

Mark R. Katrosh. FORAMINIFERAL PALEOECGLOGY AND BIOSTRATIGRAPHY OF THE YORKTOWN AND PUNGO RIVER FORMATIONS: BEAUFORT, PAMLICO, CRAVEN, AND CARTERET COUNTIES, NORTH CAROLINA. (Under the direction of Dr. Scott W. Snyder) Department of Geology, March 1981.

Benthic foraminiferal assemblages of the Pungo River Formation from the central North Carolina Coastal Plain indicate deposition in near-shore inner continental shelf to middle shelf environments.

In Beaufort and Pamlico Counties, part of the Aurora Embayment, faunas from the lower part of the formation (Units A and B) are dominated by Buliminella elegantissima, Caucasina gracilis, and Elphidium excavatum. Florilus pizzarensis, Cibicides lobatulus, Elphidium limatum, Nonionella miocenica, Hanzawaia concentrica, and H. nipponica occur sporadically and are of secondary importance when present. High faunal dominance (averaging greater than 50%), low diversity values (Shannon-Wiener Information Function averaging 1.4), and the rarity of planktic foraminifera suggest that these units were deposited in near-shore, shallow water environments. With the exception of E. limatum, dominant species from the upper part of the formation (Units C, D, and DD) are those of secondary importance in the lower units. Faunal dominance averages 33%, diversity values are moderate (averaging 2.3), and planktic specimens are more abundant. These units were deposited in more open water marine environments.

In Craven County, along the northern flank of a pre-Miocene topographic high, the dominant species throughout the formation are Cassidulina laevigata and Uvigerina calvertensis, forms suggesting an

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outer shelf environment. However, high faunal dominance, moderate diversity values (2.0 to 2.7), and the rarity of planktic specimens are inconsistent with an outer shelf setting. Perhaps typical offshore species migrated shoreward in response to favorable conditions related to the adjacent high. Assemblages of the unit associated with this high (Unit CC) grade laterally into the units farther north.

In Carteret County, south of this high and along the northern edge of Onslow Bay, faunas are similar to those from Units C, D, and DD in the Aurora Embayment. Several species present here are absent in the Aurora Embayment, their migration perhaps prevented by environments associated with the intervening topographic high.

Based on planktic foraminifera, an age range from the latter part of Zone N. 7 to the latter part of Zone N. 8 (late Early Miocene) is tentatively proposed for the entire Pungo River section in the study area.

Benthic foraminiferal assemblages from the Yorktown Formation indicate deposition during an initial marine transgression (the lower Yorktown) followed by a general marine regression (the upper Yorktown). The lower Yorktown is a fining upward sequence of terrigenous sediments dominated by Buliminella elegantissima, Caucasina gracilis, and Florilus pizzarensis. Species of secondary importance include Cibicides lobatulus, Nonionella miocenica, Fursenkoina fusiformis, and Elphidium excavatum. Species diversity values are generally high (averaging 2.7) and faunal dominance is low (averaging 34%). The upper Yorktown is a coarsening upward sequence of terrigenous sediments in which planktic specimens become progressively scarcer. It is dominated by Cibicides

lobatulus, Elphidium excavatum, Hanzawaia concentrica, Florilus pizzarensis, and Bolivina lowmani. Species of secondary importance include Cancris sagra, Globocassidulina crassa, Bolivina paula, and Uvigerina subperigrina. Species diversity values are generally lower than those for the lower Yorktown (averaging 2.4). Faunal dominance averages 35%, ranging as high as 47% in one sample. There is a general shift upward through the unit from characteristic mid-shelf assemblages to faunas indicative of more nearshore environments. Water depths were probably no greater than 50 to 60 meters during maximum transgression, and were $\leq$ 30 or 40 meters during that portion of the regressive cycle that has been preserved.

Planktic foraminifera indicate an age of late Early to early Late Pliocene (middle of Zone N. 18 to the lower-middle of Zone N. 20) for Yorktown and equivalent strata (Duplin Formation).

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PUNGO RIVER FORMATIONS: BEAUFORT, PAMLICO, CRAVEN, AND
CARTERET COUNTIES, NORTH CAROLINA

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Mark Ralph Katrosh

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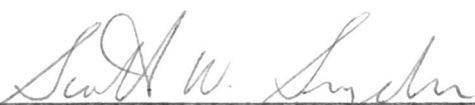
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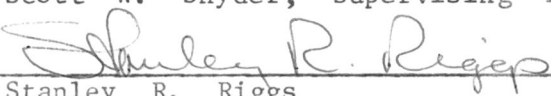
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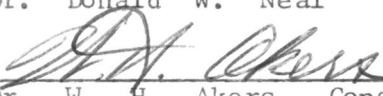
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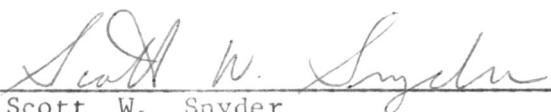


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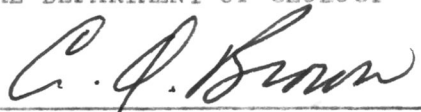
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INTRODUCTION

The late Early Miocene Pungo River Formation and late Early to early Late Pliocene Yorktown Formation are present in the subsurface throughout much of the central Coastal Plain of North Carolina. Core samples of both formations from 11 localities throughout this region were examined for benthic and planktic foraminifera.

An attempt was made to interpret the depositional environment for each of the lithologic units that were recognized within the two formations by superimposing information from the benthic foraminiferal assemblages on the lithologic framework. This phase of the study utilized the sedimentological data presented by Scarborough (1981) for the Pungo River Formation. Planktic foraminifera were studied in an attempt to ascertain the biostratigraphic relationships among the strata. The age assignments of the formations determined from this project were compared with those of other regional studies (Akers, 1972; Gibson, in press; Snyder et al., in press).

Because the phosphate accumulations within the Pungo River Formation are economically important, delineation of the constituent lithologic units and interpretation of their respective depositional environments will help to determine the extent of minable deposits in the central North Carolina Coastal Plain. This approach may also contribute to an understanding of phosphate genesis. Combined with a similar analysis of the Yorktown Formation, this study should help to further the understanding of the geologic history of the Atlantic Coastal Plain during Pungo River and Yorktown time.

GEOLOGIC AND GEOGRAPHICAL SETTING

The area of study encompasses the central Coastal Plain of North Carolina from northern Beaufort County southward through southern Carteret County (Fig. 1). The land is characterized by low relief and elevations that range from 0-15 meters above mean sea level. Swamplands, many of which have been drained for farming, and pocosin highlands dominate the terrain. The region is drained by two major river-estuarine systems, the Pamlico River to the north and the Neuse River to the south, both of which flow in an easterly direction and empty into Pamlico Sound.

The generalized regional subsurface geology includes approximately 500 to 600 meters of Mesozoic-Cenozoic sediments and sedimentary rocks that overlie a pre-Cretaceous crystalline basement, all of which dip oceanward (Clark et al., 1912). The Mesozoic-Cenozoic wedge of sediments thickens rapidly to the east, reaching a maximum thickness of more than 3 kilometers at Cape Hatteras (Harris et al., 1979; Prouty, 1946; Spangler, 1950). Marine transgressions and regressions throughout Mesozoic-Cenozoic time, contemporaneous with structural deformation of the underlying basement complex along zones of flexure, have controlled the depositional patterns exhibited by the sediments in this region (Harris et al., 1979; Miller, 1971).

The Yorktown and Pungo River Formations are part of the Early Miocene to early Late Pliocene Chesapeake Group. Sediments of this group occur within the Atlantic Coastal Plain in Delaware, New Jersey,

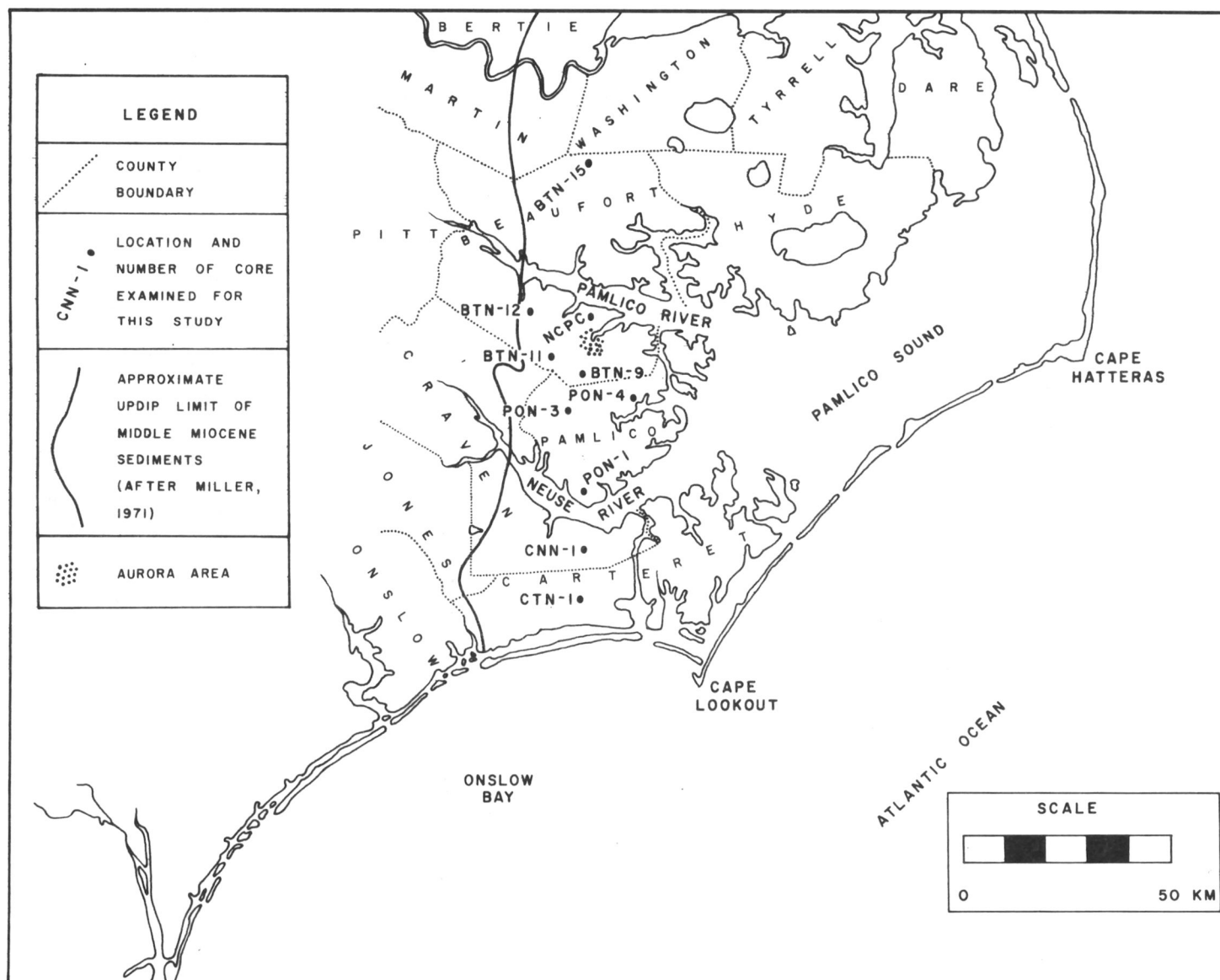


Figure 1. Map of study area showing location of cores.

Maryland, Virginia, and North Carolina (Bailey, 1973). Regional stratigraphic relationships of the formations in this group are shown in Figure 2. A progressive southward shift in the locus of deposition through Chesapeake Group time resulted in the maximum development of the Miocene Calvert, Choptank, and St. Marys Formations in Maryland; whereas the Pliocene Yorktown Formation is best developed in Virginia and North Carolina (Gibson, 1967).

The Pungo River Formation, a less extensive deposit than the Yorktown Formation, is confined to North Carolina, bounded by the Norfolk Arch to the north and by the White Oak Lineament to the west (Snyder and Hine, in press). A nearly east-west trending feature with its axis in the vicinity of New Bern, North Carolina, the Cape Lookout High of Snyder et al. (1980), divided the Pungo River depositional basin into two systems. Comparisons of the northern and southern systems will be discussed in more detail in the section on the Pungo River Formation.

The Yorktown depositional basin, with its primary locus of deposition in the Albemarle Embayment, was bounded to the south by the Cape Fear Fault (Harris et al., 1979) and to the north by the Norfolk Arch (Gibson, 1967; Murry, 1961). The southern limit of the Albemarle Embayment proper, which occupied only a portion of the total Yorktown depositional basin, was marked by the Cape Lookout High. Southward from the Cape Lookout High to the area of the Cape Fear Fault, Yorktown-equivalent strata (Duplin Formation) indicate a shallower depositional environment than do strata to the north of the high. This fact, along with its apparent influence on the Pungo

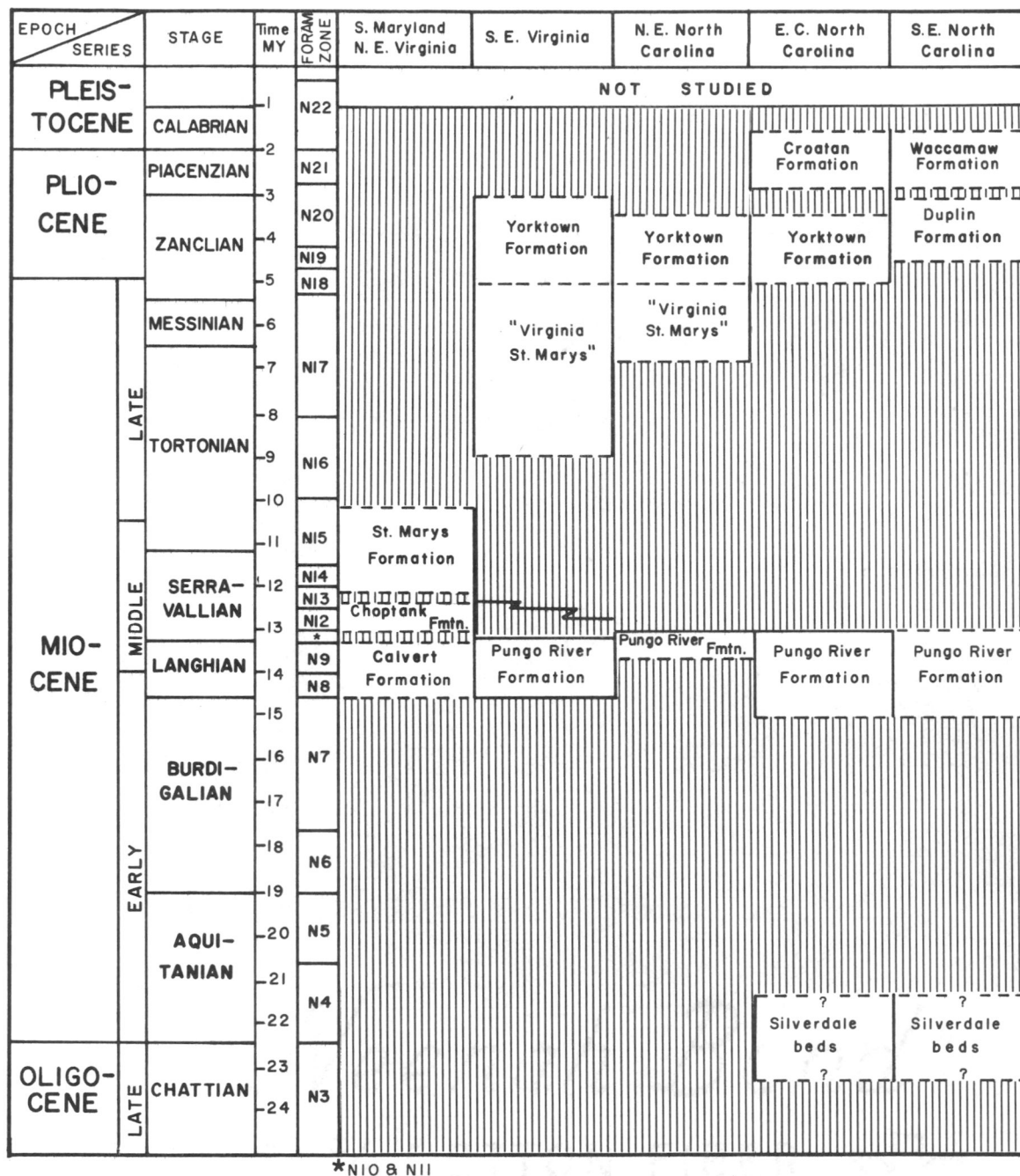


Figure 2. Regional stratigraphic relationships of Late Oligocene through Early Pleistocene strata, central Atlantic Coastal Plain (modified from Gibson, in press). Foraminiferal Zones are after Blow (1969).

River depositional system, indicates that this topographic high in the vicinity of the Neuse River was a positive feature during Pungo River and Yorktown time (Bailey, 1973; Gibson, 1970; Miller, 1971).

METHODS OF STUDY

Cores from a portion of the North Carolina Coastal Plain that includes Beaufort, Pamlico, Craven, and Carteret Counties were examined during this study (Fig. 1). Descriptions of the foraminiferal assemblages for the Pungo River Formation within this area are based on detailed studies of five cores (BTN-9, PON-1, PON-4, CNN-1, and CTN-1) selected from a series of 66 cores taken by Riggs (1967) during a study conducted for the International Minerals and Chemical Corporation. Each core is designated by two capital letters that represent the first and last letters of the county in which it is located, and by a capital "N" and numerals that indicate the position of the core within the series taken for that county. An additional core was selected from a series of cores taken by the North Carolina Phosphate Corporation and is designated by the letters NCPC. Several other cores from the International Minerals and Chemical Corporation Project (BTN-12, BTN-11, and PON-3) were spot sampled in order to check faunal characteristics noted within the six cores that were analyzed in detail. Foraminiferal assemblages of the Yorktown Formation and its stratigraphic equivalents were recognized in eight cores (BTN-15, BTN-12, BTN-9, NCPC, PON-1, PON-4, CNN-1, and CTN-1). A nearly complete Yorktown section was present in all but the NCPC core. Together, these cores provide a north-south and an east-west transect through eastern North Carolina from northern Beaufort County to southern Carteret County.

Composite samples from selected stratigraphic intervals, each representing a distinct lithologic unit, were available for this study. Most samples were processed for microfossils by 1) boiling in a dilute solution of Quaternary "0" (alkyl imidazolinium chloride), 2) wet sieving (U.S. Standard Sieve No. 230), and 3) flotation using carbon tetrachloride. The sample fraction that did not float was routinely examined to ensure that no specimens were being preferentially lost. Some samples were washed and sieved but the flotation step was eliminated. Comparison of the two techniques indicated that no significant bias was introduced by flotation.

Where available, a minimum of 300 benthic foraminiferal specimens were picked in order to ensure the statistical validity of resultant data concerning the relative abundance of each species (Chang, 1967). In samples where 300 specimens could not be recovered, benthic species were identified but statistical analyses were not employed.

Paleoecologic reconstruction of the depositional basin during Pungo River and Yorktown time was attempted by analyzing the changes in the physical parameters of depth and water chemistry as indicated by comparison of fossil benthic assemblages with modern faunas (action pair analysis of Lawrence, 1971). Interpretations were supplemented by statistical analyses of faunal variability and equitability. These values were determined using the Shannon-Wiener Information Function because it is independent of sample size and the occurrence of rare species (Gibson and Buzas, 1973; Sanders, 1968), allowing one to work more easily with samples of varying sizes. The function is

calculated as follows:

$$H(S) = -\sum p_i \ln p_i ,$$

where S represents the total number of species in the sample and p_i represents the observed proportion of individuals that belong to the i th species ($i = 1, 2, \dots S$). $H(S)$ is the index of information that can be used to statistically characterize an assemblage. A low index value, characteristic of assemblages with few species, indicates stressed conditions. A high index value, characteristic of assemblages with many species that are roughly equally distributed in terms of relative abundance, is indicative of more stable conditions.

Faunal dominance, the occurrence in percent of the most abundant species in a given assemblage, was also measured. This characteristic is inversely proportional to the variability of the fauna and directly proportional to the variability of the environment. Therefore, an assemblage dominated by a few species will have high dominance and low diversity values; and an assemblage characterized by many species that are roughly equally distributed will have low dominance and high diversity values. The former indicates shallow water, marginal marine conditions; the latter, more offshore, stable conditions.

Samples were also examined in order to identify planktic species that might be biostratigraphically useful. Worldwide studies on the distribution of Neogene planktic foraminifera (Banner and Blow, 1965; Blow, 1969; Berggren and Van Couvering, 1974; numerous JOIDES reports)

have allowed workers to establish zonations and correlations of units which can be related to European type sections. This allows for the correlation of units, separated by long distances and not necessarily near the type section, using European stratigraphic terminology. The capability is thus created for a more precise definition of many Cenozoic formations (Akers, 1972).

The relative abundance of planktic versus benthic specimens was estimated as a further indicator of paleobathymetry, but no detailed analysis of the relative abundance of individual species within the planktic assemblage was attempted. Because biostratigraphic analysis does not require computation of the relative abundance of each species, no specific minimum number of specimens is required. Age assignments of the strata were made using the planktic zonations of Blow (1969). Results were then compared to those of other regional studies of planktic assemblages (Akers, 1972; Gibson, in press; Snyder et al., in press).

The data gathered from the foraminiferal analyses were then superimposed on the lithostratigraphic framework. Results for the Pungo River Formation are quite detailed because Scarborough (1981) has described the regional lithostratigraphy of that formation. No comparable lithostratigraphic study has been undertaken for the Yorktown Formation. Therefore, conclusions concerning faunal-sediment relationships within the Yorktown Formation must be more generalized.

PUNGO RIVER FORMATION

Introduction

The Pungo River Formation is the oldest formation of the Chesapeake Group found in North Carolina. Brown (1958) first described sediments that were later assigned to the Pungo River Formation from the subsurface of Beaufort County, North Carolina. He correlated these sediments with the Middle Miocene Calvert Formation of Maryland, thus placing them in the basal portion of the Chesapeake Group. Kimrey (1964) formally named the formation using a core from the vicinity of Belhaven, North Carolina as the type section. His lithologic description of the sediments has since been modified by Miller (1971) and Scarborough (1981) to include an unconsolidated to consolidated, shelly, quartz bearing dolomite that lies immediately above the sedimentary sequence of the type section.

The Pungo River Formation unconformably overlies sediments of Eocene to Early Miocene age. Eocene sediments belong to the Castle Hayne Formation; Early Miocene sediments, to the Silverdale Formation. The latter formation has been called Late Oligocene in age by Gibson (in press). Other workers (Baum et al., 1978; Kellum, 1925, 1926; Vokes, 1967, 1970) place this formation higher in the section, calling it Early Miocene in age. The Pungo River Formation is unconformably overlain by the Yorktown Formation of late Early to early Late Pliocene age (Snyder et al., in press) and by the Duplin Formation, which is correlative with the upper Yorktown

Formation (Gibson, in press) (Fig. 2).

Pungo River sediments are present in the subsurface of North Carolina from approximately 77°00' west longitude eastward to the coastline (Miller, 1971). Within the study area the formation ranges from a maximum thickness of approximately 70 meters in Pamlico County to less than one meter near its updip limit in Beaufort County. It also thins to about 15 meters across a pre-Miocene topographic high (the Cape Lookout High) located in southern Craven County. In addition, Pungo River sediments have now been identified from Onslow Bay off the southeastern coast of North Carolina (Lewis *et al.*, in press).

The study area can be subdivided into three regions on the basis of both the lithologic and faunal characteristics of the Pungo River Formation. The northernmost region, hereafter referred to as the Aurora Embayment, includes Beaufort, Pamlico, and portions of northern Craven Counties. The sedimentary units and associated foraminiferal assemblages recognized within this embayment change rather abruptly just south of the Neuse River in southern Craven and northern Carteret Counties. These changes are related to the Cape Lookout High (Snyder *et al.*, 1980) that demarcates the southern extent of the Aurora Embayment. The distinctive lithology and fauna of Pungo River sediments across this topographic high constitute the second subdivision of the study area. A third region lies immediately to the south, in central and southern Carteret County. The lithologic units and foraminiferal assemblages from this region are quite similar to those from the upper part of the Pungo River section in the Aurora Embayment.

Previous Work

Gibson (1967) examined the planktic and benthic foraminiferal assemblages of the Pungo River Formation at Lee Creek, North Carolina. His correlation, based on the presence of key foraminiferal and molluscan species, of the upper calcareous Pungo River beds with the Calvert Formation corroborated the interpretations of Brown (1958). Gibson stated that Pungo River sediments were deposited in a north-east-southwest trending oceanic embayment located south of the Norfolk Arch in southern Virginia and north of a positive feature with its axis in the vicinity of New Bern, North Carolina. The latter feature probably represents the Cape Lookout High of Snyder et al. (1980). Gibson's interpretation of the depositional environment was as follows: water depths of 100 to 200 meters for the phosphorite beds, and depths of less than 70 meters for the upper calcareous beds. Leutze (1968) stated that water depths may have been significantly shallower than those suggested by Gibson.

Miller (1971) conducted an extensive regional study of the Pungo River Formation based on core data from the North Carolina Coastal Plain. On the basis of the benthic foraminiferal fauna, he proposed an open marine, normal salinity, shallow shelf environment of deposition. Down-basin wells containing a sequence of basal phosphorite and calcareous sands yielded foraminiferal species indicative of a Middle Miocene age, thus documenting that the entire formation lies within the Middle Miocene.

Gibson (in press) has refined the age assignment of the Pungo River Formation on the basis of key planktic and benthic foraminiferal species. He correlates portions of the formation with planktic foraminiferal Zones N. 8 and N. 11 (Blow, 1969). Strata belonging to the intervening Zones N. 9 and N. 10 have not been recognized. Planktic assemblages indicating Zone N. 11 are reported only from northeastern North Carolina; those indicating Zone N. 8, from the vicinity of Norfolk, Virginia to south of the Neuse River in North Carolina.

Generalized Lithologic Framework

Scarborough (1981) has recognized seven major lithologic units within the Pungo River Formation. The following descriptions are brief, characterizing only the general lithology of each unit. The geographic and stratigraphic distributions of the units, none of which are continuous throughout the entire study area, are presented in Figures 3 and 4. The lowermost unit in the Aurora Embayment (Unit A) is a fine to medium, dolomitic, muddy phosphorite sand capped by a phosphatic, quartz bearing dolomite. Overlying this is Unit B, a fine, dolomitic, muddy phosphorite sand that is also capped by a phosphatic, quartz bearing dolomite. A thick section of diatomaceous clay encountered in the easternmost portion of the study area (core PON-4) has been mapped as a facies of Unit B. Unit C, a fine to medium, muddy phosphorite sand interbedded with phosphatic, quartz bearing, moldic limestones, overlies Unit B. With the exception

Figure 3. North - south distribution of major lithologic units in the Pungo River Formation (descriptions from Scarborough, 1981).

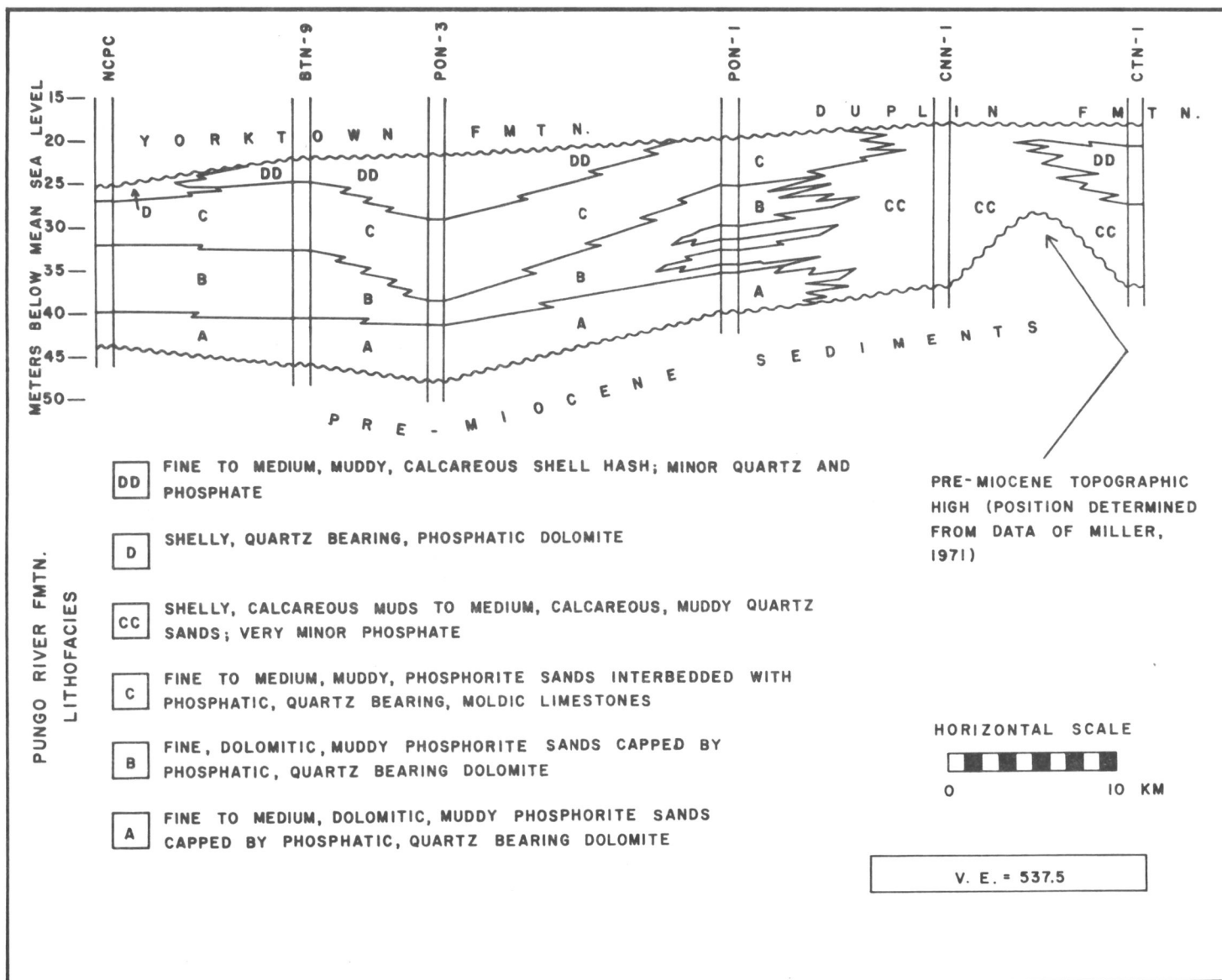
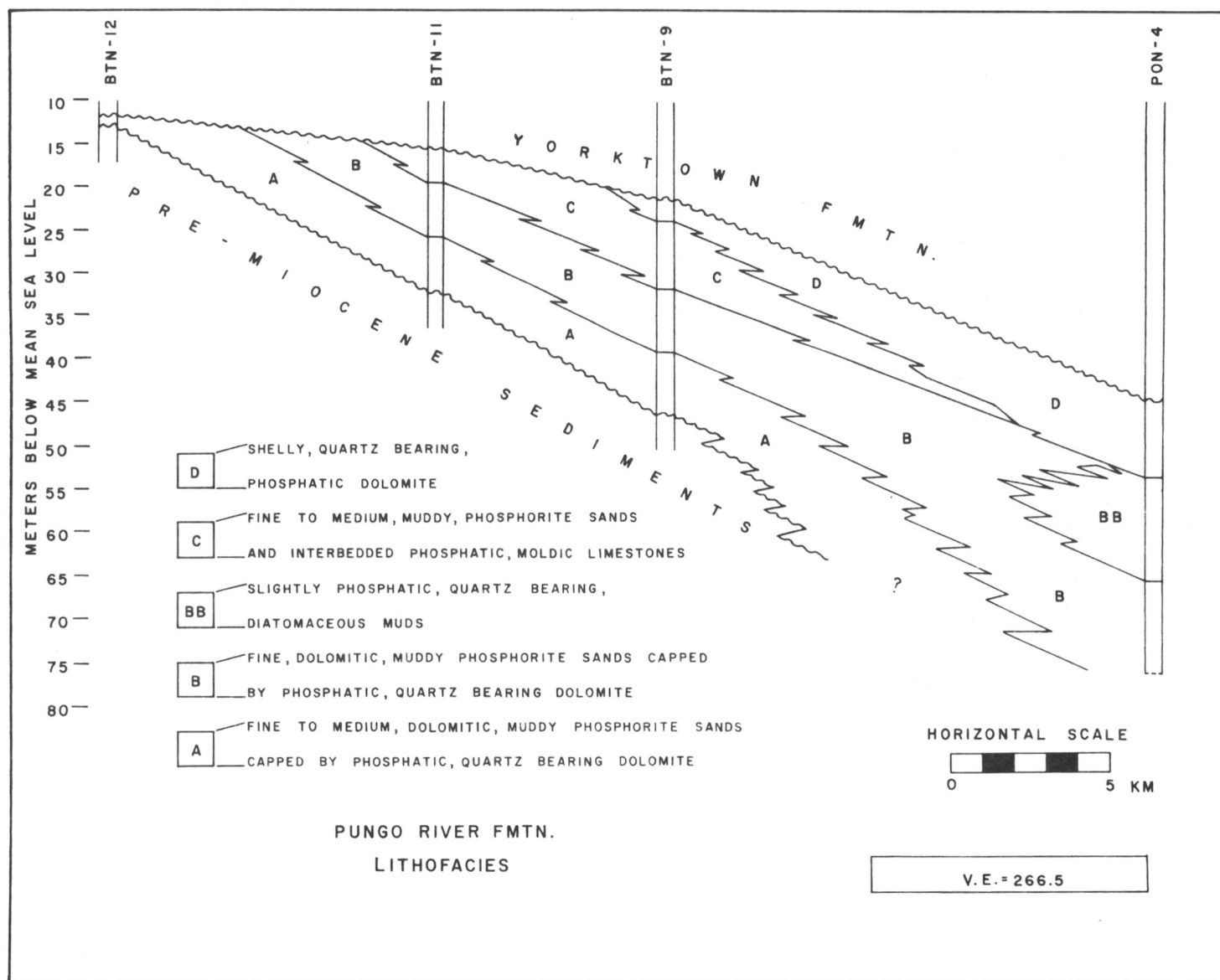


Figure 4. East - west distribution of major lithologic units in the Pungo River Formation (descriptions from Scarborough, 1981).



of Unit C, which thins and pinches out in an eastward direction, these units extend laterally throughout the Aurora Embayment. Unit D is an unconsolidated, shelly, quartz bearing dolomite that occurs only in the northern portion of the study area.

Three of the units described above (A, B, and C) appear to grade southward into Unit CC, a shelly, calcareous mud to calcareous, muddy, quartz sand with very minor phosphate content. Unit CC is characteristic of the entire Pungo River section in southern Craven County where it is associated with the Cape Lookout High. This unit appears to be continuous across the axis of the high and onto the southern flank of the feature in northern Carteret County. The lateral relationship between Unit CC and other units is highly interpretive. More detailed coverage along the flanks of the topographic high will be necessary for more detailed resolution.

Unit DD is a fine to medium, muddy, calcareous shell hash with minor amounts of quartz and phosphate. It lies above Unit C throughout most of the Aurora Embayment. It is also present in Carteret County where it grades into and may be interbedded with Unit CC.

Appendix I shows the lithologic units of the Pungo River Formation from each core in contact with the lower units of the Yorktown Formation throughout the study area.

Benthic Foraminifera

Aurora Embayment (Beaufort, Pamlico, and northern Craven Counties)

Two distinct benthic foraminiferal assemblage zones, one lying

stratigraphically above the other, are present within the Pungo River Formation in the Aurora Embayment. Assemblage Zone 1 is characteristic of and confined to lithologic units A and B, the lower portion of the formation (Figs. 5 and 6). Assemblage Zone 2 is consistently associated with lithologic units C, D, and DD, the upper portion of the formation (Figs. 5 and 6). All species that are numerically important in either of these zones are figured in Plates 1-3.

The dominant species of Assemblage Zone 1 are:

Buliminella elegantissima (d'Orbigny),

Caucasina gracilis (Cushman),

Elphidium excavatum (Terquem).

Species of secondary importance, both in terms of numerical abundance and frequency of occurrence among the samples, include

Florilus pizzarensis (Berry), Cibicides lobatulus (Walker and Jacob),

Elphidium limatulum Copeland, Hanzawaia concentrica (Cushman), H.

nipponica Asano, and Nonionella miocenica Cushman. Buliminella

elegantissima and Caucasina gracilis are abundant in both units A

and B. Elphidium excavatum is most abundant in Unit A and, although

still a very important faunal element, is less abundant than the

previous two species in Unit B. Species diversity values are gener-

ally low. The mean value for all samples from this assemblage zone

is 1.4 and many values below 1.0 were recorded. In this portion of

the formation foraminiferal specimens are often too scarce to permit

calculation of the information function. However, low diversity

values characterize even the richest, best preserved samples. Faunal

dominance within Assemblage Zone 1 is generally high, averaging 51%

Figure 5. North - south distribution of foraminiferal faunal assemblages in the Pungo River Formation.

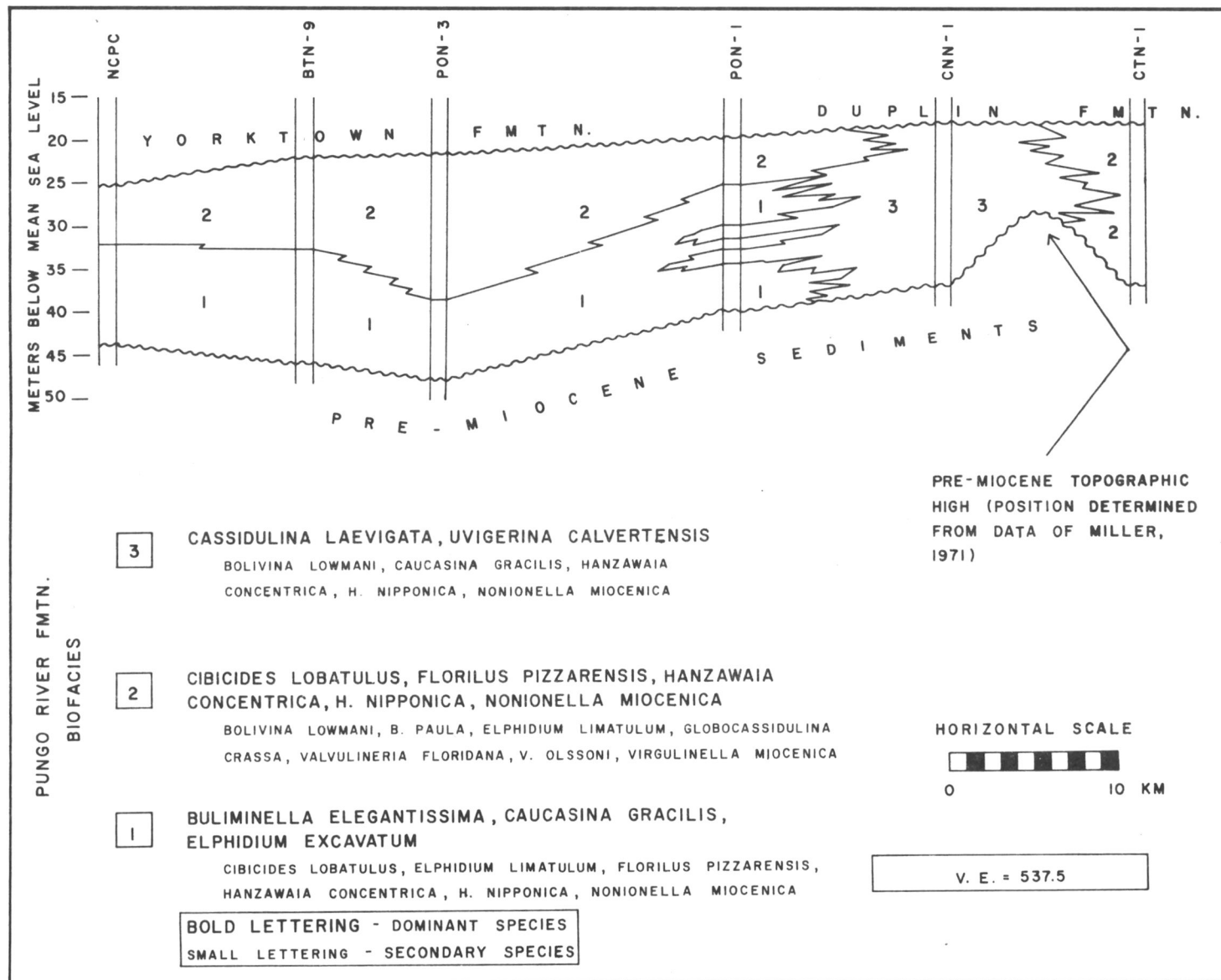


Figure 6. East - west distribution of foraminiferal faunal assemblages in the Pungo River Formation.

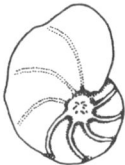
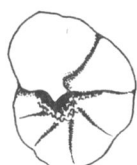
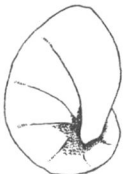
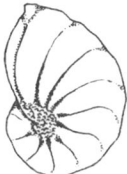
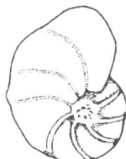
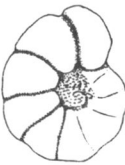
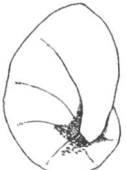
and ranging as high as 90% in some samples. Planktic specimens are rare to absent.

The dominant species of Assemblage Zone 2 are:

Hanzawaia concentrica (Cushman),
Hanzawaia nipponica Asano,
Florilus pizzarensis (Berry),
Cibicides lobatulus (Walker and Jacob),
Nonionella miocenica Cushman.

Species of secondary importance include Virgulinella miocenica (Cushman and Ponton), Globocassidulina crassa (d'Orbigny), Bolivina lowmani Phleger and Parker, B. paula Cushman and Cahill, Elphidium limatulum Copeland, Valvulineria floridana Cushman, and V. olssoni Redmond. Buliminella elegantissima and Caucasina gracilis occur in nearly all the samples from Assemblage Zone 2 but they are never numerically abundant. In the northern portion of the Aurora Embayment three subassemblages are present within Assemblage Zone 2 (Fig. 7). In Subassemblage 2-A, the stratigraphically lowest of the three, Cibicides lobatulus is numerically dominant, with Nonionella miocenica and Elphidium excavatum ranking second and third respectively. Moving upward within the section, Subassemblage 2-B is dominated by Nonionella miocenica, Florilus pizzarensis, and Virgulinella miocenica. Hanzawaia concentrica, H. nipponica, and Cibicides lobatulus are present in lesser abundance. The latter three species become numerically dominant in Subassemblage 2-C. Associated with them, but occurring in lesser abundance, are Virgulinella miocenica, Valvulineria floridana, V. olssoni, and Globocassidulina crassa. Southward toward the axis of

Figure 7. Subassemblages within Assemblage Zone 2 of the Pungo River Formation in the Aurora Embayment.

ASSEMBLAGE	ZONE	SUBASSEMBLAGE	SPECIES COMPOSITION	
			SPECIES THAT CHARACTERIZE EACH SUBASSEMBLAGE ARE ARRANGED FROM MOST ABUNDANT AT THE LEFT TO PROGRESSIVELY LESS ABUNDANT TOWARD THE RIGHT	
			DOMINANT SPECIES	SECONDARY SPECIES
2		2-C	 HANZAWAIA CONCENTRICA  HANZAWAIA NIPPONICA  CIBICIDES LOBATULUS	 VIRGULINELLA MIOCENICA  GLOBOCASSIDULINA CRASSA  VALVULINERIA FLORIDANA  VALVULINERIA OLSSONI
		2-B	 NONIONELLA MIOCENICA  FLORILUS PIZZARENSIS  VIRGULINELLA MIOCENICA	 HANZAWAIA CONCENTRICA  HANZAWAIA NIPPONICA  CIBICIDES LOBATULUS
		2-A	 CIBICIDES LOBATULUS  NONIONELLA MIOCENICA  ELPHIDIUM EXCAVATUM	 BOLIVINA PAULA

the embayment these subassemblages are more difficult to recognize because Bolivina lowmani and B. paula become more abundant within each of them. Sediments along the southern margin of the embayment contain species characteristic of Assemblage Zone 2, but the subassemblages cannot be differentiated. It is in this area that Elphidium limatulum attains its greatest abundance.

Species diversity values for Assemblage Zone 2 are generally higher than those for Assemblage Zone 1. The mean value for all samples is 2.3 and only several values below 2.0 were recorded. Faunal dominance is generally lower, averaging 33%. Benthic foraminifera are abundant but preservation ranges from fair to poor. Planktic specimens are rare to common.

Pre-Miocene Topographic High (southern Craven County)

The southern extent of the Aurora Embayment is defined by a roughly east-west trending pre-Miocene topographic high (Cape Lookout High) extending from southwest Carteret County through southeast Craven County (Miller, 1971). Pungo River sediments recovered from the northern flank of this high (core CNN-1) belong to Unit CC (Fig. 3), as defined by Scarborough (1981).

The benthic foraminiferal assemblages from this unit, here designated as Assemblage Zone 3, are distinct from those found either to the north or to the south. Both geographic and stratigraphic distributions of this zone are shown in Figure 5. The dominant species throughout the entire Pungo River section in this area are Cassidulina laevigata d'Orbigny and Uvigerina calvertensis Cushman (Plate 3). Species diversity values are moderate, ranging from 2.0 to 2.7;

faunal dominance averages 27%. Planktic specimens are consistently present but always rare.

Northern Edge of Onslow Bay (Carteret County)

South of the pre-Miocene topographic high, along the northern edge of Onslow Bay, the Pungo River Formation consists of Units CC and DD (Fig. 3). The foraminiferal assemblages are similar to those in Units C, D, and DD of the Aurora Embayment, and they are placed into Assemblage Zone 2 (Fig. 5). Dominant species, diversity values, faunal dominance, and the abundance of planktic specimens compare closely to those same characteristics within the upper Pungo River sediments of the Aurora Embayment. However, the subassemblages recognized in that embayment cannot be distinguished in samples from Carteret County. In addition, several forms that were not recorded from the Aurora Embayment are present in the southern region. These forms include Siphogenerina lamellata Cushman, which has been recorded by other authors (Gibson, 1967; Miller, 1971) from areas farther north.

Paleoecologic Interpretations

Assemblage Zone 1

Several of the numerically dominant species from this zone survive to the Recent, and information is available concerning their respective ecological optima and tolerances. Buliminella elegantissima, by far the most abundant species throughout the lower Pungo River sediments, occurs in abundance in water depths of 12 to 60 meters (Walton, 1964). Schnitker (1971) recorded small numbers of this

species from nearshore environments of the Atlantic Continental Shelf. He did not report it from areas farther offshore. It flourishes in nearshore areas characterized by high organic content and nutrient rich waters, such as sewage outfall areas (Seiglie, 1968). The dominance of B. elegantissima suggests that Units A and B were deposited in exceptionally nutrient rich waters. Elphidium excavatum is abundant in water depths of 12 to 36 meters (Walton, 1964) and Schnitker (1971) considered it to be characteristic of nearshore environments. It is a highly variable species (Feyling-Hanssen, 1972) with broad ecological tolerances, and it seems to be opportunistic, becoming numerically important where conditions are not suitable for most other species. The ecological tolerances of Caucasina gracilis are poorly understood perhaps, in part, because of its frequent misidentification as a species of Bulimina.

Ecological tolerances for species of secondary importance are generally consistent with conditions suggested by the most abundant species. Nonionella miocenica is characteristic of water depths from 16 to 60 meters (Walton, 1964), and species of the genus Florilus are common and consistent faunal elements of nearshore and mid-shelf environments (Schnitker, 1971). Many of these secondary species are, however, associated with more open marine conditions than those suggested by Buliminella elegantissima and Elphidium excavatum.

High faunal dominance, low diversity values, the scarcity of planktic specimens, and the ecological tolerances of numerically important species suggest a nearshore, shallow water environment of deposition. Dominant species indicate unusual conditions, perhaps

related to water chemistry or nutrient supply, that were not generally suitable for most species. However, the occasional occurrence of more open marine forms indicates that the area was periodically exposed to normal marine circulation. Water depths probably did not exceed 40 to 50 meters.

Assemblage Zone 2

Ecological tolerances for a number of species that characterize this zone are well known. Hanzawaia concentrica is characteristic of mid-shelf environments off the modern North Carolina coast (Schnitker, 1971). Todd (1979) stated that it occurs abundantly from inner shelf to upper slope regions. Hanzawaia spp. attain maximum abundance in water depths of 20 to 50 meters in the Gulf of Mexico (Walton, 1964). Cibicides lobatulus has been recorded from littoral (Bhatia, 1956; Choung, 1975) to abyssal depths (Parker, Phleger, and Pierson, 1953) and is a common species in many modern shallow water areas. Bolivina lowmani is abundant in water depths of 12 to 20 meters (Walton, 1964) and is present in lesser abundance from nearshore to shelf edge waters (Schnitker, 1971). Smith (1968) stated that species of Valvulineria indicate bathyal depths, but Schnitker (1971) recorded the genus in mid-shelf to shelf edge environments. Tolerances of Nonionella miccenica and species of Florilus have been discussed previously.

Moderate diversity values, lower faunal dominance, the common occurrence of planktic specimens, and the ecological tolerances of abundant species suggest an open marine depositional environment. Although a mid-shelf environment is indicated, water

depths may not have been significantly greater than they were during the deposition of Assemblage Zone 1. Deposition of sediments associated with Assemblage Zone 2 could have occurred in waters as shallow as 50 to 60 meters.

Assemblage Zone 3

This zone is numerically dominated by Cassidulina laevigata and Uvigerina calvertensis. C. laevigata is a common and consistent faunal element in shelf edge waters (Schnitker, 1971). Todd (1979) listed it as characteristic of mid-shelf to upper slope environments, and Walton (1964) recorded Cassidulina spp. in water depths of 56 to 400 meters. Modern species of the genus Uvigerina occur from inner shelf to upper slope environments (Todd, 1979). Walton (1964) recorded Uvigerina in depths of 80 to 400 meters, but considered abundant occurrences indicative of continental slope environments.

The dominant species of this zone suggest an outer shelf to upper slope environment. However, the scarcity of planktic specimens, relatively high faunal dominance, and moderate diversity values are not consistent with such an interpretation. Perhaps typical offshore species migrated shoreward in response to favorable conditions associated with the topographic high that existed in this region. Smaller scale features of this nature, where generic dominance zones trend across bathymetric contours, were noted by Walton (1964) in surface sediments of the Gulf of Mexico.

Biostratigraphy

Benthic Foraminifera

A number of benthic foraminiferal species are restricted to the Pungo River Formation throughout the study area. Unfortunately, most of them are rare and some individual samples contain no diagnostic forms. Those species found to be most useful as indicators of Pungo River sediments include Bolivina calvertensis Dorsey, Siphogenerina lamellata Cushman, Hopkinsina bononiensis (Fornasini), Nonion marylandicum Dorsey, Virgulinitella miocenica (Cushman and Ponton), and Uvigerina calvertensis Cushman. Although several of these species have been reported from sediments that are younger than those of the Pungo River, the absence of younger Miocene units within the study area makes them useful stratigraphic markers. In addition to the species listed above, several new species described by Gibson (in press) as diagnostic forms for the Pungo River Formation were found. These include Bolivina pungoensis, Bolivinitopsis fairhavenensis, Cibicides cravenensis, and Florilus chesapeakeensis.

Specimens of Uvigerina calvertensis and Florilus chesapeakeensis were found throughout the study area, occurring in all three assemblage zones. However, it is only within Assemblage Zone 3 that these species were recorded in significant numbers. Although U. calvertensis has been reported from younger sediments (Mauger, 1979), Miller (1971) stated that the abundant occurrence of this species is indicative of Pungo River strata. These are the only diagnostic benthic species for the Pungo River Formation found in Assemblage

Zone 3.

Rare specimens of Bolivina calvertensis and rare to fairly common specimens of Bolivinopsis fairhavenensis were recorded from sediments of Assemblage Zones 1 and 2 in the Aurora Embayment and northern Onslow Bay regions. These species have been reported by Gibson (in press) to be restricted to the Pungo River Formation (planktic Zone N. 8). Virgulinella miocenica also occurs within Assemblage Zones 1 and 2, reaching its greatest abundance in sediments of Assemblage Zone 2. It is found throughout the study area except in southern Craven County. This species has a reported range of latest Early Miocene (Zone N. 8) through the Late Miocene (Zone N. 17) (Gibson, in press).

Species characteristic of only Assemblage Zone 2 are Bolivina pungoensis, Cibicides cravenensis, Nonion marylandicum, Hopkinsina bononiensis, and Siphogenerina lamellata. All of these species, with the exception of S. lamellata, occur throughout the Aurora Embayment and northern Onslow Bay regions. H. bononiensis has been reported to be restricted to the upper section of the Pungo River Formation by Gibson (in press), who recorded it from strata falling into Zone N. 11. N. marylandicum ranges from early Middle Miocene into the Upper Miocene (Gibson, in press). B. pungoensis and C. cravenensis are reported by Gibson (in press) to be entirely restricted to the Pungo River Formation. S. lamellata was recorded only in sediments from Carteret County. Its reported range is throughout the Pungo River Formation, but it was recorded only from the upper portion of the formation in this study.

These diagnostic benthic species are figured in Plates 3, 4, and 5.

Planktic Foraminifera

Planktic foraminifera occur throughout the Pungo River section in the study area. However, it is only within sediments of Assemblage Zone 2 that they occur in any abundance. Specimens are scarce to absent in samples from Assemblage Zones 1 and 3. Planktic species identified during this study are listed below.

Globigerina euapertura Jenkins

G. praebulloides pseudociperoensis Blow

G. juvenilis Bolli

G. woodi woodi Jenkins

Globigerinoides altiapertura Bolli

G. subquadratus Bronnimann

G. quadrilobatus quadrilobatus (d'Orbigny)

Globigerinatella insueta Cushman and Stainforth

Globoquadrina altispira altispira (Cushman and Jarvis)

G. altispira globosa Bolli

G. dehiscens (Chapman, Parr, and Collins)

Globigerinita glutinata (Egger)

G. uvula (Ehrenberg)

Globorotalia (Turborotalia) birnageae Blow

G. (T.) peripheroronda Blow and Banner

G. (T.) scitula praescitula Blow

G. (T.) cf. G. (T.) siakensis (LeRoy)

Praeorbulina glomerosa glomerosa (Blow)

Cassigerinella chipolensis (Cushman and Ponton)

The stratigraphically restricted species Globigerina euapertura, G. praebulloides pseudociperoensis, G. woodi woodi, Globigerinoides altiapertura, G. subquadratus, Globoquadrina dehiscens, Globigerinatella insueta, Globorotalia (Turborotalia) birnageae, G. (T.) peripheroronda, G. (T.) scitula praescitula, G. (T.) siakensis, Praeorbulina glomerosa glomerosa, and Cassigerinella chipolensis suggest an age for the formation from the latter part of Zone N. 7 to the latter part of Zone N. 8 (Fig. 8). This range allows for a correlation of Pungo River strata with the Globigerinatella insueta Zone of Trinidad, for which a Burdigalian age is assigned (Blow, 1969).

The upper limit of this range is based on the occurrence of Globigerina euapertura and Globigerinoides altiapertura, neither of which have been reported from sediments younger than Zone N. 8. One specimen of Praeorbulina glomerosa glomerosa was found, indicating an age no older than the middle of Zone N. 8. The fact that it was recorded from the Craven County section, along with the presence of significant numbers of Globorotalia (Turborotalia) birnageae (Zone N. 7 to Zone N. 9) and several specimens of Globigerina praebulloides pseudociperoensis (Zone N. 7 to Zone N. 12) supports the lower age limit proposed above. Although planktic specimens were rare in the lower section (Assemblage Zone 1) and within Assemblage Zone 3, representatives of some stratigraphically significant forms were found, allowing for a tentative correlation of the entire formation.

Figure 8. Stratigraphic ranges of planktic species present in the Pungo River Formation (data from Blow, 1969; Bronnimann and Resig, 1971; Akers, 1972; Jenkins and Orr, 1972; Kennett, 1973; Fleischer, 1974; Gibson, in press).

BIOSTRATIGRAPHIC ZONES		AGE		GEOLOGIC	
N. 23	Cassigerinella chipolensis	N. 23	Pleistocene	Paeorbulina glomerosa glomerosa	Globoquadrina dehiscens
N. 22		N. 22			
N. 21		N. 21			
N. 20		N. 20			
N. 19		N. 19			
N. 18		N. 18			
N. 17		N. 17			
N. 16		N. 16			
N. 15		N. 15			
N. 14		N. 14			
N. 13		N. 13			
N. 12		N. 12			
N. 11		N. 11			
N. 10		N. 10			
N. 9		N. 9			
N. 8		N. 8			
N. 7		N. 7			
N. 6		N. 6			
N. 5		N. 5			
N. 4		N. 4			
N. 3		N. 3			
N. 2		N. 2			
N. 1		N. 1			

This age assignment agrees with that proposed for the upper Pungo River section by Gibson (in press), who also suggested a range from the latter part of Zone N. 7 to the latter part of Zone N. 8. Species that he interpreted as indicating an age of Zone N. 11 were not found. This is not surprising as the only reported occurrence of Pungo River sediments of this age is to the north of the study area.

Akers (1972), proposing an age range of Zone N. 7/ Zone N. 8, correlated the Chipola Formation of Florida with the Globigerinatella insueta Zone of Trinidad. This age assignment was supported by Gibson (1967). Within this formation, Akers found several stratigraphically restricted species that are also present in Pungo River sediments. Vokes (1965) on the basis of the Muricinae (Mollusca: Gastropoda), suggested that the Chipola Formation might be equivalent to the Helvetian (Tortonian) of western Europe rather than to the Burdigalian. This is interesting because several benthic and planktic species that would indicate a younger age for the Pungo River Formation were tentatively identified during this study. A great deal remains to be learned about this planktic assemblage, and further studies of these assemblages from coastal plain sediments of similar age is necessary in order to resolve these apparent inconsistencies.

YORKTOWN AND DUPLIN FORMATIONS

Introduction

The Yorktown Formation is the youngest formation of the Chesapeake Group, and it occurs only in the states of Virginia and North Carolina (Fig. 2). It was formally named by Clark and Miller (1906) for sands that crop out along the south bank of the York River near Yorktown, Virginia. The term Yorktown is used in North Carolina only for sediments to the north of the Neuse River. Yorktown-equivalent deposits to the south of the Neuse River, extending into the area of the Cape Fear Fault, have been referred to the Duplin Formation (Copeland, 1964). Within the study area, the Yorktown and Duplin Formations unconformably overlie the Pungo River Formation. North of the Neuse River the Yorktown strata are unconformably overlain by Plio-Pleistocene sands, clays, and shell gravels. In the central Coastal Plain of North Carolina, the Plio-Pleistocene unit directly overlying Yorktown sediments is a fossiliferous, blueish, shelly to gravelly quartz sand with abundant whole shells and shell fragments. It is here referred to as the Croatan Formation, which is equivalent, at least in part, to the James City Formation of Dubar et al. (1974). The Duplin Formation is unconformably overlain by the Plio-Pleistocene Waccamaw Formation, a highly fossiliferous, poorly indurated quartz sand with varying amounts of silt and clay (Howard, 1966; Richards, 1969).

The study area can be divided into two regions, corresponding

to the geographic distribution of the Yorktown and Duplin Formations, respectively. The northern and central portions of the study area will be referred to as the Aurora Embayment, the same terminology that was used for discussing the Pungo River Formation. This area, which encompasses Beaufort, Pamlico, and northern Craven Counties, lies in the southern portion of the larger Albemarle Embayment. The Aurora Embayment was a well defined depositional center during Pungo River time. Although this smaller embayment cannot be easily distinguished from the larger Albemarle Embayment during Yorktown time, the terminology has been retained in order to provide continuity with discussions of the Pungo River Formation. In the study area, Yorktown sediments occur only within the Aurora Embayment. Southern Craven County and Carteret County make up the second region. This area lies to the south of the Neuse River and corresponds to the distribution of Duplin strata in that portion of the Coastal Plain examined during this project.

Previous Work

Biostratigraphy

A zonation of the Yorktown Formation based on the molluscan fauna was proposed by Mansfield (1943). It is still considered workable for the Yorktown Formation in Virginia (Bailey, 1973; Hazel, 1971). Mansfield divided the formation into two biostratigraphic zones, a lower Zone I (Pecten clintonius) and an upper Zone II (Turritella alticostata).

McLean (1956) summarized the studies dealing with foraminiferal biostratigraphy of Yorktown strata, dealing primarily with the benthic assemblages from the York-James Peninsula in Virginia. However, these early foraminiferal studies failed to provide more accurate interpretations than did those involving the molluscan faunas.

Gibson (1967) interpreted the planktic foraminiferal assemblages from the lower portion of the exposure at Lee Creek, North Carolina as Middle to Late Miocene in age. He correlated these assemblages with the Pecten clintonius Zone of Mansfield (1943). Akers (1972) examined planktic assemblages from the Yorktown Formation, including the localities at Lee Creek and Rice's Pit, Virginia, and proposed that at least part of the formation at the latter location is Early to early Middle Pliocene in age. On the basis of calcareous nannoplankton, Akers and Koepfel (1973) suggested a Middle Pliocene age for the Yorktown section at Lee Creek. In the most recent and comprehensive work on the planktic fauna from Yorktown sediments at Lee Creek, Snyder et al. (in press) proposed an age range of late Early to early Late Pliocene (from just below the base of Blow's Zone N. 19 to the middle of his Zone N. 20). Gibson (in press) states that the "uppermost Yorktown" sediments in more northern exposures are Late Pliocene in age. However, the sediments that Gibson places in the Yorktown Formation contain species indicating an Early Pleistocene age (Snyder et al., in press) and have been referred to the Chowan Formation by Blackwelder (1980).

A zonation based on ostracode assemblages was established by

Hazel (1971) who concluded that Yorktown sediments from the Chowan River near Mt. Gould, North Carolina are Pliocene in age. The Duplin Formation has been proposed as a biostratigraphic equivalent of the upper portion of the Yorktown (Zone II, Turritella alticostata) by Gibson (in press).

Paleoecology

Studies on the paleoenvironment of the Yorktown Formation have been largely based on the foraminiferal and molluscan faunas. Dall (1904) suggested a temperate climate, shallow shelf environment of deposition for the Miocene sediments of Maryland on the basis of the molluscan fauna. Bailey (1973) concluded that the bivalve assemblages represent a transition from an initial transgressive sequence to a regressive sequence upward through the Yorktown section.

Based on the analysis of benthic foraminifera, Gibson (1967) suggested that the Yorktown Formation represents deposition in waters of approximately 100 meters in depth (lower portion of the section), the water gradually becoming shallower as deposition continued until a depth of less than 15 meters and probable brackish conditions were reached. Mauger (1979), in her detailed study of the Lee Creek section, stated that the Yorktown sediments were deposited in shallow, normal open marine conditions (depths of less than 90 meters) during a transgressive and subsequent regressive sequence. A nearshore environment of deposition, ranging from sublittoral depths to depths of 20 to 35 meters was suggested by Schnitker (1970) for the Yorktown section near Grimesland, North Carolina. This was a study of the formation near its updip limit in Pitt County (Fig. 1), and this exposure

probably represents a shallow water facies of the sediments examined at Lee Creek.

Howard (1966) stated that the Duplin Formation was deposited on a regressive cycle. The lowermost sediments were deposited on an open shelf at depths ranging from intertidal to approximately 45 meters, while sediments in the upper part of the formation were deposited on an open shelf at depths no greater than 12 meters.

Generalized Lithologic Framework

Mauger (1979) recognized five lithologic units within the Yorktown Formation at Lee Creek. These can be combined into three more generalized units designated as the lower, middle, and upper Yorktown. At the base of the formation (lower Yorktown) the sediments are composed of fine to coarse (fining upwards), muddy, gravelly, fossiliferous, blue-grey phosphatic quartz sands. These grade upward into very sandy (fine to very fine calcareous quartz sands), fossiliferous, slightly glauconitic, blue-grey muds to fine to medium, very muddy, slightly gravelly, fossiliferous, blue-grey quartz sands (middle Yorktown). Internal molds of bivalves and gastropods, particularly Turritella, and abundant echinoid spines make up a significant portion of the gravel fraction in the upper lower and lower middle parts of the section. Above the sediments of the middle Yorktown are those of the upper Yorktown, which have been informally referred to as the "Boulder Bed". Coarse to very coarse, moderately muddy, gravelly, fossiliferous, intermittently indurated, light grey quartz sands

characterize this upper unit. This tripartite sedimentary sequence is similar to that described by Gibson (1967) for the Lee Creek section. However, he included sediments above the "Boulder Bed" within the Yorktown Formation. These post "Boulder Bed" sediments are now placed in the Croatan Formation.

Detailed sedimentological data comparable to that available for the Pungo River Formation were not available for the Yorktown Formation. The only available sources of information to determine the vertical extent of the formation in each of the sampling localities were the lithologic field logs recorded by Riggs (1967). Although less detailed than might be desired, general lithologic trends throughout the region could be delineated by this method.

On the basis of the lithologic logs, the Yorktown Formation can be divided into two generalized lithologic units (lower and upper) that are fairly consistent throughout the study area. The lower Yorktown is characterized by fine to medium (fining upwards), dark green, slightly to moderately muddy, gravelly, phosphatic quartz sands. There is often abundant phosphate in the gravel fraction. The transition to sediments of the upper Yorktown is marked by an increase in mud and a general decrease in gravels. The mud fraction is usually greatest near the bottom of the upper unit where it is composed of a dark green, sometimes very tight clay with occasionally abundant echinoid spines. The sands, where present, are usually calcareous in this part of the unit. Moving upward in the section there is a moderate decrease in mud and a coarsening of the sand fraction. The upper portions of this unit are characterized by medium

to coarse grained, slightly muddy quartz sands to interbedded sands and clays. Although this entire sequence is not present at every locality, it represents the general lithologic trends found within the Yorktown Formation throughout this region. The pattern is quite similar to that described by Mauger (1979) and Gibson (1967) at Lee Creek.

Howard (1966) described the Duplin Formation in North Carolina as a fine to coarse, slightly muddy, abundantly fossiliferous quartz sand, with the basal portion containing abundant phosphate. Sections of the Duplin encountered in this study (CNN-1 and CTN-1) are less fossiliferous and contain more mud than the sediments discussed by Howard. They are placed within the Duplin Formation primarily on the basis of their geographic location (south of the Neuse River). Planktic foraminiferal data indicate that these sediments are equivalent, at least in part, to those of the Yorktown Formation to the north, thus supporting this stratigraphic interpretation.

Recognition of the lower contact of the Yorktown Formation within this region was no problem because distinctive lithologies of the Pungo River Formation directly underlie the Yorktown and Duplin Formations throughout the study area. The contact between the Yorktown and the Croatan Formations and the Duplin and the Waccamaw Formations was more difficult to recognize. Samples from this portion of the section are frequently unfossiliferous. However, there is a fairly consistent blueish grey, slightly muddy, very gravelly (shell fragments and whole shells) quartz sand unit that occurs immediately above the Yorktown and Duplin sections throughout the study area.

The lithologic characteristics of this unit are similar to those described by other authors for the Croatan and Waccamaw Formations (Dubar, 1959; Howard, 1966). The placement of this contact is highly interpretive because sedimentological data were not detailed enough to confidently place the sand unit either in the "Boulder Bed" (upper Yorktown) or in the lowermost Croatan and Waccamaw Formations. Where present, foraminiferal data support the higher stratigraphic placement of this unit.

Appendix I shows columnar sections with lithologic descriptions and faunal associations for each of the cores that were examined. The regional distribution of the Yorktown Formation throughout the study area is presented in Figures 9 and 10.

Benthic Foraminifera

Samples yielding sufficient numbers of foraminiferal specimens to determine paleoecologic trends were the exception rather than the rule for most of the Yorktown Formation examined during this study. For example, in core PON-4, which contains more than 40 meters of Yorktown sediments, foraminifera were recovered from only one sample. In contrast to the section at Lee Creek, Yorktown sediments are characteristically unfossiliferous throughout much of the region. This lack of regional faunal data makes it difficult to define the paleoecologic characteristics of the depositional basin during Yorktown time because no distinct assemblage zones can be recognized. Although certain species are more abundant in the lower versus the

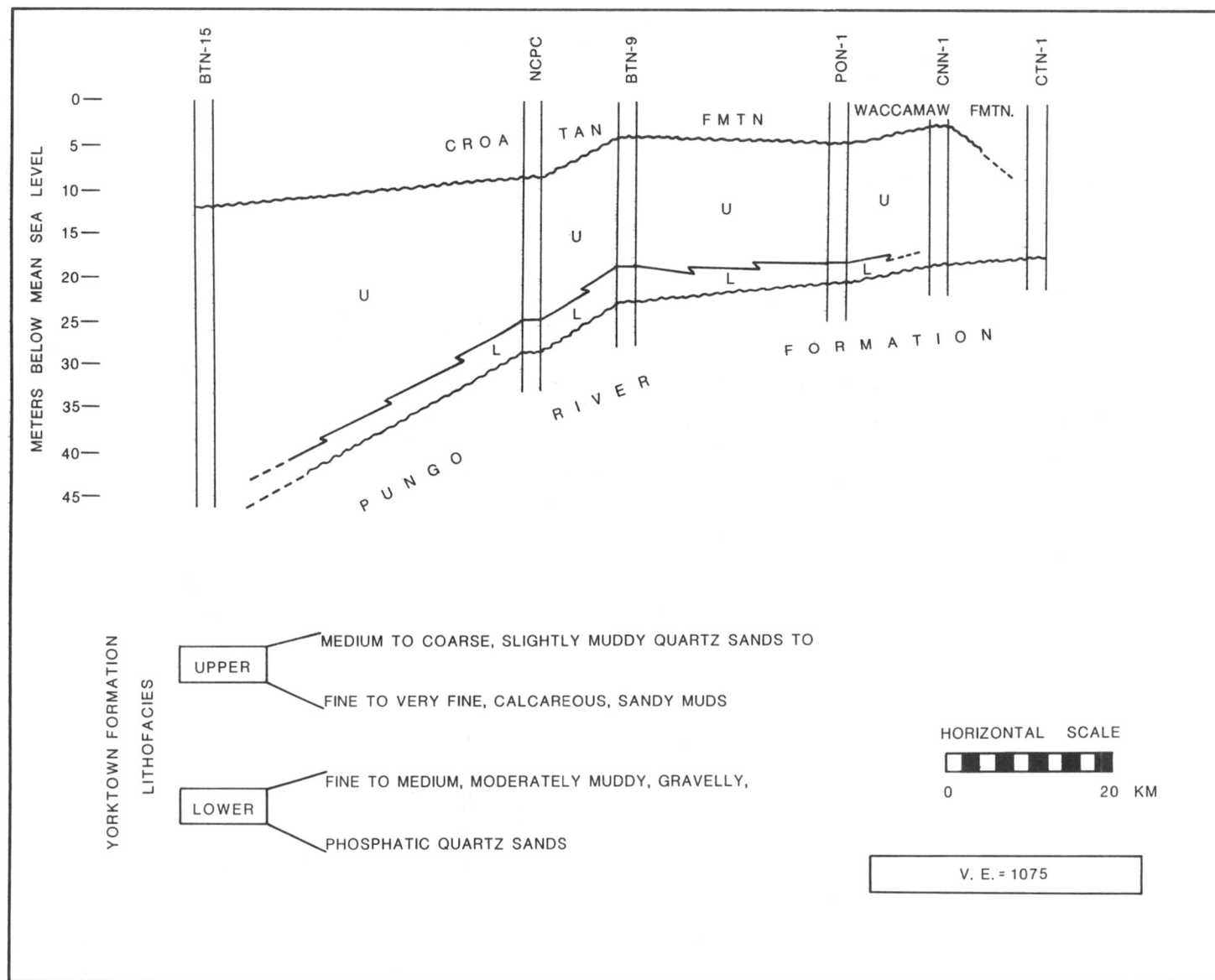


Figure 9. North - south distribution of major lithologic units in the Yorktown Formation.

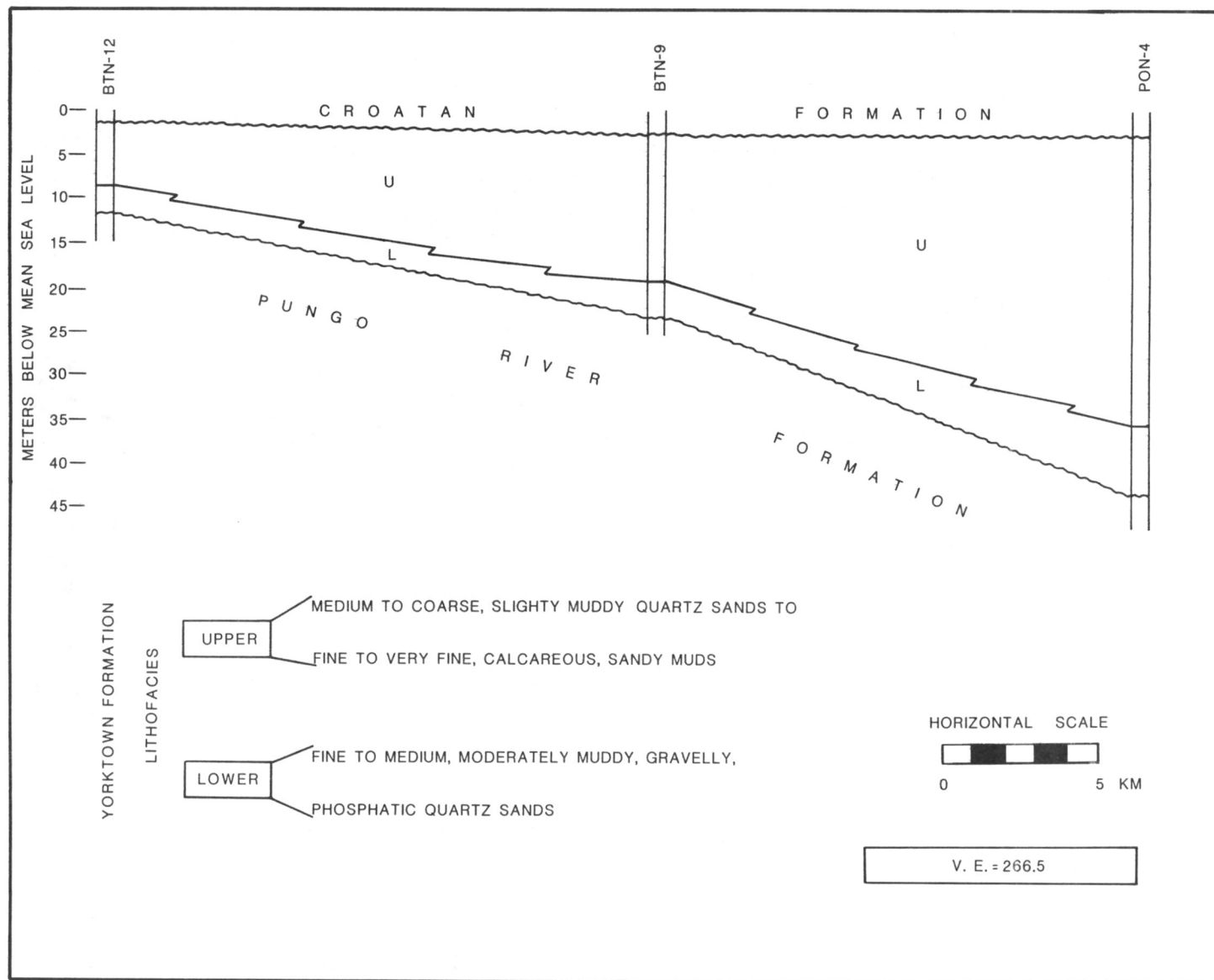


Figure 10. East - west distribution of major lithologic units in the Yorktown Formation.

upper part of the formation, their distributions are not continuous across the basin. This is unlike the condition seen in the Pungo River Formation, where characteristic faunal assemblages can be traced throughout each of the regions studied. Therefore, paleo-ecologic information for the Yorktown Formation is, of necessity, more general. More data will be necessary to resolve the regional events during this period of geologic time.

In discussing the foraminiferal information, the same format used for the Pungo River section will be followed. Occurrences of important species within each sampling locality are present along with the columnar sections in Appendix I.

Aurora Embayment (Beaufort, Pamlico, and northern Craven Counties)

Two general foraminiferal assemblages can be recognized in this area, one corresponding to the upper and the other to the lower Yorktown lithologic units. However, the numerically dominant forms comprising these assemblages do not have a continuous distribution across the region. Thus, the one major change in species composition is often difficult to recognize (i.e., cores PON-4 and BTN-9).

The dominant species of the lower Yorktown are:

Buliminella elegantissima (d'Orbigny),

Caucasina gracilis (Cushman),

Florilus pizzarensis (Berry).

Species of secondary importance, both in terms of numerical abundance and frequency of occurrence among the samples, include Cibicides lobatulus (Walker and Jacob), Nonionella miocenica Cushman, Fursenkoina fusiformis (Williamson), and Elphidium excavatum (Terquem). Dominant

species from this part of the formation exhibit the most continuous distribution seen throughout the Yorktown section. Species diversity values are generally high. The mean value for all samples from the lower Yorktown is 2.7, and one value above 3.0 was recorded. Faunal dominance is generally low, averaging 34% for all samples. Planktic specimens are rare to abundant in this part of the section.

The dominant species of the upper Yorktown are:

Cibicides lobatulus (Walker and Jacob),

Elphidium excavatum (Terquem),

Hanzawaia concentrica (Cushman),

Florilus pizzarensis (Berry),

Bolivina lowmani Phleger and Parker.

Species of secondary importance include Cancris sagra (d'Orbigny), Globocassidulina crassa (d'Orbigny), Bolivina paula Cushman and Cahill, and Uvigerina subperigrina Cushman and Kleinpell. C. lobatulus, E. excavatum, and H. concentrica occur in abundance in most samples of the upper Yorktown throughout the Aurora Embayment, E. excavatum becoming most important in the upper part of this unit in northern Beaufort County. F. pizzarensis is most abundant in sediments from the lower part of this unit in central and southern Beaufort County. C. sagra, G. crassa, and U. subperigrina are most important in northern Beaufort County from the lower part of the upper Yorktown unit. B. lowmani and B. paula reach their greatest abundance in eastern Pamlico County. Species diversity values are generally lower than those for the lower Yorktown, averaging 2.4 for all samples. One value greater than 3.0 was recorded from eastern Pamlico

County. Faunal dominance averages 35%, ranging as high as 47% in one sample. Planktic specimens are rare to abundant.

Southern Region (southern Craven and Carteret Counties)

Sediments of this region, correlative with the Yorktown Formation to the north, have been placed in the Duplin Formation. Only three samples from this formation yielded foraminifera; thus, no biostratigraphic subdivision of the section was possible.

Dominant species of the Duplin Formation in this region are:

Cassidulina laevigata d'Orbigny,

Cancris sagra (d'Orbigny),

Bolivina paula Cushman and Cahill.

Species of secondary importance include Caucasina gracilis (Cushman) and Uvigerina calvertensis Cushman. C. laevigata along with U. calvertensis dominate in southern Craven County, the other species being most important in Carteret County. Species diversity values are fairly high, averaging 2.6 for all samples. Faunal dominance is low, averaging 33% with values ranging as high as 46% for one sample. Planktic specimens are rare to abundant in sediments from this region.

Paleoecologic Interpretations

Yorktown Formation

Most of the species that are important in determining the paleoecological setting of the Yorktown Formation are also important in the Pungo River Formation. Because their ecological tolerances and

preferences have been presented in discussions of the Pungo River Formation, they will not be reiterated here.

There is a general increase in diversity upward through the lower Yorktown Formation, with maximum values occurring at the boundary between the lower and upper Yorktown units. This trend, along with the occurrence of Fursenkoina fusiformis, a form that is characteristic of upper slope environments (Todd, 1979), indicates a deepening of the Aurora Embayment associated with a marine transgression during the deposition of lower Yorktown sediments. The numerical dominance of Buliminella elegantissima in the lower part of the section suggests that initial water depths may not have been very great, ranging from nearshore to mid-shelf. The co-occurrence of open water forms and the generally high numbers of planktic specimens indicate that open marine circulation was maintained throughout lower Yorktown time.

A general decrease in diversity values upward through the upper Yorktown unit, along with a transition from characteristic mid-shelf species (Cancris sagra, Hanzawaia concentrica, and Florilus pizzarensis) to more nearshore forms (Elphidium excavatum, Bolivina lowmani, and Cibicides lobatulus), indicate a shallowing of the embayment during the deposition of these sediments. This interpretation is supported by the occurrence of the highest faunal dominance values near the top of the section, and by the general decrease in abundance of planktic specimens moving upward through the formation. The maximum transgression is most likely associated with the uppermost

lower and the lowermost upper Yorktown sediments, because it is here that the highest diversity values for individual samples occur.

Water depths probably did not exceed 50 to 60 meters during the time of maximum transgression, and they were most likely $\leq$ 30 or 40 meters during deposition of sediments at the very bottom and top of the formation.

The sedimentological data are consistent with these faunal trends, as terrigenous sediment sequences generally fine upward from the base of the formation through the lower portion of the upper Yorktown unit and then coarsen upward through to the top of the formation. The highest diversity values and the presence of foraminiferal faunas characteristic of deeper waters are associated with the extremely muddy sand unit marking the boundary between the lower and upper Yorktown units.

This paleoecologic reconstruction is quite similar to that proposed by Mauger (1979) for the section at Lee Creek. The similarity may be enhanced by the general nature of the study, as the characteristics of the Aurora Embayment surely changed somewhat moving away from the Aurora area. For example, a high diversity value for the sample from the upper Yorktown section in eastern Pamlico County suggests a general deepening of the embayment to the east.

Duplin Formation

The abundance of foraminiferal species such as Cassidulina laevigata and Cancris sagra, along with a generally abundant planktic fauna, suggest that Duplin sediments were deposited in a mid-shelf to outer shelf environment, probably similar to that suggested for the

lower unit of the Yorktown Formation to the north. This interpretation is supported by the fact that the diversity values for the Duplin correspond closely with values for the lower Yorktown section. Sedimentological trends within the two formations parallel one another. However, no classic Duplin lithology was observed in the two sampling locations; and a mid-shelf to outer shelf environmental setting does not conform to interpretations of previous workers, most of whom see the Duplin Formation as a shallow water deposit equivalent to the upper Yorktown. Because only several Duplin samples contained foraminifera, my interpretation must be considered tentative. More extensive sampling will be needed to rectify these apparent discrepancies.

Biostratigraphy

As with the benthic fauna, planktic foraminiferal assemblages occur sporadically throughout the Yorktown and Duplin sections. Because of this, no detailed distributional patterns of planktic assemblages could be recognized within either section. The biostratigraphic ranges of species identified do, however, permit a generalized interpretation for both formations. Planktic species identified are listed below.

Globigerina bulloides apertura Cushman

G. bulloides bulloides d'Orbigny

G. calida praecalida Blow

G. decoraperta Takayanagi and Saito

- G. juvenilis Bolli
G. nepenthes Todd
Globigerinita glutinata (Egger)
Globigerinoides bollii Blow
G. obliquus extremus Bolli
G. obliquus obliquus Bolli
G. quadrilobatus quadrilobatus (d'Orbigny)
G. ruber (d'Orbigny)
Globoquadrina altispira globosa Bolli
G. cf. G. venezuelana (Hedberg)
Globorotaloides hexagona hexagona (Natland)
Globorotalia (Globorotalia) crassula Cushman and Stewart
G. (G.) cultrata limbata (Fornasini)
G. (G.) cultrata menardii (Parker, Jones, and Brady)
G. (G.) exilis Blow
G. (G.) hirsuta praehirsuta Blow
Globorotalia (Turborotalia) acostaensis acostaensis Blow
G. (T.) acostaensis humerosa Takayanagi and Saito
G. (T.) praeoscitans Akers
Hastigerina siphonifera siphonifera (d'Orbigny)
Orbulina suturalis Bronnimann
O. universa d'Orbigny
Sphaeroidinellopsis subdehiscens subdehiscens Blow
Turborotalita humilis (Brady)
T. quinqueloba (Natland)

The stratigraphically restricted species Globigerina bulloides

apertura, G. calida praecalida, G. nepenthes, Globoquadrina altispira globosa, Globorotalia (Globorotalia) crassula, G. (G.) hirsuta praehirsuta and Globorotaloides hexagona hexagona suggest that Yorktown and Duplin sediments range from the latter part of Zone N. 18 to the lower-middle part of Zone N. 20 (Fig. 11). This corresponds to an age of late Early to early Late Pliocene (Early Zanclean to Early Piacenzian) for the Yorktown/Duplin strata. The lower limit of this range is based on the occurrence of G. (G.) hirsuta praehirsuta, G. (G.) crassula, and G. hexagona hexagona, none of which appeared before the middle of Zone N. 18. The presence of G. bulloides apertura and G. altispira globosa, neither of which have been reported from sediments younger than the middle of Zone N. 20, provides an upper limit for the age of these strata. Only one specimen of G. nepenthes was recovered. This species ranges from the base of Zone N. 14 to the boundary between Zone N. 19 and Zone N. 20. Because this form is extremely rare, and because it ranges well into the planktic zones suggested by more common species, the slightly younger upper limit for the age range assignment (middle of Zone N. 20) is retained.

This age agrees with that proposed by Snyder et al. (in press) for the Yorktown Formation at Lee Creek (from just below the base of Zone N. 19 to approximately the middle of Zone N. 20). Both of these ranges are older than that proposed by Gibson (in press), who extends the upper limit of the Yorktown Formation into Zone N. 21. Planktic assemblages recovered during this study are quite similar to those recorded by Akers (1972) for the Jackson Bluff Formation

Figure 11. Stratigraphic ranges of planktic species present in the Yorktown and Duplin Formations (data from Blow, 1969; Akers, 1972; Jenkins and Orr, 1972; Poag, 1972; Snyder et al., in press).

BIOSTRATIGRAPHIC ZONES		Globigerina					Globigerinoides					Globorotalia												GEOLOGIC AGE							
		bulloides apertura	bulloides bulloides	calda praecalida	decoraperta	juvenilis	nepenthes	Globigerinita glutinata	bolli	obliquus extremus	obliquus obliquus	quadrilobatus quadrilobatus	ruber	Globoquadrina altispira globosa	Globoquadrina cf. G. venezuelana	Globorotaloides hexagona hexagona	Turborotalia acostaensis acostaensis	Turborotalia acostaensis humerosa	Turborotalia praescitans	Globorotalia crassula	Globorotalia cultrata limbata	Globorotalia cultrata menardii	Globorotalia exilis			Globorotalia hirsuta praehirsuta	Hastigerina siphonifera siphonifera	Orbulina suturalis	Orbulina universa	Sphaeroidinelopsis subdehiscens subdehiscens	Turborotalia humilis
N. 23																															PLEISTOCENE
N. 22																															
N. 21																															PLIOCENE
N. 20																															
N. 19																															LATE MIOCENE
N. 18																															
N. 17																															MIDDLE MIOCENE
N. 16																															
N. 15																															EARLY MIOCENE
N. 14																															
N. 13																															OLIGOCENE
N. 12																															
N. 11																															
N. 10																															
N. 9																															
N. 8																															
N. 7																															
N. 6																															
N. 5																															
N. 4																															
N. 3																															
N. 2																															
N. 1																															

of Florida and the Agueguexquite Formation of Mexico, both of which were assigned an Early to Middle Pliocene age. As mentioned earlier, his age assignment for part of the Yorktown Formation at Rice's Pit, Virginia falls into this same range.

The only species predominantly restricted to one part of the section was Globorotalia (Turborotalia) praeoscitans, which occurs abundantly only in the lower Yorktown unit. A similar distributional pattern was noted by Snyder et al. (in press) and Mauger (1979) at Lee Creek. On the basis of this, they suggested that it might be a reliable indicator of lower Yorktown sediments within this portion of the Atlantic Coastal Plain.

SUMMARY

Pungo River Formation

The Pungo River Formation of the central North Carolina Coastal Plain represents deposition within three distinct systems: 1) the Aurora Embayment in Beaufort, Pamlico, and northern Craven Counties; 2) a pre-Miocene topographic high (Cape Lookout High) in southern Craven and northern Carteret Counties; and 3) another embayment in central and southern Carteret County that corresponds to the northern edge of the Onslow Bay system.

Two benthic foraminiferal assemblage zones are present in the Aurora Embayment. Assemblage Zone 1, the lower portion of the Pungo River Formation that includes lithologic Units A and B, is characterized by high faunal dominance, low diversity, a sparse planktic fauna, and numerically dominant benthic species that indicate near-shore, shallow water conditions. The dominance of Buliminella elegantissima suggests that water chemistry or nutrient supply was an important factor in limiting faunal diversity within the embayment. Water depths probably did not exceed 40 to 50 meters, and occasional pulses of more normal marine circulation are indicated by the sporadic occurrence of mid-shelf faunal elements. Assemblage Zone 2 is associated with the upper part of the section that includes lithologic Units C, D, and DD. It is characterized by greater diversity, lower faunal dominance values, more abundant planktic specimens, and benthic species that indicate open marine, mid-shelf conditions.

Although the faunal trends indicate that Pungo River sediments in the Aurora Embayment were deposited during a marine transgression, the actual change in water depth may have been small. The mid-shelf association of Assemblage Zone 2 could have occurred at depths as shallow as 50 to 60 meters. Assemblages from the Aurora Embayment are similar to those described by Smith (1968) for the Middle to Late Miocene phosphorites of the Monterey Shale in California. Smith interpreted the assemblages as representing deposition in water depths of 200 feet or less. Perhaps the transition from Zone 1 to Zone 2 was due in large part to changes in organic content and nutrient supply. Another factor that may have contributed to this transition is the nature and mode of accumulation of the sediments. Cibicides lobatulus, an attaching form that is influenced more by substrate type than by depth (Parker, 1952), is a minor constituent of Assemblage Zone 1, but it suddenly becomes dominant in Zone 2. Certainly, the factors that caused observed faunal changes cannot be linked solely to bathymetry.

The pre-Miocene topographic high (Cape Lookout High) in southern Craven County is characterized by sediments (Unit CC) and foraminiferal assemblages (Assemblage Zone 3) that are conspicuously different from those in the Aurora Embayment. The numerically dominant species, Cassidulina laevigata and Uvigerina calvertensis, suggest deposition in an outer shelf environment. But the relatively high faunal dominance, moderate diversity values, the scarcity of planktic specimens, and the association of this assemblage with a topographic high are inconsistent with such an interpretation. Perhaps these offshore

species migrated shoreward in response to favorable environments associated with the flank of this high. The lateral relationships of this sediment system are highly interpretive; more concentrated coverage will be necessary to precisely determine them.

Benthic foraminiferal assemblages from the northern edge of the Onslow Bay system are similar to those of Assemblage Zone 2 in the Aurora Embayment, and a similar depositional environment is indicated for them. However, several species are present here that were not recognized in samples from the Aurora Embayment. Their migration into the more northern embayment may have been prevented by environments associated with the intervening topographic high. No sediments containing the fauna of Assemblage Zone 1 were encountered in this area. However, detailed work on the Onslow Bay system has just begun, and accurate comparisons between the two systems cannot be made until this work is completed.

A number of benthic and planktic species are reliable indicators of Pungo River sediments within the study area. An age range from the latter part of Zone N. 7 to the latter part of Zone N. 8 (late Early Miocene) is tentatively proposed for the entire Pungo River section in the study area. Further studies, especially more detailed studies of the entire planktic assemblage, may refine the precision of the biostratigraphic interpretations.

Yorktown and Duplin Formations

The Yorktown Formation of the central Coastal Plain of North

Carolina represents deposition during an initial marine transgression followed by a general marine regression. Deposition of the formation in the area studied was confined to the Aurora Embayment in Beaufort, Pamlico, and northern Craven Counties.

The sediments and foraminiferal assemblages can be divided into a lower and an upper unit. The lower Yorktown is characterized by a fining upward sequence and faunal assemblages suggestive of a transgression that was initiated sometime during the deposition of sediments within this unit. Maximum transgression was concurrent with the deposition of the upper lower Yorktown to lower upper Yorktown sediments. It is at this point that the finest grained terrigenous sedimentary material was accumulating. In addition, the highest faunal diversity values were recorded in this portion of the section. This maximum transgression was followed by a general marine regression, as indicated by decreasing diversity and increasing faunal dominance values, a decrease in the abundance of planktic specimens, and a coarsening of the sediments upward through the section. Water depths, as indicated by the benthic foraminiferal assemblages, were probably no greater than 50 to 60 meters during the time of maximum transgression, and were $\leq$ 30 or 40 meters during deposition of the upper and lower portions of the formation.

The paleoecologic significance of the sediments and benthic fauna of the Duplin Formation remains problematic because the data suggest deposition in a mid-shelf to outer shelf environment, similar to that suggested for the lower Yorktown Formation to the north. This environmental setting is atypical when compared to that proposed by

other workers (Copeland, 1964; Howard, 1966), who see the Duplin Formation as a shallow water deposit equivalent to the upper Yorktown Formation. More detailed analysis will be necessary in order to resolve this problem.

An age assignment of late Early to early Late Pliocene (middle of Zone N. 18 to the lower-middle of Zone N. 20) is indicated for both formations on the basis of planktic foraminiferal assemblages. As with the Pungo River Formation, this must be taken as a generalized range for the Yorktown/Duplin strata of this region. Detailed resolution of the distribution of diagnostic species within the formations was impossible because significant portions of the section contain no foraminifera.

ANNOTATED FAUNAL LIST

The organizational scheme used in this section follows Beem (1973), presenting all species grouped within generic categories that are listed alphabetically. Generic concepts follow the Treatise on Invertebrate Paleontology (1964). No suprageneric classification is given and only original species descriptions are cited. Benthic foraminifera from both the Yorktown and Pungo River Formations are listed together. Planktic foraminifera are listed separately for each formation.

Diagnostic morphological characteristics are briefly summarized for each species, and information pertaining to their stratigraphic occurrence and geographic distribution within the study area is given. For those species that survive to the Recent, or that have closely related modern representatives, generalized ecological tolerances are discussed. The relative abundance of benthic species within individual samples is presented in Appendix II.

It is hoped that this organizational scheme will allow specialists and non-specialists alike, to locate and make use of the information presented in a relatively simple and straightforward manner.

BENTHIC FORAMINIFERA (PUNGO RIVER AND YORKTOWN FORMATIONS)

Genus BOLIVINA d'Orbigny, 1839

BOLIVINA CALVERTENSIS Dorsey

Plate 4, Figure I

Bolivina calvertensis DORSEY, 1948, Maryland Dept. Geology, Mines, Water Resources Bull. 2, p. 268-321, pl. 36, fig. 17 a-c

The test is elongate, approximately 2 times as long as broad, somewhat compressed, and gently tapering. Closely spaced, numerous longitudinal costae cover all but the last few chambers. Sutures are distinct with the inner portion slightly curved and later portions becoming straight. There are generally 10 pairs of chambers in the adult test. This form can be distinguished from Bolivina marginata multicostata by its smaller size, more numerous and finer costae that cover more of the test, and lack of a keel.

Discussion: Rare specimens were found within Assemblage Zones 1 and 2 from the Aurora Embayment and Onslow Bay regions. It has been reported from the middle and upper Calvert Formation in Maryland (Dorsey, 1948) and from Pungo River strata placed in planktic zone N. 8 by Gibson (in press).

BOLIVINA LOWMANI Phleger and Parker

Plate 1, Figure G

Bolivina lowmani PHLEGER AND PARKER, 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 13, pl. 6, figs. 20, 21

This species characteristically has curved, depressed sutures with slightly curved chambers that are generally inflated somewhat towards the

inner end. It is one of the most coarsely porous of all the species of Bolivina encountered during this study. The test is often slightly twisted with a round, slightly lobulate periphery.

Discussion: B. lowmani is extremely rare to common within the Pungo River and Yorktown sections. It reaches its maximum abundances in both formations in samples from Pamlico County. B. lowmani has been reported in nearshore to shelf-edge waters of the Atlantic Continental Shelf (Schnitker, 1971). It also occurs in water depths of 12-20 meters in Chandeleur Sound, Gulf of Mexico (Walton, 1964), attaining its greatest numbers in waters adjacent to the Mississippi Delta.

BOLIVINA MARGINATA Cushman

Bolivina marginata CUSHMAN, 1918, U. S. Geol. Survey Bull. 676, p. 48, pl. 10, fig. 1

This species possesses a narrow keel, numerous chambers, and a sub-acute to acute periphery. Larger specimens with a well developed keel and numerous longitudinal costae on the early chambers were placed into Bolivina marginata multicostata Cushman (Cushman, 1937). A few specimens of the latter form were found in the Pungo River section.

Discussion: B. marginata is extremely rare to rare but persistent throughout the Pungo River and Yorktown sections.

BOLIVINA PAULA Cushman and Cahill

Plate 1, Figure F

Bolivina paula CUSHMAN AND CAHILL, 1932, in Cushman and Ponton, Florida Geol. Survey Bull. 9, p. 84, pl. 12, fig. 6 a, b

This species is distinguished by its minute size, parallel sides,

and subacute periphery. Some specimens might be confused with immature specimens of B. lowmani; however, the latter species is more coarsely porous with generally fewer chambers. B. paula has a smooth, shiny, transparent to translucent surface.

Discussion: B. paula is extremely rare to common throughout the Pungo River and Yorktown sections. Within the Pungo River Formation, the most significant occurrences are in sediments from southern Beaufort and Pamlico Counties. Modern specimens have been reported from extremely shallow waters associated with a reef complex in Jamaica (Buzas et al., 1977). This species is a common form in Oligocene and Miocene sediments from the Atlantic Coastal Plain.

BOLIVINA PUNGOENSIS Gibson

Plate 5, Figure D

Bolivina pungoensis GIBSON, in press, Smithsonian Contr. Paleobiology, n. 41

Characteristic features of this species include a moderately compressed test with a subacute periphery in the early part, becoming more inflated with a rounded periphery in the latter portion. The inner basal portion of the chambers extends as a lobe over earlier chambers, the lobular projections becoming more pronounced in the later chambers. The test has moderately sized pores, some specimens being almost as coarsely porous as B. lowmani.

Discussion: B. pungoensis is extremely rare in the Pungo River section and is confined to Assemblage Zone 2. Gibson (in press) reported B. pungoensis as rare (up to 3%) in most samples of the

Pungo River Formation at Lee Creek, all of which fall into planktic zone N. 8. He places this species within a morphologic group that appears in the Early and early Middle Miocene. Affiliated species are B. advena Cushman, B. floridana Cushman, and B. plicatella mera Cushman and Ponton.

Genus BOLIVINOPSIS Yakovlev, 1891

BOLIVINOPSIS FAIRHAVENENSIS Gibson

Plate 5, Figures G, H

Bolivinopsis fairhavenensis GIBSON, in press, Smithsonian Contr. Paleobiology, n. 41

This species is characterized by a small test with distinct sutures forming approximately a 45° angle with the periphery. An early, moderately compressed, planispiral stage gives way through growth to a less compressed biserial stage. Both stages have about the same width.

Discussion: B. fairhavenensis is extremely rare to rare throughout Assemblage Zones 1 and 2 of the Pungo River section.

Bolivinopsis is most common in Cretaceous to Eocene strata, B. fairhavenensis being one of the geologically youngest species of this genus (Gibson, in press). It has been reported as characteristic of the lower portion of the Calvert Formation (Fairhaven Member) in Maryland. Gibson has previously recorded it from one sample of the Pungo River section at Lee Creek, establishing the upper age limit of this species as late Early Miocene (planktic zone N. 8).

Genus BUCCELLA Anderson, 1952

BUCCELLA FRIGIDA (Cushman)

Pulvinulina frigida CUSHMAN, 1922, Contr. Canadian Biol., n. 9, p. 144,
(no figures)

This species is characterized by its generally small size, broadly rounded periphery, and 5 to 6 chambers in the final whorl. The umbilicus, sutures, and basal margin of the final chambers on the umbilical side are covered with pustulose material.

Discussion: B. frigida is extremely rare to common throughout the Yorktown section. It is most persistent in sediments from northern Beaufort County. It is extremely rare throughout the Pungo River section. This species is found in relatively shallow waters from Hudson Bay south along the Atlantic Coast to Maryland. Slightly larger specimens of the same form occur along the Pacific Coast. It has been reported from the Pliocene and Pleistocene of North Carolina and the Pleistocene of Maryland.

BUCCELLA INUSITATA Anderson

Buccella inusitata ANDERSON, 1952, Jour. Wash. Acad. Sci., v. 42, n. 5,
p. 148, figs. 10, 11

This species can be recognized by its medium sized, equally biconvex test, with an acute and limbate periphery. The amount of pustulose material on the umbilical side is generally less than that found in B. frigida. There are 7 to 8 chambers in the final whorl.

Discussion: B. inusitata is extremely rare to rare but persistent throughout the Yorktown and Pungo River sections. This species has been reported from the Pliocene and Pleistocene of North Carolina.

BUCCELLA VICKSBURGENSIS (Cushman and Ellisor)

Eponides vicksburgensis CUSHMAN AND ELLISOR, 1931, Contr. Cushman Lab.

Foram. Research, v. 7, pl. 7, fig. 8 a-c

This species is characterized by a thick coating of pustulose material on the umbilical side (thicker than that of B. frigida and B. inusitata), and its subacute periphery. It can be distinguished from B. frigida by its more limbate sutures on the spiral side and by its greater number of chambers in the final whorl (generally 7 to 8).

Discussion: B. vicksburgensis is extremely rare to rare throughout the Yorktown section and extremely rare in the Pungo River section, occurring in only two samples. This species has been reported from the Pliocene and Pleistocene of North Carolina.

Genus BULIMINELLA Cushman, 1911

BULIMINELLA ELEGANTISSIMA (d'Orbigny)

Plate 1, Figure A

Bulimina elegantissima D'ORBIGNY, 1839, Voy. 1'Amer. Meridionale, v. 5, pt. 5, "Foraminiferes", p. 57, pl. 7, figs. 13, 14

This small, elongate species is characterized by numerous, tall, narrow, slightly inflated chambers arranged in a high spire containing approximately three volutions. The aperture is an elongate opening in a depression high on the apertural face.

Discussion: B. elegantissima is extremely rare to abundant throughout the Pungo River and Yorktown sections. Within the Pungo River Formation, it is the most dominant species in Assemblage Zone 1. In the Yorktown Formation, it is most abundant in sediments of the lower section. B. elegantissima is a

common species in Recent seas and is the dominant species along the coast of southern California from shallow waters (less than 50 meters) in sewage outfall areas (Bandy et al., 1964). Seiglie (1968) reported that high numbers of Buliminella occur in organic rich bottom muds. In the Gulf of Mexico, species of Buliminella are most frequently encountered in water depths of 12 to 60 meters and B. elegantissima has been recorded in nearshore environments of the Atlantic Continental Shelf (Schnitker, 1971). This form is well known from the Miocene and Pliocene of the Atlantic Coastal Plain and is the most abundant benthic foraminifer in the Choctawhatchee Formation of Florida (Beem, 1973).

Genus CANCRIS de Montfort, 1808

CANCRIS SAGRA (d'Orbigny)

Rotalina (Rotalina) sagra D'ORBIGNY, 1839, in de la Sagra, Histoire ... de l'Ile de Cuba, "Foraminifères", p. 77, Tab. 5, figs. 13-15

Species characteristics include a biconvex test that is longer than broad, an acute periphery, few chambers, and a weakly developed keel on the final chamber. Specimens also showed the development of a slight lip near the aperture on the umbilical side.

Discussion: C. sagra is uncommon in Pungo River sediments from southern Craven and Carteret Counties. It is extremely rare to abundant throughout the Yorktown section, reaching its greatest abundance in Carteret County (Duplin Formation). Schnitker (1971) reported C. sagra as a common and consistent faunal element in mid-shelf waters of the Atlantic Continental Shelf. It was recorded by Todd (1979) from mid-shelf to upper slope environments,

being common in the latter. This species is known from the Oak Grove and Chipola Formations (Miocene) of Florida through the recent.

Genus CASSIDULINA d'Orbigny, 1826

CASSIDULINA CARIBEANA Redmond

Cassidulina caribea REDMOND, 1953, Jour. Paleontology, v. 27, n. 5, p. 729, pl. 77, fig. 6 a, b

This species is distinguished by a clear, stellate umbonal area on both sides of the test, its small size, and a slight inflation of the final chambers. Specimens encountered in this study lacked any development of a keel.

Discussion: C. caribea is extremely rare to common throughout the Yorktown section and extremely rare to rare throughout the Pungo River section, reaching its greatest abundance in sediments of Assemblage Zone 3. This is a warm water species of the Atlantic and Caribbean. It is known from the Miocene and Pliocene of the Atlantic Coastal Plain, the West Indies, and northeastern South America.

CASSIDULINA LAEVIGATA d'Orbigny

Plate 3, Figures G, H

Cassidulina laevigata D'ORBIGNY, 1826, Annales Sci. Nat., v. 7, p. 282, Tab. 15, figs. 4, 5, modele 41

Lenticular specimens from the Yorktown and Pungo River Formations are characterized by equally inflated chambers that extend into the umbilicus. This species can be distinguished from C. carinata Silvestri (not C. laevigata var. carinata Cushman, 1930) by its slightly more inflated

test and lack of development of any keel.

Discussion: C. laevigata is extremely rare to abundant throughout the Pungo River and Yorktown sections. This form is one of the two dominant species that characterize the Pungo River sediments of Assemblage Zone 3. C. laevigata is a common and consistent faunal element in shelf-edge waters (Schnitker, 1971) and has been reported as a characteristic form of mid-shelf to upper slope environments (Todd, 1979). Walton (1964) recorded Cassidulina spp. in water depths of 56 to 400 meters in the Gulf of Mexico. This species is known from the Miocene of Louisiana, the West Indies, Italy, and Morocco (Akers and Dorman, 1964); the Pliocene of North Carolina; and the Lower Pliocene of Orange County, California (White, 1956).

Genus CAUCASINA Khalilov, 1951

CAUCASINA GRACILIS (Cushman)

Plate 1, Figure B

Bulimina gracilis CUSHMAN, 1930, Florida Geol. Survey Bull. 4, p. 43, pl. 8, fig. 5 a, b

This species is characterized by a smooth, straight to slightly twisted test, inflated chambers, and triserial to biserial chambering. It is placed in the genus Caucasina due to its early discorbine stage.

Discussion: C. gracilis is extremely rare to common in the Pungo River section. It is one of the dominant species of Assemblage Zone 1 and is found in lesser abundance throughout the remainder of the section. It is extremely rare to abundant throughout the Yorktown section in all cores except BTN-15 where no

specimens of this form were found. This species is known from the Miocene and Pliocene of the Atlantic Coastal Plain of the southeastern United States from Maryland to Florida.

CAUCASINA PREACANTHIA (McLean)

Bulimina preacanthia MCLEAN, 1956, Bull. Amer. Paleontology, v. 36, n. 160, p. 345, pl. 45, figs. 2, 3, 7

This species possesses the same early discorbine stage as C. gracilis, but it can be differentiated on the basis of its much smaller size and the tendency of the specimens to flare towards the apertural end. The greatest diameter of the test is in the upper portion.

Discussion: C. preacanthia is extremely rare to uncommon but persistent throughout the Pungo River and Yorktown sections. This species has been reported from the Pliocene at Carter's Grove, Virginia and at Lee Creek, North Carolina.

Genus CIBICIDES de Montfort, 1808

CIBICIDES CRAVENENSIS Gibson

Plate 5, Figures B, C

Cibicides cravenensis GIBSON, in press, Smithsonian Contr. Paleobiology, n. 41

This species is characterized by a biconvex test, a prominent umbilical plug, and a very slightly lobulate, keeled, acute periphery. Sutures are limbate and strongly recurved on both sides of the test.

Discussion: C. cravenensis is extremely rare to uncommon in Pungo River sediments of Assemblage Zone 2. Gibson (in press) reported this species as occurring in abundance in the carbonate facies of the Pungo River Formation in the Croatan National

Forest area between New Bern and Morehead City, North Carolina.

CIBICIDES LOBATULUS (Walker and Jacob)

Plate 2, Figures A, B

Nautilus lobatulus WALKER AND JACOB, 1798, in Kanmacher, Adam's Essays on the Microscope, ed. 2, p. 642, pl. 14, fig. 36

I have followed the ideas of Mauger (1979) in considering this extremely variable species conspecific with:

Cibicides cf. C. lobatulus (Cushman),

C. lobatulus var. ornatus (Cushman),

C. sublobus (Cushman),

Dyocibicides biserialis Cushman and Valentine,

Cibicidella variabilis (d'Orbigny).

The morphological variation of this species has been attributed to its attaching life habit, the shape of the object to which it attaches influencing the adult growth pattern. The complete range of morphologic types was seen; however, the majority of the specimens exhibited the more "regular" growth pattern.

Discussion: C. lobatulus is extremely rare to abundant throughout the Pungo River and Yorktown sections. It reaches its greatest abundance within the Pungo River Formation in sediments of Assemblage Zone 2 where it comprises up to 41% of the fauna in one sample. In the Yorktown Formation it occurs in abundance most often in sediments from Beaufort County. C. lobatulus has been recorded from littoral (Bhatia, 1956; Choung, 1975) to abyssal depths (Parker et al., 1953) and is a common species in many modern shallow water areas. Parker (1952) found that the

distribution of C. lobatulus was influenced more by substrate type than by water depth. It is a well known form from the Tertiary of the Atlantic Coastal Plain.

CIBICIDES PUNGOENSIS Gibson

Cibicides pungoensis GIBSON, in press, Smithsonian Contr. Paleobiology, n. 41

One poorly preserved specimen possessing large pores, a strongly developed umbo, and limbate sutures was found. It differs from C. cravenensis in its more lobulate periphery and its flat to concave spiral side. It compared favorably to Gibson's description and illustrations of the holotype.

Discussion: C. pungoensis is extremely rare in one sample of the Pungo River Formation in southern Beaufort County that was placed into Assemblage Zone 2 on the basis of the dominant species. Gibson (in press) recorded C. pungoensis as rare to common in the Pungo River Formation from Gatesville, North Carolina. He sets the stratigraphic range as early Middle Miocene (planktic zone N. 11).

Genus ELPHIDIUM de Montfort, 1808

ELPHIDIUM COMPRESSULUM Copeland

Elphidium compressulum COPELAND, 1964, Bull. Amer. Paleontology, v. 47, n. 215, p. 262, pl. 37

This fairly large species is characterized by a strongly compressed test and well developed retral processes that are most conspicuous along the sutures of intermediate chambers.

Discussion: E. compressulum is extremely rare to rare and occurs

only in sediments of the upper portion of the Yorktown Formation from northern Beaufort County. This species was described from the Duplin Formation at Natural Well and has been reported from the Yorktown Formation at Lee Creek.

ELPHIDIUM EXCAVATUM (Terquem)

Plate 1, Figure C

Polystomella excavatum TERQUEM, 1875, Essai sur le classement des animaux qui vivent sur la plage et dans les environs de Dunkerque, pt. 1, p. 25, pl. 2, fig. 2 a-f

Feyling-Hanssen's (1972) concept of this highly variable species is followed in this study. Most specimens that were encountered could be placed into forma selseyensis (sutures opening into the umbilicus, abundant, fine pustulose material filling the umbilicus and extending up into the sutures) or forma clavatum (generally closed sutures with occasional weakly developed retral processes, a central umbonal boss is most often present). The figured specimen would fall into forma selseyensis, it being the most common form seen in the study.

Discussion: E. excavatum is extremely rare to abundant throughout the Pungo River and Yorktown sections. It reaches its greatest abundance within the Yorktown in sediments from northern Beaufort County. It is one of the dominant species of Assemblage Zone 1 in the Pungo River Formation where it makes up to 48% of the fauna in one sample. E. excavatum is abundant in water depths of 12 to 36 meters (Walton, 1964), and Schnitker (1971) considered it to be characteristic of nearshore environments, where he reports it as the dominant form in waters north of Cape

Hatteras, North Carolina. It is a common shallow water species in modern seas, including the Arctic and the Mediterranean. It has been reported from the Pliocene and Pleistocene of the Atlantic Coastal Plain.

ELPHIDIUM LIMATULUM Copeland

Plate 1, Figure E

Elphidium limatulum COPELAND, 1964, Bull. Amer. Paleontology, v. 47, n. 215, p. 263, pl. 37, fig. 5 a, b

This species is characterized by a smooth, glossy white test with numerous umbilical pustules, a rounded periphery, and poorly developed although usually numerous retral processes. Although occasional specimens show no development of the retral processes, this has been an acceptable variation within this species according to other workers. The sutures remain closed into the umbilicus, which serves to distinguish poorly preserved specimens from E. excavatum forma selseyensis.

Discussion: E. limatulum is extremely rare to common in sediments of the upper portion of the Yorktown section throughout the study area. One specimen was present in one sample from the lower portion of the section in Beaufort County. It is extremely rare to rare throughout most of the Pungo River section. It attains its greatest abundance in sediments of Pamlico County where it makes up to 11% of the fauna in one sample. E. limatulum was described from the Duplin Formation at Natural Well and Barwick. It has previously been reported from the Pliocene and Pleistocene of North Carolina.

Genus EPISTOMINELLA Husezima and Maruhasi, 1944

EPISTOMINELLA DANVILLENIS (Howe and Wallace)

Pulvinulinella danvillensis HOWE AND WALLACE, 1932, Louisiana Dept.

Conserv. Bull. 2, p. 71, pl. 13, fig. 7 a-c

This is a small, biconvex form with a very circular outline.

Sutures were generally straight, and specimens averaged 7 to 9 chambers in the final whorl.

Discussion: E. danvillensis is extremely rare to uncommon but persistent throughout the Pungo River and Yorktown sections. This species was described from the Eocene of Louisiana, and has subsequently been reported from the Eocene of Georgia and Florida. It has also been reported from the Miocene and Pliocene of the Atlantic Coastal Plain.

Genus FLORILUS de Montfort, 1808

FLORILUS CHESAPEAKENSIS Gibson

Plate 4, Figures G, H

Florilus chesapeakeensis GIBSON, in press, Smithsonian Contr. Paleobiology, n. 41

This species can be distinguished from F. pizzarensis by its more numerous chambers and by the more dramatic flaring of the test. The face of the last formed chamber has an almost heart-shaped appearance. Sutures are moderately to strongly limbate.

Discussion: F. chesapeakeensis is extremely rare in several samples from the Yorktown section. It is extremely rare to uncommon in the Pungo River section, reaching its greatest numbers in sediments from Pamlico County. This species is known from the Calvert, Choptank, and St. Mary's Formations of Maryland

and Virginia. It has been reported from the Pungo River Formation of North Carolina by Gibson (in press).

FLORILUS PIZZARENSIS (Berry)

Plate 2, Figure C

Nonion pizzarensis BERRY, 1928, Jour. Paleontology, v. 1, n. 2, p. 269, fig. I (1-3)

This species is characterized by its generally large size, moderately flaring test, and its slight trochospiral coiling. Granular material is commonly developed on one side of the umbilicus. The test is usually smooth, opaque, and very finely porous.

Discussion: F. pizzarensis is extremely rare to abundant throughout the Pungo River and Yorktown sections. It reaches its greatest abundance within the Pungo River Formation in sediments of Assemblage Zone 2. Schnitker (1971) reported that species of the genus Florilus are common faunal elements of nearshore and mid-shelf environments on the Atlantic Continental Shelf. It has also been recorded off the coast of California. F. pizzarensis is known from the Miocene of California and from the Miocene and Pliocene of the Atlantic Coastal Plain from Maryland to North Carolina.

Genus FURSENKOINA Loeblich and Tappan, 1961

FURSENKOINA FUSIFORMIS (Williamson)

Bulimina pupoides d'Orbigny var. fusiformis WILLIAMSON, 1858, On the

Recent Foraminifera of Great Britain, p. 63, pl. 5, figs. 129, 130

This small, sigmoid to biserial species often showed a Buliminella-like aperture among juvenile specimens. I have followed Mauger (1979)

in tentatively placing this form in the genus Fursenkoina because, as she points out, the adult growth stage is consistent with the current concept of Fursenkoina presented by Beem (1973).

Discussion: F. fusiformis is extremely rare to rare throughout the Pungo River section and extremely rare to common in the Yorktown section, reaching its greatest abundance in sediments of the lower Yorktown Formation in Beaufort County. F. fusiformis has been reported as a common faunal element of mid-shelf waters by Schnitker (1971), and as characteristic of upper slope environments by Todd (1979).

Genus GLOBOCASSIDULINA Voloshina, 1960

GLOBOCASSIDULINA CRASSA (d'Orbigny)

Plate 3, Figure E

Cassidulina crassa D'ORBIGNY, 1839, Voy. l'Amer. Meridionale, "Foraminiferes", v. 5, pt. 5, p. 56, pl. 7, figs. 18-20

This species is characteristically small, subcircular in outline, with generally inflated chambers, especially so in the later chambers. The aperture is an elongate slit.

Discussion: G. crassa is extremely rare to common throughout the Yorktown section and extremely rare to abundant in the Pungo River section, reaching its maximum abundance in sediments of Assemblage Zone 2. Phleger (1951) reported that this species is most abundant in waters greater than 100 meters, not being found in waters less than 50 meters in depth. However, Wilcoxon (1964) recorded G. crassa as a common species at depths of less than 50 meters. This species has previously been

reported from the Pliocene of North Carolina and the Miocene of Florida.

Genus HANZAWAIA Asano, 1944

HANZAWAIA CONCENTRICA (Cushman)

Plate 3, Figures A-D

Truncatulina concentrica CUSHMAN, 1918, U. S. Geol. Survey Bull. 676,
p. 64, pl. 21, fig. 3

This species showed variable degrees of fusion of the chamber flaps on the umbilical side. In general, those forms that exhibited the least amount of fusion possessed a deeper, more concave umbilical region than those in which the flaps were completely fused. Because all other morphologic characteristics fall within the generally accepted limits for this species, both types were placed in H. concentrica. There is a keel or the suggestion of a keel on all the specimens encountered in this study. This feature serves to distinguish H. concentrica from H. strattoni (Applin).

Discussion: H. concentrica is extremely rare to abundant throughout the Pungo River and Yorktown sections. Within the Pungo River Formation, it reaches its maximum abundance in sediments of Assemblage Zone 2 where it is one of the dominant forms. It is present in significant numbers in Yorktown sediments from northern Beaufort and Pamlico Counties. H. concentrica is characteristic of mid-shelf environments off the modern North Carolina coast (Schnitker, 1971) and is reported as an abundant form from inner-shelf to upper slope regions (Todd, 1979). It is relatively common in water depths of less

than 70 meters in the Gulf of Mexico (Bandy, 1954, 1956; Walton, 1964). It is known from the Miocene and Pliocene of the Atlantic Coastal Plain of the southeastern United States from Maryland to Florida.

HANZAWAIA NIPPONICA Asano

Plate 2, Figures D, E

Hanzawaia nipponica ASANO, 1944, Geol. Soc. Japan Jour., v. 51, n. 606, p. 97-98, pl. 4, figs. 1-6

This species differs from H. concentrica in having recurved, strongly limbate sutures on the spiral side, a large distinct umbo, and a pronounced keel. The chamber flaps on the umbilical side are smaller than those of H. concentrica and are often obscured by poor preservation.

Discussion: H. nipponica is extremely rare to uncommon in four samples from the Yorktown section and extremely rare to abundant in the Pungo River section where it is one of the characteristic species in sediments of Assemblage Zone 2. It reaches its maximum abundance in areas south of the Aurora region. H. nipponica was described from the Pliocene of Japan and is also known from the Miocene. It is a widespread form in modern seas.

Genus HOPKINSINA Howe and Wallace, 1932

HOPKINSINA BONONIENSIS (Fornasini)

Plate 4, Figure C

Uvigerina bononiensis FORNASINI, 1888, Bollettino della Societa Geologica Italiana, v. 7, p. 48, pl. 3, fig. 12-12a

This costate, elongate species is characterized by triserial to biserial chambering and chambers that have lobulate projections over

earlier formed chambers. Approximately 20 costae, which never extend over the sutures, are present on each chamber.

Discussion: H. bononiensis is extremely rare to rare and occurs only in Pungo River sediments of Assemblage Zone 2. It is widespread in Miocene and Pliocene sediments of Europe and North Africa. The first reported occurrence of H. bononiensis in North America was from the Pungo River Formation by Gibson (in press), who recorded it from planktic zone N. 11 strata at Gatesville, North Carolina.

Genus LENTICULINA Lamarck, 1804

LENTICULINA cf. L. AMERICANA (Cushman)

Cristellaria americana CUSHMAN, 1918, U. S. Geol. Survey Bull. 676, p. 50, pl. 10, figs. 5, 6

Small, lenticular specimens compare favorably with Mauger's (1979) description and illustrations of this species from Lee Creek, North Carolina. A peripheral keel is generally well developed, but it is often obscured by poor preservation.

Discussion: L. cf. L. americana is extremely rare throughout the Yorktown section and extremely rare to uncommon within the Pungo River section. This species is most abundant in sediments of Assemblage Zone 3. It has been reported from the Miocene and Pliocene strata of the Atlantic Coastal Plain of the southeastern United States.

Genus NONION de Montfort, 1808

NONION MARYLANDICUM Dorsey

Plate 5, Figure E

Nonion marylandicum DORSEY, 1948, Maryland Dept. Geology, Mines, Water Resources Bull. 2, p. 305, pl. 35, fig. 2 a-c

This planispiral, involute species is characterized by a broadly rounded periphery, a depressed umbilical region with varying amounts of pustulose material, and deeply incised sutures. The aperture is a narrow slit at the base of the apertural face.

Discussion: N. marylandicum is extremely rare to uncommon in Pungo River sediments and is largely restricted to Assemblage Zone 2. This species is known from the Miocene Calvert and Choptank Formations of Maryland and Virginia.

Genus NONIONELLA Cushman, 1926

NONIONELLA MIOCENICA Cushman

Plate 2, Figure F, G

Nonionella miocenica CUSHMAN, 1926, Contr. Cushman Lab. Foram. Research, v. 2, pt. 3, p. 64

This species is characterized by a moderately compressed, slightly trochospiral test with 9 to 10 chambers in the final whorl. The final chamber sweeps over the umbilicus forming a bulbous flap. The nature of the flap is highly variable within this species. Therefore, I have followed Mauger (1979) in placing the following forms in synonymy with N. miocenica:

Nonionella auris (d'Orbigny) of Cushman and Kellett (1929)

N. miocenica var. stella Cushman and Moyer

N. pseudo-auris Cole

N. pulchella Hada

Discussion: N. miocenica is extremely rare to common throughout

the Yorktown section and extremely rare to abundant throughout the Pungo River section, reaching its maximum abundance in sediments of Assemblage Zone 2 where it is one of the dominant forms. This species occurs off the western coast of Mexico (Cushman, 1939) and off the coast of California at depths of 50 meters or less, where the variety stella is an abundant form (Bandy, 1953). Walton (1964) reported N. miocenica as characteristic of water depths from 16 to 60 meters in the Gulf of Mexico. This species was first reported from the Miocene of California and is also known from the Miocene and Pliocene of Florida, North Carolina, and Maryland.

NONIONELLA sp.

Plate 4, Figures D, E

This form can be distinguished from N. miocenica by the reduced development of the umbilical flap and by its much stronger trochospiral coiling, which produces a knob-like area on the early chambers on the spiral side.

Discussion: N. sp. is extremely rare to common in Pungo River sediments of Pamlico County where it is restricted to strata of Unit B in Assemblage Zone 1.

Genus ROSALINA d'Orbigny, 1826

ROSALINA cf. R. CAVERNATA (Dorsey)

Plate 4, Figures A, B

Discorbis cavernata DORSEY, 1948, Maryland Dept. Geology, Mines, Water Resources Bull. 2, p. 311, pl. 37, fig. 2 a-c

This species is characterized by a deep umbilicus that forms a

large, cavernous depression which is surrounded by bulbous growths on the chamber flaps. The test is planoconvex with all chambers visible on the spiral side. Specimens from this study differ from those illustrated and described by Gibson (in press) in that they are significantly more compressed. All other morphologic characteristics compare favorably with his specimens.

Discussion: R. cf. R. cavernata is extremely rare to uncommon throughout the Pungo River section, most often occurring in sediments of Assemblage Zone 2. It has previously been reported from the Miocene Calvert Formation of Maryland.

ROSALINA FLORIDANA (Cushman)

Discorbis floridanus CUSHMAN, 1922, Carnegie Inst. Washington Bull. 311, p. 39, pl. 5, figs. 11, 12

This species characteristically shows a deep furrow along the edge of the chamber flaps of the final one or two chambers. It has a rounded periphery and incised sutures on the umbilical side. The number of chambers is variable; however, there are generally 6 to 8 in the final whorl.

Discussion: R. floridana is extremely rare to common throughout the Yorktown section, attaining its greatest abundance in sediments of northern Beaufort County. It is extremely rare to rare throughout the Pungo River section. Todd (1979) reported this species as dominant in inner-shelf to mid-shelf environments and characteristic of shelf edge to upper slope waters. It has been recorded from the Recent seas of Florida, the north coast of Cuba, Brazil, and the Gulf of Mexico (Akers

and Dorman, 1964). It is known from the Mid-Tertiary of Florida, Jamaica, the Dominican Republic, and Columbia (Mauger, 1979) and from the Miocene, Pliocene, and Pleistocene of the Atlantic Coastal Plain.

ROSALINA GLOBULARIS d'Orbigny

Rosalina globularis D'ORBIGNY, 1826, Annales Sci. Nat., ser. 1, v. 7, p. 271, pl. 13, figs. 1-4

This variable species could be distinguished from other species of the genus encountered in this study by its more inflated and variable final chamber and by the thickened sutures of the early chambers on the spiral side.

Discussion: R. globularis is extremely rare to common throughout the Yorktown section, showing its maximum abundance in sediments of northern Beaufort County. It is extremely rare to rare throughout the Pungo River section. Schnitker (1971) reported this species as a common and consistent faunal element in mid-shelf waters. It is an abundant form in the Gulf of Mexico in water depths of less than 100 meters (Parker, 1954). It has previously been reported from the Yorktown Formation at Lee Creek, North Carolina.

Genus ROTORBINELLA Bandy, 1954

ROTORBINELLA BASSLERI (Cushman and Cahill)

Rotalia bassleri CUSHMAN AND CAHILL, 1933, U. S. Geol. Survey Prof. Paper 175-A, p. 30, pl. 10, fig. 7

This species is characterized by its small size, biconvex test, thick "cordlike" keel, and a distinct, round umbilical plug. The sutures

are slightly recurved and slightly limbate on the spiral side. The aperture extends from near the periphery to the umbilical plug.

Discussion: R. bassleri is extremely rare to uncommon but persistent throughout the Pungo River and Yorktown sections. This species is known from the Miocene and Pliocene of the Atlantic Coastal Plain of Maryland, Virginia, and North Carolina.

Genus SIPHOGENERINA Schlumberger, 1882

SIPHOGENERINA LAMELLATA Cushman

Plate 5, Figure F

Siphogenerina lamellata CUSHMAN, 1918, U. S. Geol. Survey Bull. 676, p. 55-56, pl. 12, fig. 3

This elongate species is characterized by early triserial chambering that later becomes uniserial. Ornamentation consists of longitudinal costae of varying strength. Sutures are distinct, flush to strongly depressed with a U-shaped pattern. The aperture is terminal with a short cylindrical neck and lip.

Discussion: S. lamellata is uncommon, reaching a maximum relative abundance of 4% in one Pungo River sample from Carteret County. This sample contains a foraminiferal association that belongs to Assemblage Zone 2. This was the only occurrence of S. lamellata in the study area. It is known from the Miocene of Venezuela and the Atlantic Coastal Plain of the southeastern United States. McLean (1956) recorded one specimen, which he attributed to reworking, from the Yorktown Formation in Virginia.

Genus SPIROPLECTAMMINA Cushman, 1927

SPIROPLECTAMMINA EXILIS Dorsey

Plate 4, Figure F

Spiroplectammina exilis DORSEY, 1948, Maryland Dept. Geology, Mines,
Water Resources Bull. 2, p. 275, pl. 27, figs. 1, 2

This species can be distinguished from S. mississippiensis by its greater degree of inflation, a subacute to narrowly rounded periphery, more curved sutures, and its elongate shape.

Discussion: S. exilis is extremely rare to uncommon in Pungo River sediments of Assemblage Zone 2 in Beaufort and Carteret Counties. One specimen which closely resembled this species was found in the Yorktown Formation from Pamlico County. It has been reported to be a characteristic form in the Choptank Formation of Maryland and Virginia (Gibson, in press).

SPIROPLECTAMMINA MISSISSIPPIENSIS (Cushman)

Plate 5, Figure A

Textularia mississippiensis CUSHMAN, 1922, U. S. Geol. Survey Prof.
Paper 129-E, p. 90, pl. 14, fig. 4

This finely arenaceous species is characterized by a compressed test with an acute periphery. Chambers are planispirally coiled in the early portion and later become biserial. Whole specimens exhibiting this early coiling were uncommon. Sutures are straight to slightly curved.

Discussion: S. mississippiensis is extremely rare to rare in Pungo River sediments of Assemblage Zone 2 from central Beaufort and Carteret Counties. It is known from the Eocene of Texas to Virginia, the Oligocene of the Gulf Coast region, and

the Miocene Calvert and Pungo River Formations. The latter is probably the youngest recorded occurrence of this species (Gibson, in press).

Genus TEXTULARIA Defrance, in de Blainville, 1824

TEXTULARIA AGGLUTINANS d'Orbigny

Textularia agglutinans D'ORBIGNY, 1839, in de la Sagra, Histoire ... de l'Ile de Cuba, "Foraminifères", p. 136, pl. 1, figs. 17, 18, 32-34

This large species can be distinguished from other species of the genus encountered in this study by its rounded periphery, inflated chambers, and its coarsely arenaceous test.

Discussion: T. agglutinans is extremely rare to rare but persistent throughout the Yorktown section. It is extremely rare in the Pungo River section. Todd (1979) reports this species to be dominant in inner-shelf to shelf edge environments and characteristic of upper slope waters. It is known from the Miocene and Pliocene of the Atlantic Coastal Plain from Maryland to Florida.

TEXTULARIA ARTICULATA d'Orbigny

Textularia articulata D'ORBIGNY, 1846, Foraminifères fossiles du bassin Tertiaire de Vienne, p. 250, pl. 15, figs. 16-18

This species is characterized by a compressed test, an acute and slightly keeled periphery, and generally 10 or more pairs of chambers.

Discussion: T. articulata is extremely rare to uncommon but persistent throughout the Yorktown section and extremely rare to rare in the Pungo River section. This is a well known species

from the Miocene and Pliocene of the Atlantic Coastal Plain from Maryland to Florida.

TEXTULARIA CANDEIANA d'Orbigny

Textularia candeiana D'ORBIGNY, 1839, in de la Sagra, Histoire ... de l'Ile de Cuba, "Foraminifères", p. 143, Tab. 1, figs. 25-27

This species is distinguished by compressed early chambers that give way to highly inflated final chambers to produce a club-shaped appearance.

Discussion: T. candeiana is extremely rare to rare but persistent throughout the Yorktown section. It is extremely rare in the Pungo River section, occurring only in sediments of Assemblage Zone 1 in Beaufort County. This species has been reported as characteristic of inner-shelf to upper slope environments (Todd, 1979). It has previously been recorded from the Pliocene of Japan and from the Atlantic Coastal Plain in the southeastern United States.

TEXTULARIA CONICA d'Orbigny

Textularia conica D'ORBIGNY, 1839, in de la Sagra, Histoire ... de l'Ile de Cuba, "Foraminifères", p. 143, Tab. 1, figs. 19, 20

This small species is characterized by a rapidly flaring test, a flattened apertural face, and distinct, almost horizontal sutures.

Discussion: T. conica is extremely rare to rare but persistent throughout the Yorktown section. It is extremely rare in the Pungo River section where it is restricted to sediments of Assemblage Zone 3. Todd (1979) found that this species dominates in inner-shelf to shelf edge environments and that it is

characteristic of upper slope environs.

TEXTULARIA MAYORI Cushman

Textularia mayori CUSHMAN, 1922, Carnegie Inst. Washington Bull. 311,
p. 23, pl. 2, fig. 3

This compressed, fairly rapidly flaring species characteristically shows curved sutures and the development of spinose projections on the peripheral edges of the chambers.

Discussion: T. mayori is extremely rare to rare. It occurs only in the upper portion of the Yorktown section in northern Beaufort County. This species is known from the Recent of the Atlantic Ocean and from relatively shallow waters of the Gulf of Mexico (Phleger and Parker, 1951). It has been recorded from the Miocene of Virginia and Florida and from the Pliocene and Pleistocene of North Carolina.

Genus TRIFARINA Cushman, 1923

TRIFARINA OCCIDENTALIS (Cushman)

Uvigerina occidentalis CUSHMAN, 1923, U. S. Nat. Mus. Bull. 104, pt. 4,
p. 169

This species is characterized by angular later chambers and longitudinal costae present on all but the final chambers. It can be distinguished from T. bradyi by its fewer number of chambers and greater inflation of the test.

Discussion: T. occidentalis is extremely rare to uncommon but fairly persistent throughout the Yorktown and Pungo River sections. Species of the genus Trifarina have been reported to be most abundant in deeper waters such as shelf edge environments (Schnitker, 1971; Todd, 1979).

Genus UVIGERINA d'Orbigny, 1826

UVIGERINA CALVERTENSIS Cushman

Plate 3, Figure F

Uvigerina calvertensis CUSHMAN, 1948, Maryland Dept. Geology, Mines,
Water Resources Bull. 2, p. 22, pl. 15, figs. 9, 10

This elongate, fusiform species has a pointed initial end and a lobulate periphery. The ornamentation consists of numerous, high, thin costae which are generally continuous but occasionally are broken, serrate, or irregularly branching. The final chambers may be finely hispid and lacking costae, but this condition was rarely seen.

Discussion: U. calvertensis is extremely rare to abundant throughout the Pungo River section. It reaches its maximum abundance in sediments of Assemblage Zone 3 where it codominates with C. laevigata. It ranges from extremely rare to common in three samples from the Yorktown Formation where it comprises 12% of the fauna in a sample from Craven County. This species has been recorded from the Miocene Calvert Formation of Maryland and the Yorktown Formation of Maryland, Virginia, and North Carolina.

UVIGERINA SUBPERIGRINA Cushman and Kleinpell

Uvigerina subperigrina CUSHMAN AND KLEINPELL, 1934, Contr. Cushman Lab.
Foram. Research, v. 10, pt. 1, p. 12, pl. 2, figs. 9, 11

This stout, fusiform species is characterized by relatively narrow, smooth longitudinal costae that decrease in strength toward the apertural end. The test is longer than broad, the widest part being at the last few chambers.

Discussion: U. subperigrina is extremely rare to uncommon throughout the Pungo River section. It is extremely rare to common throughout the Yorktown section, making up 11% of the fauna in one sample from northern Beaufort County. This species has been reported from waters less than 40 meters deep in the Gulf of Paria and the Gulf of Mexico (Beem, 1973). It is known from the Miocene and Pliocene of the Atlantic Coastal Plain from Virginia to Florida.

Genus VALVULINERIA Cushman, 1926

VALVULINERIA FLORIDANA Cushman

Plate 1, Figures H, I

Valvulineria floridana CUSHMAN, 1930, Florida Geol. Survey Bull. 4, p. 54, pl. 10, fig. 6

This species is characterized by its moderately compressed test, distinct apertural flap, and slightly curved to straight sutures. There are generally 5 to 6 chambers in the final whorl. Occasionally, specimens will show slightly limbate sutures on the early chambers on the umbilical side.

Discussion: V. floridana is extremely rare to uncommon throughout the Yorktown section and extremely rare to common throughout the Pungo River section. It reaches its greatest abundance in sediments of Assemblage Zone 2 where it is one of the characteristic secondary species. V. floridana was described from the Choctawhatchee Formation of Florida. It is also known from the Miocene and Pliocene of Maryland, Virginia, and North Carolina.

VALVULINERIA OLSSONI Redmond

Plate 1, Figures J, K

Valvulineria olssoni REDMOND, 1953, Jour. Paleontology, v. 27, n. 5,
p. 725, pl. 76, fig. 5

This species can be distinguished from V. floridana by its curved, limbate sutures on both sides of the test, a greater number of chambers in the final whorl, and its less circular outline. Some specimens show a poorly developed keel on the early portion of the test, although the presence or absence of this feature may be a function of the degree of preservation.

Discussion: V. olssoni is extremely rare to uncommon throughout the Yorktown section in Beaufort and Pamlico Counties only. It ranges from extremely rare to common throughout the Pungo River section. As with V. floridana, it reaches its greatest abundance in sediments of Assemblage Zone 2. V. olssoni was first described from the Miocene-Pliocene of California. It has also been reported from the Pliocene of North Carolina.

Genus VIRGULINELLA Cushman, 1932

VIRGULINELLA MIOCENICA (Cushman and Ponton)

Plate 1, Figure D

Virgulina miocenica CUSHMAN AND PONTON, 1931, Contr. Cushman Lab. Foram.
Research, v. 7, p. 32, pl. 4, figs. 14-16

This elongate species has a test approximately three times as long as broad, tapering towards both ends. Chambers are inflated, with strongly developed retral processes connecting previous chambers. The

aperture is an elongate slit, extending from the base of the final chamber nearly to the apex.

Discussion: V. miocenica accounts for 1% of the fauna in one sample of the Yorktown Formation. Specimens are badly weathered and most likely represent reworking upward through the Miocene-Pliocene section. It is extremely rare to abundant throughout the Pungo River section, making up a maximum of 28% of the fauna in one sample from Assemblage Zone 2. This species has been reported from the Calvert, Choptank, and St. Mary's Formations in Maryland and Virginia and from the Pungo River Formation in North Carolina.

PLANKTIC FORAMINIFERA (PUNGO RIVER FORMATION)

Genus CASSIGERINELLA Pokorný, 1955

CASSIGERINELLA CHIPOLENSIS (Cushman and Ponton)

Cassidulina chipolensis CUSHMAN AND PONTON, 1932, Florida Geol. Survey

Bull. 9, p. 98, pl. 15, fig. 2 a-c

This small species is characterized by subglobular, inflated chambers, 4 pairs making up the final whorl, and by a strongly lobulate periphery. It has a very fine surface texture and strongly depressed, distinct sutures.

Discussion: C. chipolensis is rare to fairly common throughout the section. Blow (1969) reported a range from Zone P. 18 to Zone N. 13.

Genus GLOBIGERINA d'Orbigny, 1826

GLOBIGERINA EUAPERTURA Jenkins

Globigerina euapertura JENKINS, 1960, Micropaleontology, v. 6, n. 4,

p. 351, pl. 1, fig. 8 a-c

This species characteristically has 4 chambers in the final whorl, a restricted, closed aperture, and a coarse surface texture. The final chamber is often somewhat flattened.

Discussion: G. euapertura is rare throughout the section. Jenkins and Orr (1972) reported a range from Zone P. 18 to Zone N. 13. Fleischer (1974) reported a range from Zone P. 22 to Zone N. 7/ N. 8.

GLOBIGERINA PRAEBULLOIDES PSEUDOCIPEROENSIS Blow

Globigerina praebulloides pseudociperoensis BLOW, Proc. First Internatl.

Conf. Planktonic Microfossils, p. 381-382, pl. 17, fig. 8, 9

This moderate sized species is characterized by 5 chambers in the final whorl and a wide, open, and deep umbilicus. The dorsal spire is fairly high in the specimens encountered in this study.

Discussion: G. praebulloides pseudociperoensis is rare to uncommon throughout the section. Blow (1969) reported a range from Zone N. 7 to Zone N. 12.

GLOBIGERINA JUVENILIS Bolli

Globigerina juvenilis BOLLI, 1957, U. S. Nat. Mus. Bull. 215, p. 110, pl. 24, fig. 5 a, b

This species can be distinguished by its closed slit-like aperture, occasional specimens showing a distinct apertural lip. There are 3-4 chambers in the final whorl, the chambers increasing rapidly in size as added. The surface texture is generally fairly coarse.

Discussion: G. juvenilis is rare to fairly common throughout the section. Blow (1969) reported a range from Zone N. 4 to Zone N. 23.

GLOBIGERINA WOODI WOODI Jenkins

Globigerina woodi JENKINS, 1960, Micropaleontology, v. 6, n. 4, p. 352, pl. 2, fig. 2 a-c

This generally small species is characterized by 4 chambers in the final whorl and a semicircular interiomarginal umbilical aperture almost centered over the antepenultimate chamber. The last chamber is often somewhat protruded in the radial direction. The surface texture is fairly coarse.

Discussion: G. woodi woodi is rare to fairly common throughout the section. Jenkins and Orr (1972) reported a range

equivalent to Zone N. 4 to Zone N. 17. Kennett (1973) extended its upper range into Zone N. 22.

Genus GLOBIGERINOIDES Cushman, 1927

GLOBIGERINOIDES ALTIAPERTURUS Bolli

Globigerinoides triloba altiapertura BOLLI, 1957, U. S. Nat. Mus. Bull. 215, p. 113, pl. 25, figs. 7 a, 8

This species characteristically has 4 chambers in the final whorl. The open, circular, interiomarginal umbilical primary aperture is centered over the antepenultimate chamber.

Discussion: G. altiapertura is rare throughout the section. Blow (1969) reported a range from Zone N. 5 to early Zone N. 7. Bronnimann and Resig (1971) extended the range to include strata from Zone N. 4 to Zone N. 7/ N. 8. Gibson (in press) suggests that it ranges into Zone N. 9 because it is present in Bed 10 of the Calvert Formation.

GLOBIGERINOIDES QUADRILOBATUS QUADRILOBATUS (d'Orbigny)

Globigerina quadrilobata D'ORBIGNY, 1846, Foraminifères fossiles du bassin Tertiaire de Vienne, p. 164, pl. 9, figs. 7-10

This species is characterized by its quadrate outline, 4 chambers in the final whorl, and a low interiomarginal umbilical primary aperture with no apertural lip. The surface texture is generally quite coarse.

Discussion: G. quadrilobatus quadrilobatus is common throughout the section. Blow (1969) reported a range from Zone N. 4 to Zone N. 23.

GLOBIGERINOIDES SUBQUADRATUS Bronnimann

Globigerinoides subquadratus BRONNIMANN, in Todd, Cloud, Low, and

Schmidt, 1954, Amer. Jour. Sci., v. 252, p. 680, pl. 1, fig. 5

This species has 3 chambers in the final whorl and a fairly large interiomarginal umbilical primary aperture which is located symmetrically above the intercameral suture between the penultimate and antepenultimate chambers.

Discussion: G. subquadratus is rare to fairly common throughout the section. Blow (1969) reported a range from Zone N. 5 to the top of Zone N. 13.

Genus GLOBIGERINITA Bronnimann, 1951

GLOBIGERINITA GLUTINATA (Egger)

Globigerina glutinata EGGER, 1893, Abh. K. Bayer. Akad. Wiss. Munchen, Cl. II, v. 18, p. 371, pl. 13, figs. 19, 21

This small species is characterized by 4 chambers in the final whorl and a singular, low arched interiomarginal umbilical aperture in specimens lacking the development of a modified final chamber. Those specimens having a modified final chamber that extends across the umbilical region possess multiple apertures at the umbilical margin of the chamber. Both types were seen in approximately equal amounts. The surface texture is finely perforate.

Discussion: G. glutinata is one of the most common forms encountered in the Pungo River section. Blow (1969) reported a range for this species, which he recognized as Globigerinita ambitacrena (Loeblich and Tappan), from Zone N. 5 to Zone N. 23.

GLOBIGERINITA UVULA (Ehrenberg)

Pylodexia uvula EHRENBURG, 1861, K. Preuss, Akad. Wiss. Berlin,

Monatsber., p. 276-277, 308

This species can be distinguished from G. glutinata by its much more highly spired test.

Discussion: Only one specimen of G. uvula was found from sediments of Assemblage Zone 2 in Beaufort County. Blow (1969) reported a range from Zone N. 4 to Zone N. 23.

Genus GLOBIGERINATELLA Cushman and Stainforth, 1945

GLOBIGERINATELLA INSUETA Cushman and Stainforth

Globigerinatella insueta CUSHMAN AND STAINFORTH, 1945, Cushman Lab.

Foram. Research, Spec. Pub. 14, p. 69, pl. 13, figs. 7-9

This species possesses a series of separated bullae and a pustulose surface texture. It is highly inflated with a roughly circular outline.

Discussion: One specimen of G. insueta was found in sediments of Assemblage Zone 2. Blow (1969) reported a range from the base of Zone N. 6 to the early part of Zone N. 9.

Genus GLOBOQUADRINA Finely, 1947

GLOBOQUADRINA ALTISPIRA ALTISPIRA (Cushman and Jarvis)

Globigerina altispira CUSHMAN AND JARVIS, 1936, Contr. Cushman Lab.

Foram. Research, v. 12, pt. 1, p. 5, pl. 1, figs. 13 a-c, 14

This extremely high spired species characteristically has 4-5 chambers in the final whorl, the chambers being much higher than broad in the adult form. The aperture is located on the inner margin and opens into an open but fairly deep umbilicus. Specimens from this study did not always show the characteristic plate-like tooth covering of the umbilicus, but this was most likely due to poor preservation.

Discussion: G. altispira altispira is rare throughout the section. Its most concentrated occurrence is in Carteret County. Blow (1969) reported a range from early Zone N. 4 to the early part of Zone N. 21.

GLOBOQUADRINA ALTISPIRA GLOBOSA Bolli

Globoquadrina altispira globosa BOLLI, 1957, U. S. Nat. Mus. Bull. 215, p. 111, pl. 24, figs. 9, 10

This species generally has 4-5 chambers in the final whorl, the chambers increasing moderately in size as added. The umbilicus is fairly wide and deep with a high interiomarginal umbilical aperture. It can be distinguished from G. altispira altispira by its more open aperture and its lower spire. Akers (1972) found no stratigraphic reason to separate the two, although he recognized G. altispira globosa as a distinctive morphotype.

Discussion: G. altispira globosa is rare throughout the section. Blow (1969) reported a range from Zone N. 3 to Zone N. 19 or the earliest part of Zone N. 20.

GLOBOQUADRINA DEHISCENS (Chapman, Parr, and Collins)

Globoquadrina dehiscens CHAPMAN, PARR, AND COLLINS, 1934, Linn. Soc.

London, (Zoology), Jour., v. 38, n. 262, p. 569, pl. 11, fig. 36

This species is characterized by a subconical test, about as broad as it is high, with a flattened spiral side. The umbilical side is strongly convex, the margin is rounded, and there are 4 chambers in the final whorl. The aperture is an elongate slit extending almost the entire length of the inner margin of the last formed chamber.

Discussion: G. dehiscens is rare throughout the section. Blow

(1969) reported a range from Zone N. 5 to Zone N. 19. Akers (1972) indicated that he had not seen documentation of G. dehiscens (not G. quadraria Cushman and Ellis var. advena Bermudez) above Zone N. 17.

Genus GLOBOROTALIA Cushman, 1927

Subgenus TURBOROTALIA Cushman and Bermudez, 1949

GLOBOROTALIA (TURBOROTALIA) BIRNAGEAE Blow

Globorotalia birnageae BLOW, 1959, Bull. Amer. Paleontology, v. 39, n. 178, p. 210-211, pl. 17, fig. 108 a-c

This moderately inflated species is characterized by 4-5 tightly coiled chambers in the final whorl, a closed umbilicus, and an interiomarginal umbilical-extraumbilical slit-like aperture with a well developed apertural lip. It lacks any development of a peripheral keel.

Discussion: G. (T.) birnageae is rare to fairly common throughout the section. Blow (1969) reported a range from within Zone N. 7 to the latter part of Zone N. 9. Bronnimann and Resig (1971) recorded this species as low as Zone N. 6.

GLOBOROTALIA (TURBOROTALIA) PERIPHERORONDA Blow and Banner

Globorotalia (Turborotalia) peripheroronda BLOW AND BANNER, 1966, Micropaleontology, v. 12, n. 3, p. 294, pl. 1, fig. 1 a-c; pl. 2, figs. 1-3

This species is characterized by 6-7 chambers in the final whorl, a rounded periphery, a fairly coarse surface texture, the lack of a peripheral keel, and a slit-like interiomarginal umbilical-extraumbilical aperture located at the base of the final chamber and oriented at

approximately 90° to the final axis of coiling.

Discussion: G. (T.) peripheroronda is rare throughout the section. Blow (1969) reported a range from Zone N. 6 to Zone N. 11. Bronnimann and Resig (1971) place its first appearance as early as Zone N. 5.

GLOBOROTALIA (TURBOROTALIA) SCITULA PRAESCITULA Blow

Globorotalia scitula praescitula BLOW, 1959, Bull. Amer. Paleontology, v. 39, n. 178, p. 221, pl. 19, fig. 128 a-c

Diagnostic characteristics of this species include 4 chambers in the final whorl, a subacute to rounded periphery, fine surface texture, the lack of a peripheral keel, and a slit-like interiomarginal umbilical-extraumbilical aperture oriented approximately 45° to the final axis of coiling. An apertural lip is fairly well developed on most specimens.

Discussion: G. (T.) scitula praescitula is rare to fairly common throughout the section. This is the second most abundant species of Globorotalia in the Pungo River Formation. Blow (1969) reported a range from Zone N. 5 to near the end of Zone N. 9.

GLOBOROTALIA (TURBOROTALIA) cf. G. (T.) SIAKENSIS (LeRoy)

Globigerina siakensis LEROY, 1939, Natuurk. Tijdschr. Nederl.-Indie, v. 99, n. 6, p. 39-40, pl. 3, figs. 30, 31

This species is characterized by 5-6 chambers in the final whorl, an open but deep umbilicus, and a fairly low, elongate interiomarginal umbilical-extraumbilical aperture. An apertural lip is usually present but generally not well developed. According to Blow (1969),

it can be distinguished from G. (T.) acostaensis humerosa Takayanagi and Saito by the shape of the chambers in the final whorl. The chambers of G. (T.) siakensis become appressed and triangular in both umbilical and spiral aspect, but the peripheral margin remains strongly lobulate. Specimens from this study did not always show this distinction, so the species assignment is somewhat tentative.

Discussion: G. (T.) cf. G. (T.) siakensis is fairly common throughout the section. Blow (1969) reported a range from the latest part of Zone N. 2 to the top of Zone N. 14.

Genus PRAORBULINA Olsson, 1964

PRAORBULINA GLOMEROSA GLOMEROSA (Blow)

Globigerinoides glomerosa glomerosa BLOW, 1956, Micropaleontology, v. 2, n. 1, p. 65, text-fig. 1, n. 15-19; text-fig. 2, n. 1, 2

This species possesses a globular final chamber enveloping slightly less than 75% of the earlier globigerine chambers. There are multiple slit-like apertures in the suture between the final and earlier chambers.

Discussion: P. glomerosa glomerosa is extremely rare. Only one specimen was found near the top of the section in Craven County. Blow (1969) reported a range from the middle part of Zone N. 8 to the basal part of Zone N. 9.

PLANKTIC FORAMINIFERA (YORKTOWN FORMATION)

Genus GLOBIGERINA d'Orbigny, 1826

GLOBIGERINA BULLOIDES APERTURA Cushman

Globigerina apertura CUSHMAN, 1918, U. S. Geol. Survey Bull. 676, p. 57,
pl. 12, fig. 8 a-c

This species can be distinguished from G. bulloides bulloides by its large, semicircular aperture which opens into the central umbilical cavity. Its test is compressed with 4 chambers making up the final whorl. The surface is smooth and finely perforate.

Discussion: G. bulloides apertura is common throughout the section. Blow (1969) reported a range from Zone N. 16 to Zone N. 19. Snyder et al. (in press) extended the range into Zone N. 20.

GLOBIGERINA BULLOIDES BULLOIDES d'Orbigny

Globigerina bulloides D'ORBIGNY, 1826, Annales Sci. Nat., v. 7, p. 277,
modele n. 1

This species is characterized by a low trochospire with 4 chambers in the final whorl. The umbilicus is small but depressed. The aperture is a long low arch, interiomarginal and umbilical in position. Some specimens possess an associated apertural rim. The surface texture is smooth and finely perforate.

Discussion: G. bulloides bulloides is common throughout the section. This was the most frequently encountered species in the Yorktown Formation. Blow (1969) reported a range from within Zone N. 16 (where G. praebulloides praebulloides gives rise to this species) to Zone N. 23.

GLOBIGERINA CALIDA PRAECALIDA Blow

Globigerina calida praecalida BLOW, 1969, Proc. First Internatl. Conf.

Planktonic Microfossils, p. 380-381, pl. 13, figs. 6, 7; pl. 14, fig. 3

This species characteristically has 4-5 chambers in the final whorl. Chambers are arranged in a very low dorsal spire. The chambers are inflated but are not appressed or embracing to any great extent. The umbilicus is wide, open, and deep. The characteristics of the spire and the more lax coiling mode serve to distinguish this species from G. praebulloides pseudociperoensis Blow.

Discussion: G. calida praecalida is rare throughout the section. Blow (1969) reported a range from the middle of Zone N. 17 to Zone N. 23.

GLOBIGERINA DECORAPERTA Takayanagi and Saito

Globigerina druryi Akers decoraperta TAKAYANAGI AND SAITO, 1962, Sci.

Repts. Tohoku Univ., ser. 2 (Geology), Spec. v. n. 5, p. 85, pl. 28, fig. 10

This small, lobulate species is characterized by 4 chambers in the final whorl, the chambers increasing rather rapidly in size as added. The last chamber protrudes in a radial direction. A medium sized, fairly high interiomarginal umbilical aperture lies directly opposite the antepenultimate chamber.

Discussion: G. decoraperta is rare to fairly common throughout the section. Blow (1969) reported a range from Zone N. 14 to Zone N. 21.

GLOBIGERINA JUVENILIS Bolli

Refer to the discussion of this species in the Pungo River section.

Discussion: G. juvenilis is fairly common throughout the Yorktown section.

GLOBIGERINA NEPENTHES Todd

Globigerina nepenthes TODD, 1957, U. S. Geol. Survey Prof. Paper 280-H, p. 301, pl. 78, fig. 7 a, b

This small species is characterized by 4 compactly coiled chambers in the final whorl with a 5th protruding chamber extending downward at an angle to the axis of coiling. The aperture, which is quite small and arched, is located at the umbilical edge of the protruding chamber. The surface texture is fairly coarse.

Discussion: G. nepenthes is extremely rare. A single specimen was found in sediments from Pamlico County. Blow (1969) reported a range from the base of Zone N. 14 to the boundary between Zones N. 19 and N. 20.

Genus GLOBIGERINOIDES Cushman, 1927

GLOBIGERINOIDES BOLLII Blow

Globigerinoides bollii BLOW, 1959, Bull. Amer. Paleontology, v. 39, n. 178, p. 189-191, pl. 10, fig. 65 a-c

This species characteristically has 4 chambers in the final whorl. Successive chambers become progressively more compressed in a lateral, oblique manner, and the last chamber is often reduced. The chambers are strongly embracing. It has a small, almost circular interior-marginal umbilical primary aperture.

Discussion: G. bollii is rare throughout the section. Blow (1969)

reported a range from early Zone N. 16 to within Zone N. 21.

GLOBIGERINOIDES OBLIQUUS EXTREMUS Bolli and Bermudez

Globigerinoides obliquus extremus BOLLI AND BERMUDEZ, 1965, Bol. Informativo, Assoc. Venezolana de Geol., Min. y Pet., v. 8, n. 5, p. 139, pl. 1, figs. 10-12

The final whorl of this species has 4 chambers that become progressively more compressed in a lateral, oblique manner. It has a narrow umbilicus, and an interiomarginal umbilical primary aperture that is a distinct arch of medium height. The surface texture is rather fine for this genus.

Discussion: G. obliquus extremus is rare throughout the section. Blow (1969) reported a range from the early part of Zone N. 16 to within Zone N. 21.

GLOBIGERINOIDES OBLIQUUS OBLIQUUS Bolli

Globigerinoides obliqua BOLLI, 1957, U. S. Nat. Mus. Bull. 215, p. 113, pl. 25, figs. 9, 10; text-fig. 21, n. 5

This species can be distinguished from G. obliquus extremus by the fact that the chambers of the final whorl are less compressed in a lateral, oblique manner.

Discussion: G. obliquus obliquus is rare throughout the section. Blow (1969) reported a range from the latest part of Zone N. 5 to Zone N. 22.

GLOBIGERINOIDES QUADRILOBATUS QUADRILOBATUS (d'Orbigny)

Refer to the discussion of this species in the Pungo River section.

Discussion: G. quadrilobatus quadrilobatus is common throughout the Yorktown section.

LOBIGERINOIDES RUBER (d'Orbigny)

Globigerina rubra D'ORBIGNY, 1839, in de la Sagra, Histoire ... de l'Ile de Cuba, "Foraminifères", p. 82, pl. 4, figs. 12-14

This species has 3 strongly inflated chambers in the final whorl. An interiomarginal umbilical, moderately high, semicircular primary aperture is symmetrically located above the intercameral suture between the penultimate and antepenultimate chambers. The umbilicus is small and very shallow. This species is quite similar to G. subquadratus; however, it can be distinguished by its 3 chambers in the final whorl in contrast to the latter species which has 4. The two are also stratigraphically separated.

Discussion: G. ruber is fairly common throughout the section.

Blow (1969) reported a range from Zone N. 16 to Zone N. 23.

Genus LOBIGERINITA Bronnimann, 1951

LOBIGERINITA GLUTINATA (Egger)

Refer to the discussion of this species in the Pungo River section.

Discussion: G. glutinata is rare to common throughout the section.

Genus GLOBOQUADRINA Finely, 1947

GLOBOQUADRINA ALTISPIRA GLOBOSA Bolli

Refer to the discussion of this species in the Pungo River section.

Discussion: G. altispira globosa is rare throughout the section.

GLOBOQUADRINA cf. G. VENEZUELANA (Hedberg)

Globigerina venezuelana HEDBERG, 1937, Jour. Paleontology, v. 11, p. 681, pl. 92, fig. 7

This species typically has four and one-half inflated chambers in the final whorl, with the last chamber being wider and more embracing than the previous chambers. The interiomarginal umbilical aperture is located at the base of the final chamber and opens into a deep umbilical region.

Discussion: G. cf. G. venezuelana is extremely rare. Only one specimen was found in sediments of northern Beaufort County.

Poag (1972) reported a range from Zone N. 14 to the middle of Zone N. 21.

Genus GLOBOROTALOIDES Bolli, 1957

GLOBOROTALOIDES HEXAGONA HEXAGONA (Natland)

Globigerina hexagona NATLAND, 1938, Univ. Calif., Scripps Inst. Oceanography Bull., Tech. Ser., v. 4, n. 5, p. 149, pl. 7, fig. 1

This low spired species characteristically has 5 chambers in the final whorl. The chambers increase rapidly in size as added. The surface texture is quite distinctive, consisting of individual hexagonal pits. The aperture is a slightly arcuate opening between the umbilicus and the periphery at the base of the final chamber.

Discussion: G. hexagona hexagona is extremely rare. Two specimens were found in different samples from Beaufort County.

Blow (1969) reported a range from within Zone N. 18 to Zone N. 23.

Genus GLOBOROTALIA Cushman, 1927

Subgenus GLOBOROTALIA Cushman, 1927

GLOBOROTALIA (GLOBOROTALIA) CRASSULA Cushman and Stewart

Globorotalia crassula CUSHMAN AND STEWART, 1930, San Diego Nat. Hist.

Trans., v. 6, p. 77, pl. 7, fig. 16, (not fig. 1 a-c)

Specimens with three and one-half to four chambers in the final whorl, a moderately keeled periphery, an unequally biconvex test (more planar on the spiral side), a coarsely granular surface, and a quadrate outline were placed in G. crassula. These forms compared favorably to those illustrated by Snyder et al. (in press) from the Yorktown Formation at Lee Creek, North Carolina.

Discussion: G. (G.) crassula is extremely rare. Two specimens were found from sediments of Beaufort County. Blow (1969) reported a range from within Zone N. 18 to Zone N. 22.

GLOBOROTALIA (GLOBOROTALIA) CULTRATA LIMBATA (Fornasini)

Rotalia limbata D'ORBIGNY in FORNASINI, 1902, Roy. Acad. Sci. Inst.

Bologna, Mem. Sci. Nat. Bologna, ser. 5, v. 10, p. 56, text-fig. 55, ("disegno inedito")

This species is characterized by 5 to 6 chambers in the final whorl, an acute and strongly keeled periphery, and an almost biconvex test. Except for the development of a pustulose area on the first chamber of the final whorl, the surface is smooth. The umbilicus is small but fairly deep. The aperture is a low interiomarginal umbilical-extraumbilical arch extending from the umbilicus almost to the periphery.

Discussion: G. (G.) cultrata limbata is rare, except for one sample (CNN-1-6) where it was fairly common. It was the most abundant species of Globorotalia (Globorotalia) encountered in this study. Blow (1969) reported a range from Zone N. 13 or N. 14 to Zone N. 21.

GLOBOROTALIA (GLOBOROTALIA) CULTRATA MENARDII

(Parker, Jones, and Brady)

Rotalia menardii PARKER, JONES, AND BRADY, 1865, Ann. Mag. Nat. Hist.,
(ser. 3), v. 16, p. 20, pl. 3, fig. 81

This species has 5 chambers in the final whorl, the chambers increasing rapidly in size as added, a strongly keeled periphery (less lobulate than G. (G.) cultrata limbata), and an unequally biconvex test which is more planar on the spiral side. The aperture is moderately arched and interiomarginal umbilical-extraumbilical in position. The surface is smooth throughout.

Discussion: G. (G.) cultrata menardii is extremely rare. One specimen was found in Beaufort County sediments; two, in Carteret County sediments. Blow (1969) reported a range from Zone N. 14 to Zone N. 23.

GLOBOROTALIA (GLOBOROTALIA) EXILIS Blow

Globorotalia (Globorotalia) cultrata exilis BLOW, 1969, Proc. First
Internatl. Conf. Planktonic Microfossils, p. 396, pl. 7, figs.
1-3; pl. 42, figs. 1, 5

A specimen having 7 chambers in the final whorl, a nearly biconvex test, a strongly keeled periphery, and possessing a projecting lip on the final chamber that does not quite extend to the umbilicus was referable to G. exilis. In addition to these characteristics, the limbate portion of the intercameral sutures on the spiral side is somewhat concealed by the overlap of succeeding chambers in the final whorl.

Discussion: G. (G.) exilis is extremely rare. One specimen

was found in northern Beaufort County. Jenkins and Orr (1972) recorded a maximum range for this species from the G. (G.) plesiotumida Zone (N. 17) to the Globigerinoides fistulosus Zone (N. 21).

GLOBOROTALIA (GLOBOROTALIA) HIRSUTA PRAEHIRSUTA Blow

Globorotalia (Globorotalia) hirsuta praehirsuta BLOW, 1969, Proc. First Internatl. Conf. Planktonic Microfossils, p. 400-402, pl. 43, figs. 3-7

This slightly lobulate, nearly plano-convex species characteristically has 4 chambers in the final whorl with a subacute, narrowly keeled peripheral margin. The sutures of the spiral side are fairly strongly recurved in a posterior direction. There is no distinct umbilical region. This species can be distinguished from G. (G.) hirsuta hirsuta on the basis of the latter species' greater development of an umbilical depression, a less plano-convex test, and more deeply incised sutures on the umbilical side (Blow, 1969).

Discussion: G. (G.) hirsuta praehirsuta is extremely rare.

One specimen was found in Beaufort County and one in Carteret County. Blow (1969) reported a range from within Zone N. 18 to the early to middle parts of Zone N. 22 (where it gives rise to G. (G.) hirsuta hirsuta).

Subgenus TURBOROTALIA Cushman and Bermudez, 1949

GLOBOROTALIA (TURBOROTALIA) ACOSTAENSIS ACOSTAENSIS Blow

Globorotalia (Turborotalia) acostaensis acostaensis BLOW, 1969, Proc.

First Internatl. Conf. Planktonic Microfossils, p. 344-345, pl. 9, figs. 13-15; pl. 13, figs. 1, 2

This species characteristically has 5-6 generally inflated chambers in the final whorl, the last chamber occasionally becoming somewhat displaced towards the umbilical side. The umbilicus is small but deep. The aperture is interiomarginal umbilical-extraumbilical, usually with a distinctive lip. The spiral side is slightly convex to almost flat. There is no development of a peripheral keel.

Discussion: G. (T.) acostaensis acostaensis is rare throughout the section. Blow (1969) reported a range from Zone N. 16 to Zone N. 21.

GLOBOROTALIA (TURBOROTALIA) ACOSTAENSIS HUMEROSA

Takayanagi and Saito

Globorotalia humerosa TAKAYANAGI AND SAITO, 1962, Sci. Repts. Tohoku

Univ., ser. 2 (Geology), Spec. v. n. 5, p. 78, pl. 28, figs. 1, 2

This species can be distinguished from G. (T.) acostaensis acostaensis by its biconvex test, a wide and deep umbilicus, and less displacement of the final chamber toward the umbilical side. There are usually 6-7 chambers in the final whorl.

Discussion: G. (T.) acostaensis humerosa is common throughout the section. This was the most common globorotaliid encountered in the Yorktown Formation. Blow (1969) reported a range from Zone N. 16 to Zone N. 23.

GLOBOROTALIA (TURBOROTALIA) PRAEOSCITANS Akers

Globorotalia (Turborotalia) praeoscitans AKERS, 1972, Tulane Stud.

Geology Paleontology, v. 9, p. 116-118, pl. 32, fig. 3; pl. 36, fig. 3; pl. 50, fig. 2; pl. 51, fig. 3

This species is characterized by 4 chambers in the final whorl.

The final chamber characteristically exhibits abrupt inflation both laterally and vertically. The large, semicircular interiomarginal umbilical-extraumbilical aperture generally has a narrow lip associated with it. The surface is finely perforate. There is no development of a peripheral keel.

Discussion: G. (T.) praeoscitans is fairly common in samples from the lower Yorktown, but it is extremely rare throughout the rest of the section. This species was described from Yorktown sediments at Rice's Pit, Virginia (later part of Zone N. 18 to the later part of Zone N. 19) and has also been reported from the Jackson Bluff Formation of Florida and the Yorktown Formation at Lee Creek (Akers, 1972; Snyder et al., in press).

Genus HASTIGERINA Thomson, 1876

HASTIGERINA SIPHONIFERA SIPHONIFERA (d'Orbigny)

Globigerina siphonifera D'ORBIGNY, 1839, in de la Sagra, Histoire ...
de l'Ile de Cuba, "Foraminiferes", p. 83, pl. 4, figs. 15-18

This was the only planispiral to nearly planispiral planktic species encountered in this study. The chambering serves to distinguish it from the other species of the assemblage. The tightness of coiling varied slightly among the specimens.

Discussion: H. siphonifera siphonifera is rare throughout the section. Blow (1969) reported a range from within Zone N. 12 to Zone N. 23.

Genus ORBULINA d'Orbigny, 1839

ORBULINA SUTURALIS Bronnimann

Orbulina suturalis BRONNIMANN, 1951 (part), Contr. Cushman Found.

Foram. Research, v. 2, pt. 4, p. 135, text-fig. 2, n. 1-2, 5-8, 10; text-fig. 3, n. 3-8, 11, 13-16, 18, 20-22; text-fig. 4, n. 2-4, 7-12, 15-16, 19-22

This species is characterized by a globular final chamber that does not completely envelop the preceding globigerine chambers. The Globigerina-like chambers appear as a rounded area that projects slightly above the surface of the final chamber. Specimens encountered in this study showed a fairly wide range of transition from partial to almost complete envelopment.

Discussion: O. suturalis is rare to fairly common throughout the section. Blow (1969) reported a range from the base of Zone N. 9 to Zone N. 23.

ORBULINA UNIVERSA d'Orbigny

Orbulina universa D'ORBIGNY, 1839, in de la Sagra, Histoire ... de l'Ile de Cuba, "Foraminiferes", p. 2, pl. 1, fig. 1

This spherical species is characterized by the last chamber completely enveloping the earlier globigerine portion of the test so that none of the chambering of the initial stage can be seen.

Discussion: O. universa is rare throughout the section except for several samples from Beaufort County where it is fairly common. Blow (1969) reported a range from early to middle Zone N. 9 to Zone N. 23.

Genus SPHAEROIDINELLOPSIS Banner and Blow, 1959

SPHAEROIDINELLOPSIS SUBDEHISCENS SUBDEHISCENS Blow

Sphaeroidinella dehiscens subdehiscens BLOW, 1959, Bull. Amer. Paleon-

tology, v. 39, n. 178, p. 195, pl. 12, figs. 71, 72

All but one of the specimens of this species encountered in this study showed an extremely coarse surface texture due to the removal of the smooth outer cortex. This distinctive surface texture serves to distinguish them from other similarly chambered species. The aperture is an interiomarginal umbilical elongate slit or low arch, occasionally with a thickened rim. There are three to three and one-half chambers in the final whorl.

Discussion: S. subdehiscens subdehiscens is rare to fairly common throughout the section. Blow (1969) reported a range from the base of Zone N. 13 to within Zone N. 19. Snyder et al. (in press) showed an extended range to near the top of Zone N. 21.

Genus TURBOROTALITA Blow and Banner, 1962

TURBOROTALITA HUMILIS (Brady)

Truncatulina humilis BRADY, 1884, Rept. Voy. Challenger, Zoology, v. 9, pt. 22, p. 665-666, pl. 94, fig. 7 a-c

This species can be distinguished from T. quinqueloba by its generally greater degree of inflation and less pronounced elongation of the final chamber. Forms with and without a bulla were encountered.

Discussion: T. humilis is extremely rare. Two specimens were found, one from Beaufort County and one from Carteret County. Blow (1969) reported a range from early Zone N. 18 to Zone N. 23.

TURBOROTALITA QUINQUELOBA (Natland)

Globigerina quinqueloba NATLAND, 1938, Univ. Calif., Scripps Inst.

Oceanography Bull., Tech. Ser., v. 4, n. 5, p. 149, pl. 6, fig. 7

This small species characteristically has 5 chambers in the final whorl, the last chamber being quite elongated in comparison to the previous four. The aperture is an elongate slit with an overhanging lip that sweeps across and almost completely covers the umbilicus.

Discussion: T. quinqueloba is rare to fairly common throughout the section. Blow (1969) reported a range from within early Zone N. 17 to Zone N. 23.

PLATE 1

Figure

- A Buliminella elegantissima (d'Orbigny), X170
- B Caucasina gracilis (Cushman), X170
- C Elphidium excavatum (Terquem), X170
- D Virgulinella miocenica (Cushman and Ponton), X130
- E Elphidium limatulum Copeland, X170
- F Bolivina paula Cushman and Cahill, X330
- G Bolivina lowmani Phleger and Parker, X250
- H, I Valvulineria floridana Cushman, X170
- J, K Valvulineria olssoni Redmond, X100

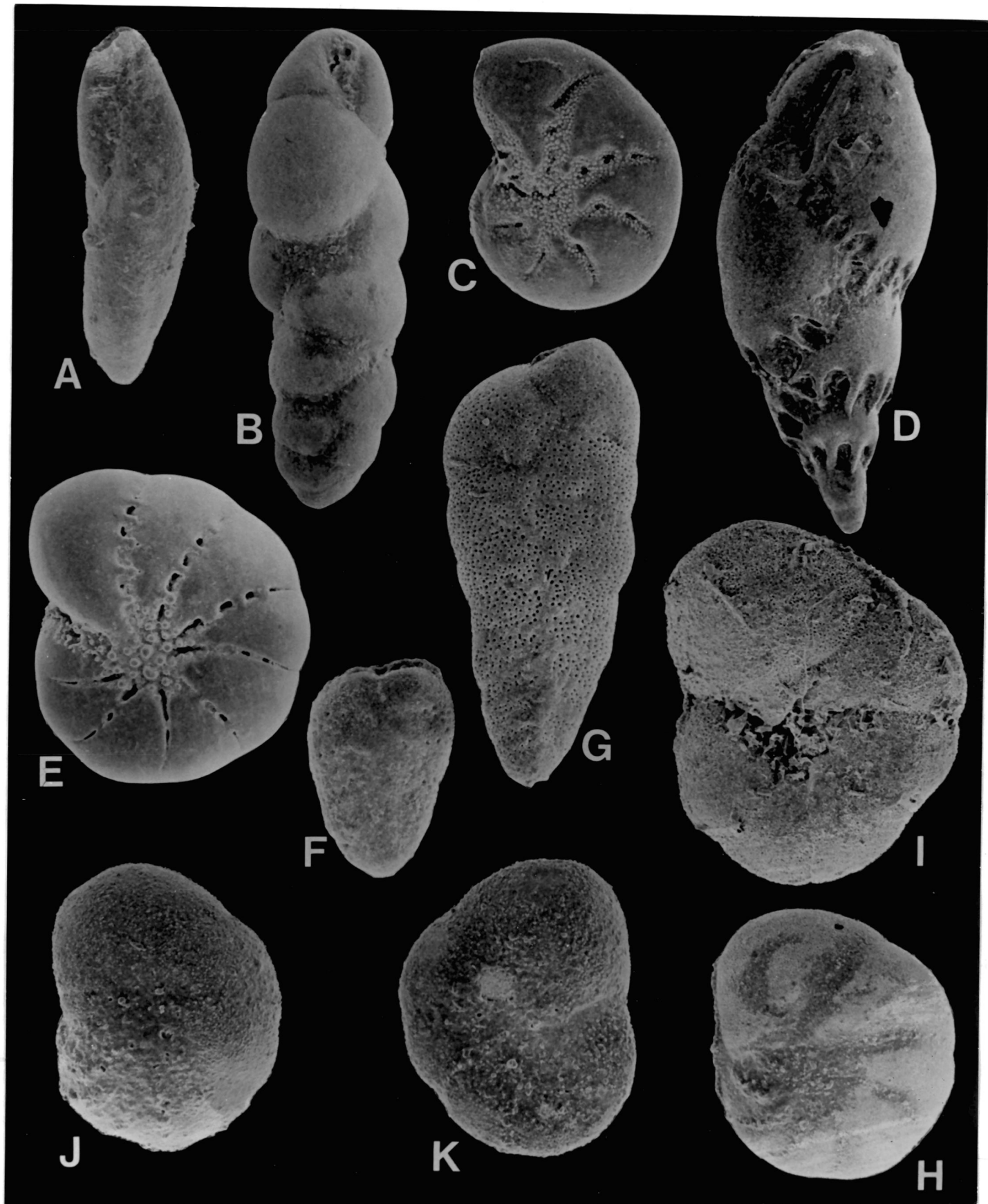


Plate 1

PLATE 2

Figure

- A, B Cibicides lobatulus (Walker and Jacob), X170
- C Florilus pizzarensis (Berry), X170
- D, E Hanzawaia nipponica Asano, X170
- F, G Nonionella miocenica Cushman, X170

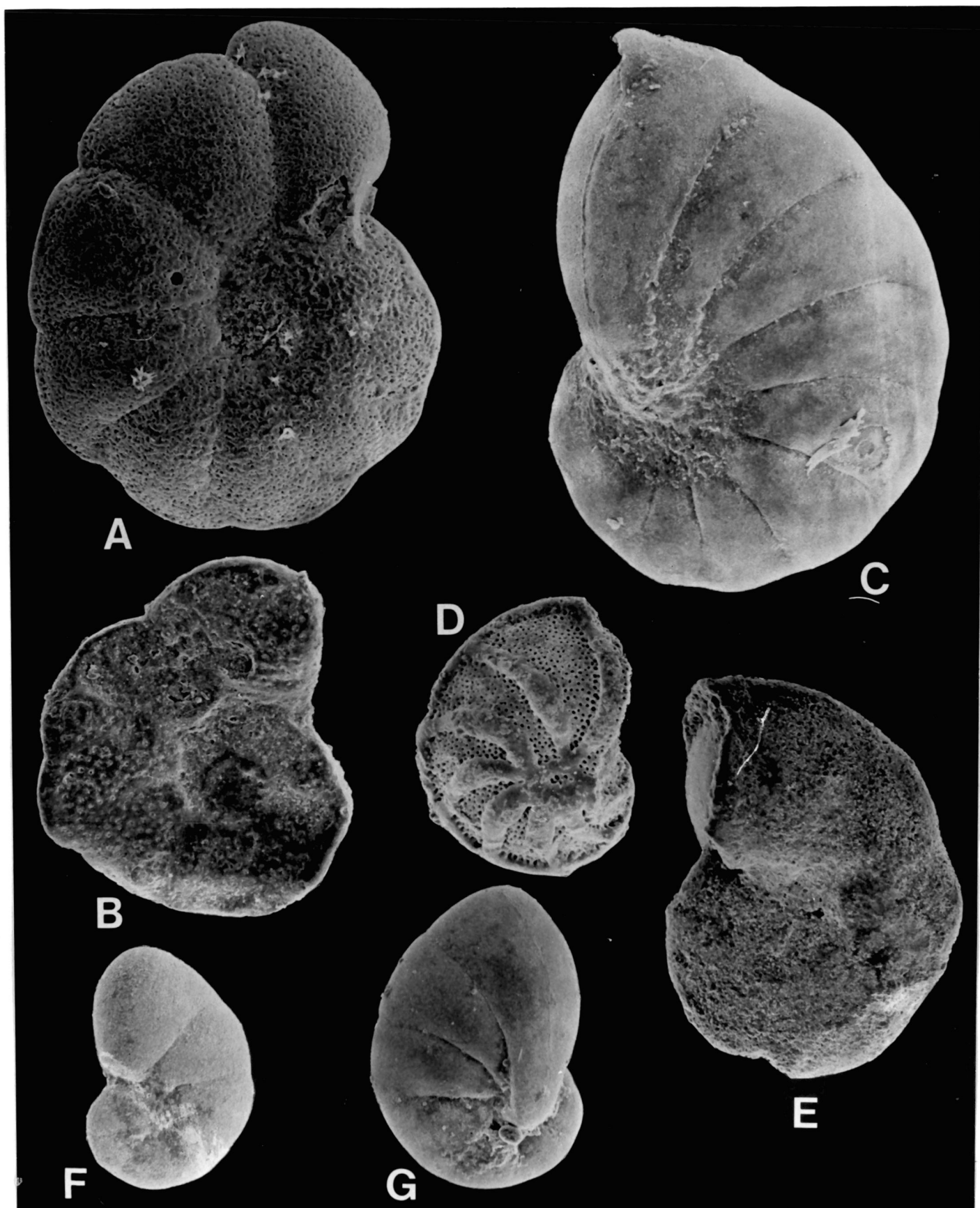


Plate 2

PLATE 3

Figure

- A-D Hanzawaia concentrica (Cushman), X170
- E Globocassidulina crassa (d'Orbigny), X250
- F Uvigerina calvertensis Cushman, X170
- G, H Cassidulina laevigata d'Orbigny, X170

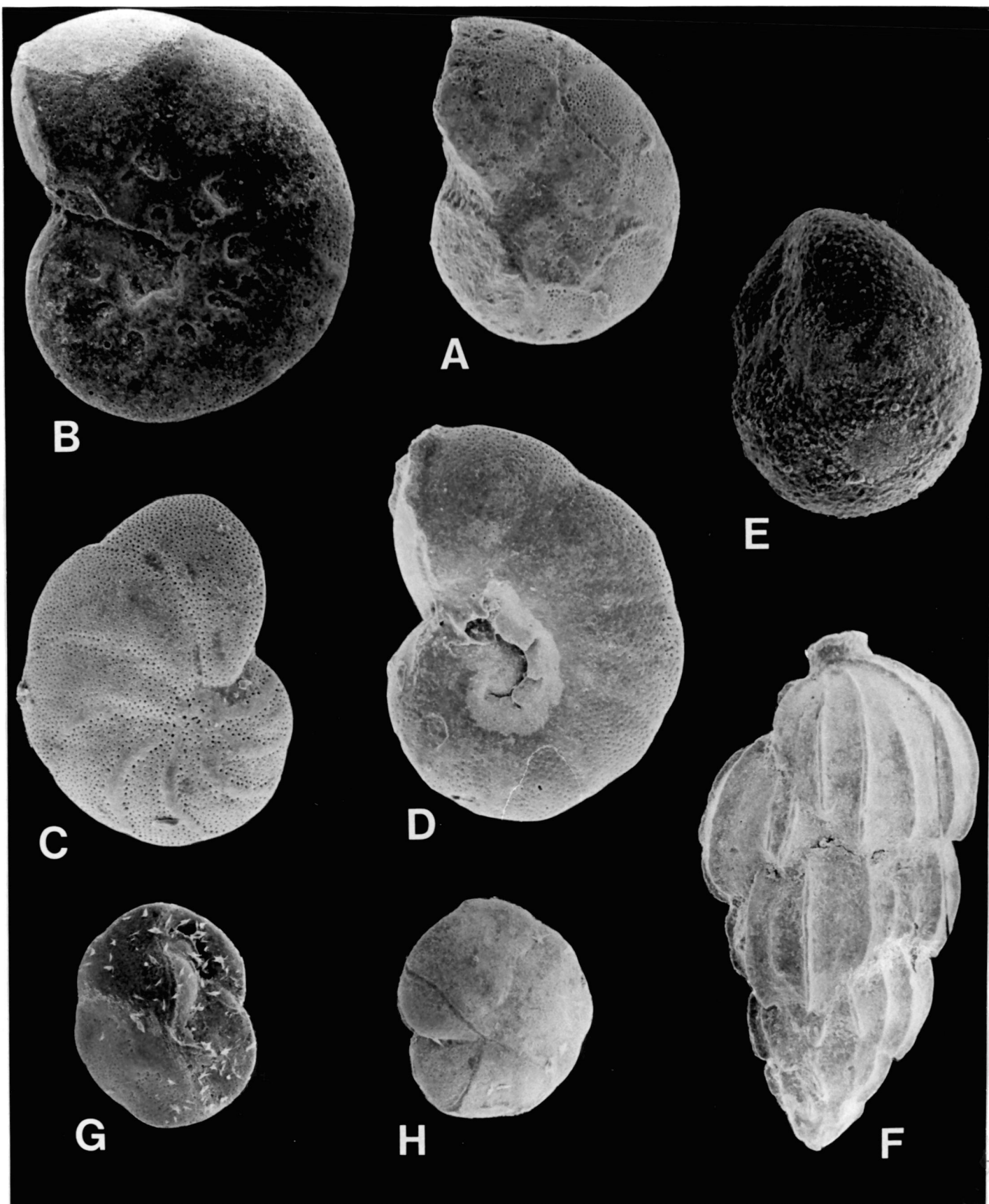
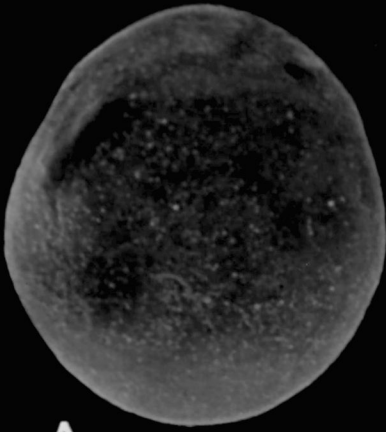


Plate 3

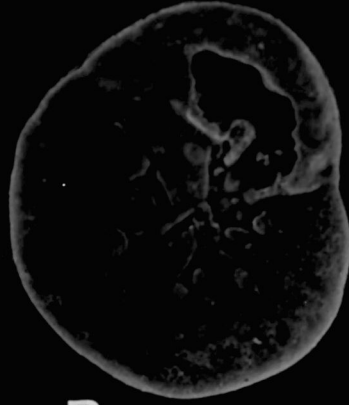
PLATE 4

Figure

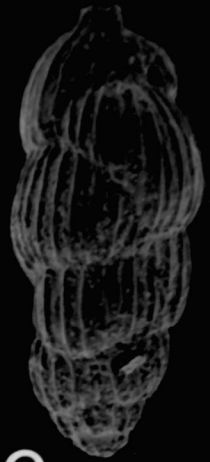
- A, B Rosalina cf. R. cavernata (Dorsey)
 A. X280
 B. X220
- C Hopkinsina bononiensis (Fornasini), X130
- D, E Nonionella sp.
 D. X260
 E. X290
- F Spiroplectammna exilis Dorsey, X115
- G, H Florilus chesapeakeensis Gibson
 G. X60
 H. X70
- I Bolivina calvertensis Dorsey, X250



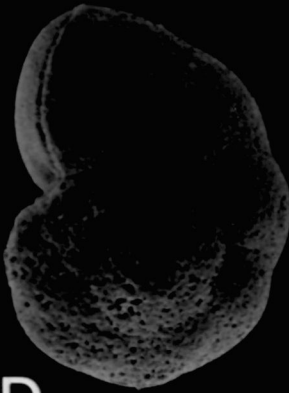
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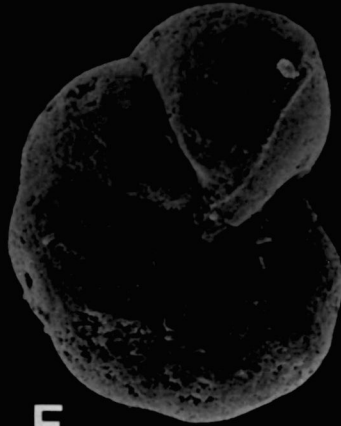
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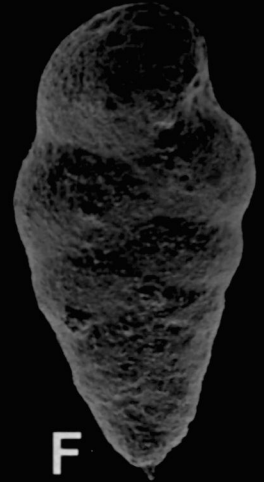
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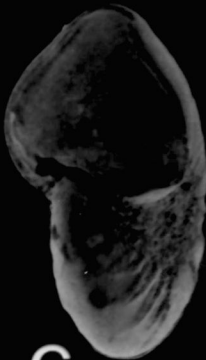
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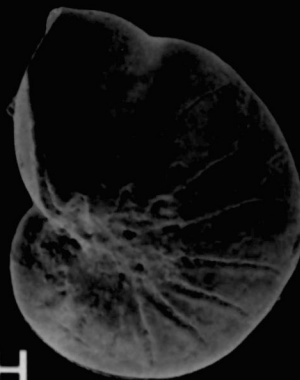
E



F



G



H

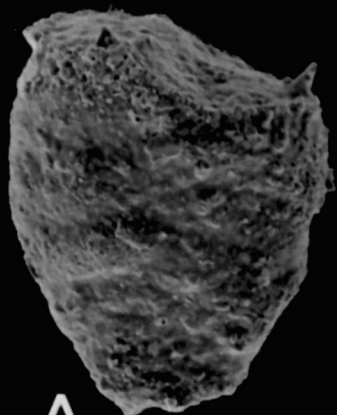


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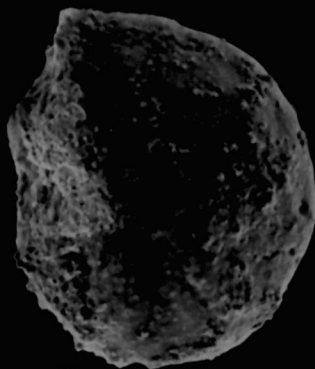
PLATE 5

Figure

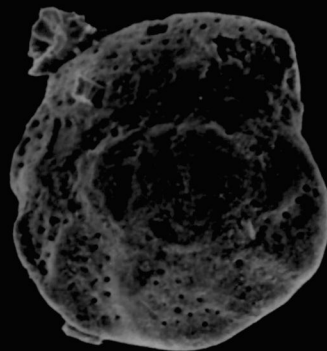
- A Spiroplectammina mississippiensis (Cushman), X220
- B, C Cibicides cravenensis Gibson
 B. X220
 C. X300
- D Bolivina pungoensis Gibson, X190
- E Nonion marylandicum Dorsey, X160
- F Siphogenerina lamellata Cushman, X115
- G, H Bolivinopsis fairhavenensis Gibson
 G. X300
 H. X320



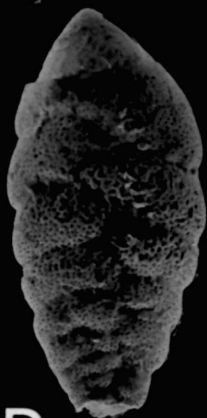
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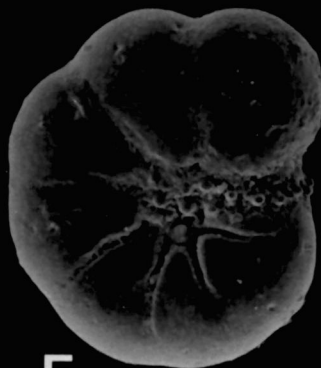
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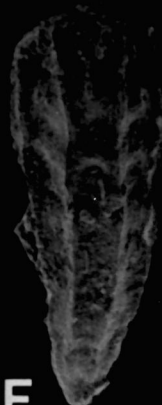
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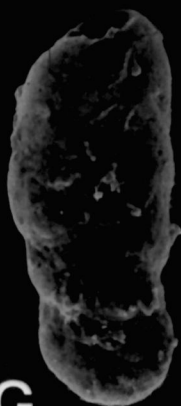
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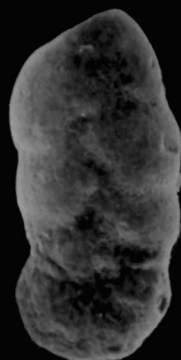
E



F



G



H

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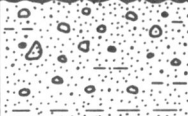
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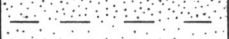
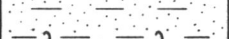
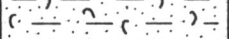
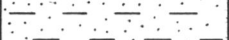
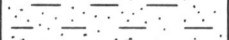
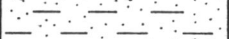
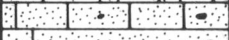
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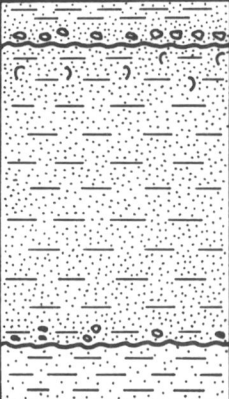
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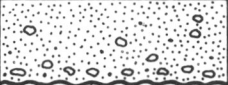
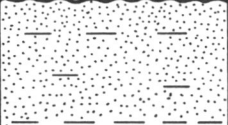
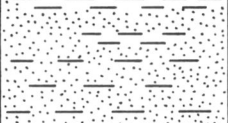
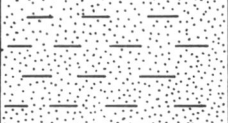
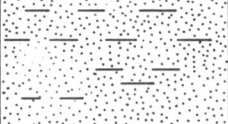
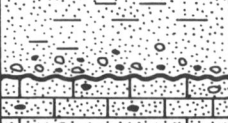
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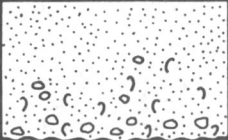
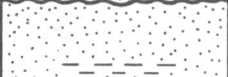
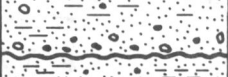
APPENDIX I. Columnar sections and faunal associations of the Yorktown and Duplin Formations within each core from the study area.

METERS	SAMPLE NO.	FORMATION	LITHOFACIES	SECTION (BTN-15)	LITHIC DESCRIPTION	FAUNAL ASSOCIATION
8	5	CRO.			Blueish, glauconitic, slightly muddy shell hash and shell gravelly quartz sand	
10	6					
12	7	YORKTOWN	UPPER		Dark grey, coarse, poorly sorted quartz sand with large quartz pebbles	Elphidium excavatum (38%)
14	8				Slightly muddy quartz sand	Elphidium excavatum (32%)
16	9				Dark blueish green, interbedded clays and sands	Elphidium excavatum (38%) Hanzawaia concentrica (24%) Cibicides lobatulus (18%)
18	10				Olive green, glauconitic, medium, muddy quartz sand with some fine shell fragments	Cibicides lobatulus (40%) Elphidium excavatum (23%) Hanzawaia concentrica (14%)
20	11				Dark green, very tight clay with decreasing carbonate content downward	Elphidium excavatum (19%) Globocassidulina crassa (14%)
22	12				Dark green, slightly sandy mud with some phosphate	Canceris sagra (17%) Cibicides lobatulus (15%) Uvigerina subperigrina (11%)
24	13				Grey, phosphatic quartz sand	Elphidium excavatum (28%) Cibicides lobatulus (11%)
26						
28						
30						
32						
34						
36						
38						
40						
42						
44						

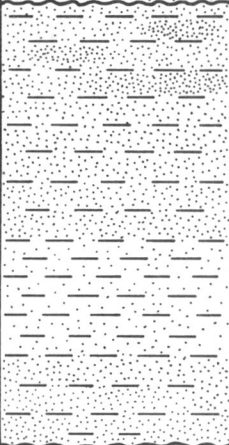
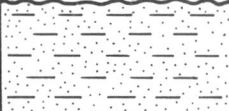
METERS	SAMPLE NO.	FORMATION	LITHOFACIES	SECTION (NCPC)	LITHIC DESCRIPTION	FAUNAL ASSOCIATION
7	1 2 3	CRO.			Slightly muddy, shell gravelly quartz sand	
9		YORKTOWN	UPPER		Moldic, calcareous quartz sand	
11					Echinoid rich, fine sandy mud	
13					Shelly, sandy mud	
15					Grey, very clayey silt with 2% phosphate in silt fraction and abundant echinoid fragments	
17					Grey, very clayey silt with 2% phosphate in silt fraction and abundant echinoid fragments	
19					Grey, very clayey silt with 2% phosphate in silt fraction and abundant echinoid fragments	
21					Grey, very clayey silt with 2% phosphate in silt fraction and abundant echinoid fragments	
23					Grey, very clayey silt with 2% phosphate in silt fraction and abundant echinoid fragments	
25		P. R.	LOW.		Light grey green to dark green, fine to medium, slightly muddy, phosphatic quartz sand	- Cibicides lobatulus (15%) - Nonionella miocenica (11%)
27					Light grey green to dark green, fine to medium, slightly muddy, phosphatic quartz sand	- Florilus pizzarensis (17%) - Nonionella miocenica (15%) - Fursenkoina fusiformis (13%) - Buliminella elegantissima (12%)
29					Shelly, quartz bearing, phosphatic dolomite	Assemblage Zone 2
31					Shelly, quartz bearing, phosphatic dolomite	Assemblage Zone 2
33					Shelly, quartz bearing, phosphatic dolomite	Assemblage Zone 2

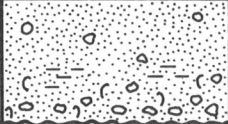
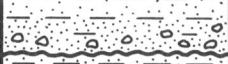
METERS	SAMPLE NO.	FORMATION	LITHOFACIES	SECTION (BTN-12)	LITHIC DESCRIPTION	FAUNAL ASSOCIATION
2	3	CR.			Fine to coarse, sandy clay to slightly muddy quartz sand	
4	4	YORKTOWN	UPPER		Light green, slightly muddy, shelly quartz sand	Cibicides lobatulus (30%) Elphidium limatum (10%)
5	5				Greyish green, calcareous, muddy quartz sand	
6	6		LOW.		Dark olive green, slightly muddy quartz sand with increasing phosphate downward	Caucasina gracilis (30%) Florilus pizzarensis (29%)
10		P.R.	A		Fine to medium, dolomitic, muddy phosphorite sand capped by phosphatic, quartz bearing dolomite	Assemblage Zone 1
12						

METERS	SAMPLE NO.	FORMATION	LITHOFACIES	SECTION (BTN-9)	LITHIC DESCRIPTION	FAUNAL ASSOCIATION
2	4	CRO.			Black to brown, medium, organic rich quartz sand	
4	5	YORKTOWN	UPPER		White, medium, glauconitic quartz sand with occasional thin clay lenses	
6					Dark to light green grey, slightly muddy quartz sand changing to sand with increasing carbonate matrix downward	Florilus pizzarensis (26%) Cibicides lobatulus (17%) Elphidium limatulum 16%)
8						Caucasina gracilis (48%)
10						Buliminella elegantissima (25%) Elphidium excavatum (10%)
12						
14		YORKTOWN	LOWER		Fine to medium, slightly muddy quartz sand with increasing phosphate content downward	
16						
18		P. R.	D D		Fine to medium, muddy, calcareous shell hash with minor quartz and phosphate	Assemblage Zone 2
20						
22						
24						
26						

METERS	SAMPLE NO.	FORMATION	LITHOFACIES	SECTION (PON-1)	LITHIC DESCRIPTION	FAUNAL ASSOCIATION
2	1	CRO.			Blue grey, slightly muddy shell hash and shell gravelly quartz sand	
4		YORKTOWN	UPPER		Medium, very clean quartz sand interbedded with thin clay lenses	Hanzawaia concentrica (47%)
6					Dark olive green, very tight, laminated mud	
8					Fine to coarse, poorly sorted, muddy quartz sand	
10					Diatomaceous, laminated mud	
12					Diatomaceous, sandy mud	
14					Medium to coarse, phosphatic, slightly muddy quartz sand	
16	7	YORKTOWN	LOW.		Medium to coarse, phosphatic, slightly muddy quartz sand	
18					Fine to medium, muddy, phosphorite sands interbedded with phosphatic, quartz bearing limestones	Assemblage Zone 2
20		P. R.	C		Fine to medium, muddy, phosphorite sands interbedded with phosphatic, quartz bearing limestones	Assemblage Zone 2
22						

METERS	SAMPLE NO.	FORMATION	LITHOFACIES	SECTION (PON-4)	LITHIC DESCRIPTION	FAUNAL ASSOCIATION
2	2	CRO.			Blueish, shell gravelly quartz sand	
2	3	YORKTOWN	UPPER		Fine to medium, slightly gravelly quartz sand	Bolivina lowmani (24%) Bolivina paula (13%)
4					Dark grey horizontal interaminations of muddy quartz sands and clean quartz sands	
6					Dark greenish grey, massive, poorly sorted, muddy quartz sand	
8					Medium to coarse, very clean quartz sand	
10	4				Blue grey, medium, slightly muddy quartz sand	
12					Moderately muddy quartz sand with some echinoid material	
14	5					
16	6					
18						
20						
22	7					
24		YORKTOWN	LOWER		Medium to coarse, phosphatic, slightly muddy quartz sand	
26					Dark olive green, medium to coarse, glauconitic, moderately muddy quartz sand	
28						
30						
32	8	R. R.	D		Shelly, quartz bearing, phosphatic dolomite	Assemblage Zone 2
34	8					
36	9					
38						
40	10					
42	11					
44	12					
46						
48						

METERS	SAMPLE NO.	FORMATION	LITHOFACIES	SECTION (CNN-1)	LITHIC DESCRIPTION	FAUNAL ASSOCIATION
2	2	WAC.			Semi-indurated, slightly muddy, shell gravelly quartz sand	
4	3	DUPLIN			Dark olive green, muddy quartz sand interbedded with clean quartz sand lenses	Cassidulina laevigata (46%) Uvigerina calvertensis (12%)
6					Medium, moderately muddy quartz sand with occasional quartz granules	
8					Sandy mud to 100% mud with irregular to mottled bedding	
10					Fine, phosphatic, moderately muddy quartz sand	
12	5					
14	6					
16						
18						
20		P. R.	C C		Shelly, calcareous mud to medium, calcareous, muddy quartz sand	Assemblage Zone 3

METERS	SAMPLE NO.	FORMATION	LITHOFACIES	SECTION (CTN-1)	LITHIC DESCRIPTION	FAUNAL ASSOCIATION
8	5	WAC.			Blue grey, shell gravelly quartz sand	
10		DUPLIN			Medium, slightly muddy quartz sand with occasional quartz granules	
12					Olive green, slightly sandy, silty clay	Bolivina paula (21%)
14					Light olive green, moderately muddy, phosphatic quartz sand	Cancris sagra (33%) Caucasina gracilis (12%)
16	8					
18	20	P. R.	CC		Shelly, calcareous mud to medium, calcareous, muddy quartz sand	Assemblage Zone 2
20						

APPENDIX II. Species range charts of benthic foraminifera in the Pungo River Formation
(✓ indicates a non-statistical occurrence).

SAMPLE NUMBERS SPECIES	NCPC-6	NCPC-7	NCPC-8	NCPC-9	NCPC-10	NCPC-11	NCPC-12	NCPC-13	NCPC-14	NCPC-18	NCPC-19	NCPC-24	CTN-1-9	CTN-1-10	CTN-1-11	CTN-1-12	CTN-1-14	PON-4-13	PON-4-14	PON-4-16	PON-4-17	PON-4-18	PON-4-19	PON-4-20	BTN-9-11	BTN-9-12	BTN-9-13	BTN-9-14	BTN-9-15	BTN-9-16	BTN-9-17	BTN-9-18	PON-1-8	PON-1-9	PON-1-10	CNN-1-7	CNN-1-8	CNN-1-9	CNN-1-10				
Ammonia beccarii										<1	✓											<1														<1							
Amphicoryna sp.																																					2	<1	✓	<1			
Bolivina calvertensis	<1										<1					<1					<1	<1	<1											<1									
Bolivina lowmani	1				1	2	✓		<1		<1	✓		<1		3	23					<1	1		11	5		3					✓	✓	1	2	3				6		
Bolivina marginata	<1	1		<1	<1			✓	✓				1		4		<1			1		<1				4	<1																
Bolivina marginata multicostata	2							<1											1																								
Bolivina paula	<1				<1	<1	<1	2	✓	✓	1		3			3			15	6			<1	3	2	12	17	7	11		✓		✓		✓	1	4	3				8	
Bolivina pseudoplicata										<1				<1					1									<1	<1												<1		
Bolivina pungoensis						<1			✓							1		<1																									
Bolivina subexcavata				<1			<1	<1	✓	✓	<1								<1											<1													
Bolivinopsis fairhavenensis							<1									<1							<1	3	1	<1	2	<1				✓											
Brizalina striatula																																											
Buccella frigida				<1								<1	✓																														
Buccella inusitata				<1			<1		✓	4	✓	2																						✓									

SAMPLE NUMBERS SPECIES																																											
	NPC-6	NPC-7	NPC-8	NPC-9	NPC-10	NPC-11	NPC-12	NPC-13	NPC-14	NPC-18	NPC-19	NPC-24	CTN-1-9	CTN-1-10	CTN-1-11	CTN-1-12	CTN-1-14	PON-4-13	PON-4-14	PON-4-16	PON-4-17	PON-4-18	PON-4-19	PON-4-20	BTN-9-11	BTN-9-12	BTN-9-13	BTN-9-14	BTN-9-15	BTN-9-16	BTN-9-17	BTN-9-18	PON-1-8	PON-1-9	PON-1-10	CNN-1-7	CNN-1-8	CNN-1-9	CNN-1-10				
Buccella mansfieldi													2																					✓									
Buccella viksburgensis													<1																				✓										
Buccella sp.												✓							<1																								
Bulimina marginata				<1																								<1										<1	<1				
Buliminella aff. B. bassendorffensis						<1	2						<1						1				<1	1		<1	3	1	✓								<1	<1					
Buliminella brevior																										<1	1																
Buliminella elegantissima						3	1	4	✓	✓	3	✓	1			1		3	37	✓	80	65	14	90	3	6	7	11		✓		✓	✓	✓	✓	53	2	1	✓	3			
Cancris cf. C. danvillensis											1		<1		3	<1	✓																			<1							
Cancris sagra													4		2	2	✓										<1											4	5	✓	4		
Cassidulina caribea	<1			<1	<1	✓	✓	1					<1		<1			<1										<1					✓				<1	3					
Cassidulina laevigata						<1		✓	2				✓																					✓			16	25	✓	32			
Cassidulina neocarinata										<1																		<1															
Cassidulina norcrossi australis						<1					<1																																
Cassidulinoides bradyi				<1															<1																								

SAMPLE NUMBERS SPECIES																																								
	NCPC-6	NCPC-7	NCPC-8	NCPC-9	NCPC-10	NCPC-11	NCPC-12	NCPC-13	NCPC-14	NCPC-18	NCPC-19	NCPC-24	CTN-1-9	CTN-1-10	CTN-1-11	CTN-1-12	CTN-1-14	PON-4-13	PON-4-14	PON-4-16	PON-4-17	PON-4-18	PON-4-19	PON-4-20	BTN-9-11	BTN-9-12	BTN-9-13	BTN-9-14	BTN-9-15	BTN-9-16	BTN-9-17	BTN-9-18	PON-1-8	PON-1-9	PON-1-10	CNN-1-7	CNN-1-8	CNN-1-9	CNN-1-10	
Globulina inaequalis															2	<1																					<1			
Guttulina cf. G. lactea										✓	<1		<1		3	3	✓	1					<1										✓		<1	<1				
Guttulina problema											<1				<1	1																				<1	1	✓	<1	
Gyroidina soldanii																																				<1	<1	<1		
Gyroidinoides cf. G. limbata																																	✓							
Gyroidinoides spp.												✓																												
Hanzawaia concentrica	20	67	27	24	29	3	56	✓	✓	1			16	7	6	✓	12	<1					<1		6	7	6	8	✓			✓	✓	6		<1			1	
Hanzawaia nipponica													26	<1	<1			1								<1	5	10	20	✓			✓		2	9	4	✓	5	
Hopkinsina bononiensis															2														<1											
Lagena acuticosta				<1	<1		<1		✓						<1																									
Lagena globulohispida					<1											<1																								
Lagena intermedia				<1						<1	✓			<1	<1						<1		<1													<1	<1			
Lagena laevis				<1			<1		✓	✓	3																													
Lagena palmerae											<1																						✓			2			<1	

SAMPLE NUMBERS SPECIES																																											
	NCPC-6	NCPC-7	NCPC-8	NCPC-9	NCPC-10	NCPC-11	NCPC-12	NCPC-13	NCPC-14	NCPC-18	NCPC-19	NCPC-24	CTN-1-9	CTN-1-10	CTN-1-11	CTN-1-12	CTN-1-14	PON-4-13	PON-4-14	PON-4-16	PON-4-17	PON-4-18	PON-4-19	PON-4-20	BTN-9-11	BTN-9-12	BTN-9-13	BTN-9-14	BTN-9-15	BTN-9-16	BTN-9-17	BTN-9-18	PON-1-8	PON-1-9	PON-1-10	CNN-1-7	CNN-1-8	CNN-1-9	CNN-1-10				
Lagena pseudosulcata														<1	<1																												
Lagena striaticollis										✓																																	
Lagena substriata																																										4	
Lagena tenuis																																									<1		
Lagena cf. L. torsicostata																															✓												
Marginulina sp.															<1	<1																											
Nodosaria catesbyi											<1																												2	1	<1		
Nonion advenum pustulosum											<1										<1																						
Nonion cf. N. calvertensis												✓									<1																						
Nonion marylandicum								<1		4	✓	✓	✓				✓	<1	✓									<1						✓									
Nonion sp. "A"														<1				<1																				<1					
Nonion sp. "B"																																								<1	✓		
Nonionella miocenica				2	8	11	40	10		✓	9		1	3	5	✓	4	<1		1	4	<1	<1	25	14	<1		✓	✓		✓	✓	2	7	11	✓	4						
Nonionella sp.																				<1	10		2																				

SAMPLE NUMBERS	SPECIES	NCPG-6	NCPG-7	NCPG-8	NCPG-9	NCPG-10	NCPG-11	NCPG-12	NCPG-13	NCPG-14	NCPG-18	NCPG-19	NCPG-24	CTN-1-9	CTN-1-10	CTN-1-11	CTN-1-12	CTN-1-14	PON-4-13	PON-4-14	PON-4-16	PON-4-17	PON-4-18	PON-4-19	PON-4-20	BTN-9-11	BTN-9-12	BTN-9-13	BTN-9-14	BTN-9-15	BTN-9-16	BTN-9-17	BTN-9-18	PON-1-8	PON-1-9	PON-1-10	CNN-1-7	CNN-1-8	CNN-1-9	CNN-1-10								
	Oolina melo										2	✓					<1																															
	Parafissurina cf. P. bidens							<1			✓						<1	✓																														
	Parafissurina sp.											<1																																				
	Polymorphina nuda																					<1																										
	Reussella glabrata									✓																																						
	Reussella miocenica					<1																																										
	Rosalina cf. R. cavernata	4												<1					2	<1				<1				<1	<1	✓								<1										
	Rosalina floridana						<1		✓	3	✓						✓	<1																	✓						✓							
	Rosalina globularis				<1	<1			✓	4	✓						<1			<1				<1											✓								<1					
	Rotorbinella bassleri	<1			<1				✓	✓	<1						<1		2	<1	<1		1		3	1	1	<1																1				
	Saracenaria cf. S. acutauricularis															<1	<1																															
	Saracenaria sp.													<1																																		
	Sigmomorphina semitecta															<1	✓																															
	Siphogenerina lamellata																4																															

SAMPLE NUMBERS SPECIES																																										
	CNN-1-10	CNN-1-9	CNN-1-8	CNN-1-7	PON-1-10	PON-1-9	PON-1-8	BTN-9-18	BTN-9-17	BTN-9-16	BTN-9-15	BTN-9-14	BTN-9-13	BTN-9-12	BTN-9-11	PON-4-20	PON-4-19	PON-4-18	PON-4-17	PON-4-16	PON-4-14	PON-4-13	CTN-1-14	CTN-1-12	CTN-1-11	CTN-1-10	CTN-1-9	NPC-24	NPC-19	NPC-18	NPC-14	NPC-13	NPC-12	NPC-11	NPC-10	NPC-9	NPC-8	NPC-7	NPC-6			
Valvulineria aff. V. bolivarensis													<1									<1		1	<1																	
Valvulineria floridana					<1		✓					4	<1	7	5	<1							4	✓	3	<1	13	12		<1		✓	3	<1	5	20	9					
Valvulineria olssoni					<1	✓						<1	2	9	9							<1	4	✓	3	8	14	14		4	✓											
Ventrostoma fovigera																														<1												
Virgulinella miocenica					1							<1	<1	<1	2	<1							<1	✓							✓	3	28	11	4	<1						
																													</													

APPENDIX II. Species range charts of benthic foraminifera in the Yorktown and Duplin Formations
(✓ indicates a non-statistical occurrence).

SPECIES	SAMPLE NUMBERS																
	BTN-12-6	BTN-12-5	GNM-1-6	PON-1-7	PON-1-4	BTN-9-10	BTN-9-9	BTN-9-8	BTN-9-7	BTN-9-6	PON-4-11	PON-4-10	PON-4-7	CTN-1-8	CTN-1-7	CTN-1-5	NCPC-3
<i>Ammonia beccarii</i>	<1							<1								<1	
<i>Amphicoryna</i> sp.														1			<1
<i>Anomalinoidea</i> sp.																	
<i>Astrononion stelligerum</i>																	
<i>Baggina</i> sp.																	
<i>Bolivina barbata</i>																	
<i>Bolivina</i> cf. <i>B. donezei</i>																	
<i>Bolivina lowmani</i>																	
<i>Bolivina marginata</i>																	
<i>Bolivina paula</i>																	
<i>Bolivina pseudoplicata</i>																	
<i>Bolivina subexcavata</i>																	
<i>Bolivina</i> spp.																	
<i>Buccella frigida</i>																	

SAMPLE NUMBERS	SPECIES																														
		BTN-15-7	BTN-15-8	BTN-15-9	BTN-15-10	BTN-15-11	BTN-15-12	BTN-15-13	NCPC-1	NCPC-2	NCPC-3	CIN-1-5	CIN-1-7	CIN-1-8	PON-4-7	PON-4-10	PON-4-11	BTN-9-6	BTN-9-7	BTN-9-8	BTN-9-9	BTN-9-10	PON-1-4	PON-1-7	CNN-1-6	BTN-12-5	BTN-12-6				
	Buccella inusitata	1	2	<1	<1	4	2	3	1	2	✓	2		1	2			<1	4	<1			3			9	4				
	Buccella mansfieldi	2		<1	1		<1	<1				<1	<1	<1								1									
	Buccella vicksburgensis	1	2	<1	<1	4		<1		2		<1	<1	<1	3								<1			2	<1				
	Bulimina marginata						<1																		<1	<1	<1				
	Bulimina cf. B. ovula																	<1													
	Buliminella aff. B. bassendorffensis							<1				3	5						1												
	Buliminella elegantissima	1				<1	<1	<1	<1	12	✓	1	4		6		✓	1	<1	25			8			1					
	Cancris cf. C. danvillensis				<1		2						3	1											<1						
	Cancris sagra	<1		<1	2	<1	17	5					3	33												7	1	1			
	Cassidulina caribea	1	2			9	2		3	1		<1			2			1	<1	3							1	<1			
	Cassidulina laevigata				<1		<1		4	2	✓				1			<1	6	<1		✓				46		1			
	Cassidulina neocarinata								1	<1	✓				<1			<1	8	<1								<1			
	Cassidulina norcrossi australis		<1									<1	1																		
	Caucasina gracilis									5	✓		5	12	2				1	48	4	✓		<1		5		30			

SAMPLE NUMBERS SPECIES	BTN-12-6	BTN-12-5	CNN-1-6	PON-1-7	PON-1-4	BTN-9-10	BTN-9-9	BTN-9-8	BTN-9-7	BTN-9-6	PON-4-11	PON-4-10	PON-4-7	CIN-1-8	CIN-1-7	CIN-1-5	NCPG-3	NCPG-2	NCPG-1	BTN-15-13	BTN-15-12	BTN-15-11	BTN-15-10	BTN-15-9	BTN-15-8	BTN-15-7
Caucasina preacanthia	1				<1			<1	2	<1			<1		2		1✓			<1						
Ceratobulimina sp.																								<1	<1	
Cibicides floridanus	<1																		<1							
Cibicides lobatulus	2	3	50	1				5		17			2✓	<1	1	8	1✓	11	11	11	15	3	40	18	6	6
Criboelphidium poeyanum																									<1	
Discorbis cf. D. farishi																				<1						
Discorbis sp.															2									<1		
Elphidium compressulum																					<1	2	3			
Elphidium discoidale				1											3						<1	<1				
Elphidium excavatum				7				10	<1	1	2✓	2	4	2	13	5✓				28	4	19	23	36	32	38
Elphidium gunteri															<1											
Elphidium incertum (Williamson)				5				<1						1	<1								<1			
Elphidium limatum	10			8				<1	2	16				1	2	2		<1					<1	3	3	
Epistominella danvillensis								2		<1			2		1	3	✓	<1	3		4			1		

SAMPLE NUMBERS	SPECIES	BTN-12-6	BTN-12-5	CNN-1-6	PON-1-7	PON-1-4	BTN-9-10	BTN-9-9	BTN-9-8	BTN-9-7	BTN-9-6	PON-4-11	PON-4-10	PON-4-7	CTN-1-8	CTN-1-7	CTN-1-5	NCPG-3	NCPG-2	NCPG-1	BTN-15-13	BTN-15-12	BTN-15-11	BTN-15-10	BTN-15-9	BTN-15-8	BTN-15-7
	Eponides repandus																1										
	Eponides tumidulus																						<1				
	Eponides sp.																1										
	Fissurina aequilabialis								<1	<1															<1		
	Fissurina cf. F. laevigata									<1	<1					1	4				<1	<1			<1		
	Fissurina lucida																	1	1			<1	<1				
	Fissurina marginato-perforata																					<1					
	Fissurina cf. F. pseudoglobosa																1	<1	<1	5					<1		
	Fissurina quadrata																	<1			1						
	Fissurina spp.																1	3	<1	<1	1		<1				
	Florilus chesapeakeensis								1																<1	<1	
	Florilus grateloupi									1																<1	
	Florilus pauperatum																2	<1	<1				<1				
	Florilus pizzarensis	<1					<1							<1							3	17	✓				

SAMPLE NUMBERS SPECIES	SPECIES																									
	BTN-12-6	BTN-12-5	CNN-1-6	PON-1-7	PON-1-4	BTN-9-10	BTN-9-9	BTN-9-8	BTN-9-7	BTN-9-6	PON-4-11	PON-4-10	PON-4-7	CTN-1-8	CTN-1-7	CTN-1-5	NCPC-3	NCPC-2	NCPC-1	BTN-15-13	BTN-15-12	BTN-15-11	BTN-15-10	BTN-15-9	BTN-15-8	BTN-15-7
Fursenkoina fusiformis	<1	<1	<1				<1	3	<1				<1	2			✓	13			<1	<1			1	<1
Fursenkoina pontoni																	✓									<1
Fursenkoina punctata			<1													<1		<1		<1						
Globocassidulina crassa		<1						2		1			2		1	6	✓	<1		6	5	3	14		4	2
Globulina gibba																<1										
Globulina inaequalis		<1								<1								1								<1
Guttulina cf. G. lactea		<1						3	<1	1			<1	1	<1			<1			1	<1		1		
Guttulina problema					<1	✓							<1													<1
Guttulina rectiomata		4								<1						<1										
Gyroidina soldanii															<1											
Gyroidinoides cf. G. limbata											✓															
Gyroidinoides regularis																<1										
Gyroidinoides spp.													<1						3							
Hanzawaia concentrica	8	4	1	✓	7			<1	1			✓	2	1	3					2	2	1	<1	14	24	3

SPECIES	SAMPLE NUMBERS														
	BTN-12-6	BTN-12-5	CNN-1-6	PON-1-7	PON-1-4	BTN-9-10	BTN-9-9	BTN-9-8	BTN-9-7	BTN-9-6	PON-4-11	PON-4-10	PON-4-7	CIN-1-8	CIN-1-7
<i>Hanzawaia nipponica</i>			9				1							<1	6
<i>Lagena acuticosta</i>									<1						✓
<i>Lagena</i> aff. <i>L. clavata</i>									<1	<1					
<i>Lagena intermedia</i>					1									<1	<1
<i>Lagena laevis</i>									1	1	<1		<1	1	✓
<i>Lagena palmerae</i>					1			<1		2				<1	1
<i>Lagena pseudosulcata</i>									<1						<1
<i>Lagena substriata</i>													<1	1	1
<i>Lagena sulcata</i>														1	
<i>Lagena tenuis</i>									<1						
<i>Lagena</i> sp.															
<i>Laryngosigma williamsoni</i>										<1	<1			<1	2
<i>Lenticulina americana</i>											✓	<1			
<i>Lenticulina</i> cf. <i>L. occidentalis</i>														1	1

SPECIES	SAMPLE NUMBERS																									
	BTN-12-6	BTN-12-5	GMN-1-6	PON-1-7	PON-1-4	BTN-9-10	BTN-9-9	BTN-9-8	BTN-9-7	BTN-9-6	PON-4-11	PON-4-10	PON-4-7	CTN-1-8	CTN-1-7	CTN-1-5	NCPG-3	NCPG-2	NCPG-1	BTN-15-13	BTN-15-12	BTN-15-11	BTN-15-10	BTN-15-9	BTN-15-8	BTN-15-7
Lenticulina sp.			<1																							
Marginulina sp.		<1	<1											<1												
Neoconorbina terquemi														<1												
Nodosaria catesbyi														<1	<1											
Nonion cf. N. granosum					<1																					
Nonion sp. "A"							<1								10	1					2	3	<1			
Nonion sp. "B"										2					<1	<1				<1						
Nonionella miocenica			4							3	4				3	9	8	✓	15	11	5	3	9	<1	2	1
Oolina melo																				<1	1	<1				
Oolina sp.																			1							
Parafissurina cf. P. bidens							<1						<1							<1	2	<1			<1	
Parafissurina sp.							<1	<1																		
Planulina ariminensis														1												
Polymorphinidae "forma fistulosae"							<1																			

SAMPLE NUMBERS	SPECIES	BTN-12-6	BTN-12-5	CNN-1-6	PON-1-7	PON-1-4	BTN-9-10	BTN-9-9	BTN-9-8	BTN-9-7	BTN-9-6	PON-4-11	PON-4-10	PON-4-7	CTN-1-8	CTN-1-7	CTN-1-5	NCP C-3	NCP C-2	NCP C-1	BTN-15-13	BTN-15-12	BTN-15-11	BTN-15-10	BTN-15-9	BTN-15-8	BTN-15-7
	Pyrulina albatrossi				<1																						
	Quinqueloculina lamarckiana											✓				<1									<1	2	<1
	Quinqueloculina seminula															<1					1			4	3	7	4
	Quinqueloculina seminul angulata															<1											
	Quinqueloculina sp.																									<1	<1
	Ramulina sp.													<1													
	Rosalina candeiana																				<1	<1	<1				
	Rosalina concinna																<1		3								
	Rosalina floridana												1	✓			3			<1	1	9	8	3	1	2	4
	Rosalina globularis												1	✓			3		1		2	4	2	6	3		<1
	Rosalina cf. R. nitida														<1												
	Rosalina subaraucana																		<1								
	"Rotalia" translucens																										
	Rotorbinella bassleri																										

SPECIES	SAMPLE NUMBERS														
	BTN-12-6	BTN-12-5	CNN-1-6	PON-1-7	PON-1-4	BTN-9-10	BTN-9-9	BTN-9-8	BTN-9-7	BTN-9-6	PON-4-11	PON-4-10	PON-4-7	CIN-1-8	CIN-1-7
<i>Sigmomorphina nevirera</i>				<1											
<i>Sigmomorphina semitecta</i>		1												<1	
<i>Textularia agglutinans</i>		4	1							<1	2		2		<1
<i>Textularia articulata</i>		3	2						1	3		✓	<1	<1	<1
<i>Textularia candeiana</i>		<1							<1	<1			<1		
<i>Textularia conica</i>		2	<1						1	<1				1	
<i>Textularia cf. T. obliqua</i>		<1													
<i>Textularia mayori</i>															
<i>Textularia spp.</i>		<1	1												
<i>Trifarina bradyi</i>															
<i>Trifarina occidentalis</i>															
<i>Triloculina trigonula</i>		<1													
<i>Uvigerina calvertensis</i>															
<i>Uvigerina hispida</i>															

SPECIES	SAMPLE NUMBERS																											
	BTN-15-7	BTN-15-8	BTN-15-9	BTN-15-10	BTN-15-11	BTN-15-12	BTN-15-13	NCPC-1	NCPC-2	NCPC-3	CTN-1-5	CTN-1-7	CTN-1-8	PON-4-7	PON-4-10	PON-4-11	BTN-9-6	BTN-9-7	BTN-9-8	BTN-9-9	BTN-9-10	PON-1-4	PON-1-7	CNN-1-6	BTN-12-5	BTN-12-6		
Uvigerina juncea						2																						
Uvigerina modeloensis						1	<1		1																			
Uvigerina subperigrina	<1			<1	1	11	6	<1	1	✓	<1	<1		<1											<1	1	5	
Valvulineria aff. V. allomorphinoides						<1																				<1		
Valvulineria floridana						3	<1					3	8	<1												1		
Valvulineria olssoni					<1	<1					<1	1	6													1		
Ventrostoma fovigera					<1																							
Webbinella concava	<1																											