. 4, figs 1-6; p. 115, text-figs. 21-26.
Globigerinatheka barri Bronnimann, Stainforth *et al.*, 1975, p. 171, fig. 37, no. 1-6.

Globigerinatheka mexicana kugleri (Bolli, Loeblich, and Tappan, 1957)
Plate 11, figures 1, 2

Globigerapsis kugleri, 1957, Bolli, Loeblich, and Tappan, p. 34, pl. 6, fig. 6.
Globigerinatheka mexicana kugleri (Bolli, Loeblich, and Tappan), Bolli, 1972, pl. 2, figs. 6-7; p. 115, text-figs. 12-17.

Globigerinatheka kugleri (Bolli, Loeblich, and Tappan), Stainforth *et al.*, 1975, p. 198, fig. 59, no. 1a-c, 2, 3.

Globigerinatheka mexicana mexicana (Cushman, 1925b)
Plate 10, figure 16

Globigerina mexicana Cushman, 1925b, p. 6, pl. 1, fig. 8.
Globigerinatheka mexicana mexicana (Cushman), Bolli, 1972, pl. 2, figs. 1-5; pl. 4, figs. 1-6; p. 115, text-figs. 1-11.
Globigerinatheka mexicana (Cushman), Stainforth *et al.*, 1975, p. 206, fig. 67, no. 1-4a-d, 5, 6.

Genus GUEMBELITRIA

Guembelitria columbiana (Howe, 1939)
Plate 11, figure 11

Guembelitria columbiana Howe, 1939, p. 62, pl. 8, figs. 12-13.
Guembelitria columbiana Howe, Oman, 1965, p. 78, pl. 5, fig. 9.

Remarks - Oman (1965) reported this species from the Lisbon Formation of Alabama and considered it to be a megalospheric form, sexually dimorphic with the microspheric *Guembelitria stavensis* Bandy, 1949. *G. stavensis* has more chambers, and a smaller size resulting in a more elongate test than *G. columbiana.* Because *G. stavensis* seems to be junior synonym of *G. columbiana,* I adopt the latter name for specimens of this study.

Genus HANTKENINA

Hantkenina longispina Cushman, 1925a
Plate 11, figures 6, 7

Hantkenina longispina Cushman, 1925a, p. 2, pl. 2, fig. 4.
Hantkenina longispina Cushman, Stainforth *et al.*, 1975, p. 203, fig. 64, no. 1-6.

Remarks - Blow (1979) considered this species synonymous with *H. alabamensis* Cushman 1925, and cited its stratigraphical range as from the later part of Zone P12 to basal P17.

Genus MOROZOVELLA

Morozovella spinulosa (Cushman, 1927) s.l.
Plate 8, figures 10-12

Globorotalia spinulosa Cushman, 1927, p. 114, pl. 23, fig. 4.
Globorotalia spinulosa Cushman, Stainforth *et al.*, 1975, p. 231, fig 88, no. 1a-c, 2-6.
Morozovella spinulosa (Cushman), Benjamini, 1980, p. 341, pl. 3, figs. 18-22.

Morozovella lehneri (Cushman and Jarvis, 1929)
Plate 8, figures 13-15

Globorotalia lehneri Cushman and Jarvis, 1929, p. 17, pl. 3, fig. 16.
Globorotalia lehneri Cushman and Jarvis, Stainforth *et al.*, 1975, p. 199, fig. 60, no., 1a-c, 2a-b, 3-8.
Morozovella lehneri (Cushman and Jarvis), Ulrich, 1976, p. 73, pl. 2, figs. 3-4.

Genus PLANOROTALITES

Planorotalites renzi (Bolli, 1957)
Plate 10, figures 7, 9, 10

Globorotalia renzi Bolli, 1957, p. 168, pl. 38, figs. 3a-c.
Globorotalia (Planorotalites) renzi Bolli; Jenkins, 1971, p. 243, pl. 9, figs. 224-226.
Globorotalia renzi Bolli, Stainforth *et al.*, 1975, p. 223, fig. 81, no. 1-4a-c, 5.

Genus PSEUDOHASTIGERINA

Pseudohastigerina sharkriverensis Berggren and Olsson, 1967
Plate 10, figures 14, 15, 15a

Pseudohastigerina sharkriverensis Berggren and Olsson, 1967, p. 286, pl. 1, figs. 7-11; p. 273-274, text-figs. 7-8.

Remarks - This species is difficult to distinguish from *P. wilcoxensis* (Cushman and Ponton 1932) because both species can possess bipartite apertures. Fleisher (1974) had a similar problem in differentiating the two species. Berggren *et al.*, (1967) noted the closely similar morphologies of *P. sharkriverensis* and *P. wilcoxensis* and considered *P. sharkriverensis* to have evolved from *P. wilcoxensis.* Benjamini (1980) noted similar *Pseudohastigerina* morphotypes as identified in this study in Eocene deposits in Israel, but did not differentiate them stratigraphically.

Pseudohastigerina wilcoxensis (Cushman and Ponton, 1932) transitional with Pseudohastigerina micra (Cole, 1927)
Plate 10, figures 8, 11-13

Nonion micrus Cole, 1927, p. 22, pl. 5, fig. 12.
Pseudohastigerina micra (Cole), Stainforth *et al.*, 1975, p. 207, fig. 68, no. 1a-b, 2-5.
Pseudohastigerina wilcoxensis (Cushman and Ponton) transitional with *Pseudohastigerina micra* (Cole), Cordey, Berggren and Olsson, 1970, p. 241, figs. 7-26.

Remarks - This is the most abundant *Pseudohastigerina* morphotype found in this study. Specimens match well with Cordey *et al.* (1970) drawings of *P. wilcoxensis* transitional with *P. micra.*

Genus SUBBOTINA

Subbotina eocaena (Gumbel, 1868) s.l.
Plate 9, figures 1-6

Globigerina eocaena Gumbel, 1868, p. 662, pl. 2, fig. 109.
Globigerina eocaena Gumbel, Stainforth *et al.*, 1975, p. 271, fig. 115, no. 1a-c, -4a-c, 5-7.
Subbotina yeguaensis (Weinzierl and Applin), Benjamini, 1980, p. 342, pl. 4, figs. 1, 2, 6, 7, 10, 11.

Remarks - This is the most abundant planktic species in the samples of this study, displaying great variety in size and test morphology. The concept of this species I adopt follows closely that of Stainforth *et al.*, (1975) as one of the standard forms within the intergradational plexus of the *Globigerina (Subbotina) linaperta* Finlay, 1939, group, whereby *G. (S.) yeguaensis* Weinzierl and Applin, 1929, is considered a junior synonym of *G. (S.) eocaena.*

Subbotina galavisi (Bermudez, 1961)
Plate 9, figures 7, 8

Globigerina galavisi Bermudez, 1961, p. 1183, pl. 4, fig. 3.
Dentoglobigerina galavisi (Bermudez), Blow, 1979, pl. 16, figs. 4, 5.

Remarks - Found only in the Ideal Cement Company Quarry, sample IC-6, New Hanover County. Blow (1979) placed this species in *Dentoglobigerina.*

Subbotina linaperta (Finlay, 1939)
Plate 8, figures 16-18

Globigerina linaperta Finlay, 1939, p. 125, pl. 13, figs. 54-56.
Globigerina (Subbotina) linaperta Finlay, Jenkins, 1971, p. 261, pl. 18, figs. 551-554.
Globigerina linaperta Finlay, Stainforth *et al.*, 1975, p. 202, fig. 63, no. 1a-c, 2-5.

Genus TENUITELLA

Tenuitella aculeata (Jenkins, 1971)
Plate 10, figures 1-3

Globorotalia inconspicua aculeata Jenkins, 1966, p. 1118, fig. 13, no. 119-125.
Globorotalia (Turborotalia) aculeata Jenkins, 1971, p. 245, pl. 10, figs. 250-256.

Remarks - Specimens of *T. aculeata* from New Zealand Eocene deposits sent to me by G. Jenkins are identical to specimens from this study. This species is intergradational with *Testacarinata inconspicua* (Howe, 1939), which, according to Jenkins (1971) evolved from *Tenuitella aculeata* by developing a sharp, peripheral carina.

Genus TESTACARINATA

Testacarinata inconspicua (Howe, 1939)
Plate 10, figures 4-6

Globorotalia inconspicua Howe, 1939, p. 85, pl. 12, figs. 20-22.
Turborotalia inconspicua (Howe), Oman, 1965, p. 80, pl. 5, figs. 9, 10.
Globorotalia (Testacarinata) inconspicua Howe, Jenkins, 1971, p. 253, pl. 14, figs. 398-401.

Remarks - Specimens of *Testacarinata inconspicua* from New Zealand Eocene deposits sent to me by G. Jenkins are very similar to specimens from this study. New Zealand specimens tend to have 1 or 2 more chambers in the final whorl. This species is intergradational with *Tenuitella aculeata* (Jenkins, 1971) from which it probably evolved (Jenkins, 1971).

Testacarinata inconspicua is also similar in appearance to *Pararotalia* sp. *B.*, a benthic form, identified in this study. It differs from *P.* sp. *B.* in being plano-convex, smaller, and lacking the median ridge that extends outward as blunt spines on the periphery of chambers of the last whorl on *P.* sp. *B.* Well-preserved specimens of *P.* sp. *B.* also have umbonal plugs and comma-shaped apertures located high on the apertural face of the last chamber which *Testacarinata inconspicua* lacks. In North Carolina, *T. inconspicua* seems restricted to, and is a good marker of, middle Eocene age in core material that lacks large, well-developed middle Eocene planktic foraminifers of other genera.

Turborotalia cerroazulensis frontosa
(Subbotina, 1953)
Plate 9, figures 11-13

Globigerina frontosa Subbotina, 1953, p. 84, pl. 12, figs. 3-7.
Globorotalia cerroazulensis frontosa (Subbotina), Toumarkine and Bolli, 1970, p. 139, pl. 1, figs. 1-3.
Globigerina frontosa Subbotina, Stainforth et al., 1975, p. 188, fig. 51, no. 1-3, 4a-c, 5a-c, 6-10.
Turborotalia cerroazulensis frontosa (Subbotina), Benjamini, 1980, p. 345, pl. 5, figs. 10-13.

Remarks - Blow (1979) reported a range of P10-P11 for subspecies *T. frontosa frontosa* and *T. frontosa boweri* that are essentially equivalent to my definition of this subspecies. Stainforth et al., (1975) reported a range of P9-P12 for *Globigerina frontosa.* The top of zone P12 is accepted as the uppermost range of *T. cerroazulensis frontosa* in this study.

Turborotalia cerroazulensis pomeroli
(Toumarkine and Bolli, 1970)
Plate 9, figures 14-16

Globorotalia cerroazulensis pomeroli Toumarkine and Bolli, 1970, p. 140, pl. 1, figs. 10-18; p. 143, pl. 2, figs. 1-2, 11-19.
Globorotalia cerroazulensis pomeroli Toumarkine and Bolli, Stainforth et al., 1975, p. 260, fig. 109, no. 1-9, 10a-c.
Turborotalia cerroazulensis pomeroli (Toumarkine and Bolli), Benjamini, 1980, p. 345, pl. 5, figs. 17-20.

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PLATES

NOTE ON PLATES

All benthic and planktic foraminifera were photographed with a Cambridge 150 Model scanning electron microscope (SEM). For most planktic species, three orientations (dorsal, ventral, and axial) are illustrated. In general, fewer orientations of benthic species are presented owing to space limitations; however, the essential characteristics of each species are illustrated. Scale bar equals 0.1 mm (1000 um) except where indicated. Specimens illustrated may be considered "average" or "typical" size for the species as observed in the Eocene section studied.

Because specimens illustrated were prepared with silver paint for the SEM, removal of the paint would result in destruction of most specimens. Therefore, specimens illustrated were not selected as types (hypotypes). Instead, specimens not illustrated but representative of the species (homeotypes) were deposited in the Cushman Collection, National Museum of Natural History, under the USNM number (= catalog number of former U. S. National Museum) listed for each species.

PLATE 1

Figs. 1, 2 - *Spiroplectammina angulomarginata* Copeland.
Sample PC-3, Pender County. 1, side view, x 91; 2, side view, elongate variety, x 35. USNM 319901.

3 - *Spiroplectammina natchitochensis* Howe.
Sample 17, Duplin County, side view, x 95. USNM 319902.

4 - *Textularia cuyleri* Davis s.l.
Sample 17, Duplin County, side view, x 89. USNM 319903.

5 - *Textularia dibollensis* Cushman and Applin.
Sample ON3 - 2, Onslow County, side view, x 65. USNM 319904.

6 - *Textulariina* incertae sedis 1.
Sample PC-3, Pender County, side view, x 77. USNM 319905.

7, 8 - *Textularia* sp. A.
7, sample PC-3, Pender County, side view, x 22; 8, Chinquapin Branch, Jones County, edge view, showing acute peripheral margin, x 26. USNM 319906.

9 - *Textularia* sp. B.
Chinquapin Branch, Jones County, side view, x 26. USNM 319907.

10 - *Textularia* sp. C.
Sample PC-3, Pender County, side view, x 66. USNM 319908.

11 - *Textularia adalta* Cushman.
Sample PC-3, Pender County, side view, x 25. USNM 319909.

12, 18 - *Quinqueloculina* sp. A.
Sample FUS-1, Duplin County. 12, side view, etched specimen, x 83; 18, opposite side view, x 83. USNM 319910.

13, 14 - *Gaudryina* sp. aff *G. pyramidata* Cushman.
Sample 19, Duplin County. 13, apertural view, x 83; 14, side view, x 57. USNM 319911.

15 - *Textularia* sp. E.
Sample ON3-2, Onslow County, side view, x 35. USNM 319912.

16, 17 - *Siphotextularia breviforma* Copeland
16, sample 17, Duplin County, side view, x 67; 17, sample PC-3, Pender County, edge view, showing siphonate aperture, x 43. USNM 319913.

19, 23 - *Textularia* sp. D.
Core CR-C3-79, 66 ft 2 in, Craven County. 19, side view, x 146; 23, apertural view, x 141. USNM 319914.

20 - *Textulariina* incertae sedis 2
Sample IC-2, New Hanover County, side view, x 101. USNM 319915.

21 - *Textulariina* incertae sedis 3
Sample IC-5, New Hanover County, side view, x 94. USNM 319916.

22 - *Textularia eyrei* Finlay
Sample IC-2, New Hanover County, side view, x 33. USNM 319917.

24, 25 - *Guadryina jacksonensis* Cushman.
Sample IC-3, New Hanover County. 24, apertural view, x 30; 25, side view, x 14. Bar equals 0.2 mm. USNM 319918.

26 - *Quinqueloculina* sp. B.
Sample ALC-4, Duplin County, side view, x 77. USNM 319919.

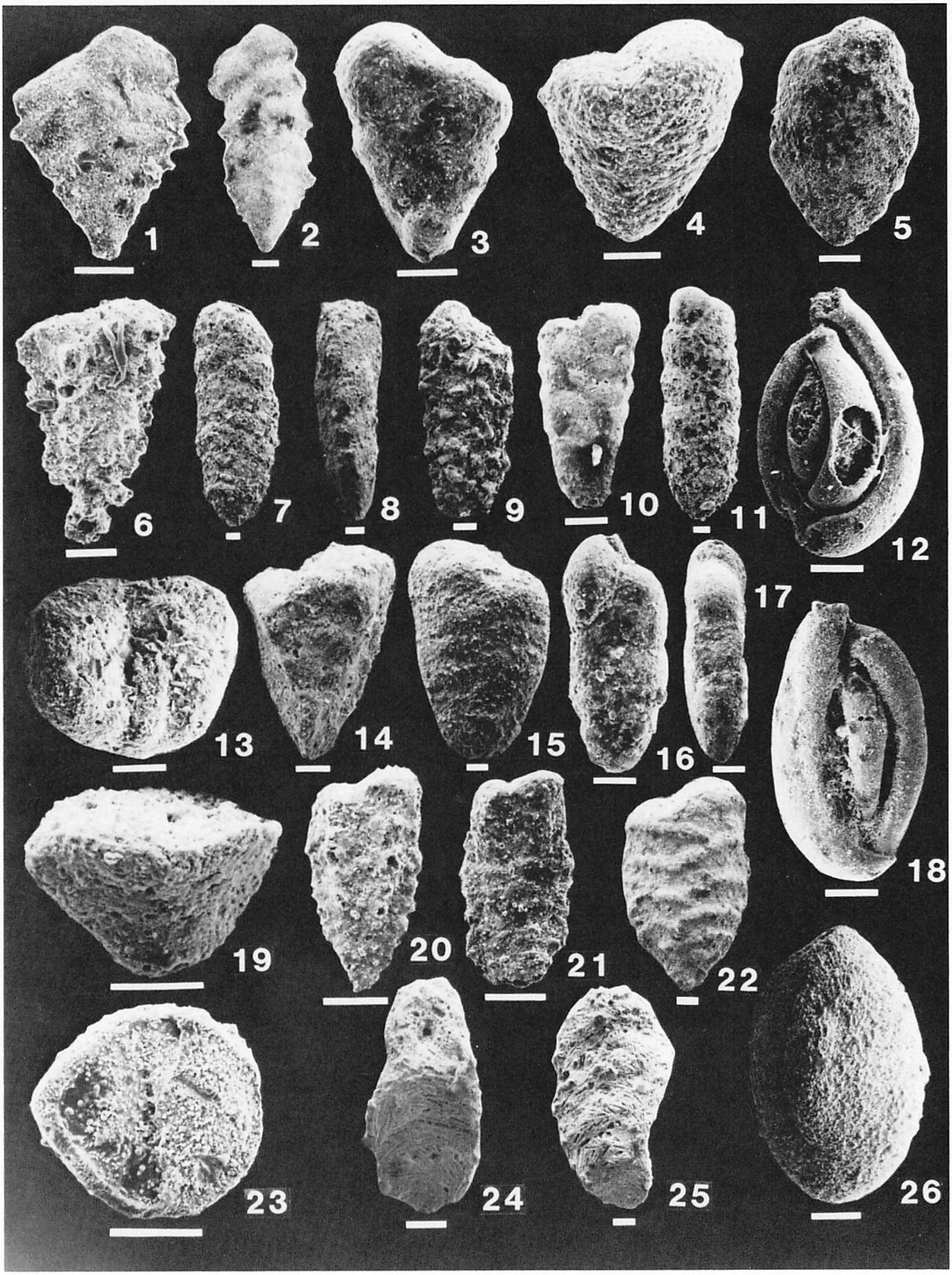


PLATE 1

PLATE 2

Fig. 1 - *Quinqueloculina* sp. C.
MM Ward Core, 59 ft, Craven County, side view, x 123. USNM 319920.

2 - *Lagena protea* Chaster.
Sample PC-3, Pender County, side view, x 79. USNM 319921.

3 - *Lagena orbignyana semiconcentrica* Cushman
Sample CHMM-1, New Hanover County, side view, x 66. USNM 319922.

4 - *Lagena sulcata spirata* Bandy.
Sample CHMM-3, New Hanover County, side view, x 88. USNM 319923.

5 - *Lagena howei* Bergquist.
Sample IC-5, New Hanover County, side view, x 83. USNM 319924.

6 - *Nodosaria magnoliaensis* Copeland.
Sample 17, Duplin County, side view, x 47. USNM 319925.

7 - *Nodosaria latejugata* Gümbel.
Sample IC-6, New Hanover County, side view, x 35. USNM 319926.

8 - *Dentalina soluta* Reuss.
Sample 23, Duplin County, side view, x 54. USNM 319927.

9, 10 - *Dentalina jacksonensis* (Cushman and Applin)
9, sample PC-3, Pender County, side view, showing loosely appressed chambers, x33,; 10, sample 23, Duplin County, side view of curved variety with numerous chambers, x 30. USNM 319928.

11 - *Dentalina nasuta* Cushman.
Sample IC-3, New Hanover County, side view, x 54. USNM 319929.

12 - *Dentalina budensis* Hantken.
Sample IC-6, New Hanover County, side view, x 16. Bar equals 0.2 mm. USNM 319930.

13 - *Nodosaria longiscata* d'Orbigny.
Sample IC-5, New Hanover County, side view, x 24. USNM 319931.

14 - *Dentalina vertebralis albatrossi* (Cushman).
Sample IC-6, New Hanover County, side view of broken specimen, x 14. Bar equals 0.2 mm. USNM 319932.

15 - *Dentalina* sp. A.
Sample IC-5, New Hanover County, side view, x 35. USNM 319933.

16 - *Nodosaria* sp.aff. *N. radicula* (Linnaeus).
Sample IC-6, New Hanover County, side view, x 132. USNM 319934.

17 - *Astacolus magnoliaensis* Copeland.
Sample 17, Duplin County, side view, x 89. USNM 319935.

18 - *Lagena globosa* (Montagu) s.l.
Sample CHMM-1, New Hanover County, side view, x 132. USNM 319936.

19 - *Lagena fenestrissima* Howe and Ellis.
Sample 17, Duplin County, side view, x 75. USNM 319937.

20 - *Lagena ouachitaensis* Howe and Wallace.
Sample 23, Duplin County, side view, x 123. USNM 319938.

21 - *Lagena altahumerifera* Copeland.
Superior Quarry Core, 10 ft 8 in - 12 ft 2 in, New Hanover County, side view, x 112. USNM 319939.

22 - *Lagena multicostata* Copeland.
Sample 17, Duplin County, side view, x 112. USNM 319940.

23 - *Lagena laevis* (Montagu).
Sample PC-3, Pender County, side view, x 72. USNM 319941.

24 - *Lagena torsicostata* Copeland.
Sample 17, Duplin County, side view, x 91. USNM 319942.

25 - *Lagena wallacei* Bandy.
Sample CHMM-3, New Hanover County, side view, x 104. USNM 319943.

26 - *Lankesterina nuda* (Howe and Roberts).
Sample RL-1A, Craven County, side view, x 77. USNM 319944.

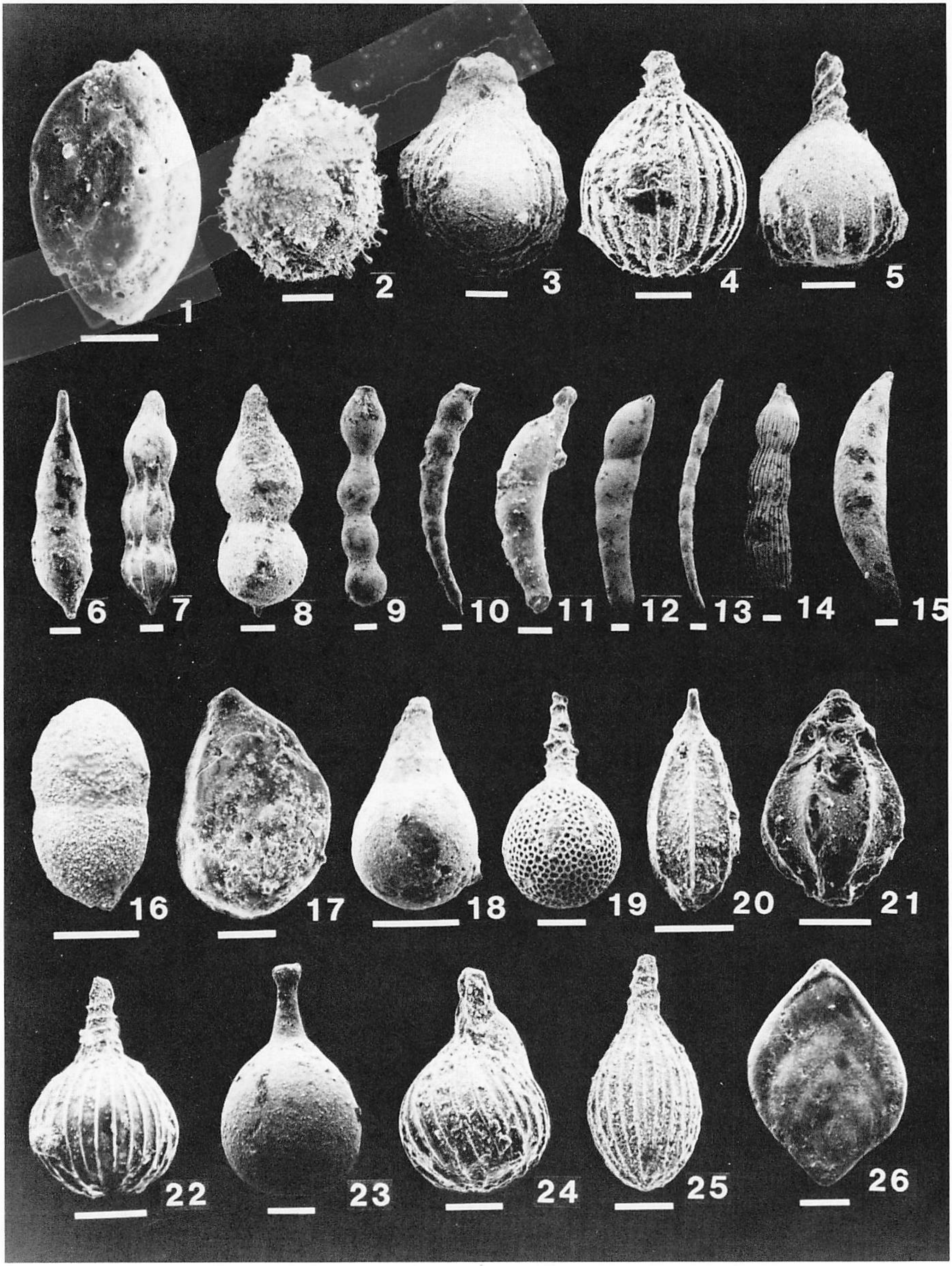


PLATE 2

PLATE 3

Figs. 1, 1a - *Lagena* sp. B.
1, Chinquapin Branch, Jones County, side view, x 93; 1a, sample IC-3, New Hanover County, apical view, showing projecting spines, x 252. USNM 319945.

2, 2a - *Lagena* sp. A.
Sample PC-3, Pender County. 2, side view, x 88; 2a, apical view, showing basal ring, x 208. USNM 319946.

3 - *Lenticulina alato-limbatus* (Gümbel).
Sample SS-3, Jones County, side view, x 43. USNM 319947.

4 - *Lenticulina* sp. cf. *L. clericii* (Fornasini).
Sample IC-5, New Hanover County, side view, bar equals 0.2 mm, x 19. USNM 319948.

5 - *Lenticulina* sp. cf. *L. convergens* (Bornemann).
Superior Quarry core, 10 ft 8 in - 12 ft 2 in, New Hanover County, side view, x 87. USNM 319949.

6 - *Lenticulina deformis* (Reuss).
Chinquapin Branch, Jones County, side view, x 62. USNM 319950.

7 - *Lenticulina* sp. cf. *L. mayi* (Cushman and Parker).
Sample IC-3, New Hanover County, side view, x 67. USNM 319951.

8 - *Lenticulina jugosis* (Cushman and Thomas)
Superior quarry core, 12 ft 2 in - 13 ft 8 in, New Hanover County, side view, x 102. USNM 319952.

9 - *Lenticulina brantlyi* (Garrett).
Sample 11, Jones County, side view, x 39. USNM 319953.

10 - *Lenticulina ovalis* (Reuss).
Sample CHMM-1, New Hanover County, side view, x 123. USNM 319954.

11 - *Lenticulina* sp. cf. *L. propinquus* (Hantken).
Superior Quarry core, 9 ft 2 in - 10 ft 8 in, New Hanover County, side view, x 114. USNM 319955.

12 - *Planularia* sp. cf. *P. georgiana* Cushman and Herrick. Sample IC-6, New Hanover County, side view, x 63. USNM 319956.

13 - *Planularia ouachitaensis* Howe and Wallace.
Sample PC-3, Pender County, side view, x 33. USNM 319957.

14 - *Marginulina moodysensis* Cushman and Todd.
Sample 17, Duplin County, side view, x 58. USNM 319958.

15 - *Marginulina triangularis danvillensis* Howe and Wallace.
Sample IC-6, New Hanover County, side view, x 46. USNM 319959.

16 - *Marginulina winniana* Howe.
Sample 17, Duplin County, side view, x 77. USNM 319960.

17 - *Vaginulina* sp. A.
Sample 17, Duplin County, side view, x 90. USNM 319961.

18 - *Pseudonodosaria laevigata* (d'Orbigny).
Sample IC-5, New Hanover County, side view, x 62. USNM 319962.

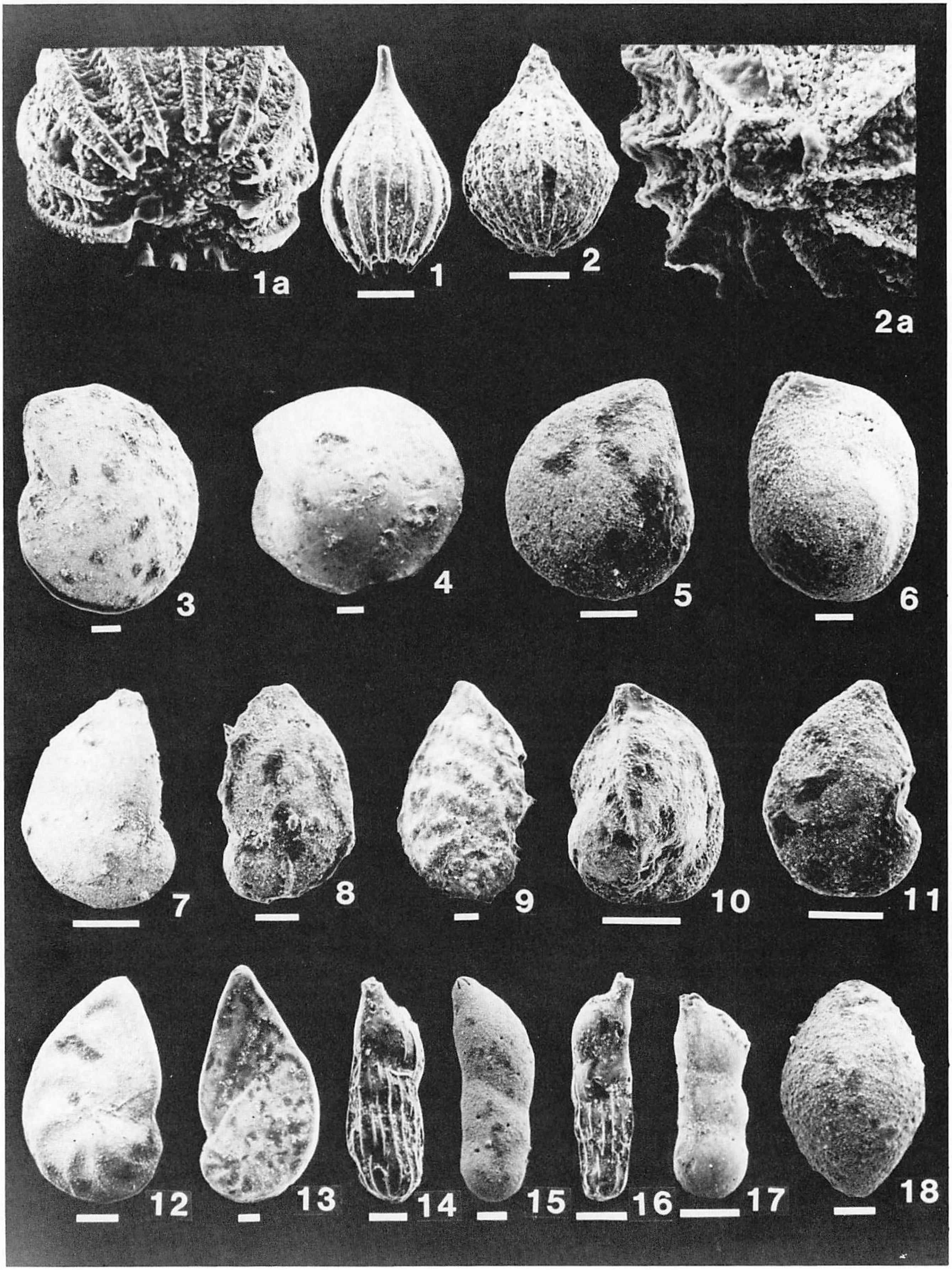


PLATE 3

PLATE 4

Fig. 1 - *Saracenaria moresiana* Howe and Wallace.
Chinquapin Branch, Jones County, side view, x 65. USNM 319963.

2 - *Lingulinopsis* sp. A.
Sample IC-3, New Hanover County, side view, x 39. USNM 319964.

3 - *Saracenaria* sp. A.
Core DUP-C1-80, 170 ft 6 in - 175 ft 6 in, Duplin County, oblique view, x 91. USNM 319965.

4, 8 - *Globulina gibba* d'Orbigny s.l.
4, core CR-C3-79, 66 ft 2 in, Craven County, side view, x 94; 8, sample CHMM-1, New Hanover County, side view, fistulose variety, x 115. USNM 319966.

5 - *Guttulina communis* (d'Orbigny) s.l.
Well CR-A40-62, 80 ft - 85 ft, Craven County, side view, x 87. USNM 319967.

6 - *Sigmomorphina* sp. cf. *S. pulchra* Todd.
Core CR-C2-79, 68 ft 10 in, Craven County, side view, x 83. USNM 319968.

7, 11 - *Sigmomorphina semitecta terquemiana* (Fornasini).
7, Superior quarry core, 6 ft 2 in - 7 ft 8 in, New Hanover County, side view, x 94; 11, sample IC-6, New Hanover County, side view, fistulose variety, x 39. USNM 319969.

9 - *Guttulina hantkeni* Cushman and Ozawa.
Sample IC-5, New Hanover County, side view, x 89. USNM 319970.

10 - *Sigmoidella plummerae* Cushman and Ozawa.
Sample TRC-1, Craven County, side view, x 31. USNM 319971.

12 - *Ramulina globulifera* Brady.
Sample IC-5, New Hanover County, side view, x 48. USNM 319972.

13 - *Oolina morsei* (Kline).
Sample 17, Duplin County, side view, x 125. USNM 319973.

14 - *Fissurina howei* (Cushman and Todd).
Sample PC-3, Pender County, side view, x 76. USNM 319974.

15 - *Fissurina* sp. A.
Core PEN-C1-80, 68 ft, Pender County, side view, x 180. USNM 319975.

16, 17 - *Fissurina* sp. B.
Well CR-A44-62, 110-115 ft, Craven County. 16, side view, x 110; 17, apertural view, x 201. USNM 319976.

18 - *Buliminella elegantissima* (d'Orbigny).
Core CR-C1A-79, 120 ft, Craven County, apertural view, x 171. USNM 319977.

19 - *Brizalina broussardi* (Howe and Roberts)
Core DUP-C1-80, 170 ft 6 in - 175 ft 6 in, Duplin County, side view, x 180. USNM 319978.

20 - *Brizalina striatellata* (Cushman and Applin, emend. Bandy).
Core CR-C1A-79, 118 ft 1 in, Craven County, side view, x 119. USNM 319979.

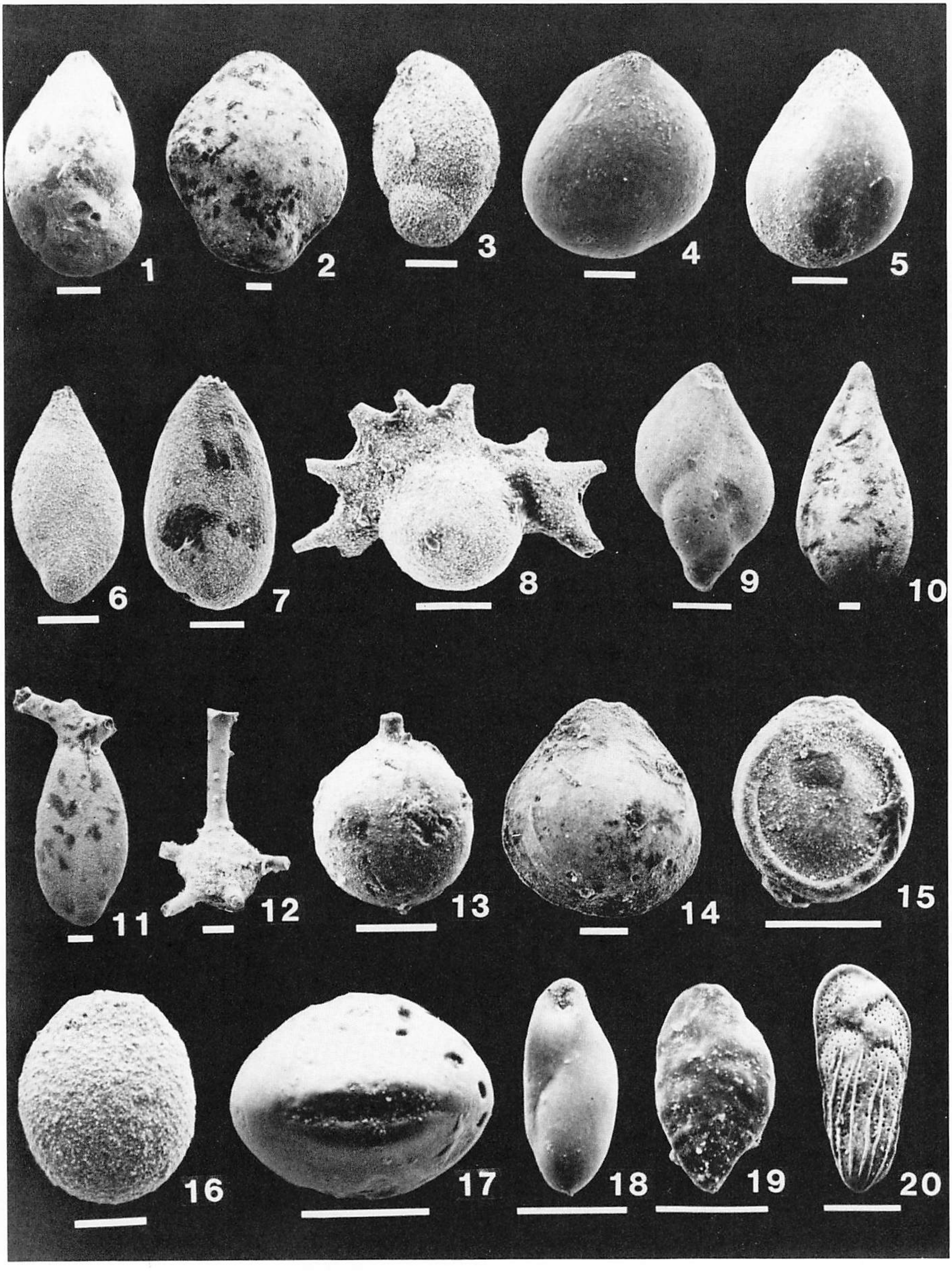


PLATE 4

PLATE 5

Fig. 1 - *Bulimina* sp. A.
Core CR-C1A-79, 120 ft, Craven County, apertural view, x 189. USNM 319980.

2 - *Siphonodosaria nuttali gracillima* (Cushman and Jarvis).
Sample IC-4, New Hanover County, side view, x 32. USNM 319981.

3 - *Bulimina cooperensis* Cushman.
Sample CHMM-1, New Hanover County, apertural view, aperture filled with calcite, x 75. USNM 319982.

4 - *Uvigerina cocoaensis* Cushman.
Sample SS-3, Jones County, side view, x 66. USNM 319983.

5, 6 - *Uvigerina rippensis* Cole - *U. gardnerae* Cushman species group.
5, sample CHMM-1, New Hanover County, side view, hispido-costate variety, x 67; 6, core ON-C4-79, 285 ft, Onslow County, side view, costate variety, x 84. USNM 319984.

7 - *Kolesnikovella elongata* (Halkyard).
Sample IC-3, New Hanover County, side view, x 124. USNM 319985.

8 - *Trifarina danvillensis* (Howe and Wallace).
Sample RL-1A, Craven County, side view, x 87. USNM 319986.

9 - *Trifarina parvaspinata* (Copeland).
Sample PC-3, Pender County, side view, x 90. USNM 319987.

10 - *Trifarina wilcoxensis* (Cushman and Ponton).
Sample IC-6, New Hanover County, side view, x 83. USNM 319988.

11 - *Trifarina* sp. A.
MM Ward core, 59 ft, Craven County, side view, x 144. USNM 319989.

12, 13 - *Caucasina* sp. A.
Newton Grove outlier, Sampson County. 12, apertural view, x 220; 13, opposite side view, x 223. Bar equals 0.05 mm. USNM 319990.

14, 15 - *Eoeponidella hemisphaericus* (Cushman).
Sample NBQ-1, Craven County. 14, dorsal view, x 146; 15, ventral view, x 139. USNM 319991.

16, 17 - *Rosalina assulata* (Cushman).
16, sample IC-3, New Hanover County, dorsal view, x 62; 17, sample IC-4, New Hanover County, ventral view, x 88. USNM 319992.

18, 19 - *Rosalina* sp. aff. *R. assulata* (Cushman).
Sample SS-3, Jones County. 18, dorsal view, x 58; 19, ventral view, x 72. USNM 319993.

20, 21 - *Rosalina* sp. aff. *R. havanensis* (Cushman and Bermudez).
Sample IC-6, New Hanover County. 20, dorsal view, x 32; 21, ventral view, x 40. USNM 319994.

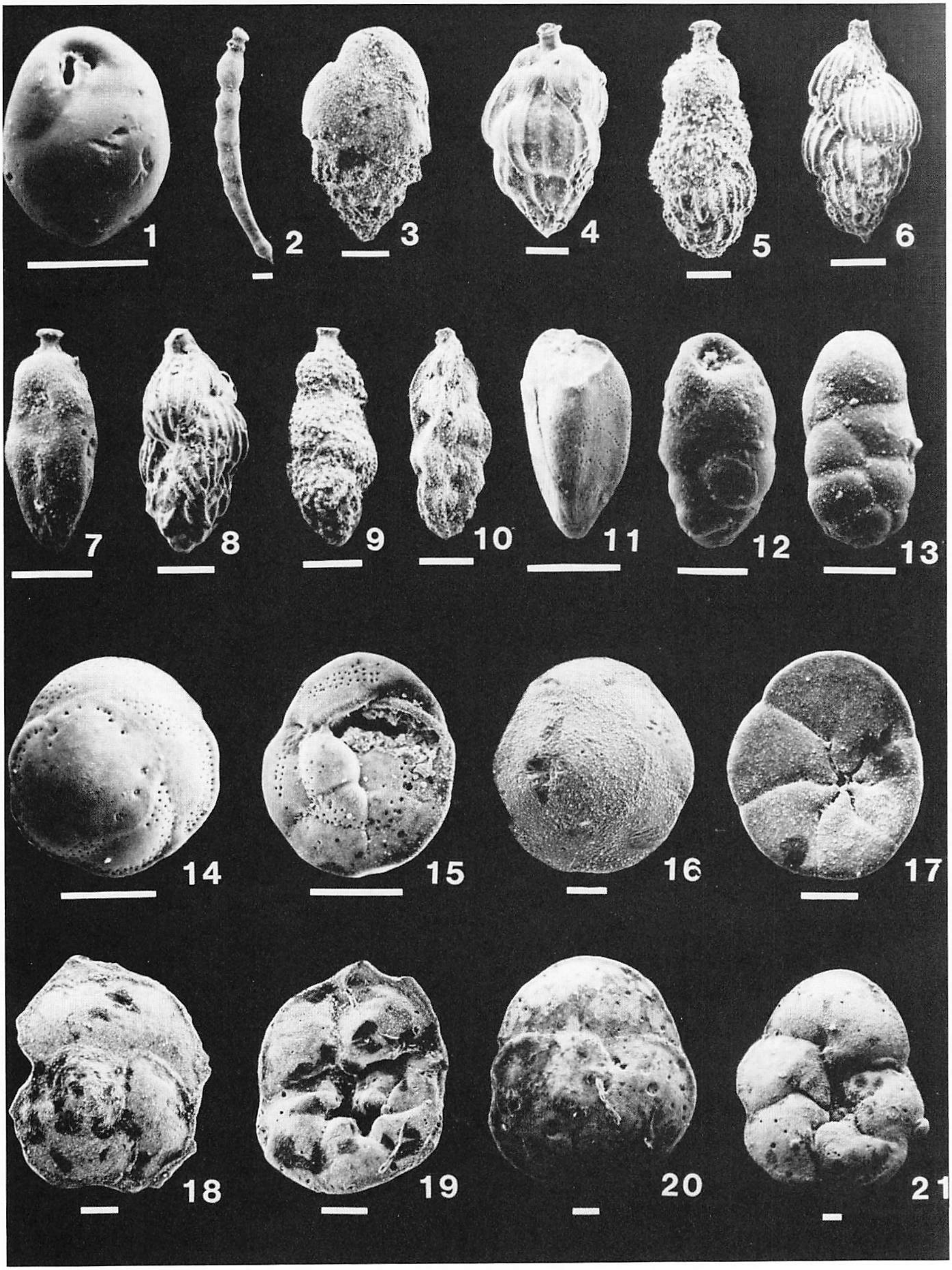


PLATE 5

PLATE 6

Figs. 1, 2 - *Cancris claibornensis* Howe.
1, core DUP-C1-80, 170 ft 6 in - 175 ft 6 in, Duplin County, dorsal view, x 76; 2, well BEA-T-38, 99-100 ft, Beaufort County, ventral view, x 87. USNM 319995.

3, 4 - *Cancris involutus* Copeland.
3, Goldsboro, Wayne County, dorsal view, x 70; 4, well CR-A40-62, 80-85 ft, Craven County, ventral view, x 52. USNM 319996.

5, 6, 7 - *Valvulineria involuta* Cushman and Dusenbury.
5, sample NR-3, Wayne County, dorsal view, x 77; 6, sample NR-3, Wayne County, ventral view, x 76; 7, Newton Grove Outlier, Sampson County, apertural view, x 101. USNM 319997.

8, 9 - *Valvulineria* sp. A.
Sample 17, Duplin County. 8, dorsal view, x 110; 9, ventral view, x 119. USNM 319998.

10, 11 - *Valvulineria texana* Cushman and Ellisor.
10, Sample 17, Duplin County, ventral view, x 112; 11, sample RL-1A, Craven County, dorsal view, x 134. USNM 319999.

12, 13 - *Siphonina danvillensis* Howe and Wallace.
12, well BEA-T-38, 99-100 ft, Beaufort County, dorsal view, x 74; 13, sample IC-5, New Hanover County, ventral view, x 83. USNM 320000.

14, 15 - *Asterigerina texana chattahoocheensis* Oman.
14, well BEA-T-38, 98-99 ft, Beaufort County, dorsal view, x 93; 15, well CR-A40-62, 110-115 ft, Craven County, ventral view, x 74. USNM 320001.

16 - *Spirillina* sp. A.
Core DUP-C1-80, 170 ft 6 in - 175 ft 6 in, Duplin County, side view, x 179. USNM 320002.

17 - *Pattelina?* sp. A.
Sample IC-4, New Hanover County, dorsal view, x 153. USNM 320003.

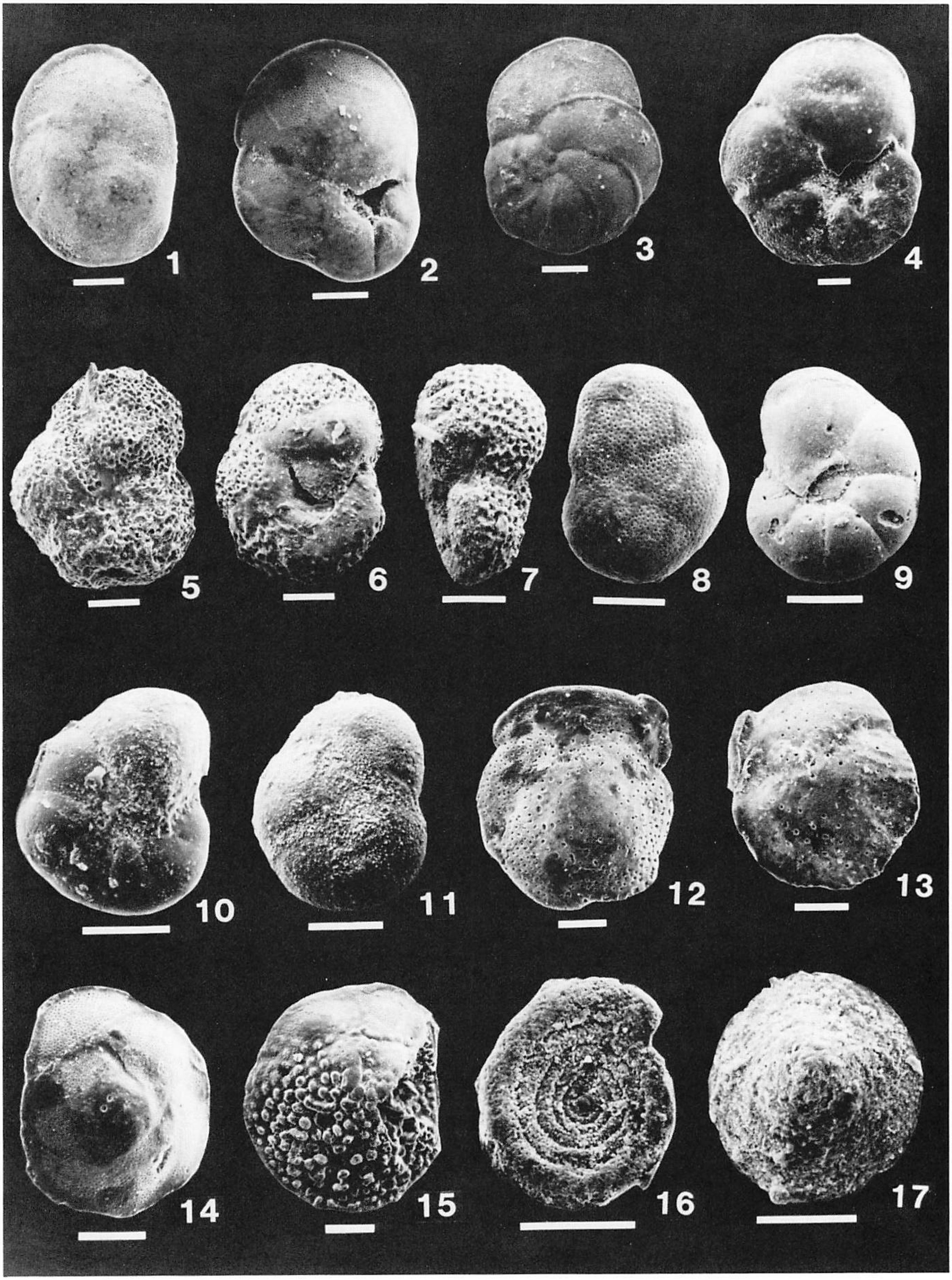


PLATE 6

PLATE 7

Figs. 1,2,3 - *Pararotalia?* sp. A.
Sample NR-3, Wayne County. 1, dorsal view, x 145; 2, ventral view, x 102; 3, apertural view, x 110. USNM 320004.

4, 5, 6, 7 - *Pararotalia* sp. B.
Sample ALC-4, Duplin County. 4, dorsal view, x 125; 5, apertural view, x 110; 6, ventral view, showing umbonal plug, x 102; 7, oblique apertural view, x 113. USNM 320005.

8, 9 - *Cribononion advenum* (Cushman).
8, sample 13, Jones County, side view, x 119; 9, core CR-C1A-79, 118 ft 1 in, Craven County, apertural view, x 127. USNM 320006.

10, 11, 11a - *Cribrononion rolshauseni* (Bandy).
Core JON-C5A-79, 26 ft 4 in, Jones County. 10, side view, x 58; 11, apertural view, x 70; 11a, close-up apertural view, showing multiple apertures, x 238. USNM 320007.

12, 13, 14 - *Acarinina* sp. aff. *A. pentacamerata* (Subbotina).
12, sample IC-6, New Hanover County, spiral view, x 123; 13, well BEA-T-38, 98-99 ft, Beaufort County, edge view, x 96; 14, sample IC-6, New Hanover County, umbilical view, x 113. USNM 320008.

15, 16, 17 - *Acarinina bullbrooki* (Bolli).
Core CR-C@-79, 57 ft 8 in, Craven County. 15, spiral view, x 130; 16, umbilical view, x 134; 17, edge view, x 127. USNM 320009.

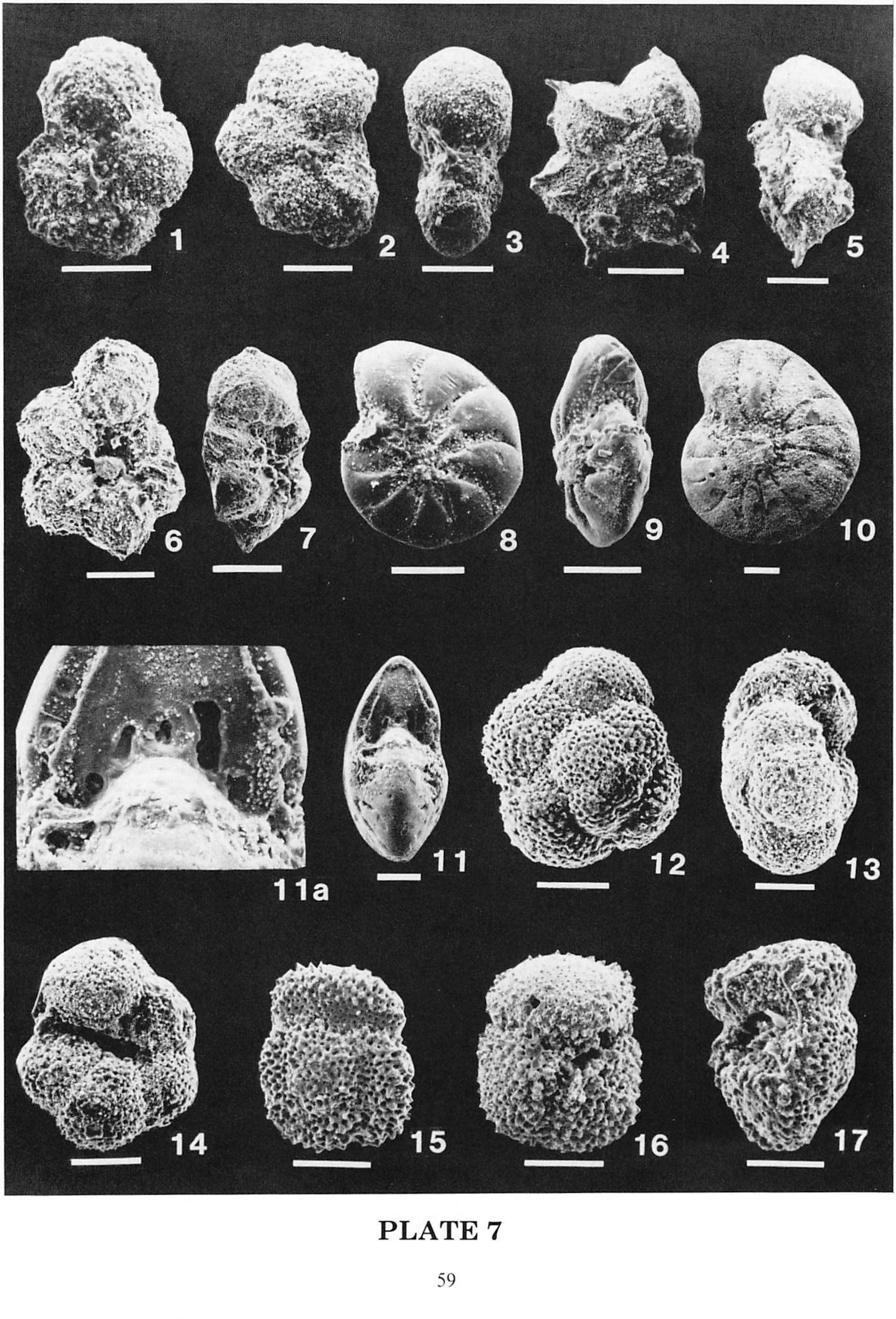


PLATE 7

PLATE 8

Figs. 1, 2 - *Acarinina* sp. A.
Well BEA—T—38, 98-99 ft, Beaufort County. 1, spiral view, x 128; 2, umbilical view, x 123. USNM 320010.

3, 4, 5, 6 - *Truncorotaloides topilensis* (Cushman).
3, well CR-A40-62, 80-85 ft, Craven County, spiral view, x 85; 4, well CR-A40-62, 80-85 ft, Craven County, close-up spiral view, showing supplementary sutural aperture, x 208; 5, well BEA-T-38, 98-99 ft, Beaufort County, umbilical view, x 72; 6, well BEA-T-38, 98-99 ft, edge view, x 119. USNM 320011.

7, 8, 9 - *Truncorotaloides rohri* Bronnimann and Bermudez.
7, sample IC-2, New Hanover County, spiral view, x 117; 8, core CR-C3-79, 67 ft 2 in, Craven County, umbilical view, x 119; 9, William and Mary Motel well, 13-15 ft, Sampson County, edge view, x 139. USNM 320012.

10, 11-12 - *Morozovella spinulosa* (Cushman) s.l.
10, well CR-A40-62, 115-116 ft, Craven County, spiral view, x 82; 11, Neuse River Stop 1, Craven County, umbilical view, x 101; 12, well CR-A40-62, 80-85 ft, Craven County, edge view, x96. USNM 320013.

13, 14, 15 - *Morozovella lehneri* (Cushman and Jarvis).
13, well BEA-T-38, 95 ft 9 in, Beaufort County, spiral view, x 89; 14, Newton Grove outlier, Sampson County, umbilical view, x 120; 15, well BEA-T-38, 95 ft 9 in - 96 ft 4 in, Beaufort County, edge view, x 92. USNM 320014.

16, 17, 18 - *Subbotina linaperta* (Finlay).
16, William and Mary Motel well, 27-48 ft, Sampson County, spiral view, x 182; 17, Newton Grove outlier, Sampson County, umbilical view, x 127; 18, well BEA-T-38, 98-99 ft, Beaufort County, edge view, x 138. USNM 320015.

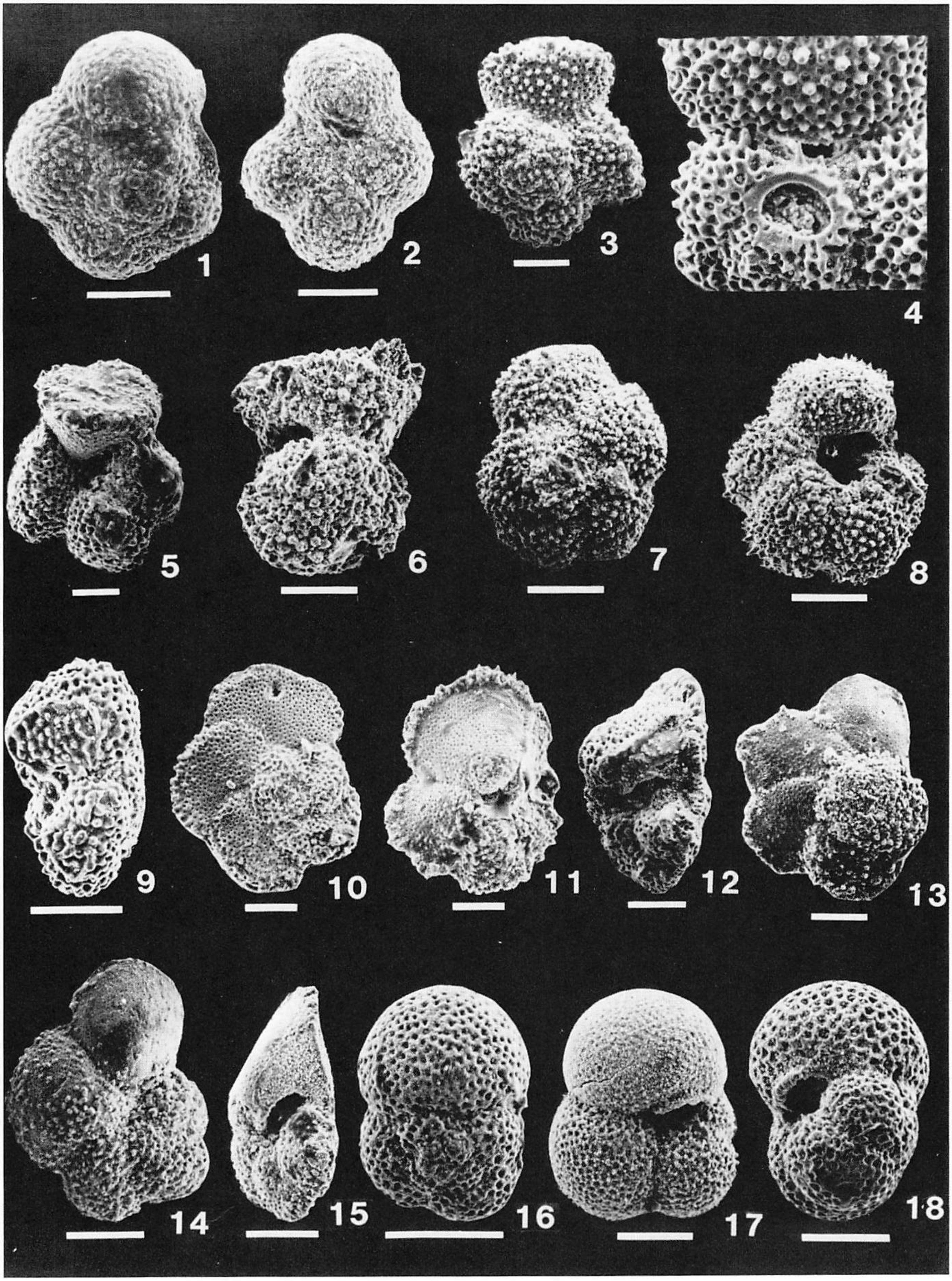


PLATE 8

PLATE 9

Figs. 1,2,3 - *Subbotina eocaena* (Gümbel) s.l.
1, well BEA-T-38, 98-99 ft, Beaufort County; spiral view, x 119; 2, sample IC-6, New Hanover County, umbilical view, x 127; 3, sample IC-2, New Hanover County, edge view, x 90. USNM 320016.

4, 5, 6 - *Subbotina eocaena* (Gümbel) s.l., loosely appressed variety.
Core CR-C3-79, 48 ft 6 in - 53 ft 6 in, Craven County. 4, umbilical view, x 101; 5, spiral view, x 107; 6, edge view, x 112. USNM 320017.

7, 8 - *Subbotina galavisi* (Bermudez).
Sample IC-6, New Hanover County. 7, spiral view, x 102; 8, umbilical view, x 94. USNM 320018.

9, 10 - *Catapsydrax perus* (Todd).
9, sample IC-6, New Hanover County, spiral view, x 114; 10, sample IC-2, New Hanover County, apertural view, x 126. USNM 320019.

11, 12, 13 - *Turborotalia cerroazulensis frontosa* (Subbotina).
11, sample IC-6, New Hanover County, spiral view, x 91; 12, core JON-C5-79, 26 ft 6 in, Jones County, umbilical view, x 141; 13, core CR-C3-79, 67 ft 2 in, Craven County, edge view, x 112. USNM 320020.

14, 15, 16 - *Turborotalia cerroazulensis pomeroli* (Toumarkine and Bolli).
Sample IC-6, New Hanover County. 14, spiral view, x 91; 15, edge view, x 136; 16, umbilical view, x 97. USNM 320021.

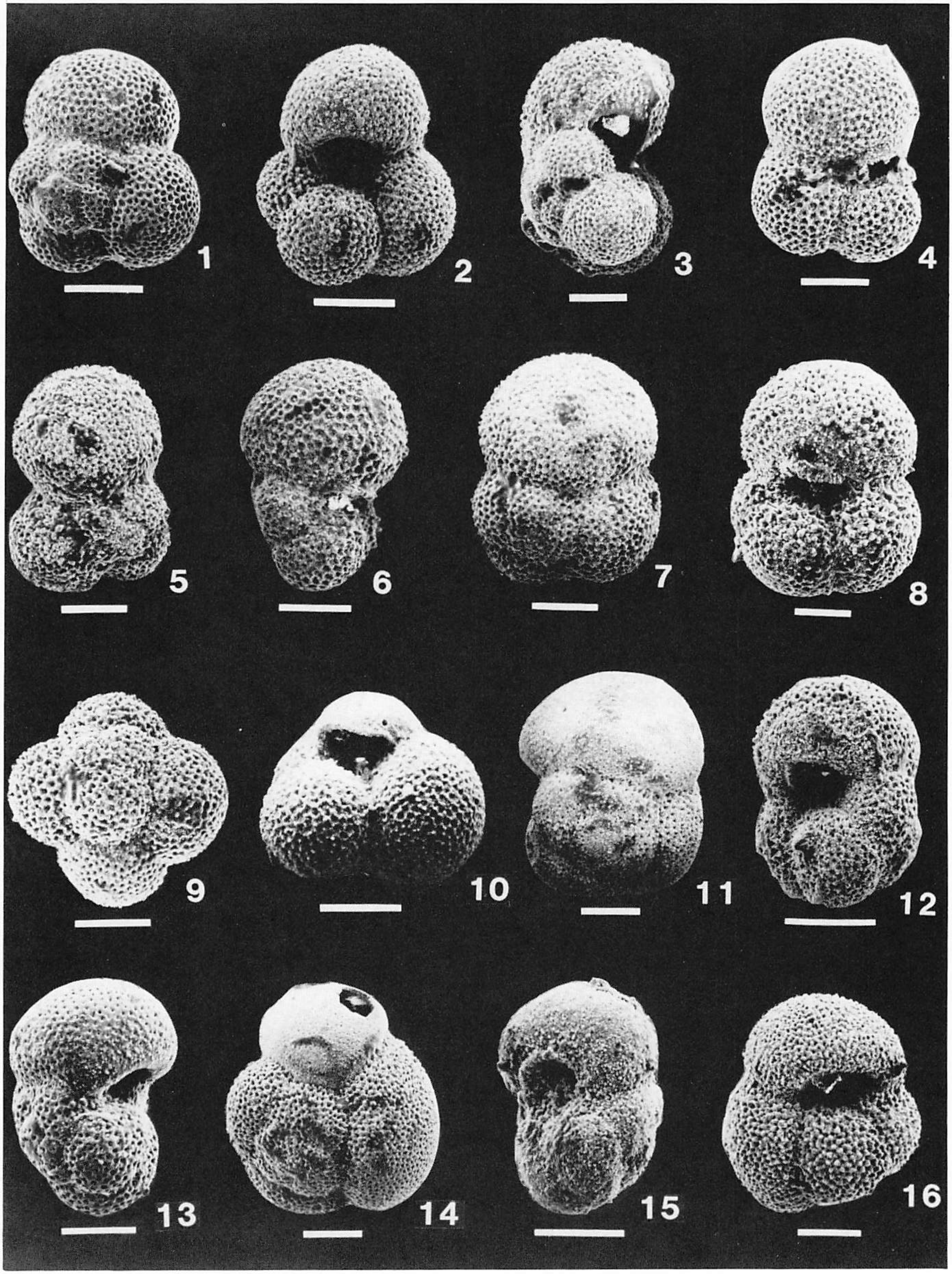


PLATE 9

PLATE 10

Figs.

1, 1a, 2, 3 - *Tenuitella aculeata* (Jenkins).
1, sample RL-1A, Craven County, spiral view, x 176; 1a, sample RL-1A, Craven County, close-up, spiral view, showing pustules and fine pores, x 396; 2, core CR-C1A-79, 118 ft 1 in, Craven County, edge view, x 117; 3, core CR-C1A-79, 118 ft 1 in, Craven County, umbilical view, x 195. Bar equals 0.05 mm. USNM 320022.

4, 5, 6 - *Testacarinata inconspicua* (Howe).
4, well CR-A40-62, 80-85 ft, Craven County, spiral view, x 205; 5, well CR-A40-52, 80-85 ft, Craven County, umbilical view, x 193; 6, core CR-C1A-79, 118 ft 1 in, Craven County, edge view, x 165. Bar equals 0.05 mm. USNM 320023.

7, 9, 10 - *Planorotalites renzi* (Bolli).
7, William and Mary Motel well, 27-48 ft, Sampson County, spiral view, x 139; 9, well BEA-T-38, 98-99 ft, Beaufort County, umbilical view, x 178; 10, core JON-C5A-79, 26 ft 4 in, Jones County, edge view, x 171. USNM 320024.

8, 13 - *Pseudohastigerina wilcoxensis* (Cushman and Parker) transitional with *Pseudohastigerina micra* (Cole) compressed variety.
8, sample PC-3, Pender County, apertural view, x 113; 13, sample IC-2, New Hanover County, side view, x 173. USNM 320025.

11, 12 - *Pseudohastigerina wilcoxensis* (Cushman and Parker) transitional with *Pseudohastigerina micra* (Cole) inflated variety.
Sample NR-3, Wayne County. 11, side view, x 104; 12, apertural view, x 113. USNM 320026.

14, 15, 15a - *Pseudohastigerina sharkriverensis* Berggren and Olsson.
14, core CR-C2-79, 57 ft 8 in, Craven County, side view, x 134; 15, sample PC-3, Pender County, apertural view, x 132; 15a, sample PC-3, Pender County, close-up, apertural view, showing bipartite aperture, x 347. USNM 320027.

16 - *Globigerinatheka mexicana mexicana* (Cushman).
Superior Quarry core, 12 ft 2 in - 13 ft 8 in, New Hanover County, side view, x 93. USNM 320028.

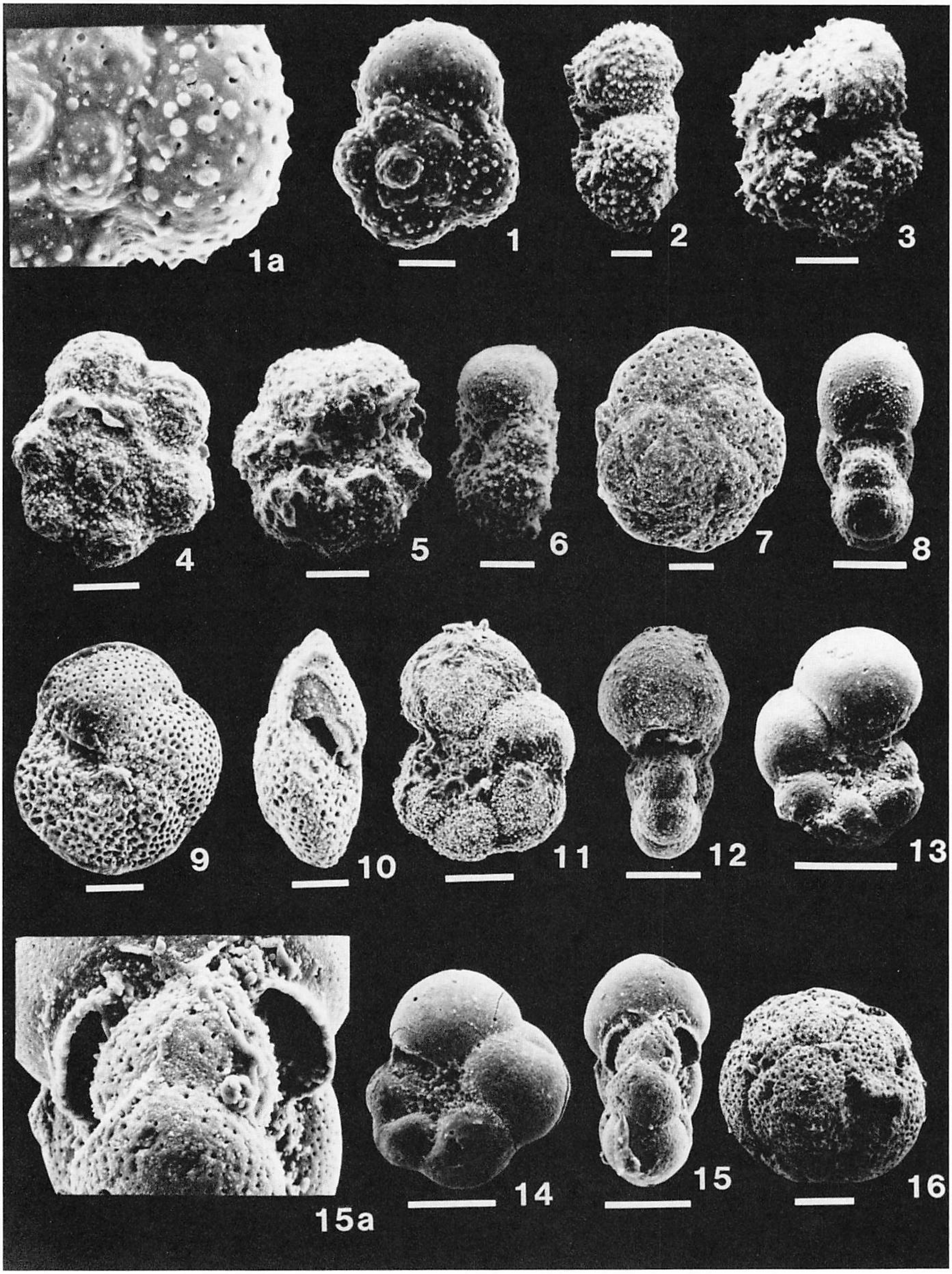


PLATE 10

PLATE 11

Figs. 1, 2 - *Globigerinatheka mexicana kugleri* (Bolli, Loeblich, and Tappan).
1, sample IC-6, New Hanover County, side view, showing 2 apertures, x 102; 2, Superior Quarry core, 6 ft 2 in - 7 ft 8 in, New Hanover County, side view showing no visible apertures, x 83. USNM 320029.

3, 4 - *Globigerinatheka index* (Finlay) s.l.
Sample IC-6, New Hanover County. 3, umbilical view, x 78; 4, side view, showing supplementary apertures, x 97. USNM 320030.

5, 5a - *Globigerinatheka mexicana barri* (Bronnimann).
Sample IC-6, New Hanover County. 5, side view, opposite globigerine coil, x 79; 5a, side view, showing globigerine coil, x 80. USNM 30031.

6, 7 - *Hantkenina longispina* Cushman.
6, William and Mary Motel well, 15-27 ft, Sampson County, side view x 123; 7, sample IC-2, New Hanover County, close-up, apertural view, showing apertural flange, x 101. USNM 320032.

8, 9 - *Chiloguembelina martini* (Pijpers).
8, Superior Quarry core, 6 ft 2 in - 7 ft 8 in, New Hanover County, side view, x 125; 9, sample IC-6, New Hanover County, apertural view, x 132. USNM 320033.

10 - *Chiloguembelina cubensis* (Palmer).
Core PEN-C2-79, 8 ft 3 in - 8 ft 5 in, Pender County, side view, x 238. Bar equals 0.05 mm. USNM 320034.

11 - *"Guembelitria" columbiana* Howe.
Core CR-C2-79, 57 ft 8 in, Craven County, oblique apertural view, x 248. Bar equals 0.05 mm. USNM 320035.

12, 13, 14,
15, 15a - *Cassigerinella* sp. aff. *C. winniana* (Howe).
Core CR-C1A-79, 120 ft, Craven County. 12, oblique apertural view, x445; 13, edge view, x 242; 14, apertural view, x 346; 15, side opposite aperture view, x 270; 15a, close-up, pore ultrastructure, x 1782. Bar equals 0.05 mm. USNM 320036.

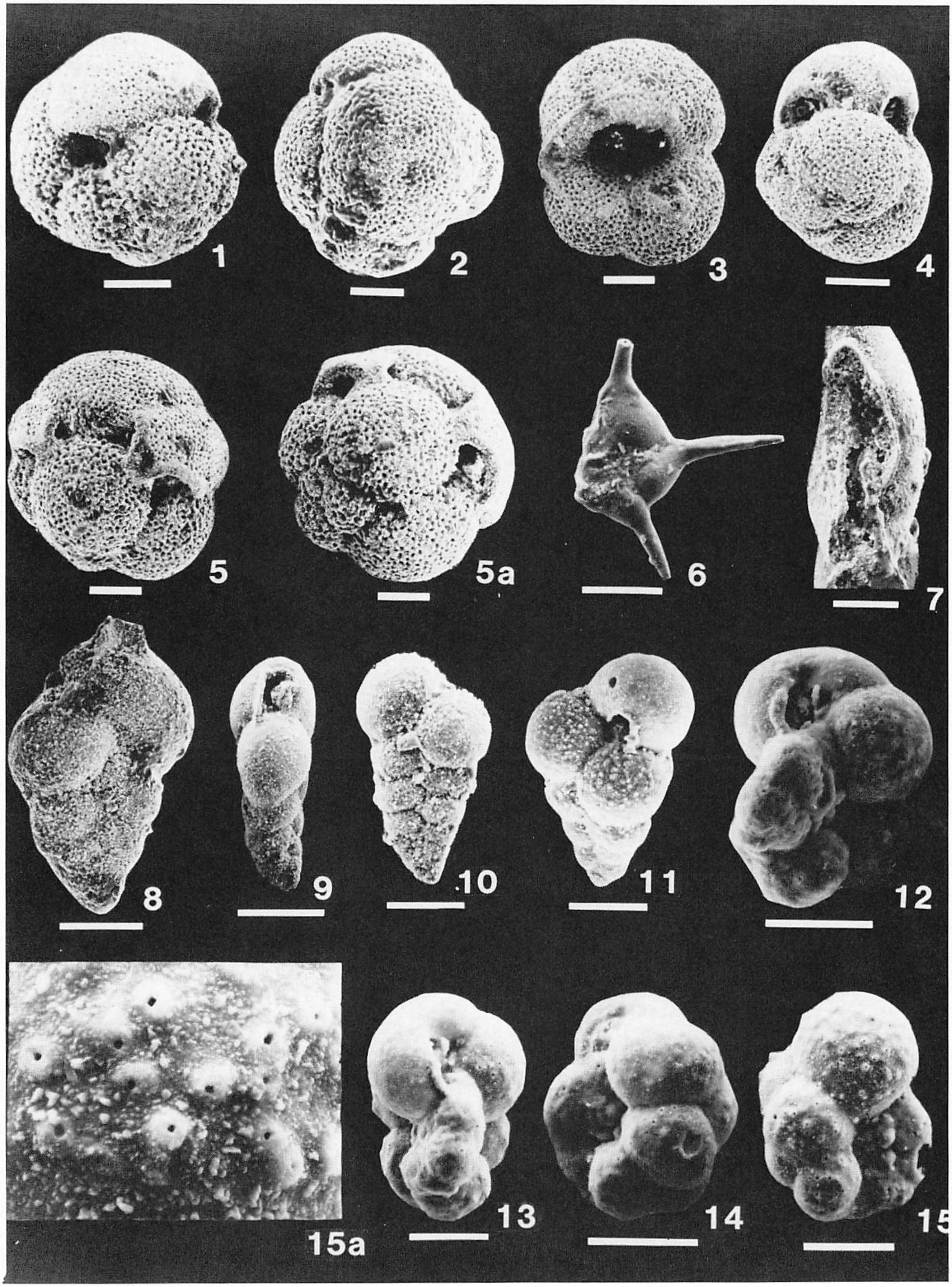


PLATE 11

PLATE 12

Figs. 1, 2 - *Eponides carolinensis* Cushman.
Sample PC-3, Pender County. 1, dorsal view, x 29; 2, ventral view, x 34. USNM 320037.

3, 4 - *Eponides cocoaensis* Cushman.
Sample PC-3, Pender County. 1, dorsal view, x 68; 2, ventral view, x 59. USNM 320038.

5, 6 - *Eponides ouachitaensis* Howe and Wallace
5, sample RL-1A, Craven County, dorsal view, x66; 6, Neuse River Stop #1, Craven County, ventral view, x 84. USNM 320039.

7, 8 - *Cibicidina blanpiedi* (Toulmin).
7, sample CHMM-1, New Hanover County, ventral view, x 92; 8, sample IC-3, New Hanover County, dorsal view, x 89. USNM 320040.

9, 10 - *Cibicidina* sp. aff. *C. howei* (Cushman and Todd).
9, well CR-A40-62, 110-115 ft, Craven County, ventral view, x 76; 10, Poker Shack well, 42 ft, Craven County, dorsal view, x 77. USNM 320041.

11, 12 - *Cibicidina minuta* Copeland - *C. cooperensis* (Cushman) species group.
11, sample IC-3, New Hanover County, ventral view, x 87; 12, core ON-C4-79, 285 ft, Onslow County, dorsal view, x 83. USNM 320042.

13, 14 - *Cibicidina mississippiensis* (Cushman).
Sample 17, Duplin County. 13, ventral view, x 134; 14, dorsal view, x 121. USNM 320043.

15, 16 - *Cibicides* sp. A.
15, sample 17, Duplin County, ventral view, x 163; 16, sample IC-4, New Hanover County, dorsal view, x 91. USNM 320044.

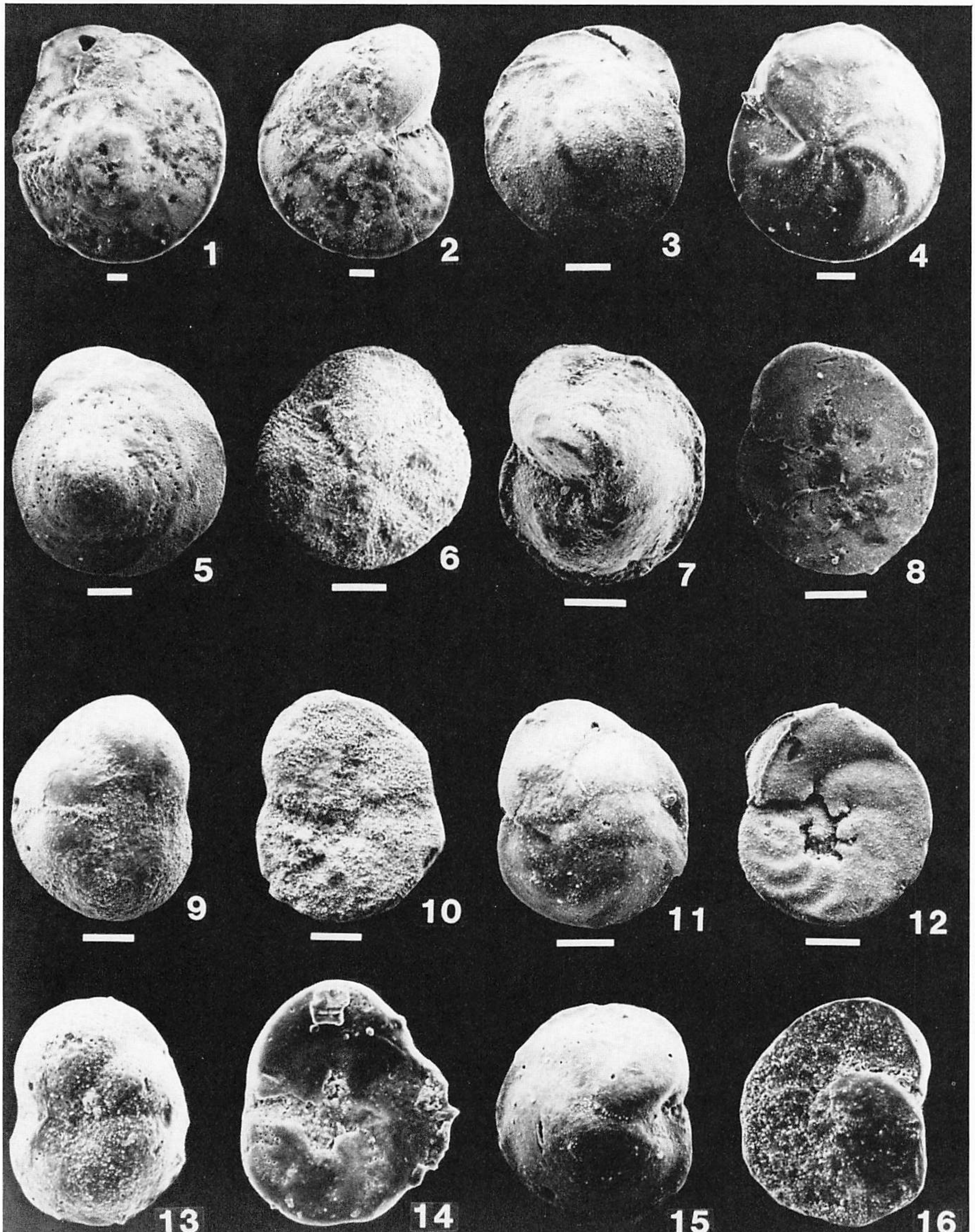


PLATE 12

PLATE 13

Figs. 1, 2 - *Cibicidina praeconcentricus* (Cushman).
MM Ward core, 59 ft, Craven County. 1, ventral view, x 117; 2, dorsal view, x 112. USNM 320045.

3, 4 - *Cibicidina* sp. aff. *C. williamsoni* (Garrett).
Poker Shack well, 42 ft, Craven County. 3, ventral view, x 79; 4, dorsal view, x 59. USNM 320046.

5, 6 - *Cibicidina* sp. A.
Sample RL-1A, Craven County. 5, ventral view, x 94; 6, dorsal view, x 80. USNM 320047.

7, 8 - *Cibicides mimulus* Bandy.
Sample RL-1A, Craven County. 7, ventral view, last chamber broken, x 64; 8, dorsal view, x 85. USNM 320048.

9, 10, 11 - *Cibicides praecipuus* Copeland.
Sample PC-3, Pender County. 9, ventral view, x 62; 10, dorsal view, x 61; 11, dorsal view, folded variety, x 81. USNM 320049.

12, 13 - *Cibicides* sp. aff. *C. praecipuus* Copeland.
Well BEA-T-38, 98-99 ft, Beaufort County. 12, ventral view, x 99; 13, dorsal view, x 124. USNM 320050.

14, 15 - *Cibicides sculpturatus* Cushman and Cederstrom.
Sample RL-1A, Craven County. 14, ventral view, x 40; 15, dorsal view, x 46. USNM 320051.

16 - *Cibicides westi* Howe.
Sample ALC-4, Duplin County, ventral view, x 103. USNM 320052.

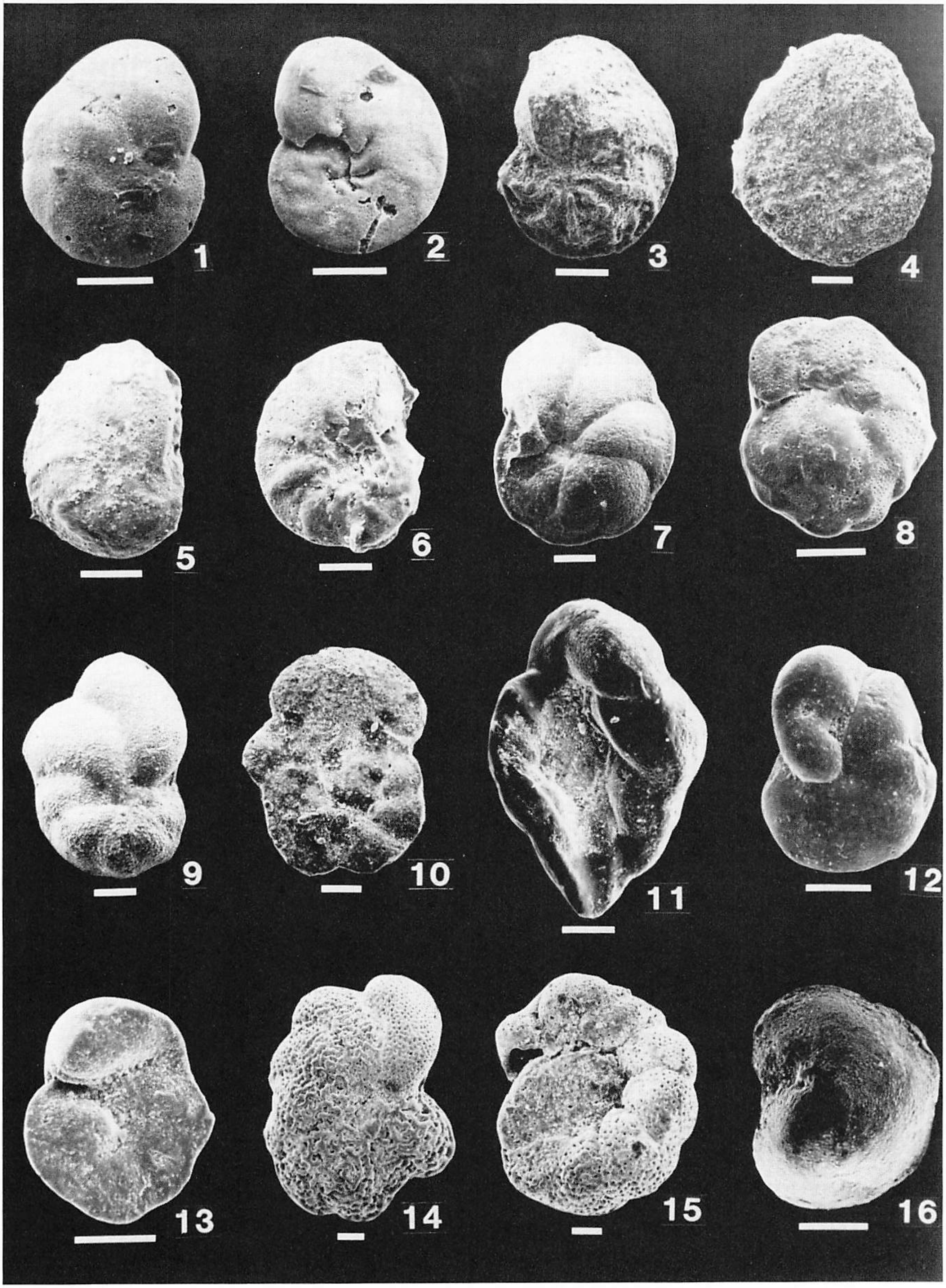


PLATE 13

PLATE 14

Fig. 1 - *Cibicides westi* Howe.
Sample 5, Craven County, dorsal view, x 114. USNM 320052.

2, 3 - *Cibicides* sp. B.
Kilpatrick #1, Craven County. 2, ventral view, x 101; 3, dorsal view, x 123. USNM 320053.

4, 5 - *Cibicides* sp. C.
Core CR-C2-79, 57 ft 8 in, Craven County. 4, ventral view, x 173; 5, dorsal view, x 171. USNM 320054.

6, 7, 8, 9 - *Carpenteria* sp. A.
Sample IC-6, New Hanover County. 6, dorsal view, inflated variety, x 41; 7, ventral view, inflated variety, x 56; 8, dorsal view, digitate variety, x 29; 9, ventral view, digitate variety, x 31. USNM 320055.

10 - *Pleurostomella cubensis* Cushman and Bermudez.
Sample ON3-2, Onslow County, apertural view, x 91. USNM 320056.

11 - *Sigmavirgulina* sp. aff. *S. tortuosa* (Brady).
New Bern Quarry core, 61 ft 5 in, Craven County, side view, x 78. USNM 320057.

12 - *Globocassidulina subglobosa* (Brady).
Sample CHMM-3, New Hanover County, apertural view, x 141. USNM 320058.

13, 14 - *Cassidulina armosa* Bandy.
Sample CHMM-1, New Hanover County. 13, side view, x 86; 14, opposite side view, x 112. USNM 320059.

15 - *Nodosarella silesica* (Jedlitschka).
Sample PC-3, Pender County, side view, x 36. USNM 3210060.

16 - *Fursenkoina* sp. aff. *F. dibollensis* (Cushman and Applin).
Sample IC-5, New Hanover County, side view, x 57. USNM 320061.

17 - *Cassidella zetina* (Cole).
Core DUP-C1-80, 170 ft 6 in - 175 ft 6 in, Duplin County, side view, x 120. USNM 320062.

18, 19 - *Nonion mauricensis* Howe and Ellis.
18, sample 17, Duplin County, side view, x 116; 19, core CR-C1A-79, 66 ft 2 in, Craven County, apertural view, x 106. USNM 320063.

20, 21 - *Florilus spissa* (Cushman).
20, well BEA-T-38, 98-99ft, Beaufort County, ventral view, x 89; 21, sample IC-5, New Hanover County, dorsal view, x 136. USNM 320064.

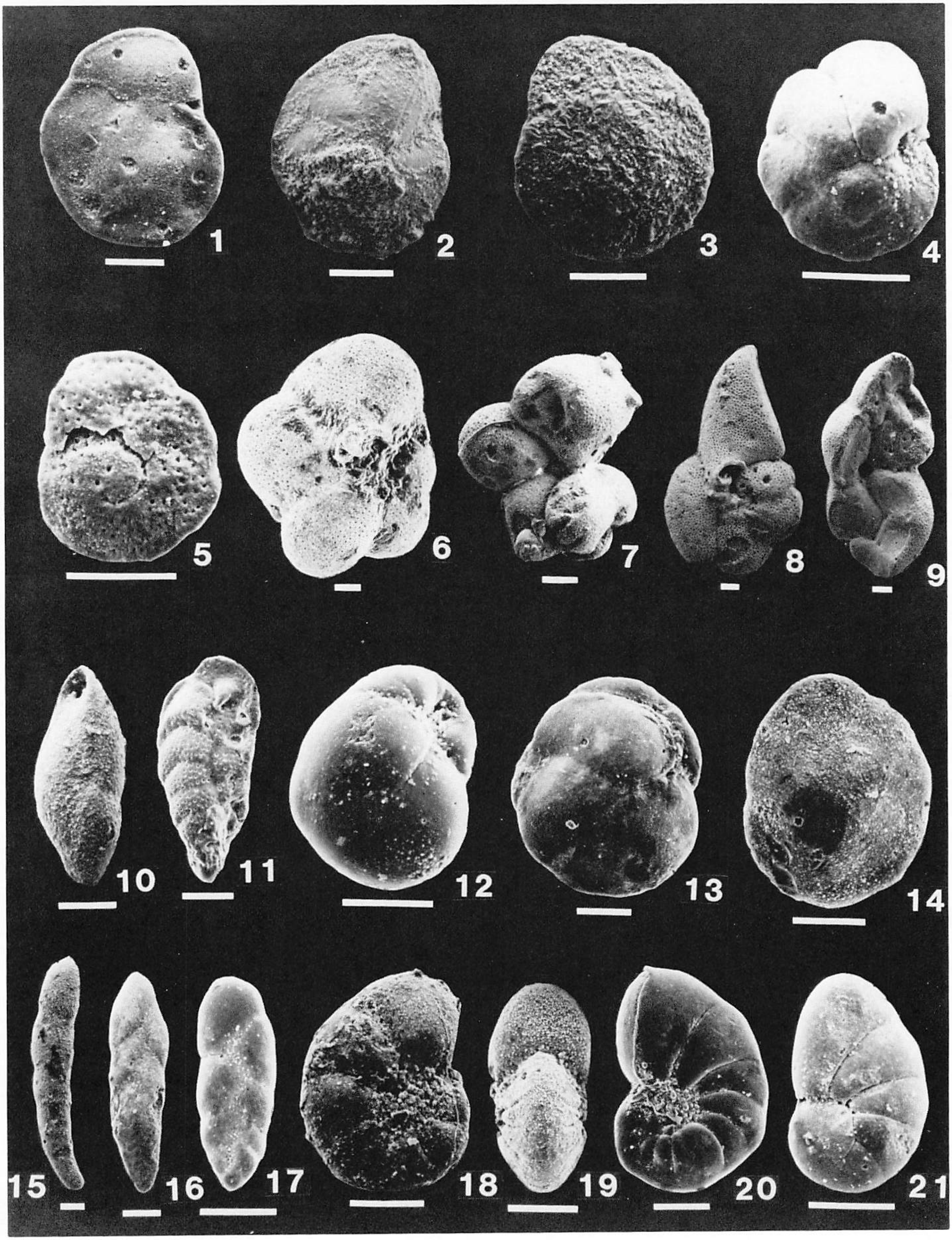


PLATE 14

PLATE 15

Figs. 1, 2 - *Nonionella jacksonensis* Cushman.
1, sample 13, Jones County, side view, x 130; 2, core CR-C3-79, 66 ft 2 in, Craven County, opposite side view, x 139. USNM 320065.

3 - *Chilostomella cylindroides* Reuss.
Sample IC-3, New Hanover County, side view, broken specimen, x 46. USNM 320066.

4, 5 - *Pullenia quinqueloba* (Reuss).
4, sample IC-3, New Hanover County, side view, x 119; 5, core ON-C4-79, 285 ft, Onslow County, apertural view, x 94. USNM 320067.

6, 7 - *Alabamina mississippiensis* Todd.
6, well BEA-T-38, 98-99 ft, ventral view, x 127; 7, sample 17, Duplin County, dorsal view, x 99. USNM 320068.

8, 8a, 9 - *Epistominella* sp. A.
8, core CR-C1A-79, 118 ft 1 in, Craven County, ventral view, x 231; 8a, core CR-C1A-79, 118 ft 1 in, Craven County, apertural view, x 396; 9, core PEN-C1-80, 68 ft, Pender County, dorsal view, x 167. Bar equals 0.05 mm. USNM 320069.

10, 11 - *Gyroidina?* sp. A.
Sample ALC-3, Duplin County. 10, ventral view, x 38; 11, dorsal view, x 40. USNM 320070.

12, 13 - *Gyroidinoides octocameratus* (Cushman and Hanna).
12, sample PC-3, Pender County, ventral view, x 119; 13, core CR-C1A-79, 118 ft 1 in, Craven County, dorsal view, x 108. USNM 320071.

14, 15 - *Anomalina umbonata* Cushman.
Sample 17, Duplin County. 14, side view, x 69; 15, opposite side view, x 93. USNM 320072.

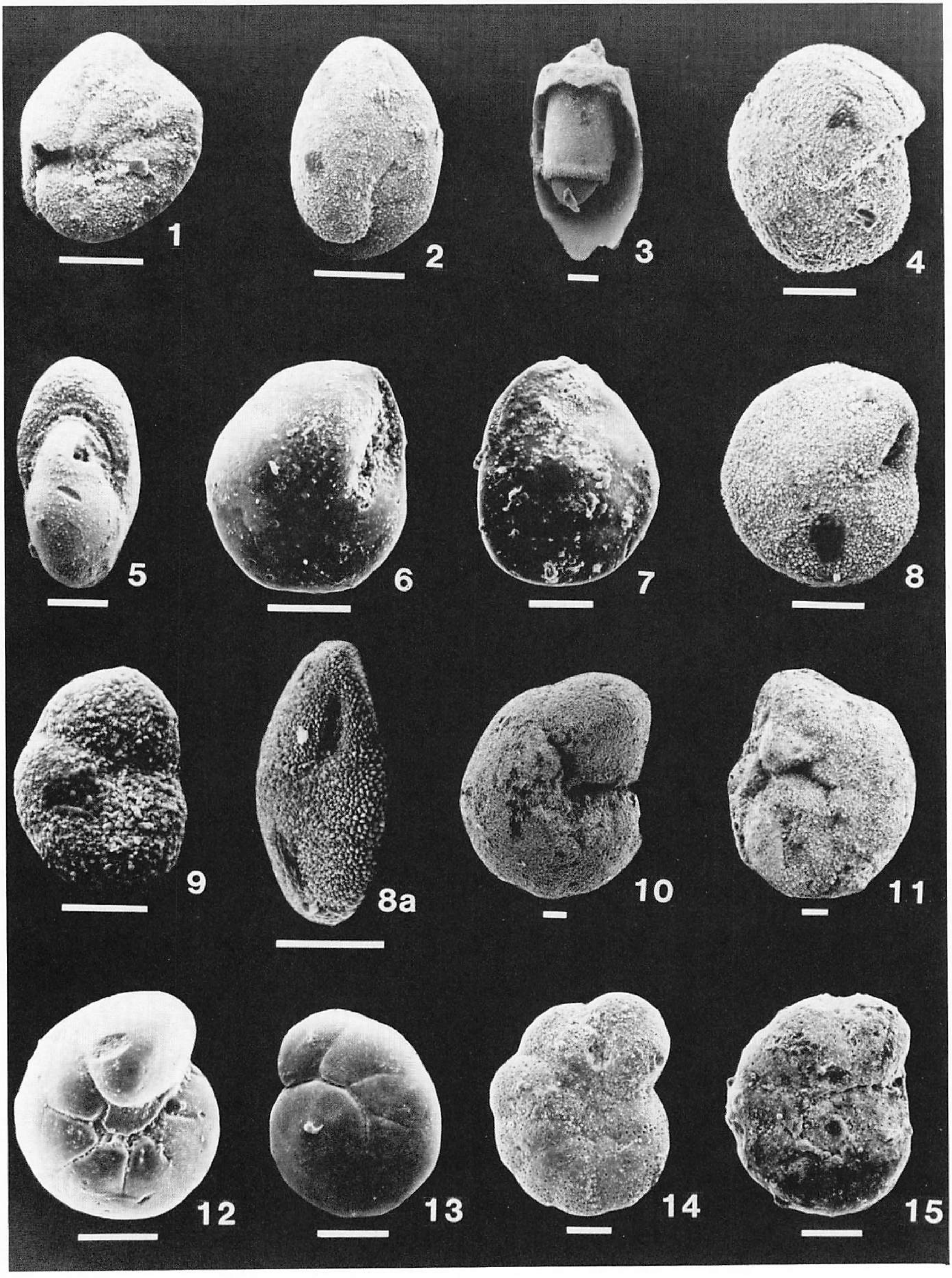


PLATE 15

PLATE 16

Figs. 1, 2 - *Anomalinoides* sp. A.
Core CR-C2-79, 68 ft 10 in, Craven County. 1, side view, x 139; 2, opposite side view, x 168. USNM 320073.

3, 4 - *Cibicidoides neelyi* (Jennings).
New Bern Quarry core, 32.75 ft, Craven County. 3, ventral view, x 104; 4, dorsal view, x 101. USNM 320074.

5, 6 - *Cibicidoides truncatus* (Bandy).
5, sample 5, Craven County, ventral view, x 121; 6, core JON-C5A-79, 26 ft 4 in, Jones County, dorsal view, x 102. USNM 320075.

7, 8 - *Melonis planatus* (Cushman and Thomas).
7, core CR-C2-79, 57 ft 8 in, Craven County, apertural view, x 89; 8, sample PC-3, Pender County, side view, x 72. USNM 320076.

9 - *Robertina mcguirti* Howe.
MM Ward core, 59 ft, Craven County, apertural view, x 122. USNM 32007.

10 - *Cibicidinae* incertae sedis 1.
Sample PC-3, Pender County, dorsal view, x 39. USNM 320078.

11, 12 - *Webbinella* sp. A.
11, sample IC-6, New Hanover County, dorsal view, x 60; 12, sample CHMM-3, New Hanover County, ventral view, x 87. USNM 320079.

13 - *Cibicidinae* incertae sedis 2.
New Bern Quarry core, 32.75 ft, Craven County, ventral view, x 40. USNM 320080.

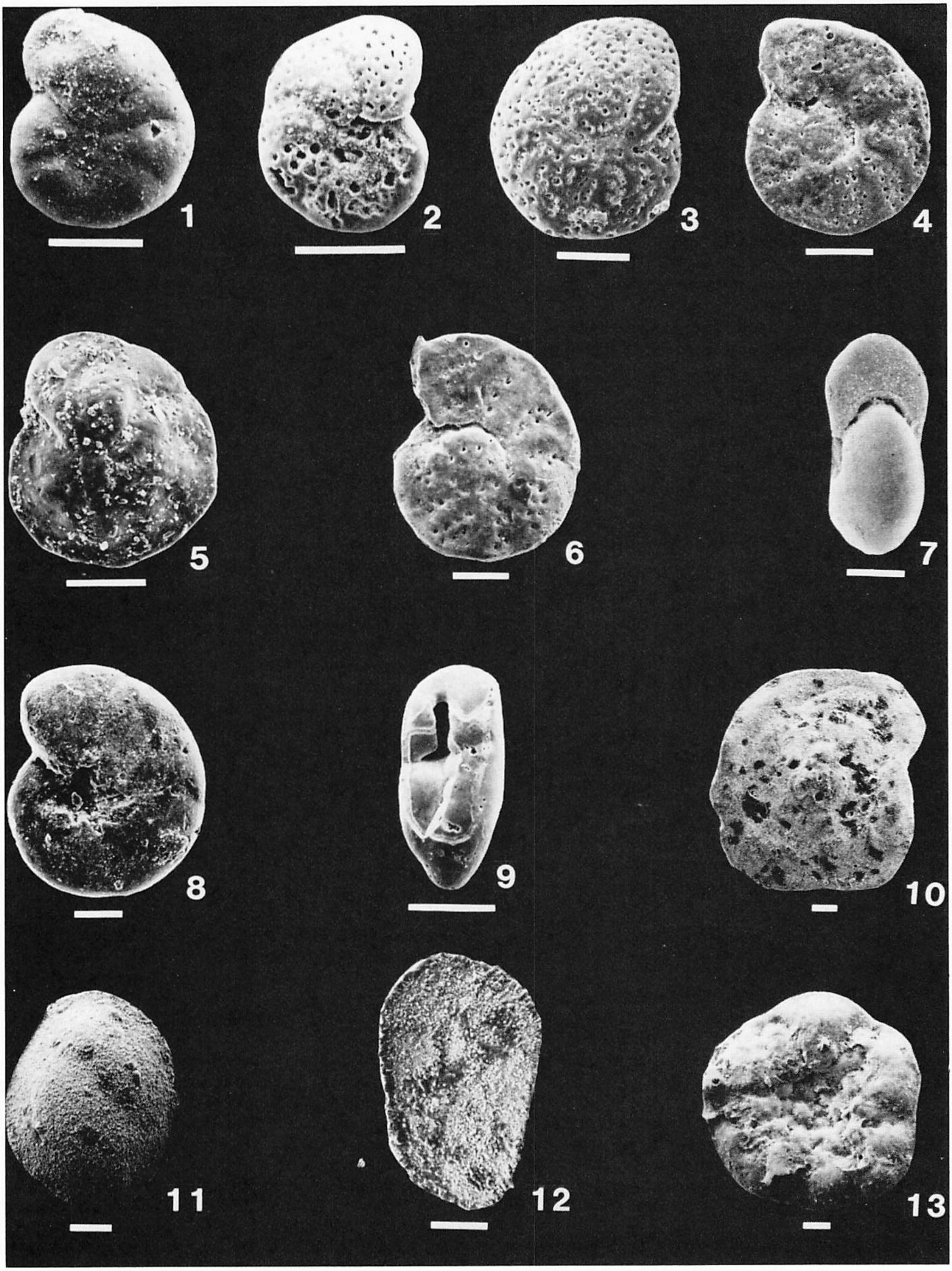


PLATE 16

APPENDIX A

A. SAMPLE REGISTER

A list of the locations of outcrop, core, well, and auger hole samples of the Eocene section that yielded foraminifera are arranged alphabetically by county. The lithofacies, interpreted foraminiferal biofacies, and planktic foraminiferal zonal resolution of each sample are given as follows:

1. Lithofacies (see Fig. 3)

1: phosphate pebble lithocalcirudite
2: bryozoan-echinoid biocalcirudite
3: fine to coarse calcarenite
4: sandy, molluscan-mold biocalcirudite

(Lithofacies abbreviated in register; e.g., Lithofacies 3 = L-3.)

2. Foraminiferal Biofacies

A, B: outer shelf, 50-100m water depth
C: middle shelf, 15-50m
D, E: inner shelf, 0-15m

(Biofacies abbreviated in register; e.g., Biofacies C = B-C.)

3. Planktic Foraminiferal Zonal Resolution (see Fig. 4)

P-zone resolutions are listed in register, m = middle part of zone.

BEAUFORT COUNTY

Wells

1. BEA-T-38: Lat 35°30′30″, Long 77°00′20″
   Sample 98′-99′: L-2; B-C; P12-P13

BRUNSWICK COUNTY

Wells

1. Sunny Point 2-5: Lat 34°01′52″, Long 77°57′43″
   Sample 112.0′-112.3′: L-2; B-B; P12-m.P14

CRAVEN COUNTY

Outcrops

1. Sample 2: In woods at end of road 1473, in sinkholes known locally as Indian Wells. L-3; B-C; P12.
2. Sample 5: Biddle Landing, south bank of Neuse River, 2.0 miles north of Fort Barnwell. L-3; B-D; P12-P13
   Sample 6: L-3; B-E; P11-m.P14
3. Samples NBQ-1,2: Martin Marietta Quarry, New Bern Quarry, northwest of New Bern, 0.5 mile northeast of Route 55 on road 1402. L-4; P11-P12
4. Sample RL-1A: Rock Landing, 2.5 miles north of Jasper, south bank of Neuse River. L-4; B-E; P11-P13
5. Sample TQC-1: 0.1 mile above Rock Landing at mouth of Turkey Quarter Creek, south bank. L-3; B-C; P12-m.P14
   Sample TQC-2: L-4; B-C; P12
6. Neuse River Stop 1: Along banks of Neuse River, from about 1.0 mile west of where road 1470 crosses the Neuse River, downstream to about 0.5 mile southwest of where road 1449 ends near Neuse River. L-3; B-D
   Stop 2: L-3; B-E
   Stop 3: L-3; B-D

Cores

1. CR-C1A-79: Lat 35°02′23″, Long 77°01′39″
   Sample 118′2″: L-4, B-D; P12-P13
2. CR-C2-79; Lat 35°17′33″, Long 77°22′27″
   Sample 57′8″: L-2; B-E; P12
   68′10″: L-2; B-C; P12
3. CR-C3-79: Lat 35°14′10″, Long 77°12′06″
   Sample 66′2″: L-2; B-C; P12
4. New Bern Quarry: Lat 35°08′04″, Long 77°05′10″
   Sample 32.75′: L-4; B-E; P11-P12
5. MM Ward Quarry: Lat 35°08′07″, Long 77°05′10″
   Sample 59′: L-4; B-E; P11-P12

Wells - Auger Holes

1. AA-2, 32′: About 1.0 mile due west of Woodrow (auger). B-C
2. AA-6, 27′: In field just north of road 1228, about 0.5 mile from junction of roads 1228 and 1224 (auger). B-E
3. Kilpatrick Farm #1: In field at end of road 1474 near Halfmoon Creek (auger). L-2; B-D
4. CR-A40-62: Lat 35°20′15″, Long 77°05′48″ (well)
   Sample 80-85′: L-2; B-C; P12-P13
   115-116′: L-2; B-D; P12-P13
5. CR-A44-62: Lat 35°17′55″, Long 77°04′55″ (well)
   Sample 110-115′; B-C; P12
6. CR-A45-62: Lat 35°16′00″, Long 77°04′20″ (well)
   Sample 105-110′: L-2; B-C; P12-m.P14
7. Clarks Crossroads: Lat 35°08′12″, Long 77°10′10″ (well)
   Sample 160-170′: B-C; P12-P13
8. AA-1: Lat 35°11′05″, Long 77°10′25″ (well)
   Sample 80′; B-C
9. BB-3: Lat 35°16′55″, Long 77°10′58″ (well)
   Sample: 27′: B-D
10. Poker Shack: Lat 35°12′54″, Long 77°11′43″ (well)
    Sample 42′: L-2, 3?; B-D

DUPLIN COUNTY

Outcrops

1. Samples 15, 16, 17: 1.8 miles southwest of Magnolia, just east of road 1003, in sinkhole known locally as Natural Well. L-3; B-C; P12-P13
2. Sample 21: Lanier property, in spoils piles in back yard, 0.8 mile southwest of Bethel Church, north side of road 1001. L-2; B-C; P12
3. Sample 23: In spoils piles, 0.2 mile west of junction of Route 41 and road 1001, on west side of Route 41. L-2; B-B; P12-P13
4. Sample ALC-1, 4: Atlantic Limestone Company Quarry, 2.5 miles southeast of Magnolia, just east of Route 117. L-2; B-D; P12-P13
   Sample ALC-3: L-2; B-E

5. Sample FUS-1: Billy B. Fussell Company Quarry, 1.0 mile west of Rose Hill on road 1102 L-2; B-E; P12-m.P14
   Sample FUS-2: L-2; B-C; P12-P13

Cores

1. DUP-C1-80: Lat 34°49′24″, Long 77°49′03″
   Sample 40′8″: L-2; B-C; P11-P13
   Sample 144′8″: L-2; B-B; P12-P13
   Sample 170′6″-175′6″: L-2; B-E; P11-m.P14

HARNETT COUNTY

Outcrops

1. HAR-0-1-55: East of junction of roads 1139 and 1141; no longer accessible. L-3; P11-Late Eocene

JONES COUNTY

Outcrops

1. Sample 9: Just north of Trenton at junction of Cherry and Market Streets, on western bank of Trent River. L-4; B-E; P11-P14
2. Sample 11: 0.8 mile north of Phillips Crossroads, where road 1129 crosses Big Chinquapin Branch, under bridge. L-2; B-B; P12-P13
3. Sample 12: Banks of Beaver Creek, southeast of bridge where road 1316 crosses creek. L-3; B-C; P12-m.P14
4. Sample 13: Banks of Beaver Creek; just southeast of bridge where road 1315 crosses creek. L-3; B-C; P12-m.P14
5. Sample JC-1: Underneath bridge where road 1121 crosses Trent River, 0.5 mile west of Oak Grove. L-4; B-E; P12-P13
6. SS-1: South bank of Trent River, 0.75 mile southwest of Comfort Depot, on farm of Miss Sallie Simmons. L-4; B-D; P12-P13
   SS-2, 3, 4: L-2; B-B; P12-P13
7. Chinquapin Branch: Just northeast of bridge where road 1129 crosses Little Chinquapin Branch, along stream banks. L-3; B-B; P12

Cores

1. JON-C4-79: Lat 34°58′10″, Long 77°08′10″
   Sample 121′: L-4; B-D; P12-P13
2. JON-C5-79: Lat 35°02′34″, Long 77°15′58″
   Sample 26′6″: L-4; B-D; P12
3. JON-C5A-79: Lat 35°02′34″, Long 77°15′58″
   Sample 26′4″: L-4; B-E; P12

NEW HANOVER COUNTY

Outcrops

1. Sample CHMM-1: Martin Marietta Company Quarry, Castle Hayne, 1.75 miles east of Castle Hayne, 0.5 mile north of road 1002. L-2; B-A; P12-P13
   CHMM-2: L-2; B-B; P12-P13
   CHMM-3: L-2; B-A; P12
   CHMM-4: L-2; P12-P13
   Glauconite Layer: L-2; B-B; P12-P13
2. Sample IC-1: Ideal Cement Company Quarry, 2.5 miles east of Castle Hayne, north of road 1002, at end of road 2023. L-2; B-B; P12-P13
   IC-2: L-2; B-A; P12-P13
   IC-3: L-2; B-B; P12
   IC-4: L-2; B-A; P12
   IC-5: L-2; B-B; P12
   IC-6: L-2; B-A; P12
   IC-7: L-2; P12-m.P14

Cores

1. Superior Quarry: Lat 34°21′51″, Long 77°52′15″
   Sample 12′2″-13′8″: B-B; P12-P13

ONSLOW COUNTY

Outcrops

1. Sample ON3-2: Under bridge where road 1314 crosses the New River. L-2; B-C; P12-P13
   ON3-3: L-3; B-B; P12-P13

Cores

1. ON-C4-79: Lat 34°49′52″, Long 77°80′25″
   Sample 285′: L-2; B-B; P12

PENDER COUNTY

Outcrops

1. Sample PC-3: Just northwest of where paved portion of road 1520 becomes dirt; in irrigation ditches of farm. L-2; B-B; P12-P13
2. Samples EC-1, 2, 3: East Coast Limestone Company Quarry, 1.5 miles west of Maple Hill, 0.5 mile southwest of intersection of Routes 53 and 50. L-2; P12-m.P14

Cores

1. PEN-C1-80: Lat 34°22′15″, Long 77°42′52″
   Sample 68′: L-2; B-B; P11-m.P14
   Sample 107′8″: L-2; B-B; P12
2. PEN-C2-79: Lat 34°39′11″, Long 77°42′56″
   Sample 5′4″-5′6″: L-2; B-B; P12-13

SAMPSON COUNTY

Outcrops

1. Sample 14: In drainage ditch along north side of Route 701, 0.5 mile east of Newton Grove. L-3; B-D; P12-P13
2. Newton Grove Outlier: South of Route 701 about 0.8 mile east of Newton Grove. L-3; B-C; P12-P13

Wells

1. William and Mary Motel: Lat 35°15′02″, Long 78°22′19″
   Sample 15-27′: L-3; B-D; P13

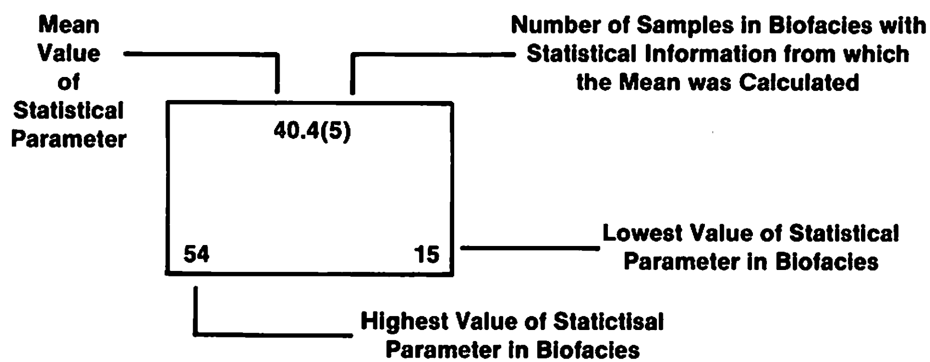
WAYNE COUNTY

Outcrops

1. Samples NR-2, 3: 0.25 mile upstream of the bridge on road 111, on south bank of Neuse River. L-3; B-D; P12-P13
2. Goldsboro: About 2.0 miles upstream from NR-2 and 3; south bank of Neuse River. L-3; B-D; P12-m.P14

MEANS OF STATISTICAL FORAMINIFERAL DATA FOR BIOFACIES A-E

BIOFACIES	A	B	C	D	E
Number of Samples In Biofacies	5	18	20	17	13
Percentage of Planktic Individuals	40.4 (5) 54 15	52.4 (18) 85 12	25.5 (18) 67 4	23.5 (11) 59 1	10.2 (8) 38 2
Number of Planktic Species	18.8 (5) 23 16	13.9 (18) 22 7	11.9 (18) 17 6	10.0 (12) 16 2	6.3 (11) 19 2
Benthic Diversity	3.30 (5) 3.63 2.99	3.07 (12) 3.84 2.66	2.97 (15) 3.29 2.52	3.03 (10) 3.80 2.09	2.87 (6) 3.38 1.99



Explanation