ESTUARINE FORAMINIFERAL ASSOCIATIONS OF THE BEAUFORT AREA, NORTH CAROLINA

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I. ABSTRACT

An inventory of foraminifera in the Beaufort area shows that patterns of distribution are similar to those of other estuarine environments. The known geographic ranges of several species reported previously from Trinidad and the northern Gulf of Mexico are extended northward to the Beaufort area. Living foraminifera were found at low tide in an intertidal marsh among the roots of *Spartina alterniflora* in moist mud of the upper few centimeters down to 35–40 centimeters below the marsh surface. A new species of *Miliammina* is described from the surface sediments of this marsh.

II. INTRODUCTION

A. *The Area*

The study area extends from the continental shelf into Beaufort Inlet, up Core Creek to Adams Creek, and into the Neuse River. The Newport River between Core Creek and Newport, North Carolina, is included in order that faunal changes along a complete salinity gradient may be observed. General types of environments sampled include the inner sublittoral zone of the continental shelf, *Spartina* marshes, mud flats, sand flats, the littoral zone of sand beaches, and fluvial-marine channels. Collecting stations are shown in Figure 1. General en-

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vironmental conditions and seasonal fluctuations of temperature and salinity are described for the Beaufort area by Pearse *et al.* (1942) and Stephenson and Stephenson (1952).

B. *The Problem*

Objectives were threefold: first, to investigate the pattern of foraminiferal associations in the subject area; second, to inventory the species as to living and post-mortem components of the assemblages; and third, to determine whether foraminifera live at depths below the sediment surface in intertidal estuarine environments comparable to depths reported for sublittoral areas.

C. *Previous Work*

The living foraminiferal meiofauna of the intertidal zone has been long neglected except for certain perennially subaqueous environments such as swamps, stream channels, and tidal pools, the general assumption among foraminiferalogists being that uninterrupted submergence is necessary for survival. Boltovskoy (1966) has already reviewed the meager literature on survival at various depths in sediments from subtidal areas, and in his own research he has found 16 centimeters to be the maximum depth at which specimens containing protoplasm occurred below the sediment surface at three localities in Chile. The number of species and individuals was observed to increase with decrease in depth, and this vertical penetration was thought to be related to aeration, although Boltovskoy emphasized that oxygen requirements might actually be less than generally believed.

Little previous work has been done on foraminifera in the Beaufort area. Hadley (1936) listed 23 species from a beach locality and two dredgings in the neritic zone near Beaufort. His investigation was not of an ecologic nature, and protoplasm tests were not conducted. *Asterigerina* and *Quinqueloculina* were reported from sand beaches at Beaufort (Pearse *et al.,* 1942), but no distinction was made as to whether specimens were living or dead. It is not unlikely that the tests were reworked from nearby formations of Yorktown or Waccamaw age. (Fossil *Amphistegina lessonii* was found by the present writer in supralittoral sands on Bogue Banks, near Morehead City, North Carolina.) Miller (1953) listed 42 species from nine stations in Mason Inlet, North Carolina, most of which were sublittoral. Tests for the presence of protoplasm were not conducted, and salinity was estimated by taste. Substratum conditions were concluded to control the distribution of foraminifera within the inlet. Farther removed from the study area, Nichols and Ellison (1967) subdivided the Rappahannock Estuary, northeastern Virginia, into three microfaunal biofacies: river, shoal, and basin. They evaluated the ratio method (living specimens to total tests) of estimating relative rates of sedimentation.

D. *Procedure*

Approximately 80 cubic centimeters of material was collected at the sediment surface from each station. Additional samples were taken below the sediment surface at selected stations by either manual insertion of a plastic core-liner that was marked off vertically in centimeters (inside diameter, 5.7 centimeters) or by excavation by means of a spade with direct measurement of the depth. Channel and continental shelf samplings were recovered by dredge and grab devices on board the "Beveridge", 55-foot trawler of Duke University Marine Laboratory. Water depth was recorded by fathometer; temperature, by reversing thermometer; and salinity, by hydrometer. Other environmental factors noted are recorded in the station descriptions to follow. Samples were prepared with hexamethyleneamine buffered formaldehyde and, prior to examination, immersed in a solution of Rose Bengal to stain the protoplasm of specimens alive at the time of sampling, as recommended by Walton (1952). Each sample was wet-sieved on a U. S. Standard Sieve Series no. 180 screen (openings of 83 microns), dried, and examined for the microfauna. Both stained and unstained foraminifera were transferred from the residues to slides for identification. Relative numbers of species and individuals were estimated during observation of the assemblages, and this method was regarded to be as significant and accurate for the purposes of the present survey as sophisticated statistical calculations, such as "foraminiferal numbers" or counts derived by aliquot splits for a cubic centimeter of sediment. In this report, "rare" is

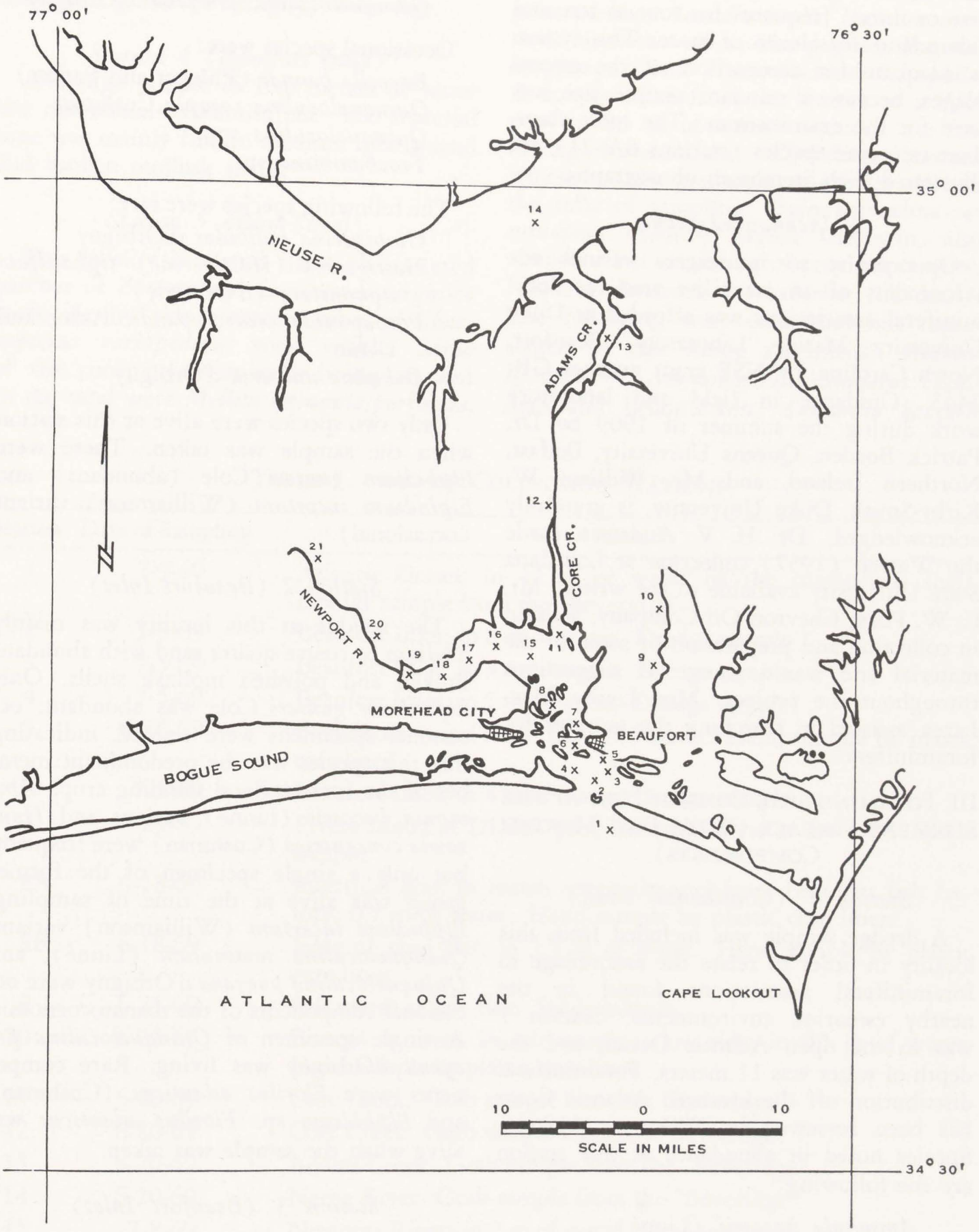

FIGURE 1. COLLECTING STATIONS, BEAUFORT AREA, NORTH CAROLINA

FROM U. S. DEPT. OF COMMERCE COAST AND GEODETIC SURVEY, CAPE HATTERAS TO CHARLESTON, C. AND G. S. 1110. SCALE: 1:432,720 AT LAT. 34 DEGREES.

used for a single individual, "occasional" for two or three, "frequent" for four to ten, and "abundant" for eleven or more. This system is adequate for comparison of the assemblages, because a standard sample size was used for the examinations. The most abundant estuarine species (stations 8A–21) are illustrated with Stereoscan photographs.

E. *Acknowledgments*

Opportunity to investigate various environments of an estuarine area for foraminiferal associations was afforded at Duke University Marine Laboratory, Beaufort, North Carolina, by NSF grant number GB-7443. Guidance in field and laboratory work during the summer of 1969 by Dr. Patrick Boaden, Queens University, Belfast, Northern Ireland, and Mr. William W. Kirby-Smith, Duke University, is gratefully acknowledged. Dr. H. V. Andersen made the Warren (1957) collection at Louisiana State University available to the writer. Mr. C. W. Poag, Chevron Oil Company, assisted in collection and preparation of some of the material and was a source of suggestions throughout the project. Mrs. Louisa MacLaren assisted in searching the samples for foraminifera.

III. Foraminiferal Communities at the Sediment Surface (With Post-Mortem Components)

Station 1 (Continental Shelf)

A dredge sample was included from this locality in order to relate the assemblage to foraminiferal associations found in the nearby estuarine environments. Station 1 was in the open Atlantic Ocean, and the depth of water was 11 meters. Foraminiferal distribution off the southern Atlantic Coast has been reviewed by Wilcoxon (1964). Species noted in abundance at this station are the following:

Ammonia beccarii (Linné)
Elphidium gunteri Cole
Hanzawia concentrica (Cushman)
Quinqueloculina seminulum (Linné)

The following species were frequent:

Cibicides pseudoungerianus (Cushman)
Elphidium incertum (Williamson) variant
Florilus atlanticus (Cushman)
Globigerinoides ruber (d'Orbigny)
Quinqueloculina poeyana d'Orbigny

Occasional species were:

Buccella hannai (Phleger and Parker)
Quinqueloculina compta Cushman
Quinqueloculina spp.
Trochammina sp.

The following species were rare:

Globigerina bulloides d'Orbigny
Hastigerina (Hastigerina) siphonifera siphonifera (d'Orbigny)
Poroeponides cribrorepandus Asano and Uchio
Orbulina universa d'Orbigny

Only two species were alive at this station when the sample was taken. These were *Elphidium gunteri* Cole (abundant) and *Elphidium incertum* (Williamson) variant (occasional).

Station 2 (Beaufort Inlet)

The residue at this locality was mainly medium to coarse quartz sand with abundant broken and polished mollusk shells. Only *Elphidium gunteri* Cole was abundant; occasional specimens were stained, indicating that this species was the predominant member of the foraminiferal standing crop. *Ammonia beccarii* (Linné) variant and *Hanzawia concentrica* (Cushman) were frequent, but only a single specimen of the former group was alive at the time of sampling. *Elphidium incertum* (Williamson) variant, *Quinqueloculina seminulum* (Linné), and *Quinqueloculina poeyana* d'Orbigny were occasional components of the thanatocoenoesis. A single specimen of *Quinqueloculina poeyana* d'Orbigny was living. Rare components were *Florilus atlanticus* (Cushman) and *Elphidium* sp. *Florilus atlanticus* was alive when the sample was taken.

Station 3 (Beaufort Inlet)

The sediments here consisted of medium to coarse quartz sand and polished fragments of mollusks. A small foraminiferal assemblage was present of which only specimens of *Elphidium gunteri* were living. Empty tests of this species were abundant, however. Occasional empty tests of *Hanzawaia concentrica, Quinqueloculina poeyana,* and *Quinqueloculina seminulum* were found; *Am-*

monia beccarii variant and *Globulina* cf. *Globulina gibba* (d'Orbigny) were rare.

Station 4 (Beaufort Inlet)

A dredge sample in five meters of water did not contain foraminifera. The material here was mainly fine to medium quartz sand and broken mollusk shells.

Station 5 (Bird Shoal)

This locality is a sand flat with scattered patches of *Zostera* and *Crassostrea virginica* reefs. At low tide numerous tubes of *Chaetopterus variopedatus* were visible. Some of the conspicuous animals living on and in the sand were *Mellita quinquiesperforata, Dosinia discus, Aequipecten irradians, Tagelus plebius, Anadara ovalis, Busycon caricum, Nassarius vibex, Uca pugnax, Pagurus longicarpus,* and *Hymeniacidon heliophila.* A sample taken from the bottom of a tidal pool in 0.5 m of water contained the following foraminifera: *Elphidium gunteri,* which was the predominant species alive at the time of sampling; *Quinqueloculina seminulum* (Linné) *jugosa* Cushman, also abundant but consisting of only empty tests; frequent *Hanzawaia concentrica* (all dead). The following were occasional but represented by rare living specimens: *Ammobaculites* cf. *Ammobaculites dilatatus* Cushman and Bronnimann, *Ammonia beccarii*

TABLE 1. LOG OF COLLECTING STATIONS

Station	Date of Sampling	Remarks
1	7-9-69	Atlantic Ocean; in 11 m of water on the continental shelf. Dredge sample from the "Beveridge"
2	7-5-69	Beaufort Inlet; in 8 m of water. Dredge sample
3	7-5-69	Beaufort Inlet; in 4 m of water. Dredge sample
4	7-5-69	Beaufort Inlet; in 5 m of water. Dredge sample
5	6-16-69	Bird Shoal (sand flat), 0.5 m of water. Hand sample by plastic core liner
6	7-5-69	Beaufort Inlet; in 4 m of water. Dredge sample
7	6-29-69	Pivers Island at DUML pier; intertidal zone at low tide. Spade sample.
8A	6-18-69	Intertidal pool in marsh across channel from Beaufort fish factory; 0.5 m of water. Hand sample by plastic core liner.
8B	6-18-69	Edge of sand flat; in 1.5 m of water. Hand sample by plastic core liner
9	6-25-69	Salt marsh at low tide. Spade sample
10	6-25-69	Bottom of creek in salt marsh at low tide; in 0.5 m of water. Hand sample by plastic core liner
11	6-20-69	Core Creek. Grab sample from the "Beveridge"
12	6-20-69	Core Creek. Grab sample from the "Beveridge"
13	6-20-69	Adams Creek. Grab sample from the "Beveridge"
14	6-20-69	Neuse River. Grab sample from the "Beveridge"
15	7-8-69	Newport River; in 2 m of water. Dredge sample
16	7-8-69	Newport River; in 1.5 m of water. Dredge sample
17	7-8-69	Newport River; in 2 m of water. Dredge sample
18	7-8-69	Newport River; in 1 m of water. Dredge sample
19	7-8-69	Newport River; in 1 m of water. Dredge sample
20	7-8-69	Newport River; in 1 m of water. Dredge sample
21	7-9-69	Newport River at Newport, North Carolina; in 1 m of water. Grab sample

variant, *Cibicides* cf. *Cibicides refulgens* Montfort, and *Elphidium incertum* variant. Occasional empty tests of *Globigerinoides ruber* (d'Orbigny) and *Globigerinoides conglobatus conglobatus* (Brady) (both small in size) were found. Only the rare, empty tests of the following were found: *Elphidium* sp., *Florilus atlanticus, Globigerinoides quadrilobatus sacculifer* (Brady), *Nodobacullariella* sp., and *Textularia* sp.

Station 6 (Beaufort Inlet)

Quartz sand and broken mollusk shells constituted the bulk of this sample, and the detrital origin of the sediment is further attested to by the occurrence of two worn specimens of *Siphogenerina lamellata* Cushman, which could only have been derived from Tertiary beds, since this species is extinct and belongs to a paleoecological position much farther oceanward than the turbulent inlet type of environment. *Elphidium gunteri* was abundant and the dominant living species here. *Ammobaculites* cf. *Ammobaculites dilatatus* and *Quinqueloculina seminulum* were represented by abundant empty tests, but living specimens were only frequent and occasional, respectively. *Ammotium salsum* (Cushman and Bronnimann) was frequent both in empty tests and in living specimens. Frequent empty tests but only occasional living individuals were found for *Ammonia beccarii* variant, *Elphidium incertum* variant, *Hanzawaia concentrica,* and *Psammosphaera fusca* Schulze. Frequent empty tests but no living specimens were recorded for *Buccella hannai* (Phleger and Parker). Occasional dead but only rare living representatives were found for *Cibicides* sp. cf. *Cibicides refulgens, Elphidium* sp., and *Globigerinoides ruber.* Occasional empty tests but no living individuals were seen for *Globigerinoides conglobatus conglobatus* and *Rosalina floridana* (Cushman). *Ammotium* sp. was represented by a single live specimen. Only rare, empty tests were found of *Florilus atlanticus, Globigerinoides quadrilobatus sacculifer, Hastigerina (Hastigerina) siphonifera siphonifera, Quinqueloculina seminulum jugosa,* and *Textularia* sp.

Station 7 (Pivers Island)

The upper two centimeters of sand from an area about four centimeters in diameter were removed from the intertidal zone at low tide near the Duke University Marine Laboratory pier, Pivers Island. *Uca pugilator* and *Nassarius obsoletus* were among the more conspicuous animals on the surface of this area. The sediment was mainly fine to medium quartz sand. Large empty tests of tropical and subtropical planktonic foraminiferal species were found among the living specimens, and it is suspected that bottom sediments from the continental slope or deeper oceanic regions may have been dumped at the pier after a voyage by the "Eastward" to a more southern region. Planktonic species noted were *Pulleniatina obliquiloculata obliquiloculata* (Parker and Jones), *Globorotalia (Globorotalia) menardii* (Parker, Jones and Brady), *Globigerinoides quadrilobatus sacculifer* (Brady), *Globigerinoides ruber* (d'Orbigny), *Globigerinoides conglobatus conglobatus* (Brady), *Globorotalia (Globorotalia) truncatulinoides* (d'Orbigny), and *Globoquadrina dutertrei* (d'Orbigny). The living population was dominated by *Elphidium gentri* and *Ammonia beccarii* variant (both abundant). *Ammotium salsum, Ammonia beccarii* variant and *Elphidium* sp. A were frequent but only occasional in living specimens. Only the empty tests of *Trochammina laevigata* were observed (frequent). Occasional empty tests were found of *Ammobaculites* cf. *Ammobaculites dilatatus, Buccella hannai,* and *Hanzawaia concentrica.* Of these, only the first was living at the time of sampling. Rare, dead specimens of *Florilus atlanticus* and *Quinqueloculina seminulum* were seen.

Station 8A (Intertidal Pool)

An intertidal pool in a *Spartina* marsh with a bottom of silt, very fine quartz sand, and plant fibers yielded occasional living specimens of *Ammobaculites* cf. *Ammobaculites dilatatus* and *Ammotium salsum.* The former was frequent in a subsequent sampling. This is a rather low standing crop, and it is possible that these species may have been living in a higher frequency in the surrounding marsh among the densely matted roots of *Spartina.*

Station 8B (Sand Flat)

A sample from the edge (at low tide) of the above marsh in 1.5 m of water with a

higher percentage of fine to medium quartz sand was more productive, as shown below:

Species	Empty Tests	Live Specimens
Ammobaculites cf. *Ammobaculites dilatatus* Cushman and Bronnimann	occasional	occasional
Ammonia beccarii (Linné) variant	0	rare
Ammotium salsum (Cushman and Bronnimann)	frequent	occasional
Elphidium gunteri Cole	abundant	frequent
Hanzawaia concentrica (Cushman)	occasional	0
Psammosphaera fusca Schulze	occasional	0

Station 9 (Salt Marsh)

This locality, a *Spartina* marsh with abundant burrows of the fiddler crab, *Uca minax,* was sampled at low tide about 25 meters from standing water. Although the marsh surface at low tide easily bears the weight of a man, the ground never dries appreciably, the mud and matted roots of dense *Spartina alterniflora* retaining enough saline water to be soggy. The residue was dominantly fine to medium quartz sand with abundant plant fragments and foraminifera. Salinity at the surface becomes drastically reduced with heavy periodic rains. The diatom, *Coscinodiscus* sp. was abundant. The foraminiferal population is shown as follows:

Species	Empty Tests	Live Specimens
Ammonia beccarii (Linné) variant	0	abundant
Ammotium pseudocassis Cushman and Bronnimann	abundant	abundant
Arenoparrella mexicana (Kornfeld)	abundant	abundant
Haplophragmoides wilberti Anderson	abundant	abundant
Miliammina beaufortensis, n. sp.	abundant	abundant
Miliammina fusca (H. B. Brady)	abundant	abundant
Psammosphaera sp.	abundant	abundant
Siphotrochammina lobata Saunders	abundant	abundant
Sulcophax palustris Warren	frequent	0
Textularia palustris Warren	abundant	frequent
Tiphotrocha comprimata (Cushman and Bronnimann)	abundant	abundant
Trochamminita irregularis Cushman and Bronnimann	abundant	abundant
Trochammina laevigata Cushman and Bronnimann	abundant	abundant

Although rare in relation to total fauna, over 100 specimens of *Ammonia beccarii* variant were found (pl. 3, figs. 3–4). All of these were alive, and most were corroded, suggesting that acid conditions in marshes may dissolve the empty tests of calcareous forms, as postulated by Lankford (1959, p. 2077) and Parker and Athearn (1959, p. 338).

Station 10 (Stream in Salt Marsh)

A relatively poor fauna was recovered from the bottom of a flowing creek in another salt marsh. The water in this stream was 0.5 meters deep at low tide.

Species	Empty Tests	Live Specimens
Ammobaculites cf. *Ammobaculites dilatatus*	occasional	0
Arenoparrella mexicana	occasional	0
Miliammina fusca	occasional	0
Tiphotrocha comprimata	frequent	occasional
Trochammina laevigata	frequent	rare

Stations 11 to 14 are in creek and river channels. Samples were recovered by dredge from the "Beveridge". Phleger (1960, pp. 159–160) has referred to this type of milieu as the "fluvial marine" environment, that is, essentially an estuary where there is an invasion of a salt-water wedge along the bottom. Salinity is highly variable depending upon the tides and rainfall. A range in salinity was found in this series of stations from 35.7‰ to 12.4‰ for the bottom waters. Salinity of surface waters ranged from 34.1‰ to 10.6‰.

Station 11 (Core Creek)

Water depth, 5 m. Salinity of upper water, 34.1‰; bottom, 35.7‰. Temperature of upper water, 83°F; bottom, 83°F.

Species	Empty Tests	Live Specimens
Ammobaculites crassus Warren	rare	0
Ammonia beccarii variant	rare	0
Ammotium salsum	abundant	frequent
Elphidium incertum variant	abundant	occasional
Elphidium sp. A	frequent	0
Hanzawaia concentrica	rare	0
Haplophragmoides wilberti	rare	0

Station 12 (Core Creek)

Water depth, 4–5 m. Salinity of upper water, 26.8‰; bottom, 27.3‰. Temperature of upper water, 82°F; bottom, 82°F.

Species	Empty Tests	Live Specimens
Ammonia beccarii variant	abundant	0
Elphidium gunteri	rare	0
Quinqueloculina seminulum jugosa	rare	0

This was a sparse foraminiferal assemblage. The stream current apparently was fast at the exact location from which the sample was obtained. The sediment here was mainly medium to coarse quartz sand and broken mollusk shells.

Station 13 (Adams Creek)

Water depth, 5 m. Salinity of upper water, 18.3‰; bottom, 27.8‰. Temperature of upper water, 83°F; bottom, 82.5°F.

Species	Empty Tests	Live Specimens
Ammobaculites crassus	frequent	rare
Ammonia beccarii variant	rare	0
Ammotium salsum	occasional	rare
Trochammina laevigata	rare	0

Station 14 (Neuse River)

Water depth, 3–4 m. Salinity of upper water, 10.6‰; bottom, 12.4‰. Temperature of upper water, 81.5°F; bottom, 83°F.

Species	Empty Tests	Live Specimens
Ammoastuta inepta (Cushman and McCulloch)	rare	0
Ammobaculites crassus	abundant and predominant	
Ammobaculites subcatenulatus Warren	abundant	abundant
Ammodiscus (?) sp.	0	rare
Ammonia beccarii variant	frequent	frequent
Ammotium salsum	abundant and predominant	
Elphidium incertum variant	0	rare
Haplophragmoides wilberti	occasional	0
Miliammina fusca	abundant	abundant

A complete salinity range in fluvial marine environments was provided by seven stations in the Newport river. The sediment in all seven samples was predominantly plant fibers and fine silt. Oyster beds were in proximity to stations 16–18. The salinity varies here with the tides and rainfall. Over a year, the bottom salinity has varied between 11.3 and 28‰ at station 16 according to Mr. John Culliney of Duke University Marine Laboratory. At station 20 bottom salinity is known to vary between 1.3 and 27.4‰. The salinity of the Newport river at Newport, North Carolina (station 21), is usually close to 0‰, but during periods of drouth, it may rise to 1 or 2‰ in the bottom of the channel. Surface salinities at the time of sampling (high tide, July 8, 1969) were as follows: station 15, 33.8‰; station 16, 33.7‰; station 17, 20.0‰; station 18, 19.5‰; and station 19, 5.6‰. The species found at these stations are shown in the following tables:

Station 15

Species	Empty Tests	Live Specimens
Ammonia beccarii variant	occasional	0
Elphidium gunteri	frequent	occasional
Elphidium incertum variant	0	rare

Station 16

Ammonia beccarii variant	abundant	rare
Elphidium gunteri	frequent	0
Elphidium incertum variant	abundant	occasional

Station 17

Ammobaculites crassus	occasional	occasional
Ammonia beccarii variant	abundant	frequent
Ammotium salsum	abundant	abundant
Elphidium gunteri	abundant	abundant
Elphidium incertum variant	rare	occasional
Elphidium sp.	abundant	abundant
Miliammina fusca	0	rare

Diatoms were abundant at station 17.

Station 18

Ammoastuta inepta	frequent	0
Ammobaculites crassus	rare	0
Ammonia beccarii variant	abundant	occasional
Ammotium salsum	abundant	0
Elphidium gunteri	abundant	0
Elphidium incertum variant	abundant	0
Haplophragmoides manilaensis Andersen	rare	0
Haplophragmoides wilberti	frequent	0
Tiphotrocha comprimata	occasional	0

Thecamoebians were present but quite rare.

Station 19

Ammobaculites crassus	abundant	0
Ammotium salsum	abundant	abundant
Arenoparrella mexicana	frequent	0
Haplophragmoides manilaensis	occasional	0
Haplophragmoides wilberti	frequent	0
Miliammina fusca	frequent	0
Tiphotrocha comprimata	rare	0
Trochammina laevigata	occasional	0

All of the species in the above list are arenaceous. The bottom sediments here consisted mainly of fine to medium quartz sand.

Station 20

Ammoastuta inepta	abundant	0
Ammobaculites crassus	abundant	rare
Ammotium salsum	abundant	frequent
Arenoparrella mexicana	abundant	0
Haplophragmoides manilaensis	frequent	0
Haplophragmoides wilberti	abundant	0
Miliammina fusca	abundant	rare
?*Psammosphaera* sp.	abundant	0
Tiphotrocha comprimata	abundant	0
Trochammina laevigata	abundant	0

Diatoms, particularly *Coscinodiscus*, were abundant.

Station 21

Ammoastuta inepta	rare	0
Ammobaculites crassus ?	rare	0
Trochammina laevigata ?	rare	0

All of the above specimens were extremely small. *Coscinodiscus* was abundant, and at least five species and perhaps as many genera of thecamoebians were present.

IV. Distribution (Below Sediment Surface) of Living Foraminifera in a Salt Marsh

A sample was collected 30 cm below the sediment surface at station 9 by spade and with direct measurement of the depth. Care was taken to avoid the numerous *Uca* burrows in the area. The penetrated material was soggy, as was the surface of this intertidal marsh, and water flowed into the bottom of the excavation within a few minutes. The sample, even at 30 cm below the surface, was mostly a mat of *Spartina alterniflora* with clay and fine silt size sediment. The

following foraminifera were counted in 50 cubic centimeters of wet material from a depth of 30 cm below the marsh surface:

Species	Empty Tests	Live Specimens
Arenoparrella mexicana	81	17
Miliammina fusca	11	0
Siphotrochammina lobata	4	0
Tiphotrocha comprimata	49	5
Trochammina laevigata	45	5

The above data for living specimens prompted a subsequent investigation approximately two weeks later in the same area, again at low tide. A second hole was dug about 25 meters from the first, again 25 meters from standing water. The results from this excavation (each sample consisting of 50 cubic centimeters of wet material) were as follows:

5–10 cm below the sediment surface

Arenoparrella mexicana	3	0
Miliammina fusca	14	1
Tiphotrocha comprimata	2	0
Trochammina laevigata	28	1

10–20 cm below the sediment surface

Ammonia beccarii variant	1	0
Arenoparrella mexicana	10	0
Miliammina fusca	43	0
Tiphotrocha comprimata	7	0
Trochammina laevigata	31	2

15–20 cm below the sediment surface

Ammonia beccarii variant	0	1
Arenoparrella mexicana	39	2
Miliammina fusca	26	1
Tiphotrocha comprimata	19	5
Trochammina laevigata	52	5

25–30 cm below the sediment surface

Arenoparrella mexicana	18	2
Miliammina fusca	14	1
Tiphotrocha comprimata	28	0
Trochammina laevigata	66	5

30–35 cm below the sediment surface

Arenoparrella mexicana	19	0
Miliammina fusca	39	4
Siphotrochammina lobata	15	0
Tiphotrocha comprimata	32	2
Trochammina laevigata	90	7

35–40 cm below the sediment surface

Ammobaculites sp.	4	0
Ammonia beccarii variant	6	0
Arenoparrella mexicana	15	0
Miliammina fusca	38	0
Siphotrochammina lobata	13	0
Tiphotrocha comprimata	14	0
Trochammina laevigata	58	1

45–50 cm below the sediment surface

Ammobaculites sp.	2	0
Ammonia beccarii variant	8	0
Arenoparrella mexicana	18	0
Miliammina fusca	13	0
Siphotrochammina lobata	18	0
Tiphotrocha comprimata	41	0
Trochammina laevigata	39	0

V. Discussion

The term, "estuarine," as used in the title of this report, includes a variety of environments that have been referred to as "marginal marine" (Phleger, 1960, p. 125), and a tabulation of such areas includes marine marshes, rivers, lagoons and bays, beaches, and the adjacent portion of the continental shelf. A glimpse of all of these in the Beaufort area reveals similarities with other regions, such as Barnstable, Massachusetts (Phleger and Walton, 1950), Poponesset Bay, Massachusetts (Parker and Athearn, 1959), Long Island Sound (Parker, 1952), San Antonio Bay, Texas (Parker *et al.,* 1953), and the Mississippi delta area (Phleger, 1955; Lankford, 1959), particularly in the generic composition of foraminiferal faunas of the various types of marginal marine environments. The assemblage at station 1, for example, has a relatively high generic and species diversity similar to assemblages elsewhere from the open-ocean nearshore environment. Lagoonal faunas, such as those at stations 6, 7, and 8, have a lower species diversity index and are characterized by a few species of the calcareous genera, *Elphidium* and *Ammonia,* and a few species of the arenaceous genera, *Trochammina* and *Ammobaculites.* A similarity between fluvial marine and salt marsh faunas has been noted by Phleger (1960, p. 153), and this relationship holds for the study area, although the extremely high frequency of several arenaceous species living at station 14 appears to be quite distinctive for the upper reaches of an estuary (Neuse River). *Ammobaculites crassus*, in particular, constituted a high standing crop at this station and may, with investigation of other estuaries of the Atlantic coast, prove to be an "ecological marker" in fluvial marine environments with the salinity range at station 14.

A low species diversity is also characteristic of marsh faunas, and some of the species have a very wide geographic distribution. Phleger (1960, p. 175) has noted that *Ammoastuta inepta* has world-wide distribution, being reported from Trinidad, California, northern Gulf of Mexico, northeastern United States, Panama, and Ecuador. It was abundant at station 20 in the narrow Newport River bed. None of the specimens were alive at the time of sampling, and all of the empty tests were probably derived by outwashing from the surrounding marsh. Other characteristic species of Gulf of Mexico–

Caribbean marshes which also occur in the station 9 marsh in very high frequency are *Trochammina laevigata, Miliammina fusca, Arenoparrella mexicana,* and *Tiphotrocha comprimata.* To our knowledge, this is the first report of living foraminifera (at station 9) at some distance from a body of water. The abundance of stained specimens strongly suggests that the intertidal *Spartina* marsh is the preferred habitat for these species.

Stations in the upper reaches of the Newport River are additional documentation that foraminifera thrive in saline waters but give way to the Thecamoebina when there is no longer a tidal (saline) influence. Foraminifera may be abundant in even brackish environments of periodical low salinity, but they diminish as the salinity approaches 1‰. The thecamoebians, on the other hand, thrive in fresh water streams (Bolli and Saunders, 1954) and diminish toward saline water.

Several arenaceous species of foraminifera were found living at a depth of 30–35 cm and a single specimen of *Trochammina laevigata* at 35–40 cm below the sediment surface in an intertidal *Spartina* marsh at low tide. These are the deepest recorded occurrences of foraminifera living below the sediment surface.

Phleger (1960, p. 177) has suggested that calcareous tests cannot survive the low pH of marsh environments. This may be the reason that mostly foraminifera with arenaceous tests have been found so deep below the sediment surface. No pH values were available for the present report, and this is indeed a factor for which more data are needed.

VI. Systematics

Order Foraminifera Eichwald, 1830
Suborder Textulariina Delage and Herouard, 1896
Superfamily Ammodiscacea Reuss, 1862
Family Saccamminidae Brady, 1884
Subfamily Psammosphaerinae Haeckel, 1894
Genus Psammosphaera Schulze, 1875

Psammosphaera fusca Schulze

Psammosphaera fusca Schulze, 1875, Comm. Wiss. Untersuchung Deutsch. Meere Kiel, Jahresber., Jahrg. 2–3, p. 113, pl. 2, figs. 8a–f.

Two specimens were found at station 8B.

?Psammosphaera sp.

Plate 1, fig. 5

This is a variable form in which the aperture is in the end of a short, simple neck. Some specimens have a single aperture; others have two and even three.

The species, although abundant at station 9, was not found elsewhere in the Beaufort area.

Family Ammodiscidae Reuss, 1862
Subfamily Ammodiscinae Reuss, 1862
Genus Ammodiscus Reuss, 1862

Ammodiscus (?) sp.

A single specimen was found at station 14.

Superfamily Lituolacea de Blainville, 1825
Family Hormosinidae Haeckel, 1894
Subfamily Hormosininae Haeckel, 1894
Genus Sulcophax Rhumbler in Wiesner, 1931

Sulcophax palustris Warren

Plate 1, fig. 6

Sulcophax palustris Warren, 1957, Cushman Found. Foram. Res., Contr., v. 8, pt. 1, p. 31, pl. 3, figs. 1–4.

Rare specimens from station 9 are identical with Warren's specimens from the Buras-Scofield Bayou region of southeast Louisiana. Comparisons were made with the holotype (LSU Geology Museum Locality No. 2009). The occurrence here is the first record of this species outside of the type locality (Buras-Scofield Bayou, Louisiana).

Family Rzehakinidae Cushman, 1933
Genus Miliammina Heron-Allen and Earland, 1930

Miliammina beaufortensis, new species

Plate 4, figs. 1–3

Test small, elongate oval, half as thick as broad; length almost twice the width. Chambers in quinqueloculine arrangement. Wall agglutinated, composed of minute, tabular particles, oriented so as to present a smooth, polished surface, pale tan to buff in color. Aperture an elongate arch above penultimate chamber, without tooth but with external low ridge, almost as wide as opening, arising threshold-like from penultimate chamber.

Length of holotype (Pl. 4, figs. 2a–c), 0.27 mm, breadth, 0.15 mm, thickness, 0.12 mm.

Miliammina beaufortensis is similar to *Miliammina pariaensis* Todd and Bronnimann in the texture and smooth, polished appearance of the test wall and in the incipient spiroloculine arrangement of the later chambers. The Beaufort form, however, is not so compressed as the larger Trinidad species and characteristically has a low threshold-like ridge below and external to the aperture which is not seen in *Miliammina pariaensis*.

MILIAMMINA FUSCA (H. B. Brady)
Plate 1, fig. 1

Quinqueloculina fusca H. B. BRADY, 1870, Ann. Mag. Nat. Hist., ser. 4, v. 6, p. 47, pl. 11, figs. 2a–c, 3.
Miliammina fusca (H. B. Brady). TODD AND BRONNIMANN, 1957, Cushman Found. Foram. Res., Spec. Publ., no. 3, p. 26, pl. 3, fig. 1.

Specimens from the Beaufort area are conspecific with those from estuarine environments of the Gulf of Mexico–Caribbean region that have been assigned by various authors to this taxon.

Family LITUOLIDAE de Blainville, 1825
Subfamily HAPLOPHRAGMOIDINAE Maync, 1952
Genus HAPLOPHRAGMOIDES Cushman, 1910

HAPLOPHRAGMOIDES MANILAENSIS Andersen

Haplophragmoides manilaensis ANDERSEN, 1953, Cushman Found. Foram. Res., Contr., v. 4, pt. 1, p. 22, pl. 4, figs. 8a, b.

Specimens are typical.

HAPLOPHRAGMOIDES WILBERTI Andersen
Plate 1, fig. 4

Haplophragmoides wilberti ANDERSEN, 1953, Cushman Found. Foram. Res., Contr., v. 4, pt. 1, p. 21, pl. 4, figs. 7a, b.

Specimens are typical and abundant in the salt marsh environment.

Genus TROCHAMMINITA Cushman and Bronnimann, 1948

TROCHAMMINITA IRREGULARIS Cushman and Bronnimann
Plate 1, fig. 2

Trochamminita irregularis CUSHMAN AND BRONNIMANN, 1948, Cushman Lab. Foram. Research, Contr., v. 24, pt. 1, p. 17, pl. 4, figs. 1–3.

This species is abundant at station 9, but specimens with typical apertures are rare. The test is extremely fragile, and several specimens bearing apertures were broken when they were manipulated for photography. The geographic range of *Trochamminita irregularis,* which was originally described from brackish waters of Trinidad and later reported from polyhaline marshes of coastal Louisiana, is extended to the Beaufort area by this investigation.

Subfamily LITUOLINAE de Blainville, 1825
Genus AMMOASTUTA Cushman and Bronnimann, 1948

AMMOASTUTA INEPTA (Cushman and McCulloch)
Plate 1, fig. 3

Ammobaculites ineptus CUSHMAN AND MCCULLOCH, 1939, Allan Hancock Pacific Exped., v. 6, no. 1, p. 89, pl. 7, fig. 6.
Ammoastuta salsa CUSHMAN AND BRONNIMANN, 1948, Cushman Lab. Foram. Research, Contr., v. 17, pt. 3, p. 17, pl. 3, figs. 14–16.
Ammoastuta inepta (Cushman and McCulloch). TODD AND BRONNIMANN, 1957, Cushman Found. Foram. Res., Spec. Publ., no. 3, p. 23 (not figured).

This species is found in the Beaufort area at several stations where the water is fresh enough to drink. It was not found at stations with salinity higher than 19.5‰.

Genus AMMOBACULITES Cushman, 1910

AMMOBACULITES CRASSUS Warren
Plate 2, figs. 3–4

Ammobaculites crassus WARREN, 1957, Cushman Found. Foram. Res., Contr., v. 8, pt. 1, p. 32, pl. 3, figs. 5–7.

Sediment from station 14 (Neuse River) literally teems with large specimens of this species. Many individuals have chambers in excess of the maximum reported by Warren for the taxon.

AMMOBACULITES cf. AMMOBACULITES DILATATUS Cushman and Bronnimann

Ammobaculites dilatatus CUSHMAN AND BRONNIMANN, 1948, Cushman Lab. Foram. Res., Contr., v. 24, pt. 2, p. 39, pl. 7, figs. 10, 11.

Rare specimens were found at a few of the estuarine stations.

AMMOBACULITES SUBCATENULATUS Warren

Ammobaculites subcatenulatus WARREN, 1957, Cushman Found. Foram. Res., Contr., v. 8, pt. 1, p. 32, pl. 3, figs. 11–13.

This species was abundant only at station 14 in the Neuse River.

Genus AMMOTIUM Loeblich and Tappan, 1953

AMMOTIUM PSEUDOCASSIS (Cushman and Bronnimann)
Plate 2, fig. 1

Ammobaculites pseudocassis CUSHMAN AND BRONNIMANN, 1948, Cushman Lab. Foram. Res., Contr., v. 24, pt. 2, p. 39, pl. 7, figs. 12a, b.

This variable form is abundant at station 9.

AMMOTIUM SALSUM (Cushman and Bronnimann)
Plate 2, fig. 2

Ammobaculites salsus CUSHMAN AND BRONNIMANN, 1948, Cushman Lab. Foram. Res., Contr., v. 24, pt. 1, p. 16, pl. 3, figs. 7–9.

This species is characteristic of the fluvial estuarine stations 14–20.

Family TEXTULARIIDAE Ehrenberg, 1838
Subfamily TEXTULARIINAE Ehrenberg, 1838
Genus TEXTULARIA Defrance *in* de Blainville, 1824

TEXTULARIA PALUSTRIS Warren
Plate 2, fig. 7

Textularia palustris WARREN, 1957, Cushman Found. Foram. Res., Contr., v. 8, pt. 1, p. 34, pl. 4, figs. 3–5.

Specimens were compared with the holotype from Louisiana, and they are identical. The species was observed only at station 9 in the Beaufort area.

TEXTULARIA SP.

A single fragment, unidentifiable as to species, was found at station 6.

Family TROCHAMMINIDAE Schwager, 1877
Subfamily TROCHAMMININAE Schwager, 1877
Genus TROCHAMMINA Parker and Jones, 1859

TROCHAMMINA LAEVIGATA Cushman and Bronnimann
Plate 2, fig. 5

→

PLATE 1

Figure
1 *Miliammina fusca* (H. B. Brady)
a, b Opposite sides, × 146
Length, 0.42 mm; breadth, 0.20 mm
2 *Trochamminita irregularis* Cushman and Bronnimann
a, b Opposite sides, × 160
Length, 0.39 mm; breadth, 0.16 mm
3 *Ammoastuta inepta* (Cushman and McCulloch)
a Side view, × 154
b Apertural view, × 656
Length, 0.42 mm; breadth, 0.25 mm
4 *Haplophragmoides wilberti* Andersen
a Edge view, × 160
b Side view, × 160
Maximum diameter, 0.39 mm; thickness, 0.19 mm
5 ? *Psammosphaera* sp.
× 160
Maximum diameter, 0.36 mm
6 *Sulcophax palustris* Warren
× 107
Length (early portion lost), 0.46 mm

Figure 3, Station 20; all others, Station 9.

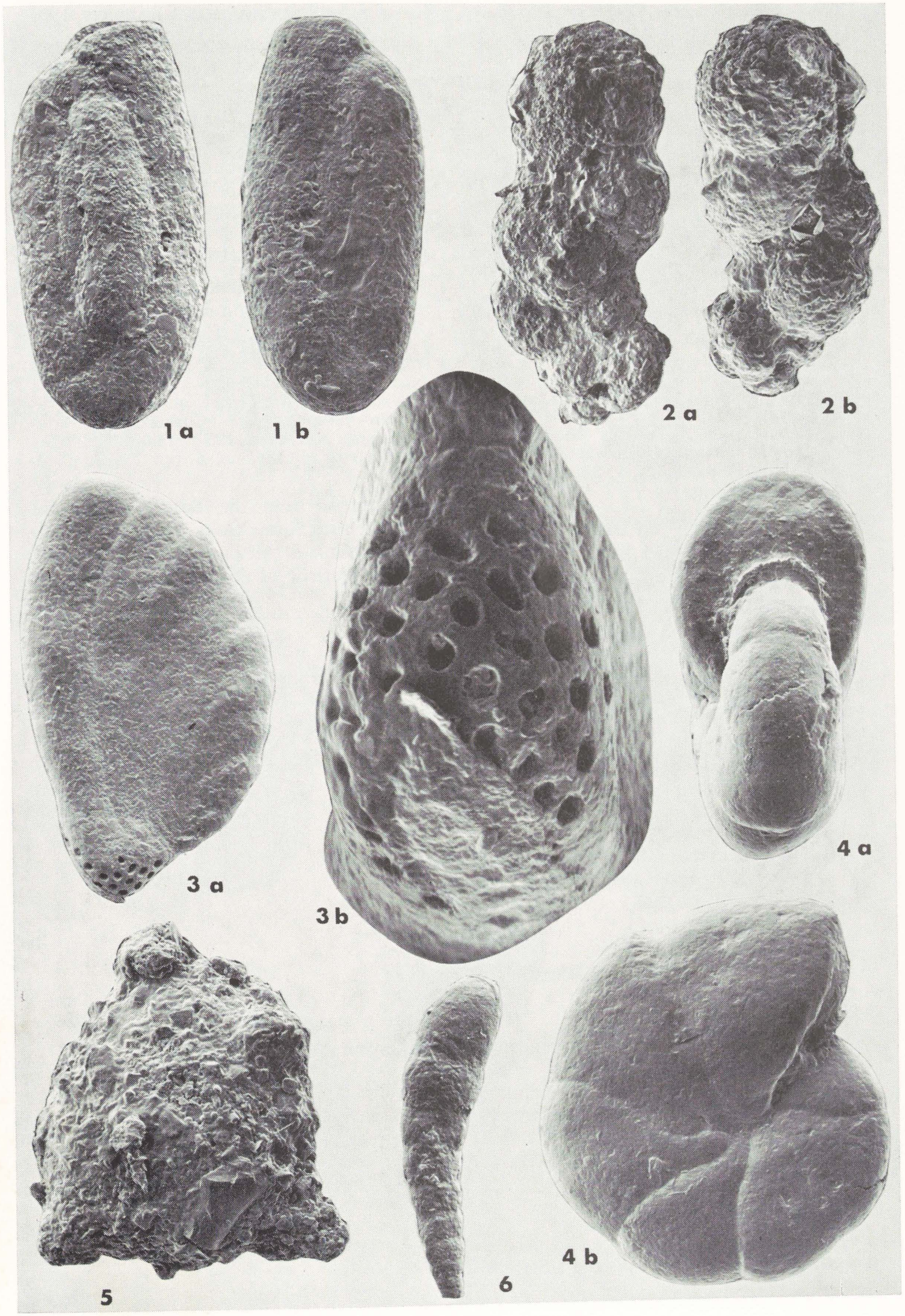

PLATE 1

Trochammina laevigata CUSHMAN AND BRONNIMANN, 1948, Cushman Lab. Foram. Res., Contr., v. 24, pt. 2, p. 41, pl. 7, figs. 21, 22.

This species was abundant at station 9 both at the marsh surface and below the sediment surface. Specimens are identical with forms from Trinidad and the northern Gulf of Mexico.

TROCHAMMINA SP.

A few specimens, unidentifiable as to species, were found at station 1.

Genus ARENOPARRELLA Andersen, 1951

ARENOPARRELLA MEXICANA (Kornfeld)
Plate 2, fig. 6

Trochammina inflata (Montagu) var. *mexicana* KORNFELD, 1931, Contr. Stanford Univ. Geol. Dept., v. 1, p. 86, pl. 13, figs. 5a–c.
Arenoparrella mexicana (Kornfeld). ANDERSEN, 1951, Jour. Paleontology, v. 25, no. 1, p. 31, figs. 1a–c.

Beaufort specimens are typical. The highest frequencies observed were at stations 9 and 20.

Genus SIPHOTROCHAMMINA Saunders, 1957

SIPHOTROCHAMMINA LOBATA Saunders
Plate 3, fig. 1

Siphotrochammina lobata SAUNDERS, 1957, Smithsonian Misc. Collections, v. 134, no. 5, pp. 9–10, pl. 3, figs. 1, 2.

This species was abundant in the marsh at station 9. It was not identified at any of the other localities.

Genus TIPHOTROCHA Saunders, 1957

TIPHOTROCHA COMPRIMATA (Cushman and Bronnimann)
Plate 3, fig. 2

Trochammina comprimata CUSHMAN AND BRONNIMANN, 1948, Cushman Lab. Foram. Res., Contr., v. 24, pt. 2, p. 41, pl. 8, figs. 1–3.
Tiphotrocha comprimata (Cushman and Bronnimann). SAUNDERS, 1957, Smithsonian Misc. Collections, v. 134, no. 5, pp. 11–12, pl. 4, figs. 1–4.

Specimens from the Beaufort area are identical with forms from Trinidad and the northern Gulf of Mexico. Living specimens are characteristic of the marsh environment.

→

PLATE 2

Figure
1 *Ammotium pseudocassis* (Cushman and Bronnimann)
Side view, × 90
Length, 0.73 mm; maximum width, 0.19 mm
2 *Ammotium salsum* (Cushman and Bronnimann)
a Side view, × 55
b Edge view, × 55
Length, 1.04 mm; thickness, 0.22 mm
3 *Ammobaculites crassus* Warren
a Side view, × 45
b Edge view, × 45
Length, 1.47 mm
4 *Ammobaculites crassus* Warren
Side view, × 44
Length, 1.19 mm
5 *Trochammina laevigata* Cushman and Bronnimann
a, b Opposite sides, × 84
Maximum diameter, 0.68 mm
6 *Arenoparrella mexicana* (Kornfeld)
a, b Opposite sides, × 98
Maximum diameter, 0.50 mm
7 *Textularia palustris* Warren
× 161
Length, 0.43 mm

Figures 2, 3, 4, Station 14; all others, Station 9.

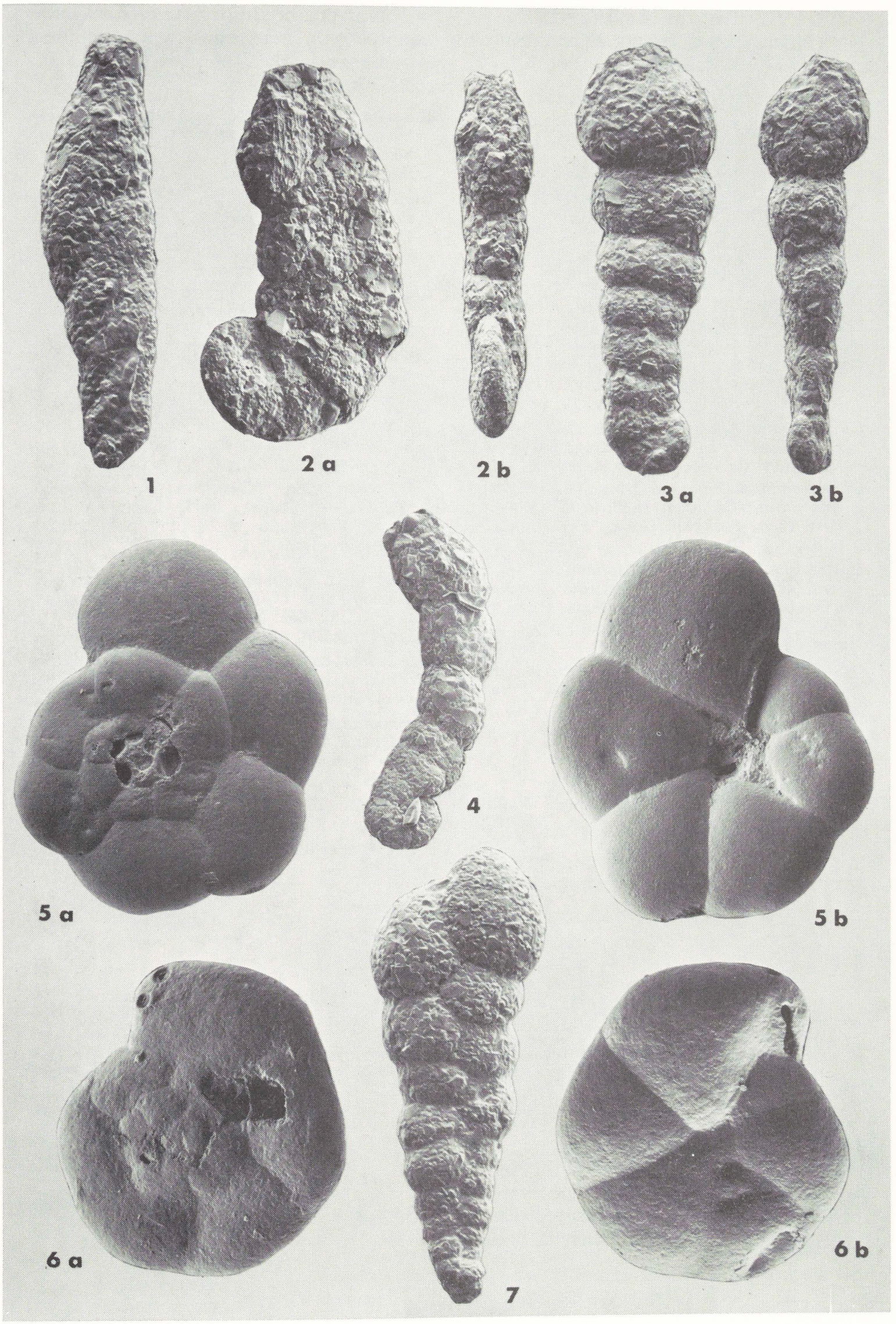

PLATE 2

VII. Faunal References (Neritic and Outer Estuarine Foraminifera)

Calcareous foraminifera, with the notable exception of *Ammonia beccarii* variant, were found only at the neritic and outer estuarine stations (station 1 to station 8B). Following is an alphabetized reference list of all of the calcareous forms identified in this study:

Planktonic Forms

Globigerina bulloides bulloides d'Orbigny = *"Polymorphium tuberosum et globiferum"* Soldani, 1791 (part), Testaceogr. ac Zoophytogr., vol. 1, pt. 2, p. 117, pl. 123, fig. 0.

Globigerinoides conglobatus conglobatus (Brady) =*Globigerina conglobata* Brady, 1879, Quart. Jour. Micros. Sci., new ser., v. 19, p. 286.

Globigerinoides quadrilobatus sacculifer (Brady) = *Globigerina sacculifer* Brady, 1877, Geol. Mag., new ser., decade 2, v. 4, no. 12, p. 535.

Globigerinoides ruber (d'Orbigny) = *Globigerina rubra* d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 82, pl. 4, figs. 12–14.

Hastigerina (*Hastigerina*) *siphonifera siphonifera* (d'Orbigny) = *Globigerina siphonifera* d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 83, pl. 4, figs. 15–18.

Orbulina universa d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 2, pl. 1, fig. 1 (*fide* Ellis and Messina, 1940 *et seq.*)

Benthonic Forms

Ammonia beccarii (Linné) variant $\overset{?}{=}$ *Nautilus beccarii* Linné, 1758, Syst. Nat., ed. 10, p. 710.

This is one of the few calcareous forms composing the inner estuarine foraminiferal assemblages in the Beaufort area. See discussion under station 9.

Buccella hannai (Phleger and Parker) = *Eponides hannai* Phleger and Parker, 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 21, pl. 10, figs. 11–14.

Cibicides pseudoungerianus (Cushman) = *Truncatulina pseudoungeriana* Cushman, 1922, U. S. Geol. Surv. Prof. Paper, no. 129-E, p. 97, pl. 20, fig. 9.

Cibicides cf. *Cibicides refulgens* Montfort $\overset{?}{=}$ *Cibicides refulgens* Montfort, 1808, Conch. Syst., v. 1, p. 122.

Elphidium gunteri Cole, 1931, Florida State Geol. Surv., Bull. 6, p. 34, pl. 4, figs. 9, 10.

Elphidium incertum (Williamson) variant $\overset{?}{=}$ *Polystomella umbilicatula* Walker and Boys var. *incerta* Williamson, 1858, Rec. Foram. Great Britain, p. 44, pl. 3, fig. 82a.

Florilus atlanticus (Cushman) = *Nonionella atlantica* Cushman, 1947, Cushman Lab. Foram. Res., Contr., v. 23, pt. 4, p. 90, pl. 20, figs. 4, 5.

Globulina cf. *Globulina gibba* (d'Orbigny) $\overset{?}{=}$ *Polymorphina* (*Globuline*) *gibba* d'Orbigny, 1826, Ann. Sci. Nat., Paris, France, ser. 1, tome 7, p. 266.

Hanzawaia concentrica (Cushman) = *Truncatulina concentrica* Cushman, 1918, U. S. Geol. Surv., Bull. 676, p. 64, pl. 21, fig. 3.

Poroeponides cribrorepandus Asano and Uchio *in* Stach, 1951, Illustrated Catalogue of Japanese Tertiary smaller Foraminifera, pt. 14, p. 18, tfs. 134, 135.

Quinqueloculina compta Cushman, 1947, Cushman Lab. Foram. Res., Contr., v. 23, pt. 4, p. 87, pl. 19, fig. 2.

→

Plate 3

Figure

1 *Siphotrochammina lobata* Saunders
- a, b Opposite sides, × 160
  Maximum diameter, 0.39 mm

2 *Tiphotrocha comprimata* (Cushman and Bronnimann)
- a, b Opposite sides, × 82
  Maximum diameter, 0.63 mm

3 *Ammonia beccarii* (Linné) variant
- a, b Opposite sides, × 215
  Maximum diameter, 0.24 mm

4 *Ammonia beccarii* (Linné) variant
- a, b Opposite sides of a corroded specimen, × 214
  Maximum diameter, 0.24 mm

All specimens are from Station 9.

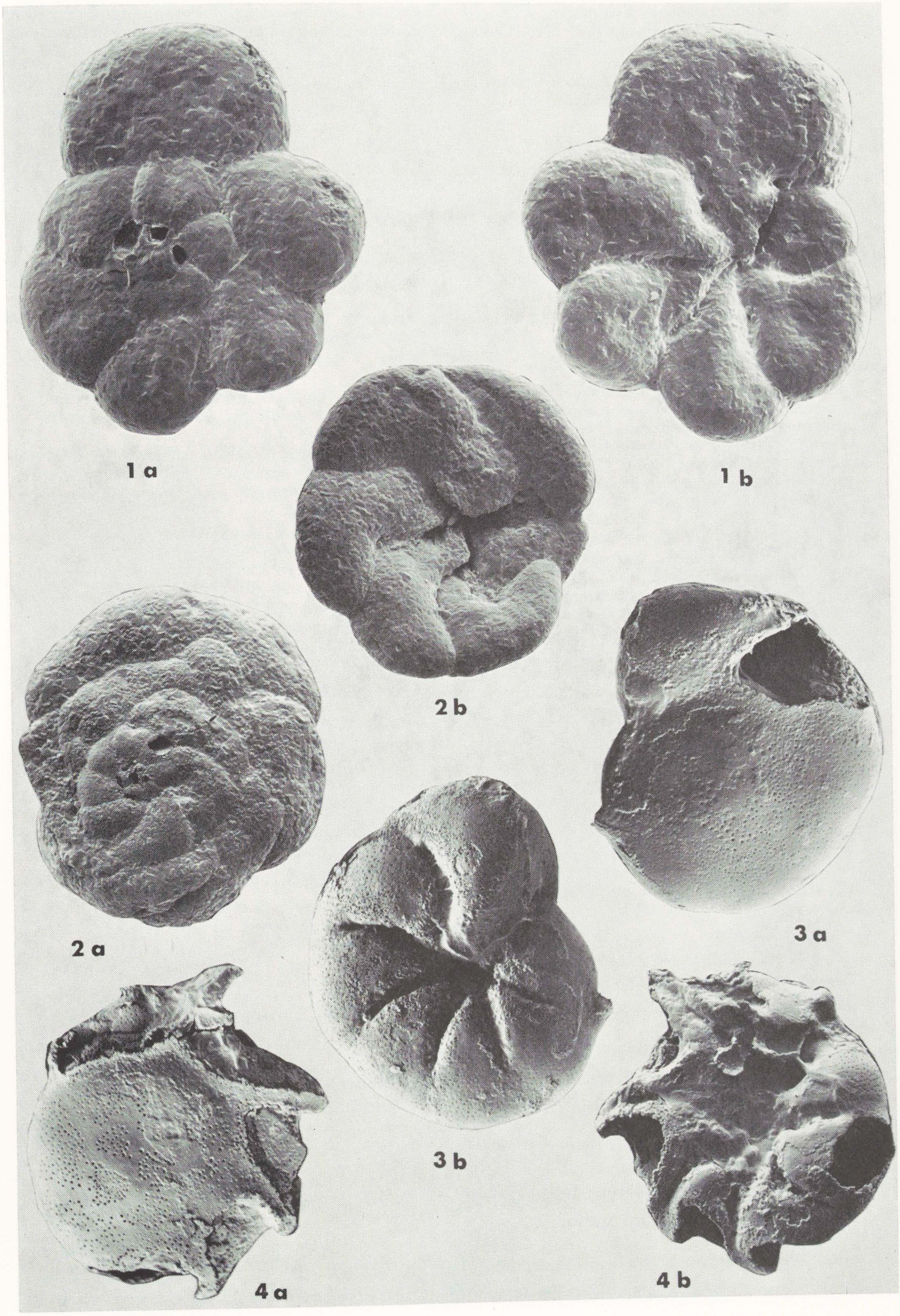

PLATE 3

Quinqueloculina poeyana d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 191, pl. 11, figs. 25–27.

Quinqueloculina seminulina (Linné) = *Serpula seminulum* Linné, 1767, Syst. Nat., ed. 12, p. 1264.

Quinqueloculina seminulina (Linné) *jugosa* Cushman = *Quinqueloculina seminulina* (Linné) var. *jugosa* Cushman, 1944, Cushman Lab. Foram. Res., Spec. Publ. 12, p. 13, pl. 2, fig. 15.

Rosalina floridana (Cushman) = *Discorbis floridanus* Cushman, 1922, Carnegie Inst. Washington, Publ. no. 311, p. 39, pl. 5, figs. 11, 12.

VIII. Literature Cited

Bolli, H. M., and J. B. Saunders, 1954, Discussion of some Thecamoebina described erroneously as foraminifera: Cushman Found. Foram. Res., Contr., v. 5, pt. 2, p. 45–52.

Boltovskoy, Esteban, 1966, Depth at which foraminifera can survive in sediments: Cushman Found. Foram. Res., Contr., v. 7, pt. 2, p. 43–45.

Hadley, W. H., 1936, Recent foraminifera from near Beaufort, North Carolina: J. Elisha Mitchell Sci. Soc., v. 52, p. 35–37.

Lankford, R. R., 1959, Distribution and ecology of foraminifera from east Mississippi Delta margin: Amer. Assoc. Pet. Geol., Bull., v. 43, no. 9, p. 2065–2099.

Miller, D. N., Jr., 1953, Ecological study of the foraminifera of Mason Inlet, North Carolina: Cushman Found. Foram. Res., Contr., v. 4, pt. 2, p. 41–63.

Nichols, M. M., and R. L. Ellison, 1967, Sedimentary patterns of microfauna in a coastal plain estuary: Estuaries (ed. G. H. Lauff), publ. 83, Am. Assn. Adv. Sci., p. 283–288.

Parker, Frances L., 1952, Foraminiferal distribution in the Long Island Sound-Buzzards Bay area: Bull. Mus. Comp. Zoology, v. 106, no. 10, p. 427–473.

Parker, Frances L. and William D. Athearn, 1959, Ecology of marsh foraminifera in Poponesset Bay, Massachusetts. Jour. Paleontology, v. 33, no. 2, p. 333–343.

Parker, Frances L., F. B Phleger, and J. F. Peirson, 1953, Ecology of foraminifera from San Antonio Bay and environs, southwest Texas: Cushman Found. Foram. Res., Spec. Publ. no. 2, 75 pages.

Pearse, A. S., H. J. Humm, and G. W. Wharton, 1942, Ecology of sand beaches at Beaufort, N. C.: Ecol. Monogr., v. 12, p. 135–190.

Phleger, F. B, 1955, Ecology of foraminifera in southeastern Mississippi Delta area: Amer. Assoc. Pet. Geol., Bull., v. 39, no. 5, p. 712–752.

Phleger, F. B, 1960, Ecology and distribution of Recent foraminifera: Johns Hopkins Press, 297 pages.

Phleger, F. B, and W. R. Walton, 1950, Ecology of marsh and bay foraminifera, Barnstable, Massachusetts: Amer. Jour. Sci., v. 248, p. 274–294.

Stephenson, T. A., and Anne Stephenson, 1952, Life between tidemarks in North America; II. Northern Florida and the Carolinas: J. Ecol., v. 40, p. 1–49.

Walton, W. R., 1952, Techniques for recognition of living forminifera: Cushman Found. Foram. Res., Contr., v. 3, pt. 2, p. 56–60.

Warren, A. D., 1957, Foraminifera of the Buras-Scofield Bayou Region, Southeast Louisiana: Cushman Found. Foram. Res., Contr., v. 8, pt. 1, p. 29–40.

Wilcoxon, J. A., 1964, Distribution of foraminifera off the southern Atlantic coast of the United States: Cushman Found. Foram. Res., Contr., v. 15, pt. 1, p. 1–24.

→

Plate 4

Miliammina beaufortensis, new species

Figure

1 a-c Paratype
  a, c Side views, × 216
  b Edge view, × 216
    Length, 0.27 mm; breadth, 0.16 mm; thickness, 0.13 mm

2 a-c Holotype
  a, c Side views, × 225
  b View of apertural area, × 757; aperture contains some extraneous material.
    Length, 0.27 mm; breadth, 0.15 mm; thickness, 0.12 mm

3 a-c Paratype
  a, c Side views, × 214
  b Edge view, × 214
    Length, 0.28 mm; breadth, 0.17 mm; thickness, 0.12 mm

All three specimens are from Station 9.

April 12, 1971

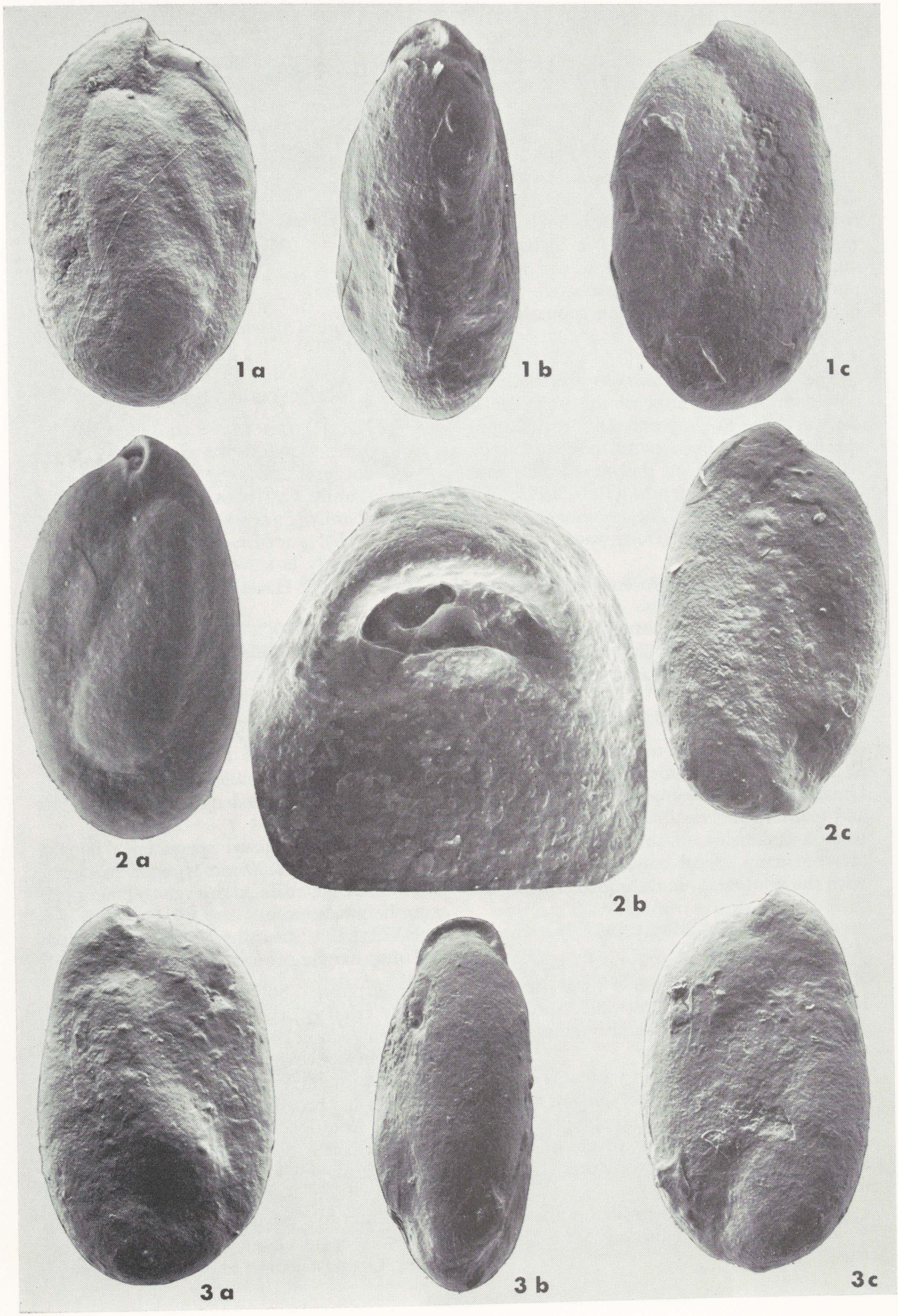

PLATE 4